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Sedimentary processes on the Mekong subaqueous delta: Clay mineral and geochemical analysis

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ABSTRACT

Sedimentary processes on the inner Mekong Shelf were investigated by examining the characteristics of sediments sampled in gravity cores at 15 locations, including grain size, clay mineralogy, sediment accumulation rates, and the elemental and stable carbon isotopic composition of organic matter (atomic C/N ratios and δ^{13}C). Deltaic deposits exhibit contrasting characteristics along different sides of the delta plain (South China Sea, SCS hereafter, to the east and Gulf of Thailand, GOT hereafter, to the west) as well as on and off the subaqueous deltaic system. On one hand, cores recovered from the subaqueous delta in the SCS/GOT are consisted of poorly/well sorted sediments with similar/different clay mineral assemblage with/from Mekong sediments. Excess ^{210}Pb profiles, supported by ^{14}C chronologies, indicate either "non-steady" (SCS side) or "rapid accumulation" (GOT side) processes on the subaqueous delta. The δ^{13}C and C/N ratio indicate a mixture of terrestrial and marine-sourced organic matter in the deltaic sediment. On the other hand, cores recovered from areas with no deltaic deposits or seaward of the subaqueous delta show excess ^{210}Pb profiles indicating "steady-state" accumulation with a greater proportion of marine-sourced organic matter. Core analysis's relevance with local depositional environment and previous acoustic profiling are discussed.

1. Introduction

As a connection between land and oceans, continental shelf sediments bear the characteristics of both riverine systems from which they are discharged and the coastal environments where they are temporally/permanently deposited. Sedimentary deposits, including those that accumulate in subaqueous deltas and clinothems around river mouths and those on the open shelf, have been extensively investigated to: (1) interpret sequence stratigraphy and construct local sea-level curves (e.g. Liu et al., 2004 in the Yellow Sea); (2) examine interactions between sedimentary processes and morphodynamics (e.g. Wolinsky and Pratson, 2007); (3) establish Late Quaternary sediment/carbon budgets (e.g. Goni et al., 2008 in the Fly River Delta); and (4) evaluate the influence of episodic events such as storms and typhoons on sediment dynamics and coastal morphodynamics (e.g. Milliman and Kao, 2005 in Taiwanese rivers).

The six major fluvial systems in the Western Pacific, i.e. the Yellow (Huanghe), Yangtze (Changjiang), Pearl (Zhujiang), Red (Songhong), Mekong (Lancang), and Taiwanese Rivers, deliver approximate 2.2 billion tons of sediments to the Bohai Sea, Yellow Sea, East China Sea, and South China Sea (SCS hereafter) annually (Milliman and Syvitski, 1992; Liu et al., 2008). These sediments account for approximately 17% of the terrestrial sediment flux to the global coastal ocean (12.6 billion tons/yr, Syvitski et al., 2005). The Mekong River is the largest river in the tropical Western Pacific in terms of length and freshwater/sediment inputs. It originates in the Tibetan Plateau, runs through China, Myanmar, Thailand, Lao PDR, Cambodia, and enters the SCS in southern Vietnam (Fig. 1). The Mekong River has a length of ~4750 km and a basin area of 832,000 km^2 (Xue et al., 2011). Every year it discharges ~495 × 10^9 m^3 of fresh water and ~160 million tons of sediment into the SCS through the Mekong River Delta (MRD hereafter) (Milliman and Syvitski, 1992). As the population and economy booms, another 200 new dams will be added to the Mekong basin in the next couple of decades (Xue et al., 2011). Dams will not only hold a large amount of riverine sediments and decrease the sediment flux downstream, but also shift the original rhythm of water/sediment discharge controlled by monsoon forcing.

The MRD has an area of 49,500 km^2 and is the third largest delta plain in the world (Le et al., 2007; Coleman and Roberts, 1989). It is bordered by two different circulation systems: to the east is the

