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Coupling breakage with liberation models to predict mineral exposure in the crushing stage of Critical Raw Materials

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INTRODUCTION & AIM

- Mineral liberation prediction is key for optimizing the processing of **Critical Raw Materials**
- Roll crusher tests were performed on a **coarse pyritic ore** to study mineral liberation before and after size reduction.
- The crushed products were characterized using **Particle Size Distribution (PSD)** and **Mineral Liberation Analysis (MLA).**
- MLA was used to quantify the liberation of **chalcopyrite, sphalerite, and galena**.
- Based on PSD and liberation data, comminution was simulated using a roll crusher **breakage Model B (Austin & Luckie, 1972; Austin et al., 1993)** and **Gaudin's statistical liberation model (Gaudin, 1939)**, linking crusher operating parameters, breakage behavior, and mineral liberation.

METHOD

- The **Run-of-mine (ROM)** material was characterized using **Particle Size Distribution (PSD), X-ray diffraction (XRD), X-ray fluorescence (XRF),** and **automated Mineral Liberation Analysis (MLA)** to establish a qualitative and quantitative mineralogical baseline.

Composition	%	Composition	%	Composition	%
SO_3	41.68	CaO	0.74	SnO_2	0.03
Fe_2O_3	21.02	K_2O	0.59	SrO	0.02
SiO_2	17.79	P_2O_5	0.23	Yb_2O_3	0.02
Al_2O_3	5.85	As_2O_3	0.21	V_2O_5	0.01
ZnO	3.77	Co_3O_4	0.10	CdO	0.01
BaO	1.47	TiO_2	0.09	TeO_2	0.01
MgO	1.44	MnO	0.05	Eu_2O_3	0.01
CuO	1.43	Sb_2O_3	0.04	IrO_2	0.01
PbO	0.98	Ta_2O_5	0.04	Tl_2O_3	0.01

Table 1 - Chemical composition of the material by XRF analysis

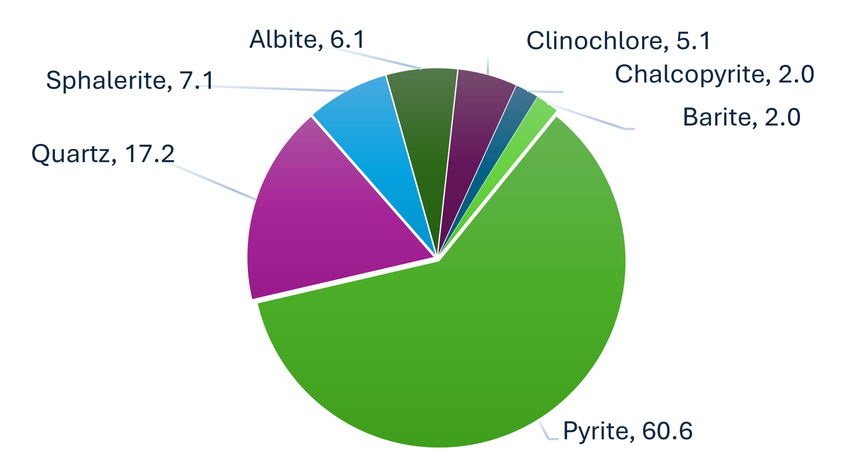
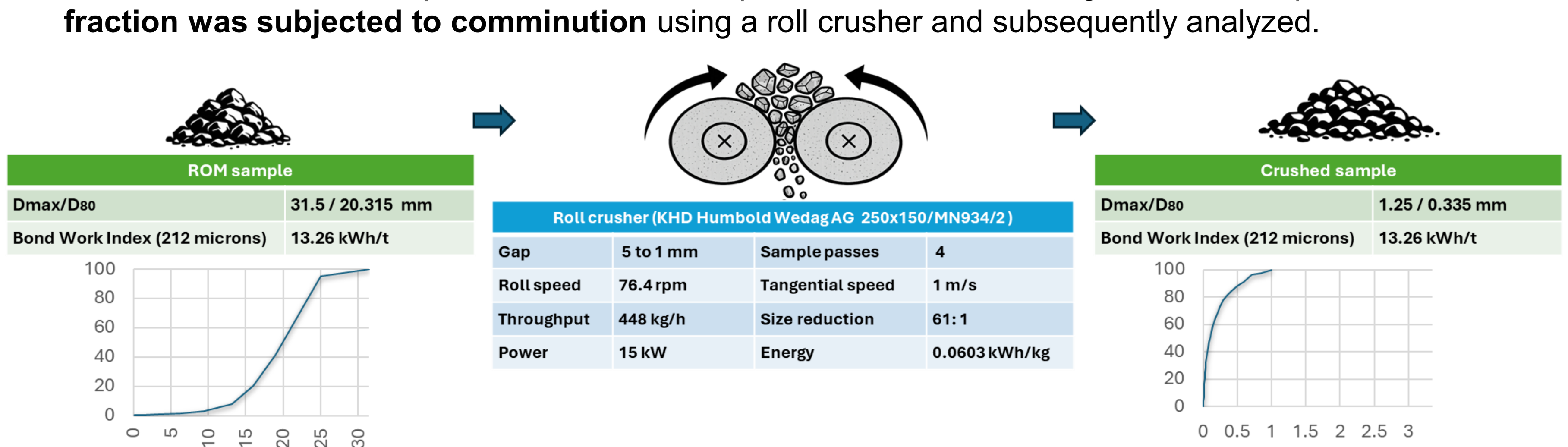


