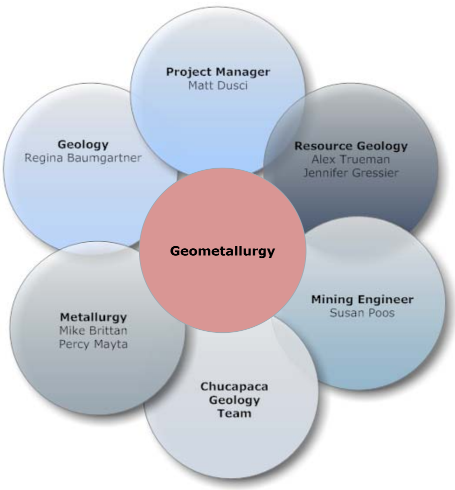
Chucapaca Project

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

GOLD FIELDS

Canahuire Geometallurgy – The Players

Towards a geometallurgical model



A team and interdisciplinary approach

GOLD FIELDS

2

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

GOLD FIELDS

Canahuire Geometallurgy – The construction

Agenda

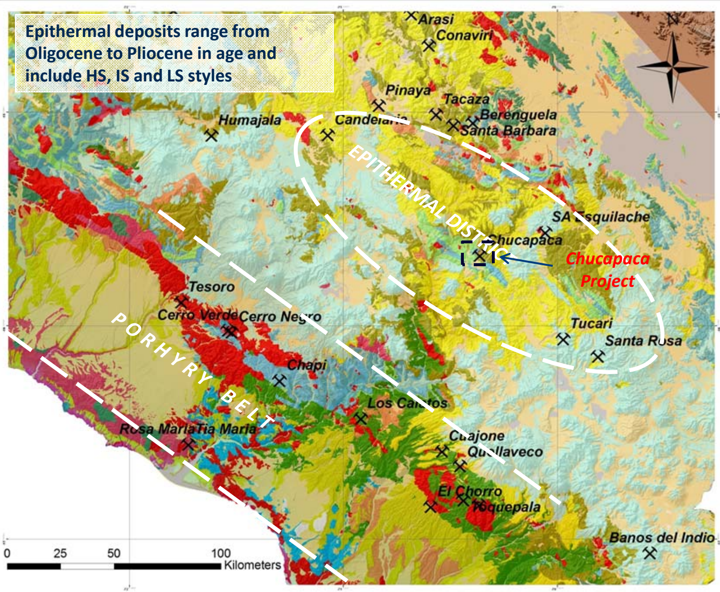
- Geological setting
- Domaining
- Sampling
- Variability metallurgical testwork
- Mineralogy and Geochemistry
  - Au deportment
- Step forward
- Conclusions

GOLD FIELDS

Chucapaca Project – Location and Regional Geology

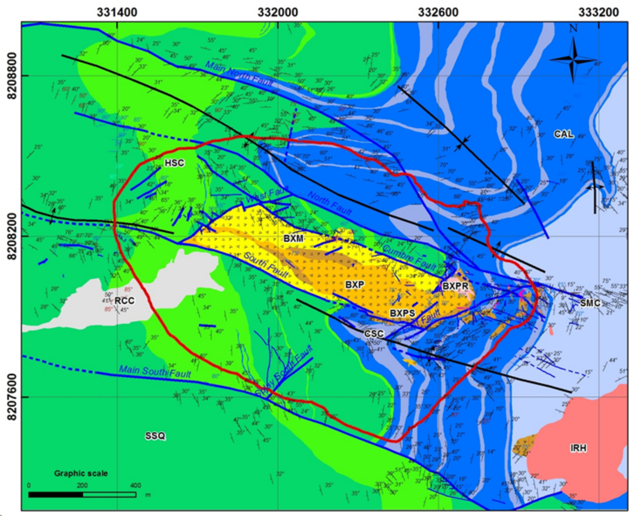
SIMPLIFIED STRATIGRAPHY

- Glacier
- Lake
- Quaternary superficial deposits
- Late Miocene - Recent volcanic rocks
- Plio - Pleistocene sediments
- Miocene volcanic rocks (undifferentiated)
- Miocene sedimentary deposits
- Paleogene volcanic rocks
- Paleogene sedimentary rocks
- Cenozoic volcanic rocks (undiff)
- Cretaceous sedimentary rocks
- Cretaceous arc volcanics
- Cretaceous marginal basin volcano-sedimentary rocks
- Jurassic sedimentary rocks
- Jurassic intermediate lavas and volcaniclastic rocks
- Mesozoic sedimentary rocks (undiff)
- Mesozoic marginal basin volcanic and sedimentary rocks
- Paleozoic rocks
- Precambrian basement
- Granitoid - Dioritoid - Gabbroid



