COMMINUTION EFFECTS ON MINERAL GRADE DISTRIBUTION: THE CASE OF AN MVT LEAD-ZINC ORE DEPOSIT

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INTRODUCTION

Every mining operations is followed by a beneficiation process aimed to deliver quality material to the transformation industry. Most of mineral processing is focused on comminution and grinding of extracted ore that is crucial for the following separation steps in order to divide gangue from valuable minerals. Comminution is the most energy consuming phase and the quality of the results is strictly related to the characteristic of the material under treatment.

In order to understand the crushing behaviour of a mixed sulphide ore, A preliminary study has been performed. The analysed material was sampled in a Mississippi Valley Type (MVT) deposit in Northern Italy and contains mainly galena and sphalerite. This study examines the distribution of concentration of target minerals among the different sized products of the crushing process. Ore samples have been examined and characterized through thin sections observation and SEM analyses for the determination of the grain liberation size, while XRD quantitative analyses have been performed for the definition of the concentrations. The selected crushing circuit comprises lab-scale impact crusher, jaw crusher, disk mill and rod mill. The collected products are below the free grain size threshold and granulometric analyses have been performed. All these evaluations brought a clearer overview on how different minerals react to the same comminution pathway.

The importance to have a clear comprehension on the redistribution of target minerals in mid-processing products could lead to an efficient separation. Benefits that could be achieved can enhance a reduction in end-process waste, as same as control on water use, reagents and machinery utilization during beneficiation stage.

1. THIN SECTIONS CHARACTERIZATION

OPTICAL MICROSCOPY

OM observations underlined an abundant presence of sphalerite (Sph) surrounded by a calcite (Cal) matrix. Sph minerals show a yellow-brownish or black coloration in Parallel Light (PL) (Fig. 1a) with a transparent behavior, while they are opaque in Cross Polarized Light (XPL) (Fig. 1b). Calcite (Cal) appears white and striated with transparent behavior in PL and XPL. Opaque mineralization in PL such as galena (Gal) and cerussite are few and usually occurring around Sph grains.

