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Anthropogenic trace metals in the sedimentary record of the Llobregat continental shelf and adjacent Foix Submarine Canyon (northwestern Mediterranean)

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Abstract

Anthropogenic trace-metal concentrations and inventories were studied on the Llobregat continental margin, from the Llobregat river mouth to the Foix submarine canyon. A prodelta sedimentary depocentre was identified along with a previously known canyon depocentre. Significant upward increases in trace-metal contents were detected in sediment cores of the prodelta and upper part of the canyon (down to 860 m depth). Metal enrichment factors ranged between 1.8 and 10 on the continental shelf and between 1.2 and 2.7 in the submarine canyon. These metal enrichments occurred during the 20th century and can be correlated with the period of maximum increase of population and industrial activities in the Barcelona area and the consequent anthropogenic metal inputs. Maximum trace-metal enrichments are located in the prodelta depocentre and significant enrichments were also measured in the southern prodelta and in the Foix upper canyon as a consequence of efficient shelf–canyon sediment and metal transfer. Deeper in the canyon, at 1370 m depth, no metal enrichments were detected, probably because of particle dispersion and dilution with uncontaminated sediment within the canyon. This study shows that, in some Mediterranean sedimentation systems, anthropogenic trace metal contamination is affecting not only the littoral and the continental shelf, but also the adjacent continental slope sediments through submarine canyons.

Keywords: submarine canyon; anthropogenic trace metals; shelf–slope transfer; marine sediment record; Mediterranean Sea; Barcelona; industrial times contamination

1. Introduction

Continent–ocean sediment transfer is controlled by inputs and forcing conditions such as river discharge, hydrodynamic processes (waves, tides and currents), shelf and slope morphology and sediment instability

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(Milliman and Syvitski, 1992; Nittrouer and Wright, 1994). The continental shelves submerged during the present high sea level stand, contribute to separate direct river discharges from the continental slope. This favours the accumulation of sediment on the continental shelves and reduces the transfer towards the deep sea in comparison with low sea level stages. In industrial times, anthropogenic contaminants such as trace metals are often associated with fine sediment particles and afected by sediment accumulation processes. Many studies have been carried out to trace and date the impact of anthropogenic activity in soils and sediments. In the marine environment, sediment contamination has been studied mainly in coastal areas (e.g. Frignani et al., 1997 and Bay et al., 2003), and less attention has been paid to contamination in deep environments, where the impact can be slighter due to dilution and dispersion. To attribute trace-metal enrichments in surface sediment to modern contamination it is necessary to discriminate that they are not produced by changes of sediment composition or texture or by remobilization during early-diagenesis (Salomons and Förstner 1984; Gobeil et al. 1999).

At present, off-shelf transfer of matter takes place mainly during high-energy events, such as storms, river floods and dense shelf-water cascading (Walsh and Nittrouer, 1999; Puig et al., 2003, Palanques et al., 2005; Martin et al., 2006; Canals et al., 2006; Palanques et al., 2006a), which are followed by the advection of the removed sediment supplied to the water column (Nittrouer and Wright, 1994). Off-shelf transfer follows preferential pathways depending on prevailing currents and bottom morphology. Among the morphological features controlling shelf–slope sediment transfer are submarine canyons, which, despite the present high sea level stand, still act as preferential conduits of sediment supply towards deeper parts of the margin (Gardner, 1989; Monaco et al., 1990; Heussner et al., 1999; Mullenbach and Nittrouer, 2000; Puig et al., 2003; Martin et al., 2006; Canals et al., 2006; Palanques et al., 2006a), especially on narrow margins. However, to what extend shelf contaminants are transferred off-shelf by physical processes and trace particle dynamics or what is the role of submarine canyons in the off-shelf transfer of contaminants are questions that have not been completely elucidated so far. Some authors observed that canyons with low sedimentary activity, where sediment–water interface is not disturbed as vigorously as in active canyons, can be a sediment trap for trace metals (Maurer et al., 1994).

In the northwestern Mediterranean, the morphology of the continental shelves and the energy of the hydrodynamic processes allow prodeltaic deposits to accumulate on the inner and mid-shelf around the mouths of most rivers. In this sedimentological scenario, there is an accumulation of present sedimentary supplies and associated contaminants discharged by rivers in several modern prodeltas (Frignani et al., 1978; Palanques et al. 1998, Puig et al., 1999; Roussiez et al., 2006). This has been detected even in small river systems whose average water discharge is only a few cubic metres per second and whose contaminant load is less diluted, providing inputs to the continental shelf with even higher concentrations of contaminants than the big rivers (Palanques et al., 1998, Puig et al., 1999). Some of the few places in the Mediterranean where the history of sediment contamination has been studied in detail are on the Venice Lagoon (Frignani et al., 1997) and on the Besòs continental shelf (Palanques et al., 1998).However, the history of sediment contamination from the shelf to the slope had been never studied and correlated.

Present-day hydrodynamic processes in the northwestern Mediterranean also allow off-shelf sediment transfer through preferential pathways such as some submarine canyons. One of the sedimentary systems that connects an important source of contamination to a submarine canyon is the Llobregat margin, located south of the city of Barcelona (Fig. 1). This narrow margin receives inputs mainly from the Llobregat River. It is affected by industrial and domestic waste discharges and is incised by the Foix submarine canyon, which has been identified as a preferential shelf–slope sediment pathway (Puig and Palanques, 1998a).

The main objectives of this paper are to study the anthropogenic trace-metal enrichments and accumulation in the Llobregat marine sedimentary system, from the inner shelf to the adjacent submarine canyon, and to define the present-day role of canyons as transport pathways and sinks of contaminated matter transferred off the continental shelf to the ocean.

2. Study area

The Llobregat River has a drainage basin of 4950 km^2, and its average water discharge is about 20 $m^3\ s^{-1}$. During the Holocene, this river has generated a prodeltaic deposit that extends 165 km^2 on the continental shelf and has a maximum thickness of about 60 m (Checa et al., 1988). The width of the Llobregat continental shelf ranges only between 7 and 10 km, and the shelf-edge is at about 90 m depth. The continental slope is also narrow (10 km) and is sharply incised by the Foix submarine canyon, whose head reaches the shelf break at 90 m depth (Fig. 1).