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Characteristics and genetic mechanism of the Cuihua Rock Avalanche triggered by a paleo-earthquake in northwest China

Yan Lv [a], Jianbing Peng [a,*], Genlong Wang [b,*]

[a] Key Laboratory of Western Mineral Resources and Geological Engineering Ministry, Chang'an University, Xi'an, Shaanxi 710054, PR China
[b] Key Laboratory of Geo-hazards in Loess Area, Xi'an Centre of Geological Survey, China Geological Survey, Xi'an, Shaanxi 710054, PR China

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ABSTRACT

The Cuihua Rock Avalanche, 30 km south of Xi'an, China, is located within a marvelous geological landscape and was triggered by an ancient paleo-earthquake. The area is mainly characterized by cliffs, stone seas and a dammed lake (Shuiqiu Pool), with a total area of 5×10^5 m^2 and a volume of 1.8×10^7 m^3. Field investigations, historical records, dating methods and typical seismic profiles indicated that its occurrence could be correlated with an earthquake in 780 BC that most likely triggered the landslide. The results also showed that a) the formation of the rock avalanche was associated with high-steep slope created by lifting of Qinling Mountain and cutting of rock fractures, and b) the high-steep slope and several preferred structural planes play an important role in controlling the slope instability. Based on conjectures, the failure process of the rock avalanche can be divided into four stages: the preliminary stage, the starting-up stage, the accelerating stage, and the accumulating stage.

1. Introduction

As the most important city in Northwest China, Xi'an held the position of capital city for 13 dynasties over a period of 1120 years. It was also the earliest cradle of mankind, and an exchange center for ancient western and eastern cultures (Wang, 1990). The Cuihua Mountain is located 30 km to the south of Xi'an City, and is famous for rock avalanches caused by paleo-earthquakes (Figure 1). The Heritage Site of the Cuihua Rock Avalanche ranks third in volume in the world (following the Usoi Rock Avalanche in Tajikistan and the Waikaremoana Rock Avalanche in New Zealand).

The earliest study of the avalanche can be traced back to a paper by Nan and Cui (2000). In it, they reported some characteristics of the rock avalanche in detail, such as rock slope failure in stages and block movement with high speeds. After that research, other studies have been conducted upon the formation. For example, Wu and Peng (2001), Weidinger et al. (2002), He et al. (2005), Guo (2005), Li et al. (2007), and Lv et al. (2013) studied respectively, the cause, characteristics, value and environmental effects of the rock avalanche based on field investigations from the view of geomorphology. All of this research has given Mt. Cuihua great scientific support. However, the results have been limited because of the small amount of evidence and data available. In order to provide reasonable and scientific bases for the development and protection of tourist resources for Mt. Cuihua, the authors relied on remote sensing imaging, shallow seismic exploration and C14 dating to best define the characteristics related to the genetic mechanism.

2. Characteristics of the Cuihua Rock Avalanche

2.1. Geological setting

The Cuihua Rock Avalanche is in the Dongcha Gully, an eastern branch of Taiyi River. It is within the northern margin of Qinling Mountains which is representative of intercontinental orogenesis, magmatic activities and strong compressional movement during the Mesozoic–Cenozoic. Furthermore, the Mt. Qinling in the south, as well as the Weihe Plain (also known as Guanzhong Plain or Weihe Basin) in the north, are the two most east–west-striking geomorphic units. The Northern Qinling Margin Fault (Figure 2) extends eastward for over 310 km from Baoji to Tongguan and is the largest and most intensely active fault in this area (Zhang et al., 1995). The formation lithology in the region of the rock avalanche is mainly composed of migmatitic granite ($T\gamma_5^1$). These intrusive rocks were either generated during the tectonic phase of Y'ngsan or during the phase of Y'ngsi (Zhang et al., 2001). Quaternary deposits (Figure 2) mainly outcrop on the alluvial fan of Mt. Qinling and the alluvial plain of Weihe River.

