



Landslides triggered by the 1949 Khait earthquake, Tajikistan, and associated loss of life

Stephen G. Evans^{a,*}, Nicholas J. Roberts^{a,1}, Anatoli Ischuk^b, Keith B. Delaney^a, Galina S. Morozova^a, Olga Tutubalina^c

^a Landslide Research Programme, Department of Earth and Environmental Sciences, University of Waterloo, 200 University Avenue West, Waterloo, Ontario, Canada N2L 3G1

^b Institute of Earthquake Engineering and Seismology, Academy of Sciences of the Republic of Tajikistan, 121 Aini Street, Dushanbe 734029, Tajikistan

^c Faculty of Geography, Moscow State University, Moscow, Russia

ARTICLE INFO

Article history:

Received 6 September 2008

Received in revised form 17 July 2009

Accepted 13 August 2009

Available online 22 August 2009

Keywords:

1949 Khait earthquake

Earthquake-triggered landslides

Loess flows

ASTER Global DEM

Landslide disaster

Rockslide

Tajikistan

ABSTRACT

Earthquake-triggered landslides are a major geological hazard in Central Asia. In July 1949, the M7.4 Khait earthquake triggered many hundreds of landslides in a mountainous region near the southern limit of the Tien Shan Mountains, central Tajikistan. These landslides involved widespread rock-slope failure as well as large numbers of flowslides in loess that mantles the steep slopes of the region. In the Yasman valley hundreds of loess landslides coalesced to form a massive loess flow (est. vol. 245 Mm³) that travelled up to 20 km on a slope of only 2°. In an adjacent valley, the Khait landslide involved transformation of an earthquake-triggered rockslide into a very rapid flow by the entrainment of saturated loess into its movement. It travelled 7.41 km over a vertical distance of 1421 m with an estimated average velocity of ~30 m/s. We estimate its volume as 75 Mm³, an order of magnitude less than previously published estimates. The Khait landslide was simulated using DAN. The number of casualties due to earthquake-triggered landslides in the epicentral region was considerable. Approximately 4000 people were killed in the Yasman valley loess flow as 20 villages (*kishlaks*) were overwhelmed. In the Khait landslide alone we estimate ca. 800 people lost their lives when the villages of Khait and Khisorak were overrun by rapidly moving debris. Our data indicates that a total of approximately 7200 people were killed by earthquake-triggered landslides in the epicentral region of the Khait earthquake and that, in terms of loss of life, the 1949 Yasman valley loess flow was one of the most destructive landslides in recent history.

© 2009 Elsevier B.V. All rights reserved.

1. Introduction

1.1. Earthquake-triggered landslides in the mountains of Central Asia

Earthquake-triggered landslides in rock and soil are a major geological hazard in the mountains of Central Asia. The region is located in the Asia–India continental collision zone where the northward-moving Indian Plate indents the Eurasian Plate (Molnar and Tapponnier, 1975; Fig. 1). The ongoing collision has resulted in high mountain topography which is subject to active deformation, contemporary faulting and frequent strong earthquakes (Gubin, 1960; Burtman and Molnar, 1993; Pavlis et al., 1997), that combine to give rise to widespread landsliding including massive rock slope failure in both the Pamir and Tien Shan Mountains (e.g., Gaziev, 1984; Strom, 1998; Havenith et al., 2003; Strom and Korup, 2006; Evans et al., 2006; Abdrakhmatov and Strom, 2006). In addition, much of

the topography of the region is mantled by Quaternary loess (Goudie et al., 1984; Dodonov, 1991), a material that is particularly prone to flowslides triggered by seismic shaking and/or heavy rains (Gubin, 1960; Ishihara, 1989; Ishihara et al., 1990). For these reasons Tajikistan (population density ~50 persons/km²; Central Intelligence Agency, 2007) is identified as one of the world's landslide hazard hotspots (Fig. 8 in Nadim et al., 2006) and is characterised by some of the highest landslide risk in Central Asia (Fig. 13 in Nadim et al., 2006).

Many earthquake-triggered landslides involving large-scale rock-slope failure occurred in Tajikistan in the twentieth century (e.g., Zolotarev et al., 1986). The best known example is the Usoi rockslide (Fig. 1) triggered by the 1911 Pamir Earthquake (M7.4). The rockslide (est. vol. 2.2 Gm³) dammed the Murgab valley to form the now 75 km long Lake Sarez (Preobrajensky, 1920; Gaziev, 1984; Schuster and Alford, 2004; Evans et al., 2006) and the stability of the rockslide dam is still of current concern (e.g., Rislely et al., 2006).

