Quaternary Geochronology 20 (2014) 78–88

Contents lists available at ScienceDirect

Quaternary Geochronology

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

Research paper

Evaluating OSL-SAR protocols for dating quartz grains from the loess in Ili Basin, Central Asia

Shengli Yang[a,*], Steven L. Forman[b,*], Yougui Song[c], James Pierson[b], Jeaneth Mazzocco[b], Xinxin Li[c], Zhengtao Shi[d], Xiaomin Fang[e]

[a] College of Geographical Sciences & Jiangsu Key Laboratory of Environmental Change and Ecological Construction, Nanjing Normal University, Nanjing, 210023, China
[b] Luminescence Dating Research Laboratory, Department of Earth and Environmental Sciences, University of Illinois at Chicago, Chicago 60607, USA
[c] State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, Chinese Academy of Sciences, 10 Fenghui Nan Road, Xi'an 710075, China
[d] School of Tourism and Geography, Yunnan Normal University, Kunming 650092, China
[e] Key Laboratory of Continental Collision and Plateau Uplift, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100101, China

ARTICLE INFO

Article history:
Received 1 February 2013
Received in revised form
6 October 2013
Accepted 21 November 2013
Available online 4 December 2013

Keywords:
Luminescence dating
SAR
Loess
Desert
Ili Basin
Central Asia

ABSTRACT

Late Pleistocene records of loess deposition are a critical archive for understanding terrestrial paleoenvironment changes in Central Asia. The age of loess is not well known for the deserts regions and surrounding high plateaus in Central Asia. Previous studies have shown that there remains a disparity between ages for loess deposition by luminescence and ^{14}C dating. This study evaluates the potential of optically stimulated luminescence (OSL) to date a loess sequence resting on fluvial sands in the east Ili Basin, Central Asia. The single-aliquot regenerative-dose (SAR) protocol on coarse grain quartz was employed for equivalent dose determinations. The basal fluvial sand returned a secure OSL age, with low overdispersion value in equivalent doses (19 ± 2%) of ca. 36 ka and provides a close, but maximum age estimate (within 5 ka) on the initiation of loess deposition. However, the loess yielded high overdispersion values for equivalent doses and age reversals, coincident with diffuse paleosols; indicating that pedoturbation with loess deposition may be a dominant process. OSL ages between ca. 45 and 14 ka calculated using a maximum age model and OSL ages from other sites in the Basin suggests that the latest major period of loess deposition was between 70 and 10 ka ago. A future hypothesis to test based on these analyses is that there may be three periods of heightened loess deposition at ca. 45, 35 to 19 and 14 ka, when desert source areas to the west were particularly dry.

1. Introduction

The timing and extent of late Pleistocene loess deposition in continental interiors is a critical archive for understanding terrestrial paleoenvironment changes (Muhs, 2013). Loess deposits are widespread in the surrounding deserts regions and high plateaus in Central Asia. The spatial and temporal signature of loess deposits in central Asia are less known than loess-paleosol sequences from the Chinese Loess Plateau (e.g. Liu and Ding, 1998; Ding et al., 2002). Previous research of Central Asian loess have focused mainly on areas in south Tajikistan (e.g. Dodonov and Baiguzina, 1995; Frechen et al., 2001; Dodonov et al., 2002; Ding et al., 2002) or Uzbekistan (e.g. Zhou et al., 1995; Smalley et al., 2006). Recently, the loess deposits near the Tianshan Mountains in the south Kazakhstan (Machalett et al., 2006, 2008; Feng et al., 2011) and Xinjiang of China (Ye, 2001; Fang et al., 2002; Song et al., 2008, 2010, 2012; ChongYi et al., 2012) have been investigated in more detail.

