IODP Expedition 353: Indian Monsoon Rainfall
Site U1444 Summary

Background and Objectives

The main scientific objective of IODP Expedition 353 is to analyze the variability of the salinity gradient in the Bay of Bengal on suborbital to orbital time scales. To achieve these objectives, site locations were selected according to their proximity to the main sources of fresh water feeding the Northern Bay of Bengal, including the Mahanadi and the Ganges-Brahmaputra river complex, and the Andaman Sea, including the Irrawaddy and Salween river systems.

Within one month prior to the expedition start, an alternate drilling plan was requested, one that included only sites in international waters. To accommodate this we utilized existing site survey data acquired by the University of Bremen in 1997 and 2006 to locate drilling targets in the central Bengal Fan, following a latitudinal transect approach. This alternate plan is comprised of sites at three different latitudes in international waters at 11°N, 14°N and 17/18°N.

Drilling these alternative sites is unlikely to fulfill the paleoclimatic time-series oriented scientific objectives of the Expedition 353 scientific party, since the sedimentary archive of the Bengal Fan does not record the salinity history of the Indian monsoon core region nor do the abundant turbidite sequences have the stratigraphic integrity required for high-resolution reconstruction of climate change. However, the results of these alternate drill sites on the Bengal Fan are complementary to the transect approach of Expedition 354 (France-Lanord et al., 2014). One of the crucial issues for Expedition 354 is the continuity of the terrigenous flux from the Himalayan source to the ~8°N drilling targets. Channel migration may, at times, decouple the middle fan from the supply. The addition of holes north of 8° to those targeted by the Expedition 354 Scientific Party may help to evaluate these processes, and provide additional material for the understanding of terrigenous flux into the Bengal Fan, one of the main objectives of the Expedition 354 drilling proposal.

Site U1444 (14°N, 84°49.74′E; 3133 mbsl) is located at CMP 1302 on seismic line GeoB97-041 (Schwenk and Spiess, 2009). The site is located in the western part of the lower Bengal Fan, close to the westernmost abandoned channel that was feeding the

western part of the lower fan (Emmel and Curray, 1985). Interpretation of the seismic lines suggests that these sediments are composed of a series of buried channel-levee sequences incised into hemipelagic sediments atop the underlying 85°E Ridge. Schwenk and Spiess (2009) identified two prominent unconformities (Uc and Ud) bounding a more transparent hemipelagic unit between 4.32 and 4.20 sec TWT (corresponding to ~105 to 185 mbsf). These unconformities can be traced for several hundred kilometers to the east along GeoB97-041 (Schwenk and Spiess, 2009). Similar regional-scale unconformities in the lower fan have been correlated to DSDP 218 and dated as earliest Pliocene (~4.8 Ma) and middle Pleistocene (~0.65 Ma) in age (Von der Borch et al., 1974; Schwenk and Spiess, 2009). Uc and Ud are inferred to be Pleistocene and Pliocene in age as well but no means of correlating them with confidence yet exists. A primary objective of this site is to determine the lithological changes associated with seismic reflectors Uc and Ud and to date these reflectors in an effort to assess the degree to which turbidite and intercalated hemipelagic sequences can be correlated from the upper to lower fan regions.

Operations

At Site U1444, Holes U1444A and U1444B were drilled to total depths of 330.6 and 128.6 m DSF, respectively. In Holes U1444A and U1444B, the full-length (9.7 m long) APC system and the XCB systems were primarily used. The half-length APC (HLAPC, 4.7 m long) was only used for Core U1444A-24F. For Holes U1444A and U1444B, the APC system was used to refusal. Following refusal of the APC system, the XCB was deployed to total depth. A total of 46 cores were recovered for the site. A total of 156.21 m of core over a 160.0 m interval were recovered using the APC system (98% recovery). The cored interval with the HLAPC system was 4.8 m with a recovery of 3.94 m of core (82%). The cored interval with the XCB system was 246.9 m with a recovery of 140.06 m of core (57%). Hole U1444B contained drilled interval from 47.5–95.0 m DSF. The overall recovery percentage for Site U1444 was 73%.

