IODP Expedition 363: Western Pacific Warm Pool

Site U1489 Summary

Background and Objectives

International Ocean Discovery Program (IODP) Site U1489 (WP-04A) is located on the western slope of the southern Eauripik Rise at 2°7.19′N, 141°1.67′E, in 3421 m water depth. The site is situated on seismic reflection profile RR1313 WP4-2 at the intersection with seismic reflection profile RR1313 WP4-3. The seismic profile shows a continuous succession of hemipelagic, carbonate-rich sediments with basement at >650 m below seafloor. Site U1489 is located ~81 km west–northwest of Site U1488 and ~105 km northwest of Deep Sea Drilling Project (DSDP) Site 62 and shows a similar sedimentary cover (Winterer et al., 1971).

Site U1489 is situated on the western slope of the southern part of 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 U1489 is located ~2° north of the equator and thus is suitable for reconstructing the hydrographic history of the WPWP. The comparatively low sedimentation rate at this site allowed us to reach the middle Miocene at a relatively shallow depth, which was not possible at Site U1488, offering the opportunity to reconstruct the evolution of the WPWP from the middle Miocene climate optimum (MMCO) to the middle Miocene climate transition associated with expansion of the Antarctic ice sheet. At a depth of ~3400 m below sea level (mbsl) the site is bathed by, and hence useful to monitor past changes in modified Lower Circumpolar Deepwater. Since this site is close to Site U1488, but at ~900 m deeper water depth, comparing results from both sites also offers the opportunity to investigate potential diagenetic effects of foraminifer geochemical proxies records. 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 44 nmi transit from Site U1488, the vessel stabilized over Site U1489 (WP-04A) at 1442 h (all times are local ship time; UTC + 10 h) on 24 November 2016. Site U1489 was an alternate site that was added during the expedition to complement the record cored at Site U1488. We initially planned to core three holes to 200 m below seafloor (mbsf); however, we requested and received permission to core to 5.0 s TWT at our site location on seismic reflection profile RR1313 WP4-2. We ultimately cored four holes at Site U1489. Hole U1489A consisted of a single full advanced piston corer (APC) core, which indicated we missed the mudline. Hole U1489B was APC cored to 129.2 mbsf. We terminated coring in this hole due to coring difficulties that resulted in poor recovery and core disturbance. Hole U1489C cored to 385.6 mbsf using a combination of APC, half-length advanced piston corer (HLAPC), and extended core barrel (XCB) coring, and Hole U1489D was APC cored to 127.2 mbsf, drilled without coring to 274.0 mbsf, and then cored with the XCB to 385.6 mbsf.

Hole U1489A was cored with the APC system using orientation and nonmagnetic hardware. Core 363-U1489A-1H recovered a full core barrel, indicating that we had missed the mudline, so we terminated coring. We collected 9.53 m of core over 9.5 m of coring (100% recovery) in Hole U1489A.

Hole U1489B was cored to 129.2 mbsf with the APC coring system using orientation and nonmagnetic hardware (Cores 363-U1489B-1H through 14H). Downhole formation temperature measurements using the Advanced Piston Corer Temperature Tool (APCT-3) were taken on Cores 4H (34.2 mbsf), 7H (62.7 mbsf), 10H (91.2 mbsf), and 12H (110.2 mbsf); however, only one measurement was of good quality (10H). The measurements taken while collecting Cores 4H and 7H showed possible movement related to heavy seas, and the measurement from Core 12H was of very poor quality. We also collected high-resolution interstitial water (IW) samples at a frequency of one 5 to 10 cm whole-round samples per section over the entire cored succession in Hole U1489B. Coring difficulties included premature failure of the APC shear pins due to ship motion on Cores 3H and 8H, as well as one core with no recovery (11H), and two cores requiring a second coring attempt to retrieve the sediment (Cores 12H and 13H). As these cores appeared very disturbed, we opted to terminate coring in Hole U1489B. We collected 120.66 m of core over 129.2 m of coring (93% recovery) in Hole U1489B.

Hole U1489C was cored to 269.5 mbsf (Cores 363-U1489C-1H through 29H) with the APC using orientation and nonmagnetic hardware. Core 29H required a drillover to extract it from the formation, indicating APC refusal. We switched to the HLAPC and cored only to 278.9 mbsf

(Cores 30F and 31F) before excessive overpull indicated HLAPC refusal. We then switched to the XCB coring system to core to 385.6 mbsf (Cores 32X through 42X), where we terminated coring. We collected 376.35 m of core over 385.6 m of coring (98% recovery) in Hole U1489C.

Hole U1489D was cored to recover material for the splice over the upper ~120 mbsf that was heavily sampled for IW in Hole U1489B, and to collect a second copy of the deeper succession at Site U1489. Hole U1489D was cored with the APC using orientation and nonmagnetic hardware to 127.2 mbsf (Cores 363-U1489D-1H through 14H). Since several of the APCT-3 measurements provide spurious results in Hole U1489B, we opted to take additional measurements in Hole U1489D while collecting Cores 4H (32.2 mbsf), 7H (60.7 mbsf), 10H (89.2 mbsf), and 13H (117.7 mbsf). All four measurements provided good results. We drilled without coring from 127.2 to 274.0 mbsf, and then cored using the XCB to 385.6 mbsf (Cores 16X through 27X), where we terminated coring. We collected 229.24 m of core over 238.8 m of coring (96% recovery) in Hole U1489D.

