UDC 622.271

B. Yu. Sobko[1], Dr. Sc. (Tech.), Prof., O. V. Lozhnikov[1], Cand. Sc. (Tech.), Assoc. Prof., A. M. Haidin[2], Cand. Sc. (Geol.-Mineral.), O. M. Laznikov[3]

1 – State higher educational institution "National Mining University", Dnipro, Ukraine, e-mail: sobko.boris.nmu@gmail.com
2 – JSC "GIRKHIMPROM", Lviv, Ukraine
3 – Motronivskyi MPP, Vilnohirsk, Ukraine

SUBSTANTIATION OF RATIONAL MINING METHOD AT THE MOTRONIVSKYI TITANIUM-ZIRCONIUM ORE DEPOSIT EXPLORATION

Б. Ю. Собко[1], д-р техн. наук, проф., О. В. Ложніков[1], канд. техн. наук, доц., А. М. Гайдін[2], канд. геол.-мінер. наук, О. М. Лазніков[3]

1 – Державний вищий навчальний заклад „Національний гірничий університет", м. Дніпро, Україна, e-mail: sobko.boris.nmu@gmail.com
2 – ВАТ „ГІРХІМПРОМ", м. Львів, Україна
3 – Мотронівський ГЗК, м. Вільногірськ, Україна

ОБҐРУНТУВАННЯ РАЦІОНАЛЬНОГО СПОСОБУ РОЗРОБКИ МОТРОНІВСЬКОГО РОЗСИПУ ТИТАНО-ЦИРКОНІЄВИХ РУД

Purpose. Substantiation of effective ways of mining titanium-zirconium ores deposits with high levels of flooding at the exploration Motronivskyi site of Malyshevskyi Deposit.

Methodology. The correct definition of hydrogeological parameters on Motronivskyi site by constructing wells in the relief depressions for the establishment of an average filtration coefficient in Miocene aquifer complex with the graphic-analytical method. The digital model of the area of Motronivskyi placers is based on the publicly available software package "VISUAL MODFLOW" considering laboratory and field studies. Substantiation of effective technology of overburden operations and underwater ore extraction, based on the received digital model of the area was carried out using a technical and economic analysis.

Findings. The technological scheme of underwater mining of mineral deposits at Motronivskyi deposit allows refusing from the use of wells for pit dewatering. The capital cost of the facility amounts to 10.5 million Euros, according to the bankable feasibility study by "Vattenfall" company. There is also a reduction in the cost of mining Sarmatian sands and spreading it in the basis of internal dump. Instead of loading into trucks and transporting around the quarry at a distance of about 2 km, Sarmatian sand, in the proposed scheme, is pumped to a distance 300 m in the slurry form.

Originality. The results of studies to establish the dependency of the average filtration coefficient of the Miocene aquifer on the parameters of the field are promising for the use in underwater mining operations, especially in case when the level of groundwater in the Neogene-Paleogene aquifer remains unchanged.

Practical value. Determination of hydrogeological parameters on Motronivskyi deposit and creation of the area digital model allows substantiating the choice of the efficient technology of overburden and mining minerals from previously used schemes with shovel and road trucks and new schemes for mining titanium-zirconium ores with the use of dredgers and hydraulic transport.

Keywords: *placer deposits, hydrogeological parameters, dredger*

Introduction. The exploitation of placer titanium-zirconium deposits in Ukraine began more than half a century ago. For this time various methods and technological schemes of mining operations have been implemented. As a result of researchers and production workers' creative efforts, a technology was found and brought to a high productive performance, which includes mining ore with dragline, transporting it to points of the integrated hydraulic ripping, washing-out with a hydraulic giant and pumping as slurry (pulp) to the concentrator.

Successful use of this technology gave rise to the idea of its perfection and universality. Therefore, this technology was proposed in the drafts for mining Motronivskyi site (MS) of Malyshevskyi deposit as well as weathering crust of Stremyhorodske magmatic deposits.

However, the experience of practical application of the above technology while developing a particular field indicates its incapability. This is due to the unique hydrogeological conditions and engineering geological properties of rocks in the Motronivskyi site of Malyshevskyi Deposit. Therefore, there is an urgent issue which is to develop a new technology for developing titanium-zirconium ore at Motronivskyi site deposite [1].

