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DEBRIS FLOW DANGERS OF THE 21ST CENTURY IN THE NORTHERN CAUCASUS (RUSSIA)

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ABSTRACT

The negative impact of debris flow processes on vital facilities is expected to increase as a result of the forecasted degradation of mountain glaciation, related to the changes in the climate. In the Caucasus region of Russia, where debris flows stand out for the frequency of occurrence in space, time and the power of their energetic manifestation and are mostly of glacial origin, that follows from the analysis of the developing situation, which relies on the knowledge of facts of the last 30 years (events on the Kullumkol-Su, Kaya-Arty-Su, Genaldon, Gizeldon, Birdzhaly-Su, Bulungu-Su and Sylyk-Suu rivers). As glacier tongues retreat to higher true altitudes (~300 m for the last 50 years), massifs of friable single-grained, primarily moraine, formation become exposed, periglacial water bodies rapidly (comparatively speaking) appear, gradients of tributaries, in which water torrents may become saturated with friable detritus, increase. Threats and risks of initiation of regimes of debris flows grow. Most considerable debris flows, in terms of their destructive effect, are connected with outbursts of lakes, lying close to glaciers. Discharge of intraglacial hollows more and more frequently acts as a triggering mechanism for the start and further development of a debris flow process. In every potentially dangerous debris flow basin of the region, due to peculiarities of the Quaternary period, there are various ways of realisation of disaster scenarios for mouth parts of mountain rivers. Even in the territorially close basins there may develop various flows of processes of hard material transport by water torrents, [various] distances and volumes of deposit transport, which depend on morphologic conditions along the course of movement. The length of the period of high temperatures in July-August, which causes heightened ablation of ice masses against the background of a lowered general and (or) filtering stability of natural retaining dams, is most significant. At the same time not every close-to-a-glacier hollow or glacial hollow with the realisation of the outburst scenario thereupon is able to initiate a debris flow process – for that to happen outer slopes of a natural dam (usually of most recent moraine) should have 30-35° steepness (~20° steepness is insufficient whereas within the 20-30° steepness range the possibility of an avalanche-like increase of conditions for transformation of a water flood into a debris flow may be realised only with certain water mass volumes (~ ≥ 80-100 thousand cubic metres) and relative heights of an eroding slope (~ ≥ 80-100m). Herewith every occurred significant debris flow changes geomorphological preconditions for the next one. Landslides towards river mouths, wherewith short-lived blockage-caused water bodies are formed, are sometimes responsible for secondary waves of debris flows, which have originated from glacial sites (the Buzulgan landslide on the Gerhozhan-Su river and a landslide in the Rakyt river valley).

Key words: *degradation of glaciers, dammed lake neoformations, outburst processes, disastrous debris flows, moraine-ice complex*

INTRODUCTION

Russia tends to be more sensitive to global warming than the rest of the world: the range of anomalies in average annual temperatures comes up to 3-4°C whereas the range of anomalies in average global temperatures only slightly exceeds 1°C. Having started in the 1910s, the warming continues, now applying to all seasons of a year. In 2037 against 2007 a global temperature rise of 1.4±0.3° for the territory of Russia is expected (Gruza & Rankova, 2009)

The high mountains of the Caucasus have been reacting to such changes in climate through degradation of glaciers, which has been especially significant since after the 1950s. Thus reduction of only two glaciers on the northern slopes of Elbrus Mount – Birdzhalychiran and Chungurchatchiran – from 1957 to 2007 totalled more than 4 km^2 (Bagov *et alii*, 2009). The margin of the Birdzhalychiran glacier sad retreated up to 300m since 1987, and for the period of 1957 to 1987 it retreated 850m in length, and from 3149 to 3320m in absolute height (1957-1997) (Zolotarev, 2009; Rototaeva, Nosenko, 2009)..

The rapid reduction of glaciers in the latest decades has lead to the outcropping of areas of loose moraine formations and emergence of lake neoformations on territories, freeing from ice – the area of a group of lakes on the north-eastern slope of Elbrus increased more than sixfold from 1957 to 2005 (Chernomorets *et alii*, 2009).

