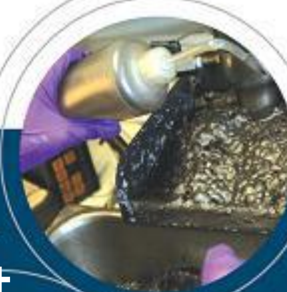
COREM



Innovation en géométallurgie et comminution

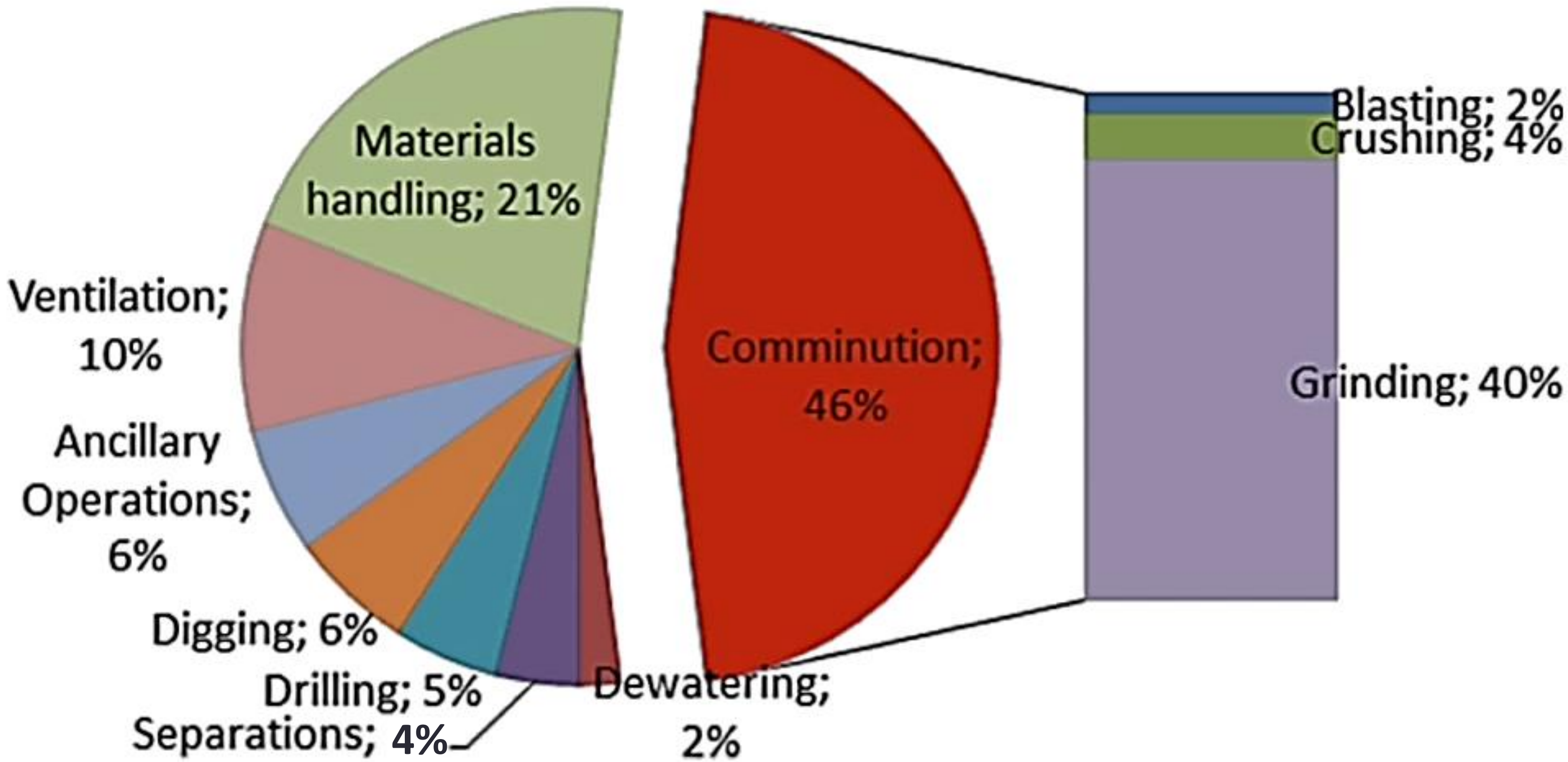
Frédéric Couët, ing., Ph. D.

Financial Partners:

Québec
• Ministère de l'Énergie et des Ressources naturelles
• Ministère de l'Économie, de la Science et de l'Innovation

Canada Economic Development for Quebec Regions
Développement économique Canada pour les régions du Québec
Canada

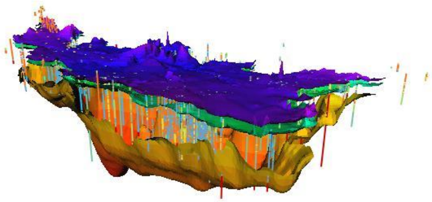
Comminution
Crushing and grinding

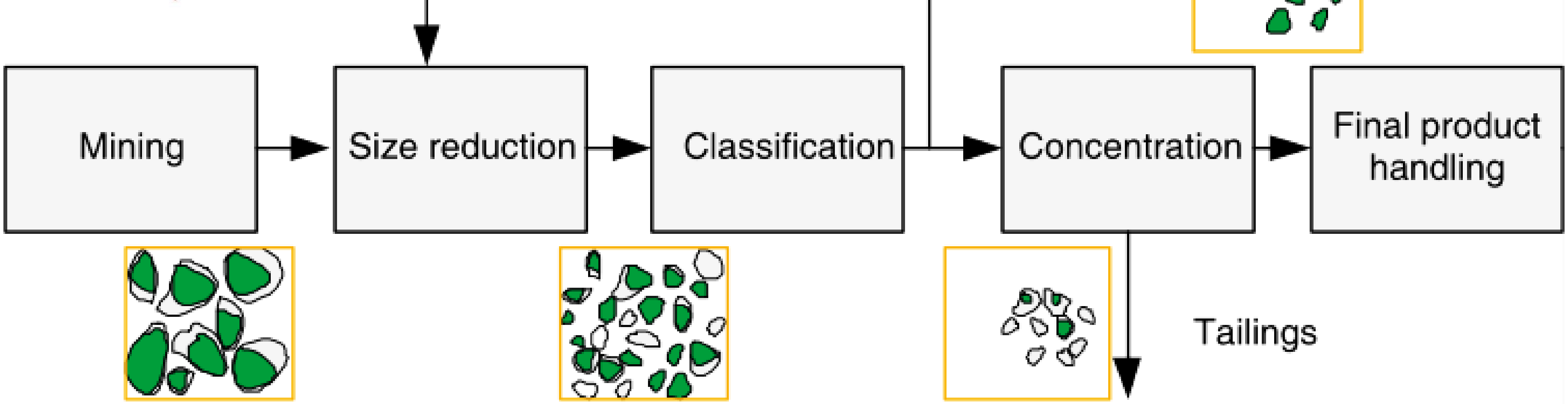


Energy bandwidth study (DOE, 2010)

Geometallurgy

Spatial model and process model



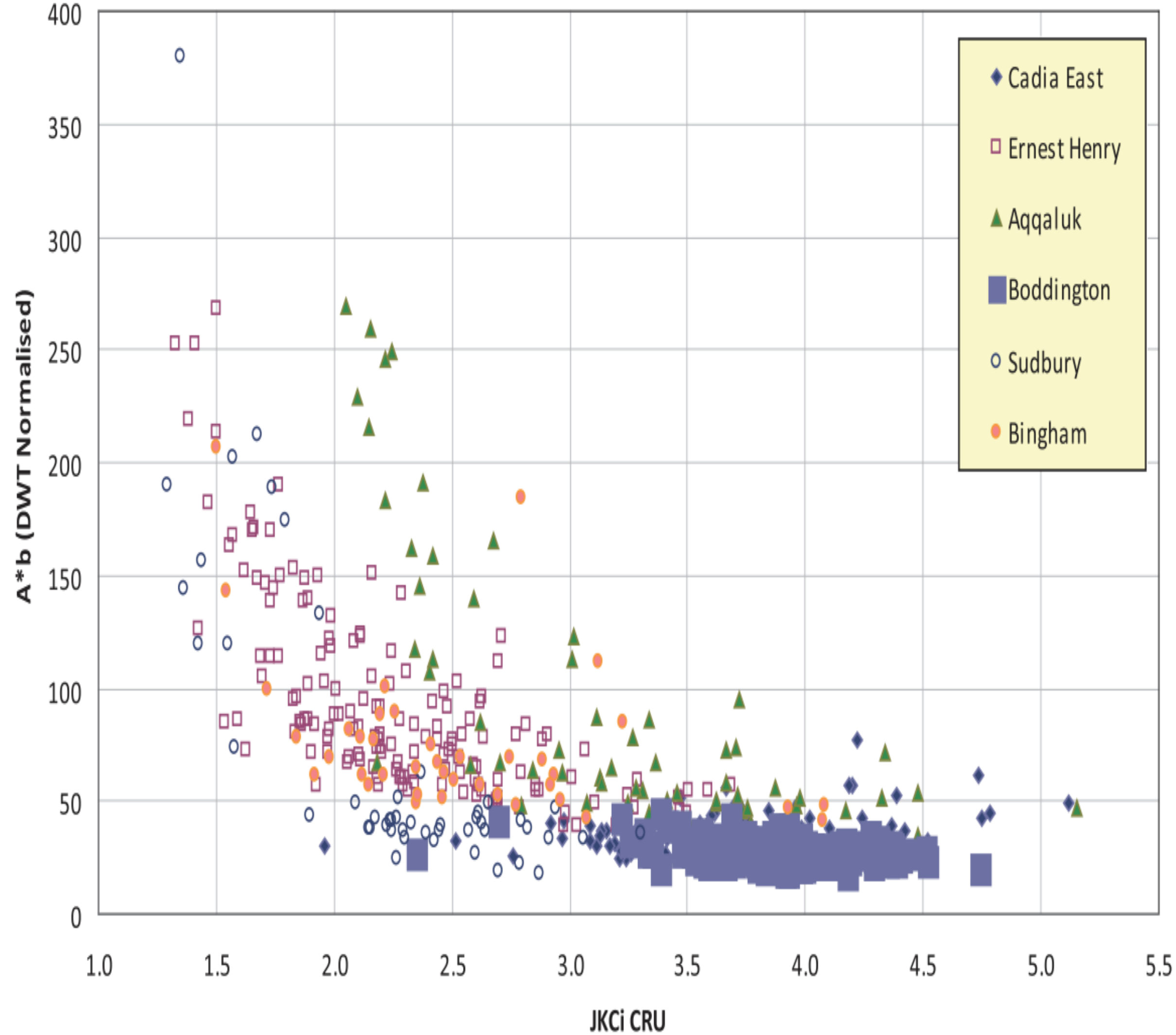


COREM

From Metso.com

Drop weight test

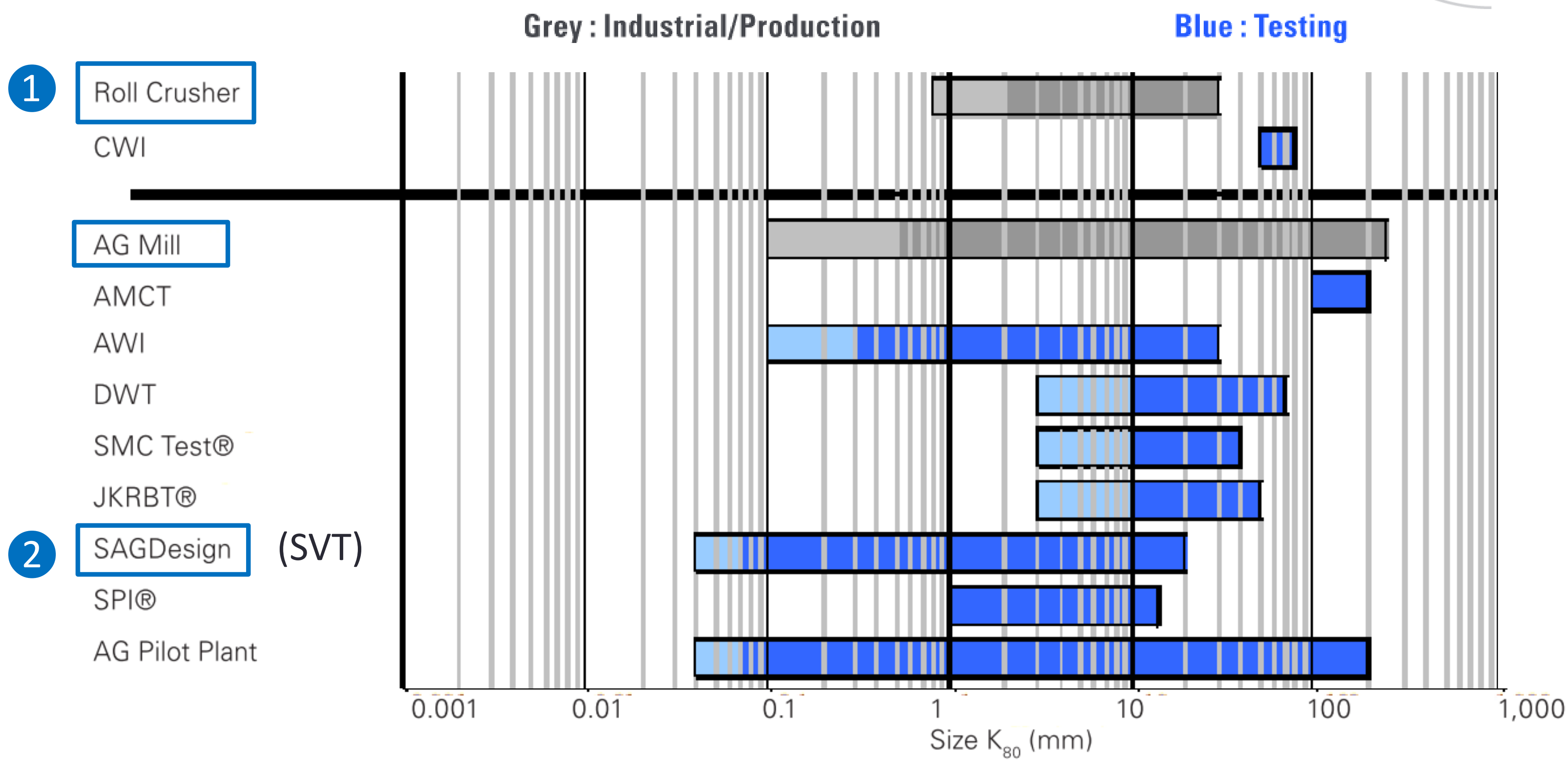
GeM Comminution index
Geometallurgical mapping



Kojovic et al. (2010) XXV International mineral processing congress.

AG/SAG mill testing

Procedures available to characterize grindability



Verret, F.-O., Chiasson, G. & McKen, A., 2011. SAG mill testing - An overview of the test procedures available to characterize ore grindability. *SGS*.

