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Methodological principles of the selection of a resource-saving technology while developing water-bearing placer deposits

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Abstract

Purpose. The present paper aims to develop methodological principles for the selection of effective parameters of resource-saving technologies while developing water-bearing titanium-zirconium deposits basing on the complex of analytical studies.

Methods. The paper applies a complex of research methods: analytical – to analyze and generalize the main differences of the development technology for water-bearing placer deposits and problem statement; technical-economic analysis for identifying the effect of a resource-saving technology on the indices of land use of the open-pit mining and involvement of associate raw materials in the economic activity; forecasting – to determine the influence on complex development of a titanium-zirconium deposit on the operating parameters of the regional nonmetallic raw material open pits.

Findings. Effective trends in using the associate raw materials located in the enclosing and overburden rocks of a titanium-zirconium deposit are identified. Key differences between the technologies of associate raw material mining from the overburden rocks and their recovery from the enclosing rocks while mineral mining are defined. Predictive influence of a resource-saving technology of the development of titanium-zirconium deposits on the extraction of building materials from the regional nonmetallic open pits is specified. Volumes of possible associate raw material mining while developing the Motronivskyi GZK open pit during its operation are determined.

Originality. New dependences of a land capacity coefficient while mining nonmetallic raw material in the region, prime cost of ore development as well as number of open pits for sand and clay production in the region on the volumes of involved associate raw material of the titanium-zirconium open pits are identified.

Practical implications. A structural-logical scheme is elaborated for the selection of a resource-saving technology while operating open pits for the development of titanium-zirconium deposits.

Keywords: *open-pit mining, water-bearing deposits, resource-saving technology, hydromechanized mining, associate minerals*

1. Introduction

1.1. Statement of the problem

Open-pit mining is accompanied by a large volume of overburden operations that depend on the mineral type as well as type of deposit occurrence; it is represented by the overburden ratio. While developing horizontal sedimentary deposits, it can reach 5–8 m^3/t while during the development of nonmetallic minerals of irregular shapes it is 2-3 m^3/t [1]. The same indices correspond to the development of inclined and steep deposits [2].

Apart from the indicated volume of the overburden rocks while mining ore deposits containing metal minerals, there arises the necessity in their processing; that results in the formation of additional waste volumes. They contain valuable components with low metal content that is sent to tailing dumps [3], [4]. Thus, the ratio between the general volume of rock mass under development and the volume of commercial products at these mining enterprises can be from 50 up to 100:1.

In this context, a problem of the elaboration and implementation of new technologies of complex mineral development in the open-pit mining is rather topical [5]. Moreover, it is critically important for the environmental and ecological sustainability of mineral resources mining [6]-[8]. The main objective of new technological solutions should be in the provision of sustainable development of a mining region both in terms of ecology and economy by involving greater volumes of the associate raw materials being today the mineral industry wastes [9]-[12]. However, in case of building industry those wastes can be a source of material production.

As is known from the concept of selective extraction of minerals and formation of technogenic deposits [13], the formulated problem should be solved by prioritizing the extraction of main and associate minerals from the deposit. Moreover, both the main and associate minerals should be considered as the equal raw materials. Such a solution will help reduce the anthropogenic load on the environment and increase the overall level of environmental safety in a mining region.

1.2. Analysis of the recent studies and publications

Paper [14] studies an effective technology of the development of water-bearing titanium-zirconium deposits; how-

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ever, it does not consider the problems of complex development of the mineral raw materials, and the main attention is focused on the minimization of economic costs while mineral mining. The main research results of paper [15] involves the improvement of technological schemes of mining the water-bearing placer deposit; the problems of dealing with the considerable volumes of production wastes and placement of concentration wastes in a tailing dump at the open pit surface are still unsolved.

The authors of paper [16] studies a possibility to increase the resource-saving efficiency at the open pits of titanium-zirconium ores by using the associate raw material in other economic industries; however, there is still a problem of development of placer deposits with great water-bearing characteristics. The problems of complex use of mineral raw material of placer deposits are examined in paper [17] with little attention paid to the handling sandy and argillaceous enclosing rocks in the ore. A general analysis of the improvement of resource-saving efficiency while mining titanium-zirconium deposits is represented in paper [3]. Nevertheless, a problem of complex use of mineral raw material of the water-bearing placer deposits remains to be unsolved.

