Predicting and Managing Waste Impacts through a Holistic and Life-of-mine Geomet Application

Karin Olson Hoal, *JKTech Pty Ltd, Brisbane Australia and Colorado School of Mines*

John Jackson, *JKTech Pty Ltd, Brisbane Australia*

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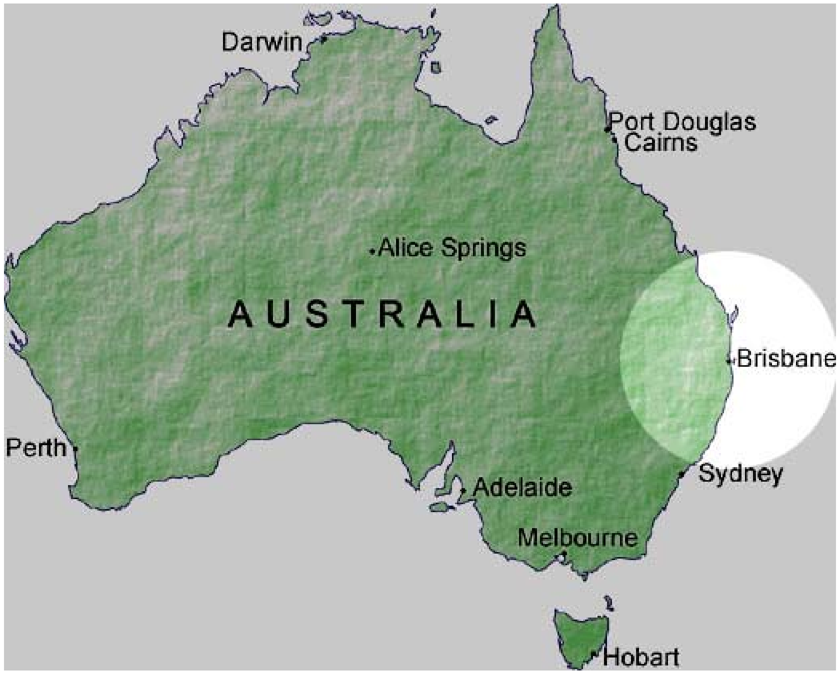
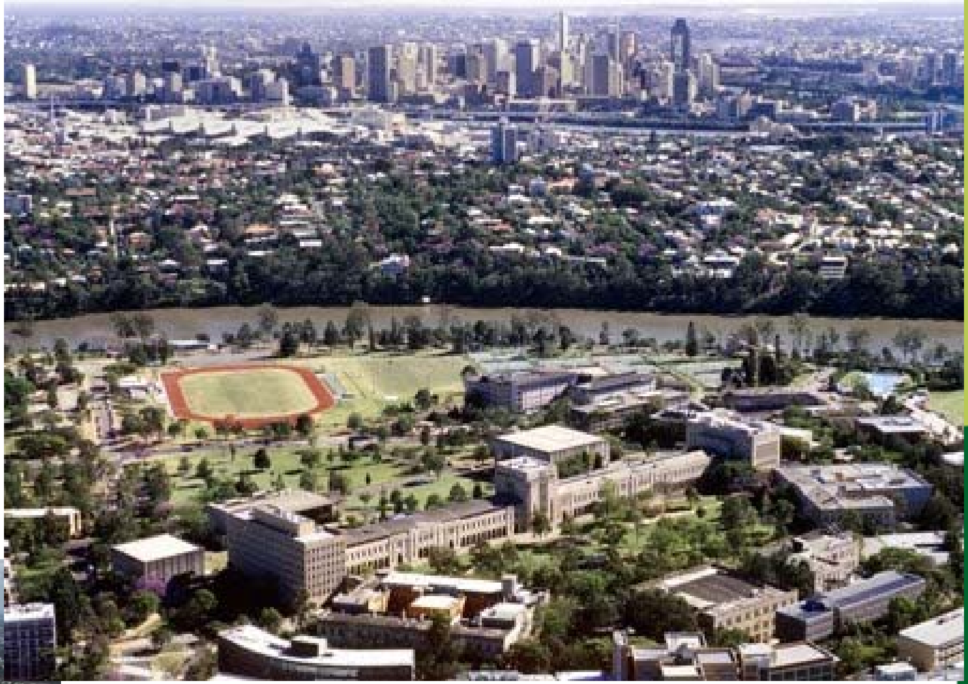
U.S. EPA Hardrock Mining Conference:
Advancing Solutions for a New Legacy
April 4 2012





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Sustainable Minerals Institute

JKtech SMI Technology Transfer

1986 - 2011 25 Years

RESEARCH, EDUCATION & CONSULTATION

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SMI CMLR
Centre for Mined Land Rehabilitation

Promoting sustainable outcomes through environmental research

SMI – Centre for Mined Land Rehabilitation

The Centre for Mined Land Rehabilitation (CMLR) is a research centre that builds on the strengths of the diversity of backgrounds and disciplines of its staff and postgraduate students to address the environmental challenges of the minerals industry with quality science. Through working closely with industry, governments and communities, we aim to translate research outcomes into practices that will lead to the continual improvement of rehabilitation and environmental outcomes for a sustainable future.

People

Integrating and involving a diversity of backgrounds to provide knowledge and learning

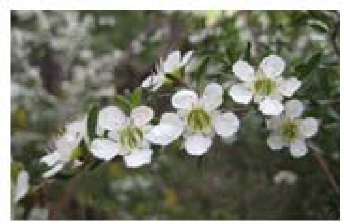
Our People →

Partners

Engaging with industry, government and community for national and global benefit

Our Partnerships →

Programs



Discovering and delivering research solutions to the resources sector through science

Research →

CMLR Updates

Life-of-Mine 2012
10 - 11 July 2012, Brisbane

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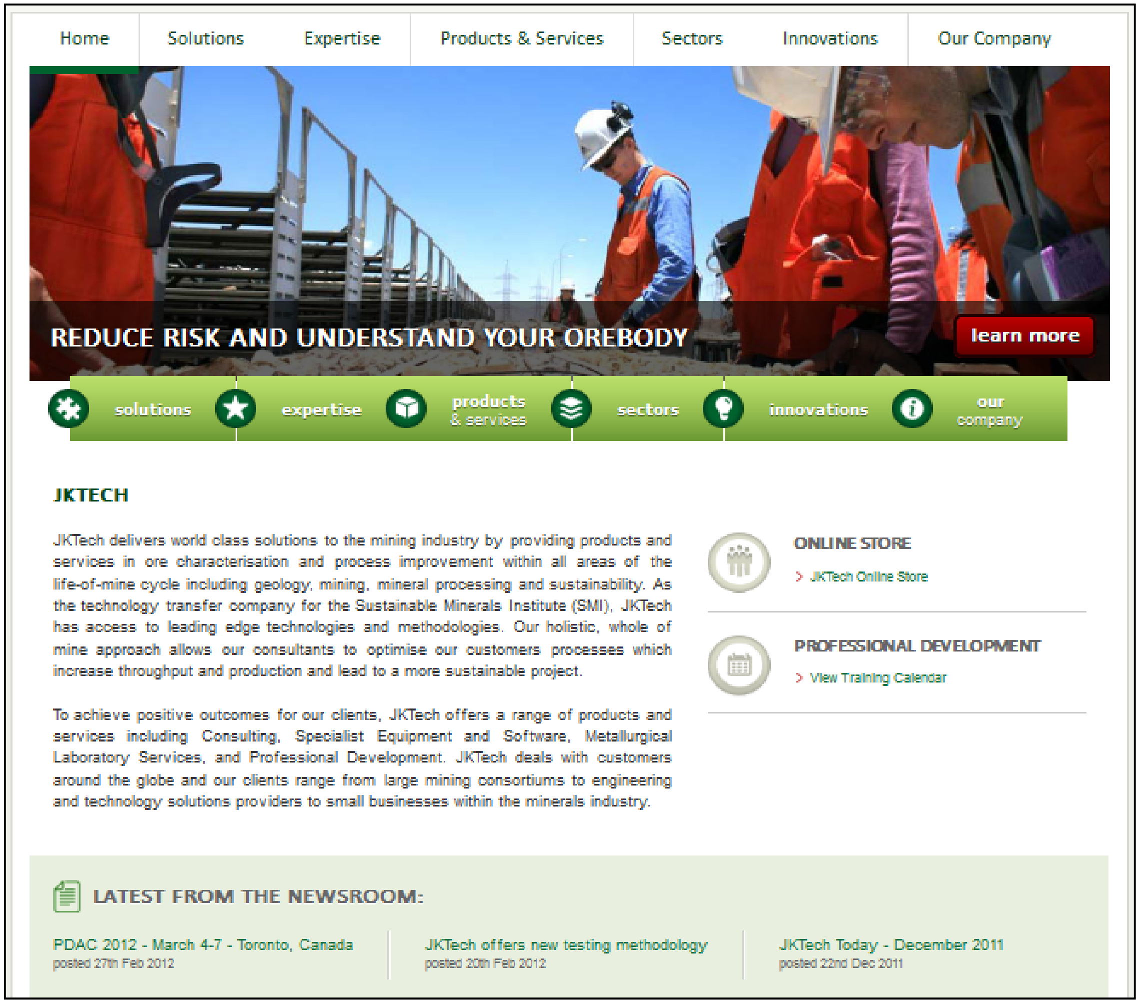

Brisbane Perth Johannesburg Denver Santiago

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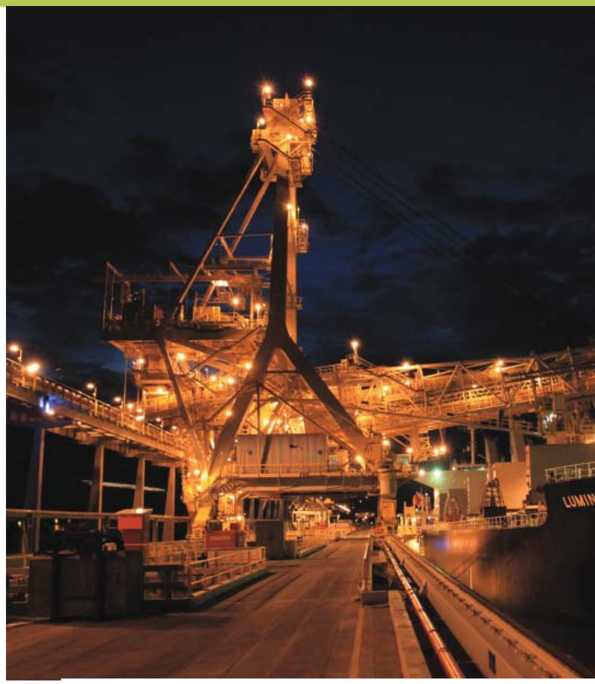
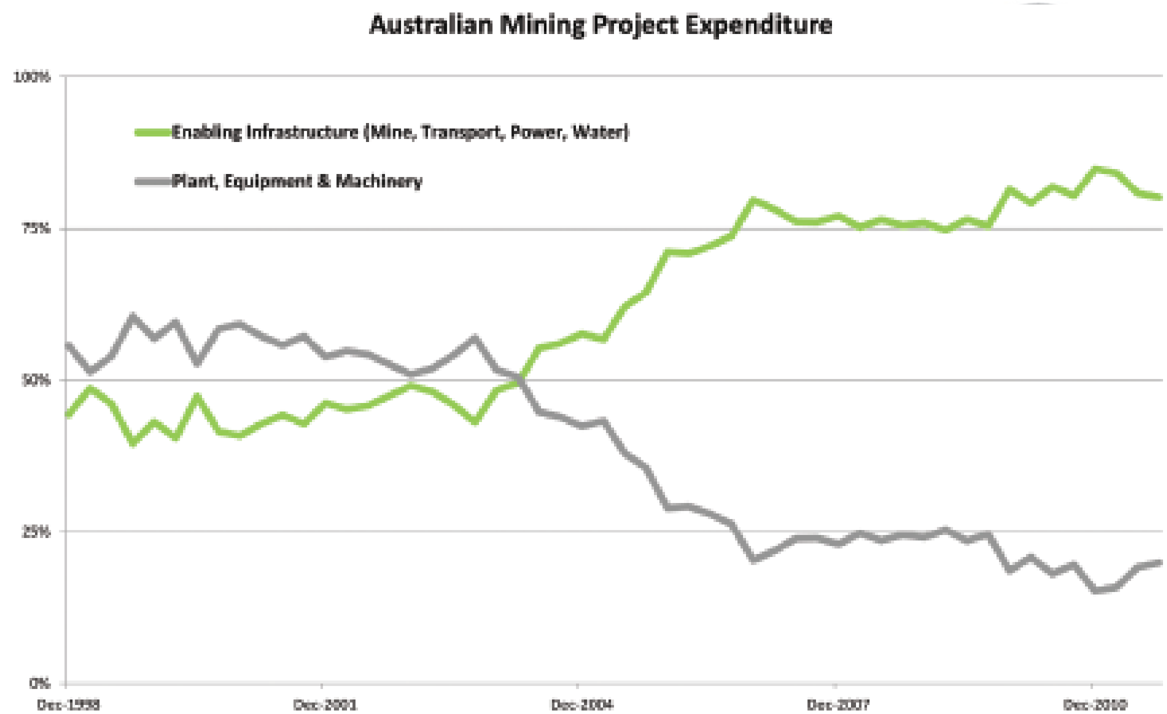
Mining: Challenges

- Lower grade deposits
- Increasingly inaccessible deposits
- Higher operating costs
- Higher energy costs
- Critical water issues
- Perceptions

