Górnictwo i Geoinżynieria • Rok 33 • Zeszyt 4 • 2009

Savas Özün, Ümit Atalay*, Yusuf Kagan Kadıoğlu***

INVESTIGATION ON POSSIBILITY OF OPAQUE MINERALS REMOVAL FROM FOID BEARING ROCK

1. Introductıon

Feldspathoids form the main mineral compositions of silica undersaturated magmatic rock units and have general compositional formula of Na, K aluminum silicate. They are indispensable raw materials in glass, ceramics and filler industries. However, nepheline is one of the most common of these compositions. Nepheline syenite or foid bearing syenite is one of the predominant rock units of the alkaline magmatic rocks in CACC. Due to its high alkali and alumina content per unit weight, it has been a formidable competition to feldspar. In ceramic industry, the low fusion point of nepheline syenite lowers the melting temperature, promotes faster melting, higher productivity, fuel savings; the high fluxing capacity of nepheline, allows it to act as a good vitrifying agent. In glass, nepheline syenite also supplies alumina, which gives improved thermal endurance, increased chemical durability and increased resistance to scratching and breaking [4, 7].

The presence of Fe_2O_3 rich opaque minerals within the foid bearing , may cause to act one of the major factors in preventing the development of many of the worlds nepheline syenite deposits, although magnetic separation can remove Fe_2O_3 bearing minerals such as biotite, ilmenite and magnetite, its applicaition solely is not found sufficient. Commercial nepheline syenite ore must have less than 2% Fe_2O_3 content, a property that unfortunately is not very common in deposits that are close to markets. With the exception of colourless glass, nepheline syenite for glass production requires the Fe_2O_3 content to be reduced to 0.35% through processing [2].

* Mining Engineering Department, Middle East Technical University, Ankara, Turcja
** Geological Engineering Department, Ankara University, Ankara, Turcja

2. Materials and methods

The representative ore sample (Nepheline Syenite) used in studies was obtained from CACC, Turkey. XRD pattern and mineralogical studies including microscopic examination of thin sections showed that the representative ore sample contains 45% feldspathoid, 22% orthoclase, 20% plagioclase, 7% amphibole, 4% biotite. In addition to this respectively smaller quantities of ilmenite, magnetite, hematite minerals were also present in the nepheline syenite.

Conventionally feldispatoid/feldspar dominant rocks are concentrated by four stages according to their mineralogical compositions. The first stage is the removal of slime bearing minerals which affect flotation negatively. Second stage is removal of mica minerals like muscovite and biotite in acidic condition using amin type collector by flotation. Third stage is removal of heavy minerals like rutile, magnetite and hematite using sulphonate type collector again in acidic condition by flotation [5, 6]. The last stage is removal of quartz using HF as a deppessant for quartz and amine as a collector for feldspar in acidic condition by flotation [1, 3].

The nepheline syenite sample used in experiments was ground to − 150 micron which apparently corresponds to the liberation size as confirmed by mineralogical analyses. Microscobic analysis were done by Leica DMLP research polarising microscope. Then the sample was screened to remove slime like part by 38 microns sieve and representative samples of the ore each weighing 125 g were prepared prior to flotation experiments.

In this study, the nepheline syenite sample which did not contain quartz mineral was concentrated by flotation and high intensity wet magnetic seperation combined. The chemical analysis' results for ROM ore are given in table 1.

TABLE 1
Chemical analysis results of ROM ore

Content, %	ROM Ore
Na_2O	10.88
K_2O	7.44
SiO_2	57.16
Al_2O_3	25.53
CaO	0.19
TiO_2	0.12
Fe_2O_3	1.36

The flotation experiments were performed following the slime removal by using Aero 704 which is an oleic acid based collector with hidden chemical formula by Cytec Industries

Inc. to remove mica and iron-titanium oxide minerals. 125 gr of sample was subjected to flotation in cell of Wedag Flotation machine. Magnetic seperation experiments were carried out by high intensity wet magnetic seperator of Carpco Company (HIWMS) with 20000 gauss. Chemical analysis were carried out by Spectro X-Lab2000 PEDXRF.

3. Results and discussion

The effect of pH

The objective of flotation test work was to study the effect of pH, amount of collector on the separation characteristics of mica and iron-titanium oxides. Prior to the flotation tests, the samples were deslimed by sieving. The particles finer than 38 microns were removed as slimes.

In these tests, while pH was varied between 9 and 10.5, Aero 704 was used as the collector of which dosage was kept constant at additions of 1500 g/t. The adjustment of pulp pH was accomplished by addition of diluted NaOH solution. The test conditions and the results are summarized in table 2 and table 3 respectively.

