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II INTERNATIONAL CONGRESS ON MINERAL CRUSHING, GRINDING, HPGR & CLASSIFICATION

"Estimating ROM and SAG Size Distribution by Inverse Simulation"

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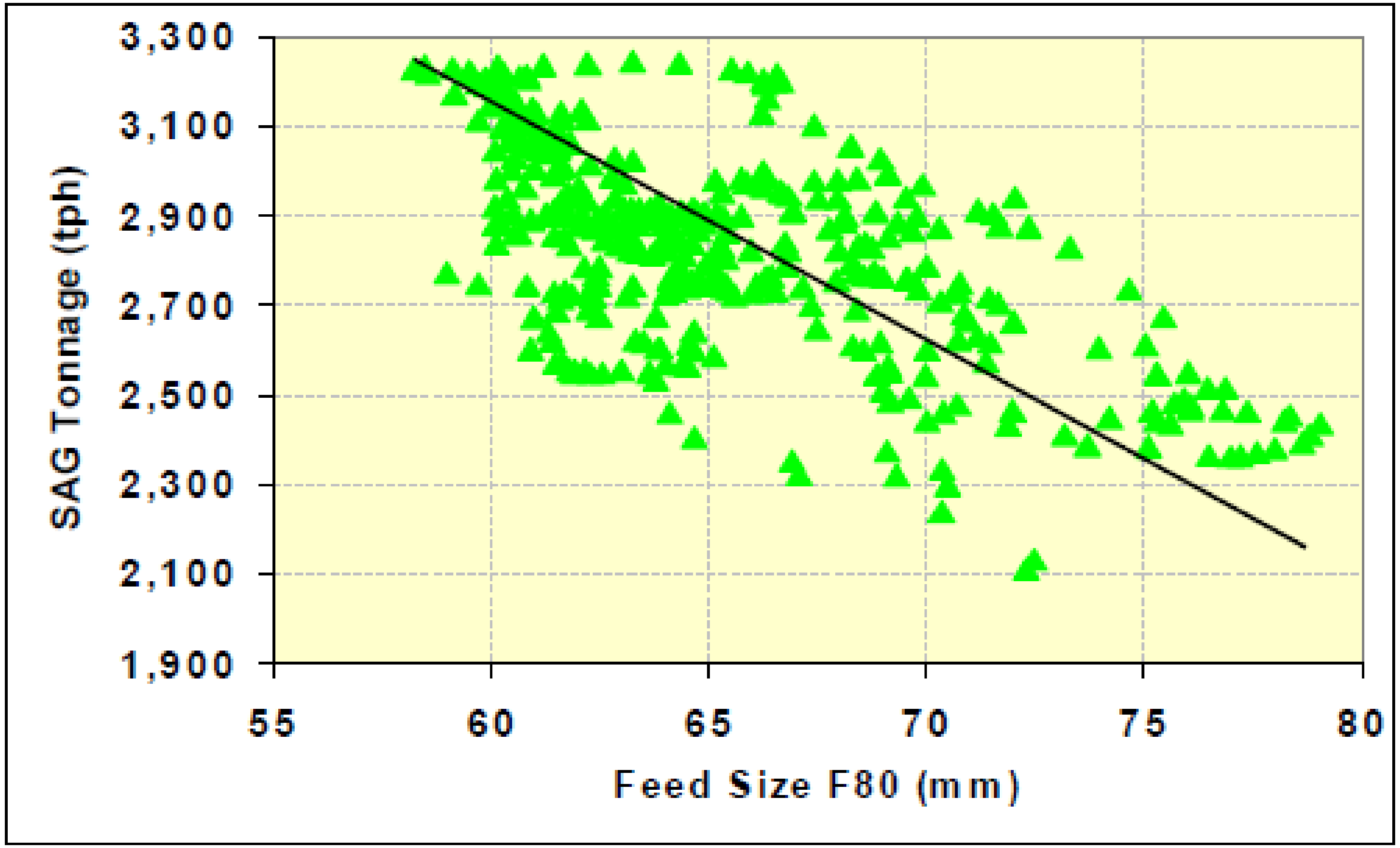
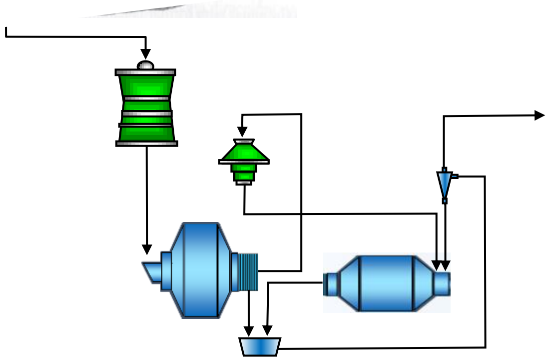
Organized by: InterMet

Agenda

- ✓ Framework
- ✓ Fragment Size Distribution
- ✓ Inverse Simulation Need
- ✓ Appropriate Tools
- ✓ Study Case
- ✓ Remarks

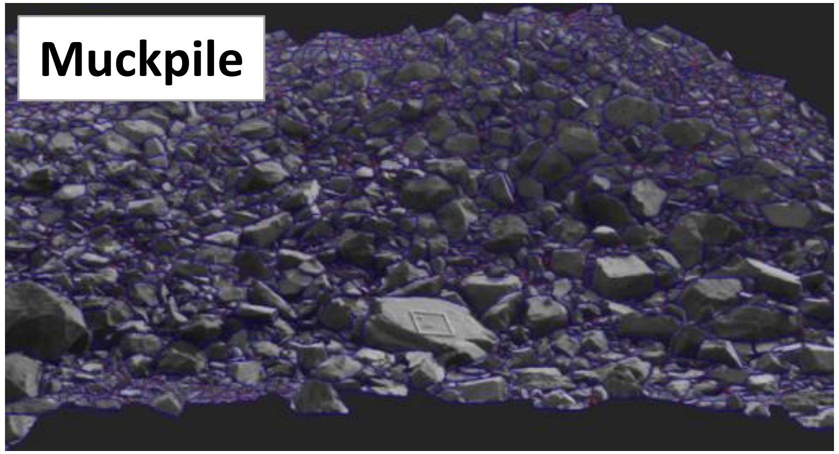
The Mine-to-Mill Concept

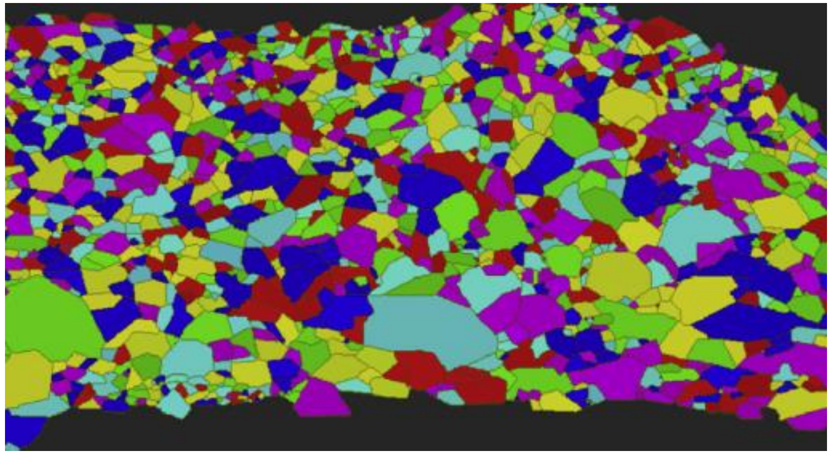




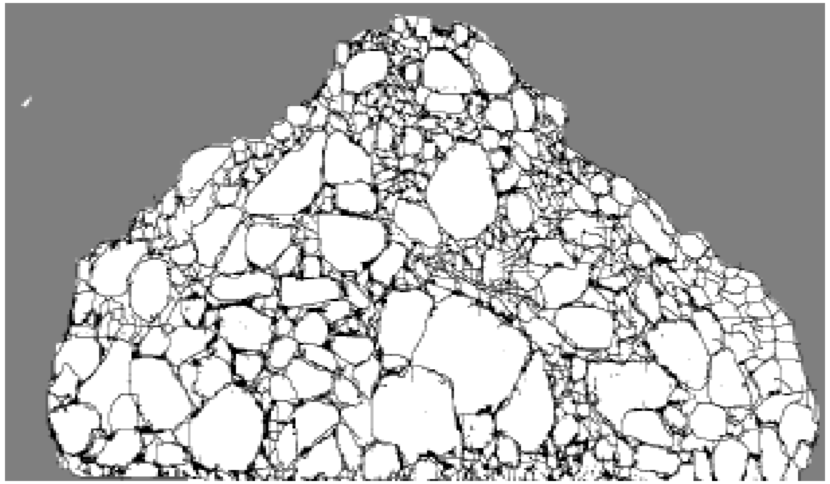
E. Rybinskiet al., Optimisation and continuous improvement of Antamina comminution Circuit. Antamina and Metso Pub., 2010.

