Quaternary Research 85 (2016) 290–298

Contents lists available at ScienceDirect

Quaternary Research

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

Geochemical and grain-size evidence for the provenance of loess deposits in the Central Shandong Mountains region, northern China

Shuzhen Peng [a,b], Qingzhen Hao [b,*], Luo Wang [b], Min Ding [a], Wei Zhang [a,b], Yanan Wang [a], Zhengtang Guo [b]

[a] Key Laboratory of Tourism and Resources Environment in Universities of Shandong, Taishan University, Taian 271021, China
[b] Key Laboratory of Cenozoic Geology and Environment, Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing 100029, China

ARTICLE INFO

Article history:
Received 12 August 2015
Available online 28 February 2016

Keywords:
Loess Provenance
Central Shandong Mountains
Chinese Loess Plateau
Geochemistry
Grain-size

ABSTRACT

Widespread loess deposits in the Central Shandong Mountains yield valuable paleoclimatic records for this currently semi-humid monsoonal region of northern China. The grain-size distribution and major element composition for bulk samples and two grain-size fractions (<20 and 20–63 μm) for the loess in the Central Shandong Mountains were compared with loess from the Chinese Loess Plateau and sediment from the Yellow River to help determine its provenance. The presence of a significant percentage of medium- and coarse-silt, and the difference in relatively immobile major element ratios of TiO_2/Al_2O_3 and K_2O/Al_2O_3 for the <20 and 20–63 μm fractions, suggests that sediment that forms the loess deposits in the Central Shandong Mountains was not blown directly from the northern deserts of China as is the case for the loess deposits of the Chinese Loess Plateau. Rather, this suggests that sediments exposed during glacial times on the North China fluvial plain, including the floodplain of the Yellow River, were the major dust source for the loess in the Central Shangong Mountains. In addition, the wide distribution of perimontane loess in the Central Shandong Mountains region indicates the occurrence of strengthened local aridification during glacial times since the middle Pleistocene.

Introduction

The identification of aeolian dust sources is important for understanding the atmospheric transport of dust and for reconstructing past climatic and environmental conditions (e.g., Tsoar and Pye, 1987; Biscaye et al., 1997; Derbyshire et al., 1998; Sun et al., 2013; Israel et al., 2015). As archives of aeolian dust, loess deposits have been used extensively to reconstruct Quaternary climatic changes and synoptic-scale circulation patterns by tracking the variations in source, mode of transport and depositional areas of the dust (Lu and Sun, 2000; Sun, 2002; Guo et al., 2004; Li et al., 2007; Marković et al., 2007; Guan et al., 2008; Újvári et al., 2008, 2013, 2014; Hao et al., 2010; Stevens et al., 2013). Although most of this work is based on the deposits of the Chinese Loess Plateau there has recently been increasing interest in tracing the sources of Chinese loess deposits outside the region (e.g., Fang et al., 2002; Hao et al., 2010; Yang et al., 2010; Qiao et al., 2011, 2014; Zhang et al., 2012a,b; Liu et al., 2014; Song et al., 2015).

To the east of the Chinese Loess Plateau, loess deposits are widely distributed in two regions: i) the northern piedmont and intermontane valleys of the mountains in central Shandong Province; and ii) the northern coastal area of the Shandong Peninsula (Fig. 1). Both areas currently have semi-humid climates (Liu, 1985). Earlier studies, based on the spatial distribution of loess and on field observations, suggest that the sediment comprising the loess was derived from the deserts of northwestern China (Liu, 1985). Thus, these eastern loess-soil sequences have the potential for providing valuable paleoclimate archives for the eastern floodplain region of the eastern Asian monsoon regime, and more specifically they may potentially help improve our understanding of the spatiotemporal variability of the East Asian monsoon. In addition, tracing the provenance of the widely-distributed loess deposits in Shandong Province is important because they reveal the occurrence of dramatic climatic changes and dust sources during the middle Pleistocene.

