IODP Expedition 356: Indonesian Throughflow

Week 8 Report (20–26 September 2015)

Week 8 of Expedition 356 (Indonesian Throughflow) was the last week of operations. We completed coring and attempted logging at Site U1464, and then began our transit to Darwin, Australia. The science party completed all of their analyses, which primarily consisted of measurements from Site U1464, and they have begun writing up their final site reports.

Operations

Week 8 of Expedition 356 (Indonesian Throughflow) began while coring from 303.7 mbsf with the APC system in Hole U1464B. Coring continued through Core U1464B-34H to 313.2 mbsf, where APC refusal was reached. The HLAPC system was then deployed and we recovered Cores U1464B-33F to 35F to 316.9 mbsf by advancing by recovery. Two of these HLAPC cores (33F and 35F) had to be drilled over to release the core barrel from the formation, indicating that piston coring refusal was reached. At the conclusion of coring (0240 h, 20 September), the drill string was recovered and Hole U1464B ended at 0615 h. In Hole U1464B, the APC system penetrated 313.2 m and recovered 288.52 m of core (92%), while the HLAPC system was only used to core 3.7 m and recovered 3.75 m. The total time spent on Hole U1464B was 21.5 h (0.9 d).

After offsetting the vessel 20 m south of Hole U1464B, the RCB coring system was assembled and Hole U1464C was started at 0940 h on 20 September. After drilling without coring 308.0 m, the center bit was pulled, a nonmagnetic RCB core barrel was dropped, and coring began. We recovered Cores U1464C-2R to 56R to 840.0 mbsf by 1435 h on 22 September. The 55 RCB cores from Hole U1464C penetrated 532.0 m and recovered 94.03 m of core (18%).

After finishing the coring in Hole U1464C, we started to prepare the hole for wireline logging. High viscosity mud was circulated to clean the hole of cuttings and the RCB coring bit was dropped in the bottom of the hole. After releasing the bit, the end of the drill string was raised up to 800.3 mbsf and heavy mud was pumped to prevent backflow of water from the drill string on the rig floor. The end of the drill string was raised up to 567.3 mbsf and the continued backflow from the hole became excessive, so the hole was circulated out and two more high viscosity mud sweeps were pumped to clean the borehole. The end of the drill string was raised up to 363.1 mbsf and the circulating head was installed to displace the upper 363.1 m of the hole with heavy mud. After the end of the pipe was set at 86.9 mbsf, we displaced this uppermost part of the hole with more heavy mud and then started to assemble the first logging tool string. The triple combination tool was assembled at 0015 h on 23 September, and contained the following tools: magnetic susceptibility sonde (MSS), Hostile Environment Natural Gamma Ray Sonde

(HNGS), Hostile Environment Litho-Density Tool (HLDT), Enhanced Digital Telemetry Cartridge (EDTC), and logging equipment head-q tension (LEH-QT). The tool string was deployed at 0115 h. After the tool string exited the drill pipe, the active heave compensator was turned on. A downlog was performed from just above seafloor until the tool string encountered a bridge at 783.7 mbsf (~46 m above the bottom of the cored hole). The hole was logged up with the triple combo tool string to ~619.1 mbsf when the tool string became stuck. After having no success trying to free the logging tools, we decided to lower the open-ended drill pipe down the hole and over the logging wireline in an attempt to recover the tool string. The end of the drill pipe was lowered from 86.9 to 625.6 mbsf, washing through any obstructions that were encountered, over the logging wireline, and finally over the triple combo tool string. The logging tool string was then slowly pulled up to the rig floor using T-bars on the wireline. Finally, at 0030 h on 24 September, the logging tools were dissembled and the logging wireline was secured. No damage was found to any of the logging tools. However, while pulling the tool string from the hole, the drill pipe became stuck and a combination of overpull, rotation, and pumping was required to free it from the formation. The end of the drill pipe arrived back on the rig floor at 0830 h on 24 September, ending Hole U1464C. The total time spent on Hole U1464C was 98.25 h (4.1 d).