With this in view, debris flow dangers sharply increase, their negative impact on vital facilities intensifies (Zaporozhchenko, 2007), which for the Northern Caucasus is substantiated with actual facts of the last 40 years of the 20th century and the first decade of the 21st century – disasters on the rivers of Kulumkol

Fig. 1 - Study area

(in 1983), Gerhozhan (in 2000), Genaldon (in 2002), Malkin (in 2006), Chegem (in 2007 and 2010) (Fig 1)

The most significant threats for the Central sector of the Caucasus come from lake neoformations, forming near glacier tongues behind young frontal moraine. In practice it is only possible to protect the mouth sections of debris flow channels from disastrous consequences by organizing the engineered channelling of the flows into the main receiving river.

The most powerful debris flows on the Gerhozhan-Su river in 1960, 1977 and 2009 were connected with outbursts of outwash lakes near glaciers: Eastern, Central and Western Kaya-Arty, correspondingly (Zaporozhchenko, 2002)

A debris flow that originated in the steep front moraine of the Western Dzhaylyk glacier (in July 1983) was also connected with a rapid discharge of an outwash lake near the glacier tongue. Having travelled down the Kulumkol-Su river, it caused disastrous destruction at a comfortable sport camp (Zaporozhchenko, 1985, 2005; Bozhinskiy *et alii*, 2008).

Flows that have formed in origination sites, located in the upper reaches of lateral tributaries of main rivers, and that are caused by rapid discharges of waters, accumulated in intraglacial hollows (as on the Rakyt river in 2007) or due to a local discharge of an atmospheric thunderstorm front (storm rainfall) on these debris flow origination sites, also turn disastrous for populated river mouth areas (Zaporozhchenko & Kamenev, 2010).

DEBRIS FLOW DISASTERS OF THE 21ST CENTURY

Consequences of a rapid travel of water-snow-rock-ice masses from the upper reaches of the Genaldon river (2002, the toll was 125 human lives) have had vast scientific press coverage (Zaporozhchenko, 2003; Poznanin, Gevorkyan, 2007 and others). The years 2006 and 2007 brought new debris flow related misfortunes to the Central Caucasus suffered – debris flows went down the Birdzhaly-Su (2006, a tributary of the Malka river), Bulungu-Su (2007, a tributary of the Chegem river) and Sylyk-Suu (2010, a tributary of the Chegem river) rivers (Kabardino-Balkar Republic).

BIRDZHALY-SUU – 2006

A debris flow on 11 August 2006, which caused destruction at "Dzhily-Su" spa, repeated the event of 1909 with regard to the consequences and the scenario of the discharge process of waters accumulated near the marks of tongue parts of the same glacier (Birdzhalychiran): ~3060 m a.s.l. in 1909 and ~3300 m a.s.l. in 2006 (Fig. 2)

The drive for extending the use of water resources of the Caucasus, on the one hand, and the intensification of the debris flow danger in glacial origination sites of the region, typical for northern slopes of high mountains of the Main Caucasus Ridge, on the other hand, make it necessary to assess the tendency for development of a debris flow situation at infrastructure and spa facilities, at such as, for instance, those located on tributaries of the Malka river – the Kara-Kaya and Birdzhaly-Su rivers (in the mouth of the Kara-Kaya-Su river a hydro-electric dam is being designed; in the mouth of the Birdzhaly-Su river a medical and preventive treatment institution, which operates on the basis of a complex of mineral springs, is located).

Debris flows on the Kara-Kaya-Su in the historic period did not reach its mouth (the length of the river is 9.7km, its average gradient – 0.13). Debris flows on the Birdzhaly-Su river (length – 8.7 km, average gradient – 0.116) for the last 100 years have twice discharged into the receiving river (the Malka river).

On the basis of the developing situation as of July 2006, the Debris Flow Association of Russia forecasted an outburst of a lake neoformation (fell ~550 thousand m^3) in the Birdzhalychiran ice cup through overflow of ~400 thousand m^3 and destruction of an ice riegel-crossbar, to be accompanied by formation of a debris flow, capable of reaching the "Dzhyly-Su" spa. The forecasted scenario became a reality in a natural manner on 10-11 August 2006. The sweeping swell reached the outlets of the "Dzhyly-Su" springs at 4 a.m. on 11 August 2006. Deposits of the debris flow, that had a sediment-water composition, covered the area of 9750 m^2 with a layer of an average thickness of 3.4 m. The volume of hard deposits was 33 thousand m^3. Taking into account the material that got into the Malka river, in the morning of 11 August 2006 the total of ~50 m^3 was transported to the mouth of the Birdzhaly-Su river.

