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Climatic and palaeoecological changes during the mid- to Late Holocene transition in eastern China: high-resolution pollen and non-pollen palynomorph analysis at Pingwang, Yangtze coastal lowlands

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ABSTRACT

The transition to the Late Holocene/Neoglacial occurred as a worldwide process of climatic deterioration from the optimum thermal conditions of the mid-Holocene, culminating in an abrupt decline around 4200 cal yr ago, in a period of severe climatic deterioration that lasted for two or three centuries. This sudden climatic event has been recorded in many proxy data archives from around the world, and its effects were manifest in different ways depending on the reaction of regional weather systems and conditions, but often as greatly increased aridity and/or cold temperatures. It has been regarded as causing or contributing to the sudden collapse of several well-established human societies at that time, including advanced agricultural Late Neolithic cultures in eastern China. We have used high-resolution pollen and non-pollen palynomorph analysis to examine the nature of this climatic transition through its impacts on the vegetation and hydrology at Pingwang, a site in the Yangtze coastal lowlands which has no evidence of complicating environmental influences such as sea-level rise or significant human land-use activity, factors previously suggested as alternative reasons for changes in forest composition. Our results show two phases of forest alteration, one gradual from about 5500 cal BP and one sudden at about 4200 cal BP., in which the frequencies of subtropical forest elements fall and are replaced by those of conifers and cold-tolerant trees. Total arboreal pollen frequencies do not decline and the proportion of temperate forest trees, tolerant of a wide range of temperatures, remains unchanged throughout, both ruling out human land clearance as a cause of the change in forest composition. As these dates accord very well with the known timings of climate deterioration established from other proxy archives in the region, we conclude that climate was the main driver of vegetation change in eastern China at the mid- to Late Holocene transition. Our hydrological results support the view that a combination of rising local water level and climatic cooling during the 4200 cal BP event was the probable cause of societal collapse in the lower Yangtze valley.

1. Introduction

Holocene climate history is now relatively well understood at the global scale, with the recognition of a series of significant temperature events that occurred within the longer-term evolution of the present interglacial's temperate climate, some of which represent tipping points, major shifts that mark phase transitions between longer periods of more stable thermal conditions. One of the most important of these climatic shifts is Holocene Event 3 (Bond et al., 2001), occurring relatively abruptly around 4200 years ago (hereafter cal BP) and having major environmental impacts worldwide, recognised (Walker et al., 2012) as the global transition from early and mid-Holocene thermal maxima (Renssen et al., 2012) to the Late Holocene (Neoglacial), with its colder, more extreme and more variable climatic regimes (Marchant and Hoogiemstra, 2004; Jessen et al., 2005; Wanner et al., 2011). This major climatic shift to unstable Neoglacial conditions in the centuries preceding 4000 cal BP has been recorded across the globe in a range of proxy climate data

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archives (Gear and Huntley, 1991; Jian et al., 1996; Phadtare, 2000; Stott et al., 2004; Booth et al., 2005; Magny et al., 2009; Geirsdóttir et al., 2013), affecting major atmospheric systems such as the North Atlantic Oscillation (Olsen et al., 2012), ENSO (Schulmeister and Lees, 1995), the Indian Monsoon (Overpeck et al., 1996; Gupta et al., 2003; Staubwasser et al., 2003) and the East Asian Monsoon (EAM) through global climatic teleconnections (Wang et al., 2000; Liu et al., 2004; Hong et al., 2005; Tan et al., 2008). A gradual onset of globally cooler conditions can be noted at around 5500 cal BP, with the major Neoglacial intensification at ca 4200 cal BP (Geirsdóttir et al., 2013). The EAM, which forms the focus of this paper, accords very well with the global data, with ample evidence of its progressive weakening after the mid-Holocene at ca 5500 cal BP, culminating in an abrupt decrease in its strength in the centuries before 4000 cal BP (An, 2000; An et al., 2000; Morrill et al., 2003; He et al., 2004; Yuan et al., 2004; Wang et al., 2005; Selveraj et al., 2007; Cosford et al., 2008; Cai et al., 2010).

