

IODP Expedition 397: Iberian Margin Paleoclimate

Site U1385 Summary

Background and Scientific Objectives

Site 397-U1385 represents a reoccupation of Site 339-U1385 (the “Shackleton site”), drilled during IODP Expedition 339. Site 339-U1385 served as a proof-of-concept for demonstrating the potential of the Iberian Margin for providing long, continuous records of millennial climate variability (MCV). As expected, Site 339-U1385 recovered a 1.45 My sequence with continuously high sedimentation rates. Postcruise studies demonstrated the great potential of the site to yield detailed records of MCV that can be correlated to the polar ice cores and the European terrestrial sequences. On the basis of the success of Site 339-U1385, Expedition 397 sought to extend the length of this remarkable sediment archive to 400 m below seafloor (mbsf), spanning the entire Quaternary into the early Pliocene.

Site 397-U1385 is located ~1 km to the southwest of Site 339-U1385 in a water depth of 2592 m below sea level (mbsl), in the core of lower North Atlantic Deep Water (NADW). It is the second shallowest site along the Expedition 397 bathymetric transect (“paleo-CTD” [Conductivity-Temperature-Depth]), and it is designed to provide a marine reference section from the core of NADW. During glacial periods, Site U1385 was influenced by a relatively greater proportion of deep water sourced from the Southern Ocean.

The overall objective of Site 397-U1385 is to recover a Pliocene/Pleistocene sediment sequence that can serve as a marine reference section for reconstructing the long-term history of orbital- and millennial-scale climate variability and to understand its underlying causes and evolving contextuality. Isotope and X-ray fluorescence records from Site 339-U1385 have demonstrated that MCV was a persistent feature of glacial climates over the past 1.45 My. But does similar MCV persist during glacial periods beyond 1.5 Ma throughout the entire Quaternary? How does the nature (intensity, duration, pacing) of MCV change with orbital configuration and climate background state throughout the Quaternary? How did MCV change with the intensification of Northern Hemisphere glaciation (NHG) during the late Pliocene? Was MCV suppressed during the warm Pliocene prior to the intensification of NHG as it was during most interglacial stages of the Pleistocene? How did millennial climate change interact with the effects of orbital forcing to produce the observed patterns of glacial-interglacial cycles through the Pliocene/Pleistocene? How did the relative importance of obliquity and precession evolve in the Pliocene/Pleistocene? What was responsible for the strong precession cycle observed in sediment color throughout the record? These are some of the questions that will be addressed by collaborative postcruise investigations among Expedition 397 scientists.

Operations

The vessel made the transit to Site U1385 with the thrusters deployed in dynamic position navigation mode between 15 and 16 November 2022. The move took 12.75 h with the vessel arriving on site at 0220 h on 16 November.

Site U1385 was previously occupied during Expedition 339, during which five holes were cored. Expedition 397 began operations in Hole U1385F. The plan for the reoccupation of Site U1385 was to core four new holes with the advanced piston corer (APC) system to refusal (estimated to be at ~135 mbsf) and then core to 400 mbsf using the extended core barrel (XCB) coring system. Orientation was planned for all APC cores in all four holes. Downhole measurements with the triple combo tool string also were planned for Hole U1385I.

Once on site, weather conditions and high seas caused some delays, and the coring strategy was adjusted to take full advantage of all operational time to achieve the best possible core quality. Five holes (U1385F, U1385G, U1385H, U1385I, and U1385J) were eventually cored. Two holes were drilled ahead without coring (U1385F to 96.9 mbsf and U1385H to 114.6 mbsf) to allow for XCB coring in the lower section of the holes to the total depth (400 mbsf). In the other three holes, the APC system was deployed from the seafloor until the first partial stroke was registered, and then the holes were extended to 400 mbsf using the XCB coring system. Logging was attempted in Hole U1385J using the triple combo tool string, but a portion of a bowspring centralizer on the tool broke and wedged in the lockable float valve, trapping the tool string inside the pipe; therefore, logging was abandoned.

All APC cores used nonmagnetic core barrels and were oriented using the Icefield MI-5 orientation tool. In total, 1537.5 m were cored using both the APC and XCB coring systems with an overall core recovery of 99%. Site U1385 took 336.0 h (14.0 d) to complete, including 101.0 h (4.2 d) of waiting on weather.

Principal Results

1. Drilling at Site 397-U1385 recovered a continuous 4.5 Ma record of hemipelagic sediments to the early Pliocene with an average sedimentation rate between 11 and 9 cm/ky.
2. A complete splice section was constructed to a depth of 453 m core composite depth below seafloor (CCSF-A) using five holes (397-U1385F through U1385I).
3. We reproduced the upper 158 mbsf of the sequence recovered previously at Site 339-U1385, which will provide additional sediment for sampling of these high-demand cores. We also recovered a more complete record of MIS 11 at Site 397-U1385 than at Site 339-U1385, which was partially missing in a hiatus.
4. Extension of the Site 339-U1385 record beyond the last 1.45 Ma (MIS 47) will permit the study of MCV for the earlier part of the Quaternary and late Pliocene, prior to the intensification of NHG, including linkages and phase relationship with the polar ice core and European terrestrial records.

