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Field and Laboratory Study of Accumulated Debrisflow-Forming Solid Mass Sediment on the Example of River Chokheltkhevi (Mtskheta-Mtianeti Region, Georgia)

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Abstract

The paper presents the results of the field and laboratory research carried out in the Chokheltkhevi river basin, according to which the sediment-forming solid mass accumulated in the bed of the Chokhelthkhevi river was recorded and its granulometric and chemical composition, as well as physical-mechanical characteristics, were studied. Based on the results of the research, it can be said that in the debrisflow channel of the Chokheltkhevi River, coarse and sandy-clay soils are mainly accumulated, which represent an unstable mass for the expected debrisflow in the gorge, which, together with other geological, hydrological and climatic factors, helps to increase the scale of the expected ecological danger. According to the results of the laboratory research, it can be concluded that the soil accumulated in the drainage channel is low in ion concentration, and the humus content in it is minimal, which indicates the possibility of easy displacement of the solid mass accumulated in the drainage channel and, accordingly, the risk of a catastrophic debrisflow.

Keywords

Georgia, Geology, Debrisflow, Mudflow, Laboratory

1. Introduction

Despite the long period of study of mudflow events and the wide geographical area of their distribution, observation of this natural phenomenon requires special efforts of researchers in order to minimize the damage caused by it. This issue is particularly acute in mountainous regions, where less powerful or catastrophic debris/mudflows occur almost every year. The mountainous territory of Georgia and its unique climatic-geographical-geological environment create all the prerequisites for the spread of natural disasters in most of the country. Nowadays, there is almost no mountainous region where the population, industrial or agricultural objects do not suffer from the destructive effects of debrisflows. In addition, due to the lack of suitable areas, the population is often forced to live in the narrow valleys and floodplains of mountain rivers, despite the fact that there is a high probability of the formation of catastrophic debris/mudflows in such places (Chakhaia et al., 2017; Diakonidze et al., 1988; Gaprindashvili et al., 2021; Tsereteli et al., 2022).

Among the alluvial river basins in Georgia, the most important is riv. Aragvi, especially the Tetri Aragvi river basin, which is joined by many debrisflow forming tributaries from the right, of which the catchment basin of the Chokheltkhevi river is particularly noteworthy, where factors contributing to the occurrence of debrisflows are: Climate, Geological structure, geomorphological, hydrographic and hydrological features (Tsanava & Dadiani, 2007; Tsanava, 2004).

2. Study Area

Based on Administrative zoning study area is situated in Dusheti Municipalty, Mtskheta-Mtianeti Region. Morphologically is situated in moderate and high mountainous relief subzone, with erosive-tectonic ridges and gorges, developed on upper Jurassic and Cretaceous suites (**Figure 1**).

Riv. Chokheltkhevi catchment is characterized by the climatic features characteristic of the medium and high mountain regions of the southern slopes of the Eastern Caucasus—harsh winters and cool summers. The average annual temperature is 5˚C - 6˚C, the maximum is 30˚C, the minimum is −32˚C. Spring and early summer are characterized by sharp temperature fluctuations: if the average temperature in May does not exceed 8˚C - 10˚C, on certain days it may

