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Average Annual Temperature Changes in the Holocene in China

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Abstract In 1876 Blytt proposed a post–glacial climatic classification, maintaining that the then temperature fluctuated 1–2℃ higher or lower than that today. Lamb (1969) held that in Europe " the axis of the subtropical high pressure belt was generally displaced north by about 10° latitudes" during the Hypsithermal and that the temperature was three to six times higher than that in the postglacial period.

In China, there appear relict beachrocks (living fossils) in tropical tidal zones from the Bohai Bay (40° N) to coastal areas in South China. Many relict tropical marine fossils were discovered, such as *Ostrea gigas* in Tianjin (which is larger than that found today in Hainan), *Placuna placenta* in Zhejiang and *Spondylus* sp. in Fujian. In Hebei, Henan and Zhejiang provinces and Guilin of Guangxi, such tropical fossil animals as *Elephas maximus* and *Rhinoceros* sp, were discovered, and in Hebei and Jiangsu provinces such fresh water fossils as *Unio douglasiae* were found. Their living species are still seen in South China today. Skeletons of Banpo Man discovered at Xi' an are more similar to those of the " South Chinese race, and human skulls found at Guilin possess characteristics of the "Australoid–Negroid race".

All phenological evidence shows that the average annual temperature of every warm phase in the Holocene in China was 10–15℃ higher than the present temperature in North China and 10℃, 7℃ and 2℃ higher than the present values in Zhejiang, Fujian and Hainan, respectively.

Key words: Holocene temperature of China, range of average annual temperature changes, a cycle of about 500 years, Hypsithermal, historical records, beach rock, tropical fossil animal

1 Introduction

The range of Holocene temperature changes is a complex, difficult and sensitive problem. A.G.Blytt, a Swedish geologist, put forward a classification of post–glacial climate in 1876, which was later refined by J.R.Sernander, a Swedish botanist. Based on this classification the postglacial period is divided into the Preboreal, Boreal, Atlantic, Subboreal and Subatlantic climatic intervels. This scheme holds that Holocene temperatures have a fluctuation range of 1–2℃ upwards or downwards under present temperature conditions. However, Lamb considered (1969) that " the axis of the subtropical high pressure belt was generally displaced northwards by 10 latitudes" in Europe, which was three to six times higher than that estimated by Blytt–Sernander (1–2℃ upwards).

Some phenological evidences of the Holocene Hypsithermal have been discovered in many countries, tropical and subtropical evidences (observed in China).

2 Cycle of Holocene Climatic Changes and the Blytt Division

Based on the phenological evidences recorded in the Chinese history and the dating of beachrocks, animals, glaciers and sea–level changes, we have revealed that the cycle of Holocene climatic changes is about 500 years in China with either the cooling or the warming phase spanning half of this cycle, i.e. about 250 years (Bi and Yuan, 1988, 1993).

The climatic classification proposed by Blytt–Sernander more than 100 years ago is far from perfect. In fact, it was formulated only based on insufficient age data and limited research. For instance, it holds that for the Hypsithermal occurring in 7700–3300 BC and the cool intervel in 5500–4500 BC the first two ages mark a warming phase and the last two indicate a cooling phase, but many warming and cooling phases that occurred in the Hypsithermal and cool intervels are not mentioned in this scheme, such as glacier advances occurring at about 8500, 7500, 5000, 4500, 4000, 3500, 3000, 2500, 2000, 1500, 1000 and 500 a B.P. discovered in the northern hemisphere (Bi and Yuan, 1993). Besides, marine and terrestrial fossil animals of the tropics and south subtropics of 7580, 7235, 6310, 5600, 5140, 4690, 3830, 3200 and 2747 a B.P. have been found in the present temperate and subtropical zones of China (Bi and Yuan, 1993).

Research results both in China and other countries show that Holocene phenological study is going in depth day by day, while the Holocene climatic classification of Blytt–Sernander is somewhat out of date. Therefore, it is necessary to cast off the trammels of this classification in order to quicken the study of Holocene climate.