Fig. 2 - 10 September 2009. The state of the breakthrough passage of the ice crossbar at the Birdzhalychiran lake at the site ofdischarge of water masses on 10 August 2006. View from the downstream. The source of the Birdzhaly-Su river

The maximum debris flow discharge was instrumentally determined based on the marks left at three non-erodible sections. It turned out to be 125 m^3 per second (see Tab. 1).

Carried out works made it possible to give a further forecast of the development of the situation and propose measures, directed at implementation of engineering protection of the near-the-mouth area of "Dzhily-Su" and confirm an issued earlier Opinion letter (negative) on the possibility and problems of construction of a hydropower station at the mouth of the Kara-Kaya-Su river

BULUNGU-SU – 2007

The Bulungu-Su river (basin area of 43.8 square km) is formed due to confluence of the Koru and Rakyt rivers and in its mouth part it runs through the skirts of the village of Bulungu. The latest occurred debris flow came to the mouth of the Bulungu-Su river on 19 July, 1983, bringing about great destruction. In connection with the appearance of previously unmarked (on maps as of 1968) lake neoformations near glaciers on aerophotography pictures, a survey of the upper reaches of the Koru river and the glacier of the same name was carried out in September, 2002. It was established that

Profile section, #	ω, m^2	B, m	h, m	i	V, m/s	Q, m^3/s
1	24.1	6.0				
2	23.0	7.0				
3	16.2	6.0				
Average	21.6	6.3	3.4	0.12		
Sediment-water	$V=4.5\, h_{average}^{0.67}\, i^{0.17}$				5.81	125

Tab. 1 - Characteristics of the debris flow on 11.08.2006 on the Birdzhaly-Su river w – the area of the cross section, B – the width of the channel, h – the depth of the flow, i – longitudinal gradient at the site, V – velocity of the flow at the site, Q – maximum flow discharge the debris flow danger originated from moraine-ice masses, that were filling the northern "horseshoe" of "Dzhosharty" and that the outburst of the water from the intraglacial hollows would lead to the initiation of a mud-water-ice flow; and a debris flow of great destructive power and of large volumes may come to the river mouth (the village of Bulungu). The river channel of the Bulungu river would not let through even a sediment-water flow under the highway, which leads to the upper reaches of the Chegem river.

On 3 August, 2007, at 00.15 a.m., a high density debris flow came down the river channel to the fringes of the south-western part of the village of Bulungu. The underbridge span was almost immediately clotted by blocks and drowned wood and the debris flow mass, "dumped" on the right hand of the course, ~250 m above the bridge, went through residential houses and adjoining plots of land (Fig. 3).

At that:

– the debris flow (after the "dumping" on 03.08.2007) flatly spread across the village and it only consisted of a mud mass near the mouth;

– over the remaining stretch, up to the origination site, the transporting potential of the flow allowed it to carry boulders weighing up to 40 tons;

– the "high water" level in the first several days was well pronounced, and boulders and rock blocks of debris flow swells were mud coated;

– the total volume of deposits along the channel of movement was calculated to be ~400 thousand cubic metres; on the territory of the Bulungu village per se ~80 thousand cubic metres of the debris flow material were deposited;

– the debris flow came from the upper reaches of the Rakyt river's right source, whose catchment basin is half as much as that of the central source and ~5 times as less as the basin of the main (left) source; under the conditions of presence of friable, well waterabsorbing single-grained moraine deposits here, atmospheric precipitation, that had been there prior to the debris flow in the form of light rain up to the mark of ~3200 m a.s.l. (it had been snowing higher), was not the cause of the debris flow;

– ~900 m down from the debris flow origination site the discharge of the flow in the concentrated channel had the value of ~200 cubic metres per second; lateral debris flow swells appeared already ~200 m beneath the modern position of the glacier tongue (at the mark of ~3300 m in true altitude), at the first fracture of the relief, after the debris flow groove, uncovering buried ice here and there;

– the area of the outer western part of the Western glacier under the peak of Rakyt at true altitude of ~3650 m a.s.l. (Fig. 4) was the source of the water component (water impulse) of the debris flow; there, apparently, an almost instant discharge of a great volume of water (~20 thousand cubic metres ± 10 thousand cubic metres), that had been concentrated inside intraglacial hollow(s), with a further outflow (possibly, a short-time one) and building-up of the outflow volume, took place;

