

# Characteristics of mudflow occurrence and the study of mudflow deposits in the Azerbaijani part of the Greater Caucasus mountain

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## ABSTRACT

**Problem definition.** In recent years, a series of hydrological observations of the studied area show that mudflows not only weaken, but also in a number of regions where mudflows were not previously noted, began to manifest themselves in an active form. This is explained by the fact that in recent years, the detection of mudflows has increased the saturation of emissions of mixed chemical waste into the lower layers of the atmosphere, associated with military actions in the southwestern part of Eurasia, as well as between Russia and Ukraine. Incoming winds to the territory of Azerbaijan from west with chemical waste, pollute air masses compared to the northern ones. In the troposphere, the radiation balance is increased, which pollutes it and, as a result, the ecological balance is disturbed and affects the passage of mudflows along the Greater Caucasus.

**The purpose of the study.** The aim of the study is to analyze the distribution of mudflows taking into account the regional specifics of the Greater Caucasus and the natural factors influencing them, causing the formation of mudflows. The rivers of the territory under consideration are generally characterized by the prevalence of all types of mudflows compared to other areas. Mudflows of rivers of the southern slope of the Greater Caucasus are special.

**Methodology of the study.** While performing this study, mainly geographic-hydrological and comparative methods, as well as the analysis of expedition data and their hydrological monitoring were used. Hydrological data are almost the only objective source for judging the formation of mudflows. Therefore, the initial material for this study was the data of stationary observations of the largest discharges of suspended sediments, as well as the results of field expeditionary studies.

**Discussion of results.** It was determined that mudflows, along with changes in synoptic processes and the intensity of daily precipitation, depend on the direction of highlands to lowlands and vice versa, their precipitation. For these reasons, with the same rainfall, in the first case, mudflows occur on rivers, and in the second case river floods. This is explained in the first case by a sufficient, and in the second case, insufficient amount of weathering products from surface washout.

**Conclusion.** It was determined that in the belt section, especially formed by strong mudflows, the lithological relationship of differentiation of weathering products, forming the cone deltas, clearly appears. In the nearest foothills of the lowlands to the piedmonts in parts of the cone delta, the section almost entirely consists of coarse-grained material with ripple-wake suspensions, with gravel and coarse sands. As moving away from the piedmont plain to the plain, the presence of sloping sands is observed, which are presented in the section of dry deltas and cause water strikes flows. Similar is observed on the cone deltas of the Talachay, Naibbulag rivers, on the cone deltas near the village of Suvagil where water strikes on the surface of the land.

**Keywords:** mudflow, riverbed, debris flow, erosion, sediment transport, suspended load, exogenous process, heavy rain.

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**Problem definition.** In areas with high mountainous relief, the activity of the river network, as well as the amount and type of annual runoff, is characterized by complex dynamics. Although the water regime of these rivers is more stable in winter, with the onset of snowmelt in early spring the beginning of the high-water period occurs, and with the increase in precipitation this runoff may transform into floods and mudflows [1]. In river basins with an impulsive runoff regime, precipitation starting from mid-spring turns into mudflows because

infiltration in the upper layers of water-saturated soils is delayed. The accumulation of water on the surface flows down steep and highly inclined slopes, thereby conditioning the formation of mudflows [8]. In the Azerbaijani part of the Greater Caucasus mountains, there are a considerable number of river systems with such a regime [25]. The highest peak of this mountain system within the territory of Azerbaijan is Bazarduzu (4466 m). In the high-altitude belt of the mountainous area, permanent glaciers are present (Bazarduzu, Tufan, Shahdag, Qavdanvas,

Yatigdara, etc.) [5, 7]. Mudflow is characterized by its high velocity and transport capacity, the movement of stones, gravel, soil, mud, and large boulders together with water, its sudden occurrence, and its highly destructive power [23].

As an exogenous process, the mudflow phenomenon is uncontrolled both abroad and in our country, often assuming a catastrophic character, causing severe damage to the economy, regional centers, and villages, leading to human fatalities and the contamination of drinking water [20]. At present, taking into account the influence of climate change, the study of flood and mudflow events is of particular importance [21].

For the study of mudflow events, it is necessary to measure the maximum discharges of water and suspended sediments, to identify the regularities of mudflow hydrodynamics, to determine the characteristics of mudflow deposits, their granulometric composition, the volume of mudflow material, the zoning of mudflow deposits, and to develop a scientifically detailed classification of mudflow events. Therefore, the study of mudflow phenomena requires interaction with the parameters of natural factors.

