UDC 622.271.1:622.236.52

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IMPROVEMENT OF A TREATMENT PROCESSES OF HIGH-CLAYEY GOLD-BEARING PLACERS

Characteristics of the placers with increased clayiness of gold-bearing bed and high content of fine and thin gold of the Far Eastern region, as well as technological approaches to processing, including the main process – disintegration, are analyzed. It is established that a reagentless gravitational working up based on generation of acoustic vibrations in fluid media is promising and requires its development. Energy-dispersive microanalysis by means of a scanning electron microscope, phase analysis using a diffractometer, as well as granulometric, dispersed and acoustic analyses have been applied to clay conglomerates selected at a high-clayey section of the deposit under consideration on the Malaya Nesterovka River in Primorskyi Krai. The presence of a wide range of noble metals, including gold and silver, rare earth and other elements was revealed. The data obtained on the composition and properties of clay conglomerates made it possible to determine the need for a more intensive process of the sand micro-disintegration to extract fine and thin particles of valuable components based on expanding the use of gravity technologies. It is noted that the known technologies would not ensure effective extraction of valuable components. A gravitational technology with cavitation reactors, which provide a power inputs reduction by several times in comparison with known devices, is proposed and validated. The hydrodynamic generator design is developed based on the concept of the fluid flow kinetic energy converting into the energy of hydroacoustic vibrations and jet streams of mineral hydromixtures in constrained conditions taking into account the similarity theory in modeling the cavitation processes. The proposed technology will reduce in-process losses of precious and other valuable metals, increase profitability and environmental safety in comparison with known processes.

Keywords: *high-clayey sands, energy-dispersive microanalysis, phase analysis, microdisintegration, cavitation, hydrodynamic generator, fine and thin gold.*
DOI: *10.17580/em.2020.02.07*

Based on multiple classification one can distinguish the objects of gold placer deposits of the Far East region, involving of which into operation is restrained by the insufficient level of equipment and mining technologies because of high content of fine and thin gold and increased clayiness of gold-bearing bed of sands [1–2]. According to geological research, gold-bearing placers of the Russian Far East contain in some cases up to 90 % of the clay fraction. The highest content of clays is found in many deposit plots in the flood-lands of the Nagima, Ulunga Rivers and the Yernichny, Genrikhovsky, Kutum, Bolotisty, Besheny, Kolchan and some other streams. On the objects of Kolchan, Kamenisty, Kedrovka, Rokosuevsky, Angochikan, Kaygachan, Blagodatny-Mainura, Maiskii deposits, the content of fine gold with fraction size < 0.5 mm make up more than 90 %, in some cases with a predominance of fractions size < 0.3 mm for the most.

Placer deposit, located in the southeast of Khabarovsk Krai within the Sooli-Tormasin ore zone, has a swampy stream, and the lower swampy block is composed of bottom tuffaceous-silt sandstone with rock fragments covered by clays, tuff conglomerate and alluvium. Geological sections include low-resistance clays and clay-cemented rock fragments. Through electrotomography shooting, it was found that the clay bed contains alluvial gold [3]. The use of imperfect technologies for drag and hydraulic mining of gold-bearing sands leads to significant losses of fine, thin gold and that in intergrowths [4]. Special difficulties are produced by combination of high clayiness with high content of extremely fine and thin gold.

Currently, industrial devices PGSh-50 (ПГШ-50) with additional sluices and drag plants of standard type are widely used at gold-bearing placer deposits, where losses of fine and thin gold vary from 60 to 90%. Known installations that combine the disintegration and screening processes require limiting maximum size of the processed material and reducing operational costs [5]. Devices that generate acoustic vibrations in fluid media by means of the fluid flow excitation of rods, plates and membranes or as a result of a liquid jet modulation are proposed for mastering [6–14].

