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Exodynamic Processes in Upper Racha

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Abstract

Upper Racha is among the most geologically and environmentally challenging regions of Georgia due to the frequency and intensity of exodynamic processes and the significant damage they inflict on the environment and local population. The southern slope of the Central Caucasus, encompassing the Shoda-Kedela and Lechkhumi ranges, is characterised by complex and diverse relief. The upper part of the territory lies within high-mountainous subalpine, alpine, and nival zones. The southern portion of Upper Racha is dominated by deeply incised erosional valleys of the Rioni River and its tributaries, with some valleys exhibiting incision depths exceeding 1,000 metres and slopes ranging between 40° and 60°. This erosional-denudation relief has developed on Jurassic sediments and is shaped by active exodynamic processes affecting strongly dislocated rocks of Liassic age. These processes give rise to a range of geomorphological phenomena, including erosion, riverine and lateral erosion, mudflows, landslides, rockfalls, and snow avalanches. The region's high seismicity and abundant atmospheric precipitation further exacerbate these dynamics. A striking example of these processes occurred in late July 2023, when Upper Racha experienced alternating periods of extreme heat and torrential rainfall. Combined with the active ablation of the Buba Glacier, these conditions significantly increased the saturation of moraine material with liquid water, disrupting the gravitational stability of the slope. This triggered a catastrophic landslide that destroyed buildings at the Shovi resort, resulting in the tragic loss of 35 lives. This study aims to investigate the exodynamic processes in Upper Racha, identify their driving factors and development patterns, analyse the mechanisms behind such natural events, assess their impact on the formation and sustainability of the Shovi–Glola tourist hub, predict the future deve lopment of these processes, and propose effective preventive measures.

Keywords: Exodynamic processes, nival zone, moraine material, taluses, flowing landslides, mudflows

Introduction

Racha, located in the mountainous regions of western Georgia, represents one of the country's most picturesque yet geologically complex landscapes. The region is distinguished by the high frequency and intensity of exodynamic processes, which exert significant impacts on both the environment and local communities (Salukvadze, 2022). These processes, including riverine erosion, mudflows, denudation-gravitational phenomena, and snow avalanches, are integral to the geomorphological evolution of the region and warrant comprehensive investigation to understand their underlying mechanisms, triggers, and spatiotemporal patterns.

A salient feature of Racha's geodynamics is its high seismicity. Situated within a seismically active zone, with earthquakes reaching magnitudes up to 9 on the Richter scale, Racha is highly vulnerable to earthquake-induced geomorphic instability. Seismic events frequently act as catalysts for catastrophic exodynamic phenomena, amplifying the hazard potential of the terrain. Moreover, the region's steeply

dissected relief, combined with abundant precipitation, intensifies the occurrence and scale of such processes. This interplay of tectonic activity, climatic conditions, and relief complexity necessitates a multidisciplinary approach for effective hazard assessment and mitigation.

This study focuses particularly on the upper Rioni River basin, with detailed attention to the Chanchakhi, Jejora, Gharula, Sakaura valleys, and their tributaries. The Chanchakhi River basin lies on the southern slopes of the Central Caucasus, between the main Caucasus range and its southeastern branch, the Shoda-Kedela Ridge. This area exhibits considerable geomorphic diversity and also possesses substantial tourism potential, owing to its unique natural resources—coniferous forests, mountain trails conducive to trekking and equestrian activities, and the "Glola Boulders" (granite moraine formations listed in the Red Book of Georgia)—in addition to mineral springs and cultural heritage sites (Gavasheli, 1978).

Anthropogenic influences further compound the environmental dynamics of Racha. Agricultural activities—such as slope ploughing, deforestation, and annual crop cultivation—have significantly altered land cover and soil stability, contributing to erosion and increased vulnerability to exodynamic processes (Salukvadze, 2022). These human-environment interactions underscore the importance of integrating socio-economic factors into geomorphological and hazard assessments.