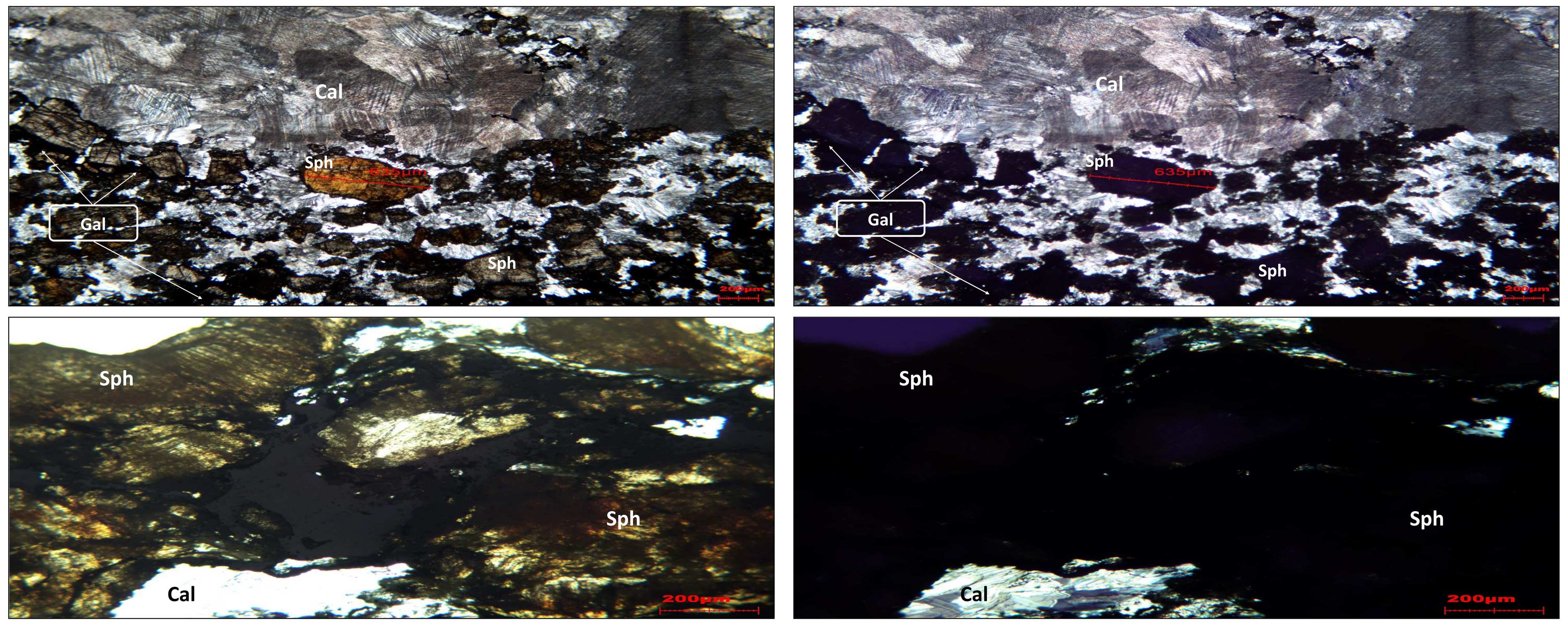


Fig. 1a — Parallel Transmitted Light, 4x mag.

Fig. 1b — Polarized Transmitted Light, 4x mag.

SEM

Punctual analyses has been carried out in order to understand the elemental composition of intergranular filling material. SEM observations (Fig. 2) confirm a spread presence of sphalerite (Sph) and highlighted the presence of Pb-Zn alteration compounds, such as cerussite (Cer) and smithsonite (Sm). Presence of organic matter (Org) has been detected in microfractures filling.

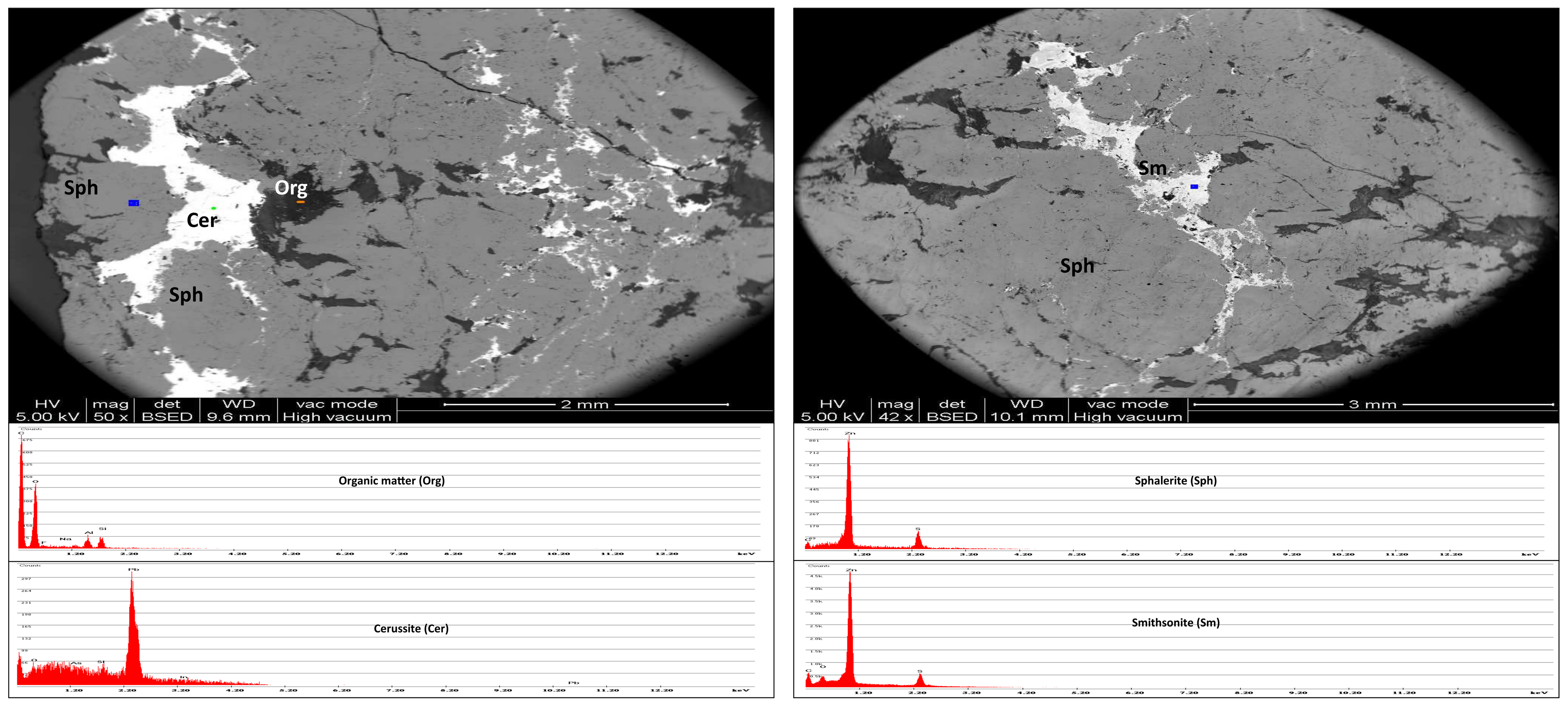


Fig. 2 — Thin sections SEM images and EDAX spectra. Left img.: Sphalerite (blue dot), Cerussite (green dot), Organic Matter (orange dot). Right img.: Sphalerite and Smithsonite (blue dot)

