CHINESE GEOGRAPHICAL SCIENCE
Volume 5, Number 3, pp. 232-241, 1995
Science Press, Beijing, China

RECONSTRUCTION OF PALEOVEGETATION AND PALEOCLIMATE OF HOLOCENE HYPSITHERMAL IN THE HEMUDU REGION

Zhou Zikang (周子康)　Xia Yuejiong (夏越炯)　Liu Weilun (刘为纶)
(*Department of Geography, Hangzhou University, Hangzhou* 310028, *PRC*)
Wu Weitang (吴维棠)
(*Zhejiang Natural Museum, Hangzhou* 310012, *PRC*)

ABSTRACT: In this pater, the paleovegetation and paleoclimate in the Hemudu region of Zhejiang Province during 7000 to 6000 a B. P. are reconstructed. Firstly, using Andersen's method, a correction is made for the percentage of pollens of various plants excavated at Hemudu Site. Secondly, on the basis of the results, the dominant species and constructive species and types of zonal forest vegetation are identified, then the paleovegetation of Holocene Hypsithermal is reconstructed. Finally, by contrasting the above mentioned paleovegetation with the vegetation of Wuyanling Natural Reserve (WYLNR) in south Zhejiang and Dinghushan Natural Reserve (DHSNR) in Guangdong today, and on the analogy of above results, the paleoclimate is also reconstructed.
KEY WORDS: Holocene, paleoclimate, paleovegetation, Hemudu

I. INTRODUCTION

Hemudu Site is situated at the southern bank of Hangzhou Bay, 25 kilometers east of Yuyao City. It lies in the intersection of 29°58' North Latitude and 121°22' East Longitude. It is one of the important sites of neolithic age in China.

Four cultural layers (about 7000 to 5100 a B. P.) can be classified according to the characteristics of excavated animal and plant remains from different layers at Hemudu site. Much remains and sporo-pollen were found in the third and fourth layers (about 7000 to 6000 a B. P.). They are the reliable data for understanding the zonal vegetation and climate during the above period. In the past years a number of work has been done on the study of the pale-

ovegetation and paleoclimate in the Hemudu region during 7000 to 6000 a B. P., and great achievements have been obtained[1-9]. However, the problems are worthy to be further studied, because they are very important frames of reference for the possible extremes of mankind life-supporting environment in the future[10-11].

According to the needs, this paper attempts to rearrange and analyse the data mentioned above for the purpose to solve the following major questions: identifying the dominant species and the floristic composition of zonal forest vegetation so as to reconstruct the paleovegetation of Holocene Hypsithermal in the Hemudu region; reconstructing the paleoclimate through making a comparison among the paleovegetation and the vegetation of WYLNR in southern Zhejiang and DHSNR[12,13] in Guangdong at present, and by analogy. It is the main aim of this paper to provide some valuable information for possible future change trend of life-supporting environment in the eastern China.

II. THINKING AND APPROACH

The reconstruction of zonal vegetation wants to analyse the layers of tree, shrub and herb. When the marked changes of climate occur, trees, which are taller and bigger than others, will change greatly in first (including the displacement between zones). So it is highly important to judge the geographic floristic composition of tree.

Due to great difference in many aspects of spore and pollens among plants, such as production rate, size, shape and diffusivity, etc., the genera or species and their quantity in a deposit do not present the same rate with that in the nearby region where they lived then. A correction must be made for the percentage of pollens of various plants obtained from deposits. Clearly, it is one of the keys raising the accuracy of the reconstruction of paleovegetation. Andersen[6] had put forward following correction rate for the percentage of pollens of various plants obtained from deposits:

Quercus, *Betula*, *Alnus*, *Pinus*	1:4
Carpinus	1:3
Ulmus, *Picea*	1:2
Fagus, *Abies*	1
Tilia, *Eurya*	2

Based on above considerations, we will proceed as follows. Firstly, after Andersen's fashion, a correction is made for the percentage of pollens, and the dominant species of the zonal vegetation are identified, then paleovegetation in the Hemudu region during 7000 to 6000 a B. P. is reconstructed. Secondly,

through contrasting this paleovegetation with vegetation in WYLNR and in DHSNR respectively belonging to central subtropics and south subtropics at present, and combining it with the distribution of biotic extant species (or genera), the main climatic characteristics in the Hemudu region in the period of 7000 to 6000 a B. P. are also judged.

