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Magnetic properties of sediments from major rivers, aeolian dust, loess soil and desert in China

Chao Li [a], Shouye Yang [a,*], Weiguo Zhang [b]

[a] State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, PR China
[b] State Key Laboratory of Estuarine and Coastal Research, East China Normal University, Shanghai 200062, PR China

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ABSTRACT

The continent of China delivers huge terrigenous sediments to the East Asian marginal seas and northwest Pacific Ocean by riverine and aeolian inputs, which exerts a great impact on marine sedimentation, primary productivity and biogeochemical cycle. In this study, magnetic properties of the sediments from the Changjiang and Huanghe river systems were investigated, in order to provide potential provenance tracers. Besides, the top soil from the Loess Plateau, Taklimakan desert sand and dust storm particles were comparatively studied to reveal the controls of magnetic properties in various depositional environments.

The Changjiang sediment is characterized by the highest concentration of magnetic minerals and the largest variations for most magnetic parameters, while the Huanghe sediment has much lower content of magnetic minerals. The loess soil sediment yields the highest frequency-dependent susceptibility $\chi_{fd}\%$, while the aeolian dust has similar magnetic susceptibility but higher saturation isothermal remnant magnetization and lower anhysteretic remnant magnetization χ_{ARM}. The desert sand has the lowest values of all magnetic parameters, indicating the lowest ferrimagnetic mineral concentration with coarser grain size. The magnetic properties of the Changjiang sediments are primarily determined by the diversity of lithology in its large drainage basin, while the sediment grain size basically accounts for the variation of magnetic parameters in the Huanghe sediment. The gradual increase of $\chi_{fd}\%$ towards the lower reaches suggests it may potentially indicate grain size fractionation in the catchments. Although some magnetic parameters can apparently discriminate the origins of fluvial and aeolian sediments, reliable magnetic proxy for distinguishing sediment origins in marine environment can only be established if hydrodynamic differentiation and post-depositional diagenetic alteration of magnetic minerals are fully understood.

1. Introduction

The land–ocean interactions and relating earth surface processes are being conceived worldwide. Owing to the unique topography and monsoon climate, the East Asian continent delivers a huge amount of terrigenous material primarily through riverine and aeolian transport to the East Asian marginal seas and northwest Pacific Ocean, which exerts a great impact on marine sedimentation, primary productivity and biogeochemical cycle (Milliman and Meade, 1983; Duce et al., 1980; Jickells et al., 2005; Maher et al., 2010). The Changjiang (Yangtze River) and the Huanghe (Yellow River) are the two largest rivers in China (Fig. 1), transporting about 1.5×10^9 tons of sediment in total annually to the estuarine and shelf areas, which accounts for about 10% of the global sediment discharge (Milliman and Meade, 1983). Nevertheless, the sediment loads of the Changjiang and Huanghe decrease significantly over the last two decades primarily due to the constructions of numerous reservoirs in both drainage basins such as the world's largest dam, the Three Gorges Dam (Yang et al., 2006, 2007). The tremendous material from the Changjiang and Huanghe dominates the sedimentation in the East Asian marginal seas such as the Bohai, Yellow Sea and East China Sea. However, major part of the fluvial sediments is trapped in the deltaic, coastal and continental shelf due to the mild gradient, estuarine process and littoral currents (Chen et al., 1985), and thereby the fine-grained terrigenous material to the open ocean is mostly delivered by atmospheric dust (Duce et al., 1980; Jickells et al., 2005; Maher et al., 2010).

The global dust flux is estimated to range from 1000 to 2150 Tg/yr (Andreae and Rosenfeld, 2008), of which 8% is from central China (Tanaka and Chiba, 2006). Compared to the river input, nutrients and trace elements transported by aeolian dust are more significant in the open ocean (Jickells et al., 2005). Dust acts as one

* Corresponding author. Address: State Key Laboratory of Marine Geology, Tongji University, 1239 Siping Road, Shanghai 200092, PR China. Tel.: +86 21 6598 9130; fax: +86 21 6598 6278.
E-mail address: syyang@tongji.edu.cn (S. Yang).

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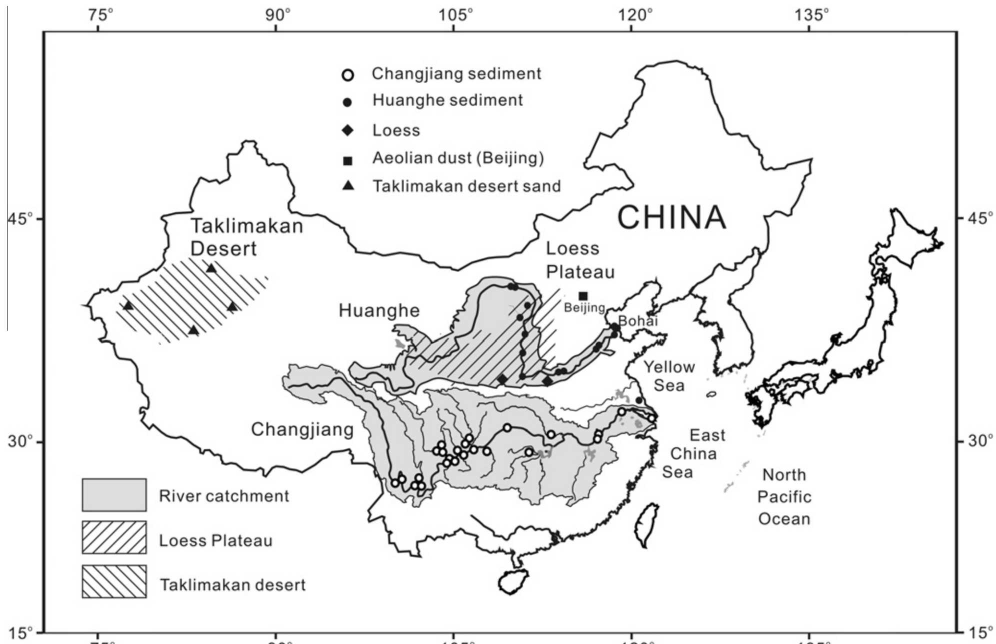

