APPLICATION OF THE METHODOLOGY OF MINERALOGICAL QUANTIFICATION BY PARTICLE CLASSES AS A FORESEEABILITY TOOL OF CONCENTRATION PROCESSES [1]

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Abstract
The application of mineralogical analysis through optic microscopy has been proven as an excellent tool in defining and optimizing beneficiation process routes. With the objective of decreasing the time of answer, and taking into account the content mainly focused on beneficiation processes, a new technique to survey mineralogical data has been developed, which emphasizes particle release level. This new methodology quantifies particles by association classes and their distribution percentage. From the results it is possible to focus on foreseeability of beneficiation processes behavior, such as jigging, magnetic concentration and flotation, among others. A practical example shall also be provided, in which a mathematic simulation was used to foresee the quality of products in jigging and magnetic concentration processes and has shown good approximation when compared to results obtained from pilot scale tests.
Key words: Mineralogy; Foreseeability; Beneficiation processes.

Resumo
A aplicação da análise mineralógica, utilizando microscopia ótica, tem se mostrado uma excelente ferramenta na definição e otimização de rotas de processo de beneficiamento. Porém essa metodologia clássica mostra como desvantagem maior tempo para o levantamento dos dados e sua interpretação. Pensando na diminuição deste tempo bem como no conteúdo voltado principalmente para os processos de beneficiamento, foi desenvolvida uma nova técnica de levantamento de dados mineralógicos com ênfase no grau de liberação de partículas.Esta nova metodologia quantifica as partículas por classes de associação e seu percentual de distribuição. A partir dos resultados é possível focar na previsibilidade do comportamento de processos de beneficiamento como, por exemplo, jigagem, concentração magnética e flotação entre outros. Também será mostrado um exemplo prático, onde foi utilizada simulação matemática para prever qualidades de produtos de processos de jigagem e concentração magnética, apresentando boa aproximação quando comparados com os resultados obtidos a partir de testes em escala piloto.
Palavras-chaves: Mineralogia; Grau de liberação; Processos de beneficiamento.

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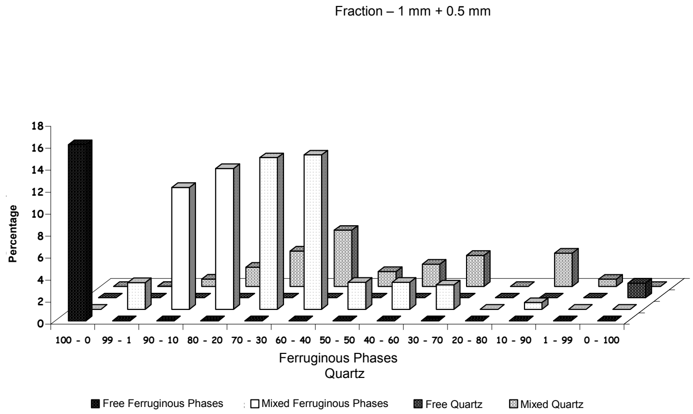
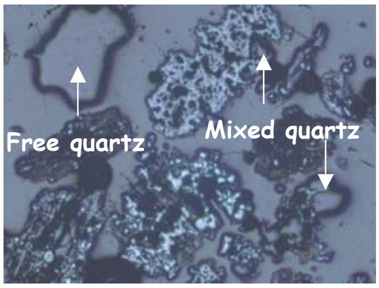
1 INTRODUCTION

