



# Geometallurgy of Battery Minerals – The Way Forward

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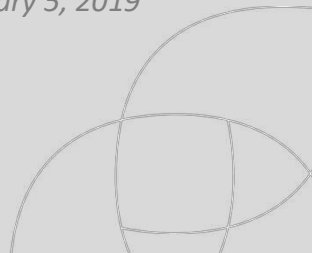
Date: 21<sup>st</sup> February 2019

# The Future of Battery Minerals and Metals

*"Benchmark Mineral Intelligence is now tracking 70 lithium ion battery mega-factories under construction across four continents, 46 of which are based in China with only five currently planned for the US. .... in October 2017, the global total was at 17."*

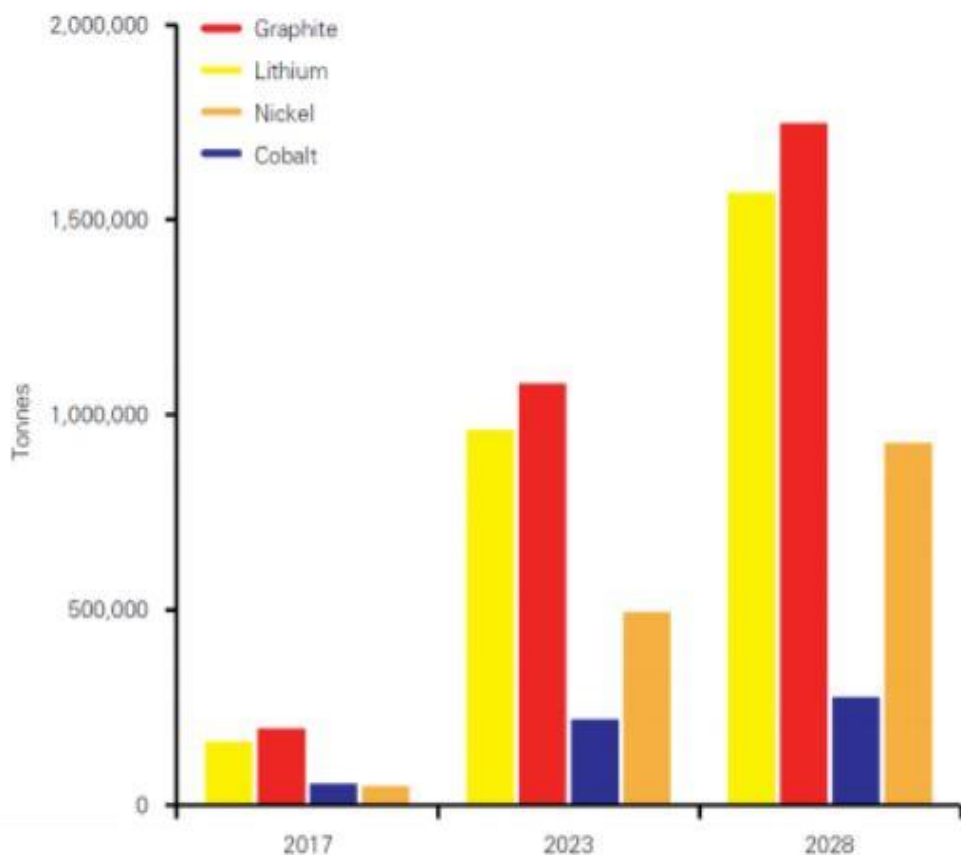
*"The factories are being built almost exclusively to make lithium ion battery cells using two chemistries: nickel-cobalt-manganese (NCM) and nickel-cobalt-aluminium (NCA)."*

Source: Mining.com February 5, 2019



# The Future of Battery Minerals and Metals

## Lithium ion Battery Megafactory Raw Material Demand (tonnes) at 100% Utilisation Rate



MATERIAL	2017	2023	2028
LITHIUM	162,752	961,351	1,570,020
GRAPHITE ANODE	194,160	1,080,360	1,747,800
COBALT	54,354	219,679	276,401
NICKEL	48,584	494,774	928,018

