IODP Expedition 353: Indian Monsoon Rainfall

Site U1447 Summary

Background and Objectives

Site U1447 is located in the Andaman Sea, ~45 km offshore Little Andaman Island at 1392 mbsl. The site lies within a basin on the eastern flank of a rise separating north–south oriented basins associated with the Eastern Margin and Diligent faults, both related to the underlying accretionary wedge complex. The objectives at this site are to recover Miocene to recent sediments in order to reconstruct changes in summer-monsoon rainfall and runoff from the Irrawaddy and Salween rivers at tectonic to sub-orbital timescales. The location yields access to older sediments but is not protected from potential turbidite deposition.

Operations

At Site U1447, Holes U1447A, U1447B, and U1447C were drilled to total depths of 738.0 m, 24.4 m, and 158.9 m DSF, respectively. In Hole U1447A the APC system (9.5 m long), the half-length (4.7 m long) APC system (HLAPC), and the XCB system were deployed. In Holes U1447B and U1447C only the APC system was used. Overall, 108 cores were recovered for the site. A total of 451.27 m of core over a 444.3 m cored interval were recovered using the APC system (102% recovery). The cored interval with the HLAPC system was 67.8 m with a recovery of 69.12 m of core (102%). The cored interval with the XCB system was 409.2 m with a recovery of 395.15 m of core (97%).

The overall recovery percentage for Site U1447 was 99%. The total time spent on Site U1446 was 6.13 days.

Principal Results

Lithostratigraphy

The sediments recovered from Site U1447 are principally composed of Late Pleistocene to late Miocene hemipelagic clays with a significant biogenic component, and occasional thin turbidites, composing four distinct lithological units (I–IV). Unit I is 126 m thick and composed of Late Pleistocene greenish gray clayey nannofossil oozes with foraminifers and foraminifer-rich nannofossil oozes with clay. Unit II is 193 m thick and composed of Late Pleistocene–late Pliocene greenish gray clayey nannofossil oozes with foraminifers, foraminifer-rich nannofossil oozes with clay, and clayey calcareous oozes with varying

proportions of foraminifers. This unit is also characterized by the presence of numerous thin to thick light gray turbidites, described as foraminifer-rich sand or silt and bioclastic-rich layers with authigenic carbonate and foraminifers. Unit III is 180 m thick and composed of early Pliocene to late Miocene greenish gray clayey nannofossil oozes to calcareous oozes with varying amounts of glauconite. Unit IV is 240 m thick and comprised of late Miocene greenish gray–gray clayey nannofossil ooze with glauconite or biosilica, biosilica-rich clay with varying proportions of glauconite and nannofossils, and nannofossil-rich clay with biosilica. The observed lithological differences between the units are primarily the result of varying abundances of biosilica (principally diatoms and sponge spicules), turbidites, and nannofossils.

Biostratigraphy

Calcareous nannofossils are abundant or common throughout Hole U1447A. Their preservation is generally very good to moderate, except in two samples that contain poorly preserved, overgrown nannofossils. Foraminifers are dominant to abundant and very well preserved throughout the Pliocene–Pleistocene, with a few exceptions in the turbiditic interval of Lithostratigraphic Unit II where the preservation decreases to moderate or poor and/or the abundance decreases to common. Foraminifers are dominant to abundant in most Miocene sediments as well, though abundance decreases to common or few in samples where diatom abundance is high. Preservation in the Miocene continues to be good with only two exceptions where moderate preservation accompanies low foraminifer abundances. Diatoms are sporadically present in the uppermost 566 m CSF-A of Hole U1447A. Their abundance varies between abundant and few downcore. Valve preservation ranges from good to poor, and valves are better preserved whenever abundance is higher than common.

The frequency and distribution of nannofossil and foraminifer bioevents meant that we were able to construct a high-resolution age model for Site U1447. Diatoms were also useful for age-estimation below 556.11 m CSF-A. A few paleomagnetic reversal datums fit well into the general age model. The base of the Latest Pleistocene was delineated by the last occurrence of *Globigerinoides ruber* (pink) at 32.25 m CSF-A. The Pliocene/Pleistocene boundary (2.59 Ma) is placed just below the last occurrence of *Discoaster pentaradiatus* (2.39 Ma), which occurs between 299.78–301.89 m CSF-A. The Miocene/Pliocene boundary (5.33 Ma) occurs between 468.89 m to 470.19 m CSF-A

based on the last occurrence of *Triquetrorhabdulus rugosus* (5.28 Ma) and the first occurrence of *Ceratolithus acutus* (5.35 Ma) in this interval.

The oldest calcareous nannofossil sample studied contained *Discoaster hamatus*, suggesting an age greater than 9.53 Ma. The oldest planktonic foraminifer datum encountered is the first occurrence of *Neogloboquadrina acostaensis* (9.83 Ma). *Globorotalia limbata* is found, suggesting that the basal age of Hole U1447A is between 9.83 and 10.66 Ma. The oldest diatom datum is the FO of *T. burckliana,* (between 719.87–721.31 m CSF-A), suggesting that the bottom of Hole U1447A is slightly older than 9.1 Ma. Based on linear fits including all biostratigraphy and magnetostratigraphy data, sedimentation rates at Site U1447A are highest in the Pleistocene (on average 12 cm/k.y. linear sedimentation rate, LSR), moderate in the Pliocene and most of the Miocene (on average 6.5 cm/k.y. LSR) and possibly lowest in the Miocene below 700 m CSF-A.

