



GSEU

GEOLOGICAL SERVICE | FOR EUROPE

GSEU WP2 TRAIN-THE-TRAINER COURSE

Module: Introduction

Level 1

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www.geologicalservice.eu



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the European Union



9h05 – 10h05

Mineral resource estimations



Mineral resource estimations and estimation uncertainties

“In general, an ounce of geology is worth a pound of geostatistics; this may be disappointing to geostatisticians with no geological background; tough”

Harry Parker

Resource estimation is the process of creating a three-dimensional reflection of in situ mineralisation based on sparse samples, current geological thinking and truck load of common sense.

Jacqui Coombes

Coombes 2008, The Art and Science of Resource Estimation





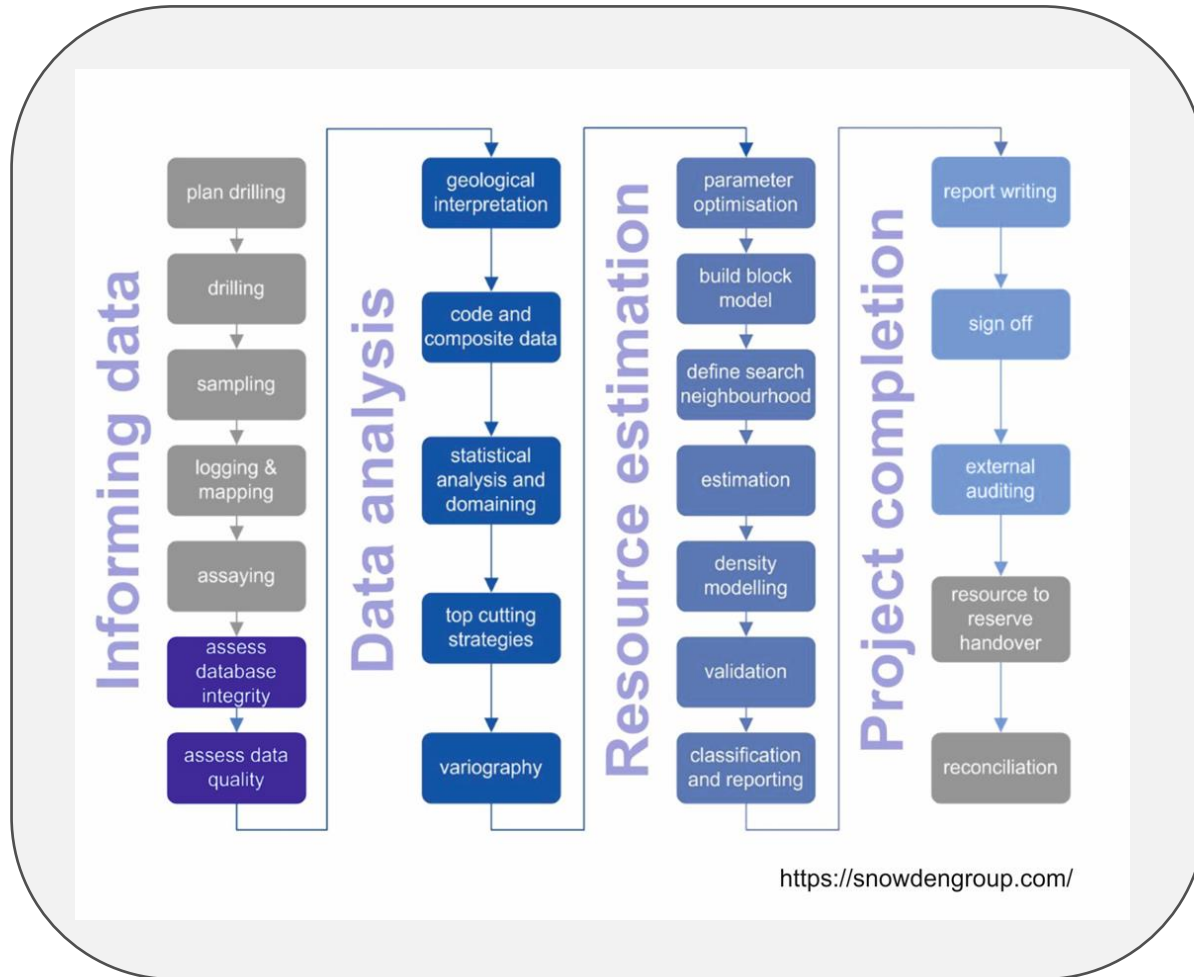
Resource estimation

- Database
- Geological modelling (explicit or implicit modelling)
- Exploratory data analysis (EDA)
- Estimation domain definition
- Variography
- Block model
- Grade estimation
- Resource classification
- Resource validation
- Resource reporting

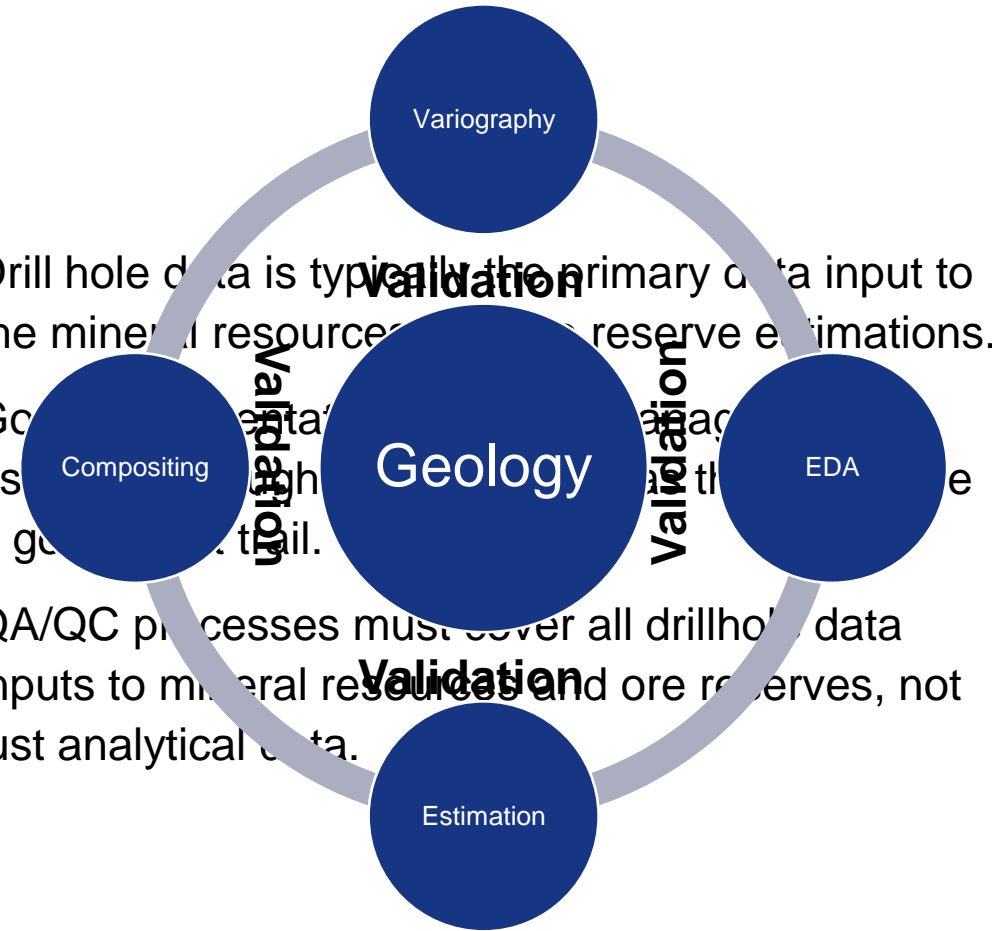




Resource estimation



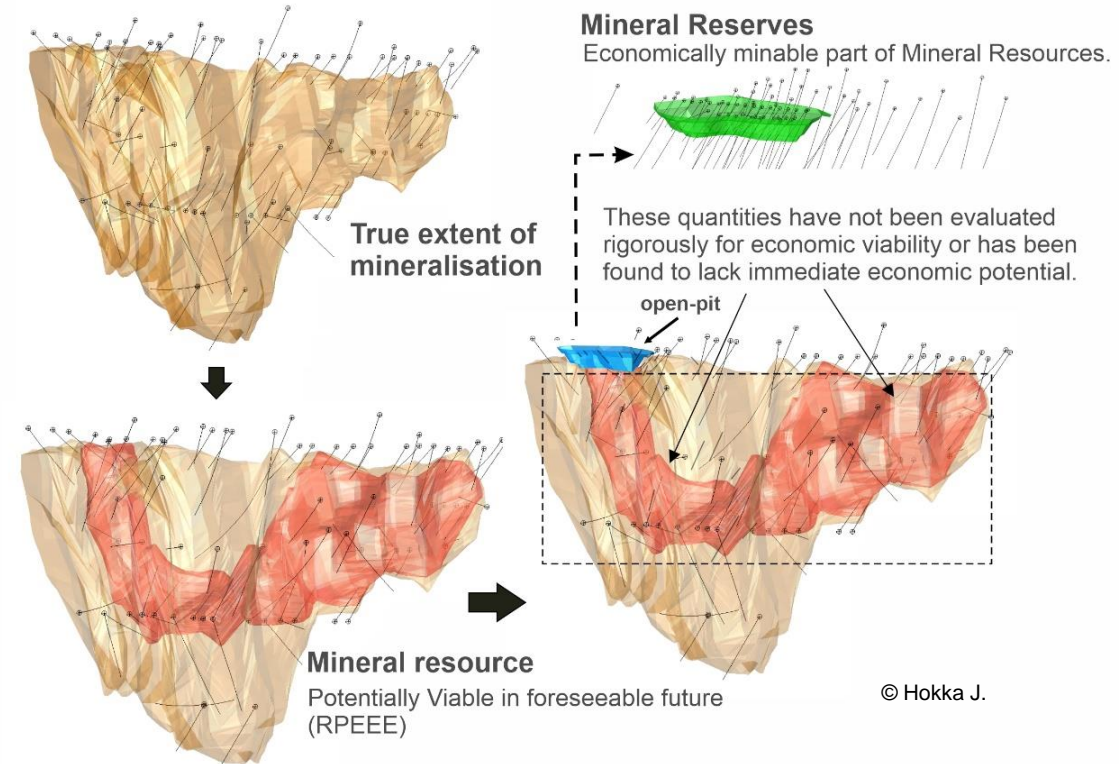
- Drill hole data is typically the primary data input to the mineral resource and reserve estimations.
- Geology data is used to validate the resource and reserve estimations. A geology audit is a good practice to ensure the data is accurate and reliable.
- QA/QC processes must cover all drillhole data inputs to mineral resource and ore reserves, not just analytical data.





