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The 1786 earthquake-triggered landslide dam and subsequent dam-break flood on the Dadu River, southwestern China

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Abstract

Chinese historic documents recorded that on June 1, 1786, a strong M=7.75 earthquake occurred in the Kangding-Luding area, Sichuan, southwestern China, resulting in a large landslide that fell into the Dadu River. As a result, a landslide dam blocked the river. Ten days later, the sudden breaching of the dam resulted in catastrophic downstream flooding. Historic records document over 100,000 deaths by the flood. This may be the most disastrous event ever caused by landslide dam failures in the world. Although a lot of work has been carried out to determine the location, magnitude and intensity of the 1786 earthquake, relatively little is known about the occurrence and nature of the landslide dam. In this paper, the dam was reconstructed using historic documents and geomorphic evidence. It was found that the landslide dam was about 70 m high, and it created a lake with a water volume of about 50×10^6 m^3 and an area of about 1.7 km^2. The landslide dam breached suddenly due to a major aftershock on June 10, 1786. The peak discharge at the dam breach was estimated using regression equations and a physically based predictive equation. The possibility of a future failure of the landslide seems high, particularly due to inherent seismic risk, and detailed geotechnical investigations are strongly recommended for evaluating the current stability of the landslide.

Keywords: Landslide dam; Breach; Flood; Discharge; Earthquake

1. Introduction

Natural damming of rivers by landslides may cause significant hazards in many countries. It presents serious threats to people and property due to possible upstream flooding as the impounded lake water level rises and possible downstream flooding due to dam breach and rapid release of the impounded water. Attempts in recent years to collect and classify data on landslide dams result directly from increasing hazard awareness. Costa and Schuster (1991) presented the most comprehensive inventory and bibliography of 463 landslide dams throughout the world. Clague and

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Evans (1994) described 16 existing and 22 historical landslide dams in the Canadian Cordillera. Casagli and Ermini (1999) presented an inventory of 68 present and historic landslide dams in the northern Apennines. Hewitt (1998) provided an excellent guideline on how to reconstruct landslide-damming events from geomorphic evidence.

In China, Chai et al. (1995) presented an inventory of 147 present and historic landslide dams, although it is by no means complete due to the remote nature of landslide-damming events and the vagaries of reporting such incidents. This inventory and more recent landslide-damming events suggest that at least 5500 deaths have been caused by landslide dams in China since 1900. A few of these incidents are well documented. On August 25, 1933, an earthquake of M=7.5 near Diexi, Sichuan Province, caused the formation of three landslide dams with a maximum height of 160 m on the Min River and nine landslide dams on its tributaries. The three lakes behind the landslide dams merged into a large lake because of the continuous inflow of water from upstream and the higher elevation of the most downstream dam. The dam was overtopped 45 days later, and a flood of water rushed down the valley for a distance of 250 km, killing at least 2500 people (Sichuan Seismological Bureau, 1983; Chai et al., 2000). On June 8, 1967, a huge landslide with a volume of 68×10^6 m^3 occurred at Tanggudong on the Yalong River, Sichuan Province, forming a natural dam with a height of 175 m and a reservoir with a capacity of 680×10^6 m^3. Nine days later, the dam broke by overtopping, lasting 13 h and resulting in a maximum flood discharge of 53,000 m^3/s (Chen et al., 1992), but no loss of life occurred because of precautionary evacuations. More recently, the Yigong River in southeastern Tibet was dammed on April 9, 2000, by a huge landslide with a volume of 300×10^6 m^3. This natural dam, about 130 m high and 1.5 km long, was created in 8 min. The dam partially failed on June 10, 2000 (Shang et al., 2003). The resultant flood traveled more than 500 km downstream, damaged many bridges and created numerous new landslides along both banks of the river. The flooding also resulted in 30 deaths, more than 100 missing people and more than 50,000 homeless in the five districts of Arunanchal Pradesh, India (Zhu and Li, 2001).

Historic records revealed that the 1786 Kangding-Luding earthquake in southwestern China triggered a large landslide that dammed the Dadu River, which, 10 days later, breached suddenly, resulting in over 100,000 deaths due to downstream flooding. In our knowledge, this incident may constitute the world's most disastrous landslide-damming event ever recorded. Although a lot of work has been carried out to determine the location, magnitude and intensity of the 1786 Kangding-Luding earthquake (Wang and Pei, 1987), relatively little is known about the nature of the landslide dam. This paper presents an attempt to address the location and nature of this landslide dam and to reconstruct the peak discharge at the dam breach based on historical documents and geomorphic evidence.

2. Geographic and geological setting

The Kangding-Luding area in Sichuan, southwestern China, is located in the convergence of the NE–SW trending Longmenshan, NW–SE trending Xianshuihe and N–S trending Anninghe active fault zones (Fig. 1). This area is one of the most seismically active areas in China, although seismic activity, in terms of magnitude, at the south extremity of the Longmenshan fault zone is considered to be moderate (Wang and Pei, 1987). The spatial and temporal characteristics of historic earthquakes along the Anninghe fault zone indicate that its seismic activity tends to decrease northward. The seismic activity of the Kangding-Luding area is controlled primarily by the Xianshuihe active fault zone (Wang and Pei, 1998). The zone is one of the most active fault systems in the world and can be divided into five segments: the Moxi fault, Selaha fault, Zheduotang fault, Yalahe fault (Fig. 2) and northwest segment (Allen et al., 1991; Zhou et al., 2001). As the Selaha and Zheduotang faults are at most only 10 km apart and they converge toward their ends, it is possible that they dip steeply toward each other and merge at depth (Allen et al., 1991; Zhou et al., 2001). The northwestern end of the Xianshuihe fault overlaps with the southeastern end of the Ganzi-Yushu fault, with a left end echelon step-over of about 40 km (Fig. 1). The southeastern extremity of the Xianshuihe fault zone connects with the Anninghe fault.