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Reconstruction of paleohydrological and paleoenvironmental changes using organic carbon and biomarker analyses of sediments from the northern East China Sea

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ABSTRACT

Paleohydrological and paleoenvironmental changes were reconstructed using sedimentary records from the northern East China Sea, representing the past 15,000 years (from the last glacial period to the Holocene). The *n*-alkane distributions show many factors, from the changing origins (plant types) of organic matter input to marine sediments. Two climatic conditions were distinguished (warm/humid and cold/dry) by comparing the organic carbon isotope ratio ($\delta^{13}C_{org}$) with the reported planktonic foraminiferal oxygen isotope ratio ($\delta^{18}O$) of *Globigerinoides ruber*. A shift in the *n*-alkane-specific $\delta^{13}C$ values reveals that the hydrological changes in the northern East China Sea were related to the carbon sources for aquatic macrophytes. The alkenone sea surface temperatures [SSTs ($U^{K'}_{37}$)] record of the 07YSPC12 shows a range of 20.3 °C–26.5 °C (average 22.9 °C). Lower temperature SSTs were recorded during the Younger Dryas, with an average of 21.7 °C. The variation in the alkenone SSTs is interpreted to indicate the environmental conditions of the growth of alkenone synthesized organisms.

1. Introduction

The East China Sea is a marginal sea located between the Yellow Sea and the South China Sea on the western rim of the Pacific Ocean. This region, which is a semi-closed marginal sea, is thought to be sensitive to hydrological and climatic changes. The sea level during the glacial period was more than 130 m lower than its current position (Peng et al., 1984), resulting in the establishment of a river system in the area of the East China Sea during the dry and cold climate conditions of the last glacial age (Li et al., 2005). The late Quaternary climatic pattern of the East Asia regions was predominantly governed by the East Asian Monsoon (EAM).

The EAM is formed as a result of unequal heating across the Asian landmass and the Pacific and Indian Oceans and a subsequent energy redistribution (Yu et al., 2011). It is, therefore, an integral part of the global and regional hydrological and energy cycles (An, 2000; Yu et al., 2011). The EAM alternates between dry-cold winter monsoons and warm-humid summer monsoons (An, 2000). Changes related to the East Asian paleomonsoon and its marine sediments have been studied extensively (Jian et al., 2000; Ishiwatari et al., 2001; Fujine et al., 2006; Zhao et al., 2006; Yu et al., 2011; Khim et al., 2012). The research carried out by An (2000) provided a framework showing the dynamic control of the paleomonsoon on the EAM evolution over the last 130 ky. Xu and Oda (1999) used planktonic foraminifera to reconstruct a surface-water evolution of the eastern East China Sea for the last 36,000 years. Ijiri et al. (2005) adopted the use of carbon and oxygen isotopes of planktonic foraminifera, as well as alkenone SSTs, to monitor paleoceanographic changes in the East China Sea, and Hu et al. (2013) utilized grain size analysis on Haitan Island, China to determine the history of the East Asian winter monsoon. In order to determine paleohydrological and paleoenvironmental changes based on the marine and lacustrine environments, multiproxy approaches have been used, focusing on the stable isotopic composition of sedimentary organic matter (Yu et al., 2011; Pérez et al., 2013; Wang et al., 2013) and molecular fossils (biomarkers) (Ficken et al., 2000; Ishiwatari et al., 2001; Bendle et al., 2009;

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Ortiz et al., 2010; Wang et al., 2012; Garel et al., 2013; Ronkainen et al., 2013).

Other research has focused on *n*-alkanes, which are produced by plants, algae, phytoplankton and bacteria in marine environments, as their resistance to degradation and early diagenetic alteration (Meyers, 1997; Radke et al., 2005) enables them to be used to identify the source of OM in marine sediments (Harji et al., 2008). Long-chain *n*-alkanes (>n-C_{23}) are found in abundance in higher plants. In contrast, algae and plankton tend to maximize at a shorter chain length (n-C_{15} to n-C_{19}). Recently, *n*-alkanes have been studied in terms of the shift in vegetation over time, demonstrating their use as a potential tool in paleoecological studies. Studies on bog peat have shown that different plant groups can be distinguished by comparing *n*-alkane distributions and ratios. Some examples are the P_{aq} ratio of $(C_{23} + C_{25})/(C_{23} + C_{25} + C_{29} + C_{31})$ as an indicator for terrestrial/emergent and submerged/floating plants; n-C_{23}/n-C_{29} and n-C_{23}/n-C_{31}, which can be used to discriminate between submerged/floating aquatic macrophytes; and n-C_{27}/n-C_{31}, which indicates the relative proportion of woody plants to grass vegetation (Ficken et al., 2000; Nichols et al., 2006; Wang et al., 2012).