III. RECONSTRUCTION OF THE PALEOVEGETATION

1. The Geographic Floristic Composition of Seed Plants

Based on the analyses of the sporo-pollen and remains of plants unearthed from the third and fourth layers at Hemudu Site, there are 64 families with 85 genera in all, including 48 families with 63 genera of seed plants. They contain main families of the subtropical zonal forest vegetation , such as Fagaceae, Lauraceae, Theaceae, Magnoliaceae, Rutaceae, Moraceae, Euphorbiaceae, Styracaceae, Chloranthaceae, Hamamelidaceae and Aquifoliaceae, etc.

Table 1 shows the floristic composition of seed plants in the Hemudu region during 7000 to 6000 a B. P. There are 20 genera representing elements of tropical flora (making up 31. 7% of the total genera number), in which 7 genera belong to Indo-Malaysia elements.

It indicates that elements of tropical Asia flora occupy a relative dominant position in tropical flora. On the other hand, there are 19 genera representing elements of north temperature flora. This reveals that the paleovegetation in the Hemudu region was strongly influenced by north temperate elements. By the way, it is notable that in ferns the number of genera belonging to tropical flora possesses 50% of total genera number.

2. The Identification of the Dominant Species and Types of the Zonal Vegetation

According to the analyses by Wei Fen and Wu Weitang[9], there were many kinds of geographical landscape types near the Hemudu region during that period, such as low mountains, hilly lands, plain, river and lake, swamp, forest, grassland, etc. , so some non-zonal vegetation types were then developed.

The zonal vegetation can reflect the basic characters of macroclimate, so the identifying of the dominant species and types of the zonal vegetation has become a key for dissecting the paleovegetation and paleoclimate.

Table 1 Florical compositions of seed plants in the Hemudu region (7000-6000 **a B. P.**)

Type	Taxa (genera)
1. Cosmopolitan	*Gentiana*, *Rubus*, *Rhamnus*, *Chenopodium*, *Carex*, *Polygonum*, *Typha*, *Phragmites*, *Myriophyllum*, *Potamogeton*
2. Pantropic	*Celtis*, *Ficus*, *Ilex*, *Styrax*
3. Trop. Asia &Trop. Amer. disjuncted	*Phoebe*, *Litsea*, *Eurya*
4. Old World Tropics	*Melia*
5. Trop. Asia & Trop. Australasia	*Cinnamomum*, *Mallotus*
6. Trop. Asia &Trop. African	*Lagenaria*, *Oryza*
7. Trop. Asia(Indo-Malaysia)	*Engelhardtia*, *Lindera*, *Altingia*, *Chloranthus*, *Castanopsis*, *Marraya*, *Coix*
8. North Temperate	*Salix*, *Myrica*, *Juglans*, *Alnus*, *Betula*, *Carpinus* *Corylus*, *Quercus*, *Fagus*, *Ulmus*, *Rhus*, *Acer*, *Spiraea*, *Tilia*, *Lonicera*, *Artemisia*, *Rubia*, *Pinus*, *Sparganium*
9. East Asia & North Amer. disjuncted	*Carya*, *Liquidambar*, *Magnolia*, *Netumbo*, *Caulophyllum*
10. Old World Temperate	*Zelkova*, *Trapa*, *Prunus*
14. East Asia	*Cyclobalanopsis*, *Deutzia*, *Choeropondias*, *Actinostemmo*, *Euryale*, *Pterocaraya*
15. Endemic to China	*Camptotheca*

Generally, the tree whose pollens present the higher frequency and mean percentage in all 19 samples should take the first place in deciding vegetation type. Table 2 shows the frequency and mean percentage of pollen and spore of various plants. In Table 2, the correction rates of evergreen broad-leaved trees are taken as 2, being the same as *Tilia*, whose leaf growth is before blooming. The correction rate of *Liquidambar*, whose leaf growth is associated with blooming, is regarded as 1. A lot of plant remains (leaves and seeds) have been observed in the fourth layer: *Phoebe sheareri*, *Quercus gilva*, *Cinnamomum chingii*, *Castanopsis tibetana*, *Quercus myrsinaefolia*, *etc.*

As shown in Table 2 and Table 3, *Altingia chinensis*, *Castanopsis sclero-*

phylla and C. tibetana, *Quercus gilva and Q. myrsinaefolia*, *Cinnamomum chingii and Liquidambar formosana*, etc., can be regarded as the dominant species of zonal forest vegetation in the Hemudu region during that period. Particularly, *Altingia chinensis*, *Castanopsis sclerophylla and C. tibetana* possess higher frequency and the highest mean percentage of the pollen in 19 samples. The above species are named "constructive species".