Chen et al. noted that, in order to demonstrate the destructiveness of mudflows, often only the impulse carried by the distinct wave front is used. The researcher classified the erosion pattern into two types (surface erosion and deep erosion). For wave flows accompanied by erosion–deposition distribution, significant downstream erosion potential was confirmed, and the erosion caused by the mudflow wave was evaluated as deep erosion [2].

In recent years, global warming observed on Earth has led to spatio-temporal shifts in precipitation in the Greater Caucasus region. Snowfall occurring during the cold season melts rapidly due to short-term warming of the air. In mountainous regions, the increase in recurrence of maximum precipitation of torrential character has resulted in the formation of mudflows and an increase in their frequency [4].

After a mudflow event, chaotically fragmented material accumulates on the surface of river basins. The accumulated sediment material should be considered as a source for the subsequent occurrence of mudflow events. The main mudflow events occur in the river basins carrying mudflows on the southern slopes of the Greater Caucasus [18].

In recent years, global warming has had a particular impact on the formation of mudflow events. Unfortunately, due to prolonged dry summers (with relative humidity down to 40 %) and sharp diurnal fluctuations of air temperature, rock weathering has intensified, leading to the accumulation of fragmented material along mountain slopes [6]. The necessary conditions for the occurrence of mudflow

events include the predominance of xerophytic vegetation with anti-erosion properties, the rapid burning and disappearance of grass cover, intense precipitation (sometimes up to 3 mm per minute), and the presence of large slopes in valleys, basins, and rivers.

The lithological composition of rocks plays a crucial role in the formation of mudflow events. In this regard, the most active mudflow factors are weathered and eroded rocks. For example, in the northern slope of the Eastern Caspian depression, within the Lower Kura depression, widely distributed sand-clay, clay, and various shales contribute to the formation of mudflow events [10].

Erosional activity exposes mountain slopes, leading to the formation of large talus deposits, the transportation of mineral residues, the accumulation of sediments, and the lowering of the relief. This includes ravines and gully formations [15]. A large portion of sediment material moves downslope at a rate of about 3 mm/min and is transported by rainfall to accumulate in the form of cone-deltas. During hot, dry summers, when intense torrential rains occur, part of the material is transported downslope from high mountain areas into river valleys (particularly Samur, Mukhakhchay, Kurmukhchay, Shinchay, Kishchay, Demiraparanchay, Goychay, Atchay, Shabbranchay, etc.); however, due to water deficiency, only part of this material is carried further by rivers [16, 17].

In previous studies, mudflow events have been classified in a differentiated form. The formation of mudflow volume mainly depends on the amount of precipitation from the high mountainous areas down to the lower hills. The largest mudflow volume is observed when precipitation falls in this direction. Depending on the nature of the main rocks of river basins, mudflow events may occur in the form of muddy, detrital, or water–rock flows, with various transitional forms between them [3]. During the summer months in the Greater Caucasus, on washed slopes under the influence of orography, strong rainfall is frequently observed due to the convective movement of moist air masses toward the mountains in the first half of the day. Sometimes daily precipitation exceeds 100 mm [7].

During the transport of mudflows from high mountainous areas to lower hills, the failure of natural rock or debris dams further intensifies mudflow events. Conditions for the formation of such dams exist in the Talachay, Mukhakhchay, Kurmukhchay, Kishchay, and Shinchay valleys, where snow avalanches and landslide events occur, and riverbeds exhibit sharp meanders [14]. The failure of these dams triggers mudflow events, producing mudflow volumes several times greater than the maximum discharge of rain-induced floods.

On the southern slopes of the Greater Caucasus,

due to complex orographic and hydrometeorological conditions, mudflow events are strong and exhibit varied regimes. For example, the previously mentioned rivers experience severe catastrophic mudflows. In the Shinchay and Kishchay rivers and their tributaries, mudflow events occur on easily erodible rocks and in river basins with steep slopes [18]. In the Sariguney and other tributaries, the basins are almost entirely devoid of trees; mudflow events form in the high-altitude zone, producing strong mudflow currents. The occurrence of mudflow events has also been facilitated by deforestation for economic purposes, slope plowing, and unregulated grazing of livestock [9]. As a result, the soil and grass cover have lost their soil-stabilizing function, with intensively eroded soils, gullies, and ravines, along with fragmented materials from highly eroded bedrocks and slope deposits, accumulating in riverbeds [19].

In contrast, the Katekhchay and other rivers, flowing through forested zones, are almost devoid of rock-derived sediment supply, and therefore strong mudflow events do not form [17]. On the northeastern slopes, the Samur River exhibits its highest water content not only in spring but also during summer. However, in the northeastern slopes, particularly in the high mountainous areas, the ac-

cumulation of mudflow deposits is almost absent. In the river valley, the majority of mudflow sediments are retained, especially in areas characterized by complex orographic structures and intermountain depressions [26].

