

# Enhanced recovery methods for development of technogenic placers

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**Abstract.** The article deals with the structure of gold mining and the prospects of the placer deposits development. The timeliness of the issue on the technogenic placer development has been justified. Their formation causes analysis has been made and the author has been performed the integrated estimation of remaining reserves in-place after the primary deposit development depending on the mining conditions of occurrence and the kind of valued component. The main methods of the enhanced recovery for the placer deposits reworking are offered. General difficulties of the technogenic placer reserves estimation by means of contemporary methods of geological exploration are presented. The author suggested the methods of indirect estimation considering the exploration results of unrecovered deposits and their exploitation during primary placer development. It has been observed that simplification and the speeding up of reserves estimation for technogenic placer makes it possible to enhance its development.

## 1. Introduction

Nowadays within the total quantity of mined gold, its proportion extracted from placer deposits is constantly decreasing. For instance, in the middle of the XIX century around 90% of placer gold was mined worldwide (excluding Russia), whereas in end of that century the amount was less than a half; in the first quarter of the XX century – 15-20%, in the last quarter – 10-15%, and at the moment only few percent. Before the Revolution of 1917, 85% of placer gold was mined in Russia, in the 1960s the amount accounted for 70-80%, in the 1990s – 72%, whereas in the beginning of the 2000s – less than 60%.

The main cause of this drop in placer gold-mining is the resources depletion, and also mining and climatic conditions complications of their exploitation. There are practically no new placer deposits having the favourable mode occurrence and high content of valued component. Newly developing placer deposits are usually located in remote regions with harsh or permafrost climate and are characterized by deep occurrence mode of producing layer, high clay or till content, or low content of the valued component.

At the same time, technogenic deposits formed in the course of placer development that have reasonably high valued component content occupy the area of hundreds thousands hectares only in Siberia. Technogenic placer deposits contain huge gold reserves which account for a few hundreds to thousands of tons in the main extraction territories. The total amount of gold in technogenic placer deposits all over Russia is estimated to 3.3-5.0 thousand tons and its reserves make up to not less than



18% of this metal total reserves in placer deposits. The current enterprises can develop these placer deposits for 15-70 years according to the different estimates[1, 2].

## 2. Results and Discussion

The major quantities of technogenic deposits formed while placer developments in the Russian Federation are drag dumps. In the second half of the XX century drags were used to develop 60-75% of sands. It should be noted that half of the amount of valued minerals are wasted using these development techniques, including 30-45% being the mining losses in the productive rock mass. That is why the primary technogenic reserves in placer are in most part the produce of dragging. According to the specialists estimate [3, 4], in the total proportion of technogenic placer deposits, the main part (60-80%) accounts for drag sites.

At present, a lot of mostly successful experience has been gained in the sphere of drag sites reworking [5, 7]. Some case studies of placer deposits reworking showed that economic efficiency of works using technogenic reserves is commensurable to the development of unrecovered deposits with the best quality of the raw stock. Besides, the exploitation results of technogenic deposits are quite stable. While performing the secondary dragging works at diamond-placers there were extracted 40-50% at the average of the originally mined amount of valued components during seven years. In Transbaikalia, 34-60% of the originally mined gold was extracted while developing drag dumps by means of two drags [8]. The extracted amount of gold upon developing drag dumps in Lensky gold field accounted for 45%. On average, according to the placers reworkings results, 30% of the originally developed valued components are extracted secondarily [5-8].

According to the exploitation experience of technogenic placers by mining enterprises, metal extraction prime costs in this case are considerably less in comparison with the development of unrecovered reserves. The latter is due to the considerable minimization in preparatory for mining and hydroengineering works, as well as the washability betterment of the raw stock.

In addition to the extracted valued components and consequently sustainable use of natural resources, the competitiveness of technogenic deposits development is determined to a large extent by ecological indexes. Since the extraction works are performed at the territories with already disturbed landscape, there will not be any fertile soil degradation and the necessity of mining allotment enlargement with new agricultural and forestry areas.

It is also worth evaluating and paying attention to social indicators showing the employment rate at the placer mine settlement. The explored placer deposits are almost developed, life of field production for many natural resources accounts for less than ten years. The production of outputs from technogenic resources in the already developed man-made environment including mining industry regions with housing constructions, transportation facilities, power supply sources, capital funds, infwure and residents makes it possible to preserve the established infrastructure, to provide the workplaces for the inhabitants and to increase budget revenues.

With that, there is some negative experience of technogenic placers redevelopment which is in most cases caused by the insufficient knowledge on the remained reserves, lack of analysis on the primary sands development and utilization of conventional technologies for extraction and washing of the raw stock. That is why, before dealing with technogenic placers and starting their redevelopment, it is essential to estimate the remained after the primary development reserves.

The issue of technogenic placer reserves estimating evolved in Russia back in the middle of the last century, when the dumps formed in the prewar and war time were put into the production in north-eastern regions.

