Building a Geometallurgical Model for Early-Stage Project Development – A Case Study from the Canahuire Epithermal Au-Cu-Ag Deposit, Southern Peru

Canahuire Geometallurgy - The Players
Towards a geometallurgical model

A team and interdisciplinary approach
Canahuire Geometallurgy - The objective

Objectives

- No surprises from the beginning
- It’s all about knowing the deposit (ore and waste) and “unlocking the picture”
- Establishing a team culture. Until now no resistance and program well accepted

Canahuire Geometallurgy - The construction

Agenda

- Geological setting
- Domaining
- Sampling
- Variability metallurgical testwork
- Mineralogy and Geochemistry
  - Au deportment
- Step forward
- Conclusions
Chucapaca Project – Location and Regional Geology

Epithermal deposits range from Oligocene to Pliocene in age and include HS, IS and LS styles.

SIMPLIFIED STRATIGRAPHY
- Glacier
- Late Miocene - Recent volcanic rocks
- Plio-Pleistocene sediments
- Miocene volcanic rocks (undifferentiated)
- Miocene sedimentary rocks
- Paleogene volcanic rocks
- Paleogene sedimentary rocks
- Cenozoic sedimentary rocks
- Jurassic marginal basin volcanic-sedimentary rocks
- Jurassic intermediate lavas and volcaniclastic rocks
- Jurassic sedimentary rocks (undifferentiated)
- Jurassic intermediate lavas and volcaniclastic rocks

Chucapaca Project – Deposit Geology

Lithology

Legend:
- Lithology
- Structural lines
- Drilled holes
- Air photo lines

Map showing deposit geology with various lithological units and structural features.
**Chucapaca Project - Deposit Geology**

**Alteration**

- Au-Cu-(Ag) intermediate sulphidation epithermal mineralisation
- Hosted mainly in limestones (replacement) but also in breccias (matrix replacement and cavity infill)
Chucapaca Project - Geometallurgy

Sampling
- Since only few metallurgical tests were available, geological domains were used for variability sampling
- Geological domains considered:
  - Rock types
  - Alteration
  - Grade

<table>
<thead>
<tr>
<th>Domain BX Au-Cu</th>
<th>Domain 50% Au</th>
<th>Domain 50% Cu</th>
<th>Domain 50% Ag</th>
</tr>
</thead>
<tbody>
<tr>
<td>BX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Au</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alteration</th>
<th>BXP</th>
<th>CAL</th>
<th>SED</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SID</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mineralisation</th>
<th>AX high/Cu high</th>
<th>AX high/Cu low</th>
<th>AX high/Au high</th>
<th>AX high/Au low</th>
</tr>
</thead>
<tbody>
<tr>
<td>AX high/Cu high</td>
<td>AX high/Cu low</td>
<td>AX high/Cu high</td>
<td>AX high/Au low</td>
<td>AX high/Au high</td>
</tr>
</tbody>
</table>

After Hoal, 2008

Knowing the orebody

Canahuire - Domaining

Location of domain BX Au-Cu

22 samples

Looking North
Canahuire - Domaining
Location of domain CAL Au

23 samples

Looking North

Canahuire - Domaining
Location of domain SED Au

6 samples

Looking North
**Chucapaca Project – Deposit Mineralisation**

Mineralisation hosted in breccias and replacing limestones

- **BXP**, **BXM**, **BXPS**
- **CAL replacement**
- **CAL veins**

**Domain BX Au-Cu**

**Domain CAL Au**

**Domain SED Au**

---

**Samples selected**

- Spatial distribution of the 51 variability samples shown – good spatial distribution

Looking North
The objective was to obtain Au recoveries from the different domains:

- Final flow sheet consisted of flotation and CIL on flotation tails which was, at the time, the final flow sheet.
- High "metallurgical" variability of the ore throughout the deposit apparently independent of host rock, alteration, grade and thus domains.

**Need to understand the Au recovery variability**

**Chucapaca Project - Gold losses**

Metallurgical issues

Why do we have such a large variability in the metallurgical responses?

