Ways of reducing commercial deposits loss in interstep and intermediate pillars during alluvial dredging

B L Talgamer, V I Snetkov, F V Dudinskiy

Irkutsk National Research Technical University, Russia

E-mail talgamer@ex.istu.edu

Abstract. The drawbacks of the alluvial dredging are mining loses of commercial deposits, which increase due to complication of mining conditions and depth increase of the deposits occurrence. The greatest losses appear in interstep and intermediate pillars during alluvial dredging; where up to 10 – 15 % mineral deposits are left. These losses can be reduced by dredge design changes, additional extraction units; more complicated maneuvering does not provide high efficiency of dredging at more complex alluvial deposits. It is suggested to reduce a significant part of mining losses by preliminary preparation of the polygon to dredging, with parametric control and qualitative characteristics of the productive stratum, as well as by forming interstep and intermediate pillars from stripping soils or low-grade productive sediments. Preliminary mechanical sand loosening allows using dredge as a cleaning unit and reduces processing loss of valuable components.

1. Introduction

Alluvial dredging, thanks to continuous mining, sand processing, and wastes reclamation is the most productive and least expensive method that allows developing low-grade deposits [1, 2, 3]. Nowadays, dredges are used to develop gold alluvial deposits with 80 – 150 mg/m^3 of the gold content. Thanks to high mechanization, production and processing costs of 1 m^3 of sands with dredges are several times (7.4 times) lower [1], than during separate production.

At the same time dredging is characterized by high losses of mineral deposits.

The main reason of big losses of mineral deposits in situ is absence of visual control during extraction. According to estimation [9], half of the gold is lost during dredging, including 40 – 50 % of mining losses in situ. Most of these losses are those in interstep and intermediate pillars and bedding rocks (about 30 – 35 %) [5]. Less metal losses are caused by pit wall development (about 2 %), that is conditioned mostly by lower metal content in sands along the survey loop perimeter.

When digging depth increases losses in interstep and intermediate pillars and deep alluvial deposits can be up to 10 % of mineral reserves, or even up to 20 % [6]. Metal losses in bedding rocks depend on their surface, fracture intensity, strength of rock components and in some cases can significantly outweigh losses in pillars (see below). According to test boring at abandoned alluvial deposits metal losses in bedding rocks are 5.7 % [5]. The losses are especially great at irregular fractured bedding rocks. Due to impossibility of the digging monitoring significant amount of mineral deposits can be left in holes.

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On the average, losses with the account of small and medium sized sand alluvial deposits left in interstep pillars is not great - about 1 – 2 % [5]. Almost the same are losses in intermediate pillars. Due to greater gold content in the bedrock-adjacent layer the commercial components loss in intermediate pillars is greater, taking into the account greater gold content in bedrock-adjacent layers (accourding to some data it is 2 – 5 times greater, than in average dredge bulk [7, 8]). Analysis of exploration works at more than 30 alluvial deposits also confirms higher (2.5 – 3.5 times) gold content in the bedrock-adjacent layer 1 – 2 m in depth in comparison with productive formation thickness. That is why metal losses in interstep and intermediate pillars will be 2 – 3 times greater than sand losses. Calculated metal losses in interstep pillars at deep deposits are about 4-6%. Metal losses in intermediate pillars at broad deposits may be up to 5 – 8 %.

2. Methods and materials

Research results of metal distribution in deep alluvial deposits confirm the necessity to find the ways to reduce sand losses in the bedrock-adjacent layers and the bedding rock.

During dredging of wide and middle alluvial deposits significant sand losses happen in loss banks which increase with lixiviation and soft sediments thickness increase and can reach up to 7 – 8 %.

According to some data they can be up to 30%. But in reality losses in intermediate pillars even at maximum digging depth and sand lixiviation in any mining conditions will be not more than 10 %.

The losses are especially undesirable in intermediate banks at alluvial deposits with high metal content in the bedrock-adjacent layer and legacy placers development, where as sample data show the main quantity of mineral deposits is correlated with the bedding rock. In these cases sand and metal loses in intermediate pillars at dredging without overlapping the previous step can be 10 – 15 %. Accourding to the underground survey [5], actual cross section area of intermediate pillars is many times larger than the calculated one, which is caused by natural pit walls flattering and incomplete development of shear angles at bedding rocks.

