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Mid-Holocene environmental and human dynamics in northeastern China reconstructed from pollen and archaeological data

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Abstract

A pollen record from the Taishizhuang site (40°21.5′N, 115°49.5′E) located in the transitional forest–steppe zone near the present-day limit of the summer monsoon is used to reconstruct vegetation and climate. Quantitative biome reconstruction suggests that between ca. 5700 and 4400 cal. years B.P. temperate deciduous forest dominated the vegetation cover around the Taishizhuang site. After that time the landscape became more open and the scores of the steppe biome were always higher than those of the temperate deciduous forest except for two oscillations dated to ca. 4000 cal. years B.P. and ca. 3500 cal. years B.P. However, ca. 3400–2100 cal. years B.P. the common vegetation became steppe and the landscape was more open in comparison with the previous time interval. The results of the pollen-based precipitation reconstruction suggest that annual precipitation was ca. 550–750 mm (ca. 100–300 mm higher than present) during the mid-Holocene 'forest phase', and ca. 450–650 mm during the following 'forest–steppe phase'. From ca. 3400 cal. years B.P. during the 'steppe phase' annual precipitation was similar to modern values (ca. 300–500 mm). Archaeological records from 100 sites prove the habitation of northeastern China during the prehistoric and early historic periods from ca. 8200 cal. years B.P., but do not provide evidence of the use of wood resources intensive enough to influence the regional vegetation development and to leave traces in the pollen assemblages. Both archaeological and palaeoenvironmental data support the conclusion that changes in pollen composition in northeastern China between 5700 and 2100 cal. years B.P. reflect natural variations in precipitation and not major deforestation caused by humans.

Keywords: Holocene; Pollen record; Reconstructed biomes; Changes in atmospheric precipitation; Human impact on vegetation

1. Introduction

Traditionally, human activities before the 19th century are not considered as a force changing Earth's climate (e.g. Crutzen and Stoermer, 2000) and interactions between humans and environments are discussed in terms of the influence of climatic changes and environmental catastrophes on civilizations (e.g. Yasuda, 2001; Battarbee et al., 2004; Yasuda and Shinde, 2004). Recently, however, a hypothesis suggesting the onset of the 'anthropogenic greenhouse era' about 8000 years ago as a result of forest clearance and agricultural practices was proposed to explain the pre-industrial rise in CO_2 and CH_4 concentrations (Ruddiman, 2003). Consequently, humans were deemed the 'rescuers' of the Earth from a new Ice Age, otherwise predicted at about 4000 years ago. Opponents

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of this hypothesis continued arguing that natural forces were responsible for the pre-industrial increase in greenhouse gases (e.g. Broecker and Clark, 2003; Joos et al., 2004). These contradictory views on the mechanisms and forces driving the Holocene climate have provoked the current debate (Claussen et al., 2005; Crucifix et al., 2005;

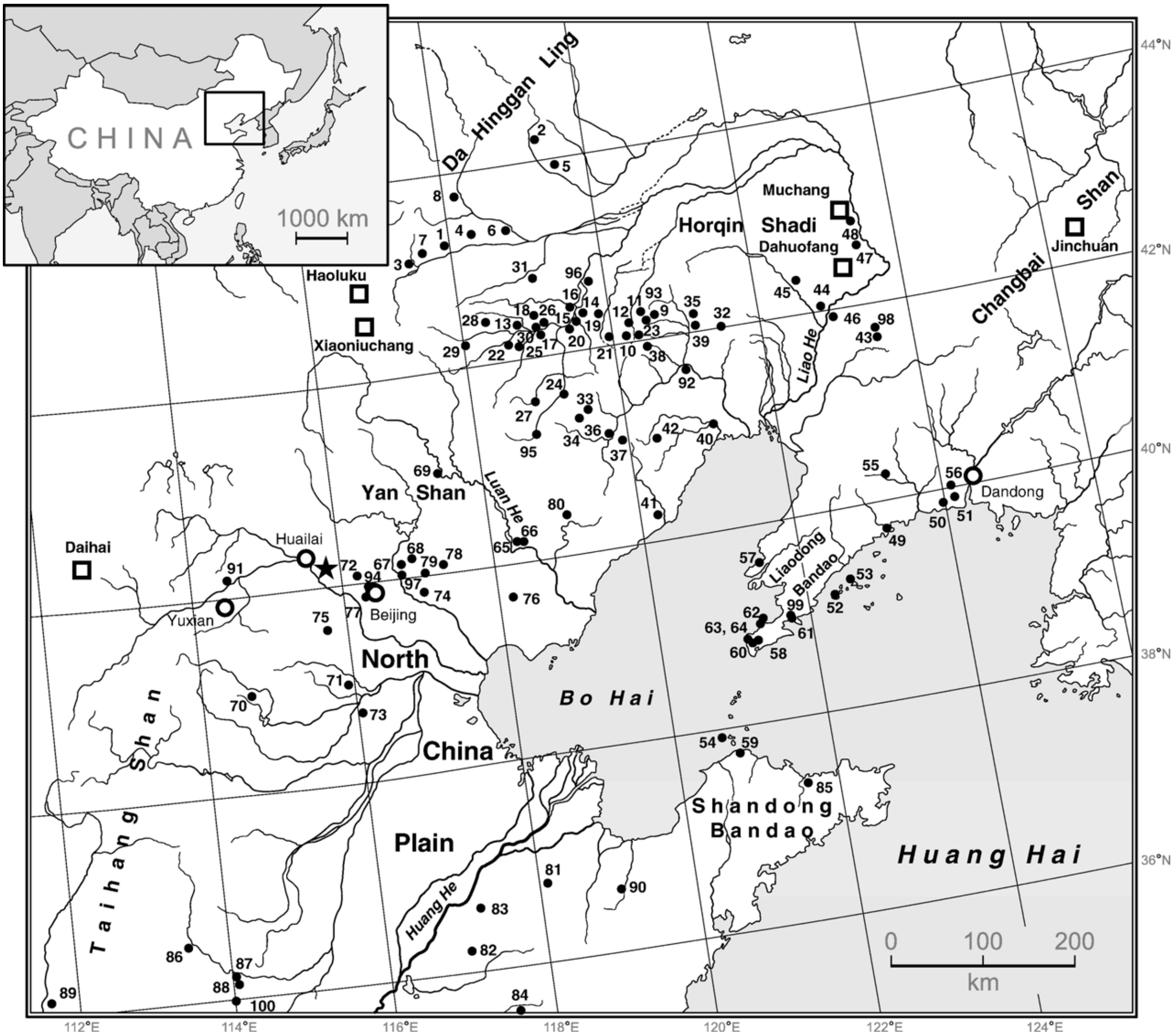

Fig. 1. Sketch map of Asia, where the enlarged study area of northeastern China is indicated with a *square*. In the enlarged regional map a *star* indicates the location of the Taishizhuang pollen record, *closed circles* indicate the archaeological sites, *open circles* indicate meteorological stations and *open squares* indicate other sites with palaeorecords discussed in the paper. Archaeological sites are numbered as follows: 1—Baiyinchanghan, 2—Fuhegoumen, 3—Nantaizi, 4—Shuiquan-LX, 5—Erdaoliang, 6—Nasitai, 7—Shangdian, 8—Dajing, 9—Xinglongwa, 10—Zhaobaogou, 11—Xiaoshan, 12—Nantaidi-2, 13—Xishuiquan, 14—Sandaowanzi, 15—Silingshan, 16—Hongshanhou, 17—Zhizhushan, 18—Danangou, 19—Shiyangshihushan, 20—Nantaidi-1, 21—Fanzhangzi, 22—Sifendi, 23—Dadianzi, 24—Xiaoyushulinzi, 25—Yaowangmiao, 26—Xiajiadian, 27—Nanshangen, 28—Xindian, 29—Xishangen, 30—Dongbajia, 31—Longtoushan, 32—Chahai, 33—Niuheliang, 34—Sanguandianzi, 35—Hutougou, 36—Dongshanzui, 37—Shuiquan-JP, 38—Fengxia, 39—Pingdingshan, 40—Shuishouyingzi, 41—Fengjia, 42—Weiyingzi, 43—Xinle, 44—Gaotaishan, 45—Ping'anbao, 46—Pianbu, 47—Wanliu, 48—Shunshantun, 49—Beiwutun, 50—Dagang, 51—Houwa, 52—Xiaozhushan, 53—Shangmashi, 54—Beizhuang, 55—Beigouxishan, 56—Shifoshan, 57—Santangcun, 58—Guojiacun, 59—Zijingshan, 60—Jiangjunshan, 61—Dazuizi, 62—Shuangtuozi, 63—Yujiacun, 64—Yujiacun Tuotou, 65—Xizhai, 66—Dongzhai, 67—Beiniantou, 68—Shangzhai, 69—Houtaizi, 70—Wufang, 71—Jiecun, 72—Xueshan, 73—Yabazhuang, 74—Datuotou, 75—Jiancun, 76—Xiaoguanzhuang, 77—Liulihe, 78—Weifang, 79—Zhangjiayuan, 80—Chaodaogou, 81—Houli, 82—Dawenkou, 83—Chengziya, 84—Yinjiacheng, 85—Zhaogezhuang, 86—Shibeikou, 87—Xiapanwang, 88—Hougang, 89—Xiajin, 90—Yaoguanzhuang, 91—Jiangjialiang, 92—Kangjiatun, 93—Xinglonggou, 94—Baifu, 95—Xiaoheishigou, 96—Zhoujiadi, 97—Jundushan, 98—Zhengjiawazi, 99—Gangshang, 100—Anyang.

Ruddiman, 2005; Tarasov et al., 2005) and were the starting point for this article.

China is one of the key regions where agricultural civilizations already flourished several millennia ago. Did they do so at the expense of forests? 'Yes, of course' would be the easiest and, at first sight, logical answer (e.g. Simmons, 1996; Yasuda, 2001; Ruddiman, 2003). However, proving this hypothesis and verifying it by separating anthropogenic and natural trends in vegetation changes is a joint task for archaeologists and palynologists.

Pollen data have been used as a major source to reconstruct changes in vegetation, caused by natural and anthropogenic factors. A first comprehensive synthesis of Late Glacial and Holocene pollen data from China was published by Winkler and Wang (1993). The IGBP-PAGES BIOME 6000 Project (Prentice and Webb, 1998) stimulated further compilation of available modern and fossil pollen data from China and quantitative reconstruction of the mid-Holocene and Last Glacial Maximum biomes (Yu et al., 1998, 2000). The last decade of intensified international cooperation in the field of palaeoenvironmental studies saw a growing number of publications presenting high-resolution Holocene pollen records, particularly from the northern and western regions of China (e.g. Pachur et al., 1995; Gasse et al., 1996; Liu et al., 1998; Li et al., 2003a; Herzschuh et al., 2004; Makohonienko et al., 2004; Xiao et al., 2004; etc.). Ren and Beug (2002) compiled 142 pollen diagrams from China in order to map Holocene changes in pollen percentages of key pollen taxa and to emphasize the spatial and temporal heterogeneity of forest distribution caused by climatic changes and by human activities.

