



Middle Holocene marine flooding and human response in the south Yangtze coastal plain, East China

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ABSTRACT

Coastal flooding catastrophes have affected human societies on coastal plains around the world on several occasions in the past, and are threatening 21st century societies under global warming and sea-level rise. However, the role of coastal flooding in the interruption of the Neolithic Liangzhu culture in the lower Yangtze valley, East China coast has been long contested. In this study, we used a well-dated Neolithic site (the Yushan site) close to the present coastline to demonstrate a marine drowning event at the terminal stage of the Liangzhu culture and discuss its linkage to relative sea-level rise. We analysed sedimentology, chronology, organic elemental composition, diatoms and dinoflagellate cysts for several typical profiles at the Yushan site. The field and sedimentary data provided clear evidence of a palaeo-typhoon event that overwhelmed the Yushan site at ~2560 BCE, which heralded a period of marine inundation and ecological deterioration at the site. We also infer an acceleration in sea-level rise at 2560–2440 BCE from the sedimentary records at Yushan, which explains the widespread signatures of coastal flooding across the south Yangtze coastal plain at that time. The timing of this mid-Holocene coastal flooding coincided with the sudden disappearance of the advanced and widespread Liangzhu culture along the lower Yangtze valley. We infer that extreme events and flooding accompanying accelerated sea-level rise were major causes of vulnerability for prehistoric coastal societies.

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1. Introduction

Global sea-level rise is predicted to accelerate during the 21st century and could rise 65 ± 12 cm by 2100 compared with 2005 (Kopp et al., 2016; Nerem et al., 2018), which will increase the frequency of extreme events and the risk of coastal flooding (Woodruff et al., 2013). The vulnerability of low-lying coastal plains and deltas across the world is further exacerbated due to human-induced sediment starvation and land sinking (Syvitski et al., 2009; Giosan et al., 2014). The west Pacific Ocean coast is one of the most vulnerable regions in the world because it is characterized by active tropical cyclones (Woodruff et al., 2013) and, in recent decades, its rate of relative sea-level rise is three times higher than the global mean (Nicholls and Cazenave, 2010). In the densely-

populated Yangtze delta, East China (Fig. 1), models under future climate scenarios predict an increase in flood risk from extreme events and relative sea-level rise by 150%–400% in the next 50 years (Tessler et al., 2015). In fact, Typhoon Fitow (the strongest October typhoon making landfall in China for over 60 years) in 2013 caused flooding to a depth >0.5 m across most of the Yaojiang Plain, south east of the Hangzhou Bay (Fig. 1C). There is thus clearly an urgent need for integrated research on sea-level rise, extreme events, coastal flooding and human response.

Coastal flooding is not a new threat. The fact that the south Yangtze coastal plains (Fig. 1B) hold relative thick and rich archaeological records, preserved in marine and deltaic flood basin sediments (Zong et al., 2007; Zheng et al., 2012), is direct witness of past flooding of these areas during human occupation. Neolithic people including the well-known Kuahuqiao, Hemudu and Liangzhu cultures settled and practiced flood management on the coastal wetlands of Hangzhou Bay (Fig. 1) since ~6000 BCE (Zhao, 1998; Zong et al., 2007; Liu and Chen, 2012; Qin, 2013; Liu et al.,

