Development of Environmentally Safe Mining Technologies Taking into Account Thermomechanical Conditions of the Permafrost Zone

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Abstract. The Republic of Sakha (Yakutia) belongs to the most important mineral resource and mining industrial region of Russia and occupies a leading place in the extraction of diamonds, gold, tin, antimony, and also has huge reserves of peat. An analysis of the state of violations during mining operations was performed. The thermomechanical state of health of the active layer has been studied. It is established that the complete freezing of the seasonal layer occurs in October-November, which is taken into account when developing new, earth-saving mining technologies. As a result of the carried out researches and new technologies of mining, providing simultaneous internal dumping, which reduces the areas of disturbed lands. Key words: deposits of the permafrost zone, placer deposits, peat, disturbance of the earth, active layer, earth-saving technologies of mining operations.

1. Introduction
The Republic of Sakha (Yakutia) belongs to the most important mineral and raw materials and mining regions of Russia and occupies a leading place in the extraction of diamonds, gold, tin, antimony, oil and gas. The share of mineral resources in the Republic of Sakha (Yakutia) in the mineral and raw material potential of Russia is 82% for diamonds, for gold 78%, for uranium 61%, for antimony 82%, for iron ore 5%, for coal - 5%, for tin - 28%, for mercury - 8%. There are significant reserves of rare-earth elements, silver, lead, zinc and tungsten [1, 2]. All these mineral resources are located in the permafrost zone.

In the north of the Republic of Sakha (Yakutia) there are 213 gold deposits with reserves of more than 285 tons of gold, of which 184 alluvial deposits, 22 diamond deposits, tin province (13 indigenous and 37 placer deposits) are concentrated about 37% of the proven reserves of tin, 2 deposits of 90 thousand tons, 20 deposits of tungsten with a total amount of reserves of about 60 thousand tons, as well as a lead deposit with reserves of 280 thousand tons. The richest Tomtor rare metal deposit containing such ores as niobium, yttrium, scandium and a large group of rare-earth elements (lanthanum, cerium, neodymium, praseodymium, samarium, europium), with a much higher concentration than the richest analogous deposits in the world, resources are 154 million tons of ore. In prospect the development of 18 coal deposits with accounted balance reserves of over 670 million tons, as well as numerous peat deposits in the central and arctic regions of the republic.

The development of deposits in severe natural and climatic conditions is accompanied by a violation of the landscape for a long period and requires simultaneous restoration and reclamation of disturbed lands. Since the natural growth of dumps occurs in 10-30 years.
It is established that for extraction of 1 million cubic meters of sands, the existing technology requires the violation of 200-250 ha of the earth's surface. Annually, when developing placer deposits, more than 120 thousand hectares are violated, and no more than 2% of the area is recovered. On the other hand, the variety of mining and geological conditions of the deposits made it possible to develop new mining technologies. Thus, in the conditions of permafrost and the sharply continental climate, the development of environmental technologies for mining operations is very relevant.

2. Methodology
In order to study the extent of the disturbance of lands by open mining operations, studies of the dump sites with the help of a laser scanner HDS-8800 were performed. As a result, it has been established that dumps in the development of alluvial deposits occupy 20 to 40% of the disturbed lands, depending on the capacity of the overburden see figure 1.

![Figure 1. Dumps in the development of placer deposits](image)

At the same time, the development of deposits is accompanied by extensive disruptions: the worked out space, dumps, tailing dumps, technological roads and sites. Since there is no uniform system of accounting and the elimination of disturbed lands, dumps and tailings is currently being accumulation of disturbed lands, and overall increase in environmental damage. Numerous studies have been carried out to assess the extent, types of violations, pollution of the environment and the development of remediation technologies for disturbed lands. The results of these studies are presented in [3, 4, and 5]. These works are aimed only at researching methods and technical means in the restoration of disturbed lands and do not contribute to the reduction of disturbed lands. In this regard, the desirability of developing new technologies of mining operations, ensuring the reduction of disturbed areas and their simultaneous reclamation.

