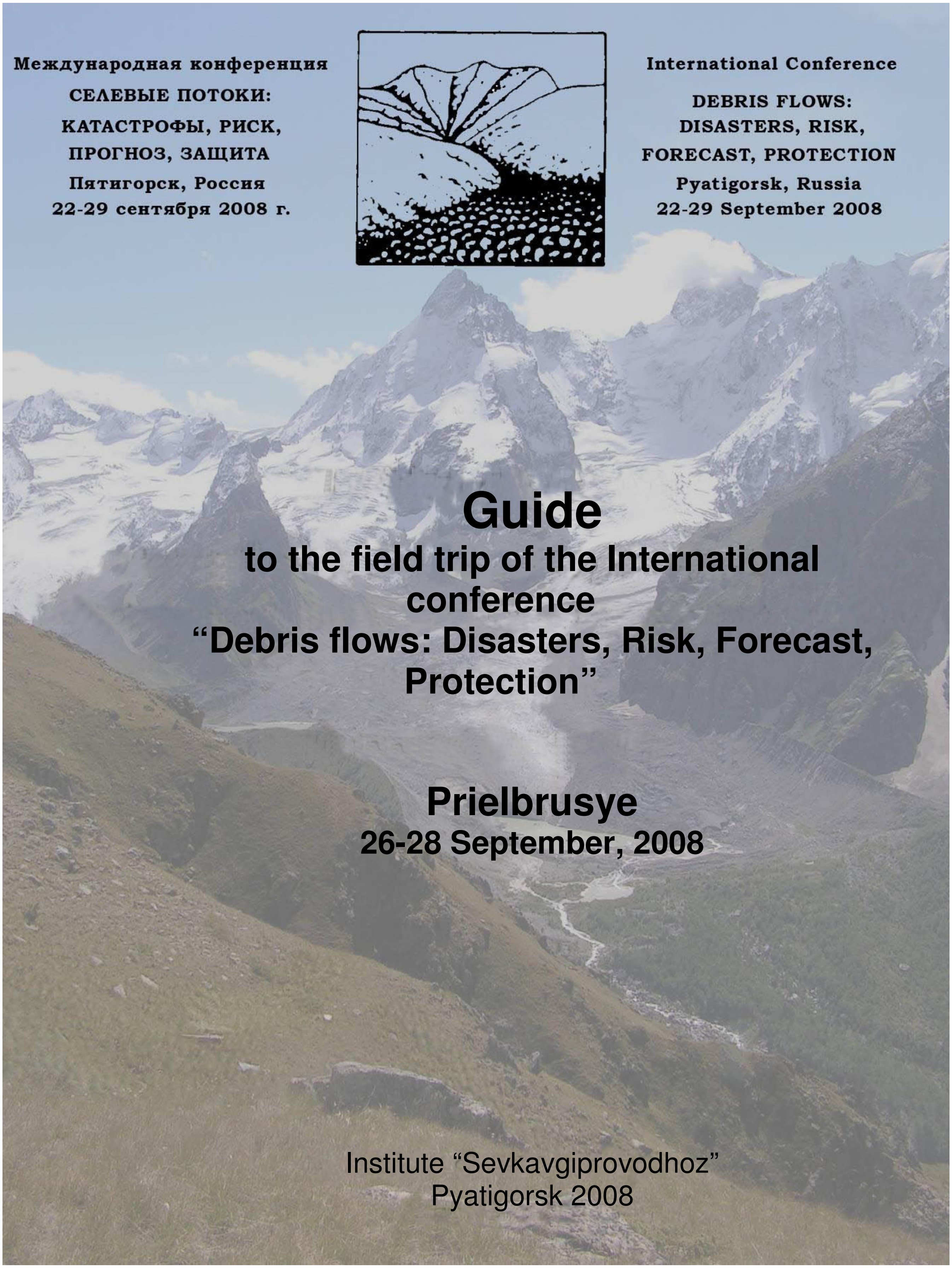

Международная конференция
СЕЛЕВЫЕ ПОТОКИ:
КАТАСТРОФЫ, РИСК, ПРОГНОЗ, ЗАЩИТА
Пятигорск, Россия
22-29 сентября 2008 г.

International Conference
DEBRIS FLOWS:
DISASTERS, RISK, FORECAST, PROTECTION
Pyatigorsk, Russia
22-29 September 2008

Guide

to the field trip of the International conference "Debris flows: Disasters, Risk, Forecast, Protection"

Prielbrusye

26-28 September, 2008

Institute "Sevkavgiprovodhoz"
Pyatigorsk 2008

Compiler: A.M. Tarbeeva
Edited by: E.V. Zaporozhchenko and S.S. Chernomorets
English translation: D.V. Pavlov

References:

1. Gnezdilov Yu.A. Assessment of a hypothetical outburst of Bashkara lake. JSC "Sevkavgiprovodhoz", Pyatigorsk, 2006, 9 p.

2. Zaporozhchenko E.V. Debris flows in the Gerkhozhan-Su river basin: history of manifestation, conditions of formation, energy characteristics. Collected scientific articles of JSC "Sevkavgiprovodhoz". Issue 15. Pyatigorsk, 2002, p. 80-148.

3. Zaporozhchenko E.V. The Gizhgit river as the source of flood and debris flow hazards for the Tyrnyauz ore-dressing and processing enterprise structures. In Collected articles: Issues of increasing the construction effectiveness. Issue 2. Nalchik, 2004, p. 159-169.

4. Zaporozhchenko E.V. Northern Caucasus. Global warming and glacial debris flows // Land reclamation and water economy, N°2, 2007, p. 13-16.

5. Koronovskiy N.V., Milanovskiy E.E. Origination of the Tyubele swell in the Baksan gorge (Central Caucasus) // Vestnik MGU [bulletin of the Moscow State University], geology series, 1960, N°5. P. 69-77.

6. Krylenko I.V., Petrakov D.A., Tutubalina O.V., Chernomorets S.S., Zhuravleva P.G. The dynamics of the debris flow basin of the Gerkhozhan-Su river (Kabardino-Balkaria) after the disaster in July, 2002. // Materials of glaciology research, Issue 96, 2004, p. 159-166.

7. Milanovskiy E.E., Koronovskiy N.V. Geological structure and history of the Elbrus volcano formation. "VAGT works", Issue 6, 1960.

8. Prielbrusye nature management. M.: MGU. 1992, 196 p.

9. Seinova I.B., Zolotarev E.A. Glaciers and debris flows of Prielbrusye (Evolution of glaciation and of debris flow activity). M.: Nauchnyj Mir, 2001. 204 p.

10. Khadzhiev M.M. Assessment of the debris flow hazard in the Tyrnyauz area. Abstract, candidate of geographic sciences. Nalchik, VGI, 2005.

11. Chernomorets S.S., Petrakov D.A., Krylenko I.V., Krylenko I.N., Tutubalina O.V., Aleynikov A.A., Tarbeeva A.M. Dynamics of the Bashkara glacier lake complex and assessment of the debris flow hazard in the Adyl-Su river valley (Caucasus). // Earth cryosphere, vol. XI, No1, 2007a, p. 72-84.

12. Chernomorets S.S., Petrakov D.A., Tutubalina O.V., Seinova I.B., Krylenko I.V. Outburst of the glacier lake on the north-eastern slope of Mount Elbrus on the 11th of August, 2006: forecast, incident and effects. // Materials of glaciology research, Issue 102, 2007b, p. 211-215.

13. Seinova I.B., Popovnin V.V., Zolotarev Y.A. Intensification of Glacial Debris Flows in the Gerkhozhan River Basin, Caucasus, in the Late 20th Century. Landslide News. N°14/15, 2003.

14. Zaporozhchenko E.V. Problems of Debris Flow in Russia: Past, Present and Future in the Changing Climatic Conditions at the beginning of the 21st Century. Conference "Water Resource Systems Management under Extreme Conditions". Moscow, 2008, pp. 606-607.

Photograph acknowledgements: E.V. Zaporozhchenko, A.N. Kapitanov, I.N. Kargapolova, V.V. Krylenko, I.V. Krylenko, M.Yu. Nikitin, I.B. Seinova, A.M. Tarbeeva, O.V. Tutuballina, S.S. Chernomorets, M.S. Shakhmina.