Chucapaca Project – Deposit Geology

Lithology



LEGEND

Lithology
- RCC - Colluvial (Quaternary)
- Tuffisite dykes
- BXP - Polymictic breccia with juvenile clast
- BXPR - Polymictic breccia with rhyolite clast
- BXM - Monomictic breccia
- BXPS - Polymictic sedimentary clast
- IRH - Rhyolite (Dyke /Dome)
- SSQ - Quartz sandstone (Hualhuani Fm.)
- HSC - Sandstone and shale (Hualhuani Fm.)
- CAL - Limestone (Gramadal Fm.)
- CSC - Sandstone and shale (Gramadal Fm.)
- SMC - Sandstone and shale (Labra Fm.)

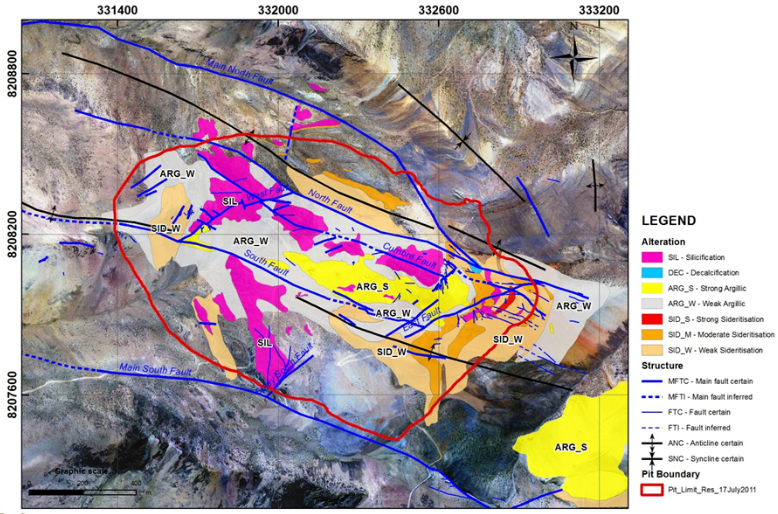
Azimuth/Dip
- BD - Bedding
- FT - Fault
- ST - Structure
- CN - Contact
- FB - Flow Banding

Structure
- MFTC - Main fault certain
- MFTI - Main fault inferred
- FTC - Fault certain
- FTI - Fault inferred
- ANC - Anticline certain
- SNC - Syncline certain

Pit Boundary
- Pit_Limit_Res_17July2011

Chucapaca Project – Deposit Geology

Alteration



GOLD FIELDS

Chucapaca Project – Deposit Geology

Mineralization

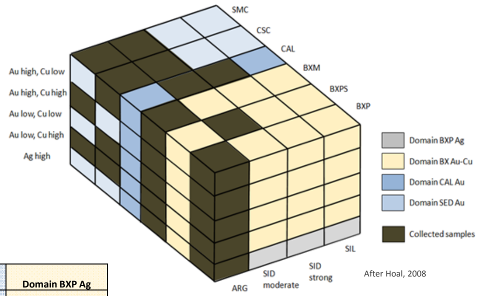
- Au-Cu-(Ag) intermediate sulphidation epithermal mineralisation
- Hosted mainly in limestones (replacement) but also in breccias (matrix replacement and cavity infill)

GOLD FIELDS

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



After Hoal, 2008

	Domain BX Au-Cu	Domain CAL Au	Domain SED Au	Domain BXP Ag
Lithology	BXP	CAL	CSC	BXP
	BXPS		SMC	
	BXM			
Alteration	ARG	SID strong	SID moderate	ARG
	SID moderate	SID moderate		
Mineralisation	Au low/Cu low	Au low/Cu low	Au low/Cu low	Au low/Cu low
	Au low/Cu high	Au high/Cu high	Au low/Cu high	Au low/Cu high
	Au high/Cu high	Au high/Cu low	Au high/Cu high	Au high/Cu high
	Au high/Cu low		Au high/Cu low	Au high/Cu low