There are known the technologies of gold sorption by coal [15], breaking apart of the frozen clay rock under influence of chemical reagents and aqueous medium [16–18], various processes of acting by chemically active substances, including soda-halide mixture and sodium hexapolyphosphat in the presense of soda for the size of –0.071 mm and subsequent hydrocyclone acting [19, 20].

Object and methods of research

Recently there is not enough analytical material amassed to evaluate the host rocks of high-clayey sands of placers of precious and rare metals, which would allow one to justify approaches to solving the problem of treatment based on gravitational processes, including hydrodynamic effects. The purpose of this study is to analyze the composition and properties of host rocks of the high-clayey area in the Malaya Nesterovka River flood-lands in Primorsky Krai to create approaches for improving treatment process, which reduces the loss of small particles of valuable components. It was ascertained that alluvial deposits of the left part of the river valley, overlaied by a slope of gravelly-loamy material are the most metal-rich. The explored placer in the plan has a ribbon-like shape, with a length of about 3 km; the width varies from 20 to 180 m. Gold-bearing bed of capacity 0.4–2.0 m is bounded to the lower interval of alluvial deposits and the upper part of the weathered basement rocks, penetrating the rocks of the balsa up to 1 m. The metal distribution in plan and vertically is extremely nonuniform; the content varies from fractions of an integer to as much as the first g/m^3. The average gold fineness of the placer is 930. The gold along the entire length of the placer is well rounded, the grain size along the lines varies from 1.29 to 2.4 mm, averaging at 1.72 mm. The color of gold grains is bright yellow, rarely with touches of brownish and gray color; the shape is very diverse: cloddy, cake-shaped, amebiform, drusy; the surface is pitted.

Energy-dispersive microanalysis of rock samples was performed using a JCM-6000 PLUS NEOSCOPE (JEOL, Japan) scanning electron microscope. The systematic inaccuracy of the scanning electron microscope when meeting all the requirements, including adjustment and checking functioning of the elements, lies in the range of 0.01–0.001.

Phase analysis with the use of a DRON-7 diffractometer (NPP "Burevestnik", St. Petersburg) was performed in order to determine the clay composition of the samples. Tube voltage was 40 kV, discharge current was 20 μA, the scan step at the angle of 2Theta is 0.05°. The sensitivity to the substance content of a DRON-7 diffractometer is 2–3%, the beam angle error is –0.3°. To identify the lines of X-ray spectra, the PDWin software package (NPP "Burevestnik") was used. Granulometric analysis of the sands was performed by standard sieve method. Mass of fractions (+2; –2 +1; –1 +0.5; –0.5 mm) was determined on a ONUS Scout Pro SPU202 (Mettler Toledo, China) laboratory electronic scales with systematic inaccuracy of ±0.001 g. The source mass of the samples was 302–314 g. The dispersibility of the fraction < 0.5 mm was determined using the Fourier spectrum in a mineral hydromixture medium by means of an Analysette 22 MicroTec Plus (Fritsch GmbH, Germany) laser diffraction microanalyzer, which uses physical principle of electromagnetic wave scattering to determine the particle distribution by size. To recognize elastic characteristics of the sands, the velocity of longitudinal waves in samples with natural humidity was measured by through scanning with the use of a "Pulsar–1.1" device (NPP "Interpribor", Chelyabinsk). The working frequency was 60 kHz. The experiment has been carried out at an average air temperature of 22° C and relative humidity of 72 %. The density and humidity of the samples have been determined by standard methods, and natural humidity of the samples was determined according to the State standard GOST 5180-84.

