IODP Expedition 363: Western Pacific Warm Pool

Site U1486 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1486 (WP-05A) is located ~215 km west–southwest of Manus Island at 2°22.34′S, 144°36.08′E in 1332 m of water. The site is situated at the intersection of seismic reflection profiles GeoB13-084 and GeoB13-088. The seismic profile shows a continuous succession of hemipelagic sediment with acoustic basement estimated at ~225 m below seafloor (mbsf). This site was targeted to recover a complete Pleistocene record with unprecedented resolution for the Western Pacific Warm Pool (WPWP).

The tectonic setting of Sites U1486 and U1487 (as for that of the northern Papua New Guinea (PNG) Sites U1484 and U1485) was shaped by the oblique northward movement of the Australian plate as it rapidly converged with the Pacific plate. This collision resulted in a complex plate boundary zone that includes volcanic arcs, but also resulted in the formation and rotation of microplates within this zone, as well as lithospheric rupture that formed small oceanic basins (Baldwin et al., 2012). The Bismarck Sea, on the northeastern side of PNG, forms a back-arc basin with respect to the New Britain arc and is divided into the North Bismarck (NBS) and South Bismarck (SBS) microplates, separated by the active Bismarck Sea left-lateral transform fault and spreading segments (Taylor, 1979). Site U1486 is located on the North Bismarck microplate. To the north, the NBS microplate is bordered by the Manus Trench, which defines the boundary between it and the Pacific plate. Within this complex tectonic regime, the southwestern side of the Manus Basin is considered one of the more stable regions. Magnetic anomalies in the Bismarck Sea indicate rapid asymmetric spreading since 3.5 Ma (Taylor, 1979). The continuous collision between the Australian and Pacific plates caused the SBS microplate to rotate rapidly clockwise (~9°/My), whereas the NBS microplate is rotating slowly anticlockwise (0.3°–1.25°/My) (Baldwin et al., 2012). Asymmetric rotation of the North and South Bismarck Basins likely changed the position of New Britain and adjacent islands relative to PNG. Ocean Drilling Program (ODP) Leg 193 focused on the eastern part of the Manus Basin, exploring the tectonic, volcanic, and seafloor hydrothermal system activity in this convergent plate margin setting.

An isotope record from piston Core MD05-2920 located near Site U1486 indicates a sedimentation rate of ~10 cm/ky, substantially higher than that found in other open ocean Pacific sites, with no discernible disturbance for the past ~400 ky (Tachikawa et al., 2011; 2013). The abundant $CaCO_3$ content (25–45 wt%) and well-preserved foraminifer tests suggest the potential to generate a suborbitally resolved paleoceanographic record of unprecedented quality through the Pleistocene. X-ray fluorescence scanning of core MD05-2920 demonstrates that centennial precipitation variability can be resolved from the elemental content of the sediment (Tachikawa et al., 2011).

This site was targeted because of its potential to provide an excellent Pleistocene paleoceanographic record to examine orbital-scale climate variability at high resolution through the Pleistocene. It is also ideally located to monitor the contribution from the New Guinea Coastal Current and Undercurrent, which is the southern branch of the westward, cross-equatorial flowing South Equatorial Current, and constitutes the main southern Pacific contribution to the Indonesian Throughflow. At a water depth of ~1300 mbsl, the sediment is bathed by Upper Circumpolar Deepwater originating from the Southern Ocean, and thus will allow for the reconstruction of past variability of this water mass.

Operations

After a 117 nmi transit from Site U1485, the vessel stabilized over Site U1486 at 0921 h (all times are local ship time; UTC + 10 h) on 14 November 2016. The original operations plan included three holes using the advanced piston corer (APC) to 200 mbsf. We ultimately cored four holes. Hole U1486A consisted of a single full core and was terminated since it did not recover the mudline. Holes U1486B and U1486C were cored to 211.2 and 201.3 m below seafloor (mbsf), respectively. Hole U1486D was cored to 186.5 mbsf to fill coring gaps and intervals where significant numbers of interstitial water (IW) samples were taken from Hole U1486B for construction of the composite section.

Hole U1486A was cored to 9.5 mbsf with the APC coring system using orientation and nonmagnetic hardware. When Core 363-U1486A-1H retrieved a full core liner, indicating that we missed the mudline, we terminated coring in this hole. A total of 9.95 m of sediment was recovered over 9.5 m of coring (105% recovery) in Hole U1486A.

