Sedimentary Geology 321 (2015) 123–138

Contents lists available at ScienceDirect

Sedimentary Geology

journal homepage: www.elsevier.com/locate/sedgeo

A novel sedimentological method based on CT-scanning: Use for tomographic characterization of the Galicia Interior Basin

Anxo Mena [a,*], Guillermo Francés [a], Marta Pérez-Arlucea [a], Pablo Aguiar [b], José Daniel Barreiro-Vázquez [c], Alfredo Iglesias [d], Andrés Barreiro-Lois [e]

[a] Dpt. Xeociencias Mariñas e O. T. Facultade de Ciencias do Mar, Universidade de Vigo, C.P.: 36310 CUVI, As Lagoas-Marcosende, Vigo (Pontevedra), Spain
[b] Fundación Ramón Domínguez, Complexo Hospitalario Universitario de Santiago de Compostela, Facultade de Medicina, Universidade de Santiago de Compostela, Spain
[c] Servizo de Diagnóstico por Imaxe, Hospital Veterinario Universitario Rof Codina, Estrada da Granxa s/n, C.P.: 27002, Lugo, Spain
[d] Dpt. de Enxeñería Mecánica, Escola de Enxeñería Industrial, Universidade de Vigo, C.P.: 36310 CUVI, As Lagoas-Marcosende, Vigo (Pontevedra), Spain
[e] Dpt. Ciencias Clínicas Veterinarias, Facultade de Veterinaria, Universidade de Santiago de Compostela, Spain

ARTICLE INFO

Article history:
Received 9 December 2014
Received in revised form 9 March 2015
Accepted 10 March 2015
Available online 20 March 2015

Editor: Dr. J. Knight

Keywords:
Computed Tomography
Sediment analysis
Heinrich Events
Galicia Interior Basin
Numeric treatment of tomographic data

ABSTRACT

Non-destructive techniques of core analysis, especially of marine cores, are being broadly employed for sedimentary, paleoceanographic and paleoclimate research. In particular, Computed Tomography scanning (CT-scanning) allows acquisition of 3D and 2D images, according to desired planes, and thus the identification of sedimentary structures, large grains and their distributions as well as direct measurements of material densities. The most significant contribution of this technique is the possibility of getting results before opening the core. In this work CT-scan data obtained for five cores from the Galicia Interior Basin (GIB, NW Peninsula Iberia) are presented and discussed, focussing on (1) methodology of the CT-scan use, (2) tomographic description of sedimentary facies identified in the GIB, (3) treatment of the numeric data obtained with CT-scanning using specific software (anidoC), and (4) comparison of tomographic data with data obtained by conventional methodologies of core analysis.

The most singular feature of GIB cores is the presence of Ice Rafted Debris (IRD) deposited during late Pleistocene Heinrich Events (HE), which can be easily recognized using the CT-scan by the presence of high radio-density grains immersed in a low radio-density matrix. Comparison of CT-scan data with analytical sedimentary data and HE proxies performed on the cores validates the CT-scanning method as a powerful tool to improve correlations, identify well-constrained events, and make more accurate basin reconstructions without opening all the cores in an oceanographic study.

1. Introduction

During the last few years the study of sedimentary cores has been approached from a multi-disciplinary point of view that has led to the introduction of novel techniques for core analysis (Tucker, 1988; Fischer and Wefer, 1999; Jarraro and Vanden Berg, 2006; Nederbragt et al., 2006; Rothwell, 2006; Dorador and Rodríguez-Tovar, 2014). Using these techniques, such as XRF, colour logging and Multi-Sensor Core Logging, relevant data can be obtained, allowing more complete and accurate paloclimatologic, paleoceanographic, sedimentary interpretations, among others. Regarding this, non-destructive methodologies have been developed in order to obtain data on, for example, physical properties, elemental composition or internal structure of sediments. Some of these techniques can be applied without splitting the cores and disrupting the sediment, allowing more accurate correlation between cores, more efficient sampling strategies, and lower human and economic costs.

