IODP Expedition 339: Mediterranean Outflow
Site U1391 Summary

Background and objectives

Site U1391 (proposed site WI-01B) is located on the SW Iberian Margin (37°21.532' N and 9°24.656' W) about 50 km NW of the Sao Vicente Cape, in a water depth of 1085 m. This is the most distal of our sites under the influence of MOW. It lies on the broad, gently inclined mid-slope region of the SW Portuguese margin, on which the seismic data indicate an extensive plastered drift that stretches alongslope for about 90 km between the Sao Vicente and Setubal downslope-oriented submarine canyons.

We consider this plastered drift as part of the larger Cadiz Contourite Depositional System (CDS). On seismic profiles it shows a well-layered internal acoustic structure with laterally extensive, mainly aggradational seismic depositional units, and gentle thickening of the Quaternary succession towards the axial region of the drift. Deeper within the section, there are one or more unconformities apparent in the seismic profiles, and potentially some influence of tectonically-induced downslope mass-movement. There is no separate designation of MOW Upper and Lower Cores along the Portuguese margin, although in terms of water depth, Site U1391 would be closer to the Lower Core.

Our primary objective at this site was to recover a Pliocene, Pleistocene and Holocene sedimentary succession formed under the influence of the MOW, and so to compare this record with that found at Sites within the Gulf of Cadiz that are closer to the Gibraltar Gateway. Very little is known about contourite deposition along this margin, so that all data will be new and significant in this regard. It will also provide a direct comparison with hemipelagic sedimentation at Site U1385, which is removed from contourite input and under the influence of North Atlantic Deep Water.

Site U1391 was occupied on 8 January 2012. 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 a total depth of 672 m in the third hole, U1391C. Downhole logging was carried out at Hole U1391C using the Triple Combo and FMS-Sonic tool strings. Overall recovery for Site U1391 was 359 m (105%) with the APC, 331

m (91%) with the XCB, and 269 m (81%) with the RCB. The total cored interval for Site U1391 was 1038.1 m and total recovery was 958.6 m (92%).

Main results

The sedimentary succession at Site U1391 extends for 672 m from the mid Pliocene to Holocene. It is represented by a thick, very uniform series of mud-rich contouritic sediment, with rapid rates of sedimentation through the later Quaternary. It has been divided into two lithostratigraphic units (Units I and II), both of which are dominated by calcareous mud-rich contourite deposition, with more minor lithologies including silty mud, sandy mud, nannofossil mud and biosiliceous mud. Silty bioclastic sand is rare. These lithologies are generally organized as bi-gradational sequences and partial sequences, with bioturbated and gradational upper and lower contacts. Carbonate content ranges from 18 -48%, and total organic carbon from 0.5-1.8%.

Unit I is subdivided into Sub-Unit IA, which has a greater number of silty (and sandy) intervals, as well as a distinct alternation of greenish and reddish-colored units. Sub-Unit IB is even more mud-rich and with mainly grey to dark-grey color cyclicity. The Unit I to Unit II boundary occurs at a possible minor hiatus, below which there is a slightly more mixed system, including a thin debrite, some minor faulting, more biosiliceous material, and a 50 cm-thick, well-cemented, dolomitic mudstone below a probable second minor unconformity. The mud-rich sediments in Unit II have an intermediate contourite-hemipelagite aspect.

Calcareous microfossils (nannofossils, planktonic and benthic foraminifera, and ostracods) are mostly common to abundant, with moderate to good preservation throughout. The sedimentary record appears to be relatively continuous through the Quaternary period, with an average sedimentation rate of 27 cm/ky for the later Pleistocene and 17 cm/ky for the early Pleistocene. However, there may be minor hiatuses present at around 0.7-0.9 Ma and 2.41-2.5 Ma. The average sedimentation rate for the Pliocene section recovered is 13 cm/ky, although there is also evidence for a minor hiatus at 3.0-3.19 Ma or, alternatively, for much reduced rates of sedimentation at this time.