Paper [18] represents modern solutions concerning the improvement of the technology of selective mineral deposits; however, the proposed approaches belong to the development of the deposits with a low water-bearing level. They cannot be applied to the hydrogeological parameters of the watered titanium-zirconium deposits. The authors of paper [14] offer their technological solutions on the development of water-bearing placer deposits though they do not consider the possibility of selective extraction of the associate raw material in the enclosing rocks in the open pit middle, which will make it possible to reduce greatly the volumes of transport operations. The development of the water-bearing placer deposits at seacoasts is studied in paper [19]; however, the proposed technological solutions are of low efficiency while developing the deposits in terms of limited land resources due to the necessity to store large volumes of production wastes in the external tailing dumps.

Processes of the formation of tailing dumps in terms of placer ore deposits at seacoasts are described in paper [20] though the studies are focused on the problem of mining the deposits with relatively insignificant accretions of the overburden rocks up to 15 m that does not meet the development conditions of Ukrainian titanium-zirconium deposits. Papers [21], [22] represent modern approaches to the development of water-bearing placer deposits but without any consideration of complex development of mineral raw materials. The studies in papers [23], [24] help determine effective equipment for the development of ore deposits; the disadvantage here is insufficient analysis of a problem concerning the selection of facilities in terms of considerable watering of ore sands where the volume of enclosing rocks reaches 95%.

Papers [25], [26] consider the issues of secondary recovery of heavy minerals from tailing dumps of ore placer deposits; nevertheless, a problem of handling the enclosing rocks being accumulated repeatedly in the recycled tailing dumps is still unsolved. Papers [27], [28] deal with the development of technological schemes of placer deposit development; however, while analyzing, the main efficiency criterion is minimization of costs for mineral mining that does not take into consideration a problem of modern placer deposit development in terms of limited land resources.

The problems of determining the parameters of effective technological schemes of hydromechanized method of mineral mining from the open pits and technogenic formations are analyzed in papers [29], [30]; but there is still no solution for a problem of determining the influence of secondary raw material use on the indices of land capacity of mining. Papers [31], [32] deal with the increasing efficiency of the placer deposit development. Despite the fact that the issue of resource saving in these papers is of high priority, the research results do not take into account handling the enclosing rocks of titanium-zirconium ores.

As the analysis of the world practice shows [33], [34], the main trends in the sphere of resource saving while open-pit mining involves the following:

– increase in the completeness of the recovery of useful components from a mineral and overburden rocks;

– replacement of the use of minerals from the building-material open pits with the similar minerals from the ore open pit wastes;

– reduction of the resources while mining and processing;

– recirculation of the secondary resources;

– reduction of the areas of disturbed lands for the location of both external dumps and tailing dumps;

– decrease in the negative influence on the land, water, and air resources;

– reduced consumption of electric energy and fuel;

– decreasing specific amount of metal of the production.

Each of the identified trends is a perspective one to be used practically. However, their combination will help provide balanced use of the primary natural resources and secondary raw materials to reduce technogenic load on the natural environment.

1.3. Singling out of the previously unsolved tasks of a general problem

Analysis of the research papers concerning the topic under study allows stating that in terms of titanium-zirconium open-pit mining, the development of associate minerals along with the main raw materials help increase considerably a level of resource saving both during the open pit operation and after its completion.

To reduce the waste volumes while placer deposit developing, it is extremely important to work out methodological statements on the selection of a resource-saving technology since the available practice of the development of titanium-zirconium open pits with the use of walking dredges at the mining edges demonstrates low efficiency due to considerably reduced productivity. It is important to consider hydrogeological indices to make decisions as for possible hydromechanized method of ore body extraction as well as location of floating hydromechanized mining complex with the function of preliminary separation of heavy minerals from the enclosing ores of ore sand within the open pit.

It is possible to solve a problem of selecting the parameters of a resource-saving technology of the development of a water-bearing titanium-zirconium deposit by elaborating the structural and logical scheme of selection that will take maximum amount of possible mining and hydrogeological conditions of the deposit development as well as types of mining equipment being efficient for mining.