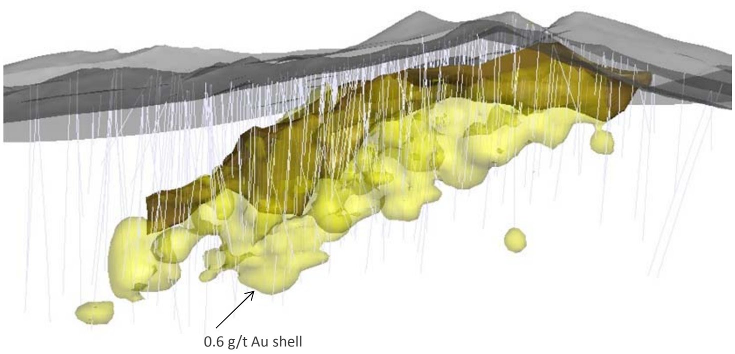
GOLD FIELDS

Knowing the orebody

Canahuire – Domaining

Location of domain BX Au-Cu

22 samples



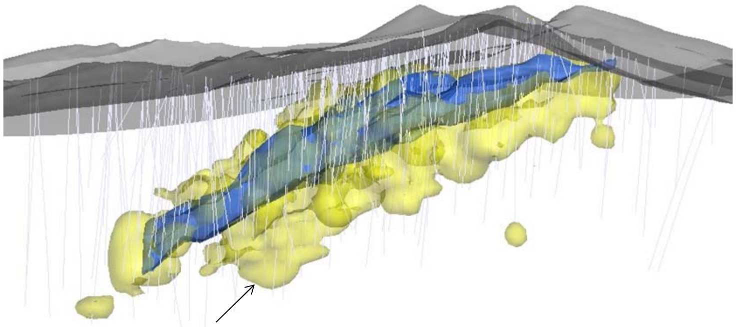
GOLD FIELDS

Looking North

Canahuire – Domaining

Location of domain CAL Au

23 samples



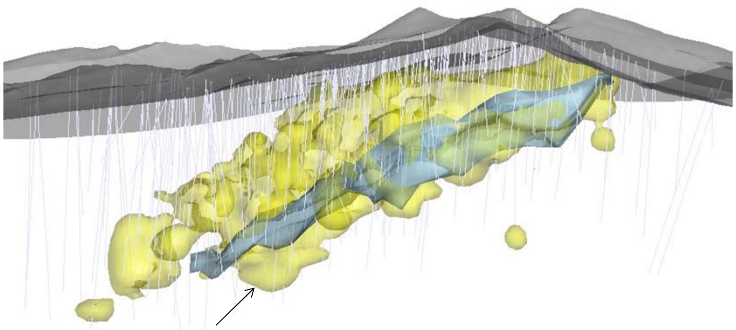
Looking North

GOLD FIELDS

Canahuire – Domaining

Location of domain SED Au

6 samples

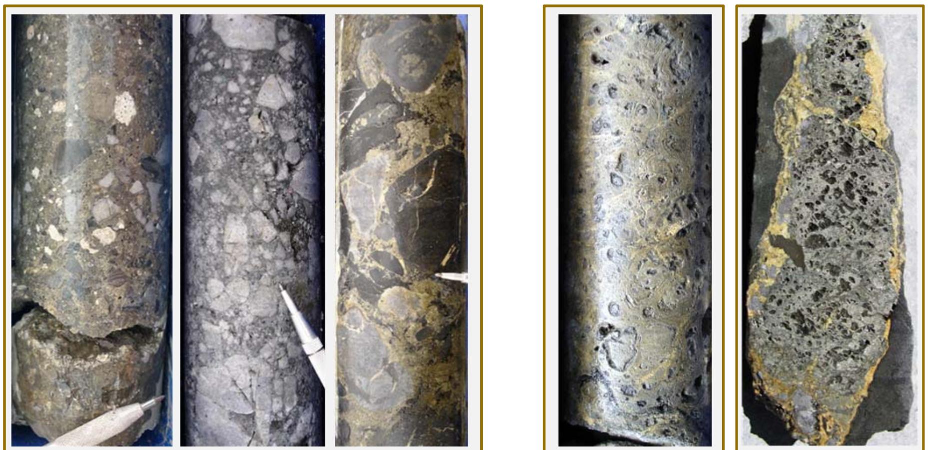


Looking North

GOLD FIELDS

Chucapaca Project – Deposit Mineralisation

Mineralisation hosted in breccias and replacing limestones



BXP BXM BXPS

CAL replacement

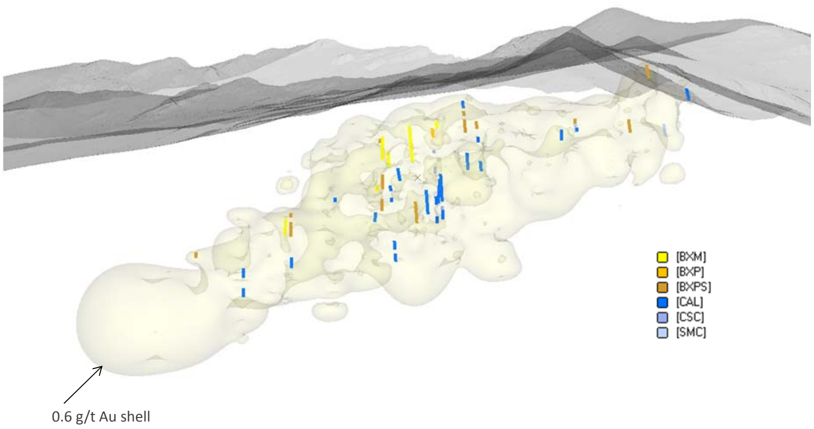