The Ili Basin, an intermontane depression of the Tianshan Mountains (Fig. 1), exposes loess tens to more than one hundred meters thick deposited over alluvial terraces and piedmont surfaces. Paleomagnetic analysis indicates that loess deposition commenced at ca. 0.8–0.9 Ma (Fang et al., 2002; Shi, 2005). However, loess deposits of Late Pleistocene age are more widespread (Ye, 2001). Many exposures have yielded a time series of magnetic susceptibility and particle size variations which are the basis for proxy climatic reconstructions. The records of magnetic susceptibility and particle size are distinctly different than stratigraphic sequences of the Chinese Loess Plateau (Song et al., 2010). The high values of magnetic susceptibility of the Ili loess are coincident with

* Corresponding authors.
E-mail address: yangshengli09@gmail.com (S. Yang).

1871-1014/$ – see front matter
http://dx.doi.org/10.1016/j.quageo.2013.11.004

an increase in the coarse fraction (Fig. 2), rather than horizons of pedogenesis like in the Chinese Loess Plateau, possibly reflecting a higher concentration of magnetic minerals in the loess than the paleosol (Song et al., 2010; Zan et al., 2012; Liu et al., 2012; Chen et al., 2012). The enhancement of magnetic susceptibility in the Ili loess sequence is probably complex related to multiple sources areas for dust in Central Asia and pedogenesis (Song et al., 2010; Zan et al., 2012). An increase in grain size of loess dated by thermoluminescence (TL) was correlated to Heinrich events in the North Atlantic, coincident with glacial conditions (Ye et al., 2000). Alternatively, the increase in coarse particle sizes may indicate heightened aridity in the surrounding deserts and an increase in westerly winds (Dodonov et al., 2002; Ding et al., 2002; Fang et al., 2002; Song et al., 2008).

Chronologic control for Ili loess deposition is provided by paleomagnetism, TL, optical stimulated luminescence (OSL) and ^{14}C dating. However, there is little agreement in the age for loess deposition from these analytical approaches (Ye, 2001; Fang et al., 2002; Shi, 2005; Feng et al., 2011). Previous studies have focused specifically on OSL and ^{14}C dating of the Ili loess sequences but there remains a troubling disparity between resolved ages. Feng et al. (2011) compared fifteen accelerator mass spectrometer (AMS) ^{14}C ages (one on bulk sediment and 14 on snails) with eight corresponding OSL ages on fine-grained (4–11 μm) quartz extracts by the simplified multiple aliquot regenerative dose (SMAR) protocol from the Zeketai section (Fig. 1b). The OSL ages span from ca. 70 to 30 ka which is somewhat older than former TL ages from ca. 65 to 20 ka (Ye, 2001). However, the AMS ^{14}C ages are considerably younger between ca. 48 and 3 ka, with the majority of loess <10 ka old. Feng et al. (2011) questioned the veracity of the OSL ages on the basis of partial solar resetting of grains and, thus favored the AMS ^{14}C ages obtained on the snails. It is problematic to invoke partially solar resetting in a loess depositional environment with documented processes of tropospheric suspension of fine grained particles for hours to days and sunlight exposure on the depositional surface for similar lengths of time which would preclude inheritance of luminescence (Pye, 1987, p. 39–62; Crouvi et al., 2008). ChongYi et al. (2012) argue that quartz grains from the loess are suitable for OSL dating and reported ages of ca. 72 to 14 ka from the same section by single-aliquot regenerative-dose (SAR) protocols using principally the standardized growth curve (SGC) method. ChongYi et al. (2012) also suggest that the previous AMS ^{14}C ages on snail shells are underestimates reflecting recent contamination. Recently, Song et al. (2012) compared AMS ^{14}C ages and post-infrared (IR) OSL ages from a polymineral fine-grained fraction and also using a multiple-aliquot regenerative dose (MAR) protocol from the Zhaosu Poma section in the south Ili Basin (Fig. 1b). They also report underestimates in age by ^{14}C dating due to contamination by recent carbon in disseminated organic matter and concluded that luminescence ages provide a credible chronology for loess sequences in this area. However, it has been shown that the post-IR OSL signals may be susceptible to the feldspar fading, and could return underestimates (e.g. Zhang and Zhou, 2007; Schmidt et al., 2010; Vasiliniuc et al., 2013).

