Obstacle-related contourite drifts in the El Araiche Mud Volcano field, Southern Gulf of Cadiz

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Abstract: *This study presents geophysical evidence for the existence of at least three different contourite drifts at water depths between 550 and 800 meters in the El Arraiche Mud Volcano field (southern Gulf of Cádiz).The drift systems are affected by local tectonism (e.g. uplift of ridges) and by the presence of both mud volcanoes (e.g. Gemini Mud Volcano) and cold-water corals (e.g. at the foot of the Pen Duick Escarpment).The drift system at the foot of the Pen Duick Escarpment has been studied in detail and originated at the base of the Quaternary, with a major change around the Mid-Pleistocene Revolution. An Antarctic Intermediate Water origin is inferred as the driving mechanism for this drift system and the presence of Mediterranean Outflow Water could not be substantiated. Likewise, at the two more northern drift systems (Renard and Vernadsky drift) Mediterranean Outflow Water is currently not present. LADCP data indicate the presence of slow (<10cm.s^{-1}) bottom currents in the moats of the drifts. The Pen Duick drift experiences a general west to east flow direction, while the Renard and Vernadsky drifts experience an east to west flow direction, implying the last two could possibly originate from the same watermass.*

Key words: *obstacle-related drifts, Antarctic Intermediate Water, El Araiche Mud Volcano Field, seismic stratigraphy, LACDP.*

INTRODUCTION

The northern Gulf of Cádiz is receiving a lot of attention due to IODP Expedition 339 which drilled through the contourite depositional system created by the Mediterranean Outflow Water (MOW) (Expedition 339 Scientists, 2012). The temporal and lateral variation of this contourite system has been described in great detail, e.g. by Llave et al. (2011). In contrast, the southern Gulf of Cádiz, south of the Strait of Gibraltar, is far less studied, although diapiric ridges, cold-water corals and mud volcanoes are present (Van Rensbergen et al., 2005). This study focuses on several small obstacle-related drift systems in the El Araiche mud volcano field (Fig. 1). A description of the different drifts and their relation to the past and present oceanography is the aim of this research.

MATERIAL AND METHODS

A large high-resolution, single channel, sparker, reflection seismic dataset (>1500km), obtained during four campaigns (between 2002 and 2013), and a SIMRAD EM 1002 multibeam dataset (700km²) have been used in order to describe the drift system at the foot of the PDE. The seismic profiles have been processed with the DECO geophysical RadexPro processing software, applying a bandpass and swell filter, spike removal and amplitude corrections.

The oceanography of the El Arraiche Mud Volcano field was interpreted from CTD data from the World Ocean Database (temperature and salinity) (http://www.nodc.noaa.gov/OC5/WOD/pr_wod.html) and displayed in Ocean Data View (http://odv.awi.de/). CTD (SeaBird SBE19) and LADCP (Teledyne RDI ADCP 300kHz) data acquired during the 2013 Belgica campaign "COMIC" were also used in this study.

RESULTS AND DISCUSSION

The multibeam data (Fig. 1) show the presence of several important features: the Renard and Vernadsky Ridge, numerous mud volcanoes (e.g. Gemini Mud Volcano) and channels on the seabed in the area.

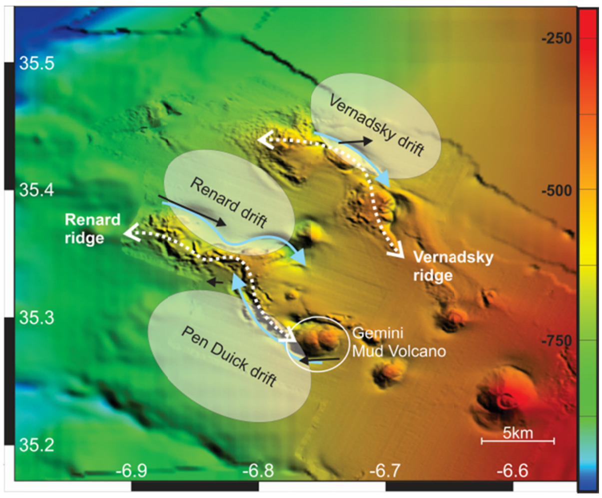

FIGURE 1. Multibeam bathymetric map of the El Arraiche area with indication of the three observed drift systems. The light blue arrows indicate the position of the different moats and the inferred flow directions in them. The black arrows show the direction and relative bottom current strength, derived from the preliminary LADCP data.

Based on the location of the drifts, the moats and the coriolis deflection, the directions of the bottom currents are inferred (light blue in Fig. 1). These are compared to preliminary LADCP-results, acquired during the June 2013 Belgica campaign (indicated by the black arrows in Fig. 1). The highest bottom current velocities (about 8-10cm.s^{-1}) are recorded just north of the Renard ridge. South of the Gemini mud volcano, velocities exceeding 5cm.s^{-1} are recorded. Except for the Vernadsky drift, the inferred direction of bottom currents agree nicely with those observed in the LADCP data.

