**IODP Expedition 345: Hess Deep Plutonic Crust**

**Week 4 Report (30 December 2012–5 January 2013)**

This week of IODP Hess Deep Expedition we completed operations in Hole U1415I and started Hole U1415J, establishing a shallow cased re-entry structure using a novel nested free-fall funnel strategy. We recovered 11 cores of primitive gabbroic lithologies that show primarily low-temperature alteration and deformation.

## Operations

RCB coring continued in Hole U1415I to 35.2 mbsf under challenging conditions. We spent many hours attempting to stabilize the hole so that we could hang the drill pipe off at the rig floor to deploy a Free-Fall Funnel (FFF), but were unable to get the bit below 8 mbsf. We eventually abandoned the effort to deploy a Free-Fall Funnel (FFF) due to excessive risk to the bottom-hole assembly (BHA). We pulled the bit out of the seafloor and retrieved a core barrel (Core U1415I-5G) that contained 0.21 m of gabbroic rocks. The RCB bit/coring assembly was changed out for a 14.75 inch tri-cone drilling assembly and deployed back to the seafloor. When the camera system reached bottom, we easily found the mound of cuttings around Hole U1415I; however, the hole appeared to be collapsed, precluding a bare-hole re-entry. We decided to abandon Hole U1415I and drill a new hole nearby instead.

## Hole U1415J

We offset the ship 10 m to the north, verified the seafloor was free of any boulders, and observed the bit tag the seafloor at 4850.0 mbrf. After we recovered the camera system, Hole U1415J was spudded at 1855 h on 31 December. Drilling proceeded at ~1.2 m/h from 0 to 7 mbsf, then slowed to about 0.6 m/h until a total depth (TD) of 4865 mbrf (15 mbsf). After three wiper trips to clean the hole, we assembled a Free Fall Funnel (FFF) around the drill string in the moon pool. The base of the FFF has an opening of 16 inches and we did not attach a stinger the FFF. We dropped the FFF and the drill string began taking weight soon after the FFF was deployed. We spent 11.25 h washing and reaming the bottom 10 m of the hole. After one last wiper trip, the drill string and the 14.75 inch bit were recovered on the rig floor at 1400 h on 2 January 2013. A 15 m string of 10.75 inch casing was made up and hung off the moon pool doors for free fall deployment. A new RCB BHA was made up and lowered through the casing to the seafloor for re-entry. The 16 inch FFF was found buried upright in the cuttings pile of Hole U1415J; only the upper part of the rim and deployment shackles were visible. The FFF was re-entered at 0420 h on 3 January and the camera system was retrieved. The drill string began taking weight at 9 mbsf and was easily washed down one more meter to 10 mbsf. The cone of a FFF was assembled around the drill string in the moon pool and connected to the cut-off joint of 10.75 inch casing that had been previously hung off in the moon pool. The total length of the casing was 15.0 m from the cone base to the end of the casing shoe. The assembly was free fall deployed at 0730 h on 3 January. The hole was then washed and reamed to TD (15 mbsf) and circulated clean with two 25 barrel mud sweeps. A core recovered from this washing and reaming ("ghost" core; Core U1415J-2G) was recovered from the cleaned interval at 1045 h; it contained 0.2 m of rock

fragments and 2 buckets full of coarse sand, interpreted to be drill cuttings. RCB coring then resumed and Cores U1415J-3R to -5R were retrieved. Hole problems required washing and reaming around 32 and 35 mbsf, during which "ghost" Cores U1415J-6G and U1415J-7G were recovered by 0100 h on 5 January. Another fresh core barrel was dropped and on this attempt, the bit made it easily to TD (34.9 mbsf) and RCB coring resumed. The hole drilled smoothly and Core U1415J-8R was recovered from 34.9 to 45.2 mbsf at 0805 h with 3.22 meters of core. During retrieval, the area between 4878 and 4882 mbrf (28 and 32 mbsf) remained problematic and was once again reamed and conditioned multiple times. RCB coring resumed at 0900 h and Core U1415J-9R was cut from 45.2 to 55.3 mbsf and arrived on deck with 0.94 m of rock at 1200 h on 5 January.

