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BENEFICIATION OF FELDSPAR ORES FOR THE CERAMICS INDUSTRY

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ABSTRACT: The paper is concerned with the problem of beneficiating crude ores for producing feldspathic materials used in the ceramics industry, such as granite rocks and their acid differentiae. Two cases have been considered, an albitite and a granite, and the possibility examined of obtaining good quality commercial products by means of a single mineral processing technique or a combination of different treatments. The washability by gravity concentration, floatability and amenability to magnetic separation have been experimentally determined. Based on the findings of these tests, processing schemes have been devised and the possible technical results simulated.

1. INTRODUCTION

The low~ melting temperature of alkaline feldspars makes them an essential raw material in the manufacture of ceramics.

As temperature is increased feldspar based ceramic mixes begin to soften and the slow, gradual decrease in viscosity brings about the vitrification of the bulk as the other ingredients dissolve (Leonardelli, 1989).

The main sources of feldspars are pegmatites and the acid granite differentiae, such as aplitic and heuritic rocks. The rapid and steady expansion of the ceramics industry over these last ten years has however accelerated the depletion of traditional resources and manufacturers have been forced to turn their attention to potential alternative resources including granites in particular, which are readily and widely available (SVI.MI.SA., 1991).

However, in general the original composition of these alternative resources, and more so that of granites, precludes their direct use in the ceramics sector owing to their low alkali content, or more commonly, to the presence of more or less large proportions of undesirable impurities, particularly detrimental being the elements containing iron, titanium and copper.

In fact the presence of Fe, Ti and Cu has a decisive effect on one of the main parameters on which the quality of the end products is judged, namely whiteness, the other main parameter being firing temperature

In order to meet the quality requirements laid down by the ceramics industry these materials are submitted to preliminary treatment The processes must necessarily be simple and cheap on account of the low price that these materials fetch on the market.

Two cases of commercial interest are considered here, currently being examined by two suppliers who between them hold a large share of the Italian market for feldspars. Italy is in fact one of the world's largest producers of ceramics

The two mineralizations concerned are ubicated in central-southern Italy One is an albitite rock originating from the metasomatic alteration of granites and the second is a granite rock chosen on the basis of its favourable texturals features and minero-petrographic properties.

The possibility has been explored of obtaining marketable products by experimenting the technical applicability of different mineral processing techniques, or a combination thereof, namely gravity and magnetic separation and, for the albitite, already marketed for the manufacture of low quality ceramic materials, flotation too.

Based on the results of laboratory tests, processing schemes have been devised and the possible technical results have been simulated.

A brief outline of the quality requirements laid down by the Italian ceramics industry for the main feldspathic materials is given below to give the reader a more complete picture

2. MARKET SPECIFICATIONS

The feldspathic materials used in the ceramics industry are generally mixtures of orthoclase and albite, in no matter what ratio. The presence of minor amounts of anorthite is tolerated whereas chlorite is not.

Market specifications vary depending on the kind of product to be manufactured (Curreli et al,1990).

The following sectors can be distinguished:
- hard porcelain;
- vitreous china;
- vitreous tiles;
- semivitreous tiles.

Table 1 shows the main specifications for grade and particle size (BARIOSARDA SpA, 1990). Understandably the above limits are only indicative, as the final judgement hinges above all on the firing tests (temperature) and corresponding whiteness grade, which is normally assessed by comparison with predetermined standards.

Table 1. Quality requirements for feldspathic materials used in the ceramics industry

Product	Grade, %			Particle size % passing	
	Na_20+K_20	Fe_20_3	$Ti0_2$	0.075 mm	5 mm
Hard porcelain	>12	<0.06	<0.01	>99	
Vitreous china	9-10	<0.25	<0.1	>98	
Vitreous tiles	8-9	<0.5	<0.3		100
Semivitreous tiles	8-9	<1	<0.6		100

Obviously the better the quality, the higher the market value. In fact feldspathic materials used for producing hard porcelain, vitreous china and vitreous tiles fetch prices 6, 3, and 1.5 times higher than those used for manufacturing semivitreous tiles.