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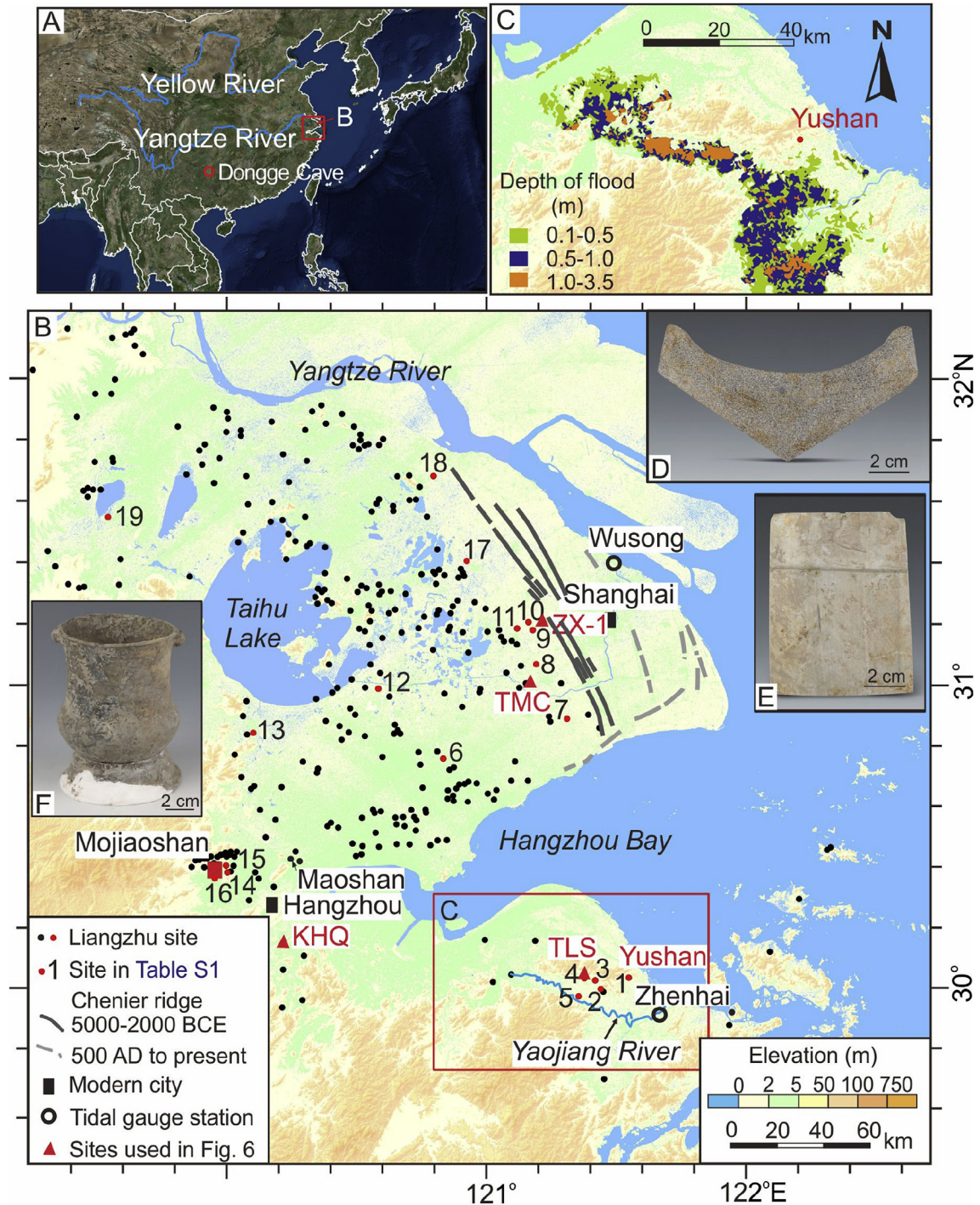


Fig. 1. Location maps. (A) East Asia and the location of the study area. (B) The south Yangtze coastal plain, showing the locations of the Liangzhu sites and all sites for which radiocarbon dates for the Liangzhu and post-Liangzhu cultural layers were available. These sites are numbered according to their distance from the Yushan site (Table S1). Note that the Liangzhu settlements are distributed mainly on the Taihu Plain of the southern Yangtze Delta plain and the Yaojiang Plain on the south east bank of Hangzhou Bay. (C) The flooding to a depth of >0.5 m across most of the Yaojiang Plain caused by Typhoon Fitow (the strongest typhoon to make landfall in China for over 60 years), October 2013 (data source: Ningbo gauge station, 2013. <http://www.nbswz.com.cn/Html/201405/26/11669.html>). (D–F) Typical artefacts of the Liangzhu culture discovered from the Yushan site, now deposited in Ningbo Municipal Institute of Cultural Relics and Archaeology. (D) Stone cutter (*Shi Dao*); (E) stone woodworking tool (*Youduan Shi Beng*); (F) black pottery two-lugged necked jar (*Shuangbi Hu*), with some remains of black slip. The maps were generated with the ArcGIS 10.1 software (www.esrichina.com.cn) using the topographic dataset provided by the International Scientific & Technical Data Mirror Site, Computer Network Information Centre, Chinese Academy of Sciences (<http://www.gscloud.cn>).

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