

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

### **Week 4 Report (23–29 August 2015)**

Week 4 of Expedition 356 (Indonesian Throughflow) consisted of coring in three additional holes at Site U1461 (U1461B, U1461C, and U1461D) and downhole logging in Hole U1461D. Site U1461 operations were completed by the end of the week, and the vessel started the transit to Site U1462 (proposed site NWS-3A).

#### **Operations**

Week 4 began with continued XCB coring in Hole U1461B. Cores U1461B-124X to 129X penetrated from 827.1 to 879.2 mbsf. Hole U1461B ended at 1640 h on 23 August. In Hole U1461B, the HLAPC system cored 152.2 m and recovered 157.50 m, the APC system cored 216.6 m and recovered 225.55 m, and the XCB system cored 360.19 m and recovered 510.4 m (85%). The total time spent on Hole U1461B was 122.25 h (5.1 d).

After offsetting the vessel 20 m north of Hole U1461B, the top drive was picked up and spaced out. Hole U1461C was started at 1915 h on 23 August. Based on the recovery of the mudline core (8.4 m), the length of which was requested by the stratigraphic correlators, the seafloor depth was calculated to be 127.5 mbsl. The orientation tool was installed and APC cores were oriented starting with Core U1461C-2H. Coring continued with non-magnetic core barrels through Core U1461C-23H to 215.5 mbsf with the APC system, after which the orientation tool was removed because APC refusal was reached. Three formation temperature measurements with the APCT-3 tool were made on Cores U1461C-4H, 10H, and 16H. The HLAPC system was then used to recover Cores U1461C-24F to 73F to 443.9 mbsf, which was HLAPC refusal. The final temperature measurement for the hole was taken on Core U1461C-24F. A single interval was drilled without coring (289.0–292.0 mbsf) to aid in correlation between Holes U1461A, U1461B, and U1461C. Hole U1461C ended at 0510 h on 25 August. A total of 225.4 m was cored with the HLAPC system and recovered 230.37 m, while the APC system recovered 218.16 m of 215.5 m cored (102%). The total time spent on Hole U1461C was 36.5 h (1.5 d).

The vessel was offset 20 m north of Hole U1461C, and a coring plan was prepared for Hole U1461D based on the total depth and core recovery of Hole U1461B. Hole U1461D was started at 0940 h on 25 August and was drilled without coring from the seafloor to 455 mbsf. The center bit was removed and a non-magnetic RCB core barrel was deployed and we started coring. Cores U1461D-2R and 3R were recovered from 455.0 to 474.4 mbsf. The center bit was dropped back in and the hole advanced by drilling without coring to 503.0 mbsf. We then cut Core U1461D-5R to 512.7 mbsf. The hole was drilled again without coring from 512.7 to 565.0 mbsf. After retrieving the center bit one last time, we resumed continuous RCB coring. While RCB coring, we conducted a 15 min transfer of a few passengers and cargo with the M/V *Lobo*. Cores U1461D-7R to 23R were recovered to 729.9 mbsf. Operations were halted for 30 min to

troubleshoot and repair a leaking wash pipe on the swivel. Coring resumed with the recovery of Core U1461D-24R and continued to a final depth of 1095.3 mbsf (Core U1461D-61R), which was reached at 1905 h on 28 August. A total of 559.4 m were cored with the RCB system, recovering 325.51 m (58%).

