Electrohydraulic pretreatment method for the purpose of complex enrichment of fine clay ores of weathering crust

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Abstract. The paper substantiates the possibility of applying the technology based on the use of electrohydraulic effect for the preliminary preparation of clay ores with fine mineral phases. The technology was developed in the laboratory by conducting experimental studies on samples of several types of clay rocks and ores that differ in the composition of inclusions of solid fractions in them. Experiments have confirmed that with the optimal selection of operating modes of a specially created electrohydraulic unit, high selectivity is achieved for crushing and dispersing different strength minerals and mineral phases of sample materials, which ensures the destruction of the clay component while maintaining the integrity of solid fractions. Removal of water-soluble clay fraction with the pulp and washing of the resulting intermediate product provides a high degree of cleaning of solid inclusions from clay. This makes it possible to recommend the use of electrohydraulic technology for cleaning solid fractions of fine clay ores from clay at the initial stage of ore preparation, followed by the extraction of valuable minerals from the resulting intermediate product of enrichment by traditional methods.

1. Introduction

Part of the World’s recoverable reserves of natural mineral resources, for example, hypergenic silicate-oxide ores, are concentrated in the weathering crust [1-4] of ultrabasic rocks. Weathering crusts are characterized by a pronounced vertical zoning and specific features of ore deposits are: zonal structure of ore deposits, consisting, as a rule, of several mineral types; their complex mineral composition; high dispersion and low degree of crystallinity of minerals; uneven distribution of metals in them. At the same time, the raw materials are contained in them mainly in a fine form, mostly associated with clay mineral phases and enclosed in loose clay host rocks [5-7]. This prevents the achievement of a high concentrate yield when such ores are enriched with traditional methods of mineral phase disintegration based on physical and chemical (electrochemical) principles [8-12]. A similar situation occurs with the enrichment of techno genic formations of placer gold deposits [13-15].

The solution to this problem is possible through the use of modern technologies for processing and complex enrichment of fine mineral raw materials [16]. Unfortunately, the technology based on the method of selective crushing of ores, defragmentation of rocks and disintegration of mineral phases using the electrohydraulic effect can be considered as one of them. It is important to note that in the
latter case, we are not talking about the method of electric pulse grinding, the technology of which was thoroughly studied in 1970-1990 [17,18,19] and still attracts the attention of specialists [20]. In contrast to this technology, in which an electric pulse discharge passes inside a solid body along the boundaries of various mineral phases and splits it from the inside, the essence of electrohydraulic technology is to supply a series of high-voltage electrical pulses to the water medium with the initial mineral raw material placed in it, accompanied by the appearance of ultra-high hydraulic pressures in the discharge zone, the shock wave from which is able to perform useful work [21]. The impact of such shock waves destroys the crushed material due to its compression. Previous studies of the application of this effect for crushing rocks and ores with different hardness of their components in a water medium have shown that it is possible to ensure a high degree of selectivity of the impact, when some of the components are destroyed, and other, more solid - electrohydraulic factors do not have a destructive effect, which ensures their safety [22]. This led to the assumption that by selecting the appropriate mode of electrohydraulic action on clay ore placed in the water medium, it is possible to ensure the destruction and removal of the water-soluble clay component in the pulp. The remaining clay-free solid ore fractions are then subjected to complex enrichment using traditional methods in order to extract the required mineral from them.

1.1. Justification of the object, subject and tasks of the research

The purpose of the study was to establish the principal possibility of using the technology based on the existing factors of the electrohydraulic effect for the disintegration of mineral phases of fine clay ore at the initial stage of preparation for further complex enrichment.

The selectivity of action of destructive factors of electrohydraulic effect is achieved by the selection of operating modes of electrohydraulic unit, so the task of the study was to justify the rational parameters of the technology process of disintegration of clay ore in the unit, namely, - the capacitance of the storage capacitors C (µf), discharge voltage U (kV) frequency F (Hz) and number N (PCs.) supplied to the medium of discharge impulses. Clay ore with the inclusion of solid fractions of various compositions was used as the object of research. The subject of the study was the process of electrohydraulic desliming (deslimation) of these solid fractions of ore from clay.

2. Methods and materials

Research method – laboratory experimental study on samples of various types of clay ore, containing in its composition of the solid fraction of fine mineral raw materials. A special electrohydraulic unit was developed and manufactured for experimental studies of the process of removing solid fractions from the clay that are part of the ore.