Figure 1 - Mineralogy of the material, detected by XRD

- The ROM material was split into two fractions: particles smaller and larger than 1250 µm. The **oversize fraction was subjected to comminution** using a roll crusher and subsequently analyzed.



ROM sample	
Dmax/D80	31.5 / 20.315 mm
Bond Work Index (212 microns)	13.26 kWh/t

Roll crusher (KHD Humbold Wedag AG 250x150/MN934/2)			
Gap	5 to 1 mm	Sample passes	4
Roll speed	76.4 rpm	Tangential speed	1 m/s
Throughput	448 kg/h	Size reduction	61:1
Power	15 kW	Energy	0.0603 kWh/kg

Crushed sample	
Dmax/D80	1.25 / 0.335 mm
Bond Work Index (212 microns)	13.26 kWh/t

Figure 2 - Operating conditions of the roll crusher and feed-product parameters

- The **breakage model B (Anticoi et al., 2019)** was calibrated using the PSD data of the **4 crushing stages** and implemented in **MATLAB®** to simulate particle breakage. MLA measurements of the crusher feed and product were used to quantify mineral liberation and generate model predictions trough **Gaudin's statistical liberation model (Pérez-García et al., 2018,)** for chalcopyrite.

RESULTS & DISCUSSION

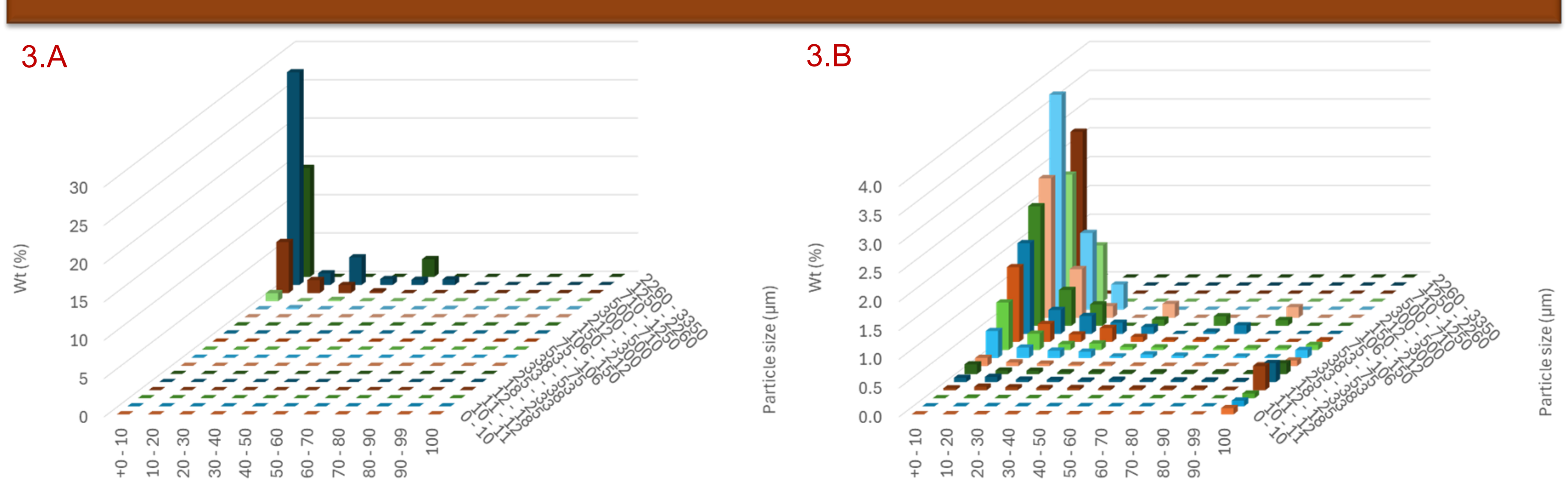
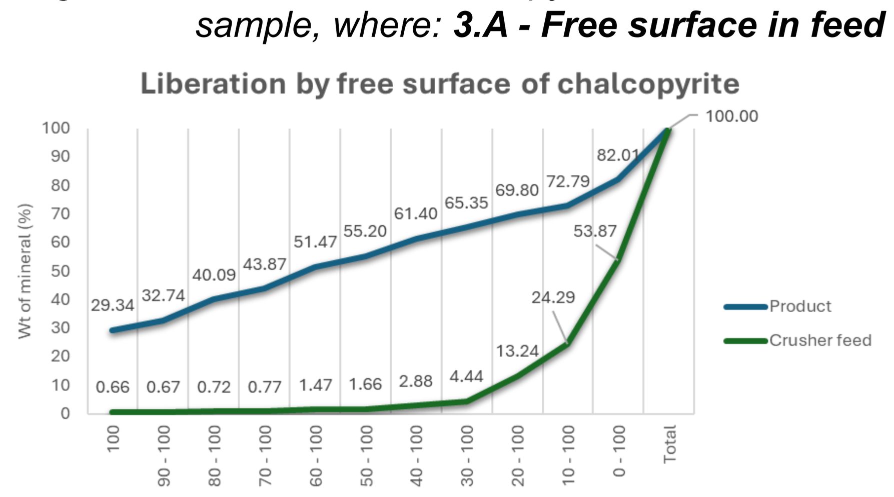
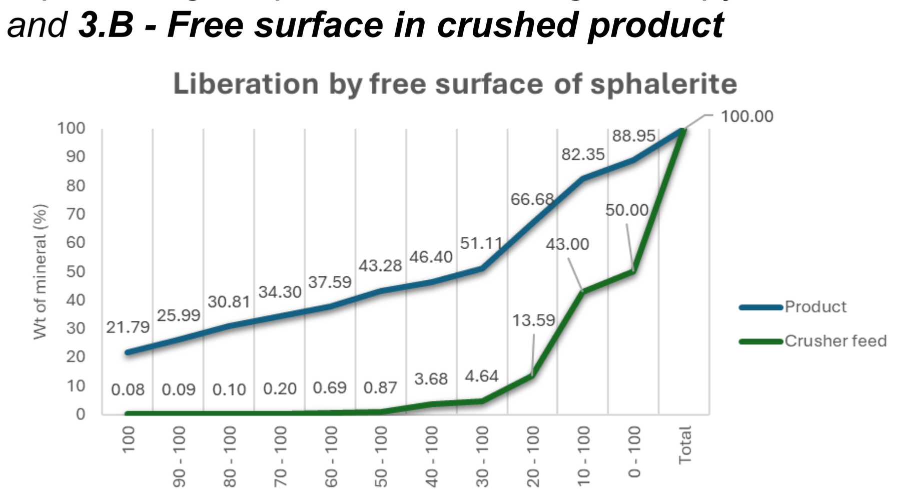