Lithium >800%

Graphite >700%

Nickel >1900%

Cobalt >400%

Source: Benchmark Mineral Intelligence

Source: Mining.com February 5, 2019

# The Future of Battery Minerals and Metals

**Australia is well-placed to become a major force in the Battery metals and minerals industry.**

## **Lithium**

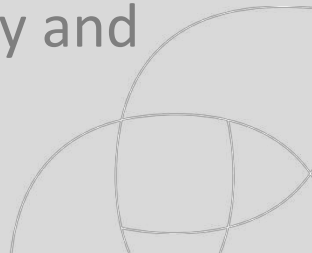
- WA has five operating lithium mines, two under construction and one undergoing planning approvals.

## **Cobalt**

- The Democratic Republic of Congo currently produces two-thirds of the global output of cobalt.

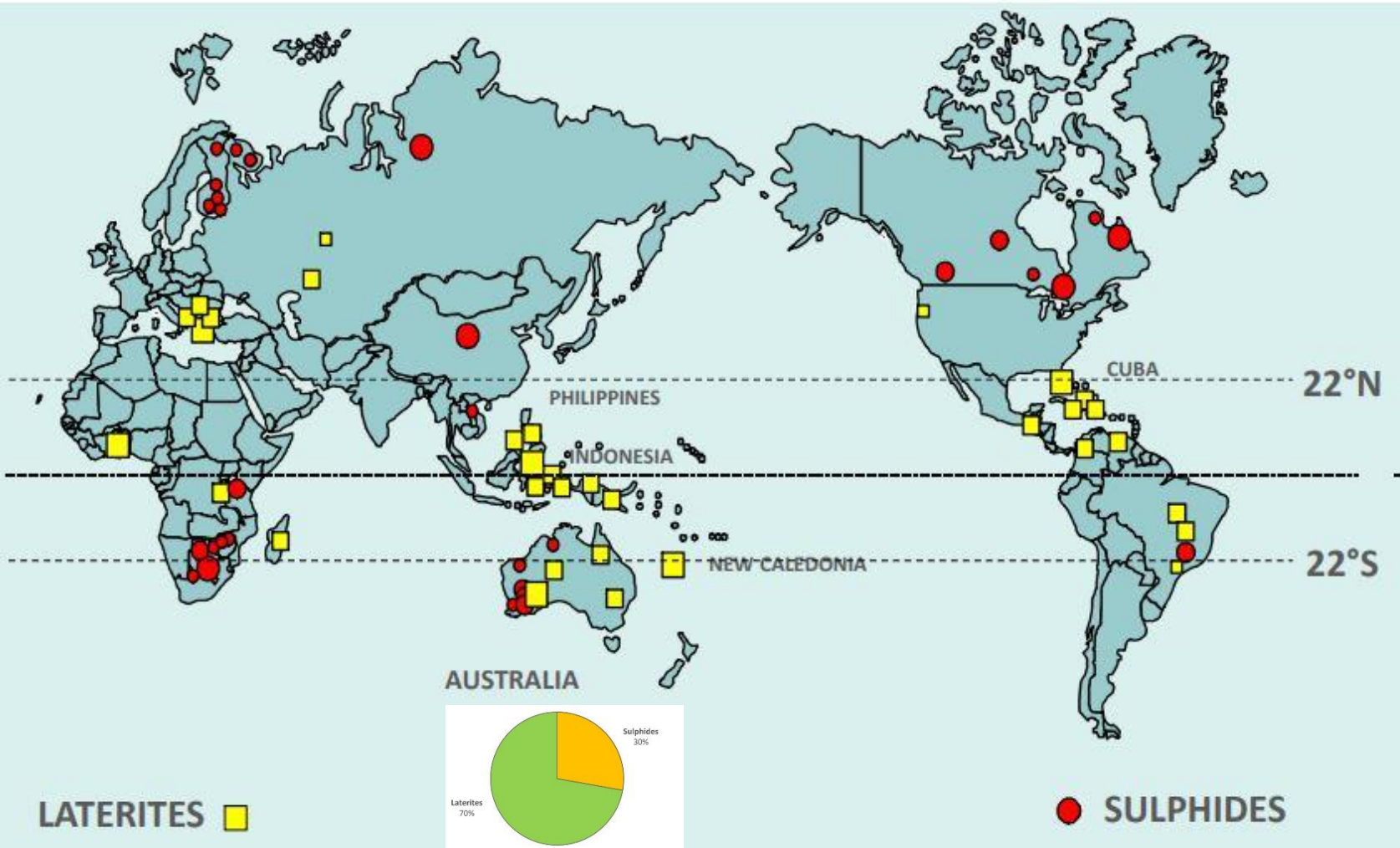
## **Graphite**

- China and Africa are currently the big players for supply and production of both synthetic and natural graphite.



# The Future of Battery Minerals and Metals

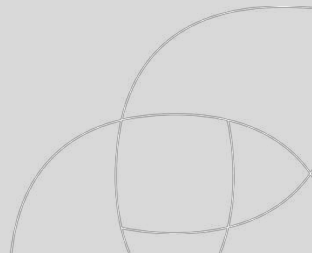
