Inundation, Sea-Level Rise and Transition from Neolithic to Bronze Age Cultures, Yangtze Delta, China

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Petrological, faunal and floral information derived from a new drill core taken in the Yangtze delta, coupled with data from borings recovered earlier, record a marked transition to warmer, wetter conditions which resulted in widespread inundation of the delta about 4000 years ago. Also identified for that time on the delta plain is a major discontinuity between the Neolithic Liangzhu and Bronze age Maqiao cultures. The cultural discontinuity is indicated by: (1) absence of *in situ* material between the two at ~4000 yr B.P.; (2) missing Maqiao material in strata above many Liangzhu sites; (3) less sophisticated Maqiao material than in the older Neolithic phase; and (4) notably fewer Maqiao sites in more restricted areas of the delta plain. It is of note that the change from the Liangzhu to the younger Maqiao does not show an increasingly complex cultural advancement of the type generally associated with the foundation of Chinese civilization. We propose that this cultural discontinuity was caused by the interplay of increased environmental stress and new population migrations into the delta.

INTRODUCTION

This study identifies fluctuations of sea level and climate that affected the Yangtze delta along the east coast of China in mid-Holocene time, and suggests that these and related physical processes in this region induced a marked alteration in the human record about 4000 years ago. Special attention is paid herein to lithologic, faunal and floral changes during this period as revealed by a boring recently collected for this investigation and also in earlier studied sediment cores in the Yangtze delta plain (Figure 1).

Most investigations have emphasized the increasing complexity and diversification of Neolithic to early Dynastic cultures in China. Moreover, it is likely that the evolution to early Dynastic civilization occurred at a somewhat different time and manner from region to region (Dong, 1986). Our focus here is on the potential role of environmental stress during the transition from prehistory to the Dynastic period in China's Yangtze delta. The archaeological record on this delta plain indicates

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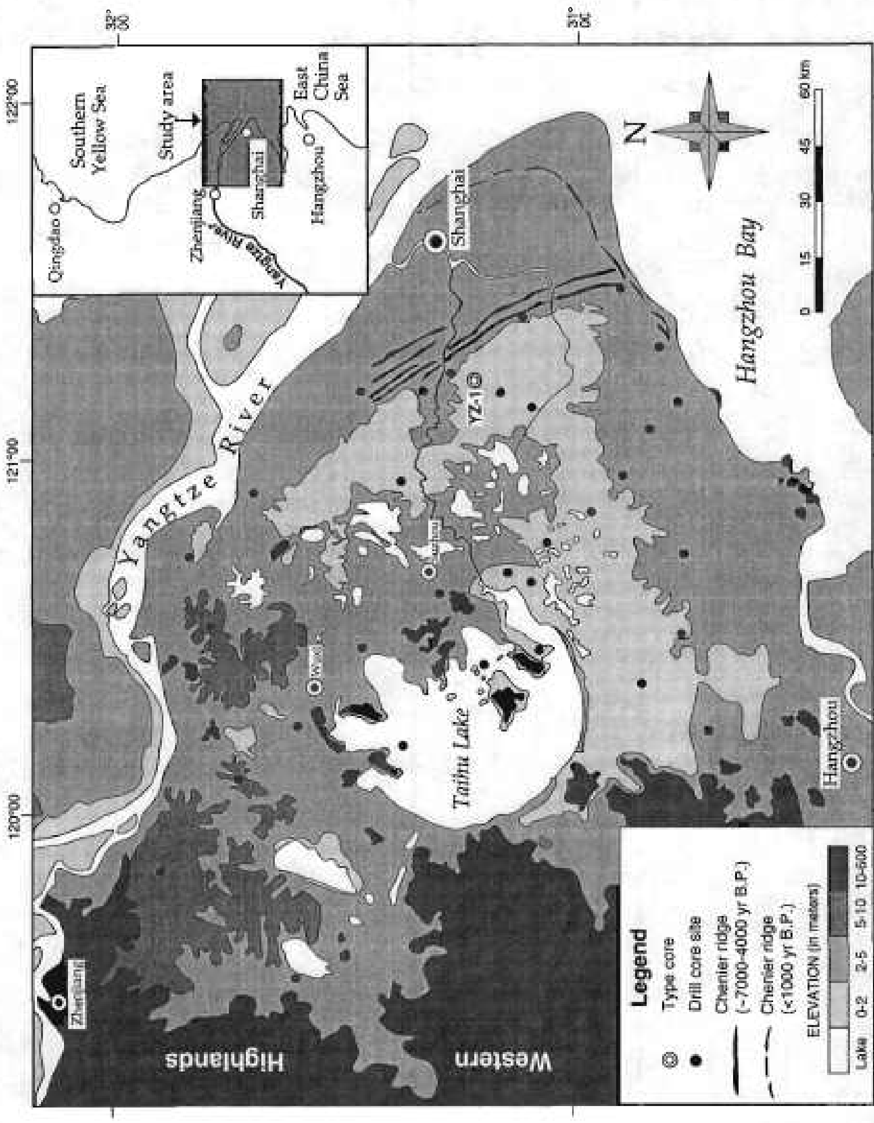