5. Variations in sediment color and other physical properties at Site U1385 display very strong cyclicity throughout the Pliocene and Pleistocene, permitting the development of an orbitally-tuned timescale and correlation to Mediterranean cyclostratigraphy. The cycles can be matched one-for-one between Site U1385 and those from Sites U1586 and U1587, providing a powerful cross-check of the completeness of the stratigraphic sections.
6. Complete recovery of Pliocene sediments to 4.5 Ma will permit studies of variability under warmer climate conditions and atmospheric CO₂ concentrations similar to today.

One lithostratigraphic unit was defined across Holes U1385F, U1385G, U1385H, U1385I, and U1385J, consisting primarily of nannofossil ooze with varying amounts of clay, indicating the dominance of hemipelagic sedimentation. Cyclic color-banding is evident throughout all cores. Drilling disturbance is present in many cores from all holes, ranging from slight to severe, which varies with the drilling system, operational conditions (ship heave), and gas (methane) content of the sediments.

Based on 15 nannofossil and 11 planktonic foraminifera bioevents, the ~400 m thick sedimentary succession at Site 397-U1385 ranges in age from the Pleistocene to the early Pliocene (~4.5 Ma). Both nannofossils and foraminifera show good preservation and are very abundant to common throughout the section. The zonal schemes of the two microfossil groups are in good agreement and consistent with previous biostratigraphy of Site 339-U1385 for the upper 150 mbsf.

Magnetostratigraphy of Site U1385 was established based on the natural remanent magnetization (NRM) after 20 mT demagnetization using inclination and orientation-corrected declination data from archive half core sections and stepwise NRM demagnetization data from discrete cube samples. The Brunhes/Matuyama boundary (0.773 Ma) is identified in APC cores from Holes U1385G, U1385I, and U1385J. The Jaramillo Subchron is recorded in XCB cores from Holes U1385F, U1385G, U1385I, and U1385J. The Olduvai Subchron (1.775–1.934 Ma) and the Matuyama/Gauss boundary (2.595 Ma) are recorded in XCB cores from Holes U1385F, U1385G, U1385H, and U1385J. The magnetostratigraphy and biostratigraphy are generally in good agreement and sedimentation rates vary between 11 and 9 cm/ky.

In the upper 150 mbsf, the interstitial water chemistry of Site 397-U1385 was very similar to that of Site 339-U1385. Sulfate shows a two-step decrease before reaching values of zero by 48.8 mbsf. The first step represents organoclastic sulfate reduction and the second represents anaerobic oxidation of methane. Once sulfate reaches zero, methane increases, reaching maximum values of ~35,000 ppmv between 100–280 mbsf. Alkalinity, ammonium, and phosphate also increase in the upper 50 mbsf in conjunction with sulfate reduction.

The CaCO₃ content of the sediment averages 38.8 wt%, varying between 15.2%–63.3%, and is positively correlated with L* reflectance and negatively correlated with natural gamma radiation (NGR). Total organic carbon (TOC), nitrogen (TN), and sulphur (TS) values in Site U1385 are generally low, with a mean value of 0.48 wt%, 0.005 wt%, and 0.115 wt%,

respectively. Organic C/N ratios (mean 20.2 wt%) suggest that organic matter is marine dominated with higher terrestrial input in the upper 75 mbsf.

Bulk sediment geochemistry suggests that Ca is primarily biogenic carbonate, and because of the incorporation of Sr into biogenic carbonates, both elements show an inverse relationship with Al. Barium is weakly correlated with Al or Ca, likely due to the presence of barite. Manganese seems to be mainly associated with carbonate. Elemental ratios of Ca/Ti, Si/Al, Ti/Al, Zr/Al, K/Al, Sr/Ca, and estimated biogenic Ba are suggested as potential proxies of provenance, weathering, and productivity.

Physical properties data acquired from whole-round measurements follow those from split-core measurements. A decline in magnetic susceptibility (MS) in the upper 50 m follows sulfate reduction in the sediment pore waters, suggesting that H₂S from sulfate reduction reacts with Fe in magnetite to produce iron monosulfides and pyrite. The cyclic variations in MS, NGR, and L* color reflectance parameter values are particularly strong throughout all holes at Site U1385, showing lower MS and NGR values in carbonate-rich sediments with higher L* values, and higher MS and NGR values in clay-rich sediments with lower L* values. The gradual increasing trend of bulk densities, thermal conductivity, and P-wave velocities, and the decreasing trend in porosity are attributed to the compaction of sediments with depth. The X-ray images revealed the presence of authigenic minerals, gas expansion, and drilling disturbance.

Stratigraphic correlations between holes at Site U1385 were accomplished using Correlator software. Tie points were established using the L* color reflectance parameter, whole-round MS, and the blue color channel extracted from the core images (RGB-blue). We constructed a splice from 0 to 452.7 m CCSF-A using all five of the newly drilled holes at the site (U1385F, U1385G, U1385H, U1385I, and U1385J). The data from Site 397-U1385 will be integrated postcruise with Holes 339-U1385A to U1385E to produce a common splice. The Pliocene sequence correlates cycle-for-cycle to Sites U1586 and U1587.