Conventional mineralogical analysis has been employed for several decades now in quantifying and qualifying ores.[1-5] Its level of specialization, especially for iron ore, became increasingly clear as the years passed, and today ferruginous minerals and their possible morphologic variations[6] are quantified, and several distinctive answers are known, depending on the mineral association present in beneficiation processes, concentration and grinding,[7-8] as well as in metallurgic processes.[9]
However, as quick answer for the planning of benchmark and pilot tests – besides possible product type estimate – a new technique is being employed, in which the level of particle release by class is being employed, and it is being quite efficient.
The use of dense liquid tests (bromophorm and LCT) for this kind of response has proven itself as little efficient, particularly for samples with coarse size and/or that show high quartz contents.
Image analysis, a technique quite widespread today, cannot be used with precision for iron ores due to subtle differences in color displayed by ferruginous phases, as well as in contaminants, especially quartz – usually mistook for embedding resin – besides al the other problems intrinsic to this method, such as image processing ad stereological conversion.[10-12]
This paper shows a simplified methodology to quantify mineralogical phases present in iron ores by using optical microscopy. This methodology is focused on identifying sample release level, a property that determines efficacy and the use of concentration and grinding methods.
This method is also more agile than conventional mineralogical analysis of ferruginous phases and ganga, since distinctive ferruginous phase types and their morphologies are not quantified.
But the biggest gain for this type of analysis is the ability to simulate the action of several concentrative processes, precisely taking into account which flow – concentrate or tailings – each particle shall go to.

2 MATERIALS AND METHODS

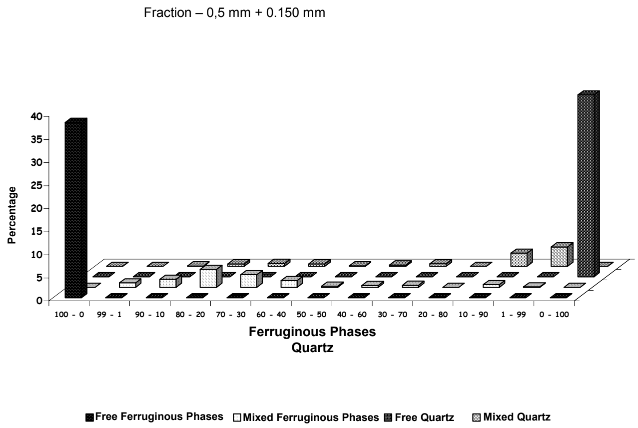
This methodology can be applied to any kind of samples, either drill hole or mine fronts, provided they have been crushed and screened or ground to size fractions that shall be submitted to the several kinds of concentration processes.
After individual material preparation, polished cuts are made for the previously-defined size fractions; these shall be analyzed on an optical microscope.
Quantification is made in a manner similar to that of conventional mineralogical analysis: particles are measured taking into account first whether they are free or mixed. Mixed particles are assed and sorted into classes that take into account variations in iron and quartz percentages on a grain-by-grain basis. Results are presented in printing by means of tables comprising release level and phases percentages, in addition to the Andrews-Mika diagram, as shown in Figures 1 and 2.
It should be pointed out that this method also quantifies particle porosity.

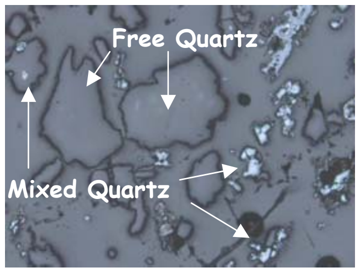




Mineralogical analysis														Total
Classes	**100-0**	**99-1**	**90-10**	**80-20**	**70-30**	**60-40**	**50-50**	**40-60**	**30-70**	**20-80**	**10-90**	**1-99**	**0-100**	
Free Ferruginous Phases	16, 02	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	16, 02
Mixed Ferruginous Phases	0, 00	2, 44	11, 09	12, 81	13, 80	14, 04	2, 46	2, 46	2, 22	0, 00	0, 62	0, 01	0, 00	61, 95
Total Ferruginous Phases	16, 02	2, 44	11, 09	12, 81	13, 80	14, 04	2, 46	2, 46	2, 22	0, 00	0, 62	0, 01	0, 00	77, 97
Free Quartz	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	1, 35	1, 35
Mixed Quartz	0, 00	0, 01	0, 67	1, 75	3, 23	5, 12	1, 35	2, 02	2, 83	0, 00	3, 03	0, 67	0, 00	20, 68
Total Quartz	0, 00	0, 01	0, 67	1, 75	3, 23	5, 12	1, 35	2, 02	2, 83	0, 00	3, 03	0, 67	1, 35	22, 03
Release Level	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	100, 00	6, 12

Figure 1 – Mineral phase percentage and release level by classes for a sample with -1 mm +0.5 mm size.





