Procemin·GEOMET·2017

13th International Mineral Processing Conference
4th International Seminar on Geometallurgy

Geometallurgical Block Model vs Geometallurgical Units

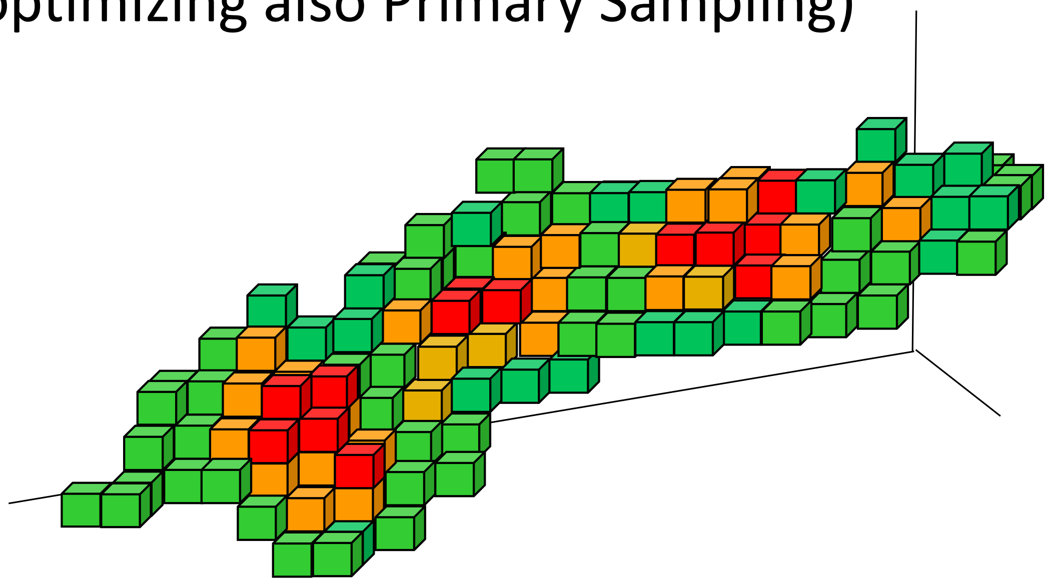
Bch. Ing. MSc.
Samuel Canchaya Moya

Gerente General **SAMPLING OK SAC**
Catedrático UNI y PUCP-Lima Perú

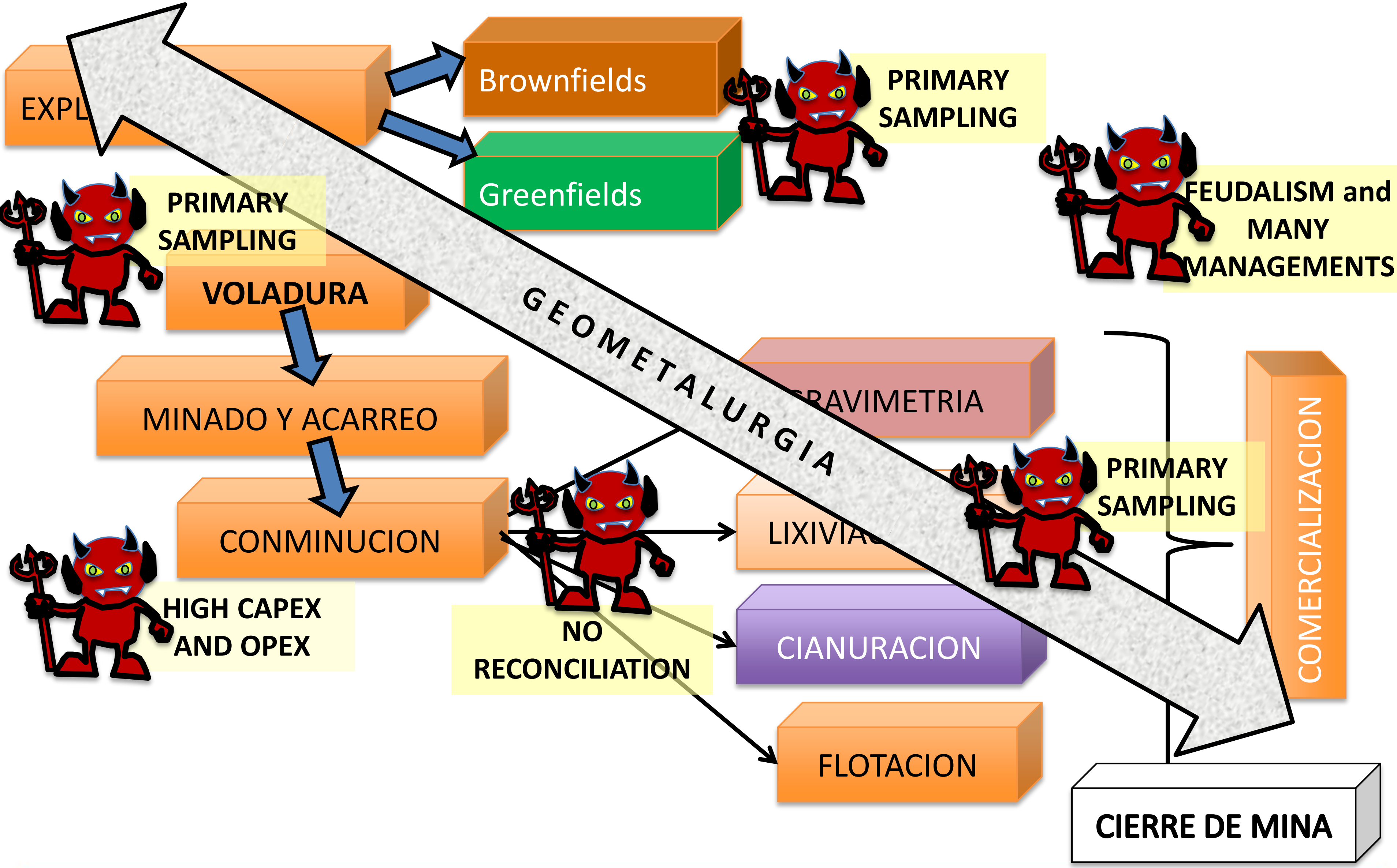
Secular main problems of Mining Industry

- High CAPEX and OPEX
- Low productivity
- Low recovery and extraction in plants, piles and pads
- Bad selection Ore vs Waste
- No Reconciliation (optimizing also Primary Sampling)

SOLUTION: GEOMETALLURGICAL BLOCK MODEL (GMBM)



Main stages of mining activity



Intelligent Blasting

"Comminution begins with Blasting"

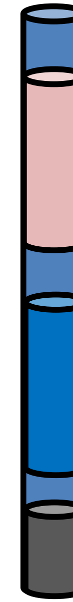
RQD

Geometallurgical logging

Fracture type

Fracture density

Best choice of components and their proportions



Blasting tests to optimize blasting parameters

Different blasting grids depending on country rock characteristics

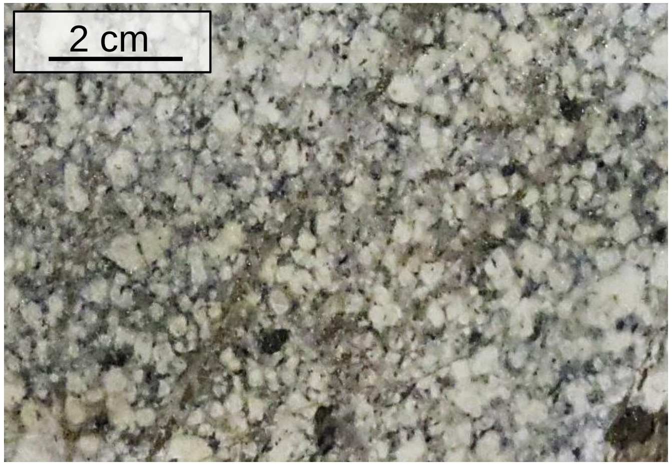
Shahuindo (high sulfidation Au deposit in Cajamarca-Perú) is a pioneering example of a project where blasting has been optimized, and therefore do not need crushing facilities.

