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GEOMETALLURGICAL VARIABLES ON MINE PLANS AT CDA

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Ago, 2013

CDA Location

Production at CDA

LX-SX-EW Plant

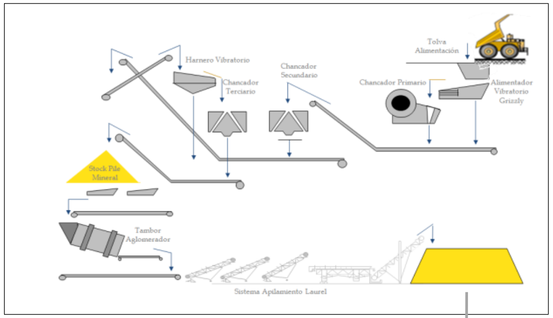
1996

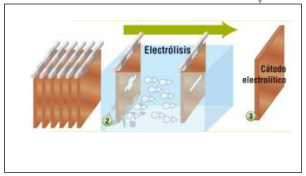
2014

Conc. Plant

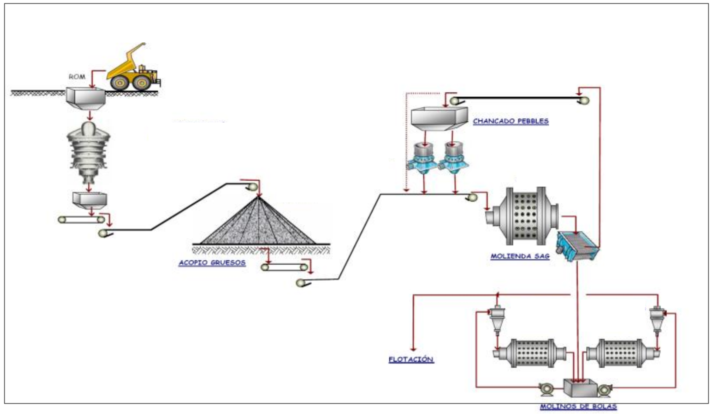
2010

2037





SX-EW



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Presentation Outline

- **Introduction : Operational issues and associated solutions**
- **CDA Case. Throughput variability example**
- **Geological and Resource Models**
- **DWi Modeling Path**
- **Mine Planning adjustment based on Geometallurgical Model. An Example.**

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Introduction: Operational issues

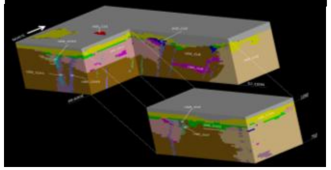
- Reconciliation of the Geological Model
- Assays (QA/QC)
- Grade Control and Ore Destination
- Production Reconciliation
- Availability and Utilization of Equipment
- Crusher Tph, Tpd
- SAG Tph, Tpd
- Recovery
- Concentrate Quality
- Filters
- Etc, etc…

Some Solutions

1. Increase our understanding of the Deposit

- Validate and intensify data collection process
- Applied Technology
- QA/QC

Validated Geologic Models



2. Use geological information in a broader mining context

- Geological Information in relation to the other mining components
- Geologist being cognizant:
  - ➢ Mine and Plant Processing (drilling, throughput, etc.)
  - ➢ Quality of the concentrate/final product

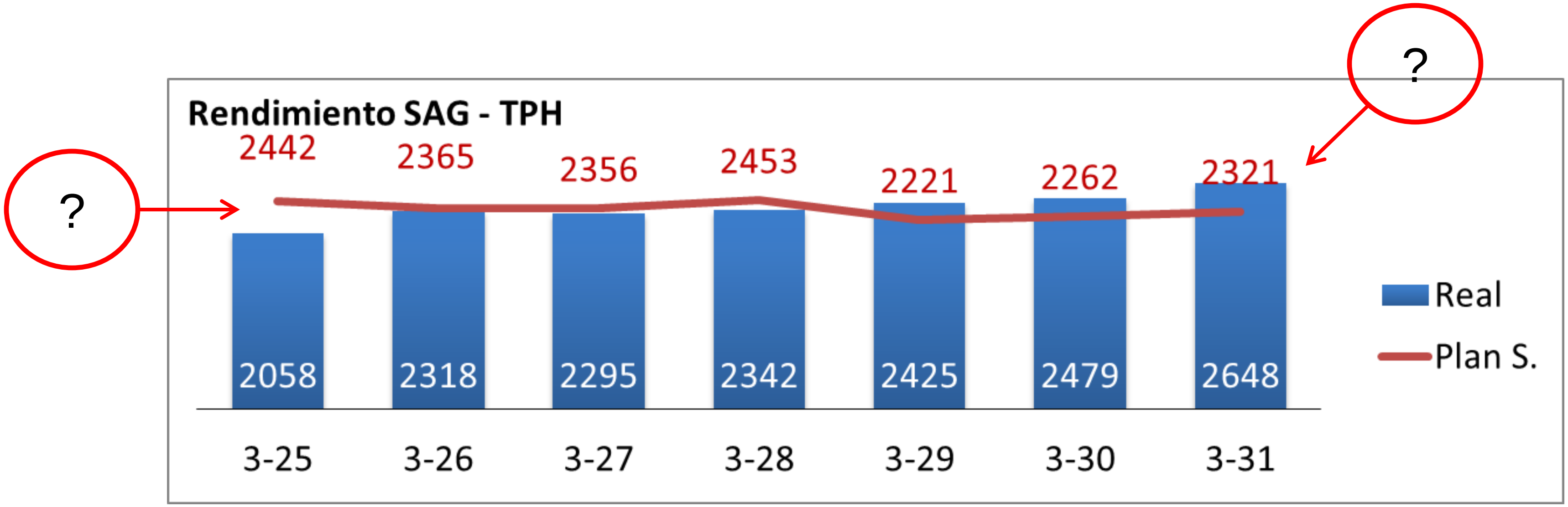
3. Teamwork

Mine Engineers
+ Metallurgist
+ Geologist

Throughput variability example



Tph:



…then, we went to look within our Block Model…

Geological and Resources Model

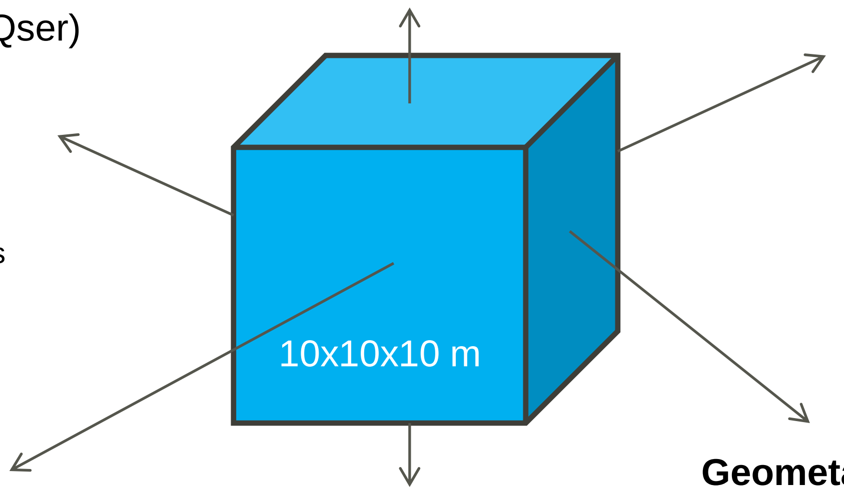


Into the CDA Block Model, each block has:

Geological Features:
- Structural Domains
- Lithology
- Dominant Alteration
- Secondary Alteration (%Qser)
- Mine Zone
  - Lx –Ox
  - Strong Enrichment
  - Weak Enrichment
  - Primary with Cavities
  - Primary without Cavities
- Sulfate Roof (SO_4)
- Carbonate Roof (CO_3)

Assays:
- Tcu
- Scu
- Hg
- Au
- Mo

Geotechnical Parameters:
- RQD
- FF
- RMR
- GSI
- PLT
- Uniaxial Compression
- Triaxial Compression
- Traction
- Corte Directo



Phisical Parameters:
- Specific Gravity
- Wave Velocity

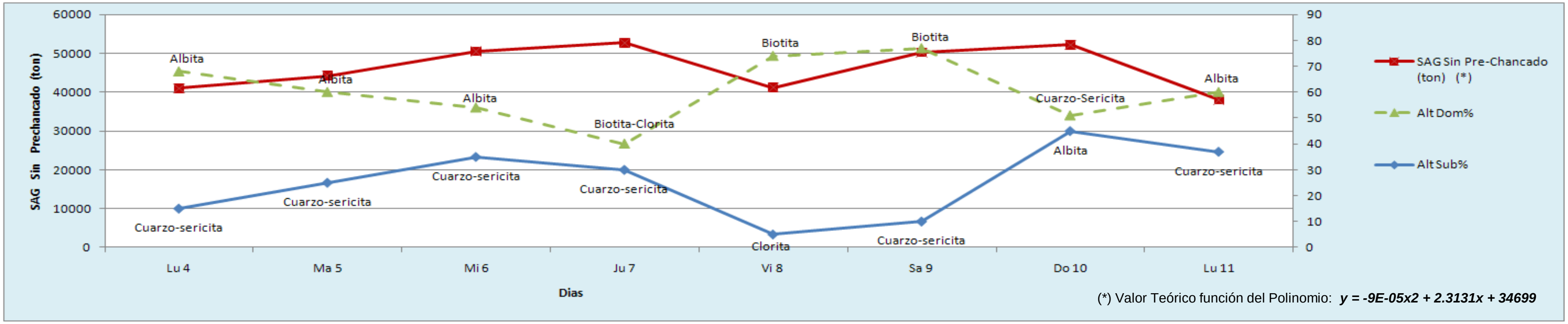
Working on:
- Hg mineralogical species
- Cpy, Py
- Leeb

Geometallurgical Parameters:
- Cu Rec
- Dwi
- BMWi

A geological explanation?



Alteration vs. throughput:



- Throughput variation was associated with the main alteration, but better with the secondary assemblage.