3 Holocene Phenological Features

In his paper on climatic changes in the past 5000 years, Chu Ko–chen, a famous Chinese professor in phenology, suggested that the average annual temperature was about 2℃ higher than the present one with a 2–3℃ fluctuation (Chu, 1973). No data have been registered yet for a period as long as more than 2000 years (5600–3400 a B.P.) and even the data for the past 3000 years are disjointed. Therefore, it was impossible to have a thorough study of the average annual temperature changes at that time.

As early as 1944, Prof. Hu Houxuan suggested in his paper entitled "Climatic Changes and a Study of the Climatic Conditions of the Yin Dynasty" that the temperature of the Yellow River Valley of 3000 years ago was as warm and moist as that of the present Yangtze River Valley (Hu, 1944). Jia Lanpo (1980), the world–renowned archaeologist, concluded that " the climate at that time was much warmer than the present" and " the climate of North China was just the same as the present climate of South China" through studying the tropical fossil animals *Elephas maximus, Rhinoceros sumatrieasis* and *Pavo* sp., at the ruins of Xiawanggang, Zhechuan County of Henan Province (Chia and Chang, 1977), *Elephas maximus* (3830+85–3630+90 a B.P.) from the Dingjiabao Reservoir of Yangyuan County, Hebei Province, and such fresh water fossils as *Corbicula aurea*, the living species of which occurs in South China today, that is to say, in North China the temperature of the Holocene Hypsithermal was about 10℃ higher than the present.

In what range did the Holocene temperatures change in China? The answer should come out of actual climatic data rather than others' preceding assertions.

Table 1 Holocene marine and terrestrial phenological evidence and changes of average annual temperatures in China

Sampling locality	Sample and ^{14}C age (B.P.)		Migrating latitude of phenological sample		Average annual temperature (℃)			Data source	Remarks
	Sample	Age	Present area	Migrating latitude	Sample area	Present area	Range of change		
Rushan, Shandong 37° N, 121° 30′E	Beachrock; *Sanguinolaria virescens*	3770 ± 100 4115 ± 130	South of 16° N	21°	11°	26°	15°	Bi and Yuan, 1991 Han, 1986	Tropical beachrocks and fossils
Xiangshan, Zhejiang 30° N, 122° E	Beachrock; *Placuna placenta*	3210 ± 170 * 3765 ± 170	South of 16° N	14°	16°	26°	10°	Bi, Yuan and Wen, 1992; * Ma et al., 1993	Tropical beachrocks and fossils
Putian, Fujian 25° 30′N, 119° E	Beachrock; *Spondylus* sp. etc.	2747 ± 100	South of 16° N	9°	20°	26°	6°	Bi and Yuan, 1991, 1992	Beachrocks and tropical fossils
Tianjin coastal areas 39° E, 117° 30′E	*Ostrea gigas*	3705 ± 180 Holocene	South of 20° N	19°	12°	24°	12°	Bi and Yuan, 1991	Up to 46 cm long
Jurong, Jiangsu 32° N, 119° 10′E	*Unio douglasiea* etc.	5145 ± 84	South China	7°	15°	19°	4°	Cao et al., 1989	
Yangyuan, Hebei 40° 6′N, 114° E	*Cobicula aurea* etc.	3630 ± 90 3830 ± 85	South China	15°	6°	19°	13°	Jia et al., 1980	
Yangyuan, Hebei 40° 6′N, 114° E	*Elepas maximus*	3630 ± 90 3830 ± 85	Xishuangbanna, Yunnan	18°	6°	22°	16°	Jia et al., 1980	
Anyang, Henan 36° N, 114° E	*Elepas maximus* *Phinoceros* sp.	1365–1324?BC. 3340 ± 155 *	Xishuangbanna, Malai Peninsula	14°	12°	22°	10°	Hu, 1944; * Qiu, 1972	
Yuyao, Zhejiang 30° N, 121° 10′E	*Elephas maximus* *Phinoceros* sp.	6310 ± 100 *	Xishuangbanna, Yunnan	8°	16°	22°	6°	Zhejiang Museum, 1978; * Cai et al., 1985	
Zengpiyan, Guilin 25° N, 110° 20′E	*Elephas maximus* etc., human skeletons	7580 ± 410 11310 ± 180	Xishuangbanna, 10° N ±	3° 5°	19° 19°	22° 26°	3° 7°	Li et al., 1978; Zhang et al., 1977	
Banpo, Xi' an 34° 20′N, 109° E	Human skeletons *Hydropotes inermis*	5600 ± 105 * 6065 ± 110	South China	6° 3–4°	13° 13°	17° 16°	4° 3°	Li et al., 1978; Zhang et al., 1977; * Ji, 1985	Human skulls characterized by "Australoid–Negroid race"
Kano, Xichang 31° N, 97° 10′E	*Hydropotes inermis*	4690 ± 105	South China		7.6°	16°	8°	Ji, 1985	Human skulls much closer to those of the "South Chinese race"