After offsetting the vessel 20 m west of Hole U1464C, we started APC coring in Hole U1464D at 1400 h on 24 September. Based on the recovery of the mudline core (3.55 m), the seafloor depth was calculated to be 264.7 mbsl. We recovered Cores U1464D-2H to 32H to 293.5 mbsf, at which depth APC refusal was reached. Formation temperature measurements with the APCT-3 tool were made while taking Cores U1464D-5H, 8H, 12H, 16H, 22H, and 28H. The APC core orientation tool (Icefield) was removed after the last full APC core. After recovering Core U1464D-32H, the XCB system was used to core from 293.5 to 529.6 mbsf (Cores U1464D-33X to 58X). We cored 293.5 m with the APC system and recovered 265.89 m of core, while the XCB system penetrated 236.1 m and recovered 34.85 m of core. Overall recovery for Hole U1464D was 57%. After the completion of coring, the drill string was pulled back to the rig floor and the seafloor positioning beacon was recovered at 1820 h on 26 September, ending Site U1464. At 2100 h, we started the transit to Darwin, Australia. The total time spent on Hole U1464D was 60.50 h (2.5 d). The total time spent on Site U1464 was 185.25 h or 7.7 d.

At the end of week 8, the vessel was underway to Darwin, Australia, having completed Expedition 356 coring and logging operations.

Science Results

Lithostratigraphy

The lithostratigraphy of Site U1464 is divided into five units. The unit boundaries were defined using visual core description, smear slide observations, NGR data, XRD, and thin-section analyses from Holes U1464B, U1464C, and U1464D.

Unit I (0–44.10 m CSF-A (Hole U1464B); 0–43.00 m CSF-A (Hole U1464D)) is 43–44 m thick and consists of unlithified, creamy-gray sediments with coarse silt- to fine sand-sized peloids in varying abundances, with the last occurrence of peloids marking the base of the unit. The sediment is composed of mainly skeletal grainstone in the upper part, mudstone dominating the middle and lower part of the unit, and short intercalated packstone and wackestone intervals. The generally low siliciclastic content of the unit is dominated by mica with minor amounts of quartz. The unit contains abundant foraminifers and pteropods with some macrofossils (e.g., scaphopods, bivalves, and solitary corals).

Unit II (44.10–138.20 m CSF-A (Hole U1464B); 43.0–140.39 m CSF-A (Hole U1464D)) is ~95 m thick and consists mainly of unlithified, homogeneous wackestone that includes a packstone interval and a relatively high abundance of authigenic glauconite and glauconitized microfossils. The top of the unit is defined by the loss of peloids as a common sedimentary component. Macrofossils are sparse and concentrated in coarser-grained intervals. Bioturbation is slight to moderate throughout the unit. Disseminated pyrite grains are common in the lower part of the unit along with occasional pyrite nodules and celestite concretions. Siliciclastic content generally increases but is variable, particularly in the lower half of the unit.

Unit III (138.20–308.86 m CSF-A (Hole U1464B); 140.39–308.74 m CSF-A (Hole U1464D)) is ~170 m thick, with the top of the unit marked by a transition from wackestone to mudstone and by a decrease in sand-sized siliciclastic content and an increase in clay-sized sediment. Overall siliciclastic content is very fine grained in Unit III, with a near absence of coarse-grained material. The unit consists mainly of unlithified, grayish-green to greenish-gray homogeneous mudstone with moderate bioturbation and common disseminated pyrite and pyrite concretions. Macroscopic bioclasts are very sparse but microfossils are abundant and well-preserved with a marked increase in calcareous nannofossils noted in smear slides.

Unit IV (308.86–316.95 m CSF-A (Hole U1464B); 308.00–521.40 m CSF-A (U1464C); 308.74–523.97 m CSF-A (Hole U1464D)) is ~215 m thick and marked by a transition to dolomitic packstone. The unit consists of three main intervals of dolomitic limestone separated by two intervals of skeletal limestones. Gypsum nodules are common in the dolomitic intervals and commonly co-occur with anhydrite nodules in the lower 46 m of the unit. Karstic surfaces, cavities, and moldic porosity are also common, especially in the skeletal limestones. Macrofossils are present and diverse in both lithologies, often occurring as molds. Bioclasts include many organisms typical of shallow habitats, including larger benthic foraminifers (e.g.,

Cycloclypeus), some zooxanthellate corals, and crustose coralline algae. Siliciclastic material is generally absent in Unit IV.