In the present study we discuss mid-Holocene environmental and human dynamics in northeastern China reconstructed from pollen and archaeological data. A pollen record from the Taishizhuang site (40°21.5′N, 115°49.5′E) located in the forest–steppe zone near the modern limit of summer monsoon has been chosen as suitable for a quantitative biome reconstruction and palaeoenvironmental interpretation. These results are compared with other palaeoenvironmental records from northeastern China dated to 6000–2000 cal. years B.P. For the first time consistently analysed archaeological records from 100 sites (Wagner, 2006) dated to prehistoric and early historic periods are used for the interpretation of human dynamics in the study region.

2. Regional setting

The study area extends from ca. 35° to 45°N and from ca. 112° to 125°E in northeastern China (Fig. 1). It consists of two low-elevated plains—the North China Plain and the Liao He Basin, coastal lowlands around Bo Hai and Huang Hai (the Yellow Sea), a chain of mountain ridges, including the Taihang Shan, Yan Shan, Da Hinggan Ling and Changbai Shan elevated to ca. 1000–2900 m and the Horqin Shadi Plateau (Fig. 1). The area has a well developed hydrological network, including the Huang He (Yellow River), Luan He, Liao He and their tributaries. Alluvial deposits are well represented in the intermountain valleys and at the coastal plains. Loess sediments occur discontinuously in the mountains and sand dunes make up the surface of Horqin Shadi (Zhao, 1994).

The area belongs to the warm-temperate region (Domrös and Peng, 1988). It has a strong contrast between cool-dry winters and warm-wet summers (Fig. 2), which is typical of a monsoon climate. During the cold season the weather is controlled by air masses from Siberia and Mongolia and northwesterly winds associated with the Siberian High. During the warm season southeasterly winds bring warm and wet air from the Pacific Ocean. At sea level mean January temperatures vary from −8 °C in the north to −4 °C in the south. In the mountains it may fall to −12 °C. Mean July temperatures are moderately high (ca. 20–24 °C) in the mountains and near the sea (see data from the meteorological stations Yuxian and Dandong in Fig. 2A), while in Beijing area they reach 28–30 °C. Precipitation distribution patterns have a more pronounced east–west gradient (Fig. 2B). Thus, hilly and mountainous parts of the Liaodong Bandao and Shandong Bandao (peninsula) receive about 1000–1200 mm precipitation per year and climate there is classified as 'humid' (Domrös and Peng, 1988). The North China Plain south of the Yan Shan experiences 'sub-humid' climate and the mountainous areas west and north of Beijing are classified as 'semi-arid'.

Natural vegetation of the area is defined as temperate deciduous and mixed conifer forests dominated by oak and pine, changing into steppe–woodland and temperate steppe north- and westward (Wu, 1980; Hou, 2001). The Vegetation Atlas of China (Hou, 2001) shows that except for poplar plantations, patches of zonal forest can be found in the mountains. *Quercus*, *Betula, Corylus*, *Ostryopsis*, *Ulmus, Tilia, Acer, Juglans, Fraxinus*, *Pinus* and *Juniperus* are mentioned among the most common arboreal taxa. Boreal coniferous forests grow on higher elevations and consist of *Larix*, *Picea* and *Abies* species.

The study area is densely populated and natural forests are badly preserved. The alluvial plains are extensively used for crop, vegetable and fruit production. Tobacco and cotton are grown in the Huang He valley, and sugar beet, rape, soy, corn, sorghum, millet and wheat are

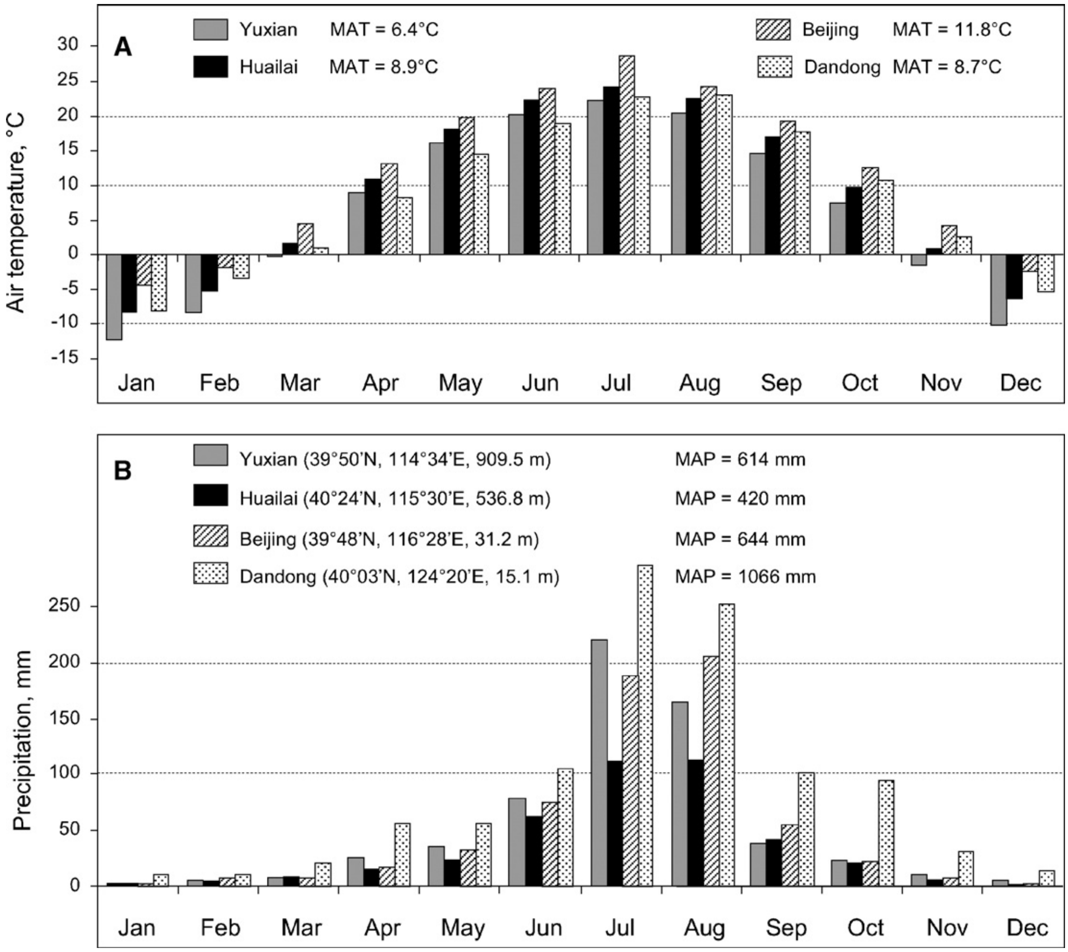

Fig. 2. Mean monthly temperatures (A) and precipitation (B) values at four climatic stations from north China (see Fig. 1 for locations) for the period 1951–1980 (after Domrös and Peng, 1988).

successfully cultivated everywhere at low elevations (Hou, 2001).

3. The Taishizhuang site: materials and methods

3.1. Local environments

Samples for pollen and radiocarbon analyses were collected near Taishizhuang village in Huailai County, Hebei Province (Jin, 1999; Jin and Liu, 2002). The village is situated on the alluvial terrace in the Guishui He Valley (Fig. 3). The Guishui He is a left tributary of the Yongding He flowing to Bo Hai Bay. The lower reaches of the Guishui He were transformed into the Guanting water reservoir (shuiku). The width of the valley within 500-m isohyps is about 15 km and the elevations of the surrounding hills vary between 800 and 1800 m a.s.l. (Fig. 3).

Mean monthly temperature and precipitation values from the Huailai meteorological station (40°24′N; 115°30′E, 536.8 m) located 26 km northwest of the study site (Fig. 3) are given in Fig. 2. The mean January temperature is −8.2 °C and the mean July temperature is 24.1 °C. Precipitation from December to February is extremely low (ca. 8 mm), whereas June–August contribute about 70% to the annual precipitation sum of 420 mm.

Natural vegetation around the site is strongly modified by human activities. Patches of temperate deciduous forest dominated by oak (mainly *Quercus liaotungensis*) and birch (*Betula platyphylla*) with *Corylus heterophylla* and *Syringa* shrubs in the understorey occur within 50-km radius from Taishizhuang (Hou, 2001). Conifers represented by several temperate and boreal species, including *Larix kaempferi, Picea wilsonii, P. meyeri, Pinus tabulaeformis* and *Juniperus rigida* grow at higher

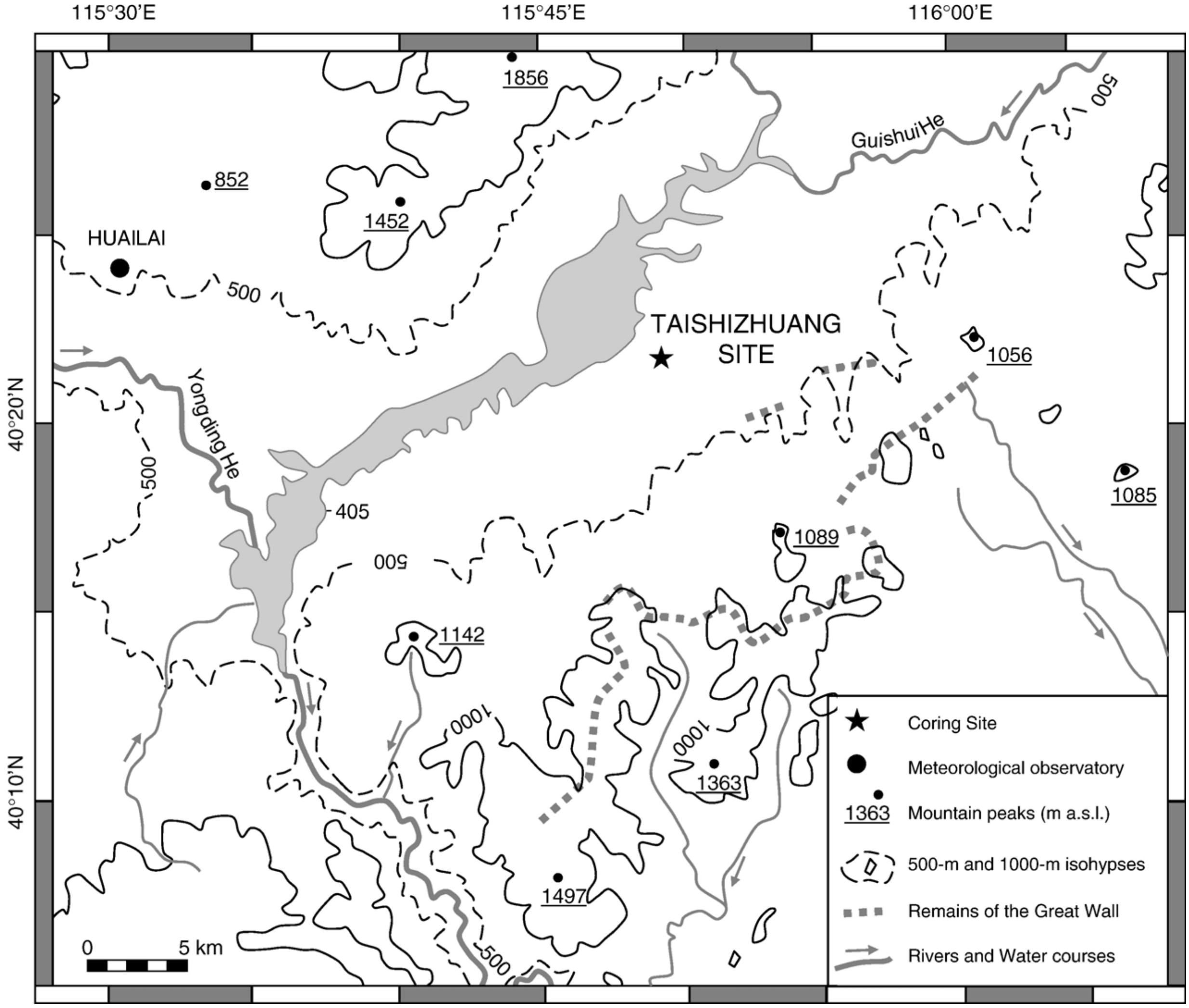

Fig. 3. Simplified map of the Taishizhuang area.

elevations north and south of the study site. Poplar (mainly *Populus davidiana*) plantations appear in the river valleys and around the water reservoir (Hou, 2001). A decrease in evaporation losses and an increase in precipitation at higher elevations (see data from Yuxian in Fig. 2B) allow tree growth in the mountains, while steppe grasses (e.g. *Stipa grandis, S. bungeana, S. gobica*) and *Artemisia* species occupy intermountain depressions and dry slopes. Sedges (e.g. *Carex*) are common species of wetlands and marshes.

