IODP Expedition 363: Western Pacific Warm Pool

Site U1488 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1488 is located on top of the southern part of the Eauripik Rise at 2°2.59′N, 141°45.29′E, in 2604 m water depth. The site is situated on seismic reflection profile RR1313 WP3-1, ~4.4 km southwest of the intersection with seismic reflection profile RR1313 WP3-3. The seismic profile shows a continuous succession of hemipelagic, carbonate-rich sediments with basement at >650 m below seafloor (mbsf). Site U1488 is located ~28 km northwest of Deep Sea Drilling Project (DSDP) Site 62 and close to the location of Core MD97-2140 used to reconstruct the Pleistocene sea-surface temperature (SST) history of the Western Pacific Warm Pool (WPWP) (de Garidel-Thoron et al., 2005). DSDP Leg 7 recovered a nearly continuous sequence of upper Oligocene to Quaternary chalks and carbonate-rich oozes from Site 62 (Winterer et al., 1971). However, recovery was relatively poor and the sediment frequently disturbed due to the use of the rotary core barrel (RCB) system.

Site U1488 is situated on the Eauripik Rise, within the Caroline Basin north of Papua New Guinea. The roughly N–S trending Eauripik Rise is a wide aseismic ridge (~1000 m elevation above the surrounding seafloor) that separates the East and West Caroline Basins of the Caroline microplate. It was formed by a series of NE-trending spreading centers and represents the youngest spreading of the Caroline microplate (Hamilton et al., 1979). The extinct spreading center is characterized by a broad crest at ~2500 m water depth with gently sloping sides. Marine magnetic anomalies C13–C9 trend roughly E–W and indicate seafloor spreading from 36 to 27 Ma. The anomalies are asymmetrically arranged about relict spreading centers now called the Kiilsgaard and West Caroline Basin Troughs. Seismic refractions show thickened ocean crust beneath the Eauripik Rise, and a small free air anomaly and positive geoid anomaly indicate a compensated structure reaching deep into the mantle (Hegarty and Weissel, 1988). Although there are no discernible magnetic lineations on the Eauripik Rise, these data and the recovery of tholeiitic basalt at DSDP Site 62 (Winterer et al., 1971) make it difficult to argue that it is a remnant of ancient continental material. The igneous rocks recovered from the bottom of DSDP Site 62 were slightly vesicular, highly altered, and contained calcite veins with well-preserved foraminifers and nannofossils. The dolomitization of overlying limestone suggests that these basalts intruded into marine chalk leading to extensive diagenetic reactions near the base of the sedimentary succession.

Site U1488 is located ~2° north of the equator and is thus suitable for reconstructing the hydrographic history of the WPWP. The comparatively low sedimentation rate at this site will be used along with the record of Site U1490 to reconstruct the evolution of the WPWP since the late Miocene. At a depth of 2600 m below sea level (mbsl) the site is bathed by modified Upper Circumpolar Deepwater and hence will be useful to monitor past changes in this water mass.

High-resolution interstitial water sampling at this site will be used for geochemical reconstructions of the deep Pacific water mass ($\delta^{18}O$, salinity, and seawater chemistry) during the Last Glacial Maximum (LGM).

Operations

After a 333 nmi transit from Site U1487, the vessel stabilized over Site U1488 (WP-03A) at 0400 h (all times are local ship time; UTC + 10 h) on 20 November 2016. The original operations plan called for three holes: the first to advanced piston corer (APC) refusal, estimated at 250 mbsf, followed by two holes to 300 mbsf using both the APC and extended core barrel (XCB) coring systems. We ultimately cored three holes using only the APC and half-length advanced piston corer (HLAPC), with the deepest penetrating to ~315 mbsf.

Hole U1488A was cored with the APC coring system using orientation and nonmagnetic hardware to 300.4 mbsf (Cores 363-U1488A-1H through 32H). Downhole formation temperature measurements using the Advanced Piston Corer Temperature Tool (APCT-3) were taken on Cores 4H (34.4 mbsf), 7H (62.9 mbsf), 10H (91.4 mbsf), and 13H (119.9 mbsf), obtaining good results on all four deployments. We also collected high-resolution interstitial water (IW) samples at a frequency of one 5 to 10 cm whole-round sample per section over the upper 150 mbsf of Hole U1488A. After Cores 31H and 32H had excessive overpull and required drillovers to extract them from the formation, we switched to the HLAPC and continued coring to 314.5 mbsf (Cores 33F through 35F). Since Cores 33F and 35F required drillovers, indicating HLAPC refusal, we terminated coring. We collected 327.20 m of sediment over 314.5 m of coring (104% recovery) in Hole U1488A.

Hole U1488B was cored to 304.9 mbsf (Cores 363-U1488A-1H through 33H) with the APC using orientation and nonmagnetic hardware. Cores 31H through 33H required drillovers, indicating APC refusal, so we terminated coring. We collected 315.77 m of core over 304.9 m of coring (104% recovery) in Hole U1488B.

Hole U1488C was cored to recover material for the stratigraphic splice over the upper 150 mbsf, since high-resolution IW sampling was conducted in Hole U1488A over this interval. APC coring using orientation and nonmagnetic hardware proceeded to 159.3 mbsf (Cores 363-U1488C-1H through 17H), where we terminated coring.

