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Peat $\delta^{13}C_{cellulose}$-recorded wetting trend during the past 8000 years in the southern Altai Mountains, northern Xinjiang, NW China

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ABSTRACT

There have been large discrepancies in the proposed mechanisms accounting for the wetting trend since ~8.0 cal. kyr BP in the Altai Mountains and the surrounding areas. To validate or invalidate the widely reported wetting trend, we obtained a carbon isotope of cellulose ($\delta^{13}C_{cellulose}$)-recorded warm-season moisture history from a Narenxia (NRX) peat core in the southern Altai Mountains, northern Xinjiang, NW China. The $\delta^{13}C_{cellulose}$-recorded warm-season moisture reconstruction of the NRX peat core provides a strong support to the widely-reported proposition that the climate was generally dry before ~8.0 cal. kyr BP and was changed to a wetting trend during the past ~8000 years in the Altai Mountains and the surrounding areas. The wetting trend since ~8.0 cal. kyr BP well resembles the increasing trend of the reconnaissance drought index (RDI) that was calculated on the basis of pollen-inferred temperature and precipitation data from the same core. The resemblance implies that the wetting trend during the past ~8000 years resulted from the combined effect of temperature and precipitation.

1. Introduction

As one of the most prominent mountain ranges in Central Asia, the Altai Mountains are shared by Russia, Mongolia, Kazakhstan and China (Fig. 1a). It is well documented to be an important climatic boundary where the westerlies climate system from the west has interacted with the East Asian Monsoon climate system from the east (Blyakharchuk et al., 2004, 2007; Chen et al., 2008, 2016; Feng et al., 2017; Rudaya et al., 2009). It is also widely reported to be an important cultural bridge along the "Eurasian Steppe Silk Road" that linked the oriental cultures with the occidental cultures (Blyakharchuk and Chernova, 2013; Rudaya et al., 2012). The importance of the Altai Mountains calls for an in-depth understanding of the past climate change. The Holocene (i.e., past 11,500 years) is of particular interest for two reasons (Ruddiman, 2008). First, the aforementioned cultural importance is of greatest significance during the Holocene. Second, the human-induced climate change that we are experiencing has been occurring in the context of the natural climate change during the Holocene.

With regard to the mechanisms controlling the natural climate change during the Holocene in the Altai Mountains and the surrounding areas, several proposals have been put forward to explain the proxy records. First, the westerlies system was advocated to have dominated southern Siberia that includes the Altai Mountains during the Holocene (Chen et al., 2008; Long et al., 2017; Ran and Feng, 2013; Wang and Feng, 2013). Second, the Asian Summer Monsoon was speculated to have extended to southern Siberia during the Holocene warm interval (Harrison et al., 1996; Tarasov et al., 2000; Winkler and Wang, 1993). The third proposal stated that different parts of the Altai Mountains were controlled by different climate systems during the different time intervals of the Holocene (Blyakharchuk et al., 2004, 2007; Rudaya et al., 2009).

With regard to the Holocene trend of natural climate change in the Altai Mountains and the surrounding areas, many recently retrieved high-resolution proxy records have nearly unanimously revealed that the climate was dry before ~8.0 cal. kyr BP and was changed to a wetting trend since ~8.0 cal. kyr BP (Blyakharchuk, 2003; Blyakharchuk and Chernova, 2013; Chen et al., 2008, 2016; Feng et al., 2017; Hong et al., 2014; Long et al., 2017; Kleinen et al., 2011; Kremenetski et al., 1997; Ran and Feng, 2013, 2014; Rudaya et al., 2012; Wang and Feng, 2013; Zhang et al., 2016). However, there have

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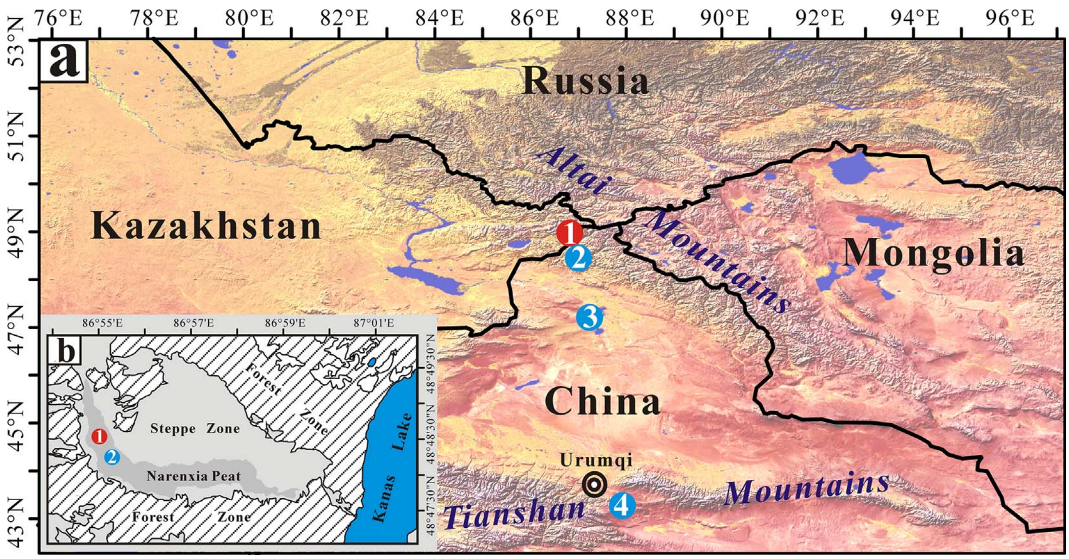

