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Temporal and spatial variations in magnetic properties of suspended particular matter in the Yangtze River drainage and their implications

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ABSTRACT

As the largest river of China, the Yangtze River transports large amounts of sediments to the adjacent oceans. Provenance of these ancient marine sediments can only be deciphered when the source-to-sink process of modern sediments in the Yangtze River is fully understood. Many methods have been used to study the provenance of river sediment and an environmental magnetic method is applied in this study because of its fast, nondestructive advantages. Magnetic properties of suspended particulate matter (SPM) along the Yangtze River were measured to provide a holistic understanding about magnetic properties of sediments in this river and its controlling factors. The results indicate that the dominant magnetic mineral in SPM is magnetite, with a small contribution of hematite and goethite. Significant spatial variation was observed in most of the magnetic parameters, which primarily reflects the distribution of major geologic units along the drainage area of the river. Anthropogenic influences are also recorded in the magnetic parameters. The Three Gorges Dam results in a dramatic decrease of magnetic minerals in the downstream reaches, since its construction in 2003. In addition, small variations in magnetic properties of SPM are found along water depth, together with a clear seasonal shift at Datong station. This seasonal variation of magnetic properties of SPM is driven by variability in both hydrology and source contributions. This complicates the use of magnetic parameters for provenance studies. Magnetic properties of sediments in rivers are capable of tracing provenance areas, but caution must be taken into account.

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1. Introduction

By serving as a major pathway for erosion products, large river systems are key components in the study of source-to-sink processes, which is one of the key research objectives of the interMARGINS Program. Yangtze River, the largest and longest river in China, connects the Asian continent with the Pacific Ocean. It transports 9×10^{11} m^3 of water and 4.7×10^8 t of sediments to the Chinese marginal seas (Milliman and Meade, 1983). The enormous quantity of erosional products from the basin plays a dominant role in regulating the deposition and sedimentary evolution of the marginal sea system (Clift et al., 2002; Clift, 2006).

Geochemical and mineralogical methods have played an important role in provenance investigations of river sediments (Yang et al., 2006a, 2007, 2009; Wang et al., 2007; Luo et al., 2012; He et al., 2013). Over these years, environmental magnetism became a fast growing avenue for provenance identification due to its fast, low-cost and nondestructive advantages (Yu and Oldfield, 1989; Watkins and Maher, 2003; Hatfield and Maher, 2008; Wang et al., 2010; Zhang et al., 2012). Therefore, this approach was applied to sediments of the Yangtze River to trace sources and indicate pollution (Zhang et al., 2008a, 2008b; Wang et al., 2009; Li et al., 2011a).

However, most of the previous studies have a limited spatial and temporal coverage of samples analyzed. They either focus on estuarine or on specific basins within the drainage and sampling was never conducted over more than two seasons. Seasonal discharge of the Yangtze River is controlled by the Asian monsoon which can be up to an order of a magnitude higher in the monsoon season than that in the non-monsoon season (The Changjiang Water Resources Commission. See http://www.cjw.gov.cn). Precise calculations of annual fluxes and accurate understanding of the processes that control the properties of sediments in rivers can

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only be achieved by time series investigation, which at least covers a complete year (Kirchner and Neal, 2013; Luo et al., 2014; Voss et al., 2014). An additional limitation is introduced by sampling techniques. Most of the samples used in previous studies were taken from river beds, alluvial plains or water surface. Few data are available for the magnetic properties of suspended particulate matter (SPM) of the Yangtze River, although it accounts for about 98% of the sediment load (Yang et al., 2002). SPM is comparable with the contemporaneous source-to-sink process of rivers, making it more suitable for provenance studies. Besides, no previous work has investigated the influence of dams on source indicators. Anthropogenic influences along the Yangtze River drainage, such as the construction of the Three Gorges Dam (TGD) - the largest dam in the world - has affected the source to sink pattern of the sediment by trapping sediments within the river and activating channel erosion.

Comprehensive knowledge about spatial and temporal variations of magnetic properties of SPM in the Yangtze River is currently data-limited, which might lead to biased conclusions in provenance and environmental studies. Here, we present the first systematic data set of magnetic properties of SPM from the Yangtze River to understand the variations of magnetic properties at different scales and their implications for provenance. Two sets of sample are collected: (1) a geographic transect along the river from headwater to estuary, and (2) a time series of samples collected from different depth at the Datong hydrological station between June 2010 and June 2011 (Luo et al., 2012, 2014). This detailed and systematic study creates a framework which is essential for offering secure source indications and will provide a better understanding about the evolution of the Yangtze River and the monsoon system.