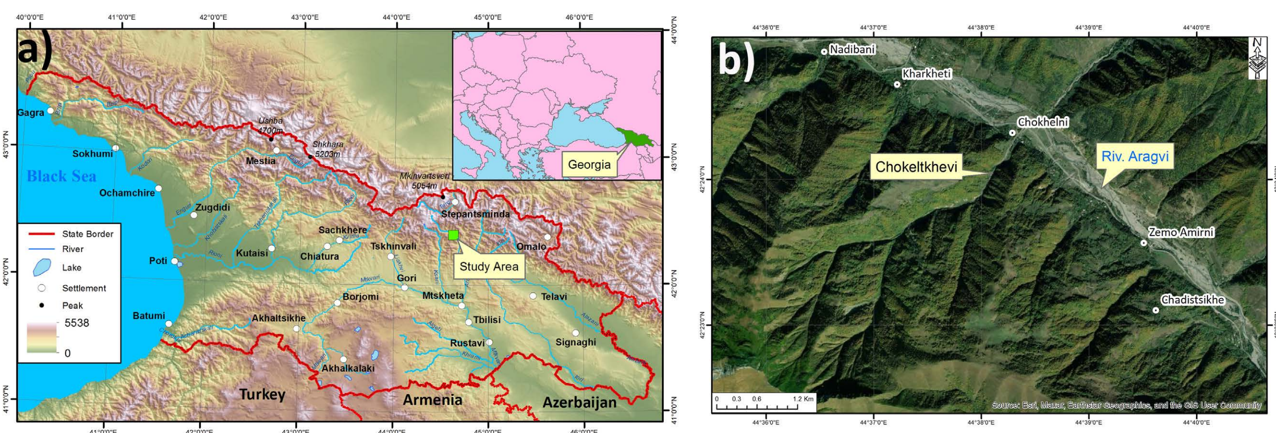


Figure 1. Study area: (a) Overview of Georgia; (b) Tributaries of riv. Tetri Aragvi.

reach 25˚C, which contributes to the rapid melting of snow. The height of the snow cover exceeds 3.0 m in some periods.

Among the climatic features, the annual amount of precipitation is also important, which amounts to 1000 mm, and especially the daily maximum—100 - 110 mm, which is one of the main triggering factor of debrisflows.

Among the geological factors, the lithological structure of the Chokheltkhevi river basin is worth noting. It is included in Mestia-Tianeti tectonic zone and is represented by carbonate-terrigenous flysch of Berriasian-Valanginian and Hotrivian layers (**Figure 2**). These suits are made up of alternating clastic limestones and sandstones, turbidites, pelagic marls, limestones, argillites and claystones. Rocks of such a geological structure easily succumb to the processes of exhaustion, which creates an important prerequisite for the creation of mudflows sources at the upper section of this valley (Kupravishvili, 2019).

Among the geomorphological features of the Chokheltkhevi river catchment area, the steepness of the slopes, the large area of the catchment area and the V-shaped distribution should be distinguished (**Figure 3**).

The hydrographic network of the Chokheltkhevi river basin and its characteristic features are also an important factor in triggering of debrisflow formation. These are a network of well-developed erosive bends, which, due to the great slope of the bed, represent classic debris/mudflow channels (Kupravishvili, 2019).

