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EVALUATION BENEFICIATION AND UTILIZATION OF KOGA NEPHELINE SYENITE AS GLASS AND CERAMICS RAW MATERIALS

Part II. Beneficiation and Pilot Plant Studies

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The present investigation shows that commercial grade feldspar, the raw material for glass and ceramic industry, could be produced from nepheline syenite rocks. Pilot plant beneficiation of bulk samples were undertaken to study the grade-recovery parameters. Rod mill grinding in close circuit with a classifier was found superior to ball mill grinding. The grindability studies gave a work index of 13-14.7 Kwh. A recovery of 70 % on classified feed basis with Fe content of less than 0.1 % was achieved in three stages. The study led to the development of a process flow sheet for subsequent designing and operational trials.

Key words: Nepheline; Syenite; Beneficiation;

INTRODUCTION

In view of the projected future demand [1] and the non-availability of good grade potash bearing alkali feldspar, alternative sources were explored. Sizeable and economic reserves of nepheline syenite deposit occurring in Koga area was found on the basis of chemical and mineralogical composition to be an excellent substitute for alkali feldspar [2]. The rock itself contained high Fe_2O_3 contents (1.8-3.8 %) in the form of iron bearing minerals such as biotite, pyroxene, amphibole and ilmenite. The iron bearing minerals can be removed by using magnetic separation as shown in the previous studies [2, 3]. The magnetic content upto 0.2 % Fe is suitable for coarse ceramics, 0.1 % for fine ceramics and upto 0.08 % Fe content is acceptable in the glass industry.

A batch of 50 tonnes of bulk sample was collected from Landhi Patao body I and II and the Agarai area of Koga. Experiments were conducted using pilot plant equipment for producing raw material for glass and ceramic industries. The objective on the beneficiation study was to find the grade and recovery of the concentrate and to optimize conditions for different types of rocks in Koga area. A tentative process flow sheet (Fig. 6) based on the finding of this investigation was developed and submitted to the Sarhad Development Authority.

EXPERIMENTAL

Results of different separation techniques. Different sized fractions prepared by grinding rock in a ball mill were subjected to minerals separation or beneficiation by (i) heavy liquid technique (HLS), using Clerici solution of 1.53 refractive index, corresponding to 2.9 specific gravity; (ii) high intensity magnetic separation (HIM), using Isodynamic magnetic separator (HIM); and (iii) by combination of HLS and HIM separation techniques by first separating by means of HLS and cleaning by HIM. The results are summarized in Table 1.

Table 1.

Mesh (size)	Fe (%) in HLS conc.	Fe (%) in HIM conc.	Fe (%) in HLS + HIM oonc.
30-60	0.38	0.29	0.23
60-80	0.35	0.17	0.17
80.150	0.29	0.10	0.08
150-200	0.23	0.06	0.09

It could be concluded that no significant difference is found in the HLS & HIM combination technique. The HLS technique could not yield the desired products, whereas the HIM technique alone is sufficient for mineral purification.

Bulk processing of agari ore by dry magnetic sepration. Davies Non-Entraining Magnetic separator (model No. 51V, Davies Magnetic Works Limited, Herts, England) was employed for dry magnetic separation. Bulk ore was ground in a rod mill and classified using 30, 60 and 200 mesh sieves. The ore was subjected to magnetic separation at 3.5 and 4.5 amperes. The Fe % in various fractions is given in Table 2.

Table 2.

	Size fraction	Fe %
a)	– 30+ 200 Head (– 30 + 200)	2.6
	Non-Non-magnetic 1st pass at 4.5A	1.3
	Magnetic 1st pass	13.5
	–200 mesh size	2.5
	Non-magnetic fraction after 3 passes at 4.5A	0.46
b)	– 60 + 200	
	Non-magnetic 1st pass at 4.5A	0.85
	Non-magnetic 2nd cleaning	0.57
	Non-magnetic 3rd cleaning	0.40
	Magnetics	18.10
c)	– 60 + 200	
	Isodynamic cleaning in the laboratory	0.20

Experiments on bulk processing using wet circuit. The rock was crushed in a rod mill fitted with a hydrocyclone classifier in a closed circuit. The classified fractions were fed to Eriez CF-5 Model magnetic separator (of Eriez, Pennsylvania, USA), at 7800 gausses. Further cleaning results are given in Table 3.