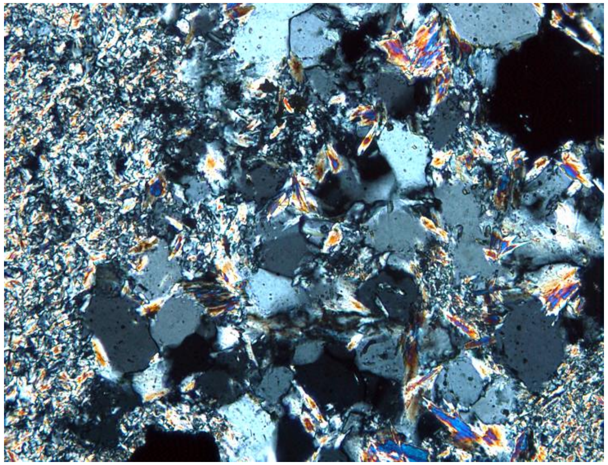
The "Total Rock Concept" (TRC)

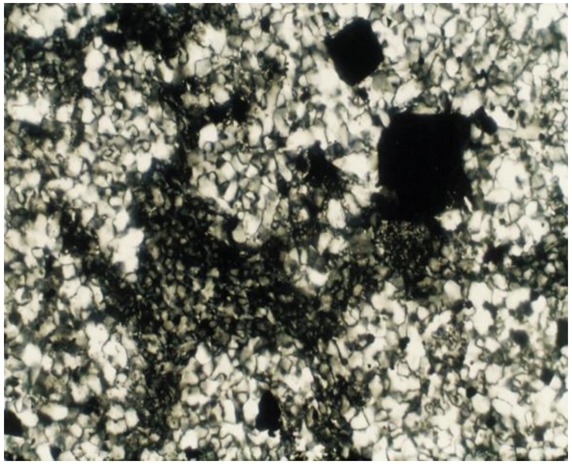
- The philosophical basis of the Geometallurgy, in how we propose and apply it, is the TOTAL ROCK CONCEPT (TRC) as defined by Canchaya (2008).
- This concept considers the rock as a whole and that designations of ore and waste are circumstantial and established by the human being based on their requirements or currently needs generally juncture or cultural.
- Therefore, the differentiation between ore and gangue will be only a valid exercise if they are considered as parts of a whole.
- The assumption of the TRC means the reconciliation of the ORE with the GANGUE; in a certain way is the claim of the gangue, sometimes called in a very derogatory way as "waste", when we know that gangue minerals are the main actors in different metallurgical circuits, such as crushing, grinding, flotation, cyanidation, acid leaching, etc.
- Additionally the main problems that occur in plants are mainly related to gangues, especially due to its relative abundance, which in some types of deposits, especially in the low-grade, are largely predominant.

