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KURUMS

Abstract

The paper is devoted to the study of kurums – typical periglacial formations. The geographic range, the history of their formation and the terminology have been analysed. Latitudinal zoning and altitudinal zonation of kurum formation predetermined by the interrelation of the climatic factor, the lithologic features of the rocks and the composition of unconsolidated deposits have been shown. The movement of the rudaceous mantle of the kurums caused by a number of factors, the main of which is „deserptium", has been investigated in detail. The interrelation of kurum dynamics with the temperature regime of the underlying rocks has also been shown.

Kurums (= rock streams) are widespread in the mountain regions of areas with extreme continental climate and permafrost. They are a typical periglacial phenomenon.

An investigation of kurum composition, origin and special features of movement was carried out by the authors in Zabaikalye and Yakutia. The diversity of features of kurum permafrost-facies and the connection of these with the mechanisms and velocities of debris movement have been shown for the first time (TURIN, ROMANOVSKIJ, POLTEV, 1982). However, a number of general problems concerning the geographical zonation of these formations, their impact on the temperature regime, movement peculiarities and others, require further study. Some of the problems are considered in this paper.

THE CONCEPTION OF KURUMS

There are a lot of definitions of the term *kurum* and *kurum formation* in literature. MAKEROV (1913) was the first to use this term in Russian literature to denote rock glaciers and rock streams in Siberia. A great number of terms is used to denote special kinds of kurums such as stone stream, block stream, rock debris stream, moving rock waste stream, stone river, stone sea, block tract, stone placer, kurum field. In Georgian and Armenian mountains similar formations are called "chinghilas" (GABRELAN, 1961), in the mountains of Altai and Saiany – "uronniky" (GLAZOVSKIJ, 1978). Polish scientists use the term "gołoborza" to denote coarse waste accumulations on slopes, i.e. places devoid of vegetation,

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rock detritus, rock "rozvals" (ŁOZIŃSKI, 1909) (rozval – disintegrated blocks piled up on mountain slopes).

The great number of term for kurums shows that there is no common opinion as to kurum formation and development of this process. There are several quite different points of view concerning the definition of kurums. MAKEROV (1913), GLADCIN (1930), S. N. MATVEEV (1938), KOLOMENSKY, KOMAROV (1964), NIKITENKO (1950), DOLGUŠIN (1951), N. P. MATVEEV (1963) name the rudaceous formations, both on level surface and on slopes, kurums. Actually they unite essentially different genetic forms of rudaceous formations. FIDELY, EPŠTEIN (1962), SOLDATENCOV, FREEDMAN (1973) consider kurums as accumulations of rudaceous material necessarily moving down slope.

It is significant that different authors choose only one of a number of interrelated factors, undoubtedly characteristic of kurum formation, and only on its basis do they give the definition of the process as a whole. For example, ZOLOTAREV, *et al.* (1969), DRUŽININ, KHLEBNIKOV (1970), NIKITENKO (1970) take the kurum genesis as the main factor when defining a kurum. The most complete definition of kurums taking into account the peculiarities of kurum composition, genesis and movement is given in SIMONOV'S works (1972). The authors of this paper consider kurums to be accumulations of rudaceous material formed under severe climatic conditions on slopes the steepness of which is less than the angle of a natural debris slope and moving under the influence of cryogenic and thermogenic deserptium and in some cases under the influence of other mechanisms.

THE HISTORY OF INVESTIGATION

Historically kurum formation has been investigated by two scientific schools. One of them studied the kurums in Western Europe, the other studied kurum formation on the territory of our country, in Siberia. These groups of scientists were engaged in studying kurums which in fact were on different stages of development: in Western Europe relict forms prevail, while in Siberia kurum formation is mainly of present day nature. Because of these differences the problems which each group of scientists were interested in, are quite different. Western scientists were mainly engaged in the problems of genesis, while the main object of Russian geologists was the finding of laws governing the distribution of kurums and their movement dynamics.

