IODP Expedition 356: Indonesian Throughflow
Site U1463 Summary

Background and Objectives

Site U1463 is ~150 m from the industry well Picard-1 (141 m water depth) on a flat outer ramp region (James et al. 2004). It is 100 km southwest of Site U1464 and is a continuation of the Expedition 356 latitudinal transect. The seabed in the region is a poorly-sorted, carbonate-rich (>90%) sediment made up of bioclastic gravel, sand, and mud (Jones, 1973; James et al., 2004). The wireline gamma log data from the Picard-1 well reveals high variability and an upward reduction interpreted to be related to subsidence, glacio-eustatic sea level fluctuations, and climate variability from the Pliocene to Recent.

The primary aim of coring Site U1463 was to obtain a Plio–Pleistocene tropical/ subtropical carbonate record to allow us to determine the subsidence rates, interglacial Australian Monsoon, and tropical shelf-edge oceanographic histories of the region. An additional objective was to date a distinctive irregular seismic reflector postulated to be of Miocene age. Thus, improving the age constraints on this feature will enhance regional seismic interpretations.

Operations

Site U1463 consisted of three holes. Hole U1463A was started with the XCB system to determine the nature of the seafloor. After recovering two cores, one of which contained soft mud, we decided that the APC system would work at this site. Therefore, we piston cored Hole U1463B with both the APC and HLAPC systems to 284.4 mbsf. After partial strokes with the HLAPC system, we changed over to the XCB system. The hole was cored to a final depth of 530 mbsf. With excellent hole conditions, we decided it would be prudent to attempt the planned logging program for Site U1463. This had several advantages, including allowing us to allocate time more accurately for the remaining operating time at the site. Thus, after the completion of coring in Hole U1463B, a go-devil was pumped down the drill string to open the lockable float valve and the hole was conditioned for logging, including displacing the upper 360 m of the hole with heavy mud. Three logging tool deployments were completed. The triple combination tool string reached 454.7 m WSF and completed both a down and up pass for the full depth of open

borehole. The Versatile Seismic Imager (VSI) tool string was assembled and a single station was completed before we canceled the experiment due the presences of whales. The Formation MicroScanner and sonic imager (FMS-sonic) tool string was deployed to 445.7 m WSF before encountering a bridge. After two FMS-sonic passes along the full length of open hole, logging was completed and the tools were recovered. The drill string was pulled out of the hole and the vessel was offset 20 m south of Hole U1463B. Hole U1463C was cored to APC refusal (280.7 mbsf). We then switched to the HLAPC system and coring continued to 392.2 mbsf. After completing Hole U1463C and offsetting the vessel 20 m west, Hole U1463D was started. Hole U1463D was a virtual duplicate of Hole U1463C, except that the total depth was limited to 352.8 mbsf because this was the highest interval of scientific interest and the time allocated for Site U1463 ran out. The drill string was pulled back to the surface and secured for transit. The seafloor positioning beacon was recovered and the thrusters and hydrophones were pulled back into the ship's hull before beginning the transit to Site U1464. The total time spent on Site U1463 was 147.0 h (6.13 d).

The APC system penetrated 840.3 m and recovered of 835.29 m (99%). The HLAPC system cored 189.1 m and recovered 189.69 m of material (100%). The XCB system cored 265.0 m and recovered 126.56 m (48%). The overall recovery for Site U1463 was 89%.

Principal Results

Lithostratigraphy

The lithostratigraphy of Site U1463 is divided into four units, defined by visual core description and smear slide observations, and assisted by XRD and petrographic thin-section analyses. The lithology of Unit I (9.7–13.98 mbsf (Hole U1463A); 0–11.71 mbsf (Hole U1463B); 0–14.31 mbsf (Hole U1463C); 0–15.40 mbsf (Hole U1463D)) is primarily unlithified, creamy gray to light greenish gray wackestone and mudstone with abundant peloids. Macrofossils are abundant and diverse, and include bivalves, gastropods, bryozoa, serpulids, echinoderms, pteropods, scaphopods, and small benthic foraminifera. Bioturbation is moderate but only occurs intermittently and there are a few contact surfaces (e.g., gradational, bioturbated, and erosive). The bottom boundary of Unit I is defined by the disappearance of peloids in the sediment. Unit II (13.98–18.29 mbsf (Hole U1463A); 11.71–112.4 mbsf (Hole U1463B); 14.31–112.11 mbsf

