IODP Expedition 397: Iberian Margin Paleoclimate

Site U1586 Summary

Background and Scientific Objectives

Site U1586 is the deepest (4692 m below sea level [mbsl]) and farthest from shore of all the IODP Expedition 397 sites. It is located at the toe of the Promontório dos Príncipes de Avis in an elevated region protected from bottom currents and turbidite deposition. As the deepest site in the bathymetric transect, it is bathed by Lower Deep Water (LDW), which consists of Antarctic Bottom Water that has been modified by mixing during its transit from the South Atlantic.

Because of relatively lower sedimentation rates at Site U1586 compared to other sites, drilling at this site represents our best opportunity to obtain the oldest sediment (Miocene) to be recovered during Expedition 397. The main drilling objective is to recover a high-resolution record of the Late Miocene/Pleistocene with which to study the evolution of the surface and deepest water masses of the northeast Atlantic. Of specific interest are the time periods associated with: (1) the water exchange between the Mediterranean and the Atlantic before, during, and following the Messinian salinity crisis (latest Miocene to the base of the Pliocene); (2) the Mid-Pliocene warm period characterized by atmospheric CO_2 concentrations similar to the present values (400 ppm); (3) the late Pliocene intensification of the Northern Hemisphere glaciation (~2.9 Ma); and (4) the Pleistocene (last 2.6 Ma) when millennial climate variability was superimposed upon glacial/interglacial cycles.

Site U1586 is positioned at common midpoint 1330 on seismic Line 2 of Cruise JC089 near the intersection with Line 3 in a region with good continuity of reflectors. The objective is to drill to the package of high-amplitude reflectors. A target drilling depth of 350 m below seafloor (mbsf) was approved by the IODP Environmental Protection and Safety Panel.

Operations

IODP Expedition 397 began on 11 October 2022 at 1045 h (UTC + 1 h) upon the arrival of the *JOIDES Resolution* at Rocha Pier in Lisbon, Portugal, at the end of Expedition 397T. On 16 October, the *JOIDES Resolution* left port by 0830 h Portuguese time, reaching Site U1586 at 1834 h. A water depth reading with the ship's precision depth recorder was taken as the vessel arrived on site, giving a seafloor depth of 4702.4 m below rigfloor (mbrf)/4691.4 mbsl.

The plan for Site U1586 was to core five holes. Holes U1586A through U1586C were to be cored with the full-length advanced piston corer (APC) and the half-length APC corer (HLAPC) to refusal (estimated to be approximately 250 mbsf), then cored to a maximum depth of 350 mbsf using the extended core barrel (XCB) coring system. Holes U1586D and U1586E were to be cored to the APC/HLAPC refusal depth. Formation temperature measurements were planned for Hole U1586A using the advanced piston corer temperature

(APCT-3) tool, and downhole wireline logging measurements were planned for Hole U1586C using the triple combo tool string.

Once on site, weather conditions and high seas caused ~48 h of delay over the planned 14.8 d of operations, and the coring strategy was adjusted. The high core quality obtained using the XCB coring system fitted with a polycrystalline diamond compact (PDC) bit and cutting shoe in Hole U1586A allowed for it to be deployed earlier than normal in Holes U1586B through U1586D, eliminating the need to use the HLAPC system. Therefore, a revised plan was executed, consisting of using the full-length APC system until the first partial stroke and then extending the hole to total depth using the XCB coring system. Site U1586 consisted of four holes to 350 mbsf. Hole U1586D was logged using the triple combo tool string. All APC and HLAPC cores used nonmagnetic core barrels and APC cores were oriented using the Icefield MI-5 orientation tool. In total, 1399.1 m were cored using the three coring systems, with an overall recovery rate of 96%. Operations at Site U1586 took 349.5 h (14.6 d) to complete.

Principal Results

Site U1586 yielded several significant findings and observations, some of which were unexpected:

1. Operationally, the quality of the cores recovered using the XCB system was surprisingly good with high recovery and relatively minor disturbance (biscuiting), which is attributed to the use of a PDC bit and cutting shoe.
2. A ~335 m spliced sedimentary sequence of Holocene to middle Miocene (14 Ma) was recovered, nearly twice the age (7 Ma, late Miocene) predicted from the interpretation of the seismic profiles.
3. The occurrence of “convoluted banded sediment,” interpreted as slumps, was found in all the holes at the same stratigraphic position, indicating slope instability associated with possible sea level fluctuations or tectonic activity. Slumped intervals were carefully noted by sedimentologists and can be recognized by the low-amplitude signal of physical properties measurements. Although the occurrence of slumps interrupts the stratigraphic section, many continuous intervals suitable for paleoclimate studies are identified.
4. The Pliocene sequence at Site U1586 is remarkably complete and unaffected by slumping. Sediments are marked by very strong cyclic variations in color and other physical properties (magnetic susceptibility [MS] and natural gamma radiation [NGR]), which are dominated by an apparent precession signal and offer much promise for developing an orbitally tuned age model and correlation to Mediterranean sequences.
5. A serendipitous finding was an exceptionally high peak in MS that was detected at the same stratigraphic interval in all the holes. The sediments were found to contain abundant metallic particles, some of which are spherical and interpreted to be of cosmic origin. The estimated age of the layer is 3.6 Ma by correlation of the color reflectance signal to precession and the identification of the Gilbert/Gauss polarity boundary.

