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Engineering of Complex Structure Apatite Deposits and Excavating-Sorting Equipment for Its Implementation

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Development of Oshurkovskoye apatite deposit with conventional methods, using drilling, blasting and then processing of extracted ore by means of flotation and construction of hydraulic structures to store wet tailings, turns out to be impossible, as the reservoir is located in a special ecological zone of Transbaikal; moreover, the deposit has a complex geological structure and a low grade of valuable component in the orebody. Refinement of the mineral product occurs primarily during its processing; however, ore grade can already be controlled in the process of its extraction. Advancement of technical facilities opens up new opportunities of selective mining for complex structure deposits. The purpose of this research is to create a technology, which will upgrade the quality of mineral substance, fed to the processing plant, directly at the extraction stage. The paper proposes a technological development scheme for Oshurkovskoye deposit using an excavating-sorting complex containing a transport-sorting facility and a measuring unit for estimation of the grade in a milled rock mass; it allows to separate a rich fine fraction of substandard ore, which under conventional mining practices would have been sent to the stockpile of temporarily substandard ore. Separation of fine fractions of apatite ore in the transport-sorting facility allows to reduce dusting during production and cuts the losses of valuable component, associated with aeration of fine fractions during loading and transportation of the rock mass. Positioning of oversize material in the open trench with its subsequent selective extraction by the loading machine facilitates non-stop operation of the mining-sorting equipment, which provides an increase in the productivity of mining operations.

Key words: excavating-sorting complex; rock mass; sorting; processing; valuable component; navigation system; selective loading

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Introduction. In the Far East of Russia, the majority of agricultural land is characterized by acidic reaction of the environment and low provision with mobile phosphoric acid, therefore improvement of agrochemical properties of the soil by introducing phosphates has a positive impact on the crop yield. The absence of nearby plants that mine and process phosphates compels producers to transport them from the western part of the country or from abroad. Hence, there is a need for local production of phosphorous fertilizers. It also should be noted that geographic and economic position of the Far Eastern south allows to develop such industry and in a longer run to focus it on export shipments (North China, Japan), as the favorable infrastructure is in place. There is a number of explored apatite deposits in the Far East and Transbaikal, including the large ones – Oshurkovskoye and Seligradskoye. Seligradskoye apatite deposit is located in the southern part of the Republic of Sakha (Yakutia), 30 km from the town of Aldan, average grade of the valuable component – phosphorous pentoxide P_2O_5 – equals 6.7 %, apatite ore reserves are estimated at 1,277 million tons [7]. Oshurkovskoye deposit is located in the Republic of Buryatia, 12 km to the north-west from Ulan-Ude, on the left shore of Selenga River, ore reserves of the deposit are estimated at 996 million tons [9]. In the Amur Oblast and Khabarovsk Krai several small apatite deposits have been studies, some of them have an advantageous proximity to the Baikal-Amur Mainline. A production license has been received for one of these deposits, but its development has not started yet due to a low grade of the valuable component in the ore (4.02 % P_2O_5).

Problem statement and status of the issue. Development of those apatite deposits in the Far East and Transbaikal that have a geographically advantageous location is held back by both low grade of the valuable component and complex geological structure of the reservoirs. In order

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to maintain planned production volumes using conventional technologies under initially low and subsequently deteriorating ore quality the plant will have to extract and process huge amounts of rock mass. Apart from significantly increasing the cost of the market product due to greater consumption of toxic agents and larger quantities of finely-ground tailings, treatment of low-grade ores of variable composition leads to additional environmental impact in the region of mining operations.

Oshurkovskoye deposit is the most promising for development; however, its exploitation is held back by several significant constraints related to its location in a special ecological zone of Transbaikal [1, 3]. Oshurkovskoye deposit is composed by the rocks of variable composition, contacts between them are gradual and permeative. In the deposits, apatite is one of the rock-forming minerals for almost all types of rocks [4]. Its distribution in the rocks mass is very irregular, the content varies not only in the rocks of different composition, but also in the same ones, which happens due to post-magmatic processes. Average P_2O_5 content in the standard ores of Oshurkovskoye deposit equals 4.37 % at the cut-off grade of 3.5 %, given that ore bodies can have regions of substandard ore with P_2O_5 content from 1 to 3.5 % (on the average – 2.84 %). The most part of the rock mass is presented by soft ores with compressive strength around 30 MPa [3]. Areas of standard and substandard ores form continuous ore-rock zones of various shapes, sizes and structures (Fig.1).

