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Assessment of Gold Reserves in Technogenic Placers Within the Republic of Tuva

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Abstract**—** *This article examines the results of an analysis of worked-out gold placers located in the Republic of Tuva. The research focuses on the formation processes of technogenic placers, their chemical composition, spatial distribution, and the advantages of exploiting these resources in the context of significant depletion of traditional alluvial gold reserves. The main objective of the study is to investigate the resource potential of technogenic gold placers, which opens up possibilities for their reprocessing. To achieve this goal, an assessment of the resource potential was conducted through the method of pilot testing of technogenic slopes, using medium-volume composite samples with sizes of 0.2-0.3 m³, based on which industrial gold reserves were calculated. This study relies on the analysis and generalization of archival data obtained during geological prospecting. The analysis revealed that technogenic deposits in the Maly and Bolshoi Algiyak, Kara-Khem, Oina, and O-Khem areas have significant potential for reprocessing. In these technogenic placers, a predominance of medium-grade gold is observed, which in turn ensures a high level of extractability. Furthermore, attention is drawn to small, non-commercial technogenic gold placers, which could be used for the development of tourist-oriented gold mining in the Republic of Tuva. Thus, the results of this study make a significant contribution to the expansion of the mineral resource base of Tuva and Russia as a whole, by involving technogenic deposits in economic circulation. The study's conclusions emphasize the importance and necessity of further research into technogenic placers as a promising source of minerals, which will not only increase the efficiency of resource utilization but also have a positive impact on the economic development of the region, stimulating the creation of new jobs and supporting the sustainable development of the local economy.*

Keywords**—** *Placer, placer gold, man-made placers, gold, section, deposit, Tuva*.

I. INTRODUCTION

Economic transformations in Russia and the transition to market relations have allowed precious metals, particularly gold, to play a significant role in the country's economy. In times of economic crisis, gold serves as a reliable means of protection against currency devaluation in extreme circumstances. Gold is a reliable strategic reserve for the financial and economic stability of the country, as well as a global currency. This factor underscores the necessity of developing and maintaining the gold mining industry and its resource base at the level of leading countries.

The Republic of Tuva is one of Russia's richest resource regions. It is located in the center of Asia and possesses a favorable geographical position, bordering Mongolia, the Republics of Khakassia, Altai, and Buryatia, as well as the Krasnoyarsk Territory and Irkutsk Oblast. The republic experiences complex climatic and topographic conditions for conducting economic activities. Tuva is separated from neighboring regions by mountain ranges and is situated in a mountainous-basin area, resulting in a sharply continental climate.

A wide variety of minerals comprises the mineral resource industry of the Republic of Tuva. Its subsoil contains reserves of coking and thermal coal, ferrous, non-ferrous, rare, and precious metals, mineral construction materials, fresh and mineral groundwater, and non-metallic raw materials [1, p. 55].

The territory of the Republic of Tuva is one of the oldest gold mining regions; since 1838, gold-bearing placers have been predominantly developed here. Gold mineralization of industrial significance has been discovered over an area exceeding 900 sq. km, encompassing the valley of the Systyg-Khem River and its tributaries. This discovery indicates a significant potential for gold mining in this area, which includes various deposits, both exogenic and endogenic. Exogenic deposits explored in the region include Bolshoy and Maly Algiyak, Belelig, Chernaya, Shet-Khem, Bazhi-Khem. These deposits are characterized by the presence of gold on the surface and in the upper layers of sedimentary deposits, making them less costly to develop. Explored reserves suggest the possibility of economic development of these sites [2, p. 90].

Currently, two placer gold mining enterprises operate in the region – the "Oyna" and "Tyva" prospectors' artels, whose industrial gold reserves are estimated to last only for the next few years. Mining is carried out using open-pit methods, involving separate extraction of gold-bearing sands and overburden, followed by the use of a closed-loop water supply system. Overburden and sands are mainly transported using bulldozer-scraper equipment, and less frequently by trucks.

Simple sluice installations are used for sand enrichment, providing material loosening and feeding the sands for washing in the form of pulp using water-jet pumps or hydro-monitors. Further processing of the concentrate obtained from the sluices is carried out on gravity concentration equipment, which improves its quality and increases the efficiency of gold extraction.

Over the past 170 years, more than 50 tons of gold have been extracted from the subsoil of the Republic of Tuva [3, p. 6]. The long-term exploitation of placer gold in this region has led to a significant depletion of existing reserves, and the prospects for increasing these reserves through the discovery of new placers are limited.

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Intensive development of gold-bearing placers has led to the formation of large dumps of washed sands at mining sites. This fact draws increased attention to technogenic formations – worked-out placers, containing significant potential for the re-extraction of gold.

Objective: The aim of this study was to investigate the resource potential of technogenic formations from worked-out gold placers located within the Republic of Tuva, focusing on the feasibility of their re-exploitation.

