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# Olympic Dam – is it really complex?

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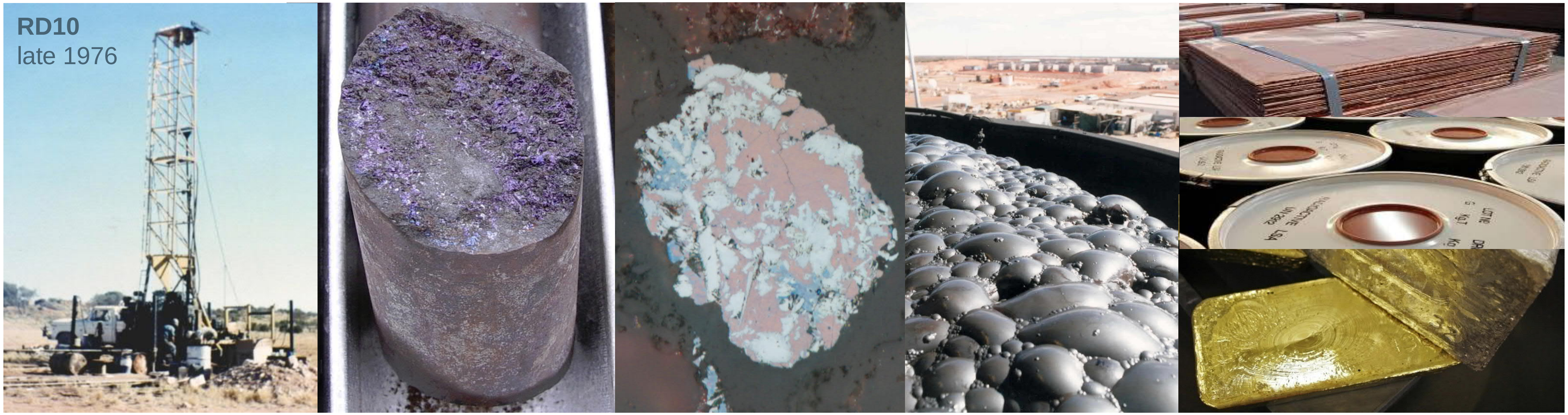
14 February 2019: AusIMM Adelaide Branch Technical Meeting



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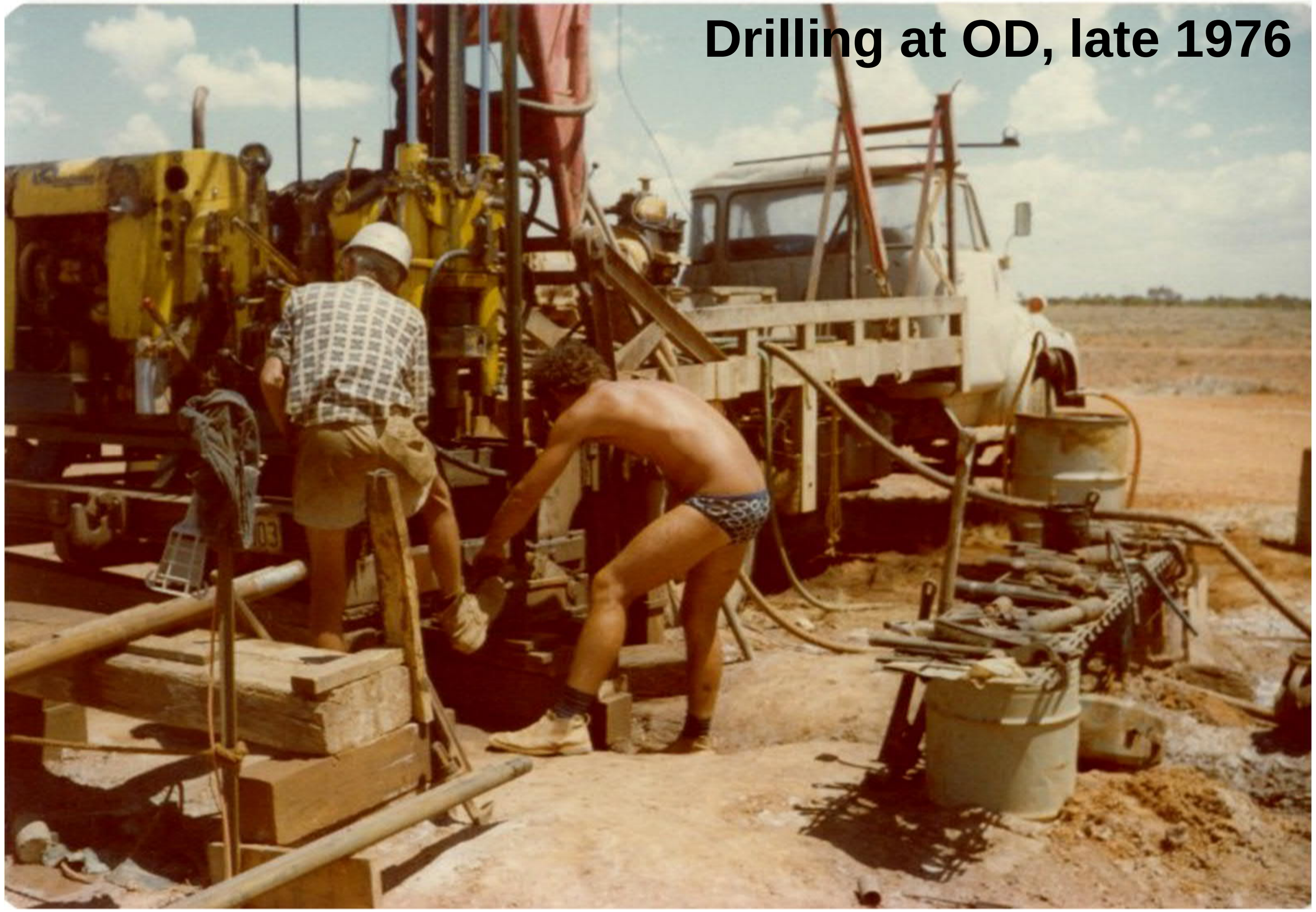

# Acknowledgements

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- +120 geoscientists who have worked at Olympic Dam

