Climate neutrality, the circular economy, and earth materials

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United Nations Educational, Scientific and Cultural Organization

International Geoscience Programme

Earth Materials for a Sustainable and Thriving Society

UNESCO Lecture Series

Organised in collaboration with IUGS and iCRAG

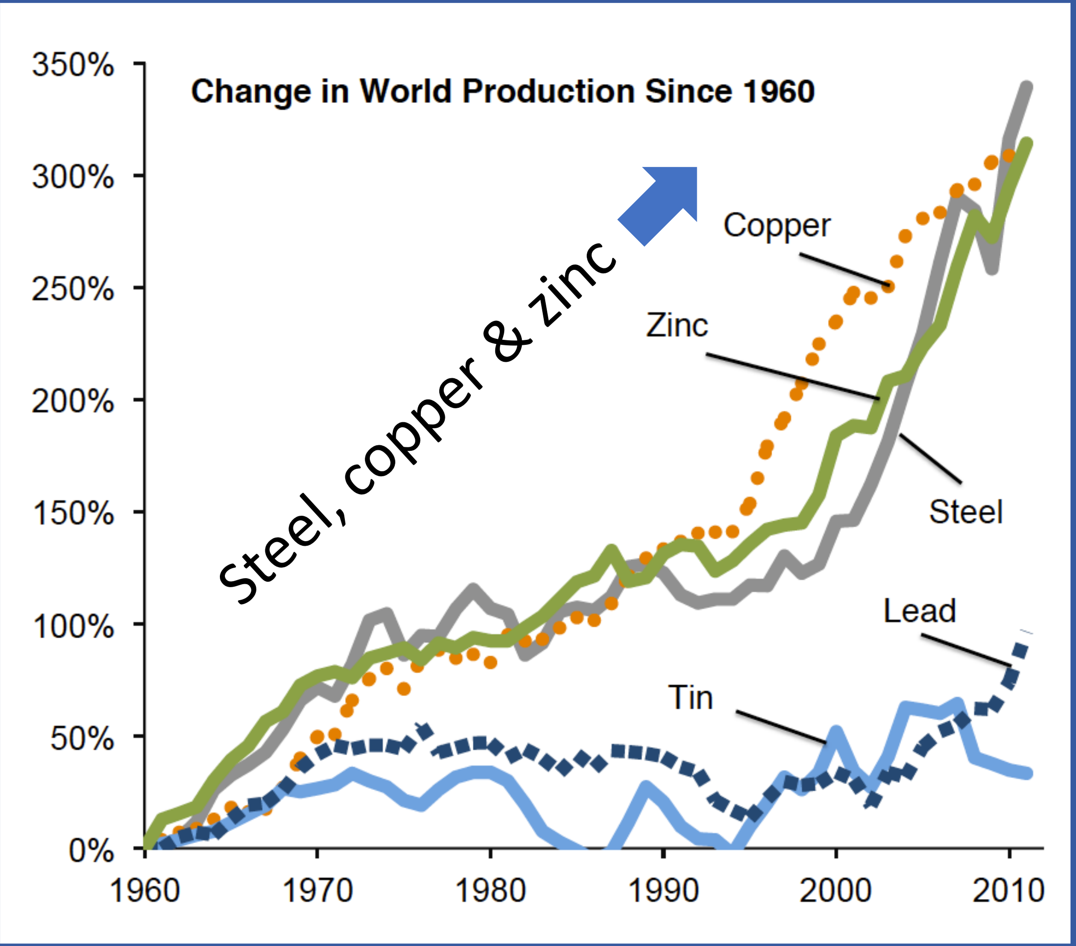
Key points

Reimagining metal supply to meet demand and societal expectations

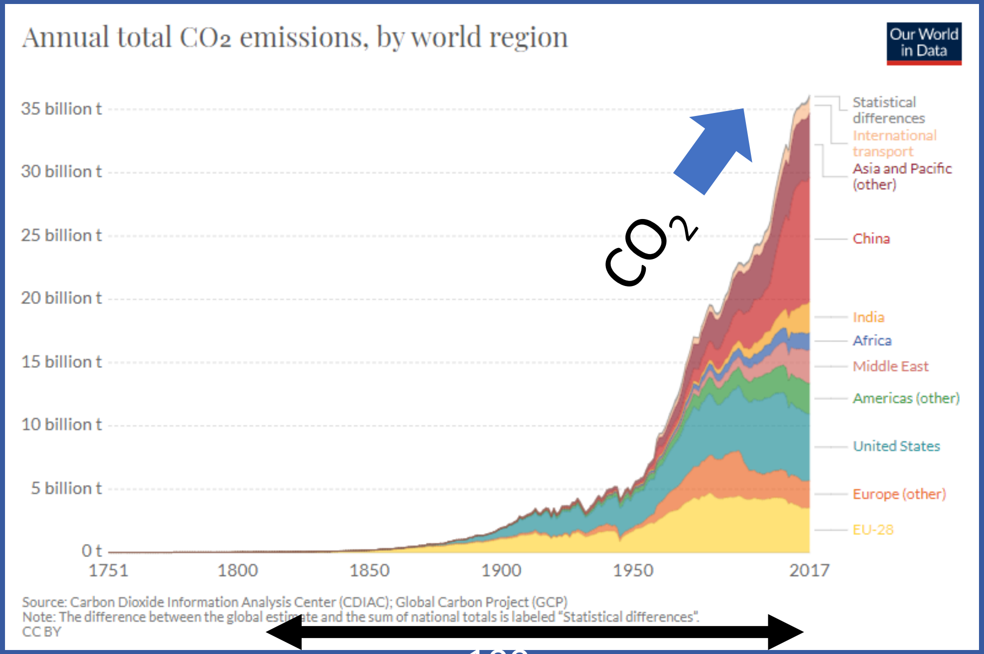
- Climate neutrality – energy transition, metal use, and supply
- Circular economy – metal reuse and recycling – necessary but challenging
- Responsible primary extraction – technical and social change
- Joining up the value chain – optimizing collaboration from source to customer to reprocessor

