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The Neolithic Culture and Paleogeographic Environment Evolution in the Eastern Jianghuai Area

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Abstract: According to previous studies, the Lixiahe area in the east of the Jianghuai River was an alternate environment of land and sea in the middle Holocene, and it was not until the late Holocene that the eastern Jianghuai completely became a terrestrial environment. However, recent archaeological studies have found that the extensive Neolithic sites in the Lixiahe area have recorded the rich human activities and cultural connotations of the prehistoric civilization in the Middle Holocene. In this paper, the Gangxi section of Jianhu Lake, Jiangsu Province (GX2) was selected and pollen analysis was fulfilled, then the geomorphic evolution process of the study area from sea to land was investigated according to the palynological assemblages and algae fossils of brackish water, semi-saline water, fresh water and terrestrial in the section strata. During the period of 8500–3800 cal. BP, GX2 was affected by multiple factors such as sea surface fluctuation, ocean flow and sediment deposition carried by seagoing rivers. Since 5800 cal. BP, the area east of the Grand Canal between the Yangtze River and the Huaihe River, and the west of the Yangzhai town, Funing–Longgang town, Yancheng–Dagang town and Yancheng–west of the Dongtai–Hai'an line, have become a terrestrial environment. After the eastern Jianghuai became a land, the Liangzhu culture (5300–4300 cal. BP) in the Taihu Lake basin in the south wing of the Yangtze River delta expanded to the eastern Jianghuai area, and the Longshan culture and Yueshi culture in the Haidai area in the north also migrated south to the eastern Jianghuai area. Admittedly, the main reason in the process of Neolithic cultural development is the internal motivation that the ancient ancestors struggled with nature and pushed forward the continuous development of civilizations. However, our study explains the palaeogeographical origin of Neolithic culture in the eastern and coastal areas of Jianghuai in the middle Holocene, and meanwhile, provides an example for the man–land relationship research on Neolithic culture.

Keywords: east Jianghuai plain; Holocene environment; neolithic culture; man–land relationship

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1. Introduction

The eastern Jianghuai Plain is an area located between the Yangtze River as the south boundary and the Huaihe River as the north boundary, and between the Beijing–Hangzhou Canal (Ancient HanGou) and the Yellow Sea in Jiangsu Province (Figure 1). Among them, the area between the east of the Canal, south of the Huaihe River, west of the Chuanchang River and north of the Tongyang Canal is the Lixiahe area. Since the Holocene, the Yangtze River, Huaihe River and Yellow River have flowed into the sea. Since the 1970s, especially in this century, it has been revealed that there were numerous Neolithic cultural sites in the Lixiahe area during the middle and late Holocene by archaeological research [1–6], which mainly have: Longqiuzhuang culture (6600–5500 cal BP), Liangzhu/Dawenkou culture (5300/5500–4300 cal BP), Longshan culture (4300–4000 cal BP) and Yueshi culture (3950–3450 cal BP) (Table A1). The eastern Jianghuai Plain is regarded as an inlaid, densely distributed and converged region with the Liangzhu culture in the Taihu Lake basin south of the Yangtze River and the Dawenkou culture and Longshan culture of the Haidai area in the north. Since the beginning of this century, the man–land relationship research in prehistoric times has become a hot topic in the global multi-disciplinary research space. The paleoenvironmental evolution during the Holocene is the key natural element for the development or restriction of prehistoric civilization [7–14]. As one of the important birthplaces of Neolithic culture in China, lots of Holocene environmental archaeological works have been performed on the Yangtze River Delta by many scholars [15–23], and it is believed that there is a positive correlation between the emergence, development and extinction of Neolithic culture in the Yangtze River Delta and the Holocene's paleoclimate evolution [24]. Another view is that the fluctuation of the sea surface caused by climate change is the main factor affecting the rise and fall of Neolithic culture in the Yangtze River Delta [17,23]. Though the results of paleoenvironmental research may unconsciously exaggerate the determining role of the paleoenvironment in the development of Neolithic culture, indeed, the prehistoric people had to live and settle on land adjacent to or with fresh water. However, apparently, it cannot be explained how to form the number and scale of Neolithic archaeological sites in the eastern Jianghuai Plain by the alternating or uninterrupted sea–land environment of this area in the middle and late Holocene [25–27]. The GX2 section at Jianhu, Yancheng, located east of the Jianghuai Plain, is sensitive to the sea–land alternation during the Holocene. The GX2 palynogram was studied by choosing the combination of pollen and algae with sea–land ecological implications, using the research materials of chronology and archaeology and the palynological method. The suitable living space for prehistoric ancestors was explored, and the key natural factors affecting and restricting the development of Neolithic culture in the Lixiahe area, eastern Jianghuai Plain were discussed. This study provides a paleogeographic environmental background for archaeology to further enrich the Neolithic culture in the eastern Jianghuai area and also provides a new argument and palynological evidence for the sea–land changes in the eastern Jianghuai Plain during Holocene.

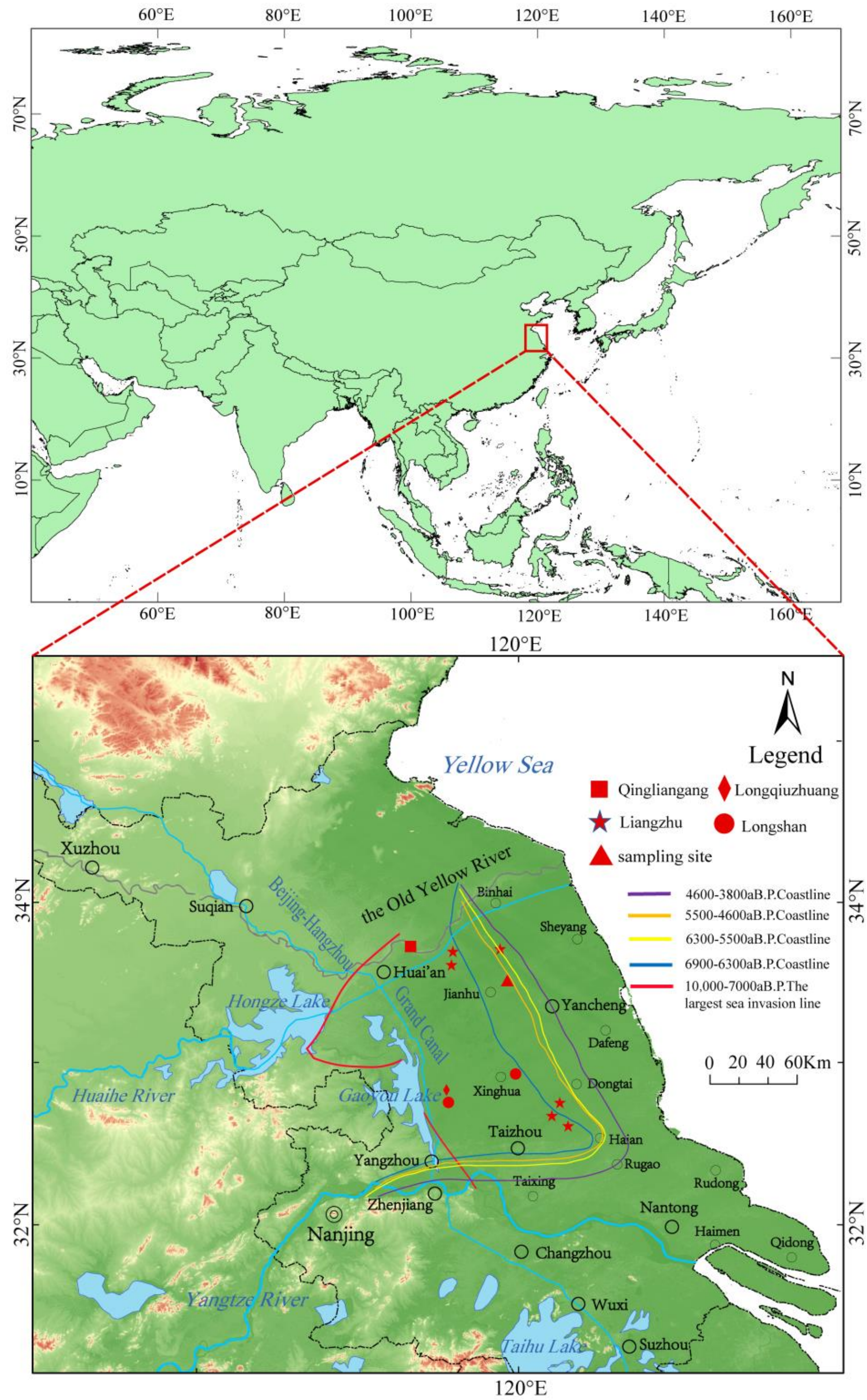

Figure 1. Location of the study area and the coastline in different periods.

