Radio-density signal of bigradational sequences adjacent to the Southern Channel: a tomographic approach to contourite deposits in the the Gulf of Cádiz.

Señal de radiodensidad de las secuencias bigradacionales adyacentes al Canal Meridional: aproximación tomográfica a los depósitos contorníticos del Golfo de Cádiz.

A. Mena[1], M. García[2,3], G. Francés[1], M. Pérez-Arlucea[1], F.J. Hernández-Molina[3], L.M. Fernández-Salas[3]

1 Dpto. Xeociencias Mariñas e Ordenación do Territorio. Facultade de Ciencias do Mar. Universidade de Vigo. Avda. das Abelleiras s/n 36310. Vigo, Pontevedra. anxomena@uvigo.gal, gfrances@uvigo.es.
2 Instituto Andaluz de Ciencias de la Tierra (CSIC-UGR). Avda. de la Palmeras 4, 18100 Armilla, Granada. m.garcia@csic.es
3 Instituto Español de Oceanografía, Centro de Cádiz. Muelle Pesquero S/N, 11006 Cádiz, Spain. luismi.fernandez@ieo.es
4 Department of Earth Sciences, Royal Holloway University of London. Egham Hill, Egham TW20 0EX, UK. javier.hernandez-molina@rhul.ac.uk

Abstract: *The tomographic study of three gravity cores obtained in a transect crossing different sedimentary environments through the Southern Channel of the Contourite Depositional System of the Gulf of Cádiz, allows correlating the radio-density values of the sediment with its grain size and composition. In the studied cores an increase in radio-density is observed through the transect rom out of the channel towards the inner part, where the MOW (Mediterranean Outflow Water) velocity is more intense. Since the grain size is linked in this study area to the speed of the MOW and its erosive / depositional capacity, the variations in radio-density, and therefore, in grain size, can be tentatively correlated with variations in the e MOW speed. In this way, at least three bigradational sequences typical of the contourites sequence model can be observed and could correspond to at least three major pulses of current intensification*

Keywords: *CT-scan, radio-density, bigradational sequences, contourites, Gulf of Cádiz.*

Resumen: El estudio tomográfico de tres testigos de gravedad obtenidos en un transecto que atraviesa distintos ambientes sedimentarios a través del Canal Sur del Sistema Deposicional Contornítico del Golfo de Cádiz, permite correlacionar los valores de radio-densidad del sedimento con su composición y tamaño de grano. En los testigos estudiados se observa un aumento de la radiodensidad a medida que nos acercamos o introducimos en el canal siguiendo el transecto y la velocidad de la MOW (Agua Mediterránea de Salida) se intensifica. Al estar el tamaño de grano ligado en esta área de estudio a la velocidad de la MOW y su capacidad erosiva/deposicional, las variaciones de radiodensidad, y por tanto, de tamaño de grano, se pueden correlacionar tentativamente con variaciones en la velocidad de esta masa de agua. De esta manera, se pueden observar al menos tres secuencias bigradacionales típicas del modelo de secuencia contornítica que se corresponderían con al menos tres pulsos principales de intensificación de la corriente.

Palabras clave: CT-scan, radio-densidad, secuencias bigradacionales, contornitas, Golfo de Cádiz.

INTRODUCTION

The INPULSE Project focuses on the interactions between the oceanographic and sedimentary processes in the nothern continental slope of the Gulf of Cadiz. In this area, the extensive Cádiz Depositional System (CDS) has evolved since the instauration of the present-day oceanographic exchange of water masses through the Strait of Gibraltar after the Late Miocene. This system results from the interaction between the Mediterranean Outflow Water (MOW) and the sea sea-floor topography.

