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Pollen evidence for increased summer rainfall in the Medieval warm period at Maili, Northeast China

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Abstract. A 2000-year fossil pollen series from Maili Bog, Northeast China, is presented. In the pollen record, which has a time resolution of 28 years during the last 1000 years, the period 1000-660 yr. BP stands out as unique because it witnessed a remarkably increased pollen accumulation for almost all the taxa. This change could not be explained by the relaxation of human interference stress, because population density and intensity of agricultural activities during Liao and Jin Dynasties (AD 916 to AD 1234) were generally larger than any previous time in the study area. Instead, it may indicate increased summer monsoon rainfall in Northeast China during the time comparable to the Medieval warm period of Europe. The general summer warming over Eurasia relative to the oceans during the period is assumed to be the cause for the strengthened monsoon circulation and increased rainfall in the temperate monsoon area of East Asia.

Introduction

Evidence for climate changes in the Medieval warm period have been widely found in Europe (Lamb, 1977), North America (Bernabo, 1981; Koerner, 1977; Scuderi, 1993; Stine, 1994; Davis, 1994), Russian Arctic (Graybill and Shiyatov, 1992; Shiyatov, 1995), Greenland (Herron et al, 1981), the Sargasso Sea (Keigwin, 1996) and Patagonia (Villalba, 1990; Stine, 1994). According to the work by Zhu (1973), however, the temperature variation in eastern China is a little different, with the warm period occurring some 200-300 years earlier, and it was rather cold in the 13th century corresponding to the peak warming in Europe (Zhu, 1973; Crowley and North, 1991). In the last years, two studies of the historic data show that the 13th century may have been fairly warm instead (Man and Zhang, 1990; Zhang, 1994), though some major questions, such as the timing and duration of the warm period, the contemporary rainfall changes and the seasonal variation of the climatic anomalies, still remain unsolved. Here I present a 2000-year record of fossil pollen, which reveals that the monsoon rainfall in Northeast China was apparently higher during a time comparable to the Medieval warm period of Europe. The summer monsoon circulation in East Asia may have been more vigorous then, which may have resulted from the higher summer temperature over Eurasia as compared with the Pacific.

Study site and environment

The sampling was carried out at Maili Bog on the southeastern fringe of the Horqin Sand Land (42°52' N, 122°53' E; 155 m above sea level) (Ren and Zhang, 1997). The bog is 3 km long and 0.5 km wide, and it is surrounded by sand dunes, most of which are stabilized or partly stabilized. Climate at the study site is characterized by the temperate monsoon, with the mean temperatures ranging from -14 ℃ in January to 23 ℃ in July and the annual precipitation of 490 mm. More than 80 percent of the annual precipitation falls within the plant-growing period which is in consistence with the summer monsoon season from the beginning of June to the end of August.

Being near the ecotone between the deciduous forest to the east and the temperate steppe to the west, the stabilized dunes around Maili Bog are supporting an open forest. It simply consists of *Quercus mongolica*, *Ulmus pumila*, *Acer truncatum* and *Celtis bungeana*. The partly stabilized dunes are mainly covered by the herbaceous plants of *Artemisia*, Chenopodiaceae and Gramineae (Wu, 1980; Study Group of Academia Sinica, 1985; Ren and Zhang, 1997). In addition, *Carex*, *Phragmites communis*, *Glyceria aquatica* and *Menyanthes trifolia* are the dominant components of the smash vegetation in the bog.

Method and dating

A peat profile of 244 cm deep was prepared from a drainage ditch that was excavated in mid 1970's. Contiguous sampling were taken at 2 cm intervals. All the 40 samples above 80 cm and those of odd numbers below 80 cm were analyzed for pollen, following the procedure described by Moore and Webb (1976). The pollen percentages are based on a sum of total terrestrial pollen including Cyperaceae, and the pollen concentrations are expressed as grains per cubic centimeter of dry sample. Because the sedimentation rate of peat remained almost constant for the profile, as will be seen in the next paragraph, the relative

