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STUDY ON VEGETATION AND CLIMATE CHANGES IN BEIJING REGION SINCE LATE PLEISTOCENE①

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ABSTRACT: A complex history of the Late Pleistocene vegetation and environmental changes for the northern part of the deciduous forest is revealed in an exceptionally well- dated pollen diagram from Dongganchi in Beijing area. In 15 800- 14 700 a B. P., the arbors and aquatic plants were sparse, and the climate was cold and dry. In 14 700- 13 400 a B. P., forest growth was limited, it was dominated by conifers, presumably in responded to a cooling climate. Aquatic plants became abundant. During 13 400 to 12 600 a B. P., there was a widespread development of coniferous and broad-leaved mixed forest, aquatic plants decreased which corresponded to climate gradually becoming warming and dry. In 12 600- 11 400 a B. P., there was alternation of coniferous and broad-leaved mixed forest, so were aquatic plants. From 11 400 to 9 600 a B. P., the decreasing of trees and increasing of herbs and shrubs suggested an opening up of the vegetation in responded to cooling, probably corresponded to Younger Dryas from 10 600 to 10 300 a B. P. About 9600- 7270 a B. P., the climate changed from cooler and dry to warmer and humid. About 7270- 3390 a B. P., the coniferous and the broad-leaved mixed forest increased, it was in responding to the "climatic optimum". About 3390- 1000 a B. P., climate became cooler and dry. After 1000 a B. P., there was a severe fluctuation, indicating the temperature drop and the environmental deterioration.

KEY WORDS: Beijing, Late Pleistocene, vegetation change, climate change, pollen analysis

1 INTRODUCTION

Since the 1980s a series of research plan including IGBP (the International Geosphere. Biosphere Programme) have been set up, of them, PAGES(the Past Global changes) is an important core project. The nature records of ocean deposit, terrestrial (loess, lakes and swamp) deposit, ice cores, tree growth ring and coral can be used to reconstruct the history of the global climate and environmental changes. In our research the fields reconstructing the history of vegetation and climate changes since the Late Quaternary in North China based on ^{14}C dating and pollen analyses, LOI(the Loss-on-ignition), geomagnetic variations, archaeology and cultural relics have been paid attention to. In the PAGES study, pollen analysis has been one of the important methods of the Quaternary paleoclimate reconstruction. Recently, with the deepening of global change researches, many scientists try to understand in detail the climate change in China by studying the pollen records of land soils and lakes and swamps. For a long time, the study on the history of North China climate and environmental changes, in particular in Beijing area have been paid great attention to. During the past three decades, the researchers have made survey and

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studies on the geomorphology, sedimentary strata and their ages and crustal movements, and obtained a number of practical data of the area, in the meantime, the pollen records, ^{14}C dating, the geomagnetic secular variations, archaeology and cultural relics of Beijing region have been studied (Kong *et al.*, 1982; Liu, 1988; Zhu *et al.*, 1994; Zhou *et al.*, 1978; Zhao *et al.*, 1984; Zhang *et al.*, 1981). All of them in a certain extent deepen understanding the history of vegetation and climatic change in Beijing area. As to Beijing Plain region, the climatic change is a main influencing factor in landcover change and the development of lakes and swamps since the Late Pleistocene. The aquatic and marsh plants are important composition in plantae and changes in population directly affected lakes and swamps and hydrological environment. Based on pollen analysis, charcoal fragment, the ^{14}C data and LOI, the reconstruction of the history of vegetation and climatic change in Beijing region since the Late Pleistocene, lake and swamp changes and plant functional types have been discussed in the paper.