In particular, non-destructive tests based on X-ray computed tomography (CT) scanning have already been proposed for the analysis of sediments and rocks (Kenter, 1989) and also for marine cores (Orsi et al., 1992, 1994; Soh et al., 1993; Tsuchiyama et al., 2000; Goldfinger et al., 2013). Although it is clear that there is great potential of this technique in the geosciences (e.g., Cnudde et al., 2006), it is still not widely used, probably due to high investment for dedicated scanners and the limited availability of conventional scanners for non-medical applications, in the sedimentary field.

A summary of the uses and applications of the CT in the geosciences was compiled by Mees et al. (2003). In this work no mention of marine sediment analysis with CT was presented, and only some works were discussed that focused on non-consolidated sediments from soils and lakes. They state that the major application of this technique is based in geo-technical studies (Duliu, 1999). The uses of the tomography in geoscience includes topics based on soil processes, bioturbation analysis, sediment structure and microstructure characterization

* Corresponding author. Tel.: +34 986814017; fax: +34 986812556.
E-mail address: anxomena@uvigo.es (A. Mena).

http://dx.doi.org/10.1016/j.sedgeo.2015.03.007
0037-0738/

(e.g., Dorador et al., 2014; Kneafsey and Moridis, 2014; Uramoto et al., 2014; Viggiani et al., 2014).

CT-scanning is a promising tool for sedimentary cores analysis because it provides a radio-density dataset that can be treated by means of appropriate software in order to obtain high-resolution 3D and 2D views of desired orientated sections (Duchesne et al., 2009; Gagnoud et al., 2009; St-Onge and Long, 2009). It allows the researcher to distinguish stratigraphic intervals based on different densities, sedimentary structures, concentration and distribution of particles, etc. Some approaches to tomographic facies characterization were developed in marine sediment cores using CT-scanning, focusing on particular characteristics of the tomographic data including sedimentary structures, water content and grain size (Geiger et al., 2009; Fortin et al., 2013; Goldfinger et al., 2013). However, these studies do not focus on radio-density variability and changes along and across the cores, or establish a tomographic characterization of facies and their relationship with standard lithostratigraphic description. The CT-scan has been used in some works as an approach to the physical properties of the sediment, mainly focussed on sediment density (Tanaka et al., 2011; Fortin et al., 2013), or internal structures related to deformation processes (Kilfeather and van der Meer, 2008).

The aim of this work is to study the feasibility of using X-ray CT scanning for analysing deep sea cores from a numeric and image analysis perspective. To this end, a novel procedure was developed for tomographic analysis and then applied to the characterization and interpretation of five cores from the Galicia Interior Basin (GIB). The proposed method involved a technical protocol for CT acquisition and the implementation of dedicated software for the quantitative analysis of CT data.

2. Materials and methods

The Galicia Interior Basin (GIB) is a narrow (100 km, 2500–3000 m depth) N-S orientated basin located at the NW Iberian margin, delimited by the Galicia Bank to the west and the continental slope to the east (Fig. 1). Holocene sediments are mainly of pelagic and hemipelagic origin, but turbidity and contouritic processes during the last glaciation have been identified, as well as glacio-marine intervals (Bender et al., 2012). For the purpose of this study, five gravity cores with sediments covering the last 63 ka (Mena, 2014) were retrieved along a latitudinal transect at depths between 2150 and 2780 m (Table 1).

Before opening, the cores were analysed using a clinical equipment of Computerized Tomography (HITACHI ECLOS 16 Multislice CT) at the Veterinary Teaching Hospital Rof Codina of Lugo (Galicia). The cores were then analysed, conventionally combining non-destructive (physical properties and XRF elemental composition) and destructive (sedimentary, micropaleontological and stable isotope analyses) methodologies in order to compare tomographic results with other data obtained by means of more classical techniques. The age model of the records was obtained by means of AMS^{14}C dating together with correlation with other published records (Mena, 2014).