The seismic stratigraphy of the Pen Duick drift consists of 5 units: the lower 2 are affected by the uplift of the Pen Duick Escarpment (PDE) and the upper 4 units are intersected with mud extrusions from the nearby Gemini Mud Volcano (Fig. 2). The Pen Duick drift consists of a pre-contourite (hemi-)pelagic phase, a phase with sheeted drift deposits (2.6Ma to 0.92Ma) and a phase with mounded drift deposits (920ka till recent). Within unit 3 (920 – 575ka), three small (<50ms TWT) mounds are present, resembling cold-water corals (Vandorpe et al. 2014).

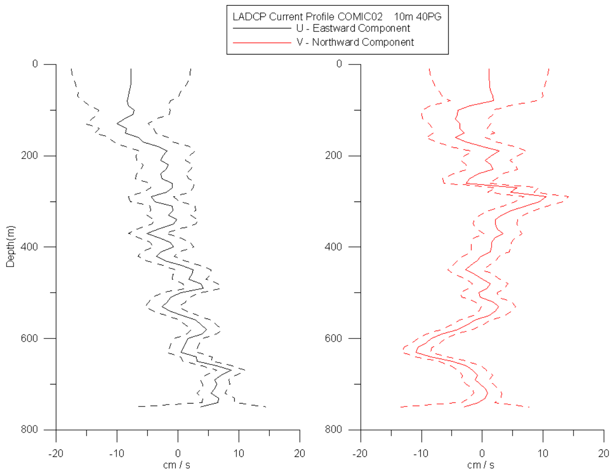

FIGURE 2. Preliminary result of a LACDP profile in the Renard drift (35°22.856'N and 6°50.726'W) at a water depth of 745m.

The chronostratigraphy of the Pen Duick drift differs from MOW-controlled drifts in the Northern Gulf of Cádiz (Llave et al., 2011) and the Le Danois area, Bay of Biscay (Van Rooij et al., 2010). Also, the CTD data do not indicate the presence of MOW at the foot of the PDE (Vandorpe et al., 2014). Both observations indicate that MOW is not involved in the build-up of the drift. Antarctic Intermediate Water (AAIW) is proven to be present in the area (e.g. Vandorpe et al., 2014) and could be intensified by the deflection against the Gemini Mud Volcano and the PDE. The Renard and Vernadsky drifts are not necessarily influenced by the same bottom currents as those responsible for creating the Pen Duick drift due to the contrasting direction (west- versus eastwards) of the bottom currents. Although, a secondary flow pattern around the complex topography of the Renard Ridge is also a possibility (Martins et al. 2014). Which bottom currents and which water mass are involved in the build-up of the Renard and Vernadsky drifts is the aim of this ongoing research.

CONCLUSIONS

The El Arraiche mud volcano field yields several examples of obstacle-related drift deposits. The Pen Duick drift is probably created by the deflection of AAIW against two topographies. The Renard and Vernadsky drift are not necessarily influenced by the same water mass as LADCP data indicate a different current compared to the Pen Duick drift, but a complex flow pattern around the Renard Ridge cannot be excluded.

ACKNOWLEDGEMENTS

The authors would like to thank the FWO for financing this research (KaN Contourite-3D) and the captain and crew of the R/V Belgica.

REFERENCES

Expedition 339 Scientists, 2012. Mediterranean outflow: environmental significance of the Mediterranean Outflow Water and its global implications, Integrated Ocean Drilling Project Preliminary Reports, 339.

Llave, E., Matias, H., Hernández-Molina, F., Ercilla, G., Stow, D., Medialdea, T., 2011. Pliocene–Quaternary contourites along the northern Gulf of Cadiz margin: sedimentary stacking pattern and regional distribution. Geo-Marine Letters 31, 377-390.

Martins, I. & Vitorino, J., 2014. A physical oceanography contribution to understand the processes affecting El-Arraiche Mud Volcano field (NW Moroccan Margin). 2nd Deep-Water Circulation Congress, Ghent, Belgium.

Van Rensbergen, P., Depreiter, D., Pannemans, B., Moerkerke, G., Van Rooij, D., Marsset, B., Akhmanov, G., Blinova, V., Ivanov, M., Rachidi, M., Magalhaes, V., Pinheiro, L., Cunha, M., Henriet, J.-P., 2005. The El Arraiche mud volcano field at the Moroccan Atlantic slope, Gulf of Cadiz. Marine Geology 219, 1-17.

Van Rooij, D., Iglesias, J., Hernández-Molina, F.J., Ercilla, G., Gomez-Ballesteros, M., Casas, D., Llave, E., De Hauwere, A., Garcia-Gil, S., Acosta, J., Henriet, J.P., 2010. The Le Danois Contourite Depositional System: Interactions between the Mediterranean Outflow Water and the upper Cantabrian slope (North Iberian margin). Marine Geology (2010) 274, 1-20.

Vandorpe, T., Van Rooij, D., de Haas, H., 2014. Stratigraphy and paleoceanography of a topography-controlled contourite drift in the Pen Duick area, southern Gulf of Cádiz. Marine Geology 349, 136-151.