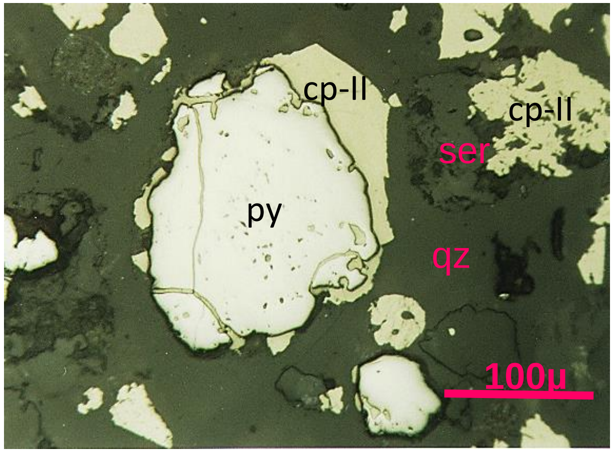
Cu(Mo) porphyry

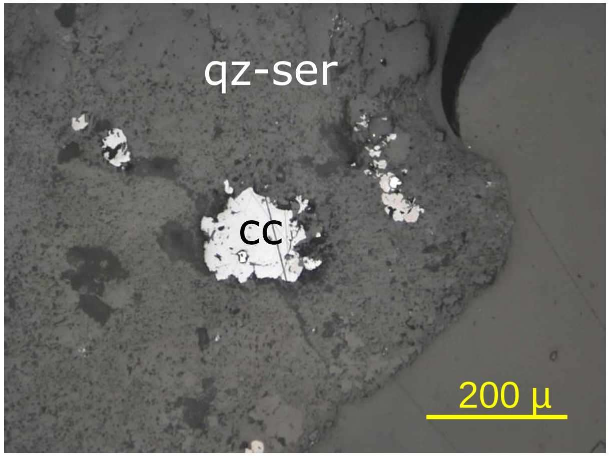
Ore < 2 or 3 %
Gangue > 97 %

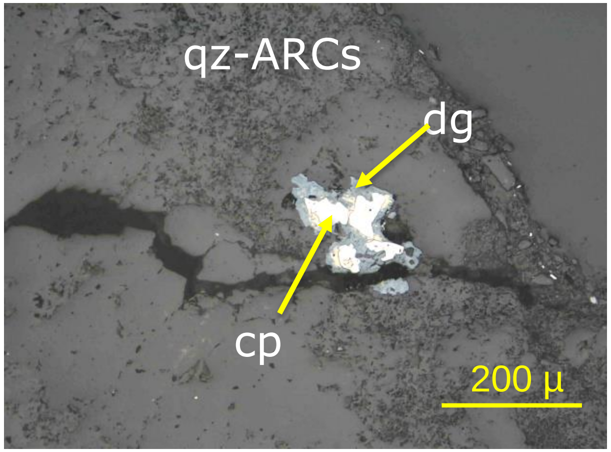








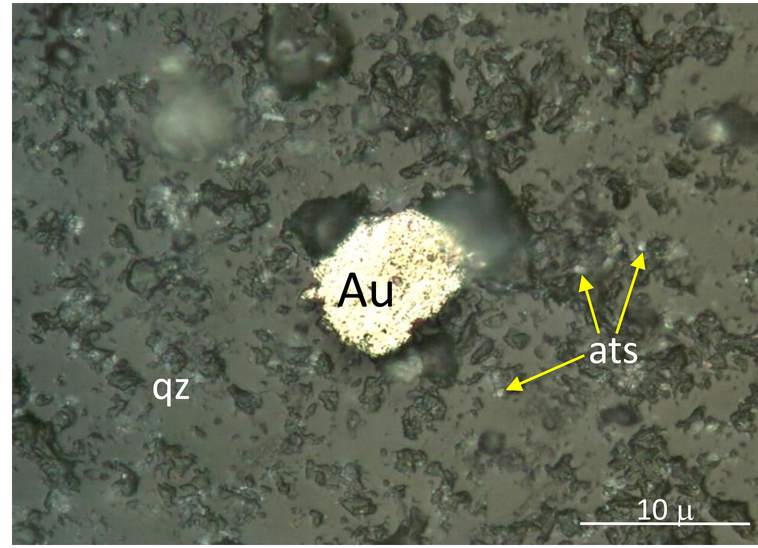




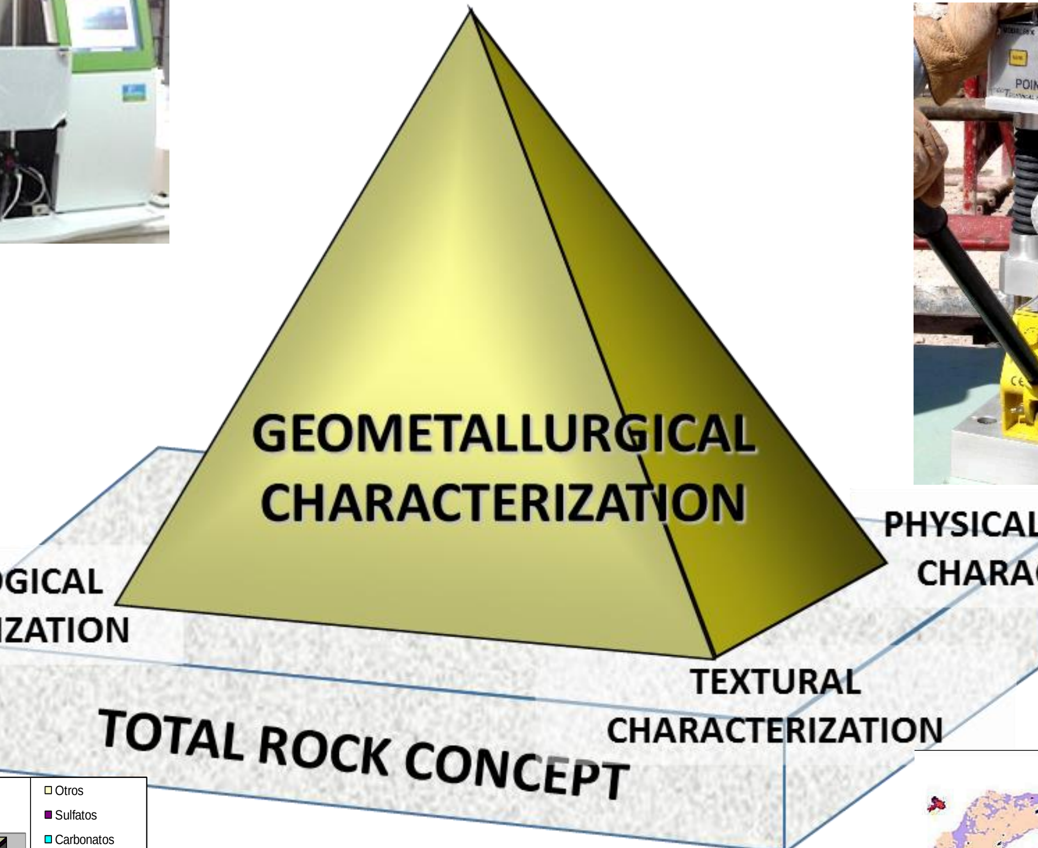
HS epithermal Au deposit

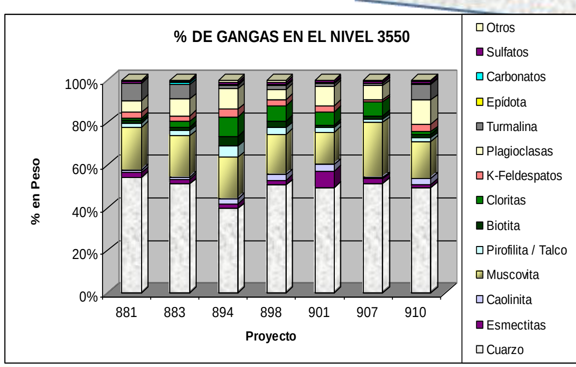
Ore: 1 ppm <> 1 gr/t <> 0.0001 %

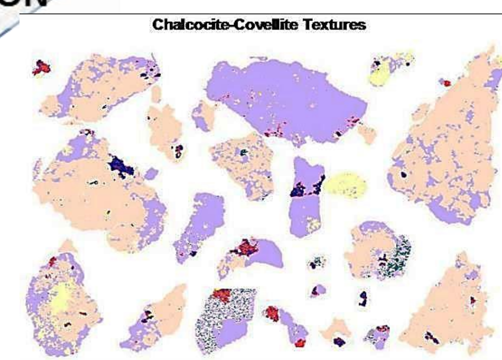
"Gangue" > 99.9999X %; x ε (1,9)



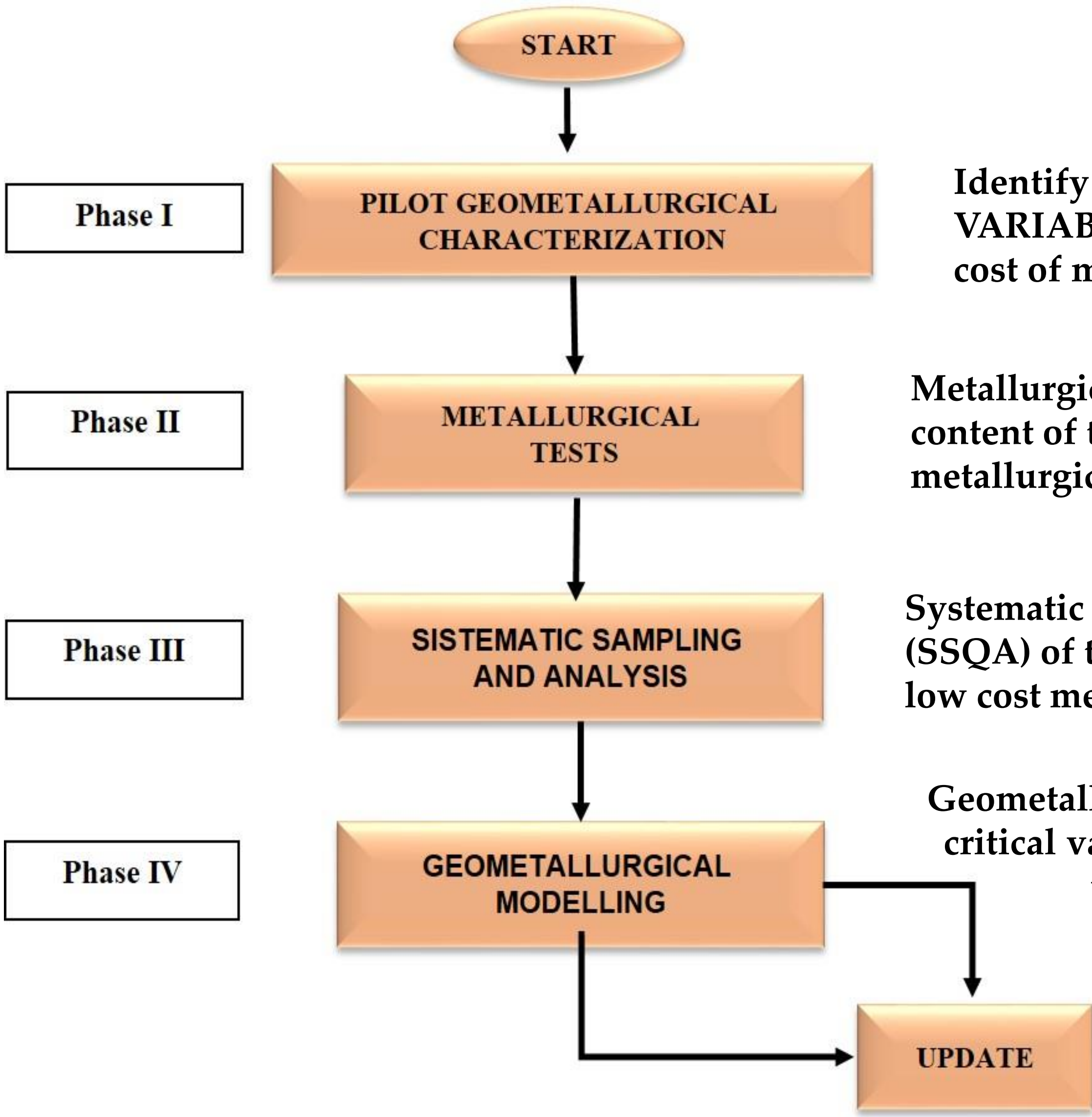
Geometallurgical characterization based on TRC







