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Sediment accumulation in the western Gulf of Lions, France: The role of Cap de Creus Canyon in linking shelf and slope sediment dispersal systems

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Abstract

Previous work in the Gulf of Lions (western Mediterranean Sea) has suggested that significant amounts of sediment escape through the western part of this tectonically passive margin, despite it being far removed from the primary sediment source (the Rhone River, ~160 km to the NE). The primary mechanism behind this export is hypothesized to be the interaction of a regional, southwestward sediment-transport path with a canyon deeply incising the southwestern part of the shelf, Cap de Creus Canyon.

To understand the pattern of off-shelf sediment export from the western Gulf of Lions, and more specifically, the role of Cap de Creus Canyon in this transport, box cores were collected within the canyon and on the adjacent shelf during five cruises from November 2003 to April 2005. Geochronology (^{210}Pb-derived accumulation rates), grain-size distributions, and sedimentary structures (X-radiography) were analyzed to assess temporal and spatial sedimentation patterns. Results indicate two mid-shelf depocenters (30–90 m water depth) in the northern and southern portions of the study area, separated by a zone of bypassing due to current acceleration around a headland (Cap Bear). Estimates of a sediment budget indicate that ~6–8% of the sediment input to the Gulf is sequestered on the shelf region.

Within the Cap de Creus Canyon, there is a significant spatial asymmetry in both grain size and accumulation rates. The northern flank is a modern depocenter of fine-grained sediments, while the southern flank is primarily non-depositional for mud and includes locations of apparent erosion. This suggests the influence of multiple oceanographic processes supplying sediment to the canyon: advection of nepheloid layers from the northern rim that provide a relatively continuous sediment supply (over decadal timescales), and episodic strong currents affecting the southern rim, which can scour sediment from the southern flank. The mid-depth thalweg has an ephemeral mud layer, overlying sand and consolidated mud. The mud layer appears to be flushed down canyon periodically. The canyon head contains coarse material, suggesting reworked sands may be entering.

The 100-year sediment budget, based on accumulation rates for the fine-grained fraction in the upper canyon, indicates that ~1% of the total sediment input to the Gulf is accumulating in upper Cap de Creus Canyon. However, this number may significantly underestimate the total sediment entering the canyon because water-column measurements show that sediment is likely moving through the upper canyon during major dense-water cascading events from the shelf and being deposited deeper in the canyon system. The ephemeral mud layer also indicates rapid deposition and frequent flushing of sediment through the upper canyon. Overall, this study

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shows that Cap de Creus Canyon is an active conduit of sediment past the shelf break, despite its location distal to the primary sediment source to the Gulf.

Keywords: Submarine canyon; Gulf of Lions

1. Introduction

Submarine canyons are common bathymetric features that can strongly impact across-margin sediment dispersal patterns (Shepard and Dill, 1966; May et al., 1983). Many canyons incise far onto the continental shelf, effectively narrowing the distance between fluvial sediment sources and the shelf break and slope. This property allows canyons to intersect along-margin transport and serve as preferential conduits of sediment past the shelf break (Mullenbach et al., 2004). Off-shelf transport is particularly enhanced in canyons along many modern collisional margins where narrow shelves and high fluvial sediment input co-exist (e.g. Milliman and Meade, 1983; Paull et al., 2003; Walsh and Nittrouer, 2003). In contrast, canyons on tectonically passive margins can be less effective at exporting sediment due to greater shelf width and presence of estuaries, which can trap sediment (e.g. Gardner, 1989).

A necessary component for off-shelf transport via canyons is the interception of active sediment-transport pathways. For some collisional margins, a canyon may be nearly connected to a river mouth, directly funneling the fluvial sediment to the deep sea (e.g. the Sepik and Monterey) (Kineke et al., 2000; Paull et al., 2003). On active margins, canyons also have been shown to intercept significant along-shelf fluxes associated with proximal river discharge (e.g. the Eel and Quinault) (Hickey et al., 1986; Mullenbach, 2002; Puig et al., 2003). The interception of along-margin sediment dispersal can create significant off-shelf sediment escape, which may not be directly related to the distance between a fluvial sediment source and a canyon head.