Hole U1486B was cored to 211.2 mbsf (Cores 363-U1486B-1H through 23H) using the APC coring system with orientation and nonmagnetic hardware. Downhole formation temperature measurements using the Advanced Piston Corer Temperature Tool (APCT-3) were taken on Cores 4H (34.5 mbsf), 7H (63.0 mbsf), 10H (91.5 mbsf), and 13H (120.0 mbsf), obtaining good results on all four deployments. Core 23H seemed to be a full stroke; however, only 5.67 m of core was recovered. When drilling out the “rathole,” drilling stalled at 211.2 mbsf, indicating something hard at that depth that the core barrel had been unable to penetrate. Given that the acoustic basement at Site U1486 was estimated at ~225 mbsf, we speculate that we encountered the acoustic basement at a somewhat shallower depth. The presence of a few small basalt fragments in the core catcher of Core 23H supports this interpretation. We collected 215.49 m of sediment over 211.2 m of coring (102% recovery) in Hole U1486B.

Hole U1486C was cored to 201.3 mbsf (Cores 363-U1486C-1H through 23H) using the APC with orientation and nonmagnetic hardware. We decided to terminate coring above the hard layer encountered in Hole U1486B. Two drilled intervals (each 2 m) were used to advance the hole without recovery for stratigraphic correlation and one core (Core 11H) did not recover any material. We collected 172.70 m of sediment over 197.3 m of coring (88% recovery) in Hole U1486C.

Hole U1486D was cored to 186.5 mbsf in order to fill gaps in the composite section. Continuous coring penetrated to 153.2 mbsf (Cores 363-U1486-1H through 16H) with the APC using orientation and nonmagnetic hardware. We then drilled ahead without coring to 177 mbsf (23.8 m advance) to shoot Core 19H to capture a paleomagnetic reversal, which was recovered in Hole U1486B but had fallen within a core gap in Hole U1486C. We collected 166.53 m of core over 162.7 m of coring (102% recovery) in Hole U1486D. Operations at Site U1486 ended at 1015 h on 17 November. Total time spent at Site U1486 was 73.0 h (3.0 d).

A total of 63 APC cores were recovered at this site, collecting 564.67 m of sediment over 580.7 m of coring (97% recovery).

Principal Results

Sediments at Site U1486 are composed of ~211 m of upper Pliocene to recent volcanogenic sediments, biogenic sediments, and authigenic minerals overlying presumed oceanic crust, which was not cored. The relative abundance of the volcanogenic and biogenic components varies significantly downhole. We assign the recovered succession to one lithologic unit (Unit I), which is divided into three subunits. Subunit IA is an ~57 m sequence of mid-Pleistocene to recent mainly greenish gray biogenic sediments (predominantly foraminifer-rich nannofossil ooze) with clay minerals and rare ash layers. Biosilica is also present, usually in trace amounts, and consists of radiolarians, diatoms, and silicoflagellates. Pteropod tests are also found in the uppermost part of this subunit. The base of the subunit is placed at the first downhole black tephra layer. Subunit IB (~85 m thick) consists mainly of lower Pleistocene biogenic (predominantly nannofossil) sediments mixed with volcanogenic materials, which occur both as dispersed particles and distinct layers (tephra) and clay minerals. Foraminifers are present in varying abundances, as are radiolarians and diatoms, although they always constitute <10% of particles. This subunit is distinctly darker than Subunit IA due to larger proportions of volcanogenic sediment. The dominant lithologies are greenish gray foraminifer-rich nannofossil clay to dark greenish gray ash-rich nannofossil clay. Tephra layers are more abundant in Subunit IB and are typically felsic in composition. Pumice fragments are also present. The base of Subunit IB is defined at a prominent black volcanic ash layer that is marked by an increase in magnetic susceptibility; below this layer the sediments are distinctly darker in color. Subunit IC (~70 m thick; late Pliocene to early Pleistocene) is dominated by the volcanogenic component (ash), which occurs as discrete laminae and layers ranging from a few centimeters to >50 cm thick. These layers show a variety of depositional styles and occur both interbedded and mixed with the biogenic and lithogenic sediments (primarily foraminifer-rich nannofossil clay). The volcanogenic sediments in Subunit IC are more mafic in composition and include brown-colored volcanic glass and scoria fragments. The bottom ~4 m of Subunit IC are permeated by authigenic zeolites of probable hydrothermal origin. Centimeter-size fragments of basalt with olivine and pyroxene phenocrysts are also found in the bottom part of Subunit IC.