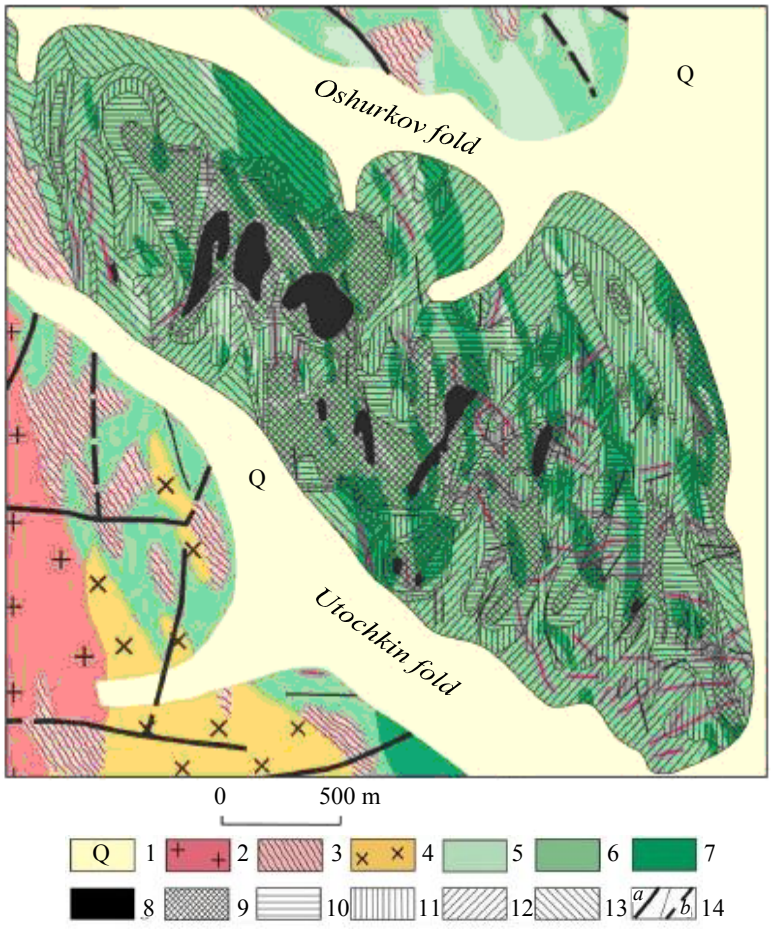


Fig.1. Isoline plan of P_2O_5 content at Oshurkovskoye deposit according to S.V.Kostromin (1964)

1-7 – rocks (1 – quaternary deposits, 2 – leucocratic granites, 3 – metarocks (gneiss, migmatite), 4 – syenites (marginal granite facies), 5 – leucocratic gabbroids, 6 – mesocratic gabbroids, 7 – melanocratic gabbroids); 8-13 – P_2O_5 content (8 – 5 % and higher; 9 – from 4 to 5 %; 10 – from 3.5 to 4 %; 11 – from 3 to 3.5 %; 12 – from 2 to 3 %; 13 – from 1 to 2 %), 14 – fault lines (*a* – registered, *b* – predicted)

Irregular distribution and low grade of the valuable component requires selective extraction of the rock mass with the minimal possible addition of adjacent rocks. Existing environmental constraints rule out the possibility to develop the deposit by drilling and blasting, as well as to enrich extracted ore using conventional method of flotation and formation of hydraulic structures to store wet tailings [3]. A solution to this problem is development and implementation of advanced technologies of ore mining and processing that provide complex and full extraction of the valuable component, reduce energy consumption and costs, minimize the losses and environmental consequences of the operations [2, 6]. Up to this day there are systems of ore quality management based on equalization or separation principles [11, 14], which have been implemented at several Russian and foreign plants. There are scientific studies that take into account existing constraints at Oshurkovskoye deposit and propose to develop it using mechanical production tools, like sur-

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face miners [9], and to enrich the obtained mineral mass in a dry process of getting rough apatite concentrate [3] and applying the effect of vibrational pseudofluidization [13, 16]. It is suggested that after regrinding, obtained rough concentrate will be brought up to a marketable condition at Transbaikal flotation plants that have available production capacities.