For loss reduction in intermediate pillars a rill face with a dredge dump slope to the inactive pit wall are used, that allows reducing pit wall dumping with the commercial mineral content. This method of sand extraction allows partial pit wall dumping reducing and complicates dredging, especially in shear angles that results in the dredge efficiency loss. When rock lixiviation is high, thickness of soft sediments pit wall dumping cannot be excluded even during sand extraction with a rill as angle change of dredge maneuvering within tolerable limits does not provide necessary dump slope displacement to the inactive pit wall [10]. During development of fine-grains tailing dump extraction (due to enhanced formation disruption during their second treatment) increases that is why fine grain storing is problematic in this case.

Elimination of intermediate pillars in alluvial mining with adjacent faces is more effective. But its application is restricted by alluvial parameters. This method of dredge maneuvering increases idle hours because it is necessary to change pit-faces. Besides, sand losses are not excluded here as during extraction in the corners of the second advance, adjacent to mined-out space, rock extracting with digging buckets onto the areas of the preceding step take place.

In reality to decrease losses in intermediate pillars overlapping of the fulfilled parallel steps with the adjacent step is done at the distance of 6.5 to 9.5 m [10]. It results in cost supplement of the mineral deposits and extraction volume reduction due to the sand impoverishment with the rocks from the previous steps. Due to the slight angle of the dragged damped rocks slope, containing fine-grained rocks, impoverishment due to caving-in into the dragging zone can many times (8 – 12 times) exceed the number of sands in a pillar between steps.

Alluvial dredging itself conditions interstep, intermediate and pit wall pillars, which are caused by the existing dredge construction and digging bucket. That is, why it is worth not to eliminate pillars but reduce loss of commercial elements in them.

In order to reduce pillars formation between steps some specialists suggest improving dredge construction with a slewing spreader and fine-grain gripping jaws [6, 9].

3. Results

The authors suggest a new dredge construction with a turnable stacker and fine-grain gripping jaws into right and left sides relative to longitudal axis. For this a stacker foot support is fixed to the gear-driven traversed platform with locking members to fix turning members. Yaw of the fine-grain gripping jaws is fulfilled by the tail ropes and a rotary joint of the fine-grain gripping jaws in the places where they go out of the foot support superstructure.

But this engineering solution is unlikely to be applied as suggested changes in dredge construction are significant and require complete reconstruction of this equipment, which is unreasonable taking into account their long-time application. Secondly, stacker and fine-grain gripping jaws rotation can cause dredge inclination and emergency situations. Additional complexes on the right and left sides of pontoons on their stern significantly complicates dredge maneuvering due to impossibility of the face development onto stacker and fine-grains gripping jaws rotation side (as a pontoon stern from this side is fine-grained). Thirdly, change of direction of the fine-grain sand and pebble stream during rotation of the dumping equipment results in significant complexity of the equipment construction (with a pebble pan and fine-grain gripping jaws).

That is why we suggest not making changes in the dredge construction but reducing sand and metal losses in pillars between steps.

Loss reduction in interstep pillars can be achieved by changes in ground preparation to dragging. It is suggested to reduce the sand layer in the distant cut from the next adjacent step by their removal at the depth sufficient for dredge damping without additional charge of the high wall (a. s. №1765420). After extraction the sands are damped near the border of the allied steps. Developing broad clayed alluvial deposits rich in finely grained rocks the sand layer is reduced by the whole cut width sand piling on the neighboring stope. Sand developing starts with the stope where the sand layer is decreased.

Sand cut depth and other parameters of developing and bulks are determined by dredge size, rock composition, occurrence mode, deposits characteristics and can be calculated by existing methods, allowing predicting side walls dumping [5].

This method allows firstly, to reduce commercial material losses, to reduce its impoverishment during sand extraction in the shear angles by reducing parameters of interstep pillars, secondly, maintain dredge high efficiency by abandoning asymmetrical dredging applied nowadays for the same purposes.