Mining: Drivers





JKAurecon: The link to infrastructure

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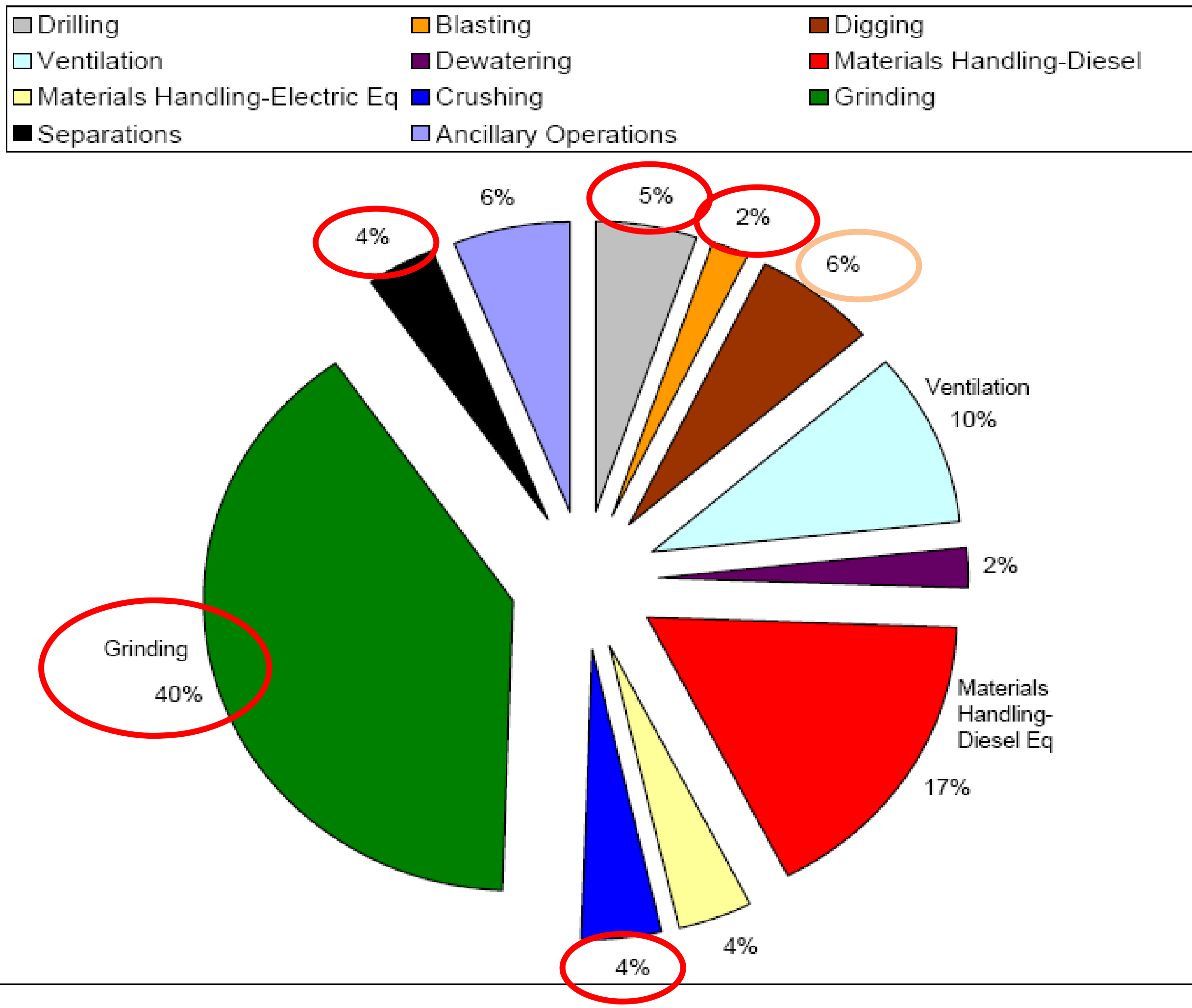
Energy

• 6-7% Australia's energy on comminution

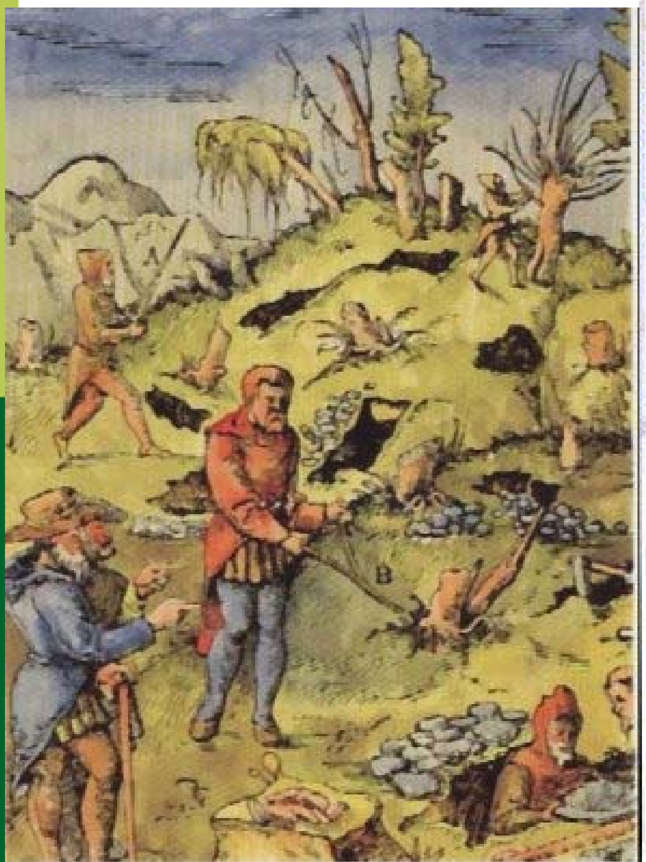
•Mining houses target of 10-20% reduction



BCS, June 2007. Mining industry energy bandwidth study. US Department of energy

(The following slides are Taken from JKMRC/JKTech/CRCORE 2010 presentation)

Mining: Perceptions



Lawrence Gipe, “Rosemont Copper Girl:, 2011

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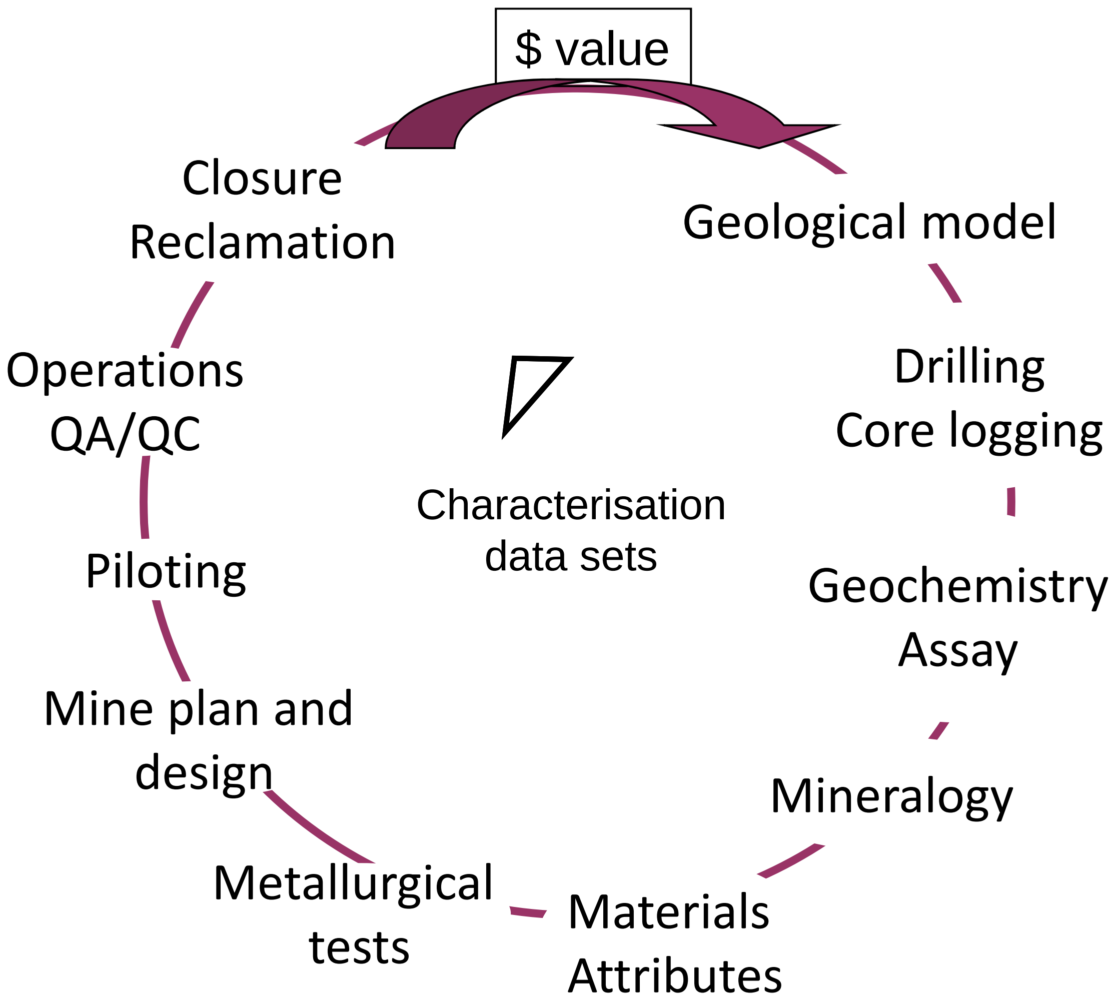
eorg Bauer

Perceptions

2010 World Economic Forum Report Mining & Metals Scenarios to 2030:

"…not anticipate any technological breakthroughs that would transform key aspects of the industry such as operations, metals and mineral use or energy technologies" for 30 years..

Life-of-mine geomet application



Value

- Locked in variable ore relationships
- Team-based approach
- Integrate data sets
- Operating cost reduction
- Risk mitigation through life of project

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New approaches

- Reconcile extraction with sustainable practice
- Operational state-of-the-art approaches to integrated extraction beneficiation and mineral processing
- Effective prediction
- Environmental and economic impacts

Predict …. Plan …. Manage

PREDICT performance

Recognize variability and geological drivers
Model relationships among attributes
Interpolate throughout mineral deposit

PLAN proactively

Integrate into mine plan and scheduling
Reduce uncertainty
Improve performance

MANAGE impacts

Understand and control environmental consequences
Reduce overall project risk
Recognize financial value through NPV and IRR options

Front end

Intrinsic Rock Properties

Defining Physical Control

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Understanding the variability in the deposit: Identifying the drivers of mining and processing responses

Proxies	Indices	Attributes
Geology, Assays,Equotip, Sonic, NIR	*RBTEx, GeMCi*	SPI, DWT, RBT

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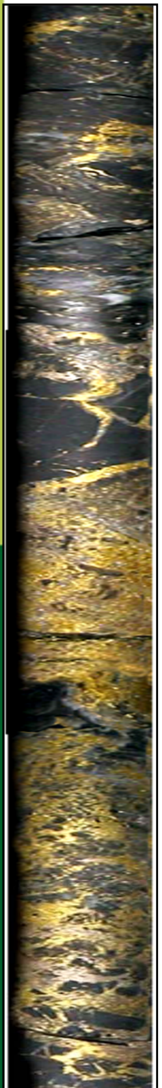

Met tests for variability vs composites

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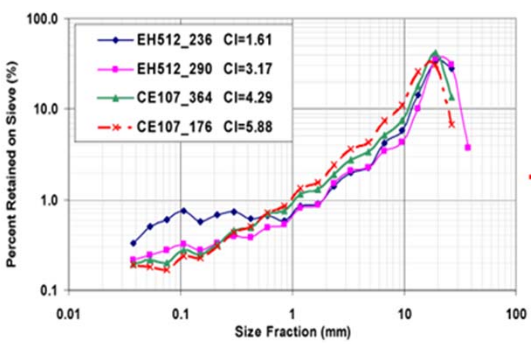
GeM Ci test

2m core intervals

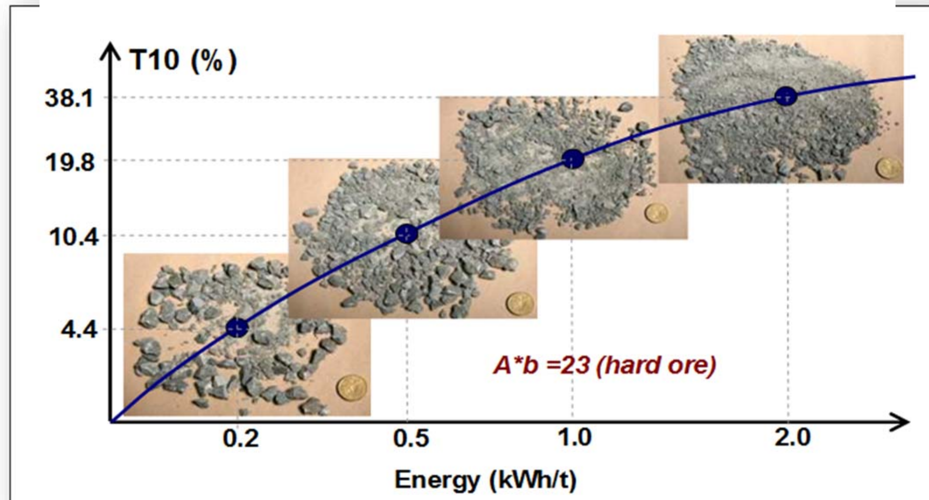
Crush core at
2.5:1 reduction ratio
&
Measure Size Distribution



