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# Aeolian dust in mountain areas of Tibet and Mongolia

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## Abstract

Aeolian, loess-like sediments distributed as mantles of silt covering the bedrock and debris are widespread depositions in the mountain environments of Central and High Asia; sand and gravel gobi mainly occur in the basins. Up to now little is known about the distribution and timing of such late Quaternary sediments originated from far and local transported aeolian dust and sand. They represent valuable archives about environmental change during the late Quaternary. This fine material is important for growth of the vegetation cover and for water storage and nomadic life. Luminescence and radiocarbon dating provide information concerning their timing to the end of the last glacial cycle and especially to the Holocene, as some of them include loess-paleosol sequences. In addition, valuable information on paleoenvironmental conditions was acquired by grain-size distribution and geochemical analyses. In this abstract examples are given from the Russian and Mongolian Altai, from central and northern Mongolia, from the Qilian Shan and from the eastern Tibetan Plateau.

*Keywords: Aeolian silts; Mongolia; Tibetan Plateau; Holocene paleosol.*

## 1. Introduction

Research on loess and loess-paleosol sequences mainly concentrates on thick sequences in the Chinese Loess Plateau (CLP) or the foreland of the Russian Altai in southern Siberia (Fig. 1). Mantles of silt-sized particles in the mountains of Tibet and Mongolia are first described by Lehmkuhl (1997). In this paper the author summarizes results concerning the current state of research on the aeolian mantles in this vast region. This includes the distribution and timing of these mountain silts shown in three transects and based on six case studies (Fig. 2).

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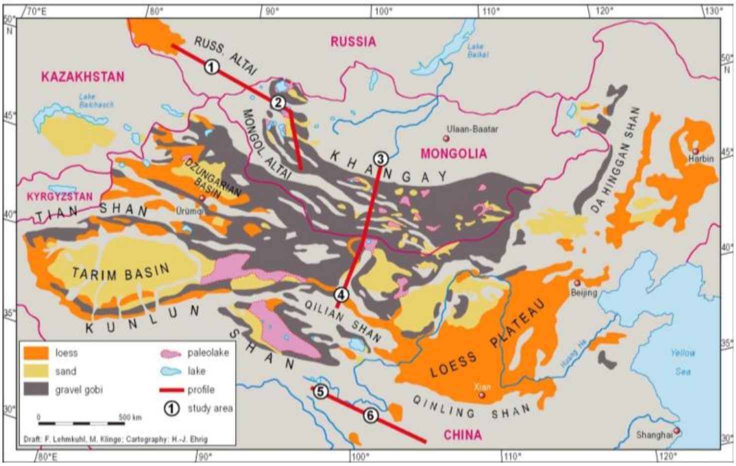


Fig. 1. Loess distribution in Tibet and Mongolia including location of three cross sections. (based on different sources and own mapping, modified according to Lehmkuhl (1997)).

The map in Fig. 1 provides the spatial distribution of loess, sand, gravel gobi and paleolakes mainly for China and Mongolia. Loess is mapped in this scale in the Chinese Loess Plateau (CLP), in regions of western China including the mountains around the Tarim Basin and Dzungarian Basin. There is considerable literature on the Quaternary aeolian processes and loess in deserts, especially about China and adjacent areas. Moreover, the loess sequences from the CLP are the best-known and most intensively studied ones within China (e.g.,, An et al., 1991). In addition, there is loess north of the Russian and Mongolian Altai in southern Siberia (e.g., Rutter et al.,2003). In the basins (e.g., Valley of the Great Lakes in western Mongolia, Tarim Basin, and Dzungarian Basin) paleolake sediments, mainly from the early to mid Holocene indicate a humid period (Yang et al.,2004, Chen et al.,2008). In addition gravel gobi, often a result of alluvial fans during glacial cycles, occur. In addition, large areas with sand dunes are distributed, especially in the Tarim Basin and locally east of the basins or large river systems, such as in the Uvs Nuur Basin or the Badain Jaran Shamo east of the Heihe River. Grunert and Lehmkuhl (2004) described the aeolian sedimentation in western Mongolia and provided a model for the horizontal and vertical transport of aeolian sediments in the basin and range area of Western Mongolia during the Pleistocene and Holocene.

