Mineral resources and sustainability

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Earth – a special place

- Living dynamic planet with an environment that supports life
- Earth processes concentrated resources – available for human use

Earth processes – metal concentration

Ocean floor vents – copper, zinc, gold, silver

Hot springs – gold, silver

Context

- Increasing demand
  - Human needs
  - Energy transition
- Constraints
  - Societal
  - Environmental – climate
- Responsible metal production
- Reduce – reuse – recycle

Human transition

- 1 to 3 billion people need
  - access to electricity – promotes education
  - heat without use of wood, charcoal, coal, dung
  - sanitation and clean water
- Requires energy and metals

Technology and the low carbon economy

- Technology
- Clean energy
- Transportation
- Complexity

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World Bank 2017: amount of metal required to deliver clean energy and efficient transportation (electric vehicles) to restrict climate change to 2°C or 4°C by 2050

Metal	% increase by 2050
Aluminum	207
Copper	174
Nickel	139
Lithium	1060
Cobalt	1060

What are the options

- Reduce demand/increase efficiency
  - Societal change, better products, substitution
- Find and develop new resources
  - At surface, below surface and at depth
- Increase/improve production at existing mines
- Change mining and develop new sources
  - New approaches
  - Natural resources – seafloor, space?
- Reuse and recycle – circular economy

Chuquicamata – the mine dilemma

- MMH – Chuquicamata – Radomiro Tomic zone
  - Annual production: ~3-4% of global mined Cu
  - Too deep – not economic
- Chuquicamata – underground by 2021
  - 140,000 tpd
  - Technological and societal/cultural challenges

Can we align mining and sustainability?

Supply – mines

- New discoveries
- Mine improvements
- New approaches
- New sources

New discoveries

- People
  - Traditional exploration
  - New tools and techniques
  - Data

Data generation

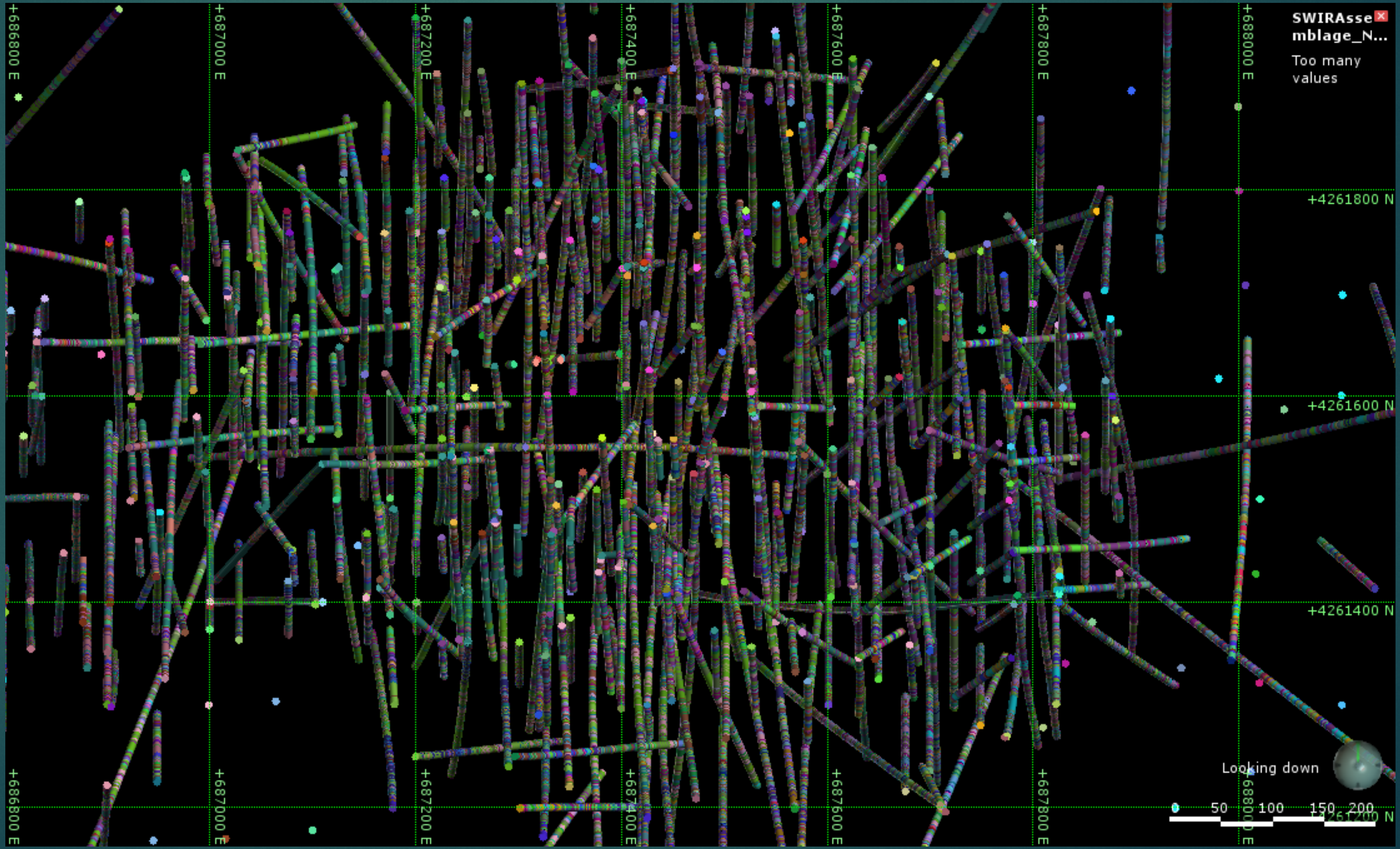
- Technology
- Drones to drills
  - More cheaper, faster drill holes = more discoveries

