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Loess deposits in the northern Kyrgyz Tien Shan: Implications for the paleoclimate reconstruction during the Late Quaternary

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ABSTRACT

Loess deposits on the northern slopes of the Kyrgyz Tien Shan were examined. Their particle size characteristics show silt size dominancy (>80%) with minor contribution from sand (12%) and clay (7%). The loess was dated using optically stimulated luminescence (OSL) and radiocarbon methods to define the timing of deposition. The OSL ages of fine and coarse quartz fractions were consistent with each other within 2σ uncertainty level, except several samples deposited during MIS 2. Based on the OSL ages, four major loess depositional periods are recognized in the northern Kyrgyz Tien Shan during the Late Quaternary: the Holocene, MIS 2, MIS 3, and MIS 4. The rate of dust accumulation in the northern Tien Shan during MIS 2 was greater than that during MIS 3 or MIS 4. This implies that cold–dry conditions varied significantly during the Late Quaternary in the study area. The accumulation patterns of the Kyrgyz loess deposits in the northern Tien Shan are closely related to climate fluctuations during the Late Quaternary, influenced by changes in the mid-latitude westerlies, Asian summer monsoons, and Siberian High Pressure (SHP) systems, during which there was no significant cessation of deposition.

1. Introduction

The Quaternary was characterized by remarkable large-amplitude cyclic variations associated with climatic fluctuations, sea level changes, and the advance and retreat of glaciers. Understanding of Quaternary environmental changes provides information on climate variability and predictions about future climate changes. Numerical dating of Quaternary terrestrial fine sediments, such as loess, has contributed to long-term archival records of environmental change, and to an understanding of how local environments have changed in response to climate shifts occurring on global and hemispherical scales. Continental loess deposits provide one of the most important archives of data on climate fluctuations during the Quaternary; they are especially sensitive indicators of dry–windy conditions associated with glacial activity (Burbank and Li, 1985; Derbyshire et al., 1997; Guo et al., 2002; Kapp et al., 2011; Pye, 1995; Sun et al., 2008). Thick and extensive loess deposits are present in a wide band across Asia, extending from northwestern Europe to Central Asia and China.

The Chinese Loess Plateau (CLP) is known for its long succession of loess and paleosols, which provides first-order proxy records of alternating glacial and interglacial cycles related to climate change. Northern Central Asian regions, located north of the Tien Shan, also preserve multiple levels of thick and extensive loess deposits. However, except for a handful of pioneering research studies (Bronger et al., 1995; Ding et al., 2002; Dodonov and Baiguzina, 1995; Forster and Heller, 1994; Frechen and Dodonov, 1998; Machalett et al., 2006; Shackleton et al., 1995), relatively little attention has been given to the quantitative study of these loess deposits. Despite the lack of detailed researches, loess in northern Central Asia is likely to be useful for reconstructing past climate changes, based on correlations with loess records on the adjacent CLP and nearby regions. Some attempts to compare the loess records of Central Asia with those of the CLP have suggested that both regions share similar loess–paleosol sequence cyclicities, as based on global ice volume correlations. The climatic cycles preserved in the loess of northern Central Asia, such as the Chashmanigar loess–soil sequences in southern Tajikistan and the Remisowka loess in Kazahstan, are well correlated with CLP records (Ding et al., 2002; Dodonov and Baiguzina, 1995; Machalett et al., 2006). The data from both regions show that loess deposits accumulated during the cold–dry glacial period, and that they have been altered to paleosols through pedogenic processes occurring during the warm–humid period when rates of loess accumulation were reduced.

In recent years, optically stimulated luminescence (OSL) dating has been applied extensively to loess deposits throughout the world (Küster et al., 2006; Machalett et al., 2006; Olley, 2004; Roberts, 2008; Roberts et al., 1999; Stevens et al., 2006, and more references therein). In this study, we also applied OSL dating method to establish chronology of loess deposition in the northern part of the Kyrgyz Range in the Kyrgyz Tien Shan.

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At present, the study area in the northern part of the Kyrgyz Range is dominated by mid-latitude westerlies and Siberian high-pressure (SHP) systems, both of which contribute to an extreme continental climate. The influence of these systems, together with the Asian monsoon, is likely to have varied throughout the Quaternary (Kukla, 1987; Pye, 1995; Shackleton et al., 1995). In this study, we examine the past climate changes of the late Quaternary in the northern part of the Kyrgyz Tien Shan using OSL dating and other sedimentary characteristics of loess deposits.