A drawing from book "Debris Flows" by S.M. Fleishman (Moscow: Geografgiz, 1951, p. 51) has been used in creating the logotype.

Cover photo: Dzhantugan Mountain (A.M. Tarbeeva)

The field trip of the International conference "Debris flows: Disasters, Risk, Forecast, Protection" will take place in Prielbrusie on the 26-28th September, 2008. Below is the description of the route of the trip and the main stops on route. In accordance with the topic of the conference the major focus in the Guide is on description of debris flow processes and their effects, debris flow protection structures. General information on weather conditions of Prielbrusie along with a short historic excursus as well as information on volcanism and glaciation of the area, which are linked with the development of the debris flow processes, are provided.

Participants of the field trip are recommended to bring trekking shoes and windbreak moisture proof clothes.

We hope that the weather during the field trip will be favourable. However one should bear in mind that the air temperature on the coldest stretch of the route – the Elbrus slope – may go down to zero, with possible wind at 10-15 m/s and rain.

***

The route of the field trip begins in the town of Pyatigorsk and runs into the south-eastern direction over the foothills of the Northern Caucasus up to the town of Baksan, situated at the entrance to the Baksan gorge. Further the route runs in the south-western direction over the valley of the Baksan river, successively crossing the Lesisty, Pastbichshny, Skalisty and Bokovoy ridges of the Main Caucasus.

The following stops are intended: in the area of the village of Zayukovo near a large landslide on the right bank of the Baksan river; in the town of Tyrnyauz, affected by the latest disastrous debris flow of 2002; in the mouths of other debris flow tributaries of the Baksan river, viz. the Bolshoy Mukulan, Maly Mukulan, Sagayevsky streams. Then the route runs along one of the tributaries of the Baksan river, viz. the Adyl-Su river, its debris flow hazardous valley with lakes near the edge of the Bashkarinsky glacier and on to the Chegem glade. The last stop is intended at the Azau glade, situated at the foot of the Elbrus volcano. A cablecar/chairlift ascent to the slope of the Elbrus will be organized.

The route map is given in Fig. 1.

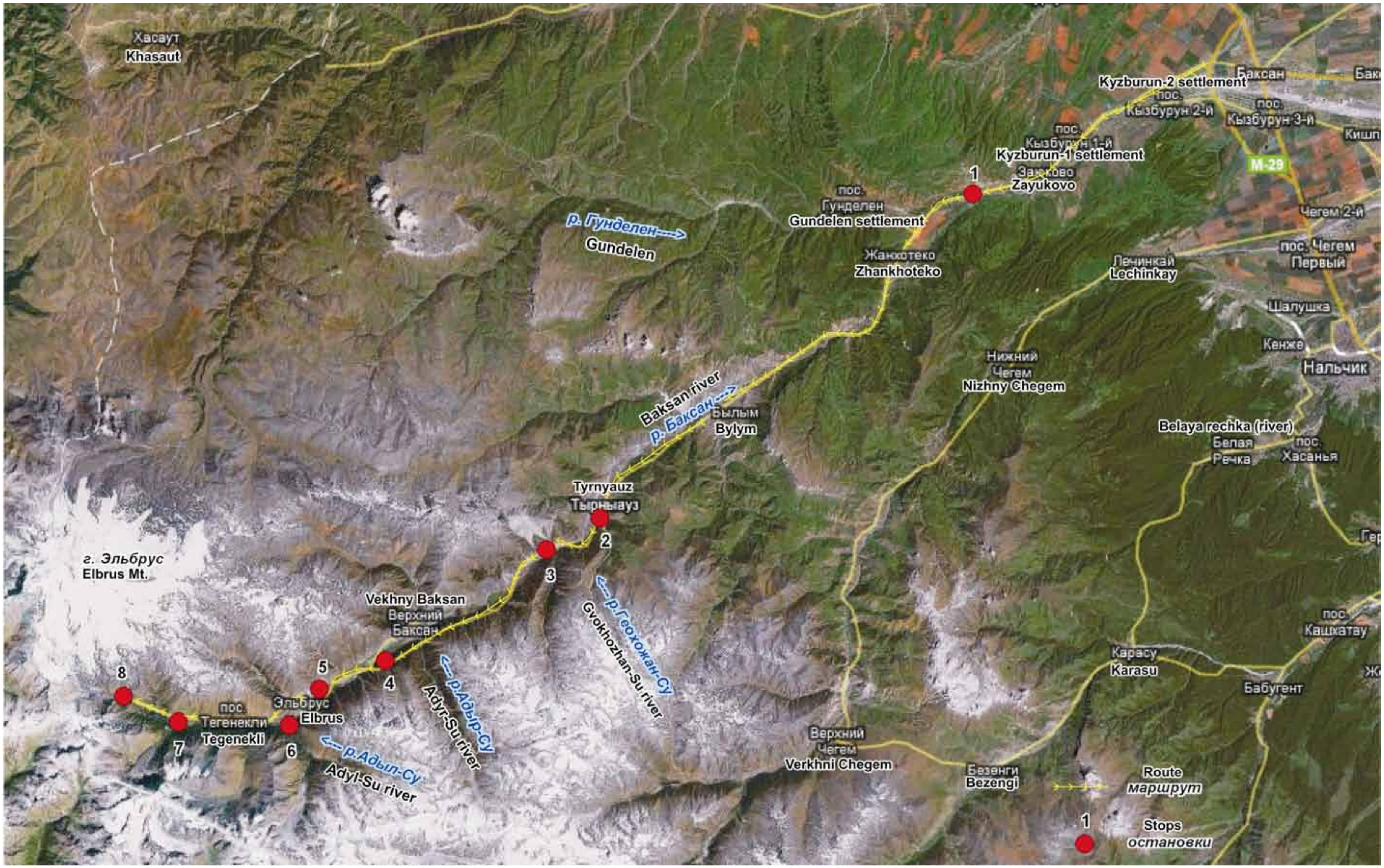

Fig. 1. The map of the route over the valley of the Baksan river (background image: ©2008 Google photo)

Prielbrusie is part of the Large Caucasus stretching from the western approach area to the Elbrus on to the basin of the Chegem river in the east. The Prielbrusie area is situated on the southern border of the Russian Federation, in terms of administrative districts it lies in the Republic of Kabardino-Balkaria. The southern border runs along the Main Caucasus Ridge. With it Prielbrusie borders Georgia and Karachaevo-Cherkessia in the west.

High-mountain and mountain regions of Kabardino-Balkaria as early as in the first millennium were inhabited by tribes, on the basis of which the Balkar and Karachay nationalities were later formed. The Karachays and Balkars, who are among the most ancient dwellers of the mountain part of the Caucasus, originate from the merging of Northern Cacuasian tribes with the Iranian and Turkic newcomers. Some scholars consider them 2 ethnic groups of one nationality. The Balkars dwell in high-mountain regions on the eastern side of Elbrus, the Karachays – on its western spurs. The Kabardins appeared here in the XII-XIII centuries. Their ancestors, under the name of Zikhs, Kerkets and under other names, originate from one and the same root of the Adyghian (Adygei) peoples. The Kabardins call themselves Adyghes.

In World War II fierce battles raged in the mountains of Prielbrusie. Due to the symbolic significance of Elbrus as the highest peak in Europe from August, 1942 up to January, 1943 it was the point of confrontation of the Soviet and German forces. In the memory of those events on the slope of Mt. Elbrus at the height of 3450 m, in the building of the “Mir” station, The Caucasus Defence Museum was established.

The two-headed Elbrus volcano, rising up above the snow peaks of the Caucasus, since olden times has attracted travellers. In the middle of the XIX century the first ascents were made.

In the Soviet times Prielbrusie became the spot of mass climbing alpiniads, the largest of which in 1967 numbered 2400 participants. Preparation and selection of alpinist sportsmen for participation in the climbings of Everest and other summits higher than 7000 are held on Elbrus.

In 1963 in Prielbrusie the first cablecar system to the Cheget mountain was set in operation. An active development of a ski complex began.

Around Elbrus a national park “Prielbrusie” was organised. Thousands of Russians and foreign tourists, alpinists and downhill skiers come here for active holidays in the mountains.