Climate, energy, and metals

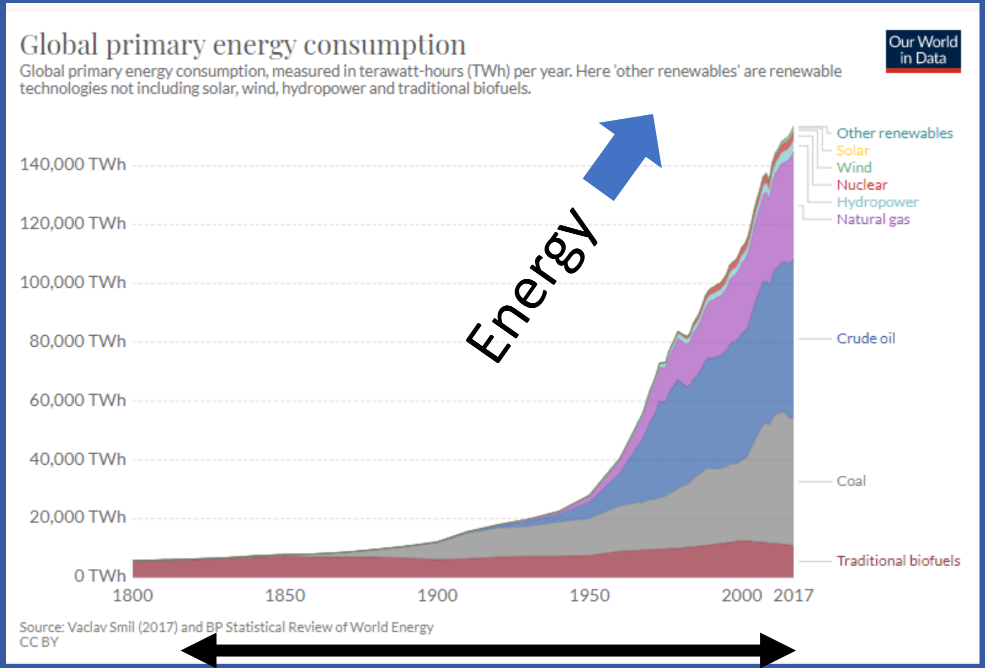
Increasing and increasing……



Arndt et al., 2017 – data from USGS



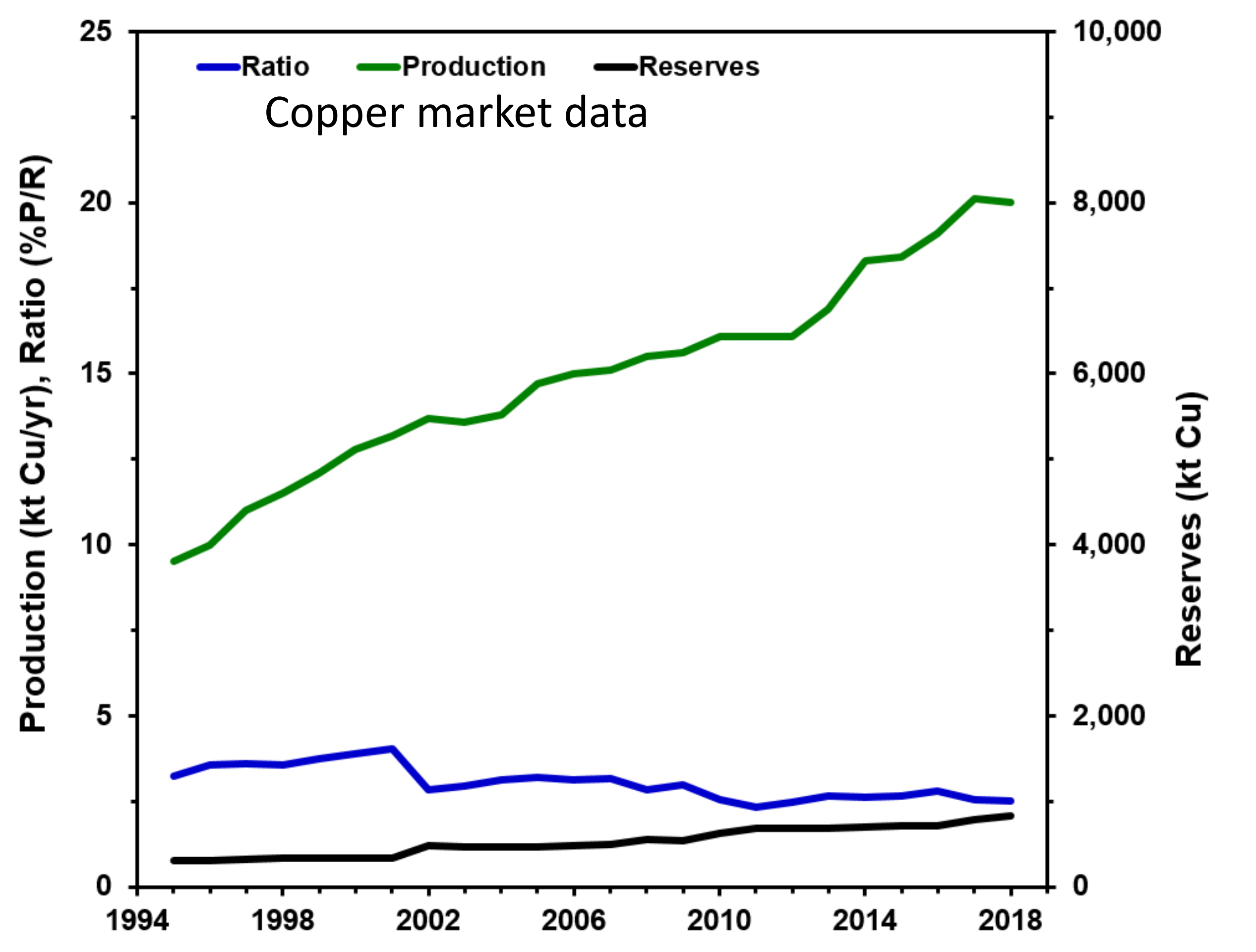
100 years



100 years

Metal production and reserves – supply

- Increasing production
- Increasing reserves
- Reserve/production ratio – relatively constant
- Metal availability – reserves and resources – is not an issue in the short to mid-term
- Providing metal with minimum impact is the challenge



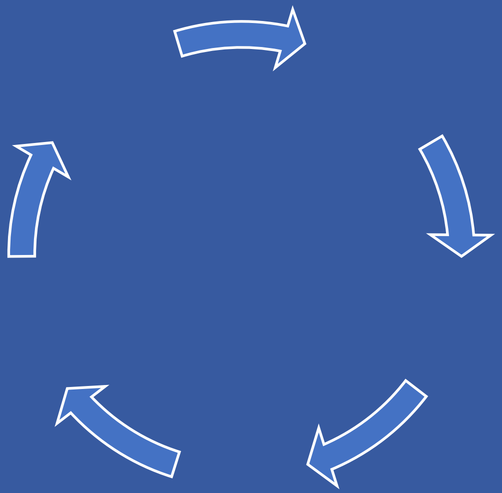
Adapted from Jowitt et al., 2020; USGS data

UN Sustainable Development Goals – SDGs

- Mining and metal production – linked to all SDGs
- Metal use is critical to several SDGs:
  - Major component in renewable energy and electrification of transportation – SDGs: 1, 6, 7, 9, 11, 12 and 13
- Negative impact of metal extraction and use must be reduced:
  - SDGs: 3, 8, 11, 13, 14, 15, 16

Circular economy – importance and challenges

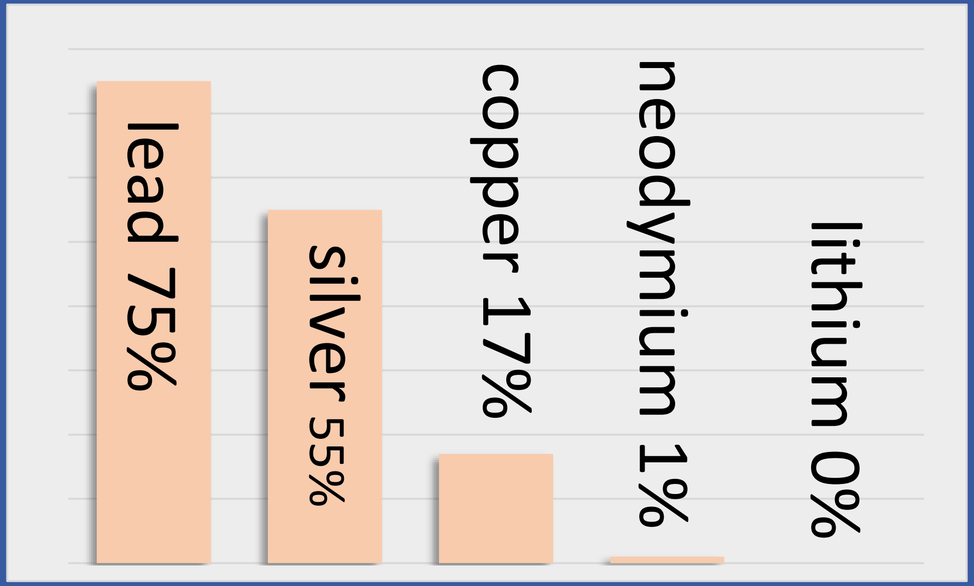
Circular economy?



RECYCLING

X

Recycling Input Rates (EU Raw Materials Scoreboard)



Circular economy?

