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The Hattian Bala rock avalanche and associated landslides triggered by the Kashmir Earthquake of 8 October 2005

S.A. Dunning *, W.A. Mitchell, N.J. Rosser, D.N. Petley

International Landslide Centre. Department of Geography, Durham University, Science Site, Durham. DH1 3LE, United Kingdom

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Abstract

The Kashmir Earthquake of the 8 October killed an estimated 87 350 people, 25 500 through co-seismic landslides. The largest landslide associated with the earthquake was the 68×10^6 m^3 Hattian Bala rock avalanche that destroyed a village and killed around 1000 people. The deposit blocks the valley to a depth of 130 m impounding a lake that reached the dam-crest in April 2007. An outburst flood now threatens a major settlement 3 km downstream. A series of space images reveals landslide clusters in the rock avalanche source area prior to the earthquake. The images also reveal a large slow-moving landslide with its toe in the lake, failure of this landslide may induce dam failure through overtopping and scour. Eighty five landslides in the Hattian Bala catchment predate the shaking of 8 October 2005, a further 73 are co-seismic with the main shock, and 21 postdate it in the period up to October 2006. Landslide magnitude–frequency distribution plots derived from satellite images allow an assessment of the contribution of seismically triggered events as compared to background rates of activity.

Keywords: Rock avalanche; Landslide dam; Kashmir Earthquake; Landslide distribution; Landslide fatality; Pakistan

1. Introduction

On the 8th October 2005 a magnitude 7.6 earthquake and subsequent aftershocks for the following months struck the Lesser Himalaya of northern Pakistan devastating the region of Pakistani administered Kashmir and to a lesser extent parts of Indian administered Kashmir (Fig. 1). It is estimated that around 87 350 people died in Pakistan and 10 300 in India (Hussain et al., 2006); of this number in the order of 26 500 were as a direct result of landslides (Petley et al., 2006). Within these statistics are the largest single-cause loss of life event triggered by the earthquake, the Hattian Bala rock avalanche that destroyed a village and killed an estimated 1000 people, 1.1% of the total earthquake fatalities, and 3.7% of the deaths caused by landslides and so one of the more devastating recorded historical landslide events (see Alexander, 1989 and Petley et al., 2005 for historic landslide fatality statistics). The total number of landslides mapped for the earthquake is currently 2424 though this includes some number of pre-existing slide masses (Sato et al., In press) and will underrepresent those slides with current displacement below the resolution of the sensor used for identification. Of prime concern for future risk management is the landslide dam formed by the Hattian Bala rock-avalanche deposit and the evolution of the surrounding destabilised slopes now threatening the impounded lake. Stability analyses and monitoring of the rates of lake filling are currently being undertaken by the Pakistani Army and

* Corresponding author. Tel.: +44 191 3341918; fax: +44 191 3341800.
E-mail address: s.a.dunning@dur.ac.uk (S.A. Dunning).