Physiographic characteristics

The Caucasus mountains began acquiring their modern appearance about 10 million years ago in the epoch of alpine Orogeny. The mountain belt was formed in the seam zone of the Scythian bed and the Transcaucasian microcontinent, moving up under it from the south (Milonovsky, Koronovsky, 1960). The axial part of the Caucasus mountains is composed of granitoid rocks (granites, plagiogranites, biotite and leucocratic granites), intruding along deep breaks in the axial part of the central uplift – anticlinorium – made of metamorphic and sedimentary rocks of the Palaeozoic era. The wings of the anticlinorium form the foothills of the Caucasus; they are cuestas, represented by Lesisty, Pastbichshny, Skalisty and Bokovoy ridges. As a result of a continuous uplift, the height of the mountains in the axial part of the Main Caucasus Ridge has reached 4-5 thousand metres. The Central Caucasus, that lies between the volcanoes of Elbrus and Kazbek, is an area of the maximum amplitude of movements. The modern rates of rising are 10-12 mm/year.

The intensive manifestation of underground processes of the Earth in the focal point of crossing of the largest Caucasus breaks (the southern Shtulu-Kharez, northern Pshekish-Tyrnyauz and western Elbrus ridges) is linked with the formation of the Elbrus volcanic centre (at the last stages of alpine Oregeny). At present Elbrus is an extinct volcano, the last eruptions of which happened in the historic time.

The relief of the Caucasus mountains has been much transformed by the activity of glaciers. Many peaks are karlings, valleys of the rivers of Prielbrusie – troughs of ancient glaciers. The upper reaches of the valleys are filled with moraine as well as with debris flow and slope deposits of the warming periods.

Prielbrusie is one of the most significant centres of modern glaciation of the Caucasus. It is stimulated by the general northern exposition of the slopes and rather heavy precipitation – from 800 to 1500 mm. The river Baksan (one of the largest tributaries of the Terek river) originates from glaciers of Elbrus. The total number of glaciers of the Baksan river basin is about 150 (Catalogue of Glaciers, 1970). The largest are valley glaciers and conical peak glaciers (those of Elbrus). In number, hanging and corrie glaciers prevail.

The lower boundary of modern glaciers is at the height of 2700-3500 m. At the heights of 2100-3100 there are alpine and subalpine meadows. The upper boundary of forest on the northern slope of the Large Caucasus on average runs at the heights of 2200-2400 m. Pine forests with strips of birch crooked forest on the avalanche slopes are typical.

During the longest phase of the Pleistocene glaciation the Caucasus mountains were under thick ice cover. Melting and freeing of the surface off glaciers favoured activation of intrinsic motions of the Earth's crust, which was accompanied by earthquakes, powerful slope, debris flow and channel (riverbed) processes.

Remaining traces of the debris flow disasters date to the historic stages of glaciation, mainly to the period of degradation of the still continuing Little Ice Age (with maximum glaciation in the XVII-XIX centuries).

For the last 150 years the glaciation of the Caucasus has declined by about 50%. This has led to the formation of massifs of dead ice, near-glacier lakes, and also to the activation of debris flow and slope processes (Prielbrusie nature management, 1992). The most active processes of degradation have manifested themselves in the last 50 years (Zaporozhchenko, 2008). The following disastrous debris flow incidents are connected with them: those of 1983 (alpinist camp "Dzhaylyk"), 2000 (the town of Tyrnyauz), 2002 (Karmadon), 2006 (Dzhyly-Su), 2007 (the village of Bulungu).

Stop 1. The Village of Zayukovo

Manifestation of landslide processes in the valley of the Baksan river in the neighbourhood of the village of Zayukovo ranks with the most peculiar natural phenomena that happened at the turn of the 21^{st} century in Northern Caucasus.

On the 24^{th} of May 2005 at 23.30 on the right bank of the Baksan river valley at the reach opposite the mouth of the left tributary (r. Gundelen) shearing of a part of an ancient landslide massif took place (Fig. 2, 3). The volume of the landslide body was 9-10 million cubic metres, its area – 0,62 square kilometre, the length of the sole along the Baksan river – 1100 m, its width – up to 750 m, the thickness of the landslide deposits – up to 20-30 m.

The landslide had been formed on the reforest slope with a north-western exposition and a 15-30^{o} gradient; it covers almost all the surface of the slope from the watershed (water divide) to the sole, the former riverbed of the Baksan river being its basis. Based on the fact that residents of the Zayukovo village do not remember such disasters, and on the fact that the slopes of the massif are covered with forest, one may suppose that the previous large shearing took place not less than 100 years ago.

The movement of the landslide body happened on the black clay stratum in the upper layer of the Albian stage of the upper Cretaceous (K1a1). The main deforming horizon is represented by the carbonate strata of the Turonian, Coniacian, Santonian stages of the upper Cretaceous (K2t, k, st), made up of limestone with rare interlayers of marl and clay (Fig. 4.)

Fig. 2. The Baksan river valley in the area of the western outskirts of the Zayukovo village.

the boundary of the ancient landslide massif

the ancient detachment planes

the boundary of the shearing on the 24th May, 2005

(photo by TC GMSN "Kabbalkgeomonitoring" on the 22.09.2000, from a helicopter)

Fig. 3. The central part of the landslide with two rock detachment planes

(photo by TC GMSN "Kabbalkgeomonitoring" on the 25.05.2005, from a helicopter)

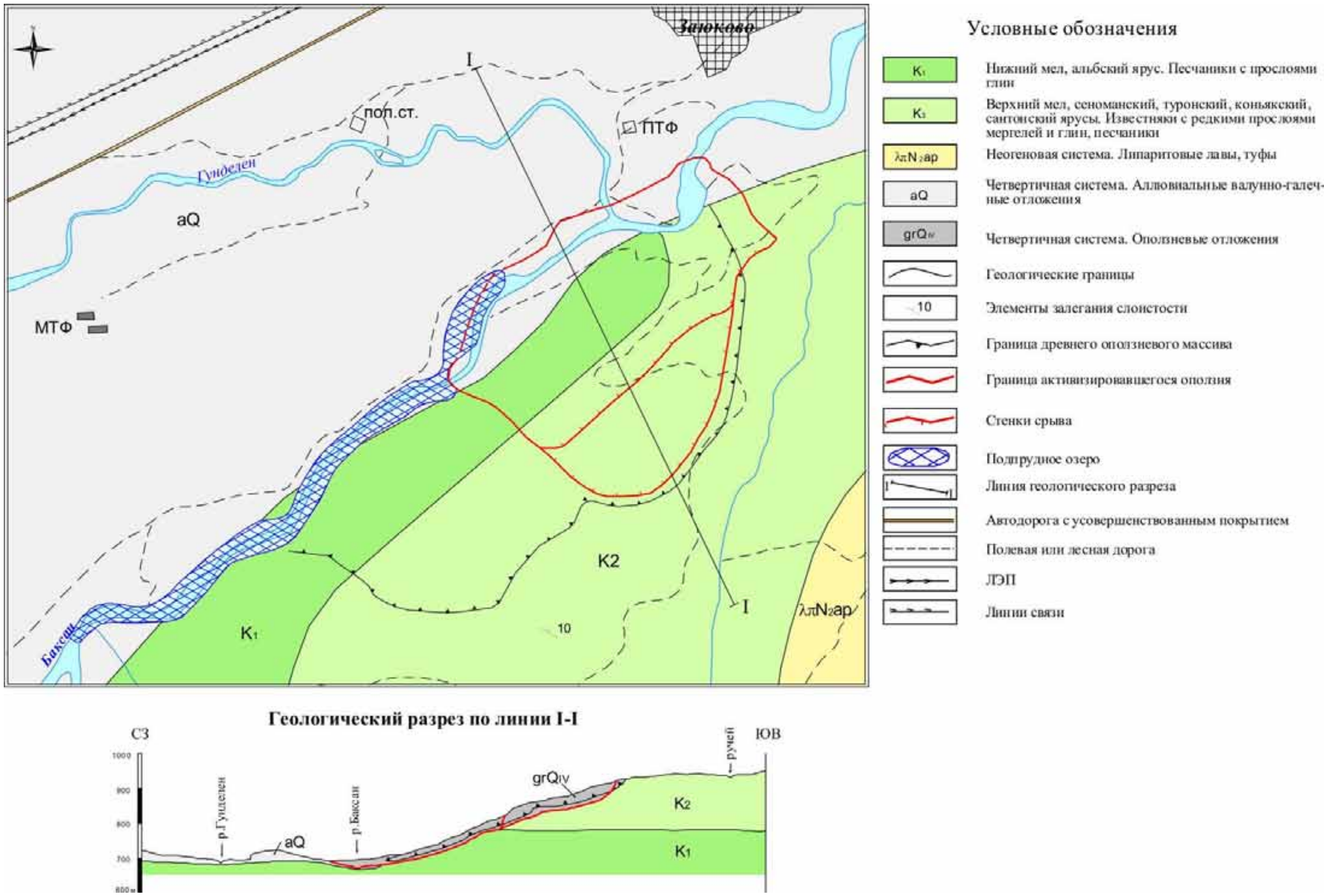

Fig. 4. Geological map of the area of the Zayukovo landslide in the Baksan valley (according to A.F. Baranovsky)

