



Beneficiation of a feldspar ore for application in the ceramic industry

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Synopsis

Beneficiation studies were conducted on a Portuguese feldspar ore, in order to obtain final products capable of being used in the ceramic industry. A simple scrubbing operation is enough to break the lumps in the feed. The ore deposit contains ca 35×10^6 tonnes from which, by screening, three main products could be obtained. This paper focuses on the beneficiation of the 500/74 μm fraction, which constitutes about 27% of the ore, assaying 9.42% Al_2O_3 , equivalent to approximately ca 46% feldspar, with a mean iron content of 0.29% iron oxides.

Magnetic separation and froth flotation testwork was carried out, in order to decrease the iron contamination and increase the feldspar content. Magnetic separation alone decreased the iron content of the feed to values between 0.04 and 0.08% iron oxides with an average yield greater than 90%. Flotation with HF, provided a feldspar recovery of 45–46% with a concentrate assaying 17.6% Al_2O_3 . The use of H_2SO_4 , gave a recovery of 35–36% of feldspar concentrate, assaying 16.1% Al_2O_3 . However, economic and environmental advantages of using sulphuric acid may compensate for the lower mass recovery. The iron content of 0.12% iron oxides in these concentrates, could be reduced to 0.04–0.05%, by further magnetic separation.

Introduction

The demand for feldspar as a raw material for the ceramic industry is continuously increasing. In Portugal, the traditional sources of feldspar^{1,2}, pegmatitic and aplopegmatitic lodes and feldspathic sands from old mine dumps are becoming either exhausted or lacking quality. This implies an increase in the imports of high quality raw material. It became therefore imperative to look at other types of deposits, such as this arkose, a sedimentary rock originated from the erosion of granites, where the resulting particles were deposited after a hydraulic transport.

Mineralogically this particular arkose is mainly formed from variable proportions of quartz, feldspar and kaolin, and smaller amounts of mica and iron-containing minerals. The ore reserve is approximately 35×10^6 tonnes of siliceous and feldspathic sand and kaolin³.

This paper describes the application of

magnetic separation and froth flotation techniques for the beneficiation of the 500/74 μm fraction, in which the feldspar is naturally concentrated.

Mineralogical and liberation studies

The mineralogical studies showed that intergrown feldspar/quartz particles were practically absent in sizes smaller than 500 μm . A very low content of mica was also noted in the 500/74 μm fraction. The main minerals incurring penalties, which were identified by Scanning Microprobe Analysis, were tourmaline and ilmenite. These were less than 0.35% of this fraction. Traces of zircon, andaluzite, rutile, iron oxides and spodumene, were also found.

The -74 μm fraction is a kaolin with 54% kaolinite, 12% montmorillonite, 11% mica, 14% quartz and 8% K-feldspar, with a possible ceramic application. In order to avoid slime coating in the separation processes, the -74 μm fraction was removed. This is a common procedure in industry.

The +74 μm material was classified into narrow size fractions, in which the feldspar contents were determined. The cumulative grades and distribution of feldspar in the size fractions are illustrated in Figure 1. A natural concentration of feldspar can be observed between 74 and 700 μm . However, the difficulty in maintaining the pulp particles in suspension, which is a characteristic of the Denver flotation machine used in the testwork, limited the treatment of the 500/74 μm fraction.

The chemical composition of a representative ore sample divided into the three relevant size fractions, was determined by X-ray fluorescence and is shown in Table 1.

From the values in this table, it can be seen that by a selective screening process after scrubbing, it was possible to obtain the following products:

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Table I

Size analysis and chemical composition of a representative arkose sample

Size μm	Mass %	SiO ₂ %	Al ₂ O ₃ %	Fe oxides %	MnO %	MgO %	CaO %	NaO %	K ₂ O %	TiO ₂ %	P ₂ O ₅ %	L.I. %
+500	45.6	94.8	2.85	0.11	trace	trace	0.01	trace	1.9	0.03	trace	0.32
500/74	27.3	81.68	9.42	0.29	0.02	trace	0.02	0.47	7.05	0.03	0.02	0.29
-74	27.1	60.56	21.86	2.27	0.02	0.72	0.11	0.24	4.87	0.59	0.05	8.38
TOTAL	100	81.92	9.74	0.74	0.02	0.19	0.03	0.2	4.1	0.26	trace	2.49

