

IODP Expedition 359: Maldives Monsoon and Sea Level

Week 6 Report (1–8 November 2015)

Overview

This week, we completed scientific coring operations at Site U1467 (MAL-9A) and started operations at Site U1468 (MAL-03A).

Five holes were drilled at Site U1467: Hole U1467A (0–32 mbsf), Hole U1467B (0–617.2 mbsf), Hole U1467C (0–714 mbsf), Hole U1467D (0–201 mbsf) and Hole U1467E (0–714). Hole U1467E was a dedicated hole for wireline logging. Total core recovery at Site U1467 was 1061.8 m of core (90%).

Operations

Coring continued in Hole U1467C using the APC coring system through Core U1467C-22H to 198.7 mbsf. The XCB was then used to drill ahead to a depth of 325.8 mbsf before a center bit had to be deployed. The XCB with center bit advanced to 578.6 mbsf and the center bit was recovered via wireline. At 2030 h on 2 November, XCB coring was initiated, continuing through Core U1467C-37X to 714.0 mbsf. This was the approved EPSP depth for the site. A mud sweep was circulated to clean the hole one final time, and the drill string was recovered and spaced out for wireline logging with the bit placed at 101.8 mbsf. At 1400 h on 3 November wireline logging began. As the triple combo tool string was being made-up, the rig crew noted backflow of water coming from the tool joint at the rig floor. The triple combo tool string was removed so we could add heavy mud the drill pipe to prevent further backflow. While attempting to reinsert the tool string, a fiberglass connection on the bottom of the magnetic susceptibility tool broke off and the connected lockable float valve (LFV) go-devil fell through the drill string. This was not a significant concern as these go-devils were free-fall deployed in the past. After manufacturing a new fiberglass connector sleeve and changing out the magnetic susceptibility sonde (MSS) tool with the onboard spare, the triple combo tool string was redeployed. The tool string was run to the total depth of the hole (714 mbsf) without any problems. After completing the first logging run, it was determined that the borehole diameter was too large (>22 inch) for collecting useful data with the FMS-sonic and the Versatile Seismic Imager (VSI) tool strings, so the triple combo was recovered and the tools were rigged down.

We decided to drill a dedicated logging hole utilizing a 9 $\frac{7}{8}$ inch tri-cone drill bit after completing one additional APC hole to ~200 mbsf. The drill string was pulled clear of the seafloor at 0010 h on 4 November. The top drive was picked up, the drill string was spaced out to 1.5 mbsf, and coring in Hole U1467D started at 0130 h. This space out was used to spread out the breaks between cores in adjacent holes to enable the recovery of a complete section for

paleoceanographic studies. APC coring (not orientated) continued through Core U1467D-22H to 201.0 mbsf. The drill string was then recovered back aboard ship with the bit arriving back on the rig floor at 1325 h on 4 November.

Our final operation at Site U1467 was to drill a dedicated logging hole. The ship was offset 20 m east of Hole U1467A. The bottom-hole assembly (BHA) was changed to a non-coring drill bit and the drill string was lowered back to the seafloor. The top drive was picked up and the drill string was spaced out using an offset seafloor depth of 498.4 mbsf taken from Hole U1467A. Drilling of Hole U1467E started at 1710 h on 4 November. This dedicated logging hole was drilled without coring to 714.0 mbsf in 25 h. A mud sweep was circulated to clear cuttings out of the hole and two wireline runs were made to release the bit in the bottom of the hole and reverse shift the mechanical bit release (MBR) sleeve. Because of the stability seen in the previous holes at this site and while drilling the hole, we decided that a wiper trip was not necessary and there was no need to displace the hole with heavy mud. The drill string was raised back up the hole and the end of the pipe was placed at 98.6 mbsf. We started rigging up for wireline logging at 2230 h on 5 November. The triple combo was run into the hole and reached the total depth at 714.0 mbsf. Caliper logs from this deployment indicated a hole diameter of 11–17 inch. The triple combo string was recovered and rigged down by 0600 h on 6 November. Taking advantage of daylight and following the marine mammal protection protocol, the vertical seismic profile (VSP) experiment was conducted next. The VSI tool was able to reach ~684 mbsf or ~30 m off bottom, apparently due to fill in the borehole, and data were collected up from there. A very good signal was received at each VSP station, thus providing the necessary information for an accurate time-depth conversion of the core and seismic data. The FMS-sonic tool string was deployed at 1200 h on 6 November and reached 664 mbsf, where it stopped because of further filling at the bottom of the borehole. After the FMS-sonic data was obtained, the tool string was recovered and rigged down by 1900 h on 6 November.