- Throughput variation correlates very well with the quartz-sericite alteration:

  ➔ Intense Qtz-Ser alteration = Higher throughput

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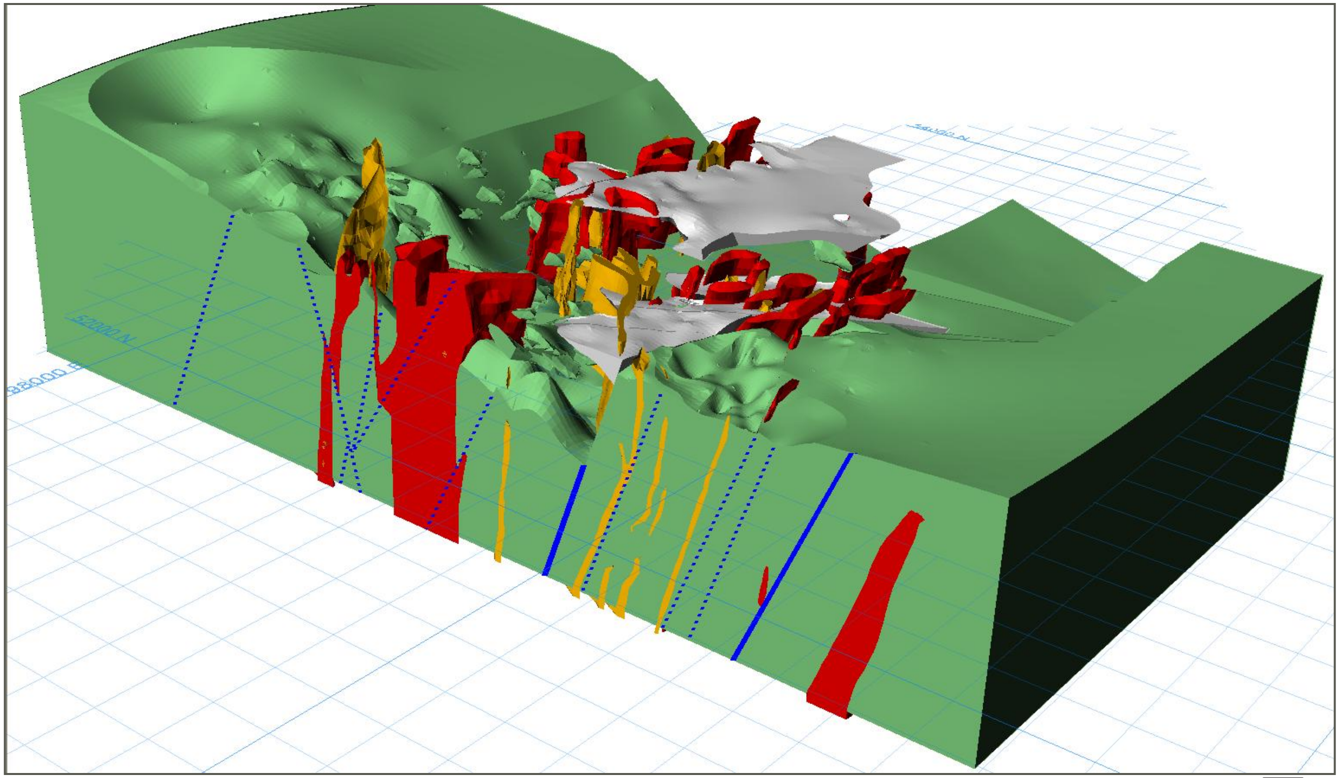
A geological explanation

- We later found that the throughput was not solely related to the alteration but also dependable of the rock type and mineralogical zone (Leach zone, Supergene zone, Hypogene zone and Sulphates Roof).



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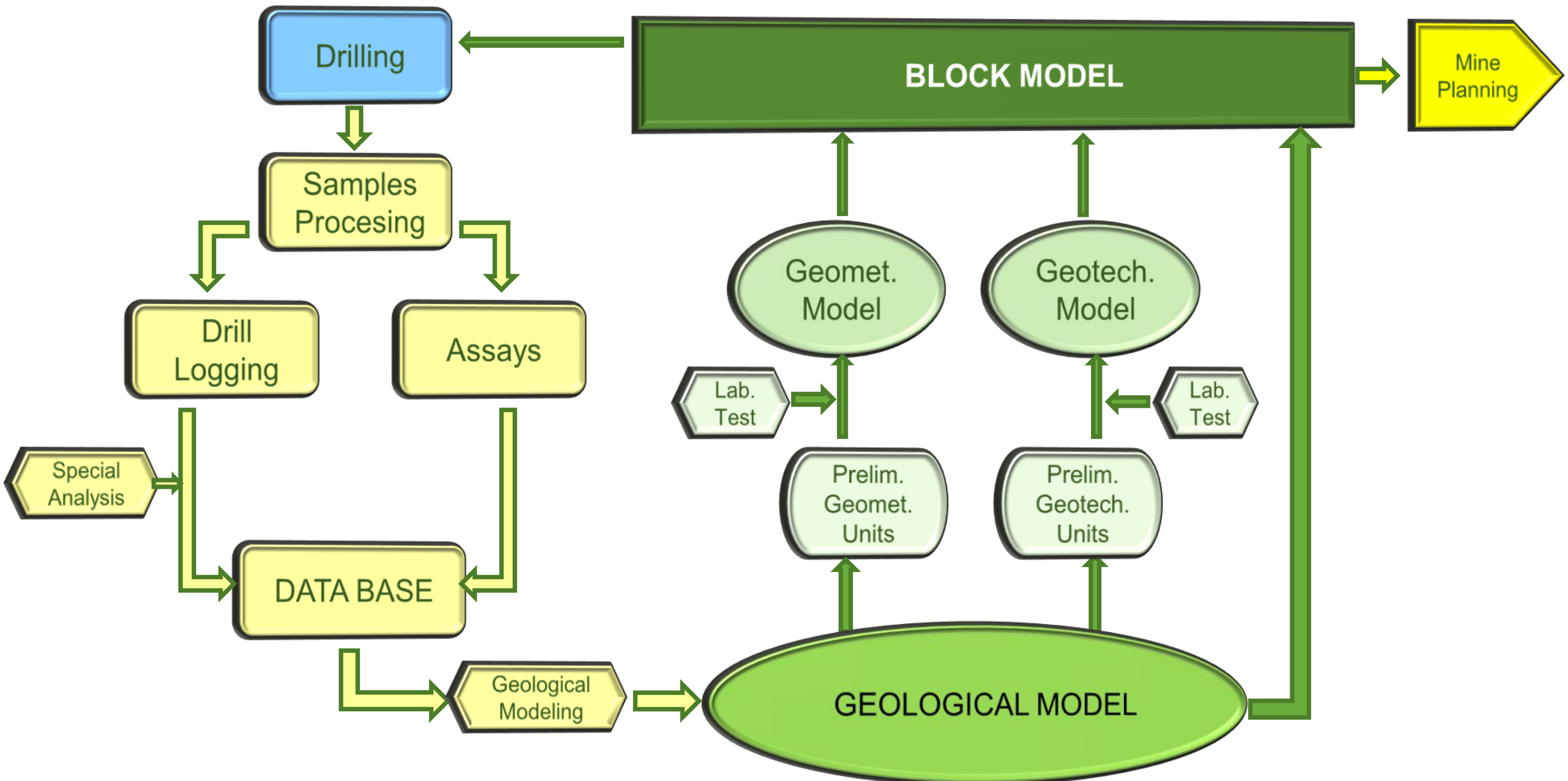
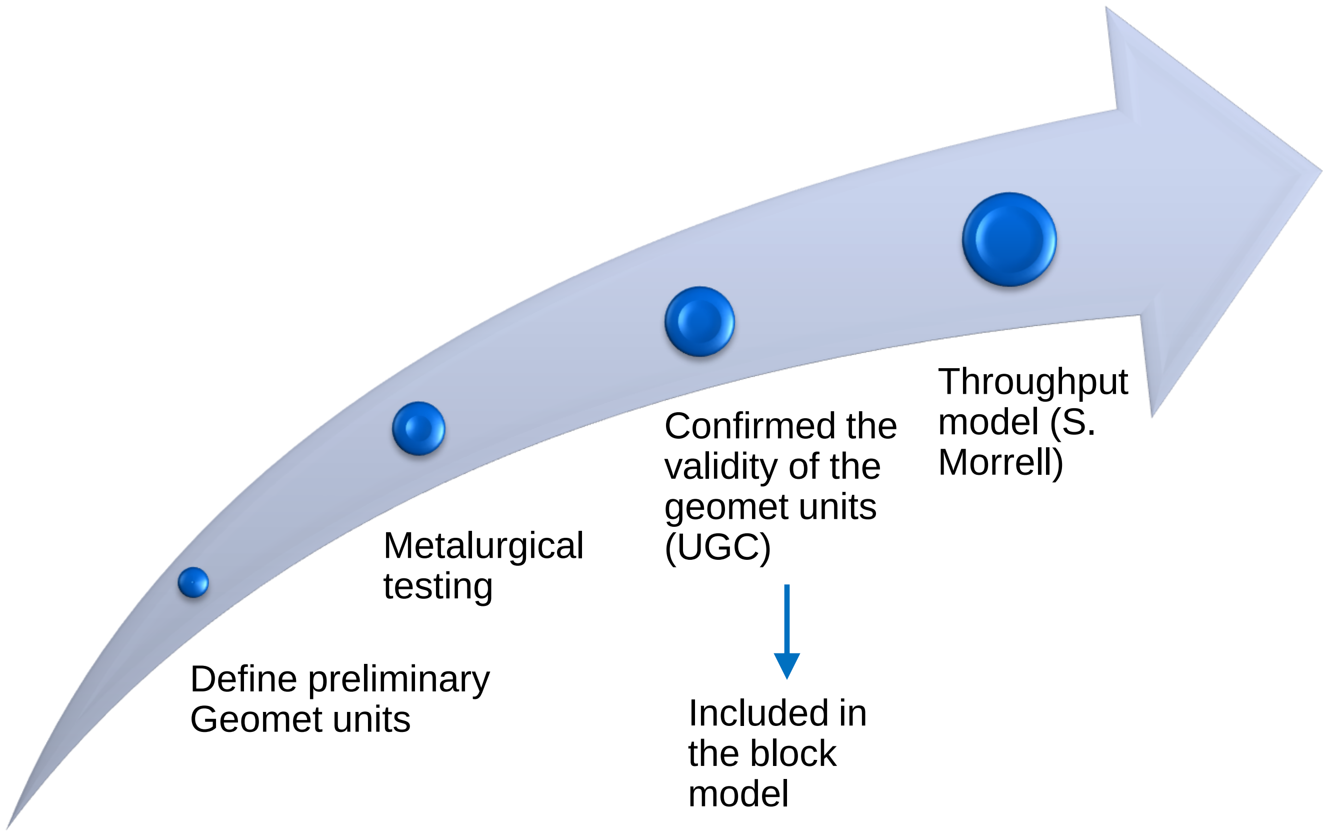
The drilling data in the context of the mining continuum