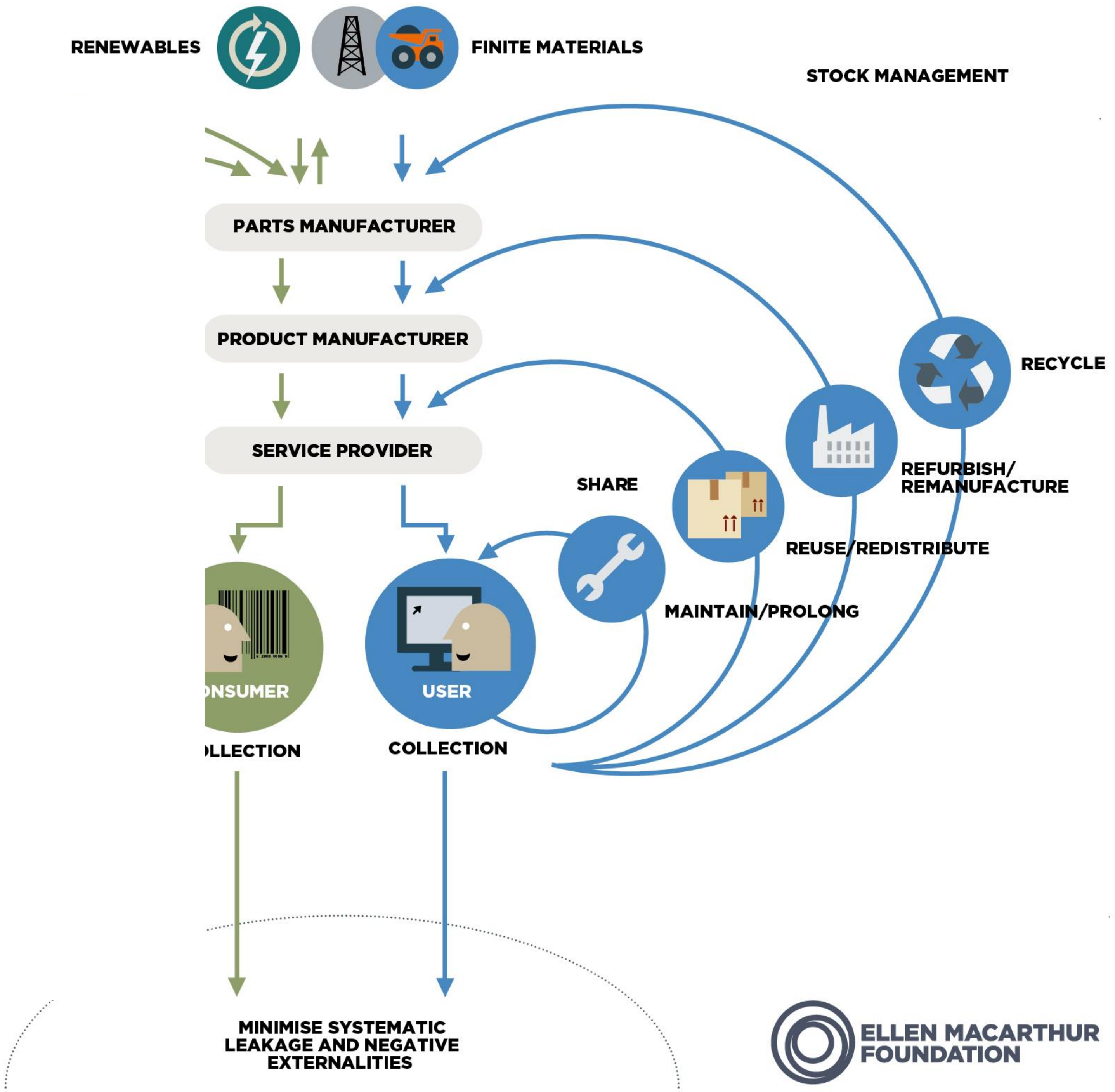
RE-USING MINE TAILINGS

X

Panasqueira Mine, Portugal (F. Wall)

- 350 Gt produced worldwide each year
- 20 times all municipal solid waste
- 70 billion elephants (Earth to Mars)
- by far our largest wasteform

Vallero & Blight (2019). OI: 10.1016/B978-0-12-815060-3.00006-2



Ellen MacArthur Foundation
Circular economy systems diagram (February 2019)
www.ellenmacarthurfoundation.org
Drawing based on Braungart & McDonough,
Cradle to Cradle (C2C)

ELLEN MACARTHUR FOUNDATION

‘Circular economy is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.’

(*Ellen MacArthur Foundation*)

‘Designing out waste and pollution’

Don’t’ forget earth materials determine many characteristics of a mine

Geology

- Grade of ore
- Composition and mineralogy of the ore
- Size of ore deposit
- Depth of ore deposit
- Location of ore deposit

Geometallurgy

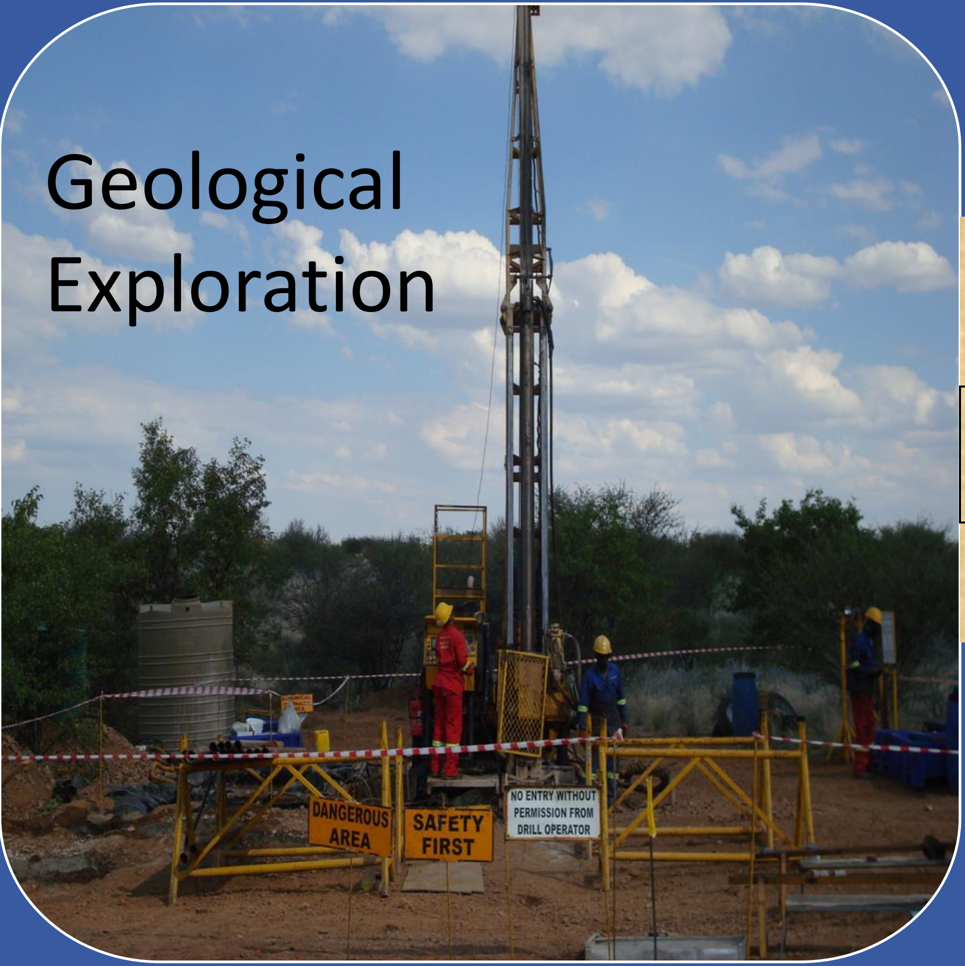
Mining and Processing

- Resource efficiency
- Energy use
- Carbon footprint
- Water use
- Environmental contamination
- Financial profitability
- Biodiversity and landscape degradation

Corporate Social Responsibility

- Health and safety and well-being of work force
- Community interaction and well-being
- Contribution to national economy
- Compliance with regulatory frameworks
- Land use during and after mining

‘designing out waste and pollution’



Geological Exploration

Environment and Social responsibility

Desk study

First results, e.g. preliminary economic assessment

Prefeasibility study

Feasibilty study

Mine

Life Cycle Assessment

See Wall et al (2017) Elements, 13, 313-318 for discussion of use of LCA in responsible sourcing of rare earths