## Nickel



# The Concept of Geometallurgy

*“Geometallurgy relates to the practice of combining geology or geostatistics with metallurgy, or, more specifically, extractive metallurgy, to create a spatially or geologically based predictive model for mineral processing plants.”*

*Source: Wikipedia*



# The Concept of Geometallurgy

- Corporate
- Mining, Mine Planning or Process Engineer
- Mine Geologist
- Exploration Geologist
- Process Engineer or Metallurgist

*“If you manage the Bad Bits, the Good Bits tend to look after themselves.”*

**Geometallurgy or GEOmet is a cross-disciplinary approach which connects geological, mineralogical and processing information to provide a comprehensive model for production planning and management.**

# First Prize is the Ore Control Model

## Geometallurgical Test Work

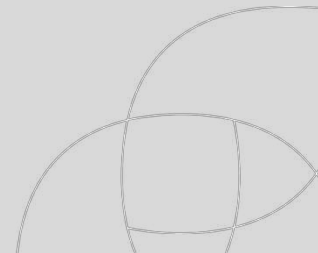
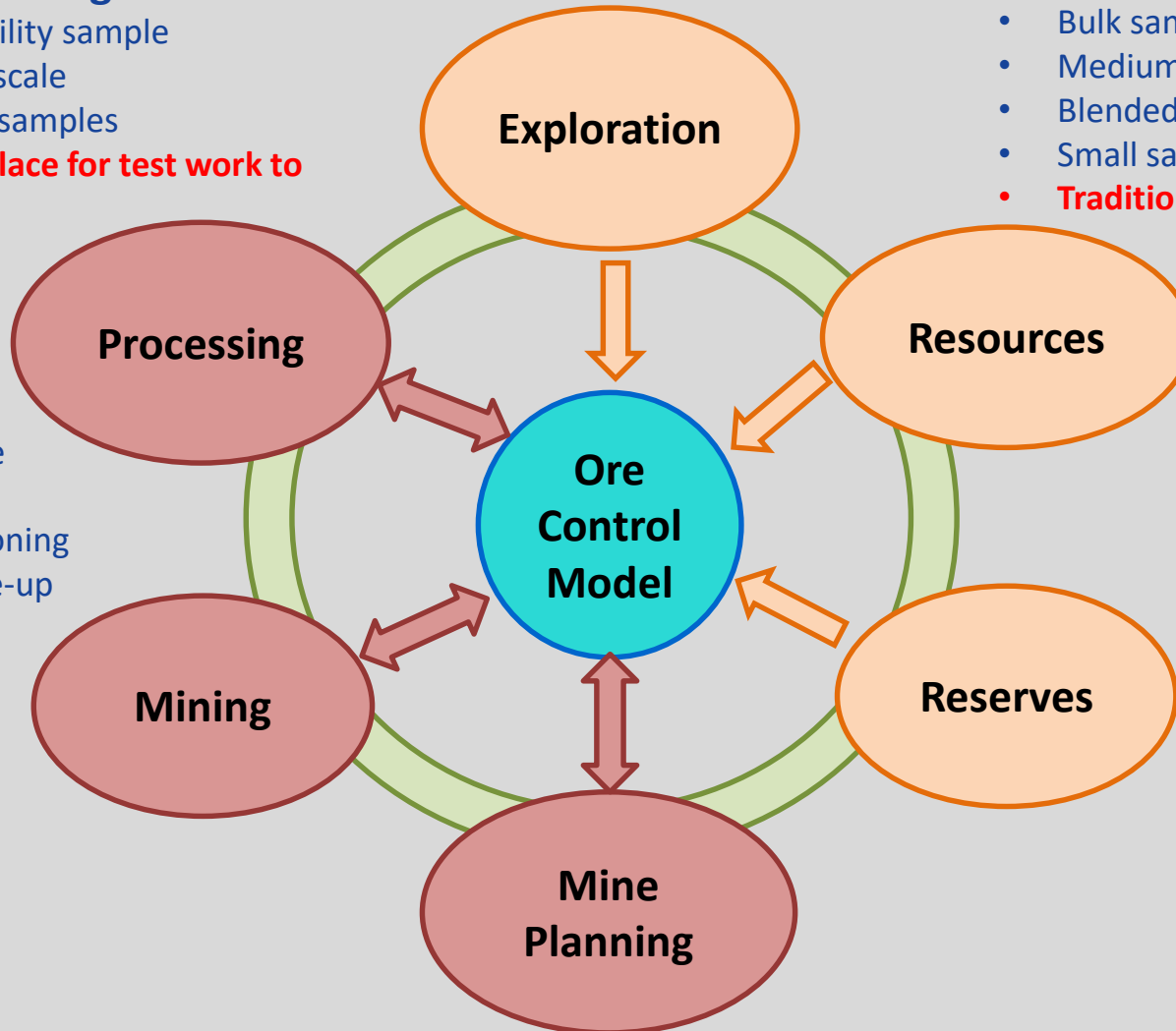
- Variability sample
- Small scale
- Many samples
- **Best place for test work to begin**