3.2. Sediment lithology and ^{14}C dating

During the field survey in September 1997 (Jin, 1999; Jin and Liu, 2002) well preserved peat layers overlain by a sandy loam sediment were found north of Taishizhuang village (Fig. 3). The sampling site (40°21.5′N, 115°49.5′E) was selected in the central part of the topographic depression, where organic layers reached maximum thickness. Samples for radiocarbon dating and pollen analysis were collected from a 270-cm deep ditch. The sediment lithology was described by visual inspection during the field work (Fig. 4A).

Six 2-cm-thick samples of bulk material were collected from undisturbed organic sediment layers and dated by the Laboratory of Radiocarbon Dating, Institute of Geology of China Seismological Bureau (Jin, 1999). Dates were converted to calendar ages using CalPalA-University of Cologne Radiocarbon Calibration Program Package (http://www.calpal.de). An age–depth model applied to the pollen record was built up on the basis of calibrated dates taking into account error

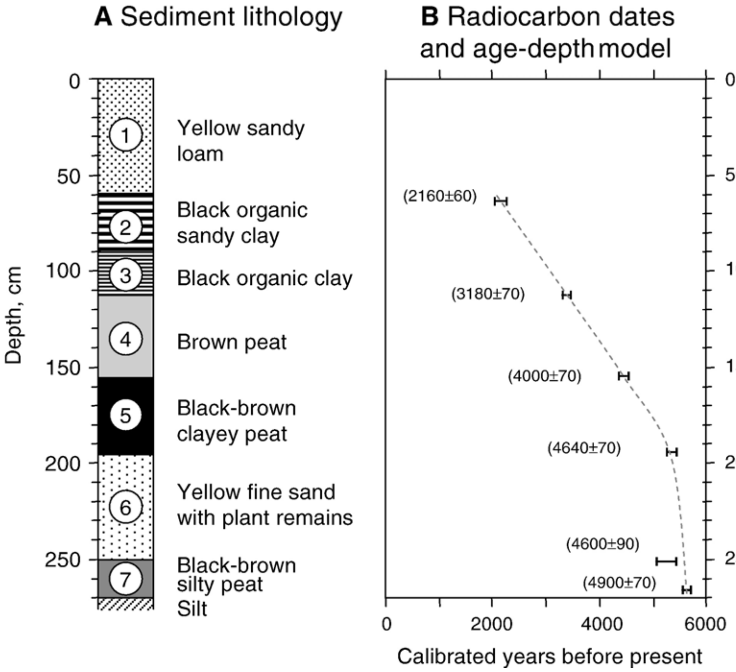

Fig. 4. Lithology (A) and age–depth model (B) of the Taishizhuang pollen record (40°21.5′N, 115°49.5′E). Ages in brackets are uncalibrated ^{14}C dates. Horizontal bars indicate calibrated age ranges (cal. years B.P.) covering a ±1 sigma probability interval. An age model based on five radiocarbon dates calibrated with CalPalA (http://www.calpal.de) is indicated by the *gray dashed line*. One radiocarbon date from 250–252 cm depth with large error bars appears slightly too young and is not used in the age model.

bars (one standard deviation or ±68%) of the age estimations (Fig. 4B).

3.3. Pollen analysis

Samples for pollen analysis were taken at 2.5- to 4.5-cm intervals. Pollen extraction from the sediment samples was performed using standard procedures of HCl, KOH and HF treatment and the following acetolysis (Berglund and Ralska-Jasiewiczowa, 1986). The pollen residues were mounted in silicone oil.

Pollen preservation and content in the samples from inorganic uppermost and lowermost layers of the sediment profile was very poor. About 250 to 2000 arboreal and non-arboreal pollen (AP and NAP) grains per sample, excluding spores, aquatics and Cyperaceae, were counted in the samples from 61–270 cm depth. In total, 49 pollen and spore taxa were identified. The percentage pollen diagram (Fig. 5) was constructed with the Tilia/TiliaGraph software (Grimm, 1991). The relative frequencies of arboreal and non-arboreal pollen taxa were calculated based on the sum of all terrestrial pollen taken as 100%. Percentage calculation for Cyperaceae and other aquatics was based upon the sum of terrestrial and aquatic taxa. Discontinuously found fern spores are only a minor component of the pollen and spore assemblages (0–1.8%) and are not shown in the diagram.

3.4. Biome reconstruction method

The biomization method (Prentice et al., 1996) allows robust assignment of analyzed pollen spectra to the vegetation types or biomes defined on the basis of the ecology and geographical distribution and bioclimatic tolerance of modern plants. Bioclimatic limits of the major biomes included in the BIOME1 model (Prentice et al., 1992) are used for the semi-quantitative palaeoclimatic interpretation of pollen-based biome reconstruction results (e.g. Tarasov et al., 1998a,b; Yu et al., 1998, 2000; Prentice and Jolly, 2000).

The equation used to calculate the affinity scores for all pollen samples was published by Prentice et al. (1996):

$$A_{ik} = \Sigma_j \delta_{ij} \sqrt{\{\max[0, (p_{jk} - \theta_j)]\}}, \qquad (1)$$

where A_{ik} is the affinity of pollen sample k for biome i; summed for all taxa j; δ_{ij} is the entry in the biome versus taxon matrix for biome i and taxon j; p_{jk} are the pollen percentages, and θ_j is the universal threshold pollen

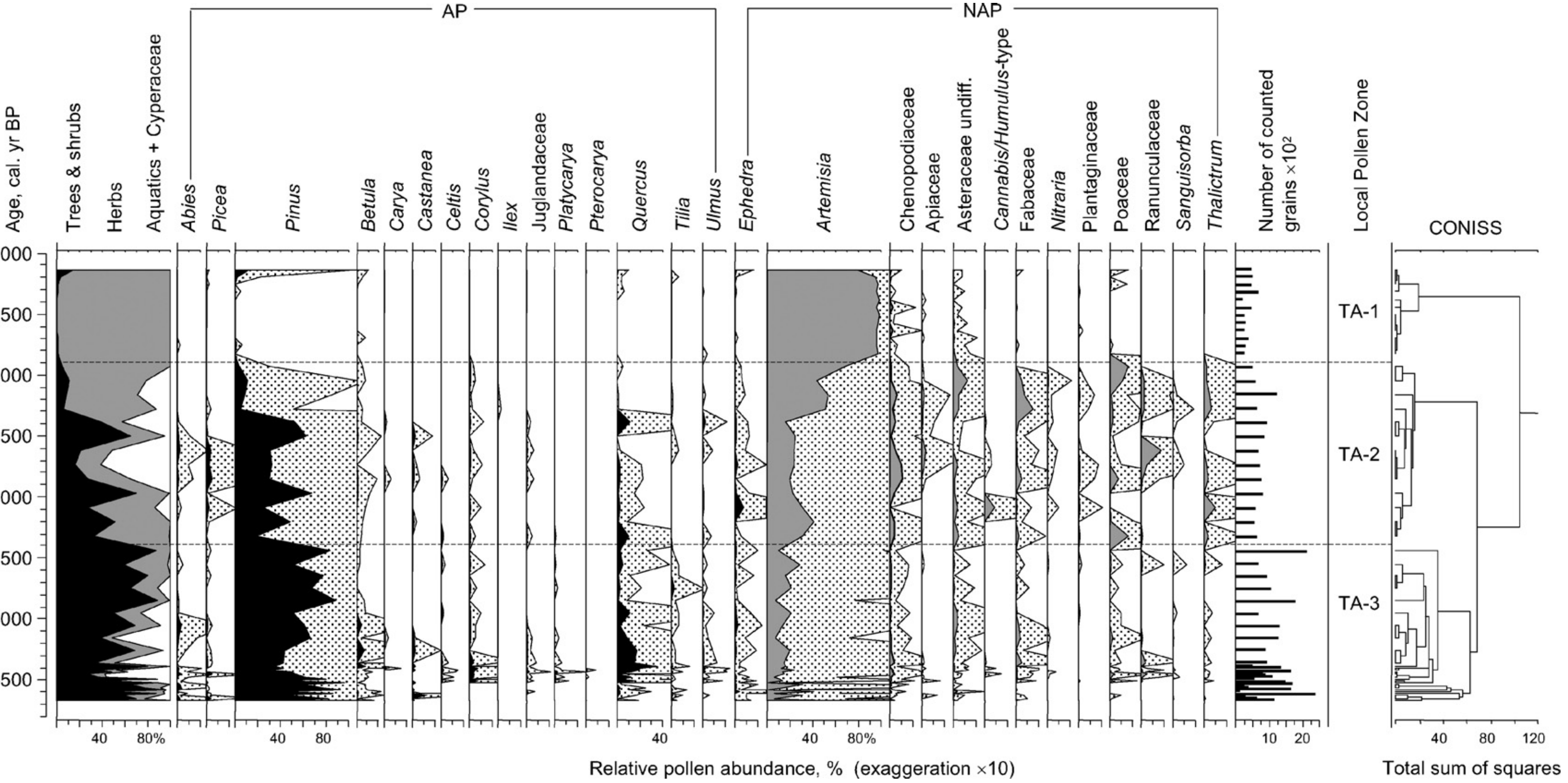

Fig. 5. Pollen percentage diagram from the Taishizhuang record. Percentage values calculation for individual pollen taxa based upon a sum of arboreal (AP) and non-arboreal (NAP) pollen (excluding aquatics and Cyperaceae) taken as 100%. Cumulative diagram in the first graph shows relative changes in pollen percentages of AP (black area), NAP (gray area) and aquatics (white area). Magnification by 10 is used to emphasize the changes in the percentages of the minor taxa.

percentage of 0.5% suggested for minimization of possible noise mainly due to long-distant transport or re-deposition of exotic pollen grains (Prentice et al., 1996). The given pollen spectrum is then assigned to the biome with the highest score or, when several biomes have the same score, to the one defined by a smaller number of taxa.

