Finex 2014 Julius Wernher Lecture

Evolution of Mineral Resource Classification from 1980 to 2014 and Current Best Practice

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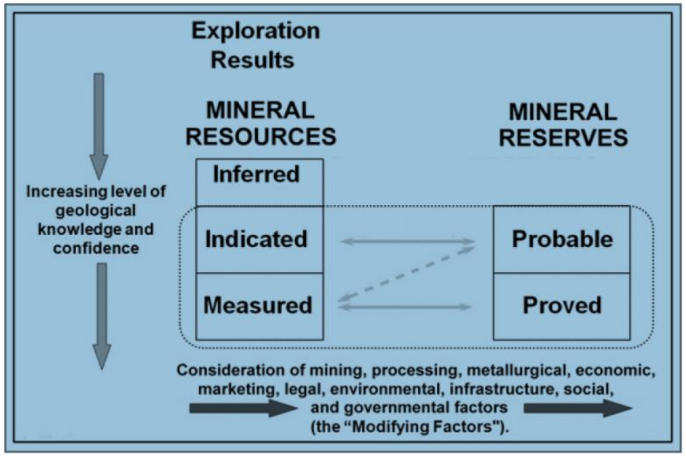
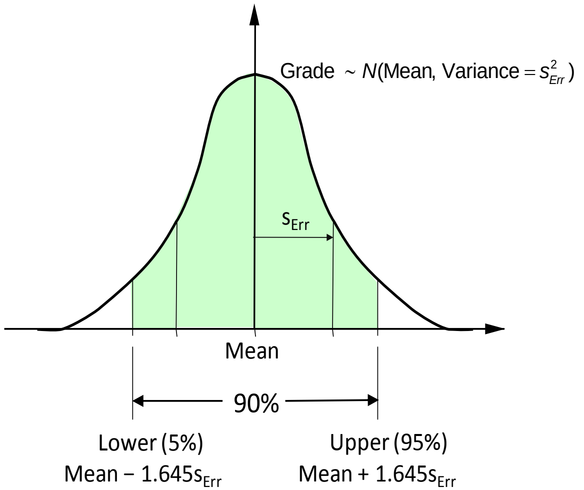
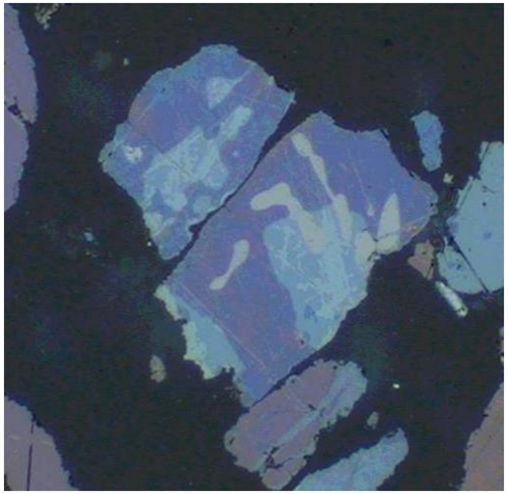






Abstract

Mineral Resource classification has evolved starting with a system based on geological confidence in USGS/USBM Circular 831 in 1980. The 1989 JORC Code added a requirement for reasonable expectations for eventual economic extraction. The JORC Code definitions were adopted by SME, CIM, IMM, AusIMM and SAIMM in the 1997 Denver Accord. The next evolutionary step came in 2000 with the CIM's introduction of the concept that Indicated and Measured Resources had to support mine planning. In 2012-13 the Committee for Mineral Reserves International Reporting Standards further broadened the requirement that the grade or quality, densities and shape of an Indicated or Measured Mineral Resource are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

Best practices now include consideration of geological continuity of both orebody grade and shape, deleterious elements, quantification of the accuracy of estimates at local scales and the impact of uncertainty on financial performance, and implicit levels of mining selectivity. Because of the number of assessment criteria now involved in classifying mineral resources, a scorecard approach has been developed and is utilized by the Anglo American Group that rates criteria according to confidence level and importance. An example is provided for a zinc deposit. This approach is also beginning to be adopted elsewhere, and an example is provided for a porphyry-hosted deposit.

Outline

- Introduction
- USGS-USBM Circular 831
- JORC Code (1989)
- Denver Accord and CIM (2000)
- CRIRSCO (2012)
- Continuity
- Confidence limits
- Consideration of modifying factors
- Scorecards

Introduction

- Resource classification has evolved: (surprise!)
- 1980: Mineral inventory categorized by confidence
- 1989: Reasonable prospects for eventual economic extraction
- 1997-2000 Ability of Measured and Indicated Resources to support mine planning, adequacy to support application of technical, economic and financial parameters
- 2012: Measured and Indicated Resources must support application of Modifying Factors; majority of Inferred expected to convert to Indicated with further exploration
- Key issues in current practice:
  - Classify based on data quality
  - Classify based on continuity of grade
  - Classify based on continuity of grade, thickness, orebody geometry
  - Classify based on byproduct credits
  - Classify based on knowledge of deleterious elements
  - Should resources incorporate allowances for ore loss and dilution?
  - Use of scorecards to rate confidence in various factors

USGS Circular 831 (1980) – Principles of a Resource/Reserve Classification for Minerals

- Successor to and amplification of USGS Bulletin 1450A (1976)
- Developed by US Bureau of Mines and US Geological Survey
- Resource – A concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible

- A resource is currently or potentially feasible; how is *potentially* defined?
- The answer is shown in the next slide. USGS/USBM intended a sub-classification according to economic, marginally economic, sub-economic

The McKelvey Box (McKelvey was Director of USGS in 1970s)

RESOURCES OF (commodity name)

[A part of reserves or any resource category may be restricted from extraction by laws or regulations (see text)]

AREA: (mine, district, field, State, etc.) UNITS: (tons, barrels, ounces, etc.)

Cumulative Production	IDENTIFIED RESOURCES			UNDISCOVERED RESOURCES	
	Demonstrated		Inferred	Probability Range (or)	
	Measured	Indicated		Hypothetical	Speculative
ECONOMIC	Reserves		Inferred Reserves		
MARGINALLY ECONOMIC	Marginal Reserves		Inferred Marginal Reserves		
SUB-ECONOMIC	Demonstrated Subeconomic Resources		Inferred Subeconomic Resources		

Other Occurrences	Includes nonconventional and low-grade materials

Circular 831 Led to Use of Many Modifiers for Resources

- Economic
- Marginal
- Subeconomic
- Undiscovered
- Speculative
- Hypothetical

- In Canada, 1990s:
  - Geological (everything to center of the earth)
  - Mineable (within a pit)

Let's Look at the Definitions USGS Circular 831 (1980)

Measured.- Quantity is computed from dimensions revealed in outcrops, trenches, workings, or drill holes; grade and (or) quality are computed from the results of detailed sampling. The sites for inspection, sampling, and measurement are spaced so closely and

the geologic character is so well defined that size, shape, depth, and mineral content of the resource are well established.

Indicated.- Quantity and grade and (or) quality are computed from information similar to that used for measured resources, but the sites for inspection, sampling, and measurement are farther

apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for measured resources, is high enough to assume continuity between points of observation.

Inferred.- Estimates are based on an assumed continuity beyond measured and(or) indicated resources, for which there is

geologic evidence. *Inferred resources may* or may not be supported by samples or measurements.

Comments on Circular 831 Definitions

- Largely based on confidence in geological information
- Inferred can be declared without any samples or measurements

Next Step was the JORC Code (1989)

- Introduced relationships between resources and reserves; separate terms for each

Figure 1. REPORTING TERMINOLOGY

IDENTIFIED MINERAL RESOURCES (in situ)		ORE RESERVES (mineable)
INFERRED		
INDICATED	⟷	PROBABLE
MEASURED	⟷	PROVED

Increasing level of geological knowledge and confidence

Consideration of economic mining, metallurgical, marketing, environmental, social and governmental factors

JORC Code (1989) Did Away with the Modifiers of Circular 831 Relating to Economics

- Only Inferred, Indicated and Measured modifiers permitted
- The term "Resource" is defined as an identified in situ mineral occurrence which excludes "Pre-Resource" mineralisation, from which valuable or useful minerals may be recovered. A resource maybe reported as:

- an Inferred Resource

- an Indicated Resource

- or a Measured Resource

- In defining a resource. the competent person will only take Into consideration geoscientific data. It must be appreciated, however, that in reporting a resource, there is an implication that there are reasonable prospects for eventual economic exploitation.

JORC (1989) Definitions

The term "Measured Resource" means a Resource intersected and tested by drill holes, underground openings, or other sampling and procedures at locations which are spaced closely enough to confirm continuity and where geoscientific data are reliably known.

The term "Indicated Resource" means a ·Resource.

Sampled by drill holes, underground openings, or other sampling procedures · at locations too widely spaced to ensure continuity but close enough to give a reasonable indication of continuity and where geoscientific data are known with a reasonable level of reliability.

The term "Inferred Resource" is an estimate, inferred from geoscientific evidence, drill holes, underground openings, or other sampling procedures and before testing and sampling information is sufficient to allow a more reliable and systematic estimation.

Comments on JORC 1989 Definitions

- The appropriate resource category must be determined by a Competent Person
- Advances in thinking:
  - Reasonable prospects for eventual exploitation (later changed to *extraction*)
  - Must have geoscientific evidence to support Inferred

Denver Accord (1997)

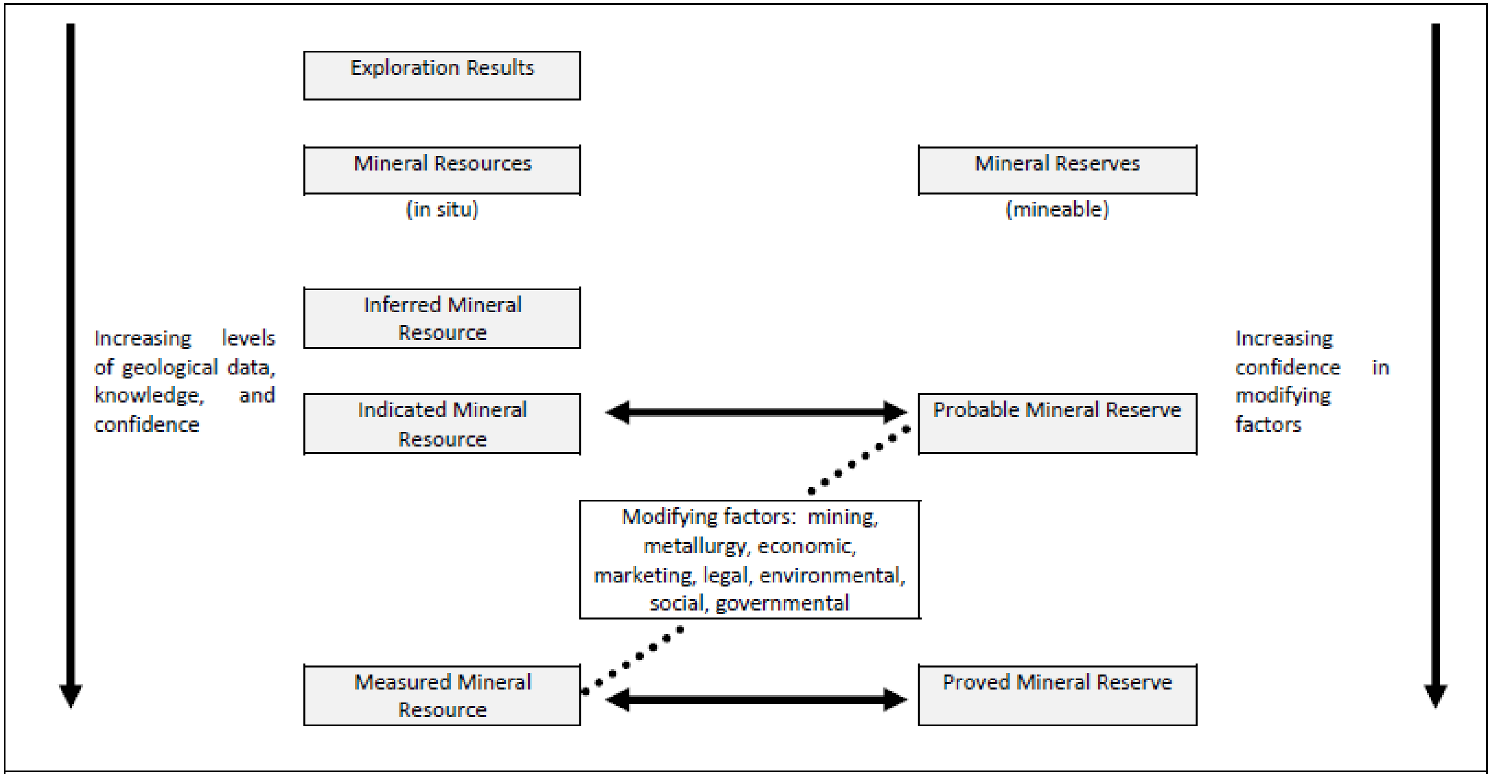
- AusIMM, CIM, IMM, SME, SAIMM represented as members of Council of Mining and Metallurgical Institutions (CMMI)

Figure 3 **Representatives at the Denver CMMI meeting on international definitions for reporting mineral reserves and resources: (from left to right) Eur Ing Gordon Riddler (IMM), Dr Ferdie Camisani-Calzolari (SAIMM), David Armstrong (SME), Norman Miskelly (Australasian JORC and CMMI), John Postle (CIM), Jean-Michel Rendu (SME) and Dr Kadri Dagdelen (SME)**

Denver Accord – Clean-up Terminology

- *Extraction* preferable to *exploitation*
- *Confidence* preferable to *certainty*
- Avoid use of *accumulation* (has specific meaning as grade X thickness)
- *Inferred* required for continuous disclosure
- Resources are *in-situ*; reserves are *mineable*

Denver Accord – Schema



- Added dotted line between Measured Mineral Resource and Probable Mineral Reserve (down-grade for uncertainty of Modifying Factors

Denver Accord – Mineral Resource

A Mineral Resource is an in-situ concentration or occurrence of material of intrinsic economic interest in or on the earth's crust in such form an quantity that there are reasonable prospects for eventual economic extraction. Portions of a deposit that do not have reasonable prospects for eventual economic extraction should not be included in a Mineral Resource.

