Paper VI
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Published as:

Oghazi, P., Pålsson, B., 2011. Comparing the mineralogical characterization of iron ore by using QEMSCAN and PTA. Published and peer reviewed in: 10th International Congress for Applied Mineralogy (ICAM), Trondheim, August 2011.

COMPARING THE MINERALOGICAL CHARACTERIZATION OF IRON ORE BY USING QEMSCAN AND PTA

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Abstract

Automatic scanning systems can be used to detect valuable minerals in polished sections. These instruments have now reached a maturity level for the actual analysis, but since they generate a lot of information the bottleneck is now the interpretation of the data flow to get quantitative information. For example, today most industries are interested to use automated scanning system to achieve better products or to simplify the process by having better knowledge of the material that they are using in production.
In this case two methods: Particle Texture Analysis (PTA) and QEMSCAN are checked for differences. Measured properties were modal mineralogy, mineral associations and mineral liberations in several samples over the same size fraction 38-53 μm. The difference is the largest for the degree of liberations, probably since this measure is sensitive for the computational assumptions made.

Keywords: Automatic scanning, QEMSCAN, Particle Texture Analysis, Liberation

1 INTRODUCTION

The economy is a crucial factor in beneficiation of the ore. Another important factor is the quality of the product. Today high quality is a necessity for ore beneficiation companies. As a consequence detailed information from the raw material is required. According to Andersen et al. [1] it is important for profitability and optimisation to have a good understanding in relating mineralogy texture and particle characterization with each other by automated methods.

The context of mineralogy gives information about the ore and if it is beneficial to extract it, and where microscopic analysis uncover the mineralogy for us regarding the efficiency of processing the ore [2]. Petruk [3] explains how applied mineralogy can be used in different steps in a mining company. He also mentions different techniques that are used for determining the mineral characterization. According to Petruk, applied mineralogy is the key for an engineer in matter of selecting the type of process technique for concentrating a mineral.

During the last decades, mining industries have opened the doors for new instruments and methods to streamline the production. Scanning Electron Microscopy (SEM) has been used for a long time and QEMSCAN is one of the better known techniques for mineral characterization, associations and mineral texture. This SEM-EDS technique gives also information about, among other things, the chemical assays [4]. Particle Texture Analysis (PTA) is another system based on scanning electron microscope different from the Oxford Inca software [5].

All these techniques are used to identify minerals and mineral compositions. In the present paper, identical samples are analysed with the two difference techniques to see if there are any differences between the systems. In this case it is very interesting to investigate mineral associations and liberation for gangue minerals and the magnetite. This result can be obtained by the systems and show if there are some mixed magnetite particles that are gangue containing and may affect the processing or create future process problems.

2 ANALYTICAL SYSTEMS

2.1 Particle Texture Analysis

The Particle Texture Analysis (PTA) was developed at the Norwegian University of Science and Technology (NTNU). By using Back Scattered Electron (BSE) from the scanning electron microscopy, images are analysed by means of grey levels. Simply the polished section is scanned under the beam and every grain that is overlapping or has similar grey-levels is also analysed by X-rays. All analysed grain size fractions are imported to the PTA software, where images analyses are done offline to process and evaluate if grains occur as liberated or in composite particles. For more detailed description see Moen [5]. The equipment that was used/applied for the PTA is listed in Tables 1 and 2.

2.2 QEMSCAN

There are some articles that explain QEMSCAN very well, that is Butcher [6] and Gottlieb [4]. Each mineral has its own distinctive energy dispersive X-ray spectra, and QEMSCAN is an automated system based on a scanning electron microscope. When the particles are analysed, QEMSCAN uses the raw data from X-ray spectra to compare with a mineral identification library known as the Species Identification Program (SIP), for more information see Lotter [7]. The data for each examined point are evaluated against the list elements that exist in the sample. The system is normally equipped with four x-ray detectors, some species with similar x-ray spectra and backscatter images are differentiated by their element ratio. Some minerals such as magnetite and hematite with similar x-ray spectra are differentiated with the back scatter images [4]. These analyses provide us with information from mineral liberation, modal mineralogy, and also mineral association. The equipment that was used/applied for QEMSCAN is listed in the Tables 3 and 4.