– beneath the Korgashinlitau ridge and the peak of Rakyt there are currently three separate glaciers, that ~50 years ago comprised a single ice massif (according to the aerial survey at the end of the 1950s); tongues of the glaciers have of late years gone up 200

Fig. 3. 3 August 2007. The debris flow on the street of the village of Bulungu

Fig. 4 - 15 July 2008. The Western Korgashinlitau glacier. The source of the Rakyt-1 river. 1 – the area of origination of the 2 August 2007 debris flow and the path of movement of outburst water masses from an intraglacial hollow; 2 – the outflow grotto, formed in 2008

m in true altitude; the surface of the Central and Eastern glaciers is steep (45-50°), for the latter there are no conditions in their bed for accumulation of subglacial and intraglacial waters; in the upper third of the Western glacier such conditions do exist: here, at the break of the ice relief, there is a cup-like area in the bedrock;

– slopes, surrounding the Western glacier, are steep and greatly fractured; debris, accumulating on the surface of the glacier in the form of "fresh" rock and ice fragments, continuously went down the glacier and the rocks during the week after the main debris flow event (not detected at the glacier tongue);

– the Western glacier was ready for shifting and for an externally provoked opening of water-filled hollows;

– the debris flow of 02-03.08.2007 travelled the path of ~8.5 km from the site of discharge of water masses of the glacier to the road bridge across the Bulungu-Su river at Bulungu village for 1 hour ± 15 minute;

– the mouth of the Koru river was not blocked by the debris flow on the Rakyt river.

Works to establish the debris flow characteristics (with special attention to determination of the maximum discharge on the basis of marks left in non-deformable sections) were carried out. Examinations of cross-section profiles and slopes were executed instrumentally. Discharges were determined at mouth reaches (Fig. 5): the Rakyt river (1 profile) and the Bulungu-Su river (2, 3 profiles). Their peak discharges were 244 m^3/s and 302 m^3/s, respectively (Tab. 2) (the starting discharge in the upper reaches 0.9 km from the origination site was ~200 m^3/s according to a semi-instrumental assessment). The height of the debris flow wave at the vertex of the debris fan of the Bulungu-Su river measured up to 5.8 m.

Thus:

– the Rakyt and Koru rivers, representative for consideration of modern debris flow activity tendencies, in connection with the changing glacial situation due to the warming of the climate, are becoming extremely debris flow dangerous in the upper reaches;

– the nature of processes, leading to creation of conditions for a water torrent development according to the debris flow scenario with disastrous parameters for the lower reaches of the Bulungu-Su river, is various in the basins of its tributaries: steep corrie Rakyt glaciers retreat while the general stability of the glacial section lowers, the possibility of opening of the intraglacial hollows increases, as does the role of impacts of collapses on the surface and structure of the ice massif; the gentler sloping Koru glacier with its pit lakes and thermokarst lakes advances (due to the decreasing lateral areal resistance at the “ice-banks” contacts due to the rapid melting of ice on rocks;

– the intraglacial origination site of the debris flow of 2007 exhausted its potential for several nearest debris flow risk periods;

– however, the threat of activation of origination sites in the upper reaches of the main (left) stream of the Rakyt and especially Koru rivers is high. The energy of the debris flow on the latter may surpass the energy, “discharged” in August, 2007, by several times; the mouth part, unprotected by engineering means, within the debris fan area of the Bulungu-Su river was not able to take in the debris flow, that had come from the origination site through the Rakyt river; consequences of the debris flow, having started to

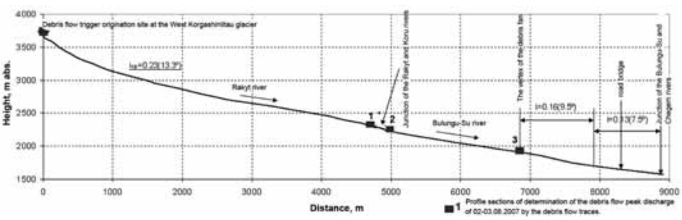

Fig. 5 - Grade profile of the riverbeds of the Rakyt – Bulungu-Su rivers

Profile section, #	ω, m^2	B, m	h, m	i	V, m/s	Q, m^3/s
1	68.5	17.0				
2	66.2	22.0				
3	50.5	18.0				
Average	61.7	19.0	3.25	0.16		
Mud-rock	$V=3.75\ h_{average}^{0.5}\ i^{0.17}$				4.9	302

Tab 2 - Characteristics of the debris flow on 02-03.08.2007 on the Bulungu-Su river.

originate on the Koru river, will be more significant;

– outbursts of lake neoformations (rapidly increasing their volumes in the last decades) near moraine-ice complexes prevail among other factors of debris flow formations of the glacial origin.

