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Marine Geology 250 (2008) 64–88

MARINE GEOLOGY
INTERNATIONAL JOURNAL OF MARINE GEOLOGY, GEOCHEMISTRY AND GEOPHYSICS

www.elsevier.com/locate/margeo

Sedimentary features and processes in the Nazaré and Setúbal submarine canyons, west Iberian margin

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Received 6 September 2007; received in revised form 28 November 2007; accepted 4 December 2007

Abstract

Here we present part of the first complete sidescan sonar dataset of the Nazaré and Setúbal Canyons, west Iberian margin, which, in combination with multibeam bathymetry, shallow seismic profiles and precise piston coring of intra-canyon targets, are used to characterise the sedimentary dynamics of these deep-sea settings. The results show that Nazaré and Setúbal Canyons are highly complex environments. They display a range of sedimentary features and processes that reflect changes in downslope canyon geometry and a transition from erosive proximal to more depositional distal sections. The proximal (upper) sections of both canyons are characterised by a deeply incised, narrow, V-shaped thalweg, flanked by small gullies and terraces. Numerous small and localised intra-canyon landslides and rock avalanches occur in this section, triggered by instability processes that are preconditioned by the steep topography. Sequences of stacked thin-bedded, fine-grained turbidites occur locally on intra-canyon terraces, and are interpreted to be the result of small-volume, possibly river flood-generated turbidity currents that do not appear to reach the lower canyon. In Nazaré Canyon these turbidites are associated with abundant coalified organic fragments. Part of the upper section in Nazaré Canyon has acted as an apparent depocenter through the Holocene, with very high sedimentation rates related to enhanced nepheloid layer activity. Much larger slope failures are sourced from the shelf break and canyon head and are the result of occasional releases of large volumes of sediment, likely related to earthquake activity. These failures rapidly evolve into large-volume, high-energy, sand-rich turbidity currents that flush the entire canyon and dominantly deposit in the lower canyon and distal abyssal plains. This episodic turbidity current activity results in highly heterogeneous sediment distribution across the distal (lower) U-shaped floor of both canyons, with abundant erosional scours and depositional bedforms such as sediment waves. Our results highlight the complex interplay of sedimentary processes operating within major canyon systems, and have potential implications for efficient characterisation of hydrocarbon reservoirs, accurate spatial and temporal prediction of geohazards, and the distribution of benthic ecosystems in canyon environments.

Keywords: Nazaré; Setúbal; submarine canyon; landslide; sediment wave; turbidity current

1. Introduction and aims

Previous work on submarine canyons has established that they are major pathways for the transport of sediment (and associated pollutants and organic carbon) from land to the deep ocean (e.g. Berner, 1982; van Weering et al., 2002; Canals et al., 2006). Sediment enters the canyon heads from fluvial and/or along-shelf transport sources, and accumulate in a sediment pile in the upper section over time, producing a temporary sediment reservoir (Mastbergen and van den Berg, 2003). Failure of this prograding sediment can occur due to higher supply rates and/or faster progradation and intense resuspension caused by energetic bottom currents at the canyon head during storms and floods (e.g. Mulder et al., 2001; Liu et al., 2002; Puig et al., 2004a). Failure in the upper canyon can also be preconditioned by instability processes leading to sediment oversteepening on the steep slopes (Mullenbach et al., 2004; Puig et al., 2004a) or initiated by earthquake-triggered deformation and liquefaction of sediment (e.g. Jones and Omoto, 2000). The transport of this

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0025-3227/$ - see front matter © 2007 Elsevier B.V. All rights reserved.
doi:10.1016/j.margeo.2007.12.006

failed sediment therefore generally involves low frequency, high-energy, sediment gravity flows (e.g. Normark and Piper, 1991; Puig et al., 2004a; Canals et al., 2006), rather than continuous sedimentation. However, the frequency, timing and processes of gravity flows in most modern canyons are poorly constrained, as is their overall role in the offshore export of sediment. This is due to the difficulties involved in direct monitoring of flows in canyons (Khripounoff et al., 2003; Paull et al., 2003; Xu et al., 2004), and also the technological problems that arise when sampling in such rugged canyon topography.

Submarine canyons along European continental margins have recently been extensively studied as part of the EC-EURO-STRATAFORM project, which attempted to relate modern sedimentation to preserved strata on continental margins, and included investigating the role of canyons in offshore sediment flux. This research has continued as part of the Hotspot Ecosystem Research on the Margins of European Seas (HERMES) project (Weaver et al., 2004), an international, multidisciplinary research programme investigating the effects of physical processes on Europe's deep marine ecosystems and seafloor environments. In particular, the two projects have generated a significant amount of new data from Nazaré and Setúbal Canyons, offshore west Iberia (Fig. 1). Here, we present some of these new data, including part of the first complete deep-towed sidescan sonar map of both canyons (Fig. 2), in combination with multibeam bathymetry and shallow seismic profiles. This detailed geophysical coverage has facilitated precise piston coring of intra-canyon targets such as terraces and bedforms.

