Geometallurgy of Battery Minerals – The Way Forward

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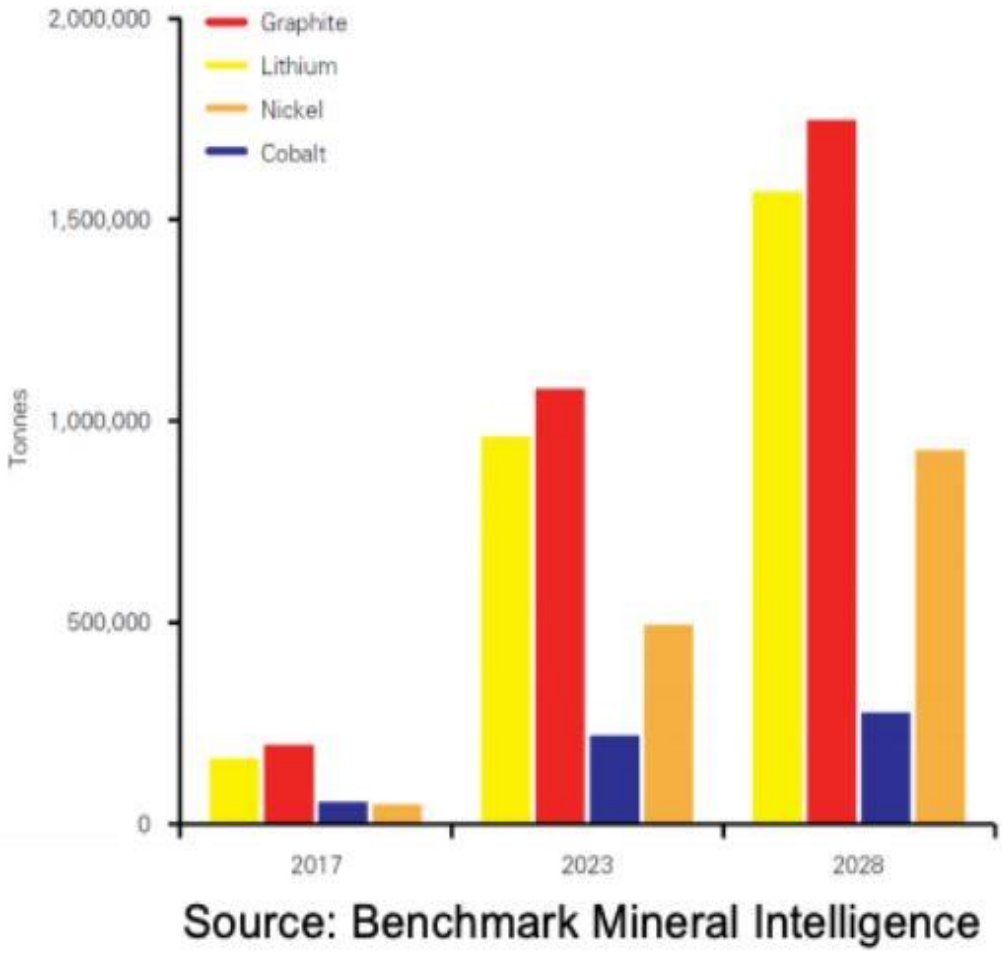
The Future of Battery Minerals and Metals

"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."

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



Source: Benchmark Mineral Intelligence

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: Mining.com February 5, 2019

Australia – A Major Force in Battery Metals

Lithium

- WA - five operating mines.

Cobalt

- The DRC produces two-thirds of the global output of cobalt.

Graphite

- China and Africa are currently the big players.