The rig floor was secured from logging operations by 2000 h, and by 2015 h the upper guide horn was raised in preparation for pressure testing the new fiber optics-based subsea camera system. The camera was deployed down the drill string to the seafloor. This system was installed prior to the last expedition (Expedition 356); however, due to all of the shallow water operating depths during Expedition 356, the system has only been tested to ~90 mbrf. We needed to test this system prior to the next expedition (Expedition 360) that will require multiple deployments of the system for making bit changes in the course of drilling a single 1500 m deep RCB hole into gabbro in ~700 m of water. Testing the camera system at Site U1467 (473 m) indicated that the system is 100% operational. The camera was back on board and secured within 1 h and the drill string was pulled clear of the seafloor and recovered back to the ship. After the seafloor positioning beacon was recovered and the ship secured for transit, we began the ~13.6 nmi transit to Site U1468 (MAL-03A) at 0024 h on 7 November. The transit required only 1.5 h, and at 0232 h the ship was switched to dynamic position and the rig crew began assembling the APC/XCB BHA. Coring in Hole U1468A started at 0830 h on 7 November. A seafloor depth of 521.5 mbsl was established. APC coring (not orientated) continued through Core U1468A-13H

to 112.6 mbsf. Coring using the HLAPC then followed until reaching APC refusal on Core U1468A-38F at 225.6 mbsf. Coring with the XCB coring system continued, and as of 2400 h on 8 November, coring had progressed to 427.7 mbsf (Core U1468A-65X). At this point, the hole appears to be stable with little or no fill on connections, normal drilling torque, and no overpull or drag experienced with the drill string. Mud sweeps are being pumped every other core to maintain good hole conditions.

Science Results

Overview

Site U1467 is located in the Inner Sea northwestward of North Male about 9 km southward of ODP Site 716 in a water depth of 487 m. The site is located in a distal position in relation to the platform margins and moats. The nearly horizontally layered seismic reflections of the drift sequences at Site U1467 show no truncations and no indications of mass wasting from the adjacent platform margin; therefore, it should provide a complete undisturbed succession of all drift sequences and the youngest platform sequences, and it is the main paleoceanographic site of Expedition 359, comprising a continuous record from the Middle Miocene to the Present.

Site U1468 is the easternmost site of the northern transect drilled in the Inner Sea of the Maldives. This site was chosen for coring as the seismic lines show that it records the sedimentary evolution of the platform growth and drowning in a basinal position, thus having the potential to recover a hemipelagic sequence of sediments which contains planktonic foraminifers and calcareous nannoplankton suitable for a biostratigraphic analysis.

Lithostratigraphy

Five holes were drilled at Site U1467, one of them (Hole U1467E) as a dedicated logging hole. Five lithologic units were recognized at the site. Unit I, from the seafloor to ~110 mbsf, consists of unlithified foraminifera-rich wackestone to mudstone. Unit II, between ~110 and ~215 mbsf, is formed of interlayered unlithified and partially lithified wackestone. Unit III, from ~215 to ~310 mbsf, comprises of partially lithified wackestone to packstone. Unit IV, from ~310 to 500 mbsf, consists of lithified wackestone to packstone. Unit V, from ~510 to 714 mbsf, consists of white colored lithified wackestone to packstone.

At this stage of coring at Site U1468 (Hole U1468A) only two major lithological units have been observed. The first unit, from the seafloor to 45 mbsf, is comprised of unlithified planktic foraminifera-rich grainstone, and Unit II is comprised of medium to coarse grained, unlithified to lithified large benthic foraminifera-rich grainstone to packstone. Throughout Unit II, large benthic foraminifera (*Sphaerogypsina globulus*, *Lepidocyclina*, *Amphistegina*) are abundant and indicate deposition in shallow water.

Biostratigraphy

All core catcher samples from the 714 m sediment succession at Site U1467 were analyzed for biostratigraphy. Biostratigraphic markers indicate that the sequence represents a continuous succession from the Holocene to the Middle Miocene. Planktic and benthic foraminifera, calcareous nannofossils and radiolarians were used to construct the age model at Site U1467. Variability in benthic foraminifera and ostracods assemblages indicates changes in benthic paleoenvironmental conditions, in particular high primary production in Samples U1467B-77X-CC, and U1467C-26X-CC through U1467C-32X-CC.

At Site U1468, we started to build the age model, but the absence of planktic foraminifera and calcareous nannofossils for over a hundred meters of the sediment sequence has prevented us from estimating an age for the base of the cored section.

Geochemistry

Geochemical analyses of IW samples (alkalinity, chloride, pH, and minor trace elements) and sediments (X-ray diffraction, percent carbonate and organic carbon, and trace element analysis) were completed for Holes U1467A, U1467B, and U1467C. The carbonate content ranges between 70.5% and 95.6% with only a few samples exceeding 95 wt%. The results of XRD analysis show that the sediments in the upper ~120 mbsf consist of ~28% to 57% aragonite, with the remainder being low magnesium calcite (LMC) and a small amount of high magnesium calcite (HMC). In addition, the XRD analyses revealed that there are several occurrences of celestite (SrSO_4) between 163 and 393 mbsf, indicating pore water concentrations of Sr^{2+} and SO_4^{2-} are super saturated with respect to this mineral. Below 50 mbsf in Hole U1467B, the concentration of aragonite decreases to less than ~15% at 125 mbsf and the Sr^{2+} of the pore water substantially increases. These changes support the theory that the decrease in the concentration of aragonite is a result of diagenesis rather than reduction in the input from adjacent platforms. The profiles of alkalinity and SO_4^{2-} of the interstitial fluids from Site U1467 indicate that significant remineralization of organic material has occurred below 50 mbsf.