Loess and associated aeolian and slope deposits are present in the mountain areas (Fig. 2), dunes and (paleo)lakes in the basins. Aeolian deposits have the potential to provide additional information for reconstructing Quaternary landscape development and they also provide important comparisons for the lacustrine archives, which have been regularly studied in the region. Local studies in different areas using luminescence and radiocarbon dating provide evidence for the timing of these late Quaternary aeolian sediments and paleosols. In the following the case study areas are described from north to south.

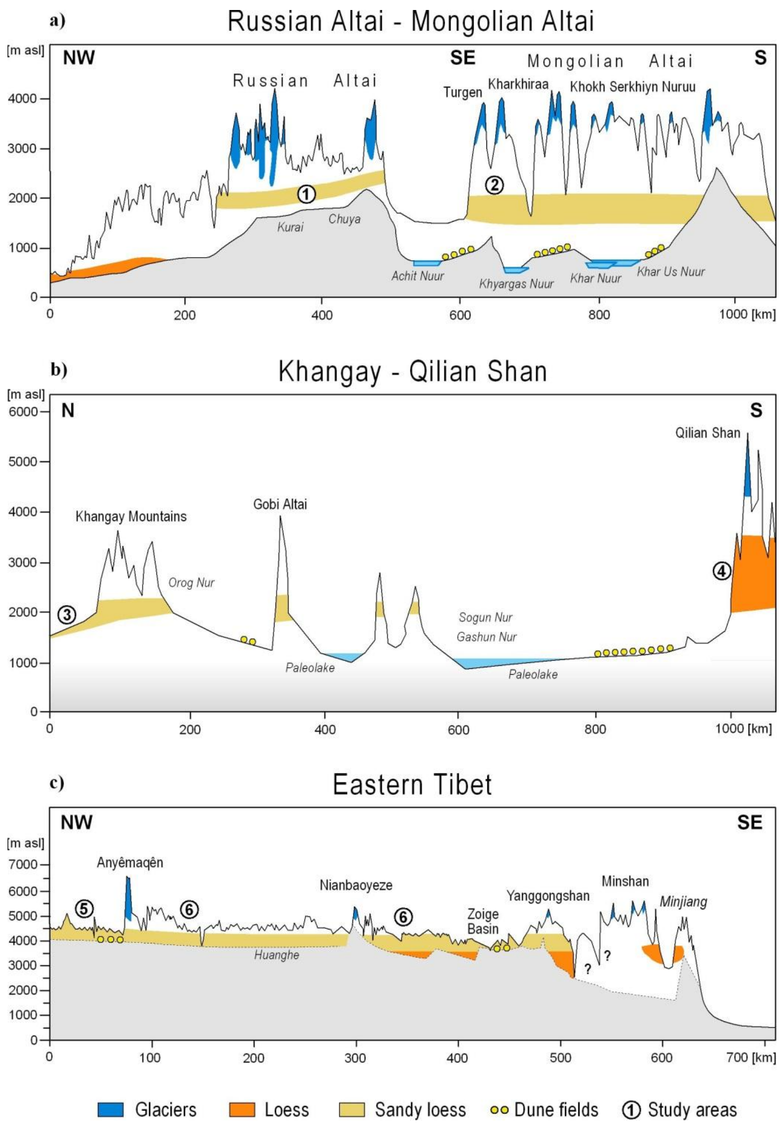


Fig. 2. Cross sections indication the distribution of Aeolian mantles in the mountain areas of Mongolia and Tibet Loess distribution in Tibet and Mongolia including location of three cross sections.
(based on own mapping, modified according to Lehmkuhl (1997)).

