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SCIENCE DIRECT
Quaternary International 136 (2005) 25–32

Lacustrine and eolian records of Holocene climate changes in the Mongolian Plateau: preliminary results

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Available online 19 January 2005

Abstract

This study compares two pairs of adjacent lacustrine and eolian sections at sites in the southern and northern Mongolian Plateaus in order to test spatial climate variability during the Holocene. Based on the lithology, proxy data, and ^{14}C dated and the interpolated ages, the following observations can be made. In the northern Mongolian Plateau, a best developed Holocene paleosol dated at 8672 ^{14}C yr BP at the Shaamar section and the carbonate-rich laminated layer in the Gun Nuur lake core mark the interval of warmer and dryer climate during the early Holocene. Younger paleosols at the Shaamar section and corresponding organic-rich layers in the Gun Nuur core were formed under distinctly cooler and more humid conditions. The Baahar Nuur lake core in the southern Mongolian Plateau and the Dingxi-type section in the northern part of the Western Chinese Loess Plateau appear to indicate that a prolonged interval of maximum humidity prevailed in this region during the early and mid-Holocene (9000–4000 ^{14}C yr BP). By contrast, in the northern Mongolian Plateau the most humid conditions seem to have occurred from 4500 to 2500 (possibly to 1650) ^{14}C yr BP. This discrepancy implies that the concept of the Holocene climatic optimum has limitations and may have to be reconsidered if it is intended to have a large-scale connotation.

1. Introduction

Possible human-induced climate change and adverse human impacts on environment alert us to assess the future climatic stability and environmental sustainability. However, this assessment requires a solid understanding of the natural climatic variability on different time scales. The Holocene is of particular interest in that regard because the climatic boundary conditions are similar to those experienced now and possibly in the near future. Of a special and most likely global significance to the Holocene climatic history is the traditionally defined Maximum Postglacial Warmth event (Winkler and Wang, 1993) when large-scale climatic systems were interpreted to have reorganized (Stager and Mayewski, 1997; Steig, 1999). Its onset has been variously placed at 10,000–7500 yr BP and its end at 5000–2000 yr BP (An et al., 2000). The Maximum Postglacial Warmth was reported to have occurred synchronously between 8500 and 3000 yr BP across east–central Asia with the climax (equivalent to the Climatic Optimum defined by An et al., 2000) from 7200 to 6000 yr BP (Shi et al., 1994a,b). However, An et al. (2000) recently argued that the Climatic Optimum was time-transgressive from northwest to the southeast in the summer monsoon-influenced area of China (i.e. eastern China).

To understand the global Holocene climate changes and the controlling mechanisms, temporal and spatial

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1040-6182/$ - see front matter
doi:10.1016/j.quaint.2004.11.005