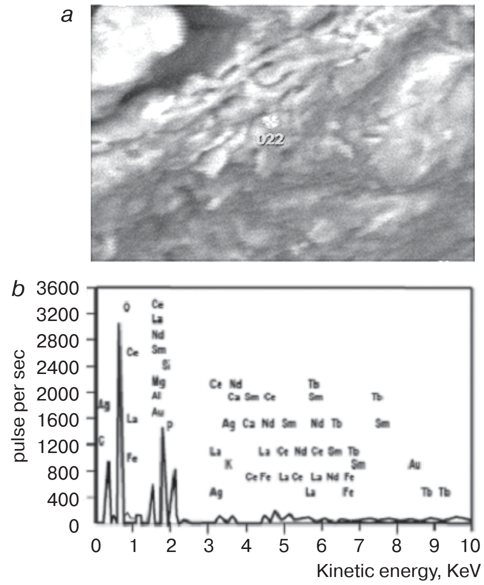

Fig. 1. Data on the test sample:
(*a*) image of the scanned surface; (*b*) spectrogram of trace elements

Results of experimental investigations of the samples

According to energy-dispersive microanalysis of the samples, there have been revealed trace elements of a wide range of noble metals, including gold and silver, as well as rare earth and some other elements: Fe, P, Si, Ca, K, Al, Mg, Hg, O, C (**Fig. 1**). When determining the sample composition by phase analysis, the presence of the following minerals hass been established: nontronite $Na_{0.3}Fe_2Si_4O_{10}(OH)_2{\cdot}nH_2O$; gerasimovskit $(Mn,Ca)(Nb,Ti)_5O_{12}{\cdot}nH_2O$; qilianshanite $NaH_4(BO_3)(CO_3){\cdot}2H_2O$; albite $Na[AlSi_3O_8]$, amphibole $(Na,Ca)Al(Si,Al)_3O_8$; muscovite $KAl_2[AlSi_3O_{10}](OH)_2$; jacobsite $Mn_{0.98}Mg_{0.006}Fe_{2.009}O_4$; hydromicas celadongreen (glauconite) $2K_2O{\cdot}3MgO{\cdot}Al_2O_3{\cdot}24SiO_2{\cdot}12H_2O$; tazheranite $(Zr,Ca,Ti)O_2$; almandine $Fe_3Al_2(SiO_4)_3$; quartz SiO_2. Nontronite of a ferriferous type is a mineral from montmorillonite group – vermiculite; it is characterized by weak water permeability and swell greately forming a crust with the highest durability under moist condition.

The presence of clay minerals that form difficult-to-break structural bonds, as well as the revealed predominance of iron compounds in the samples, stipulates complication of the process of deep disintegration of sands up to microlevel. The findings of the granulometric composition studies have showed an increased content of fractions with a size of <0.5 mm in all the samples, which amounted to 80–86% of the total sample mass. According to dispersion analysis, the content of particles with a diameter <300 μm is 99%, that <200 μm is 98%, that <5 microns is 95%.

To evaluate the destruction of structural bonds of clay conglomerates, the elastic characteristics were determined experimentally and analytically. From the entire sampling, the share of maximum values of the shear modulus of the studied sands is 60% (1.783 GPa). The wave resistance value of the sands varies in the same ratio. Taking into account the increased values of the sand elastic characteristics it becomes obvious that total destruction of rigid structural bonds by known methods will be carried out with low effectiveness.

Recommendations on practical application of results of the work

Processing of sands is usually fulfilled using a hydroelevator sluice device (PGSh). Considering, however, involving into development the man-caused grounds with low gold content and increased content of fine and thin fractions, there also has been considered the jigging enrichment technology with direct jigging of sands of size < 15 mm, pre-disintegration and screening of sand in a trommel scrubber washing macine. The washing complex includes: a loading tray; a trommel scrubber; the main jigging machine MOD-2M; a cleaner jigging machine MOD-1M; a concentrating table SKO-7.5. A concentrating table SKO-0.5 is a part of the finishing jig at the placer gold-concentrating site (GCP). During processing, the original sands with a size of –300 mm are fed to the receiving bin, then into the trommel scrubber, where they are disintegrated to the following classes: –300+50 mm; –50+15 mm and –15 mm. The class –300+15 mm is sent to the pebble dump, and the class –15 mm is fed to the primary concentration into a MOD-2M