The sediment succession at Site U1486 contains planktonic foraminifers, benthic foraminifers, and calcareous nannofossils that are generally excellently preserved, although some foraminifers are fragmented or show evidence of cementation or incipient recrystallization. There is no obvious change in preservation state with depth; instead, foraminifers in layers with higher proportions of volcanogenic material appear slightly better preserved than those in the biogenic sediments. The benthic foraminifer assemblage is indicative of upper bathyal depths throughout the succession, with planktonic/benthic ratios around 99:1. *Planulina wuellerstorfi* is present in most core catcher samples. The significant amount of volcanic ash in the sediments below ~130 mbsf does not significantly affect the composition of the foraminifer and calcareous nannofossil assemblages.

Calcareous nannofossil and planktonic foraminifer biohorizons, together with magnetostratigraphic horizons, show good agreement. The base of the sedimentary sequence is assigned a late Pliocene age between 2.49 and 3.33 Ma, constrained by the presence of *Discoaster surculus* (biohorizon top 2.49 Ma) and *Gobigerinoidesella fistulosa* (biohorizon base 3.33 Ma) in the absence of *Globorotalia truncatulinoides* (biohorizon base 2.47 Ma). In the latest Pliocene and earliest Pleistocene, sedimentation rates were high, ~14 cm/ky. Extrapolation of these sedimentation rates yields an age of 2.7 Ma for the base of the recovered succession, which is consistent with the age range based on biohorizons. Sedimentation rates declined markedly through the middle to late Pleistocene to a long-term average of ~6 cm/ky. Based on these linear sedimentation rates, the Pliocene/Pleistocene boundary (2.58 Ma) is placed at ~183 mbsf, just below the base of Chron C2r.2r (2.581 Ma).

Paleomagnetic investigations at Site U1486 involved 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. We took two to three discrete samples per core from Hole U1486B (n = 49) to characterize the NRM demagnetization behavior and to investigate the rock magnetic properties of the sediment. Discrete magnetic susceptibility, Isothermal Remnant Magnetization (IRM), and IRM ratios indicate relatively high ferrimagnetic mineral concentrations in the upper ~62 mbsf, greater influence of higher coercivity minerals between ~62 and 204 mbsf, and strongly ferrimagnetic phases in the bottom of the hole. Coarser magnetic grain sizes and higher magnetic concentrations in Subunit IC likely reflect the increased occurrence of mafic-rich volcanogenic sediment, with the highest magnetic concentrations associated with primary and altered basaltic fragments found at the bottom of the hole.

The Icefield MI5 orientation tool was deployed with nonmagnetic hardware for all cores, which permitted azimuthal correction of declination. Corrected declination is largely coherent between cores; however, absolute values in all holes cluster around 180° for normal polarity and 0° for reversed polarity, suggesting that the issues of the baseline offset experienced at the majority of sites during Expedition 363 affected these measurements. Across all three holes we observe eight coeval and distinct ~180° changes in declination. The Brunhes/Matuyama boundary (0.781 Ma) is identified at a depth of ~47 mbsf. Below this we observe the upper (~55 mbsf, 0.988 Ma) and lower (~60 mbsf, 1.072 Ma) boundaries of the Jaramillo normal (C1r.1n), the upper (~66,5 mbsf, 1.173 Ma) and lower (~68.5 mbsf, 1.185 Ma) boundaries of the Cobb Mountain subchron (C1r.2n), and the upper (~102 mbsf, 1.778 Ma) and lower (~113 mbsf, 1.945 Ma) boundaries of the Olduvai normal (C2n). The Gauss-Matuyama boundary (2.581 Ma) is found at ~182 mbsf. Continued normal polarity below this depth in all three holes implies that the recovered sediment is <3.032 Ma, as we do not observe the upper boundary of the Kaena reversed subchron (C2An.1n). These reversal horizons and estimated sedimentation rates are in excellent agreement with both the calcareous nannofossil and planktonic foraminifer datums.