Unit V (521.40–832.90 m CSF-A (Hole U1464C)) is 311.50 m thick and consists primarily of dolomitic limestones (mudstone, wackestone, packstone, and grainstone) and dolostone. The top of the unit is defined by the first occurrence of littoral deposits. The upper part of the unit (~100 m) contains several heavily dolomitized intervals, while the lower part (~55 m) is composed of lithified, increasingly coarser packstones and grainstones. Macrofossils include fragments of molluscs, echinoid spines, bryozoa, and large benthic foraminifers. Fossil content generally decreases towards the base of the hole, while bryozoans increase in abundance and become common in the lower 10 m. Siliciclastic content continues to be generally absent to low with angular sand-sized quartz noted in the lowermost interval.

Biostratigraphy and Micropaleontology

A total of 101 smear slides were examined from Holes U1464B (23 samples), U1464C (37 samples), and U1464D (41 samples), revealing common to dominant calcareous nannofossils with moderate to good preservation throughout the late Miocene–Pleistocene section. Barren intervals were found in most samples from 330 m CSF-A in Holes U1464C and Hole U1464D. The top of biozone NN16, which includes the Pliocene–Pleistocene boundary, is marked by the presence of *D. surculus* (2.49 Ma) between 97.42–108.29 m CSF-A. Late Miocene–early Pliocene marker species were rare (e.g., *Amaurolithus* spp. and *Ceratolithus* spp.), making the Miocene–Pliocene boundary difficult to constrain, but this is tentatively placed between 228.4 m CSF-A (>4.2 Ma) and 281.39 m CSF-A (<5.59 Ma). The late Miocene marker taxa (e.g., *Reticulofenestra rotaria* and *Nicklithus amplificus*) were observed at the bottom of Hole U1464B (316.95 m CSF-A) and above the barren intervals in Holes U1464C and U1464D. The marker species *Cyclicargolithus floridanus* (>11.85 Ma) and *Coronocyclus nitescens* (>12.12 Ma) were found within the otherwise barren intervals in Hole U1464C. These marker species were first observed between 541.67 m CSF-A and 552.5 m CSF-A, indicating middle Miocene age. The age of the bottom part of the Hole U1464C and Hole U1464D cannot be further constrained, as calcareous nannofossil marker taxa are absent below ~600 m CSF-A.

Nineteen samples were examined from Hole U1464B, 27 from Hole U1464C, and 37 from Hole U1464D for planktonic foraminifer content. Planktonic foraminifers recovered at Site U1464 represent a stratigraphic succession from the mid-Miocene to Recent. Preservation ranged from moderate to very good in Hole U1464B (down to ~293.2 m CSF-A) and was accompanied by 8–17 species per sample and up to 80% planktonic foraminifers relative to benthic foraminifers. From ~312.8 m CSF-A (early Pliocene), downhole preservation was generally poor (poor to barren), and accordingly the abundance of planktonic foraminifers decreased in all holes. The middle Pleistocene boundary (transition biozone Pt1a–Pt1b) at 0.61 Ma, marked by the top of *Globorotalia tosaensis*, is found in Sample U1464B-2H-CC (11.51 m CSF-A). The early Pleistocene is characterized by the base of *Globorotalia truncatulinoides* (base Biozone Pt1a;

1.93 Ma) in Sample U1464B-6H-CC (49.82 m CSF-A) followed by the transition into the Pliocene below the top of *Globorotalia limbata* (PL5; 2.39 Ma) in Sample U1464B-10H-CC (88.17 m CSF-A). Pliocene marker species, such as *Dentoglobigerina altispira* (3.47 Ma, Top PL4, 126.3 m CSF-A), *Pulleniatina primalis* (3.66 Ma, Top PL3, 163 m CSF-A), and *Globorotalia margaritae* (3.85 Ma, Top PL2, 163 m CSF-A), were found at the same depth intervals in Holes U1464B and U1464D, and additionally, early Pliocene PL1 Biozone was identified at Site U1464 by the top of *Sphaeroidinellopsis kochi* (top 4.53 Ma) in Section U1464C-30H-5 (272.57 m CSF-A).