Nickel

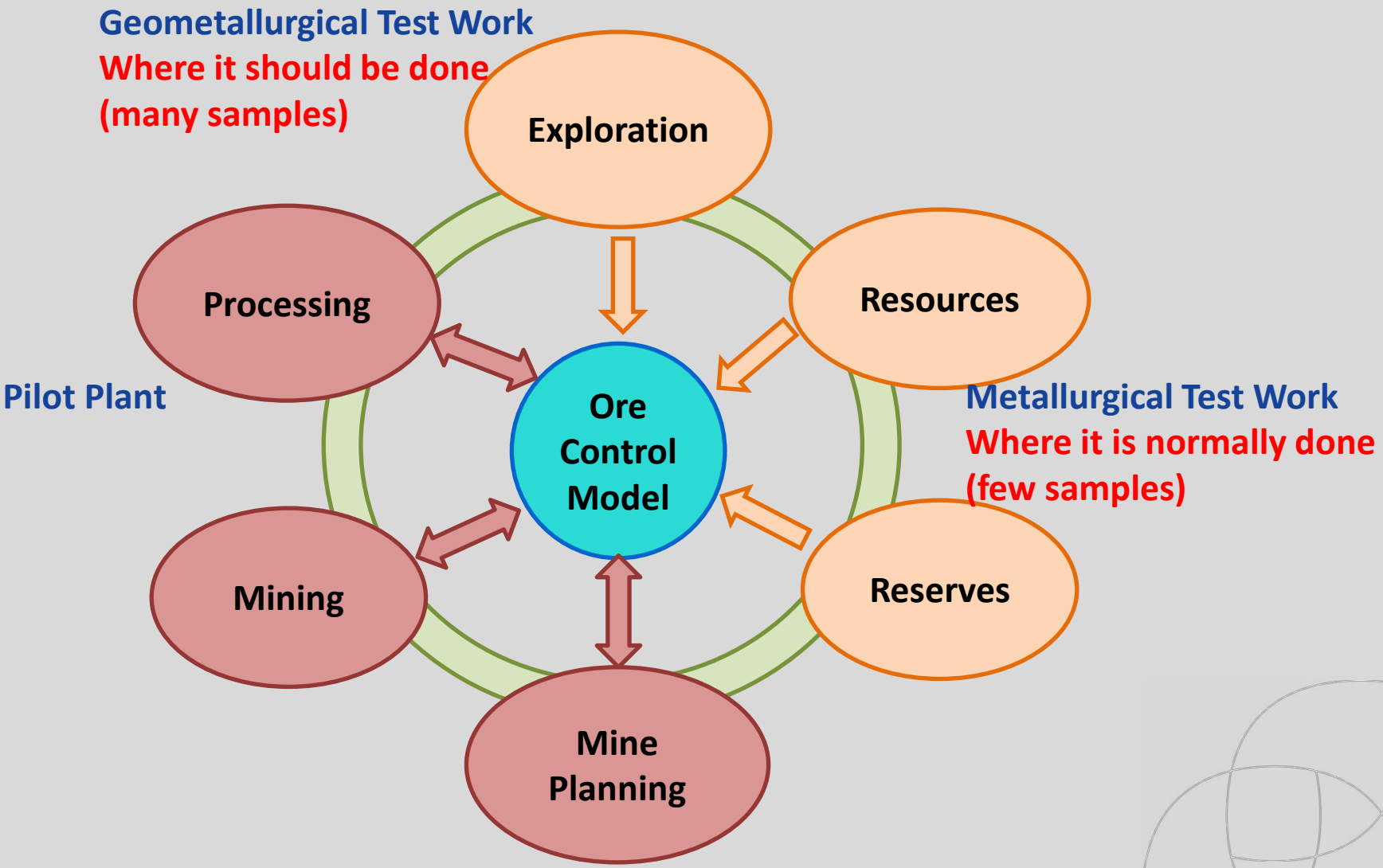
- Largest economic reserves.

The Concept of Geometallurgy

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.

"If you manage the Bad Bits, the Good Bits tend to look after themselves."

First Prize is the Ore Control Model



GEOmet Variability During Exploration

Battery metal orebodies are extremely variable in grade, mineralogy, alteration and physical properties

- Collect sufficient and appropriate GEOmet data as early as possible; during the Exploration phase of a project is the ideal time.
- **TOBK** - comprehensive knowledge and understanding of element and mineral behaviour.
- An informative Ore Control Model – a solution to successful process circuit design.

The GEOmet Process – Variability Sampling

Do it!

Do more of it!

Do it sooner rather than later!

- Spatial distribution across the ore body.
- High and low grade sample
- Statistical robustness.
- Multi-element geochemistry

The GEOmet Process – What to do Today?

With exploration field activities currently curtailed, what can be done to facilitate the advancement of TOBK via GEOMet?