(Hole U1463C); 15.40–114.30 mbsf (Hole U1463D)) consists of wackestone, packstone, and mudstone intervals. Lithological changes are also expressed as subtle color variations ranging from light greenish gray to creamy gray. Isolated macrofossils occur in darker, coarse-grained wackestone and packstone intervals and include a diverse range of mollusks (gastropods, bivalves, and scaphopods), echinoderms, serpulids, and bryozoans. Bioturbation is slight in this unit, and only some sedimentary and diagenetic features (gradational to sharp contacts, and rare concretions) were noted. The top of Unit III (112.40–399.10 mbsf (Hole U1463B); 112.11–392.49 mbsf (Hole U1463C); 114.30–352.80 mbsf (Hole U1463D)) marks the end of the creamy-gray intervals in the alternating lithologies of Unit II. Instead, Unit III is composed predominantly of well-sorted, homogeneous mudstone containing fine sand-sized grains and is divided into two subunits, IIIa (112.4–305.81 mbsf (Hole U1463B); 112.11–307.11 mbsf (Hole U1463C)) and IIIb (305.81–399.10 mbsf (Hole U1463B); 307.11–392.49 mbsf (Hole U1463C)), based on a sharp increase in quartz content observed in smear slides. Visual core description for this unit indicates subtle changes in both color and bioturbation, in an otherwise uniform moderately to heavily bioturbated mudstone with rare wackestone. Sedimentary features include rare wavy, sharp, scoured, and gradational contacts, and sporadically preserved parallel lamination. Fossils include common small benthic foraminifers and bivalve fragments and less common constituents include fragments of gastropods, bryozoans, echinoderm spines, crustaceans, scaphopods, barnacles, and worm tubes. Occasional concretions (celestite) occur lower in Subunit IIIa (~150–250 mbsf), with disseminated pyrite grains and nodules becoming common in Subunit IIIb. Units IV and V were only recovered in Hole U1463B. The upper boundary of Unit IV (399.10–428.20 mbsf) is defined by the first occurrence of grainstone with abundant macrofossils (mainly bivalve fragments). The unit is further characterized by an increased dolomite content as observed in both smear slides and XRD analyses. Unit V (428.20–525.25 mbsf) is creamy gray to light brown dolostone with sand-sized grains of pyrite and/or glauconite that occur in patches and as scattered grains throughout the matrix. Gypsum/anhydrite nodules, dissolution features, and fine vein structures characterize the dolostone. Both bioturbation and macrofossils are locally common, and bioclasts consist mainly of bivalves and occasional bryozoans and foraminfers.

Biostratigraphy and Micropaleontology

Site U1463 yielded a complete stratigraphic succession from the early Pleistocene to late Miocene, with abundant and well-preserved calcareous nannofossils. The Pliocene–Pleistocene boundary (2.59 Ma; within NN16) is placed between 240.7–265.87 mbsf, and the Miocene–Pliocene boundary (5.33 Ma; within NN12) between 345–379 mbsf. The abundance and preservation of planktonic foraminifers at Site U1463 was the best among all investigated sites so far during Expedition 356. Moderate to very good preservation was encountered in the entire Pleistocene to Pliocene with common to abundant planktonic foraminifers between 7.78–378.9 mbsf. Biostratigraphic marker species were identified for the mid-Pleistocene boundary (0.61 Ma; Top *Globorotalia tosaensis*) at 46 mbsf, the Plio–Pleistocene boundary below the Top of *Globorotalia limbata* (2.39 Ma; 220.54 mbsf), *Dentoglobigerina altispira* (3.47 Ma; 265.87 mbsf) for the mid-Pliocene, and *Sphaeroidinellopsis kochi* (Top 4.53 Ma; 334.71 mbsf) for the early Pliocene. An extended interval that was barren, or contained heavily recrystallized foraminifers and very rare nannofossils, occurs below 429.28 mbsf to the bottom of Hole U1463B (~530 mbsf). The final biostratigraphic datum (nannofossils) suggests the material in Sample U1463B-48X-CC (412.44 mbsf) is older than 5.94 Ma (Top *Reticulofenestra rotaria*, NN11).