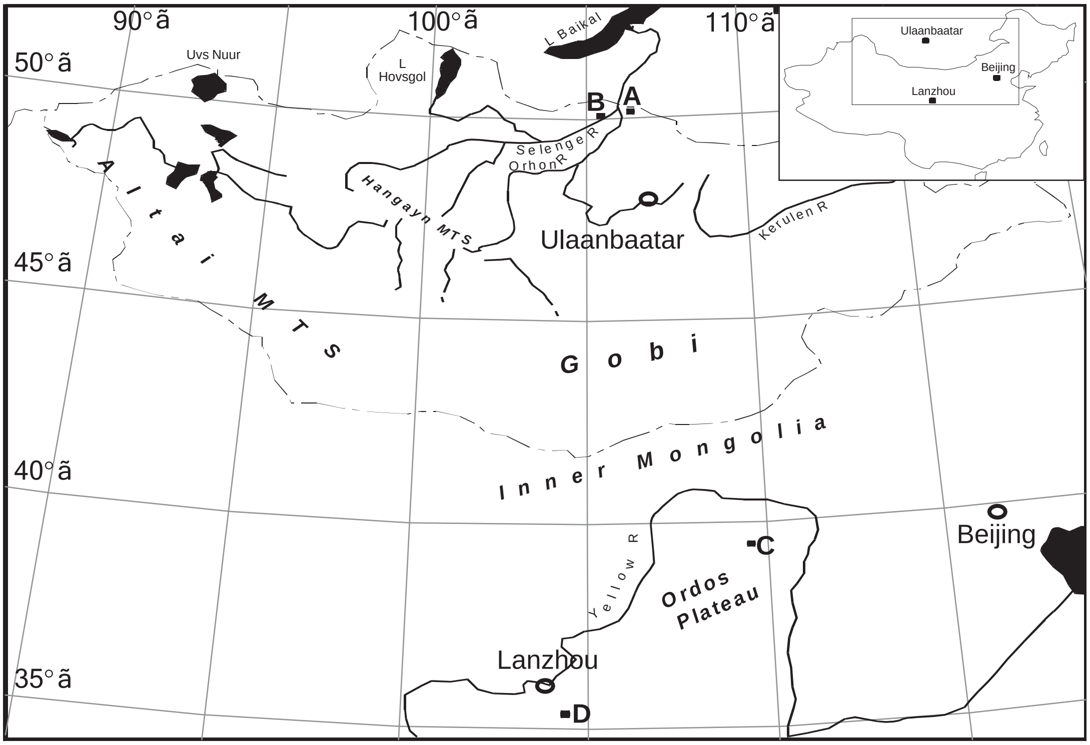

Fig. 1. Sketch map showing the study sites: A—Gun Nuur; B—Shaamar; C—Baahar Nuur; D—Dingxi.

climatic records are needed from different and climatically sensitive regions. The Mongolian Plateau situated at the core of the east–central Asia (Fig. 1) is one such sensitive region. High-resolution records from the Mongolian Plateau might provide important regional evidence of the Holocene global climatic events for the following three reasons. Firstly, the North Atlantic Oscillation (NAO) and North Pacific Oscillation (NPO) affect the strength of the Siberia–Mongolian High (Kerr, 1999; Gong et al., 2001; Hoerling et al., 2001), which in turn modulates the strength of the East Asian winter monsoon. Secondly, the strength of the East Asian summer monsoon influencing the southern Mongolian Plateau is directly related to the interactions between El Niño-South Oscillation (ENSO) and Intertropical Convergence Zone (ITCZ) in the tropical Pacific (Tudhope et al., 2001). A third system affecting the Mongolian Plateau is the NAO-modulated westerlies in the middle latitudes (Visbeck, 2002). Therefore, the reconstruction of the paleoclimate changes in the Mongolian Plateau should significantly improve our understanding of the mechanisms and processes of large-scale Holocene climate changes.

However, the temporal and spatial Holocene climate sequences in the Mongolian Plateau have not yet been well established and recently published data have already shown the geographic differentiation of the Holocene climate variations. For example, a review of the recently published data by An (2004) shows that a warm and wet climate (i.e., Postglacial Warmth) occurred from 8000 to 3500 ^{14}C yr BP with the climax from 8000 to 5900 ^{14}C yr BP (i.e., Climatic Optimum). The Postglacial Warmth in the northern Mongolian Plateau within the Mongolian Republic appeared synchronously with that in the southern Mongolian Plateau within China (approximately 37–42°N and 95–115°E), but the Climatic Optimum seems to have occurred much later in the northern Mongolian Plateau, i.e., from 4500 to 2500 yr BP (Karabanov et al., 2000; Peck et al., 2002; Fowell et al., 2003).

2. Stratigraphy and chronology

In this paper we attempt to further test the geographic differentiation of climate across Mongolian Plateau by examining eolian and lacustrine records from both the southern and northern Mongolian Plateaus. We selected a pair of sections (one eolian and one lacustrine) in the northern Mongolian Plateau and one lacustrine section in the southern Mongolian Plateau matched by an eolian section from nearby northern part of the western Chinese Loess Plateau (Fig. 1). In this study, all ^{14}C dates were AMS analyzed in either the NSF AMS

Facility at University of Arizona (noted as AA-samples) or at Beta Analytical Inc. (noted as Beta-samples) except for one date (4780±80) that was conventionally dated at Lanzhou University (Table 1). The calendar ages are calibrated using the INTCAL98 calibration database (Stuiver et al., 1998).