To prepare the hole for wireline logging, high viscosity mud was circulated through the hole and the RCB coring bit was released in the bottom of the hole. After releasing the bit, the end of the drill string was raised up to 500.1 mbsf and the circulating head was installed. The upper 500.1 m of the hole was displaced with 250 barrels of +11 ppg mud. The end of the pipe was raised up to logging depth (78.1 mbsf) and the rig floor prepared for downhole logging. The triple combination tool string was assembled and deployed by 0400 h on 29 August. It contained the magnetic susceptibility sonde (MSS), High-Resolution Laterolog Array (HLRA), Hostile Environment Litho-Density Sonde (HLDS), Accelerator Porosity Sonde (APS), Hostile Environment Natural Gamma Ray Sonde (HNGS), Enhanced Digital Telemetry Cartridge (EDTC), and logging equipment head-q tension (LEH-QT). After the tool string exited the drill pipe, the active heave compensator was turned on. A downlog was performed from just above seafloor to 1031.7 mbsf, and then an uplog was produced to 1020 mbsf for a calibration pass. While attempting to return to bottom, surface tension was lost on the wireline, but tension remained at the cable head. It was determined that the upper section of the hole had collapsed. The hole was then logged up to the end of the drill pipe, experiencing overpull the entire time. The overpull reached ~5000 lb between 750–650 mbrf and even more significant tool tension was experienced from 440–350 mbrf, which is the suspected depth where the hole collapsed. The caliper was closed at 405 mbrf to retrieve the tool string. As the tools approached the end of the drill pipe, circulation was initiated to aid the tool string's reentry into the drill string. The tools were pulled from the hole and rigged down at 1200 h. The FMS-sonic tool string was then assembled with the Formation MicroScanner (FMS), Dipole Sonic Imager (DSI), Hostile Environment Natural Gamma Ray Sonde (HNGS), Enhanced Digital Telemetry Cartridge (EDTC), and the logging equipment head-q tension (LEH-QT). At 1310 h, the tool string was lowered without difficulty through the drill pipe, activated, and the hole was logged down to ~190 mbsf. After trying unsuccessfully to pass deeper, the hole was logged upwards. Two passes were made over this length of open hole. The tool string was pulled back to the surface and rigged down by 1630 h. The drill string was pulled from the hole and the rig floor was secured for transit. The thrusters and hydrophones were then pulled and secured, ending Site U1461. The total time spent on Hole U1462D was 111.5 h (4.6 d), and the total time spent on Site U1461 was 12.3 d. At 2048 h on 29 August, the vessel began the transit to Site U1462 (proposed site NWS-3A).

## Science Results

### *Lithostratigraphy*

The lithostratigraphy of Site U1461 is divided into four units, with six subunits in Unit II. The lithostratigraphic units and their boundaries are defined by changes in lithology (identified by visual core description and smear slide observations), physical properties, color reflectance ( $L^*$ ,  $a^*$  and  $b^*$ ), XRD, petrographic section analyses, and seismic data. Unit I (~11.25 m thick) consists of mainly unlithified, homogeneous olive gray to brown to greenish gray packstone with benthic foraminifers and bivalves. Unit II (~432–455 m thick) is divided into six subunits (IIa, IIb, IIc, IId, IIe, IIf in descending order). All subunits except subunit IIa consist of two intervals that alternate between 1) an upper coarser-grained, darker-colored, thicker interval composed of unlithified, dark greenish gray to olive gray packstone/wackestone, and 2) a lower, finer-grained, light-colored, thinner interval composed of unlithified, homogeneous, cream to light gray mudstone. The exception, subunit IIa, consists entirely of a light-colored mudstone/wackestone. Throughout Unit II, the lower interval of each subunit is always thinner than the upper interval. These upper and lower intervals are further distinguished by differences in degree of bioturbation, and abundances of macrofossils, peloids, and, in the case of subunit IIc, the presence of low-angle cross stratification and normal grading. Unit III (~527 m thick) is composed of lithified wackestone ranging in color from greenish gray to olive gray. Bioturbation is common throughout the unit, and burrows are often filled with coarse sand. Foraminifers are common, whereas fragments of bivalves and gastropods are very rare. In the lower half of Unit III there are a variety of sedimentary contacts, ranging from sharp to wavy, gradational, and scoured. The occurrence of these contacts often coincides with numerous sedimentary features, including parallel lamination, thin bedding, normal grading, load casts, slump folds, and intraclasts. Pyrite is also present in the lower half of Unit III as disseminated grains and nodules. Unit IV (~95 m thick) consists of lithified, light greenish gray, fine sand-sized packstone (interbedded with wackestone with mud-sized grains) that grades into creamy gray packstone with coarse sand-sized grains (interbedded with packstone with coarser sand-sized grains). Near the base of the unit, the lithology transitions to back to light greenish gray packstone with fine sand-sized grains, interbedded with wackestone with mud-sized grains. Bioturbation, benthic foraminifers, and pyrite are more abundant in muddy intervals. Bedding contacts are sharp. Planar laminae and normal grading are present in the coarser-grained intervals.

