IODP Expedition 360: SW Indian Ridge Lower Crust and Moho

Week 3 Report (13–19 December 2015)

Operations

Week 3 of Expedition 360 (Southwest Indian Ridge Lower Crust and Moho) began while still underway to Site U1473 (Prospectus Site AtBk-6), at a speed of 11.3 kt, ~1960 nmi into the 2817 nmi transit. On 13 December from 0430–1715 h, the ship's speed was reduced and the course changed to maneuver around the center of tropical depression Ex-Bohale. On 16 December a pre-spud meeting was held with key personnel to review Site U1473 operations. The vessel arrived at the coordinates for Site U1473 and switched to dynamic positioning mode at 1700 h on 16 December. The 2817 nmi sea voyage was completed in 262 h at an average speed of 10.7 kt.

The hydraulic releasing tool (HRT) was picked up, assembled, and racked back in the derrick with a 20 ft knobby and a joint of drill pipe. An APC/XCB bit, bit sub, drill collars and new 5 inch drill pipe were made up and lowered to 668 mbrf. The subsea camera system was installed and lowered to just above the bit in preparation for a survey to select a site appropriate for drilling at or near Prospectus Site AtBk-6 (32°42.3402′S, 57°16.6910′E). The survey strategy was to proceed in a square "spiral" pattern increasing at 10 m intervals away from this start point until a sufficiently flat bare-rock spot at least 5 m in diameter was located. The drill pipe and camera were raised and lowered by up to several meters as required by the seafloor morphology. No suitable site was found during the initial 50 m × 50 m survey; accordingly the survey was extended to the south by a further 50 m in the direction of the most promising seafloor. After a total of 5.5 h of survey a suitable location for Hole U1473A was found at 32°42.3622′S, 57°16.6880′E, at 710.2 mbsl, 40 m south of the original start point. Total survey operations lasted from 0530–1530 h.

After recovery of the camera system and drill pipe, an acoustic beacon was dropped at 1342 h on 17 December 2015 to provide additional positioning information into the dynamic positioning system.

Next we assembled the drill-in casing reentry system, consisting of a 12.25 inch tricone bit, bit sub, underreamer, and mud motor. A pump-in sub was installed on top of the mud motor and connected with a high-pressure hose to the mud manifold to verify the proper functioning of the the mud motor and underreamer. The mud motor began turning at 15–20 spm, and the retractable arms on the underreamer opened at 40 spm and 300 psi. The HRT running tool was attached to the drilling assembly and this entire drilling stinger was racked back in the derrick.

One joint of 13.375 inch casing was picked up and trimmed to 11.35 m length. The previously assembled drilling stinger was inserted into the casing and the 13.375 inch casing hanger and the

HRT were made up to the casing, with all casing connections stitch-welded. The assembly was lowered to the moonpool and the hard rock landing skirt was then welded underneath the casing collar. The entire assembly was lowered to the seafloor and the subsea camera system was run to just above the casing hanger to observe the drill-in process. The top drive was picked up and drilling in Hole U1473A started at 0535 h on 18 December. During the first hour, drilling was punctuated with erratic torque, which was only detectable by the camera system. Drilling smoothed noticeably after the underreamer was drilled into the seafloor. A bull's eye level mounted on the landing skirt broke off and disappeared from view about 1 h into the drill-in process.

The signals from the two subsea cameras were lost at 1445 h and the camera was pulled to the surface. A backup telemetry pod was installed and the cameras were redeployed by 1700 h. Drilling continued without the camera system except while handling the camera frame at the surface. After a period of no advancement, at 1845 h we stopped drilling out of concern that the underreamer and bit assembly may have had a problem. With the 16.5 inch cased hole now extending to 11.5 mbsf, we circulated a mud sweep and started recovering the subsea camera system.

The HRT free-fall funnel was assembled and dropped at 2015 h. We observed its successful landing on the 13.375 inch casing hanger via the redeployed subsea camera system from 1915 h to 2045 h. The stinger with bit, mud motor, and underreamer was released from the casing by pumping a release piston down the pipe and into the HRT. The casing dropped ~1.7 m to the bottom of the 16.5 inch hole. The camera system and the stinger with HRT, mud motor, underreamer, and bit were pulled clear of the reentry system by 2230 h and tripped back to the surface.

With the knowledge that the 13.375 inch casing had landed on the bottom of the 16.5 inch hole, we decided that attempting to cement the casing would not be prudent. If we were unable to push cement into the annulus between the casing and the hole we might instead end up cementing inside the casing and up to the funnel.

On 19 December from 0500–1215 h, the rotary core barrel (RCB) BHA was made up with a C-7 drill bit and lowered to 668 mbrf. Next we deployed the subsea camera system and performed a short survey of the reentry system, which showed that the reentry installation was higher than our initial numbers indicated. Our current estimate has the seafloor at 721 mbrf (710.2 mbsl). The initial drilled depth is 730.5 mbrf (9.5 mbsf), with the casing shoe at 728.4 mbrf (7.4 mbsf). The 12.25 inch rat hole is ~2 m deep and the top of the cone is at ~714 mbrf (703.2 mbsl). The reentry installation appeared stable.