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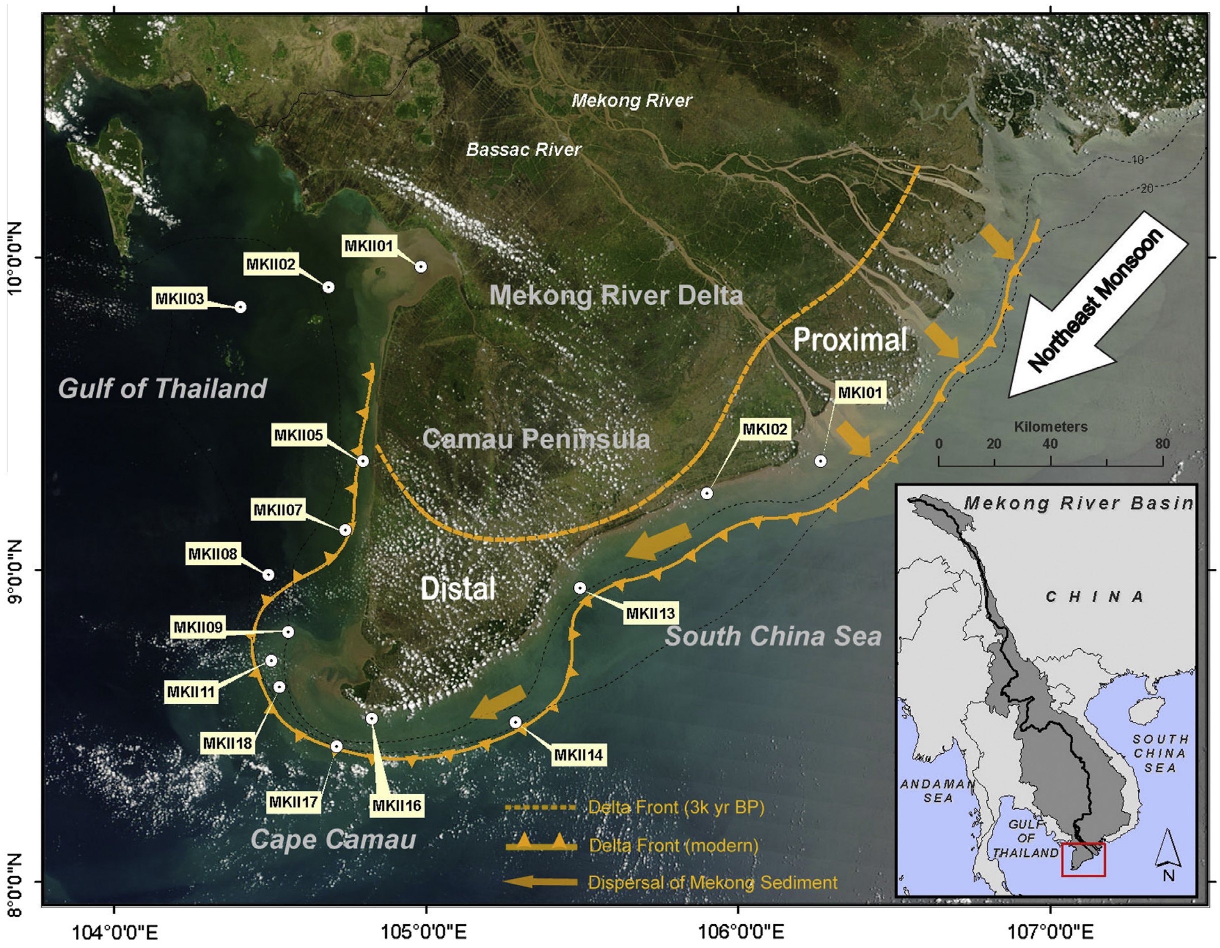

Fig. 1. Map of the Mekong River Delta, positions of gravity cores. Positions of delta front are from Nguyen et al. (2000) (3000 yrs BP) and Xue et al. (2010) (modern), respectively.

southern SCS, characterized by a regular semidiurnal tide with 3.5 m tidal range; to the west is Gulf of Thailand (GOT hereafter), characterized by an irregular diurnal micro-tide with 0.8–1.0 m tidal range. The circulation patterns of the intermediate to upper layers of both systems are forced by monsoon systems. For both southern SCS and the GOT, the circulation is predominantly cyclonic in winter and anticyclonic in summer (Wyrtki, 1961; Kenzo et al., 1998). While the large-scale circulation is well understood, existing observations are too sparse to resolve the detailed structures and dynamics of the Mekong Shelf. For near shore areas around the Mekong River mouth, a general consensus is that waves and currents generated by the strong northeast winter monsoon dominate the net along-shelf sediment transport (Gagliano and McIntire, 1968; Nguyen et al., 2000; Xue et al., 2010). Results of the global HyCOM model (Interannual North and Equatorial Pacific Ocean 1/12 Simulation, Kelly et al., 2007) shows that the coastal currents along the SCS side of the delta plain shift its direction twice annually during May (from southwestward to northeastward) and October (from northeastward to southwestward). Current velocity along the GOT side is much smaller than the SCS side in both northeast monsoon and southwest monsoon seasons (see vertical integrated currents averaged during 1991–2003 in Fig. 2).

Sea level research on the Sunda shelf revealed that the sea level was about −120 m around 19,000 cal yr BP (Hanebuth et al., 2009). For the MRD area, a sea level curve for the last 15,000 yrs was rebuilt based on inland boreholes (Ta et al., 2002a). Both of the two curves show a rapid sea level rise since the last glacial episode. Borehole studies also showed that the MRD began its progradation 8000 cal yr BP as a result of decelerating sea-level rise (Tamura et al., 2009). It has prograded 250 km from the Cambodian border toward the southeast over the past 5500 yrs (Nguyen et al., 2000). A recent geophysical survey on the inner Mekong Shelf revealed an up to 20-m-thick clinoform, i.e. the Mekong subaqueous delta, surrounding the modern delta plain (Xue et al., 2010). This subaqueous delta/clinoform system was correlated to the “delta front” facies defined in boreholes recovered from the modern delta plain (Ta et al., 2002b). The Mekong subaqueous delta is characterized by a relatively high gradient clinoform with strong reflectivity along the SCS side of the delta plain (SCS side), a high gradient clinoform around Cape Camau, and a relatively low gradient clinoform with weak reflectivity along the GOT side of the delta plain. Based on the volume of the subaqueous delta, a sediment budget of the Mekong system was made and it was concluded that around 80% of the sediment has been trapped around the delta plain over the past 3000 yrs (Xue et al., 2010).

The MRD’s progradation process was not a continuous one: a phase shift occurred from a “tide dominated” delta to a “tide and wave dominated” delta around 3000 cal yr BP, based on facies variations within the boreholes as well as the emergence of alongshore river-mouth bars recovered from the delta plain (Ta et al., 2002a,b; Tamura et al., 2012). As shown in Fig. 1, the MRD exhibits a morphological asymmetry with a huge downdrift delta plain, named the Camau Peninsula, providing direct evidence for along-shelf, wave-driven sediment transport as indicated by Ta et al. (2005). Xue et al. (2010) further proposed a seasonal transport mechanism