The samples from Holes U1463A to U1463C contain between 10%–100% benthic foraminifera with *Cibicidoides* spp. as the most common taxa. Five assemblages were identified based on the abundance of *Quinqueloculina* spp., and *Textularia* spp. (Assemblage 1), *Operculina* spp. and *Amphistegina* spp. (Assemblage 2), *Cibicidoides* spp., *Rotalinoides gaimardii,* and *Lenticulina* spp. (Assemblage 3), *Pseudorotalia* spp., *Neoeponides* spp., *Planorbulinella larvata*, and *Bolivina* spp. (Assemblages 4), *Cibicidoides* spp., *Anomalinoides* spp., and *Amphistegina lessonii* (Assemblage 5). One to 43 species are present in the samples and the assemblages suggest paleodepths that start moderately deep (middle to outer shelf—Assemblage 1) and continues to fluctuate between mid- to outer shelf and bathyal settings for the remainder of the site (Assemblage 3) with frequent downslope-transported, diverse, shallow-water taxa within deeper foraminiferal assemblages (Assemblages 2, 4, and 5). Preservation was affected by fragmentation, abrasion, and encrustation, and varied from very good to poor throughout the site but was most frequently good to moderate with poor preservation only occurring from depths greater than 390 m to the base of the site.

Geochemistry

At Site U1463, 56 samples were analyzed for headspace gas content, 25 samples (5–15 cm whole-rounds) for interstitial water geochemistry measurements, and 25 samples for total organic carbon (TOC), calcium carbonate ($CaCO_3$), and total nitrogen (TN). No interstitial water samples were collected in Holes U1463C or U1463D because these two holes recovered a section already sampled in Holes U1463A and U1463B. Only one sample was taken from Hole U1463A. In general, elevated salinity characterizes the site, with a value of 35 at the top, increasing gradually with depth to a value of 111 at the bottom (~530 mbsf), with a mean value of 70. Similar to the previous Site U1462, the high salinity, as well as a number of elemental trends noted in the interstitial water samples, appears to be related to the presence and dissolution of anhydrite, which was observed at the bottom of the site (Lithostratigraphic Unit V; 428.20–525.25 mbsf). A number of elements exhibit increasing concentrations with depth including sodium, chloride, barium, bromine, calcium, potassium, and sulfate. Site U1463 is characterized by low concentrations of headspace gases, with methane ranging in concentrations from 1.6 to 13.4 ppmv and almost no detection of higher molecular weight hydrocarbons. Further, this site is characterized by high calcium carbonate content (mean value 77.5%), low values of TOC (mean value 0.7%), and low values of TN (mean value 0.031%).

Paleomagnetism

Paleomagnetism investigations focused on natural remanent magnetization (NRM) and alternating field (AF) demagnetization measurements. Superconducting rock magnetometer (SRM) results are reported for APC and XCB cores from 0–390 mbsf from Holes U1463B and U1463C. A total of 11 discrete samples were taken from Holes U1463B and U1463C. Isothermal remanent magnetism (IRM) acquisition and backfield IRM measurements were performed for three selected discrete samples from Hole U1463B to characterize the demagnetization behavior of sediment at this site. Saturation isothermal remanent magnetization (SIRM) values exhibited a broad range. Two out of the three selected discrete samples exhibited SIRM at ~100–200 mT; for one sample it was not possible to reach saturation in an impulse peak field of 1.2 T. Remanent coercivity values of the three samples ranged between 35 mT and 75 mT. One of the discrete samples was chosen for AF demagnetization after IRM acquisition, yielding a median destructive field between 30 and 40 mT. Bulk susceptibility measurements were also performed on all 11 discrete samples from 282–311.96 mbsf, and results ranged

from −5.1–140.7 × 10^{-6} SI units. These values exhibit an increasing trend that is similar to the equivalent measurements on the whole-round and split-cores reported by the physical properties team.

Archive-half core sections from Holes U1463B and U1463C were measured on the SRM. In the upper two thirds of Hole U1463B (0–275 mbsf), there is a steep, negative inclination pattern, compared to NRM values, after AF cleaning up to 20 mT. The inclination values of the NRM and 20 mT measurements begin to converge at ~275–290 mbsf, indicating the presence of a second, higher coercivity phase in that interval. The transition at ~290 mbsf could be related to lithological changes from partially lithified mudstones to wackestones and the formation of iron sulfide magnetic carriers, such as greigite (Fe_3S_4) and pyrrothite ($Fe_{1-x}S$), from alteration of disseminated pyrite. However, the demagnetization behavior of Sample U1463B-37X-1W, 86–88 cm (311.96 mbsf) clearly indicated that the characteristic remanent magnetization (ChRM) cannot be achieved using the standard AF demagnetization step sequence (NRM, 10 mT, and 20 mT) for the lower sediments (~270–390 mbsf). Therefore, demagnetization steps at NRM, 15 mT, and 30 mT were used in this interval for Hole U1463C and produced a more accurate determination of the ChRM, which is used for magnetostratigraphic interpretations. Magnetostratigraphic data for Hole U1463C indicate the Gauss/Gilbert boundary (3.596 Ma) is at ~282 mbsf. In addition, it is possible that the transition between C3n–C3r intervals (5.235 Ma) occurs at ~375 mbsf, where it corresponds with a biostratigraphic datum of 5.59 Ma at ~392.5 mbsf.