To determine the efficiency of the proposed solutions, it is necessary to develop a methodology to determine the predicted effect from the involved associate raw materials of a

titanium-zirconium open pit into the building material industry. That should be done taking into account the average coefficient of land capacity in a region while developing associate minerals of placer deposits, annual requirement of a region for quartz sand and clay extraction, and changes in the number of open pits, which mine that raw material in a region while involving associate minerals of a titanium-zirconium deposit.

1.4. Formulation of the paper objective and statement of the problem

The research objective is to develop methodological grounds for the selection of a resource-saving technology while mining water-bearing placer deposits. To reach the objective, following tasks were formulated and fulfilled:

– to perform comparative study of the connection between the main raw material and types of associate minerals during the period of open pit operation;

– to specify key trends in the use of associate minerals of the water-bearing titanium-zirconium deposits in construction and other industries;

– to develop methodological principles of the selection of a resource-saving technology while mining water-bearing titanium-zirconium deposits taking into consideration their technical and hydrogeological parameters;

– to identify the effect of a resource-saving technology of the development of water-bearing placer deposits while using associate minerals on the indices of land use and volumes of using basic raw material of nonmetallic open pits.

2. Research methods

To perform a comparative study of the connection between the main mineral and associate raw material while developing water-bearing titanium-zirconium deposits, a method of analysis and systematization of mining-geological parameters is applied. Motronivsko-Annivskyi site of Malyshevske deposit of titanium-zirconium ores is taken as the object to study the distribution of the main and associate raw material while open-pit mining. Currently, the site is the most perspective for mining as it has considerable mineral reserves.

The key trends in the use of associate minerals of the water-bearing titanium-zirconium deposit in construction and other industries are identified involving analytical methods of research. Since the general volume of titanium-zirconium minerals in rock mass of the open pit of Motronivskyi GZK reaches only one per cent, minimization of mining wastes is possible only by involving the associate raw material in the economic activity. Otherwise, overburden and enclosing rocks, according to the development project, will be located in the external and internal dumps while sandy-argillaceous processing wastes will be sent to tailing dumps.

Analysis of the possible ways of the use of associate raw materials and identification of the potential consumers in the regional economy and country in general will help increase the efficiency of complex development of the water-bearing placer deposits. To solve the specified problems, it is required to study the applicability of the overburden and enclosing rocks to their use in other industries.

The efficient parameters of a resource-saving technology while mining the water-bearing titanium-zirconium deposits are selected by the development of methodological principles of identification of technological schemes of opening and mining operations taking into consideration mining and hydrogeological parameters of the deposit. While elaborating the methodological principles of the technological scheme selection, one should consider that the associate minerals are both in the overburden rocks and in the mineral layer. Consideration of the available extraction and loading equipment at the open pit is also an important component. It is known that while developing the open pit of Motronivskyi GZK, the associate mineral can be extracted from the overburden rock by means of hydraulic excavators applied in the current technological scheme. In such a way, the costs for excavation operations remain the same while transportation indices will depend on changes in the points of associate mineral unloading.

Solution of the problem concerning selection of a technological scheme of associate mineral mining from the enclosing rock of a pay streak is more complicated. It is due to the fact that according to the project of Motronivskyi GZK open pit mining, 2.7 mln m^3 of rock mass, represented by a sandy-argillaceous mixture, will be mined annually. In this context, certain share of the associate minerals in the pay streak reaches 95%.

Since the pay streak at the open pit will be developed by a hydromechanized method, the associate mineral is possible to be mined without any changes in the extraction technology. The sandy-argillaceous mixture from the titanium-zirconium minerals is separated by water concentration at the concentration plant at the open pit edge with the following transportation to a tailing dump in the internal dump. However, there are certain technologies that make it possible to perform water concentration of minerals with the help of a floating concentration plant located in the water-bearing open pit face near a dredge ship.

In this context, the main requirement for the technology of water concentration at the floating concentration plant located in the open pit is the organization of its operation considering the resource-saving principles. As it has been mentioned before, composition of the pay streak minerals is represented by a sandy-argillaceous mixture. In case when a concentration process has no clay separation from the mineral, the sandy-argillaceous mixture is sent to a tailing dump that requires involvement of additional land resources for the production. However, selection of enclosing rocks allows obtaining two types of secondary raw material for the industry: clay and quartz sand. Similarly, the selection will help form a technogenic deposit of quartz sands in the internal open pit dump at the expense of changes in the filtration properties of rocks. As a result of that separation, there is a possibility to exclude construction of a tailing dump to store sandy-argillaceous mixture.

