Quaternary Geochronology 10 (2012) 32–36

Contents lists available at SciVerse ScienceDirect

Quaternary Geochronology

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

Research paper

Quartz OSL dating of last glacial sand dunes near Lanzhou on the western Chinese Loess Plateau: A comparison between different granulometric fractions

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ARTICLE INFO

Article history:
Received 10 October 2011
Received in revised form
6 December 2011
Accepted 8 December 2011
Available online 22 December 2011

Keywords:
OSL dating
Quartz of different grain-size fractions
Sand dune sediments
Chinese Loess Plateau
Palaeoclimatic changes

ABSTRACT

Optically stimulated luminescence (OSL) dating technique is a reliable method to determine the ages of sand dune sediments. While it seems logical to assume that for these windblown materials (such as sand dune sediments) grains from different sized fractions are suitable for optical dating and would yield identical ages, this was not previously explicitly demonstrated yet. In this study, six samples were selected from the sand dunes intercalated in loess strata near Lanzhou, western Chinese Loess Plateau, and different grain-size quartz fractions (e.g. 38–63 μm, 90–150 μm, 150–200 μm, 200–250 μm and 250–300 μm) were extracted to compare the OSL ages of different grain-size quartz. The results show that: (1) quartz OSL ages derived from different grain-size fractions produce identical ages within errors, confirming that the ages resulting from both coarse silt-sized (or middle grain of 38–63 μm) and sand-sized (90–300 μm) quartz can represent the periods of sand dune accumulation; (2) the OSL ages of the selected sand dune samples fall into ca. 28–18 ka, suggesting that the sand dune accumulation occurred during the marine isotope stage 2 (MIS 2) in current study area, which might imply regional increased aridity on the western Chinese Loess Plateau.

1. Introduction

Dune systems represent important palaeoenvironmental archives and therefore provide valuable information on past climate conditions (Singhvi and Porat, 2008). A precise age determination of the aeolian activity itself is a crucial step towards a better understanding of past environmental conditions. Although sedimentary records from these archives, as well as their geomorphic process, have provided useful information on the timing, frequency and the amplitude of past climatic changes, the sand dunes sediments can only be fully understood, and their significance evaluated, once a robust chronological frame is established.

Optically stimulated luminescence (OSL) dating is the most commonly used dating technique to reconstruct numerical chronologies for sand dune sediments due to its ability to directly date the moment of sediment deposition. This technique uses grains of quartz or feldspar, which are both specially abundant in dunes. The windblown nature of dunes ensures that the luminescence clock is normally completely reset prior to deposition, a prime requisite for luminescence dating. Recently, this method has been successfully applied in many studies on sand dune evolution from North America (Forman et al., 2005; Miao et al., 2010), China (Lu et al., 2005; Mason et al., 2009; Yang et al., 2010) and Africa (Lancaster et al., 2002; Thomas and Shaw, 2002; Bristow et al., 2007). Most of these studies used sand-sized (coarse grain, CG) (90–300 μm) quartz for OSL dating material due to sand dune sediments mainly consisting of such sized grains. For extracting quartz from these sand-sized sediments, however, it's necessary to treat samples with hydrofluoric acid (HF) which is very dangerous to laboratory people, and even the impacts of feldspar inclusion on the purity of CG quartz are sometimes not able to be avoided. While fine silt-sized (fine grain, FG) (4–11 μm) quartz has also been used for OSL dating (Lu et al., 2007), it's hard to extract grains of 4–11 μm from sand dune sediments due to the lack of FG component in such sediments. Furthermore, it might be difficult to isolate pure quartz from fine grain multi-mineral (Roberts and Wintle, 2001; Watanuki et al., 2003), and it was at best a tedious operation, and in some cases impractical (Buylaert et al., 2008; Lai, 2010). For instance, by using various dilutions of fluorosilicic acid and different treatment times, Roberts and Wintle

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doi:10.1016/j.quageo.2011.12.002

(2001) showed that the chemically isolated quartz component had low yields and still contained feldspars when checked using infrared stimulation. After these treatments some samples did not yield enough quartz to allow dating measurements (Watanuki et al., 2003). To overcome these problems, coarse silt-sized (middle grain, MG, e.g. 38–63 μm) quartz was occasionally used for OSL dating of sand dune sediments (e.g. He et al., 2010; Yang et al., 2010; Long et al., in press). Compared with the CG, the MG are more convenient in extracting pure quartz from the sediments (Lai, 2010). However, based on comparison of OSL ages from different grain-size fractions, Fan et al., 2010 suggested that fractions coarser than 125 μm yield more reliable burial ages, while the fraction finer than 90 μm yields underestimated ages for lakeshore sediments from the arid region of north China, which could be due to that fine materials moved down after the dominant deposition due to percolation of water or due to soil development after lakeshore sediments were exposed above water. Although, for windblown material (such as sand dune sediments), it seems logical to assume that grains from different fractions are suitable for optical dating and would yield identical ages (Timar-Gabor et al., 2011), this has not been explicitly demonstrated yet. And, as yet, no studies are available that compare the luminescence characteristics and age of quartz grains of different granulometric fractions extracted from sand dune sediments.