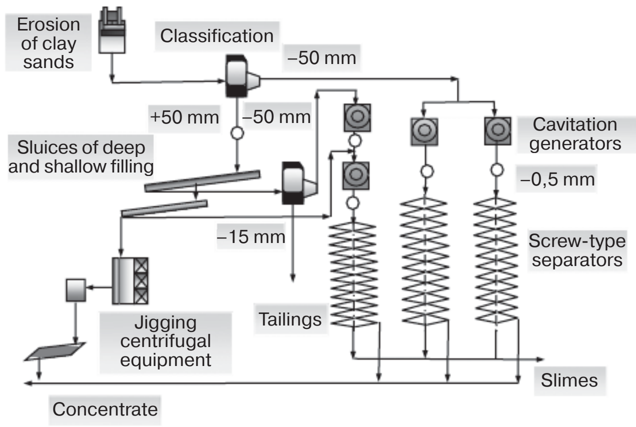

Fig. 2. Scheme of processing of high-clayey sands with cavitation generators

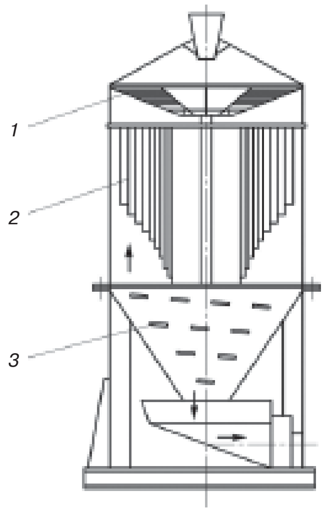

Fig. 3. Hydrodynamic cavitation generator for microdisintegration:
1 – flow turbulator; *2* – stationary plate elements; *3* – confuzator zone with cavitation thresholds

jigging machine, then it follows by gravity flow to the cleaner operation into a MOD-2M jigging machine. The oversize of jigging machines (lixiviation tailings) is sent to the dump, and the undersize concentrate with a size of –5 mm is fed by gravity flow to a concentrating single-deck table SKO-7.5. Rough concentrate and final tailings are obtained on the table. Rough concentrates from the tables are collected and sent to GCP for processing on the finishing table SKO-0.5. In some cases, the dilution of sands during mining and preparatory work is up to 40 %, and the planned losses with an average gold content amounts from 492 kg/mg^3 to 1 kg. Other known technical means for preparing clay sands for processing will not also provide an effective disintegration of high-clayey sands for the subsequent extraction of fine and thin gold particles. Given that the investigations have established high content of difficult-to-break montmorillonite clays in the host rocks, as well as an increased content of fine and thin gold, the use of traditional technologies during processing will not provide the required loss reduction as applied to fine and thin fractions of valuable components. Cavitation, a developed turbulence, hydraulic shocks and some others can be attributed as the factors that intensify hydrodynamic processes. The direction of research based on the initiation of cavitation phenomena in hydromixtures that provide microdesintegration of the solid component is at present of particular importance. There are known developments in various areas of production, which are based on the cavitation initialization by means of reflectors and flexible obstacles in the form of mechanical resonators that form parametric resonance vibrations in a fluid medium. It is interesting to develop a multi-stage hydroblow and cavitation device for fine grinding in the flow mode of rebeillous ores based on the hydroblow mode created by constrained conditions between the stator and the rotor, which have slots in the side walls. This design will ensure grinding of material of rebeillous ores and cleaning rejects when transferring out of balance ores to the category of technologically processed ones [21]. However, by virtue of certain conditions, including the need to build up not only powerful electric power installations that can ensure destruction of mineral particles, but also the less energy-intensive ones, this development does not meet the necessary requirements. Following the path of development of less energy-intensive installations, V. P. Terekhin with co-authors proposed a device [22] that initiates acoustic vibrations in a fluid medium due to its movement about flexible obstacles equipped with cavitators mounted on mechanical resonators with the formation of a pulsating cavitation zone. However, the low efficiency factor, stipulated by geometric dependence of the excitation conditions of vibrations and the inability to use high flow rates for processing media, limits the use of the device for disintegrating mineral components of hydromixtures. It should be pointed out that the initialization of cavitation by modulating the hydrodynamic outflows of jets and flows of mineral hydromixtures with the use of stationary elements is currently being developed [23, 24].

