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Origin and transport of trace metals deposited in the canyons off Lisboa and adjacent slopes (Portuguese Margin) in the last century

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ABSTRACT

Submarine canyons play an important role in the transfer of contaminated sediments from shelf areas to the deeper ocean. To evaluate the importance of submarine canyons adjacent to the Tagus and Sado estuaries (Portuguese Margin) as sediment pathway major and trace elements, ^{210}Pb radionuclides, organic carbon, calcium carbonate and grain size were analyzed in fifteen short sediment cores from the Cascais and Lisboa–Setúbal submarine canyons and neighbor slopes at the Estremadura Spur and off Sines. Mass accumulation rates (MAR) vary between 0.02 and 0.40 g cm^{-2} y^{-1} with the highest values in the upper Cascais and Lisboa canyons. Mercury and Pb enrichment factors exceed 2 and show a continuously increasing trend since 1950 AD in the upper sections of the Cascais Canyon and in the Lisboa–Setúbal Canyon system, implying an anthropogenic source. Mercury and Pb anthropogenic inventories also present highest values in the canyon heads, which is consistent with its proximity to the Tagus and Sado river mouths. To a lesser extent, the Estremadura and Sines slopes and the deeper sections of the canyons also have slightly increasing Hg and Pb enrichment factor trends towards the present-day. For these areas, with a major influence of pelagic sedimentation, we infer atmospheric transport as a complementary source of contaminants. Therefore, our data suggest that although canyons are preferential conduits to transport sediments to the deep sea when compared to the slopes, Hg and Pb derived from human activities have reached both domains with different intensities down to a depth of 2000 mwd.

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1. Introduction

Submarine canyons are the main natural conduits of particulate material from the shelf and slope to the deeper areas of the continental margin (e.g. Puig and Palanques, 1998; Mullenbach and Nittrouer, 2000; Canals et al., 2006; Palanques et al., 2006; de Stigter et al., 2007; Lastras et al., 2009). Several studies on the northwestern Portuguese Margin focused on recent accumulation, transport and sedimentation processes and on the influence of the Nazaré Canyon in such processes (e.g. Jouanneau et al., 2002; van Weering et al., 2002; de Stigter et al., 2007; Oliveira et al., 2007). The central western Portuguese Margin is also dissected by submarine canyons, such as the Cascais and Lisboa–Setúbal canyons, whose geomorphology and sedimentary features reveal complex environments with differences in the downslope canyon geometry (Arzola et al., 2008; Lastras et al., 2009). Those canyons head are located near the Tagus and Sado rivers, flowing through two of the most industrialized and densely populated Portuguese cities (Lisboa and Setúbal).

Anthropogenic metal enrichments in estuarine, shelf and deep-sea sediments were reported all around the world (e.g. Jickells et al., 1984; Windom et al., 1989; Schropp et al., 1990; Boyle, 2001). The Tagus and Sado estuaries (e.g. Cortesão and Vale, 1995; Paiva et al., 1997; Silva et al., 2004; Caeiro et al., 2005; Canário et al., 2005; Vale et al., 2008) and the adjacent shelf area (e.g. Jouanneau et al., 1998; Mil-Homens et al., 2009) also exhibit anthropogenic enrichments. Nevertheless, only few and recent works concentrated on the dispersal of anthropogenic metals through canyons and the adjacent slopes on the Portuguese Margin (Costa, 2008; Richter et al., 2009; Jesus et al., 2010).

The objectives of the present study are to characterize spatial and temporal variability of trace metals for Portuguese submarine canyons and adjacent open slopes, to assess their natural and anthropogenic

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origin, and to quantify contaminant Pb and Hg through calculation of fluxes and inventories.

2. Morphological setting

The central western Portuguese Margin is characterized by a relatively narrow shelf (5–60 km; Dias, 1987) and steep irregular slope, dissected by several deep canyons such as the Nazaré, Cascais, Lisboa and Setúbal canyons (Fig. 1). The Estremadura spur on the continental shelf north of Lisboa consists of a nearly flat surface above the 120 m isobath and a slightly dipping outer surface with alternation of faulted or gullied truncation surfaces and sedimentary sheets (Vanney and Mougenot, 1981). The Estremadura cores transect aligns along this slope. Off Lisbon, the shelf off the Tagus River mouth holds the fine-grained deposit of the Tagus Prodelta (Vanney and Mougenot, 1981). The Cascais Canyon is one of the shortest canyons of the western Iberian Margin, located NW of the Lisboa–Setúbal Canyon and separated from the latter by the ~1000-m high ridge of the Afonso Albuquerque Plateau (Vanney and Mougenot, 1981). Its head is located at the shelf edge area adjacent to the Tagus Prodelta, at around