## 2. Regional setting

Extending over the arid parts of Central and High Asia, the study area covers wide parts of the Asian mountain systems and adjacent basins, and a correspondingly wide range of climates and environments (Fig. 1). The Altai Mountain system and the Khangai Mountains are situated at the northern border of Central Asia between the Siberian taiga in the north and the steppe to desert steppe regions in the central part. In the central part of the area large basins such as the Tarim Basin and with elevations even below zero in the Turpan depression, are dominating. They are separated by several, mainly west-east trending mountain ranges, such as the Tian Shan and the ranges of the Gobi Altai. Towards the south the high mountain areas of the Qilian Shan and the northern part of the Tibetan Plateau are situated.

The area is influenced by two major climatic systems: the mid-latitude westerlies and the East Asian monsoon. The highest amount of annual rainfall occurs in the western Altai, which is influenced by the westerlies. Central parts of the deserts in Mongolia and China are situated in a rain shadow and are consequently more arid. The monsoonal influence is greatest on the eastern slopes of the Qilian Shan and the eastern Tibetan Plateau, which experience a pronounced summer maximum in precipitation. Annual temperature and precipitation cycles vary with the degree of continentally and altitude. In general, the mountains receive higher amounts of precipitation.

## 3. Result from the different regions

### *3.1 Russian and Mongolian Altai*

The aeolian mantles in the Russian and Mongolian Altai occur in elevations between about 1,500 and 2,500 m asl (Fig. 2a). Luminescence dating was carried out in the central part of the Russian Altai (Fig. 2a, No. 1). Most samples from loess, loess-like sediments and sandy loess taken from different terrace sequences within the Altai Mountains provide IRSL ages suggesting a main aeolian deposition period between 25 - 15 ka (Lehmkuhl et al., 2007). These data are consistent with those from the adjacent Mongolian Altai (Fig. 2a, No. 2; Grunert et al., 2000). Dune sands at some places provide evidence for late Glacial and early Holocene aeolian activity. The youngest sand sheets gave deposition ages of about 1.5 ka. These sediments cover graves and paleosols. They are related to overgrazing and provide evidence for the significant human impact on the environment since about 3 ka (Schlütz & Lehmkuhl 2007).

### *3.2 Central and northern Mongolia*

Despite the remarkable extent of aeolian sediments in Mongolia, only a few papers have focused on them. Russian and Mongolian scientists have described some areas covered with loess and loess-like sediments restricted to the northern part of central Mongolia, in the vicinity of the rivers Orkhon and Selenga. On the southern slope of the Khangay Lehmkuhl & Lang (2001) described such aeolian sediments. Fig. 2b shows the distribution in the Khangay Mountains towards the Qilian Shan in the south. A summary on the current state of research is given in Lehmkuhl et al. (2011, 2012). Geomorphological and sedimentological investigations in the middle and lower reaches of the Orkhon River in northern Mongolia (Fig. 2b, No. 3) and at the southern slope of the Khangay provide evidence for the beginning of the sedimentation of aeolian material in the late Pleistocene to early Holocene (Lehmkuhl & Lang 2001, Lehmkuhl et al., 2011, 2012). OSL and radiocarbon data from aeolian sediments and paleosols indicated soil formation at around 11-10 ka, 7-6 ka and 3 ka. These periods can be associated with more humidity found in other areas of Central Asia as well. Since mid to late Holocene paleosols were covered by aeolian sediments in some regions, especially since about 3 ka. Evidence of such periods marking the end of soil formation and the beginning of aeolian activity can be found in northern Mongolia and in the upper Orkhon valley.