During the INPULSE cruise (2019) on board of the R/V Ángeles Alvariño three gravity cores, IN19-GC 35(690 meters below sea level, mbsl), 36 (629 mbls) and 37 (715 mbsl), were recovered in the exploration Zone 3 along a transect across the Southern Channel, in the vicinities of the Strait of Gibraltar (Fig. 1). The sites of these cores correspond with the proximal scour and sand ribbons sector (sector 1; 37) and the overflow sedimentary lobe sector (sector 2; 35 and 36), characterized by an intense and turbulent MOW flow and with separate small MOW fluxes respectively (Hernández-Molina et al., 2006). The overflow sedimentary lobe sector presents sedimentary features linked to the interaction of the MOW with the diapiric structures and with the overflow of this current from the sandy bank which divides sector 1 and 2 and constitutes the meridional limit of the Southern Channel (Hernández-Molina et al., 2014).

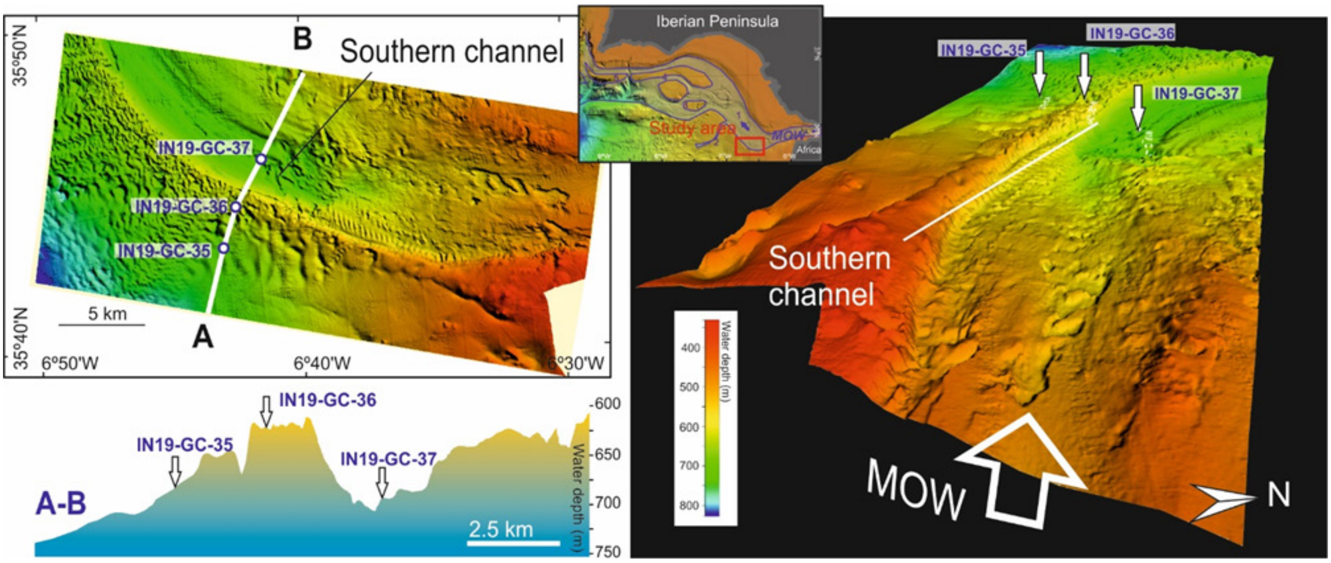

FIGURE 1: Bathymetry, 3D projection and relative position of the studied gravity cores in the South-North transect through the Southern Channel of the Gulf of Cadiz.

The main objective of this work is to identify and characterize the relationship between the MOW velocity and the physical properties (radio-density) of the sediment by means of the tomography (CT-scan) technique.

DATA AND METHODS

The tomography (CT-scan), allows us to obtain images and numerical radio-density data with a direct correlation with sediment properties. The three cores were analysed before opening using the CT-scan from the University Veterinarian Hospital Rof Codina of Lugo (Galicia) using a Hitachi ECLOS 16 Multislice CT. Images were obtained using free software MRicro (Rorden and Brett, 2000) and the data were treated and processed using the software anidoC and its acquisition protocol (Mena et al., 2015).

AnidoC allows us to extract numerical data radio-densities histograms (Fig. 2) and radio-densities profiles (Fig. 3) from the CT-scan numerical data for each analysed core. Besides, this software extracts the abundance profile of the data by ranges of radio-density previously selected.

