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Holocene aeolian activity in the Headwater Region of the Yellow River, Northeast Tibet Plateau, China: A first approach by using OSL-dating

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ABSTRACT

The Headwater Region of the Yellow River (HRYR) is the catchment upstream of Duoshi Gorge, covering an area of 29,588 km^2. The HRYR is located in the northeastern Tibet Plateau with an altitude higher than 4000 m above sea level, and is especially sensitive to climate change. Since the late 19th century, the mean annual temperature in Tibet Plateau has increased sharply. As a result of increasing air temperature, a significant number of environmental problems have occurred during the past decades, including aeolian desertification. In recent decades, aeolian desertification has become a severe environmental problem in the Tibet Plateau due to permafrost degradation, because permafrost plays an important role in maintaining the grassland vegetation. With the increase in ground temperature, the aeolian activity in the HRYR is likely to become more serious. However, the history of aeolian activity in the HRYR remains unknown due to a lack of chronological studies. In this study, 15 Optical Stimulated Luminescence (OSL) ages from three typical sections were used to reveal the history of aeolian activities in the HRYR during the Holocene. All of the OSL ages were late Holocene, and the oldest age is 2.13 ± 0.16 ka BP. The relative young OSL ages and deep aeolian sediment indicated very high sedimentation rates in the late Holocene, especially after around 1 ka BP. The intensive aeolian activity and low TOC content indicate a drier climate in the late Holocene. The well-sorted sediments and similar grain size distributions of the three sections imply their similar wind regimes. Based on the evolution history of the Yellow River's headward erosion, it is inferred that little aeolian activity occurred in this region during the early and mid-Holocene.

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1. Introduction

Tibet Plateau is called "the Earth's Third Pole" and "the Water Tower of Asia", because it is home to some 40,000 glaciers, storing more freshwater than any other region except the North and South poles. The region is the source of ten of the continent's biggest rivers. The Yellow River is the third-longest river in Asia, following the Yangtze River and Yenisei River, and the sixth-longest in the world, originating in the Bayan Har Mountains in Qinghai province of western China (Fig.1). The Headwater Region of the Yellow River (HRYR) is located in the northeastern Tibet Plateau with an altitude higher than 4000 m above sea level. Due to the high altitude, the HRYR is especially sensitive to climate change (Chen et al., 1999; Liu and Chen, 2000). Since the late 19th century, the mean annual temperature in Tibet Plateau has increased by 0.7 °C, which is one of the largest temperature increases recorded on the Tibet Plateau and significantly higher than the range of global average values (0.3–0.6 °C) (Jin et al., 2011; Liu and Chen, 2000). As a result of increasing air temperature, significant environmental problems occurred during the past decades, such as grassland vegetation degradation (Cui and Graf, 2009; Na et al., 2013; Yi et al., 2012; Zhou et al., 2015), permafrost degradation (Changwei et al., 2015; Cheng and Jin, 2012; Luo et al., 2014; Wu et al., 2007), and aeolian desertification (Hu et al., 2013; Xue et al., 2009; Yan et al., 2009).

In cold and high-altitude regions in the Tibet Plateau, temperature increase is a key climatic factor responsible for aeolian desertification (Xue et al., 2009), because soil water retention was very important to protect the original grassland vegetation for the hydrological process (Yi et al., 2012). Alpine cold ecosystems with a permafrost environment are quite sensitive to temperature increases, and a temperature increase in permafrost can significantly affect the alpine ecosystem (Hu et al., 2008; Wang et al., 2006), because permafrost plays an important role in maintaining the grassland vegetation in the Tibet Plateau. This is because permafrost layers maintain water around plant roots by blocking infiltration of soil water into deeper (frozen) layers. This barrier also retains soil nutrients leached from the upper soil horizons and leads to an accumulation of soil organic matter. Degradation of the permafrost has been shown to lead to a loss of soil water and organic matter around the plant roots, leading to drying of soils and eventually to aeolian