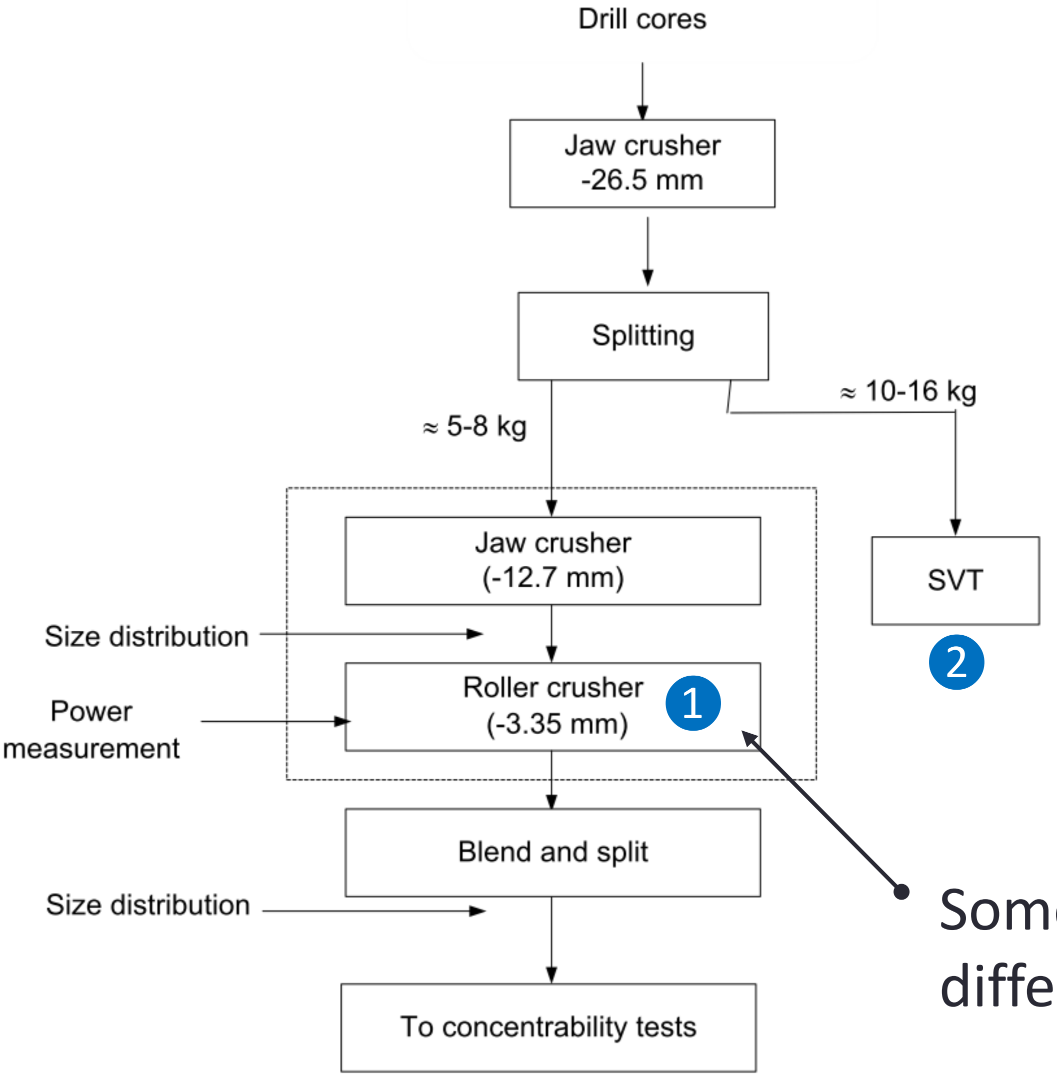
SAGDesign

SAG variability test (SVT)

- Uses a bench scale mill similar to SAG mill operation.
- Is similar to Bond methodology.
- Gives SAG grindability in kWh/t.

Crusher indicator versus SVT

Set-up and methodology

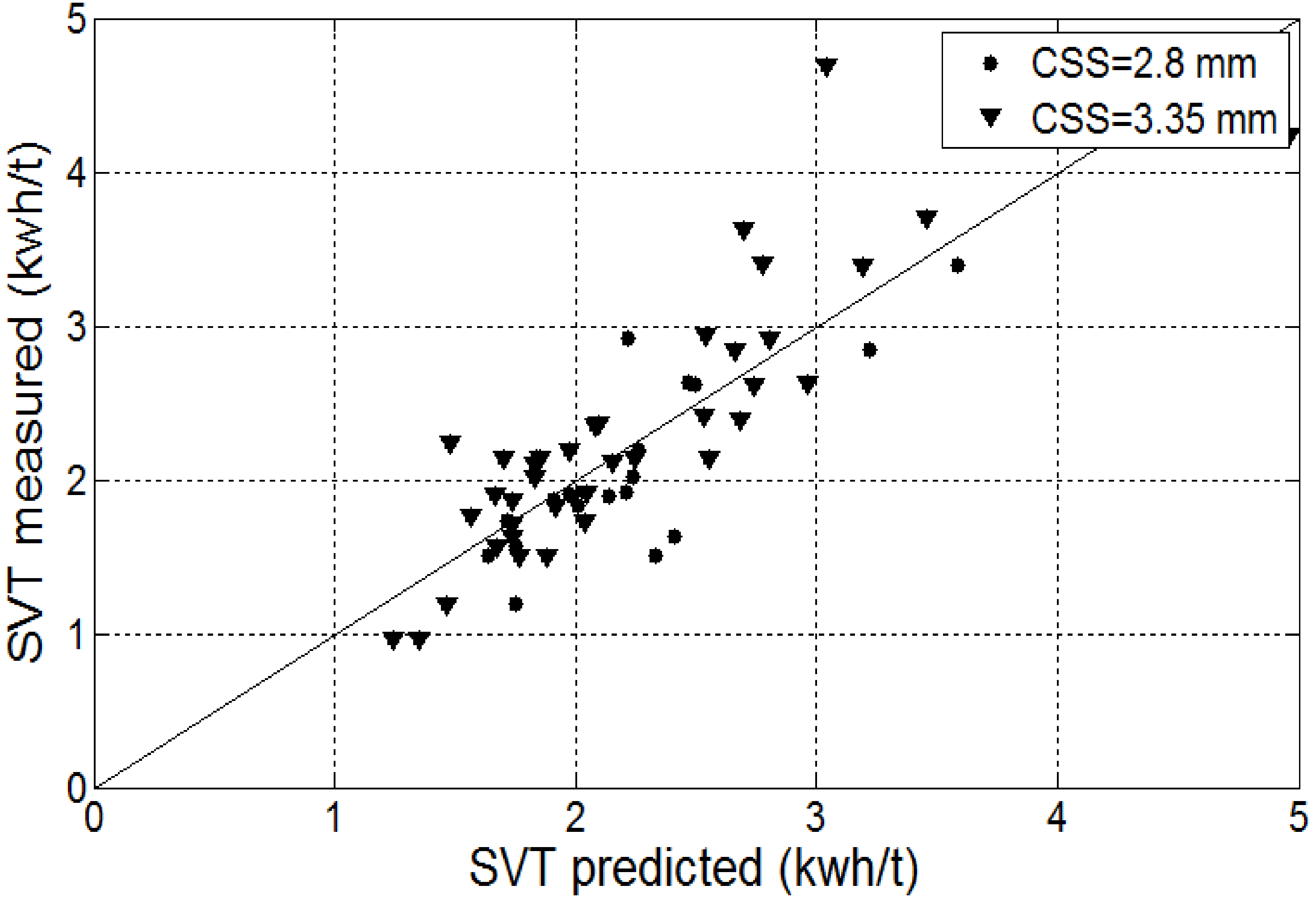


Some samples were tested at two different closed size settings.

Linear regression model

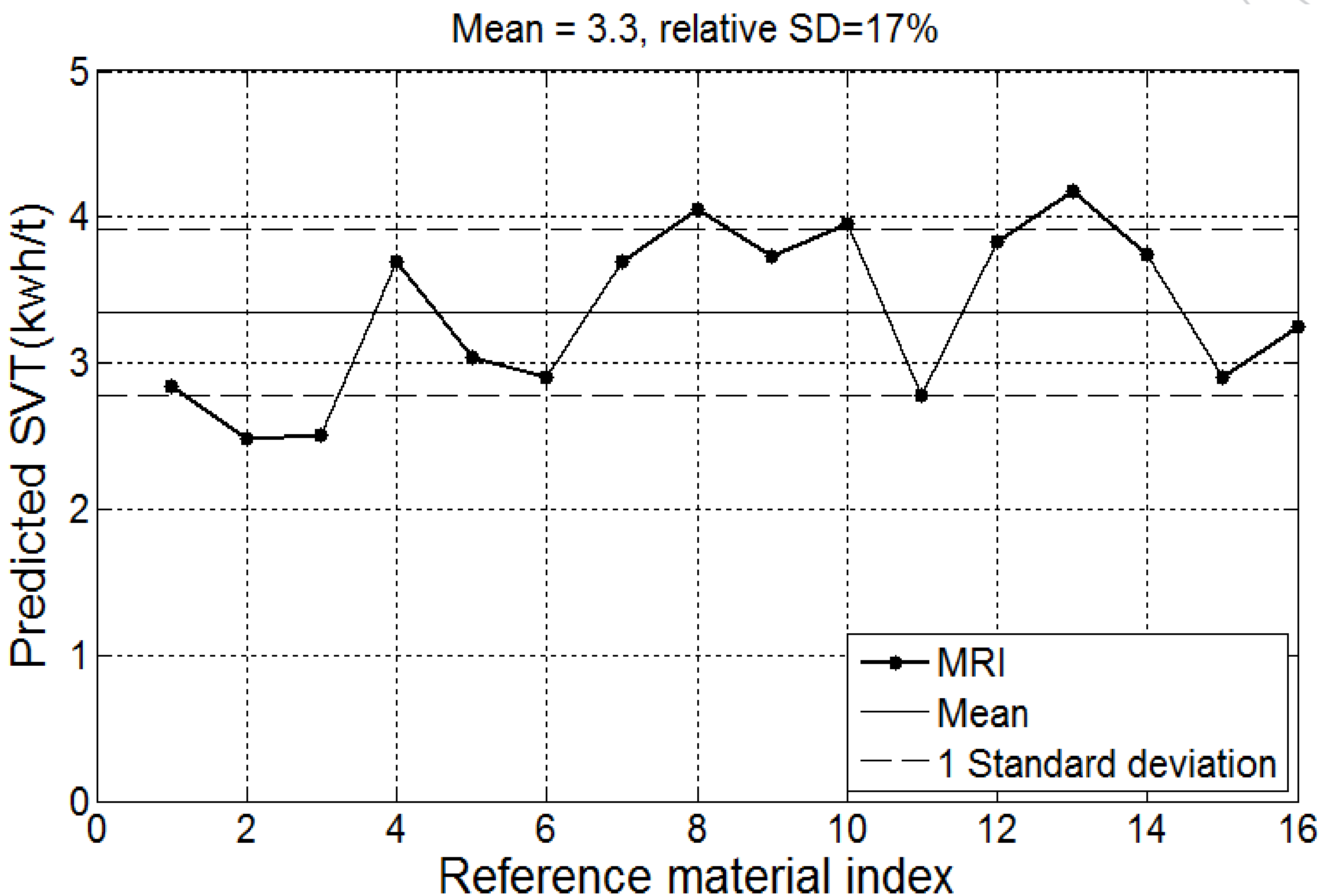
SVT ~ $b_0 + b_1 F_{70} + b_2 P_{70} + b_3 P_{70} E_m$

$R^2 = 0.71$ (5 times 5-fold cross-validation)