At Site U1464, 68 samples have been examined this week for benthic foraminifers. Preservation is generally moderate to good with only poor preservation in cores retrieved from >300 m CSF-A. The number of species per sample ranges from one to 43 species with an average of 18. The samples remain largely dominated by *Cibicidoide*s spp. and other dominant species within isolated phases include *Bolivina* spp., *Brizalina semilineata*, *Lenticulina* spp., *Clavulina subangularis*, *Planorbulinella larvata*, *Reophax* spp., and other larger foraminiferal species including *Neoeponides margaritifer*, *Rotalinoides gaimardii,* and *Pseudorotalia indopacifica*. Of particular note is that this site has revealed a suite of particularly large endosymbiotic foraminiferal species, many of them soritid genera, including *Amphisorus*, *Cylcloclypeus*, *Sorites*, *Sphaergypsina*, *Nephrolepidina*, *Miogypsina*, *Tribliolepidina,* and *Lepidosemicyclina*.

Geochemistry

All geochemical analyses on the squeeze cake and interstitial water samples from Holes U1464B and U1464C, including total organic (TOC) and inorganic carbon content, total nitrogen (TN), and major and minor element content, were completed. Geochemical measurements of interstitial water samples were not possible below 318 m CSF-A because of low core recovery and low amounts of pore water present in sediments. Calcium carbonate, TOC, and TN measurements were also taken on three additional sediment samples, two in distinct black layers (Sections U1464C-24R-2 and U1464C-25R-2) and a third one in a nearby laminated section as reference (U1464C-25R-5), to characterize the material in the black layers. In total, 85 samples were analyzed for headspace gas content, 20 samples (5–15 cm whole rounds) for interstitial water geochemistry measurements, and 23 samples for calcium carbonate, TOC, and TN measurements. Headspace gas analysis for routine safety monitoring revealed the presence of methane in very low concentrations in all 85 samples analyzed (<4 ppmv). With the exception of the two samples from the discrete black layers, samples at this site are characterized by high calcium carbonate content (mean value 78.8%) and low TOC (mean value 0.6%) and TN (mean value 0.018%). Such variation of the calcium carbonate content is similar to Site U1463. The two samples from the black layers (Sections U1464C-24R-2 and U1464C-25R-2) have extremely low calcium carbonate content (3.6% and 2.7%, respectively) but exhibit different characteristics in TOC and TN values, suggesting they are not from the same source. A trend of increasing salinity with depth is noted; it increases from 39 at 40 m CSF-A to 105 at ~300 m CSF-A, and,

similar to previous sites, the major elements (sodium, chloride, calcium, sulfate) associated with this also display the same trends. Below 300 m CSF-A, salinity values decrease from 105 to 87.

Paleomagnetism

In the beginning of the week, we concluded the interpretation of the magnetostratigraphic data for Hole U1463C, which indicated the Gauss/Gilbert boundary (3.596 Ma) is at ~282 m CSF-A. In addition, it is possible that the transition between the C3n–C3r intervals (5.235 Ma) occurs at ~375 m CSF-A, where it corresponds with a biostratigraphic datum of 5.59 Ma at ~392.5 m CSF-A. The Site U1463 Report was also finalized.

Later in the week, we conducted paleomagnetism and rock magnetism investigations on 20 discrete samples from Holes U1464B, U1464C, and U1464D, including natural remanent magnetization (NRM), alternating field (AF) demagnetization, isothermal remanent magnetization (IRM) and backfield IRM, and susceptibility measurements. Two of the samples (U1464C 22R-4, 50–52 cm, and U1464C 34R-1, 46–48 cm) reached saturation IRM at ~100 mT, Sample U1464C-24H-3, 70–72 cm, saturated at ~400 mT, and Sample U1464C-18H-4, 74–76 cm, did not reach saturation in fields up to 1.2 T. Remanent coercivity values of the four samples ranged between 44 mT and 83 mT. Bulk susceptibility measurements were also performed on all of the discrete samples, and results ranged from –7.95 to 110.24 × 10^{-6} SI units.

Archive-half core sections from Hole U1464D yielded intensity values that generally ranged from 10^{-5} to 10^{-3} A/m, with exceptions that correspond to high susceptibility intervals from Whole-Round Multisensor Logger (WRMSL) and Section Half Multisensor Logger (SHMSL) data for which intensity values reached ~10^{-1} A/m. A persistent negative inclination trend occurs from the seafloor to ~210 m CSF-A (Core U1464D-23H), from which there was a gradual shift towards lower inclination values and more frequent positive inclination intervals. Magnetostratigraphic data for Hole U1464D indicate the Gauss/Gilbert boundary (3.596 Ma) is at ~282 m CSF-A. In addition, it is possible that the C3n/C3r boundary (5.235 Ma) occurs between 272.66–277.85 m CSF-A because it is constrained by biostratigraphic datum of 5.59 Ma at 281.39 m CSF-A.

