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Postglacial Vegetation and Environmental Record from Longnan, Southern Yangtze Delta, SE Jiangsu Province, East China

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Abstract This paper presents vegetation and environmental history during the past 9000 BP from Longnan at the lower Yangtze valley in East China, based on pollen analysis and radiocarbon dates for the RN98D core. Results show that the early/mid-Holocene was dominated by subtropical evergreen broad-leaved forest of *Lithocarpus/Castanopsis* and *Quercus Cyclobalanopsis*, which characterises the vegetation of South China to the south of 30-32° N today. At ca. 5000 BP, the *Lithocarpus/Castanopsis* rapidly decreased, giving way to open forest where *Q. Cyclobalanopsis* remained abundant. At ca. 3000 BP dense forest returned, forming evergreen and deciduous broad-leaved mixed forest dominated by *Q. Cyclobalanopsis* with some *Q. Lepidobalanus*, *Lithocarpus/Castanopsis*, *Carpinus*, Ulmaceae, *Myrica*, *Liquidambar*, *etc* which may be the potential natural vegetation of the Yangtze delta. This vegetation/environmental history is consistent with prior Holocene pollen data accumulated in the lower Yangtze valley, suggesting hypsithermal (warmer than present) climate in the mid-Holocene followed by a cooling trend toward the present. Influence of the Neolithic human activities was relatively small compared with regional archaeological backgrounds. Apparent human evidence with intense agriculture is represented as increases in *Pinus* and Brassicaceae near the top of the diagram, which agrees with the parallel Cauduntou record from western hillsides.

Key words: palynology, vegetation, Yangtze River, China, palaeoclimate, Holocene, hypsithermal.

The flat, low-lying deltaic regions in East China are densely populated and are sensitive to climate changes, and the lower Yangtze River valley around Shanghai (Fig. 1) is one of the economic centres of East China that may be vulnerable to a certain sea level rise. Formation and evolution of the delta plain related to past sea level changes have been studied for the last decades (Wang and Wang, 1980; Hong, 1991; Fang, 1991; Chang and Liu, 1996; Yu *et al.*, 1999). These results revealed large-scale migration of the Yangtze delta shoreline during the past 10,000 years. Tai Lake (Taihu), one of the biggest fresh-water lakes in China, was formed as late as 4000 BP. In a larger scale, Pleistocene environments of the Yangtze region have been affected by glacial eustasy, which almost drained the East China Sea at the Last Glacial Maximum (LGM) at 21 ka (Zhao *et al.*, 1979; Peng *et al.*, 1984; Qin and Zhao, 1991). Hundreds of Neolithic cultural sites have been developed around the southern Yangtze delta

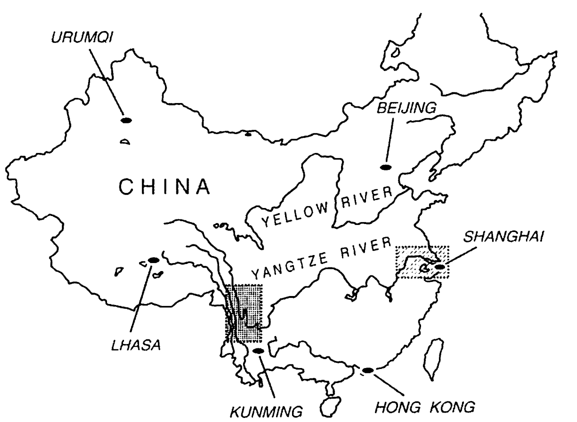

Fig. 1. Map of our research areas in China, based on the research project of the Natural History Museum and Institute, Chiba entitled 'Vegetation and environmental changes in East Asia and the Pacific regions' organised by M. O. Hutched: the lower Yangtze River valley, SE Jiangsu province (this study). Shaded: the upper Yangtze River valley, NW Yunnan province (Okuda *et al.*, 2005).

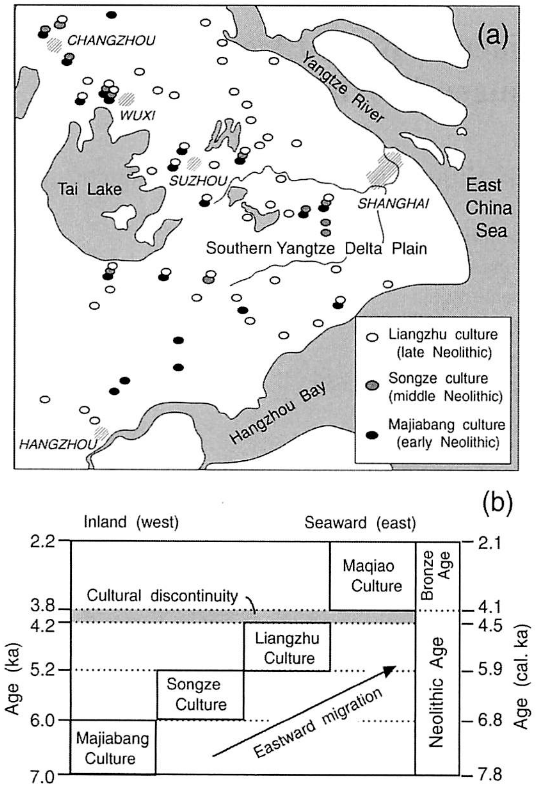

Fig. 2. Neolithic culture in the southern Yangtze delta plain. (a) locations of the early to late Neolithic cultural sites (after Zheng *et al.*, 1994). (b) Time ranges of the Neolithic to Bronze Age cultures around the Yangtze delta (after Yi *et al.*, 2003).

plain since 7000 BP (see Zheng *et al.*, 1994) (Fig. 2a). These Neolithic cultures consisted of the Majiabang culture (7-6 ka), the Songze culture (6-5 ka) and the Liangzhu culture (5-4 ka) around the Yangtze delta, followed by the Bronze Age civilization after a temporal cultural discontinuity (Fig. 2b). Many sites were located near the past shorelines, suggesting a relation between the Neolithic human settlements and sea level history during the Holocene. Recent archaeological and molecular genetic studies suggested that the lower to middle Yangtze valley is the origin for growing paddy rice in East Asia (Wu, 1983a; Glover and Higham, 1996; Yasuda, 2002; Sato, 2002).

