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Evaluation of Mineral Resource risk at a high-grade underground gold mine

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Project Background

Beaconsfield Gold Mine, Tasmania

- 240,000 tpa underground mining operation
- Orogenic lode-gold deposit (quartz-ankerite reef)
- Multiple mining headings / methods
- Free and refractory gold (60:40)
- Gravity / bacterial oxidation circuits
- Mine constrained





“Tasmania Reef” Mineralisation Characteristics

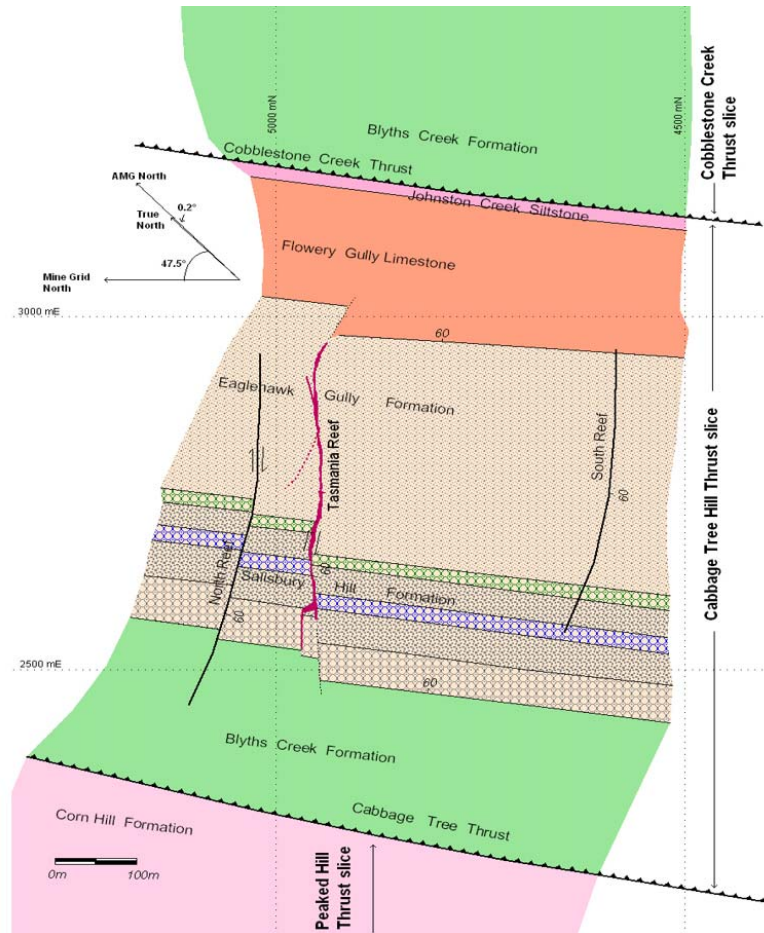
- Mechanical characteristics of the host rocks governed development of the fault which contained the reef
- Laminated textures suggested episodic crack-seal vein growth
- Width of reef 0 to 8 m (average 2.2 m)
- Grade of reef 0 to 300 g/t Au (average 20 g/t)
- Majority of gold is less than 100 microns in size
- 2 Moz on a single structure