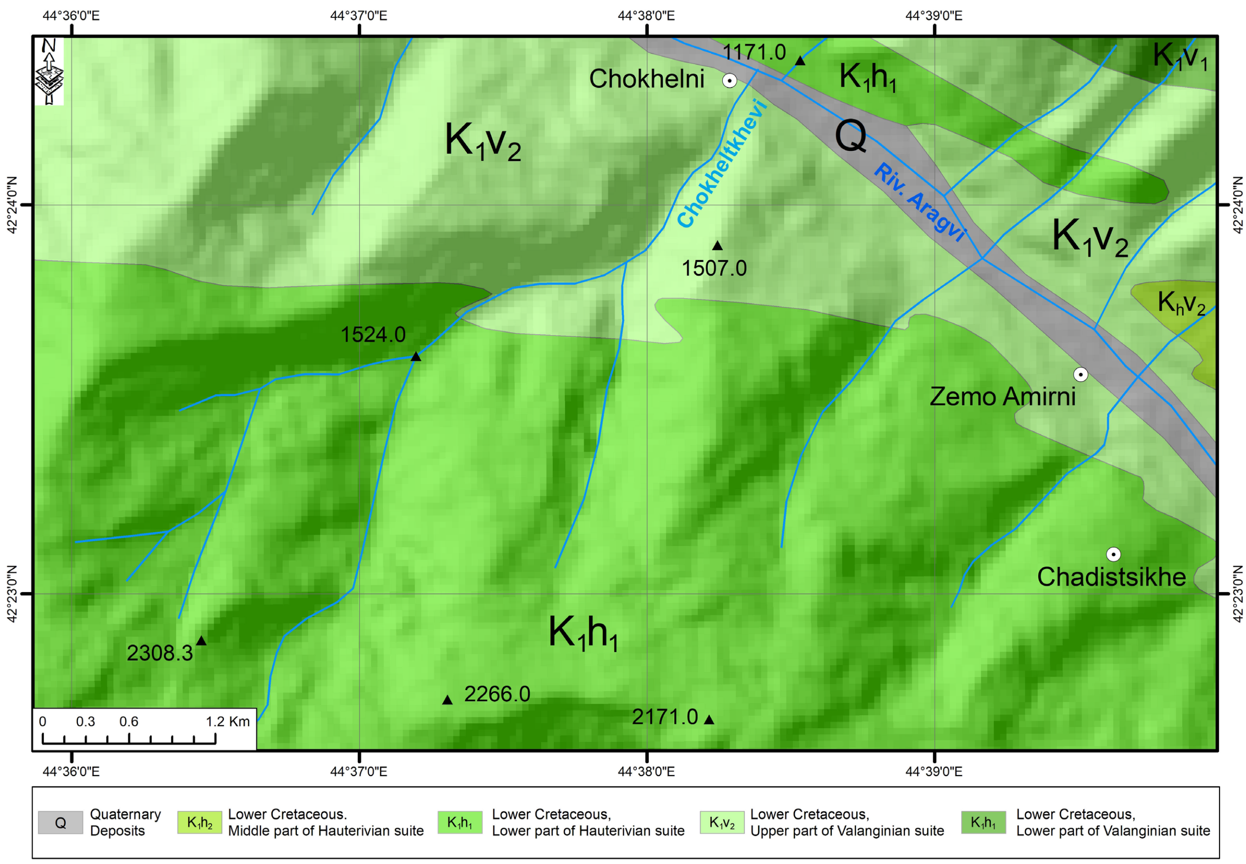


Figure 2. Geology map of study area.

Figure 3. General view of the Chokheltkhevi River bed.

Recently, the research carried out in the catchment basin of the Chokheltkhevi River has established that the formation of mudflows in the channel of the Chokheltkhevi River is mainly triggered by heavy rains, as a result of which the water runoff brings with it the accumulated denudation material in the basin (**Figure 4**), which contributes to the formation of mudslides, which is often It brings catastrophic results.

3. Methodology and Results

A prominent example of this is the mudflow formed in 1984 and 1986 on the Chokheltkhevi River, which brought out a large amount of decomposed material. The resulting mudslide destroyed many buildings, destroyed gardens and orchards, created danger for the population, and a powerful debris/mudflow formed in 1987 killed several people (Diakonidze et al., 1988).

Based on the above, it is clear that there is a need for a detailed study of the debrisflow events in the Chokheltkhevi River, using modern technologies, in order to determine the ecological risks there and to design adequate measures to ensure the minimization of ecological risks.

Taking into account the above, in order to identify the alluvium-forming mass accumulated in the bed of the Chokheltkhevi River and to study its stability characteristics, we carried out field-reconnaissance and laboratory studies, during which it was observed that coarse and sandy-clay soils are mainly accumulated in the alluvial channel (**Figure 5**), the granulometric composition was determined by the field photometric method (**Figure 6(a)**, **Figure 7(a)**, **Figure 8(a)**, **Figure 9(a)**, **Figure 10(a)**, **Figure 11(a)**, **Figure 12(a)**), and from the same sections (**Figure 6(b)**, **Figure 7(b)**, **Figure 8(b)**, **Figure 9(b)**, **Figure 10(b)**, **Figure 11(b)**, **Figure 12(b)**) soil samples were tested in laboratory conditions.

The results of office-processing of the above photographic material are given in **Table 1**, **Table 2**.

Also, the granulometric and chemical composition of the sand-clay rocks accumulated in the Chokheltkhevi riverbed was determined in laboratory conditions (**Table 3**, **Table 4**).

Figure 4. Denudation material accumulated in the bed of Chokheltkhevi river.

