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Large Slip and Fault Friction: Proposal to Drill the Fault of the 2011 Tohoku Earthquake

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The shallow distribution of large slip for the 2011 Tohoku earthquake provides an unprecedented opportunity to directly access a fault that has recently moved tens of meters. We have proposed to the Integrated Ocean Drilling Program (IODP) that a 800 to 1000 m borehole be drilled into the seafloor to penetrate the slip surface of the megathrust. Analyses of the deformation textures, chemical properties, and mineralogy of the fault zone will likely provide valuable information about the faulting process of the recent and past earthquakes.

Another important focus of this project is the rapid drilling into the fault zone to capture time-dependent data that is only available immediately after the earthquake. The highest priority is for temperature measurements across the fault zone to determine the amount of frictional heat generated by the earthquake. We plan to make observations of a decaying temperature signal over several years, to estimate the level of dynamic friction during the large rupture. The dynamic friction is the basic parameter that controls the behavior of the fault slip during an earthquake. To obtain good resolution of the thermal signal, initial measurements need to be made within 2 years. Therefore, with consideration of time for thermal stabilization and logistical constraints, the borehole should be completed by summer 2012. In addition to the temperature observations, other time sensitive measurements, such as borehole stress and changing chemical compositions will provide insights on the rupture mechanisms.

Key scientific questions and methods to addresses these issues include,

1) What was the stress state on the fault that controls rupture during the earthquake and was the stress completely released?

Dynamic friction during the rupture - Potentially the most significant result of this project will be a value for the dynamic coefficient of friction. The temperature measurements will be used to estimate the frictional heat produced at the time of the earthquake, which can be used to infer the level of dynamic friction.

Rupture to the tip of accretionary wedge - Past thinking was that sediments in this region are weak, so earthquake instability should not nucleate or easily propagate through this region. Measurements of current stress and stress during the earthquake can be used to explore different models to explain how slip occurred in this region.

2) What are the characteristics of large earthquakes in the fault zone, and how can we distringuish present and past events in the fault zone cores?

Core Analyses – Detailed analyses of textures and small-scale structures of core samples of the fault zone will be used to infer the role of fluids and pressurization during rupture. We will look for evidence of melting from pseudotachylytes. Trace elements will be used to estimate the thermal history of the recent and past events.

Laboratory Experiments - High-speed friction and petrophysical experiments on fault material can be used to characterize the frictional behavior of the fault.