Figure 3 - Distribution of chalcopyrite liberation as mass percentage of particles containing chalcopyrite in the sample, where: ***3.A - Free surface in feed*** *and* ***3.B - Free surface in crushed product***





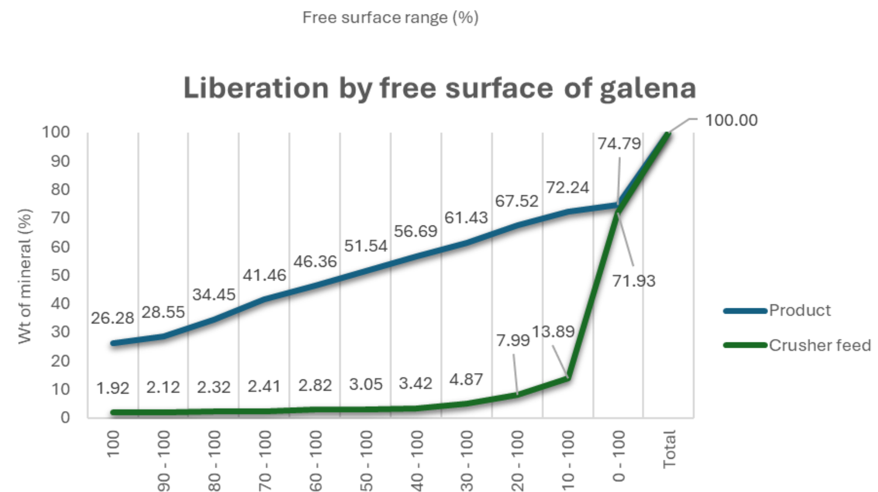


Figure 4 - Comparison of the ***cumulative mineral free surface of chalcopyrite, sphalerite, and galena*** *in the crushing feed and the crushed product. The results show that size reduction with a roll crusher increases the liberation of the target minerals and significantly reduces the amount of material that must pass through subsequent separation or liberation processes, such as milling or flotation.*