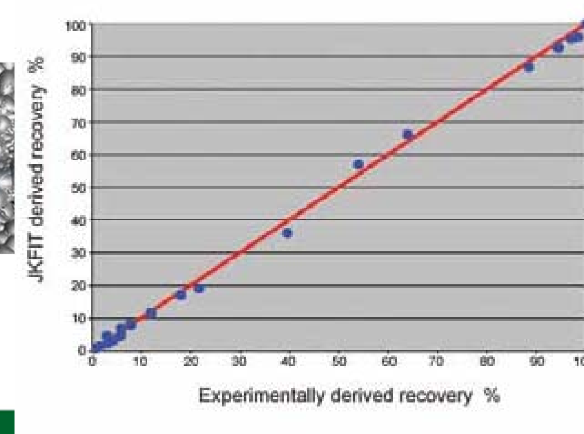
JKCi CRU

JKCi GRD

Rotary Breakage Tester



JKFI and MSI



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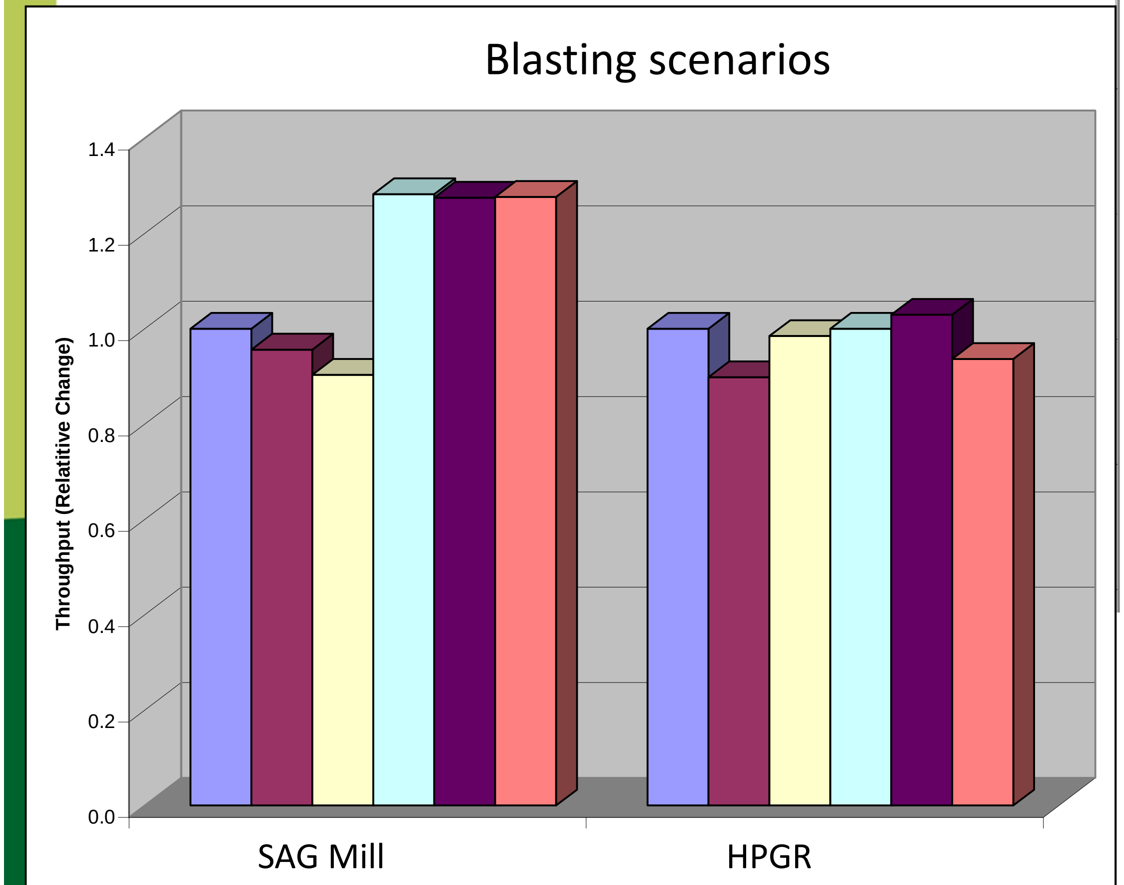
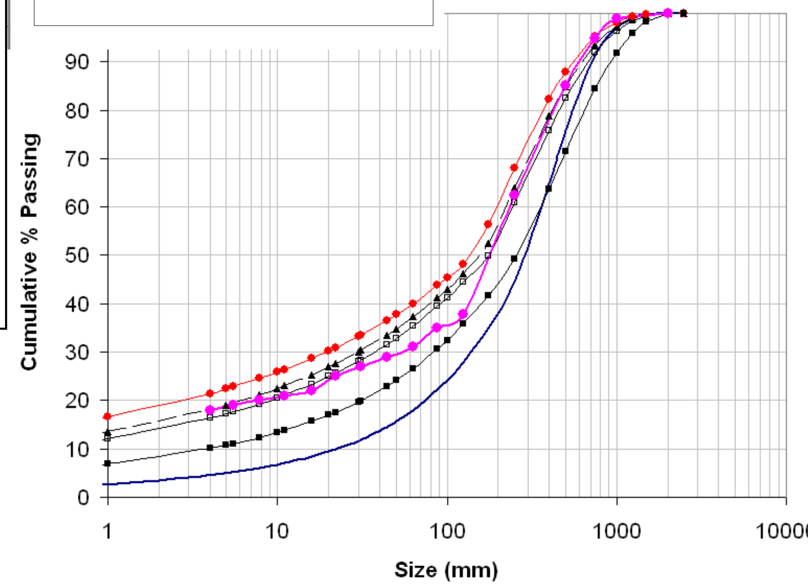
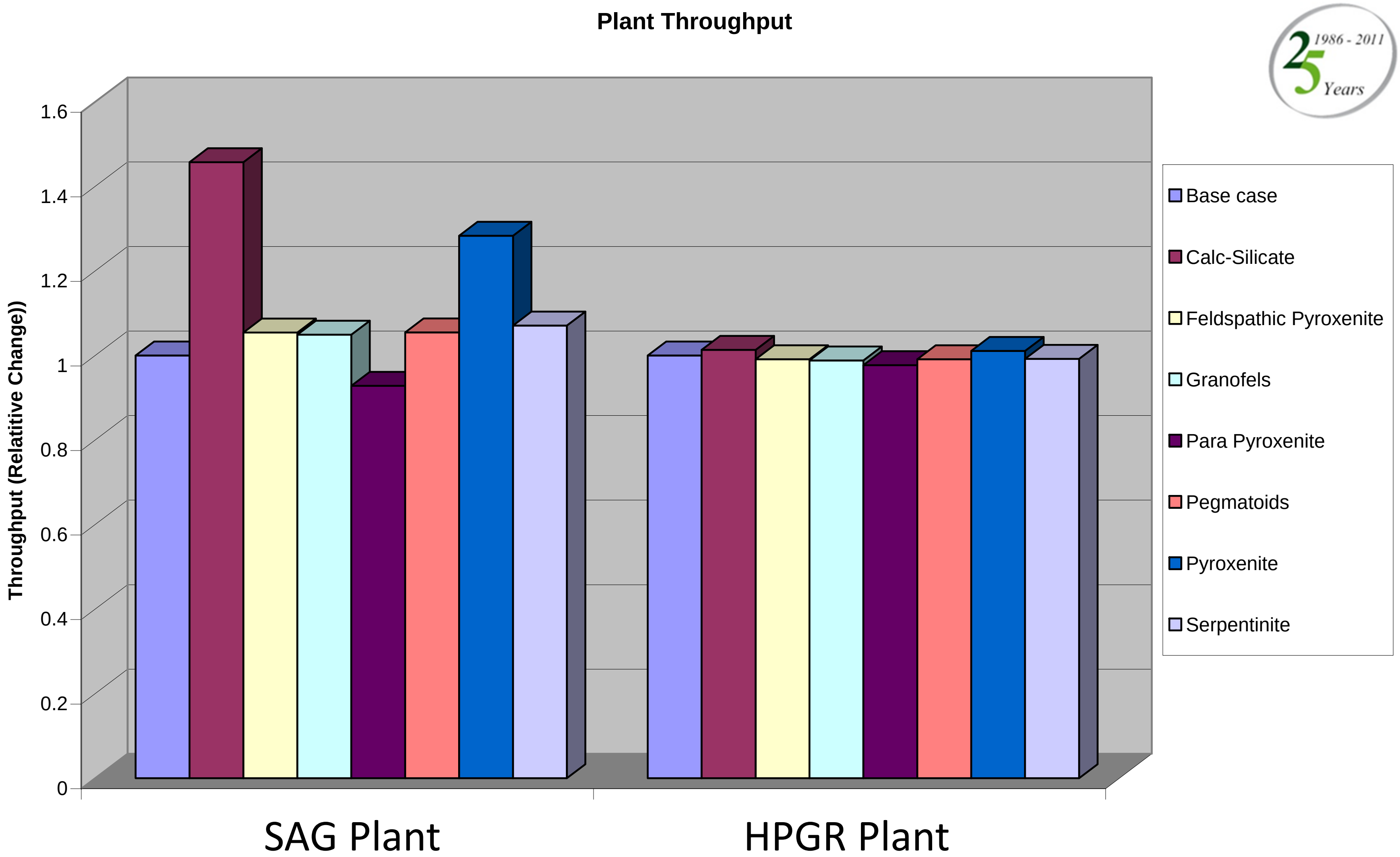
Blasting variability for mill



- Base case
- Blast S5 -
- Blast S1 -
- Blast S2 -
- Blast S3 -
- Blast S4 -



Comminution variability by lithology



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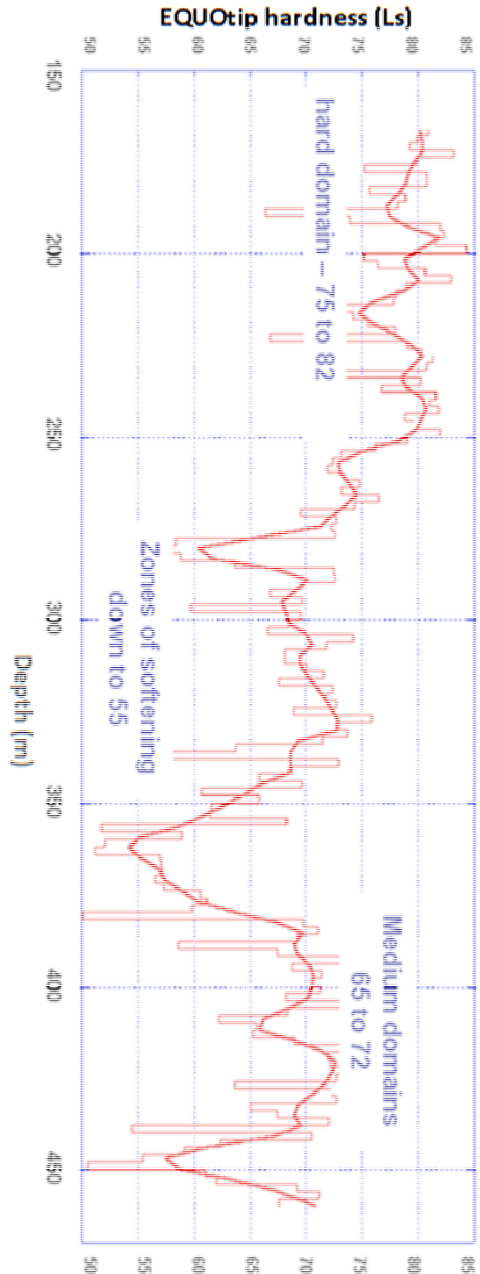
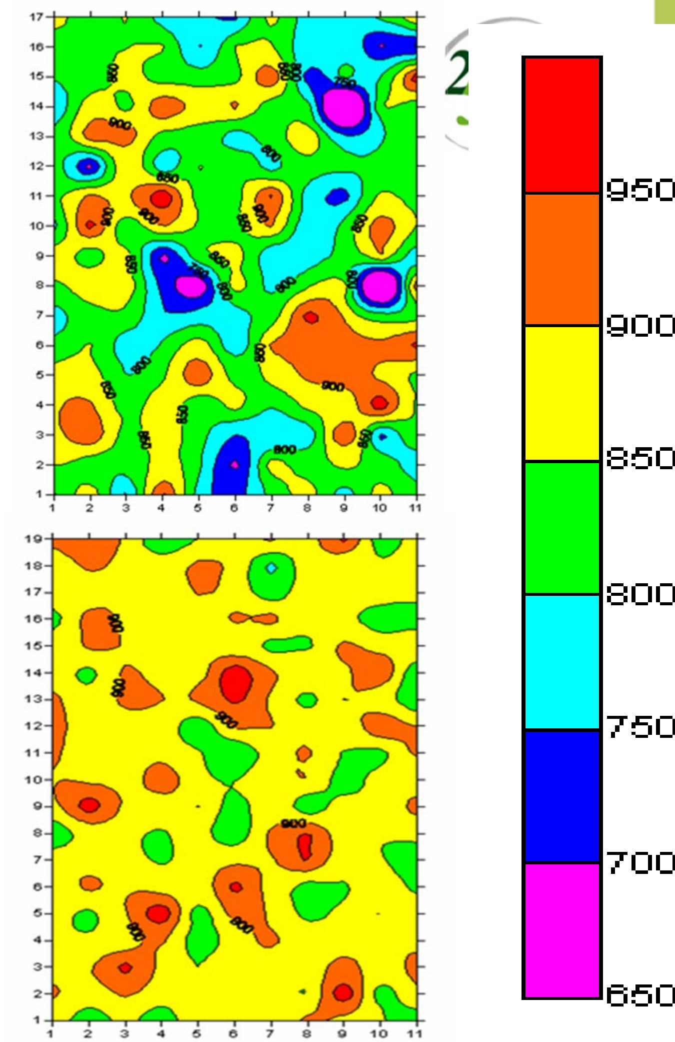
Spatial understanding

eg Equotip





1cm x 1cm grid

(From AMIRA P843)