Project Geology

Geology – Plan





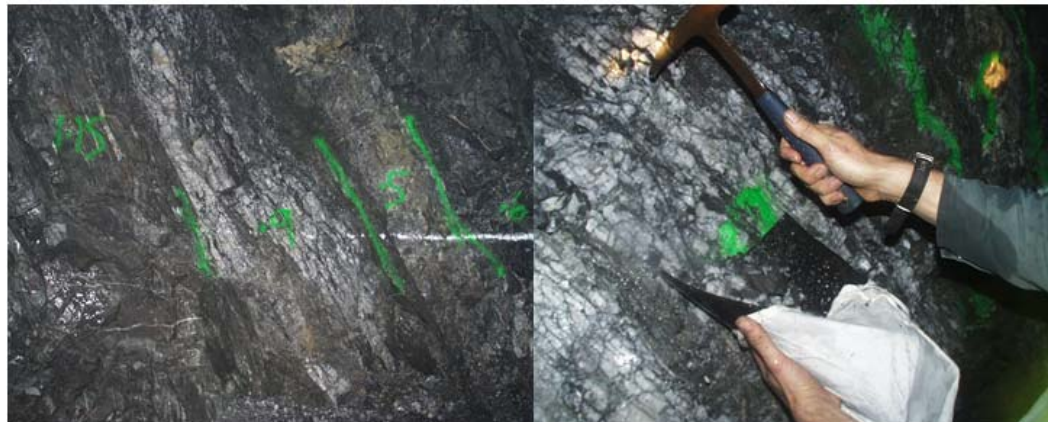
Project Geological Issues

- Significant “unexpected” grade and width variation on a month by month basis which caused financial volatility
- Achieved production targets but ounces often weren’t realised
- Led to understandable frustration
- Triggered a review of data, geology and estimation techniques



Face Sampling Data

- Continuous chip sampling at chest height 1.5 m from the floor of underground drives every 2.2 m
- Horizontal development allows face sampling to be completed every 13 m vertically
- Faces washed with survey control for location
- QC data supports quality





Diamond Drilling Data

- Nominal diamond drill pattern (NQ) of approximately 25 m E by 50 m RL
- Slight low bias compared with face sampling data but probably due to coarse spacing
- QC data supports quality



Broad Characteristics

- Large relatively continuous reef
- Local structural complexity difficult to predict prior to mining
- Potential for structural intersections to enhance grades
- Geological controls well understood





Summary of Techniques

- Industry standard software
- Wireframe modelling robust
- ID2 / OK interpolation with top cutting
- MIK also used
- No majors issues detected





Summary of Findings

- Data quality OK
- Geology well understood
- No material issues with modelling / estimation found
- All methods “smooth the data” and none were able to reproduce the inherent variability of the deposit
- A decision was then made to quantify Mineral Resource uncertainty through conditional simulation techniques





Estimation versus Simulation

Estimation	Simulation
Block scale	Point scale
Single estimate	Many realisations
Smooths sample data	Reproduces sample histogram and variogram
	Enables uncertainty assessment





Conditional Simulation Background

- Conditional simulation is the process of building numerous equally probable 'realisations' of a particular variable
- The difference in these images provides a measure of uncertainty of unsampled values in space
- Nearby data and previously simulated values used
- Realisations are conditional in that each realisation honours data values and variography
- A range of outcomes for any given variable and location (or block) can then be determined