Operations at Site U1488 ended at 1030 h on 24 November 2016. Total time spent at Site U1488 was 102.5 h (4.3 d). A total of 82 APC cores were recovered at this site, collecting 781.74 m of sediment over 764.6 m of coring (102% recovery). We also collected 3 HLAPC cores, retrieving 14.83 m of sediment over 14.1 m of coring (105% recovery).

Principal Results

We recovered an ~315 m succession of upper Miocene to recent foraminifer-rich nannofossil ooze to foraminifer–nannofossil ooze in three holes at Site U1488. The sediment is assigned to a single lithologic unit (Unit I). Siliciclastic (mainly clay minerals), siliceous (radiolarians, diatoms, sponge spicules, and silicoflagellates), and volcanogenic (ash) particles are present as minor sediment components. Authigenic sulfide precipitates and authigenic clay minerals (e.g., smectite–chlorite) also occur as accessories. The sediment varies downhole with small changes in the color and abundances of different components. The upper ~50 mbsf is composed of light greenish gray clay- and foraminifer-rich nannofossil ooze, transitioning to greenish white foraminifer-rich nannofossil ooze between ~50 and ~250 mbsf. The bottom part of the site (below ~250 mbsf) is primarily yellowish white radiolarian/diatom-bearing foraminifer-rich nannofossil ooze. Bioturbation is slight to moderate. Three volcanic ash layers, composed of fresh, angular, and colorless glass shards, are found at ~6.5 mbsf, ~93 mbsf, and ~100 mbsf.

Site U1488 consists of a 315 m thick succession of foraminifer-rich nannofossil ooze with varying proportions of clay. Calcareous microfossil assemblages and preservation are typical of a pelagic, relatively deepwater bathyal environment throughout the recorded succession. Unlike previous sites (Sites U1482 through U1487), microfossil preservation at Site U1488 shows a marked increase in recrystallization (foraminifers) and some fragmentation, etching, and overgrowth (foraminifers and calcareous nannofossils) downhole. Biostratigraphic and magnetostratigraphic horizons indicate recovery of a continuous sequence of pelagic sediments spanning the last ~10 million years. The oldest sediments recovered at Site U1488 are constrained to be younger than ~10.47 Ma by the absence of the planktonic foraminifer *Paragloborotalia mayeri*, and older than 9.69 Ma by the presence of the calcareous nannofossil *Catinaster coalitus* (~315 mbsf). The Miocene/Pliocene boundary (5.333 Ma) is placed at ~149 mbsf based on linear interpolation between the biohorizon base *Ceratolithus armatus* (5.35 Ma) and biohorizon base *Ceratolithus cristatus* (5.12 Ma). The base of the late Pliocene (3.60 Ma) is placed at ~92 mbsf, between the biohorizon top *Reticulofenestra pseudoumbilicus* (3.70 Ma) and biohorizon top *Sphenolithus abies* (3.54 Ma). The Pliocene/Pleistocene boundary is placed at ~60 mbsf, just below the base of magnetochron C2r.2r at 59.70 mbsf, and the base of the middle Pleistocene is at the base of magnetochron C1n at ~19 mbsf. The middle/upper Pleistocene boundary is placed between the biohorizon top *Pseudoemiliania lacunosa* (0.44 Ma) and biohorizon top *Globigerinoides ruber* (pink) (0.12 Ma) at ~12 mbsf. Long-term average sedimentation rates through the late Miocene and Pliocene are remarkably consistent at ~4 cm/ky. These rates roughly halve through the early Pleistocene (~2 cm/ky), before increasing in the middle to late Pleistocene (~3 cm/ky). Benthic foraminifer assemblages are characteristic of intermediate to deep bathyal depths with *Laevidentalina* spp. and *Uvigerina* spp. being the dominant forms.

Paleomagnetic investigations at Site U1488 involved measurement of the natural remanent magnetization (NRM) of archive half sections from Hole U1488A, the upper ~67 mbsf of Hole

U1488B, and to ~102 mbsf in Hole U1488C before and after demagnetization in a peak alternating field (AF) of 15 mT. Corrected declination is largely coherent between cores; however, absolute values in all holes cluster between 90° and 180° for periods of normal polarity and between 270° and 0°/360° for reversed polarity, suggesting that the issues of a baseline offset experienced at the majority of sites during Expedition 363 and on previous expeditions (Stow et al., 2013; McNeill et al., 2017) also affected these measurements. Relatively soft ferrimagnetic minerals are concentrated in the top ~45 mbsf. Between ~45 and ~50 mbsf, NRM_{15mT}, magnetic susceptibility (MS), and saturation remanent magnetization (SIRM) values decrease, and below ~50 mbsf average MS values fall to 0.6×10^{-5} SI units. NRM_{15mT}, mass corrected MS (χ), and SIRM values below ~50 mbsf are ~2 orders of magnitude lower than in the upper ~45 mbsf and often approach the noise level of their respective instruments, indicating a significant reduction in magnetic mineral concentration below ~50 mbsf. We identify six 180° shifts in declination in Holes U1488A and U1488B, and nine horizons in Hole U1488C. The deepest of these are the Gauss/Matuyama boundary (2.582 Ma) at ~60 mbsf in Holes U1488A and U1488B, and the upper boundary of C2An.2n (~82 mbsf [3.207 Ma]) in Hole U1488C.

