Atmospheric Environment 120 (2015) 369–375

Contents lists available at ScienceDirect

Atmospheric Environment

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

Geochemical evidence for seasonal variations in potential loess sources of the western Chinese Loess Plateau

Xunming Wang [a, b, *], Lili Lang [a], Hui Li [b], Ting Hua [b], Guangtao Wang [b], Na Zhou [a], Linlin Jiao [a]

[a] *Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China*

[b] *Key Laboratory of Desert and Desertification, Cold and Arid Regions Environmental and Engineering Research Institute, Chinese Academy of Sciences, Lanzhou 730000, China*

HIGHLIGHTS

- Source of the loess deposited on the western Chinese Loess Plateau (CLP) varies.
- Dust-event frequency may not be an effective index for loess deposition rates.
- The link between particle size and geochemistry of loess source areas is complex.
- Both dry and wet deposition are equally important on the western CLP.
- Using loess-sequence geochemistry as a regional climate proxy should be appraised.

ARTICLE INFO

Article history:
Received 8 April 2015
Received in revised form
2 September 2015
Accepted 4 September 2015
Available online 8 September 2015

Keywords:
Loess
Source
Principal components analysis
Chinese Loess Plateau

ABSTRACT

This paper aims to characterize seasonal variations in the potential sources of loess deposited on the western Chinese Loess Plateau (CLP). Fallout was sampled every five days between March 2013 and August 2014 at Jiuzhoutai, the site with the largest loess deposits in northwest China. A total of 45 macro and trace elements, as well as rare earth elements, were analyzed in the samples. The results show that, at present, the potential sources of loess are mixed with pollutants. After exclusion of the pollutants, principal component analysis (PCA) showed significant seasonal variations in the potential loess sources on the western CLP. During the spring, summer–autumn, and winter periods, there are possibly six, four, and two potential loess sources, respectively, with crustal provenance at Jiuzhoutai. No significant differences in fallout amounts were found on the western CLP during periods with and without dust events, which suggests that the frequency of dust events may not be an effective index for deposition rates in areas of loess formation. The relatively high proportion of coarser material (>50 μm in diameter) in the fallout indicates that at least part of the loess in the fallout samples originated from adjacent deserts and associated systems, and that both dry and wet deposition contributed equally to the fallout. Based on the significant seasonal and spatial variations in the loess sources, combined with variations in the link between the different particle size classes and the geochemical characteristics of potential components of the loess on the western CLP, the use of the geochemical characteristics of loess stratigraphic sequences as a proxy for regional paleoclimatic and environmental reconstructions should be carefully appraised.

1. Introduction

Dust generated by the prevailing winds in arid, semiarid, and semi-humid areas of central Asia, which then accumulates via dry or wet deposition, is a potential source of the sediment that forms the Chinese Loess Plateau (CLP; Liu, 1985; Pye, 1987). The post-depositional effects of weathering (Liang et al., 2009) and pedogenesis (Zhang et al., 2012) generate variations in the composition of loess stratigraphic sequences, and these variations have been

* Corresponding author. Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
E-mail address: xunming@igsnrr.ac.cn (X. Wang).

http://dx.doi.org/10.1016/j.atmosenv.2015.09.009

used as a proxy to reconstruct regional paleoclimates (Sun, 2005; Jeong et al., 2008; Sun et al., 2008; Hu et al., 2013; Wimpenny et al., 2014) and past atmospheric circulations (Gallet et al., 1996). In recent decades, many studies have suggested that the dominant sources of loess on the CLP are gobi and sandy deserts (Torii et al., 2001; Sun, 2002), deflation pans (Kapp et al., 2011), and piedmont alluvial fans (Derbyshire et al., 1998; Wang et al., 2008). Some have also suggested that the loess has multiple sources, and that before deposition these materials are mixed by changes in the local-to regional-scale atmospheric circulations (Kreutz and Sholkovitz, 2000). In addition to variations in loess sources, it has been suggested that the low wind velocity, low temperatures, and decreased precipitation during glacial periods (i.e., stages that are marked by colder temperatures and glacier advances) led to an increased frequency of dust events (Guan et al., 2013; Peng et al., 2014), and that this had a significant impact on the thickness of loess on the CLP (Porter, 2001; Vriend et al., 2011).

The great significance of the CLP loess stratigraphic sequences to paleoclimatic and environmental reconstructions has led to considerable interest in their potential source areas and composition (Lu and Sun, 2000; Lu et al., 2012). To date, most studies have focused on sediment sampled in the potential loess source regions, or used the composition of deposits in the loess stratigraphic sequences, to identify the source areas for the CLP. However, the amount of material supplied by the distinct loess sources may vary seasonally, and this may lead to uncertainties when attempting to determine potential loess sources and use them as an indicator of past environmental change. To improve our understanding of the characteristics of the potential loess sources, we collected fallout samples on the western CLP at five-day intervals between March 2013 and August 2014. The aim of this program was to fingerprint the possible loess sources, estimate the seasonal variations in the output from each source, and calculate the deposition rates of the loess accumulating on the western CLP. In addition, we appraised the seasonal variations in loess composition and considered their significance in order to facilitate the interpretation of paleoclimate records based on loess deposits.

