IODP Expedition 345: Hess Deep Plutonic Crust

Week 5 Report (6–12 January 2013)

This week of IODP Hess Deep Expedition consisted primarily of RCB coring and remedial cementing and reaming in Hole U1415J. We obtained seven RCB cores (U1415J-10R to -20R), three cores from previously cored intervals (U1415J-14G, -15G and -17G). The overall recovery for Hole 1415J to date is 12%. The lithologies recovered this week continue to be primitive gabbros that are primarily altered at low-temperature greenschist facies conditions with abundant prehnite. Magmatic fabrics dominate with localized, superimposed low-temperature cataclasis.

Operations

RCB coring continued in Hole U1415J until Core U1415J-13R that extended the hole to 79.4 mbsf. A wiper trip was conducted and the bit was raised up to 6.5 mbsf without encountering any problems. The bit was then lowered back into the hole and took weight at ~37 mbsf. The driller was able to wash and ream down to 45 mbsf. The bit was then lowered and encountered weight again at 57 mbsf. The driller washed and reamed the hole to the total depth (TD) at 79.4 mbsf. The bit was raised off the bottom of the hole and became stuck at 72 mbsf with high circulation pressure, no rotation, and no ability to move the bit up or down. The pipe was worked for two and a half hours before it was pulled free with 100 kips overpull. The bit was pulled up to 6 mbsf inside the 10.75 inch casing. The core barrel that was in place during this wiper trip was recovered (Core U1415J-14G) with 0.15 m of recovery and a new core barrel was dropped. We decided to use cement to help stabilize the hole. However, we had not yet observed the nested Free-Fall Funnels (FFFs) and therefore did not know how far the 15 m of casing attached to the FFF extended into the borehole. So we raised the bit back up into the 10.75 inch casing and deployed the camera system to constrain the height of the FFF above seafloor. The top of the second, "upper" funnel appeared to be about two meters above the rim of the first, leaving the casing shoe at about 13 mbsf. After retrieving the camera system, we wanted to get the bit as deep as possible before cementing. After passing a tight spot at 38 mbsf, we were able to wash and ream down to 57 mbsf. However, we could not get past this depth and stopped trying at 0800 h on 7 January. At this time, the core barrel that was in place during this washing and reaming was retrieved (Core U1415J-15G) with 0.64 m of gabbroic rocks. We deployed a new core barrel, washed and reamed back down to 57 mbsf, and pumped 25 barrels of class G cement that contained 0.25 lb/sack of celloflake lost circulation material. After the cement was in place, we raised the bit up to 15 mbsf and the 10.75 inch casing was flushed to remove any cement from this area. The bit was then pulled out of the hole and the drill string was flushed to clear out any remaining cement residue. We slipped and cut 115 ft of drill line and then retrieved the drill string. The bit was back on the rig floor at 2315 h on 7 January. We assembled a new bottom-hole assembly (BHA) with a 9.875 inch tri-cone bit for drilling out the cement. This bit does not recover core, but has a more robust cutting structure for reaming and clearing operations. The drill string was lowered to the seafloor and we reentered Hole U1415J at 1130 h on 8 January. After recovering the camera system, the bit was run to 47 mbsf without encountering any cement, then down to 57 mbsf before encountering fill without any evidence of cement. The hole was reamed once again to 77 mbsf and swept with high viscosity mud. The bit was pulled up to