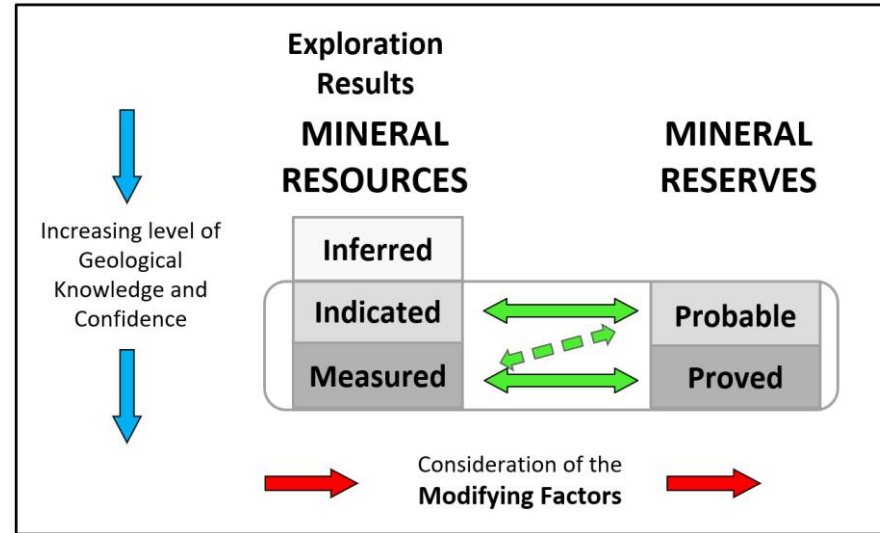
What are Resources and Reserves?

- 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 (RPEEE)**.
- A **Mineral Reserve** is the **economically mineable part** of a Measured and/or Indicated Mineral Resource that incorporate assessment of “**modifying factors**”.
- Resources and reserves only make up a small part of the true extent of mineralisation.
- The latter may well be known but cannot be reported because the confidence in the geological and grade continuity of the mineralisation and associated economic prospects may not be sufficient to meet the criteria needed for resource or reserve reporting.





What are Resources and Reserves?



Criteria	Inferred Resource	Indicated Resource	Measured Resource
Geological evidence is sufficient to	imply but not verify geological and grade continuity	assume geological and grade continuity	confirm geological and grade continuity
<u>Confidence in the estimate</u> to allow the application of Modifying Factors	<ul style="list-style-type: none"> Reasonably expected that the majority of Inferred... could be converted to Indicated... with continued exploration 	<ul style="list-style-type: none"> supports mine planning and economic evaluation of economic viability 	<ul style="list-style-type: none"> supports detailed mine planning and final evaluation of economic viability.
Quality of Information	<ul style="list-style-type: none"> limited geological evidence and sampling 	<ul style="list-style-type: none"> adequate detailed and reliable 	<ul style="list-style-type: none"> detailed and reliable

After Coombes (2016)



Terminology

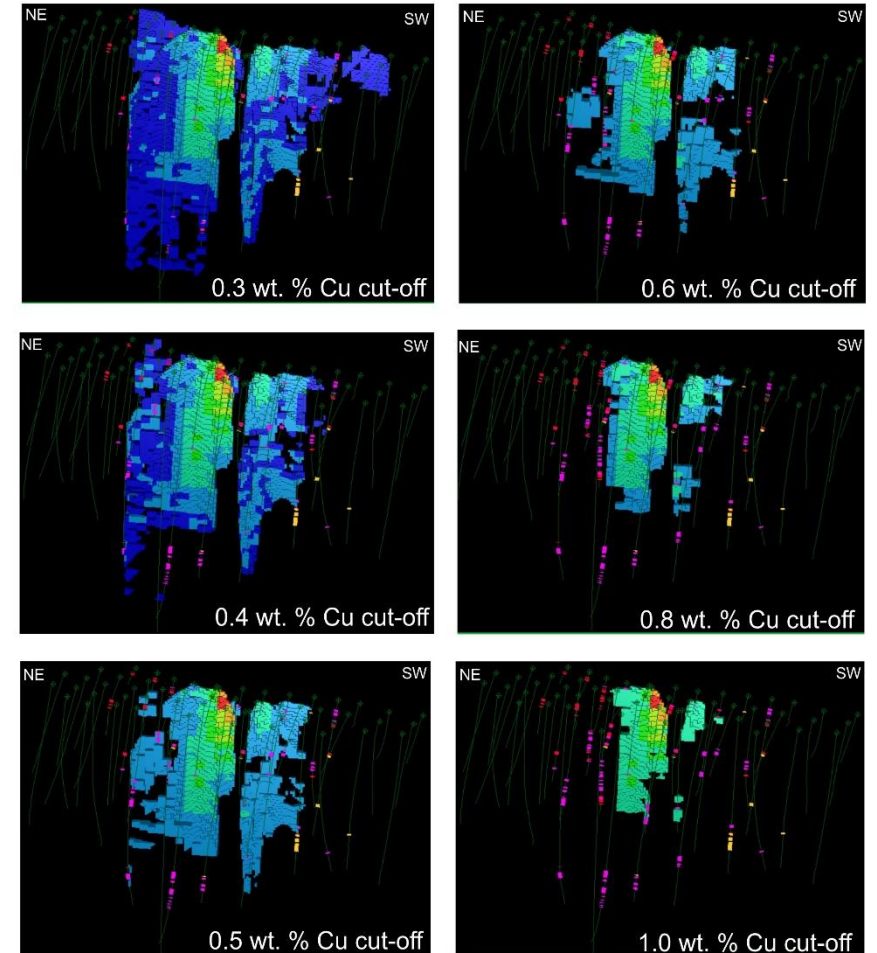
Cut-off grade

a grade below which the value of contained metal or mineral in a volume of rock does not meet certain specified economic requirements.

Complex economic problem that is tied to the concept of operation costs (per ton).

Dilution

- result of mixing non-ore-grade material with ore-grade material during production.
- Always present to certain degree in the mining operations
- → increase in tonnage and decrease in mean grade relative to plan
 - *Internal (low-grade material surrounded by high-grade material)*
 - *External (low-grade material marginal to high-grade material)*



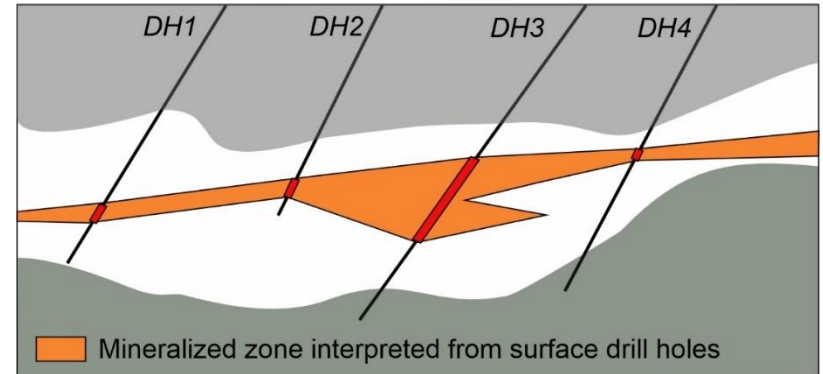
© Hokka J.



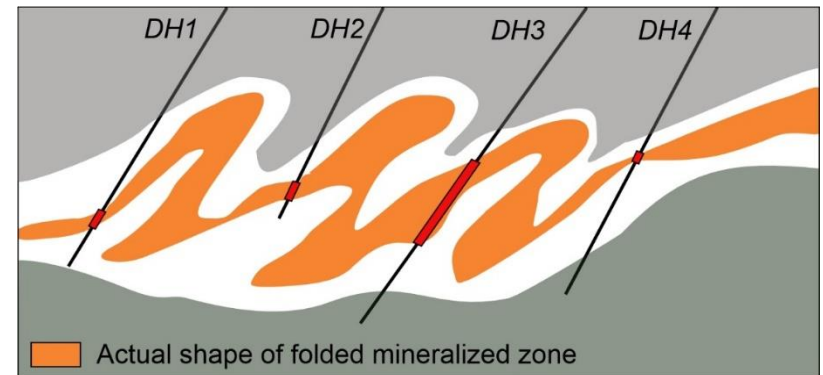
Terminology

Continuity

- Described as physical occurrence of geologic feature that control mineralisation and grade values.
- A classification of mineral resources and mineral reserves depends first and foremost on an appreciation of mineralization continuity.
- **Geological continuity:** *the geometric continuity of the geological structure(s) or zone(s) hosting mineralization (e.g., orebody thickness and up-/down-dip continuation); and*
- **Grade continuity:** *the continuity of grade that exists within a specific geological zone, sometimes called the value continuity.*



Ore lens assumed as linear structure (no structural data)



Ore lens actually occurred in a tightly folded complex. © Hokka J.



Terminology

Continuity



Resource/Reserve Class	Data Density	Geological Continuity	Grade Continuity
Inferred Mineral Resource	<ul style="list-style-type: none"> Based on geological information, and widely spaced and potentially isolated data. 	<ul style="list-style-type: none"> Global continuity assumed (in either 2D or 3D), but not established. Local continuity issues unresolved. Local continuity potentially resolved along, but not between drill holes. Semi-quantitative estimate of global tonnage with high error margin. 	<ul style="list-style-type: none"> No continuity established except along axes of drill holes. Approximate nature of orezone(s) defined (assumed), but not established. Semi-quantitative estimate of global grade with high error margin.
Indicated Mineral Resource (Probable Ore Reserve)	<ul style="list-style-type: none"> Based on geological information, and moderately spaced data. 	<ul style="list-style-type: none"> Global continuity partly realized in 3D. Local continuity issues potentially partly resolved. Local continuity resolved along drill holes. Global/local estimate of tonnage with a medium margin of error. 	<ul style="list-style-type: none"> Local continuity may be partly established. Local continuity resolved along drill holes. Some resolution of orezone(s) grade distribution and geometry. Quantitative estimate of global/local grade with a medium margin or error.
Measured Mineral Resource (Proved Ore Reserve)	<ul style="list-style-type: none"> Based on geological information and close-spaced data. May also involve underground development, and bulk sampling/trial mining. 	<ul style="list-style-type: none"> Global continuity realized in 3D. Local continuity resolved. Global/local estimate of tonnage with a low margin of error. 	<ul style="list-style-type: none"> Local continuity well established. Detailed resolution of orezone(s) grade distribution and geometry. Quantitative estimate of grade and local estimate, with low margin of error.

Note: The content of this table provides some general characteristics for guidance only. It is important that the CP treats each deposit on an individual basis. It should be noted that various other parameters should also be considered when reporting Mineral Resources and Ore Reserves (e.g., drilling techniques, sample recovery, assay quality etc.), and not just continuity. The reader is referred to Table 1 of the JORC Code for more detail on some of the relevant issues (JORC, 1999).

