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Evolution of the Yellow Sea Warm Current and the Yellow Sea Cold Water Mass since the Middle Pleistocene

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A B S T R A C T

The Yellow Sea Warm Current (YSWC) and the Yellow Sea Cold Water Mass (YSCWM) are the most significant hydrological characteristics of the Yellow Sea as they strongly influence the matter transportation, sedimentation, and the benthic and pelagic environments of the region. Previous studies focused mostly on formation and evolution of the YSWC and the YSCWM on shorter time scales (e.g., since the Holocene) and studies on longer time scales are rather sparse. This study conducted a high-resolution magnetostratigraphic investigation on core DLC70-3 (with a water depth of 71.2 m) in the northern part of the south Yellow Sea. Results show that the Brunhes/Matuyama polarity reversal boundary is located at a depth of 59.08 m. Constrained by both magnetostratigraphy and ^{14}C dating, three sedimentation episodes revealed by the benthic foraminifera content correspond to high sea level periods of marine isotope stage (MIS) 5–MIS9, MIS11–MIS17, and MIS19–MIS21, respectively. Cold-water benthic foraminifera species, total organic carbon, total sulfur, molybdenum element, and long-chain unsaturated alkenones index of the studied sediments show that both the YSWC and the YSCWM have evolved since the middle Pleistocene mainly due to combined effects of fluctuations of sea level and local tectonic subsidence. More specifically, both the YSWC and the YSCWM were intensified during high sea level periods of MIS5e–MIS9, MIS19 and MIS21. In addition, occurrence of the YSWC and the YSCWM are not always coeval as in the MIS5a–5d period, which is characterized by relatively stronger YSCWM but absence of the YSWC. These studies significantly improve our understanding of the evolution mechanism of both the YSWC and the YSCWM in this region.

1. Introduction

The Yellow Sea Warm Current (YSWC) is a branch of the Tsushima Warm Current (TWC), which primarily supplies both heat and salt to the Yellow Sea (YS) (Guan, 1994), and flowed into the Japan Sea at every interglacial highstand since 1.71 Ma (Kitamura et al., 2001; Kitamura and Kimoto, 2006; Hoiles et al., 2012; Gallagher et al., 2015). The YSWC carries along warm and highly saline seawater and thus has important influences on matter transportation, sedimentary system, and marine environment of the area (Qin et al., 1989). Previous studies have investigated intensively the source, path, and driving mechanism of the modern YSWC using both satellite observations and modeling simulations, which indicate that the YSWC is a compensating current of the wind driven coastal currents in the YS in winter and is forced by the pressure gradient along the YS Trough during the relaxation of the northerly wind bursts (Yang, 2007; Xu et al., 2009; Yuan and Hsueh, 2010). In order to determine the evolution mechanism of the YSWC, sediment cores since the last interglacial have been systematically investigated (Kim and Kennett, 1998; Kim et al., 1999; Kim and Kucera, 2000; Kong et al., 2006; Xiang et al., 2008; Liu et al., 2008, 2010a). There is a consensus that the YSWC was formed around 6–7 cal kyr B.P., a period of high sea level that is close to the modern sea level (Kim and Kennett, 1998; Kim et al., 1999; Kim and Kucera, 2000; Liu et al., 2008, 2010a). Salinity of the south YS increased significantly after the formation of the Holocene YSWC (Xiang et al., 2008; Xing et al., 2012).

Besides the YSWC, the second interesting feature of the YS is the presence of the Yellow Sea Cold Water Mass (YSCWM). Cold (<10 °C), high salinity (32.0–33.0 psu) bottom-water mass occupies in the deep water area (>50 m) of the central YS (Xiang et al., 2008) (Fig. 1). In