The location, quantity, grade/quality, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge.

Mineral Resources are subdivided, in order of increasing geological confidence into Inferred, Indicated and Measured categories.

- First clause reflects Circular 831
- Follows JORC code, requires geological evidence and reasonable prospects for eventual economic extraction

Denver Accord - Measured Mineral Resource

A Measured Mineral Resource is that part of a Mineral Resource which has been explored, sampled and tested through appropriate exploration techniques at locations such as outcrops, trenches, pits, workings and drill holes which are spaced closely enough to confirm geological/grade continuity and from which collection of detailed data allows tonnage/volume, densities, shape, physical characteristics, quality and mineral content to be interpreted with a high level of confidence.

This category requires a high level of confidence in, and understanding of the geology and controls of the concentration or occurrence. Confidence in the estimate of a Measured Mineral Resource is sufficient to allow the adequate application of technical, economic and financial parameters and to enable an evaluation economic viability.

- The second paragraph states the confidence level must be high enough to enable an evaluation of economic viability

Denver Accord – Indicated Mineral Resource

An Indicated Mineral Resource is that part of a Mineral Resource which has been explored, sampled, tested through appropriate exploration techniques at locations such as outcrops, trenches, pits, workings, and drill-holes which are too widely spaced or inappropriately spaced to confirm geological and grade/quality continuity but which are spaced closely enough to be able to assume geological and grade/quality continuity and from which collection of reliable data allows tonnage/volume, densities, shape, physical characteristics, quality and mineral content to be estimated with a reasonable, but not high level of confidence.

An Indicated Mineral Resource is estimated with a lower level of confidence than for a Measured Mineral Resource, but with a higher level of confidence than for an Inferred Mineral Resource. Confidence in the estimate of an Indicated Mineral resource is sufficient to allow the adequate application of technical, economic and financial parameters and to enable an evaluation of economic viability.

- The second paragraph states the confidence level must be high enough to enable an evaluation of economic viability

Denver Accord – Inferred Mineral Resource

An Inferred Mineral Resource is that part of a Mineral Resource inferred from the geological evidence and with assumed but not verified, continuity where information gathered through appropriate exploration techniques from locations such as outcrops, trenches, pits, workings and drill-holes is limited or of uncertain quality and reliability, but on the basis of which tonnage/volume, quality and mineral content can be estimated with a low level of confidence.

The level of confidence associated with an Inferred Mineral Resource is lower than that for an Indicated mineral resource.

Denver Accord – Inferred Mineral Resource Guidance

This category is intended to cover situations where a mineral concentration or occurrence has been identified and limited measurement and sampling completed, but where data are insufficient to allow the geological and grade/quality continuity to be confidently interpreted. It should not be reasonably assumed that all or part of an Inferred Mineral Resource will be upgraded to an Indicated or Measured Mineral resource by continued exploration.

Because of the low level of confidence in this category, in the reporting of Inferred Mineral Resources they must not be combined with Measured and Indicated Mineral Resources, but must be shown separately.

Confidence in the estimate of Inferred Mineral Resources is not sufficient to allow the adequate application of technical, economic and financial parameters or to enable an evaluation of economic viability

CIM (2000) – Measured Mineral Resource

A 'Measured Mineral Resource' is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, physical characteristics are so well established that they can be estimated with confidence sufficient to allow the appropriate application of technical and economic parameters, to support production planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations

such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough to confirm both geological and grade continuity.

- Note must support production planning

CIM (2000) – Indicated Mineral Resource

An 'Indicated Mineral Resource' is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics, can be estimated with a level

of confidence sufficient to allow the appropriate application of technical and economic parameters, to support mine planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough for geological and grade continuity to be reasonably assumed.

- Note must support mine planning and evaluation of economic viability

CIM (2000) – Inferred Mineral Resource

An ‘Inferred Mineral Resource’ is that part of a Mineral Resource for which quantity and grade or quality can be estimated on the basis of geological evidence and limited sampling and reasonably assumed, but not verified, geological and grade continuity. The estimate is based on limited information and sampling gathered through appropriate techniques fromlocations such as outcrops, trenches, pits, workings and drill holes.

Due to the uncertainty which may attach to Inferred Mineral Resources, it cannot be assumed that all or any part of an Inferred Mineral Resource will be upgraded to an Indicated or Measured Mineral Resource as a result of continued exploration. Confidence in the estimate is insufficient to allow the meaningful application of technical and economic parameters or to enable an evaluation of economic viability worthy of public disclosure. Inferred Mineral Resources must be excluded from estimates forming the basis of feasibility or other economic studies

JORC Code (2004) Provided More Flexibility In its Guidance on Inferred Mineral Resources

Commonly, it would be reasonable to expect that the majority of Inferred Mineral Resources would upgrade to Indicated Mineral Resources with continued exploration. However, due to the uncertainty of Inferred Mineral Resources, it should not be assumed that such upgrading will always occur.

Confidence in the estimate of Inferred Mineral Resources is usually not sufficient to allow the results of the application of technical and economic parameters to be used for detailed planning. For this reason, there is no direct link from an Inferred Resource to any category of Ore Reserves (see Figure 1).

Caution should be exercised if this category is considered in technical and economic studies.

Canadian National Instrument 43-101 (2005) Allowed Preliminary Assessments

"preliminary assessment" means a study that includes an economic analysis of the potential viability of mineral resources taken at an early stage of the project prior to the completion of a preliminary feasibility study

an issuer may disclose a preliminary assessment that includes inferred mineral resources, if … the disclosure includes:

(i) a proximate statement that the preliminary assessment is preliminary in nature, that it includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves, and there is no certainty that the preliminary assessment will be realized, and

(ii) the basis for the preliminary assessment and any qualifications and assumptions made by the qualified person.

- This led to widespread issuance of preliminary assessment studies and general ignorance of CIM guidance to the contrary

Meanwhile SME (2007) Was Trying to Tighten the Standards…

- In order to gain US SEC recognition of resources

The term "reasonable prospect" implies that Measured, Indicated, and Inferred Mineral Resources are constrained within pit shells or cones for open pit mines, or constrained to coherent zones which support mining, processing and development cost estimates for underground extraction. A deposit model is required, which may be a computer-generated block model or a model based on cross- or long-sections. Economic tests should be documented in technical studies, but the disclosure of Mineral Resources should not require formal detailed technical and economic studies such as those required for reserve disclosure. Economic criteria should be applied equally to all categories of Mineral Resources (Measured, Indicated and Inferred).

Inferred Mineral Resources should exclude material for which there are insufficient data to allow the inference of geological or grade continuity. Inferred Mineral Resources are intended to be sufficiently defined that overall tonnages, grades and mineral contents can be estimated with a reasonable level of confidence.

Enter CRIRSCO – A New Accord (2012)

- CRIRSCO is the Committee for Mineral Reserves International Reporting Standards. It succeeded CMMI about 2003. Current members are:
  - Australasia
  - Canada
  - Chile
  - Europe
  - Mongolia
  - Russia
  - South Africa
  - United States

- Simple definitions – left to national reporting organizations to determine guidance

CRIRSCO (2012) – Mineral Resource

A Mineral Resource is a concentration or occurrence of solid material of economic interest in or on the Earth's crust in such form, grade or quality and quantity that there are reasonable prospects for eventual economic extraction.

The location, quantity, grade or quality, continuity and other geological characteristics of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge, including sampling.

- Pretty much the Denver Accord
- Restricted to Solid Material

CRIRSCO Standard Definitions (2012) – Measured Mineral Resource

A Measured Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape, and physical characteristics are estimated with confidence sufficient to allow the application of Modifying Factors to support detailed mine planning and final evaluation of the economic viability of the deposit.

Geological evidence is derived from detailed and reliable exploration, sampling and testing and is sufficient to confirm geological and grade or quality continuity between points of observation.

A Measured Mineral Resource has a higher level of confidence than that applying to either an Indicated Mineral Resource or an Inferred Mineral Resource. It may be converted to a Proved Mineral Reserve or to a Probable Mineral Reserve.

- Denver Accord with addition of “support detailed mine planning”

CRIRSCO Standard Definitions (2012) – Indicated Mineral Resource

An Indicated Mineral Resource is that part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are estimated with sufficient confidence to allow the application of Modifying Factors in sufficient detail to support mine planning and evaluation of the economic viability of the deposit.

Geological evidence is derived from adequately detailed and reliable exploration, sampling and testing and is sufficient to assume geological and grade or quality continuity between points of observation.

An Indicated Mineral Resource has a lower level of confidence than that applying to a Measured Mineral Resource and may only be converted to a Probable Mineral Reserve.

- Denver Accord with addition of "support mine planning"

CRIRSCO Standard Definitions (2012) – Inferred Mineral Resource

An Inferred Mineral Resource is that part of a Mineral Resource for which quantity and grade or quality are estimated on the basis of limited geological evidence and sampling.

Geological evidence is sufficient to imply but not verify geological and grade or quality continuity.

An Inferred Resource has a lower level of confidence than that applying to an Indicated Mineral Resource and must not be converted to a Mineral Reserve. It is reasonably expected that the majority of Inferred Mineral Resources could be upgraded to Indicated Mineral Resources with continued exploration.

Comments on CRIRSCO (2012)

- Adopted by members of CRIRSCO. Has now been rolled out by SME, CIM, JORC, PERC, MRC. New Samrec, Naen, Chilean codes in progress

- Note emphasis on requirement to support planning and declaration of probable and proved reserves. Implies Modifying Factors need to be proactively taken into consideration. Still being debated as to how much. Up to Competent or Qualified person

- Note that Inferred tightened to extent that majority can be expected to convert to Indicated with continued exploration.