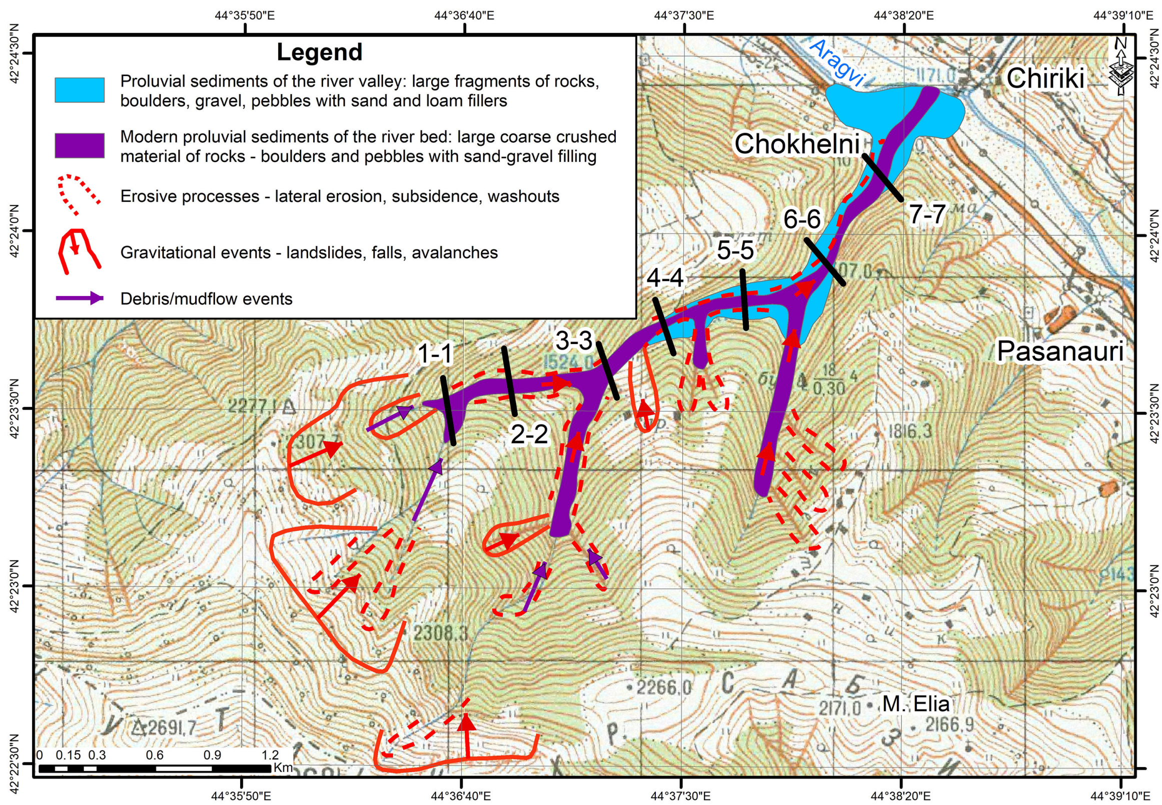
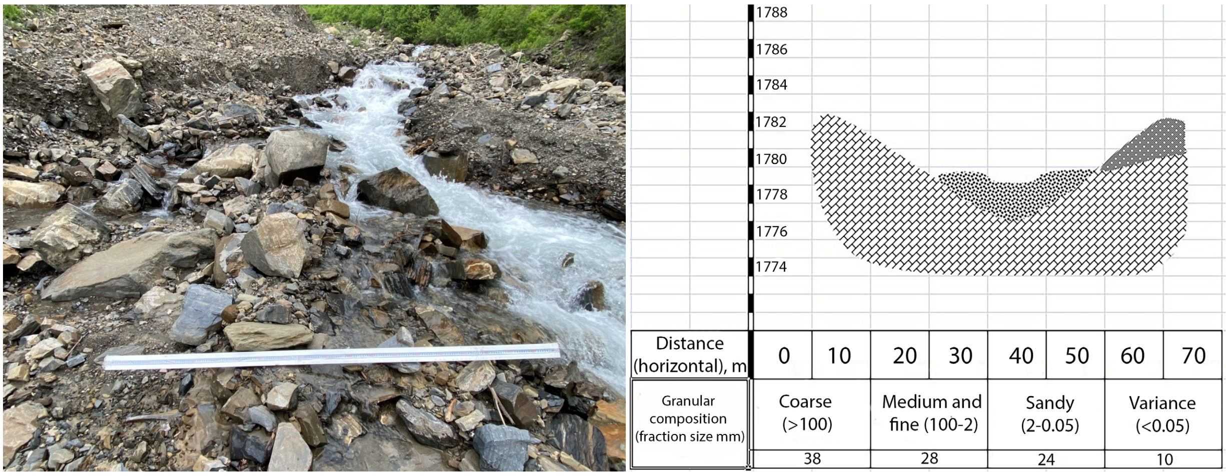
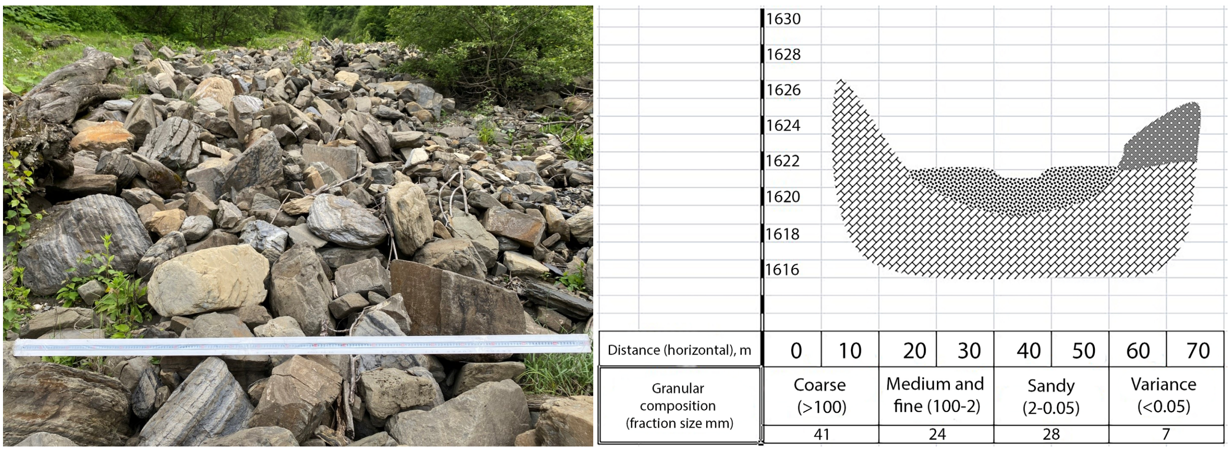