The presence of marine foraminifera in the loess deposits of the northern coastal area of the Shandong Peninsula indicates that the loess is derived from sediments in the Bohai Sea, which were exposed by a falling sea level during the last glacial providing data on sea level changes (Cao et al., 1988; Li et al., 2002; Zhang et al., 2012a). In contrast, however, the loess in the Central Shandong Mountains does not contain foraminifera and thus it is unlikely to be derived from the Bohai Sea. The traditional view is that, as is the case for the Chinese Loess Plateau, these eastern loess deposits are mainly derived from dust blown from the deserts in northern China during times of increased aridity in these source areas and an intensified East Asian winter monsoon (Liu, 1985; Yang et al., 1991). Grain-size analysis of the Qingzhou loess (Fig. 1c) reveals that it contains a significant proportion of coarse particles, which are unlikely to have been transported by wind from the distant deserts of northern China (Liu et al., 2000; Peng et al., 2007, 2011). Therefore, an

* Corresponding author. Fax: +86 10 62010846.
E-mail address: haoqz@mail.iggcas.ac.cn (Q. Hao).

http://dx.doi.org/10.1016/j.yqres.2016.01.005
0033-5894/

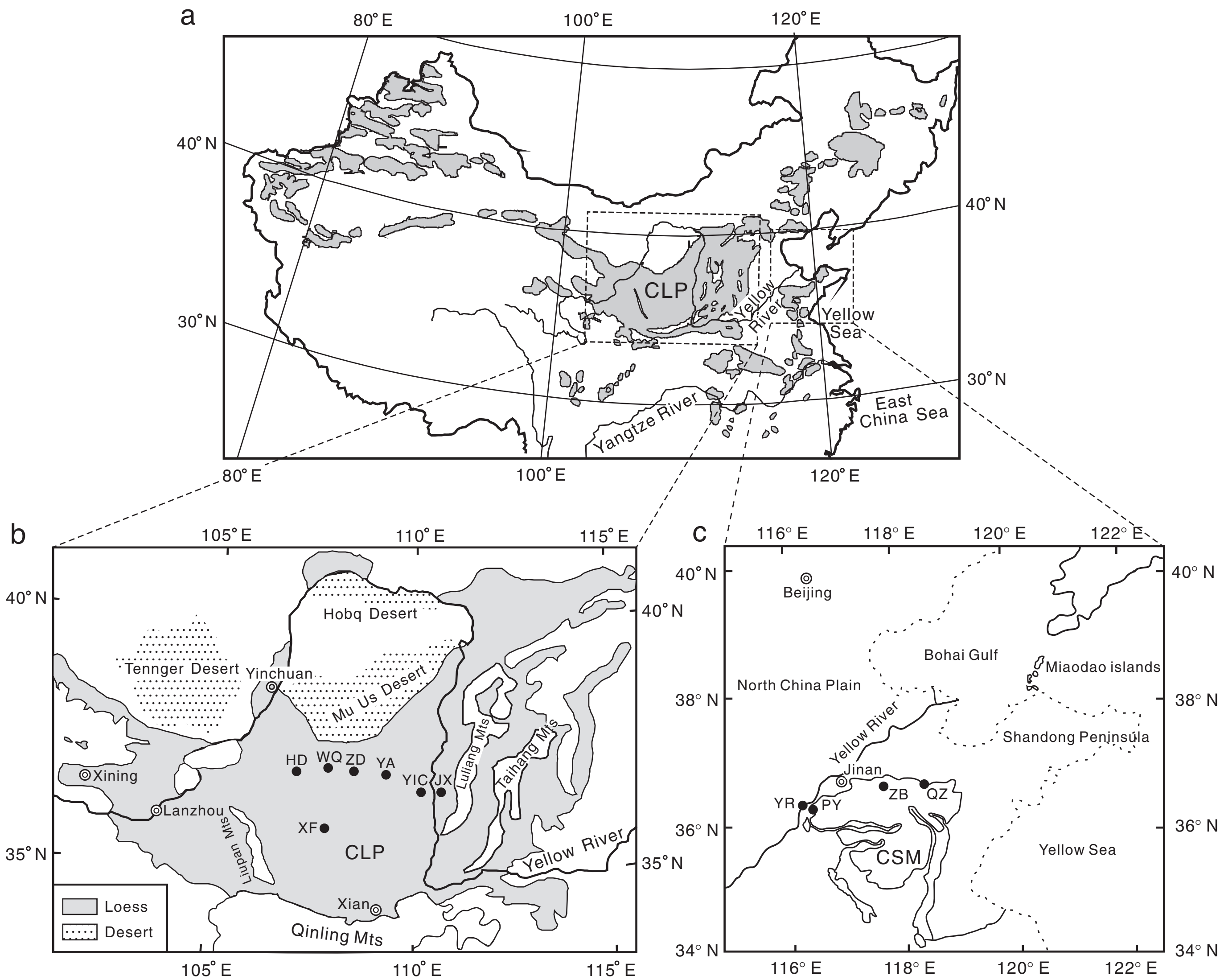

Fig. 1. a) Distribution of loess deposits in China and location of the study region of the Central Shandong Mountains. CLP refers to the Chinese Loess Plateau. b) Chinese Loess Plateau and location of some of the sites mentioned in the text. c) Location of the studied loess sections in the Central Shandong Mountains (Pingyin — PY; Zibo — ZB; and Qingzhou — QZ) and location of the sediment samples obtained from the lower reaches of the Yellow River (YR).

alternative interpretation for the provenance of these deposits is that, in addition to a long-distance component from northwestern China, the sediments from the fluvial plain of the lower reaches of the Yellow River were an important contribution to these deposits (Liu et al., 2000; Peng et al., 2007, 2011). However, heretofore analysis of geochemical