PROBLEMS AND PROSPECTS OF TERRITORIALLY CONJOINED TECHNOGENIC OBJECTS DEVELOPMENT IN GOLD PLACER DEPOSITS

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ABSTRACT

Alluvial gold mining that takes place in dozens of countries, among them Russia, presently progressively gives way to hard-rock mining, as well as to this precious metal extraction from other sources, including nontraditional. At the same time both in Russia and in other territories of placer gold mining a lot of former or still operational mining sites exist that contain residual precious metal in significant quantities. In conjunction with modern technologies, they may become appreciable sources of gold mining.

In the described research, both domestic and foreign experiences were analyzed. It was found that problems of mutually close technogenic gold-bearing objects' development are remaining very poorly investigated. As a result, the necessity has been substantiated for new methodological and technological-economic approaches formulating, which would secure effective and large-scale integrated management of territorially contiguous technogenic placer deposits' development. A number of methodological propositions for one of such approaches were formulated. Besides, an algorithm and a computer programs' set were developed, which may be used for technical-economic indicators calculating that describe conjoint or mutually close technogenic objects of placer gold deposits' simultaneous development.

In addition, typical merger processes in regional and national economies' mining sectors were analyzed, their features examined, advantages and negative aspects of integration processes compared and critically evaluated. That may serve as an important instrument in solving economic problems, which are accompanying residue technogenic object development.

Keywords: *alluvial gold deposits, territorially conjoined technogenic placer objects, complex technologies for alluvial objects simultaneous development, computer software package.*

INTRODUCTION

In the Russian Far East (RFE) territories of traditional placer gold minning the majority of known rich and easily accessible alluvial deposits are already worked-off, whereas those retaining small residual metal contents and/or those having ingredients with off-grade quality are of no interest for mining industries. A decrease in gold mining from alluvial deposits has led to some socio-economic critical situations in a number of Russian Far East (RFE) areas, where it was traditional. In this regard, it is necessary to continue geologic explorations for new development objects [1].

One of the options to preserve gold mining output at its present level or, which is preferable, to further increase it, is the intensification of geologic exploration aimed at sufficiently large-scale pristine alluvial deposits detection. At the same time, significant reserves of gold and other valuable components are available in objects left from former mine sites or exist alongside those still functioning. We propose to name such man-made entities as Territorially Conjoined Technogenic Objects (TCTOs) of former or actually operational placer deposits. Substantiation of their industrial development is not only a scientific task, but also a way for drawing management structures' and miners' attention to solution of economic, social and environmental problems in the RFE region.

Steadfast scientific interest to technogenic deposits (TGDs) development highlighted itself in early 1970s, when TGD and a number of related terms first appeared in publications of academicians Agoshkov M.I., Melnikov N.V., Trubetskoi K.N. Essential contributions in theoretical and applied aspects of TGDs economic disposal and ecological losses reduction were made by such Russian, among them RFE's scientists, as Makarov A.B., Makarov V.A., Mamayev Yu.A., Mirzekhanov G.S., Mirzekhanova Z.G., Myazin V.P., Sekisov G.V., Umanets V.N., Yakovlev V.L., et al. Currently several FEB RAS academic institutes, our Mining Institute among them, are actively working in these research directions [2].

ASSESSMENT OF MODERN RELEVANT RESEARCH DIRECTIONS (Beginning at this point following discussion is based on publications [3], [4], [5], [6])

After working off the geogenous placers, several billion cubic meters of pebble, dredging waste, peat dumps and reloaders from the dumps have accumulated. The annual volume of gold mining from technogenic placers is about 10-15% of the extracted metal, which is completely inadequate in conditions of a significant decrease in the reserves and resources of geogenous placers. According to expert data, the total amount of gold in all technogenic placer formations is 5,022 tons or 57% of the total amount of gold mined in the history of placer exploitation. This convincingly confirms the thesis that technogenic placers are an important resource of the mineral and raw materials base of placer mining.

In several studies was revealed that practically in all worked-off placers residual gold contents were at 10-15 % level of those extracted, while in other cases these quantities reach as high as 50 %. Despite sufficiently low average contents

(up to 100-150 mg / m^3), almost each technogenic placer has objects with gold contents, which are quite acceptable for profitable extraction. According to expert estimates, ancillary mining from technogenic and non-traditional sources can provide at least 7-10 % of the total annual all-Russian production.