Table 2 Frequency and mean percentage of spore and pollen of main plants at Hemudu Site (7000—6000 **a B. P.**)

	Frequency	Mean percentage* (%)	
		Main tree plants	
Altingia	5/10	5.3	(10.6)
Gastanopsis	14/19	2.1	(4.2)
Quercus	17/19	12.3	(3.1)
Liquidambar	14/19	3.0	(3,0)
Myrica	5/19	0.6	(1.2)
Fagus	5/19	1.1	(1.1)
Ulmus	11/19	2.0	(1.0)
Mallotus	8/19	0.7	(0.7)
Zelkowa	5/19	1.2	(0.6)
Pinus	16/19	2.1	(0.5)
		Main spore plants	
Lygodiaceae	7/19	1.9	
Polypodiaceae	7,19	0.6	
Osmunda	5/19	0.5	

* *The numbers within brackets stand for corrected values.*

Reconstructed zonal vegetation in the Hemudu region during 7000 to 6000 a B. P. is shown in Table 3. In contrast to the vegetation in WYLNR, the southern elements of flora in Hemudu region are far more. However, in contrast to the vegetation in DHSNR, the south elements of flora are far less.

In summary, the main characters of paleovegetation in the Hemudu region during 7000 to 6000 a B. P. are as follows.

1) So far as floristic composition of seed plants, tropical element accounts for 31.7% of the total genera number, in which tropical Asia element is in a relative dominant position. North temperate element strongly influences the vegetation composition in the Hemudu region. In zonal forest vegetation, central

Table 3 Reconstructed zonal vegetation in the Hemudu region during 7000 to 6000 a B. P.

Layer	Scientific name	Layer	Scientific name
Tree	*Altingia chinensis*	Shrub	*Lindera chienii*
	Castanopsis sclerophylla		*L. glauca*
	C. tibetana		*Litsea cubeba*
	Liquidambar formosana		*Ilex* sp.
	Phoebe sheareri		*Ficus beecheyana*
	Cinnamomum chingii		*Deutzia* sp.
	Q. gilva		*Chloranthus fortunei*
	Engelhardtia		*Eurya* sp.
	Mallotus paniculatus	Herb	*Microsorium superficiale*
	Quercus sp.		*Lemmaphyllum carnosum*
	Melia azedarach		*Pyrrosia martinii*
	Camptotheca acuminata		*Phymatopsis hastata*
	Murraya paniculata		*Polypodium* sp.
	Rhus sp.		*Lepidogrammitis*
	Tilia sp.		*Belvisis* sp.
	Choerospondias axillaris		*Lepisorus* sp.
	Alnus sp.		*Osmunda* sp.
	Betula sp.		*Hicriopter is laevissima*
	Carpinun sp.		*Loxogramme chinensis*
	Celtis sp.		*Sinopteris* sp.
	Ulmus sp.		*Plagiogyria simulaus*
	Zelkova sinica		*Pteris subsimplex*
	Carga sp.		*Dryopteris* sp.
	Petero carya		*Araiostegia yunnanensis*
	Fagus lusida		*Humata* sp.
	Myrica sp.		*Davallia* sp.
	Pinus sp.		*Ophioderma pendula*
	Acer sp.		*Selaginella* sp.
	Prunus davidiana		*Lycopodium* sp.
	Juglans sp.		*Chenopodium* sp.
	Styrax sp.		*Rubia cordifolia*
Shrub	*Lonicera hypoglauca*		*Coix* sp.
	Rubus sp.		*Carex* sp.
	Magnolia coco(?)		*Caulophyllum*
	Rhamnus sp.		*Gentiana heterophylla*
	Corylus sp.	Climbing	*Lygodium polystachum*
	Spiraea blumei		*L. salicifolium*
			L. microstachyum

Vegetation type	Broad-leaved forest
Vegetation Subtype	Subtropical evergreen and deciduous broad-leaved mixed forest
Association	*Castanopsis*+*Altingia*+*Quercus-Lindera*-Polypodiaceae

and south subtropic elements make up 73% of the total genera number of tree

plants. In tree and shrub, no typical tropical species is discovered.

