СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

Труды
8-й Международной конференции

Тбилиси, Грузия, 6–10 октября 2025 г.

Ответственные редакторы
С.С. Черноморец, Г.В. Гавардашвили, К.С. Висхаджиева

ООО «Геомаркетинг»
Москва
2025

DEBRIS FLOWS: Disasters, Risk, Forecast, Protection

Proceedings
of the 8th International Conference

Tbilisi, Georgia, 6–10 October 2025

Edited by
S.S. Chernomorets, G.V. Gavardashvili, K.S. Viskhadzhieva

Geomarketing LLC
Moscow
2025

ღვარცოფები: კატასტროფები, რისკი, პროგნოზი, დაცვა

მე–8 საერთაშორისო კონფერენციის მასალები

თბილისი, საქართველო, 6–10 ოქტომბერი, 2025

რედაქტორები
ს. ს. ჩერნომორეც, გ. ვ. გავარდაშვილი, კ.ს. ვისხაჯიევა

შპს „გეომარკეტინგი“
მოსკოვი
2025

УДК 551.311.8
ББК 26.823
С29

Селевые потоки: катастрофы, риск, прогноз, защита. Труды 8-й Международной конференции (Тбилиси, Грузия). – Отв. ред. С.С. Черноморец, Г.В. Гавардашвили, К.С. Висхаджиева. – Москва: ООО «Геомаркетинг», 2025. 496 с.

Debris Flows: Disasters, Risk, Forecast, Protection. Proceedings of the 8th International Conference (Tbilisi, Georgia). – Ed. by S.S. Chernomorets, G.V. Gavardashvili, K.S. Viskhadzhieva. – Moscow: Geomarketing LLC, 2025. 496 p.

ღვარცოფები: კატასტროფები, რისკი, პროგნოზი, დაცვა. მე–8 საერთაშორისო კონფერენციის მასალები. თბილისი, საქართველო. – პასუხისმგებელი რედაქტორები ს.ს. ჩერნომორეც, გ.ვ. გავარდაშვილი, კ.ს. ვისხაჯიევა. – მოსკოვი: შპს „გეომარკეტინგი“, 2025. 496 с.

Ответственные редакторы: С.С. Черноморец (МГУ имени М.В. Ломоносова), Г.В. Гавардашвили (Институт водного хозяйства имени Цотне Мирцхулава Грузинского технического университета), К.С. Висхаджиева (МГУ имени М.В. Ломоносова).

Edited by S.S. Chernomorets (M.V. Lomonosov Moscow State University), G.V. Gavardashvili (Tsotne Mirtskhulava Institute of Water Management, Georgian Technical University), K.S. Viskhadzhieva (M.V. Lomonosov Moscow State University).

При создании логотипа конференции использован рисунок из книги С.М. Флейшмана «Селевые потоки» (Москва: Географгиз, 1951, с. 51).

Conference logo is based on a figure from S.M. Fleishman’s book on Debris Flows (Moscow: Geografgiz, 1951, p. 51).

ISBN 978-5-6053539-4-2

Shovi catastrophic debris flow

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Abstract. The Shovi catastrophic debris flow, which occurred on August 3, 2023, developed in the gorge of the right tributary of the Chanchakhi River – the Bubustskali River. It is formed in Jurassic and Lower Cretaceous sedimentary rocks and creates a sharply expressed erosion-denudation relief. The Buba Glacier has been actively retreating over the past decades due to intense melting. In parallel with this process, the glacier's front, bottom and side moraines were exposed. Their material consists of unprocessed boulders, between which snow accumulated in winter. It did not have time to melt completely in summer. At the end of July 2023, extremely hot days and torrential rains alternated in Upper Racha, the alternation of which with active ablation sharply increased the saturation of the moraine material with liquid mass. As a result, the gravitational equilibrium of solid material was disrupted, and the accumulated rain and melted snow water, together with the swollen river flow, carried a large amount of solid mass into the valley, which, upon entering the forest zone, also tore off weakly rooted coniferous plants from the slopes. All this descended at great speed towards Shovi and destroyed the resort buildings. The Shovi tragedy clearly demonstrates the complexity and unpredictability of natural processes, as well as human criminal carelessness and ignorance of these processes.