Analysis of the recent research. Hydrogeological conditions in the period of exploration Motronivskyi titanium-zirconium placer were not studied sufficiently. The source of information for the development of the project documentation was the report of "Tsentrukrheolohiia", a subsidiary of NAK "Nadra Ukraine" in 2002.

The seventies of the last century saw active improvement of mining technology for placer mineral resources with a high degree of irrigation. Thus, an underwater method was proposed to develop the mineral, which was also used for Irshanskyi deposits of continental origin. Stripping was performed with a dragline, and the ore sand was removed with bucketline dredges. Due to the complexity of the ore deposit shape and mutability of the minerals content, the control over the pulp composition was insufficient [2]. This led to increased losses and mineral dilution.

The world practice of open cast mining has also dealt with solving this problem. While analyzing research works, we considered the experience of the mining of coastal placer deposits in Australia, India, America, and New Zealand, where the minerals are extracted from the water by dredgers or drags. Typically, dredgers for ore extraction are installed with dressing tools, which are mounted on barges. Only rough concentrate is transported to the coast. The experience of dredger application to dewater Lebedinsky iron ore pit was analyzed as well.

Unsolved aspects of the problem. Existing developments in the local and foreign scientific-research and design works does not allow applying known solutions while mining the Motronivskyi placer without a detailed substantiation of the hydrogeological conditions of the deposit. This is explained by the fact that Motronivskyi site is an ancient marginal-marine deposit. The field is different from continental ones by the flat roof surface. The sole of ore deposits is determined by the conditioning of the mineral content and varies little in space.

The identification of Motronivskyi placers hydrogeological parameters allows moving on to the technological component of the task, which is to select effective technological schemes of mining flooded placer deposits of titanium-zirconium ores.

Objectives of the article. The definition of correct hydrogeological parameters of Motronivskyi placer due to the construction of wells in a lower part of relief allows establishing the average filtration coefficients of the Miocene aquifer complex. The development of digital models of Motronivskyi placers based on public software package "VISUAL MODFLOW" was made according to laboratory and field studies. Substantiation of effective technology of overburden and under water ore mining was based on the obtained digital models of the deposit area.

Presentation of the main research. The area of the deposit field features spreading water in the cracks of the primary igneous rocks and in sediments of the Kyivskyi, Buchatskyi, Kharkivskyi, Poltavskyi and Sarmatian ages (Fig. 1).

The last two horizons are identified as Miocene aquifer system. Glauconite sand of the Kharkivskyi

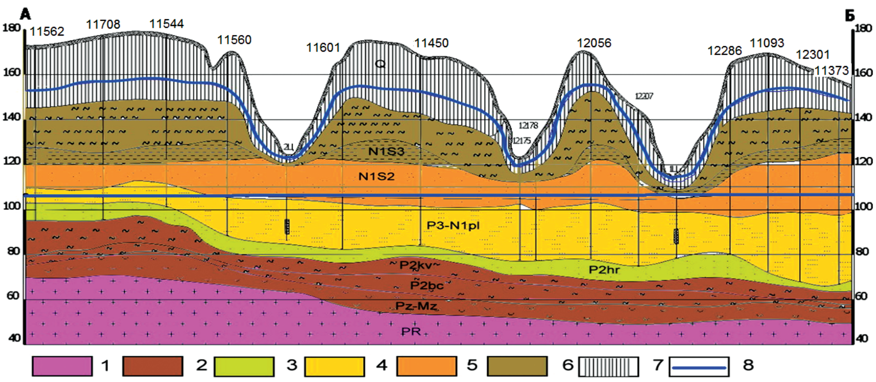

Fig. 1. Schematic hydrogeological section of Motronivskyi-Annovskyi site:

1 — water in fractured crystalline basement rocks; 2 — water in the crust of weathering, the sand of buchatskyi and kyivskyi layers; 3 — relatively aquifuge sand of kharkivskyi layer; 4 — sands of the poltavskyi series; 5 — sarmatian sands; 6 — seat clay; 7 — partially flooded loess loams; 8 — groundwater levels in the quaternary sediment and in the Miocene aquifer complex layer in this area of clay has a firm consistency. It is adopted for aquifuge bed that divided Miocene aquifer complex from aquifers which are located below.

