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Holocene geomorphic processes and landscape evolution in the lower reaches of the Orkhon River (northern Mongolia)

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ABSTRACT

Geomorphological and sedimentological investigations in the lower reaches of the Orkhon River in northern Mongolia provide evidence for Late Pleistocene terraces, Holocene soil development, aeolian accumulation, soil erosion and slope wash. Optically stimulated luminescence (OSL) and radiocarbon dating of aeolian and colluvial sediments including paleosols show different sedimentation and soil formation periods. Luminescence data of 12.3 ka and 11.0 ka were obtained for basal sand deposits overlying slope bedrock and the Pleistocene terraces of the Orkhon River. 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.

1. Introduction

This paper presents the initial results of geomorphological and sedimentological investigations concerning Late Quaternary and especially Holocene landscape evolution from the lower reaches of the Orkhon River in northern Mongolia. The study mainly focuses on different aeolian and fluvial sediments overlying Pleistocene terraces and Pleistocene to Holocene alluvial fans including their Holocene soil development. Moreover, climatic and anthropogenic influences on these aeolian deposits are discussed. Since the chronologies for the investigated sites were obtained by luminescence and radiocarbon dating of aeolian, colluvial and fluvial sediments and paleosols, they thus allow the timing of the inferred climatic changes during the Late Quaternary. This study, describes nine sections, six of which are concentrated in the environs of the Kharaa River and Orkhon River bifurcation nearby the city of Darkhan.

In the western literature only a few results have been published on the Quaternary geology of aeolian deposits and alluvial fans from Mongolia (e.g. Feng et al., 2005, 2007; Grunert and Lehmkuhl, 2004; Grunert et al., 2000; Lehmkuhl and Lang, 2001; Lehmkuhl et al., 2011; Owen et al., 1998). Most research concerning the Holocene paleoenvironmental change concentrate on lacustrine records. Lake level variations have already been reported by the early explorers of Mongolia, such as Berkey and Morris (1927) and Murzaev (1954). Most of the lakes and lake deposits are situated in the so-called "valley of lakes", which can be divided into the basin of the large lakes in northwestern Mongolia and the Valley of Gobi Lakes between Khangay and Gobi Altai in the southern part of Mongolia. Lakes in the investigated climate and vegetation zone are as follows (Fig. 1): (1) Bayan Nuur (Naumann and Walther, 2000) and Uvs Nuur (Walther, 1999), (2) Telmen Nuur (Fowell et al., 2003; Peck et al., 2002), (3) Hovsgol Nuur (Prokopenko et al., 2007), (4) Ugii Nuur (300 km further southwest: Schwanghart et al., 2009; Wang et al., 2009), (5) Lake Baikal (Karabanov et al., 2000), (6) Gun Nuur (Wang et al., 2004), (7) Khonin Nuga (peat bog; Schlütz et al., 2008). In addition, An et al. (2008), Herzschuh (2006), Lehmkuhl and Haselein (2000), Tarasov and Harrison (1998), Tarasov et al. (2000), and Yang et al. (2004) presented an overview concerning the Holocene lacustrine and/or vegetation history. Watanabe et al. (2009) summarized results from Lake Baikal and Lake Hovsgol. Chen et al. (2008) presented a moisture index for well-dated key sections for selected lakes of mid-latitude arid Central Asia that include four lakes from northern Mongolia: i.e., the Bayan Nuur, Telmen Nuur, Gun Nuur and the Hovsgol Nuur (Fig. 1, No. 1–3 and 6).

Located in the interior of the Asian continent, the study area is part of the Mongolian Plateau. According to Feng et al. (2007) this region belongs to the loess-covered Baikal–Ulaanbaatar Corridor (48–53° N, 104–108° E), where numerous aeolian sections were reported (Feng et al., 2005, 2007; Khosbayar, 1989).