- It is interesting to note the evolution of definitions over a 30 year period. The evolution has been slow enough that many practitioners or company executives have in mind definitions they learned when they entered the industry and have not kept up with the changes

Review of Best Practices

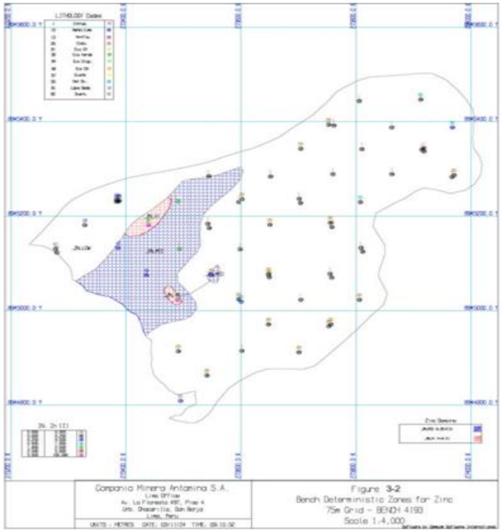
Continuity

- Very important consideration

- Consider grade continuity (use variogram distance to 50% of sill for Measured, 75% of the sill for indicated, 100 to 200% of the final range for Inferred) – We consider this crude; better to inspect the cross sections and plans

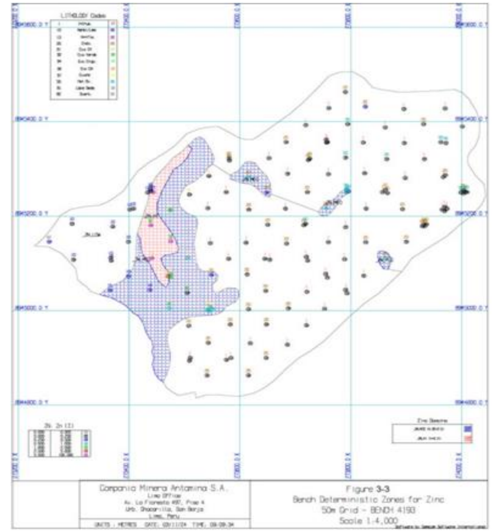
- In some deposits thickness more uncertain than grade, and should govern the classification (example nickel laterite/saprolite deposits)

Continuity – Zinc at Antamina; blue is [0.25, 2.5%), pink is ≥ 2.5%



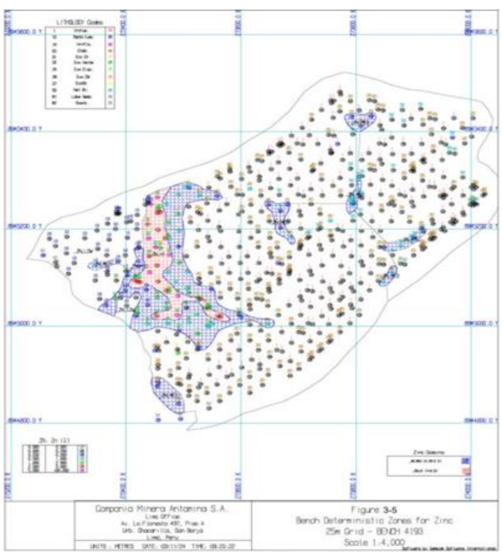
75 X 75 m Spacing; High-grade is under represented

Inferred



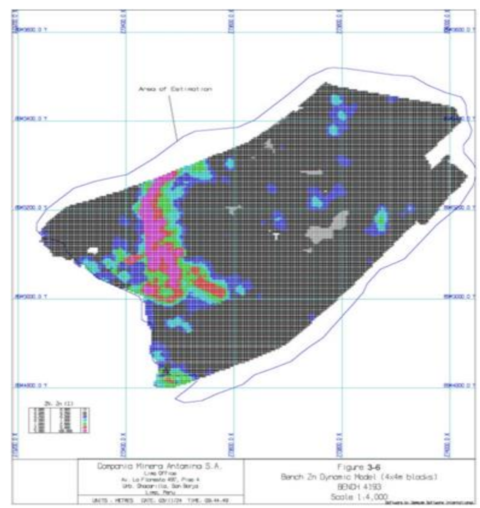
50 X 50 m Spacing; High-grade is still under represented

Indicated



25 x 25 m Spacing (High-grade is fairly well represented)

Measured



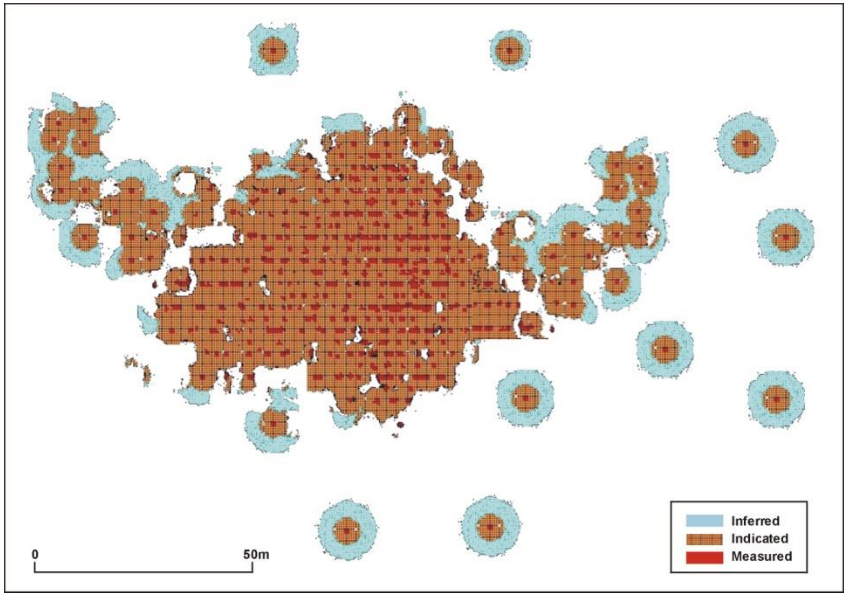
Ground-truth Based on Blast Holes

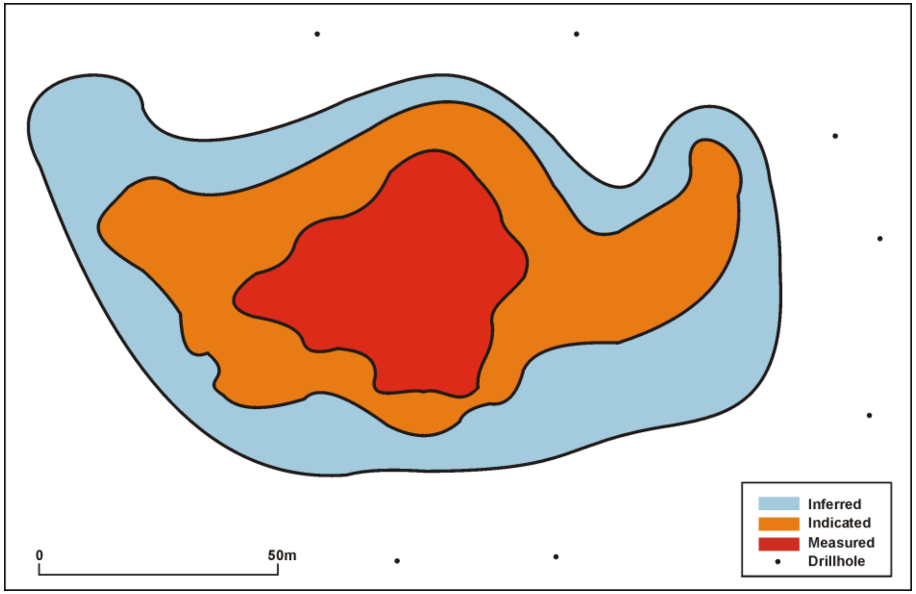
(7 X 7 m Spacing)

Figures modified from Parker, 2014

Best Practice

- Look through sections and plans
- Down-grade classification where locally uncertain
- Faults (Inferred corridors)
- Dykes (barren or deleterious alteration e.g. talc in iron deposits)
- Avoid spotted dog





Figures from Stephenson et al. (2006)

Sensitivity of Economic Parameters to Changes in Grade

% Cu	% Chg	Cash Flow Year 2 (M$)	% Chg	NPV(8%)	% Chg	Payback Years
0.66%	10%	218.9	30%	886.5	60%	4
0.63%	5%	193.9	15%	720.4	30%	4
0.60%	0%	169.0	0%	554.3	0%	5
0.57%	-5%	144.0	-15%	388.1	-30%	6
0.54%	-10%	119.1	-30%	222.0	-60%	7

- Small error can have serious implications on cash flows and NPV if error is a bias that persists over life-of-mine

From Parker, 2014

Target Relative Accuracy

$$\text{Relative Accuracy} = \frac{(\text{Predicted} - \text{True})}{\text{True}}$$

Necessary Components

- Time period or production increment
- Confidence Interval: probability within range
- Magnitude: ± %

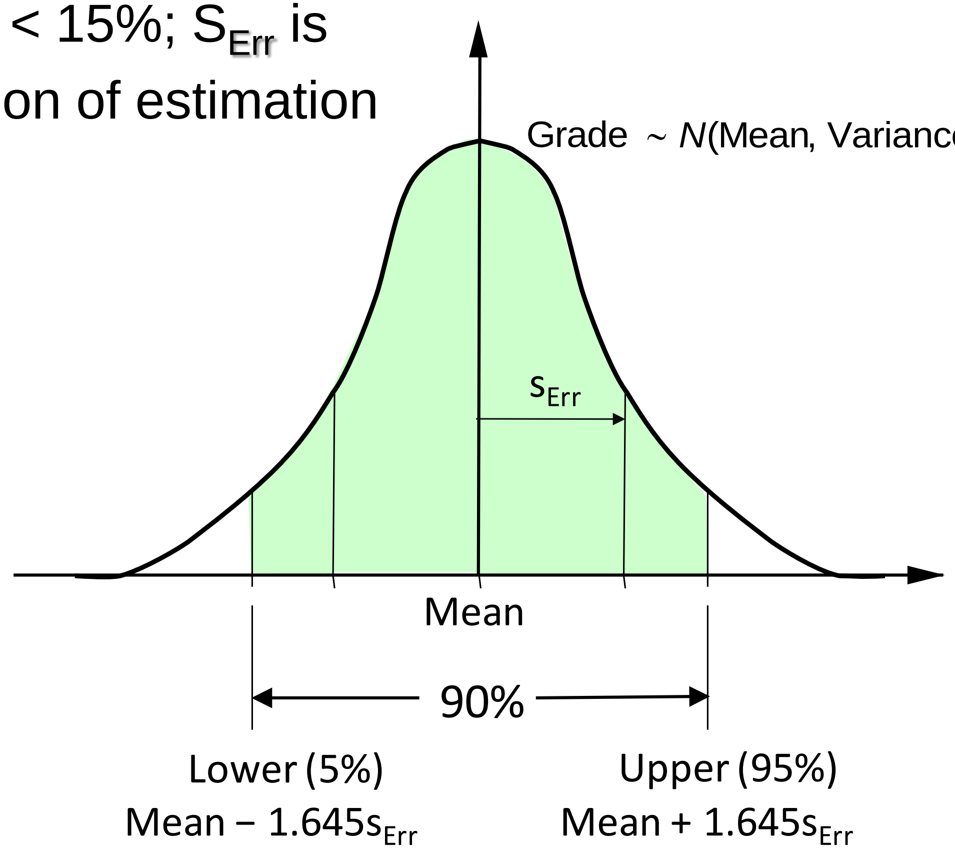
Typically We Use a 90% Confidence Interval; Target Relative Accuracy ≤ 15%

Assuming a normal distribution of errors

Relative Accuracy is 1.645 S_{Err}/Mean

Our target Relative Accuracy is

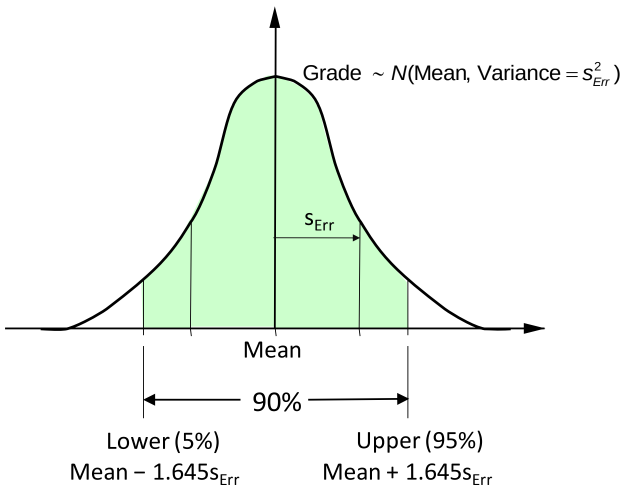
1.645 S_{Err}/Mean < 15%; S_{Err} is standard deviation of estimation error

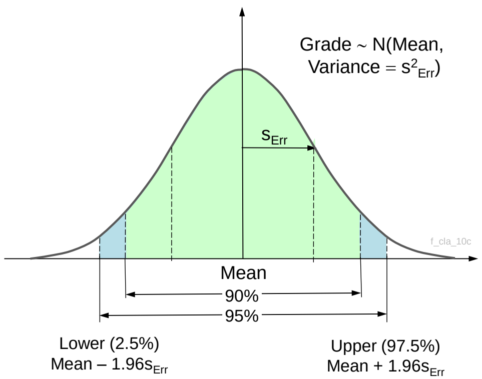


Sensitivity of Confidence Limits

- If the time period is larger, S_{Err} will be smaller because the variance of large production increments is less than the variance of small production increments. A broader drill spacing can be used for large increments to obtain the same level of accuracy

- If the confidence interval is increased, say from 90 to 95%, the factor 1.645 increases to 1.96. The confidence limits broaden:





- If the Percent Relative Accuracy broadens from say ±15 to 20%, the confidence interval broadens.