The lower Yangtze region also provides themes for the vegetation science. The long, intense human settlements during the last millennia have altered the landscapes of this region, and the natural vegetation of the Yangtze valley is merely imagined from small patches of native forest surviving on surrounding hills (see Wu, 1983b). Numbers of pollen records have been accumulated in and around the Yangtze delta to supplement the knowledge of palaeovegetation and environments (Wang *et al.*, 1984; Liu *et al.*, 1992; Sun and Huang, 1993; Liu and Chang, 1996; Xu *et al.*, 1996; Yu *et al.*, 2000; Han *et al.*, 2000; Yi *et al.*, 2003). The southern Yangtze delta plain has thick (ca. 200-300 m) Quaternary deposits of alluvial, lacustrine and marine origins (Zhu *et al.*, 1987; Shao *et al.*, 1991), being suitable for the Holocene/Pleistocene palynological studies. These studies have reported palynoflora with abundant mesic trees around Tai Lake (Xu *et al.*, 1996; Yi *et al.*, 2003), although core sites in estuary region yield abundant pines and herbs in the earlier periods of the Holocene (Liu and Chang, 1996; Yu *et al.*, 2000).

Biogeographically, the plain of mid-lower reaches of the Yangtze River lies between the temperate deciduous forest of North China and subtropical evergreen forest of South China (Li *et al.*, 1995). The plain consists of a sort of transitional zone between the two major climate/vegetation regimes of China (Fig. 3a). This means that the vegetation of the Yangtze valley are relatively sensitive to thermal changes, because both warming and cooling are recorded as significant vegetation migration. According to reconstructed vegetation, the mid-/lower Yangtze valley was 2°C

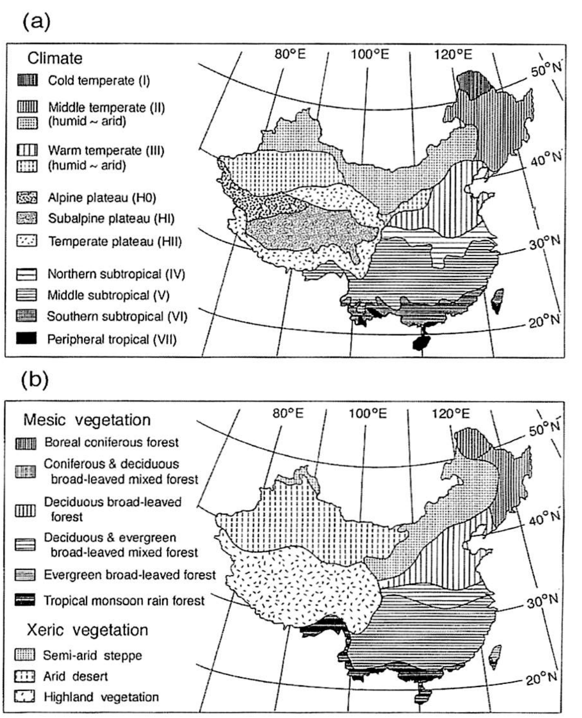

Fig. 3. Geographical properties of China. (a) Modern climate regimes based on meteorological observations (terms by Domrö and Peng, 1988); (b) Potential natural vegetation regimes speculated by the climate and present/past vegetation information (illustration after Shi *et al.*, 1993).

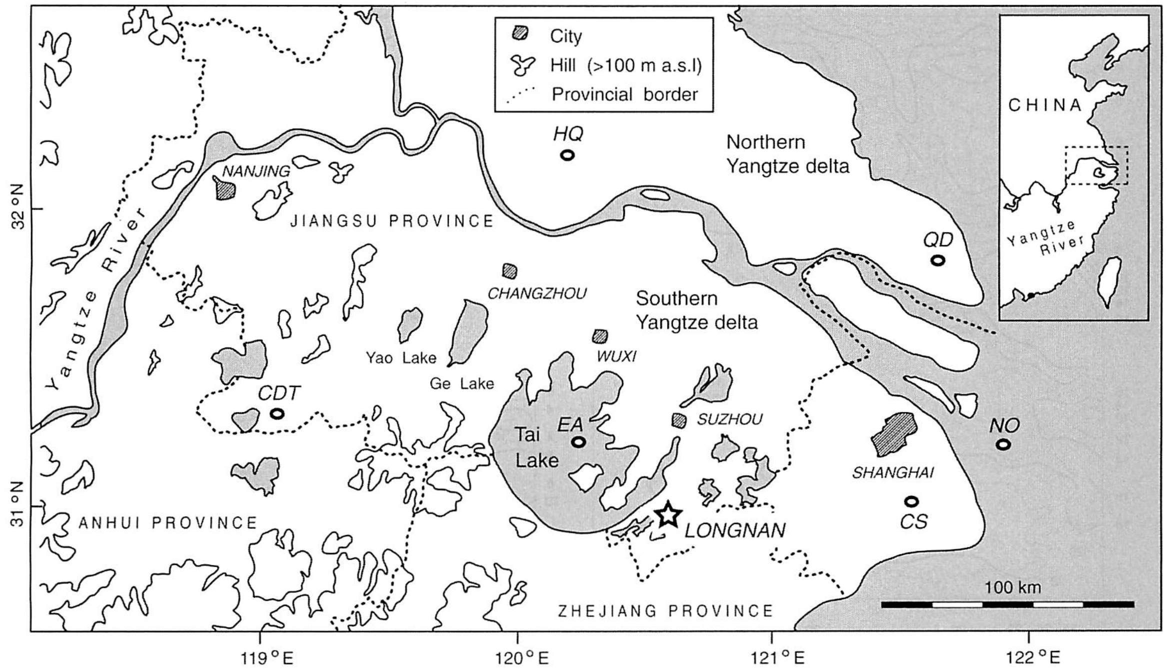

Fig. 4. Map of the lower Yangtze region, East China, with locations of Longnan and prior palynolotical sites. NO denotes the No.11 core site (Wang *et al.*, 1984). QD denotes Qidong (Liu *et al.*, 1992). EA denotes E_2A in Taihu Lake (Xu *et al.*, 1996). CS denotes the CS-05 (Yu *et al.*, 2000). HQ denotes HQ98 (Yi *et al.*, 2003). CDT denotes Cauduntou (Okuda *et al.*, 2003). An open star denotes Longnan (present study).

warmer than at present under the hypsithermal conditions in 6-7 ka (Wu, 1983a; Shi *et al.*, 1993; Zheng *et al.*, 1999). These vegetation migration records seen in fossil pollen may be informative when considering the vegetation response to the future global warming.

