Catena 147 (2016) 586–594

Contents lists available at ScienceDirect

Catena

journal homepage: www.elsevier.com/locate/catena

Radiocarbon anomalies suggest late onset of agricultural intensification in the catchment of the southern part of the Yangtze Delta, China

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ARTICLE INFO

Article history:
Received 8 October 2015
Received in revised form 30 July 2016
Accepted 9 August 2016
Available online 15 August 2016

Keywords:
ANOVA
Alluvial
Holocene
TOC
$\delta^{13}C$
Rice

ABSTRACT

Previously underused information from radiocarbon dates in well-characterised sedimentary sequences in the southern Yangtze Delta, China, is here utilised in reconstruction of patterns of ancient erosion. The southern Yangtze Delta was an important focus of food production in the early Neolithic. Anomalous radiocarbon dates in Holocene sediments from the southern part of the delta are unevenly distributed through time. Two clusters of dates – in sediments ca. 9000–7000 cal. BP and ca. 3000–1000 cal. BP – most likely indicate two periods of intensive erosion and redeposition of organic materials. The older of the two clusters may have been associated with a marked episode of marine transgression, whereas the younger cluster could reflect increasing levels of human disruption of soils and sediments in the catchment. A relatively late increase in anthropogenic soil erosion supports recent archaeological evidence that, following its early Neolithic origins, agricultural expansion and intensification occurred later on the southern Yangtze Delta than previously thought.

1. Introduction

Alluvial deposits in the lower reaches of large rivers were foci of early agriculture in many parts of the world (Bellwood, 2005). Soil that was tillable and that had its fertility frequently replenished during periods of inundation, additional nutritional security provided by aquatic and wetland resources, and ease of travel and trade proved attractive to early human settlers (Stanley and Warne, 1997). Sedimentary evidence has the potential to provide information on the activities of early settlers, and their interactions with the environment. Understanding the history of human settlement and activity and the interactions between early farmers and their environment in these locations is, however, often hampered by the dynamism of the sedimentary environment. This dynamism not only impacts the length and continuity of sediment records, but can also severely affect the quality and reliability of chronological control (Brown, 1997). Radiocarbon, as a principal method for establishing the age of material dating to the last ca. 50,000 years (Walker, 2005), often produces high percentages of dating anomalies – i.e. radiocarbon measurements that disagree with other dated evidence or that are associated with irregularities in age-depth profiles (Stanley and Chen, 2000; Hunt et al., 2015).

Anomalous radiocarbon dates in alluvium, through erosion and redeposition of old carbon, are common, including in the lower part of the Yangtze River (Stanley, 2001). Organic carbon in surface soil and sediments in a drainage basin often experiences temporary storage and remobilisation, the latter resulting from increased fluvial activity (Hoffmann et al., 2009) or soil erosion. The time between the initial fixing and burial of carbon and its subsequent re-exposure and remobilisation varies, and can be as long as several millennia (Galy and Eglinton, 2011). Organic carbon in sediments deposited along the lower reaches of a river with an extensive catchment may thus come from a diversity of sources and incorporate a range of different ages (Stanley, 2001). Dating anomalies are likely in this situation, which is a major reason why radiocarbon dates in alluvial environments often show systematically older ages than expected (Stanley and Hait, 2000).

The southern part of the Yangtze Delta, China (Fig. 1), is a prime example of an alluvial plain that became a focus of early agriculture. Human populations, their settlements and level of technological achievement and changes in the development of food production, are manifested in a series of cultural phases that left their mark on the archaeology of the region (Zong et al., 2012b). Rice (*Oryza sativa*) is a crop that is now consumed by more than half of the world's population (Khush, 2005). The Lower Yangtze valley is thought to have been a centre of origin of rice-based agriculture (Bellwood, 2005; Fuller et al., 2009; Fuller and Qin, 2010). The palaeoenvironmental context, early history and trajectory of rice-based food production on the southern Yangtze Delta is still poorly understood, however, in part owing to

