Consideration of the Method of Borehole Hydraulic Mining in Relation to Gold-Bearing Placer Deposits of Yakutia

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Abstract: The purpose of the study was a detailed study of the applicability of the use of the method of borehole hydro mining in placer gold deposits, in conditions of the spread of permafrost soils. The main idea of the work was to consider a well-known, little-used, environmentally safe and economically profitable method of developing placer gold deposits. The method is based on the extraction of minerals not by open and underground mining, but with the help of wells. Laboratory studies of the study of this technical solution were carried out on the basis of the Technical Institute (branch) North-Eastern Federal University named after M.K. Ammosov in Neryungri, field experiments on one of the placer deposits of the Iengra River of the Neryungri district. Monitoring of mining operations at each stage is carried out with the help of a software and hardware complex, various measuring instruments and materials, sensors and other materials. Measuring instruments recorded and monitored the frequency of experimental studies according to certain set and obtained parameters, then the data were processed using software. This article presents some results achieved with the help of laboratory and real conditions of experimental reality. Based on the results of the work, the conclusions of the conducted research and the further expediency of further study of the process are made. The methods of conducting the experimental part are described.

1 INTRODUCTION

Mining in Yakutia is mainly carried out by open-cut or underground methods. At the same time, the open-cut or surface method of mining has a negative effect on the environment, while the underground method is very expensive and time-consuming. A replacement for the above methods is the geotechnological method of hydraulic borehole mining, which creates favorable conditions for nature protection and life safety (Arens, Khcheyan, 2001). Using this method of development, we refuse stripping, blasting, and loading operations, avoid dust and gas contamination of the atmosphere, as well as hard work that is harmful to human health.

Based on mining and geological conditions, the most suitable objects for using the method of borehole hydraulic mining (BHM) are gold placer deposits. The sand layer in such deposits consists of sandy-clay-pebble deposits with a small number of boulders. In addition, placers in a thawed state in the warm season are in a watered state, therefore, powerful equipment must be used to lift the pulp. In Yakutia, the placers are mostly in a frozen state, where the top of the gold-bearing formation is quite stable. This makes it possible to extract a large percentage of gold-bearing pulp from the bowels of the earth, which brings this method into the category of inexpensive.

Recently, placers located closer to the surface of the placer are being depleted and buried gold deposits, with a depth of up to 350 m, are becoming more and more in demand. The average gold content in this case is sometimes higher than on the surface and reserves reach several tens of tons. The method of borehole hydraulic mining in these fields will be more acceptable than the others.

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All of the above proves that studying the applicability of the BHM method in conditions is an urgent problem.

In addition, it can be seen from geological materials that there are quite a lot of gold-bearing placer deposits in Yakutia, where the BHM method can be used, but scientific, technical and structural developments of its applicability are necessary.

For the prospect of using borehole hydraulic mining on placers, it is necessary to conduct field experiments, and build mathematical models for various types of deposits in the permafrost zone.

When studying the technology of borehole hydraulic mining, numerous literary sources were studied (Arens, Khcheyan, 2001; Vishnyakov, Khasanov, Khamin, 2017).

The idea of borehole hydraulic mining technology was first put forward in 1936 by research engineer P. M. Tupitsyn. He proved that in some deposits it was more profitable to extract minerals through wells of a certain diameter, without stripping operations (Rukovich, Rochev, 2017).

The rocks located above the pay section are characterized by resistance to collapse and aggregate state. In placers located at great depths, gold is contained in the lower part of alluvial deposits and in any condition the top is unstable. In the frozen state, special conditions are required for the top of the soil, because frozen rocks in the borehole thaw and collapse during mining.