For deep processing of rebeillous material of placer deposites, the Institute of Mining of the Far Eastern Branch of the Russian Academy of Sciences has developed the systems that simulates the processes of multi-stage acoustic-jet disintegration of mineral component of the hydromixture [24]. The scheme of enrichment of high-clayey sands with high content of fine and thin gold and other valuable components includes cavitation reactors that provide resonance acoustic phenomena in the hydraulic flow (**Fig. 2, 3**). The proposed scheme, makes it possible to separate by double classification the clay aggregates containing fine and thin particles of valuable components, and destroys the structural bonds of clay aggregates at the microlevel by means of cavitation-hydrodynamic generators (See Fig. 3). The generators separate particles at the microlevel and in combination with screw locks reduce the losses of fine and thin fractions of precious metals and at the same time ensure environmental safety of extraction of valuable components. At the same time, the consumption of chemical reagents is reduced; the effectiveness of their impact rises in the conditions of increasing the specific surface area of particles of valuable components. One example of such an impact is the proposed technology of initialization of microdesintegration of mineral component of the hydromixture, which includes a high-speed jet supply to the zone of an evasion stack located in the upper part of the hydrodynamic generator (see Fig. 3), and subsequent treatment of the hydromixture under active hydrodynamic actions by means of a flow turbulator *1* [24]. Vertical stationary plate elements *2* placed inside the housing provide deeper disintegration of the hydromixture mineral component to the microlevel with the conversion of the liquid flow kinetic energy into the energy of hydroacoustic vibrations initiated by cavitation.

For the cross-sections between vertical stationary plate cavitation elements *2* (see Fig. 3) the Bernoulli equation is valid [25]:

$$\rho\,(V^2/2) + P = C, \qquad (1)$$

where ρ is a fluid density; V is a velocity of flow; P is a liquid pressure in the flow; C is a constant.

The sum of the kinetic energy density and pressure in the flowing liquid is constant. The narrower the slits, the greater the velocity in them and the lower the pressure P, which causes the formation of many discharged areas inside the generator that initiate cavitation. It is theoretically proved that cavitation is based on the process of liquid rupture. The density of a perfectly pure liquid is calculated by formula [26]:

$$P = P_o \frac{2.2\cdot 10^8}{\sqrt{\lg A\tau}} \sqrt{\frac{\sigma^3}{T}}, \qquad (2)$$

where P_o is a liquid saturated vapor pressure, kgf/cm^2; σ is a surface tension, kgf/cm; $A = 10^{14} \div 10^{36}$ is a pre-exponential factor, $(s\cdot cm^3)^{-1}$; τ is an average waiting time for the liquid break in the liquid volume of 1 cm^3; T is absolute temperature, K. Many studies have found that the strength of a real liquid saturated with gases and solid mineral inclusions is much lower than the calculated one. And since the mineral hydromixture has higher density compared to that of an ideal liquid, the value of the first term in formula (1) will increase, and the value of the second term – pressure – will decrease to a critical level, providing a rupture of the flow entirety in three zones of a hydrodynamic disintegrator, including one in the middle zone with stationary plate cavitation elements. The influence of a hydromixture under working pressure on the edges at the entry to the zone of cavitatating plates *2*, creates microturbulization. Additional jet separation with increase in cavitation-acoustic acting on the hydromixture mineral component to obtain a given average value of the volume density of the hydrodynamic impact on microparticles also occurs at the outlet of a hydrodynamic generator by accumulating the flow in the confuser zone with cavitation thresholds *3* (see Fig. 3), installed in a spiral. The proposed technology with the use of cavitation plants able to disintegrate high-clayey sands up to the microlevel is significantly more efficient than the traditional ones.

