УДК: 910.2

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CONDITION OF GLACIERS OF THE AREA OF ACTIVITIES OF THE KUMTOR GOLD MINING ENTERPRISE IN KYRGYZSTAN

Состояние ледников района деятельности золоторудного предприятия «Кумтор» в Кыргызстане

Кыргызстандындагы «Кумтор» алтын кен ишканасы жайлашкан аянттындагы мецгулердун абалы

Abstract: *This article studies the impact of the activities of "Kumtor Operating Company" (KOC), a gold mining company, in the mountain range glacier Ak-Shyirak in Kyrgyzstan. Company "KOC" actively uses "Lysyi" and "Davydov"'s glaciers as a place of storage of waste rock dumps. Large areas of the ice melted away during the operation of the Kumtor gold deposit between 1996 and 2015.*

Аннотация: *исследуется влияние деятельности золотодобывающего предприятия «Кумтор Оперейтинг Компани» (КОК) на ледники хребта Ак-Шыйрак в Кыргызстане. Предприятие «КОК» активно использует ледники «Лысый» и «Давыдова» как места складирования отвалов пустых пород. Большие площади льда потеряны при эксплуатации золоторудного месторождения «Кумтор» в 1996-2015 гг.*

Аннотация*: макалада «Кумтор Оперейтинг Компани» алтын кен ишканасынын (КОК) Кыргызстандагы Ак-Шыйрак тоосунун мвцгулврунв тийгизген таасири изилденилет. «КОК» "Лысый" жана "Давыдов" мвцгулврун касылып жаткан бош тектин твгундулврун сактоочу орду катары пайдаланат. Муздардын чоц квлвмг 1996-2015 жылдарда Кумтор алтын кенин казыланып иштетуу учурунда жоюлган.*

Keywords*: gold mining; disappearance of glaciers; Ak-Shiyrak Ridge; technogenic influence*

Ключевые слова*: золотодобыча; исчезновение ледников; хребет Ак-Шыйрак; техногенное влияние.*

Негизги свздвр*: алтын казуу; мвцгулврдт жоголушу; Ак-Шыйрак тоосу; техногендик таасири.*

History of research, orography, topography and climate

The history of the study of the glaciers of the Ak-Shyirak range traces back a century and a half. Ak-Shyirak glaciation and orography were first time mentioned by A.V. Kaulbars. He named the largest glacier after Lieutenant Petrov, who made a survey in these cold places.

In 1886, some areas of the Tien Shan were visited by A. N. Krasnov. A.N. Krasnov explored the history of the development of the Tien Shan flora, but we can find in it some information on glaciers and the Petrov glacier.

In 1911-1913, the Military Topographic Department conducted instrumental topographic surveys in Tien Shan mountains. These maps were highly rated by N.N. Palgov and T.A. Avsyuk.

In 1925, Central Asian Meteorological Institute researchers headed by A. K. Davydov visited the northwestern part of Ak-Shyirak. In 1929 N.M. Prokopenko climbed up the Petrov Glacier. From the end of 1929 the meteorological station "Tien Shan", located near the Petrov Glacier, conducts regular observations. In his "Catalog of Glaciers of Central Asia" N.L. Korzhenevsky tells about 29 glaciers of the Ak-Shyirak ridge [2].

The second international polar year (1932-1933) was a turning point in the study of the Ak-Shyirak glaciation of. Members of the Naryn-Khantengri research group used theodolites to cover the ends of many glaciers and were the first to describe such interesting glaciers as the glaciers of the hanging valleys.

In 1932, a group of climbers led by A.A. Letaveta ascended the peak of the SNK of Kyrgyzstan and collected some material on the glaciation of Ak-Shyirak. After a long break, the study of the Ak-Shyirak glaciation is resumed based on the Tien Shan Physicogeographical Station. Between 1946-1947 and 1949 T.A. Aksyuk [2] studied the of Ak-Shyirak glaciers. He proposed a new scheme for glaciological zoning and outlined new views on the Ak-Shyirak orography.

