Reducing human-induced earthquake risk

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Credit: AI-generated image (disclaimer)

Researchers at EPFL and the Swiss Federal Office of Energy have devised strategies for reducing the earthquake risk associated with geothermal energy, CO_2 storage and other human activities happening deep underground.

Although most earthquakes are attributable to natural causes, some are triggered—directly or indirectly—by human activity. These minor tremors, known as "induced seismicity," are one of the biggest challenges posed by deep geothermal energy, CO_2 storage, and other activities that involve injecting gases and liquids deep underground.

Researchers at EPFL's Laboratory of Soil Mechanics (LMS) and the Swiss Federal Office of Energy (SFOE) have devised new strategies for reducing human-induced earthquake risk. Their findings have been published in *Geophysical Journal International*.

Custom-training deep geothermal reservoirs

Deep geothermal systems provide a sustainable, renewable, zero-carbon source of power and are consistent with the Swiss government's 2050 energy strategy and its pledge to go carbon-neutral. Yet the technology used in Switzerland, known as Enhanced Geothermal Stimulation (EGS), has faced setbacks after triggering earthquakes in Basel in 2006 and in St. Gallen in 2013.

EGS involves a process called hydraulic injection, where pressurized liquid is injected into hot, dry, impermeable rock—some 3 km or more below the Earth's surface—to create an artificial geothermal reservoir. The problem is that this process can cause microseismicity, or minor tremors and earthquakes.

As the water is injected underground and fills the rock matrix, the interstitial pore pressure increases. "There's a commonly held belief that this is the only cause of induced seismicity," says Barnaby Fryer, a doctoral assistant at the LMS and the paper's lead author. "But it's not that straightforward. Tectonic stress, or fault geometry and movement, also comes into play."

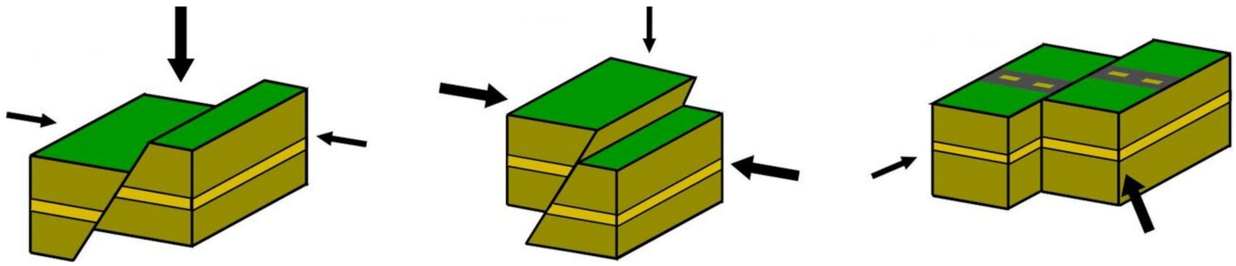

Image © Barnaby Fryer / EPFL Left to right: normal (extensional) fault, reverse (compression) fault, strike-slip fault

A delicate balancing act

Faults are caused by vertical and horizontal forces acting on sections of the Earth's crust. They fall into one of three categories: normal or extensional faults (where the two sections pull apart), reverse or compression faults (where the two sections push against one another), and strike-slip faults (where the two sections move horizontally).

The joint EPFL and SFOE team started from the premise that faults are more stable—and the likelihood of an earthquake therefore reduced—when the differential stress (i.e. the difference between the maximum and minimum stresses) is lower. "That observation raised an obvious question," says Gunter Siddiqi, deputy section head of energy research at the SFOE and the paper's second author. "What type of fault are we dealing with, and what can we do to limit major quakes and tremors?"

The researchers came up with the idea of "training" the reservoir before the stimulation process begins. In the case of a reverse fault, which involves high horizontal stresses, cold fluid is injected underground over a period of at least 12 months. "As the reservoir cools, the rock contracts," explains Fryer. "This lowers the horizontal forces acting on it, thereby reducing differential stress and making earthquakes less likely."

Turning up the pressure

Contrary to popular belief, injecting high-pressure fluids into the Earth's crust doesn't always cause earthquakes. "In almost all reservoirs, it's only the horizontal stresses that change significantly," says Fryer. "With a normal fault, vertical stresses are much greater than horizontal stresses. When you inject a liquid into the rock, the interstitial pressure rises. This, in turn, increases the horizontal stresses and closes the gap between the horizontal and vertical values."

In other words, injecting fluids in this way can actually stabilize the fault, provided the stresses inside the reservoir are responsive enough to changes in interstitial pressure. "That's why it's so important to understand the properties of a reservoir before you start injecting," adds Fryer.

Promising applications

This research provides important insights for industry, potentially helping companies devise ways to reduce the likelihood of induced seismicity. "Understanding every possible scenario and acting accordingly could pave the way for some promising real-world applications," says Siddiqi.

More information: B Fryer et al. Injection-induced seismicity: strategies for reducing risk using high stress path reservoirs and temperature-induced stress preconditioning, *Geophysical Journal International* (2019). DOI: 10.1093/gji/ggz490

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