IODP Expedition 339: Mediterranean Outflow
Site U1386 Summary

Background and objectives

Site U1386 (proposed site GC-01A) is located on the southern Iberian Margin (36°49.685' N, 7°45.321' W) about 25 km SSE of the Portuguese city of Faro, in a water depth of 561 m. It is the most distal of our sites away from the Gibraltar Gateway, within the depositional sector of the Cadiz Contourite Depositional System (CDS). The site targets the eastern end of an elongated mounded and separated drift (the Faro drift), which has a total length of 100 km, a width up to 20 km and a maximum thickness of around 700 m.

The Faro drift represents a classic example of middle-slope contourite deposits, which shows a well-layered internal acoustic structure with laterally extensive, aggradational to progradational seismic depositional units, and widespread discontinuities. Faro drift has been developing along the mid-slope over the past 4-5 million years, under the direct influence of Mediterranean Outflow Water (MOW). It therefore holds a clear signal of MOW through the Gibraltar Gateway, which re-opened following tectonic adjustments at the end of the Messinian Salinity Crisis.

Our primary objective was to recover a key Pleistocene and Holocene sedimentary succession formed under the influence of the Upper Core of MOW, and hence a clear record of MOW influence on the North Atlantic Ocean. The high accumulation rates and expanded sedimentary record of this drift site should permit high-resolution examination of past environmental change (climatic and eustatic). This site is complementary to Site U1387, which is located about 4.1 km toward the southeast, and will target a Pliocene and Lower Pleistocene sedimentary record also due to the MOW upper core.

Site U1386 was occupied on 30 November 2011. Three holes were drilled and cored using the advanced piston corer (APC), the extended core barrel (XCB), and the rotary core barrel (RCB) system, achieving the target depth of 526 m in Hole U1386C. Downhole logging was carried out in Hole U1386C using the Triple Combo, FMS-Sonic and VSI tool strings. Overall recovery for Site U1386 was 351 m (102%) with the APC, 417.6 m (89%) with the XCB, and 82 m (58.5%) with the RCB. The total cored interval for Site U1386 was 954.4 m and total recovery was 850.6 m (89%).

Main results

The sedimentary succession at Site U1386 extends from the latest Miocene to Holocene. It is divided into two lithologic units (Unit I and Unit II), distinguished on the basis of inferred depositional process. Unit I is a Pleistocene-Holocene sequence dominated by classic contourite deposition, including nannofossil mud, calcareous silty mud and silty bioclastic sand lithologies. These three lithologies are generally organized as bi-gradational sequences, the most complete of

which coarsen upward from nannofossil mud to calcareous silty mud to silty bioclastic sand, and then fine upward through calcareous silty mud into nannofossil mud. Unit I is subdivided into three sub-units (IA, IB and IC), based on the relative importance of the silty muds and silty sands. Thin turbidite intercalations occur very rarely in the upper Unit IA and more commonly in the lower 30 m of Unit IC.

Unit II is a late Miocene-Pleistocene sequence characterized by the deposits of downslope processes, interbedded with contouritic and hemipelagic nannofossil muds. The downslope facies include medium and thick-bedded, disorganized turbidites and thick to very thick-bedded, chaotic debrites. Quartz-lithic-rich turbidites are more common in the upper part, whereas debrites and bioclastic (shelly) turbidites are typical of the lower part. The lowermost 10 m are mud dominated without obvious downslope input.

Calcareous microfossils (nannofossils, planktonic and benthic foraminifera, and ostracods) are mostly common to abundant, with moderate to good preservation through Lithologic Unit I, but occur more sporadically and with poorer preservation through Unit II. The sedimentary record is continuous for the most part of the Holocene and Pleistocene to about 1.9 Ma, with an average sedimentation rate of 35 cm/k.y. between 0 and 384 mbsf (contourite-dominated) decreasing to 15 cm/k.y. between 384 and 453 mbsf (turbidite-dominated). Preliminary shipboard dating suggests the presence of a major hiatus below 1.9 Ma, which cuts out much of the early Pleistocene and late Pliocene, and a somewhat discontinuous record through the debrite-dominated section. The lowermost 15 m of the record is most likely of Messinian age (< 5.8 Ma)

