IODP Expedition 335: Superfast Spreading Rate Crust 4
Hole 1256D Summary

The Superfast campaign, echoing long standing ocean lithosphere community endeavors, was designed to understand the formation, architecture and evolution of ocean crust formed at fast spreading rates. IODP Expedition 335 "Superfast Spreading Rate Crust 4" (13 April to 3 June 2011) was the fourth scientific drilling cruise of the Superfast campaign to ODP Hole 1256D. The cruise aimed to deepen this basement reference site several hundred meters into the gabbroic rocks of intact lower oceanic crust to address the following fundamental scientific questions:

- Does the lower crust form by subsidence of a crystal mush from a high-level magma chamber (gabbro glacier), or by intrusion of sills throughout the lower crust, or some other mechanism? How does melt percolate through the lower crust, and what are the reactions and chemical evolution of magmas during migration?
- Is the plutonic crust cooled by conduction or hydrothermal circulation? What are the role and extent of deeply penetrating seawater-derived hydrothermal fluids in cooling the lower crust, and the chemical exchanges between the ocean crust and the oceans?
- What are the relationships among the geological, geochemical, and geophysical structure of the crust and, in particular, the nature of the seismic Layer 2-3 transition?
- What is the magnetic contribution of the lower crust to marine magnetic anomalies?

ODP Hole 1256D is located on 15 Ma crust in the eastern equatorial Pacific Ocean (6°44.163'N, 91°56.061'W). Oceanic crust that formed at a superfast spreading rate (>200 mm/yr) was specifically targeted to exploit the observed relationship between spreading rate and depth to axial low velocity zones, thought to be magma chambers, seismically imaged at active mid-ocean ridges. This was a deliberate strategy to reduce the drilling distance to gabbroic rocks because thick sequences of lavas and dikes have proved difficult to penetrate in past. Previous cruises to Site 1256 (ODP leg 206; IODP Expedition 309/312) have achieved their Leg and Expedition specific objectives, but not the overarching strategic goals of the Superfast campaign to understand magmatic accretion at fast spreading ocean ridges. However, the three previous cruises achieved the first complete sampling of intact upper oceanic crust and successfully drilled through ~800 m of erupted lavas and thin (~345 m) sheeted dike complex and sampled gabbros at ~1157 meters sub-basement. The lowermost 100 m of the hole is a complex dike-plutonic transition zone and comprises two gabbro lenses intruded into very strongly contact metamorphosed, granoblastically recrystallized sheeted dikes.

Expedition 335 reentered Hole 1256D more than five years after our last visit, and encountered and overcome a number of significant engineering challenges, each unique but of natures not unexpected in a deep, uncased, marine borehole into igneous rocks. The patient, persistent efforts of the rig floor teams cleared a major obstruction at 920 mbsf that initially prevented reentry into the hole to its full depth of 1507 mbsf. The 920-960 mbsf interval was then cemented to stabilize the borehole wall. A short phase of

coring deepened Hole 1256D approximately 13 m before the hard formation (C-9) coring bit failed and was ground to a smooth stump. A progressive, logical course of action was then undertaken to clear the bottom of the hole of metal junk from the failed bit, open up a short interval of under-gauge hole and remove a very large amount of drilling cuttings from the hole. This was successfully completed and the hole was opened to its full depth (1521.6 mbsf). The hole cleaning phase was followed by wireline caliper and temperature measurements of the complete hole to assist the planning of cementing operations to stabilize the lowermost 10 meters of the hole and the problematic interval at 910-940 mbsf. These remedial efforts are intended to facilitate reentry and coring on a future return to Hole 1256D.

In addition to the few cores drilled, the junk baskets deployed during the successive fishing runs to the bottom of the hole recovered a unique collection of samples including large cobbles (up to 5 kg), angular rubble and fine cuttings of principally, strongly to completely recrystallized granoblastic basalt with minor gabbroic rocks and evolved plutonic rocks. The large blocks exhibit intrusive, structural and textural relationships, and overprinting and cross-cutting hydrothermal alteration and metamorphic paragenetic sequences that hitherto have not been observed due to the small diameter of drill cores and the very low recovery of the granoblastic dikes cored so far. The high extent of metamorphic recrystallization exhibited by the granoblastic basalts, combined with operational information provide strong evidence that most of this material comes from the lowermost reaches of Hole 1256D (~1495 to ~1522 mbsf). Including the ~60 m-thick zone of granoblastic dikes that reside above the uppermost gabbros, the dike-gabbro

transition zone at Site 1256 is over 170 m thick, of which more than 100 m are recrystallized granoblastic basalts. When the textural and contact relationships exhibited by these samples are placed in the geological context of the Hole 1256D stratigraphy, vision emerges of a complex, dynamic thermal boundary layer zone. This region of the crust between the principally hydrothermal domain of the upper crust and the intrusive magmatic domain of the lower crust is one of evolving geological conditions. An intimate coupling between temporally and spatially intercalated magmatic, hydrothermal, partial melting, intrusive, metamorphic and retrograde processes is recorded in the recovered samples.

IODP Expedition 335 left Hole 1256D after making only a very modest advance, and we are yet to recover samples of cumulate gabbros required to test models of ocean ridge magmatic accretion and the intensity of hydrothermal cooling at depth. However, a remarkable sample suite of granoblastic basalts with minor gabbros, some of which intrude previously recrystallized dikes, were recovered and provide a detailed picture of a rarely sampled critical interval of the oceanic crust. Most importantly problematic intervals of the hole have been stabilized and the hole cleared of debris to its full depth so deepening in the future can achieve the ultimate science objective of the Superfast campaign.