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Structural effects of tidal exposures on mudflats along the French Guiana coast

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Abstract

Wetting and drying cycles on intertidal mudflats vary considerably with altitude, modifying the physical characteristics of surface sediment in ways favoring (or not) plant colonization. In this context, sediment properties were investigated by means of laboratory experiments and field surveys on a wide range of fluid to desiccated muds from the highly dynamic coastline of French Guiana. Changes in physical parameters, such as sediment erodability (yield stress), water loss and pore water salinity indicated a long term compaction of mudflats as well as fluctuations related to the successive wetting and drying cycles. Mudcracks constituted a spectacular feature representative of the contractional stress. They (re)opened after a few days of dewatering and (re)healed during the subsequent wetting. From the analysis of field data, the trapping of *Avicennia germinans* propagules in ephemeral mudcracks turned out to be responsible of 95% of the sprouting on the coastal fringe. Thus, desiccation process, usually considered as a typical feature of erosion, revealed herein to be a major mechanism of colonization. This mechanism undoubtedly affects the 1600 km long Amazon coastal system and is believed to exist in many other tropical environments submitted to important siltation.

Keywords: Amazon; French Guiana; coastal dynamics; mudflat; desiccation; mangrove

1. Introduction

During the last decade, several surveys carried out over temperate mudflats have demonstrated the spatio-temporal variability of intertidal cohesive sediment stability under the combined influences of physical, geological and biological processes (Friend et al., 2003; Lesourd et al., 2003; Widdows et al., 2000; among others). For example, Widdows et al. (2000) gave evidence of the reactivity of an intertidal mudflat at Humber Estuary (UK) with regard to the changing immersion time over a single spring-to-neap tidal cycle. More recently, a clear effort has been made to understand the short-term structuring processes of tropical intertidal mud, particularly along the mud system of the northeastern coast of South America (Baltzer et al., 2004). The present study aims at further constraining the complex interactions that exist between sediment stabilization, duration of air exposure episodes and mangrove settlement in this unique environment.

The S. American system, which extends from Amapá (NE Brazil) to the Orinoco River delta (Venezuela), is the longest muddy coast fronting the open ocean in the world. This extremely complex and unstable coast is constantly affected by the huge mud discharge of the

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Amazon River, estimated at some $1.1–1.3 \times 10^9$ tons $year^{-1}$ (Meade et al., 1985). While about half of this fine-grained sediment supply settles on the continental shelf in the vicinity of the Amazon mouth, 15% to 20% migrates northwestward to the Guianas coastal plain. The huge mudbanks so formed along the northwestern coast of Amapá (Allison et al., 2000) then transit rapidly along the Guianas coast, resulting in successions of depositional and erosional phases that considerably alter the morphology of this highly dynamic shore. The extremely smooth slope of the intertidal fringe (averaging 1 : 1600) explains the considerable offshore extension of the mudflats. These deposits are exposed to air during more or less prolonged low-tide periods, and display different aspects depending on their location on a given mudflat (Fig. 1b). Thus, sectors adjacent to the coast (upper mudflat), are characterized by visco-plastic sediments having reached significant states of firmness, whereas others are composed of soft, bare muds likely to be transported (Allison and Lee, 2004). On the lee side of the banks, which also are accreting faces, massive arrivals of fluid mud in the form of mud lakes are frequently observed (Lefebvre et al., 2004; Baghdadi et al., 2004). Important mass transfers occurring under the combined action of tidal currents and mud liquefaction promote the accumulation of these thixotropic fluid muds along the coastline. Wave energy is strongly damped over the sheltering mud lakes, so that the complex hydro-sedimentary dynamics may produce a progressive stabilization of muds, followed eventually by initial plant colonization. From a remote-sensing-based analysis, Gardel and Gratiot (in press) estimated a two-and-a-half-year-period between the arrival of the maximal extension of the intertidal zone and the initiation of mangrove settlement processes at the same site. In the pioneer zones, where a dense recruitment of mangrove propagules occurs, the survival of small plants in their initial phase of development depends above all on the number of consecutive days of continuous air exposure (Chapman, 1976; Wells and Coleman, 1981). The structural states of the sediment bed, which are strongly variable over the mudflats, appear to be closely related to the establishment and maturation stages of mangroves.

The main objective of the present study is to assess the effects of emergence durations on the consolidation and structuration of intertidal mudflats in the meso-tidal semi-diurnal coastal system of French Guiana. More specifically, it aims at investigating the evaporation processes that are particularly strong in this tropical environment where the mean annual total insulation reaches 2200 h and the monthly average air temperature oscillates between 26 and 29 °C (Donet, 2004). To that end, the settling of fluid mud in glass prisms subject to immersion regimes based on different tidal rhythms was investigated in the lab and a field campaign was carried out over several major mudflats of the Guianese coastline to examine the interrelationship between fluid mud evolution, vegetation and tidal regime.

2. Materials and methods

2.1. Study sites

The mudflat areas studied are located on five large mudbanks of the French Guiana coast that are presented on Fig. 1a. They are listed as follows in the chronologic order of the missions: (1) on the right bank of the

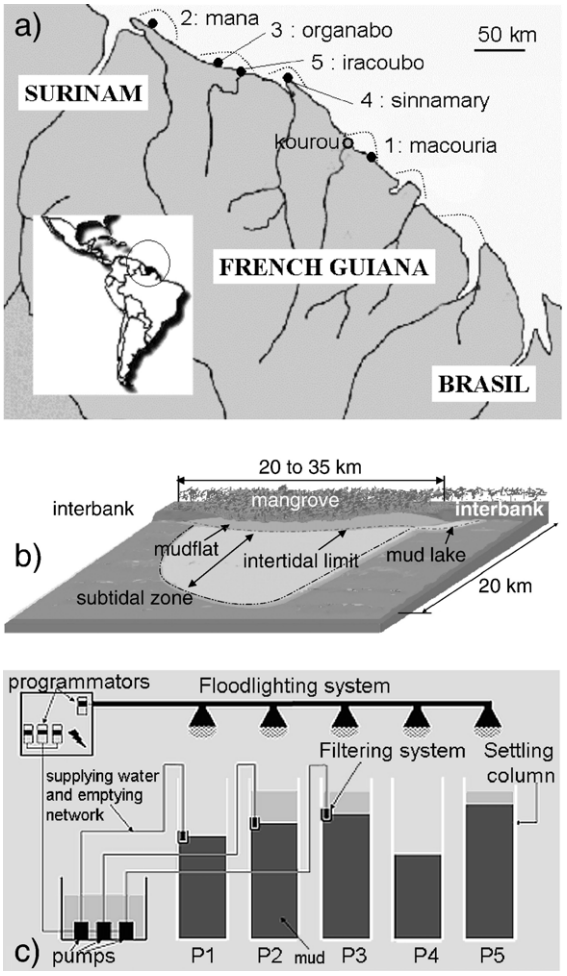

Fig. 1. Field and laboratory investigations. (a) Location map of the field sampling stations. Dotted lines correspond to the approximate position of the main intertidal mudflats in 2004. (b) Schematic representation of a mudbank (adapted from Baghdadi et al., 2004). (c) Schematic representation of the experimental set up. On this picture, muds in P1 and P4 are exposed to air, P1 because of a phase of emergence.