This paper focuses on the OSL dating of coarse-grained quartz extracts from the Nilka loess section in the east Ili Basin (Fig. 1) to test if the latest episode of loess deposition occurred ca. 75 to 10 ka (ChongYi et al., 2012) or 48 to 3 ka, with the majority of deposition in the past 10 ka (Feng et al., 2011). We present the OSL data and associated statistical analyses (Galbraith and Roberts, 2012) of equivalent dose values from a SAR protocol (Murray and Wintle, 2003). We infer that pedoturbation may be far more dominant in the Ili Basin than other loess sequences in Asia, which impacts the interpretation of OSL ages. Thus, in the final analyses we provide bracketing OSL ages on loess deposition which started in marine isotopic stage 3 and persisted through stage 2, consistent with an expansion of desert sources of loess in central Asia (Yang et al., 2011).

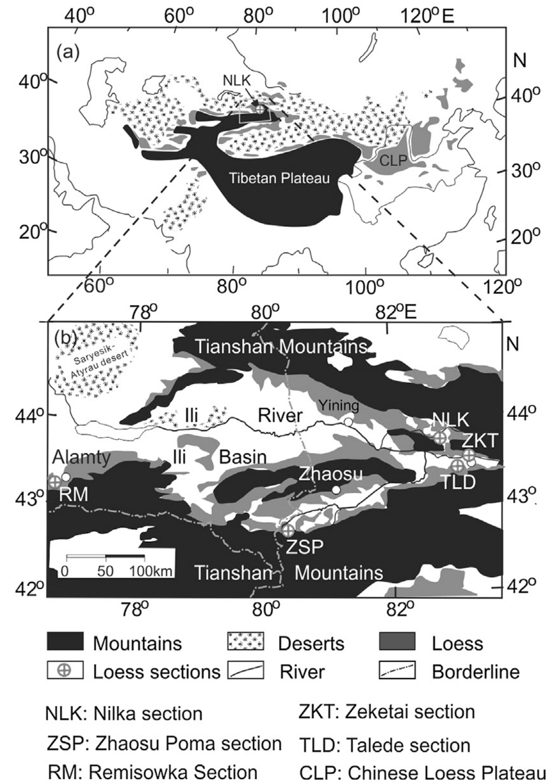

Fig. 1. The Ili Basin in the Tianshan Mountains (b) and the locations of the studied sections (after Song et al., 2012).

2. Study area and stratigraphic context

The Ili Basin is surrounded by the Tianshan orogenic belt in east Central Asia, with gentle topography to the west. The basin opens to the west and funnels winds and cyclonic disturbances down its axis, often associated with prevailing westerly winds (Ye, 2001). The Ili Basin has a temperate, continental, arid climate with a mean annual temperature that varies from 2.6 °C at 1850 m to 10.4 °C at 660 m; the mean annual precipitation varies correspondingly from 512 to 257 mm (Ye et al., 1997; Ye, 2001). The surface soils are a sierozem (aridosols) with desert steppe vegetation distributed widely. The vegetation coverage is <50%, which mainly includes *Artemisia* spp. and *Chenopodiaceae* spp. (Ye et al., 2000). There are no obvious accumulations of organic matter in the surface horizon of the modern soil.

To the west of the Ili Basin is the vast central Asian Gobi Deserts, such as Saryesik-Atyrau Desert (Fig. 1), the probable source of dust for Late Pleistocene loess deposits. The loess deposits are widely distributed on piedmont of the Tianshan Mountains, river terraces and the margin of deserts (Fig. 1). The loess sequence thickens from west to east in the basin, from ~20 m in west to about ~80–100 m at Talede area in the east Ili Basin. Most of the loess appears to be deposited since the last interglacial period (ca. 130 ka; Ye, 2001; Song and Shi, 2010). In comparison to the central Chinese Loess Plateau (CLP) (Ding et al., 2001; Kohfeld and Harrison, 2003) loess deposits in the past ca. 130 ka in the Ili Basin are often thicker and show less pedogenic alteration with poorly developed, diffuse paleosols.

The Nilka section (83.25 °E, 43.76 °N, 1253 m a.s.l) was located on the high terrace, 23 m above the Kashi River, a branch of Ili River,