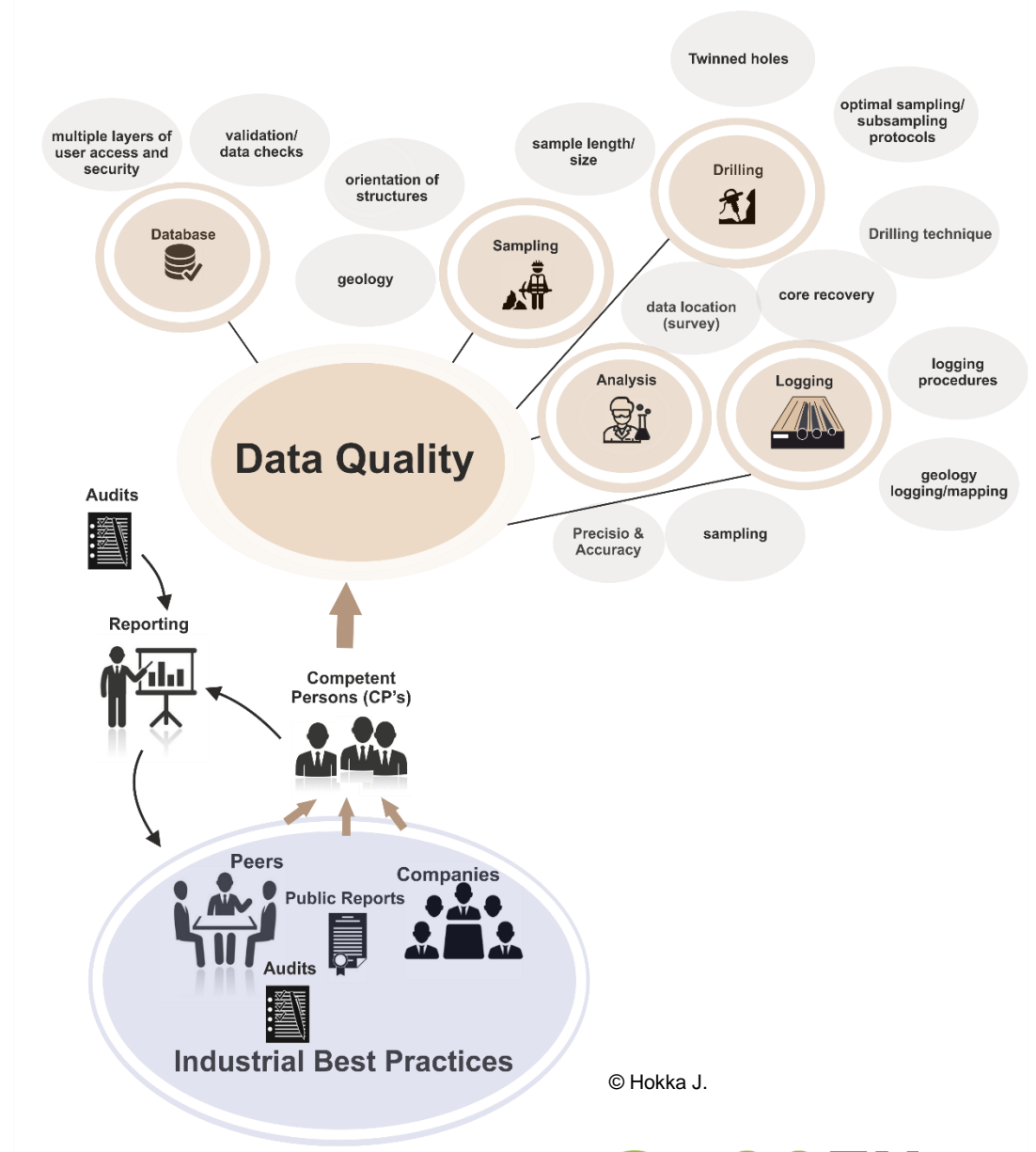
Dominy 2004



Terminology

QA/QC

- Data collection and technical work should always follow the **Industry Best Practice (IBP)**
- **Data quality covers the whole estimation process** and must be carefully planned and implemented from the first stage of sampling to final stage of reporting.
- There are many inputs to a resource estimate and many parties are responsible of collecting this data.
- Nevertheless, Competent Person (s) are always responsible of the whole estimation process and to prove the data quality.



© Hokka J.





Terminology

Chain of Custody

- **Chain of custody** refers to all steps in the sampling chain from the field (outcrop or rig) to the analytical laboratory.
 - Sufficient and secured sample storage in the field if necessary (e.g., core storage at the drilling rig)
 - Secure transportation of samples from the field to the camp (logging or sampling facility)
 - Routine sample (core) handling procedures including core cutting and sampling practices (e.g., marking the sample number on the tray where intervals have been taken for assay and adhesive sample number tags carrying the same sample numbers as those in the sample book).
 - Secured package of samples for shipment and communication with the analytical laboratory.
 - Quality Control (QC) monitoring of samples from sample preparation to assay results.



Drilling



Logging



Handling



Sampling



Storage



Submission

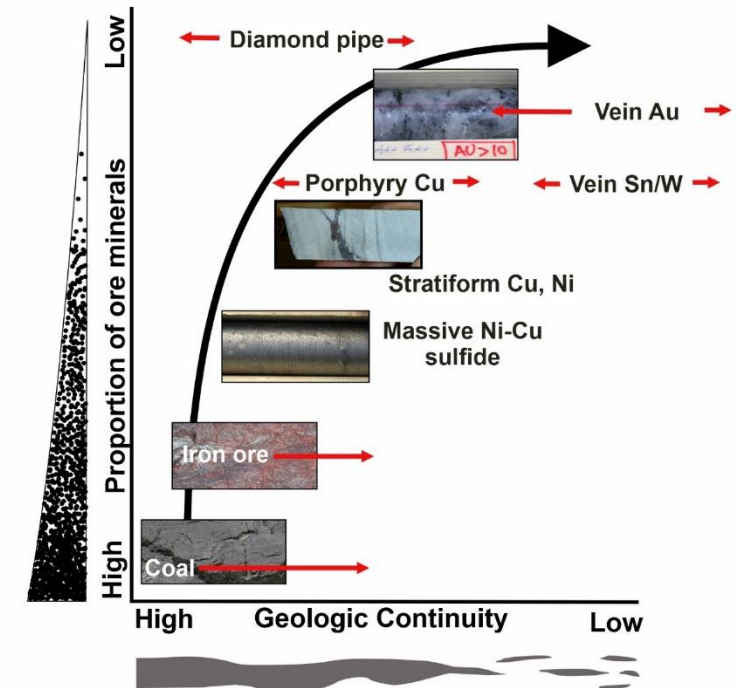
© Hokka J.



Deposit types and style of mineralizations

- There needs to be a comprehensive understanding of the geological base to mineral estimation (e.g., domains, boundaries, and continuity.)
- Geostatistics should not supersede geology but instead should be integrated with geology in a practical manner.
- Resource geologists need to continually ask themselves questions regarding the underlying geology.

- *Do I understand the local geology and mineralization model?*
- *How much confidence do I have in this model?*
- *Where are the areas of doubt, concern or unexplained areas?*
- *Do the constraints put on the modelling process (e.g., composites) do justice to the true nature of the deposit?*
- *Are my assumptions around the geology and mineralizations well founded?*

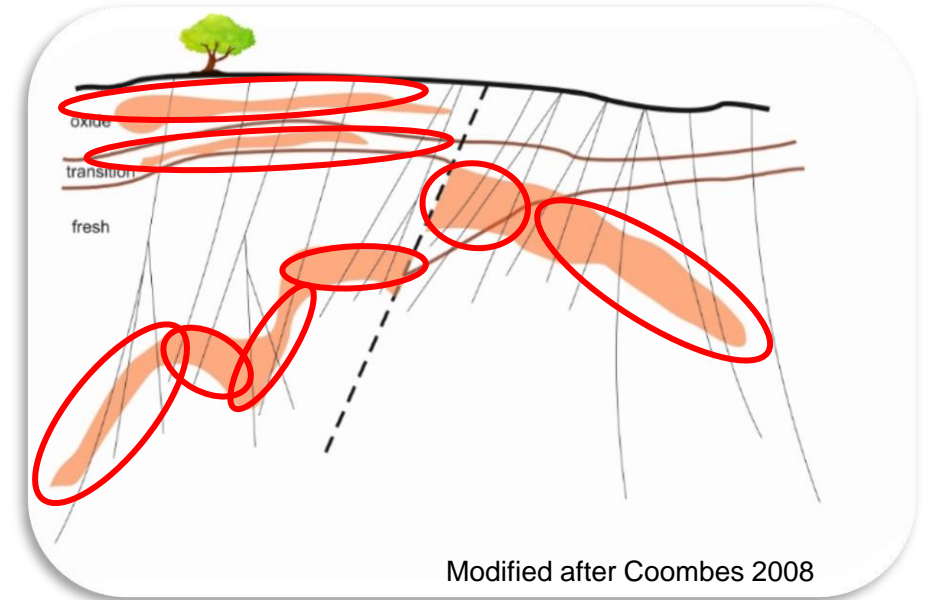


Modified after Sinclair & Blackwell 2002



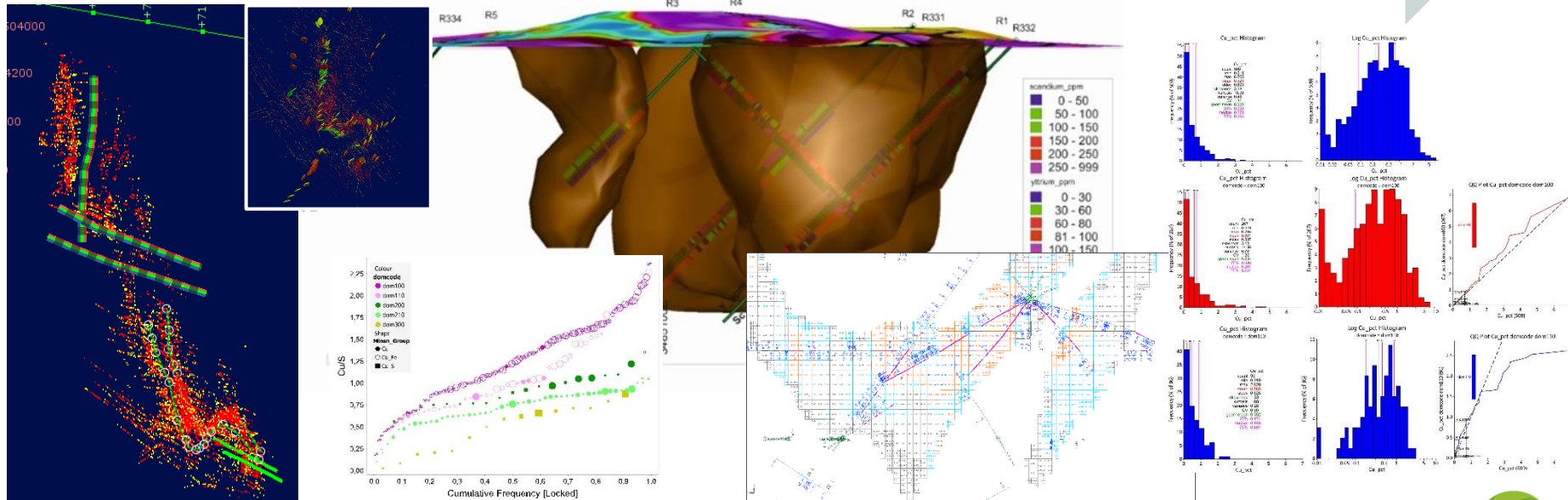
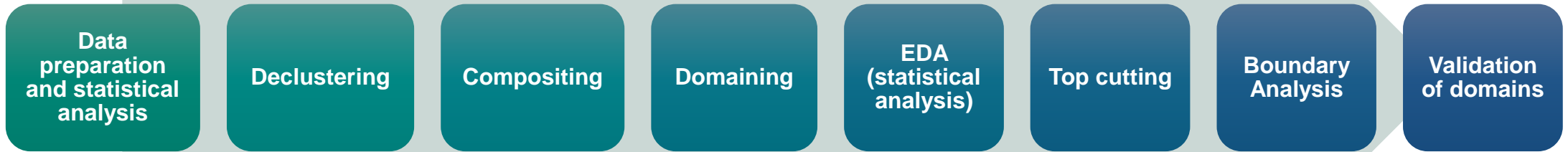
Domaining