14 mbsf for a wiper trip, and then lowered back down to 76 mbsf. The bit was then positioned at 63 mbsf and a second remedial cement job was performed using 35 barrels of class G cement. During the cement job, the bit was lowered to 71 mbsf. After the cement was pumped, the bit was raised up to the casing shoe and the 10.75 inch casing was flushed to ensure that no cement remained in this interval. The bit was pulled clear of the seafloor and the drill string was circulated to flush any remaining cement from the pipe. Because we wanted to drill out the cement with the same bit, we had to wait for the cement to harden. While waiting for this to happen, we conducted a near-bottom camera and 3.5 kHz pinger survey of two other potential drill sites. At the completion of the survey, we reentered Hole U1415J at 2215 h on 9 January. We felt that the cement still needed a little more time to harden, so we kept the bit in the 10.75 inch casing until 0630 h. Then, we lowered the bit into the hole. Although we encountered the same obstruction at ~35 mbsf, it was easily passed. The bit encountered cement at 63 mbsf, which we drilled out to 73 mbsf. Several hours were required to drill back down to the total depth of Hole U1415J (79.4 mbsf), but little advancement could be made until we significantly reduced the pump strokes to ~30 spm. Each time a mud sweep was pumped, clear pump pressure changes were observed suggesting that the cuttings might now be getting circulated out of the hole. We then drilled 5 m of new hole (to 84.4 mbsf) without coring in an unsuccessful attempt to reach a more competent formation. We decided to retrieve the drill string to switch back to a RCB coring BHA. The bit was back on the rig floor at 0600 h on 11 January. We assembled a new BHA with a RCB coring bit, lowered it to the seafloor, and reentered Hole U1415J at 1700 h on 11 January. The bit began to take weight at the 35 mbsf again, but was able to pass through quickly. The hole was then washed and reamed, reaching the TD of 84.4 mbsf at 0130 h on 12 January. The core barrel used during this reaming was recovered (Core U1415J-17G) with 0.12 m of rock on deck at 0230 h on 12 January. We dropped a new core barrel and resumed RCB coring. Core U1415J-18R advanced from 84.4 to 89.1 mbsf and recovered 1.5 m of nicely cored gabbro (32%). All drilling parameters appeared stable and good. Initial indications were that the two remedial cement jobs were successful and that the cuttings were now being expelled from the hole. New fill on bottom between cores appears to be from the immediate formation being drilled into and not from uphole. Core U1415J-19R was advanced from 89.1 to 94.1 mbsf and recovered 0.77 m with some cored pieces (15%). Coring parameters remained reasonably constant at 60 rpm with 250 to 300 amps of torque, 300 psi pump pressure at 40 spm, and 15 kips weight-on-bit (WOB). The penetration rate was initially 2.5 m/h, but it jumped up to 5.0 m/h midway through cutting Core U1415J-19R. After recovering Core U1415J-19R, we were struggling to get back down to the bottom of the hole. At the end of this week (1200 h on 12 January), the driller was continuing to work/clean up the lowermost ~5 m to resume coring.

Science Results

Igneous Petrology

This week focused on the macroscopic description of Cores 345-U1415J-7G to -15G (29 to 79.4 mbsf), and on the microscopic descriptions of Hole U1415J (40 thin sections). The proportion of lithologies in Hole U1415J recovered during RCB coring consists of olivine gabbro and olivine-bearing gabbro (36%), troctolite (23%), clinopyroxene oikocryst-bearing gabbros (troctolites and olivine gabbros, together 27%), and other (14%), mainly gabbroic rocks (gabbro, olivine-bearing gabbronorite, orthopyroxene-bearing olivine-gabbro, and oxide and orthopyroxene-bearing

gabbro) with minor basaltic rocks that are restricted to the upper rubble zone. This excludes "ghost" cores recovered from hole cleaning operations through previously cored intervals. Most of the lithologies are medium grained with granular textures, which range to granular-poikilitic where clinopyroxene oikocrysts are present. A coherent zone of layered gabbroic rock (Sections U1415J-5R-1, -2) is dominated by olivine-rich gabbro and troctolite, which is characterized by the presence of up to several cm-sized clinopyroxene oikocrysts.

Olivine, with anhedral habit and irregular to amoeboidal shape, is omnipresent in the troctolitic matrix but does not occur as chadacrysts in the oikocrysts (only at the outermost rims), while plagioclase chadacrysts are quite common, with features very similar to plagioclase in the troctolitic matrix (bent crystals, crystal plastic deformation, well-equilibrated plagioclase patterns with 120° triple junctions). In contrast, granular olivine and clinopyroxene coexist in troctolites from the deeper part of the core, in a manner that is very similar to "olivine-rich troctolite" recovered from Hess Deep at Site 895, Leg 147.