2) The dominant species are *Altingia chinensis*, *Castanopsis sclerophylla*, *C. tibetana*, *Quercus gilva*, *Q. myrsinaefolia*, *Cinnamomum chingii and Liquidambar formosana*, etc.

3) The constructive species are *Altingia chinensis*, *Castanopsis sclerophylla* and *C. tibetana*. Their coexisted area belongs to the southern part of Central

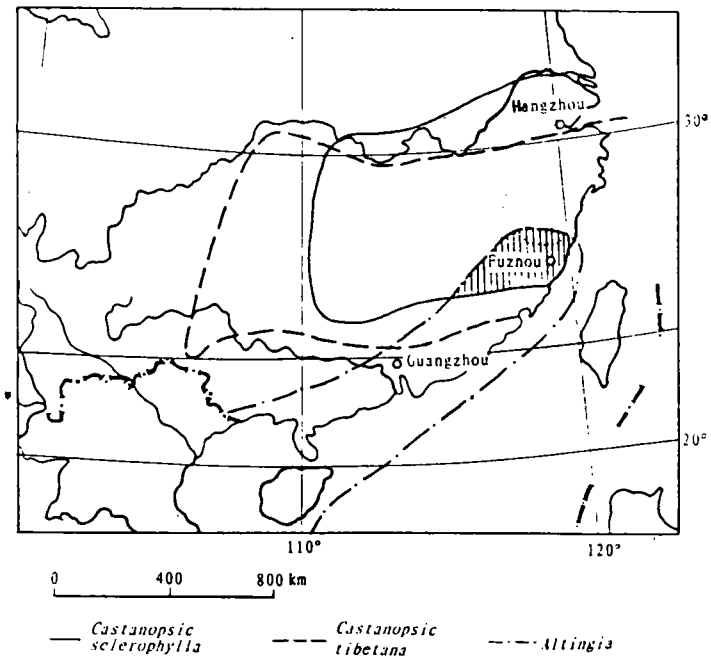

Fig. 1 Present distribution areas of *Castanopsic sclerophylla*, *C. tibetana and Altingia chinensis* in China

Subtropical Zone in China at present (Fig. 1).

4) In ferns, there are tropical species, and the south subtropical and tropical elements are more than others.

5) The zonal vegetation type is a subtropical evergreen and deciduous broad-leaved mixed forest. The association is *Castanopsis*+*Altingia*+*Quercus* (*glauca*)-*Lindera*-Polypodiceae.

IV. RECONSTRUCTION OF THE PALEOCLIMATE

1. Present Distributions of Some Biotic Extant Species or Genera Unearthed at Hemudu Site

Table 4 shows the present distributions of some biotic extant species or

genera unearthed at Hemudu Site. From Table 4 we see that many extant species or genera of plants can only be found in southern Zhejiang or even in the southern subtropical and tropical regions at present, such as *Altingia chinensis*, *Ophioderma pendula* and *L. salicifolium* etc. The remains of the elephant (*Elephas maximus*) and Rhinos (*Rhinoceros* sp.) also have been found here. It is reported that in the region where the elephant is living, the mean January temperature must be above 10℃. Above facts reveal that the climate was then warmer and damper than the present, particularly in winter.

Table 4 Present distribution of some biotic extant species (or genera) unearthed at Hemudu Site in China

Scientific name	Distribution areas *	Climatic zones * *
Altingia chinensis	F,Gd,Ha,Zs	c—t
Engelharditia	Zs, F,Gd,Gx,S,Y	c—t
Choerospondias axillaris	Zs,F,Gd, Hu	c—t
Quercus gilva	Zs,F,Hu,T	c—t
Murraya paniculata	Gd,Gx,Hu,Gz,Y	s—t
Ophioderma pendula	Y,Ha,T	t[8]
Lygodium microstachyum	Gd,Gx,F,Gz	s—t[15]
L. salicifolium	Y,Ha	t[8,16]
Microsorium superficiale	Y	t[8]
Loxogramme chinensis	Zs,Gd,F,Y,Gx	c—t
Lemmaphyllum carnosum	Y,Gd,Ha,T	s—t[8,17]
Rusa unicolor	T,Gd,Y	s—t
Rhinoceros sp.	Malaya,Indonesia	t
Elephas maximus	Y	t
Macaca speciosa	Y,S,Gd,Gx,F	s—t