Comminution Modeling Path
(Comminution Geometallurgical Units) (UGC)





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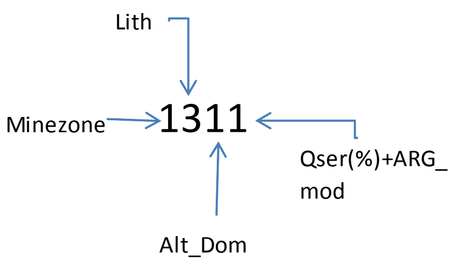
Preliminary UGC Definition



Outline key geological features that influence throughput to defined preliminary geomet units

UGC	Mine zone	Lith	Alt_Dom	qser (%)+ARG_mod	% en LOM2011
1000	PRIMS	All	All	All	7,9
1320	PRIMC	TBIND	BIO	All	1,33
1410		ANIND	ALB	All	2,76
1430			QSER	All	0,68
1331	PRIMC + ESEC2	TBIND	ALB	(qser (%)+ARG_mod)<10	24,92
1332				(qser (%)+ARG_mod)>=10	
1420		ANIND	BIO	All	47,84
1210		PFIND	ALB+BIO	All	5,17
2320	ESEC2	TBIND	BIO	All	0,43
3000	ESEC1	All	All	All	2,08
0500	All	BXH	All	All	0,63
				Total	**93,74**

DEFINICIÓN DE CÓDIGO:



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Metallurgical Testing



2010-2011

56 samples ½ HQ

JK RBT Lite (Axb estimated)

Bond Test (BMWi)

2011

80 samples HQ

SMC (Dwi, Axb)

Bond Test (BMWi)

2012

84 samples HQ

SMC (Dwi, Axb)

Bond Test (BMWi)

Previously (from the 2005-2006 program): 120 individual samples (SPI – Test Bond)

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Comminution Geometallurgical Units (UGC)



- Geomet units (UGC) results

Mine zone	Lith	Alt_Dom	qser (%)+ARG_mod	UGC	DWi (median)	Wi (median)
PRIMS	All	All	All	1000	10.13	16.00
PRIMC	TBIND	BIO	All	1320	8.62	13.40
	ANIND	ALB	All	1410	8.64	13.56
		QSER	All	1430	6.45	13.99
PRIMC + ESEC2	TBIND	ALB	qser<10%	1331	7.38	14.27
			qser>=10% y/o ARG_modelo	1332	5.53	12.19
	ANIND	BIO	All	1420	7.83	14.82
	PFIND	ALB+BIO	All	1210	7.99	13.25
ESEC2	TBIND	BIO	All	2320	6.70	12.79
ESEC1	All	All	All	3000	6.06	12.00
All	BXH	All	All	0500	4.94	12.48

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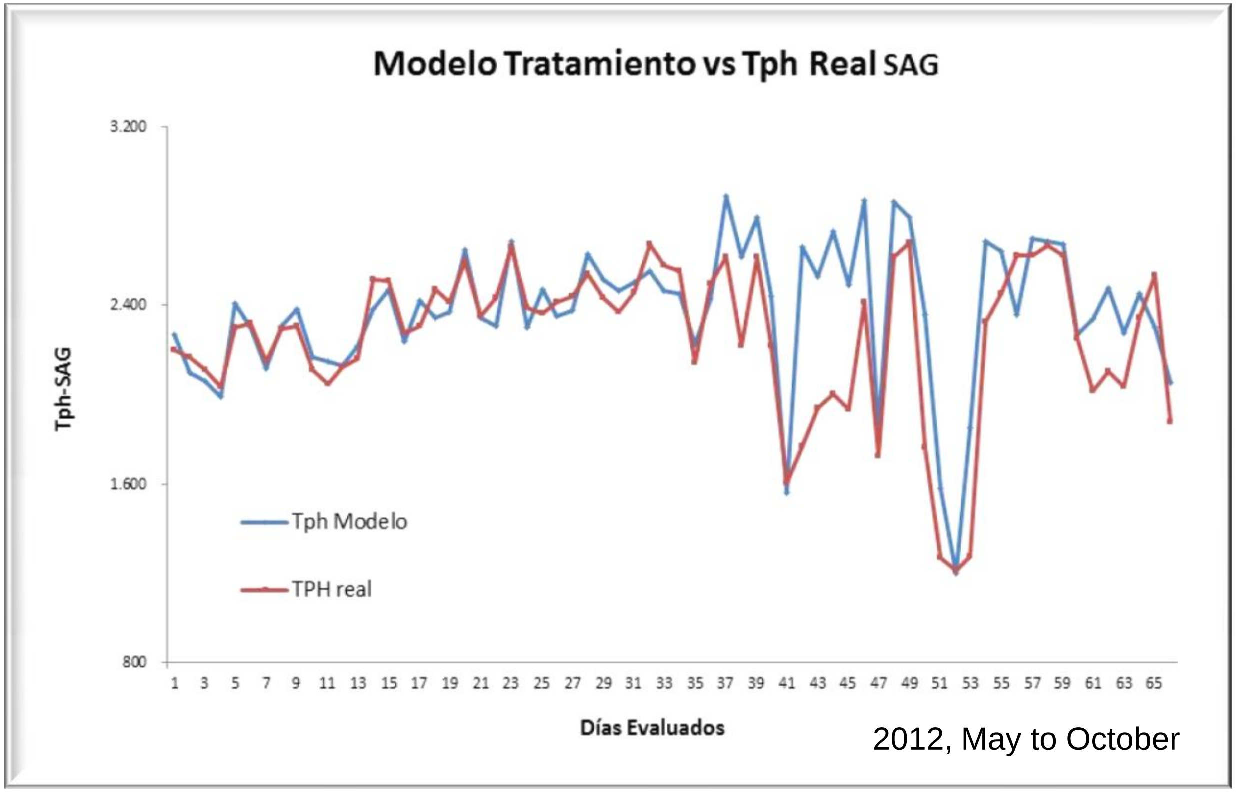
Operational Validation of the UGC