Metamorphic Petrology

Alteration of Hole U1415J cores is highly variable, ranging from nearly fresh (<30% mineral replacement) in the shallower cores (Cores U1415J-5R to -11R) to nearly complete replacement (60–90% replacement) in the deeper cores (e.g. Cores U1415J-12R to -13R). These two deeper cores include zones of intense cataclasis, and pervasive greenschist to sub-greenschist facies alteration.

Away from the cataclastic intervals, olivine is altered from 30–60%, and is replaced by serpentine and magnetite. In more intensely altered intervals, olivine is 60–90% replaced by talc, amphibole, clay minerals, magnetite and sulfides. In the most altered core (Core U1415J-12R), olivine is completely replaced by talc, and is identified by chlorite rims formed in plagioclase surrounding the relict olivine. Plagioclase is minimally altered (<10–30%) away from the cataclastic intervals where it is replaced by prehnite, chlorite, and zeolites. Plagioclase replacement is characterized by chloritic rims adjacent to relict olivine, and by prehnite- and zeolite-filled microfractures apparently associated with olivine replacement. Alteration of clinopyroxene is quite variable, ranging from unaltered oikocrysts to nearly completely decomposed grains; the replacing phase is predominantly colorless to pale green amphibole. In cataclastic zones, comminuted plagioclase is strongly (60 to >90%) replaced by prehnite and zeolites. Chlorite, clay minerals, and carbonates are also associated with the cataclastic zones, implying low temperature conditions of brittle deformation. Veins contain chlorite, clay minerals, prehnite and carbonates, and are commonly spatially associated with cataclastic zones. Prehnite veins commonly cross cut across cataclastic fabric.

Structure

The week was spent completing detailed macro- and microscopic observations of Cores U1415J-10R to -20R recovered from 46–80 mbsf. Magmatic fabrics defined by decimeter scale modal (and sometimes grain size) layering comprise >22% of the core; magmatic foliation defined by shape preferred orientation (SPO) of plagioclase, olivine, and pyroxene (parallel to layering) >71%. Moderate- to strong magmatic foliation is best developed in medium grained, olivine rich gabbroic rocks throughout the hole. The mean dip of all magmatic fabrics in Hole U1415J is 35° (excluding ghost cores); comparable magmatic fabrics with a similar dip occur at the same depth

interval in Hole U1415I. Section U1415J-7G-1 exhibits a mean dip of 59° and likely is a rotated block that slumped into the hole. Lithologically, it is most similar to the upper part of Section U1415J-5R-1.

Thin section observations are consistent with crystal plastic deformation within the crystal mush. New observations include tiling/imbrication of plagioclase crystals suggesting flow or shear during foliation development and textures suggesting dissolution of plagioclase crystals within pyroxene oikocrysts.

Evidence of high-temperature subsolidus crystal plastic deformation remains rare and very localized in the recovered pieces. Possible plastic deformation and/or reaction weakening of low-temperature minerals (serpentine, chlorite, talc(?)) is recognized in two very thin intervals of core. Cataclastic deformation (≥1.5 m thick) is localized in Core U1415J-12R, with minor zones of cataclasis recorded elsewhere throughout Hole 1415J. Thin (<0.1 cm) alteration veins are present in ~65% of the pieces recovered from Hole U1415J in generally low abundance (density <<1% of the recovered cores), and increase in the interval dominated by cataclastic deformation, showing no preferred orientation.

Paleomagnetism

The paleomagnetic team has been processing archive half core demagnetization data from Holes U1415I and U1415J, and building summary spreadsheets for both archive half core and discrete sample paleomagnetic data.