In 1957-1959, Tien Shan Physicogeographical Station took part in the work within the program of the International Geophysical Year. The Ak-Shyirak glaciers were studied by using exact methods of research (photo-theodolithic surveying, determination of glacier movement velocities, observation of ablation, etc.). It is proved that "a small area of Ak-Shyirak Range houses almost all types of glaciers characteristic of the vast expanses of the Tien Shan, and therefore Ak-Shyirak can be called a kind of glaciological museum of the world." In subsequent years the Ak-Shyirak glaciers were studied by M.V. Maksimyak, V.K Tkachenko, V. I. Burakov, R.D. Zabirov, L.G. Bondarev and others [2,7].

Ak-Shyirak consists of three closely-spaced parallel ridges, located in an orderly manner and oriented from the northeast to the southwest. There is watershed of two large Asian basins on the territory of Ak-Shyirak. The rivers of the western part feed the upper reaches of the Naryn River belonging to the Aral Sea basin with their waters, and the rest of the territory belongs to the Sary-Jaz (Aksu) basin in China.

The Alpine relief zone lies 4000-4100 m above. The slightly hilly swampy space of the Arabel and Kumtor valleys adjoining the western slope of Ak-Shyrak is a region of ancient glacial accumulation. The average absolute height here is 3550-3650 m, the relative excess is 1000-1200 m.

The depressions of the ancient moraine relief have many lakes some of which have no runoff.

The climate in the region is severe. The average annual air temperature is -8.1°C. A. Kh. Zavodovsky [2] compares the climatic conditions of the upper reaches of Naryn and Matochkin Shar (Polar region). In winter, the minimum temperature can drop to almost -50°C.

Analysis of glaciers before the start of gold mining "Kumtor"

Ak-Shyirak is the third largest in terms of size, and the middle in terms area glaciation area of the Tien-Shan (432.2 km^2) [1]. Ak-Shyirak glaciers are concentrated in a relatively small space, about 33-37 km. Glaciers occupy ⅓ part of this rectangle. Ak-Shyirak range has 131 independent glaciers (including small hanging glaciers). With the tributaries of the valley glaciers considered, the total number of glaciers exceeds 150. The total volume of ice and firn of Ak-Shyirak glaciers in water transfer is equal, according to G.A. Avsyuk's estimates, to 39052 million m^3, and the annual flow is 727 million m^3 [2].

Below, we will look only at those glaciers, where the Kumtor company is extracting gold.

The "Lysyi" Glacier originates in a vast two-chamber circle with asymmetric glaciers that gravitates toward the most shaded areas. The glacier is also fed from the left slope of the north-eastern valley. The right slope is strongly dissected right slope, and its upper erosion reaches have small hanging glaciers and snowfields at altitudes of 4120-4230m.

The height of the snow line within the valley is unstable. On the shaded slope of the north-eastern exposition it is 4100-4150 m, and on small glaciers of the right slope it rises to 4350-4400 m. The area of the Lysyi Glacier is 4.4 km^2, and together with the hanging glaciers on the right slope the glaciation occupies is 4 65 km^2. Ice thickness near the end of the main glacier reaches 70 m, its surface in the axial part is calm and smooth with the 4-5°average slope.

The first information about "Lysyi" Glacier refers to 1927 (L. K. Davydov). In 1932, S. V. Kalesnik found the marks left by L. K. Davydov near the glacier, which made it possible to determine its spatial variation between 1925 and1932. For 7 years, the glacier retreated by 13 m. Information on annual changes in the glacier during the seven-year period can be found in the works of N.L. Korzhenevsky [2]. In 1926, "Lysyi" Glacier retreated by 1 m, in 1927 - by 6 m, and the years of 1929, 1932 and 1933 saw the glacier advancing. In 1932-1943, the end of the glacier maintained a stationary position. In the period between 1943 and 1957 the glacier retreated to 60-70 m. In 1961, L.K. Davydov's marks were found and the magnitude of the reduction for 1925-1961 equalled to 174.5 m. The shape of the end part of the glacier has also changed. The steepness of the tail was 10-50° (21-26° in 1980-1990), and 14° (later - 4-5°) on the flattest middle part [2].