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SYLYK-SU – 2010

On the right bank of the Chegem river, in the narrow strip of the terrace above the flood-plain lies the village of Bulungu, whose south-eastern outskirts suffered from the 2007 debris flow, which went down the Bulungu-Su river. The centre of the village is divided by the Sylyk-Su river. The last but one debris flow on the Sylyk-Su river took place 12 July, 1995, causing casualties and destruction. The last one happened 20 July 2010 (Fig. 6). It was forecast with an 8-hour earliness.

It had been considered that a debris flow on the Sylyk-Su river, capable of reaching Bulungu, would primarily follow the 1995 channel due to more favourable conditions with regard to the state of accumulated slope loose debris. Moreover, the upper reaches and bottom slopes of the main Sylyk-Su valley were “inferior” to those of its right (and its sole) tributary valley. But the weather – and this is characteristic for mountains - “amended” [the development of the process]: precipitation of the latter half of the day of July, 20, 2010 covered only debris flow origination sites of the main valley, whereas the neighbouring valley’s origination sites remained in the storm’s “blind spot”, not getting a sufficient water component for the initiation of the process development according to a debris flow scenario. (From the practical viewpoint of safety assurance for dwellers of Bulungu village as well as their housing and property, the expected location of debris flow origination sites in the upper reaches has no fundamental importance, as debris flows come out on to the village area at one place – out of the gorge on to the vortex of the debris fan).

The foremost swell of the 20 July 2010 mud-and-stone flow reached the vortex of the debris fan at about 8 p.m. The first approximately 100 m of the river channel did hold the incoming masses, but downstream the debris flow discharge surpassed the capabilities of the natural section, overflew onto the village and through buildings and household plots reached the receiving river of Chegem (Fig. 7).

The volume of the material deposited within the village was estimated at 5000 m^3. There was no erosion of the natural river channel upstream from the overflow site. The peak discharge of the flow determined at two representative profiles on this reach measured up to 190 m^3/s (Tab. 3). Profiles of the 1995 and 2010 debris flow channels are given in Fig. 8.

The upper reaches of the main valley of the Sylyk Su river by 20 July 2010 were practically free of snow patches. 4 origination sites, located beneath the western spur of the Korgashinglitau ridge at about 3500 m, were involved in the formation of the debris flow

Debris flows on the Sylyk-Su river may be expected in the foreseeable future. Without the engineering channelling of debris flows into the Chegem river through channels of sufficient clear area (as per estimated flows), such debris flows will time and again travel through settlements, causing new destruc-

Fig.7 - 26 July 2010The village of Bulungu. A destroyed house. The household plot is covered with debris flow deposits

Fig 6 - 27 July 2010. Viev on the village of Bulungu (Upper Chegem) tion and casualties. Steep slopes of river channels at the place of their falling into the Chegem river (the last 100 m, the cusp of the high terrace above the floodplain) are favourable for the organisation of such channelling (through debris flow check canals).

LANDSLIDES AS FACTORS OF INFLUENCE

Debris flows, originated in proglacial zones, before they come out to the mouth parts of movement channels (usually to the vertices of debris fans of similar processes of previous years), under the conditions of Central Caucasus region travel over a distance of up to 10-15 km. The flows re-form, disintegrate or on the contrary get enriched with hard material: it depends on morphological, engineering and geological peculiarities of bottoms and slopes of transit valleys. That's where they are "surrounded" with dangers of being blocked by sliding masses, caused by bottom and lateral erosion. Failure to take into account such circumstances may lead to an erroneous prediction of negative consequences and prescription of erroneous engineering protection measures. Thus, the damming of the Gerhozhan-Su river (the undercutting of the tongue part of the "Buzulgan" landslide 4 km above the outfall mouth section of the river with the first wave of the debris flow), the backing and further breach of the temporary earth dam led at the same time to a more powerful (second) wave of the flow with disastrous consequences for the town of Tyrnyauz, the deepening of the bottom of the river at the landslide front up to 20m to uncover the bedrock of crystalline shale and phyllite (Fig. 9). The long-living landslide massif is composed of strata of a tectonic fragmentation zone. (Zaporozhchenko, 2002; 2003).

