The work is devoted to the study of the effect of an electric explosion on the selectivity of the destruction of quartz raw materials. The object of the study is quartz ore of the Nadyrbay deposit of the Republic of Kazakhstan. An electrohydroimpulse plant for crushing and grinding quartz raw materials has been developed and assembled. Using the electrohydroimpulse method, the granulometric composition of quartz can be adjusted. This makes it possible to adjust the magnitude of the voltage in the discharge channel and time. In this technology, quartz ore processing was carried out with an increase in the discharge voltage of the storage from 14 kV to 25 kV, the length of the interelectrode distance from 8 to 12, the capacitance of the capacitor 0.5 μF, 0.75 μF and the processing time of 5 min. Using the electrohydroimpulse method, quartz ore particles with an initial fraction of 5 mm, 10 mm and 1 mm were crushed to 0.8. The results of the grinding of quartz raw materials with the influence of an underwater electric explosion in a liquid medium allowed us to determine the degree of grinding of the material.

The obtained results can be used in the course of studying the characteristics of crushing and grinding of ores. In the food industry, quartz sand within 0.25–0.5 millimeters can be used as a filler to create filters for water purification, as well as products from oil, industrial effluents, etc. Particles ranging in size from 0.5 to 1 millimeter can be used for rough processing of metal, stone and glass.

The structural and quantitative analysis of powdered quartzite samples was made using a scanning electron microscope and the stoichiometry of the elements was calculated

Keywords: quartz ore, crushing, electric explosion, discharge channel, capacitor, stoichiometry, energy spectrum

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A RESEARCH OF THE EFFECT OF AN UNDERWATER ELECTRIC EXPLOSION ON THE SELECTIVITY OF DESTRUCTION OF QUARTZ RAW MATERIALS

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1. Introduction

Most quartz concentrates are currently obtained from natural quartz after its processing. Crushing operations and especially fine grinding are energy intensive, and their costs account for a significant proportion of the total ore processing costs (from 40 to 60 %). Therefore, it should be borne in mind that grinding should always be completed at the stage when the precious metals will be sufficiently opened for their final extraction or for their intermediate concentration.

Currently, underwater electric explosion has found wide application in many industries [1]. It is used for intensifying heat exchange, fixing pipes in the pipe boards of heat exchangers, cleaning castings, stamping metals, destruction of monolithic objects [2], processing industrial waste in order to extract valuable components, destroying and grinding rocks and ores, separating impurities from various kinds of crushed materials.

The rapid development of the most important areas of scientific and technological progress in recent years has required the creation of new materials with unconventional properties and, as a result, new methods of their processing. Progress in industry significantly depends both on the creation of new materials and on the success of the development of methods for their processing. Therefore, a natural mineral (quartz) attracted special attention. The wide prevalence of the mineral and the ease of diagnosis predetermined its first use in industry.

There are large reserves of quartz-containing raw materials on the territory of the Republic of Kazakhstan [3], some of them are used for the production of simple building materials, and a small part is used in high-tech industries.

Quartz raw material is a chemically pure finely dispersed powder with a given granulometric composition obtained from natural quartzites [4]. Natural quartzites have impurities of both minerals and chemical compounds in their composition. To isolate pure SiO_2, complex and expensive processing is required, which involves several stages of crushing, grinding, several types of enrichment and chemical purification [5].

The consumption of non-metallic quartz materials, which are the basis for the development of modern industry, requires an increase in production volumes and mineral enrichment.

Therefore, research on the development of electrohydroimpulse technologies is relevant.

2. Literature review and problem statement

There are a number of methods for crushing and grinding natural minerals. The most common method of disintegration of quartz raw materials is the mechanical stadial method [6], which provides for destruction in jaw or inertia crushers, roller and ball mills.

This method allows you to obtain products with the required size with high process performance. However, the use of traditional mechanical devices does not allow obtaining chemically pure products. This is due to the low selectivity of the destruction process in traditional mechanical devices, which does not allow separating minerals during destruction, as well as contamination of products with hardware metal.

In [7], the authors studied the relationship between the characteristics of grinding polymetallic complex ore and its constituent minerals pyrrhotite, sphalerite and quartz under the action of abrasion based on selective grinding methods. As the authors of the works show, when exposed to polymetallic complex ore of abrasive action, the crushing effect of the ore is enhanced by the presence of sphalerite and reduced by the presence of pyrrhotite and quartz, that is, pyrrhotite and quartz play a negative role in the crushing effect of the ore.

However, sphalerite had a more noticeable effect on the grinding properties of the ore. Therefore, individual results can make it possible to select the operating mode of the plants used during grinding.

Also, the studied methods of processing natural raw materials and existing industrial installations require large energy costs, perform incomplete production of pure quartz from ores. The pure product obtained from quartz ore according to existing technologies for further use in industry is not quite effective in terms of economy, labor intensity and ecology and is only 50 %.