The «Davydov» Glacier has an area of 12.13 km^2 with a length of 4.4 km. It was already in a state of degradation in 1932. In 1933, the participants of the Naryn-Khantengri research group found that the glacier was retreated by 15.5 m per year. S. V. Kalesnik considered this figure an exaggeration.

The magnitude of the linear retreat from between 1932 and 1943 is equal to 290m; from 1943 to 1957 - 380 m. The annual flattening of the glacier (1.6 m per year) for a profile of 300-350 m from the end of the glacier is determined by the difference in heights of the watercourse terraces that drained the lake at the left edge of the glacier. By interpolation, it was found that the average annual flattening value over the same period for the entire surface of the glacier was 0.7 m per year [2].

The glacier regression is also evidenced by the presence of 10-15m tall ablative breaks along the edges of the tongue. They arise due to melting from the heat radiated by stony slopes. Between 1943 and 1957 the upper reaches of these ablative forms constituted 350 m upstream.

The "Sary-Tor" Glacier has an area of 3 km^2 and a length of 4.2 km. During the 2nd International Polar Year, in 1932 this glacier was described under the name "Sary-Tor-2", and its end was surveyed by using a theodolite. Twenty-five years later, during the glaciological studies conducted by the Tien-Shan Physics and Geography Station within the International Geophysical Year Program, a phototheodolite survey of the glacier was performed. When comparing these materials, it can be seen that the glacier has changed insignificantly, with slight retreat (by 50-70 m) of the left end.

On July 31, 1961, a mark established in 1932 by the Naryn-Khantengri research group was discovered. This made it possible to determine the amount of retreat of the left part of the glacier between 1932 and 1961. The glacier retreat equals to 71m.

It is interesting to note a noticeable slowing of the ice movement, although the speed of "Lysyi" and "Davydov" Glaciers movement was determined during the 2nd International Polaw Year as well as the 3rd International Geophysical Year. A zone of fixed ice was identified at the right edge of the "Davydov" glacier. Obviously, these changes have resulted from the reduction of these glaciers and a decrease in their capacity [2].

During the reduction of glaciation over the past 20 years, several glaciers in Ak-Shyirak have fallen into separate parts. Directly, such disintegration is a result of cumulative processes, including:

- ablation;
- changing nature of complex glacier movement;
- eroding effect of meltwater currents;
- impact of technogenic processes.

The “Lysyi” and “Davydov” Glaciers were one joint piece in 1993 and their disintegration into two or three glaciers was especially fast.

Large (in percentages) ice areas were lost during the operation of the Kumtor gold-mine company in 1994-2013. This is due to the fact that gold mining is intensive, and the process of decay and melting of glaciers occurs quickly and irreversibly. At present, the Lysyi Glacier is destroyed, because it is now the quarry of a Canadian enterprise, and the «Davydov» Glacier is used as a dump of overburden removals (Fig. 1).

Evolution of glaciers between 1996 and 2013.

Within the period of 1978 and 1990, the Kyrgyz exploration geologists discovered, explored, and calculated the reserves of gold, silver, tellurium, tungsten and pyrite sulfur in the region of Kumtor glaciers («Petrov», «Lysyi», «Davydov» and «Sary-Tor») and have them approved in the State Commission on Mineral Reserves under the Council Ministers of the USSR (GKZ USSR). In 1992-199, the Canadian company Cameco received a concession for the development of the Kumtor field for a period of 50 years.

According to the feasibility study (Feasibility Study), the extraction of ore was projected to be carried out in an open manner. The quarry is located at 3.5 km south-east of the concentrator. In total, within 11.2 years of the exploitation of the quarry, 273 million tons of gangue and material with a low gold content, as well as 53.481 million tons of ore will be excavated. The preparation of the field will take approximately 3 years. During this time, prior to the start-up of the concentrator, it will be necessary to build a road for transportation of ore between the quarry and the crushing plant, build access roads to the upper ledges of the quarry, remove ice, perform an overburden of the ore body, make pitches in the quarry for the main mining equipment and prepare ore dumps. The deposit is located in the zone of permafrost development and partially covered with ice. The ice thickness in the quarry section reaches 50 m, and therefore, according to estimates, it will be necessary to remove 8 765 000 m^3 of ice.

