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Millennial-scale East Asian Summer Monsoon variability recorded in grain size and provenance of mud belt sediments on the inner shelf of the East China Sea during mid-to late Holocene

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ABSTRACT

The response of the monsoon climate on the inner shelf of the East China Sea (ECS) to abrupt climate changes events within the monsoonal Yangtze River drainage is contentious. Repositioning of the monsoon front is thought to have been responsible for the changes in hydroclimate over the Yangtze River drainage, which has exerted great impact on the sedimentation of the inner shelf of the ECS during the Holocene. Here, we present high-resolution analyses of grain size and provenance of the sediments from core MD06-3040 recovered from the inner shelf of the ECS during MD155-Marco Polo II-IMAGES XIV cruise. Significant variability occurred in the core MD06-3040 with notable decrease in East Asian Summer Monsoon precipitation (presumably drought events) at 6000 BP, 5300 BP, 4500 BP, 3700–3300 BP, 2200 BP, 1400–1300 BP, and 800–600 BP, which coincide with the $\delta^{18}O_w$ record in the northern ECS and stalagmite $\Delta\delta^{18}O_{sp}$ records from southern China. Similar patterns of these temporal variations suggest that the Yangtze River discharge associated with EASM precipitation has been a dominant control on the sedimentation on the inner shelf of ECS.

1. Introduction

The sedimentary successions are an archive of past climatic and environmental changes. The characteristics of the sedimentary record are controlled by the sediment supply, sediment dispersal process governed by the water and sediment discharges, tides, waves, and coastal currents, as well as the area available for sediment accumulation. The inner shelf of East China Sea (ECS) is of primary importance owing to massive inputs of terrestrial materials from the Yangtze River, one of the largest rivers in the world in terms of sediment load and freshwater discharge (Milliman and Meade, 1983; Milliman et al., 1985; Milliman and Syvitski, 1992) with complex ocean circulation on the shallow (<130 m) and broad (500 km) ECS shelf (Qin, 1979; Qin et al., 1987). The study of the river-derived sediment dispersal, transport, and deposition is crucial to understand more thoroughly sedimentary processes on the inner shelf of ECS, and thus receives considerable attention.

Geological and geophysical investigations have demonstrated that the mud belts elongated along coast on the inner shelf of ECS are continuous with high sedimentation rates (Hori et al., 2001, 2002; Saito et al., 2001; Liu et al., 2002, 2007; Xiao et al., 2004, 2006; Zheng et al., 2010). The detailed characteristics of this elongated inner-shelf mud belt were documented by Liu et al. (2006, 2007), which presented a mud belt of 800 km extending from the Yangtze estuary southward off the Zhejiang and Fujian coasts into the Taiwan Strait based on high-resolution CHIRP seismic profiles. The development history of these Yangtze-derived sediment was proposed and the preliminary sediment budget have been discussed (Saito et al., 2001; Hori et al., 2002; Liu et al., 2006, 2007; Xiao et al., 2006; Liu et al., 2007; Zheng et al., 2010). The previous research summarized that transport mechanisms and deposition of sediments in the mud belts are mainly affected by sedimentological

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conditions associated with the dynamic hydrological regime such as sediment load, river discharge, and water mixing driven by the intensity of currents, tides, and waves. The extracted information from this region should indicate the possible influence of the sediment load and water discharge from the Yangtze River during high runoff in summer. Previous study has revealed that intervals characterized by lower magnetic mineral concentrations and higher coercivities are identified in the core sediment of inner shelf of ECS indicating the relationship between magnetic properties and paleoclimatic parameters related to East Asian Summer Monsoon (EASM) (Zheng et al., 2010). On the other hand, abrupt increases in mean grain size of the fine silt in the core sediment from the inner shelf of ECS were suggested to reflect sudden strengthening of the Chinese Coastal Current (CCC), which was driven by the East Asian Winter Monsoon (EAWM). In this case, the grain-size variations were interpreted as a proxy for the EAWM (Xiao et al., 2006, 2010). As the depositional history of the mud belt system off the Zhejiang-Fujian Coast has been controlled by the Yangtze River discharge and various ocean circulation system in the ECS, the sediment cores taken from this area should be useful to understand a complex interplay between hydrological cycles of the Yangtze River and redistribution of sediment on the inner shelf. The detrital grain size (Xiang et al., 2006; Xiao et al., 2006), clay minerals (Xu et al., 2009; Liu et al., 2010), magnetic parameters (Zheng et al., 2010) have been examined to reconstruct variations in fluvial processes, sea levels, and temperature/precipitation conditions. Despite a large amount of data, our knowledge on the sediment dispersal system on the inner shelf of ECS has been limited due to relatively short penetration depths of piston and gravity cores as well as limited radiocarbon dates.

Here, we present the results of analyses for grain-size and quartz characteristics in the sediment cores MD06-3039/3040 collected from the inner shelf of ECS spanning the whole Holocene in order to discuss the alongshore transport of the Yangtze-derived sediment, development of sedimentary facies in situ as well as potential sediment provenance. The variability in the Yangtze River discharge and sedimentation process of river-derived sediments associated with temporal changes in EASM during the Holocene has been illustrated.