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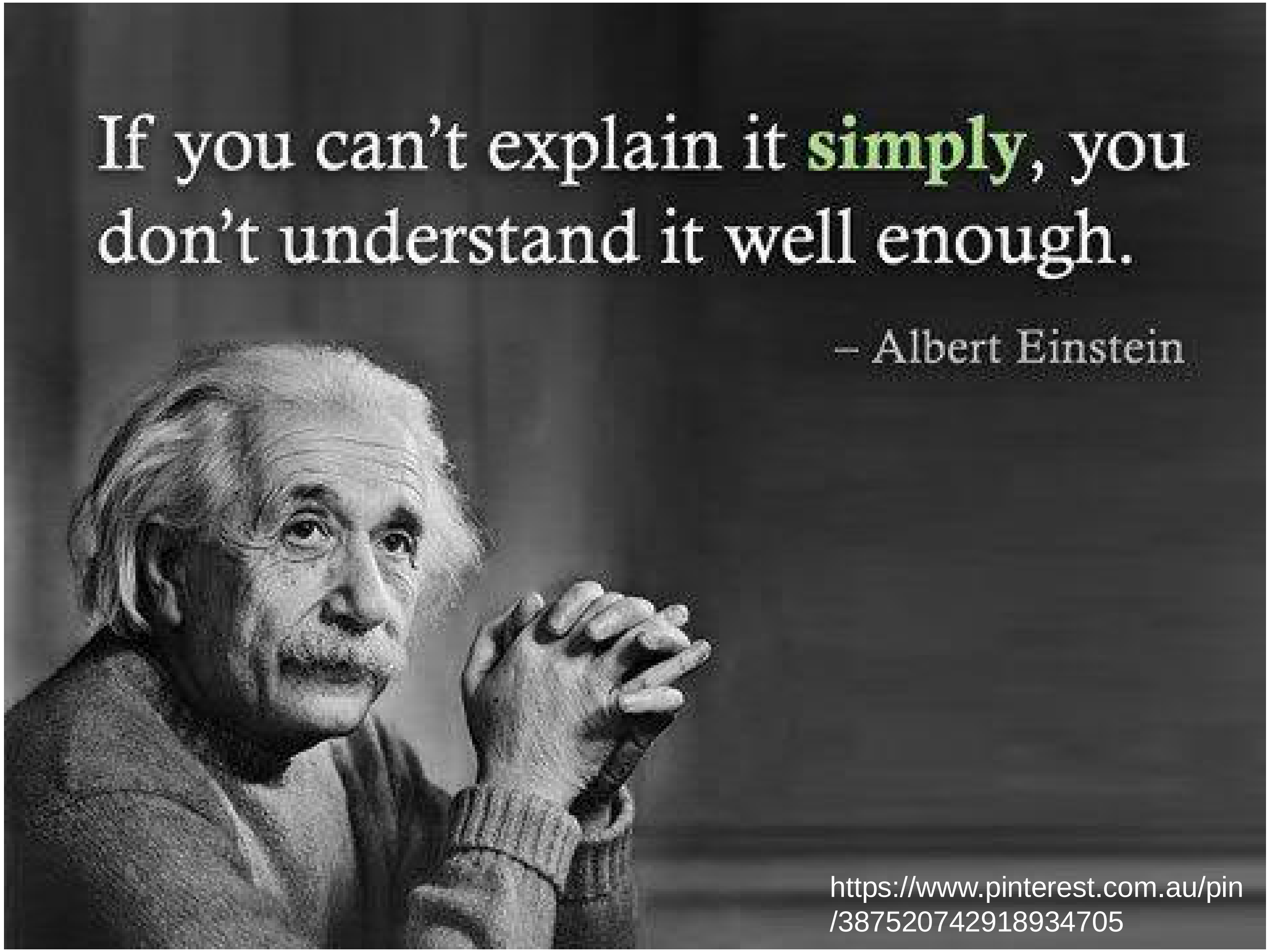
- Trace elements in iron oxides project (FOX project)
- Copper Uranium Hub project (joint ARC project IH130200033)

# Complex Orebodies

## *What does this really mean?*

**"… complex…" often used as an excuse for poor performance**

image: https://www.shutterstock.com/image-vector/funny-tongue-emoji-face-disguist-unique-518839492


If you can't explain it simply, you don't understand it well enough.
– Albert Einstein
https://www.pinterest.com.au/pin/387520742918934705

# “Simplifying Complexity”

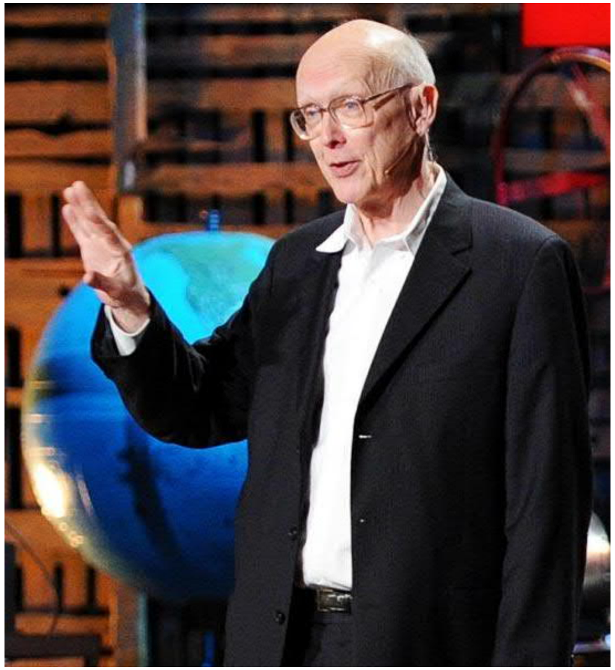
## Eric Berlow – TEDGlobal 2010

https://www.ted.com/talks/eric_berlow_how_complexity_leads_to_simplicity

- complexity does not necessarily = complicated
- when faced with complex / complicated problems, the more you step back, the clearer the problem becomes

# "Toward a Science of Simplicity"

## George Whitesides – TED 2010



https://www.ted.com/talks/george_whitesides_toward_a_science_of_simplicity?language=en

- simple = reliable, predictable, repeatable
- complex = multiple components, interact with each other, usually do unexpected (emergent) things
- *"… academics like complexity and emergence…"* because *"… not responsible for outcome…"*

**Significant Opportunity –**
not constrained,
yet there needs to be an outcome

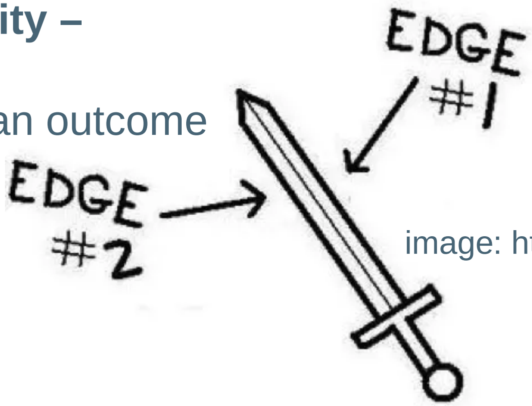



image: https://auroa.com



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# Characteristics of Simple-Complicated-Complex Systems*

| Simple or Complicated Systems | Complex Systems |
|---|---|
| ***Homogeneous:*** identical / indistinguishable structural elements | ***Heterogeneous:*** large number of structural variations |
| ***Linear:*** a relationship with constant proportions | ***Nonlinear:*** cause does not produce a proportional effect |
| ***Deterministic:*** same result always occurs for a given set of circumstances; predictable | ***Stochastic:*** an element of randomness leads to a degree of uncertainty about the outcome |
| ***Static:*** nothing changes over time | ***Dynamic:*** changes over time; past has an impact on the future |
| ***Independent:*** subsystems are not influenced or controlled by other parts of the system | ***Interdependent:*** subsystems are interconnected or interwoven not just interacting |
| ***No feedback:*** open chain of cause and effect | ***Feedback:*** a closed chain of causal connections |
| ***No adaption or self-organization*** | ***Adaptation and self-organization:*** ability of a system to structure itself, to create new structure, to learn, or diversify |
| ***No connection between levels or subsystems*** | ***Emergence:*** collective behaviour that cannot be simply inferred from the behaviour of components |

* Source: Finegood, D.T., Johnston, L.M., Steinberg, M., Matteson, C.M., Deck, P.B. Complex Systems and Behavior Change. In: Health Behavior Change in Populations. Kahan, S., Green, L.W., Gielen, A., Fagen, P. (eds). Johns Hopkins University Press, 435-458, 2014.