As found at the other CDS sites, there is a distinctive variability in benthic foraminifer assemblages, which reveals significant environmental changes through the Pliocene-Holocene succession. In general, the later Quaternary shows typical upper bathyal assemblages that are indicative of increased organic matter input and reduced ventilation; this signature is also evident during some earlier intervals. The remainder of the Quaternary and Pliocene succession shows lower nutrient supply and improved or variable ventilation. Certain signature taxa show somewhat lesser influence of the MOW on the Portuguese margin than in the Gulf of Cadiz. Although nannofossils show common reworking in parts of the succession, it is less evident than at the Cadiz sites, and there is no evident reworking of planktonic foraminifers. Pollen and spores are abundant in most of the samples analyzed, together with microcharcoal and dinocysts. They show a similar assemblage and pattern to that found at the other sites on this expedition.

Paleomagnetic measurements showed that the Brunhes/Matuyama polarity transition (0.781 Ma) occurs below 175 mbsf, but is not clear perhaps due to the inferred hiatus across this boundary. Specific identification was made of the top and bottom of the Olduvai Subchron (1.778 and 1.945 Ma), and the Matuyama/Gauss transition (2.581). These give reliable confirmation of the biostratigraphic dating for Site U1391, although some of the inferred polarity boundaries need further confirmation**.**

As has been observed at the other sites drilled, physical property data show relatively close tracking of magnetic susceptibility and bulk density in much but not all of the section. These may correlate or anti-correlate with NGR values, and with color reflectance (L* and a* values). Both larger-scale trends and smaller-scale cycles are evident, with some correlation at the small-scale with lithology. In lithostratigraphic Unit II, there is much lower NGR variability and very low MS values.

The pore water profiles at Site U1391 show some significant distinction from those of Site U1385, commensurate with their deposition under MOW rather than North Atlantic Deep Water. Rates of sedimentation and hence of organic matter accumulation are greater at Site U1391, which makes for a shallower zone of sulfate reduction.

Downhole measurements were made in Hole U1391C to near the bottom of the hole at a depth of 668 mbsf. The borehole was very rugose with many narrow washouts that

affected log quality. There are minor changes in log characteristics at around 562 mbsf, which correlates closely with a lithostratigraphic boundary. The deeper interval has generally lower natural gamma ray values, and includes two zones with poor core recovery that may 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. Ten downhole temperature measurements were made in the top 146 m of section, yielding a geothermal gradient of 14.2 °C/km, the lowest on this expedition.

The three holes cored provide a complete composite stratigraphic section to the base of the APC cored section at 171 mbsf, and a virtually complete section all the way down to 354 mbsf. The section below this is cored only in Hole U1391C to a total depth of 671.5 mbsf, with some short gaps between cores and larger gaps in the few instances where core recovery was low.

Highlights

We recovered core to a total depth of 672 mbsf at Site U1391 on the SW Portuguese margin. The site lies under the influence of MOW at the depth of the Lower Core and penetrates through a relatively complete Quaternary and late Pliocene section of a plastered contourite drift. This is the most distal of our MOW sites and is distinctly more mud-rich throughout than those in the Gulf of Cadiz. Nevertheless, sedimentation rates (27 cm/ky) for the later Quaternary are equally as high as those of the Faro Drift, and the contouritic signature of uniformity and bi-gradational sequences is ever present. Important similarities with other sites include an upward increase in sedimentation rate, the number of silt/sand intervals and organic matter supply, as well as reduced ventilation. These all support enhanced MOW influence through the Quaternary. Hiatuses, possible hiatuses or much reduced sedimentation rates are noted at around 0.7-0.9, 2.4-2.5 and 3.0-3.2 Ma, all of which are recognized at one or more of the Cadiz sites. These are interpreted as episodes of enhanced MOW and bottom current activity.