Be efficient in maximising what you already have

- Do a Gap Analysis on your existing data and prioritise the important gaps to be filled

Be mindful of working towards TOBK

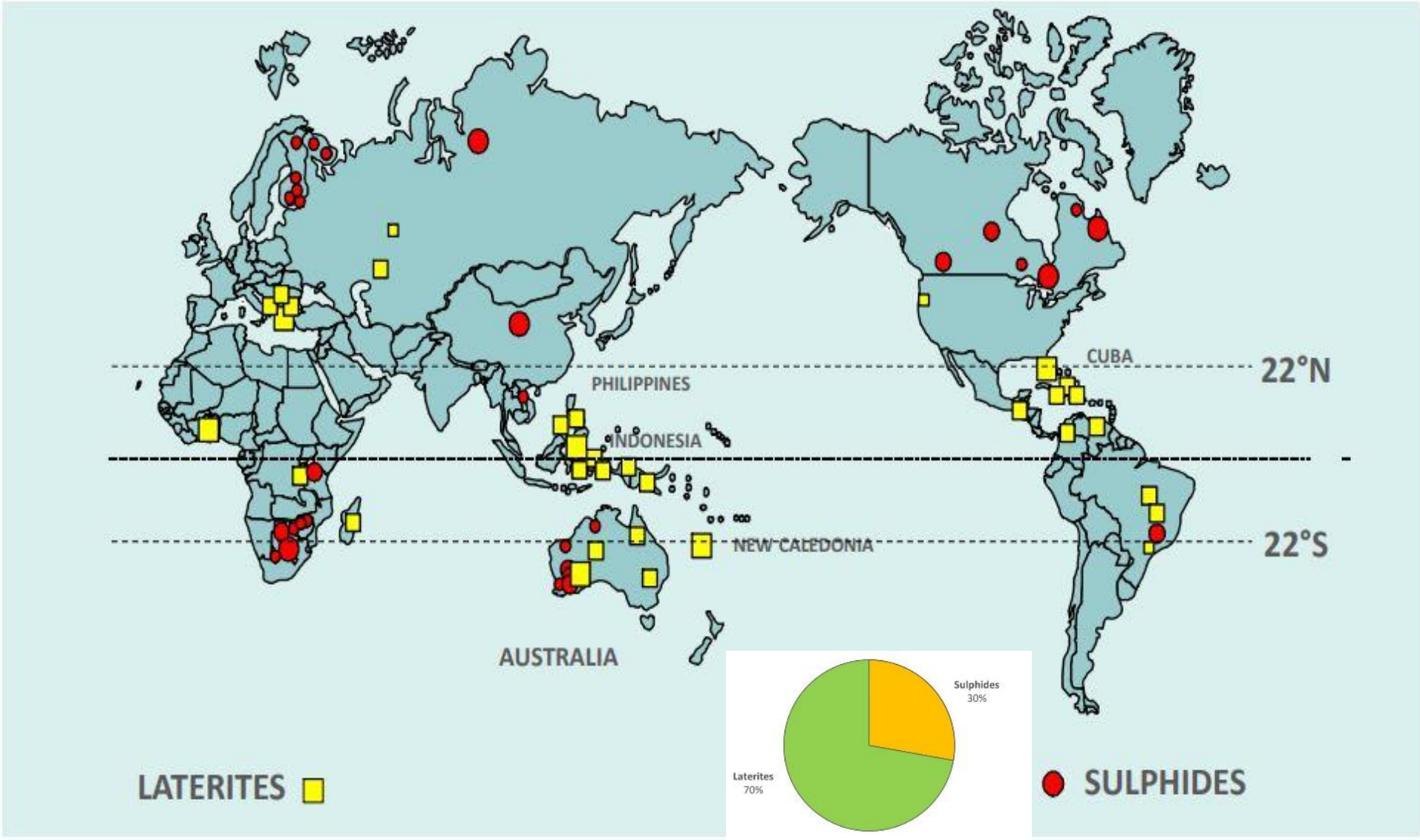
- Identify those gaps which could have the highest impact on downstream ore recovery

