Geomorphology 125 (2011) 109–121

Contents lists available at ScienceDirect

Geomorphology

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

Catastrophic partial drainage of Pangong Tso, northern India and Tibet

Jason M. Dortch [a,*], Lewis A. Owen [a], Marc W. Caffee [b], Ulrich Kamp [c]

[a] Department of Geology, University of Cincinnati, Cincinnati, OH 45221, USA
[b] Department of Physics/PRIME Laboratory, Purdue University, West Lafayette, IN 47906, USA
[c] Department of Geography, The University of Montana, Missoula, MT 59812-1018, USA

ARTICLE INFO

Article history:
Received 30 April 2010
Received in revised form 25 August 2010
Accepted 27 August 2010
Available online 18 September 2010

Keywords:
Floods
Ladakh
Himalaya
^{10}Be dating
Strath terraces
Pangong Tso

ABSTRACT

Catastrophic partial drainage of Pangong Tso, one of the largest lakes in Tibet, is supported by the geomorphology of the Tangtse Valley, Ladakh, northern India and cosmogenic ^{10}Be nuclide ages of roche moutonnées, strath terraces, and a flood deposit downstream from the former spillway. The former spillway for Pangong Tso is ~20-m-high and likely allowed ~18 km^3 of water to drain catastrophically down the Tangtse Valley over a period of about 2 days sometime during the latest Pleistocene to early Holocene. The largest flood deposit, composed of imbricated granitic boulders up to 4.5 m in length, is present ~33 km downvalley of the spillway. These boulders have a cosmogenic ^{10}Be exposure age of 11.1 ± 1.0 ka, the age of the outburst flood. The minimum calculated discharge was ~110,000 m^3 s^{-1}. One set of strath terraces, upvalley of the flood deposit along the flood's drainage path, shows that the rate of fluvial incision 0.3 ± 0.1 mm y^{-1} during 122–10.5 ka increased to 1.5 ± 0.5 mm y^{-1} during 10.5 ka to the present. The temporal overlap of this increase in the rate of fluvial incision with the main flood deposit suggests that the flood was important in defining the incision along the Tangste valley. A second set of strath terraces shows little change in incision, from ~0.6–0.9 to ~0.9–1.4 mm y^{-1}, sometime between 18 and 27 ka. Roche moutonnées, upvalley from strath terraces, yield a cosmogenic ^{10}Be age of 35.8 ± 3.0 ka, defining the time when glaciers last occupied the Tangtse valley. However, the lack of glacial sediment along the Tangste valley suggests that the flood eroded glacial depositional landforms and sediments resulting in high sediment loads in the floodwater, which in turn increased fluvial incision to form strath terraces. Much of the eroded glacial sediment was subsequently redeposited as the main flood deposit. The catastrophic drainage of Pangong Tso may be the result of breaching of the Pangong–Tangste spillway during very high lake levels in a period of intensified monsoon (10.7–9.6 ka) and/or possibly the consequence of seismic activity along the Karakoram Fault that is associated with the initial formation of Pangong Tso.

1. Introduction

Catastrophic flooding associated with the sudden release of water impounded by glaciers, moraines, and landslides in high relief, high topography environments such as the Himalaya has a profound impact on the evolution of mountain landscapes, such as in the Himalaya (Hewitt, 1964, 1982; Ives, 1986; Vuichard and Zimmermann, 1987; Liu and Sharma, 1988; Yamada, 1993; Mool, 1995; Coxon et al., 1996; Reynolds, 1998; Richardson and Reynolds, 2000; Ballantyne, 2002, 2004; Korup and Montgomery, 2008; Seong et al., 2009). There are many large structurally controlled lakes in the Himalayan–Tibetan orogen, which potentially have significantly higher flood discharge and longer duration than more typical GLOFs. Such large events may affect the sediment budget and the distribution and preservation of landforms in high relief, high topography environments (Coxon et al., 1996). However, catastrophic flooding from bedrock dam failure is not common so its impact on mountain landscapes has not been fully assessed. In this paper, we examine evidence of a paleo-flood produced by the failure of a bedrock dam including: its deposit, resultant landforms, and the impact on the landscape development of the region.

Our study is centered in the Tangtse valley in the Pangong Range of the Transhimalaya. In the Tangtse valley, a series of flood deposits and strath terraces are present together with many well-preserved alluvial fans, lacustrine deposits, and roche moutonnées (Figs. 1 and 2). Our study focuses on examining these landforms and determining their origins using geomorphic mapping, remote sensing imagery, and cosmogenic ^{10}Be exposure dating. The late Quaternary and Holocene geomorphic evolution of the Tangtse valley is complex; but through our analysis of the various landforms present (in particular flood deposits and strath terraces), we are able to show that the valley's present morphology and distribution of landforms can be linked to a catastrophic outburst of water from Pangong Tso. Insights into quantitative aspects of erosion and deposition during this outburst flood were gained using Hydrologic Engineering Centers River Analysis System 4.0.

* Corresponding author. Now at Department of Chemical and Physical Sciences, University of Toronto Mississauga, Mississauga, ON L5L 1C6, Canada. Tel.: +1 905 8285397.
E-mail address: jason.dortch@utoronto.ca (J.M. Dortch).