According to BERENDT'S hypothesis kurums were believed to be some variety of moraines. This point of view did not hold long as kurums are spread far beyond the limits of the front moraines of all Pleistocene glaciers. MIDDENDORF (1860) and DARWIN (1953) thought earthquakes to be the cause of the formation of kurums. The first investigations of kurum formations on the territory of our country were begun only at the end of the 19th century, when SEVERS (1896) found kurums in the Yablonovy ridge. At the beginning of the 20th century a series of works were published in which the authors connected the formation of kurums with different slope processes going on under severe conditions both in the Pleistocene and at present (ANDERSSON, 1906; PASSARGE, 1911). In some papers of the middle of the 20th century one can find solifluction interpretation of kurum origin (ZOLOTAREV, 1956; ŠANCER, 1966). GLADCIN (1930) believes kurums to develop at present only under arctic and subarctic climatic conditions. Similar formations in areas with temperate climates are Pleistocene relics. FESER (1953) proved the Schwarzwald kurums to be of fossil nature. KOLOMENSKIJ (1969) assigns the main part in the formation of kurums to the present day surface outwash. The investigation of rock streams undertaken by PISSART (1953) in the Ardennes showed that they had formed as a result of heaving of rock fragments out of loam strata. According to him blocks and dispersed filler are the products of bedrock weathering. He believes surface run-off to play an important part in kurum formation.

There have been some other theories of kurum origin. So KLEMM (1917) and PENCK (1924) connected the formation of kurum mantles with purely lithological features of the bedrocks. They came to this conclusion after having analysed the regularities of kurum distribution in areas with temperate climate where they were confined only to the outcrops of solid rocks. This standpoint was being developed in the thirthies and the forties (SCHOTT, 1931; DEECKE, 1934). The effect of climatic factors was not taken into account by these researches.

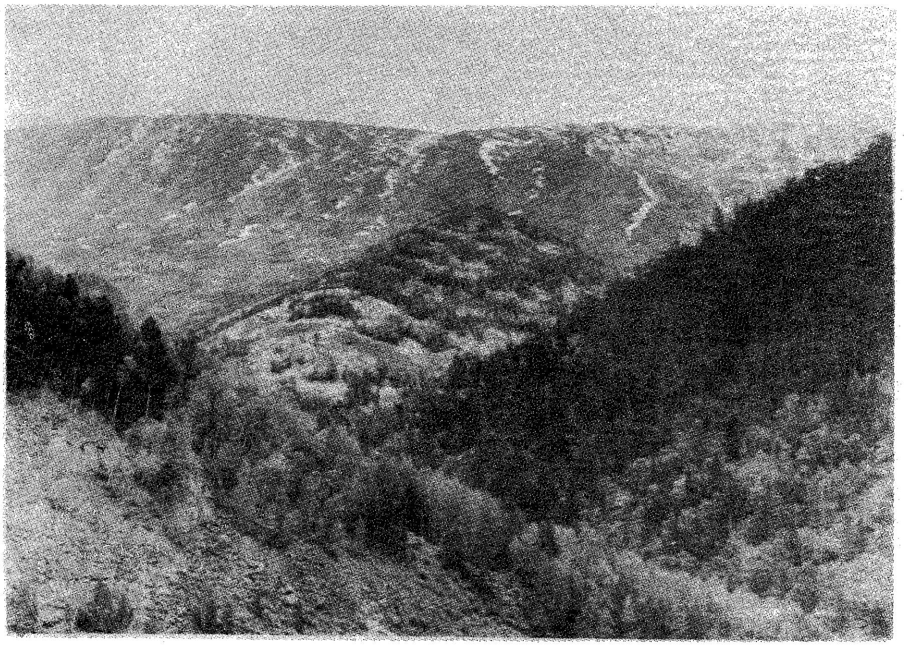
At the very first stages of the development of the kurum origin studies, ŁOZIŃSKI (1911, 1912) proved that kurum formation was the result of the complex influence of both climatic and lithologic factors. He considered the kurums in the Carpathians, the Sudetes and the Świętokrzyskie mountains to have been formed as a result of frost weathering of rocks in areas immediately adjacent to the Pleistocene glacier front. ŁOZIŃSKI'S works were the first of the investigations in which the climatic effect was not separated from the bedrock composition.