The parameters of a resource-bearing technology of the development of the Motronivskyi GZK open pit are selected basing on the available geological and hydrogeological indices of the deposit development. In such a case, the technology development requires the data on overburden rocks, main raw material as well as associate minerals located within the open pit outline. Identification of the hydrogeological indices is required for decision-making as for possibility of a hydromechanized method of mineral mining as well as location of a water concentration plant in the open pit.

When the geological and hydrogeological indices of the deposit are determined, the extraction-loading and transportation facilities are selected (Fig. 1).

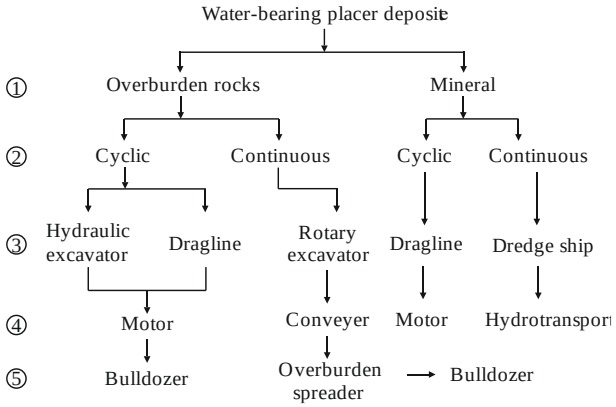

Figure 1. Scheme of the selection of extraction-loading and transportation facilities while developing a mining technology for a water-bearing placer deposit: 1 – type of rock mass; 2 – type of equipment operation; 3 – extraction-loading facilities; 4 – type of transport; 5 – type of dump formation

When the main tendencies in using associate minerals are identified and technological schemes of the overburden and mining operations are determined, one should specify the predicted effect of a resource-saving technology of the development of water-bearing placer deposits on the indices of land use and volumes of consumption of the basic raw material of nonmetallic open pits involving a method of technical and economic modelling.

Correct technical and economic substantiation while selecting an effective resource-saving technology of the development of water-bearing placer deposits should consider the indices of involvement of the associate minerals in the financial activity of an enterprise by determining the additional costs for their extraction as well as the income from their sale [34]. It should also be taken into account that the involvement of associate minerals in the economic activity while open-pit mining has its certain influence on the indices of nonmetallic open pit operations, i.e. on the decreasing dynamics in the expansion of areas disturbed by their development. First of all, that concerns the operations of quartz sand and clay open pits.

It is proposed to evaluate the efficiency of involvement of associate minerals while developing a water-bearing placer deposit with the help of four key parameters:

1. Average coefficient of land capacity while sand and clay mining in the region:

$$K_L = \sum_{i=1}^{n} \frac{S_{Pi}}{V_{Mi}}, \text{ ha/thousand t,} \quad (1)$$

where:

S_{Pi} – area of the lands disturbed as a result of quartz sand and clay extraction at the open pits of main raw material in the region, ha;

V_{Mi} – annual extraction volume of quartz sand and clay in the region, thousand t;

i – year of the deposit development; n is lifespan of the open pit operations, years.

2. Predictive economic needs of the mining region as for quartz sand and clay mining in the region:

$$Q_P^y = Q_M \cdot (1+r)^y, \text{ ha/thousand t,} \quad (2)$$

where:

Q_M – current need in the raw material, mln t;

r – index of the national economic growth, %;

y – year of the deposit development.

3. Number of the nonmetallic raw material open pits (N_P) extracting quartz sand and clay that is determined by the statistic analysis method taking into account annual need in the raw material and lifespan of the available open pits.

