Global and Planetary Change 110 (2013) 223–235

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

Modern sedimentation and morphology of the subaqueous Mekong Delta, Southern Vietnam

Daniel Unverricht [a,*], Witold Szczuciński [b], Karl Stattegger [a], Robert Jagodziński [b], Xuan Thuyen Le [c], Laval Liong Wee Kwong [d]

[a] Institute of Geosciences - Department of Sedimentology, Christian-Albrechts-University of Kiel, Germany
[b] Institute of Geology, Adam Mickiewicz University, Poznań, Poland
[c] Institute of Resources Geography, VAST, Ho Chi Minh City,Vietnam
[d] Environment Laboratories, International Atomic Energy Agency, 4 Quai Antoine 1er, MC 98000, Monaco

ARTICLE INFO

Article history:
Received 28 April 2011
Revised 25 August 2012
Accepted 14 December 2012
Available online 14 January 2013

Keywords:
Mekong Delta
sedimentation
grain size distribution
subaqueous delta morphology
sediment accumulation rate

ABSTRACT

The Mekong River Delta is among the Asian mega-deltas and is influenced by various factors including tides (meso-tidal system), waves, coastal currents, monsoon-driven river discharge and human impact (agriculture, fishing, sand dredging, tourism). The present study aims to document the seafloor relief, sediment distribution and sediment accumulation rates to interpret modern sediment transport directions and main sedimentation processes in the subaqueous Mekong Delta. The major results of this investigation include the detection of two delta fronts 200 km apart, one at the mouth of the Bassac River (the biggest branch of the Mekong Delta) and the other around Cape Ca Mau (most south-western end of the Mekong Delta). Additionally, a large channel system runs in the subaqueous delta platform parallel to the shore and between the two fronts. The sediment accumulation rates vary greatly according to the location in the subaqueous delta and have reached up to 10 cm/yr for the last century. A cluster analysis of surface sediment samples revealed two different sediment types within the delta including a well-sorted sandy sediment and a poorly sorted, silty sediment. In addition, a third end member with medium to coarse sand characterised the distant parts of the delta at the transition to the open shelf. The increase of organic matter and carbonate content to the bottom set area and other sedimentary features such as shell fragments, foraminiferas and concretions of palaeo-soils that do not occur in delta sediments, supported grain size-based classification. Beginning in front of the Bassac River mouth, sedimentary pattern indicates clockwise sediment transport alongshore in the western direction to a broad topset area and the delta front around Cape Ca Mau. Our results clearly show the large lateral variability of the subaqueous Mekong Delta that is further complicated by strong monsoon-driven seasonality. River, tidal and wave forcing vary at local and seasonal scales with sedimentary response to localised short-term depositional patterns that are often not preserved in long-term geological records.

1. Introduction

The ongoing natural and human-driven global changes result in important variations in the sediment flux from land to ocean (Syvitski et al., 2005), which are perceptible in the coastal zone and particularly in river deltas (Syvitski and Saito, 2007; Syvitski et al., 2009). The recent reduction of sediment input due to river damming and the resulting coastal erosion impacted the coastal zone (Milliman and Ren, 1995). Ranked among the 10 largest suppliers of sediments to the world's oceans (Milliman and Meade, 1983), and with estimated sediment discharge of 160 million tonnes per year (Milliman and Ren, 1995), the sediment discharge of Mekong River may diminish due to existing dams (Kummu et al., 2010; Wang et al., 2011). Large river systems complicate the comparison of the sediment flux estimates with the actual fluxes in the coastal zone because the final destination of the river sediments and the dominating sedimentary processes remain little understood.