3. Results and discussions
Lack of new technologies and the concept of mining with the use of resource-saving technologies has led to the exclusion of economic circulation of hundreds of thousands of hectares of disturbed land, in practice, be conserved for decades mineral resources-mining. In this regard, there is a need to develop permafrost fields to solve the problem of creating land safe technology based on complex technological and technical science-based solutions. To do this, it is necessary to radically change the traditional technology for the development of permafrost fields with the goal of creating an environmentally safe technology that allows restoring disturbed lands.

The existing technology of open development of permafrost rocks in the specific permafrost-climatic conditions of the North is characterized by year-round production of overburden works and seasonal performance of mining and washing operations and provides, as a rule, external dumping with loosening and transportation of the productive formation in the winter period to the heap of the beneficiation plant, which is more costly than summer sand washing as they are defrosted and do not meet the requirements of environmental protection. It should be borne in mind that the territory of Yakutia, where development of placer and peat deposits is expected, is characterized by deep seasonal freezing, the depth of which depends on the local microclimate, vegetation cover, relief, and the composition of loose deposits. When
freezing occurs qualitative changes in the strength of rocks, which affects the technology of mining. Seasonal freezing of the rock strata occurs when the temperature of the air passes through the 0 °C isotherm in October-November. Further, the negative temperature of the near-surface layer is observed from October to April. Below the active layer, a stable negative temperature of the massif with a temperature of -5 to -7 °C is observed. During the summer from May to September thawing of the seasonally frozen layer occurs, in which the rocks of the seasonally frozen layer lose their strength and stability. These changes in the thermomechanical state of the active layer of permafrost must be taken into account when conducting mining operations: the development of placer deposits and peat deposits, the host rocks of which are represented by loose sediments.

In connection with this, when developing both types of deposits, it is necessary to take into account and use the state of the active layer of permafrost, since in the summer the active layer thaws, and in winter freezes at different depths depending on the latitude.

In connection with this, studies were made of the temperature state of the permafrost and active layer during the year in different geographical latitudes of Yakutia. In Figure 2 shows the results of temperature studies of the array through thermometric wells. The final result of the temperature measurement was fixed after the complete stabilization of the thermal equipment along the depth of the well. In Figure 2 "a" presents the results of studies of temperature by months in the region of South Yakutia (latitude -56˚C), in Figure 2 "b" presents the results of temperature studies by months in the area of the Polar Circle (latitude - 66˚C).

Temperature graphs show that in the first case the defrost depth of the active layer is 2-2.5 m, in the second - 1-1.5 m. see figure 3.

![Figure 2. Results of temperature studies of the massif: "a" - South Yakutia; "b" - the Polar circle.](image-url)
Figure 3. Thermo-islets of loose sediments of permafrost.

The temperature regime of loose deposits of the permafrost region has its own formation features and differs from other geocryological types of frozen rocks. In the continuous permafrost to negative transition temperature array begins in late September and October, and stable negative temperature established in October at -5°C level, and in November to a depth of 2 - 2.5 m is set constant temperature of -10 - -15 °C. In the second half of November complete freezing occurs seasonally active layer gets frozen layer with an array of permafrost, wherein the loose deposits and the underlying permafrost converted into a monolithic array by acquiring high strength and resilience, processability providing environmentally safe mining.

Thus, the presence sectional permafrost active layer determines the specific temperature array mode in general, determines the power-Layer in continuous permafrost, and also depends on the geographical latitude of the region depends on the temperature of the underlying strata of the ground frozen array (their thickness within from 1 to 2.5 m), which determines the thermomechanical state of the rocks of the active layer.

Taking into account the results of studies of the temperature regime of rocks in the active layer, new environmental protection technologies for mining operations have been developed, which ensure a reduction in the areas of disturbance and simultaneous reclamation of disturbed lands.