At Site U1586, four holes (U1586A to U1586D) were drilled to 350 mbsf and a total of 1346.85 m of sediment was recovered. The primary lithology consisted of various proportions of nannofossil ooze and clay/silt. Very fine to coarse calcareous sands were found near the base of the holes below 310 mbsf and may have resulted from sediment gravity flows (turbidites). Different types and intensities of drilling disturbance were observed in the cores, with the most common being uparching, flow-in, soupy, and slurry in the APC cores, and biscuiting and fall-in for the XCB cores. Bioturbation varied from absent to complete disturbance of sedimentary layers. Pyrite nodules filling burrows are commonly observed in X-ray images.

A well-constrained biostratigraphic age model was developed for Site U1586 based on analyses of calcareous nannofossils and planktonic foraminifera. Overall, 51 calcareous nannofossils and planktonic foraminifera bioevents were identified. The integrated biostratigraphy suggests a reasonably complete sequence from Holocene to middle Miocene.

Magnetostratigraphy of Site U1586 was established based on the natural remanent magnetization (NRM) by combining NRM (after 20 mT demagnetization) inclination and orientation-corrected declination data from archive half core sections, and stepwise NRM demagnetization (up to 50 or 80 mT) data from cubes. Identified polarity reversals include the Brunhes/Matuyama, Matuyama/Gauss, and Gauss/Gilbert boundaries and the following subchrons: Jaramillo, Olduvai, Cobb Mountain, Mammoth, Cochiti, and Thvera.

Whole-round samples (5–10 cm thick) were taken for interstitial water (IW) from the base of every section for the uppermost 34 mbsf, and then from the penultimate section recovered from every core in Hole U1586A. IW analysis shows relatively constant salinity, sodium, and chloride throughout Hole U1586A, with values close to seawater, while potassium declines downhole with a relatively constant slope. Decreasing sulfate concentration is indicative of organic matter respiration via sulfate reduction; however, sulfate never reaches zero and methane concentration never exceeds 15 ppmv. Peaks in redox-sensitive elements, such as iron and manganese, are similarly indicative of microbially mediated respiration reactions within the sediments. At depths below 200 mbsf, Ca, Sr, and Si concentrations increase while Mg decreases. Whereas dolomitization may explain the Mg, Ca, and Sr profiles, by liberating Ca and Sr and using Mg, the high silicon concentration near the bottom of the hole indicates important Si dissolution within the silty clay layers of lithostratigraphic Unit III. Mean $CaCO_3$ in Hole U1586A is 37.4 wt% and values increase steadily but nonmonotonically with depth. Total organic carbon values in Hole U1586A are generally low (mean 0.48 ± 0.32 wt%), ranging from 0 to 2.02 wt%. They are highest in the upper 50 m (0.57 ± 0.21 wt%) and steadily decline with depth (0.33 ± 0.27 wt% in the bottom 50 m). Methane is the only detectable gas and its concentration ranges from 0 to 14.10 ppmv, with a peak between 100 and 150 mbsf.

Sediment physical properties data acquired from whole-round measurements for Site U1586 are generally in good agreement with those from split-core measurements for gamma ray attenuation and moisture and density bulk densities, *P*-wave logger and *P*-wave caliper velocities, and MS loop and point count measurements. The cyclic variations in MS, NGR, and L^* color reflectance values are particularly distinct throughout all holes, showing lower

MS and NGR values in carbonate-rich sediments with higher L^* values, whereas higher MS and NGR values occur in clay-rich sediments with lower L^* values. The gradual increasing trend of bulk densities, thermal conductivity, and *P*-wave velocities, and decreasing trend of porosity are attributed to compaction of sediments with depth. Downhole changes in physical properties characteristics overall are coherent with the defined lithofacies based on sedimentological observations. MS gradually declines over the top ~100 m, coinciding with a decrease in pore water sulfate. This reflects the reaction of fine-grained magnetite with hydrogen sulfide, produced by sulfate reduction, to form iron sulfides (e.g., pyrite).

Downhole logging was conducted in Hole U1586D with the triple combo tool string between 84.6 (bottom of the pipe) and 255.3 mbsf. Comparison of the processed logging and core physical properties data reveals a good correlation in the NGR and less so for density and MS. Four downhole formation temperature measurements were made in Hole U1586A. The calculated in situ sediment temperatures ranged from 4.27°C at 34.9 mbsf to 5.77°C at 120.4 mbsf, resulting in a geothermal gradient of 26.9°C/km.

Stratigraphic correlation among holes at Site U1586 was accomplished using Correlator software. Tie points were established using the L* color reflectance, the MS, and the blue channel extracted from the color images (RGB-blue). A splice was constructed from 0 to 320 m core composite depth below seafloor (CCSF-A) using four holes (Holes U1586A, U1586B, U1586C, and U1586D). The splice has complete overlap and only one potential small gap in the upper Pliocene where overlap is equivocal. Slump intervals noted by the sedimentologists were correlatable among all holes and have disturbed/removed variable amounts of intact stratigraphy. These include four in the middle to upper Pleistocene sequence and two in the upper Miocene. Gaps in core recovery were evident when offset holes were compared and appear to correlate with the sea state. For example, gaps of up to 4 m were noted in the XCB section of Hole U1586B, which was drilled during heavy swells.

In summary, the preliminary age model based on biostratigraphy and magnetostratigraphy suggests that the sedimentary sequence recovered at Site U1586 covers the last 14 Ma. The combination of nearly continuous recovery, moderate sedimentation rates, clear cyclic variations in physical properties and sediment color, and a rich array of well-preserved calcareous microfossils suggests Site U1586 will provide an important record of North Atlantic surface and deepwater variability for the middle Miocene to Pleistocene.