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Drilling to the Crust-Mantle Boundary: SloMo Project, Phase 1

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IODP Expedition 360, with scientists from 14 partner-countries drilled leg 1 of the SloMo Project, a Multi-Phase Drilling Program to drill through the Moho at a slow-spreading ocean ridge. SloMo has two phases: Phase 1 plans drilling 3 km through the crust-mantle boundary in an oceanic core complex at Atlantis Bank on the SW Indian Ridge. Phase II proposes using the Japanese riser drill ship Chikyu to drill 6 km through the Moho itself, believed to lie ~5.5 km below the seafloor (1). Based on geologic mapping and seismic evidence, Moho beneath Atlantis Bank is believed to be a serpentinization front – not the crust-mantle boundary. This raises the possibility of a sub crustal biosphere at slow spreading ridges, as serpentinization is a methanogenic process.

At Atlantis Bank, overlying lavas and dikes were removed by detachment faulting, exposing the lower crust directly to the seafloor. This emplaced an enormous 400-km^2 gabbro massif over 4 m.y into the rift-mountains flanking the Atlantis II Transform. Following a transtensional spreading direction change, the Bank was uplifted above sea level, before subsiding to its present 700-m depth. The top of Atlantis Bank is a 25 km^2 wave-cut platform with a thin bioclastic carbonate skirt of 2-4 Ma lithified beach sands around low sea stacks exposing lower crustal gabbros. 1,508-m deep Hole 735B was drilled on the western flank of the platform during ODP Legs 118 and 176 (2) showing ideal conditions for ultra deep drilling before it was blocked by unexpected and catastrophic pipe failure.

The major Leg 1 SloMo objective was to establish a deep re-entry hole for Leg 2. Expedition 360 Hole U1473A was offset 2.2 km NNE of Hole 735B in the center of the wave-cut platform, and drilled 789.7 m through massive gabbro. Down to 570 m it encountered 7 fault systems ranging from 5-cm thick cataclasites to a 50-m thick carbonate-veined chlorite-rich fault zone, with 44% recovery and relatively poor drilling conditions. From 570 to the bottom of the hole, however, there were excellent drilling conditions similar to Hole 735B, with 96% recovery. This is the deepest single-leg basement hole drilled in ocean crust, is in overall good condition, and it can be reoccupied by Leg 2.

The Leg 1 specific objectives included drilling through a magnetic reversal projected to lie below the site (3), which was not reached, and exploring the lateral variability of the Hole 735B stratigraphy. Hole U1473A and 1105A (4) structural geology and igneous and metamorphic petrology demonstrate a continuity of process reflecting the complex interplay of magmatic accretion and steady-state detachment faulting over a 128,000 year time period, with a ~600 m interval of sheared, dominantly porphyroclastic to ultramylonitic, gabbro. Preliminary assessment indicates that both holes reflect repeated intrusion of 100-m scale upwardly differentiated olivine gabbro cumulates. The bulk of these are too fractionated to be in equilibrium with the MORB hanging wall debris. Fe-Ti rich oxide gabbros and gabbronorites layers and patches occur within the olivine gabbros, and in shear zones. These appear to have crystallized from late melt compacted out of the olivine gabbro cumulates, representing late-stage melt migration of through the section. Approximately 1.8% of the section consists of trondhjemite and hornblende diorite vein. Several diabase dikes were found, and intruded the gabbro under granulite to greenschist facies conditions. These included granoblastic hornblende diabase that partially melted the crystal-plastically deformed gabbro host to trondhjemite.

References:

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