Mineralogical analysis														Total
Classes	**100-0**	**99-1**	**90-10**	**80-20**	**70-30**	**60-40**	**50-50**	**40-60**	**30-70**	**20-80**	**10-90**	**1-99**	**0-100**	
Free Ferruginous Phases	38, 04	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	38, 04
Mixed Ferruginous Phases	0, 00	0, 97	1, 76	3, 90	2, 73	1, 46	0, 24	0, 39	0, 44	0, 00	0, 59	0, 08	0, 00	12, 55
Total Ferruginous Phases	38, 04	0, 97	1, 76	3, 90	2, 73	1, 46	0, 24	0, 39	0, 44	0, 00	0, 59	0, 08	0, 00	50, 60
Free Quartz	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	39, 47	39, 47
Mixed Quartz	0, 00	0, 01	0, 11	0, 53	0, 64	0, 53	0, 13	0, 32	0, 56	0, 00	2, 88	4, 22	0, 00	9, 94
Total Quartz	0, 00	0, 01	0, 11	0, 53	0, 64	0, 53	0, 13	0, 32	0, 56	0, 00	2, 88	0, 67	39, 47	49, 40
Release Level	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	100, 00	79, 90

Figure 2 - Mineral phase percentage and release level by classes for a sample with -0.5 mm +0.15 mm size.

Quantification by association classes takes into account percentage variation between mineral phases from 0% to 100%. Phase sum by grain equals 100%; that is, a particle with 80% ferruginous phases has 20% associated quartz.

Added to particle porosity, association level of iron ore to quartz interferes in the response of the several concentration processes.

After ferruginous phases and quartz are quantified, chemical percentages for iron and silica are calculated by mineralogy. These results are compared to analytical chemical data obtained for the sample; this procedure, in its turn, servers as a

validation parameter for the mineralogical analysis, a maximum of five percent relative errors being allowed.
Simulations are run from the results to assess the quality of products from the supposed concentration methods to be applied.

3 RESULTS OBTAINED

In this item we shall provide an application example and also show results obtained through the release level method compared to values found for pilot tests done.
Jigging and magnetic concentration were the concentrative methods that were simulated and used in the example.
Analyzed sample was made up of a combination of friable itabirite, goethite itabirite and aluminous itabirite. Table 1 shows size and chemical distribution for pilot test feeding. We have a much hydrated material and large mineralogical phase variation, as shown in Figure 3.

Table 1: Particion in mass and analytical chemical results for pilot test feeding.

Mesh (mm)	Particion (%)	Fe (%)	SiO_2 (%)	Al_2O_3(%)	P (%)	Mn (%)	PPC (%)
-8mm + 2mm	11, 91	57, 87	11, 51	0, 94	0, 078	0, 136	4, 27
-2mm + 1mm	3, 91	57, 12	12, 67	0, 97	0, 076	0, 173	4, 00
-1mm + 0, 5mm	3, 93	51, 82	20, 91	0, 97	0, 070	0, 167	3, 42
-0, 5mm + 0, 15mm	19, 73	40, 11	40, 45	0, 50	0, 029	0, 059	1, 36
-0, 15mm	60, 53	53, 43	20, 15	1, 18	0, 042	0, 097	1, 88
Global	**100**	**51, 04**	**23, 17**	**1, 06**	**0, 048**	**0, 099**	**2, 34**

Lithological types making up the pilot sample were also individually analyzed using the proposed simplified methodology.
The result obtained for ferruginous and quartz phase estimate in jigging feeding is given in Figure 4. Figure 5 shows silica estimate in the concentrate, which was simulated using data from simplified mineralogical analysis method, where expected silica average in concentrate was around 6%.
Figure 6 shows pilot results obtained from silica contents using jigging. Notice that it varies according to recovery level in mass. Minimum 5% silica content is close to the estimated 6% figure.
Two kinds of concentration were used for magnetic separation tests: medium intensity and high intensity.

