Quaternary International xxx (2016) 1–11

Contents lists available at ScienceDirect

Quaternary International

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

Grain-size distribution of Pleistocene loess deposits in northern Iran and its palaeoclimatic implications

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ARTICLE INFO

Article history:
Available online xxx

Keywords:
Grain size
Iranian loess
Pleistocene
Palaeoclimate
Aeolian process

ABSTRACT

The loess deposits in northern Iran are located in a key region connected to the European and central Asian loess belts. However, the lack of previous detailed sedimentological and palaeoclimatic studies of the Pleistocene loess in the region limits our understanding of the nature of ancient aeolian processes and loess history in the mid-latitudes of Euro-Asia as a whole. Here, we present the results of grain-size analyses of the Pleistocene loess from the so-called Iranian Loess Plateau (ILP) in northern Iran. Our results reveal that the grain-size distribution of the deposits is characterized by trimodal and bimodal distributions, comprising a dominant well-sorted coarse dust component (ca. 7–75 μm), a small poorly-sorted fine dust component (ca. 2–7 μm), and a minor pedogenic clay component (<2 μm). The dominance of the coarse dust component in the samples suggests that the main part of the Pleistocene loess in northern Iran was transported predominantly by the local low-level winds from proximal source regions. The modal size of the coarse dust component is systematically coarser in the lower Pleistocene loess succession than in the lower Pleistocene loess–palaeosol sequence, indicating a progressively intensifying wind strength during the Pleistocene. The proportion of the clay fraction (<2 μm) decreases systematically from the lower Pleistocene to the upper Pleistocene loess strata, suggesting a relatively drier and colder climate in northern Iran during the late Pleistocene than during the early Pleistocene.

1. Introduction

The loess deposits in the mid-latitudes of Euro-Asia provide unique long-term terrestrial archives for reconstructing the history of palaeoclimatic changes and wind-patterns in the continental interior. Extensive studies have been performed on the loess deposits in China (e.g., Heller and Liu, 1982; Liu, 1985; Kukla, 1987; Sun et al., 1998; Ding et al., 1999; An et al., 2001; Guo et al., 2002; An, 2014); central Asia (e.g., Dodonov and Baiguzina, 1995; Frechen and Dodonov, 1998; Ding et al., 2002; Yang et al., 2006); and Europe (e.g., Fink and Kukla, 1977; Smalley, 1995; Frechen et al., 2003; Haase et al., 2007; Marković et al., 2008, 2009, 2015; Stevens et al., 2011). However, the correlation of the loess records between these regions is relatively poor (e.g., Vasiljević et al., 2014), mainly due to the lack of well-studied loess records from the transitional zones. The loess deposits in northern Iran are located in a critical region connecting the European and central Asian loess belts (Fig. 1, Muhs, 2007), and understanding the palaeoclimatic record of their loess deposits and the dynamics of dust mobilization, transport and deposition could facilitate correlations between the two loess belts.

Previous loess studies in northern Iran mainly focused on the chronology and sedimentology of the middle–upper Pleistocene yellowish loess successions. For example, Kehl et al. (2005), Kehl (2010), and Khormali and Kehl (2011) described the lithology and stratigraphy of the middle–upper Pleistocene loess–palaeosol sequences along a climatic gradient in northern Iran; Frechen et al. (2009) and Lauer et al. (2015, 2016a,b) reported the results of luminescence dating of representative sections from the ILP and the

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http://dx.doi.org/10.1016/j.quaint.2016.01.058
1040-6182/