Measuring ROM PSD





P.K. Singh et al., J. of Rock Mechanics and Geotechnical Engineering (8) 2016, 225-237.



https://im-mining.com/2017/08/31/blast-fragmentation-measurements-open-pits/

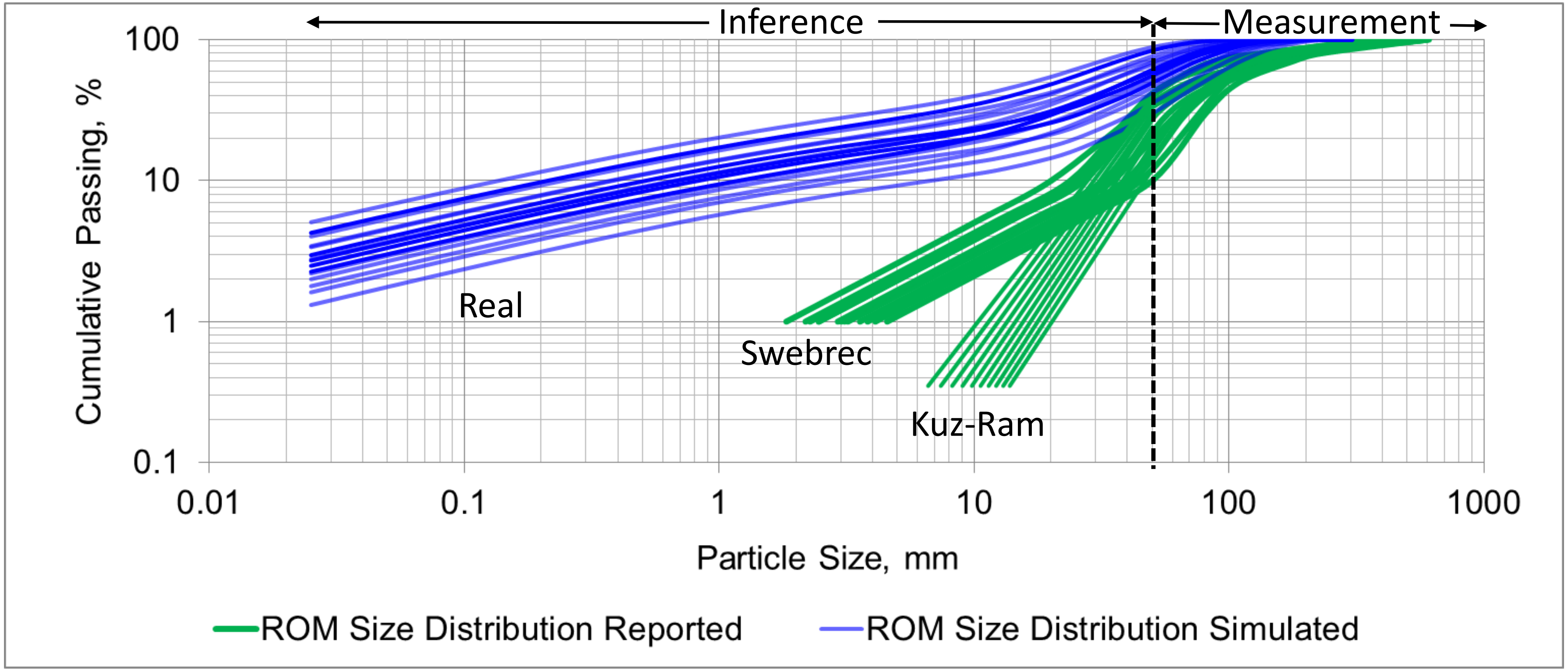
Current Inference Models

- Most are empirical equations
- The Kuz-Ram equation (linear im log – log space) is used with poor prediction of the fines content
- The JKRMC "*Crushed Zone Model*" and the "*Two Component Model*" use a combination of two Kuz-Ram equations to improve the fines estimate
- The Ouchterlony model has two versions of the Swebrec function
- The DRM model is phemenological in nature

Only the DRM model and the extended Ouchterlony´s Swebrec function show real bimodal response in log – log space as really is found

Finn Ouchterlony, The Swebrec© function: linking fragmentation by blasting and Crushing, Mining Technology (Trans. Inst. Min. Metall. A) March 2005 Vol. 114 A29 – A44

The Practical Result



Requirement for Assertive Production Planning within a Mine-to-Mill Frame

- ✓ A reliable physical quality model for the orebody
- ✓ A realistic estimate of the complete ROM fragment size distribution and
- ✓ A reasonable estimate of the impact of fragment size distribution on SAG mil throughput

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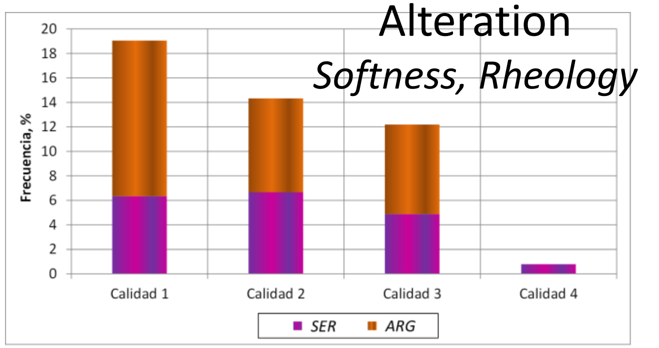
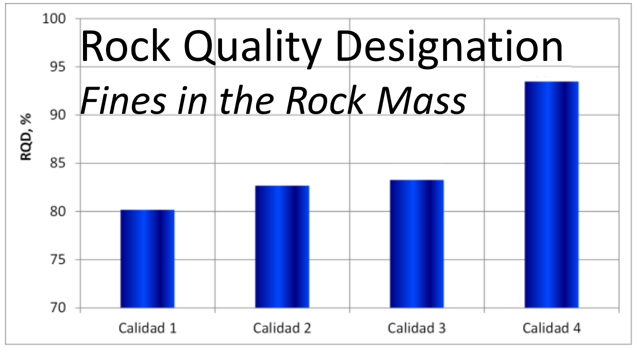
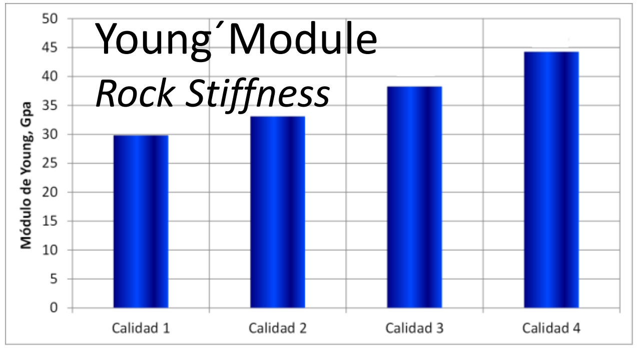
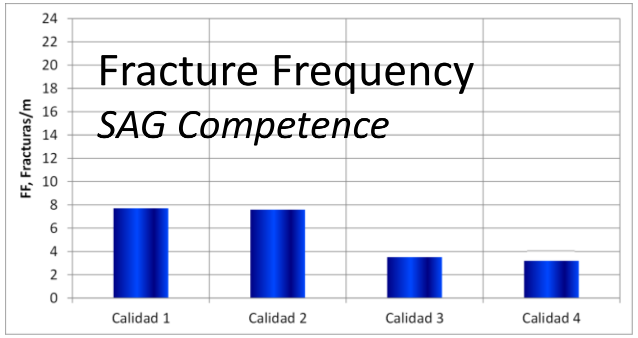
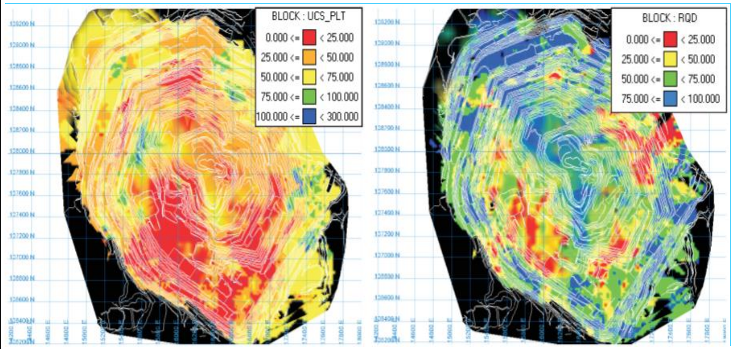
The DRM Physical Quality Approach "*Q-Model*"