0169-555X/$ – see front matter © 2010 Elsevier B.V. All rights reserved.
doi:10.1016/j.geomorph.2010.08.017

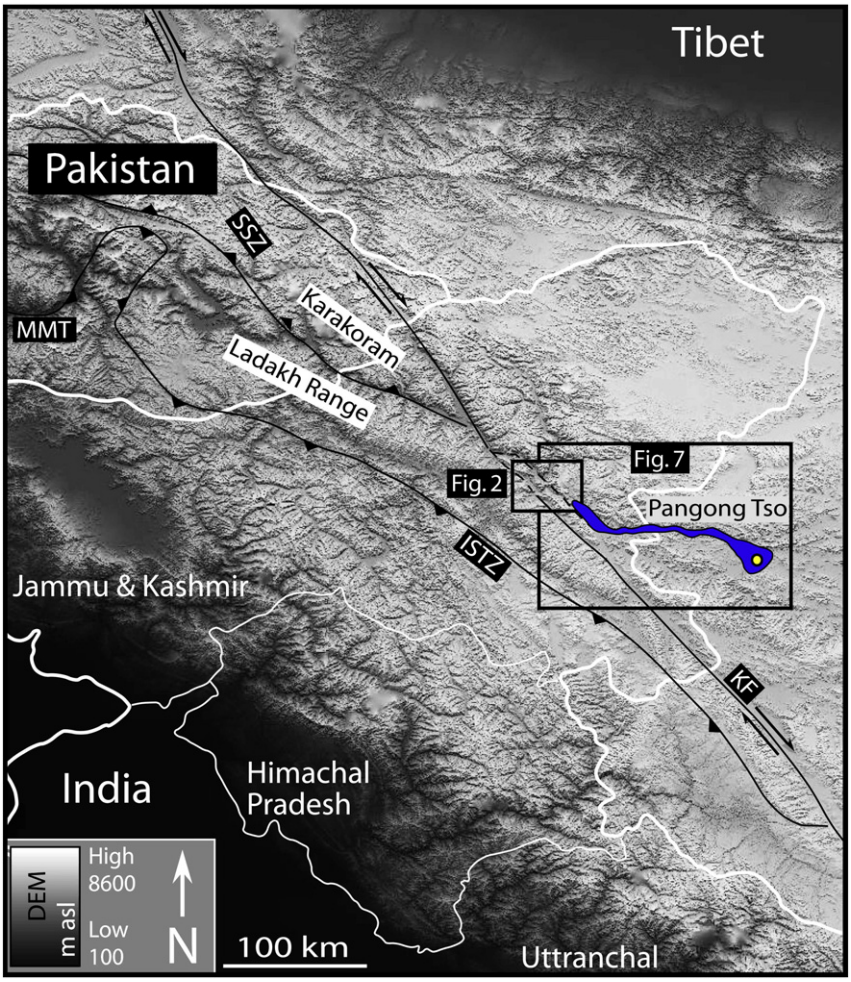

Fig. 1. SRTM DEM of the NW Indian Himalaya. The field area is highlighted by a box labeled "Fig. 2." Yellow dot marks the location of the sediment cores taken by Gasse et al. (1996).

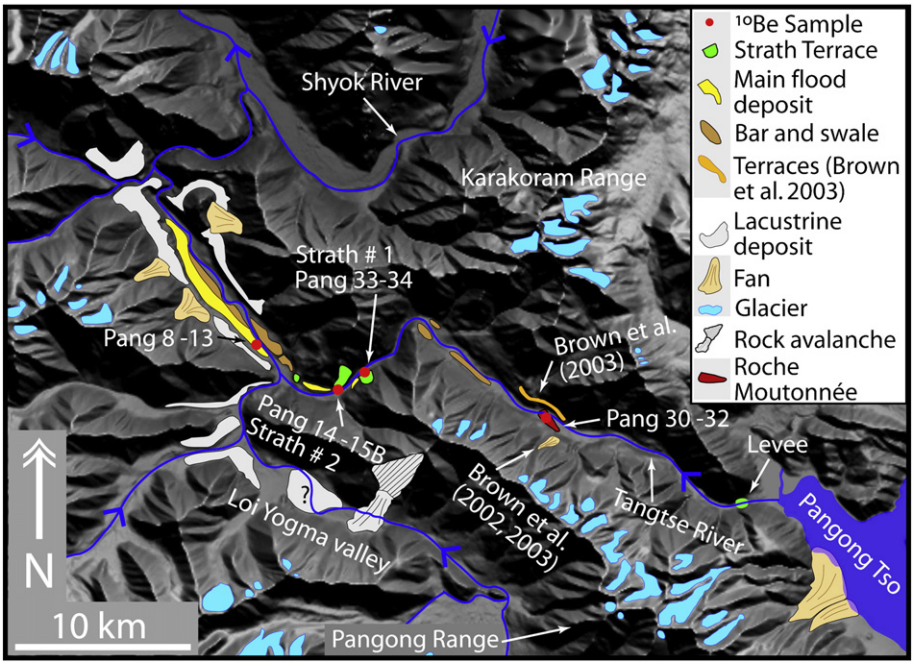

Fig. 2. Hillshade SRTM DEM with locations of mapped landforms. Contemporary glaciers in the Tangtse Valley are only present on the northern side of the Pangong Range.