IODP Expedition 354: Bengal Fan

Week 3 Report (8–14 February 2015)

The third week of the IODP Bengal Fan Expedition 354 consisted of coring operations in two holes at Site U1449 (8–10 February) and then the transit to and coring at Site U1450 (MBF-2A; 10–14 February).

Operations

Hole U1449A

This week started with continued coring in Hole U1449A after the first two APC cores had reached 9.9 m DSF. After Core U1449A-2H, we drilled 1 m without coring through a hard layer (9.9–10.9 m DSF) and then XCB cored to 17 m without any recovery. We then used both piston coring systems and penetrated 22.5 m (17.0–39.5 m CSF-A; Cores 5H, 6F, 7H, and 8H) and recovered 18.3 m of core (82%). Orientation was attempted on Cores 8H and 9H, but with poor results. Core 8H was also the only time we deployed the APCT-3 to obtain a formation temperature measurement. Core 9H did not penetrate the formation, so we switched to XCB coring and Cores 10X–12X extended from 39.5 to 68.4 m CSF-A but recovered only 0.86 m (3%). We switched back to the half-length APC system (HLAPC) and Cores 13F–17F penetrated 19.6 m of formation (68.4–88.0 m CSF-A) and recovered 20.03 m (102%). Since we wanted to core deeply at this site, HLAPC takes longer than the APC, and the formation appeared soft enough, we switched back to the full-length APC. Cores 18H–21H extended from 88.0 to 113.4 m DSF and recovered 25.02 m of core (99%); however, all but the first core were only partial strokes (7.6 m, 4.9 m, and 3.4 m) and were advanced by recovery.

We switched to the HLAPC and Cores 22F–31F penetrated 43.1 m (113.4–156.5 m DSF) and recovered 45.33 m; the last two were only partial strokes. As the formation still appeared to be too firm for full APC coring, and achieving our primary objective of obtaining deeper samples would take much longer with the HLAPC, we deployed the XCB coring system. Cores 32X–36X penetrated 48.5 m (156.5–205.0 m CSF-A) but only recovered 1.17 m of sediment (2%). We then switched back to APC coring, first with HLAPC Core 37F that penetrated from 205.0 to 209.7 m DSF and recovered 4.79 m (102%). The final core of Hole U1449A was another attempt at a full-length APC Core 38H that only partially stroked out from 209.7 to 213.5 m CSF-A and recovered 3.87 m of core.

Since we (a) had achieved a substantial part of this site's objectives, (b) had exceeded the operational time allocated for this site, and (c) have many high priority expedition objectives remaining, we decided to not to spend any more time attempting to sample to the full 300 m originally planned.

The full-length APC system penetrated a total of 57.1 m of formation and recovered 52.37 m (91%; but includes advance by recovery and one core that did not penetrate the formation). The HLAPC penetrated 71.9 m of formation and recovered 74.98 m (104%). The XCB system penetrated a total of 83.5 m of formation and recovered only 2.03 m (2%).

Hole U1449B

After finishing coring in Hole U1449A, we offset the ship 20 m to the east and obtained a single mudline core in Hole U1449B for high-resolution microbiological and geochemical sampling. The bit was spaced out to 3661.0 m DRF in an attempt to recover approximately 7.0 m on the mudline core. Core U1449B-1H extended from the seafloor down to 7.9 m. We then retrieved the drill string, secured the rig floor, and started the short transit to Site U1450 (MBF-2A) at 1530 h on 10 February.

Hole U1450A

After the short 26 nmi transit from Site U1449, we arrived at Site U1450 at 1830 h on 10 February and lowered the bit to the seafloor. We spudded Hole U1450A at 0255 h on 11 February and the mudline core established the seafloor at 3655.3 mbsl. We used the APC system for the first three cores (Cores U1450A-1H to 3H, 0–11.7 m DSF; 20.2 m cored; 18.63 m recovered). Since the latter two were partial strokes, we switched to the HLAPC. Cores 4F to 8F extended from 20.2–43.7 m DSF with a range of recoveries (0%–72%); despite this we did not advance by recovery but rather the full 4.7 m length each core.