3. MINERALS

3.1 Albitite

The formation of the deposit is associated with metasomatic sodic alteration of primary granites and pegmatitic facies. The ore body consists of two distinct albititic lenses embedded in grandiorites. The two outcropping lenses display a fairly homogenous mineral composition with no inclusions of gangue and have a high albite content with variable proportions of chlorite (clinochlore) of secondary origin, quartz, and subordinate orthoclase, plagioclase and secondary accessories such as titanite, epidote and iron oxides. Table 2 shows the chemical composition of commercial products (SN-3 and SN-6) extracted from the two lenses and employed in the manufacture of semivitreous and vitreous tiles respectively.

3.2 Granite

The granite comes from a formation which analyses showed to have favourable characteristics. Minero-petrographic analyses revealed the total absence of alteration, the almost complete alteration of calcic plagioclase and an overall alkaline feldspar content of over 60 %.

The interesting feature of this granite is the grain size at which the major component species (orthoclase, albite, quartz and biotite) are liberated (Bomioli et a1, 1989). The chemical composition of the as received rocks is shown in table 2.

4. EXPERIMENTAL

Samples of as received rock were first crushed in a jaw „rusher to passing 10 mm and then further com-

Table 2. Chemical composition of the raw materials.

Product	Grade, %							
	Na_2O	K_2O	MgO	CaO	SiO_2	Al_2O_3	TiO_2	Fe_2O_3
Albitite SN-3	8.5	0.2	4.1	1.1	63.8	18.9	0.55	0.49
Albitite SN-6	9.3	0.1	3.1	0.5	66.5	18.1	0.41	0.20
Granite	3.5	5.0	0.1	0.2	78.1	11.4	0.04	0.79

minuted to below 3 15 mm in closed circuit in a roll mill The top size of 3 15 mm was chosen insofar as the liberation size between albite and chlorite in the case of albitites, and between feldspar and quartz in the case of granite seemed to be sufficiently high

The crushed material was first screened into the particle sizes ranges -3 15+2 0 mm, -2 0+10 mm, -1.0+0 5 mm, -0 5+0 2 mm and -0 2 mm For each of these screen sizes the dense media (tetra-bromoethane) separation curves were determined for the purpose of evaluating the possibility of cleaning by means of gravity separation

The same sizes were then tested for amenability to magnetic separation using a dry Permroll magnetic separator with permanent magnets and field intensity of 1 6 Tesla for particle sizes down to 0 2 mm and a WHGMS basket separator for particles smaller than 0 2 m m

Flotation tests were conducted on the two albitite samples SN-3 and SN-6 after grinding wet in a closed circuit ball mill to below 0 25 mm Based on findings of preliminary tests, an inverse flotation technique was employed, at neutral pH, using carboxylic collectors (Pamak 4, Hercules Powder Co)

5 RESULTS

5 1 Washability

Figure 1 shows an example of the washability curves as well as the grade curves, versus density for the -3 15+2 0 mm and -1 0+0 5 mm particle sizes Figure 2 gives the same curves for the granite for particle sizes of -3 15+1 0 mm and -1 0+0 5 mm

The results indicate that

- for both minerals, logically, washability improves with decreasing particle size,
- though the albitites did not respond well to gravity washing, acceptable results were achieved for the granite, at least as far as the separation of the feldspattık components from the quartz is concerned

Industrial gravity concentration processes however would necessitate resorting to machines with high separation efficiency insofar as these devices can only be adjusted over a narrow density range (between 2 56 and 2 60)

In the simulations we considered a dynamic dense media separator (Tri-flo) which, over the above density range, assures probable error of separation or Ecart probable (Ep) comprised between 0 03 and 0 035