4. Prime cost of ore development while switching to the technology of complex development inclusive of discounting according to the expression:

$$E^y = \frac{P_1^y + P_2^y + P_3^y - C_1^y - O_2^y + S_L^y}{Q_T (1+r)^y}, \text{ ha/thousand t,} \quad (3)$$

where:

P_1 – income from the selling of main raw material, c.u.;

P_2 and P_3 – incomes from the selling of associate raw material in the pay streak and overburden rocks, respectively, c.u.;

C_1 – capital costs, c.u.;

O_2 – operating costs, c.u.;

S_L – loss reduction owing to reduced areas of disturbed lands of nonmetallic raw material open pits, c.u.;

Q_T – annual productivity of the open pit that mines basic raw material.

The developed methodological approaches to determining the efficiency of applied technologies of complex development of water-bearing placer deposits make it possible to perform predictive analysis of the efficiency of involvement of the associate minerals into the use while developing an open pit taking into consideration saving of mineral raw material and land resources.

3. Results and discussion

While establishing the relation between distributions of the basic raw material and associate minerals, uniqueness of Motronivsko-Annivskyi site of Malyshevske deposit of titanium-zirconium ores were taken into consideration. It is located within a large area (more than 1000 ha) that means considerable project period of the open pit operation (up to 55 years). It is defined that the mineral content in the ore bed is 4-20% on average while overburden rocks have great reserves of the associate minerals. They are represented by the following deposits: loessial loam (up to 2 m), quaternary loams with red-brown clays (up to 25 m), gypsified band clays (up to 12 m), and Sarmatian sands containing clay, kaolin, and aluminum silicate (up to 27 m, average thickness along the deposit is 16.7 m). Thickness of the mineral layer with the commercial content of the titanium-zirconium mineral components reaches 24 m, in terms of average thickness of 11.2 m that contains Poltava sands with clay admixtures.

It has been defined that the average content of the titanium-zirconium minerals in the pay streak of a placer deposit is 5% while the volume of argillaceous rocks reaches 15%. Another part of the pay streak is represented by quartz sands – 80%. The results of the analysis of geological data of the Motronivsky GZK open pit make it possible to determine the ratio between the types of basic and associate minerals within the open pit field (Fig. 2).

While determining the main parameters of using the associate minerals in construction and other industries, it is specified that while operating the Motronivskyi GZK open pit more than 840 mln m^3 of rock mass is mined; in this context, about 700 mln m^3 in this volume accounts for the overburden rock.

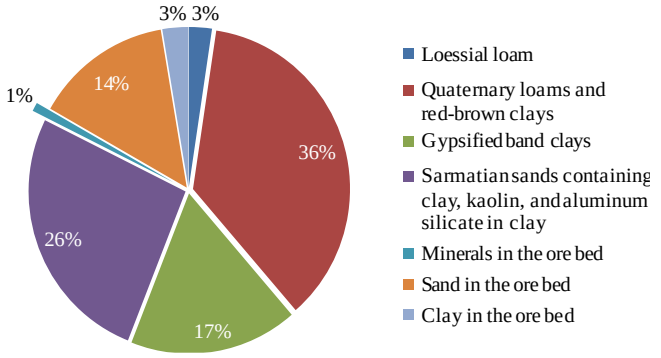

Figure 2. Ratio between the basic rock types and mineral in the rock mass of the Motronivsky GZK open pit

In terms of 157 mln m^3 of mineral extraction, only 7.5 mln m^3 are minerals of the titanium-zirconium group. Thus, under the current technology of deposit mining, more than 832 mln m^3 of rock mass are production wastes.

Analysis of the overburden and enclosing rocks of the Motronivskyi GZK open pit has helped identify that the overburden rock contains loessial loams in the form of sedimentary disperse rock consisting of clayey, sandy, and dusty particles. Due to insignificant adherence, such composition is in rather dusty condition during dry seasons. Moreover, in case of precipitations, the loams get wet very fast and become free flowing. Thus, the rock is of low value for manufacturing different building materials; however, the results of studies in the sphere of material development for road surface facilities show that in case of correct arrangement, loessial loams can be used as the road-building materials, if being cement-reinforced.

The second layer of Motronivsko-Annivske deposit is represented by the quaternary-period rocks formed 2.6 mln years ago. The rocks include quaternary loams and red-brown clays that can be used as raw materials for bricks. The red-brown clay indicates that it is fire-resistant and suitable only for making coarse ceramic that includes ceramic brick and tile.