Table 3.

	Head	Fe %
	Head	2.12
Non-magnetic	First pass at 7A	0.31
	(First pass at isodynamic	0.12)
	First pass –40 mesh	0.41
	First pass – 60 mesh	0.17
	First pass –80 mesh	0.12
Non-magnetic	Second pass at 7A	0.150
Non-magnetic	Third pass at 7A	0.11

Grindability studies. Tests in the laboratory and pilot plant were carried out in ball mills and rod mills both in dry and in wet state. Grinding in a ball mill showed an excessive generation of fines. The rod mill grinding, working in closed circuit with a classifier, showed that a reasonable amount of the desired size fraction was obtained at relatively smaller proportions of fines as compared to the ball mill grinding.

It was observed that operating the mill below 100 % circulating load, overground the material. The effect of circulating load on the generation of fines (-200 mesh) is illustrated in Fig. 1 and 2. The optimum grinding conditions were obtained in wet grinding in a rod mill operating with 2 sets of hydrocyclones, at 100-200 % circulating load when 12-14 % fines were generated. Table 4 and 5 shows size analysis of products in 45 cm x 100 cm rod mills operating dry and wet at about 100 % circulating load.

Bond work index. The relationship between energy input and particle size made from the given feed for the nepheline syenite samples was determined using the Bond crushing and grinding theory [4]. The tests were performed in a standard 30cm ball mill, manufactured by Bico Braun Inc. USA.

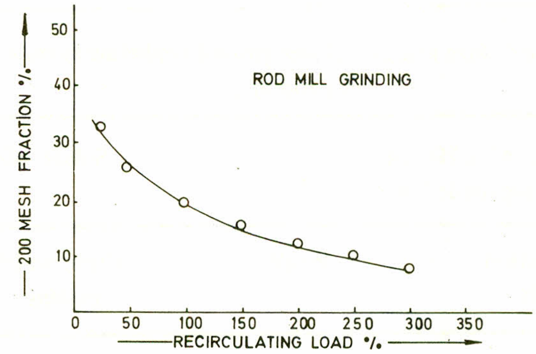


Fig. 1. Effect of recirculation load on the generation of fines.

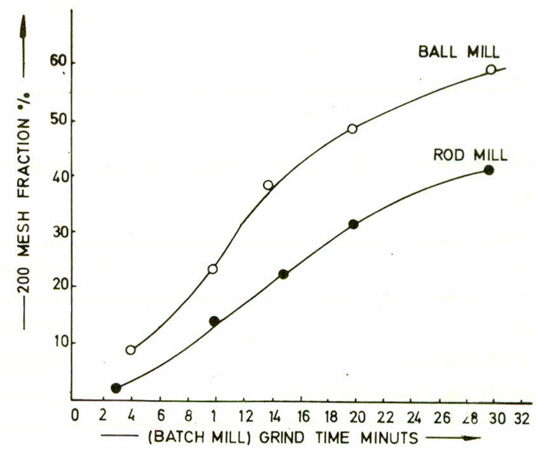


Fig. 2. Effect of grind time on the generation of fines C-2000 mesh fraction.

Table 4. Size analysis of dry ground nepheline syenite in a rod mill.

Ore charge: 67 Kg Mill size: 45 x 100 cm

Circulating load (oversize Recycled): 110 %

Size fraction mesh	Wt. (%)	Cum. (%) passing
+40	51.61	48.39
+60	14.84	33.55
+70	1.94	31.61
+80	5.16	26.45
+85	0.64	25.81
+120	4.51	21.30
+150	1.29	20.01
+200	7.74	12.27
–200	12.25	00.00

Table 5. Size analysis of wet ground nepheline syenite in a rod mill.