Terrestrial pollen taxa identified in the Taishizhuang record (Table 1) were attributed to biomes (Table 2) following Tarasov et al. (1998a, 1999) studies, addressing methodological problems of the biomization method in reconstructing the forest–steppe boundary in northern Eurasia. In a few cases, correct attribution of taxa absent in the data set from northern Eurasia (e.g. *Carya*, *Platycarya*) to the appropriate biome was based on regional papers by Yu et al. (2000) and Gotanda et al. (2002). Cyperaceae was attributed to the tundra biome as in the biomization schemes for Europe (Prentice et al., 1996) and northern Eurasia (Tarasov et al., 1998b) assuming that it is only in tundra that sedges become a zonal component in the vegetation cover. However, the presence of Cyperaceae in the matrix does not affect the results of biome reconstruction at the Taishizhuang site, where Cyperaceae pollen mainly originated from sedges growing in the local swamps and wetlands.

4. Archaeological data

Archaeological investigations in northeastern China started at the beginning of the 20th century and intensified during the past 50 years (e.g. Beijing, 1976; Dong and Han, 1987; Dian and Xin, 1994; Yang, 1994; Zhongguo, 1996a,b, 1997; Luan, 1997; Liaoning, 1998; Dalian, 2000; Cultural Bureau, 2004; Institute, 2004). A substantial amount of data was obtained due to systematic surface surveys, salvage and research excavations performed by archaeologists from national and provincial universities and archaeological institutions. Excavation reports published in Chinese in periodicals or as monographs serve as primary sources for the reconstruction of human dynamics during the prehistoric and early historic periods. From the many known sites we compiled 100 sites (Fig. 1) which can be clearly attributed to one of the archaeological periods (Table 3). The sites are settlements, graveyards and smaller units (e.g. single tombs), which are indispensable for chronological or cultural considerations. The archaeological periods are defined using the stratigraphy of cultural layers, pottery typology and calibrated radiocarbon dating (Wagner, 2006 and references therein).

Table 1
Terrestrial pollen taxa identified in the Taishizhuang record and used in the biome reconstruction

*Adenophora**, *Abies*, Apiaceae, *Artemisia*, Asteraceae undif., *Betula* sect. *Albae*, Brassicaceae*, *Cannabis/Humulus*, Caprifoliaceae, *Carpinus**, *Carya*, Caryophyllaceae, *Castanea*, *Celtis*, Chenopodiaceae/Amarantaceae, Convolvulaceae*, Cornaceae*, *Corylus*, Cyperaceae, *Ephedra*, Fabaceae, *Ilex**, Juglandaceae, Lamiaceae*, Liliaceae, *Nitraria*, *Picea*, *Pinus*, Plantaginaceae, *Platycarya*, Poaceae, Polygonaceae, *Pterocarya**, *Quercus* (deciduous), Ranunculaceae, *Rhamnus**, Rutaceae, *Sanguisorba*, *Syringa**, *Thalictrum*, *Tilia*, *Ulmus*

Taxa whose percentages in the pollen spectra do not exceed 0.5% and do not influence results of biome reconstruction are indicated with an asterisk.

5. Results

5.1. Fossil pollen assemblages and reconstructed vegetation changes

A summary pollen diagram of the Taishizhuang record (Fig. 5) shows pronounced changes in pollen composition between the local pollen assemblage zones (LPZ) defined by CONISS—a statistical program incorporated in Tilia/TiliaGraph. In the TA-3 LPZ the AP content is highest throughout the record. The relative abundance of *Pinus* pollen reaches 60–80% ca. 5700–5500 and ca. 4900–4400 cal. years B.P. The interval from ca. 5500 to 4900 cal. years B.P. is characterized by a noticeable increase in percentages of *Quercus* up to 35% at ca. 5400 cal. years B.P. From about 5500 cal. years B.P. the first appearance of temperate deciduous arboreal taxa as *Carya*, *Celtis*, *Corylus*, *Platycarya*, *Pterocarya* and a slight increase in abundance of *Betula, Tilia*, *Ulmus* and Juglandaceae are recorded.

In the TA-2 LPZ (ca. 4400–2900 cal. years B.P.) the AP content is generally lower than 50%, except for two short-term oscillations dated to ca. 4000 and 3500 cal. years B.P. *Pinus* is still an important component of the pollen assemblages. However, NAP represented mainly by *Artemisia* show higher frequencies compared to the TA-3 zone. An increase in *Artemisia* pollen content from 20% to 70% is evident for the uppermost part of the TA-2 zone, from ca. 3400 to 2900 cal. years B.P. The Poaceae pollen curve experiences three distinct oscillations from almost zero up to 10–15%. These peaks are dated to ca. 4300, 3900 and 3000 cal. years B.P. and follow peaks in *Pinus* percentage curve with a delay of one to three centuries.

The pollen assemblages of the TA-1 LPZ (ca. 2900–2100 cal. years B.P.) reveal a very low number of registered pollen types, a negligible role of AP and an absence of Cyperaceae and other aquatics. *Artemisia*

Table 2
Final biome–taxon matrix used in the biome reconstruction from the Taishizhuang pollen record

Biome name and biome order in the matrix	Taxa included
(1) Tundra	Cyperaceae, Poaceae, Polygonaceae
(2) Cold deciduous forest	*Betula* sect. *Albae*, *Pinus* undif.
(3) Taiga	*Abies*, *Betula* sect. *Albae*, Caprifoliaceae, Cornaceae, *Picea*, *Pinus* undif.
(4) Cold mixed forest	*Abies*, *Betula* sect. *Albae*, Caprifoliaceae, *Carpinus*, Cornaceae, *Corylus*, *Pinus* undif., *Tilia*, *Ulmus*
(5) Cool conifer forest	*Abies*, *Betula* sect. *Albae*, Caprifoliaceae, *Carpinus*, Cornaceae, *Corylus*, *Picea*, *Pinus* undif., *Tilia*, *Ulmus*
(6) Temperate deciduous forest	*Abies*, *Betula* sect. *Albae*, Caprifoliaceae, *Carpinus*, *Carya*, *Castanea*, *Celtis*, Cornaceae, *Corylus*, *Ilex*, Juglandaceae, *Pinus* undif., *Platycarya*, *Pterocarya*, *Quercus* (deciduous), *Rhamnus*, *Syringa*, *Tilia*, *Ulmus*
(7) Cool mixed forest	*Abies*, *Betula* sect. *Albae*, Caprifoliaceae, *Carpinus*, Cornaceae, *Corylus*, *Picea*, *Pinus* undif., *Quercus* (deciduous), *Syringa*, *Tilia*, *Ulmus*
(8) Warm mixed forest	*Betula* sect. *Albae*, Caprifoliaceae, *Carpinus*, *Carya*, *Castanea*, *Celtis*, Cornaceae, *Corylus*, *Ilex*, Juglandaceae, *Pinus* undif., *Platycarya*, *Pterocarya*, *Quercus* (deciduous), *Rhamnus*, Rutaceae, *Syringa*, *Tilia*, *Ulmus*
(9) Desert	*Artemisia*, Chenopodiaceae/Amarantaceae, *Ephedra*, *Nitraria*, Polygonaceae
(10) Steppe	*Adenophora*, Apiaceae, *Artemisia*, Asteraceae undif., Brassicaceae, *Cannabis/Humulus*, Caryophyllaceae, Chenopodiaceae/Amarantaceae, Convolvulaceae, Fabaceae, Lamiaceae, Liliaceae, Plantaginaceae, Poaceae, Polygonaceae, Ranunculaceae, Rutaceae, *Sanguisorba*, *Thalictrum*

pollen exceeds 90–95% and becomes a dominant component in this zone.

The results of the biome reconstruction (Fig. 6A) suggest that ca. 5700–4400 cal. years B.P. temperate deciduous forest played an important role in the vegetation around the Taishizhuang site. The scores of the steppe biome do not exceed those of the forest, but are high enough, allowing us to suppose that the area around the site was not densely forested. From ca. 4400 cal. years B. P. the landscape became more open and the scores of the steppe biome were always higher than those of the temperate deciduous forest except for two oscillations around 4000 cal. years B.P. and ca. 3500 cal. years B.P. Between 3400 and 2100 cal. years B.P. the dominant vegetation was steppe (Fig. 6B). The very low scores of the temperate deciduous forest biome suggest greater openness of the landscape in comparison to the earlier time interval.

The results of the biome reconstruction (Fig. 6) complement the qualitative interpretation of the Taishizhuang pollen record (Fig. 5), suggesting three main phases in the development of the regional vegetation ca. 5700–2100 cal. years B.P. The results of pollen analysis suggest that dominant taxa in the mid-Holocene forests were pine and deciduous oak trees. The presence of pollen of insect-pollinated warm-temperate taxa (e.g. *Castanea*, *Platycarya*), which are not mentioned in the modern flora of the area (Hou, 2001), might indicate that mid-Holocene forests around Taishizhuang were richer in species. Slightly higher percentages of *Picea* pollen corresponding to the intervals with an increase in steppe biome scores and a decrease in AP probably suggest the long-distance transport of spruce pollen from mountains during the deforestation episodes.

Transition from predominantly forested landscape to forest–steppe vegetation at ca. 4400 cal. years B.P. (Fig. 6B) fits well with the boundary between pollen zones TA-3 and TA-2 suggested by CONISS (Fig. 6C). On the other hand, biome reconstruction suggests that transition from forest–steppe to steppe vegetation occurred at about 3400 cal. years B.P., e.g. 500 years earlier than the TA-2/TA-1 boundary in the pollen diagram. In our interpretation however we rely more on the results of biome reconstruction, which takes into account plant ecology and not only statistical similarity between pollen assemblages.

5.2. Human dynamics

The onset of the inhabitation of northeastern China by sedentary peasants can be established for ca. 8200 cal.

Table 3
Chronology of the archaeological periods and cultures used in this study

Dates (cal. years B.P.)	Archaeological periods (after Wagner, 2006)	Conventional archaeological cultures (after Yang, 1994)	Conventional stages in civilization development
2800–2200	Yuhuangmiao	Upper Xiajiadian	Iron Age
3200–2800	Zhoujiadi		Bronze Age
3500–3200	Shuangtuozi III		
4000–3500	Shuangtuozi II	Lower Xiajiadian	
4300–4000	Shuangtuozi I		
4600–4300	Beigouxishan II	Xiaoheyan	Late Neolithic
5000–4600	Danangou		
5700–4900	Niuheliang II	Hongshan	Middle Neolithic
6400–5700	Niuheliang I		