Mass Mineralogical Quantification (%)												
HC's	HM	MA	GO	GT	QL	QM	MN	CA	GB	OT	PO	GL
34, 84	5, 47	18, 42	21, 63	8, 00	1, 97	9, 00	0, 00	0, 15	0, 72	0, 00	23	18

CAPTION			
HCs: Compact hematite	**GT:** Earthy Goethite	**CA:** Kaolinite	**GL:** Release level
HM: Martitic hematite	**QL:** Free Quartz	**GB:** Gibbsite	
MA: Magnetite	**QM:** Mixed Quartz	**OT:** Others	
GO> Goethite	**MN:** Manganese	**PO:** Porosity	

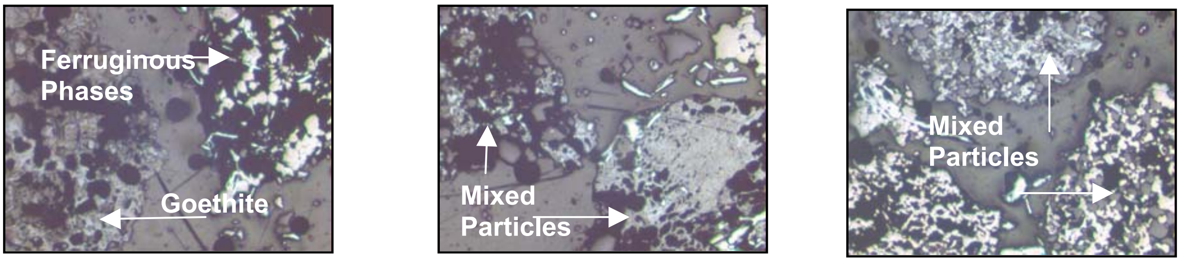
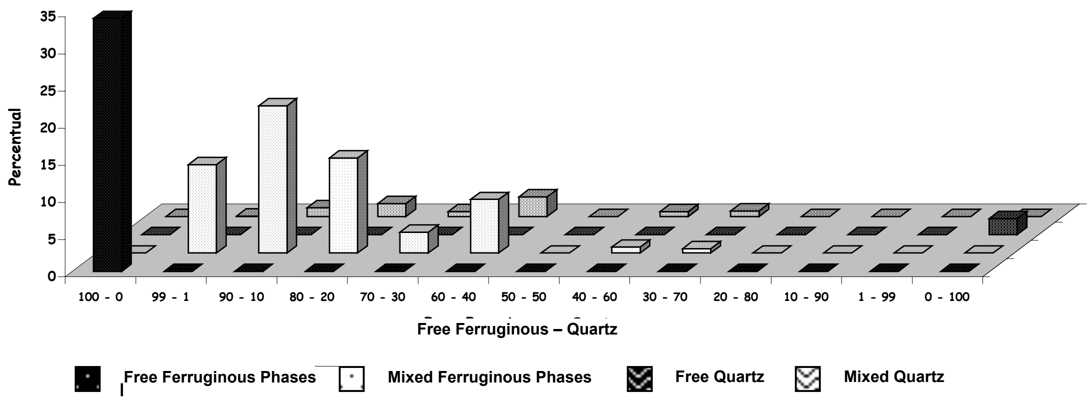


Figure 3: Conventional mineralogical quantification obtained for pilot test feeding.