Mill size: 45 x 100 cm Solids: 60 %
Circulating load: 100 %

Size fraction mesh	Wt (%)	Cum. wt (%) passing
+50	26.56	73.44
+100	29.72	43.72
+150	10.27	33.45
+200	11.27	22.18
–200	22.18	–

The Bond Work Index of the three ores was calculated as follows :

Ores	*Work Index*
Agarai	12.95
Landi Patao Body-1	14.24
Landi Patao-Agarai Body-II	14.70

Dry magnetic separation. A high intensity separator manufactured by Davies (England) Model No. 51V was used. Feed rates were adjusted to about 250 kg/hr. After first cobbing at 3A (2500 gauss) the non-magnetics were given two more passes at 4A and 5A (4500-5000 gausses). The flow sheet used for cleaning operation is shown in Fig. 3. The final non-magnetic fraction showed 0.4 % Fe content, at weight recovery of 78 % based on classified head feed.

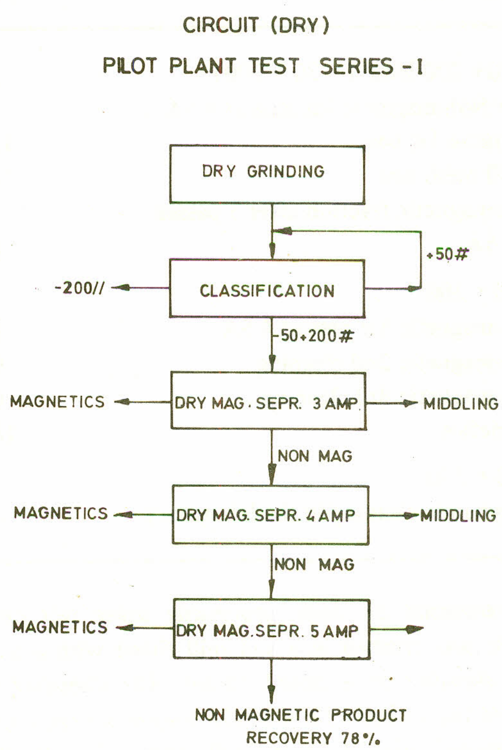


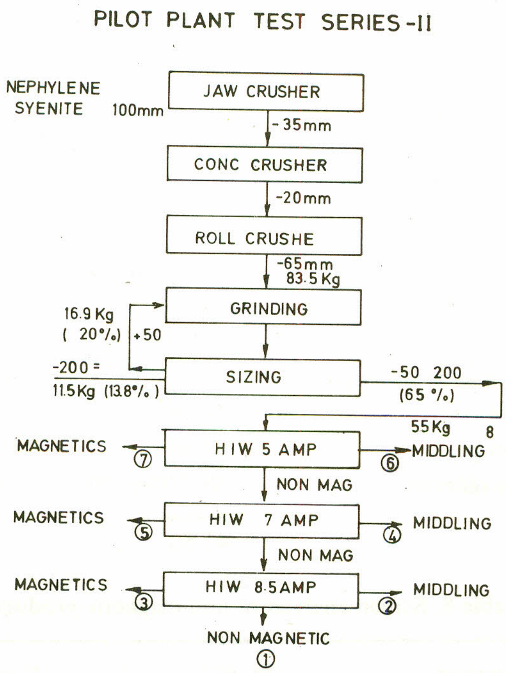
Fig. 3. High intensity magnetic separation.

The test showed that higher power was required to effect any further cleaning. Subsequent tests were carried out on Eriez CF-5 HIW magnetic separator.

Wet magnetic separation. A wet circuit was used for grinding, classification and high intensity magnetic separation. A number of separation trials were carried out at different intensities of the magnetic field. Typical flow sheets developed for the high intensity magnetic separation circuits are shown in Fig. 4 and 5. Material balance for various fractions are given in Table 6 and 7.