2.3 Experimental and material overview

For this investigation representative samples were collected at the LKAB concentrator at Malmberget. Ores that are fed to the concentrator come from different ore bodies, which are mined and mixed for the beneficiation process. The samples are material from input and output to three ball mills in series from two parallel grinding sections. Flowsheets for the grindings section were reported by Oghazi et al. [8]. The samples were weighted and then filtered at Malmberget. All the samples were then dried and cut by a Jones splitter into suitable proportions in the laboratory at Luleå University of Technology (LTU). The dry material was sieved with a Ro-Tap shaker down to 75 μm and wet sieved further to 38 μm. Polished thin sections were made of the sieved fractions at NTNU.

3 RESULT AND DISCUSSION

The PTA and QEMSCAN results are represented by modal mineralogy charts in Figures 1 to 4. Charts of modal mineralogy are showing the percentages of minerals found in the analysed grain-size fraction based on examination of a sample. There is no large difference between the sections, although it is shown that the magnetite content in section 5 is slightly higher than in section 6. Comparing section 5 by the analytical method used, the similarities are very obvious. The magnetite amount that is detected is almost the same, and the gangue minerals amount also. However, there are some few more percent gangues minerals detected for section 5 in the QEMSCAN compared to the PTA. Reason for that could be the limits setup in the secondary SIP file. The sip-file is the term used in QEMSCAN terminology to describe the relationship between mineral data and analysed data. This relationship is used to convert the electron detectors' raw output to mineral output. In this correlation it is important to be correct to ensure that the right mineral data output is produced [9].

For section 6 the overall representation is the same as for the previous section with both methods, the gangue minerals detection in QEMSCAN is more clearly presented compared to section 5. By comparing the incoming material to the primary mill in section 6, QEMSCAN detect almost 73-percent magnetite and 27-percent gangue minerals (counting the unclassified to the gangue minerals). While in PTA same sample show roughly 79-percent magnetite and the rest were gangue minerals. Another interesting point is the amount of feldspar and pyroxene that is detected in the primary mill for section 6. For both the input and output it is a notable difference between the two analysing system. In QEMSCAN the amount of these minerals are larger compared to the PTA analysis. Once again the divergences were found in section 6 between the systems, while for section 5 the result were almost identical. As mention before due to the setups in the SIP file and also grey-scale values of the image can contribute to the shown result.

Minerals that are associated to apatite as detected by QEMSCAN and PTA are shown in Table 5. Note, that the magnetite association is almost identical, while K-feldspar is more detected in PTA compared to QEMSCAN.

Liberation of apatite differs considerably between the instruments as shown in Figure 5. It appears that for QEMSCAN the liberation analysis are more detailed compared to PTA. In PTA, back scattered images are segmented by using grey-levels; an off-line software is used to create the liberation analysis. However, in QEMSCAN back scatter images is also used but it is equipped with up to four x-ray detectors to identifies the minerals at each point by collecting an energy dispersive x-ray spectrum that is analysed to give the chemical composition in every point [4], [6]. This might be the reason for the perception that QEMSCAN gives more mixed grains in the liberation analyses. Another possibility is that the algorithms used differ to some degree.

4 CONCLUSIONS

QEMSCAN is used today in commercial research; QEMSCAN gives detailed quantification information of the process material. It also provides a detailed particle mapping which is an advantage, furthermore the system is rapid. Another advantage with QEMSCAN is that the result can visibly been shown very clear how the gangue population is present, how this population is associated and even if there are some inclusion in the magnetite or vice versa. One benefit of the PTA is the extraction of good information about particle size, mixed particles and liberation.

In a QEMSCAN a SEM and four EDS detectors is used, although an advanced software package for identification and quantification of the minerals and phases must be accessible. So, a disadvantage with this system is the investment cost for the QEMSCAN.

Both systems give almost identical results for the mineralogical identification and mineral content. The differences come into play, when the data is further processing. In particular the liberation analyses seem to be dependent on the algorithms used, and their tolerance limits.

Also, not mentioned earlier, is that PTA can easily deliver morphological data output for further processing. QEMSCAN is a more "locked in" system than PTA. This is good for quantitative industrial research, but a disadvantage in more fundamental investigations.

