Geosciences researcher pushing the boundaries on how we measure the spectrum of earthquakes

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Penn State researcher Demian Saffer (middle) has been helping to lead several international teams focused on installing new earthquake monitoring equipment in Japan. Here, Saffer stands with fellow co-chief scientists Lisa McNeill from the United Kingdom's National Oceanography Centre and Sean Toczko from the Japan Agency for Marine-Earth Science and Technology. Credit: Demian Saffer / Penn State

Japan's Nankai Trough is home to some of the world's biggest earthquakes, but researchers are now seeing another type of earthquake in the trough that is not well understood: slow earthquakes. Only discovered in the last few decades, slow earthquakes are evidence that earthquakes come in many forms, from normal earthquakes releasing energy over seconds or minutes to slow earthquakes unfolding over days to weeks. Penn State researcher Demian Saffer has been at the forefront of devising ways to monitor these slow earthquakes in regions far offshore and helping to lead international teams on missions to collect new data about their geologic context.

Saffer, a professor of geosciences at Penn State, recently completed his third stint as a co-chief scientist on board an International Ocean Drilling Program (IODP) expedition to install new monitoring devices in the Nankai Trough. Located in the Ring of Fire, the trough extends for 500 miles just offshore of Japan and has been the source of magnitude 8–class earthquakes every one to two centuries.

"One reason the Nankai Trough has been the focus of international research is because there is a 1,300-year historical record of major earthquakes occurring there every 100 to 150 years," says Saffer. "Most of these earthquakes have been magnitude 8 or larger, and because the fault is beneath the ocean floor, the earthquakes commonly generate tsunamis that affect major population centers in coastal Japan."

The trench is at a subduction fault zone, where one tectonic plate is being dragged beneath an over-riding tectonic plate. In the course of this tectonic movement, stress accumulates over many years and then is released in a matter of minutes—resulting in a major earthquake every 100-150 years in the Nankai Trough. But, the team has discovered, slow earthquakes are another result of tectonic activity occurring periodically in the trough.

Located south of Japan's Honshu island and part of the Ring of Fire, the Nankai Trough is home to a spectrum of earthquakes. Credit: Penn State

Slow earthquakes: domino or other effect?

Slow earthquakes can disperse the same amount of energy as a typical earthquake but over a longer period of time. In traditional earthquakes, stress builds up over years or decades and is relieved in a matter of seconds to minutes, and the fault might slip at rates of one meter per second or more.

"Slow earthquakes might host the same amount of slip, but it occurs over days to weeks. It doesn't shake anything, but it relieves a comparable amount of stress," says Saffer.

Scientists are grappling with the implications of this physical relieving of stress.

Saffer (L) discusses the mission's science plan. The international team, which Saffer co-led, installed new earthquake monitoring equipment beneath Japan's sea floor. Credit: Demian Saffer

"There's speculation that they could be tightening the screws on nearby fault patches, thus increasing the hazard for future earthquakes. We're not at a stage where we can say definitively how slow earthquakes affect the loading of the fault or potential earthquake slip in the future. They could create different outcomes in different contexts by relieving stress in some cases and increasing it in others," Saffer says.

To know more about these processes, researchers need to know more about the frequency, magnitude and location of slow earthquakes, and that's what Saffer and the IODP team have set out to do. Collecting data from a trough beneath the sea floor has been a longstanding challenge. The shifting ocean adds unwanted noise to the data they are collecting, making it hard to pinpoint the low-frequency signal of slow earthquakes.

Avoiding vibration pollution

To get around the noise issue, the IODP team placed its instruments under the sea floor, which is more than 1.5 miles below the ocean's surface. The team drilled almost half a mile below the ocean floor to install a suite of instruments known as a long-term observatory, which Saffer helped conceive. It's the second observatory the team has installed in the trough since 2010, and the two observatories work in tandem to collect data on rock deformation, changes in fluid pressure and tilt, and the occurrence, magnitude and frequency of small earthquakes. Each observatory is connected to a wired network that can feed data, sampled in one-second intervals, in real time to scientists worldwide.