The solution of the problems of grinding quartz ores is possible by using non-traditional methods of destruction, which have increased selectivity of the process and do not introduce additional contaminants into the finished product. In this regard, an electrohydroimpulse method is proposed for crushing and grinding ore, operating on the principle of using an underwater electric explosion created by a pulsed discharge in a liquid.

It is described in [8] that a high-voltage pulse discharge (HVPD) enhances the separation characteristics of magnetite quartzite. The technical parameters of the concentrate grade 61.76 % and extraction 83.26 % were obtained with a pulse number of 90, a load voltage of 35 kV and a grinding time of 9 min. The output of destruction products was improved by 26.81 percentage points due to HVPD. The release of grinding products was also significantly increased by HVPD, whereas the advantage of HVPD was weakened by an increase in grinding time.

Thus, the use of an underwater spark discharge allows you to select the installation modes for selective grinding of materials, as well as to select the granulometric composition of the product.

The electrohydroimpulse method is one of the most promising methods for the formation of an underwater electric explosion in a liquid. The paper [9] discusses the technology of high-voltage electrical pulses (HVEP) used in the grinding of magnetite ore as a pretreatment for grinding. The effect of HVEP pretreatment on the pulverizability, release and separation efficiency of magnetite ore has been investigated by systematic experimental study. The results showed that pretreatment with high-voltage electrical pulses created some intergranular microcracks inside the ore, reduced mechanical strength and improved release. This gave an additional advantage in case of further breakage, thereby reducing energy consumption and grinding time. In addition, HVAP pretreatment prior to grinding was potentially useful for extracting the released minerals during subsequent magnetic separation. However, the main parameters of the pre-grinding plant before magnetic separation are not specified.

The paper [10] discusses the mechanisms of disintegration of mineral coalescence and changes in the structural and chemical state of the mineral surface under the influence of powerful nanosecond electromagnetic pulses and dielectric barrier discharge irradiation. High productivity and potential limitations of the impact of pulsed energy and low-temperature plasma obtained during the processing of geomaterials by the dielectric barrier discharge method are discussed from the point of view of directional changes in the technological properties of minerals to improve the enrichment of refractory minerals and ores.

The mechanisms of selective destruction of rocks and ores using powerful nanosecond electromagnetic pulses, despite many years of research by scientists, are still controversial and require further scientific and technological research.

The paper [11] presents the main results of research on increasing the selectivity of dissociation of useful and rocky minerals during pretreatment and enrichment of recalcitrant polymineral ore of the Rubtsovsky deposit. Useful minerals in this ore are galena, wurtzite (a type of sphalerite), pyrite and magnetite. The average percentage of metals in it reaches 6.2 for Fe, 2.3 for Pb and 4.9 for Zn. The mountainous part includes quartz, calcite and orthoclase. The proportion of mixed sulfide was 90–95 %. The uneven distribution of minerals in the ore is typical for the sample under study. Before crushing, the ore was crushed to a size of 3 mm using a jaw crusher and divided into samples to study the selectivity of disintegration and dissociation. For the subsequent flotation enrichment of lead-zinc ore, ~80 % of the material with a grain size of –0.071 mm is required.

However, flotation enrichment of ores leads to the consumption of reagents. When grinding ore, the use of a jaw crusher does not allow obtaining chemically pure products.

The paper [2] describes the existing problems of safe and environmentally friendly destruction of solid objects located in confined spaces. The work presents the results of studying the possibility of solving this problem by replacing the detonation of a solid structure with explosives with its destruction using an electrohydraulic shock effect. The physical nature of the electrohydraulic effect is described, design schemes and methods for calculating the optimal parameters of the bursting device are given.

The results obtained during the study confirm the practical possibility of environmentally friendly and safe destruction of solid rocks using the effect of electrohydraulic action.

Thus, studies of the influence of an underwater electric explosion on the selectivity of the destruction of quartz raw materials include all enrichment processes, and the choice of the processing method is justified.

Therefore, the electrohydroimpulse method meets the basic criteria of an effective method of destruction of rocks and ores. And also, it allows you to adjust the granulometric characteristics of the finished product within certain limits by changing the energy parameters of the high-voltage pulse and pulse frequency.

As part of this work, calculations of the stoichiometry of the elements of the quartzite compound treated with an underwater electric explosion were carried out [12]. Stoichiometry calculations are important for determining the amount of impurity elements in the composition of quartz raw materials. It should be noted that stoichiometry calculations for quartz ore have not been performed to date.

3. The aim and objectives of the study

The aim of the study is to experimentally research the effect of an electric explosion on the selectivity of the destruction of quartz ore. This allows you to use this material in the future without additional cleaning.

To achieve the aim, the following objectives were set:

– to obtain the dependences of the mass of grinding of quartz ore on the diameter of the fractions when the discharge of the accumulator is applied, the length of the discharge gap on the air discharger of the electrohydroimpulse installation;

– to determine the content of elements in the composition of quartz samples using a scanning electron microscope;

– to determine the stoichiometry of the elements of the quartzite compound after electrohydroimpulse treatment.