Table 1
Radiocarbon dates in sediment sections of this study

Lab No.	Sample No.	Site	Depth (cm)	$\delta^{13}C$, PDB	Age
Beta-182732	GN0-5	Gun Nuur	0–5	−18.2	1090±40
Beta-171822	GN3	Gun Nuur	64	−23.1	1870±40
Beta-171823	GN8	Gun Nuur	151	−24.1	2520±40
Beta-171824	GN12	Gun Nuur	240	−21.0	3180±40
Beta-171825	GN16	Gun Nuur	342	−22.7	4870±40
Beta-171826	GN18	Gun Nuur	391	−20.9	5750±50
AA-51953	GN22	Gun Nuur	485	−5.2	7836±63
AA-51956	GN25	Gun Nuur	561	−5.6	8324±63
Beta-171827	GN34	Gun Nuur	743	−26.8	9530±50
AA51936	SH02-06	Shaamar-2	140	−24.8	620±35
AA51935	SH02-04	Shaamar-2	195	−24.5	1423±35
AA51934	SH02-02	Shaamar-2	245	−23.1	1681±37
Lanzhou3465	Sh02	Shaamar-1	430		4780±80
AA51928	MN-14	Shaamar-1	760	−25.9	8672±90
Beta-171828	BN3	Baahar Nuur	487	−23.8	13910±70
Beta-171829	BN6	Baahar Nuur	385	−24.8	8850±40
Beta-171830	BN8	Baahar Nuur	327	−24.9	7960±40
Beta-181619	BN11	Baahar Nuur	227	−24.2	7510±40
Beta-181620	BN13	Baahar Nuur	167	−24.2	6350±40
Beta-181621	BN16	Baahar Nuur	81	−23.8	5460±40
AA44886	SJW410	Dingxi	410	−24.9	8885±55
AA44886T	SJW355	Dingxi	355	23.4	5581±50
AA44885	SJW305	Dingxi	305	−24	3805±45
Beta-181612	SJ295	Dingxi	295	−22.8	3770±40
Beta-181611	SJ90	Dingxi	90	−23.1	1960±40

2.1. Northern Mongolian sequences

A 7.45 m lake core was drilled in the center of Gun Nuur Lake (50.25°N and 106.6°E, 600 m above sea level) in the northern Mongolian Plateau, about 100 km south of Lake Baikal (site A in Fig. 1). Gun Nuur is a freshwater lake, about 4 km^2 in area and 5 m deep in the center. The following lithology was observed in the Gun Nuur lake core: a silty mud unit at the depth of 0–570 cm; a unit of laminated carbonate mud at the depth of 570–720 cm; and a sand unit at the bottom 25 cm of the core (Fig. 2). The chronology is based on nine bulk AMS ^{14}C dates shown in Fig. 2 (also see Table 1). The ^{14}C date at the top (surface) of the core indicates that the carbon reservoir effect in the Gun Nuur Lake is about 1200 years with an assumption that this carbon reservoir effect applies to the entire Holocene. In our interpretation, we rely on uncorrected dates to compare with other uncorrected dates. For instance, the laminated carbonate layer in our core is bracketed by the bulk dates of 8324 and 9500 ^{14}C yr BP. Our bulk dates are in good agreement with dates on organic fraction by Dorofeyuk and Tarasov (1998), who bracketed the correlative carbonate layer in their core from Gun Nuur Lake between 8150 and 9550 ^{14}C yr BP.

Our second focal section is the Shaamar sand/palaeosol section (50.2°N, 105.2°E, 650 m above sea level), the thickest and well-preserved eolian section we found in the northern Mongolian Plateau (site B at Fig. 1). The section is about 100 km west to the Gun Nuur Lake in the northern Mongolian Plateau, where numerous eolian sections were reported (Feng et al., 1998; Feng, 2001; Khosbayar, 1989; Logatchov, 1989). According to the ^{14}C dates, the Shaamar outcrop section

