

Setting up the Stage for Project MoHole: Seismic Studies of Fast-Spread Ocean Lithosphere

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The mid-ocean ridges and the new oceanic lithosphere that they create are the principal pathway for energy and mass exchange and physical/chemical interactions between the earth's interior, the hydrosphere, and the biosphere. Bio-geochemical reactions between the oceans and oceanic crust occur throughout its lifetime, and hence the ocean lithosphere records the inventory of global thermal, chemical and biological exchanges. The MoHole, an initiative to drill an ultra-deep hole in an intact portion of oceanic lithosphere, through the crust to the Mohorovičić discontinuity (Moho), and into the uppermost mantle is a long-standing goal of scientific ocean drilling. It remains critical to answer many fundamental questions about the dynamics of the Earth and global elemental cycles; its fundamental goals include:

- Determine the bulk composition of the oceanic crust to establish the chemical links between erupted lavas and primary mantle melts, understand the extent and intensity of seawater hydrothermal exchange with the lithosphere, and estimate the chemical fluxes returned to the mantle by subduction,
- Test competing hypotheses of the ocean crust accretion at fast spreading mid-ocean ridges, and quantify the linkages and feedbacks between magma intrusion, hydrothermal circulation and tectonic activity,
- Determine the geological meaning of the Moho in different oceanic settings,
- Determine the in situ composition, structure and physical properties of the uppermost mantle (and its variability), and understand mantle melt migration,
- Calibrate regional seismic measurements against recovered cores and borehole measurements, and understand the origin of marine magnetic anomalies,
- Establish the depth extent of deep biosphere and hydrological/geobiological processes in the lithosphere.

More detailed scientific rationale for the MoHole can be found in recent workshop reports:

- <http://www.iodp.org/mission-moho-workshop/>

- <http://www.interridge.org/WG/DeepEarthSampling/workshop2009>

A forthcoming workshop to be held in Kanazawa, Japan, in June 2010

(<http://earth.s.kanazawa-u.ac.jp/~Mohole/>) will identify 2-3 potential MoHole sites in the Pacific where the scientific community will focus geophysical site survey and post-drilling research efforts over the next few years. The type, resolving power, and coverage of geophysical data needed for site selection and to accomplish the post-drilling scientific goals will be amply discussed during the workshop.

In particular, seismic surveys are expected to be a fundamental component of MoHole critical to accomplish the goals of this ambitious project. These surveys will be more efficiently conducted through international collaborations involving several platforms of different characteristics. Among these platforms, the *R/V Langseth* will undoubtedly be a key resource because of her state-of-the-art seismic capabilities. We envision *Langseth* contributing to acquisition of one or more of several types of seismic data needed to support Project MoHole, which include:

(1) 3D multichannel seismic (MCS) data. MCS reflection imaging of the oceanic Moho is often degraded by in- and out-of-plane energy scattered by the rough igneous basement [e.g., *Kent et al.*, 1996]. Among the many benefits of 3D MCS data and 3D processing techniques is the possibility of accurately collapsing the scattered wavefield to its source location; therefore significantly improving image quality. In addition, obtaining geometrically accurate images of steeply dipping faults that may cut an entire crustal section (and therefore perhaps affecting the physical properties of the Moho) [e.g., *Nedimović et al.*, 2009] will also require 3D MCS data/processing. The potential benefits of combining 3D MCS with 3D borehole VSP for a project of these characteristics need to be explored.

(2) 2D long-offset (³8-km streamer) MCS data. In recent years 2D MCS data collected with 6-km-long hydrophone streamers have resulted in seismic images of the lower oceanic crust, Moho, and sub-Moho structure of unprecedented quality and detail, contributing to a better understanding of the geological processes that form the lower crust and Moho [*Canales et al.*, 2009; *Nedimović et al.*, 2005]. Acquiring MCS data with an 8-km-long streamer, as current *Langseth* capabilities allow, will further improve imaging of lower crustal and uppermost mantle features, as well as enabling amplitude-vs-offset studies of the physical properties of such deep targets. An added value of long-offset MCS data is their potential for conducting high-resolution waveform tomography studies to obtain the fine-scale seismic velocity structure of the upper- and mid-crust in the vicinity of a deep drill hole, thus contributing to a better integration of drilling sampling/results and regional geophysical data.

(3) 3D large-scale Ocean Bottom Seismometer (OBS) data. *Langseth* offers a superb powerful airgun array for active-source 3D wide-angle refraction/reflection OBS experiments. Using traveltimes tomography techniques, these type of data allow resolving the 3D *P*- and *S*-wave velocity and anisotropy structure of the crust and uppermost mantle at scales of several kilometers, which will help interpretation of drilling results and placing them in the appropriate tectonic context.

(4) 2D high-resolution OBS data. Data acquired with a large number of densely spaced OBSs, in conjunction with *Langseth*'s excellent seismic source, can be used for high-resolution determination of the velocity structure of the Moho transition zone (MTZ) in the vicinity of a drill hole using waveform tomography approaches [e.g., *Operto et al.*, 2006]. At long source-receiver offsets (~15-40 km), the MTZ seismic signature is a high-amplitude wide-angle reflection ideal for frequency-domain waveform tomography

studies [e.g., *Brenders and Pratt, 2007*].

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