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A Holocene record of millennial-scale climate changes in the mud area on the inner shelf of the East China Sea

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ABSTRACT

Core MZ01 from the mud area on the inner shelf of the East China Sea (ECS) was studied to detect millennial climate changes during the Holocene based on a modified version of accelerator mass spectrometry (AMS) ^{14}C dating age model, sediment grain size, oxygen isotopes and the Mg/Ca ratio of benthic foraminifera shells. On the basis of multiproxies of this core, eight abrupt cooling events were identified that occurred at 8.2, 7.2, 6.2, 5.1, 4.2, 3.2, 2.3 and 1.2 ka BP, within the uncertainties of the revised age model. The timing of the abrupt Holocene surface hydrographic events reconstructed from the core, particularly 8.2 ka, expressed pronouncedly in the mud area on the inner shelf of the ECS appear to be coincident with the records from the North Atlantic, the South China Sea and an adjacent land cave and Greenland ice cores, suggesting global climatic teleconnections. The abrupt climate changes during the Holocene displays periodicities of 820–830 years and 350–420 years, which may be related to solar activity but suggests a robust regional feature of hydrographic changes in the western tropical Pacific. We conclude that the singularity of the particular hydrographic patterns and mechanisms responsible for the patterns and periodicities of these abrupt events merits further studies by more intensive dating controls and novel proxy reconstructions.

1. Introduction

Holocene climate change has been a heavily researched topic in the study on rapid global climate change. In recent years, ice cores, peat, pollen, tree rings, lake sediments, stalagmites and marine sediments have been progressively used in high-resolution paleoclimatic and paleoenvironmental evolution studies because they contain environmental information (Hong et al., 1998; Liu et al., 1998; Shi et al., 1999; Wang et al., 1999, 2001; Jian et al., 2000; Wang et al., 2005). The continental shelf edge as a junction and interaction area between continents and oceans is extremely sensitive to global sea level fluctuation, tectonic activity and climate change, thus playing a vital role in global climate and environment changes.

In recent years, marginal seas in the western Pacific Ocean have become the focus of paleoclimatic and paleoceanographic studies because of their unique settings. The East China Sea (ECS), located between the largest continent (Asia) and the largest ocean (Pacific), receives riverine inputs from the Yangtze and Yellow rivers, which are two of the largest rivers in the world. The Kuroshio Warm Current flows northward along the eastern edge of the continental shelf, thus separating the ECS from the open ocean. The ECS is therefore an ideal setting for studying the paleoclimatic history of East Asia, which is dominated by a monsoon regime.

Numerous studies have been conducted on mud sediment distribution, sediment dynamics, material sources and paleoenvironmental evolution in the inner shelf of the ECS (Xiao et al., 2005; Xu et al., 2009; Liu et al., 2010; Shi et al., 2010; Zheng et al., 2010; Xu et al., 2012). However, research on paleoceanography is relatively scarce (Zhao et al., 2009). In this study, we report detailed investigations of core MZ01, which was retrieved by the R/V Kan 407 from the inner shelf of the ECS.

Combined with sediment grain size, oxygen isotopes and the Mg/Ca ratio of benthic foraminifera shells, ice cores, adjacent land

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and deep-sea sediment records are used in this study to identify Holocene millennial-scale climate events that occurred abruptly in the mud area of the ECS, particularly for an 8.2 ka cold event. In addition, the possible driving factors leading to such abrupt cold events are discussed.

2. Regional setting

The East China Sea Coastal Current (ECSCC), which intensifies in winter, carries Yangtze River fresh water and sediment discharge southward along the inner shelf (Milliman et al., 1985; Qin et al., 1987). Conversely, the Taiwan Warm Current (TWC) flows northward offshore and retains Yangtze-delivered sediments on the inner shelf (Xiao et al., 2006; Liu et al., 2007; Xu et al., 2012). Therefore, nearly all of the sediments on the inner shelf and, in particular, the mud 'tongue,' originate from the upstream regions of the Yangtze River (Qin et al., 1987; Hori et al., 2001; Liu et al., 2006, 2007). Other inputs from small rivers south of the Yangtze River, such as the Qiantang Jiang, Ou Jiang and Min Jiang, in addition to biogenic production and Aeolian dust, make relatively small contributions to the mud wedge compared with those originating from the Yangtze River (Qin et al., 1987).

3. Material and methods

3.1. Core description

During the 'Coastal Investigation and Research Project of China' cruise in 2007, core MZ01 was recovered from the mud wedge off the coast of Zhejiang Province on the inner continental shelf of the ESC (26.55°N; 120.85°E) at a water depth of 64.7 m (Fig. 1). Core MZ01 is 2.96 m in length.