RESULTS AND DISCUSSION

2D representative images of the three cores were obtained from the multi-slice tomographic results (Fig. 3), trying to optimize the visualization window with the radio-density variations (Fig. 2) and a representative colour scale). The abundance of data in the selected ranges (Fig.2) was calculated. These ranges were defined in base of the histogram distribution trying to identify the main radio-density populations (Fig. 2) that tentatively can be correlated with sediment properties, such as the grain size, composition and textural variations, assuming the existence at least of 4 sediment types attending to the radio-density properties. Besides the radio-density profile of each core (Fig. 3) were calculated together with the variations in depth for each of the four radio-density ranges.

Attending to the sedimentary continuity and the sedimentary structures of the cores, the images do not show any trace of erosive features. Only core 37 presents sand-gravel bioclastic content (broken shells, spicules) at the top and the base of the core. The upper level could be related to the present-day surface sedimentation in the channel where current intensity is strongest and most persistent (Hernández-Molina et al., 2014).

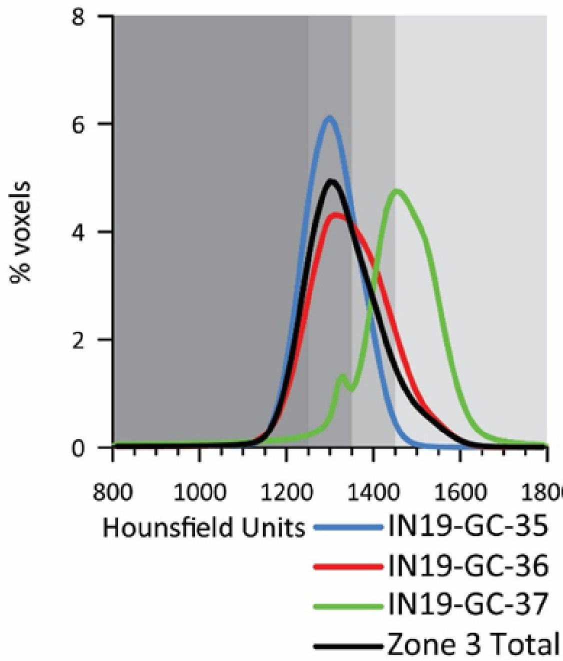

FIGURE 2: Radio-density data abundance for the three gravity cores and for the total of the INPULSE zone 3.

The radio-density measured in the three gravity cores reveals an increase of the mean value of the sediment along the studied transect (Fig. 2) from sector 2 to sector 1 (south to north, Fig. 1) probably linked to the proximity of the sites to the main channel and hence, with the velocity of the MOW in this two sectors (Sánchel-Leal, et al., 2017). The increase in the radio-density along the transect is evident too in the higher abundance of the higher radio-density ranges (Fig. 3).

In general, higher radio-densities of the sediment can be linked to a coarser grain-size and higher proportion of carbonate (Mena et al., 2018). Based on the continuity of the sediment, and assuming that sedimentation in core 37 is totally produced by the MOW activity in the Southern Channel (Sánchez-Leal et al., 2017), the radio-density variations of the sediment, and hence, grain-size and composition, can be correlated with the variations in the MOW intensity in the current surface and in recent sediments. This fact allows correlating a higher radio-density value with a more intense MOW flow.

Besides, the sedimentary record of the cores (Fig. 3) reveals a gradual and fine variation in the radio-density profiles and images easily comparable with the contourite bigradational sequences model (Faugères and Stow, 2008). These sequences are more evident in the radio-density ranges, showing that the abundance of higher radio-density ranges increase as we approach to the channel and consequently to a more intense MOW flow.

Core 35 records two of these radio-density bigradational sequences and core 36 records three sequences. In core 37, although it shows a sedimentary record totally dominated by a strong MOW flow and do not exist a typical bigradational sequence, three intervals potentially linked with an enhanced MOW, and therefore, related to at least three MOW flow intensified.