Extensive research experience has been accumulated in the largest institutes of the country on hydromechanized destruction of rocks in open-pit mining using hydraulic monitors. These studies were mainly devoted to finding the relationship between the parameters of the jet from the hydromonitor and the strength characteristics of the soil mass that are being destroyed. In borehole hydraulic mining, it is impossible to obtain a jet with high hydrodynamic characteristics, because the design features of a hydraulic monitoring tool are limited by the diameter of the borehole and the thickness of the formation. To do this, it is necessary to increase the reach of the hydraulic jet during borehole hydraulic mining. The solution to this problem involves adding water-soluble polymer additives to the water, using various types of dampening agents in front of the nozzle, inside it, and (Vishnyakov, Khasanov, Khamin, 2017) installing a mesh with a small mesh size in front of the nozzle. But all this turned out to be not an actual solution.

Theoretically, many scientists and researchers, such as V.Zh. Arens (Arens, Khcheyan, 2001; Arens, Fazlullin, Khrulev, Khcheyan, 2019; Arens, Khcheyan, Khrulev, 2013), A.S. Khrulev (Khrulev, 2002; Khrulev, 2001) and many others (Babichev, Nikolaev, 2000; Britan, 2013; Gevalo, 2019; Ermakov, Burakov, Batugina, 2016; Nicevich, Tsurlo, Yanushenko, 2011; Podoprygorov, 2017; Rochev, 2016; Ashok, 2015; Vishnyakov, Khasanov, Khamin, 2017.) were engaged in mining from boreholes using water pressure. This method is recommended for use in the development of coal and ore deposits (Litvitsev, Alexeev, Kradenykh, 2018; Litvintsev, 2015; Litvintsev, Sas, 2018), amber-containing clays (Malukhin, Mukhin, Vilmis, Shcherbakov, 2013) and other minerals both in thawed and frozen soils, as well as during the construction of underground tanks for storing national products and refrigerators in Arctic conditions.

2 RESEARCH METHODS

2.1 Laboratory tests

Laboratory tests were carried out in the laboratory “Non-traditional technologies” of the Technical Institute (branch) of the North-Eastern Federal University, Neryungri. The test material used was soils brought from various placer gold deposits, which were placed in an experimental installation, which corresponds to the constructed mathematical model (Fig. 1).

The created artificial section of the deposit, which was close to real conditions, consisted of a sand gravel mix with a low content of clay component. The gold in the sands was replaced by magnetite, which corresponded to the geomechanical characteristics.

To create more realistic conditions, sand and peat were frozen to a temperature of -3°C using special heating elements.

A production pipe was built into the borehole using cotter pins and then a supply pipe with a smaller diameter was placed inside. At the top of the supply pipe there were two nozzles: an aqueous solution was supplied into one, and air at a certain pressure into the other. In the lower part there was a hydraulic monitor for washing out frozen rock. The supply pipe was adjustable in depth and rotated 3600. Experiments have shown that when the diameter of the supply pipe nozzles changes from 3.5 and 6.5 mm, the pressure of the aqueous solution is in the range from 0.04 to 0.08 MPa.

If we increase the diameter of the nozzle, the water pressure will automatically increase, the rate of

soil destruction will increase, and the percentage of rock uplift will increase (Arens, Khcheyan, 2001). But the extraction of minerals depends on the power of the supply and airlift equipment.

A centrifugal surface pump was used to supply water. The creation of a eddying of the destroyed rock in the borehole and an increase in the speed of water was carried out using a compressor. The mixture was extracted to the surface using a mud pump.

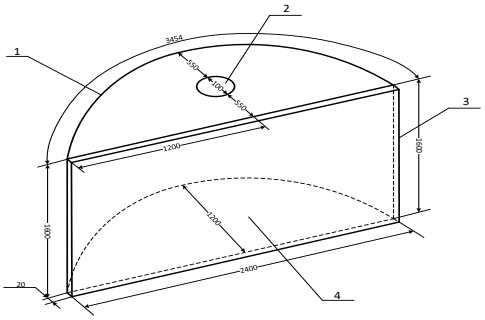

Figure 1: Diagram of a laboratory installation for studying the technology of borehole sand excavation.

where, 1 - removable lid, 2 - borehole, 3 - plexiglass wall for observation, 4 - camera.