composition of these loess deposits in the Central Shandong Mountains (e.g., Muhs et al., 1996; Muhs and Bettis, 2000; Sun, 2002; Yang et al., 2007a,b; Guan et al., 2008; Újvári et al., 2008, 2013, 2014; Liang et al., 2009; Hao et al., 2010; Buggle et al., 2011) has not been used to trace the source of their sediment.

In this paper, we therefore compare the grain-size distribution and relatively immobile major element composition of three typical Shandong loess sections on a W–E transect across the northern piedmont regions of the Central Shandong Mountains with loess from the Chinese Loess Plateau and sediments from the Yellow River. A comparison is made on the basis of analysis of bulk samples, and the 20–63 and <20 μm grain-size fractions. The results suggest that local sediments in the North China fluvial plain, including the floodplain of the Yellow River, were the major dust source for the loess deposits in the Central Shandong Mountains region.

Materials and methods

Materials

The Central Shandong Mountains are located in the North China Plain (Fig. 1c). The region consists of hills and low mountains, with elevations ranging from 200 to 1545 m above sea level. The region has a warm and semi-humid monsoon climate with a distinct seasonality. Northwesterly winds prevail in winter (Fig. 2) and southeasterly winds in summer. Annual temperature and precipitation are typically 12.6–14.5°C and 615–794 mm, respectively. Thick loess deposits occur in the Central Shandong Mountains, mainly occurring along an east–west direction along the northern piedmont region.

We investigated three typical loess sections in the region. The most typical section, Qingzhou (QZ, 36°40′N, 118°27′E) (Fig. 1c), a vertical loess cliff, has a thickness of ~28.2 m and is underlain by fluvial sands (Liu et al., 2000; Peng et al., 2007, 2011). Paleomagnetic and optically-stimulated luminescence (OSL) dating suggest that the basal age is ~0.5 Ma (Peng et al., 2011). The section is sub-divided into four lithological units: i) modern cultivated soil (0–0.85 m); ii) Holocene soil