Along-margin variability, such as changes in shelf width and shoreline irregularity (e.g. headland intrusion), can control the proximity of canyons to large sediment fluxes on the shelf and potentially create off-shelf steering far from a fluvial source. Oceanographic conditions, such as favorable along- and across-shelf currents, also play a role in the primary location of off-shelf transport within a system (i.e. distal vs. proximal to the source). Determining the main area of sediment export from a shelf can have implications for identifying long-term depocenters. If distal canyons are active, the specific processes allowing sediment to escape need to be further defined.

The western Gulf of Lions (GOL) is a wide, passive margin in which the primary area of off-shelf sediment escape is hypothesized to be at a location distal to the main sediment source (Durrieu de Madron et al., 1990; Courp and Monaco, 1990; Got and Aloisi, 1990; Durrieu de Madron, 1994; Frignani et al., 2002) (Fig. 1). Previous studies have shown that significant quantities of sediment do not reach the shelf break adjacent to the Rhone River mouth (Got and Aloisi, 1990; Arnau et al., 2004). Rather, hydrodynamical modeling and canyon mooring studies suggest that sediment is funneled towards the narrowing, southwestern portion of the Gulf and the westernmost canyon, Cap de Creus Canyon (Palanques et al., 2006; Heussner et al., 2006; Ulses et al., this issue). This canyon, although far from the primary sediment source (~160 km), may directly intercept the regional transport pathway and therefore serve as a primary conduit of sediment escape for the entire GOL.

The overall goal of this project is to understand the processes of sediment export from the western GOL and, more specifically, the role of Cap de Creus Canyon in this transport. The objectives are to: (1) identify modern depocenters on the western shelf and within Cap de Creus Canyon, (2) infer transport mechanisms creating the observed depositional patterns, and (3) calculate a sediment budget for upper Cap de Creus Canyon and the

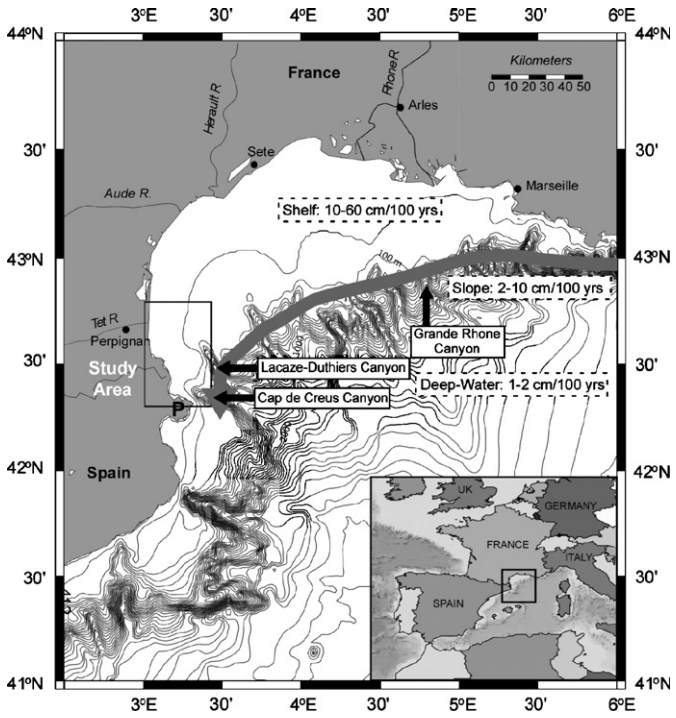

Fig. 1. Map of the GOL, including inset to show location of the Gulf and box to show study area. The approximate location of the Liguro-Provencal-Catalan Current is shown by the gray arrow, with the main canyons discussed in this paper marked. Dashed boxes include accumulation rate ranges for different margin areas as determined by Zuo et al. (1997). Cap de Creus (marked by a P for promontory), the cape on the northern coast of Spain, critically influences the regional currents.