This paper provides a 5 m-long pollen record from Longnan (or Ryunan in Japanese pronunciation, providing the code RN), located 10 km apart of the Tai Lake coast as well as 35 km south of Suzhou (Fig. 4). This area is occupied by innumerable small water pools, facing the provincial border to the Zhejiang province. Three radiocarbon dates are obtained to give a time scale to the vegetation history. To the ca. 150 km west, we have settled a parallel study site termed Cauduntou, with a 2.5 m-long pollen diagram published in Okuda *et al.* (2003). In this paper, we integrate the knowledge from the two palynological studies as well as prior representative pollen data in the vicinity, in order to show the vegetation and environmental history of the lower Yangtze valley during the past 9000 years.

Site Information with Modern Vegetation and Climate

Longnan (30°59'N, 120°35'E, 2-3 m a.s.l.) is one of the Neolithic cultural sites located in the alluvial plain of the southern Yangtze delta. Mesozoic basement rocks form small hills to the west of Tai Lake, hydrologically dividing Longnan and Cauduntou. The Longnan site is today in the midst of rice fields and the vegetation has completely been altered from the natural state. On the highlands of Anhui Province, nevertheless, there are small patches of *Quercus* (deciduous oak), *Liquidambar, Platycarya, Carpinus, Ulmus, Acer, etc* (Editorial Board of China Vegetation, 1995). On Mt. Baohuashan (440 m a.s.l.) near Nanjing, abundant evergreen oaks (*Quercus glauca, etc*) were observed in a nature protective area (Han *et al.*, 2000). Deciduous trees such as *Celtis, Juglans, Acer, Liquidambar, Phoebe, Sapindus, Hovenia* and *Albizzia* associated with the oak forest. From the observation on cultivated plants, the growth limit of subtropical (evergreen) plants seems to be along the northern border of the Yangtze valley (ca. 33°N). Orange, loquat, tea plants and bamboo cannot be cultivated to the north of the Huai River (32-33°N). *Eucalyptus* and *Cunninghamia*, which are common immigration trees in central China, cannot grow to the north of the boundary, either (Ren, 1982).

The modern climate distribution of East China is summarized in Figure 5. Along the coastal regions between the Leizhou and Liaodong Peninsulas (22-42°

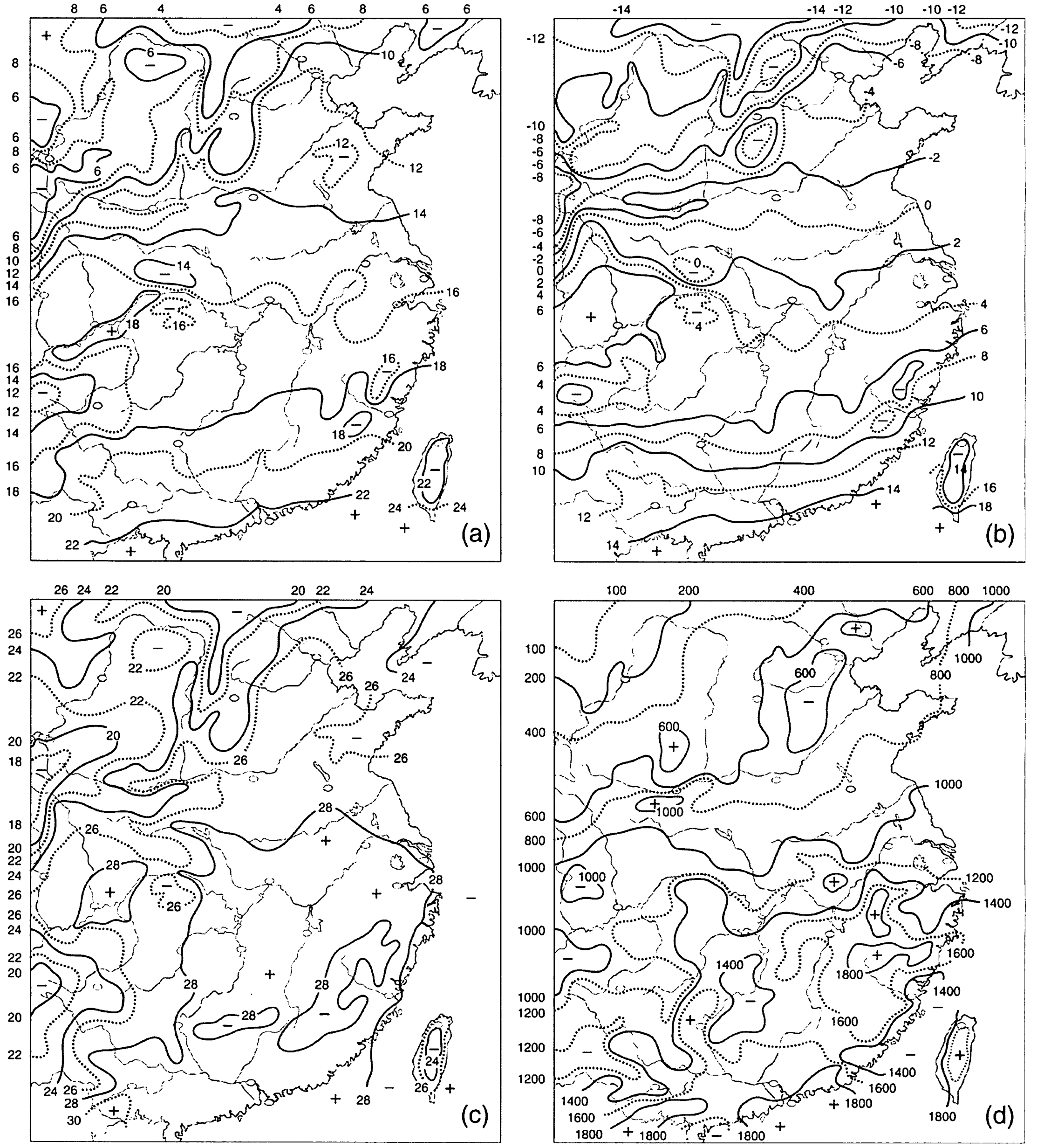

Fig. 5. Modern climate distribution of East China between 20°N and 42°N (data from Chinese Atlas Publishing House. 1984). (a) Annual mean temperature (°C); (b) January mean temperature (°C), July mean temperature (°C), Annual precipitation (mm/y).