Key words: *debris flow, sedimentary rocks, moraines, ablation*

Cite of this article: Lominadze G., Gongadze M., Kavlashvili G. Shovi catastrophic debris flow. In: Chernomorets S.S., Gavardashvili G.V., Viskhadzhieva K.S. (eds.) Debris Flows: Disasters, Risk, Forecast, Protection. Proceedings of the 8th International Conference (Tbilisi, Georgia). Moscow: Geomarketing LLC, 2025, p. 246–251.

Катастрофический сель в Шови

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Аннотация. Катастрофический сель Шови, произошедший 3 августа 2023 г., образовался в долине р. Бубусцкали – правого притока реки Чанчахи. Он был сформирован преимущественно в юрских и нижнемеловых осадочных породах в условиях резко выраженного эрозионно-денудационного рельефа. Ледник Буба активно отступает в течение последних нескольких десятилетий из-за интенсивного таяния. Параллельно с этим процессом обнажались фронтальная, нижняя и боковые морены ледника. Их материал состоит из неокатанных валунов, между которыми зимой скапливается снег, который летом полностью не тает. В конце июля 2023 г. в Верхней Раче чередовались экстремально жаркие дни и проливные дожди, чередование которых с активной абляцией резко увеличило насыщенность моренного материала жидкой массой. В результате гравитационный баланс твердого материала был нарушен, а накопившиеся дождевые и талые воды вместе с речным потоком вынесли в долину большое количество твердой массы, которая, попав в лесную зону, срывала со склонов слабо укоренившиеся хвойные растения. Все это на огромной скорости обрушилось на Шови и разрушило здания курорта, в результате чего погибло 35 человек. Трагедия Шови наглядно демонстрирует сложность и непредсказуемость природных процессов, а также преступную халатность и незнание этих процессов со стороны человека.

Ключевые слова: *грязевой поток, осадочные породы, морены, абляция*

Ссылка для цитирования: Гонгадзе М., Ломинадзе Г., Кавлашвили Г. Катастрофический сель в Шови. В сб.: Селевые потоки: катастрофы, риск, прогноз, защита. Труды 8-й Международной конференции (Тбилиси, Грузия). – Отв. ред. С.С. Черноморец, Г.В. Гавардашвили, К.С. Висхаджиева. – М.: ООО «Геомаркетинг», 2025, с. 246–251.

Introduction

Racha, known for its frequent exodynamic processes and the resulting damage to the environment and population, is one of the most challenging regions in Georgia. The aim of our research is to study these processes, identify their causes, and observe patterns of development. The region experiences a variety of natural phenomena, such as riverine erosion, debris flows, denudation-gravitational processes, and snow avalanches. Complicating matters further is the high seismic activity, with Racha and southern Georgia situated in a zone prone to 9-point earthquakes. Earthquakes often act as triggers for catastrophic exogenic processes, exacerbated by a rugged, high-mountainous terrain and abundant precipitation. This article seeks to analyze the mechanisms behind these natural exodynamic processes, predict their potential development, and propose preventive measures.

Fig. 1. Caucasus Mountains in Racha region

Methods and materials

Our field studies utilized geomorphological and geological methods. The morphological method was employed to identify the main relief forms, their contours, and arrangement. Morphometric analysis determined the dimensions of these forms, while the morphostructural method helped establish the relationship between relief and geological structures. Geological methods included lithological analysis, sedimentary layer sequencing, and granulometry studies. Literature and cartographic materials were also reviewed to support our findings. The conclusions presented in this article are based on the data gathered through these methods.

Geological formations

The northern wing of the Upper Racha syncline consists mainly of thick-bedded marls from the Upper Jurassic period, carbonate shales, and interlayers of limestones. Tectonic

movements in Lower Cretaceous sediments have created wrinkled structures, with young and old faults of various directions visible in the relief. [*Adamia et al., 2004*]. Relatively recent sediments include eluvial, deluvial, colluvial, alluvial, proluvial, and fluvioglacial layers from the Quaternary period.