Figure 1. Topographic map of the modern Yangtze delta, eastern China, showing broad raised margins around the delta, saucerlike depression forming the central plain, and chenier ridges (modified from Chen and Stanley, 1998). Also denoted are positions of core YZ-1 and other representative cores consulted for the study.

that a marked discontinuity exists between ~4200 and 3900 years before present (yr B.P.; dates in this study are uncalibrated). This break coincides with the change from Liangzhu phase (~5200–4200 yr B.P.) in the latter part of the Neolithic, to the subsequent Maqiao dynastic culture (~3900–3200 yr B.P.). The discontinuity between the two cultures is denoted by major differences in ceramics, signs, and symbols (Li, 1989; Song, 1990; CPAM, 1997).

It has been previously proposed that external anthropogenic pressures, including possible population migration from south of the study area to the delta (Song, 1988, 1990; Li, 1989), were in part responsible for the discontinuity between Neolithic and younger dynastic phases. Of special interest here are potential environmental linkages that may have substantially modified the delta plain in the mid-Holocene and that also could have affected the human record.

METHODOLOGY

Petrologic, faunal and floral data have been collected in more than 100 long (>50 m) cores and in numerous trenches dug throughout the Yangtze delta plain (summarized in Yan and Xu, 1987; Yan and Hong, 1988; Chen and Stanley, 1995). Radiocarbon-dated cores have penetrated the typically gray silty mud Holocene facies that range in thickness from 10 to 50 m; underlying these are dark green stiff muds of Pleistocene age (Li et al., 1986; Liu et al., 1992). Many of the earlier cores were insufficiently sampled and analyzed to derive high-resolution information for environmental interpretations.

A new core, YZ-1, was taken on the eastern Yangtze delta plain so as to examine more closely-spaced intervals throughout a near-complete Holocene section. The 20 m-long core, positioned at 121°11′02″ longitude, and 31°08′01″ latitude (Figure 1), was recovered at a ground surface elevation of 2.67 m above mean sea level (msl, based on the Wushong datum plane). This core was sited near Liuxia and ~10 km west of a series of NW–SE trending shelly sand coastal ridges, termed cheniers. The top of these elongate features (Figure 1) rises about 1 m above the adjacent delta plain, and ~5–6 m above msl. Study of cheniers has shown that they formed from ~7000 to 4000 years ago along the delta coast, and their position thus serves as a marker of former eastern delta shorelines (Zhang et al., 1982). Core YZ-1 recovered Holocene strata, which included alluvial plain, fresh water to salt marsh and lagoon deposits, and that accumulated to the lee (west of) these coastal barriers.

The core (with a 10 cm diameter) was sampled down-boring at close intervals (~30 cm) to identify changes of petrology and biogenic (foraminifera, pollen, spores) assemblages through time (Figure 2). The Pleistocene section was reached at a depth of ~15 m below ground elevation. Grain-size (Figure 2), magnetic and geochemical analyses were made at 50 sample horizons between the top and base of core. Foraminifera were counted and identified in 16 samples, and pollen and spores were counted (300–500/sample) and identified in an additional 55 samples. Twelve organic-rich (including peat) samples were radiocarbon-dated, using both