To determine the hydrogeological parameters, two welt clusters were built in depressions of relief – beams. The Central borehole was drilled with a diameter of 600 mm and equipped with filter columns of pipes with a diameter of 219 mm. The filters were installed in the layer of the Poltava deposits. The space between the side of the hole and the filter was filled with gravel. During the experiment test pumping of water was carried out with a constant flow at one fall. The results showed the average filter factor of the Miocene aquifer complex, equal to 3 m/day.

The obtained parameters were taken as the basis in the calculation of dewatering system within the feasibility study for MS mining by German engineering company "Vattenfall". The planning schemes of deposits dewatering due to dewatering well with filters were installed in the bottom of the Poltavskyi and Kharkivskyi sediments. The complexity for the proposed systems has caused the need for detailed analysis of existing materials and additional hydrogeological investigations.

To refine the hydrogeological parameters, the filtration properties of rocks are determined using different methods: 1) the calculation according to the results of granulometric analysis; 2) studies with laboratory instruments; 3) field experimental-filtration works; 4) the solution of inverse problems according to digital simulation models.

Granulometric composition of the ore sands are given in Table 1.

As we can see from the data given in Table 1, ore "sand" contains 74 % of very fine sand, 17.8 % of dust, and 8.2 % of clay.

According to the engineering-geological classification of rocks [3] regarding grain-size composition ore sand is not sand, it is light dust loam. The filtration coefficient is a function of granulometric composition and porosity. For the well-known empiric formulas their filtration coefficient is 0.0034 m/day, which is three orders of magnitude smaller than adopted in the design.

Sarmatian Sands are more coarse-grained than Poltavskyi sands.

Granulometric composition of the Sarmatian stage sands is given in Table 2.

According to the granulometric analysis, the filtration coefficient of Sarmatian sands is from 1.4 to 12.4 m/day.

For better certainty, laboratory measurement of the filtration coefficient Sarmatian sands was conducted using a modified device of G. N. Kamensky. The obtained values of filtration coefficient are 2–6 g/day. Laboratory testing of permeability coefficient of sands ore was not possible because they have water loss close to zero. The water in them has a bound form.

The obtained results of calculations and laboratory studies allow conducting an alternative interpretation of the pumping test results from well made by different organizations previously.

Although the filters of central welt cluster were located in the interval of Poltavskyi sands, the occurrence of gravel between the wall of the borehole with a diameter of 600 mm and pipes with a diameter of 250 mm has stipulated the free water flowing in the filter interval of the Sarmatian deposits (Fig. 2).

The water conductivity (k·m) designed by the graphic-analytical method was 70 m/day. This means that the parameters do not refer to Poltavskyi, but refer to the Sarmatian sediments. If the resulting water conductivity – 70 m/day is attributed to the layer of flooded Sarmatian sands – 5.5 m, we will receive a filter factor of 12.7 m/day.

Refinement of hydrogeological parameters is made while observing pumping water out of the trench in size of 36 × 77 m, mined by the Esh10/50 Dragline to a depth of 3 m below the water level. In the trench, a pump was installed and water pumping was done with a flow rate of 40 m^3/hour.

Table 1

Granulometric composition of the ore sands

Parameters	Size fractions, mm								Total
	–0.800 +0.500	–0.500 +0.250	–0.250 +0.100	–0.100 +0.050	–0.050 +0.010	–0.010 +0.050	–0.005 +0.001	<0.001	–
Content, %	0.01	3.61	20.73	49.21	6.44	7.27	3.94	8.19	100

Table 2

Granulometric composition of the Sarmatian stage sands

Parameters	Size fractions, mm						Slope angle	
	0.5–2	0.25–0.5	0.1–0.25	<0.1	d60	D10	Dry soil	Under water
Content, %	1.3	39.2	45.4	14.1	0.2–0.26	0.04–0.12	32	29