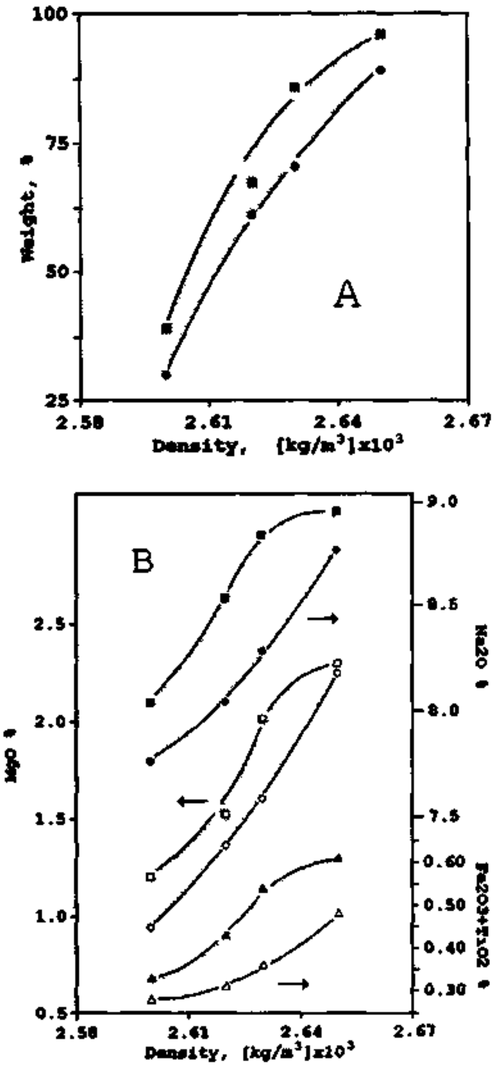

Figure 1 SN-3 albitite Washability curves (A) and grade curves (B) versus density for the different particle sizes (the upper and lower bounds of the dotted areas refer to the -3 15+2 0 mm. -1 0+0 5 mm size ranges respectively)

The results of the simulation for three different separation densities are shown in Table 3 and they confirm the previous observations concerning feldspar-quartz separation

The separation of the iron, for the most part associated with the biotite, was far less satisfactory

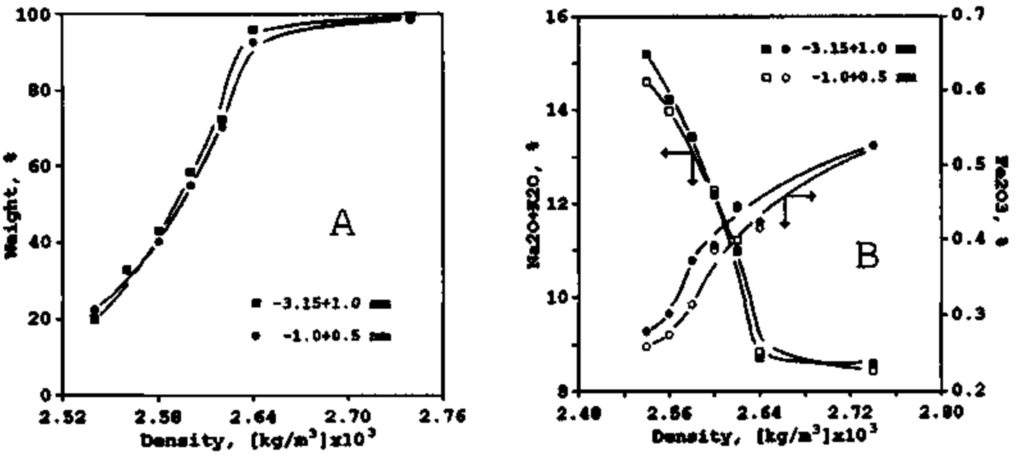

Figure 2. Granite. Washability curves (A) and grade curves (B) versus density for two different particle size ranges

The results suggest integrating gravity separation with another cleaning stage using magnetic separation to remove the ferromagnesian components.