On the 24.05.2008 there was no precipitation. There were downpours at the end of April, when a monthly rate of precipitation (45,6 mm) fell for 4 days. In the first half of May (from the 1^{st} to the 16^{th}) there were rains everyday and their total was also within the monthly rate (109,1 mm). The gravitational shift was probably provoked by a seismic tremor with a 5-point magnitude, registered on the 24^{th} of May, 2005, in Dagestan.

As a result of shearing of landslide masses, the channel of the Baksan river was dammed and ponded over a stretch of 700 m, and the river itself was driven off to the north-west by a distance of 150 m. Near the landslide blockage (dam), whose height was about 20 m, a dam lake was formed for a length of 1750 m, with an area of about 130 thousand square metres. With an average depth of 6 m, the volume of accumulated water in the lake reached 780 thousand cubic metres.

A rapid discharge of water masses could mean formation of a wave of a sediment water flow or water-rock flow, threatening the Zayukovo village and other settlements. However the lake discharge happened in a natural way, gradually, and within 24 hours the water level decreased by 3 m (Fig. s 5, 6 and 7).

Fig. 5. 26.06.2008. The high-velocity stretch in the Baksan river channel in the area of the washed out blockage landslide dam (photo by E. Zaporozhchenko).

The landslide destroyed 250 m of a high-pressure gas pipeline, as a result of which a number of settlements of Elbrus region were left without gas supply for several days. About 1000 m of an earth motor road were destroyed.

Fig. 6. 26.06.2006. In the tail-water (downstream reach) of the bloackage landslide dam of the Baksan river (photo by E. Zaporozhchenko).

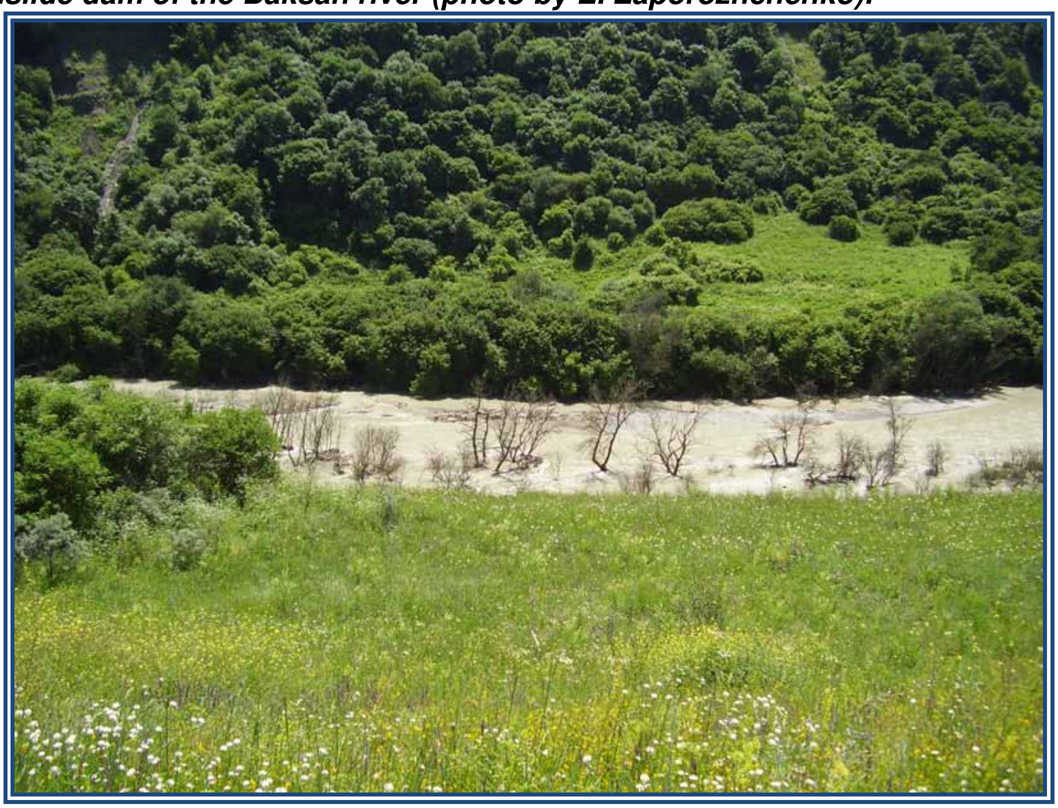

Fig. 7. 26.06.2008. Even three years after the landslide shearing the Baksan river channel upstream the former blockage dam is ponded (photo by E. Zaporozhchenko).

Stop 2. The town of Tyrnyauz

The town of Tyrnyauz is located 89 km south-east of Nalchik, in the valley of the Baksan river, at the place where its right bank tributary, r. Gerkhozha-Su, and left tributary, r. Kamyk, flow into it. In connection with the discovery of the Tyrnyauz tungsten-molybdenum deposit in 1934 on the site of the Balkar village of Kirkhozhan, the settlement of Tyrnyauz was founded. Later, the settlement was renamed Nizhny Baksan (Lower Baksan), and when it got a town status, the former name – Tyrnyauz – was returned, which, translated from the Balkar language, means “tight gorge”. The present area: 37 square km. Population (as of 2007): 20,2 thousand.

The major part of the town is situated at the fan of the Gerkhozhan-Su river, one of the most debris flow hazardous rivers of Kabardino-Balkaria (Zapoozhchenko, 2002): destructive debris flows were registered in 1937, 1960, 1961, 1962, 1977, 1999 and 2000 (Seinova et al, 2003) (Fig. 8).

