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The role of sea-level rise, monsoonal discharge and the palaeo-landscape in the early Holocene evolution of the Pearl River delta, southern China

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ABSTRACT

The early Holocene history of the Pearl River delta is reconstructed based on a series of sediment cores obtained from one of the main palaeo-valleys in the basin. Sedimentary and microfossil diatom analyses combined with radiocarbon dating provide new evidence for the interactions between sea-level rise, antecedent topography and sedimentary discharge changes within the deltaic basin since the last glacial. These new records show that river channels of last glacial age incised down to c. −40 m into an older (possibly MIS5 age) marine sequence which forms the floor of the deltaic basin and exists primarily at c. 10 m–15 m below present mean sea level. Rapid postglacial sea-level rise flooded the incised valleys by the beginning of the Holocene, and prior to c. 9000 cal. years BP, marine inundation was largely confined within these incised valleys. The confined available accommodation space of the incised valleys combined with strong monsoon-driven freshwater, high sediment discharge and a period of rapid rising sea level meant that sedimentation rates were exceptionally high. Towards c. 8000 cal. years BP as sea level rose to about −5 m, marine inundation spilled out of the incised valleys and the sea flooded the whole deltaic basin. As a result, the mouth of the Pearl River was forced to retreat to the apex of the deltaic basin, water salinity within the basin increased markedly as the previously confined system dispersed across the basin, and the sedimentation changed from fluvial dominated to tidal dominated. Sea level continued to rise, albeit at a much reduced rate between 8000 and 7000 cal. years BP, and deltaic sedimentation was concentrated around the apex area of the basin. During the last 7000 cal. years BP, the delta shoreline moved seawards, and the sedimentary processes changed gradually from tidal dominated to fluvial dominated.

1. Introduction

Deltas and estuaries are fast evolving landforms. It has long been proposed that changes of these landforms during the postglacial period have been largely controlled by sea-level movements (e.g. Stanley and Warne, 1994). During the late Pleistocene, sea level rose rapidly (e.g. Hanebuth et al., 2000; Siddall et al., 2003; Bassett et al., 2005), and vast areas of now continental shelves were inundated by the sea (e.g. Steinke et al., 2003). As a result of the continuous rise in sea level in the early Holocene, marine water transgressed many coastal basins and palaeo-river valleys. In river mouth regions, deltas or estuaries formed during the middle and late Holocene as sea level stabilised. The characteristics of these coastal landforms are largely determined by the relative sea-level history of the region (e.g. Smith et al., 2011), the amount of sediment supply from their respective rivers (e.g. Woodroffe, 2000), other coastal processes including tides and waves (e.g. Tanabe et al., 2006), and human activity in the late Holocene (e.g. Zong et al., 2009a).

Over the past decades, the evolutionary history of many large deltas has been investigated, e.g. the Yellow River delta (Saito et al., 2000, 2001), the Yangtze delta (Li et al., 2000, 2002; Hori et al., 2001), the Han River delta (Zong, 1992), the Song Hong River delta (Tanabe et al., 2003a, 2006; Li et al., 2006a,b; Funabiki et al., 2007), the Mekong delta (Nguyen et al., 2000; Ta et al., 2001, 2002), the Ganges–Brahmaputra delta (Goodbred and Kuehl, 2000), the Mississippi delta (Coleman, 1988), the Nile delta (Chen et al., 1992), and other deltas (Woodroffe, 2000; Tanabe et al., 2003b), with some studies expanded to the subaqueous deltas (e.g. Chen et al., 2000; Liu et al., 2004; Wang et al., 2010). These investigations have revealed

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the influence of different driving mechanisms for deltaic evolution, primarily highlighting the importance of sediment supply and sea-level change. A few recent studies have focused on a possible sea-level jump in the early Holocene around 8200 cal. years BP and its effects on sedimentary infill in incised valleys and a widespread marine transgression (Yim et al., 2006; Hori and Saito, 2007; Tamura et al., 2009). Such work has been rather controversial as there is a lack of direct (glacial) evidence for such sea-level jump at this time. Furthermore, a reflection in sea-level rise was reported from Singapore, which indicates further details of sea-level history between 8000 and 7000 cal. years BP (Bird et al., 2007, 2010). Despite the amount of research carried out in many large deltas, there is a lack of sedimentary records that reveal the detailed response of the landscape to rapid sea-level rise in the late Pleistocene and early Holocene.