Table 3. Granite - Results of the simulating gravity separation with dynamic dense media of the -3.15+0.5 mm particle sizes for different Ep.

Density	Ep	Float Weight, %	Grade, % Na_20+K_20	FtûjOs	TİO2	Recovery, % Na_20+K_20	FezOj	• TiOj
2.56	0.030	33.66	12.3	0.37	0.016	48.8	17.2	13.1
	0.035	34.73	11.9	0.38	0.017	47.8	18.2	14.0
2.58	0.030	45.70	11.6	0.39	0.017	63.5	24.4	18.9
	0.035	45.98	11.3	0.40	0.018	61.1	-25.0	19.4
2.60	0.030	58.08	10.9	0.41	0.018	74.4	32.3	25.3
	0.035	57.49	10.7	0.41	0.018	72.3	32.3	25.5
Feed			8.5	0.73	0.042			

5.2 Magnetic separation

5.2.1 Albitites

Magnetic separation performed on each of the particle size classes of the rock crushed to below 3.15 mm, showed that the removal of the ferromagnesian elements did not improve substantially with decreasing average particle size.

This may also be attributed to the fact that both the clinochlore and the other elements tend to concentrate in the finer sizes.

So here only the experimental results of dry magnetic separation in a Permroll separator for the entire -3.15+0.05 mm size range of both samples SN-3 and SN-6 are shown (Table 4).

Cleaning efficiency for Mg, Fe and Ti was calculated using the formula E = 100(X-Y)/X %, where, X and Y are the MgO, Fe_203 and $Ti0_2$ grades in the feed and in the non-magnetic product respectively.

These results confirm the minero-petrographic observations, namely that the Fe is associated for the most part to the clinochlore (magnetic) and the Ti to the albite.

At any rate, taking into account the whiteness grade of specimens obtained in firing tests on the non-magnetic products, the results show that the latter are suitable for the manufacture of higher

Table 4. Results of magnetic separation (Permroll) of the SN-3 and SN-6 albitites. -3 IS +0.05 mm size range.

Ore	Product	Weight, %	Grade, %				E, %		
			Na_2O	MgO	TiO_2	Fe_2O_3	Mg	Ti	Fe
SN-3	Magnetic	13.33	5.84	11.60	1.24	1.40			
	Non- magnetic	76.63	9.00	2 04	0.33	0 20	52.0	38.9	59.2
	Fines <50 um	10.04	5.55	11.33	1.21	1.51			
	Feed	100.00	8.23	4.25	0.54	0.49			
SN-6	Magnetic	.8.17	6.80	13.20	1.12	0.93			
	Non- magnetic	82.39	9.77	1.24	0.27	0.07	59.3	35.7	65.0
	Fines <50 um	9.44	7.91	10.04	1.09	0.67			
	Feed	100.00	9.35	3.05	0.42	0.20			

quality ceramic materials than the as received minerals and specifically:

- the albitite SN-6 for vitreous china;
- the albitite SN-3 for vitreous tiles.

5.2.2 Granites

The findings that emerged from the study concerning the washability of the as received rocks pointed to the need for further cleaning the float of dense media separation.

So separation with ferrosiliceous static dense media was carried out in the laboratory, at density of 2.58 for the entire -3.15+1.0 mm size range.The resulting float was then further treated by means of magnetic separation using a Permroll separator (two passes with recleaning of the magnetic product).

The results, shown in table 5, point to the poor efficiency of iron removal which implies that it has not been sufficiently liberated in the -3.15+1.0 mm size range. Consequently further tests were carried out grinding the float to below 1.0 mm, dedusting the 0.05 mm undersize and performing magnetic separation on the dedusted fraction.

Magnetic separation was carried out both dry in a Permroll separator (two passes) and wet in a WHGMS separator (Boxmag, Rapid Magnetic) adjusted to a field intensity of 2.0 Tesla.