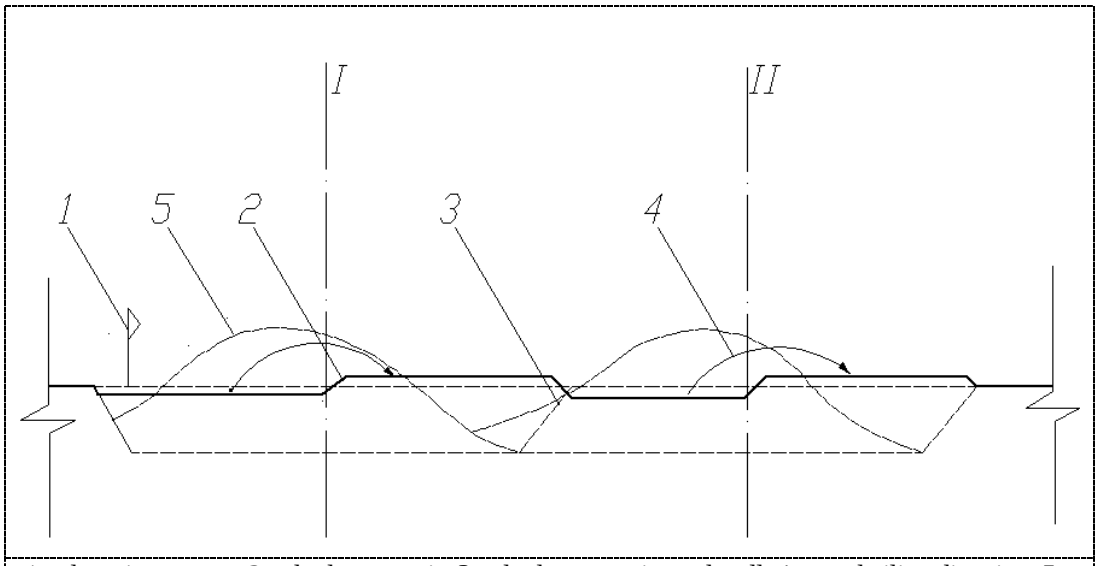
Nowadays, some additional complexes are used on some dredges to remove dragging wastes that use dredge pumps, which allow creating monostratal dumps, simplifying water retaining constructions in the mined out space and simplifying restoration. Dragging wastes removal with a stacker is important in final developing of legacy placer gold, as after the stock development the disturbed areas are developed and must be restored.

Despite the advantages of the monostratal dumping it does not solve the problem of dredge cut walls dumping, but also complicates it by dragging wastes flowing from the pebble dump into the dredge slots but also increases material wastes in stroke banks and sand impoverishment during adjacent stroke development.

Preliminary preparation of the polygon for dragging allows lessening sand impoverishment and loss in stroking banks by reducing pit walls dumping. It is suggested while preparing the sands to dragging to place coarse fraction rocks on the spoil-pile wall. It is easily done when developing legacy placer gold which makes the main part of dredging deposits and during reworking washing plants dumps.

During polygon preparation an emergency dike of coarse grained material is formed on its surface along the spoil-pile wall, and the dike of dredging wastes, after that the coarse grained material is placed in the middle of the open pit mine, adjacent to the operational open pit wall, and finely grained material on the opposite side. While rock mass dragging after stepping develop a coarse grained material dump with piling finely grained material in next but one piles on the spoil-pile wall side, after that the remaining deposits are extracted by all equipment for finely-grained material.

Finely grained material on the operational open pit wall is pipelined along the stacker, over the peal of coarse grain material to the previous cut so that fine pulp flows into the trench between piles.