You can still start building your GEOmet and Ore Control models

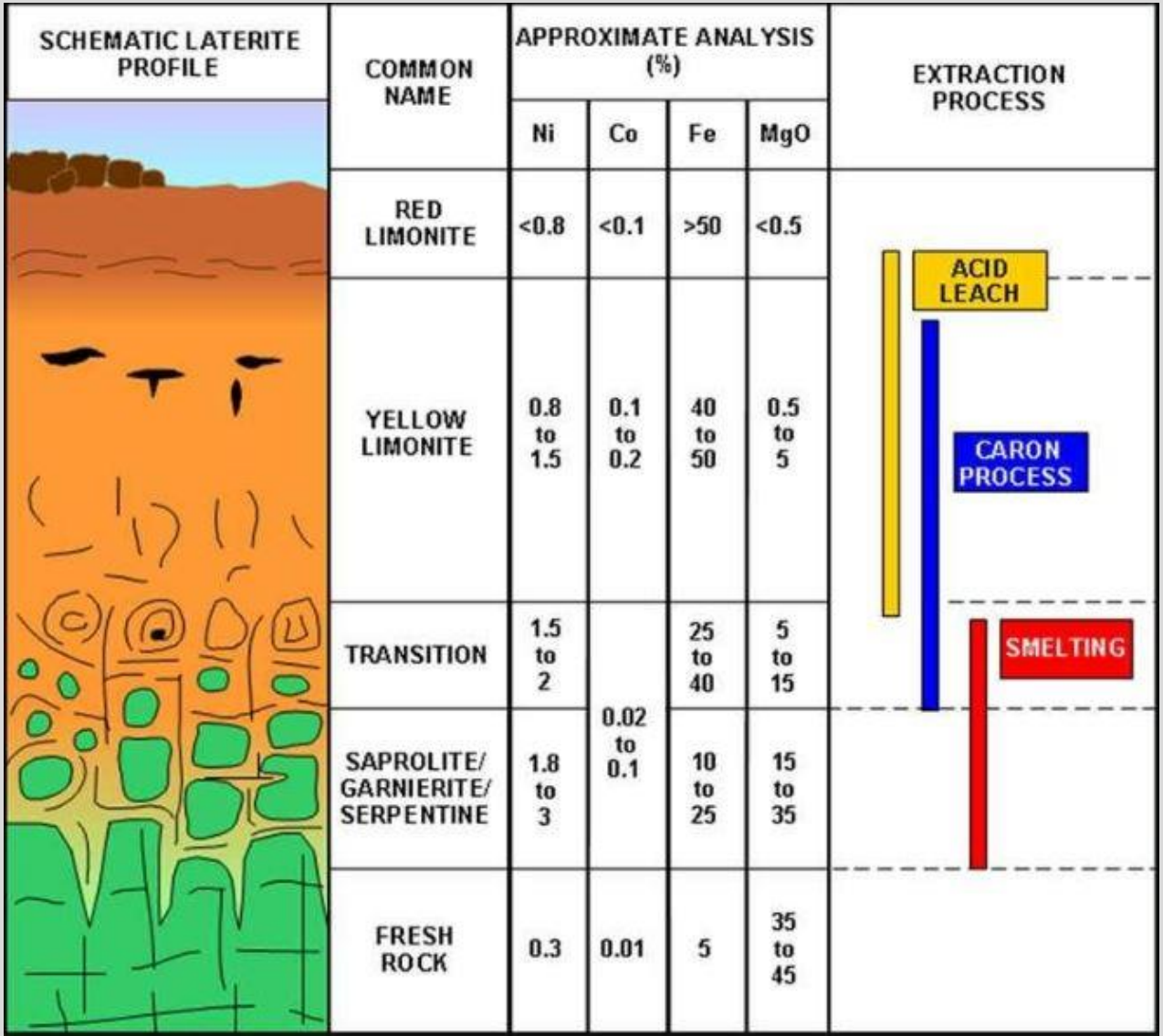
The GEOmet Process and the Ore Control Model

- GEOmet model - spatial 3-D modelling of variability based on assay results and hyperspectral analysis
- geostatistical, multi-element regression predictive techniques
  - Rock/ore type
  - Mineralogy
  - Alteration
  - Clay speciation/mineralogy