All physical properties at Site U1488 exhibit excellent reproducibility between holes. GRA bulk density shows an increasing trend with depth from 1.4 g/cm^3 at the seafloor to 1.8 g/cm^3 at the bottom of the hole, likely due to compaction. There is a break in this trend between ~245 and 285 mbsf where values remain at ~1.75 g/cm^3, before then increasing to 1.8 g/cm^3. *P*-wave velocity also shows an increasing trend with depth due to compaction, increasing from 1500 m/s at the seafloor to ~1600 m/s at 310 mbsf. NGR values are ~25 counts/s at the seafloor, and then rapidly decrease to ~8 counts/s by 8 mbsf. NGR gradually decreases to 2 counts/s over the length of the record. MS also initially exhibits moderate susceptibility (~30×10^{-5} SI) before decreasing abruptly at ~45 mbsf to values averaging <3×10^{-5} SI to the bottom of the site. Thermal conductivity increases from 0.9 to 1.3 W/(m·K) from the seafloor to the bottom of the hole. Below 150 mbsf, the thermal conductivity slope decreases and variability increases. Downhole formation temperature measurements indicate a geothermal gradient of 59°C/km.

We constructed a continuous splice for Site U1488 from 0 to 324.89 m core composite depth below seafloor (CCSF) using three holes (U1488A, U1488B, and U1488C). Tie points were established with Whole-Round Multisensor Logger (WRMSL) MS, gamma ray attenuation (GRA) bulk density, and *P*-wave velocity data, as well as natural gamma radiation (NGR) and L* color reflectance data. Since the upper 150 mbsf (equivalent to ~162 m CCSF) of Hole U1488A was heavily sampled (one 5 or 10 cm whole-round sample per section) for high-resolution interstitial water analyses, our general approach was to avoid using material from that interval in Hole U1488A, as Hole U1488C was cored specifically to recover material for the splice. The splice is continuous and well constrained from 0 to 324.89 m core composite depth below seafloor (CCSF), although there are a few tentative tie points that should be verified during postcruise research. Only Hole U1488A penetrated deeper than 324.89 m CCSF and therefore we appended the last two cores of Hole U1488A to the bottom of the splice.

At Site U1488, a total of 113 whole-round samples and one mudline sample were collected for interstitial water (IW) analysis. High-resolution IW sampling was conducted in the upper 150 mbsf of Hole U1488A, with the goal of reconstructing the [Cl^-] and $\delta^{18}O$ of Upper Circumpolar Deepwater (UCDW) during the Last Glacial Maximum (LGM). The IW profiles at Site U1488 are controlled in a large part by carbonate diagenesis, with a minor influence of organic matter (OM) remineralization in the uppermost 50 mbsf, and a likely influence of deep fluids below 100 mbsf. In general, $CaCO_3$ is the major component constituent of the sediment of Site U1488, with an average content of 83.5 wt%. $CaCO_3$ content increases with depth, from ~70 wt% near the seafloor to over 90 wt% at ~170 mbsf. Total organic carbon (TOC) content shows several stepwise decreases downhole, from ~0.5 to 0.2 wt% in the top 25 mbsf, and then further decreases at ~170 mbsf to minimal values that often are below the detection limit. Total nitrogen (TN) content shows a similar trend with TOC content. Above 80 mbsf, where both TOC and TN contents are above the detection limit, the C/N ratio is low, suggesting that the majority of the organic matter is derived from marine production. Preliminary shipboard chlorinity measurements suggest that reconstruction of the salinity of UCDW will be possible with the samples collected at this site.

References

de Garidel-Thoron, T., Rosenthal, Y., Bassinot, F., and Beaufort, L., 2005. Stable sea surface temperatures in the western Pacific warm pool over the past 1.75 million years, *Nature,* 433, 294–298.

Hamilton, W., 1979. Tectonics of the Indonesian region, USGS Professional paper 1078, US Gov't printing office, Washington, D.C.

Hegarty, K.A., and Weissel, J.K., 1988. Complexities in the development of the Caroline Plate Region, western equatorial Pacific, The Ocean Basins and Margins, p. 277–301.

McNeill, L., Dugan, B., Petronotis, K., and the Expedition 362 Scientists, in preparation. Sumatra Subduction Zone. *Proceedings of the International Ocean Discovery Program,* 362: College Station, TX (International Ocean Discovery Program).

Stow, D.A.V., Hernández-Molina, F.J., Alvarez Zarikian, C.A., and the Expedition 339 Scientists, 2013. Mediterranean Outflow. *Proceedings of the Integrated Ocean Drilling Program,* 339: College Station, TX (Integrated Ocean Drilling Program).

Winterer, E. L., et al., 1971, *Initial Reports of the Deep Sea Drilling Project,* Volume VII. Washington (U.S. Government Printing Office).