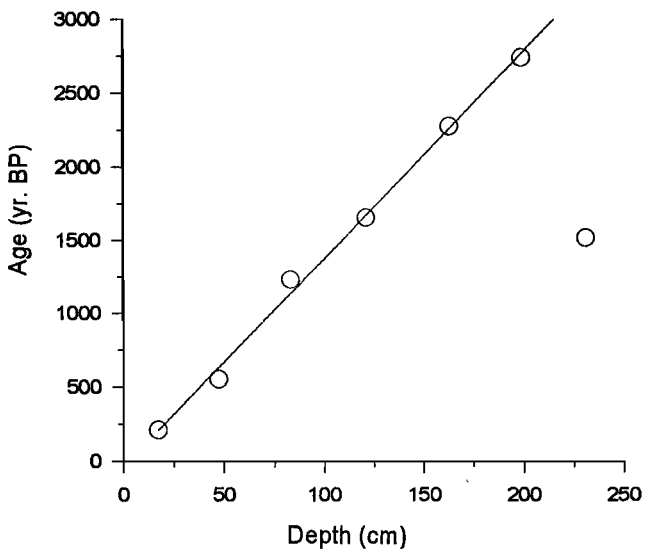

Figure 1. Relationship between radiocarbon dates and depths on Maili peat profile.

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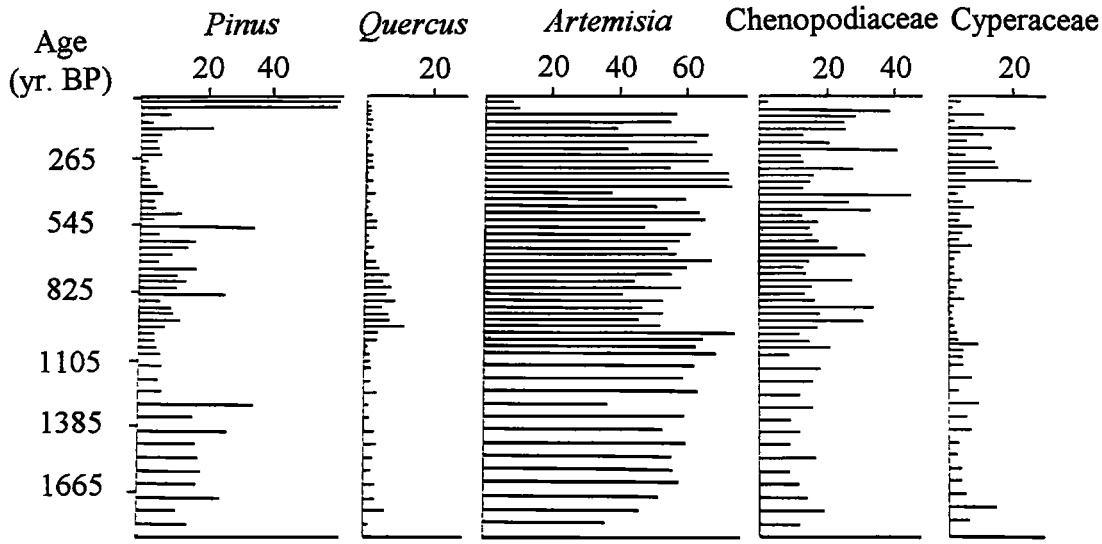

Figure 2. Pollen frequency variation from Maili Bog section. The main arboreal and herbaceous taxa are shown. Pollen frequencies are expressed as percentages of a sum of terrestrial pollen grains.

changes in the pollen concentrations are nearly the same with the pollen influxes (grains/cm^2/year).

Seven radiocarbon dates were obtained from the peat profile (Ren and Zhang, 1997) (Table1). Excluding an outliner, or sample ML 8 at 230 m, an excellent correlation exists between the dates and depths, making it reasonable to construct an equation using the least square method (Fig. 1). The equation is expressed as

$$A = 14\,D - 29$$

in which A is the radiocarbon ages, and D, the depths. According to the equation, the latest sedimentation dates in the study site are around 1979, a year very close to the excavating time of the drainage ditch. As the radiocarbon dates are very close to the calendar ones for the last 2000 years, little difference exists between the age models developed from the original and calibrated dates. Here I use the original radiocarbon dates and the age model derived from them.