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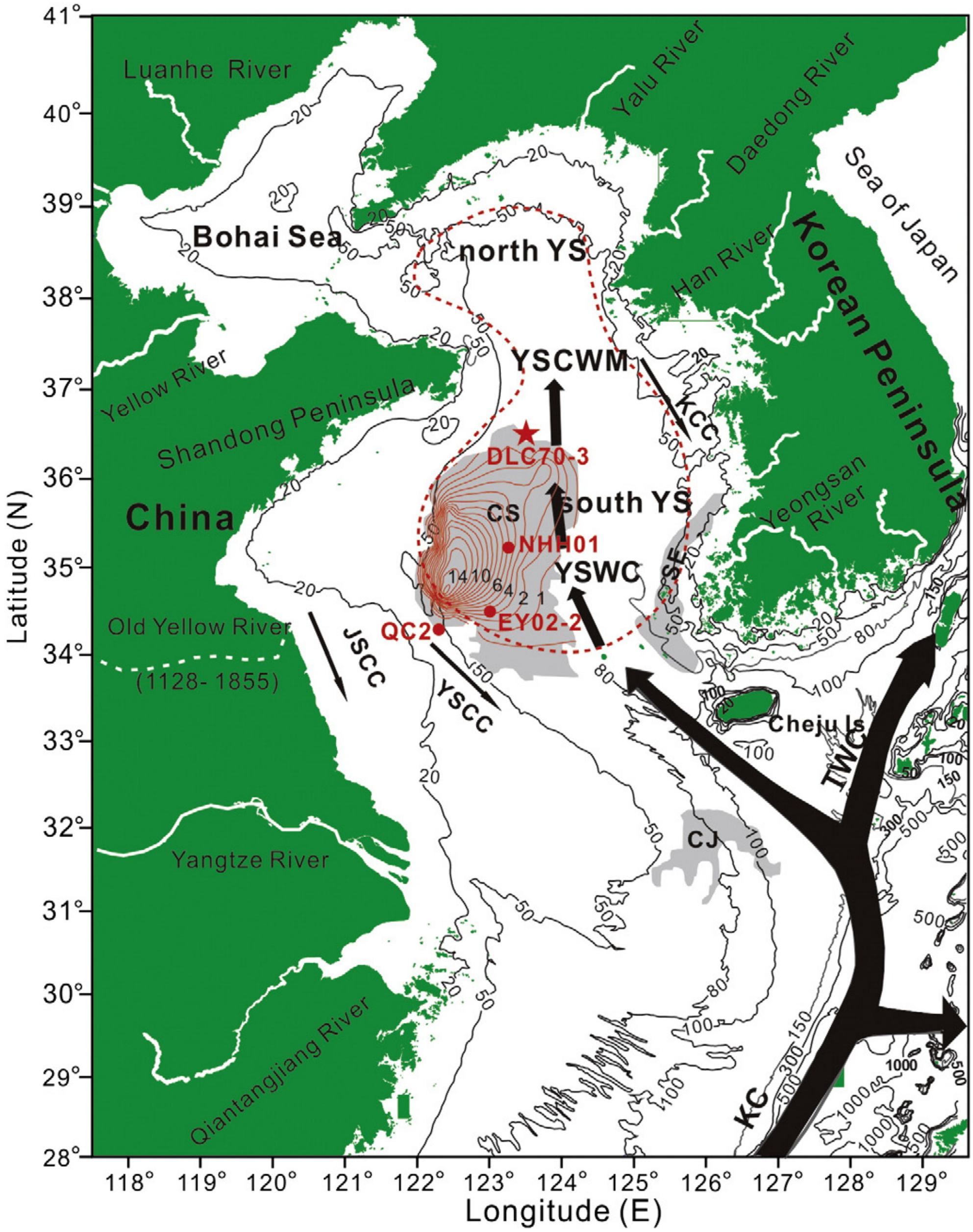

Fig. 1. Location of core DLC70-3 and other cores mentioned in the text, with surface currents in the south Yellow Sea (YS) superimposed (modified after Liu et al., 2010b). Black arrows indicate paths of currents including Kuroshio Current (KC), Yellow Sea Warm Current (YSWC), Tsushima Warm Current (TWC), Jiangsu Coastal Current (JCC), Yellow Sea Coastal Current (YSCC), Korea Coastal Current (KCC); the red curve area indicates the spatial distribution of the Yellow Sea Cold Water Mass (YSCWM) (modified from Yu et al., 2006); the gray area indicates the mud distribution area of south Yellow Sea including the central south YS Mud area (CS), southeastern YS Mud area (SE), the mud area southwest off Cheju Island (CJ) (modified from Wang et al., 2014); red curve for Holocene isopach in thickness of mud deposit CS (modified from Wang et al., 2014).

winter, when the shelf water column is nearly homogeneous, the YSWC sometimes intrudes into the NYS and even into the Bohai Sea (Guan, 1994). In summer, the YSCWM are present in the central YS. The YSWC is too weak to reach north of 35°N in summer because the cold water mass in the south YS intrudes southward, hindering the warm current's flow. The seasonal cold water eddy is considered to be responsible for the muddy deposits in the central YS (Hu, 1984). Ge et al. (2003) observed that low magnetic susceptibility values distribute mainly in the central south YS mud below the cold water mass via systematic studies on surface sediments (0–5 cm). They suggested that a powerful thermocline and pycnocline in the cold eddy sedimentation area prevents the water bodies to engage in a vertical mixing which then results in a reducing environment, in which the detrital iron oxides can be dissolved and results in low magnetic susceptibility (Ge et al., 2003). Previous studies have explored the oxidation–reduction conditions during formation of the YSWC and the YSCWM via element geochemistry, magnetic minerals, and authigenic pyrite indices (Kim et al., 1999; Liu et al., 2005). The sedimentation occurring during cold water mass conditions was formed under a relatively strong reducing environment, which is also consistent with results of the present-day cold eddy-related sedimentation area (Kim et al., 1999; Liu et al., 2005). In addition, concentrations of the cold-water benthic foraminifera and ostracoda species in the sediments of four cores, i.e., QC2, SYS0701, SYS0702, and SYS0803, in the south YS, all reached their peak in the high sea level sediments of early MIS5 period but failed to be detected in other horizons, which indicates that the ancient cold water mass had already appeared in the high sea level during the period of MIS5 (Yang et al., 1998; Liu et al., 2010b).