December 28, 2005

IODP EXPEDITION 312:
SUPERFAST SPREADING RATE CRUST 3
SITE 1256 SUMMARY

IODP Expeditions 309 and 312, “Superfast Spreading Rate Crust 2 and 3”, are the second and third drilling legs in a multi-phase mission to Site 1256 in the eastern equatorial Pacific (6.736°N, 91.934°W). The main goal, to recover a complete section of upper oceanic crust, from lavas through underlying dikes and into uppermost gabbros, was successfully accomplished. Ocean Drilling Program (ODP) Hole 1256D was started in 2002 on ODP Leg 206 and reached 752.1 mbsf (502.1 msb). Expedition 309 deepened Hole 1256D in July-August of 2005 by 503 m to a total depth of 1255.1 mbsf (1005.1 msb), having passed through 754 m of lavas and ending within the sheeted dike complex. The hole was subsequently deepened on Expedition 312 in November-December, 2005, by 250.2 m to 1507.1 mbsf (1257.1 msb), having passed through the sheeted dikes (345 m thick) and 100.5 m into plutonic rocks consisting of gabbros with dike screens. Gabbros were first encountered at 1406.6 mbsf, near the middle of the depth range predicted from geophysical observations. On both expeditions the hole was logged with a full suite of wireline tools, and the hole is open and ready for further drilling into the plutonic foundation of oceanic crust. Hole 1256D is now the fourth deepest hole drilled into oceanic basement and the second deepest penetration into *in situ* ocean crust behind Hole 504B.

Preliminary subdivision of the upper oceanic crust at Site 1256 is based on results from the three drilling expeditions. The Lava Pond (250 to 350 mbsf) includes a Massive Ponded Flow >74 m thick, which overlies the Inflated Flows (350 to 534 mbsf), an interval of massive, sheet and pillow flows with flow inflation structures. These two lava groups are interpreted to have formed off-axis, giving a total thickness of off-axis lavas of 284 m. Sheet and Massive Flows (534-1004 mbsf) comprise mainly cryptocrystalline to microcrystalline sheet flows, < 3 m-thick, with massive fine grained lavas becoming more abundant with depth. The lithologic Transition Zone (1004-1061 mbsf) is marked by a Cataclastic Massive Unit comprising subvertically oriented cryptocrystalline basalt clasts hosted by highly altered, brecciated, fine grained basalt cut by veins and cataclastic stringers. The first subvertical intrusive contact was recovered at 1018 mbsf and chilled dike margins become more common downhole. Subvertical fracture sets possibly indicative of diking into nearby rocks are common in the Transition Zone, as are breccias of various styles.

The upper boundary to the Sheeted Dikes (1061-1406 mbsf) is defined by a change from sheet flows to massive basalts beginning at 1000 mbsf. Dikes and massive basalts are mostly aphyric and non-vesicular, and range from crypto- and microcrystalline to fine grained rocks that have holocrystalline or doleritic groundmass textures. Subvertical chilled intrusive dike contacts are common in the dike complex. In the lower portion of the sheeted dikes (1349 – 1406 mbsf), the rocks are highly to completely altered and are locally recrystallized to granoblastic textures that contain secondary clinopyroxene, leading to their designation as the Granoblastic Dikes.

Gabbroic rocks were first encountered at 1406.6 mbsf, and the Plutonic Section extends from 1406.6 mbsf to the bottom of the hole at 1507.1 mbsf. This section consists of a 52.3 m thick Upper Gabbro unit (1406.6-1458.9 mbsf) and a 24.0 m thick Lower Gabbro unit separated by a metamorphosed dike screen having granoblastic textures. The gabbroic rocks are intrusive into the dikes and range from gabbro to disseminated oxide gabbro, oxide gabbro, orthopyroxene-bearing gabbro, trondhjemite and to quartz-rich oxide diorite (or FeTi Diorite). The base of the section contains a gabbronorite of uncertain origin (intrusive gabbronorite or metamorphosed dike) and is cut by a late dike.

Phenocryst abundance decreases downward, with mainly aphyric rocks in the sheeted dikes. The dominant phenocryst phase (when present) changes from olivine in the upper 500 m of the lavas to plagioclase in the lower lavas and dikes. Lavas and dikes have similar compositions and stratigraphic variations in the lavas show evidence for fractionation and replenishment. Trace element concentrations are within one standard deviation of average EPR MORB, albeit on the relatively trace element depleted side. Weighted average bulk compositions of the two gabbroic bodies fall at the primitive end of compositions for the lavas and dikes and are depleted in highly incompatible trace elements. The average gabbro composition is evolved relative to primary magma in equilibrium with mantle olivine, however, so residual cumulates must be found at greater depths.

Volcanic rocks altered by seawater at low temperatures and characterized by saponite ± celadonite ± iron oxyhydroxides are present down to ~965 mbsf. These minerals and associated black, brown and mixed alteration halos and dark alteration patches reflect alteration by low-temperature hydrothermal fluids and oxidizing seawater. The abundance of oxidation effects is low compared to other basement sites, and rather than decreasing with depth the oxidation effects occur irregularly with depth in Hole 1256D, commonly associated with steep vein networks. A transition to hydrothermal alteration occurs from 964 to 1028 mbsf, and is characterized by pyrite, mixed layered chlorite/smectite, and common anhydrite.

