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Millennial-scale Holocene climate variability in the NW China drylands and links to the tropical Pacific and the North Atlantic

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Abstract

A loess–paleosol sequence and a lake sediment record from the central Hexi Corridor in the drylands of NW China show patterns of persistent millennial- to centennial-scale climate variability during the Holocene epoch, which can be well correlated with abrupt climatic events reported from the North Atlantic and the Asian monsoon-dominated regimes. Our results show that the drylands in NW China might have been regulated both by the westerlies and by the East Asian summer monsoon (EASM) in a roughly synchronous manner. It seems that cold–dry intervals in the central Hexi Corridor may generally correspond to cooling phases in high latitudes of the Northern Hemisphere, and that cold/warm–wet intervals largely correlate with relatively warm phases in northern high latitudes. A candidate mechanism involving NAO/AO and ENSO dynamics is tentatively proposed to account for this synchroneity. Climatic patterns may be spatially different in the NW China drylands in response to the changing predominant control of either the westerlies or the EASM, depending on the contrast of their relative strengths. Glacier meltwater discharges associated with alpine warming may be partly responsible, at least for the two records discussed in this paper, for such spatial heterogeneity of climatic changes during the Holocene. More work is needed to evaluate the individual roles and combined impacts of the EASM, the westerlies and alpine glacier meltwater regulation on the NW China dryland dynamics.

Keywords: Millennial-scale climate variability; Holocene; NW China drylands; East Asian summer monsoon; Westerlies

1. Introduction

Unraveling the complex Holocene environmental responses to globally interlinked changes and understanding the respective roles of the different elements of the Earth's environmental systems represent major challenges to earth scientists (Sarnthein et al., 2002). To this end, stratigraphic evidence with resolution capable of recording high-frequency changes from climatically sensitive regions is essential for shaping general patterns of climatic change histories during key periods of the Holocene, and may contribute to the detailed understanding of causes and mechanisms of millennial- or finer scale variability in the mid-latitude Asian drylands. The vast drylands in NW China, and of central Asia as a whole, are located at the boundary between the East Asian summer monsoon (EASM) and the

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Northern Hemisphere westerly winds (Lehmkuhl and Haselein, 2000; Yang and Williams, 2003). They are climatically sensitive regions which are likely to have experienced conditions during the Holocene which were quite different to those of the present (Fontes et al., 1996; Lehmkuhl and Haselein, 2000).

Previous work on NW China's drylands focused primarily on the Shiyang River drainage basin in the eastern Hexi Corridor (Chen et al., 1999, 2001; Zhang et al., 2000; Shi et al., 2002; Ma et al., 2003), the Badain Jaran Desert (Yang, 2000; Yang and Williams, 2003; Yang et al., 2004b), southern Inner Mongolia (Chen et al., 2003), and northern Xinjiang (Sun et al., 1994; Wünnemann et al., 2003). However, there is still a lack of evidence from the middle part of the Hexi Corridor, a key region that climatically links the EASM, the westerlies and the regulation of the Tibetan Plateau. An investigation of this region, integrated with previous reports from adjacent sites, will help us to understand general patterns, spatial heterogeneity and forcing mechanisms of Holocene climate changes over the east-central Asian drylands.

To this end we present a multiproxy reconstruction of the Holocene section of a 40-m-long sediment core (GT40 core) recovered from the Yanchi playa (39°45′ N, 99°18′ E), in the central Hexi Corridor in arid NW China. In addition, a 3-m-long loess section (BDK section) from Biandukou (38°13′ N, 100°52′ E), in the subalpine part of the eastern Qilian Shan, ~200 km southeast of the Yanchi playa, is chosen for a regional comparison. Because the Yanchi playa may be linked hydrologically via the Ruoshui River to the alpine glaciers in the eastern Qilian Shan, the BDK section serves as an important complementary archive to the GT40 record. First, alpine glaciers may respond sensitively to climatic changes of regional and/or global significance. Second, changes in glacier meltwater discharges in response to alpine warming may effectively regulate patterns of environmental changes in the downstream arid areas, namely the central Hexi Corridor. Third, by correlating these two records with regional and global climatic evidence we hope to contribute to the understanding of major factors that control the evolution of the central Asian drylands during the Holocene in the context of global changes.

Unless otherwise stated all ages, including those from cited references, are given in calendar yr/kyr before 1950 A.D. (cal. yr/kyr BP) with 2σ errors. Although the GT40 chronology is poorly constrained, our results suggest that millennial-scale abrupt climate variability may persist over east-central Asia during the entire Holocene. Through careful correlations we tentatively attribute this pattern to roughly synchronous operations of the westerlies and the EASM. Further work with finer sample resolution and refined chronology is needed to assess quantitatively and more precisely the specific signatures of these controlling factors and their combined impacts on the evolution of arid environments in NW China and the east-central Asia.

2. Study areas and methods

2.1. Physical settings and stratigraphy

The Yanchi playa, a tectonically subsiding basin, is located in the middle part of the Hexi Corridor (Fig. 1),

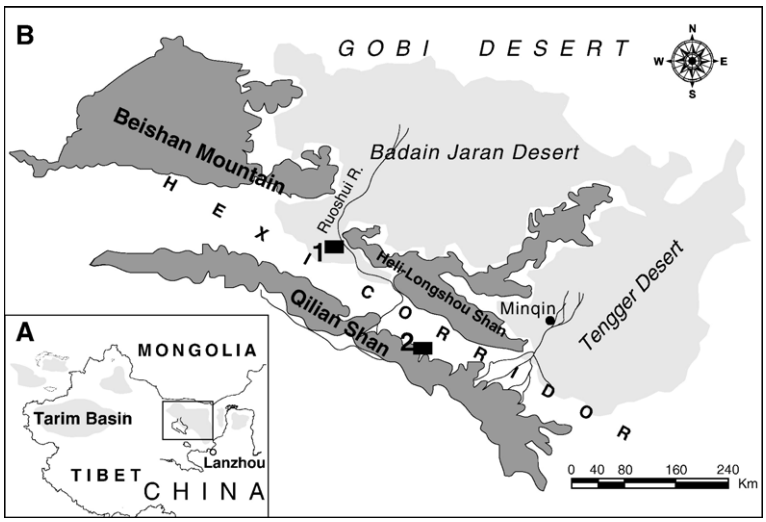

Fig. 1. Location map showing the positions of the study areas (B) relative to the northwestern China (A). 1: GT40 core from the Yanchi playa; 2: Biandukou (BDK) section in the eastern Qilian Shan. Light shaded areas represent the Badain Jaran Desert and the Tengger Desert.