Figure 5. Layout of pre-selected sections of the river bed to study the granulometric composition of the sediment-forming mass accumulated in the transit zone of the Chokheltkhevi River.



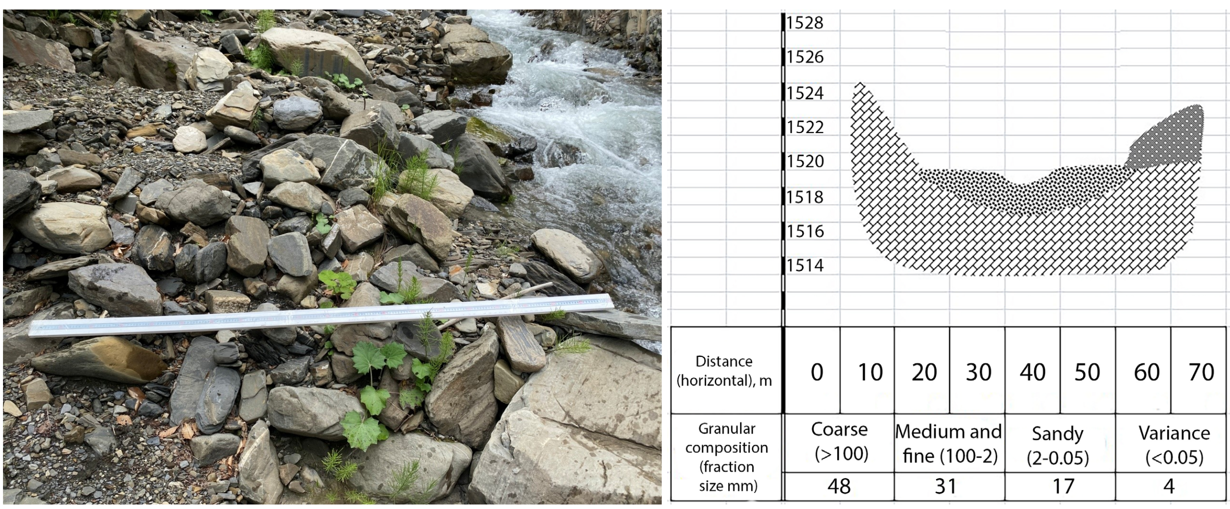
(a) (b)

Figure 6. (a) Granulometric composition of solid mass according to section 1-1. (b) Riv. Chokheltkhevi cross section #1-1.