Data to knowledge

- Massive amounts of field, survey, and laboratory data
- Data integration and interrogation
  - Patterns, vectors, targets and conceptual ideas
  - Artificial intelligence (AI) and machine learning (ML)
- New and modified deposit models
  - Better understanding of complex ore systems

Kişladağ – alteration data

Spectral data – raw SWIR mineral assemblages

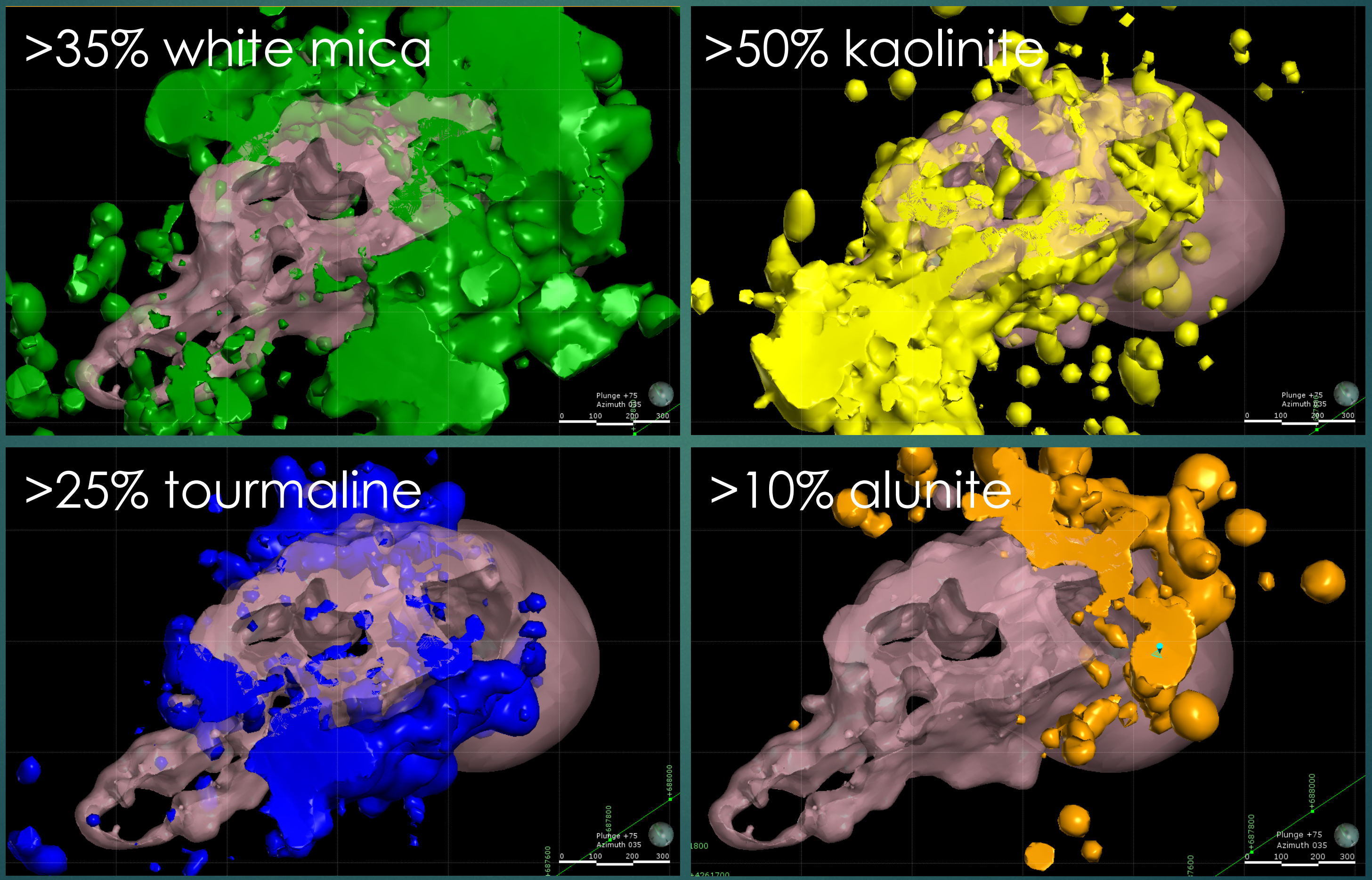


Eldorado Gold

Kişladağ – alteration mineralogy

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

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



300 m

* Artifical Intelligence Spectral InfraRed Interpretation System

Eldorado Gold and AusSpec

Mining: ongoing improvements

- Digital transformation
  - Automation
  - Grade engineering and sorting
  - Integrated operations
  - Transparency
- New approaches
  - In-pit crushing and conveying
  - Bulk underground mining
  - Mine-to-metal
- Waste reduction and management