# Olympic Dam Operations

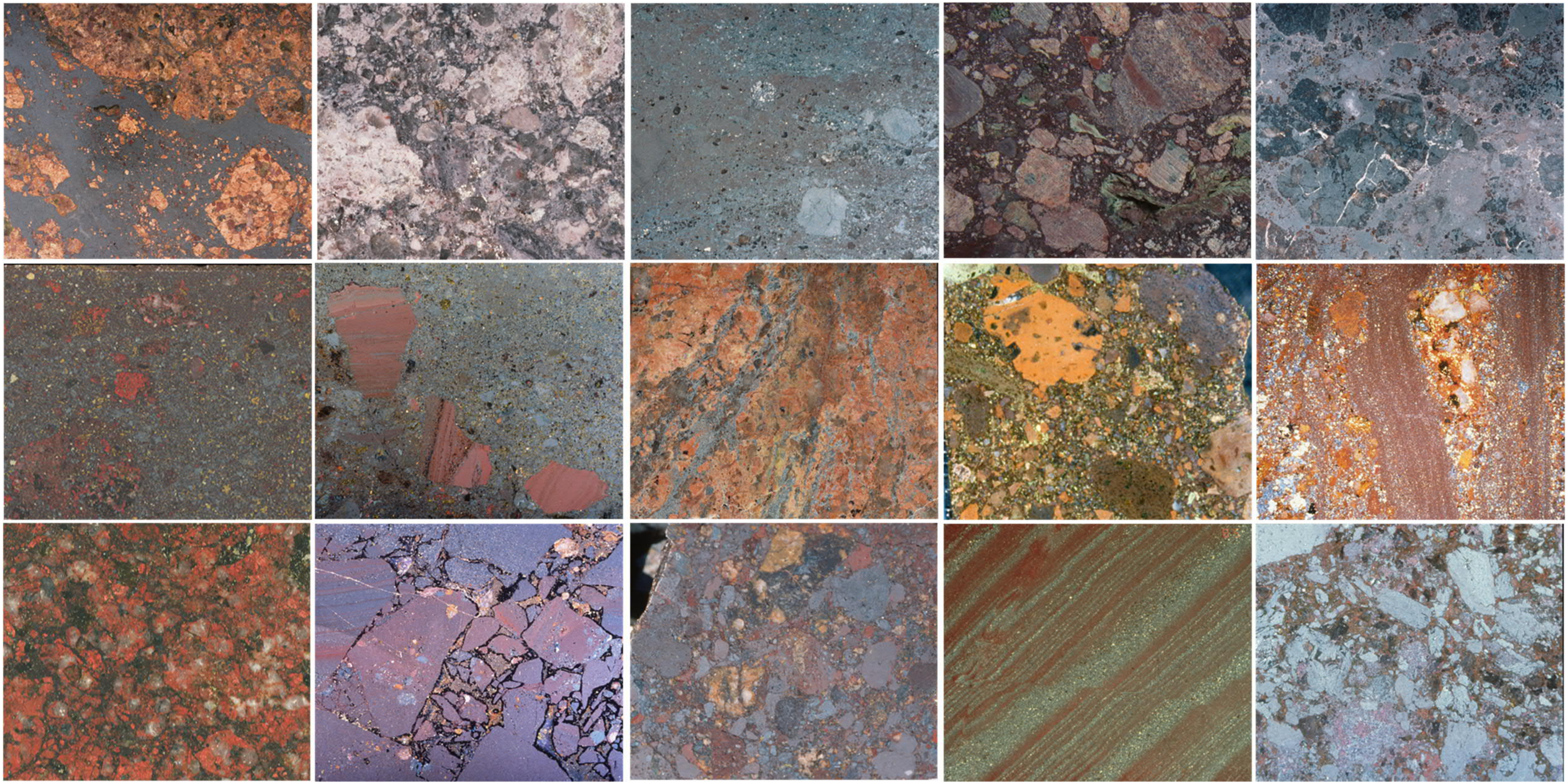

**History**

- Deposit discovered by WMC in July 1975
- Turned out to be a NEW deposit type

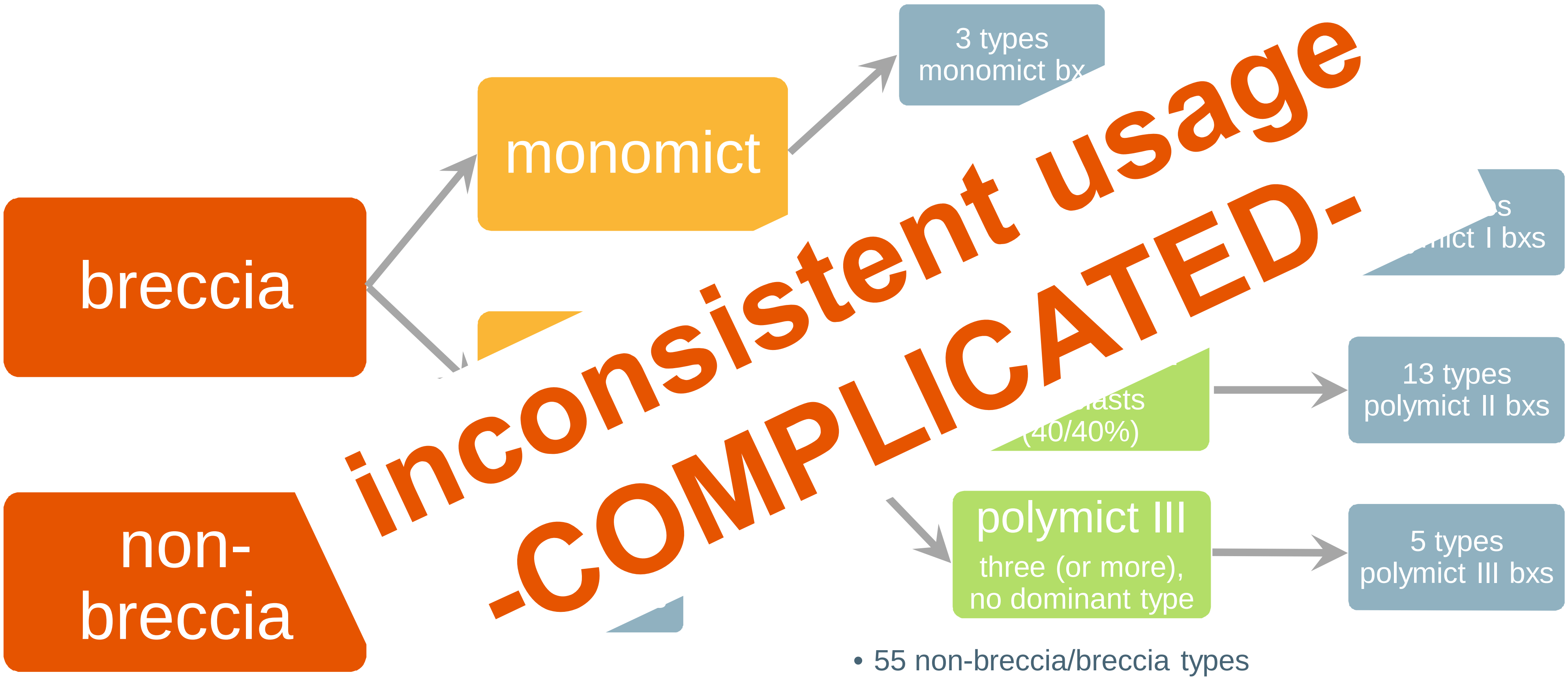
**Current operation**

- Mechanised sublevel open stope mining
- Grinding and sulphide concentrator
- Hydrometallurgical circuit- **U** extraction
- Single stage flash smelter
- Acid plant production
- ER-EW Cu refineries ⇒ **Cu cathode**
- Precious metals refinery (**Au, Ag bullion**)