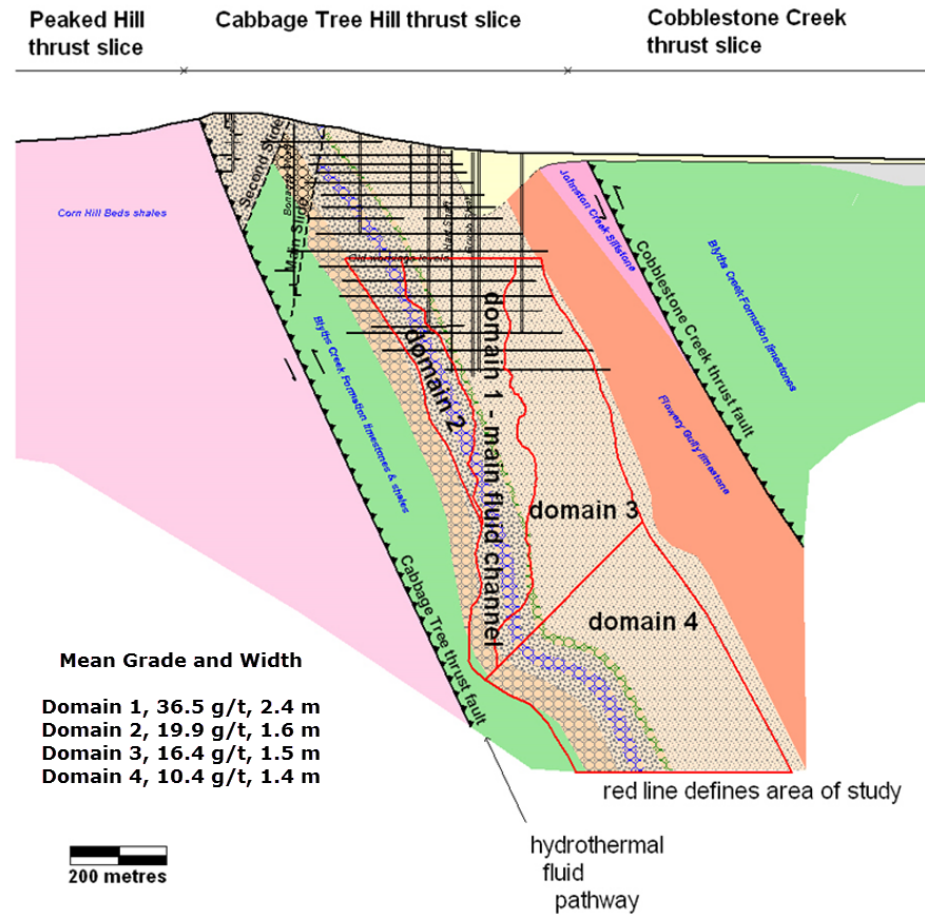


Conditional Simulation Case Study

- Step 1 – Set domains and complete variography
- Step 2 – Compile raw data into domain-coded nodes file
- Step 3 – Run simulations (100) – node path varies between each simulation to give different results
- Step 4 – Block averaging required to get block results