Geologically, the northern flank of the Upper Racha syncline is dominated by thick-bedded marls of Upper Jurassic age, carbonate shales, and interbedded limestones. Lower Cretaceous tectonic activity has generated folded structural formations, while the area is intersected by both young and ancient faults oriented along multiple latitudinal directions. These structures are further complicated by strike-slip and discontinuous dislocations, which strongly influence the morphology and stability of the terrain. Quaternary sediments—including eluvial, deluvial, colluvial, alluvial, proluvial, and fluvioglacial deposits—form a significant component of the surface cover, influencing hydrological dynamics and slope processes (fig. 1).

This research aims to systematically analyse the mechanisms driving these exodynamic processes, assess their spatial and temporal distribution, and develop predictive models to guide hazard mitigation and sustainable land-use strategies. Such integrated research is crucial for the preservation of both the environmental integrity and socio-economic resilience of Racha.

Figure 1. Glaciers Tbilisa and Buba. Photo by M. Gongadze

Methods and Materials

In the field studies, we utilized a combination of geomorphological and geological methods. The morphological method was used to identify the primary landforms in the study area, as well as their contours and spatial arrangement. The morphometric method was employed to measure the dimensions of these forms, while the morphostructural method helped to clarify the relationship between the landforms and underlying geological structures. Additionally, various geological techniques were applied, including lithological analysis of materials, determination of the sequence of sedimentary layer formation, and examination of granulometry and material rounding. In the office, we conducted a literature review and analyzed relevant cartographic materials. Based on the results from these methods, the conclusions presented at the end of the article were drawn.

Results

Relief Types and Morphostructural Characteristics of Upper Racha

Upper Racha exhibits two principal types of relief, each distinguished by specific morphostructural and lithological characteristics:

1. Nival High-Mountainous Relief

The first type is nival high-mountainous relief, displaying clear signs of both ancient and modern glaciation, notably in areas such as Zopkhito, Laboda, Tbilisa, Buba, and Chanchakhi. This relief type develops predominantly on sedimentary and metamorphic formations of Jurassic age (fig. 2). Erosion and denudation processes are particularly active here, shaping the terrain into steep slopes, sharp ridges, and deeply incised valleys. Morphostructurally, this zone is characterized by denudational forms bounded by major fault systems to the north and south. The presence of easily erodible flysch formations contributes to relatively subdued topographic forms and the development of deep erosional valleys.