Fig. 1. A sketch map showing the drainage basins of the Changjiang and Huanghe rivers, and sampling locations of all the studied samples. The distributions of the Loess Plateau and Taklimakan are modified from Liu (1985) and Honda and Shimizu (1998).

main source of iron to the open ocean where the availability of iron may limit primary productivity (Martin, 1990; Jickells et al., 2005). Bory et al. (2003) found that the dust from both the Mongolian and Taklimakan deserts could be recognized in ice cores from Greenland, and more recent study suggests that the finest particles from Taklimakan dust even had circled the globe more than once (Uno et al., 2009). Overall, Sandy desert, Gobi desert, Loess Plateau and the mixed barren soil in Northern China and Mongolia, are the main sources of Asian dust (Duce et al., 1980; Jickells et al., 2005; Engelbrecht and Derbyshire, 2010; Maher et al., 2010).

Although the Changjiang, Huanghe and aeolian dust are considered to be the main sources of terrigenous input to the west Pacific marginal seas, the discrimination method of these different sediment sources are still not well established (Yang et al., 2003). Traditional studies on provenance discrimination of the Changjiang and Huanghe sediments were primarily based on geochemical and mineralogical methods, while magnetic properties of these two river sediments have only been investigated until recent years (Niu et al., 2008; Zhang et al., 2008; Wang et al., 2009; Liu et al., 2010b), with a main aim to identify the sediment origins in marine environments. As a fast, low-cost and sensitive analysis of sediment character, environmental magnetism has been developed about 30 years ago (Thompson and Oldfield, 1986), and widely applied in paleoenvironmental study (Heller and Liu, 1986; Kukla and An, 1989; Zheng et al., 1991; Maher and Thompson, 1991; Verosub and Roberts, 1995; Kissel et al., 2003; Liu et al., 2007a; Roberts, 2007), agrology (Thompson and Oldfield, 1986; Taylor et al., 1987), and heavy metal contamination indication (Scoullos et al., 1979; Hunt et al., 1984; Zhang et al., 2001; Li et al., 2011). Previous studies on magnetic property of the Changjiang and Huanghe sediments primarily gave emphasis to the estuarine and inner shelf areas (Liu et al., 2003, 2010b; Zhang and Yu, 2003; Zhang et al., 2008; Wang et al., 2004, 2009, 2010; Niu et al., 2008; Zheng et al., 2010; Horng and Huh, 2011), while the whole drainage basins, especially the upper and middle reaches, and the major tributaries have rarely been investigated. Compared to the fluvial sediments, environmental magnetism of the loess–paleosol profile and aeolian dust has been more widely applied to decipher the Quaternary paleoenvironmental changes (Liu, 1985; Heller and Liu, 1986; Kukla and An, 1989; Maher and Thompson, 1991; Zheng et al., 1991; Liu et al., 2007a; Sun et al., 2010; Zhao and Roberts, 2010). But detailed comparative study on environmental magnetism of the sediments from river, loess–paleosol and aeolian dust, however, has seldom been carried out yet. Furthermore, whether magnetic proxy can be established to identify the sediment origins in marine environments remain enigmatic (Liu et al., 2010a; Wang et al., 2010; Zheng et al., 2010; Horng and Huh, 2011).

The present study attempts to compare magnetic properties of the river sediment, aeolian dust, loess–paleosol, and desert sand. Meantime, systematic sediment samples taken from the major tributaries and mainstream of the Changjiang and Huanghe were also investigated, aiming to provide a better understanding of magnetic properties in the large rivers. Furthermore, this paper discusses the possibility of using magnetic properties to discriminate the sediment origins of East China marginal seas.

2. Geological settings

The Changjiang is the longest river in Asia, which flows about 6300 km from the glaciers on the Tibetan Plateau, with elevation above 4000 m and finally empties into the East China Sea. The river course of the Changjiang is traditionally divided into three sections. The mountainous upper reaches ranges from the headwater in western Tibetan Plateau to the city of Yichang. Particularly, the section from confluence with the Batang River, near Yushu, to Yibin is named Jinshajiang River. The middle reaches flows through a flat plain from Yichang to Hukou, and the lower reaches stretches from Hukou to the estuary in Shanghai before finally entering the East China Sea. The Changjiang drains one-fifth of China's land area and its watershed feeds one-third of China's population. The water discharge and sediment load of the Changjiang are about 900 km^3/yr and 4.78×10^8 t/yr, respectively, based on the long term hydrological observation (Milliman and Meade, 1983; Yang et al., 2004). The Changjiang catchment is primarily located in the temperate climate zone, with an annual precipitation of 1100 mm. Framed by the Mesozoic Yenshanian orogenic belt and mostly situated in the Yangtze Craton, the Changjiang river basin is characterized by complex geological settings. The upper basin comprises widely