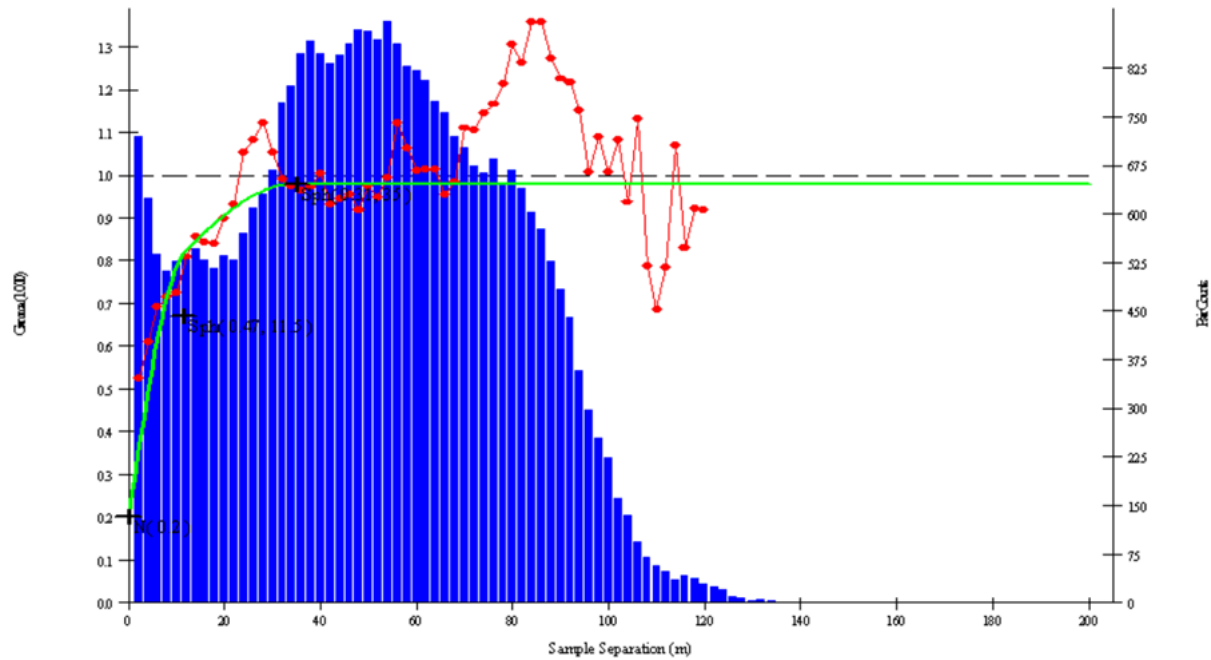


Domaining – Long Section

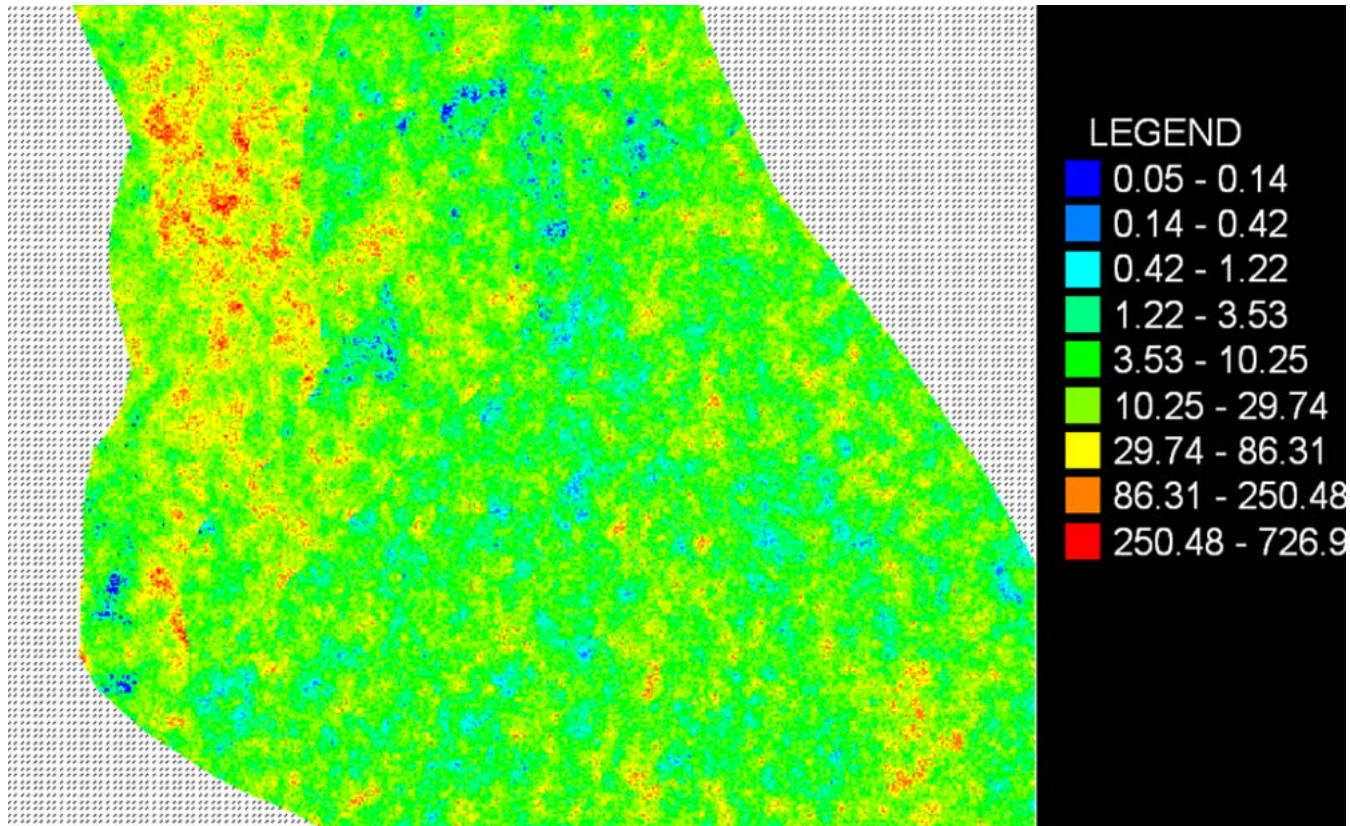


Au Variography

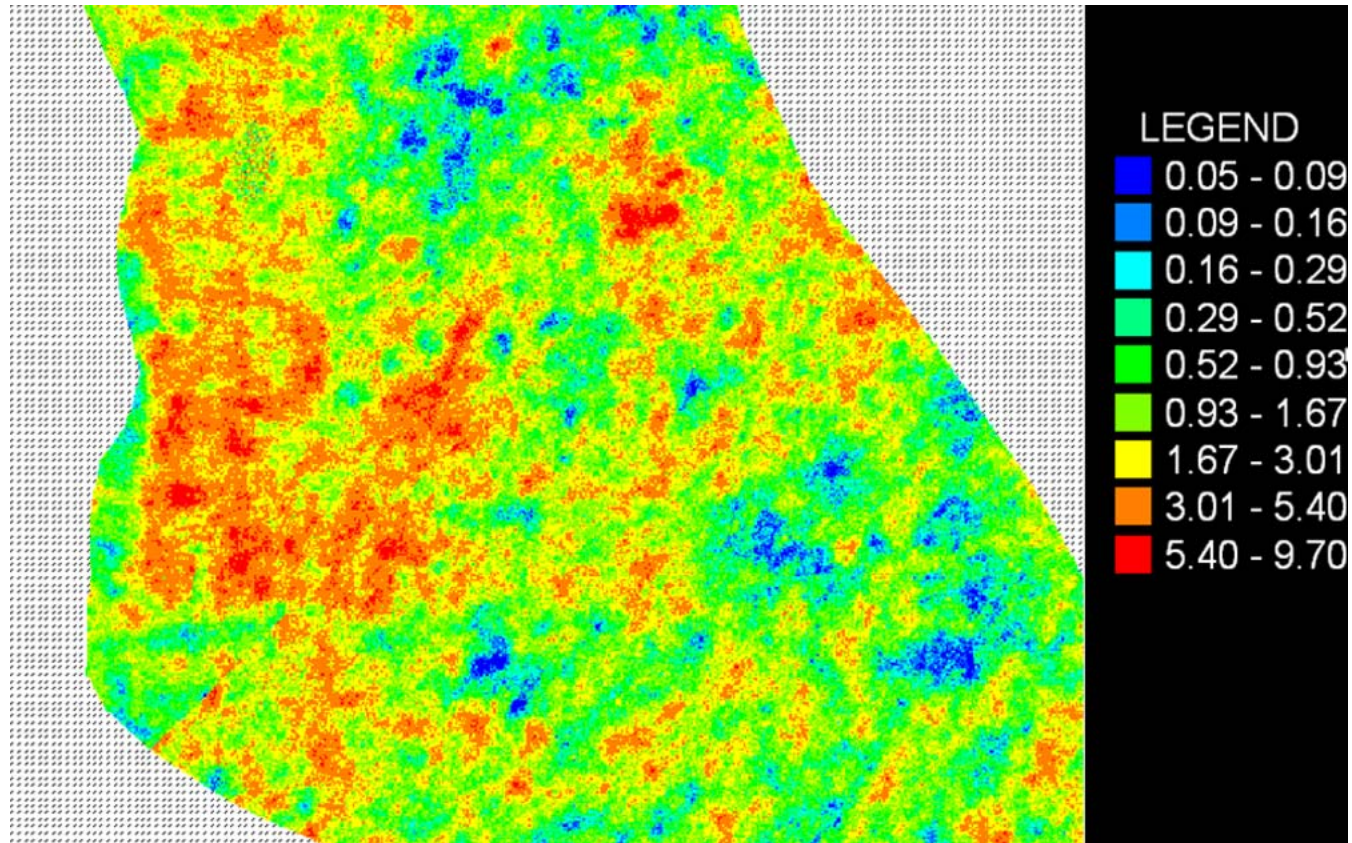
(Direction 2) 10-->090: Normal Scores Continuity for Au
DOMAIN 1



Au Simulation – Long Section



Thickness Simulation – Long Section



Conclusions

- Significant difference between Au realisations, particularly at depth
- Reasonable difference between thickness realisations, particularly at depth
- At distances > 10 m from data points, significant differences existed between realisations
- How do we use this data to communicate resource uncertainty to stakeholders?
- What mitigation strategies are available?