- Criteria for Analyses: SAG Utilization > 70% ; SAG > 1500 tph



Rel. Error = 9.3%
Corr. Coef. = 0.84

Real Media = 2,231 tph
Model Media= 2,339 tph

Tph Diff. = 108 tph

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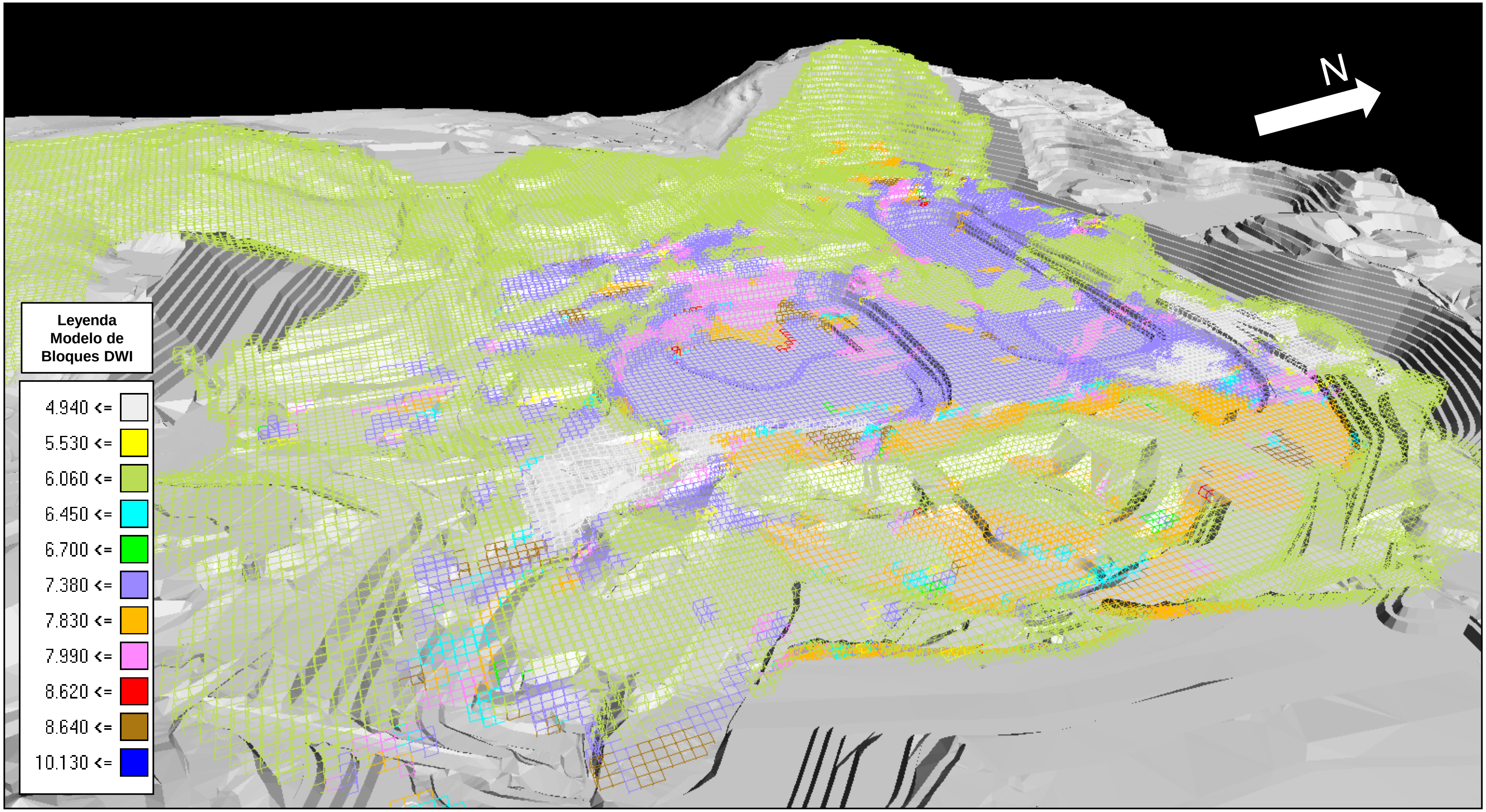
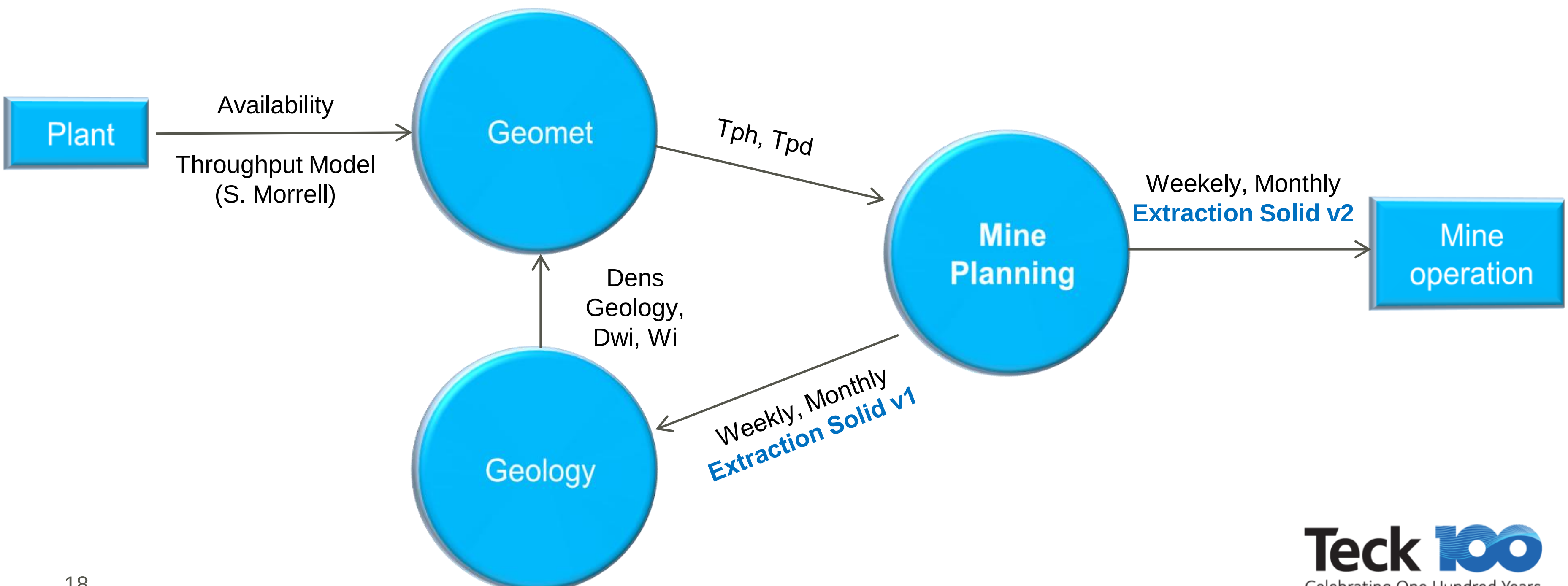
Dwi Block Model



Mine Planning adjustment based on Geometallurgical Model

CDA Geology, Metallurgy (Plant - P&D) and Mine Planning are working in a collaborative manner in order to formulate short term mine plans, based on the application of geometallurgical variables.



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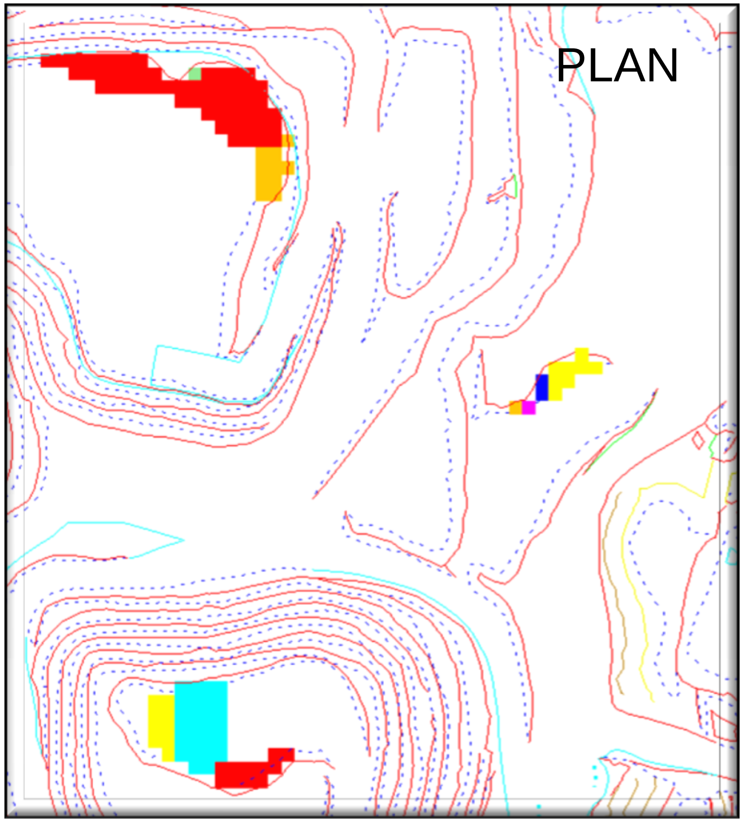
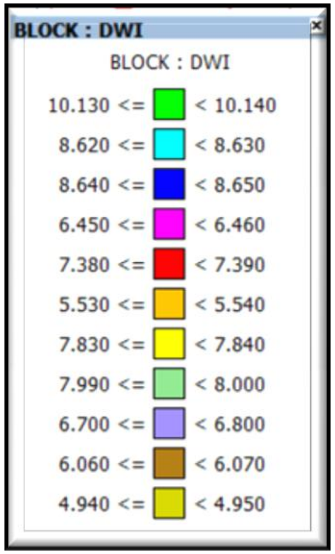
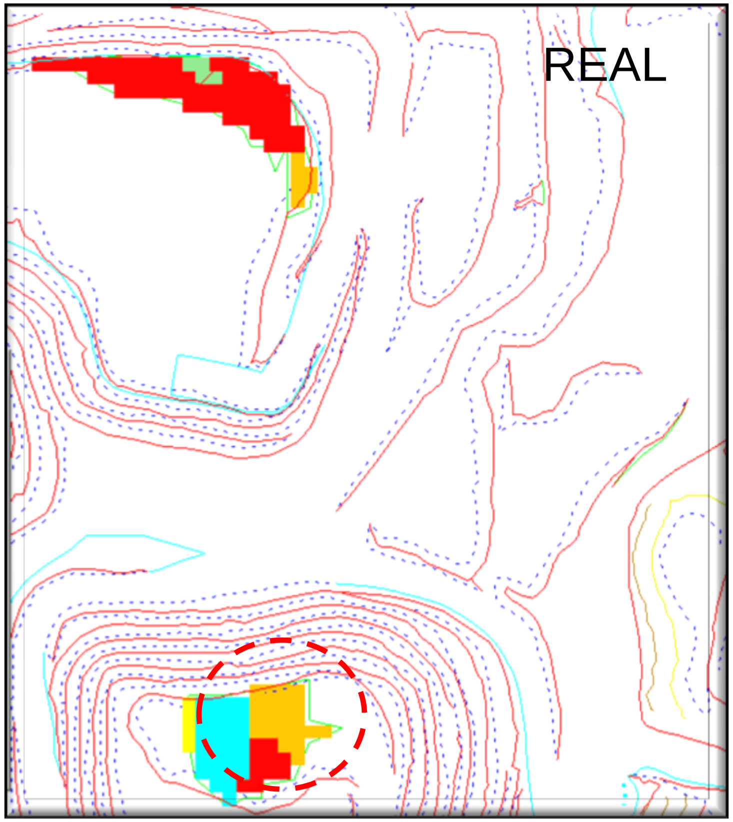
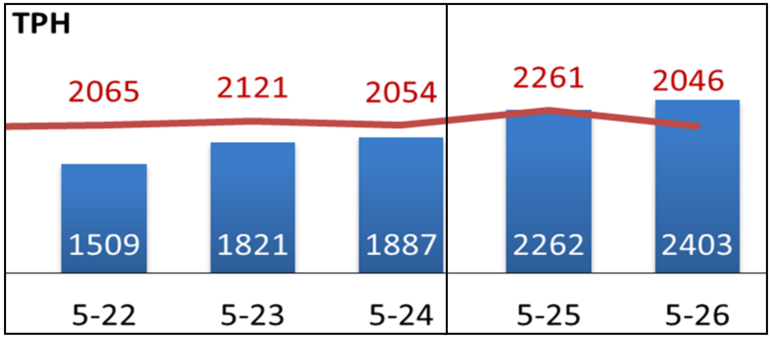
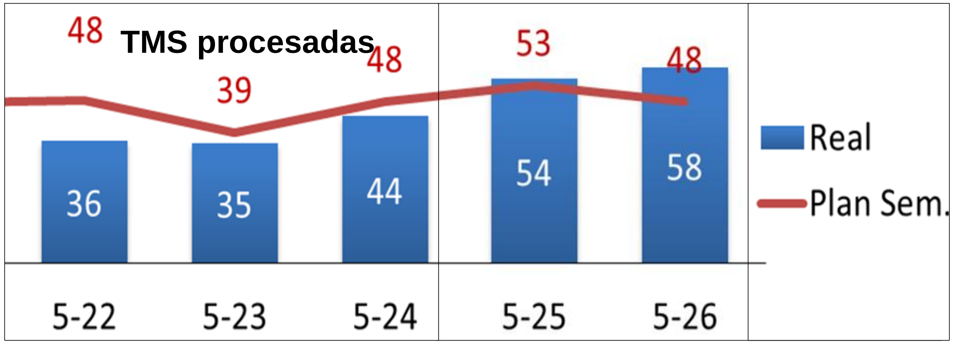
Example: Changes in Weekly Program to improve SAG throughput











Conclusiones



✓ Having a validated and available geometallurgical model is very useful for the stabilization and improvement of metallurgical processes.