Geochemistry

The geochemistry at Site U1447 mainly reflects the anaerobic processes of sulfate reduction and methanogenesis associated with microbial degradation of organic matter. The organic carbon content ranges from 0.1 wt% to 2.0 wt% (average 0.8 wt%). Sulfate declines rapidly from 28 mM at the sediment/water interface to nearly zero values at approximately 20 m (CSF-A). A convex-up shaped sulfate profile indicates sulfate reduction by means of organic matter degradation while the role anaerobic methane oxidation appears low. Alkalinity peaks at 20 m depth, consistent with the production of bicarbonate during sulfate reduction. A gradual increase in dissolved Ba concentration with depth suggests ongoing barite dissolution and potential deep sulfate reduction. Changes in the concentration of other elements and ions (Fe, Mn, Ca, B, ammonia, and Sr) in interstitial water can be readily explained by microbially mediated chemical reactions and their effects on pH, alkalinity and mineral dissolution and precipitation. Headspace methane concentrations in sediment peak at 125 m, abruptly decrease below the peak, and are consistently low to the bottom. High methane/ethane ratios suggest that the methane is mostly of biogenic origin (methanogenesis). Carbonate content varies significantly between 9 wt% to 55 wt%.

Paleomagnetism

Paleomagnetic measurements were conducted on archive half-sections for all three holes at Site U1447, with alternating field (AF) demagnetization up to 10 mT. Discrete samples taken from the working half-sections of Holes U1447A were also analyzed, with stepwise AF-demagnetization up to 40–80 mT. Characteristic remanent magnetizations (ChRMs) of these discrete samples were calculated using the principal component analysis (PCA) technique. Both data became noisy below ~90 m CSF-A, with predominant drilling-related overprint. Tentative magnetostratigraphy was proposed on the basis of these data down to 1.778 Ma at ~220 m CSF-A for Hole U1447A. In addition, anhysteretic remanent magnetization (ARM) was acquired and measured on a selection of Hole U1447A discrete samples for preliminary insight into depth variations in Site U1447 sediment bulk magnetic properties.

Physical Properties

The physical properties data collected at Site U1447 were found to be in good agreement with the lithostratigraphic data. However, based on overall physical properties data we have divided Hole U1447A into four units. The changes in bulk density and porosity reflects changes in sediment composition. We observe similar trends in all physical properties data between Holes U1447A and U1447C. Long term cyclic variability in NGR values may reflect periodic changes in lithogenic input.

Stratigraphic Correlation

A composite scale (CCSF-A) and a splice were constructed for Site U1447 with Holes U1447A and U1447C using magnetic susceptibility, natural gamma ray and RGB data. Splicing among these holes enabled us to construct a continuous stratigraphic sequence down to ~147 m CCSF-D. Due to data quality and time availability issues, correlation should be viewed with caution below ~112 m CCSF-A.

Highlights

Site U1447 exhibits a nearly complete hemipeagic succession from the Recent (mudline with common fragile epifaunal tubular agglutinated foraminifers of the genera *Rhabdammina* and *Saccorhiza*) to middle Miocene (~9.8 Ma) with all nannofossil biostratigraphic markers present.

Unconformities with possible short term stratigraphic hiatuses in the upper part of the sedimentary succession include: (1) a massive carbonate turbidite bed in the uppermost (Holocene) part of the succession at ~1.40–2.4 m CSF-A; (2) a hiatus at ~290 m CSF-A is indicated by the co-occurrence of several biostratigraphic events at within the same stratigraphic interval. This unconformity may be associated with a prominent turbidite bed at U1447-A-36F-1, 40 cm, close to the Pliocene–Pleistocene transition; (3) a similar possible hiatus is indicated by a cluster of biostratigraphic events at 340 m CSF-A within the early to late Pliocene transition; (4) a third possible hiatus is located at 470 m CSF-A within the Miocene to Pliocene transition. The sedimentary succession in this interval shows a distinct unconformity at the base of a distinct black layer at interval U1447A-60X-4, 70–73 cm.

These unconformities may be related to distinct regional tectonic events and further investigation of their stratigraphic and regional extent will provide new inside into the Miocene–Recent tectonic evolution of the Andaman accretionary wedge complex.

The expanded stratigraphic section at Site U1447 provides a first high resolution record of middle–late Miocene Indian Monsoon variability in the Bay of Bengal. Shipboard investigations provided the first evidence for a link between monsoonal intensity and biosiliceous paleoproductivity patterns in the Andaman Sea over the last 9.8 Ma. All Pleistocene and most of the Pliocene sediments of Site 1447 are virtually barren of diatoms, which exhibit last common occurrences below the Miocene/Pliocene boundary. This temporal distribution pattern is distinctly different from the late Miocene–early Pliocene “biogenic bloom” observed throughout the open tropical Indo-Pacific and Atlantic Oceans. The maximum in diatom abundance in the Andaman area (roughly between 9.8 and 6.5 Ma at Site U1447) together with an increase in authigenic pyrite and carbonate started earlier and lasted shorter than the open ocean “biogenic bloom.” These peculiar productivity changes within the Bay of Bengal could either reflect the availability of nutrients brought into the Bay of Bengal by rivers under a variable monsoonal intensity since the middle Miocene or be related to the presence or absence of a seasonal freshwater lid, that would prevent upwelling of nutrient-rich intermediate waters during the monsoon season.