DEBRIS FLOWS:
Disasters, Risk, Forecast, Protection

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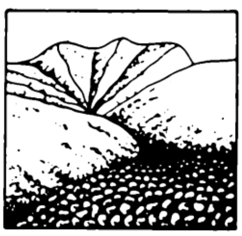

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СЕЛЕВЫЕ ПОТОКИ: катастрофы, риск, прогноз, защита

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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).

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Origin and classification of debris flows

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The problem of formation and distribution of debris flows is considered in the article. Based on the work of several authors, an attempt was made to classify the debris flows by the following parameters: the particle size distribution, the frequency of debris flows, their influence on structures, water sources, water content, mass of solid particles of the flow, the key factors of flow formation and the prerequisite of flow formation.

debris flows, formation of debris flows, classification of debris flows.

Формирование и классификация селевых потоков

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В статье рассматривается проблема образования и распространения селевых потоков. На основе работ нескольких авторов сделана попытка классификации селевых потоков по следующим параметрам: гранулометрический состав, частота селей, их влияние на строения, источники воды, содержание воды, масса твердых частиц потока, ключевые факторы образования потока и предпосылка образования потока.

селевые потоки, образование селевых потоков, классификация селевых потоков

Georgia belongs to the highlands where debris flows are quite active, which are caused by geographical location and natural-climatic conditions of the country. It should be noted that the area is dominated by steep slopes; is often observed weathering of mountain rocks, reduction of vegetation cover, intensive atmospheric sediments with hail; debris flow basins are rich in loose solid materials that support the formation of debris flow body; in recent times, also increased activity of debris flows caused by anthropogenic impact.

The debris flow is a mud or quail trap that is composed of water and rocky pieces, characterized by the ability of an unexpected appearance and destructive power.

It is widely known in the Caucasus, Carpathians, Crimea, Urals, Pamirs, Altai’s, Tian Shan, Altai and Suhani mountains.

Most mountainous regions, according to the solid mass in the stream, are characterized by the abundance of several types of debris flow. For example, in the Carpathians, we often encounter stony-water debris flow and the Caucasian - stone-mud and Central Asia - debris flows.

The velocity of debris flow is 2,5-4,0 m/s, but in case of dike eruptions, it can exceed 8-10 m/s. The result of debris flows passing, in this case, may be catastrophic.

The debris flow can be spread over long distances and generate massive obstacles and destabilization on the path of its movement (at the transit zone). At the same time, the volume of debris flow and the expenditures at the transit zone may be increased ten times higher than the initial.

The formation of debris flows is mainly due to simultaneous execution of three conditions, namely:

- The existence of mountain rocks on the slopes of the debris flow basin;
- The amount of water required for the loosening and transportation of loose solid material from the slope;
- Steep slopes of water flow.

The main reason for the collapse of mountain rocks is the sharp variation of the air temperature, causing the creation of the numerous cracks and the collapse of the rocks. The process is further contributed to freezing and draining of water in the cracks. In addition, the destruction of mountain rocks causes chemical and organic weathering.

In most cases, the cause of debris flows is caused by heavy rains, more rarely, snow intensity, and breakage of moraine type lakes, landslides, and earthquakes. However, every mountain region is characterized by a certain cause of debris flow.

For example, the causes of debris flow for the whole Caucasus are as follows: heavy rains and rains - 85%, snow melting - 6%, breakthrough moraines - 9%.

In general, the process of formation of debris flows caused by heavy rains is going on in the following way.

Initially, water-filled holes and cracks of rocks. Besides, the strength of the particle trap is dramatically reduced and the equilibrium condition of the loose rocks is collapsed. The water begins to flow on the surface, which results in the movement of small particles of soil, then the gravel and the crust, and finally the stones and boulders. The process increases in an avalanche manner. The resulting mass is flowing into the bed. On the way, it adds new masses of mountain rocks.

In recent times, natural causes of debris flows have been added such anthropogenic factors as massive cutting of timber on mountain slopes; Degradation of soils caused by grazing; Explosions during highway and railway construction; Mining works; Improperly provided irrigation works; Dissemination of plant cover due to waste of enterprises.

In order to choose the right anti-debris flow measures and to maximally protect the territories in the risk zone as well as the objects located on them, needed a correct classification of debris flows according to different indicators. In particular: according to granulometric composition, genesis, flooding frequency risk, structural impacts, water content, causing factors, etc.

Over the years, many researchers have worked on this issue [*Vinogradov, 1980; Sheko, 1980; Perov, 1981; Natishvili, 1998; Natishvili et al., 2016; Kruashvili et al., 2016, 2017*]. Based on analyzing these works, we have found the most common classification based on famous scientist's research.