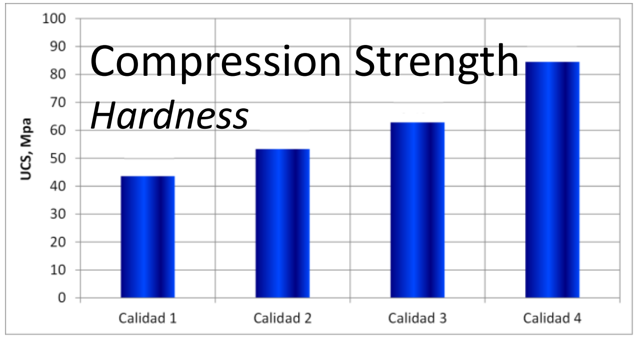


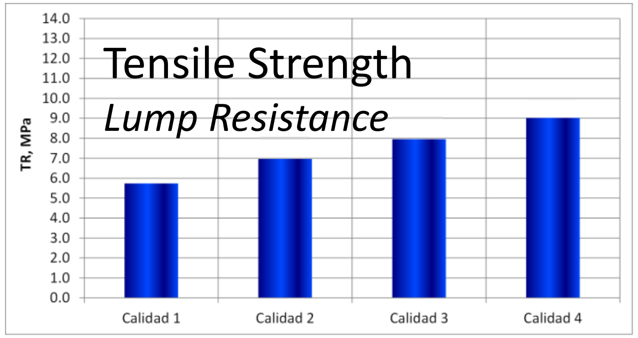


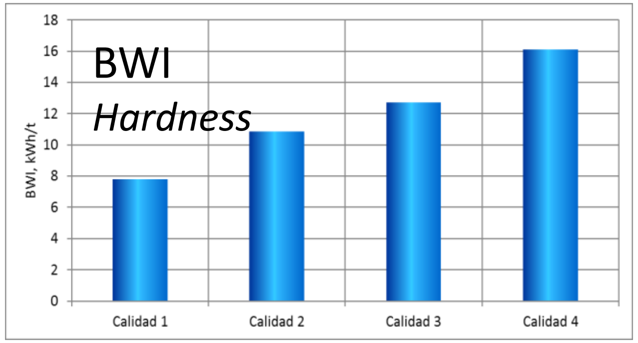


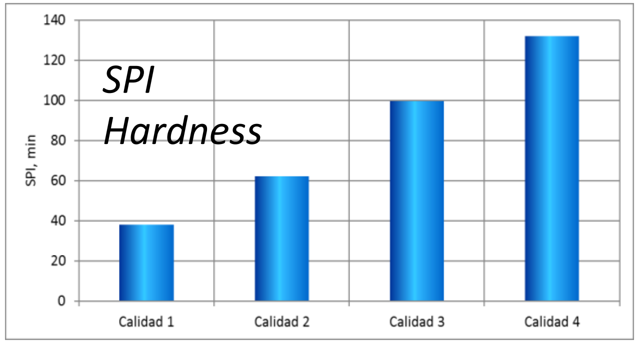










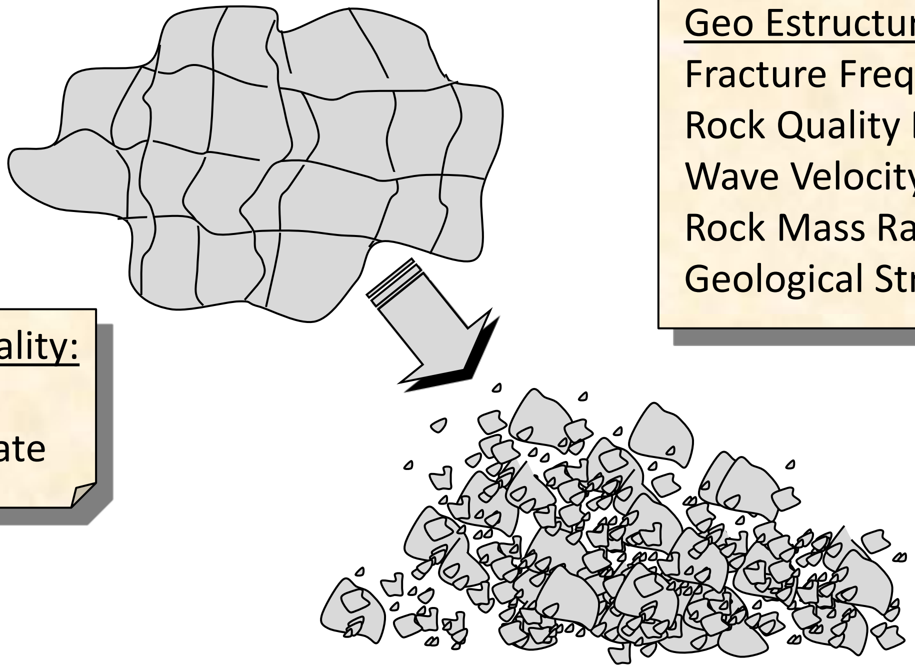


The DRM Blasting Model Approach

Blast Design Variables:
Powder Factor
Burden and Spacing
Drill Diameter and Length
Bench Height
Top Stemming
Sub Drill
Iniciator Mode

Massive Rock Variables:
Geology
Geomechanics
Geotechnics

Explosive Variables:
Type
Energy Factor



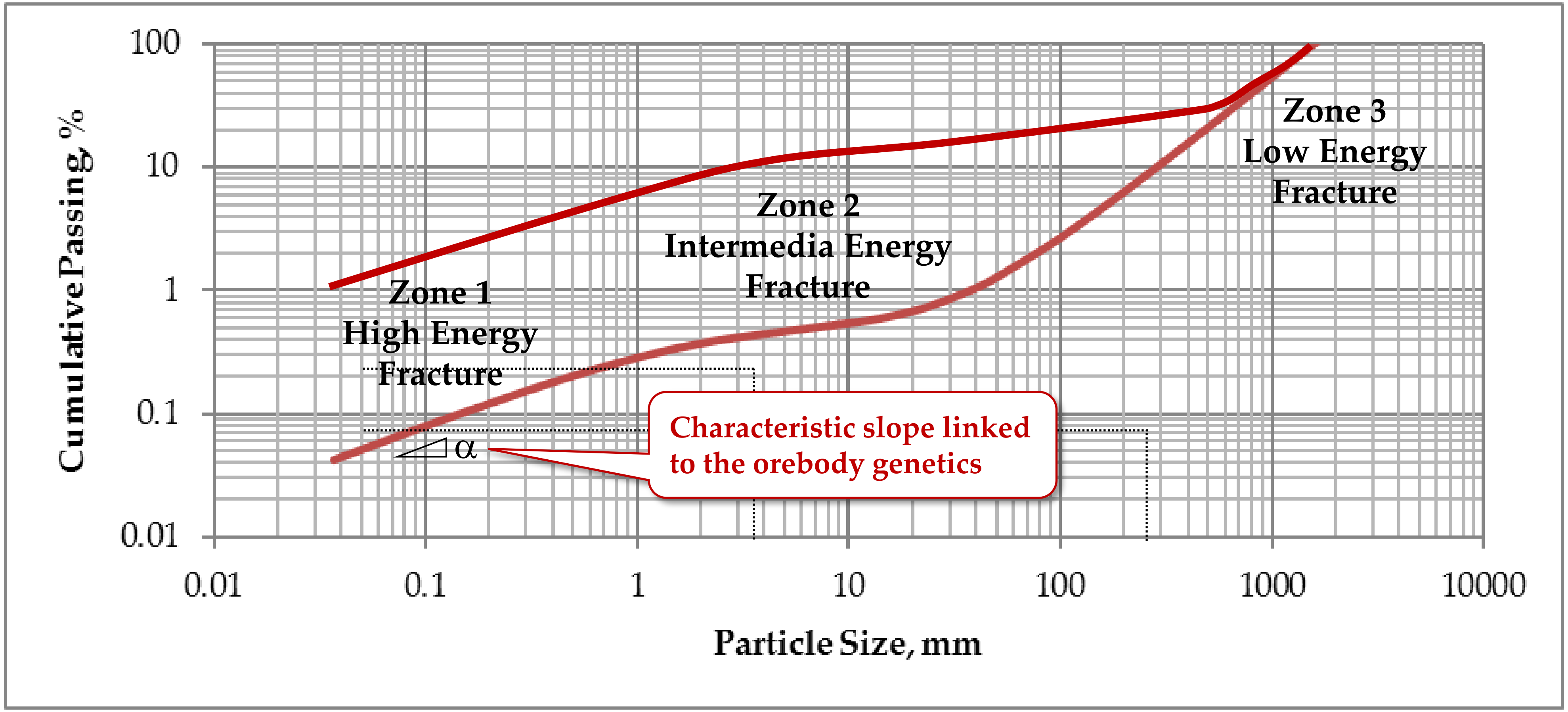
Geo Estructural Variables:
Fracture Frequency, FF
Rock Quality Designation, RQD
Wave Velocity (n and p)
Rock Mass Rating, RMR
Geological Strength Index, GSI

Internal Variables per Quality:
Fragmentation Habit
Specific Fragmentation Rate

Responses:
ROM - PSD
Energy Consumption

Menacho, J.M., L.A. Verdugo and G.E, Vega, New predictive blasting model oriented to optimum production planning, PROCEMIN 2018.