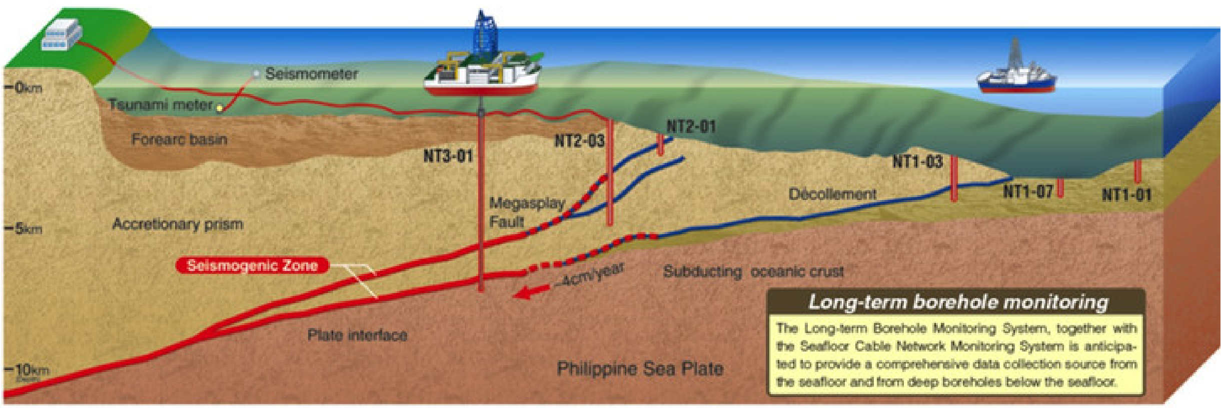
Specialized equipment allowed the team to drill down more than 1.5 miles below the ocean's surface, where they installed their long-term monitoring equipment. Credit: Demian Saffer

When installing the most recent long-term observatory, the team also retrieved a simpler temporary data collection device termed a "genius plug" that included sensors attached to a seal clamped inside the borehole (which Saffer also helped devise), and which serves as a low-tech version of the observatory. Saffer says he's been working feverishly to analyze the five years of data that the device collected.

"One thing that's really exciting is that we see repeated slow earthquakes that appear to occur approximately every year or so over a couple weeks' time, but only in outermost reaches of the subduction zone, near the trench," he says.

The team is also beginning to link slow earthquakes to bigger earthquakes, such as the magnitude 7 earthquake that struck Kumamoto, Japan, on April 16, 2016.

"The Kumamoto earthquake happened on land, on a different island from where our sensors were stationed. But we still detected slow earthquakes afterward. It's too far away to be an aftershock, but it's almost like we've detected a tectonic kick that may have triggered the slow slip," he says.



Cross-section of the location where the IODP team installed new monitoring equipment. Credit: The NanTroSEIZE Scientific Team - CC BY-SA 3.0

Homing in on slow earthquakes in New Zealand

Saffer now has his sights set on New Zealand, which researchers recently discovered is a hotbed of major slow earthquakes with slip equivalent to magnitude 6 or 7 events, but not large normal earthquakes. So the team applied for, and received, funding for another IODP drilling project, which is scheduled to begin in 2018. It will be the first IODP project to target slow earthquakes from the outset.

"We want to find out what's going on in the fault zone that's resulting in slow earthquakes instead of damaging normal ones. Does the slow slip reduce the risk of major earthquakes? Are they adding or relieving stress to adjacent fault patches?" says Saffer, who serves as lead principal investigator on the project.

As they gather more data, the team will get closer to understanding the implications of slow earthquakes and whether they are linked to larger, more damaging earthquakes.

"As a scientist who studies subduction zones, the real exciting problems are occurring in the ocean where tectonic plates meet," says Saffer. "Getting into the subsurface and collecting data in the near-field of the fault zones will help us understand key processes and conditions in the Earth that facilitate slow earthquakes, why they occur where and when they do, whether they pose a risk for uplifting the sea floor and generating tsunamis, and overall what kinds of possible impact these events might have."

Provided by Pennsylvania State University

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