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Role of flocculation and settling processes in development of the mangrove-colonized, Amazon-influenced mud-bank coast of South America

Nicolas Gratiot [a], Edward J. Anthony [b,*]

[a] Laboratoire d'étude des Transferts en Hydrologie et Environnement (LTHE), UMR 5564, Bâtiment OSUG-B, Domaine universitaire, BP 53, 38041 Grenoble Cedex 09, France
[b] Aix Marseille Université, Institut Universitaire de France, CEREGE, UM 34, Europôle Méditerranéen de l'Arbois, B.P. 80, 13545 Aix en Provence Cedex, France

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ABSTRACT

The Guianas coast downdrift (northwestward) of the Amazon River mouth is characterized by the periodic migration of mud banks that originate from the Amazon. The characteristic sizes of these banks as well as their rates of alongshore migration have been estimated from remote sensing. However, the physical mechanisms leading to their displacement are not yet fully understood. The present work is aimed at investigating a number of micro-scale processes involved in the coastal and estuarine dynamics of fine sediments, and expected to occur during the migration of mud banks. The relative magnitudes of flocculation, hindered settling and consolidation have been determined.

Sampling of coastal mud was carried out during a field survey in 2001 that focussed on the fluid mud layer in the leading edge of a mud bank in French Guiana. Settling column experiments were conducted under quiescent conditions for various mean sediment concentrations in the range of 2.5–110 $g.l^{-1}$, which is typical of mud bank concentrations. The time dependent vertical profiles of suspended sediment concentration were monitored using an optical settling tank equipped with 32 pre-calibrated optical sensors. The corresponding settling velocities were deduced from the equation of the conservation of mass.

The results show that the timescales of hindered settling and consolidation processes are much larger than the timescales of mixing mechanisms such as tides or propagating waves. The individual floc settling velocities are too small to counterbalance the turbulent mixing induced by breaking waves. Hindered settling, favoured by wave action and by the high background suspended sediment concentrations, is thus an overarching process in wave-driven mud bank migration. This pervasive hindered settling regime is characteristic of the wave-exposed outer and leading edges of mud banks where active mobilization of mud assures mud bank migration. As a result, consolidation is theoretically precluded. The experiments pointed out, however, that additional flocculation and differential settling should enhance sedimentation during slack water and under low wave conditions. We deduce from this that enhanced settling in the inner, subtidal–intertidal, parts of leading edges of banks during such conditions is important in the temporary sedimentation that generates gel-like fluid mud patches and mud bars. These low-energy inner, leading parts of banks form an accreted substrate colonized by mangroves, which further contribute to enhanced settling and rapid sedimentation.

1. Introduction

The size of grains is an important parameter in fine-grained coastal sedimentation through its effect on settling velocity and resuspension, while being a crucial control on patterns and mechanisms of suspended sediment delivery to the ocean by plumes (Geyer et al., 2004; Winterwerp and Van Kesteren, 2004). An important consideration, therefore, when processes of fine-grained coastal sedimentation are considered, is that of fundamental changes in grain size brought about by aggregation, which results in the binding together of small organic and inorganic particles by bacteria, other organisms, and organic detritus into porous aggregates or flocs (e.g., Droppo, 2001; Droppo et al., 2005; Verney et al., 2009). The dynamically active process of flocculation alters the settling velocity of cohesive sediments, modifying vertical concentration gradients, and, consequently, the rates and patterns of deposition and accumulation. An important fraction of fine sediment in turbid discharge plumes forms large flocs. Although the size of flocs may be affected by turbulent shear stresses in ways that do not command unanimity, the net result of flocculation is an overall increase in the size and settling velocity of the fine-grained material that favours deposition of silt- and clay-sized sediment. Each floc may comprise up to 10^6 individual particles, may be hundreds to thousands of micrometres in diameter, and may sink at speeds in the

* Corresponding author.
E-mail addresses: nicolas.gratiot@ird.fr (N. Gratiot), anthony@cerege.fr (E.J. Anthony).

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range of 0.01 to 2 mms^{-1} (e.g., Xia et al., 2004; Fox et al., 2004; Gratiot and Manning, 2004; Voulgaris and Meyers, 2004; Graham and Manning, 2007; Manning and Dyer, 2007; Uncles et al., 2010), but values predicted from equations can exceed this range (e.g., Uncles et al., 2006). The size, density and strength of flocs are dependent on a large range of conditions that include the total amount of sediment in