The project provides monitoring of glaciers. In 1995, a network of monitoring points was installed on the "Davydov" and "Lysyi" Glaciers to monitor the movement of glacial masses. The monitoring points were established due to the fact that waste masses were being dumped on the slopes of both glaciers. The following monitoring data on the movement of glaciers are extracted from the environmental reports of Kumtor Operating Company (KOC) [3,4,5,6].

The “Lysyi” Glacier

The “Lysyi” Glacier has a network of 31 monitoring points installed, and they can be reinstalled, if needed. The dumps of waste rock No. 3 and No. 4, as well as the experimental dump are located on the western side of the glacier.

Over the past year, the glacier movement over the open pit was estimated to range from 0.4 to 1.9 m/year, an average of 0.08 m/month. Observations of the territory located above the waste rock dump No. 3 and the experimental dump show the absence of significant movements. According to monitoring data, during the year the *movement of the glacier* was in the range from 0.9 to 2.7 m/year, an average of 0.16 m/month. There is a tendency that *glacier moves* more actively in summer compared to winter. A more intensive *movement of the glacier* was noted at the monitoring points located above the lower edge of the waste rock dump # 3.

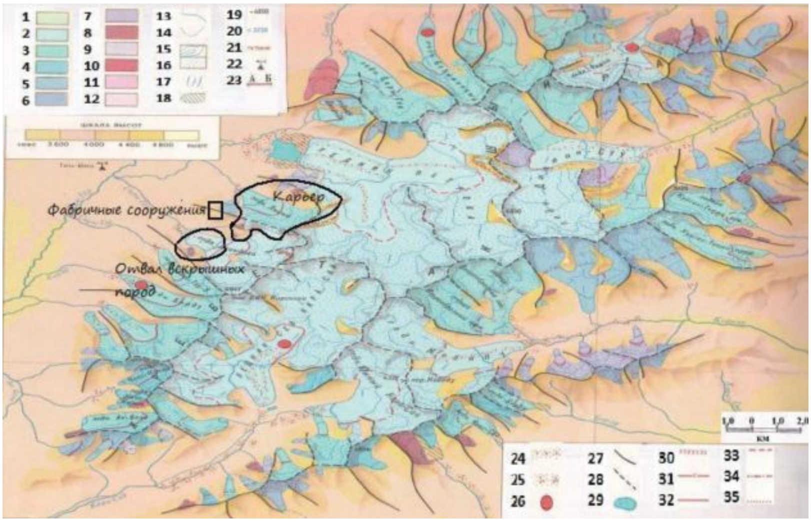

Fig. 1. *Glaciation of the Ak-Shyirak massif [1] Morphological types of glaciers: 1 - dendritic; 2 - complex valley; 3 - the valley; 4 -caro-valley; 5 - hanging valley; 6 - carous; 7 - Carob-suspended; 8 - suspended; 9 -hanging carous; 10 - flat top; 11 - prasclonovy; 12 - sloping; 13 - the boundaries of glacial languages; 14 - boundaries of the firn basins; 15 - ice surface; 16 - firn fields and snowfields; 17 - glacial cracks; 18 - ice booked moraine; 19 - elevation marks; 20 - water marks; 21 - rocks; 22 - meteorological stations; 23 - profile lines on glaciers; 24 - surface moraines; 25 - delayed moraines; 26 - pulsating glaciers; 27 - watersheds; 28 - ice breaks; 29 - Preglacial lakes; height of the feed boundary: 30 - below 4 000 meters; 31 - 4 000-4 100 meters; 32 - 4 100-4 200 meters; 33 - 4 200-4 300 meters; 34 - 4300-4 400 meters; 35 - above 4,400 meters.*

The «Davydov» Glacier.