Guidance

Inferred: Insufficient geological information to establish confidence levels.

Indicated: ± 15% accuracy with 90% confidence over annual production increment. Actual will be within 85 and 115% of the estimate 90% of the time. Annual production increments are typically used for Pre-feasibility and Feasibility cash flows. Can stand one in year in 20 as being below 85% of the estimate – normal business risk. If actual is less than 85%, very often the mine will run a loss

Measured: ± 15% accuracy with 90% confidence over a quarterly or monthly production increment. Actual will be within 85 and 115% of the estimate 90% of the time. Quarterly or monthly production increments are typically used for Operating Budget cash flows. If error is less than 15% can usually rework the mine plan and prevent a loss

See Verly et al. (2014) for historical precedents and further explanation

Calculation of Simplified Confidence Limits on Production Increments

- Calculate estimation variance for large blocks, which when combined can be considered to be spatially independent – May represent monthly or quarterly increments

- Standard error is square root of estimation (kriging) variance

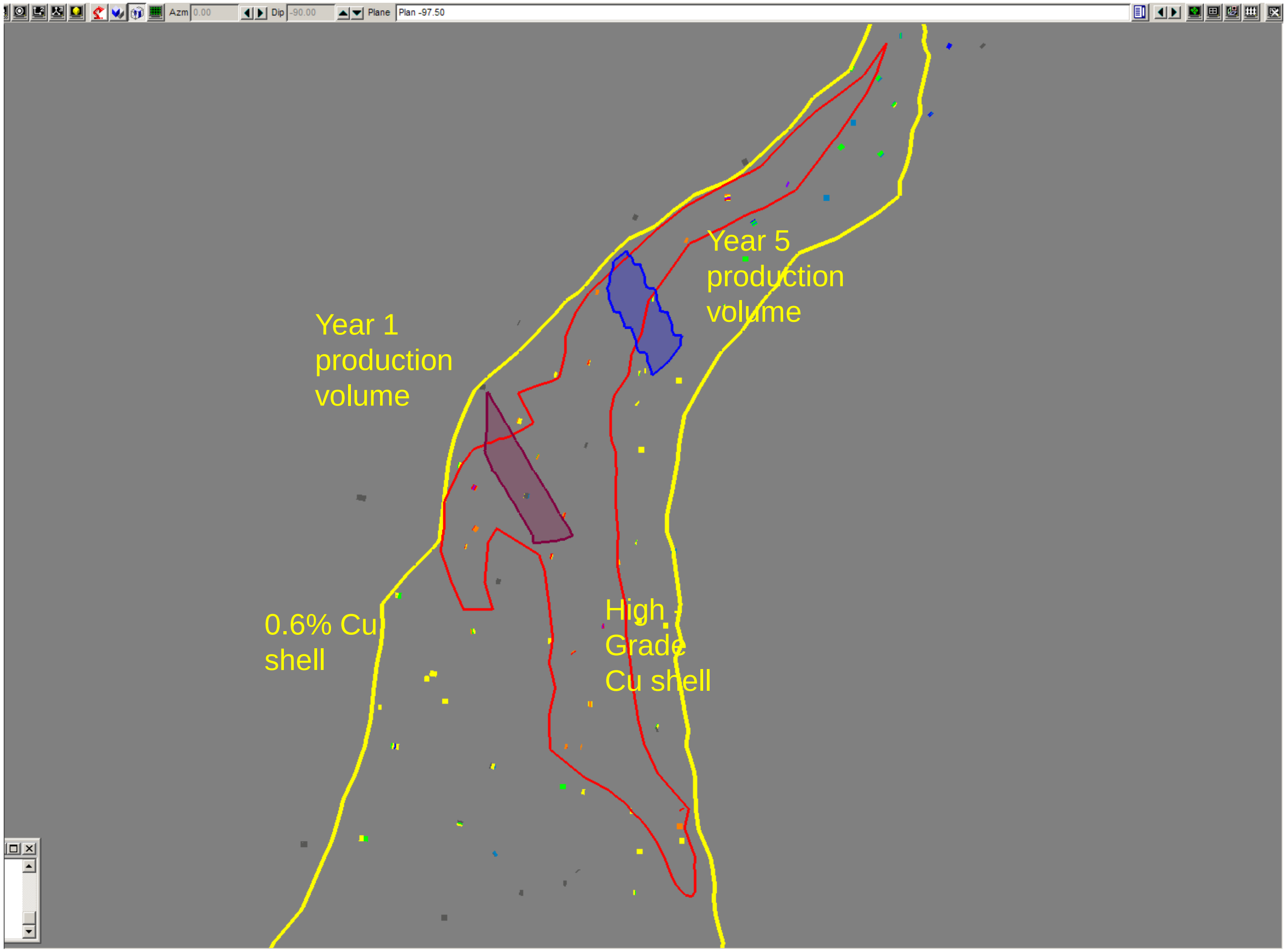
- Standard error a for a period = $S_{Err\ period} = S_{Err\ block}/\sqrt{N}$
  N is the number of large blocks in a period

- 90 % Confidence limits = 1.645 $S_{Err\ period}$ /Mean

- Try various drill spacings. Find drill spacing that yields target 90% confidence limits

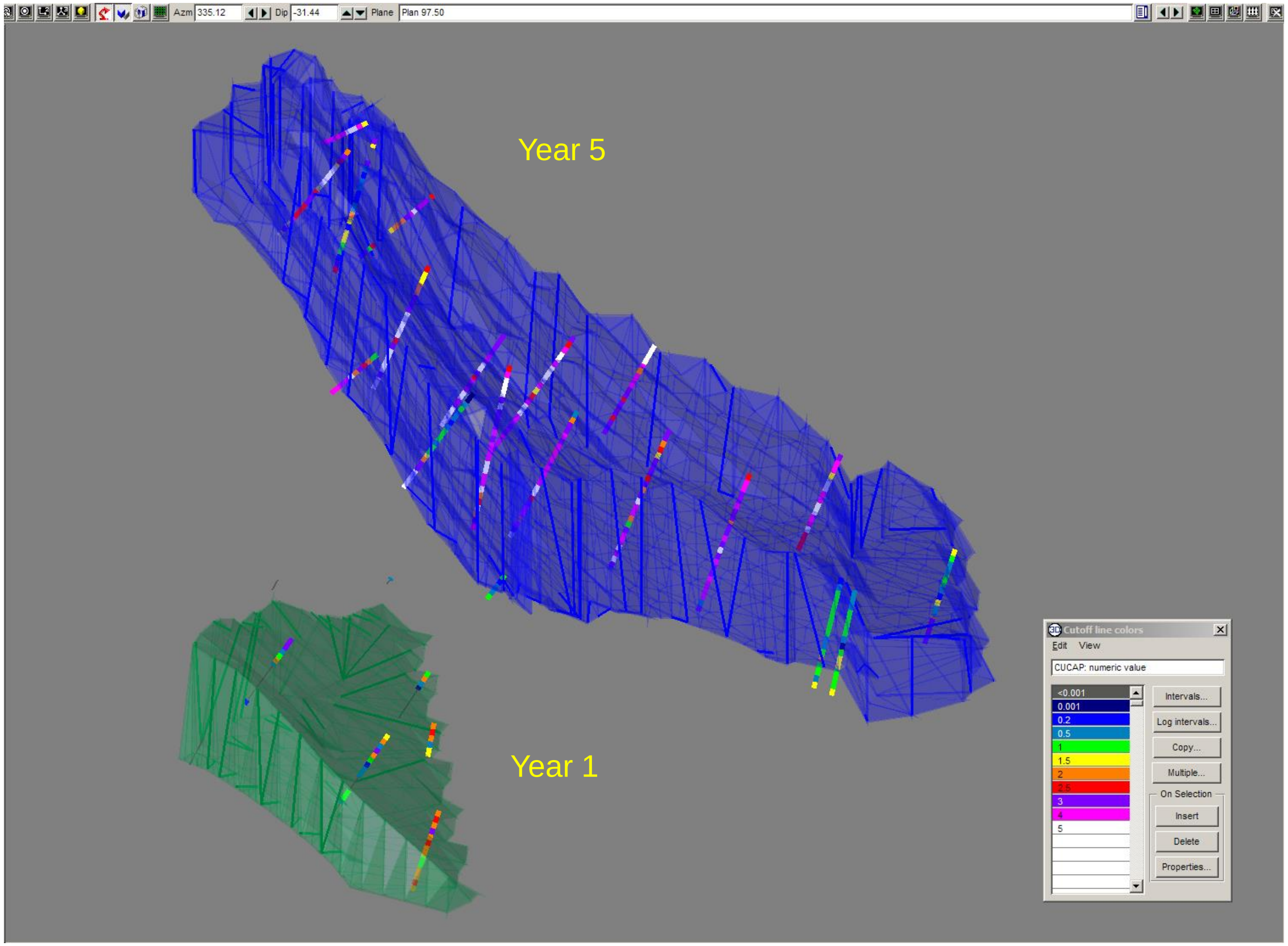
- Calculate estimation variance for resource model blocks using the drill spacing. Apply to block model. Helps where have irregularly spaced drilling

Oyu Tolgoi Case (2010) – Cu Grade Shells Plus Year 1 and Year 5 Production Caves



Provided courtesy of OT LLC; designs have been superseded

Drill Spacing (actual)



Provided courtesy of OT LLC; designs have been superceded

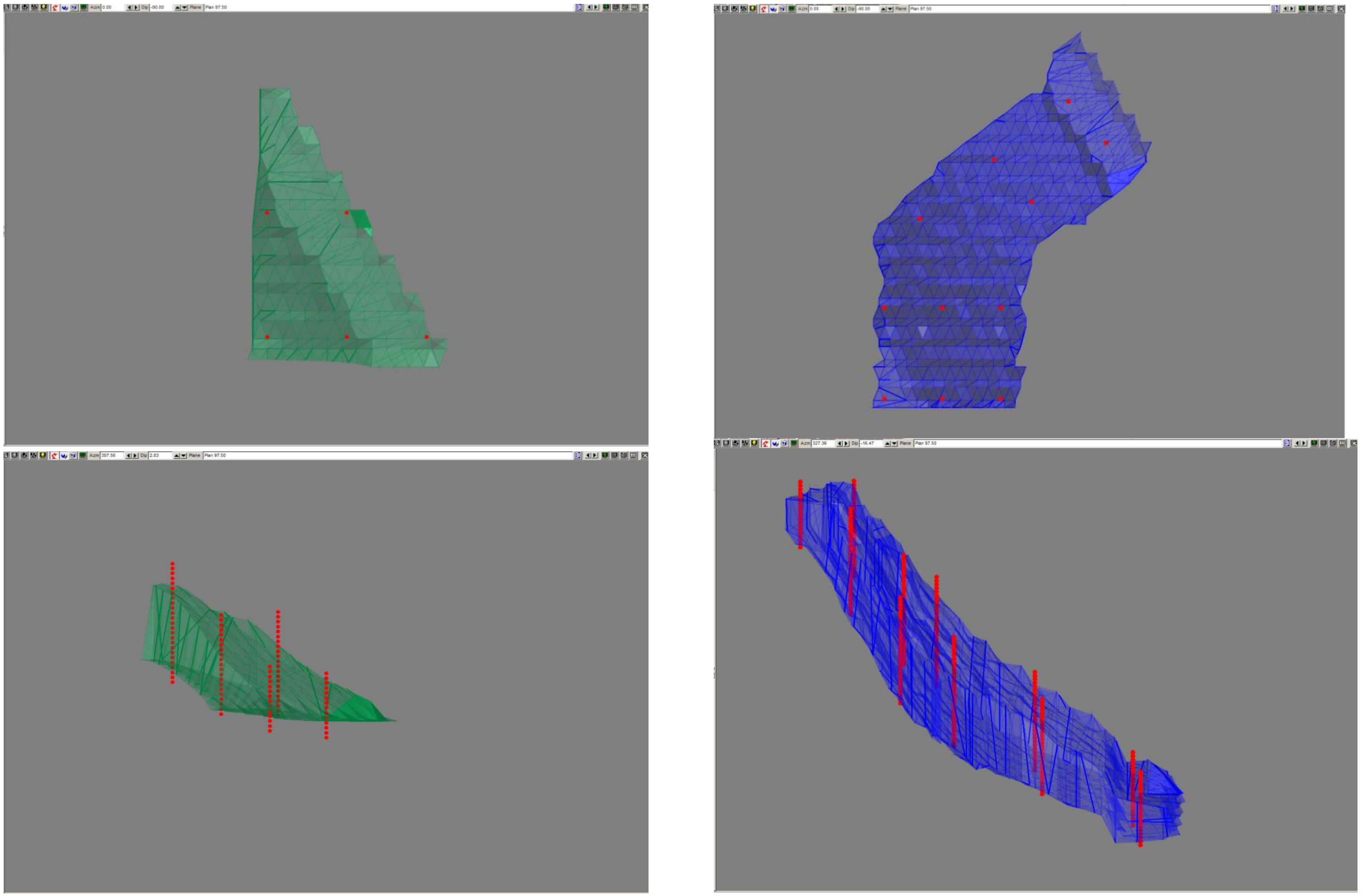
Layout Using 75 x 125 m drill spacing; This Was Used for Preliminary Economic Assessments