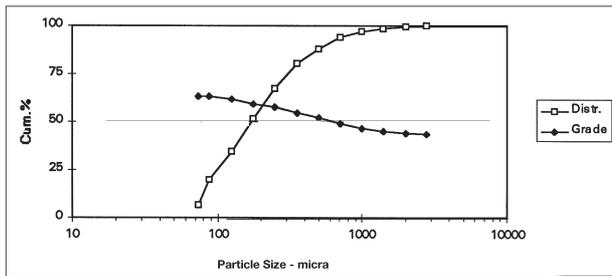


Figure 1—Cumulative grades and distributions of feldspar vs particle size

- At +500 μm, approximately 46% of the ore material, rich in quartz and with the lowest iron oxide content
- At 500/74 μm, approximately 27% of the ore, rich in feldspar (≈46%), with a mean total iron oxide content averaging 0.29%
- At -74 μm, approximately 27% of the ore, mainly kaolin, with a mean iron oxide content of 2.27%.

Magnetic separation testwork

The beneficiation tests were done on the 500/74 μm product, with a wet or dry feed, using a Jones mini model wet magnetic separator from Stearns-Roger and an Induced Roll from Boxmag-Rapid at different intensities of the magnetic field, namely 12, 18 and 20 kGauss, and a Perm Roll from Master Magnets, which has a permanent intensity of approximately 12 kGauss.

Table II contains the yields and the mean iron oxide grades obtained with the 500/74 μm material and the 500/212, 212/106, and 106/74 μm fractions. These results are also plotted in Figures 2, 3, and 4, to illustrate a better comparison of the wet and dry processes.

In the results obtained with the Jones and the Induced Roll separators, a similarity can be seen for all the wet feed fractions and the dry feed particles coarser than 106 μm.

At 12 kGauss, an iron oxides content between 0.05% and 0.13%, corresponding to yield values of about 97% was achieved; at 18 kGauss the iron oxides in the final product were reduced to values between 0.04–0.08% with the above-

Table II

Reduction of the iron content in various size fractions of the 500/74 μm material, at different intensities of the magnetic field

TEST		Total Fe oxides in the feed **	Intensity of the magnetic field (kGauss)				No improvement was obtained when compared to results achieved with 18kG	
			12		18			20
			YIELD %	Total Fe oxides, %	YIELD %	Total Fe oxides, %		
DRY Box-Mag Rapid	500/212	0.20	97.8	0.05	95.5	0.04		
	212/106	0.43	96.3	0.10	93.0	0.06		
	106/74	0.45	88.8	0.13	82.3	0.07		
	500/74	0.29	94.5	0.11	92.5	0.06		
WET Jones	500/212	0.20	97.5	0.07	93.7	0.05		
	212/106	0.43	97.1	0.13	94.9	0.06		
	106/74	0.45	97.2	0.13	94.3	0.08		
	500/74	0.29	97.3	0.12	94.5	0.07		
Permroll	500/212	0.2	86.6	0.08				
	212/106	0.43	85.8	0.10				
	106/74	0.45	79.5	0.11				
	500/74	0.29	81.7	0.08				

* Size distribution of the (500/74) μm sample: (500/212) μm - 50.4%, (212/106) μm - 39.7% and (106/74) μm - 9.9%

** All assays conducted by Atomic Absorption

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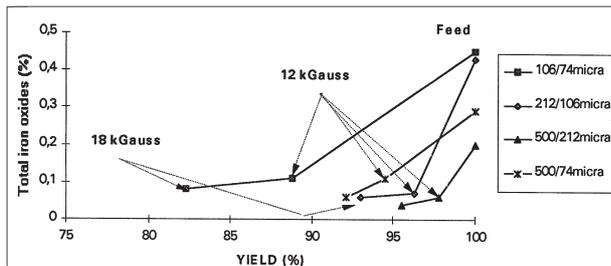


Figure 2—Results obtained with a DRY FEED, by varying the field intensity on the Induced Roll magnetic separator