There is a matter of principle before the beginning of drag dumps reworking and that is reliability of the remnant reserves estimation. The answer is simple at first sight: on-balance reserves minus extracted mineral products and plus losses. Nevertheless, the experience of unrecovered placers and drag dumps development shows that the issue is more complicated in practice.

Firstly, almost all placers are not explored to the full, which is characterized by the so called "aggrade coefficient", in other words natural resources extraction even considering mining losses, as a

rule, exceeds the reserves that are on the balance sheet of an enterprise. Similar situation can occur during the next reworking of a dump.

Secondly, it is impossible to maintain the continuous monitoring of losses which occur in the process of extraction and concentration of sands. That is because mining losses (interpace and interthrow pillars, in the edges at the drag turn, due to spillage in the frame slot, incomplete depth working and some others) are determined according to the underground survey data in certain scheduled periods. Besides, technological losses during the concentration process are estimated according to the laboratory and pilot tests and are calculated for some averaged conditions. In fact, the washability of sands at different placer zones is not equal, so technological losses can considerably differ from the projective ones.

Thirdly, seasonality in drag operation also influences the extraction of the raw stock. In spring and autumn the disintegration of the mined sands becomes noticeably worse, as well as the quality of bedrock-adjacent reserve parts due to the incomplete defrosting of rocks.

Fourthly, during the processing, the washed sands are moved in a fanlike way at the direction opposite the drag travel to the distance of 60m, sometimes even 120m. So, with consideration for the complicated throws trajectory it is impossible to accurately correlate the blocks of remnant resource with the initial.

The accuracy of the resources estimation in placer during the exploration work depends on the number of factors, including:

- methods of exploration work;
- complexity of reserves deposition;
- the kind and grain size of the valued component as well as its tenor;
- the occurrence mode of valued components in unconsolidated deposits;

The accuracy of reserves calculation is to a large extent determined by the amount of sands sampling. The least reserves values set by the geologists are registered while drill-hole surveying. The usage of exploring shafts and channels increases the amount of calculated reserves and the accuracy of their calculation. And finally, using trenches together with bulk sampling provides the most accurate estimation for the valued components amount in placer. In a number of cases the estimation difference for the upright reserves in placers by means of hole-drilling and trenches was two and three-fold.

The increase in complexity of the reserves occurrence where there are different placers with multiple interstratified beds and a complex structure of loose deposits in one field remarkably reduce the accuracy of reserves calculation. It is the same for the sand areas with the increasing irregularity of valued components spread. Therewith, the irregularity of valued components occurrence in placer specified according to the exploration data proves to be much greater than the actual. If the grain size of valued components in sands increases (their content being the same), it is very difficult to detect them by means of exploratory workings. Thus, the commercial mineral reserves, as a rule, become underestimated. The less the proportion of valued components in sands is (for diamonds  $5 \div 10 \times 10^{-8}$ ), the more difficult it is to detect the reserves and the larger the aggrade coefficient is (the exceedance amount of the extracted mineral over its value according to the exploration data) during the exploitation.

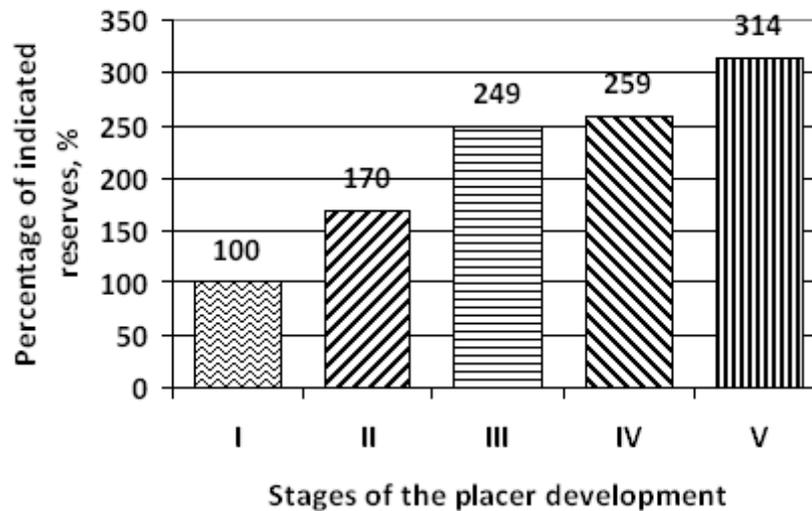
Thus, in most cases the actual amount of gold in placer is 1.5÷2.0 times greater, and for diamonds – 2.0÷3.5 times greater than it was calculated by the geologists (Figur 1).

It is considerably difficult to estimate the remaining after the primary development reserves in placer not only because of their calculation inaccuracy committed by geologists, but also due to the losses during mining operations (which are rarely compensated for the additionally extracted metal due to the development of edge zone productive deposits).

The losses of natural resources also depend on the number of factors, including:

- mine technical conditions of reserves occurrence;
- development method;
- concentration technologies;
- composition of rock;

- permafrost occurrence;
- valued component characteristics.