Implementation of the Geometallurgical Block Modell



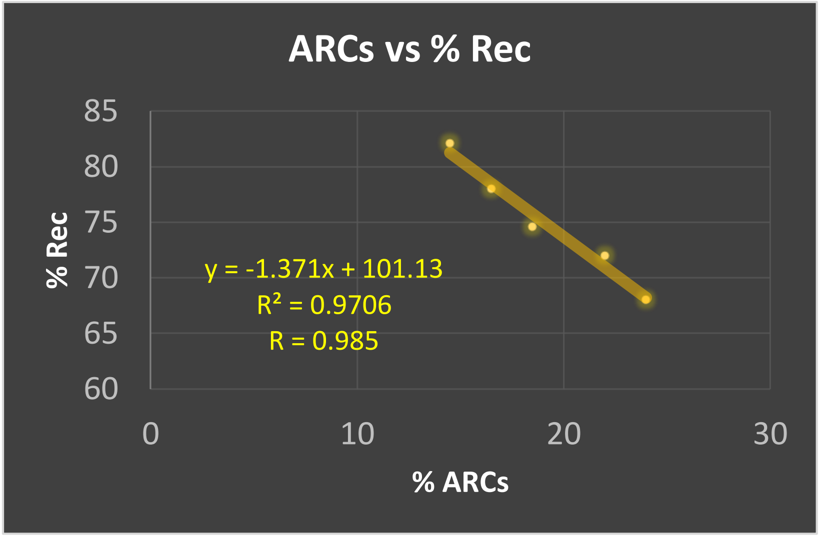
Identify and characterize CRITICAL VARIABLES that will influence success and cost of mining and metallurgical process.

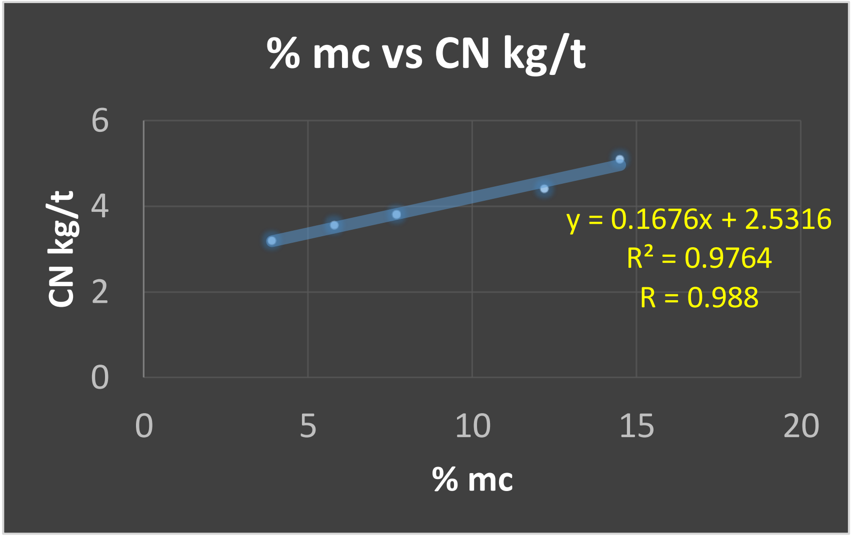
Metallurgical testing of samples with known content of the critical variables, to model its metallurgical behaviour.

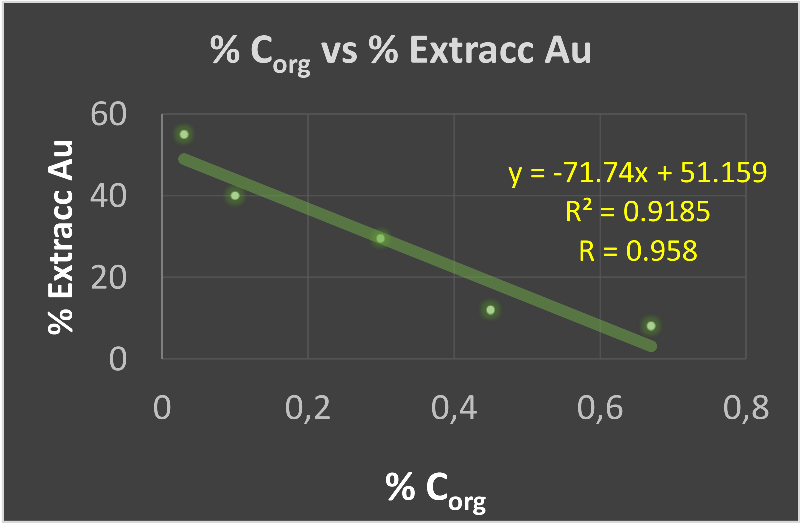
Systematic sampling and quantitative analysis (SSQA) of the critical variables, with fast and low cost methods.

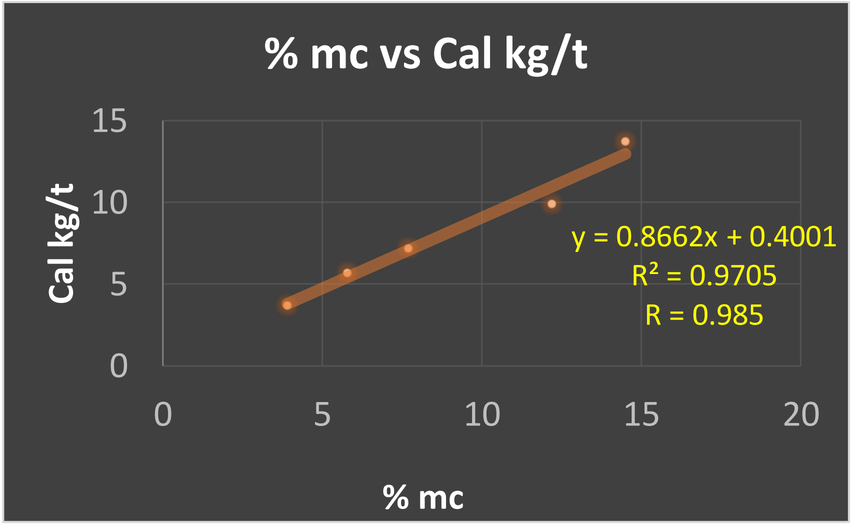
Geometallurgical block modelling of every critical variable, by kriging or simulations using geometallurgical databases

