Scientists may have solved mystery of giant Midwest earthquakes

Elizabeth Deatrick, Science Magazine, 9-26-16

Two centuries ago, a series of giant earthquakes rocked the tiny town of New Madrid, Missouri, collapsing chimneys and shaking houses more than 1000 kilometers away. It was even said that parts of the Mississippi River momentarily flowed backward as the riverbed heaved upward. Modern seismologists estimate that all three quakes in 1811–1812 registered above a 7.0 on the Richter scale—the largest known quakes east of the Rocky Mountains. Even today, the New Madrid Seismic Zone (NMSZ) generates more than 200 small tremors each year—and now a team of geophysicists thinks it knows what causes all the shaking.

In a new study, they use tomographic information about Earth's interior to show how blobs of dense rock from the lower crust rise up underneath the region. This dense rock gravitationally tugs on everything else around it, changing regional stresses in a way that makes some NMSZ faults more likely to slip. The approach not only confirms some scientists' suspicions about the driving force behind the NMSZ earthquakes, but it also opens the door to identifying other potentially deadly seismic areas. "We're interested in creating an honest-to-goodness map of where we think earthquakes will occur in the future," says lead author Will Levandowski, a geophysicist with the United States Geological Survey (USGS) in Golden, Colorado.

The NMSZ has been difficult to study. The region doesn't generate large earthquakes often enough for seismologists to have a detailed historical record, and there is no obvious mechanism driving the seismic activity. Elsewhere in the world, earthquakes tend to occur along active faults, like the San Andreas Fault in California, where two tectonic plates meet and push, pull, or slide against one another. But the NMSZ is smack in the middle of the quiet, solid North American plate. "Here, in the center of a plate, we don't have a theory that we can attribute the earthquakes to," says Christine Powell, a seismologist at the University of Memphis in Tennessee. "So in order to understand why they're occurring, you have to think outside the box."

One idea is that an ancient rifting event plays a role. Between 700 million and 540 million years ago, what is now the North American Plate was being pulled apart as it broke away from a supercontinent. The plate failed to split completely, but geologists think that the event left scars below the NMSZ: a buried rift zone, where the rocks are weak and fractured, over plutons—blobs of dense igneous rock—that themselves rose from an upwelling of unusually dense lower crust. Although this scenario has been proposed before, the researchers combined different data sets to provide strong support for the idea that the lower crust wells up beneath the NMSZ, they report in a study published 30 August in *Geophysical Research Letters*.

Key to the team's analysis was seismic velocity data from the U.S. Transportable Array, a traveling grid of seismometers that "listens" for low-level earthquakes and tracks the way their energy passes through the subsurface. The speeds of these seismic waves are related to the density of the rocks underground, and they allow researchers to construct a tomographic view of Earth's interior, like a computerized tomography scan.

The researchers also calculated how the presence of this dense lower crust would alter the stresses that drive earthquakes. The dense rocks' higher gravity pulls the surrounding land inward and downward. Already, the Mid-Atlantic Ridge, which runs down the middle of the Atlantic Ocean, is spreading and putting pressure on the North American plate, pushing it westward. But the high-density rocks below the NMSZ redirect that pressure downward, putting faults in the buried rift zone under significantly more pressure than the surrounding terrain. Under the right conditions, that pressure can be released as an earthquake.

Identifying potential earthquake triggers, however, is more difficult, and the researchers suggest that quakes might be set off by any number of factors. Between 16,000 and 10,000 years ago, for instance, geologic evidence suggests that the region became seismically active after the Mississippi River eroded too much soil from the ground above. Without the weight of the soil, faults that had been locked in place were unclamped, and could release energy through earthquakes.

Experts say the work could be used to explain why some areas are more prone to human-induced earthquakes, such as Oklahoma, which now sees more earthquakes than California. Fracking-related activities might be more likely to trigger an earthquake in an area that was already under stress, according to Roland Bürgmann, a geophysicist at the University of California, Berkeley. “I think the approach [the authors] take here is a useful one to bring to bear on that,” he says.

In addition, the approach could be used to identify regions that are naturally under stress and prone to earthquakes. Levandowski suggests that using similar techniques, USGS might be able to find other vulnerable faults that haven’t produced an earthquake in recorded history. Though Powell approves of the team’s New Madrid analysis, she is skeptical of its broader application—in part because each of these seismic zones is unique. “I think it’s going to take careful study and investigation to really sort out what we’re seeing,” she says.