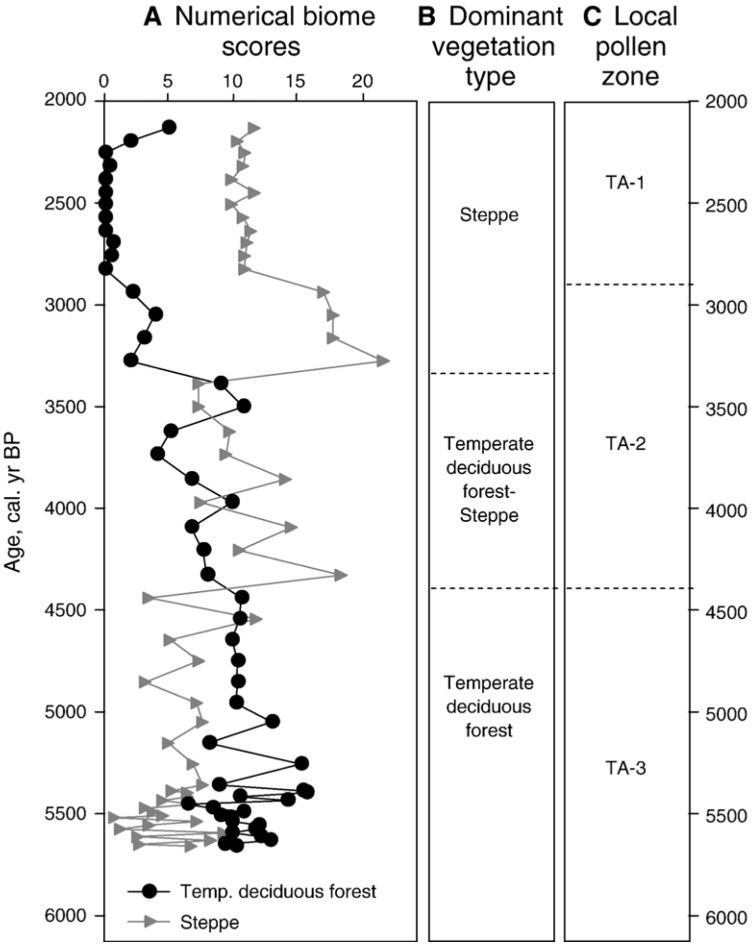

Fig. 6. Biome scores reconstructed from the Taishizhuang pollen record: time series of individual biomes with highest scores (A). Calculations were performed using PPPBASE software for statistical analysis of paleoecological data (Guiot and Goeury, 1996); the dominant biome (vegetation type) in the Taishizhuang area (B) and local pollen zones suggested by CONISS (C).

years B.P. at sites such as Baiyinchanghan (Fig. 1, site 1) (Institute, 2004), Xinglongwa (Fig. 1, site 9) (Yang and Liu, 1997) and Chahai (Fig. 1, site 32) (Dian and Xin, 1994). These sites were all villages with a chessboard-like house arrangement. The archaeological excavation results indicate very limited use of wood as building material at that time. The autochthonous Neolithic development with increasing social complexity continues without a cultural rupture until the middle of the sixth millennium before present when a materialized culmination occurs in the form of monumental tomb pyramids with adjoining sacrificial altars made of worked limestone. The ritual landscape of Niuheliang (Fig. 1, sites 33, 34) of about 50 km^2 (Barnes and Guo, 1996)–conventionally perceived as hallmark of Hongshan Culture–comprises burial and sacrificial clusters on hill outcrops surrounding a large ritual center with fragments of life-size human and animal sculptures in the so-called 'Temple of Goddess' (Cultural Bureau, 2004). For reasons as yet unknown, this culture ends around 5000 cal. years B.P. and with it ends the tradition of expressive depictions of forest animals on pottery (Fig. 1, sites 10–12) (Yang and Zhu, 1987; Zhongguo, 1997) and in three-dimensional art (Fig. 1, sites 6, 33–36) (Dong and Han, 1987; Cultural Bureau, 2004). The archaeological records show a break at this moment of prehistory.

Next the region experienced a sparse spread of people with Dawenkou Culture origin from the lower and middle reaches of the Huang He (Fig. 1, site 82). Features of the few graveyards and houses they left behind allow their classification as Xiaoheyan Culture (Fig. 1, sites 1, 7, 18–20) (Liaoning, 1998). Between Xiaoheyan Culture and the subsequent Lower Xiajiadian Culture clear links have been ascertained (e.g. Liaoning, 1998). Consequently, Lower Xiajiadian Culture follows up around 4300 cal. years B.P. without a gap (Fig. 1, sites

17, 21–30, 34, 37–40, 44, 45, 74, 76, 77, 79 and 92). On the basis of its entire material inventory this culture can be linked with the cultures of the late fifth millennium before present, to Taosi Culture at the southern part of the Taihang Shan (Fig. 1, site 89) and to Longshan Cultures which spread along the lower reaches of the Huang He in particular (Fig. 1, sites 83–85, 88, 90) (Luan, 1997). In the absence of an absolute age determination, the end of Lower Xiajiadian Culture is still subject to debate. Based on correlation with the cultural sequence on Liaodong Bandao (Fig. 1, sites 61, 62) (Zhongguo, 1996a; Dalian, 2000) there are good arguments to assume an end for the main body of this culture (Table 3, Shuangtuozi I Period) at around 4000 cal. years B.P. in line with the related neighboring cultures. Nevertheless, according to current archaeological data, interpretation and terminology, their collapse discussed by Wu and Liu (2004) represented the abrupt end not of the Neolithic but of the earliest Bronze Age cultures (Chang, 1999, several discussants in Zhongguo, 2001) in the northern periphery of the Chinese core area. Translated into terms of human dynamics, the scenario based on archaeological information appears to suggest instead that several complex, perhaps state-like societies (Liu and Chen, 2003) coexisted all over northern China including the Huang He drainage during the late fifth millennium before present. Only the northernmost of them were in possession of bronze casting technology (Mei, 2003; Li et al., 2003b); however, they perished at about 4000 cal. years B.P., leaving the north only sparsely populated for the following few centuries. Life continued in the area south of the Taihang Shan, where the bronze technology became fully developed during the Shang Dynasty (36th to 31st century B.P.) (Chang, 1986).

During Shuangtuozi III and the Zhoujiadi Period northeastern China was again well populated, as archaeological remains indicate (Table 3). Copper mining and smelting site (Fig. 1, site 8) and a comprehensive type-set of weapons, vessels and ornaments (Fig. 1, sites 27, 31, 37, 41, 43, 47, 48 and 94–96) are signs of local bronze production, commonly referred to as ‘Northern Bronze Complex’ (Lin, 1986; Barnes, 1993; Di Cosmo, 1999). Field cultivation was a distinctive economical characteristic beside animal husbandry during this period but plays only a minor role during the second half of the third millennium B.P. Features of nomadic pastoralism dominate the inventory of the Yuhuangmiao Period (Table 3, 2700–2200 cal. years B.P.).

Since the late fourth millennium B.P. when the Shang capital was moved to the “forested plains” (Chang, 1986) near present-day Anyang (Fig. 1, site 100), the area south of the Yan Shan became the contact zone and field of constant mutual territorial claims of Chinese kingdoms and peoples from the north. After founding the state of Yan (Fig. 1, site 77) in ca. 3000 cal. years B.P., the Zhou Dynasty (1045–771 B.C.) presented itself in this colony with military and ritual power as reflected in their elite cemetery (Rawson, 1999 and references therein concerning the Liulihe site). Written sources account for the expansions of the then independent state of Yan northwards beyond the Yan Shan during the Spring and Autumn Period (770–481 B.C.) and the Warring States Period (480–221 B.C.) (Lewis, 1999). However, at the moment no archaeological or historical data compilation is available indicating the total number of settlements or the spatial extension of Yan at particular times. Mobile pastoral communities are underrepresented in archaeological records because they rarely leave settlement traces and not all of their burials, by which they are usually recognized, can be found. Sets of grave goods discovered close to Beijing (Fig. 1, site 97) exhibit a strong affiliation to the west, e.g. Daihai and Ordos regions, whereas tomb construction, equipment and weaponry in burials east of the Liao He and on Liaodong Bandao (Fig. 1, sites 98 and 99) indicate a culturally quiet distinct group that is native to the east. The united Chinese empire of Qin in 221 B.C., including the former territory of Yan, for the first time defined and fortified a wide-ranging northern frontier and was soon confronted by a likewise consolidated power of pastoral nomads, including the eastern tribes, known as Xiongnu or Huns (Di Cosmo, 1999).

6. Interpretation and discussion

6.1. Changes in vegetation: natural or human-induced?

AP variations in the pollen records from semi-arid regions are frequently discussed in terms of changes in precipitation and moisture conditions (e.g. Yu et al., 1998; Tarasov et al., 2000; Liu et al., 2002; Herzschuh et al., 2004 and references there). The results of pollen analysis and biome reconstruction from the Taishizhuang record can be interpreted in the same way. The interpretation would only be reliable, however, if recorded changes in pollen assemblages/biome scores could be explained by natural climatic forces, and not by human activities, including forest clearance using slash-and-burn agriculture and wood cutting.

What caused vegetation changes around Taishizhuang: climate change or human activities? Conventional ways of proving the anthropogenic character of vegetation changes are to find human-indicator taxa in the pollen records and to look for archaeological/historical information. The Taishizhuang pollen record does not provide direct evidence of human activities close to the study site. The presence in the TA-3 zone pollen of *Castanea* and Juglandaceae family, e.g. *Juglans*, *Carya*, *Platycarya* and *Pterocarya* trees producing eatable nuts, cannot establish their cultivation by humans beyond doubt. All these plants can grow naturally in temperate deciduous and mixed forests in valleys and on mountain slopes under modern temperature conditions. The transport of their pollen from distant sources also cannot be excluded. Wind transport of *Platycarya strobilaceae* and *Pterocarya* pollen grains, systematically identified in the late Holocene peat samples from Horqin Shadi, was suggested by Makohonienko et al. (2004). Pollen grains of Poaceae identified in the Taishizhuang record do not belong to the *Cerealia*-type. Thus, the interpretation of peaks in Poaceae percentages at ca. 4300, 3900 and 3000 cal. years B.P. (Fig. 5) as evidence of crop cultivation following initial forest clearance, and not as natural vegetation development, would be very speculative.

Archaeological records (Fig. 1) provide evidence of a long habitation history of northeastern China (e.g. Yang, 1994; Nelson, 1995; Pak, 1996; Chang, 1999; Shelach, 1999; Wagner, 2006). However, a recent compilation of archaeological data (Figs. 1 and 7) does not prove the existence of archaeological sites in the immediate vicinity of Taishizhuang between 6000 and 2200 cal. years B.P., although a relatively high density of archaeological sites is recorded in the Liao He drainage (Fig. 1), ca. 300–700 km northeast of Taishizhuang, from about 8200 cal. years B.P.

During the reconstructed 'forest phase' (Fig. 6) the area of northeast China experienced the terminal phase of the local Neolithic development 5700–4900 cal. years B.P. (Fig. 7A), followed by a gradual spread of population from the south and southwest about 5000–4600 cal. years B.P. and from the southeast via the peninsulas about 4600–4300 cal. years B.P. (Fig. 7A). It has not been possible so far to attribute a high number of sites to any of these culturally distinct groups of people. The Niuheliang II Period of Hongshan Culture (Table 3) is represented by exceptionally large and architecturally complex funeral and sacrificial localities. To take them to be signs of a socially complex society (Nelson, 1995; Barnes and Guo, 1996; Linduff et al., 2004) conflicts with the fact that habitation places have not been found yet, except for a few single houses and pits. So far archaeological remains from northeastern China do not provide evidence of excessive use of wood or forest clearance due to agriculture for the period of 5700–4300 cal. years B.P.

