Progress in Environmental Evolve-ment and Environmental Archaeology Study in the Yangtze Delta (China)

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Abstract  A review was conducted on the environmental evolvement and environmental archaeological research since the 1980s in the Yangtze Delta. Former environmental evolvement and environmental archaeological research results can be summed up into 4 aspects: 1) Formation and evolution of the Taihu Lake; 2) Transgression and sea-level changes in the Holocene epoch; 3) Reconstruction of the pre-historical environment; and 4) Impacts of environmental variations on the rise and fall of human civilization (formation of the cultural interruptions). Based on this review, some limitations in the present research methods and possible outcomes are pointed out in this paper.

Keywords  Yangtze Delta; environmental evolvement; environmental archaeology; review and look forward

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Introduction

In 1986, the International Council of Scientific Unions (ICSU) organized and implemented the International Geosphere and Biosphere Program (IGBP), and the global climatic changes served as the core program. Environmental archaeology played an important role in the Past Global Changes (PAGES) research. Environmental archaeology is a burgeoning science, being the result of the development of archaeology, geography (Quaternary Geology) and biology[1]. The Environmental archaeological study in China started in the 1960s. Before the 1980s, however, environmental archaeological research focused mainly on the reconstruction of human living environment resorting to the materials and data from quaternary geology[2]. As an interdisciplinary science, environmental archaeology prevailed in paleoclimatic reconstruction after the 1980s, greatly promoting the progress of PAGES in China.

Archaeological excavations over many years in the Yangtze Delta constructed a successive cultural series[3]. About 410 sites were excavated and studied in the Yangtze Delta[4]. Continuous biostratigraphical and sedimentological records from cultural sites provided exceptional information for the understanding of the past climatic changes and its impacts on the rise and fall of human civilization.

In this paper, environmental archaeological research after the 1980s was reviewed. Limitations of the present research methods are discussed and possible outcomes are also pointed out. Some suggestions are given for further future study on the environmental archaeological research in the Yangtze Delta.
1 Environmental variations in the Yangtze Delta

1.1 Formation and evolution of the Taihu Lake

Scientists paid attention to the formation and evolution of the Taihu Lake. "Formation and shrinkage of the Taihu Lake", raised by Ding et al [5], increased concerns from academic circles in the argumentation on the formation and evolution of the Taihu Lake [6-9]. Generally, three hypotheses can be summed up into three points: ① Lagoon theory [6,10]; ② Structural formation theory [11]; ③ Multi-factor formation theory. The Holocene sea level fluctuations played a key role in the formation and evolution of the Taihu Lake [8]. Inner and outer structural dynamics and sea level changes combined to influence the evolution of the Taihu Lake [8]. Since the middle Holocene, rising sea level and the development of the Yangtze Delta led to the formation of the low-lying depression [12,13]. Low-lying terrain and excessive precipitation led to the large-scale lake system.

Evidence from environmental archaeological studies demonstrated that numerous Neolithic sites were excavated in the Taihu Plain like Suzhou, Kunshan and Qingpu, and some sites were found at the bottom of the Taihu Lake and Dianshan Lake. Based on these facts, some scientists insisted that the transgression never occurred at the Taihu Plain since the Holocene epoch [14-16]. Paleo-wells of the Song Dynasty were also discovered at the bottom of the Yangcheng Lake, Huangtiandang Lake and Chenghu Lake, which revealed that the Taihu Plain remained suitable for human settlement since the Holocene epoch. Therefore, the formation of the lakes today occurred during the neoteric periods. Some scientists tried to determine the time of formation of the Taihu Lake by evidences from archaeology. 800 paleo-wells and cultural relics at the bottom of the Chenghu Lake seemed to corroborate that the formation of the Chenghu Lake was during 1107AD and 1170AD [17]. Plowland can also be seen from the satellite photos at the bottom of the Chenghu Lake. The Taihu Lake formed and expanded after Spring-Autumn Warring periods [18]. Excavation of large numbers of cultural relics, Neolithic sites and wells indicates that the formation of the Taihu Lake is less than 2~3ka [19]. In the future, more evidence from archaeology will be helpful in deciding when and how the Taihu Lake came into being.