N), a variable climate component is winter temperature (January mean), ranging from -5°C in Beijing (<-10°C in the base of the Liaodong Peninsula) to > 18°C in the southern tip of the Taiwan island. This N-S thermal distribution is almost proportional to latitude except for a warm anomaly in the Sichuan basin (> 6°C), with satellite cold anomalies on the marginal plateau (0 to ~ -10°C) (Fig. 5b). By contrast, summer temperature variations are quite small, compared with Beijing where the mean temperature of July rises to 26°C. In most cities of central to south China (Shanghai, Chongqing, Hong Kong, Nanning, *etc*), the temperatures do not exceed 28-29°C (Fig. 5c). The precipitation range of the East China coast is 600-1800 mm/y (Fig. 5d), with the maximum reaching 4000 mm/y on central Taiwanese mountains (Chinese Atlas

Publishing House, 1984).

The feature of the Yangtze valley climate is hot summers and cold winters under the dominant East Asian summer monsoon. Basically East China (at least coastlands) receives sufficient rains so the main limiting factor against tree growth is winter colds. The mean annual precipitation of Shanghai is 1130 mm/y, with mean temperatures of 28°C and 3.3°C in July and January, respectively. The absence of high mountains to the north of the region leads to the exposure to winds from the Siberian cold air mass during the winter. In some cases, less than -10°C of extreme minimum temperature is recorded. It seems that the winter colds hinder the expansion of subtropical evergreen forest in the lower Yangtze valley despite its low latitude. By contrast, the summer temperature significantly rises, and the mid-/lower reach of the Yangtze River is one of the summer-hottest regions in China (Ren, 1982).

Materials and Methods

The RN98D core from Longnan (or Ryunan) is 680 cm in total length, comprising three lithological units (Units 1-3). Unit 1 (680-570 cm) consists of greenish-grey light coloured clay with highly inorganic appearance. Unit 2 (570-490 cm) is a band of grey-coloured silts with fine-grained sand materials. Unit 3 (490-0 cm) is dark-grey clay/silt with abundant humus. These units are generally homogeneous, containing few visible macroremains. The basal part of Unit 3 contains a lot of thin (< 1 cm) sandy bands and the Unit 2/3 boundary is somewhat unclear. Sediment materials for pollen analyses were subsampled from Units 1-3 with 10-20 cm spacing, as well as bulk sediments collected from three horizons for radiocarbon dating. The pollen samples were analysed in the pollen laboratory at the Natural History Museum and Institute, Chiba (Japan). The radiocarbon samples were pretreated and dated by the Institute of Accelerator Analysis Ltd. (IAA), Kawasaki, Japan.

Pretreatments for pollen analysis followed the standard method by Moore *et al.* (1991). The sediment samples were milled and bathed in a 10% HCl solution overnight to remove calcium carbonate. After excess HCl was rinsed off, the samples were boiled in a 10% KOH solution for 10 minutes to remove humic acids. The resulting suspension was cleaned with repeated centrifugation and decanting to remove clay-sized particles. Fossil pollen was extracted from heavier particles by heavy liquid flotation using saturated $ZnCl_2$ solution. The samples were finally acetolysed and mounted with 100% glycerol solution. More than 300 pollen grains of trees and terrestrial herbs excluding wetland herbs were counted for each sample, forming the sum for percentage calculation. Percentages of wetland herbs and pteridophyte spores were calculated based on the total sporopollen. Pollen identification followed Huang (1972) and Wang *et al.* (1997).

Radiocarbon samples were pretreated by IAA along the standard acid treatment using hot (80°C) 1N HCl. Any visible fibrous or organic fragments have manually been removed with wet sieving of 300 μm. The CO_2 obtained by combustion under 500°C for 30 minutes and 850°C for 120 minutes was converted to graphite for AMS measurements.

Results

1. Pollen analysis

Results of the pollen analysis are shown in Figure 6. Four local pollen zones P1, P2, P3 and P4 are given to Unit 3, with the zonation determined primarily by the alternation between trees and terrestrial herbs. Units 1 and 2 are barren yielding no fossil pollen.

P1 (490-245 cm)

Zone P1 is dominated by evergreen broad-leaved trees of *Lithocarpus / Castanopsis* and *Quercus Cyclobalanopsis*, associated with *Q. Lepidobalanus*, *Carpinus*, Ulmaceae, *Betula*, Juglandaceae, *Fagus*, *Alnus*, *etc.* The reconstructed vegetation for zone P1 is dense subtropical evergreen broad-leaved forest. In coniferous assemblages, *Pinus* (*Diploxylon*-type) occurs with persistent *Abies*, *Tsuga* and T-C-C (Taxaceae-Cephalotaxaceae-Cupressaceae). *Liquidambar* shows a temporary peak below 450 cm.

P2 (245-125 cm)

Zone P2 is characterised by the reduction of *Lithocarpus/Castanopsis* replaced by abundant herbs (in this case Poaceae). All other trees except *Q. Cyclobalanopsis* reduce to almost zero in this zone. Decreases in forest density are more or less resulted, and the reconstructed vegetation for zone P2 is open forest of *Q. Cyclobalanopsis* mixed with some deciduous trees. The abundant grasses grew in and around the forest and/or the sedimentary basin.

P3 (125-50 cm)

Zone P3 is characterized by the return of *Q. Cyclobalanopsis* up to 50-60% of the whole pollen assemblage. Several broad-leaved trees show simultaneous increases such as *Corylus*, *Carpinus*, Ulmaceae, *Myrica*, *Lithocarpus/Castanopsis* and *Liquidambar*, indicating the restoration of dense mesic forest. The reconstructed vegetation for zone P3 is evergreen and deciduous broad-leaved mixed forest mainly of *Q. Cyclobalanopsis*. In this zone *Sparganium/Typha* show

