Geomorphology 217 (2014) 193–203

Contents lists available at ScienceDirect

Geomorphology

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

Chronology of relict lake deposits around the Suwalong paleolandslide in the upper Jinsha River, SE Tibetan Plateau: Implications to Holocene tectonic perturbations

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ARTICLE INFO

Article history:
Received 12 December 2013
Received in revised form 24 April 2014
Accepted 25 April 2014
Available online 5 May 2014

Keywords:
Landslide dam
Paleo-dammed lakes
Radiocarbon dating
Luminescence dating
Jinsha River

ABSTRACT

The Suwalong paleolandslide is located in the Batang–Zhongza reach of the upper Jinsha River, at the southeast margin of the Tibetan Plateau where tectonic activity is very strong, and has formed a great deal of large paleolandslides or their relicts. The relict deposits that have been exposed around the Suwalong paleolandslide provide an opportunity to understand the formation process and potential origin of a former landslide-dammed lake in the active belt region. Two-level platforms of ancient dammed lake deposits were found on both the upstream and downstream sides of the relict landslide dam. The chronology of the landslide and its surrounding relict lake deposits were studied by using ^{14}C dating and OSL dating. The minimum age of the Suwalong landslide blocking the Jinsha River was shown to be about 1355 yr BP, and those of its surrounding two platforms of lacustrine sediments were shown as 1.8 and 1.3 ka BP. The recordings of the soft-sediment deformations induced by seismic liquefaction were found in the dammed lake sediments, thus providing substantial evidence for the existence of the paleoseismic events. We can infer that the Suwalong landslide may have been triggered by a paleoearthquake or combination of paleoearthquake and rainfall events. The chronology of the landslide-dammed lake deposits around the relict Suwalong landslide dam reveals that the large-scale landslides in the Batang–Zhongza reach of the upper Jinsha River were formed during numerous periods, namely the large-scale landslides may have been triggered by several paleoearthquake events (occurring at around 1900, 1355, and 1115 yr BP), indicating that the Jinsha River faults in the area may have been quite active since the late Holocene.

1. Introduction

The results of numerous studies have indicated that natural processes can form various types of natural dams, including the common landslide dams, glacier-ice dams, moraine dams, fluviatile dams and volcanic dams (Costa and Schuster, 1988). Among these, dammed lakes formed by landslides, collapses, or debris flows or ice sediments blocking rivers exist widely throughout the world (Korup, 2005; Korup and Clague, 2009; Phartiyal et al., 2009). In China, landslide dams blocking rivers induced by earthquakes and dammed lakes are a common geomorphic phenomenon, especially in the southeast margin of the Tibetan Plateau (Chen et al., 2013; Dai et al., 2005; Korup and Montomery, 2008).

Some dams existed for only several minutes, while others may have persisted for decades or even centuries in the natural formation process (Costa and Schuster, 1988). With a relatively stable dam and water in dynamic balance, dammed lakes will eventually form. Consequently, lake deposits would be produced after a period of stable deposition (Liu et al., 2004). Typically, lacustrine sediments may record the events that occurred during the deposition (Korup and Clague, 2009; Reneau and Dethier, 1996; Trauth and Strecker, 1999).

The Suwalong paleolandslide is located in the Batang–Zhongza reach of the upper Jinsha River, at the southeast margin of the Tibetan Plateau. Earthquake activities are very frequent in this region owing to the influence of the Jinsha River fault zone. In addition, paleoearthquakes have induced a great deal of large-scale ancient landslide dams, and a rich abundance of ancient dammed lake sediments have occurred along the river valley (Chen et al., 2013). In this paper, the chronology and potential origin of the lake sediments around the Suwalong ancient landslide are studied, the results of which may serve toward the reconstruction

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http://dx.doi.org/10.1016/j.geomorph.2014.04.027
0169-555X/

of the formation and evolution process of the ancient landslides and landslide dams in the Batang–Zhongza reach of the upper Jinsha River.

2. Regional geologic and geomorphologic settings

The Batang–Zhongza reach is located in the upper Jinsha River at the southeastern margin of the Tibetan Plateau (Fig. 1), is about 90 km in length, and acts as the transition zone of the Tibetan Plateau to the Yunnan–Guizhou Plateau and Sichuan basin. The Suwalong landslide is located at about 300 m down the downstream side of Suwalong Township, Batang County, Sichuan Province (Fig. 2). The Jinsha River flows through the west side of Batang County from north to south, and mountains have developed along both sides of the river where the valleys are incised deeply. The average elevation of the area is above 2200 m; and the slopes here are steep, most being >40°, while the slope of the bedrocks at the elevation of 100 m near the river is >60°. Narrow and broad valleys are present: the narrow ones being 100–200 m in width, but the broad ones are as wide as 200–400 m. The channel bars and sands were developed by riverbed deposits in the wide valleys, but at the same time rare riverbed deposits caused by rapids were found in the narrow valleys. The basic characteristics of the landforms in the area are undulating terrain, alpine terrain, and deep valleys.

The lithology of the exposed rocks along the valley sides are mainly Mesozoic schist, marble and limestone, granite, and other volcanic rocks (Fig. 2).

The phenomenon of drought here is very serious and the climate is categorized as an arid desert and semidesert valley. Although Batang is located geographically in a subtropical climate zone, most of the region other than the Jinsha River valley area has a continental monsoon climate because of its high altitude, and it is also influenced by the surrounding mountains from north to south, along with the atmospheric circulation. The annual rainfall concentrated within the period of July–September of every year under Zhubalong on the east side of the Jinsha River is only about 400 mm, while the average temperature is about 16 °C, but the highest temperature can reach 35 °C, thus it can be considered as a subtropical dry-hot valley (Chen et al., 2008).