Although noted by Seed (1968) in his 1967 Terzaghi Lecture, little is known about the landslides triggered by the M7.4 Khait earthquake which struck north-central Tajikistan in July 1949 or their impact on the population of the region. It is the general objective of this paper to fill this knowledge gap.

* Corresponding author. Tel.: +1 519 888 4567x33232; fax: +1 519 746 7484.

E-mail address: sgevans@uwaterloo.ca (S.G. Evans).

¹ Now at Department of Earth Sciences, Simon Fraser University, 8888 University Drive, Burnaby, British Columbia, Canada V5A 1S6.

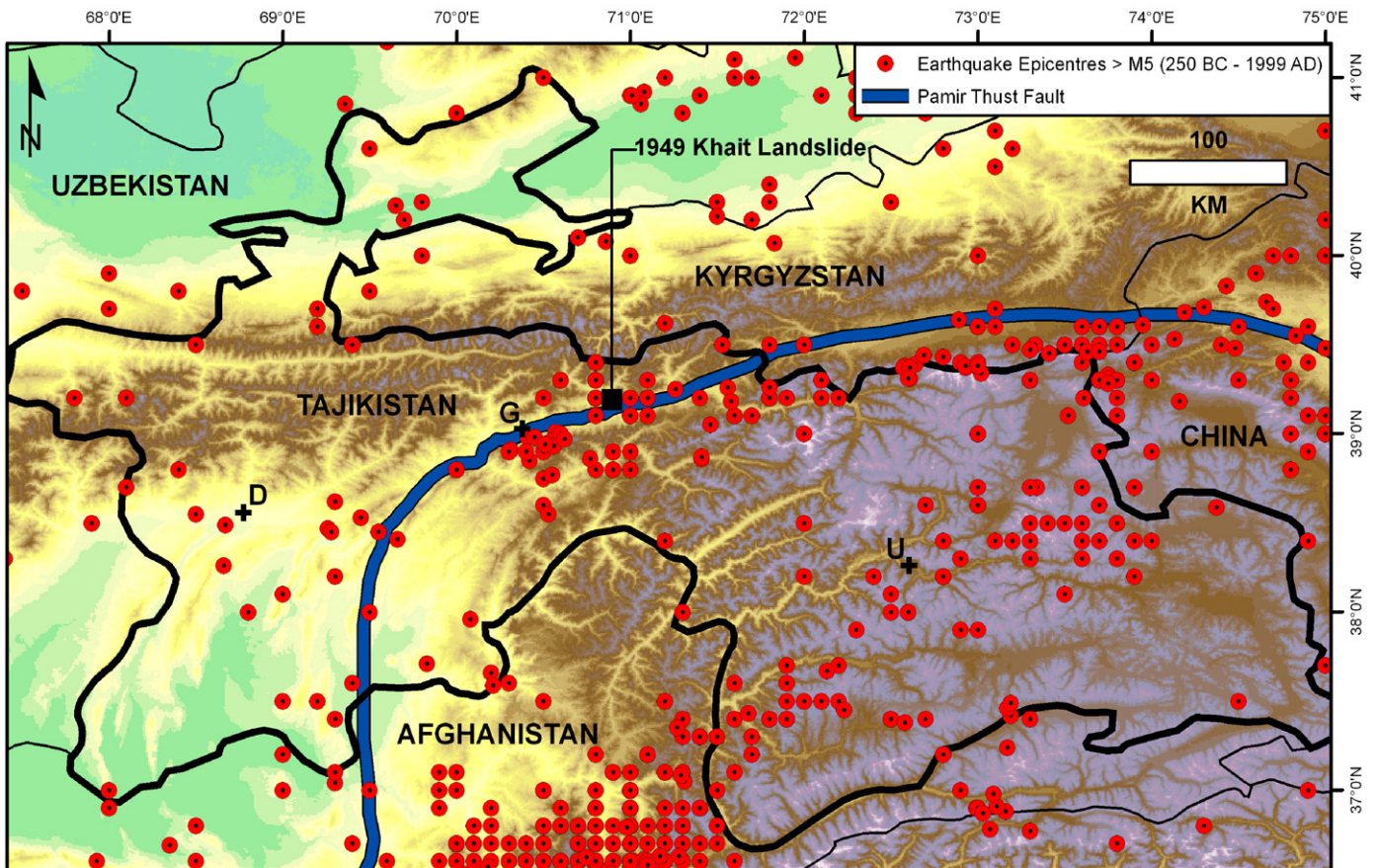


Fig. 1. Map of Tajikistan showing epicentres of earthquakes > M5.0 for the period 250 BC to 1999 AD (Rautian and Leith, 2002) and the location of the 1949 Khait landslide. Thrust fault forming the boundary of the Pamir Salient is marked (Pavlis et al., 1997). Key to letters; D = Dushanbe, G = Garm, U = 1911 Usoi rockslide that impounds Lake Sarez.

1.2. The 1949 Khait² earthquake, Tajikistan

On July 10, 1949 a major earthquake struck a mountainous region near the southern limits of the Tien Shan, 195 km west–northwest of Dushanbe, Tajikistan (Fig. 1). The magnitude of the earthquake has been estimated to be 7.4 (Rautian and Leith, 2002) and the epicentre was located close to the town of Khait (Figs. 1 and 2). The earthquake, known as the Khait earthquake, triggered many landslides in its epicentral region including hundreds of flowslides in loess that in the Yasman valley coalesced to form a massive loess flow that devastated the valley floor (Figs. 3 and 4; Gubin, 1960; Leonov, 1960) burying a large number of *kishlaks*,³ and the Khait landslide that overwhelmed the larger settlements of Khait and Khisorak (Figs. 3 and 5; Panasenko, 1952; Gubin, 1960; Leonov, 1960).

Although the effects of the earthquake have been broadly summarised in a number of Russian-language publications dating from the Soviet era, detailed documentation of the landslides triggered by the earthquake, especially the Khait landslide (Fig. 5), have not been published to date. In addition, the total loss of life in the landslides has never been examined in detail (Yablokov, 2001). The total death toll is variously estimated as being between 5000 and 28,000, in the range of one of the largest regional landslide disasters in recent history (Evans, 2006).

1.3. Objectives and data sources

