

## **IODP Expedition 356: Indonesian Throughflow**

### **Week 3 Report (16–22 August 2015)**

Week 3 of Expedition 356 (Indonesian Throughflow) consisted of the transit to Site U1461 (proposed site NWS-4A) and coring operations in two holes (U1461A and U1461B). Hole U1461A was cored to piston coring refusal. Hole U1461B was also cored to piston coring refusal and then continued deeper with XCB coring, which is still in progress. The science party activities included finalizing all remaining analyses and reports from Site U1460, as well as documenting the first results from Holes U1461A and U1461B. In addition, the scientists received the final processed Hole U1459C log data from shore.

### **Operations**

The vessel arrived at Site U1461 at 1407 h on 17 August 2015 after a 469 nmi transit (42.3 h) from Site U1460. The vessel was offset 50 m to the west of the site coordinates and a seafloor positioning beacon was deployed at 1437 h. After offsetting the vessel from the beacon, drill floor activities commenced. Given previous difficulty with the mudline core at Site U1459 (broken core barrel), we decided to tag the seafloor with the bit. A non-magnetic HLAPC core barrel was dressed with a core liner in preparation for spudding Hole U1461A. The first attempt to establish the mudline resulted in a water core. After adjusting the bit depth, coring in Hole U1461A started at 1825 h on 17 August. Based on the recovery of the mudline core, the seafloor depth was calculated to be 127.2 mbsl. Cores U1461A-1F to 3F were recovered with the HLAPC system before we changed to the APC system. Cores U1461A-4H to 8H were recovered; a hard layer was encountered at ~54 mbsf and we changed back to the HLAPC system. Core U1461A-9F was a partial stroke and only recovered 0.37 m. An XCB core barrel was then dropped and a short (2.5 m) core was attempted through the hard layer, but Core U1461A-10X recovered no material. The HLAPC system was deployed again and coring continued through Core U1461A-12F to 66.6 mbsf. We then switched to the APC system and recovered Cores U1461A-13H to 29H to 228.1 mbsf. At that depth, the overpull to release the core barrel reached 100 klb and we were unable to pull the core barrel out of the formation. The core barrel had to be drilled over to release it from the formation. The HLAPC system was deployed and Cores U1461A-30F to 42F were recovered to 284.7 mbsf, where piston coring refusal was reached. At the conclusion of coring, the bit was raised up to 230.6 mbsf and the top drive was set back. The bit was pulled to just above the seafloor at 1430 h on 18 August 2015, ending Hole U1461A. A total of 77.4 m were cored with the HLAPC system with 77.12 m recovered. The APC system recovered 210.43 m from 204.8 m cored. The one XCB core recovered nothing. Overall, recovery for Hole U1461A was 101%. The total time spent on Hole U1461A was 24.5 h.

The vessel was offset 20 m north of Hole U1461A and Hole U1461B was started at 1600 h on 18 August. The stratigraphic correlators requested the bit be positioned to obtain a 4.5 m mudline core so that gaps between Hole U1461B cores would be offset from those in Hole U1461A.

Based on the 4.4 m long mudline core recovered, the seafloor depth was calculated to be 128.0 mbsl. The orientation tool was installed and cores were oriented from Core U1461B-2H. Coring continued through Core U1461B-7H to 55.1 mbsf. A single APCT-3 formation temperature measurement was made on Core U1461B-4H. At ~55 mbsf, the core barrel encountered the same hard layer from Hole U1461A. The HLAPC system was used to recover Core U1461B-8F. We switched back to the APC system and recovered Cores U1461B-9H to 25H, when the orientation tool was removed. Additional formation temperature measurements were taken on Cores U1461B-9H, 13H, and 16H. We then switched to the HLAPC system and recovered Cores U1461B-26F to 39F to 284.2 mbsf. An XCB core barrel was dropped and Core U1461B-40X was cut to 290.6 mbsf. The HLAPC system was again deployed and coring continued to Core U1461B-58F to 375.2 mbsf, where we determined that the HLAPC system had reached refusal. The XCB system was then used to recover Cores U1461B-59X through 123X to 827.1 mbsf by the end of the week. Thus far, 152.2 m were cored with the HLAPC system with 157.5 m recovered; the APC system cored 216.6 m with 225.55 m recovered; and the XCB system advanced 473.8 m with 325.41 m of core recovered. The recovery for Hole U1461B during week 3 was 86%.

