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Depositional variability of estuarine intertidal sediments and implications for metal distribution: An example from Moreton Bay (Australia)

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ABSTRACT

This study examines the patterns of depositional variability, sediment geochemistry and metal distribution in intertidal areas of Moreton Bay, southeast Queensland, Australia. Recent concern over increasing human impact on the bay has generated the need to obtain evidence on how the disturbance of the depositional setting might affect the natural estuarine environment.

Sediment stratigraphy, major, and trace element analyses of sediment cores show that the sedimentation pattern is unique to each intertidal site. Disturbed ^{210}Pb and ^{137}Cs activity profiles of some of the cores indicate that sediment reworking occurs across the intertidal flats up to a depth of at least 80 cm. With some notable exceptions, an accurate geochronology of the surface sediments could not be established due to low ^{210}Pb activities and sediment mixing. Thus, an increase in Pb, Zn and Cu towards the surface sediments observed at various sites is attributed to both anthropogenic contribution following the rapid urban development in the last century and to post-depositional diagenetic processes, bioturbation and sediment re-suspension induced by tides, storms or floods. Sediment cores are representative only of the local sedimentation and may not always allow extensive correlation to larger areas. Vertical profiles of heavy metals reflect the different depositional environment controlled by the complex hydrodynamics of the bay. Local hydrologic, physical, and tidal conditions might induce metals redistribution at different scales. This information is of critical importance in view of sediment remobilization caused by future development such as dredging, intertidal areas reclamation or excavation of new navigational channels.

1. Introduction

Moreton Bay, located in southeast Queensland is one of the largest estuarine systems in Australia and is internationally recognized for its biodiversity and ecological significance (Dennison and Abal, 1999). Last century's accelerated urban, agricultural and industrial development led to substantial modifications of the region with only 28% of the catchment area remained undisturbed after intensive land clearing, deforestation, agriculture and urbanization (Capelin et al., 1998; Neil, 1988; Dennison and Abal, 1999). The western sides of the bay are facing continuous pressure from new developments and intensive alterations of the intertidal areas, such as the establishment of the Brisbane port and airport and the construction of recreational harbors. Sediment deposition in marine coastal environments is a natural process controlled by geography, geology, geomorphology, and climate variability. However, following the rapid urbanization, sediments transported from the catchment to the bay have increased together with the associated metal loads and nutrients (Neil, 1988; Dennison and Abal, 1999; Duke et al., 2003; Cox and Preda, 2005; Healthy Waterways, 2012; Morelli et al., 2012), and represent a major environmental problem. For example, nitrate and phosphate concentrations in the Brisbane River waters increased by 22 and 11 times, respectively, in the last 50 years (Dennison and Abal, 1999; Duke et al., 2003; Cox and Preda, 2005). Frequent blooms of *Lyngbya*, a toxic cyanobacteria, in the western side of the bay possibly reflect high nutrient contents in the waters, with western Moreton Bay considered to be eutrophic (Dennison and Abal, 1999) and to have an altered hydrogeological regime (Logan et al., 2010). Most importantly, sediments deposited in bays and estuaries represent a potential sink for anthropogenic-derived metals in any

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aquatic environment because of their large adsorption capability (Siegel, 2002). Hence, estuarine sediments deposited in the past may be more contaminated than recent sediments (e.g. Pirrie et al., 1997; Cearreta et al., 2002; Cundy et al., 2003). Post-depositional disturbance by reworking processes (bioturbation, floods, tidal currents or dredging) can result in sediment re-suspension and release of potential contaminants into the food chain (Tessier and Campbell, 1988), thus contributing to the long-term contamination of many estuaries (e.g. Forstner and Wittman, 1981; Eyre and McConchie, 1993; Swales et al., 2002; Cundy et al., 2003; Förstner and Salomons, 2008; Smith et al., 2008; Larrose et al., 2010).

Due to its sub-tropical location, Moreton Bay is subjected to seasonal intense floods during the wet season, resulting in significant events of sediment deposition and/or resuspension (Neil, 1988). Consequently, it is important to have a clear understanding of the depositional setting, distribution and source of sediments together with trace elements variability to support any management strategy for the protection of this estuarine ecosystem. A number of studies have characterized trace metal distribution in Moreton Bay sediments (Cox and Preda, 2005; Brady et al., 2014a, 2014b; Morelli and Gasparon, 2014) and provided some information at the whole-bay scale. A study on sediment cores revealed considerable variability in sedimentation rates across four intertidal areas (Morelli et al., 2012). It remains to be established, however, whether the depositional and geochemical properties of the intertidal sediment profiles are consistent across the bay. This characterization is critical to identify the natural and anthropogenic components of the sediments, and to monitor possible sediment contamination in view of any disturbance of the sediment column due to excavation and maintenance of navigational channels, intertidal areas reclamation or increased recreational activities.