Even though there is a remarkable cover of aeolian mantles in Mongolia, only a few recent papers have focused on them. The distribution of loess and loess-like sediments in Mongolia is still a matter of

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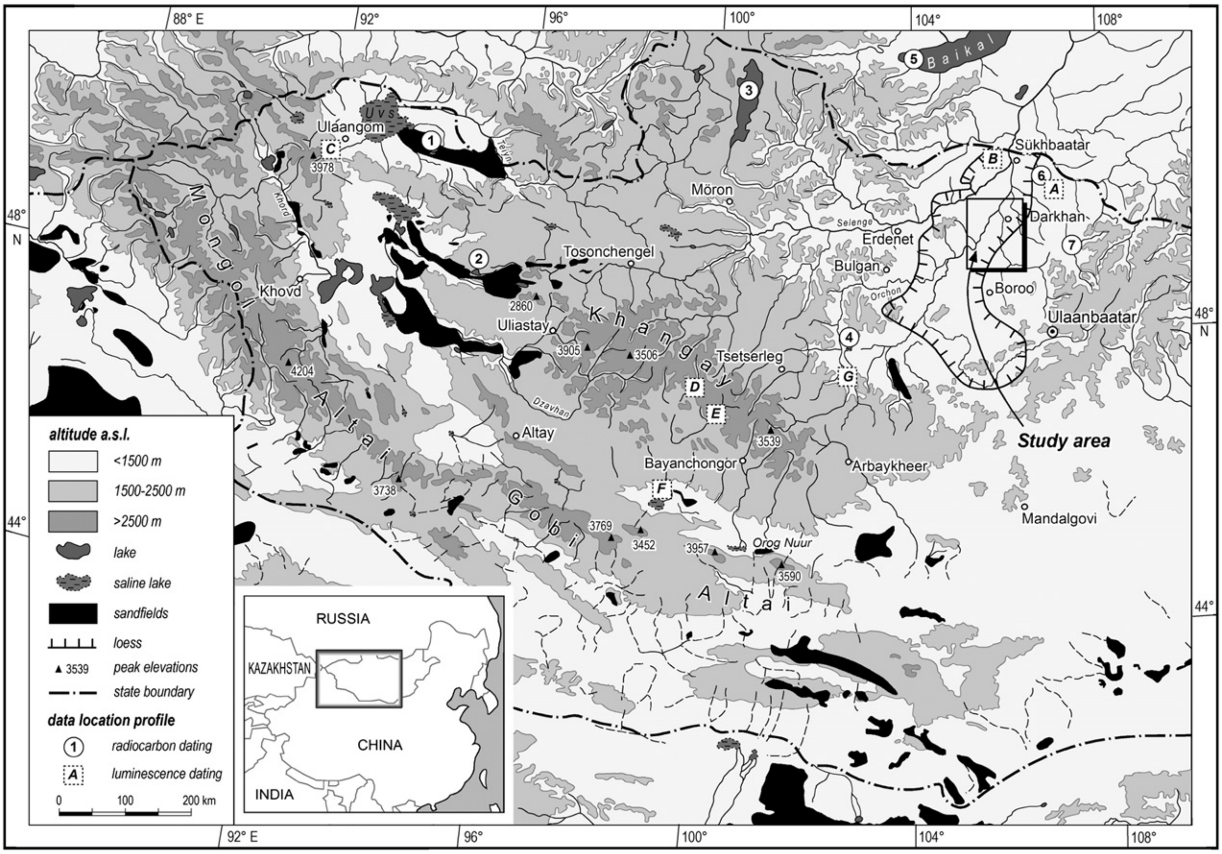

