IODP Expedition 360: SW Indian Ridge Lower Crust and Moho

Week 8 Report (17–23 January 2016)

Operations

Week 8 of Expedition 360 (Southwest Indian Ridge Lower Crust and Moho) began while coring Core U1473A-67R at 614.0 mbsf. Coring continued to Core 71R (648.4 mbsf), with 30-barrel mud sweeps pumped as required. At 2215 h on 17 January we had to suspend coring and pull out of the hole because of high ship heave. Given the time spent on the bit already we decided to use the downtime for an early bit change and retrieved the drill string with the bit clearing the rig floor at 0240 h on 18 January.

A new RCB C-7 drill bit was installed and lowered toward the seafloor. By that time the swell had subsided and we reentered Hole U1473A at 0653 h (the 18th reentry). RCB coring resumed at 1030 h on 18 January and Core 72R was advanced from 648.4 to 651.9 mbsf with varying torque and mud sweeps every few meters. At 1215 h, the drill pipe became stuck with the bit at 651.9 mbsf, with loss of rotation despite applying torque up to 800 A and overpull up to 175 klb. The driller gradually increased the pressure and overpull on the drill string, opening and closing the heave compensator in the process, and was able to work the bit up to 648 mbsf. The pipe suddenly became free at 1400 h and rotation and circulation were reestablished. As we pulled up to 555 mbsf the torque gradually normalized. We think that a significant piece of rock fell from higher up in the hole onto the tapered drill collar and the drill string became free when the rock was gradually broken up. Core 72R (648.4–651.9 mbsf) was retrieved at 1615 h, recovering 3.6 m (103%). The sudden release of energy when freeing the pipe was cause for concern. It was therefore decided to retrieve and inspect the bottom-hole assembly (BHA) and the drill bit to minimize the overall risk to the hole. Before pulling the drill string, the major traveling equipment on the rig was inspected for any visible damage. While pulling the drill string with the top drive, the torque was carefully monitored; everything appeared normal. The bit arrived back on the rig floor at 2015 h and was inspected. With <2 h of coring time, the bit looked as good as new and was reassembled to the BHA.

Hole U1473A was reentered at 2350 h on 18 January (19th reentry) and the bit lowered to the bottom of the hole without encountering any fill. Coring resumed and we retrieved Cores 73R through 81R (651.9–721.3 mbsf), recovering 65.6 m (95%), pumping 30-barrel high-viscosity mud sweeps every 5 m. At 0200 h on 21 January, drill bit rotating time had reached 40 h and it was time for a pipe trip to replace the bit. The drill string was retrieved and the bit arrived back on the rig floor at 0635 h on 21 January.

We made up another RCB C-7 coring bit, this time with a mechanical bit release to allow us to drop the bit on the seafloor after coring, reenter the hole, and conduct wireline logging without the need for a full pipe trip. The bit was lowered to the seafloor and Hole U1473A was reentered

for the twentieth time at 1038 h on 21 January. The bit reached the bottom of the hole without drag or excessive torque and, after a 30-barrel mud sweep, coring resumed at 1515 h. We retrieved Cores 82R through 89R (721.3–789.2 mbsf) and recovered 66.0 m (97%), pumping 30-barrel high viscosity mud sweeps every 5 m and a 50-barrel mud sweep at the end.

At 1445 h on 23 January we began our wireline logging program for Hole U1473A, which will include three tool string deployments. First, the triple combo tool string will measure bulk density, bulk resistivity, spectral natural gamma radiation, and magnetic susceptibility. Second, the FMS-sonic tool string will measure resistivity using four multi-probe array pads to generate a partial borehole wall image, as well as propagation and waveforms of compressional and shear waves. Third, the Ultrasonic Borehole Imager (UBI) will generate a complete borehole wall image using ultrasound. All three tool strings will measure total natural gamma radiation and borehole fluid temperature.

With the bit near the bottom of the hole, we displaced the hole with 290 barrels of drill water (fresh water) to enhance the salinity contrast between a relatively small amount of formation pore fluid and a relatively large amount of borehole fluid. We raised the drill bit to 205 mbsf and displaced the upper part of the hole with another 49 barrels of drill water. Next we pulled the bit out of the hole, clearing the seafloor at 1830 h, and offset the ship 30 m east with the bit ~10 m above the seafloor. Using two wireline runs with the rotary shifting tool (RST), we dropped the drill bit onto the seafloor at 1930 h. Next we repositioned the ship and reentered Hole U1473A at 2145 h on 23 January, lowering the end of the pipe to 45.5 mbsf. The subsea camera system was recovered and the rig floor prepared for logging. At 2330 h on 23 January we began to rig up the logging tools for the triple combo run.