The observed variability in both benthic foraminifer and ostracod distribution seems to reveal significant changes in depositional processes, bottom water ventilation, temperature, and food availability over the last ~5 m.y. In general, there is marked mixing with shelf-derived taxa in the lower part of the succession as a result of direct input from downslope processes, and progressive upward increase in cold-water taxa. Periodic increases in bottom current energy and ventilation are indicated by both lithological changes and benthic faunas. Pollen and spores are abundant in all the samples analyzed, together with microcharcoal and dinocysts. Together, these indicate significant changes in terrestrial climate and vegetation comparable with the marine record.

Paleomagnetic measurements identified the Brunhes/Matuyama polarity transition (0.781 Ma) as well as the termination and beginning of the Jaramillo Subchron (C1r.1n) (0.988 and 1.072 Ma respectively). These give reliable confirmation of the biostratigraphic dating for Site U1386, and confirm the relatively high rates of sedimentation through the contourite succession.

Based on the physical property data distinct changes have been identified that are commonly related to boundaries between the defined lithological units. In addition, cyclic variation in natural gamma ray (NGR) and magnetic susceptibility (MS) values, and a persistent covariation of both parameters with sediment color, appear to track decimetric-scale cyclicity noted in lithological character. Especially high magnetic susceptibilities correspond to the turbidite-dominated section between 420-445 mbsf. Below 445 m, low values in NGR and MS conform with a shift in the lithology to debrites and turbidites below a major hiatus.

The pore water profile at Site U1386 is dominated by organic matter diagenesis with a shallow sulfate reduction zone in the top 12.5 mbsf and methanogenesis below. High alkalinity associated with sulfate reduction and anaerobic methane oxidation has resulted in authigenic calcite and dolomite formation. Iron sulfide minerals formed as a consequence of sulfate reduction. A maximum in $\delta^{18}O$ and δD of interstitial water preserves an attenuated signal of $\delta^{18}O$ and δD enrichment of seawater during the last glaciation.

Downhole measurements were made in Hole U1386C to a total depth of 526 mbsf. Despite a certain degree of borehole rugosity, the combination of logs used closely reflects both lithological changes and cementation recorded in the recovered cores. This has allowed us to infer lithologies from some of the gaps in core recovery. Preliminary inspection has also revealed a marked cyclicity from 102-346 mbsf through the contourite section, which seems to relate to Milankovitch precession cycles of around 20 k.y. These data will be carefully scrutinized together with cycles observed in both the lithological and physical properties records.

The measured geothermal gradient at Site U1386 is about 34.3 °C/km and the estimated heat flow is 42.1 mW/m^2.

Highlights

Site U1386 on the Faro Drift recovered a thick Pleistocene-Holocene succession of mud/silt contourites, as anticipated. These showed a continuous record of drift sedimentation over the past 1.9 m.y., at an average sedimentation rate of 35 cm/ky for the past 1 m.y. What was not expected was to reach into the latest Miocene at around 515 mbsf.

We confirmed the classic contourite model of metric-scale bi-gradational cyclicity, with an apparent millennial-scale forcing. There was also evidence of a strong lateral supply of terrigenous material to the bottom currents. We also recognized decimetric-scale cycles characterized by relative abundance and thickness of silty contourites. These are provisionally related to seismic cycles with Milankovitch-scale forcing.

At the base of the main constructional drift there are interbedded turbidites and contourites, underlain by a 40 m thick unit of early Pleistocene turbidite sandstones, which probably represent deposition at sea-level lowstand. These directly overlie a major hiatus of 0.3-2.2 m.y. duration, which we provisionally relate to aggressive erosion by bottom currents sometime after the onset of MOW. The early Pliocene succession comprises bioclastic debrites and turbidites, most likely the result of widespread tectonic activity and slope instability. These events at the very beginning of the Pliocene might be related to the final stages in the opening of the Gibraltar Gateway.