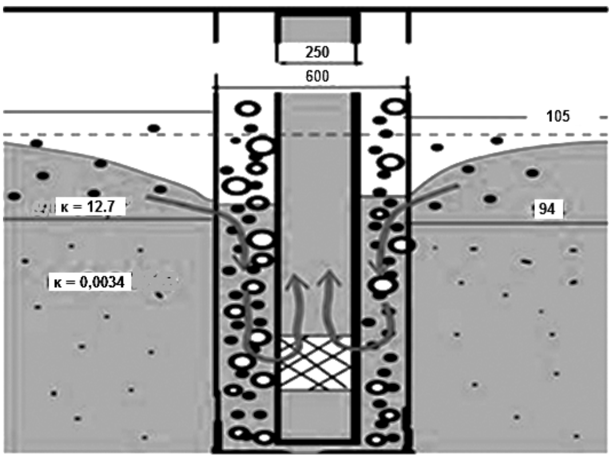

Fig. 2. Diagram of the water flow through gravel strew while conducting pumping tests

The filtration coefficient was determined according to the formula of Theis for non-stationary mode, m/day

$$K = Q \cdot \ln(2{,}25 \cdot a \cdot t/r2)/4\pi \cdot S,$$

where Q is the pumping flow rate, m^3/h; a is the coefficient of piezoconductivity of bed, m^2/h; t is time, h; r is given radius of the excavation, m; S is demotion, m.

Since the formula is not solved regarding filter coefficient explicitly, the method of iteration is applied, which results in a value of K = 13.2 m/day. This result almost coincides with the results of calculations of the pumping tests (12.7 m/day).

Considering laboratory and field studies the digital model of the area Motronivskyi placers was developed. It is based on publicly available "VISUAL MODFLOW". software package. Solving the inverse problem, we found the following filtration characteristics of the key rocks of the Miocene aquifer: 1) the deposits of the Poltava series – filtration coefficient 0.0034 m/day, Sarmatian sand in beams – 12.7 m/day, the rest of the area – 1.4 m/day. The water loss equals 0.1.

These parameters were adopted in prediction calculations of water inflow into a prospective quarry with the open method of drainage. The simulation results in the flow of water are not more than 1000 m^3/day, 50 m^3/hour. To pump this amount of water would not present any problems. However, to drain the deposits in Poltava series is not possible due to the lack of water loss.

The establishment of geotechnical properties of rocks was performed using analysis of geological documentation of the deposits in the Poltava series, where it is listed as sand. However, according to the engineering-geological classification of rocks according to grain-size composition, they are light dust loam [3].

Such water-saturated soils are thixotropic, under the action of dynamic loads or hydrodynamic pressure they deliquesce. In mining and construction, they are defined as the quicksand [3]. They outpour from the excavator bucket and the truck body. The walls of boreholes are become swollen.

This is confirmed by the fact that the selection of technological samples of titanium-zirconium ore was conducted from the wells using an auger, and notably 75 tons of sand was produced from bore No. 2 [3]. Under the action of gradient filtering on trickling sites, water depth career become swollen. As a result, a swollen niche is formed, which provokes the collapse of the thicker Sarmatian sediments lying above the ore deposits. In such rocks, the excavation of drainage ditches and sumps is not possible. The only possible way is the underwater excavation of ore.

The first industrial tests of the underwater mining method for Motronivskyi placers were held at the authors' suggestion in 2015.

To master the underwater technology a dredger of ZGM-2m 42·8 type has been installed with the following technical data: performance of the dredge pump for slurry 2000 m^3/h, for solid 300 m^3/h. Normal depth of excavation is 11 m, the maximum one reaches 18 m.

Fig. 3. Dredge in Motronivskyi open cast mine

The movement of the dredge is of an anchor type. Fig. 3 shows a photo of the dredger working in Motronivskyi cast.

The dredger is mounted in the pit with a depth of about 1.6 m from the water level and a volume of 9600 m^3 which was built using the dragline. The first test run of the dredge was held in late August, 2015. When trying to start the operation, the available supply of water in the pit was nearly exhausted within three hours and a dredger ran aground. The groundwater inflow was scanty and further dredging work was not possible. In this regard, the technology needs the reverse water supply and recharge from an external source. After that the pit was expanded and filled with water collected in a temporary pond. At a distance of about 300 m from the excavation, a temporary hydraulic-mine dump was built.

From October, 2015 the regular dredger works started. It was found that the sand of Sarmatian horizon was washed out quite effectively. The swath walls, which a dredger forms, are first held in a vertical position, but within a few hours they become swollen. The maximum angle of bottom inclination after passage of the dredge is 28–32°.