The onset of the Bronze Age in northeastern China (4300–4000 cal. years B.P.) reveals a bigger quantity of sites (Fig. 7B). Large fortified settlements were among

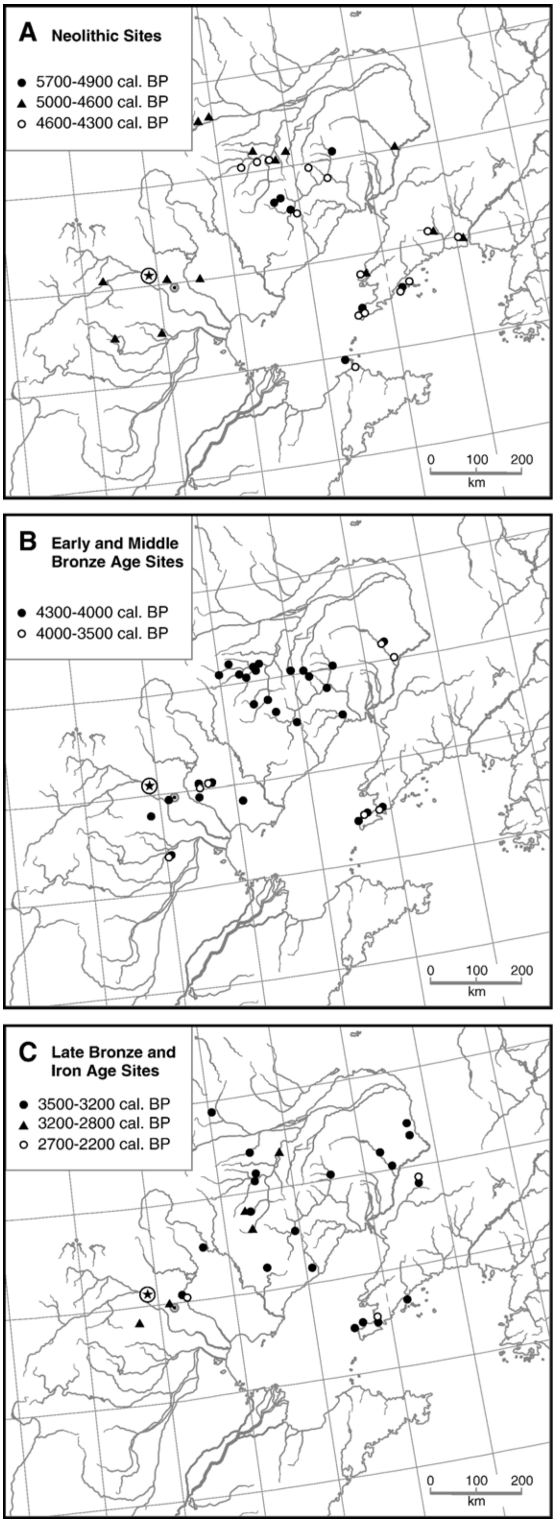

Fig. 7. Distribution of representative archaeological sites in northeastern China from 5700 to 2200 cal. years B.P.: A—Neolithic sites, B—Early and Middle Bronze Age sites, C—Late Bronze Age and Iron Age sites. For the names of archaeological cultures and periods, see Table 3.

the new cultural traits, but again, wood was apparently not preferred for constructing house and city walls. Instead, earth pit houses, occasionally lined with mud bricks (Zhongguo, 1996b), and walls and floors consisting of stone (Liaoning, 2001) and rammed earth (Zhongguo, 1996b; Jin and Wagner, 1998) have been found. The use of wood for coffins has been established (Zhongguo, 1996b), but as a rare phenomenon. Without absolute population estimates the greater amount of sites is commonly interpreted as population growth (Shelach, 1999; Linduff et al., 2004), which is then related to a growing need for arable land. However, this assumption is not proof that people seeking arable land cleared forests instead of making use of naturally available open land. The number of sites again noticeably decreased between 4000 and 3500 cal. years B.P. (Fig. 7B). We have to conclude that also for the reconstructed 'forest–steppe phase' archaeological records do not attest a sustainable human impact on the forest vegetation.

Things look different once the Beijing area was incorporated into the realm of the Chinese Dynasties Shang and Zhou by the end of the fourth millennium B.P. and communities north of the Yan Shan intensified pottery and bronze production ca. 3500–3200 cal. years B.P. (Fig. 7C). For the first time we see elite tombs in Shang-custom lavishly furnished with timber as far north as the Liulihe site (Fig. 1, sites 77, 94) (Beijing, 1976; Rawson, 1999). North of 40° stone chamber tombs prevailed (Wagner and Parzinger, 1999). And again it is a question of quantity: does coffin wood and fuel add up to an environmentally significant amount? Without a single bronze casting workshop known to date the answer can only be 'no' according to the archaeological data available at present.

Coming back to the palaeobotanical indicators of human activities in northeastern China during the last 5000 years we refer to Makohonienko et al. (2004) in which detailed pollen and plant macrofossil records from Muchang (43°09′05″N; 123°27′52″E) and Dahuofang (42°40′N; 122°37′E) sites (Fig. 1) are presented. The authors reconstructed a mosaic vegetation represented by oak and pine forests graded in the *Artemisia*–Poaceae steppe ca. 5000–1000 cal. years B.P. Despite the relatively high density of archaeological sites in the area, man-made deforestation accompanied by buckwheat cultivation is not found until medieval times, ca. 900–1100 AD. An earlier human involvement in forest destruction is suggested around 2800–2900 cal. years B.P. (Makohonienko et al., 2004) based on a short-term oscillation in the oak pollen curve and a higher content of charcoal particles, indicating fire. However, bearing in mind the short-term character of this event and the absence of similar changes in the Dahuofang record, the reconstruction of human impact on regional forests before the Liao Empire (907–1125 AD) is not regarded as very convincing.

6.2. Climatic control of vegetation dynamics

Meteorological data from northeastern China (Domrös and Peng, 1988; Fig. 2) indicate that the total amount of annual precipitation is a key factor explaining spatial differences in vegetation (Wu, 1980; Hou, 2001). Interannual precipitation variability is another factor which can harm natural forest distribution and growth of cultivated plants in the area. In Beijing, for example, the coefficient of variation in annual precipitation was 32% and the mean standard deviation of precipitation was 193 mm during the observation period from 1724–1980 (Domrös and Peng, 1988). Ten times over the last century precipitation in Beijing was below 400 mm/year and once less than 300 mm/year, causing severe droughts and water shortages. Mean annual precipitation in the semi-arid regions of northeastern China, including the Taishizhuang area, is about 200 mm lower than in Beijing (Fig. 2B). In dry years associated with a weaker-than-average summer monsoon, the water deficit affects forest vegetation there much more severely than in the coastal regions.

Recorded changes in AP percentages (Fig. 8A) and calculated biome scores suggest that during ca. 5700–2100 cal. years B.P. the dominant vegetation around the Taishizhuang site changed from temperate deciduous forest to temperate forest–steppe and then to steppe (Fig. 8B). In the BIOME1 vegetation model (Prentice et al., 1992) replacement of tree vegetation by steppe communities requires a decrease in the moisture index (the ratio of actual to potential evapotranspiration) to below 0.65. At Taishizhuang the moisture index calculated from modern climate data (Leemans and Cramer, 1991) is 0.57, consistent with the semi-arid climate and steppe vegetation around the site.

In theory, the mid- to late-Holocene decrease in the moisture index suggested by the Taishizhuang record can be explained by a decrease in precipitation or/and an increase in summer temperatures. Reconstruction of the Holocene temperature trends in China based on historical/archaeological (e.g. Chang, 1986; Domrös and Peng, 1988; Zhang, 2004) and palaeoenvironmental records (e.g. Winkler and Wang, 1993; Tan and Cai, 2005) tend to support a decrease in summer temperatures through the middle to the late Holocene, leaving a decrease in precipitation as the most probable factor explaining changes in vegetation inferred from the Taishizhuang record (Figs. 6 and 8B). In order to

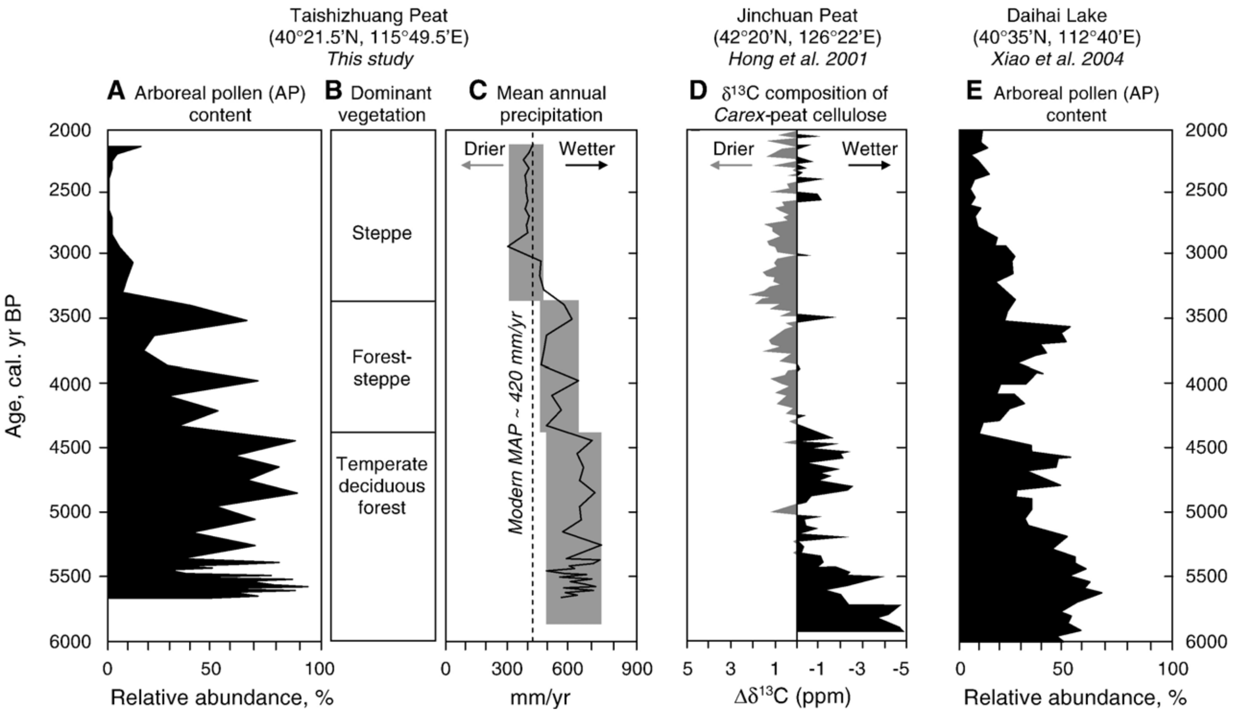

Fig. 8. Changes in AP content (A), dominant vegetation (B) and atmospheric precipitation (C) derived from the Taishizhuang Peat pollen record compared with the other palaeoclimatic proxies from northeastern China: $\Delta\delta^{13}$C composition of *Carex*-peat cellulose from the Jinchuan Peat (after Hong et al., 2001) (D) and AP variations in the Daihai Lake record (after Xiao et al., 2004) (E).

quantify past changes in precipitation a transfer function developed by Shi and Song (2003) was applied to the Taishizhuang pollen assemblages. Eq. (2) (Shi and Song, 2003) is a multiple regression established with a representative set of surface pollen spectra collected in northeastern China from natural steppe and forest environments.

$$\begin{aligned}\mathrm{MAP} = {} & 580.291 + 9.3Q + 6.3J + 1.8P \\ & + 4.6C - 1.4Pc - 1.5Cy - 9.3E - 1.9A - 4.4Ch \\ & + 7.6As - 10.9Po,\end{aligned} \tag{2}$$

where MAP is the mean annual precipitation and Q indicates relative pollen abundance (%) for *Quercus* deciduous, J—for *Juglans*, P—for *Pinus* undif., C—for *Carpinus*, Pc—for *Picea*, Cy—for Cyperaceae, E—for *Ephedra*, A—for *Artemisia*, Ch—for Chenopodiaceae, As—for Asteraceae undif. and Po—for Poaceae.