According to the granulometric composition, the debris flow classification can be formulated as follows:

- Stony water - a mixture of water and major rocks, including boulders and rocks. Volumetric mass 1,1-1,5 t/m^3. Mainly formed in solid rock zones;
- Muddy - a mixture of water, clay and dust particles, with a small concentration of stones. Volumetric mass of 1,5-2,0 t/m^3;
- Stony-Muddy - a mixture of water, fine grain, pebbles, gravel and small sized stones. However, it is possible that even small quantities of large rocks that sometimes flow out and sometimes continue to move with them. Volume mass is 2,1-2,5 t/m^3
- Climber-snowy - the transitional stage between debris flows and snowballs in which water is transported.

This classification shows that the debris flow is too heavy and the power of the debris flow is reached by 5-12 t/m^2.

According to genesis, debris flows are divided into the following types:

- Alpine type is characterized by the rapid seasonal snowfall of snow (USA, Canada, Andes, Alps, Himalaya);
- Desert type - occurs in the arid or semi-arid regions of unexpected rainfall during the rainy season (Arizona, Nevada, California);
- Lahars - volcanic muddy flows, are formed by rainfall on the slopes of the volcanoes.

According to the frequency of debris flows:

- High debris flow activity - once in 3-5 years
- Average debris flow activity - once in 6-15 years recurrence;
- Low debris flow activity - recurrence once in 16 years and more rarely.

According to their impact on the construction:

- Small capacity -slight washing out, jamming of the aditus outlets;
- Medium power – strong washing out, complete wedging of the aditus, damage and destruction of faceless structures
- Powerful - a great destructive force, destruction of bridge fires, piers, stone structures and roads;
- Catastrophic - complete destruction of constructions and roads and covering them by sediment.

According to water source:

- Rain caused - characteristic for medium and lowland debris flow basins that do not water from glaciers. The main condition of the formation of such debris flow is the atmospheric precipitation of the atmospheric sediments that can cause washout and transportation of decomposing rocks;
- Glacier - characteristic for high-glacier debris flows basins, with modern glaciers and moraines. The main source of watering for such type of debris flows are moraines the melting which glaciers, as well as the outburst of glacial and moraine lakes, provoke the development of debris flows. The formation of glacier debris flows greatly depends on air temperature;
- Volcanogenic - can develop during the earthquake. In some cases (when volcanic eruptions), when the formation of solid and liquid constituents of debris flow develop simultaneously.

According to water content:

- Linked (structural) streams - a mixture of water, clay, and sand, which has properties of a plastic substance. The flow moves as a single mass. In comparison with the water flow, it does not move according to the burden of the bed, but it destroys or corrects the riverbed or reinforces contractions;
- Unlinked streams - moving at great speed; There is a constant collision of stones, the processing of their facets. It contains a large amount of water that is represented as a transporter. The stream was mostly flowing a river bed and destroys in some places (See Table 1).

Based on the main factors of creation:

- Zonal - the main cause of formation is climatic conditions (precipitations). Debris lows are systematic. Transit zone is relatively constant;
- Regional - the main cause of formation is geological factors. The debris flows are episodic and transit zones are variable;
- Anthropogenic - the outcome of the human activity. Wherever the mountain landscape is on the big loading. The debris flows are episodic (see. Tabl. 2).

Table 1. The types of debris flows, according to the solid mass transported.

The size of the debris flow	Debris flow volume
Little	0,1-1,0 thousand m^3
Big enough	1,0-10 thousand m^3
Great	10-100 thousand m^3 (Once in 2-3 years)
Very big	0,1-1,0 Mln. m^3
The greatest	1-10 Mln. m^3
Grand	10-100 Mln. m^3

Table 2. In accordance with the prerequisites.

Type	Prerequisites	Origin and distribution
Rain	Heavy rains, frequent rains	The most common debris flow type. Coming out of the slopes and landslides.
Snow	Intense snow melt	It originates in subarctic mountains. It is related to the moisture and detachment of snow masses.
Glacier	Intense ice melt	In mountainous regions. The melting point is associated with the flow of glacier waters.
Volcanogenic	Volcanic eruption	In the volcanoes regions. The largest is the emergence of intense snow melting and the breakdown of crater lakes.
Seismogenic	Strong earthquakes	Strong seismic regions. Cut off the ground masses from the slopes.
limnogenous	Development of lake dams	In mountainous regions. Dams break.
Anthropogenic, direct action	Accumulation of technogenic rocks. Poor land dams	Rocks accumulation sites The removal of technogenic rocks. Dam is damaged.
Anthropogenic, indirect action	Soil and Soil cover Damage	Places of the destruction of trees and meadows, washout of beds and slopes

The presented classification conducts the conditional nature, as we have different interpretations of the works of individual authors and are not yet accepted uniform standards.

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