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Provenance study of the Holocene sediments in the Changjiang (Yangtze River) estuary and inner shelf of the East China sea

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A B S T R A C T

The source to sink process of terrigenous sediment from East Asia continent to the marginal seas is crucial for the understanding of land–ocean interaction and marine sedimentary process in the West Pacific continental margin. This paper presents element geochemical and Sr–Nd isotopic records of core CM97 in the Changjiang (Yangtze River) Estuary and core MD06–3040 on the inner shelf of East China Sea, aiming to reconstruct the Changjiang sediment source–to–sink transport process and its major controlling mechanism during the Holocene. Driven by the asynchronous evolution of the Indian and East Asian summer monsoon, the provenance of sediments accumulated in the Changjiang Estuary gradually changed from the upper catchment during the late glacial period to the mid–lower valley in the early–mid Holocene. With the intensive agricultural cultivation and urbanization development in the catchment during the late Holocene, the major source of Changjiang sediment into the sea shifted back to the upper catchment, again. The high–frequency ENSO activity may superimpose the effect of human disturbances on sediment source–to–sink process in the late Holocene. Therefore, the Holocene provenance evolution of Changjiang sediments in the East China Sea witnessed the changes of governing sediment erosion process within a large catchment from monsoon climate–dominated to anthropogenic driving. Our study also suggests the strong effect of hydrodynamics in coastal and shelf environments on sedimentary geochemical compositions, which deserves more attention in further sediment provenance study.

1. Introduction

The East China Sea (ECS) is located in the East Asian continental margin, linking the largest continent, Eurasia, with the largest ocean, the Pacific. It is characterized by a broad continental shelf, huge terrigenous sediment input from surrounding rivers including the Changjiang (Yangtze River), strong land–sea interaction and striking paleoenvironmental changes during the late Quaternary. The complicated oceanic circulations and tidal currents, as well as sea level variability, primarily govern the distribution and dispersal patterns of terrigenous sediments in the ECS, forming unique muddy and sandy sedimentary systems on the shelf (Hu, 1984; Gao and Collins, 2014; Li et al., 2014; Yang et al., 2014, 2015). During the Holocene, several muddy systems are developed off the Changjiang estuary, on the southwest shelf of Cheju Island and on the inner shelf along the Zhejiang–Fujian coastal area, as well as on the west slope of the Okinawa Trough (Guo et al., 2003; Liu et al., 2006, 2007; Lim et al., 2007; Xu et al., 2009a, 2012; Dou et al., 2010; Chen et al., 2011; Gao and Collins, 2014; Li et al., 2014; Yang et al., 2014). Due to the high sedimentation rate and relatively stable sedimentary environment, these mud sedimentary systems on the ECS shelf preserve a wealth of high–resolution information about Holocene climate change and land–ocean interaction. Over the last decade, the distribution pattern of shelf muds (Liu et al., 2006), their geochemical characteristics and sediment provenances (Xu

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et al., 2009a,b; Liu et al., 2014), paleoclimatic and paleoenvironmental evolutions (Xiao et al., 2006; Xu et al., 2009a; Liu et al., 2010; Wang et al., 2014) have been widely documented.

The mud system on the inner continental shelf of ECS, also named the Zhe–Min coastal mud belt/wedge (Fig. 1), is distributed along the coastal areas of East China, occupying the shelf area of <90 m in water depth. This mud patch is supposed to have been formed since 7 ka with the fine–grained sediments predominantly from the Changjiang River, carried by the Zhejiang and Fujian coastal currents (ZMCC) (Hori et al., 2001; Saito et al., 2001; Xiao et al., 2006; Liu et al., 2006, 2007; Zheng et al., 2010, 2011; Wang et al., 2014; Yang et al., 2014, 2015), or driven by the contour–parallel gravity current (Wu et al., 2015). Nevertheless, whether a part of the fine–grained sediments in the inner–shelf mud wedge were derived from the rivers in southeastern China and Taiwan remains controversial.

The data of X–ray diffraction (XRD) and sediment grain size analyses indicate that the inner shelf sediments in the ECS represent the mixing of clay sediments from the Changjiang River and silty to sandy sediment from Taiwan rivers (Xu et al., 2009b). In addition, smaller local rivers from mainland China, especially the Minjiang River, also contributed clayey sediments to the southern shelf of ECS (Shi et al., 2010). Recently, Liu et al. (2014) investigated the clay mineral compositions of Core MZ02 from the inner shelf of ECS, and suggested that mixing clays from the Changjiang, Minjiang, and Taiwan rivers. Therefore, it remains an open question whether the sediment sources other than the Changjiang, e.g. from the local rivers in Zhejiang and Fujian Provinces or small mountainous rivers in Taiwan, could also contribute to the inner shelf mud. In addition, more substantial evidences are needed to test whether the changes of sedimentary geochemical compositions of the inner shelf mud could be caused by the temporal variability of Changjiang sediment compositions controlled by monsoonal climate and enhanced human activities in the Changjiang River basin (Wang et al., 2014) or by hydrodynamic sorting effect.