Digital transformation

- Automation
  - Improved safety
  - More efficient
  - Lower energy

Grade engineering – sorting

Variability and real-time sensor-based data

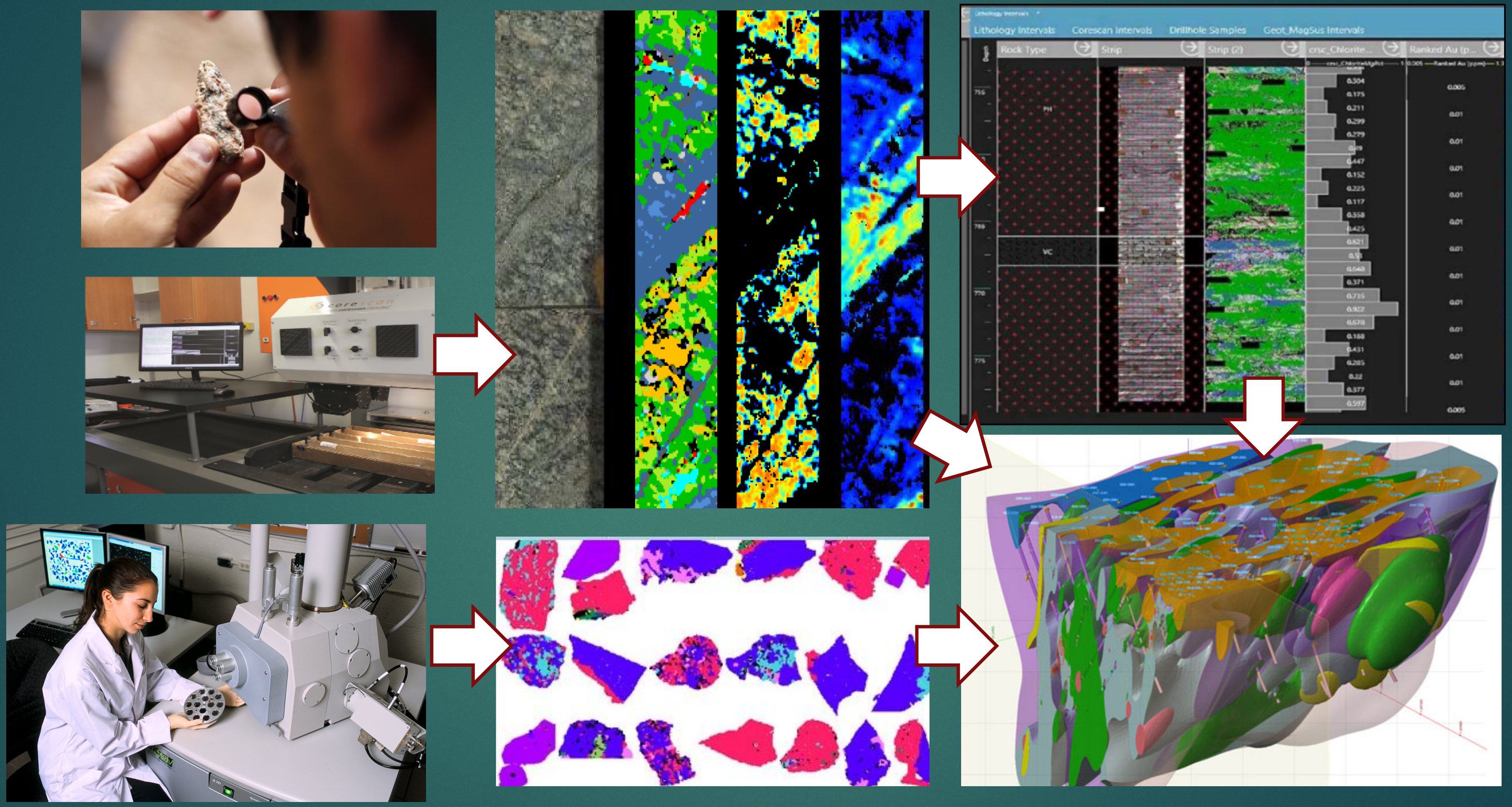
➡ Separate metal-rich rocks from waste

➡ Less rock processed, reduced tailings

➡ Lower energy

MineSense

Mapping variability – data to knowledge



Data collection → Interpretation → Integration → Understanding

Waste – Tailings