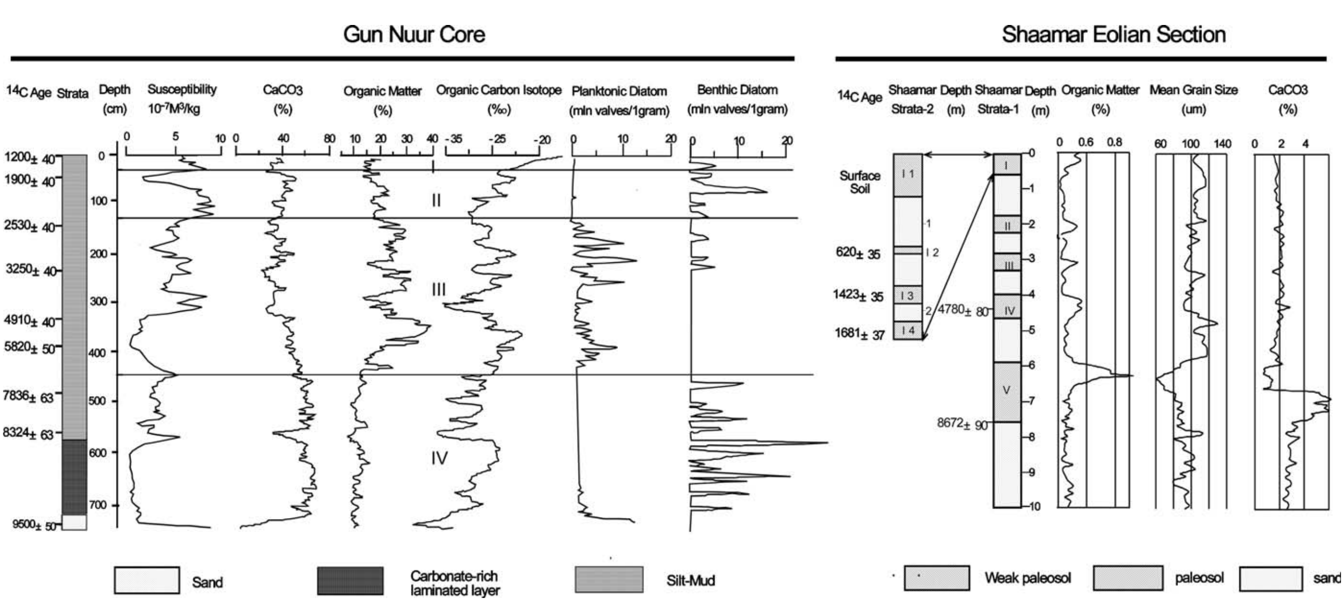

Fig. 2. Strata and proxy data in Gun Nuur lake core and Shaamar sand/paleosol section.

contains approximately 10 m of Holocene subaerial sediments interbedded with five paleosols (I, II, III, IV, and V in Fig. 2) intervened with sand units. A weak paleosol (IV) in the Shaamar section at the depth of 400–500 cm was dated at 4780 ± 80 yr BP (Lanzhou University) and the bottom (760 cm) of a well-developed paleosol (V) was dated at 8672 ± 90 yr BP (Table 1). A clinosol-amplified "top" soil (I) was found at the foothill of the Shaamar gully and three sub-paleosols (I2, I3, and I4) were AMS dated (on charcoals) at 620 ± 35, 1423 ± 35 and 1681 ± 37 yr BP, respectively (Fig. 2). The ages of paleosol II and III can be inferred from two dates: 4780 yr BP in the middle of the paleosol IV (430 cm) and 1681 yr BP at the bottom of the top soil (60 cm) assuming that the depositional rate was relatively constant between the two dates. The assumption is reasonably supported by the fact that the mean grain size from 430 cm to 60 cm is relatively constant (see Fig. 2). The inferred age for the paleosol II is about 3000 yr BP and the age for the paleosol III is about 3800 yr BP.

2.2. Southern Mongolian sequences

A 5.3 m lake core was drilled in the middle of Baahar Nuur Lake (39.1°N, 109.2°E, 1450 m above sea level), a recently desiccated salt lake located at the Yellow River Bend area (Ordos Plateau) in the southern Mongolian Plateau (site C in Fig. 1). The section consists of sand layers and carbonate-silt mud layers (Fig. 3). Six AMS ^{14}C bulk samples were dated at Beta Analytic Inc. (Fig. 3). The carbon reservoir effect was not specifically tested in the Baahar Nuur core. However, a date of 1935 yr BP that we obtained (bulk sample) at the surface of recently desiccated saline lake (Gouchi), about 100 km southwest to this lake core, and the reservoir effect of about 2000 yr estimated at other sites in the southern Mongolian Plateau (Chen et al., 2003b; Li et al., 1990; Ren, 1998) may be acceptable for the Baahar Nuur lake core. Subtracting the carbon reservoir effect of 2000 yr suggests that the lake originated about 10,000 yr BP and ended about 3640 yr BP.

To search for Holocene eolian records compatible with the lacustrine records, we found a well-preserved and relatively thick loess/wetland section (Dingxi section), a representative (or type) section of the northern part of the Western Chinese Loess Plateau (Site D in Fig. 1), only about 100 km away from the southern margin of the southern Mongolian Plateau. Underlying three loess units interbedded with three weak soils is a layer of grayish-blue clayey silt, which was dated at 3805–8885 yr BP (Fig. 3 and Table 1). Aquatic molluscs are abundant in this layer, and powdery carbonate and half-decomposed organic matter (plant litter) are readily visible. This grayish-blue layer can therefore be interpreted confidently as wetland/swamp deposits (An et al., 2003; Feng et al., 2004). In addition, the first and third loess units in Dingxi section were dated at 1960 ± 40 and 3770 ± 40 yr BP at the depth of 90 and 295 cm respectively (Fig. 3).