Physical property data collected for Site U1486, in particular MS, show variations that correlate well with the three lithologic subunits defined for the site. MS values are very low in the upper 57 mbsf (~20–50 × 10^{-5} SI), corresponding to lithologic Subunit IA that consists primarily of biogenic sediment (foraminifers and nannofossils) mixed with clay and rare tephra layers. Over the same interval, gamma ray attenuation (GRA) bulk density values increase from 1.4 to 1.6 g/cm^3, although variance remains quite low. Between 57 and 140 mbsf (Subunit IB), average MS values increase to ~75–100 × 10^{-5} SI, with frequent peaks reaching 200–400 × 10^{-5} SI. Within this interval, distinct peaks in MS, GRA bulk density, and *P*-wave velocity are coincident with darker, volcanogenic-rich layers, superimposed on a background of nannofossil ooze with varying proportions of foraminifers and clay. GRA bulk density values increase to 1.6 g/cm^3 in Subunit IB. Below 140 mbsf (Subunit IC), MS average values increase (~200 × 10^{-5} SI) and distinct peaks in MS, GRA bulk density, and *P*-wave velocity occur more frequently, reflecting the dominance of volcanogenic material in the deepest part of the succession. GRA bulk density reaches 1.8 g/cm^3 by 200 mbsf, before decreasing to 1.7 g/cm^3 in the deepest part of Hole U1486B. Unusually high *P*-wave velocities above 1800 m/s are also found in this interval. These high velocities coincide with the appearance of indurated sediment that contains cemented zeolite precipitates and other minerals associated with the alteration of volcanic glass by hydrothermal fluids, suggesting hydrothermal alteration likely due to close proximity to the basaltic basement. Natural gamma radiation (NGR) decreases linearly downhole, with initial values of ~20 counts/s, decreasing to 8 counts/s at the bottom of the sedimentary sequence.

We constructed a continuous splice for Site U1486 from 0 to 222.59 m core composite depth below seafloor (CCSF) using three holes (U1486B, U1486C, and U1486D). Tie points were established mainly using Whole-Round Multisensor Logger (WRMSL) MS data, aided occasionally by NGR. Since Hole U1486B was heavily sampled for interstitial water (IW) measurements (one 5–10 cm whole-round sample per section), we avoided using material from this hole for the splice from 0 to 150 mbsf, although this was unavoidable over a few intervals with poor recovery. The deepest core collected at Site U1486, which contains basalt fragments and is presumed to be within meters of volcanic basement, was appended to the end of the splice.

Site U1486 was sampled at high resolution (one 5–10 cm whole-round sample per section down to 150 mbsf) for IW geochemistry. A total of 106 whole-round samples were taken from Hole U1486B. Of these, 39 IW samples and one mudline sample were processed for all standard shipboard analyses. The IW profiles reflect the variable sedimentation and tectonic evolution of the site over the past several million years. In the upper 60 mbsf, IW geochemistry profiles are dominated by moderate changes in alkalinity, sulfate, phosphate, ammonium, and bromine that reflect a modest degree of organic matter remineralization. The minimum sulfate concentration observed in Hole U1486B is ~19 mM and methane is low (<4 ppm), which is consistent with the amounts of total organic carbon (TOC) content present at the site (average 0.5 wt%). The $CaCO_3$ content is highly variable, ranging from to 0.3 to 75.4 wt%, with an average of 40.5 wt%. Overall, $CaCO_3$ content is higher in the upper 138 mbsf. Extremely low $CaCO_3$ content is found in ash and silt samples.

Below 60 msbf, the IW profiles show largely linear gradients toward the base of the hole that demonstrate the influence of upward diffusion on the IW profiles. Superimposed on these linear gradients is smaller scale variability, particularly noticeable in K^+, B, Na^+, pH, Cl^-, and Fe, which can be explained by the interaction of IW with reactive volcanogenic sediments/minerals and clay mineral alteration. The inverse relationship between calcium (increasing with depth) and magnesium (decreasing with depth) is a common feature of sites that have been drilled to oceanic basement. The increase in Ca^{2+} is attributed to submarine weathering of basal sediments and basalt, whereas formation of authigenic clays near the basement can serve as a sink for Mg^{2+}. Marked changes in chlorinity, manganese, and iron occur below 170 mbsf. Together with the overall increase in IW sulfate between the base of the hole at ~211 mbsf and 60 mbsf, these profiles suggest communication not only between IW and basement rock and sediments, but also with crustal fluids.

References

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