Metallurgical testing of CRITICAL VARIABLES

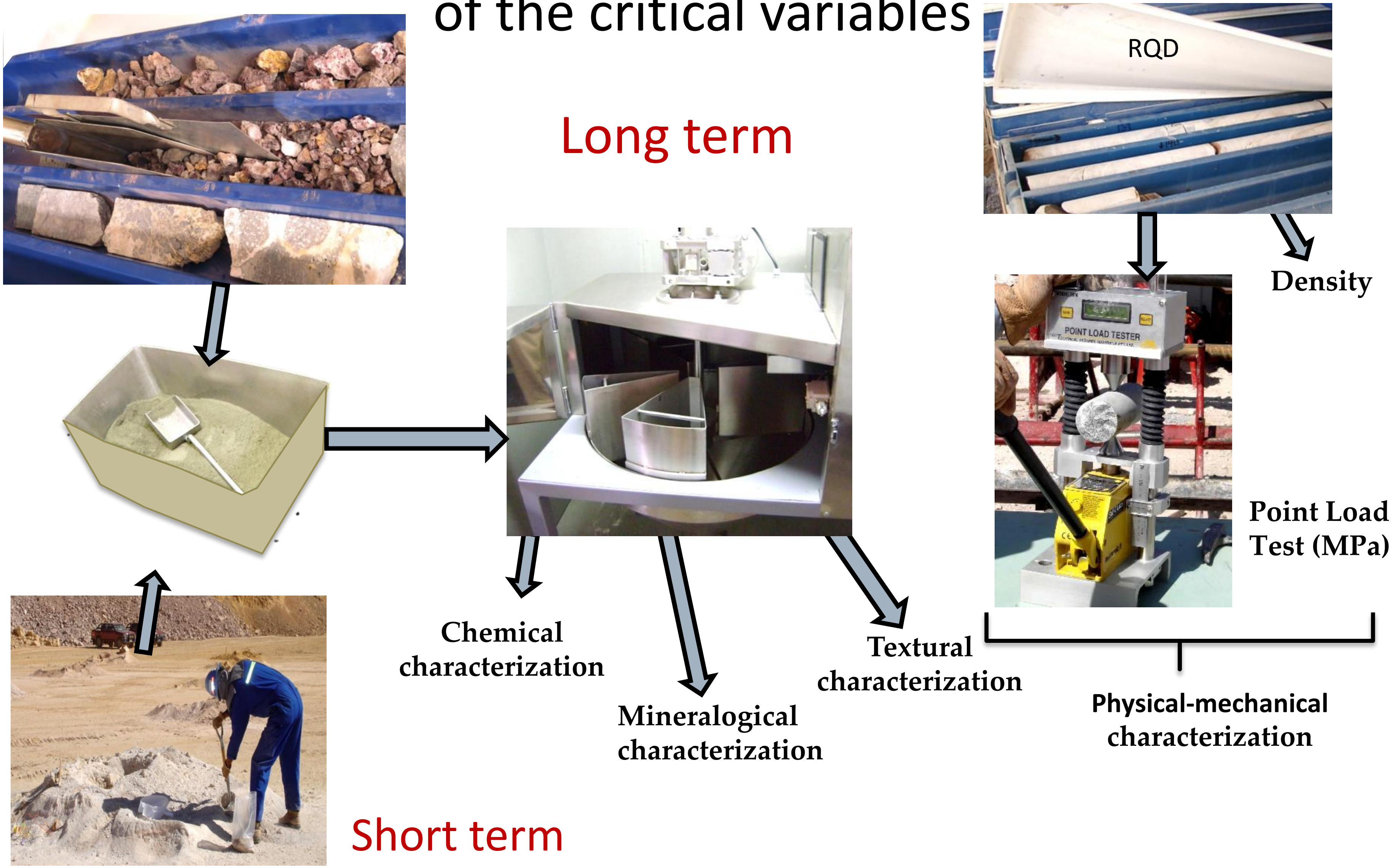






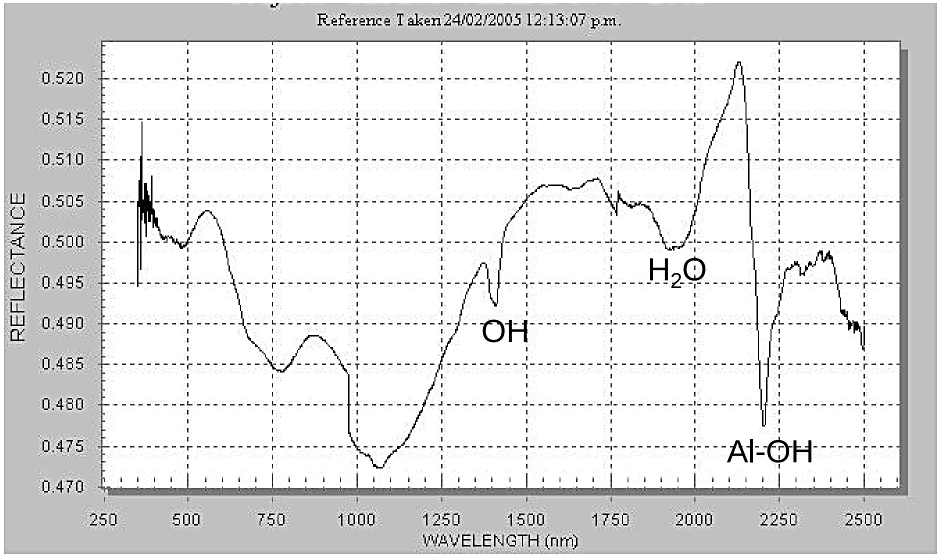


Systematic sampling and quantitative analysis (SSQA) of the critical variables



Spectrometry NIR

- **PIMA (Portable Infrared Mineral Analyzer)**
- **ASD Terraspec**



- **FeMn (Hidro)Oxides**
- **REE**

VNIR (Visible-NIR) 400 a 1,100 nm

- **Micas**
- **Clays**
- **Carbonates**
- **Clorites**
- **Epidote**
- **Alunites**
- **Jarosite**
- **Sulfates, etc.**

SWIR (Shortwave-IR) 1,100 a 2,500 nm

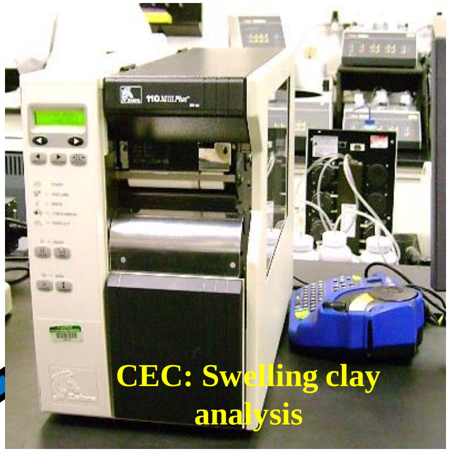
- **Quarz**
- **Feldspar**
- **Piroxens**
- **Garnets, etc.**

