QUALITY ASSURANCE IN THE PROCESS FROM ROCKS TO CATHODES.

Gerencia Funcional Ingeniería y Procesos
Vicepresidencia de Proyectos

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INTRODUCTION

ALONG THE VALUE CHAIN OF THE MINING BUSINESS, FROM ROCK TO CATHODES, MANY CRITICAL DECISION ARE BASED ON SAMPLES AND ASSAYS

(P. Carrasco et al 2004)
What Happened when a Proper Sampling Device was Installed in a Tail Discharge?

Before the proper sampling device was installed the copper tail grade was assumed to be 0.15 %, the real value was 0.2%.

The flow rate was 96,000 tons/day.

The annual copper losses were 17,520 ton/year

Considering a copper price of 1 dollar/pound

The annual loss is 38,544 MUS$
Some few years ago, Codelco decided to sell 51% of El Abra deposit. Due diligence process encountered assays were biased by - 0.06% Cu in the oxide zone. Because of the high tonnage and low grade of the deposit, impact of analytical bias caused economic loss of 300 MUS$.
Define standards and procedures of the best practices to ensure and confirm the quality, robustness and reliability of the geo/mining/metallurgy base in order to obtain the economic benefits expected by the project, helping to maximize long-term economic value of the Corporation.
STANDARD, BEST PRACTICE GUIDES AND ANALYTICAL PROTOCOLS.

- Optimizing Sampling Protocol
- Implementing Sampling Protocol
- Preserving Sample Integrity
- Analytical Error

Errors:
- Fundamental Error
- Grouping & Segregation Error
- Delimitation Error
- Extraction Error
- Preparation Error
IMPLEMENTATION OF SAMPLING PROTOCOL

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HETEROGENEITY TEST TO DETERMINE SAMPLING CONSTANTS AND NOMOGRAMS FOR SAMPLE PREPARATION
SAMPLING CONSTANT

SAMPLING CONSTANT (d=1 cm) vs GRADE
CHILEAN PORPHYRY ORES.

\[ Y = 25X^{-0.34309} \]

- Cut Sulfides
- Mo Sulfides
- As Sulfides
- Cut Green Oxides
- Cut Black Oxides
- Cut Clay Oxides
IMPLEMENTATION OF SAMPLING PROTOCOL

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STANDARD CONDITIONS OF SAMPLING STATIONS FOR MATERIAL BALANCE AND TRANSFER POINTS OF PRODUCTS
SAMPLING METHODS

Manual, not equiprobabilistic

Automatic Sampler
IMPLEMENTATION OF SAMPLING PROTOCOL

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QUALITY ASSURANCE IN DIAMOND DRILL CUTTING
IMPLEMENTATION OF SAMPLING PROTOCOL

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INGAMELL’S TEST
SUB SAMPLING IN A LABORATORY
Ingamells test

Keep the position (X, Y) for every analysis and put it into a graphic.
STATISTICAL ANALYSIS FOR THE TEST

Head flotation plant SAG circuit, Andina Division

Sampling plus analytical error Cu %

Test portion [g]

- X + 2 S
- X - 2 S
- X prom.
- Mode

WCSB5 SAMPLING 2011
5ª Conferencia Mundial de Muestreo y Mezclas
25 - 28 de octubre 2011. Santiago, Chile
IMPLEMENTATION OF SAMPLING PROTOCOL

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SAMPLING AND CHEMICAL ANALYSIS OF COPPER CATHODES
The correct sampling of copper cathodes is a profound issue in the copper industry, worldwide. The determination of various impurity contents has vast economic consequences for the copper cathode producers, and especially for the copper cathode users. F.Pitard (2002)

It is necessary to perform experiments to better understand variability within cathodes, between cathodes, and between processing units.
STRATIFIED RANDOM SAMPLING

Figura 2. Ilustración de la selección correcta de las 9 ubicaciones de perforación utilizando un modo de muestreo aleatorio estratificado.
PRESERVING SAMPLE INTEGRITY

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STANDARD CONDITIONS TO FULFILL DURING SUBSAMPLING OPERATIONS AT THE LABORATORY
PREVENTION OF ANALYTICAL ERROR

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PREPARATION AND OBTENTION OF REFERENCE MATERIALS
When using Atomic Absorption methods or other non absolute methods, the final outcome corresponds just to a recommended value.