The results of the pollen-based reconstruction (Fig. 8C) suggest that annual precipitation reached ca. 550–750 mm during the mid-Holocene 'forest phase' (ca. 5700–4400 cal. years B.P.) being ca. 100–300 mm higher than at present. Precipitation values were ca. 450–650 mm/year during the following 'forest–steppe phase'. From ca. 3400 cal. years B.P. during the 'steppe phase' annual precipitation fell to ca. 300–500 mm and became similar to modern-day values.

In order to find out whether precipitation changes reconstructed from the Taishizhuang pollen record were of local or regional scale we compared the results (Fig. 8C) with a 6000-year δ^{13}C record of peat cellulose (Hong et al., 2001) from Jinchuan site (42°20′N, 126°22′E) located in the Changbai Shan (Fig. 1). This record was used to reconstruct moisture and precipitation changes associated with the summer monsoon (Fig. 8D). Visual comparison between Taishizhuang (Fig. 8A–C) and Jinchuan (Fig. 8D) shows the close correspondence of the reconstructed patterns. In both cases the transition from wetter to drier climate occurred after ca. 4400 cal. years B.P. The interval between 3400 and 2500 cal. B.P. is interpreted as the driest phase in both records. Consistently with these reconstructions, results of charcoal analysis of the Dahuofang profile (Fig. 1) suggest repeated occurrence of local fires after ca. 3500 cal. B.P. (Makohonienko et al., 2004). The fact that the δ^{13}C composition of peat cellulose is not affected directly or indirectly by past human activities supports our conclusion that changes in vegetation at Taishizhuang were natural rather than man-made and that reconstructed precipitation changes were regional rather than local.

Pollen studies suggest that forest vegetation occupied a larger area in China during the mid-Holocene (e.g. Yu et al., 1998, 2000; Ren and Beug, 2002) as a consequence of warm and wet climate associated with greater-than-present summer insolation and stronger Pacific monsoon activity (e.g. Winkler and Wang, 1993). Available pollen records from the study area help to refine this general interpretation. The pollen diagram from Daihai Lake (Xiao et al., 2004) located west of Taishizhuang shows highest through the entire Holocene content of AP (ca. 70%) about 5700 cal. years B.P. (Fig. 8E). The synchronous pollen spectra from the Taishizhuang record contain up to 95% of AP (Fig. 8A). A replacement of the oak–pine woodland and steppe with a dry steppe vegetation is reconstructed from Haoluku (42°57.38′N, 116°45.42′E) and Xiaoniuchang (42°37.05′N, 116°49.02′E) sequences (Fig. 1) after ca. 3500 cal. years B.P. (Liu et al., 2002), synchronously with the Taishizhuang record. Changes in vegetation accompanied with an increase in coarse sand accumulation, suggesting a strengthening of eolian activity due to increased aridity, became especially pronounced after 3000 cal. years B.P. (Liu et al., 2002).

7. Conclusion

Changes in the pollen composition at Taishizhuang between 5700 and 2100 cal. years B.P. are interpreted in terms of variations in precipitation and not as a consequence of deforestation caused by humans. Over-interpretation and generalization of archaeological data may lead to the opposite hypothesis. On the question of the direct evidence of human activities in the area, we can conclude that the archaeological records for the period under review are rich in qualitative information but do not provide evidence of use of wood resources intensive enough to influence the regional vegetation development and to leave traces in the pollen assemblages. Simply converting site numbers to human population densities provides neither facts nor knowledge. Systematic joint archaeological, archaeobotanical and archaeozoological research defining the economic conditions of communities and calculating the actual size of populations in a given space and time period are needed for a quantitative reconstruction of the human impact on the vegetation cover.

Changes in humidity/precipitation derived from pollen and isotope records from different parts of the study area (Fig. 8) show great similarity, indicating that a climatically driven shift towards drier vegetation and environments was synchronous across a broad belt of northeastern China between ca. 112°E and 127°E. Another conclusion coming from this comparison is that the climate aridization in northeastern China was not a gradual process. Dry episodes occurred synchronously ca. 5300–5000, ca. 4400, ca. 3400 and after 3000 cal. years B.P. They were interrupted by wet pulses distinguished around ca. 5700, ca. 4600 and ca. 3500 cal. years B.P. To investigate the nature of these short-term climatic fluctuations and their impact on human dynamics in the area is an objective for future studies.

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References

Barnes, G.L., 1993. China, Korea and Japan. The Rise of Civilization in East Asia. Thames and Hudson, London.

Barnes, G.L., Guo, D.S., 1996. The ritual landscape of ‘Boar Mountain’ Basin: the Niuheliang site complex of north-eastern China. World Archaeology 28 (2), 209–219.

Battarbee, R.W., Gasse, F., Stickley, C.E. (Eds.), 2004. Past Climate Variability through Europe and Africa. Developments in Paleoenvironmental Research, vol. 6. Kluwer Academic Publishing, Dordrecht.

Beijing shi wenwu guanlichu (Ed.), 1976. Another important archaeological find in Beijing area. Kaogu, vol. 4, pp. 246–258. 228 (in Chinese).

Berglund, B.E., Ralska-Jasiewiczowa, M., 1986. Pollen analysis and pollen diagrams. In: Berglund, B.E. (Ed.), Handbook of Holocene Palaeoecology and Palaeohydrology. Interscience, New York, pp. 455–484.

Broecker, W.S., Clark, E., 2003. Holocene atmospheric CO_2 increase as viewed from the seafloor. Global Biogeochemical Cycles 17 (Art. No. 1052 May 21).

Chang, K.C., 1986. The archaeology of ancient China. Yale University Press, New Haven.

Chang, K.C., 1999. China on the eve of the historical period. In: Loewe, M., Shaughnessy, E.L. (Eds.), The Cambridge History of Ancient China from the Origins of Civilization to 221 B.C. Cambridge University Press, New York, pp. 37–73.

Claussen, M., Brovkin, V., Calov, R., Ganopolski, A., Kubatzki, C., 2005. Did humankind prevent an early glaciation? Comment on Ruddiman’s hypothesis of a pre-historic anthropocene. Climatic Change 69, 409–417.

Crucifix, M., Loutre, M.F., Berger, A., 2005. Commentary on "The anthropogenic greenhouse era began thousands of years ago". Climatic Change 69, 419–426.

Crutzen, P.I., Stoermer, E.F., 2000. The "Anthropocene". IGBP Newsletter 41, 12.

Cultural Bureau of Chaoyang City, Liaoning Provincial Institute of Archaeology and Cultural Relics (Eds.), 2004. Niuheliang Site. Academy Press, Beijing.

Dalian Institute of Cultural Relics and Archaeology (Ed.), 2000. Dazuizi. A Report on Bronze Age Site Excavation in 1987. Dalian Press, Dalian (in Chinese).

Dian, C., Xin, Y., 1994. Three excavation campaigns from 1987 to 1990 at Chahai site, Fuxin County, Liaoning. Wenwu 11, 4–19 (in Chinese).

Di Cosmo, N., 1999. The Northern Frontier in Pre-Imperial China. In: Loewe, M., Shaughnessy, E.L. (Eds.), The Cambridge History of Ancient China. From the Origins of Civilization to 221 B.C. Cambridge University Press, Cambridge, pp. 885–966.

Domrös, M., Peng, G., 1988. The climate of China. Springer, Berlin.

Dong, W., Han, R., 1987. Survey of Nasitai site, Bairin Youqi, Inner Mongolia. Kaogu 6, 507–518 (in Chinese).

Gasse, F., Fontes, J.Ch., Van Campo, E., Wei, K., 1996. Holocene environmental changes in Bangong Co basin (Western Tibet). Part 4: Discussion and conclusions. Palaeogeography, Palaeoclimatology, Palaeoecology 120, 79–92.

Gotanda, K., Nakagawa, T., Tarasov, P., Kitagawa, J., Inoue, Y., Yasuda, Y., 2002. Biome classification from Japanese pollen data: application to modern-day and Late Quaternary samples. Quaternary Science Review 21, 647–657.

Grimm, E., 1991. TILIA and TILIAGRAPH. Illinois State Museum, Springfield, Illinois.

Guiot, J., Goeury, C., 1996. PPPBASE, a software for statistical analysis of paleoecological and paleoclimatological data. Dendrochronologia 14, 295–300.

Herzschuh, U., Tarasov, P., Wünnemann, B., Hartmann, K., 2004. Holocene vegetation and climate of the Alashan Plateau, NW China, reconstructed from pollen data. Palaeogeography, Palaeoclimatology, Palaeoecology 211 (1–2), 1–17.

Hong, Y.T., Wang, Z.G., Jiang, H.B., Lin, Q.H., Hong, B., Zhu, Y.X., Wang, Y., Xu, L.S., Leng, X.T., Li, H.D., 2001. A 6000-year record of changes in drought and precipitation in northeastern China based on a $\delta^{13}C$ time series from peat cellulose. Earth and Planetary Science Letters 185, 111–119.

Hou, H. (Ed.), 2001. Vegetation atlas of China. Science Press China, Beijing.

Institute of Cultural Relics and Archaeology, Inner Mongolia Autonomous Region (Ed.), 2004. Baiyinchanghan. An Excavation Report on the Neolithic Site. Science Press, Beijing (in Chinese).

Jin, G. (1999). Mid-Holocene Climate Change in North China and its Effect on Cultural Development. PhD Thesis, Inst. of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China.

Jin, G., Liu, T., 2002. Mid-Holocene climate change in North China, and the effect on cultural development. Chinese Science Bulletin 47 (5), 408–413.

Jin, G., Wagner, M., 1998. Surface building forms in Northeast China around 2000 B.C.—Walls: Communities make themselves visible. In: Boese, M., Hofmann, J. (Eds.), Forschungsergebnisse zur Klimageschichte und Reliefentwicklung Nordafrikas und Asiens. Festschrift fuer Dieter Jaekel zum 65. Geburtstag. Berliner Geographische Abhandlungen, 63, pp. 67–82.

Joos, F., Gerber, S., Prentice, I.C., Otto-Bliesner, B.L., Valdes, P., 2004. Transient Simulations of Holocene Atmospheric Carbon Dioxide and Terrestrial Carbon since the Last Glacial Maximum. Global Biogeochemical Cycles 18 (GB2002), 1–18.

Lewis, M.E., 1999. Warring States: Political History. In: Loewe, M., Shaughnessy, E.L. (Eds.), The Cambridge History of Ancient China. From the Origins of Civilization to 221 B.C. Cambridge University Press, Cambridge, pp. 587–650.

Li, X., Zhou, W., An, Z., Dodson, J., 2003a. The vegetation and monsoon variations at the desert–loess transition belt at Midiwan in northern China for the last 13 ka. Holocene 13, 779–784.

Li, Y., Gu, H., Zhu, Y., 2003b. A preliminary Study on Bronzes from Dadianzi Tombs. Wenwu 7, 78–84 (in Chinese).