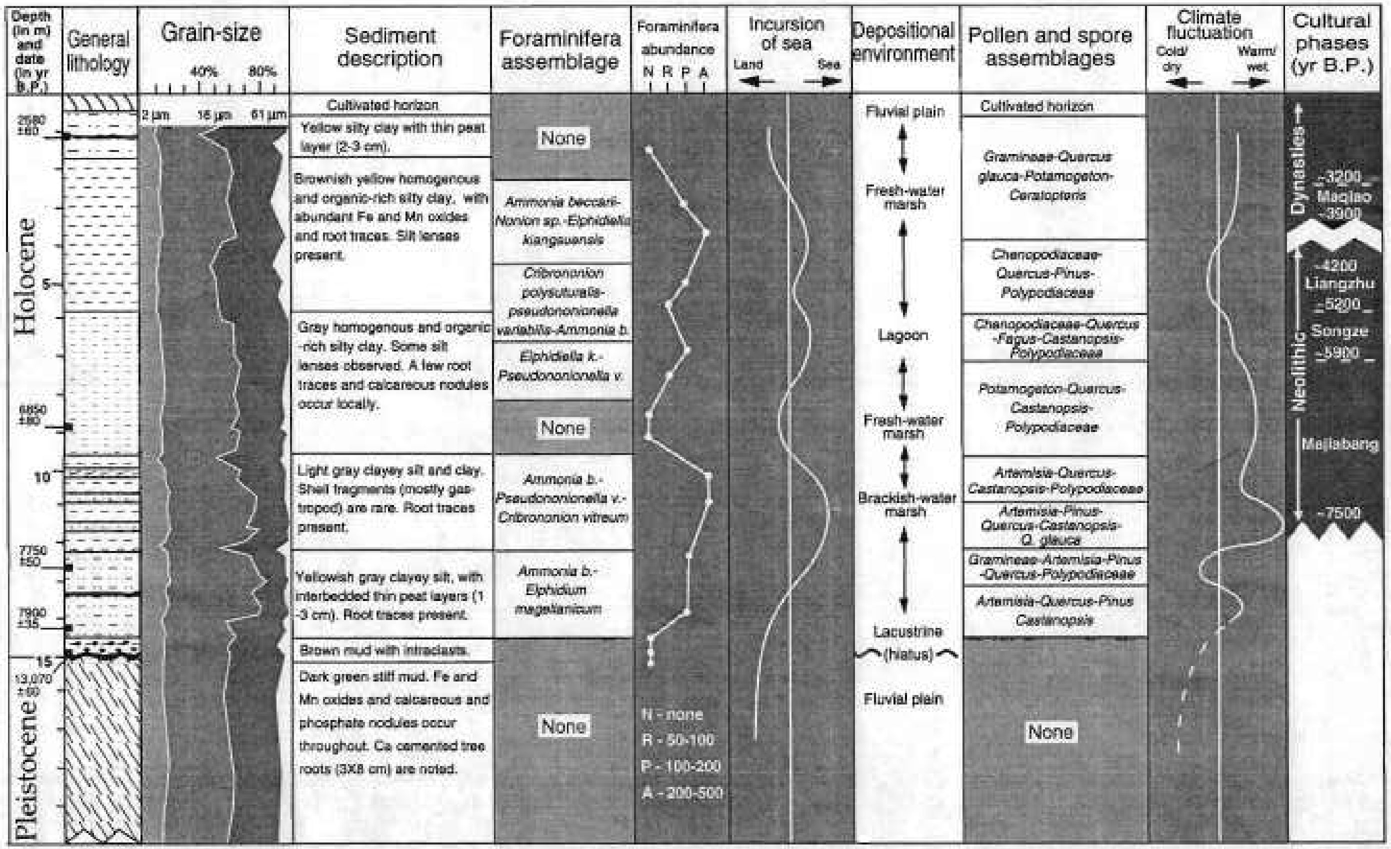


Figure 2. Lithologic log of core YZ-1 (see Figure 1) denotes late Pleistocene and Holocene sediment sequences and assemblages of foraminifera, pollen and spores. Together, the foraminiferae and floral records are used to help interpret the discontinuity between the Liangzhu and Maqiao cultures discussed in text.

conventional and AMS methods, and five of these provided reliable dates used in this study (Figure 2).