The "Bulungu" landslide (limestone, marl) on the southern flank continuously advances into the channel at the vertex of the debris fan of the Bulungu-Su river (Fig. 10). As the opposite bank is composed of non-erodible hard rock here, the scale of surges may be such so that the river will not cope with the wash-out of landslide masses moving into it.

A landslide (of clay slate) in the channel of a Rakyt river tributary (Fig. 11) was a triggering cause for a debris flow in the summer of 2008; it reached the mouth of the Bulungu-Su river and jammed the underbridge clearance of a motor road.

Debris flows - which are mainly natural - are in recent history indicative of the variety of causes and factors of and possible initial impulses for water masses' development in a debris flow mode even in territorially close basins of lateral tributaries of a main river as a receiver of debris flow deposits. Thus (under otherwise equal conditions, created as a result of degradation of glaciation on the northern slope of the Main Caucasus Range):

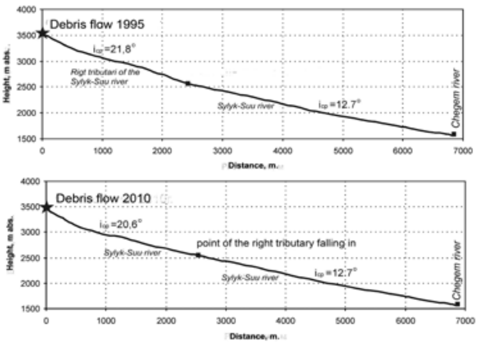

Fig.8 - The Sylyk-Su river basin. Profiles of the 1995 and 2010 debris flow channels

Fig. 9 - 31 August 2001. «Buzulgan» landside (left side) which blocked the debris flow on 19 July 2000

Profile section, #	ω, m²	B, m	h, m	i	V, m/s	Q, m³/s
1	45.3	19				
2	46.4	20				
Average	45.9	19.5	2.35	0.15		
Mud-rock	$V=3.75\ h_{average}^{0.5}\ i^{0.17}$				4.13	190

Tab 3 - Calculation sections of the transit channel of the Sylyk-Su river and results of determination of the peak 20 July 2010 debris flow discharge

Fig. 10 - 3 August 2007. Active flank part of the "Bulungu" landslide. The right bank of the Bulungu-Su river at the debris fannear the village of Upper Chegem

Fig. 11 - 17 July 2009. Landslide in the mouth part of the Rakyt-2 river at the time of activation, caused by the bottom and lateral erosion, creates backwater of surface runoff

Fig. 12 - 17 August 2010. The moraine-ice complex advancing and blocking the C. Rakyt river valley.

Fig. 13 - 19 August 2010. The upper reaches of the Koru river. A moraine-ice complex advancing on the foreground and slopes of the valley. -----> direction of movement.

– debris flows on the Sylyk-Su river (in 1995 and 2010) are consequences of involvement of loose single-grained formations of the upper reaches by streams, caused by passage of storm fronts;

– the debris flow on the Rakyt-2 (in 2008) is a result of the breach by a surface water stream of a dammed water-body, created by a landslide dislocation in the left-side mouth part;

– the debris flow on the Rakyt-3 (in 2007) is linked to the discharge of water masses from intraglacial hollows (as of now, the sole reliable recorded instance in the Northern Caucasus region);

– the debris flow on the Birdzhaly-Su river (in 2006) was formed by an outburst discharge through an ice crossbar of a lake neoformation;

– a potential debris flow danger lurks in the interior of the so-called "dead ice" in the upper reaches of the C. Rakyt and Koru rivers. The advance of the "dead ice" onto the slopes and bottoms of the valleys, whereas generally there has been a retreat of open ice surfaces for the last 50 years, is evidenced from the turn of the century (Figs. 12, 13).