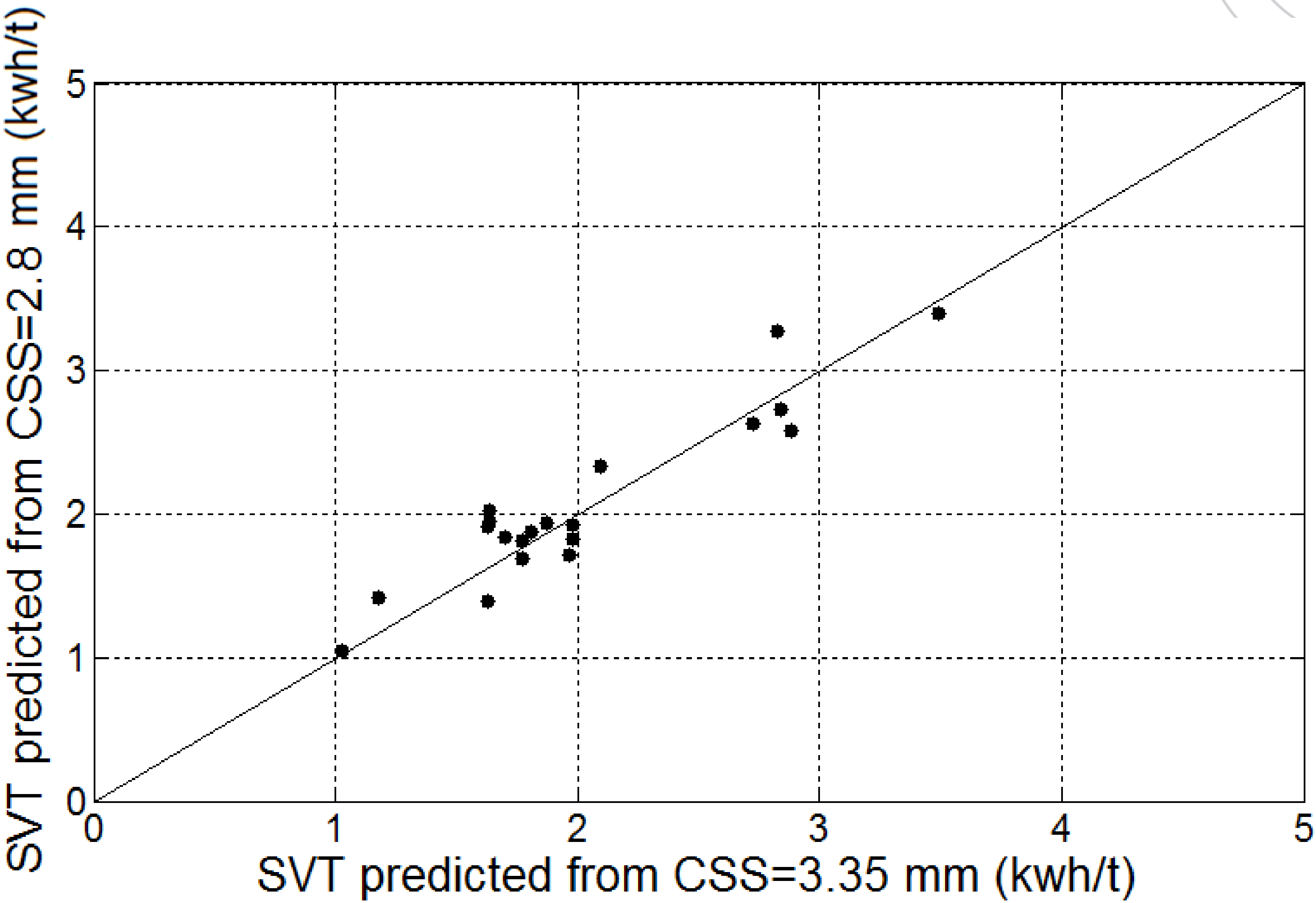
Repeatability

16 repetitions on a reference material



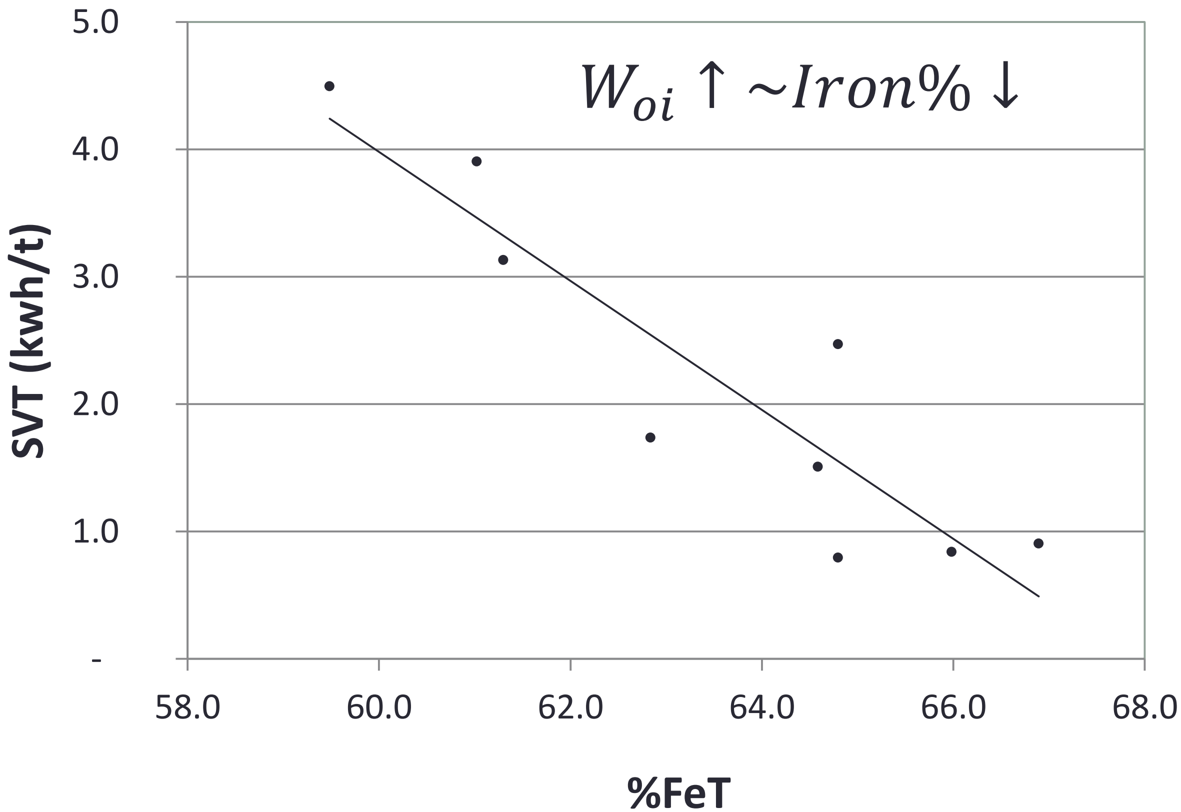
Robustness

Closed side setting drift



Effect of iron grade on rock hardness

- Composition is correlated to Sag Variability Tests for drill cores.

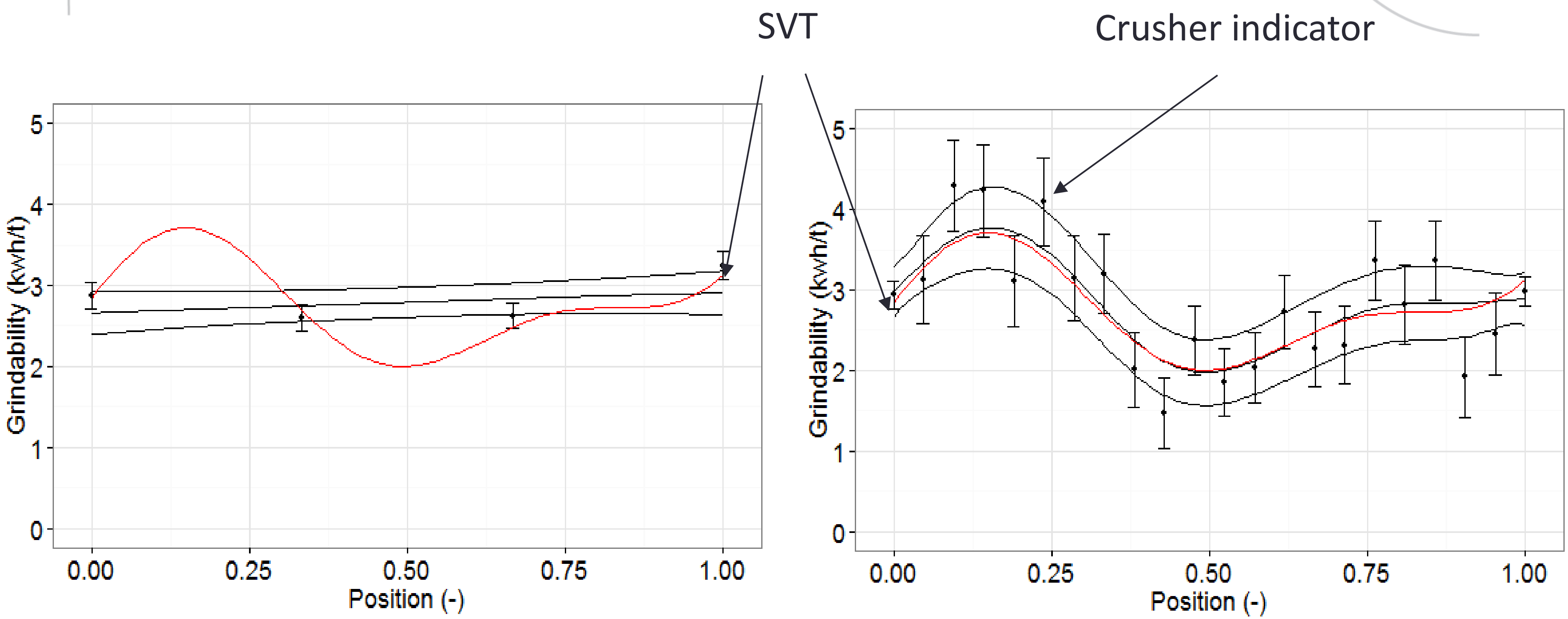


Characterization

A typical characterization campaign scenario

- 50: SVT (±10%)
- 500: Crusher index (±17%)
- All: Chemical analysis
- Models
  - SVT ~ Crusher index (with energy)
  - SVT ~ Crusher index (without energy)
  - SVT ~ Chemical analysis
- Grindability for all samples but with different confidence intervals

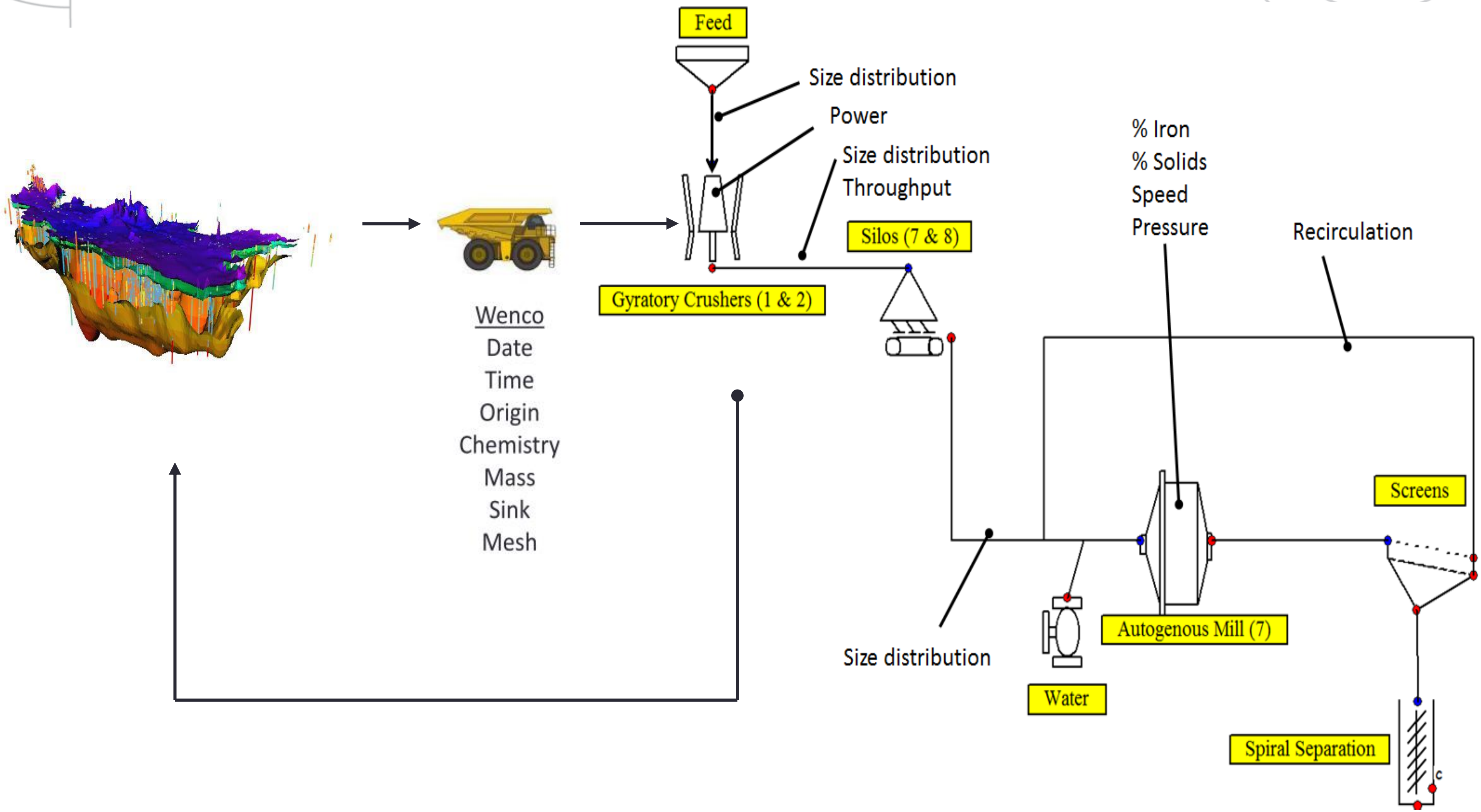
Sequential spatial sampling



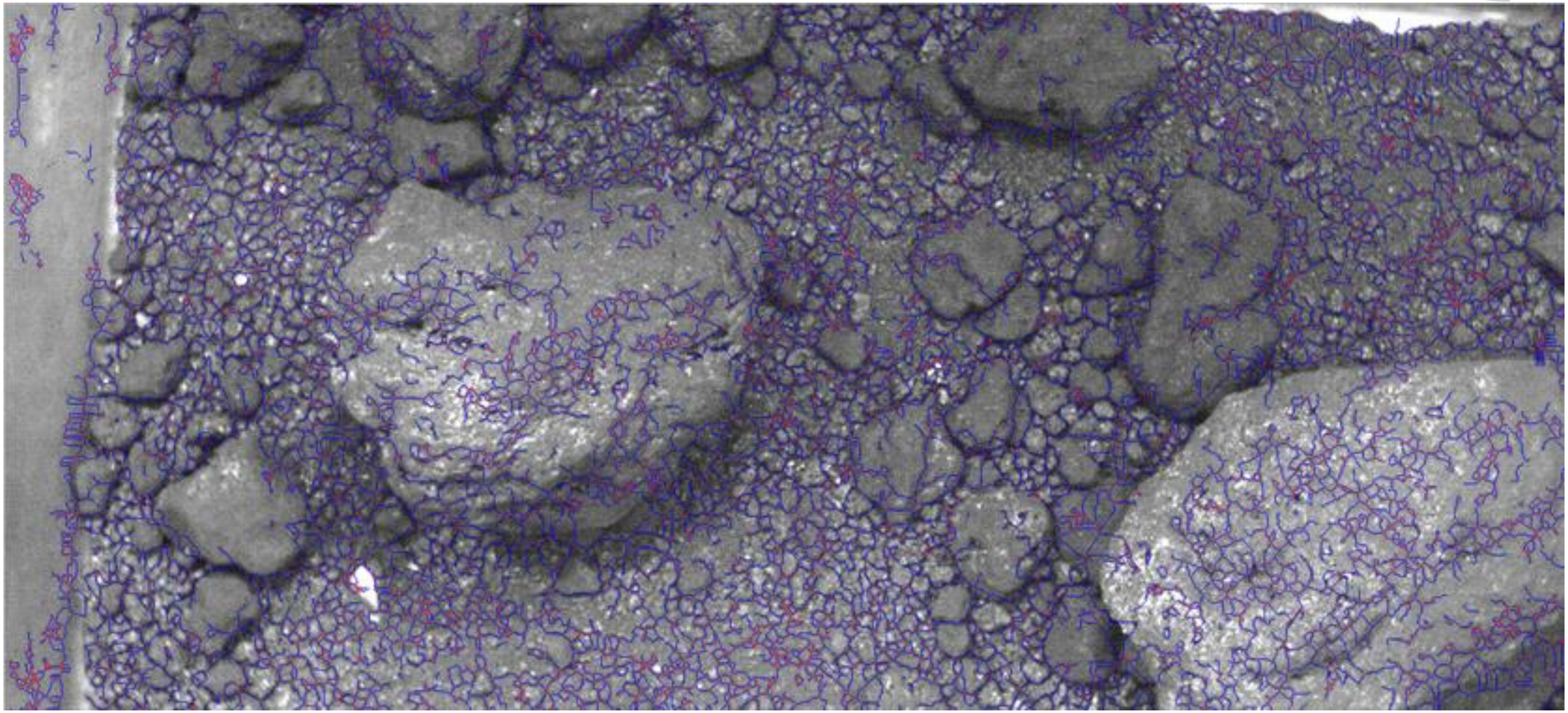
Couet, F. et al., 2015. A new methodology for geometallurgical mapping of ore hardness. *Proceedings of SAG conference*, Vancouver.