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http://dx.doi.org/10.1016/j.catena.2016.08.017
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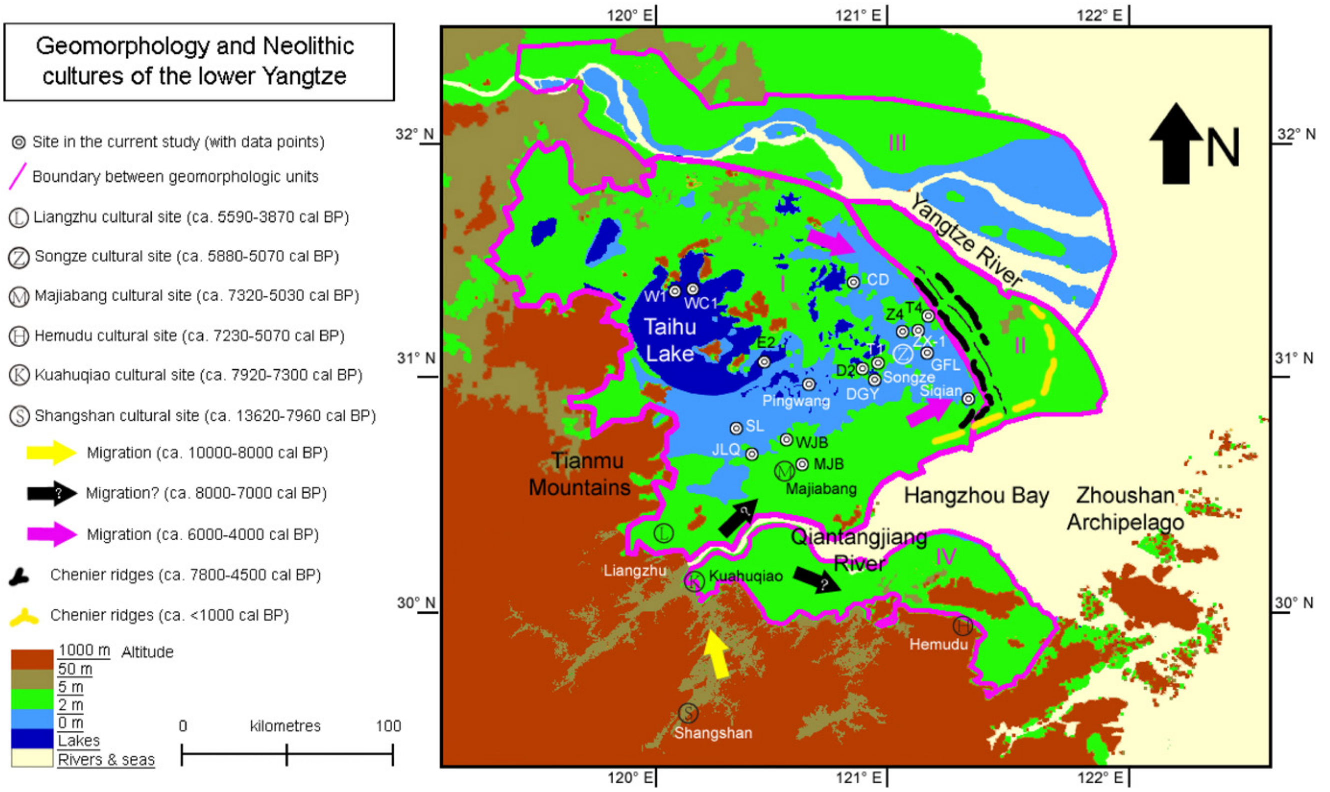

Fig. 1. A map of geomorphology and archaeology in the Lower Yangtze. Region I = region west of the chenier ridges on the southern Yangtze Delta; region II = region east of the chenier ridges on the southern Yangtze Delta; region III = the main Yangtze Delta; and region IV = the Ningshao Plain. Typical Neolithic sites are shown on the map. The locations of the 17 sediment sequences examined in the current study are labelled on the map: CD (Long et al., 2014), D2 (Stanley and Chen, 2000), DGY (Zhao et al., 2007), E2 (Wang et al., 2001), GFL core (Wang et al., 2012), JLQ (Stanley and Chen, 2000), MJB (Long et al., 2014), Pingwang (Zong et al., 2011), Siqian (Zong et al., 2011), SL (Stanley and Chen, 2000), T1 (Stanley and Chen, 2000), T4 (Stanley and Chen, 2000), W1 (Wang et al., 2001), WC1 (Stanley and Chen, 2000), WJB (Qin et al., 2011), Z4 (Stanley and Chen, 2000), and ZX1 (Stanley and Chen, 2000).