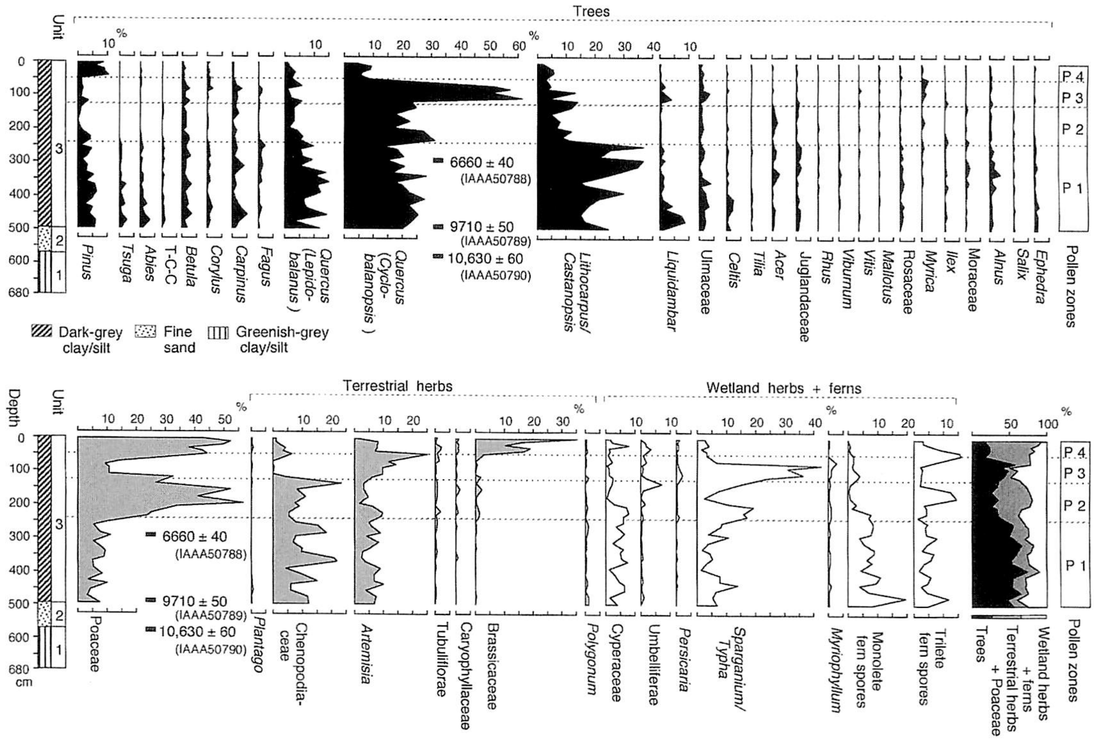

Fig. 6. Results of pollen analysis for the RN98D core, SE Jiangsu Province, East China. Trees and terrestrial herbs form the sum for percentage calculations. Percentages of wetland herbs and pteridophyte ferns are based on the total pollen plus spores.

prominent peaks, suggesting the expansion of swamp communities under some moister environments.

R 4 (50-0 cm)

Zone P4 is characterized by rapid decreases in arboreal pollen to 20-30% of the pollen assemblage. Another important features of this zone are increases in *Pinus* and Brassicaceae, which separates zone P4 from the lower pollen zones. Decreases in wetland herbs and ferns suggest reduction of local swamps. As a parallel record to zones P3-4, the selected pollen diagram from Cauduntou (code: CDT-3) is attached for comparisons (Fig. 7).

2. Radiocarbon dating

Results of radiocarbon dating are listed in Table 1. Three AMS ^{14}C dates of 6660 ± 40 BP, 9710 ± 50 BP and 10,630 ± 60 BP (IAAA50788-50790) are provided from 275-280 cm, 485-490 cm and 575-580 cm in depths, respectively, providing at least 9000 BP of time range to the RN98D record.

Discussion

The palaeovegetation record from the RN98D core can agree with regional climate history of the lower Yangtze region, corresponding to epochs Q_4^1 to Q_4^3 during the Holocene (Table 2). Zone P1, dominated by *Lithocarpus/ Castanopsis* and *Quercus Cyclobalanopsis*, is chronologically correlated with epochs Q_4^1 to Q_4^{2-1}. In prior pollen data from the Yangtze delta (*e.g.*, Wang *et al.*, 1984), epoch Q_4^{2-1} (7500-5000 BP) showed relatively dense forest of *Castanopsis, Q. Cyclobalanopsis, Liquidambar, Ilex, Myrica, Eurya, etc,* being analogous to the subtropical evergreen forest of South China (ca. 20-30° N) today (see Fig. 3b). Concerning the past sea-level records, the Yangtze delta has experienced large (50-100 km) westward transgression in 9-7 ka. (Hong, 1991; Zheng *et al.*, 1999). This 'Megathermal' period, termed for the hypsithermal period of China (Shi *et al.*, 1993), was allegedly 1° C (South China), 2° C (the Yangtze valley), 3° C (North/ Northeast China) and possibly 4-5° C (the Tibetan plateau) warmer than at present, according to a compilation of palaeotemperature indices in the Chinese territory (Shi *et al.*, 1993, Fig. 8). A similar compilation was provided by Winkler and Wang (1993) as 'snapshots' for 6000 and 9000 BP of China. The larger warming trend in the northern regions and interior highlands can agree with the 6000 BP palaeotemperature map of Europe (Fig. 9), reconstructed from the comparison between the fossil and surface pollen through the European continent (Huntley and Prentice, 1988). The time range of the warmer environment was floating among the regions, but in North China the persistence to 4-3.5 ka was given, which was longer than the Atlantic period of Europe (8-6 ka). The mechanism for the temperature rises is given by the insolation theory with the maximum 65° N summer insolation around 9 ka (Kutzbach and Street-Perrott, 1985), invoking the strengthened Asian monsoons with northward advance of the intertropical convergence zone (ITCZ) during the early/ mid-Holocene (Webb III *et al.*, 1993a; Kutzbach *et al.*, 1996; Roberts, 1998). Radiometrically, zone P1 extends back to epoch Q_4^1 (the earliest Holocene) with 'cool/ dry' climate (Zheng *et al.*, 1994) which is not consistent with our subtropical palynoflora. In HQ98 from the northern Yangtze delta, however, Yi *et al.* (2003) restricted his boreal cooling to the short cool event around 8.2 ka (*e.g.*, Rohling and Palike, 2005), and our superficially stable P1 palynoflora may be a result of lower resolution. The preboreal phase with increasing *Liquidambar*, which is a component of subtropical forest of South China (Zheng, 1991; Li *et al.*, 1995), requires further researches.