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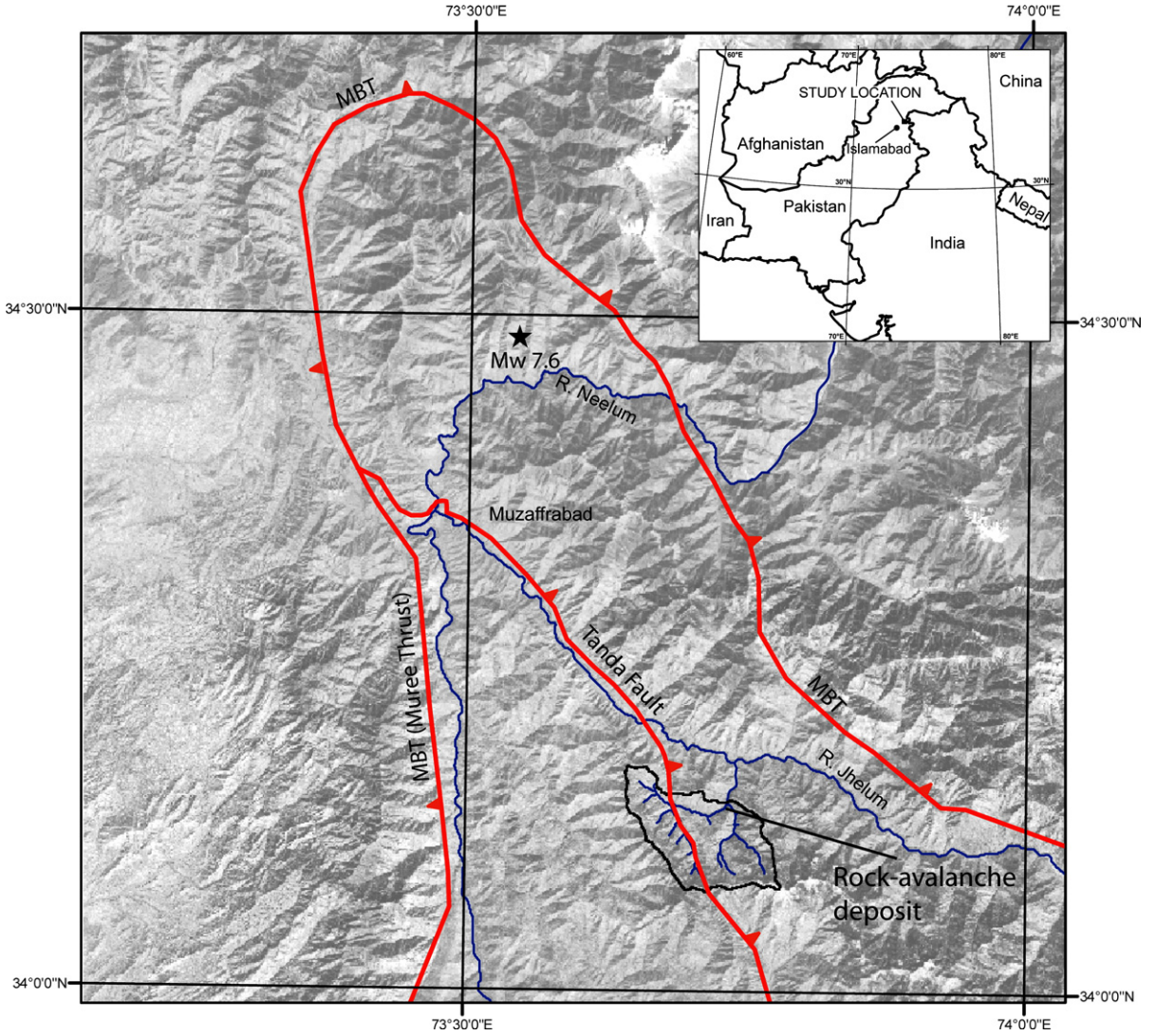

Fig. 1. Overview map of the study catchment and the broad scale regional tectonics of northern Pakistan.

Geological Survey of Pakistan and considerable engineering works have taken place to create a spillway over the dam. This paper reports on the geomorphology and geometry of the Hattian Bala rock-avalanche deposit and the landslide distribution in the upstream catchment both predating and postdating the seismic shaking.

1.1. Geological setting of the 8 October earthquake

The western termination of the Himalaya in which the earthquake struck is structurally complex but broadly defined by a major anticline, the Hazara–Kashmir Syntaxis (Calkins et al., 1975). The Hazara–Kashmir Syntaxis is bounded to the west by the Murree Thrust which brings westerly Hazara Formation phyllites and slates over Miocene Murree Formation siltstones and sandstones. The Murree Thrust (also termed the Jhelum Fault), trends N–S in the region of Muzaffrabad (Fig. 1) before turning to the south-east further north, defining the Main Boundary Thrust (MBT) in this region (Avouac et al., 2006). It is at Muzaffrabad that the Murree Thrust intersects with the Muzaffrabad Fault (also termed Jhelum Thrust or Balakot–Bagh Fault) and its south-eastern continuation, the Tanda Fault. The Muzaffrabad Fault exhibits an opposite sense of motion to the Murree Thrust and has brought Neoproterozoic Muzaffrabad Formation dolomites south-westerly over Murree Formation rocks.

The complex structural setting and ongoing tectonics control much of the current landscape. The Jhelum