From 43.7 to 132.9 m DSF (after Core 8F and down to Core 27F), we took a series of HLAPC cores interspersed with six 4.8 m long advances without coring. These APC were taken consecutively when non-sand zones were encountered. This interval included two coring attempts with the full length APC system (Cores 22H and 24H), but these only recovered 3.35 m of sediment. These were the only two cores where core orientation was attempted. Note that non-magnetic core barrels were used on all cores unless otherwise noted and the non-magnetic drill collar was in the BHA.

Based on our experiences in the top of Hole U1450A and at the previous Site U1449, we decided to deepen the hole by an alternating series of 4.7 m long half-length APC cores (HLAPC) followed by 4.8 m advances without coring. This was due to that fact that the full APC coring system could not sufficiently penetrate/recover this formation, and the XCB system, although it could penetrate it, would not recover core from this type of formation. In addition, the science objectives required deep penetration sampling at multiple sites, which could not be accomplished in time if the HLAPC was used continuously. This alternating pattern penetrated 403.5 m of formation from 132.9 m to 536.4 m DSF (Cores U1450A-28F to 112F). The only exception to this pattern was one short interval from 379.9 m to 403.4 m where HLAPC Cores 80F–84F were taken consecutively. The 45 HLAPC cores taken from this interval (U1450A-28F to 112F)

penetrated 211.5 m of formation and recovered 169.1 m of core (80%). Forty 4.8 m advances without coring penetrated 192.0 m of formation.

We conducted five formation temperature measurements with the APCT-3 tool at 86.3 m, 118.7 m, 156.6 m, 175.6 m, and 318.1 m DSF (while taking Cores 17F, 24H, 32F, 36F, and 66F). The last of these measurements is the deepest APC formation temperature measurement ever obtained.

As the week ended, we were continuing to deepen Hole U1450A with this alternating pattern of 4.7 m long HLACP cores and 4.8 m advances without coring.

Schlumberger wireline logging activities:

- Checked surface computer systems.
- Swapped logging head to LEH-MT to provide mud temperature measurements.
- Verified data delivery method—raw data files to be deposited on downhole technician's computer in Dropbox folder for transmission to LDEO-BRG for processing.

Science Results

Overview

Site U1449 is the first of a six-site transect to study the late Pleistocene architecture and evolution of the middle Bengal Fan. Different structural elements like levees, interlevee areas, and hemipelagic sequences were cored to characterize sedimentological, physical, and geochmical properties of the material delivered mostly through turbidity currents and likely originating from the source region of the Himalaya.

Site U1450, the second of our six-site transect, targets a 900 m thick late Miocene to Recent sedimentary section. In addition to addressing the shallow-penetration late Pleistocene objectives started at Site U1449, this site also provides insight into long term changes in the delivery systems of the fan and the climatically and tectonically influenced sediment supply. This deeper portion of Site U1450 will be compared with two complementary sites on our East–West transect on top of Ninetyeast Ridge and 85°E Ridge, respectively (proposed sites MBF-3A and MBF-1A).

Lithostratigraphy

Two holes were cored (U1449A, U1449B; MBF-6A) to a total depth of 213.57 m CSF-A (61% recovery) and 7.91 m CSF-A (100% recovery), respectively. The predominant lithology is siliciclastic and comprised of normally-graded intervals of mica-rich quartz-dominant fine sand, silt and clay of varying thicknesses (i.e. turbidites). The observed mineralogical assemblage is characteristic of sediments found in Himalayan rivers. Turbidite sequences are generally

separated by clay- and silt-sized mottled pelagic and hemipelagic intervals containing foraminifera, and occasionally by glassy volcanic ash layers. Lithological differences between siliciclastic units and variations in grain size and bed thickness reflect cycles of proximal turbidity current channel activity, including activation, flow-stripping, avulsion, and abandonment. Bioturbated pelagic and hemipelagic oozes likely represent times of channel-levee inactivity and hence reduced deposition through the settling of suspended sediment from the pelagic zone.