What is the reality of China' s climatic changes? (1) Many tropical and subtropical fossil animals which lived in marine and terrestrial areas have been discovered in present temperate zones, plateau areas and subtropical areas of China. Table 1 lists part of the evidences for the above. (2) Many phenological evidences have been found in marine strata of the coastal zones, extending more than 18,000 km and crossing 38 middle–low latitudes from temperate zones through the subtropics to the south tropics. (3) China' s winter is the coldest among the countries at the same latitudes in the world. For example, the average annual temperature in January is lower than those of the same latitude areas and the difference is 14–18℃ for Northeast China, 8℃ for the Yellow River Valley, 5℃ for the South Yangtze Valley and about 5℃ for the coastal areas of South China (Atlas of China, 1984).

The phenological characteristics of China' s Holocene climate, including inorganic and organic, animal and plant, and marine and terrestrial evidences, which can prove one another, show that the range of temperature changes of the Holocene warm phases was very large as compared with that at present.

3.1 Phenological features of beachrocks

The beachrock is a rock composed of bioclasts and terrigenous clasts and cemented by aragonite or high–magnesian calcite in a special environment of tropical or subtropical coasts (Yuan et al., 1989; Bi, Yuan and Wen, 1992; Bi and Yuan, 1993). This rock possesses the following characteristics: aragonite and high–magnesian calcite transform into calcsparite on land in most cases; the average annual temperature for its formation is over 26.5℃ (Bi et al., 1991); the formation cycle is about 500 years with the genetic phase and interrupting phase being about 250 years respectively; and during every warm phase and every small warm phase in the Holocene, the beachrock–forming areas advanced northwards extensively, while during every cooling phase they moved southwards to a great extent (Bi and Yuan, 1991, 1993). Therefore, beachrock serves as a " living fossil" (a kind of moving–rock) for studying ancient environments and palaeoclimate and also a thermometer and timetable for temperature changes.

The authors first discovered the beachrock–forming cycle of about 500 years and then developed a sequence dating model of Holocene beachrocks, followed by the sequence dating models for Holocene tropical and subtropical strata, Holocene glacial strata and Holocene coastal uplift and subsidence (cycle) (Bi and Yuan, 1988, 1993; Bi, Yuan and Wen, 1992). These models show that beachrocks are the strata favourable for Holocene climatic and environmental changes.

During every warm phase (about 250 years) of the climatic cycle (about 500 years), the beachrock–forming areas gradually advanced northwards from south to the Xisha Islets and expanded to the coasts of Guangdong, Fujian, Zhejiang and Shandong provinces early or late; while in a cooling phase (semicycle of about 250 years) between two (small) warm phases, according to the data up till now, the coasts and islets from 40° –16° N (the Xisha Islets) were not good for beachrock formation. Since 2850 a B.P., beachrocks have been deposited and formed in Zhejiang, Fujian and southern Hainan provinces early or late in some small warm phases (Bi and Yuan, 1993; Bi, Yuan and Wen, 1992).