### *Biostratigraphy and Micropaleontology*

The biostratigraphy team continued to process core catcher (CC) samples from Site U1461 at 20 m intervals, completing Holes U1461C and U1461D. The bottom of Hole U1461C (248.96–443.88 mbsf) was studied and suggests early-late Pleistocene age. In Hole U1461D, the abundance and preservation of calcareous nannofossils and planktonic foraminifera drastically decreases around 1008.3 mbsf (Section U1461D-52R-CC) with possible reworking, suggesting

an unconformity is present. The bottom of Hole U1461D was dated to middle Miocene age (nannofossils).

Fifty-three smear slides were analyzed revealing rare to abundant calcareous nannofossils that are poor to well preserved in Hole U1461C (13 samples) and Hole U1461D (40 samples). The base of Hole U1461C (443.88 mbsf) is early Pleistocene in age (NN19, <1.93 Ma). The sediments retrieved from Hole U1461D are middle Miocene to Pleistocene in age. The Pliocene–Pleistocene boundary in Hole U1461D was marked by the Top of *D. surculus* (NN16, 2.49 Ma) at 713.39 mbsf (Sample U1461D-22R-CC). The abundance and preservation of calcareous nannofossil drastically decreases between Samples U1461D-51R-CC (1001.7 mbsf) and U1461D-52R-CC (1008.3 mbsf). Calcareous nannofossils are found within a micritic matrix with the presence of  $\mu\text{m}$ -scale dolomitic rhombic crystals from Core U1461D-52R that increases in abundance further downhole. An age marker for the late Miocene (Zone NN12) was not found in Hole U1461D, indicating a hiatus near the Miocene–Pleistocene boundary. Nevertheless, *C. macintyreii* is present at the bottom of Hole U1461D (Sample U1461D-61R-CC, 1088.92 mbsf) suggesting the material is middle Miocene (<13.36 Ma) in age.

Forty samples were examined from Holes U1461C and U1461D for planktonic foraminifera. In general, preservation ranged from moderate to (very) poor. The poor preservation in Hole U1461C (Cores U1461C-59F [381.64 mbsf] to 73F [443.8 mbsf]) yielded few identifiable markers; *Globorotalia tosaensis* was only found in Cores U1461C-62F (395.75 mbsf) and 69F (426.71 mbsf), indicating a middle Pleistocene age. In Hole U1461D, the co-occurrence of *G. truncatulinoides* and *G. tosaensis* in Sample U1461D-17R-CC (665.6 mbsf) indicates a minimum age of 1.93 Ma for the material. Sample U1461D-20R-CC (700.6 mbsf) was the Top of *G. extremus*, which suggests the material is 1.99 Ma. The appearance of Top of *G. limbata* in Section U1461D-24R-7 (740.17 mbsf) marks biozone PL6 (2.39 Ma) and the Top of *D. altispira* (Sample U1461D-29R-CC, 788.3 mbsf) marks biozone PL5 (3.46 Ma); the Plio–Pleistocene boundary is present within this interval. Additional Pliocene age markers include the co-occurrence of *P. primalis* and *S. seminulina* (biozone PL4; 3.57–3.65 Ma) in Sample U1461D-33R-CC (817.63 mbsf), Top of *G. margaritae* (biozone PL3; 3.85 Ma) in Sample U1461D-39R-CC (883.86 mbsf). The Pliocene–Miocene boundary was not identified but the appearance of *G. plesiotumida* in Samples U1461D-45R-CC (943.15 mbsf) and 41R-CC (904.72 mbsf) indicates the material is late to middle Miocene (<8.52 Ma) in age. Species identification was not possible below Core U1461D-53R (1012.7 mbsf) due to heavy cementation.

