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Holocene water-level changes inferred from a section of fluvio-lacustrine sediments in the southeastern Mu Us Desert, China

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ABSTRACT

A natural exposure of fluvio-lacustrine sediments (the DSGL section) on the left bank of Salawusu River, located at the southeastern margin of the Mu Us Desert in North China, was studied in order to reconstruct Holocene water-level changes. A chronology was established based on 11 AMS ^{14}C dates, and variations in the lithology and grain-size C-M variations were used to assess the forcing factors of local hydrological changes during the Holocene. A lake-swamp environment with high hydrodynamic energy occurred from 9.6 to 9.2 ka cal yr BP, which was succeeded by a full lake environment at around 9.6 ka cal yr BP; however, an interval of sand deposits and peat sediments from 9.2 to 8.6 ka cal yr BP indicates unstable hydrodynamic conditions. The Salawusu paleo-lake reached its maximum level between 8.4 and 6.5 ka cal yr BP and gradually shrank thereafter. After 1.2 ka cal yr BP a shallow lake environment returned, indicating a humid phase which may be correlative with the relatively warm and moist Medieval Warm Period (MWP). After 0.68 ka cal yr BP, broadly coeval with the Little Ice Age (LIA), a fluvial environment appeared. The variations in water level were mainly triggered by the East Asian monsoon; however, site-specific factors may have also have been important.

1. Introduction

The Mu Us Desert in Northern China is situated in the loess-desert transitional zone, on the northern margin of the East Asian monsoon (EAM). The area is climatically sensitive and is therefore suitable for studies of long-term paleoclimatic and paleoenvironmental changes (Sun et al., 1999; Zhou et al., 2002, 2009; Ding et al., 2005). In particular, the transitional area at the desert boundary provides an excellent record of phases of desert expansion and retreat (Sun et al., 1999; Yang et al., 2004), while variations in water level reflect changes in the strength of hydrodynamic forcing factors such as the EAM. The Mu Us Desert has accumulated a diverse range of sediments, including aeolian sand, paleosol, loess and peat, which are useful for reconstructing the history of desert development on local and regional scales (Li et al., 1998). Compared with aeolian sediments, fluvio-lacustrine sediments can provide more direct evidence of water-level changes; moreover, variations in hydrological conditions may dominate the sedimentary effects of aeolian activity in this region.

Fluvio-lacustrine sediments are potentially useful archives of paleoenvironmental information because of their continuous accumulation and suitability for accurate dating (Wagner et al., 2000; Roberts et al., 2001; Chen et al., 2002; Wolfe et al., 2004; Eris, 2013). The multi-proxy indices typically analyzed in fluvio-lacustrine sediments include grain-size (Solohub and Klovan, 1970; Chen et al., 2004; Lu et al., 2011; Zhang et al., 2014), geochemistry (Leng and Marshall, 2004; Li et al., 2008; Wuennemann et al., 2010; Mishra et al., 2015), and pollen assemblages (Bigler et al., 2002; Shen et al., 2005; Brisset et al., 2015). Overall, fluvio-lacustrine sediments are sensitive to hydroclimatic changes.

The Salawusu River Valley is located on the southeastern margin of the Mu Us Desert and the Salawusu Formation found in this

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region has been regarded as a standard site for fluvio-lacustrine strata in China for the Upper Pleistocene (Dong et al., 1999) and since its discovery in the early 1920s numerous stratigraphic (e.g., Pei and Li, 1964; Yuan, 1978; Dong et al., 1983; Sun et al., 1996) and paleoclimatic (e.g., Gao et al., 1985; Li et al., 2005; Du et al., 2012; Rao et al., 2013) investigations have been carried out. However, previous work has mainly been focused on long-term climatic evolution and only a small number of studies (Li et al., 2012a; Liu and Lai, 2012) have emphasized water-level reconstruction during the Holocene based on fluvio-lacustrine deposits. Therefore, more work is needed to reconstruct water-level variations during the Holocene. Grain-size C-M patterns (Passega, 1957, 1964) provide insights into the hydrodynamic conditions of sedimentation and this information can potentially be used to infer changes in climatic controls on the sedimentary environment. In the present paper, we select a new section which is situated at Dishaogouwan on the left bank of Salawusu River and use grain-size C-M patterns, combined with sedimentary facies characteristics, to reconstruct changes in hydrodynamic conditions and the sedimentary environment, especially variations in water-level, during the Holocene.