Only in the Khabarovsk Krai during the period from 2000 to 2007, technogenic placer complexes of more than 400 million m^3 were formed, characterized by a wide group of chemical elements with a toxic effect. Technogenic ore and placer formations lead to a change in the natural landscape, geochemical and geo-mechanical fields' creation in the rocks, which convert into bases of the technogenic massifs, as well as provoke change in the hydrological regimes of these areas.

This is a huge environmental burden on the habitat of humans, flora and fauna. Therefore, the development of these facilities, followed by subsequent reclamation of disturbed lands, are not only of economic but also of social significance.

According to generalized analytical calculations, gold resources of only 149 technogenic alluvial deposits of the Khabarovsk Krai total 124.3 tons. These technogenic placers are characterized by ordinary and low metal contents, calculated on the entire processed rock mass of the deposit. Because the residual gold fractions concentrate mainly in dredging wastes, therefore one should expect their actual metal contents to increase by 2-3 times (depending on the ratio of dredging/gravel waste fractions in the dump complex).

Results of many similar studies allow drawing following conclusions:

a) Single processing of natural placer does not lead to full extraction of gold and its losses remain significant. Amounts of not extracted metal (rafts, side and residual tiles) or sands lost during washing (dredging wastes, pebble dumps, mud) reach 10 to 150 % or more of its volume in the primary placer;

b) Repeated mining of technogenic placers exacerbates impact on the environment, expanding the range and severity of environmental problems. Therefore, in case of full and integrated extraction of useful components that will allow the territory to be recultivated and cleaned of harmful substances.

Results of planned now future studies may become a scientific and technological basis for large-scale development of complex resources, compiled in various residual mineral objects, at least in terms of rock mass volumes. However, a special approach is required to tackle the problems that inevitably will accompany such studies and their results' implementations. On that score, we propose a new strategic approach – the integrated development of geographically close technogenic placers, combined with the processing of rock mass on stationary washing devices or specialized dressing plants.

All the factors listed above show that the creation of scientific and methodological foundations of technology for the geographically conjoined technogenic placers development is an actual fundamental-and-applied task aimed at addressing, among other things, the socioeconomic and environmental problems of the region.

Up to now, we have failed to find exact analogs to the proposed line of research with respect to technogenic placers. Nevertheless, there are a number of related studies, devoted to the development of ore and placer deposits, as well as certain methodological approaches to the organization of their rock mass processing.

With respect to sub-standard ores, which at present cannot be gainfully worked out as specific raw material, Academician K.N. Trubetskoy highlights the possibility of mining operations' resource-reproducing functions, executed by artificially changing sub-standard ores' in situ dredging operations in accordance with their ambient conditions. Essentially, during sub-standard ores indirect (in passing) open-cast mining, accompanied by separable stockpiling at the earth surface, or as a result of technogenic deposits creating, characterized by certain predetermined parameters, such sub-standard ores are converted into real MRs, adequate for further profitable excavation.

This approach is certainly relevant for solving the problem of large-scale and complex development of technogenic placers.

Both in Russia and abroad, other technical solutions are known that are close to the planned research.

In V.R. Kabirov's dissertation "Economic efficiency assessment of the geographically conjoined (metal) ore deposits' group development", following stages of such deposits' development are listed:

1. Consideration of a group of geographically-adjacent deposits from the standpoint of technological possibilities for their development;
2. Possibilities identifying for creating common links of infrastructure for a group of geographically adjacent deposits;
3. Selection of a variant for the development of geographically adjacent deposits;
4. Sequence determination for each field involvement in the development.

The peculiarity of this approach is that a unitary infrastructural base is formed there on the premises of optimal choice both for processing complexes location and for their number.

Opryshko D.S. proposed a rational technology version for small continental placer gold deposits development. The result of the study is technical and technological possibility substantiation for small gold-bearing placers involvement into effective exploitation, including currently unprofitable technogenic ones, by using existing small-sized machinery, eventually improvement thereafter, in relation to specific mining-geological and climatic conditions. This technology version may be seen as promising, but it is ineffective during conjoined placers development.

M.Kh. Peshkova, N.A. Matsko, M.Yu. Kharitonova in their work theoretically deeply substantiated methods for increments and quality estimation with respect to conjoined placers reserves within a single river valley, where along with easily accessible placers the low-margin ones exist, which are often never involved in development, although, as practice shows, they are licensed by a single mining

enterprise. Joint development of such placers in some cases may prove to be economically viable, and thus active part of gold placer's raw-material base can be substantially expanded. The resulting availability of the entire valley's reserves is determined by the main deposit's availability, while the commissioning sequence of other fields is typically determined by the subsoil user. This is one of the principal differences of this technology with ours.