The study of mudflow events and their genesis in the Republic of Azerbaijan cannot be considered fully resolved. In this regard, conducted expeditions and hydrological monitoring indicate that mudflow events continue to recur frequently.

**The purpose of the study** In the study, the deposition and erosion characteristics of mudflow sediments associated with the formation of mudflows in the Greater Caucasus are analyzed. Particular emphasis is placed on the investigation of mudflow sediments transported by rivers of the southern slope of the Greater Caucasus, which are distinguished by their specific features.

**Research methodology and factual materials.** The study is based on expedition data, as well as on our hydrological monitoring, mainly after 2021 (Figure 1).

The results of the field work are presented in the table 1.

**Results of study.** The conditions of mudflows formation are different despite the equality of one and the same factor. As known, mudflow phenome-



Fig. 1. Measurement of the largest water discharges, suspended sediments and mudflow materials by the author: 1. Measurement of the largest water discharges and suspended sediments in the Gusarchay River - Kuzun village. 2. Reconnaissance work on denudation in the Gusarchay River drainage ditch area. 3 and 4. Measurement of mudflow materials on the cone delta of the Talachay River - Zagatala city

Characteristics of mudflow deposits of the cone delta

Distance from the right side of the cone delta, m	Volume of mudflow deposits of the cone delta, m <sup>3</sup>		Total weight of mudflow deposits, t
	wash-out	accumulation	
1. Talachay River nearby Zagatala city (near the new bridge)			
0-15	27000		54000
15-19			
19-32		163500	327000
32-48		311500	423000
48-58		150000	300000
58-65		1725000	345000
65-72		219000	438000
72-82		282000	564000
82-99		463500	927000
99-100		319500	639000
110-126.5		561000	1122000
	Σ 27000 m <sup>3</sup>	Σ2542500 m <sup>3</sup>	Σ5139000 m <sup>3</sup>

na occur in nature with different intensity of torrential rains. As indicated above, not every torrential rain causes the formation of mudflows. For the formation of mudflow, in addition to intensive torrential rains, it is necessary to have loose material prepared for removal. Therefore, to study the mudflows is relevant today and in the future.

Mudflow phenomena are explained as a result of a complex and highly fragmented mountain terrain, destroyed forest cover, unsystematic plowing of the land and grazing of cattle above the norm. Therefore, the activity and frequent recurrence of mudflows can cause the destruction of the catchment surface of rivers. Especially mudflows are formed as a result of torrential rains with an intensity higher than 1-3 mm/s. Torrential rains with heavy rainfall (50-60 mm) can be observed annually, with rainfall between 80-100 mm 2 times in 10 years, and with 100 mm 1 time in 20 years or more.

The above-mentioned influencing factors on mudflows allow us to study them according to geomorphological, climatic, soil and plant cover conditions.

A number of researchers were studied the relief of the Azerbaijani part of the Greater Caucasus. The relief is distinguished by flat and mountainous, as well as north-eastern and southern slopes of the mountains [27].

**Discussion of results.** While previous studies emphasized the formation of mudflows, our research focuses on the characteristics of sediment deposition and erosion associated with mudflows. In recent years, due to global warming, the amount of eroded material in mudflow basins has increased, and its transport by mudflows has intensified the damage to agricultural lands in deposition cones.

Nevertheless, the transported sediments related to mudflows are of practical importance as construction material and as a source of mineral fertilizer in crop production. It has been determined that coarse-grained mudflow deposits are practically suitable for use as a substitute for crushed stone in construction. In particular, the adhesive properties of the sand-sized fraction of coarse-grained mudflow deposits are advantageous in cement production. Accordingly, depending on their formation, priority has been given to studying mudflow sediments.

Geomorphological conditions of mudflow formation, as in the process of mudflow formation of the territory, distinguish high-mountain, mid-mountain and low-mountain belts.

The high-mountain belt, above 3000 m, covers the territory from the upper limit of alpine meadows to the crest of the Main Caucasian Range. This part of the territory is characterized as a wall in front of humid air masses of the Main Caucasian Range chain from the north, numerous side chains and spurs, which are steep, sheers cutting by narrow, deep gorges.

Here, bedrock is often exposed. They are composed of clay shales, sandstones and limestones [2], which are quickly subject to weathering and destruction. The increase in slope heights and their steepness allow weathering products to slide down the slope at high speed, repeatedly destroying them, and accumulate in most cases directly in river beds. The specified relief form is typical for the valleys of the rock belt and is important in the process of formation and origin of mudflows. The high-mountain belt is a convenient place for accumulation of loose deposits and the leading source of mudflow formation.

