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By C. W. Smith and T. O. Llewellyn



UNITED STATES DEPARTMENT OF THE INTERIOR



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**UNITED STATES DEPARTMENT OF THE INTERIOR
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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

in	inch	st	short ton
lb	pound	μm	micrometer
min	minute	wt pct	weight percent
pct	percent		

PIONEERING STUDIES ON THE FLOTATION OF CORUNDUM FROM A MONTANA GNEISS

By C. W. Smith¹ and T. O. Llewellyn²

ABSTRACT

The Bureau of Mines conducted laboratory-scale beneficiation tests on a sample of corundum gneiss from Montana to devise a method for beneficiating corundum for use as a substitute for refractory-grade bauxite. A flotation process utilizing petroleum sulfonate as the collector in an acid circuit was devised. Results showed that two flotation schemes each produced a concentrate exceeding the national stockpile specifications for calcined bauxite. From a feed containing 28 pct corundum, concentrates containing up to 92.5 pct alumina (Al_2O_3) were produced with a corundum recovery of 78.5 pct.

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INTRODUCTION

High-alumina refractories such as those made from refractory-grade bauxite have widespread applications. They are extremely durable, possess excellent thermal properties, have good hot load strength, and are corrosion resistant (1).³ High-alumina refractories are essential in many basic industries such as iron, steel, copper, glass, and cement manufacturing (2). The United States is dependent on imports for over 90 pct of the refractory-grade bauxite used in making high-alumina refractories (1). This trend will likely continue; therefore, domestic substitutes must be characterized and evaluated. One such potential substitute is corundum.

Corundum is naturally occurring alumina and is a common constituent in many igneous and metamorphic rocks. Several States have corundum deposits, the major ones being North Carolina and Montana (3). Although many of these deposits are reported to be small, some large-scale high-grade deposits do occur (4).

In the past, corundum was used exclusively as an abrasive. Therefore, demand for corundum ended when synthetic abrasives such as silicon carbide came

into widespread use. Approximately 10,000 st of corundum was produced from domestic sources between 1870 and 1906. Since 1906, no corundum has been produced in this country except for a few small test lots during each of the World Wars (5).

Bauxite consists chiefly of hydrated aluminum oxide minerals and must be calcined at high temperatures to remove the contained water prior to use in refractories. National stockpile specifications for calcined bauxite call for a minimum of 87.0 pct Al_2O_3 . Maximum levels of impurities, in percent, are as follows: 7.00 SiO_2 , 2.50 Fe_2O_3 , 3.75 TiO_2 , 0.50 $K_2O + Na_2O$, and 2.00 $MgO + CaO$ (2).

Corundum has two advantages over bauxite as a source of alumina for refractories. First, corundum deposits occur in the United States. Second, corundum does not require thermal processing for conversion to alumina. The Bureau therefore initiated this research to devise a method for beneficiating corundum for use as a substitute for refractory-grade bauxite.

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and Geology, Butte, Mt. in locating and collecting the sample of corundum ore used in this study.

DESCRIPTION OF THE SAMPLE

An 800-lb sample of corundum gneiss was obtained for this study. The sample was collected from the Camp Creek corundum deposit at the southwest end of Ruby Range, Beaverhead County, MT. Chemical analysis showed the sample to contain approximately 28 pct corundum. Because some of the minerals in the sample other than corundum also contained alumina, all test samples (taken from the bulk sample)

were analyzed for both total alumina and corundum. Corundum analyses were made according to the method described by Pratt (3).

As received, the sample consisted of pieces of corundum gneiss up to a diameter of 12 in. The rocks ranged from massive to well foliated with euhedral corundum crystals up to 3/8 by 1 in. Mineralogical content, in order of abundance as determined by optical microscopy and X-ray diffraction analysis, was corundum, biotite, plagioclase, muscovite, calcite, dolomite, chlorite, prehnite, amphibole, and quartz. Petrographic

³Underlined numbers in parentheses refer to the list of references at the end of this report.

examination revealed the corundum to be liberated at 14 mesh; however, heavy liquid analysis at a specific gravity of 3.3 showed some contamination of the corundum throughout all size fractions.

Electron beam microprobe examination revealed this contamination to occur as minute inclusions within the corundum crystals.

