Chemical Geology xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Chemical Geology

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

# Sr–Nd isotopic geochemistry of Holocene sediments from the South Yellow Sea: Implications for provenance and monsoon variability

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## ARTICLE INFO

*Keywords:*
Sr–Nd isotopes
Provenance
Monsoon
Yellow Sea
Holocene

## ABSTRACT

Elemental geochemical and Sr–Nd isotopic signatures are used to decipher terrigenous sediments provenances and transport mechanisms in the South Yellow Sea during the Holocene. $^{87}Sr/^{86}Sr$ ratios in the Chinese and Korean riverine sediments overlap each other, whereas εNd values of Korean riverine sediments are generally less radiogenic in comparison to the Changjiang and Huanghe. Moreover, εNd values of these two large rivers appear unaffected by mineral sorting and are relative stable during the Holocene. We propose a three end-members (i.e., the Changjiang, the Huanghe, and Korean rivers) mixing model to explain sediment provenances in the Central Yellow Sea Mud (CYSM). Mixing calculations show that the Huanghe is the major sediment contributor to the CYSM before ~8 ka (thousand years before 1950 CE), whereas the Changjiang has become the predominant sediment source after ~8 ka. Holocene changes in riverine sediment supplies to the CYSM are closely related to the oceanic circulation, monsoon climate, and drainage changes. After examining several hypotheses to explain the variations in $^{87}Sr/^{86}Sr$ ratios of Core YSC-1 during the past ~8 kyr, we tentatively attribute that to changes in the erosion patterns of the Changjiang Basin. This in turn is associated with the asynchronous evolution of monsoon precipitation in the upper (Indian Summer Monsoon) and middle-lower Changjiang (East Asian Summer Monsoon). Therefore, our results highlight significant influences of monsoon climate on erosion patterns within the Changjiang catchment at millennial timescales.

## 1. Introduction

Large rivers of East Asian, originating in the Himalaya and the Tibetan Plateau, discharge an estimated 20% of the global river sediment flux (Milliman and Farnsworth, 2011). Tectonics (active uplift) and climate (monsoon-related intense precipitation) are two main agents governing the high sediment yields within these large river basins on geological time scales (Clift et al., 2008; Clift, 2010). However, the relative roles of tectonic and climatic factors on erosion and weathering remain uncertain, resulting from the complex interplays and threshold effects in this coupled system (West et al., 2005; Willenbring and von Blanckenburg, 2010; Cogez et al., 2015). Continental shelves are the key interfaces between terrestrial sediment source areas and deep-sea depositional systems, by which they can serve as capacitors or conveyors in the sediment-rounting systems, depending on the shelf width, climatic forcings, and timescales (Covault et al., 2011; Covault and Fildani, 2014). Commonly, continental shelves on passive margin have long transfer zones containing sediment sinks that can store sediment temporarily or permanently, and thus sedimentary deposited on them can serve as natural "recorders" of environmental signals at intermediate timescale (centennial to millions of years) (Romans et al., 2016). However, complex processes occur in the erosion, transport and storage of sediments (as well as their interactions) from the upland to the marginal seas, which probably disturb the original environmental signals and cause troubles for paleoclimatic reconstruction based on the sedimentary record.

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https://doi.org/10.1016/j.chemgeo.2017.12.033
Received 8 April 2017; Received in revised form 29 November 2017; Accepted 31 December 2017