4. Materials and methods

The object of the study was quartz ore of the Nadyrbay deposit, which is located on the territory of the Karaganda region of the city of Dzhezkazgan of the Republic of Kazakhstan, studied as a potential source of raw materials for obtaining high-purity quartz concentrate (Fig. 1).

Since the volume of quartz ore before processing was large, it is first mechanically crushed to the desired fraction. To determine the granulometric composition of the obtained quartz powder, standard laboratory sieve containers with cell sizes from 1 mm to 40 microns were used.

The analysis of scientific publications of recent years shows that the use of the electrohydroimpulse method for the destruction of materials attracts the increasing interest of researchers.

In order to obtain high pressure at the shock wave front, crushing and grinding of solid fractions are carried out by an electric discharge in an aqueous solution of quartz raw materials. Also, to study the effect of an underwater electric explosion on the selectivity of the destruction of quartz raw materials, an experimental installation was developed and assembled (Fig. 2).

The pulse voltage (U – from 14 to 30 kV) was measured and monitored using a C100 mirror kilovoltmeter, where the limit of the permissible value of the basic error in the working part of the scale is ±2.0 %.

The following Fig. 3 shows the working part of the quartz ore crushing and grinding plant.

The study of this method made it possible to intensify the technological process of grinding quartz ore [13]. The crushed quartzite obtained by the proposed method can be used in the refractory, ceramic, chemical, glass, construction industries, metallurgy, optics and electrical engineering and other industries [14].

a *b*

Fig. 1. Quartz samples:
a – quartz ore d=70.3 mm; *b* – crushed quartz d=0÷0.8 mm

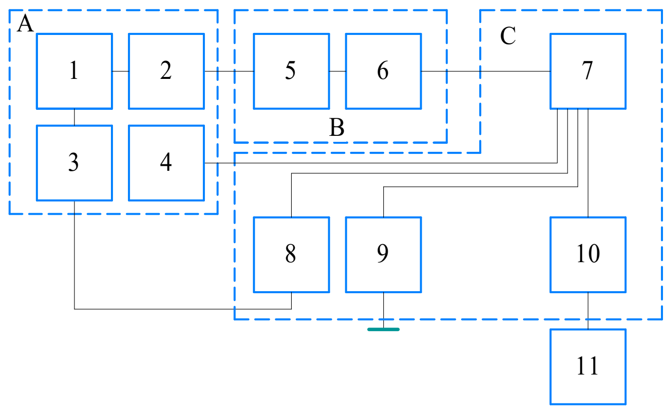


Fig. 2. Block diagram of an installation for obtaining an underwater electrical explosion: A – remote control; B – HPT; C – energy storage with protection system; 1 – power supply 220 V; 2 – current limiting element; 3 – emergency shutdown system; 4 – high voltage indicator; 5 – transformer; 6 – high voltage rectifier; 7 – energy storage unit; 8 – protection system; 9 – residual stress relief system; 10 – air gap; 11 – working part for crushing and grinding quartz mineral

a *b*

Fig. 3. The working part of the experimental plant for crushing and grinding quartz mineral: *a* – main body; *b* – working electrodes; 1 – cylindrical housing with a diameter of 100 mm; 2 – positive electrode with a diameter of 3 mm; 3 – negative electrode; 4 – caprolon cap with a diameter of 110 mm; 5 – fasteners

5. Results and discussion of the effect of an underwater electric explosion on the selectivity of the destruction of quartz materials

5. 1. The main results of processing quartz material using an underwater electric explosion

Table 1 shows the values of the ore grinding mass *m* (g) from the length of the discharge gap (*l*=8–12 mm) on the air arrester of the electrohydroimpulse installation, where the initial size of the quartz raw material is d_0=15 mm and the capacity of the capacitor bank *C*=0.5 µF. In the experiments, the mass of quartz ore was *m*=100 g, the processing time was 5 min.

In subsequent experiments (Tables 2, 3), the ore grinding masses *m* (g) are presented from the discharge voltage of the electrohydroimpulse storage unit (from 14 kV to 25 kV), where the initial size of the quartz raw material is 5 mm, 10 mm (fixed capacitance of the capacitor bank *C*=0.5 µF, *C*=0.75 µF). Ore mass *m*=100 g, processing time 5 min.

It can be seen from the tables that with a diameter of d_0=5 mm and a capacitor bank capacity of *C*=0.5 µF, small particles with a diameter of 0÷0.8 mm are crushed most intensively. Based on the results obtained, it can be seen that with an increase in voltage in the discharge channel, the intensity of crushing and grinding of quartzite increases.