***Simple, Complicated or Complex?***



# Early Geological Legend (focus on clast type)




- 55 non-breccia/breccia types
- many qualifiers
  - matrix type – gangue minerals (10)
  - alteration type (4)
  - sulfide + Cuº/Auº mineralisation (9)

# Breccias obscuring view ….


Image credits

**Credit:** Paul Kinsella via CartoonStock -

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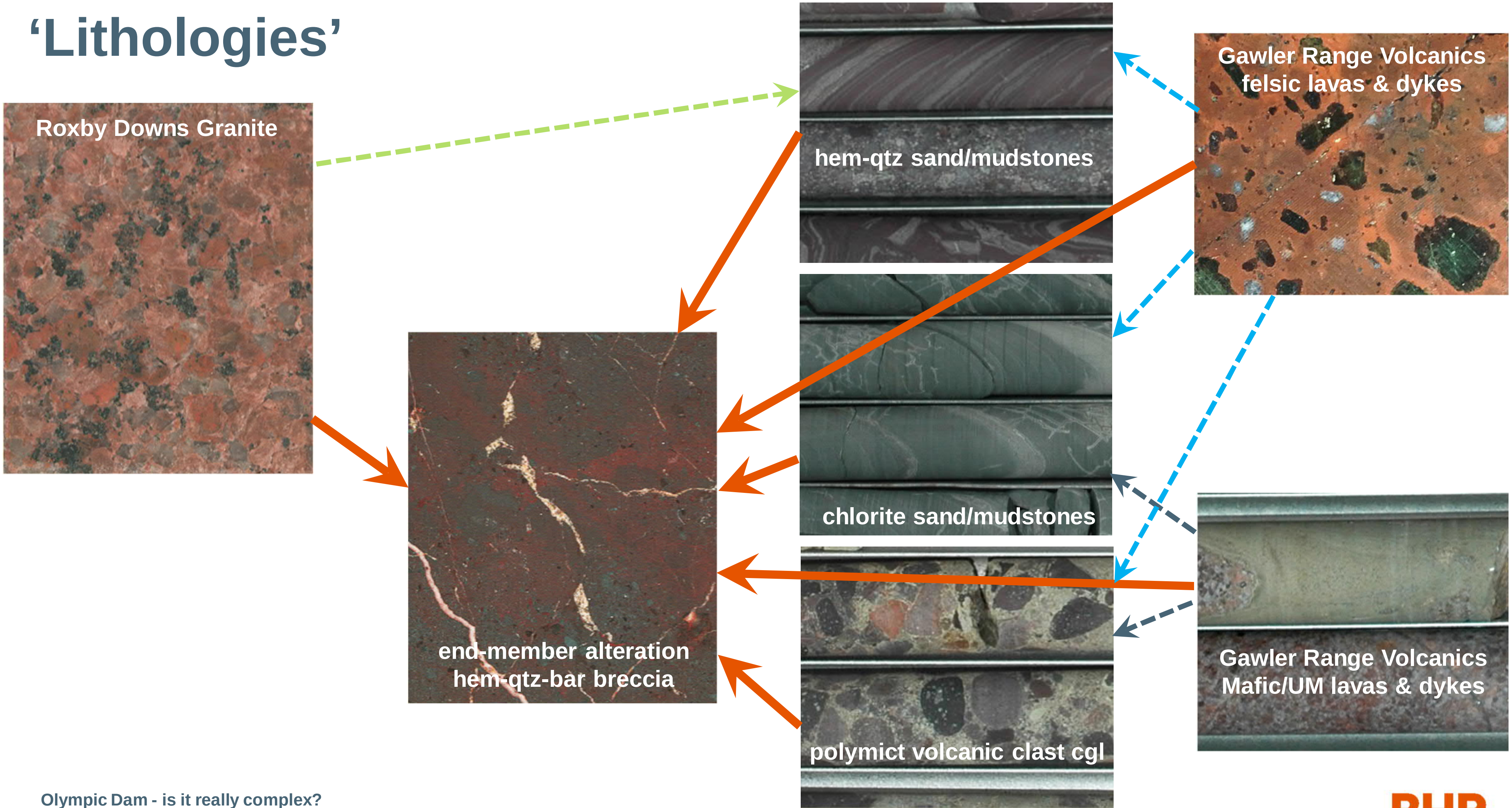
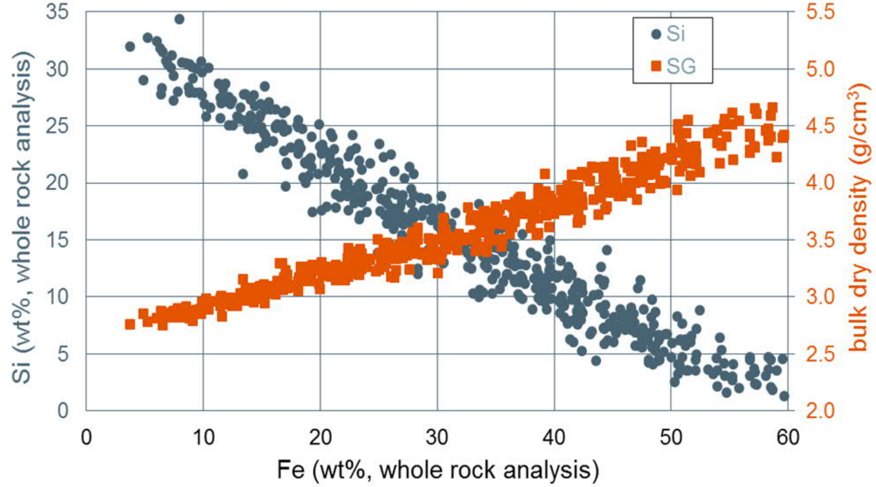
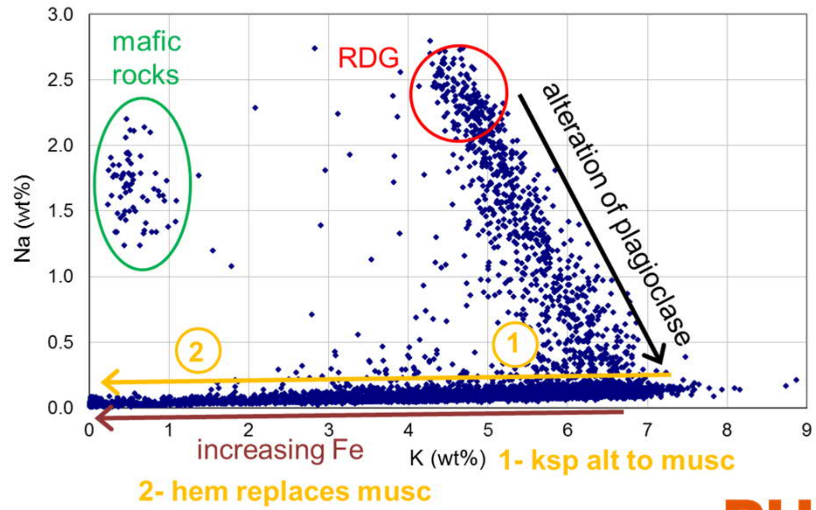
# ‘Lithologies’



# Granite to hematite-rich breccias


- Intense brecciation and texturally destructive hematite-alteration of RDG and other lithologies
- Chemical basis for sub-classification of RDG/other lithologies- to hem-rich bxs

*****COMPLICATED BRECCIA TEXTURES*****
**BUT**
*****SIMPLE CHEMICAL COMPOSITIONS*****



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# Systems from a thermodynamic perspective*