Physical Properties

Physical properties measurements were performed using the Whole-Round Multisensor Logger (WRMSL), natural gamma ray (NGR) sensor, and discrete sampling on cores. NGR measurements revealed similar trends and variations in all holes. Magnetic susceptibility (MS) values revealed 10–20 m scale variability, with maximum amplitude (about 30 SI) from 270–330 mbsf. MS patterns are consistent between holes and between the WRMSL and the Section Half Multisensor Logger (SHMSL). Variability at the 10–20 m scale was also observed in NGR and *P*-wave velocity measured on the WRMSL, which was verified through discrete measurements. *P*-wave velocity increases from about 1500 m/s to 1900 m/s in the top 300 m of the site. From 300–390 mbsf, discrete measurements of *P*-wave velocity showed diverging trends between Hole U1463B (cored

by the XCB system) and Hole U1463C (cored by the HLAPC system), suggesting that coring methods impact these measurements. Porosity decreases from 64% to 40% at 250 mbsf and below 270 mbsf is scattered with a range of 13% to 43%.

Downhole Logging

Downhole measurements were conducted in Hole U1463B. The triple combination (triple combo) tool string was run between 452 m WMSF and the seafloor and was used to measure borehole width, NGR, bulk density, porosity, resistivity, and MS. In the upper part of the borehole, NGR increased with depth in a stepwise manner with steps at ~78 m and ~110 m WMSF, the first of which corresponded to the end of the drill pipe. Between 110–200 m WMSF, NGR showed strong meter-scale variability and ranged between 30 and 80 cps. At 208 m WMSF, a prominent peak in NGR was observed. Between 210–385 m WMSF, the NGR remained relatively high and ranged between 30 and 60 cps. The wireline NGR log was in good agreement with the core-based NGR and allowed for the correlation of wireline and core data. MS measurements were affected by changing borehole temperatures and were judged to be of insufficient quality for interpretation. Wireline bulk density and porosity measurements correspond to the results of discrete sampling of cores in most of the logged interval. *P*-wave sonic velocities measured with the FMS-sonic tool string from 444–122 m WMSF are consistently higher than sonic velocities measured on cored material. However, the same 20–30 m scale variability in sonic velocity is observed in both wireline logs and core-based measurements. Although borehole diameter was relatively large (~16 inch), the FMS images are generally of good quality with both passes yielding consistent images. From ~443 m WMSF upwards, the FMS showed 20–50 cm wide horizontal resistive bands with diffuse edges about 5 m apart. Below ~406 m WMSF, there were occasional sharp bands of high conductivity with thicknesses <5 cm. Starting at ~380 m WMSF, these thin conductive bands became more prevalent and some have the appearance of being tilted from the horizontal by <20°.

Stratigraphic Correlation

Site U1463 was triple-cored using the APC and HLAPC piston coring systems and the XCB system in order to recover a complete and continuous section. The stratigraphic correlators provided coring guidance to ensure recovery gaps between holes did not overlap and to determine the depth at which the mudline core was taken for the second and third APC holes. Correlation was possible for the upper ~350 m between Holes

U1463B, U1463C, and U1463D, and a splice of the upper 300 m was generated from the correlation. Variability in lithology and coring methods between holes causes some uncertainty in the correlation, which is based the sediment physical properties data. These values also change downhole to the extent that a switch from a magnetic-susceptibility-based to an NGR-based correlation became necessary.

Sedimentation rates are generally high at this site, well above typical pelagic values. Specifically, sedimentation rates are moderate through the Pliocene, and increase (11–19 cm/k.y.) in the Pleistocene (NN18/NN19 boundary to PT1a/Pt1b boundary) before declining to moderate levels (5 cm/k.y.) in the mid-Pleistocene to recent.

References

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