There is a well-known rationale for the expediency and commissioning order of kimberlitic quarries group, belonging to MIBA mining company (Democratic Republic of Congo), which takes into account both sustainable schedule creation of overburden operations for each quarry in the group, as well as feeding costs minimizing for several concentrator factories procuring with raw materials.

A.B. Anisimova in her dissertation arguments an idea of solid minerals and raw materials base replenishing, which implies effective development economic evaluation of homotypic conjoined deposits, registered in unallocated and unaccounted subsoil MRs fund.

The analysis of domestic and foreign experience shows that the problem of developing geographically conjoined technogenic placers is not fully explored, therefore promoted study is important from both scientific positions, and from technological, economic and environmental ones.

Technogenic placers have features that differ from those of pristine ones. These are: lower gold content (not always!); their granulometric peculiarities, expressed in the predominance of fine fractions; significant dispersion of rock mass volumes, depending on the methods of primary placers mining; spatial disunity of technogenic objects promising for development; good rinsing capacity of technogenic formations, determined by the granulometric homogeneity of dumps materials; various degree of technogenic formations integrity in the modern relief, etc.

In our earlier studies [4], [5] peculiarities of gold placers, resource potential were singled out, characterized by the effect of their renewability under the influence of natural processes, as well as new technological directions were proposed concerning development of alluvial deposits' technogenic complexes.

It is necessary to note especially the presence in the sands of other valuable associated components, which, on the one hand, makes their exploitation difficult, and on the other hand, can increase their economic attractiveness. Associated components of gold-bearing placers can be of considerable significance and used in various spheres of the national economy. The dumps of placers' technogenic complexes contain rare earth minerals suitable for the production of composites, high-magnetite sands – for further processing that leads to materials obtaining used for the production of paints or iron ore, the rock mass of thin clay dredging waste heaps can be used as gravel for road construction. Only in the Khabarovsk Krai, in addition to the gold-platinum reserves of complex placer deposits, dozens of technogenic alluvial gold deposits exist that contain cassiterite, wolframite, magnetite, ilmenite, and rare earth elements.

DIRECTIONS AND METHODS OF RESEARCH

All of the above stimulate a search for new methodological, technological and economic approaches to solving the problem of effective and large-scale integrated development of geographically close technogenic placers.

Currently, we have determined the number of methodological propositions for the substantiation of chosen approach, an algorithm has been created and a computer software package developed to calculate the technical and economic indicators that describe the simultaneous development of several selected placer-related technogenic objects, associated with different placers (processes being modeled are rock mass excavating, transporting it to a special site, delivered rock mass processing on a stationary flushing device or dressing plant). Location selection for the stationary flushing device or dressing plant is determined by the software complex, programmed at transportation and operating costs minimization.

The acceptance of methodical, project-technological and financial-economic solutions for the development of a number of closely related technogenic placer sites is sequenced according to following stages:

1. The mining and geological parameters of geographically conjoined technogenic placers of a particular region, the resources of the basic metal and valuable associated components are determined by calculations or expert assessments, based on satellite imagery or, if available, on design-engineering documentation of the worked-out geogenous placers.
2. If a license is available and the selected fields are included in the list of developed fields, a full range of geological exploration is carried out at all fields, or exploration work is carried out in the course of actual mining in order to refine the complex resources of the fields.
3. The type of flushing device or dressing plant equipped with additional dressing equipment is being chosen, its productivity is calculated. With the help of the developed software package, a rational location (by economic, technological and ecological indicators) of a stationary flushing device is determined. A procedure is being developed for the stockpiled rock mass preparation on a special site near the flushing device and its subsequent processing, provided that the reserves of all deposits are uniformly offset for the established planning period.

Let us consider in more detail the operation of the software.

Matlab R2013b has been selected to compile a mathematical model of the mining site. This mathematical package is well optimized for working with the matrix data type. The Matlab core allows you to work easily and quickly with matrices, which is an important factor for large amounts of data.

The main idea in creating a mathematical model is to break up the study area into elementary areas of a given size and to represent the resulting set of elementary sites and the entire territory as a whole in matrix form.

To compile a matrix representing the area under investigation, we use the developed application, implemented in C ++, using the Visual Studio 2013 software environment.