The results, also given in table 5, show that with this procedure a feldspathic product can be obtained that meets market specifications for vitreous china.

Obviously, as far as the type of separator is concerned, the dry method is to be preferred as WHGMS separators are more capital intensive and more expensive to run

5.3 Flotation

5.3.1 Albitite

Preliminary inverse flotation tests on the albitites ground to below 0.25 mm showed that carboxylic collectors (Pamak 4, Hercules Powder Co.) at neutral pH produced substantially higher grade con-

Table 5. Granite: results of density separation followed by magnetic separation.

Process	Product	Weight, %	Grade, %			E,%
			Na_2O+K_2O	Fe_2O_3	TiO_2	Fe
Classification	-3.15+1.0 mm	78.8	85	0.68	0.04	68.5
Heavy Media	Float	51.5	10.8	0.40	0.06	41.2
Permroll	Float NM(*)*	50 2	nd	031	0.02	22.5
Permroll	-1.0+0.05 mm NM(*)	48.5	n.d.	0.23	0.01	42.5
WHGMS		49.9	n.d..	0.22	0.01	45.0

NM(*)= Float Non-magnetic

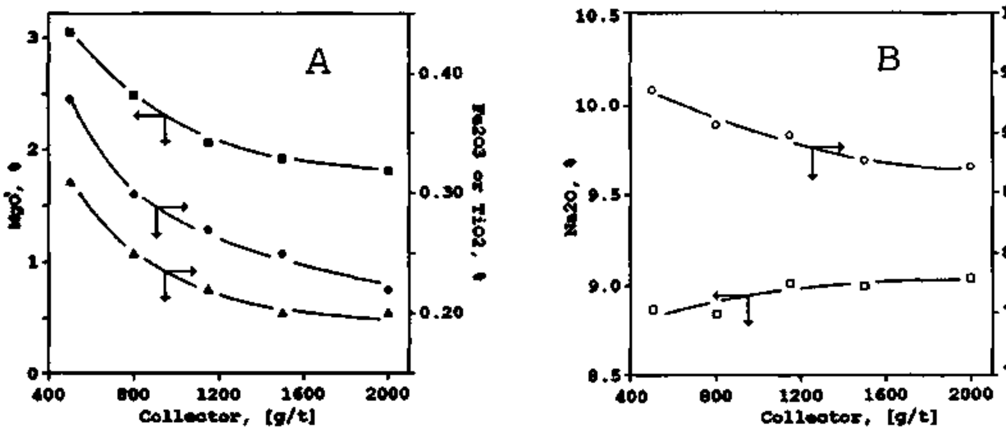

Figure 3. SN-3 albitite. (A) MgO, TiO_2 and F e ^ grades of the concentrate versus amount of collector (Parnate 4), (B) Na_2O grade and recovery versus amount of collector.

centrâtes than did sulphonate collectors (Aero-promoter series 800, Cyanamid) at acid pH.

Thus only the results obtained with the first method are presented here.

Figures 3 and 4 sum up, for SN-3 and SN-6 respectively, how the grades of Na_2O, MgO, Fe_2O_3 and TiO_2, together with Na_2O recovery vary with amount of collector.

Table 6 shows, by way of example, the results considered optimum, base on the combined judgement of grades and whiteness of fired specimens. This table also gives the results of the test carried out, for comparative purposes, on a deslimed -20 um feed of SN-6 albitite.

Despite the fact that the results indicate that high quality products can be obtained with flotation, investment and running costs are higher and for this reason in commercial applications magnetic separation is more convenient and as such to be preferred

Table 6. Granite: example of results of inverse flotation of albitites using carboxylic collectors.