Spatial 3D domains

1. Grade
2. Distribution of lithology and facies
3. Distribution of weathering and alteration
4. Mineralogy
5. Structural – geotech
6. Spatial distribution of met variables
7. Sampling and analytical precision

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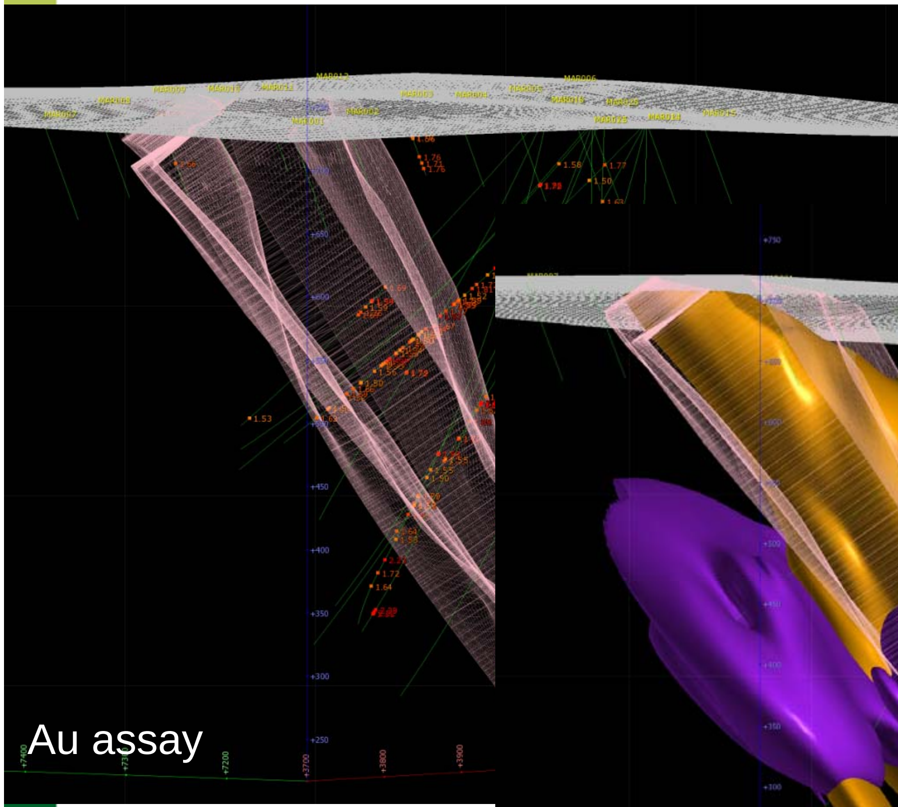
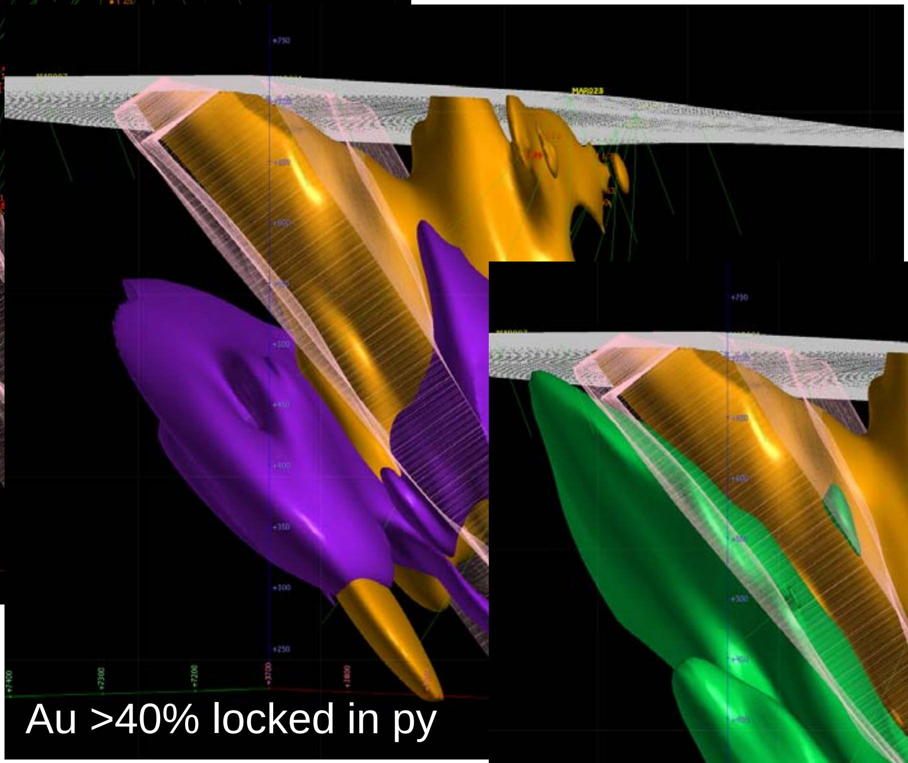
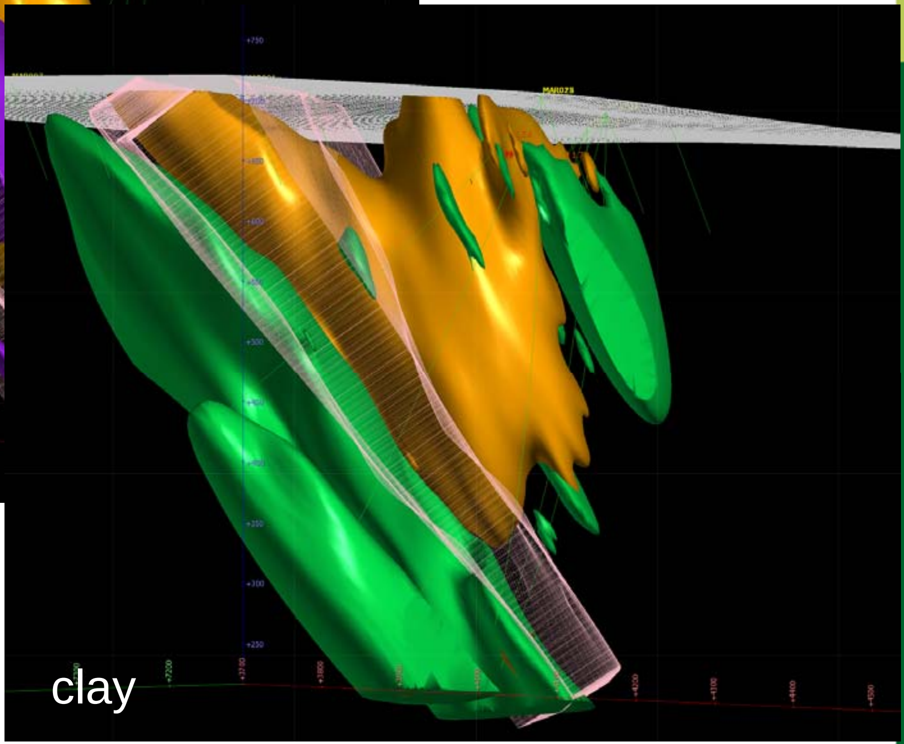
Gain spatial understanding of geological controls





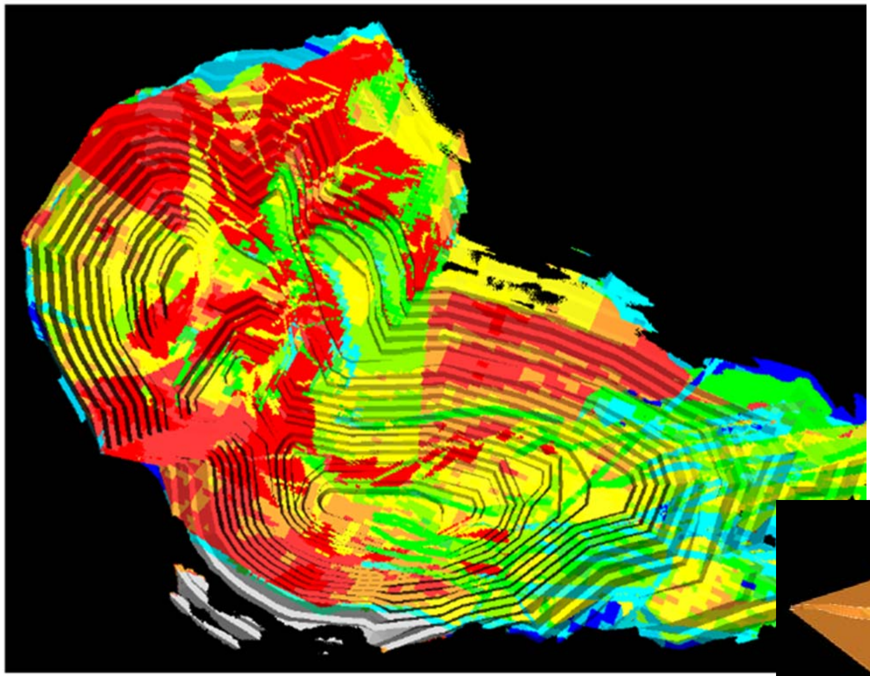


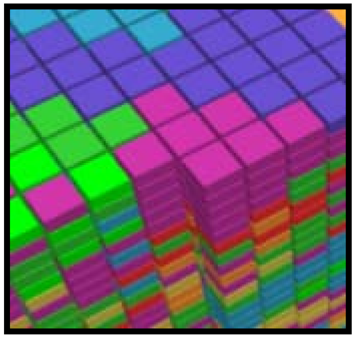
Planning: Attributes into Block Model

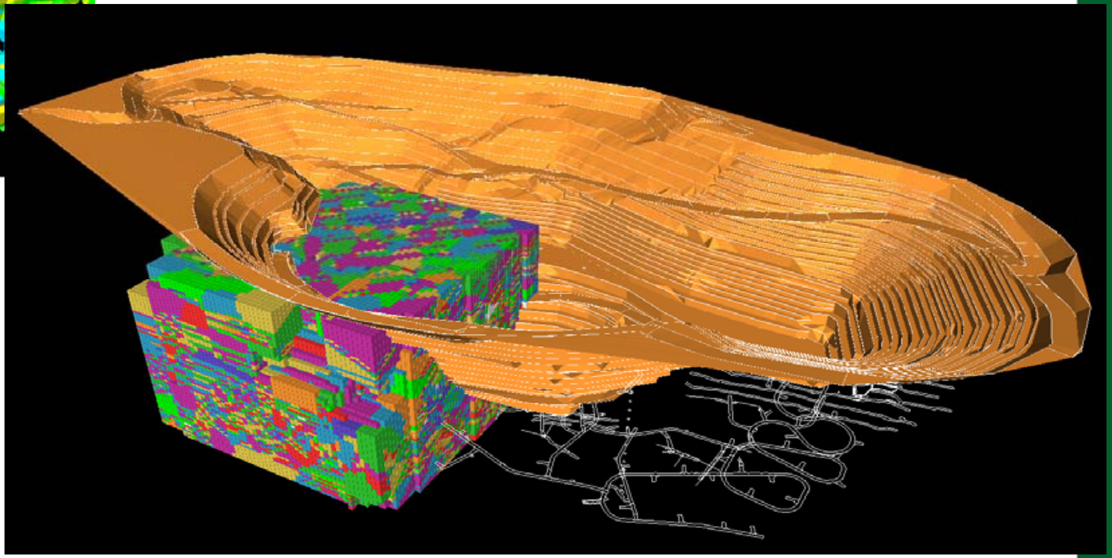
Each Model Cell to Contain
- **Intrinsic Rock Properties**
- **Performance Attributes**

⇩

Performance Parameters







Predict …. Plan …. Manage

PREDICT process performance

- Recognize variability and geological drivers
- Model relationships among attributes
- Interpolate throughout mineral deposit

PLAN proactively

- Integrate into mine plan and scheduling
- Reduce uncertainty
- Improve performance

MANAGE impacts

- Understand and control environmental consequences
- Reduce overall project risk
- Recognize financial value through NPV and IRR options

Back end:
Variability and environmental impact

Acid rock drainage:

Predict acid potential and neutralization potential

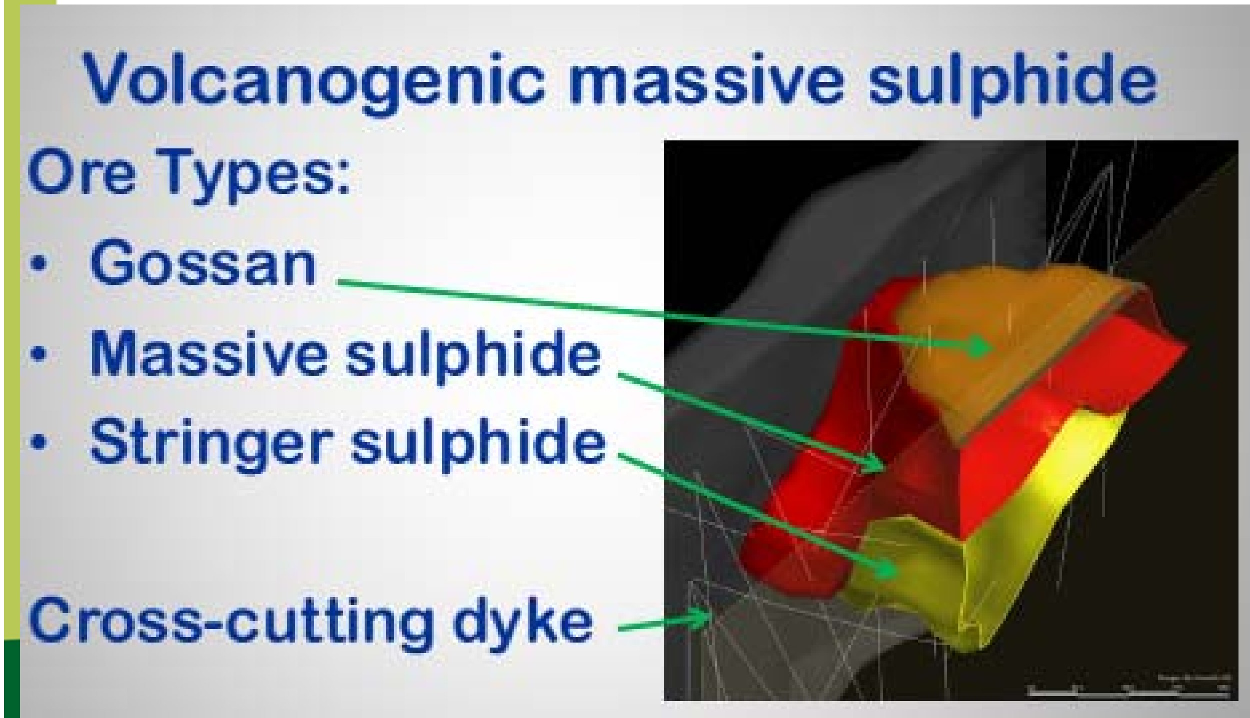
mineralogy: total sulfides, carbonates, silicates

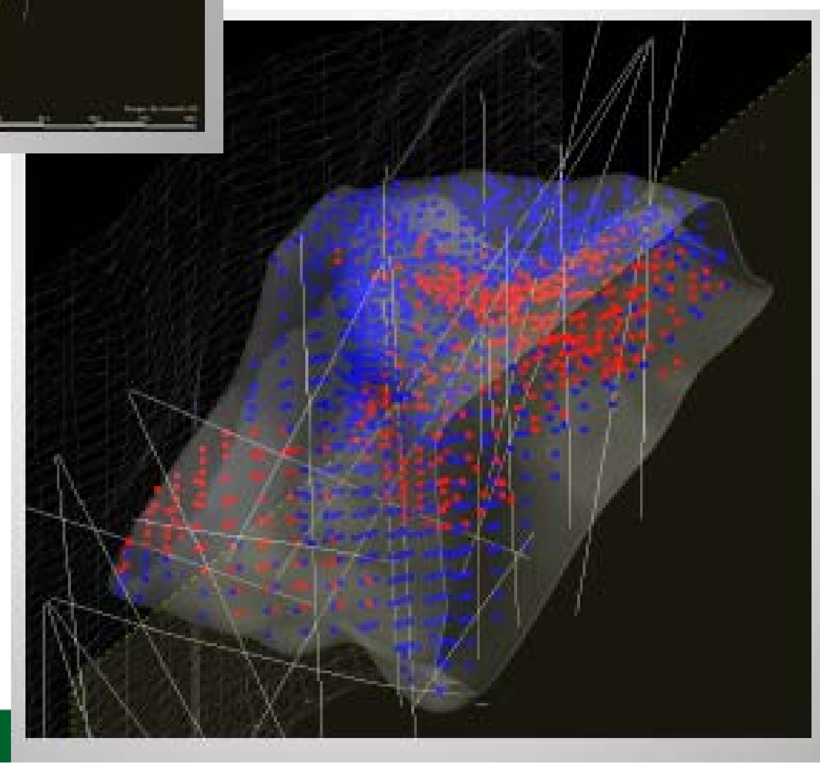
Metal deportment (eg Cd, Sb, As, etc)

Predict where metals are concentrated and liberated

mineralogy: sulfide species

Modelling geology and grade

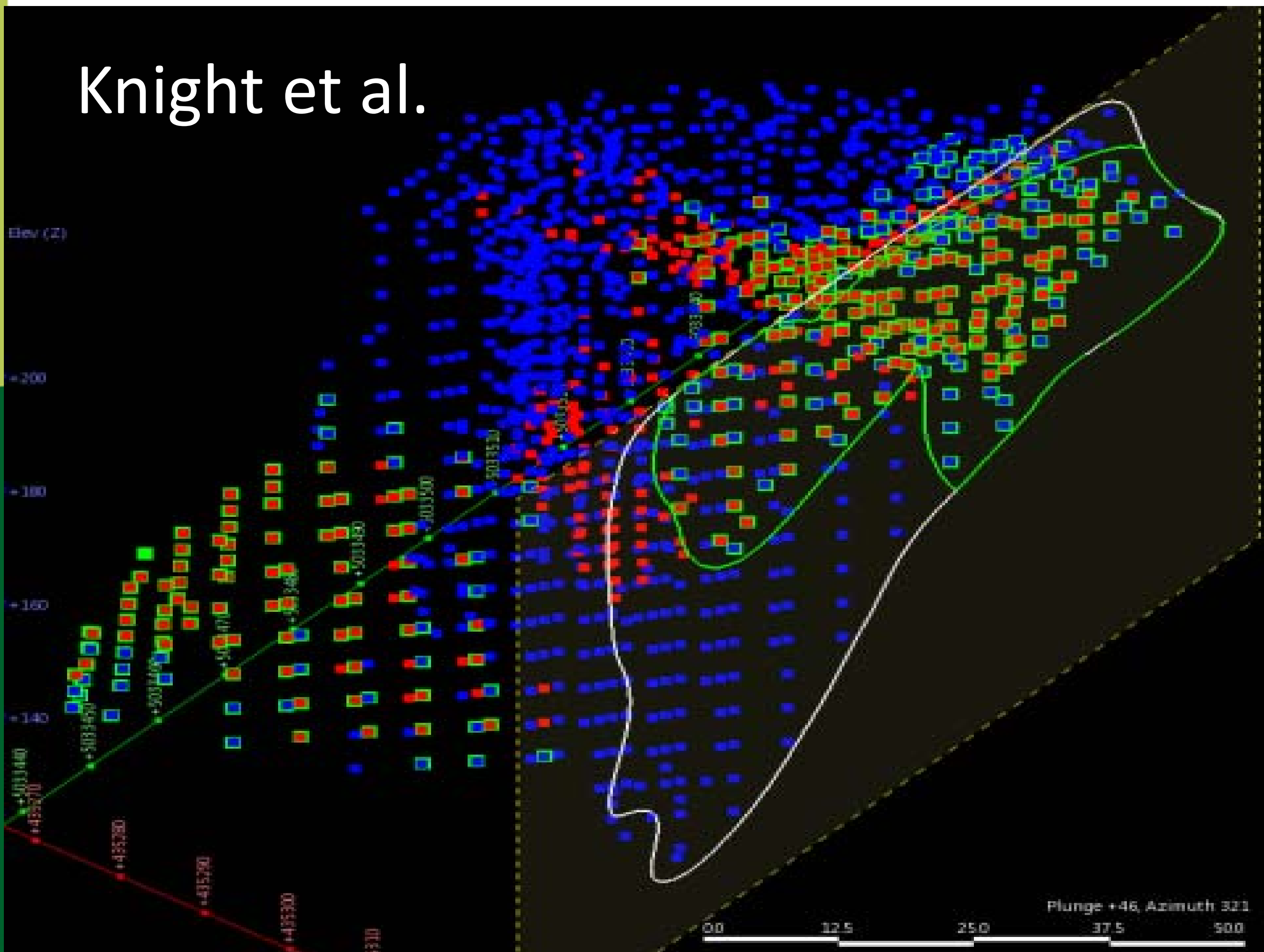




- Ore grade
- SG
- Tonnage
- Value

Knight et al., 2011

Resource-calculated ore with problematic Cd, As, Sb contents



Is it still "ore"?

Stable Landforms and Sustainable Substrates

- Effective store-release cover design for containment of waste
- Remediation of problematic soil conditions, Yarraman mine
- Options and strategies for tailings revegetation
- Organic matter in mine rehabilitation and the carbon balance

Water and contaminants in the landscape

- Geochemistry of mine water in monsoonal climates
- Lead pathways study
- Acid mine drainage and geochemistry, Croydon Mine
- Rehabilitation of oilfield brine impacts in an arid environment

Ecosystem Structure and Function

- Restoration of brigalow plant communities on degraded landscapes
- Potential impacts of subsidence on the Newness Plateau, Centennial Coal
- Long-term monitoring and research strategies at North Stradbroke Island
- Sustainability of koala populations in mining environments



Monitoring and Mapping Technologies

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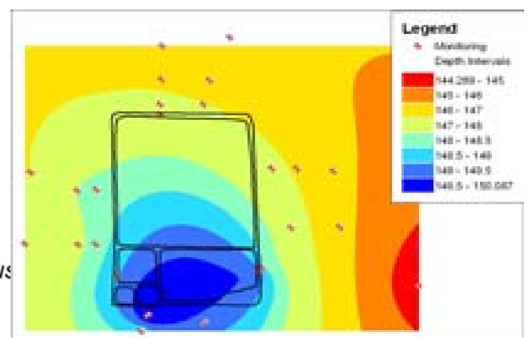
- SPOTing long-term changes in vegetation over short-term variability
- Surface conditions of swamps subject to subsidence with high-resolution imagery
- Mapping and validation of strategic cropping land
- Spatial and temporal modelling for vegetation monitoring uncertainty

Mine closure and end-use planning

- Closure strategy for tailings storage facilities
- Risk assessment tools for post-mined line
- Pre-operational rehabilitation research
- Early ore body characterisation for the prediction of acid and metalliferous drainage

