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Hydrology

The Shovi Debris Flow Disaster: Causes, Expected Risk, Forecast and Protection

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Abstract. This paper examines the potential causes of the debris flow formation on the Buba River at the Shovi resort on August 3, 2023, with a particular focus on the role of water discharge in the formation process. Based on the conducted theoretical research, it can be concluded that a stony-mud debris flow occurred on the Buba River. The primary causes, alongside rockfalls, the calving of ice from the glacial tongue, and increased water accumulation within glacial crevasses, likely included a temporary, short-lived obstruction of the riverbed at the headwaters by rock avalanches and glacial moraines. The paper also provides information regarding the risk of recurrent debris flow generation within the Buba River channel and outlines corresponding protective measures. *© 2026 Bull. Natl. Acad. Sci. Georg.*

Keywords: debris flow, water runoff, erosion, glacier, climate, radiosounding

Introduction

Processes associated with global climate change have significantly exacerbated glacial hazards worldwide, as evidenced by the catastrophic events at the Jankuati, Kolka, and Devdorak glaciers. Despite modern remote sensing and monitoring technologies, determining the potential location and timing of such glacial catastrophes remains highly problematic. Specifically, there is a substantial deficit of observational data required to assess the processes occurring on the Buba Glacier over recent decades. Consequently, it is improbable that an accurate virtual model of the glacial debris flow in the Buba Valley could have been conceived that would match the scale of the actual event.

The natural disaster (the formation of a debris flow) that occurred on August 3, 2023, in the resort town of Shovi, Oni Municipality, is one of the gravest tragedies in the history of Georgia, claiming the lives of 33 people. A catastrophic event of this magnitude has not been recorded in the region within the last century. While there are reports that debris flows have occurred in the Buba River catchment area previously, they were of significantly lower intensity compared to the 2023 disaster and did not cause substantial damage to the Shovi settlement. This paper seeks to evaluate the

factors contributing to the formation of the debris flow, specifically focusing on the mechanisms of water flow generation, and to analyze the associated potential risks.

Main Part

The Buba River originates on the southern slope of Mount Buba at an elevation of 2,970 meters above sea level and joins the Chanchakhi River near the Shovi resort at an altitude of 1,520 meters. The river is 9.97 kilometers long, with a catchment area of 41.3 square kilometers.

Essential research materials are contained in the National Environmental Agency's report evaluating the natural processes in the Buba River valley on August 3, 2023. This report was prepared based on the study conducted by the Swiss specialized company GEOTEST AG, titled "Georgia, Shovi Disaster, Event Analysis" (Report Nr. 1423094.1; 28.11.2023). It provides a compelling presentation of the primary causes of the debris flow formation, identifying them as follows: a rock avalanche in the high periglacial zone of the Buba Glacier, likely triggered by a seismic event and climate change factors. The collapsed rock mass was supplemented by glacial fragments and excessively saturated eroded material from the slopes within the river channel. The total volume of the debris mass at the alluvial fan reached approximately 1 million cubic meters. According to the debris flow classifications recognized in Georgia (Gagoshidze, 1970; Natishvili, 1988; Natishvili and Tevradze, 2007; Vinogradov, 1980), the natural catastrophic event of August 3, 2023, was a stony-mud debris flow. Furthermore, the disaster occurred due to the overlap/superposition of several natural factors, making accurate prediction impossible.

A particularly significant element related to the Buba Glacier catastrophe is the recording of seismic vibrations generated by the glacier collapse. These recordings clearly indicate that two destructive events occurred on the Buba Glacier within an interval of several seconds; these are more closely associated with a rockfall than with the calving of ice from the glacial tongue. According to witnesses of the event in Shovi, the acoustic wave served as the first alarm signal. Thus, it can be assumed that rockfalls or icefalls on the Buba Glacier were among the triggering causes of the destruction process.

There is a hypothesis that the rock avalanche on the Buba Glacier could have breached the integrity of subglacial water reservoirs, and the subsequent release of a large volume of water triggered the glacial debris flow. The impact of global climate change is particularly pronounced on the upper part of the glacier, where the slope gradient is steeper than in the lower section; therefore, the reduction in ice thickness could have been a primary cause of the collapse on the Buba Glacier. Consequently, there remains a possibility of new collapses on the Buba Glacier and the recurrence of debris flows in the valley. Accordingly, one of the vital tasks is monitoring the thickness of the Buba Glacier, especially in its upper reaches. For this purpose, the radio-echo sounding method is particularly effective, as it determines the magnitude of shear stress at the glacier bed and the difference between the elevation of the glacier crest and its base using the following formula (Lavrentyev et al., 2014):

$$\tau = 0.005 + 1.598\Delta H - 0.435\Delta H^2, \qquad (1)$$

$$h = \frac{\tau}{\beta \rho g \sin\alpha} \cdot c, \qquad (2)$$

h is the ice thickness; β is the shape factor of the glacier's cross-section; ρ is the density of the ice; g is the gravitational acceleration, α is the angle of surface inclination relative to the horizontal plane; c is a quantitative coefficient.