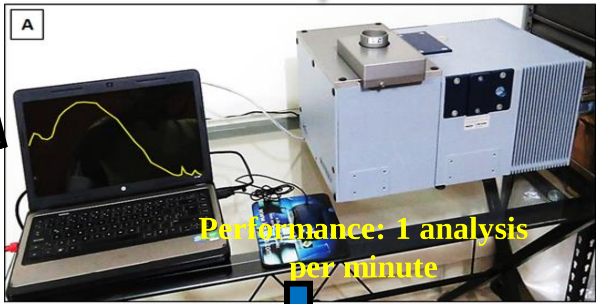
TIR (Thermal IR) 5,000 a 14,000 nm

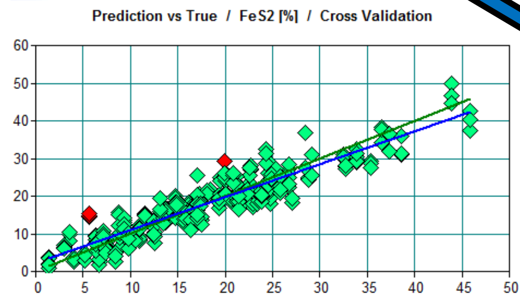
FTNIR Mineralogical Analysis

(Fourier Thermal Near Infra Red)

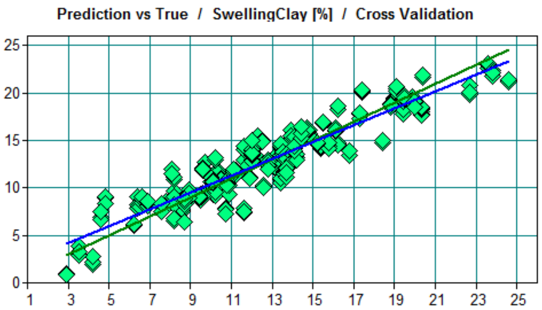
CALIBRATION
100 to 200 representative samples







Offset: 2.186 Slope: 0.873 Corr. Coeff.: 0.926
Rank: 10 R^2 = 85.71 RMSECV = 3.5 Bias: 0.0777 RPD: 2.65



Offset: 1.542 Slope: 0.885 Corr. Coeff.: 0.9321
Rank: 7 R^2 = 86.84 RMSECV = 1.69 Bias: -0.0597 RPD: 2.76

_Depth	Interval	SampleID	Siderite	FeS2	SwellingClay	Jarosite	Muscovite	Goethite	Arsenopyrite	Szomolnokite
200.20	1.30	127565	47.73	15.62	4.34	7.62	0.01	0.03	0.00	10.30
201.70	1.30	127566	42.65	13.27	5.92	7.97	0.37	0.55	0.00	12.16
80.40	2.00	129052	51.95	10.90	4.74	3.82	0.33	0.00	0.00	9.12
82.40	2.00	129053	42.85	13.28	5.02	4.67	0.26	0.00	0.00	12.34
84.40	2.00	129054	47.39	10.49	5.18	4.64	0.36	0.00	0.00	10.26
86.40	2.00	129055	43.87	7.83	6.29	5.22	0.47	0.00	0.00	11.18
170.70	2.00	129106	49.05	8.48	8.03	3.91	0.60	1.58	0.00	7.93
172.70	2.00	129107	51.58	7.99	6.75	3.38	0.52	1.00	0.00	7.86
174.70	2.00	129109	39.68	3.58	12.96	3.15	0.88	2.43	0.00	10.11
176.70	2.00	129110	38.29	2.04	13.61	3.72	0.94	2.89	0.00	8.24
178.50	1.80	129111	38.57	4.85	12.31	4.62	0.84	2.21	0.29	9.29
180.10	1.60	129112	28.19	8.15	13.88	5.05	0.94	2.85	0.00	11.73
181.30	1.20	129113	28.06	1.45	16.16	3.38	1.15	4.24	0.00	10.37
183.50	2.20	129114	39.14	4.00	11.19	4.35	0.78	1.99	0.00	9.39
185.50	2.00	129115	35.29	2.11	13.62	4.24	0.97	2.29	0.00	9.00
187.50	2.00	129116	35.26	3.87	11.46	4.09	0.80	2.62	0.00	11.56
189.50	2.00	129117	34.21	3.48	13.55	3.99	0.95	2.73	0.00	9.99
190.80	1.30	129118	35.84	5.87	11.37	4.20	0.71	2.83	0.00	8.83
191.50	0.70	129119	43.92	9.52	7.88	3.76	0.57	1.70	0.00	10.23
195.00	2.00	129121	36.99	9.34	9.61	2.28	0.64	2.20	0.00	12.19
197.00	2.00	129122	34.23	5.72	11.55	2.21	0.76	2.37	0.00	12.49
211.60	2.50	129131	42.60	10.08	7.54	3.49	0.47	1.58	0.00	10.60
213.60	2.00	129132	40.18	5.22	7.71	3.85	0.49	1.34	0.00	12.68

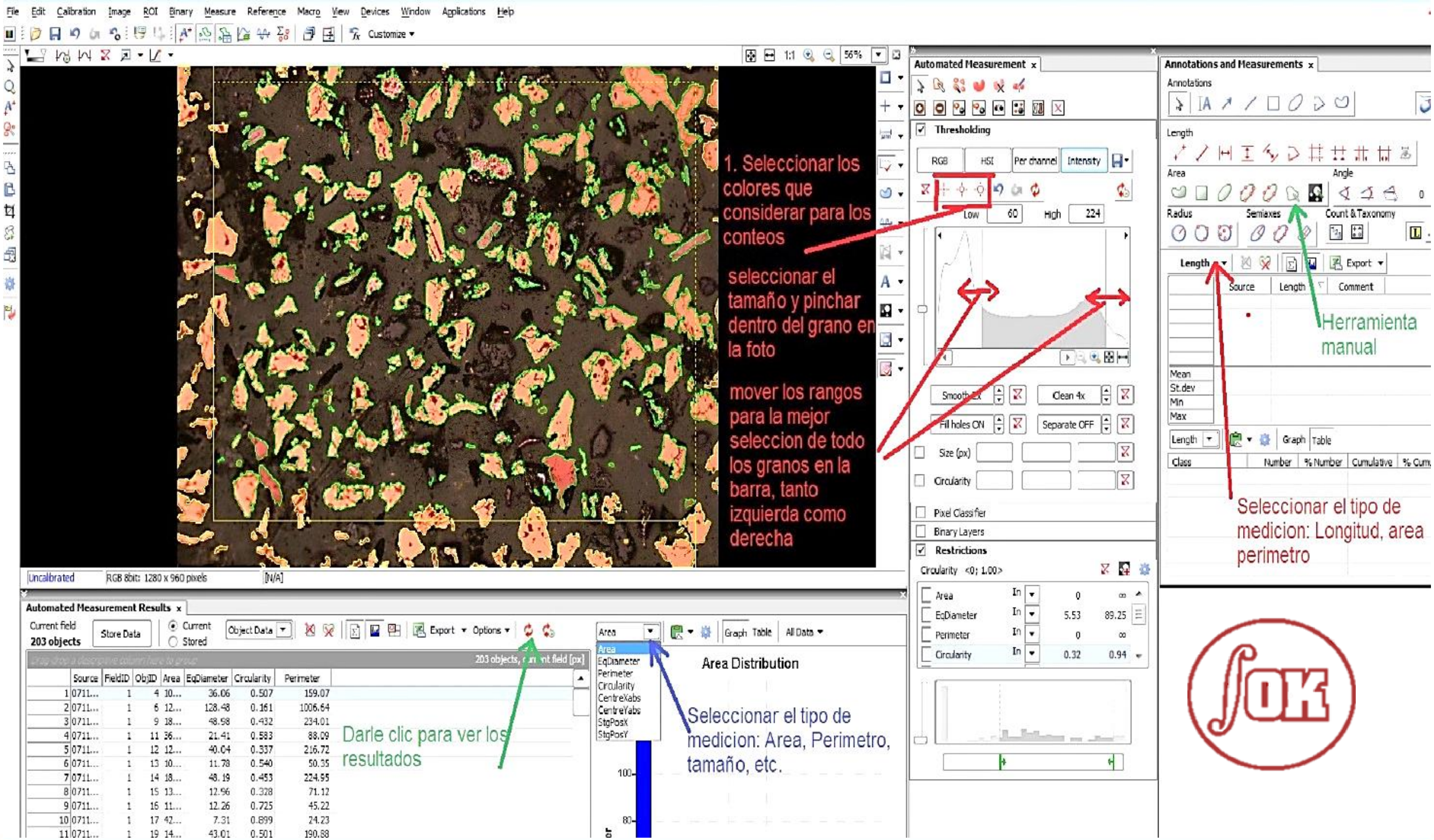
Comparative performance of common Mineralogical analysis