Year 1 Cave

Year 5 Cave

Plan

Section



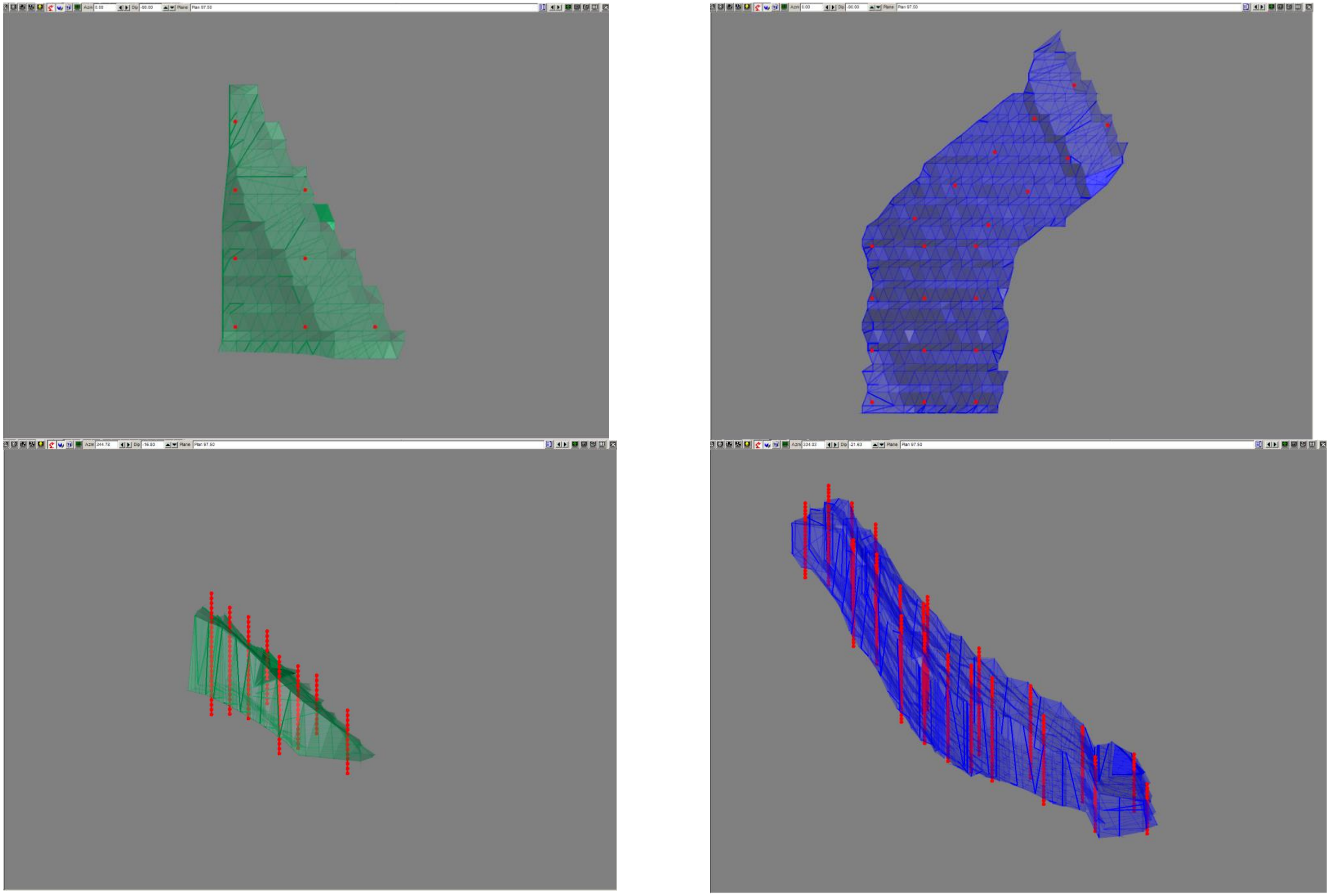
Provided courtesy of OT LLC; designs have been superseded

Layout Using 70 x 70 m Drill Spacing

Year 1 Cave | Year 5 Cave

Plan

Section



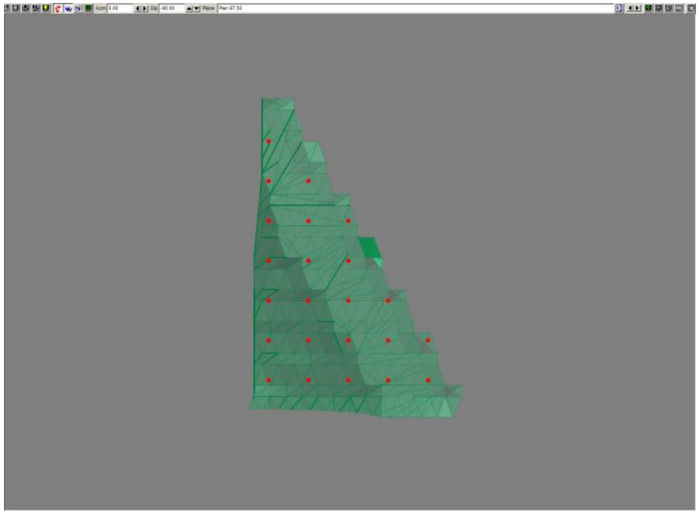
Provided courtesy of OT LLC; designs have been superseded

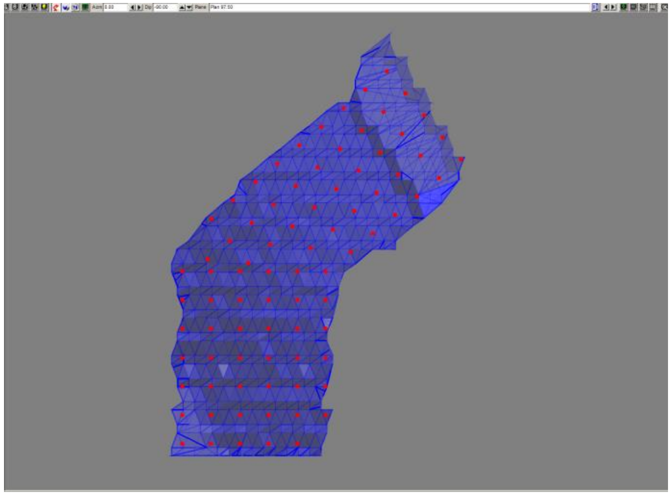
Layout Using 35 x 35 m Drill Spacing

Year 1 Cave

Year 5 Cave

Plan





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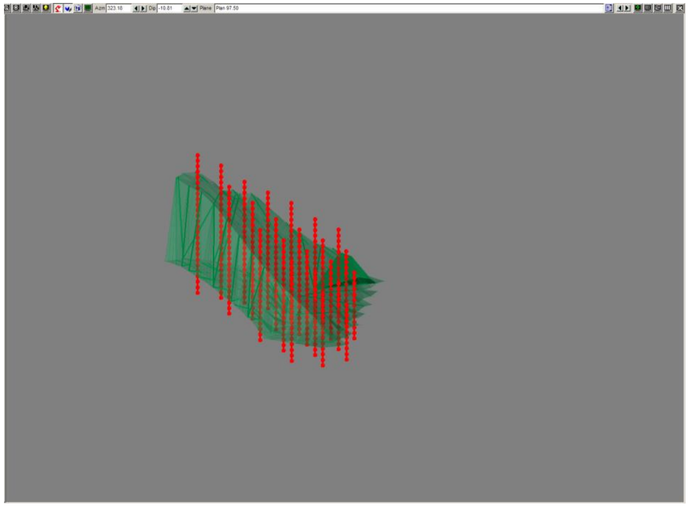
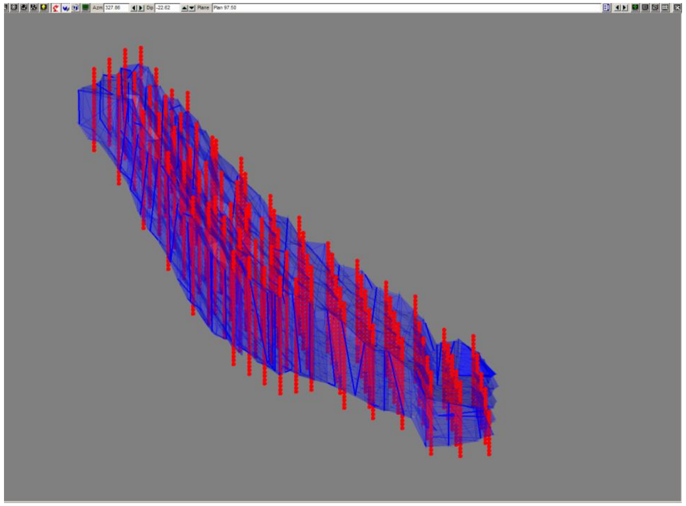




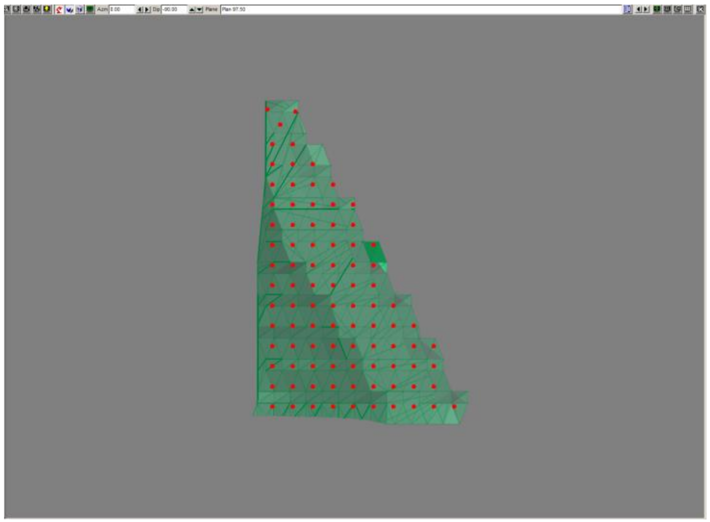
Provided courtesy of OT LLC; designs have been superseded

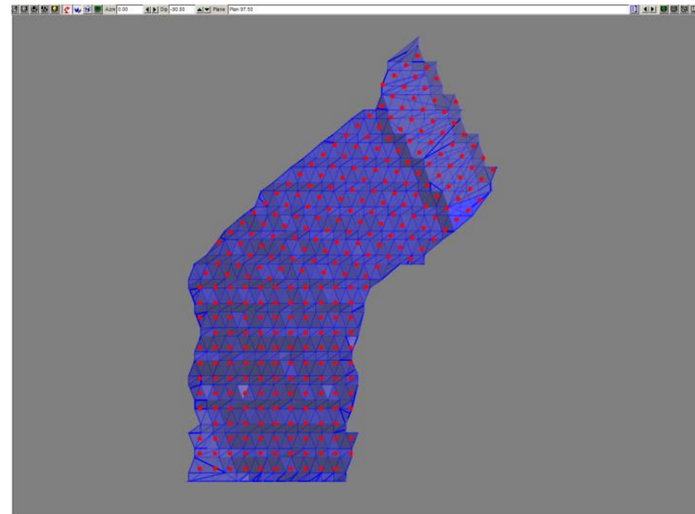
Layout Using 17.5 x 17.5 m Drill Spacing