**Figure 1.** The detection of reserves at a diamantiferous placer: I – according to the exploration works results, II – after primary development, III – primary and reworking put together, IV – the sum of double and in part triple developments, V – prospective in-place reserves

It is obvious that losses of natural resources considerably increase along with the reserves mode of occurrence complication. The abundance of boulders in sands, rugged relief of the rock-floor and its heightened hardness cause exploitation losses of valued components. The extraction of valued components to the full is determined by their characteristics, in the first place, by the mineral granularity.

There are maximum losses of natural resources while performing drag workings which are, first of all, connected with the wet excavation of sands and full absence of the visual inspection over this process. Fig.1 shows the results of multiple placer workings by means of drags without any significant changes (upgrading) of concentration equipment. That is why, technogenic deposits with the biggest potential for development are formed precisely in the process of reserves drag working-off which is characterized by the maximum sand exploitation losses. Besides, the more complicated the conditions of the primary reserves exploitation have been (permafrost, abundance of boulders and clay in deposits, retractions in the rock-floor), the higher the probability of successful placer reworking is. The practicability of reworking of concentration tailings at gold-bearing placers is conditioned by the amount of fine-grained as well as coarse gold (nuggets) which is very difficult to extract.

The reworking of placers with simple composition and washable sands is not efficient.

The stated above makes it possible to formulate the main ways to intensify the development of technogenic placers. First of all, it is well-grounded reserves calculation, secondly, the usage of high-productive equipment for the development of lower-grade and less solid deposits, and finally, the usage of state-of-the-art (for the extraction of valued components from the finest and coarsest fractions) mineral processing equipment. The last two tasks can be quite successfully solved by means of drags with the expanded large-scale schemes of sand concentration. The first task does not have an unambiguous solution.

Thus, the efficiency of technogenic placer development in the first place is determined by the accuracy of remnant mineral resource estimation and the availability of data on the valued component distribution in the newly formed deposits.

However, despite the obvious actuality of starting to exploit technogenic placers their development is being impeded due to the complexity of reserves calculation.

The reserves calculation using conventional exploration methods, such as drill-hole surveying, exploring shafts and trenches at the technogenic deposits turns out to be more difficult for some reasons, including broken accidented relief with the slope angles close to their limit of stability, heavy water cut of deposits and their high water permeability, ribs instability because of the loose rocks friability, segregation of stored mine tailings, as well as considerable unevenness of valued components distribution in dumps.

Thus, the estimation of reserves in technogenic placers according to the results of exploration is time-consuming and requires large material and labour costs. The combination of technogenic factors (the occurrence of loose material, water entry into exploratory workings, rough land forms, mosaic distribution of argillaceous deposits and sites with different sand excavation completeness according to their capacity) and natural factors heighten the uncertainty about the results accuracy for technogenic placers in comparison with unrecovered deposits. The recurrent placer exploration results, which are costly to obtain, are not reliable enough, and they cannot contribute to the distribution of the considered method for the reserves estimation in technogenic placers.

In view of the above stated, considerable technical and economic difficulties of performing exploratory works at technogenic placers, different specialists repeatedly tried to estimate or calculate reserves by means of indirect methods. Some methods used the results of sands losses monitoring during extraction, as well as valued components losses during concentration processes at primary reserves development.

The analysis of some indirect methods for technogenic placer estimation [9] revealed a number of drawbacks and difficulties in their usage. Considering the mentioned above, it is proposed to determine the remaining reserves in technogenic placer proceeding from the equation:

$$Q_r = Q_v \left( \frac{K_c}{K_e \cdot K_s \cdot K_v} + \frac{V_c}{Q_m} \right) - Q_e,$$

with  $Q_r$  – mineral reserves in technogenic placer (remaining);

$Q_v$  – mineral reserves in virgin placer;

$K_c$  – aggrade coefficient (is determined in the course of primary placer development);

$K_e$  – sand excavation from the subsoil coefficient (is determined according to the efficiency analysis of the excavation method utilized at the given deposit);

$K_s$  – sand delivery coefficient (is determined according to the characteristics of the excavation equipment);

$K_v$  – coefficient of valued component recovery from sands (is determined according to the characteristic of the processing equipment and sands washability);

$V_c$  – valued component losses along with the peat (are conditioned via technologies of overburden operations);

$Q_m$  – amount of valued component within mining outlines according to exploration results;

$Q_e$  – amount of mined (extracted) valued component while placer development.

### 3. Conclusion

The described indirect (analytical) method of reserves proving in technogenic placers according to their exploration and exploitation results, as experience has shown, does not yield in accuracy to other methods, based on the field geological data which are both effort and time consuming. The method is recommended for the application even in those cases when there are possibilities and conditions for bulk sampling at technogenic deposits by means of the drag mining.

The indirect method of technogenic reserves estimation makes it possible to significantly simplify and forward the reserves calculation, and thus enhance the development of technogenic placers.

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