IODP Expedition 363: Western Pacific Warm Pool

Site U1483 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1483 is located on the northwest Australian margin at 13°5.24′S, 121°48.25′E, and 1733 m below sea level (mbsl). The site is situated on seismic Line BR98-117, 1300 m northeast of the intersection with seismic Line BR98-168 and ~0.8 nmi southeast of the ~40 m long piston Core MD01-2378, which provides insights into late Pleistocene sedimentation and stratigraphy at this location (e.g., Holbourn et al., 2005; Kuhnt et al., 2015). The interpretation of Miocene seismic reflectors is based on comparison to the Australian Geological Survey Organisation (AGSO) regional seismic survey Line 119-04 (well control by Buffon 1 and Brewster 1A) and the BBHR Line 175/10 (well control of distal part by Argus 1). A major unconformity marks the top of the prograding sequence at 0.72 s two-way traveltime (TWT) below seafloor and is interpreted as the middle Miocene sequence boundary corresponding to a major sea level drop associated with rapid expansion of the Antarctic Ice Sheet (Mi-3; 13.8 Ma).

Site U1483 is situated on the Scott Plateau at the northwestern margin of northeast-trending Browse Basin, which underlies the Australian northwest margin between the onshore Kimberley Basin and the Scott Plateau (Symonds et al., 1994). This region, which is adjacent to some of the oldest ocean crust still in the world's ocean (Argo Abyssal Plain), has remained a stable passive margin since the breakup of Gondwanaland and the separation of northwest Australia from a Tethyan landmass (Gradstein et al., 1992). The Mesozoic section beneath the Scott Plateau is strongly influenced by breakup-related tectonism and forms the acoustic basement through much of the Scott Plateau area (Stagg and Exon, 1981). The postbreakup sedimentary succession forms a ~2000 m thick, relatively uniform blanket over the Scott Plateau and the northeastern margin of Browse Basin. Site U1483 is located south of the Sunda Arc, where ongoing collision between Australia and the Eurasia/Pacific Arc system has occurred since the Miocene (Keep et al., 2007; Hall, 2012). However, intense Neogene faulting is mainly observed in the southernmost parts of the Browse Basin (Barcoo Sub-basin), whereas the northern parts are relatively devoid of intense Neogene deformation (Keep et al., 2007).

Site U1483 is located ~142 mi northeast of Site U1482. Both sites are within the hydrographic transition that separates the warm tropical water of the Indo-Pacific Warm Pool (IPWP) from subtropical water masses. Jointly, the two sites are suitable to monitor changes in the southward extent of tropical warm water related either to circulation or global climate trends. Both sites are close to the oceanographic front between relatively cool, nutrient-rich water carried northward in the Eastern Indian Ocean by the West Australian Current and warm, oligotrophic Leeuwin Current waters, which results in a steep north–south sea-surface temperature (SST) gradient.

The sedimentation rate at Site U1483 is about twice the rate at Site U1482, which will allow for the reconstruction of late Pliocene to recent paleoceanography in greater resolution than at Site U1482. Combined, the two sites will allow reconstruction of the southwestern extent of the IPWP since the early late Miocene. Furthermore, the sites are located along the route of the Indonesian Throughflow (ITF) as it exits into the Indian Ocean through the Timor Strait between NW Australia and Java. The Timor Strait is one of the three main exits of the ITF to the eastern Indian Ocean (Gordon, 2005). Thus, Sites U1482 and U1483 are ideally located to monitor changes in the intensity and thermal structure of ITF water masses entering the eastern Indian Ocean (e.g., Xu et al., 2008).

Operations

After a 142 nmi transit from Site U1482, the vessel stabilized over Site U1483 at 0630 h (all times are local ship time; UTC + 8 h) on 26 October. We cored three holes at Site U1483 (proposed Site WP-11B). The original operations plan called for coring to advanced piston corer (APC) refusal (estimated at 250 m below seafloor [mbsf]), followed by two additional holes deepened to 350 mbsf using the extended core barrel (XCB) coring system. Instead, we cored three holes using the APC to <300 mbsf.