- Geology (geological model) is the cornerstone of any accurate resource model.
- The vast majority of mineral deposits the controls on mineralisation are primarily geological.
- In resource estimation, a robust domain is a spatial volume where:
 - *The geology is consistent (geological and mineralogical homogeneity)*
 - *Contains a single grade population (statistical and numerical homogeneity)*
 - *Stationarity*
 - *Has a single orientation for search*





Estimation and model building





CRIRSCO-aligned reporting standards and codes



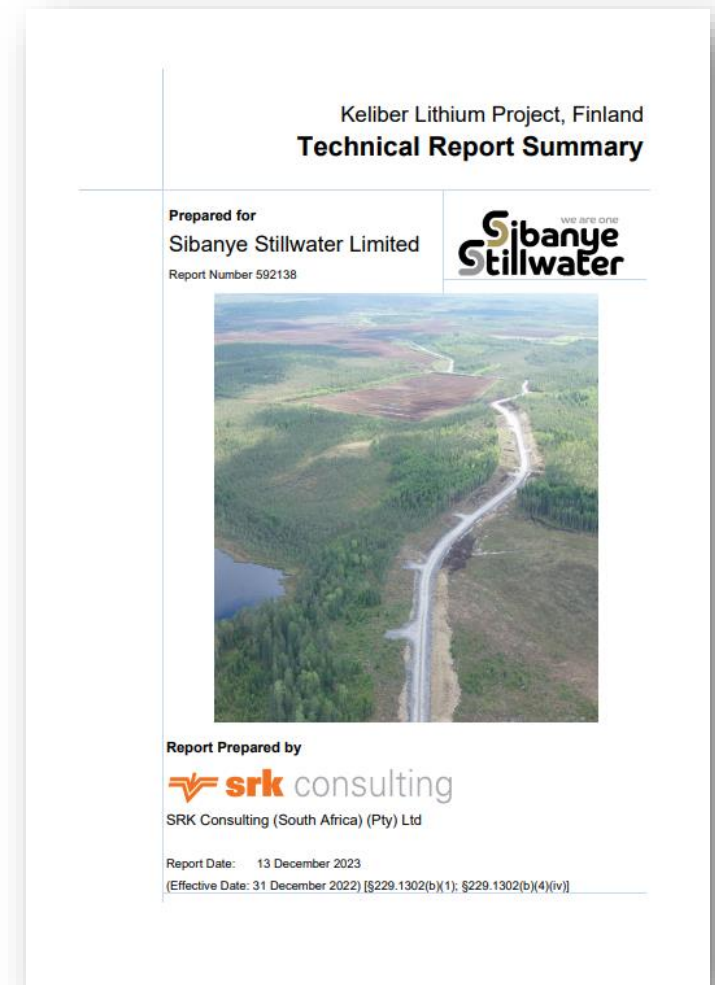
CRIRSCO-aligned standards and codes

- Sets the **minimum standards for public reporting** of Exploration Results, Mineral Resources and Mineral Reserves
 - *Provides a mandatory system for classification of tonnage/grade estimates according to geological confidence and technical/economic considerations*
 - *Requires Public Reports to be based on work undertaken by a Competent Person; describes the qualifications and type of experience required to be a Competent Person*
 - *Provides extensive guidelines on the criteria to be considered when preparing reports on Exploration Targets, Exploration Results, Mineral Resources, and Ore Reserves*
- **Does not regulate the procedures** used by Competent Persons to estimate and classify Mineral Resources and Mineral Reserves
- Provide the **standards for reporting**, not estimating!
- The standards and codes represent **industry best practice**, and when followed honestly and diligently, they **provide a strong measure of due diligence protection** for Competent Persons.



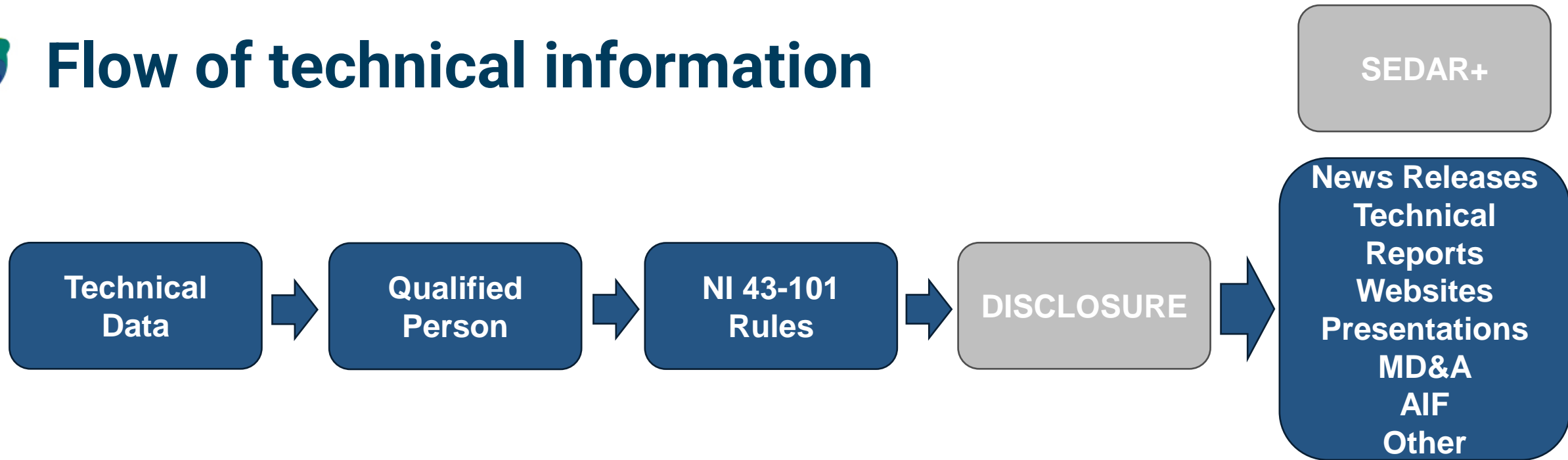
What is a Public Report?

- Public Reports are reports prepared for the purpose of informing investors or potential investors and their advisors.
- They include, but are not limited to:
 - *annual and quarterly company reports*
 - *press releases*
 - *information memoranda*
 - *technical papers*
 - *website postings, and*
 - *public presentations of Exploration Results, Mineral Resources, and Ore Reserves estimates*





Flow of technical information



- All DISCLOSURE of scientific and technical disclosure on a material property must be prepared by or approved by a QP who is named

Source: https://www.osc.ca/sites/default/files/pdfs/irps/ni_20180307_43-101_mineral-disclosure.pdf



Background for resource disclosure

- **The Poseidon bubble**
 - Poseidon NL's discovery of a nickel deposit in western Australia, in September 1969. At that time, Poseidon shares had been trading at A\$0.80 each, and peaked at A\$280 each in February 1970. As a result, the Australian government established the 'Rae Committee', which, in 1974, recommended changes to the regulation of stock markets, leading to Australian securities legislation.
- **The Bre-X scandal**
 - Bre-X Minerals Ltd, a Canadian company that allegedly discovered the Busang gold deposit. Bre-X started out on the Alberta Stock Exchange and was listed in 1989 at C\$0.30 a share. In October 1995, Bre-X announced it had discovered a deposit with approximately 2.7 million ounces of gold. As a result of the Bre-X debacle, the Mining Standards Task Force was established by the TSX and the Ontario Securities Commission, and it recommended sweeping changes to disclosure for mining companies listed on exchanges in Canada.

Scandals like Bre-X helped lead to the creation of NI 43-101



THE WALL STREET JOURNAL.

BUSINESS AND FINANCE - ASIA

**Bre-X Confirms Worst Fears:
Busang Has Virtually No Gold**

May 4, 1997



Committee for Mineral Reserves International Reporting Standards (CRIRSCO)



COMMITTEE FOR MINERAL RESERVES
INTERNATIONAL REPORTING STANDARDS

CRIRSCO was formed in 1994 and it currently representing fifteen national reporting organisations (NROs) around the world.

The CRIRSCO Template provides:

- a framework for the CRIRSCO-aligned reporting codes and standards.
- recognized and adopted world-wide for market-related reporting and financial investment.
- The CRIRSCO Template is the international standard for the reporting of Exploration Targets, Exploration Results, Mineral Resources, and Mineral Reserves and represents current international leading practices for the preparation of Public Reports by Mineral Companies.