✓The joint effort between Mine Planning, Geometallurgy and Geology is fundamental to optimize the mining programs.

✓For the construction of a Geometallurgical Model, preliminary units should be established so that they can undergo tests.

✓To validate these units they should be included in the Block Model. If the project is in operation, a reconciliation between the model vs what actually came out of the mine should be done.

✓An adequate geological model is necessary in the construction of any geometallurgical model.

Andacollo a Historical Mining Town

… Thank You

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BACK UP

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In-put to Throughput Model



Tph

Mineral

- Dwi (kWh/m³)
- BMWi (kWh/t)
- SG (t/m³)

Granulom. Profile

- P80 Chancado (µm)
- P80 Pre chancado (µm)

Equipment

- Potencia de molinos (kW)
- Disponibilidad (%)
- tph pre chancado

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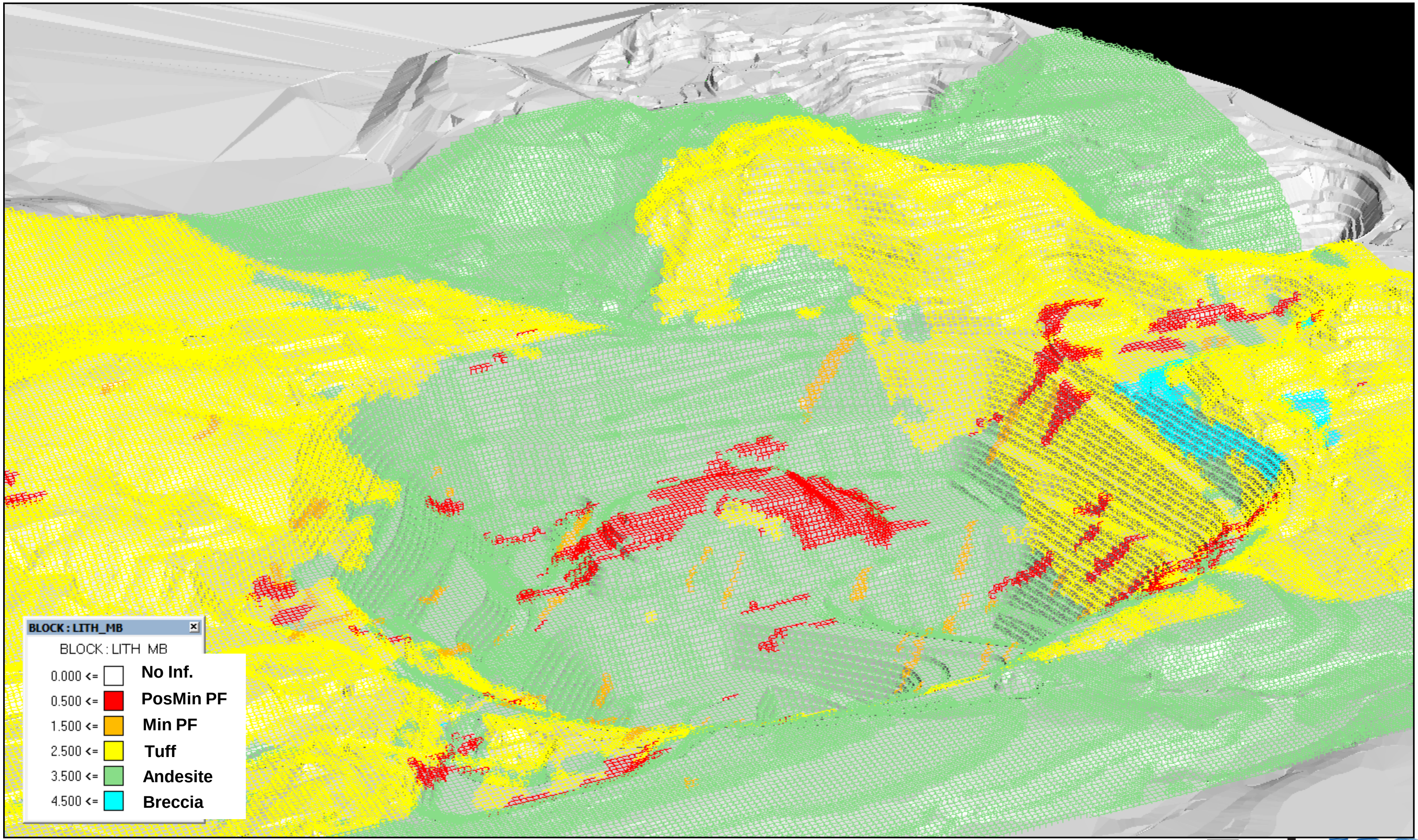
Lithologic Model in Pit 2031

View to NW



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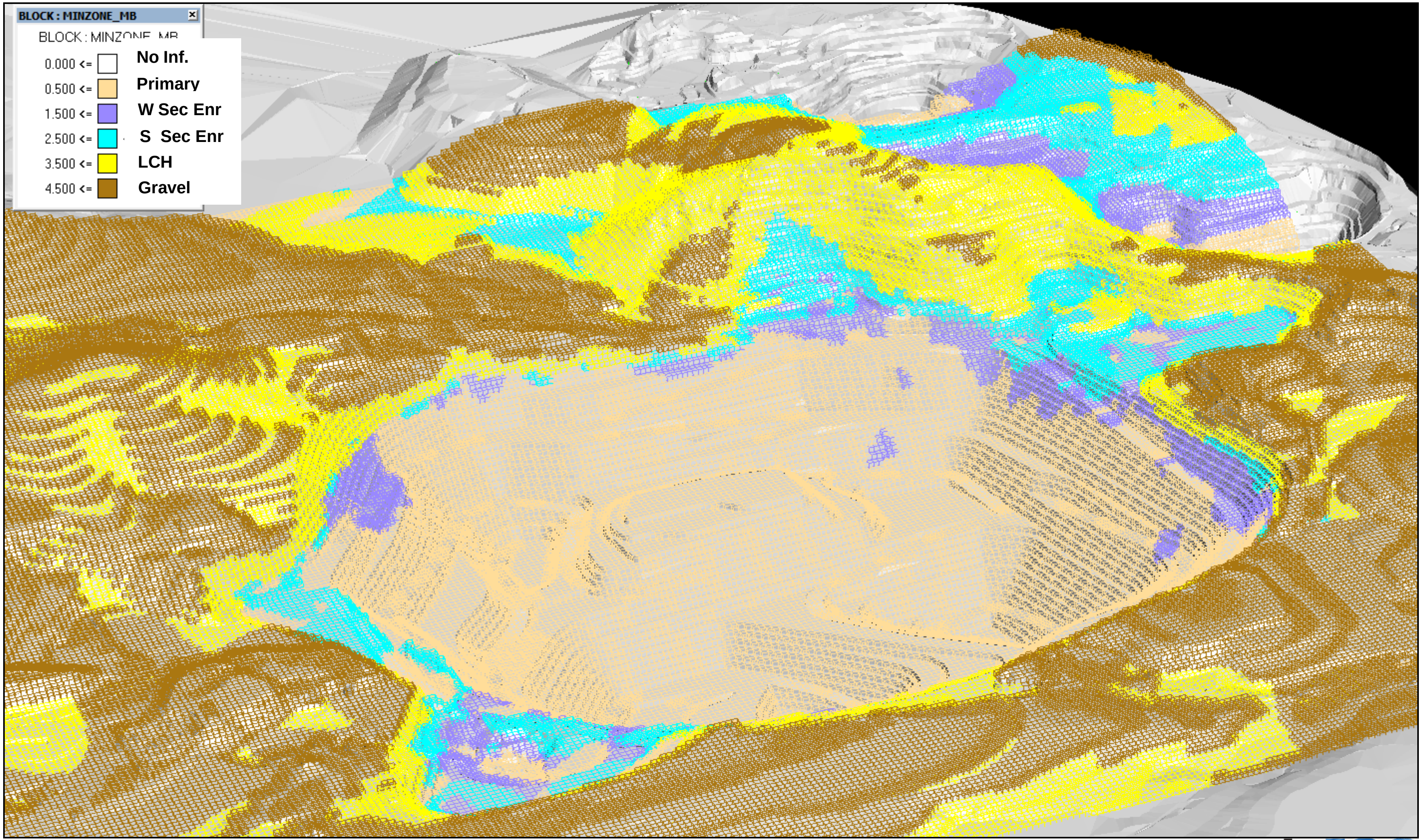
Minzones Model in Pit 2031