- Frequent disasters – unacceptable
- New management approaches
- Less waste

2015 Samarco, Brazil

2014 Mt Polley, Canada

2018 Brumandinho, Brazil

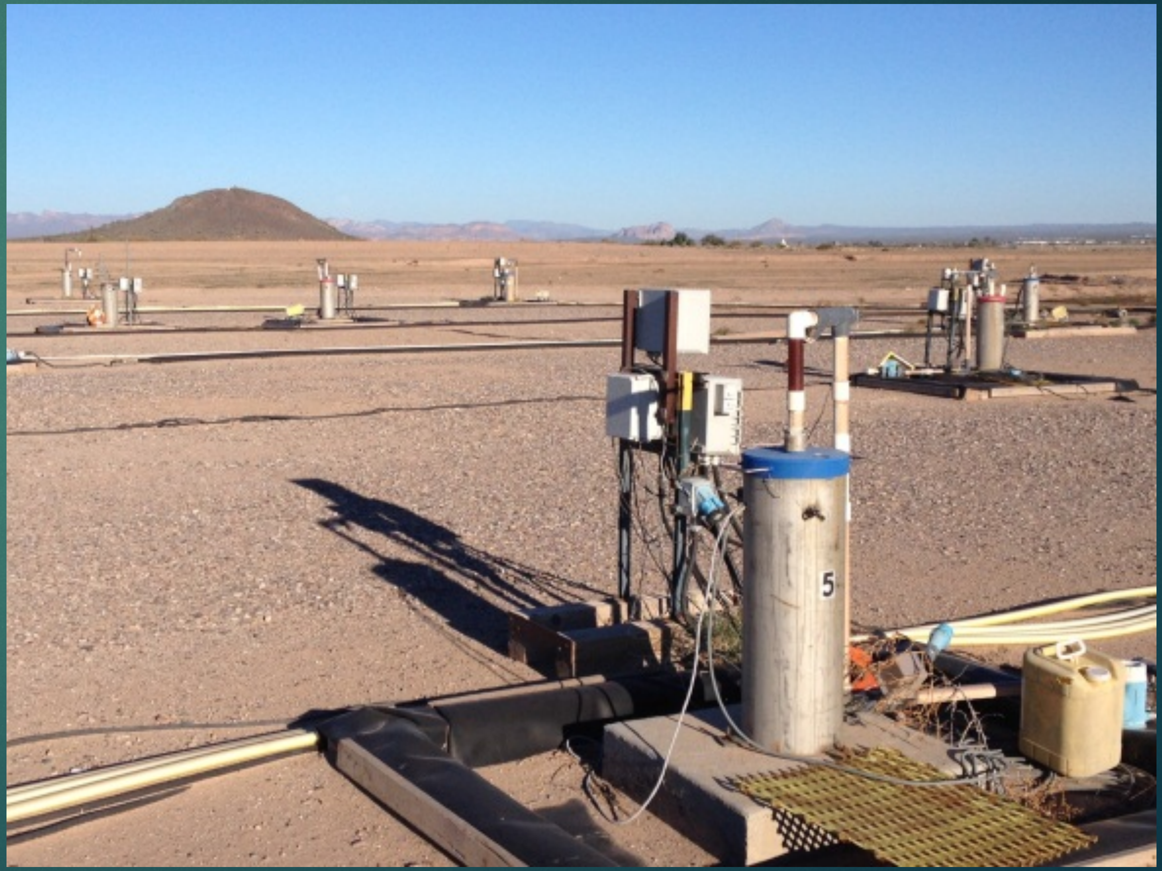
New approaches and solutions

- In-situ leaching
- Deposit clusters
- Land use mapping
- Recycling

In situ recovery

Dissolve the metals in place – underground

- Already used for potash and uranium
- Advantages
  - No mining – no waste
  - Low cost
- Challenge
  - Water management