II. Materials And Methods

The research objects considered in this work include the dumps of rewashed sands found at the technogenic placer deposits of Maly Algiyak, Kara-Khem, and Proezdny. The evaluation of the resource potential was conducted by means of experimental sampling of the technogenic dump complex using medium-sized, representative samples with a volume of 0.2-0.3 m3 in 2023. To achieve the stated objective, the methodology also incorporated analysis, collection of information, and compilation of relevant data sources.

III. Results And Discussion

Technogenic Placer Maly Algiyak. Placer gold at the Maly Algiyak deposit was mined from 1838 to 1921 using manual labor. Subsequently, from 1991 to 2018, a transition to mechanized mining methods began. Mining was carried out using open-pit technology. Areas selected for development were determined based on preliminary shaft surveys, taking into account the thickness of peat layers and sandy deposits, gold content, and hydrogeological conditions of the terrain. The total volume of production amounted to 4119 kg of gold. Two types of dumps are formed during operations: overburden and dumps for washing the ore body (so-called tailings). The technogenic dump complex contains pebble-tailing dumps that were formed as a result of the enrichment of sands from the original placer deposit at washing facilities. These bars are the most sorted and have good washing characteristics. Prediction of technogenic placer resources was carried out by calculation method, taking into account permissible losses of 10% of the explored reserves, as well as based on data obtained from experimental sampling of pebble-tailing dumps. The predicted gold reserves are estimated at 428 kg with an average content of 184 mg per cubic meter [4, p. 130] (figure 1).

Fig. 1. Dump complex formed as a result of the development of the Maly Algiyak placer deposit.

Technogenic Placer Kara-Khem. The development of the placer deposit in the valley of the Kara-Khem River dates back to 1905 [5, p. 81]. Prior to 1918, three mines operated; the lowest of these used the dredging method from 1912 to 1918, while the muscular method was used at other mines. In total, approximately 2100 kg of gold were extracted from the open pit from 1905 to 1994. Various technologies were used in the processing, such as muscular, hydraulic, and separate hydromechanical methods. Due to the specific characteristics of the landscape and the composition of the technogenic sediments, the worked-out deposit was divided into sections, classified according to the previously used extraction methods - dredging, manual, and hydraulic. As a result, a thorough assessment of each of the sections was carried out separately. This assessment was formed on the basis of information contained in the report entitled "Search and Evaluation Works on Placer Gold in Technogenic Sediments of the Kara-Khem River Valley". This report was prepared by the "Tyva" prospectors' artel based on their research work, carried out under the leadership of Gorshkov V.S. in the period from 1997 to 1999. According to the results of the analysis, the predicted reserves of gold in the industrial technogenic placer reach 140.8 kg with an average content of 376 mg/m³. In addition, the predicted reserves in the areas where dredging and hydraulic mining were carried out amount to 65.9 kg, with a gold content of 59 and 139 mg/m³, respectively. The results of a sieve analysis of the Kara-Khem technogenic placer indicate that the main part of the gold is represented by large fractions, accounting for 78.4% of the total volume. There is also the presence of slightly rounded gold (more than 90%), as well as lumpy and flattened forms. The fineness of the extracted gold is 860‰, which indicates its high purity.

Technogenic Placer Proezdny. This placer was discovered in 1932. It is located in the area of the Bolshoy and Maly Proezdny streams. Exploration, during which the reserves of placer gold were estimated, was carried out in 1944. The main stage of gold mining took place between 1956 and 1968, when the Kyzyl Exploration and Exploitation Enterprise operated the deposit.

The Maly Proezdny placer is characterized by a length of 2.2 km and a width of 10-15 to 60 meters. The thickness of the seam containing precious metal is 1 m., and the thickness of the peat is 3-4 m. The gold content is predicted to be 300 mg/m³.

The Bolshoy Proezdny placer is characterized by a length of 0.8 km and a width of 80 to 100 m. The thickness of the gold-bearing seam is from 1 to 4.5 m, the thickness of the peat is from 10 to 99.5 m. Gold content: varies from 100 to 300 mg/m³ and can reach 1000 mg/m³.

The gold in the placer is represented by large, slightly rounded nuggets. Among them, there can be found intergrowths with quartz, which indicates the complex geological processes that contributed to the formation of this deposit [6, p. 68].

Over the entire period of operation of the Proezdny placer, 372 kg of gold were extracted. This information underscores the importance of the deposit for the region and the precious metals industry as a whole. Taking into account the fineness,

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content, and nature of the gold in the future can help in making decisions regarding possible promising work on this placer. The processed Proezdny placer is classified into sections of muscular, hydraulic, and hydromechanical mining based on the methods of work. This division allows for a more accurate assessment of the state and potential of gold-bearing resources.