2. The Natural Conditions of the Study Area

Located in the area north of the Yangtze River, south of the Huaihe River, east of the Beijing–Hangzhou Canal and west of the south Yellow Sea, the longitude/latitude of the eastern Jianghuai Plain is about 31°42′–34°6′ N/118°56′–121°57′ E (Figure 2), and the present average altitude is 2–4 m. In its geological structure, it belongs to the continuous and strong subsidence area of the Northern Jiangsu Depression [28]. Since the last deglaciation, the global climate has warmed and the sea surface has risen, and the sea–land interaction during the Holocene has become strong. The Yangtze River, Huaihe River and ancient

Yellow River flowed into the sea along the coast of Jiangsu province, and the delta continued to develop [29,30] and then evolved into the Lixiahe Plain, with the lowest lying north of the Yangtze River, and water network distribution and dense river ponds located in the north of the Yangtze River, Jiangsu Province. The regional climatic zone belongs to the north subtropical zone. Due to its proximity to the Yellow Sea, the water and heat are affected by the marine climate. Compared with other regions at the same latitude in China, the eastern area has the characteristics of a smaller annual temperature range and rich annual precipitation. The average annual temperature is about 14.5 °C, and the average annual precipitation is about 1000 mm. Such a natural environment is a livable land for human beings. Since the Neolithic Age, human beings have settled and bred here, and continue to the present day, thus becoming a region with a high population density and three major, highly developed industries in China. Therefore, there is basically no native vegetation distribution on the surface, which is generally transformed into towns, factories, farmland and lakes, and only scattered cultivated forests are distributed beside farmhouses and riverbanks.

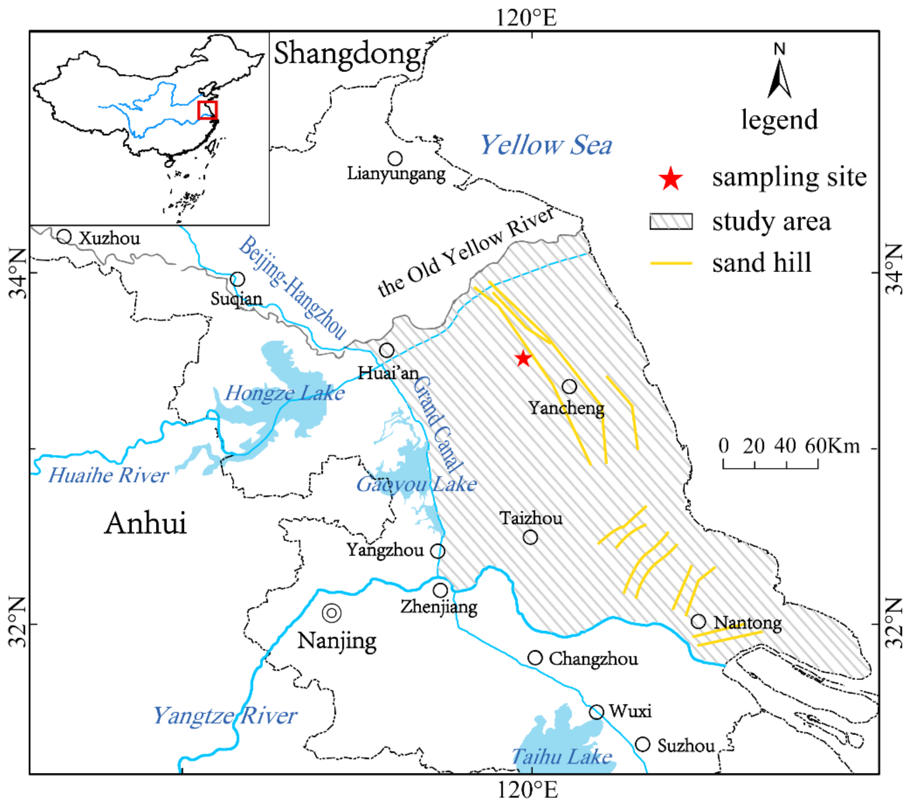

Figure 2. Location of sampling site and sand hills.

3. Sample Collection of GX2 Section and its Lithologic Characteristics

In December 2015, the soil pit section of the Gangxi Town brick and tile factory in Jianhu, Yancheng, Jiangsu, was selected as the research material. The sampling was carried out of the 130-cm-long GX2 section with a spacing of 1 cm. Totally, 130 samples were collected for palynological analysis. The lithology and age of GX2 are shown in Table 1 and Figure 3. The previous works on GX2 [31] have revealed the evolution process of the paleovegetation and paleoenvironment in the eastern Jianghuai Plain from 8500 to 400 cal. BP and can be compared with the paleoclimate evolution in the Yangtze River Delta and its surrounding areas [32–36], which will not be covered again in this paper.

Table 1. Sediment AMS ^{14}C dating results of GX2 section.

Lab No. (Beta-)	Sample No.	Descripition	Sampling Depth (Cm)	^{14} C Age (BP)	2σ Age of Calibration with Tree Ring (Cal. BP)
426590	GX2-0	Raw material of clay	0	340 ± 30	395 ± 55
454404	GX2 29–30	Raw material of clay	30	3450 ± 30	3709 ± 71
454405	GX2 49–50	Raw material of clay	50	4100 ± 30	4588 ± 68
454406	GX2-60	Raw material of clay	60	4900 ± 30	5626 ± 38
426589	GX2-130	Raw material of clay	130	7640 ± 30	8432 ± 48

Note: Dating in Beta Laboratory, USA; Half-life of ^{14} C is 5568a, corrected by program calib. 7.0 (the error is ±2σ), Intcal 13 Non-Marine Land Correction model in Northern Hemisphere.