Science Results

During Week 8, all laboratory teams described and measured the gabbros recovered in Cores U1473A-67R through 89R (607–789 mbsf). Most of the cores are olivine gabbro largely devoid of crystal-plastic deformation and displaying coarse-grained subophitic texture. In intervals where deformation is more pronounced, the texture is granular. Igneous layering is common and highlighted by grain-size and modal variations down to Core 73R. Other common grain-size variations (from fine-grained to very coarse-grained) are common, often with a patchy organization. Horizons containing small amounts of oxide are rare and are slightly more common in the deepest part of the current hole. Felsic veins are observed throughout the studied section; here trondhjemite is dominant rather than the leucodiorite encountered at shallower levels.

The interval has weak magmatic fabrics. Several millimeter- to meter-thick porphyroclastic to ultramylonitic shear zones, many felsic veins, and limited alteration veins and brittle deformation crosscut the gabbros. Distinct 5–12 cm scale grain size and modal layering were observed in Cores 64R–72R. Layering ranges from horizontal to moderately inclined and some layers appear

to show fining upward sequences. Weak magmatic fabrics are best seen in the layered gabbros and are best developed in the finer-grained layers; they are commonly subparallel to contacts and can be observed in both the fine- and coarse-grained sides of the contact.

The majority of the crystal-plastic fabrics consist of millimeter- to centimeter-thick, Fe-Ti oxide-rich mylonite and ultramylonite that range in dip from subhorizontal to steep. Commonly, a thin millimeter- to centimeter-thick mylonite crosscuts and transposes a previous crystal-plastic fabric. The larger shear zones are 1–11 m thick and all have porphyroclastic intervals that grade into thinner mylonitic to ultramylonitic bands. For example, in Sections 76R-4 through 78R-5, an 11 m thick shear zone grades from undeformed layered olivine gabbro to progressively more sheared gabbro and develops into shallowly to moderately dipping mylonite. The shear zone culminates in a 5 cm thick, normal-sense, Fe-Ti oxide-rich ultramylonite. Overall, these shear zones reveal multiple generations of deformation and indicate that high-temperature deformation extends down to at least 750 mbsf.

The felsic veins are a few millimeters to 10 cm thick, have steep to horizontal dips, and exhibit a variety of textures from tapered, branched, to pull apart structures. One of the two observed pull apart structures has a reverse-sense of shear. The majority of felsic veins, however, are undeformed. In Section 68R-4, a narrow shear band cuts the vein. In Section 68R-1, a subhorizontal felsic vein has xenoliths of mylonite, indicating the vein disrupted a previously formed mylonite. The relationship between felsic veins and deformation indicates complex interaction of melt generation and deformation.

Alteration veins are mostly restricted to Cores 70R–75R and are almost absent from the remainder of the section here. Those that are present are moderately to steeply dipping chlorite or chlorite-amphibole veins, some of which are sheared. Macroscopically observable fracturing is limited to a small population of shallowly dipping discrete cracks; however, microfractures in plagioclase and locally in pyroxene are observable microscopically in some intervals. Overall, brittle deformation and alteration are significantly less deep in the hole than in its upper part.

Background static alteration intensity in Cores 66R to 86R is variable, mostly ranging from <3 vol% to 60 vol%, but locally exceeds 60 vol% near veins. Secondary plagioclase is the most dominant phase with subordinate amphibole, chlorite, and talc. The assemblage of these minerals indicates greenschist facies conditions. Mylonitic rocks contain clinopyroxene, olivine, and plagioclase neoblasts, which indicate dynamic recrystallization at granulite to amphibolite facies. Overprinting by greenschist facies alteration probably causes the milky white appearance of the plagioclase neoblasts. As noted above, vein density is significantly lower than in cores from shallower levels, and veins are filled by chlorite or chlorite-amphibole veins rather than carbonate veins.

A final suite of samples was selected for shipboard geochemical analysis, bringing the total number of samples analysed during Expedition 360 to >200 and extending the geochemical profile to 650 mbsf. To date the dominant olivine gabbro samples have Mg# varying from 82 to

55, which correlate systematically with Ca# and with minor and trace element concentrations (e.g., Ti, Y, Cr, Ni). These chemical parameters vary in a broadly systematic manner downhole, with separate Mg# maxima at ~50 mbsf, 300 mbsf, and 650 mbsf. The 200–300 m scale of the crustal cycles in Mg# and related parameters is similar to that observed in Hole 735B. It is possible that these dimensions reflect the intrusion of individual magma batches into the crust.