Fig. 1. Geomorphological settings of Narenxia Peat. a: location of Narenxia Peat (NRX) in the context of the Altai Mountains and other mentioned sites (1, NRX core; 2, Tielishahan core; 3, Wulungu Lake; 4, Chaiwopu Peat); b: NRX core (site 1) and Tielishahan core (site 2) within Narenxia Peat.

been large discrepancies in the proposed mechanisms accounting for the wetting trend since ~8.0 cal. kyr BP. For example, one group of scholars attributed the wetting trend to temperature decreasing (Blyakharchuk, 2003; Kleinen et al., 2011; Zhang et al., 2016). Another group proposed that the precipitation increasing was responsible for the wetting trend (Chen et al., 2008, 2016; Zhang et al., 2015). It is of course likely that the wetting trend could have resulted from a combination of temperature decreasing and precipitation increasing (Ran and Feng, 2013; Wang and Feng, 2013).

The objective of this study was to validate or invalidate the widely reported wetting trend by presenting a high-resolution Holocene sequence of carbon isotope of cellulose ($\delta^{13}C_{celluose}$) from Narenxia (NRX) peat in the southern Altai Mountains, northern Xinjiang, NW China. The carbon isotope of cellulose ($\delta^{13}C_{celluose}$) was used as a proxy for warm-season moisture (Hong et al., 2001, 2014; Zhang et al., 2017). To deduce the possible reasons of the moisture variations, the moisture variation inferred from the NRX $\delta^{13}C_{celluose}$ sequence was then compared with the reconnaissance drought index (RDI). And, the RDI was calculated on the basis of pollen-inferred temperature and precipitation data from the same core. This present work not only expanded our previous work (Feng et al., 2017) but also reconciled the aforementioned discrepancies in the proposed mechanisms accounting for the wetting trend since ~8.0 cal. kyr BP.

2. Regional setting

Narenxia (NRX) peat (48°48′N, 86°54′E, 1760 m a.s.l., site 1 in Fig. 1a and b) is situated in an intermontane depression of the southern Altai Mountains in northern Xinjiang, NW China. The depression is occupied by meadow steppes and is surrounded by taiga forests growing on the mountain slopes (Fig. 1b). The prevailing westerlies dominate the Altai Mountains and the surrounding areas throughout a year (Aizen et al., 2001) and the Siberian High is of a great importance in cold seasons. According to instrumental records (1971–2000) at the nearby Kanas Meteorological Station, the mean annual temperature (MAT) is −0.2 °C with the lowest temperature of −37 °C in January and the highest temperature of 29.3 °C in July. The mean annual precipitation (MAP) is approximately 1065.4 mm and the mean annual evaporation is approximately 1097 mm. It should be added that the NRX peat is composed predominantly of *Carex altaica* and *Carex pamirensis* and fed primarily by precipitation (including snow melting in early springs).

3. Methods

3.1. Stratigraphy and chronology

A 390-cm long core (NRX core) was obtained using a Holland-made peat corer in 2013 and the upper 298 cm is the peat portion that is the focus of this paper. The 298-cm peat portion of the core can be divided into four units according to peat decomposition degrees and identifiable plant residues. Unit 1 (298–274 cm) is a transition from lacustrine deposition to peat accumulation (repetitive lake-peat alternations). Unit 2 (274–120 cm) is a highly decomposed peat layer and the identifiable plants are primarily sedge residues. Unit 3 (120–60 cm) is a poorly decomposed peat layer and the identifiable plant residues are shared by sedge and *Sphagnum* species. Unit 4 (60–0 cm) is a poorly decomposed peat layer and the identifiable plants are primarily sedge residues.

Nine sedge samples were selected from the peat portion for radiocarbon AMS dating at the NSF-AMS Facility, University of Arizona (Table 1). These dates were published previously in Feng et al. (2017). The age-depth model was established by invoking the Bayesian age-depth model package Bacon 2.2 (Blaauw and Christen, 2011) using the mathematics software "R" version 3.4.2 with an assumption that the surface age (0 cm) was 2013 AD (i.e., −63 cal. yr BP) (Fig. 2). All dates were calibrated to calendar years before present (BP = before 1950 AD; cal. kyr BP = thousand years before 1950 AD) using the IntCal13 calibration curve (Reimer et al., 2013).

Table 1
Dating results of Narenxia Peat sequence (Note: these data has been reported in Feng et al. (2017)).

Code	Depth/cm	Dated material	$\delta^{13}C$ (‰)	^{14}C age (yr BP)
AA102070	39–40	Sedge	−25.9	379 ± 39
AA102071	69–70	Sedge	−25.9	1499 ± 40
AA100610	99–100	Sedge	−26.7	3214 ± 46
AA102072	129–130	Sedge	−26.0	3857 ± 45
AA102073	159–160	Sedge	−25.3	4368 ± 46
AA100609	189–190	Sedge	−26.7	5530 ± 42
AA102074	219–220	Sedge	−26.8	6046 ± 75
AA102075	249–250	Sedge	−27.7	6408 ± 51
AA100611	289–290	Sedge	−27.0	7448 ± 72