The third layer is represented by gypsified band clays that have sufficient durability and in some cases need preliminary loosening before mining. Since this mixture is of sufficient strength and water resistance, it can be used for making the tailing dump basis as well as its surface layer that prevents from its contacting with the environment. These rocks can be used for making a cultural layer during reclamation of the internal and external dumps.

The fourth rock layer is formed by Sarmatian sands, which age is from 5 to 7 mln years. This layer contains sands and clays that include kaolin and aluminum silicates. Glass, dry, and building sands can be mined from the Sarmatian stage. In terms of Vilnohirsk GMK operation, 20 thousand t of glass sand and 9 mln t of dry sand were mined annually. Aluminum silicates are widely used in food industry, for medical and cosmetic purposes. Kaolins are of high fire resistance as well as low plasticity and viscosity. They are applied for making porcelain, faience ware, fine ceramics, and as the admixtures for building and cosmetic materials.

A mineral layer is represented by Poltava quartz sands and argillaceous rocks, in which titanium-zirconium ore occurs. Quartz sands of Poltava stage are similar to the sands of Sarmatian stage; thus, they can be used in similar industries. Being separated from the sandy mixture, clays can be used while manufacturing coarse ceramics, road surface or insulating material during the dump formation and construction of tailing dumps.

As the performed analysis demonstrates, in terms of complex approach to the extraction of valuable components of associate minerals, a considerable share of the overburden rocks can be used in different industries. Dynamics of the overburden rock development and extraction of mineral reserves while operating the Motronivskyi GZK open pit are represented in the graph (Fig. 3).

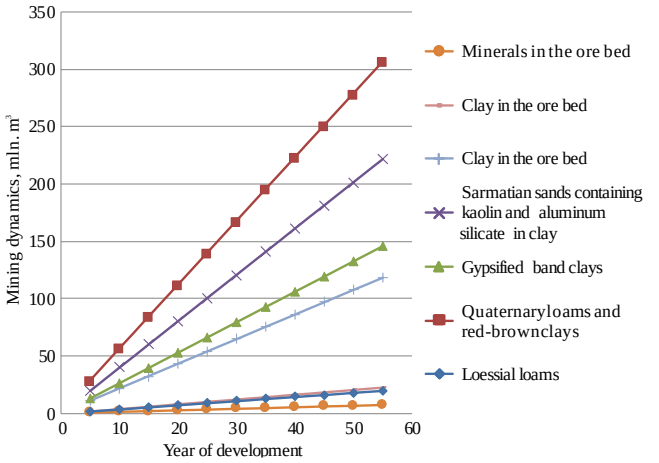

Figure 3. Dynamics of the extraction of mineral reserves and overburden rock development at the open pit of Motronivskyi GZK

When geological and hydrogeological parameters of the deposit development are determined, the equipment for open pit operation is selected according to the type of the previously elaborated principles (Fig. 1). Considering the identified types and amount of equipment, a structural-logical scheme for the selection of a technology of complex development of a water-bearing placer deposit is proposed (Fig. 4).

Since the number of possible technological schemes considered during the selection can be of great significance depending on the number of possible equipment combinations (Fig. 1), the problem should be solved involving technical-economic substantiation with the help of experts and designers. When the main parameters of the resource-saving technological schemes, that can be applied, are defined one should select the most efficient one taking into account both technical-economic and resource-saving indices as well as the effect of the use of associate minerals on the operation of nonmetallic raw material open pits.

Determination of the principles of a resource-saving technology of the development of water-bearing placer deposits involving associate minerals on the land use indices and nonmetallic open pit operations is based on the specification of key technical-economic parameters and land protection. As mining practice shows, implementation of a resource-saving technology means extraction of associate minerals that results in the growing amount of capital and operational costs. Thus, growing costs for mining operations, on the one hand, and additional income from selling the associate minerals and land protection, on the other hand, require technical-economic estimation of the efficiency of the resource-saving technologies.

Basing on the developed methodological principles aimed at determining the efficiency of complex deposit mining technologies in terms of open-pit mining for water-bearing placer deposits, the efficiency of involvement of associate minerals in the use taking into consideration the land protection indices is predicted (Fig. 5).