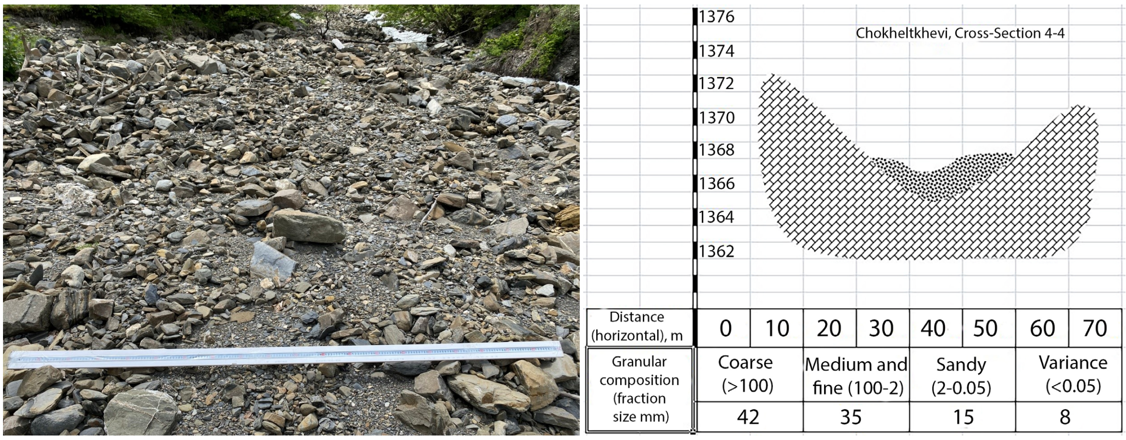
(a) (b)

Figure 7. (a) Granulometric composition of solid mass according to section 2-2. (b) Riv. Chokheltkhevi Cross section #2-2.



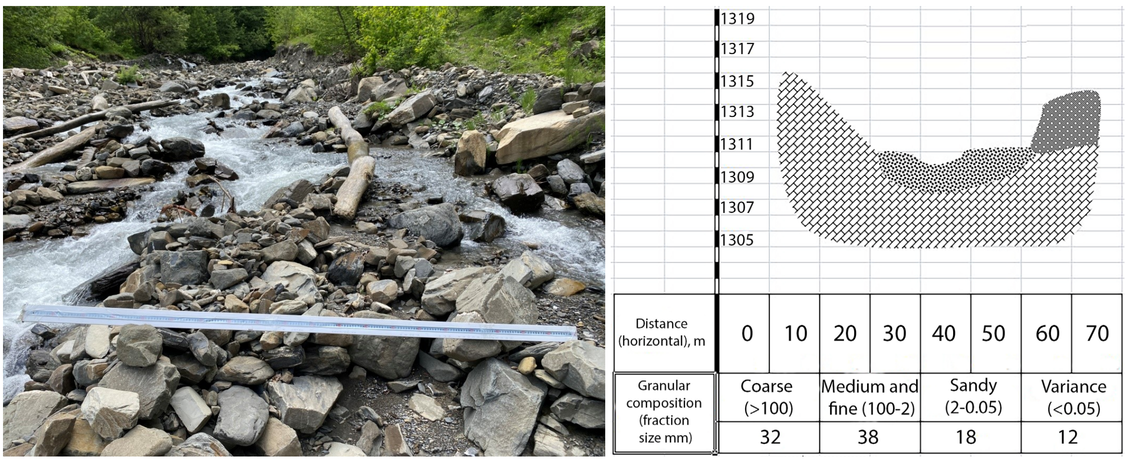
(a) (b)

Figure 8. (a) Granulometric composition of solid mass according to section 3-3. (b) Riv. Chokheltkhevi Cross section #3-3.



