Journal of Asian Earth Sciences 114 (2015) 203–211

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Bedrock river incision response to basin connection along the Jinshan Gorge, Yellow River, North China

Hao Liang [a,b,*], Ke Zhang [a,b], Jianli Fu [c], Li Li [a,b], Jun Chen [a,b], Shubo Li [a,b], Liye Chen [a,b]

[a] School of Earth Science and Geological Engineering, Sun Yat-Sen University, 510275, China
[b] Guangdong Key Laboratory of Geological Process and Mineral Resources Exploration, Guangzhou 510275, China
[c] Institute of Geomechanics, Chinese Academy of Geological Sciences, 100081, China

ARTICLE INFO

Article history:
Received 6 January 2015
Received in revised form 1 July 2015
Accepted 13 July 2015
Available online 13 July 2015

Keywords:
Yellow River
Fluvial terrace
Longitudinal profile
Drainage system
River incision

ABSTRACT

The Jinshan Gorge of the Yellow River, connecting the Hetao and the Fenwei Basins, is a key area for understanding the formation and evolution of the drainage system in response to bedrock river incision. We have measured fluvial terraces along the gorge in the field in detail. The longitudinal profile and published dating of terraces indicate that rapid river incision occurred in the late Pleistocene. The deactivated boundary faults and uniform lithology of the gorge have no measurable influence the incision. Changes in precipitation are consistent with incision rate in late Pleistocene, rapid in MIS5 and low in MIS3, whereas appearing inconsistent in MIS7 when high rainfall was associated with low incision rates. We infer the variation of discharge to large paleolakes drainage in response to connection of the Hetao and Fenwei Basins. Revealed by lacustrine platform in these two basins, fast paleolake regressions took place approximately at 0.22 Ma in the Fenwei Basins, leading to base level fall, and then 0.10 Ma in the Hetao Basins, causing an abrupt increase in discharge. These two events made major contributions to the rapid bedrock river incision.

1. Introduction

One of the most significant aspects on the Earth's surface is bedrock river incision that shapes valleys and canyons, forms knickpoints in river channels and induces surface erosion. In general, bedrock river incision is driven by uplift, discharge and variations in rock resistance (Bridgland and Westaway, 2008; Cutler et al., 2003; de Winter et al., 2012; Fuchs et al., 2013; Johnson et al., 2011; Viveen et al., 2013; Whipple and Tucker, 1999). Changes in erosion rate due to changes in climate and sediment supply lead to phases of incision. These factors have great effect on discharge, thereby incision and deposition. In a steady state situation, rivers and their drainage basins are in equilibrium and so can be considered as unified systems. However, disequilibrium between rivers and their basins can be induced by significant landscape events that abruptly change discharge and/or sediment supply. Explaining how bedrock river incision responds to such processes is therefore an important geomorphologic study.

The Yellow River, originating from the northern Tibetan Plateau, is the second largest river in China. It crosses the Hetao Basins, enters the Jinshan Gorge along the eastern Ordos Plateau carrying a high sediment load (average of 900 million tons per year), and partially deposits this sediment in the Fenwei Basins downstream of the gorge. Further downstream, it down cuts the Sanmen Gorge, finally entering the Bo Sea (Fig. 1a). The Yellow River is generally considered to have formed by connection of various basins along its course (Cheng et al., 1998; Jiang et al., 2007; Pan et al., 2012; Qiu et al., 2008; Zhang et al., 2009; Zhang, 2012). The Hetao and Fenwei Basins are the most separated (about 700 km) so the development of the Jinshan Gorge is critical for establishing connection of the c. 5700 km long Yellow River. With well-preserved terraces profiles along the Jinshan Gorge, it has been investigated as a source of information on both fluvial landscape development and climate change. Previous work that focused on the planation surface provides an initial incision age of the gorge (c. 1.4 Ma) and infers uplift of the eastern Ordos Plateau (Hu, 2012; Li et al., 2001; Pan et al., 2012); dating of terraces along the gorge constrains river incision ages (Cheng et al., 1998; Guo et al., 2012; Qiu et al., 2008, 2014; Wang, 2006; Zhang et al., 2009); observations and magnetostratigraphic measurements on loess-overlain terraces reveal how climatic variability affects the formation of

* Corresponding author at: School of Earth Science and Geological Engineering, Sun Yat-Sen University, 135#, West Xingang Rd., Guangzhou 510275, China.
E-mail address: liangh27@mail2.sysu.edu.cn (H. Liang).