Fig. 1. Map of western Mongolia including the study area and sites of Late Quaternary records mentioned in the text and in Table 1. Sites with terrestrial records and luminescence dating: A Khyaraany section (Feng et al., 1998); B Shaamar section (Feng et al., 2007); C Mongolian Altai and Uvs Nuur Basin (Grunert et al., 2000); D Khangay (Lehmkuhl and Lang, 2001); E, F Valley of Gobi Lakes (Lehmkuhl and Lang, 2001; Owen et al., 1998); G Karakorum (Lehmkuhl et al. 2011). Sites with lacustrine records and radiocarbon dating: 1 Bayan Nuur (Naumann and Walther, 2000) and Uvs Nuur (Walther, 1999); 2 Telmen Nuur (Fowell et al., 2003; Peck et al., 2002); 3 Hovsgol Nuur (Prokopenko et al., 2007); 4 Ugii Nuur (Schwanghart et al., 2009; Wang et al., 2009); 5 Lake Baikal (Karabanov et al., 2000); 6 Gun Nuur (Wang et al., 2004); 7 Khonin Nuga (Schlütz et al., 2008). Draft: F. Lehmkuhl, A. Ehrig.

debate. Lehmkuhl (1997) briefly described loess-like sediments in mountains of Central Asia, including Mongolia. For northern Mongolia, Feng et al. (2005, 2007) summarized some results from recent investigations. The sedimentological record from northern Mongolia provides evidence for aeolian activity between 40 and 30 ka, and colluvial activity from 30 to slightly younger than 24 ka (Feng et al., 1998). This suggests that more humid conditions prevailed in the latter (30–24 ka) than in the former (40–30 ka) time period. Feng et al. (2007) compared the record of the Khyaraany section (50.2° N and 106.7° E, Fig. 1: A) and Shaamar section (50.2° N and 104.2° E, Fig. 1: B) with those of the Siberian loess region south of Novosibirsk and the Chinese Loess Plateau. Both sections also show Holocene paleosols dated with radiocarbon.

Both loess and aeolian sands have been recorded in the study area. Luminescence or radiocarbon data on aeolian and/or fluvial sediments are provided for a few sections from western and southern Mongolia only. Feng et al., 1998, 2007 (Fig. 1: A and B) presented first results from the loess-covered Baikal–Ulaanbaatar Corridor. Moreover, Grunert et al. (2000) and Grunert and Dash (2004) reported about high aeolian activity along the dunefield Böröög Delyin Els in western Mongolia around the Younger Dryas period (Uvs Nuur Basin and adjacent Mountains, in Fig. 1: C). Luminescence data from selected sections of the Khangay Mountains and Gobi Desert are given by Lehmkuhl and Lang, 2001 (Fig. 1: D–E) and Owen et al., 1998 (Fig.1: F). Lehmkuhl et al. (2011) have shown Holocene climate fluctuations from some sections near Karakorum (the present day Kharkhorin) in the upper reaches of the Orkhon about 350 km further southwest of Darkhan (Fig. 1: G).

2. Regional setting

The study area is situated in northern Mongolia in the lower reaches of the Orkhon River. Besides depicting some sections (S1, S2 and S8, S9) for comparative reasons, this study concentrates on the area between the Orkhon River and Kharaa River (Fig. 2). The upper catchments are flanked by the Khangay Mountains in the west and by the Khentey Mountains in the east. The Orkhon River has its origin in the Khangay and reaches the Selenge River about 50 km further north.

The investigations concentrate on the area covered with loess-like sediments dominated mainly by chernozem and dark kastanozem as major soil types. Bedrock is mainly composed of granite rocks and crystalline schists and slates. However, this current study focuses on the Late Quaternary covering layers.

The climate conditions are extremely continental and show a high range of temperature with mean winter temperatures under −20 °C and mean summer temperatures exceeding 18 °C. The average annual rainfall is 300 to 350 mm (Academy of Sciences of Mongolia and Academy of Sciences of USSR, 1990). Furthermore, the vegetation is characterized by steppe species typical for the Khangay forest-steppe (Hilbig, 1995; Schlütz et al., 2008). In addition, barley can be cultivated in the area.

3. Methods

3.1. Geomorphological mapping, site selection and sampling strategy

Field research for nine sections (S1–S9) is presented here (Table 1). Natural exposures with thicknesses ranging from 2 m to 8 m were