Press Releases

December 6, 2013
JAMSTEC
Kyoto University
Tukuba University
Tohoku University
Yamagata University

Structural, mechanical and thermal characteristics of the shallow plate boundary fault of the 2011 Tohoku-Oki earthquake, revealed by the IODP *Chikyu* Expedition.

The Japan Agency for Marine-Earth Science and Technology (JAMSTEC: Asahiko Taira, President) scientific drilling vessel *Chikyu* expeditions (Expeditions 343 and 343T) have been conducted off Tohoku from 1st April to 24 May and 5 to 19 July, 2012, and successfully recovered core samples and conducted temperature measurement in the borehole from the extreme ocean depths of nearly 7000 meters.
Three papers will be published in SCIENCE (2:00 p.m. U.S. Eastern Time on Thursday, 5 December), which show tremendous results of the Expeditions.

Structure and composition of the plate-boundary slip zone for the 2011 Tohoku-Oki earthquake (Chester et al.)

The mechanics of great subduction earthquakes are influenced by the frictional properties, structure, and composition of the plate-boundary fault. We present observations of the structure and composition of the shallow source fault of the 2011 Tohoku-Oki earthquake and tsunami from boreholes drilled by the Integrated Ocean Drilling Program Expedition 343 and 343T. Logging-while-drilling and core-sample observations show a single major plate-boundary fault accommodated the large slip of the Tohoku-Oki earthquake rupture, as well as nearly all the cumulative interplate motion at the drill site. The localization of deformation onto a limited thickness (less than 5 meters) of pelagic clay is the defining characteristic of the shallow earthquake fault, suggesting that the pelagic clay may be a regionally important control on tsunamigenic earthquakes.

Low coseismic shear stress on the Tohoku-Oki megathrust determined from laboratory experiments (Ujiie et al.)

Large coseismic slip was thought to be unlikely to occur on the shallow portions of plate-boundary thrusts, but the 11 March 2011 Tohoku-Oki earthquake [moment magnitude (Mw) 9.0] produced huge displacements of ~50 meters near the Japan Trench with a resultant devastating tsunami. To investigate the mechanisms of the

very large fault movements, we conducted high-velocity (1.3 meters per second) friction experiments on samples retrieved from the plate-boundary thrust associated with the earthquake. The results show a small stress drop with very low peak and steady-state shear stress. The very low shear stress can be attributed to the abundance of weak clay (smectite) and thermal pressurization effects, which can facilitate fault slip. This behavior provides an explanation for the huge shallow slip that occurred during the earthquake.

Low coseismic friction on the Tohoku-Oki fault determined from temperature measurements (Fulton et al.)

The frictional resistance on a fault during slip controls earthquake dynamics. Friction dissipates heat during an earthquake; therefore, the fault temperature after an earthquake provides insight into the level of friction. The Japan Trench Fast Drilling Project (Integrated Ocean Drilling Program Expedition 343 and 343T) installed a borehole temperature observatory 16 months after the March 2011 moment magnitude 9.0 Tohoku-Oki earthquake across the fault where slip was ~50 meters near the trench. After 9 months of operation, the complete sensor string was recovered. A 0.31°C temperature anomaly at the plate boundary fault corresponds to 27 megajoules per square meter of dissipated energy during the earthquake. The resulting apparent friction coefficient of 0.08 is considerably smaller than static values for most rocks.

*1. The Integrated Ocean Drilling Program (IODP)
(from October 1st, IODP stands for the International Ocean Discovery Program) IODP is an international marine research drilling program dedicated to advancing scientific understanding of the Earth by monitoring and sampling subseafloor environments. Through multiple platforms, scientists explore IODP's principal themes: the deep biosphere, environmental change, and solid Earth cycles. IODP has been in operation since October 2003, funded jointly by the Japan Ministry of Education, Culture, Sports, Science and Technology and by the U.S. National Science Foundation. Additional support is provided by the 18-member European Consortium of Ocean Research Drilling (ECORD), the People's Republic of China, the Republic of Korea, India, Australia and New Zealand (ANZIC) and Federative Republic of Brazil.