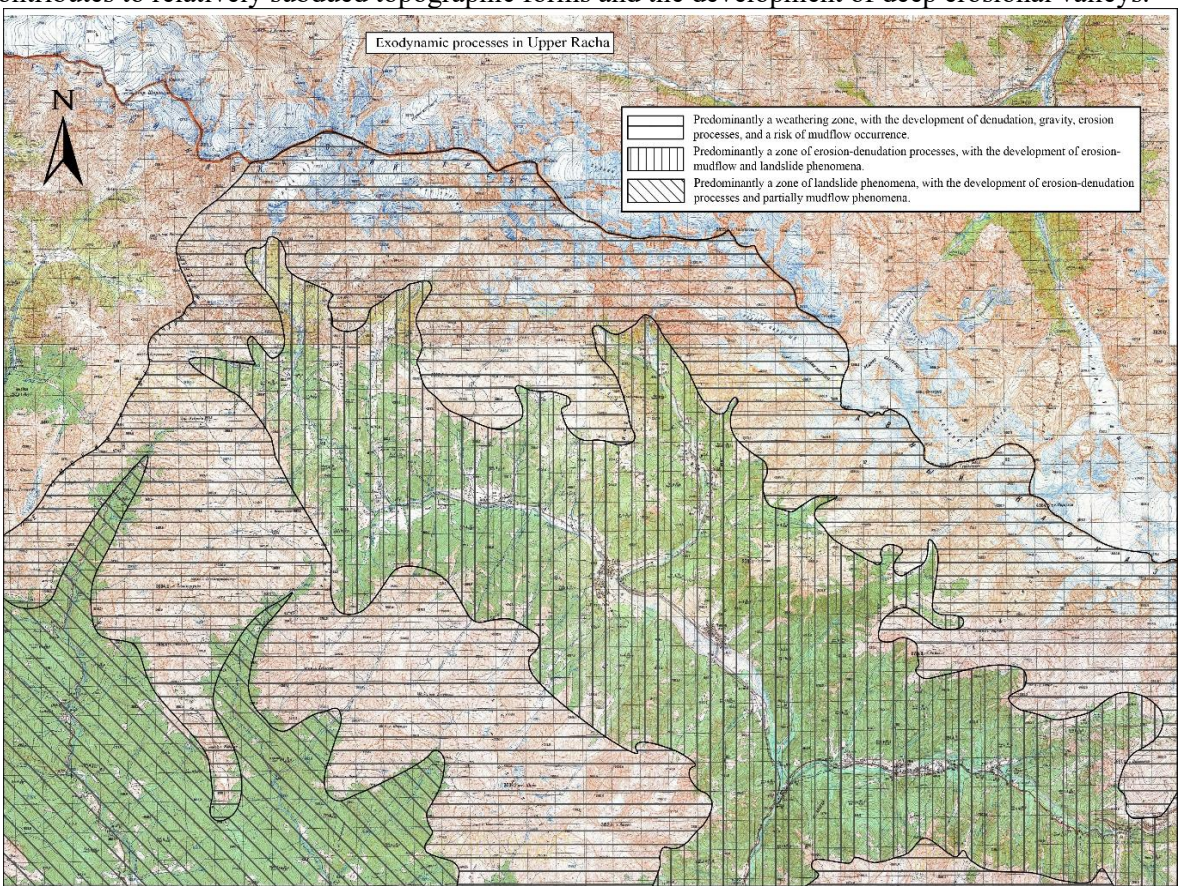

Figure 2. Exodynamic processes in Upper Racha. Map created by the authors

A distinct morphological feature in this region is the transverse uplift of the Buba River, which connects to the Bubistskali River valley through Upper Pleistocene moraine deposits. At relatively lower elevations within this relief type, denudational forms are accompanied by active manifestations of mudflows and landslides.

The southern slope of the Central Caucasus, including the Shoda-Kedela and Lechkhumi ranges, presents highly diverse relief forms. The uppermost parts of this area belong to the high-mountainous subalpine and alpine zones, with elevations ranging from approximately 3,500 to 4,000 m above sea level and are dominated by nival-glacial and glacial-erosional morphologies. The lower slopes are deeply dissected by the Rioni River and its tributaries, with valley incisions exceeding 1,000 m in depth in certain locations and slope inclinations ranging between 40° and 60°.

Erosion-denudation relief in this context develops on a substrate of Jurassic sediments. The relatively smooth nature of some relief forms is determined by the impact of erosion-denudation processes acting upon strongly dislocated igneous sandstones and shales of Liassic age. Valley profiles are typically V-shaped; however, where slopes consist of shale, ravine-shaped valleys predominate. For example, near the village of Ghebi, the width of the Rioni floodplain is approximately 150 m, widening to 280 m between Ghebi and Chiora, and narrowing to 230 m near Chiora.

2. Erosion-Denudation Relief of Medium-Mountainous Terrain

The second type is erosion-denudation relief characteristic of medium-mountainous terrain, marked by valleys with erosional dissection ranging from 300 to 600 m in depth and slope inclinations between 30° and 45°. This relief type is widespread in the central and southern parts of Upper Racha and represents the eastern extension of the Racha-Lechkhumi synclinal depression. It develops primarily on clayey-sandy and carbonate rock formations from the Upper Jurassic, Cretaceous, and Tertiary periods.

This zone contains abundant remnants of ancient landslide forms, and contemporary landslide activity remains significant. Such processes are particularly active along the slopes of the Rioni and Jejora rivers and their tributaries, where intense mudflow activity is also observed. Villages most affected include Khideshlebi, Mazhieti, Somitso, Skhieri, Kristesi, and Khirkhonisi. Slope profiles in these locations often display stepped and wavy configurations, indicative of ongoing landslide movements.

