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Process of paleofloods in Guanting basin, Qinghai Province, China and possible relation to monsoon strength during the mid-Holocene

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ABSTRACT

Prehistoric disasters including paleofloods and earthquakes in Guanting basin, Qinghai Province, China, and their impact on Neolithic cultures have attracted academic attention over the last decade. However, the process and mechanism of paleofloods in the basin remain unsolved. This paper describes studies of the periodicity and process of paleofloods in Guanting basin during the mid-Holocene and their relations to monsoon strength, based on geological and archaeological investigations, including analysis of magnetic susceptibility and color reflectance, application of radiocarbon dating and comparison with the stalagmite oxygen isotope record in Dongge Cave. During the mid-Holocene, paleofloods in Guanting basin began between 7550 cal a BP and 6510 cal a BP, and lasted to 2220 cal a BP at least. Four cycles of frequent followed by infrequent paleofloods have been detected. Three periods of infrequent paleofloods occurred during 4380–3970 cal a BP, 2850–2720 cal a BP and 2310–2140 cal a BP respectively. The other one took place around 5000 cal a BP, coinciding well with periods of weak Asian monsoon events. The process of paleofloods in Guanting basin during the mid-Holocene was possibly dominated by the precipitation changes responding to Asian monsoon strength.

1. Introduction

The recently increasing intensity and frequency of flood disasters in the valleys of major rivers around the world pose a great threat to the safety of humans and the development of economy and society (Milly et al., 2002; Wilby et al., 2008; Botzen and Van Den Bergh, 2009; de Moel et al., 2009), and these events have attracted considerable international attention. In order to predict and mitigate the hazard of future floods, the periodicity and mechanism of current floods must be thoroughly understood in the context of global warming. However, historical gauge records provide too brief a base for thorough study of the relation between climate change and floods, whereas paleoflood records can be used to explore the linkages between climate change and hydrological events in the long-term and at a large-scale. Since the 1970s, paleoflood hydrology has been applied successfully to extend flood records in North America, Europe, Australia and Japan (Kochel and Baker, 1982; Ely et al., 1993; Baker, 2008), and used to evaluate the links between flood hydrology and climate variability (e.g. (Ely, 1997; Knox, 2000; Benito, 2003; Yu et al., 2003; Howard et al., 2004; Baker, 2008). It is suggested that the relation between paleofloods and climate change is complicated and might vary in dissimilar climatic zones (Benito, 2003; Benito et al., 2003; Macklin and Lewin, 2003; Macklin et al., 2006; Zielhofer and Faust, 2008) and during different stages (Macklin and Lewin, 2003; Thorndycraft and Benito, 2006; Macklin et al., 2010). Studies of the process of paleofloods and their relations to the Asian monsoon during the mid-Holocene are valuable because the relationships between paleofloods and climatic oscillations in the Asian monsoon region during the Holocene are poorly understood.

Mid-Holocene paleofloods on the Yellow River have been studied mainly in the river's middle and lower reaches (e.g. Yang et al., 2000; Yang et al., 2003; Huang et al., 2010). However, the relations between those paleofloods and the Asian monsoon have received little attention. Although recent work demonstrates the complex linkages between anomalous climatic circulation regimes and hydrologic responses in the middle reaches of the Yellow River (Huang et al., 2007), these are far from being fully understood.