3. Laboratory analysis

Magnetic susceptibility was measured by the procedure of Thompson and Oldfield (1986) using a

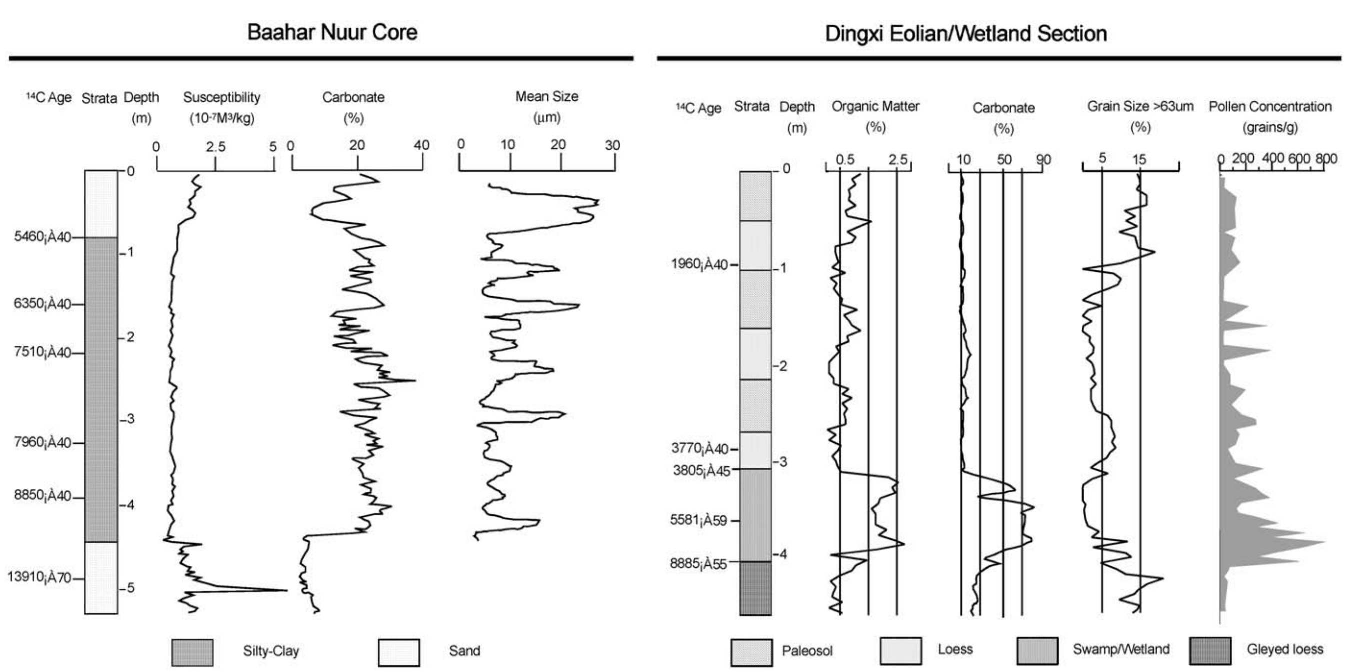

Fig. 3. Strata and proxy data in Baahar Nuur lake core and Dingxi loess/wetland section at the southern part of Mongolian Plateau.

Bartington MS2 susceptibility meter and the particle size of bulk samples was measured using a Malvern Co. Ltd. Mastersizer 2000 laser diffraction particle size analyzer. Organic matter content was determined by the antititration method with sulfuric acid (H_2SO_4) and potassium dichromate ($K_2Cr_2O_7$), and carbonate content was measured using a Bascomb Calcimeter (Singer and Janitzky, 1986). For pollen analysis, the sediments were treated with HCl (10%), NaOH (10%) and HF (36%). Exotic *Lycopodium* tablets were added for calculation of pollen concentration and 100–500 pollen grains were counted. Samples (3–5 g) for organic carbon stable isotope analysis were first decalcified by treating with 15% HCl for 24 h. The decalcified samples were then repeatedly washed with distilled water and dried at 60 °C in an oven. The processed samples were combusted with O_2 at around 800 °C and the derived CO_2 was analyzed using a Delta Plus mass spectrometer. The carbon isotope is expressed as $\delta^{13}C$ in per mil relative to the PDB (Pee Dee Formation Belemnite) standard. Diatom counting was done in Geology Institute of Mongolian Academy of Sciences (by Dr. Narantsetseg) according to the procedures described in Karabanov et al. (2000). Analytical interval is 6 cm for diatom and 2 cm for other types of analyses (susceptibility, carbonate, organic matter, and organic carbon stable isotope).