2. Regional setting

The Mu Us Desert, with an area of about 39,000 km^2, is situated on the margin of the East Asian monsoon (EAM), in the transitional area between the Ordos Plateau and the Loess Plateau (Fig. 1). The regional climate is dominated by the EAM. The mean annual rainfall is 250–440 mm and the mean annual temperature is 6.0–8.5 °C. Warm and humid air brought by the East Asian summer monsoon (EASM) delivers more than 60% of the annual precipitation, which falls mainly from June to August. The modern vegetation consists mainly of *Artemisia ordosica* Krasch., *Tamarix chinensis* Lour., and *Hippophae rhamnoides* Linn. The regional geomorphic types are varied and include stabilized, semi-stabilized and active sand dunes, shallow lake basins and seasonally-flowing streams, and loess-mantled hills and sandy loess platforms (Zhou et al., 1996). A natural exposure of fluvio-lacustrine strata, the DSGL (Dishaogouwan Left bank) section (37°43′N, 108°31′E), 1300 m above sea level and on the left bank of the Salawusu River in the southeastern margin of the Mu Us Desert, was chosen for study. The sequence is 4.04 m thick (Fig. 1a and b).

3. Materials and methods

232 samples were collected from the DSGL section at 2 cm or 5 cm intervals for grain-size analyses. The measurements were made using a Mastersizer 2000 with a measurement range of 0.02–2000 μm at the Key Laboratory of Environmental Change and Natural Disasters, Ministry of Education of China, Beijing Normal University. The pretreatment procedure is described by Jia et al. (2015).14 samples of organic sediments were collected, according to their lithological characteristics, for AMS ^{14}C dating. The measurements were made at the Beta Analytic Radiocarbon Dating Laboratory and detail of the pretreatment procedure is at http://www.radiocarbon.com/pretreatment-carbon-dating.htm#Washes. The AMS ^{14}C dates were converted to calendar ages using the program Calib 7.02 based on the INTCAL 13 calibration (Reimer et al., 2013).

4. Results

4.1. Chronology

The AMS ^{14}C dates are listed in Table 1. The ages are generally in chronological order, although there are some inversions: at the base of the section which probably result from involutions, possibly caused by freeze-thaw processes; and at the top of the section where there are three dates which were clearly anomalously old and were excluded from the final age model. The uppermost part of the section contains reworked material (section 4.2) and the three anomalous dates may be the result of the incorporation of ancient organic material. We established a final age model using piecewise linear fitting (Fig. 2) and the age of each sample was determined by linear interpolation. Viewed in the context of previous dating results (Fig. 3) from the adjacent region we are confident that chronological framework is reliable.

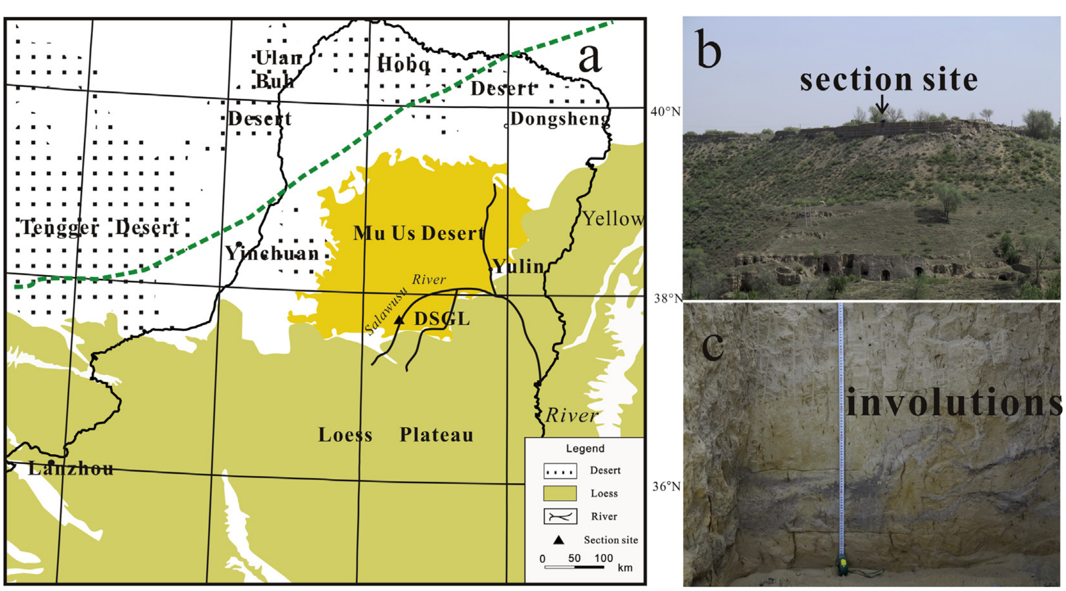

Fig. 1. (a) Location of the DSGL section on the southern margin of the Mu Us desert (orange shaded area). The green dashed line indicates the modern Asian summer monsoon limit and the inset map shows the location of the study area in China. (b) The location of DSGL section. (c) The involutions at the bottom of the section. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)