2. Study area

The Tien Shan, located at approximately 40°–45°N, 67°–95°E, extends in an east–west direction across Central Asia. They are ~2000 km long and ~400 km wide, and include ranges with several high peaks (elevations of >6000 m a.s.l). The mountain belt borders the Tarim Basin and the Taklamakan Desert to the south and plains dotted with mid-latitude continental deserts such as the Karakum, Kysylkurm, and Muyunkum deserts, to the north (Fig. 1). The belts

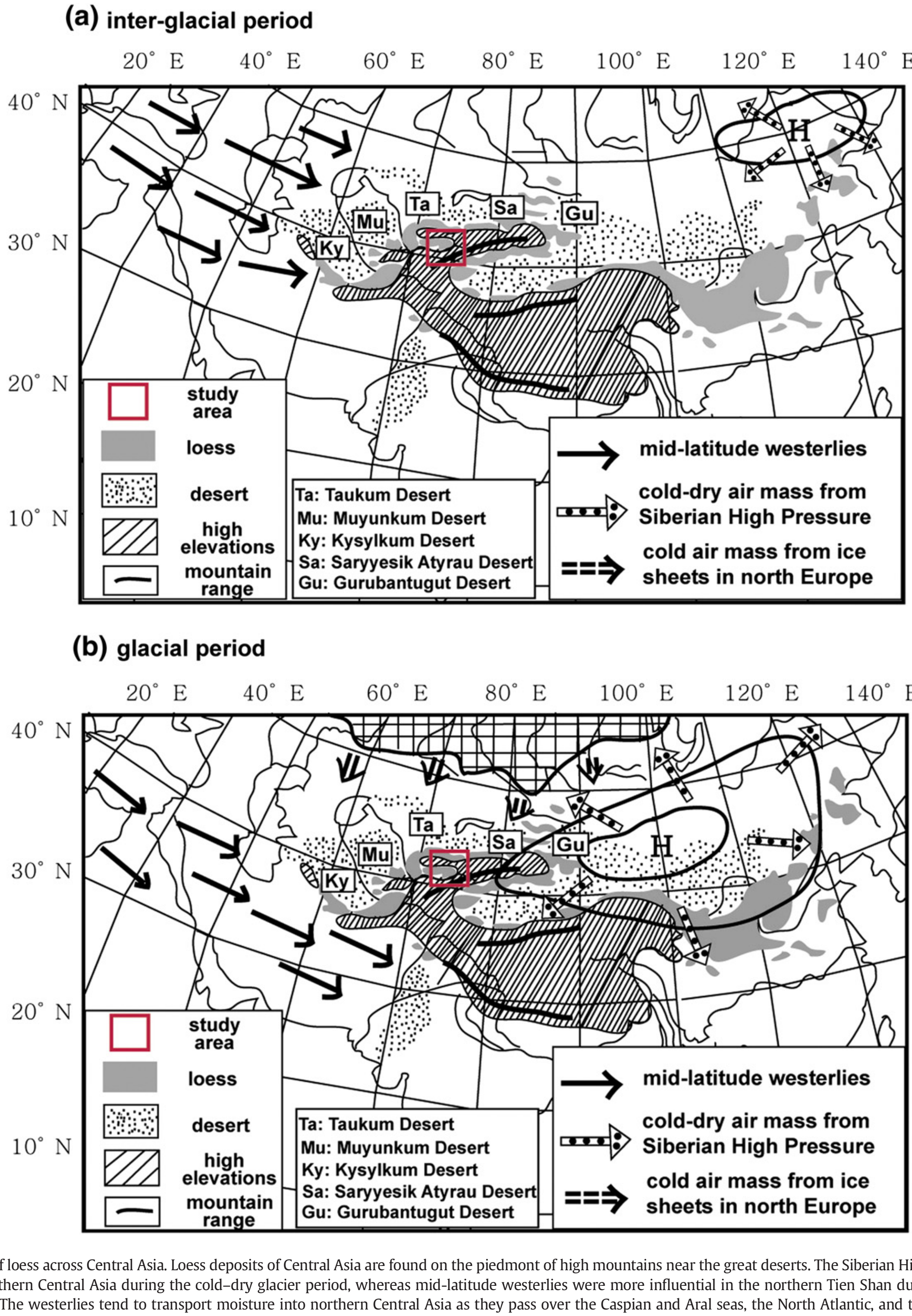

Fig. 1. Distribution of loess across Central Asia. Loess deposits of Central Asia are found on the piedmont of high mountains near the great deserts. The Siberian High Pressure (SHP) was strengthened in northern Central Asia during the cold–dry glacier period, whereas mid-latitude westerlies were more influential in the northern Tien Shan during the warm–humid interglacial periods. The westerlies tend to transport moisture into northern Central Asia as they pass over the Caspian and Aral seas, the North Atlantic, and the Mediterranean Sea. The diagram is modified from Dodonov and Baiguzina (1995).