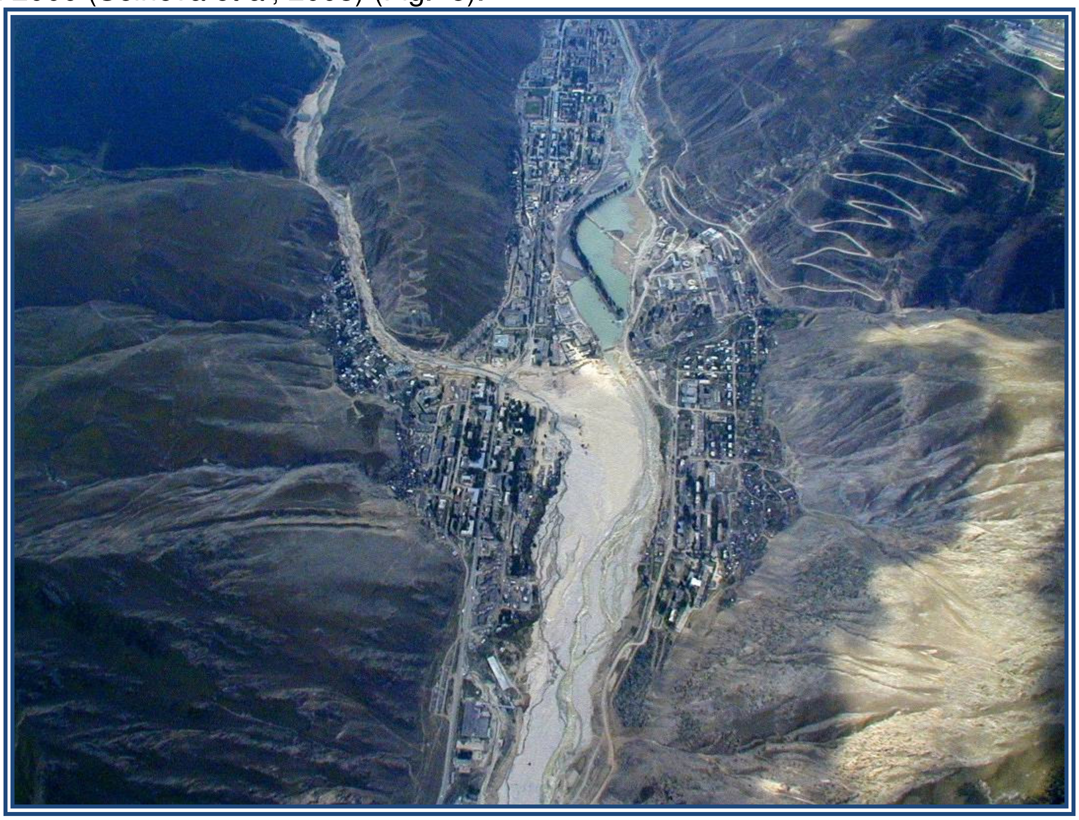

Fig. 8. Debris flow in 2000 (photo by M.Yu. Nikitin, from a helicopter)

Debris flows in the Gerkhozhan-Su valley are of a glacial origin. The main debris flow origination sites are a complex of moraine deposits and fluvioglacial formations of the modern and historic stages of glaciation, located at the heights of 2900-3500 m in the upper reaches of the Kayarty-Su and Sakashili-Su rivers – two components of the Gerkhozhan-Su river. Preliminary development of a debris flow process happens as a result of accumulation of melt waters of a glacier in dam lakes and their successive outburst. Meltwaters, moistening moraine material, ‘prepares’ the process of debris flow formation. 90% of cases of debris flow manifestations take place in July-August. The maximum volume of debris flow mass transport on the Gerkhozhan-Su river is estimated at 3-4 million cubic metres (Krylenko and others, 2004).

The first debris flow in the Tyrnyauz settlement took place in 1937, almost immediately after its foundation. The debris flow destroyed a road bridge.

The growth of the Tyrnyauz town in the 40-50's coincided with the period of a low debris flow activity. By 1960 the fan of the Gerkhozhan-Su river had been almost fully built up with multi-storey buildings. Debris flows of the 60's travelled right through the town.

After the debris flows of 1960 and 1961 a decision on building a debris flow check canal / chute, whose design had been carried out by JSC “Sevkavgirpovodhoz” as early as in 1957, was taken. The chute, however, was not finished – about 500 m of the tail stretch of its outlet to the Baksan river were not constructed. In August 1977 it fulfilled its function as a debris flow conduit main, thus having protected a large town district. One street in the floodplain of the Baksan river, adjacent to the unfinished end reach of the chute, suffered.

After the destructions in 1977 the chute had been restored and reconstructed by 1983, but according to another design (that by “Armniprocvetmet” institute), whereby the reconstruction consisted in arranging cross reinforced concrete beams (dikes) every 15 m along the channel, which contradicted the idea of the initial design.

In 1987 on the river of Gerkhozhan-Su 3 km upstream from the town, construction of a dam of prefabricated reinforced concrete structures began. The designed height of the dam was 30 m.

Construction of the structure continued 12 years and was finished in the summer of 1999. In August of the same year the dam was destroyed by a debris flow (Fig. 9)

Fig. 9. The dam on the Gerkhozhan-Su river, destroyed by a debris flow in 1999 (photo by I.B. Seinova).

The most powerful debris flows in the history of Tyrnyauz were those on the 18-25th July 2000. The debris flow in 2000 claimed human lives. Several blocks of flats were destroyed (Fig. 10).

The disastrous effects were caused not only by natural factors, but also by anthropogenic ones. After the debris flow of 1999 the debris flow check chute was not cleared and therefore was not able to let through the expected discharge. As the debris flow materials moved out above the mark of the top of the debris flow control chute, a 9-storey residential building, erected close to a channel on the turn of the river, was damaged. Near the conjunction of the Gerkhozhan-Su river with the Baksan river a formation of a dam lake, with an area of 0,55 square metres, took place. The central part of the town was flooded with water 3-4 m thick for a period of 2 months.

Fig. 10. Residential building in the town of Tyrnyauz, affected by a debris flow in 2000 (photo by S.S. Chernomorets)

Reconstruction of the debris flow control chute according to the design of JSC "Sevkavgiprovodhoz" was finished in 2008. (Fig. 11).

Almost unlimited volumes of loose material are typical for the upper reaches of the river of Gerkhozhan-Su. The debris flow hazard for the Tyrnyauz town still remains.

Fig. 11. Reconstruction works on the debris flow control chute in the mouth of the Gerkhozhan-Su river (photo by S.S. Chernomorets)

On the left bank of the Baksan river opposite the Gerkhozhan-Su mouth another debris flow hazardous Baksan tributary – r. Kamyk - falls into it (Zaporozhchenko, 2004). The length of the stream is 8,5 km, the catchment area is 24,2 square km. The volume of mass transport reaches 50-100 thousand cubic metres. Debris flows on the Kamyk river were registered in 1967 and 1977 and both had a storm origin.

In the upper reaches of the Kamyk river stocking of piles of the Tyrnyauz ore-dressing and processing enterprise has for a long time been carried out.

Debris flows on the Kamyk river, as well as on the Gerkhozhan-Su river, lead to ponding of the Baksan river. For the sake of protection of the town in 2006 a design of a mouth debris flow control chute was drafted and approved by JSC "Sevkavgiprovodhoz".

Stop 3. The Bolshoi and Maly Mukulan streams

The Bolshoi and Maly Mukulan streams fall into the Baksan river from the left bank of the valley, 130 and 132,5 km from its mouth, respectively, 1,5 and 4 km upstream of the Tyrnyauz town. The basins of the Bolshoi and Maly Mukulan have the catchment areas of 5,2 and 2 square km and are located on the south-eastern exposition slope of the Peredovoy Ridge. Downstream from the mouth of the Bol.Mukuklan the right tributary of the Baksan river, the river of Tyutyu-Su, also debris flow hazardous, falls into it.

From 1968 to 1994 on the Mukulan open pit, located on the spurs of the Peredovoy Ridge, open pit mining was carried out by the Tyrnyauz ore-dressing and processing enterprise. The basins of the streams were used for stocking overburden of the open pit for 20 years (Fig. 12).

Fig. 12. The dumps of the Tyrnyauz ore-dressing and processing enterprise in the basins of the Bolshoi and Maly Mukulan (photo by Yu.N. Nikitin, from a helicopter).

The bulk of the overburden is located in the basin of the Bol.Mukulan. The dumps are blocky crushed stone materials with sandy-loam filling. The thickness of the dumps in the Bolshoi Mukulan valley is 300 m. The total volume of the dumps, accumulated for the period of mining of the Mukulan pit, is about 440 million cubic metres (Seinova, Zolotarev, 2001; Khadzhiev, 2005).

The technology of building up waste massifs provides for their sufficient stability while they are dry. Under the influence of precipitation, the washout of loose masses takes place, erosion cuts up to 5 m deep and up to 10 m wide are formed, being the origination environment for debris flows (Fig. 13). In the mouths of both streams significant fans were formed, opening to the channel of the Baksan river (Fig. 14). In natural conditions (before the development of the open pit in 1968-1969) the formation of debris flows had only happened under intensive storms (more than 50 mm), with an occurrence of once in 30 years. The volumes of mass transport of debris flows had not exceeded 50-100 thousand cubic metres, due to the limited stock of loose materials on the slopes. On the Mal. Mukulan there had been no debris flows.

Debris flows of the Tyutyu-Su river have a glacier-and-rain origin. The maximum volume of mass transport is 100-500 thousand cubic km, with a recurrence rate of once in 20 years. In 1934 simultaneous debris flows on the Bol. Mukulan and Tyutyu-Su were registered, damming the Baksan river channel for a while.