Jigging Feeding



Mineralogical analysis														Total
Classes	100-0	99-1	90-10	80-20	70-30	60-40	50-50	40-60	30-70	20-80	10-90	1-99	0-100	
Free Ferruginous Phases	32, 87	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	32, 87
Mixed Ferruginous Phases	0, 00	11, 49	19, 14	15, 47	2, 71	6, 96	0, 00	0, 77	0, 58	0, 00	0, 00	0, 00	0, 00	57, 12
Total Ferruginous Phases	32, 87	11, 49	19, 14	15, 47	2, 71	6, 96	0, 00	0, 77	0, 58	0, 00	0, 00	0, 00	0, 00	90, 00
Free Quartz	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	2, 11	2, 11
Mixed Quartz	0, 00	0, 06	1, 16	2, 11	0, 63	2, 54	0, 00	0, 63	0, 74	0, 00	0, 00	0, 00	0, 00	7, 89
Total Quartz	0, 00	0, 06	1, 16	2, 11	0, 63	2, 54	0, 00	0, 63	0, 74	0, 00	0, 00	0, 00	2, 11	10, 00
Release Level	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	0, 00	100, 00	21, 28

Figure 4: Mineralogical estimate per particle association classes foreseen in jigging feeding.

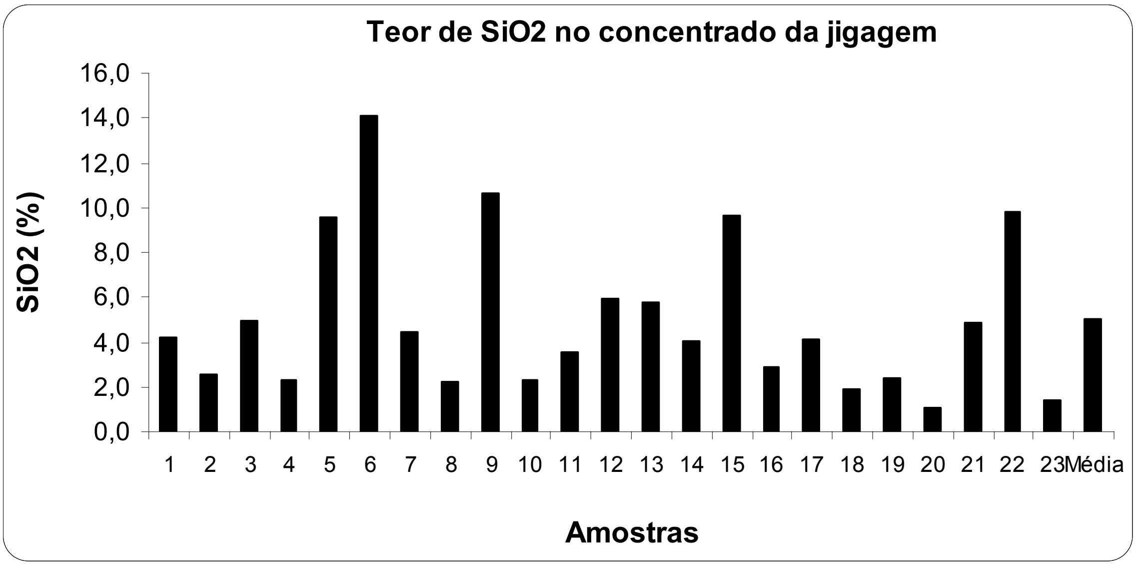


Figure 5: Silica percentage estimate present in jigging concentrate, which was obtained by simulating results surveyed through simplified method.