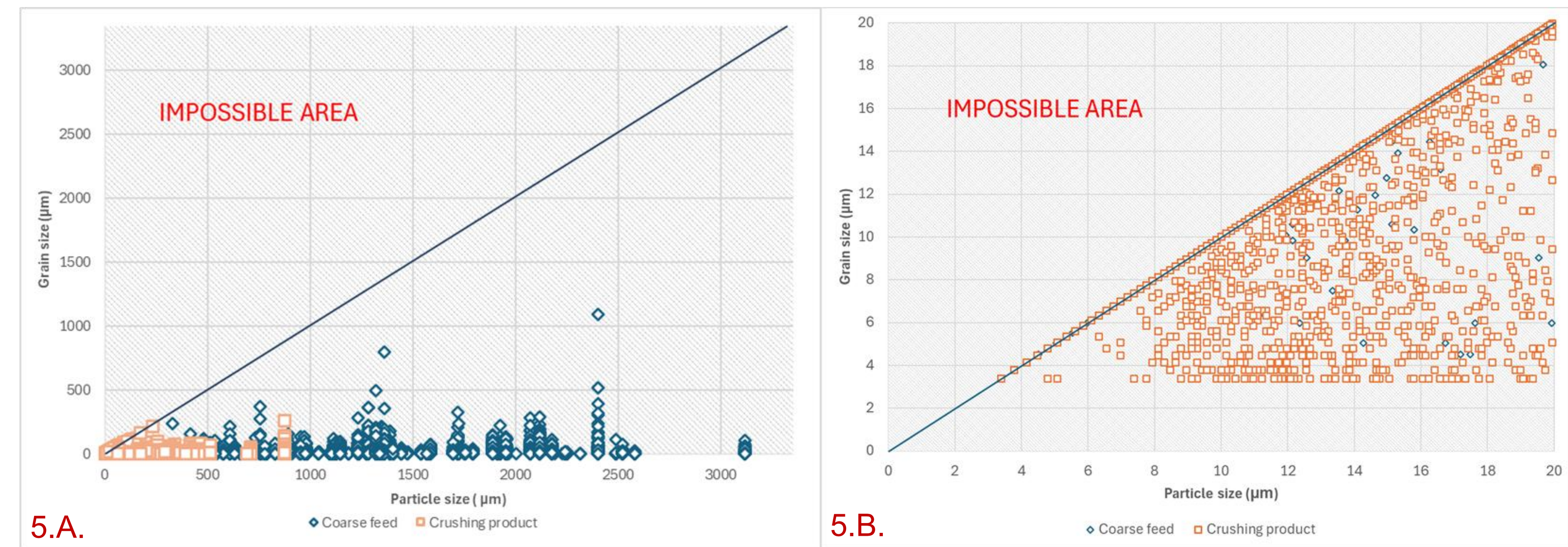


Figure 5 - Grain-particle size relationship for the coarse feed and crushing product indicating the theoretical ***liberation boundary of chalcopyrite (y =x)****, where: 5.A - View of the entire sample size range* ***(0-3350 µm)*** *and 5.B - Zoomed view of the fine size range* ***(0-20 µm)***

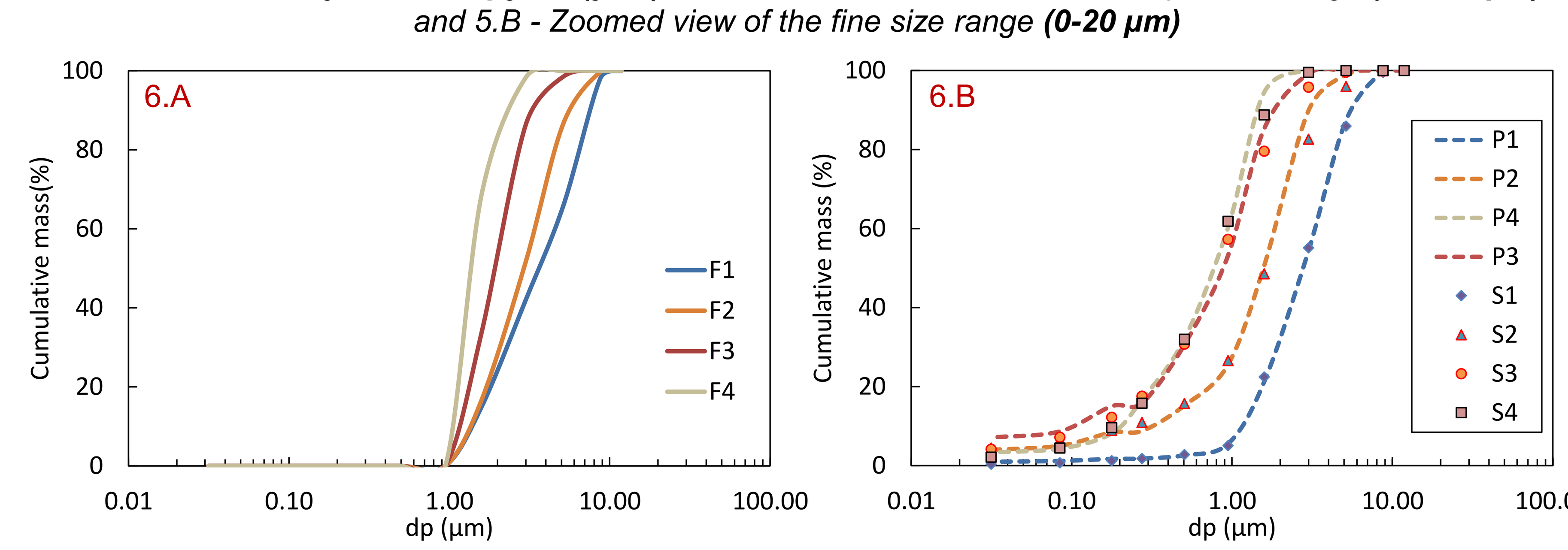


Figure 6 – Breakage modelling of the coarse feed in which: ***6.A - PSD of the crusher feed*** *after each stage, where* ***the fine product under 1250 um of the previous stage has been removed (F1-F4)*** *and* ***6.B - PSD of the crusher product*** *after each stage* ***(P1-P4)*** *and its simulation through the breakage function* ***(S1-S4)***