Application of Results

- Probabilistic cash flow models (communicate impact of resource uncertainty on profit)
- Drill pattern risk assessment (risk versus cost)

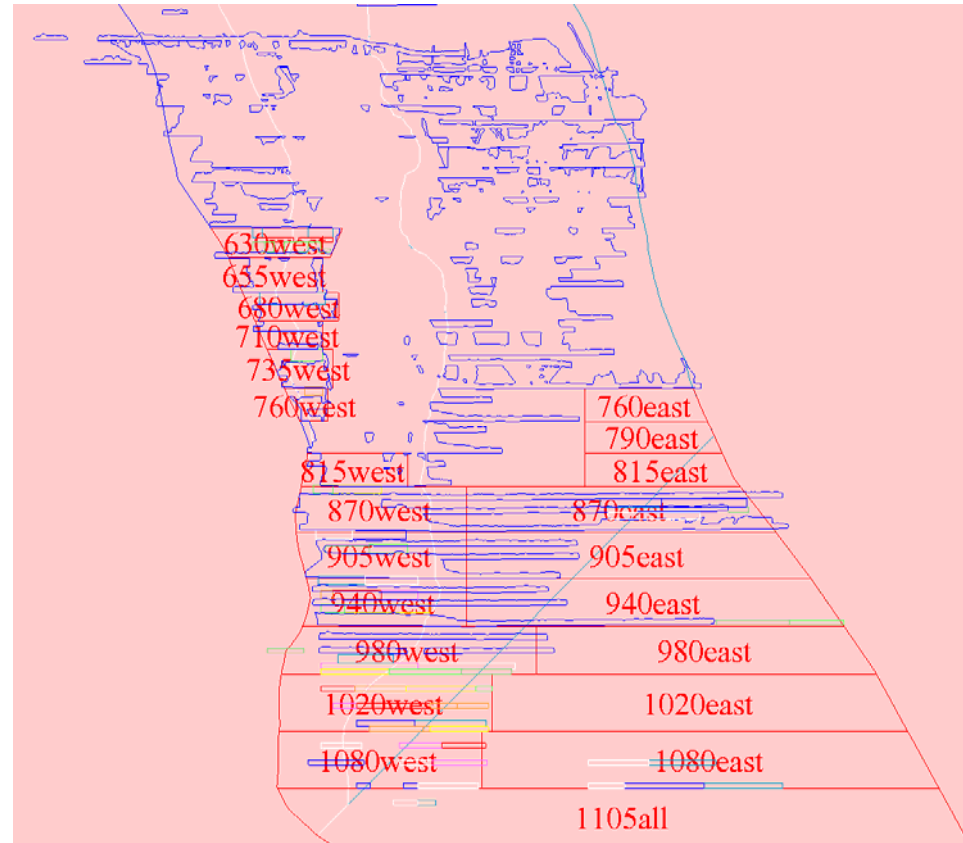


Probabilistic Cash Flow Model

- Spreadsheet constructed using @Risk software
- Width and grade simulation data imported and probability distributions fitted to data (per mining area per month for annual schedule)
- Operating Cost (normal), exchange rate (uniform) and gold price (uniform) distributions defined based on historical volatility
- Monte Carlo simulation (2000 scenarios) employed to randomly sample each distribution to achieve a profit range result
- Variables ranked by impact

