**IODP Expedition 339: Mediterranean Outflow**

**Site U1389 Summary**

## Background and objectives

Site U1389 (proposed site GC-11A) is located on the southern Iberian Margin (36°25.515' N and 7°16.683' W) about 90 km W of the Spanish city of Cadiz, in a water depth of 644 m. This is one of two sites in the 'channels and ridges' sector of the larger Cadiz Contourite Depositional System (CDS). It is perched on a relative topographic high, which is currently elevated 50-250 m above the flanking contourite channels, and lies approximately 4 km NW of the of the Guadalquivir diapiric ridge.

We designate this as the *Huelva* sheeted/patch drift, which is in fact a small remnant of a much larger middle-slope sheeted drift system that has been dissected by several contourite channels. Huelva Channel lies along the northern flank and Guadalquivir Channel along the southern flank of Huelva drift. On seismic profiles it shows a well-layered internal acoustic structure with laterally extensive, mainly aggradational seismic depositional units, and widespread discontinuities. There is a complex erosional-depositional relationship between drift and flanking channel. Huelva drift has been developing in this region over the past 4 million years, at least, and is presently under the influence of the Lower Core of the Mediterranean Outflow Water (MOW).

Our primary objective at this site was to recover a Pliocene, Pleistocene and Holocene sedimentary succession formed under the influence of the Lower Core of MOW, and so to compare this record with that found at Sites U1386 and U1387, which formed under the Upper Core of MOW.

Site U1389 was occupied on 21 December 2011. Five 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 990 m in the fifth hole, U1389E. Downhole logging was carried out at Holes U1389A and U1389E using the Triple Combo, FMS-Sonic and VSI tool strings. Overall recovery for Site U1389 was 307 m (104%) with the APC, 464 m (91%) with the XCB, and 352 m (54%) with the RCB. The total cored interval for Site U1389 was 1463.4 m and total recovery was 1123.5 m (77%).

**Main results**

The sedimentary succession at Site U1389 extends for 990 m from the early Pliocene to Holocene. It is represented by a thick, rapidly accumulated, and very uniform series of contouritic sediment, which has been assigned to a single lithostratigraphic unit and divided into five sub-units (Units IA to IE). Unit I is dominated by classic contourite deposition, including calcareous mud, silty mud, sandy mud and silty bioclastic sand lithologies. These are generally organized as bi-gradational sequences and partial sequences, of which base-cut-out, normally-graded sequences are more common that top-cut-out inversely-graded sequences. Carbonate content ranges from 21-35%, and total organic carbon from 0.3-1.8%. The division of Unit I into five subunits is based on subtle changes in the relative abundance of the different lithologies and silt/sand intervals.

Calcareous microfossils (nannofossils, planktonic and benthic foraminifera, and ostracods) are mostly common to abundant, with moderate to good preservation throughout. Pteropod fragments are more common than at any of the other sites, mainly within the uppermost 30 m. The sedimentary record is continuous through the Holocene and Pleistocene to about 2.1 Ma, with a sedimentation rate of between 30-40 cm/ky. A relatively short hiatus (2.1-2.4 Ma) occurs at around 640 mbsf, below which the average sedimentation rate is 25 cm/ky. There is some evidence from lithological, physical property and downhole logging data for two other minor hiatuses, at around 0.4 and 0.9 Ma, but not yet confirmed by the micropaleontological data. The deepest part of the section is < 3.7 Ma.

There is a distinctive variability in benthic foraminifer assemblages, which reveals significant environmental changes through the Pliocene-Holocene succession, closely comparable with that observed at other sites. The upper 0.9 My of the Quaternary shows typical upper bathyal assemblages indicative of increased organic matter input and reduced ventilation. The remainder of the Pleistocene shows lower nutrient supply, greater influence of the MOW, and significant mixing with shelf-derived taxa. Pliocene assemblages suggest high-nutrient, low-oxygen conditions, and generally warmer waters. 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 upper Pleistocene, a transitional zone mixed

with corroded, reworked forms, and no pines, then a Pliocene succession with mostly corroded conifers.

Paleomagnetic measurements identified the Brunhes/Matuyama polarity transition (0.781 Ma), the top and bottom of the Olduvai Subchron (1.778 and 1.945 Ma), the Matuyama/Gauss transition (2.581), the Gauss/Gilbert transition, and potentially three minor excursions. These give reliable confirmation of the biostratigraphic dating for Site U1389, although some of the inferred polarity boundaries need further confirmation**.**

Physical property data show relatively close tracking of magnetic susceptibility and bulk density with the more sand/silt-rich intervals within the Pleistocene succession, but a much more complex pattern within the Pliocene. The downhole distribution of porosities shows higher values in an interval of high interstitial water chlorinity, arguing in favor of a lateral advection of brine-related fluids through more permeable strata.

The pore water profiles at Site U1389 shows distinct maxima in several elements at around 530 mbsf, with relatively sharp transitions above and below. This suggests either a barrier to vertical diffusion or enhanced fluid flux laterally. The increase in concentrations is likely due to dissolution of minerals, most likely carbonates. There is also a strong negative correlation between $\delta^{18}O$ and $\delta D$, which is characteristic of clay mineral dehydration reactions that take place at temperatures greater than 50°C. This requires that the fresh signal is a result of fluid migration from a deeper, higher temperature source.

Downhole measurements were made in Hole U1389A to a depth of 355 mbsf and in Hole U1389E to a bridged-hole depth of 568 mbsf. A good suite of FMS image logs was obtained in Hole U1389A. There is a distinct change in log characteristics at around 320 mbsf, which correlates closely with a lithostratigraphic boundary and with a zone of poor core recovery. This zone would appear to be more sand-rich on the basis of borehole logs, although no sands were recovered by coring. Distinct cyclicity is apparent in some parts of the section, corresponding with both lithological and physical properties data. Nine downhole temperature measurements were made in the top 100 m of section, yielding a geothermal gradient of 20.9 °C/km, relatively lower than at other sites on this expedition

**Highlights**

We recovered core to a total depth of 990 mbsf at Site U1389, the deepest penetration of the expedition. The site lies under the influence of MOW Lower Core and is perched on a topographic high between contourite channels. For much of its Pleistocene history, it has only received sediment from either bottom current or hemipelagic processes. Especially notable is the extreme uniformity of the succession and its rapid accumulation at rates of 25-40 cm/ky. The sediments are distinctively contouritic in character throughout, with mixed terrigenous-biogenic composition and characteristic bi-gradational or partial contourite sequences. Significantly, the long-duration hiatus observed at both Sites U1386 and U1387 on the Faro Drift under MOW Upper Core, and related to a phase of highly active MOW, is reduced at Site U1389 to 2.1-2.4 Ma. Two other minor hiatuses are inferred at around 0.4 and 0.9 Ma, and are also indicative of enhanced MOW at these times.