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Middle-Holocene sea-level fluctuations interrupted the developing Hemudu culture in the lower Yangtze River, China

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ABSTRACT

The eastern coastal zone of China is densely populated and widely recognized as a center of rice domestication, which has undergone dramatic sea-level fluctuation during the Holocene epoch. Hemudu culture is distributed mainly in the eastern coastal area and was once presumed as a mature agricultural economy based on rice, making it an ideal case for examining the remarkable human-environment interaction in the Lower Yangtze River. Though numerous studies have been conducted on the cultural evolution, ecological environment, and rice domestication of Hemudu culture, the impact of sea-level fluctuation on human settlement and food production remains controversial. In this study, we report high-resolution pollen, phytolith, and diatom records, and accurately measured elevation from the Yushan site, which is the closest site of Hemudu culture to the modern coastline. Based on the data gathered, we suggest that the Hemudu culture and subsequent Liangzhu culture developed in the context of regression and were interrupted by two transgressions that occurred during 6300-5600 BP and 5000-4500 BP. The regional ecological environment of the Yushan site alternated between intertidal mudflat and freshwater wetlands induced by sea-level fluctuations in the mid-late Holocene. Though rice was cultivated in the wetland as early as 6700 BP, this cultivation was subsequently discontinued due to the transgression; thus, full domestication of rice did not occur until 5600 BP in this region. Comprehensive analysis of multiple proxies in this study promote the understanding of the relationship between environmental evolution, cultural interruption, and rice domestication.

1. Introduction

Though low-elevation coastal zones (below 10 m in elevation) currently contain more than 10 percent of the world population (McGranahan et al., 2007; Small and Nicholls, 2003), these regions are highly vulnerable to risks resulting from sea-level rise and climate change (FitzGerald et al., 2008; Nicholls and Cazenave, 2010; Nicholls et al., 2007; PAGES, 2009). The Lower Yangtze River sits in the interface zone between marine and terrestrial areas that has experienced a dramatic evolution of sea level and climate during the Holocene (Chen and Stanley, 1998; Qin et al., 2011; Song et al., 2013; Yi et al., 2003). Accordingly, this area serves as an ideal place for studying human-environment interaction (Zong et al., 2011b, 2012).

The Lower Yangtze River is densely distributed with Neolithic sites and is widely regarded as a core area where rice agriculture originated (Fuller, 2011; Silva et al., 2015; Stanley and Chen, 1996; Wu et al., 2014b). These cultural sequences comprise the Shangshan (11,000-8500 BP), Kuhuqiao (8000-7400 BP), Majiabang (7000-6000 BP), and Hemudu Culture (7000-5000 BP) during the early to middle Holocene (Fig. 1a) (Liu and Chen, 2012; The Institute of Archaeology and China Academy of Social Sciences, 2010; Underhill, 2013). The Hemudu culture is the most significant