Quality enhancement of the mineral mass is primarily achieved at the processing stage; however, ore grade can already be managed at the stage of its extraction [10]. Thanks to technological advancement, the possibilities of selective mining at complex structure deposits expand. Surface miners are successfully applied in the development of complex structure deposits of coal, limestone, oil shale, phosphates, etc. [5, 8, 17, 20].

Thus, a transition from bulldozer-loosening equipment and wheel loaders to a surface miner in the course of extracting two low-power layers (0.35-1.0 m each) at Jeroy-Sardinskoye phosphate deposit in Uzbekistan resulted in a reduction of losses and ore dilution from 10 to 9 % and from 22.4 to 15 %, respectively [5]. Performed ore sampling in two stockpiles demonstrated that the ore extracted with a new technology had P_2O_5 content from 19 to 21 %, whereas the grade of the valuable component in the ore, extracted with a conventional technology, amounted to 13 %.

In the study [9] in order to control ore grade of Oshurkovskoye deposit it is proposed to use a surface miner and an X-ray radiometric measuring unit, installed above the discharge conveyer. It is suggested that for each portion of the rock mass (dump truck capacity) no less than 60 measurements should be performed to calculate the average P_2O_5 content in the loaded rock mass, after which the truck receives the unload address. The disadvantage of this technology is gross loading of the rock mass with various grade of the valuable component in to the truck body, where it gets mixed; thus the measuring unit only provides a more accurate estimation of the average grade in the rock mass portion.

The general disadvantage of the technology relying on surface miners and dump trucks is that, as the trucks replace each other, the miners have an idle period, which takes up from 10 to 20 % and more of the milling time [19], as well as dusting and loss of fine fractions due to aeration in the process of milling, loading and transportation (Fig.2). At the same time various studies confirm that ores of many minerals have the highest grade of valuable component in their fine fractions.

Thus, examination of a technological sample of raw apatite-nepheline ores from the deposit Oleniy Ruchey in Murmansk Oblast, –200 mm in size and weighing 2 tons, has demonstrated an uneven distribution of the principal component in fractions of various size. Average grade of the technological sample was 10.1 %, in the fraction above 20 mm average P_2O_5 content was 5.5 %, at the same time in the fraction –20+10 mm apatite content reached 16.5 %, in the mining residue of –10 mm there were 18.05 % of apatite [6]. Examination of a similar technological sample of poor apatite-nepheline ores from Oleniy Ruchey demonstrated that under average apatite content of 5.4 %, in the fraction –200+20 mm



Fig.2. Surface miner development of a phosphate deposit in Uzbekistan

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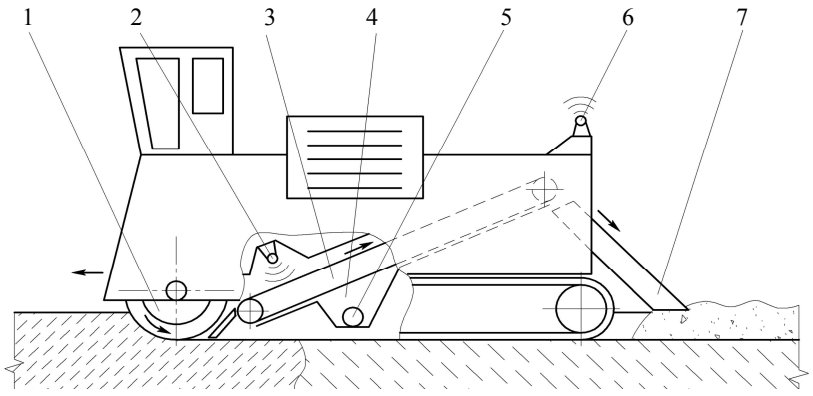


Fig.3. Development of a complex structure apatite deposit using excavating-sorting equipment

average P_2O_5 content was 3.66 %, in the fraction –20+10 mm – 4.16 %, in the mining residue –10 mm – 7.22 % [6].