## Metallurgical Test Work

- Bulk sample
- Medium scale
- Blended
- Small sample number
- **Traditional place for test work to begin**

## Pilot Plant

- Large scale
- Ramp-up
- Commissioning
- Plant Scale-up  
(additive)





# First Prize is the Ore Control Model

- An informative Ore Control Model is the solution to successful process circuit design, control optimization and problem solving.
- Comprehensive knowledge of element and mineral behaviour is essential for the development of an appropriate Ore Control Model and is obtained via GEOmet data.
- The collection of sufficient and appropriate GEOmet data early enough in the project life will have a value-multiplying effect through the project life.

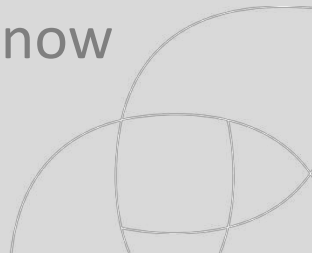
**The best and most cost effective time to begin GEOmet variability sampling is during the exploration drilling phase of a project.**

# First Prize is the Ore Control Model

**Do it**

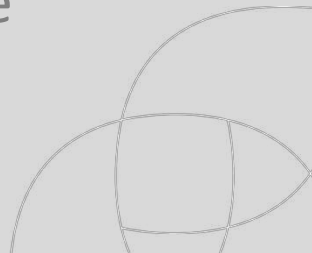
**Do it sooner rather than later**

- Test data should be generated using samples taken from a spatial distribution across the ore body.
- Include both high and low grade samples for test work.
- Take plenty of samples to ensure statistical robustness.
- Do multi-element geochemistry because you don't know what you will get or need.