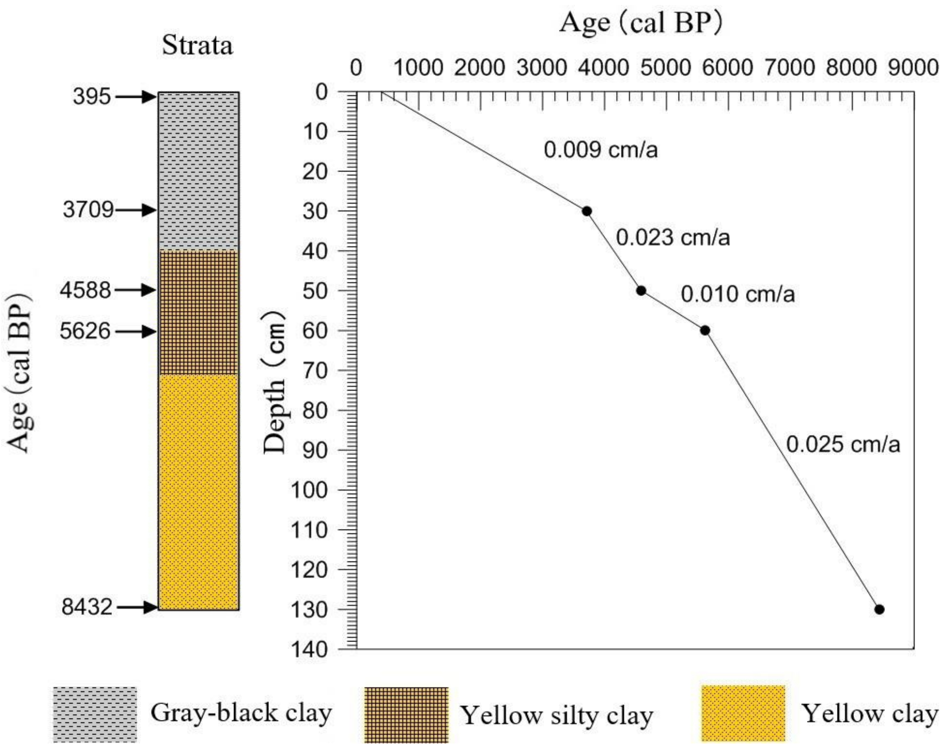

Figure 3. The lithologic characteristics, age and deposition rate of the GX2 section.

Forest, shrub and grassland are the visible vegetation community landscape on the surface, and the woody flora is especially more sensitive to environmental changes. Therefore, woody plant pollen is a reliable indicator for reconstructing ancient vegetation and the paleoenvironment in palynological sequences. However, some palynologists pointed out that some pollen and algae representing latent vegetation in quaternary sediments have not been taken into consideration enough [37], and thus, some paleoenvironmental information may be ignored. The previous palynology work on the GX2 section mainly focused on analyzing the pollen of woody plants to recover the regional vegetation and paleoenvironment [31] but did not fulfill in-depth paleoenvironmental studies on the pollen of Chenopodiaceae, Cyperaceae and Poaceae and spores of *Ceratopteris* and fossil algae such as *Pediastrum*, *Zygnema*, *Hystrichosphaera* and *Spinifrites*, which are of great ecological significance in the study area. The *Hystrichosphaera* and *Spinifrites* are Marine algae, which can be commonly found in coastal and shallow waters near the shore [38]. They are also credible evidence to reconstruct the changes of local ancient coastlines and reflect the changes of sea and land. The genera *Pediastrum* and *Zygnema* are recognized as freshwater algae [37–40]. However, the *Pediastrum* can be found in brackish lagoons and estuaries in the eastern coastal waters of China and around springs of salt lakes on the Qinghai–Tibet Plateau [41,42]. Waterferns are ferns that grow in ponds, paddy fields and other freshwater conditions in subtropical areas of China [39]. Therefore, focusing on the quantitative changes of these palynological and algal fossil assemblages can provide credible signals for revealing the location of ancient shorelines and the process of sea–land transition. At present, many palynological assemblages belonging to different families and genera have been found to indicate the location of the shore, shallow sea and ancient coast. For example, mangrove pollen assemblages in tropical regions can accurately indicate the nearshore location of ancient coastal lines [39], and the pollen content variation of Pinus and some certain herbs can indicate changes in the shoreline and sea level [43]. The changes in the number of Quinoa, grasses and Cyperaceous flowers were used by some researchers to reconstruct the sea–land transition of the Cariaco Basin borehole in South America since the MIS3 stage, and the H event was accurately retrieved at once [44,45].

On the eastern coast of the Chinese mainland, deltas in estuarine areas or near-shore radiating sand bars are formed with the mud and sand from rivers flowing into the sea. When the accumulation of mud and sand is greater than the range of sea-level fluctuation, a large and relatively flat delta plain is formed. The salt marsh vegetations grow on the landward side. From the supratidal zone to the land, with the gradual reduction in the surface sediment salinity, there is a zone-like distribution of the *Suaeda* community (Form *Suaeda* sp) of Chenopodiaceae -*Suaeda* and the Phragmites community (Form. *Suaeda* sp + *Phragmites* sp) -*Phragmites* community -Cyperaceae (Form. *Cyperaceae*) in parallel to the coastal line, for example, salt marsh vegetation along the coastlines of Jiangsu and Liaoning. We have collected topsoil samples from the mean tidal line up to the reed community in the silty tidal flats of the above two provinces and focused on the quantitative relationship between the pollen of Chenopodiaceae, Gramineae and other herbs [46]. The slope of the ancient intertidal zone near the sea in the Jianghuai Plain is gentle and relatively wide, and the distribution of the *Suaeda* community along the coastal line can reach more than 3 km. It is reasonable to assume that the high content of the Chenopodiaceae–Gramineae pollen combination of herbaceous vegetation is a reliable index revealing the paleoenvironment of coastal salt marsh vegetation on muddy beaches in subtropical and temperate zones, and then the subsequently high content of Cyperaceous vegetation showed that the ancient beach evolved into land which was unaffected or less affected by the ocean water caused by regression in the past period.

The pollen percentage and concentration of six palynological types in the palynological schema of GX2 was used to draw the change curve (Figures 4 and 5). The six types are: halophytic *Spinifrites* + *Multispinula*, freshwater *Pediastrum* and *Ceratopteris* (water ferns), and herbs Chenopodiaceae, Cyperaceae and Poaceae. The sea–land transition process in the Jianhu Lake area of Jiangsu from 8500 cal. BP to now was further discussed. During the period of 8500 to 6800 cal. BP, there were a large number of halophytic *Spinifrites* and *Multispinula*, and the content fluctuated between 3 and 18%, with an average content of about 11%. The concentration value was 3–30 $\times 10^2$/g, with an average of about 15 $\times 10^2$/g. The average content of Chenopodiaceae pollen was about 16%, and the concentration value was individually more than 20 $\times 10^2$/g and generally less than 20 $\times 10^2$/g. The average content of terrestrial Cyperaceae is about 12%. The concentration value was 0–19 $\times 10^2$/g, and the mean value was around 15 $\times 10^2$/g. The mean for the Poaceae content was 10%, and the mean for the Poaceae concentration was about 8 $\times 10^2$/g. The freshwater species *Pediastrum* appeared continuously, and the water fern spores only appeared sporadically. It is presumed that it was a littoral or shallow marine environment under the intertidal zone of the shoreline for the GX2 section. During the period of about 6800–5800 cal. BP, there were still some halophytic *Spinifrites* and *Multispinula*, with a range of 2–16% and an average content of about 8%. The concentration values ranged from 0 to 24 $\times 10^2$/g, with an average of about 8 $\times 10^2$/g. Chenopodiaceae pollen showed a high content of 20–76%, the average was about 50%, and the concentration value was 10–80 $\times 10^2$/g. The average value of terrestrial Cyperaceae was about 8%, and the average concentration was about 8 $\times 10^2$/g. The mean value of Poaceae was about 6%; in fresh water, the spores of water ferns and *Pediastrum* appeared sporadically, and the concentration value was relatively low. According to this, it is inferred that the environment of GX2's location is the shoreline intertidal zone. Between 5800 and 4200 cal. BP, the halophytic *Spinifrites* and *Multispinula* were no longer present. The content of Chenopodiaceae pollen fluctuated from 20% to less than 5%, and the concentration value approached zero. The content of terrestrial Cyperaceae showed an increasing trend, with an average of about 13%, but the concentration value was 0–2 $\times$ 10^2/g. The average percentage of Gramineae was about 8%. The abundance of *Pediastrum* fluctuated between 1% and 17%, with a mean value of about 12%. The mean concentration was lower than 0.5 $\times$ 10^2/g. Water fern spores appeared continuously and stably with an average of about 10% and a concentration value of 0–1.5 $\times$ 10^2/g. It is assumed that GX2's location has been transitioned from the intertidal zone to the terrestrial zone with an inland freshwater wetland environment. From 4200 to 3800 cal. BP, Chenopodiaceae pollen appeared sporadically. The mean value of Cyperaceae was about 8%, and the concentration value was 0–10 $\times$ 10^2/g. The mean value is 4–5% for Poaceae and about 3% for *Pediastrum*. The mean value of water fern spores was about 30%, and the concentration value was about 2 $\times$ 10^2/g. It is presumed to be a lake pond wetland environment with a developed surface water system. During the period of 3800–300 cal. BP, Chenopodiaceae pollen appeared sporadically, and the content of Cyperaceae increased sharply, with an average of about 34%, and the average concentration was about 25 $\times$ 10^2/g. The mean value of Poaceae was about 14% and of *Pediastrum* was less than 2%. The mean value of water fern spores was about 30%, and the mean concentration was 11 $\times$ 10^2/g. Compared with the previous period, the land area was expanded, but it was still a plain environment with suitable water and vapor conditions.

