IODP Expedition 354: Bengal Fan

Site U1453 Summary

Background and Objectives

Site U1453 is located in the center of the seven site, ~200 m penetration transect drilled during Expedition 354 to study the Pleistocene fan architecture and evolution of the middle Bengal Fan at 8°N. Site U1453 is located at 8°0.42′N, 86°47.90′E, in a water depth of 3690.5 m. In combination, these sites will provide a complete inventory of Pleistocene fan architecture and evolution in the 300 km long central segment of the Bengal Fan. The seismic data along the transect reveal characteristic structures and patterns of fan deposition related to channel-levee systems. The objectives are to characterize the lithologies building the structural and depositional elements of the fan and to estimate accumulation rates related to different depositional processes. Combined with the other transect sites, Site U1453 will document depocenter migration and quantify the overall sediment delivery to 8°N since in the Pleistocene.

Site U1453 is located ~1 km south and ~5 km east of a prominent surficial channel. The channel exhibits pronounced meandering, point bars, and internal terraces. Sediment transported by this channel has therefore significantly influenced deposition at this site during the channel's lifetime. A prominent buried point bar is located <1 km to the west of the site. The overall seismic reflectivity at the drill site is relatively high, indicating coarse material throughout most of the drilled section, except for the lower portion of the drill hole. Distinct and variable local spillover deposits were expected at the site in response to the channel and meander evolution. Toward the base of the hole, lower seismic reflectivity and distinct layering was inferred to reflect hemipelagic or distal levee deposition.

In addition to coring, downhole logging was introduced as an important objective of Site U1453 after attempts to log at Sites U1450 and U1451 were unsuccessful. Logging data were considered to be essential for determining the inventory of lithofacies and structures in the fan, given the limitations in recovery of unconsolidated coarse material as well as the need to measure in situ physical properties and to image fine-scale sedimentary structures. Therefore, we decided to log Hole U1453A despite its shallow penetration to only ~215 m to increase chances that we could acquire this critical in situ log data. This

was particularly important to characterize the in situ properties of thick sandy intervals that HLAPC cores returned as loose and liquefied sand.

Principal Results

Site U1453 contributes to the overall seven-site transect drilled by Expedition 354. When integrated with the seismic profile and refined chronostratigraphic data this will document the fan construction processes and depocenter migration time frame. More particularly, Site U1453 provides an almost completely recovered succession of silt and/or sand-dominated sheeted units, which are related to the formation and evolution of a large meandering channel system lacking a distinct levee unit. Intercalation of these sheets with thinner levee units either from the large channel or from nearby smaller channels may help to understand why the channel had been apparently maintained in this position for a relatively long time period. This type of configuration is part of the different processes that influence interlevee deposition. A few thin hemipelagic layers are also observed between sandy turbiditic units, which may indicate that sheeted sedimentation may be restricted to short time periods only, and is not always followed by an erosional and levee formation phase. The interval cored between 144 and 159 m represents an expanded hemipelagic unit, dated to the time interval between 0.8 and 1.2 Ma. Fan sedimentation intensified between 800 ka and 300 ka, the basal age of the surface hemipelagic unit. Accordingly, fan deposits grew by 100 m in 500 k.y., equivalent to an average sedimentation rate of 20 cm/k.y.

Acquisition of the expeditions only downhole log data will allow detailed comparison of how well the fine-scale (centimeter to decimeter) structure in the formation has been preserved in cores. Particularly, the proportion of sand in the formation versus the amount recovered by coring is of interest to calibrate the sedimentary records from other sites.

Analyzing some graded variations within the sandy units using magnetic susceptibility data from both cores and downhole data shows that, despite the HLAPC coring process and curational procedures (vertical settling of sands), the average physical properties still match with in situ data and can be used to characterize the formation. This match confirms that cored structureless sand truly reflects, on average, the sand unit at depth even though several meter thick sand cores were recovered with HLAPC that apparently did not fully penetrate the formation.

Operations

In Hole U1453A, APC and HLAPC coring penetrated from the seafloor to 172.9 m, except for one 5 m interval advanced without coring. Most of the coring was done with the HLAPC system. However, the full-length APC system was used for the uppermost four cores and one deeper core around 145 m that attempted to recover a hemipelagic layer in a single core. From 172.9 to 215.7 m the hole was deepened with HLAPC cores, alternating with five 4.8 m advances without coring. Hole U1453 was penetrated to 186.7 m of which 164.8 m were cored with 88% recovery.

After coring was completed, we collected downhole logging data with two tool strings (triple combo and FMS-sonic). Logging was very successful with good hole conditions and reached the full depth of the hole.

Lithostratigraphy

The overall lithology of Site U1453 is similar to the other Expedition 354 sites, in that it is dominated by mica- and quartz-rich sand, silt and clay turbidites separated by bioturbated nannofossil-rich calcareous oozes, and occasional glassy volcanic ash layers. Turbidite sequences in Site U1453 represent cycles of channel-levee activity and abandonment that have constructed the fan. The base of the section contains thick sand units, which are most likely sheet deposits from nearby channels. Above these sands, a moderately thick (~15 m) section of calcareous clay indicates a time when channel activity was reduced. The middle of the section contains a 127 m thick interval of fine sand interbedded with mud turbidites and occasional calcareous clay beds, suggesting an onset and waxing and waning of proximal channel activity and levee building. The stratigraphic section is topped with 10 m of calcareous clay, indicating reduced siliciclastic input here.