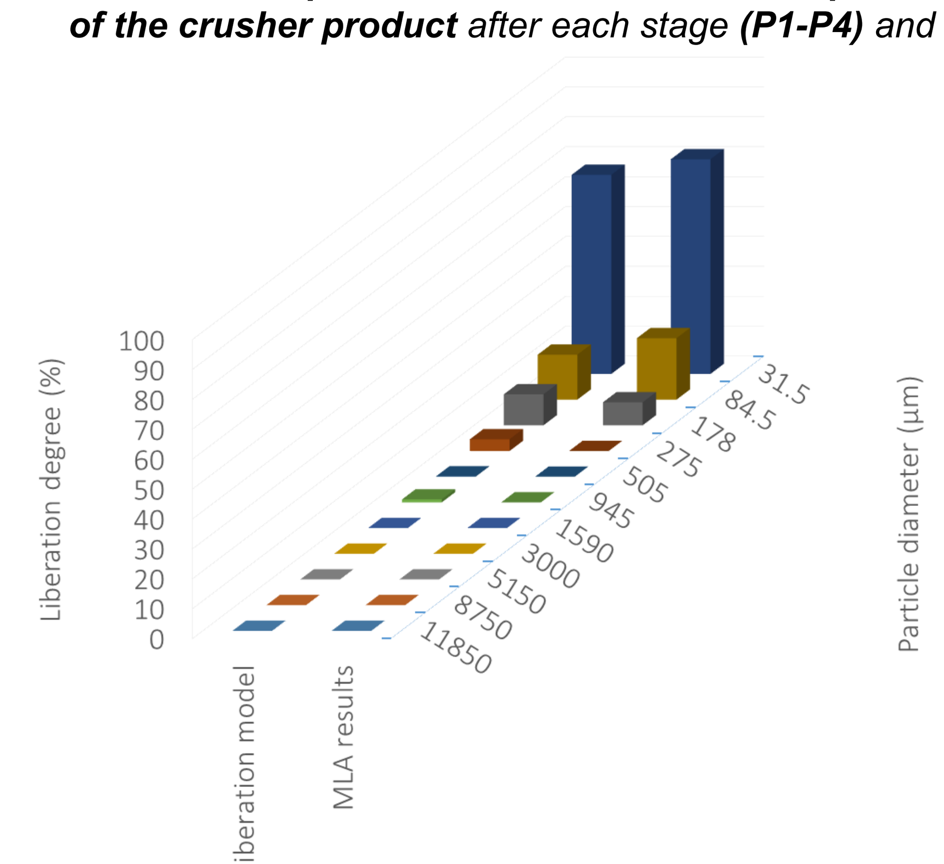


Figure 7 – ***Predicted mineral liberation of chalcopyrite*** *as a function of particle size fraction based on the ore grades. If* ***liberation is considered as particles with 80–100% free surface****, the model shows good agreement with the particle size distribution produced by the roll crusher, supporting the proposed relationship between crushing granulometry and mineral liberation.*

CONCLUSION

- Roll crusher comminution enhances the liberation of chalcopyrite, sphalerite and galena in the coarse fraction pyritic ore.
- MLA and PSD analyses show consistent trends, with **higher degrees of liberation in finer size fractions**.
- The **breakage–liberation modelling framework** shows **good agreement with MLA results**.
- **Crushing can reduce downstream grinding**, potentially **improving energy efficiency**.
- The methodology links crusher parameters, particle breakage, and mineral liberation in sulfide ores.

FUTURE WORK / REFERENCES

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BLOOM

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