CONCLUSIONS

1. The first warming in the 20th century on the territory of Russia in 1910-1945 was noticed by Russian scientists and it was named "the warming of the Arctic". The second wave period (after 1976), lasting up to date, is witnessed not only by the scientific community, but also experienced in everyday life, especially by mountain climbers: many ice routes of the beginning of the second half of the 20th century have now become rock-talus. Our contemporaries' lot is to live in the period of "the warming of the Caucasus".

2. At the turn of the 21st century the global warming tendency has caused reduction of ice-sheet in the alpine areas of the northern slope of the Caucasus mountain system. With glacier tongues retreating to higher true altitudes, massifs of friable singlegrained, primarily moraine, formations become exposed; peri-glacial water-bodies rapidly (comparatively speaking) appear, grow and disappear. Threats and risks of emergence of regimes of debris flows on river channels grow. Most signifi-

cant (with regard to their destructive power) debris flows originate from outbursts (discharges) of lake neoformations, lying close to glaciers, and rapid outflows of waters from intraglacial hollows.

3. In every potentially dangerous debris flow basin, due to peculiarities of the Quaternary period, there are various ways of realization of disaster scenarios for mountain rivers' mouth parts (debris fans) under economic development. Even in the territorially close basins there may form different developments of processes of hard material transport by water torrents, distances and volumes of debris flow deposits transport, which depend on morphologic conditions along the debris flow channel.

4. For glacial zones with debris flow origination sites the length of the period of high temperatures in July-August, causing heightened ablation of ice masses against the background of lowered general and/or filtering stability of natural retaining dams (not necessarily absolutely watertight), is most significant.

5. Not every water body, lying close to a glacier, or glacial water body at the realization of the outburst scenario thereupon is able to initiate a debris flow process – for this to happen outer slopes of the natural dam (most often of most recent moraine) should have 30-35° steepness; ~20° steepness is insufficient, and within the 25-30° steepness range the possibility of an avalanche-like development of conditions for transformation of a water flood into a debris flow may be realized only with certain water mass volumes (~≥ 80-100 thousand cubic metres) and respective heights of the eroding slope (≥ 80-100 m). At that every occurred significant debris flow changes geomorphological preconditions for the subsequent one.

6. Landslides towards river channels followed by formation of short-lived dammed water bodies are sometimes responsible for secondary waves (including disastrous waves) of debris flows, originated in glacial sites.

7. On the tributaries of the upper reaches of the main rivers of the northern slope of the Central Caucasus, whose open glacierderived nourishment in connection with climatic changes has substantially decreased, or ceased altogether, and where in potential debris flow origination sites a practically infinite volume of loose materials is accumulated, the initiation of conditions for formation of debris flows depends not only and as much on the gradient of transit channels (the latter always the more significant, the more minor the tributary) as on peculiarities of storm atmospheric front discharges: the valley of a lateral tributary may happen to be in the storm "blindspot", while a pinpoint precipitation fallout in a neighbouring valley of the same tributary will lead to a debris flood, despite a "softer" profile of the channel and better morphological conditions for the flow disintegration, characteristic for the latter.

8. The rapid reduction of glaciation areas leads to the accumulation of ice masses (moraine-ice complexes), buried under surface moraine in the steep upper reaches of mountain valleys and losing contact with a mother glacier. With plastic properties of ice and high feeding with melt waters (from open glacier surfaces lying above) such complexes (with bedrock gradients of ≥10° on the C. Rakyt and Koru rivers) since the beginning of the 21st century have started advancing upon valley bottoms and slopes, that have had time to get grass-covered for the previous decades, in the mode of viscoplastic movement and block-gliding along the bedrock. With this, there emerge threats (unpredictable with regard to their triggering effect) of outflow of gravity water from buried glacial hollows to be followed by formation of an outburst debris flood (along transit channels of effluent seepage from under the foundations of frontal parts of such complexes).

9. Attempts to stem river mouth high-density debris flows, the latter characteristic for the Northern Caucasus (for example the event in Tyrnyauz in 1999), are doomed. Free channelling of such debris flows along check canals and free transportation (without blockages) of material via the main receiving river should be organized. Parameters of such facilities (height, target, design parameters) should be designated with regard to the expected (calculated) debris flow characteristics. This is a feasible engineering task.

No reliable and effective ways of artificial "global cooling" have been devised so far. Nature is stronger than man after all. We often forget about it, but that is the case. Disregard for the past errors is fraught with numerous losses in the future.

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