CAL veins

Domain BX Au-Cu **Domain CAL Au** **Domain SED Au**

GOLD FIELDS

Samples selected

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



Looking North

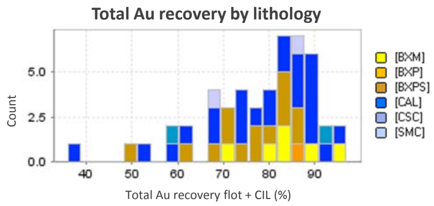
GOLD FIELDS

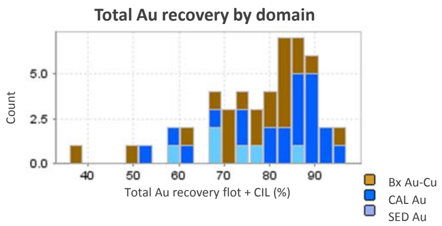
Chucapaca Project –Geometallurgy

Metallurgical variability testwork

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?

↓

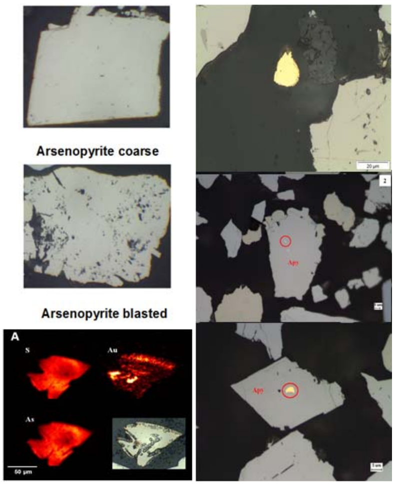
Gold deportment study

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



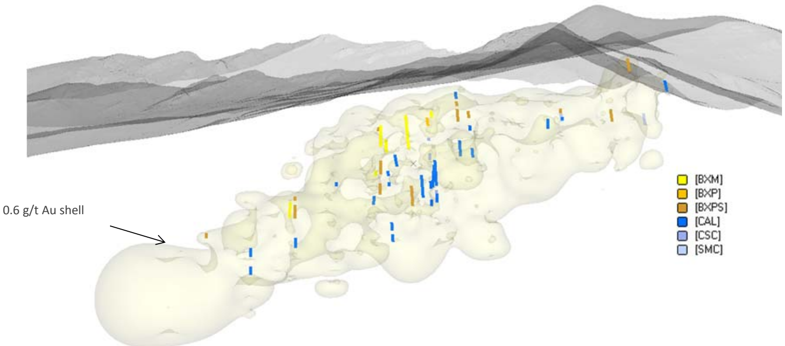
SIMS image

Where does spatially occur liberated and encapsulated gold?