In theory, the Pearl River should have incised into the older marine sequences when sea level was low during the last glacial. If such palaeo-valleys have incised down as far as to the bedrock, i.e. to c. −40 m (Zong et al., 2009b), these valleys may have been inundated as early as the beginning of the Holocene. Recent drilling in the Pearl River delta has revealed one possible palaeo-valley (e.g. Wu et al., 2007; Liu et al., 2008) that contains sediment of early Holocene age. Subsequently, we carried out a drilling programme to identify palaeo-incised valleys within the Pearl River deltaic basin and to obtain sediments for examination. This paper reports new high-resolution palaeo-environmental data collected from an incised valley. With these new data, we explain the sedimentary processes in the early Holocene and examine the complex interactions between sea-level rise, monsoonal discharge and the palaeo-landscape which took place in an important time period of contemporaneous rapid sea-level rising (Zong, 2007) and strengthened summer monsoon (Wang et al., 2005).

2. The Pearl River delta

The Pearl River delta lies in the transitional zone between the upland landscape of the catchment basin and the deposition centre of the northern continental shelf of the South China Sea (Fig. 1a). Since the collision between the Indian plate and the Eurasian plate around 34 Ma (Aitchison et al., 2007), the upland region gradually uplifted, whilst the continental shelf subsided, the latter receiving sediment from the Pearl River. During the Late Quaternary, major faults were active (Huang et al., 1982), and the current deltaic basin was gradually formed through subsidence. Along some faults, several valleys were formed. The lower part of these valleys was filled with the MIS 5 marine sediment unit, and the surface of this unit is about −10 m to −15 m (Zong et al., 2009b). The Holocene deltaic formation lies on the older marine unit (Zong et al., 2009a).

The Pearl River catchment is under the climatic influence of the Asian Monsoon. The history of monsoon climate of the region is revealed by the Dongge Cave record (Yuan et al., 2004; Wang et al., 2005), which shows a period of rapid warming, albeit with

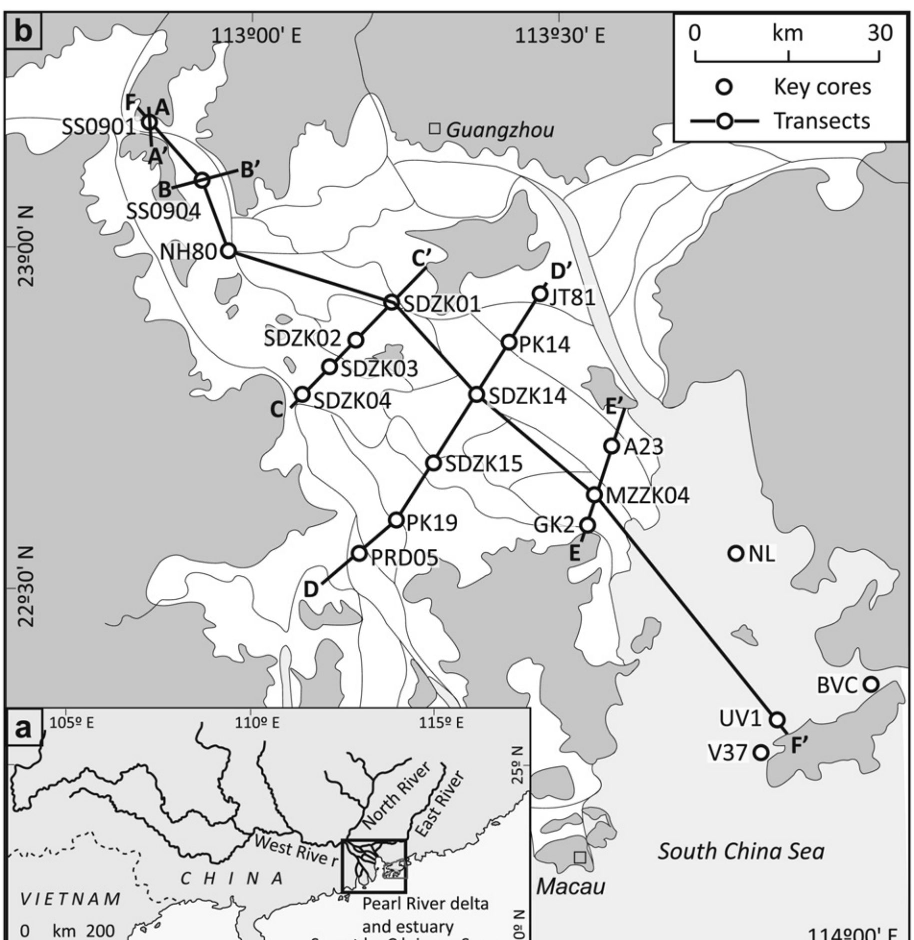

Fig. 1. (a) Locations of the Pearl River catchment, the Pearl River delta and the northern continental shelf of the South China Sea, and (b) Locations of the lithostratigraphic transects across the Pearl River delta plain and key sediment cores for this study.