Hole U1483A was cored with APC coring using orientation and nonmagnetic hardware to 293.3 mbsf (Cores 1H through 31H), where a partial stroke indicated APC refusal. Downhole temperature measurements using the Advanced Piston Corer Temperature Tool (APCT-3) were taken on Cores 4H (37.1 mbsf), 7H (65.6 mbsf), 10H (94.1 mbsf), and 13H (122.6 mbsf), obtaining reliable results on three of the four deployments. A total of 308.58 m of sediment was recovered over 293.3 m of coring (105% recovery) in Hole U1483A.

Hole U1483B was then cored with the APC coring system using orientation and nonmagnetic hardware to 287.0 mbsf (Cores U1483B-1H through 31H). A total of 301.62 m of sediment was collected over this interval (105% recovery). Oriented APC coring with nonmagnetic hardware continued in Hole U1483C and reached 284.8 mbsf (Cores U1483C-1H through 31H). One drilled interval (3 m) advanced the hole without coring to avoid alignment of core gaps for stratigraphic correlation. A total of 292.42 m of core was recovered over 281.8 m of coring (104% recovery). Operations at Site U1483 ended at 0800 h on 30 October 2016. Total time spent on the site was 97.5 h (4.1 d).

A total of 92 APC cores were recovered at this site, collecting 902.62 m of sediment over 862.1 m of penetration (105% recovery).

Principal Results

The sediment cored at Site U1483 is assigned to a single lithologic unit composed of ~293 m of lower Pliocene to recent nannofossil ooze with variable amounts of clay, foraminifers, and siliceous microfossils (primarily diatoms and radiolarians). Tephra layers occur sporadically throughout the unit. Lithologic Unit I is divided into three subunits. Subunit IA is a ~56 m sequence of middle Pleistocene to recent greenish gray clay-bearing and clay-rich nannofossil ooze. Sponge spicules and mollusk shell fragments are common throughout this subunit, whereas pteropods are restricted to the upper 40 mbsf. Alternations between dark greenish gray and light greenish gray sediment at multiple-meter scale are apparent and also recorded in the natural gamma radiation (NGR) and L* records. The boundary between Subunits IA and IB is defined by the first downcore appearance of brownish gray diatom-rich nannofossil ooze. Subunit IB (lower to middle Pleistocene) is a ~130 m thick sequence of greenish gray clay-rich nannofossil ooze, diatom-rich nannofossil clay, and clay-rich diatom-nannofossil ooze. This subunit is distinguished by higher biosiliceous content than in Subunit IA. Clay content increases towards the bottom of Subunit IB. Color alternations are at the section scale (~1.5 m), which is more frequent than in Subunit IA. The darker colored intervals have higher siliceous microfossil and organic matter content than the lighter colored intervals. Shell fragments are also common throughout this subunit. The boundary between Subunits IB and IC is denoted by a significant reduction in the abundance of siliceous microfossils. Subunit IC is composed of ~105 m of greenish gray foraminifer-rich nannofossil clay. There are two significant intervals of soft-sediment deformation in this subunit. The upper unit is ~24 m thick, whereas the lower unit has varying thicknesses among the holes. These intervals include inclined bedding, folding, and microfaulting. Dark gray clay layers that exhibit high bulk density also occur in the deformed intervals.

The 293 m succession recovered at Site U1483 contains abundant, diverse, tropical calcareous nannofossil and planktonic foraminifer assemblages. Planktonic foraminifers dominate the >63 μm size; however, other microfossil groups are also present and include benthic foraminifers, radiolarians, silicoflagellates, and occasionally ostracodes. The planktonic to benthic foraminifer ratios are typically 99:1. Preservation is generally excellent to very good throughout the entire succession, although a minor decrease in preservation is noted with depth.