Alkenones are biosynthesized by *Emiliania huxleyi*, producing a series of compounds that contain 37, 38 and 39 carbon atoms, with either two or three double bonds (unsaturation, e.g., $C_{37:2}$ and $C_{37:3}$). The relative concentrations of these compounds vary in direct response to temperature changes. As a result, they are used in the estimation of sea surface temperatures (SSTs). Based on the temperature-dependent distribution of $C_{37:2}$ and $C_{37:3}$ alkenones, the unsaturated index ($U^{K'}_{37}$) is mathematically defined as $U^{K'}_{37} = C_{37:2}/(C_{37:2} + C_{37:3})$ (Prahl and Wakeham, 1987). $U^{K'}_{37}$ can then be used to estimate the water temperature, according to the experimental relationship derived by Prahl and Wakeham (1987): $U^{K'}_{37} = 0.033T + 0.043$.

The investigation of vegetation shift using the P_{aq} ratio has not, to our knowledge, been fully studied in open water. As a consequence, it is unclear whether the application of the biomarker ratio (P_{aq}) is a robust approach for paleoecological studies of the region, as the East China Sea is sensitive to the hydrological and climatic changes that resulted in the establishment of a river system during the last Ice Age. This study applies selected organic geochemical analyses ($\delta^{13}C_{org}$, C/N ratio, P_{aq}, n-C_{23}/n-C_{29}, n-C_{23}/n-C_{31} and alkenone SSTs) to study the paleohydrological and paleoenvironmental changes in the northern East China Sea. We aimed to determine (1) the agreement among the selected organic geochemical proxies of the paleohydrological and paleoenvironmental changes in the northern East China Sea and (2) if the P_{aq} ratio can be used as a potential tool for paleoecological studies in the open sea.

2. Geological and hydrographic conditions

The East China Sea (ECS) is one of the largest marginal seas along the Pacific rim and is characterized by a broad continental shelf that has a less than 200 m water depth (Ijiri et al., 2005) (Fig. 1). Modern surface mud found in the inner shelf of the ESC is thought to be derived mostly from suspended sediments from the Yangtze River, transported southward by the winter coastal current (Guo et al., 1999; Hu and Yang, 2001) The surface water circulation in the ESC is characterized by a combination of the Kuroshio Current (KC) and coastal waters, diluted by the river discharge from the Chinese continent (Wang and Wang, 1988). The KC transports large

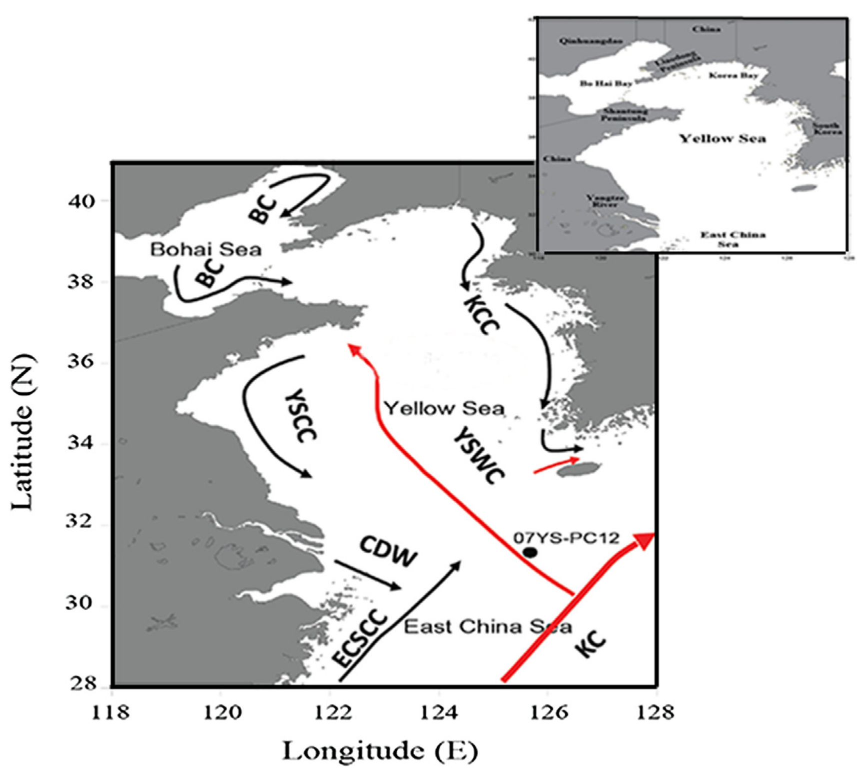

Fig. 1. Location of North East China Sea in respect to China and bathymetric map of the Yellow Sea and core locations. Arrows indicate the Yellow Sea Warm Current (YSWC), Yellow Sea Coastal Current (YSCC), Changjiang Diluted Water (CDW), Korea Coastal Current (KCC), Bohai Coastal Current (BC), East China Sea Coastal Current (ECSCC) and the Kuroshio Current (KC). Black arrows signify cold water, red arrows signify warm water. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)