A XRF Core Scanner (Avaatech; GRC-Geociencias Marinas at the University of Barcelona, Spain) was used to obtain semi-quantitative elemental composition of the cores with 1 cm resolution. This semi-quantitative analysis allows approaching accurately the abundance of principal elements (Fe, Ca, Ti, K) in the sediment (Richter et al., 2006).

2.1. Facies identification in the Galicia Interior Basin

Facies analysis of the GIB cores was undertaken by means of conventional techniques and visual characterization (Mena, 2014). The sediments are grouped in five facies associations (Fig. 2). The cores and facies correlations shown in Fig. 2 was done using a multi-proxy approach based on sedimentological, micropaleontological, chronostratigraphic tools (Mena, 2014). The principal sedimentary characteristics of these facies are as follows (bioturbation degree was established following the bioturbation index by Tucker, 2003):

Pelagic Facies

These are massive or poorly laminated, white to brown, very fine sand and silt with a mean grain size of 7-12 μm. Clay is very scarce

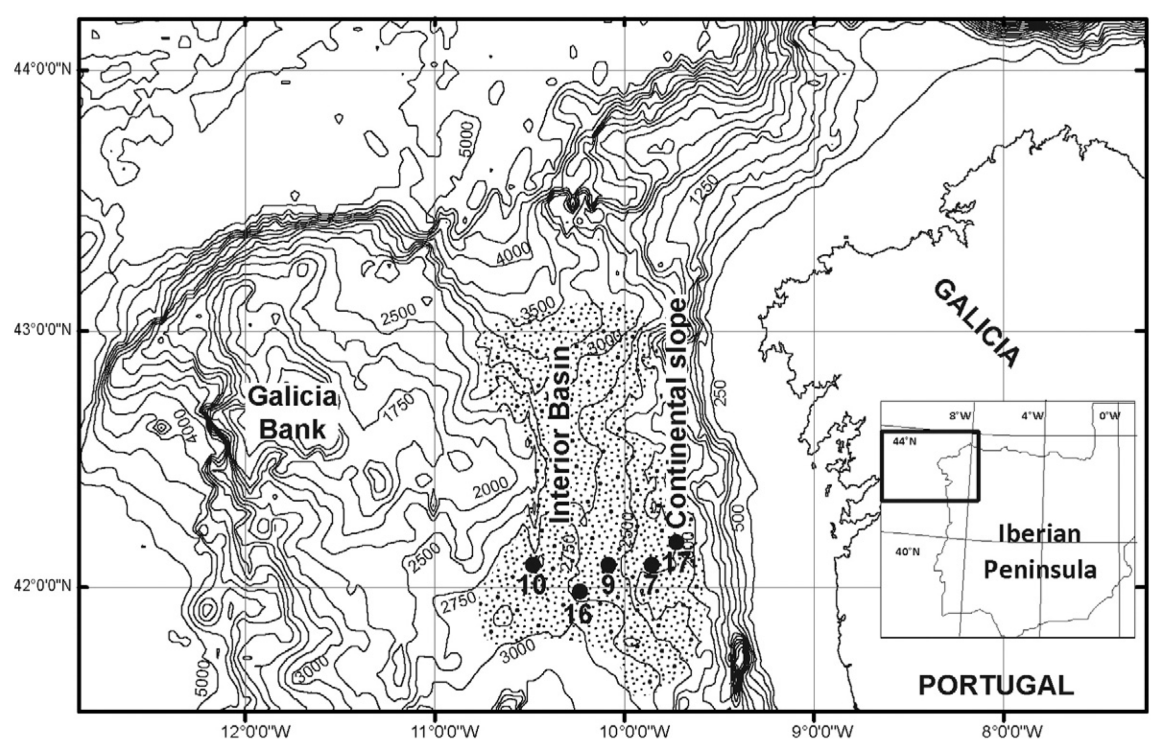

Fig. 1. Location of the cores FSG09 along the transect from the Galicia continental slope to the east flank of the Galicia Bank crossing the Galicia Interior Basin in the NW of the Iberian Peninsula (marked by the stippled area).