At the second site (Hole U1450A; MBF-2A), the predominant lithology of recovered cores to date is mica-rich quartz-dominant fine sand with drilling disturbances. Minor lithologies are silty clay and a few calcareous oozes and volcanic ash layers. Some intervals contain fine sand turbidites intercalated with silt and clay ("mud") turbidites.

Biostratigraphy

Calcareous nannofossil and foraminiferal biostratigraphy was conducted at Sites U1449 and U1450. At Hole U1449A, 53 nannofossil smear slides and 34 foraminiferal samples were prepared and the fossils, where present, were identified and the abundances of species were recorded. Integrated biostratigraphic controls suggest that the base of Hole U1449A extends to the Lower Pleistocene. At Site U1450, 77 nannofossil smear slides and 50 foraminiferal samples have been prepared so far. Sample 344-U1450A-100F-CC defines an age range of 2.6–3.6 Ma based on nannofossil biostratigraphy (Zone NN16).

Paleomagnetics

We completed a preliminary paleomagnetic study on 30 of the 38 cores collected from Hole U1449A, avoiding deformed or sandy intervals. Most cores were unoriented, so we relied on inclination for core-to-core comparisons, and declination data within each core, both from discrete samples and archive section halves. The upper 88 m (CSF-A) in Hole U1449A have normal polarity, corresponding to the Brunhes chron (<0.781 Ma). A pelagic deposit between 88 and 97 m (CSF-A) contains several magnetic polarity zones corresponding to the Matuyama chron (>0.781 Ma; beginning at ~89.0 m CSF-A) and the Jaramillo (0.988–1.072 Ma; ~93.8–95.05 m CSF-A) and Cobb Mountain (1.173–1.185 Ma; 96.28–96.58 m CSF-A) subchrons. Interpretation of the magnetic polarity below the pelagic unit is difficult, but there are at least two cores (U1449A-20H and 22H; 105.1–109.9 m and 113.4–118.1 m CSF-A) with reverse magnetization. We expect that correlation between the multiple holes in the Expedition 354 transect, particularly in pelagic and hemipelagic intervals, will help to clarify the interpretation of the magnetostratigraphy of Hole U1449A.

Physical Properties

At Sites U1449 and U1450 physical property data were acquired on almost all cores and allow three broad lithological categories to be distinguished. Sand-dominated lithologies have high

acoustic velocity (~1700 m/s), high wet bulk density (~2.1 g/cm^3), generally high magnetic susceptibility (~50–200 SI units), and intermediate levels of NGR (~70 cps). Silty-clay lithologies have intermediate values of acoustic velocity (~1550 m/s), wet bulk density (~2.0 g/cm^3) and susceptibility (30–100 SI units), and the highest NGR levels (~90 cps). Hemipelagic lithologies are easily distinguished by their low acoustic velocity (~1500 m/s), low wet bulk density (~1.6 g/cm^3), very low magnetic susceptibility (0–20 SI units), low NGR (~25 cps), and the lightest color. In cores that have fluidized sand and/or gap between the core and core liner, physical property measurements typically underestimate the expected true values for these sediments. As the sediments become progressively more compacted and lithified deeper in the succession in Hole U1450A, density and velocity values increase, particularly for the hemipelagic sediments, which are starting to become lithified at shallower depths than the other lithologies.

The contrast between the physical property values between sand and silty clay allows individual turbidites to be identified, which is useful to understand the involved processes of turbidite sedimentation on the Bengal Fan. The turbiditic sequences recovered at Site U1449 vary from fine-grained, muddy turbidites to coarse-grained and sandy.