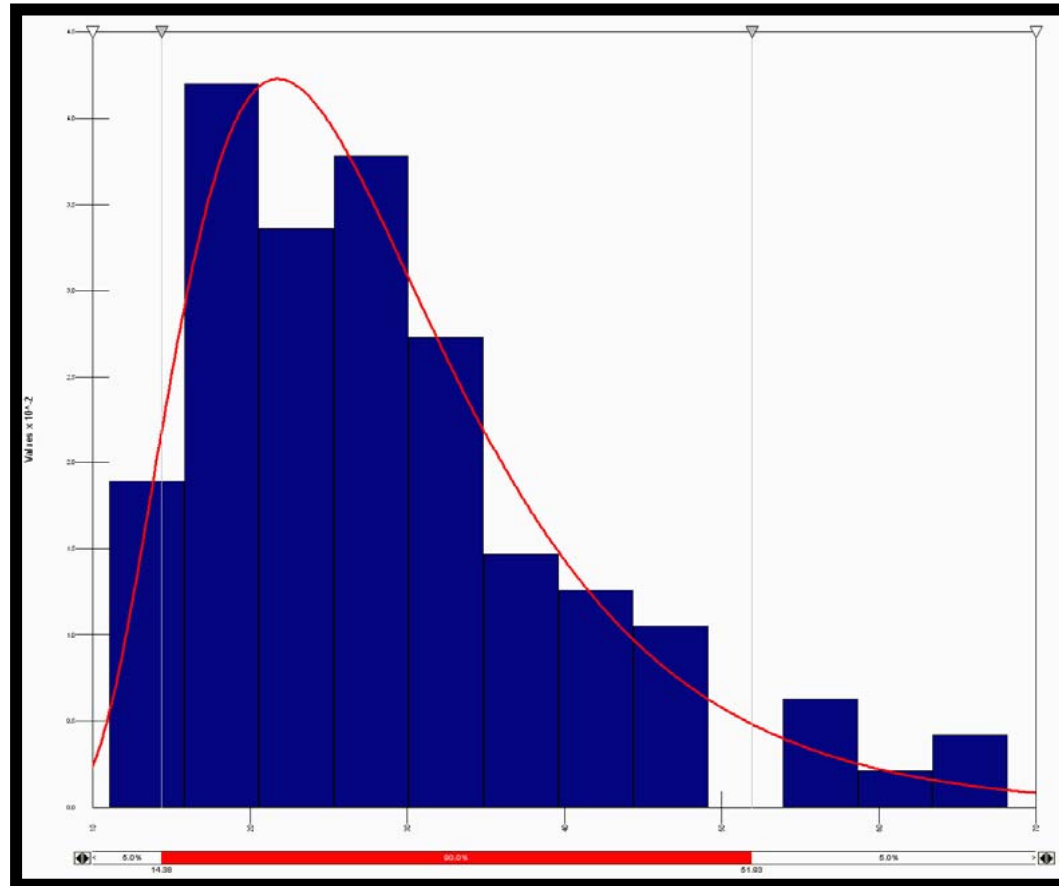


12 Month Schedule (Long Section)





Single Stope Au Distribution for One Month





Conclusions

- Grade is king – the most influential variable in every month in determining profit
- Periods of loss over short-term inevitable
- Highlights importance of understanding Mineral Resource uncertainty when assessing project economics