	Collector (g/t)	Product	Weight %	Grade, % Na_2O	MgO	TiO_2	Fe_2O_3	Recovery Na_2O, %
SN-3	1500	Froths	21.3	5.1	149	2.0	1.8	13.2
		Concentrate	78 7	9.0	1.9	0.25	0.20	86.8
		Feed	100.0	82	4.7	0 62	0.54	100.0
SN-6	1500	Froths	18.2	65	16.8	1.9	1.0	13.5
		Concentrate	81.8	93	04	0.11	0.04	86.5
		Feed	100.0	8.8	34	0.43	0.21	100.0
SN-6	1000	Froths	7.6	46	27.0	2.3	1.3	3.9
deslimed		Concentrate	77.4	9.3	0 75	017	0.06	81.1
-20 um		<20 um	15.0	8.9	48	0.43	081	15.0
		Feed	100.0	8.9	3.4	0 43	0.21	100.0

6. PROPOSED PROCESSING FLOWSHEETS

Figures 5 and 6 show the beneficiation processes for the two minerals.

Regarding the albitites (SN-3, SN-6) processing consists of:

- 3-stage comminution for complete reduction to below 3 mm;
- dedusting of the -3 mm with wind separator;
- dry magnetic separation of the dedusted product using a Permroll separator (two passes with recleaning of the magnetic product).

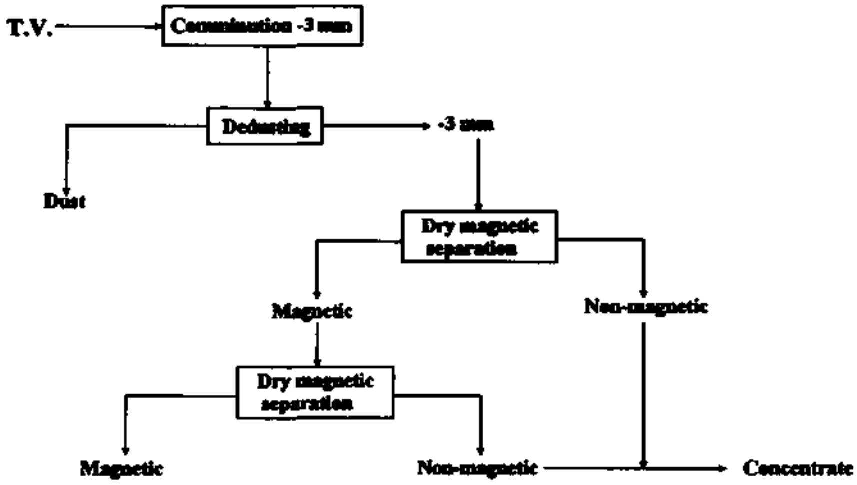

Figure 5. Albitite treatment: schematic flowsheet.