2.1. Design of an experimental electrohydraulic unit

The main element of the unit is a working container for placing the processed clay ore in the water medium, equipped with built-in electrodes. The electrodes are powered by a discharge circuit, which in turn is charged from an external power source [23]. The working container with a sample of clay ore loaded into it is filled with water. After switching on the unit, an electric charge begins to accumulate in the capacitor. When the set voltage is reached in the pulse capacitor, the switching device is activated. The pulse capacitor is discharged into the working gap in the working container, which is accompanied by a hydraulic shock that causes the dispersion of the clay components of the ore and the release of its more solid fractions. After processing, the water-clay pulp is drained through a filter into a container for its collection. The design scheme and the principle of organizing the process in the working container are shown in figure 1. Figure 2 shows a general view of the laboratory electrohydraulic unit. Water is fed into the working container from below and flows through the upper drain pipes to the geotextile filter. The first, electrohydraulic stage of separation of clay and solid fractions, occurs in the working container. The size of the solid fraction particles washed out with the pulp is determined by the speed of the liquid flow inside the working container. By adjusting the speed of water supply, we can adjust the size of the solid fraction washed out with the pulp. The
second stage of separation occurs on the filter. Here solid particles washed out of the working container settle, which it does not pass. Water-clay pulp passed through the geotextile is settled in a special container under the filter.

Figure 1. Design scheme and principle of organization of the process of removing solid fractions of ore from clay in the working container of an electrohydraulic unit: 1 - Working electrode; 2 - Removable cover for loading materials; 3 - Damper; 4 – Working fluid supply; 5 - The output of pulp; 6 - Mixture of the processed material with water; 7 - Metal grounded bottom.

Figure 2. Experimental electrohydraulic unit for removing solid ore fractions from clay.

2.2 Parameters of the material processing mode
In the experiments, the mode of operation of the electrohydraulic unit was determined not only by the discharge voltage, the capacitance of the storage capacitors, the working gap in working discharger, the number and frequency of pulsing, but the speed of upward fluid flow, stripping the composition of the pulp and released a light solid fraction. The number of series of discharge pulses sufficient to complete the processing process was limited to the start of draining clean water from the unit instead of clay pulp. Rational values of these indicators for the process of washing solid rock fractions from clay, selected experimentally, are shown in table 1.

Table 1. Operating mode of the electrohydraulic unit.

| Indicator                      | Indicator value |
|--------------------------------|-----------------|
| Capacitance of storage capacitors, µf | 3.0             |
| The discharge voltage, kW      | 40.0            |
| Working gap, m                 | 0.04            |
| The number of series of discharges | 3.0             |
| Number of discharges in the series | 100.0           |
| Pulse frequency, Hz            | 3.0             |
| Water consumption, l / min     | 17.0            |

The effectiveness of the selected mode was tested by electrohydraulic method of removing solid fractions from clay (desliming) in samples of several different types of clay ore, differing in the composition of inclusions of solid minerals. When preparing each sample intended for desliming, it was weighed. During the experiments, the geotextile filter was replaced after each series of 100
discharges. After complete processing (a total of 300 discharges), the working container was disassembled and the solid fraction of ore cleaned from clay was removed from it. The washed solid fraction and its residues, washed with pulp and settled on filters, were weighed, thoroughly washed by hand, and to determine the yield of the intermediate product cleared of clay, they were weighed again. To assess the fractional composition of washed solid particles, they were dispersed on classification sieves after drying.

3. Research results and discussion
In accordance with the purpose of the study, the authors considered its results from the position of confirming the possibility of desliming from the clay component of all components of solid fractions of clay ore at the initial stage of ore preparation. It is assumed that the subsequent extraction of valuable minerals from the resulting industrial product is provided by appropriate traditional methods. To increase the reliability of the study, five natural samples of fine clay ores, delivered from various mineral deposits located in southern Africa, were used in the experiments.

As a result of experiments with each sample, a solid component of ore of various fractional composition cleaned from clay was obtained. The algorithm for estimating the yield of industrial product cleaned from clay for samples of all five types of studied clays is given on the example of one of the samples (No 1). Quantitative indicators of the processing result for this sample are shown in table 2.