We picked up the top drive and reentered Hole U1473A at 1535 h. At 1745 h, after recovering the camera system and washing back to bottom (~2 m of fill), the core barrel was dropped and cutting of the first Core U1473A-2R began. By the end of the week, coring had advanced from 9.5 mbsf to 10 mbsf.

Science Results

The Expedition 360 Co-Chief Scientists, the IODP engineers, and *JOIDES Resolution* crew conducted a seafloor survey of Site 1473 by moving the drill string and the subsea camera system using dynamic positioning over a 110 m × 90 m area in the vicinity of proposed Site AtBk-6, in the north-central part of the ~700 m deep summit of the Atlantis Bank platform. The survey started with a 50 m box covered by a square "spiral" increasing outwards at 10 m spacing from the location of AtBk-6 (32°42.3402′S, 57°16.6910′E) derived from the JR31 site survey. The greater part of the area within this initial box was flat, at about 713 m water depth (as determined from pipe length measurements) with ~1 m of gentle relief. The seafloor consisted of indurated carbonate with occasional ripple marking and areas of thin manganese crust, in a few places with isolated clusters of projecting gabbro boulders and local thin accumulations of white unconsolidated sand. At the southwestern edge of the initial survey box, we observed a dense boulder field and possible outcrop, and accordingly extended the survey in this direction to investigate it further. Via a total of six E–W lines, again spaced 10 m apart, we found and mapped out a substantial outcrop of massive dark rock, which we assume to be the gabbro pavement that was sampled during the JR31 site survey. This outcrop rises steeply by 8–9 m out of the carbonate cap rock, cresting to about 703 m depth, and extends over at least 40 m by 30 m elongate northwest–southeast. It has a generally low-relief bare-rock upper surface with local thin carbonate cap and minor sand. In line with our overall interpretation of the geomorphology of the Atlantis Bank platform, the outcrop probably represents a low gabbro seastack, an erosional remnant of the underlying gabbro massif. After completing crossing lines over the outcrop we selected a site for Hole U1473A in its center, at 32°42.3622′S, 57°16.6880′E (710.2 mbsl), 40 m south of the original start point of AtBk-6.

The Expedition 360 science party spent much of the week redescribing and measuring legacy cores from ODP Leg 179. This focused on archive section halves (108) and thin sections (71) from Cores 179-1105A-1R through 30R (15–157 mbsf) that were sent from the Kochi Core Center to the *JOIDES Resolution* for our expedition. The objective of this effort was to establish, learn, or refine laboratory methods and procedures, and to generate an equivalent database to enable direct comparison of Hole 1105A with the stratigraphy of legacy Hole 735B and new stratigraphy to be drilled at Site U1473. Igneous petrology, metamorphic petrology, and structural geology teams tested their description methodology, based on realistic amounts of time available for description, and made significant adjustments to their initially envisioned description templates and product specification in preparation for Site U1473. The paleomagnetism and petrophysics teams measured the available archive section halves at high resolution and determined suitable measurement and data processing parameters.

The igneous petrology team described the plutonic rocks of the 157 m section at Site 1105, which are mostly coarse-grained gabbroic rocks with subophitic to granular textures. Subophitic textures clearly dominate in the undeformed samples. Lithologies are dominated by olivine gabbro and oxide gabbro followed by gabbro. A significant portion of olivine gabbro and gabbro

contains small quantities of oxide and is referred to as disseminated-oxide gabbro (1%–2% oxides), and oxide-bearing gabbro (2%–5% oxides). Overall, plutonic rocks with oxides >1% clearly dominate the recovered cores below 35 mbsf. Some thin intrusions of fine-grained clinopyroxene-rich troctolite are observed at 60–75 mbsf. Numerous felsic veins are observed and are mostly located at 15–60 mbsf, and 135–155 mbsf. Detailed observations in the corresponding thin sections have allowed us to document the evolution of late-stage melts within the crystallizing mush, and to track the origin of oxide minerals in this apparently oxide-enriched oceanic crustal section.

The observations made by the metamorphic petrology team revealed variations in static background alteration intensity ranging from low to moderate degrees. Hundreds of alteration veins were logged in collaboration with the structural geology team. Recrystallized neoblasts in mylonitic gabbro intervals are mainly clinopyroxene and plagioclase with subordinate amounts of olivine, brown amphibole, and oxides. Static alteration and vein-forming minerals are secondary clinopyroxene, brown and green amphiboles, chlorite, serpentine, talc, clay minerals, and secondary plagioclase. The mineral assemblages are indicative of a sequence of alteration events under granulite to sub-greenschist facies conditions.