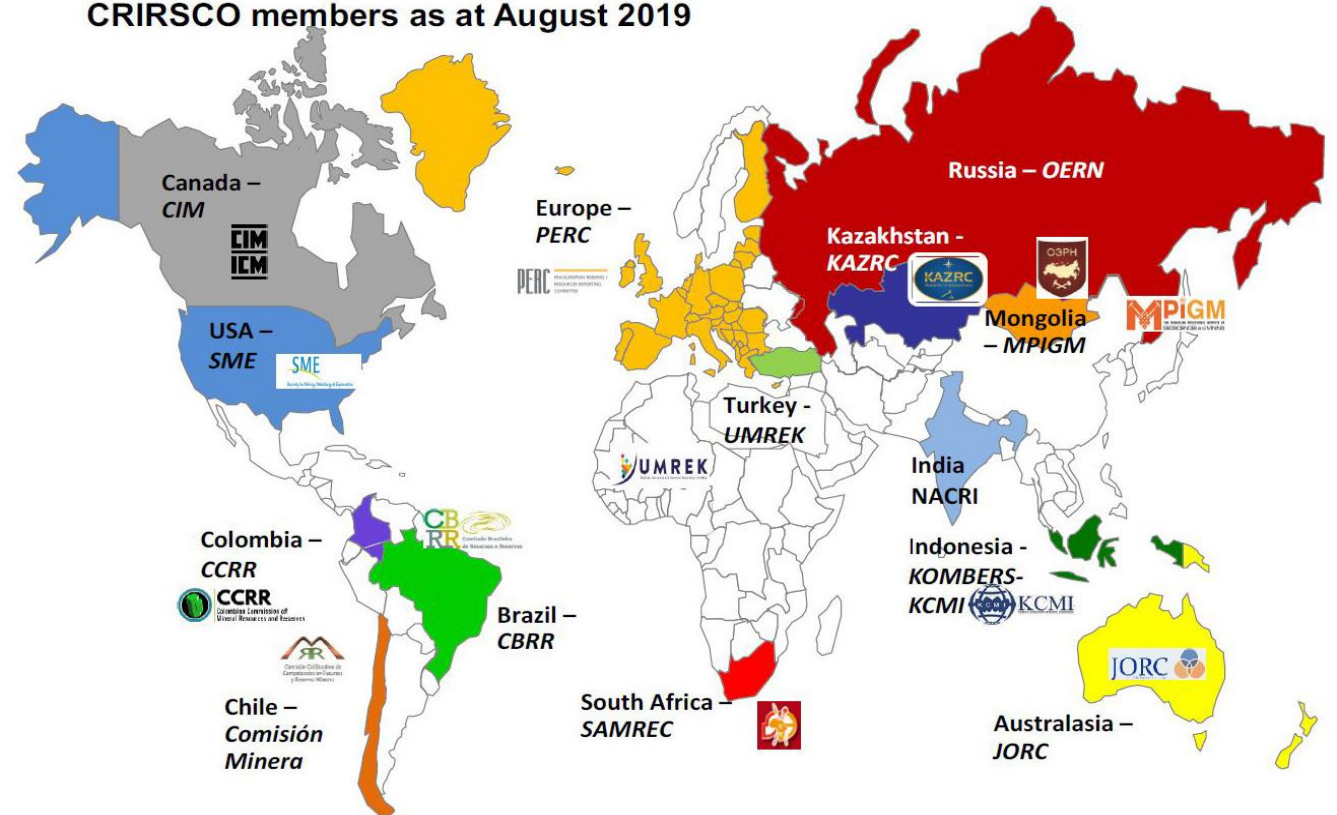


CRIRSCO: International reporting standards



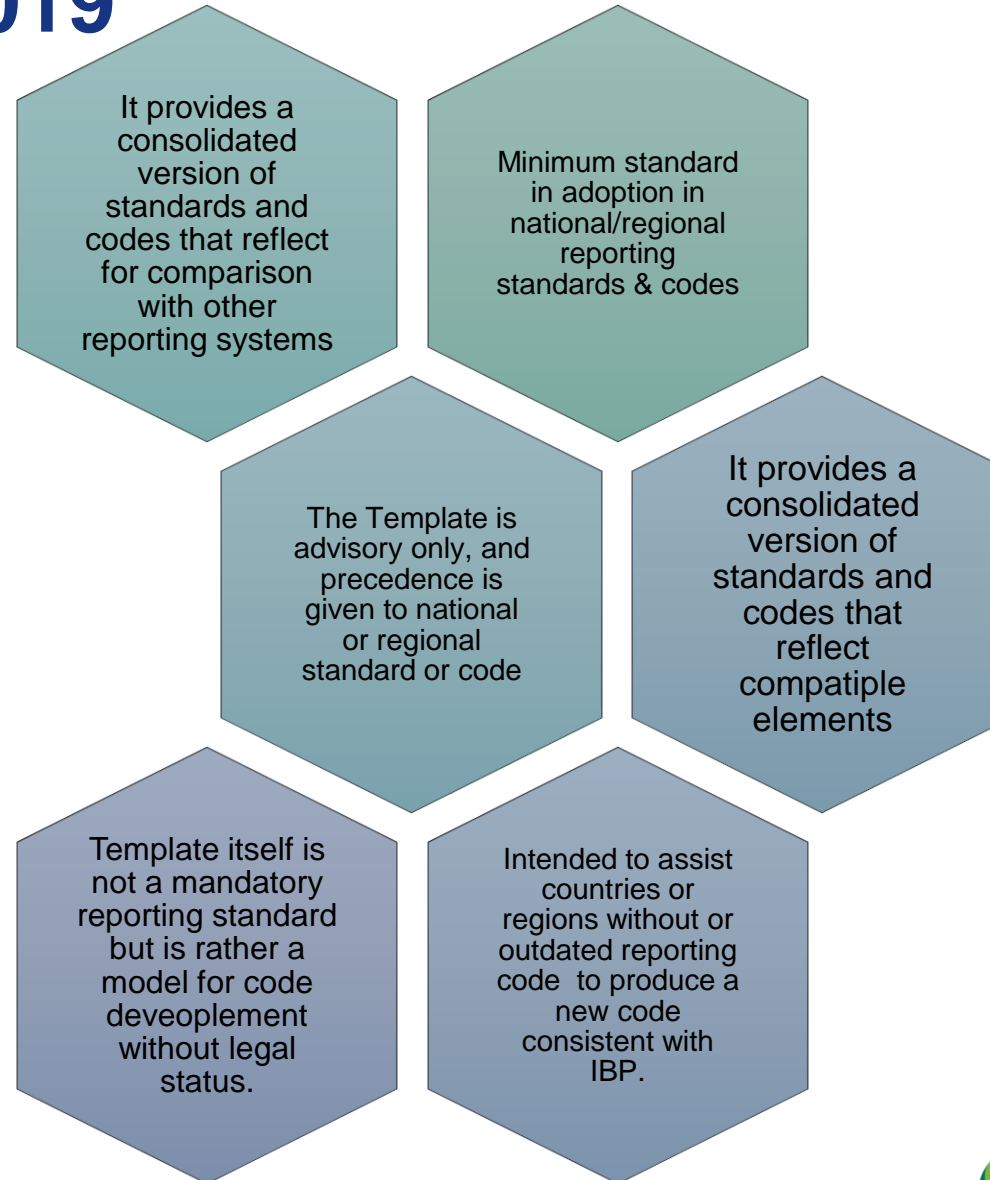
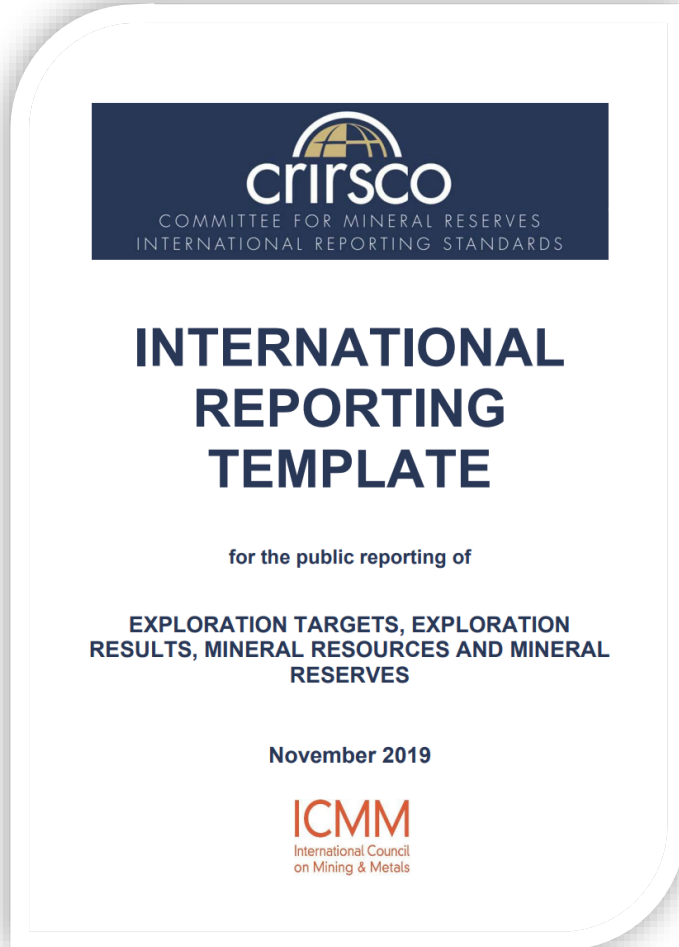
- CRIRSCO is to promote **International Best Practice in Public Reporting of Mineral Exploration Results, Mineral Resources, and Mineral Reserves**

CRIRSCO members as at August 2019





CRIRSCO Template 2019

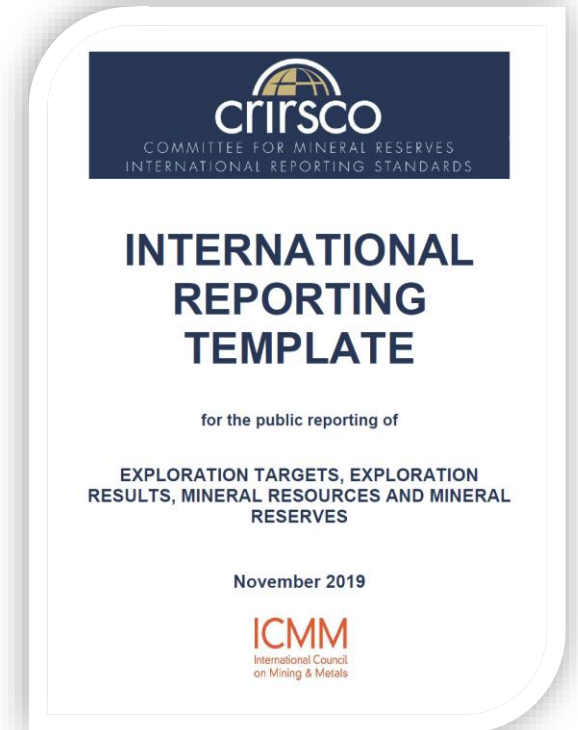




Competency & Qualification

CRIRSCO Template, 2019, 3.1-3.12

- A **Competent Person** is:
 - a minerals industry professional,
 - A member of Professional Organisation (PO) or other Recognised Professional Organisations (RPOs)
 - These organisations have **enforceable disciplinary processes** including the powers to suspend or expel a member.
- A **Competent Person** must have:
- A Competent Person must have a **minimum of five years relevant experience** in the style of mineralisation or type of deposit under consideration and in the activity which that person is undertaking.



3.1 A Public Report concerning a company's Exploration Targets, Exploration Results, Mineral Resources and/or Mineral Reserves is the responsibility of the company acting through its Board of Directors. Any such report must be based on, and fairly reflect the information and supporting documentation prepared by or under the direction of and signed by a Competent Person.



Competency & Qualification

PERC Reporting Standard

- PERC is a constituent member of the Committee For Mineral Reserves International Reporting Standards (CRIRSCO) and is recognised by CRIRSCO as the National Reporting Organisation (NRO) for the Europe Region.
- **PERC Participating Organisations** may be professional associations of geologists, engineers, or other specialists involved in preparation of Competent Person reports on mineral reserves and resources, or may be industry associations, governmental or intergovernmental organisations, or other types of organisations with an interest in setting, promoting and maintaining professional practice standards in solid minerals reporting.