ROM Fragment Size Distribution



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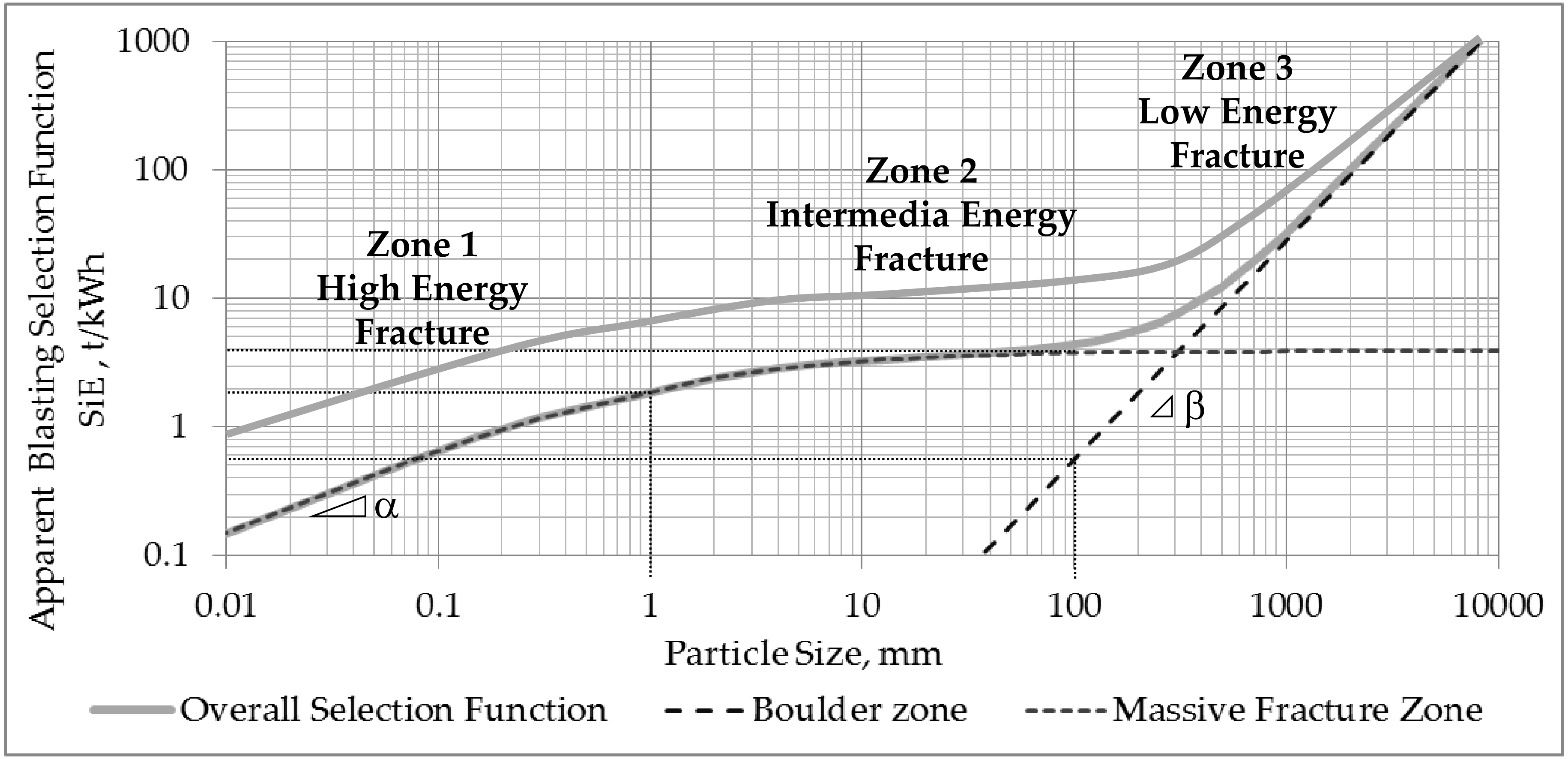
The Apparent Blasting Selection Funtion



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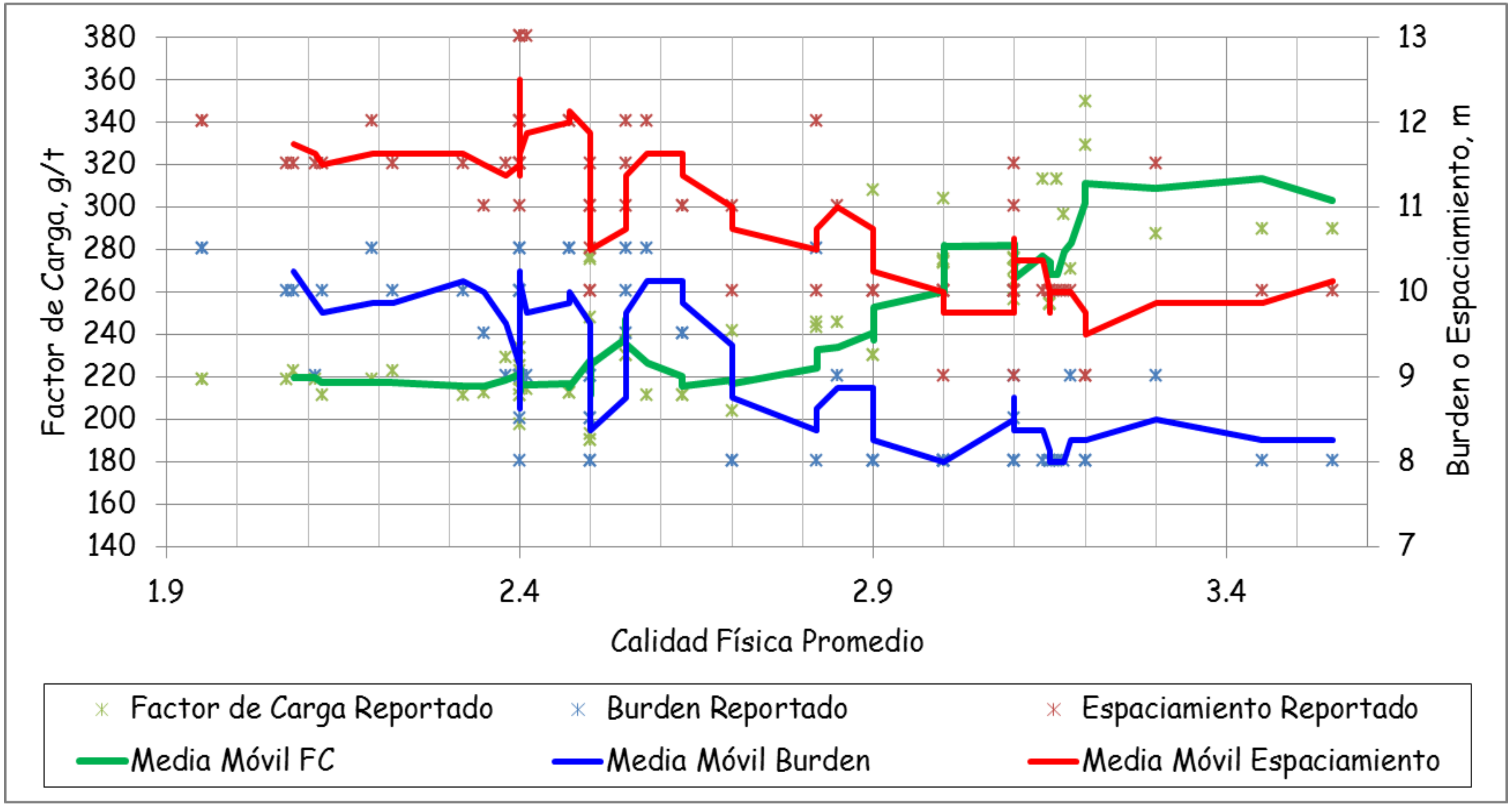
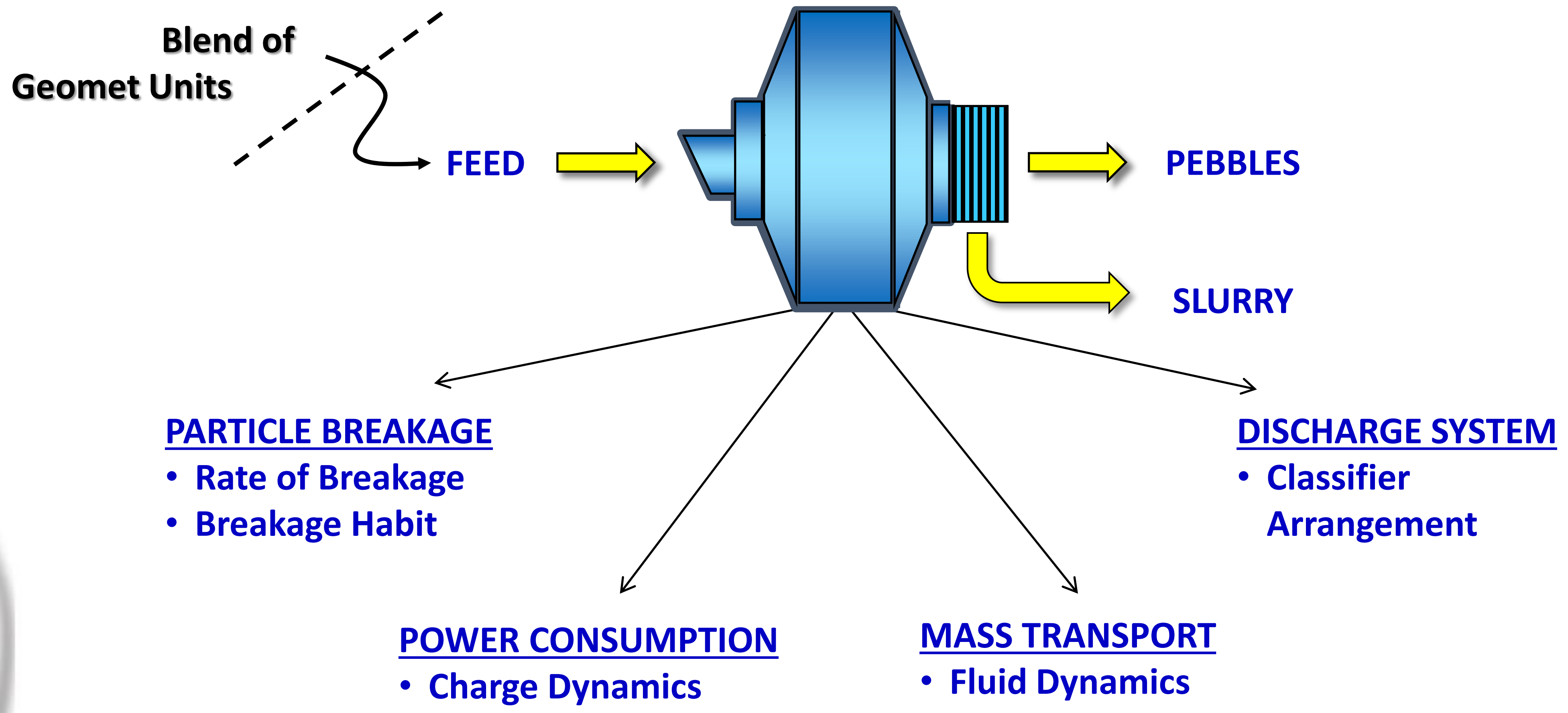
Managing the Blasting Performance