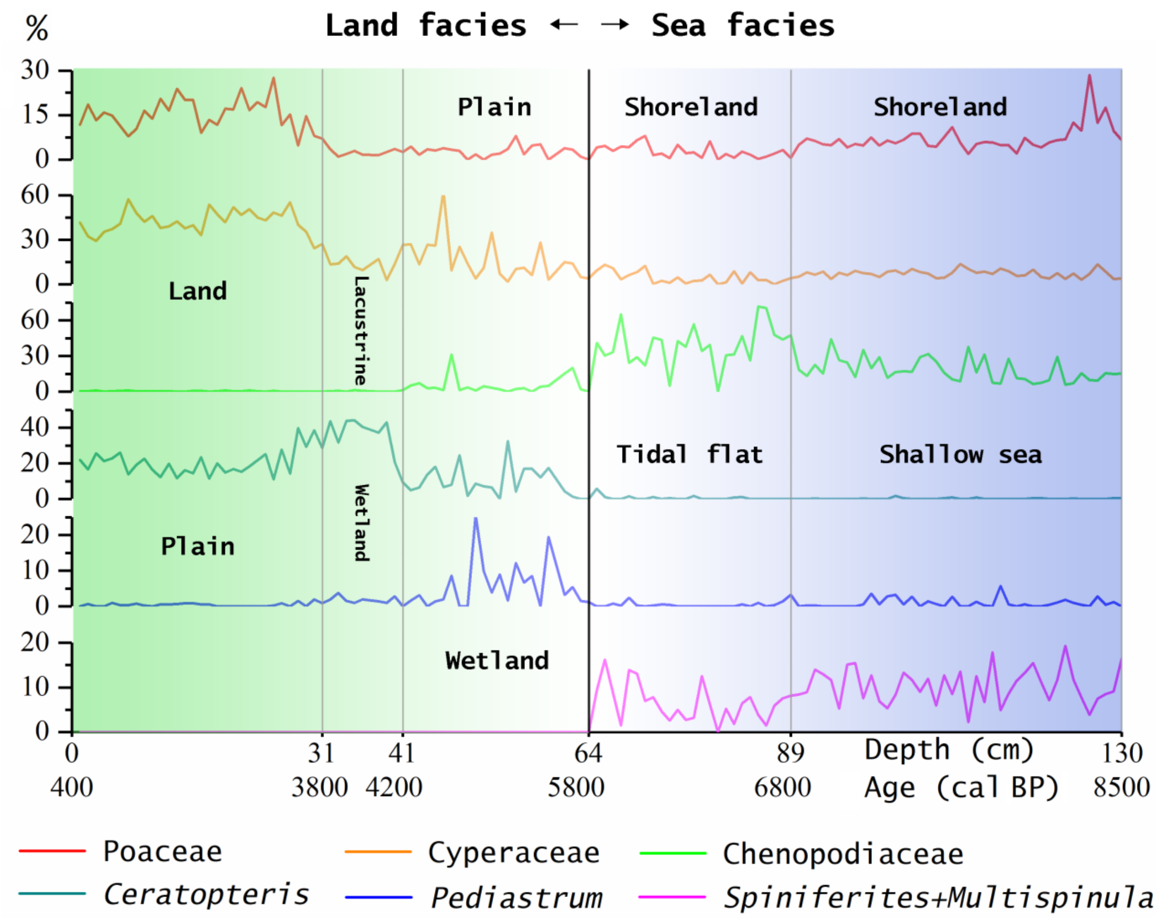

Figure 4. Pollen percentage of some aquatic algae and terrestrial herbs of the GX2 section and geomorphic evolution.

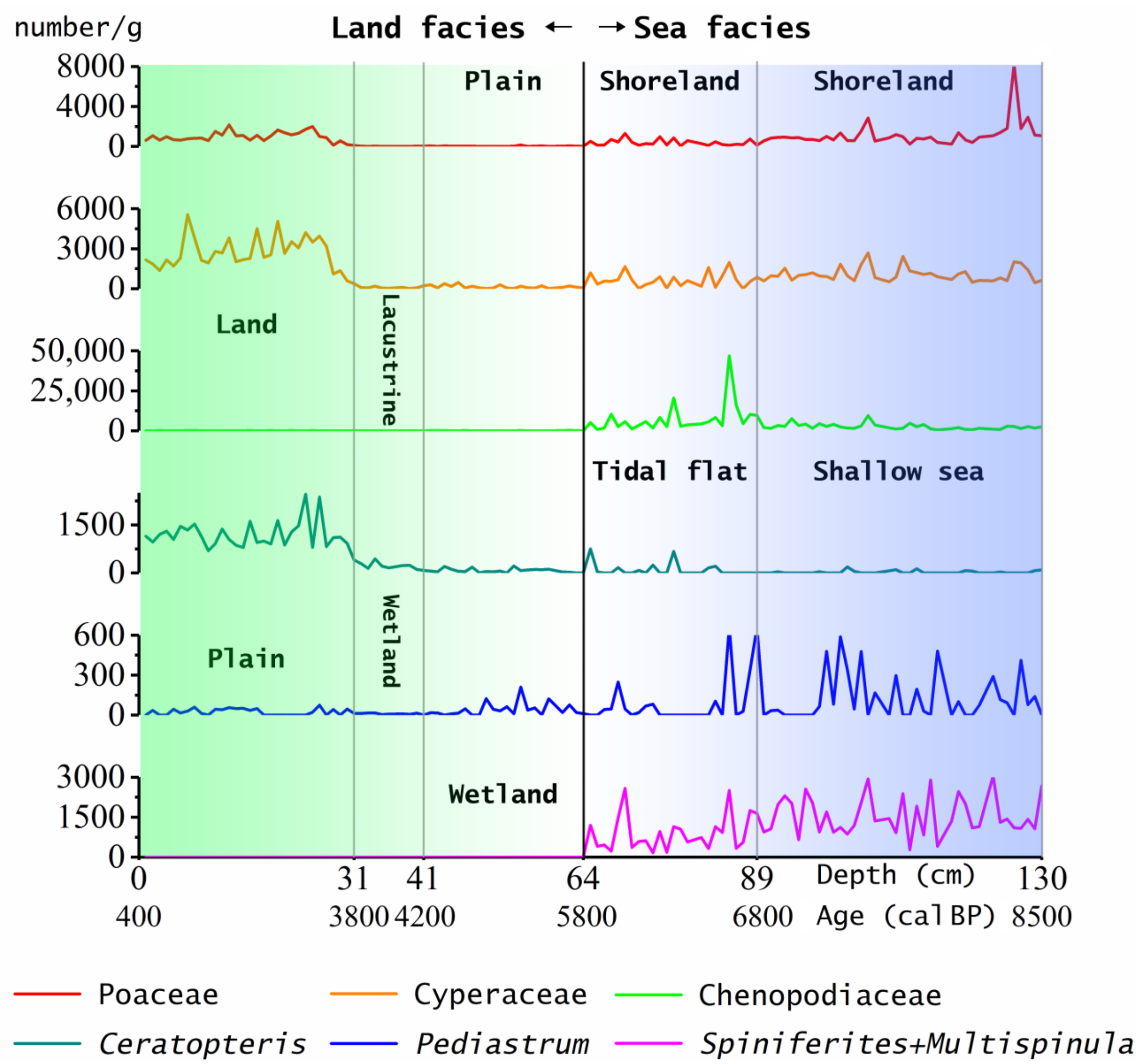

Figure 5. Pollen concentration of some aquatic algae and terrestrial herbs of the GX2 section and geomorphic evolution.

