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Sediment deposits and organic carbon sequestration along mangrove coasts of the Leizhou Peninsula, southern China

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ABSTRACT

Mangroves are an important affecter of atmospheric CO_2 level via sequestrating carbon and trapping sediments. However, their sequestrating effectiveness varies with vegetation development and sedimentation processes under site-specific hydrogeomorphic settings. In order to detect the determinants of organic carbon sequestration, this study investigated four mangrove fringing locations along the coast of the Leizhou Peninsula. Surface and core sediment samples were collected from these sites and analyzed for grain-size distribution, sedimentary organic carbon content (SOCC) and stable isotope signature ($\delta^{13}C_{org}$). It is found that a significantly higher concentration and density of organic carbon were preserved in the interior surface sediments regardless of location or surface grain size distribution. The sedimentary environments, as indicated by core sediment analysis, are controlled under low-to moderately low-energy conditions. Fluvial action on these sedimentary environments decreases from the river dominated site to the tide dominated site. The more stable energy condition favored both sediment and organic carbon accumulation in the mudflat subzone. However, as revealed by $\delta^{13}C$ signature, sedimentary organic carbon of the core samples from the four sites was dominantly derived from suspended particulate matter except the tide-dominated offshore core. Whereby, we conclude that vegetation provided control on the surface sedimentary organic carbon distribution via its influence onmangrove debris input and fluid energy condition over the intertidal surface, while hydrogeomorphology determined the long-term organic carbon burial via its impact on the local sedimentation accretion rate and the proportion of autogenous organic carbon sequestration.

1. Introduction

Mangrove sediments are characterized by intense carbon processes with a potentially high impact on the global carbon budget (Alongi, 2007; Kristensen et al., 2008 and Bianchi et al., 2013). Due to their attractive characteristics, such as rapid sediment accretion, high productivity, and low ratio of sediment respiration, mangrove ecosystems are regarded as a potentially efficient pool for long-term sequestration of organic carbon (Jennerjahn and Itekkot, 2002; Lugo and Snedaker, 1974; Zhang et al., 2012), providing valuable regional and site-specific functions in response to sea level change and increased atmospheric CO_2 level (Alongi, 2008; Gilman et al., 2008). Generally, the involved processes of material exchange in mangrove ecosystems include different original inputs to sedimentary organic carbon, carbon fluxes between mangroves and their adjacent systems, and organic carbon cycling within the system (Ye et al., 2011, Yang, et al., 2013). Site-specific hydrogeomorphic settings (tidal amplitude and asymmetry, river discharge) often give rise to the spatial variability in these processes. For example, the export of mangrove material in coastal waters depends largely on longshore currents, which can prevent the mixing of estuarine and adjacent coastal waters (Wolanski et al., 1992; Jennerjahn and Itekkot, 2002). In addition, in river- and tide-dominated mangrove substrate, the high rates of sediment and carbon inputs from either land or sea contribute significantly to the rapid accretion of organic-rich sediments (Wolanski et al., 1992; Alongi et al., 2000). Although many reports on sedimentation rates and carbon storage in mangrove sediments have expanded our knowledge of carbon sequestration in mangrove sediments (Victor et al., 2004; Adame et al., 2010; Sanders et al., 2010; Zhang et al., 2012), the critical role of vegetation and hydrogeomorphology is still not fully understood. The link may be a significant determinant of the amount of organic carbon accumulated in mangrove sediments, as well as the proportion of that carbon produced within a mangrove forest.