The results showed that the flotation of iron and titanium bearing minerals were not very sensitive to pH in the range under investigation. Since the Fe_2O_3 content of feldspar concentrate was important, it was decided to carry out the remaining tests at pH 10.

TABLE 2
Flotation conditions for optimum *pH* determination tests

		Flotation Stage
Pulp Density, % by Wt	Conditioning	50
	Flotation	20
Rotor Speed, rpm	Conditioning	1700
	Flotation	1500
pH		9–10.50
Collector Dosage, g/t		1500
Frother Dosage, g/t		–
Conditioning Time, min		5
Flotation Time, min		4

TABLE 3
The results of optimum *pH* determination tests

Content, (%)	pH 9.0	pH 9.50	pH 10.0	pH 10.50
Na_2O	9,85	10,29	10,65	10,05
K_2O	8,25	8,07	7,89	7,92
SiO_2	56,91	57,98	57,08	57,41
Al_2O_3	25,28	25,02	25,52	25,64
CaO	0,15	0,17	0,17	0,18
TiO_2	0,09	0,07	0,06	0,09
Fe_2O_3	1,13	1,08	0,93	1,00

The effect of collector amount

At these tests all the flotation parameters were kept constant including pH, conditioning time, flotation time, pulp density and rotor speed. The collector dosages were varied from 1000 g/t to 7000 g/t in flotation experiments in order to investigate the effect of collector dosage and determine the optimum collector dosage on removal of discoloring impurities. Increasing the amount of collector did not have any significant effect on the quality of feldspar concentrates, but reduced their recovery. The promising quality concentrate was obtained with consumption higher than 2000 g/t. Table 4 shows the results of collector dosage on removal of opaque minerals.

TABLE 4
The effect of collector dosage on removal of opaque minerals

Content, %	1000 g/t	1500 g/t	2000 g/t	3000 g/t	4000 g/t	7000 g/t
Na_2O	10.7	10.65	10.73	10.51	10.81	10.39
K_2O	7.89	7.89	7.99	7.95	8	8.33
SiO_2	57.1	57.08	57.23	57.05	57.93	58.49
Al_2O_3	25.22	25.52	25.28	25.83	25.06	24.6
CaO	0.19	0.17	0.19	0.16	0.15	0.16
TiO_2	0.085	0.059	0.065	0.061	0.031	0.022
Fe_2O_3	1.11	0.93	0.87	0.78	0.76	0.77

As seen in the table 4, the iron and titanium oxide values were not low enough for industrial uses. In order to decrease the amounts of contaminants in the nepheline syenite floated, HIWMS applications were carried out for 3 times for the concentrates of flotation experiments. Nevertheless, it is easily figured out from the table 5 that the results could not meet the market specifications in terms of iron and titanium oxide values.

TABLE 5
The effect of HIWMS on concentrations of flotation stages

Content, %	3000 g/t Collector + HIWMS	4000 g/t Collector + HIWMS	7000 g/t Collector + HIWMS
Na_2O	11,47	11,14	10,49
K_2O	7,71	7,762	8,13
SiO_2	58,16	58,61	58,35
Al_2O_3	24,83	24,75	25,2
CaO	0,14	< 0,001	0,09
TiO_2	0,036	0,045	0,03
Fe_2O_3	0,42	0,45	0,49

The effect of multi stage conditioning and flotation

The results showed that although amounts of iron and titanium oxides gradually decreased with increasing colloctor dosage, their content were not sufficiently low to meet the demand of ceramic and glass industries. In order to decrease the amount of contaminants of the concentrate, multi stage flotation experiments were performed with different collector dosages.

Considering the results in table 5, even though the collector dosage was increased to high amounts, iron and titanium oxide values did not decrease enough. Hence, multi stage flotation experiments were conducted by disregarding two stage flotations with different dosages since the results of them may not meet the demand. Three cleaning steps were applied in order to compare single stage flotation with eqivalent quantity of collector applying multi stage flotation experiments. The pH, conditioning time, flotation time and rotor speed were kept constant in every stages considering the previous experiments. The collector dosage varied 1500 to 3000 g/t and kept constant in every stages too. Table 6 shows the test experiments' results for three cleaning step flotation.

Compared to the single stage flotation, three cleaning step flotations gave more reasonable results in terms of grade of concentrate. When single stage flotation results with 4000 and 5000 g/t collector dosages were taken in to account, three step conditioning and flotation provided higher grade values with almost eqivalent collector dosages. Following the flotation, HIWMS was conducted three times to remove possible iron-titanium contaminants of three stage flotation concentrates. The results of HIWMS processes applied to flotation concentrates were given in table 7.