Geochemistry

Twenty-three samples were selected for geochemistry: two gabbronorites at Holes U1415H and U1415E, six samples at Hole U1415I (three samples of the sand cuttings from Core U1415I-3R and three olivine- and orthopyroxene-bearing gabbros) and 15 samples at Hole U1415J (one aphyric basalt, two samples of the sand cuttings recovered in Core U1415J-2G, seven olivine gabbros and five troctolites). The LOI was determined on all samples. The CO_2, H_2O and sulfur composition of 15 samples was determined using gas chromatography (CHNS); this allowed us to critically assess and improve the CHNS analytical protocol for the sampled rock types. The final batch of samples and duplicates are now being analyzed. The first batch of ICP-AES analyses (major and some trace elements) was realized on 10 samples. After some changes in the analytical protocol that should improve the quality of the data, a second set of samples is now being analyzed (12 new samples and three duplicates).

Physical Properties

Most core sections from Hole U1415J were run through the Whole Round Multisensor Logger and the Section Half Multisensor Logger. Natural gamma ray radiation is very low in all cores (<1.6 count/s), barely above background level. Magnetic susceptibility remains generally low, due to the absence of Fe-Ti magmatic oxides in the recovered lithologies. The highest recorded values (up to ~9000 x 10^{-5} SI) are locally related to magnetite in serpentinized olivine in troctolitic rocks. We completed measurements on discrete samples taken to date from cores recovered in Hole U1415J. Grain density ranges from 2.8 to 3 g/cm^3, and porosity ranges from 0.2 to 2.9%. *P*-wave velocity measured in olivine-bearing gabbros and gabbronorites, olivine

gabbros and troctolites ranges from ~5.8 to 6.6 km/s; not surprisingly, variations in Vp measurements at room pressure are primarily controlled by porosity. Thermal conductivity was measured in seven core pieces taken at irregularly spaced intervals along Hole U1415J. It ranges from 2.10 to 2.96 W/m·K.

Education and Outreach

There have been 11 broadcasts this week; feedback from the evaluation forms has been very positive. Next week there will be 17 broadcasts. Five expedition related activity packages have been designed, piloted, and sent to the Deep Earth Academy (DEA).

A new animation explaining the primary reasons we are drilling at Hess Deep has been uploaded onto YouTube (see http://www.youtube.com/watch?v=ny31rW0Ftr4&feature=youtu.be). The shipboard education officers have had articles published in newspapers as well as one of our broadcasts was filmed for French TV (http://pluzz.francetv.fr/videos/jt_1213_cote_dazur_,75378206.html).

We continue to follow the drifter launched from the *JOIDES Resolution* on Christmas day. This drifter is part for a French educational program "Argonautica" to study the oceans currents. Fifty schools in France are following drifters with this program (http://www.cnes.fr/web/CNES-fr/7161-argonautica.php). Drifty, as our buoy is named, initially drifted to the northwest in the Equatorial Current. Last week, however, it moved far enough north that it is started sailing to the east in the Equatorial Counter Current. This week, it started sailing faster to the east. The drifter is now 355 km from the ship at an azimuth of 016°.

Technical Support

Science mission support:

- Technical staff continued to provide core processing and analytical support for the Science Party.
- Camera/sub-bottom surveys were conducted while waiting on cement to set. Excellent sub-bottom profiles were captured until the batteries died.

Other technical activities:

- Minor software updates continued on various LIMS reports.
- Work continued on the Conference Room video cabinet.
- Electronics and Arduino training classes continued.
- In the Underway Lab work on mitigation of old Windows XP 32-bit applications to Windows 7 64-bit computers on the instrument hosts was ongoing.
- Routine maintenance on the fantail deck crane was initiated.

HSE activities:

- The weekly fire and abandon ship drill was held as scheduled.
- Completed inventory of hazardous material storage lockers and created an “Approved Contents” list for each.
- Positing NFPA signs on all storage lockers and near the entrances of all IODP spaces where hazardous materials are stored.