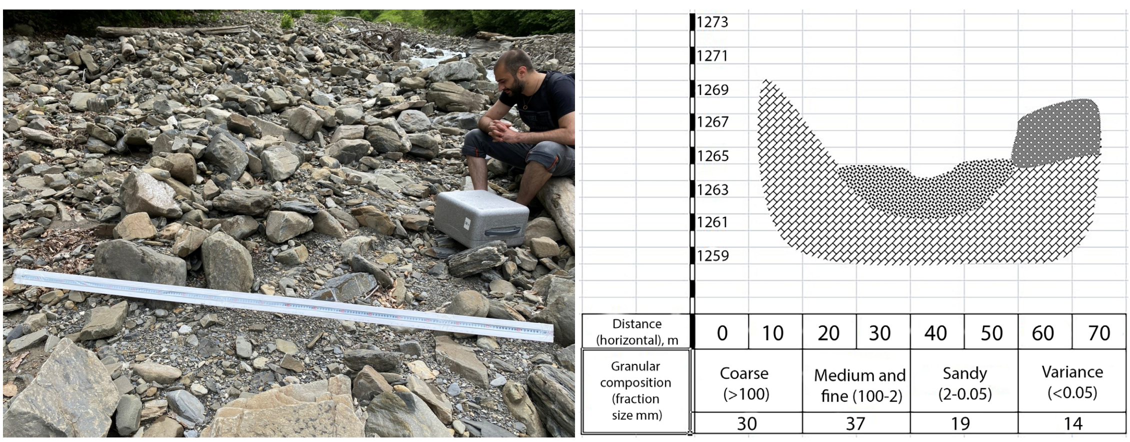
(a) (b)

Figure 9. (a) Granulometric composition of solid mass according to section 4-4. (b) Riv. Chokheltkhevi cross section #4-4.



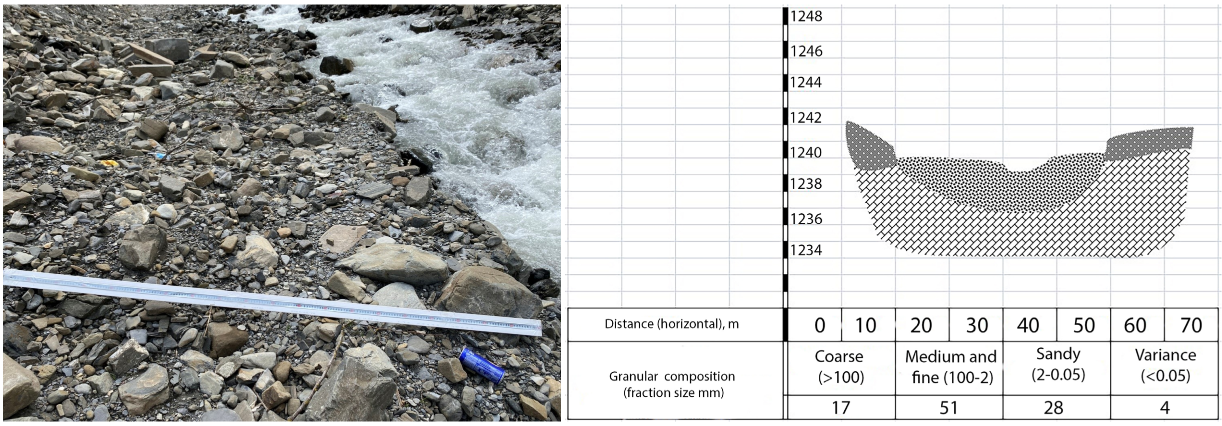
(a) (b)

Figure 10. (a) Granulometric composition of solid mass according to section 5-5. (b) Riv. Chokheltkhevi cross section #5-5.



(a) (b)

Figure 11. (a) Granulometric composition of solid mass according to section 6-6. (b) Riv. Chokheltkhevi cross section #6-6.



(a) (b)

Figure 12. (a) Granulometric composition of solid mass according to section 7-7. (b) Riv. Chokheltkhevi cross section #7-7.

Table 1. Granulometric composition of solid mass accumulated in the bed of Chokheltkhevi river.

Types of coarse and sandy soils of Chokheltkhevi according to percentage granulometric composition (Construction norms and rules—“Foundations of buildings and structures—PN 02.01-08”)								
Coarse fraction		Fine and medium fraction		Sandy fraction			fine-dispersed fraction	
Boulder <500	Cobble 500 - 100	Gravel 100 - 10	Pebble 10 - 2	Coarse sand 2 - 0.5	medium sand 0.5 - 0.1	fine sand 0.1 - 0.05	Dust 0.05 - 0.002	Clay <0.002
20	15	22	13	11	6	4	5	3

Table 2. Physical-mechanical characteristics of solid mass accumulated in the bed of Chokheltkhevi river.

