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Stratigraphic signatures due to flood deposition near the Rhône River: Gulf of Lions, northwest Mediterranean Sea

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Abstract

Episodic flood delivery provides the bulk of the solid discharge for many small to moderate river systems, including the Rhône River in the northwestern Mediterranean. Several recent studies have demonstrated that the fate of this sediment depends on the coherence between river discharge and energetic ocean conditions. The deposition of flood sediment in the ocean can be confirmed by common signatures of episodic discharge events: presence of ^{7}Be, physical stratification, and elevated clay content associated with low ^{210}Pb activities.

Previous research has indicated that the Rhône River discharge is episodic and generally independent of oceanic conditions. Sometimes the floods coincide with energetic storms and winds from the southeast, which facilitate the movement of sediment towards the southwestern Gulf of Lions. High-resolution coring near the mouth of the Rhône River provides a detailed record of sedimentation associated with past flood events. Cores were collected on two cruises, October 2004 and April 2005, in a study area seaward of the Rhône subaerial delta. Episodic sediment discharge from the Rhône River routinely deposits on the seabed in water depths shallower than 40 m. This is documented by the presence of ^{7}Be in the surficial sediments of physically stratified cores. Through identification of a dilution signature in ^{210}Pb profiles (i.e., increased clay content, decreased ^{210}Pb activity), past flood events are recognized. Greater water depths and distances from the river mouth allow bioturbation to erase these signatures, except in the most extreme events where physical stratification is preserved. Excess ^{210}Pb and ^{137}Cs were ubiquitous in cores from this study, indicating apparent accumulation rates in the range of 2.5 to >10 cm/yr. This study confirms that although flood-event signatures provide a basis with which to examine recent flood deposits of all scales, only the thickest deposits are likely to be preserved over the long term (>100 yr).

Keywords: Mediterranean Sea; Gulf of Lions; Rhône River delta; Flood deposit; ^{210}Pb

1. Introduction

Subaqueous portions of deltas are important shelf regions, where many of the initial interactions between terrigenous sediment supply and marine processes occur, controlling the extent and morphology of sedimentary deposits. The delta front is the relatively steep, submerged region at the leading edge of the prograding river mouth. Farther seaward, muddy deposits of the prodelta extend onto the continental shelf (Roussiez et al., 2005). In the Mediterranean Sea, the prodelta deposits can be extensive in the direction of regional sediment transport (Trincardi et al., 2004). Recent studies have shown that the fate of riverine sediments in river-mouth environments is highly dependent on the coherence between fluvial discharge, storm events and regional circulation (Estournel et al., 1997; Wheatcroft and Sommerfield, 2005).

In many rivers (e.g., Po River), exceptional flood events surpass the seasonal high discharge (i.e., autumn rains and spring snowmelt), thus dominating the annual sediment supply to the shelf. This is especially the case for smaller rivers (e.g., Eel River), which are commonly dominated by episodic flood events in response to high precipitation events. In both cases, flood deposits exhibit the following characteristics: presence of ^{7}Be (short-lived radionuclide associated with terrestrial supply; $t_{1/2} = 53.3$ days), primary physical stratification (i.e., initially little biological