Principal Results

Lithostratigraphy

The sediments recovered from Site U1444A can be subdivided into four lithostratigraphic units based on visual description, smear slide description, and physical property measurements. The recovered lithologies are siliciclastic and comprised of turbidites and hemipelagic intervals. Unit I (0–95.01 m CSF-A) is comprised of silty sand and silty clay

with numerous turbidites. Unit II (95.01–168.91 m CSF-A) is primarily nannofossil-rich clay with silt and foraminifers. Turbidites in Unit II are less abundant, thinner, and finer than in Unit I. Unit III (176.1–255.6 m CSF-A) is characterized by very poor recovery and is dominated by silty fine-to-medium sand. Unit IV is comprised primarily of nannofossil-rich clay and clayey silt interbedded with sand and silt turbidites. Turbidites at this site show typical erosional bases and normal (upward-fining) grading, but rarely show structures typical of classic Bouma or Stow sequences (e.g. parallel, wavy, or lenticular laminae). Structureless turbidites suggest very rapid sedimentation and/or disturbance of the water-saturated sands during drilling and recovery of the cores. Turbidites can be classified by their maximum grain size as either silt or sand. At Site U1444, turbidites can be classified compositionally as mica-rich, well-sorted quartz-dominant, organic debris-rich, and glauconite-rich. The overall lithological differences between units and variation in turbidite grain size and thickness are consistent with fluctuations in the proximity of active turbidity current channels on the Bengal Fan.

Biostratigraphy

The biostratigraphic age model for Site U1444 was established by combining nannofossil and planktonic foraminifer datums from samples from Hole U1444A. Age-depth relationships for the two fossil groups show good agreement. All samples were nearly or completely barren of diatoms. Calcareous microfossils (nannofossils, planktonic, and benthic foraminifers) at Site U1444 were rare or absent in turbidite-rich sequences and common to abundant in hemipelagic sediment sequences. Where calcareous microfossils were present, preservation was good to moderate and rarely poor. Foraminifers ranged in preservation from poor to good in the samples in which they occur.

Nannofossil assemblages were of Pleistocene to late Miocene age and tropical/subtropical in character. Most Pleistocene, Pliocene, and late Miocene calcareous nannofossil bioevents used to define the biostratigraphic zones were present. This enabled us to assign all samples from hemipelagic sediment sequences and many samples from turbidite-rich sequences to a single biozone. *Emiliania huxleyi* is present in Sample U1444A-9H-CC near the bottom of Lithologic Unit I, suggesting that this entire unit (95 m) was deposited during the Late Pleistocene and Holocene. The top of Lithologic Unit II (95–177 m CFS-A) was placed within nannofossil Zone NN20. Sample U1444A-20X-CC (168.89 m CFS-A), near the base of Unit II, falls within nannofossil Zone NN16

in the late Pliocene. The Lithologic Unit IV sequence spans Zones NN13 in the middle Pliocene to NN11 in the late Miocene. Sample U1444A-37X-CC, 18 cm, collected 12 cm above the bottom of Hole U1444A, contained common *Discoaster loeblichii*, which suggests that the oldest sediments in Hole U1444A are younger than 7.53 Ma (late Miocene).

Planktonic foraminifer assemblages at Site U1444A are tropical to subtropical throughout the Neogene and include species indicative of upwelling. The last occurrence of *Globigerinoides ruber* (pink) in Sample U1444A-4H-CC and the first occurrence of *Globorotalia flexuosa* in Sample U1444A-14X-CC indicate that sediments between 35.80 and 119.42 m CSF-A are of Pleistocene age. Pliocene datums were found in Samples U1444A-16X-CC through 19X-CC (137.41–166.53 m CSF-A) and in Cores U1444A-32X and 33X (282.00–290.50 m CSF-A). Eleven core-catcher samples from 168.89–270.34 m CSF-A were either barren or contained no index species range. Miocene sediments are identified in Samples U1444A-35X-CC and 36X-CC. The occurrence of *Candeina nitida* in Sample U1444A-36X-CC indicates that it can be no older than 8.43 Ma.

Site U1444 is characterized by large variations in sedimentation rate that occur because of high frequency, large-scale episodes of terrigenous deposition. Mean sedimentation rates reach >20 cm/k.y. in Lithologic Unit I (0–95 m CSF-A) and >30 cm/k.y. in Unit III (264–323.5 m CSF-A). Lithological Units II and IV are mostly hemipelagic with sedimentation rates an order of magnitude lower than Units I and III, around 1.39 cm/k.y. for Unit II and 1.60 cm/k.y. for Unit IV.

Geochemistry

Site U1444 is varied geochemically as reflects the depositional history of this section of the Bengal Fan. Significant changes in bulk and pore water chemistry are seen reflecting the major changes in lithology; Lithologic Unit I features a complete drawn down of sulfate and increases in methane, alkalinity, and nutrients. Deeper units are less reducing with opposing trends in many elements, including pronounced secondary peaks in sulfate, silicate, B, Li, Mn, and K. Organic C is low but variable, ranging between 0 and 2%, while carbonate content tracks lithologic units: Units I and III are low while II and IV are variable but generally higher (10–30 %).