1.2 Holocene transgression and sea level changes

The low-lying Yangtze Delta is prone to sea level changes. Therefore, sea level changes have tremendous impacts on environmental variations. Scientists paid attention to the research of sea level changes in the Yangtze Delta region. Chen et al. suggested that during the Holocene Magethermal period (~6000aBP), large-scale transgression occurred at the Taihu Plain [6]. Yang et al. argued that 5 transgression events occurred at the Taihu Plain [8]. The transgression during ~7000aBP reached its peak value, approaching the line of Danyang-Liyang -Wuxing, and resulted in the formation of the Taihu Bay. Shao held the viewpoint that, during 7-6500aBP, large-scale transgression occurred at the Taihu Plain, and the coastal line expanded to the east of the Maoshan Mountain [20]. Large areas of beaches, tidelands and shallow lagoon appeared in the middle of the Taihu Plain.

All in all, characteristics of sea level changes in the Yangtze Delta can be summed up as follows, according to the research results mentioned above [21]: 1) Higher sea level occurred during 7.0~6.5kaBP, and the sea level closed to today’s sea level except at the Hemudu cultural site [22-25]; 2) Lower sea level occurred during 6.3~5.6kaBP. Secondary alluvium-diluvium loess sediments formed spatially wide near the margin of the Yangtze Delta and the foothills regions, e.g. the secondary loess along the piedmonts in the Zhenjiang, Longtan regions formed before 5.6kaBP [23]; 3) During 5.2~4.9kaBP, the sea level was 2m higher than it is today. Higher sea level raised the ground water level, resulting in swampy sediments along the Taihu Lake, Zhenjiang, west Jiangsu Plain and coastal highlands; 4) 4.5~4.0kaBP is characterized by low sea level. Abrupt and short-term higher sea level occurred in 4.3kaBP. During this period, many Neolithic sites were lower than the sea level in altitude in the Yangtze Delta, about -1~3m below the ground surface. Some sites
were covered with muddy and swampy layers, showing the impacts of sea level changes on human settlements; 5) Higher sea level occurred during 3.8 ~ 3.5kaBP and 1.3 ~ 1.0kaBP respectively, and lower sea level occurred during 3.0 ~ 2.4kaBP.

2 Possible impacts of environmental variations on the rise and fall of human civilization

2.1 Environmental variations and development of human civilization in the Yangtze Delta

Spatial distribution of the sites is in close connection with the deposition and formation process of the Yangtze Delta[26]. Majiabang Cultural sites and Songze Cultural sites distributed in the regions west to the line along Jiangyin–Xieqiao–Taicang–Maqiao–Jinshan–Wangpanshan–Hanpu–Zhushan–Zhuantang, which is just the demarcation line for continent and ocean. Only the distribution scope of Liangzhu Cultural sites and Maqiao Cultural sites exceeds this demarcation, expanding with the development of the Yangtze Delta[4,12,27,28].

Therefore, the sedimentation and formation of the Yangtze Delta provided space for the development of human civilization. Majiangbang Culture, Songze Culture and Liangzhu Culture are successive cultural developments[29], with specific cultural features and connected spatial structure forms[27].

In Majiabang Cultural period, people created the irrigation system, and people in Liangzhu Cultural period created the stone plough, hoeing instruments, pottery, mortar and wooden pestle, and all these production instruments constitute the technological system of the paddy field cultivation in the Yangtze Delta. These production instruments and watery environmental conditions led to the beginning of rice agriculture as early as ~8kaBP. During ~6kaBP, rice agricultural production prevailed in the Yangtze Delta and reached a higher production level[30]. This shows the impacts of environmental conditions on human lives.

Climatic changes play the key role in the rise and fall of human civilization in the Yangtze Delta. During ~7kaBP, the end of large-scale transgression and warmer climatic conditions led to the flourishing of the Neolithic human civilization; the abrupt and extremely harsh environmental conditions during 4kaBP, however, induced the collapse of the flourishing Liangzhu culture[31,33]. Based on these, we can conclude that the rise and fall of Neolithic cultures reflect the extraordinary adaptability of human beings in a harsh environment and the existence of a critical environmental threshold[34].

