

# Research of Concentratibility of Low Quality Bauxite Raw Materials

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**Abstract**—Processing of high-silicon bauxite on the base of the traditional clinkering method is related to high power consumption and capital investments, which makes production of alumina from those ores non-competitive in terms of basic economic showings. For these reasons, development of technological solutions enabling to process bauxites with various chemical and mineralogical structures efficiently with low level of thermal power consumption is important. Flow sheet of the studies on washability of ores from the Timanskoe and the Severo-Onezhskoe deposits is on the base of the flotation method.

**Keywords**—Low-quality bauxite, resource-saving technology, optimization, aluminum, conditioning of composition, separation characteristics.

## I. INTRODUCTION

**F**AST pace of development of aluminum industry in Russia requires raising of aluminum containing raw materials usage efficiency, expanding raw material base of aluminum production and reduction of thermal power consumption. Quality of bauxite as raw material is evaluated primarily by the silicic module and mineralogical forms. Silicic module for bauxite must be at least 2.6. In other countries, bauxite is processed with a silica content of not more than 5%, which corresponds to the silicic module of raw materials not less than 9.

Quality of bauxite mined in Russian continuously declines, and there is not only a reduction of the silicic module, but also increase of content of noxious impurities such as chromium compounds, sulfur, carbon dioxide, organic substances and so on. In the early 50-ies average alumina content of the processed bauxite was about 55%, in the early 70s, by bringing into production of bauxite of deposits Turgay, average alumina content has fallen to 49%. Currently, the share of involved in the production of low-quality bauxite increased up to 30; a tendency to increase of this share is apparent. In recent years, the only high-quality bauxite deposit on Ural in Russia in connection with the transition to deeper horizons of groove provides raw materials with increased content of sulfides, carbonates and other impurities.

Bauxite is complex rock, which contains aluminum in several kinds of hydroxides, diaspore and boehmite ( $\text{Al}(\text{OH})_3$ ), gibbsite or its polymorphic versions ( $\text{Al}(\text{OH})_3$ ). Along with hydroxides, there can be other minerals such as corundum,

kaolinite, etc. that contain aluminum in the forms. Besides, bauxites also contain iron, calcium titan and other elements in the form of various chemical compounds. Chemical compositions of bauxites, as well as their physical properties are rather different. They contain 35-70% of  $\text{Al}_2\text{O}_3$ , up to 25% of  $\text{SiO}_2$ , 2-40% of  $\text{Fe}_2\text{O}_3$  and up to 11% of  $\text{TiO}_2$ . Content of several elements in bauxites is measured by basic points and even thousandths of one percent (e.g. vanadium 0.025-0.15%, gallium 0.001-0.007%). One of characteristic features of bauxites is extremely high dispersity of their component elements which is often close to dispersity of colloids. Aluminum hydroxides in bauxites are divided into diaspore, boehmite, gibbsite and compound ones, which depends on their mineralogical form. Compound bauxites contain two forms of aluminum hydroxide (diaspore-boehmite and gibbsite-boehmite bauxites). Proportion of aluminum oxides and silicon in bauxite has the largest impact on its quality [1]-[4]. Ratio between contents of  $\text{Al}_2\text{O}_3$  and  $\text{SiO}_2$  (in terms of weight) in bauxite is called the silicon module of bauxite. Quality of bauxite is characterized by a silicon module: the higher the silicon module, the higher the quality of bauxite.

## II. THE RESEARCH

The study of bauxite with an electron microscope revealed that bauxite consists of lithified particles of less than 100-200 microns (Fig. 1) associated with finely dispersed clay material. The particles have a heterogeneous structure, the folded of conglomerate compositionally different grains of size less than 10 microns, which in turn shows the heterophase structure consisting of a more or less uniform submicron domain under high magnification. Based on the analysis of the chemical composition of the particles, both point and area, we can say that each particle represents a fusion of the particulate mosaic main ore minerals: hydroxides of aluminum, iron and kaolinite, it being understood that such a structure is not conducive to better enrichment of bauxite.

Bauxite particles are a heterogeneous mixture of oxides and hydroxides of aluminum and iron containing aluminium silicate component - clay. Size of homogeneous domains of particles is submicroscopic. In principle, the darker domain particles, the more aluminum oxide therein - is brighter than the more iron and titanium.