2. Collection site and analytical methods

The sampling site was located at the summit of Jiuzhoutai (35°58′N, 103°12′E; 2066.8 m above sea level), near Lanzhou City, northwest China (Fig. 1). Here, the mean annual wind velocity is 2.3 m/s and the dominant wind direction is from the NW with no evident seasonal changes. The annual temperature, precipitation, and evaporation are 9.3 °C, 329.7 mm, and 1332.7 mm, respectively. Loess began to accumulate at the site at about 1.4 Ma (e.g., Fang et al., 1997) and it is now 318.2 m thick. This is a representative site for the use of loess stratigraphic sequences to reconstruct paleoclimatic changes on the western CLP (Liu et al., 2009). The fallout was collected using trap fixed to the roof of a building with no shading within 100 m, at a height of >3 m above the ground surface. The fallout trap was a square glass vessel that was 50 cm long and 100 cm high. Field testing showed that after capture no fallout escaped from the vessel, even when wind speeds exceeded 3 m/s, which is relatively high for this site. Every five days, the samples within the trap were transferred into plastic bags for analysis, and then the vessel was washed with demineralized distilled water prior to further sample collection. During the rainy season, the collection interval was sometimes extended to 6–10 days until the samples were spontaneously dried. A total of 62 samples were collected between March 2013 and August 2014.

The samples were weighed prior to analysis by ICP–MS (Elan DRC-e, PE, USA) and ICP–OES (Optima 5300DV, PE, USA) at the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, China. First, 0.05 g subsamples were dissolved in ultrapure solutions of HNO_3 (3 ml), HF (3 ml), and $HClO_4$ (1 ml), and heated in Teflon crucibles at 120 °C for 30–45 min and then at 180 °C for about 6 h. After the solutions were dried, 1 ml HF, 1 ml HNO_3, and 0.1 ml $HClO_4$ were added to the samples and they were then heated again for 7–10 h. These procedures were repeated until no solid particles remained in the solutions. After the solutions were cooled, 3 ml aliquots were extracted with a plate and then heated until the solutions reached boiling point. After the samples cooled again, they were diluted with ultrapure water and made up to 25 ml solutions, and the concentration of trace elements, REEs, and macro-elements in the samples was then determined.

The Chinese National Reference Materials GSS-8 (loess sediments sampled in Luochuan, CLP) and GSD-6 (river sediments sampled in Zhaduo, Qinghai) were used to monitor the accuracy of the analytical procedures (see Wu et al., 2009). Repeated

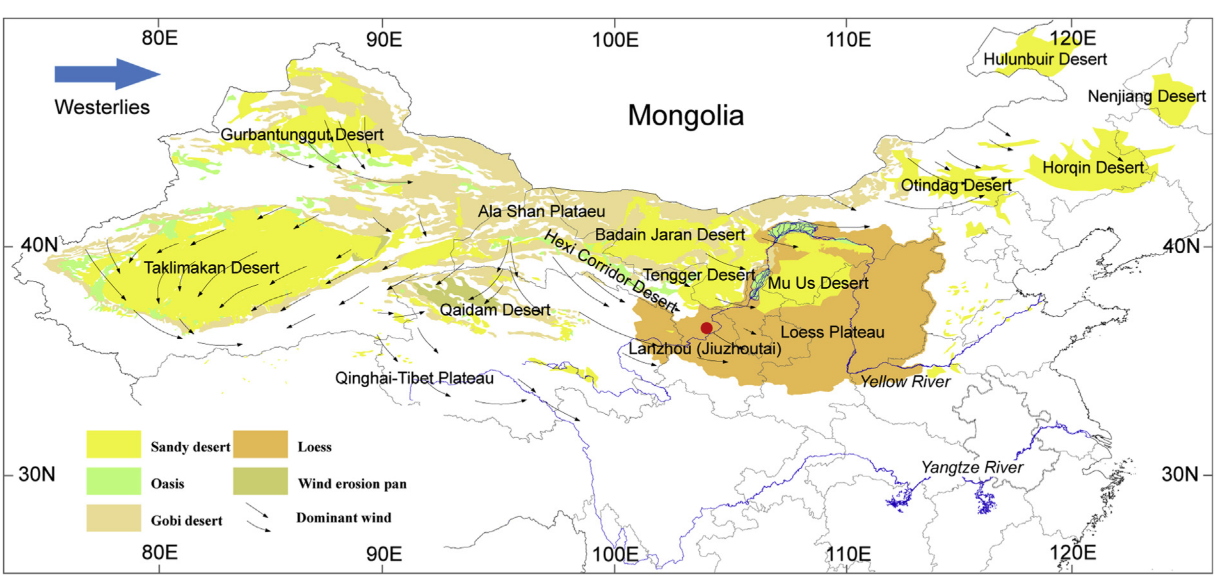

Fig. 1. Map showing loess distribution in China and the location of the sampling site.