The most conservative is the method of open development of permafrost deposits with internal heaping with the formation of large blocks of overburden [6]. The method involves the formation of large-sized blocks by one of the known methods, for example, drilling and blasting, mechanical. Then, stripping works are performed with the placement of overburden rocks in the form of large blocks (KGB) into the worked out space. The technology includes the operations of penetrating the original split trench, forming large blocks. Moving overburden from large-sized blocks to the internal dump, extracting the productive formation and forming an internal dump. Thus, simultaneous internal sheeting from large-sized blocks is achieved.

Also, the technology of development of deposits with the filling of the worked-out area with an ice-whole whole [7] is proposed. The idea of the recultivation method in the cryolithozone conditions is that, in order to significantly reduce the cost and intensify the work, the filling of the worked out space is made by the ice-breeding material produced on site. The technology of creating an ice-material is to water the water in the internal dump during the winter, covered further by a heat-insulating layer of overburden rocks, a thickness that ensures the stability of the negative temperature. To produce a large amount of man-made ice, the Grad-6 sprinkler is used, with a capacity of 6 to 10 thousand cubic meters. ice per day. freezing method consists in that the main heat required for the formation of ice, a high-pressure pump and long-distance sprinkler is transferred from the surface freezing a considerable height (18-20 m) dispersion zone smallest water droplets in the constantly changing volume of cold air. The
resulting water-ice mixture falls on the frozen base in the form of a liquid non-spreading gruel, coarse-grained irregularities of the litter and rapidly fading. Freezing takes place not only under the influence of cold air and a much accelerated by the fact that part of the frozen water droplets in the air without encountering the crystallization of grain falls in a supercooled state, quickly become covered with ice touching ice on a mat. After the freezing of the necessary volume of the ice prism, excavation or bulldozer of the previously loosened overburden is started on it and an internal dump is formed. And the thickness of the latter should exceed the power of seasonal defrost and ensure the thermal insulation of the ice prism.

A method for open development of permafrost placer deposits with internal heaping is also proposed, with separation of the career field into blocks. The method involves weakening the rocks with one of the known methods, for example drilling and blasting, mechanical or hydraulic thawing. Then, stripping works are carried out with the placement of overburden rocks in the worked-out space of the used block [8]. The method includes the steps of initial penetration of the split trenches 1, separation of deposits on the blocks 2, 3 the separation unit 4 to the previous and subsequent stope 5, moving overburden 6, 7 productive formation and the formation of the inner blade 8 (Figure 4).

The method is carried out in the following way. First, the cut trench 1 passes, then the overburden rocks of the block 2 are placed in the trenched waste space, for example, a bulldozer with mechanical loosening. After that, block 2 is divided into blanks. The productive stratum of the subsequent bluff 5 is placed on the productive stratum of the previous bluff 4, and the stripping rocks of block 3 are placed on the cleared area of the bluff 4. The cycle is then repeated. After washing the productive formation, a part of the overburden of the blocks placed on the previous passes is placed on the liberated area.

![Figure 4. A method for the open development of placers with internal heap.](image)

Thus, extraction of the productive formation is achieved by the most economical technology as the bulldozer defuses with simultaneous internal heaping.

The proposed technologies for the development of deposits allow, at a significant cost reduction, to simultaneously fill the worked out space with the overburden piles and enrichment, to preserve and reduce the area landscape in the mining zone.

4. Conclusions

- With the open development of placers and peat deposits represented by loose sediments, an extensive and practically inconsistent disturbance of the landscape occurs, as a result of which there is an increase in the accumulation of disturbed lands, while the share of dumps in the development of alluvial deposits, depending on their capacity and stripping volumes, falls from 20 to 40% of the land being destroyed.
- The presence of an active layer in permafrost soils characterizes the specific thermomechanical state of the rock massif as a whole and determines the thickness of the seasonal layer in the
The continuous distribution of permafrost, which must be taken into account when developing new environmentally safe and efficient technologies.

- Taking into account the results of investigations of the thermomechanical state of the active layer rocks, new environmental protection technologies for mining operations in deposits with loose sediments have been developed, which ensure a reduction in the areas of disturbed lands with their simultaneous reclamation.

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