Mining ore while deepening the working body of the dredge below the base of Sarmatian sand is easy. By the end of November a trench was formed with a width of 100 m and a length of about 200 m. The depth map of the pit, which was formed as of 19 November, 2015, is shown in Fig. 4.

The maximum depth of excavation, reached on November 23, 2015, was 8 m at a distance of 50 m from the shore. The tangent of the bottom slope was equal 0.18, which corresponded to the angle of 10°.

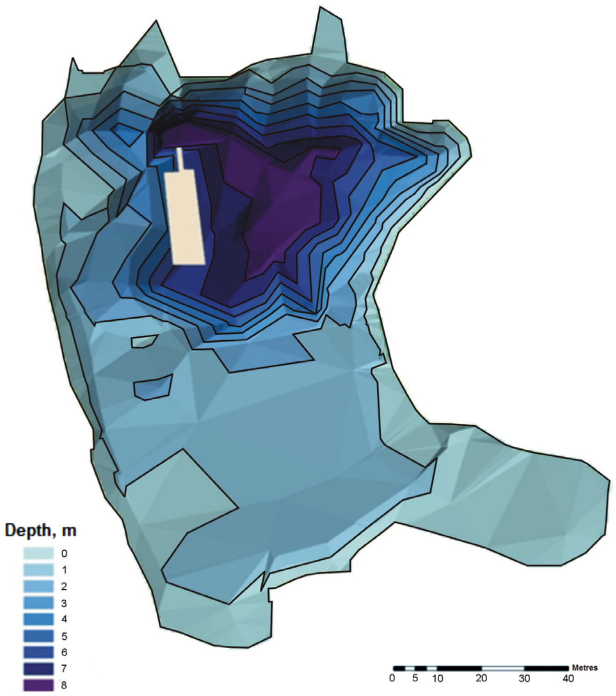

Fig. 4. The map of the open-cast mine depths in November 2015

While trying to deepen the excavation to the roof of the ore sand, the internal erosion takeaways occurred that led to the leveling of the pit bottom. Along the side on the surface cracks appeared, indicating a drawdown of thickness of Sarmatian sand over the flow core in the ore sand. Overall, the experience with the use of a dredger to conduct stripping and mining operations gave a positive result. Further, it is worth mastering the system practice determining the optimal producing cards size, organization of dredgers movements, etc.

After the establishment of the basic hydrogeological parameters of the Motronivskyi placer, the sequence of mining works was defined. According to the concept of the authors, the technology of overburden and mining minerals from the underwater condition can be implemented in several different ways.

According to the first method, the Sarmatian deposits are developed in a mechanical way, according to the second one in a hydromechanic way. To implement the first method it is necessary to construct a pit and reduce the water level in the roof of ore deposits using a dredger (Fig. 5). The dragline is placed on berm in the sandstones above the water level and protects the roofing of ore formation, creating a berm on the roof of the ore. The width of the berm must be such that with the displacement of the ore ledge, the line of the cliff does not reach the soles of the Sarmatian sands and with the collapses in the Sarmatian sands, the products of the collapse do not reach the sand ore.

The water level in the pit should be at a few decimeters below the roof of ore deposits, for visual inspection when cleaning the roof with an excavator. In the case of water level rise due to heavy precipitation, the dredge elevates a suction pipe and pumps the water into the reservoir. At the lowering of water level, water is supplied from the storage pond. The first method implementation is complicated by the fact that the Sarmatian sand below the water level also has properties of quicksand. Another negative factor is the large cost of transportation of Sarmatian sand inside the internal dump with dump trucks, due to the considerable distances, because the full development of the quarry will reach a width of over 1.5 km.

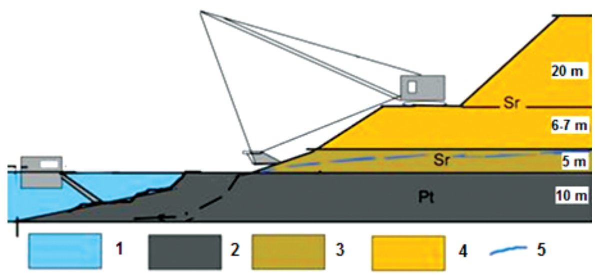

Fig. 5. The scheme of stripping and mining ore (method 1):

