IODP Expedition 356: Indonesian Throughflow
Site U1459 Summary

Background and Objectives

Site U1459 (proposed site NWS-13A) lies in the northern part of the Perth Basin, about 1 nmi basinward of both Site U1458 and the Houtman-1 industry well on the northern Rottnest Shelf (James et al., 1999; Collins et al., 2014). It was originally intended as an alternate to Site U1458 (proposed site NWS-6A). The ship moved to Site U1459 after having difficulty coring the uppermost sediments at Site U1458. Like Site U1458, Site U1459 is directly seaward of, and downdip from, the Houtman-Abrolhos main reef complex, which contains the most southerly tropical reefs in the Indian Ocean. Sites U1458 and U1459 comprise the southernmost sites of our latitudinal transect. The objectives for Site U1459 are the same as those for Site U1458. The evolution of the Houtman-Abrolhos reef complex is directly related to the path of the Leeuwin Current. Dating of sediments cored at Site U1459, coupled with seismic correlation, will provide insight into the pre-Quaternary history of these reefs and a long-term perspective on Leeuwin Current evolution at the tropical/subtropical boundary off western Australia. In addition, it has been suggested that subsidence rates over 140 k.y. were low compared to those of the Carnarvon Basin reefs (Collins and Testa, 2010). Subsidence analyses of the shelf wedge drilled at this site will extend this record and allow more precise modeling of dynamic subsidence along the western margin of Australia. An additional objective was to use any finer grained facies in this section to yield a Pliocene–Pleistocene record of the onset and variability of the southern Australian winter-dominated rainfall regime.

Operations

Site U1459 consisted of three holes. The original plan called for three APC holes to refusal with the last two holes being extended by the XCB system to 330 mbsf. It became immediately apparent on Hole U1459A that the APC system would not penetrate the surface formation. After breaking the first APC core barrel, the HLAPC core barrel was run and recovered 0.1 m of core. Fourteen cores were subsequently recovered from Hole U1459A using both the HLAPC and XCB systems (70.3 m cored, 30.59 m recovered). The first hole was challenging, with multiple hard layers interspersed through the upper 55 m, and resulted in 44% overall recovery for the entire hole. After a stuck core barrel forced the abandonment of Hole U1459A at 70.3 mbsf, a detailed coring plan for Hole

U1459B was developed using information gained from Hole U1459A. The alternating use of the HLAPC (for soft intervals) and XCB (for harder intervals) systems in Hole U1459B greatly increased core recovery (78%). Below ~55 mbsf, HLAPC coring encountered no resistance and continued to 218.9 mbsf. The third hole became necessary when the XCB system failed at 233.0 mbsf, destroying an XCB cutting shoe in the process. The drill string was recovered and a RCB BHA was assembled with a coring bit and a mechanical bit release. Hole U1459C was drilled without coring to 205.8 mbsf. The center bit was retrieved and RCB coring began at 205.8 mbsf. RCB coring continued to 400.0 mbsf (194.2 m cored, 22.6 m recovered, 12%). After dropping the bit in the hole, two separate logging tool runs were completed in Hole U1459C with the triple combination and FMS-sonic. The total time spent on Site U1459 was 6.9 d. The overall core recovery for Site U1459, which utilized the HLAPC, XCB and RCB systems, was 47%.

Principal Results

Lithostratigraphy

The lithostratigraphic units and their boundaries at Site U1459 were defined by changes in lithology (identified by visual core description and smear slide observations), physical properties, color reflectance (L*, a*, and b*), x-ray diffraction, and petrographic thin section analyses. Site U1459 consists of seven lithostratigraphic units. The major lithologic differences between units are in texture, degree of lithification, fossil content, diagenetic changes, and mineralogical components. Unit boundaries are defined based on the first occurrence of a new lithology downhole. The lithologic descriptions are based primarily on sediments recovered from Hole U1459B for depths of 0–233.02 mbsf, augmented with observations from Holes U1459A and U1459C. Descriptions for depths below 233.02 mbsf come exclusively from Hole U1459C.

The lithostratigraphic units are as follows:

Unit I (0–32.78 mbsf [Hole U1459A]; 0–23.06 mbsf [Hole U1459B]) is a lithified skeletal packstone to floatstone.

