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Changes in the source of sedimentary organic matter in the marginal sea sediments of Eastern Hainan Island in response to human activities during the past 200 years

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ABSTRACT

Marine sediments have been frequently used to reconstruct the records of environment change and human activities. We collected four sediment cores from Wanquan River estuary and the eastern continental shelf of Hainan Island in the South China Sea, and analyzed the down-core physical and chemical properties of sub-samples. Based on ^{210}Pb dating, the longest core had a record of the most recent 200 years, while the other three profiles were slightly younger. The results show that both the TOC/TN ratios and fossil fuel-corrected organic $\delta^{13}C$ of marine sediments for all four cores remained relatively constant before 1950 AD, indicating relatively stable sedimentary material sources. However, after 1950 AD, the TOC/TN ratios and organic $\delta^{13}C$ in all four sediment cores displayed decreasing and increasing trends, respectively, indicating that the proportion of marine-derived material increased, whereas the land-derived materials that were mainly transported by the Wanquan River decreased. This is consistent with the obvious decrease in runoff and sediment discharges of the Wanquan River due to the increase in human activities, including industrial and agricultural production, and domestic water use in Hainan Island since 1950 AD. Therefore, we suggest that environmental changes on the land were recorded by changes in the source material of marine sediments collected from coasts and estuaries.

1. Introduction

The global environment has changed greatly in the last 200 years due to both natural causes and human activities. For example, land-surface temperatures have increased rapidly especially in the 20th century (Mann and Jones, 2003; Rutgersson et al., 2014), and ice cover has reduced (Omstedt et al., 2004), which has led to an sea level acceleration from the end of the 18th century to the present day, of about 0.01 mm/yr^2 (Jevrejeva et al., 2008). The distribution of monsoons and precipitation events, which is considered to be associated with global climate change, appears to have changed, with different trends experienced in different regions of the world (Burns et al., 2002; Burroughs, 2007). Moreover, the increasing atmospheric deposition of trace metals and metalloids reflects the levels of pollution from human activities (Bao et al., 2015). In addition, vegetation, land use, and land cover have changed substantially as a result of the expansion of human populations (Meiyappan and Jain, 2012; Anupama et al., 2014), and these may have negative effects on the distribution of plant and animal species (Hooper et al., 2012; Svobodová et al., 2014). Almost all aspects of the natural environment have changed over time through the process of "global change", with most effects unfortunately being negative, especially in the last 200 years. Because these changes have known or unknown feedbacks on human beings (Stern, 2007), the reconstruction of historical environmental change is necessary and important to improve our understanding of the interrelationship between human activities and natural environmental changes.

In terms of paleo-environmental studies, traditional marine sediments have been widely used to reconstruct records of sea surface temperatures (SST), material provenances, monsoon strength, and other environmental conditions (Li et al., 2003; Boulay et al., 2005; Xiang et al., 2007; Kong et al., 2014) due to

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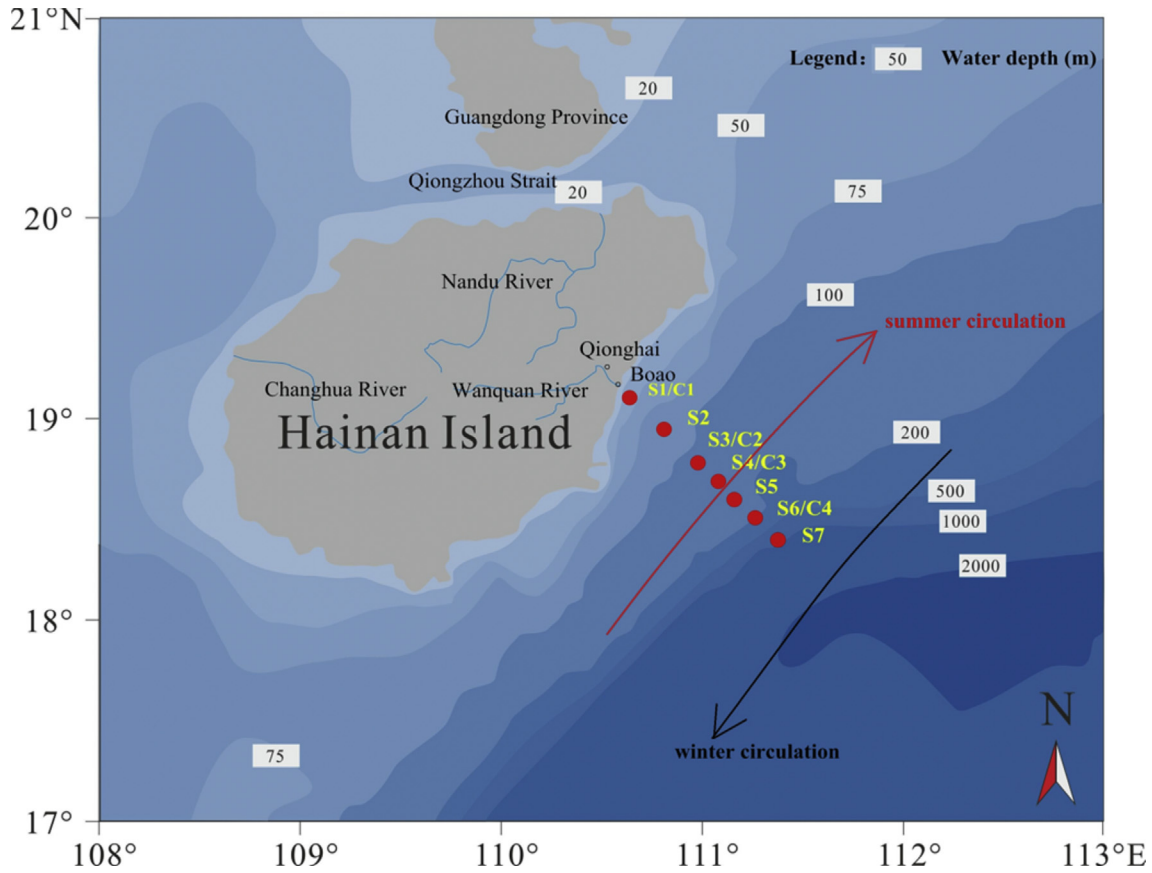