It was found that a class - 0.01 + 0.005 mm has the lowest silicon module. This clayey product is characterized by increased content of alkali metals due to the concentration therein of potassium feldspar and muscovite (hydromuscovite) and, possibly, of analcime. Here are concentrated titanium minerals and most of the accessory minerals. Thus, at low

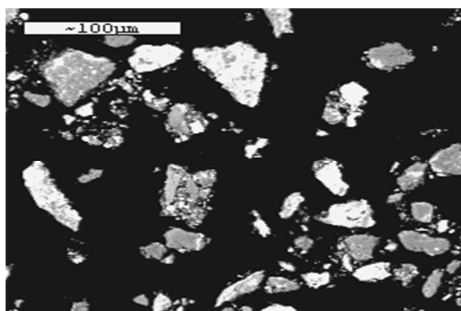
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content of high quality durable rock in bauxite, differentiation of bauxite on quality is carried out only under intensive methods of mechanical stress, breaking rocks to the level of microstructural elements. The main consequence of mechanical grinding is exemption bauxite material from kaolinite, fine iron minerals, etc. When mechanical grinding are two parallel processes are in mechanical grinding- simple mechanical disintegration of large fragments of the original rocks into smaller (before opening the microstructural elements) and selective dispersion of the most soft and fragile kaolinite, gibbsite, boehmite and other mono-mineral formations.

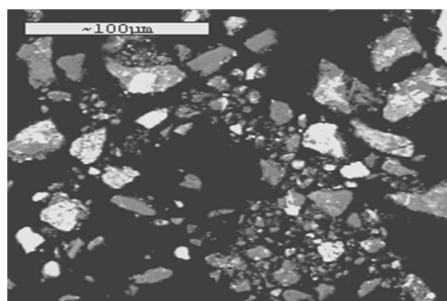
The preliminary study on washability, which includes studying of mineralogical structure of ore and kinetic of crushed ore grinding, analysis of content of main component elements of raw material by size grades, experiments on elutriation, dry and wet magnetic separation, flotation and compound enrichment was carried out to define possibilities of enrichment of high-silicon bauxite ores of the Timanskoe and Severo-Onezhskoe deposits on conventional dressing methods [5]-[8].

The silicon module in the sample of ore from the Timanskoe deposit stands at 4.5 and of the ore from the Onezhskoe deposit at about 3.

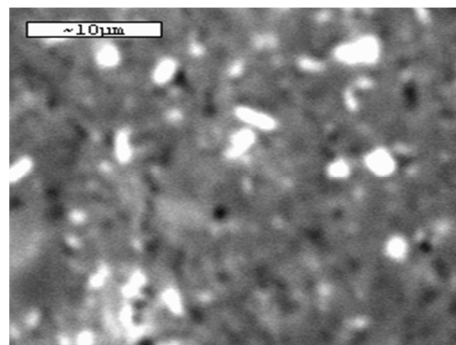
A wet sizing analysis of the source material grinded into 10 mm and 1mm particles has been carried out. Analysis of size composition of ore, including that one of fine fractions, has demonstrated that the silicon module of the ore mined at the Timanskoe deposit does not change in terms of size grades, and the silicon module of the ore mined at the Onezhskoe deposit decreases together with decrease in size (from 3.7 in the classes -1+0.1 to about 2.4 in the classes -0.03 +0.01 mm).



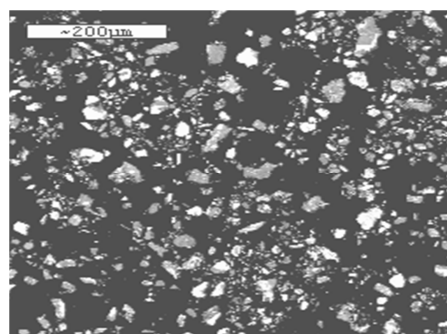
(a) The original ore (general view)



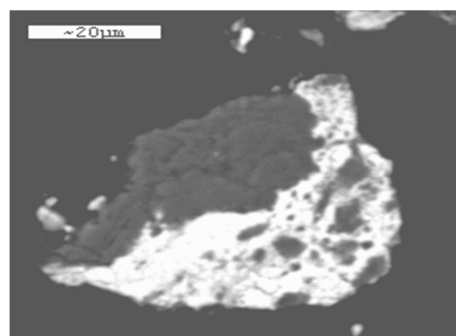
(b) The original ore (general view)