- Several CIL tails still have between 0.8 - 1g/t Au. Encapsulated and/or submicroscopic gold?
- Samples with low recoveries have largely encapsulated gold?
- Presence or sub-microscopic gold?
- Other?

**Gold deportment study**

**Au deportment study key to understand gold losses**
**Chucapaca Project – Gold losses**

**Au deportment**

- Liberated gold and encapsulated gold in arsenopyrite
- Presence of free gold in CIL tails as well as gold encapsulated in arsenopyrite (limited in pyrite and other sulphides). Some of the gold is not recovered by CIL but might be recovered by gravity
- When gold is encapsulated, it occurs as small grains < 10 μm
- Free gold (or liberated) ranges between 15 and 150 μm
- Presence of sub-microscopic gold mainly in arsenopyrite (pyrite and marcasite contain low contents of Au). Up to 51 ppm Au

---

**Chucapaca Project – Geometallurgy**

**Mineralogy understanding**

- Detailed mineralogy throughout the deposit and on the 51 variability samples
  - Optical mineralogy
  - Quantitative mineralogy (MLA/QemScan and assay recalculation) for 51 samples

---
• High mineralogical variability of the ore throughout the deposit apparently independent of host rock, alteration, or grade.

Mineralogy at Canahuire is divided in two stages:

• An early stage composed pyrrhotite, arsenopyrite, chalcopyrite, wolframite, sphalerite, Bi sulphosalts, quartz and later replaced by marcasite, pyrite, magnetite, and siderite.

• A main stage composed of gold, pyrite, marcasite, arsenopyrite, chalcopyrite, sulphosalts, siderite, and quartz. The main stage replaces the first stage.

Variability in mineralogy is explained by the fact that in both stages, and thus within domains, the mineralogy is similar and varies locally.

Characterization of domains by mineralogy is difficult.

Similar mineralogy throughout the mineralized zone.
Calculation of mineralogy from assays - siderite

Siderite abundance calculated with adjustment for Fe in pyrite and addition of Mn for rhodochrosite.

May be used to estimate quantitatively from 50,000 samples and estimate in the block model data to CN consumption for example.

Calculation of mineralogy from assays - pyrite

Quantitative determination of mineral abundances for the AR soluble minerals pyrite and siderite confirmed by MLA.

Pyrite abundance may be calculated with adjustment for Fe in siderite (using molar C) and asp, and S corrected for asp.
Calculation of mineralogy from assays - pyrite

Quantitative determination of pyrite may be estimated in the block model data for acid generation.

Canahuire mineralogy - geochemistry

Are the 51 variability metallurgical samples representative?

Met samples cover chemical variability (as shown by PCA of the AR variables) – coloured dots on PCA 1 – PCA 2 (greyed out background)
Challenge to find a direct determination of the location and the proportion of liberated or encapsulated gold. Potential proxies:

- Total sulphur provides a partial proxy for encapsulated gold.
- Try to recalculate the content of arsenopyrite throughout the deposit using assays.
- Amount of siderite and quartz may be used as proxy by which high amounts would favour the presence of liberated gold.
- Currently, the metallurgical responses are used with caution. Some low recoveries contain low total S contents and should theoretically return higher recoveries. Artefact due to the lack of gravity in test work.
- With the findings, build different domains: Au recovery, waste rock, CN consumption, ...

**Proxies**

---

Modify the current domains using the established proxies (Total S and alteration)
- Additional targeted variability samples in order to confirm modified domaining
Chucapaca Project - Geometallurgy

Conclusions

• Challenging deposit due to early stage

• High variability of metallurgical responses within geological domains due to:
  • Met test work not optimum, missing gravity circuit
  • It’s gold!

• Data interpretation shows that recoveries depend on Au head grade, but also on arsenopyrite, pyrite, siderite content...

• The principal causes of gold losses identified:
  • Encapsulated gold mainly in arsenopyrite
  • Sub-microscopic gold present in arsenopyrite

• Au deportment is key in geometallurgy in gold deposits. Downside: costly and time consuming. Critical and should be conducted in early stages

• Currently working on identification of geometallurgical domains which will be characterized by parameters having an impact on metallurgical responses

Thanks