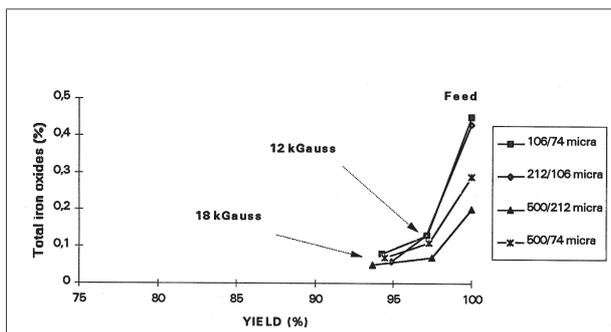


Figure 3—Results obtained with a WET FEED, by varying the field intensity on a Jones magnetic separator

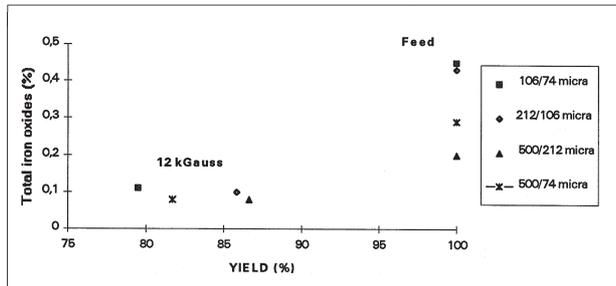


Figure 4—Results obtained with a DRY FEED on a Permroll magnetic separator

mentioned separators. However, for the size range 106/74 μm (the finest fraction), the achievement of this target for the iron oxides content with the Induced Roll separator, implied a significant reduction of the yield (ca 82%).

The iron oxide grades obtained with the Permroll are comparable to those of the other two separators, at the same intensity. It can be seen that the yields are generally much lower and very similar to those obtained with the fraction between 74 μm and 106 μm when treated in the Induced Roll. As a contribution for the understanding of this behaviour, it seems that these results are mainly due to an intrinsic feature of the treatment by dry magnetic separation, being related to an indiscriminate adhesion of non-magnetic particles to the magnetic fraction, which is enhanced in the finest sizes.

The graphs of Figures 2, 3 and 4, also illustrate a typical behaviour of well-liberated feed samples. This permits the

removal of penalty-incurring minerals, without significant losses of material.

No improvement was achieved at still higher intensities.

Froth flotation testwork

Preliminary testwork

Extensive batch testwork was carried out in order to optimize techniques and this included the effectiveness and consumptions of HF and H_2SO_4 as pH value regulators and testing of various collectors. The preliminary testwork indicated:

- (i) the necessity of submitting the sample to a desliming at 74 μm , after scrubbing
- (ii) the technical impossibility of conducting experiments with particles greater than 500 μm in a Denver laboratory flotation machine
- (iii) a very slow flotation of mica associated with the iron-bearing minerals, regardless of the collectors used
- (iv) a high reagent consumption in all the testwork.

The feed (1kg of 500/74 μm product) was placed in a 3L Denver cell and, based on the above information, the experiments were conducted with the following steps:

- Flotation of mica + iron-bearing minerals at a pH value of 3.5
- Flotation of feldspar at a pH value of 2.4
- Reduction of the iron content of the feldspar concentrate by magnetic separation.

Results

The flotation of mica and iron-bearing minerals was efficiently achieved with petroleum sulfonate collectors such as Aero 801 and 825, although the final feldspar concentrate still needed a cleaning by magnetic separation. A rougher and a scavenger stage were used. Both collectors were added to each stage, in equal dosages of 200g/t. The frother used was MIBC in two separate additions of 30g/t each.

Separation of feldspar from quartz can be achieved with cationic collectors in acid circuit, at a pH value in the vicinity of 2.4. Other workers⁵, found that at the pH range of 2.5 to 3, a maximum selectivity could be achieved. Various collectors were tested. The comparison of the concentrates obtained, shows that the choice of the Akzo Nobel anionic collectors, Armoflote 820 (alkylamine acetate, an alternative to tallowalkylamine acetate, which has the advantage of being liquid) and Armoflote 543 (a water dispersible version of Duomeen TDO) when HF or H_2SO_4 respectively were the pH regulators, led to a reasonably selective feldspar flotation, using the following procedure.

No frother was added and the collector dosages were optimised at

- Armoflote 820 (1500g/t) with HF (ca 1000g/t) and
- Armoflote 543 (1800g/t) with H_2SO_4 (ca 2000g/t).

