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Late Quaternary climatic forcing on the terrigenous supply in the northern South China Sea: Input from magnetic studies

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A B S T R A C T

The detrital component of marine sediment is a powerful recorder of paleoenvironmental changes in a marginal sea such as the South China Sea. This is in particular valid for the magnetic fraction that is one of the key parameters for paleoenvironmental studies in the South China Sea, although poorly used so far. We report here on the analysis of the magnetic properties of a 50 m-long sedimentary sequence retrieved from the northern South China Sea, on the continental slope off the Pearl River mouth. Magnetic minerals with different coercivities (magnetite, pyrrhotite, and hematite) are mixed. The variations in relative content of these magnetic minerals illustrate influences of various external forcing mechanisms at different timescales. The pyrrhotite content exhibits a long-term increase, which is also observed in illite + chlorite content, indicating a continuous enhancement of supply from Taiwan most likely related to active Taiwan orogeny. Glacial–interglacial fluctuations are characterized by more magnetite and pyrrhotite with coarser silt and magnetic grains during glacials than interglacials. This is attributed to sea-level changes with the enormous continental shelf exposed during glacials, in turn affecting the sediment transport distance and pathway. On a shorter timescale, larger hematite inputs in fine-grained sediments coincide with precession minima. We suggest that this periodic hematite supply change is related to the eolian dust deposited at the studied site in addition to the fluvial and oceanic transported materials.

1. Introduction

The South China Sea (SCS) is the largest East Asian marginal sea, bounded by South China and Indochina, Taiwan, Philippine islands and Great Sunda islands. More than 700 million tons of detrital sediments are delivered from these landmasses to the SCS by the well-developed drainage systems, including three of the largest rivers in the world (Milliman and Farnsworth, 2011). These terrigenous sediments are produced under diverse climatic, tectonic, and lithological processes on land and a large variety of mineral assemblages and element compositions are documented at present in the terrigenous sediments on land (e.g. Schopka et al., 2011; Horng et al., 2012; Kissel et al., 2016, 2017; Liu et al., 2016). Drained into the SCS, these terrigenous sediments are then transported and geographically distributed by various currents related to the East Asian monsoon winds and intrusion of Kuroshio Current at the surface and to deep water exchanges with Pacific (Yuan et al., 2014; Zhao et al., 2014).

The evolution of the East Asian monsoon dominating the climate of the SCS and its surroundings mainly concerns the wind speed and precipitation rates and duration. This contributes to the physical, chemical, and biological processes both on land and at sea, and marine terrigenous proxies provide the possibility to extend the historical record of the East Asian monsoon evolution at different timescales (e.g. Boulay et al., 2005; Clift et al., 2014; Hu et al., 2012; Liu et al., 2003; Sun et al., 2008b; Wang et al., 1999).

The terrigenous sediments deposited in the SCS are also sensitive to global climate changes, not only because of the continental weathering but also because of the presence of vast shelves that emerged during low sea-level periods. This gave rise to very different glacial land–sea distributions around the SCS and to the closure of all the straits but the Luzon strait. Consequently, both fluvial transport and oceanic circulation were affected, resulting in a different pattern of terrigenous sediment deposition during glacial periods (Liu et al., 2003; Wang et al., 1999). The detrital sediments therefore illustrate mixed signals of continental environment, global climate and oceanic transport, making the SCS a

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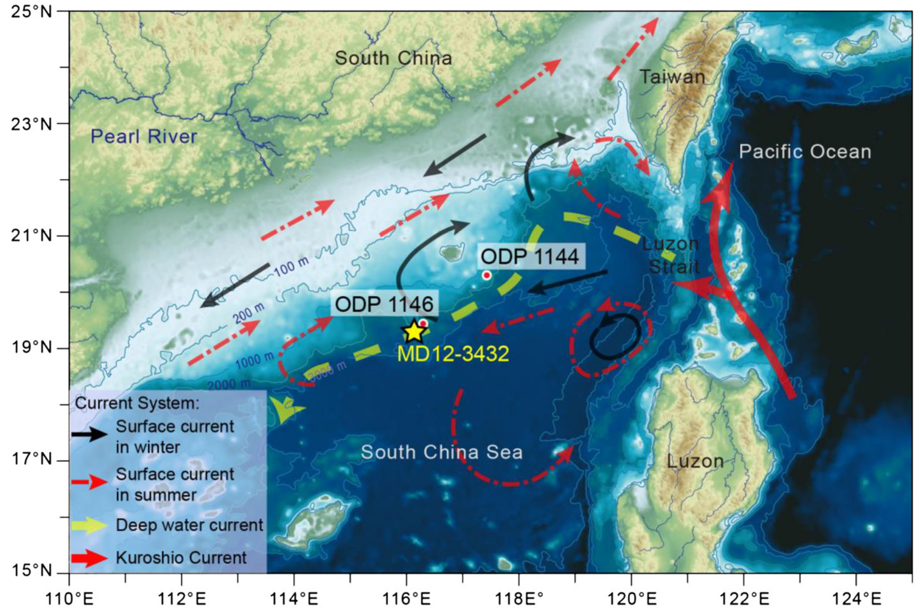