Year 1 Cave

Year 5 Cave

Plan





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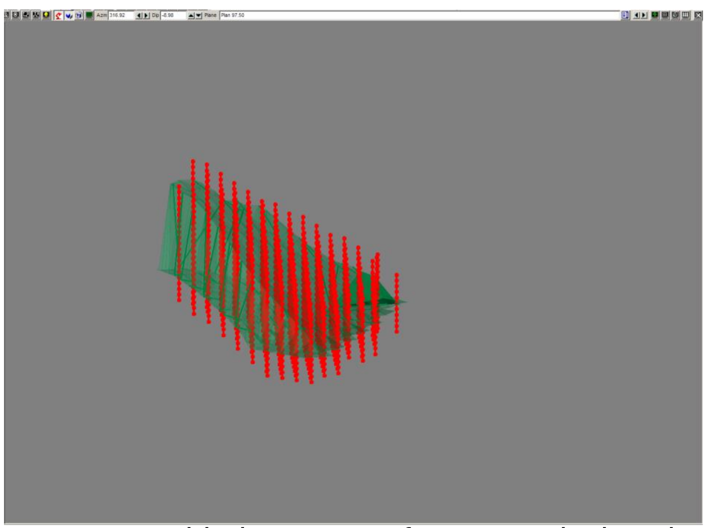
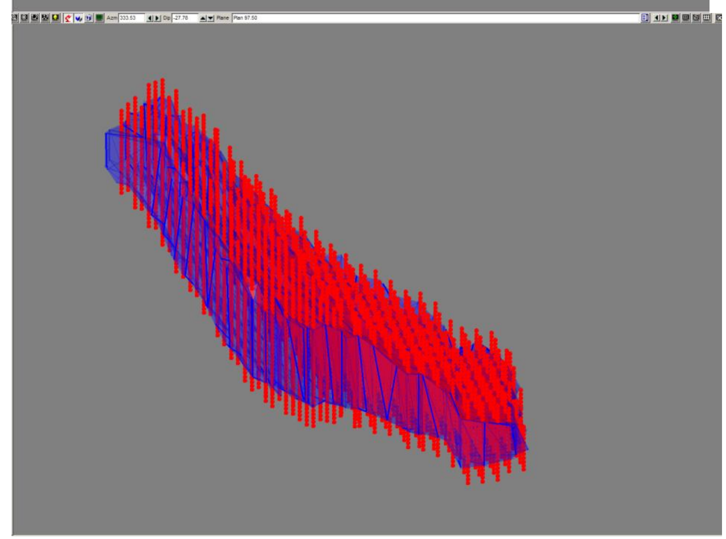




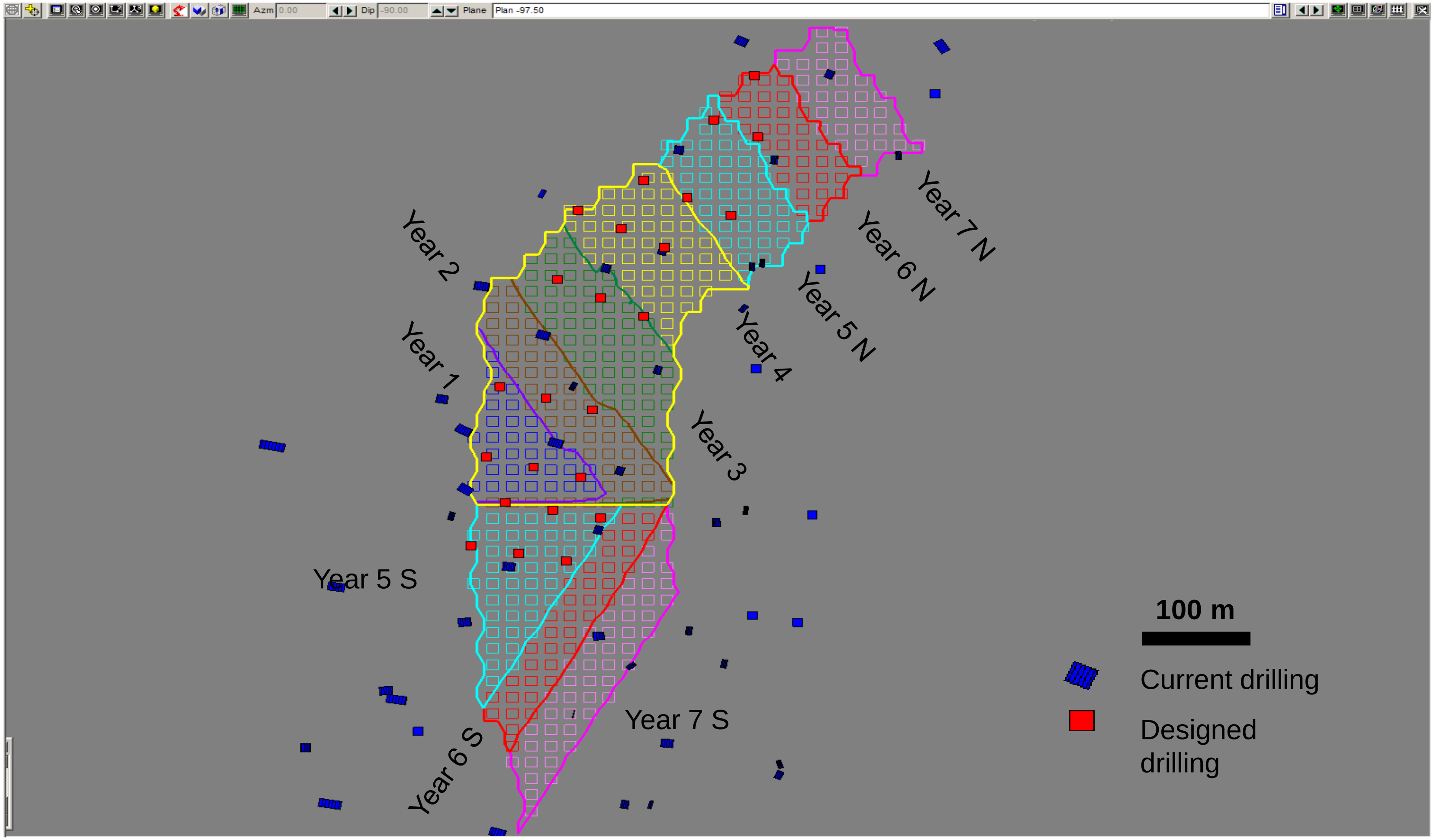
Provided courtesy of OT LLC; designs have been superseded

Confidence Limits Versus Drill Spacing

Case	Drill Spacing (m)							
	Current	17.5X17.5	25X25	35X35	50X50	70X70	100X100	75X125
Year 1: ±90% Confidence Interval	28.7%	6.0%	7.7%	11.0%	18.3%	25.7%	52.4%	32.7%
Year 5: ±90% Confidence Interval	11.6%	1.5%	2.4%	2.8%	6.7%	8.8%	14.7%	19.5%
Excludes effect of dykes								
Inferred (> 15%)								
Indicated (7.5 to 15%)								
Measured (≤ 7.5%)								

- Year 1 has broader confidence intervals because it is about 10% of Year 5 tonnage

Current and Planned 2010 Drilling by OT LLC – 50 X 75 m Spacing



Provided courtesy of OT LLC; designs have been superseded

Confidence Limits for Current Drilling and Current + Planned (2010) Drilling

Case	Period						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
± 90% Relative Confidence Interval	**56.1%**	**26.0%**	**11.1%**	**8.5%**	**11.4%**	**12.9%**	**13.6%**
With Current Drilling							
± 90% Relative Confidence Interval	**34.3%**	**17.3%**	**8.2%**	**6.5%**	**7.0%**	**8.1%**	**9.1%**
With Current + Planned Drilling							
Includes effect of dykes							
Inferred (> 15%)							
Indicated (7.5 to 15%)							
Measured (≤ 7.5%)							

- First and second years are not at full production

Other methods

- The estimation variance method is quick and easy to use; sometimes adjust for local variance of the data used to estimate a block (Arik, 2002)

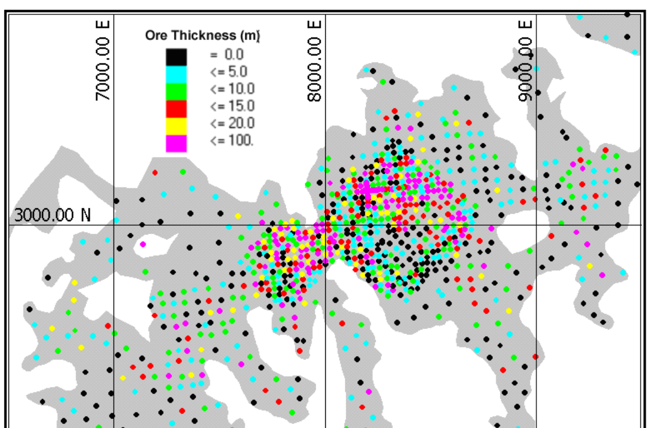
$$S'_{Err} = S_{Err}\sqrt{(\text{local variance})}$$

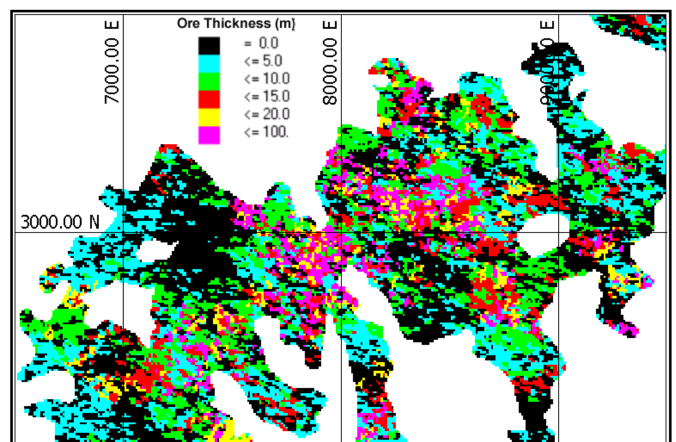
- Perform conditional simulation; upscale the standard error to a production period = $S_{Err\ period} = S_{Err\ block}/\sqrt{N}$

  Still need to prove independence of errors between blocks

- Conditional simulation is becoming best practice at many companies; examples are Anglo American, BHP Billiton, Rio Tinto, Newmont

Data



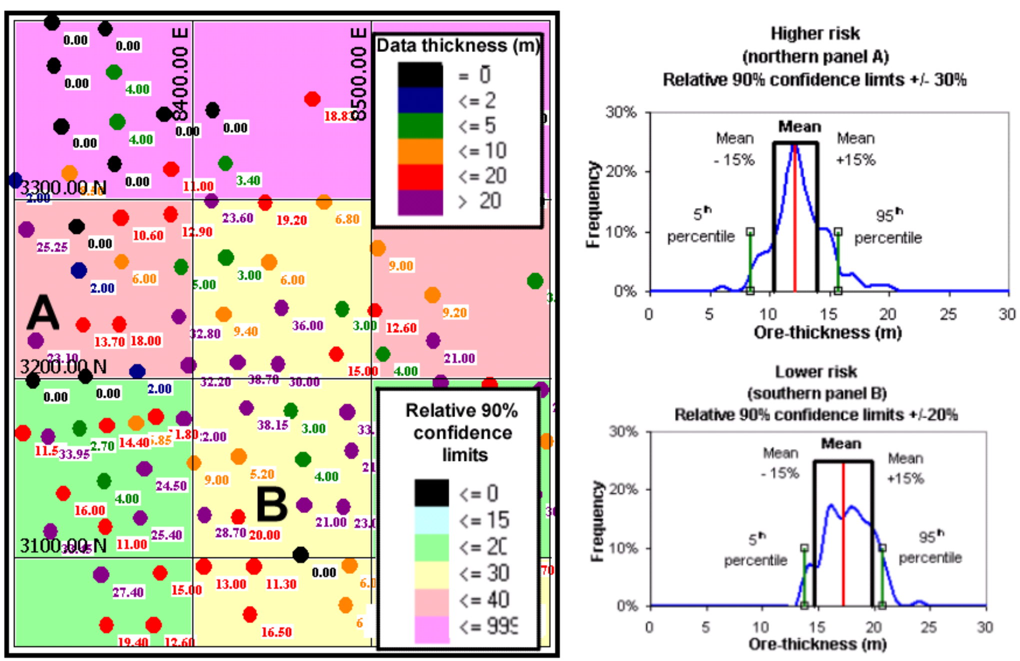


Conditional Simulation

From Murphy et al. (2004)

Use of Conditional Simulation

- Conditional simulation takes local variability into account, and enables customization of drill spacing.



- Both panels drilled on 28 m spacing
- Panel A is ± 30%
- Panel B is ± 20%
- Do we need more holes in Panel A?

From Murphy et al. (2004)

Reasonable Prospects for Eventual Economic Extraction

Make a simple conceptual economic analysis.