Fig. 1. Map of Hainan Island showing sampling sites.

their global distribution and good preservation. Marine sediments collected from coasts and estuaries can not only provide a unique record of great changes such as river migrations (Wu et al., 2015) and large earthquakes (Sun et al., 2012), but can also be used to assess the consequences of human behavior, because these areas are key connective zones between the land and the sea. Based on these sedimentary samples, scientists from China have acquired large amounts of data from the South China Sea. For example, some studies have shown that the heavy metals and POPs (persistent organic pollutants) derived from industrial and agricultural production have influenced the chemical components of sediments (Li et al., 2001; Mai et al., 2002; Liu et al., 2011). From a down-core variation of organic $\delta^{13}C$ and C/N, Zong et al. (2010) revealed the evolution of organic matter sources and the corresponding vegetation growth patterns. However, to the best of our knowledge, most of the relevant studies of coastal and estuarine sediments in the South China Sea have focused on the Pearl River Estuary because of the adjacent large population size and advanced economy, while the offshore sea area around Hainan Island has received relatively little attention.

Hainan Island is also an important area for the study of the tropical climate and environmental change. Yao et al. (2009) described the Early and Middle Eocene palaeovegetation and palaeoclimate of the Changchang Basin, Hainan Island, based on spores and pollen analysis. Zheng et al. (2003) and Yang et al. (2009) reconstructed the Holocene records of climate change and the geomagnetic field using sediments from Shuangchi Maar Lake, Haikou City, to the north of Hainan Island. At shorter time scales, elemental ratios for Mg/Ca, Sr/Ca, and U/Ca of a Porites coral from Sanya Bay, in the southern part of Hainan Island, have been analyzed and then used to reconstruct changes in SST over recent decades (Wei et al., 2000). Liu et al. (2013) had presented a sea surface temperature record (1876–1996 AD) of western boundary upwelling in the northern South China Sea derived from coral Porites Sr/Ca. In addition to the reconstruction of natural environmental changes, some studies have revealed anthropogenic pollution in the surface marine sediments around Hainan Island. For example, Xu et al. (2008) calculated the current deposition rate of metals in cores from offshore locations around Hainan Island based on ^{210}Pb dating, and found that Cd, As, and Pb were primarily anthropogenic after determining the concentration of several major and trace metals or metalloids in surface sediment samples from the eastern continental shelf of Hainan Island (Xu et al., 2015). However, reports of the reconstruction of relatively high-resolution environmental change and the effects of human activity in the last 200 years are still very scarce around Hainan Island.

According to a statistical analysis of recent meteorological observation data, the annual precipitation of Hainan Island has increased slightly in recent decades (Wang et al., 2006; Wu et al., 2007). However, both runoff discharges and sediment discharges from the three largest rivers on Hainan Island, including Wanquan River, have decreased significantly in recent decades as a result of human activities such as farmland irrigation, dam construction, and sand excavation from the river mouth (Yang et al., 2013). The change in the amount of land-based material transported by the river may have resulted in a change in the sedimentary environment in the marginal sea around Hainan Island. In this study, we analyzed the sedimentary environmental change of four sediment cores retrieved from the Wanquan River estuary and the outer eastern continental shelf of Hainan Island, and used the $\delta^{13}C_{org}$ and

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