To date, 24 samples have been examined from Holes U1461C and U1461D for benthic foraminifera to target horizons not previously observed in Holes U1461A and U1461B. Preservation is generally poor; however, there are frequent horizons where it increases to moderate or good. These include ~400 mbsf (Sample U1461C-64F-CC, 403.94 mbsf) and between 883.86–953.23 mbsf (Samples U1461C-39R-CC to 47R-CC). Poor preservation is largely due to encrustation by calcite, iron, and micrite. The number of species per sample across these two holes ranges from 8 to 28, with an average of 15. Foraminiferal assemblages remain

largely dominated by *Cibicides* spp. and *Cibicidoides* spp. with the addition of several assemblages where dominant species include larger benthic foraminifer (LBF) species, particularly *Neoeponides margaritifer*, and smaller infaunal species including *Bolivina* spp. and *Uvigerina* spp.

### *Geochemistry*

At Site U1461, bulk geochemical analyses on the squeeze cake and interstitial water samples from Holes U1461A and U1461B, including total organic and inorganic carbon content, total nitrogen, and major and minor element content were finished. Samples for interstitial water composition (including pH, alkalinity, salinity, and major and minor element content) were not taken from Hole U1461D due to extremely low interstitial water content. In general, elevated salinity characterizes the site, with values of 35 at the top, increasing with depth to values of 137 at 870 mbsf. The site is also characterized by high percentages of calcium carbonate (mean value of ~80%) and low total organic carbon (mean value of 0.9%) and total nitrogen (mean value of 0.04%). Headspace gases monitored in each core of Hole U1461D revealed hydrocarbon concentrations lower than those in Holes U1461A and U1461B. Initial observations from Site U1461 material, including the presence of propane and higher molecular weight hydrocarbons in sections of the hole, suggests this site is likely not suitable for paleoenvironmental reconstructions based on organic geochemical proxies. However, pilot samples will be measured directly post-expedition.

### *Paleomagnetism*

Paleomagnetic investigations focused on natural remanent magnetization (NRM) and alternating field demagnetization (AFD) measurements from Site U1461. The SRM experienced technical difficulties throughout the week in the form of flux jumps. Sections that were affected most were re-measured. More than 70 discrete samples underwent AF demagnetization in an attempt to get accurate directional data despite the technical difficulties associated with the SRM. Comparisons between results from the archive-half and discrete sample measurements reveal discrepancies in inclination data. A few discrete samples have inclination values proximal to archive-half values, but a majority of the discrete samples reflect reversed (positive) polarity while the archive-half results are dominated by normal (negative) polarity values. It is not yet understood what causes the discrepancy. Due to conflicts in directional data, there is still no clear evidence for the Brunhes/Matuyama boundary.

Rock magnetism investigations continued on selected samples from Holes U1461B, U1461C, and U1461D. AFD, isothermal remanent magnetization (IRM) acquisition, and backfield IRM acquisition measurements of discrete samples from extended core barrel (XCB) cores showed stable directional data and very high coercivity mineral composition, associated with hematite or goethite. X-ray diffraction results confirmed that magnetite, titanomagnetite, maghemite, hematite, greigite, and goethite were present in Section U1461B-90X-2 (~579 mbsf). Many other discrete samples have unstable demagnetization behavior, but some, such as those from Sections

U1461C-12H-3 (101 mbsf) and 46F-2 (315 mbsf) exhibit reliable reversed polarity directions. Samples from Hole U1416D, ranging from 464 to 836 mbsf, have varying coercivity values, and generally reflect normal polarity.