2. COMMINUTION FLOWSHEET AND TEST

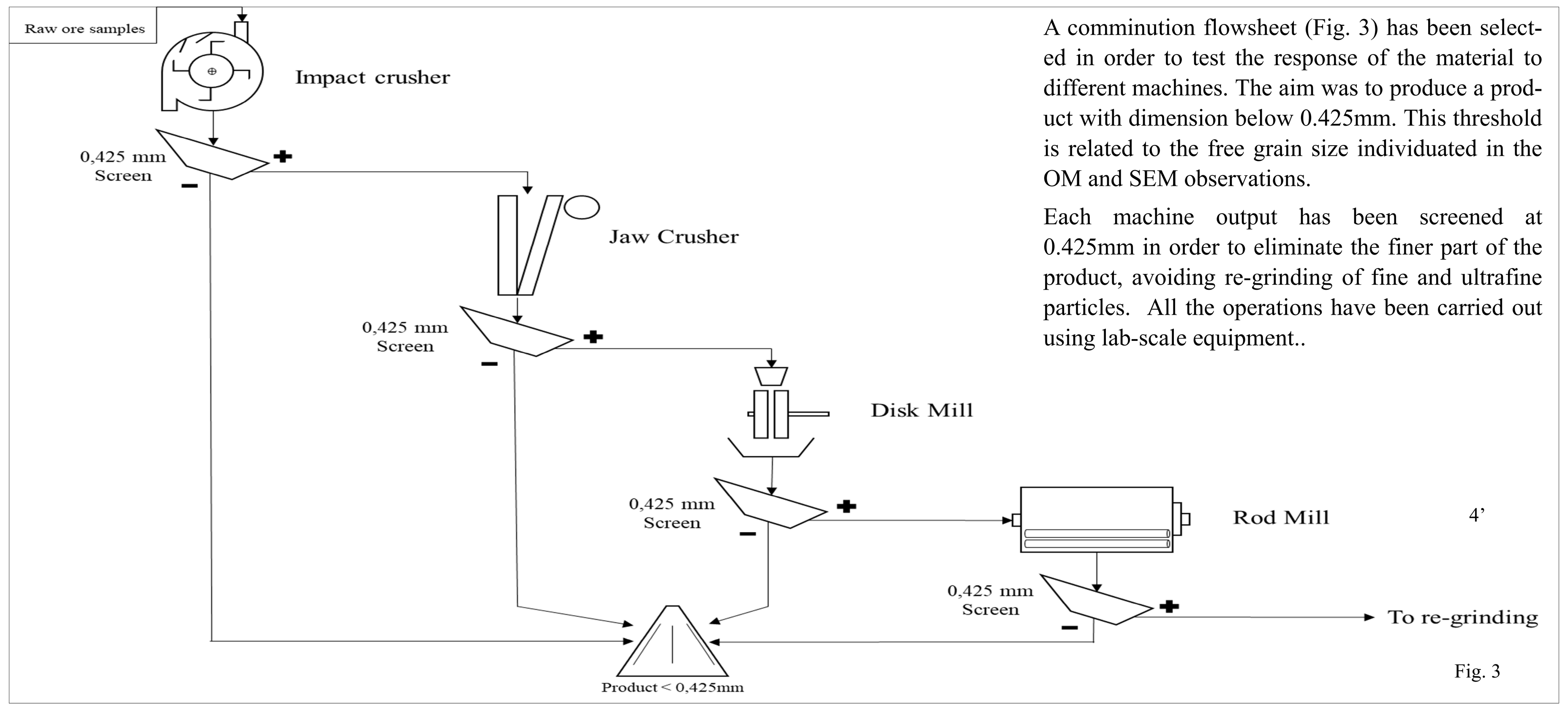


Fig. 3

A comminution flowsheet (Fig. 3) has been selected in order to test the response of the material to different machines. The aim was to produce a product with dimension below 0.425mm. This threshold is related to the free grain size individuated in the OM and SEM observations.