At the end of the fifties and the beginning of the sixties there appeared works in which kurum formation was considered to be the result of the influence of a whole complex of factors. So, for instance, DEMEK (1960) connected the formation of kurums with the lithological features of the bedrocks, their jointing and with climatic conditions. But he considered frost weathering of rocks the main factor of kurum formation. Of great importance in understanding the kurum formation processes is the investigation carried out by GLAZOVSKIJ (1978) and KLATKA (1962).

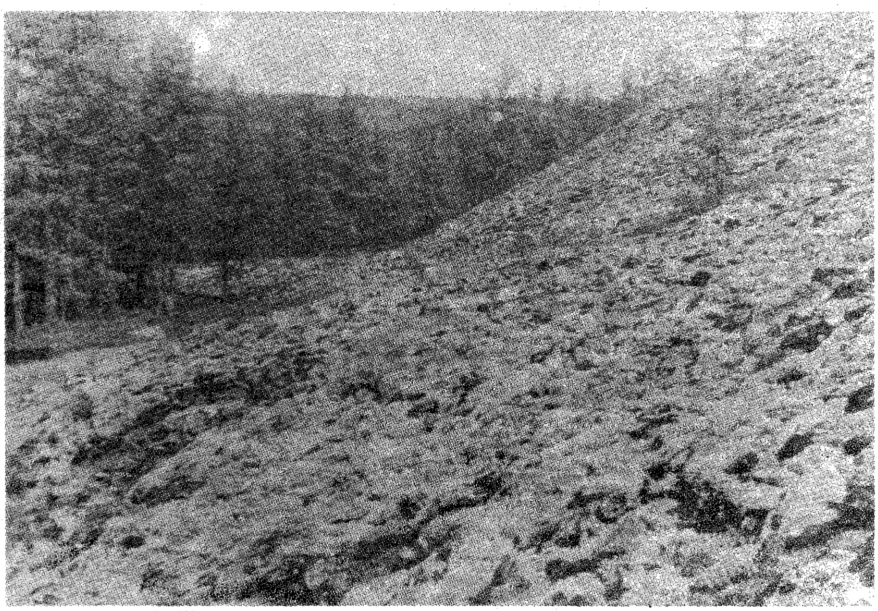
GEOGRAPHICAL DISTRIBUTION OF KURUMS

Kurums are found in many parts of the world. They occupy large areas in our country in the Urals, in Central and Eastern Siberia, in the Far East, in Zabaikalye (Pl. 1, 2, 3). Kurum formation is determined by climate, lithological features of solid rocks, composition of unconsolidated deposits, ruggedness of relief and tectonic features of the area. The climate factors which determine the possibility of kurum formation are, first of all, extreme continental climate and considerable humidity. The thickness of the kurums depends on the depth of the seasonally thawing layer (STL). On Wrangel Island, Novaya Zemlya, Severnaya Zemlya and in other parts of the Arctic Region kurums are of a "filmy" type (30–40 cm). In the North-East of the USSR and the North of the Central Siberian highland their thickness reaches up to 1 m and even more, tending to increase to the south. Within South Yakutia and North Zabaikalye the thickness of the kurums averages 3–4 m. In the same regions the age and present day conditions of the kurums depend on their latitudinal position. So, in the Northern and Polar Urals the greater part of the kurums is recent, active, but in the Southern – there are more ancient, "dead" kurums. According to MATVEEV'S (1963) data the age of the Polar Urals kurums the most favourable conditions for kurum formation are found in regions with higher humidity. In regions with temperate climates intensive modern kurum formation occurs within the golets mountain belt and the upper part of the timber line. Each climatic zone is characterized by its own range of altitudes at which kurum formation may be observed. So, in the Arctic zone kurums are developed in the range of elevations up to 50 to 160 m above sea level on the Franz Josef Land, on the Novaya Zemlya – at an elevation up to 400–450 m, and in the North of the Central Siberia highland – up to 700–1500 m. In Subarctic these elevations are of about 500–600 m in the North and West of Northern Scandinavia, 1000–1200 m in the Polar Urals in the south and east parts of Northern Scandinavia, in the Khibiny Mountains and in the North Urals. In the continental areas of the temperate zone kurums are found at altitudes of 400–500 m in the southern part of the Central Siberian highland, at 800–1300 m on the Aldan Upland and at 1800–2000 m in south-western Zabaikalye. In more humid areas kurums are known to occur at different altitudes: at 600 m in the Western Sudetes, at 1500 m in the Appalachians, 2000 –3000 m in the Italian Alps. In the continental part of the subboreal zone kurums are found at altitudes of 600–2000 m in the Kuznets Ala Tau, and at 1600–3500 m in Tuva. In the mountains of subtropical Asia they are developed at altitudes of 2000–3400 m.