### *Physical Properties*

Physical properties measurements were performed using the Whole-Round Multisensor Logger (WRMSL), natural gamma ray (NGR) logger and on discrete samples in Holes U1461B, U1461C and U1461D. The spatial resolution of NGR measurements was 10 cm in Holes U1461B and U1461D and 20 cm in Hole U1461C. Below 375 mbsf in Holes U1461B and U1461D, there was an observed discrepancy between bulk density measured by gamma ray attenuation (GRA) on the WRMSL and discrete bulk density measurements, related to the fact that the cored material (from the XCB and RCB systems) did not completely fill the liners. The same observation was made when loop magnetic susceptibility (MS) measurements on the WRMSL and discrete point MS measurements from the Section Half Multisensor Logger (SHMSL) were compared. A drift in the MS measurements made by the SHMSL was observed and quantified by repeated measurements of a core liner filled with Styrofoam. These were used to correct SHMSL MS measurements on sediments. Thermal conductivity of the sediments increased gradually with depth from about 1 W/(m·K) in the upper meters of Holes U1461A and U1461B to ~1.8 W/(m·K) at ~1000 mbsf in Hole U1461D. Between 125 and 450 mbsf, sonic velocity measurements obtained by the WRMSL and discrete sampling were often unsuccessful, as the cored material was characterized by a large degree of expansion, hampering such measurements. However, in the deeper parts of Holes U1461B and U1461D, discrete measurements of sonic velocity were successful and show a gradual increase with depth, from ~1750 m/s (450 mbsf) to ~2800 m/s (925 mbsf). In the lower part of Hole U1461D (925–1080 mbsf), sonic velocities were relatively constant and ranged between 2400 and 2900 m/s. Discrete physical properties measurements of Hole U1461D were within a few hours of being finished by the end of the week, and the Site Report for U1461 was in preparation.

### *Downhole Logging*

The downhole measurements team completed its preliminary analysis of the processed logs from Site U1459C and the corresponding report.

At Site U1461, successful in situ temperature measurements with the APCT-3 tool were made on Cores U1461C-10H, 16H, and 24F. These were combined with the three in situ temperature measurements made during the previous week on Cores U1461B-9H, 13H, and 16H. The heat flow was estimated by combining the in situ temperature measurements and the thermal conductivity measurements made on cores from all four holes of Site U1461. The quality of the heat flow estimate was judged to be quite good as there was a linear relation between thermal resistance and temperature with six temperature measurements down to 220 mbsf. Downhole logging at Site U1461 was limited to the triple combo (to ~1030 mbsf) and ~the upper 200 m of

Hole U1461D before hole conditions deteriorated and precluded additional measurements. All of the preprocessed logs were passed on for onshore processing.

### *Stratigraphic Correlation*

During week 4 we monitored the coring of Holes U1461C and U1461D to obtain optimal recovery of the entire Site U1461 stratigraphy. The primary focus of Hole U1461C coring was to fill in recovery gaps from Holes U1461A and U1461B to produce a splice for the upper 280 m, so a coring adjustment was made, resulting in a shorter Core U1461C-32F. The secondary focus was to increase the recovery of an interval (Core U1461B-60X, 390 mbsf) that contained an unexpected shallow benthic foraminifera fauna, and coring adjustments successfully achieved this. Finally, spot coring was utilized in Hole U1461D to recover some intervals in Hole U1461B that were not recovered by the XCB system (~455–560 mbsf). The remainder of the week was spent producing the splice and summaries for Holes U1461A–U1461C.

### **Education and Outreach**

The education and outreach team did three school broadcasts this week: Jupiter Christian in Florida (USA) on 24 August, Marina Del Rey in California (USA) on 27 August, and Kittredge Magnet school in Georgia (USA) on 29 August. The team continued to engage with social media, post blogs (currently featuring a series on the different science teams), and work on individual projects, and they are organizing a Reddit “Ask me Anything” event.

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

Technical staff primary activities included initial archiving of cores, supporting core flow through the laboratories, and laboratory maintenance. Specifically, a BugWin upgrade has been installed, and a light alignment and calibration of the Section Half Imaging Logger (SHIL) has been performed. Two IODP Marine Instrumentation Specialists boarded the vessel on 26 August by boat transfer (M/V *Lobo*).

#### *HSE Activities*

- Safety showers and eyewash stations were tested.
- A fire and boat drill was conducted on 28 August.