IODP Expedition 339: Mediterranean Outflow
Site U1387 Summary

Background and objectives

Site U1387 (proposed site GC-09A) is located on the southern Iberian Margin (36°48.321' N and 7°43.1321' W) about 29 km SSE of the Portuguese city of Faro, in a water depth of 559.1 m. It is a close companion to Site U1386 at the eastern end of the Faro Drift and part of the larger Cadiz Contourite Depositional System (CDS). Although lying only 4 km to the SE of site U1386, interpretation of the seismic records indicates a slightly reduced Pleistocene section and an expanded Pliocene succession.

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 at this site was to recover a full Pliocene, Pleistocene and Holocene sedimentary succession formed under the influence of the Upper Core of MOW, and also to penetrate the Miocene/Pliocene boundary. As for its companion site, the high rates of accumulation and expanded sedimentary record of this site should permit high-resolution examination of past environmental change (climatic and eustatic).

Site U1387 was occupied on 8 December 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 870 m in the third hole, U1387C. Downhole logging was carried out at Hole U1387C using the Triple Combo, FMS-Sonic and VSI tool strings. Overall recovery for Site U1387 was 97 m (103%) with the APC, 578.4 m (97%) with the XCB, and 409.5 m (71%) with the RCB. The total cored interval for Site U1387 was 1270.7 m and total recovery was 1085m (85%).

Main results

The sedimentary succession at Site U1387 extends for 870 m from the latest Miocene to Holocene. It is divided into four lithologic units (Units I to Unit IV), distinguished on the basis of lithological character and 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, generally organized as bi-gradational sequences. Thin turbidite intercalations occur more commonly than at Site U1386, particularly in the lower 100-150 m of the Unit.

Below a significant unconformity, Unit II is capped by two well-cemented dolomite horizons. For the most part the Unit represents Pliocene sedimentation characterized by a clear cyclic arrangement of lighter-colored facies having turbidite affinity and darker-colored facies of contourite affinity. There is close interaction between processes that requires further study. These processes also affect the nature of bioturbation, which has been, for the most part, continuous throughout. In Unit III, the evidence of downslope re-sedimentation is still more apparent than in Unit II, including poorly-sorted turbidite sandstones, chaotic debrites and slump-units up to 5 m thick. Shallow-water bioclastic debris is common, and re-sedimented lignitic material occurs in places. Below about 680 mbsf there is a 50 m thick section, which includes hard calcite-cemented sandstone turbidites, and showed generally poor core recovery. This Unit is mainly early Pliocene in age, but may start in the latest Miocene.

Unit IV is a relatively thin succession of late Miocene age with a quite different character, being dominated by mid-slope hemipelagic sediments – nannofossil muds and muddy oozes.

Calcareous microfossils (nannofossils, planktonic and benthic foraminifera, and ostracods) are mostly common to abundant, with moderate to good preservation through Lithologic Unit I and IV, and relatively poorer preservation through Units II and III, where considerable reworking is also apparent. The sedimentary record is continuous through the Holocene and Pleistocene to about 1.8 Ma, with an average sedimentation rate of 25 cm/ky. A Plio-Pleistocene hiatus (1.8-3.2 Ma) occurs at 450 mbsf. Below the hiatus, the mean rate is approximately 15 cm/ky although a significant proportion of this section comprises instantaneous downslope deposits. The lowermost Unit is most likely of Messinian age (< 5.8 Ma).

The observed variability in both benthic foraminifer and ostracod distribution reveals significant environmental changes over the last ~5 My, closely comparable with that observed at Site U1386. In general, the Pleistocene succession shows typical upper bathyal assemblages indicative of increased organic matter input and reduced ventilation. There is marked mixing with shelf-derived taxa in the Pliocene part of the succession as a result of direct input from downslope processes, and progressive upward increase in cold-water taxa, as noted also by planktonic assemblages. Periodic increases in bottom current energy and ventilation are indicated by both lithological changes and benthic faunas. Pollen and spores are abundant in most of the samples analyzed, together with microcharcoal and dinocysts. Together, these indicate normal (fresh) supply from Mediterranean forests and grasslands for the Pleistocene, a transitional zone mixed with corroded, reworked forms, and then a Pliocene succession with a notable absence of freshly-derived pollen.

Paleomagnetic measurements identified the Brunhes/Matuyama polarity transition (0.781 Ma), no clear Jaramillo Subchron, but a reliable end of the Olduvai subchron (1.778 Ma) towards the base of Unit I. These give reliable confirmation of the biostratigraphic dating for Site U1387, and confirm the relatively high rates of sedimentation through the contourite succession. Cyclic variation in the intensity of natural magnetic remanence and magnetic susceptibility require further study.

Physical property data show generally high values of natural gamma ray (NGR), magnetic susceptibility (MS) and (bulk) density within the topmost 50 m of Unit I, with lower values down-section. Cyclic variation in values, and the presence or absence of covariation between different parameters (and with sediment color), show a complex tracking of decimetric-scale cyclicity noted in lithological character. In some cases, high magnetic susceptibility values correspond to individual turbidites within the Pleistocene section, but not for those in the Pliocene.

The pore water profile at Site U1387 shows a similar shallow sulfate reduction zone to that found at Site U1386, followed by transition to methanogenesis. This is assumed related to high rates of organic matter accumulation. High alkalinity associated with sulfate reduction and anaerobic methane oxidation has resulted in authigenic calcite and dolomite formation. Iron sulfide minerals also formed as a consequence of sulfate reduction.

Downhole measurements were made in Hole U1387C to a bridged-hole depth of 649 m with the first tool string. There was further bridging at shallower depths for subsequent tool strings. Moderately severe borehole rugosity has severely hampered shipboard interpretation, although the combination of logs used reflects in general both lithological changes and cementation observed in the recovered cores. Apparent cyclicity in some parts of the section will require further study following an attempt to correct for variation in borehole diameter. The sonic log and vertical seismic profile will be useful in refining our interpretation of key reflectors on seismic profiles at this site. Only one downhole temperature measurement was achieved at the site.

Highlights

Although only 4 km apart, Sites U1386 and U1387 on the Faro Drift showed some interesting and significant differences, as well as similarities. There was the same thick Pleistocene-Holocene succession of mud/silt contourites at Site U1387, indicating a continuous record of mounded drift construction over the past 1.8 My, at an average sedimentation rate of 25 cm/ky. Metric-scale bi-gradational contourite cyclicity was common, also with evidence of a strong lateral supply of terrigenous material to the bottom currents, especially before about 1.8 Ma. Decimetric-scale cycles characterized by relative abundance and thickness of silty contourites are most evident on physical property and downhole logs. These correlate well between sites and with probable orbital-scale forcing. At Site U1387, the same extended Pliocene-Pleistocene hiatus as recognized at Site U1386 is also present, but occurs within the drift rather than at the floor of a channel, which was the case at Site U1386. We relate this to a phase of highly active MOW, which lasted for 1-2 My.

Interbedded contourites and turbidites characterize the later Pliocene phase of sheeted drift construction, with clear evidence of process interaction. The early Pliocene is dominated by resedimented facies, including, debrites, slump deposits, and channel-fill turbidite sandstones. This is likely due to widespread tectonic activity and resulting slope instability at a time close to the opening of the Gibraltar Gateway.