Method	Deliverable results	Execution time per sample	20,000 samples
FTNIR Spectrometry	Semi-quantitative mineralogical analysis (clays, sulphates, carbonates, limonites, micas, etc.)	Tens of seconds	15 days
X-Ray diffraction	Quantitative "Bulk" mineralogical analysis.	Tens of minutes	417 days
Optical microscopy with automatic image analysis	Modal mineralogical analysis of ore and gangue; intergrowths analysis, liberation degree, etc.	Several tens of minutes	515 days
LMA – QEMSCAN-TESCAN	Full automatized chemical, mineralogical and textural analysis	Hours	850 days

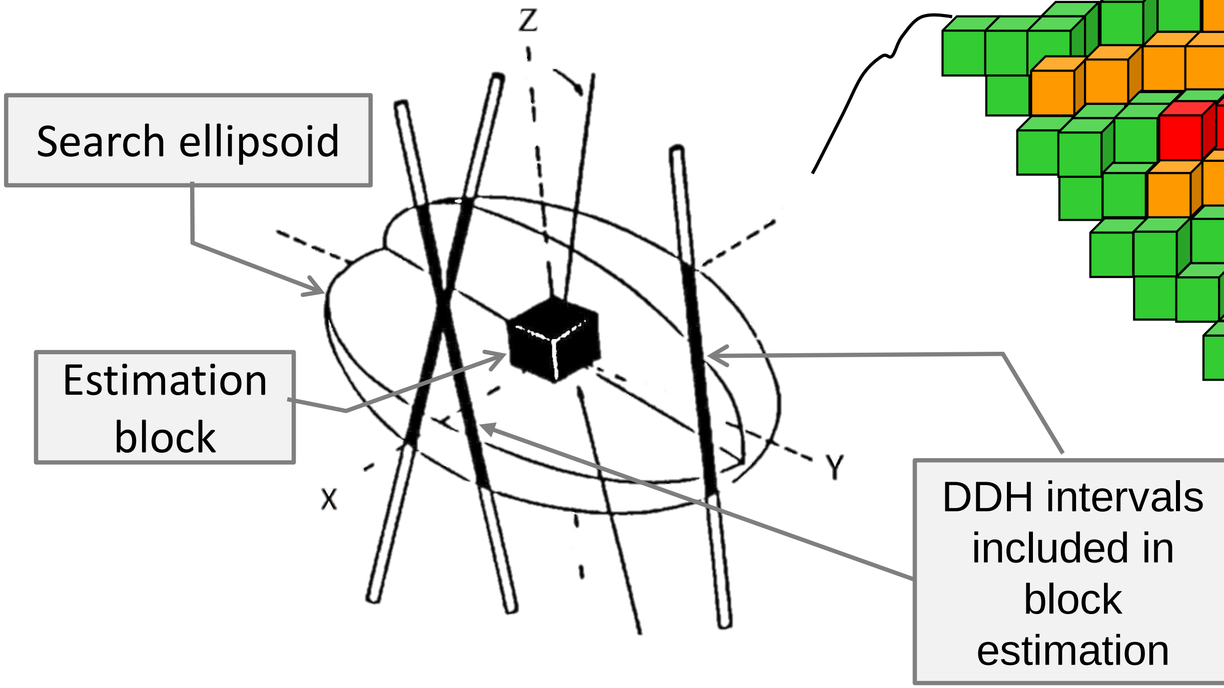
Textural-Structural Characterization

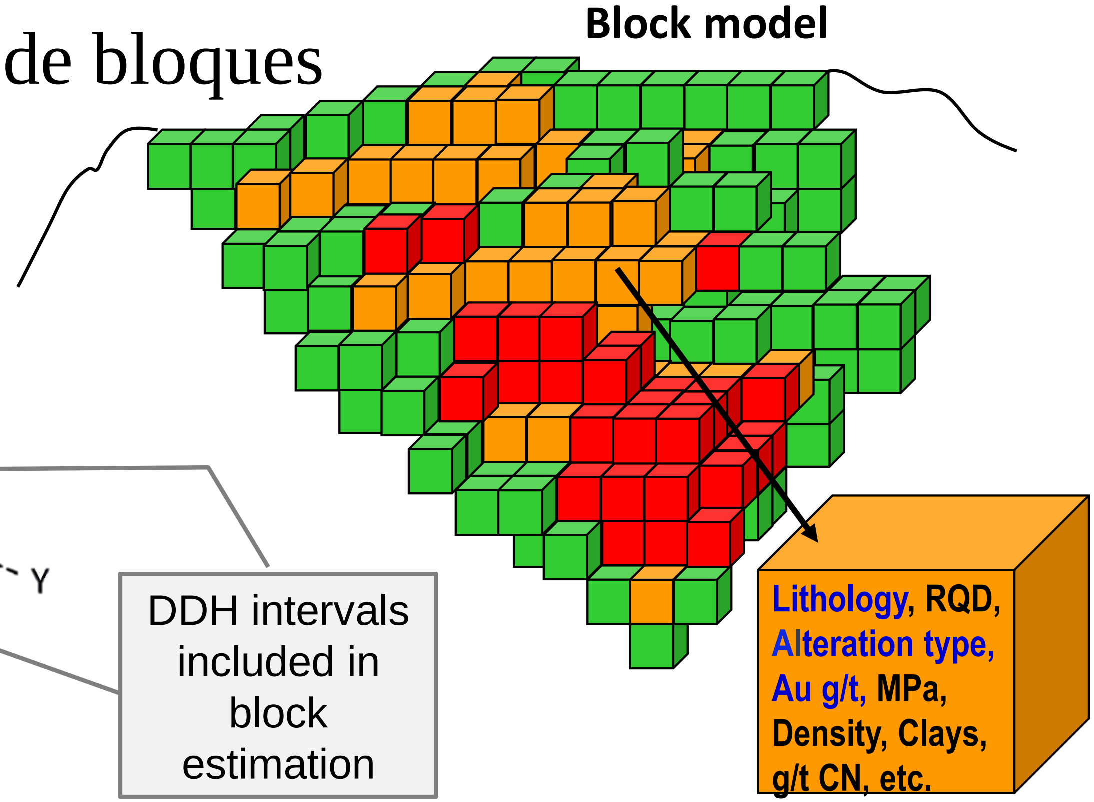
SCALE	DOMAIN	TOOLS	MAIN APLICATIONS
MEGASCOPIC	ROCK MASS	Geological mapping by cells. Macro-images processed by automatized image analyzer software (AIAS)	Blasting optimization
	DDH CORE	%RQD	
MACROSCOPIC	DDH OR RC	Geometallurgical logging	Blasting and comminution optimization. Metallurgical treatment
MICROSCOPIC	HAND SPECIMENS AND POLISHED/ THIN SECTIONS	Optical microscopy with AIAS Electronic microscopy (SEM/EDS o WDS), LMA/QEMSCAN/TESCAN	Mineralogical modal analysis; mineral intergrowths, liberation degree of ore and minerals carriers of penalty elements
SUB-MICROSCOPIC		Electronic microscopy (SEM/EDS o WDS), LMA/QEMSCAN	For submicropic, structural, solid solution and colloidal occurrence of Au, Ag, As, Sb, etc.

