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Pollen assemblages of tauber traps and surface soil samples in steppe areas of China and their relationships with vegetation and climate

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ABSTRACT

We use 86 pollen trap and surface soil pollen samples in steppe areas of China to explore the relationships between modern pollen, vegetation, and climate. The modern pollen spectra from both sources have comparable compositions with regard to the major pollen taxa. However, the number of taxa in the traps was higher than in the surface soil samples. Both pollen accumulation rates and pollen concentrations are higher in the typical steppe areas than in the desert steppe areas. Discriminant analysis indicates that pollen spectra from trap and surface soil samples roughly reflect the vegetation zones of desert steppe and typical steppe, especially in the case of the trap samples. Detrended canonical correspondence analysis suggests that pollen assemblages have a significant relationship with the temperature of the coldest month and the mean annual precipitation.

1. Introduction

The aim of this study of modern surface pollen is to get a better understanding of the relationships between pollen, vegetation, and climate that can be used as a reference for better interpreting fossil assemblages. Many studies on surface samples from soil (Davis, 1984; Liu et al., 1999; Herzschuh et al., 2003; Reese and Liu, 2005), bogs and lakes (Davis 1963; Andersen, 1970; Davis and Brubaker, 1973; Rolf, 1988; Jackson, 1994; Bunting et al., 1998; Xu et al., 2005; Wilmshurst and McGlone, 2005), or moss pollsters (Gaillard et al., 1992; Räsänen et al., 2004) have investigated the relationship between vegetation and the pollen signal. However it is difficult to specifically relate the pollen data to vegetation, as we do not know how far away each pollen type comes from and how long a period the samples cover. Therefore, pollen traps are given more attention in recent years, especially in the quantitative investigations of pollen production (Bunting et al., 2005; Räsänen et al., 2007; Sugita, 2007) and pollen dispersal (Hicks et al., 2001; Koff, 2001; Sugita et al., 2006), because traps yield both pollen composition and pollen accumulation rates (PAR: numbers of pollen grains cm^{-2} yr^{-1}; Barnekow et al., 2007), which may more objectively reflect the pollen sedimentation patterns at given spatio-temporal ranges (Davis et al., 1973; Hicks, 1997). A Pollen Monitoring Programme has been carried out in Europe (Hicks et al., 2001) with the aim of monitoring the pollen deposition of key tree and shrub species across vegetation transitions from closed forest to open vegetation. Based on results of research in pollen production and pollen dispersal, a model of pollen source area was suggested by Prentice (1985), and refined by Sugita (Sugita et al., 1999, 2006; Sugita 2007), and the POLLANDCAL (pollen-landscape-calibration) network is attempting to infer quantitative changes in past land cover and to better understand long-term ecological processes, as well as to use historical models in modern landscape management (Broström, 2002; Bunting, 2002; Bunting et al. 2004; Eklöf et al., 2004; Broström et al., 2004; Giesecke and Bennett, 2004; Nielsen, 2004; Räsänen et al., 2004; Broström et al., 2005, Soepboer et al., 2007).

However, surface samples are still common in the study of relationships between pollen, vegetation and climate, especially in China (Li, 1990; Yu and Han, 1995; Tong et al., 1996; Yan et al., 1996; Yu and Liu, 1997; Liu et al., 1999; Xu et al., 2000; Lü et al., 2004), as the samples are easy to obtain. Several surface soil pollen studies have been carried out in the steppe area of China (Wang et al., 1996; Liu et al., 1999; Li et al., 2000; Herzschuh et al., 2003; Li et al., 2005). However, no research has previously been done based on pollen traps in the steppe area of China, or even in other areas of China apart from

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the Changbai Mountain (Sun and Wu, 1988; Xu et al., 2007). Studies of PAR in grasslands are also rare in other areas of the world (Hall, 1990, 1992, 1994; Hoyt, 2000).

In China, steppe, which stretches across 17° in latitude (from 35°N to 52°N) and 44° in longitude (from 83°E to 127°E), is one of important vegetation types (Wu, 1980; Animal Husbandry Vet Central Station of the China, 1995). Herbs dominate the steppe pollen spectra. However, the interpretation of herb pollen in fossil records is always ambiguous because of different representation of various pollen taxa. For example, the vegetation is usually reconstructed as "*Artemisia* steppe" if *Artemisia* dominated the pollen assemblage. But in fact, the study on modern surface soil pollen shows that *Artemisia* pollen always dominates the pollen assemblages in most typical steppe areas of China, even though Poaceae are the dominant plants in the vegetation composition (Liu et al., 1999; Li et al., 2005). Therefore it is necessary to obtain information on pollen accumulate rates from pollen traps to infer how and to what extent the local flora and vegetation is reflected in the pollen assemblages from steppe regions.

Here, we present pollen data from traps and surface soil sediments to study the relationships between pollen, vegetation, and climate in typical and desert steppes of China. This study represents the first published results from a controlled annual pollen monitoring from this area.

