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Holocene palaeoflood events recorded by slackwater deposits along the Jin-shan Gorges of the middle Yellow River, China

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ABSTRACT

Palaeoflood slackwater deposits (SWDs) are the natural record of overbank flooding and are often found within aeolian loess-soil profiles along the river valleys of the middle Yellow River basin. Palaeohydrological field investigation was carried out along the Jin-shan Gorges of the middle Yellow River after the great flood in 2012. We founded the new palaeoflood SWDs profile (YHG-B) on the basis of previous results in the YHG site, and collected the 2012 flood slackwater deposits. Analytical results, including magnetic susceptibility and particle size distribution, which is similar to the flood SWDs in 2012, indicate that these well-sorted palaeoflood SWD beds were deposited from the suspended sediment load in floodwaters. They have recorded the extraordinary palaeoflood events which occurred between 3200 and 3000 a BP as dated by the optically stimulated luminescence method in combination with pedo-stratigraphic correlations with the previously studied Holocene pedo-stratigraphy in the Yellow River drainage basin. According to the palaeoflood peak stages indicated by YHG-A and YHG-B, the peak discharges of these palaeoflood events vary in a range from 28 340 to 48 410 m^3/s by using HEC-RAS one dimensional model. This discharges result error is less than 5% with previous published discharges by using Slop-Area method in 2012. The extraordinary flood events were documented not only on the Yellow River, but also on its tributaries such as the Weihe River, the Jinghe River, and the Qishuihe River. The flooding events are therefore considered to be a regional expression of known climatic events in the northern hemisphere and demonstrate Holocene climate was far from stable. This work will increase our understanding of the interactions between fluvial environment and climatic change in the semi-arid and sub-humid regions, and provide information that is useful for interpretation and calibration of the modern short-term gauged records.

1. Introduction

In the semi-arid and sub-humid zones of the monsoonal climate, Holocene climatic variations are often manifested by hydrological change that is characterized by severe droughts and extraordinary floods (Gasse, 2000). The study of palaeofloods enables linkages between extreme events in fluvial systems and global climate change to be established over a long time-scale (Knox, 2000; Huang et al., 2010, 2011, 2012a, 2012b). Palaeoflood hydrology is studied with the multidisciplinary methods of fluvial geomorphology, Quaternary sedimentology and geochronology for identification of palaeoflood stages, and further for estimation of palaeoflood discharges using hydraulic calculation models (Baker, 1987, 2006, 2008). Thus, palaeoflood study will also play an important role in mitigating flood risks and in improving flood design in hydraulic engineering (Benito et al., 2004; Benito and Thorndycraft, 2005). Bedded sequences of flood slackwater deposits along a river valley record individual floods. These palaeoflood slackwater deposits (SWDs) are suspended sediment load in flood flow deposited in areas of flow separation and preserved after the flood recession (Baker and Kochel, 1988).

Extremely high sediment discharge and flood disasters are of concern to geographers and hydrologists in the Yellow River. It is well known that the Yellow River annual sediment discharge is 1.6×10^9 tonnes and the highest sediment discharge in the word. But the 1.6×10^9 tonnes of sediment discharge is the average between 1919 and 1985 in the Sanmenxia gauge station in the middle Yellow River. In fact, the sediment discharge has been

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reduced because the Project of Returning Farmland to Forest (Grass) in the Loess Plateau Region. The annual sediment discharge is 5.89 × 10^8 tonnes from 1987 to 2010. The annual sediment discharge is reduced to 2.19 × 10^8 tonnes in the last five years in the Sanmenxia gauge station. Affected by the reduction in annual precipitation and runoff volume since the early 1980s, water resources was growing shortage in the middle Yellow River (Xu et al., 2009). And the frequency of drought and flood occurred increasing (Zhang et al., 1999; Peng et al., 2011). These phenomena indicate intensified variability and instability of the hydro-climatic system in semi-arid and sub-humid regions, and imply that the region might have been influenced by global change. The development of water resources and water energy, the flood disaster governance and utilization and regulation of flood resource are needed to master the long scale flood hydrological data in the middle Yellow River.

This paper presents five bedsets of newly discovered palaeoflood SWDs in the Jin-shan Gorges, middle reach of the Yellow River (Fig. 1). We focus on the identification of the palaeoflood events recorded by slackwater deposits, the hydrological reconstruction of these extraordinary floods, and on the examination of their links to past climatic change.