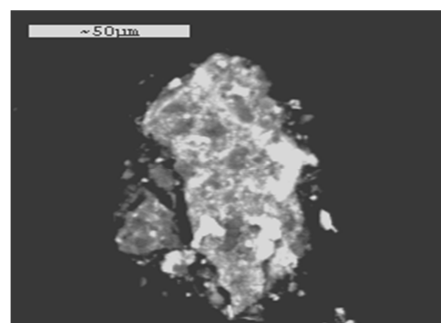
(c) The original ore, analysis was carried out with the entire image area (enlarged fragment of particles with a)



(d) The original ore (general view)



(e) The original ore



(f) The original ore

Fig. 1 Photomicrographs of the original ore (particle size is 1 + 0 mm)

Grindability of ore was studied in a ball mill with the volume of about 1.5 l (length stood at 127 mm and diameter at 121 mm); ball load amount was 3.4 kg; ball diameters were 19-25 mm; sample stood at 100 g and water-solid ratio was 1:1. Results of the grinding are shown in Figs. 2 and 3.

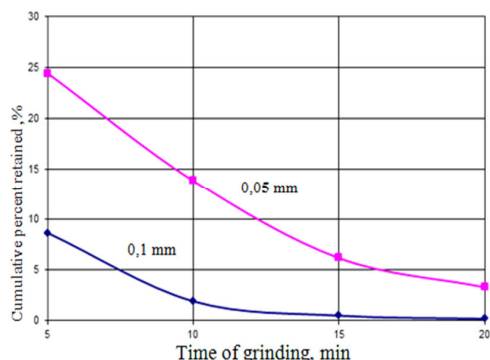


Fig. 2 The kinetics of grinding (material grinded into 1mm. Ore from the Timanskoe deposit)

Experiments on kinetic of grinding have demonstrated that the ores can be easily grinded, especially the ore from the Onezhskoe deposit.

Elutriation experiments have been carried out to remove kaolinite in tailings. The sample of the source ore with the size of 0-1 mm was mixed with water with the help of an impeller mixer within 1.5 hour. Dilution in all experiments amounted to 2:1. We made the attempt to intensify the process of elutriation using the hydromagnetic classification. The method combines both magnetic separation and hydraulic classification that is in the moment of classification the particles are exposed to magnetic field. Results of the kaolinite elutriation tests have demonstrated rising of the silicon module underflow fractions, to 4.29-6.7 in the ores from the Timanskoe deposit and to 4.21-5.29 for the ores from the Severo-Onezhskoe deposit.

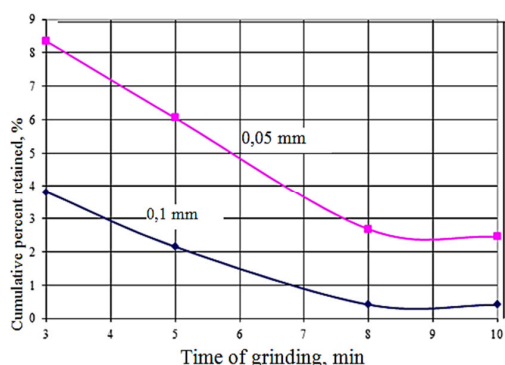


Fig. 3 Kinetic of grinding (material grinded into 1mm. Ore from the Severo-Onezhskoe deposit)

We have carried out several experiments on autogenous milling of bauxite ores with following screening of grinded products. Autogenous milling of the ore from the Timanskoe deposit has demonstrated that silicon and aluminum oxides are

distributed by size grades almost evenly. For the ore from the Severo-Onezhskoe deposit, in some experiments, one could observe decreased module in fine grade (-0.05 mm) but yield of the grade stands at not more than 60%, and for the reason, the result is of no practical interest.

#### A. The Scheme of the Experiment

Several experiments have been done on magnetic separation in strong field on the electromagnetic separator. For the ore from the Timanskoe deposit, magnetic separation of ore of various size grades in strong field after autogenous milling enabled to raise the silicon module of the non-magnetic fraction to 7.24-8.4 for some size grades. For the ore from the Severo-Onezhskoe deposit, identical experiments did not demonstrate positive results.

Flow sheet of the studies on washability of ores from the Timanskoe and the Severo-Onezhskoe deposits on the base of the flotation method is shown on Fig. 4.