3.2. Oxygen and carbon isotope and Mg/Ca measurements

Specimens of benthic foraminifera *Ammonia compressiuscula* were hand-picked from larger than 154 μm size fractions for isotopic analysis. The oxygen and carbon isotope analysis followed the method described by Cheng et al. (2005), with standard deviations of 0.07‰ *Pee Dee Belemnite* (PDB) and 0.04‰ PDB (Cheng et al., 2005), respectively.

For the Mg/Ca analysis, *A. compressiuscula* were also hand-picked from size fractions larger than 154 μm. Specimens were pretreated and cleaned by using a reductive step (Martin and Lea, 2002) and were measured by inductively coupled plasma atomic emission spectroscopy (ICP-AES).

The oxygen and carbon isotope and Mg/Ca measurements were all performed in the State Key Laboratory of Marine Geology, Tongji University. The analyses were performed on 74 samples at ~4 cm intervals; the average resolution was approximately 120 years.

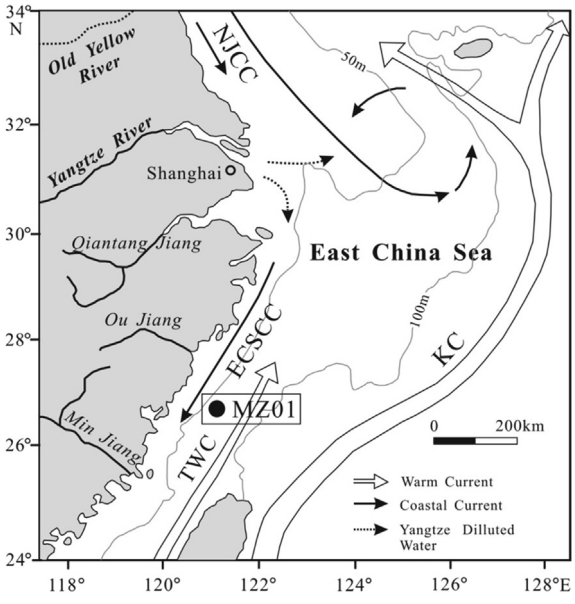

Fig. 1. Location of the studied sediment core and regional circulation pattern in the East China Sea (ECS; Modified after Qin et al., 1987). TWC: Taiwan Warm Current; NJCC: North Jiangsu Coastal Current; ECSCC: East China Sea Coastal Current.

4. Results

4.1. Lithology

The lithology of core MZ01 is homogeneous and is composed mainly of grey and dark grey clay silt from the top downward. This core can be divided into the following four sections according to lithology such as colour, sedimentary structure and grain-size parameter: a bottom section (296–275 cm), an upper middle section (275–137 cm), a lower middle section (137–73 cm), a top section (73~0 cm). The detailed characterization of these sections has been described by Liu et al. (2010).

4.2. Chronological framework and sedimentation rate

The chronological framework for core MZ01 used in this study is based on a revised version of accelerator mass spectrometry (AMS) ^{14}C dating age models based mixed benthic foraminifera (Table 1) (Liu et al., 2010, 2013). The dates were all performed by Liu et al. (2010) at the National Ocean Sciences Accelerator Mass Spectrometry Facility (NOSAMA), Woods Hole Oceanographic Institution, Massachusetts, USA. However, we calibrated the ages differently from Liu et al. (2010) here by applying the program Calib 5.0 (Stuiver and Reimer, 1993) and the calibration data set Marine 04, which includes a constant average global reservoir age of 400 years. Moreover, we made another attempt here to delete the oldest dating (292–294 cm depth; Table 1), as the dating was from the bottom of the core by which the effects of reservoir age and old carbon contamination are hard to estimate. By the modified version of age model, we found that the core spans approximately 9.13 ka BP, and the sedimentation rate ranges from 32.4 cm/ky to 54.9 cm/ky (Table 1, Fig. 2).

Table 1
Accelerator mass spectrometry (AMS) ^{14}C dating and sedimentation rate of core MZ01

Depth (cm)	^{14}C age (BP)	Calibrated age (BP(2δ))	Layer (cm)	Sedimentation rate (cm/ky)
66–68	1780 ± 35	1220 (1115–1300)	0–67	54.92
130–132	3810 ± 35	3602 (3462–3723)	67–131	26.87
186–188	4940 ± 30	5117 (4969–5258)	131–187	36.96
232–234	6190 ± 45	6493 (6371–6632)	187–233	33.43
276–278	8020 ± 35	8364 (8271–8468)	233–296	23.51
292–294	7930 ± 35	8279 (8175–8365)		

4.3. Oxygen and carbon isotope of benthic foraminifera

The measured δ^{18}O variation spans ~2‰ (−1.95 to 0.06‰ PDB) with an average of −1.19‰ PDB. The measured δ^{13}C variation spans ~2‰ (−1.24 to 0.08‰ PDB) with an average of −0.51‰ PDB. The curve of the δ^{18}O values is clear divided into two parts with the