Development of Alkaline Aluminosilicates Processing Technology

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Abstract

Alkaline aluminosilicates are of significant interest to the metallurgical and chemical industries, and deposits are widespread in countries like Russia, USA, China, Canada, Venezuela, Mexico, Iran, Egypt, Portugal, Spain, Bulgaria. They can present a viable alternative to bauxites. Complex and waste-free alkaline aluminosililcate processing technology to produce alumina, soda ash and cement was developed by VAMI in the 1st half of twentieth century, from idea to successful realization in several Russian facilities. Till now this technology has ensured competitive alumina production costs by processing all raw material elements into commercial products. For alumina production using this technology, the following raw materials are used: nepheline concentrate after apatite extraction from apatite-nepheline ores in the Khibiny mountains at Kola peninsula, and the Kiya Shaltyr nepheline deposit in the Krasnoyarsk region with a uniquely high alumina content (Al_2O_3 26 – 28 %). Other nepheline sources in Russia and other counties are generally of lower quality (Al_2O_3 19-22 %), and their processing results in more cement produced per tonne of alumina. An economically efficient beneficiation technology has been developed that opens the possibility for more efficient industrial processing of comparatively poor aluminosilicate raw materials in Russia and the rest of the world.

Keywords: alkaline aluminosilicates; processing properties; quality, beneficiation.

1. Introduction

Alkaline aluminosilicates (nepheline syenites, leucites, anorthosites, dawsonites) being widespread in the world are a promising but underestimated raw material source for aluminium production. Nepheline ores are the second most significant raw material for alumina production after bauxites. To date, alumina is produced from nepheline ores at industrial scale only in Russia using two major sources (Kiya-Shaltyr in the Kemerovo Region in Siberia; Kukisvumchor, Yukspor, Rasvumchor in the Murmansk Region). The industrial value of alkaline aluminosilicates is defined by the possibility to produce multiple products (soda ash, potash, cement, Ga, Cs, Rb), assuring the profitability of processing the raw material where the silica content is 1.5 – 2.5 times higher than that of alumina. Russia has pioneered the processing of this raw material into alumina. Continuous improvement of the technology by RUSAL is creating the possibility to widen the existing raw material base by including aluminosilicate raw materials with lower alumina content of which there are huge resources globally.

2. Nepheline Syenite Raw Material Base Review

Igneous Nepheline rocks vary greatly in structural features, the presence of secondary elements, and quantitative interrelation between coloured and colourless components (theralites, nepheline syenite, miaskites, mariupolites etc.). The most industrially important are the nepheline syenite, ijolite and urtite ores.

Nepheline syenites are the most common type of nepheline deposit, and form a quite abundant group of igneous alkali minerals comprising 20-45 % of nepheline $Na_3K[Al_2Si_4O_{16}]$, 20-60 % of alkali feldspar $(K,Na)[AlSi_3O_8]$ (these two minerals generally making 80-90 % of the rock), orthoclase or microcline $K[AlSi_3O_8]$, and auxiliary minerals of biotite, alkali pyroxene, amphibole, apatite, augite and others. The chemical composition of the rock is typically: 50-56 % SiO_2, 19-24 % Al_2O_3, 12-17 % K and Na, some Ca and Mg.

Igneous rocks of this group form often large, often isometric, intrusive deposits that stretch over dozens of kilometers. Due to their formation, such deposits often have pillar like structures and penetrate up to hundreds of metres deep. This ensures their potential for long life open cast mining. The majority of such masses develop within crystalline shields (such as Canadian, Baltic, Ukrainian, Zimbabwe, Malagasy etc.), and in folded mountain regions (Kuznetsk Alatau, Andes, Urals etc.).

Nepheline syenites are widely distributed in Russia (Kola peninsula and Siberia), Canada (Ontario, British Columbia), USA (Arkansas, New Jersey / Beemerville, Massachusetts, Texas), South Greenland, Mexico, Norway (Northern Norway, Oslo district), Sweden, Finland, Italy, Germany (Dresden district), Czech Republic, the Ukraine, Kazakhstan (Priishimye), China, Iran (Razgah deposit), Pakistan, India, South Africa (Kenya, Uganda etc.), Madagascar, Chile, Bulgaria, Brazil, etc.. The mines and deposits of nepheline ores are shown at Figure 1.

Figure 1. Nepheline mines and deposits of the world (adapted from [1]).