Geochemistry

The chemistry laboratory spent the week processing and analyzing samples from Holes U1449A, U1449B, and U1450A for headspace gases, and pore water and sediment geochemistry. The single core from Hole U1449B was sampled for high-resolution pore water chemistry and microbiology. Headspace gas measurements were conducted on every core. In Hole U1449A, methane concentrations reach several thousands ppmv in the levee deposits. Ethane concentrations were always below 1 ppmv. A comparable range of concentrations were measured in Hole U1450. Interstitial waters were extracted from APC and HLAPC cores by rhizon in the upper 80 m of Holes U1449A and U1450A, and by squeezing 5 cm whole-round samples below 80 m. Cores from Holes U1449A and U1450 where substantial mixing/disruption of sands occurred were avoided for pore water sampling. Analyses for total inorganic carbon (TIC), total carbon (TC), and total nitrogen (TN) have been completed for Hole U1449A and are underway for Hole U1450A. TIC varies from 0.5 to 5 wt% in lithologies where carbonate is mainly detrital in origin, and from 3 to 7 wt% in lithologies dominated by hemipelagic carbonates. Total organic carbon (TOC) calculated by difference between TC and TIC varies from 0.08 to 0.86 wt%, with sands displaying systematically lowest TOC. Analyses of pore waters for alkalinity, chlorinity, pH, major elements, and anions are underway for Holes U1449A, U1449B, and U1450A. Bulk sediment chemistry by ICP is currently underway.

Summary

As indicated in the Operations section, challenges regarding recovery, particularly of sands intercalated between muddy units, were experienced. As anticipated, recovery was limited using the XCB, and a “spot” coring approach using HLAPC was chosen to ensure timely penetration to

the desired target depth of 900 m at Site U1450. As much as a sedimentary fan itself constrains the achievable resolution in geologic time by only intermittently delivering material to a given location, HLAPC interval sampling and limited recovery affect sampling in the same direction; however, this leads to a coarse but continuous sampling when applied across the transect by hitting laterally shifting depocenters. The HLAPC approach was revealed to be particularly efficient to sample both turbiditic sequences and loose sand intervals. It returned excellent sampling of turbiditic sequences in levees identified on the seismic survey as well as in interlevee formations. Thick sand layers (up to several meters) were also recovered demonstrating massive sand transport to this distal position in the middle Bengal Fan.

Having said this, we view the recovered geologic record at Site U1449 as superb, having collected large volumes of sand throughout the section, having cored a complete >40 m thick levee succession and retrieving enough hemipelagic material to establish a chronostratigraphy based on biostratigraphy and magnetic reversals. The comparison of the shallow sections at both Sites U1449 and U1450 further confirms the transect approach, as a well-constrained correlation based on bio-, magneto- and seismostratigraphy can be anticipated. Altogether, both sites show that the high accumulation rate of turbiditic deposition was disrupted by significant low accumulation episodes within the Pleistocene.

Education and Outreach Activities

As part of our Education and Outreach activities for the Bengal Fan Expedition, we posted daily updates and photos on our official social media outlets (Facebook [https://www.facebook.com/joidesresolution], Twitter [https://twitter.com/TheJR], and Instagram [http://instagram.com/joides_resolution]). We also began compiling activity metrics from these websites. We posted blogs on the American Geophysical Union (AGU) blog "The Plain Spoken Scientist" and on http://joidesresolution.org/, including one guest blog by a member of the science party. To prepare for our live video interactions with schools and museums around the world, we continued to communicate with shore-based educators to schedule broadcasts and carried out several test connections. We held live broadcasts with an elementary school in Michigan and two high schools in New Hampshire and Washington, DC. One of the Education Officers, a videographer, completed production of a new video called "Aboard the *JOIDES Resolution*."

Technical Support

Technical staff is fully engaged supporting coring and science operations at Sites U1449 and U1450. Bathymetric data was collected on the transit between the two sites. Laboratories are fully operational with no major issues to report.

Laboratory Activities

- Password and Uploaders: Minor issues continue, most resolved.
- Exhaust Hood: Fan belt replaced on the C8 extractor.
- SEM: Replace filament.
- XRD: Fixed minor cooling water issue similar to previous expedition.

Developer Activities

- SCOR-QA: Work continues.

MCS Activities

- VSAT: Worked with Rignet to upgrade VSAT bandwidth. Increase implemented successfully.
- Back-up Tape: Repaired drive issue. All four tape drives now working normally.
- Windows OS: Applied multiple Windows updates to PCs throughout the ship.
- BugWin: Installed the program in the Microscope Laboratory for scientist data acquisition.
- SonicWALL: License successfully updated. Now good through 6 February 2016.

HSE Activities

- The weekly fire and abandon ship drill was held.