In areas where massive chalk limestones are exposed, prominent cornices reaching heights of 20–50 m are common (e.g., in Khirkhonisi and Skhieri). Colluvial soils at the base of these cornices facilitate erosion and slope instability, thereby promoting further landslide development. Additionally, relict river terraces occur along the slopes of river valleys, notably in the vicinities of Skhieri, Kristesi, Somitso, and Komandeli. The first terraces situated approximately 1.5–4 m above the current riverbed, extend along the Rioni River, and the town of Oni itself is established upon one such terrace.

In areas dominated by Cretaceous and Tertiary limestones, active karst processes are widely observed, resulting in the formation of karst poljes, sinkholes, and cave systems. These features are particularly abundant in regions underlain by extensive Barremian limestones of Lower Cretaceous age, including the northern sector of the northwestern slope of the Racha Ridge and localities such as Khikhat, Khirkhonisi, Shkmere, Usholta, Kharistvali, Mravaldzali, Futieti, and Skhvava, as well as the Lower Bari, Upper Bari, and Mukhli areas (Gavasheli, 1978).

The valleys of the right and left tributaries of the Rioni River develop under comparable geomorphological, geological, and microclimatic conditions. This results in sharply inclined valley beds and steep, often denuded slopes, fostering intense erosion, denudation, and slope failure processes. These conditions, when coupled with periods of intense precipitation, create favourable conditions for catastrophic mudflows. A significant example occurred between 26 and 27 July 2020, when precipitation exceeded the daily norm, reaching 120 mm according to the Hydrometeorological Department of the National Environmental Agency. This extreme rainfall event resulted in extensive damage, including the destruction of tens of kilometres of highway embankments, as well as the impairment of bridges and agricultural infrastructure across the affected region. Notably, heavy precipitation was recorded not only in the lower reaches of the Rioni Gorge but also at higher altitudes. Field observations above the village of Chiora (altitudes between 2,200 and 2,600 m above sea level) confirmed evidence of intense atmospheric precipitation during this event.

The Chanchakhi River is characterised by a bifurcated bed, consisting of a main channel and a secondary channel activated during high-flow events. The incision depth of the main channel reaches up to 1.5 m, while both banks accumulate proluvial deposits containing organic matter such as wood and plant debris. Boulder sizes within the riverbed range from 0.2 to 0.7 m, with bulk deposit thicknesses reaching up to 1.5 m. River islands densely vegetated with alder trees exhibit clear evidence of historic mudflows (fig. 3).

During the July 2020 rainfall event, significant overflow occurred in the Rioni and Chanchakhi rivers, including their tributaries, resulting in destructive mudflows that severely damaged infrastructure, highways, and bridges within Upper Racha's villages (Tsereteli, 2020).

Further downstream, the Chanchakhi River receives inflow from the left bank via the Dgviora River. This tributary originates from a heavily deformed glacial cirque on the northern slope of the Shoda-Kedela Range, oriented parallel to the Central Caucasus. The region exhibits distinct glacial and erosional-glacial features, including sharply defined trough valleys, moraine deposits, and isolated erratic boulders. Alpine and subalpine landscapes extend to comparatively low elevations. In this system, the bedrock lithology, slope gradients, and prevailing climatic conditions serve as primary controls on the development of exodynamic processes.