The sources enriching mudflows with detrital-loose material are divided into the following morphological groups: taluses, avalanches, placer deposits, landslides, old moraines, alluvial cones of local inflows of rivers, terraces, floodplains and channel deposits. As a result of intensive weathering, in the transitional and especially rocky belts, taluses accumulate in different geomorphological conditions.

According to the degree of their participation in mudflow formation, talus is divided into two groups:

- The first accumulates directly in river beds and participates in their formation;

- The other mass of talus accumulates far from river beds on low terraces and floodplains.

It should be noted that depending on their location in any belt, taluses are fixed in different ways. They can be divided into mobile, semi-fixed and fixed. To clarify the soil-protective role of vegetation in the mountains, we indicated in the following works [12].

Mobile taluses, starting from the sources of formation to their base, do not encounter plant obstacles. They actively participate in the formation of the mudflow, are developed mainly within the rocky belt, are widely observed in the transitional and, partially, in the mid-mountain belts.

Semi-fixed taluses are developed mainly in the transitional belt, and are also found in the mid-mountain belt. Its lower part is fixed by herbaceous vegetation and forest.

When distributing taluses over the territory, the slope of rivers and catchments has a special role. The slope of the river in the upper reaches of the Samur River is 37.2-81.4 ‰, in the rivers of the north-eastern slope of the Greater Caucasus is 82-186 ‰ and in the southern slope is 100-190 ‰, increasing they take a wall-like shape.

In the high-mountain belt of the Greater Caucasus in the source of the mudflow, large daily maximums of atmospheric precipitation are characteristic and show that on the north-eastern slope of the Greater Caucasus in the rivers Gudialchay, Velvelichay, and on the southern slope in the rivers Talachay, Mukhakhchay, Kurmukhchay, Kshshchay, Shinchay, Eyrichay, Damiraparanchay, Pirsatchay mudflows occur with a maximum precipitation of 60-80 mm, (in rare cases catastrophic mudflow in Talachay with 188.2 mm) and with torrential rains with an intensity of 1-3 mm/s. and more [22]. Next to below the transitional belt is located up to 2000-2200 m, it covers the upper forest line, subalpine and alpine meadows. This belt stands out as an independent one, since the conditions of formation, movement and accumulation of loose sediments here are more intense than in the mid-mountain and weaker than in the rocky belt. Here, weathering

products accumulate within the upper forest line, sometimes in the form of alluvial cones fixed by vegetation cover. The slope of the rivers increases to 80-90 ‰ and more. Scarps and scarp slopes are near river beds is observed here. Balakenchay, Talachay, Mukhakhchay, Shinchay, Kurmukchay, Kishchay, Damiraparanchay, Goychay, Velvelechai, Gudialchay, Agchay, Kharmidorchay and others are typical rivers. They are mainly divided into weakly mudflow-bearing, strongly mudflow-bearing and catastrophic. The catastrophic mudflow rivers include Talachay, Mukhakhchay, Kurmukchay, Shinchay, Kishchay, Goychay, etc. [11].

The mid-mountain belt consists 1000-2000 m is almost everywhere covered by dense forest, which protects the slopes from intensive surface washout and weathering. Its area occupies a wider strip than other belts. The mudflows increase due to terraces, floodplains of taluses and covers of loose sediments, which favors the accumulation of mudflow deposits directly on the bottom of the valleys, as well as in river beds. The loose materials accumulated here enrich mudflows more than in the mid-mountain areas, where they are washed away and quickly carried into the rivers during intense torrential rains.

The slopes of the rivers in the mid-mountain belt, depending on the exposure of the mountain slopes, change within the range of 28.3-37.2 ‰, 59-73 ‰ and 52-84 ‰.

The analysis shows that the mid-mountain belt takes a certain part in the additional enrichment of mudflows.

The low-mountain belt is 600-1000 m, covers the northern part of the Ganykh-Eyrichay valley, making up a strip along the entire length from northwest to southeast approximately 400 m in wide. It is almost completely covered with forest. The slopes of the rivers in the low-mountain belt, depending on the exposure of the mountain slopes, are 15.1-48 ‰, 20-57 ‰ and 22.8-5 ‰ and physical weathering is weak, and mechanical and anthropogenic are expressed comparatively more strongly. The low-mountain belt and river alluvial cones are the initial accumulation zone of mudflows. Taluses formed within the mid-mountain and low-mountain belts are fixed by forest vegetation.