Start early with life cycle assessment

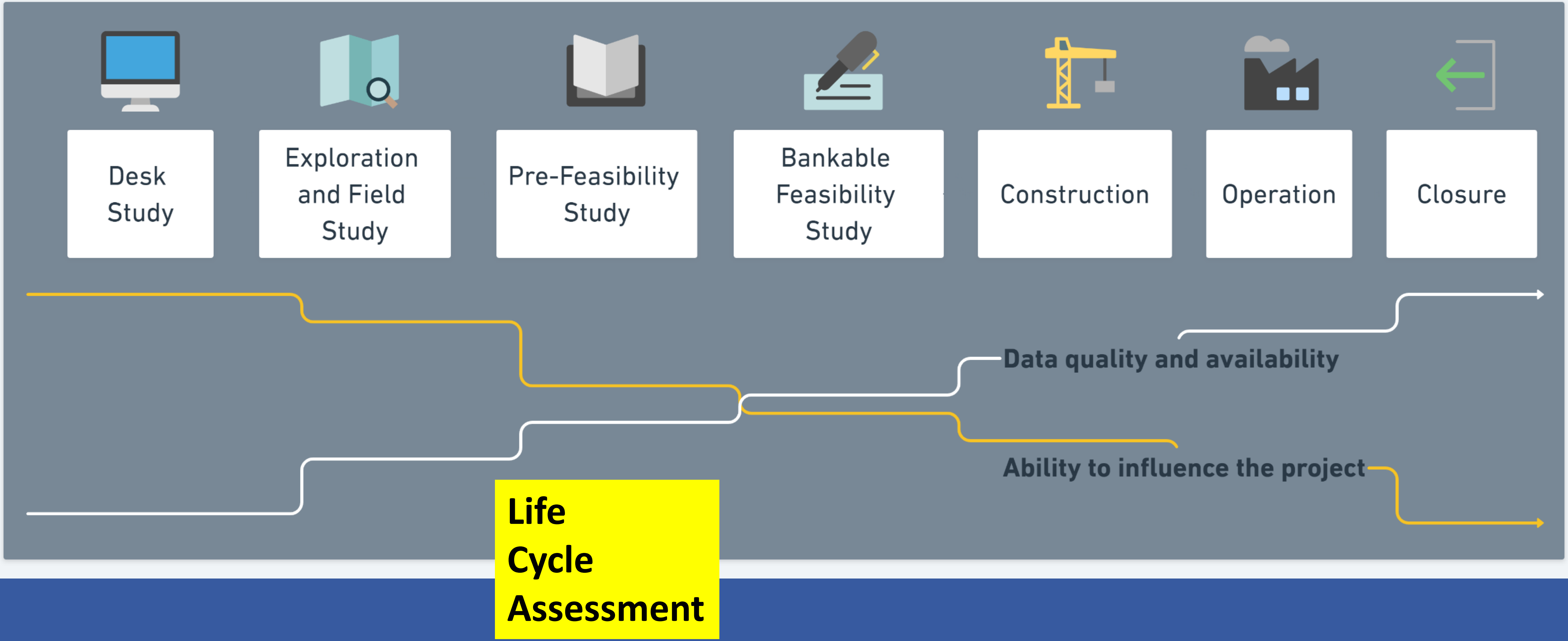
Environment and Social responsibility

Desk study → First results, e.g. preliminary economic assessment → Prefeasibility study → Feasibilty study → **Mine**

Life Cycle Assessment

Pell et al. (2019) *Journal of Environmental Management*.
Pell et al. (2019) *Minerals Engineering*, 135, 64-73, DOI:10.1016/j.mineng.2019.02.043

Start early with life cycle assessment



‘keeping products and materials in use’

Sara Kurfess

https://www.mining.com/rio-launches-its-first-closed-loop-recycling-service/
courtesy of rio tingo

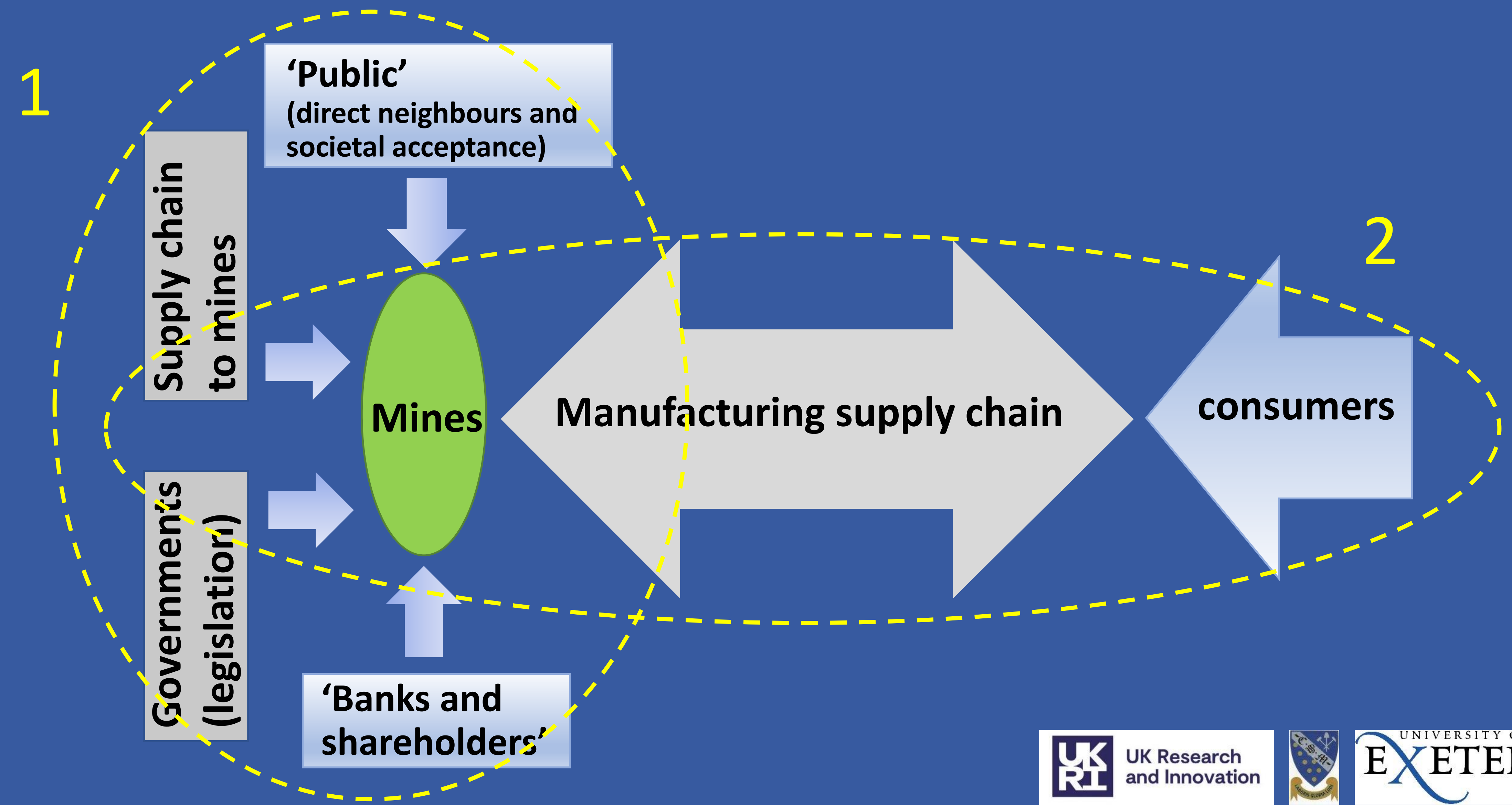
Do you need a new smartphone?

Rio Tinto customers in North America will have a new scrap take-back solution for production of high quality alloys made with recycled content.

‘and regenerating natural systems’

B2 Gold, Namibia (photos F Wall)

‘Sustainable mining’ – two views – both good!