difficulties in establishing reliable chronologies. According to Stanley and Chen (2000), about 75% of radiocarbon dates from the Yangtze Delta appear 'erroneous', with the vast majority of these thought to be anomalously old.

Previous studies on the Yangtze Delta (e.g. Tao et al., 2006; Long et al., 2014) have circumvented the potential problem of using 'erroneous' dates by filtering out those that appear to be anomalous, and instead utilising only those over which there is a reasonable level of confidence that they represent the time of sediment deposition. For example, ages that do not fit into an a priori chronological framework for a particular set of cultural remains (such as pottery from an archaeological site) in the same layer with these dates are often considered not reliable and were discarded when establishing site-based chronologies (e.g. Archaeology Institute of Zhejiang Province, 2005). Unfortunately, such filtering may also remove potentially useful information, while leaving too few dates that are deemed acceptable to establish a robust and reliable chronology. The approach to dating adopted in previous studies on the Yangtze Delta, though reliant on highly constrained sources of data, is thus sub-optimal.

Fundamental improvements in chronological control will largely involve future developments in absolute dating methods that already offer some promise, including further improvements in techniques, such as luminescence dating. This paper adopts a different approach, however, in the form of a more effective use of previously underused radiocarbon dating information to better understand the early histories of occupation and food production on the southern part of the Yangtze Delta. In particular, information associated with radiocarbon dating anomalies, which was overlooked in previous studies, is utilised. Results presented here suggest that an Early Holocene (ca. 9000–7000 cal. BP) marine transgression may have been responsible for a cluster of radiocarbon dating anomalies, and support a relatively late date (after ca. 3000 cal. BP) for a widespread intensification of human activity in the catchment for and on the southern part of the Yangtze Delta.

1.1. Research region

The early development of agriculture and associated human populations in the Lower Yangtze Valley is commonly viewed as a cultural sequence that is sub-divided into several, supposedly distinct phases, the dating of which remains somewhat contentious (see Long and Taylor, 2015). These cultural phases comprise the Shangshan (ca. 13,620–7960 cal. BP), Kuahuqiao (ca. 7920–7300 cal. BP), Hemudu (ca. 7230–5070 cal. BP)/Majiabang (ca. 7320–5030 cal. BP), Songze (ca. 5880–5070 cal. BP), Liangzhu (ca. 5590–3870 cal. BP) and Maqiao (ca. 3810–3010 cal. BP).

Shangshan and Kuahuqiao-aged sites, equating to the earliest period of the Neolithic, are located south of Hangzhou Bay (Zong et al., 2007). The centre of Neolithic activity in the Lower Yangtze region appears to have moved to the north of Hangzhou Bay after ca. 7000 cal. BP (Zheng and Chen, 2005). After ca. 4200 cal. BP, the Liangzhu cultural phase appears to have declined and, after an archaeological hiatus, was replaced by the Chalcolithic Maqiao (ca. 3810–3010 cal. BP) (Stanley et al., 1999; Long and Taylor, 2015). Compared with the earlier Liangzhu and the contemporary Shang Dynasty civilisation (ca. 3600–3000 cal. BP) along the middle reaches of the Yellow River (Zong et al., 2012a; Wagner et al., 2013), the Maqiao in the Lower Yangtze was thought to represent something of a cultural backwater.

The southern plain of the Yangtze Delta, especially the area to the north of Hangzhou Bay and west of a series of shelly chenier ridges (Wang et al., 2012) (Fig. 1), provided a setting for the development of food production during the Neolithic (Zong et al., 2011). Sediments in this part of the delta are largely sourced locally, from the delta plain