4. Proxy data and interpretations

4.1. Northern Mongolian Plateau

The variations of proxies in the Gun Nuur lake core are shown in Fig. 2. In the upper portion of the core (0–450 cm), the magnetic susceptibility, a concentration indicator of magnetic minerals formed by biogenic processes in lacustrine environments or/and pedogenic processes in the watershed (Hu et al., 2001), is negatively correlated with organic matter content and to a lesser degree the organic $\delta^{13}C$ ratio. In the lower portion (450–745 cm), the susceptibility seems to be negatively correlated with the carbonate concentration (%). The low susceptibility values are likely due to organic matter and carbonate dilution or/and less magnetic mineral input from the watershed (Wang et al., 2004). The organic matter content, a proxy of primary productivity (Chen et al., 2002), is constantly low in the lower portion (450–745 cm) and has four progressively smaller peaks in the upper portion at 380–330, 270–220, 200–130, and 100–50 cm. The carbonate concentration is relatively low from 0 to 330 cm and relatively high from 330 to 720 cm. The interpretation of organic $\delta^{13}C$ ratios is relatively complicated due to various factors (see Yu et al., 2001). The organic $\delta^{13}C$ ratio variations can be divided into four zones (I, II, III, IV in Fig. 2) based on the relationship between the organic $\delta^{3}C$ ratio and the organic matter content. The topmost Zone I (0–30 cm) is characterized by an extremely high (i.e., positive) organic $\delta^{13}C$ ratio with a relatively low organic matter and few benthic diatoms, possibly resulting from recent human disturbances (Shen et al., 2004). Zone II (130–30 cm) is the zone in which the organic $\delta^{13}C$ ratio increases with a decrease in the organic matter content. Progressive trend of increasing $\delta^{13}C$ associated with increasing benthic diatom abundance may be related to evaporative isotope enrichment of Gun Nuur waters. Organic $\delta^{13}C$ ratio in Zone III (130–450 cm) is positively correlated with the organic matter content and also with the planktonic diatom abundance. It is noticeable that in Zone III organic matter content is anti-correlated with the magnetic susceptibility. In Zone IV (450–720 cm) magnetic susceptibility is negatively correlated with carbonate content, whereas organic $\delta^{13}C$ ratio does not seem to correlate with the organic matter content. It appears that the organic $\delta^{13}C$ ratio variations in Zone IV are associated with the variations in benthic diatom abundance. Overall, the organic $\delta^{13}C$ ratio peaks (i.e., positive) in Gun Nuur section tend to be associated with peaks of planktonic or benthic diatom abundance, except for the Zone I. It is therefore possible that troughs in the organic $\delta^{13}C$ profile are associated with the contribution of terrestrial C3 plant material, which has more negative organic $\delta^{13}C$ ratios than diatoms and shallow-water macrophytes (e.g., Wu et al., 1996; Yu et al., 2001; Shen et al., 2004).

Below are our environmental reconstructions of the four zones starting from the bottom of the Gun Nuur lacustrine sequence (720 cm):

Zone IV (720–450 cm: approximately 9500–6800 ^{14}C yr BP): a general high content of benthic diatom indicates a shallow lake, and low organic matter content suggests a low primary productivity. A general low magnetic susceptibility suggests limited terrestrial (fluvial and eolian) input from the watershed. Deposition of the carbonate-rich laminated layer recovered in the lower part of Gun Nuur core (720–570 cm) suggests strong seasonal evaporation (high summer temperature?) and low lake level. A chronologically corresponding loessial and carbonate-rich paleosol dated at 8672 ^{14}C yr BP at the Shaamar section suggests that earlier Holocene was less windy and warmer than the rest of the Holocene that was characterized by alternative changes between sand depositions and sandy soil formations (see later discussions for the Shaamar section). This interpretation is supported by relatively high organic $\delta^{13}C$ ratios and high abundance of benthic diatoms. In addition, Dorofeyuk and Tarasov (1998) found that this time interval in the Gun Nuur record is characterized by highest abundant *Cyperacea* pollen, supportive of lowered lake level. This laminated carbonate unit in our core is bracketed by the bulk dates of 9500 and 8324

^{14}C yr BP (Fig. 2, Table 1). Our dates agree with earlier estimates by Dorofeyuk and Tarasov (1998) who reported the date 8760 ^{14}C yr BP for the lower part of the laminated carbonate unit and the date 8150 ^{14}C yr BP for the base of the overlying layer.

Zone III (450–130 cm: approximately 6800–2200 ^{14}C yr BP) is characterized by higher primary productivity as indicated by increased organic matter content and possibly by higher organic δ^{13}C ratio, whereas higher lake level is clearly documented by increased planktonic diatom abundance. Dorofeyuk and Tarasov (1998) also noted this past expansion of planktonic diatoms in Gun Nuur Lake. However, they suggested that the maximum lake level corresponds to the time interval 8300–5400 ^{14}C yr BP.