The investigated territory is divided into a matrix of a given size, where each element of the matrix is an elementary site of the terrain. An identifier is assigned to each site, defined by the program logic, depending on the site type. During compiling the matrix form for the investigated territory, the elementary parts of the terrain are divided into several types:

- accessible parts of the terrain – areas where the dressing plant can be located, and through which the route from the field to the plant can be laid, an identifier of the section is 1;
- inaccessible areas of the terrain – areas where it is impossible to locate the dressing plant and the route (elevations, ponds), site identifier 0;
- deposits – places where the rock is exported to the dressing plant, an identifier of the site is 4;
- the proposed optimal location of the dressing plant, the site identifier is 3;
- the route from field to plant, the site identifier is 2.

The relevant areas are noted in the application that forms the matrix. The remaining sections are marked as accessible ones. The optimum location of the dressing plant and the routes from the fields to the plant are determined during the calculation of the mathematical model.

To determine the distance from the deposits to the prospective location of the dressing plant, an algorithm for finding the shortest path has been developed. The beginning of the algorithm operation is that starting from the selected elementary section, where the deposit is located, the distance from adjacent accessible elementary sites to the proposed location of the factory is calculated. Neighboring sites are classified in terms of Moore's neighborhood, where all eight sites are considered to be neighboring. Unavailable sites, if any, are excluded from the calculation.

From obtained distance values, the smallest is chosen; the segment with the smallest distance is defined as the route to be laid. The following calculation is made between the neighboring sections with the previous elementary sections obtained during the last calculation by the route laid. A site with the shortest distance to the proposed location of the plant becomes the next point on the route. Such computations proceed until the final section is reached.

To determine the optimal location of the flushing device or dressing plant, a cell is selected that is accessible at the beginning of the matrix map and it is marked as a cell on which the dressing plant is located. The program determines the shortest routes from the deposits to the prospective site of the dressing plant. Then, based on the initial data that characterize fields and both transport and mining equipment used, the program calculates the profitability of the plant, placed in the specified cell. After that, the next available cell is selected, for which, on the same principle, the profitability of the plant is determined when it is placed in a new cell. Thus, all available cells are calculated. After calculation, the cell with the maximum

profitability index is selected. The resulting cell on the plan is rendered as the most optimal location for the dressing plant.

Thus, a software method has been developed for determining the optimum location of the flushing device or dressing plant for effective development of the conjoined technogenic placers or adjacent small (possibly unprofitable) natural placers.

The proposed approach will require subsoil users to attract significant financial resources, use modern and efficient mining and processing equipment. Therefore, primarily small and medium-sized enterprises, in terms of extracted metals' volumes, may need a rearrangement of their structure through, for example, horizontal integration. This is a real opportunity to carry out the large-scale development of technogenic placers with high efficiency even with minimal conditional contents of useful components.

CONCLUSION

Modern approaches to technogenic placers development insufficiently effective. Hence, new methods and technological solutions are required. Taking into account the fact that technogenic deposits are often appear as conjoined or adjacent objects of various sizes, there is reason to recycle their mining in conjunction (simultaneously or sequentially), utilizing state-of-the-art technologies and equipment, designed exclusively or *ad hoc*.

For this ideas realization the authors propose R&D direction shortly described above. Already reached stages of this theoretic and applied project include following results.

(1) As is shown, development problems and prospects, concerning territorially conjoined TCPDs, are investigated only fractionally. In some aspects they remain virtually unexplored both in theoretical and in applied aspects.

(2) Necessity is substantiated to search for methodical and techno-economic approaches to cope with problems that hamper effective and large-scale development of territorially conjoined technogenic placer deposits.

(3) Several methodic theses are formulated that substantiate proposed approach. Computer algorithm is designed for techno-economic indices calculation, which characterize simultaneous mining operations performed on territorially conjoined technogenic objects, pertaining to gold placer deposits.

(4) Analysis was carried out with respect to enterprises amalgamation processes in mining economic sector. Revealed advantages and negative sides of these processes may serve as instruments in neutralization of technological and economic problems that emerge during territorially conjoined technogenic placers development.

In addition to said above, analysis of domestic and foreign publications demonstrated that strategic questions of territorially conjoined technogenic gold placers development do not enjoy high popularity and as a result poorly

investigated. Meanwhile their real importance is substantially great and, taking into account current placer gold mining reduction, it steadily tends upward [2].

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