# First Prize is the Ore Control Model

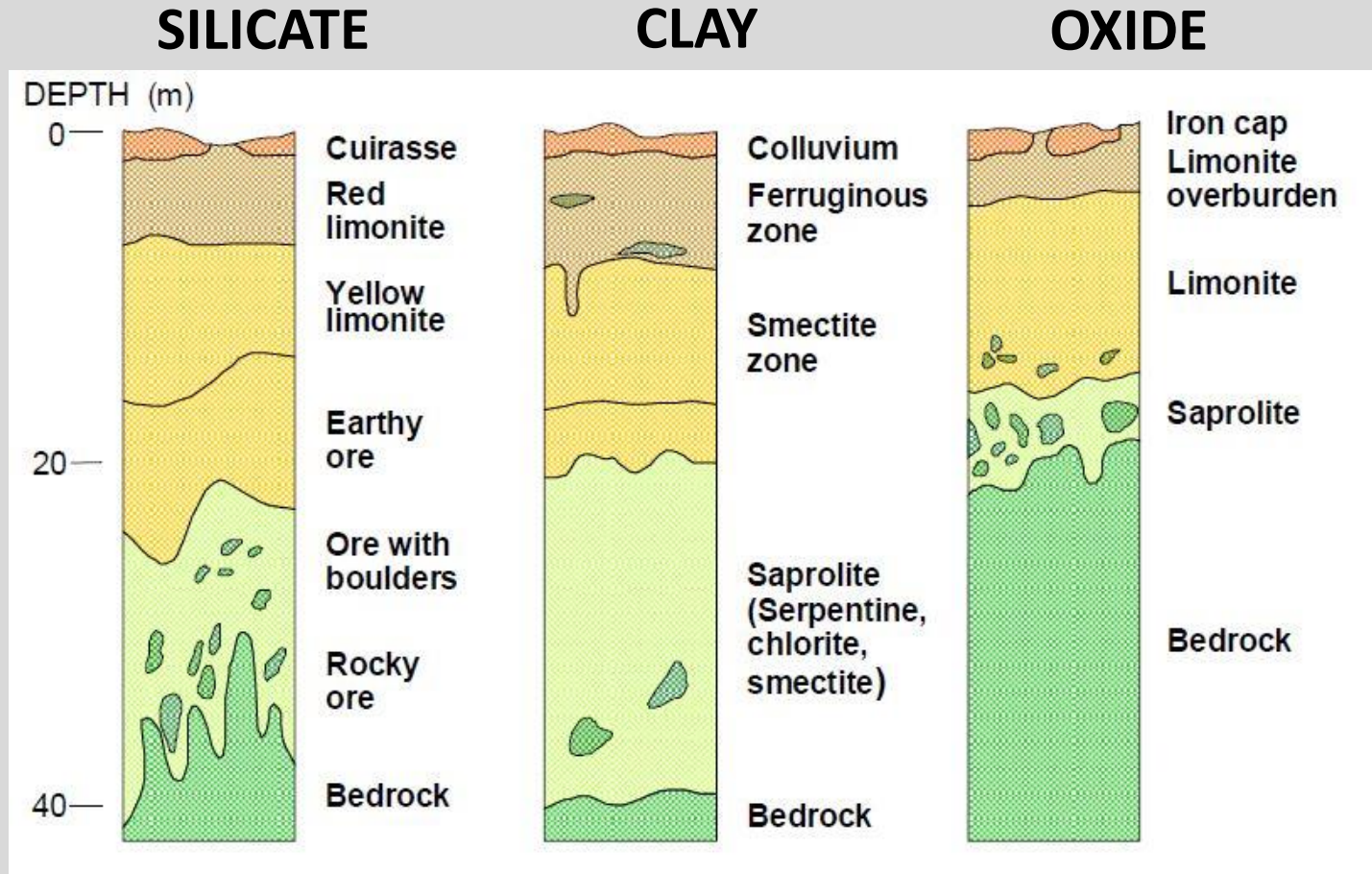
- Spatial 3-D modelling of variability based on assay results and hyperspectral analysis (geostatistical, multi-element regression)
  - Rock/ore type
  - Mineralogy
  - Alteration
  - Clay speciation/mineralogy
- Sampling for variability will lead to insight into critical process parameters such as milling rate, grind size, concentrate grade, upgrade factors and recovery factors.