2. Regional setting

The Yangtze River, also called Changjiang, has the largest (1,800,000 km^2) drainage area and the longest (6300 km) length in Asia, and ranks fifth globally in terms of water discharge and fourth in terms of sediment load. The Yangtze River discharges approximately 960 $\times 10^9$ m^3 of freshwater into the ECS annually. Although annual sediment load has been reduced from 0.5 $\times 10^9$ t/y in the 1960s to 0.34 $\times 10^9$ t/y in the 1990s because of dam construction and water consumption, the Yangtze River is still predominant sediment supplier to the delta and coastal areas (Milliman and Meade, 1983; Milliman et al., 1985; Chen et al., 1988; Milliman and Syvitski, 1992; Yang et al., 2002). The sediment load by the Yellow River transported into the ECS is estimated at <0.02–0.16 $\times 10^9$ t/y (Demaster et al., 1985; Su and Huh, 2002). Contributions from other local rivers, such as Qiantang River, Min River, Ou River, and Jiao River in the coastal areas of Zhejiang and Fujian are 0.007 $\times 10^9$ t/yr, 0.006 $\times 10^9$ t/yr, 0.003 $\times 10^9$ t/yr, 0.001 $\times 10^9$ t/yr, respectively (Deng et al., 2006). The total sediment supply from the coastal rivers including Yangtze River into the ECS is estimated to be 0.6–0.7 $\times 10^9$ t/y. Other major potential sources such as the coastal erosion of the abandoned Yellow River Delta, Taiwan Island, and atmospheric aerosols could account for about 37% of total input to the ECS (Tong and Cheng, 1981; Zhang and Liu, 2002).

The water masses in the ECS are characterized by various components, including Changjiang Dilute Water (CDW), Chinese Coastal Current (CCC), Taiwan Warm Current (TWC), Kuroshio Current (KC), and are influenced by tidal mixing and atmospheric forcing (Chang and Isobe, 2003; Liu et al., 2003; Lee and Chao, 2003). As is shown in Fig. 1, the CCC, including the Jiangsu Coastal Current (JCC) in the north and the Zhejiang-Fujian Coastal Current (ZFCC) in the south, flows south to southwestward along the Chinese coast. The saline and warm TWC flows northeastward along the 50 m isobath and intrudes into the submerged river valley off the Yangtze River. The warm and salty Kuroshio Current (KC) travels northward along the continental shelf break (Yang and Xie, 1984; Chen et al., 1986; Yang et al., 1992; Chang and Isobe, 2003).

Hydrographic and current meter data describing the spatial and temporal structure of the Yangtze River discharge over the inner and middle continental shelf of ECS show that in summer during high runoff, the freshwater discharge near the estuary of the Yangtze exhibited a bimodal distribution with the freshest water extending in a band to the south along the coast, and a relatively shallow, low salinity plume-like structure extending offshore on average towards the northeast (Beardsley et al., 1985). The thin jet theory of Robinson and Niiler (1967) also suggests that the strength and orientation of the river discharge are important. During the summer when winds are relatively weak and river discharge high, the theory implies that the structure of the discharge plume over the inner shelf will be strongly influenced by the inertia of the discharge, vortex stretching, and bottom friction. The enormous amounts of sediment load carried by the Yangtze River sustain delta

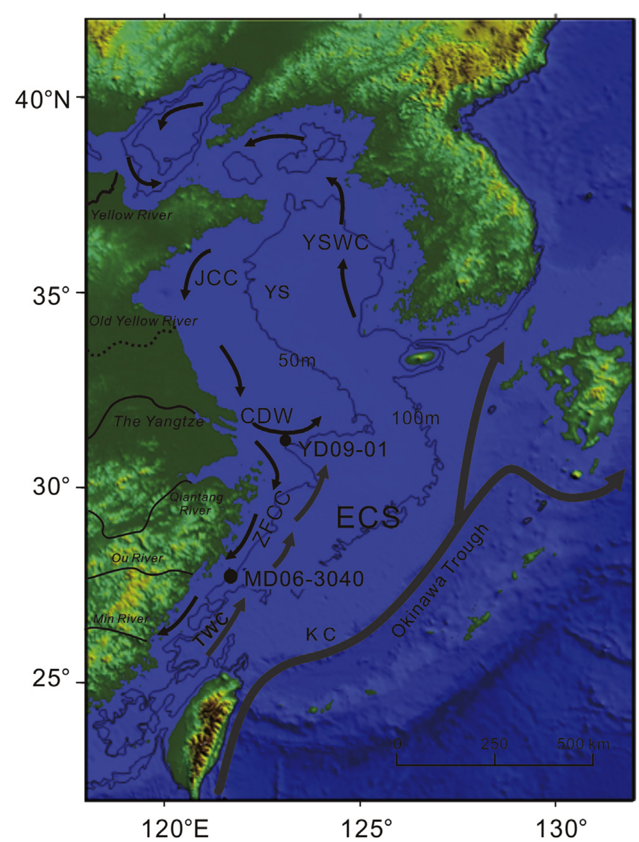

Fig. 1. Regional ocean circulation pattern in the East China Sea. Changjiang Dilute Water (CDW), Chinese Coastal Current (CCC), Zhejiang Fujian Coastal Current (ZFCC), Jiangsu Coastal Current (JCC), Yellow Sea Warm Current (YSWC), Taiwan Warm Current (TWC), Kuroshio Current (KC). The shade areas represent the mud belts located in the Yangtze River delta and the inner shelf of ECS.