The main climatic factors of mudflow formation are significant daily variations in air and soil temperature, contributing to physical weathering observed in the warm period of the year, preceded by prolonged dry periods, upcoming mudflows, and heavy rainfall. These factors are at the same time the conditions for the formation of mudflows, which in the absence of one of them are not observed or are expressed weakly.

Among the climatic factors, as the main source of energy, total solar radiation and its components

are directly related to mudflows. An increase in its value, especially direct radiation, contributes to the intensification of weathering processes, and with a predominance of the number of days with diffuse radiation, this process is weakened. The annual values of total radiation in the area of alluvial cones are 120-125 kcal/cm<sup>2</sup>, and in the high-mountain zone at 3000-3500 m, and in the higher part it reaches up to 140-145 kcal/cm<sup>2</sup>. The annual values of the radiation balance, with the exception of some high-mountain peaks, are positive. In the low-mountain part of the catchments area they reach up to 50 kcal/cm<sup>2</sup> in places, and in the mudflow formation zone they decrease up to 15 kcal/cm<sup>2</sup> and lower. Zonal and high-altitude circulation in the warm season is characterized by the transfer of sea air masses of temperate latitudes in the Azores high system and their entry into the territory of Azerbaijan [19].

In the studied territory of the southern slope of the Greater Caucasus, frequent passage of mudflows is observed in the Kishchay River in mid-summer and early autumn. The tributaries of the Kishchay River are divided into two groups: weakly mudflow-bearing and strongly mudflow-bearing [1]. In recent years, highly mudflow-hazardous rivers have predominated. The Gainar, Duluzdara, Dodudere and other rivers are considered weakly mudflow-hazardous. They are located within the low-mountain and partly mid-mountain belts. Their catchments are completely covered with forests and meadows. About the slopes of the rivers we noted above. There are no real opportunities for mudflows to pass in their catchments. Small rocks are very rare in the river beds. Mud torrents are mainly observed on such rivers. This phenomenon is accompanied by a terrible roar.

Mudflow forming sources are confined in the Kishchay River catchment area mainly above the forest belt boundary. Mudflow forming sources in the Kishchay River in the east and southeast are more active than mudflow forming sources on the slopes to the north and northwest.

A strong analysis of mudflow forming sources of catchment area of the Kishchay River shows that the most dangerous mudflow source is the rock belt, which cover a large area.

The area of the sources enriching mudflow in the catchment of the Kishchay River is 75 km<sup>2</sup> or about 46% up to the river outlet and cone.

An analysis of mudflow-forming sources of the catchment area of the Kishchay River shows that the most dangerous mudflow source is the rocky belt. The tributaries of the Damarchik River are short and directly connected to the main channel, as a result of which they can almost simultaneously carry their material there. This feature is absent in the catchments of other rivers. Mudflow sources of the

Goytepe, Takachukhur, Sarytorpag rivers occupy a small area and cannot individually cause strong mudflows. These rivers, after the formation of mudflows, enter widened sections of the valley, where their strength decreases sharply.

At the same time, the formed flow in the middle part of the river is significantly enriched with channel debris. Depending on the location in one or another belt, talus is fixed in different ways. In accordance with the degree of fixation, they can be divided into mobile, semi-fixed and fixed.

Mudflows in the catchment area of the Kishchay River were observed in 1896, 1901, 1910, 1911, 1916, 1926, 1941, 1955, 1957, 1958, 1959 and 1963. They constantly threaten the city of Sheki and its villages, as well as the villages of Kish, Ohud, Dody, Baltaly located in the mudflow cone of the rivers, often putting the main structure of the Sheki hydroelectric power station out of order, destroying roads, etc. The most catastrophic mudflows were observed in 1896, 1910, 1936 and 1958. One of these flows of the river Kishchay on average carries out more than 1 million m<sup>3</sup> of solid material.

The conducted studies and approximate calculations, based on the traces of the passing mudflows, show that the greatest amount of mass brought by mudflows can reach 10 million m<sup>3</sup>. The most catastrophic mudflows, based on the above noted, are recurrence once every 20 years or more, which corresponds to the frequency of daily precipitation maximums exceeding 100 mm. The remaining tributaries of the rivers Kishchay, Damarchik, Saryguney, etc. are considered highly mudflow-bearing. As mentioned above, their sources are located within the meadow and mainly rocky belts. Mudflows occur in them differently. In some, mudflows are very strong, while in others weak. Weakened mudflows cannot move down along the valley for a long distance.