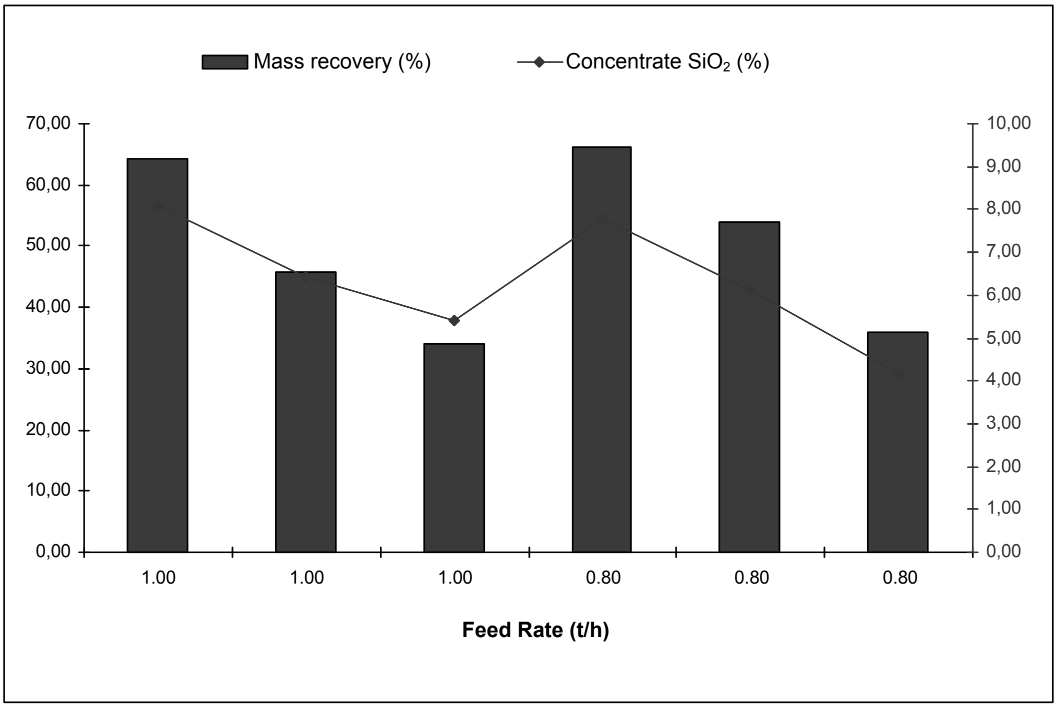


Figure 6: Pilot results obtained for jigging.

The Figure 7 shows the grade of SiO_2 on the magnetic concentrate foreseen by mineralogy.