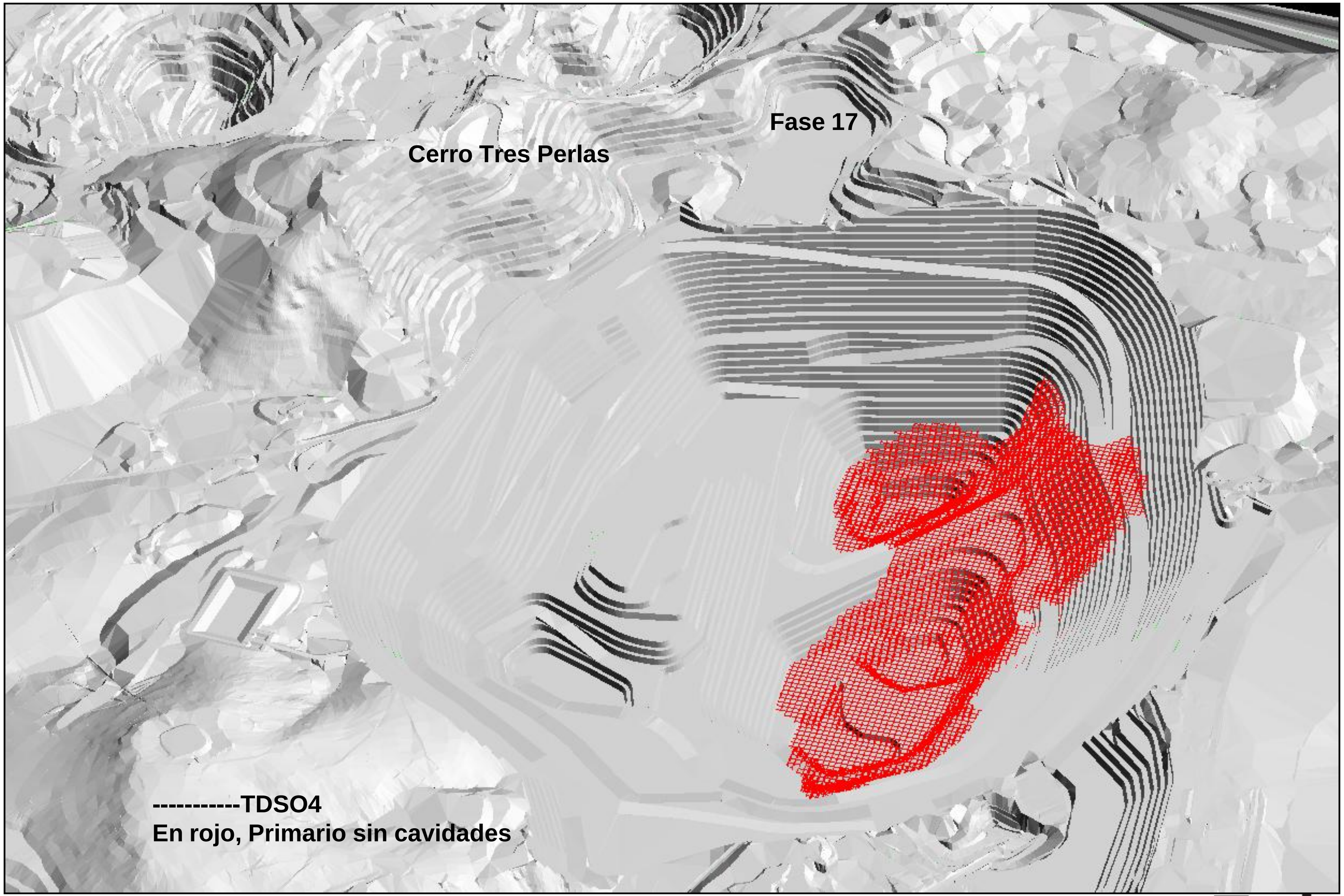
View to NW





$TDSO_4$ in Pit 2031

View to NW



Sericita / Albita: Diferencias de Dureza en Bancos tronados. (Toba F-01H, Bco. 990)

DEFINICIONES



Alteración de Rocas

Es el resultado de la transformación de los minerales de las rocas en nuevos minerales, como consecuencia de procesos naturales ocurridos al interior de la corteza y en su superficie, que modifican las condiciones originales de su formación.

Los minerales originales se transforman porque tienden a estar en equilibrio con las nuevas condiciones físicas, químicas y termodinámicas del medio.

Tipos de Alteración de Rocas

***Alteración Tardimagmática*:** Cambios en las rocas por la acción de soluciones hipógenas salinas cloruradas, de altas temperaturas (T >300° C): *ej: Albítica*

***Alteración Fílica*:** Cambios en las rocas producto de la circulación de soluciones hipógenas extremadamente ácidas, de temperaturas medias (100° < T < 300° C*): Ej: Cuarzo-Sericítica*

***Alteración Supérgena*:** cambios producidos por los fenómenos atmosféricos que generan una tabla de agua de mediana acidez y baja temperatura (T< 100° C) *Ej: Argílica*

Sericita (muscovite) / Albita : Propiedades Químicas



General Muscovite Information

http://webmineral.com/data/Muscovite.shtml

Chemical Formula: KAl2(Si3Al)O10(OH,F)2

Composition: Molecular Weight = 398.71 gm

Potassium	9.81 %	K	11.81 %	K2O
Aluminum	20.30 %	Al	38.36 %	Al2O3
Silicon	21.13 %	Si	45.21 %	SiO2
Hydrogen	0.46 %	H	4.07 %	H2O
Oxygen	47.35 %	O		
Fluorine	0.95 %	F	0.95 %	F
_	- %	F	-0.40 %	-O=F2
	100.00 %		100.00 %	= TOTAL OXIDE

Empirical Formula: $KAl_3Si_3O_{10}(OH)_{1.8}F_{0.2}$

General Albite Information

http://webmineral.com/data/Albite.shtml

Chemical Formula: NaAlSi3O8

Composition: Molecular Weight = 263.02 gm

Sodium	8.30 %	Na	11.19 %	Na2O
Calcium	0.76 %	Ca	1.07 %	CaO
Aluminum	10.77 %	Al	20.35 %	Al2O3
Silicon	31.50 %	Si	67.39 %	SiO2
Oxygen	48.66 %	O		
	100.00 %		100.00 %	= TOTAL OXIDE

Empirical Formula: $Na_{0.95}Ca_{0.05}Al_{1.05}Si_{2.95}O_8$

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Sericita (muscovite) v/s Albita : Propiedades Físicas



Physical Properties of Muscovite

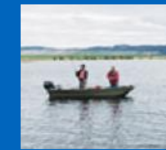
Cleavage:	{001} Perfect
Color:	White, Gray, Silver white, Brownish white, Greenish white.
Density:	2.77 - 2.88, Average = 2.82
Diaphaneity:	Transparent to translucent
Fracture:	Brittle - Sectile - Brittle fracture with slightly sectile shavings possible.
Habit:	Foliated - Two dimensional platy forms.
Habit:	Massive - Lamellar - Distinctly foliated fine-grained forms.
Habit:	Micaceous - Platy texture with "flexible" plates.
Hardness:	2-2.5 - Gypsum-Finger Nail
Luminescence:	Non-fluorescent.
Luster:	Vitreous (Glassy)
Streak:	white

Physical Properties of Albite

Cleavage:	{001} Perfect, {010} Good
Color:	White, Gray, Greenish gray, Bluish green, Gray.
Density:	2.61 - 2.63, Average = 2.62
Diaphaneity:	Transparent to translucent to subtranslucent
Fracture:	Uneven - Flat surfaces (not cleavage) fractured in an uneven pattern.
Habit:	Blocky - Crystal shape tends to be equant (e.g. feldspars).
Habit:	Granular - Generally occurs as anhedral to subhedral crystals in matrix.
Habit:	Striated - Parallel lines on crystal surface or cleavage face.
Hardness:	7 - Quartz
Luminescence:	Fluorescent, Short UV=herry-red blue, Long UV=white.
Luster:	Vitreous (Glassy)
Streak:	white

Sericita / Albita: Diferencias Texturales

(Toba F-01H, Bco. 1000 / Toba F-02H , Bco. 990)

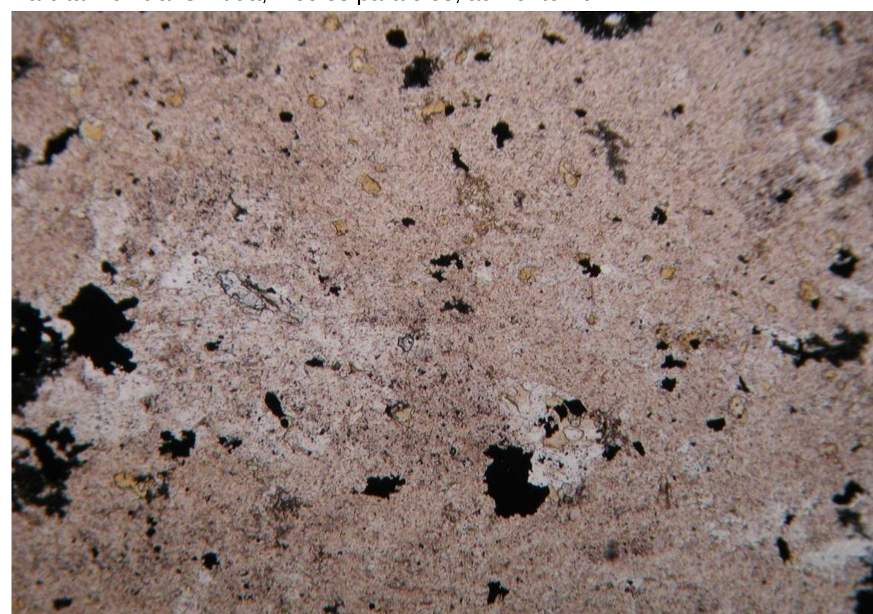




Sondaje DDH08-10: 128 metros. Cristales de plagioclasa alterados a sericita. Luz transmitida, nícoles cruzados, aumento 40 X.

CUARZO-SERICITA

Aspecto Sedoso

Sondaje DDH08-10: 117 metros. Toba de cristales con matríz reemplazada por albita. Luz transmitida, nícoles paralelos, aumento 40 X.