2 STUDY AREA DESCRIPTIONS

Beijing region is situated in northwest of North China Plain, its west, north and northeast sides are the Taihang Mountains, the Jundu Mountain, the Yanshan Mountain and their branch ranges. The Beijing Plain is built by the combined deposition of the Yongding River, Chaobai River, the Wenyu River, the Juma River and other rivers and their tributaries flowing from these mountains. From piedmont to plain, the Beijing Plain can be divided into residual hills, diluvial skirts, proluvial platforms and fans and their marginal depressions, alluvial platforms, paleochannels, alluvial plain (Zhao *et al.*, 1984). Beijing area belongs to subhumid warm temperate monsoon climate, the mean annual temperature is about 10℃, the annual precipitation is 500 – 700 mm, of which about 70% mainly occurs in the period from July to August, and greater part of which is rainstorm. The frost-free period lasts for more than 180 days, the annual potential evaporation ranges between 1536.5 to 2000 mm, at the elevation of 1500 m, the west of mid-montane is mainly inhabited by coniferous forests including *Picea*, *Abies and Larix gemlini*. The secondary plant community elevated at low-mountane (1000– 1500 m a.s.l.) is the mixed forest of *Pinus*, *Quercus*, *Betula*, *Ulmus* and *Tilia*. The principal species in the bottom of low-mountain and hills (> 100 m) are deciduous broad-leaved species including *Betula*, *Ulmus*, *Tilia* and *Celtis* ssp.; in southwest of plain piedmont steppe compound by varieties grass species is distributed, in lowland scrubs grow, which consist largely of *Prunus sibirica*, *Spirace trilobata* and *Vitex negundo*, owing to human activities the secondary scrubs are formed around the villages; in flood plain meadows are distributed; aquatic plants with *Potamogeton*, *Myriophyllum* etc. widely grow in lowland and lakes and swamps. To sum up in Beijing area, because of its biodiversity in plant communities and complex geographical environment, its land cover change inducing vegetation, lakes and swamps from the Late Pleistocene have been studied extensively.

Dongganchi profile is located at 39° 32′ N and 115° 47′ E (Fig. 1), altitude is about 49 m, about 50 km to the southwest of Beijing City, covered by

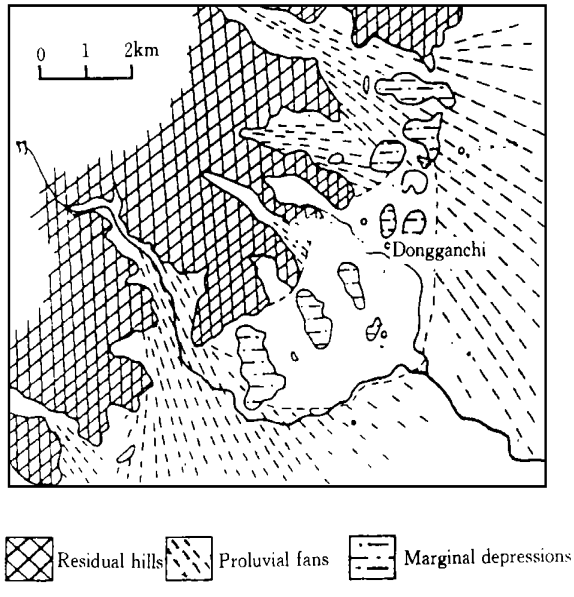

Fig. 1 The diagram of the research area site

the unconsidered sediments formed during the Late Pleistocene, some peat or sandy soil deposited in the pediment basin or paleo-river bed, on the other hand, aeolian sediments similar to loess are developed in the pediment and plateau, pollen samples were obtained in a test trench which is about 8.2 m deep (Fig. 2), from top to bottom, 6 layers can be recognized, owing to human activities, primary nature of sediments about 1.22 m in upper part has been changed (Zhu *et al*. , 1994).