The "Davydov" Glacier has 48 monitoring points, which can be reinstalled if necessary. The waste rock dumps are located along the center line and to the bottom of the glacier.

The upper reaches of the "Davydov" Glacier above the waste rock dumps is moving at a speed of 7.9 to 10.3 m/year.

The movement of the central part of the glacier was also noted, which is not affected by the waste rock dumps. The speed of movement ranges from 1.1 to 9.6 m/year, which averages 0.4 m/month. These data were obtained at a site where the slope of the glacier is smaller compared to its upper part, which causes a smaller displacement of the glacier in the lower part than at the top.

The movement of the glacier is especially marked on the territory of the waste rock blanket No. 1 - from 11.8 to 150 m/year. The intensity of the movement is affected by the slope of the glacier and the close location to the base of the waste rock dumps No. 3 and No. 5. The weight of the waste rock dumps continues to influence the intensity of the movement of the «Davydov» Glacier.

Impact of dust on glaciers

There are two main sources of dust. The first source is the result of the operation of equipment used in mining, and blasting operations in the quarry. Dust formed as a result of developments, affects only the areas within 10-20 m of the quarry. Dust from drilling and blasting is scattered by the wind and has no effect on the glacier. Dust formed on an open pit has no effect on the natural "dirty" surface of the glacier, which becomes noticeable during the summer. This conclusion is confirmed by the fact that from the first development of mine in 1995 melting of the glacier did not increase.

In 1998, Kuzmichenok, the head of the Geoinformation Systems Laboratory of the Kyrgyz Republic determined the degree of dust exposure at the mine's territory. In the course of this work, field studies were carried out, computer modeling was done with subsequent correction of the results. Upon completion of the work, he concluded that the dust resulting from mining operations and deposited on the glacier is 3-20 times less than the natural amount of dust deposited on the glacier.

Data on water pollution.

Empty rocks dumping sites are located to the north and west of the quarry, directly adjacent to the northern and western edges of the glacier and occupy an area 2-3 times the area of the quarry itself. They are separately standing mountains with an inclined truncated peak, which rises above the level of the pit's mouth by 70-90 meters. These dumps, consisting mainly of rocks of the black shale sequence of the Lower Paleozoic, cover the entire western part of the "Lysyi" and "Davydov" glaciers. The western foothills of the artificial mountain formed on the "Davydov" Glacier is washed by the Chon-Sary-Tor river. During heavy rains, the water in the river becomes dark gray. Unfortunately, the company's management does not allow public organizations to test water from this stream.

The slopes of the dumps are quite steep - up to 45-50° - because of the predominance of the large-block constituents in the mass of the dump rocks and shale "cement". Continuous observations are conducted on the physical condition of the body of the dumps, the change in its position in space, dynamics (if any), on the devices installed in the dumps.

It was mentioned above that part of the glacier is blocked by fresh dumps. A lot of small streams flow out from under the dumps, which testifies to the melting of the glacier under the influence of gravity of the body weight of the dumps and natural heating from it. Theoretically, it can be assumed that in this way, as a result of a gradual decrease in the volume of ice by melting under the heaps, all the voids that increase in size will form, where the body of the dump will fail, movements, landslides, landslides may occur. There may be overlapping of the Chon-Sary-Tor river, the accumulation of water in the dam and its breakthrough, which will present a danger to the lower buildings.

It was mentioned above that part of the glacier is blocked by fresh dumps. A lot of small streams flow out from under the dumps, which testifies to the melting of the glacier under the gravity of the body weight of the dumps and natural heating from it. Theoretically, it can be assumed that in this way, as a result of a gradual decrease in the volume of ice by melting under the heaps, all the voids that increase in size will form, where the body of the dump will fall, by resulting in landslides. They might block and accumulate the Chon-Sary-Tor river, and its breakthrough presents a danger to the buildings down the stream.

In addition, the dumps present a potential ecological hazard to the environment, primarily human health, as they contain (although in low concentrations) salts of heavy metals. They easily wash out by rain and melting waters, because rocks in dumps, in comparison with the root, have a large specific surface of crushed and significantly loosened mass. Further, these harmful elements can freely flow into the Naryn (Syr Darya) river.