DISCUSSION

The rock samples were crushed, ground and separated into different size fractions. Microscopic examination of the fractions showed that over 80 % of the iron bearing minerals viz. biotite, pyroxene, amphiboles etc., were liberated at 0.3mm (60 mesh B.S.S.) size. The samples were ground to 60 mesh using close circuit grinding-classification methods. The fraction finer than 0.076mm (200



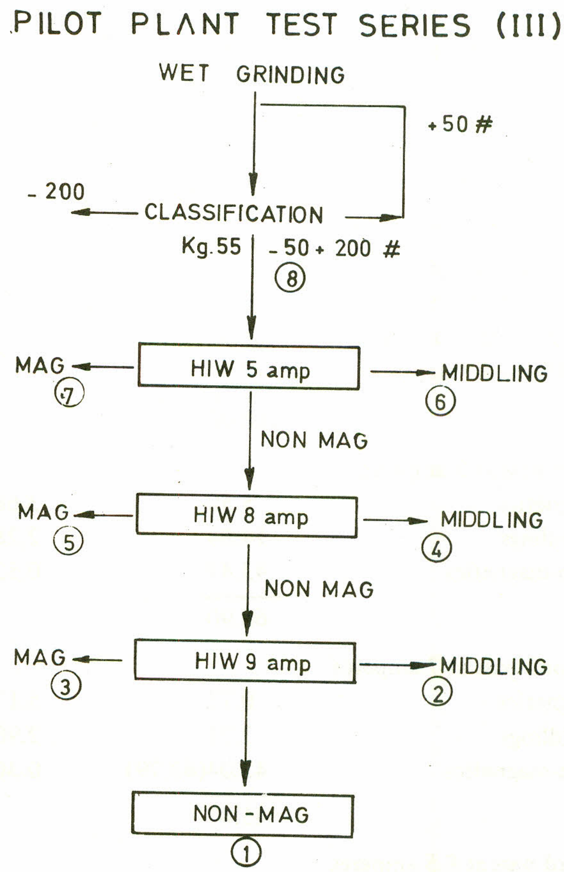
PRODUCT NO.	WEIGHT RECOVERY (Kg)	RECOVERY % CLASSIFIED FEEE BASIS
1	31.80	57.87
2	2.65	4.81
3	0.50	0.90
4	2.25	4.10
5	0.61	1.10
6	12.34	22.44
7	4.65	8.45
8 Classified feed	45.80	99.62

Fig. 4. High intensity wet magnetic separation of Koga nephylene syenite.

mesh) was removed in order to obtain the size fraction suitable for glass industry. The fraction between 60 and 200 mesh was subjected to high intensity magnetic separation using an isodynamic magnetic separator. Progressive increase in the field strength showed that optimum separation was obtained at field strength of about 1 Tesla (9500-10,000 gausses).

The present study includes crushing and grinding behaviour and grindability of the nepheline syenite from the Koga area in laboratory and pilot plant operations. This would be followed by the removal of the excess quantity of iron bearing minerals so that the upgraded material contained around 0.1 % iron. The particle size limit and the low iron content is the pre-requisite of the glass industry.

The desirable size range of the nepheline syenite for the glass industries lies between 30 mesh and 200 mesh. In the material supplied, however, adequate liberation of the iron bearing minerals, as discussed earlier, was observed at below 50 mesh size particles. It was decided that the size



PRODUCT N	Weight Kg	Recovery % Classified feed	PRODUCT N	Weight Kg	Recovery % Classified feed
1	34.00	62.96	5	0.33	0.61
2	3.25	6.02	6	10.40	19.26
3	0.094	0.17	7	3.43	6.35
4	2.26	4.19	8	53.94	99.56

Fig. 5. High intensity wet magnetic separation of Koga nephylene syenite.