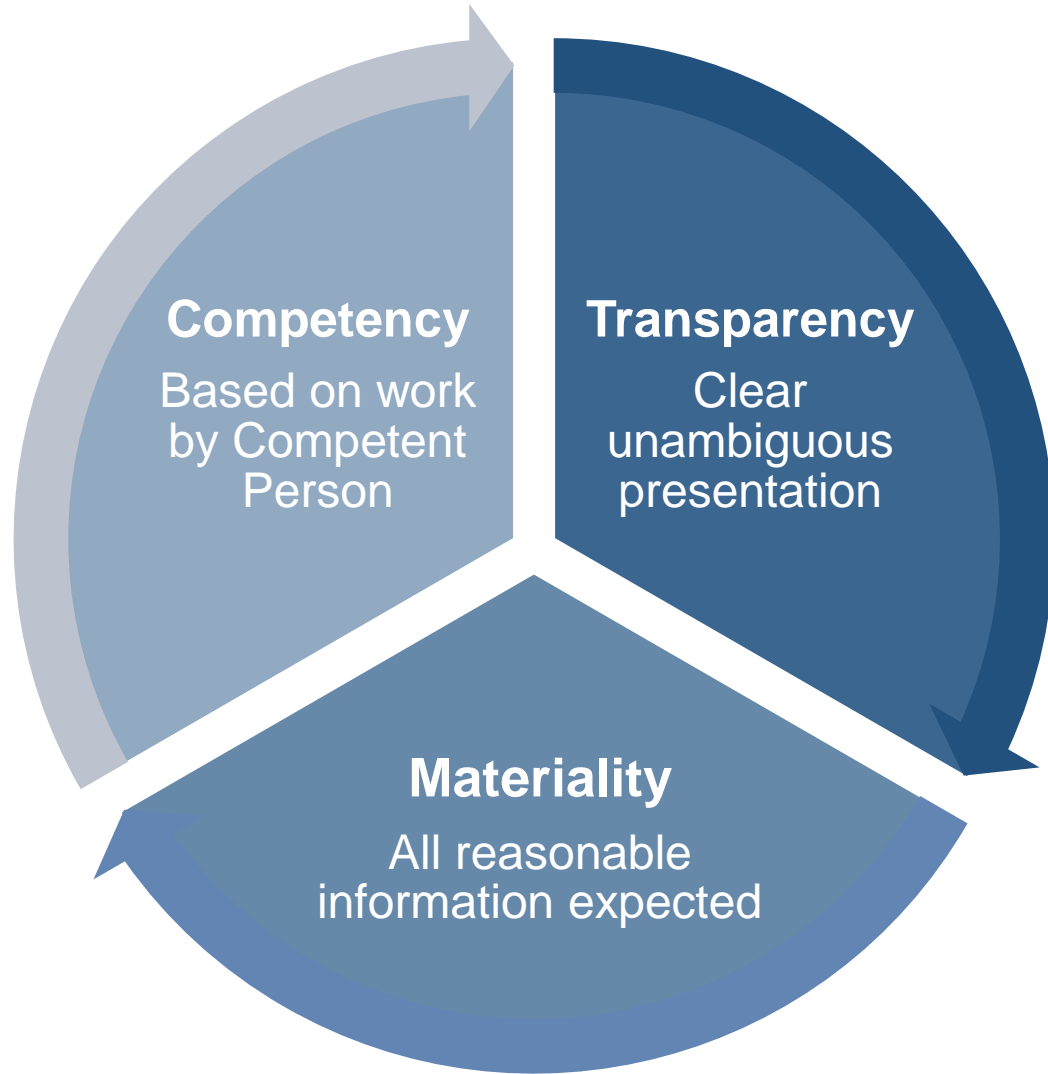
EUROPEAN RPOs RECOGNISED BY PERC, AND MEMBERSHIP LEVELS REQUIRED	
Organisation	Minimum membership class required
The Institute of Materials Minerals and Mining (IOM3)	'Member' (MIMMM) or 'Fellow' (FIMMM)
National Associations which constitute the European Federation of Geologists (EFG)	'European Geologist' (EurGeol)
The Institute of Geologists of Ireland	'Professional Geologist' (PGeo)
The Geological Society of London (GSL)	'Chartered Geologist' (CGeol) or 'Chartered Scientist' (CSci)
Fennoscandian Association for Minerals and Metals Professionals (FAMMP)	'Member'
Iberian Mining Engineers Board (IMEB)	'Member'

RPOs OUTSIDE EUROPE	
Organisation	Minimum membership class required
OERN (Russia)	'Expert'
American Institute of Professional Geologists	(AIPG) Certified Professional Geologist
The Society of Mining, Metallurgy and Exploration, Inc.	SME Registered Member
Mining and Metallurgical Society of America (MMSA)	Qualified Professional
Australasian Institute of Mining and Metallurgy (AusIMM)	Fellow or Member
Australian Institute of Geoscientists (AIG)	Fellow or Member
South African Institute of Mining and Metallurgy (SAIMM)	Fellow
South African Council for Natural Scientific Professions Professional Natural Scientist (SACNASP)	Professional Natural Scientist



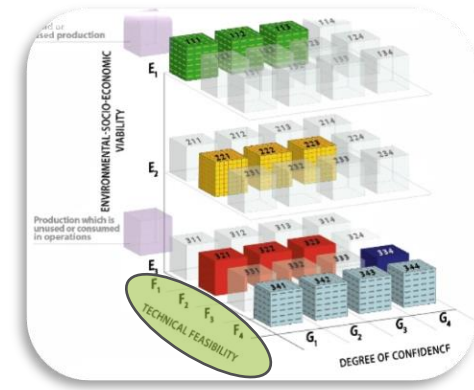


Overarching principles of reporting





Technical studies



Scoping Study

- is an order of magnitude **technical and economic study of the potential viability of Mineral Resources** that includes appropriate assessments of realistically assumed Modifying Factors together with any other relevant operational factors that are necessary to demonstrate at the time of **reporting that progress to a Pre-Feasibility Study can be reasonably justified.**

Pre-Feasibility Study

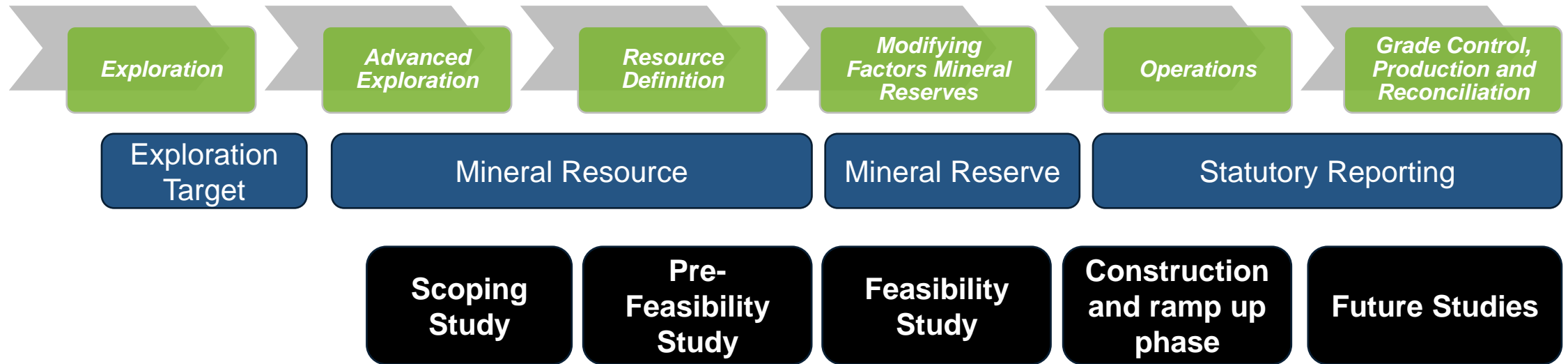
- is a **comprehensive study of a range of options for the technical and economic viability of a mineral project** that has advanced to a stage where a preferred mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, is established and an effective method of mineral processing is determined. It includes a financial analysis based on reasonable assumptions on the Modifying Factors and the evaluation of any other relevant factors which are sufficient for a Competent Person, acting reasonably, to determine if **all or part of the Mineral Resource may be converted to a Mineral Reserve at the time of reporting.** A Pre-Feasibility Study is at a lower confidence level than a Feasibility Study.

Feasibility Study

- is a **comprehensive technical and economic study** of the selected development option for a mineral project that includes appropriately detailed assessments of applicable Modifying Factors together with any other relevant operational factors and detailed financial analysis that are necessary to demonstrate at the time of reporting that extraction is reasonably justified (**economically mineable**). The results of the study may reasonably serve as the basis for a final decision by a proponent or financial institution to proceed with, or finance, the development of the project. The confidence level of the study will be higher than that of a Pre-Feasibility Study.



Technical studies



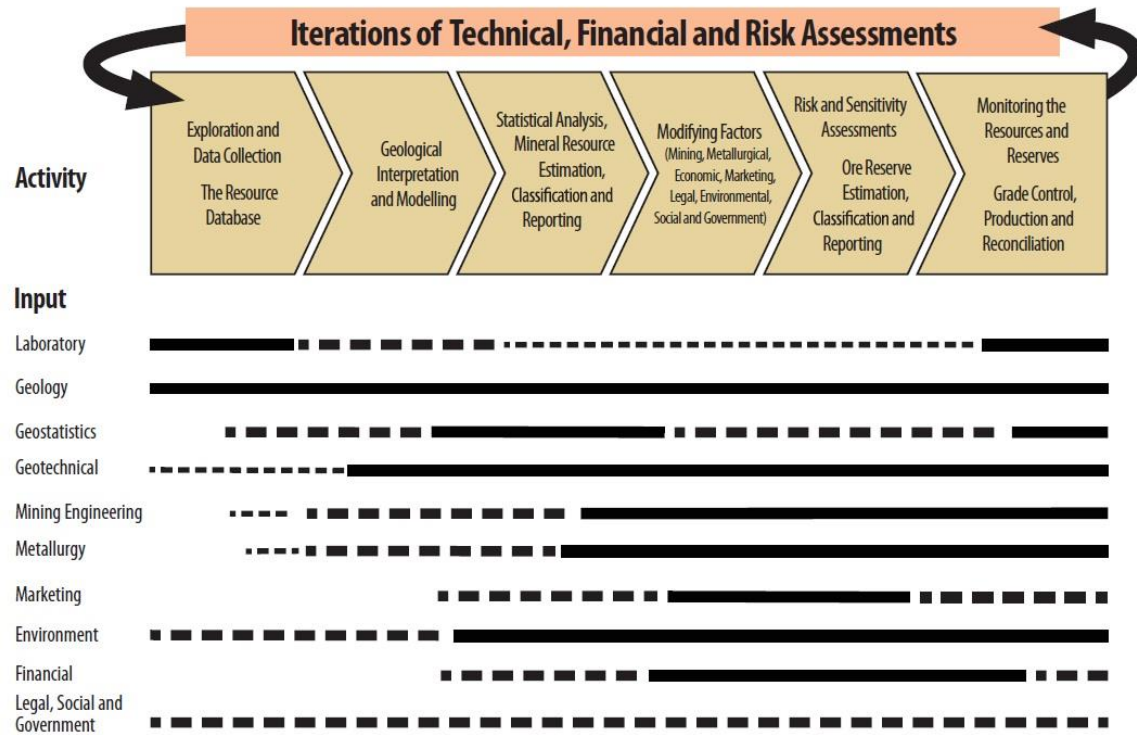
Scoping Study: Review different situations to see if the project will make enough money, but don't decide on the best option yet.

Pre-Feasibility Study: Look at various scenarios to work out what is the best one and whether that best one warrants going to full Feasibility Study.

Feasibility Study: On the single case that comes out of the Pre-Feasibility Study, conduct thorough analysis to establish a solid foundation for decisions regarding project approval by the company, funding from banks (if applicable), and as a basis for detailed engineering.