After the start of mining of the open pit the rate of debris flows began increasing. The number of anthropogenic debris flows reached the figure of 20 times a year. In 1970-1972 debris flows on Bol. and Maly Mukulans repeatedly occurred, in connection with which the road was relocated to the right bank and rendered on the debris flow fan of the Tyutyu-Su river.

In 1984 the volume of mass transport of an antropogenic debris flow on the B.Mukulan was 150 cubic m. The debris flow destroyed a road bridge and blocked the motor road, temporarily stopping the traffic between Tyrnyauz and the settlement of Terskol.

Fig. 13. The waste rocks in the basin of the Mal. Mukulan stream (photo by S.S. Chernomorets).

In 1985 for the sake of protection from anthropogenic debris flows of the Bol.Mukulan, on the periphery of the fan an earth channel was dug for the laying of a motor road tunnel. In the same year the foundation pit began filling up by sediments of multiple debris flows; construction works were stopped. During 1985-86 the foundation pit acted as a 'trap', intercepting the hard component of debris flows and protecting the road from drift.

When the foundation pit was filled inasmuch as the mud mass began spreading over the road, a new road bridge was built.

Fig. 14. The technogeneous fan of the Mal.Mukulan stream (photo by I.N. Kargapolova).

Despite the fact that in 1994 works on the Mukulan open pit were stopped, debris flow activity of the basins of the Bol. and Mal. Mukulan remains high.

In the last years the following debris flows were registered: on the 4th of March, 2004 on the B.Mukulan river – 45-50 thousand cubic metres, on the M.Mukulan – more than 100 thousand cubic metres, with a blockage of the channel of the Baksan river; on the 15th of March 2005 – on the river of B.Mukulan, 60-65 thousand cubic metres, on the river of M.Mukulan – 40 thousand cubic metres.

Since 1968 in the area of the Mukulan open pit there have not been registered any storm, close - in its parameters - to extreme, like the one on the 5th of August 1967. Should such a storm (85,9 mm with a maximum intensity of 0,4 mm/min) take place again, a disastrous debris flow should be expected.

Stop 4. The area of the Tyubele Swell

In the Baksan valley, not far from the settlement of Neitrino (25 km from the source of the river) a natural swell formation, which got its name from the Turk "tyubele" meaning "swell", made up of large block materials, is located (Fig. 15, 16). The swell blocks the whole valley; near the right bank it is cut through by the present Baksan river channel. Its height reaches 150-200 m above the bottom of the valley, its length – 600-700 m, width – 400-500 m.

The formation of this relief element is considered to be connected with a landslide, that travelled down from the massif on the mountains of Andyrchi and Kurymychi (the height of about 4000 m) in the end of the late Pleistocene, about 30 thousand years ago (Koronovskiy, Milanovskiy, 1960). The landslide was evidently caused by an earthquake. Blocks of gray granites overlapped the end part of the glacier and 'spilled up' several tens of metres onto the opposite slope of the valley. Upstream from the landslide, during the melting of the glacier a lake formed, which later drained.

Fig. 15. The swell of Tyubele in the Baksan valley (photo by S.S. Chernomorets)

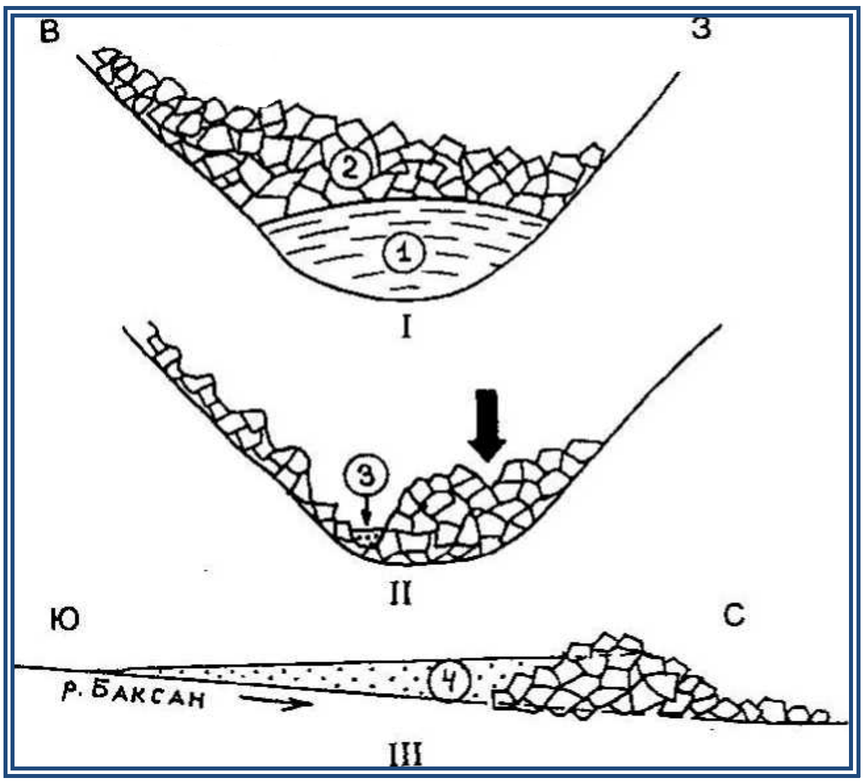

Fig. 16. The formation of the swell of Tyubele (according to N.V. Koronovsky and E.E. Milanovsky, 1960).

I – upper Pleistocene glacier in the Baksan valley blocked by a landslide of granite boulders from the river of Andyrchi: 1- glacier, 2 – landslide; II – the glacier retreated and the landslide mass subsided: 3 – the present channel of the Baksan river. The bold black arrow indicates the place of the lake outburst; III – the cross profile of the swell, upwards from which a lake (4) formed, which drained later.

On the 10th of March 2006 an avalanche with a volume of 500 thousand cubic metres travelled down one of the avalanche couluars of the massif on the Andyrchi mountain. The avalanche hit auxiliary buildings of the Baksan neitrino observatory near the settlement of Neitrino (fig. 17).

It destroyed a two-storey building of a militarised mountain rescue unit, 3 people died. A heating plant line to the settlement of Neitrino, was destroyed and buried under 8 metres of snow; heat supply to 22 residential houses (for 610 people) was disrupted. The snow mass drifted to the other side of the gorge across the Baksan river, a bus stop and several utility structures were removed.

Fig. 17. The avalanche that travelled down the Andyrchi mountain on the 10th of March 2006 (photo by I.V. Krylenko).

Stop 5. The stream of Sagayevsky

The stream of Sagayevsky is a right tributary of the Baksan river, falling into it 151,5 km from its mouth, downstream from the settlement of Elbrus. The catchement area is 2,5m km^2. The average gradient is 25^o.

The stream of Sagayevsky is one of the most active debris flow tributary of the Baksan river. Debris flows move down it once in 4 years and the volume of deposits reaches the figure of 300 thousand cubic metres. There are periods when the origination site is triggered in a year or in 2 or 3 years [after a previous debris flow]. Then there may be recesses of 10 and more years. After a long recess, as a rule, most powerful debris flows occur. There were debris flows on the Sagayevsky stream in 1967, 1972, 1979, 1981, 1984, 1995 and 2003.

The high debris flow activity of the Sagayevsku basin is connected with a large stock of loose detritus material (about 2,5 million cubic metres), accumulated as a result of nivation processes. The formation of debris flows has an erosion-and-shearing mechanism.

In the mouth of the Sagayevsky stream there is a massive fan (Fig. 18). Its main bulk was formed at the initial stage of degradation of glaciation of the Little Ice Age. The ancient part of the fan with a thickness of deposits of up to 50 m is overlaid on the terrace of the Baksan river and cut through by a canyon with an average depth of 10 m. Lower, the present debris flow fan is formed, pushing the Baksan river to the foot of the left slope. The total area of the fan is 0,70 km^2, of the present fan – 0,15 km^2, the area of the latter constantly increases.

Debris flows in the basins of the Sagayevsky stream originate under storm rainfall conditions.

In the river channel a flood is formed, increasing its strength from the sources of the stream to its mouth. Erosion, caused by it, serves as a reason for the cutting of the slopes and formation of a landslide, blocking the river channel. The outburst of the formed dam is a triggering mechanism for the river channel processes in the downstream reach.