Real-time control and reconciliation

Online hardness indicator at plant scale



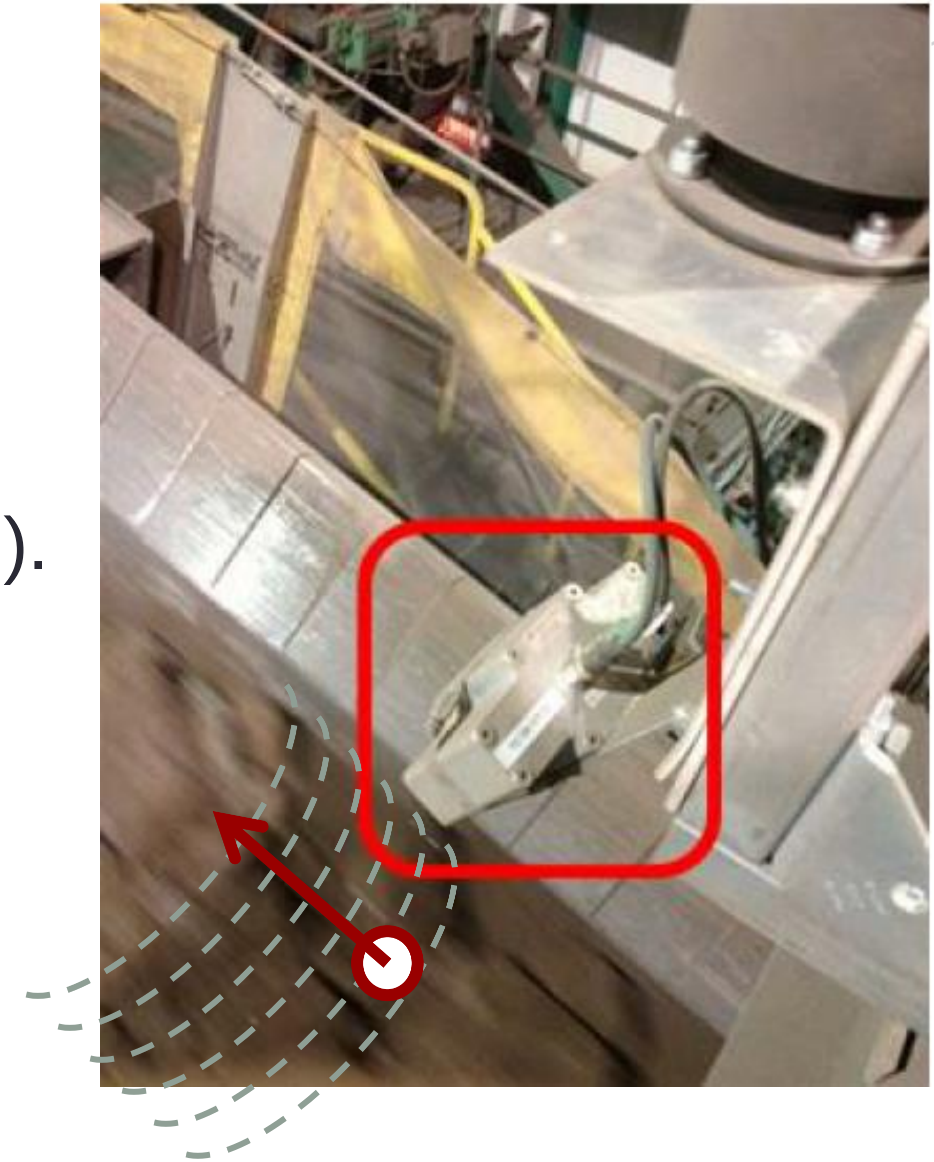
Segmentation of bimodal size distributions



3D vision system

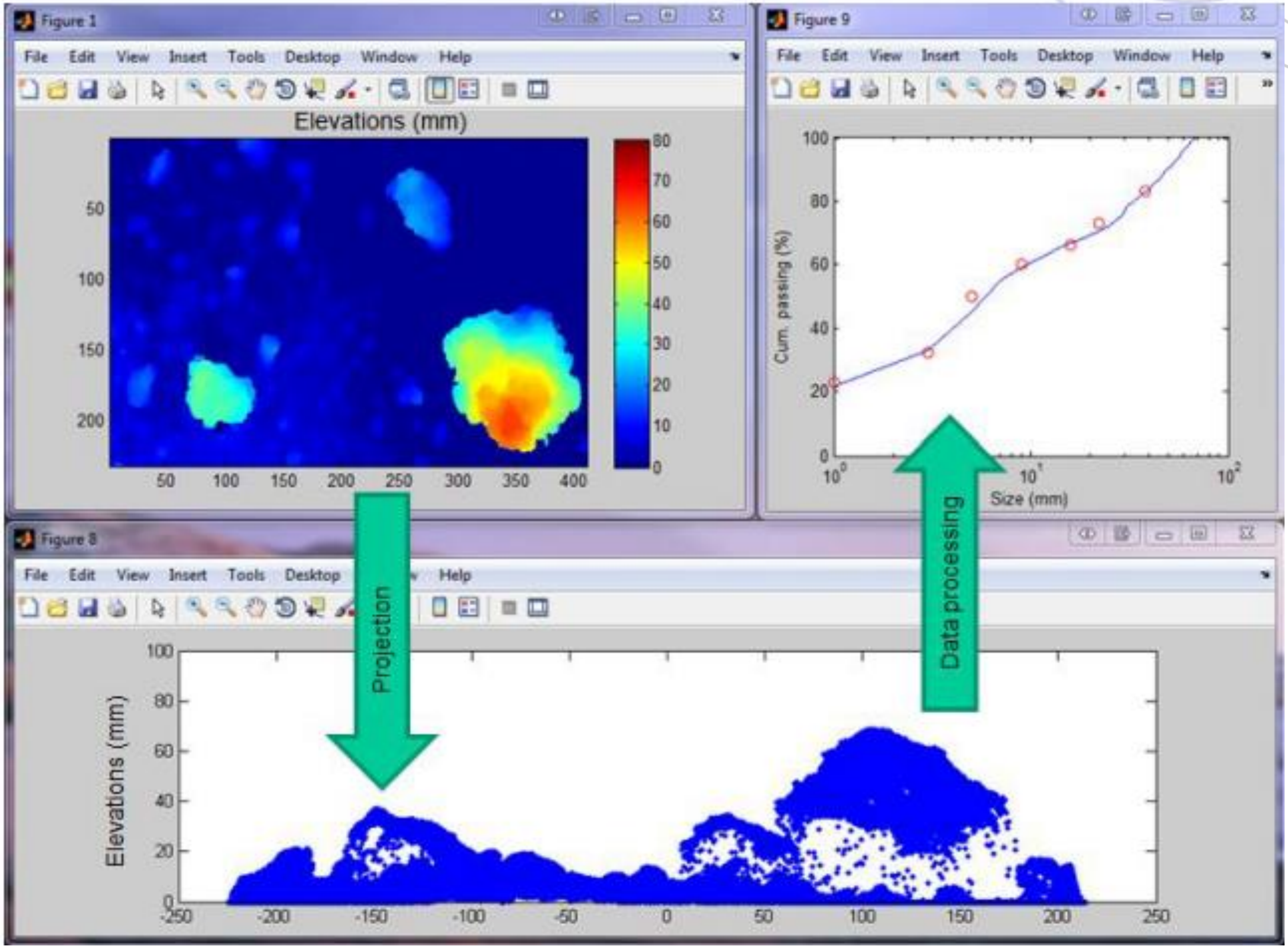
Plant data acquisition and analysis

- Estimate the conveyor geometry.
- Measure the speed of the conveyor (real-time).



3D vision system

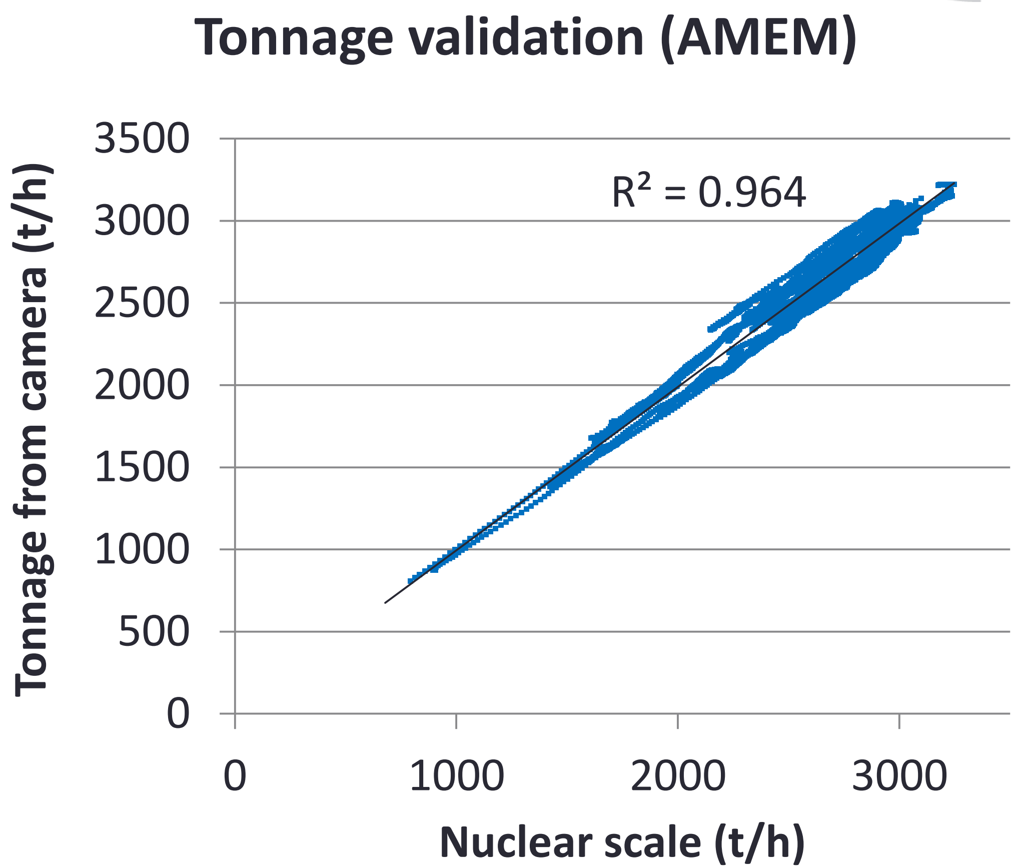
Plant data acquisition and analysis



3D vision system

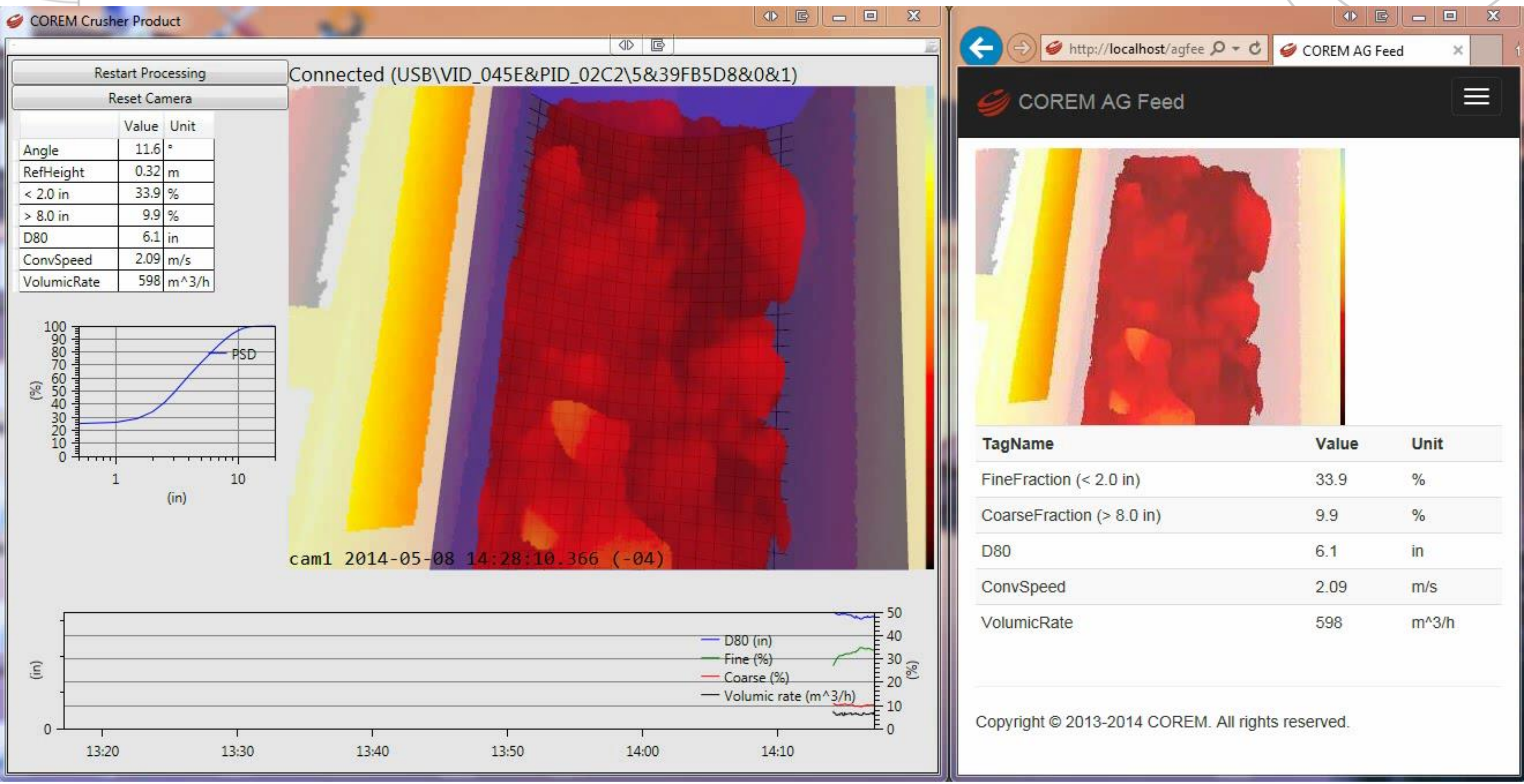
Plant data acquisition and analysis

- Use volume and speed to estimate the volume flow rate.
- Possibility to estimate bulk density and iron ore content.