*2. The Japan Trench Fast Drilling Project (JFAST)
The goal of JFAST is to understand the physical mechanisms and dynamics of large slip earthquakes that produce devastating tsunamis. During the main JFAST expedition (IODP Expedition 343, April and May 2012), a logging-while-drilling borehole was drilled to 850.5 meters below seafloor (mbsf) to locate the fault that slipped during the earthquake, and a coring hole was drilled to 844.5 mbsf to acquire core samples from the fault. Because of delays associated with severe weather and technical challenges of operating in great water depths, completion of the observatory hole was not achieved during the main expedition; however, the observatory hole was completed to 855 mbsf and the observatory sensors were successfully deployed during the short technical extension (IODP Expedition 343T, in July 2012). Observatory data were retrieved from the borehole in April 2013.

Authors

Structure and composition of the plate-boundary slip zone for the 2011 Tohoku-Oki earthquake

Frederick M. Chester, Christie Rowe, Kohtaro Ujiie, James Kirkpatrick, Christine Regalla, Francesca Remitti, J. Casey Moore, Virginia Toy, Monica Wolfson-Schwehr, Santanu Bose, Jun Kameda, James J. Mori, Emily E. Brodsky, Nobuhisa Eguchi, Sean Toczko, and Expedition 343 and 343T Scientists
Chester: Center for Tectonophysics, Department of Geology and Geophysics, Texas A&M University, College Station TX 77843-3115 USA

Low coseismic shear stress on the Tohoku-Oki megathrust determined from laboratory experiments

Kohtaro Ujiie, Hanae Tanaka, Tsubasa Saito, Akito Tsutsumi, James J. Mori, Jun Kameda, Emily E. Brodsky, Frederick M. Chester, Nobuhisa Eguchi, Sean Toczko, and Expedition 343 and 343T Scientists
Ujiie: Graduate School of Life and Environmental Sciences, University of Tsukuba, Japan, and Institute for Research on Earth Evolution, Japan Agency for Marine-Earth Science and Technology, Yokosuka, Japan

Low coseismic friction on the Tohoku-Oki fault determined from temperature measurements

Fulton, P. M., E. E. Brodsky, Y. Kano, J. Mori, F. Chester, T. Ishikawa, R. N Harris, W. Lin, N. Eguchi, S. Tozcko and the Exp. 343/343T Scientists
Fulton: Dept. of Earth & Planetary Sciences, University of California, Santa Cruz.

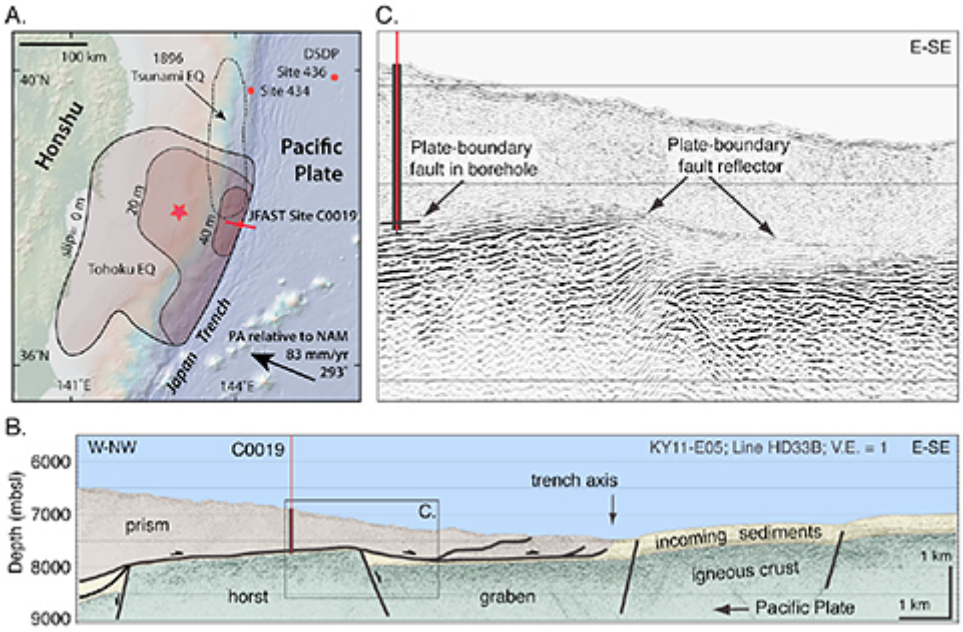

Figure 1. Location and structural setting of the JFAST drill site C0019 in the vicinity of the 2011 Tohoku-Oki earthquake rupture area. A) Drilling site and coseismic slip in meter are showed. B) Cross section of drill site. C) Detail structure at the drill site.