The use of installations based on hydrodynamic action with the inclusion of wave and oscillatory processes initiated by the working environment pressure under constrained conditions without additional power inputs when working out the high-clayey raw materials of polymineral deposits will allow to initiate microdisintegration with a significant reduction in losses of valuable components and operating costs, as well as to increase profitability, process efficiency of manufacturing as well as environmental safety.

Conclusions

As a result of energy-dispersive microanalysis, as well as phase, granulometric, dispersion and acoustic analysis of conglomerates selected at the high-clayey section of the Malaya Nesterovka River in Primorsky Krai, the presence of a wide range of noble, rare-earth and other elements was revealed. The data obtained on the composition and properties of clay samples has made it possible to determine low intensity of the microdisintegration process based on the known gravity technologies. To solve the problem of microdisintegration of high-clayey sands in order to extract gold and other valuable minerals, a technology that includes less energy-intensive hydrodynamic impact initiated by cavitation effects can become a more environmentally and technologically effective means. The proposed gravity technology with cavitation reactors will provide significant energy savings compared to jigging machines and ultrasonic installations. The developed direction of improving processes based on hydroacoustic and multi-stage hydrodynamic effects has significant technological, economic and environmental advantages.

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UDC 622.7

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MINERAL COMPOSITION AND COMMERCIAL APPLICATION FEASIBILITY OF SERICITE ORE IN HA TINH PROVINCE

Sericite is a silicate mineral, a finely disperse and partly hydrated variety of muscovite. It is widely applied in many areas of engineering and production, and has a high economic value. Sericite has been produced and used in the world for a few hundred years. In Vietnam, a new-discovered sericite deposit holds commercial quality reserves. This article presents the studies into the mineral composition of sericite ore from Ha Tinh deposit using a set of the modern analytical techniques, which prove efficiency of the commercial-level production and processing of this ore. The integrated studies into material constitution of Ha Tinh sericite ore show the uniform structure of sericite and insignificant content of unwanted impurities. The size of sericite particles markedly differs from the size of other minerals in the initial ore. The content of quartz gradually increases with increasing size of ore particles, while the content of sericite gradually grows with decreasing size of particles. In particularly, in very fine particles (size less than 10 µm), the content of sericite is higher than in the initial ore by 2 times and reaches 70%, while the content of quartz is 4 times less than in the initial ore. Impurities feature nonuniform distribution and occur in some mineral grains such as apatite $Ca_5(PO_4)_3$, iron oxides and binding particles of solid solutions. During ore processing, impurities can be separated to waste, and it is possible to produce a marketable product in the form of a high quality sericite powder which meets the application standards of the porcelain, ceramic, resin and other industries.

Thus, Hà Tĩnh sericite ore can be converted into valued products to be used in many various industries.

Keywords: *sericite ore, material constitution, sericite, quartz, feldspar, X-ray crystal analysis, electron microscopy, grain size composition, impurities, concentrate.*

DOI: *10.17580/em.2020.02.08*

Introduction

Sericite represents an association of fine micaceous particles (International Mineralogical Association) [1–3]. They belong to aluminosilicate group, with a typical characteristic; the attribute of micas is their splittability to thin layers to 1 nm thick (**Fig. 1**).

The general chemical formula of this mineral group is $(K,Na,Ca)(Al,Fe,Mg)_2(Si,Al)_4O_{10}(OH)_2$. The total chemical composition of sericite is: SiO_2 43–49%, Al_2O_3 27–37%, K_2O+Na_2O 9–11%, H_2O 4–6% [4]. The chemical composition of sericite varies at different deposits depending on the general mineral composition of ore and on the content of chemical elements included in the mineral structure. The color is white, pink, light-grey or golden brown, from transparent to semitransparent, lustrous. Sometimes sericite is confused with kaolin; the difference can be sensed in touching: sericite has a