## Science Results

### *Lithostratigraphy*

The lithology of Site U1461 is dominated by unlithified carbonate sediment. The lithology in Hole U1461A is dominated by unlithified to partially lithified skeletal packstones, wackestones, and mudstone. The bioclastic assemblage is dominated by benthic and planktic foraminifera, bivalves, echinoderms, and some bryozoans. Preliminary results suggest that the lithostratigraphy of Hole U1461A is divided into five units. Unit I (0–11.0 mbsf) is composed of unlithified homogeneous packstone and often contains benthic foraminifers and fossil bivalves. Units II (11.0–39.5 mbsf), III (39.50–96.84 mbsf) and IV (96.84–275.60 mbsf) each broadly consist of two subunits, a paired creamy gray wackestone alternating with gray or greenish gray packstone, although the subunits differ in detail. Within the Unit II subunits, Unit IIa consists of unlithified, fossil rich creamy gray wackestone to mudstone, while Unit IIb is an unlithified, homogeneous, gray packstone to wackestone. Within the Unit III subunits, Unit IIIa is a partially lithified, cream-colored wackestone, but also contains peloids and rare macrofossil fragments, and Unit IIIb consists of homogeneous dark greenish gray packstone. Finally, Unit IVa is an unlithified, homogeneous, off-white mudstone, whereas Unit IVb is an olive gray packstone to wackestone with glauconite. Partially lithified concretions are found throughout this subunit. Unit V (275.60–284.71 mbsf) is an unlithified cream mudstone and wackestone with clay. This unit contains benthic foraminifers, gastropods, and bioclasts. The upper part of the unit commonly exhibits bioturbation. Work is continuing to further characterize the lithostratigraphic units and to integrate lithologic data from Hole U1461B.

## *Biostratigraphy and Micropaleontology*

The biostratigraphy team processed core catcher (CC) samples from Site U1461 at 20 m resolution through Holes U1461A and U1461B. The bottom of Hole U1461A contains material that is of early–late Pleistocene age (Sample U1461A-42F-CC; 284.7 m CSF-A). The sediments recovered from Hole U1461B are of Pliocene–Pleistocene age, with the base of the hole (Sample U1461B-129X-CC; 877.74 m CSF-A) estimated to be older than 4.07 Ma (planktonic foraminifers) and 4.13 Ma (calcareous nannofossils). Sixty-nine smear slides were analyzed, revealing common to abundant calcareous nannofossils that are moderately to well preserved in both Holes U1461A and U1461B. The nannofossil assemblages were dominated by small, placolith-bearing species of the Noelaerhabdaceae family, including *Emiliana huxleyi*, *Gephyrocapsa* spp., *Pseudoemiliana lacunose*, and *Reticulofenestra* spp. Pleistocene marker species were found at similar depths in Holes U1461A and U1461B, confirming the preliminary age–depth constraints and good correlation between holes. In Hole U1461B, the Pliocene–Pleistocene boundary was marked by the presence of *D. surculus* (Top at 2.49 Ma) at 728.04 m CSF-A (Sample 356-U1461-106X-CC). Samples U1461B-122X-CC to 129X-CC (834.7–877.74 m CFS-A) are of late Early Pliocene age (>3.7 Ma).

For planktonic foraminifera, improved preservation in the upper 40 m of Hole U1461A (Cores 356-U1461A-1F-CC to 6F-CC) and below 677 mbsf of Hole U1461B (Core 356-U1461B-100X-CC and downhole) revealed a more diverse fauna than at previous sites. The Top of *Globorotalia tosaensis* and the Mid-Pleistocene boundary into biozone Pt1a (0.61 Ma) is at 414.99 m CSF-A (Sample U1461B-64X-CC). The transition into the Pliocene occurs after the Top of *Globorotalia limbata* (Sample U1461B-104X-CC; 704.94 m CSF-A; Biozone PL5; 2.39 Ma). Good preservation of the Pliocene sediments allowed identification of biozones PL5–PL2 culminating in an age for the bottom of Hole U1461B of just over 4 Ma (change in *Pulleniatina* coiling direction; Sample U1461B-129X-CC; 877.74 m CSF-A).