***Phases*** **are "… homogeneous bodies of matter, generally having distinct boundaries with adjacent phases, and … physically separable from them…"**

***Components*** **are "… the smallest number of formulae required to describe all phases within the system …"**



* Anderson, G.M. and Crerar, D.A., 1993, Thermodynamics in Geochemistry: Oxford University Press, New York

# Olympic Dam Mineralogy (>100 minerals)

| 15 minerals account for > 99.5% of the ores | |
|---|---|
| **pyrite, chalcopyrite, bornite, chalcocite** | **hematite**, magnetite |
| **molybdenite, sphalerite, galena** | Cr-spinels, manganosite |
| tennantite-tetrahedrite, covellite | **quartz, muscovite, orthoclase** |
| idaite, carrollite, cobaltite, arsenopyrite | **chlorite**, biotite, amphibole |
| electrum, native/alloys Au, Ag, Cu, Pd, As, Bi, Te | **barite**, anhydrite, celestite, gypsum |
| Au-Ag-Pb-Bi-Hg-Ni-tellurides | plagioclase, albite, schorl, sphene |
| Pb-Cu-selenides | corundum, diaspore, kaolinite, topaz |
| cuprite, tenorite, stibnite, enargite | **siderite**, ankerite, dolomite, calcite |
| scheelite-powellite, wolframite, cassiterite | ilmenite, rutile, ilmenorutile |
| *****uraninite, coffinite, brannerite***** | **fluorite**, sellaite |
| thorite, uranothorite, thorianite | zircon, xenotime, crandallite-group, fluorapatite |
| **bastnäsite, florencite, synchysite** | olivine, pyroxene, etc |

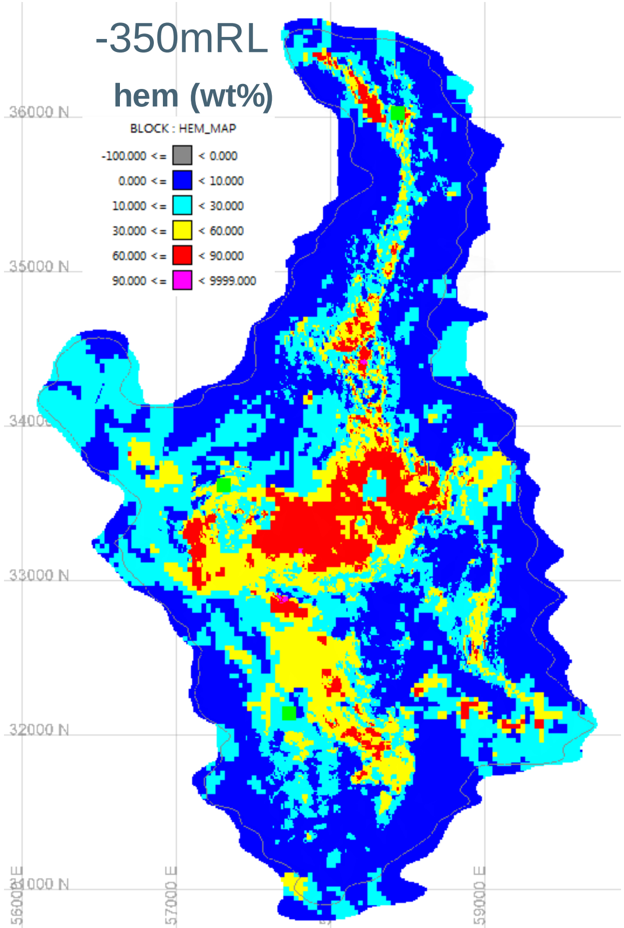
# Simplicity: mineral (wt%) = *f (sample composition)*

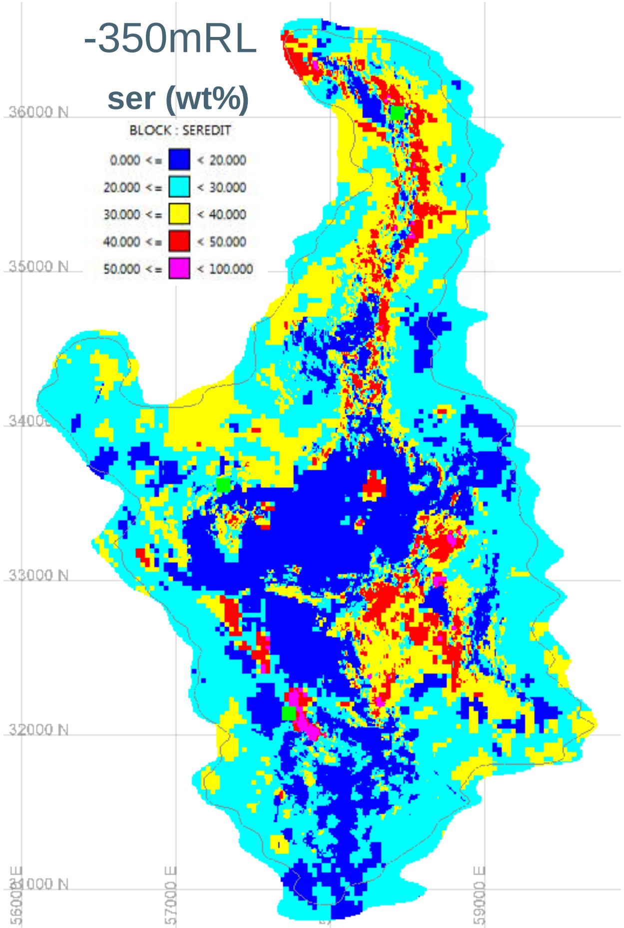
**TRANSFORMATIONAL, once we were able to fully implement, took a decade…**

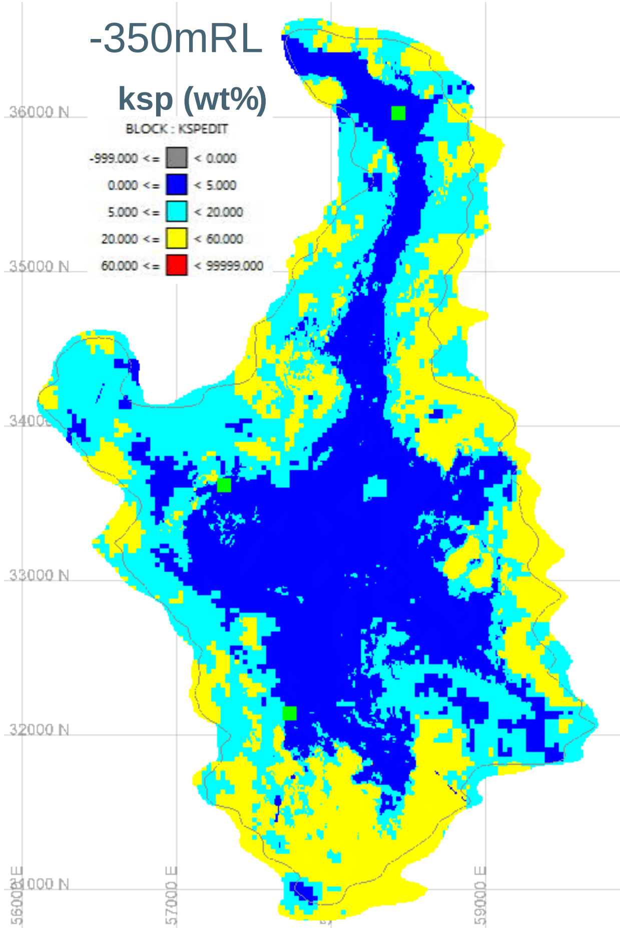
- **Quantify** geological observations on the sample scale
- **Populate** the mineralogy into the Resource Block Model
- **Include** mineralogy in the Mine Plan.