Tectonic activity in the Weihe Basin is obvious. Since the Oligocene, when the Weihe Basin (i.e., Guanzhong Plain) began to sink and accept sediment, the activity of the Qinling Piedmont Fault (also known as the northern QL margin fault) along the basin margin had been very strong. Moreover, Zhang et al. (1995) reported that the activity of the Qinling Piedmont Fault is outstanding in the Quaternary, especially since human activity began. The vertical differential movement rate of the

* Corresponding authors. Tel./fax: +86 2982339012.
E-mail addresses: dicexy_1@126.com (J. Peng), wang2006@mail.iggcas.ac.cn (G. Wang).

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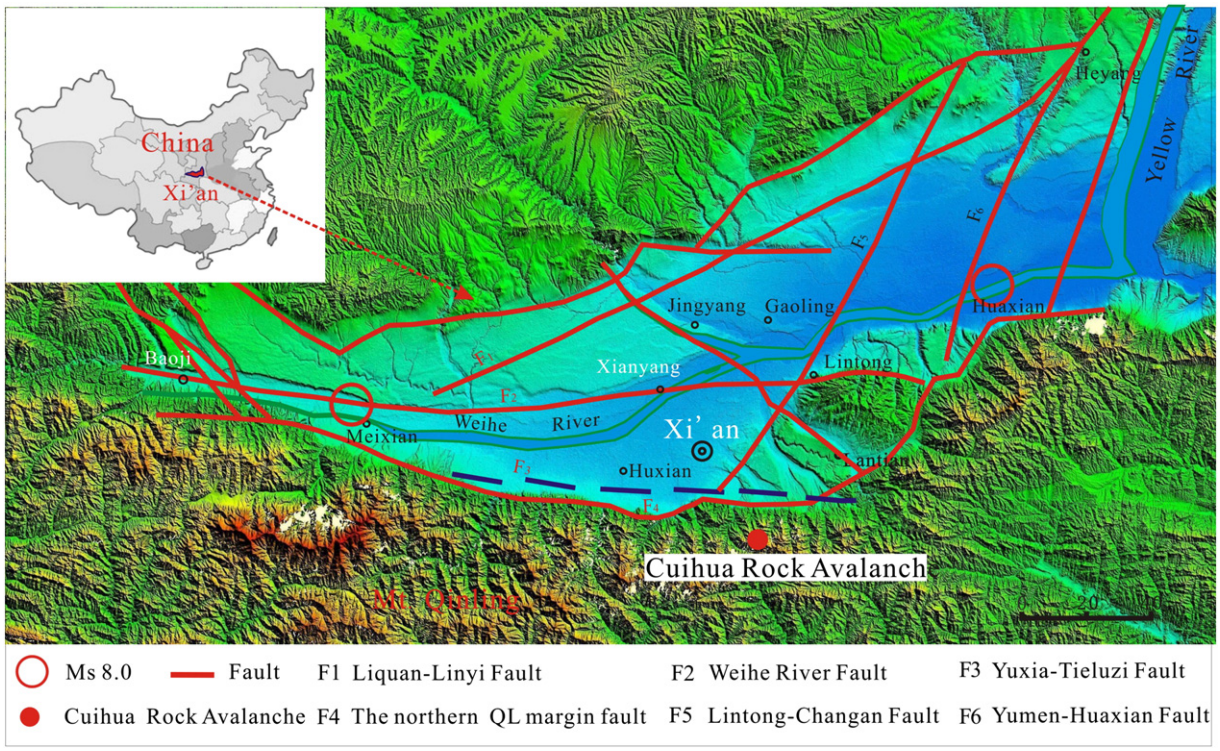

Fig. 1. Site of the Cuihua Rock Avalanche in Weihe Basin. According to historical records, two large earthquakes occurred in 780 BC, and in 1556. Both were thought to have magnitudes of larger than 8.0. And both epicenters were located in the Weihe Basin, near the Qinling Piedmont Fault.