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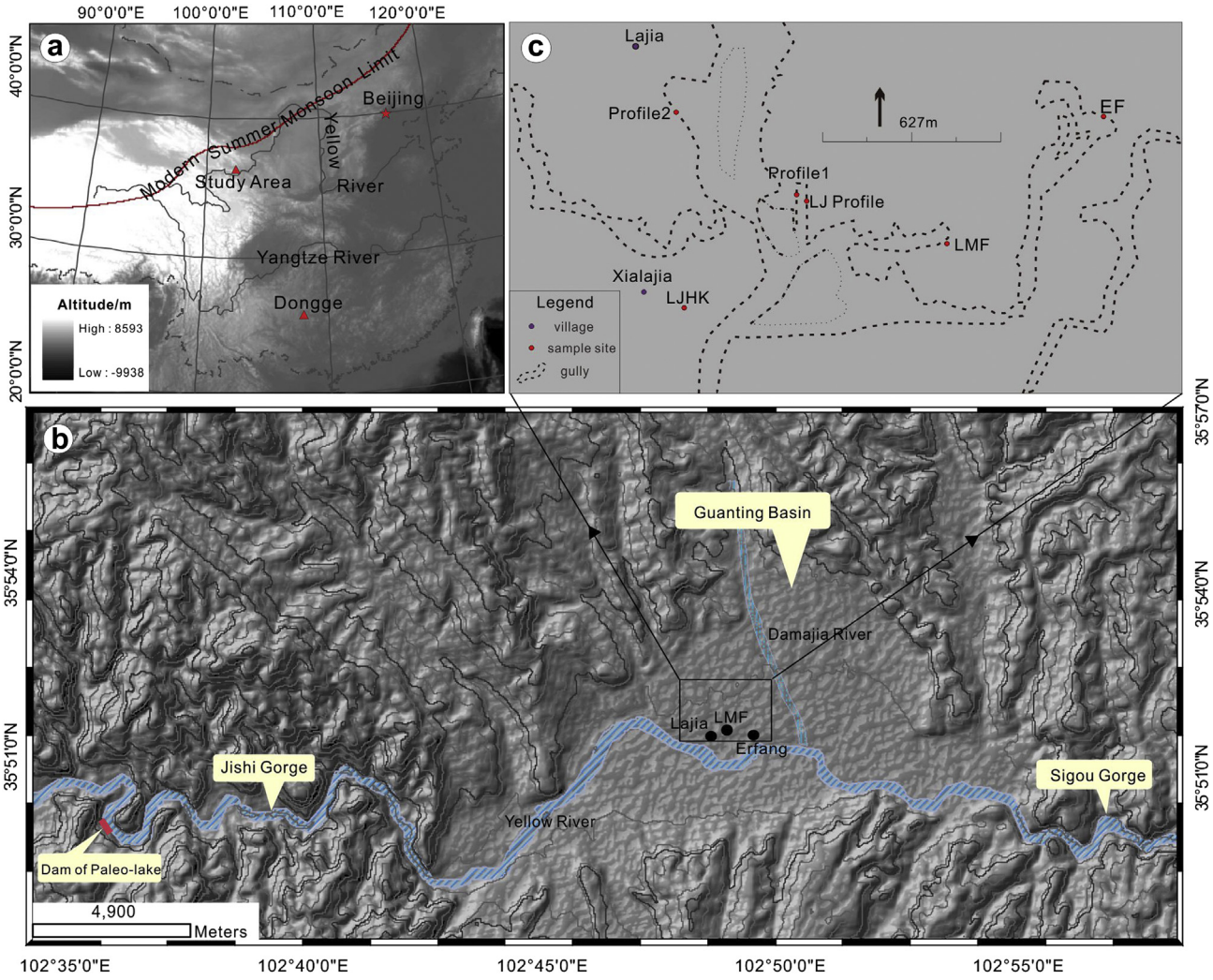

Fig. 1. Location maps of study region. (a) Location of the study region and Dongge cave in China. (b) Topographical location of the sampling archaeological sites in Guanting Basin (c) Locations of the sampling profiles.

The Guanting basin in Qinghai Province, China, is located in the upper reaches of the Yellow River and the area influenced by the Asian monsoon (Fig. 1a). Paleoflood deposits were found at the Lajia site (Yang et al., 2003), a very important settlement of the Qijia culture (2130–1635 BC) (IA et al., 2002; Xie, 2002). The evidence of paleoflood sediments has been intensively studied at this site. It has been suggested that the Qijia cultural layer at the Lajia site is covered by paleoflood sediments (Yang et al., 2003) and the flood is believed to have destroyed the Lajia site and greatly affected the evolution of Neolithic cultures in Guanting basin (Yang et al., 2003; Yang et al., 2004; Yang et al., 2005; Wu et al., 2009; Zhang et al., 2009). Otherwise, some researchers argue that Lajia site is destroyed by gully debris flows from the surrounding hills (Tarasov and Wanger, 2006) and the brownish-red clay is deposited by gully debris flows. However, more sediment evidence indicates the brownish-red clay was deposited by the overbank floods in Guanting basin.

It has been proposed that paleofloods in Guanting basin clustered during 3650–2750 a BP, with 14 paleoflood events occurring during that period (Yang et al., 2005). However, recent excavation at the Lajia site has shown that the Qijia cultural layer is embedded in the paleoflood sediments, indicating that onset of the paleoflood prior to the Qijia period (Ye, 2008). The duration and characteristics of the paleofloods remain unresolved. The paleoflood mechanism in Guanting basin is also unclear. Recently, it has been argued that the bursting of a paleo-dammed lake at the Jishi Gorge (Fig. 1b) during the mid-Holocene resulted in the paleoflood events that destroyed the Lajia site, and that the driving forces influencing Guanting basin was not climate change but tectonic events (Wu et al., 2009). This is plausible, but it does not cast light on the duration and frequency of the several other paleoflood events in Guanting basin.

Cultural layers wedged within paleoflood sediments are present in Guanting basin, and these can provide reliable dating materials (such as charcoal) to limit the periods of infrequent paleofloods. In addition, the resolution of those ages or cultural periods can be at multi-centennial scale, which can be correlated with climate events during the Holocene as recorded in stalagmites in the Asian monsoon region (Wang et al., 2005). Therefore, the relation between paleoflood process and monsoon strength can be reliably examined in Guanting basin. For these reasons, the Lajia, Lamafen and Erfang sites were investigated, where paleoflood sediments and cultural layers had been found, and collected reliable materials for radiocarbon dating. In addition, a section that included relatively intact paleoflood sediments was sampled for determining magnetic susceptibility and color reflectance. The results were compared with the stalagmite oxygen isotope record from Dongge Cave (Wang et al., 2005) as a mean of determining the ages and processes involved in paleofloods in this basin and their relations to the monsoon strength during the mid-Holocene.