Evidence suggests the sliding of the collapsed rocks occurred over the ice surface and the proglacial area, from where it migrated to the relatively lower elevations of the river's headwaters. It is of critical importance to determine the factors governing the subsequent movement of the debris mass (debris flow) within the channel

along the course of the Buba River toward the Shovi settlement. This is particularly relevant given that the transport of a debris flow along the entire length of a river channel is impossible without sufficient water discharge. Consequently, we have attempted to establish the extent to which water runoff influenced the formation and mobilization of the debris flow during the catastrophe.

When the water discharged from glacial reservoirs into the river channel encounters resistance from various types of eroded rock material and embedded stagnant ice fragments, the riverbed can become obstructed for a short period, leading to the formation of a so-called temporary natural dam. Once a critical volume of water accumulates behind this natural dam sufficient to breach the obstruction, the dam collapses, generating a stony-mud debris flow. Furthermore, it can be hypothesized that the development of this catastrophic event was facilitated by the breach of integrity of subglacial water reservoir(s) in specific local areas of the glacier. This would have caused a spontaneous discharge of water, a process typically accompanied by vibrations. It is possible that at least two reservoirs, separated by ice partitions, were breached, although such a hypothesis remains tentative. Indeed, if there were only a single water reservoir, its ice wall might have initially collapsed to a certain level before the remaining portion failed after a brief delay. While empirical evidence to confirm this specific process is lacking, it cannot be disregarded.

Based on the aforementioned factors, it must be assumed that the natural catastrophic event of August 3, 2023, likely occurred due to these specific causes, as the degree of flow turbulence in the main part of the valley was critically high. This is evidenced by the large-diameter rocky material and boulders present on the alluvial fan of the debris flow. The transport of boulders with such substantial diameters and weights within a flow would be impossible without an equivalent volume of water. While it is true that detached rock masses or glacial fragments can move over short distances due to gravitational force and steep gradients, their continued movement as part of a debris flow could not have occurred without a sufficient volume of water discharge.

Since appropriate field studies could not be conducted at the time, an attempt was made to evaluate the presence and significance of water discharge within the debris flow during its formation through theoretical research, based on the principle “that water discharge is one of the most critical factors during a debris flow event.“

According to the report presented by the Agency, the total volume of erosion-debris material formed in the Buba River basin is estimated to be between 2.5 to 3 million cubic meters. Simulation models indicate that the quantity of solid sediment transported to the alluvial fan amounted to 0.8-1 million cubic meters. This volume of sediment at the alluvial fan is identical to the amount calculated using our methodology (Gvishiani et al., 2025). The report also indicates that a certain volume of material remains in the transit and headwater zones of the valley, which continues to pose a significant hazard.

Conclusions and Recommendations

- The catastrophe that occurred on the Buba River at the Shovi resort on August 3, 2023, was a natural event of a magnitude from which total protection is virtually impossible. As for the objective cause of the debris flow, it must have been contributed to by the processes that developed on the glacier. The stream formed in the Buba River gorge was of a stony-muddy nature. The collapse of the Buba Glacier is a complex process preceded by a series of environmental conditions linked to global climate change. The reduction of ice thickness in the upper reaches of the Buba Glacier led to an increase in water accumulation within glacial crevasses and the formation of ice seracs (towers), whose displacement was accelerated

by intensive melting processes. The collapse of these ice structures within the glacial bed resulted in the destruction of ice and water reservoirs, causing a glacial debris flow to propagate through the river channel.

- In addition, at the headwaters of the Buba River, it was possible for the riverbed to be temporarily blocked by collapsed rock avalanches and ice moraines, forming a natural dam, created by rock avalanches and glacial moraines. This dam likely impounded specific volumes of water runoff; upon reaching a critical threshold, the hydrostatic pressure breached the natural barrier. The energy released by this accumulated water provided the necessary impulse to mobilize the debris mass along the river channel. This hypothesis is supported by the debris flow velocity calculated through simulation, which reached 35-40 m/s. During its progression, the flow was further augmented by eroded material from the slopes, increasing the overall volume of the debris stream.
- To protect against similar natural disasters, it is essential to implement continuous monitoring using modern Geographic Information Systems (GIS), including drones, to identify hazardous zones in a timely manner and implement appropriate protective engineering measures. Despite advances in monitoring technologies, determining the exact location and timing of such catastrophic events remains problematic. This underscores the clear need for long-term monitoring and comprehensive diagnostics of the current state of Caucasian glaciers, incorporating every new empirical observation and case studies.

ჰიდროლოგია

შოვის ღვარცოფული კატასტროფა: მიზეზები, მოსალოდნელი რისკი, პროგნოზი და დაცვა

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