Table 1

Dependence of the ore grinding mass values on the length of the discharge gap *l*, mm

l, mm	10÷15 mm	0.8÷2 mm	0÷0.8 mm
	m, g	*m*, g	*m*, g
8	33.2	13.9	11.2
10	22.8	20.5	21.5
12	5.6	25.8	46.2

Table 2

Dependence of the ore grinding mass values on the discharge voltage of the electrohydroimpulse storage unit *U*, kV (d_0=5 mm, *C*=0.5 µF)

U, kV	4÷5 mm	2÷4 mm	0.8÷2 mm	0÷0.8 mm
	m, g	*m*, g	*m*, g	*m*, g
14	45.2	26.2	14.6	13.5
16	36.5	23.8	19.5	19.2
18	32.3	18.3	22.8	25.6
20	29.8	13.5	26.3	29.8
22	26.8	9.3	28.6	34.5

Table 3

Dependence of the values of the crushed ore mass on the discharge voltage of the electrohydroimpulse accumulator *U*, kV (d_0=10 mm, *C*=0.75 µF)

U, kV	8÷10 mm	0.8÷2 mm	0÷0.8 mm
	m, g	*m*, g	*m*, g
19	21.2	12.2	24.3
21	14	13.2	26.5
22	10.4	15.8	29.2
23	8.6	17.8	32.6
25	2.3	25	40.1

5. 2. Results of structural and quantitative analysis of quartz ore samples

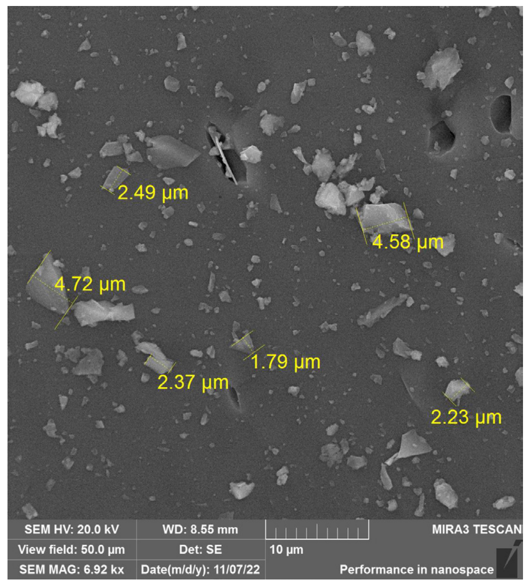
Subsequent studies were carried out with an electron microscopic device, where structural and quantitative analysis of the elemental composition of the quartzite sample was carried out.

Natural quartzites contain impurities of both minerals and chemical compounds. Isolation of pure SiO_2 requires complex and expensive processing, which includes several stages of crushing, grinding, several types of enrichment and chemical purification. One of such methods is the electrohydroimpulse method of crushing and grinding of mineral raw materials.

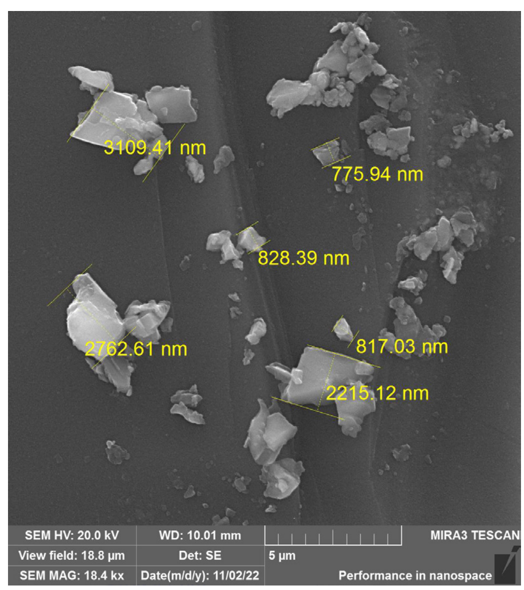
Fig. 4 shows electronic images of quartzite from the Nadyrbay deposit of the Republic of Kazakhstan obtained using a Tescan Mira 3 scanning electron microscope crushed by mechanical and electrohydroimpulse method.

The images were obtained using a secondary electron detector (SE detector) with an electron beam acceleration voltage (HV) of 20 kV and at different magnifications.

The images of the surface were obtained at different magnifications, and it is clear that the samples of quartz raw materials have a layered structure.



a



b

Fig. 4. Electronic images of powdered quartzite: *a* – mechanical processing; *b* – electrohydroimpulse processing

Fig. 5 shows the energy spectra of powdered quartzite. The images were obtained from a computer program using a Tescan Mira 3 scanning electron microscope.

This effect indicates that the influence of an underwater discharge not only grinds the material, but also makes it possible to extract the material.