Zone P2 is correlative with epoch Q_4^{2-2}. In the lower Yangtze region, this epoch is characterized by decreases in subtropical evergreen trees, replaced by *Quercus Lepidobalanus* in the Yao-Ge-Hu area (Tao and Yan, 1987) and by *Pinus* in HQ98 (Yi *et al.*, 2003). Palaeoclimatologically, the Megathermal period of China is followed by cool (and dry) conditions by 3500-3000 BP (see Table 2, Fig. 7). The Yangtze region is under lower precipitation level than the averaged world forestal regions (barely exceeding 1000 mm/ y, see Fig. 5), and have received the invasion of *Artemisia* in the lateglacial period under the semi-arid conditions (Xiao *et al.*, 2000; Yi *et al.*, 2003). This means that a similar vegetation shift to open forest could occur under the subboreal cooling trend in zone P2. In North Africa, the climate deterioration after 5000 cal BP was recorded as regional lake level lowering (Fig. 10a-b) with expansion of the Sahara, Arabia and Thar deserts to their present sizes, as the consequence of southward retreat of the ITCZ. The climatological link between the North African sector and East Asia via the Indian/ East-Asian monsoon systems deserves attention. In the Southern Hemisphere, 5000-4500 cal BP was marked by regional glacier readvance related to

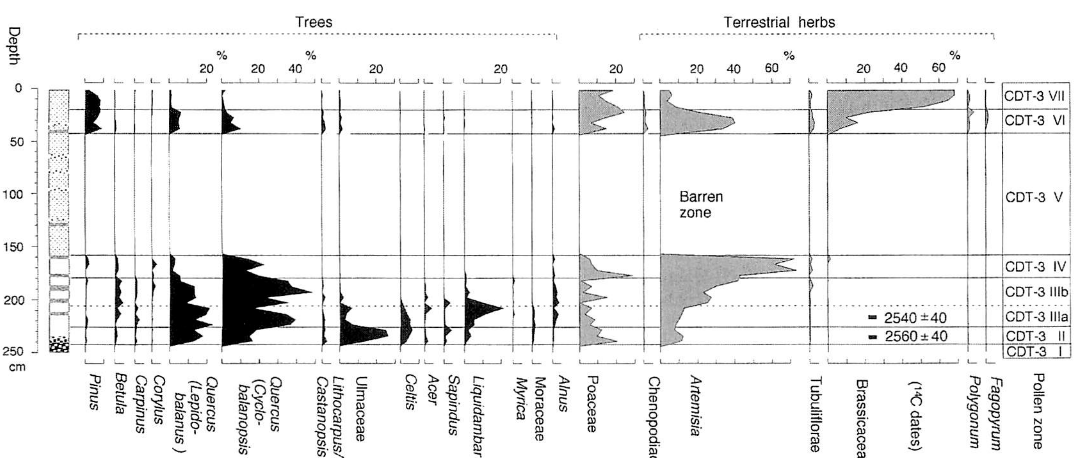

Fig. 7. Parallel pollen record from the 2.5 m section at Cauduntou, SW Jiangsu Province, East China (data published in Okuda *et al.*, 2003). Percentage calculation is based on the same criteria as Figure 5, with the pollen sum formed by total trees and terrestrial herbs.

Table 1. AMS radiocarbon dates for the RN98D core from Longnan, SE Jiangsu province, East China.

Sample name	Depth (cm)	Laboratory No.	Material dated	$\delta^{13/12}C$	Age (^{14}C yr BP)
RN98D-1	275-280	IAAA-50788	bulk sediment	-23.75 ± 0.80	6660 ± 40
RN98D-2	485-490	IAAA-50789	bulk sediment	-22.06 ± 0.67	9710 ± 50
RN98D-3	575-580	IAAA-50790	bulk sediment	-20.73 ± 0.68	10,630 ± 60

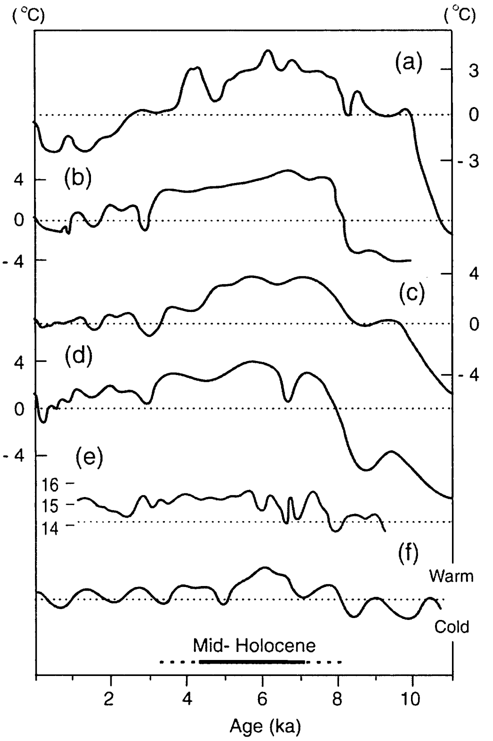

Fig. 8. Reconstructed temperature variations of China during the past 11 ka (compilation after Shi *et al.*, 1993). (a) West of Changbeishan (42° 32'N; 126° 20'E), deviation from present summer temperature (Wang *et al.*, 1990); (b) South Liaoning (39° 30'N; 122° E), deviation from present annual temperature (Guiyang Institute of Geochemistry, Academia Sinica, 1977); (c) East Hebei, deviation from present annual temperature (Tong, 1988); (d) Loess Plateau, deviation from present annual temperature (Sun *et al.*, 1991), (e) North Jiangsu (33° 50'N; 120° E), reconstructed annual temperature (Tang *et al.*, 1990); (f) Qinghai Lake (36° 54'N; 100° 11'E), qualitative warmth/colds (Kong *et al.*, 1990).

the Neoglaciation episode (Porter, 2000), which Yi *et al.* (2003) mentioned to explain the zone HQ-IIIb change of their HQ98 core. In Greenland ice cores, atmospheric methane record (Blunier *et al.*, 1995) provided parallel variations to those of the monsoon regions, which gives an explanation to the interhemispheric propagation of climate changes within the Holocene (Fig. 10c). The so-called 1500-yr climate periodicity in the North Atlantic (Bond *et al.*, 1997) has not been recognized in the Yangtze valley, though this may be due to the low data resolutions. Some researchers consider glacio-eustatic uplifting as an explanation of relative sea level lowering in the late Holocene (Roberts, 1998; p. 170), but the Yangtze valley is one of the regions providing evidence for warmer hypsithermal conditions based on tens of pollen records.