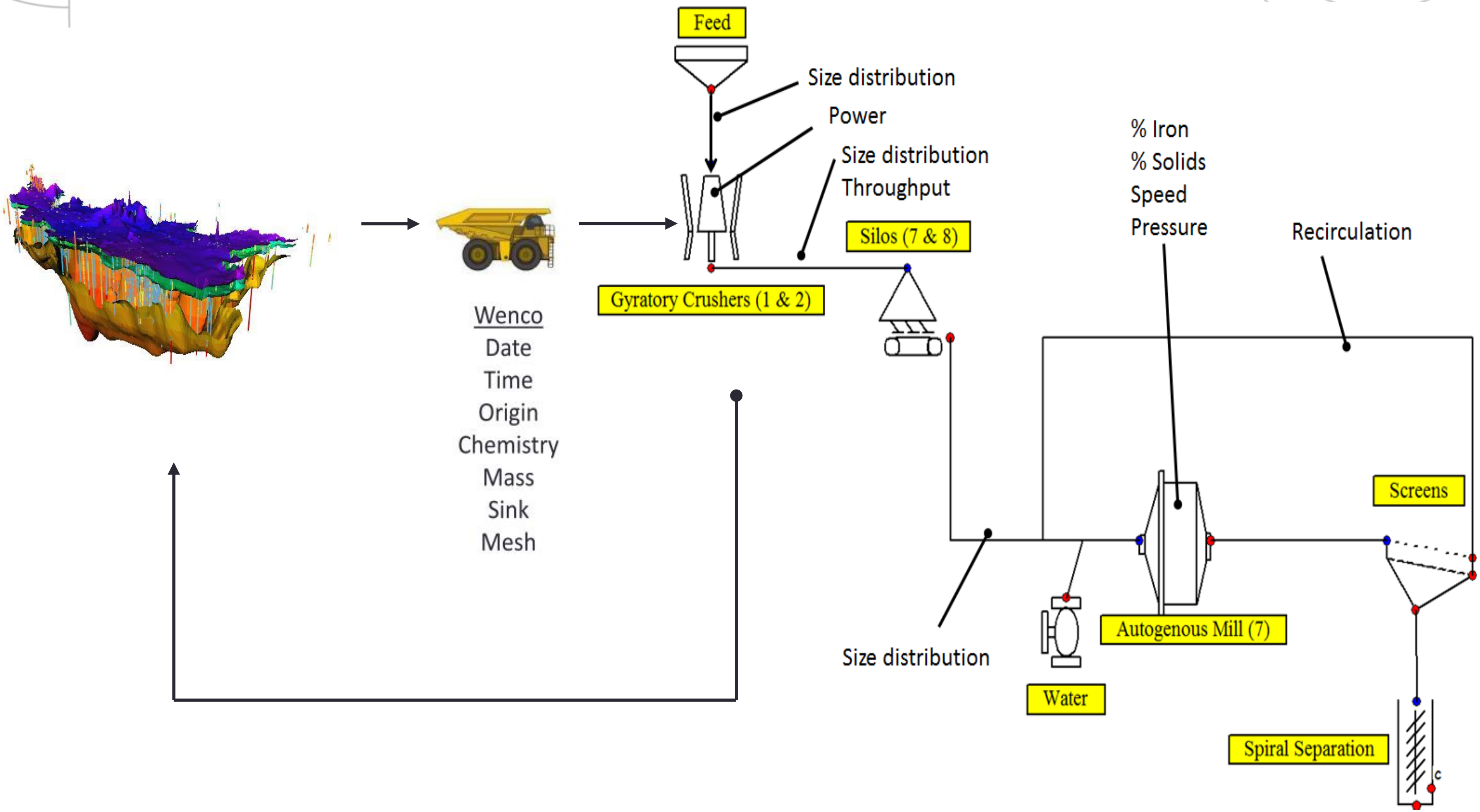
3D vision system

Plant data acquisition and analysis

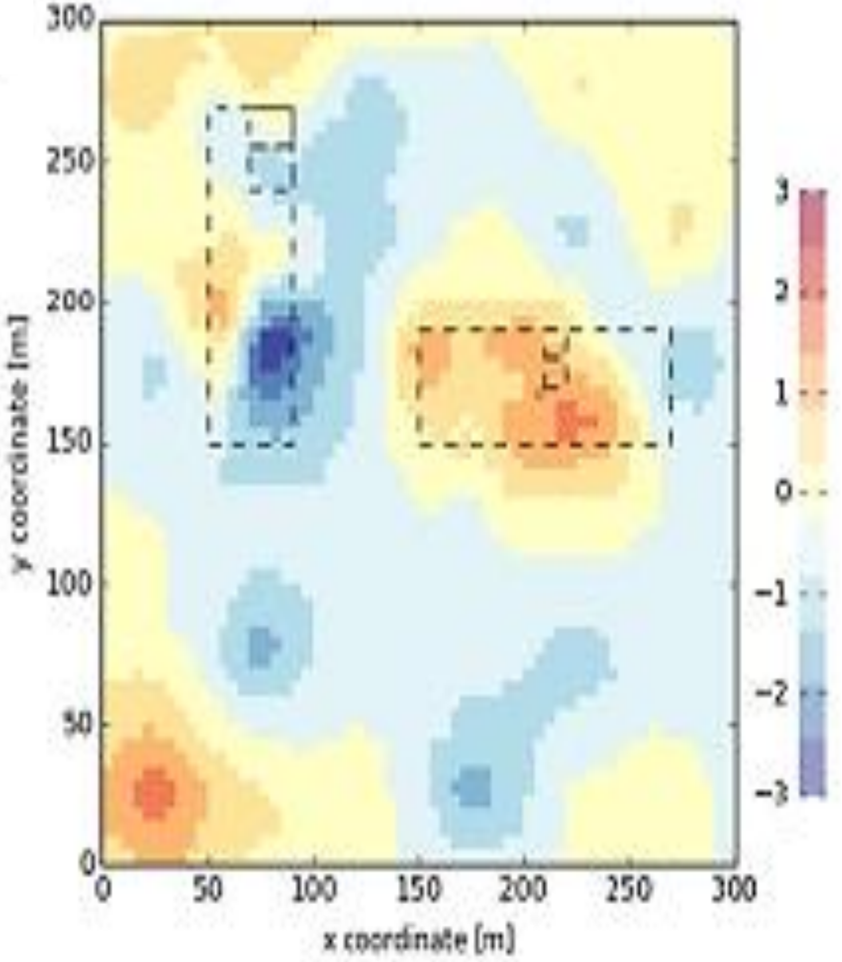


Real-time control and reconciliation

Online hardness indicator at plant scale



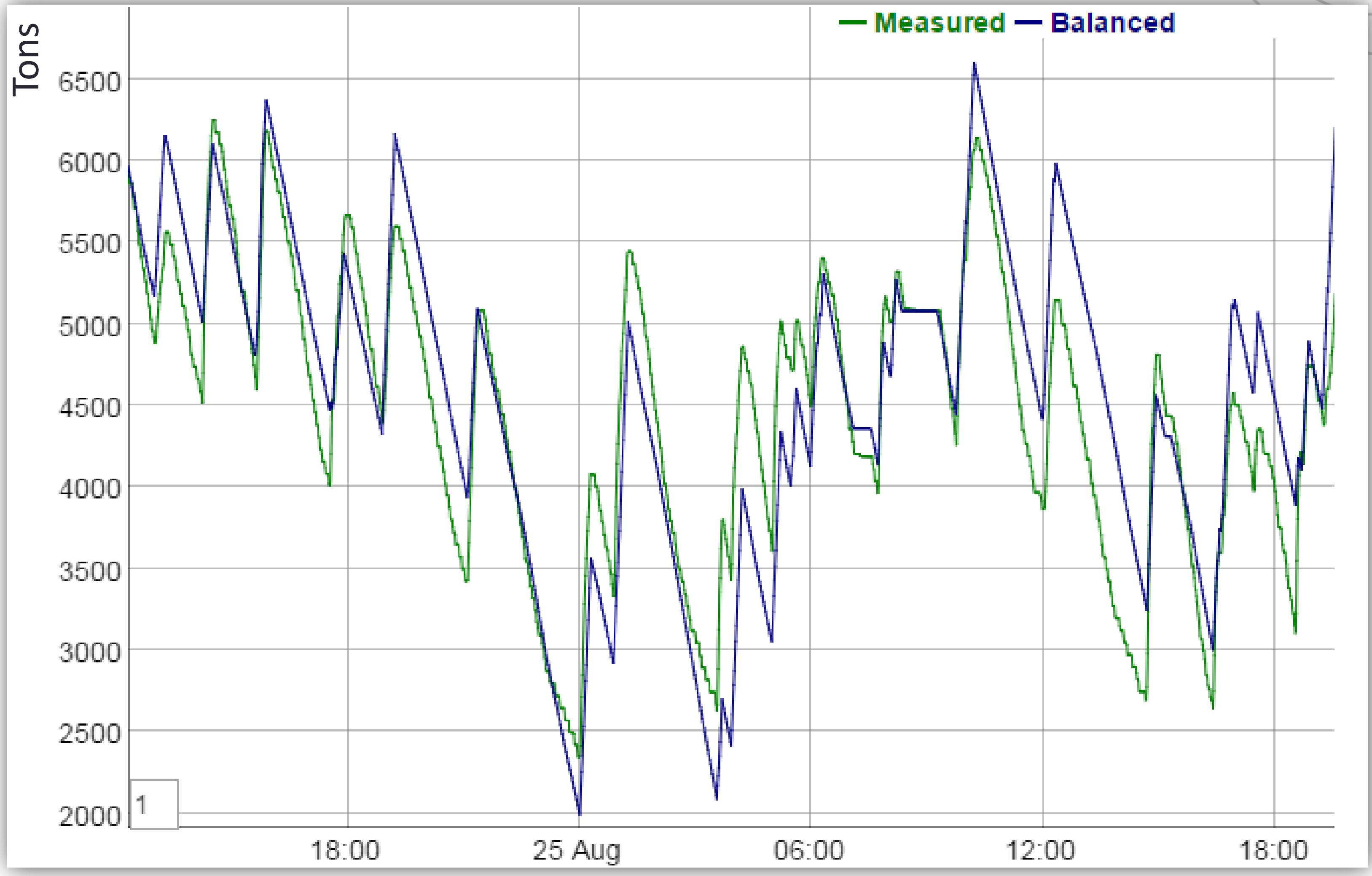
Real-time control and reconciliation
Reconciliation of the block model



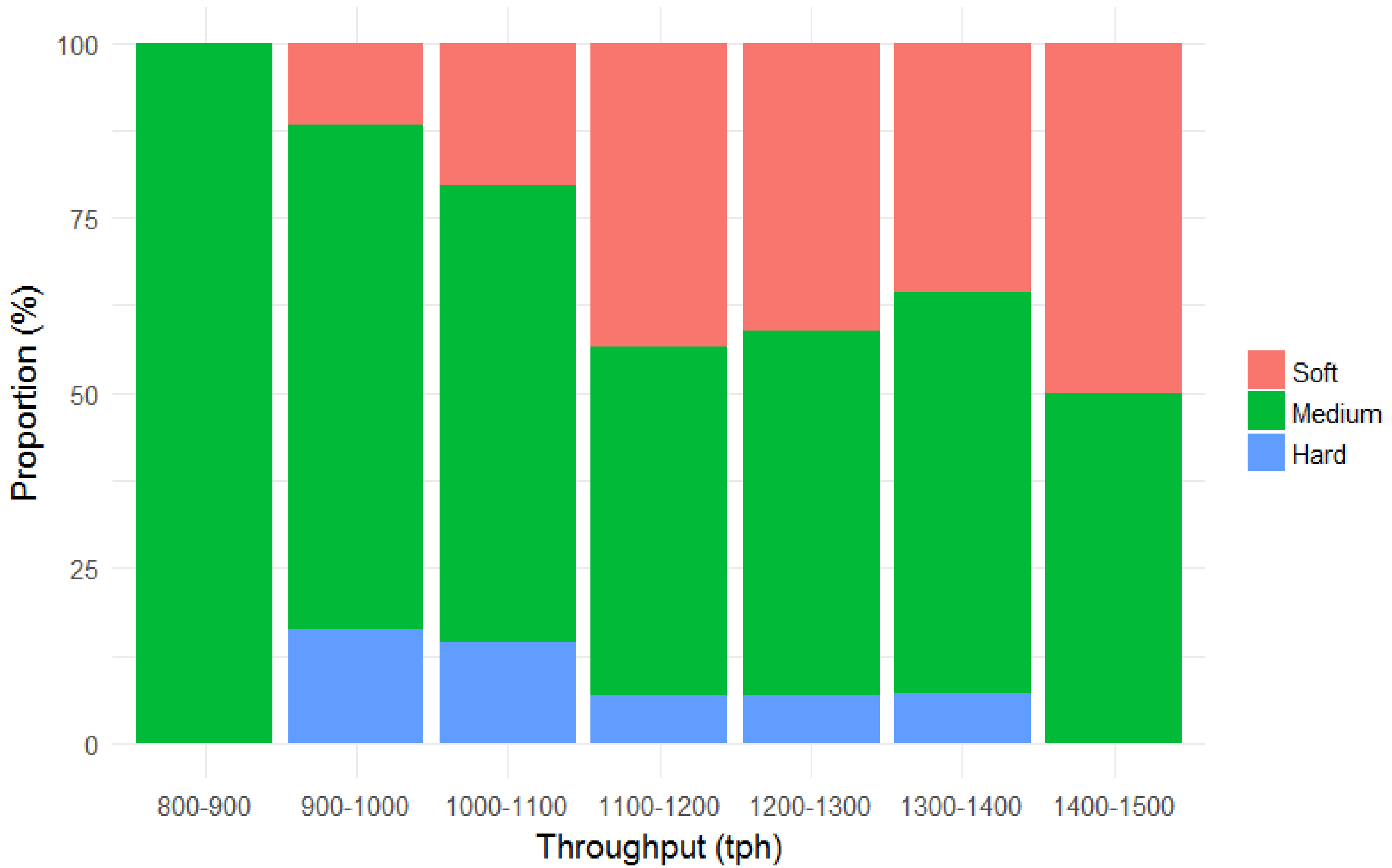
- Information from the concentrator is used to update locally the block model.

Wambeke, T. & Benndorf, J., 2017. *Mathematical Geosciences*, 49(1).