3.2 Phenological features of marine animal fossils (remains)

There were many widely dispersed Holocene remains of *Ostrea gigas* along the Tianjin coast. The thickness may reach 5–6 m and the average length was about 30 cm. The largest one is over 46 cm (Licent and De Chardin, 1927; Bi et al., 1991). The living ones in Hainan are mostly less than 30 cm in length.

Larva and adult fossil shells of *Sanguinoloria virescens* (Bi, Yuan, 1991) are found in beachrocks in Rushan of Shandong Province.

On the Xiangshan coast of Zhejiang Province, the authors discovered *Placena placenta* remains in Holocene beachrocks, belonging to present South Sea species. According to existing data (Ma, 1993), there are *Trochus niloticus* fossils in beachrocks of Xiangshan, Zhejiang, dated 4110 ± 110, 3765 ± 170 and 3210 ± 170 a B.P. and the *Mactra grondis* fossil has been found in beachrocks of Daishan of Zhejiang, dated 2770 ± 40 a B.P. The living species of the former was found in the Xisha Islets while the latter is the Pacific tropical produce (Ma et al., 1993).

In the high beachrock at Putian, Fujian Province, which has an elevation of 38 m, the authors have discovered many genera and species of tropical marine macrofossils in the horizon of 26 m dated 2747 ± 100 a B.P. and 2–5.5 cm in diameter, such as *Trochus* sp., *Spondylus* sp., *Duncanopsommia* sp., *Lunella* sp., *Septifer exsisas, Nerita* sp. and *Turbo cornatas* (Bi, Yuan and Wen,1992; Bi, Yuan and Yang, 1992; Bi and Yuan, 1994, 1998).

These tropical animals once bred on the continental coasts of China show that these areas were the tropical climatic areas in every warm phase.

3.3 Phenological Features of Fresh Fossils

In Holocene strata in the Dingjiabao Reservoir of Yangyuan County, Hebei, there occur lamellibranch fossils of *Unio douglasiae, Lamprotula bazini* and *Corbicula urea* etc., dated 3830 ± 85–3630 ± 90 a B.P. (Jia et al., 1980). Their living species are distributed in South China and areas to the south of the Yangtze River.

In the strata in Baohuashan of Jurong County, Jiangsu Province, there occur lamellibranch fossils such as *Unio douglasiae, U. compressus* and *Corbicula japonica* and their living species are found in provinces of South China (Cao et al. ,1989).

3.4 Phenological features of fossil mammals and human skeletons in China' s mainland

In the ruins of the Yin Dynasty in Anyang of Henan Province at 36° N and 114° E, species of tropical and subtropical fossils, such as *Elephas maximus* and *Rinoceros sondaicus*, have been found with ages of 1365–1324 B.C. (?) (Hu, 1994), which coincides with the result by ^{14}C dating, i.e. 3340 ± 155 and 3200+160 a B.P. (Qiu, 1972). According to the inscriptions on bones or tortoise shells of the Shang Dynasty (c. 16th–11th century B.C.), people could catch more than 40 head of *Rhinoceros* sp. at one hunting trip (Hu, 1944). A piece of bones with such inscriptions, which was studied by Professor Hu Hou–hsuan, recorded that as many as 481 head of *Elaphurus davidianus* and one head of *Elephas maximus* were caught at one hunting trip.

In the strata in the Dingjiabao Reservoir of Yangyuan County, Hebei, there were *Elephas maximus* remains with ages of 3830 ± 85–3630 ± 90 years B.P. (Jia et al., 1980).