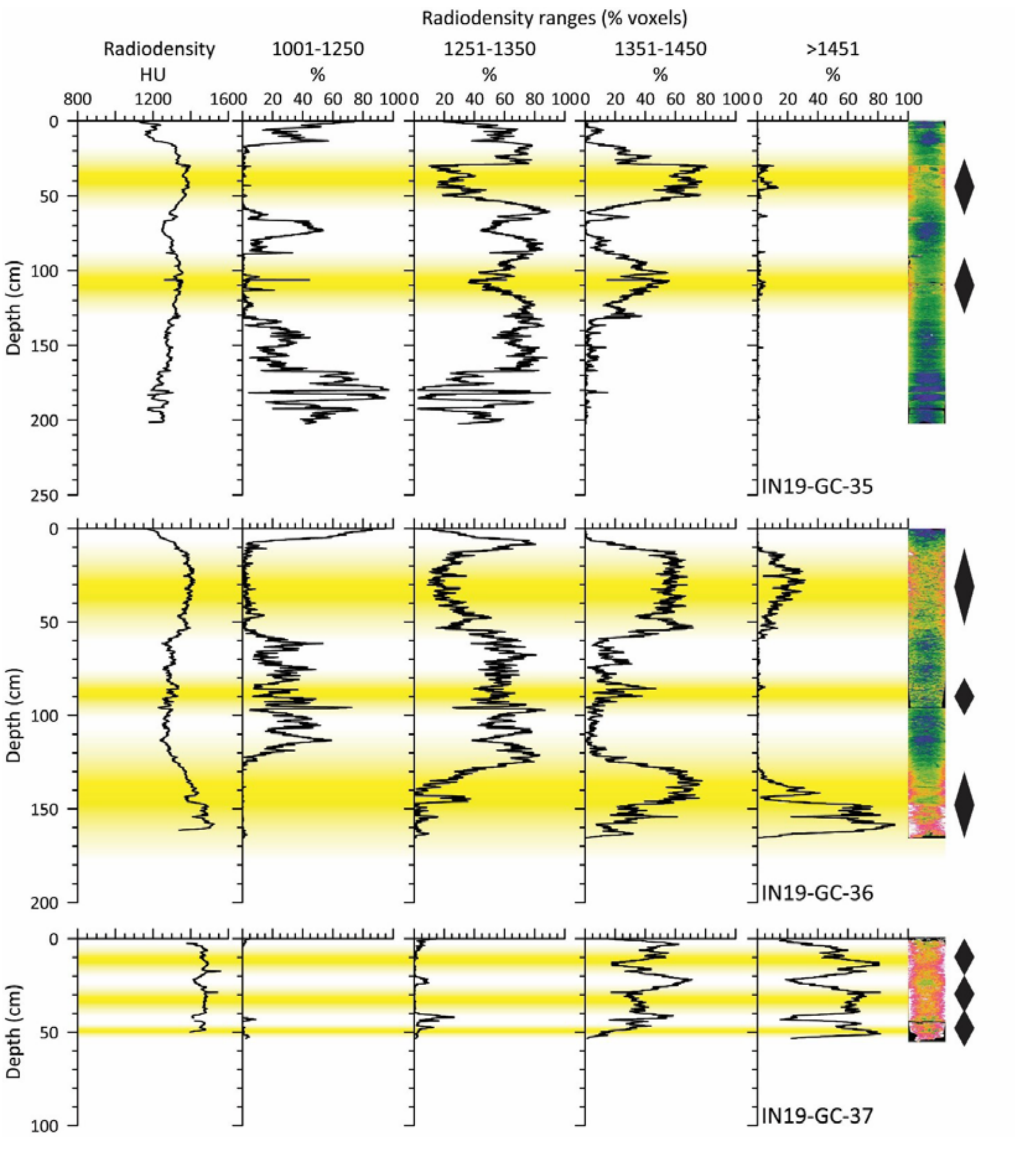

FIGURE 3 Radio-density profiles of the three gravity cores and radio-density ranges abundance. 2D tomography (Colour image) with the radio-density scale (down) Tentative bigradational sequences are marked in the records (yellow band) and in the colour image of the cores.

