Research Networking Programmes

Short Visit Grant ☒ or Exchange Visit Grant ☐

(please tick the relevant box)

Scientific Report

The scientific report (WORD or PDF file – maximum of eight A4 pages) should be submitted online within one month of the event. It will be published on the ESF website.

Proposal Title: Phyiscal oceanography of the El Arraiche area, southern Gulf of Cadiz

Application Reference N°: 6870

1) Purpose of the visit

The aim of the visit to the Instituto Hidrografico in Lisbon was to unravel the present-day oceanography of the El Arraiche area (southern Gulf of Cádiz) and relate this to the sedimentological features observed on the seafloor. The presence of tectonic ridges, mud volcanoes and cold-water coral mounds influence the bottom currents and may create contourite deposits. These contourite deposits can be used to unravel the depositional environment in which the cold-water corals thrived in this area. Specifically, processing of LADCP data (acquired in the summer of 2013) and analyses of nutrient data (from a 2009 HERMIONE cruise) were the goals of this short visit.

2) Description of the work carried out during the visit

The work carried out during this stay included processing of LADCP data, analyses of nutrient data and modelling the response of bottom currents when interacting with the topographic obstacles. The results of these methods were compared to the presence of sedimentological features on the seafloor and subsurface.

1. Processing of LADCP data

In the summer of 2013, during the "COMIC" campaign onboard the R/V Belgica, 11 Lowered Acoustic Doppler Current Profiler (LADCP) profiles have been obtained in the El Arraiche area. The goal of these profiles was to characterize the bottom currents around the Renard and Vernadsky ridge. The processing of these data was done using the LDEO matlab script, originally described by Fischer and Visbeck (1993) and refined by

Visbeck (2002). The different steps required to process the data have been described by Thurnherr (2005). The scripts were adapted to be compatible with the data obtained during the COMIC campaign. Paths had to be defined, CTD files created for the .csv files and navigation files had to be set into Julian dates. The matlab scripts were ran in an older version of windows (using virtual box software), as they were not yet updated to the newest matlab versions. In the matlab-scripts themselves, start- and endtimes of the casts had to be defined and the correct positioning and depth values inserted. For the first 3 of 11 profiles, no problems were encountered. For the remaining 8, too many spikes were present in the CTD data and due to this, the last 8 profiles have been processed without CTD data. The spikes in the data were most likely caused by a faulty CTD cable. After a quality check, figures were made, displaying the direction and intensity of the currents at different depth positions on a multibeam base map.

2. Analysis of nutrient data

During the 2009 HERMIONE campaign onboard the NRP "Almirante Gago Coutinho" , nutrient data (Si, PO_4, NOx, NO_2, NH_3) have been gathered in a small grid covering the El Arraiche Mud Volcano Field. The data from the positions closest to the bottom have been plotted onto a multibeam base map in order to be able to distinguish the pathways of the AAIW, MOW and shelf waters. The delineation of the different water masses was based on literature (e.g. Machin et al. (2006) and Louarn and Morin (2011)).

3. Modelling of bottom currents

Several small-scale topographic features are present in the area, e.g. mud volcanoes, ridges,etc. They all influence the bottom currents. Whether a current detaches from an obstacle or circles around it depends on three parameters according to Marschal and Tansley (2001): a beta effect, vortex stretching and changes in streamline curvature. Batteen et al. (2007) adapted these formulas to fit with an eastern boundary current and derived that current speed, curvature and coriolis forcing are the most important factors controlling the flow regime. In the El Arraiche area, the effect of the Renard ridge and the mud volcanoes on the behaviour of the bottom currents has been investigated. Calculations can indicate whether the current detaches from the feature or sticks to it. This can be done by changing the parameters (slope, diameter, coriolis parameter, …). Also, the effect of internal tides on sediment dispersal and the link with sedimentary features has been investigated. This was done mostly by extensive discussions with Joao Vitorino and Ines Martins. The possible currents in that region were compared to the sedimentary deposits around the topographic obstacles.

4. Presentation of the ongoing PhD work

And the end of my stay, I gave a presentation of my ongoing research (both the contourites in the El Arraiche area and the initial results on the CT scans of contourite cores). This presentation took into account the initial results obtained during this visit and also aimed to continue and improve the collaboration between the two institutes.