ENVIRONMENTAL MODIFICATION OF THE YANGTZE DELTA PLAIN

Large areas of what is now the lower Yangtze plain were subaerially exposed alluvial plain from the late Pleistocene until the early Holocene, largely as a response to lower world sea-level stands (Pirazzoli, 1991). The Yangtze delta began to form during the period between 7500 and 6000 yr B.P. (Stanley and Chen, 1996). Our study shows that the basal deltaic Holocene section in core YZ-1 began to accumulate by ~7500 yr B.P. as a function of deceleration in sea-level rise. From that time to present, sea level remained below present msl, as indicated by study of the relative sea-level curve during mid- to late Holocene compiled for this region, which shows a general decreased rate of rise until now (Chen and Stanley, 1998). Some marine and brackish water incursion on the delta plain during the early to mid-Holocene (Yan and Hong, 1988) occurred largely via river and tide channels that were incised 5 m or more into the plain surface (Sun and Huang, 1993).

Subsidence of much of the central delta has been relatively minor (Chen, 1991), as recorded by the present depth of various dated Holocene brackish and marine horizons in core YZ-1 that were originally deposited at about msl. For example, the core section at a depth of 12 m is dated at ~7750 yr B.P. (Figure 2), that is,. the appropriate depth of sea level, recorded for that time on several world sea-level curves. More important than subsidence is the reversal of delta topography that occurred from mid- to late Holocene time, in which the central delta region evolved from a delta high ground to a sector of relatively low elevation (Stanley and Chen, 1996; Chen et al., 1997). This topographic reversal is explained in the following fashion: (1) Much of the tectonically stable central plain land surface maintained a fairly constant elevation relative to sea level through the Holocene; (2) in contrast, there was expansion and aggradation of the delta perimeter (relief evolved to 2–5 m above msl), resulting from buildup of silty deposits in response to storms, high tides and sea-level rise. As a consequence, the delta surface attained its present saucer shape, with an extensive low-lying (<2 m above msl) central area surrounded by higher delta plain margins. The central delta plain became increasingly vulnerable to effects of rising sea level, as demonstrated by wide-spread distribution of brackish to freshwater marsh peats of mid- to late Holocene age. Accumulation of these organic-rich deposits occurred primarily from ~6000 to 3000 yr B.P. in various low-lying sectors west of the cheniers (Chen and Stanley, 1998).

Sediment analyses of core YZ-1 record a distinct unconformity between the late Pleistocene and early Holocene sedimentary sequences, and a generally consistent (but not necessarily uninterrupted) sediment accumulation from early Holocene to the present (Figure 2). Microfaunal analyses reveal fluctuations of biogenic components in this near-complete Holocene section which provide information with which to interpret short-term sea-level and climatic fluctuations. Foraminiferal assemblages in the core (Figure 2) record some shallow marine to brackish water intrusions at this site behind the chenier ridges during the period ~8000–6000 yr B.P. From ~6000 to 3000 yr B.P., different low-lying sectors were covered by salt marshes and brackish lagoons (Stanley and Chen, 1996: their Figure 4). Microfossils indicate no marine incursions from ~3000 yr B.P. to the present. This sequence of events, which supports the topography reversal model, is also recorded by comparable variations of fossil assemblages through time in other cores collected on the delta plain (Yan and Shao, 1989).

In the mid-Holocene, the sequence of pollen and spore assemblages in dated YZ-1 core (Figure 2) indicate that the delta plain was affected by considerably increased wet conditions. Flora in the core section dated from ~6000 to 5000 yr B.P., at a depth of 4–6 m from the top of the boring, records a relatively dry, cool climate in the lower Yangtze region. This section is characterized primarily by relatively high proportions of evergreens and grasses that were tolerant to cool temperatures, including : *Pinus* (5–10%), *Quercus* (7–12%), *Ulmus* (2–4%), *Fagus* (1–2%), *Polypodiaceae* (16–42%), and *Chenopodiaceae* (12–45%). The core section immediately above this horizon, at a depth of 4 m from the core top and dated at ~4000 yr B.P., is primarily characterized by increased proportions of deciduous and aqueous plants, including: *Quercus glauca* (8–12%), *Gramineae* (10–25%), *Artemisia* (10–15%), *Potamogeton* (5–8%), and *Ceratopteris* (8–21%). This floral evolution indicates a transition to a warmer and considerably wetter climate. Generally similar floral fluctuations during this time span have also been recorded in other Yangtze delta cores (Wang et al., 1978; Meng et al., 1989).