Biostratigraphy

Calcareous nannofossil and planktonic foraminiferal biostratigraphic analyses were conducted at Site U1453 on 37 samples and resulted in the identification of four biomarker events. The sedimentary succession at Site U1453 extends to the Early Pleistocene. As with other sites, planktonic foraminiferal assemblages are characteristic of tropical-subtropical environments. Foraminiferal preservation ranges from poor to good in samples where they occur and fragmentation of planktonic foraminifera ranges from light to severe. As at Site U1452, the LO of the foraminifera biomarker

Globorotalia tosaensis (0.61 Ma) was found at a shallower depth than the nannofossil biomarkers *Emiliania huxleyi* (0.29 Ma) and *Pseudoemiliania lacunosa* (0.44 Ma), indicating that this foraminifera was either reworked or has a longer extent in the Indian Ocean. Foraminifera biostratigraphy was limited at this site due to the large section of sands recovered from Core U1453A-10F to U1453A-28F, where samples are either barren of foraminifera or have very rare occurrence (<0.1%). The LO of the nannofossil *Helicosphaera sellii* (1.26 Ma) is found at approximately 116 m CSF-A. However, the Brunhes/Matuyama boundary (0.781 Ma) is found at 152 m CSF-A, indicating that either *Helicosphaera sellii* was reworked or has a longer extent in the Indian Ocean. This discrepancy was observed at several Expedition 354 sites and will be further studied in postcruise work.

Paleomagnetics

The Brunhes/Matuyama boundary, as well as both boundaries of the Jaramillo and the Cobb Mountain subchrons, were identified at Site U1453 in hemipelagic calcareous clay units within a depth interval of ~142–160 m. A ~180° change in declination associated with a thin ash layer is interpreted as the Brunhes/Matuyama boundary (152.59 m CSF-A). Changes in declination also clearly delineate the Jaramillo and Cobb Mountain subchrons (155.76–156.71 m CSF-A and 157.59–158.23 m CSF-A) in calcareous clay deposits at Site U1453.

Physical Properties

Physical property data were acquired on all Hole U1453A cores, including density, magnetic susceptibility, *P*-wave velocity, natural gamma radiation, and thermal conductivity. The physical property data at Site U1453 are mostly of good quality, and reflect lithological variations. Using the principal lithological name from the core description to assign five lithologies (sand, ~73 m; silt, ~11 m; clay, ~45 m; calcareous clay, ~23 m; and volcanic ash), we calculated their minimum, maximum, and average physical properties. Wet-bulk densities are rather uniform for terrigenous sediment (sand, silt, and clay), ranging from 1.89 to 1.96 g/cm^3. Calcareous clay has the lowest densities (1.62 g/cm^3), followed by volcanic ash (1.68 g/cm^3). *P*-wave velocities are highest in sand (1666 m/s on average) and lowest in silt and clay (~1530 m/s). Magnetic susceptibilities are also highest in sand (109×10^{-5} SI), followed by silt (90×10^{-5} SI) and clay (56×10^{-5} SI). The lowest values occur in calcareous clay (20×10^{-5} SI).

Natural gamma radiation is high throughout the terrigenous components sand, silt, and clay (around 70 cps) and low in calcareous clay (43 cps). Thermal conductivity is highest in sand (1.82 W/[m·K]) and lowest in calcareous clay (1.17 W/[m·K]).

Downhole Logging

The triple combo tool string (magnetic susceptibility, natural gamma radiation, and resistivity) and the FMS-sonic velocity tool strings were run in Hole U1453A. The hole was filled with 12 ppg heavy viscous mud to inhibit the collapse of the borehole walls. In contrast to our previous logging attempts, logging was successful with a single run of the triple combo tool and two runs of the FMS-sonic string down to the bottom of the hole at 220 m WSF. The hole diameter varied between 9 to 14 inches with few washout zones only.

The downhole measurements of magnetic susceptibility and natural gamma radiation match the equivalent core measurements well and permit a preliminary interpretation of lithology, based on the log data in the intervals where core was not recovered. The FMS resistivity images in particular provide a good record of the depth and thickness of the sand beds in the hole. Sand-rich cores were sometimes fluidized when recovered, but the log data could confirm that the sands in the 9.5 m core come from the same 9.5 m interval in the hole; compositional trends over several cores were similar in core and log data. Additionally, the downhole *P*-wave velocities are higher than those measured in the laboratory, reflecting in situ conditions in the borehole.

Geochemistry

The close proximity of a channel incising to a depth in excess of 100 m, associated with variable dip angle of the formations, provided the opportunity to investigate a sub-seafloor hydrology that is potentially affected more by lateral flow compared to other drill sites. A well-defined boundary between two hydrologic units is observed at Site U1453 around 30 m CSF-A, defined by depth profiles of sulfate content and alkalinity. This is very similar to what has been observed at Sites U1449 and U1452, implying only a limited local hydrological effect related to the close proximity of a channel.

Other similarities include (1) Pleistocene turbidites characterized by carbonate content of 0.8 to 5.9 wt%, and (2) hemipelagic deposits that have an average carbonate content of 25.9 wt%. For turbidites, these characteristics are similar to what is observed in modern

Ganges-Brahmaputra (G-B) river sediments, as well as the top 150 m at Sites U1449, U1450, U1451, U1452, and DSDP Site 218. Total organic carbon content (TOC) in turbidites averages 0.7 wt% and the maximum TOC values of hemipelagic lithologies (2.5 wt%) is identical to maximum values for turbiditic sediments. TOC co-varies with bulk sediment Al/Si ratios, reflecting the preferential association of organic matter with clays that is documented in both the modern G-B river system and in active channel-levee sediments in the Bay of Bengal deposited over the past 18 k.y. Bulk geochemical trends closely track those observed at Sites U1449, U1450, U1451, and U1452, as well as modern sediments in the G-B river system. Samples that are offset from the main trends are from hemipelagic units and suggest the occurrence of Fe-rich clays and/or a low K/Al subpopulation, possibly suggesting a different terrigenous input or sorting effect.