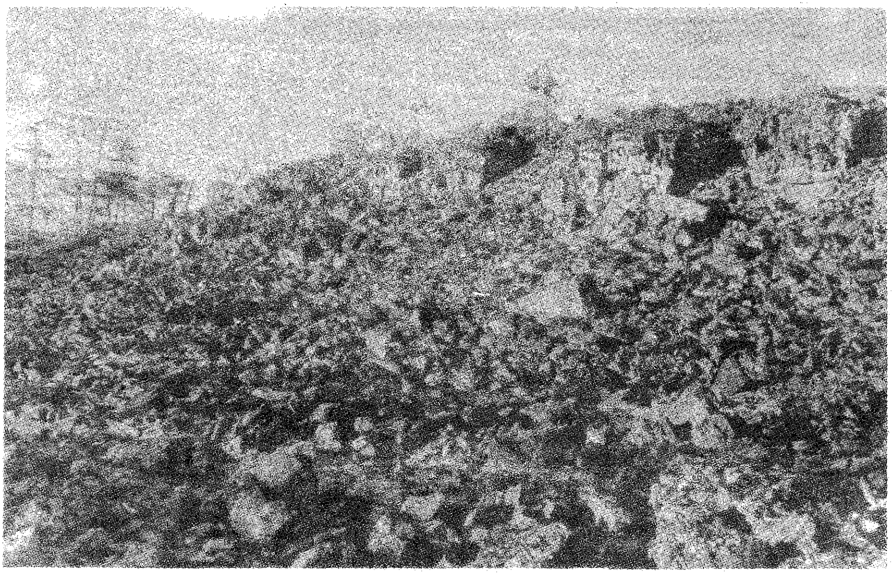
The interrelation of climatic factors with lithological features of solid rocks and the interrelation of the composition of unconsolidated deposits with the ruggedness of relief predetermines the zooning and altitudinal zonation of the



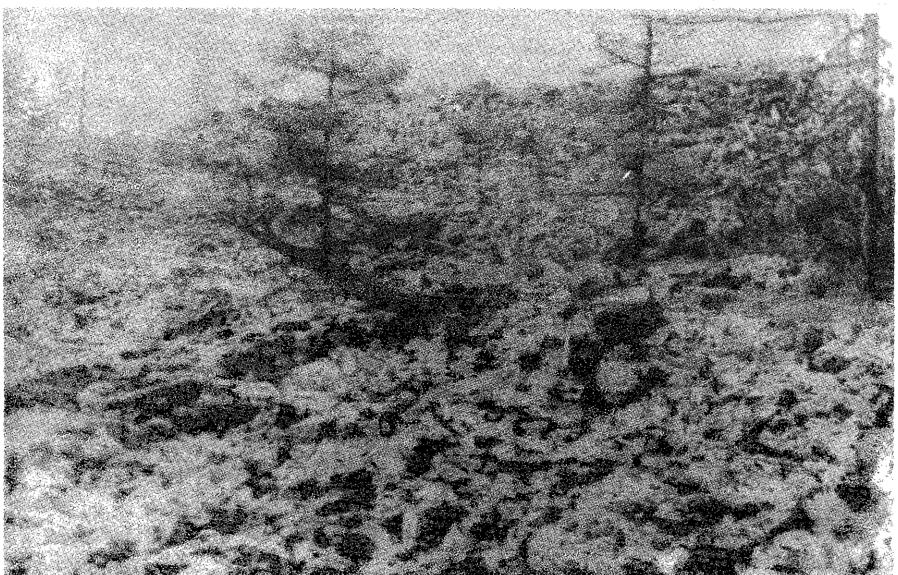
Pl. 1. The patchy nature of kurum distribution within the upper forest line and the continuous distribution in the lower part of the zone of bald mountains (in the background)