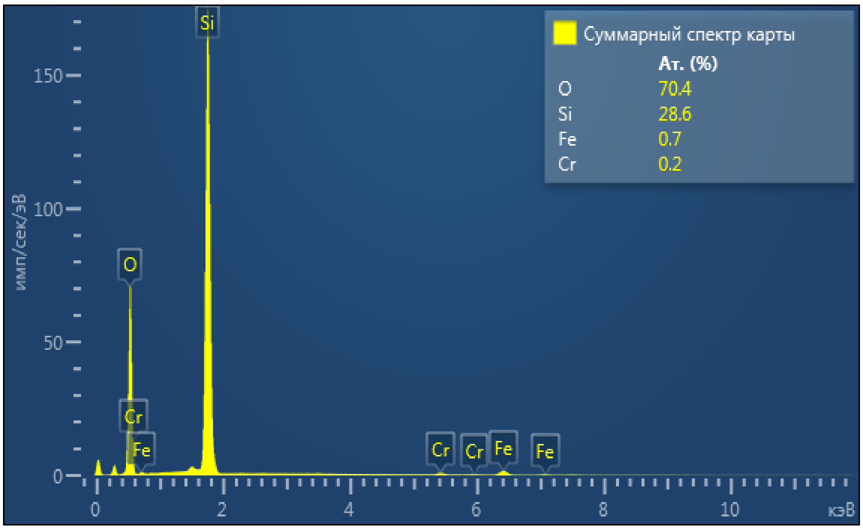
Peaks corresponding to all chemical elements of the powdered quartzite under study are easily discernible in the spectra (Table 5).

Also earlier, electronic images of powdered quartzite were obtained using a JSM 5910 scanning electron microscope. The main work was related to electron microscopic studies, the development of methods for quantitative analysis of the elemental composition of quartzite samples. The installed electron energy of the probe is 30 kV.

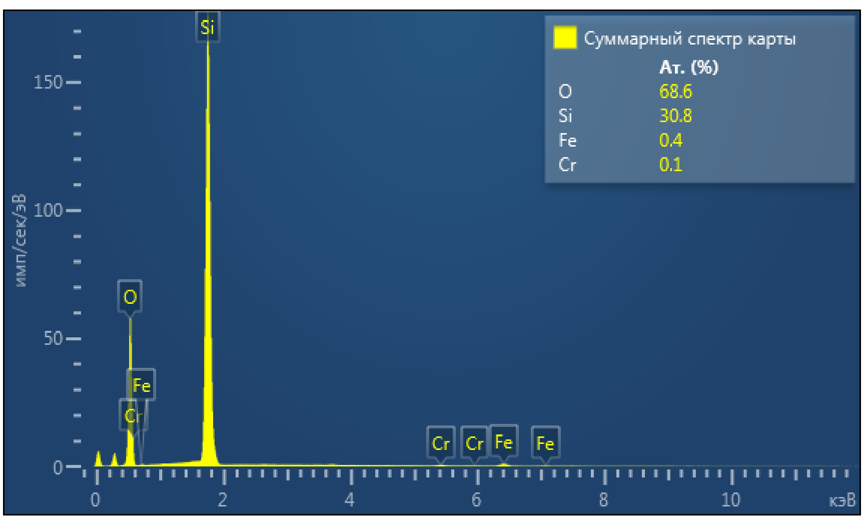
Fig. 6, *a*, *b* shows electron microscopic images after electrohydroimpulse treatment.

Fig. 7, *a*, *b* shows the energy spectrum and elemental composition of powdered quartzite samples after electrohydroimpulse treatment.

From Fig. 7, *b*, it can be seen that the quartz raw material under study has a sufficiently high content of silicon dioxide (silicon dioxide, silicon oxide SiO_2) in its composition.



a



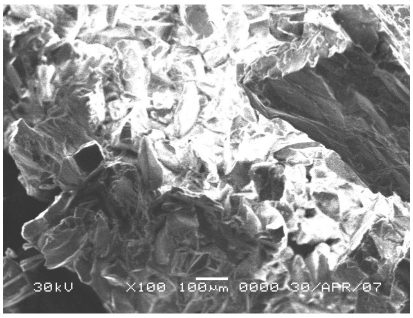
b

Fig. 5. Energy spectrum of powdered quartzite: *a* – mechanical processing; *b* – electrohydroimpulse processing

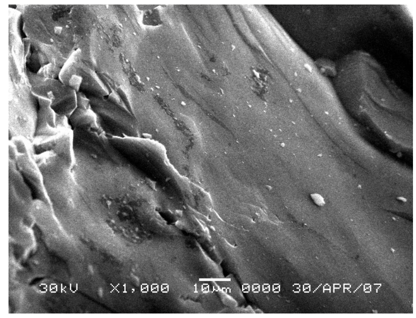
Table 5

Results of quantitative analysis of Si-Cr-Fe-O quartzite

Element	*G*, %	*At*, %
OK_α	55.02	68.6
SiK_α	43.42	30.84
CrK_α	0.32	0.12
FeK_α	1.24	0.44
Total, %	100 %	100 %