Integrated calcareous nannofossil and planktonic foraminifer biostratigraphy, together with magnetostratigraphy, indicate that the succession at Site U1483 spans the late early Pliocene to the recent. Calcareous nannofossil and planktonic foraminifer biohorizons are generally in good agreement. The age at the bottom of the recovered succession is >3.59 Ma based on the presence of *Sphaeroidinella seminulina*. Biostratigraphy in the lowermost part of the recovered section (~293–260 mbsf) suggests sedimentation rates of ~10 cm/ky during the late early Pliocene. The interval between ~260 and 193.5 mbsf includes two intervals of disturbed sediment. A clustering of biohorizons around 260–243 mbsf coincides with the deeper disturbed interval. It is overlain by what appears to be intact stratigraphy, with another interval of clustered biohorizons from

~200–193 mbsf. Based on the mixed fossil assemblages found in the two intervals, these could represent the top and base of a single, large mass movement dated to ~2.1 Ma, or two (or more) discrete events dated to ~2.8 and 2.1 Ma. Above the disturbed interval, sedimentation rates appear essentially continuous at ~10 cm/ky from 2 Ma to present.

Paleomagnetic investigations at Site U1483 included measurement of the natural remanent magnetization (NRM) of archive halves from all holes before and after demagnetization in a peak alternating field (AF) of 15 mT to remove the vertical overprint induced by the drill string. Sixty-two discrete samples were also taken to investigate paleomagnetic carriers and rock magnetic properties. NRM_{15mT} intensity is higher (~10^{-4} Am^{-1}) in the upper ~75 mbsf of each hole, decreases between 75–85 mbsf, remains low (~10^{-5} Am^{-1}) and variable below ~85 mbsf, and occasionally approaches the measurement noise level of the magnetometer. Decreases in NRM intensity below ~75 mbsf and reductions in the NRM_{15mT}/NRM intensity ratio are coeval with a decrease in interstitial water sulfate to almost zero and peak methane concentrations indicating that sediment diagenesis is likely influencing the magnetic material below ~75 mbsf. However, in contrast to Site U1482, proxies for ferrimagnetic concentration (magnetic susceptibility [MS], isothermal remanent magnetization $[IRM]_{1000mT}$), mineralogy (IRM_{300mT}/IRM_{1000mT}), and magnetic grain size (anhysteretic remanent magnetization [ARM]/saturation remanent magnetization [SIRM]) remain relatively stable downcore at Site U1483. As a result, the NRM is more likely to result from (post-) depositional remanent magnetization (pDRM) acquisition and can potentially be used to understand and reconstruct paleogeomagnetic field behavior. For Holes U1483A and U1483B, azimuthally corrected declination is internally consistent between adjacent cores, although it maintains an ~180° baseline offset in absolute values as declination should cluster around 0° during normal polarity. This phenomenon appears to have self-corrected in Hole U1483C as negative inclination (expected for normal polarity in this southern hemisphere location) in the upper part of Hole U1483C is associated with declinations that cluster around 0°/360°. Although the absolute declination values improved, between-core alignment was reduced in Hole U1483C.

The remanent magnetization of sediments is interpreted for the intervals not affected by soft-sediment deformation. The Brunhes/Matuyama boundary (0.781 Ma) is identified at ~80 mbsf. Below this we observe the upper (~93 mbsf; 0.988 Ma) and lower (~100 mbsf; 1.072 Ma) boundaries of the Jaramillo normal and the upper (~170 mbsf; 1.778 Ma) and lower (~186 mbsf; 1.945 Ma) boundaries of the Olduvai normal, with the lower Olduvai occurring a few meters above the upper interval of soft-sediment deformation. These reversal horizons are in excellent agreement with both the calcareous nannofossil and planktonic foraminifer biohorizons. In sediments between the two deformed intervals in all holes, we observe a transition from reversed polarity to normal polarity in both inclination and declination during a period of relatively high NRM_{15mT} intensity (~10^{-4} Am^{-1}) and MS. We tentatively interpret this horizon as the Matuyama/Gauss boundary based on biostratigraphic constraints that suggest that the uppermost deformed interval is between 2.1 to 2.6 Ma.