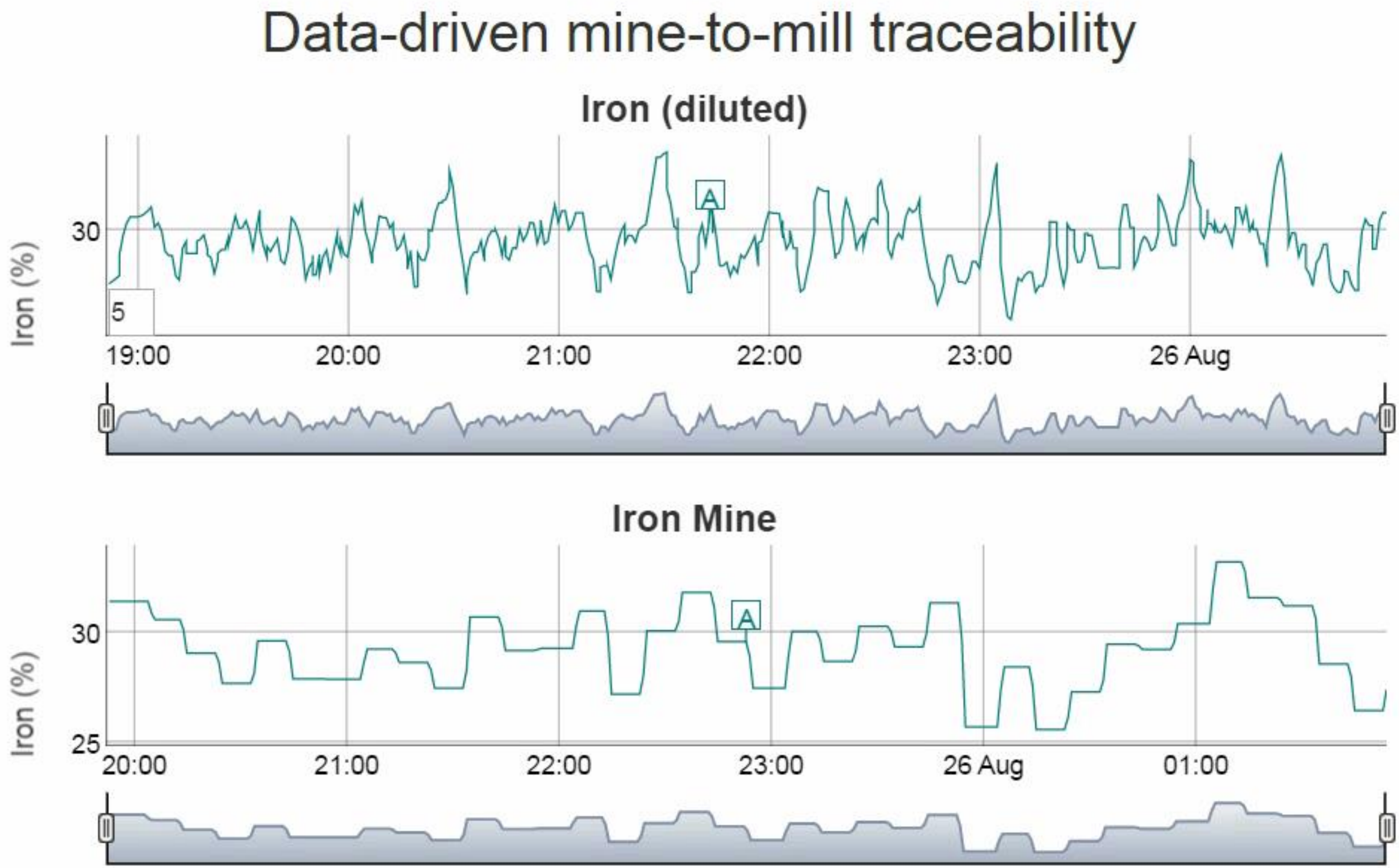
Traceability – Silo model



Traceability – From crusher to AG mill



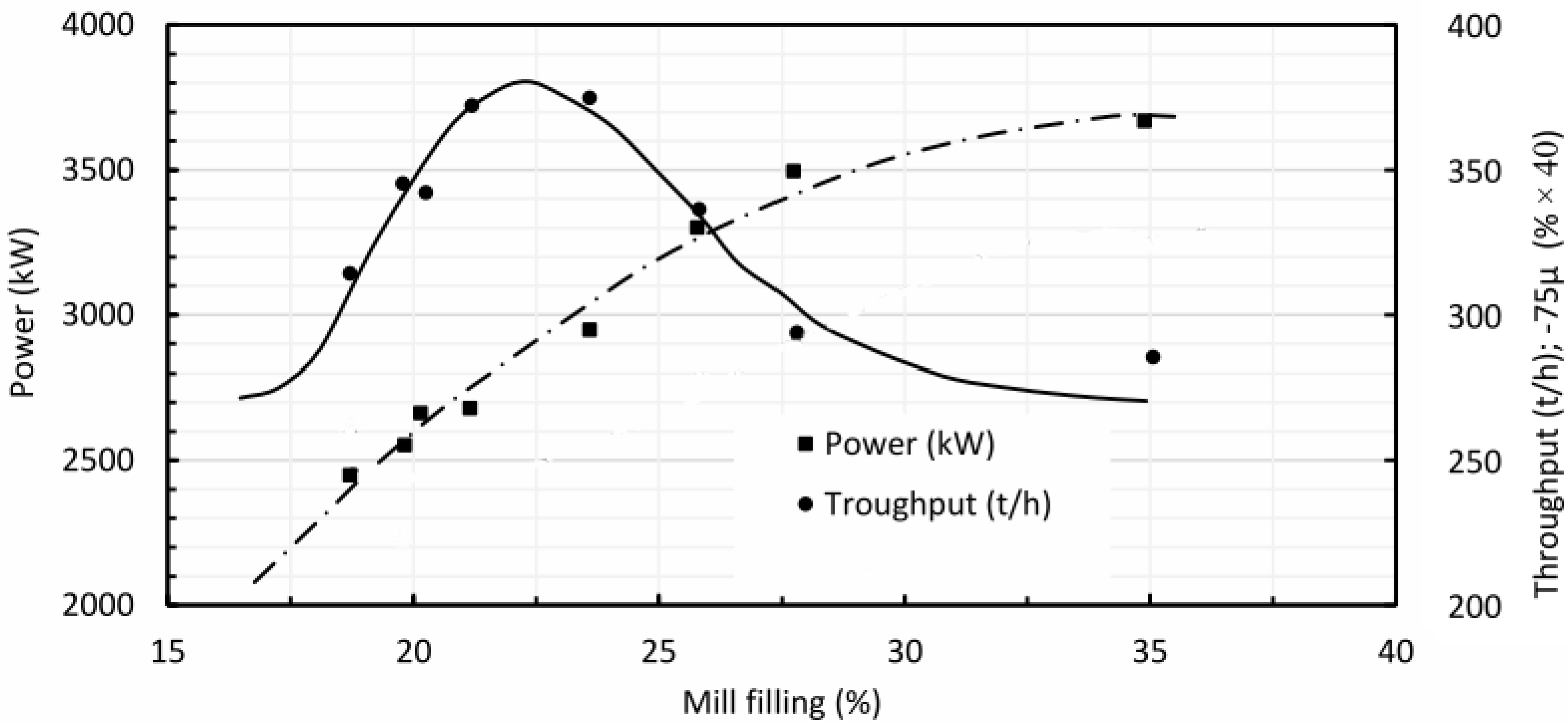
Traceability – From mine to AG mill



SAGTools

What is SAGTools?

Mill filling to optimize throughput



Powell & Mainza (2006) Extended grinding curves are essential to the comparison of milling performance.

Charge volume soft sensor

Calibration process

- Austin SAG Model

$P =$ F(DEM) SAG Tools

P is the power evolved at the mill shell,

J_x is the mill filling of component x, as a fraction of total mill volume

ρ_x is the density of a component x,

w_C is the charge %solids

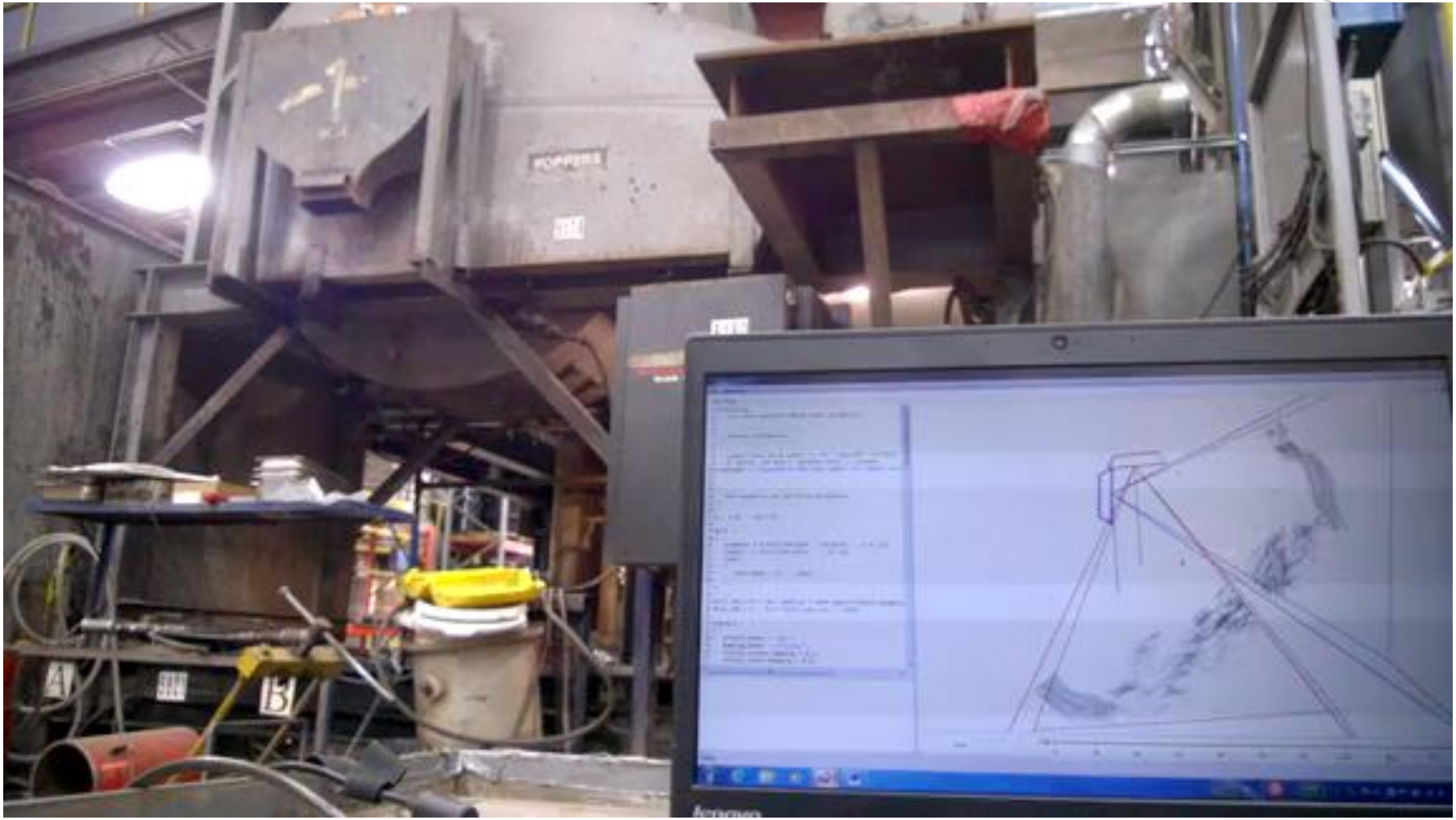
ϕ_C is the mill speed,

ε_B is the porosity of the rock and ball bed,

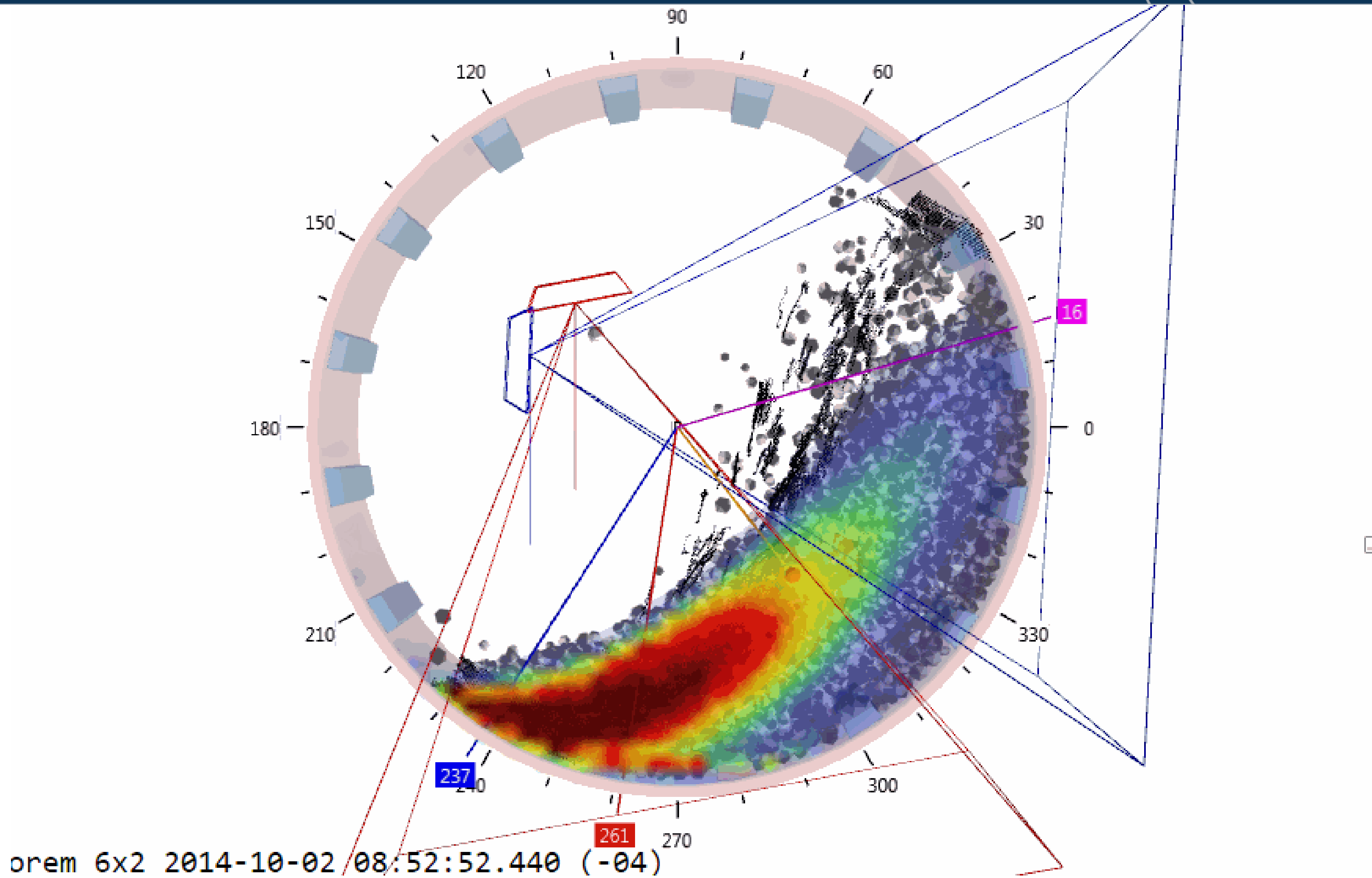
https://fredcou.shinyapps.io/demo_power_model/

Pilot plant mill instrumentation

- Installation of 3D cameras in a 6’x2’ AG/SAG mill



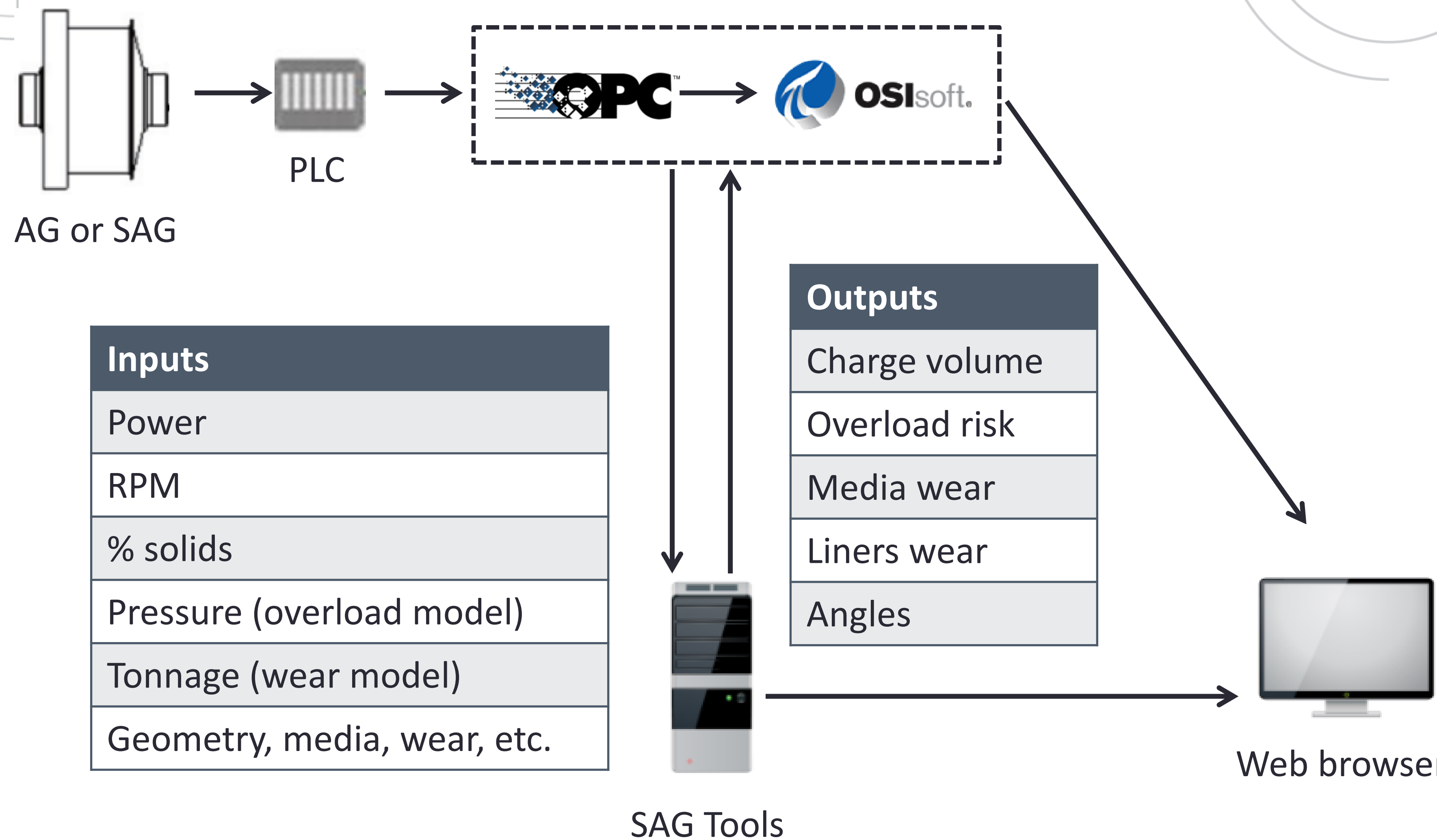
What is SAG Tools?
Discrete element method



Quebec Mine 2015

What is SAG Tools?