In June 1947, in the Damarchik River, the daily maximum precipitation was 74.8 mm, in Sheki 68.3 mm, and in June 1963, at the indicated points, the daily maximum precipitation was 55.6 and 80.9 mm, respectively. An analysis of typical years shows that, compared to the mid-mountain area, the daily maximum precipitation increases in the low-mountain areas. This is explained by the fact that in recent years, cumulus clouds saturated with chemical waste cannot rise above 1000 m above sea level, i.e. they remain in the low-mountain belts.

Vegetation cover of the catchment area of the river Kishchay varies depending on the altitude of the area and is represented by mountain-meadow and mountain forest belts. The mountain-meadow belt, covering the territory from 1800-3000 m, and the forest belt from 500-2100 m above sea level, are represented by oriental beech (*Fagus orientalis*), Caucasian hornbeam (*Carpinus betulus*) and, partial-

ly Georgian oak (*Quercus iberica* Stev.). The forests of the lower mountain forest belt up to 1000 m consist of Georgian oak, hornbeam and ashtree (*Fraxinus*). At an altitude of 1800-2100 m, beech forests gradually disappear, replaced with slate forms, which can be explained by changes in their conditions in nature.

Soil types consist of mountain-meadow and mountain-forest soils. The area of water runoff formation at an altitude of 1000 m is 47.9%, and at an altitude of 220-1000 m, in the area of runoff loss occupies 52.1% of the total catchment area.

Here, under the influence of the latest tectonic movements, gravitational-tectonic cracks have formed, are expressed in the relief. They are clearly traced between the mountains of Garaguzey, Chakhyt, Khanyailag, etc.

The next frequently recurrences mudflow is the Kurmukhchay River.

The river is formed by the confluence of four rivers: Kunakhaysu, Bulanykhsu, Hamamchay and Aghchay. The high-mountain part of the catchment area covers the source parts of the constituent tributaries of Bulanykhsu, Kunakhaysu and Hamamchay.

The catchment area of the Kunakhaysu tributary differs from other tributaries by its continuous, abundant distribution of exposed taluses [13]. The rivers are characterized by muddy and mud-stone torrents. Muddy mudflows are often accompanied by a characteristic roar. The upper part of the catchment is covered with lush alpine meadows. The relief in this part of the catchment is characterized by strong indentation by galleys and gorges, along which the waters of the main channel flow, gradually forming deep transverse valleys. The nude of the territory, the scarcity of vegetation cover, and sharp amplitudes of air temperatures are favorable conditions for intensive mechanical and physical weathering and the formation of loose debris accumulations that feed the mudflows. The mid-mountain belt is characterized by gentle slopes and relatively a stable, thick layer of soil cover. The piedmont plain is distinguished by less dissected slopes, well-developed soil cover, and forest vegetation cover.

The Bulanykhsu River is formed by the confluence of many waterfalls. Here the mountain slopes are steep, have the shape of a cirque, are strongly dissected and are completely free of soil and vegetation covers.

The source of the Hamamchay River is bare rocky, intensely denuded cirques. There are many spring outlets in this area. Washing away the slopes, they form galleys, taluses, and channel deposits in the form of cobblestones.

The Aghchay River is two kilometers long and flows along a very steep hanging valley with fre-

quent stepped sections. Mudflows are observed along it in mid-spring, summer, and early autumn.

The Talachay River is another interesting mudflow phenomenon. It is distinguished by the fact that it causes great damage to the economy. These mudflows are mainly water-stone torrents. The sound of mudflow deposits rolling along the bottom can be heard from afar. Mudflows mainly occur in the evening or at night. Here, the daily maximum precipitation reaches 188.2 mm. The small length of the river, rainfall mainly from the high-mountains to the low-mountains, the spread of easily eroded rocks in the catchment area, and the steepness of the mountain slopes contribute to the passage of strong mudflows. Such rivers include Mukhakhchay, Balakenchay, Damiraparanchay.

Mudflows on the north-eastern slope of the Greater Caucasus differ from those on the southern slope. On the north-eastern slope, mudflows are mainly observed in spring and autumn. Most do not have a large alluvial cone area due to the large intermountain troughs. Velvelechay, Gudialchay and Aghchay are typical rivers with strong mudflows.

Unlike in the past, in the modern period, due to global warming, the lack of transportation of river runoff contributes to the deposition of a certain part of the weathering product on the surface of river catchments, floodplains, terraces and intermountain troughs, and depressions, and most of them accumulate in the alluvial cone. The main reason for the accumulation of sediment in the alluvial cone is the weakening of the gravitational force, a decrease in potential energy to a minimum and a weakening of the kinetic energy of the river runoff. The transportation of mudflow deposits also depends on their geometric shape. Deposits closer to the shape of a ball travel longer distances, and other forms travel shorter distances. The falling of torrential precipitations in an integrated form in the direction from high-mountains to low-mountains leads to mass movement, which creates catastrophic mudflows.