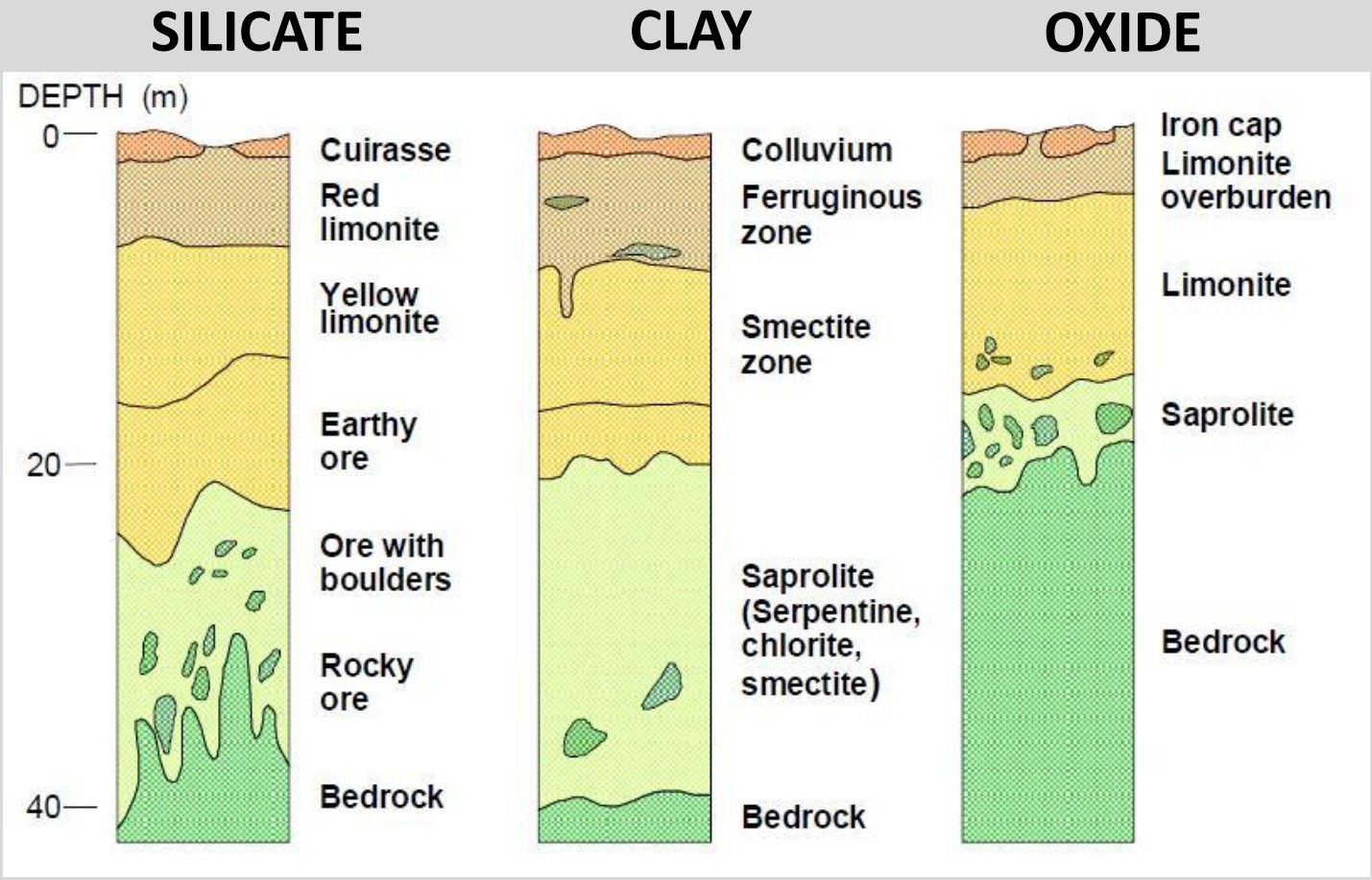
World Distribution of Nickel and Cobalt



Nickel and Cobalt Laterites



Nickel and Cobalt Laterites in WA



Every nickel-cobalt laterite deposit has its own set of unique geological and GEOmet characteristics to be recognised, identified and understood