Scientists held different viewpoints concerning the climatic variation and its role in the rise and fall of human civilization in the study region. Daniel et al. and Chen et al. suggested that sea level changes and expansion of the Taihu Lake in the Yangtze Delta region greatly affected human settlements[26,35]. Zhou et al., however, insisted that social factors played an important role in the rise and fall of human civilization, e.g. continual wars between tribes played the key role in the collapse of the Liangzhu Culture[33]. People usually lived in higher places to escape the damage from floods. However, Ding et al. suggested that ancient religious activities and human social positions rather than environmental changes decided the altitude of human settlement[36]. The authors tended to maintain that both social and natural factors impacted the development of human civilization, but as to how these factors impacted the human civilization is different from period to period.

2.2 Cultural interruptions: evidences of impacts of climatic changes on human settlements

Archaeological excavations in the region over many years have demonstrated that there were several layers of fine sand or organic mud that interrupted the consecutive culture strata in a number of Neolithic culture sites. Yu et al. suggested that the fine sand and organic mud units resulted from the expansion of land bodies both by sea-level fluctuations and increased flooding during cold and humid episodes of Holocene climates[34]. Therefore, the appearance of the cultural interruptions in the Neolithic sites was the result of harsh environmental conditions that were unsuitable for human settlements[37].

Former researches on the spatial and temporal dis-
distribution of buried trees in the Yangtze Delta showed that the buried trees correspond spatially and temporally with the cultural interruptions\cite{38}, e.g. Songze cultural site, Tinglin site, Maqiao site in Shanghai, Shahe of Jiangsu, Zhenjiang, Ganyu, Meiyang site, and Puzhen section\cite{39}. Occurrence of cultural interruptions and buried trees were mainly evident during the mid-Majiabang culture (6.7\textasciitilde6.5 kaBP), late Majiabang culture (6.1 kaBP), mid-Songze culture (5.6\textasciitilde5.5 kaBP), late Songze culture (5.1\textasciitilde4.8 kaBP), late Liangzhu culture (4.2\textasciitilde4.0 kaBP), mid-Shang-Zhou Dynasty (3.7\textasciitilde3.6 kaBP), late Shang-Zhou Dynasty (2.2 kaBP)\cite{39}.

Pollen evidences from Songze site (Qingpu), Weidun site (Changzhou), Caoxieshan site (Suzhou) and Qingdun site (Hai’an) showed the different climatic conditions when the cultural interruptions occurred: During the mid-Majiabang cultural period (~6.5 kaBP), the Yangtze Delta was of wet climatic type, with temperature 2\textasciitilde3°C higher than today, which was similar to the subtropical climate. During late Majiabang culture period (~6 kaBP) and mid-Songze cultural period (5.5 kaBP), the climatic changes showed oscillations and abrupt fluctuations and during ~6 kaBP, the climate was still similar to the subtropical climate with obvious temperature depression during ~5.5 kaBP\cite{40}. During late Songze cultural period (~5.0 kaBP), the temperature returned to warm, about 3\textasciitilde4°C higher than today\cite{41}. During late Liangzhu cultural period (~4.0 kaBP), the temperature became cooler, about 1°C lower than it is today\cite{42}. It should be mentioned here that during the mid- and late-Shang-Zhou Dynasty (~3 kaBP and 2.5 kaBP respective), the prevailing formation periods of the cultural interruptions matched the Neoglacial and low sea level period well. However, the floods still occurred frequently. Considering the frequently-occurring floods in the Little Ice Age (LIA), we can say that, in Chinese history, the arid-cold climatic modes are common\cite{43,44}, and the wet-cold climatic modes often recorded in historical documents\cite{44}. During 1431\textasciitilde1520 AD the Taihu Plain was climatically dominated by cold and wet climate. During 1521\textasciitilde1560 AD, however, the region was of warm and dry climatic type, and these two climatic periods were in the relatively long-term cold climatic period\cite{45}. This is because of the instability of the climatic system in cold periods. Subtropical high moves northwards\cite{46}, which is beneficial for the northward motion of the wetter and warmer air mass and southward motion of the cold air mass. When slow-drifting cold fronts meet the moist and stable subtropical-derived air mass in the middle and lower Yangtze River basin, the possibility of excessive precipitation will be greater. In the late Liangzhu culture period, frequently-occurring floods under the cold and wet climatic conditions led to the collapse of the Liangzhu culture\cite{31,32,37}.