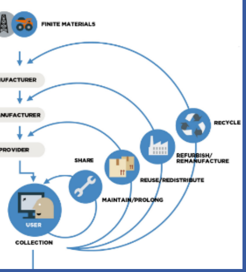


UK Research and Innovation

UNIVERSITY OF EXETER

Sustainable mining –view 2

Sustaining the life of the metals – thinking ahead to where the metals will go



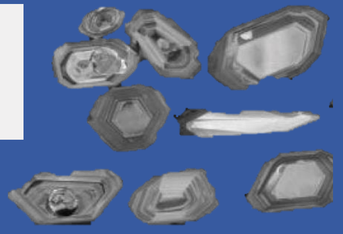
UNESCO Cornwall and West Devon Mining Landscape World Heritage Site
Photo Ainsley Cocks

Efficient and responsible primary production

- Discovery – data
- Extraction challenges and solutions
- Critical minor metals and recycling

Discovery challenge

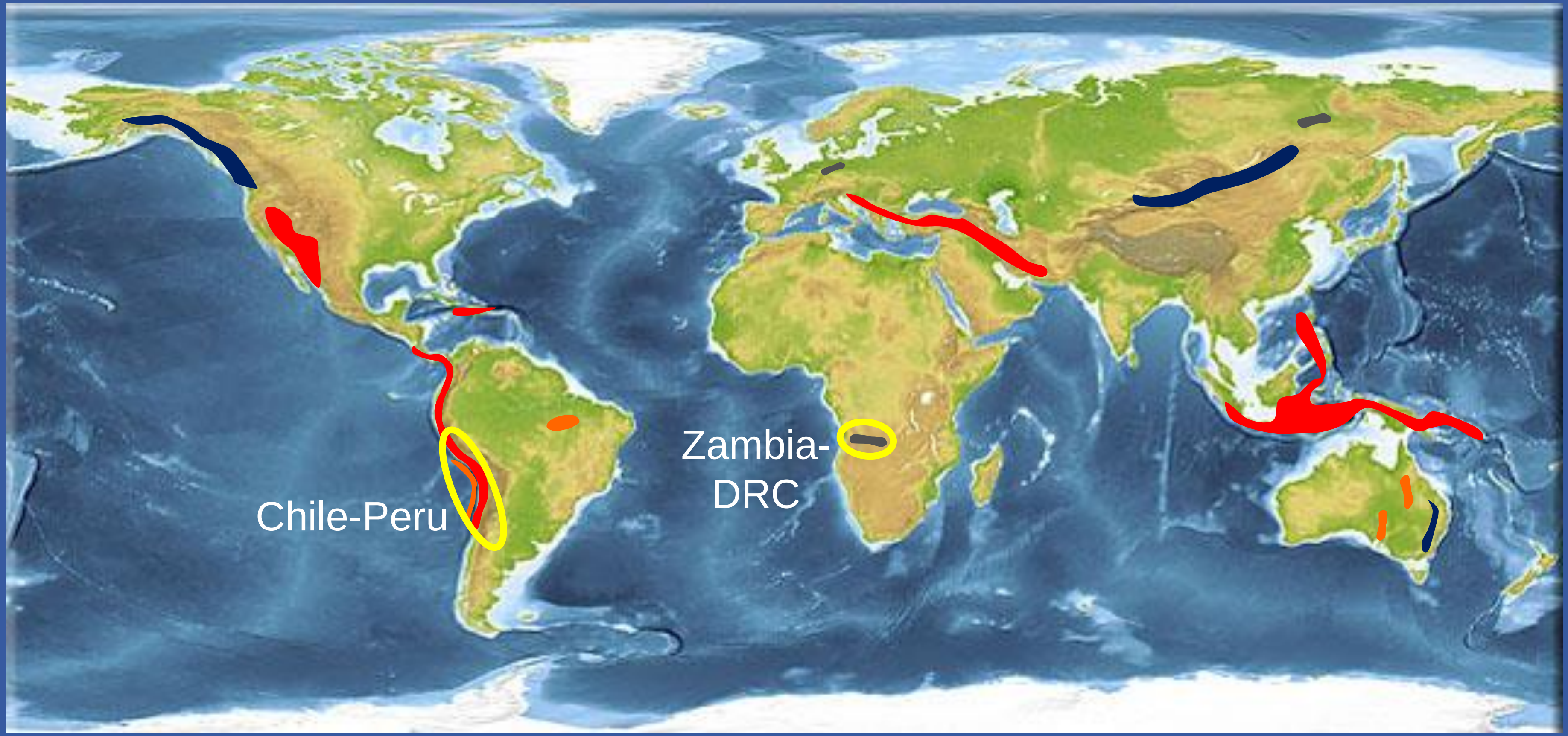
Zircons – chemical characteristics
➡ magma-fluid history



- Need for new discoveries – “quality” resources
- Select the best area to explore – understanding metallogeny and fertility

“Quality” resource:
- Metal content – grade
- Size and geometry
- Suitability for mining
- Good recovery of metals
- Environmentally benign
- No use-conflicts

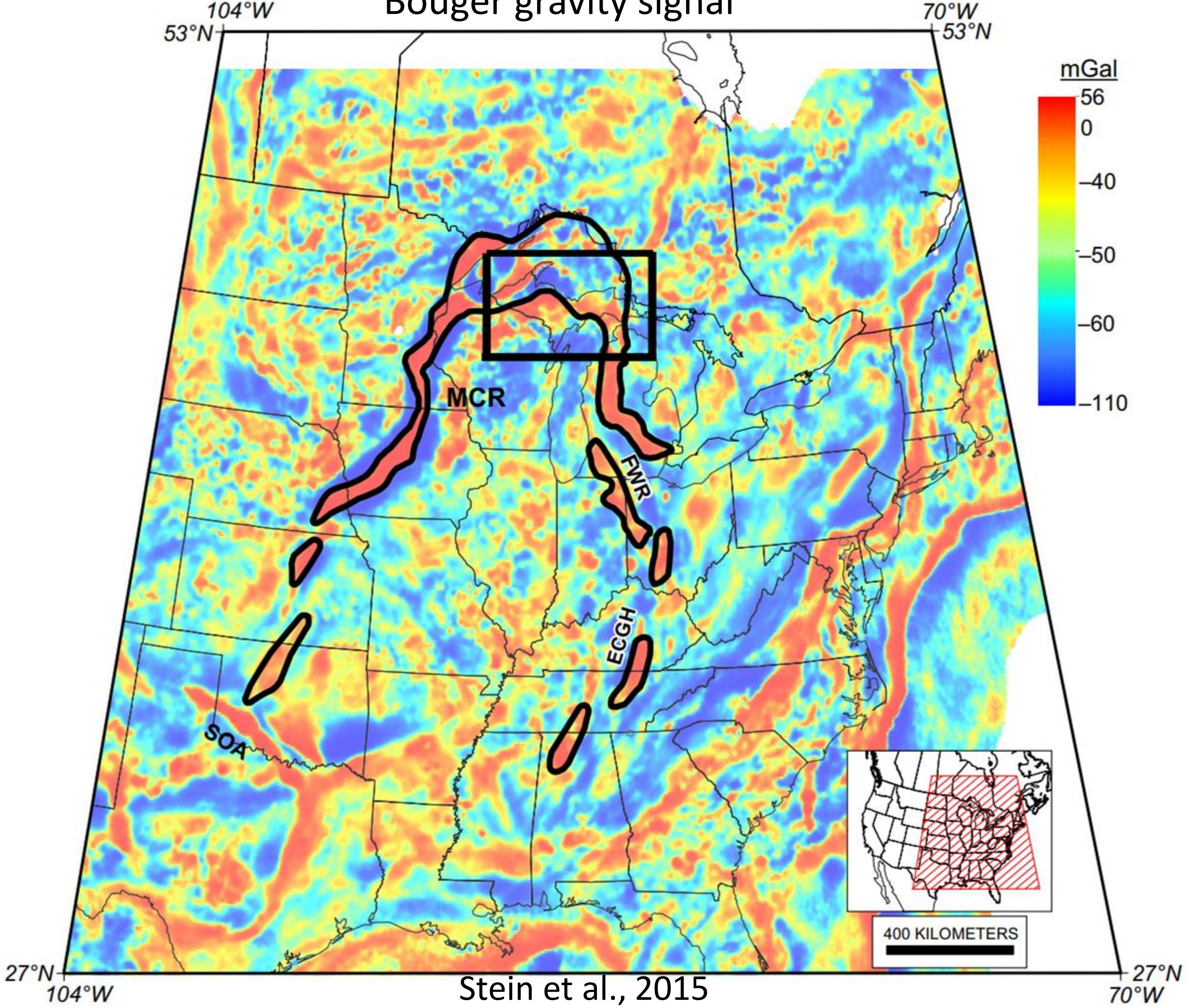
Copper deposits – types with distinct characteristics concentrated in different regions – countries