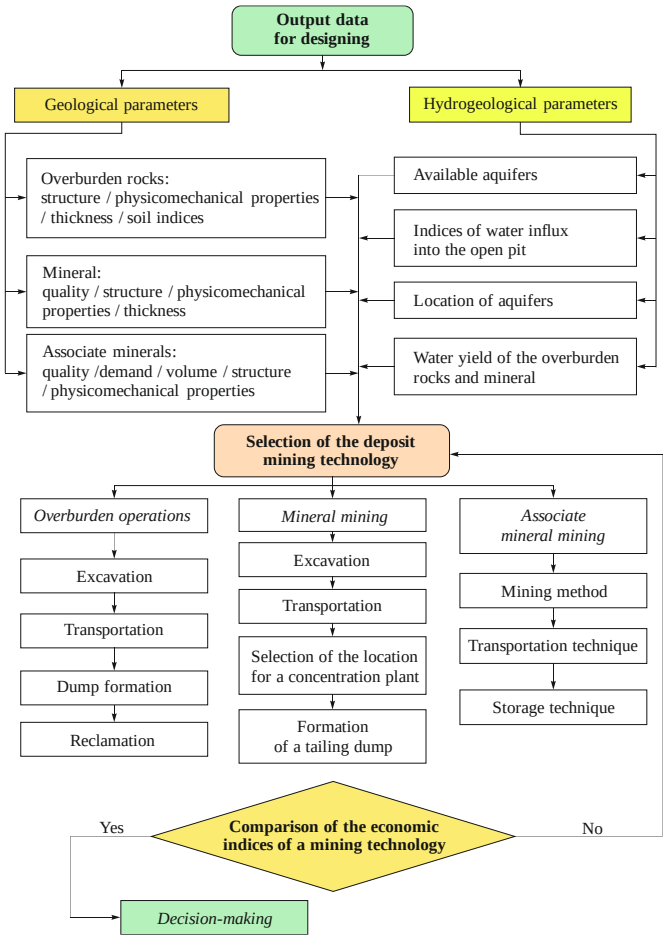

Figure 4. Structural-logical scheme of the selection of a technology for complex development of a water-bearing placer deposit

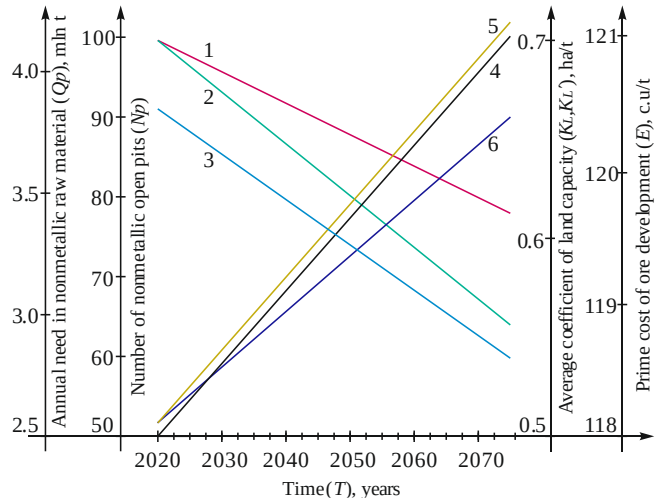

Figure 5. Prediction of the efficiency of involvement of associate minerals of the Motronivsky GZK open pit in the economic activity in terms of years of the water-bearing placer deposit development: 1 – average coefficient of land capacity while sand and clay mining in the region (K_L); 2 – average coefficient of land capacity in the country while using associate minerals from the open pit developing a water-bearing placer deposit (K_L'), ha/thousand t; 3 – prime cost of the ore development (E), c.u./t; 4 – annual need of a mining region in quartz sand and clay (Q_P), mln t; 5 – number of the open pits for sand and clay mining in the region (N_P); 6 – number of the open pits for sand and clay mining in the region in terms of using associate raw material of the open pit developing a water-bearing placer deposit (N_P')

The predictive results of the efficiency of associate raw material mining while developing basic minerals of a placer deposit (Fig. 5) make it possible to identify that the annual need of a mining region in quartz sand and clay (4) will grow constantly being in correspondence with the national economic growth. At the same time, the average coefficient of land capacity while sand and clay mining in the region in terms of involved associate raw material of the open pit developing a titanium-zirconium deposit will reduce greatly (2) contrary to the technology, in which the associate raw material will not be used in the industry (1).