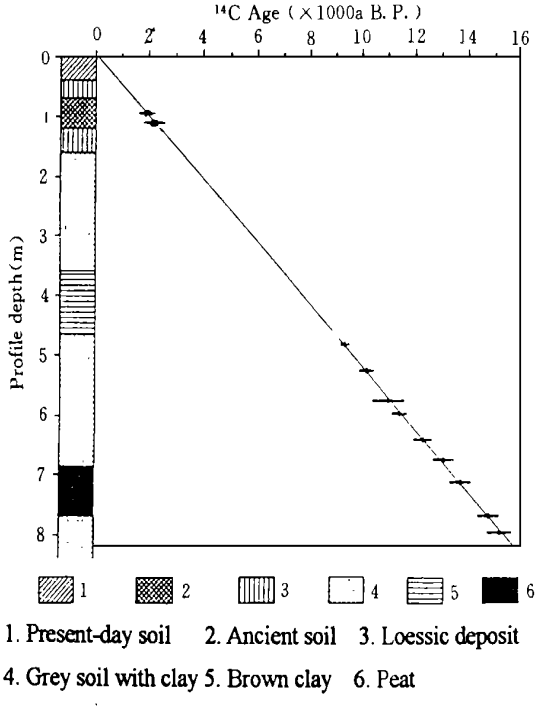

Fig. 2 Radiocarbon ages plotted against depth at Dongganchi profile

3 METHOD

The sediment samples of the profile were subsampled in the laboratory for pollen, geochemical and radiocarbon analyses. Subsamples of 2-cm interval were prepared for pollen analysis according to standard palynological techniques (Du, 1990). At least 300 pollen grains were counted for fiction, except where the concentration was very low, some unknown and deteriorated pollen grains are included in the terrestrial pollen sum. The charcoal zones were delineated by a computer, the LOI at 600℃ was obtained, all fragments from the dated sediment were identified under a microscope and used as study of forest fire in Beijing area (Zhang, 1996). The radiocarbon ages of 12 samples (Fig. 2) were plotted against their depths, to show the relationship between age and depth of sediment. Sedimentation rates were calculated from the regression lines. The net rate of sediment accumulation was about 0.0522 cm/a prior to about 13 700 a B.P., the rate decreased at that time 0.0439 cm/a, but gradually increased from 0.0508 cm/a about 11 000 a B.P. to 0.0513 cm/a after 7000 a B.P..

4 RESULTS AND DISCUSSIONS

Twenty surface soil samples were collected from the vegetation zones of Baihua Mt. (2049.9 m) and Dongling Mt. (2303 m) of Beijing, and pollen percentage were calculated, compared with modern vegetation, and represented different plant types were discussed (Zhang *et al*., 1996). Mainly based on the percentages (Fig. 3), concentrations (Fig. 4) of spore-pollen, concomitant changes in charcoal concentration, the LOI (Fig. 5) and surface soil pollen were considered, the pollen diagram are divided into ascending zone.

Zone 1 (15 800– 14 700 a B.P.): Aquatic plants are sparse, the pollen is dominated by *Artemisia* and *Chenopodiaceae*, next *Ephedra*, *Polygonum* and other xerophytic herbs, but total pollen concentrations of herbs are very low. Trees only such as *Pinus*, *Abies*, *Quercus* and *Tilia* are counted, the percentages is only 2%, the concentrations are 80–300 grains/cm^3, the peak is 22 185 grain/cm^3 at depth of the 783 cm.

Zone 2 (14 700– 13 400 a B.P.): The trees pollen increase than Zone 1, and the percentages increase 10% – 35.85%, conifer trees pollen particularly *Larix*, *Abies*, *Picea* increase, *Artemisia* pollen decline, but increase sharply in aquatic and marsh plants pollen (for example, *Typha*, *Potamogeton*, *Sparganium*), the concentrations amount to 946–1848 grains/cm^3, algae spores are abundant, *Selaginella*