Fig. 18. The fan of the Sagayevsky stream (photo by A.M. Tarbeyeva)

The bottom of the Sagayevsky stream is at the same time a chute of a most powerful avalanche, influencing the formation of debris flows. After extreme very snowy winters the avalanche snow in the river channel retains loose deposits, preventing the formation of debris flows.

Avalanches and debris flows of the Sagayevsky stream travel down out to the fan, where the outskirts of the Elbrus settlement and the road are. Recurrent blockages of the road Tyrnyauz-Terskol by debris flow masses are removed via service clearing.

Fig. 19. The clearing of the road at the fan of the Sagayevsky stream, 2003 (photo by S.S. Chernomorets)

Stop 6. The valley of the Adyl-Su river

The valley of the Adyl-Su river – the right tributary of the Baksan river – is surrounded by 4000 m peaks: Dzhantugan, Bashkara, Ullukara, Caucasus Peak, Shkhelda, which are part of the Main Caucasus Ridge. Here alpinist bases “Shkhelda” and “Dzhan-Tugan”, recreation centres and a camping are located. In the upper reaches of the valley near the tongue of the Dzhankuat glacier a Glaciology station of MGU’s Geography faculty, where fixed observations have been carried out for 30 years, is situated.

A favourable combination of orthographic and circulation climate factors have determined the development in the Adyl-Su valley of a powerful glaciation, which presently occupies 20% of the basin area. In Holocene the largest glacier of the Shkhelda river valley extended into the Baksan valley. At present the glaciation of the Adyl-Su river valley, as well as of the whole Caucasus, is in the state of degradation. As a result at the edge of the right branch of the tongue of the Bashkarinsky glacier a lake of the same name appeared.

The formation of the lake probably dates to the end of the 1930’s – the beginning of the 1940’s. It was located in the northern part of the present kettle and occupied less than half of the area of the present lake. Its northern half was located on the ancient moraine, while its southern part and the bottom – on ice. The level was hypsometrically higher than the present level. Under the tongue of the left branch of the Bashkarinsky glacier a second, smaller lake existed, which was the source of the river.

In the summers of 1958 and 1959 ‘outbursts’ of Bashkara lake were registered, which caused the formation of debris flows. Probably the draining of the lake was caused by the destruction of the ice dam and the outburst of the grotto in the body of the glacier lower than the water level in the lake. After the debris flow the water level in the lake decreased by approximately 2 metres. The lower lake, which was in the way of the outburst near the edge of the main branch of the glacier, drained too. The volume of the initial water impulse was estimated at 60 thousand cubic metres, and the volume of the debris flow deposits for the period of 1958-1959 - at 2 million cubic metres.

Traces of the two debris flows of 1958 and 1959 are observed in the middle stream of the Adyl-Su, upstream from the alpinist camp “Dzhan-Tugan”, in the form of a field of accumulated large boulder debris flow deposits (Fig. 20). The volume of water, participating in the transportation of the debris flow deposits, accumulated in the middle part of the Adyl-Su valley (on the so called “Dzhantugan glade”), with a density of about 1500 kg/m^3 is about 300-6000 thousand cubic metres.

Presently at the edge of the Bashkarinsky glacier there is a system of lakes, consisting of the Main Bashkara lake, located in the moraine loop of the right branch of the glacier, and Lake Lapa, located lower, behind the end moraine left branch of the Bashkara glacier (Fig. 21). The maximum depth of Bashkara lake is 34 m. The volume in the last years is from 751 to 786 thousand cubic metres. The area of the mirror is on average 64 thousand square metres.

Lake Lapa was formed due to the joining of several lakes, it has considerably smaller dimensions, but its area increases year by year due to the melting of the adjacent part of the glacier. The volume of water from 2001 to 2006 increased from 30 to 127 thousand cubic metres and is becoming comparable with that of the Bashkara lake before 1958.

At present the Main Bashkara lake poses the biggest potential danger. The lake lacks a pronounced tailrace (runoff canal). The water partially filters and partially runs via under-the-ice runoff canals in the much morained part of the tongue of the Bashkara glacier, prone to multiple thermokarst subsidences. The latter favours the decreasing of the width of the ice crossbar between the upper and lower lakes.

It is estimated (Chernomorets and others, 2007 a) that the maximum discharge of a possible outburst flood may total about 150 cubic metres/s, the respective discharge of the water-rock flow downstream in the valley – about 300 cubic metres/s. Yu.L. Gnezdalov estimates Qc, coming up to Lapa lake at 134 cubic metres/s, to the location of the alpinist base "Dzhantagan" – 184-322 cubic metres/s, of the alpinist base "Elbrus" – 164-274 cubic metres/s, of the mouth of the river of Shkhelda - 156-257 cubic metres/s, of the Adyl-Su river – 115-221 cubic metres/s, depending on the accepted model of the calculation.

Fig. 20. The field of accumulation of debris flow deposits upstream from the alpinist base "Dzhantugan" (photo by S.S. Chernomorets)

Fig. 21. The glacier Bashkara and Bashkarian lakes (photo by V.V. Krylenko)

On the 26th of June 2008 with the ice-moraine crossbar (2,2 m in height at its lowest part and 20 m in width), restraining the lake, there opened a leakage into the ice grotto, located about 35 m from the water's edge of the lake (Fig. 22, 23) and on the 17th of July 2008 an open spillover into it began.

Fig. 22. 26.06.2008. The Main Bashkara lake. 1 – grotto, 2 – ice-morraine crossbar (photo by E. Zaporozhchenko).

Fig. 23. 26.06.2008. The grotto about 35 m from the water's edge in the Main Bashkara lake (photo by E. Zaporozhchenko).

Stop 7. The Cheget glade

On the right bank of the valley of the Donguz-Orun river – a right tributary of the Baksan river – a skiing slope of the Cheget mountain is located, on the left bank there is mountain Kogutaibashi (3819 m), from which the Kogutai glacier descends. Between them in the bottom of the valley there lies the Cheget glade. In the skiing season up to 1,5 thousand people simultaneously gather there.

After heavy snow in the kar (cirque) of the Kogutai glacier and in the couluar of its right tributary up to 1 million cubic metres of snow accumulates. In 1987 an avalanche travelled down Kogutai mountain, which completely covered the Cheget glade. The avalanche hit the “Cheget” hotel.

Specialists of the anti-avalanche service during heavy snow trigger accumulated snow by small portions, otherwise all the buildings of the Cheget glade would be under snow.

The Cheget glade is intensively developed. Thus, right on the way of a possible avalanche, a cafe “Kogutai” has been built (Fig. 24).