2. Study area and site

The mainstream of the Yellow River is 5464 km in length, and drains a catchment area of 795 000 km^2. The river is characterized by an extremely high sediment discharge of 1.6 × 10^9 tonnes/a, the highest sediment discharge in the world (Xu et al., 2009). The Hekou town-Longmen reach of the middle Yellow River is the focus of our investigation, also known as the Jin-shan Gorges, which is underlain by Triassic mudstone, shale and sandstone formations. It has a typical dendritic drainage pattern draining from north to south between the Lvliangshan and the Huanglongshan Mountains. The mainstream is 723 km long with a drainage area of 111 600 km^2. The channel drop 607 m with 400–600 m in width

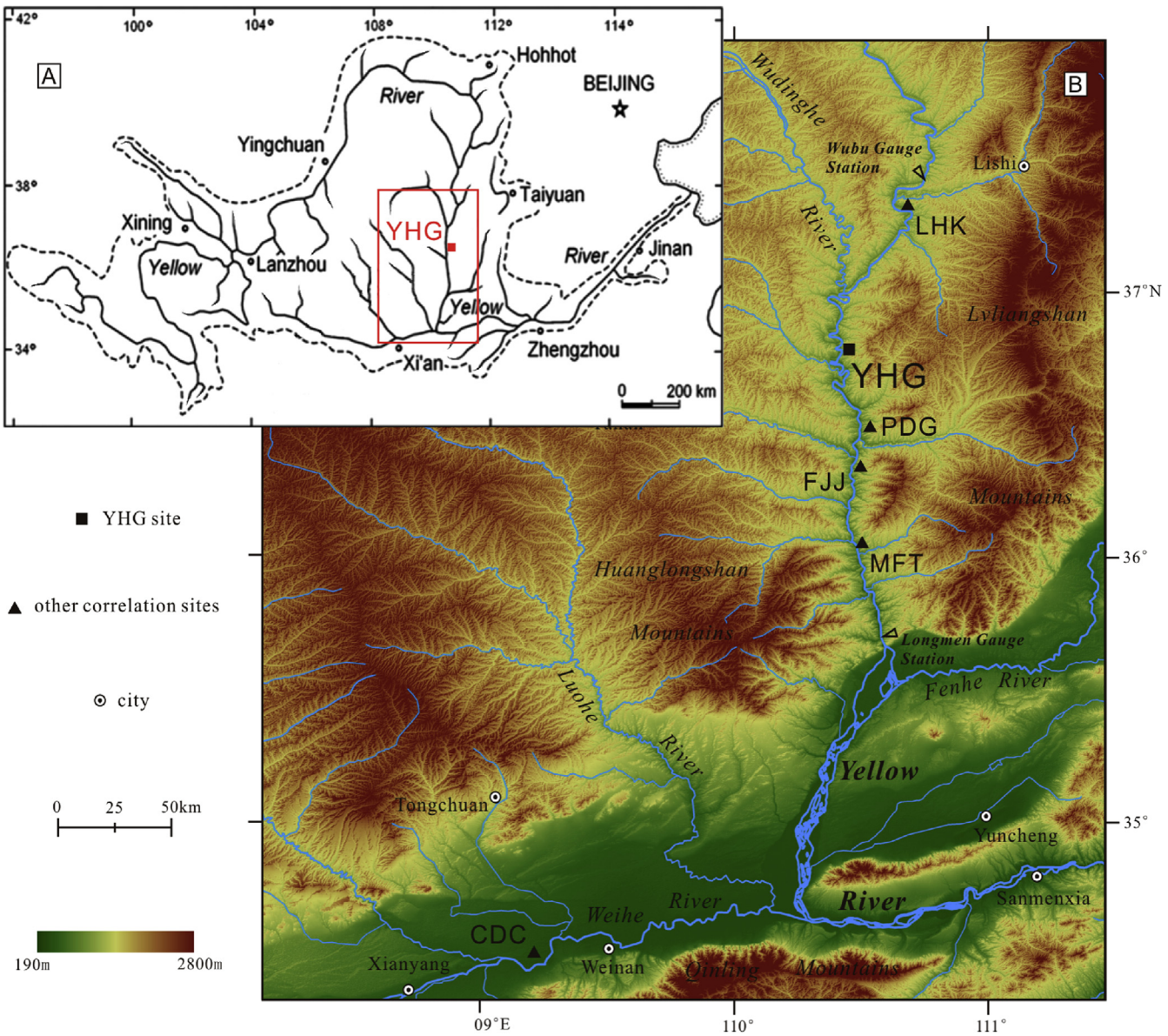

Fig. 1. A-Map showing the study reach in the Jin-Shan Gorges in middle reach of the Yellow River in China. B-The locations of the studyYHG site, and other correlation sites, where the same period palaeofloods were exposed in the Jin-shan Gorges of the middle Yellow River.

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