4. The Coastal Changes and Sedimentary Environment in the Eastern Jianghuai Plain during the Holocene

From the deglaciation period to the early Holocene, the global sea level rose rapidly with global warming. Since the Middle Holocene, sea levels have fluctuated slightly but generally tend to be stable. Since the deglaciation period, the sea surface changes in eastern China have been synchronized with others in the world [23,47]. After the last deglaciation period, the sea level rose rapidly, and the sea water drove straight into the ancient Yangtze River valley, and the Yangtze River mouth was a wide estuary. For example, the east of Hai'an Nantong is an estuarine environment at about 10,000 BP [48,49]. With the rapid rise of the sea level, the estuary continues to extend inland along the ancient Yangtze River valley. In the early Holocene, the side shoreline of the north bank of the Yangtze River Estuary was at the front of the Jiangdu, Yangzhou–Shugang terrace, Taizhou [50]. The sediments brought by the ancient Yangtze River were accumulated in the estuary, and the Yangtze River Delta was gradually formed. During the period of 8200–7700 cal. BP, land was gradually formed in the Taizhuang and Qingdun areas in the east of Hai'an Nantong [51]. Due to the superposition of sediment from the Ancient Huaihe River, the northern wing of the Yangtze River Delta gradually expanded in the middle and late Holocene, forming the eastern area of the Jianghuai Plain. In general, shoreline positions oscillated between land and sea in response to sea level changes in the Holocene. However, in the east of the Jianghuai region, there are two major river estuaries, the Yangtze River's and the Huaihe River's. Since the middle Holocene, several ancient sand banks (shell sand banks) were developed on the ancient delta, which were basically parallel to the ancient coastline, due to the combined effects of the reduction of sea level variation, tidal current movement, sediments brought by inland rivers into the sea, and the re-transport and deposition of sediments. These ancient sand banks are the key natural factors of the geomorphic environment in the eastern part of Jianghuai since the Middle Holocene, especially the Xigang (West hill land), Zhonggang (Middle hill land) and Donggang (East hill land) distributed along the NNE direction. The Xigang sandbank began to accumulate at about 6700 BP and formed at about 5500 BP [47,50,52,53]. The formation period of the Zhonggang sandbank and the Donggang sandbank was 4500–4000 BP and 3800 BP, respectively. All these sandbanks are relatively continuous and relatively stable. The thickness of the sand bank ranged from 1 m to 7 m, and the widest width could reach hundreds of meters. Xigang is approximately distributed along the line of Yangzhai, Funing–Longgang, Yancheng–Dagang–Dongtaixi–Hai'an, Nantong from north to south, representing the eastern coastline of the Jianghuai area during the period of 6500 to 5500 BP [50]. In the Hai'an–Taizhou line on the north bank of the ancient Yangtze River, the ancient ground was covered by a coastal sandbank with a thickness of about 10 m in the Late Pleistocene, and the sandbank was formed at about 6000 BP. According to the calculation, the ancient sand dike distributed along the Huai'an–Funing on the south bank of the ancient Huaihe River had already formed during the period of 6000–5000 BP [27]. The existence of three-gang ancient sandbanks formed a relatively closed lagoon (Figure 2) in the eastern plain of Jianghuai, located in the south of the Ancient Huaihe River, north of the Ancient Yangtze River and west of the Xigang River in the middle Holocene, also called "Lixiahe lagoon". In the late Holocene, the sea retreated, the shoreline retreated eastward, and the land area increased. In particular, the Yellow River began to seize the Huaihe River in a large area in 1128, bringing mud and sand to quickly form the present-day coastal plain east of Funing–Yancheng–Dongtai.

As for the evolution of the natural environment in the Middle Holocene Jianghuai Plain, especially in the lagoon area surrounded by sand hills near the sea, some scholars have studied the Liujun town of Huai'an, which is about 40km west of GX2. About 7500 cal. BP, it was a coastal marsh environment [54], which is relatively consistent with the study of GX2. However, there are different views on the sea–land transition process in the Lixiahe area during the Middle Holocene. The most famous is the Qingfeng section of Jianhu Lake, about 12 km south of GX2, which is an important research point of the Holocene climate and sea level changes in the eastern part of Jianghuai at the end of the 20th century. Relevant scholars have analyzed the Qingfeng strata with multiple indicators and revealed the changes in the ancient environment and sea level in the Qingfeng area [25,32,55]. Through saltwater fossil indicators analysis, it is suggested that the environment was a coastal marsh during the period of 9500–7500 BP, a lagoon from 7500 to 6500 BP, during which the sandbank begins to develop, a gulf during 6500–2600 BP and a coastal lowland with seawater withdrawal during 2600–2200 BP, and a freshwater lagoon after 2200 BP. It is concluded that there were three obvious sea level rises and falls during the Middle Holocene, and the sea level was higher during 7000–2600 BP than at present. It is particularly important that the gulf was submerged by sea water for nearly 4000 years during the period 6500–2600 BP. Other scholars also studied the micropalaeofossils and mollusc fossils of the Qingfeng section and concluded that the Qingfeng area was a freshwater marsh during about 9500–7700 BP and a tidal flat (beach) deposition during about 7700–1280 BP [26]. Some scholars believe that before 7000 BP, the coastline of northern Jiangsu was roughly distributed in the line of Yangzhong—Gaoyou–Xuyi–Lianshui–Guanyun–Haizhou Bay, and the east of Jianghuai was a bay [27]. It was a lagoon on the landward side of the ancient sand dike in the eastern part of the Jianghuai area during the Middle Holocene.

Only in the late Holocene did the lagoon form the Lixiahe Plain through desalination and silt deposition.