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

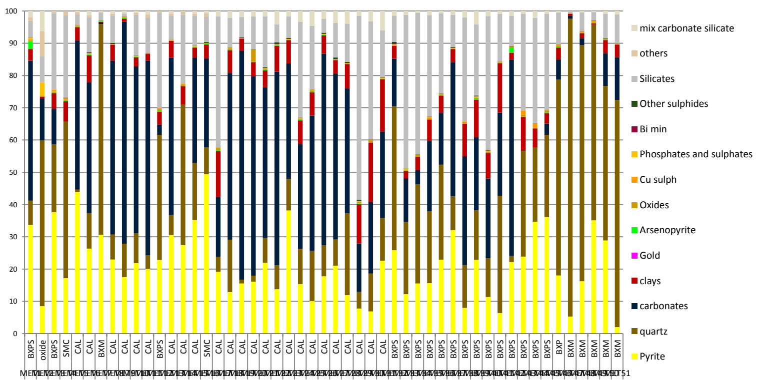


Looking north

Chucapaca Project –Geometallurgy

MLA Results

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



GOLD FIELDS

Chucapaca Project –Geometallurgy

Mineralogy variability

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

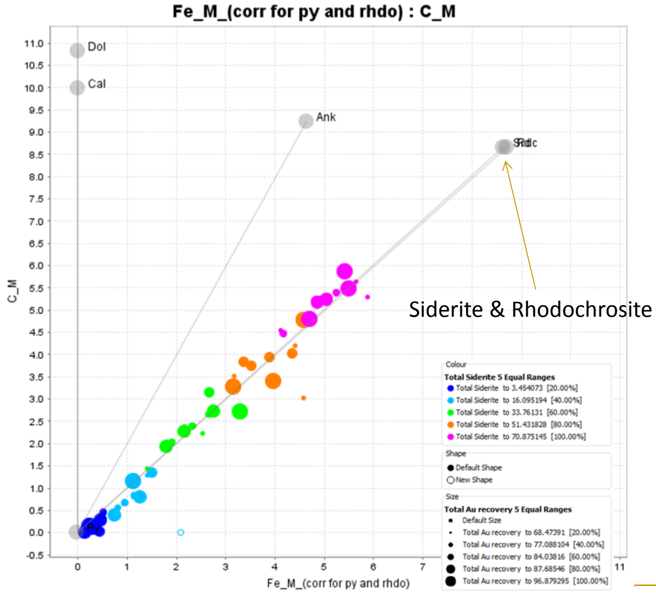
Variability in mineralogy is explained by the fact that in both stages, and thus within domains, the mineralogy is similar and varies locally.

Characterization of domains by mineralogy is difficult.

Similar mineralogy throughout the mineralized zone

GOLD FIELDS

Calculation of mineralogy from assays - siderite

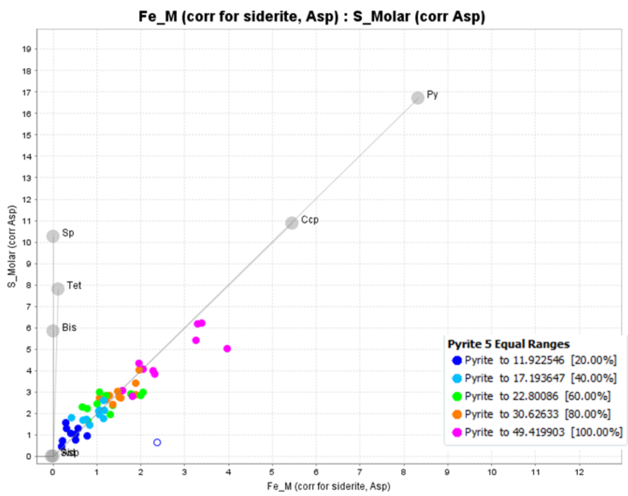


Siderite abundance calculated with adjustment for Fe in pyrite and addition of Mn for rhodochrosite

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

Chucapaca Project –Geometallurgy

Calculation of mineralogy from assays - pyrite



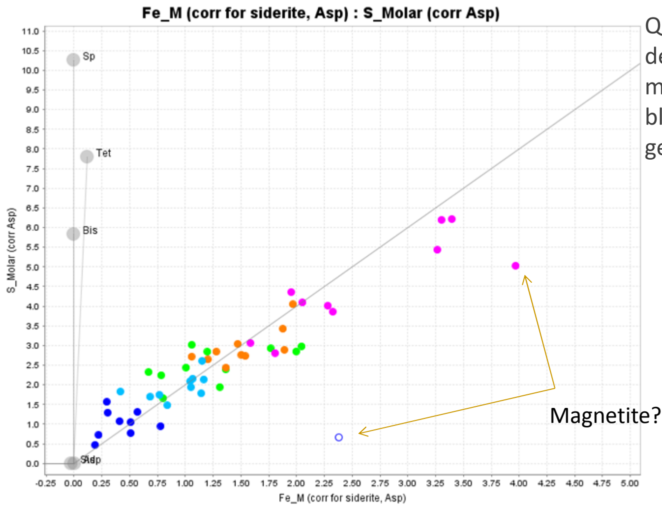
Quantitative determination of mineral abundances for the AR soluble minerals pyrite and siderite confirmed by MLA