We interpret the above change in flora as a record of marked climate shift, from cool to warm, with a rise in temperature from 1–2°C lower than present to 1–2°C higher than present. Our YZ-1 core data also show a shift to wetter conditions. This conforms with findings in other studies that indicate a precipitation increase to 200–300 mm higher than at present for the period from ~3800 to 3500 yr B.P. (Wang et al., 1978,, 1984). Information on floral and pollen content also supports the interpretation that wetland coverage expanded markedly on the delta plain, especially from ~4000 to at least 3500 yr B.P. (Wu, 1983).

ARCHAEOLOGICAL BACKGROUND

Archaeologists have identified hundreds of Neolithic sites on the Yangtze delta plain (Wu, 1988), and these comprise three major cultural phases (Chang, 1986): Majiabang (~7500–5900 yr B.P.); Songze (~5900–5200 yr B.P.); and Liangzhu (~5200–4200 yr B.P.). Previous investigations have indicated that the Liangzhu evolved from earlier Neolithic cultures in the same geographic area. Puzzling in this region, however, is the remarkable change in stylistic criteria and materials that occurred between the Liangzhu phase at the end of the Neolithic and the Maqiao phase of Bronze age. Recent study reveals a marked hiatus (Figure 2) between ~4200 (end of Liangzhu) and 3900 yr B.P. (beginning of the younger Maqiao phase). It has been shown that: (1) At sites where both Liangzhu and Maqiao material is present, the two are generally separated by a thin yellowish mud layer in which broken and worn sherds (probably water-transported) are randomly distributed and not *in situ* (Yi and Zhang, 1962; Song, 1990); and (2) at many sites on the delta plain, the Liangzhu strata is not overlain by the younger Maqiao deposits. In the latter case, older Liangzhu horizons are either covered by lake water, such as in Taihu and Dianshan (Kang, 1959; Yi and Zhang, 1962; Sun and Huang, 1993), or buried beneath mid- to upper Holocene peat layers (Dai, 1987). Of note, some sites on topographic highs, including those at the base of western highlands, and chenier ridges, do not record the chronological gap (CPAM, 1997).

Since its discovery in the 1930s (Ho, 1937), the Liangzhu culture has been defined at numerous sites on the basis of diverse criteria, such as dwelling styles, mortuary practices, implements for agriculture and fishing, vessel typology and jade styles, and bones of associated domesticated animals (Chang, 1986). Particularly characteristic are ritual jade objects (*Zhong*) from burial sites and black pottery of fine soft paste, constructed on the wheel, with high surface luster produced by polishing. Also characteristic are red sandy ceramics that incorporate rice husks, hand-stamped decorations on pot handles and ivory. Pottery making had reached a high level of sophistication, as shown by delicate and complex designs, lifelike animal shapes, and thin (to 0.13 cm) ceramic; firing temperature did not exceed 940°C. Although metal objects have not been found, fine decorations on pottery and jade during this phase appear to have been inspired from designs on metal already present in the Yangtze region (Chang, 1986; Song, 1990).

The Maqiao culture, overall, is distinct from the Liangzhu in their dwelling and pit styles, as well as ceramic, stone, and some copper artifacts (Song, 1990). Many diagnostic attributes define the Maqiao phase: variable geometric decorations on pottery inspired from bronzes; wheel-made pottery that typically includes sandy red, fine brown, and fine gray wares; and tripod (*ting*) vessels. Complicated designs on ceramics and ivory objects are usually absent. Wheel-made pottery generally shows fewer refinements than those of the Liangzhu, such as presence of bubbles preserved on the surface of pots. Firing temperature may have been as high as 1200°C.

Copper objects in the Maqiao culture differ from those of the same age elsewhere in China, in that they contain higher percentages of Cu and impurities such as silica. Metallurgy used during the Maqiao phase (starting ~3900 yr B.P.) is more similar to older methods, such as those used in northern China and dating to as far back as ~5000 yr B.P. (Song, 1990).

Some symbols and signs in the Liangzhu record can be compared with younger Chinese characters. These are usually engraved on the base of ceramics, and may include two and four or more combined symbols per object. It is of note that while signs and symbols are more numerous in the Maqiao, they are less complex than those of the Liangzhu. Moreover, markings in the Maqiao are usually engraved on the edges of ceramics, and usually one symbol is inscribed per object.