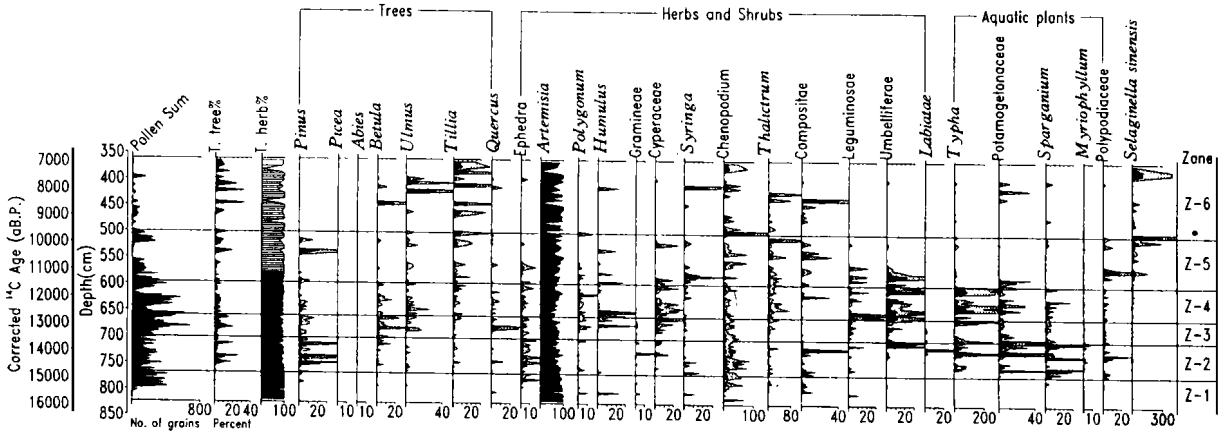

Fig. 3 Pollen percentage diagram in Dongganchi profile, Beijing (%)

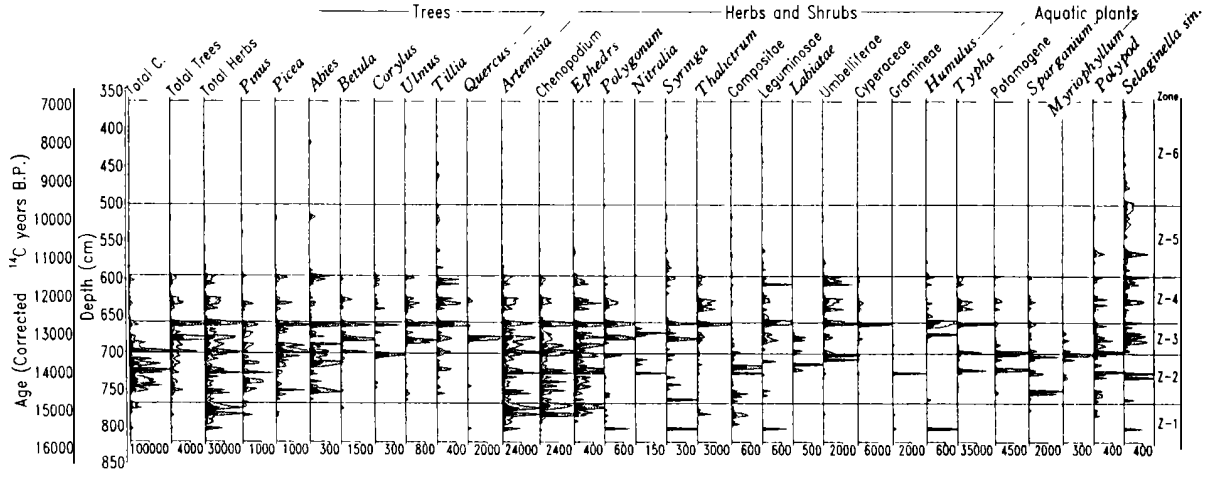

Fig. 4 Diagram of pollen concentrations in Dongganchi profile, Beijing (grains/cm^3·a)

sinsensis (a fern of dry habitat that is distributed in North and Northeast China) is counted. there are two samples at 731 cm and 703 cm with a obviously gray-white layer in black peat, the LOI are only 9. 07% and 7. 51% respectively, far lower than other depths (the mean LOI is 29. 56% in Zone 2) . The herbs are dominant.

Zone 3 (13 400– 12 600 a B. P.): It has a most high pollen concentration of trees including *Betula*, *Quercus*, *Picea* and *Pinus*, others are mestoptic herbs, there is fluctuation in aquatic plants.