***Business value can only be truly realised once observations/data are in the mine plan.***

# Simplicity: mineral (wt%) = *f(sample composition)*



# Metallurgy 101 for Geologists, and Mining Engineers …

Peter Munro
Mineralis Consultants Pty Ltd

**Rock type controls throughput, mineralogy controls metallurgy.**

**Simple, yet profound and useful !**

NW ‘Bill’ Johnson
Mineralis Consultants Pty Ltd

image sources: from Peter Munro and NW ‘Bill’ Johnson (Mineralis Consultants Pty Ltd, Brisbane)

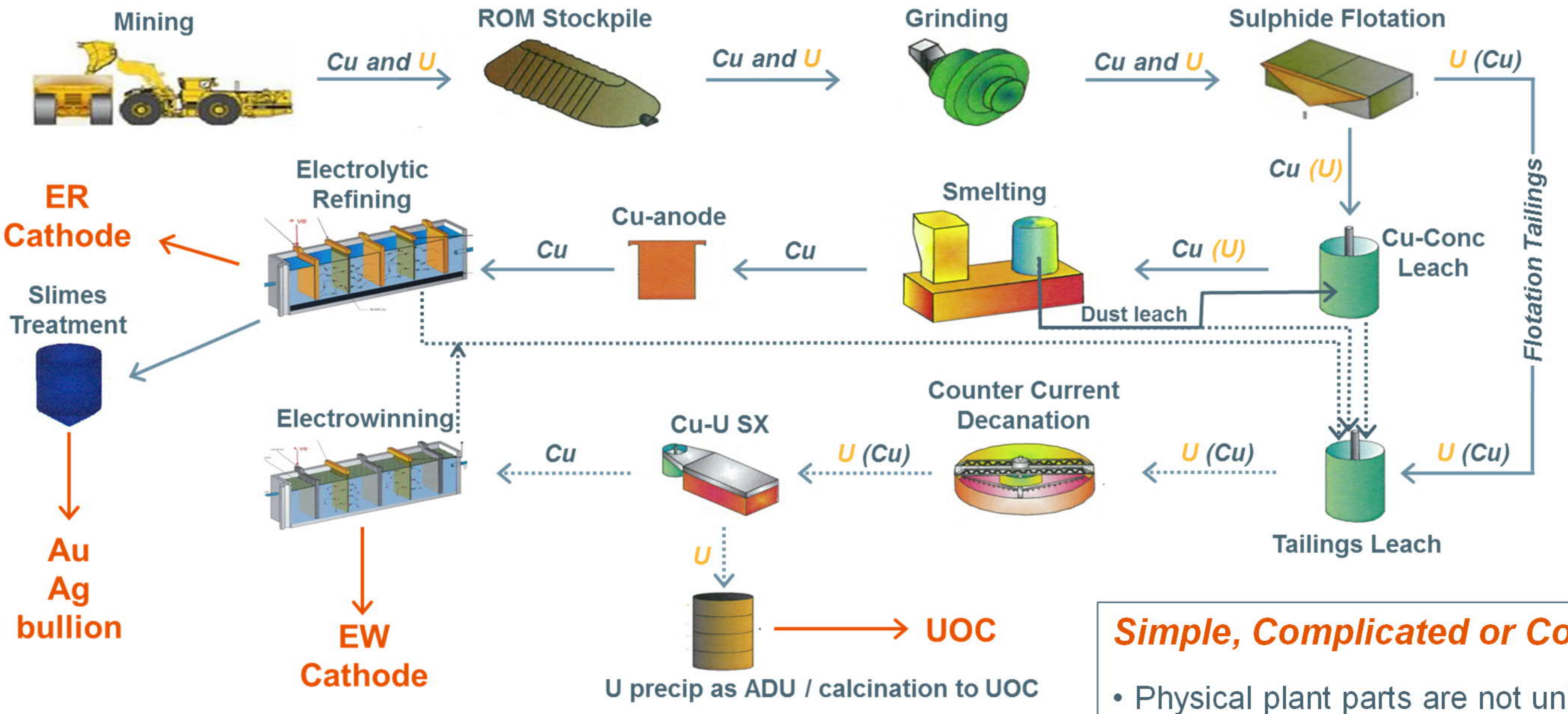
# Simplicity: Geology – Metallurgy Link

Mineral (wt%) = *ƒ(sample composition)*

'Met Performance' = *ƒ(mineralogy, ore texture, process conditions)**

** modified from Bojcevski (2004)*

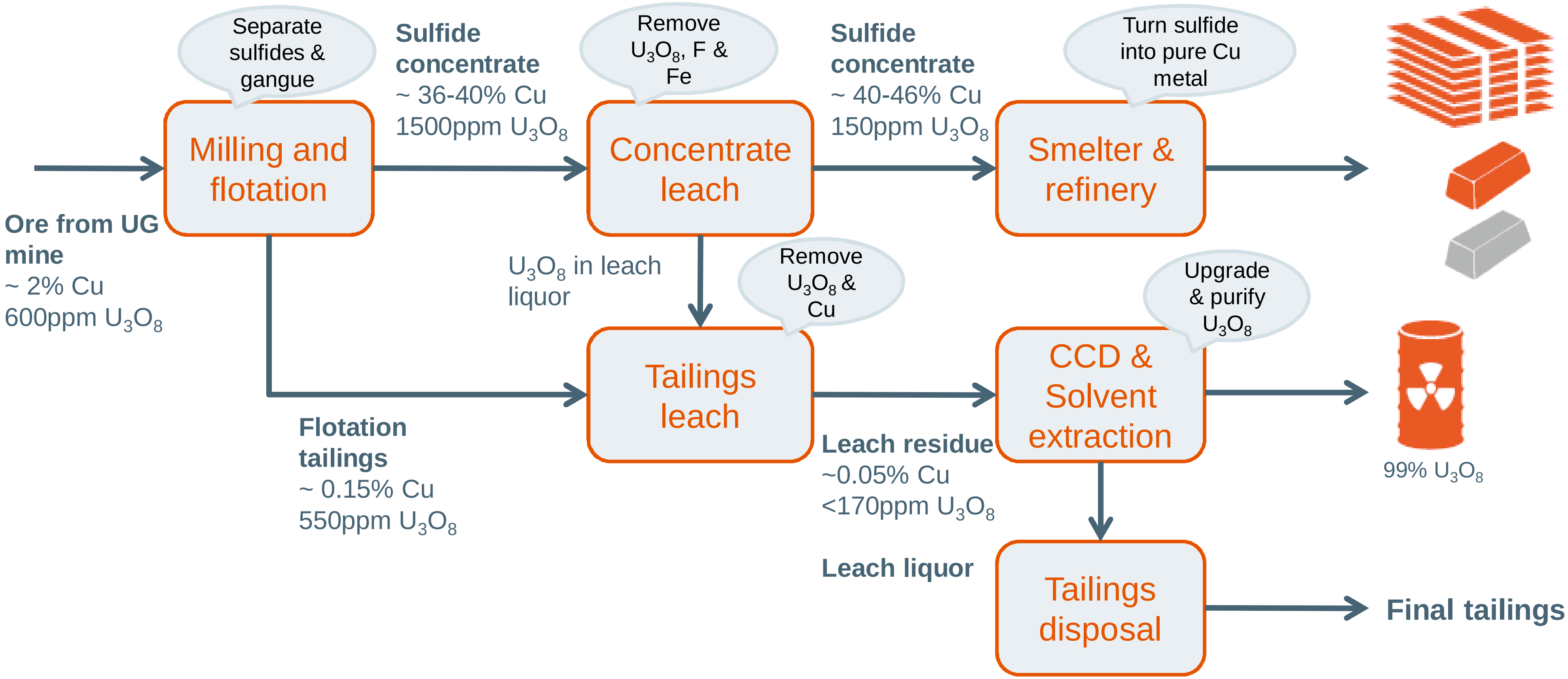
# Olympic Dam Simplified Ore Processing Flow Diagram