Mine closure and end-use planning

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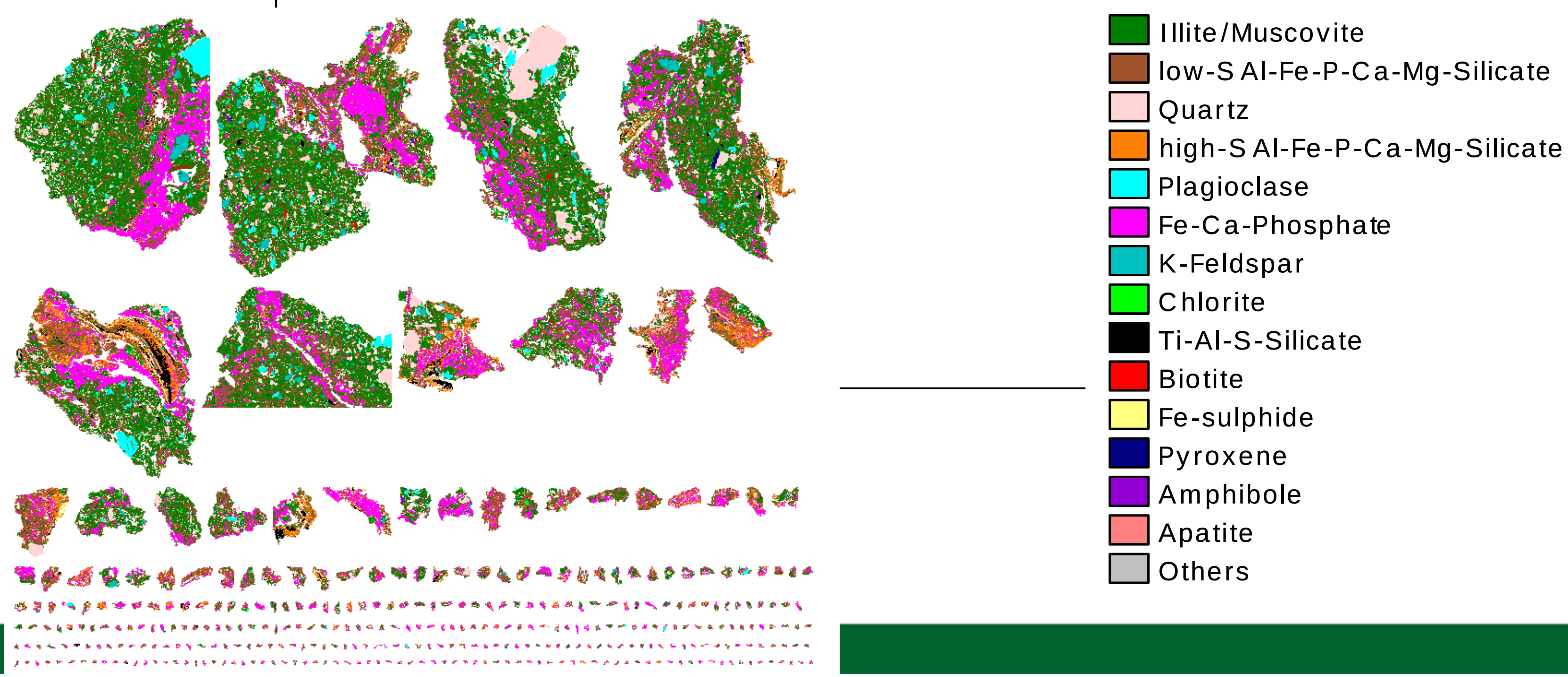
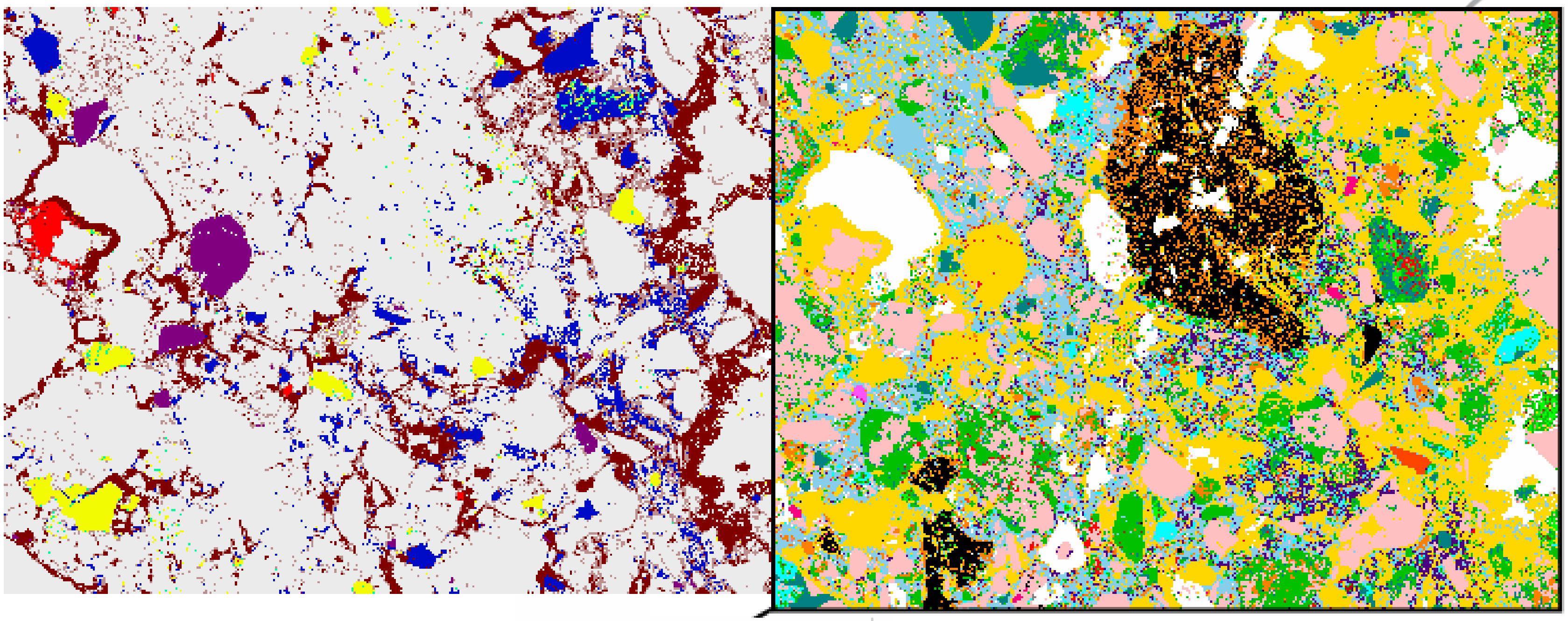
- Closure strategy for tailings storage facilities
- Risk assessment tools for post-mined line
- Pre-operational rehabilitation research
- **Early ore body characterisation for the prediction of acid and metalliferous drainage**

Same approach as for processing:

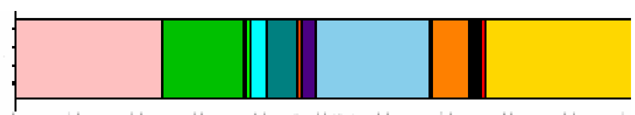
- Understand the mineralogical and geological relationships
- Locking, exposure to fluids, element deportment, bio-availability



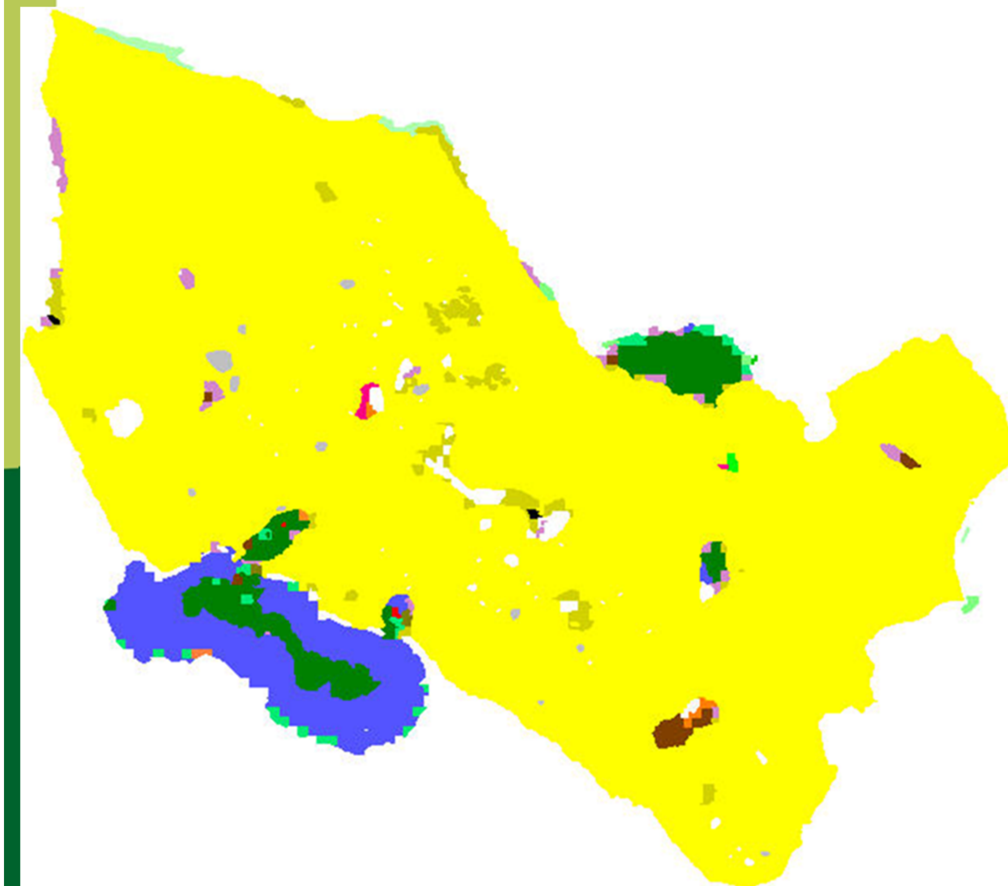
Mineral variability



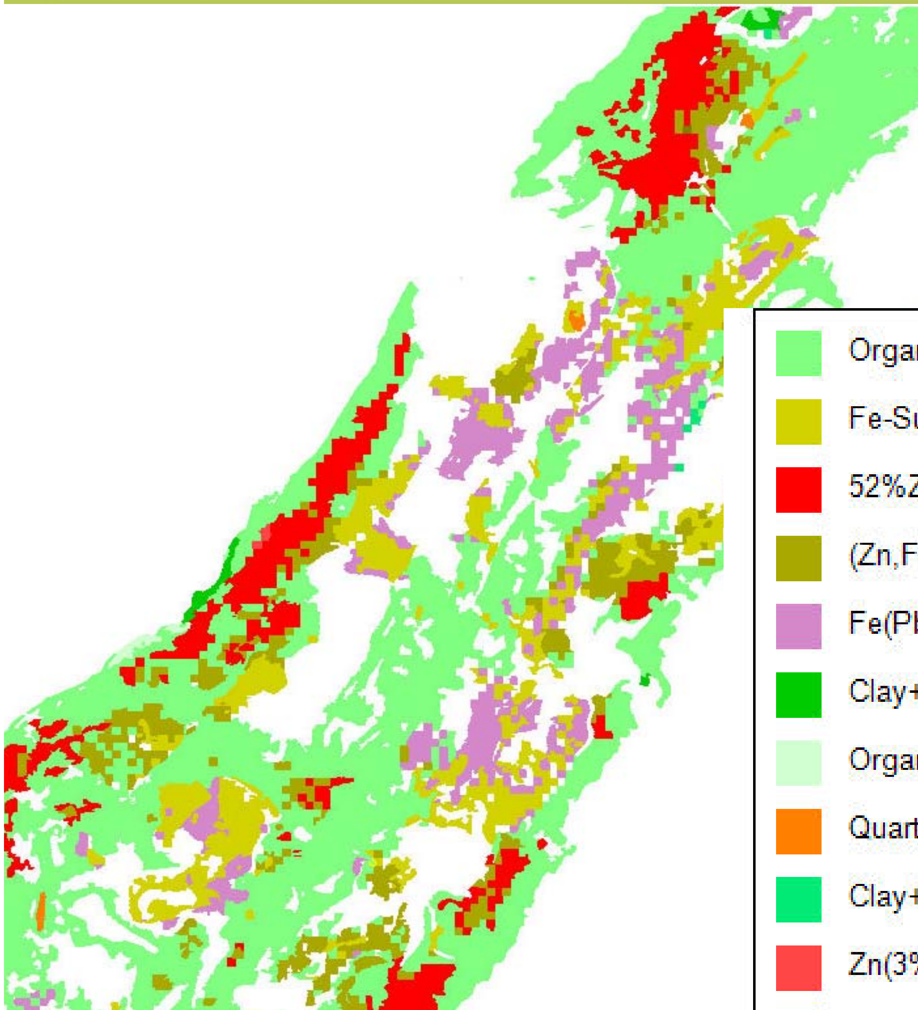
	Mass %
Quartz	23.5
Illite/Muscovite	13.2
Kaolinite	0.3
Chlorite	0.8
Biotite/Phlogopite	0.3
Plagioclase	2.4
Alkali Feldspar	5.0
Amphibole	0.6
Pyroxene	2.4
Calcite	18.2



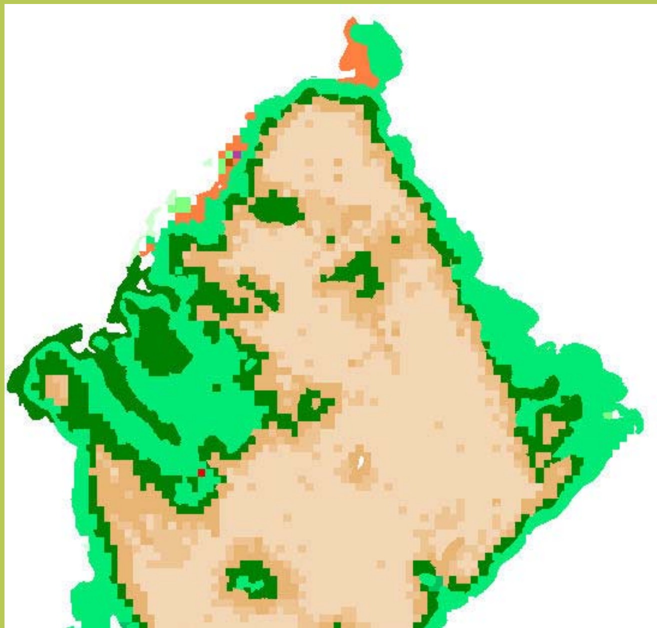
Prediction via mineral characterization



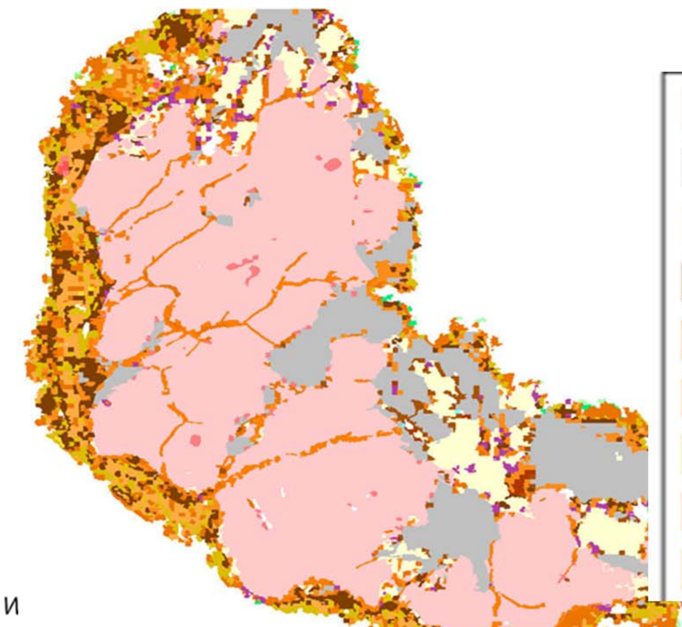
Pyrite	29252.89
ZnFeMn-Carbonate	1950.44
FeMnZn-Carbonate	984.52
Fe-Sulphate-(Zn)	485.58
Fe(Pb?)AlSi-Oxide/Sulphate	219.84
Clay+FeCaMnMg-Sulph/Phos/Carb/Oxide	166.96
Organic-SFeNaZnCuO	103.43
Na[Fe,Mg]-AlSilicate	100.33
Galena	83.87
FeMn-Mg-Carbonate	58.11
Siderite/Rhodochrosite	57.53
Organic-ZnSNaCaMnFeAlSiO	35.83
Quartz+Fe-(Oxide/Sulphate)	29.63
Unknown	24.40
K[Fe,Mg]-AlSilicate	19.18
Sphalerite	17.24
Apatite	11.62
(K,Na)-AlSi-FeCaMnZn-Oxide/Sulphate	10.27
Fe-KAlSi-Oxide/Sulphate	6.20
Magnetite-Cr	6.20
MnFeMgCa-Carbonate	5.81
Monazite-Th-LREE	4.26
Clay+(Fe,Zn)-Sulph/Phos/Carb/Oxide	1.94
Monazite-LREE	0.97



