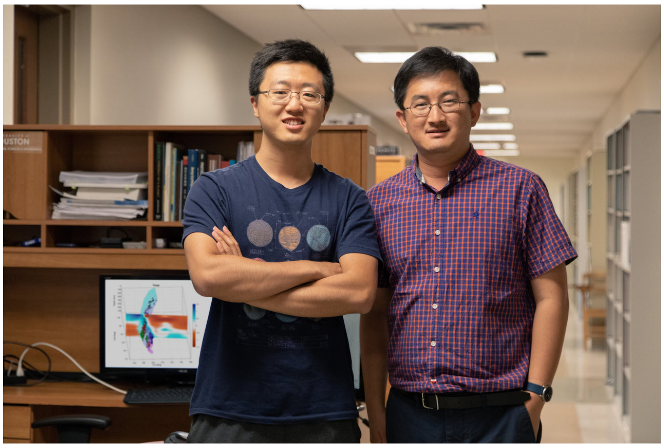
Researchers report new understanding of deep earthquakes

30 July 2018



First author Jiaxuan Li and Yingcai Zheng, assistant professor of seismic imaging at the University of Houston, led research into the ways deep earthquakes differ from shallower quakes. Credit: University of Houston

Researchers have known for decades that deep earthquakes—those deeper than 60 kilometers, or about 37 miles below the Earth's surface—radiate seismic energy differently than those that originate closer to the surface. But a systematic approach to understanding why has been lacking.

Now a team of researchers from the University of Houston has reported a way to analyze seismic wave radiation patterns in deep earthquakes to suggest global deep earthquakes are in anisotropic rocks, something that had not previously been done. The rock anisotropy refers to differences in seismic wave propagation speeds when measured along different directions.

Their findings were published Monday, July 30, by the journal *Nature Geoscience*.

Most earthquakes occur at shallow depths, according to the U.S. Geological Survey, and they generally cause more damage than deeper earthquakes. But there are still substantial questions about the causes of deep earthquakes.

Normal rocks are ductile, or pliable, at these great depths because of high temperature and thus aren't able to rupture in an abrupt fashion to produce deep earthquakes, which occur below subduction zones where two tectonic plates collide at ocean trenches. The plate being pushed under is referred to as the subducting slab. The fact that deep earthquakes occur only in these slabs suggests some unusual process is happening within the slab.

Yingcai Zheng, assistant professor of seismic imaging in the UH College of Natural Sciences and Mathematics and corresponding author for the paper, said seismologists have sought to understand deep earthquakes since the phenomenon was discovered in 1926. Hypotheses include the effect of fluids, runaway thermal heating or solid-phase change due to sudden collapse of the mineral crystal structure.

In addition to Zheng, researchers involved in the work include the first author Jiaxuan Li, a Ph.D. candidate in the Department of Earth and Atmospheric Sciences; Leon Thomsen, research professor of geophysics; Thomas J. Lapen, professor of geology; and Xinding Fang, adjunct professor at UH and concurrently associate professor at the Southern University of Science and Technology China.

"Over the past 50 years, there has been growing evidence that a large proportion of deep earthquakes do not follow the double-couple radiation pattern seen in most shallow earthquakes," Zheng said. "We set out to look at why that happens." The double-couple pattern is caused by a shear rupture of a pre-existing fault.

The work, funded by the National Science Foundation, looked at potential reasons for the differing radiation patterns; Zheng said earlier theories suggest that deep earthquakes stem from a different rupture mechanism and possibly different physical and chemical processes than those that spark shallow earthquakes.

But after studying the radiation patterns of 1,057 deep earthquakes at six subduction zones worldwide, the researchers determined another explanation. They found that the surrounding rock fabric enclosing the deep quake alters the seismic radiation into a non-double-couple pattern. "Both the common double-couple radiation patterns and uncommon patterns of deep earthquakes can be explained simultaneously by shear rupture in a laminated rock fabric," Li said.

Before the subducting plate enters the trench, it can absorb sea water to form hydrated anisotropic minerals. As the slab descends in the Earth's mantle, the water can be expelled due to high pressure and high temperature conditions, a process known as dehydration. The dehydration and strong shearing along the slab interface can make the rock brittle and lead to rupture in intermediate-depth earthquakes, defined as those between 60 kilometers and 300 kilometers deep (37 miles to 186 miles).

"We found at these depths that the anisotropic rock fabric is always parallel to the slab surface, although the slab can change directions greatly from place to place," Li said.

Anisotropy is also found in rocks at even greater depths, which suggests materials such as magnesite or aligned carbonatite melt pockets may be involved in generating the deep ruptures, the researchers said. Because the inferred anisotropy is high—about 25 percent—the widely believed meta-stable solid phase change mechanism is not able to provide the needed anisotropy inferred by the researchers.

More information: Deep earthquakes in subducting slabs hosted in highly anisotropic rock fabric, *Nature Geoscience* (2018). DOI: 10.1038/s41561-018-0188-3, https://www.nature.com/articles/s41561-018-0188-3

Provided by University of Houston