Input Variables		
Mining Ore	$ Per t ore	2.00
Mining Waste	$ Per t waste	2.00
Milling	$ Per t ore	5.00
General and Admin.	$ Per t ore	4.00
Copper Price	$/lb	2.50
Conc Grade	% Cu	29.0%
Conc Recovery		90%
Freight	$ Per t Conc	50
Smelting	$/t Conc	80
Refining	$ Per lb	0.08
Payable Cu		95%
Pounds/t		2204.62

Usually assume same for all years

Year	2
Production Schedule	
Ore Mined (Mt)	20
Waste Mined (Mt)	40
Ore Grade (%Cu)	0.60%
Concentrate (Mt)	0.372
Payable Cu (Mt)	0.103
Cash Flow Statement (M$)	
Revenues	565.5
Ore Mining	-40.0
Waste Mining	-80.0
Milling	-100.0
G+A	-80.0
Freight	-18.6
Smelting	-29.8
Refining	-18.1
Capex	-30.0
Pre-tax Cash Flow	169.0

Establishing Reasonable Prospects for Eventual Economic Extraction

- Develop conceptual pit shell, stope blocks
- Calculate costs
  - Open Pit: Process, G&A, Sustaining Capex (no mining – considered sunk)
  - Underground: Mining, Process, G&A, Sustaining Capex (No primary development)
- Determine breakeven cut-off and use for reporting:

  Cut-off = costs/[(price)(payable %)(met. Recovery)]

  - Can use a higher cut-off if there is no metallurgical sampling to support recoveries at the cutoff grade
  - Can use higher prices (15% more than long-term price used for mine planning)

- Show that net value of open pit or stope block will cover Initial Capex (often forgotten)

Modifying Factors – Dilution and Mining Recovery

- Assess dilution and mining recovery, and include discussion in resource statement

- For open-pit situations best practice is for resources to include allowances for internal dilution for an envisioned selective mining unit (SMU). An SMU is the smallest practical volume that can be segregated to ore or waste. Typical SMUs depend on production rate and bench height:

  3,000 tpd: 5 X 10 m X 5 m

  10,000 tpd: 10 X 10 m X 6 m

  40,000 tpd 15 X 15 m X 10 m

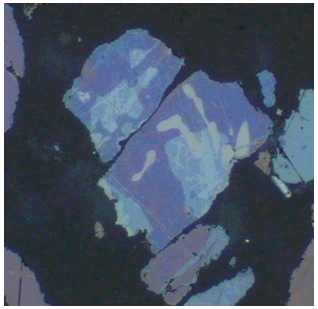
  80,000 tpd 20 X 20 m X 15 m

Common misconception: SMU related to bucket-width

- Where hard contacts used, add allowances for dilution and ore loss – usually left for reserve estimation stage

Modifying Factors – Comment on Risks

- Tenure (conversion of exploration to mining licence)
- Geotechnical and hydrogeological
- Deleterious elements, minerals – where serious may over-ride classification based on payable metals
- Likelihood of permitting
- Social licence
- Water, access roads



Wittichenite at Antamina; a Cu-Bi sulphide; courtesy P. Gomez

- There must be reasonable expectations to solve issues or the reasonable prospects for eventual economic extraction test is NOT passed

- Competent or Qualified Person must be satisfied he could face his peers and defend his work.

Scorecards

- These are being used to assess key aspects of the resource estimate. This facilitates peer review
- Companies using include De Beers, Anglo American, Codelco
- Too complicated for resource statements, but scorecards enhance transparency in public reports
- Example from block-cave operation:

Risk Factor	Information			Volume Applied	Weight
1. Original Class (in situ)	Inferred	Indicated	Measured	10 x 10 X 10 m	25%
2. Available History	Block	Drift	Drawpoint	Production Block	25%
3. Distance to Validation Holes	> 70 m	35 to 70 m	≤ 35 m	10 x 10 X 10 m	25%
4. PCBC™ matching to metal in ROM	>25%	15 to 25%	≤ 15%	Production Block	25%

A Measured block must score 75% among the 4 criteria in the "Information - Measured" column (all criteria are Measured)

An Indicated block must score at least 75% among the 4 criteria in the "Information - Measured + Indicated" columns (all criteria are Measured or Indicated)

An Inferred block must score at least 90% among the "Information - Measured + Indicated + Inferred" columns (all four criteria defined)

Anglo American Procedures – Based on Work of Christina Dohm (1 of 2)

Procedure

Depending on the geology of the deposit and the aspects considered most significant for its extraction, several key factors may be considered for evaluation and use in the classification scorecard. It is recommended to include

1 Geometry of the orebody:

- geological confidence (understanding of geometry and structural complexity)
- drilling method (DD, RC, percussion),confidence in survey data (collar and down-hole)
- confidence in logging
- drill hole spacing

2 Data integrity

- sampling and analytical data, QAQC
- data security

3 Spatial correlation

- quality of variograms, covariogram and correlograms

Anglo American Procedures – Based on Work of Christina Dohm (2 of 2)

4 Estimation Methodology

- estimation confidence (kriging efficiency, slope of regression)
- validation techniques

5 Bulk density

- determination method
- estimation e.g. (global or local)

6 Other factors that may be relevant

- mineralogy
- penalty elements
- geometallurgical data

Implementation

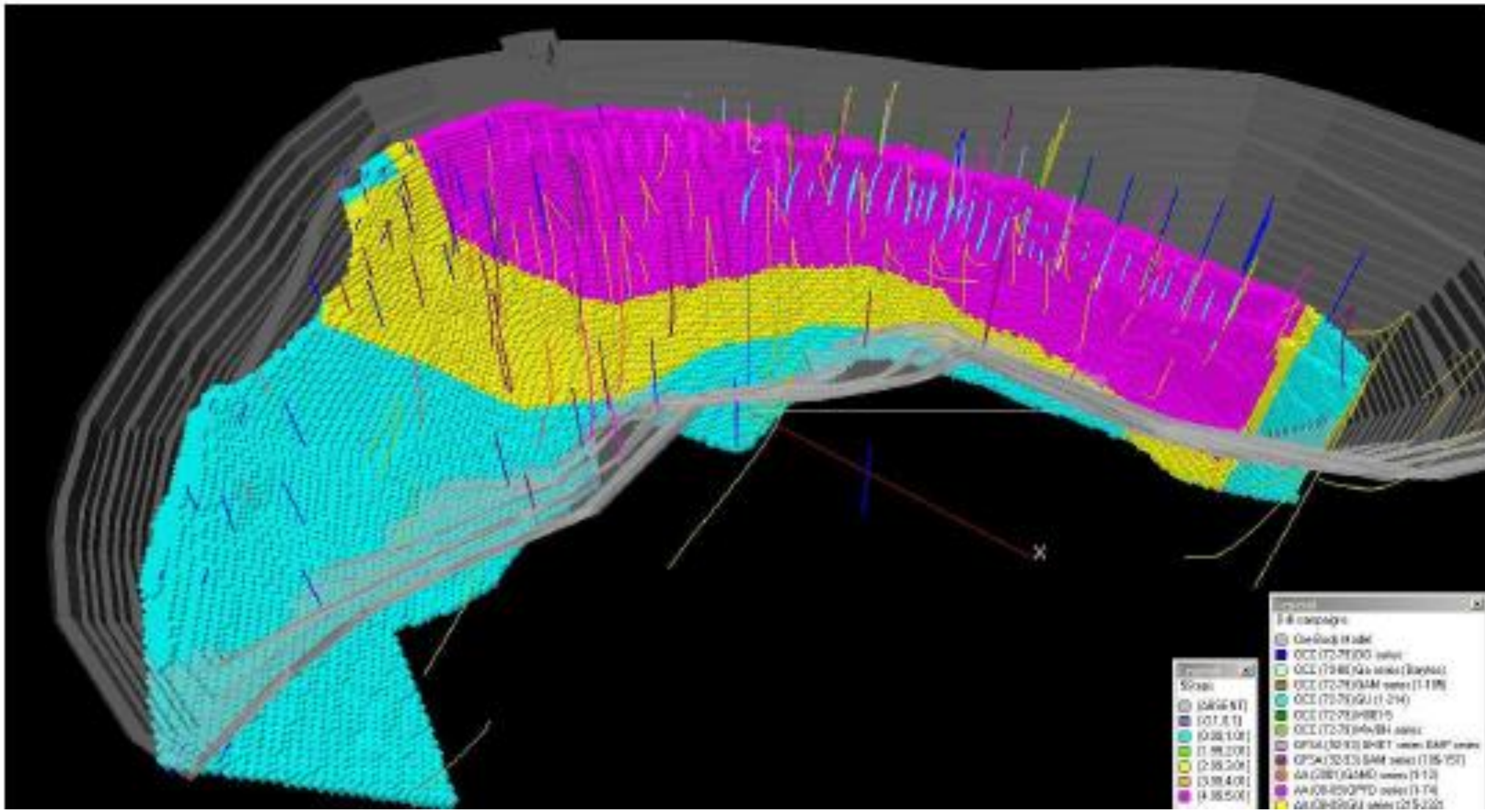
1. Each factor is assigned a specific weighting: low (1), medium (3) or high (5), depending on the importance of that factor for the specific deposit. It is important that the scores are non-linear to ensure distinction in confidence

2. Each factor is then multiplied by a confidence rating on a scale from zero (no confidence) to five(high confidence) to calculate a discrete score for the factor

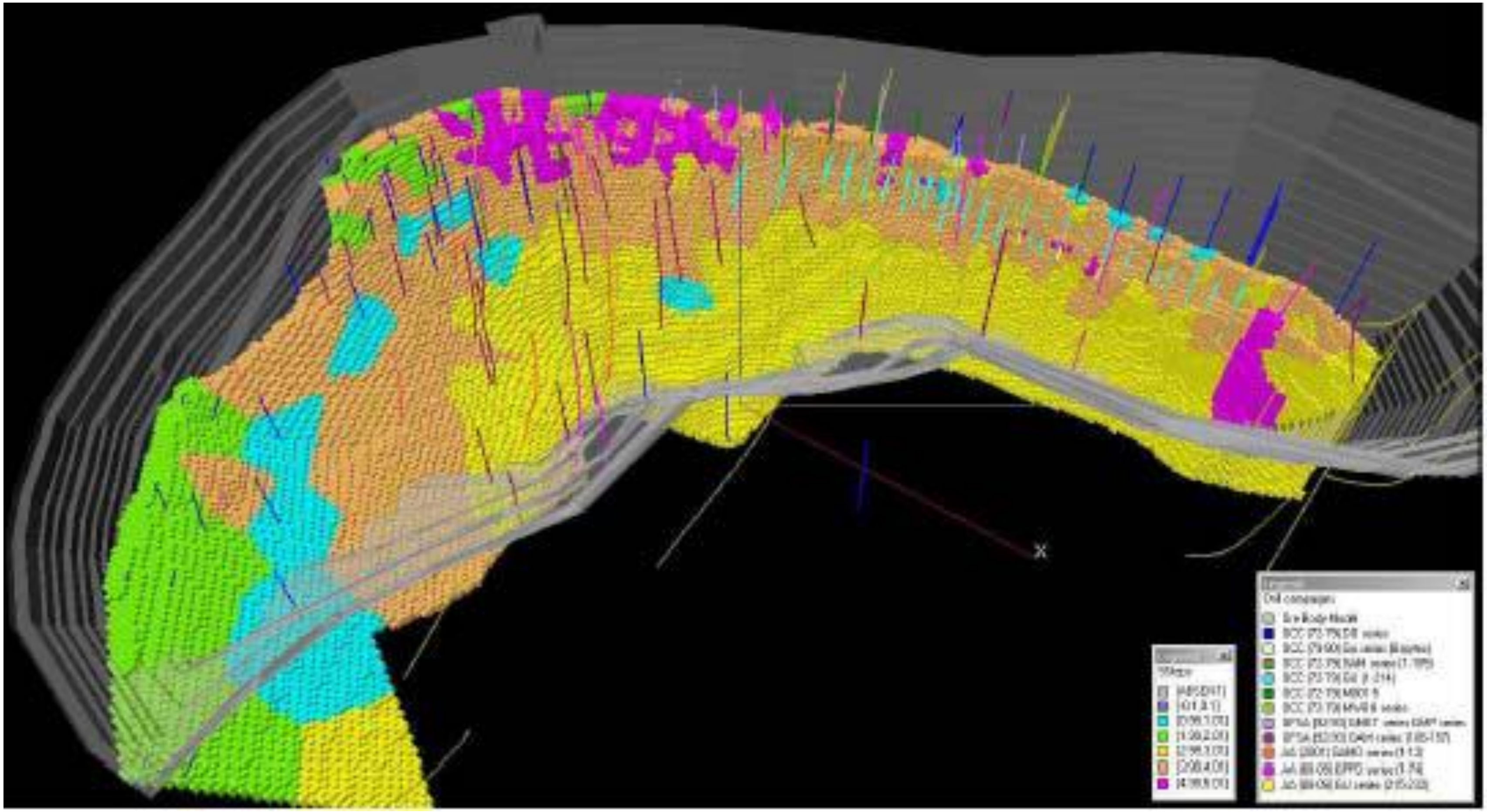
3. The scores for all factors are added up in the block model to yield a total resource classification score for the block. Finally, the resource classification score is compared against predefined ranges for Inferred, Indicated and Measured Resources