Inputs and outputs



Inputs
Power
RPM
% solids
Pressure (overload model)
Tonnage (wear model)
Geometry, media, wear, etc.

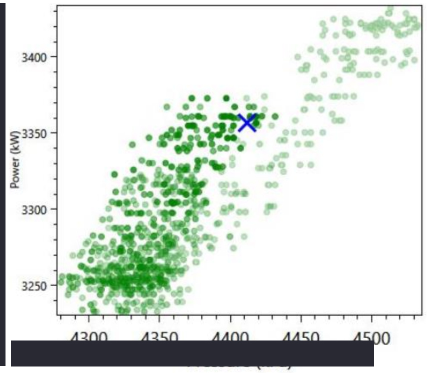
Outputs
Charge volume
Overload risk
Media wear
Liners wear
Angles

What is SAG Tools?

User interface

SAG Goldex

[redacted]



[redacted]

Tonnage: [redacted] t/h

Feed D80: [redacted] mm

Pressure (feed): [redacted]

Pressure (disch.): [redacted]

Power draw: [redacted] kW

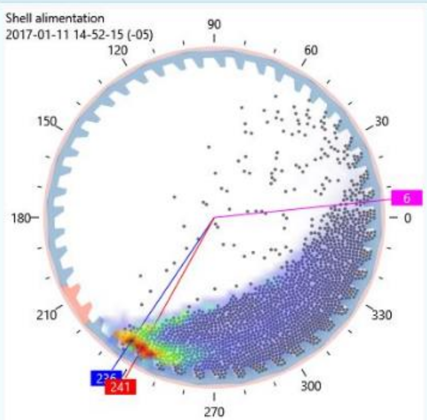
RPM: [redacted] RPM

Ball volume: [redacted] %

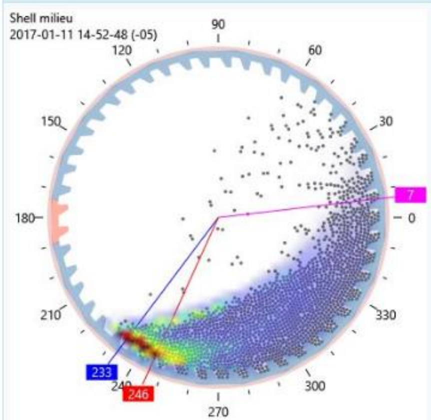
Charge volume: [redacted] %

Overload risk: [redacted] %

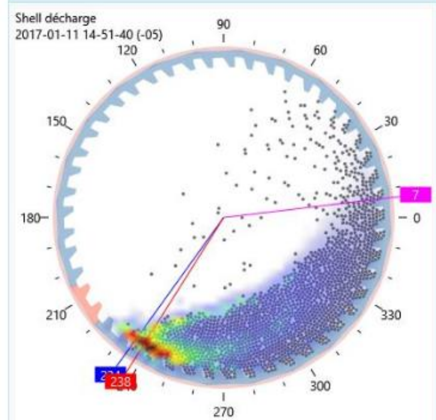
Shell feed



Shell middle



Shell discharge



Quebec Mine 2015

Mineralogy

Mineralogical tools

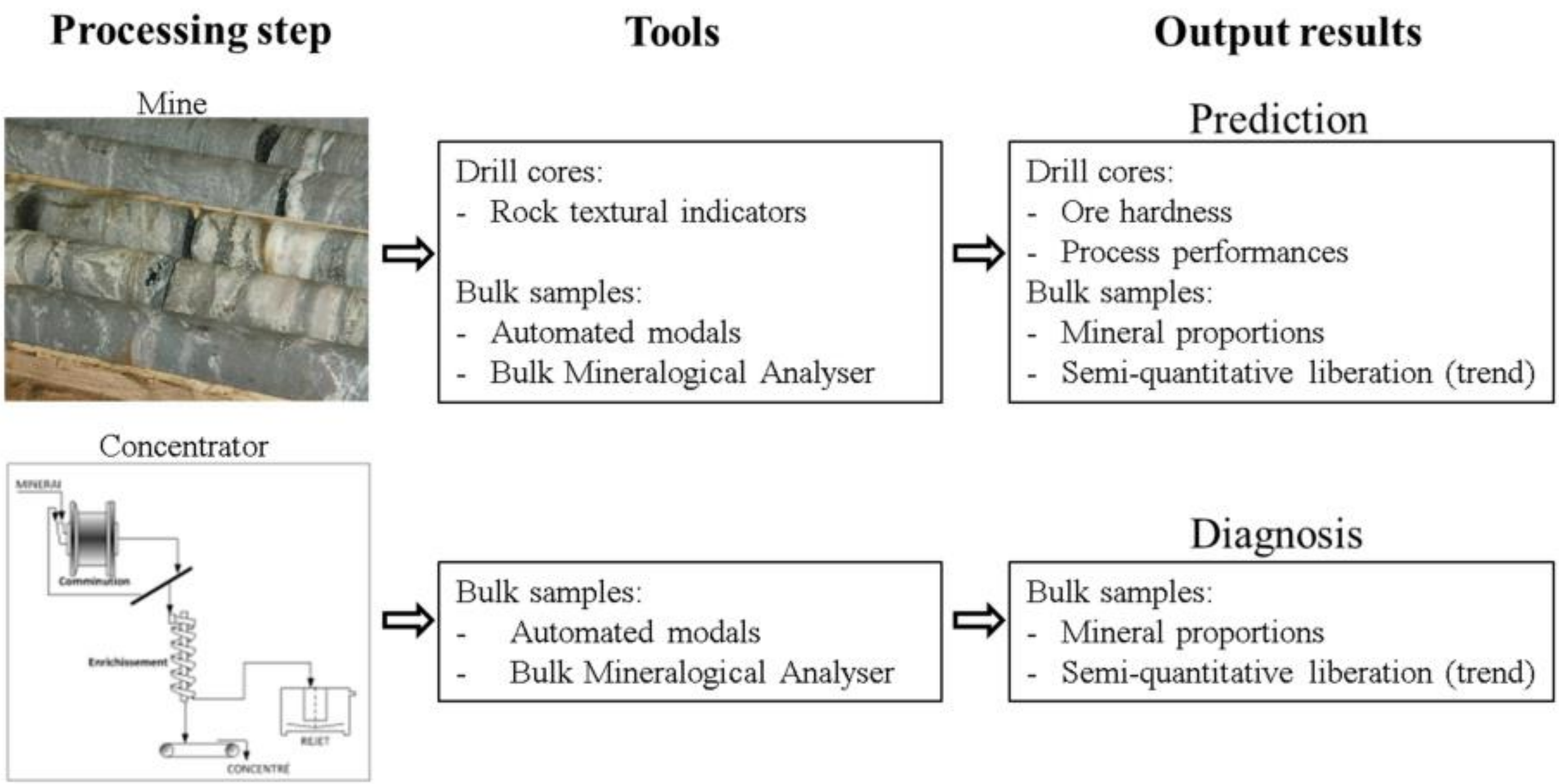
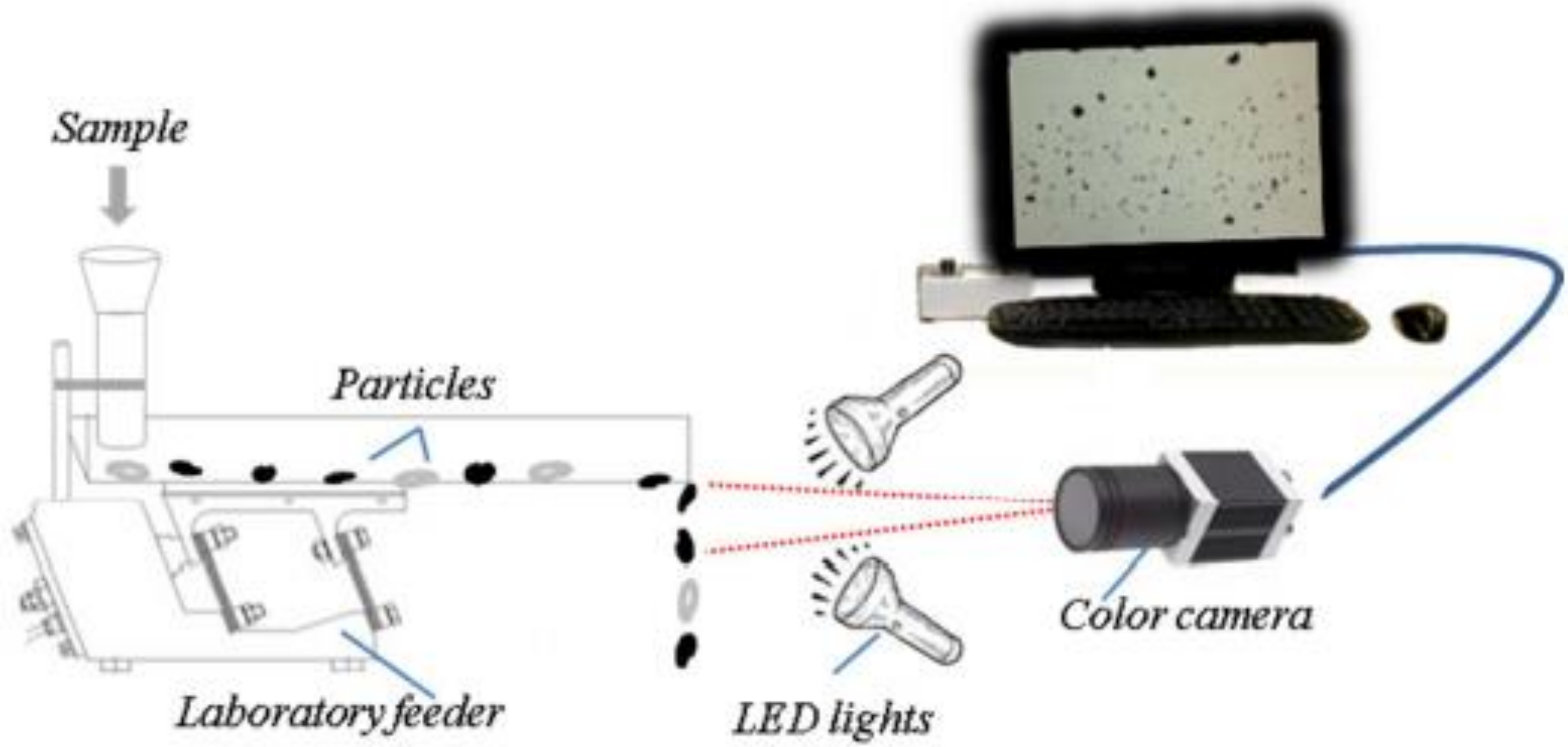


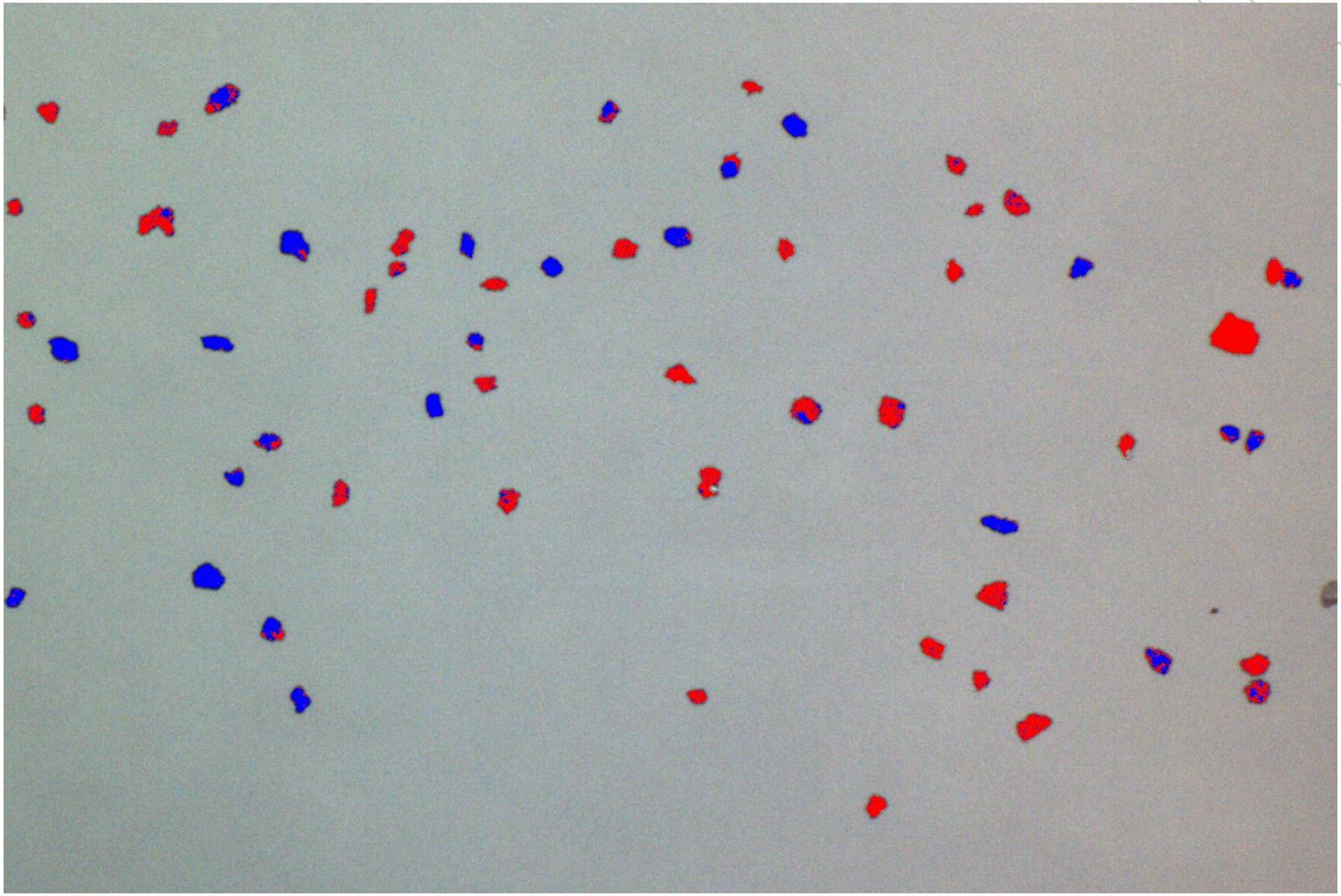
Figure 1 – Overview of the mineralogical tools being developed for the iron ore beneficiation process

Lévesque, S. et al., 2016. Mineralogical tools for ore characterization – key data at all steps of iron ore concentration. *IMPC*.