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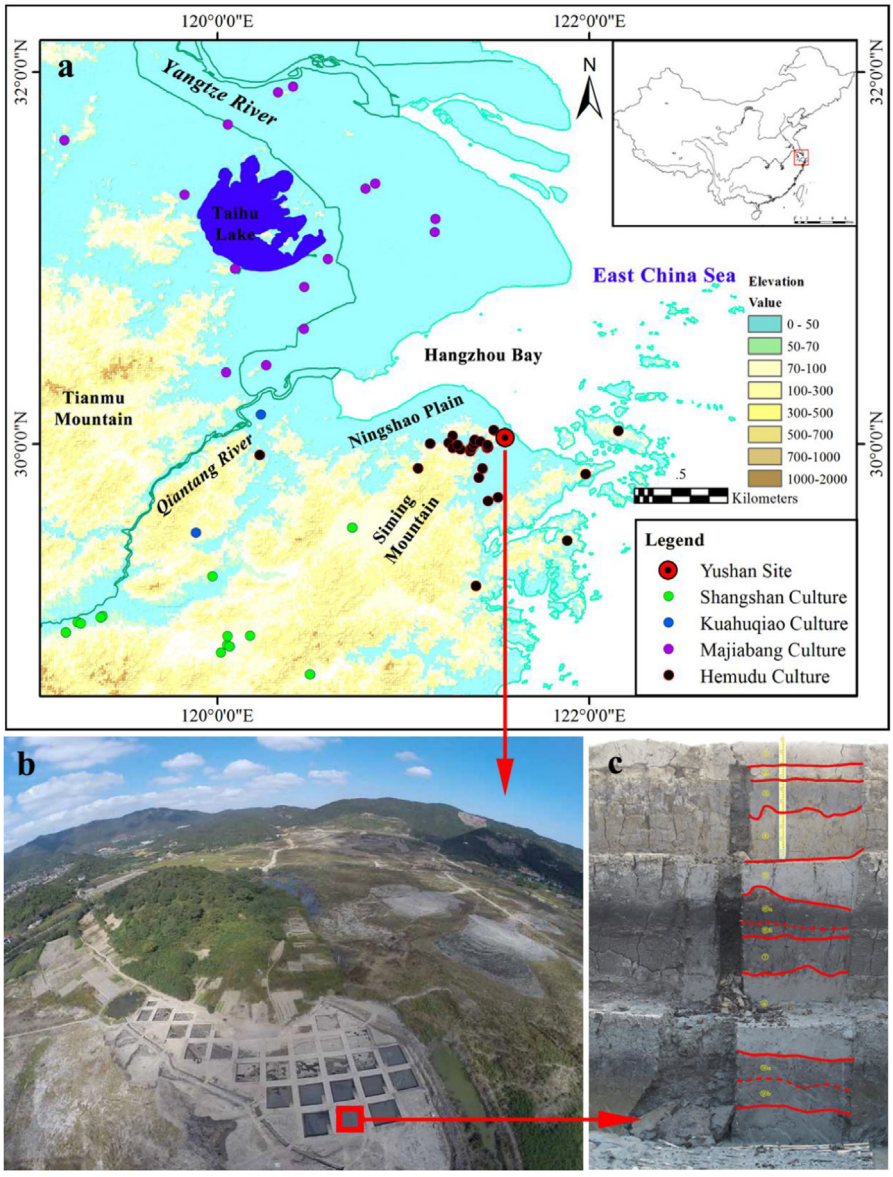

Fig. 1. Location and photographs of the Yushan site. (a) Location of Yushan site and the distribution of archaeological sites of Shangshan (11,000-8500 BP), Kuhuqiao (8000-7400 BP), Majiabang (7000-6000 BP) and Hemudu Culture (7000-5000 BP). (b) Aerial photographs of the Yushan site excavated in 2013 and the trench T0213 were circled by a red square. (c) Photograph of the profile sampled and sediment stratigraphy. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Neolithic culture and is identified by its distinct style of pile-dwellings and rice remains in southern China (Sun, 2013), which are distributed primarily in the eastern coastal area and divided into two main periods with a remarkable interruption and dispersal around 6000 BP (Wang and Liu, 2005).

The interruption and dispersal of Hemudu culture are closely related to the change in the hydrologic environment induced by sea-level fluctuation. The core dispute of sea-level curves proposed previously for the east coast of China lies in whether or not a mid-Holocene sea-level highstand exists (Chen and Stanley, 1998; Hori et al., 2001; Liu et al., 2004; Song et al., 2013; Zhao et al., 1994; Zong, 2004). Divergent views of sea-level change significantly affect the explanation of the palaeoenvironment and the subsistence of Hemudu culture in Hemudu and Tianluo sites (Li et al., 2012; Liu et al., 2016; Qin et al., 2006; Zhu et al., 2003). Nevertheless, whether the phenomenon of cultural interruption is a special case or universal experience, what environmental changes potentially caused the interruption and how the interruption affects the process of rice domestication remains controversial.

Cultural interruptions are identified by barren layers of soil (i.e., layers that lack relics) that are situated between two cultural layers common in the Lower Yangtze River (Wu et al., 2014a; Yu et al., 2000; Zhang et al., 2005). Results of pollen, phytolith, diatom, seed, and geochemistry from the Tianluoshan site reveal several cultural interruptions during and after Hemudu Culture that were induced by the two largest transgressions during 6400-6300 BP and 4600-2100 BP (Li et al., 2012; Patalano et al., 2015; Wang et al., 2010; Zheng et al., 2011). However, based on the analysis of pollen and foraminifera from the Hemudu site, some scholars argue that the sludge layers that lie within and above the Hemudu culture layer are both freshwater swamp sediments (Wang, 2006; Zhu et al., 2003), implying an expanded waterbody associated with the migration of the Yaojiang River (Liu et al., 2016; Wang and Liu, 2005; Wu, 1985). Whether the cultural interruptions were caused by marine transgression or land floods is still in dispute.

The discovery of the Hemudu site marks a milestone in Chinese agricultural archaeology with excellent preservation of organic materials in waterlogged conditions, especially abundant remains