2. Study area

The study area spans 8° in latitude and 12° in longitude, in the range of 105°59′01″–117°34′41″E, 36°05′52″–43°58′40″N, where the typical steppe and desert steppe are the major vegetation types. The typical steppe has the largest area in the Inner Mongolian Plateau, the Ordos Plateau and the eastern Loess Plateau where the typical soil type is chestnut colored soil and the altitude covers 800–1300 m a.s.l., with mean annual precipitation ranging from 250 mm to 400 mm (Gu, 1993; Li, 1993). Major plants consist of *Stipa grandis*, *S. krylovii*, *S. bungeana*, *S. capillata*, *Aneurolepidium chinense*, *Festuca ovina*, *Artemisia frigida*, *Cleistogenes squarrosa*, and *Thymus mongolicus*, with 25%–75% vegetation coverage (Wu, 1980; Inner Mongolia and Ningxia Research Group of Chinese Academy of Sciences, 1985; Gao and Dai, 1988; Hou, 1988; Li, 1993). The plant communities are similar to those found in the mixed prairie of North America situated in the mid-latitude inland (Gu, 1993). Desert steppe is the most arid steppe, and mainly located in Alashan Plateau, Ordos Plateau and western Loess Plateau, where the typical soil type is brown calcic soil, and where mean annual precipitation ranges from 250 mm to 150 mm (Gu, 1993; Li, 1993). The plants are dominated by *Stipa gobica*, *S. breviflora*, *S. glareosa*, *S. klemenzii*, *Allium polyrrhisum*, *Ajania achilleoides*, *Hippolytia trifida*, *Artemisia salsoloides*, and *A. dalailamae* with 15–30% vegetation coverage (Wu, 1980; Inner Mongolia and Ningxia Research Group of Chinese Academy of Sciences, 1985; Gao and Dai, 1988; Hou, 1988).

3. Material and methods

3.1. Field work

The Tauber traps (10 cm diameter, 30 cm height, aperture of 5.2 cm in diameter) were sunk into the ground with their top at 4–5 cm height above the ground. This not only prevents surface soil getting into the traps, but also makes it possible to compare the pollen composition with that found in surface soil samples. Surface soil pollen samples (top 1–2 cm of the soil) were collected at the same sites around the traps.

Traps were placed and surface samples collected at 30–40 km intervals along transects which cover the meadow steppe, the typical steppe and the desert steppe where human disturbance is weak (Fig. 1). A total of 102 Tauber traps were placed and 102 surface soil pollen samples were collected in July 2004. However, only 43 traps

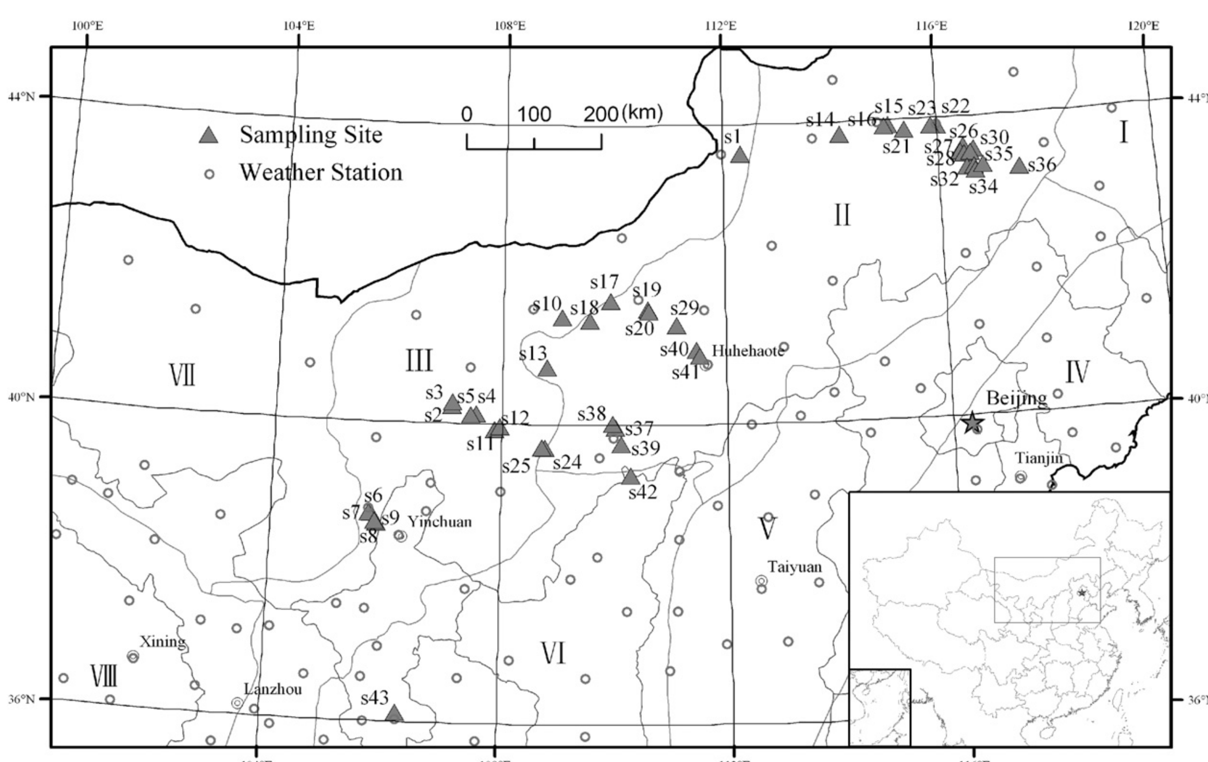

Fig. 1. Map of the location of sampling sites and weather stations in the steppe area of northern China, Hollow circle: sampling sites; solid triangle: weather stations; Roman numerals: different physical geographical zones. Notes: I: temperate forest steppe zones with black soil and black calcareous soil; II: temperate dry-steppe zones with chestnut soil; III: temperate desert steppe zones with brown and grey chestnut soil; IV: warm temperate broad leaved forest zones with brown loam soil; V: warm temperate forest steppe zones with brown soil; VI: warm temperate dry-steppe zones with black loess soil; VII: desert zones with grey and brown desert soil; VIII: alpine steppe zones (revised from Atlas of physical geography in China, Northwest Normal University and Map Publishing House, 1982).