Unit II (32.78–42.93 mbsf [Hole U1459A]; 23.06–40.5 mbsf [Hole U1459B]) is an unlithified mudstone to packstone with interlayers of skeletal grainstone.

Unit III (43.93–70.75 mbsf [Hole U1459A]; 40.65–95.6 mbsf [Hole U1459B]) is a glauconitized unlithified to partially lithified packstone to grainstone with macrofossils.

Unit IV (95.6–139.2 mbsf [Hole U1459B]) is an unlithified homogeneous packstone with glauconite.

Unit V (139.2–233.02 mbsf [Hole U1459B]; 205.8–258.25 mbsf [Hole U1459C]) is a dolomitic packstone with quartz. Subunit Va (139.2–182.3 mbsf [Hole U1459B]) is an unlithified packstone that includes a partially to fully lithified interval, while subunit Vb (182.3–233.02 mbsf [Hole U1459B]; 205.8–258.25 mbsf [Hole U1459C]) is an unlithified packstone with dolomite interbedded with lithified fine quartz sand.

Unit VI (258.25–296.4 mbsf [Hole U1459C]) is lithified beige to light brown/gray to brown dolostone.

Unit VII (296.4–397.72 mbsf [Hole U1459C]) is lithified, chert-rich packstone and microcrystalline dark gray chert.

Biostratigraphy & Micropaleontology

Nannofossils

Holes U1459A and U1459B contain Pleistocene to late Miocene sediments, while the strata in Hole U1459C were determined to be of early Miocene to early–middle Eocene age. *E. huxleyi* is present in Core U1459A-1F-CC suggesting an age of late Pleistocene to Recent, while top of *P. lacunosa* (NN19, >0.44 Ma) was present in Hole U1459A (Sample U1459A-6F-2-W) and U1459B (Sample U1459B-5F-CC). The Pliocene–Pleistocene boundary in Sample U1459B-12F-CC (64.25 mbsf) was marked by the presence of *D. surculus* (>2.49 Ma). The top of the late Miocene (5.59 Ma) was approximated by the presence of *D. neohamatus* (Core U1459B-33F) and *D. quinquerasmus* (Core U1459B-34F, 165.26 mbsf). Cores U1459B-46F to 47F were barren, but Core U1459B-48X indicated middle Miocene age. Hole U1459C (U1459C-2R to 9R) contains typical assemblages of early-late Miocene medium-to-large-sized reticulofenestrids but no biostratigraphic markers. A late Oligocene or older age was identified from U1459C-10R (*Cyclicargolithus abisectus*, >23.06 Ma). An earliest Oligocene (or older) age (>32.92 Ma) was inferred by the presence of *E. formosa* in Sample U1459C-19R-CC and *R. umbilicus* in Sample U1459C-20R-CC (293.14 mbsf). The presence of *C. reticulatum* in U1459C-26R-CC (321.19 mbsf) confirms late Eocene

age and the bottom of Hole U1459C was dated to early–middle Eocene based on the presence of *Chiasmolithus grandis*, *E. formosa*, and the absence of *R. umbilicus*.

Planktonic Foraminifers

The middle Pleistocene, defined as biozone Pt1a (0.61–1.93 Ma) can be identified between Cores U1459A-5F and U1459A-10F (51.47 mbsf). Below Core U1459B-16F (~83 mbsf), a Pliocene faunal assemblage develops (biozone PL4), which dates at least to an age of 3.47 Ma (*Dentoglobigerina altispira*). Beyond the Pliocene, severe dolomitization prevented preservation of clearly distinguished fauna. Beginning again with Core U1459C-20R (293.14 mbsf), preservation improves in that foraminifera are present, but overall preservation remains (very) poor. The first identifiable faunas appearing indicate an Oligocene age. Below Core U1459C-29R (335.7 mbsf), a well-developed Eocene faunal assemblage is present, including *Subbotina gortanii*, *Subbotina eoceana*, *Globigerinatheka index*, and *Acarinina primitiva*. These encompass biozones E14–E9 (~38–50 Ma). The bottom of Hole U1459C dates to the latest early Eocene (Biozone E7; *Acarinina bullbrooki*, FAD, and *A. alticonica*, LAD; ~50.2 Ma).