A sand-clay-gravel mixture with a moisture content of up to 20% was placed in an experimental installation. Next, the mixture was frozen using columns placed to a certain depth, into which a coolant (freon - 22) was pumped under pressure from the freezing station. The rock was frozen to a temperature of -350C and then thawed to -30C.

2.2 Field studies

Mining is carried out by specialized equipment: drilling, leveling, pipeline, energy, pumping, hydraulic mining, mineral-processing. The main equipment can be purchased and improved, but the rest of the attached and auxiliary equipment must be designed taking into account the mining and technical features of the deposit. Mining by this method consists mainly of an integrated unit, which is manufactured individually for each specific deposit and controlled from the surface.

All mining and control operations for the extraction of a commercial component are carried out from the surface of the site through boreholes using a special ground-based installation. For this purpose, either a drilling rig or a specialized self-propelled or tracked device is used.

The device for extracting pulp in the single-hole version is an assembly of a hydraulic monitor and a pulp lifter made together, or separately, and has a sequential arrangement of pipes. Under complicated conditions, it is sometimes advisable to use the option when commercial components (coal, gold, etc.) should be extracted using two boreholes: production and injection holes. We supply water under pressure into the injection hole through a pumping unit, and air to enhance the destruction effect using a compressor. We suck the pulp out of the production hole and enrich it. We improve the hydraulic monitor device for each field. It is placed on the pay string with the help of hinges and can be moved throughout the borehole in any direction. The hydraulic monitor device consists of a cylindrical pipe, nozzle, barrel, pipe and is located inside the dredger. For each deposit and mineral, its own hydraulic monitors with a length of 0.5; 1.5; 2.5 m are used. To lift the mixture from the borehole, an airlift, a hydraulic elevator, and a dredger are used. When mining from a great depth, this device is made in the form of separately mounted pipes. The lower part, which is directly involved in the destruction, is the hydraulic monitoring device itself, a mechanism for collecting and removing pulp, connected by successive pipes. The upper part is necessary for lifting the pulp to the surface and pumping water and air into the borehole. All necessary resources are supplied through an internal pipeline, and the destroyed component is returned through an additional one.

On the earth's surface, for the hydraulic mining process, a special installation is used that meets the necessary requirements and is used to control the process, move the mining device and pipes, and drill. For these purposes, we can use either a whole complex mounted on a common basis, or stand-alone units working together. As such, it is possible to use a Russian-made drilling rig on tracks or wheels, a soil-suction complex, or a home-made specialized device. These installations must meet the specifics of the field and sometimes work together. The round trip of the mining device in the borehole environment can also be carried out on the basis of the mentioned units.

When developing placer deposits, the main difference between the operation of all units is the large size of the wallrock and valuable rocks and the low density of the transported pulp. When a mineral is located at a great depth, a hydraulic mining tool has several sections: working (lower), intermediate and dispensing (upper).

For Yakutia, it is necessary to use airlift dredgers with a free pulping column for lifting large detrital rocks or with a movable suction tip.

3 RESULTS AND DISCUSSION

3.1 Laboratory tests

At the moment, a wealth of laboratory experimental material has been accumulated. As an example, we present below some obtained averaged dependencies. As a result of experimental studies, it was found that with increasing time, the depth of destruction (Fig. 2) and the radius of destruction (Fig. 3) also increase.

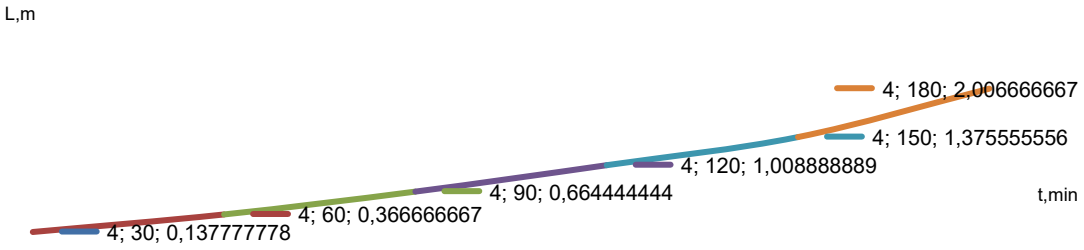

Figure 2: The dependence of the depth of destruction of frozen rocks on time.