2. Yangtze River setting

The Yangtze River originates from the Qinghai–Tibetan Plateau and extends over a length of 6300 km from its headwaters to its estuary in the East China Sea. It has a catchment area of 1.8×10^6 km^2. Traditionally, the Yangtze River is divided into the upper, middle and lower reaches (Fig. 1). The upper reaches of the Yangtze River end at Yichang, and can be further divided into Jinsha Jiang and Chuan Jiang. The Jinsha Jiang stretches out over a distance of 3300 km and ends at Yibin by the confluence with Minjiang. By flowing through the Sichuan Basin, the Chuan Jiang is joined by the Jialing Jiang and Wu Jiang before passing through the TGD. The middle reaches comprise an area from Yichang to Hukou, and is joined by the Hanjiang from the north and Yuanjiang, Xiangjiang and Ganjiang from the south. The Dongting Lake and Poyang Lake connect the tributaries with the mainstream and trap large amounts of sediments. Compared to the upper and middle reaches, no big tributaries enter the lower reaches.

The geology in the Yangtze drainage basin is complex and characterized by rock compositions with ages ranging from Archean to Quaternary. A simplified geologic map is shown in Fig. 1. Although sedimentary rocks are the main rock types in the Yangtze River drainage, different tributaries consist of distinct source rock types. The famous Late Permian continental basalts of the Emeishan Large Igneous Province dominate the Jinsha Jiang catchment between Shigu and Panzhihua. The Fe–V–Ti deposits are mainly hosted in the Hongge layered intrusion which is one of the plutonic bodies of this province. Panzhihua City is one of the most important industrial and mining bases in China with huge Fe–V–Ti magnetite deposits and is situated around the confluence of Jinsha Jiang with Yalong Jiang, (Zhong et al., 2002). A detailed description of the geological composition of the Yangtze River drainage area is given by Luo et al. (2014) and references cited therein.

Influenced by the East Asian Monsoon, precipitation across the basin exhibits a high degree of spatial and temporal variation (Zhang et al., 2005). A downstream increasing trend of annual precipitation can be observed within the Yangtze River. Water and sediment discharge varies significantly over a year, with a ten times higher discharge in monsoon season than in non-monsoon season (Xu and Milliman, 2009).

3. Materials and methods

3.1. Sample collection

SPM samples were collected in the Yangtze River basin between June 2010 and September 2011 (Fig. 2; Table 1). Temporal variation was examined by taking biweekly and monthly SPM at the

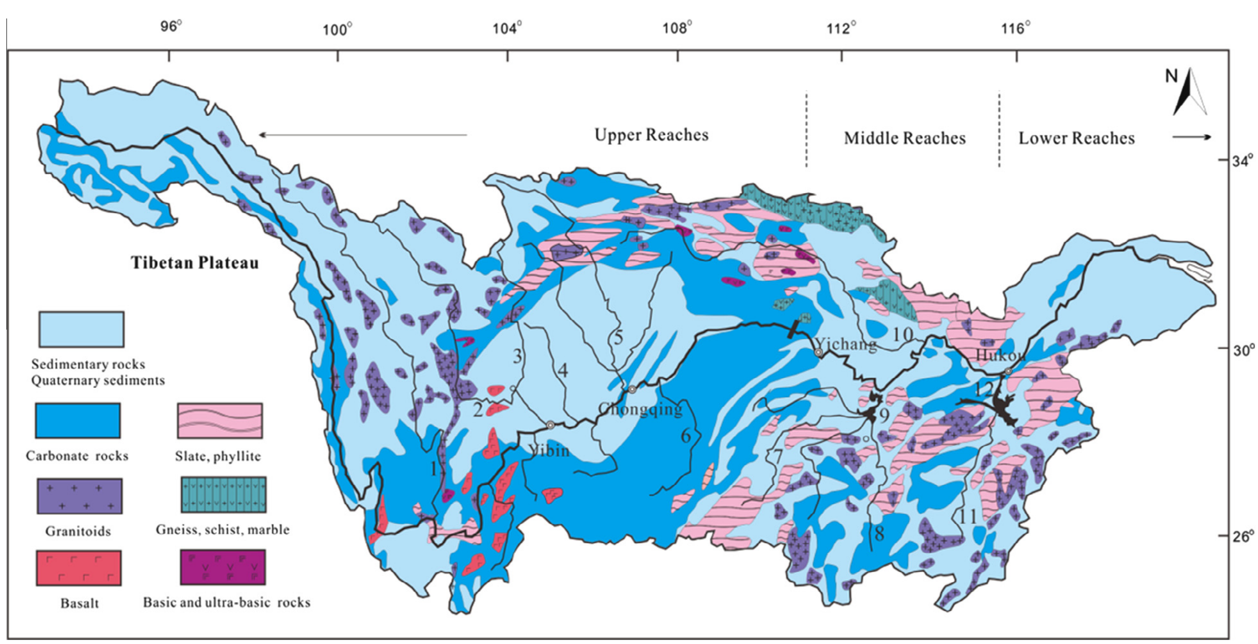

Fig. 1. Geological map of the Yangtze River basin. Modified from Yang et al. (2009). 1. Yalong Jiang, 2. Dadu He, 3. Min Jiang, 4. Tuo Jiang, 5. Jialing Jiang, 6. Wu Jiang, 7. Yuan Jiang, 8. Xiang Jiang, 9. Dongting Lake, 10. Han Jiang, 11. Gan Jiang, 12. Poyang Lake.

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