Method

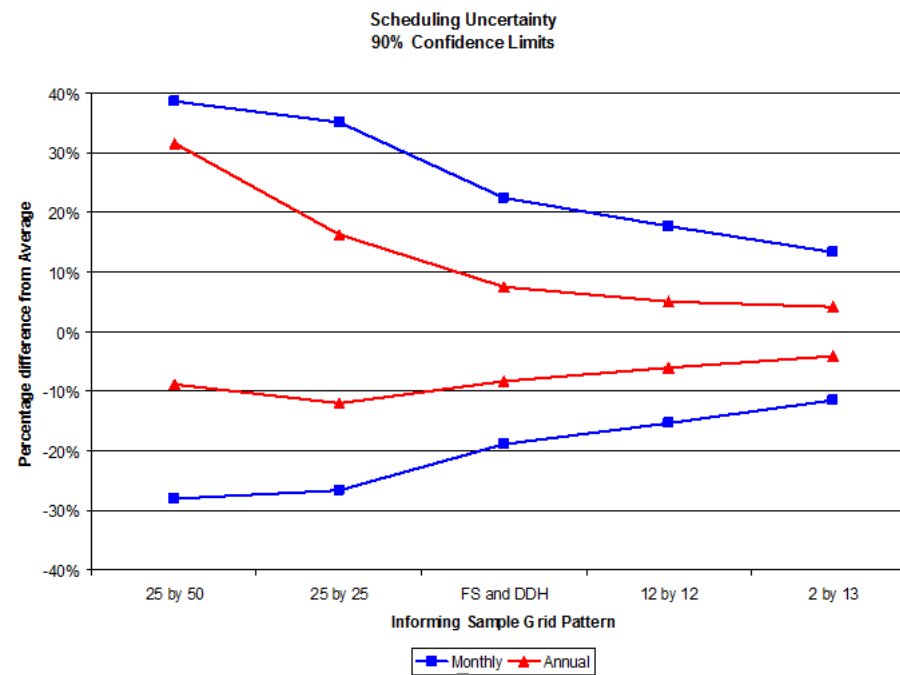
- A single realisation was re-sampled at various grids representing a range of sampling strategies (100 simulations run for each)
- 25 m by 50 m (pre mining pattern)
- 25 m by 25 m
- 12 m by 12 m
- 2 m by 13 m (nominal post mining pattern)
- 12 month mine schedule interrogated against each to assess uncertainty (monthly and annual)





Drill Pattern Case Study

Results





Results

- There is little merit in closing from the nominal exploration drill spacing of 25 m by 50 m to 25 m by 25 m
- A regular 12 m by 12 m grid performs better than the actual face sample and exploration drilling data combination
- A point of diminishing returns has been reached once the sample grid achieves the levels represented by the actual production face sampling
- **Cost and risk reduction trade-off can be assessed. Drilling pattern required to achieve a given confidence level can be determined.**



JORC Mineral Resource Classification Definitions

- **Measured** – Geological evidence ...is sufficient to **confirm** geological and grade continuity between points of observation
- **Indicated** – Geological evidence ...is sufficient to **assume** geological and grade continuity between points of observation
- **Inferred** – Geological evidence ...is sufficient to **imply** but not verify geological and grade continuity

- **Geological continuity** – geometric continuity of mineralisation (governs tonnage estimates)
- **Grade continuity** – continuity of grades within the zone of mineralisation



Case Study Geological Learnings

- Vein style deposits “come and go” due to vein pinching and / or reef offsets
- 25 m x 50 m pattern may not be sufficient to assume geological continuity and therefore report Indicated Mineral Resources
- Grade control (minimise ore loss and dilution) labour intensive. Profile control (development) critical to control stope dilution, communication with operators critical to track ore / waste movement, regular block model updates required to honour new data and reconciliation with production data to improve model and enable meaningful mine planning.





Case Study Grade Learnings

- Grade is generally the most important variable in driving project economics
- Vein-style deposits often display a medium to high nugget component **and** significant short-range variability
- Estimating grades >5 to 10 m may be difficult
- 25 m x 50 m pattern may not be sufficient to assume grade continuity and therefore report Indicated Mineral Resources



JORC Classification Thoughts

- **Measured Mineral Resources** generally not based on drilling alone
- **Indicated Mineral Resources** may be based on drilling alone for moderate / high nugget vein deposits
Judgement call – will further drilling materially change the model?
- **Inferred Mineral Resources** may be based on drilling alone but multiple intersections still required to assess geological and grade continuity
- **Judgement call – is there enough data to imply continuity?**



Vein-style Mineral Resource estimation Toolbox

- Collect high quality data with adequate QC data
- Diamond preferable to RC to enable detailed assessment of the characteristics of the mineralisation
- Critically review geological and grade continuity
- Undertake bulk sampling (if possible)
- “Pepper” a window of the deposit with drill holes to test geological and grade continuity at the local level
- Classification decisions ultimately heavily reliant on judgement of Competent Person
- Seek peer review
- Ensure transparency through documentation, discuss material issues and demonstrate competence





Thank You



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