* F—Fujian, Gd—Guangdong, Gx—Guangxi, Gz—Guizhou, Ha—Hainan, Hu—Hunan, S—Sichuan, T—Taiwan, Y Yunnan, Zs—Southern Zhejiang

* * C—Central subtropical zone, s—South subtropical zone, t—torrid zone

2. Reconstruction of Paleoclimate

It is evident from the foregoing discussion that the paleoclimate in the Hemudu region during 7000—6000 a B. p. was similar with the today's climatic

conditions between WYLNR and DHSNR. Properly speaking, it was similar with the climate of the shaded area in Fig. 1 at present.

Table 5 shows the climatic element values in WYLNR and DHSNR. By analogy with Table 5 and Fig. 1, the chief element values of paleoclimate in the Hemudu region during 700—6000 a B. P. are obtained: mean annual temperature is about 19—20℃ (3—4℃ higher than the present) with mean January temperature around 10—11℃ (6—7℃ higher than it is today), mean annual precipitation is about 1700—1800mm(400—500mm more than the present). In summary, it corresponds roughly to the climate in northern Fujian in China today.

Table 5 Climatic element values of WYLNR in southern Zhejiang and DHSNR* in Guangdong

	WYLNR	DHSNR	Yuyao
Mean annual temperature (℃)	17.5—18.0	20.9	16.2
Mean temperature in January (℃)	7.5— 8.0	12.0	4.1
Mean annual rainfall (mm)	1600—1800	1900	1300

* data from Kong Guohui et al., 1993

ACKNOWLEDGEMENT

The authors are much grateful to Prof Wei Zhi and Wu Shaoji for their helpful comments and suggestions during the preparation of the paper.

REFERENCES

[1] 曾骐，蒋乐平. 长江下游新石器时代文化的考古学年编. 见：中国原始文化论文集. 北京：文物出版社. 1989.

[2] 中国社科院考古所. 中国考古学中碳十四年代数据集. 北京：文物出版社. 1983.

[3] 吴维棠. 从新石器时代文化遗迹看杭州湾两岸的全新世古地理. 地理学报，1983，38(2)，113—115.

[4] 吴维棠. 7000年来姚江平原的演变. 地理科学，1983，3(3)，269—275

[5] 龚高法，张丕远，张瑾. 历史时期我国气候带的变迁及生物分布界限的推移. 历史地理，1987，(5)，1—10.

[6] Lamb H H. 气候的变迁和展望. 汪奕琮译. 北京：气象出版社. 1987.

[7] 浙江省博物馆自然组，河姆渡遗址动植物遗存的鉴定研究. 考古学报，1978，(1)：95—105.

[8] 孙湘君，杜月秋，陈明洪. "河姆渡"先人生活时期的古植被. 古气候. 植物学报，1981，23(2)：146—151.

[9] 魏丰，吴维棠，张明华. 浙江余姚河姆渡新石器时代遗址动物群. 北京：海洋出版社. 1990.

[10] Ye Duzheng et al. Global Change Report(No. 1). China Meteorological Press, 1993.

[11] 叶笃正. 中国的全球变化预研究. 北京：气象出版社. 1992.
[12] Kong Guohui et al. Dinhushan Biosphere Reserve, Ecological research history and perspective, Beijing New York, 1993.
[13] 中国科学院鼎河山森林生态系统定位研究站编. 热带亚热带森林生态系统研究. 广州：科普出版社广州分社，1982.
[14] 张永田. 从壳斗科植物的分布试谈武夷山自然保护区植物区系特点. 武夷山科学，1981，(1)，47—56.
[15] 候学煜，指示植物. 北京：科学出版社，1954
[16] 宋文琛. 孢子花粉分析. 北京：科学出版社，1985.
[17] 胡先. 经济植物手册. 北京：科学出版社，1955