Physical Properties

Physical properties measurements were performed using the WRMSL, natural gamma ray (NGR) sensor, and discrete sampling on cores from Site U1464. Stratigraphic overlap between Holes U1464B, U1464C, and U1464D is confirmed by physical properties patterns, including magnetic susceptibility, natural gamma radiation, and moisture and density (MAD) results. Detailed analysis of *P*-wave velocity, as measured in sediments obtained from three different coring techniques (APC, XCB, and RCB) reveal interesting variations. *P*-wave velocities of sediments cored with the XCB and APC systems are parallel, however, XCB *P*-wave velocities fall within two distinct velocity ranges. The lower range is nearly equivalent to the *P*-wave velocities obtained on APC cores, and corresponds to the "drilling slurry" portion of a disturbed

XCB core. A second range is ~150 m/s higher and corresponds to the coherent pieces of core ("biscuits"). Sediments obtained with RCB coring tend to have 400–650 m/s higher velocities than those obtained with APC coring. An estimate of the geothermal heat flux of 59.1 mW/m^2 was derived from a combination of the six formation temperature measurements taken with the APCT-3 tool and core-based thermal conductivity measurements.

Downhole Logging

Logging operations at Hole U1464C were carried out on 23 September. However, the triple combination tool string became stuck in the hole at a depth of 615 m WMSF on the first up pass. As a result, no other logging tool strings were run. The triple combination tool string measured natural gamma radiation (NGR), magnetic susceptibility (MS) and resistivity throughout the hole (0–783 m WMSF) during the down pass, and between 783–615 m WMSF during the up pass. Bulk density and porosity were only obtained during the up pass. The NGR log was in good agreement with core data and allowed for the correlation of wireline and core data. MS measurements were judged to be of insufficient quality for interpretation. Wireline bulk density and porosity measurements corresponded to the results of discrete sampling in cores in most of the logged interval. The processed downhole logs were received towards the end of the week.

Stratigraphic Correlation

Coring guidance was provided for determining the depth of the mudline cores for Hole U1464D and recovery gaps were monitored to ensure the highest continuity possible in the APC-cored upper ~300 m of Holes U1464B and U1464D, which includes an expanded early Pliocene section. One of the Hole U1464D cores was cored short to compensate for the low recovery from ~170 mbsf and below. Holes U1464B and U1464D were correlated using magnetic susceptibility measured on the Special Task Multisensor Logger (STMSL) and further constrained with NGR data. The NGR data was determined to produce the highest quality data in the upper ~170 m because the magnetic susceptibility record is not as regular between the two holes. Unfortunately, a splice can't be generated for Site U1464, but the successful correlation between Holes U1464B and U1464D will provide guidance for more continuous sampling.

Education and Outreach

This week the education and outreach team conducted eight school broadcasts: New Century (Grade 6, Fayettefulle, NC, USA), Brewarinna (Grades K–12, Brewarrina, NSW, Australia), A+ UP (Grades 6–8, Houston, TX, USA), Arlington Elementary (Grade 4, Arlington, TX, USA), Newcastle University/UK-IODP (PhD students, Newcastle upon Tyne, UK), Angelusinstituut (Grade 1, Brussels, Belgium), Cleveland High School (Grade 12, Portland, OR, USA), and The Lab School of Washington (Grades 9–12, Washington DC, USA). The Education and Outreach

team also continued to engage with social media and post blogs, and are finalizing their individual onboard projects.

Technical Support and HSE Activities

Technical staff primary activities included archiving of the cores from Holes U1464B, U1464C, and U1464D, supporting core flow through the laboratories, and laboratory maintenance. In addition, technical staff generated the shipping documents for offgoing cores and equipment and started cleaning the laboratories at the very end of the week.

HSE Activities

- Safety showers and eyewash stations were tested.
- A fire and boat drill was conducted on 21 September.