In this century, the archaeological research on the Neolithic in the eastern part of Jianghuai has achieved fruitful results [5,21]. Among the cultural series of Neolithic sites discovered so far, there are the Longqiuzhuang culture (6600–5500 cal BP), Liangzhu (Dawenkou) culture (5300 (5500)−4300 (4500) cal BP), Longshan culture (4300–4000 cal BP) and Yueshi culture (3950–3450 cal BP). Labelled as numerous sites [56], with large-scale and rich cultural connotations, the archaeological sites are a center where the Neolithic culture spread from the core zone in Jiangsu and Zhejiang of the lower reaches of the Yangtze River to the north of the Yangtze River. The remains of a large number of activities of Neolithic ancestors are obviously severely inconsistent with the ancient environment of a shallow bay, tidal flat and saltwater lagoon in the eastern part of Jianghuai from 6000 to 3800 BP. The Longqiuzhuang site of Gaoyou near ancient Han Gou in the western part of the east of Jianghuai, with an age of about 6600–5000 cal BP [2], is a large site with a burial area, living area and activity area. The fishing–hunting economy of the ancestors in Longqiuzhuang showed a stable development state, with a large number of bones and shells of freshwater aquatic creatures such as fish, turtle, *Trionyx* sinensis, clam, *Corbicula fluminea* and *Margarya Melanoide*. At the same time, more rice phytoliths and Trapa pollen were found in the cultural layer after 6300 BP. The number of rice phytoliths indicated that rice production had a certain scale at that time. *Euryale ferox*, as a larger phytolith, commonly known as chicken head rice and water chestnut, belongs to the foraged food for ancestors. In a representative sample, 5038 grains of carbonized rice were water separation. Cornstarch, water chestnut and rice grown in freshwater ponds and wetlands showed that there were large areas of fresh water and wetlands in the region near Gaoyou, east of Jianghuai, at 6300 cal BP, which provided abundant food resources for ancestors of Longqiuzhuang. In addition, there are many Neolithic sites closely related to the Liangzhu culture in the Taihu Lake Basin south of the Yangtze River, such as the Luzhuang site in Funing [1], which is about 4 km away from the abandoned Yellow River and has the characteristics of the late Liangzhu culture. The Dongyuan site in Funing [3] is distributed in Xigang, Funing, at about 5400–5200 cal BP. Located in the southeast of the Lixiahe Plain, the Kaizhuang site in Dongtai [4] was marked by late Majiabang culture or late Songze culture during the early stage and early–middle Liangzhu culture during the late stage. The most famous is the Jiangzhuang site in Xinghua, Taizhou, which is a large settlement site of Liangzhu culture north of the Yangtze River that has been found so far with the richest cultural connotation [6]. Among the plants unearthed from the ash pit, the remains were rice, *Euryale Salisb*, water chestnut, *Cucumis*, *Cucurbitaceae*, *Leguminosae*, *Diospyros*, *Potamogetonaceae*, *Nymphoides*, *Semen Nelumbinis* (lotus seeds), etc. Besides, the bones of aquatic animals such as fish and turtles were found. The aquatic species is more than terrestrial according to the remains of food. It is believed that the Jiangzhuang site was an important pathway for the Liangzhu culture crossing the Yangtze River and reaching the vicinity of the Huaihe River. The excavation of the Jiangzhuang site completely breaks through the traditional view in the field of archaeology that "Liangzhu culture does not cross the Yangtze River". The Nandang site of Xinghua [57] and Zhoubeidun site of Gaoyou [58] are the representative sites of Longshan culture and Yueshi culture in the east of Jianghuai, respectively. It can be considered that the Neolithic culture in the north moved south to the water network area in the east of the Jianghuai Plain in the late Neolithic culture. However, no Neolithic archaeological remains were found yet in the coastal plain east of Yangzhai town, Funing–Longgang town, Yancheng–Dagang town and Yancheng west of the Dongtai-Hai'an line because it was formed in the late Holocene and was adjacent to the Yellow Sea.

The existence of rice cultivation in Neolithic culture in the region of Jiangsu and Zhejiang is an indisputable fact and can also be considered as the important reason that the foods were abundant during the peak stage of Neolithic culture. The shallow water swamp and the wetland forming after the land forming of the eastern Jianghuai were very suitable for paddy agriculture. The carbonized rice was discovered at both the Longqiuzhuang site and Jiangzhuang site. The density of rice phytophiles in the cultural layer of the Longqiuzhuang site is close to that in the soil where rice has been grown [2]. It is believed that there was rice cultivation in the early period of Longqiuzhuang culture, and the planting scale expanded further in the middle and late period. In addition, there was a considerable amount of rice phytolith in the cultural layer of the Zhoubeidun site [59]. All the rice remains of above sites confirmed that the paddy cultivation of prehistoric ancestors was continuous during the Neolithic culture of about 6600–3450 cal BP. It is a pity that no ancient paddy remains of the Neolithic culture have been found in the east of Jianghuai. Despite this, it is believed that with the deepening of archaeological research and the intervention of testing methods of other disciplines, more substantial evidence will emerge on the study of the scale and development of rice farming in the eastern Jianghuai, and in turn, more credible conclusions will be drawn.

Through the palynological study of GX2, the results show that the Lixiahe Plain in the east of Jianghuai was a bay and tidal flat environment influenced by sea water before about 5800 cal. BP and then was turned into a freshwater limnology environment with sea water withdrawal. Why did previous studies suggest that there was a period of seawater influence in the Jianhu area during the middle Holocene? It is believed that the marine organisms swam upstream into the inland area following the tidal flood current and were deposited and preserved in the strata of the basin or tributaries in the process of the rivers flowing into the sea, and the effect of storm surges is more obvious. Therefore, it is possible that some petrifactions of the ancient halobios can be found in Qingfeng and its surrounding continental strata. In fact, according to the palynological data of the Qingfeng section [25], the regional vegetation was a halophyte meadow at about 7000 BP ago, and most of the vegetation was terrestrial forest at about 7000–2500 BP. After 2500 BP, the regional vegetation was sedge meadows and weed swamps. In addition to the difference in age values, it is confirmed that it should be a terrestrial environment in Qingfeng since the Middle Holocene.

5. Conclusions

The palynology sequence of GX2 represents the palynology and algae of the intrazonal vegetation, and it is considered that the ancient sand dikes such as Xigang in the east of Jianghuai Plain are the dividing point of the influence of sea and land. The area west of the Funing–Yancheng–Dongtai–Hai'an line may has been connected with the ancient South Yellow Sea from the early Holocene to 5800 cal BP, which was a littoral shallow marine environment. Except Longqiuzhuang of Gaoyou and Qingdun of Hai'an in the west of the eastern Jianghuai Plain, where there are remains of Neolithic culture, the other regions could not offer living conditions for prehistoric ancestors. Since about 5800 cal BP, it has been basically a stable terrestrial freshwater pond and wetland environment, except for the sides of the river channel into the sea, which are slightly affected by the sea due to tide fluctuation. Despite the influence by the sea level's fluctuation, the sand and silt carried by the Yangtze River and Huaihe River have been transported and accumulated by sea current and formed a continuous ancient sand dike (hill land), which blocked seawater into the eastern Jianghuai area at that time. This area evolved into the rich Lixiahe freshwater water network and finally become the developed region of eastern China.

Over the past two decades, a lot of research work in the fields of natural science and archaeology have been done and fruitful results have been achieved for Neolithic archaeological research in the eastern Jianghuai Plain. Neolithic ancestors usually chose to live near water, in which it generally refers to the freshwater environment. The fluctuation of the sea surface and the formation of sand banks in the Holocene caused the transition from a coastal lagoon to lowland plain developed by a freshwater marsh and pond between the eastern part of Jianghuai and the south–northward sand banks. It is reasonable to think that the superiority of the natural environment has provided new development space for Neolithic culture since 5800 cal BP. The rice remains such as carbonized rice and rice excavated in the above sites illuminated that an environment of freshwater and wetlands can satisfy the rice farming. Above all, the natural abundance of harvests rewarded the prehistoric ancestors' toil, which resulted in the growth of population and settlements, and thus, large sites have been discovered. The Neolithic culture in the eastern Jianghuai Plain experienced an explosive development and reached its peak with cultural connotation and then became the north expansion area of Liangzhu culture in the Taihu Lake Basin south of the Yangtze River and the south migration area of Haidai culture and Longshan culture. The palynological index of the GX2 section provides not only important palaeogeographical and palaeoenvironmental evidence but a new research perspective for re-understanding the man–land relationship around the lower Yangtze River during the Neolithic period.

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Appendix A

Table A1. The typical Neolithic sites in the eastern Jianghuai.

