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Overbank flooding and human occupation of the Shalongka site in the Upper Yellow River Valley, northeast Tibet Plateau in relation to climate change since the last deglaciation

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ABSTRACT

Increased flooding caused by global warming threatens the safety of coastal and river basin dwellers, but the relationship of flooding frequency, human settlement and climate change at long time scales remains unclear. Paleolithic, Neolithic and Bronze Age cultural deposits interbedded with flood sediments were found at the Shalongka site near the north bank of the upper Yellow River, northeastern Tibetan Plateau. We reconstruct the history of overbank flooding and human occupation at the Shalongka site by application of optically stimulated luminescence and radiocarbon dating, grain size, magnetic susceptibility and color reflectance analysis of overbank sediment and paleosols. The reliability of OSL dating has been confirmed by internal checks and comparing with independent ^{14}C ages; alluvial OSL ages have shown a systematic overestimation due to poor bleaching. Our results indicate that the Yellow River episodically overflowed and reached the Shalongka site from at least ~16 ka and lasting until ~3 ka. Soil development and reduced flooding occurred at ~15, ~8.3–5.4, and after ~3 ka, and prehistoric populations spread to the Shalongka site area at ~8.3, ~5.4, and ~3 ka. We suggest that climate change influenced the overbank flooding frequency and then affected prehistoric human occupation of the Shalongka site.

Introduction

Rise in global average temperature is already causing extreme weather events and increasing risk of flooding is beginning to affect the lives of millions (Min et al., 2011; Pall et al., 2011; IPCC, 2012). The increasing intensity and frequency of flooding in the valleys of rivers around the world pose a great threat to the safety of humans nearby (Wilby et al., 2008; Botzen and Van Den Bergh, 2009; de Moel et al., 2009; Milly et al., 2002). Prehistoric people favored settlement near river valleys in order to obtain water and subsistence resources, making them vulnerable to flooding disasters, as much as or even more than at present. Thus, the exploration of dynamic relationships between flooding and human settlement near rivers on a long term scale is of significance, and can provide perspectives on human settlement and climatic changes in areas subject to frequent flooding.

The linkages between climate change, floods and human settlements on different reaches of rivers in China have been often studied (e.g., Yang et al., 2000, 2003; Huang et al., 2010; Dong et al., 2013a; Ma et al., 2014), and it has been suggested that variable and unstable climates typified by flooding and/or droughts may have resulted in settlement destruction and abandonment. For example, the Lajia Site, a Qijia Culture site (4100–3600 cal yr BP) located in the Guanting Basin near the upper reaches of the Yellow River, was ruined by contemporary earthquakes and floods (Yang et al., 2003). Paleoflood disasters in the Guanting Basin occurred between 6500–2220 cal yr BP and influenced human settlements during that period (Hou et al., 2012; Ma et al., 2014). One of these events may have been caused by the breaching of a large dammed lake in the upper reaches of the Yellow River (Dong et al., 2014) caused by variation in monsoon precipitation (Ma et al., 2014).

The Jinghe River is a tributary of the middle reaches of the Yellow River, and extraordinary floods and droughts along the river related to abrupt climatic shifts between 4200–4000 cal yr BP resulted in settlement abandonment, and the possible decline of highly developed late Neolithic civilizations in China's monsoonal regions (Huang et al., 2010). The collapse of late Neolithic urban centers of the Longshan culture (4350–3950 cal yr BP) in the lower reaches of the Yellow River, and the Liangzhu culture in the lower reaches of the Yangtze River, have been attributed to great floods (Wang et al., 2005; Gao et al., 2007). Also in the lower Yellow River, the Sanyangzhuang site (~2100 cal yr BP) on the North China plain was inundated by a sudden burst of muddy water from a catastrophic levee breach during the late Western Han period (~202 BC–AD 9). There was apparently little warning as workers reroofing one compound left behind their tools and tiles (Kidder et al., 2012a,b). However, these previous studies have mainly focused on reconstruction of hydrological/

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cultural relationships during short episodes (e.g., Yang et al., 2000, 2003; Huang et al., 2010), while relationships among flood disasters, human settlement and climate change at long time scales are still poorly understood.

The Yellow River is located in a semi-arid region of China and is characterized by a marked flood frequency (Yang et al., 2000). As recorded in Chinese history, the Yellow River broke through its levees 1593 times with 26 major changes of course in the past 2550 years, an average of two breaches every 3 years and one major course change per century (YRCC, 1959). Paleofloods occurred frequently along the upper Yellow River during the Holocene, and at least 4 cycles of frequent flooding followed by periods of reduced flooding have been detected (Ma et al., 2014). Hundreds of prehistoric archeological sites have been found in the upper valleys of the Yellow River (BNCR, 1996; Aldenderfer, 2006; Dong et al., 2013a) and are mainly distributed on adjacent river terraces. Cultural layers sandwiched between paleoflood sediments are present in many of these valley basins (Dong et al., 2013a; Ma et al., 2014) and provide sedimentological records with which to explore relationships between ancient human occupation and flooding-related environment change.