Paleomagnetism

In the paleomagnetism laboratory we measured and analyzed the natural remanent magnetization and magnetization after stepwise demagnetization of more than 100 cores from Site U1467. In addition, we performed discrete sample measurements of magnetic susceptibility and anisotropy. A series of magnetozones were recognized between 100 and 200 mbsf in Hole U1467C and between 195 and 255 mbsf in Hole U1467B based on the relative length of each polarity zone and the biostratigraphic age model.

Physical Properties

Whole-round core measurements of velocity, density, magnetic susceptibility, and natural gamma radiation, as well as moisture and density (MAD) of discrete samples, were completed

for Holes U1467C and U1467D and in Hole U1468A down to 320 mbsf. Velocity measurements were performed by *P*-wave logger (PWL) on whole-round cores and by *P*-wave velocity (PWC) on the split-cores and discrete samples of Holes U1467C and U1467D, and they are also being performed in Hole U1468A. Additionally, thermal conductivity measurements were performed on selected core sections recovered from Holes U1467C and U1467D and are being performed in Hole U1468A. Physical properties show variability by depth, which are related to changes in lithification, bioturbation and water content of the material, and compaction and diagenetic processes.

Stratigraphic Correlation

Stratigraphic correlation of Holes U1467A through U1467D has produced a good composite section for Site U1467 for postcruise paleoceanographic studies.

Downhole Logging and Sequence Stratigraphy

The triple combo tool string was run in Hole U1467C on 3 November. The hole condition was expected to be good, based on coring operations, so seawater was used as the logging fluid. The triple combo tool string reached total depth in the hole, approximately 713 m WSF (wireline below seafloor). Natural gamma ray, porosity, density, electrical resistivity, and magnetic susceptibility were measured in the open hole interval from the bottom of the hole to 101 m WSF, the depth of the base of the pipe. The caliper that measures borehole diameter was open to its maximum extent (~17 inch) through most of the hole, with the exception of a short interval from 370 to 450 m WMSF (wireline matched depth below seafloor). The logged values primarily reflect changes in sediment lithification, with more lithified layers showing higher gamma radiation, density, and resistivity. However, due to the enlarged borehole diameter and the associated potential negative impacts on logging data quality for measurements made with the FMS-sonic and VSI tool strings, we decided to end logging operations in Hole U1467C after the triple combo run. Instead, we decided to carry out the planned downhole logging in a dedicated hole, Hole U1467E.

Hole U1467E was drilled without coring to 714 mbsf with a tri-cone bit, and the triple combo, VSI, and FMS-sonic tool strings were run in the hole on 5–6 November. Seawater was used as the logging fluid and the pipe was set at ~99 mbsf. The borehole was in good condition for logging, with diameter ranging from 11 to 17 inch. The good logging conditions were likely due to drilling a dedicated hole with a $9\frac{7}{8}$ inch tri-cone bit, which is narrower than the $11\frac{7}{16}$ inch APC bit used in Hole U1467C. Also, the sea state was very calm, which resulted in minimal downhole heave. The logged data show variations that reflect changes in sediment lithification and also potentially depositional environment (current-driven drift vs. carbonate platform sedimentation). Interlayered sediments with varying properties on the order of centimeters to tens of centimeters in thickness are resolved in FMS images, as well as velocity and resistivity logs. The vertical seismic profile (VSP) experiment yielded clear first arrivals at 12 depth stations between 150 and 690 mbsf.

Education and Outreach

This week we conducted 12 education events with high schools and elementary schools in Italy, France, the United States, Ireland, and Romania. We also conducted a live broadcast with more than 200 participants in Lisbon during the IODP day in Portugal, and more than 200 undergraduate students at Colorado State University. In addition, we posted daily updates and photos on our social media outlets (Facebook [<https://www.facebook.com/joidesresolution>], Twitter [<https://twitter.com/TheJR>], and Instagram [http://instagram.com/joides_resolution]), in personal blogs from the expedition scientists, and in blogs on the *JOIDES Resolution* website (<http://joidesresolution.org/>). During the testing of the VIT/subseafloor camera system, we sent decorated Styrofoam cups down to the seafloor as part of an education event with students in the United States.

Technical Support and HSE Activities

Laboratories

- Processing of cores and samples from Holes U1467C, U1467D, and U1468A.
- Water samples collected daily with the Wildco Beta Water Sampler at approximately 15 m water depth for analysis of plankton.
- Deployed the sound source for the first time for logging operations and performed Protected Species Observations (PSO) in conjunction with the use of the sound source.

HSE Activities

- A fire drill was conducted on 3 November.
- The eyewash stations and safety showers were tested.