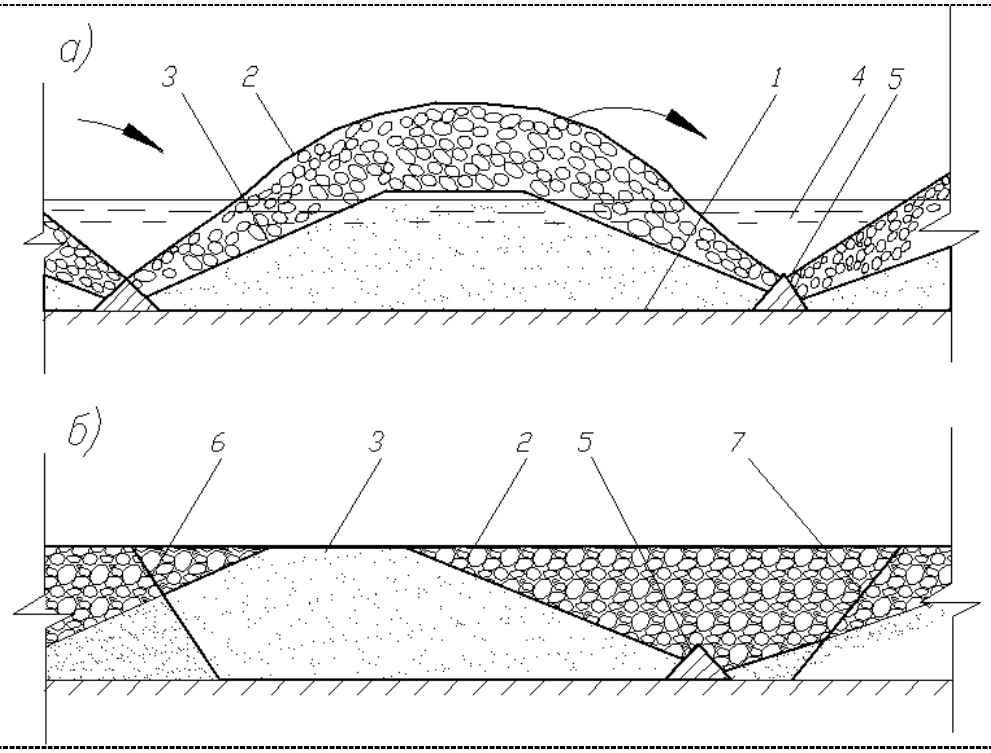
1 – deposits contour; 2 – dredge cut axis; 3 – dredge cut estimated wall; 4 – sand piling direction; 5 – expected dredge piles contour

Figure 1. Cross section of the prepared dredge polygon across the cuts (I and II) dredges.

At alluvial gold deposits the piles are formed by planning coarse material piles. Entry ways for dredger are marked so that coarse material was along the spoil-pile wall, and finely grained material was along the operational wall. Ore handling is done in the same way as in the previous case. So, in alluvial gold deposits developing it is necessary only to mark the surface, and for developing with this way it is necessary to plan dredge cut so that the boundary between the materials of different fractions was in the middle of the mining face (Picture 1). It should be noted that, besides reduction of loss and sands impoverishment at the open pit wall, the suggested method allows reducing surface marking costs as dragging wastes deleted through the stacker will flow only into one drench and the piles surfaces will be smoother. It will reduce surface water contamination, as coarse grained material adjacent to the drench is vulnerable to scouring.

During reworking the deposits developed in this way, smoother surface will prevent deposits from flood freezing. In this case sand preparation to dredging is not necessary as coarse grained and finely grained material will be placed in the necessary way.

Preliminary preparation of the polygon to dredging with piling upper layer of the productive deposits from the spoil-pile wall to the operational ones at middle depth and shallow alluvial gold placers allows avoiding the sand loss in interstep pillars (Picture 1). Reducing the sand thickness from spoil-pile wall of the dredge cut allows decreasing proportionally the number of concentration tailings, piled on the operational open pit wall and reduces rock dumping and sand loss in the interstep pillars.



a – dumps placement before development; b – developed ore placement relative to the dredge cut; 1 – bedding rock; 2, 3 –gold containing pebble and dragging waste fractions correspondingly; 4 – dredge gap; 5 – interstep pillar; 6, 7 – expected open pile walls operational and spoil-pile one correspondingly

Figure 2. Arrangement lay out for the reworking of the broad alluvial gold deposits.

During mechanical sand loosening for dredging it is possible to eliminate interstep pillars. In this case sands during loosening are piled with one step. Also, interstep pillars of gold-filtered waste are formed between dredge cuts; pit deposits can be used for this (Picture 2).

One of the ways to reduce losses in interstep pillars is lessening the dredge pace. This method reduces digging bucket filling ratio and increases operational down-time (stepping, frame lowering in shear angles). It results in dredge efficiency reduction.

The other way to reduce losses is bucket chain increasing. The latter during hard rock dredging near the bedding rock results in chain descending from the lower roll and long idle periods. Besides, an increased bucket chain tail, dragged over the ground worsens sand extraction from the holes. Simultaneously, digging bucket wear increases.

Shallow digging allows to decrease the sizes of stroke banks, but it is limited by the extreme height of the over water pit wall.