That is explained by the fact that extraction of a unit of mineral volume in another case requires that the building materials are to be mined at the nonmetallic open pits. Since the economic growth results in the increasing need in raw material (4), the necessity will arise in the long term to involve new building-material open pits in the development (5); however, the use of associate raw material of the open pit that mines a water-bearing place deposit will help reduce that dynamics (6). The main predictive results of the involvement of the associate raw material of the open pit developing a water-bearing placer deposit in the building-material industry is the reduction of prime cost of the main mineral development (3) at the expense of additional income of an enterprise from quartz sand and clay selling as well as due to reduced losses from the reduced areas of disturbed lands at mining enterprises dealing with nonmetallic mineral mining.

4. Conclusions

Analysis of scientific and technical literature has shown that numerous studies concerning selective mineral mining and formation of technogenic deposits have been carried out; however, the studies cannot be used while solving a problem of the development of water-bearing titanium-zirconium deposits due to complicated hydrogeological conditions and limited land resources. The ratio between the overburden rocks and metallic minerals of the water-bearing titanium-zirconium deposit has been defined in terms of the Motronivskyi GZK open pit. It has been specified that while operating the open pit more than 840 mln m^3 of rock mass is extracted; the metallic mineral content in this mass is only 7.5 mln m^3. Consequently, in terms of current technology, more than 832 mln m^3 of rock mass are industrial wastes.

Main tendencies in the development of resource-saving technologies while developing water-bearing titanium-zirconium deposits have been determined taking into account the use of associate minerals from both overburden and enclosing rocks in road construction and while manufacturing various building materials.

Methodological recommendations on the selection of resource-saving technological schemes have been elaborated aimed at development of a water-bearing placer deposit considering geological and hydrological parameters. When the number of possible resource-saving technological schemes is defined, the most efficient one is selected paying attention to the technical-economic indices and land protection.

The predictive effect from the involvement of associate minerals in the building-material industry has been identified taking into consideration the average coefficient of land capacity, annual need of the region in quartz sand and clay production, number of nonmetallic open pits in the region while involving the associate minerals of a titanium-zirconium deposit.

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Методологічні принципи вибору ресурсозберігаючої технології при розробці обводнених розсипних родовищ

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Мета. Розробка методологічних принципів вибору ефективних параметрів ресурсозберігаючих технологій при освоєнні обводнених титан-цирконієвих родовищ на основі комплексу аналітичних досліджень.

Методика. В роботі використано комплекс методів досліджень: аналітичний – для аналізу і узагальнення основних відмінностей технології розробки обводнених розсипних родовищ і постановки завдань; техніко-економічний аналіз для визначення впливу

ресурсозберігаючої технології на показники землеємності відкритої розробки та залучення супутньої сировини у економічну діяльність; прогнозування – для визначення впливу комплексного освоєння титан-цирконієвого родовища на показники роботи кар'єрів з видобутку нерудної сировини в регіоні.

Результати. Встановлено ефективні напрями використання супутньої сировини, що розташована у вміщуючих і розкривних породах титан-цирконієвого родовища. Виявлено основні відмінності в технологіях розробки супутньої сировини з розкривних порід від її вилучення з вміщуючих порід при видобутку корисних копалин. Визначено прогнозний вплив ресурсозберігаючої технології освоєння титан цирконієвих родовищ на видобуток будівельних матеріалів з кар'єрів нерудної сировини в регіоні. Встановлено обсяги можливого видобутку супутньої сировини при розробці кар'єру Мотронівського ГЗК за час його експлуатації.

Наукова новизна. Виявлено нові залежності коефіцієнту землеємності при видобутку нерудної сировини в регіоні, собівартості розробки руди, а також кількості кар'єрів з видобутку піску і глини у регіоні від об'ємів залучення супутньої сировини титан-цирконієвих кар'єрів.

Практична значимість. Розроблено структурно-логічну схему вибору ресурсозберігаючої технології при експлуатації кар'єрів в умовах освоєння обводнених титан-цирконієвих родовищ.

Ключові слова: *відкрита розробка родовищ, обводнені родовища, ресурсозберігаюча технологія, гідромеханізований видобуток, супутні корисні копалини*