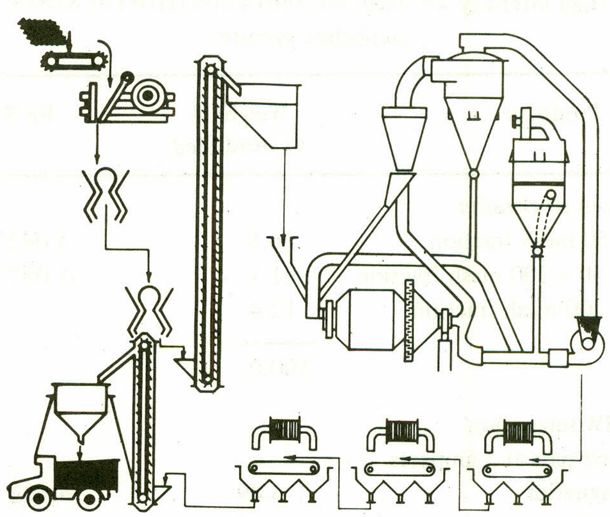


Fig. 6. Process flow sheet.

Table 6. Material balance of pilot plant test series-2 High intensity wet magnetic separation (HIW) of KOGA nepheline syenite.

Products	Weight % of head feed	Fe %
Feed to classifier		
+ 50 mesh fraction	20.3	1.20
– 50 + 200 mesh fraction	65.9	
– 200 mesh fraction	13.8	
	100.00	
First pass at 5 amperes		
Magnetics	5.59	3.683
Middlings	14.84	2.282
Non-magnetics	45.47	0.533
	65.90	
Second pass at 7 amperes		
Magnetics	0.72	5.177
Middlings	2.71	2.90
Non-magnetics	42.04(63.79)	0.302
	45.47	
Third pass at 8.5 amperes		
Magnetics	1.08	2.991
Middlings	3.19	1.620
Non-magnetics	37.77(57.31)	0.113
	42.04	

Table 7. Material balance of pilot plant test series-3 High intensity wet magnetic separation (HIW) of KOGA nepheline syenite.

Products	Weight % of head feed	Fe %
Feed to classifer		
+ 50 mesh fraction	26.5	1.092
– 50 + 200 mesh fraction	61.1	1.092
– 200 mesh fraction	12.4	
	100.0	
HIW separation		
First pass at 5 amperes		
Magnetics	3.89	4.102
Middlings	11.78	2.212
Non-magnetics	45.43	0.544
	61.10	
Second pass at 8 amperes		
Magnetics	0.37	10.584
Middlings	2.56	3.774
Non-magnetics	42.50(69.56)	0.262
	45.43	
Third pass at 9 amperes		
Magnetics	0.09	3.652
Middlings	3.68	1.910
Non-magnetics	38.73(63.39)	0.097
	42.50	

(Continued on column 2)

(Table 7, Continued)

Table 8. Screen analysis of non-magnetic products.

Size fraction mesh	Wt. (%)	Cum. (%) passing
+ 50	0.88	99.12
– 50 + 100	19.36	79.76
– 100 + 150	36.96	42.80
– 150 + 200	35.98	6.82
– 200	6.82	–

fraction to be recovered should be in the range – 50 + 200 mesh.

The ore, although was hard, on grinding generated excessive amounts of fines (-200 mesh). Fig. 1 and 2 shows the progressive generation of fines with increasing grind-time. It was considered worthwhile, therefore, to conduct grinding in close circuit with a classifier. Several variables were altered such as particle size range in the feed, circulating load, ratio of grinding media to the feed etc., in order to obtain adequate amount of the desired product size at the minimum generation of fines.

The magnetic separation exercise indicated that the iron contents in the final product could be reduced to less than 0.1 % Fe. The overall recovery of the product was calculated on the head feed basis; in the actual fact the oversized fraction (+50 mesh) which varied from 20 to 27% or even more at higher circulating load values may be regarded as part of the feed which during the closed circuit grinding mill again produce -50 mesh fraction. Thus, on the basis of classified feed, the recovery of the final non-magnetic fraction increased to about 70 %. The screen analysis of the final concentrate contains about 27 % -200 mesh fraction, which reduce the apparent value of 52.6 % to 38.4 %.

Laboratory and pilot plant tests on crushing, grinding, classification and high intensity magnetic separation led to the development of a process flow sheet, as shown in Fig. 6. This flow sheet should serve as a guideline for subsequent studies required for detailed engineering design and test work.

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