IODP³

INTERNATIONAL OCEAN DRILLING PROGRAMME

PROPOSAL 1121-FULL

J-NORTH: Northern Japan Trench Rupture and Tsunami Hazard

IODP^3 Proposal Cover Sheet

Proposal Title:

J-NORTH: Northern Japan Trench Rupture and Tsunami Hazard

Broad Geographic Area of the Proposal

Japan trench. offshore of Honshu, Japan. ~39.2 degrees north

Project Abstract

Subduction zones produce the world's largest earthquakes and most destructive tsunamis, but the mechanisms that govern earthquake propagation and slip in the near trench region that lead to tsunamis are poorly constrained. The 2011 Mw 9.0 Tohoku earthquake demonstrated the catastrophic consequences of shallow déco lement slip, generating a devastating tsunami that caused nearly 20,000 fatalities. Peak slip in the 2011 earthquake occurred up-dip of the hypocenter, and was the primary cause of the severe tsunami inundation around Sendai. However, the tsunami was even larger ~100 km to the north, along the Sanriku coast, despite apparently reduced shallow slip. This northern region also generated the 1896 Sanriku "tsunami earthquake" and has experienced multiple tsunami-generating earthquakes over the past millennia. Emerging geophysical and geological evidence suggests this portion of the margin has a fundamentally different slip behavior than farther south. Outstanding questions remain on where shallow, tsunamigenic fault slip occurs, what source processes generate tsunamis, and how variations in input lithology, hydration state, and oceanic plate roughness fundamentally change the style of slip behavior. These questions can only be addressed with scientific ocean drilling.

Here we propose a riserless scientific drilling expedition using the D/V Chikyu in the northern Japan Trench to test several leading hypotheses on the generation of tsunamigenic earthquakes. Our proposed drilling plan involves logging, coring and observatory installation to collect data that test hypotheses explaining how the properties of the shallow subduction system and incoming plate control shallow slip behaviour and promotes tsunami generation. Data from the proposed operations will also evaluate the role of fault slip and fluid flow on development and maintenance of distinct subseafloor microbial communities, the mass balance of sediment, fluids, and organic carbon in the subduction system, and climate-tectonic feedbacks in sediment routing. This proposal addresses IODP3 Flagship Initiatives and Strategic Objectives on earthquake and tsunami hazards with societal impacts, the evolution of tectonic plates, and feedbacks and mass cycling in Earth systems. The Japan Trench is an ideal location for this work, thanks to data gathered by geophysical and geological investigations and ocean drilling expeditions over the past decade that provide key constraints on expected subsurface structure and operational expertise that will help us achieve our scientific goals. The properties of this portion of the Japan trench are representative of many western Pacific subduction zones, and results will be broadly transferable to other systems worldwide.

Scientific Objectives

Our drilling proposal aims to test the following questions: Do the mechanical conditions of the shallow plate boundary promote slip-to-the-trench on the décollement and/or coseismic prism deformation? These are the two main mechanisms proposed to generate tsunami in northern Japan trench and similar subduction zones worldwide. Do volcanic alteration and roughness in the incoming plate change material properties and lead to heterogeneity in shallow décollement slip behavior and locking? Does a highly deformed prism support a well drained system that loads the margin and brings nutrients that sustain microbial communities? Understanding these conditions is critical for improving tsunami hazard models and forecasts.

To test these hypotheses we propose the following logging, core, and observatory operations on the DV Chikyu: 1) Drill the décollement on a subducted horst and graben to test for paleoseismic frictional heating signatures and quantify fault composition, architecture, and mechanical heterogeneity. 2) Drill the adjacent trench fill to test for earthquake-generated turbidites and near-trench coseismic deformation, and quantify organic carbon content and microbial communities. 3) Drill the prism to identify fault splays, measure the mechanical strength of prism and underthrust materials, quantify the composition and volume of subducted sediments, and quantify variations in microbial communities between wall rock and potentially nutrient rich fault zones. 4) Drill altered input sediments and crust to test if petit spot volcanism and crustal hydration change the mechanics of the décollemen t once subducted. 5) Install a temperature observatory to monitor fluid flow and determine hydrogeologic architecture of the plate boundary system.

Science Communication Plain Language Summary

The world's largest earthquakes and most destructive tsunamis occur at subduction zones, where one tectonic plate descends beneath another. Although we know these events happen, we still do not fully understand why some earthquakes produce devastating tsunamis while others do not.

The 2011 Tohoku earthquake and tsunami in Japan was an example of how dangerous these events can be. The earthquake generated a tsunami that caused nearly 20,000 deaths, cost billions of dollars in damages, and led to a nuclear disaster. One of the unexplained aspects of this event is why tsunami heights were so large along the northern Sanriku coast of Japan, even though the largest earthquake slip occurred 100 km to the south. Interestingly, this same region generated the deadly 1896 Sanriku tsunami earthquake as well as several other older tsunami-producing earthquakes. These observations suggest that the northern portion of the margin tends to generate tsunamis more readily than neighboring parts to the south, but the reasons remain unknown.

We propose a scientific ocean drilling expedition on the research vessel Chikyu to investigate why this region produces unusually large tsunamis. By drilling into the seafloor, collecting rock and sediment cores, measuring the physical properties of faults, and installing long-term instruments, we will determine what processes may or may not have generated tsunami in the past, and the likelihood that they may generate tsunami in the future. These data will also allow us to evaluate how differences in material properties, water content, and the roughness of the incoming oceanic plate influence earthquake rupture and tsunami generation. Furthermore, by analyzing the compositions, origins, and cell abundances of sediment and rock samples, we will evaluate how these environments support deep microbial life, how carbon and sediments are recycled into subduction zones, and how climate has influenced sediment delivery over time.

These data we propose to collect are needed to improve our understanding of earthquake and tsunami hazards in Japan and will apply to other subduction zones around the world. The findings will inform better models of tsunami generation, leading to improved hazard assessments and, ultimately, better preparedness for future disasters