Operations at Site U1489 ended at 0212 h on 30 November 2016. Total time spent on Site U1489 was 131.5 h (5.5 d). We collected a total of 58 APC cores, recovering 527.85 m of core over 535.4 m of coring (99% recovery). We also collected 2 HLAPC cores, recovering 9.05 m of core over 9.4 m of coring (96% recovery), and 23 XCB cores, retrieving 198.88 m of core over 218.3 m of coring (93% recovery).

Principal Results

The recovered sedimentary succession at Site U1489 consists of ~386 m of lower Miocene to recent nannofossil ooze and chalk with varying proportions of clay. Biosilica (especially radiolarians) are a major component in the lowermost part of the site. The recovered succession at Site U1489 is assigned to one lithologic unit, which is divided into two subunits. Subunit IA consists of ~280 m of upper Miocene to recent light greenish gray foraminifer-bearing clay-rich nannofossil ooze and white clay-bearing foraminifer-rich nannofossil ooze, with clay content decreasing downhole. Color alternations occur at centimeter to meter scale and also include thin-bedded pale yellow sediments. Grayish green and pale purple laminae are common in the upper part of Subunit IA. Soft-sediment deformation is a prominent feature in the lower part of Subunit IA (between ~100 and 260 mbsf) and is characterized by a series of large-scale soft-sediment deformation intervals intercalated with pelagic sediments. These intervals occasionally include coarse-grained foraminifer ooze or very thick-bedded homogenous clay-bearing foraminifer-rich nannofossil ooze. Subunit IB consists of ~112 m of lower to upper Miocene light greenish gray foraminifer-bearing clay-rich chalk. Near the base of the subunit, biosilica becomes more abundant and the sediment transitions to pale yellow foraminifer-bearing radiolarian-rich chalk and light gray radiolarian-rich chalk. This subunit also shows color alternations between lighter and darker chalk, as well as minor soft-sediment deformation features. There is an abrupt change to white chalk at the very base of the succession.

We cored a 386 m thick succession of clay-bearing foraminifer-rich nannofossil ooze and chalk with minor but significant amounts of biosilica in the lower part of the succession at Site U1489. Calcareous microfossil assemblages and preservation are typical of a pelagic, relatively deepwater bathyal environment throughout the site. Foraminifer preservation is generally good to very good in the upper part of the succession (Subunit IA), but is moderate to poor in the chalk of Subunit IB. Calcareous nannofossil also decreases with depth, although this is most prevalent in the discoasters, which show significant overgrowth in the chalk. The planktonic to benthic foraminifer ratio is on the order of 99:1, although the benthic foraminifers *Planulina wuellerstorfi* and *Cibicidoides mundulus* are present in most of the samples examined throughout the hole. Other common taxa include *Laevidentalina* spp.

Integrated calcareous nannofossil and planktonic foraminifer biostratigraphy generally shows excellent congruence between both fossil groups and the magnetostratigraphy. The age at the base of the succession is constrained to the early Miocene based on the biohorizon base *Sphenolithus belemnos* at ~380 mbsf and the presence of *Dentoglobigerina binaiensis* and absence of *Globigerinoides altiaperturus* and *Tenuitella munda* at ~384 mbsf). The Miocene/Pliocene boundary is placed at ~115 mbsf, above the biohorizon base *Ceratolithus armatus*. The Pliocene/Pleistocene boundary is located at ~45 mbsf based on the biohorizon top *Discoaster surculus* and the Matuyama/Gauss boundary. Long-term average sedimentation rates through the early to middle Miocene were low (~0.3 cm/ky). Average sedimentation rates in the late Miocene increased to ~2 cm/ky. In the latest Miocene and earliest Pliocene, average sedimentation rates increased to ~5 cm/ky; however, this interval is complicated by soft-sediment deformation and the estimated sedimentation rate is based on sparse bioevents (and no magnetostratigraphic events). Above this interval of deformed sediments, Pliocene and Pleistocene sedimentation rates averaged ~2 cm/ky, which is comparable to those of the late Miocene at Site U1489.