The certified value has to be obtained through a procedure where the result is a value obtained from direct measurement of a relevant parameter, traceable to a fundamental unit in the International Unit System (SI).
ABSOLUTE METHOD COPPER

ABSOLUTE METHOD MOLYBDENUM

ABSOLUTE METHOD ARSENIC
### ESPECIFICACIONES

<table>
<thead>
<tr>
<th></th>
<th>Cu %</th>
<th>ELECTRO</th>
<th>Mo %</th>
<th>FOTOMETRÍA</th>
<th>As %</th>
<th>FOTOMETRÍA</th>
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<tbody>
<tr>
<td>PROMEDIO</td>
<td>0.299</td>
<td>0.705</td>
<td>0.0061</td>
<td>0.0063</td>
<td>0.0327</td>
<td>0.0349</td>
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<tr>
<td>S</td>
<td>0.0067</td>
<td>0.0006</td>
<td></td>
<td></td>
<td>0.0009</td>
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<tr>
<td>CV</td>
<td>1.0%</td>
<td>10.35</td>
<td>2.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2S</td>
<td>0.013</td>
<td>0.0013</td>
<td></td>
<td>0.0017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3S</td>
<td>0.020</td>
<td>0.0019</td>
<td></td>
<td>0.0026</td>
<td></td>
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</tr>
</tbody>
</table>

|        |       |         |       |            |       |            |
| ES + 2S | 0.718 | 0.0076  | 0.0366|
| EI - 2S | 0.692 | 0.0050  | 0.0331|
| ES + 3S | 0.725 | 0.0082  | 0.0374|
| EI - 3S | 0.685 | 0.0044  | 0.0322|

|        | 0.8% | -3.2%  | -6.3% |

### MREP DAN STD _ 3 COBRE

- CuT
- Cu electrogravime
- VR +2S
- VR -2S
- VR +3S
- VR - 3S
- V O
QUANTIFICATION OF ANALYTICAL ERROR

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VERIFICATION OF CHEMICAL ANALYSIS RESULTS FOR MINERALS

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QUALITY ASSURANCE IN PREPARATION OF MINERAL SAMPLES FOR CHEMICAL ANALYSIS
<table>
<thead>
<tr>
<th></th>
<th>Cu A %</th>
<th>Cu B %</th>
<th>Dif. Cu (A - B) %</th>
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<tbody>
<tr>
<td><strong>PROMEDIO</strong></td>
<td>0,4534</td>
<td>0,4538</td>
<td>-0,0004</td>
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<tr>
<td><strong>VARIANZA</strong></td>
<td>0,240</td>
<td>0,244</td>
<td>0,000092</td>
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<tr>
<td><strong>DESVIACION ESTANDAR ±</strong></td>
<td>0,490</td>
<td>0,493</td>
<td>0,0068</td>
</tr>
<tr>
<td><strong>DATOS</strong></td>
<td>410</td>
<td>410</td>
<td>410</td>
</tr>
<tr>
<td><strong>ERROR MEDIO ±</strong></td>
<td></td>
<td></td>
<td>0,00034</td>
</tr>
<tr>
<td><strong>T</strong></td>
<td></td>
<td></td>
<td>-1,07</td>
</tr>
<tr>
<td><strong>CV %</strong></td>
<td></td>
<td></td>
<td>1,50</td>
</tr>
<tr>
<td><strong>% ERROR SESGO</strong></td>
<td></td>
<td></td>
<td>-0,08</td>
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</tbody>
</table>
WEIGHTING ERROR

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STANDARD CONDITIONS OF WEIGHTING SYSTEMS FOR CONVEYOR BELTS FOR METALLURGICAL BALANCE AND TRANSFER OF MATERIALS
The application of standards and best practice guides, enable quality assurance of data for resource estimation, grade control, metallurgical balance and commercial transactions.

The Quality Assurance Analytical information is essential for the development of projects in the copper industry, the correct sampling and analysis practices give a huge benefit because they eliminate hidden losses and maximize the available resources.

The use of standards help to maximize long-term economic value of the Corporation, allow the company to maintain excellence in everything we do and the practice of continuous improvement, makes us a world leader in the copper industry.
PEDRO CARRASCO MENTOR OF STANDARDS AND BEST PRACTICE GUIDELINES

Muchas Gracias