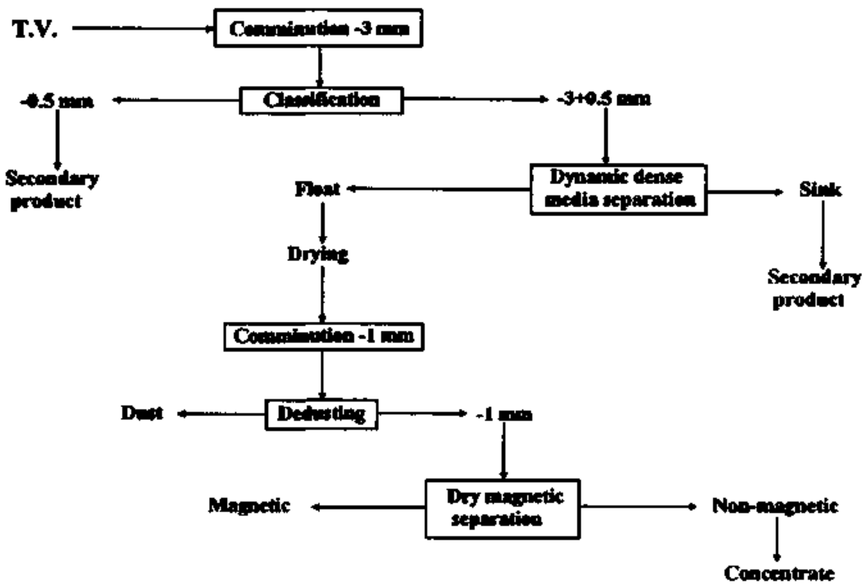

Figure 6. Granite treatmeot schematic flowsheet

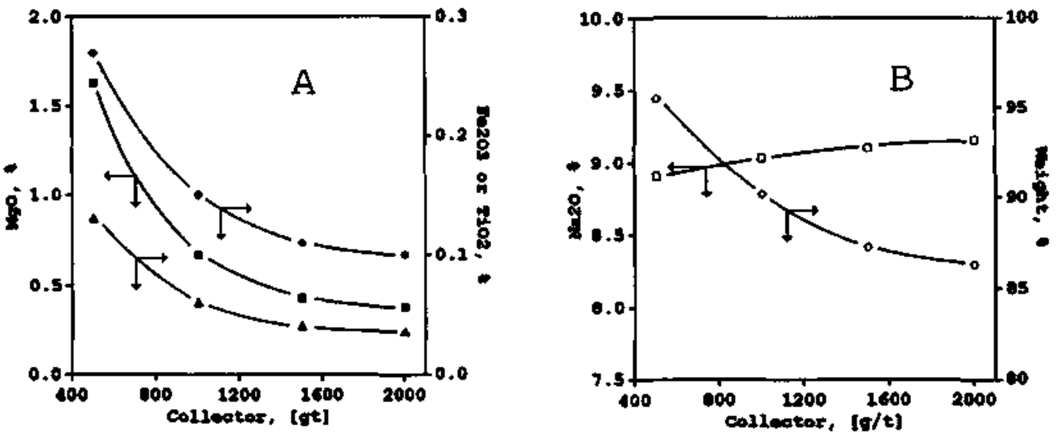

Figure 4. SN-6 albitite. (A) MgO, $Ti0_2$ and Fe2Û3 grades of the concentrate versus amount of collector (Pamak 4), (B) Na_20 grade and recovery versus amount of collector.

For the granite, the following scheme is proposed:

- 3-stage comminution for complete reduction to below 3 mm;
- size classification by means of screening dry with a Mogensen screen to 0.5 mm;
- dynamic dense media separation, Tri-flo (Ferrara et al., 1982), of the -3+0.5 mm size range. The sink with higher $Si0_2$ grade could be used for example in the construction industry, while the float which has higher alkali content is sent for further treatment,
- a drying stage followed by grinding to below 1.0 mm and dedusting with wind separator,
- a finishing stage of the dedusted -1.0 mm size by means of dry magnetic separation (Permroll) for producing a feldspar suitable for manufacturing vitreous china.

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REFERENCE

Leonardelli, A. 1989. I feldspati: Aspetti Storico - Economici e Prospettive di Ricerca in Italia. Workshop on Industrial Minerals: their Use and Tachnology, Castel Ivano (October)

SVI.MI. SA. SpA 1991. Unpublished Report. (Private comunication).

Curreli, L., Ferrara, G., Ghiani, M., Pala, M., 1990. Produzione di Feldspato per Uso Ceramico da Rocce Granitiche. Tra Rinnovamento e Innovazione , Ass. Min.Sarda Special Issue (December): 69-86.

BARIOSARDA SpA 1990. Unpublished Report.

Bomioli, R., Marini, C, Pretti, S. 1989. II Giacimento di Feldspato di Orani-Ottana (Sardegna Centrale). Workshop on Industrial Minerals: their Use and Technology, Castel Ivano (October): 105-116.

Ferrara, G., Ruff, HJ. 1982. Further developments with Dynamic Dense Medium Separation Processes with particular reference to the Tri-flo Separator. Erzmetall, 35, n.6 : 294-299 and n.7/8: 395-398.