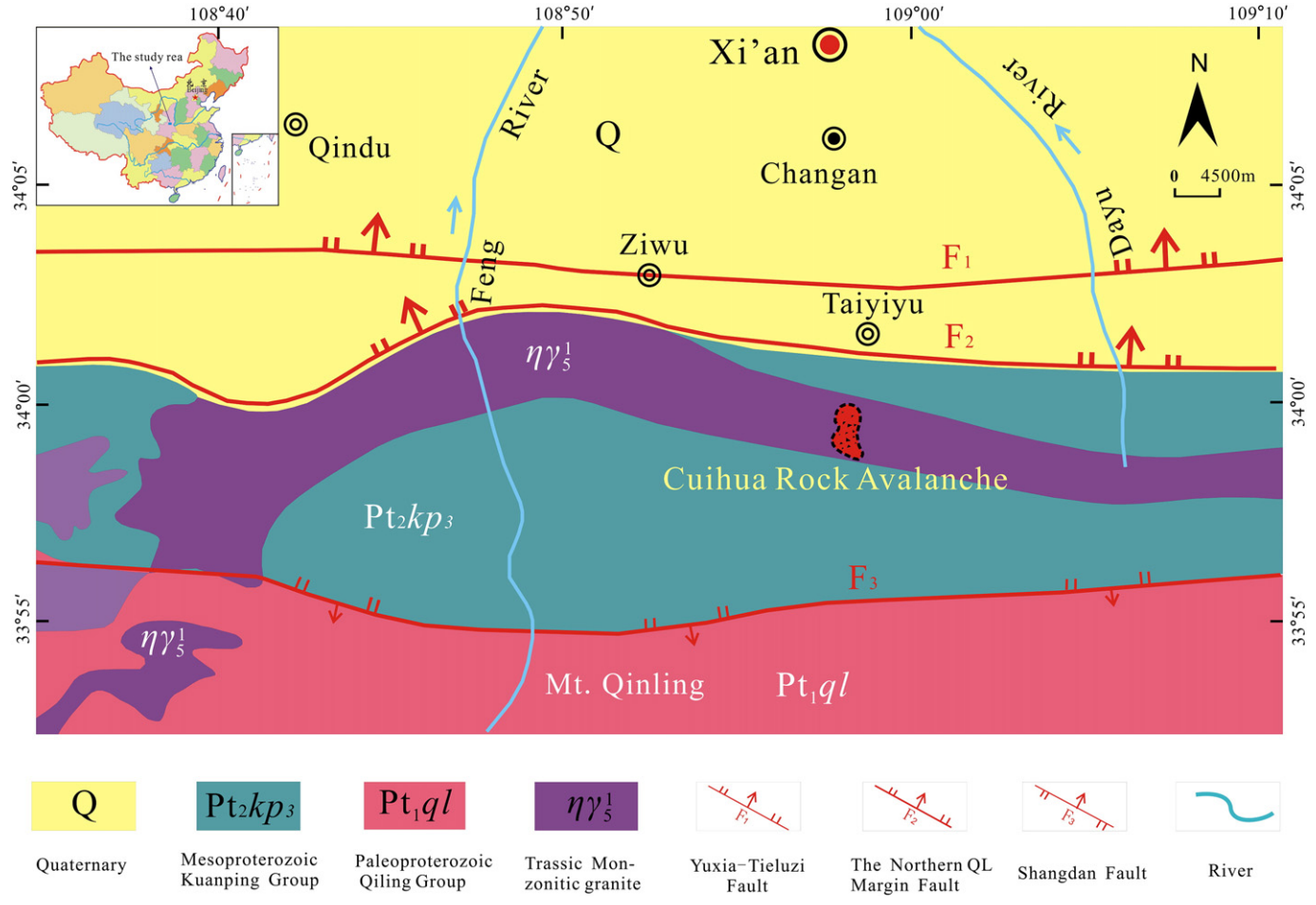

Fig. 2. Geological map of the Cuihua Rock Avalanche and the surrounding areas. The formation lithology in the region of the rock avalanche is mainly composed of migmatitic granite. Quaternary deposits mainly outcrop on the alluvial fan of Mt. Qinling and the alluvial plain of Weihe River.