These actions only partially reduce sizes of interstep pillars. They are completely eliminated at the consequent sand extraction with ejection equipment (a. s. №№243536, 275911, 283141, 292714) or during reworking of the alluvial oil deposits. Interstep pillars extraction with special equipment is more difficult and has not been applied yet.

We think it is better not to reduce the sizes of the interstep pillars and not to develop them but form the pillars from gold-filtered wastes.

The latter is done when the bedding rock depth and sliping are increased and the interstep pillars are formed from the basement rocks. But if there is no commercial deposits this method is impractical, as it reduces dredge efficiency due to increased hardness of bedding and increases digging bucket wear. If there is gold then bedding rock sliping does not reduce losses in interstep pillars.

Suggested sands preparation to dredging with mechanical loosening provides visual surface conditioning and sliping the bedding rocks and allows forming interstep pillars from gold-filtered wastes that eliminates operational losses in situ.

In order to eliminate sand losses in interstep pillars at hard to dredge and frozen alluvial deposits it is suggested during mechanical preparation of the deposits dragging between sand piles and the bedding rock to place the demarcation layer equal in height to interstep pillars. Protective overburden rock can be used for the demarcation layer left on the sands top. The volume of the protective overburden rock is sufficient to make the demarcation layer not less than 0.4 – 0.6 m that is higher than interstep pillar height.

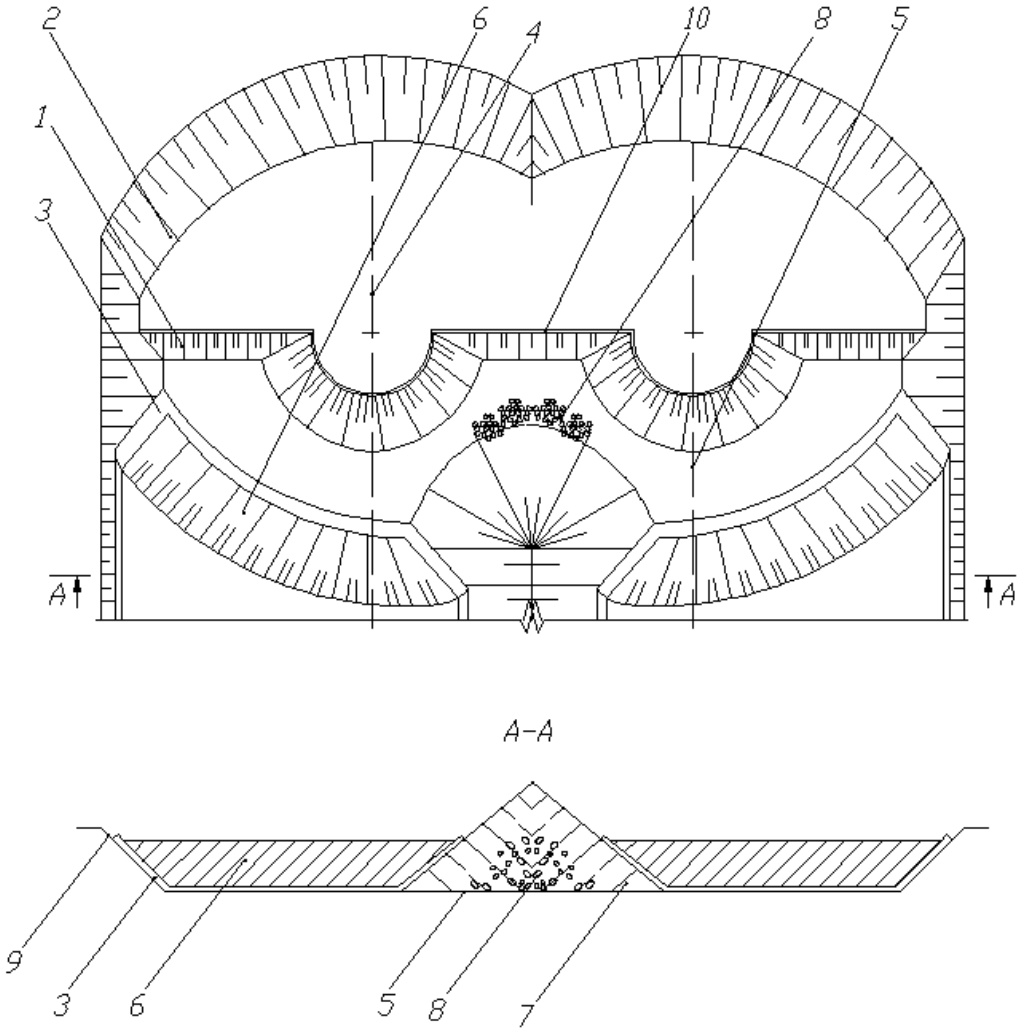
By graph analytic calculations it was determined that the interstep pillars height at dredging soft basement rocks for 150-liter dredges is 0.3 – 0.4 m; for 250-liter ones is 0.4 – 0.5 m; for 380-liter is 0.4 – 0.6 m.