Upper Racha features two distinct types of relief

High-mountainous rocky-denudation relief with modern glaciation, hosting glaciers like Tbilisa, Buba, and Chanchakhi; and high-mountainous denudation relief with evidence of past glaciation, found on sedimentary and metamorphic formations from the Jurassic era. The denudation-depressed relief is characterized by easily eroded flysch rocks, deep erosional valleys, and distinctive features like the Bubi transverse uplift. The southern slopes of the Central Caucasus, Shoda-Kedela, and Lechkhumi ranges exhibit a diverse relief, ranging from high-mountainous subalpine to alpine zones. Erosional valleys of the Rioni River and its tributaries dominate the lower part of the region, with V-shaped valleys transitioning to ravine-shaped valleys in areas with shale slopes. The width of the Rioni floodplain near the village of Ghebi is 150 m, expanding to 280 m between Ghebi and Chiora, and 230 m near Chiora [*Gongadze et al., 2024*].

The second type of relief is the erosional-denudation relief of medium-mountainous mountains and valleys, with erosional divisions of 300–600 m depth and slopes of 30–450, together with climatic and meteorological conditions that determine the active development of landslide-sedimentary processes. This type of relief is widespread in the central and southern parts of Upper Racha and is the eastern continuation of the Racha-Lechkhumi syncline depression. It is developed on a substrate of clayey-sandy and carbonatite rocks of Upper Jurassic, Cretaceous, and Tertiary age. Here, old landslide forms of the relief are preserved in abundance, and new landslides are actively developing. They are found on the slopes of the valleys of the Rioni, Jejora rivers, and their tributaries, where the origin and development of strong debris flows are also actively taking place. These processes cover the areas of the villages of Khideshlebi, Mazhieti, Somitso, Skhieri, Kristese, and Khirkhonis. The profile of the slopes here almost everywhere bears traces of the movement of landslide bodies – they are wavy-stepped. Where massive chalk limestones come to the surface, 20–50 m high cornices are developed (Khirkhonis, Skhieri), the colluvial soils formed at the bases of which create conditions for the development of erosion and landslide processes. The remains of river terraces have been preserved on the slopes of the river valleys. In the vicinity of the villages of Skhieri, Kristesi, Somitso, Komandli, and others. The first terraces above the floodplain extend along the Rioni River, at a height of 1.5–4 m from the riverbed. The city of Oni is built on such a terrace. In the zone of distribution of limestones of Cretaceous and Tertiary age, karst processes are underway, karst fields, funnels, caves have formed. They are especially numerous in the areas of spreading of massive Baerem limestones of the Lower Cretaceous age – in the northern part of the northwestern slope of the Racha ridge – in the areas of Khikhat and Khirkhonis, Shkmere and Usholta, Kharistvali, Mljadzli, Futieti, Gerohi, as well as in the areas of Kvemo, Zemo Bari, and Mkholi.

In these difficult geological and geomorphological conditions, on the southern slope of the Central Caucasus, between the Caucasus and its southeastern branch, the Shoda-Kedela ridge, the Chanchakhi River valley has formed, which in the middle of the year has developed two beds: one of the main stream, and the other – of a small stream, which is filled during heavy rainfall. The depth of the cut into the bed of the main stream is 1.5 m, along both banks proluvial boulders with tree and plant inclusions have accumulated. The dimensions of the unprocessed boulder bed vary within 0.2–0.7 m, and the thickness of the bulk reaches 1.5 m. The islands formed in the riverbed are covered with dense vegetation (mainly alder), which clearly show the strong debris flow trace.

Three main types of exodynamic processes develop in Upper Racha: constantly occurring, periodically occurring, and catastrophic natural processes.

