Insights into earthquake processes from borehole temperature monitoring within the Japan Trench plate boundary fault zone

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Sub-seafloor temperature monitoring within the Japan Trench plate boundary fault zone has revealed great insight into hydrologic, thermal, and stress conditions, and dynamic earthquake processes. These observations come from a sub-seafloor temperature observatory installed across the main plate boundary fault as part of the Integrated Ocean Drilling Program's Japan Trench Fast Drilling Project (JFAST): Expeditions 343/343T. The observatory was installed following the March 2011 Mw 9.0 Tohoku-oki earthquake and was operation from July 2012 through April 2013 during which time nearby a Mw 7.3 earthquake doublet and a large number of aftershocks occurred.

Key discoveries from the JFAST temperature observatory include:
1) Direct measurements of the frictional heat signature of the March 2011 Mw 9.0 Tohoku-oki earthquake that constrains the co-seismic plate boundary frictional stress to very low values.
2) A deep robust measure of heat flow in the near-trench area that is consistent with low long-term frictional resistance during slip along the shallow fault zone interface.
3) Characterization of the hydrogeologic structure and fault zone architecture suggesting a low-permeability fault core surrounded by a ~100 m wide more permeable damage zone above.
4) In situ observations indicative of transient fluid flow out of discrete faults and fractures in response to earthquakes.
5) Observations suggestive of damage and healing processes within the damage zone during a major aftershock sequence.

The observatory data form one component of the JFAST project that also includes logging-while-drilling data and geologic and experimental analyses on core samples from above, below, and within the plate boundary fault itself. The design of the JFAST temperature observatory builds upon thermal monitoring programs in other IODP observatories largely focused on large-scale sub-seafloor hydrogeology. The JFAST observations highlight the utility of using high-resolution (~mK accuracy), closely-spaced (m-scale) temperature sensors to characterize processes and conditions within an active fault zone. Whereas the JFAST observatory was a temporary deployment consisting only of temperature measurements, we hope to someday return to the Japan Trench and install a long-term observatory consisting of both thermal and pore pressure measurements to characterize long-term healing processes and continued transient behavior. Observations and analysis techniques gained from the JFAST observatory have provided guidance for thermal monitoring efforts in the Hikurangi Margin where observatories that integrate temperature, pore pressure, and geochemical monitoring are scheduled to be installed in areas of known shallow slow slip.

Keywords: Japan Trench, IODP Expedition 343, JFAST, temperature, observatory, fault