Creating demarcation layer out of protective over burden rocks reduces sands impoverishment and allows extracting additional amounts of metal from protective overburden rocks holes. Soft rocks in the demarcation layer reduce digging bucket wear during bedding rocks sliping.

The demarcation layer eliminates sand losses in bedding rocks hollows and cavities, which are filled by gold-filtered waste. After dumping of the gold-filtered wastes onto the smoothed bedding rocks the demarcation layer surface is flattened (planned) with the account of normal layered sand dredging in piling.

Sand losses in side banks are less significant than in all cases mentioned above (1-3% [5, 11]). They happen during alluvial deposits developing with cross sectional cuts by dredge turns and during longitudal cuts owing to serriform protrusions formation within the developed contour. It is possible to eliminate these losses. But it results in high sands impoverishment. During operation the optimal ratio of losses and impoverishment is determined which provides dredge efficient work. During dredging at deep alluvials side banks near rocking beds can make significant sand losses, as permanent rock fall of the open pit walls with shear angle dumping in its bottom prevents total extraction of the commercial deposits at the bedding rock within the determined limits. To control extraction of side banks near the bedding rocks is impossible because they are hidden by falling wastes.

Sands mechanical loosening before dredging allows eliminate losses in side banks by forming sand piles with the account of the distance of open pit walls (Picture 3).



1 – sands; 2 –peat; 3 – overburden rock demarcation layer; 4 – excavator movement axis; 5 – bedding rock; 6 – prepared sands; 7 – peat piles; 8 – stones; 9 – development side wall; 10 – overburden rocks

Figure 3. Preparation scheme to dredging middle and broad alluvials.

4. Conclusion

To reduce losses in serriform protrusions between sand piles and side walls the demarcation layer is done. Its width is equal to that one of the serriform protrusions, and the height is equal to sand piles height. With the account that the average thickness of the demarcation layer in bulk is 0.4 m, and near the sides is 1.6 m, then overburden rocks thickness 0.5-0.6 m is enough for its piling.

The research results of heavy metal migration in loosened rocks, under the influence of the filtration flow and vibration prove that even in favorable conditions (big sand fractions, clay absence) the depth of metal grains penetration is not greater than several centimeters per month.

In a great sand pile on the polygon due to the pressure of the upper rocks lower layers will stiffen, that will reduce the speed of migration further from the surface. Besides, lower levels will be gradually saturated with finely dispersed particles of the rocks out washed by drain waters from the top of the pile that will additionally prevent gold from sinking down.

If we take into account that in winter the filtration flow in most cases is insignificant or is absent than we can suppose that gold thinking happens intensively only in summer than in annual advance of mining-preparatory works maximum gold particles displacement in the lower part of the pile will be

less than 0.5 m. So, the gold "sinking" from the lower part of the sand pile will remain in the demarcation layer and will be mostly extracted during dredging.

If clay-sill particles are few or absent in the sands and there is a filtration flow in soft rocks of the deposits the thickness of the demarcation layer should be increased up to 0.8-1.0 m, or it should be done from argillaceous rocks.

Sand preparation to dredging with mechanical loosening and dredge parameters control of the face allow eliminate the losses in interstep and intermediate pillars, but thanks to visual bedding-rock cleaning-up eliminate sand losses in holes and cavities of the basement rocks. Besides if the sand pile is rather big its top part can be formed of low-grade productive sediments or from rocks of protective overburden rocks that eliminate metal loses caving-in.

Sand preparations to dredging with productive sediments parameters control their qualitative characteristics and redistribution of valuable components over the face surface allow reduce operational losses of the mineral deposits several times and significantly reduce process losses of valuable components.

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