The principal aims of this study are to (1) highlight key geophysical and sedimentary features observed in Nazaré and Setúbal Canyons, using high-resolution geophysical data in combination with a suite of accurately targeted piston cores; and to (2) interpret the processes responsible for generating the observed features. It should be noted that, due to the lack of piston cores in the upper canyon sections, the interpretation at these depths can only be geomorphological, and this is described in detail in the accompanying paper by Lastras et al. (in preparation) rather than here. Additionally, the stratigraphic evolution of these canyons is beyond the scope of this paper, and will be addressed in future publications.

Our results will have potential implications for three main areas of applied research: 1) the hydrocarbon industry — predicting variations in vertical connectivity and lateral extent of sandy deposits in deep-water channel systems will lead to a better understanding of heterogeneity within these types of reservoir, 2) geohazards — predicting the catastrophic effects and flow processes of large gravity flows and slope instabilities will help to reduce potential damage to continental margin infra-structures and communities, and 3) benthic ecosystems — the Portuguese Canyons are known to host fragile benthic ecosystems

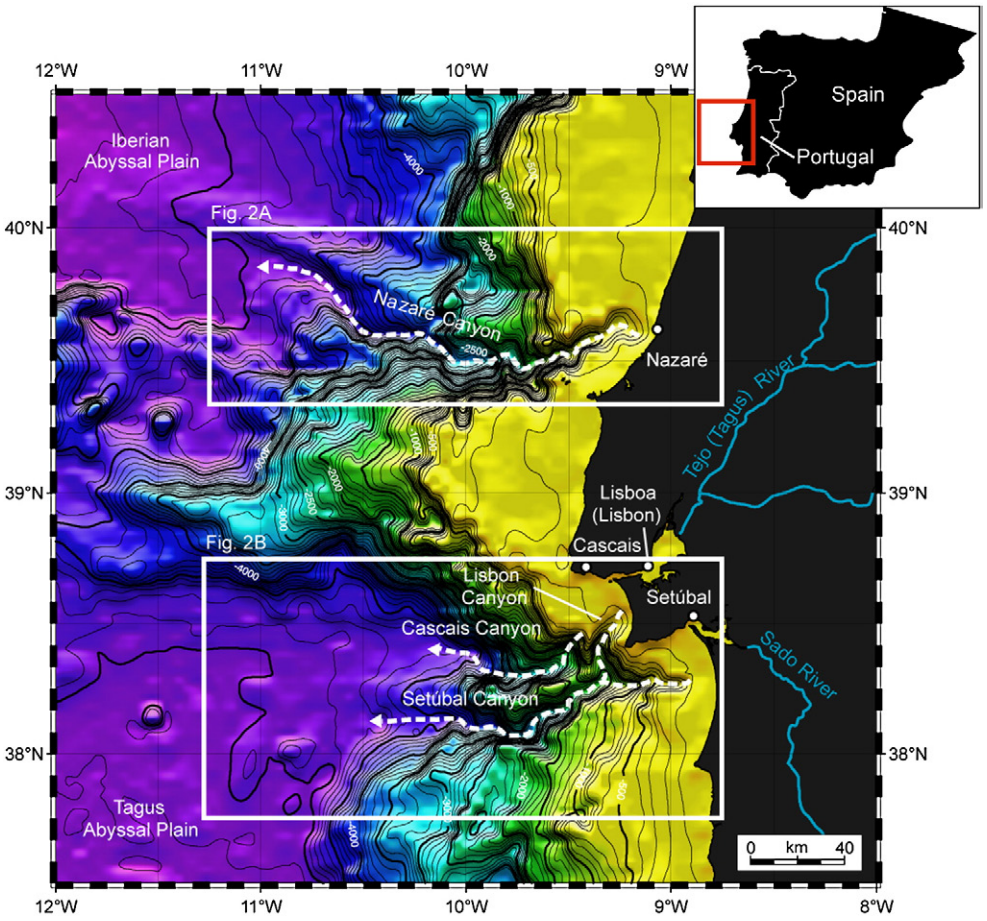

Fig. 1. Bathymetry map of the west Iberian margin showing the locations of the Portuguese canyons. Contours are every 100 m and outlined in bold every 500 m.