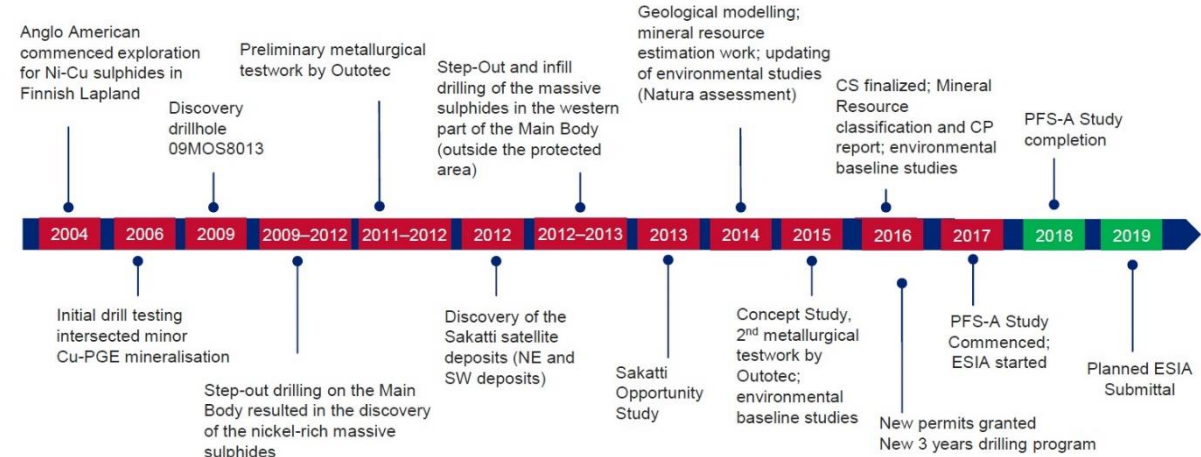


Activities and inputs related to a mining project



Baldwin et al. 2014

SAKATTI – PROJECT HISTORY



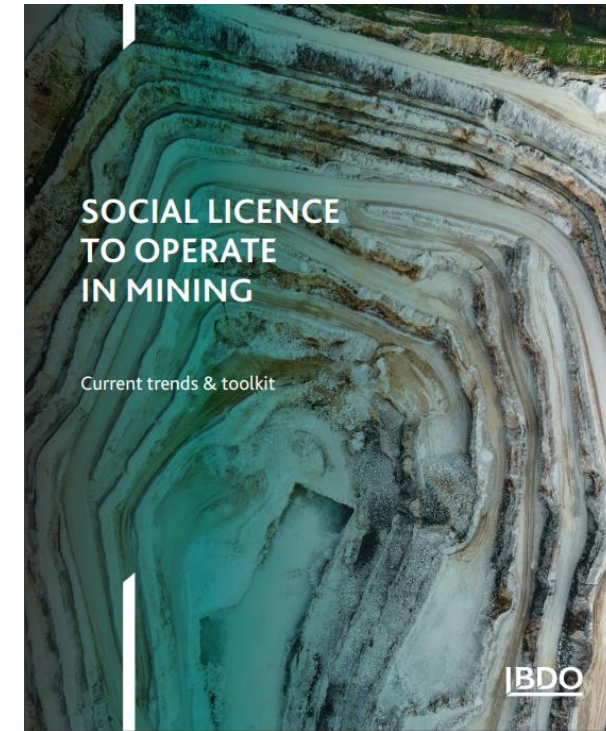
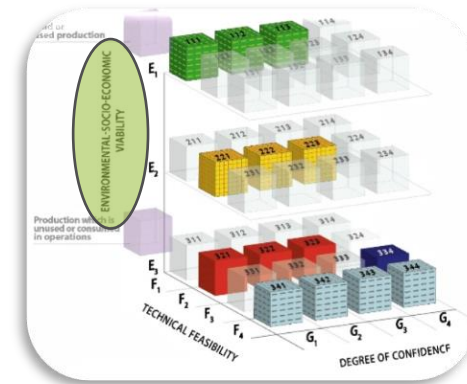
Anglo American 2017

- Generally, exploration is **enduring science-economic evaluation process** which, beside of natural resources, is dependent on socio-economic, environmental and several society related factors.
- Technical studies may easily take **10-15 years** from the discovery.



Non-geological factors matters!

- The **Modifying Factors** such as material dilution and losses during extraction, available mining, processing, and metallurgical technology, and infrastructure, economic, marketing, legal, environmental, social and governmental factors.
- Multiple non-geological factors (i.e., environmental, social, geopolitical, infrastructure) have a direct impact on mining and may hinder metal and mineral production.
 - **Social Licence to operate**
 - *Social licence requires the acceptance of the people who live and work near, or are affected by, a mining project. However, the definition of social licence has widened to include the tacit support of the society as a whole and even the international community.*
 - **Environmental, Social and Governance (ESG)**
 - *ESG refers to the three critical issues in the sustainability and societal impact of a mining project. These criteria help to better determine the future financial performance of companies and projects.*



https://www.bdo.global/getattachment/Insights/Global-Industries/Natural-Resources/Social-Licence-to-Operate-in-Mining/BDO_Social-Licence-to-Operate_2020.pdf.aspx?lang=en-GB



Environmental, Social and Governance (ESG) considerations in Public Reporting

- *”**Public Reports** must discuss the environmental, social (including health and safety), governance aspects (ESG) of the project or operation that could materially affect the project during development, operations and after closure.” (PERC, 2021).*
- In principle, all **ESG aspects and risks associated with a project or operation should be transparently described** alongside the corresponding management controls, measures, systems, and the expected outcome they generate.
- In the PERC Standard (2021) it is stated that: **“Public Reports** that include assessment of RPEE of Mineral Resource or Reserves **must include** a written consideration of **the direct and indirect environmental and social cost of extraction, processing**, and enduse in terms of environmental degradation, ecological diversity, cultural destruction or climate change.”



What does ESG mean for the mining industry?

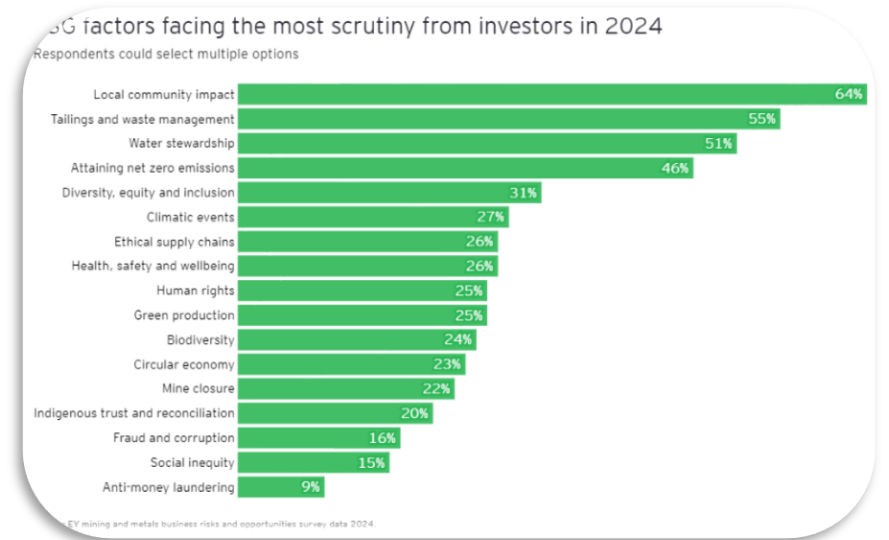
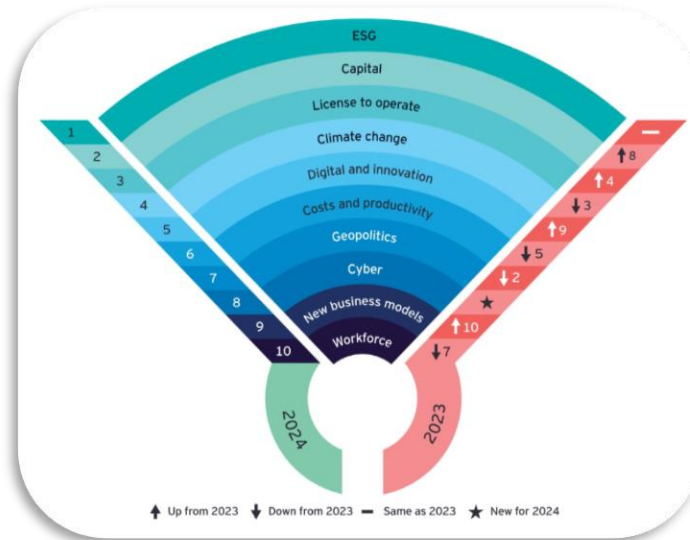
Top 10 business risks and opportunities for mining and metals in 2024

About the survey
 During June and July 2023, we surveyed or interviewed over 150 mining executives, including those in the C-suite, as well as leaders in human resources, sustainability and technology, across all major mining regions.

ESG is a complicated issue with many subtopics. Because of this complexity, we separate climate change and LTO from the broader topic of ESG to allow deeper focus on these issues.

EY
 Building a better working world

https://www.ey.com/en_gl/mining-metals/risks-opportunities



- For the third year in a row, **ESG is the biggest risk for miners**, as well as their **biggest opportunity** to drive differentiation and improvements that will create long-term value for all stakeholders.



What does ESG mean for the mining industry?



6 March 2024

Angkor Resources Receives International Attention Regarding its ESG Projects

Part of Angkor’s Environmental, Social, Governance (“ESG”) platform, which run parallel to the exploration and development activities, is to undertake needs assessments with the surrounding communities and assist in activities for communities to gain control of their livelihoods and manage their needs.

<https://www.juniorminingnetwork.com/junior-miner-news/press-releases/636-tsx-venture/ank/157126-angkor-resources-receives-international-attention-regarding-its-esg-projects.html>



A BLOG BY
**Baker
McKenzie.**

There is a growing investor focus on Environmental, Social and Governance (ESG) factors in the mining sector. In recent years, mining companies with better ESG performance have delivered materially higher shareholder returns than the wider market. Further, in order to be able to access funding, mining companies are increasingly required to demonstrate a robust commitment to addressing ESG concerns and risks, as well as a strong track record of ESG compliance.

https://www.globalcompliance.com/2023/02/01/https-insightplus-bakermckenzie-com-bm-energy-mining-infrastructure_1-global-the-continued-rise-of-esg-investor-demands-in-the-mining-sector_01262023/



by Laura Miller

28 Nov 2023

\$11trn investor group backs responsible mining commission

The Global Investor Commission on Mining 2030 has received the support of 82 investors with more than \$11trn in assets under management and advice, to develop a [socially and environmentally responsible mining sector](#) by 2030.