The physical property data collected for Site U1483 includes *P*-wave velocity, gamma ray attenuation (GRA) bulk density, MS, NGR, and thermal conductivity on whole-round cores from all holes and additional measurements on split cores and discrete samples including *P*-wave velocity, porosity, and bulk, dry, and grain densities. Despite the relatively homogeneous lithology at Site U1483, physical property parameters display long-term trends as well as high-resolution variability throughout the recovered succession. Thermal conductivity, GRA bulk density, moisture and density (MAD) dry and bulk density, and porosity are all dominated by a long-term trend of increasing compaction with depth. Subtle changes in GRA bulk density underlying the compaction trend generally correspond with the lithologic subunits and are likely related to changes in clay content. Strong peaks in magnetic susceptibility are found coeval with the occurrence of some of the tephra layers in multiple holes. Otherwise, MS and NGR are relatively stable throughout the record, unlike at Site U1482, where broad-scale trends were observed. The two intervals of observed soft-sediment deformation are coincident with elevated GRA and MAD bulk densities observed from ~195–218 mbsf and ~243–253 mbsf.

Tie points between holes at Site U1483 were established mainly with Whole-Round Multisensor Logger (WRMSL) MS data, although some were based primarily on L* data. In addition, we used WRMSL GRA bulk density data and NGR data to aid correlations. We constructed two spliced intervals, one from 0 to 211.5 m core composite depth below seafloor (CCSF) and the other from 239.8 to 266.8 m CCSF. We did not construct splices over the two intervals of soft-sediment deformation (211.5–239.8 m CCSF and below 266.8 m CCSF), as the WRMSL GRA bulk density and MS data variations indicate that there is not stratigraphic continuity between holes over these intervals. However, we did estimate offsets for the cores within the deformed intervals because there were some features that could be correlated between holes.

A total of 35 interstitial water (IW) samples were collected from Hole U1483A from the seafloor to 283.3 mbsf. The IW geochemical profiles provide an integrated record of early diagenetic processes related to organic matter degradation within the sediment, with downcore total organic carbon contents ranging from 0.4 to 1.4 wt%. The oxic/suboxic transition at Site U1483 occurs at ~7.5 mbsf, as indicated by a rapid increase in dissolved Mn^{2+} concentrations. The sulfate-methane transition zone (SMTZ) is encountered at ~50 mbsf, characterized by quantitative consumption of dissolved sulfate, an increase of pH (from 7.7 to 8.4), and substantial release of alkalinity (up to 18 mM) and phosphate (25 μM) into the surrounding IW. Dissolved Ca^{2+} decreases to 4 mM at the SMTZ, suggesting active carbonate precipitation. The evolution of Mg/Ca and Sr/Ca ratios suggests that calcite (and not high-Mg calcite and/or dolomite) is most likely the dominant authigenic phase at the SMTZ. In addition, the rapid increase in the Ba profile at the SMTZ below 45 mbsf also indicates rapid dissolution of barite at the SMTZ. In the methanogenic zone below 50 mbsf, methane concentrations increase up to about 100,000 ppmv at 140 mbsf, and then decrease to about 11,200 ppmv down to the bottom of Hole U1483A. High methane/ethane ratios suggest that the methane is mostly of biogenic origin.

Downhole potassium, magnesium, lithium, chloride, and sodium concentrations reflect a combination of clay mineral authigenesis or alteration and IW diffusion. In particular, the increasing trends in Cl^- and Na^+ IW profiles possibly reflect an upward diffusive signal from deeper and more saline fluids. Another interesting feature at Site U1483 is the IW profiles for Si, Ca^{2+}, NH^+, alkalinity, and, to a lesser extent, Li below ~250 mbsf. These IW profiles show perturbations associated with the occurrence of the soft-sediment deformation above 250 mbsf, which could reflect differences related to changing porosity and/or early diagenetic reactions taking place within and outside of these deformed deposits. Calcium carbonate ($CaCO_3$) content ranges between 38 and 78 wt% (average 59 wt%), showing a general increasing trend downcore in lithologic Subunits IA and IB. Dissolved silicon concentrations are also elevated relative to Site U1482, and the presence of diatoms and radiolarians indicates the importance of biogenic silica at this site.

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