Many genera and species of tropical fossil animals such as *Elephas maximus* and *Rhinoceros sondaicus* were discovered at Yuyao of Zhejiang, located at 30° N and 121° 10′E. Their ages are 6310 ± 100 a B.P. (Cai et al., 1985).

In the Zengpiyan ruins (25° N and 110° 20′E) at Guilin, Guangxi, Holocene *Elephas maximus* was found (Li et al., 1978), which was dated 7580 ± 410 and 11310 ± 180 a B.P. (Zhang et al., 1977). Besides, the shapes of human skulls are characterized by

"Australoid–Negroid race" to some extent (Li et al. ,1959).

Lots of subtropical fossils, e.g. *Hydreopotes tnermis, Rhizomys* cf. *troglodytes.* (Yan, 1960), dated 5600± 105 and 6065± 110 a B.P. (Zhang et al. ,1977), were discovered in Banpo (34° 20′ N and 109° E) of Xi' an. The human bones of Banpo Man have "characteristics that are closer to those of the South Chinese race" except some features which are like the North Chinese race (Ji, 1985).

The present average annual temperature of Kano, a town in Qamdo in the Tibet Plateau (31° N and 97° E), is only 7.6℃, where were found fossil *Hydreopatestnermis* and *Capricornis Sumatraensis* of 4690± 135 a B.P. and subtropical sporopollen *Pteris* and *Polypodidac* (Zhang et al., 1977).

4 Range of the Average Annual Temperature Changes

Based on the above discussion, the following laws can be summarized for the Holocene climatic changes in China.

The three models of the Holocene dating (cycle) sequence, namely beachrocks, animal strata and glacier strata, and their synchronism show that every climatic cycle is about 500 years, which was collaterally proved by historical records.

During the warming phase of every climatic cycle, the beachrock–forming areas advanced northwards by more than 20° latitudes and during the cooling phase the cold climate moved southwards by more than 20° latitudes, too. The climate reflected by tropical animals moved northwards and southwards by about 18° latitudes.

Evidences such as beachrocks reflecting tropical climate, tropical marine animals, southern fresh water animals living in northern lakes, mammal animals reflecting the tropics and subtropics, and human skeletons indicating the tropics and near–tropics are corroborated each other and all these give a true delineation of the Holocene climatic changes in China (Table 1).

In China, the average annual temperature in January is 18–5℃ on the low side compared with areas at the same latitudes in the world. This is a noticeable and unique example.

The idea that the Holocene temperature was 2–3℃ higher than the present is based on only a few data and is in effect a sort of misunderstanding.

The range of the average annual temperature changes in the Holocene in China was obtained by comparing the present average annual temperatures between the original distribution areas of fossil animals or beachrocks and the areas where these animals or rocks appear today. For example, the present average annual temperatures in Yangyuan, Hebei Province, and in Xishuangbanna, Yunnan Province, where *Elephas maximus* lives today, are 6℃ and 22℃, respectively. The average annual temperature in areas where lamellibrachs appear today, such as *Corbicula aurea*, is about 19℃. Thus, the average annual temperature suitable for *Elephas maximus* to " live" in Yangyuan today would be raised by 15℃. The present average annual temperature in Rushan of Shandong is 11℃, and that of the Xisha Islets is 26℃. Beachrocks can not be formed at these temperatures. The difference of the average annual temperatures between Rushan, where beachrocks were once formed, and the Xisha Islets, where beachrocks cannot be formed nowadays, is up to 15℃. According to an overall comparison (Table 1), the average annual temperature of every Holocene warm phase in China is 10–5℃, 9℃, 7℃ and 2℃ higher than the present temperatures of North China, Shanghai, Fuzhou, and Hainan, respectively.

5 Conclusion

Phenological evidences discovered in many marine and terrestrial areas in China's tropical and subtropical regions and the fact that China's winter at present is the coldest (18–5℃ on the low side) compared with the regions at the same latitudes in the world show that ranges of the average annual temperature changes of the Holocene are fairly large in China.

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