Bulk mineralogical analyser



Bulk mineral analyzer



IMPC 2016

Drill core textures

Automated recognition of drill core textures: A geometallurgical tool for mineral processing prediction

Laura Pérez-Barnuevo[a,*], Sylvie Lévesque[a], Claude Bazin[b]

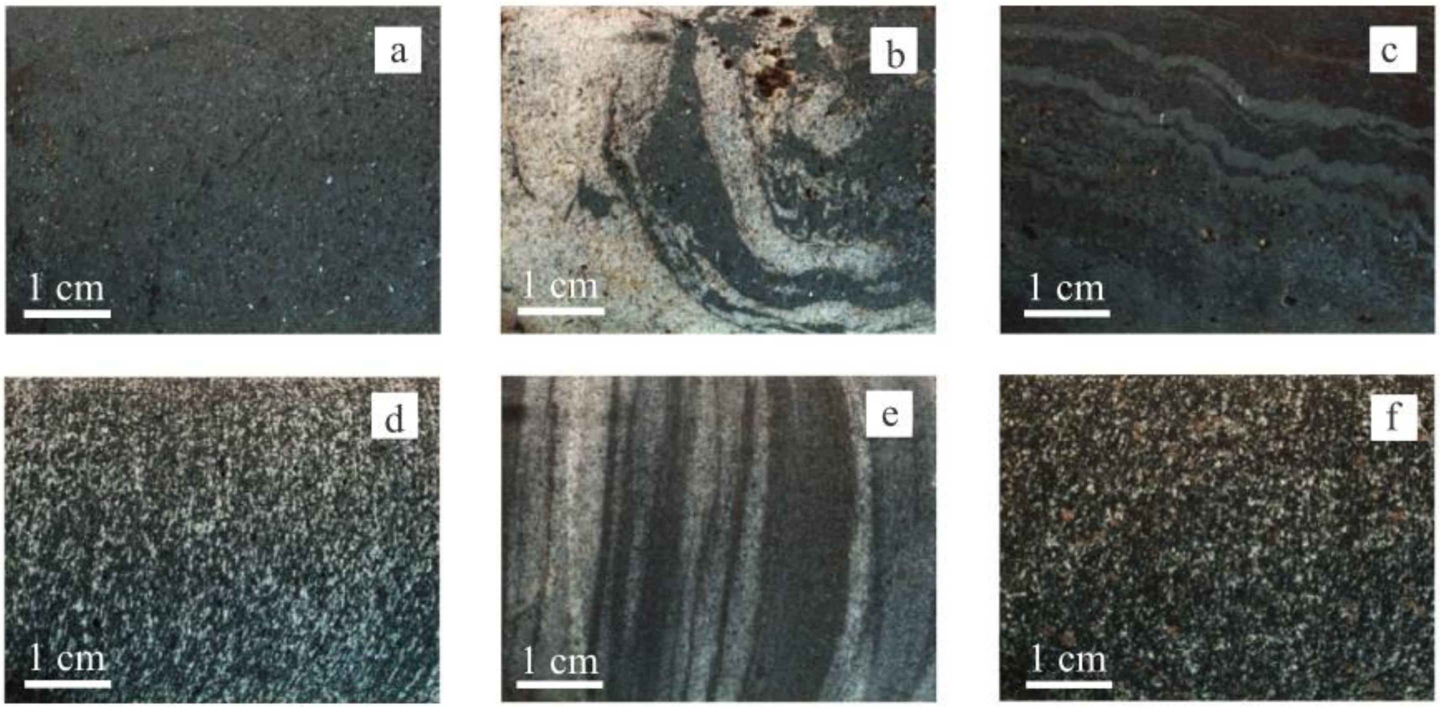
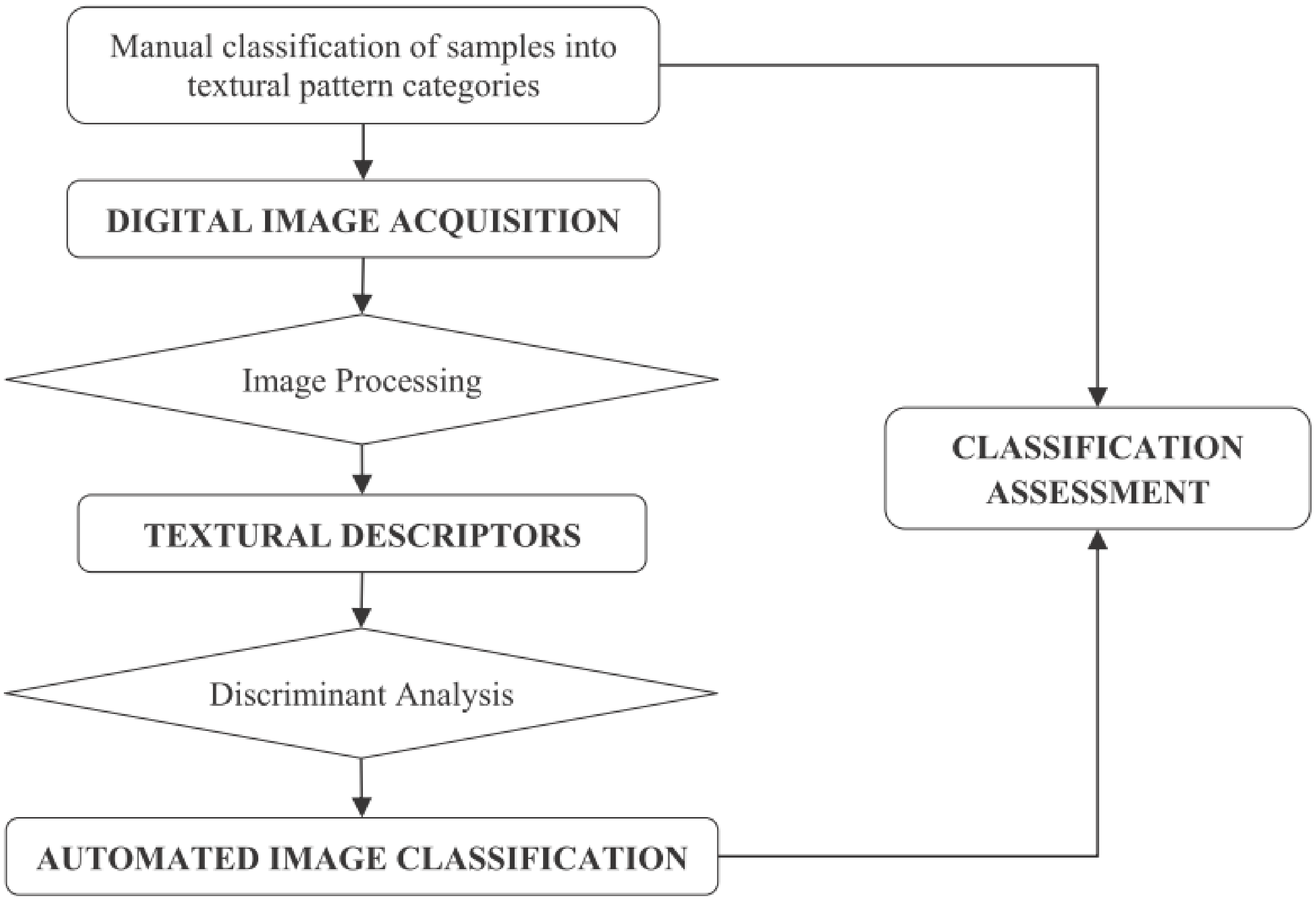


Fig. 1. Most frequent rock textural patterns identified at Mont-Wright: (a) Massive (Ms). (b) Bright banded (BBd). (c) Dark banded (DBd). (d) Mottled (Mo). (e) Layered (Ly). (f) Amphibolite (Amp). Images of the drill core round surface taken with a RGB digital camera.

Minerals Engineering 118 (2018) 87–96

Drill core textures



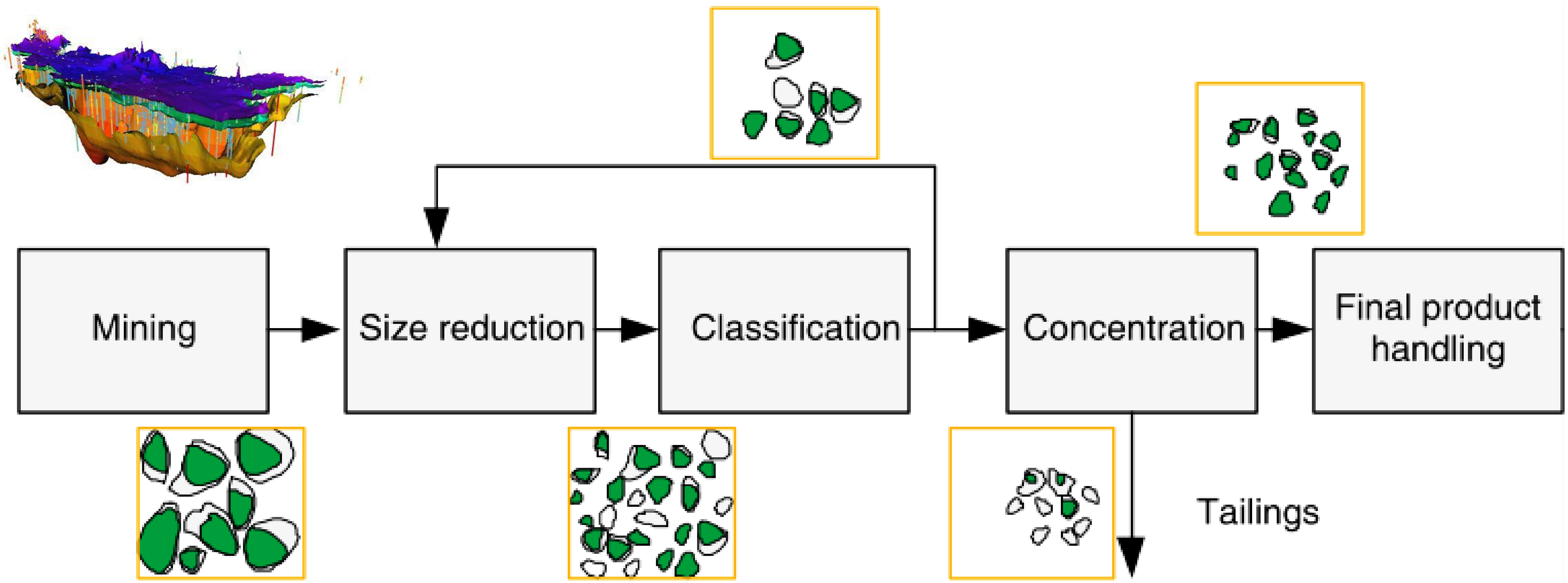
Drill core textures

Table 2
Mount-Wright drill core texture library (from Pérez-Barnuevo et al., 2017).

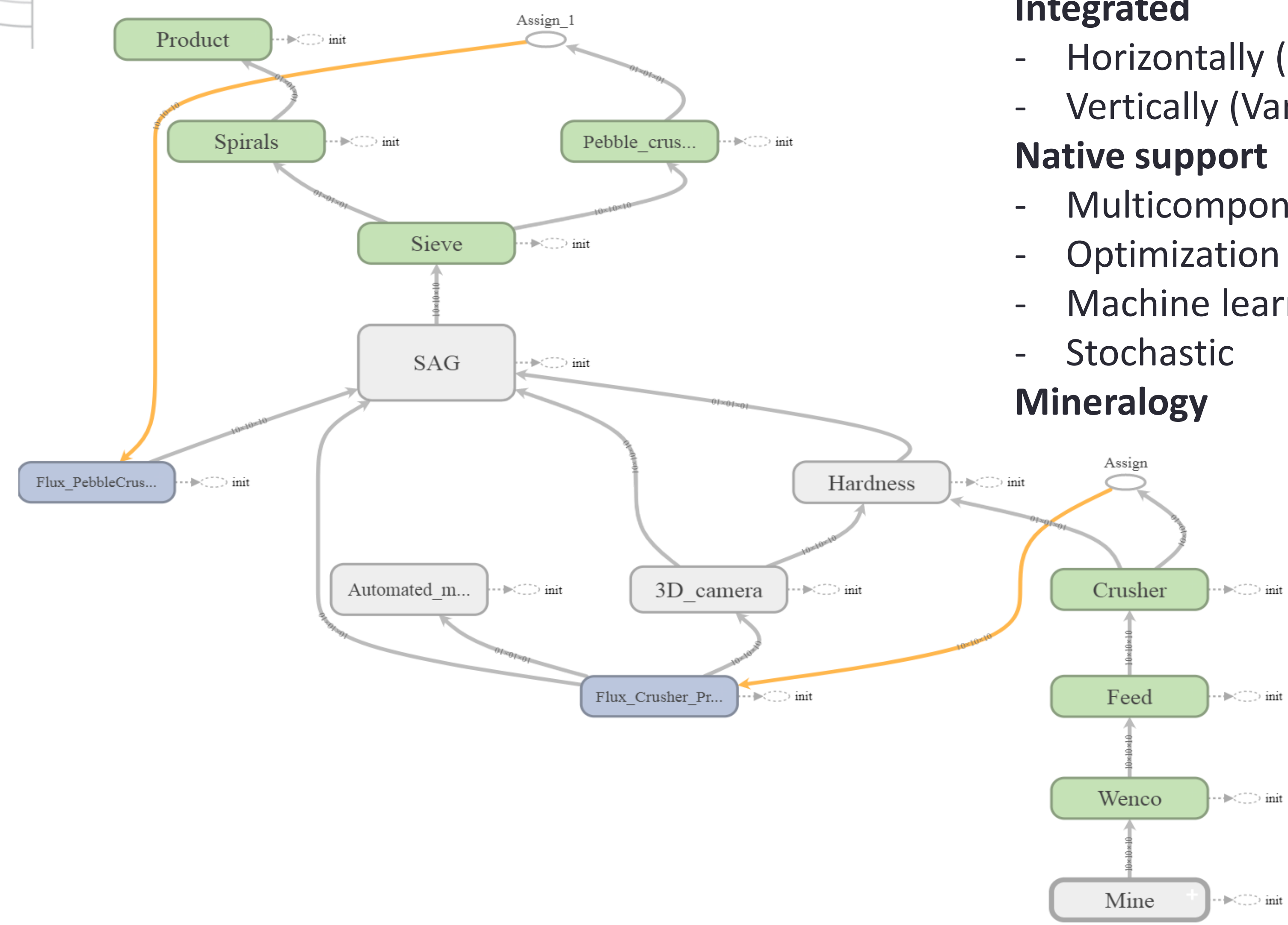
Texture	Crusher energy (kJ/kg)	Concentrate Grade		Liberation FeOx (% > 95%)	Grain size P_{80} FeOx (µm)
		Fe (%)	SiO_2 (%)		
Ms	1.5–1.8	69.7	0.3	99.4	594
BBd	2.4–4.3	67.7	2.7	91.0	431
DBd	2.7–3.0	67.9	3.2	90.6	447
Mo	1.8–2.6	68.1	3.2	89.1	406
Ly	4.2–4.5	63.5	11.6	75.6	287
Amp	4.6–5.9	40.4	36.5	–	–

Geometallurgy

Spatial model and process model



Forward



Integrated

- Horizontally (Mine-to-mill)
- Vertically (Variable resolution)

Native support

- Multicomponent
- Optimization
- Machine learning
- Stochastic

Mineralogy