### *3.3 Qilian Shan*

In the Qilian Shan, the southernmost region in Fig. 2b (No. 4), Nottebaum et al. (2014) subdivided the different geomorphological zones and sediments into three parts along an altitudinal transect: The foreland zone (<2,000 m asl) exhibiting dunes, sand sheets and alternating with alluvial/lacustrine deposits, a loess zone ranging from 2000 to 3,800 m asl, and a high mountain regions (>3,800 m asl). Based on geomorphological setting and sediments' grain size distributions they classified six sediment types and two subtypes among a surface sampling set. Along the mountain front to the foreland transition aeolian sediments, such as loess and dune sands, are widespread. Loess accumulation has been dated to start during the late Glacial-Holocene transition (i.e., 13 – 11 ka; Küster et al., 2006). An increased fine and medium silt contribution by westerlies in altitudes >3,000 m asl to loess deposits is likely. In addition, decreased fine sand availability in steep, mountainous terrain restricts the formation of sandy loess to the forelands and the intramontane basins of the Qilian Shan. Dunes and sand sheets are restricted to the foreland (Hexi Corridor) below <1,700 m asl (Nottebaum et al., 2014).

### *3.4 Eastern Tibet*

At the eastern margin of the Tibetan Plateau at elevations ranging from 2,000 to 3,500 m asl, the slopes are covered with silt deposits with thickness up to several meters. Above 3,500 m asl thinner deposits of silty sand (<1 m thick) exist (Fig. 2c; Lehmkuhl, 1997, Lehmkuhl et al., 2014). At elevations above 4,000 to 4,300 m asl silty aeolian mantles interfingering with sandy loess and sand sheets and dune fields. For example, at the Donggi Cona (Fig. 2c, No 5) dunes are situated at the eastern and southern part of the lake. Lehmkuhl et al. (2014) examine a section with loess-paleosol sequence close to Suohuduo further to the east (No. 6). These aeolian sediments, together with slope wash deposits, contain paleosol horizons and ash layers from burning that provide evidence for alternating times of landscape stability and geomorphic activity throughout the late Quaternary. This section shows two mid-Holocene paleosols at around 8 - 7 ka from ~5.5 - 4 ka which suggest a more dense vegetation cover during this time.

## 4. Conclusions

The local dust sources for these sections are the braided river systems, alluvial fans, and the periglacial environment during drier and cooler climate periods with higher aridity and sparse vegetation cover. The beginning of this sedimentation can be dated to the late Quaternary (mainly late Glacial to early Holocene). It may be related to denser vegetation cover which act as a dust trap (e.g., Stauch et al., 2012). Furthermore, especially during the late Holocene, dust emission might have been enhanced by more arid climate conditions and/or overgrazing and localized soil erosion.

The studies from the different regions from Russia and Mongolia towards China and Tibet show that even such relatively short loess sections provide valuable information concerning the paleoclimatic and landscape evolution. In the study areas aeolian sedimentation began mostly during the late Glacial with the deposition of sandy loess. However, the accumulation of sediment sequences starts earlier in the Altai (during the last glacial cycle) and later in the other regions (late Glacial to early Holocene). Coarser sediments and silt size particles indicate higher wind speeds and steppe environments with accumulation of dust interrupted by more stable and humid conditions with different soil formation processes, especially during the Holocene. In early and mid Holocene paleoesols are missing in western Qilian Shan due to lack sufficient moisture for soil formation. Periods of soil formation can be observed in the eastern and more humid part of these selected sections (central Mongolia, eastern Tibet) and associated with more humidity during the mid Holocene. These humid periods can also be found in other records, such as lakes and glaciers (e.g., An et al., 2006). In addition, the modelling approach from Jiang et al (2013) show that the mid-Holocene moisture is higher in these regions. It seems that these mid Holocene paleosols reflecting higher effective moisture and paleosols are in accordance with other paleoproxies in the called arid central Asia, which is out-of-phase with that in monsoonal Asia and starts with an dry early Holocene and an humid mid Holocene (Chen et al., 2008). Since the mid to late Holocene paleosols have been covered by aeolian sediments in several regions, especially since about 3 ka. Such periods are marking the end of soil formation and the beginning of aeolian activity. They are indicating an increase towards a more open landscape with a decrease in vegetation cover caused by higher aridity and/or stronger grazing impact since that time.

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