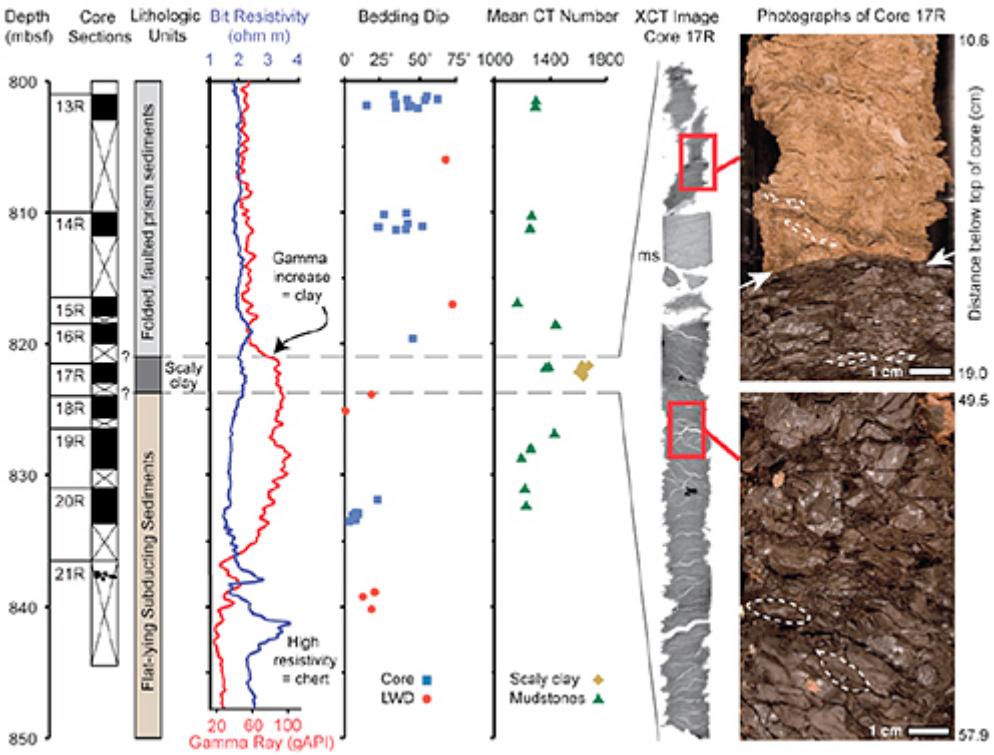

Figure 2. Logging, core description and images of the décollement sampled in core C0019E-17R-1.