The DRM SAG Mill Modelling Approach



The DRM SAG Mill Model

- Particle Breakage : Austin approach, with energy-based equations (1)
- Power Consumption : Modified Hogg/Fuerstenau equation (2)
- Mass Transport : Flow through Porous Media (Bernouilli, Ergun) (3)
- Discharge System : Classifying/Splitting devices

(1) *L.G. Austin, J.M. Menacho and F. Pearcy, "A General Model for Semi-autogenous and Autogenous Milling", - APCOM 87. Proc. 20th Int. Symp. Appl. of Computers and Mathematics in the Mineral Industries. Vol. 2: Metallurgy. Johannesburg, SAIMM, 1987. pp. 107 - 126.*

(2) *Sepúlveda, J.E., The Hogg and Fuerstenau Power model for AG/SAG mills: Recalibration with an expanded database, Proc. PROCEMIN 2017, October 4-6. 2017.*

(3) *Menacho, J.M. and P.A. Chávez, Mass transfer in SAG milling, Proc. PROCEMIN 2008.*

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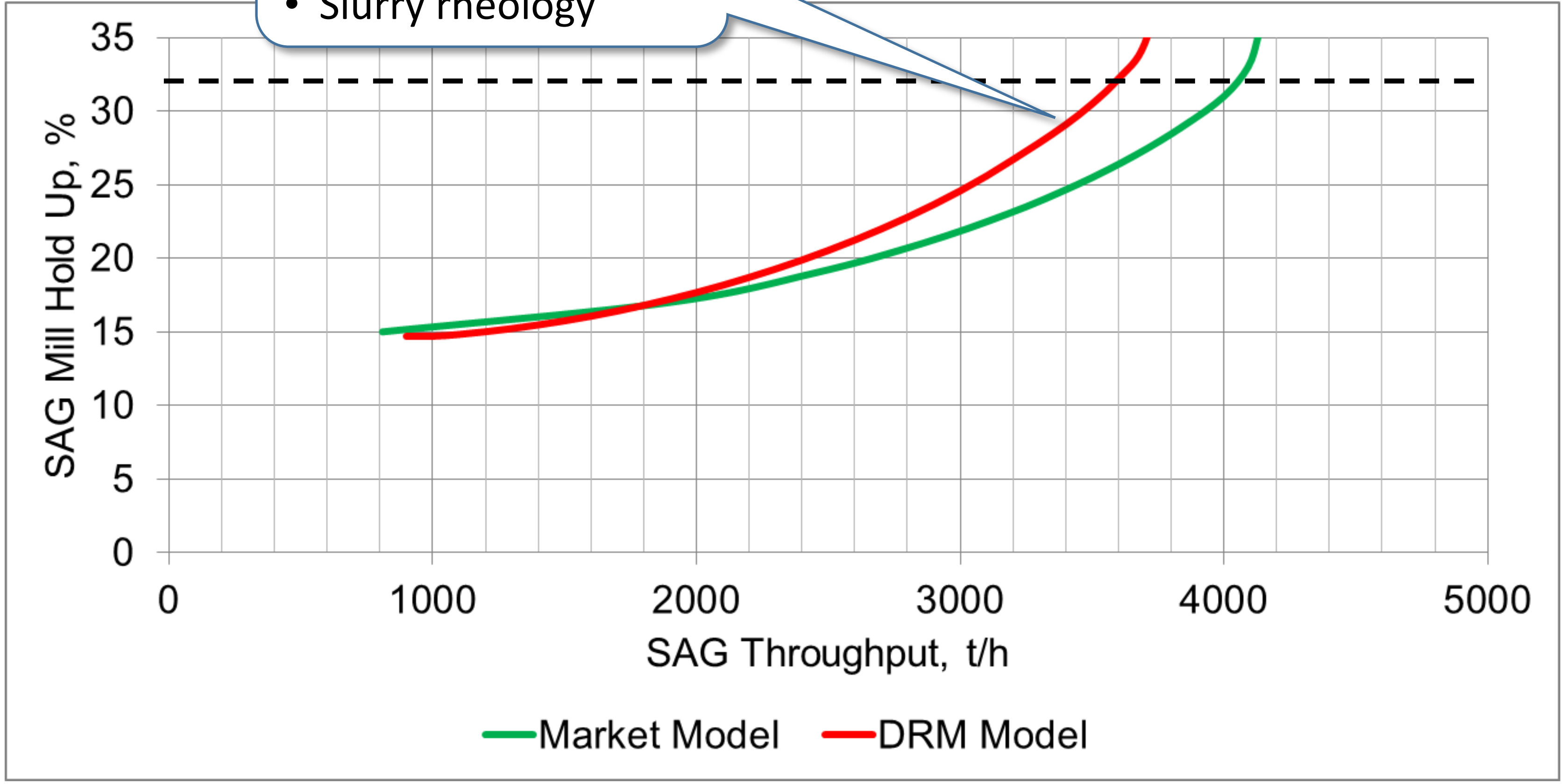
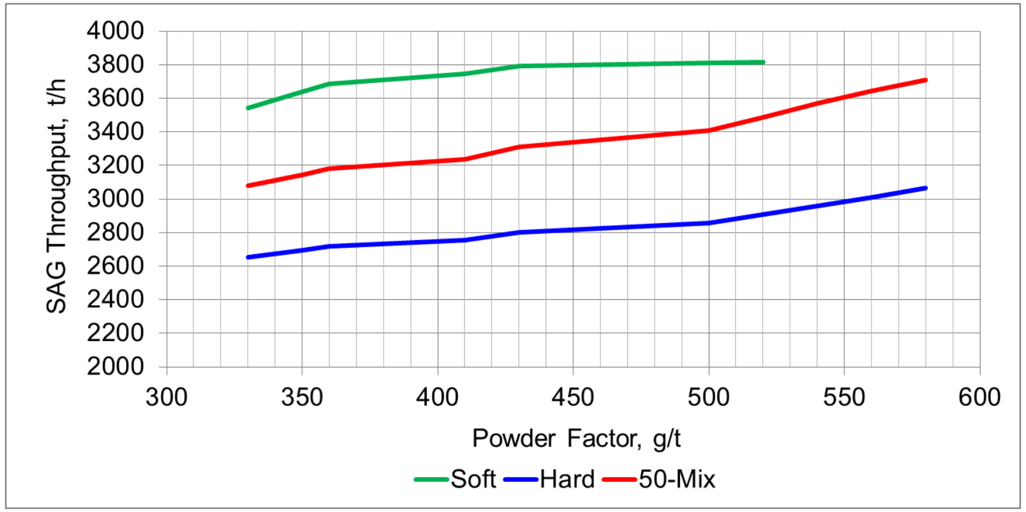
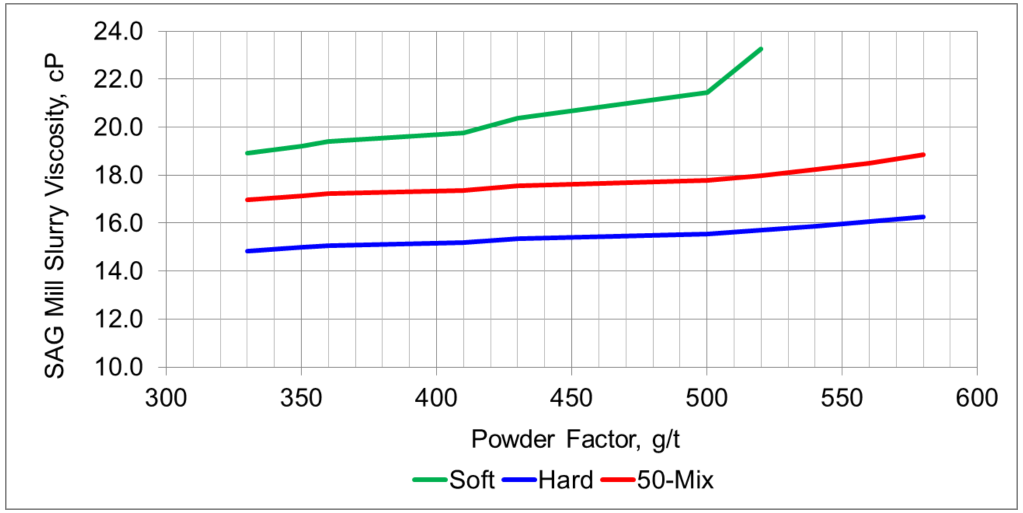
The DRM SAG Mill Model