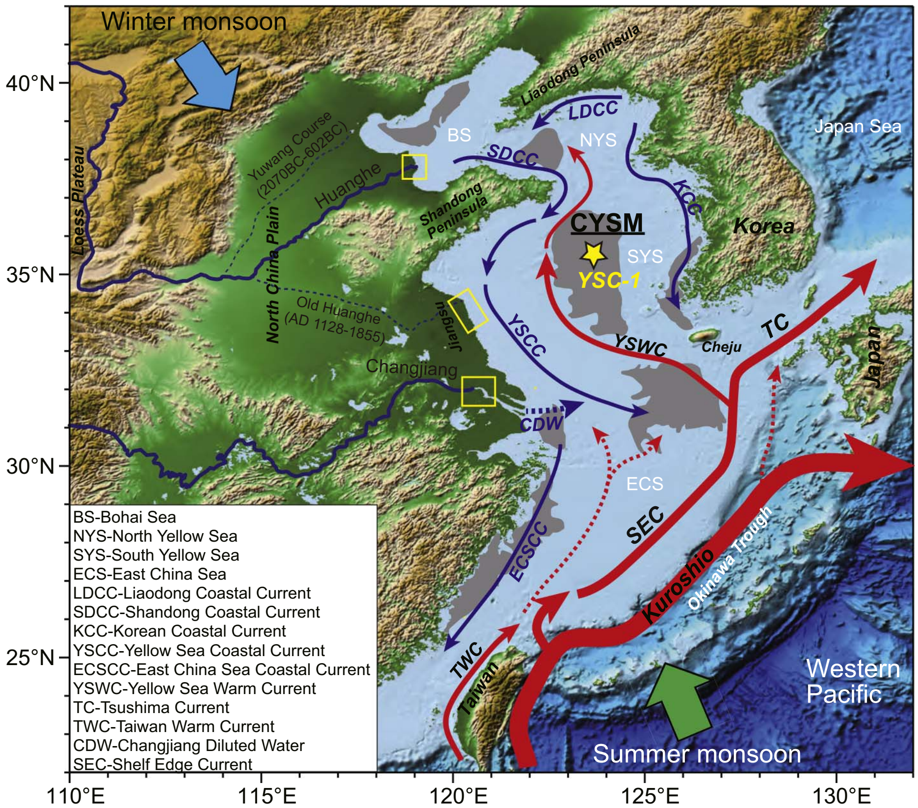


**Fig. 1.** Schematic illustration of the topography and winter oceanic currents (modified from Li et al., 2016) in the East China Seas. The red lines indicate the warm current systems, whereas the blue lines indicate the cold coastal currents. Dashed red lines are the branches from the main warm current. Shaded areas are the muddy depositional areas and CYSM is the Central Yellow Sea Mud. Riverine samples from the Changjiang, the Huanghe and the Old Huanghe (yellow rectangle) and Core YSC-1 (yellow star) are also shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

The Yellow Sea is a semi-enclosed shallow epicontinental shelf surrounded by mainland China and Korean Peninsula. Annually, the Yellow Sea received a huge amount of fluvial sediments mainly from two global large rivers [i.e. the Huanghe (Yellow River) and Changjiang (Yangtze River)], as well as some small rivers in Korea Peninsula. Although the Changjiang and Huanghe do not enter the Yellow Sea directly at present, they have been considered as the predominant sediment sources of Yellow Sea (Lee and Chough, 1989; Yang et al., 2003; Hu et al., 2011; Qiao et al., 2017). Under the combined effects of tide, wave/storm and current, several muddy depositional areas are developed in the broad and shallow shelf of Yellow Sea during the Holocene sea-level highstand (Lee and Chough, 1989; Li et al., 2014a). The Central Yellow Sea Mud (CYSM) is one of the largest muddy depositional areas on the Yellow Sea shelf (Fig. 1), resulting from the large accommodation space and abundant sediment supplies. Mud deposits in the CYSM are not only the outstanding archives of Holocene climatic and environmental changes in the adjacent continent, but also preserve essential information on the past ocean circulation patterns (Kim and Kucera, 2000; Xiang et al., 2008; Hu et al., 2012b; Ge et al., 2014; Li et al., 2014b; Wang et al., 2014; Lim et al., 2015b). Therefore, the CYSM has attracted much attention with respect to its formation mechanism and evolution history since the 1990s.

By identifying and characterizing the terrigenous sediment source areas of CYSM, detailed information can be obtained on the provenance and transport mechanisms, which are fundamental, but yet remain considerable debate (Yang et al., 2003). Considering low sediment load of Korean rivers, it has been originally presumed the CYSM is mainly supplied by the Chinese rivers (i.e., the Huanghe and Changjiang) (e.g., Lee and Chough, 1989; Alexander et al., 1991; Park and Khim, 1992). Subsequently, much efforts have been expended to discriminate surface sediment provenance in the coastal and shelf mud depositions of Yellow Sea, including geochemical (Lim et al., 2006; Yang and Youn, 2007; Lim et al., 2014; Jung et al., 2016), mineralogical (Wei et al., 2003; Li et al., 2014c), and magnetic (Wang et al., 2010; Wang et al., 2017) techniques. Almost all of them suggested that the CYSM might be a "multi-sourced deposits" consists of a mixture of Chinese large rivers and Korean small rivers, however, the relative contributions from different sources remain unclear. Several studies have attempted to decipher the changes in detrital sediment supply to the CYSM during the Holocene but rarely have any consensus been achieved, partly resulting from proxies' susceptibility, analytical error (e.g., clay minerals), and/or insufficient dating points (Yang and Youn, 2007; Lan et al., 2009; Li et al., 2014b; Wang et al., 2014; Lim et al., 2015b).

Strontium (Sr)–neodymium (Nd) isotopic ratios ($^{87}Sr/^{86}Sr$ and εNd) are widely used to decipher the source areas of terrigenous sediments, because the $^{87}Sr/^{86}Sr$ and εNd of continental detritus mainly depend on their Rb/Sr and Sm/Nd ratios and the rock ages (Frank, 2002; Grousset and Biscaye, 2005). Sr isotope composition, besides the source heterogeneity, is also associated with changes in chemical weathering intensity and hydrodynamic sorting effect (Colin et al., 2006; Cole et al., 2009; Révillon et al., 2011; Ali et al., 2015). In contrast, Nd is relatively immobile element during surficial processes, and it is often assumed that there is no significant dependence of εNd on grain size or chemical weathering (Tütken et al., 2002; Meyer et al., 2011; Garçon et al., 2014; Bayon et al., 2015; Lim et al., 2015a; Rao et al., 2017). Although Sr–Nd isotopic compositions of detrital fractions have been proven to be useful tracers on sediment provenance in the East China Seas (Dou et al., 2012; Hu et al., 2012a; Li et al., 2015; Dou et al., 2016; Bi et al., 2017; Rao et al., 2017), comprehensive provenance discrimination based on Sr–Nd isotopic compositions has not been conducted for core sediments in the CYSM until now. In this study, we use elemental and Sr–Nd isotopic compositions from Core YSC-1 (1) to constrain the provenance of terrigenous material in the CYSM and their transport mechanisms during the Holocene and (2) to discuss the potential monsoon-climate influences on the erosion pattern within the Changjiang basin at millennial timescales.

## 2. Regional settings

The Yellow Sea is a shallow, semi-closed, epicontinental sea