A recent attempt to combine data from various river systems explored the driving processes on the dispersal and accumulation of riverine sediments in the coastal zone and defined the following important criteria: sediment discharge, shelf width, and wave and tidal conditions (Walsh and Nittrouer, 2009). Many more factors may affect the delta, however, including processes acting in the river catchment, the coastal zone and the marine realm (Vörösmarty et al., 2003; Kummu and Varis, 2007; Syvitski and Saito, 2007; Kummu et al., 2010; Yang et al., 2011). In many cases, lacks of good spatial and temporal data coverage limit these discussions. Similarly, in the Mekong River Delta, the sediment depocenter in a subaqueous part of the delta was only recently

* Corresponding author at: University of Kiel, Institute of Geosciences – Sedimentology, Coastal and Continental Shelf Research, Otto-Hahn-Platz 1, 24118 Kiel, Germany. Tel.: +49 4318803469; fax: +49 4318804376.
E-mail address: unverricht@gpi.uni-kiel.de (D. Unverricht).

0921-8181/$ – see front matter
http://dx.doi.org/10.1016/j.gloplacha.2012.12.009

documented through several seismic profiles and 6 short sediment cores (Xue et al., 2010).

The deltas also changed in the past, and understanding their developments proves valuable for predicting their future evolution. In the case of the Mekong River Delta, land-based borehole data and seismic surveys recorded the Holocene delta evolution from the initiation of delta progradation around 8.0 ka BP to the present (Nguyen et al., 2000; Ta et al., 2002b; Tamura et al., 2009; Xue et al., 2010; Proske et al., 2011; Hanebuth et al., 2012; Tamura et al., 2012). During its development, the delta character changed from tide-dominated into a wave- and tide-dominated, and its shape and the orientation of the coastline changed through time (Ta et al., 2002a). The reconstruction of delta development is based on the character and structures of the sediments interpreted as a part of the subaqueous delta, but such data have not been gathered from the modern Mekong Delta, where the hydrodynamic conditions, the position of sediment within the delta and spatial and temporal relationships may be observed.

This study documents sea floor relief, sediments and sediment accumulation rates to interpret the modern sediment dispersal pattern, sedimentation processes and rates on the subaqueous Mekong Delta. Additionally, future interpretations of the Mekong River Delta evolution will benefit from this data set.

2. Regional setting

The Mekong River originates on the Tibetan Plateau and crosses China, Myanmar, Laos, Thailand, Cambodia and Vietnam, where it flows into the South China Sea (Fig. 1). Its delta plain stretches over an area of 49,500 km^2 between Phnom Penh in the Cambodian lowlands and the southeast Vietnamese coast (Le et al., 2007). Fig. 1 depicts the main distributaries, the Bassac (Hau River) and the Mekong (Tien River), which split into the 2 branches of the Bassac and 6 of the Mekong before entering the sea. Strong seasonal climatic variations in the Mekong Delta are related to the phase of the East Asian Monsoon (Hordoir et al., 2006; Mitsuguchi et al., 2008; Xue et al., 2011). The north-eastern winter monsoon dominates from November to early March with high wind stress at the south-eastern exposed coast, and the south-western summer monsoon carries precipitation towards the Mekong Delta (Mekong River Commission, 2005, 2009; Snidvongs and Teng, 2006; ISPONRE, 2009). The annual average rainfall in southern Vietnam ranges between 1600 and 2000 mm. Wind speeds can reach 20–30 m/s under stormy conditions; however, mean annual wind velocities range between 1.5 and 3.5 m/s (Institute of Strategy and Policy on natural resources and environment (ISPONRE), 2009).

The distribution of the principal surface current system in the Southern South China Sea has been attributed to the East Asian Monsoon (Wendong et al., 1998). The maximum wind stress prevails along the south-eastern coast of the Indochina Peninsula in both monsoon seasons. In the Mekong River basin, 85% (475 billion m^3) of the water discharge occurs during the wet season (May to October), and 15% (78.8 billion m^3) in the dry season (November to April) (Snidvongs and Teng, 2006; Le et al., 2007). The Mekong River Commission provides a representative documentation of the water discharge and level for the upper Mekong Delta region. Data availability of the water discharge or tidal amplitudes is however problematic for the river mouth