Radiocarbon dating is the most commonly used method for establishing chronologies of archeology sites, which has been widely applied to the archeology sites on Tibet Plateau (e.g., Sun et al., 2010, 2012; Dong et al., 2013a). However, the ^{14}C method can be problematic in dating eolian deposits because of their low organic carbon content (Li et al., 2007), and dates on organic carbon from sediment of archeology sites are often overestimated because of a reservoir effect (Björck et al., 1991; Colinan et al., 1996; Wang et al., 2002b). OSL dating technology can determine the ages of eolian and waterlain deposits by directly measuring quartz or feldspar minerals (Aitken, 1998). With the development of the single-aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000), quartz OSL dating is now being widely applied to the dating of Quaternary sediments in Tibet Plateau and other parts of northwestern China (Zhao et al., 2007; Lai et al., 2009; Zhang et al., 2012; Zhao et al., 2012; Han et al., 2014; Lai et al., 2014; Yu and Lai, 2014). In the Tibet plateau, OSL dating also has been successfully applied to the Xindian Culture site of Lamafeng on the NE edge of the Tibetan Plateau, where OSL ages have shown a good consistence to the charcoal accelerator mass spectrometry (AMS) dating ages of culture layer (Hou et al., 2012). Sun et al. (2010) dated the archeological sites in Xiao Qaidam Lake of the NE Tibetan Plateau by quartz OSL dating, and OSL ages provide the time frame for this archeological site which ranges from ~3 to 11 ka.

The Shalongka (SLK) archeology site is located on second terrace of the upper Yellow River valley in the Qunjian Basin, northeastern Tibetan Plateau (TP) (Figs. 1a, b). Artifacts representative of Paleolithic, Majiayao (5900–4000 cal yr BP) and Kayue (3400–2600 cal yr BP) cultural periods, as well as overbank deposits were found in a stream cut exposure (BNCR, 1996; Dong et al., 2013a). As a kind of fluvial process, overbank floods have often left their sedimentary records over the inundated areas in their paths. Overbank floods deposit was the suspended sediment load in floodwater flow and deposited in areas of flow separation and has been preserved after the flood recession (Huang et al., 2010). Some culture layers occur in paleosol layers interbedded in Yellow River overbank flood deposits (Fig. 2).

In this study, ^{14}C dating methods were employed to determine the ages of these culture layers and associated paleosols. OSL dating methods were applied to eolian and fluvial deposit by directly measuring quartz minerals, and a quartz single-aliquot regenerative-dose protocol was tested by the use of internal checks and equivalent dose (D_e) determinations. In the following, the reliability of OSL dating applied to potentially poorly bleached flooding deposit is discussed in comparison to independent ^{14}C dating ages and reliable eolian quartz ages. By combining the lithology, chronology, and proxy indexes of grain size, magnetic susceptibility and color reflectance analysis and comparing the results with high-resolution paleoclimatic records, we identify periods of Yellow River overbank flow at the SLK site since the last deglaciation and discuss the relationship between human settlement and changing climatic conditions.

Materials and methods

Study area, section and sampling

The upper Yellow River valley is situated in the northeastern TP. The Guanting, Xunhua-Hualun and Qunjian basins are distributed from southeast to northwest along the Yellow River. As shown in Figure 1B, the Qunjian Basin is surrounded by Songba Gorge (east), Gongbo Gorge (west), Laji Mountains (north) and Geji Mountains (east). The Yellow Rivers runs through the western part of the basin from NW to SE. The basin has a annual average temperature of 7.8°C, and annual average precipitation of 357.3 mm with 70% of that precipitation occurring during the summer. Elevations range between 1960 and 4614 m, and the Yellow River drops from 2020 m a.s.l. in the northwest to 1990 m in the southeast.

The SLK site (36.01°N, 102°E, 2021 m) is located on the second terrace of the Yellow River in the southern Qunjian Basin, ~500 m north of the present Yellow River channel. It consists of three paleosol layers interbedded in Yellow River overbank deposits. A microlithic cultural layer is present in the bottom of the middle paleosol layer. As shown in Figure 2, nine OSL samples and five ^{14}C samples were collected from the SLK site for chronological determinations. OSL samples SLK-126-130, SLK-190-194 and SLK-270-274 were collected from 126 to 136 cm, 190 to 194 cm, and 270 to 274 cm in the paleosol layers, while samples SLK-36-40, SLK-92-96, SLK-160-164, SLK-216-220, SLK-256-260, and SLK-320-324 were collected at depths of 36–40 cm, 92–96 cm, 160–164 cm, 216–220 cm, 256–260 cm, and 320–324 cm in fluvial silty sand. For ^{14}C dating, charcoal sample SLK-01 was collected from a Kayue cultural layer at 10 cm near the surface. Two bulk organic matter samples SLK-02 and SLK-03 were collected from depths of 115 cm and 180 cm in the middle paleosol, and two charcoal samples, SLK-04 and SLK-05, were collected at depths of 180 cm and 190 cm of the lowest culture layer. Bulk samples at 2-cm intervals were collected from the entire 320-cm section for environmental proxy analysis.

OSL dating and ^{14}C dating

OSL dating sample preparation and measurement

All laboratory sample preparation and luminescence measurements were carried out in a darkroom with subdued red light. All raw samples were treated with 10% HCl and 20% H_2O_2 to remove carbonate and organic matter. The samples were then sieved in water to select sediments consisting of grains with specific sizes of 90–150 μm. Heavy liquids with densities of 2.62 g/cm^3 and 2.75 g/cm^3 were then used to separate quartz and feldspar fractions of each sample. Quartz grains were treated with 40% HF for 60 min to remove the outer layer that was irradiated by alpha particles and any remaining feldspar grains. Then, all samples were treated with 1 mol/L HCl for 10 min to remove fluorides created during the HF etching.

OSL signals were measured using an automated Risø TL/OSL-DA-15 reader (Markey et al., 1997). The OSL signal was detected through two 3-mm-thick Hoya U-340 filters. Laboratory irradiation was carried out using ^{90}Sr/^{90}Y sources mounted within the reader, with a dose rate of 0.104 Gy/s. The purity of quartz extracts was verified using infrared stimulation. For the quartz grains, in order to eliminate the influence from feldspar contamination, the post-IR single aliquot regenerative protocol (SAR) was employed to measure D_e values from quartz extracts in 5-mm aliquots (Banerjee et al., 2001; Zhang and Zhou, 2007).