Each machine output has been screened at 0.425mm in order to eliminate the finer part of the product, avoiding re-grinding of fine and ultrafine particles. All the operations have been carried out using lab-scale equipment..

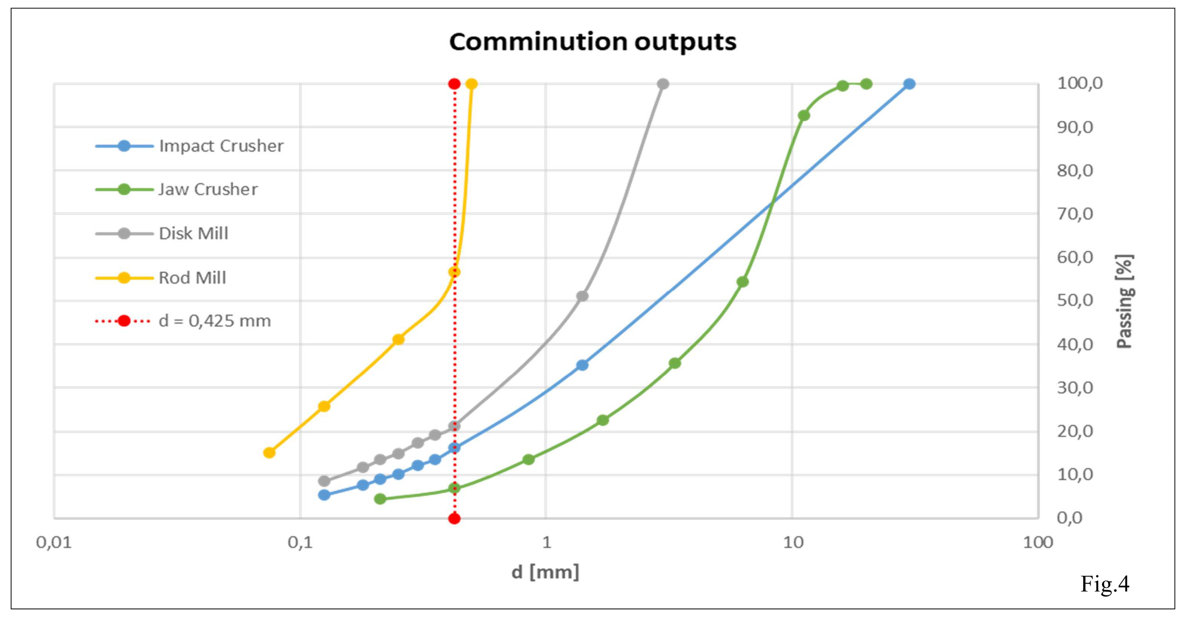


Fig.4

The output product of each comminution step has been characterized in terms of grain size distribution (Fig.4), aiming to assess the comminution behavior of the material and the reduction path related to each equipment. The red vertical line is representing the free grain size.

The entire flowsheet has been arranged in order to foster a gradual reduction of the material, controlling the reduction ratio and addressing the main reduction activity to the rod mill action. This configuration delivers 70.4% of the total input material below 0.425mm, suitable for further separation operations.