Cn compressibility of sandy soils of Quaternary origin, kPa (kdp/cm²), φn of internal friction angle and deformation modulus, MPa (kgp/cm²) Normative values					
Sandy Grounds	**characteristics designation**	**Characteristics according to porosity coefficient *e***			
		0.45	0.55	0.65	0.75
a) pebbly and large	Cn	2.0 (0.02)	1.0 (0.01)	1.0 (0.01)	1.0 (0.01)
	φn	43	40	40	40
	E	50 (500)	40 (400)	40 (400)	40 (400)
b) average	Cn	3.0 (0.03)	3.0 (0.03)	3.0 (0.03)	3.0 (0.03)
	φn	40	40	40	40
	E	50 (500)	50 (500)	50 (500)	50 (500)
c) Fine	Cn	8.0 (0.08)	8.0 (0.08)	8.0 (0.08)	8.0 (0.08)
	φn	36	36	36	36
	E	39 (390)	39 (390)	39 (390)	39 (390)

Table 3. Granulometric composition of sand-clay rocks.

Table #	Determination of the granulometric composition of sand-clay rocks by laboratory method in mm%				
	Sand			Dust	Clay
	Large	Medium	Fine	0.01 - 0.002	<0.002
	2 - 0.5 mm	0.5 - 0.05 mm	0.05 - 0.01 mm		
	1	2	3	4	5
1	28.6	39.2	21.3	2.0	8.9
2	27.2	41.4	18.9	5.0	7.5
3	23.8	42.2	19.1	2.3	12.6
4	35.8	36.0	21.2	1.3	5.7
5	41.3	20.5	19.8	8.2	10.2
6	31.3	18.2	43.8	2.8	3.9
7	37.3	25.5	29.2	1.8	6.2

Table 4. Chemical characteristics of fine-fraction solid mass accumulated in the bed of Chokheltkhevi river.

Cross Section #	Chokhi 1	Chokhi 2	Chokhi 3	Chokhi 4	Chokhi 5	Chokhi 6	Chokhi 7	Sum	Average
Potassium and sodium K + Na	1.12	2.99	29.09	8.81	31.36	18.93	20.1	112.4	16.06
Magnesium, Mg	23.03	19.16	16.36	29.01	18.64	13.11	16.8	136.11	19.44
Calcium, Ca	75.85	77.85	54.55	62.17	50.0	67.96	63.2	451.58	64.51
Chlorine, Cl	8.43	8.98	6.82	5.18	9.09	7.28	7.1	52.88	7.55
Sulphate, SO_4^{2-}	7.30	7.19	6.82	6.74	4.55	5.34	6.8	44.74	6.39
Hydrocarbonate, HCO_3	84.27	83.83	86.36	88.08	86.36	87.38	86.1	602.38	86.05
PH	6.7	6.7	6.4	6.4	6.3	6.4	6.5	45.4	6.49
Humus, %	1.2	1.2	1.3	1.3	1.1	1.3	1.3	1.4	1.3

4. Conclusion

From the above-mentioned figures, it can be seen that active erosion and landslide processes are taking place in the bed of the Chokheltkhevi river, both along the transit area and towards the headwaters, which causes the channel to be filled with mudflow-forming solid mass from the headwaters to the end of the transit area, which contributes to the formation of a large-scale debris/mudflows.

Based on the results of the above research, it can also be concluded that coarse and sandy-clay soils are mainly accumulated in the rivebed of the Chokheltkhevi, which represent an unstable (storage) mass for the expected debrisflow, which, together with other geological, hydrological and climatic factors, contributes to the expected ecological threat strengthening.

According to the results of the laboratory studies, it can be concluded that the soil accumulated in the drainage channel is a soil with a low concentration of ions, and the humus content is minimal, which indicates the possibility of the solid mass accumulated in the drainage channel being easily moved and, accordingly, the risk of a catastrophic debris/mudflows.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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