New report illuminates stress change during the 2011 Tohoku-Oki earthquake

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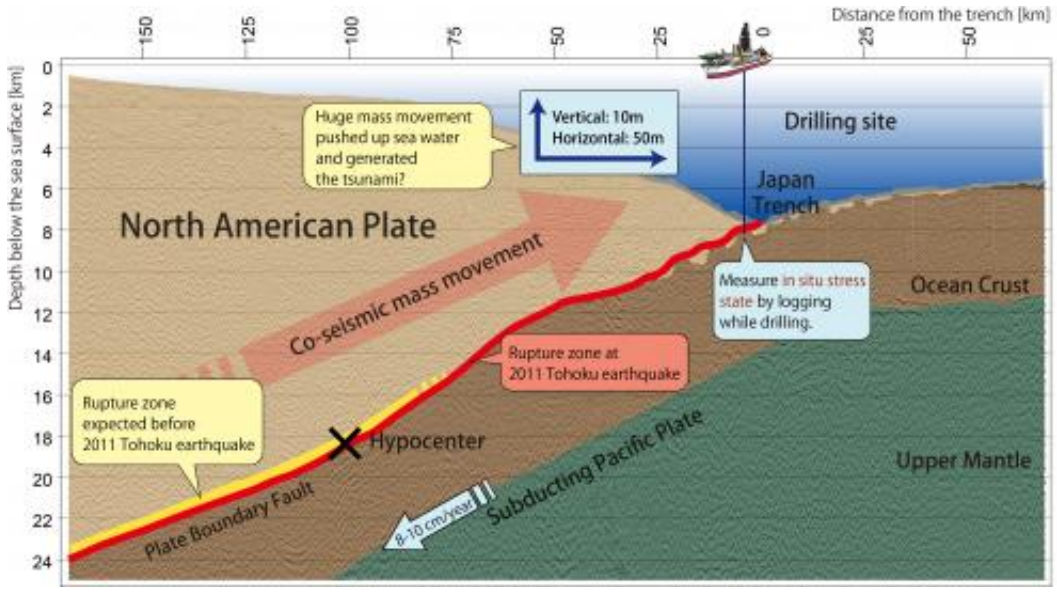

This is a conceptual image of the sub-seafloor structure at the JFAST drilling site. Credit: JAMSTEC/IODP

The 11 March 2011 Tohoku-Oki earthquake (Mw9.0) produced the largest slip ever recorded in an earthquake, over 50 meters. Such huge fault movement on the shallow portion of the megathrust boundary came as a surprise to seismologists because this portion of the subduction zone was not thought to be accumulating stress prior to the earthquake.

In a recently published study, scientists from the Integrated Ocean Drilling Program (IODP) shed light on the stress state on the fault that

controls the very large slip. The unexpectedly large fault displacements resulted in the devastating tsunamis that caused tremendous damage and loss of lives along the coast of Japan. The study, published in 8 February 2013 issue of the journal *Science*, presents compelling evidence that large slips are the results of a complete stress drop during the earthquake. These new findings from IODP Japan Trench Fast Drilling Project (JFAST) research are relevant to better understanding earthquakes and tsunamis in many areas of the world.

"The study investigated the stress change associated with the 2011 Tohoku-Oki earthquake and tested the hypothesis by determining the in-situ stress state of the frontal prism from the drilled holes," says a lead author Weiren Lin of Japan Agency for Marine-Earth Science and Technology (JAMSTEC). "We have established a new framework that the large slips in this region are an indication of coseismic fault zone and nearly the total stress accumulated was released during the earthquake."

JFAST was designed and undertaken by the international scientific community to better understand the 2011 Tohoku-oki earthquake. The expedition was carried out aboard the scientific drilling vessel Chikyu from April to July 2012. JFAST drill sites were located approximately 220 km from the eastern coast of Honshu, Japan, in nearly 7000 m of water.

"The project is looking at the stress and physical properties of the fault zone soon after a large earthquake," co-author James Mori of Kyoto University, Co-Chief Scientist who led the JFAST expedition explains.

It is the first time that "rapid-response drilling" (within 13 months after the earthquake) has been attempted to measure the temperature across a subduction fault zone. The fast mobilization is necessary to observe time sensitive data, such as the temperature signal. JAMSTEC successfully mobilized a research expedition for IODP to investigate the large

displacement by drilling from the ocean floor to the plate boundary, reaching a maximum depth of more than 850 m below seafloor (mbsf).

"Understanding the stress conditions that control the very large slip of this shallow portion of the megathrust may be the most important seismological issue for this earthquake." Mori says.

The research published this week determined the stress field from breakouts observed in a borehole around 820 mbsf, in a region thought to contain the main slip zone of the 2011 earthquake. Lin and his co-authors analyzed a suite of borehole-logging data collected while drilling with Logging-While-Drilling (LWD) tools during IODP Expedition 343. Local compressive failures (borehole breakouts) are formed in the borehole wall during the drilling and are imaged with the LWD tools. The orientation and size of the breakouts are used to infer the present direction and magnitudes of the stress field. An important finding of the paper is that the present shear stress on the fault is nearly zero, indicating that there was a nearly complete stress change during the earthquake. Usually, earthquakes are thought to release only a portion of the stress on the fault.

"This was the first time for such nearly complete stress change has been recognized by direct measurement in drilling through the ruptured fault. This is the first time direct stress measurements have been reported, a little over a year after a great subduction zone earthquake." Lin says.

The expedition set new milestones in scientific ocean drilling by drilling a borehole to 854.81 mbsf in water depths of 6897.5 meters. Deep core was obtained and analyzed from this depth. The Japan Trench plate boundary was sampled and a parallel borehole was instrumented with a borehole observatory system. The core samples and borehole observatory provide scientists with valuable opportunities to learn about residual heat, coseismic frictional stress, fluid and rock properties, and other

factors related to megathrust earthquakes.

"We will be able to address very fundamental and important questions about the physics of slip of the thrust near the trench, and how to identify past events in the rock record." says Frederick Chester, Texas A&M University, co-author of the *Science* report and the other expedition Co-Chief Scientist.

The expedition science party, comprising both ship-board and shore-based scientists, is conducting further investigations of core samples and borehole logging data. Data from the borehole observatory are expected to be retrieved later this month using the JAMSTEC ROV Kaiko7000II, and those data will be combined with the current results to continue to increase understanding of the processes involved in this large slip earthquake.

"We anticipate that the results from the JFAST expedition will provide us with a better understanding of the faulting mechanisms for this critical location," says Mori. "Investigations and research findings from the expedition have obvious consequences for evaluating future tsunami hazards at other subduction zones around the world, such as the Nankai Trough in Japan and Cascadia in the Pacific of North America."

More information: For more information about JFAST project, latest images and blogs from the expedition, visit www.jamstec.go.jp/chikyu/exp343/

"Stress State in the Largest Displacement Area of the 2011 Tohoku-Oki Earthquake," by W. Lin et al., *Science*, 2013.

Provided by Integrated Ocean Drilling Program Management

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