Automated modal and liberation analysis with optical microscope



Modelo Geometalúrgico de bloques



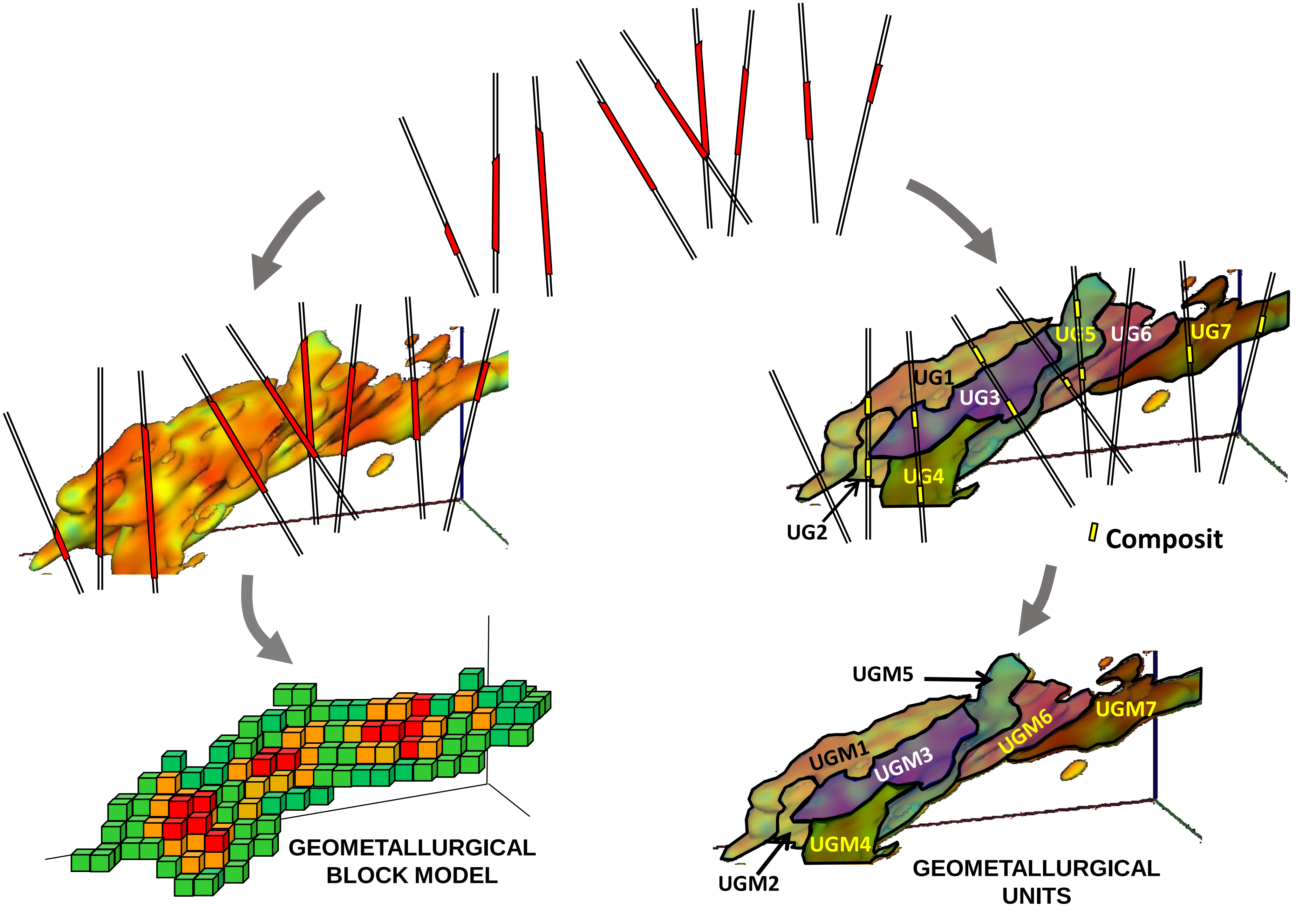


Database for: Geological Block Model

Database for: Geometallurgical Block Model

East	North	Elev.	Au gr/t	Alt	Litho	RQD %	MPa	Density gr/cm³	mc %	clays %	C_{org} %	As ppm	Hg ppb
655600	8834567	4509	0.22	4	12	10	33	2.5	0.29	1.5	1.22	32	12
655675	8835772	4484	1.23	3	12	20	56	3.3	2.33	2.3	0.76	345	23
655750	8836977	4459	1.01	4	07	38	124	7.6	1.02	7.6	0.55	123	34
655825	8838182	4434	0.56	4	12	49	156	2.6	0.98	0.6	1.01	876	65
655900	8839387	4409	1.08	2	10	85	250	2.5	0.33	0.5	0.23	34	65
655975	8840592	4384	0.45	2	12	72	200	4.3	3.45	2.3	0.07	222	13

Geometallurgical Block Model vs GMUs



Short term clay modelling from "blast holes"

Conclusions

Currently there are still a few cases of application of GMBM and in general only partially: Cu-Mo porphyry Cerro Verde (Fennel et al. 2005), Cu-Mo porphyry Trapiche (3,227 MPa and 1,050 density determinations), the mesotermal deposits San Gabriel (Canchaya et al. 2013; 3064 MPa, 5200 density determinations, 3030 FTNIR analysis, and thousands of RQD), La Granja-Río Alto (almost 3 year of Qemscan analysis) and Marcapunta (Huallpallunca & Zapata 2017; this event).

With recent technological advances of infrared spectrometers, it is already currently possible to obtain rapid semi-quantitative mineralogical analysis, less than a minute per sample. If we add systematic quick measurements of uniaxial point load, RQD and density; it is now possible to have thousands of data required to implement a probabilistic GMBM; which by far constitutes currently the best deliverable product of Geometallurgy.

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samplingok@gmail.com; canmoysa@gmail.com

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