Paleomagnetism

Paleomagnetic measurements were conducted on archive-half sections for both Holes U1444A and U1444B. Sections dominated by sand were not measured because of their unstable texture, as well as the risk of contamination to the magnetometer. All sections from XCB cores were severely affected by drilling related overprint and are difficult to interpret. A selection of discrete samples (N = 119) taken from working-half sections was also analyzed. Based on APC section measurements and discrete data, we propose tentative magnetozones throughout Hole U1444A. Magnetostratigraphic ages are given as 0.781 Ma at around ~112–118 m CSF-A and 2.581 Ma at around ~148–151 m CSF-A. Other magnetozones were difficult to correlate with the geomagnetic polarity time scale due to poor recovery at some intervals and drilling-related overprint remanence. Most of the discrete data up to ~100 m CSF-A are influenced by gyroremanent magnetization, likely due to the presence of greigite (a ferrimagnetic iron sulphide). Rock magnetic evaluation of greigite abundance revealed depth distribution in broad agreement with some interstitial water geochemistry.

Physical Properties

The physical properties data collected at Site U1444 was found to be in good agreement with the lithostratigraphic data. Four physical property units were identified in Hole U1444A, which are identical to the lithostratigraphic units, and three physical property units in Hole U1444B, which are different and are not directly related to the units defined for Hole U1444A. The magnetic susceptibility (MS) values were higher in coarse-grained sediments than in the clay-rich sections. Core-length MS trends (high values at the bottom of cores to low values at the top indicate mechanical sorting at core-length scales. These anomalies are present in APC cores that are entirely composed of coarse, watery sands. Data collected from Hole U1444B was useful for filling in a small data gap that existed for density and gamma ray in Hole U1444A.

Stratigraphic Correlation

No composite depth scale or splice was constructed for Site U1444. Coring disturbance and mechanical sorting of turbidite sands leading to a restructuring of the physical properties on a core-by-core basis in the upper part of the site (see Physical Properties) as well as lack of signal in the XCB cores in the lower part of the site prevented establishment of reliable tie points between Holes U1443A and U1444B.

Highlights

Dating the Schwenk and Spiess (2009) seismic unconformities Uc and Ud at Site U1444A

The middle Bengal Fan is characterized by channel–levee systems, which are erosionally incised into underlying hemipelagic sediments (Schwenk and Spiess, 2009). Seismic profiles indicate two major regional unconformities, which were dated at DSDP Site 218 as earliest Pliocene (~4.8 Ma) and middle Pleistocene (0.65 Ma) (Von der Borch et al., 1974; Schwenk and Spiess, 2009). The extent of the regional unconformities, the onset of levee systems, and faults terminating within Pleistocene sediments suggest that tectonic events, in addition to changes in sediment supply and transport, exerted a major control on the sedimentation patterns of the Bengal Fan (Schwenk and Spiess, 2009).

The middle-late Pleistocene regional unconformity, Uc in Schwenk and Spiess (2009), is clearly recognizable in the sedimentary succession of Site U1444. It is defined by a lithological change from hemipelagic clays and silty clays (with foraminifer and nannofossil ages of ~200 ka) to a turbidite dominated sequence composed of silty sands and silty clays, which are largely barren of microfossils. This 95 m long sequence represents the last 200 k.y. of sedimentary deposition at Site U1444. The deeper regional unconformity, Ud in Schwenk and Spiess (2009), comprises the change from very poorly recovered turbiditic silty sands and clayey silts to hemipelagic clays and silty clays in the middle Pliocene, between ~3.6 and 3.8 Ma. Within the error of the dating, which includes sedimentation rate-based extrapolations over tens of meters at Site 218, the Late Pleistocene regional unconformity could be the same age as the unconformity at Site 218. The deeper, Pliocene unconformity at Site U1444 appears to be on the order of one million years younger relative to the unconformity at Site 218.

The onset of channel–levee systems in the latest Miocene is indicated by well-data in ODP Leg 116 and seismic data along a E–W transect at 8°N (Schwenk & Spiess, 2009). These changes were possibly related to changes in the erosion and weathering regime in the drainage area of the Ganges (Schwenk & Spiess, 2009). At Site U1444 a strong increase in coarse-grained silty-sandy levee and turbidite sediments representing a fan lobe occurred later in the middle Pliocene around 3.8 Ma, while the oldest sediments of U1444A (3.8–~6 Ma) consist of fine-grained mudstones with intercalated thin-bedded levee sediments.

References

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