Total world nepheline resources are estimated to be in the range of 12-15 billion tonnes. Russia possesses the biggest nepheline resources: apatite-nepheline deposits in the Kola Peninsula are up to 4 billion tonnes of nepheline, and resources of up to 3 billion tonnes in Siberia - Kuznetsk Alatau, Northern Baikal region, Eastern Sayan Mountains, the Sengilen mountain range (South-Eastern Tuva), the Urals (Ilmen and Vishnev Mountains). In Canada about 10 large nepheline deposits are located in the south of Ontario and Quebec provinces [2]. The reserves of each deposit amount to approximately 100 Mt. Third in commercial importance is the Stjernøy deposit located in Norway, which has resources of about 300 Mt. There is the possibility for other big deposits to be explored provided the consumption of nepheline increases.

Nepheline ores are used for 2 main purposes:

(a) as raw material for alumina and by-products at Achinsk Alumina Refinery (AGK) (Kiya-Shaltyr) and in Pikalevo (Khibin concentrate);
(b) for glass and ceramic uses in Canada, China, Norway, Turkey, Russia, South Africa.

For many years two large nepheline syenite deposits have been mined in Canada (Blue Mountain) and Norway (Stjernøy) producing high-purity potassium nepheline-enriched feldspathic concentrates. The composition of the Blue Mountain nepheline ore is 23% - $A1_2O_3$, 60% - SiO_2, and 4% K_2O. Due to presence of alumina and alkali, nepheline concentrates are used as raw material for production of: 1) Glass (flux to reduce fusion temperature, ensures resistance to scratches and cracks, improved heat resistance, chemical recovery); 2) Ceramics (flux to reduce fusion temperature); 3) Filler in adhesives, paint, plastics, and sealants; 4) Mineral wool (thermal insulation); 5) Building stone, etc.

The typical quality of major nepheline ores studied by VAMI for alumina extraction in Russia of China, Iran, Pakistan and North Korea is shown in Table 1. The data shows that the quality of the Russian Raw material is better with respect to alumina and alkali content compared with other ores.

Table 1. Typical quality of major nepheline ores of Russia, China, Iran, Pakistan, North Korea.

Country	Region	$A1_2O_3$	SiO_2	Na_2O	K_2O	Fe_2O_3	CaO
Russia	Kiya-Shaltyr	26.5	40.0	7.2	4.8	4.5	7.0
	Kolsky concentrate	28.5	44.5	10.7	7.1	2.5	1.7
China	Guangzhou	22.5	55.2	0.4	0.3	2.9	-
	Heilongjiang	23.1	55	5.2	3.5	2.5	-
Iran	Razgah	20.0	54.9	6.0	3.9	3.7	2.0
Pakistan	Kota	22-24	48-48	6.5-8.7	4.3-5.7	2-3	-
North Korea	Sackshu ore concentrate	18.0-22.8	42.0-49.9	6.6-7.8	4.4-5.1	9.9-4.3	7.7- 3.8
Mexico	Arroy Grande	19.81	47.33	8.27	5.16	4.03	4.71

Besides ore quality, the commercial value of any deposit for alumina production depends on a number of other factors: remoteness, availability of infrastructure, size of resource, demand for such raw material, etc. Based on the analysis of current interest in nepheline ores we can draw the conclusion that only large deposits with high-quality ores and developed infrastructure have commercial significance.

Results of the geological investigation of many large alkaline magmatic provinces having deposits with variable quality, type and structure, give grounds to expect the discovery of new large and high quality deposits suitable for alumina production. Provided that enough investment in new geological exploration will be available, such deposits can be found in the areas like: 1. Kuznetsk Alatau (Russia), 2. South - Eastern Ukraine; 3. Iran, Razgah deposit etc.; 4. Southern part of the Canadian shield – Ontario and Quebec provinces; 5. Pakistan, 6. China; 7. Mexico. It is arguable that there has generally not been enough systematic geological investigations of such raw materials for alumina extraction in the world.

7. References

1. Virginia T. McLemore, Nepheline Syenite, *Industrial Minerals and Rocks: Commodities, Markets and Users*, *7th Edition*, Society for Mining, Metallurgy, and Exploration, Inc. (SME), 2006, pp. 653 - 670.

2. World Nonbauxite Aluminum Resources Excluding Alunite, *U.S. Geological Survey Professional Paper 1076-C*, 1990.