### 3 Discussion

#### 3.1 Methods used in the environmental archaeological research

Stratigraphical section of the sites is different from the natural section for the archaeological section that contains both the information of human activities and natural environmental variations. Theories and methods from both natural science and social science should be used in explaining the information from the site sections concerning human activities and natural climatic changes\cite{47}. It should be mentioned that human activities interfere with the sedimentation process. Therefore, more attention should be paid on the reasonability and applicability of the proxy indicators in environmental archaeological research.

Environmental archaeological research tends to collect and analyze cultural relics and natural sediments, which compose the main parts of the research\cite{48}. Conventional archaeology focuses on the cultural relics excavated, giving less attention to the research of environmental variations in the archaeological period. Scientists today realized the fact that the climate is changing temporally and spatially\cite{49}.

Reconstruction of the paleo-climate depends on fundamental theories from the chronology of event and climatology. Cultural relics (ceramics, ancient coins, etc.) provide the basic time framework. Dating methods from Radiophysics like \(^{14}\text{C}\) dating, ESR (Electron Spin Resonance) dating, AMS (Accelerated Mass spectrograph) dating and paleo-geomagnetism dating,
may decide the age of the section with more accuracy.

Reconstruction of the climatic changes in the Yangtze Delta mainly resorts to the bio-lithostratigraphy, geochemistry, environmental magnetism and sedimentology [26,31,37,50]. Some proxy indicators like pollen are influenced by human activities. Therefore, climatic reconstruction usually encounters equivocal success by pollen analysis. It should be accepted that human activities have somewhat the same influences on the changes of the proxy indicators as the environmental changes. High magnetic susceptibility values are the results of warm temperature, and which are usually in close connection to human activities, e.g. human use of fire. Therefore, uncertainty usually occurs on the reconstruction results of the climatic changes because of the proxy indicators influenced by the secondary sedimentary environment and human activities.

3.2 Some suggestions

As mentioned above, the environmental archaeological research in the Yangtze Delta should be improved in several aspects: deficient environmental proxy indicators; low temporal and spatial resolution; fewer researches are performed on the applicability and reasonability of the proxy indicators. Other more qualitative researches than quantitative researches are conducted in the present environmental archaeological research on the Yangtze Delta.

As such, some suggestions are put forward as follows: 1) Further research should be conducted on the changing features of the proxy indicators like magnetic susceptibility, pollen, geochemical elements, grain size, in today’s sedimentary environments; 2) More proxy indicators should be used when we conduct the reconstruction research of the paleo-climatic changes. Reconstruction results from different proxy indicators can be used for mutual corroboration, improving the reliability of the research results; 3) Remote sensing, GIS, etc. technologies should be used in present environmental archaeological research. Related databases concerning Neolithic sites (position, dating data, and information of holes) should be constructed for further research on temporal and spatial connections between human activities and climatic changes, improving the temporal and spatial resolution of the research results; 4) More importance should be given to the construction of the regional standard strata. Natural sections are less affected by human activities. Therefore, natural sections should be used for comparison with the archaeological sections, reducing the uncertainty of the climatic reconstruction from archaeological sections [51].

Environmental archaeology research, just like other geoscience problems, meets tremendous challenges from the research topic itself. Numerous factors and extremely complex connections are involved in this research. The rise and fall of human civilization is the result of both natural factors (e.g. arid, drought, floods, tide events) and social factors (war, famine, pestilence), which show different features during different temporal stages. However, the complexity of the research topic may lead to the breakthrough of the methodology. Till now, about 340 Neolithic sites were excavated in the Yangtze Delta, providing exceptional information for exploring the possible impacts of environmental variations on the rise and fall of human civilization in the region. Increasing academic exchanges and cooperation among scientists all over the world, and the improvement of the present methods and appearance of new methods and technology will combine to accelerate the progress of environmental archaeology in the Yangtze Delta that contributes to global climatic changes.

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