3) Description of the main results obtained

The LADCP data indicate an overal northward current up till at least 800 meters water depth in the Al Arraiche area. Based on the literature, one would expect an eastward surface and central current (part of the Azores front), but the data clearly

indicate an overall poleward current over most of the water column (e.g. at 400 meters water depth, Fig. 1). Although you have to keep in mind that our data only show the situation at a given time and do not indicate temporal variations. In the north, close to Gibraltar, the upper currents have higher velocities (>10 cm/s), while further south, velocities range between 3 and 15 cm/s with an average of about 7 cm/s. The northward current is in agreement with a poleward recirculation due to upwelling along the northwestern African shoreline.

Along Renard ridge, bottom currents are more or less directed "along ridge", west-northwestwards along the southern edge of the ridge and eastwards along the northern. Station 5 is inconsistent with this pattern, but this may be due to daily/weekely/… variations of the bottom currents. North of Vernadsky ridge, a southward bottom current is observed, which is more or less parallel to the ridge. Most of the measurements are in agreement with the sedimentological features observed on the seafloor (the presence of several drift deposits and the moats associated with them).

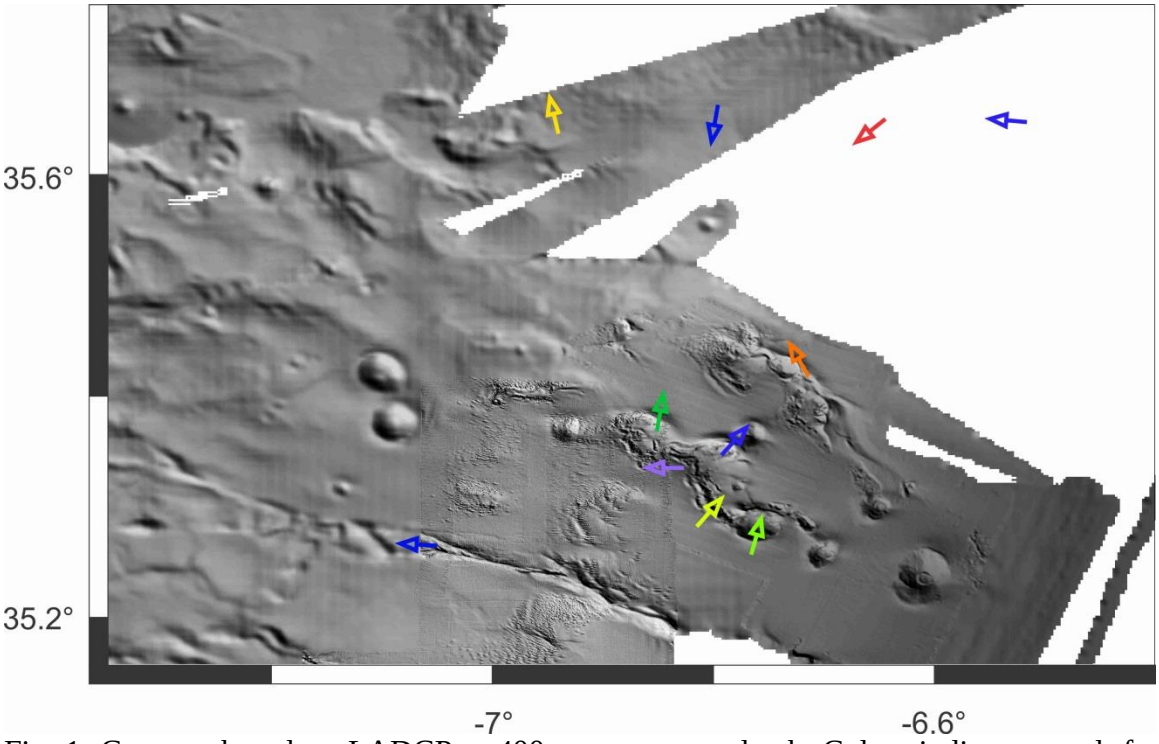

Fig. 1: Currents based on LADCP at 400 meters water depth. Colors indicate speed: from blue (low) over green (average) to red (fast).

The nutrient data (Si, PO_4, NOx, NO_2 and NH_3) indicate the pathways of the watermasses present within the area (Fig. 2 displays the NH_3 data as an example). Surface and Central waters have a low Si-content and are observed above 600-700 meters water depth. Modified Antarctic waters are known to have higher nutrient values (especially Si whose values are between 10.5 and 11.9) and are observed between 700 and 1000 meters in the El Arraiche area. Close to Gibraltar, the first indications of a westward push of the modified Antarctic waters are seen. However, more data are required to further prove this. The Mediterreanean waters in the region have lower nutrient concentrations compared to modified Antarctic waters and North Atlantic Deep Water and can thus be recognized as a "negative

anomaly" on the base map. Mediterranean waters seem to be present between 1100 and 1500 meters, but more stations are required to better delineate the position of Mediteranean Waters. Si and NOx seem to be the most promising nutrient for doing this.