1 – water; 2 – ore; 3 – water-bearing Sarmatian sand; 4 – dry Sarmatian sandstone; 5 – aquifer

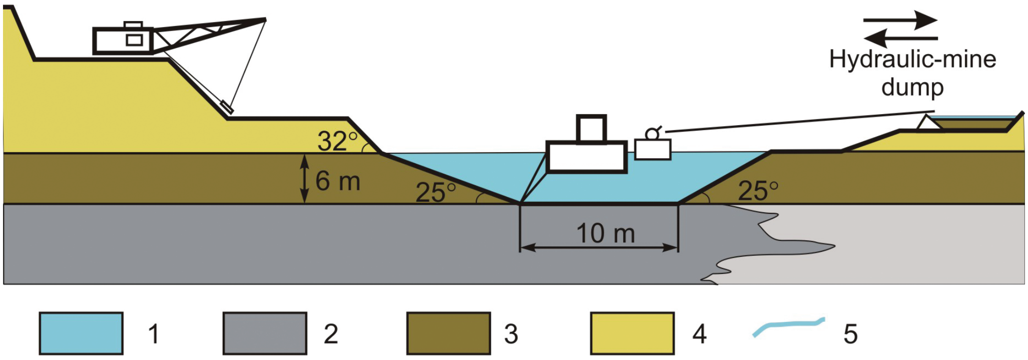

Fig. 6. The scheme of excavation of flooded Sarmatian rocks with a dredge: 1–5 are the same parameters (Fig. 5)

As for the second method, the flooded and later above-water part of the Sarmatian sand is also mined with a dredger (Fig. 6). The water level in the open cast mine corresponds to the natural one.

There are several stages in the development of mining operations. At the first stage, initial excavation, in which a dredger is installed, is constructed using the dragline. The dry part of the bench surface is left of minimum height that allows the vehicles to move. The dragline develops Sarmatian sand, which is delivered by road to the external dump. The dredger works out the Sarmatian Sands within the interval from water level to the roof of ore deposits. The slurry is fed to a temporary dump. Water from the hydraulic-mine dumps returns to the pit.

The first phase continues until the width of the pit bottom reaches 60 m. This width is determined from the condition that with the width of the berm of 30 m Sarmatian sand does not float to the extractive slaughter.

When a berm with a width of about 30 m between the mining face and the slope of Sarmatian sand is formed, we proceed to the second stage: to install a second dredger and begin the mining of the ore (Fig. 7). Extracting dredger forms a trench with a depth equal to the thickness of the ore seam and then expands it after the promotion of dredger, which performs opening.

Upon reaching the mining trench width of 30–50 m, the third stage of mining operations begins. At the same time the dragline mining of over-ore bench with Sarmatian sands is finished (Fig. 8).

The dredger is equipped with a giant monitor for wash-out of the surface ledge. The installation of a slurry pipeline is carried out for reclamation of Sarmatian sand in dump from the opposite side of the pit.