BENEFICIATION STUDIES

Previous beneficiation methods for corundum have stressed gravity concentration. Attempts at gravity concentration on this sample proved less than satisfactory; therefore, froth flotation was emphasized. Due to the high specific gravity of corundum, (4.02) all samples for flotation were ground to minus 48 mesh. A flotation scheme was developed to float the corundum while depressing the other minerals. This scheme uses petroleum sulfonate at a rate of 1.5 lb/st of feed as a corundum collector in an acid circuit. Sulfuric acid at a rate of 8.0 lb/st of feed was used to regulate the pH between 2.5 and 3.0, and hydrofluoric acid at a rate of 1.0 lb/st of feed was used as a corundum activator. Conditioning time was 5 min. Identical tests were run on samples deslimed at 400 mesh, 20 μm , 10 μm , and 5 μm to determine the lower particle size limit to be used as flotation feed. The optimum size was determined to be 400 mesh. In each of the flotation tests a rougher concentrate was floated and cleaned three times. The tailings from the three cleaner stages were combined for analysis. Table 1 gives the material balance for one such test. The resultant concentrate analyzed, in percent, 89.7 corundum, 91.7 Al_2O_3 , 3.5 SiO_2 , 1.1 Fe_2O_3 , 0.8 TiO_2 , 0.2 $\text{K}_2\text{O} + \text{Na}_2\text{O}$, and 1.2 $\text{MgO} + \text{CaO}$. Corundum recovery was 75.5 pct.

The presence of calcite and dolomite in the sample presented difficulties in maintaining the pH between 2.5 and 3.0. A flotation scheme was devised to float the carbonate minerals from the pulp prior to corundum flotation. The pH was raised to 10.0 with sodium carbonate and the carbonates were floated using 0.2 lb of sodium oleate per st of feed as the collector, 0.3 lb of dextrin per st of feed for corundum depression, and 0.1 lb of pine oil per st of feed as a frother. The sample was conditioned for 5 min, and the carbonates were floated from the pulp. The pH was then lowered to 2.5 with sulfuric acid at a rate of 5.0 lb/st of feed, and the corundum was floated as in other tests. In addition to lowering the amount of sulfuric acid needed for pH control, removal of the carbonates allowed flotation of the corundum to yield a smaller size. Table 2 gives the material balance for a typical test on a minus 48-mesh plus 20- μm flotation feed. The resulting concentrate analyzed, in percent, 91.7 corundum, 92.5 Al_2O_3 , 1.8 SiO_2 , 1.1 Fe_2O_3 , 0.6 TiO_2 , 0.2 $\text{K}_2\text{O} + \text{Na}_2\text{O}$, and 0.7 $\text{MgO} + \text{CaO}$. Corundum recovery was 78.5 pct. This scheme resulted in a higher grade and better corundum concentrate recovery than tests that did not utilize the carbonate flotation step.

TABLE 1. - Material balance for the flotation of corundum in an acid circuit

Product	wt pct	Analysis, pct		Distribution, pct	
		Corundum	Al_2O_3	Corundum	Al_2O_3
Concentrate ¹	23.4	89.7	91.7	75.5	41.5
Cleaner tailings....	9.6	19.3	39.5	6.7	7.3
Rougher tailings....	40.2	2.3	33.4	3.3	26.0
Slimes.....	26.8	15.1	48.5	14.5	25.2
Composite.....	100.0	27.8	51.7	100.0	100.0

¹Additional concentrate analyses, in percent, 3.5 SiO_2 , 1.1 Fe_2O_3 , 8.0 TiO_2 , 0.2 $\text{K}_2\text{O} + \text{Na}_2\text{O}$, and 1.2 $\text{MgO} + \text{CaO}$.

TABLE 2. - Material balance for the flotation of carbonate minerals prior to the flotation of corundum

Product	wt pct	Analysis, pct				Distribution, pct			
		Corun- dum	Al ₂ O ₃	CaO	MgO	Corun- dum	Al ₂ O ₃	CaO	MgO
Concentrate:									
Corundum ¹	24.0	91.7	92.5	0.4	0.3	78.5	45.1	1.6	1.9
Carbonate.....	23.4	11.7	37.9	4.8	9.2	9.8	18.0	18.7	55.7
Cleaner tailings..	3.8	36.1	52.2	7.0	2.3	4.9	4.0	4.4	2.3
Rougher tailings..	31.1	3.0	32.3	11.0	3.4	3.3	20.4	57.0	27.3
Slime.....	17.7	5.6	34.9	6.2	2.8	3.5	12.5	18.3	12.8
Composite....	100.0	28.0	49.3	6.0	3.9	100.0	100.0	100.0	100.0

¹Additional concentrate analyses, in percent, 1.8 SiO₂, 1.1 Fe₂O₃, 0.6 TiO₂, and 0.2 K₂O + Na₂O.

CONCLUSIONS AND RECOMMENDATIONS

Two flotation schemes were employed to produce high-grade corundum concentrates. The concentrates resulting from each scheme exceeded the national stockpile specifications for calcined bauxite. Flotation of the corundum using petroleum sulfonate in an acid circuit resulted in a concentrate containing 89.7-pct corundum with a recovery of 75.5 pct. Flotation of the carbonate minerals using sodium oleate in an alkaline circuit prior to flotation of the corundum

resulted in a higher grade concentrate containing 91.7-pct corundum with a recovery of 78.5 pct.

Further laboratory studies should be conducted to optimize recovery and grade of the concentrates. In addition, a large sample of ore should be subjected to continuous testing to determine the applicability of the flotation process. Field studies also are essential to accurately establish the domestic resource base for corundum.

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