According to Dr. Robert E. Moran (Ph.D.), an independent expert from the United States, who prepared an expert report entitled "Kumtor Gold Funds, Kyrgyzstan: Comments on Water, Environment and Related Issues, September 2011" notes that Centerra (a Canadian company that owns the Kumtor mine) "pollutes local waters and glaciers, hiding evidence of such negative consequences from public control" [9]. For example:

- The Petrov Lake, which is the largest regional source of water to the transboundary Naryn River and the main source of water in the mine, continues to be polluted by field development activities;
- Since the start of the development, the the Kumtor Operating Company produced 89 million tonnes of waste, some of which are stored in unstable conditions, and presenting a potential threat in the event of an earthquake;
- Annually the company uses about 3,650 tons of cyanide, and there is no investigation on how much of it contained in the water below the mine.

According to the Kyrgyz ecologists, the analyzes performed by domestic and foreign laboratories on soil, water, bottom sediments have established that the distribution of heavy metals at the sampling points above and below the main sources of man-made pollution exceeds maximum permissible standards by 2 to 6,5 times. In particular, arsenic - 4 times, lead - 3.43 times, cadmium - 4, 68 times, antimony - 2.8 times, cobalt - 4, 27 times [9].

Given this, it is of utmost importance to study the composition of the waters of the Chon-Sary-Tor River, and constantly monitor its chemical composition to take appropriate emergency clean-up measures in case of contamination above permissible standards.

To substantiate the decision on storing waste rocks on the Kumtor glaciers, M.B. Dyurgerov's conclusion was used. M.B. Dyurgerov's, Head of the Laboratory of Glaciological Forecasts of the Institute of Geography of the USSR Academy of Sciences (Moscow), prepared this conclusion in January 1989 specifically for a feasibility study developed by the "Ginalmazzoloto Project Institute". The conclusion indicates that the loading of a part of the "Davydov" Glacier is permissible under the supervision of glaciologists [8].

The Feasibility Study of "Ginalmazzoloto" indicates that the maximum height of stable dumps on the glacier should not exceed 35 meters. However, due to lack of practices of piling up dumps for powerful ice strata, it is advisable to continue research.

Unfortunately, the recommendations of the leading glaciologists of the USSR and designers from Ginalmazzoloto were ignored, and local "experts" from the "Ken-Too" Development Research Centre recommended to increase the height of the dumps to 90m (in fact, in a number of cases, dumps were piled up to 120m in height). By their recommendations, local «experts" authorized dumping of giant masses of rocks on the "Davydov" Glacier. In addition, the conclusion on the placement of rock dumps was received from government agencies.

This gross violation of the common practice of mining by the Kumtor Operating Company leadership is also a violation of §79 of the Uniform Security Rules [9]. Specific properties of ice and its bearing capacities that differ sharply from similar properties of rocks were simply ignored. To date, the capacity of the dumps on the "Davydov" Glacier reached 150-200m. The total mass of rocks dumped on the "Davydov" Glacier is several hundred million tons, which is comparable to 500 million tons or 430 million m^3 of ice. All this caused a change in the hydrothermal regime of the glacier with increased melting of ice and increased inflow of water into the central quarry. Over the past three years more than 54 million US dollars have been spent on pumping water from the central pit.

Thus, because of the mine's operations, the "Davydov" Glacier was virtually destroyed together with millions of tons of fresh water.

Dumping of rocks on the glacier resulted in economic damage. Dumps, stored on a glacier, had to be taken to another place, and this is additional transportation and loading costs.

In a word, in spite of the decision made by the feasibility study to dispose dumps in rock dumps located in the valleys of the Lysyi and Chon-

Sarytor streams, the leadership of Kumtor Operating Company decided from the start to dump the rock on the "Davydov» Glacier. All this threatens to turn into the destruction of the glacier, and serious environmental problems of long-term systematic nature by polluting surface waters in the Kumtor-Naryn river basin.

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