# Nickel Laterite

SCHEMATIC LATERITE PROFILE	COMMON NAME	APPROXIMATE ANALYSIS (%)				EXTRACTION PROCESS
		Ni	Co	Fe	MgO	
	RED LIMONITE	<0.8	<0.1	>50	<0.5	
	YELLOW LIMONITE	0.8 to 1.5	0.1 to 0.2	40 to 50	0.5 to 5	
	TRANSITION	1.5 to 2	0.02 to 0.1	25 to 40	5 to 15	
	SAPROLITE/ GARNIERITE/ SERPENTINE	1.8 to 3		10 to 25	15 to 35	
	FRESH ROCK	0.3	0.01	5	35 to 45	

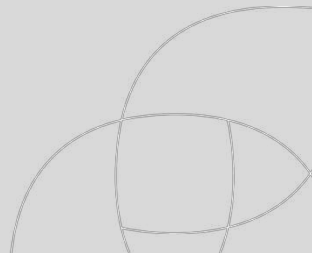
# Nickel Laterites in WA



Each nickel laterite deposit has its own set of unique geological and GEOmet characteristics which need to be recognised and understood

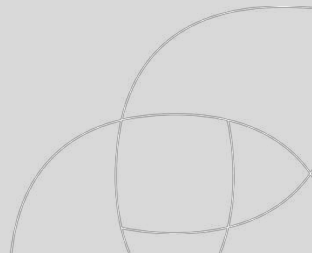
# Ni Laterites

- Composition of laterite ore is key to how it is processed and how it will be consumed
- Two distinct ore types – Limonite (Fe-rich) and Saprolite (Mg-rich)
- Ore is processed to upgrade nickel content from 1-4% to concentrates with grades in the range 10-20%
- Development of Ore Control Model critical to success



# Ni Laterites

- Ore Control model derived from a combination of the Resource Block model and a GEOmet model
- Ore control model contains information which can include-
  - Ni upgrade, recovery and Mass Recovery factors
  - Other metal recovery and upgrade factors
  - Ore domains derived from GEOmet, assay and geological sample populations
  - Recovered metal content
  - In situ (wet) density and dry bulk density
  - Acid and Reagent consumption factors
  - Economic parameters



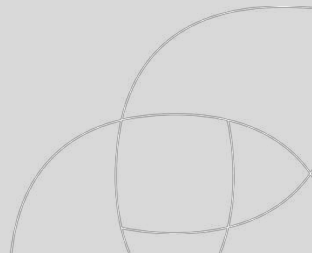
# Ni Laterites

## Murrin Murrin

- Smectite ore (texturally Saprolite, but higher Mg)
- PAL, heap leach (low grade)
- Cobalt and Nickel metal refining (briquette)

## Ravensthorpe

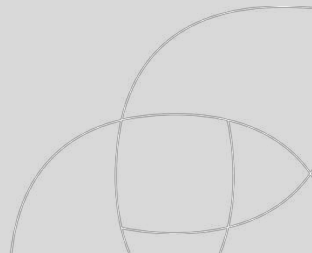
- Beneficiation
- HPAL – Limonite ore (higher recovery)
- AL – Saprolite ore
- Mixed NiCo hydroxy product for export
- Acid plant for power





# The Way Forward

- Less tolerance for sub-optimal plant design and trial and error
- Markets will become more competitive with less acceptance for product that does not meet specifications
- GEOmet data
  - reduce delays
  - optimise budget
  - confidence in product quality to market



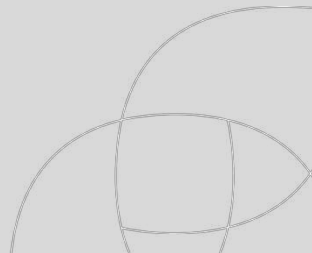
# The Big Picture

**LOOK FORWARD**

**STEP BACK**

**THINK BIG**

That exciting high grade discovery of a billion tonnes of multi-commodity battery ore will remain in the ground if you can't process it



# A Special Thanks to The Following:

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