Benthic Foraminifers

The samples contained between 15%–96% benthic foraminifera; *Cibicide*s spp. and *Cibicidoides* spp. were the most commonly recovered taxa. Four assemblage trends emerged defined by abundances of *Textularia* spp., *Uvigerina* spp., *Bolivina* spp., and epifaunal species. In each sample, 1–41 species were encountered. The first assemblage (0–46.51 mbsf) contains a range of shallow and deeper water temperate species, such as *Quinqueloculina lamarckiana*, *Heterolepa bradyi*, and *Textularia* spp. Larger benthic foraminifers, such as *Amphistegina lessonii* and *A. lobifera,* were found between Cores U1459A-5X (22.5 mbsf) to 10F (51.47 mbsf). The second assemblage (78.39–122.9 mbsf) is characterized by *Uvigerina* spp., particularly *U. peregrina*, and *Bolivina* spp., and infaunal, shallow water (50–150 m) species. The third assemblage (165.26–198.02 or 238.85 mbsf) contains low diversity and dominated by Bolivinids. The fourth assemblage (287.11–387.68 mbsf) is composed almost entirely of epifaunal species. With the exception of the two uppermost core catcher samples from Hole U1459A (Samples 1F-CC and 2X-CC), the preservation of benthic foraminiferal tests was poor to very poor throughout Site U1459. Estimated paleobathymetry ranged from shallow/neritic environments to >500 m.

Other bioclasts

Other fossil groups present included: ostracods, bryozoa, worm casings, and pteropods.

Geochemistry

At Site U1459, 63 samples were analyzed for headspace gas content, 20 samples for interstitial water geochemistry measurements, 24 samples for carbonate, and 20 samples for total organic carbon (TOC) and total nitrogen. Due to the nature of the recovered material, including chert and other lithified sediments in Hole U1459C, no geochemical analyses were performed except for carbonate and headspace gas measurements, which were made when feasible. The site is characterized by high percentages of calcium carbonate (mean value = 88%) and low TOC (mean value = 0.53%). Elevated salinity also characterizes the site, with values >37 below 45 mbsf, reaching 50 in the interval from 120–195 mbsf. Overall, many of the geochemical parameters measured exhibit a change in trend or slope at ~68 mbsf, where Sr sharply decreases from ~300–200 μM, or ~120 mbsf where Mg and SO_4^{-2} both reach maximum values of 65 mM and 40 mM, respectively.

Paleomagnetism

Paleomagnetic investigations at Site U1459 included routine measurements and partial demagnetization of natural remanent magnetization (NRM) of archive-half split-core sections and selected discrete samples from working-half sections. Rock-magnetic experiments, including extended demagnetization sequences, were also conducted on discrete samples. NRM intensity values from the archive-half range from 10^{-2}–10^{-5} A/m after AF demagnetization peak fields of 20 mT and 30 mT. Two distinct intervals have emerged from the otherwise scattered directional data: (i) three peaks of negative magnetic inclination (corresponding to normal polarity) and intensity value changes between ~130 and 140 mbsf, and (ii) another peak of positive magnetic inclination (reversed polarity) between 145 and 170 mbsf. With the integration of constraints from biostratigraphic datums, it suggests these features are >3.7 Ma and are thus tentatively correlated with the subchron C2Ar (3.596–4.187 Ma) and C3n (C3n.1n [4.187–4.3 Ma], C3n.2n [4.493–4.631 Ma] and C3n.3n [4.799–4.896 Ma]). Discrete sample results were generally comparable to archive-half intensity and inclination values. Uncertainties associated with determining the characteristic paleomagnetic directions and magnetic mineralogy are amplified by the pervasive diagenesis throughout the sediments.

Physical Properties

Physical property measurements were carried out using the multisensor logger, natural gamma radiation (NGR) sensor, *P*-wave velocity caliper, and discrete sampling. Thermal conductivity was also measured in several sections and varied between 1.0 and 1.3 W/(m·K). Bulk density was determined using both gamma ray attenuation and moisture and density. These two methods yielded consistent increases in density with depth until 160 mbsf whereafter it becomes variable. The increase may reflect increasing diagenesis and generation of dolomite from calcite. The magnetic susceptibility of the recovered sediments was rather low, with most readings ranging between −2 and 4 SI. The magnetic susceptibility data showed a rising trend from 80 to 140 mbsf where there is an overall decrease in NGR. NGR also showed several distinct peaks at 48.5, 61, and 64.5 mbsf in Hole U1459A and 65, 100, and 170 mbsf in Hole U1459B. These peaks proved to be of value for stratigraphic correlations. *P*-wave sonic velocities measured above 200 mbsf on whole-round cores and discrete samples compare very well. In the upper 200 m, velocities are typically <2000 m/s. Below this depth, *P*-wave velocities show high values (up to 6257 m/s) because they were obtained from lithified sediment, including cherts and dolomitic cobbles. Reflectance spectroscopy and colorimetry data display high-amplitude variability, consistent with notable color changes in the sediments. Porosity was generally high, ranging between 50–60% to a depth of 120 mbsf. Further downcore, porosity decreased to a minimum of 35% at 208.5 mbsf.