Remote data

- Geophysics
  - Satellite and airborne
  - Ground surveys
- Remote sensing
  - Satellite and airborne multispectral data
- Geochemistry
  - Large-scale sampling – streams, lakes, soils
  - Microbial data

Bouger gravity signal



Stein et al., 2015

Discovering quality resources

- Integrated knowledge and technology
  - Field work – geology, geochemistry, geophysics
  - Real time data – field sensors, drones
  - Data – integration, AI/ML
- Drilling: rapid testing, minimum impact

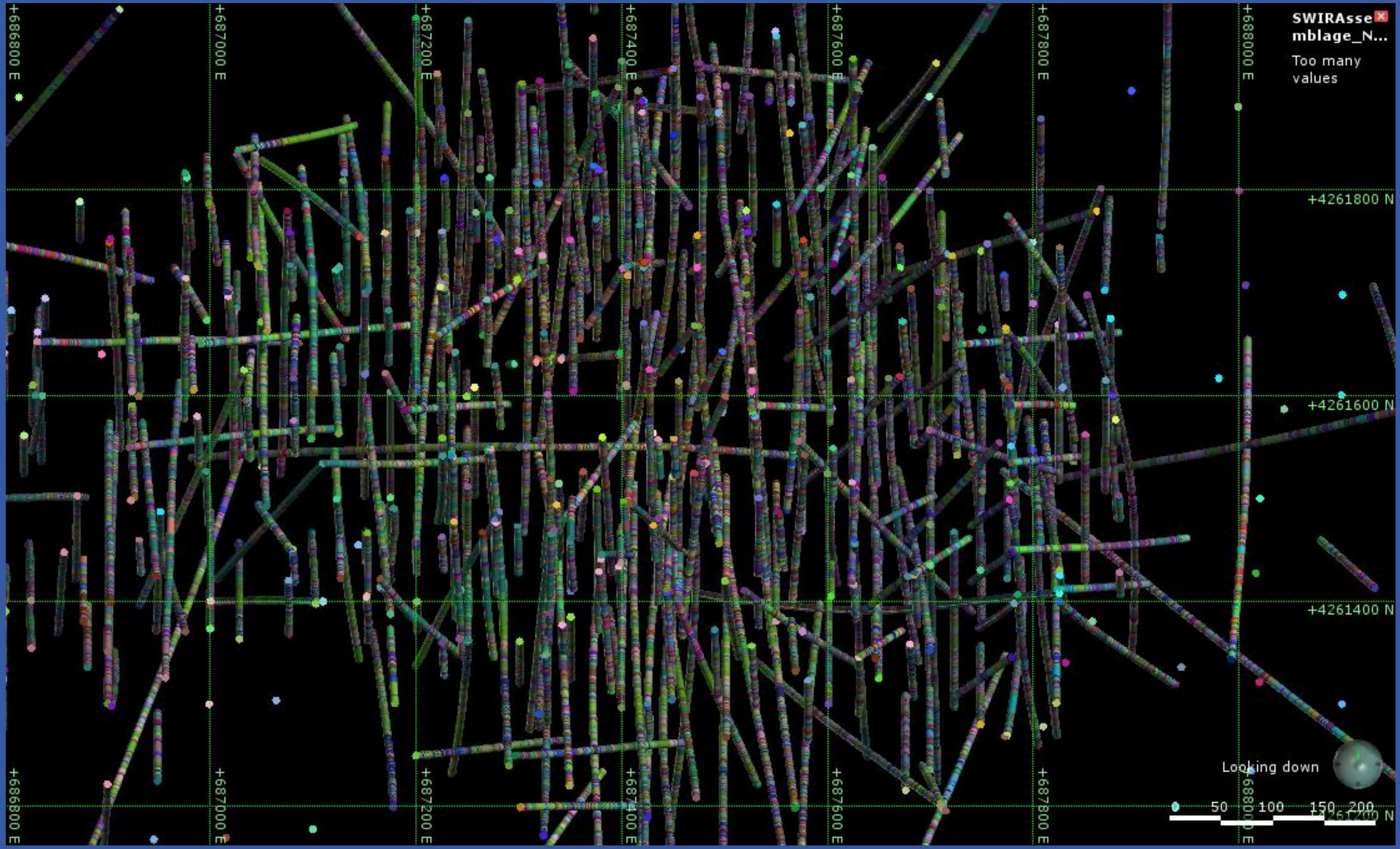






Mineral alteration data

Spectral data – raw SWIR assemblages



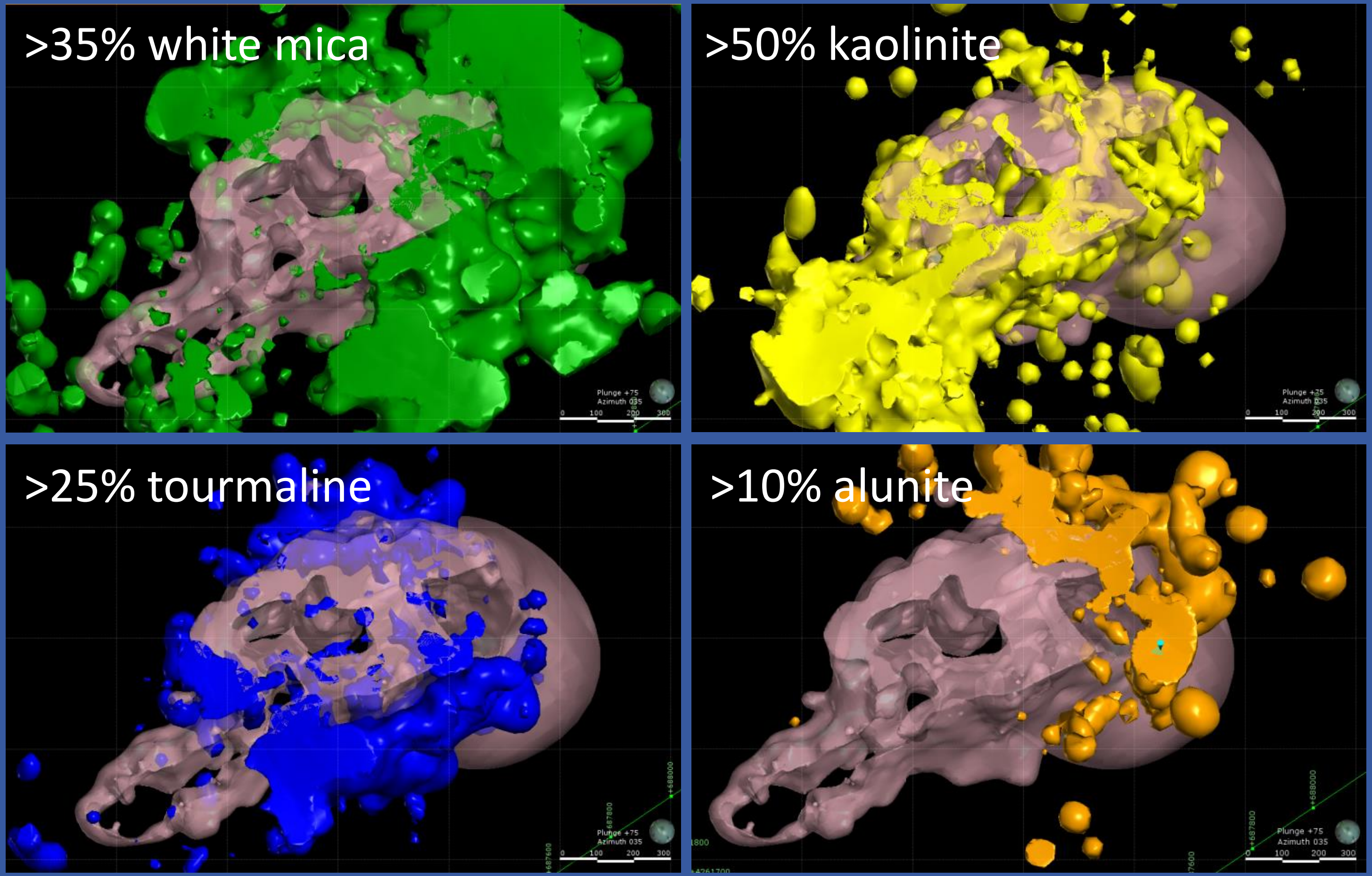
200m

Kişladağ project – Eldorado Gold

Interpreted alteration mineralogy

Mineral distribution: aiSIRIS* Spectral Contribution ('SC') data

— Machine learning spectral recognition software – library of >1M spectra