In this study, we report on such an investigation to compare OSL ages of quartz grains of different granulometric fractions for samples collected from sand dune sediments intercalated in loess strata near Lanzhou of western Chinese Loess Plateau. Long et al. (in press) previously dated these sediments using OSL signals from MG quartz. In this study, we selected six sand dune samples from the same sand dune stratum investigated by Long et al. (in press), and extract different grain-size quartz fractions (e.g. 38–63 μm, 90–150 μm, 150–200 μm, 200–250 μm and 250–300 μm) for equivalent dose (D_e) measurements. The results were compared to further check if the OSL ages resulting from MG quartz reported by Long et al. (in press) can represent the periods of these sand dune accumulations.

2. Study site and samples

The study site is located in the southern Qingwangchuan Basin, near Lanzhou of the western Chinese Loess Plateau (Fig. 1a and b). The sand dunes are commonly covered by loess, and the internal structure of the dunes is characterized by distinct cross-bedded sand layers (Fig. 1c). Six samples were taken from three palaeodunes, namely ZC2, XC2 and XC6. Two samples (ZC2-1 and XC2-E) were collected from ZC2 site and XC2 site, respectively, and other four samples (XC6-1, XC6-3, XC6-5 and XC6-7) were collected from XC6 site. Among these samples, XC2-E was already dated using OSL signals from MG quartz by Long et al. (in press).

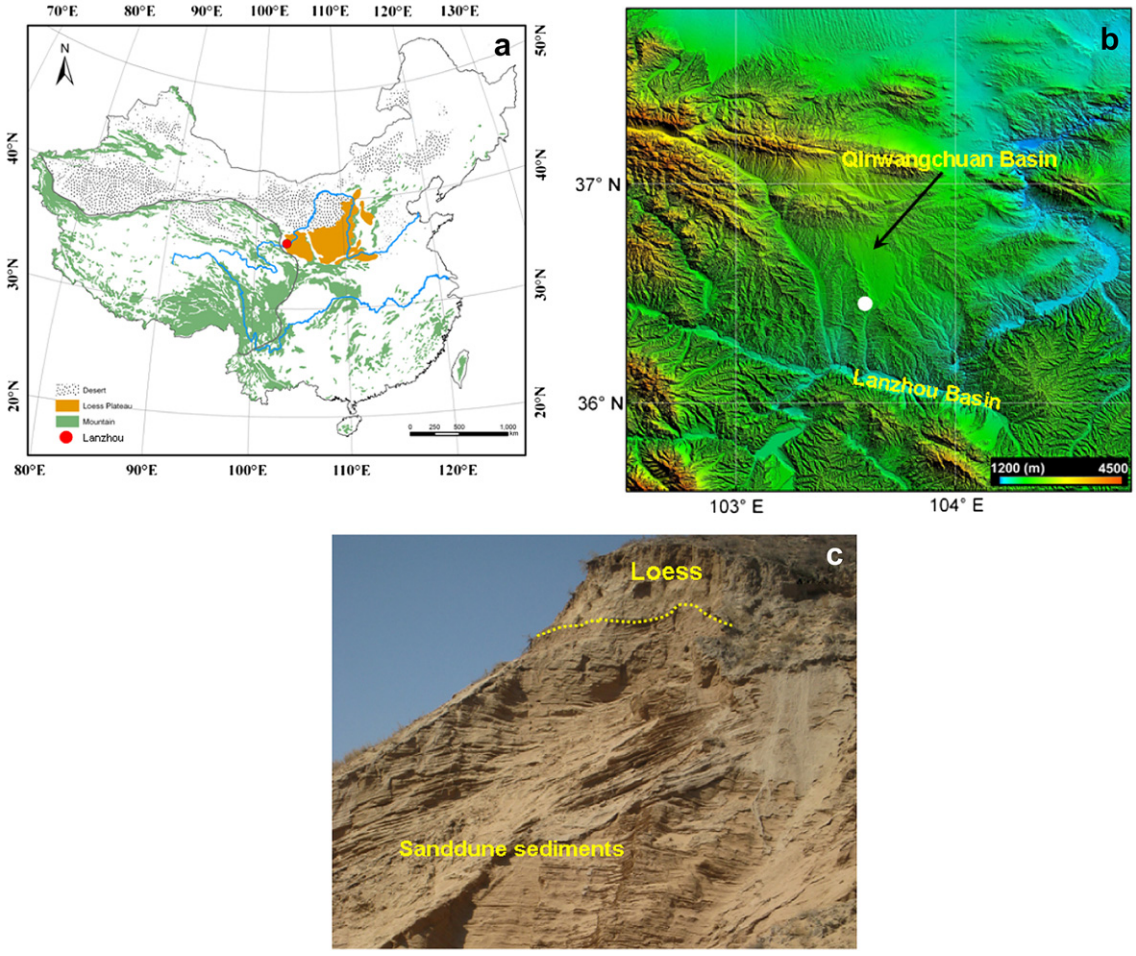

Fig. 1. (a) Map showing the location of the Chinese Loess Plateau and the desert distribution in northern China. The red filled circle indicates the city of Lanzhou, western Chinese Loess Plateau. (b) DEM map showing the geomorphic features of the Qinwangchuan Basin and its adjacent areas near the Lanzhou Basin. The sand dune site is denoted by the white filled circle. (c) Photograph of a sand dune with the structures of distinct cross-bedded sand layers. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)