Geometallurgical Block Model vs Geometallurgical Units

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gecamin.com/procemin.geomet
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

- EXPLORACION
- Brownfields
- PRIMARY SAMPLING
- Voladura
- Greenfields
- Feudalism and MANY MANagements
- Minado y acarreo
- Conminucion
- High CAPEX and OPEX
- No reconciliation
- Geometalurgia
- Lixiviation
- Cianuracion
- Flotacion
- Cierre de mina

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Intelligent Blasting
“Comminution begins with Blasting”

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.

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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 %

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HS epithermal Au deposit

Ore: 1 ppm <> 1 gr/t <> 0.0001 %
“Gangue” > 99.9999X %; x ε (1,9)
Geometallurgical characterization based on TRC

MINERALOGICAL CHARACTERIZATION

CHEMICAL CHARACTERIZATION

TEXTURAL CHARACTERIZATION

PHYSICAL–MECHANICAL CHARACTERIZATION

TOTAL ROCK CONCEPT

% DE GANAS EN EL NIVEL 3550

Otros
- Sulfatos
- Carbonatos
- Epidota
- Turmalina
- Plagioclasas
- K-Feldespatos
- Cloritas
- Biotita
- Pirofilita / Talco
- Muscovita
- Caolinita
- Esmectitas
- Cuarzo

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Implementation of the Geometallurgical Block Modell

1. Phase I: Pilot Geometallurgical Characterization
   - Identify and characterize CRITICAL VARIABLES that will influence success and cost of mining and metallurgical process.
2. Phase II: Metallurgical Tests
   - Metallurgical testing of samples with known content of the critical variables, to model its metallurgical behaviour.
3. Phase III: Systematic Sampling and Analysis
   - Systematic sampling and quantitative analysis (SSQA) of the critical variables, with fast and low cost methods.
4. Phase IV: Geometallurgical Modelling
   - Geometallurgical block modelling of every critical variable, by kriging or simulations using geometallurgical databases

UPDATE
Metallurgical testing of CRITICAL VARIABLES

**ARCs vs % Rec**
- $y = -1.371x + 101.13$
- $R^2 = 0.9706$
- $R = 0.985$

**% mc vs CN kg/t**
- $y = 0.1676x + 2.5316$
- $R^2 = 0.9764$
- $R = 0.988$

**% C$_{org}$ vs % Extracc Au**
- $y = -71.74x + 51.159$
- $R^2 = 0.9185$
- $R = 0.958$

**% mc vs Cal kg/t**
- $y = 0.8662x + 0.4001$
- $R^2 = 0.9705$
- $R = 0.985$
Systematic sampling and quantitative analysis (SSQA) of the critical variables.
Spectrometry NIR

- PIMA (Portable Infrared Mineral Analyzer)
- ASD Terraspec

- VNIR (Visible-NIR)
  400 to 1,100 nm
- SWIR (Shortwave-IR)
  1,100 to 2,500 nm
- TIR (Thermal IR)
  5,000 to 14,000 nm

- FeMn (Hidro)Oxides
- REE
- Micas
- Clays
- Carbonates
- Chlorites
- Epidote
- Alunites
- Jarosite
- Sulfates, etc.
- Quartz
- Feldspar
- Piroxens
- Garnets, etc.
FTNIR Mineralogical Analysis (Fourier Thermal Near Infra Red)

- **XRD:** Mineralogical “Bulk” Analysis
- **CEC:** Swelling clay analysis

**CALIBRATION**
100 to 200 representative samples

**Performance:** 1 analysis per minute

**Graphs:**
- Prediction vs True / FeS2 [%] / Cross Validation
- Prediction vs True / SwellingClay [%] / Cross Validation

**Table:**
- Data for different samples with various mineral and clay concentrations
Comparative performance of common Mineralogical analysis

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

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

1. Seleccionar los colores que considerar para los conteos
2. Seleccionar el tamaño y pinchar dentro del grano en la foto
3. Mover los rangos para la mejor selección de todo los granos en la barra, tanto izquierda como derecha

Seleccionar el tipo de medición: Longitud, área, perímetro

Dar clic para ver los resultados

Seleccionar el tipo de medición: Area, Perímetro, tamaño, etc.

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Database for: Geological Block Model

<table>
<thead>
<tr>
<th>East</th>
<th>North</th>
<th>Elev.</th>
<th>Au gr/t</th>
<th>Alt</th>
<th>Litho</th>
<th>RQD %</th>
<th>MPa</th>
<th>Density</th>
<th>mc</th>
<th>clays</th>
<th>Corg</th>
<th>As</th>
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<td>0.33</td>
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<tr>
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<td>12</td>
<td>72</td>
<td>200</td>
<td>4.3</td>
<td>3.45</td>
<td>2.3</td>
<td>0.07</td>
<td>222</td>
<td>13</td>
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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 mesothermal 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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