1. 15% of the area is occupied by muscular mining dumps, the age of which ranges from 40 to 60 years. The dumps are characterized by a small height, partially overgrown with vegetation, which may indicate their long-term use and minimal activity in recent years.
2. 60% of the area is occupied by hydraulic mining dumps, aged from 25 to 30 years. They are characterized by a pronounced relief, but without vegetation, which indicates their recent activity and efficiency of use. The height of the dumps is from 3 to 5 meters.
3. Underground dumps along the Maly Proezdny stream:
   - Characteristic: Low dumps with a height of 1 to 2 m, which is typical for underground mining.
4. Modern hydromechanical mining dumps (15% of the area):
   - Height: From 3 to 7 m.
   - Characteristic: The absence of vegetation and the small area occupied indicate recent work in this area.

The volumes of predicted gold resources contained in technogenic sediments are estimated at 11.5 kg, with an average concentration of 87 mg/m³. These indicators indicate the feasibility of continuing research and the possibility of re-exploitation of the deposit.

The Proezdny technogenic gold placer is characterized by 81% slightly rounded, lumpy-shaped coarse and medium gold. The fineness of gold is 902‰, which indicates a high quality of products suitable for processing.

The forecast assessment of the resources of the technogenic complex of sediments (pebble-tailing dumps) of the worked-out Kara-Khem placer was carried out using bulldozer trenches. This method includes taking bulk sectional samples, which are then washed on specialized equipment.

Both objects - the Proezdny and Kara-Khem placers - demonstrate significant potential for gold mining and require further research to optimize cleaning methods and estimate reserves. The systematic application of modern exploration methods, such as bulldozer trenches, allows for reliable results, which contributes to a more effective development of resource deposits.

A study of technogenic formations associated with worked-out placer deposits of the Oina and O-Khem rivers was conducted in the O-Khem River basin. According to the patterns of their distribution in the technogenic relief and their morphological characteristics, two main types are distinguished: the first type is residual-pillar placers, and the second is dump formations, including gravel-tailings dumps, overburden dumps, as well as silty-clay deposits in settling ponds.

Based on the results of drilling exploration work carried out in 2016 (Petrov, 2016), the presence of an industrial concentration of gold was revealed in two isolated areas on the right bank of the O-Khem River valley, as well as in four separate areas in the Oina River valley, which are covered by overburden [7, p. 92] (figure 2). These placers are classified as residual-pillar technogenic formations of the O-Khem basin and are a consequence of inefficient resource exploration in previous years. The main part of these placers has a linear configuration and is located along previously worked-out areas.

It is worth noting that, compared to other technogenic objects, the gold content in the pillars is significantly high, reaching levels of 1015 mg/m³ [8, p. 23]. This data highlights the importance of further study and justification of geotechnology parameters for the integrated development of these technogenic placers, which may contribute to the effective development of gold deposits in the region. The prospects for this type of technogenic formation are promising, and they require priority re-evaluation.

Fig. 2. Technogenic waste dump complex of the Oyne alluvial deposit.

The results of the forecast assessment works with the indication of gold prices per gram for the year 2024, presented by the authors, are shown in Table 1.

The conducted analysis showed that technogenic deposits formed as a result of alluvial mining, such as Maly Algiyak, Oyne, O-Khem, Kara-Khem, and Proyezdnoy, predominantly contain medium-grade gold. This gold is characterized by a high degree of extraction during processing. Moreover, the favorable mining and geological conditions of the technogenic alluvial deposits also contribute to their effective development. Given their high potential, small-scale gold mining enterprises can effectively re-develop these alluvial deposits. Additionally, small technogenic alluvial deposits that have been insufficiently studied and lack commercial scale may be recommended for recreational gold mining in Tuva, which would allow for the utilization of local resources and create alternative sources of income for the population.

TABLE I. Forecasted resources of technogenic gold in the Republic of Tuva.

Name of the placer	Length of the placer, m	Volume of rock mass of the technogenic complex, m^3	Gold content, mg/m^3	Gold resources, kg	Gold price, ₽/g	Value of gold, ₽
Maly Algiyak, technogenic site/area		2326200	184	428	8858.00	3791224000.00
Kara-Khem, dredge-mined area/section	1300	283735	139	39.4		
Kara-Khem, manually-mined area/section	2900	374468	376	140.8		
Kara-Khem, hydraulically-mined area/section	1500	450000	59	26.5		
Total, Kara-Khem, technogenic site/area	5700			206.7	8858.00	1830948600.00
Proyezdnoy, technogenic site/area	3000	132857	87	11.5	8858.00	101867.00

IV. CONCLUSION

Thus, the development of technogenic placer gold in the Republic of Tuva has significant potential, and with a more in-depth analysis of processes and the implementation of modern technologies, it will be possible to enhance both the economic efficiency and the ecological safety of mining. The sustainable development of the industry will depend on a comprehensive approach, including the improvement of existing technologies, workforce development, and active investment in new methods of operation.

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