The paleomagnetic team completed measurement and alternating field demagnetization of archive halves from Hole U1473A, down to Core 87R, and continued to process batches of discrete samples using a combination of alternating field demagnetization, low temperature, and thermal demagnetization. Measurements confirm that the unaltered gabbro continues to have a consistent reversed polarity magnetization. However, some limited intervals typically associated with mylonitization, alteration, or felsic veins have a normal polarity, or a normal polarity overprint.

The Petrophysics team reports that the majority of the felsic veins in the interval measured this week are associated with narrow peaks in natural gamma radiation. The felsic veins also often correlate with the highest magnetic susceptibility signals, a relationship less frequently observed in the shallower portion of the hole. Average magnetic susceptibility in this interval is about 500 Instrument Units (~10^{-5} SI). Gamma ray attenuation density is more uniform than in shallower sections, averaging about 2.7 g/cm^3 and reaching 3.1 g/cm^3 in gabbroic rock with very low alteration intensity.

P-wave velocity (V_p), porosity, and density measurements on 44 discrete samples were completed. The modestly increasing downhole trend in V_p observed through the shallower section does not persist into this interval. V_p values are slightly lower than those measured the previous week. They range from 6012 to 6978 m/s, with an average of 6630 m/s. Grain density ranges from 2.87 to 3.03 g/cm^3 and is 2.97 g/cm^3 on average. Porosity ranges from 0.2% to 1.3% and is 0.4% on average. Thermal conductivity was measured on 27 samples with an average value of 2.35 ± 0.014 W/(m·K).

The week we finalized the plans for preparing the hole for wireline logging as well as the logging tool strings to be deployed.

The Microbiology team processed 19 samples over the last week for a variety of analyses. For 11 samples we obtained material sufficient only for cell counts, carbon analyses, ATP measurements, and in some cases limited DNA-based analyses. For eight samples we obtained sufficient material for enrichment culturing, and in some cases limited metagenome, metatranscriptome, and lipid analyses and/or enzyme assays. We completed two more contamination control experiments with the PFMD tracer (bringing this to a total of 10 tracer experiments) and conducted three additional experiments with the PMFC tracer that has been used on expeditions previously. We are presently completing the gas chromatography analyses of those samples.

Education and Outreach

Interactions

- Held a total of 27 broadcasts to schools: 11 to France, nine to the USA, two to multiple European countries, two to Japan, one to Canada, one to Portugal, and one to China.
    - Total scientists engaged: 14
    - Total students reached: 1,431

Social Media

- *JOIDES Resolution* blog (http://joidesresolution.org/): seven posts, 1,540 reads.
- Facebook (https://www.facebook.com/joidesresolution): eight posts, 11,969 people reached.
- Twitter (https://twitter.com/TheJR): seven tweets, 13,300 impressions.
- Instagram (http://instagram.com/joides_resolution): five posts.

Media

- Three news stories and five photos were submitted to the Xinhua News Agency.
- Co-Chief Scientist Henry Dick gave a live interview to Science Friday on Public Radio International.
- A video interview with Co-Chief Scientist Chris MacLeod and package about SloMo was broadcast on BBC TV (CBBC Newsround).
- One article in Sudquest Dimanche (France) and one article in Livingston County News (USA).

Technical Support and HSE Activities

Laboratories

- All laboratories supported processing of cores and samples and analytical measurements.
- Our second sampling for postcruise research is in progress.
- Microbiology: PFMB tracer used while coring Core 75R; PMFC tracer run on Cores 82R, 83R and 84R.

Developer Report

- Continued bug fixing for the Thin Section Report Builder/Writer.
- DESClogik users keep trying to download entire holes worth of descriptive data, and/or downloading into multiple tabs, which DESClogik cannot handle. Downloading data in segments works, though is not as convenient. Cannot be fixed in current program.

- Moisture and Density control program MADMax generates an exception message after saving the results of a new measurement for a sample of type SPCM. Need to investigate.
- Assisted with database and content configurations to support quality control of stratigraphic splices for Expedition 353.
- Conducted additional testing and information gathering on Section Half Imaging Logger (SHIL) crash. Swapped to using instrument host SHILa. The crashes still occur intermittently.
- Repair work ongoing on SampleMaster related to drilling parameter edits not saving.

IT Report

- Continued troubleshooting apparently random errors with our VSAT system with our service provider, RigNet.
- Preparing IT shipments for return to College Station.
- Continued troubleshooting problems with the subsea camera depth overlay on the SubC computer.
- Created user accounts for Expedition 361 participants.

HSE Activities

- A Fire and Boat Drill was held on 23 January.
- Eyewash and safety showers were tested.