During the time interval approximately 2200–1550 ^{14}C yr BP corresponding to Zone II (130–30 cm) the lake became shallow again, as suggested by near disappearance of planktonic diatoms and dominance of benthics. Low organic matter content and high magnetic susceptibility indicate that the primary productivity decreased and terrestrial input of magnetic minerals became higher possibly due to reduced vegetation density in the watershed.

At the Shaamar section, the sand and paleosol units are well defined by the organic matter content and particle size (Fig. 2). That is, all paleosols are characterized by higher organic matter content and finer grain size than the sand units, indicating that less windy conditions and/or higher vegetation density prevailed during the intervals of paleosol formation. It should be particularly noted here that the bottom paleosol (V) formed in the early Holocene (i.e., dated at 8672 ^{14}C yr BP) differs from the upper four paleosols (I–IV). Specifically, this paleosol (V) is a typical mollisol, developed in a loess parent material, with a thick organic-enriched horizon and a well-developed Bk horizon. In other words, organic matter was effectively accumulated in the soil with the carbonate being leached downward to form a thick Bk horizon (Royer, 1999). It is also notable that not only the parent material of the paleosol V, but also the underlying older sand layer are consistently finer than the overlying portion containing the other four paleosols (I–IV), suggesting that the climatic or/and environmental conditions were different in the earlier portion of the Holocene than the later portion of the Holocene.

It is noticeable that the paleosols I–IV in the Shaamar section can be approximately correlated with the intervals characterized by lower susceptibility, higher organic matter content and higher organic δ^{13}C ratio in the Gun Nuur core with consideration of the uncertainties of age determination. The better developed paleosol (V) is correlative with the carbonate-rich laminated layer (570–720 cm) and therefore both sections suggest that the warmest part of the Holocene have occurred in this area of Mongolian Plateau sometime around 8000–9000 ^{14}C yr BP.

4.2. Southern Mongolian Plateau

Magnetic susceptibility and the carbonate concentration profiles in Fig. 3 shows that both the bottom and top sandy portions of the Baahar Nuur core are characterized by higher magnetic susceptibility and lower carbonate concentrations. By contrast, the middle portion (80–435 cm) consists of carbonate-rich silty-clayey lacustrine deposits with consistently low magnetic susceptibility and varying carbonate concentration and mean particle size. If the above-mentioned ~2000-yr reservoir effect is used to adjust the bulk ^{14}C dates, this carbonate-rich lacustrine unit indicates that the Baahar Nuur lake level was higher from ~9000 to 3640 ^{14}C yr BP. High carbonate concentration in this unit implies that the evaporation was also high during the early and mid-Holocene, thereby suggesting both warm and humid climate over this time interval. Although a recent review by Zhou et al. (2001) suggests that the Holocene Climatic Optimum occurred between 10,000 and 5000 ^{14}C yr BP in northern China, an earlier summary of the Holocene climate reconstructions by Shi et al. (1994a,b) indicates that the Optimum occurred between 8300 and 3800 ^{14}C yr BP with its climax between 7200 and 6000 ^{14}C yr BP in northern China. Our recent work in the western part of the Chinese Loess Plateau (Feng et al., 2004) is more supportive of the age interpretation proposed by Shi et al. (1994a,b). Following is a brief summary of our recent work at Dingxi section, a type Holocene section in the western part of the Chinese Loess Plateau.

A grayish-blue layer at the Dingxi section (site D in Fig. 1) formed in wetland/swampy conditions is characterized by high carbonate concentration and high organic matter content. The layer is finer than other stratigraphic units as indicated by grain size (e.g., >63 um fraction). Both the stratigraphy and the proxy data at the Dingxi section indicate that a humid and probably also a warm climate prevailed between 8885 and 3805 ^{14}C yr BP. The overlying three loess units interstratified with three weakly developed paleosols (including the surface soil) in the Dingxi section suggest that climate has been drier and probably also cooler in the late Holocene (after 3805 ^{14}C yr BP). It is quite interesting to note that data both from the Baahar Nuur core in the southern Mongolian Plateau and the Dingxi section in the western part of the Chinese Loess Plateau show that the climate was humid and probably also warm during the early and mid-Holocene at 35–40°N. In the late Holocene this region seems to have been dominated by a more arid and probably also cooler climate, which has ameliorated at least three times as indicated by the three weakly developed paleosols.