Zone 4(12 600– 11 400 a B. P.): The trees pollen decrease, there are alternation of mixed coniferous and broad-leaved deciduous forests, so are aquatic plants. Umbellifarea and Artemiasae increase, the maximum are 2000 grains/cm^3.

Zone 5 (11 400– 9600 a B. P.): The pollen assemblages decrease sharply, the herbs pollen concentration is less than 500 grains/cm^3, the percentages of trees are less than 10%, and aquatic and wetland plants decrease, too. In 554– 538 cm(10 600– 10 300 a B. P.) pollen and charcoal fragments can be hardly counted, and the LOI is low.

Zone 6 (9600– 7270 a B. P.): Lack trees pollen, and broad-leaved deciduous trees only include *Tilia* and *Betula*, the pollen concentrations are only 44 grains/cm^3. Aquatic plants pollen is rare.

It is pointed out that palynological evidence is still short for some layer (from 382– 60 cm) in the profile, but the percentages and influx diagram trend

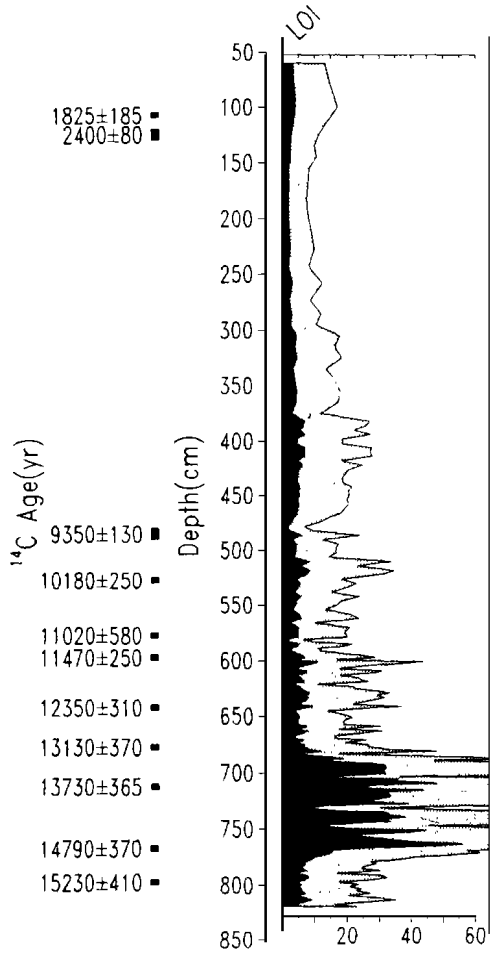

Fig. 5 Loss on ignition (LOI) diagram in Dongganchi profile, Beijing (%)

of pollen still give an evidence after 7000 a B. P. in Beijing area, then three zones (7, 8, 9) were divided and discussed.

Zone 7 (7270– 5960 a B. P.): In 7270– 6160 a B. P., in the pollen assemblages, the trees pollen is 15%, so the temperature was higher than that in the former, but after 6160 a B. P., the trees pollen has not been counted, only finds *Artemisia*, *Leguminum* pollen, aquatic plant pollen, for example, *Potamogene* has been counted. At 6160 a B. P. the LOI is 4.64%, and charcoal fragments increase. Temperature decreased, the moisture increased, so decomposition of organic matter decreased and the LOI increased. During 7000– 5960 a B. P., the forest developing was limited, it was dominated by deciduous broad-leaved forest such as *Quercus* and *Ulmus*, preasumly in responded to climate warming. Aquatic and marsh plants began increase, but the lakes and swamps in some areas were limited, too.