***Simple, Complicated or Complex?***

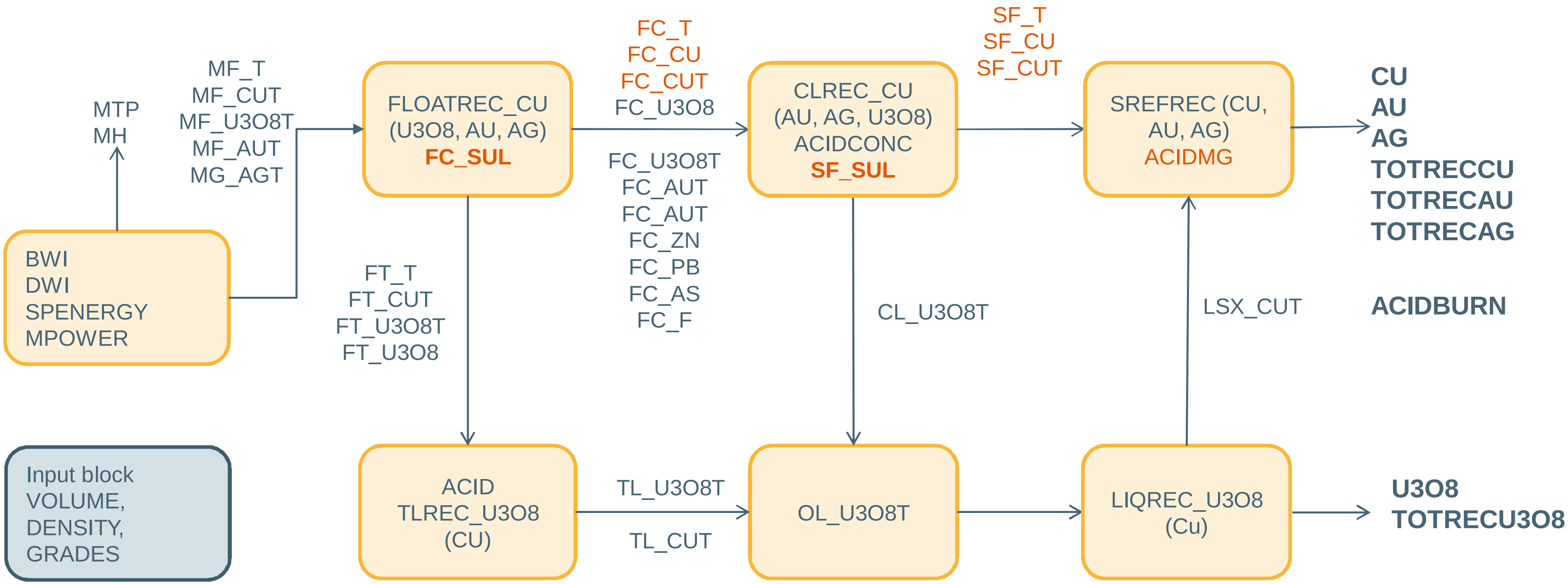
- Physical plant parts are not unique
- Significant recycle streams –not unique, but make the system complicated to operate.

# Even Further Simplified Olympic Dam process flow



# +50 geomet variables

## required to evaluate VALUE on each block in the resource model



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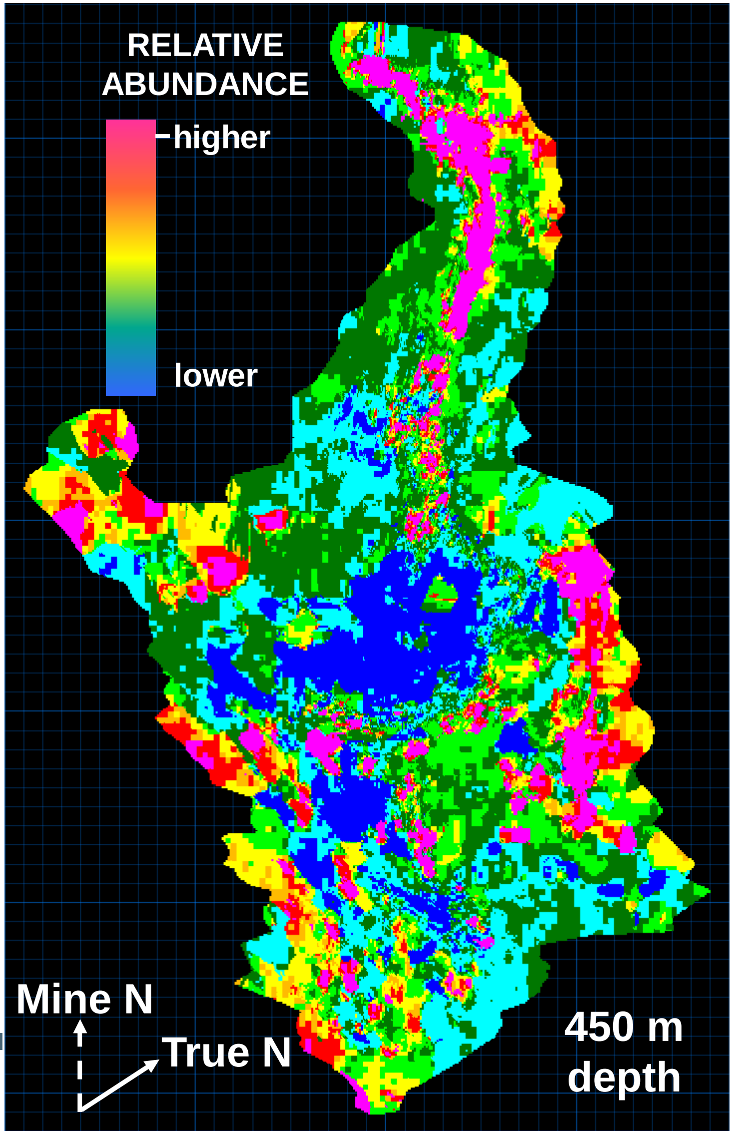
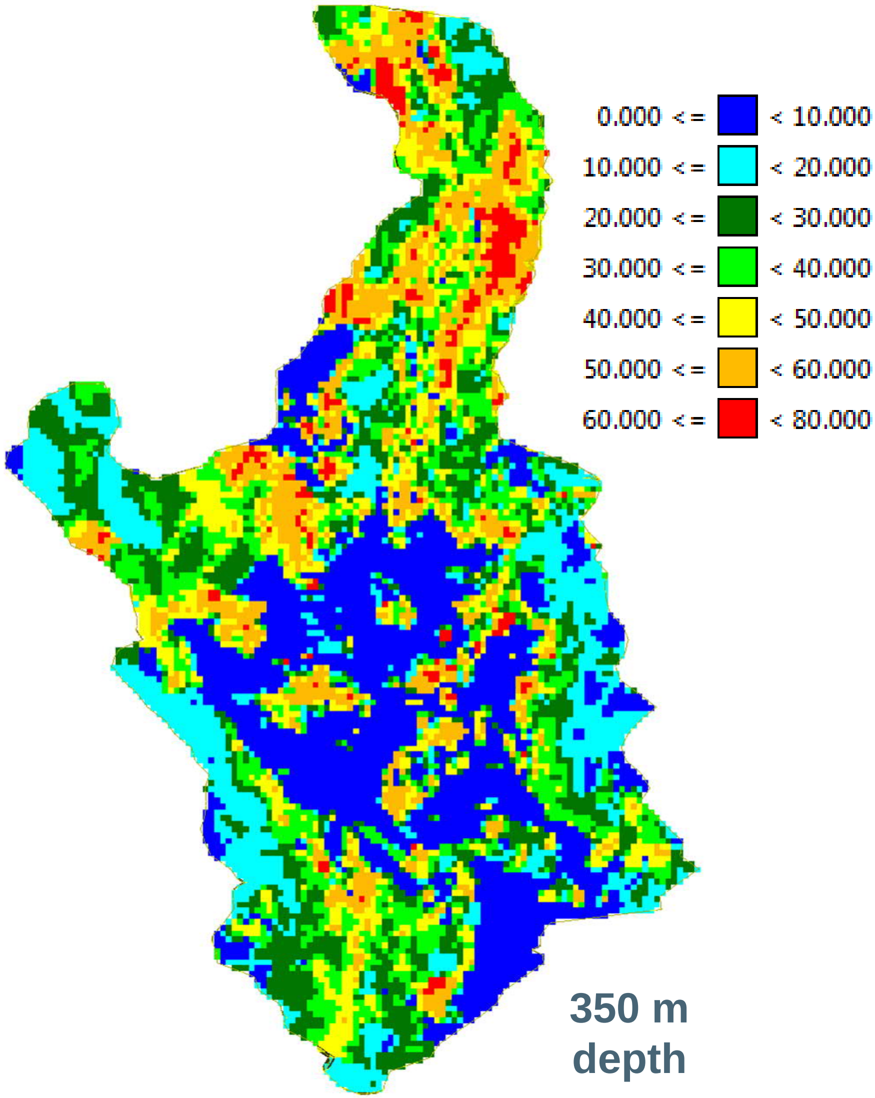
## Acid Consumption (ACID)