TABLE 6

The results of effect of three cleaning step conditioning and flotation

Content, %	3 × 1500 g/t	3 × 2000 g/t	3 × 3000 g/t
Na_2O	11.02	10.92	11.23
K_2O	7.87	8.03	7.887
SiO_2	57.37	58.38	57.95
Al_2O_3	25.38	24.00	24.82
CaO	0.15	0.11	0.15
TiO_2	0.04	0.02	0.05
Fe_2O_3	0.61	0.68	0.66

TABLE 7

The results of combined flotation and HIWMS tests

Content, %	3 × 1500g/t Collector + HIWMS	3 × 2000g/t Collector + HIWMS	3 × 3000g/t Collector + HIWMS
Na_2O	12.08	11.52	11.49
K_2O	7.58	7.38	7.63
SiO_2	58.53	59.06	58.35
Al_2O_3	24.06	24.43	24.82
CaO	0.14	< 0.01	0.08
TiO_2	0.03	0.04	0.04
Fe_2O_3	0.34	0.34	0.38

Due to the fact that the results obtained from HIWMS folowing to – 150 + 38 micron size flotation experiments were not reasonable in terms of contaminant grade of the samples. The best nepheline syenite concentrate of – 150 + 38 micron was subjected to microscobical analysis for the possible liberation defects.

Analysis showed that there were still some unliberated contaminants. Therefore, the sample was ground to – 106 + 38 micron sizes for the following tests. The previously obtained optimum flotation conditions were kept constant during flotation of new feed.

Table 8 shows the results for both effect of particle size on the three cleaning steps flotation and HIWMS following to three cleaning steps flotation. As seen in the table that HIWMS following to the three cleaning steps flotation was resulted a concentrate with 0.01% TiO_2 and 0.22% Fe_2O_3 with 62.5% recovery

TABLE 8
The results of three stage flotation and combined flotation + HIWMS tests for − 106 + 38 micron size sample

Content, %	1500 g/t Collector	3 × 1500 g/t Collector + HIWMS
Na_2O	11.23	11.22
K_2O	7.92	7.84
SiO_2	59.29	58.84
Al_2O_3	23.64	24.41
CaO	0.15	0.14
TiO_2	0.04	0.01
Fe_2O_3	0.47	0.22

4. Conclusion

1) In the light of experimental results following conclusions were drawn.
2) The discoloring minerals were floated away cooperatively by a new kind of collector namely Aero 704 Cytec Industries Inc., in alkali condition instead of applying two stage flotation separately for mica and iron-titanium oxide minerals in acidic conditions.
3) Single stage flotation of ore alone could not produce a concentrate which meets the specifications of the market in terms of iron and titanium oxide.
4) Combination of multi stage flotation followed by HIWMS was resulted a promising concentrate with 0.01% TiO_2 and 0.22% Fe_2O_3 with 62.5% recovery.
5) Further decrease in TiO_2 and Fe_2O_3 content of concentrate was not possible due to very fine dissemination of these contaminants in the nepheline syenite ore.

REFERENCES

[1] *Bayraktar I.*: Upgrading Titanium Bearing Na-Feldspar by Flotation Using Sulphonates, Succinamate and Soaps of Vegetable Oils, Minerals Engineering, Vol. I, No. 12, 1997, 1363−1374
[2] *Bolger R.*: Feldspar and nepheline syenite. Industrial Minerals 332, May, 1995, 25–45
[3] *Celik M.S.*: Removal of Titanium Impurities from Feldspar Ores By New Flotation Collectors, Minerals Engineering, Vol. 17, No. 12, 1998, 1201−1208

[4] *Guillet R.G.*: Nepheline Syenite Benificiation for Different Industrial Applications, Industrial Minerals and Rocks, 6th Edition, Senior Editor Carr D.D. Society of Mining, Metallurgy & Exploration. Inc.,1994

[5] *Gülsoy Ö.Y.*: Feldspar Production from Magmatic and Metamorphic Rocks Using Magnetic Separation and Flotation, Bulletin of Earth Sciences Application and Research Centre of Hacettepe University, Volume 30, 2005, 49–61

[6] *Gülsoy Ö.Y.*: Production of Potassium Feldspar Concentrate from Very Low Grade Pegmatitic Ore in Turkey. Mineral Processing and Extractive Metallurgy, Volume 114, 2005, 80–86

[7] U.S. Geological Survey, 2007 Minerals Yearbook, Feldspar And Nepheline Syenite [Advance Release]