Nickel and Cobalt Laterite Operations

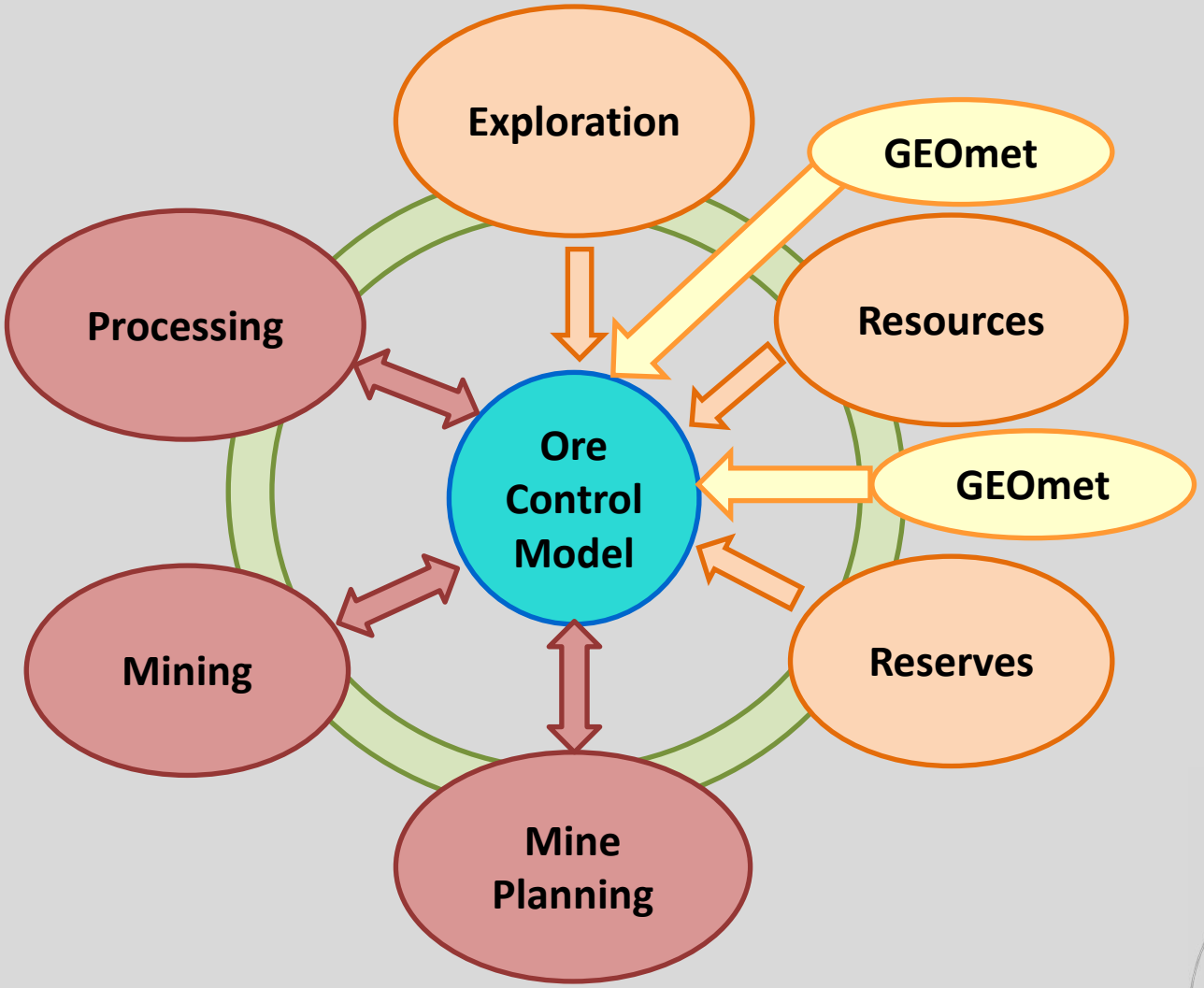
Murrin Murrin

- 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

Ore Control for Nickel and Cobalt Laterites



Nickel and Cobalt Laterites

- Composition of laterite ore is key to how it is processed and consumed.
- Two distinct ore types
- upgrade nickel content from 1-4% to concentrates with grades 10-20%.
- Ore Control Model derived from combination of resource Block model and GEOmet model.
- Mine Planning Ore Control model includes Metallurgy

The Way Forward Change in Thinking

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!

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