Fig. 1. Map of the northern South China Sea showing the location of the sites discussed in the text. The oceanic circulation pattern is also presented (after Liu et al., 2016).

natural laboratory to study the land–sea interactions and for paleoenvironmental reconstructions (Wang et al., 2014).

The SCS has indeed drawn attention from the paleoenvironmental and sedimentological scientific communities and a number of investigations have been performed to study the land–sea interactions and links among detrital sediments, East Asian monsoon, and global climate changes (Clift et al., 2014; Liu et al., 2016; Wang et al., 2014; and references therein). Many of these studies focused on the northern part of the SCS, reconstructing a general blueprint of the environmental changes in this area to support further studies.

Among all the available methods, clay mineralogy is one of the most frequently used to reconstruct erosion/weathering evolution at different timescales. On tectonic scales, clay mineral records were indeed used to illustrate the weathering history and to further reconstruct the evolution of the East Asian monsoon (Clift et al., 2014 and references therein). A glacial–interglacial cyclicity was also observed in the clay mineral assemblages from the northern SCS and interpreted as resulting from either monsoon-related oceanic current transport (Liu et al., 2003) or climate-related continental weathering/erosion balance (Clift et al., 2014 and references therein). However, some high-resolution clay mineral records did not exhibit any significant glacial–interglacial changes but, instead, varied on the precessional bands (Boulay et al., 2005). Subsequently to these analyses, the knowledge of continental provenance (Hu et al., 2012, 2013; Liu et al., 2016) and modern oceanic transport patterns (Liu et al., 2016) of clay minerals were deepened and yielded more constraints to the temporal reconstruction of weathering.

Other fractions of the detrital sediments, such as the magnetic grains, much less sensitive to weathering than clays, have the potential to yield complementary key information about the past evolution of land–sea interactions, oceanic circulation, fluvial versus eolian input directly related to atmospheric circulations (e.g. monsoon) as shown by the few magnetic studies performed in the SCS (Kissel et al., 2003; Zhang et al., 2015; Zheng et al., 2016). However, the studied sequences were unfortunately too short to discriminate changes controlled by orbital forcing from local ones related to the location/depth of the cores or they were limited in the volume of available sediment to allow the full set of magnetic parameters to be studied. Moreover, due to the lack of knowledge about magnetic mineral preservation and provenances, the link between the magnetic properties in SCS sediments and environmental changes were still difficult to assess. Recent detailed investigations of magnetic mineralogy and rock magnetism performed on lands surrounding the SCS (Horng et al., 2012; Kissel et al., 2016, 2017) allow to better and more precisely use the magnetic properties to reconstruct past climatic changes and land–sea interactions.

In order to better constrain the late Quaternary environmental changes in the northern SCS, and not only the weathering pattern, we report here a detailed study of the magnetic properties of a long sedimentary core (MD12-3432), which was retrieved from the continental slope of northern the SCS (Fig. 1). Combined with the silt grain size and compared with clay minerals and major elements (Chen et al., 2017), the changes in the magnetic properties at this location yield key information about the environmental changes and their controlling factors on different time-scales in the northern SCS, in particular land–sea interactions, East Asian monsoon and also oceanic circulation.

2. Material and sampling

Core MD12-3432 (19°16.88′ N, 116°14.52′ E, 2125 m water depth) was retrieved in 2012 with R.V. *Marion Dufresne* during the French–Chinese CIRCEA cruise. The core is 50.8 m long and it is located on the northern slope of the SCS, about 340 km off the Pearl River mouth.

The sediment lithology is homogeneously dominated by grey clays rich in foraminifera with a few 1 cm-thick light grey layers in the top three meters and a few 1 to 2 cm-thick organic matter rich layers below 20 m below sea floor (Kissel et al., 2012).

U-channel samples were collected from the center of the archive half of the core to perform continuous measurements of various magnetic properties, including volume-normalized susceptibility (κ), natural remanent magnetization (NRM), anhysteretic remanent magnetization (ARM), and isothermal remanent magnetization (IRM). About 320 small chips (2–10 mg) of sediments were also taken every 5–20 cm to measure the hysteresis parameters and about 30 of them were selected from specific horizons to conduct the decomposition in cumulative log Gaussian (CLG) anal-