## Science Results

### Igneous Petrology

Work this week focused on the macroscopic description of cores from Hole U1415I and U1415J (up to Core U1415J-7G), and on the microscopic descriptions of samples from Holes U1415E, U1415G, U1415H and U1415I. Hole U1415I consists of olivine gabbro (46%), olivine-bearing gabbro (9%), olivine-bearing gabbronorite (13%), gabbro (9%), orthopyroxene-bearing olivine gabbro (9%), with minor anorthositic gabbro, anorthositic olivine gabbro, troctolitic olivine gabbro and troctolites (all ~2%). Three sections of the third core (Sections U1415I-3R-1 to -3R-3) recovered drilling-induced disaggregated gabbro.

Some of the troctolites and troctolitic gabbros contain large clinopyroxene oikocrysts. These oikocrysts do not contain olivine chadacrysts, their plagioclase chadacrysts show random orientation while matrix plagioclase in the troctolite shows a strong foliation. Some of the plagioclase chadacrysts show plastic deformation (as is observed in the troctolitic matrix) though the clinopyroxene oikocryst is virtually undeformed.

Up to now the lithologies of Hole U1415J have been evaluated only by macroscopic observations, which revealed that the recovered rocks, both from the rotary cores as well as from the "ghost" cores, are very similar to those rocks drilled in Hole U1415I. Based on the description of the Cores U1415J-2G to -7G, it was estimated that most common rocks are the medium to coarse grained clinopyroxene-oikocryst-bearing troctolite (32%), followed by olivine-bearing gabbro (17%), olivine gabbro (16%), clinopyroxene-oikocryst bearing olivine-gabbro, (9%), gabbro (9%), olivine-bearing gabbronorite (7%), clinopyroxene oikocryst-bearing-gabbro (5%), with minor olivine- and orthopyroxene-bearing gabbro, and troctolite (all ~2%). The dominance of clinopyroxene-oikocryst bearing gabbroic rocks (46%) demonstrates the importance of this very specific feature of the drilled rocks in both Holes U1415I and U1415J.

### Metamorphic Petrology

The rocks recovered in Holes U1415I and U1415J display variable alteration. Primary mineral replacement ranges from 10% to 60%. In most pieces, olivine is altered from 60% to 100%, and is replaced by assemblages of serpentine, talc, amphibole, clay minerals, magnetite and/or sulfides. Plagioclase is minimally altered (<10–30%) and is replaced by assemblages of secondary plagioclase, chlorite, prehnite, garnet and/or zeolites. The extent of clinopyroxene

alteration is quite variable, ranging from unaltered oikocrysts to nearly completely replaced grains; the replacing phase is predominantly colorless and pale green amphibole. Orthopyroxene, if present, is typically altered (30–60%) to chlorite, talc, and/or pale or colorless amphibole. Brown or dark green amphibole, indicative of high temperature (>700°C) alteration, has not yet been observed. The most coherent cored section (Section U1415I-4R-1) is minimally altered (10–30%) relative to other sections, although alteration intensity is elevated in the relatively olivine-rich zones. Cataclastic zones are common and are associated with assemblages of prehnite, chlorite, clay minerals, zeolites and/or carbonates, suggesting low temperature conditions of brittle deformation. Veins contain chlorite, clay minerals, prehnite and carbonates, and often associated with cataclastic zones. Point-counting of recovered sands (inferred to be drill cuttings, Sections U1415I-3R-1 to -3) reveals a much higher abundance of cataclastically deformed and prehnite-bearing material relative to the solid core intervals.