To date, 48 samples have been examined from Holes U1461A and U1461B for benthic foraminifera. Preservation was good for the uppermost 60 m and moderate down to 120 mbsf in Hole U1461A. The rest of the samples in this hole have poor preservation. In fact, the majority of samples from Site U1461 exhibit poor preservation, although several samples from Hole U1461B have moderate preservation (e.g., U1461B-60X-CC, 384.9 m CFS-A; U1461B-85X-CC, 543.16 m CFS-A) and two had good preservation (U1461B-100X-CC, 677.47 m CFS-A; U1461B-104X-CC, 704.94 m CFS-A). Poor preservation is largely due to encrustation by calcite and dolomitization. The number of species per sample ranges from 7 to 65 with an average of 19, the highest species diversity in sites investigated during Expedition 356 so far. Foraminiferal assemblages remain largely dominated by *Cibicides* spp. and *Cibicidoides* spp. with the addition of several Larger Benthic Foram (LBF) species, particularly *Amphistegina lessonii* and *Neoepionides margaritifera*.

## *Geochemistry*

Geochemical analyses from our previous Site U1460 on the squeeze cake and interstitial water samples including total organic and inorganic carbon content, total nitrogen, and major and minor element content were finished. The site is characterized by high percentages of calcium carbonate (mean value of 90%) and low total organic carbon (mean value of 0.48%) and total nitrogen (mean value of 0.03%).

For Site U1461, headspace gases were monitored for each core from Holes U1461A and U1461B. The methane concentration begins to increase at 50 mbsf to relatively higher values (~2000–40000 ppmv). Relatively low concentrations of ethane (2–45 ppmv) and propane (0–85 ppmv) have also been detected. The ratio of methane to ethane decreases from ~2000 at 100 mbsf to ~500 at 500–700 mbsf. Samples for interstitial water composition (including pH, alkalinity, salinity, and major and minor element content) have been taken every 10 m from the upper 100 m and then every 30 m. The pH values of the interstitial water range from 6.8 to 8.6, and alkalinity ranges from 1.5 to 29.0 mM. Salinity in the uppermost sample is 35 and increases with depth to a maximum value of 120 at 700 mbsf. Additional squeeze cake and interstitial water samples are in various stages of preparation for other geochemical analyses, including total organic and inorganic carbon content, total nitrogen, and major and minor element content. Thus far, only samples from the upper 200 m have been measured, so the overall results have not been finalized. Calcium carbonate content ranges from 75%–93%.

## *Paleomagnetism*

Paleomagnetic investigations on discrete samples from Site U1460 were completed with alternating field demagnetization (AFD) and isothermal remanent magnetization (IRM) measurements. AFD results confirmed that characteristic remanent magnetization was isolated after 20 mT. IRM acquisition measurements showed that saturation was reached before 300 mT, indicating the presence of low coercivity minerals. Backfield IRM curves were produced for four samples and combined with IRM acquisition curves, indicating values for remanence coercivity ranged from 40.7 to 67.0 mT.

For Site U1461, we focused on natural remanent magnetization (NRM) and rock magnetism measurements from Hole U1461B because the APC cores were oriented—the first orientation data obtained this expedition. In total, 53 cores comprising the upper ~350 m have been measured thus far, and reflected a stable, normal polarity pattern with no clear evidence for the Brunhes/Matuyama boundary (0.781 Ma). This is consistent with the high sedimentation rates suggested by sedimentological and paleontological investigations. Rock magnetic measurements on seven samples include progressive stepwise AF demagnetization, IRM, and backfield IRM investigations. AFD results confirm the normal polarity of the ChRM (negative inclination) for such stratigraphic interval.