Liaoning Provincial Institute of Cultural Relics and Archaeology, Chifeng Municipal Museum (Eds.), 1998. Danangou. An Excavation Report on the Cemetery of Post-Hongshan Culture. Science Press, Beijing (in Chinese).

Liaoning sheng wenwu kaogu yanjiusuo (Ed.), 2001. Short report about the excavations at the city-site Kangjiatun, Beipiao City, Liaoning. Kaogu, vol. 8, pp. 31–44 (in Chinese).

Leemans, R., Cramer, W., 1991. The IIASA Climate Database for Mean Monthly Values of Temperature, Precipitation and Cloudiness on a Global Terrestrial Grid. RR-91-18. International Institute of Applied Systems Analysis, Laxenburg.

Lin, Y., 1986. A Reexamination of the Relationship between Bronzes of the Shang Culture and of the Northern Zone. In: Chang, K.C. (Ed.), Studies of Shang Archaeology. Yale University Press, New Haven and London, pp. 237–273.

Linduff, K.M., Drennan, R.D., Shelach, G., 2004. Early Complex Societies in NE China: The Chifeng International Collaborative Archaeological Research Project. Journal of Field Archaeology 29, 45–73.

Liu, L., Chen, X., 2003. State Formation in Early China. Duckworth, London.

Liu, K., Yao, Z., Thompson, L.G., 1998. A pollen record of Holocene climatic changes from the Dunde ice cap, Qinghai–Tibetan Plateau. Geology 26, 135–138.

Liu, H., Xu, L., Cui, H., 2002. Holocene history of desertification along the woodland–steppe border in northern China. Quaternary Research 57, 259–270.

Luan, F., 1997. Archaeological Research in Haidai Region. Shandong University Press, Jinan (in Chinese).

Makohonienko, M., Kitagawa, H., Naruse, T., Nasu, H., Momohara, A., Okuno, M., Fujiki, T., Liu, X., Yasuda, Y., Yin, H., 2004. Late-Holocene natural and anthropogenic vegetation changes in the Dongbei Pingyuan (Manchurian Palin), northeastern China. Quaternary International 123–125, 71–88.

Mei, J., 2003. Qijia and Seima-Turbino: The Question of Early Contacts between Northwest China and the Eurasien Steppe. Bulletin of the Museum of Far Eastern Antiquities 75, 5–13.

Nelson, S.M. (Ed.), 1995. The Archaeology of Northeast China beyond the Great Wall. Routledge, London.

Pachur, H.-J., Wunnemann, B., Zhang, H., 1995. Lake evolution in the Tengger desert, Northwestern China, during the last 40,000 years. Quaternary Research 44, 171–180.

Pak, Y. (1996). A Study of the Bronze Age Culture in the Northern Zone of China, Doctoral Dissertation, UMI Dissertation Services, Ann Arbor.

Prentice, I.C., Jolly, D., BIOME6000 Participants, 2000. Mid-Holocene and glacial-maximum vegetation geography of the northern Continents and Africa. Journal of Biogeography 27, 507–519.

Prentice, I.C., Webb III, T., 1998. BIOME 6000: reconstructing global mid-Holocene vegetation patterns from palaeoecological records. Journal of Biogeography 25, 997–1005.

Prentice, I., Cramer, W., Harrison, S.P., Leemans, R., Monserud, R.A., Solomon, A.M., 1992. A global biome model based on plant physiology and dominance, soil properties and climate. Journal of Biogeography 19, 117–134.

Prentice, I.C., Guiot, J., Huntley, B., Jolly, D., Cheddadi, R., 1996. Reconstructing biomes from palaecological data: a general method and its application to European pollen data at 0 and 6 ka. Climate Dynamics 12, 185–194.

Rawson, J., 1999. Western Zhou Archaeology. In: Loewe, M., Shaughnessy, E.L. (Eds.), The Cambridge History of Ancient China. From the Origins of Civilization to 221 B.C. Cambridge University Press, Cambridge, pp. 352–449.

Ren, G., Beug, H.-J., 2002. Mapping Holocene pollen data and vegetation of China. Quaternary Science Reviews 21, 1395–1422.

Ruddiman, W.F., 2003. The anthropogenic greenhouse era began thousands of years ago. Climatic Change 61, 261–293.

Ruddiman, W.F., 2005. The early anthropogenic hypothesis a year later—An editorial reply. Climatic Change 69, 427–434.

Shelach, G., 1999. Leadership Strategies, Economic Activity, and Interregional Interaction. Social Complexity in Northeast China. Kluwer Academic/Plenum Publishers, New York.

Shi, P., Song, C., 2003. Palynological records of environmental changes in the middle part of Inner Mongolia, China. Chinese Science Bulletin 48 (14), 1433–1438.

Simmons, I.G., 1996. Changing the Face of the Earth. Blackwell, Oxford.

Tan, M., Cai, B., 2005. Preliminary calibration of stalagmite oxygen isotopes from eastern monsoon China with northern hemisphere temperatures. PAGES News 13 (2), 16–17.

Tarasov, P.E., Cheddadi, R., Guiot, J., Bottema, S., Peyron, O., Belmonte, J., Ruiz-Sanchez, V., Saadi, F.A., Brewer, S., 1998a. A method to determine warm and cool steppe biomes from pollen data; application to the Mediterranean and Kazakhstan Regions. Journal of Quaternary Science 13 (4), 335–344.

Tarasov, P.E., Webb III, T., Andreev, A.A., Afanas'eva, N.B., Berezina, N.A., Bezusko, L.G., Blyakharchuk, T.A., Bolikhovskaya, N.S., Cheddadi, R., Chernavskaya, M.M., Chernova, G.M., Dorofeyuk, N.I., Dirksen, V.G., Elina, G.A., Filimonova, L.V., Glebov, F.Z., Guiot, J., Gunova, V.S., Harrison, S.P., Jolly, D., Khomutova, V.I., Kvavadze, E.V., Osipova, I.M., Panova, N.K., Prentice, I.C., Saarse, L., Sevastyanov, D.V., Volkova, V.S., Zernitskaya, V.P., 1998b. Present-day and mid-Holocene Biomes Reconstructed from Pollen and Plant Macrofossil Data from the Former Soviet Union and Mongolia. Journal of Biogeography 25, 1029–1053.

Tarasov, P.E., Peyron, O., Guiot, J., Brewer, S., Volkova, V.S., Bezusko, L.G., Dorofeyuk, N.I., Kvavadze, E.V., Osipova, I.M., Panova, N.K., 1999. Last Glacial Maximum climate of the Former Soviet Union and Mongolia reconstructed from pollen and plant macrofossil data. Climate Dynamics 15, 227–240.

Tarasov, P., Dorofeyuk, N., Metel'tseva, E., 2000. Holocene vegetation and climate changes in Hoton-Nur basin, northwest Mongolia. Boreas 29 (2), 117–126.

Tarasov, P., Brovkin, V., Wagner, M., 2005. What Drives the Climate: Man or Nature? PAGES News 13 (2), 24–25.

Wagner, M., 2006. Neolithikum und fruehe Bronzezeit in Nordchina vor 8000 bis 3500 Jahren. Die Nordoestliche Tiefebene (Suedteil). Philipp von Zabern, Mainz a. R.

Wagner, M., Parzinger, H., 1999. Bemerkungen zur inneren Gliederung der spaetbronzezeitlichen Kultur Oberes Xiajiadian und deren Bedeutung fuer die suedsibirische Kulturentwicklung. Eurasia Antiqua 4, 37–72.

Winkler, M.G., Wang, P.K., 1993. The Late-Quaternary Vegetation and Climate of China. In: Wright, H.E., Kutzbach, J.E., Webb III T., Ruddiman, W.F., Street-Perrott, F.A., Bartlein, P.J. (Eds.), Global Climates since the Last Glacial Maximum. University of Minnesota Press, Minneapolis, pp. 265–293.

Wu, Z.Y., 1980. Vegetation of China. Science Press, Beijing.

Wu, W., Liu, T., 2004. Possible role of the "Holocene Event 3" on the collapse of Neolithic Cultures around the Central Plain of China. Quaternary International 117, 153–166.

Xiao, J., Xu, Q., Nakamura, T., Yang, X., Liang, W., Inouchi, Y., 2004. Holocene vegetation variation in the Daihai Lake region of north-central China: a direct indication of the Asian monsoon climatic history. Quaternary Science Reviews 23, 1669–1679.

Yang, H., 1994. Sequence and periodisation of Neolithic and Eneolithic archaeological cultures in Liaoxi area. Wenwu 5, 37–52 (in Chinese).

Yang, H., Liu, G.X., 1997. Short report about the excavation at Xinglongwa settlement site, Inner Mongolia, Aohan Banner, in 1992. Kaogu 1, 1–26 52 (in Chinese).

Yang, H., Zhu, Y.P., 1987. Xiaoshan site, Aohan Banner, Inner Mongolia. Kaogu 6, 481–506 (in Chinese).

Yasuda, Y. (Ed.), 2001. Forest and Civilisations. Roli Books Pvt. Ltd., New Delhi.

Yasuda, Y., Shinde, V. (Eds.), 2004. Monsoon and Civilization. Roli Books Pvt. Ltd, New Delhi.

Yu, G., Prentice, I.C., Harrison, S.P., Sun, X., 1998. Pollen-based biome reconstruction for China at 0 and 6000 years. Journal of Biogeography 25, 1055–1069.

Yu, G., Chen, X., Ni, J., Cheddadi, R., Guiot, J., Han, H., Harrison, S.P., Huang, C., Ke, M., Kong, Z., Li, S., Li, W., Liew, P., Liu, G., Liu, J., Liu, K.-B., Prentice, I.C., Qui, W., Ren, G., Song, C., Sugita, S., Sun, X., Tang, L., Van Campo, E., Xia, Y., Xu, Q., Yan, S., Yang, X., Zhao, J., Zheng, Z., 2000. Palaeovegetation of China: a pollen data-based synthesis for the mid-Holocene and last glacial maximum. Journal of Biogeography 27, 635–664.

Zhang, D. (Ed.), 2004. A Compendium of Chinese Meteorological Records of the Last 3000 Years. Jiangsu Education Press, Nanjing (in Chinese with English introduction).

Zhao, S., 1994. Geography of China: environments, resources, population, and development. John Willey, New York.

Zhongguo shehui kexueyuan kaogu yanjiusuo (Ed.), 1996a. Shuangtuozi and Gangshang. Discovery and Study of Prehistoric Cultures on Liaodong Peninsula. Science Press, Beijing (in Chinese).

Zhongguo shehui kexueyuan kaogu yanjiusuo (Ed.), 1996b. Dadianzi. Excavations on the Residence and Cemetery of the Xiajiadian Lower Culture. Science Press, Beijing (in Chinese).

Zhongguo shehui kexueyuan kaogu yanjiusuo (Ed.), 1997. The Zhaobaogou Site in Aohan Banner. Neolithic Settlement. Chinese Encyclopedia Press, Beijing (in Chinese).

Zhongguo wenming qiyuan he zaoqi guojia xingtai yantaohui mishuzu (Ed.), 2001. Abstract of Papers Presented at the Symposium on the Origins of Chinese Civilization and the Form of Early States Kaogu, vol. 2, pp. 86–95. July 22–23 (in Chinese).