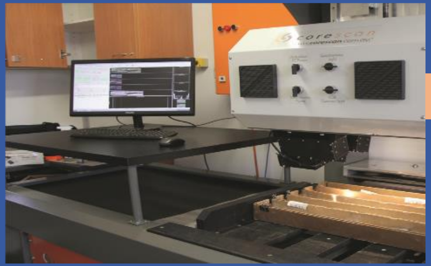


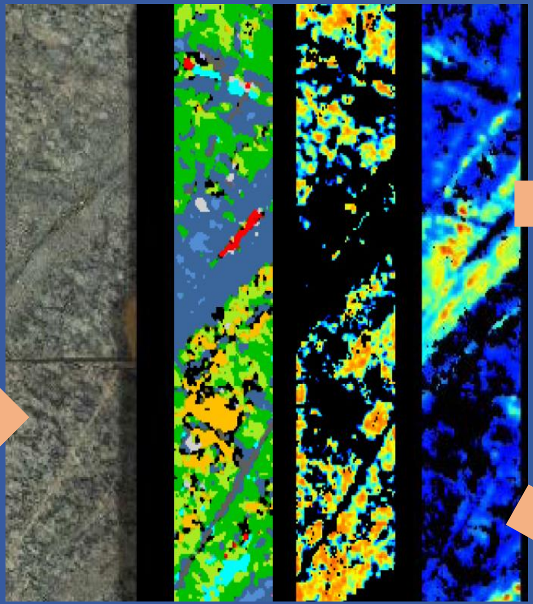
* Artifical Intelligence Spectral InfraRed Interpretation System

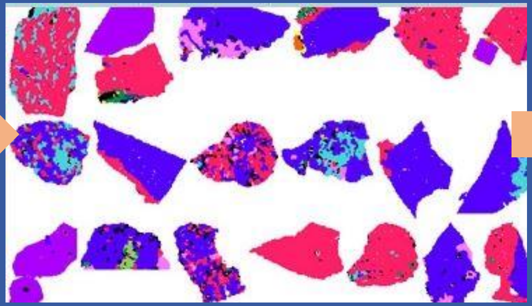
300 m

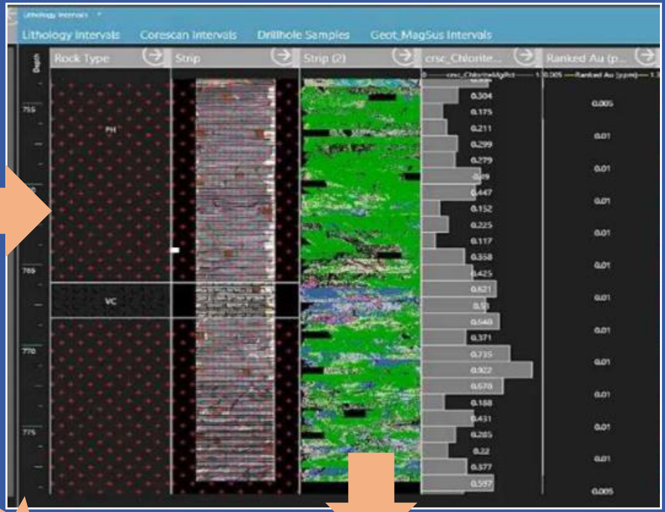
Kişladağ project – Eldorado Gold; AusSpec

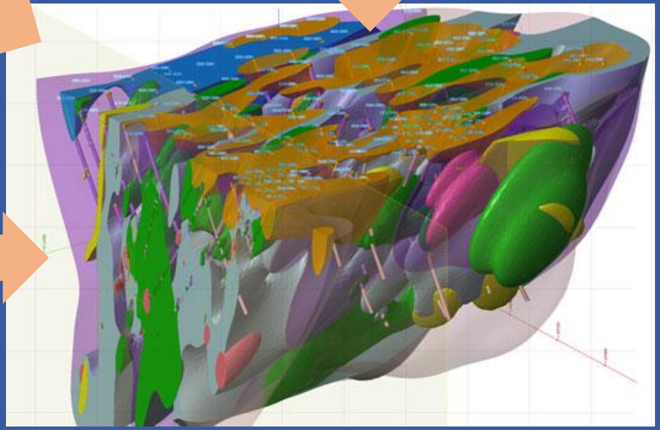
Creating quality











Data collection → Interpretation → Integration → Understanding

Mining challenge – scale

- Breaking, moving and grinding rocks – energy requirements
- Vast amounts of waste – long-term management, unacceptable disasters

2014 Mt Polley, Canada

2018 Brumandinho, Brazil

Innovation and solutions

- Electrification
- Automation
  - Improved safety and efficiency
- Improving selectivity

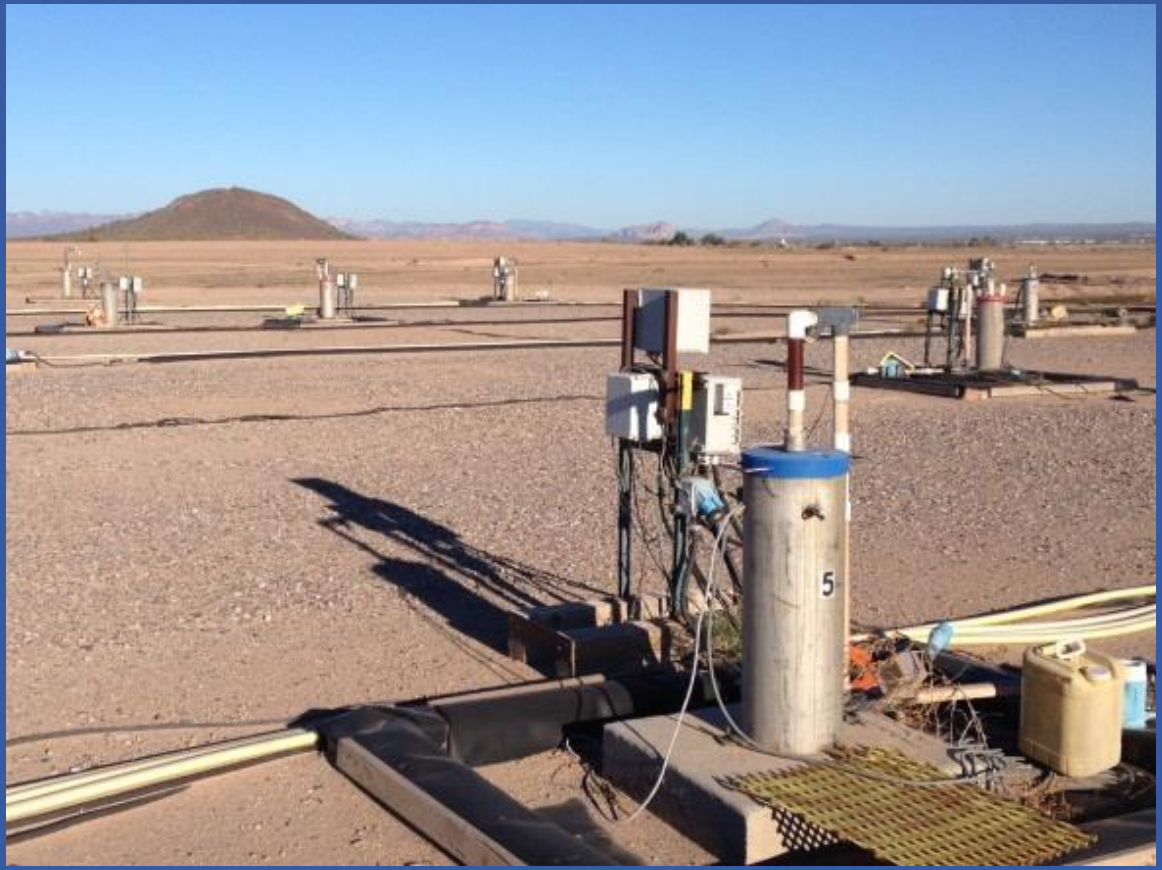
  Separate metal-rich rocks from waste during mining