Organic-ZnSNaCaMnFeAlSiO	6041.19
Fe-Sulphate-(Zn)	1200.47
52%Zn6%Cd-Sulphate	1085.03
(Zn,Fe)-Sulphate	910.84
Fe(Pb?)AlSi-Oxide/Sulphate	873.14
Clay+(Fe,Zn)-Sulph/Phos/Carb/Oxide	45.88
Organic+(SiO+S)	44.92
Quartz+Fe-(Oxide/Sulphate)	15.39
Clay+FeCaMnMg-Sulph/Phos/Carb/Oxide	11.13
Zn(3%Cd)Fe?-Sulphate-FeKAlSiOxide	5.42
Sphalerite	1.74
Pyrite	0.82
Organic-SFeNaZnCuO	0.82



	Dolomite	812.84
	Clay+FeCaMnMg-Sulph/Phos/Carb/Oxide	489.22
	FeCaMgMnZnPb-Carbonate	315.08
	Dolomite/Siderite/Rhodochrosite	283.94
	Dolomite+K-AlSilicate	179.19



	Quartz	36631.63
	Muscovite	10937.76
	Albite	5177.67
	K[Fe,Mg]-AlSilicate	3997.72
	Fe-Oxide/Sulphate+Qtz	3322.72
	Quartz+Fe-(Oxide/Sulphate)	2819.32
	Goethite+NaKCa-AlSilicates	2710.08
	Fe-KAlSi-Oxide/Sulphate	2432.14
	Fe-Oxide/Sulphate+Qtz+Clay	2417.03

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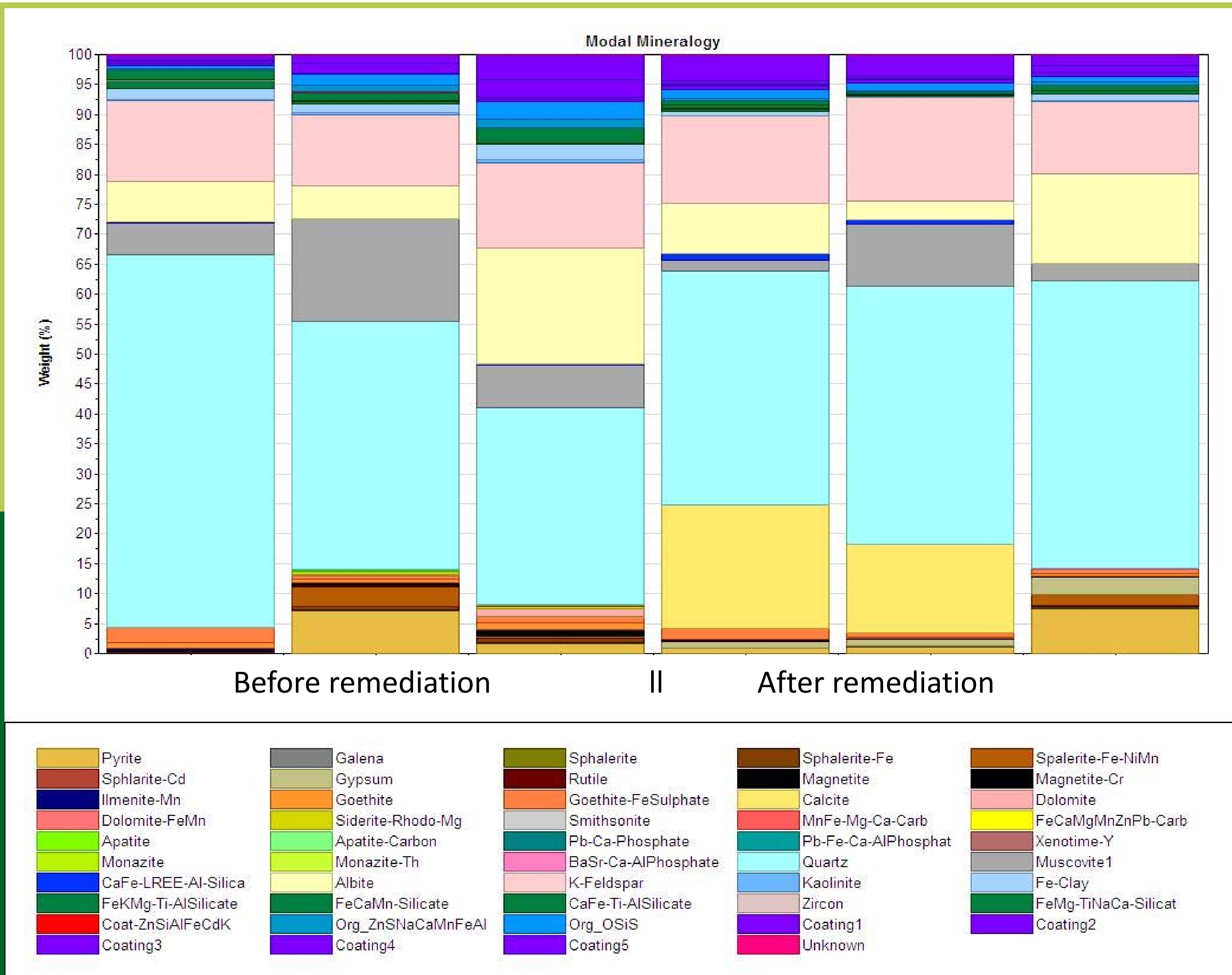


Modal Mineralogy
Weight (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Before remediation
ll
After remediation
Pyrite
Galena
Sphalerite
Sphalerite-Fe
Spalerite-Fe-NiMn
Sphlarite-Cd
Gypsum
Rutile
Magnetite
Magnetite-Cr
Ilmenite-Mn
Goethite
Goethite-FeSulphate
Calcite
Dolomite
Dolomite-FeMn
Siderite-Rhodo-Mg
Smithsonite
MnFe-Mg-Ca-Carb
FeCaMgMnZnPb-Carb
Apatite
Apatite-Carbon
Pb-Ca-Phosphate
Pb-Fe-Ca-AlPhosphat
Xenotime-Y
Monazite
Monazite-Th
BaSr-Ca-AlPhosphate
Quartz
Muscovite1
CaFe-LREE-Al-Silica
Albite
K-Feldspar
Kaolinite
Fe-Clay
FeKMg-Ti-AlSilicate
FeCaMn-Silicate
CaFe-Ti-AlSilicate
Zircon
FeMg-TiNaCa-Silicat
Coat-ZnSiAlFeCdK
Org_ZnSNaCaMnFeAl
Org_OSiS
Coating1
Coating2
Coating3
Coating4
Coating5
Unknown

Application

Brownfields

Greenfields

SEE

Sustainability & Extraction Efficiency

LOM/Long Term Planning

Short Term Planning Scheduling

SEE Lite

LOM/Long Term Planning

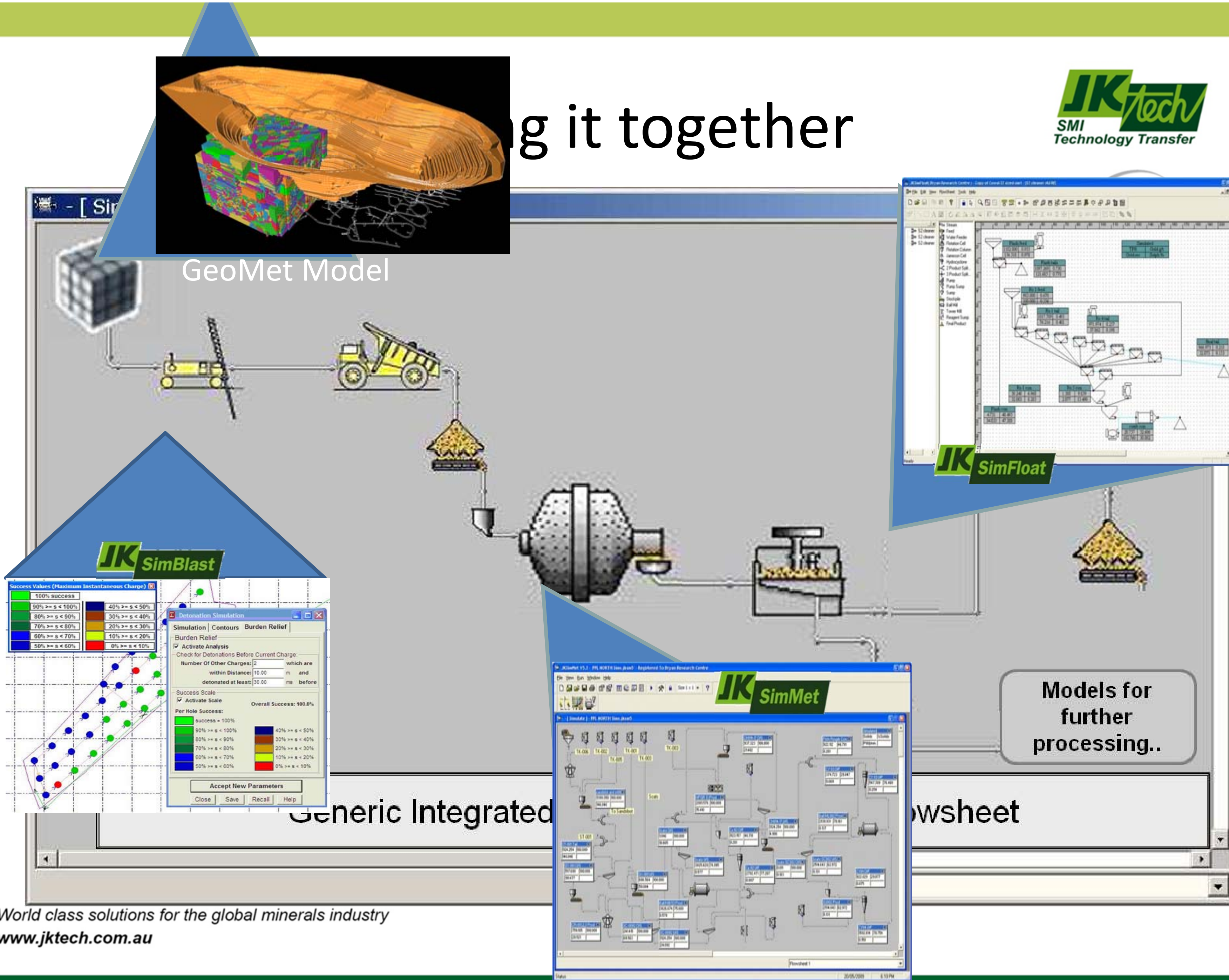
SEE: Sustainable extraction efficiency

- Historical Mine to Mill Results
  - cross-discipline (blast to S/AG Mill) intervention
  - increases mill throughput in the short term
- Geology-Mine-Plant Integration
  - fully integrated predictive optimisation process
  - considers key eco-efficiency attributes
  - enables long-term improvements

- Metal tonnes **- Cost ($/tonne)** **- Total Energy (kWh/tonne)**

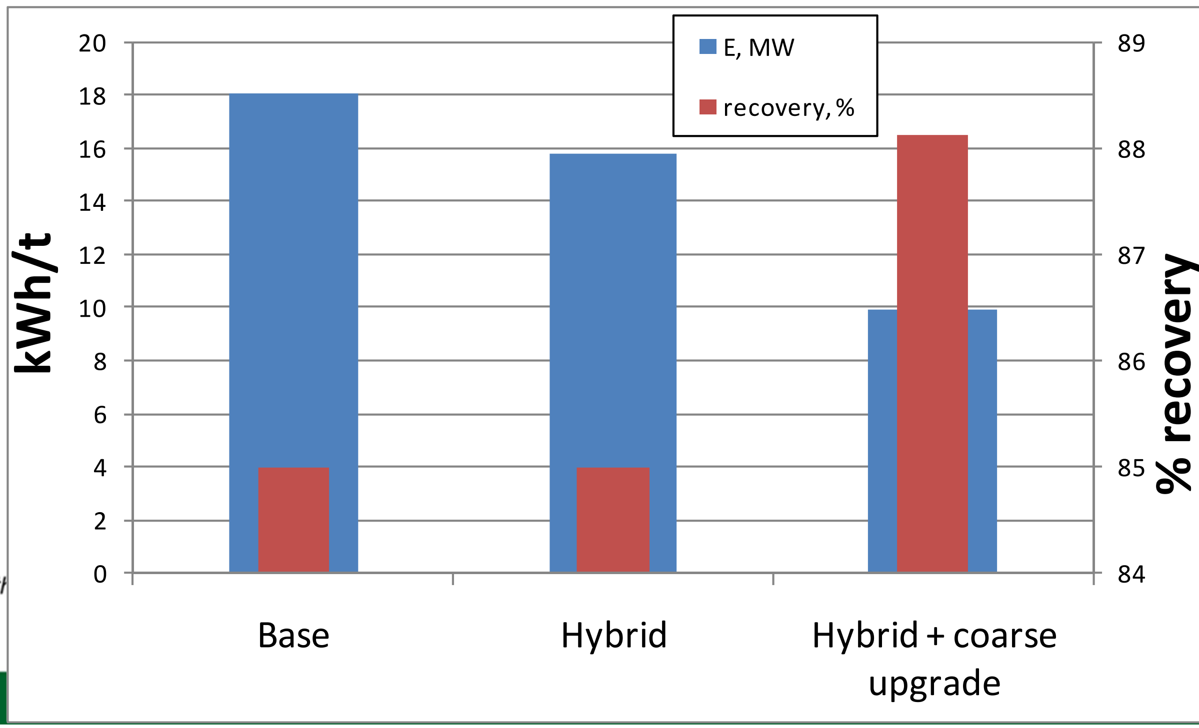
- Water (Ml/tonne) **- Carbon Emissions (CO_2/tonne)**