Effects of hydrothermal alteration under subgreenschist to greenschist facies conditions appear at ~1028 mbsf in the Transition Zone, where a Mineralized Volcanic Breccia contains hyaloclastite and basaltic clasts cemented by sub-greenschist facies minerals. Actinolite, prehnite, titanite and epidote first appear and anhydrite is common from 1027 to 1095 mbsf. Green-gray alteration halos and patches are common, with 10-100% chlorite, actinolite, titanite, albite, pyrite ± minor quartz, chalcopyrite and prehnite, replacing plagioclase and clinopyroxene and filling interstitial spaces. Actinolite becomes abundant below ~1300 mbsf in the dikes, and hornblende and secondary plagioclase are present below ~1350 mbsf, reflecting a steep thermal gradient. The basal 50 m of the sheeted dikes contain local granoblastic patches, where the rock is completely recrystallized to secondary plagioclase and equant secondary clinopyroxene, magnetite, ilmenite, and rare orthopyroxene, reflecting high-temperature recrystallization related to underlying gabbros. The gabbros are highly altered to amphibole, chlorite, plagioclase, titanite, and minor laumontite and epidote, with chlorite and epidote more abundant in the Lower Gabbro. The intensity of gabbro alteration is strongly dependent on the grain size of the rock, with coarser material being more altered.

Rocks recovered on Expeditions 309 and 312 exhibit brittle structures and minor brittle-ductile structures. The main structural features include veins, vein networks, cataclastic zones, shear veins, microfaults, and breccia. In the Sheet and Massive Flows structures and fracturing are mainly related to the cooling of lava and are most intensely developed at flow tops. Vertical veins, cataclastic zones and shear veins are present in massive units whereas breccias are more common in sheet flows. In the sheeted dikes, chilled margins are common and overall structures are generally steeply dipping. Fracture intensity is greatest in the upper dikes and lower lavas. Gabbroic rocks contain fabrics and structures related to melt transport, in addition to brittle fractures, and structures are generally less steeply dipping than in the dikes.

The intense drilling overprint and uncertainty about how completely the overprint has been removed by demagnetization necessitates caution when interpreting the paleomagnetic results from Hole 1256D. Because of the equatorial paleolatitude of the site, polarity remains ambiguous until absolute declinations can be obtained. The generally positive inclinations measured on many samples are not what is expected for the low paleolatitude and the most likely explanation is that significant portion of the drilling overprint remains on these samples.

Magnetic intensities for lavas show a recurrent concave pattern with relatively high intensities at the upper and lower boundaries of igneous cooling units and lower intensities in the unit interiors. About 70% of the volcanic units and subunits show the repeated concave patterns suggesting the presence of multiple cooling units, ~1.0 ± 0.5 m thick. Downhole variations in magnetic patterns for Expedition 312 samples are minor, with demagnetization behavior of dikes indistinguishable from that of gabbros

P-wave velocities of the Expedition 309 and 312 basalts range from 4.8 to 6.2 km/s, with an average of 5.6 ± 0.3 km/s, similar to velocities estimated from regional seismic reflection data. The average Vp of basalts increases downhole, from ~5.6 km/s at 752 mbsf to ~6.2 km/s at 1400 mbsf. Average Vp is higher in the dikes (5.9 ± 0.1 km/s) than in the lower lavas (5.4 ± 0.3 km/s). Vp decreases downward from dikes into gabbros (to as low as 5.5 km/s), although the change in average Vp is slight (from 5.9 to 5.8 km/s). Porosities of lavas range from 2 to 14%, with an average of 4%, whereas dikes have lower porosities, averaging 1.5%. Porosity increases stepwise downward from dikes to gabbros, but the average porosity of the gabbros is similar to the dikes. The average thermal conductivity in the Sheet and Massive Flows is 1.8 ± 0.2 W/m/K but there is a step-like increase to 2.1± 0.1 W/m/K downward into the Sheeted Dikes, and an increase in scatter in the gabbros (average 2.2 W/m/K). Bulk and grain densities vary more in the gabbro than in the lower dikes, consistent with the observed variability in rock types and alteration in the gabbros.

Following the completion of coring in Hole 1256D, a complete suite of geophysical wireline logs confirmed that the hole is in good condition. Caliper readings from the triple combo and FSM show generally good borehole conditions with a diameter typically between 11 and 14 inches, with the smaller diameters prevailing in the lower 150 m of the hole. The upper 500 m of basement shows an enlargement of the borehole, however, with a number of intervals strongly eroded by the drillstring. The deviation of the borehole measured at 1507.1 mbsf is ~5°. Velocities from a vertical seismic profile experiment conducted during Expedition 312 generally follow those of the sonic log and discrete samples. Preliminary analysis of downhole geophysical measurements and images show significant variation reflecting the basement lithologies, and a number of petrophysical intervals can be distinguished.