Two groups of active faults have developed in the study area, namely the Batang Fault (F1) and Jinsha River fault zone (F2) (Fig. 2). The Jinsha River fault zone is the boundary fault of the Qiangtang–Changdu block and Songpan–Ganzi orogenic belt (Fig. 3). The overall trend of the fault is in the N–S direction, and the north section outspreads to the NNW, while the south section extends to the NNE. In addition, in the plan figure it takes an east-protruding arc shape, in which the arc tip is in the near vicinity of Batang County (Zhou et al., 2005). The fault zone is mainly composed of four active faults, namely the Zengziding Fault (F2-1), Zigasi–Deeqeen Fault (F2-2), Benxie–Dagaiding Fault, and Xiongsong–Suwalong Fault (F2-4) (Fig. 2). The activities of the Jinsha River fault zone mainly have been characterized by the intense thrusting of near EW since the late Cenozoic (Song et al., 1998; Xu et al., 1992). The present GPS measurement results indicate that the eastern Tibetan block squeezes into the western Sichuan block with a rate of 17–18 mm/a from west to east, and with a slip rate of 14–16 mm/a to the western Sichuan block (Chen et al., 1998). The faulted landform and chronology show that the current right-lateral strike–slip rate of the Jinsha River fault zone is 6–7 mm/a, and the vertical rate is estimated at 2–3 mm/a (Xu et al., 2005).

The Suwalong landslide is on the west side of the Xiongsong–Suwalong Fault (F2-4), which is the main fault of the Jinsha River fault zone. Mainly located on the east side of the Jinsha River, the fault extends to the south area of Zhongza along the Zhubalong–Wangdalong reach from north to south, where the tectonic activity is very strong and formed a large number of major paleolandslides or their relicts under the influence of the fault (Fig. 2).

According to the statistical analysis of the existing historic earthquake records, seismic activities with magnitudes of >5 in Batang County and its adjacent area since 1722 were obtained (Wu and Cai, 1992), and the historic earthquakes occurring in the area are shown in Table 1.

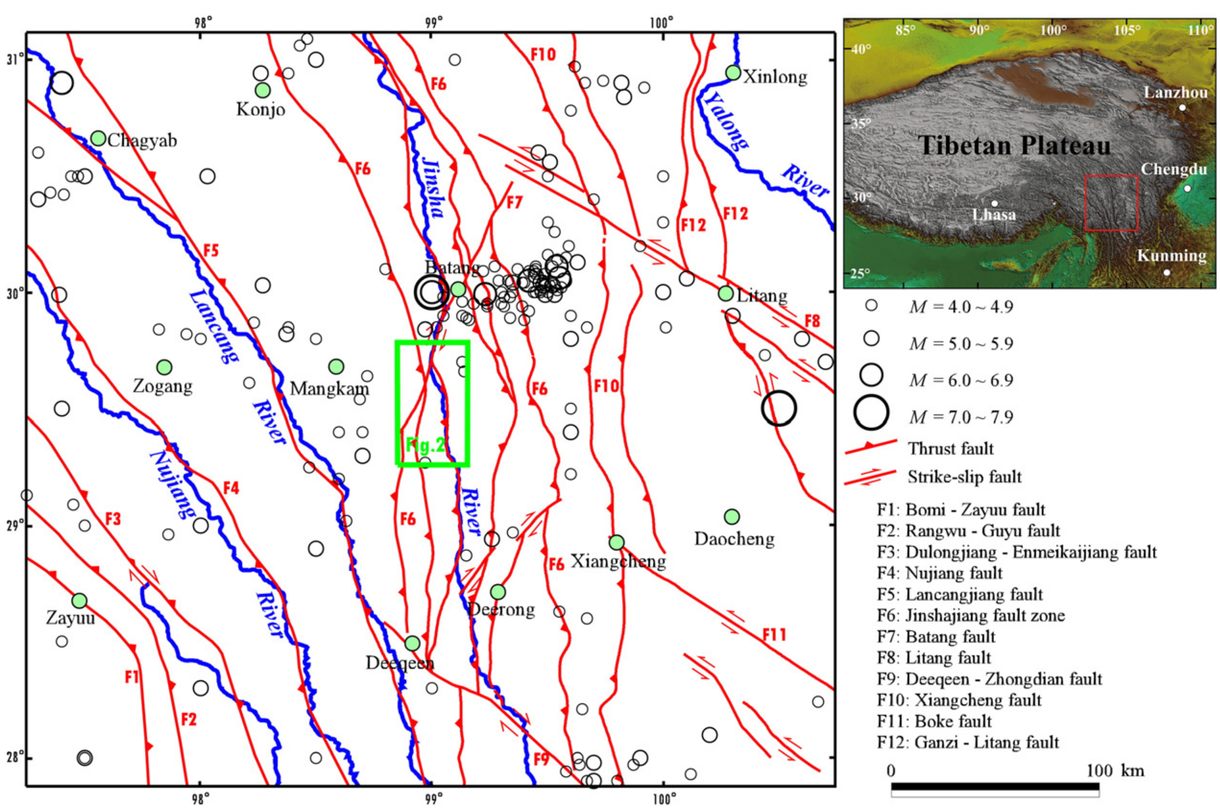

Fig. 1. Map showing the geographic locations of the study site and regional faults.