Name of Sites	Type of Culture	Characteristics and Age of Sites	Reference
Longqiuzhuang	Longqiuzhuang Culture	Large-scale settlement, about 6600–5000 cal BP	The Archaeological Team of Longqiuzhuang, 1999
Jiangzhuang	Liangzhu Culture	Large-scale settlement, Liangzhu Culture period	Nanjing Museum, 2016
Dongyuan	Liangzhu Culture	Excavated typical site, early Liangzhu Culture period	Nanjing Museum, Yancheng Museum, Culture Bureau of Funing, 2004
Kaizhuang	Liangzhu Culture	Excavated typical site, early-middle Liangzhu Culture period	Yancheng Museum, Dongtai Museum, 2005
Luzhuang	Liangzhu Culture	Excavated typical site, late Liangzhu Culture period	Institute of Archaeology, Nanjing Museum, Yancheng Antiquity Preservation committee, Yancheng Museum, 1996
Zhoubeidun	Longshan Culture	Excavated typical site, about 3310 cal BP-middle Spring and Autumn period	Institute of Archaeology of Nanjing Museum, Yangzhou Museum and Gaoyou CPAM, 1997

References

1. Institute of Archaeology, Nanjing Museum; Yancheng Antiquity Preservation Committee; Yancheng Museum; Luzhuang Relics in Funing, Jiangsu Province. *The Light of Oriental Civilization, Collected Essays in Commemoration of the 60th Anniversary of the Discovery of Liang Zhu Culture*; Hainan International Press and Publication Center: Haikou, China, 1996; pp. 130–146.
2. The Archaeological Team of Longqiuzhuang. *Neolithic Site Excavation Report in the Eastern Part of Jiang-Huai Area*; Science Press: Beijing, China, 1999; pp. 201–204, 401, 464–494, 511–512.
3. Nanjing Museum. Yancheng Museum. Funing Bureau of Culture. Neolithic Dongyuan site in Funing county, Jiangsu province. *Archaeology* **2004**, *6*, 7–21.
4. Yancheng Museum, Dongtai Museum, Neolithic Kaizhuang site in Dongtai City, Jiangsu Province. *Archaeology* **2005**, *4*, 12–26.

5. Cui, Y.J. The Research on Culture and Society in the Prehistoric Eastern Jiang-Huai Region. Ph.D. Thesis, Shandong University, Jinan, China, 2011; pp. 31–70, 121–123, 126–134.
6. Nanjing Museum. The Liangzhu cultural remains in Jiangzhuang site of Xinghua and Dongtai, Jiangsu Province. *Archaeology* **2016**, *7*, 19–31.
7. Shi, S.H. *The Environment in Holocene Megathermal and the Development of Ancient Culture in the Neolithic, Climate and Environment in the Holocene Megathermal in China*; China Ocean Press: Beijing, China, 1992; pp. 185–191.
8. Jin, G.Y.; Liu, D.S. Mid-Holocene climate change in North China, and the effect on cultural development. *Chin. Sci. Bull.* **2002**, *47*, 408–413. [CrossRef]
9. Haug, G.H.; Gunther, D.; Peterson, L.C.; Sigman, D.M.; Hughen, K.A.; Aeschlimann, B. Climate and the Collapse of Maya Civilization. *Science* **2003**, *299*, 1731–1734. [CrossRef] [PubMed]
10. Mo, D.W.; Wang, H.; Li, S.C. Effects of Holocene environmental changes on the development of archaeological cultures in different regions of north China. *Quat. Sci.* **2003**, *23*, 200–210. [CrossRef]
11. Fang, X.Q.; Ge, Q.S.; Zheng, J.Y. Progress and prospect of researches on impacts of environmental changes on Chinese civilization. *J. Palaeogeogr.* **2004**, *6*, 85–94. [CrossRef]
12. Wu, W.X.; Ge, Q.S. The climatic events in Holocene and its impact on the development of ancient culture. *Huaxia Archaeol.* **2005**, *3*, 60–67.
13. Wu, W.X.; Hu, Y.; Zhou, Y. Abrupt climate change and decline of ancient civilization. *J. Palaeogeogr.* **2009**, *11*, 455–463.
14. Chen, F.H.; Xia, H.; Gao, Y.; Zhang, D.J.; Yang, X.Y.; Dong, G.H. The processes of prehistoric human activities in the Tibetan Plateau: Occupation, adaptation and permanent settlement. *Sci. Geogr. Sin.* **2022**, *42*, 1–14. [CrossRef]
15. Xiao, J.Y. Pollen analysis report of Nandang site, Xinghua, Jiangsu province. *Cult. Relics* **1995**, *4*, 92–94.
16. Zhu, C.; Yu, S.Y.; Zhang, Q.; Hang, Y.; Li, G.; Zhao, N.X. Neolithic cultural interruptions and Holocene buried palaeo-trees in the Yangtze Delta. *J. Nanjing (Univ. Sci.)* **2000**, *36*, 693–701.
17. Zhu, C.; Wu, L.; Li, L.; Zhao, Q.H.; Zhang, W.Q.; Li, K.F.; Li, B.; Tan, Y.; Wang, K.H.; Jia, T.J.; et al. Recognition of sea-level change during the Neolithic period in the Jiangsu Area, East China. *Chin. Sci. Bull.* **2016**, *61*, 374–387. [CrossRef]
18. Zhang, Q.; Zhu, C.; Jiang, T.; Zhang, Z.H. Environmental archaeological study on the Qingdun site, Hai'an, Jiangsu province, during the Neolithic cultural period. *Geogr. Res.* **2004**, *23*, 513–520. [CrossRef]
19. Gu, W.W.; Zhu, C. Distribution Feature of Neolithic Sites in North Jiangsu Province and Environmental Archaeological Research on Its Relation with Environmental Variation. *Sci. Geogr. Sin.* **2005**, *25*, 239–243. [CrossRef]
20. Qin, J.; Taylor, D.; Atahan, P.; Zhang, X.; Wu, G.; Dodson, J.; Zheng, H.; Itzstein-Davey, F. Neolithic agriculture, freshwater resources and rapid environmental changes on the lower Yangtze, China. *Quat. Res.* **2011**, *75*, 55–65. [CrossRef]
21. Xu, S.Q.; Xiao, J.Y.; Xiao, X.Y.; Gao, Y.W.; Han, Y.; Qi, G.X. Impact of environmental evolution and coastline change on the Neolithic cultures in the eastern part of Jiang-Huai area. *Mar. Geol. Quat. Geol.* **2011**, *31*, 127–134. [CrossRef]
22. Jia, T.J.; Wu, L.; Zhu, C.; Sun, W.; Li, L.; Han, M.F. Archaeological stratigraphy of the Tingchigang Neolithic site in Funing, northern Jiangsu. *J. Stratigr.* **2012**, *36*, 741–746. [CrossRef]
23. Zheng, H.B.; Zhou, Y.S.; Yang, Q.; Hu, Z.J.; Ling, G.J.; Zhang, J.Z.; Gu, C.G.; Wang, Y.Y.; Cao, Y.T.; Huang, X.R.; et al. Spatial and temporal distribution of Neolithic sites in coastal China: Sea level changes, geomorphic evolution and human adaption. *Sci. China Earth Sci.* **2018**, *61*, 123–133. [CrossRef]
24. Zhu, C.; Zhang, Q.; Zhang, Y.; Zhang, Z.H.; Shen, M.J. Relationship Between Human and Nature in the North Part of the Yangtze Delta since the Holocene. *Sci. Geogr. Sin.* **2003**, *23*, 705–712. [CrossRef]
25. Zhao, X.T.; Tang, L.Y.; Shen, C.M.; Wang, S.H. The Holocene climate variation and sea level change in Qingfeng section, Jianhu, Jiangsu. *Acta Oceanol. Sin.* **1994**, *16*, 78–88.
26. Xue, C.T. Holocene sedimentary environments and sea level change based on Qingfeng Section, Jianhu, Jiangsu, China. *Acta Sedimentol. Sin.* **2002**, *20*, 174–177. [CrossRef]
27. Ling, S. Evolution of geography space construction in Yanfu Plain due to the changes of sea level since Holocene. *Trans. Oceanol. Limnol.* **2009**, *1*, 61–66. [CrossRef]
28. Shan, S.M.; Wang, T.K.; Jin, Q.M. *Geography of Jiangsu Province*; Jiangsu Education Publishing House: Nanjing, China, 1980; pp. 8–98.
29. Chen, Y.F.; Yan, Q.S.; Xu, S.Y. Evolution of the sedimentary environments in north Jiangsu basin and its tectonic setting. *Sci. Geogr. Sin.* **1993**, *28*, 151–160.
30. Shu, Q.; Zhao, Z.J.; Chen, Y.; Zhang, M.H.; Li, J.J. Palaeoenvironmental Significance of Geochemistry Elements and Grain Size of DS Core Sediments in Xinghua, Jiangsu Province. *Sci. Geogr. Sin.* **2009**, *29*, 923–928.
31. Yin, J.J. The Geomorphological Evolution and Man-Land Relationship in the East of Jianghuai Plain. Master's Thesis, Nanjing Normal University, Nanjing, China, 2018; pp. 1–58.
32. Tang, L.Y.; Shen, C.M.; Zhao, X.T.; Xiao, J.Y.; Yu, G.; Han, H.Y. Vegetation and climate since 10,000 BP in the Qingfeng section, Jianhu, Jiangsu. *Sci. China (Ser. B)* **1993**, *23*, 637–643.
33. Shu, J.W.; Wang, W.M.; Chen, W. Holocene vegetation and environment changes in the NW Taihu Plain, Jiangsu province, east China. *Acta Micropalaeontol. Sin.* **2007**, *24*, 210–221. [CrossRef]
34. Wang, W.M.; Shu, J.W.; Chen, W.; Ding, J.L. Holocene environmental changes and human impact in the Yangtze River Delta area, east China. *Quat. Sci.* **2010**, *30*, 233–244. [CrossRef]