Being from the bottom of the peat profile, sample ML 8 may have been contaminated by the rising water during rainy season. In the drainage ditch, water can be seen for the whole year, but the water level is obviously higher in the three summer months, especially in wetter years. The rising water, incorporating the relatively new carbon out of the peat collapsed from the upper walls of the ditch, will inundate the bottom of the profile, and may have made the date of sample ML 8 appear too younger.

Results and analyses

Pollen percentages (Fig. 2) show a little higher value for the main arboreal taxa from 1000 yr. BP to 680 yr. BP (about AD

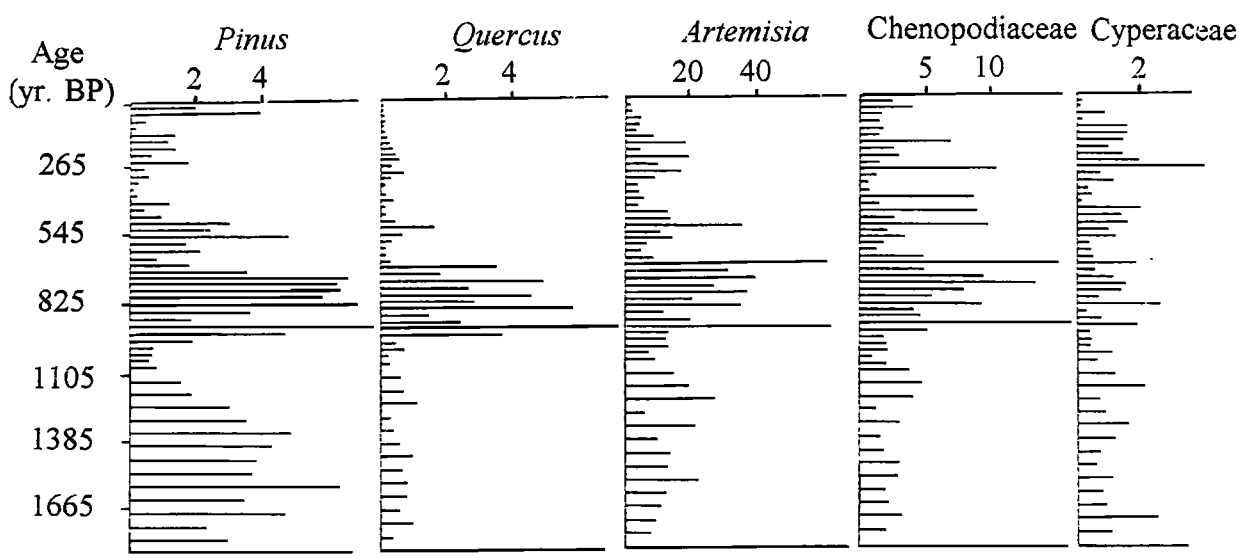

Figure 3. Pollen concentration variation from Maili Bog section. Pollen concentrations are expressed as 10^3 grains per cubic centimeter of dry sample. As sedimentation rate of the peat is nearly constant, pollen influx (grains/cm^2/yr.), which is not shown here, would have the same change pattern with the pollen concentration.

Table 1. Radiocarbon Dates of Maili Bog Profile, Northeast China

Sample No.	Depth (cm)	Material	Carbon Dates (yr. BP)	Laboratory
ML 114	16 - 18	Peat	215 ± 70	
ML 99	46 - 48	Peat	555 ± 70	Radiocarbon
ML 81	82 - 84	Peat	1235±70	Laboratory of
ML 62	120-122	Peat	1655±70	Beijing Normal
ML 41	162-164	Peat	2275±70	University
ML 23	198-200	Peat	2740±75	
ML 8	230-232	Peat	1520±70	

yr. BP — years before present (AD 1950)
Half-life of ^{14}C is 5568 years

950 - 1270), especially for *Quercus*, a main taxon in the stabilized dunes today, indicating that *Quercus mongolica* was more abundant in the region then than now. On the pollen concentration diagram (Fig. 3), significantly higher pollen accumulations during the same period are seen not merely in *Pinus*, *Quercus* and *Betula*, but in the major herbaceous taxa such as *Artemisia* and Chenopodiaceae. Since the type and rate of sedimentation did not change around the beginning and end times of the period, the marked change in pollen concentration or pollen influx may indicate that the dunes around the bog supported much denser vegetation then than any other times of the last 2000 years.