Table 2. The results of electrohydraulic processing of sample No 1.

| Indicator                                      | Number of accumulated discharges, units |
|------------------------------------------------|----------------------------------------|
| Weight of the sample up to the experiment, kg  | 3.000                                  |
| Mass of solid fraction in the working container after the experiment, kg | 0.586                                  |
| Mass of solid fraction on the filter geotextile, kg | 0.276                                  |
| Total mass of the cleaned solid fraction, kg   | 1.116                                  |
| Total fraction of solid rock fraction in the sample, % | 37.2                                   |

As can be seen from the data in table 2, no more than 300 discharges were required to completely wash the 3.0 kg sample. The maximum amount of clay materials washed out in the first 100 discharges. The total mass of solid material washed by electrohydraulic method and captured as a result of 3-stage filtration was 1116 g, which corresponds to 37.2 % of the solid rock content in the sample of clay ores. The rest is made up of water-soluble clay fraction which is not captured by the geotextile and settles in the sump.

The quality of electrohydraulic cleaning of solid fractions from the clay component for each sample was evaluated by taking a sample from the washed material and additional carefully washing it manually on a sieve with a cell of 0.16 mm. The results of additional washing for the sample studied above are shown in table 3.

Table 3. The results of the additional washing of the sample.

| Indicator                                      | Indicator value |
|------------------------------------------------|-----------------|
| Weight of sample after electrohydraulic treatment, kg | 0.84            |
| Weight of sample after an additional manual washing, kg | 0.78            |
| Percentage of washed rock, %                  | 7.14            |

From the data in table 3, it can be seen that only about 7% of the mass fraction of particles, including residual clay, was washed through a sieve with a cell of 0.16 mm as a result of additional
washing. A generalized analysis of the results of electrohydraulic treatment of all five clay samples studied showed that for high-quality washing of solid particles, no more than 300 discharges are required, and the maximum amount of clay materials in all cases is washed out in the first 100 discharges. The yield of industrial product in the form of a solid fraction in the samples that were washed was from 37 to 76%. The rest was accounted for by the clay component, which was not detected by the geotextile filter. Checking the quality of electrohydraulic washing by comparing the mass of a sample of solid ore fraction after electrohydraulic treatment with its mass after additional manual washing on a sieve with a cell of 0.16 mm showed that only 1 to 7% of particles, including residual clay, were washed out as a result of thorough manual additional washing. Thus, it can be stated that the main cleaning of solid ore fractions from the clay component occurs during electrohydraulic processing as a result of the destructive influence of the electrohydraulic effect factors.

To assess the fractional composition of washed solid particles in the study of each sample of clay, they were sieved on classification sieves into fractions with dimensions, mm: 8+; 5-8; 3-5; 2.5-3.0; 0.63-5.50; 0.16-0.63; 0.125-0.160; 0.125-.

The results of fractional analysis of the washed ore sieving for one of the samples are shown in the histogram figure 3.

![Histogram](image)

**Figure 3.** Histogram of partial residues on sieves after sieving washed rock Sample No 1.

Fractional analysis of the results of sieving of all the studied ore samples showed the presence of solid particles in each fraction, which indicates the effectiveness of selective impact of the output factors of the electrohydraulic effect, which provides almost complete destruction and removal of only clay particles with the pulp.

The resulting processing un-scattered pure solid clay component of the ore in the baseline condition for sample No 1 shown in the photographs of figure 4 and the figure 5 – solid component of the sample, scattered into factions.

![Initial State](image) ![Washed Component](image)

**Figure 4.** Un-scattered rock removed from the clay (b) in comparison with the original sample (a).
The limited capabilities of laboratory research did not allow to organize a correct assessment of the potential performance of experimental sample of the unit and the energy costs of implementing the process under study on an industrial scale. Therefore, the next step in the development of technology for the electrohydraulic method of preparing clay ores with inclusions of fine solid minerals is to conduct experimental studies to justify the most effective modes of operation of electrohydraulic equipment, not only in terms of ensuring the quality of cleaning of solid fractions of ore from clay, but also in terms of productivity and energy consumption when using this method.

4. Conclusions
The experiments have confirmed that the electrohydraulic technology of preparation of fine clay ore allows to achieve a high degree of cleaning from clay due to the selectivity of disintegration of mineral phases of different hardness. Selective impact of electrohydraulic shock on the initial ore ensures the preservation of both large and directly fine minerals in the industrial product after processing. For the subsequent extraction of valuable mineral phases from the prepared industrial product, traditional, for example, gravitational methods can be used.

The proposed technology can be used as a method for processing fine (including gold-bearing), clay ores, their placers, man-made mineral accumulations, dumps and deposits at the initial stage of ore and mineral resources preparation, as well as a method for studying geological samples during prospecting and evaluation, geophysical and geological exploration.

Figure 5. Results of sieving of ore removed from clay (Original sample No 1).

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