The addition of either HF or H_2SO_4 as pH regulators, substantially influenced the overall results. An increase in feldspar recovery was attained in the presence of hydrofluoric acid. A comparison of the results obtained with these two acids is shown in Table III.

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Table III

Comparison of results obtained with either hydrofluoric or sulphuric acids as pH regulators in feldspar flotation

pH regulator	Flotation products	Mass %	SiO ₂ %	Al ₂ O ₃ %	Total Fe oxides %	MnO %	CaO %	MgO %	Na ₂ O %	K ₂ O %	TiO ₂ %	P ₂ O ₅ %
	Feldspar conc.	45.6	66.68	17.6	0.12	0.01	0.05	trace	0.6	13.87	0.09	0.08
	Quartz sink	48.3	97.8	1.23	0.07	trace	0.02	0.02	0.16	0.73	0.03	trace
	Feldspar conc.	35.7	69.38	16.08	0.12	trace	0.09	trace	0.44	12.51	0.06	0.07
	Quartz sink	57.9	88.78	5.64	0.08	trace	0.06	trace	0.11	4.39	0.05	0.01
Average feed (500/74) μm			81.68	9.42	0.29	0.02	0.02	trace	0.47	7.05	0.03	0.02

The use of HF gave rise to concentrates assaying 17.6% Al₂O₃ (ca 88% feldspar) and quartz tailings with almost 98% SiO₂, amounting to, respectively ca 46% and ca 48% of the initial 500/74 μm feed material. With the addition of H₂SO₄, the grade of the feldspar concentrate was a little lower (ca 82% feldspar) but the yield decreased to 35.7% and accordingly the quartz tailings assayed only 88.8% SiO₂. However, economic and environmental advantages of using sulphuric acid, may compensate for the lower feldspar recovery achieved.

Conclusions

The beneficiation of a feldspar ore assaying on average, 9.74% Al₂O₃, 81.92% SiO₂, 0.74% total iron oxides, 4.1% K₂O and 0.2% Na₂O, provided several types of products capable of being used in the ceramic industry.

- (1) By screening after scrubbing, a natural preconcentration of feldspar occurs in the 500/74 μm particle size fraction. A recovery of 27% of the ore deposit by weight was achieved, to give a product with a feldspar content of approximately 46%. This represents more than 75% of the feldspar in the deposit.
- (2) By cleaning the 500/74 μm particle size fraction using magnetic separation the iron content could be reduced from 0.29% to between 0.04% and 0.08% total iron oxides. With a magnetic field of 18 kGauss, the yields

reached for both the dry and the wet feeds were about 94%, except for the dry material below 106 μm, where it was only 82%.

- (3) Flotation with HF or H₂SO₄ as the pH regulators and Armoflote 820 and 543, amine acetate collectors, led to yields of 45.6% and 35.7% respectively, and provided feldspar concentrates assaying ca 17% Al₂O₃. These concentrates contained 0.12% total iron oxides, which could be reduced to values between 0.04%–0.05% by magnetic separation.

References

1. FARINHA RAMOS, J.M., and MOREIRA, A.D. Principais Recursos Minerais Não-Metálicos, Aflorantes na Área correspondente à Folha 1 da Carta Geológica de Portugal, à escala de 1/200000. *Memórias e Notícias* no. 112. 1991. pp. 347–362.
2. GRADE, J., and CASAL MOURA, A. Estudo das Formações Gresosas Cretácicas (Albiano-Aptiano), do flanco Sul do Sinclinal Apedriz- Porto Carro, Notas e Trabalhos. Tomo 34. 1992. pp. 85–94.
3. GRADE, J. *et al.* Jazigo da Catraia: Fonte Alternativa de Fundentes Feldspáticos para a Indústria Cerâmica. *Boletim de Minas*. vol. 31 - no. 1. 1994. pp. 33–46.
4. GAUDIN, A.M. *Flotation*. 2nd Edn. McGraw-Hill Book. Co. Inc. New York. 1957. p. 491.
5. ABDEL-KHALEK, N.A., YEHA, A., and IBRAHIM, S.S., Beneficiation of Egyptian feldspar for application in the glass and ceramics industries. *Minerals Engineering*. Elsevier Science Ltd. vol. 7, no 9. 1994. pp. 1193–1201. ◆