Pl. 2. A slope covered with kurum



Pl. 3. A kurum formed as a result of frost weathering of a rock scarp



Pl. 4. Moving kurums obliterated forests

Pl. 5. In spring the rudaceous mantle of the kurum is filled with ice

kurum formation process. As a result the kurums in different climatic zones have their own special features: the thickness of the mantle, the velocity of movements, the temperature regime and others. Every kurum is a complex phenomenon sometimes quite unique. The development of a kurum depends on many factors. Besides the mentioned above main factors the geomorphological position of a kurum is of great importance. The composition and mobility of kurums are different if the kurums are undercut by a river or changed by icing, if they stop at a flood plain or terrace, fill a ravine and so on. The composition and velocity of a kurum are interconnected. It is this fact particularly that explains the contradictory information of the researches about the kurums and the velocity of their movement.

MOVEMENT OF KURUMS

The most important feature of the kurums is their movement (Pl. 4). The dislocation of the rudaceous kurum mantle is a complex process and occurs as a result of the influence of a number of factors. The most important factor of kurum movement is "deserptium" (from Latin *deserptio* – creeping, settling). The term indicates slow downslope movement of the material due to periodical change of its volume. The movement caused by the change of volume of the material as a result of periodical fluctuation of temperature is called thermogenous or temperature deserptium. Thermogenous deserptium makes only a very small contribution to the movement velocity component. It plays, however, a rather essential part in kurum formation. Even during a day rudaceous material suffers temperature deformation that causes "stirring" of the fragments, their sorting and weathering.

The essence of cryogenic deserptium is that rock heaving is normal to the slope when moisture freezes in the rocks, but the movement on thawing is vertical due to gravity.

Ice formation in kurum STL (seasonally thawing layer) begins late in autumn by crystallization of atmospheric moisture, rainwater and snow meltwater in the cooled rudaceous material. This process goes on until negative air temperatures set in which generally coincides with the formation of a stable snow cover. In the autumn-winter period a considerable part of the rudaceous mantle is in a air-dry condition. Heaving of rock fragments at this time is insignificant and is mainly due to streaky and congelation ice formation in the dispersion filler in the lower part of the section. The basal cryostructure is formed only at the bottom of mantle section and occupies a layer of 5 – 15 cm thick. The formation of this layer is connected with the late rains when the debris mantle has a negative temperature. Its thickness varies with years, sometimes it is not formed at all.

In spring when the snow thaws meltwater enters the kurum. Most of the water flows from the interstream areas as in the near-surface layer an ice crust is formed that prevents water from infiltration into the rock mass. As a result the water fills the debris mantle in the upper part of the slope. The ice forming at the expence of the crystallization of suprapermafrost water fills up all the irregularities of the underlying rock. In the rudaceous mantle of the kurum water, that is formed when the snow lying directly on the surface of the kurum, thaws, freezes too. Ice grows on the fragments in layers because meltwater is formed periodically, that is in the daytime when the temperature is above zero. The thickness of the layer depends on the heat capacity of the fragments. The rest of the water flows down the section and freezes in the area of negative temperatures. The fragments covered with ice cool at night to a negative temperature which is close to the air temperature.

The filling of interstices between the blocks of the rudaceous mantle depends on their size and the STL thickness. The smaller the fragments the greater the extent of ice filling. Down the section segregation ice only partly fills the interstices. The water formed by the thawing of ice in the upper part of the kurum mantle infiltrates through the holes and crystallizes on the underlying fragments. As a result it looks as if in time the ice-soil layer moved from top to bottom along the section. Part of the water flows down the slope and the kurum mantle becomes completely filled with ice in the lower part of the slope. The given above outline of the formation of a kurum ice-soil layer is indicative of filling inversion of the upper and lower parts of the slope, late in spring – in the lower one.

When the water freezes the debris skeleton of the kurum heaves and expands by the magnitude of the volume expansion of water. The causes bringing about heaving of rudaceous soil material have been studied insufficiently. VEDERNIKOV (1959) showed on the basis of laboratory investigations that when the temperature drops below 0°C the largest particles of the soil – blocks, rock debris, pebbles, gravel – cool faster. Ice crusts crystallize on them. Subsequently water concentrates in small closed spaces. Considerable crystallization forces, which push apart the already frozen larger particles and thus cause soil heaving, arise.

