Journal of Asian Earth Sciences 155 (2018) 58–67

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Full length article

Abrupt climatic events recorded by the Ili loess during the last glaciation in Central Asia: Evidence from grain-size and minerals

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ARTICLE INFO

Keywords:
Loess
Abrupt climatic events
Grain size
Minerals
Last glaciation
Central Asia

ABSTRACT

The loess record of Central Asia provides an important archive of regional climate and environmental changes. In contrast to the widely investigated loess deposits in the Chinese Loess Plateau, Central Asian loess–paleosol sequences remain poorly understood. Here, we present an aeolian loess section in the southern Ili Basin. Based on granularity and mineralogical analyses, we reconstruct climatic changes during the last glaciation. The results indicated that most of the abrupt climatic events (such as Dansgaard-Oeschger events and Heinrich events) were imprinted in this loess section, although their amplitudes and ages showed some differences. Compared with the millennial oscillations recoded in loess and stalagmites in East Asia, the arid Central Asia responded more sensitively to the warming events than to the cooling events. The shifting trajectory of westerlies across Central Asia played an important role in dust deposition during the stadials. The North Atlantic climatic signals may have been transmitted from Central Asia to the East Asian monsoon regions via the westerlies.

1. Introduction

Since the discovery of millennial-scale climate instability during the last interglaciation recorded in Greenland ice core (Bond et al., 1992; Bond and Lotti, 1995; Dansgaard, 1984; Dansgaard et al., 1993; Heinrich, 1988), there has been considerable effort to determine whether these climate events were a global phenomenon or just confined to the North Atlantic region, and also to identify the underlying mechanisms (Clement and Peterson, 2008; Heinrich, 1988; Rasmussen et al., 2014; Seierstad et al., 2014). Subsequently, similar abrupt climatic events have been reported from many diverse archives, such as loess sediments in the mid-latitude Chinese Loess Plateau (CLP) (Chen et al., 1997; Ding et al., 1999; Fang et al., 1999; Lu et al., 2004; Porter and An, 1995; Rao et al., 2013) or Southern Europe (Zeeden et al., 2017), lake sediments (Allen et al., 1999; Gorbarenko et al., 2007) and tropical marine sediments (Schulz et al., 1998) in low-latitude regions, or ice cores (Thompson et al., 1997) from the Tibetan Plateau.

The westerlies-dominated area of arid Central Asia is the furthest dust source from the oceans and plays an important role in global change (Fitzsimmons et al., 2017; Li et al., 2016a; Song et al., 2014; Sun, 2002; Zhao et al., 2013). Central Asia is also one of the most significant loess regions on Earth, located between the well-studied European loess sequences to the west and the extensive CLP region to the east (Machalett et al., 2008). This enables researchers to carry out interregional paleoclimatic investigations along a west-east transect across the entire Eurasian loess belt of the Northern Hemisphere. However, there are few reports of climatic change during the last glacial period in arid Central Asia. Widely distributed loess in the Tianshan mountains in Central Asia (Dodonov and Baiguzina, 1995; Li et al., 2015; Smalley et al., 2006; Song et al., 2014; Sun, 2002) has provided us with the opportunity to verify the last glacial climatic instability in Central Asia. The Ili basin is surrounded by the Tianshan mountains, and loess is widely distributed on the terraces and piedmonts (Song et al., 2014; Sun, 2002). Previous studies (Li et al., 2011, 2016a; Song et al., 2017; Ye et al., 2000; Zhao et al., 2013) in the Ili basin have also identified climatic events; however, due to geochronological limitations (E et al., 2012; Feng et al., 2011; Song et al., 2015, 2012; Yang et al., 2014) and a lack of reliable proxies (Li et al., 2017; Liu et al., 2012; Shi et al., 2007; Song, 2012; Song et al., 2010; Zhang et al., 2013) from the this region, the amplitude and frequency of climatic change and its possible driving mechanisms remain poorly understood. Here, based on an updated geochronology (Song et al., 2012), grain size and

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http://dx.doi.org/10.1016/j.jseaes.2017.10.040
Received 24 September 2017; Received in revised form 30 October 2017; Accepted 30 October 2017
Available online 31 October 2017
1367-9120/