## Concentrate Grade (FC_CU)



# Words of caution:
## Over-fitting data ⇒ reduced effectiveness of your predictor

**Classic example from a mining operation (not OD)**

- flotation recovery equation, **%rec**:

  **%rec = {90.94 – 259*sinh[0.000668*(48/x – 1)]} – [11.88*(4.2/x) + 1.46],** where **x** = feed grade%

- within the range of feed grades, sinh(n) = n within 4 decimal places, so the sinh function is redundant.
- after that, the equation collapses down to: **%rec = 89.65 – 58.22/x**

**Now isn't that simpler, and ultimately more useful?**

**OD Geomet: all variables need to either make geological, mineralogical or metallurgical sense.**

# Complicating simplicity- requires vigilance to prevent it

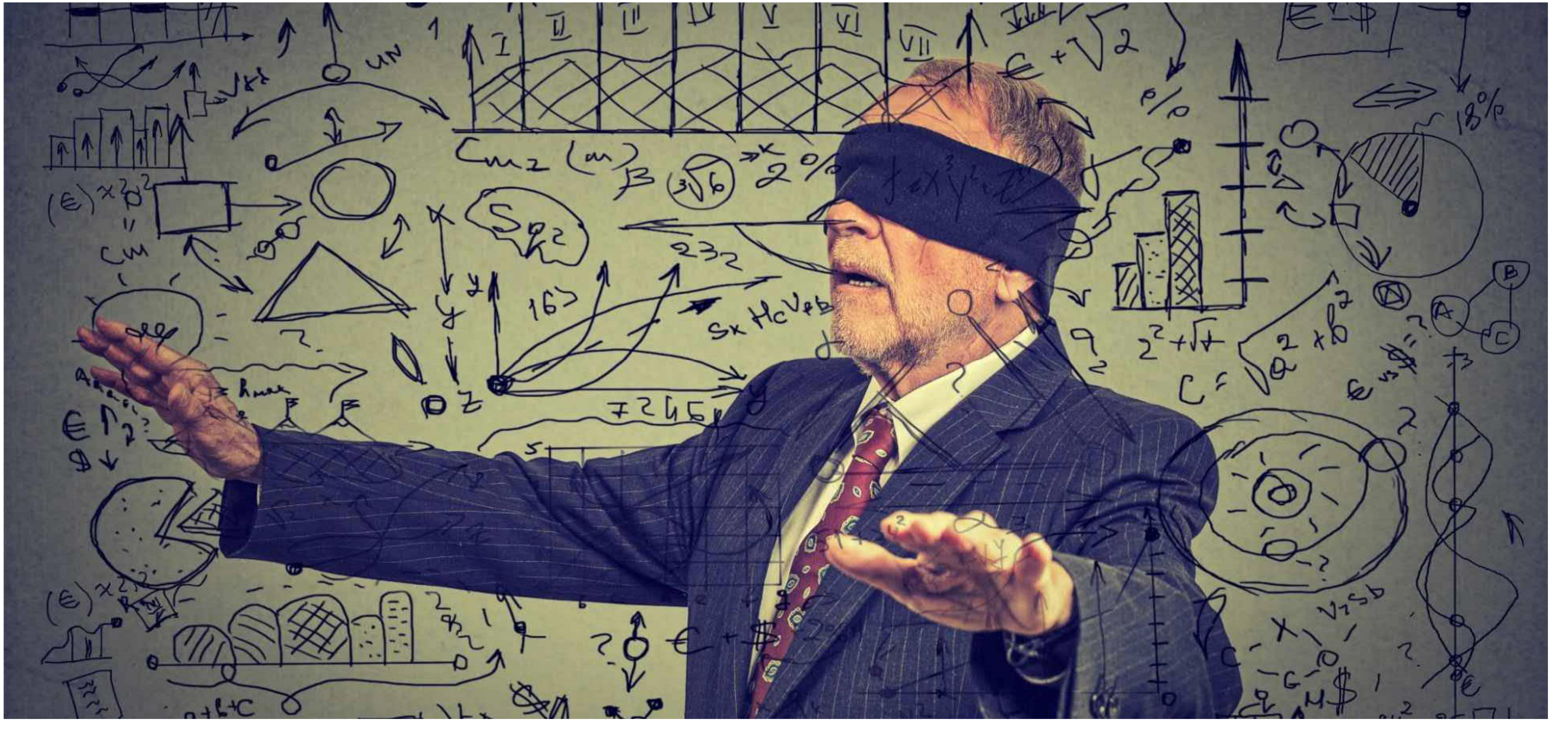


image: https://www.inc.com/gordon-tredgold/simplicity-is-the-key-to-success-here-are-26-inspiring-quotes-to-help-you-on-tha.html

# We need to be clear with our messaging

# Conclusions

**Olympic Dam – is it really complex?**

- Ore deposit genesis and breccia textures – Not complex, but certainly complicated.
- Mineralogy – No, it is simple. We perceived the mineralogy to be complicated for a very long time.
- Processing – No, most parts are simple. However, recycle streams make the processes complicated.

***As scientists and engineers, our roles are to reduce complexity,***

***and transform complicated systems into simple systems !***

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