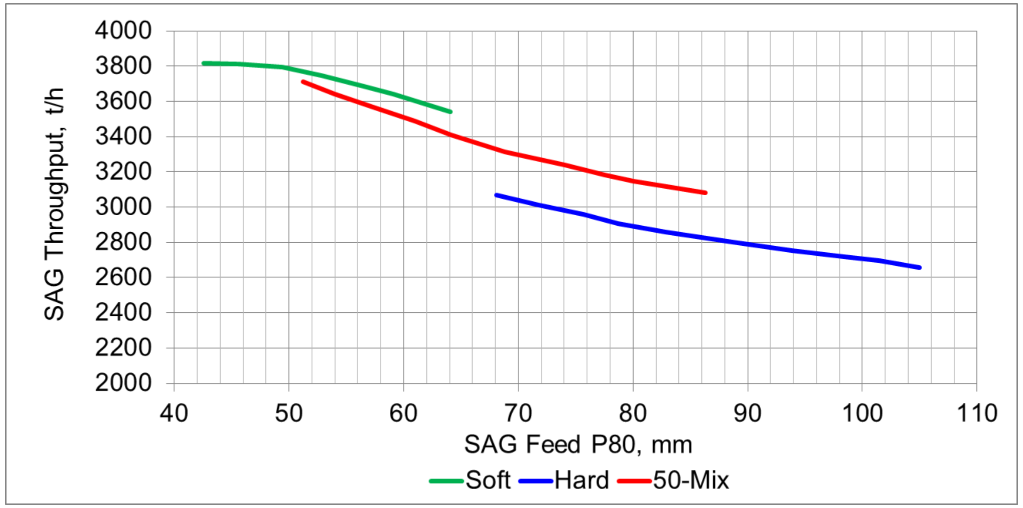
Sensitive to:
- Lump accumulation
- Slurry rheology