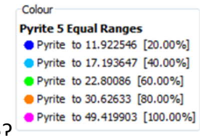
Pyrite abundance may be calculated with adjustment for Fe in siderite (using molar C) and asp, and S corrected for asp

n = 51

GOLD FIELDS

Calculation of mineralogy from assays - pyrite





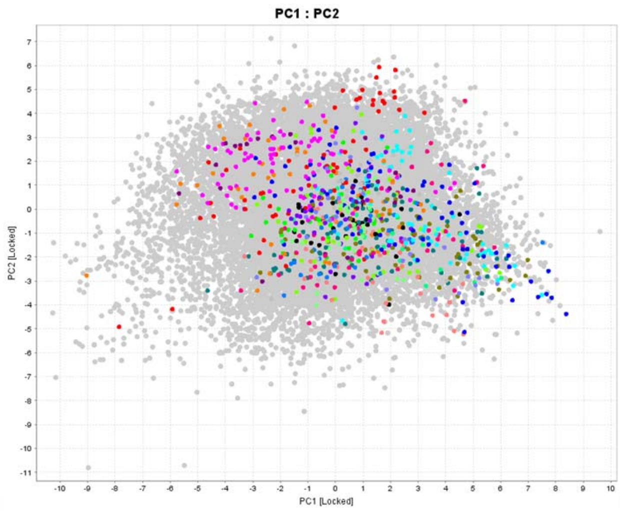
Quantitative determination of pyrite may be estimated in the block model data for acid generation

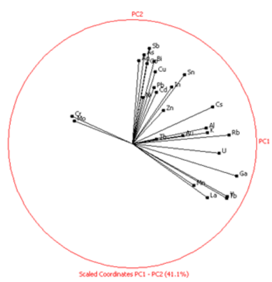
n = 51

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)





Chucapaca Project –The Next Step

Finding proxies and re-domaining?

Challenge to find a direct determination of the location and the proportion of liberated or encapsulated gold. Potential proxies:

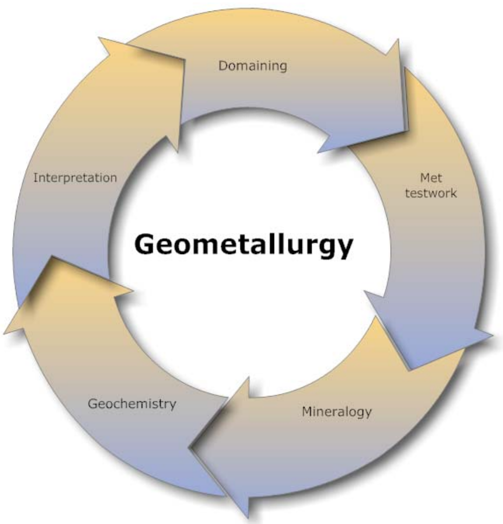
- Total sulphur provides a partial proxy for encapsulated gold.
- Try to recalculate the content of arsenopyrite throughout the deposit using assays.
- Amount of siderite and quartz may be used as proxy by which high amounts would favour the presence of liberated gold.
- Currently, the metallurgical 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

GOLD FIELDS

Chucapaca Project – summary

Wrap-up



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

GOLD FIELDS

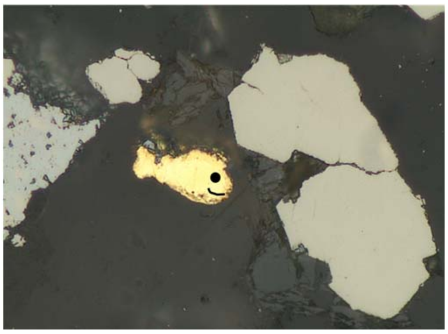
Chucapaca Project –Geometallurgy

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

GOLD FIELDS

Thanks



GOLD FIELDS