Calculations show that the maximum speed of displacement due to the heaving action of ice reaches several centimetres a year in the kurums whose rudaceous mantle does not meet any obstructions when moving (it is not undercut by a river, or by artificial excavations).

For kurums of great length the average intensity of kurum mantle displacement is to a great extent determined by the speed of its dislocation in the lower part of the slope. If at the foot of the slope the elastic mantle does not move, the seasonal ice formation in the upper parts of the kurum causes a change in the kurum structure, frost sorting takes place, the density of packing decreases, the fragments are crushed and become rounded.

With the help of modelling, the connection of the cryogenic deserptium intensity with the steepness of the slope has been investigated in the laboratory.

The results of the investigation show that the kurum movement is governed by the conditions of moisture retention in the kurum and by its relation with the steepness. On gentle slopes up to 15° conditions favourable for retention of subsurface drainage in rudaceous material are created. However, because of rather small steepness the debris displacement is insignificant during the next thawing. When the slope is 20° steep the rate of debris movement increases sharply to the optimum ratio of slope steepness and the moisture regime. On slopes the steepness of which is greater that 20° the movement is slowed down because a great amount of water has had time to run down the slope, and the increase of steepness cannot compensate the moisture deficit. When the steepness is 40°C gravitational forces affect the debris displacement and so the rate of movement increases again.

Unlike cryogenic deserptium of silt the heaving of the kurum coarse-waste mantle as unconsolidated soil results in the movement of the separate parts not perpendicularly to the slope but with some displacement downward. The fragments of the surface layer undergo the greatest displacement. As the heaving action of ice spreads evently in all directions only fragments near the kurum surface can freely move in the plane that coincides with the inclination of the slope. When the ice-soil layer thaws the ice covering the fragments, is the first to melt as the fragments have the greatest thermoconductivity. As ČIGIR (1977) says the thawing front begins to look like honeycombs. The fragments slip down slope in their cells.

Freezing at night and transformation of water films into ice make the fragments rise up in their cells. Further thawing causes the fragments to sink from the place located now lower down the slope in comparison with their original position. The trajectory of blocks moving down slope on thawing is a sawlike line. The magnitude of the day sinking and rising depends on special features of the separate parts: their size, geometrical form, thermoconductivity. On the one hand the larger the fragments the thicker the water films around them and the greater the magnitude of their diurnal movement downslope. The trajectory of downslope movement of the smaller fragments is shorter. The small particles, taking part in a greater number of cycles of downslope movement may, however, drop much lower down the slope than the larger ones.

As the front of the seasonal thawing moves deep into the kurum section, the upper layer of the waste, which does not contain any ice, is continually moving because of the changing position of the separate parts released from ice. Even insignificant movements of the lower layer of the waste result in the displacement of the overlying fragments.

The rate of deserptium is unequal under different geology-geomorphological and climatical conditions as it depends not only upon the listed above factors but upon the thickness of the rudaceous mantle and the extent of its winter chilling. As to the latitudinal plan cryogenic deserptium increases from south to north. Its maximum contribution is displayed in case of complete filling of the kurums with water which is characteristic of thin "film" kurums of the arctic belt. In mountain conditions with pronounced altitudinal zonation a similar picture can be observed. Of great importance in cryogenic deserptium is the amount of water turning into ice on freezing. With the increase of humidity and nivality of climate with a great amount of atmospheric precipitation in winter, the amount of seasonally formed ice increases.