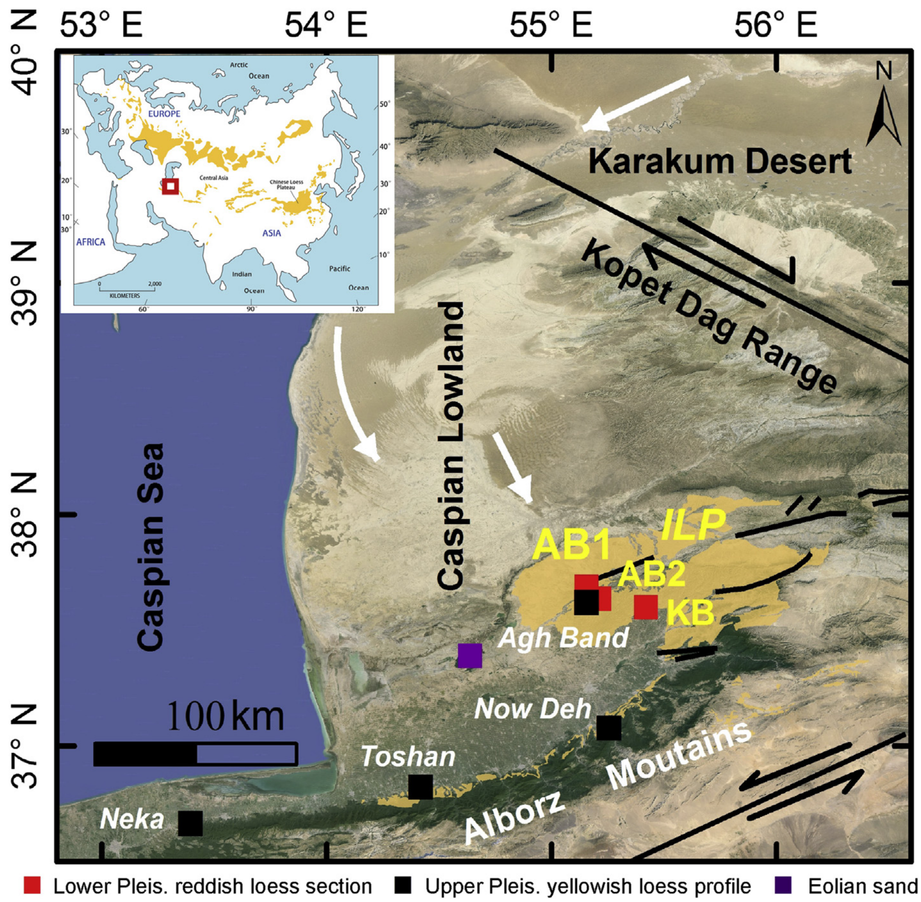

Fig. 1. Map showing the location of the ILP and the studied sections. The inset map shows the distribution of loess in Euro-Asia (modified from Muhs, 2007). The data for the distribution of loess in northern Iran is from the Central Office of the Golestan Natural Resources and Watershed Management.

northern foothills of the Alborz Mountains; and Vlaminck et al. (2016) presented the first high-resolution multi-proxy records from the Toshan Section from the northern slopes of the Alborz Mountains. These new results demonstrate that most of the loess deposits in northern Iran formed during the middle to late Pleistocene, and that the moderately-developed palaeosol and loess layers formed mainly during interglacial and glacial periods, respectively.

Recently, a Sino-Iranian international joint program was carried out to investigate the ancient loess deposits in northern Iran. Lithological and multi-proxy evidence indicate that the widespread red-coloured sediments, unconformably underlying the upper Pleistocene loess successions, are aeolian in origin; while palaeomagnetic dating results indicate that the reddish loess accumulated during ~2.4–1.8 Ma (Wang et al., 2016). This work has extended the history of Iranian loess back to the early Pleistocene; however, the nature of aeolian processes and palaeoclimatic changes in northern Iran during the Pleistocene need further investigation.

The grain-size distribution of wind-blown dust deposits is a valuable tool for reconstructing past aeolian processes and wind circulation patterns (e.g. Folk, 1966; McCave et al., 1995; Pye, 1995; Sun et al., 2002; Machalett et al., 2008; Vandenberghe, 2013). Given the specific physical properties of a given transport medium, the grain-size of the transported sediments characteristically exhibits a smooth, unimodal curve (Ashley, 1978; Bagnold and Barndorff-Nielsen, 1980). For example, wind-blown dust in the North Pacific Ocean is carried by the high-level Westerlies as a long-distance suspension component, and its grain-size distribution is characterized by a unimodal distribution with a modal size generally finer than 10 μm (Rea and Hovan, 1995). Sand dune particles in arid lands are mainly transported by strong near-surface winds in a traction mode, and their grain-size distribution is characterized by a unimodal distribution with a dominant aeolian sand component; the modal sizes generally range from 70 to 250 μm (Sun et al., 2011a; Wang et al., 2013, 2014; Li et al., 2014; Wang et al., 2015). Wind can transport particles in traction, saltation and suspension modes, depending on the balance between the settling velocity of the grain and the vertical velocity component of the wind (Pye, 1995). Consequently, the aeolian traction, saltation and suspension components are represented in a sedimentary deposit by a series of overlapping grain-size distribution curves (e.g. Middleton, 1976; Sun et al., 2002); and in principle these specific components can be mathematically identified and partitioned (e.g. Sun et al., 2002; Qin et al., 2005; Weltje and Prins, 2007; Vandenberghe, 2013).

In the present work, grain-size analyses were conducted on the upper Pleistocene yellowish loess successions as well as on the lower Pleistocene reddish loess–palaeosol sequences from the ILP. By using the grain-size distribution function approach developed by Sun et al. (2002), we determined that the grain size of the Pleistocene Iranian loess is characterized by trimodal and bimodal distributions, and that it demonstrates systematic variations in modal size and in the proportions of the specific components through time. This new dataset provides valuable information about the ancient dust dynamics and palaeoclimatic changes in northern Iran during the Pleistocene.

Please cite this article in press as: Wang, X., et al., Grain-size distribution of Pleistocene loess deposits in northern Iran and its palaeoclimatic implications, Quaternary International (2016), http://dx.doi.org/10.1016/j.quaint.2016.01.058