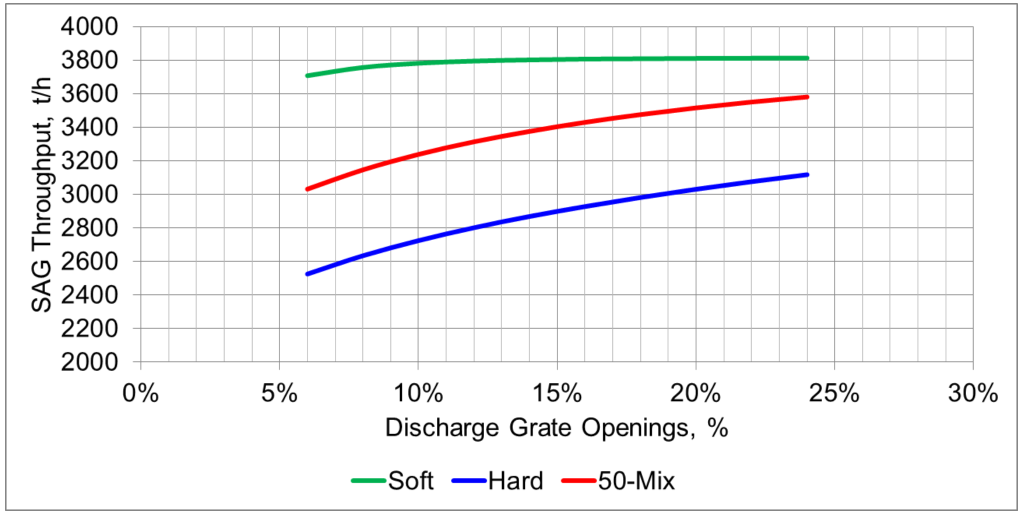


The DRM SAG Mill Model

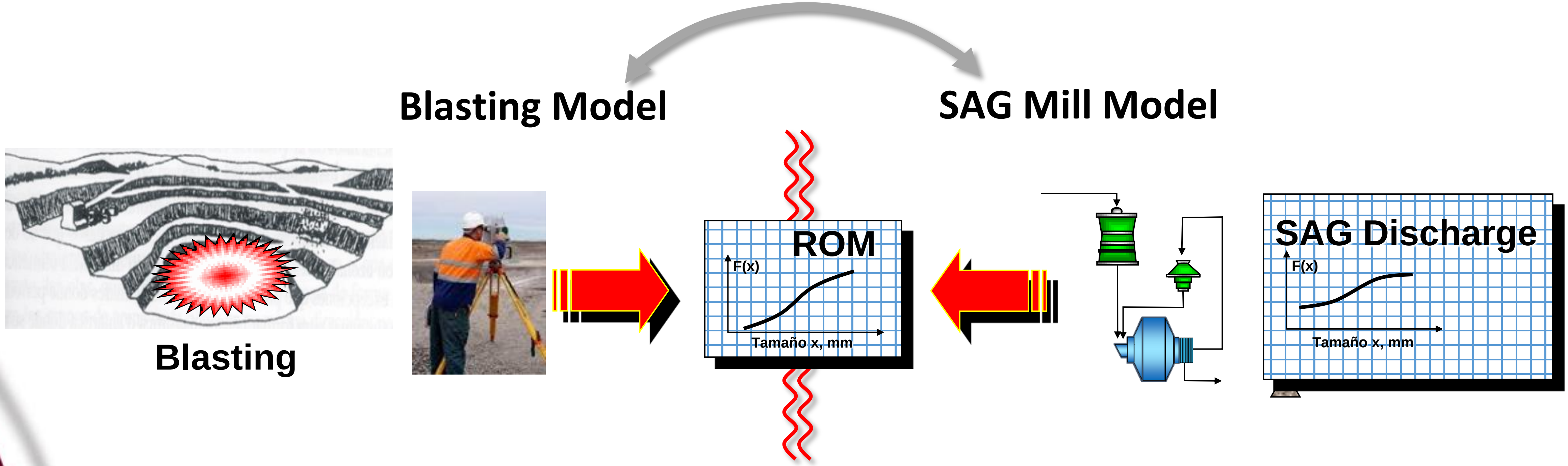






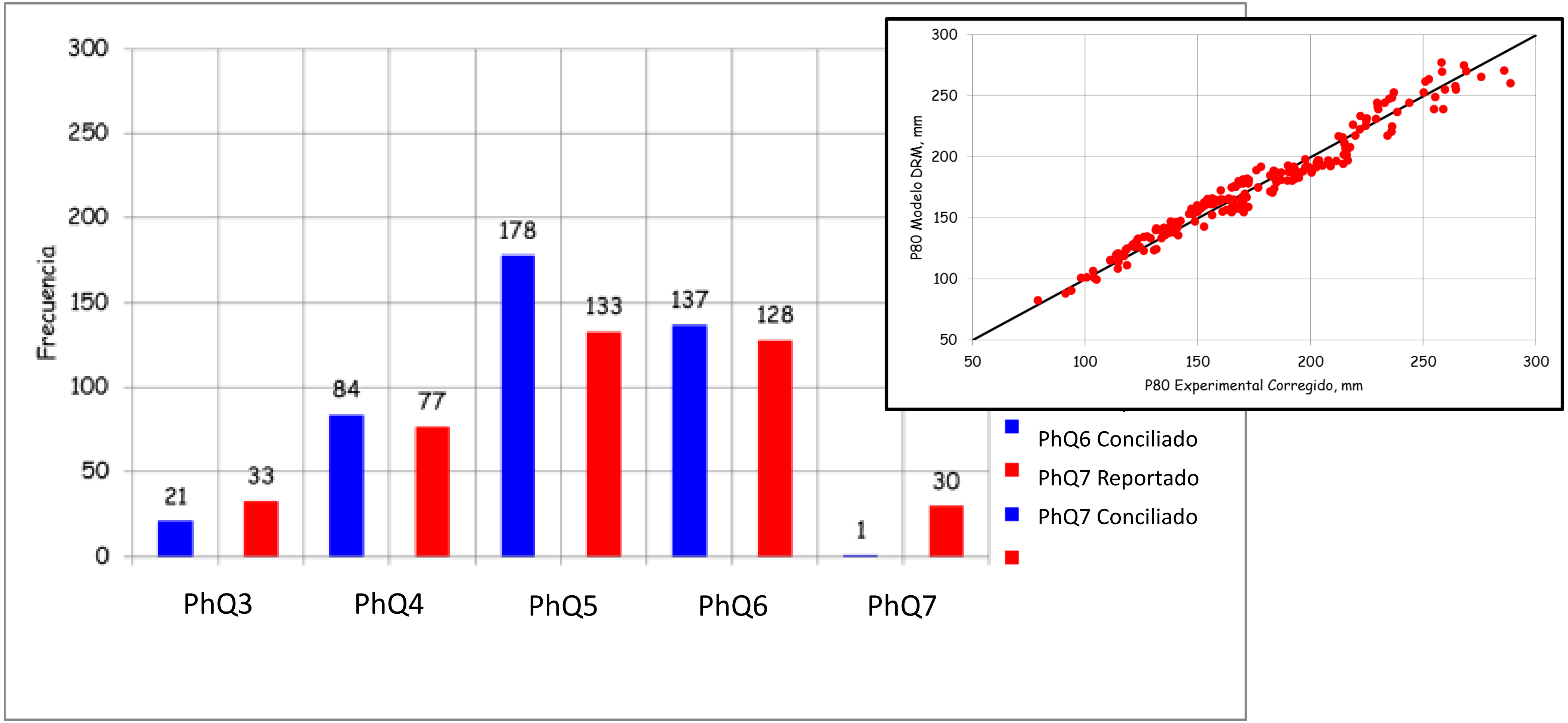


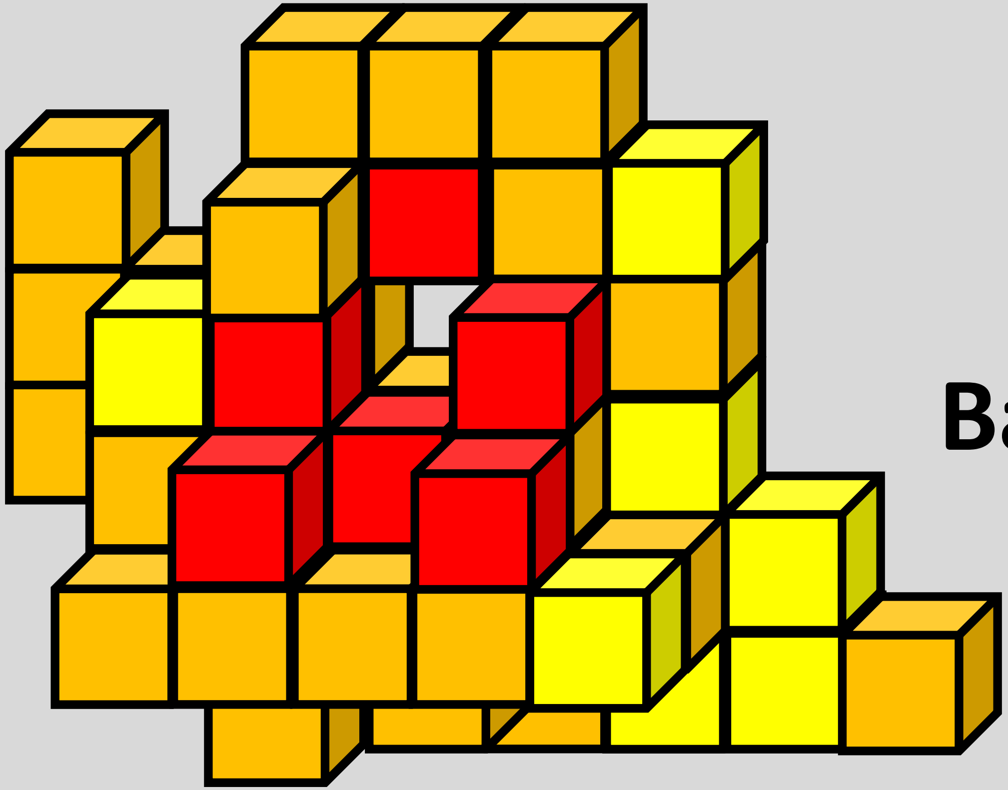
Inverse Simulation Strategy



The DRM Back - Calculation Method.

Inverse Simulation Strategy: Conciliation





Study Case:
Back Calculation Performance

Physical Quality Units

Attribute \ Quality	Q1	Q2	Q3	Q4	Q5
Alteration Ser.+Argíl.	16.1	12.41	9.12	5.34	2.50
Unit Weight., t/m^3	2.48	2.53	2.58	2.6	2.62
UCS, MPa	50.62	56.79	65.21	78.79	91.57
TR, MPa	6.72	7.45	7.74	7.95	8.10
Young´Module, GPa	31.2	32.1	33.0	35.1	46.6
RQD, %	70.51	75.47	73.40	75.47	94.84
FF, f/m	9.75	8.06	7.84	7.06	2.88
LRS, cm	168.37	175.92	183.29	187.92	191.70
GSI, %	45.88	48.91	49.96	47.91	54.82
RRD, %	3.43	3.41	3.35	3.41	3.92
BWI, kWh/t	10.8	11.3	12.9	15.3	16.4
SPI, min	65	83	95	120	140