Assuming that this is a preliminary study, that classical sedimentary analyses are still in progress, and that is necessary to establish an accurate age model for this area, the sedimentary record across the Southern Channel and proximities reveals at least three pulses of MOW intensification. Although this water mass is continuously affecting the Southern Channel, during intensification periods it overflows the channel (Hernández-Molina et al., 2006), affecting the sites of cores 35 and 36 and generating the contouritic bigradational sequences that could be identified using the tomographic data and images.

During glacial periods, the MOW is defined as a current with stronger transport and higher winnowing capacity (Schönfeld and Zahn, 2000) that could form coarser contouritic deposits than during the interglacial. Assuming that the same MOW behaviour works in lower time-scales (cold events), the three recorded pulses of the MOW intensification identified based on tomographic data across the Southern Channel, can be linked to a climatic signal.

ACNOWLEDGEMENTS

Universitary Veterinarian Hospital Rof Codina de Lugo. INPULSE Project (CTM2016-75129-C3-1-R). Postdoctoral Xunta de Galicia Grant. TALUS Project (CGL2015-74216-JIN). Grupos de Referencia Competitiva Xunta de Galicia (ED431C 2017/55). The research studies are conducted in collaboration with 'The Drifters Research Group' of the Department of Earth Sciences, Royal Holloway University of London (UK)

REFERENCIAS

Faugères, J.C. and Stow, D.A.V (2008). Contourite drifts: nature, evolution and controls in M. Rebesco, A. Camerlenghi (Eds.), *Contourites*, Elsevier: 259-288

Hernández-Molina, F.J., Llave, E., Preu, B., Ercilla, G., Fontán, A., Bruno, M., Serra, N., Gomiz, J.J., Brackenridge, R.E., Sierro, F.J., Stow, D.A.V., García, M., Juan, C., Sandoval, N. and Arnaiz, A. (2014). Contourite processes associated with the Mediterranean Outflow Water after its exit from the Strait of Gibraltar: Global and conceptual implications. *Geology* 42 (3): 227–230.

Hernández-Molina, F.J., Llave, E., Stow, D.V:A., Garcia, M., Somoza, L., Vázquez, J.T., Lobo, F.J., Maestro, A., Díaz del Río, V., León, R., Medialdea, T. and Gardner, J. (2006). The contourite depositional system of the Gulf of Cádiz: A sedimentary model related to the bottom current activity of the Mediterranean outflow water and its interaction with the continental margin. *Deep Sea Research Part II Topical Studies in Oceanography* 53(11):1420-1463.

Mena, A., Francés, G., Pérez-Arlucea, M., Aguiar, P., Barreiro-Vázquez, J.D., Iglesias, A. and Barreiro-Lois, A. (2015). A novel sedimentological method based on CT-scanning: Use for tomographic characterization of the Galicia Interior Basin. *Sedimentary Geology* 321: 123-138.

Mena, A., Francés, G., Pérez-Arlucea, M., Hanebuth, T.J.J., Bender, V. and Nombela, M.A. (2018). Evolution of the Galicia Interior Basin over the last 60 ka: sedimentary processes and palaeoceanographic implications. *Journal of Quaternary Science* 33(5): 536-549.

Rorden, C. and Brett, M. (2000). Stereotaxic display of brain lesions. *Behavioural Neurology* 12, 191–200.

Sánchez-Leal, R.F., Bellanco, M.J., Fernández-Salaz, L.M., García-Lafuente, J., Gasser-Rubinat, M., González-Pola, C., Hernández-Molina, F.J., Pelegrí, J.L., Peliz, A., Relvas, P., Roque, D., Ruiz-Villarreal, M, Sammartino, S. and Sánchez-Garrido, J.C. (2017). The Mediterranean Overflow in the Gulf of Cadiz: A rugged journey. *Science Advances* 3: 10.1126/sciadv.aao0609.

Schönfeld, J. and Zahn, R., 2000. Late Glacial to Holocene history of the Mediterranean Outflow. Evidence from benthic foraminiferal assemblages and stable isotopes at the Portuguese margin. P*alaeogeography. Palaeoclimatology. Palaeoecology*: 159: 85 - 111.