g it together

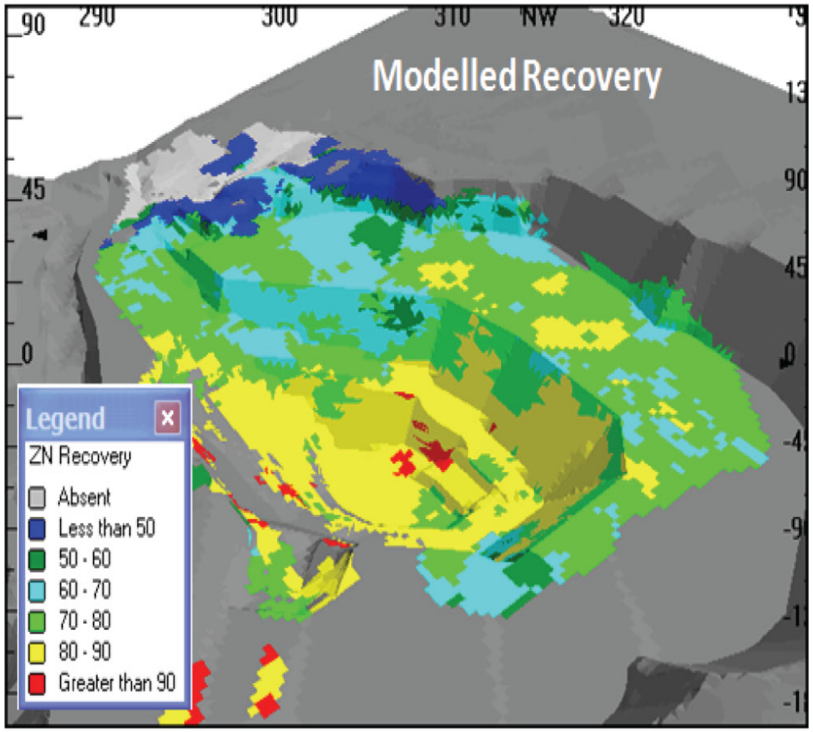


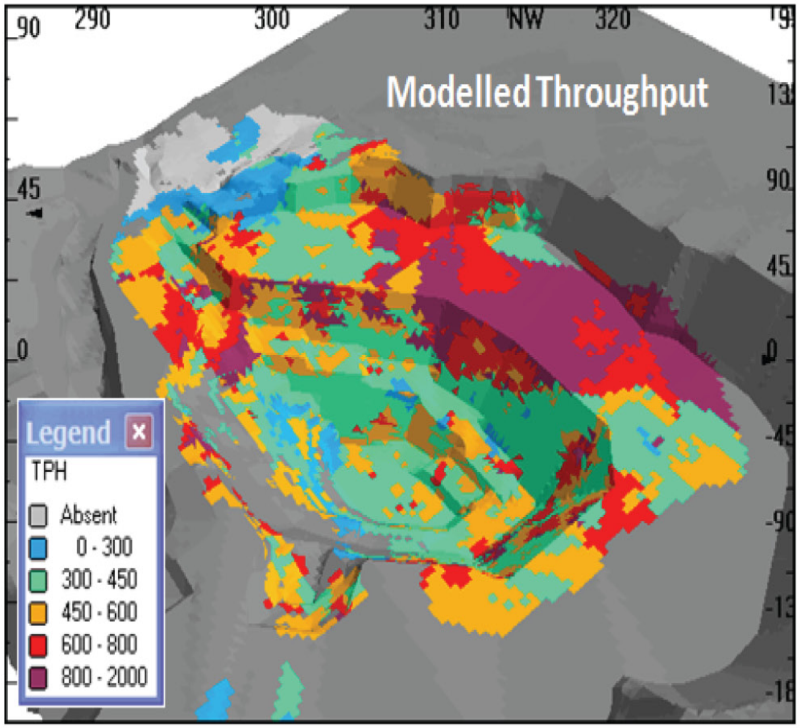
Flexible Circuits Energy impact

Scenarios	E, MW	% Energy saving	TOTAL energy with embodied	% TOTAL Energy saving	recovery, %
Base	18.1	0	25.1	0	85.0
Hybrid	15.8	13	19.3	23	85.0
Hybrid + coarse upgrade	9.9	45	9.9	61	88.1

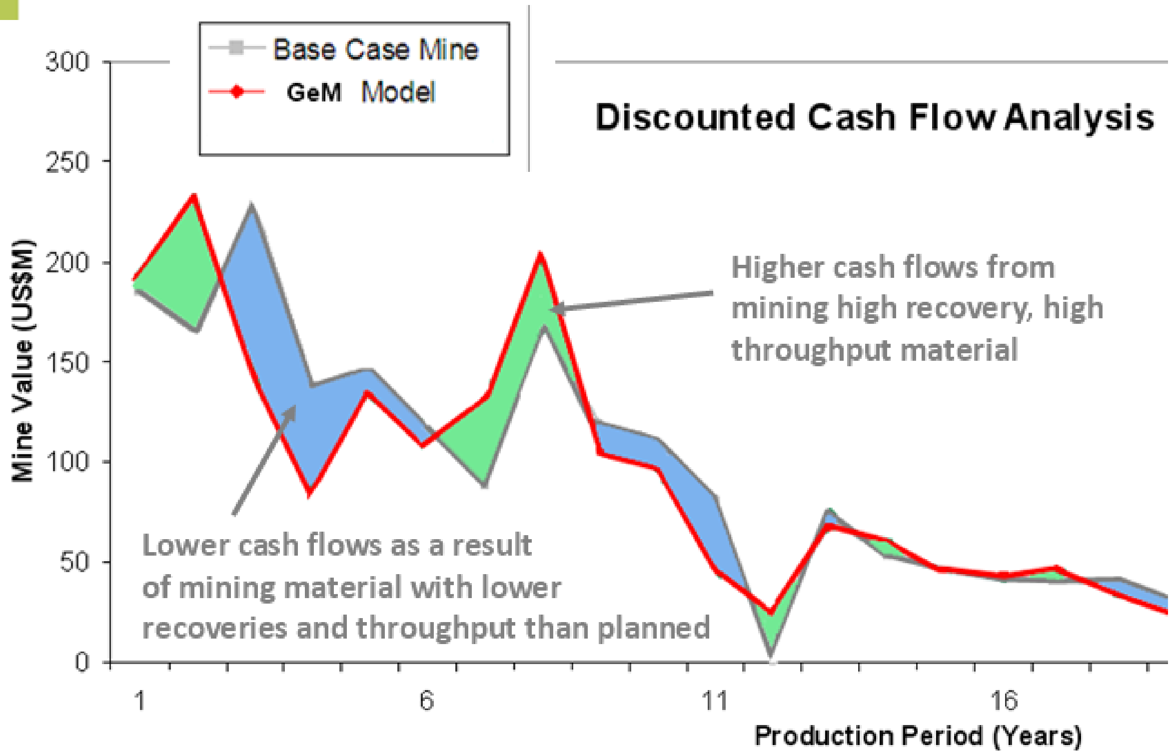


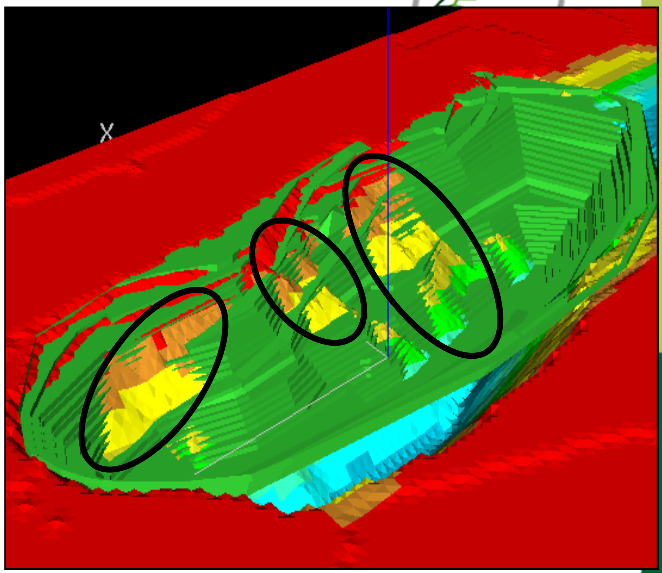
More effective project management





Impacting the cash flow





Uneconomic ore impacting cash flow

This illustrates the difference in cash flow predicted from a fully attributed GeM mine planning model versus the mines traditional ore reserve model. The variation is up to $50m per annum. This information leads to informed rescheduling to maximise value and minimise risk.

Predict …. Plan …. Manage

PREDICT process performance

Recognize variability and geological drivers
Model relationships among attributes
Interpolate throughout mineral deposit

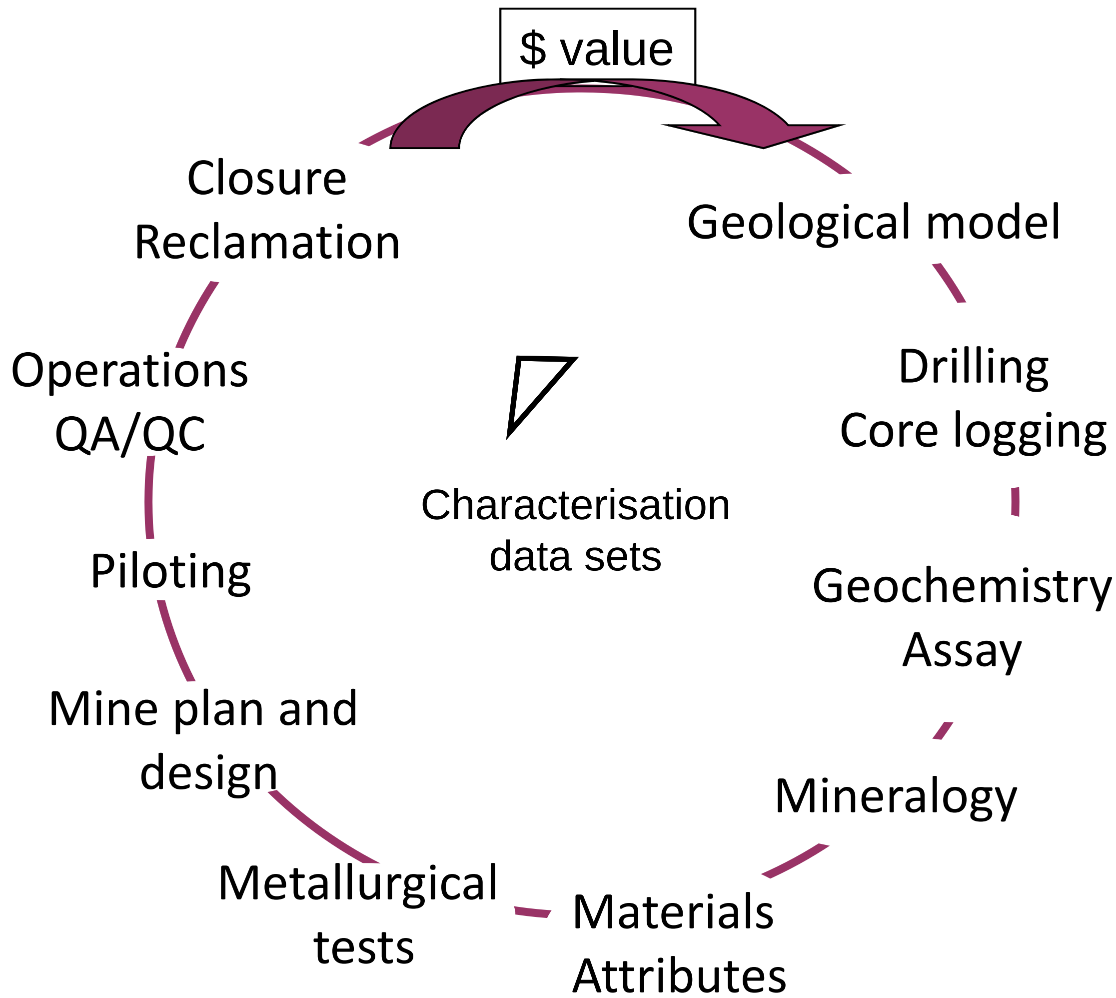
PLAN proactively

Integrate into mine plan and scheduling
Reduce uncertainty
Improve performance

MANAGE impacts

Understand and control environmental consequences
Reduce overall project risk
Recognize financial value through NPV and IRR options

Life-of-mine geomet application



Value

- Locked in variable ore relationships
- Team-based approach
- Integrate data sets
- Operating cost reduction
- Risk mitigation

  through life of project

SMI Technology Transfer

SMI CMLR
Centre for Mined Land Rehabilitation

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