There are still some development works left for the PTA, such as the software but also the integration with Oxford Inca Feature to get a better analysis. Still the PTA is young compared to QEMSCAN, and hopefully can be even more developed in the coming years.

5 REFERENCES

[1] Andersen, J, Rollinson, G, Snook, B, Herrington, R, Fairhurst (2009): Use of QEMSCAN for the characterization of Ni-rich and Ni-poor goethite in laterite ores. Minerals Engineering. 22. 1119-1129.

[2] Wills, BA, Napier-Munn, TJ (2006): Wills' Mineral Processing Technology, 7th Edition. An Introduction to the Practical Aspects of Ore Treatment and Mineral Recovery.

[3] Petruk, W (2000): Applied Mineralogy in the Mining Industry: Ottawa, Ontario, Canada, Elsevier, 268p.

[4] Gottlieb, P, Wilkie, G, Sutherland, D, Ho-Tun, E, Suthers, S, Perera, K, Jenkins, B, Spencer, S, Butcher, AR, and Rayner, J (2000): Using Quantitative Electron Microscopy for Process Mineralogy Applications. JOM, Journal of the Minerals, Metals and Materials Society, April, 24-25

[5] Moen, K (2006): Quantitative measurements of mineral microstructure. Department of Geology and Mineral Resources Engineering. Trondheim, Norwegian University of Science and Technology. Doctoral thesis, ISBN 82-471-8163-0, ISSN 1503-8181: pp 120.

[6] Butcher, AR., Helms, TA, Gottlieb, P, Bateman, R, Ellis, S, Johnson, N.W (2000): Advances in the quantification of gold deportment by QEMSCAN. In: Seventh Mill Operators Conference, Kalgoorlie, WA, AusIMM

[7] Lotter, N.O, Kowal, D.L, Tuzun, M.A, Whittaker, P.J, Kormos, L (2003): Sampling and flotation testing of Sudbury Basin drill core for process mineralogy modelling Minerals Engineering, 16 (9), pp. 857-864

[8]] Oghazi, P, Pålsson, B, Tano, K (2009): Applying traceability to grinding circuits by using Particle Texture Analysis (PTA) Minerals Engineering 22 (7-8), pp 710-718

[9] Grobler, J.D. and Bosman, J.B (2009): Gravity separator performance evaluation using Qemscan particle mineral analysis. The 7th International Heavy Minerals Conference, The Southern African Institute of Mining and Metallurgy.

Table 1: Equipment for PTA analysis.

Equipment: Field Emission SEM	**Type**: Hitachi S-4300 SE
Equipment: EDS detector	**Type**: Oxford light element detector
Equipment: Acquisition software	**Type**: Inca Feature

Table 2: The setting for the PTA analysis.	
Parameter	**Setting**
Working distance	15 mm
Accelerating voltage	20 kV
Gun Brightness	1.9 kV
Beam current	0.25-0.75 nA

Table 3: Equipment for QEMSCAN analysis.	
Equipment: QEMSCAN	**Type**: E340
Equipment: EDS detector	**Type**: Silicon Drift Energy Dispersive x-ray Detectors
Equipment: Acquisition software	**Type**: iDiscover

Table 4: The setting for the QEMSCANanalysis.	
Parameter	**Setting**
Working distance	22 mm
Accelerating voltage	20 kV
Beam current	5 nA

Table 5: Apatite association in QEMSCAN and PTA.		
	Apatite association QEMSCAN	***Apatite association PTA***
	06 Mill#1 (in)	**06 Mill#1 (in)**
Unclassified	2,34	4,5
Titanite	0,08	0
Ilmenite	0,03	0,7
Pyroxene	0,61	0
Calcite	0,00	0
Biotite	0,16	0
Chlorite	0,03	0
K feldspar	0,11	1,8
Feldspar	0,69	0,9
Quartz	0,05	0
Magnetite	3,99	4,1