The inclusion of Cyperaceae in the pollen sum would not make the above explanation ambiguous. As can be seen in Fig. 3, no evident long-term change in Cyperaceae concentration or influx occurred during the recorded length, illustrating that the increase in the pollen percentages of upland types is not due to the changes of microenvironment within the bog. As for the changes in the pollen concentration or pollen influx of upland types, the Cyperaceae pollen deposit does not influence them. In addition, the contrast between the relative constancy of Cyperaceae pollen and the sharp changes of the plants growing on the sand dunes also indicates that the smash vegetation was largely independent of the driving factors affecting the upland vegetation.

It is difficult to explain the pollen changes mentioned above by human activity. Since 10th century, the minorities in Northeast China became stronger one after another. Liao Dynasty, from AD 916 to AD 1125, was ruled by Qidan people, and the territory was controlled by Nuzhen people between AD 1115 and AD 1234. Both of Qidan and Nuzhen paid more attention to agricultural development. Historical documents and archaeological relics show that the Horqin Sand Land was more densely populated during these two dynasties than during the previous times (Zhao and Xie, 1988; Zhang, 1991). It is therefore impossible to assume the relaxation of human stress on vegetation cover as the cause for the increase in population of major taxa. Climatic amelioration may have been responsible for the vegetation change instead.

Near the Maili Bog, moisture shortage restricts the growth of the upland plants. When rainfall increases, most species will grow better, and their populations will correspondingly expand. The sensitivity of *Quercus mongolica* to rainfall is suggested by its sharp decline towards the northwest following the decrease of annual precipitation. *Quercus mongolica* is the most common species on the stabilized sand dunes near Maili Bog where annual precipitation is 490 mm. However, it can not be found on the sand dunes 50 km northwest of the sampling site, where annual precipitation decreases to 450 mm. The isopleth of precipitation of 470 mm well coincides with the northwestern boundary of the arboreal type. The expansion of major species, in particular of *Quercus mongolica*, thus indicates a rise in precipitation from 1000 yr. BP to 680 yr. BP, a time corresponding to the climate anomaly of the Medieval warm period.

Four modern pollen samples taken from the bog and surface soils under the open forest all show a relatively high pollen percentages for *Pinus* that does not grow in the area today. *Pinus tabulaeforms* is common in the western Liaoning mountains, about 120-300 km southwest of Maili Bog. *Pinus* pollen was probably transported to the study site from there by the prevailing southwesterly winds in late spring and early summer. If so, the simultaneous rise of *Pinus* pollen with the other taxa suggests that the increase of precipitation occurred over a wide region during the Medieval warm period.

Since more than 80 percent of the annual precipitation is concentrated within growing season in the region, the change in pollen record may reflect an increase in summer rainfall. A stronger summer monsoon circulation may have been formed. On the other hand, the summer monsoon circulation intensity is generally believed to be controlled by the thermal difference between the Pacific and Eurasia (Academia Sinica, 1984). It is therefore plausible that Eurasia as a whole was warmer relative to the Pacific in summer during the Medieval warm period, forming a deeper low pressure over the interior of Asia and a more vigorous monsoon circulation in East Asia, a mechanism similar to that functioning during the early Holocene (COHMAP Members, 1988). More evidence is needed to support this hypothesis, but the existing proxy records show that the summer in the Eurasia as a whole was indeed warmer during the Medieval Period (Crowley and North, 1991; Graybill and Shiyatov, 1992; Lamb, 1977).

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