The structural geology team identified and measured the orientation of igneous contacts, felsic veins, igneous layering, magmatic fabrics, crystal-plastic fabrics, alteration veins, and brittle deformation. Several complex igneous contacts were observed within Hole 1105A, as were a number of discrete zones with magmatic and crystal-plastic fabrics. One of the principal observations was that fine-grained gabbro crosscuts coarse-grained gabbro, often with crystal-plastic deformation overprinting both the fine and coarse-grained lithofacies. In some cases the fine-grained gabbro has a magmatic fabric that has been subsequently overprinted by a crystal-plastic fabric. Magmatic fabrics are typically weak and rarely moderate, and are always inclined from the horizontal. Magmatic veins are discrete, usually inclined. The crystal-plastic fabrics are intensely deformed and typically inclined. Narrow 1–5 cm wide zones of mylonitic gabbro with crystal-plastic fabrics were found in the upper part of the borehole, with slightly thicker and more numerous zones at greater depths. Fault zones were concentrated deeper in the cored interval with intermittent fractures that lack a systematic dip. Slickenlines on fracture faces have a consistent moderate plunge. Inclined alteration veins are mostly filled with amphibole, though some carbonate veins with open voids were found near the bottom of the hole.

The paleomagnetics team measured and demagnetized archive section halves from Hole 1105A using the SRM system, generating demagnetization data spaced every 2 cm. They devised an automated procedure for calculation and selection of principal components from the continuous remanence data, employing statistics-based quality criteria. The data indicate that the gabbroic rocks hold stable remanence with positive (reversed polarity) inclinations, consistent with the interpretation of marine magnetic anomalies at the site. Mean inclinations are 22° steeper than the geocentric axial dipole field direction at the site, indicating significant tectonic rotation of the Atlantis Bank footwall section.

The petrophysics team measured the point magnetic susceptibility on all archive section halves from ODP Hole 1105A. The magnetic susceptibility varies over the whole instrument range; high magnetic susceptibilities (~≥3000 Instrument Units, corresponding to ~≥0.03 SI) are classically related to abundant magnetite in gabbroic lithologies. These measurements were also used to test a filtering algorithm to remove spurious points from core data loggers. Thermal conductivity was measured on 18 pieces from Sections 179-1105A-1R-1 to 30R-2 and ranges from 1.8 to 2.3 W/(m·K) in most samples. One oxide-rich sample had a measured conductivity of 3.0 W/(m·K).

Education and Outreach

Ship to Shore Events

- Completed 16 interactive events, reaching 619 students in five countries.
    - Six broadcasts to France with eight classes, six to the US with nine classes, two to the UK, one to Canada, and one to Thailand.
    - Engaged nine expedition scientists.
- Broadcast to the IODP town hall at AGU Fall Meeting 2015.
- Opened up registration for "family and friends" broadcasts over the next two weeks.

Outreach Products

- Uploaded one new podcast episode, currently at 500+ listeners, and featured in "new and noteworthy" on iTunes.
- Began work on a virtual field trip using panoramic photos, videos, and audio clips from the *JOIDES Resolution*.

Media

- Five reports and 21 photos filed with the Xinhua News Agency, ~10,000 republished stories.
- Facilitated interviews with The Boston Globe, Scholastic Science World (US), ABC News (Australia), and De Volkskrant (Netherlands).

Social Media

- *JOIDES Resolution* blog (http://joidesresolution.org/): six new posts, 1,594 reads.
- Facebook (https://www.facebook.com/joidesresolution): nine new posts, 8,206 people reached.
- Twitter (https://twitter.com/TheJR): seven new posts, 9,910 impressions.
- Instagram (http://instagram.com/joides_resolution): six new posts.

Technical Support and HSE Activities

Laboratories

- Core Laboratory
    - Leg 179 cores were laid out and examined by the science party, and removed by the end of the week to ready the laboratory for the arrival of Expedition 360 cores.
    - The new whole-round line scan imager is being fine-tuned and tested.
- Catwalk
    - A unistrut table was fabricated to mount the core catcher arbor press. It was placed 8 ft to the right of the core catcher bench toward the rig floor. The arbor press is in the Expedition 361 surface shipment along with jigs for holding the XCB bit and core catcher flow sleeve.
- Microscope Laboratory
    - Microscopes were set up to meet the requirements of the science party.
- Microbiology
    - The tracer pumps were brought on line and making plans for tracer use.
- Developer report
    - Supported data capture on legacy cores from ODP Legs 118 and 179 and responded to numerous questions, concerns, and issues regarding desired code changes.

Miscellaneous

- Towed magnetometer during the transit to Site U1473, except for a brief period at the request of the Captain due to heavy weather and a course change.
- New Cree LED lights were installed in the chemistry, thin section and XRD labs to replace the off color LED lights.

HSE Activities

- A Fire and Boat Drill was held on 14 December.