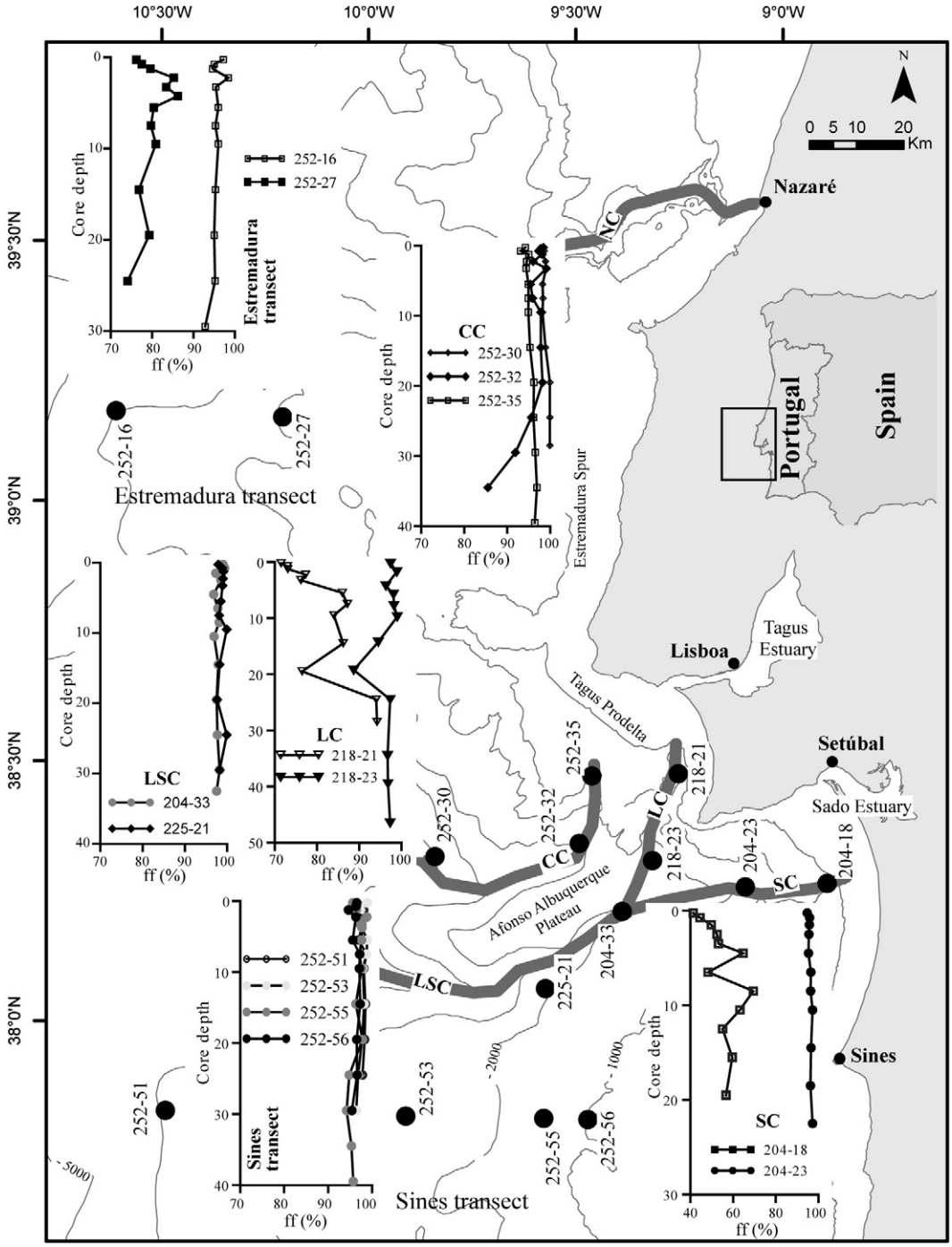

Fig. 1. Location of box- and multi-cores collected during cruises Canyons 2002, Canyons 2003, Canyons 2004 and Canyons 2006 (NIOZ) and fine fraction (ff) variation with depth. The studied cores are referred by the cruise name followed by the station number (e.g. 252–16). NC — Nazaré Canyon, CC — Cascais Canyon, LC — Lisboa Canyon, SC — Setúbal Canyon and LSC — Lisboa–Setúbal Canyon system.

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