35. Wu, L.; Li, H.Y.; Wang, C.; Zhao, W.P.; Yu, H.P.; Ke, R. The change of palynological dominance recorded in Chaohu Lake deposition since Holocene and its environmental significance. *China Sci. Technol. Inf.* **2018**, *18*, 94–96, 98.
36. Huang, K.Y.; Zhou, Y.J.; Chen, C.; Tang, Y.J.; Cen, C.F. Paleovegetation succession over the past 30000 yr and human activities during the late Holocene in Chizhou city, Anhui Province. *Acta Sci. Nat. Univ. Sunyatseni* **2022**, *61*, 151–160. [CrossRef]
37. Tang, L.Y.; Mao, L.M.; Lü, X.M.; Ma, Q.F.; Zhou, Z.Z.; Yang, C.L.; Kong, Z.C.; Batten, D.J. Palaeoecological and palaeoenvironmental significance of some important spores and micro-algae in Quaternary deposits. *Chin. Sci. Bull.* **2013**, *58*, 3125–3139. [CrossRef]
38. Tang, L.Y.; Mao, L.M.; Shu, J.W.; Li, C.H.; Shen, C.M.; Zhou, Z.Z. *An Illustrated Handbook of Quaternary Pollen and Spores in China*; Science Press: Beijing, China, 2016; pp. 132–134.
39. Wang, K.F.; Zhang, Y.L.; Li, Z. Palynological Study on the Surface Samples of Mangrove in Yingluo Bay, Guangxi. *Acta Sedimentol. Sin.* **1998**, *16*, 31–37. [CrossRef]
40. Zhang, Y.L.; Wang, K.F.; Zhang, S.L. The distribution patterns of certain marine algae in the sediments of the continental shelf and their paleoenvironmental significance. *J. Tongji Univ.* **1994**, *22*, 340–345.
41. Zhu, H.R.; Zeng, Z.Q.; Zhang, Z.Y. Fossil Pediastrum algae from the Dainan formation (Lower tertiary) of northern Jiangsu with note on their sedimentary conditions. *Acta Palaeontol. Sin.* **1978**, *17*, 233–243.
42. Wu, Y.S.; Xiao, J.Y. A preliminary study on modern pollen rain of Zabuye Salt Lake area, Xizang. *Acta Bot. Yunnanica* **1995**, *17*, 72–78.
43. Cai, Q.F.; Liu, D.Y.; Jia, P.M.; Shao, C.G. Application status of pollen proxies to paleoclimate and paleo sea-level changes in Chinese coastal zone. *J. Geol.* **2015**, *39*, 621–626. [CrossRef]
44. González, C.; Dupont, L.M. Tropical salt marsh succession as sea-level indicator during Heinrich events. *Quat. Sci. Rev.* **2009**, *28*, 939–946. [CrossRef]
45. González, C.; Dupont, L.M. Coastal vegetation evidence for sea level changes associated with Heinrich Events. *Pages News* **2009**, *17*, 70–72. [CrossRef]
46. Xiao, J.Y.; Lv, Y.; Qi, G.X. On the quantity of Chenopodiaceae pollen in salt marsh vegetation of muddy coast in East China. *Geogr. Res.* **2014**, *33*, 2157–2168. [CrossRef]
47. Xie, Z.R.; Yuan, L.W.; Lv, G.N. *Reconstruction, Monitoring and Forecast on Sea Surface-Land Surface Systems*; Science Press: Beijing, China, 2012; pp. 132–134.
48. Li, C.X.; Wang, P.X. *The Studies on Yangtze River Estuarine Stratigraphy during Late Quaternary*; Science Press: Beijing, China, 1998; pp. 114–161.
49. Li, C.X.; Fan, D.D. Development of the Holocene Changjiang delta and its influence on adjacent coastal sedimentary systems. *J. Palaeogeogr.* **2009**, *11*, 115–122. [CrossRef]
50. Ling, S. Shoal's merging into land and evolution of north coastline of Changjiang estuary. *J. Oceanogr. Taiwan Strait* **2001**, *20*, 484–489. [CrossRef]
51. Li, K.F. Study on Holocene Regression in Taozhuang site and Qingdun Site, North Jiangsu Province. Ph.D. Thesis, Nanjing University, Nanjing, China, 2014; pp. 21–23.
52. Gu, J.Y.; Yan, Q.S.; Yu, Z.Y. The cheniers of the northern coastal plain of Jiangsu province. *Acta Sedimentol. Sin.* **1983**, *1*, 47–59.
53. Zhu, C.; Cheng, P.; Lu, C.C.; Wang, W. Paleocoastline evolution law of Yangtze River delta and coastal area of northern Jiangsu province since 7000 a B.P. *Sci. Geogr. Sin.* **1996**, *16*, 207–213.
54. Gou, Y.X.; Tang, L.Y.; Sun, X.C.; Huang, B.Y.; Pan, H.Z. Holocene Marine Invasion Event and Climate Change in North Jiangsu. *Jiangsu Geol.* **1999**, *23*, 241–245.
55. Zhao, X.T.; Lu, G.Y.; Wang, S.H.; Wu, X.Z.; Zhang, J.W. The Holocene strata of Qingfeng section, Jianhu, Jiangsu and its reflection of environmental evolution and sea level change. *Sci. China (Ser. B)* **1991**, *9*, 992–999.
56. Xu, S.Q. Impact of Palaeoenvironment Evolution and Coastline Change on the Neolithic Cultures in the Eastern Part of Jiang-Huai Area. Master's Thesis, Nanjing Normal University, Nanjing, China, 2011; pp. 1–39.
57. Institute of Archaeology of Nanjing Museum; Yangzhou Museum; Xinghua Museum. Nandang site, Daijiashe, Xinghua, Jiangsu. *Cult. Relics* **1995**, *4*, 16–31.
58. Institute of Archaeology of Nanjing Museum; Yangzhou Museum; Gaoyou CPAM. Excavations of the Zhoubeidun site in Gaoyou, Jiangsu. *J. Archeol.* **1997**, *4*, 481–510.
59. Xiao, J.Y. Analysis of ancient rice silicates from the Zhoubeidun site in Gaoyou, Jiangsu. *J. Archeol.* **1997**, *4*, 512–513.