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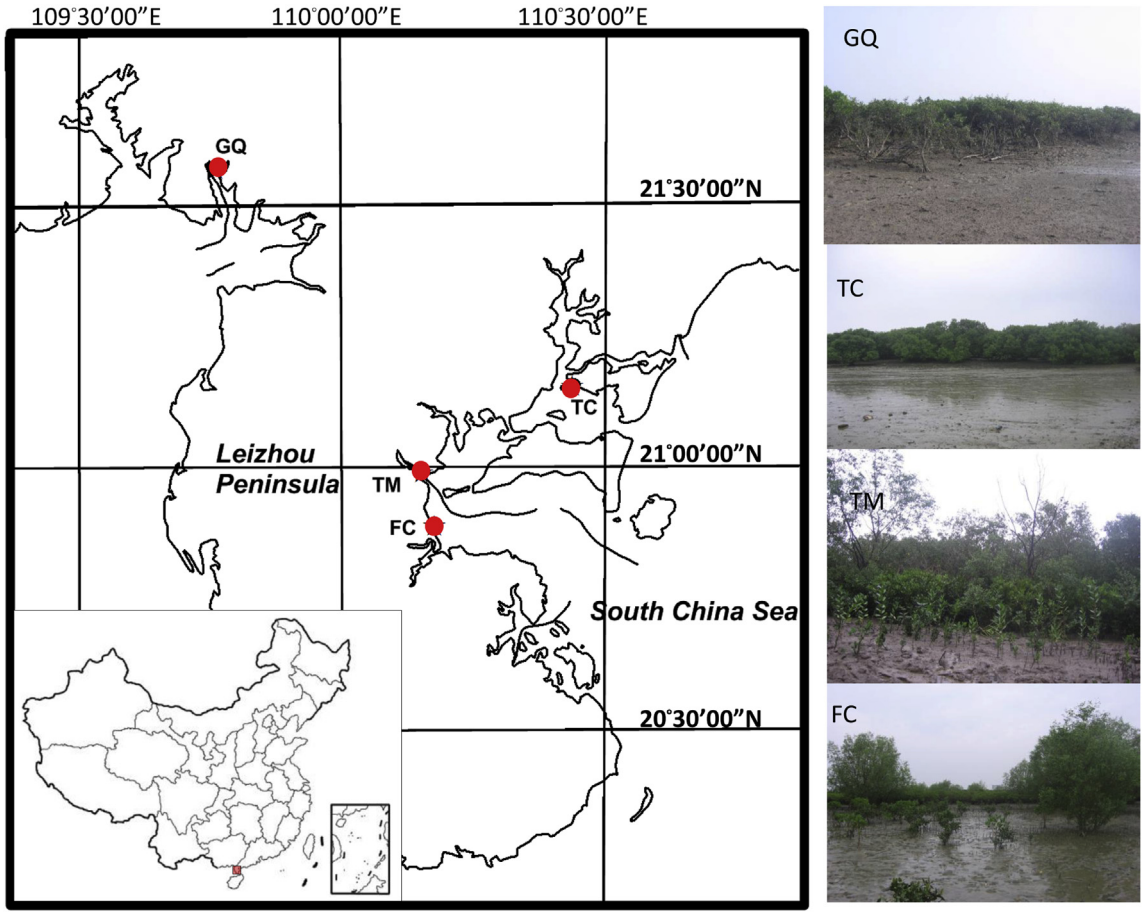

Fig. 1. Mangrove location and their appearance on the ground. Note: The dominant species are *A. marina* (GQ, estuarine), *A. corniculatum* + *K. candel* (TM, riverine), exotic *Sonneratia apetala* + *A. marina* (FC, alongshore) and *A. Marina* (TM, offshore).

As mangroves are dynamic ecosystems located at the land-sea margin and coupled to other upstream and downstream ecosystems, the mechanism of transport and deposition of sediments under different hydrogeomorphic settings can be explored by using granulometric analysis. The significant correlation between the size frequency distribution and depositional processes is considered useful for distinguishing the fluidity (viscosity) factor of the depositing medium and the energy factor of both ancient and recent depositional environment (site) (Sahu, 1964; Folk, 1966; Friedman, 1967; Hails and Hoyt, 1969). Bivariant plots of mean versus sorting, skewness versus mean, and sorting versus skewness have been used to distinguish the transport of sediments from dune sands, river sands and beach sands (Friedman, 1961; Friedman, 1967; Moiola and Weiser, 1968; Friedman and Sanders, 1978). The CM diagram (C = one percentage in microns, M = Median in microns) and Sahu's linear discriminant function are also utilized in differentiating the energy conditions and environmental origins of mangrove sediments (Ramanathan et al., 2009). Thereby, one of the study attempts is to appraise the potential of grain size analysis in gaining proper insights of the influence of hydrogeomorphology on mangrove fringing coasts. It is hypothesized that the sedimentation process exerts a dominant control over the local organic carbon deposition along the mangrove coast.

As one of the largest subtropical mangrove forest regions in China, the Leizhou Peninsula contained 14,027 ha of mangroves in the 1950s, which have decreased to only 7800 ha, accounting for 33% of the national total at present. This rapid decline was due to excessive clearing of the trees for fuel and reclamation of mangrove wetlands for shrimp farming (Ren et al., 2008; Han and Gao, 2009; Zhang et al., 2012). Deforestation has led to the mangroves being more scattered in small patches than in large, contiguous ones. The existing mangrove patches are apt to remain discontinuous and develop in a wide range of secluded sites, including estuaries, sheltered areas behind islands and open coasts where wave energy is dissipated over a wide shallow nearshore. Accordingly, the research also aims to develop a better understanding of the patterns of sedimentation and organic carbon burial under variable hydrogeomorphic conditions.

2. Methods

2.1. Study sites

The Leizhou Peninsula is located in the southernmost part of mainland China. Along its 1500-km coastline, there are many bays and estuaries where mangrove forests of diverse species and mudflats are found. The recorded mangrove species total twenty four in this region, including the most common *Avicennia marina*, *Rhizophora stylosa*, *Kandelia candel*, *Bruguiera gymnorrhiza* and *Aegiceras corniculatum*. Under the northern tropical maritime monsoon climate, the peninsula has an average annual temperature of 22.3 °C. Annual rainfall varies from 1100 to 1800 mm, concentrated mostly in the rainy season of May–September. Typhoons along the east coast bring about the heaviest rainfall in summer. Tidal range averages about 2.5 m high with a semi-diurnal tide on the east coast and a diurnal on the west coast (Han and Gao, 2009).