Mediterranean Outflow - EXPEDITION IODP 339

Sediments cored along the southwestern Iberian margin during Integrated Ocean Drilling Program Expedition 339 provide constraints on Mediterranean Outflow Water (MOW) circulation patterns from the Pliocene epoch to the present day and a reference site for paleoclimate studies (U1385 – Shackleton site) (Fig. 1).
The large gravity deposits of the Pliocene and Pleistocene in the Gulf of Cádiz

The base of the Faro contouritic drift (IODP Site U1386) on the northern margin of the Gulf of Cádiz (Algarve margin) is characterized by two sequences of frequent gravity deposits with different ages and compositions. Among these gravity deposits, several relatively thick debrites (up to 12 m) have been observed and studied in detail (Ducassou et al., 2016). Sedimentological analyses have been performed and because of non-turbulent behavior of debris flows, detailed micropaleontological studies could be realized. Planktonic foraminifera thus allowed establishing a detailed biostratigraphy of these deposits. Benthic foraminifer and ostracod assemblages were used to evaluate the origin of the sediment composing these debris flows and estimate their run-out distance.

These debrites are dated from Early Pliocene and early Pleistocene, and were deposited in a mesobathyal environment. They comprise silty mud clasts and matrixes with sand content up to 34%. The Early Pliocene debrites are bioclast-rich whereas the Early Pleistocene debrite is enriched in terrigenous particles. The data indicates that these debrites were triggered on the continental shelf and traveled less than 100 km, eroding the seafloor all along their path for the Early Pliocene debrites and only the first part of their path for the early Pleistocene debrite. Matrixes originate from failure areas whereas eroded sediments along the flow pathway are incorporated into the flow as clasts. High abundance of shelf fauna during the Early Pliocene and great supply of terrigenous particles from rivers during the early Pleistocene in the south-western Iberian margin have favored gravity flows from the continental shelf to the slope. The contouritic paleo-moat of the Faro drift has been a determining channeling feature for gravity flows along the Algarve margin during the early Pleistocene, testifying of the strong interaction between MOW circulation and downslope processes. Tectonic and diapiric activities were significant during Early Pliocene and early Pleistocene on the Algarve margin and could have been triggering parameters of failures related to these debris flows.

The Contourite Depositional Systems in the Gulf of Cádiz

The Contourite Depositional Systems (CDS) in the Gulf of Cádiz and on the West Iberian margin preserve a unique archive of Mediterranean Outflow Water (MOW) variability over the past 5.3 Ma. These CDS have been recently drilled...
in several places during the IODP Expedition 339. These drill sites now offer a new window to the internal Pliocene and Quaternary architecture of the CDS. In this study, we use downhole and core Gamma Ray (GR) shipboard data acquired from 5 sites drilled in the CDS along the middle slope and 1 site drilled in deeper setting of the lower slope, out of the MOW path. The GR data primarily tracks the clay content in the sediment and is the expression of sediment supply and, for sites drilled in the CDS, of the bottom current processes. Both appear astronomically controlled as shown by spectral analysis performed on the GR data (Lofi et al., 2016). Results also reveal that the GR log patterns correlate well across the sites over the last 1.4 My. Several GR horizons corresponding to drops in GR values were identified, most of which fit with coarse-grained deposits observed in cores and interpreted as contourite beds. The GR horizons are interpreted as isochronous horizons, providing a regional scale chronostratigraphic framework for the CDS depositional records with an accuracy of ~20 ky. We further assess the spatial and temporal variability of the CDS hiatuses at the regional scale.

The Shackleton site and the paleoclimate off the southwestern Iberian margin (Fig. 3)

One of the goals of the IODP Mediterranean Outflow (MOW) Expedition 339 has been unraveling the forcings controlling the magnitude and climate variability of past interglacials in southwestern Iberia, periods marked as at present-day by low ice volume. To this aim this expedition collected a deep-sea sedimentary sequence in the southwestern Iberian margin covering the last 1.5 million years. We focused on three interglacials: a) the best orbital analogs to our present interglacial, MIS 19 (~800,000 years ago, ka) and MIS 11 (~400 ka) (Oliveira et al., 2016; Sanchez Goñi et al., 2016; Desprat et al., 2017), and b) MIS 31 (1,070 ka) an important analog for ongoing and projected global warming (Oliveira et al., 2017). We applied a land-ocean direct correlation approach based on the study of terrestrial (pollen), marine and ice climate indicators from the same sample set. We found that MIS 31 and MIS 11 super-interglacials, the warmest at high latitudes, were not particularly warm in southwestern Iberia. MIS 31-MIS 19 and MIS 11 were marked by dominant ~5000-yr and 10,000-yr cyclicities in Mediterranean forest contractions, respectively, indicating repeated meridional shifts in the direction of the North Atlantic westerlies. These cooling and drying events were associated with warmth in the subtropical gyre leading to repeated air-sea thermal contrasts in southwestern Iberia. These cycles are not systematically associated with iceberg discharges and, therefore, to high latitude forcing. Their origin seems to be the low-latitudes triggered by the harmonics of precession. The observed thermal air-sea decoupling in southwestern Iberia enhanced moisture production that may lead to ice growth at the MIS 19c/19b and MIS 11c/11b transitions. The freshwater fluxes during MIS 19ab and MIS 11ab associated with stronger forest contractions amplified the cooling events in the North Atlantic promoting further cooling and leading to MIS18 and MIS 10 glaciations, respectively. Different dominant cyclicity of MIS 1 (~2500-yr cycles) and MIS 19 challenges the similar duration of the Holocene and MIS 19c.
Our work has also aimed to understand the interplay between the climate of southwestern Iberia and MOW during two iconic deglaciations from glacial to high latitude super-interglacials, MIS 32 to MIS 31 and MIS 12 to MIS 11, (Sánchez Goñi et al., 2016). The comparison between climate and MOW changes shows a concurrent maximum in both MOW strength (minimum percentages of clay in the lower MOW) and regional aridity (highest percentages of semi-desert plants) during MIS 12. MIS 11c was, in contrast, characterized by weak MOW bottom current and wet conditions (high percentages of Mediterranean forest and heathlands). The climatic conditions between MIS 31 and MIS 30, ~1.1-1.05 million years ago (Ma) were less contrasted with weaker MOW and wetter conditions during MIS 30 than those prevailing during MIS 12. The increase in fine particles from these glacial to interglacials and in coarse fraction from interglacials to glacial was coeval with forest and semi-desert expansions, respectively, indicating the lowering/enhancement of MOW strength during periods of regional increase/decrease of moisture. The strongest regional aridity during MIS 12 coincides with a maximum in MOW strength. This MOW intensification may have pre-conditioned the North Atlantic by increasing salinity, thereby triggering the strong resumption of the Meridional Overturning Circulation that could contribute to the great warmth that characterizes the high latitude MIS 11c super-interglacial.

Finally, the study of dinoflagellate cysts preserved in IODP site U1385 and neighboring sites during the nine interglacials of the last 800,000 years has revealed that surface waters around Iberia were characterized by the repetitive occurrence of the same dinocyst assemblage (Eynaud et al., 2016). This study also shows coherent features on both sides of the Gibraltar Strait indicating a constant interchange of populations and a permanent connection between Atlantic and Mediterranean marine biomes, even during sea-level low stands.

Emmanuelle Ducassou and Maria F. Sánchez Goñi
(EPOC, Bordeaux)

References