Recent studies paid much attention to the influence of human activities on sedimentary geochemical compositions of China marginal seas during the Holocene. Enhanced human activities such as deforestation, cultivation, and mining since the end of the Chinese Han Dynasty (220 CE) have overwhelmed the natural climatic controls on soil erosion in the Red River, which caused the erosion rate and the enrichment factors of specific elements increased by two to three times after 1.8 ka (Wan et al., 2015). The agricultural development in the Pearl River basin during the late Holocene caused a widespread reworking of old and weathered soils, which resulted in the strong enrichment of anthropogenic pollutants (e.g., Cu, Zn, and Pb) and the sharp increase of weathering intensity after 2.5 ka (Hu et al., 2013). Strong deforestation in the Changjiang basin as a result of the migration of human population from northern China started at 1.7 ka and intensified since

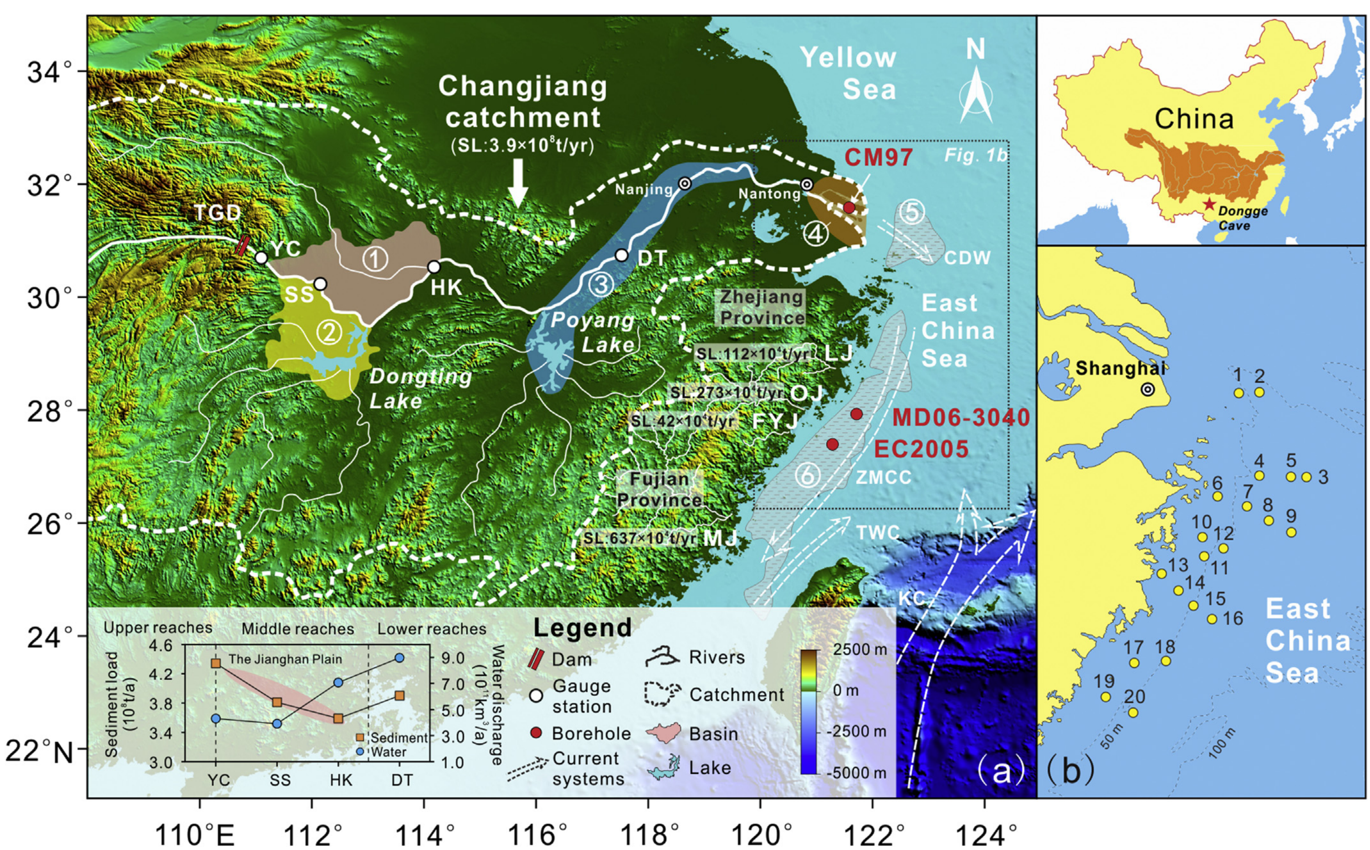

Fig. 1. A schematic map showing the East China Sea and surrounding rivers with the core locations as well as averages of annual water discharge and sediment load recorded at gauging stations along the mainstream (Data from Changjiang Water Resources Commission, http://www.cjw.com.cn/). Sediment loadings of Zhejiang–Fujian rivers are from Zhejiang Province water resources bulletin (2014) and Fujian Province water resources bulletin (2014). (a). The SRTM (Shuttle Radar Topography Mission) 90 m digital elevation data is available from the CGIAR–CSI (http://srtm.csi.cgiar.org/). The seafloor sediments sampling locations are also shown (b). The shadowed areas indicate main sedimentary basins. ①: Jianghan Basin; ②: Dongting Lake; ③: Lower Changjiang valley; ④: River mouth; ⑤: Subaqueous delta; ⑥: Inner shelf mud near Zhejiang–Fujian coasts (modified from reference Wang et al., 2008). TGD: Three Gorges Dam; YC: Yichang; SS: Shashi; HK: Hankou; DT: Datong; SL: Sediment load; LJ: Lingjiang (Zhejiang Province); OJ: Oujiang (Zhejiang Province); FYJ: Feiyunjiang (Zhejiang Province); MJ: Minjiang (Fujian Province); CDW: Changjiang Diluted Water; ZMCC: Zhe–Min Coastal Current; TWC: Taiwan Warm Current; KC: Kuroshio Current.

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