Constant processes such as erosion and denudation cover the entire territory of Upper Racha. Erosion develops more intensively in the nival zone, while deep erosion occurs in the upper reaches of the tributaries of the Rioni River. Lateral erosion is pronounced in the Rioni

River valley below the village of Saglolo. Denudation processes mainly occur on steep slopes (25–300 degrees or more) that are less covered with vegetation. On these steep slopes, cinder cones form and rock avalanches occur.

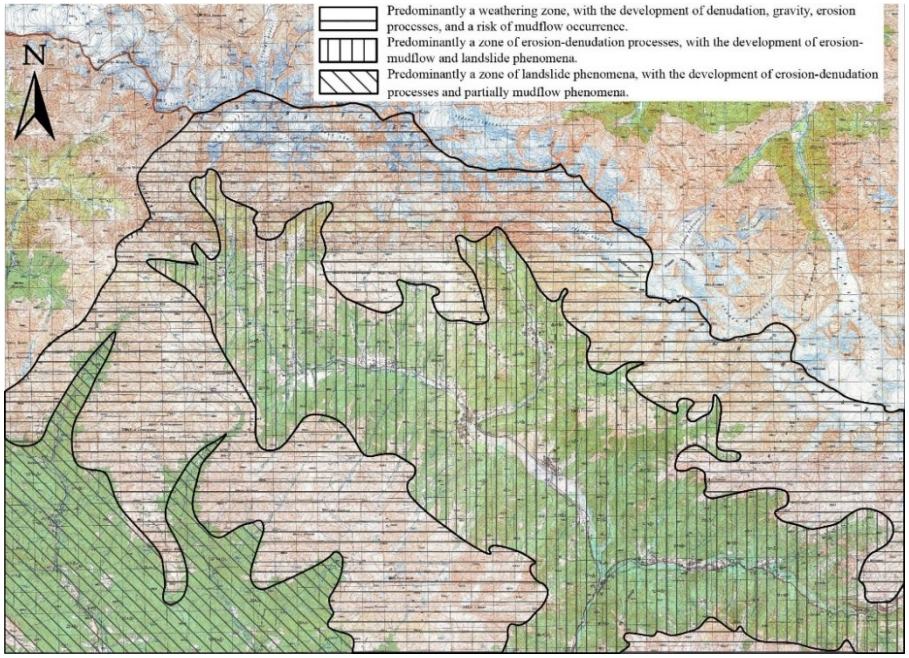

Fig. 2. Exodynamic processes in Upper Racha

Periodic processes include debris flows, which form due to heavy precipitation, accumulated material in valleys, and steep valley beds. Landslides also occur periodically, mainly on deluvial slopes with a slope greater than 25 degrees, where the lower part is washed by river flow.

Catastrophic natural processes are extreme manifestations of exodynamic processes that occur under specific meteorological conditions such as heavy rains and increased solar radiation. The debris flow that occurred in the Bubistskali gorge on August 3, 2023, resulting in 35 fatalities and significant damage to the resort of Shovi, falls into this category of exodynamic processes.

The Bubistskali River, a right tributary of the Chanchakhi River, originates from the Buba Glacier and joins the Chanchakhi River near the resort of Shovi. The Bubistskali Gorge, formed in Jurassic and Lower Cretaceous sedimentary rocks below the alpine zone, exhibits a pronounced erosion-denudation relief. The Shovi catastrophe was caused by various factors including climate, relief, and geology. The active retreat of the Buba Glacier in recent decades, due to global climate change, has exposed the glacier's front, bottom, and side moraines. Accumulated snow between these moraines, unable to fully melt in the summer, likely contributed to the debris flow in the Bubistskali Gorge. The rising air temperatures globally have accelerated glacier melting, including the Buba Glacier.