Zones P3-4 are, though there is no ^{14}C date around there, palynologically correlated with epoch Q_4^3. In the lower Yangtze region, this epoch is characterised by returns of subtropical evergreen trees, and at Cauduntou the replacement of *Ulmus/Zelkova* by *Q. Cyclobalanopsis* around 2500 BP was observed (Okuda *et al.*, 2003). The mixed forest with abundant *Q. Cyclobalanopsis* is reminiscent of the native forest surviving in the Anhui province (Han *et al.*, 2000), possibly representing potential natural vegetation of the lower Yangtze region. Concerning temperature, reconstructed thermal conditions of epoch Q_4^3 were 'warm' (Zheng *et al.*, 1994, 1999), whereas in North America a 'cool and moist' environment was given to the same period, based on the southern migration of boreal forest with simultaneous shrink of prairie grassland after 4500 cal BP (Webb III *et al.*, 1993b). Such intercontinental disagreements may require further researches.

Table 2. Correlations between the Longnan (RN98D) record and the representative pollen stratigraphy and climate history in the lower Yangtze valley, East China (compilation after Zheng *et al.*, 1994).

Holocene epoch in China (^{14}C BP) •climate status	Southern Yangtze Delta (Zheng *et al.*, 1994)	Yao-Ge-Hu area (Tao & Yan, 1987)	HQ 98 core (Yi *et al.*, 2003)	Cauduntou (Okuda *et al.*, 2003)	RN 98D (this study)	Holocene epochs in Europe (cal. BP) •climate status
Q_4^3 (2500-0) •warm, humid	Coniferous and deciduous broad-leaved mixed forest	*Lepidobalanus-Zelkova-Liquidambar-Pinus*	HQ-VI	CDT3-III to VII	P 3-4	Subatlantic (2600-0) •cool, dry
Q_4^{2-2} (5000-2500) •cool, dry	Deciduous broad-leaved forest	*Lepidobalanus-Pinus-Betula-Liquidambar*	HQ-V	CDT3-I to II	P 2	Subboreal (5700-2600) •warm, dry
Q_4^{2-1} (7500-5000) •warmer, wetter	Deciduous and evergreen broad-leaved mixed forest	*Cyclobalanopsis-Castanopsis-Liquidambar*-herb	HQ-IVb		P 1	Atlantic (7800-5700) •warmer, wetter
Q_4^1 (10,500-7500) •cool (and dry)	Coniferous and deciduous broad-leaved mixed forest	*Lepidobalanus-Pinus-Betula*-herb	HQ-III to -IVa		P 1	Preboreal-Boreal (11,500-7800) •(cool~warm) dry

We also note that human impact should be considered as another explanation to the palaeovegetational differentiation in the late Holocene. In this case, however, the human influence to the landscape seems to be relatively small, compared with obviously disturbed cases such as CS-05 (Yu *et al.*, 2000) (see Fig. 4), where Brassicaceae (Cruciferae) became abundant in as early as 5000 BP. In that record, leading components were *Pinus*, Cruciferae, *Artemisia* and various ferns (*Pteris, Hicriopteris, etc*), and the total trees except *Pinus* remained quite low (< 5%) throughout the past 6000 years. Another typical disturbance case is from the detailed 11,000-year pollen profile (E_2 A), Taihu Lake (see Xu *et al.*, 1996), where a clear vegetation change from mixed oak forest to abundant *Pinus* and *Cardamine* (Brassicaceae) was clearly recorded, with the incident age bracketed between 4765 ± 70 BP and 5495 ± 75 BP. In that data Gramineae (Poaceae) were abundant but the abundance is seen in the mixed oak forest of the lower half of the diagram, rather than the *Pinus*/ Brassicaceae phase near the top. The Poaceae most probably originated from wetland grasses (*e.g., Phragmites*) rather than cultivated rice. The point is that our results from Longnan and Cauduntou are basically agreeable with the E_2 A

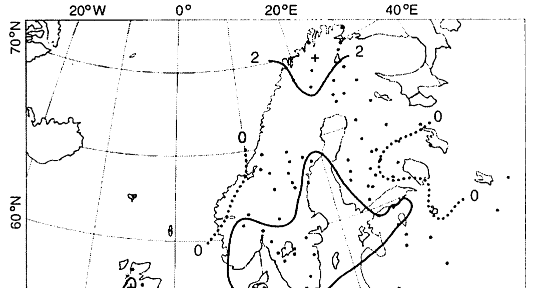

Fig. 9. Reconstructed thermal conditions at 6000 BP of the European continent. Isotherms represent the temperature anomalies from the present, based on the comparison between the compiled fossil and surface pollen datasets (Huntley and Prentice, 1988). Grey dots denote their fossil palynological sites covering 6000 BP.

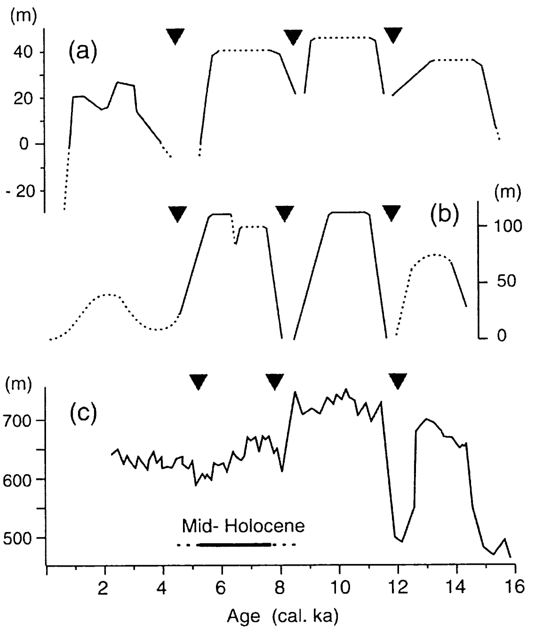

Fig. 10. North African lake level records during the past 15 ka, compared to the atmospheric methane concentration records from ice cores (compilation after Roberts, 1998). (a) Bosumtwi, Ghana (Talbot and Delibrias, 1977); (b) Ziway-Shala, Ethiopia (Gillespie *et al.*, 1983); (c) GRIP, Greenland (Blunier *et al.*, 1995).

record, and yet the onset of the *Pinus*/ Brassicaceae phase, as a regional footprint of human disturbance in the lower Yangtze, was locally delayed around Longnan and Cauduntou. *Fagopyrum esculentum* (buckwheat), effective palynological index for primitive agricultures in China and Japan (*e.g.*, Tsukada *et al.*, 1986), is completely absent in Longnan. We admit that no subdivision is made for cultivated rice from the total Poaceae spectra. The pollen identification of *Oryza sativa* (cultivated rice) becomes possible under the phase-contrast microscope (Nakamura, 1974; Miyoshi, 1985), expecting future researches. Palynologically, zone P4 is analogous to zones CDT-3 VI to VII of the Cauduntou record, indicating unambiguous human disturbance in the late Bronze Age (ca. 1000 BP or so) around the inland areas west of the Yangtze delta.