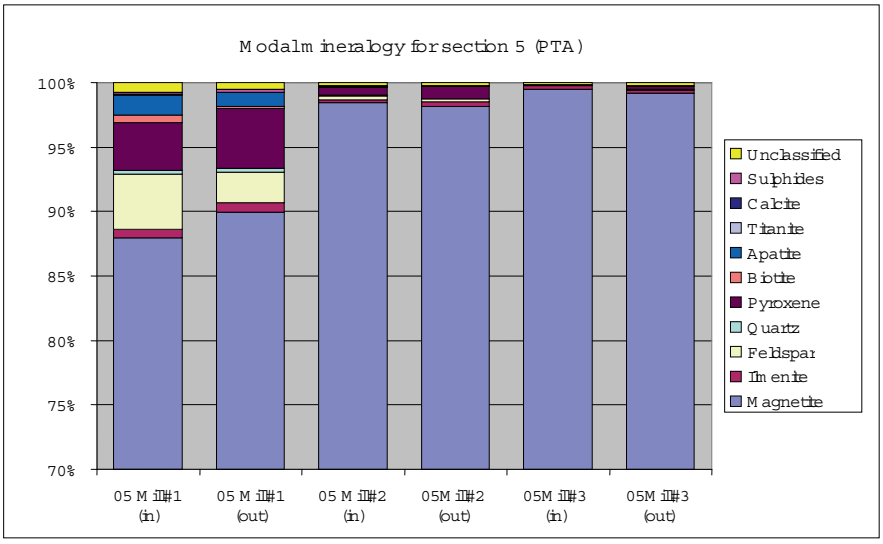

Figure 1: Modal mineralogy chart for concentrator section 5 from PTA analysis.

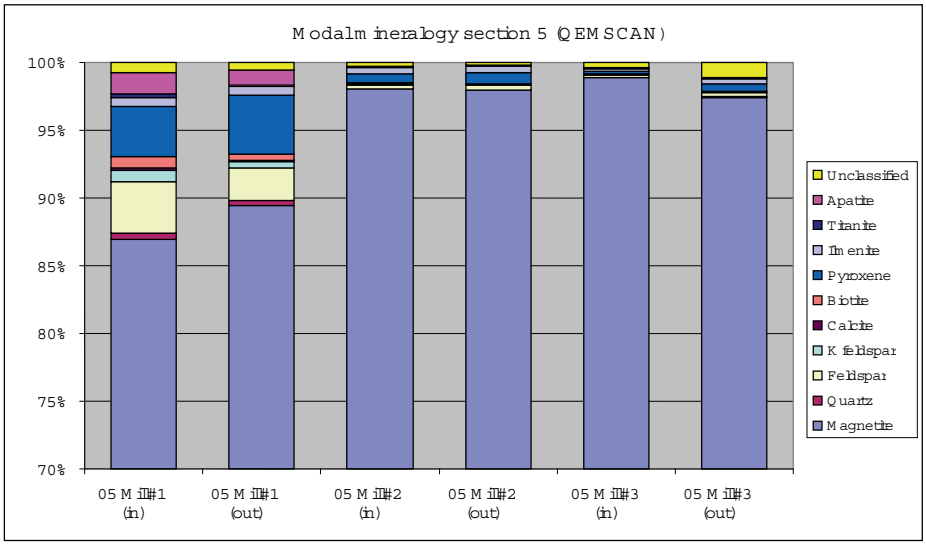

Figure 2: Modal mineralogy chart for concentrator section 5 from QEMSCAN analysis.