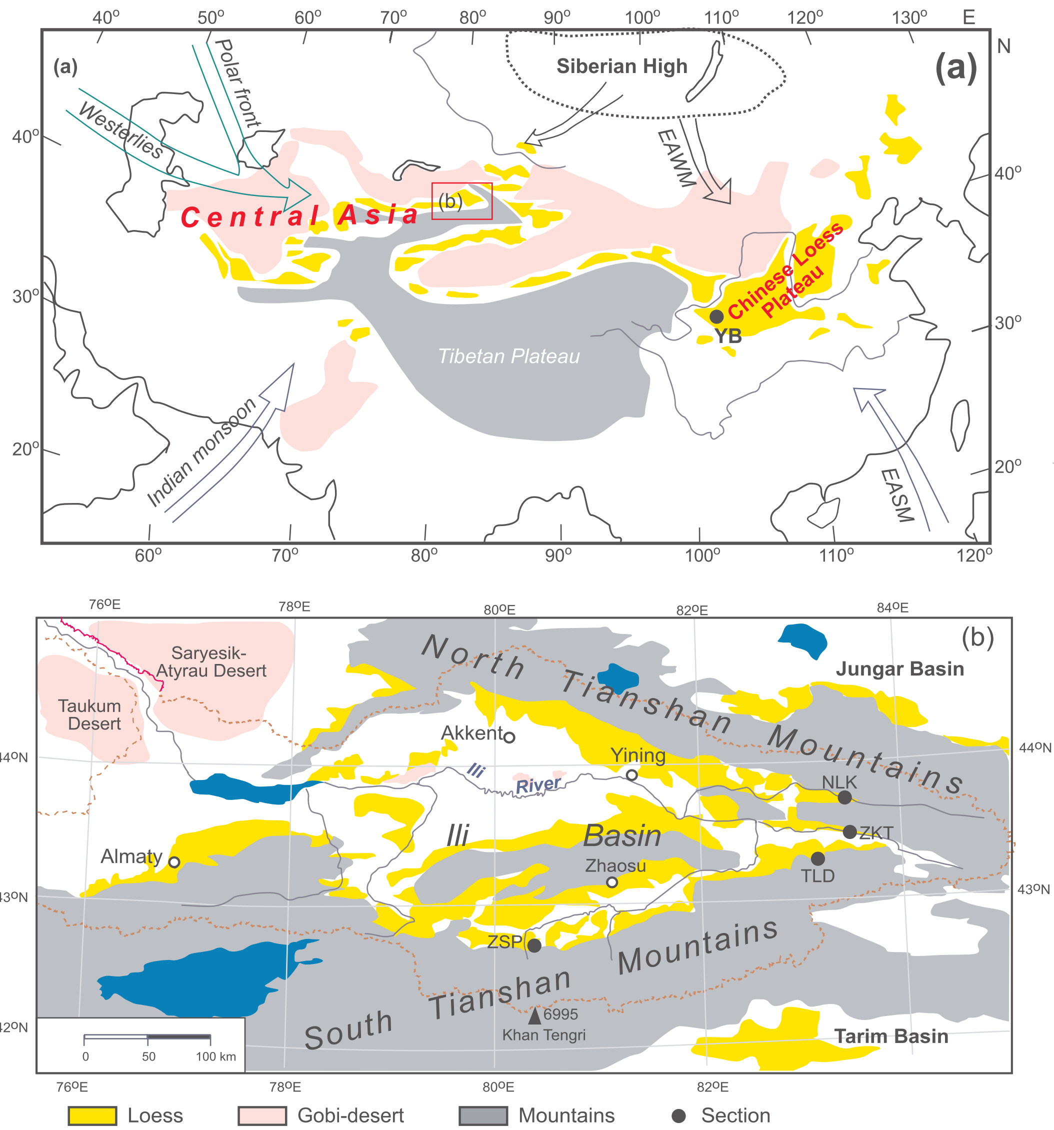

Fig. 1. Asian loess and Gobi desert distributions, and atmospheric circulation (a), and physical geography of the Ili basin (b). Modified from Song et al. (2010). Mentioned loess sections: YB: Yuanbao (Rao et al., 2013), NLK: Nileke (Song et al., 2015; Yang et al., 2014), ZKT: Zeketai (E et al., 2012; Feng et al., 2011), TLD: Talede (Kang et al., 2015; Liu et al., 2012).

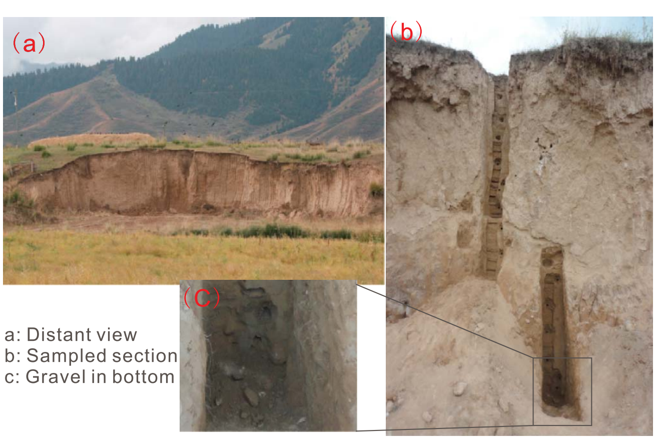

Fig. 2. Photographs of the Zhaosu Poma (ZSP) loess section.

mineralogy, we present a new loess section to determine the timing and characteristics of abrupt climatic events during the last glacial period.

2. Physical setting

The Ili basin is a Mesozoic-Cenozoic faulted depression, surrounded by the Tianshan orogenic belt which reaches altitudes > 3500 m. The topography of the Ili basin is shaped like a trumpet, with the mouth in the west; i.e., the altitudes are higher in the eastern part and lower in the western part, and the Kazakhstan Gobi Desert lies to the west (Fig. 1). The Ili River originates from north slope of Khan Tengri peak (6995 m a.s.l.), flows through the Ili Basin into the Kapchagay reservoir, before finally flowing to the west and into Balkhash Lake. Areas of Gobi desert are distributed around the Kapchagay Gorge and to the south of Akkent.

The Ili Basin is located in the inland region of the Eurasian continent and is thus far away from the ocean. The basin has a temperate semiarid continental climate and is primarily influenced by mid-latitude westerlies throughout the year (Li et al., 2011; Ye, 2001). The winter climate is mainly controlled by the intensity and position of the Asiatic polar front and Siberian high pressure cell (Fig. 1a), and is also influenced by the northern branch of the westerlies; the summer climate is