The aim of current research is to develop a technology that will enhance the quality of extracted mineral substance due to a deeper selective excavation and increase extraction rate of the valuable component due to separation of a rich fine fraction of substandard ore, which under conventional production technologies would have been sent to the stockpile of temporarily substandard ore.

Research results. Currently throughout the world occurs a global development of automated systems for managing mining, transport and other types of equipment. Development of automation and navigation systems in the process of open-pit mining enables significant transformation of technical and engineering principles of mining plant operation [12, 15, 18]; using satellite navigation systems GPS and GLONASS, special devices allow to register and map the movements of mining equipment.

The Institute of Mining, Far Eastern Branch of RAS, proposes an engineering plan of Oshurkovskoye deposit development using an excavating-sorting complex, including the milling element 1, measuring unit 2 (its operation based on X-ray radiometric method [9]), transport sorting device 3, storage unit 4 and system of pneumatic transport 5 to feed the undersize product into the vehicle container, as well as navigation system 6 and tray 7 to lower the oversize product into the open trench (Fig.3).

Transport-sorting equipment 3 is aimed at separation of rich fine fractions of the apatite ore. In the standard ore occurs separation of the fraction $-M_s$ (–20 mm), in the substandard one – of the fraction $-M_{ss}$ (–10 mm). The width of discharge slits in the grid of transport-sorting machine 3 is adjusted automatically after reception of the signal from the measuring unit 2, as the content of the valuable component is estimated in the coming rock mass.

The excavating-sorting equipment develops the complex structure reservoir layer by layer with its milling element (Fig.4). After milling, the rock mass is fed to the transport-sorting machine, where quality management of the ore grade is performed with the help of a measuring unit. When standard apatite ore is extracted, slit width of the grid is adjusted for the undersize product of $-M_s$ fraction. When substandard ore is extracted, the slit width is decreased to separate undersize product of the size $-M_{ss}$. In case of empty rock extraction, the slits of the grid are altogether closed and separation of the undersize product stops. Undersize product falls into the storage unit, from where by means of pneumatic transport it is transferred into the vehicle container and fed to the processing plant.

Oversize product, obtained in the extraction process of standard and substandard ores, as well as empty rock, is layer by layer filled from the tray to the trench. Simultaneously location of different sorts of undersize product in the trench is mapped with the use of a navigation system. The loader, also equipped with elements of navigation system, takes into account the map and performs selective loading of the standard ore, substandard ore and empty rock into dump trucks, which transport the material, respectively, to the processing plant (using dry technology