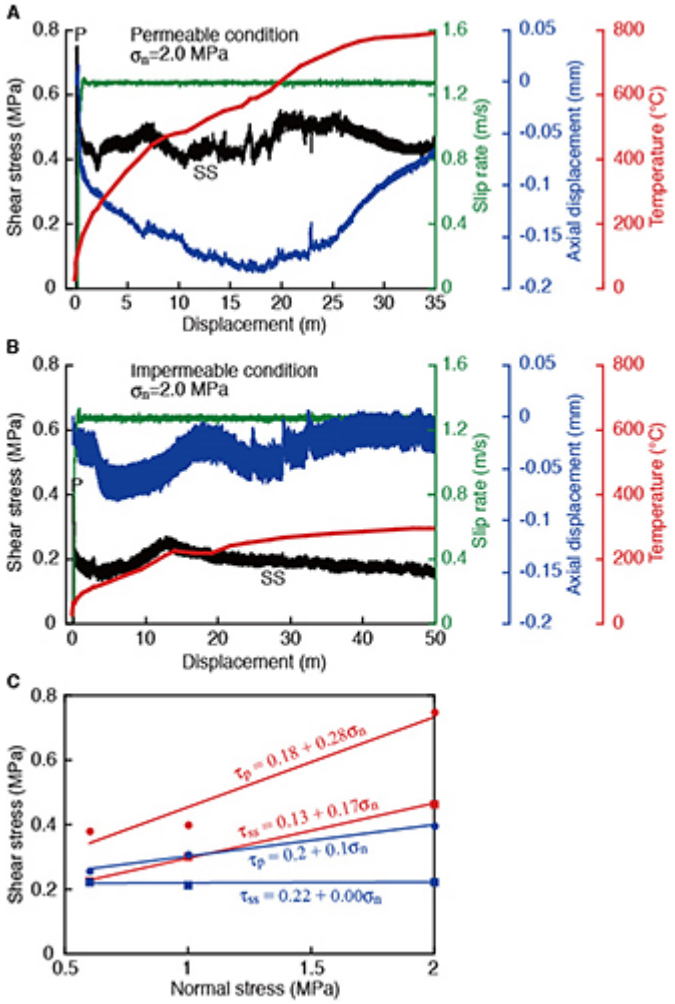

Figure 3. Experimental results for the Japan Trench décollement material at seismic slip rates. Apparent friction coefficient, slip rate, axial displacement, and temperature during high-velocity shearing under permeable (A) and impermeable (B) conditions. (C) Peak shear stress (τ_p) and steady-state shear stress (τ_{ss}) versus normal stress (σ_n) under impermeable conditions.

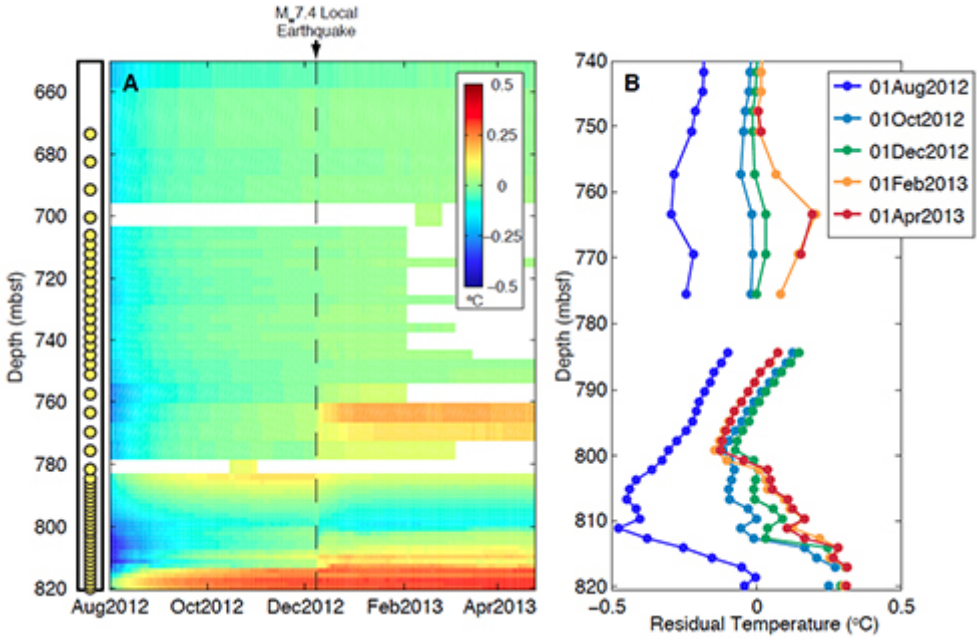

Figure 4. Subseafloor residual temperature field. A) Time/space map of data >650mbsf. B) Depth profile of residual temperature from 29 October 2012.

Contacts:
Japan Agency for Marine-Earth Science and Technology
(For *Chikyu*)
Dr. Shin'ichi Kuramoto, Deputy Director
Planning and Coordination Department
Center for Deep Earth Exploration (CDEX)

(For publication)
Kazushige Kikuchi, Section Head
JAMSTEC Public Relations Department