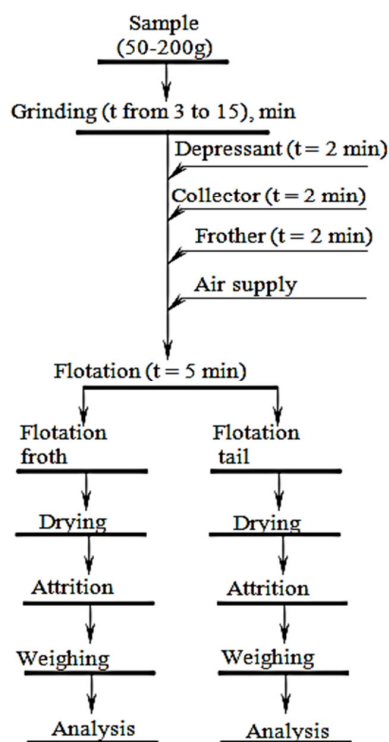


Fig. 4 Flow sheet of the studies on washability

Numerous flotation experiments, including those with usage of specialized flotation reagents, have demonstrated that it is possible to increase the silicon module insignificantly. Thus, on the base of the studies we can ascertain that mineral dressing of high-silicon bauxites does not enable to get raw materials of the "Bayer" quality.

### III. CONCLUSION

The best results have been obtained on the base of the scheme which includes autogenous milling, screening into size grades and magnetic separation of the grades so far (Table

D).

Result of the experiments that carried out on the base of the scheme:

- Technologies In Geology, Exploration and Mining, SGEM 2014 GeoConference Proceedings, 2014, June 19-25. – Vol. 3. P. 823-830.  
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TABLE I

RESULTS ON THE BASE: AUTOGENOUS MILLING – SCREENING INTRO SIZE GRADES MAGNETIC SEPARATION

| Size grade, mm | Name of product      | Yield, % | SiO <sub>2</sub> | Al <sub>2</sub> O <sub>3</sub> | Fe <sub>2</sub> O <sub>3</sub> | CaO  | μ    |
|----------------|----------------------|----------|------------------|--------------------------------|--------------------------------|------|------|
| -2.5+1.6       | Magnetic material    | 78,8     | 9,9              | 45                             | 28,5                           | 0,56 | 4,55 |
|                | Nonmagnetic material | 21,2     | 6,7              | 48,5                           | 12,6                           | 7,5  | 7,24 |
|                | Total:               | 100,0    | 9,22             | 45,74                          | 25,13                          | 2,03 | 4,96 |
| -1.6+0.8       | Magnetic material    | 85,8     | 9,7              | 45,5                           | 28,3                           | 0,57 | 4,69 |
|                | Nonmagnetic material | 14,2     | 8                | 48,8                           | 7,7                            | 10,1 | 6,10 |
|                | Total:               | 100,0    | 9,46             | 45,97                          | 25,37                          | 1,92 | 4,86 |
| -0.8+0.63      | Magnetic material    | 88,5     | 9,4              | 45,2                           | 28                             | 0,39 | 4,81 |
|                | Nonmagnetic material | 11,5     | 9,5              | 47,6                           | 10,4                           | 8    | 5,01 |
|                | Total:               | 100,0    | 9,41             | 45,48                          | 25,98                          | 1,26 | 4,83 |
| -0.63+0.2      | Magnetic material    | 82,7     | 9,2              | 44,4                           | 29,3                           | 0,5  | 4,83 |
|                | Nonmagnetic material | 17,3     | 6,7              | 49,6                           | 18                             | 4,7  | 7,40 |
|                | Total:               | 100,0    | 8,77             | 45,30                          | 27,34                          | 1,23 | 5,17 |
| -0.2+0.1       | Magnetic material    | 69,1     | 9,2              | 41,2                           | 32,8                           | 0,48 | 4,48 |
|                | Nonmagnetic material | 30,9     | 11,2             | 52,1                           | 14,2                           | 2,8  | 4,65 |
|                | Total:               | 100,0    | 9,82             | 44,57                          | 27,05                          | 1,20 | 4,54 |

On the whole, it is obvious that the ores are quite a complicated object for enrichment as they are characterized by extremely fine sizes of aluminium containing minerals, as well as by similarity of properties. Under the plans on the further research, experiments with usage of chemical enrichment (both exclusively with usage of chemical enrichment and in combination with physical methods of enrichment) are to be carried out.

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