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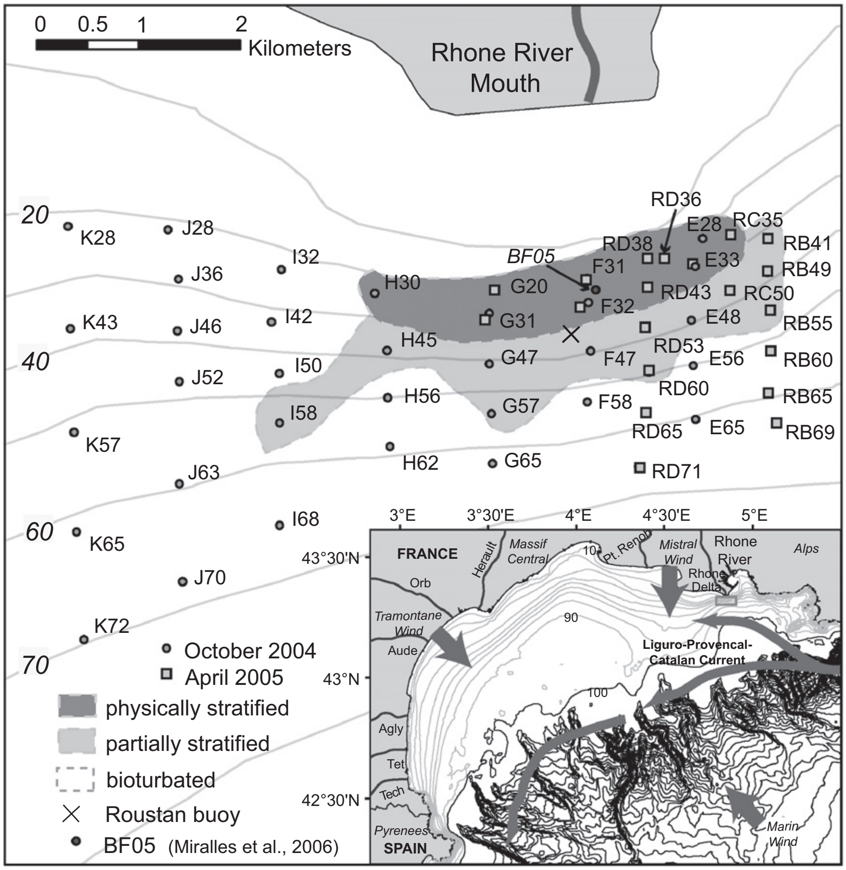

Fig. 1. Study area near the mouth of the Rhône River in the northeast Gulf of Lions. Coring sites with round and square symbols were visited in October 2004 and April 2005, respectively. The areas highlighted by grayscale illustrate regions of physically stratified and partially stratified seabeds, and are not bound by observations landward or eastward, respectively. The remaining sites have sedimentary structure dominated by mottling from bioturbation. The inset shows the Gulf of Lions with mountain ranges, major rivers, winds and general circulation; the study area is shown as a box near the Rhône mouth.

reworking), fine-grained sediment (high percentage of clay compared to preceding seabed sediment), and low $^{210}Pb_{xs}$ activity (minimal scavenging of marine ^{210}Pb) (Sommerfield and Nittrouer, 1999; Sommerfield et al., 1999; Wheatcroft and Borgeld, 2000; Mullenbach et al., 2004; Palinkas et al., 2005; Wheatcroft et al., 2006).

The significance of episodic events (e.g., floods) on a river of moderate size was recognized and examined in the Adriatic Sea near the mouth of the Po River. High-discharge events of the river were not coincident with energetic oceanic conditions (i.e., high winds, large waves, and strong currents), and resulted in seabed deposition close to the river mouth (Palinkas et al., 2005; Wheatcroft et al., 2006). This lack of coherence between high river discharge and energetic ocean conditions is also seen with the Rhône River (Fig. 1) in the Gulf of Lions (GOL), where sediment is initially deposited close to the river mouth on the delta front (Maillet et al., 2006) and some is subsequently redistributed westward on the prodelta and around the GOL continental margin (Courp and Monaco, 1990; Got and Aloisi, 1990; Monaco et al., 1990a, b).

The subaqueous delta off the Rhône River mouth extends from the shoreline to ~80–90 m water depth, mostly along a flat, gentle slope (0.004–0.005) (Touzani and Giresse, 2002). After the 1869 channeling of the Rhône River mouth, the extent of laminated muds indicative of flood deposition was restricted to an area within 3–4 km of the river mouth (a reduction from 7–8 km under natural conditions). Studies also revealed a coarsening trend in the upper sections of cores, an observation attributed to a decrease in flood supply and a longer duration of exposure to reworking processes (Touzani and Giresse, 2002). Sediment accumulation rates of prodelta cores measured using radiochemical dating techniques, ^{210}Pb, ^{137}Cs, and ^{134}Cs, demonstrate that accumulation rates range from 20 to 50 cm/yr near the Rhône River mouth and decrease southwestward to ~0.2 cm/yr on the shelf (Calmet and Fernandez, 1990; Charmasson et al., 1998; Radakovitch et al., 1999). The high accumulation rates near the Rhône River mouth were supported using pollen analyses on a long core (738 cm, near the Roustan buoy; Fig. 1) where accumulation rates were determined to be 10–50 cm/yr (Beaudouin et al., 2005).

The occurrence of multiple large floods of the Rhône River in recent years provides an opportunity to examine the preservation of flood deposits seaward of the Rhône