<https://esgclarity.com/commission-mining-investor-backing/>

Press release
12 Oct 2023 | London, GB



ESG remains the top focus for miners, but capital risks increase as mineral demand pressure builds amid energy transition

https://www.ey.com/en_gl/news/2023/10/esg-remains-the-top-focus-for-miners-but-capital-risks-increase-as-mineral-demand-pressure-builds-amid-energy-transition



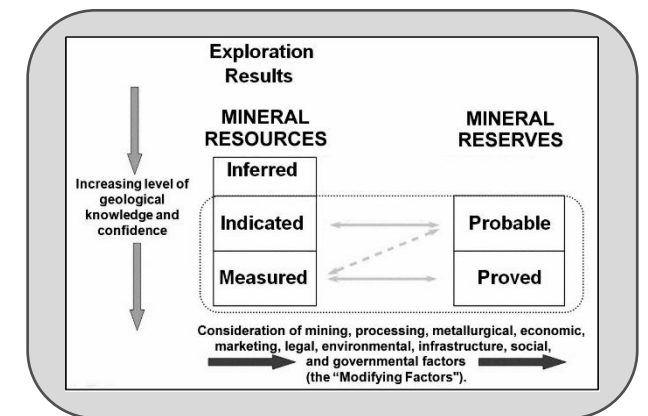
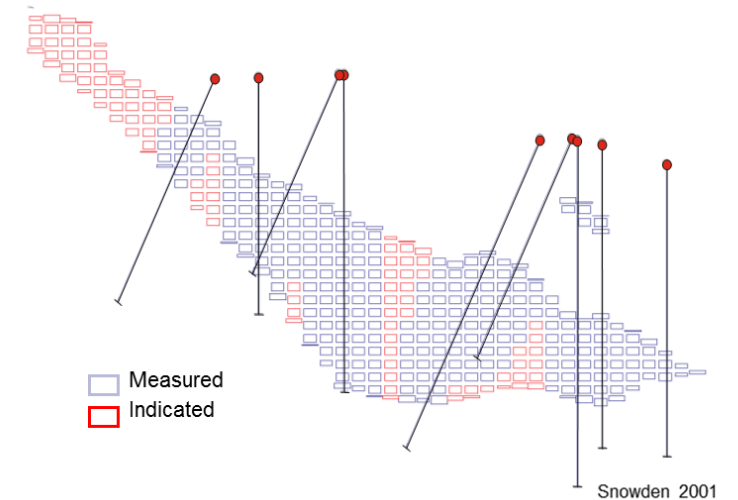


Estimation uncertainties



Why are Resources and Reserves Classified?

- Classification helps to convey the level of confidence in the estimate and informs investors about the relative risks related to the mineral deposit.
- There is no such thing as a completely reliable estimate
- Examples of information used in classification:
 - *Drilling and sampling density*
 - *Quality of sampling (sample representativity) and assay results*
 - *Confidence in the geological/structural controls on mineralization (geological continuity)*
 - *Grade continuity*

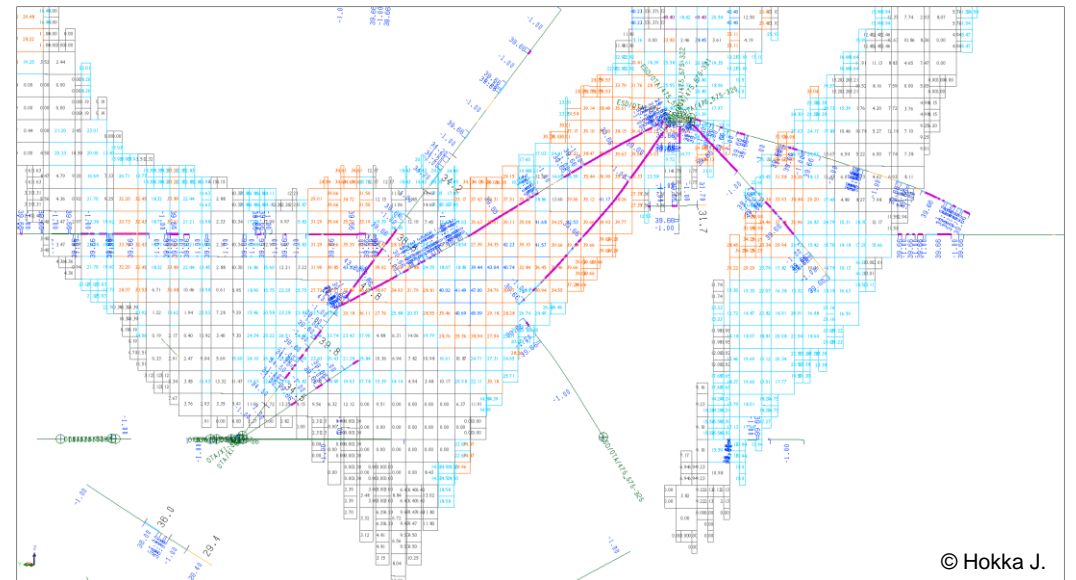




Question

Despite the international reporting standards, how can we make sure the model and estimation is correct?

- Option 1: The competent person (s) verify the results and that should always be trusted.
- Option 2: By validation, for example, using check estimates along with visual and statistical methods.
- Option 3: Third-party audits & reviews.
- Option 4: QA/QC procedures.



Let's not consider the option of verifying the model through reconciliation while the mine is in operation.

slido



Despite the international reporting standards, how can we make sure that the model and estimation is correct?

① Start presenting to display the poll results on this slide.



Mineral resource audits

“Audits are retrospective reviews by independent and/or external reviewers who rate the risk inherent with already completed process with the intention to improve the level of assurance in the reliability of estimated and reported exploration results, resources, ore reserves, and mine reconciliation. This identifies opportunities for improvement in the future (Noppe 2018).”

Noppe, Mark. 2018. Peer review and technical audit: Improved assurance for mineral resource and ore reserve estimates and reporting. MAGIC 2018, SRK Exploration Services.

Coherent assurance system is based on three defense lines:

1. Practitioner/operation level including self-assessment/peer review
2. Supervision level including oversight/peer review
3. Independent review/audit





Resource Estimation Uncertainties

Sometimes things have to go wrong in order to go right

July 20, 2012

In mining sector, projects live or die on word of independent geologists

When Barkerville Gold Mines told investors a few weeks ago that its British Columbia-based project held the potential to cough up 90 million ounces of gold, the first reaction from industry insiders was disbelief

January 11, 2016

Rubicon Minerals Corp shares plunge as miner slashes its gold resources by 88%

The junior miner slashed its gold resources by an astounding 88%, confirming Rubicon will go down as one of the worst Canadian mining meltdowns in years

July 12, 2019

Golden blunders: How a string of technical mishaps has hampered Canada's junior gold miners

Reports overestimating the amount of gold led to junior miners flying high, but the gold was 'never there'

August 24, 2019

'The gold was never there': A miner's reserves evaporate amid battle with former CEO

Even in an industry known to be high-risk, the sudden evaporation of more than a million ounces of gold raised eyebrows



Resource Estimation Uncertainties

The word of independent geologists

- The aim of the Parker Challenge was to quantify the ‘between person variance’ or ‘pattern noise’ in resource estimation.
- The Parker Challenge provided invaluable data to those involved in designing our reporting codes, investors, executives, and resource professionals of every type. **This is the first step in objectively quantifying the precision and bias introduced by the estimation practitioners.**

The Results are as follows:

- Resource estimation involves human judgment or person-to-person variation, and where human judgment is involved, there is inevitably noise.
- This implies that **resource classification is inherently a noisy activity!**
- The Parker Challenge showed that **variation exists in both aspects of estimating and classifying mineral resources.**



The dataset: Rio Tinto's Hugo Dummett South

All participants of The Parker Challenge will receive the dataset for Rio Tinto's Hugo Dummett South, a polymetallic porphyry deposit, as well as basic background information, specifications for the final model, challenge instructions and entry requirements.

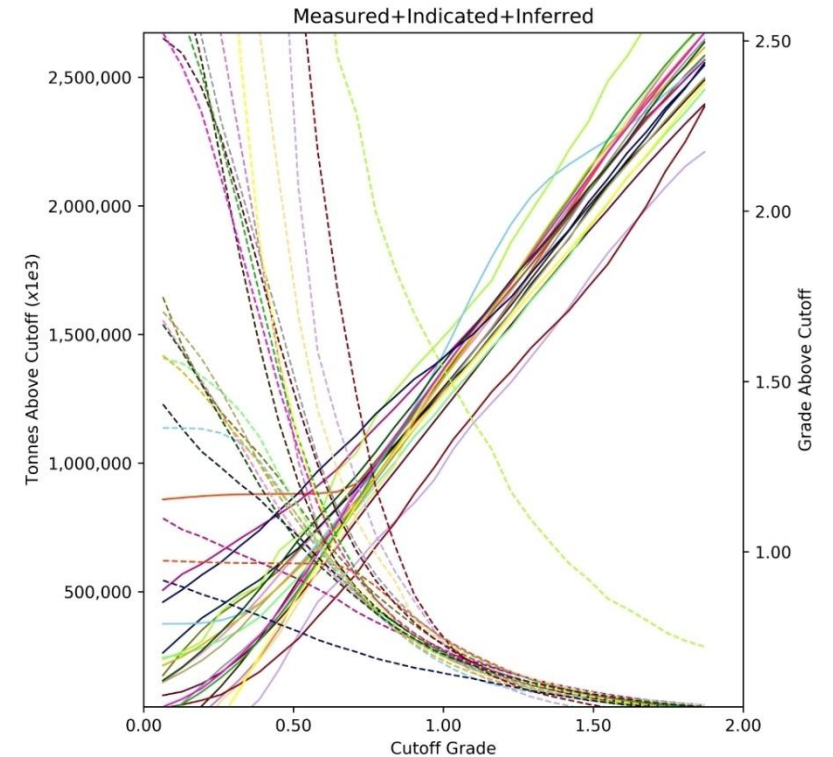


Resource Estimation Uncertainties

Results of the Parker Challenge 2023 published in the Mineral Estimation Conference, 24-25 May 2023, Perth, Australia

The results of the Parker Challenge indicate that the entire volume of estimated total resources (including Measured, Indicated, and Inferred categories) deviated by approximately +/- 200% after the removal of outliers.

Even with Measured+Indicated the range was -154 % to +143 %.
When asked from resource specialists in the poll 96 % considered that the precision for M+I was +/- 25 %.



Dunham, 2023



Examples of Uncertainties related to Estimates

There are several principal geological reasons for incorrect resource estimates:

- poor sampling and assay quality data (sample bias);
- a lack of detailed mine geology and fundamental understanding of the deposit (errors in continuity and geometry of a deposit);
- poor interpretation of grade distribution characteristics;
- poor understanding and application of computer-assisted estimation techniques;
- The failure to recognize effects of selectivity and the change of support or volume-variance effect
- Bulk density (the all-too-common assumptions that bulk density of mineralisation is constant throughout a deposit)
- Human error (misplotting of data, misplaced decimals, etc.)
- Fraud (salting, substitution of samples, nonrepresentative data, etc.)



Key points and takeaways



- Resource estimation is a complex process including **numerous steps and decisions**, inherently encompassing uncertainties arising from **complex geology and sparse sampling**. Therefore, estimation are not a precise calculation!
- CRIRSCO-aligned standards and codes sets the **minimum standards for public reporting** of Exploration Results, Mineral Resources and Mineral Reserves. They are standards for reporting, not estimating!



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Thank you for your attention

Janne Hokka, GTK

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