3. COMMINUTION FINE PRODUCTS CHARACTERIZATION

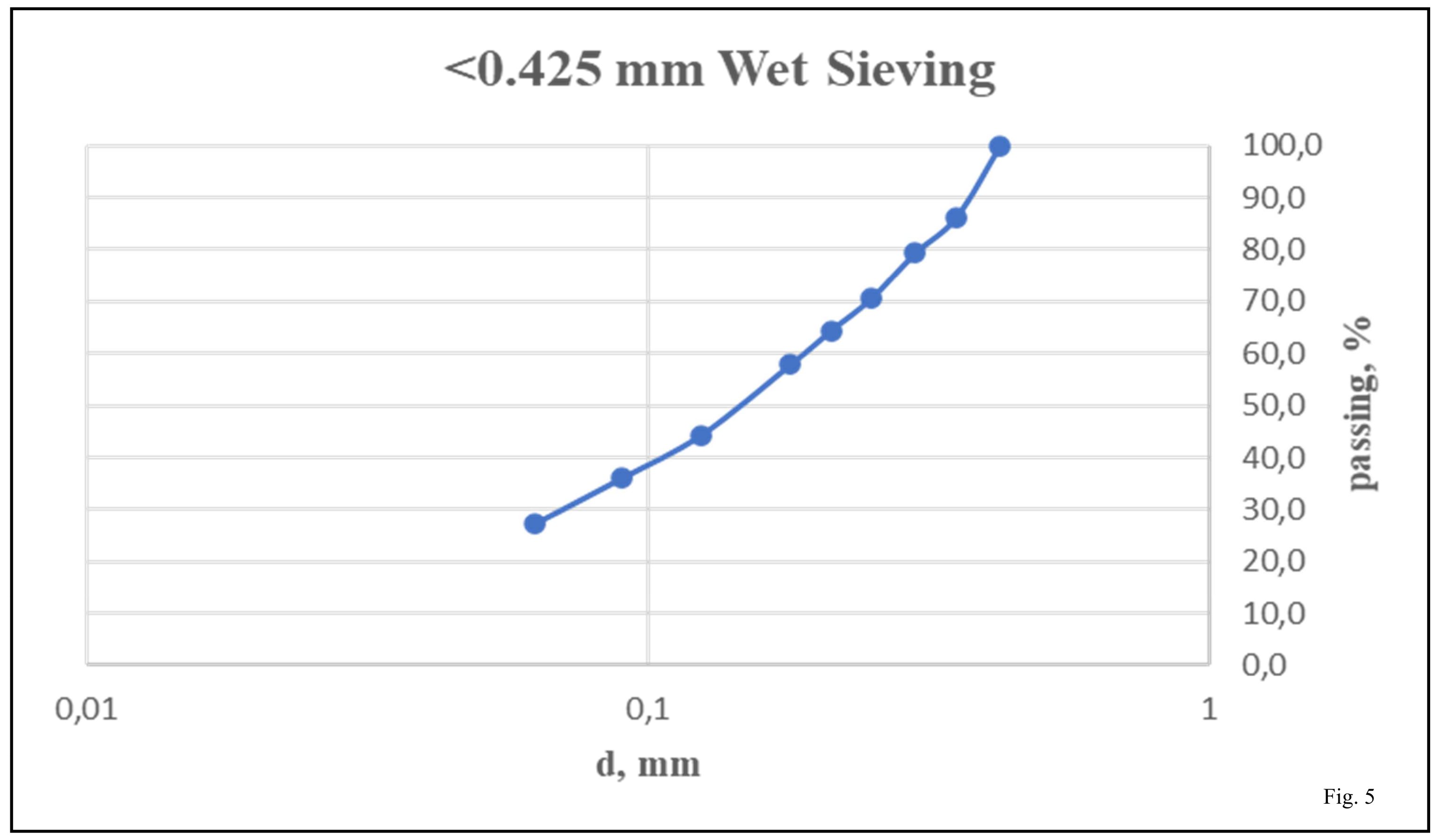
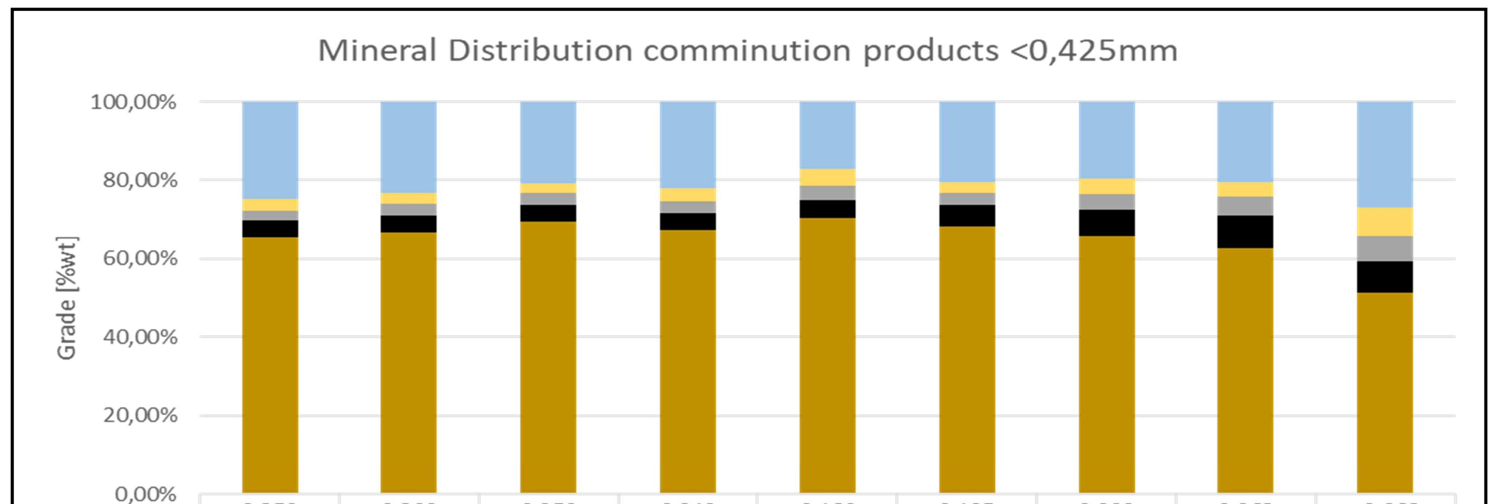