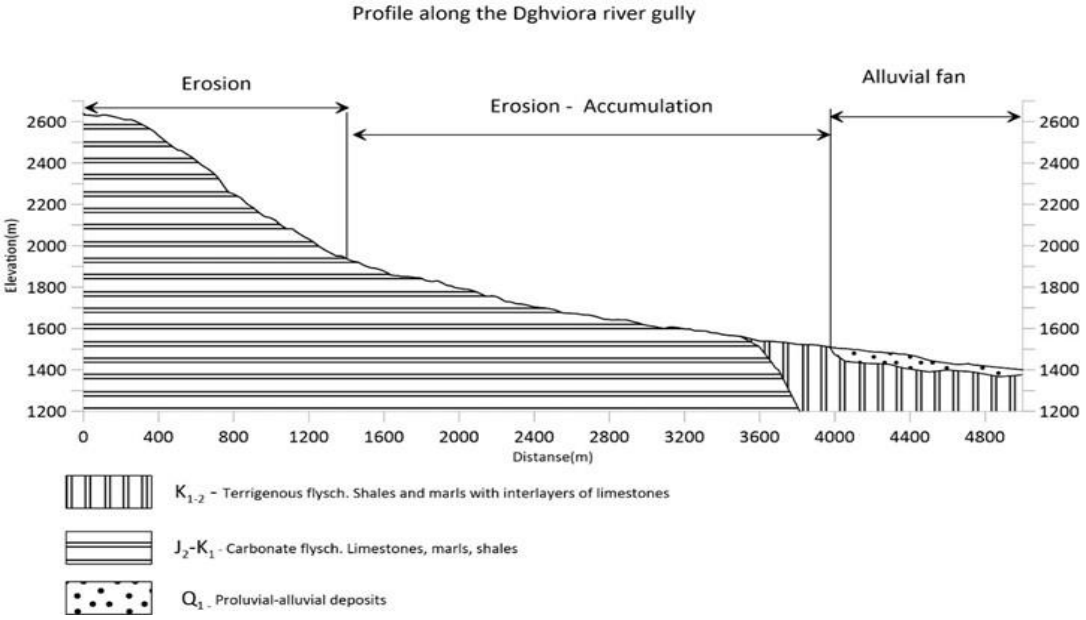

Figure 3. Profile along the Dghviora river gully

The confluence of the Dgviora and Chanchakhi rivers generates a substantial sedimentary cone, upon which the village of Glola is situated. This depositional feature is particularly susceptible to destructive mudflows during periods of heavy precipitation, frequently inflicting damage upon Glola and adjacent settlements. The July 2020 event again exemplifies this dynamic, with extreme rainfall leading to significant river swelling and consequent destructive mudflows across the Chanchakhi and Rioni basins.

Quantitative geomorphological analysis was conducted using lithofraction counting within systematically established 5 × 5 m polygons in the beds of the Gharula, Mushuani, and Dgviora rivers. These measurements identified alluvial-proluvial layers comprising between six and seven size fractions, with particle dimensions ranging from 1 cm to 1.5–2 m. Subsequent stratigraphic analysis of riverbed cuts enabled reconstruction of the timing and provenance of transported material, thereby distinguishing between natural and anthropogenic drivers of exodynamic activity. These findings are essential for developing targeted preventive strategies against such events.

The Sakaura River, entering the Rioni River from the right approximately 3 km upstream of Oni, extends over a gorge approximately 13–14 km in length, incised primarily within Middle and Upper Jurassic clay-shale and sandstone sequences. The floodplain and riverbed lithology are dominated by unprocessed large-fraction proluvial boulders (approximately 70%), supplemented by fine alluvial gravel and pebbles. Boulder sizes within the riverbed range between 0.4 and 1.2 m, with deposit thicknesses between 2.5 and 3 m above the river surface.

In the upper reaches above Khideshlebi, the left bank of the Sakaura is artificially reinforced with a 60 m long, up to 2 m high boulder wall. In the midsection of the river, near the bridge, intense incision has produced a deep, narrow erosional gorge, characterised by extensive proluvial boulder fields. Near the village of Mazhieti, the Sakaura's largest left tributary joins its bed. In 2020, mudflows entering this tributary washed away a bridge, which was rebuilt within the same year; remnants of the destroyed piers and the extensive proluvial boulder fields remain as evidence of this event.

Shovi Catastrophe

The Chanchakhi River basin is situated on the southern slope of the Central Caucasus, occupying a geomorphologically complex position between the main Caucasus range and its southeastern branch, the Shoda-Kedela Ridge. The northern flank of the Upper Racha syncline is predominantly composed

of thick-bedded Upper Jurassic marls, carbonate shales, and interbedded limestones. These lithological units have been significantly deformed by intense tectonic movements during the Lower Cretaceous, resulting in intricate folded structures.