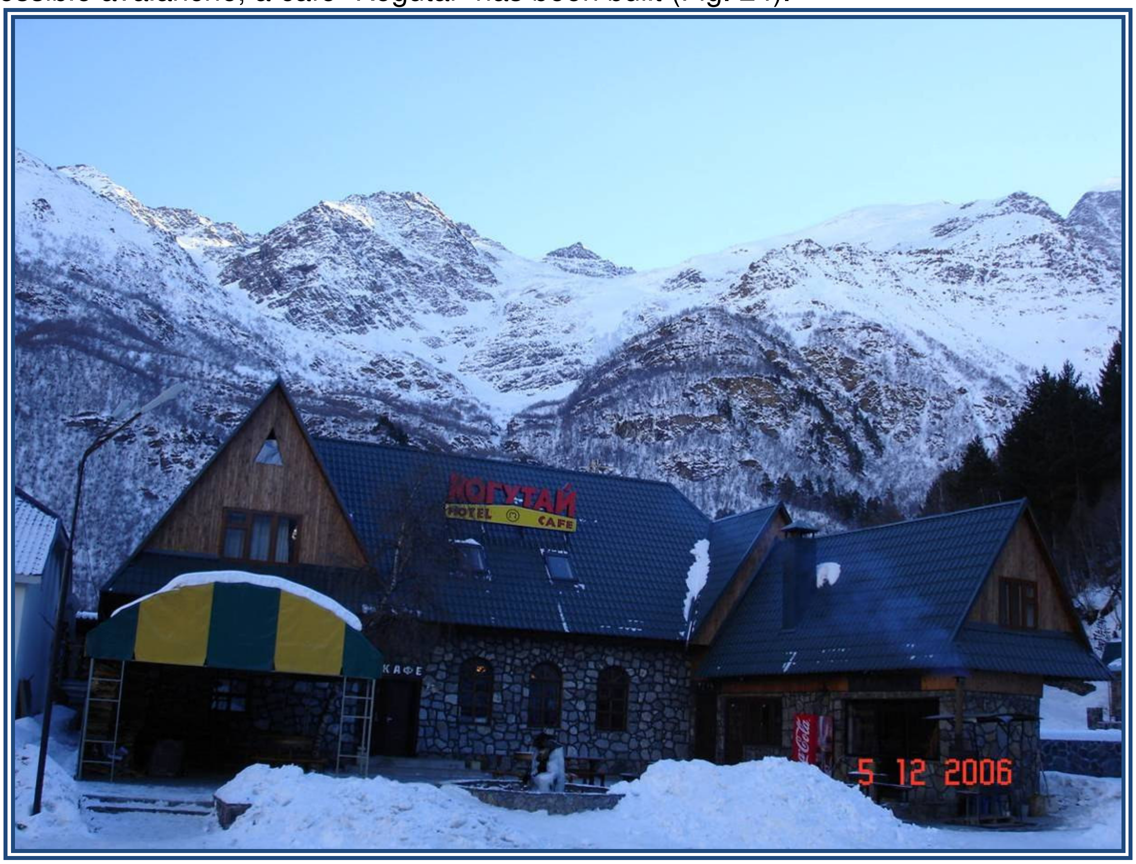

Fig. 24. “Kogutai” cafe (photo by O.V. Tutubalina)

Stop 8. The Azau glade

The Elbrus volcano (Mingi-Tau – *‘Eternal Mountain’* (Karachai-Balkar); Oshkhamakho – *‘The mountain of happiness’* (Adyghe)), 5642 m high, is the highest peak of the Caucasus, Russia and Europe.

The first documented climb was carried out in 1829 by an expedition of the Russian Geographic Society, under the leadership of General G.A. Emanuel. During the ascent Kabardian Killar Khashirov was the first to reach the East peak of Elbrus. The West, higher peak, was conquered in 1868 by English alpinists led by Douglas Freshfield and Balkar guide Akhiy Sottayev. In 1890 A.V. Pastuhov, a Russian army topographist and alpinist, ascended the West and East peaks, paving the way for a scientific study of Elbrus.

The most large-scale investigations of Elbrus were conducted in 1957-1959 throughout which in the settlement of Terskol near the foot of the southern slope of Elbrus a field station for carrying out complex glaciology observations was established.

In 1969 at the foot of Elbrus on the Azau glade The G.K. Tushinsky Elbrus training and scientific station of Geography faculty of MGU (Moscow State University) was opened (Fig. 25).

Fig. 25. Elbrus training and scientific station of Geography faculty of MGU (photo by S.S. Chernomorets)

Onto the slope of Elbrus one may go by cable car/chair-lift system. The cable car system of a modern kind was opened in December, 2006.

The Elbrus volcano rises 2-2,5 km high on the base of igneous rocks. It has an almost conical shape, truncated at the height of 5300-5400 m, where its two peaks are located (Fig. 26). The East peak (5621 m) is a younger one (Fig. 27).

The volcanic structure of Elbrus was formed through multiple eruptions at the last stages of Alpine Orogeny (Mikhanovskiy, Koronovskiy, 1960). The foundation of the volcano is made up of effusive rocks (liparite, dacite, ingnimbrite).

The volcanic activity of Elbrus is closely connected with the degradation of the glaciation. Melting and freeing of the earth surface off glaciers favoured the activation of internal movements of Earth's crust, which was accompanied by earthquakes, eruptions, powerful slope, debris flow and channel processes.

The largest eruptions and debris flow processes happened during the degradation of the maximum glaciation of the middle Pleistocene. Debris flow deposits of that period with a 10-12 m thickness are revealed in the sections of terraces of the Baksan river at a distance of 100 km from the source (Baksanskaya hydrostation).

In the interglacial period of the upper Pleistocene (about 200 thousand years ago) the formation of the west peak of Elbrus took place, in the beginning of the Holocene period the east cone was formed.

Fig. 26. Elbrus as seen from the slopes of Cheget mountain (photo by A.M. Tarbeyeva)

Fig. 27. The crater of the east peak of Elbrus (photo by A.M. Tarbeyeva)

The last powerful manifestation of volcanism over the whole territory of the Caucasus happened 5-7 thousand years ago. The outflow of the Holocene lavas primarily occurred on the northern and southern slopes of Elbrus. Flows of Holocene lavas have the look of tongues 500 m wide and 5 km long ("Pastukhov's Rocks"). Such a shape is determined by a considerable viscosity of andesite and dacite lava, flowing as a narrow high swell.

At the stage of fading volcanic activity on the eastern slope of the Holocene (eastern) cone of Elbrus a "parasite" crater functioned. According to implicit data the last eruption of it happened 1500-2000 years ago.

Presently Elbrus is at the stage of relative rest; it is a powerful centre of the modern glaciation with an area of 128 square km. The glaciation of Elbrus as well as of the whole Caucasus in the last decades has been intensively decreasing which has been accompanied by formation of near-glacier lakes, activation of debris flow and slope processes.

The Azau river, the source of the Baksan river, springs from the glaciers of Elbrus. The Azau valley is a trough, formed by a Pleistocene glacier, the morphology of which was essentially influenced by eruptions of the Elbrus volcano and further debris flow processes (fig. 28).

Fig. 28. The view of the Azau valley (photo by A.M. Tarbeyeva)

In Holocene one of the lava flows, coming down into the Azau valley, blocked the river forming a dam lake in the upper reaches. As a result of cyclic glacier expansions and contractions the destruction of the lava dam took place which caused debris flow disasters for the two last stages of historic glaciation. The volume of the large boulder component mass transport of ancient debris flows within the Azau valley is estimated at 50 million cubic metres (Seinova, Zolotarev, 2001).

Outbursts of water-ice-stone masses caused the formation of gigantic debris flows, deposits of which fill the Azau valley for a 5 km stretch down from the lava dam. Thanks to the gentle slope, an extensive zone of accumulation of debris flow deposits, with an aggregate thickness of up to 100 m, was formed there.

Dam lakes were formed at the periphery of the Elbrus volcano from the beginning of its activity, when lava flows streamed down into river valleys, filling them up or blocking them. Multiple cuts of lake deposits from early Pleistocene to the modern epoch indicate that.

The mechanism of formation of disastrous debris flows due to the destruction of lava dams is characteristic not only for the Azau valley. The ice plateau Dzhikiugankez with an area of 27 km^2 with short outflow glaciers of Birdzhaly-Chiran and Chungur-Chat-Chiran, located on the north-eastern slope of Elbrus, is also dammed with Holocene lavas.

In July 1978 a debris flow caused by an outburst of a glacier lake on the ice divide of the Bolshoi and Maly Azau was registered. The dimensions of the lake, filled by melt waters of the Maly Azau glacier, are 50x100 m. There happened a powerful fall of the edge of the glacier, hanging over the lake, and a splash of water from it. In the steep erosive cut 600 m long a mud-rock flow was formed. Then the debris flow rolled over the tongue of the Bolshoi Azau glacier (1,8 km), gradually transforming into a sediment-water flow. The bulk of the debris flow materials were deposited at the section near the MGU station. The total volume of the debris flow reached 240 thousand cubic metres, the volume of the hard component – 80 thousand cubic metres, the flow rate – up to 50 cubic metres/s, whereas the maximum rate of the water in the river Azau is 19 cubic metres/s.

The lake still exists at present. However in connection with the retreating of the edge of the glacier and its flattening, ice falls stopped. The dimensions of the lake are fairly stable (fig. 29).

Fig. 29. The lake near the edge of the Maly Azau glacier (photo by I.N. Kargapolova)

In 2006 on the northern slope of Elbrus an outburst of one of the lakes near the Birdzhaly-Chiran glacier took place (Zaporozhchenko, 2007, Chernomorets and others, 2007 b). The debris flow that was formed as a result of the outburst of the lake, destroyed the infrastructure of the Dzhily-Su spa, located in the mouth of the Birdzhaly-Su river.