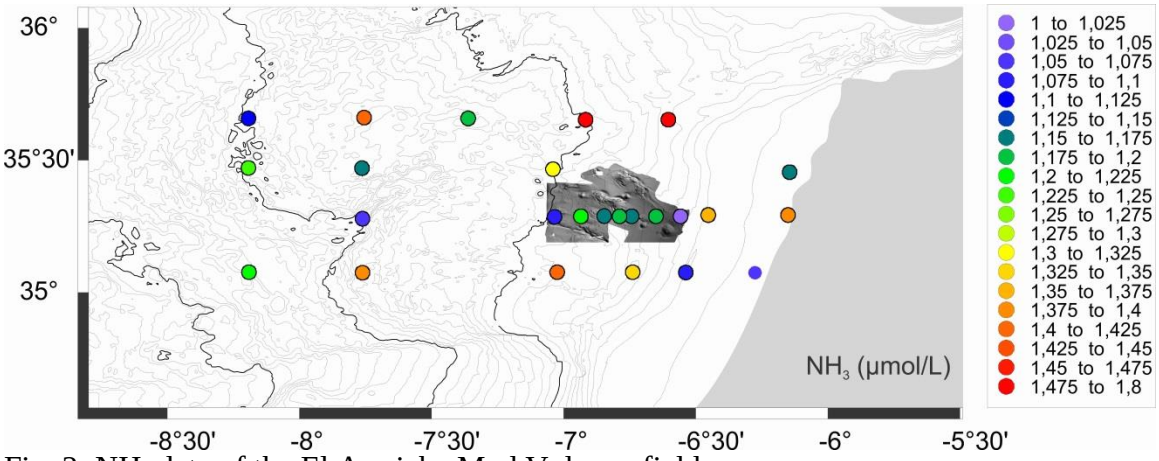

Fig. 2: NH_3 data of the El Arraiche Mud Volcano field.

The modelling results based on the papers of Batteen et al. (2007) and Marshall and Tansley (2001) are yet to be finished. First indications however point out that a bottom current up till about 10 cm/s can turn around Renard ridge without detachment, but further calculations are required to confirm this. If this hypothesis is true, it could suggest one continues bottom current flowing along the Renard ridge. Deccelarations and accelerations of this current may then be able to create the observed contourite deposits.

The poleward current (present between 100 and 700 meters water depth) is influenced by the mud volcanoes. Velocities of this current are generally between 2 and 15 cm/s with a mean around 7 cm/s. Based on this velocity (and depending on the slope), the maximum size of a mud volcano after which detachment does not longer occur is around 5000 meter (which is the diameter of Al Idrissi, the biggest mud volcano). These first results indicate that a current can be influenced by mud volcanoes, but most likely will still detach from it. However, further calculations are required to confirm this.

Internal tides are known to affect the slopes of the northwestern African margin. Initial mooring-results indicate an east-west orientation of the currents associated to this process. The direction of these currents is in agreement with the orientation of the channels around Al Idrissi and Fiuza mud volcano.

4) Future collaboration with host institution (if applicable)

In the future, Ghent University and Instituto Hidrografico will continue collaborating on several projects. Also in the framework of this PhD, the oceanography of the area will be further analyzed and linked to the prevailing sedimentological features. In the near future, the results of the modelling will be exchanged and both the oceanographic and the sedimentological data will be processed into a paper.

5) Projected publications / articles resulting or to result from the grant *(ESF must be acknowledged in publications resulting from the grantee's work in relation with the grant)*

Vandorpe T., Van Rooij, D., Hebbeln, D., Vitorino, J. and Martins, I. In prep. The connection between sedimentological features and bottom currents in the El Arraiche area, Southern Gulf of Cádiz. Marine Geology (special issue)

Exptected to be submitted in May 2015

6) Other comments (if any)

I would like to thank ESF and COCARDE for this short visit grant. It really helped linking the oceanographic and sedimentological data. The discussion with Joao Vitorino and Ines Martins enabled me to get a clear insight into the oceanography of the area and relate this to the sedimentological features observed in the seismics. This part will be a valuable asset to my PhD and result in an innovative paper.