Competence

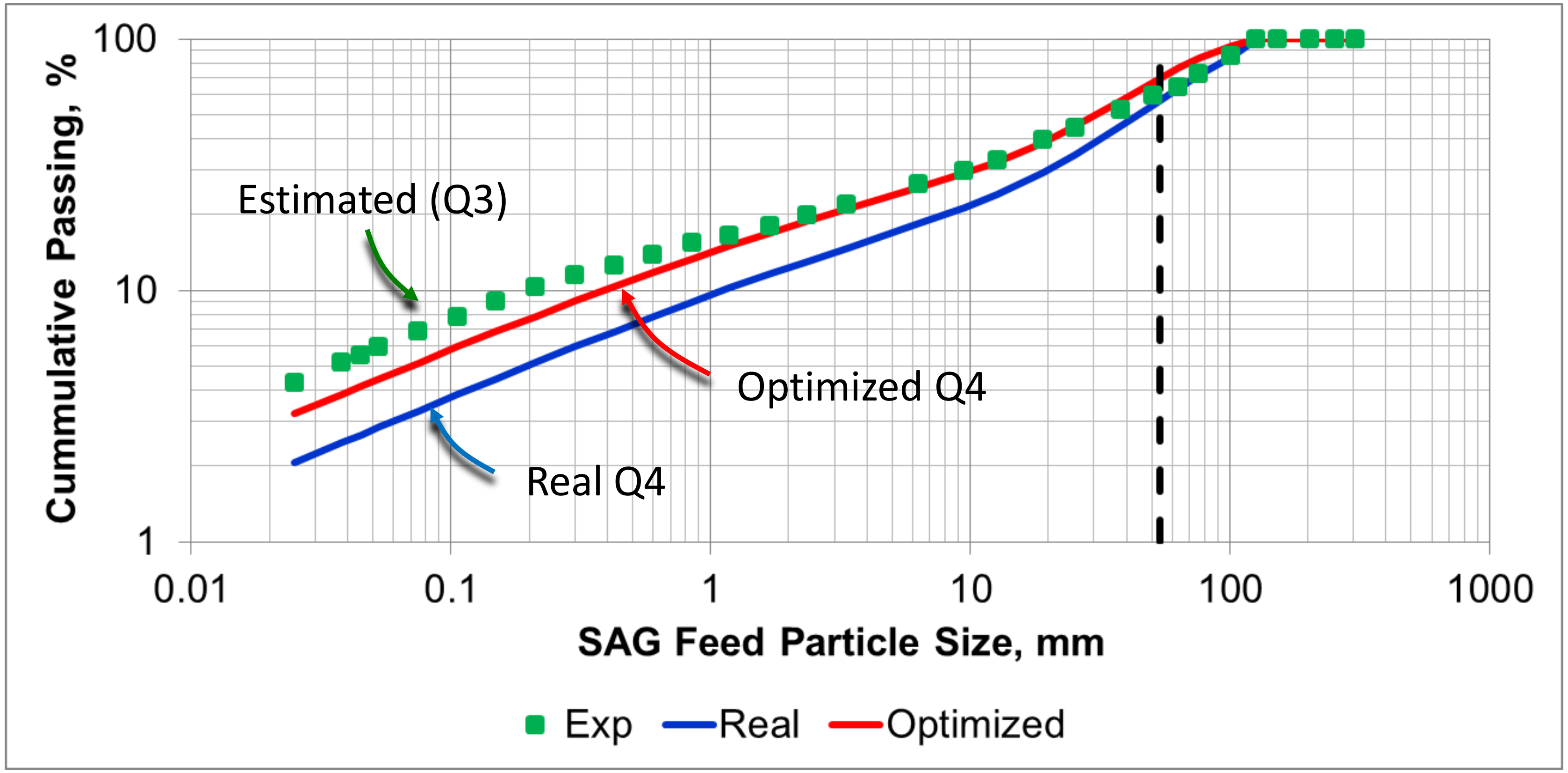
Facilities and General Conditions

Blasting Specs	
Burden, m	8 ~ 10
Spacing, m	8 ~ 10
Powder Factor, g/t	330 ~ 580
Drill hole, in	12 ¼
Ignition type	Electronic
Explosive type	Fortan 65
Physical Quality, 50% mix Q3/Q4	3.5

Primary Crusher Specs	
Crusher type	Gyratory
CSS, in	6
Size	62X75
Throughput, t/h	4,100
Power, kW	450

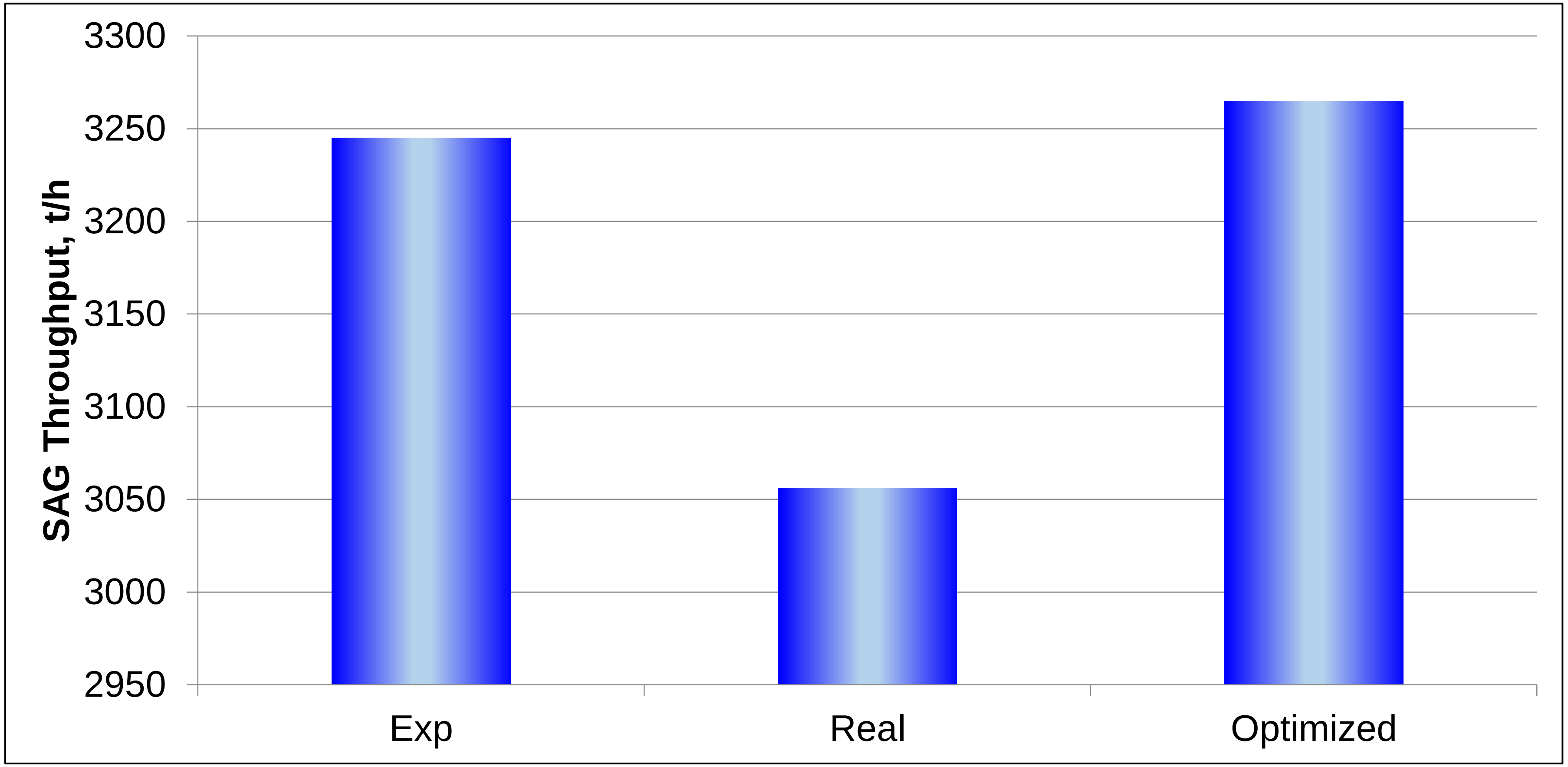
SAG Mill Specs	
Length, ft	19
Diameter, ft	38
SAG Mill Power, MW	20
Fraction Critical Speed, %	70
Ball load, %	14.7
Grate size, in	2
Design Percent solid, %	68
Design Hold Up, %	28

Study Case



PSD	Burden x Spacing, m	Powder Factor (ANFO Eq,), g/t
Real	10x10	350
Optimized	8x8	500

Study Case



SAG Throughput, t/h
3300
3250
3200
3150
3100
3050
3000
2950
Exp
Real
Optimized

Remarks

- The Mine-to-Mill approach generally offers a significant business opportunity, not only to find optimum operational point but also to support the Production Plan.
- Major conditions to make it practical are (i) A reliable physical quality model, (ii) A robust blasting model driving to realistic ROM fragment size distribution and (iii) A close estimate of the impact of fragment size distribution on SAG mil throughput.
- The mine and plant comminution responses get conciliated by facing ROM PSD deduced from plant inverse simulation with the PSD deduced from the photography analysis.

Remarks

- The ROM fragment size distribution is markedly bimodal in log – log space. The extended Swebrec empirical function and the DRM phenomenological model are able to predict this behavior.
- A physical quality model needs to consider attributes from geology, geomechanics, rock geo-estructure, soil-mechanics and also… metallurgy.
- The SAG mill capacity is limited either by lump accumulation or by slurry rheology, both explicitly included in the DRM model.
- Reliable production plan forecast need appropriate description of the comminution phenomena at the mine and the plant.