Downhole Logging

Downhole measurements in Hole U1459C were successful and consisted of runs with the triple combination (triple combo) and the Formation MicroScanner and sonic imager (FMS-sonic) tool strings. The triple combo string was deployed downhole with a reduced configuration (without the porosity, density, and resistivity tools). Using the triple combo, the borehole width, natural gamma ray, and magnetic susceptibility were measured from 72.2 (the end of the drill pipe) to 390 mbsf. Two up and down passes were made with this tool. Borehole conditions prevented the FMS-sonic tool from passing below 288 mbsf. The natural gamma ray (NGR) logs obtained with the reduced triple combo string showed good agreement with the data obtained on the whole-round cores from Hole U1459B. Many peaks and troughs observed from the Hole U1459B cores were reproduced by the downhole logs from Hole U1459C. These data show that the important NGR peaks in the upper 150 m of Hole U1459C were mainly driven by variations in

uranium content. The NGR peak in the downhole logging data at 160 mbsf corresponds to the observed NGR peak in cores from Hole U1459B at 168 mbsf, and results from an increased concentration of both uranium and potassium. The NGR peak in the downhole logging data at 185 mbsf corresponds to the NGR peak in U1459B cores at 192 mbsf, and is the result of an increased concentration of thorium and potassium, which may be consistent with an increase in detrital mineral input. The downhole magnetic susceptibility confirmed the increasing trend in susceptibility between 75–145 mbsf that was also observed in core measurements from the Whole-Round Multisensor Logger. However, between 145–155 mbsf, the core magnetic susceptibility data from Hole U1459B shows a rapid decrease that is not observed in the downhole logging data. In contrast, the latter continue to increase gradually with depth between 145–210 mbsf, although a correlation in meter- to decimeter-scale variations in the magnetic susceptibility data of cores from Hole U1459B and wireline logging potassium concentration data from Hole U1459C was noted. The FMS images reveal differences in resistivity that reflect changes in textures and lithology through the logged interval (112 to 286 mbsf). The quality of the images is high below about 250 mbsf but poor above this interval due to poor contact with the borehole walls. The spacing between alternations of high and low resistivity values below 250 mbsf range from several decimeters to 2 m, with thin (several decimeters) resistive layers embedded within broader (1–2 meters), more conductive areas. Between 100–200 mbsf, sonic velocities of Hole U1459C measured downhole tended to be a few hundred m/s higher than the sonic velocities obtained from discrete measurements with the *P*-wave caliper from Hole U1459B. At 216 mbsf, downhole sonic velocities spiked at 3228 m/s. This observation is in agreement with the discrete *P*-wave velocity measurements made on a lithified dolomitic cobble from Section U1459C-4R-1 (215.34 mbsf). These results suggest that the retrieved dolomitic cobbles can be considered representative of the formation in this interval. Between 217–245 mbsf, downhole sonic velocities were relatively constant with variations between 2150 and 2400 m/s. In this interval, discrete measurements were only possible on lithified cobbles; those sonic velocities exceeded 5000 m/s. Therefore, these cobbles should not be considered representative of the cored sediments.

Stratigraphic Correlation

Three holes were drilled at Site U1459. The highest recovery occurred in Hole U1459B and ranged from late Pleistocene to middle Miocene in age. Unfortunately, recovery at

Hole U1459A was not sufficient to allow for either detailed analysis or a high-resolution correlation between Holes U1459A and U1459B. Hole U1459C extended into the Eocene. A natural gamma wireline log was run in Hole U1459C, but the very low core recovery limited the ability to correlate between the Hole U1459C lithology and the wireline log data.

References

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