The intensity of surface washout depends on the reliability of the amount of rock weathering products and their transportation [13]. The movement of the force of the denudation process determines the gravitational force of mass mudflow materials. Therefore, the study of mudflows depends on natural factors. The combination of these factors on the influence of mudflow movement requires the compilation of theoretical curves. The solution of the problem requires their interrelation.

In recent years, military actions, as well as holiday fireworks, pollute the lower layers of the atmosphere. The radiation balance in the troposphere has increased, which pollutes it and, as a result, the ecological balance is disturbed. This can be explained by the wars between Armenia and Azerbai-

jan, Russia and Ukraine, Israel and Palestine, events in France, Iran, between Turkey and Syria, Afghanistan and Iran, etc. This contributed to an increase in the discharge of chemical waste into the lower layers of the troposphere. With the increase in positive and negative charges in the troposphere, lightning became more frequent, especially between the land surface and clouds, as a result of which accidents became more frequent. For example: in 2023, in the village of Aliabad, of the Zagatala region, the roof of a secondary school, and in the village of Mukhakh, a cowshed was burned down, and on the way, lightning killed a person, and in the Gakh and Dashkesan regions, shepherds died in the subalpine meadows.

In 2023, due to the increase in the number of thunderstorms in the lower layer of the atmosphere, intense melting of ice began, which increased the flow of water in the rivers and caused mudflows. These mudflows were distinguished by a peculiarity, since they occurred at an uncharacteristic time for them. Mudflow was occurring on June 20-21, 2023 in the Talachay and Mukhakhchay, on July 4 in the Tovuzchay and Hasansu rivers in the Lesser Caucasus, on July 5-7 in the Gapychay, Eyrichay, Velvelechay, Goychay and Damiraparanchay can be example. These mudflows caused varying degrees of damage. These mudflows are caused by sudden changes in air circulation in the atmosphere, which has led to changes in synoptic processes in recent years, namely, on September 4-5, 2023, walnut-sized hail fell in Sheki, on September 7, 23 and September 16, 2023, egg-sized hail fell between the Zagatala and Balaken regions. Similar processes were observed on 09/08/23 in the villages of the Sheki district in the form of flooding, and on 09/17/23 with a rise in the water level in Talachay by 1.5 m led to mudflows near the village of Yukhari Tala, Ashaghy Tala, Magh. At the same time, in the Astarra district, due to a large accumulation of suspended sediment in the river bed, a flood occurred.

The above-mentioned change in synoptic processes in the republic is caused by the penetration of air masses from midlatitudes. According to the researcher, the third type of air masses (Azov maximum) often causes precipitation in mountainous areas, accompanied by lightning and sudden changes in air temperature. Precipitation above the norm in April-May, July-September 2023 led to an increase in landslides, since water fills voids and cracks in the soil due to the slope of the terrain, the gravitational force leads to the sliding of the earth mass, which was observed in the administrative districts of Ismayilli, Lerik, Guba, Astarra of Azerbaijan, the Republic of Georgia, India, Peru, Colombia, Ecuador, etc.

The activation of mudflows is mainly influenced by the direction of rainfall from high-mountain regions to low-mountain regions and vice versa. Catastrophic mudflows are mostly formed under the influence of the first direction. With the same amount of precipitation, the first direction is more strong than the second. The reasons are the catchment area coverage and the integration capacity of runoff transportation. And the second direction is characterized by a smaller catchment area coverage and spontaneous transportation of water runoff.

We discovered interesting synoptic features of precipitation distribution on the southern slope of the Greater Caucasus: on August 14, 2021, at 16-17 o'clock on the Mukhakhchay catchment between the village of Mukhakh and the city of Zagatala, where intense torrential rains fell, but interestingly, in the eastern part of the territory, there was almost no precipitation.

Another interesting fact is that the above is not observed in the Lenkaran natural region. It is identified that the fine granulometric composition of rocks contributes to less water seepage than coarse. In the Lenkaran natural region, flooding is often observed due to weak seepage of clay soils.

The next interesting fact is the effect of forest cover on sediment runoff. Despite the fact that there is forest cover in the catchment areas of the rivers of the Greater Caucasus and the Lenkaran natural region, mudflows occur on the rivers of the Greater Caucasus due to easily eroded rocks, and floods occur in the Lenkaran natural region due to rocks that are difficult to erode.