  ➡ Less rock processed, less waste

  ➡ Lower energy consumption per unit
- Digital transformation – smart mines
- Mine to metal

In situ recovery – no mining, no waste

- Dissolve the metals in place – underground
- Already used for potash and uranium
- Advantages
  - Limited footprint, low cost
- Challenge
  - Water management



Capturing by-product metals

Cu concentrate

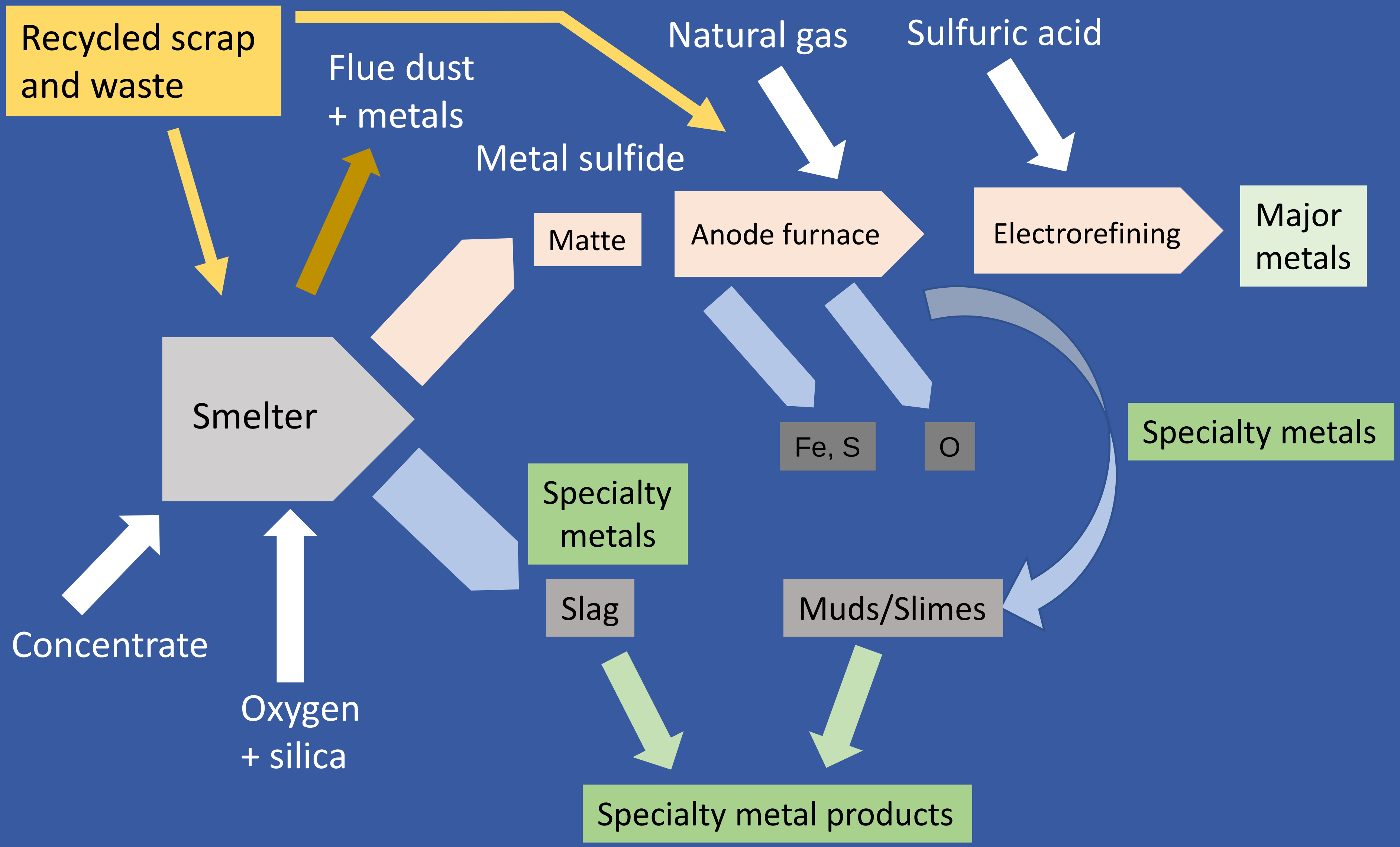
Metals in porphyry copper deposits

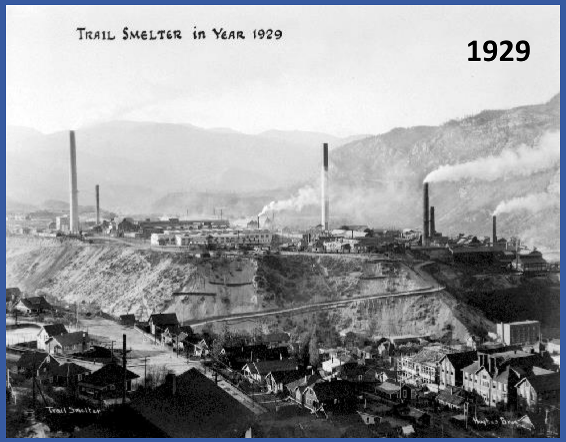
I A	II A	III A	IV A	V A	VI A	VII A	VIII A			I B	II B	III B	IV B	V B	VI B	VII B	VIII
H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lr	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

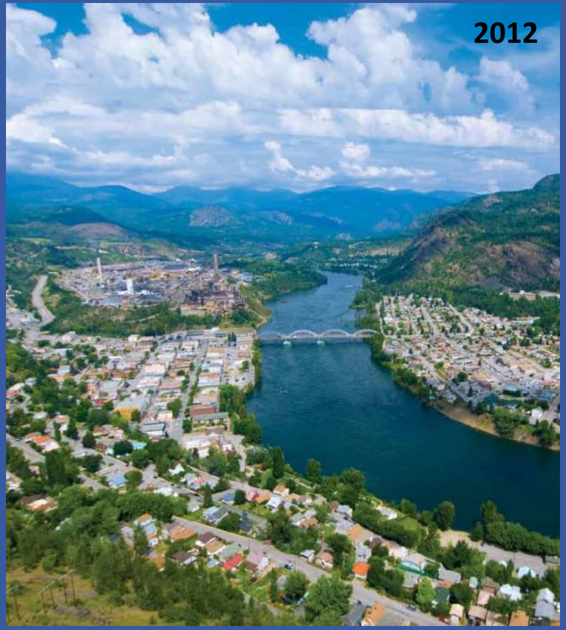
Cu concentrate – products, byproducts, byproducts/deleterious elements

Mo concentrate – products, byproduct

Smelting & refining – minor metals & recycling







Trail, BC

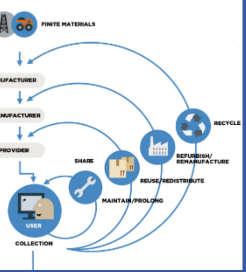
Mineral resources – a critical input

- Increasing metal demand – driven in part by SDG goals
- Efficiency and recycling – critical
- New resources will be required
- Responsible discovery, delivery and recycling
- Input to the circular economy – must be aligned with SDG goals

Joining up the value chain

new & recycled raw materials

Vision



- Mining – a valuable and responsible input
- Efficient use of metals and design of materials
- Sustainable use, capture and recycling of metals – minimum loss
- Completion of the circular economy
- Mining companies become metal/material suppliers/owners within an integrated circular economy

materials stewardship

Collaboration

- Challenges – complicated and complex
  - Maximize benefits and minimize impacts
  - Meet societal needs – metal use and ESG and SDG

Collaboration and partnerships – necessary

  - Indigenous people and communities, companies, technology providers and consumers
  - Different sectors and disciplines

HiTech AlkCarb, Italy, EU H2020 Grant Agreement no. 689909

Photos: F.Wall

HiTech AlkCarb, Malawi, EU H2020 Grant Agreement no. 689909