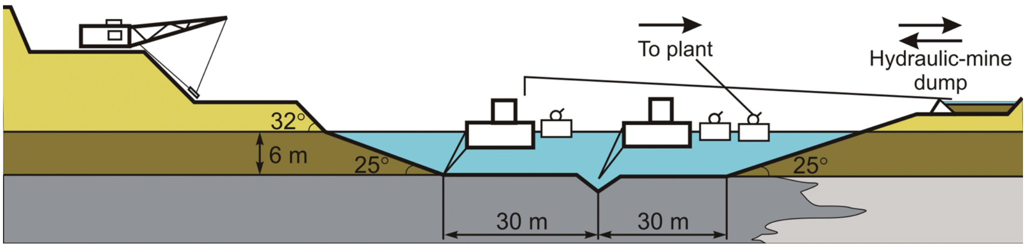

Fig. 7. The scheme of excavation of flooded Sarmatian sands and ore with dredges

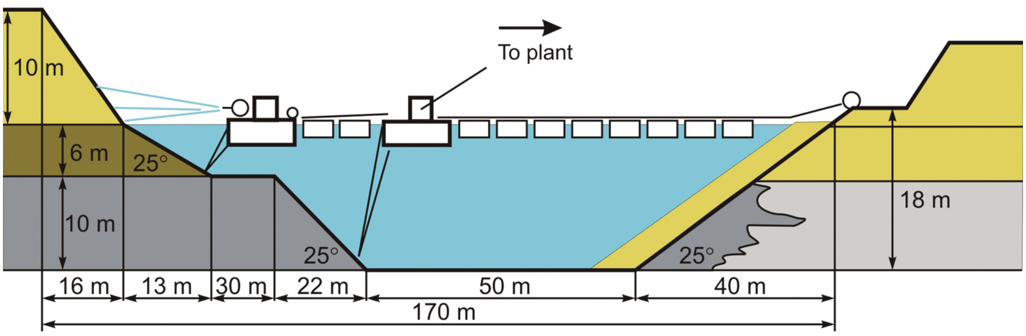

Fig. 8. Mining scheme for over-ore bench with Sarmatian sands and ore by dredges

The dredgers are moving in the direction of the front works. The worked-out area is filled with sand of Sarmatian horizon. The latter should serve as the basis for dumping rocks in the internal dumps in a mechanical way.

In order to make the height of the sand deposit greater than the excavation depth (from the water level to the soles of ore deposit), the first dredger is to develop a Sarmatian sand bench with a height of 16 m of which 6 m is under the water and 10 m is above the water.

The fourth stage of mining differs in the fact that overburden rocks which are developed for the road transport system, begin to store the rocks of the overburden into the mined-out space on the surface of washed beach with Sarmatian sand.

The fifth stage occurs after the storage of tailings on the surface of internal dumps becomes possible.

The research aimed at the use of the worked-out area and the internal dump pits for the placement of tailings started in Ukraine in the seventies of the last century. On the basis of scientific research [4], the project of the tailings dumps in the internal dump of Nikopol manganese pits was developed and in 1975 the first phase of the tailings was brought into the operation.

The technological scheme for the development of Irshanskyi ore field placers is given in [2]. After the formation of a sufficient space of mined-out areas, the refinement tailings are placed between the internal dumps. The latter are formed in a ridge shape dumps, which serve as fences dams. For conditions of Malyshevskyi titanium-zirconium deposits, these proposals are formulated in the patent [5].

The main conditions for placing the tailings on dumps surface are presented in the following way.

The dump relief is formed in such a way as to serve as tailings dams in the future. The tops of the dams correspond roughly marks a natural watershed.

Considering the fact that the volume of overburden is 4 times as large as the amount of waste, the dams should be formed with large margin of safety.

The building of dams and tailings alluvium is completed synchronously. The water discharge is provided through stoplog wells and pipes, which are laid under the dams.

As a result, landscape is formed from the system of the tailings which is similar to a system of beams blocked by dams.

Conclusions. The application of the proposed technology of mining the Motronivskyi placer allows refusing from draining careers using water depression wells. According to the bankable feasibility study developed by the "Vatenfall" company, the capital cost on the wells system construction for dewatering of the quarry would amount 10.5 million Euros. Moreover, there is no need for the construction of temporary dams in the beam to intercept and pump surface water with the subsequent dismantling of dams when the mining operations area approaches them.

The proposed technology allows rejecting the ore excavation of sand, transportation of ore to the "pulp" knot, with subsequent erosion, because ore is eroded directly by dredger. Instead of excavators and dump trucks dredges, which cost much less, are used.

Benefits from the introduction of underwater mining of minerals at the Motronivskyi placer include the reduction of costs on overburden of the Sarmatian sands and its storing in the basis of an internal dump. Instead of loading into trucks and transporting around the pit at a distance of about 2 km, Sarmatian sand in the form of slurry is pumped to a distance of 300 meters only. The power costs for pumping tailings from the mine to the concentrator decrease significantly provided the factory of preliminary ore dressing is installed on the pontoons. According to preliminary estimates, the conventional method being used, these costs reach 130 million kW-hours per day. When placing an ore dressing plant on the pontoons, the costs reduce by 10 times.

The obtained results are promising regarding the use in underwater mining of minerals, particularly when the level of groundwater in the Neogene-Paleogene aquifer remains unchanged. This helps to prevent the development cone of influence and depletion of groundwater resources. In the process of deposits exploitation the very fine-grained ore sand is replaced by coarser sand of the Sarmatian horizon in which additional reserves of groundwater are generated.