The objectives of this paper are to 1) review previous work on earthquake-triggered landslides associated with the 1949 Khait earth-

quake, 2) document the catastrophic landslides in the epicentral region, particularly the Yasman valley loess flow (Fig. 3) and the Khait landslide (Figs. 3 and 5), 3) report the results of a first-order dynamic analysis of the Khait landslide, and 4) quantify the impact of the landslides on communities in the epicentral area including an estimate of casualties.

The present paper is based on 1) a review of the literature on landslides triggered by the Khait earthquake, written mostly in Russian and dating from the Soviet era, 2) examination of large-scale topographic maps of the Khait area, 3) analysis of satellite imagery 4) analysis of digital terrain data from the Shuttle Radar Topography Mission (SRTM) and the recently released ASTER Global Digital Elevation Model, and 5) field investigations in the Khait area of Tajikistan in 2006. The WGS84 datum was used as the spatial reference in this paper.

2. Geological characteristics of the Khait area

2.1. Seismotectonics

The Khait area is situated near the southern limit of the Tien Shan Mountains, just north of the Surkhob River which runs from north-east to southwest marking the boundary of the Tien Shan and the Tajik Depression to the southeast (Fig. 1). As noted above, the area is located within the Asia–India collisional zone, on the northern edge of the Pamir salient which marks the active indentation of the India Plate into Eurasia (Fig. 1; Molnar and Tapponnier, 1975; Burtman and Molnar, 1993; Lukk et al., 1995). Khait is on the northwest edge of the Vakhsh Overthrust, a major low-angle thrust that marks the edge of deformation associated with the continental collision (Pavlis et al., 1997; Skobelev, 1977; Burtman and Molnar, 1993; Fig. 1). The Surkhob River follows the thrust zone and fluvial erosion by the Surkhob may be an important component of the thrusting mechanism (Lukk et al., 1995; Pavlis et al.,

² Alternative spellings of Khait are Hait, Kait.

³ A *kishlak* is "a densely-settled agricultural rural village in Central Asia consisting of 50 or more houses built in a relatively small area" (Christensen and Levinson, 2002).

Download English Version:

<https://daneshyari.com/en/article/4744515>

Download Persian Version:

<https://daneshyari.com/article/4744515>

[Daneshyari.com](https://daneshyari.com)