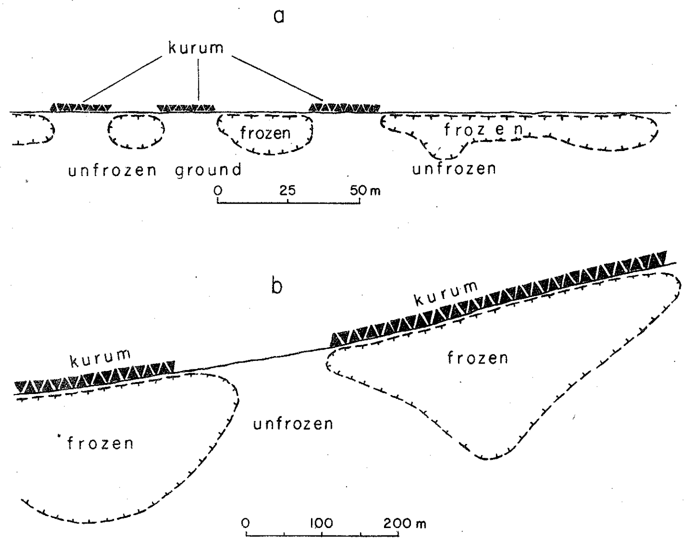


Fig. 1. a – the open taliks are situated only under the kurums (an example of winterizing effect); b – islands of permafrost are situated under the kurums (chilling effect)

In nature one finds a complex interaction of factors determining both the kurum movement as a whole and proper cryogenic deserptium. Not always can one comprehend by the change of one of them whether the rudaceous mantle will be moving faster or slower. It is connected with the fact that the change of one of the factors often entails a change in all the natural surroundings. For example, the increase of the thickness of the snow cover may result in a considerable change of the temperature regime of the rocks. The rudaceous mantle covered by a thick layer of snow cools very little as in winter in the absence of air convection its interstices exert thermal effect on the rocks. Under such kurums both open and closed taliks have been encountered (Fig. 1-a). The potential "cold reserve" in the kurum turns out to be insufficient for the retention of all the water and it flows down the slope. As a result cryogenic deserptium decreases while the thickness of the snow cover increases.

The decrease of the thickness of the kurum mantle cannot be unambiguously considered a positive feature for the increase of cryogenic deserptium. The role of the proper gravitational factor increases in movement when the thickness of the rudaceous material is great. It is particularly characteristic of steep slopes.

Cryogenic deserptium may be considerable though kurum mobility depends on the stage of its development. For instance a lot of kurums in the Viluj valley are "torn away" from their feeding source – the outcrops of trapps even now lie near the rear juncture of the terrace bordering on the slope. In the past the mobility of such kurums was considerable.

When the snow cover on the surface of the rudaceous mantle is small there remain in winter ducts along which the cold air flows down to the kurum feet chilling the kurums greatly. So the temperature under the kurums on the Viluj valley sides exposed to the north reaches 11 – 13°C below zero which is 1 – 2°C below the mean annual air temperature and 5 – 6°C below the temperature of the surrounding permafrost. Under such conditions the chilling effect of the kurums can be traced as far as 100 m or even more deep into the rock masses.

Near the southern boundary of permafrost the perennially frozen rocks often lie only under the kurums (Fig. 1-b). When the kurum is moving downslope it looks as if it is pulling after it islands of frozen rocks. From the point of view of kurum dynamics it is a very important feature as in kurums on frozen and unfrozen basements there are a lot of various factors affecting their movement. Their relative importance is also diverse. For example, in kurums lying on a basement with high ice content, the flow of ice-soil and silt suffosion are important factors of movement. Suffosion removal of silt results in the reduction of the mantle mass, its subsidence and movement down the slope. The data of three years observations on silt suffosion in one of the kurums showed that the subsurface drainage had washed away about 2 – 3 kg of material from 1 m^3 of the section. The intensity of waste displacement in the given kurum facies category reaches several centimetres annually.

Besides the listed above mechanisms, the kurum rudaceous mantle movement occurs as a result of viscous-plastic deformations of the water saturated silt, earthquakes, etc. Kurum movement is irregular not only during the year. As the rudaceous material possesses cohesion it does not sink vertically down to the bottom after heaving. Every year the hollowness of the rudaceous material increases reaching a critical state, and at the moment when the stress caused by the kurum weight exceeds the cohesion forces of the fragments, subsidence of the kurum mantle occurs. Periodicity of relief in seismic regions is upset due to dynamic impact, e.g. because of earthquakes.

The described kurum movement mechanism is zonal. The period of complete pulsation of "film" kurums is not more than one or two years. The period of complete stress relief grows with the increase of the rudaceous mantle thickness. So, for example, in South Yakutia this period lasts from 3 to 5 years.

Thus kurum formation is a zonal periglacial process. In mountain regions it is characterized by vertical zonation, there being both lower and upper limits of the development of this process. Beyond these limits the kurums are of relict nature and are connected with other climatic conditions.

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