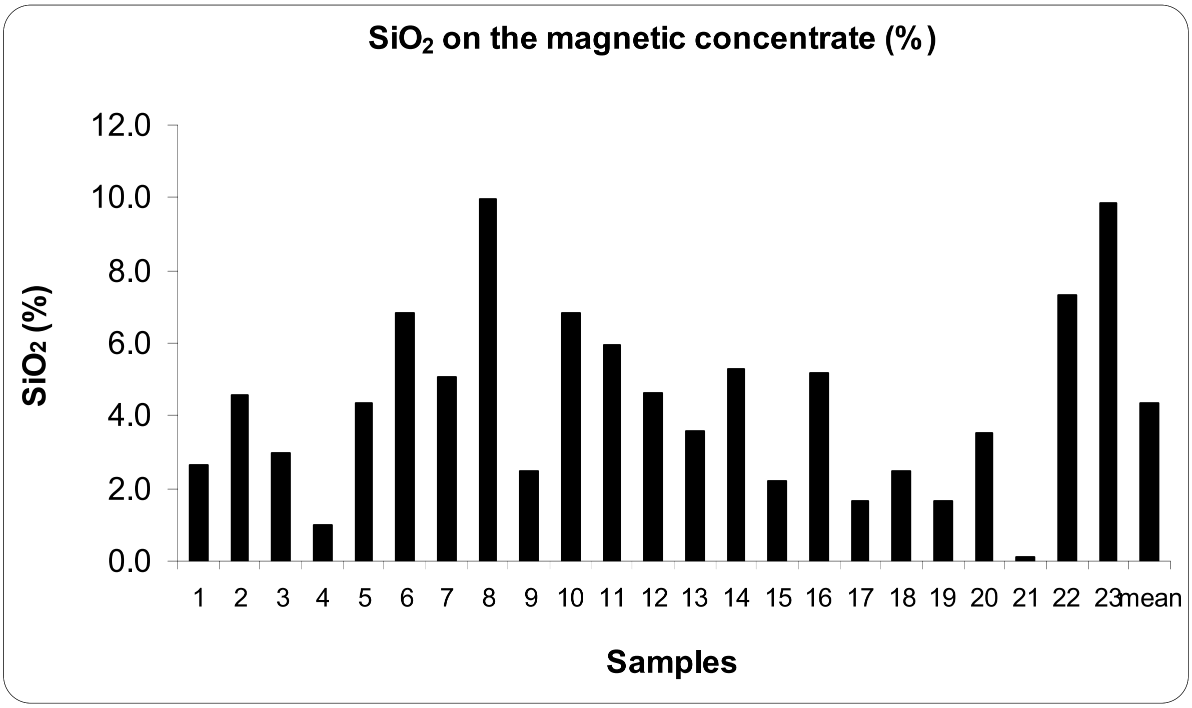


Figure 7: Grade of SiO_2 on the magnetic concentrate by mineralogy

The Figure 8 shows the comparison betwen foreseen and pilot plant results of SiO_2 on the concentrates (jigues and magnetics processes).

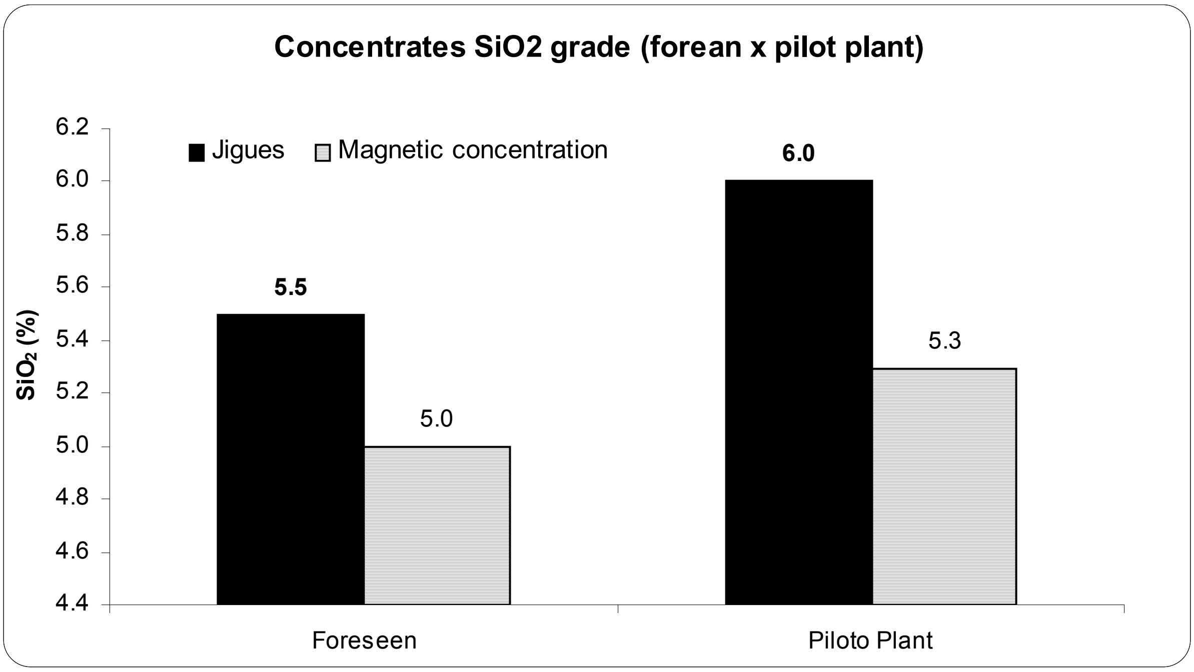


Figure 8: Grade of SiO_2 on concentrates: foreseen x pilot plant results

4 CONCLUSION

The aplication of mineralogical characterization has a prime importance on the foreseeability for the different concentration processes in the mining industry. Futhermore, the analysis of mineral associations in different size classes can reduce the answer time and increase the accuracy of the method.

The results obtained in pilot plant tests (jigues and magnetic concentration) were very close to the results foreseen by the mineralogical characterization using the mineral association in size classes methodology.

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