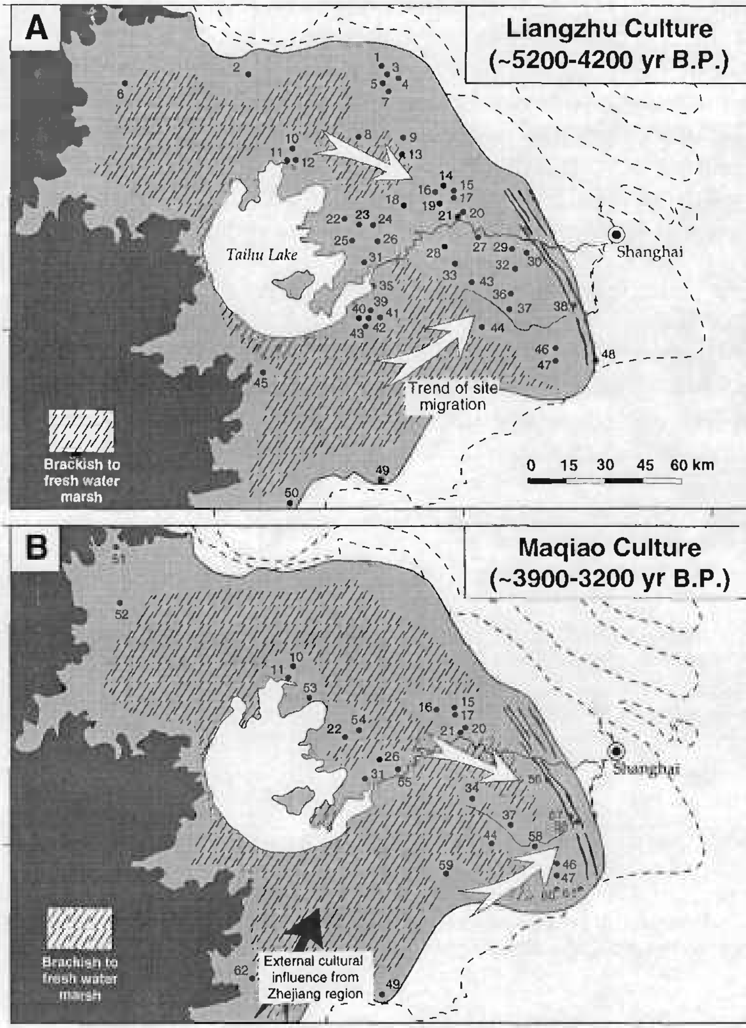
The gap in archaeological record and marked changes in cultural material occurred during a <300 year timespan, at ~4000 yr B.P. Moreover, in a number of respects, the Maqiao is less refined than the Liangzhu. It is possible, as some may contend, that this decline in "sophistication" through time is only apparent, that is, essentially the result of archaeologists not having as yet discovered more refined Maqiao material in the study area. In view of considerable exploration of the delta plain, we prefer to consider an alternative interpretation, that is, one that suggests that the Maqiao culture evolved from the interplay of two different sources. The Maqiao arose, at least in part, from the older Liangzhu culture in the delta region. Moreover, it may also incorporate possible external influences such as migrations from beyond the Yangtze delta, including the Zhejiang province south of Hangzhou bay (Song, 1988, 1990).

In any case, the apparent break in cultural styles and transition in materials from the Liangzhu to Maqiao phases does not indicate a threshold passage to an increasingly complex culture and society of the type generally associated with the foundation of Chinese civilization (Chang, 1986). The probable increased frequency and extent of interaction with cultures from beyond the delta led to acculturation (Song, 1988, 1990), but this, as we have noted, did not result in a more extensively distributed culture. Rather, our mapping of site distribution patterns in this study indicates that a marked reduction of sites occurred within a relatively short period. The number of Liangzhu sites exceeded 140 and were rather evenly distributed (50 excavated sites are shown in Figure 3[A]), while the number of Maqiao sites decreased substantially to ~30 and covered a more restricted area on the delta plain (Figure 3[B]).