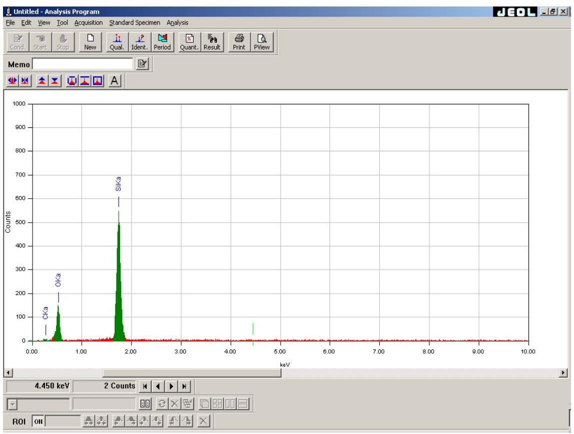


a



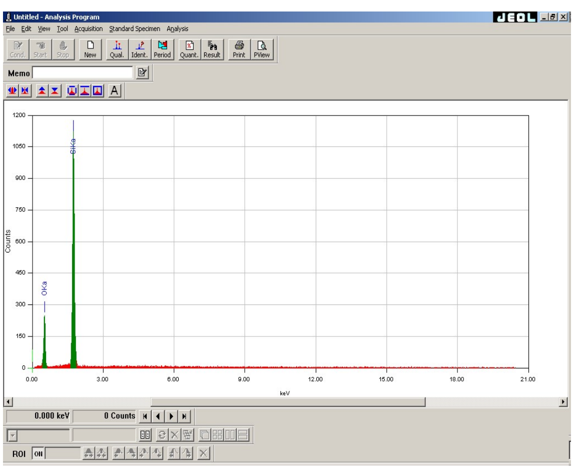
b

Fig. 6. Electronic images of powdered quartzite after electrohydroimpulse treatment with expansion: *a* – with a magnification of 100 times; *b* – with a magnification of 1,000



Element	*G*, %	*At*, %
CK_α	1.11	16.45
SiK_α	3.87	24.61
OK_α	5.28	58.94
Total, %		100 %

a



Element	*G*, %	*At*, %
SiK_α	8.71	35.28
OK_α	9.10	64.72
Total, %		100 %

b

Fig. 7. Energy spectrum and elemental composition of powdered quartzite after electrohydroimpulse treatment: *a* – with a magnification of 100 times (Si-C-O); *b* – with a magnification of 1,000 (Si-O)

5. 3. Calculation of the stoichiometry of the elements of the quartzite compound

The obtained values of the mass concentrations of quartzite are used to calculate their stoichiometry. Mathematical transformations of formulas lead to the calculated expression of the stoichiometry of elements:

$$k_i = \frac{M_1 \cdot G_i}{G_1 \cdot M_i},$$

where $G_i{\cdot}M_i$ – the mass concentration and atomic mass of the element for which k_i is estimated; $G_1{\cdot}M_1$ – the mass concentration and atomic mass of the element for which k_1=1 is estimated.

When substituting tabular values of atomic masses, we obtain the following calculation formulas for the stoichiometry of the elements of the compound.

Si-Cr-Fe-O compounds in this case k_1=1 (Si) for silica:

$$k_1 = 1,$$

$$k_2 = \frac{M_{Si} \cdot G_{Cr}}{G_{Si} \cdot M_{Cr}} = \frac{28.085 \cdot 0.32}{43.42 \cdot 51.996} = 0.004,$$

$$k_3 = \frac{M_{Si} \cdot G_{Fe}}{G_{Si} \cdot M_{Fe}} = \frac{28.085 \cdot 1.24}{43.42 \cdot 55.845} = 0.01, \quad (1)$$

$$k_4 = \frac{M_{Si} \cdot G_{O}}{G_{Si} \cdot M_{O}} = \frac{28.085 \cdot 56.82}{43.42 \cdot 15.996} = 2.3.$$

Si-C-O compounds in this case k_1=1 (Si) for silica:

$$k_1 = 1,$$

$$k_2 = \frac{M_{Si} \cdot G_{C}}{G_{Si} \cdot M_{C}} = \frac{28.085 \cdot 1.11}{3.87 \cdot 12.011} = 0.6, \quad (2)$$

$$k_3 = \frac{M_{Si} \cdot G_{O}}{G_{Si} \cdot M_{O}} = \frac{28.085 \cdot 5.28}{3.87 \cdot 15.996} = 2.4.$$

Si-O compounds in this case k_1=1 (Si) for silica:

$$k_1 = 1,$$

$$k_2 = \frac{M_{Si} \cdot G_{O}}{G_{Si} \cdot M_{O}} = \frac{28.085 \cdot 9.10}{8.71 \cdot 15.996} = 1.8. \quad (3)$$

Table 6 shows the calculated stoichiometry data of quartzite elements.

Table 6

Results of calculation of stoichiometry of powdered quartzite

Connection	k_1	k_2	k_3	k_4	Chemical formula according to the analysis data
Si-Cr-Fe-O	1	251	69.6	0.44	$SiCr_{0.004}Fe_{0.01}O_{2.3}$
Si-C-O	1	0.6	2.4	0	$SiC_{0.6}O_{2.4}$
Si-O	1	1.8	0	0	$SiO_{1.8}$

According to the metrological characteristics, it can be argued that the stoichiometries of the elements are determined with high accuracy.

