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Fast response drilling and instrumentation of the 2011 Tohoku-Oki earthquake fault: reviewing present accomplishments of IODP Expeditions 343 and 343T

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Integrated Ocean Drilling Program (IODP) Expeditions 343 and 343T were conducted as a fast response to the great (moment magnitude = 9.0) 11th March 2011 Tohoku-Oki earthquake. The event produced very large displacements of about 50 meters near the Japan Trench, causing a devastating tsunami. Objectives accomplished on the expeditions were to drill, core and instrument boreholes (IODP Site C0019) targeted at the plate-boundary fault. Logging-while-drilling and core-sample observations showed that the large slip of the earthquake rupture was accommodated on a single slip zone hosted by a pelagic clay layer of less than five meters thickness, derived from the incoming Pacific Plate (Chester et al., 2013). This smectite-rich pelagic clay is the defining characteristic of the shallow earthquake fault, and implies a regionally important stratigraphic control on tsunamigenic earthquakes.

As frictional resistance on a fault during slip controls earthquake dynamics, the fault temperature after an earthquake offers important insight into the friction coefficient. The borehole temperature observatory was installed sixteen months after the earthquake across the fault, and the sensor string was successfully retrieved after nine months of operation. A 0.31°C temperature anomaly at the plate boundary fault was recorded. This corresponds to about 27 megajoules of energy per square meter dissipated energy during the earthquake (Fulton et al., 2013). The resulting apparent friction coefficient is 0.08. This is a value considerably lower than static friction coefficients known for most rocks.

High-velocity (1.3 meters per second) friction experiments on core samples of smectite-rich clay from the plate-boundary fault show very low peak and steady-state shear stresses, low friction coefficients, and very low stress drops (Ujiie et al., 2013). The low resistance to shear can be attributed to the abundance of weak clay minerals (smectite) and thermal pressurization effects, which can facilitate fault slip. Extremely low coseismic strength of the plate-boundary fault is consistent with the inference of nearly total stress release during the earthquake from the post-seismic in situ stress determined from image logs and measurements of uniaxial compressive strength of sediments (Lin et al., 2013).

References:

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