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Geochemical provenance of sediments from the northern East China Sea document a gradual migration of the Asian Monsoon belt over the past 400,000 years

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A B S T R A C T

The reconstruction of the long-term evolution of the East Asian Monsoon remains controversial. In this study, we aim to give a new outlook on this evolution by studying a 400 kyr long sediment record (U1429) from the northern East China Sea recovered during IODP Expedition 346. Neodymium isotopic ratios and rare earth element concentrations of different grain-size fractions reveal significant provenance changes of the sediments in the East China Sea between East Asian continental sources (mainly Yellow River) and sediment contributions from the Japanese Archipelago. These provenance changes are interpreted as the direct impact of sea level changes, due to the reorganization of East Asian river mouth locations and ocean circulation on the East China Sea shelf, and latitudinal shifts of the intertropical convergence zone (ITCZ) from the interior of Asia to the western North Pacific Ocean. Our data reveal the dominance of winter and summer monsoons during glacial and interglacial periods, respectively, except for glacial MIS 6d (~150–180 ka) during which unexpected summer monsoon dominated conditions prevailed. Finally, our data suggests a possible strengthening of the interglacial summer monsoon rainfalls over the East Asian continent and Japan throughout the past 400 kyr, and between MIS 11 and MIS 5 in particular. This could result from a gradual northward migration of the ITCZ.

1. Introduction

The distribution of rainfall associated with the global monsoon system is tightly linked to the seasonal latitudinal shifts of the intertropical convergence zone (ITCZ), with high precipitation occurring in East Asia during the boreal summer when the ITCZ is located in the northern hemisphere. Our understanding of past East Asian monsoon dynamics is mainly based on reconstructions from continental archives such as speleothems (Wang et al., 2001, 2008; Yuan et al., 2004; Dykoski et al., 2005; Jo et al., 2014; Cheng et al., 2016), loess sequences (Zhisheng et al., 2001; Sun et al., 2006; Yang and Ding, 2008; Meng et al., 2018) and lacustrine sedimentary records (An et al., 2000; Xiao et al., 2004). These studies provide substantial information on the evolution of the East Asian Monsoon system during the Pleistocene, documenting paleoclimatic records exhibiting glacial-interglacial (loess records) and/or precessional cyclicities (speleothems).

Marine sediments deposited in the East China Sea, in addition to South China Sea sedimentary records (e.g. Wang et al., 1999; Liu et al., 2003), represent suitable archives for investigating the evolution of the East Asian monsoon over glacial-interglacial timescales (e.g. Chang et al., 2009). The East China Sea serves as a sink for the particulate load delivered by the Yangtze (Changjiang) and Yellow (Huanghe) rivers systems, two of the world's longest rivers. Their drainage areas are strongly influenced by monsoon-dominated climate. Sedimentary archives from the Yangtze and Yellow rivers deltas (Yi et al., 2003; Yi and Saito, 2004; Chen et al., 2005a,b; Xiao et al., 2006), as well as from the Okinawa Trough in

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the northern East China Sea (Sun et al., 2005; Yu et al., 2009; Kubota et al., 2010; Zhao et al., 2018), have been used to reconstruct the East Asian Monsoon signal back to the last glacial maximum ~20–30 ka. In these studies, the evolution of the East Asian monsoon was reconstructed from the flux of East Asian river detrital sediments to nearby oceanic areas (Saito et al., 2001; Liu et al., 2007; Hu et al., 2012). In particular, these fluxes were inferred through the tracking of the chemical and mineralogical signatures of Yangtze and/or Yellow rivers sediments as far as the Okinawa Trough (Diekmann et al., 2008; Dou et al., 2010, 2012; Xu et al., 2014; Li et al., 2015; Zhao et al., 2017, 2018). However, there are a lack of sedimentary archives recording the response of East Asian river basins to monsoon-related climatic changes over several interglacial-glacial cycles. Such records are necessary to understand the long-term variability of East Asian monsoon and its response to orbital forcing. In this study, we aim at filling this gap by studying a marine sediment record (U1429; Fig. 1) covering the last 400 kyr and recovered in the northern Okinawa Trough during the Integrated Ocean Drilling Program (IODP) Expedition 346 (Expedition 346 Scientists, 2014). The approach developed in this study is based on a detailed geochemical investigation of the detrital fraction of the U1429 Site sediments by combining major and rare earth element (REE) concentrations and neodymium (Nd) isotopic ratios. These proxies provide valuable information on sediment provenance. In the context of monsoon-dominated climates, these proxies allow us to reconstruct the response of river systems to past hydroclimate changes. Because decoupling of REE and Nd isotopes may occur between different grain-size fractions during hydrodynamic sorting and weathering processes, with possible implications for their use as provenance proxies (e.g.Meyer et al., 2011; Garçon and Chauvel, 2014; Bayon et al., 2015), we analyse several targeted grain-size fractions.