6. Discussion of the results of studying the effect of an underwater electric explosion on the destruction of quartz ore

From Table 1, we can see that as the interelectrode gap increases, the grinding mass of ore with small dimensions increases sharply. When processing quartz raw materials with an initial diameter of 15 mm with a discharge gap length of 8 mm, the non-crushed mass is 33.2 g, and the crushed mass (less than 0.8 mm) is 11.2 g. With the length of the discharge gap on the air arrester, the non-crushed mass decreases to 5.6 g, the crushed mass increases to 46.2 g of the feedstock.

As can be seen from Table 2, when processing quartz raw materials with an initial diameter of 5 mm at a voltage of 14 kV of an electrohydroimpulse installation, the initial mass is 45.2 g, and the crushed mass is about 13.5 g. At a voltage of 22 kV, the crushed mass is 34.5 g of the original mass.

Also, when processing quartz (Table 3) raw materials with an initial diameter of 10 mm at 25 kV, the crushed mass (less than 0.8 mm) reaches 40.1 g.

During mechanical processing of quartz (Fig. 4, *a*) raw materials, the diameter of large particles was 4.58 μm, the minimum diameter was 1.79 μm, during electrohydroimpulse processing (Fig. 4, *b*), the maximum particle diameter decreased by 3109.41 nm, the diameter of small particles was 775.94 nm.

Fig. 5, *a* shows that during mechanical processing, iron (Fe) is present in the composition of quartz material within 0.7 %, and after electrohydroimpulse processing, it decreased to 0.4 % (Fig. 5, *b*). Similarly, the present element chromium (Cr) decreased from 0.2 % to 0.1 %.

From Fig. 6, *b*, it can be seen that cracks form during the destruction process. In the process of force deformation, cracks are formed and destroyed areas are visible. In some areas, it can be seen that the destruction process is not completed, although the crack has passed, but partial joints are still preserved. There are still partial joints between the crack and the raised "bump", which still connect these three parts of the crystal undergoing destruction. During the passage of the subsequent shock wave, the cracking process is completed, as a result of which a complete chip of the crystal occurs. The effect of electrohydroimpulse treatment is associated with the selectivity of destruction, when grains and minerals are separated from each other by impulses along the cleavage boundaries or microcracks (Fig. 6, *b*). In this case, both minerals and microcracks containing oxides of elemental composition are exposed.

Table 5 shows the results of the quantitative analysis of Si-Cr-Fe-O quartzite. Here we can see that the atomic mass *At*, % of the elements of silicon dioxide is 99.44 %.

Fig. 7, *a*, *b* show the energy spectrum and elemental composition of powdered quartzite after electrohydroimpulse treatment with a magnification of 100 (Si-C-O) and 1,000 times (Si-O). From Fig. 7, and it can be seen that the content of silicon dioxide in the composition of quartz raw materials is quite high.

The new surfaces obtained after processing are cleaned of oxides due to turbulent fluid flows in the working volume of the chamber, which in the form of a fine dispersion pass into the surrounding liquid and are removed together with the liquid when the sample is washed and dehydrated.

When examining a quartz sample at the Nadyrbay deposit, the results revealed that the quartz ore present in the composition contains highly siliceous quartzites with a low content of impurities.

The performed analyses of quartzite and crushed, powdery materials have shown that electrohydroimpulse action of a given power crushes and grinds the natural mineral to certain sizes.

The stoichiometry of the elements of the quartzite compound was also calculated in the work. The synthesized compounds correspond to their single formula, which is confirmed by various physico-chemical methods. Table 6 shows that the phase composition of composite materials based on quartzite does not contain foreign impurities.

The main difficulties are the development and manufacture of the necessary element, i.e. a high-voltage generator that provides the necessary operation of the entire installation. In addition, difficulties arise when purchasing a pulse capacitor of the required capacity.

The results of experimental studies indicate the proposed method of crushing by pulsed electric discharge in a liquid is a promising method for obtaining fine powders. The developed technology of electrohydraulic treatment of aqueous mineral suspensions allows you to quickly and cost-effectively obtain a powder (mixture) with certain sizes of solid fractions, change its structure and characteristics, and on its basis create new materials with specified properties and optimally use the resulting metered fractions for different industries, as well as simultaneously improve sanitary and hygienic working conditions and significantly reduce environmental pollution. The proposed method and parameters are most acceptable in production conditions, it provides intensive crushing and grinding of quartz ore.

7. Conclusions

1. The dependences of the degree of grinding of quartz ore (less than 0.8 mm) on the diameter of the fractions at the set voltage values of 25 kV, the length of the discharge gap l=12 mm, the capacitance of the capacitor bank C=0.5 μF are obtained. Optimal parameters were determined: the diameter of the initial fraction is dfr=5 mm, processing time t=5 min.