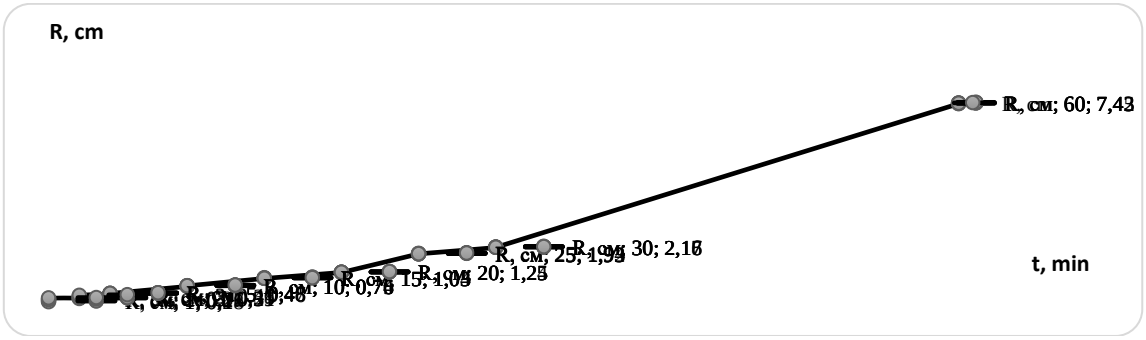

Figure 3: Dependence of the radius of destruction of frozen rocks on time.

3.2 Field studies

The final result of the experimental studies was that a pulp containing gold was raised to the daylight. The hoisting depth was 5-15 meters.

For the soils of some gold-bearing placer deposits in Yakutia, based on field studies, we calculated the main parameters for the application of the borehole mining method.

It is recommended that the drilling of soils be carried out using the rotary-drill rig 2A2 with a distance between boreholes of 40 meters (Fig.4). The upper level in the boreholes was blocked by casing pipes with a diameter of 286 mm, which were held together with couplings.

To lift the pulp, a mining dredger of the SGS-5 type was used, then it was transported through a special pipeline to an industrial device for further enrichment.

The diameter of the lifting pipe is 140 mm, the diameter of the transported pipe is 113 mm. An XAC47 compressor with a capacity of 1.6 to 5 m3/min was used to supply air into the borehole to control the speed of water outflow. A Grundfos CR series delivery pump with a capacity of up to 180 m3/h worked in parallel with the compressor. The water pressure on the hydraulic monitor nozzles with a diameter of 20 mm was 3 MPa, the water pressure on the borehole bottom was 0.6 MPa.

To lift the pulp, an additional suction pump will be used: 8NDv.

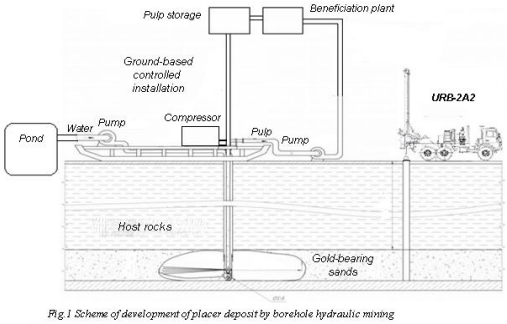

Figure 4: A scheme for the development of a placer deposit using borehole hydraulic extraction.

4 CONCLUSIONS

From the analysis of various sources, it follows that there are many placer deposits containing gold suitable for development of the above method in Yakutia and a sufficient part is unacceptable for development by open-pit and underground methods, which are expensive and not environmentally friendly, and can only be developed using non-traditional methods.

This is shown based on experimental and field studies.

In order to increase reliability and expand the scope of application, the method of borehole hydraulic extraction still requires quite serious scientific work.

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