Paleomagnetic investigations at Site U1489 involved measurement of the natural remanent magnetization (NRM) of archive-half sections from Holes U1489A, U1489B, U1489C, and U1489D before and after demagnetization in a peak alternating field (AF) of 15 mT. Corrected declination is largely coherent between cores; however, absolute values in Hole U1489B cluster around 90° for periods of normal polarity and around 270° for reversed polarity with the opposite being true (270° for normal polarity and 90° for reverse polarity) in Holes U1489C and U1489D. Relatively soft ferrimagnetic minerals are concentrated in the top ~90 mbsf. Between ~90 and 100 mbsf, NRM_{15mT}, magnetic susceptibility (MS), and saturation remanent magnetization (SIRM) values decrease, and below ~100 mbsf, average MS, NRM_{15mT}, mass corrected MS (χ), and SIRM values are ~1–2 orders of magnitude lower than in the upper ~90 mbsf and often approach the noise level of their respective instruments. They indicate a significant reduction in magnetic mineral concentration below ~100 mbsf. We identify up to twenty-two 180° shifts in declination at Holes U1489B, U1489C, and U1489D. The Brunhes/Matuyama boundary (0.781 Ma) is placed at ~15 mbsf, the Matuyama/Gauss boundary (2.581 Ma) at ~45 mbsf, and the Gauss/Gilbert boundary (3.596 Ma) at ~65 mbsf. The deepest of these declination shifts is identified as the upper boundary of the Thvera normal (C3n.3r [4.997 Ma]) at ~101 mbsf.

All physical properties measurements are generally reproducible across holes with the exception of some intervals in Hole U1489B that are likely due to core disturbance during recovery. The gamma ray attenuation (GRA) bulk density increases downhole from ~1.3 to 1.8 g/cm^3, with an increase in variability below 270 mbsf, due to an increase in sediment induration coincident with the switch to XCB coring. Magnetic susceptibility at Site U1489 starts with relatively high values of ~20–60 × 10^{-5} SI in the upper 90 mbsf, with distinct cyclicity that transitions from 1–3 m to 0.4–0.6 m-scale at 21 mbsf. MS values between 90 and 260 mbsf are extremely low (<3 × 10^{-5} SI) in the light-colored sediments, but increase to a mean of ~9 × 10^{-5} SI between 260 to 385 mbsf. Natural gamma radiation (NGR) deceases rapidly from 30 counts/s to 10 counts/s over the upper 5 mbsf, and then gradually decreases down to <1 counts/s by the bottom of the hole (~385 mbsf). There are two intervals of slightly higher NGR counts between 55 and 84 mbsf and between 310 and 360 mbsf, which correspond to higher clay content in the sediment. In general, the short-term cyclicity in MS and NGR coincide with light-dark variations in the sediment. In general, *P*-wave velocities display a slight increasing trend and increase in variability with depth. Discrete bulk density measurements display a ~0.05 g/cm^3 offset in the top 265 mbsf compared with GRA bulk density. Below 265 mbsf, where the sediment became indurated and XCB coring commenced, the variability of GRA bulk density increases and the MAD bulk density values correspond well with the highest values of the GRA bulk density. Thermal conductivity increases with depth from ~0.9 W/(m·K) to 1.3 W/(m·K), similar to the MAD bulk density and dry density, which likely primarily is due to compaction. Downhole formation temperatures were measured in both Holes U1489B and U1489D, as the APCT-3 tool showed evidence of movement in some of the measurements taken in Hole U1489B. The more reliable measurements from Hole U1489D confirmed the results from Hole U1489B and indicate a geothermal gradient of 31°C/km.

Stratigraphic correlations between holes at Site U1489 primarily used Whole-Round Multisensor Logger (WRMSL), and were aided by additional whole-round measurements of GRA bulk density, *P*-wave velocity, NGR, and optical luminosity (L*) measured on split cores. Overlap between holes provided two continuous, spliced intervals from 0 to 140.95 m core composite depth below seafloor (CCSF) and from 305.70 to 371.25 m CCSF. The interval between these spliced sections corresponds to the interval of soft-sediment deformation in the lower part of Subunit IA and was cored only once. Gaps between an additional five cores below 371.25 m CCSF in both Holes U1489C and U1489D prevented the construction of a deeper, continuous, spliced section.

A total of 100 whole-round samples and one mudline sample were collected for interstitial water (IW) analysis at Site U1489. High resolution IW sampling was conducted in the upper 128 mbsf at this site, with the goal of reconstructing the $[Cl^-]$ and $\delta^{18}O$ of Lower Circumpolar Deepwater (LCDW) during the LGM. Carbonate diagenesis and minor amounts of organic matter remineralization are the dominant controls on the IW chemistry, along with upward diffusion from a deep fluid source. Muted trends in [Ca^{2+}], [Mg^{2+}], and [Li^{+}] suggest a weaker influence of deep fluids with chemistry reflective of basalt-seawater interaction at this site relative to Site U1488. Differences in basement age and sediment thickness between the two sites likely contribute to the differences observed between the two sites. Calcium carbonate content averages 82 wt% and increases with depth, from ~50 wt% near the seafloor to over 90 wt% at depth. Total organic carbon is low (average ~0.14 wt%) and varies between 0 and 0.8 wt%, which is reflected in the moderate degree of sulfate depletion and low concentrations of bromide, ammonium, and phosphate. Nitrogen was detected in trace amounts. Preliminary shipboard chlorinity measurements suggest that reconstruction of the salinity of LCDW will be possible with the samples collected at this site.

References

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