Zone 8(5960– 3390 a B. P.): The trees pollen increase, the proportion is 6.67% – 35.29%, including *Ulmus*, *Tilia* and *Quercus*, and unknown trees pollen has been counted., the *Quercus* pollen increases by 33.33%, *Humus*, Chenopodium pollen and Concentricytes spores have been counted, aquatic and marsh plants (*Typha*, *Potamogene*) increase, fern spore rapidly increases (e. g. *Selaginlla sinensis*) and a large number of algae spores have been counted, but in 5770 a B. P., the trees pollen is low, and charcoal fragments have a low value, but LOI is higher than that before. So About 5960– 3390 a B. P., presumably in responded to climate warmer than at present. Aquatic plants began aburrdance, reflecting the widespread development of the lakes and swamps, the climate was wet with annual precipitation higher than that at present (Shi *et al.*, 1993; Zoltai *et al.*, 1990; Taira, 1979). At 5770 a B. P., and 4500 a B. P., the decline of forest cover showed two abrupt cold episodes (Zhang *et al.*, 1996). Based on historical records, from the Five Dynasties (4540– 4130 a B. P.) the climate became warmer. So in the profile, *Ulmus* and *Quercus* fictions increased and aquatic plants were abundant, range of human cutting trees was limited.

Zone 9 (3390– 1000 a B. P.), trees and aquatic plants pollen are scarce, the assemblages of herbs are *Artemisia*. Compositae and Gramineae are counted, it is possibly cultivated crop pollen. The temperature decreased then that in former, and the annual precipitation rapidly reduced in Beijing area, the lakes and swamps gradually shrank back, some of them even disappeared. By historical materials human activities was the dominating factor in the evolution of vegetation and climatic change (Tsukada, 1986). Then human activity range increased because of warmer climate, natural forest was damaged rapidly, many forest lands were used for firewood and charcoal production even as sources of grasses for fertilizing agriculture fields, and forest land was used for fields of a

slash-and-burn economy. A large number of trees were cut down to be for shifting cultivation and agriculture and animal husbandry development during the Xia, Shang, Zhou dynasties (3970– 2460 a B. P.). From the Spring and Autumn Period to the Warring States (2460– 1780 a B. P.), trees were cut down rapidly for military purposes and for building materials. After 1000 a B. P., *Umbellif arae* and *Artemisia* increased, the matrix is 2000 grains/cm^3, which indicated the temperature decreased. There was a severe fluctuation in moisture, and early during this time, it was comparatively warm and humid, but became cool and dry later, in the meantime, human activity was intensified. A lot of trees in the nearly area were fell. Agricultural activity was flourished, and large area of paddy filed was cultivated (Zhou *et al*., 1993). Due to the growth of population, the area of primeval and secondary forests decreased abruptly, the effect of human activities was the direct factor for aggravation of forests regressive succession.

5 CONCLUSIONS

The profile is located in front of marginal depressions of proluvial fans, the sedimentary environment seems unfavorable to pollen deposit, but according to pollen zones of Dongganchi profile, the vegetation and climatic changes were divided into the ascending order. From 15 800– 14 700 a B. P., the climate was cold and dry. In 14 700– 13 400 a B. P., forest developing was limited, it was dominated by coniferous one in mixed conifer and deciduous broad-leaved forest, abundant in aquatic plants, reflecting the widespread development of peat in the low land and the plain in Beijing. The climate was wet with annual precipitation higher than that at present, the lakes and swamps were developed better. At 14 060 a B. P., the cold and dry climate corresponded to Gotherrburg Drift (Zhu, 1993), and at 13 520 a B. P., the accumulation of peat was interrupted as the climate became dry and cold. From 13 400 a B. P. to 12 600 a B. P., corresponded to climate gradually becoming warmer and drier. At about 12 600– 11 400 a B. P., the trees decreased. There was an alternation of mixed coniferous and broad leaved deciduous forest, so were aquatic plants, which reflected the fluctuation of coldness and warmness in the climate, moisture changed in environment, too. From 11 400 a B. P. to 9600 a B. P., the decreasing of trees and the increasing of herbs and shrubs suggested an opening up of the vegetation in responded to cooling. An important interval from 10 600 a B. P. to 10 300 a B. P., revealed a rapid decline in pollen, charcoal concentrations and LOI, implying a colder climate, probably corresponding to Younger Dryas cooling event. About 9600– 7270 a B. P., the broad-leaved deciduous forests gradually increased, so were the aquatic plants. In Zone 7 and 8 (7000– 3390 a B. P.), the pollen of conifer and board-leaved deciduous trees in creased , particularly *Tilia* (35%), *Ulmus* (13. 3%) and *Quercus* (10%), and unknown tree pollen was added up. Aquatic and marsh plants (*Typha*, *Potamogene*, *Sparganium*) began to increase, it was in responded to the "climatic optimum". But at 5770 a B. P. and 4560 a B. P., the decline of trees pollen showed two abrupt cooling events (Zhang, 1996). In Zone 9 (3390– 1000 a B. P.), trees and aquatic plants pollen scarce, the assemblages herbs are *Artemisia*, Compositae and Chenopadiaceae, and Gramineae was counted. By historical materials human activities have kept to be the dominating factor in the evolution of vegetation and climatic change. According to archaeology, after 1000 a B. P., there was a severe fluctuation in moisture, Umbellifarae and *Artemisia* increased, the matrix is 2000 grains/cm^3, indicating the temperate decrease.