http://dx.doi.org/10.1016/j.jseaes.2015.07.010
1367-9120/

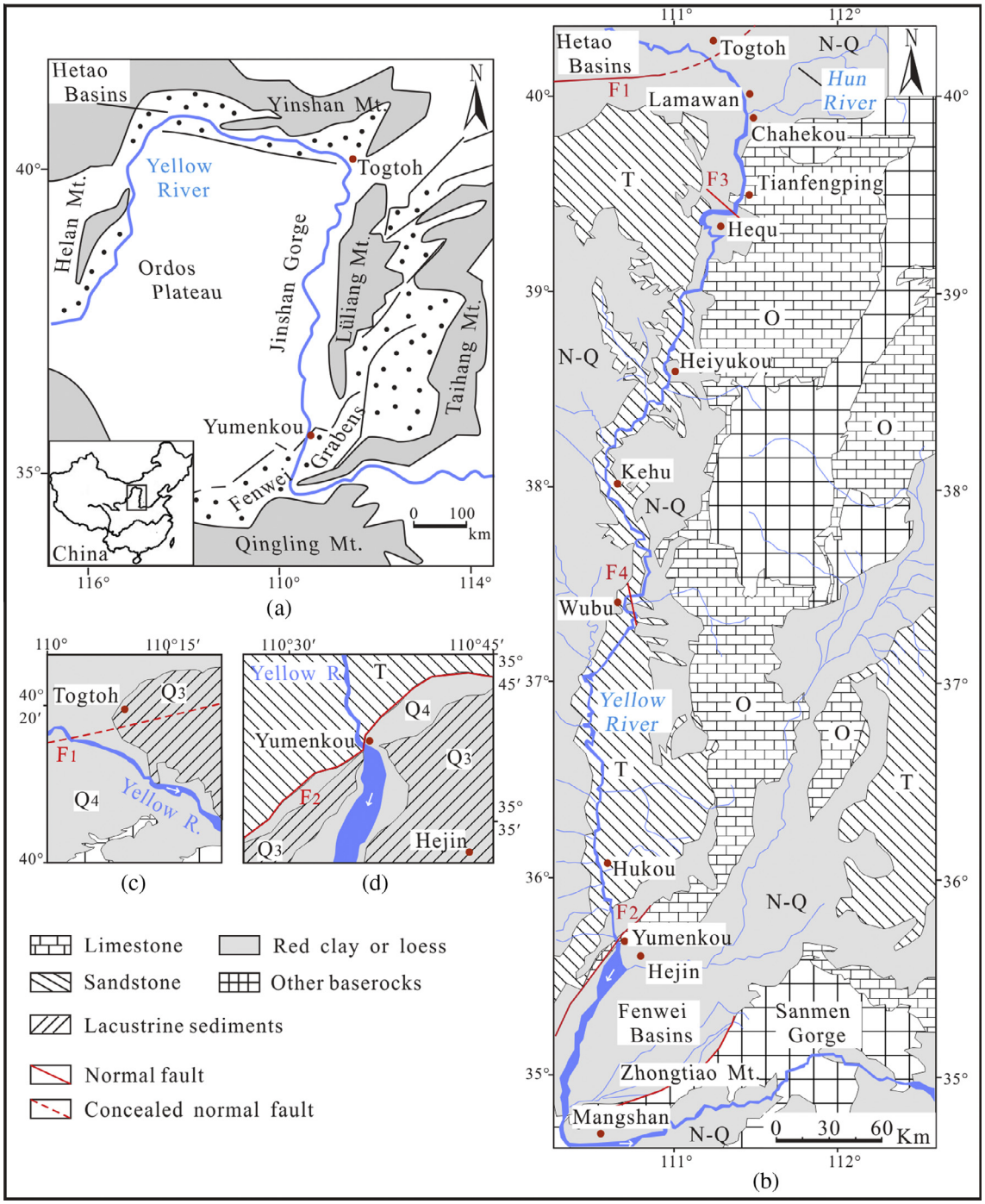

Fig. 1. Map of study area. (a) Shows locations of the Ordos Plateau, the Jinshan Gorge (modified from Qiu et al., 2014), the Hetao Basins and the Fenwei Grabens; (b) shows generalized geology along the Jinshan Gorge (compiled from Hu, 2012); (c and d) show distribution of Q3 lacustrine sediments (compiled from Li et al., 2005; Hu et al., 2011).

terraces among reaches (Cheng et al., 1998; Fu et al., 2013; Liu et al., 2007; Liu, 2013; Nugteren, 2004; Vandenberghe et al., 2004; Wang, 2006). Both tectonic movements and climatic changes had significant effects on fluvial systems in the Jinshan Gorge. However, there remains no consensus about which is the main factor promoting the rapid bedrock river incision of the gorge and establishing a final connection (Cheng et al., 1998; Pan et al., 2012; Qiu et al., 2008; Zhang et al., 2009). Here we present distribution and longitudinal profiles of river terraces derived from detailed surveying and sediment records in drainage basins, and combine these with published dating to reconstruct the correlation of terraces, river reaches and basins to interpret the causes of incision along the Jinshan Gorge.

2. Geological and geomorphic setting

2.1. Ordos Plateau and Jinshan Gorge

The Ordos Plateau in northern China is approximately 1.2 million km^2 in area and has a mean altitude up to 1400 m asl. The Ordos Plateau consists of Archean basement overlain by gently west-dipping Paleozoic to Mesozoic strata, but lacking early