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Мета. Обґрунтування ефективного способу розробки родовищ титано-цирконієвих руд з великим рівнем обводнення на прикладі Мотронівської ділянки Малишевського родовища.

Методика. Визначення коректних гідрогеологічних параметрів Мотронівського розсипу шляхом спорудження свердловин у пониженнях рельєфу для встановлення середнього коефіцієнта фільтрації міоценового водоносного комплексу за графоаналітичним методом. Цифрова модель району Мотронівського розсипу складена на основі загальнодоступного пакету програм „VISUAL MODFLOW" з урахуванням лабораторних і польових досліджень. Обґрунтування ефективної технології розкриву та видобутку руди з-під води на основі отриманої цифрової моделі району виконувалося з використанням техніко-економічного аналізу.

Результати. Розроблені технологічні схеми підводної розробки корисної копалини Мотронівської ділянки дозволяють відмовитися від використання свердловин для осушення кар'єру, капітальні витрати на спорудження яких становлять 10,5 млн євро, відповідно до розробленого фірмою „Ватенфаль" банківського ТЕО. Також відбувається зменшення витрат на розкрив сарматських пісків і їх укладку в основу внутрішнього відвалу. Замість навантажування до самоскидів та транспортування навколо кар'єру на відстань біля 2 км, сарматський пісок, при запропонованій схемі, у вигляді пульпи перекачується на відстань до 300 м.

Наукова новизна. Отримані результати досліджень зі встановлення залежностей середнього коефіцієнта фільтрації міоценового водоносного комплексу від параметрів родовища перспективні до застосування при підводному видобутку корисних копалин, особливо у випадку коли рівень підземних вод неоген-палеогенового водоносного горизонту залишається незмінним.

Практична значимість. Визначення гідрогеологічних параметрів Мотронівського розсипу та створення цифрової моделі району дозволяє обґрунтувати вибір ефективної технології розкриву та видобування корисної копалини з раніше відомих екскаваторних і автотранспортних схем та схем видобування титано-цирконієвих руд з використанням земснарядів і гідротранспорту.

Ключові слова: *розсипні родовища, гідрогеологічні параметри, земснаряд*

Цель. Обоснование эффективного способа разработки месторождений титано-циркониевых руд с высоким уровнем обводнения на примере Мотроновского участка Малышевского месторождения.

Методика. Определение корректных гидрогеологических параметров Мотроновской россыпи путем сооружения скважин в понижениях рельефа для установления среднего коэффициента фильтрации миоценового водоносного комплекса по графоаналитическому методу. Цифровая модель района Мотроновской россыпи составлена на основе общедоступного пакета программ „VISUAL MODFLOW" с учетом лабораторных и полевых исследований. Обоснование эффективной технологии вскрышных работ и добычи руды из-под воды, на основе полученной цифровой модели района, выполнялось с использованием технико-экономического анализа.

Результаты. Разработанные технологические схемы подводной разработки полезного ископаемого Мотроновского участка позволяют отказаться от использования скважин для осушения карьера, капитальные затраты на сооружение которых составляют 10,5 млн евро, согласно разработанного фирмой „Ватенфаль" банковского ТЭО. Также происходит уменьшение расходов на вскрытие сарматских песков и их укладку в основу внутреннего отвала. Вместо погрузки в самосвалы и транспортировки вокруг карьера на расстояние около 2 км, сарматский песок, при предложенной схеме, в виде пульпы перекачивается на расстояние до 300 м.

Научная новизна. Полученные результаты исследований по установлению зависимостей среднего коэффициента фильтрации миоценового водоносного комплекса от параметров месторождения перспективны к применению при подводной добыче полезных ископаемых, особенно в случае, когда уровень подземных вод неоген-палеогенового водоносного горизонта остается неизменным.

Практическая значимость. Определение гидрогеологических параметров Мотроновской россыпи и создание цифровой модели района позволяет обосновать выбор эффективной технологии вскрышных и добычных работ из применяемых ранее экскаваторных и автотранспортных схем и схем по добыче титано-циркониевых руд с использованием земснарядов и гидротранспорта.

Ключевые слова: *россыпные месторождения, гидрогеологические параметры, земснаряд*

Рекомендовано до публікації докт. техн. наук А. Ю. Дріженком. Дата надходження рукопису 22.11.15.