Another mudflow activator is the 11-year solar cycle. This feature was observed in the rivers of Crimea [24]. According to the researcher, with the exception of the Armenian Republic, in the Caucasus (especially in the Greater Caucasus) there is an increase in mudflow activity by one fourth and one second of the 11-year solar cycle (in 1951-1953, 1961-1963). Abroad, special attention is paid to theoretical methods, as well as the formation of the ecological balance of mudflows and mudflow processes of rainfall genesis [28].

When mudflows are activated, another factor is the influence of human economic activity. Especially if mountain pastures are used for grazing above the norm, which leads to increasing of weathering.

**Conclusion.** As a result of the conducted mudflow studies, the following conclusions have been drawn:

1. When studying the mudflow, emphasis was placed on the hydrological aspect of the issue, thereby paying attention not to the root cause of the phenomenon, as the mechanism of mudflow formation on mountain slopes, but also to their consequences.

2. The strong mudflow activity of the rivers in the Talachay, Mukhakhchay, Kurmukhchay, Shinchay and Kishchay catchments is most pronounced in comparison with other rivers running from the Greater Caucasus. In recent years, this can be explained by strong disruptions in synoptic processes associated with emissions of chemical waste into the lower layers of the atmosphere.

3. It was revealed that in the belt section, especially formed by strong mud-stone mudflows, the lithological relationship of differentiation of weathering products forming the alluvial cones is clearly

received.

4. Modern mudflows are of current interest both as natural phenomena and as a destructive factor of mountains, requiring serious measures to combat its harmful consequences. They are also of great interest from the point of view of the formation of piedmont plumes of the alluvial cone over a long anthropogenic period.

5. The effectiveness of anti-mudflow measures largely depends on the correct consideration of the specifics of natural conditions and the patterns of manifestation of mudflow phenomena.

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## **Характеристика виникнення селевих потоків та вивчення селевих відкладів в азербайджанській частині Великого Кавказу**

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Нахічевань, Азербайджан

За останні роки серія гідрологічних спостережень досліджуваної території показує, що селеві потоки не тільки слабшають, але й у низці регіонів, де раніше селеві потоки не відзначалися, почали проявлятися в активній формі. Це пояснюється тим, що в останні роки виявлення селевих потоків збільшило насиченість викидами змішаних хімічних відходів у нижні шари атмосфери, пов'язаних з військовими діями в південно-західній частині Євразії, а також між Росією та Україною. Вітри, що надходять на територію Азербайджану із заходу з хімічними відходами, забруднюють повітряні маси порівняно з північними. У тропосфері підвищується радіаційний баланс, що забруднює її та, як наслідок, порушується екологічний баланс і впливає на проходження селевих потоків вздовж Великого Кавказу. Метою дослідження є аналіз розподілу селевих потоків з урахуванням регіональної специфіки Великого Кавказу та природних факторів, що впливають на них, спричиняючи формування селевих потоків. Річки досліджуваної території загалом характеризуються поширеністю всіх типів селів порівняно з іншими районами. Селі річок південного схилу Великого Кавказу мають особливу особливість. Було визначено, що селі, поряд зі змінами синоптичних процесів та інтенсивністю добових опадів, залежать від напрямку високогір'я до низовин і навпаки, від їх опадів. З цих причин, при однаковій кількості опадів, у першому випадку на річках виникають селі, а в другому випадку – повені. Це пояснюється в першому випадку достатньою, а в другому випадку недостатньою кількістю продуктів вивітрювання від поверхневого змиву. Було встановлено, що в розрізі поясу, особливо утвореному сильними селевими потоками, чітко проявляється літологічний зв'язок диференціації продуктів вивітрювання, що формують конусоподібні дельти. У найближчих до передгір'їв низовинних ділянок, в частинах конусоподібної дельти, розріз майже повністю складається з грубозернистого матеріалу з хвилеподібно-плиткоподібними суспензіями, гравієм та грубим піском. У міру віддалення від передгірної рівнини до рівнини спостерігається наявність похилих пісків, які представлені в розрізі сухих дельт і спричиняють ударні потоки води. Подібне спостерігається на конусоподібних дельтах річок Талачай, Найбулаг, на конусоподібних дельтах поблизу села Сувагіл, де вода виходить на поверхню землі.

**Ключові слова:** *селевий потік, русло річки, грязьовий потік, ерозія, перенесення осаду, завислий вантаж, екзогенний процес, сильний дощ.*

**Внесок авторів:** всі автори зробили рівний внесок у цю роботу

**Конфлікт інтересів:** автори повідомляють про відсутність конфлікту інтересів

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