ALBITA

Aspecto Macizo

KPI : Cumplimiento del plan de Extracción



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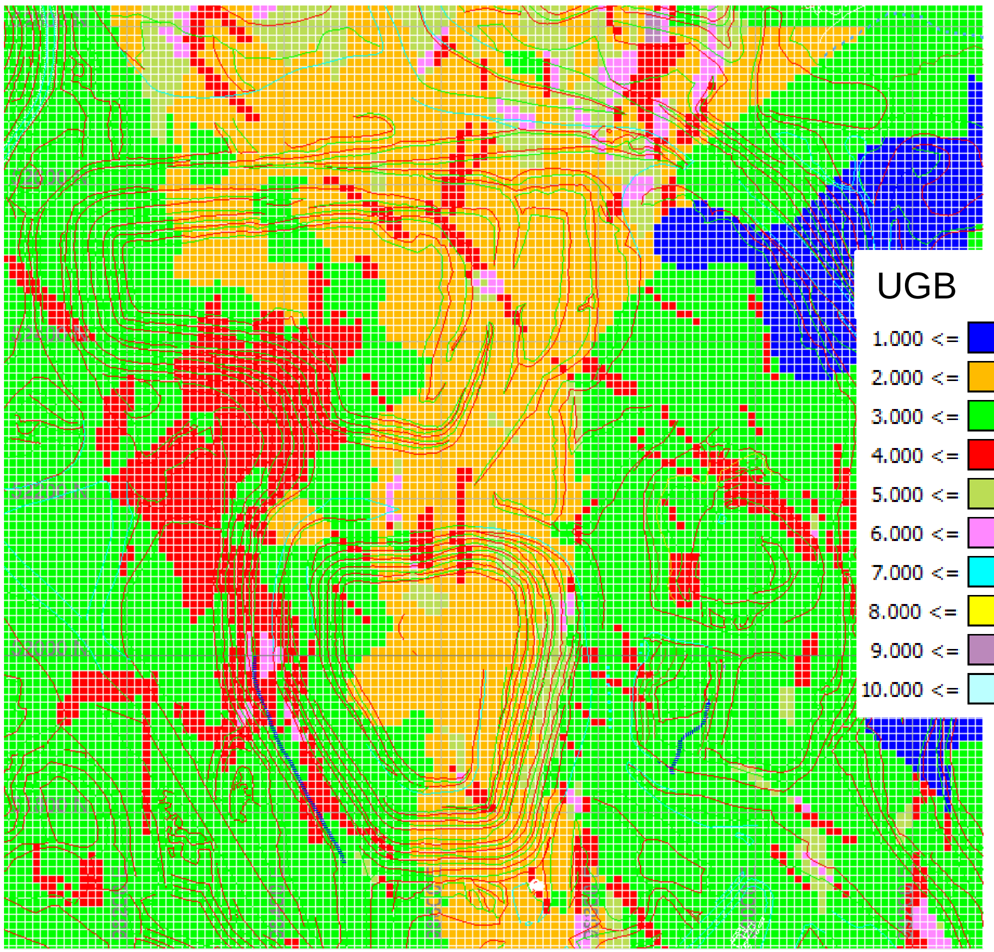
Modelo Geotécnico

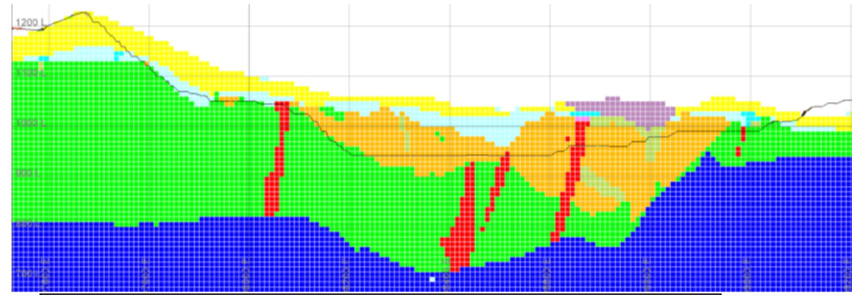
30 de mayo de 2013
René Fuenzalida

Definición de las Unidades Geotécnicas Básicas UGB



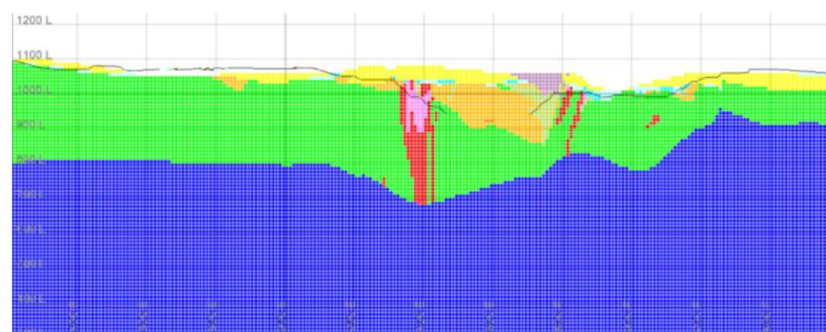
Sección 52500





UNIDAD GEOTÉCNICA BASICA

Sección 52000



Mapeo Geotécnico Estructural

Mapeo Geotécnico de Sondajes

Mapeo de Sondajes Orientados

Mapeo de Bancos

Selección de Probetas

Definición de Parámetros de Calidad Geotécnica

- RQD
- FF
- RMR
- GSI
- Resistencia de la Roca
- Mapeo de Fallas y Zonas de Debilidad

Ensayos Geotécnicos



Ensayos Laboratorio Interno

- Leeb
- PLT
- Densidad

Ensayos Laboratorio Externo

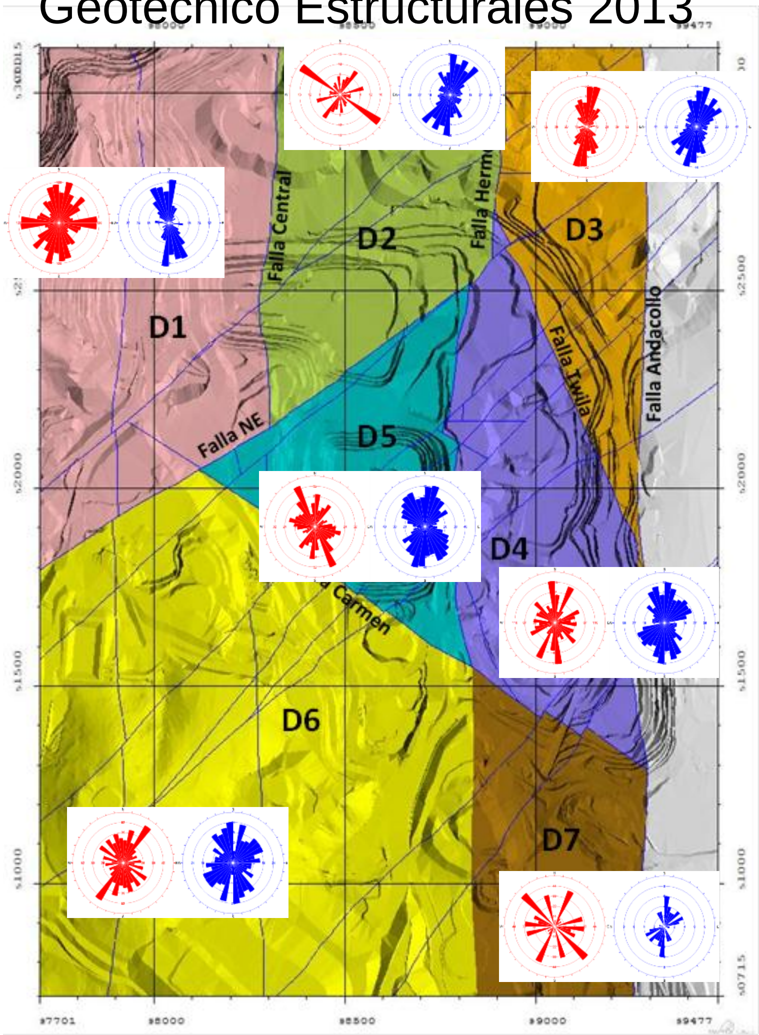
- Compresión Uniaxial
- Compresión Triaxial
- Tracción (Brasilero)
- Velocidad de Ondas
- Corte Directo

Se obtiene la caracterización de propiedades geotécnicas para roca intacta que posteriormente se escala a macizo rocoso

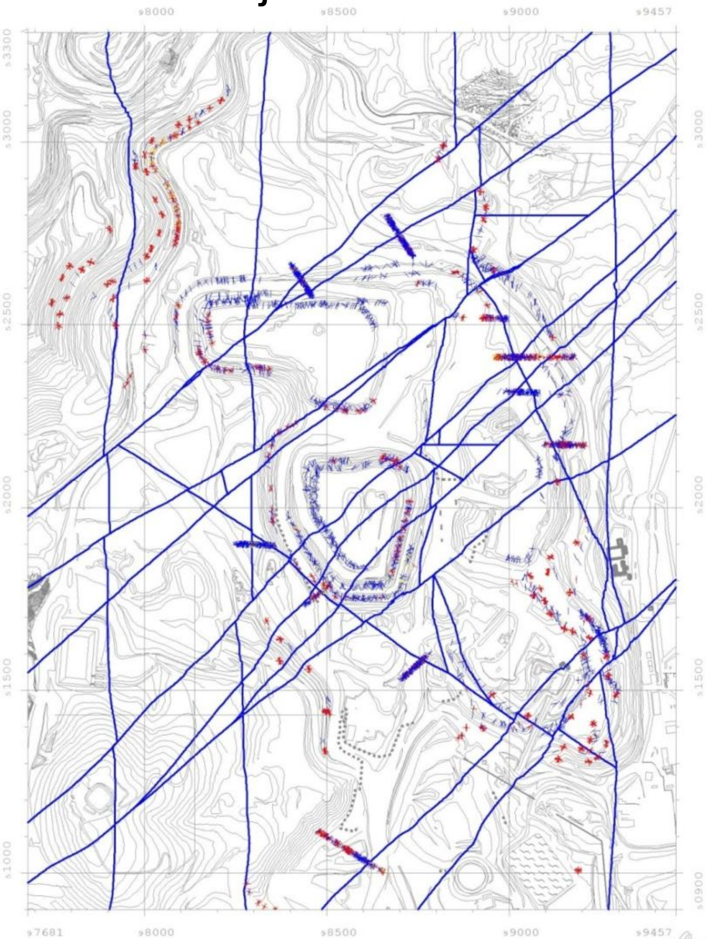
Mapeo Estructural y Dominios Geotécnico Estructurales