### *Physical Properties*

We concluded physical properties measurements of Site U1460 on 16 August and finalized the corresponding Site Report. The majority of the week was spent fine-tuning physical properties measurement protocols with the Whole-Round Multisensor Logger (WRMSL), natural gamma ray (NGR) logger, and analyses of discrete samples in Holes U1461A and U1461B. In contrast to previous sites, we changed the spatial resolution of the NGR from 20 cm in Hole U1461A to 10 cm in Hole U1461B to provide higher resolution data, which is still being analyzed. We also used two different instruments to measure thermal conductivity because we were generating unexpected reduced conductivities with depth. First, we measured thermal conductivity by the traditional method (i.e., inserting the needle through a drilled hole in the core liner), which produces a conductivity of  $1.161 \pm 0.005$  W/(m·K). We then attached the mini-puck to intact core biscuits, which produced a conductivity of  $1.573 \pm 0.069$  W/(m·K). We believe this difference is the result of core disturbance by the XCB and depends on whether the needle-probe measures the biscuits or the drilling-induced slurry between them; measurements on the intact pieces are inferred to represent in situ values.

Sonic velocity measurements acquired by the WRMSL below 60 mbsf are questionable because the cored material was characterized by a large degree of expansion, hampering such measurements. All of the obtained *P*-wave velocities fell outside the accepted range. Even on discrete samples, it was impossible to acquire velocity data for Cores U1461B-27F to 58F (230.84–375.61 mbsf) because of the characteristics of the sediments. However, below Core U1461B-72X (>457.11 mbsf), we consistently got good measurements that showed an increasing trend to 2698 m/s. In Holes U1461A and U1461B, we observed decimeter-scale variations in magnetic susceptibility, NGR, and color reflectance that were clearly interrelated. These variations likely reflect the patterns of changing paleoenvironmental conditions and attempts to perform cyclostratigraphy are ongoing.

### *Downhole Logging*

The log data from Hole U1459C were received back on the ship after routine shore-based processing. During this week, we have been analyzing these results, and comparing the downhole measurements with physical property core measurements from Site U1459. For example, initial observations documents that an NGR peak in the downhole logging data at 185 mbsf corresponds to the core-based NGR peak in Hole U1459B at 192 m CSF-A. This peak is likely the result of an increased concentration of thorium and potassium and may be consistent with an increase in the input of detrital minerals, as suggested by the lithology in Unit Vb. We are still finalizing the Site U1459 report.

At Site U1461, successful formation temperature measurements were made with the APCT-3 tool on Cores U1461B-9H, 13H, and 16H. We made a preliminary estimate of the heat flow by combining the thermal conductivity measurements made on cores from Holes U1461A and

U1461B. However, we are not yet sufficiently confident in the inferred heat flux and are planning additional measurements in the upcoming Hole U1461C.

### *Stratigraphic Correlation*

Core recovery from Holes U1461A and U1461B has been sufficient to start producing a continuous record (splice) for the upper 280 m of material. Hole U1461A had only one interval of poor recovery around 53–54 mbsf and coring with the APC system continued until 228.2 mbsf. The remaining 80 m were cored by the HLAPC system until a hardground was reached at 284.71 mbsf. Hole U1461B used the same strategy of alternating APC and HLAPC systems, but the cores were offset by 4.7 m to target the interval of poor recovery in Hole U1461A (54 mbsf). Hole U1461B continued below the hardground (284.71 mbsf) down to 375.61 mbsf with the HLAPC system. Using the recovery from Hole U1461B, we created a coring plan for Hole U1461C that will target the deeper material from Hole U1461B (~280–375 mbsf) to produce as complete a Site U1461 stratigraphy as possible. Meanwhile, we finalized the site reports for Sites U1459 and U1460; in neither of these sites were splices able to be produced.

### **Education and Outreach**

The education and outreach team has continued blogging, documenting, and engaging on social media. There were two ship-to-shore events this week: a preschool from New South Wales (Australia) and an Indian university with participation from two scientists. Approximately four additional events are scheduled for the next week. Both Education and Outreach Officers are continuing to work on their individual projects, including a board game, an interactive video, and updating/organizing the <http://joidesresolution.org> website.

### **Technical Support and HSE Activities**

Technical staff primary activities included initial archiving of cores and supporting core flow through the laboratories, as well as laboratory maintenance. Technical staff are producing thin sections. Application Developers are working with scientists and the Publications Specialist to better accommodate carbonate core description.

#### *HSE Activities*

- Safety showers and eyewash stations were tested.
- A fire and boat drill was conducted on 20 August.