1.1. Neoglacial climatic deterioration and human societies

The link between climatic and societal change can be very strong (Perry and Hsu, 2000; Caseldine and Turney, 2010; Zhang et al., 2011). It is not deterministic (Coombes and Barber, 2005) to assume that the change from the mid-Holocene climatic optimum to the much less congenial Neoglacial climate would have had significant effects upon human societies, particularly those that had developed intensive agricultural systems that supported high, sedentary populations, but which had become dependent upon stable, favourable and reliable climatic conditions. The more economically and socially specialized such societies became, the more vulnerable they would have been to any rapid environmental change (O'Sullivan, 2008). Human communities are resilient and adaptable (Anderson et al., 2007; Lu, 2007) and were able to cope and even flourish during the gradual climatic decline from the mid-Holocene thermal maximum around the world, the development of advanced agrarian societies based on the control of water resources in the major river valleys of the Middle East and China being good examples. In China such advanced, highly productive farming systems sustained the dense Neolithic populations of the Longshan, Shijiahe, Qijia and Liangzhu cultures in the Yellow River and Yangtze valleys during the millennium after 5000 cal BP (Liu and Feng, 2012; Zhuang et al., 2014). Abrupt climatic deterioration would have been difficult for such complex agrarian societies to cope with, however (Mo et al., 2011), and there is abundant archaeological and palaeoecological evidence that the rapid climate changes around 4200 cal BP caused severe economic and political dislocation, and even societal collapse, in many regions of the world (Dalfes et al., 1997; Peiser, 1998; Sandweiss et al., 1999; deMenocal, 2001). Major civilizations disintegrated at this time in India and the Middle East and the coincidence of societal failure and settlement abandonment with the rapid change to Neoglacial cold and arid conditions in these areas implies an environmental cause and a cultural effect, with climate as the driving force (Weiss et al., 1993; Cullen et al., 2000; Staubwasser et al., 2003; Drysdale et al., 2006; Staubwasser and Weiss, 2006; Riehl, 2012), although of course such a direct relationship can never be proven conclusively.

1.2. The east China example

One of the world's regions that has a clear correlation between cultural ‘collapse’ and the 4200 cal BP climate event is eastern China, and in particular the lower Yangtze valley, one of the historic heartlands of Chinese society and agricultural development. Liu and Feng (2012) and Wu et al. (2012a,b) have evaluated the evidence for the development in the fifth millennium cal BP of the advanced agrarian cultures of central and eastern China mentioned above, and their sudden, almost synchronous demise around 4200 cal BP, when severe climate deterioration occurred. Many major Neolithic archaeological sites have culturally sterile sediments of this age that seal the rich cultural layers and are interpreted as flood deposits. Many authors (e.g. Yu et al., 2000, 2003; Jin and Liu, 2002; Wu and Liu, 2004; Zhang et al., 2005; Gao et al., 2007; Chen et al., 2008) are convinced that the 4200 cal BP event must have been responsible for site abandonment and for the culturally impoverished interlude of a few centuries recorded almost everywhere in north and east China around 4200 cal BP. Clear, independent evidence that the severe climatic deterioration of Holocene Event 3 had an impact on the east Asia region at this time may be seen in marine sediment records from the South China Sea, the East China Sea and the North-west Pacific generally. Jian et al. (1996) used oxygen isotope analysis on planktonic foraminifera from deep water marine sediments in the East China Sea to reconstruct sea-surface temperatures during the transition to the Late Holocene, observing major cooling at the start of the Neoglacial around 4200 cal BP. Sun et al. (2005)'s oxygen isotope analyses from corals in the South China Sea show a major weakening of the monsoon and increase in its variability during the same period. Wang et al. (1999a,b), also using oxygen isotope data, identified a very clear abrupt cooling, the most severe in the Holocene apart from the 8200 cal BP event, at 4200–4000 cal BP in the northern South China Sea, a feature also observed by Wei et al. (1998), Chinzei et al. (1987) and Lutaenko et al. (2007) in the Sea of Japan. The ca 4200 cal BP major cooling event is well attested in proxy climate records from the east Asia region, and it coincides with the apparent collapse of the late Neolithic cultures of the lower Yangtze area.

Although the circumstantial evidence that environmental pressures of varying kinds led to the collapse of the Liangzhu culture of the lower Yangtze around 4200 cal BP is very persuasive, we still do not know in detail the vegetation changes that preceded and accompanied the 4200 cal BP event there. New, high resolution palaeoecological data are required from within the Liangzhu's core settlement and agricultural area with which to establish these environmental preconditions. Most previous palynological research has been of low resolution, or situated too close to archaeological sites to be able to separate clearly any cultural impacts from the background vegetation history, or too far away to provide evidence of conditions within the cultural heartland itself. Also, not every pollen record agrees with the hypothesis that agricultural production almost ceased in the Taihu lowlands at this time (Itzstein-Davey et al., 2007b). In this paper we use high resolution palynology (both pollen and non-pollen palynomorphs) to investigate the nature and severity of the environmental changes during the transition to the Neoglacial in the Yangtze coastal lowlands of eastern China, as expressed in vegetation patterns and hydrology. A site at Pingwang has been selected where a more regional pollen signal might be expected, minimizing the influence of local human land-use in this intensively settled area, so that natural factors rather than agricultural impacts will have been the main driving force behind the vegetation history and environmental change. Zong et al. (2011) have shown that direct inundation by marine transgression could not have been the reason for the abandonment of the Taihu lowlands by Neolithic people at this time, and this paper will explore in detail whether climate deterioration and its consequences was the environmental driving force, if one existed.

2. The study area and site

The study area chosen is the coastal lowland around the Taihu Lake west of Shanghai (Fig. 1). Between the valley of the Yangtze river and