DISCUSSION AND CONCLUSIONS

Integration of topographic, sea-level and climatic information with the archaeological record for the period at ~4000 yr B.P. provides new insight on the transition between Liangzhu and Maqiao cultures on the Yangtze delta plain. We propose that the marked transition from a cool-dry to warm-wet climate during the mid-Holocene, occurring at the time of topographic reversal in response to rising sea level in the mid-Holocene, played a major role in this cultural transition. Increased precipitation at and following the Liangzhu phase, and entrapment of much of this water on the depressed, formerly drained central delta plain, resulted in widespread inundation. The decreasing gap between elevation of the central delta surface and mean sea level made expulsion of fresh water from increased precipitation and from important Yangtze river floods more difficult. We believe that these altered conditions resulted in a major reduction of sufficiently drained land area available for occupation and cultivation after Liangzhu time.

Correlation of core sections shows that Taihu and other lakes on the delta plain at ~4000 yr B.P. increased substantially in size (Stanley and Chen, 1996). A rise in lake water level from 1 to 3 m, for example, would expand the present area of Taihu from 52% to 156% (Yang and Chen, 1985), and such a rise would explain the presence of a number of Liangzhu sites under lake water, and other sites buried by marsh peat after ~4000 yr B.P. (Dai, 1987). As a consequence of enlarged wetlands and inundated lowlands unsuitable for rice and other cultivation, humans



A. Name of Sites of Liangzhu Culture (Stanley and Chen, 1996)
1.Luyuan 2.Wujinshidun 3.Xizhang 4.Miaoqiao 5.Tangqiao 6.Beishuidang 7.Gangkou 8.Jialindang 9.Santiaoqiao 10.Xianlidun 11.Huanhulu 12.Shldun 13.Huangtushan 14.Longtanhu 15.Huangnishan 16.Zhoudun 17.Nanshiqiaonan 18.Zhuodun 19.Zhengyl 20.Rongzhuang 21.Mourong 22.Gaojingshan 23.Beihudunbei 24.Liudaiqiao 25.Bijiashan 26.Yishanqiao 27.Xidun 28.Dongzhuan 29.Fuquanshan 30.Guoyuancun 31.Yuexi 32.Qianbucun 33.Dadongwachang 34.Dianshanhu 35.Tuanjiecun 36.Guangfulin 37.Tangmiaocun 38.Maqiao 39.Longnan 40.Yuanjiadai 41.Tanwanli 42.Liuguanyu 43.Meiyan 44.Jingshanfen 45.Qianshanyang 46.Tinglin 47.Zhangyankou 48.Zhelin 49.Qianjinjiao 50.Shuitianban.

B. Name of Sites of Maqiao Culture (Chen et al.,1996)
51.Wangjiashan 52.Zhongqiao 53.Yanjidun 54.Xihaiwen 55.Goushiqiao 56.Liuxia 57.Dongjiacun 58.Yaojiaquan 59.Quemuqiao 60.Chashan 61.Qiejiadun 62.Anxi.

Figure 3. Liangzhu (50 excavated sites, shown in A) and Maqiao (29 sites, shown in B) occupation patterns on the Yangtze delta plain. In this study, the decreased number of younger Maqiao sites and their reduced occupation areas are correlated with inundation of the plain and decreased land surface available for cultivation during the mid-Holocene. Sites are numerically coded using locality names.

migrated toward higher, better drained terrains. During the period from ~4200 to 3200 yr B.P., occupied sectors included those east of Taihu lake, west of the chenier ridges and on the ridges proper (Figure 3[B]). Climate fluctuations continued to induce the waxing and waning of lakes and other wetlands, and, as a result, only some Liangzhu sites were reoccupied after ~4000 yr B.P. by the younger Maqiao culture after waters receded.

In summary, this study finds that the marked cultural discontinuity between the Neolithic and Dynastic phases in the Yangtze delta resulted from interaction of environmental stress and anthropogenic factors such as new migration onto the delta plain. It is of special note that effects of the marked climate change at ~4000 yr B.P. are also observed in other parts of China, and may have induced linkage between landscape evolution and human history in the lower Yellow River system (Jing et al., 1997). It now appears that this mid-Holocene climatic event was widespread (Gear and Huntley, 1991; Gunn, 1997), and that environmental perturbations associated with it may have influenced the human record in a number of other world deltas and their adjacent coastal plains (Coastal Environments Inc., 1977; Meggers, 1979; Wenke, 1991; Weiss et al., 1993; Ricklis and Blum, 1997).

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