This study on estuarine sedimentation and geochemistry documents the complexity of Moreton Bay intertidal areas. Results of nine intertidal sediment cores are discussed in this article and are integrated with an additional set of data from four cores described in a previous study (Morelli et al., 2012). Stratigraphic observations, major and trace element compositions, and ^{210}Pb and ^{137}Cs activities were integrated to 1) characterize the

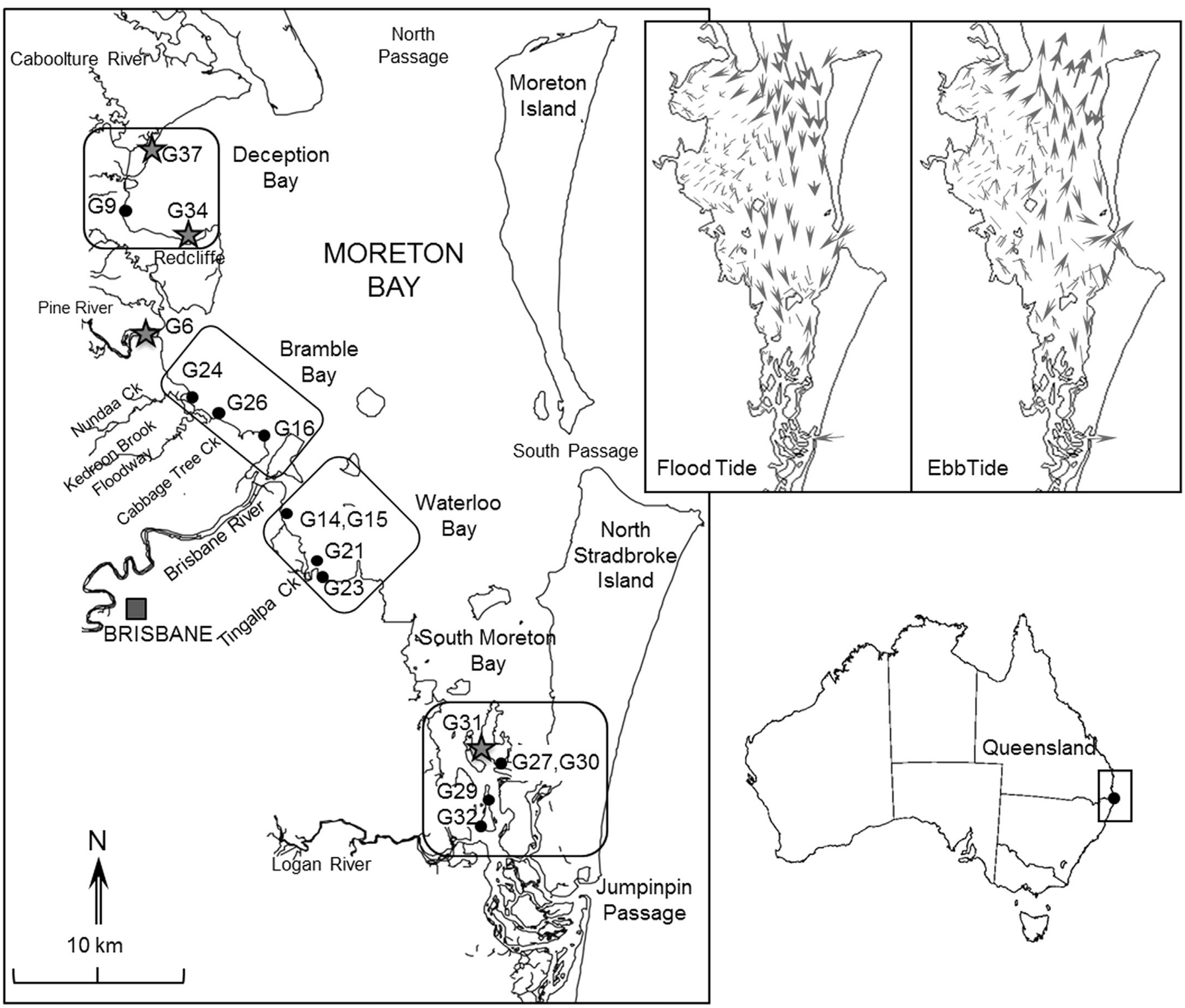

Fig. 1. Map of Moreton Bay and location of the sampling sites (black dots). Stars indicate sites previously described in Morelli et al. (2012). Results of their sediment geochemistry and stratigraphy are presented in this paper. Cores G15, G27 and G30 were collected and used only for qualitative sedimentary observations. The map in the top right shows the flood and ebb tide circulation in the bay (modified from Milford and Church (1976)).