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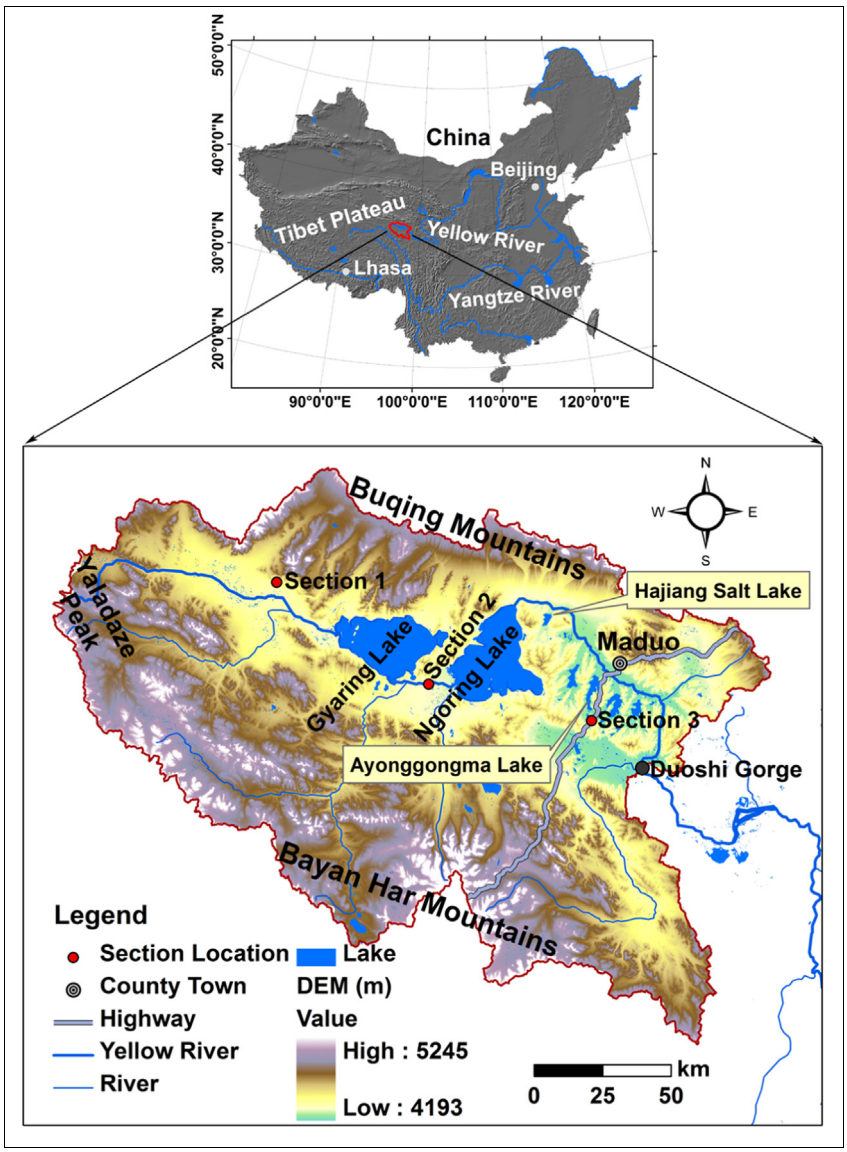

Fig. 1. Location of the Headwater Region of the Yellow River in Tibet Plateau and section locations. Topographic data was generated from the Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM). The altitude of Section 1, 2 and 3 is 4345, 4291 and 4250 m a.s.l, respectively.

desertification (Dong et al., 2009; Yang et al., 2004). Unfortunately, the mean annual ground (subsurface) temperature on the Tibet Plateau increased by 1.3 °C during 1961–2010 at an average rate of 0.3 °C per decade (Jin et al., 2011). In the HRYR, the regional average increase rate of mean annual ground surface temperatures was 0.77 °C/10a during 1980–2013 (Luo et al., 2015). Our recent investigations have revealed that aeolian desertification has become a severe environmental problem in the Tibet Plateau due to permafrost degradation, and the newly constructed Qinghai–Tibetan Railway is now threatened by blowing sand (Zhang et al., 2012). With the increase of ground temperature, the aeolian activity in the HRYR is likely to become more serious. However, the history of aeolian activities in the HRYR is still unclear. To understand the process of aeolian activities and their possible influencing factors, in this study, aeolian sediments from three sites were investigated.

Aeolian sediments are widely distributed in the HRYR, transported by the Westerlies and the Tibetan winter monsoon, and this area could be a potential dust source for the Chinese Loess Plateau and even for the Chengdu clay (Yang et al., 2010). However, the aeolian processes and their forcing mechanisms are poorly understood due to lack of chronological data. According to our knowledge, only a few ages taken from sand wedges have been reported to date (Zhou et al., 1994). Therefore, this study is the first attempt of a comprehensive description of the history of aeolian activities in this region.

2. Study area

In this study, the HRYR is defined as the catchment upstream of Duoshi Gorge (Fig.6). This region was a compressional basin formed in the Miocene (Han, 2010), and Quaternary sediments are widely distributed throughout the basin (Cheng et al., 2005). The depth of lacustrine strata is as deep as 120 m in the nearby area of Maduo (Cheng, 2006). The HRYR lies in the northeastern Tibetan Plateau, between latitudes 33°42′N and 35°29′N and longitudes 95°53′E and 98°49′E, covering an area of 29,588 km^2 (Fig.1). This region is located between Buqing Mountains in the north and Bayan Har Mountains (a spur of the Kunlun Mountains) in the south. The Yellow River originates from the Yaladaze Peak in the west of the Bayan Har Mountains (Fig.1). The altitude of this region ranges from 4193 to 5245 m, and the flat bottom of this basin mainly lies between 4193 and 4354 m above sea level. Due to the high altitude, the climate of this area is characterized by low temperatures, drastic seasonal variations in precipitation, frequent strong winds, high evaporation, and strong solar radiation. The typical vegetation

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