Actualización Dominios Geotecnico Estructurales 2013



Mapeo Estructural Bancos y Sondajes Orientados



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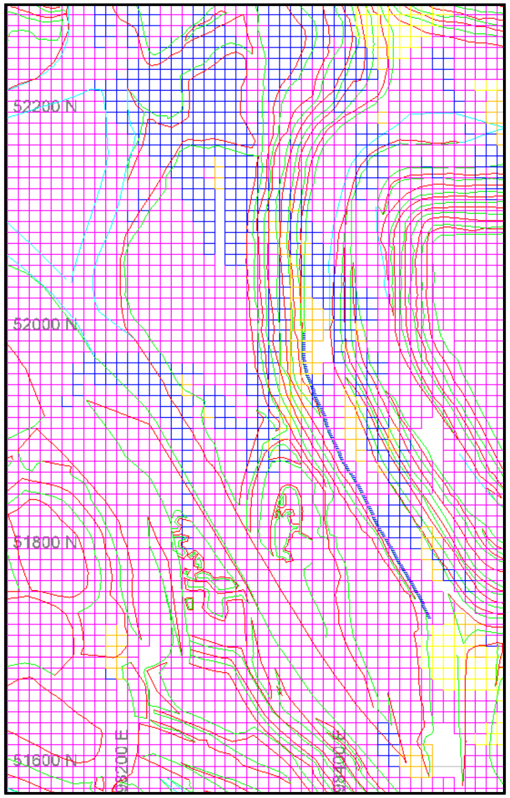
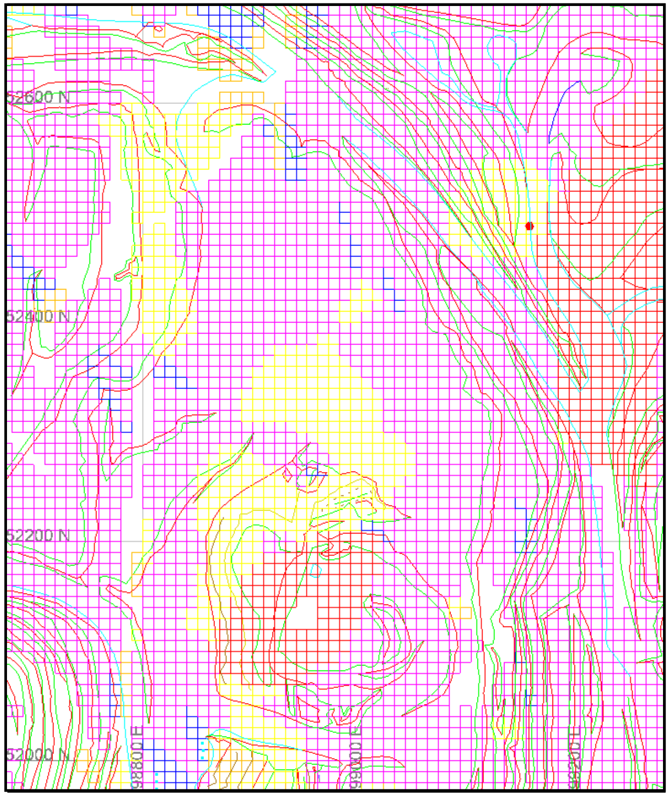
MB MY2013
Resistencia a la Compresión Uniaxial UCS



Fase 05H Nivel1025



Fase 3H Nivel 995



BLOCK : UCS

-99.000 <=	☒	< -2.000
-2.000 <=	yellow	< 40.000
40.000 <=	orange	< 60.000
60.000 <=	red	< 80.000
80.000 <=	magenta	< 100.000
100.000 <=	blue	< 120.000

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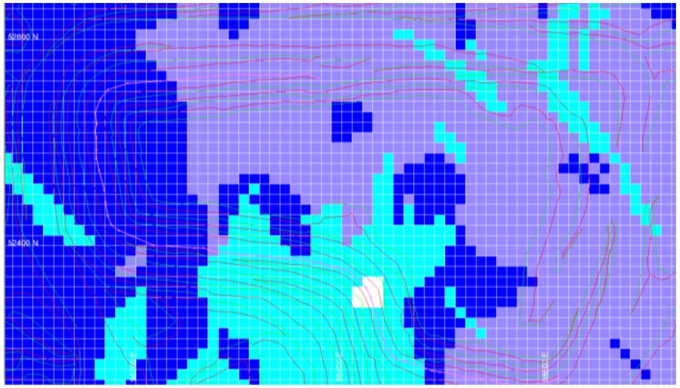
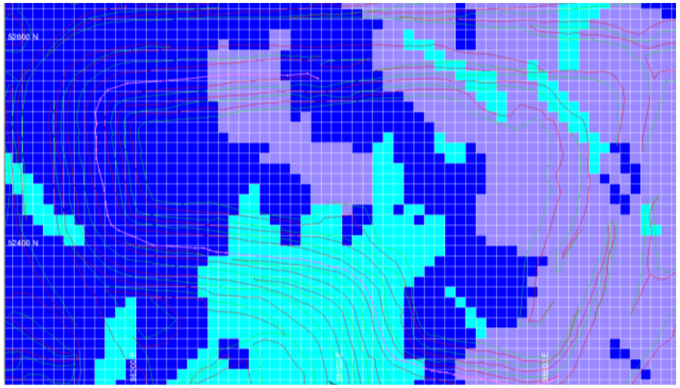
MB MY2013
Variable Velocidades de Onda



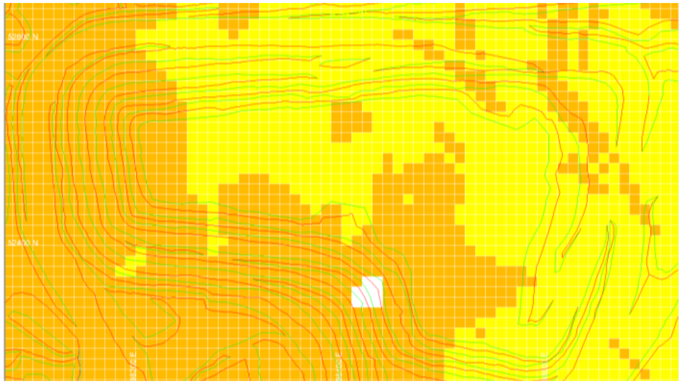
Velocidad Primaria
Fase 02H Banco 935



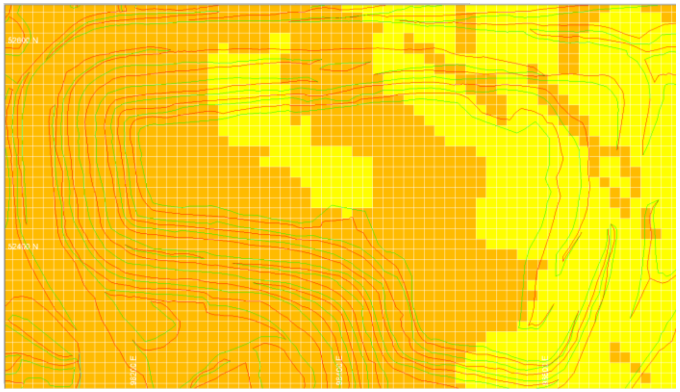
Velocidad Primaria
Fase 02H Banco 915

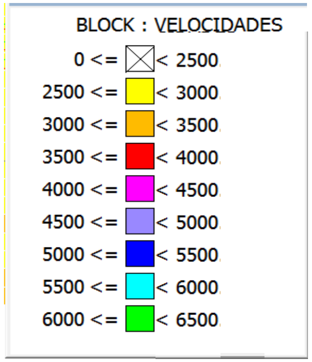


Velocidad Secundaria
Fase 02H Banco 935



Velocidad Secundaria
Fase 02H Banco 915





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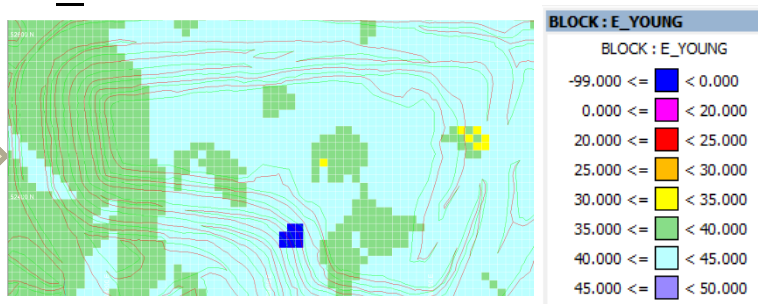
MB MY2013
Módulos de Deformabilidad

Módulo de Young

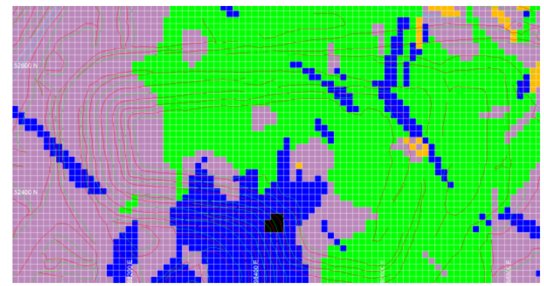
Razón de Poisson

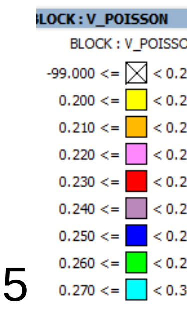
Roca Intacta

E_Fase 02H Banco 935



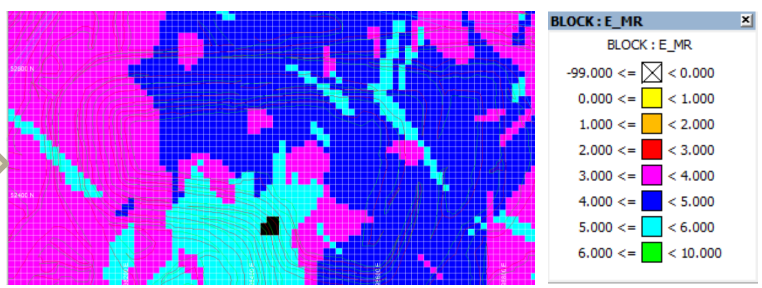
V_Fase 02H Banco 935



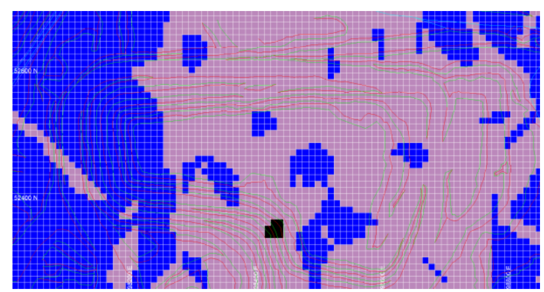


Macizo Rocoso

Em_Fase 02H Banco 935



Vm_Fase 02H Banco 935



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