**Structure**

Sixty-four percent of Hole U1415I shows decimeter scale layering defined by modal variations of olivine, and variations in the concentration of cm diameter clinopyroxene oikocrysts. The layering dips at 22–50°, with a mean dip of 33°. Comparable layering with a similar dip occurs at the same depth interval in Hole U1415J. Seventy-four percent of Hole U1415I exhibits a magmatic foliation. This is conspicuously developed in the medium grained gabbros, and less clear in the coarser grained gabbros. The foliation is defined primarily by plagioclase and olivine shape preferred orientations (SPO), and more rarely by pyroxene SPO. Medium grained gabbros show extensive annealing of plagioclase grain boundaries, possibly masking strain within the crystal mush. Plagioclase crystals show some undulose extinction, bending, deformation twinning and subgrain development; olivine shows subgrain development.

Evidence of subsolidus crystal plastic deformation is rare and very localized in the recovered pieces. Brittle structures are observed at the upper part section of Hole U1415I, as one thin sub-vertical zone of cataclasis; the lower part section of Hole U1415I shows little brittle deformation. Brittle structures in Hole U1415J are very rare, and comprise deformation along one prehnite vein. Thin (<0.1 cm) alteration veins are present in ~75% of the pieces in generally low abundance (density <<1% of the recovered cores). In the largest pieces, many vein tips are observed, and accordingly, vein length is probably not much greater than a few decimeters. Recovered veins are irregular in shape, and form networks of anastomosing, branched and crosscutting veins with complex mutual relationships. In thin section, some cross-cutting relationships between different vein generations are observed (e.g. prehnite veins cross-cutting serpentine veins). Two preferred vein orientations are noted: one with shallow dip (about 30°) sub-parallel to the igneous layering, and the second perpendicular to the igneous layering.

**Paleomagnetism**

The paleomagnetic team began a series of demagnetization experiments on discrete mini-cube samples and archive half core sections from Hole U1415I to constrain variations in remanence directions downhole.

## Geochemistry

Seven samples were selected for geochemistry: three gabbroic rocks (one orthopyroxene bearing gabbro from Hole U1415E, one olivine gabbronorite from Hole U1415H and one olivine gabbro at Hole U1415I), three samples of the sand cuttings recovered in Core U1415I-3R, and one sample of aphyric basalt from Hole U1415J. The samples are now being processed for analyses and the completion of the first batch of measurements of volatile contents is expected within the next 3–4 days (duplicate analyses). The ICP-AES measurements will be realized as soon as, at least, 10 samples are ready for analyses.

## Physical Properties

In addition to the various properties measured on whole round and half sections of cores, we measured Vp, density and porosity on three cubic olivine-bearing gabbroic rock samples. Vp ranges from 6.1 to 6.6 km/s (average 6.3 km/s), grain density is 2.9 kg/m$^3$, and porosity is 1%. The average thermal conductivity of three olivine-bearing gabbroic rocks, measured on half-core pieces, is 2.39 W/(m·K). These values are typical of oceanic gabbros measured on the *JOIDES Resolution* in the past.

## Education and Outreach

There have been four broadcasts this week, but with many schools reconvening after the holidays, there will be 12 next week. The development of cross-curricula materials is ongoing and the initial feedback on pilot packages is being provided. We continue to follow the drifter launched from the *JOIDES Resolution* on Christmas day. This drifter is part for an educational program "Argonautica" in France managed by CNES (National Space Center) 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 was drifting to the northwest in the Equatorial Current. However, it has moved far enough north that it is now sailing to the east in the Equatorial Counter Current.

## Technical Support

Science mission support:

- Technical staff continue to provide core processing and analytical support for the Science Party.
- Two more camera/sub-bottom surveys were conducted during routine VIT runs.
- Assessing fixes required to database and properly handle non-standard core types.

Other technical activities:

- Minor software updates completed.

- Started work on electronics cabinet for Conference room video system.
- Electronics and Arduino training classes continue.
- Started work on building an instrument host for Underway lab; identifying both software and hardware issues.

HSE activities:

- The weekly fire and abandon ship drill was held as scheduled.