Fig. 5

Comminution products below the grain size of 0.425mm have been assessed in details (Fig. 5). While the overpassing material has been taken apart from further evaluations, finer material has been sieved and characterized in terms of granulometry and composition. It has been crucial in order to understand the effectiveness of comminution flowsheet and the quality of the obtained material.

Wet sieving has been used to have a good resolution on classes. Selected sieve series is: 0.355 mm, 0.300 mm, 0.250 mm, 0.212 mm, 0.180 mm, 0.125 mm, 0.090 mm, 0.063 mm, -0.063 mm. Extrapolated data deliver a $d_{80} \approx 0.300$ mm and $d_{50} \approx 0.150$ mm, which are considered good parameters for further separation processes (e.g. flotation, mineral jig, shaking table).



	0,350	0,300	0,250	0,212	0,180	0,125	0,090	0,063	<0,063
CaCO3	24,87%	23,33%	20,82%	21,87%	17,26%	20,35%	19,51%	20,49%	26,90%
PbSO4	2,93%	2,67%	2,50%	3,55%	4,04%	2,79%	4,10%	3,53%	7,20%
PbCO3	2,52%	3,04%	3,08%	3,11%	3,71%	3,27%	3,97%	4,94%	6,43%
PbS	4,09%	4,14%	4,28%	4,12%	4,60%	5,37%	6,54%	8,41%	7,97%
ZnS	65,59%	66,82%	69,32%	67,35%	70,39%	68,22%	65,88%	62,63%	51,50%

Class [mm] and Mineral

Fig. 6

XRPD Analyses were carried out on samples obtained by wet sieving, each class has been qualitatively and quantitatively assessed. Micronized powder (d <10 μm) has been obtained using a mixer ball mill. Acquisitions have been performed using a Rigaku SmartLab SE diffractometer, with CuKα radiation at 40kV and 30mA, 5° - 90° range, 0.01° step width, 1,00°/min scan speed, interfaced with SmartLab Studio II software. Quantitative phase analyses have been realized using the Whole Powder Pattern Fitting (WPPF) based on the ICCD PDF-4 2020 database.

In Fig. 6 all the quantitative results has been plotted in order to compare the results among different size classes. Four main phases have been individuated (Calcite, Anglesite, Cerussite, Galena, Sphalerite) in the samples, confirming what observed by OM and SEM. In average sphalerite is the most abundant mineral in the samples ranging 50÷70%$_{w/w}$, calcite defined as gangue mineral attained 17÷27%$_{w/w}$, while galena ranges between 4÷9%$_{w/w}$. Other phases can be considered as minority.

A trend can be observed in galena and Pb-related compounds in terms of increase in their concentration with the decrease of grain size. Moreover, a different distribution in quantity of target minerals can be observed among the studied classes.

CONCLUSIONS

The purpose of this study was to understand the distribution of target minerals among mineral processing products, particularly, after a lab-scale comminution test. In order to have an overview on the characteristics of the sampled ore, petrographic observations have been necessary for the determination of the shape, composition and dimension of grains present in the mineralization. The nature and size characterization of the grains has been fundamental in order to plan the output parameters taking into account further separation steps. An important presence of sphalerite and galena has been confirmed both by OM and SEM in thin sections, with a minor presence of Zn-Pb related alteration compounds. XRPD analyses highlighted that the composition of comminution products, divided in size classes suitable for flotation separation, showed a variable mineral grade distribution varying with the reduction in dimension of the products. This phenomenon has been studied in bibliography as selective comminution, but in this case further investigation may be undergone to better define parameters related to this specific behaviour. Moreover, thanks to quantitative analyses important information have been obtained for the evaluation of the most suitable dimension cuts to be delivered to following separation stages. This important trend should be considered for further studies related to the mineral recovery rate achievable by froth flotation.

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