4. It is suggested that the total resource classification score is equivalent to at least a low confidence (rating of 2) for each of the factors selected in order to be classified as Inferred. At least half the total possible score should be realized for a resource to be classified as Indicated

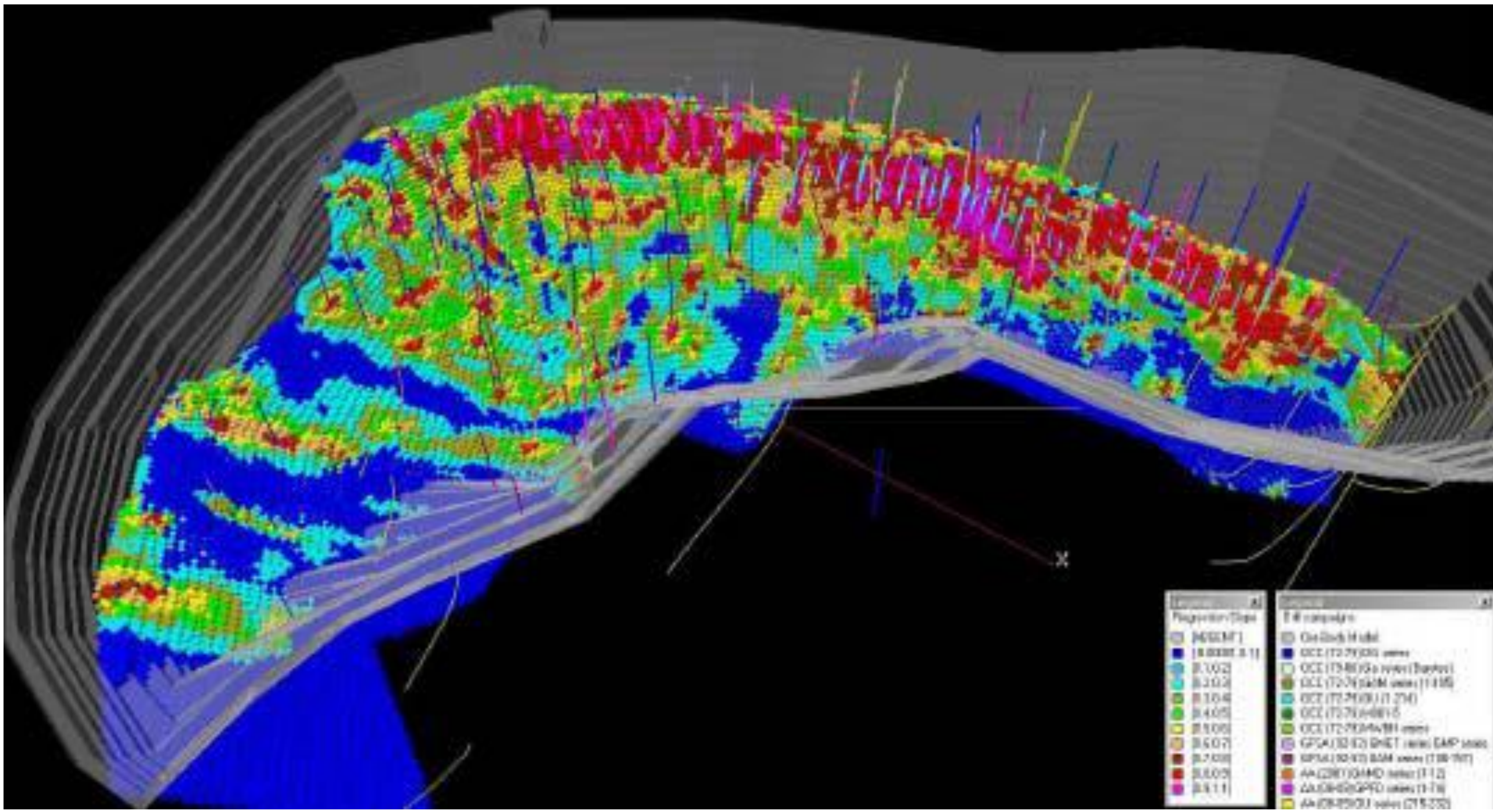
Geological Confidence



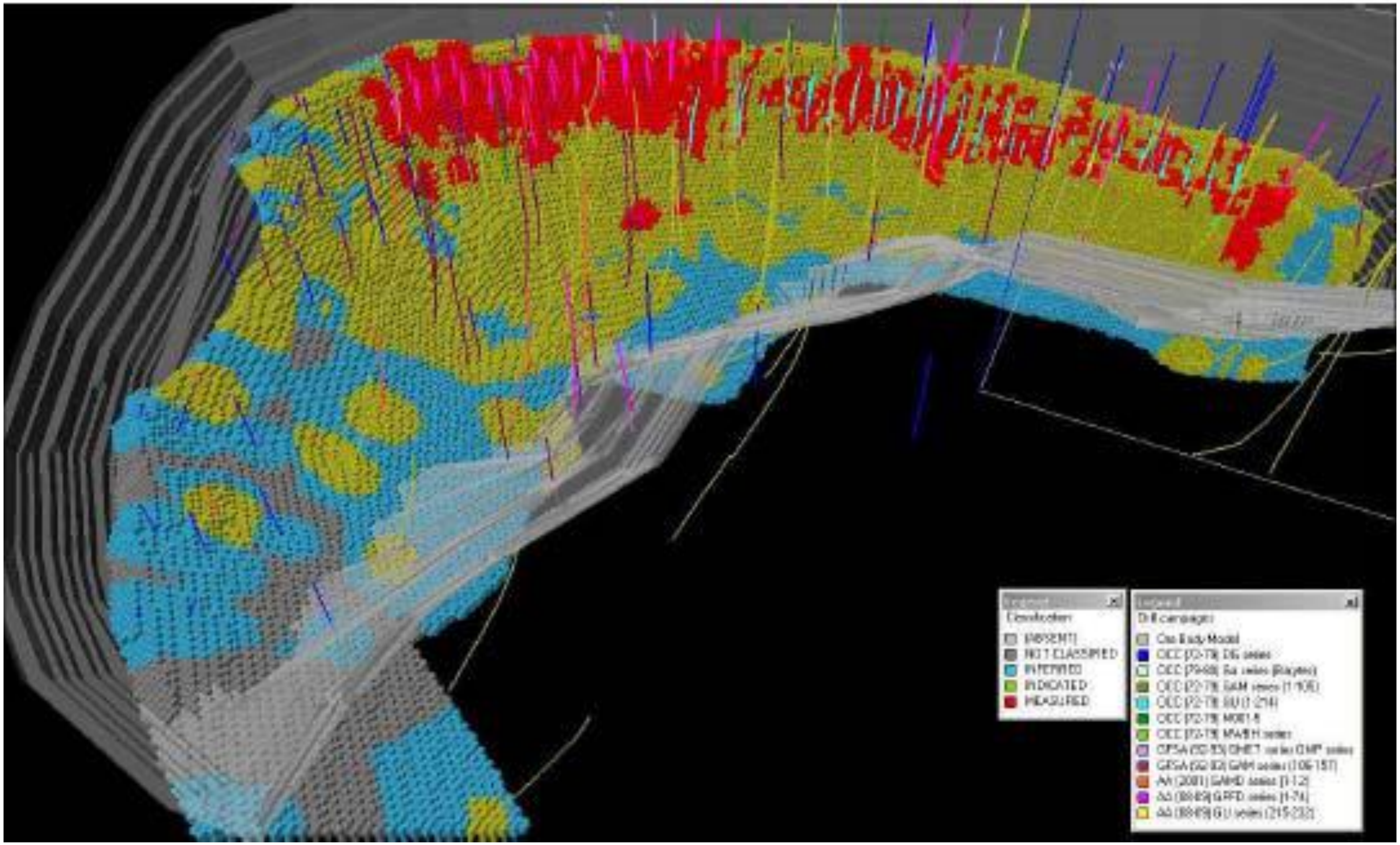
Confidence in Sample Locations



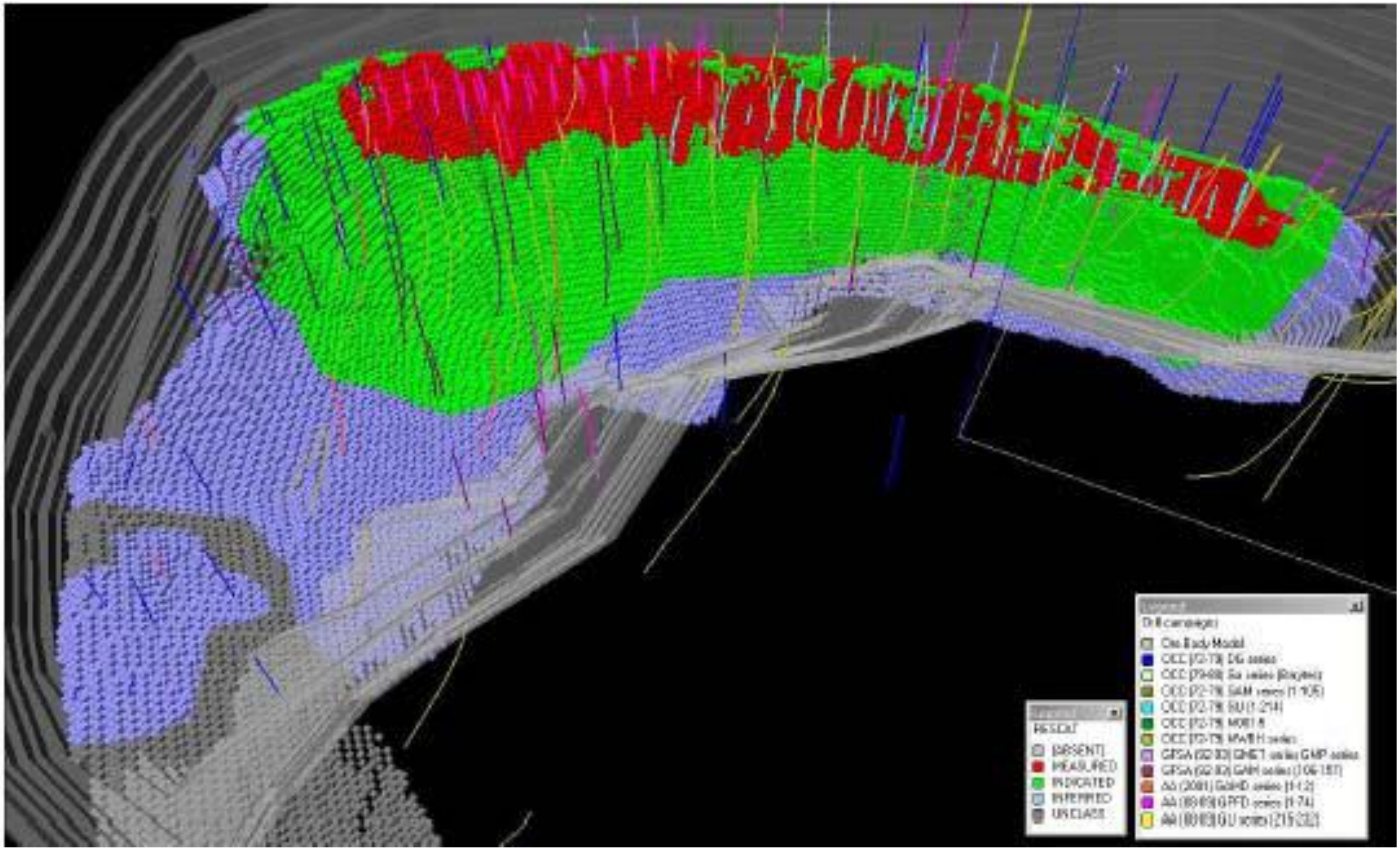
Estimation Confidence



Total Score



Smoothed Classification



Summary

- Classification continues to evolve to provide information to which Modifying Factors can be applied
- Much more rapid flow of opinions between countries via CRIRSCO
- Quality of resources is important
- Investor will place a higher value on Inferred when he knows conversion to Indicated is likely

Thank You

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