5. Discussions and conclusions

The sand/paleosol stratum at the Shaamar section has regional implications for eolian climate changes in the northern Mongolian Plateau. For example, two major paleosols dated at 8672 and 4780 ^{14}C yr BP at the Shaamar section have their counterparts at the Khyaraany eolian section (50.2°N, 106.7°E, 600 m above sea level) near Gun Nuur Lake (Feng, 2001) and the eolian sequences are further supported by the lacustrine sequence from the Gun Nuur core (Fig. 2). Again, two major magnetic susceptibility troughs, one at the depth of 310–410 cm (bulk dates 4910 and 5820 ^{14}C yr BP, Fig. 2), and another at the depth of 570–720 cm (carbonate laminated unit ~9000–8300 ^{14}C yr BP, Fig. 2) in Gun Nuur section correspond chronologically to the two major organic-enriched paleosols: one dated at 8672 ^{14}C yr BP and another dated at 4780 ^{14}C yr BP at the Shaamar section. It is likely that a reservoir correction of at least several centuries has to be applied in future to Gun Nuur age estimates to arrive at more accurate age model.

It is worthwhile to point out that the best developed Holocene paleosol (V), a typical Mollisol at the Shaamar section, and the carbonate enrichment-marked laminated layer (570–720 cm) at the Gun Nuur lake core are chronologically corresponding to the treeline advance period from 9000 to 7000 ^{14}C yr BP in the eastern Siberia (MacDonald et al., 2000), implying a warming climate. The sand unit bracketed by two paleosols dated at 8672 and 4780 ^{14}C yr BP at the Shaamar section and a significant increase in the magnetic susceptibility, accompanied with a relatively high abundance of benthic diatom, at the depth of 410–570 cm in the Gun Nuur lake core imply colder and relatively dry climate during this time interval (approximately 7000 to 5000 ^{14}C yr BP). This interpretation is consistent with observations of dry period in sedimentary proxy records from Lake Telmen, north-central Mongolia (Peck et al., 2002; Fowell et al., 2003). In addition, the interval with the highest organic matter content from 130 to 450 cm (high primary productivity, approximately 6800–2200 ^{14}C yr BP) in Gun Nuur record is correlative with the peak diatom abundance of ca. 4500–2500 ^{14}C yr BP in Lake Baikal (Karabanov et al., 2000), and also with the interval of more humid climate ca. 4060–1650 ^{14}C yr BP in NW Mongolia as inferred from pollen records at Lake Telmen site (Fowell et al., 2003; Peck et al., 2002).

The data from Baahar Nuur core and Dingxi section suggest that climate was warm and humid during the early and mid-Holocene (approximately between 9000 and 4000 ^{14}C yr BP) in the southern Mongolian Plateau and has been predominantly cool in the late Holocene (after 4000 ^{14}C yr BP), although at least three episodes of climatic amelioration seem to have occurred. The data from other lake cores in the southern Mongolia Plateau also show similar climate changes (e.g., Wang and Li, 1991; Li et al., 1992; Song et al., 1996; Zhang et al., 1997; Yang, 2001).

To sum up, although several recent studies (e.g., Chen et al., 2003a,b) suggest that the mid-Holocene was the driest period during the entire Holocene, our preliminary data from the Baahar Nuur lake core and from Dingxi section appear to be supportive to the notion that not only a ‘‘megathermal’’ climate proposed by Shi et al. (1994a,b) but also ‘‘megahumid’’ climate proposed by Feng et al. (2004) prevailed both in the southern Mongolian Plateau and in the western part of the Chinese Loess Plateau during the early and mid-Holocene (9000–4000 ^{14}C yr BP). However, most humid conditions occurred during the period from 4500 to 2500 (even to 1600) ^{14}C yr BP in the northern Mongolian Plateau. This discrepancy suggests that the Maximum Postglacial Warmth (between 8500 and 3000 ^{14}C yr BP) may still be an acceptable concept. But, the concept of the Holocene Climatic Optimum should be seriously reconsidered if the concept is intended to have a large-scale connotation. In other words, if this concept refers to ‘‘optimum’’ temperature, it may still be valid. However, if it is intended to be ‘‘optimum’’ precipitation or ‘‘optimum’’ combination of humidity and warmth, it may not be useful at all.

In addition, our study shows that there is great potential to retrieve new high-resolution proxy data from the entire Mongolian Plateau to examine the temporal and spatial patterns of the climatic or/and environmental changes. The reconstructed patterns will contribute valuable share of regional data to our global effort in depicting the global patterns and finally in understating the controlling mechanisms.

Acknowledgements

This research is financially supported by the NSFC ‘‘Outstanding Young Scholar Program’’ awarded to Feng (NSFC-40025105). A grant from the Chinese Ministry of Science and Technology (no. G2000048701), and a recent NSFC grant (NSFC-40334038) also financed this research. Radiocarbon measurements were partially supported by Grants by the US National Science Foundation (NSF-OISE98-06430, NSF-BCS00-78557, and NSF-ESH04-02509). We thank A. Prokopenko for helpful comments and suggestions.

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