The structural framework of the region is dominated by both young and ancient faults oriented along three principal latitudinal directions. These faults are further complicated by strike-slip dislocations and discontinuous faults of various orientations, all of which are clearly expressed in the regional relief. The Quaternary sediments in the basin include eluvial, deluvial, colluvial, alluvial, proluvial, and fluvioglacial deposits, which together form a diverse and dynamic sedimentary cover.

The Bubistskali River, originating from the Buba Glacier, is a major tributary of the Chanchakhi River, joining it from the right near the Shovi resort (fig. 4). Below the alpine zone, the Bubistskali Gorge is deeply incised into Jurassic and Lower Cretaceous sedimentary sequences, forming a sharply defined erosion-denudation relief.

On 3 August 2023, this gorge was the site of a catastrophic geomorphological event: a flash flood that rapidly transformed into a mudflow and subsequently developed into a high-velocity landslide. This event, hereafter referred to as the "Shovi catastrophe," was the result of a complex interplay of climatic, topographic, and geological factors. Over recent decades, the Buba Glacier has undergone significant retreat due to accelerated melting associated with climate change. This retreat has exposed extensive moraine deposits at the glacier's front, base, and lateral margins. These moraine bodies, reaching tens of metres in thickness and extending several hundred metres in length, consist of unprocessed, angular boulder material of varying size, interspersed with trapped snow that persists through the summer season.

The Bubistskali River, incising through this moraine complex, has been unable to fully mobilise and transport the accumulated debris due to its relatively gentle gradient and reduced hydraulic energy. This sediment accumulation increased the susceptibility of the system to blockage and sudden failure. Under conditions of intense rainfall and rapid snowmelt, the entrainment of moraine material triggered the cascade of processes that culminated in the flash flood, mudflow, and landslide observed in August 2023.

The Shovi event represents a striking example of the interaction between glacial retreat, moraine sediment dynamics, and extreme meteorological conditions, highlighting the growing hazard potential in high-mountain environments under climate change. Detailed geomorphological and sedimentological analysis of the Bubistskali-Chanchakhi system offers critical insights into the mechanisms governing such hazardous events and provides a basis for risk assessment and mitigation strategies in similar alpine catchments.

Figure 4. River Bubistskali gorge in the Shovi section before the disaster. Source: Esri. Maxar. Earthstar Geographics and the GIS User Company

Figure 5. River Bubistskali gorge in the Shovi section after the disaster. Source: Esri. Maxar. Earthstar Geographics and the GIS User Company

At the end of July 2023, Upper Racha experienced extreme heat followed by torrential rains, leading to a critical event in early August. The intense rainfall and melting snow increased the saturation of the moraine material, surpassing its critical threshold. This destabilised the gravitational equilibrium of the solid material, causing rainwater, melted snow, and a swollen river flow to mobilise a large number of debris. As it moved downhill, the mass uprooted coniferous vegetation and quickly advanced towards Shovi. The Bubistskali River, being short in length, was covered by the catastrophic mudflow in just 20 minutes (fig. 5).

Years earlier, an artificial barrier was built on the lower Bubistskali River, altering the course of the Chanchakhi River, and cottages were constructed in the area. Unfortunately, this region, along with the cottages, was hit by the mudslide. Eventually, with debris from the river's middle section, the mudflow turned into a landslide, burying the cottages and the plain in the centre of the resort under several metres of debris. Tragically, those in the cottages and nearby areas perished almost instantly. Only those in the older resort buildings and vacationers in the nearby forests survived.

The Shovi tragedy highlights the complexity and unpredictability of natural processes, as well as human negligence and ignorance towards these processes. Thankfully, buildings from the 1930s and 1940s were strategically placed in safe areas, allowing them to withstand the disaster. In contrast, the owners of cottages in the Bubistskali area were not as fortunate.

Conclusion

Exodynamic processes, based on their development characteristics, can be classified into three main groups: those that occur constantly, periodically, and catastrophically, both in general and specifically in Upper Racha.