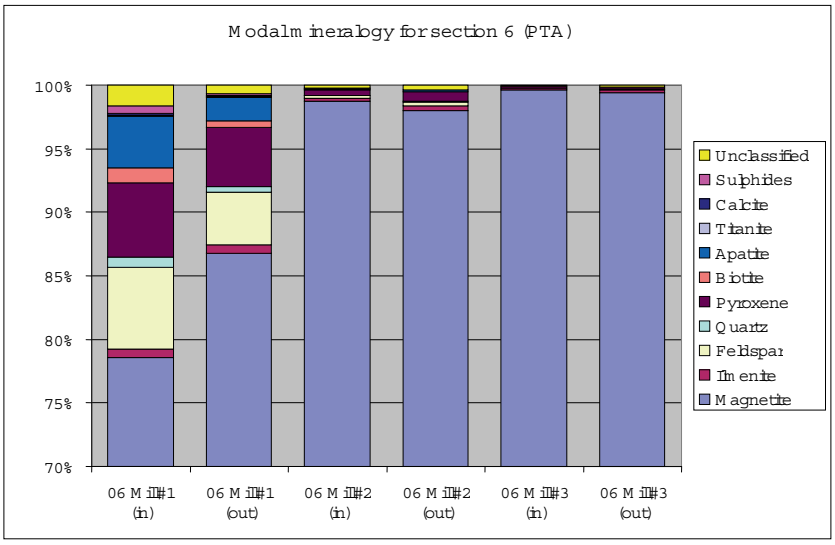

Figure 3: Modal mineralogy chart for section 6 in concentrator from PTA analysis.

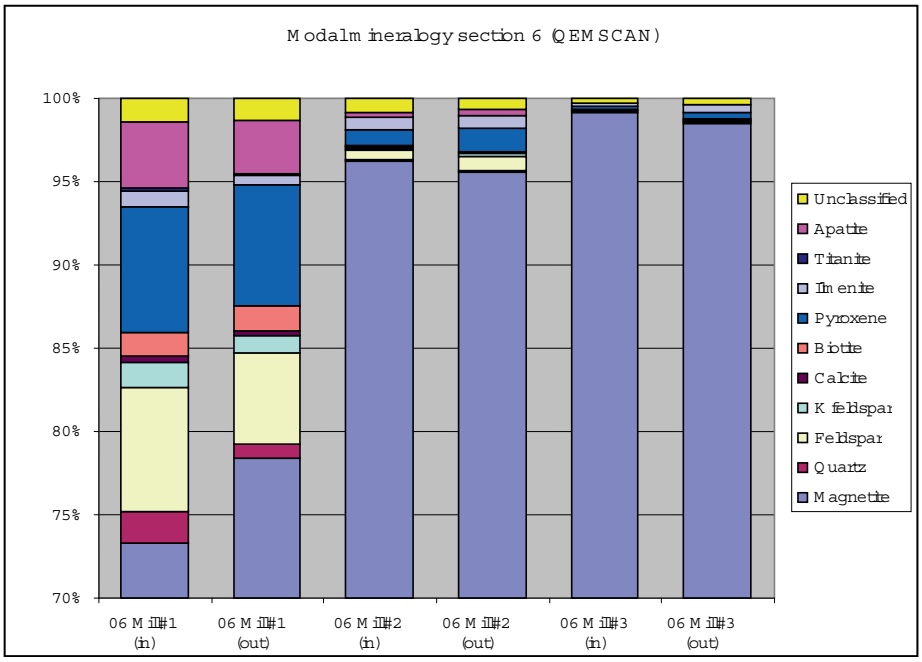

Figure 4: Modal mineralogy chart for section 6 in concentrator from QEMSCAN analysis.

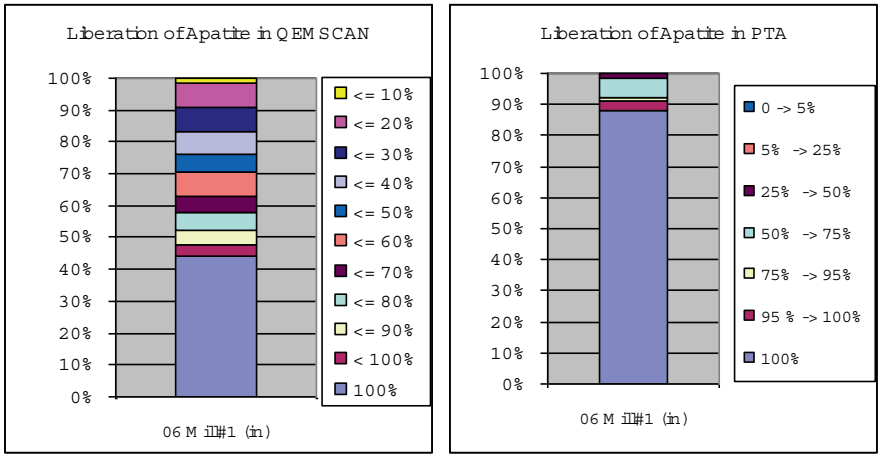

Figure 5: Liberation of apatite in QEMSCAN and PTA.