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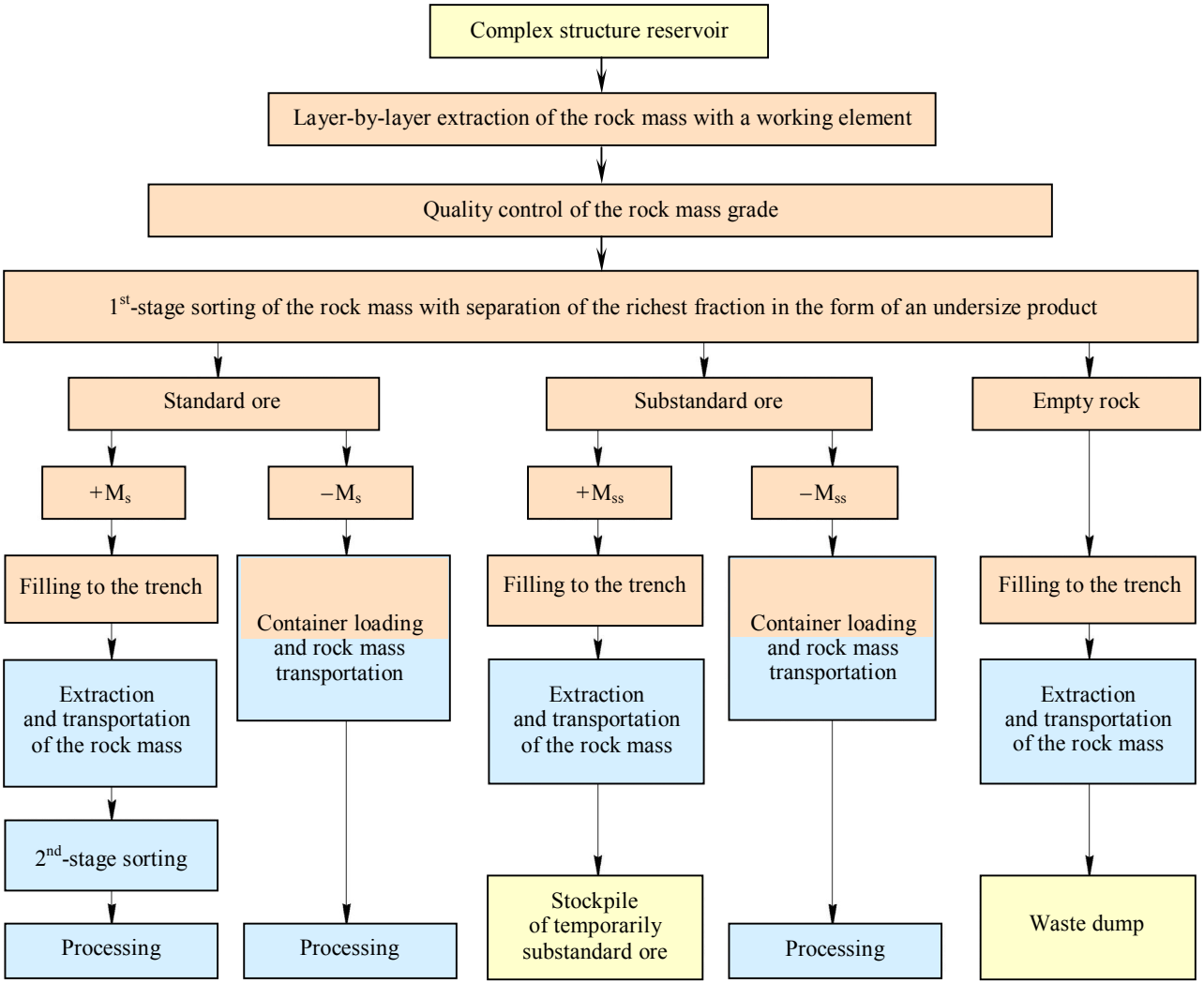


Fig.4. A diagram for development technology of complex structure apatite deposit using excavatingg-sorting complex and initial processing of the mineral material

of getting rough apatite concentrate), to the stockpile of temporarily substandard ore and to the waste dump. Judging by the presence or absence of fine fractions in the rock mass, filled in the trench, the loader operator can have an additional parameter of visual control over the shift in rock mass quality.

Conclusion. Proposed technology using excavating-sorting equipment allows to enhance the quality of mineral material extracted from complex structure deposits directly at the mining stage. Besides, it allows to separate a fine fraction of substandard ore, rich in the valuable component, which under conventional production technologies would have been sent to the stockpile of temporarily substandard ore. Separation of fine fractions of apatite ore in the transport-sorting device will allow to reduce dusting during production and to cut the losses of valuable component associated with fine fraction aeration during loading and transportation. Positioning of the oversize product in the open trench ensures independence of rock milling and transportation, which means that excavating-sorting complex can function non-stop and does not have to wait for truck replacement and spotting. Proposed technical and engineering solution allows to raise the productivity of mining operations and to reduce the number of machinery, engaged in the production cycle of subsequent processing of the mineral material, which in its turn cuts the costs of apatite concentrate and increases profitability of mining operations.

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