Table 1. Average annual temperature variation in Upper Racha

Period	January	February	March	April	May	June	July	August	September	October	November	December	Average annual
1961–1990	-4.1	-2.7	0.5	5.9	10.5	13.6	16.7	16.1	12.6	7.6	2.7	-2.3	6.4
1991–2020	-3.4	-1.9	1.6	6.7	11.9	15.4	18.2	18.2	14.3	9.4	3.1	-2.0	7.6
Difference	0.7	0.8	1.1	0.8	1.4	1.8	1.5	2.1	1.7	1.8	0.4	0.3	1.2

Source: [*https://nea.gov.ge/ge/Download/File/1314*]

One of the authors of this article took part in the glaciological expeditions of the Vakhushti Batonishvili Institute of Geography to the Tbilisi and Buba glaciers in 1971–73. During this time, the tongues of both glaciers descended approximately 400 meters below their current level. The lateral moraines are significantly larger in volume than the frontal moraine, indicating a relatively active advance of the glacier. The glaciers experienced a catastrophic retreat in the following years, exposing the bottom moraines to a length of 400–450 meters, with widths varying between 150–200 meters. In the case of the Buba glacier, the exposed bottom moraine covers around 80,000 square meters and is made up of boulders of different sizes and lithological compositions. The depth and volume of this material are challenging to determine, but it is evident that both snowfall from atmospheric precipitation and ice mass from glacier retreat accumulated over a long period. It is worth noting that the slope of the area where the moraine material accumulated does not exceed 25–30 degrees, which contributed to the relatively stable state of the moraine material. Unlike the Chanchakha river, the Bubistskali gorge has not experienced debris flow occurrences due to this reason. In late July 2023, Upper Racha experienced extremely hot days and heavy rains, setting the stage for the development of a complex catastrophic event in early August.

Table 2. Average annual precipitation variability in Upper Racha

Period	January	February	March	April	May	June	July	August	September	October	November	December	Average annual
1961–1990	83	68	81	108	126	130	114	114	96	101	90	86	1197
1991–2020	72	59	88	88	112	112	98	87	86	111	73	77	1064
Difference	-11	-9	7	-20	-14	-18	-16	-27	-10	10	-17	-9	-133

Source: [*https://nea.gov.ge/ge/Download/File/1314*]

The alternating heavy rains and active ablation significantly increased the saturation of the moraine material with liquid. This caused the gradual melting of snow and ice accumulated over decades, leading to the movement of part of the moraine material on the slope. This disruption of gravitational equilibrium exceeded the critical point. Additionally, water likely accumulated in the lower part of the glacier, near the tongue, where small reservoirs could exist within the icefall, further increasing the water volume. The rain and melted snowwater overflowed the river, carrying a substantial amount of solid mass into the valley. As the debris flow entered the forest zone, it uprooted weakly rooted coniferous plants and soil, descending rapidly towards Shovi. The volume increased sharply, and after passing through a narrow section of the gorge, it transformed into a landslide, burying the resort's central plain under a thick layer of debris.

The Geological Department of the National Environmental Agency concluded that the breaking off of ice masses in the Buba Eni section of the glacier was the primary cause of this catastrophic event, forming a glacial avalanche. The material in the resort area consisted not only of moraine fragments but also of soil, debris, and plant matter from the Bubistskali gorge. A glacial avalanche occurs on steep slopes when the descending ice simultaneously melts, excavates, and carries a large amount of soil. This mirrors the catastrophic glacial avalanche of the Devdoraki glacier in 2014.

Conclusions

The mudslide in the Bubistskali Gorge on August 3, 2023, resulting in 35 deaths and significant damage to the Shovi resort, falls under the catastrophic category of exodynamic processes. The retreat of glaciers due to global warming has been observed on a planetary scale,

affecting the Buba Glacier. The author's participation in glaciological expeditions to the Tbilisi and Da Buba Glaciers between 1971–73 highlighted the significant retreat of glacier tongues and the exposure of bottom moraines. The stable state of moraine material in the Bubistskali gorge, with no previous debris flows, changed in July 2023 due to extreme heat and heavy rains, leading to the catastrophic event in August.

The Shovi resort, established in the 1930–40ss, survived the mudslide due to careful consideration of the local environment during construction. The disaster underscores the challenges of predicting natural processes, as well as human negligence and lack of understanding of these phenomena.

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