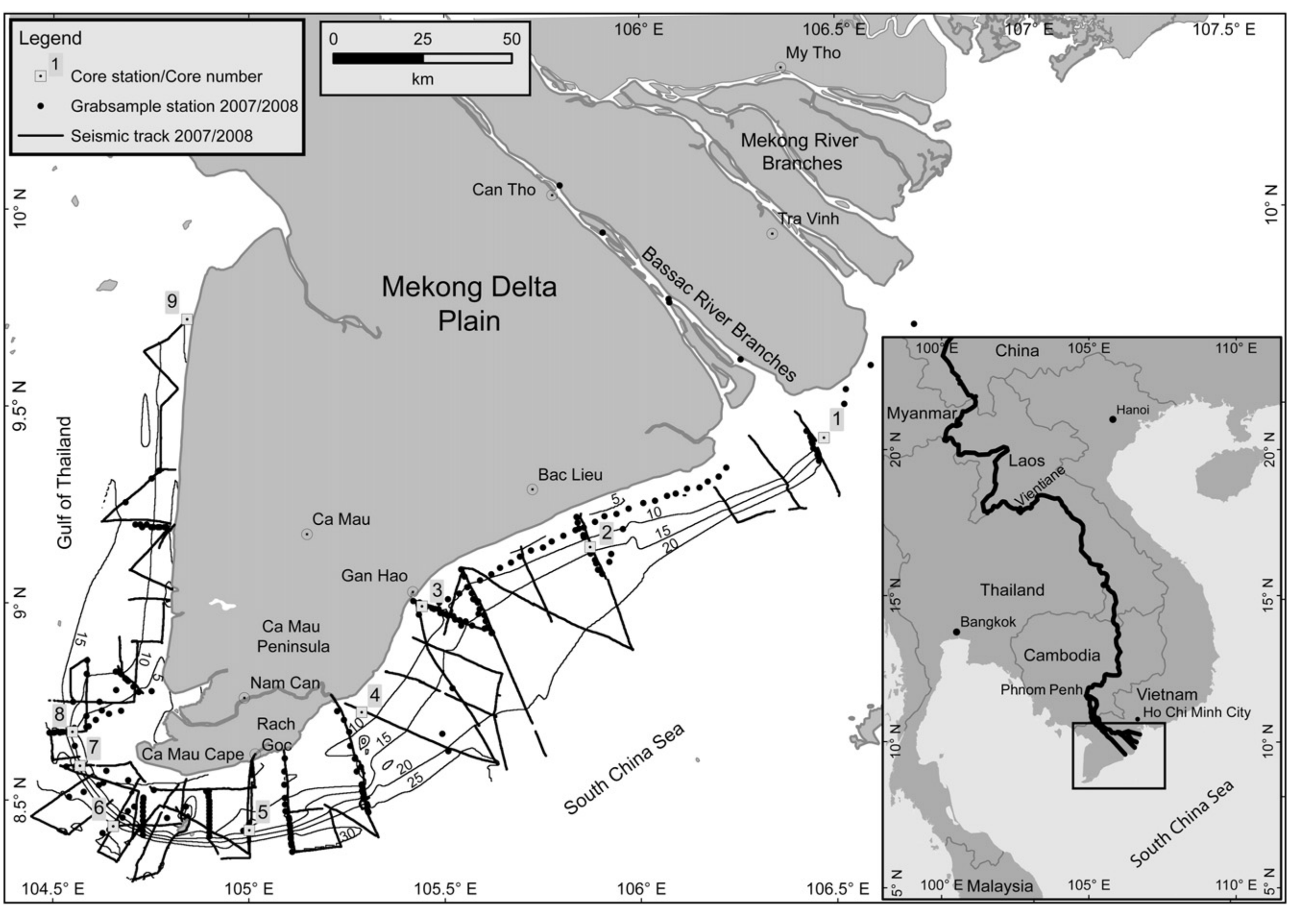

Fig. 1. The base map containing the investigated area with the subaqueous part of the Mekong Delta and adjacent continental shelf, with marked surveyed seismic lines, locations of surface sediment samples and sediment cores and the topographical features mentioned in the text. The presented bathymetry is based on own survey. The inset map shows the location of the Mekong River delta in South-east Asia.