Conclusions

As a part of the overseas expeditions in 1998-9 in and around the Yangtze delta, the Longnan site was selected initially aiming at detecting the Neolithic human activities of Majiabang, Songze or Liangznu cultures back to 7000 BP, whereas the Cauduntou site was expected to reconstruct the natural vegetation of

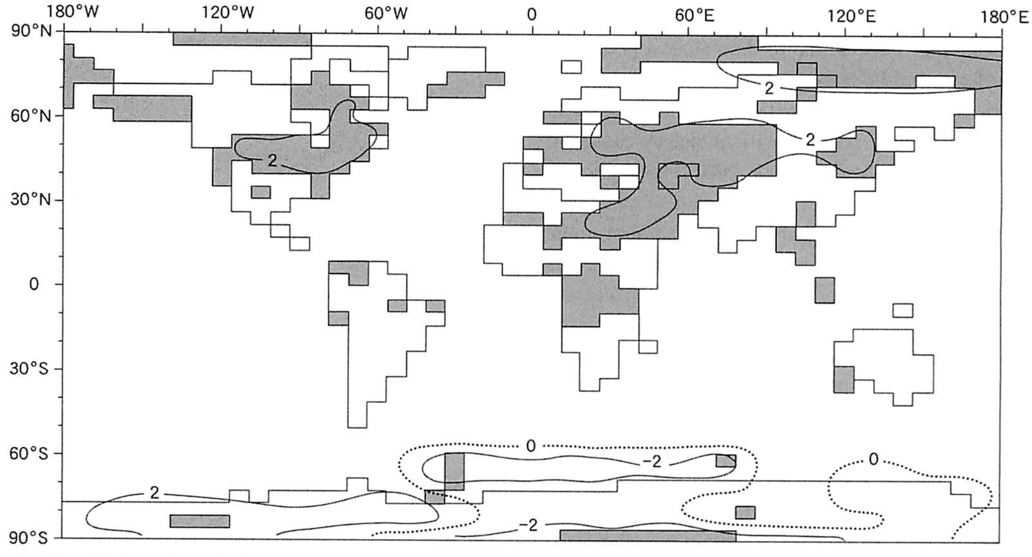

Fig. 11. GCM-simulated July temperature distribution at 6000 BP mapped as anomalies from the present (°C) (Kutzbach *et al.*, 1993), as a result of the COHMAP climate-model experiments (see Webb III *et al.*, 1993a).

the lower Yangtze valley. These research scopes were actuarised by half, and the Cauduntou record had provided temperate-mixed forest of evergreen/deciduous oaks under modern-type climate after 2500 BP. By contrast, the Longnan record provided subtropical evergreen broad-leaved forest in the early / mid-Holocene followed by the mixed oak forest in the late Holocene, extending quasi-natural vegetation history of the lower Yangtze region back to 9000 BP. Although there have been suggestions that the classic early/mid-Holocene warming theory is not sufficient to explain the 9000-yr vegetation history of Europe (*e.g.*, Huntley and Prentice,1993), the lower Yangtze is one of the regions that indicate hypsithermal warming, with 2°C isotherm (anomaly from the present) based on palaeoclimate proxy records (Fig. 8) and numerical model simulations (Fig. 11). The amplitude of the hypsithermal warmth is rather controversial in East Asia, and refined quantitative reconstruction (Nakagawa *et al.*, 2002) may be required under comparisons with recent surface pollen datasets (Okuda, 2005; Okuda *et al.* 2005, *etc*).

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中国江蘇省龍南遺跡等の花粉分析に基づく長江下流域の完新世植生および環境史

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中国・江蘇省南東部（太湖湖畔）に位置する龍南遺跡近郊から採取したボーリングコア（RN98D）に対して花粉分析および炭素14年代測定をおこなうと同時に，周辺域における既存の化石花粉データ群との比較検討を通じて長江（揚子江）下流域の過去9000年間の植生変遷と環境変動を取り纏めた．これは千葉県立中央博物館の平成12-13年度海外出張成果であり，また平成9-13年度文部科学省COE形成基礎研究費（課題番号09CE1001・代表者安田）に研究協力者として参加した成果である．また千葉中央博専門研究「東アジアおよび環太平洋域の植生変遷と環境変動」の成果の一部である．長江流域は日本列島太平洋岸から延びる暖温帯照葉樹林の中国側の北縁にあたり，植物地理的に房総を含む南関東地方と類似の条件下にあるが，紀元前からの著しい人間活動のため植生の改変の度合は日本列島の比でなく，原植生の情報源としての花粉の役割は重要である．RN98Dコアの花粉分析結果は，完新世前～中期（9000-5000年前）に関してはシイ属/マテバシイ属とコナラ属アカガシ亜属の優占する南中国型の暖温帯（～亜熱帯）照葉樹林を，5000-3000年前に関してはアカガシ亜属にイネ科草本が混生する疎林状の混交林を，約3000年以降に関してはアカガシ亜属が優占する常緑～落葉混交林を復元した．これは周辺化石花粉データの取り纏め結果とも矛盾せず，長江下流域における平均的な完新世植生史と考えられた．7000-6000年前後のいわゆるヒプシサーマル期の温暖気候とその後の冷涼気候との相違が認められた．長江河口域の新石器文化の植生への影響は完新世前～中期で比較的微弱であり，集約的農耕を明示する人間活動の記録は1000-2000年前頃，マツ属とアブラナ科花粉の急増によって示された．2500-2000年前前後に存在していたアカガシ亜属を主とする常緑落葉混交林が長江下流域の潜在自然植生に相似している可能性がある．人間活動と原植生との関係に関しては，龍南の西方150kmの朝敦頭遺跡における花粉分析結果（Okuda *et al*., 2003）との調和に基づいて議論されている．