2. The East Asian sediment-routing systems

2.1. Geography, geology and climatology of the East Asian drainage systems

The Yangtze River (6400 km in length; drainage area of 1807×10^3 km^2) and the Yellow River (5450 km in length; drainage area of 752×10^3 km^2) are the two major drainage systems in East Asia (Fig. 1). Both rivers start in the northeast Tibetan Plateau (Qinghai Province) at about 5000 m elevation and flow eastward, delivering a total sediment flux of about $1{,}600 \times 10^6$ t/yr to the East China Sea (Milliman and Syvitski, 1992; Saito et al., 2001). Although a significant part of this flux (~60%) is derived from the Yellow river, the Chinese Loess Plateau in particular, the Yangtze river was likely the main source of sediment to the East China Sea prior to the onset

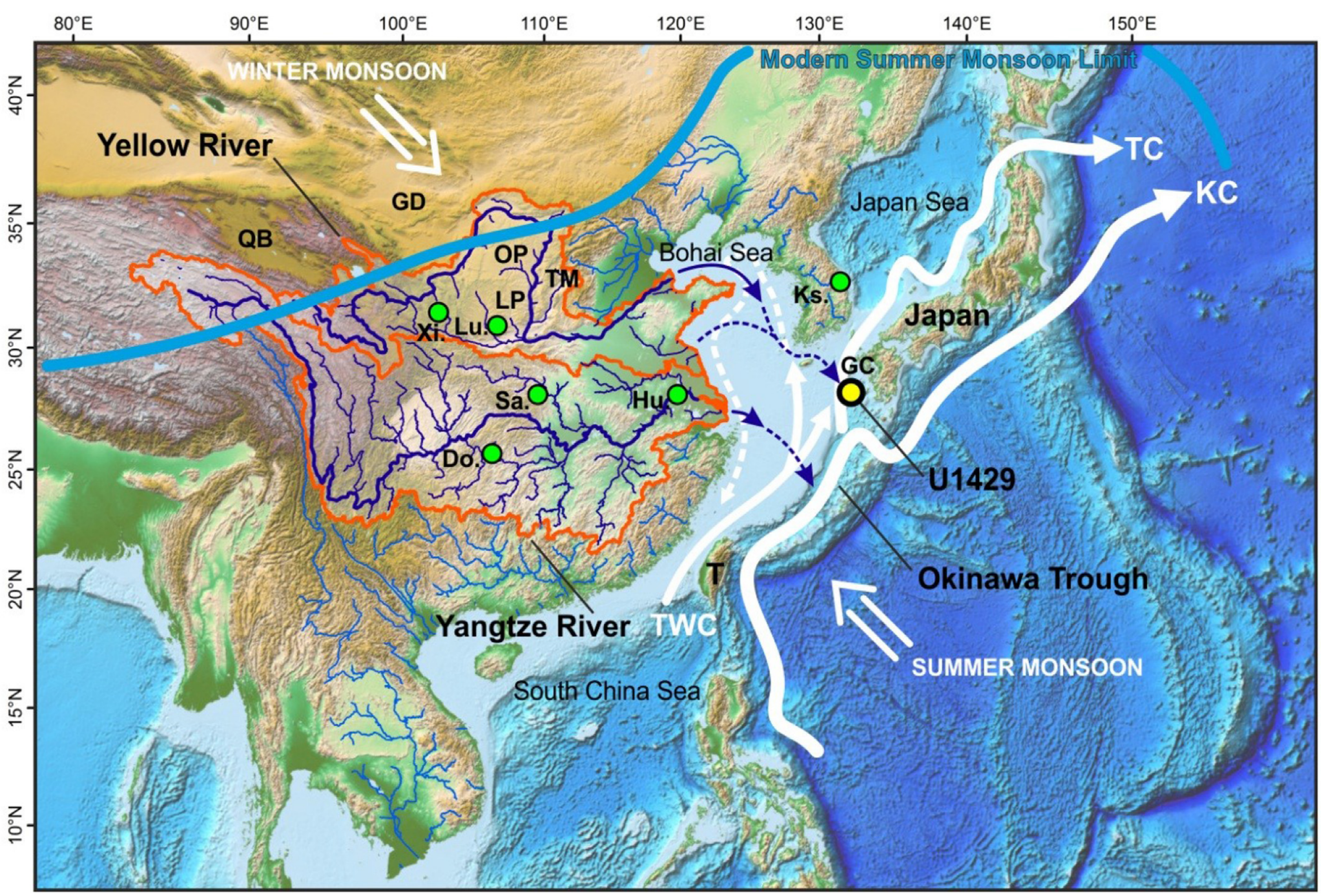

Fig. 1. Map of the study area showing the limit of modern summer monsoon front (light blue line; An et al., 2000; Jo et al., 2014), the drainage area of the Yangtze and Yellow rivers (with their glacial lowstand courses, dark blue lines; Ujiié and Ujiié, 1999; Oiwane et al., 2011; Xu et al., 2014) and the location of Site U1429 (yellow circle; Expedition 346 Scientists, 2014). The thick white arrows depict the regional ocean circulation (TC: Tsushima Current; KC: Kuroshio Current; Lee and Chao, 2003; Liu et al., 2007). The thin white arrows on the East China Sea shelf depict the Taiwan Warm Current (continuous, TWC) and the Yellow Sea Warm Current (dashed), respectively (Lee and Chao, 2003; Liu et al., 2007). The green circles denote the continental sequences (e.g. loess deposits, speleothems) discussed in the text (from West to East: Dongge Cave -Do.-, Sanbao Cave -Sa.-, Luochuan loess sequence -Lu.-, Hulu Cave -Hu.-, Korean speleothems -Ks.-). Also shown is the location of the Qaidam Basin (QB), Gobi Desert (GD), Ordos Plateau (OP), Loess Plateau (LP), Taihang Mountains (TM), Taiwan (T), and the Goto Submarine Canyon (GC). (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)