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REFERENCES

Du Naiqiu, Chen Yinshuo, 1990. Effects of heavy liquid floating on the calculation of pollen concentration. *Acta Botanica Sinica*, 31(10): 794– 798. (in Chinese)

Liu Kam-biu, 1988. Quaternary history of the temperate forests of China. *Quaternary Science Reviews*, (7): 1– 20.

Shi Yafeng, Kong Zhaochen, Wang Sumin *et al*., 1993. Mid-Holocene climates and environments in China. *Global and Planetary Change*. (7): 219– 233.

Taira K., 1979. Holocene migrations of the warm-water front and sea-level fluctuations in the northwestern Pacific. *Palaeogeography, Paleoclimatology, Palaeoecology*, 28: 197– 204.

Tsukada M., 1986. Altitudinal and latitudinal migration of *Cryptomeria Japonica* for the past 20, 000 years in Japan. *Quaternary Research*, 26: 135– 152.

Zhang Jiahua, Kong Zhaochen, Du Naiqiu, 1996. Disastrous abrupt climate events of environment change in Beijing in recent 15000 years. *J. of Catastrphology*, 11(2): 71– 75. (in Chinese)

Zhang Jiahua, Kong Zhaochen, Du Naiqiu, 1997. Charcoal analysis and fire changes in Beijing since 15000 a B. P.. *Acta Phytoecologica Sinica*, 21(2): 161– 168. (in Chinese)

Zhang Jiahua, Kong Zhaochen, Du Naiqiu, 1996. Pollen analysis of surface samples from Baihua and Dongling Mountains, Beijing. *Marine Geology & Quaternary Geology*, 16(3): 102– 113. (in Chinese)

Zhang Zhibin, Wang Ding, Ding Jiaxian, 1981. Natural environmental change since 13000 a B. P. in Beijing. *Scientia Geologica Sinica*, (3): 259– 268. (in Chinese)

Zhao Xitao, Sun Xiuping, Zhang Xingli *et al*., 1984. Geographic evolution of the Beijing Plain during the past 30, 000 years. *Scientia Sinica*, (11): 1184– 1196. (in Chinese)

Zhou Kongshu *et al*., 1978. Pollen analysis of Late Quaternary in Beijing Plain and its significance. *Scientia Geologica Sinica*. (1): 57– 64.

Zhou Xinyu, Cai Shuming, Kong Zhaochen *et al*., 1993. Primary research of vegetation and environment at Kunming Lake of the Summer Palace, Beijing. In: Zhang Lansheng (ed.). *Research on the Past Life-supporting Environment Change of China*. Beijing: China Ocean Press. 32– 43. (in Chinese)

Zhu Rixiang, Gu Zhaoyan, Huang Baochun *et al*., 1994. Geomagnetic secular variations and climatic changes since 15, 000 a B. P., Beijing Region. *Science in China* (Series B), 37 (8): 984– 990.

Zoltai Stephen C., Vitt Dale H., 1990. Holocene climate change and the distribution of peatlands in western interior Canada. *Quaternary Research*, (33): 231– 240.