IODP³

INTERNATIONAL OCEAN DRILLING PROGRAMME

PROPOSAL 1106-FULL

Extended Monitoring and Resurveying of Japan Trench Borehole Observatories

IODP^3 Proposal Cover Sheet

Proposal Title:

Extended Monitoring and Resurveying of Japan Trench Borehole Observatories

Broad Geographic Area of the Proposal

Japan Trench

Project Abstract

This proposal seeks to extend the scientific value of the borehole observatories installed during IODP Expedition 405 and 1013-APL by redeploying temperature sensor strings into Holes C0019D and C0019Q after the retrieval in 2025 and conducting borehole surveys within the existing borehole tubing to assess potential fault movement and deformation. The redeployed instruments will enable an additional ~5 years of continuous monitoring, providing long-term constraints on the hydrogeologic evolution, permeability structure, and mechanical behavior of the shallow Japan Trench megathrust.

Previous observations from the JFAST (IODP Exp. 343) and JTRACK (IODP Exp. 405) projects demonstrated that the shallow fault remains hydrologically active, with transient fluid flow responses to earthquakes and persistent advective signals. Borehole temperature monitoring has also provided critical constraints on permeability, fluid migration pathways, and stress conditions within the megathrust fault zone. However, key uncertainties remain regarding the long-term evolution of fault strength, hydrologic properties, and postseismic deformation.

To address these gaps, we propose:

1 Redeployment of temperature sensors in C0019D and C0019Q to extend the observational record and evaluate the evolution of fluid flow, permeability, and hydrogeologic transients.

2 A borehole resurvey of C0019D and C0019Q (~2030) to determine whether continued aseismic slip and borehole deformation is occurring.

3 A camera survey of C0019D (2025) to visually assess the nature of casing deformation and refine interpretations of fault movement.

These efforts will provide unprecedented long-term observations of the fault zone’s hydrologic and mechanical evolution, and will be integrated through modeling and analysis of extant pore water geochemistry and logging and core data to yield insights into postseismic fault healing, fluid pressure dynamics, and permeability structure at the Japan Trench. The results will have broad implications for megathrust fault behavior, seismic hazard assessment, and subduction zone hydrogeology, informing models of stress accumulation and earthquake recurrence.

Scientific Objectives

This project aims to test key hypotheses about the long-term hydrogeologic and mechanical evolution of the Japan Trench megathrust by redeploying temperature sensor strings in observatory Holes C0019D and C0019Q and conducting surveys of downhole deformation. Specifically, we hypothesize that permeability within the fault damage zone remains elevated relative to the plate boundary fault core and that hydrogeologic properties continue to evolve due to healing processes. Redeployed temperature sensors will allow us to assess changes over time by capturing thermal anomalies associated with fluid migration and hydrogeologic transients.

We further hypothesize that horizontal fluid flow past the borehole varies with depth, reflecting structural heterogeneities within the fault zone. A Thermal Response Test will quantify background flow rates past the borehole casing, providing direct constraints on lateral fluid migration and its role in pressure redistribution. These data will be integrated with geochemical observations and temperature time-series analysis to assess the role of fluids in modulating fault strength.

A key mechanical objective is to determine whether aseismic slip is ongoing or whether deformation observed in C0019D’s tubing occurred primarily soon after the original JFAST observatory installation in 2012. A 2024 borehole drift survey revealed casing bending at ~821 mbsf, suggesting prior fault movement. Follow-up surveys in ~2030 will test whether further deformation has occurred. Additionally, a camera survey in 2025 will provide visual evidence to distinguish between minor borehole bending and more substantial displacement. These results will improve our understanding of postseismic fault healing, stress accumulation, and megathrust behavior.

Science Communication Plain Language Summary

Subduction zones, where one tectonic plate slides beneath another, produce some of the world’s largest earthquakes and tsunamis. The 2011 Mw 9.1 Tohoku-oki earthquake off the coast of Japan was one of the most extreme examples, generating over 50 meters of seafloor movement. Understanding how these faults behave after such massive ruptures is crucial for assessing long-term earthquake and tsunami hazards.

Following the 2011 earthquake, scientists installed specialized temperature sensors deep beneath the seafloor in the Japan Trench to study how the fault was evolving. These instruments provided critical data on heat left

behind from the earthquake, fluid flow along the fault, and what happens underground during distant aftershocks. In 2024, new instruments were deployed as part of the JTRACK project to extend these observations, potentially capturing changes in fluid movement and fault behavior.

This proposal aims to continue this research by redeploying temperature sensors in two deep-sea boreholes after they are recovered in 2025 and surveying the borehole structures to detect any further fault movement. By extending observations for an additional five years, we will test whether fluid pathways within the fault zone remain open or gradually seal over time, a process that could influence future earthquake behavior. Special temperature monitoring techniques will also allow us to measure how fluid flows past the fault, improving our understanding of how water pressure affects fault strength.

In addition, a previous borehole survey found that the metal casing in one borehole had bent, likely due to movement of the fault since the sensors were first installed in 2012. However, scientists are unsure if this movement is ongoing. A proposed follow-up borehole resurvey in 2030 would test whether further deformation has occurred, while a camera inspection in 2025 would provide visual confirmation of how the casing was affected.

By continuing to monitor this fault zone, we hope to gather long-term data on how megathrust faults recover after large earthquakes. These findings will help us as scientists better understand how stress and fluid pressure influence earthquake cycles, not only in Japan but in other subduction zones worldwide. The results will provide valuable information for earthquake hazard assessment and improve models of how these massive faults behave over time.