REPOSITORIO
INAIGEM

The 2020 glacial lake outburst flood process chain at Lake Salkantaycocha (Cordillera Vilcabamba, Peru)

Recent Landslides

Landslides
DOI 10.1007/s10346-021-01670-0
Received: 20 February 2021
Accepted: 5 April 2021
© Springer-Verlag GmbH Germany part of Springer Nature 2021

Oscar Vilca · Martin Mergili · Adam Emmer · Holger Frey · Christian Huggel

The 2020 glacial lake outburst flood process chain at Lake Salkantaycocha (Cordillera Vilcabamba, Peru)

Abstract Glacial lakes represent a threat for the populations of the Andes and numerous disastrous glacial lake outburst floods (GLOFs) occurred as a result of sudden dam failures or dam overtoppings triggered by landslides such as rock/ice avalanches into the lake. This paper investigates a landslide-triggered GLOF process chain that occurred on February 23, 2020, in the Cordillera Vilcabamba in the Peruvian Andes. An initial slide at the SW slope of Nevado Salkantay evolved into a rock/ice avalanche. The frontal part of this avalanche impacted the moraine-dammed Lake Salkantaycocha, triggering a displacement wave which overtopped and surficially eroded the dam. Dam overtopping resulted in a far-reaching GLOF causing fatalities and people missing in the valley downstream. We analyze the situations before and after the event as well as the dynamics of the upper portion of the GLOF process chain, based on field investigations, remotely sensed data, meteorological data and a computer simulation with a two-phase flow model. Comparison of pre- and post-event field photographs helped us to estimate the initial landslide volume of 1–2 million m³. Meteorological data suggest rainfall and/or melting/thawing processes as possible causes of the landslide. The simulation reveals that the landslide into the lake created a displacement wave of 27 m height. The GLOF peak discharge at the dam reached almost 10,000 m³/s. However, due to the high freeboard, less than 10% of the lake volume drained, and the lake level increased by 10–15 m, since the volume of landslide material deposited in the lake (roughly 1.3 million m³) was much larger than the volume of released water (57,000 m³, according to the simulation). The model results show a good fit with the observations, including the travel time to the uppermost village. The findings of this study serve as a contribution to the understanding of landslide-triggered GLOFs in changing high-mountain regions.

Keywords GLOF · High-mountain areas · Impact wave · Moraine-dammed lake · Process chain · Rock avalanche

Introduction
Continued retreat of glaciers often leads to the formation of glacial lakes, retained behind stable rock dams (i.e. occupying glacier overdeepenings) or dammed by potentially unstable moraine dams. Such lakes can drain suddenly, releasing large amounts of water that can result in complex and potentially catastrophic downstream process chains. Glacial lake outburst floods (GLOFs) have been the subject of numerous studies covering many mountain regions around the world (Hewitt 1982; Haeberli 1983; Richardson and Reynolds 2000; Huggel et al. 2003; Breien et al. 2008; Hewitt and Liu 2010; Bolch et al. 2011; Mergili and Schneider 2011; Mergili et al. 2013; Clague and O'Connor 2014; Emmer et al. 2015, 2020; Sattar et al. 2019a, 2019b; Turzewski et al. 2019).

In the Andes of Peru, there has been a series of GLOF events in the past with devastating consequences in some cases (Carey 2010; Portocarrero 2014; Emmer 2017). An example of a recent GLOF process chain is the drainage of a subglacial lake and subsequent dam overtopping of downstream located Lake Chojñacota in the Cordillera Apolobamba (Titicaca Basin, Puno Region), which happened on November 19, 2020 (Vilca 2019). Subject of the present study is the outburst at Lake Salkantaycocha, which occurred on February 23, 2020, and resulted in a far-reaching catastrophic flood (Vilca 2020).

Given the recurrence of this type of phenomenon, event reconstruction using flow models and simulation tools can help to better understand some of the key mechanisms of such landslide GLOF process chains typical for glacierized high-mountain areas. In addition, well-documented case studies are important to better understand which questions can be addressed by simulation tools and which questions require further on-site investigations in the field (Mergili et al. 2020).

The objective of this study is to characterize and better understand the processes involved in the GLOF process chain at Lake Salkantaycocha on February 23, 2020. Field investigations, terrestrial photos and satellite scenes are employed to reconstruct the situations before and after the event. The r.avaflow tool (Mergili and Pudasaini 2020) is used to reconstruct the dynamics of the initial part of the process chain.

Study area
The Vilcabamba mountain range is mainly formed by Lower Paleozoic metamorphic rocks, intrusive rocks of Permian-Triassic age as well as sedimentary rocks of Mesozoic and Cenozoic age (Carlotto et al. 2017). The highest parts of the Salkantay massif are formed by igneous intrusions (Cordillera Occidental formation) while the eastern flanks are surrounded by sedimentary and partly metamorphic rocks of the Ordovician age and sedimentary rocks of the Permian-Triassic age (Mitu group). The southern and western flanks of the Salkantay massif are formed by partly metamorphosed sediments of Precambrian to Devonian age (Paki group). A complex system of north-south oriented parallel fault zones with perpendicular faults was mapped in the vicinity of the Salkantay massif (IGM 1975). The environment at Lake Salkantaycocha is composed mostly of igneous rocks belonging to the intrusive Machu Picchu Formation of Permian-Triassic age, characterized by granitic rocks; likewise, there are Precambrian metamorphic rocks from the Incabamba Complex (mica-schist interspersed with gneiss and amphibolite). These units have subsequently been covered by quaternary deposits of glacial, fluvio-glacial and colluvial origin.

Air masses coming from the Amazon Basin in the north and east govern the climatic conditions, resulting in a dry season in the austral winter (April–September) and a wet season in the austral summer (October–March). Annual precipitation amounts to more than 2000 mm, about 75% of which occur during the wet period from October to March (Frey et al. 2016).

The Vilcabamba mountain range has been the scene of various disastrous events, particularly in the basins of the Sacsara and Aobamba rivers. In 1998, four consecutive debris flow events were

Landslides

Published online: 15 April 2021

Autor

Vilca, Oscar
Mergili, Martin
Emmer, Adam
Frey, Holger
Huggel, Christian

Enlace de descarga

https://doi.org/10.1007/s10346-021-01670-0