Ongoing processes include erosion and denudation, which affect the entire territory of Upper Racha. However, erosion is more pronounced in the nival zone, while deeper erosion predominantly occurs in the upper reaches of the Rioni River tributaries. Lateral erosion is notably evident in the Rioni River valley below the village of Saglolo. Denudation processes primarily occur on steep slopes (25°–30° and greater), which are often sparsely vegetated. On such slopes, where vegetation cover is minimal, talus cones and rock avalanches are common.

Periodic processes include mudflows, which form due to a combination of heavy precipitation, the accumulation of depleted material in valleys, and the steep gradient of valley beds. Landslides also occur periodically, typically on deluvial slopes with gradients exceeding 25°, where the lower part of the slope is eroded by river flow.

Catastrophic natural processes are extreme manifestations of exodynamic processes. They occur as a result of the interaction of specific meteorological conditions such as intermittent heavy rains and increased melting of glaciers. Additionally, large amounts of weathered material accumulate in troughs

and valleys, with rain seeping through cracks on slopes and surface waters contributing to these processes. The catastrophic mudslide in Shovi on August 3, 2023, which ultimately transformed into a landslide and completely engulfed the resort area, was a direct result of the confluence of these factors. The mudslide destroyed the cottages designated for vacationers, significantly disrupting tourism activities in the region.

An important factor hindering the development of resorts and tourism in Racha is the increased risk of natural disasters. A tragic example of this is the mudslide that occurred in the resort of Shovi on August 3, 2023. It originated from the gorge of the river Bubustskali and covered the entire resort area. Cottages in the Bubistskali region were destroyed, and 35 people lost their lives. Initial estimates suggest that the total volume of the brought proluvial material reached 1 million m^3. The disaster dealt a severe blow to the resort, putting its operation in question.

The restoration and preservation of the Shovi resort are crucial not only for the economy of Shovi-Glola but also for the future of tourism development in Racha (Gongadze, 2024; Nadareishvili, 2024). This aspect should be the subject of further detailed research. The government has also expressed its intention to restore the resort. It is important to consider the nature of the exodynamic processes in the Shovi-Glola area when planning the restoration, with a focus on natural hazard factors. Safe zones for development should be designated based on data from pre-project studies and monitoring of natural hazards, as well as the implementation of containment and protection systems.

The authors suggest that the restoration of the resort should involve the removal of the accumulated landslide mass, which can then be used as construction inert material. This material holds special value in the current construction boom. This process will result in a cleared resort area, essential for the resort's operation.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

Merab Gongadze. and Giorgi Khomeriki. conceived of the presented idea. George Loninadze. and Giorgi Kavlashvili. performed the analytic calculations. Nikoloz Suknidze and Gela Talakhadze. took the lead in writing the manuscript. All authors provided critical feedback and helped shape the research, analysis and manuscript.

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References

Gavasheli, A. (1978). Upper Racha and its Natural Resources. 54.

Gongadze, M., Lominadze, G., Khomeriki, G., & Kavlashvili, G. (2024). Analysis of Spontaneous Exodynamic Processes in the Dghviora River Basin Taking into Consideration the Perspectives of the Shovi-Glola (Georgia) Tourist Agglomeration. *Georgian Geographical Journal*, *4*(1), 26–34. https://doi.org/10.52340/ggj.2024.04.01.04

Nadareishvili, N., Tutberidze, M., Khomeriki, G., Dzhvarsheishvili, S., Kvirkvelia, N., Tchania, E., & Tavadze, G. (2025). Prospects of Tourism Development in Zemo Racha and Their Reflection Among the Local Society. *Georgian Geographical Journal*, *5*(1), 63–73. https://doi.org/10.52340/ggj.2025.05.01.07

Elene Salukvadze. (2022). Environmental and Anthropogenic Factors in the Development of Geodynamical Processes in Racha. *Georgian Geographical Journal*, *2*(1). https://doi.org/10.52340/ggj.2022.753

Tsereteli, E. e. (n.d.). Engineering and geological zoning of Georgia according to the degree of development of hazardous geological processes. Russian.