2. The content of elements in the composition of quartz samples was determined using Tescan Mira 3 and JSM 5910 scanning electron microscopes. When machining quartz raw materials, the diameter of the crushed fine grains was 1.79 microns, electrohydroimpulse processing was 775.94 nm. As a result, the quartz sample contains silicon (Si), chromium (Cr), iron (Fe), oxygen (O) and carbon (C).

3. The stoichiometry of the elements of the quartzite compound of the Nadyrbay deposit, Republic of Kazakhstan after electrohydroimpulse treatment of Si-Cr-Fe-O, Si-C-O, Si-O was determined. From the obtained atomic mass values, chemical formulas are obtained according to the SEO analysis data $SiCr_{0.004}Fe_{0.01}O_{2.3}$, $SiC_{0.6}O_{2,4}$, $SiO_{1.8}$. According to the results, it was revealed that the quartz ore present in the composition contains highly siliceous SiO_2 quartzites with a low content of impurities.

Conflict of interest

The authors declare that there is no conflict of interest regarding this research, including financial, personal, authorship or other nature that could affect the research and its results presented in this paper.

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Data availability

Data will be provided upon reasonable request.

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References

1. Yutkin, L. A. (1986). Elektpogidpavlicheckiy effekt i ego ppimenenie v ppomyshlennocti. Leningrad: Mashinoctpoenie, 253.
2. Martynov, N. V., Dobromirov, V. N., Barsukov, V. O., Avramov, D. V. (2021). Electrohydraulic Technology for Breaking Solid Objects. Mining Industry Journal (Gornay Promishlennost), 2, 132–136. doi: https://doi.org/10.30686/1609-9192-2021-2-132-136
3. Kulinich, V. V., Sagunov, V. G., Uzhkenov, B. S. et al. (2000). Mectopozhdeniya gopnopudnogo syr'ya Kazakhctana. Almaty, 372.
4. Bur'yan, Yu. I. (2007). Kvartsevoe syr'e – vazhneyshiy vid mineral'nykh resursov dlya vysokotekhnologichnykh otrasley promyshlennosti. Razvedka i okhrana nedr, 10.
5. Kuz'mina, N. I. (2007). Kriterii opredeleniya predelov obogatimosti razlichnykh prirodnykh tipov kvartsevogo syr'ya. Razvedka i okhrana nedr, 10.
6. Gupta, V. K. (2023). Hold-up weight in continuous wet ball milling: Relationship with the size distribution of the particulate contents of the mill. Powder Technology, 415, 118137. doi: https://doi.org/10.1016/j.powtec.2022.118137
7. Yang, J., Zhu, P., Li, H., Li, Z., Huo, X., Ma, S. (2022). Research on the Relationship between Multi-Component Complex Ore and Its Component Minerals' Grinding Characteristics under Abrasion Force. Minerals, 13 (1), 6. doi: https://doi.org/10.3390/min13010006
8. Gao, P., Qin, Y., Zhang, H., Chen, H. (2022). Strengthening the magnetic separation characteristic of magnetite quartzite via high-voltage pulse discharge. Canadian Metallurgical Quarterly, 62 (1), 85–98. doi: https://doi.org/10.1080/00084433.2022.2071090
9. Gao, P., Yuan, S., Han, Y., Li, Y., Chen, H. (2017). Experimental Study on the Effect of Pretreatment with High-Voltage Electrical Pulses on Mineral Liberation and Separation of Magnetite Ore. Minerals, 7 (9), 153. doi: https://doi.org/10.3390/min7090153
10. Chanturiya, V. A., Bunin, I. Zh. (2022). Advances in Pulsed Power Mineral Processing Technologies. Minerals, 12 (9), 1177. doi: https://doi.org/10.3390/min12091177
11. Rostovtsev, V. I., Bryazgin, A. A., Korobeinikov, M. V. (2020). Improvement of milling selectivity and utilization completeness through radiation modification of mineral properties. Journal of Mining Science, 56 (6), 1000–1009. doi: https://doi.org/10.1134/s1062739120060125
12. Nesterova, T. N., Vostrikov, S. V. (2014). Stekhiometriya, material'nye i energeticheskie raschety v khimii i khimicheskoy tekhnologii. Samara: SamGTU, 403.
13. Kurytnik, I. P., Nussupbekov, B. R., Khassenov, A. K., Karabekova, D. Z., Tanasheva, N. K. (2020). About an electric pulse method of grinding gold ore. Przegląd Elektrotechniczny, 1 (10), 150–152. doi: https://doi.org/10.15199/48.2020.10.27
14. Bulkairova G. A., Khassenov A. K., Karabekova D. Zh., Stoev M., Nurgaliyeva Zh. G., Kipshakov M. S. (2019). Effects of electrohydroimpulse discharges on the crushing of the natural mineral quartz. Eurasian Physical Technical Journal, 16 (2), 89–93. doi: https://doi.org/10.31489/2019no2/89-93