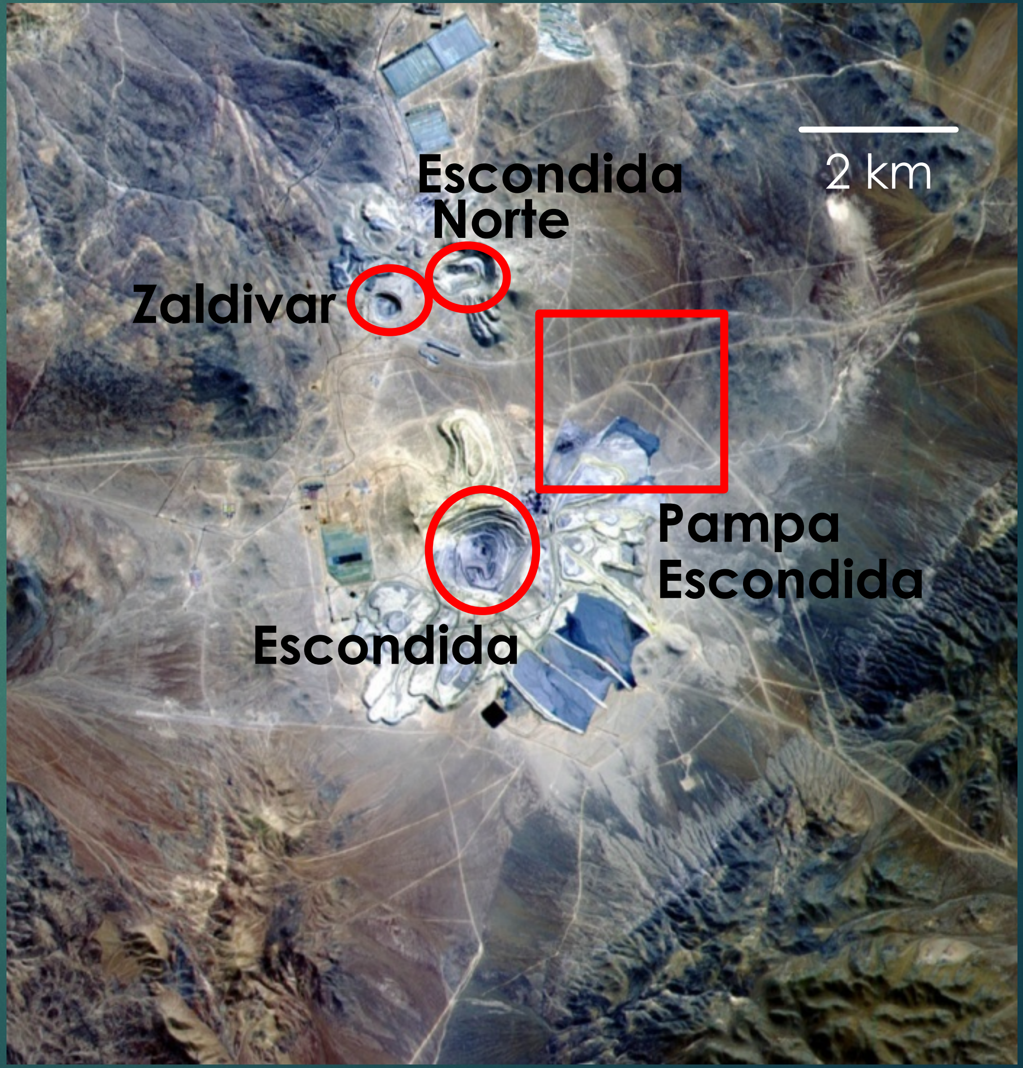
Deposit clusters

Escondida

- >1.27 Mt Cu/yr (~5% of global production)

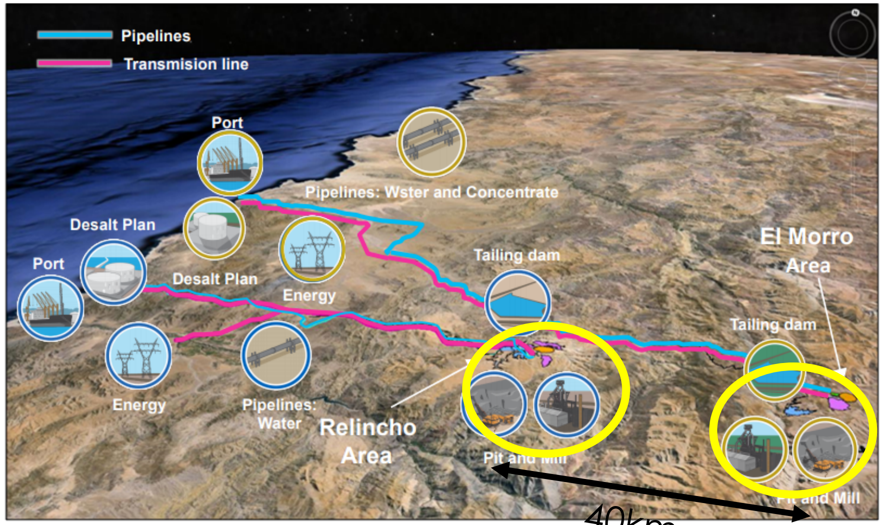
Escondida cluster

- Cluster: 4 separate deposits, 3 mines, 4 major owners (2 joint ventures)

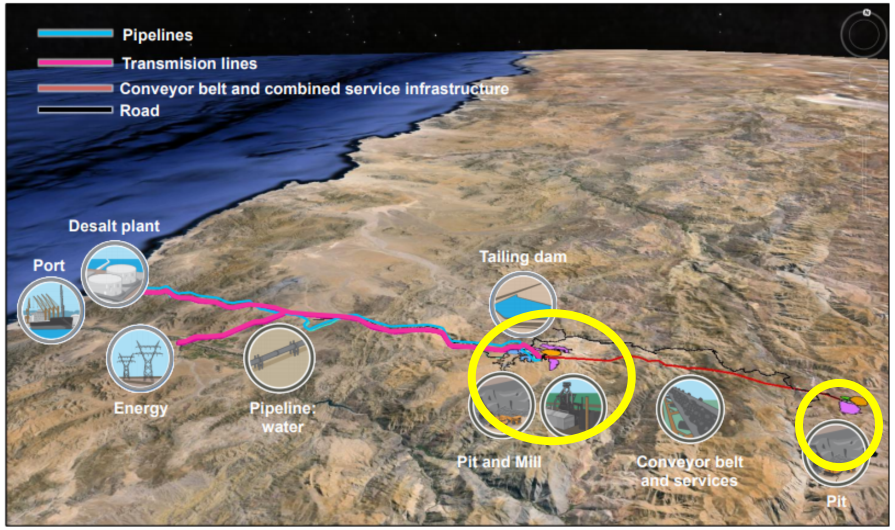


NuevaUnión project, Chile

- Two deposits – two owners
  - Newmont: El Morro Cu-Au
  - Teck: Relincho Cu-Mo
- 2015 Agreement – one operation
- Single mill, tailings facility, port, transmission line, water and concentrate pipeline and access road
- Minimizes impact



Fuente: "Ubicación de Proyecto." -28.395839, -70.486738, 4679ft. **Google Earth.**
8 de febrero de 2015. 23 de abril de 2015.



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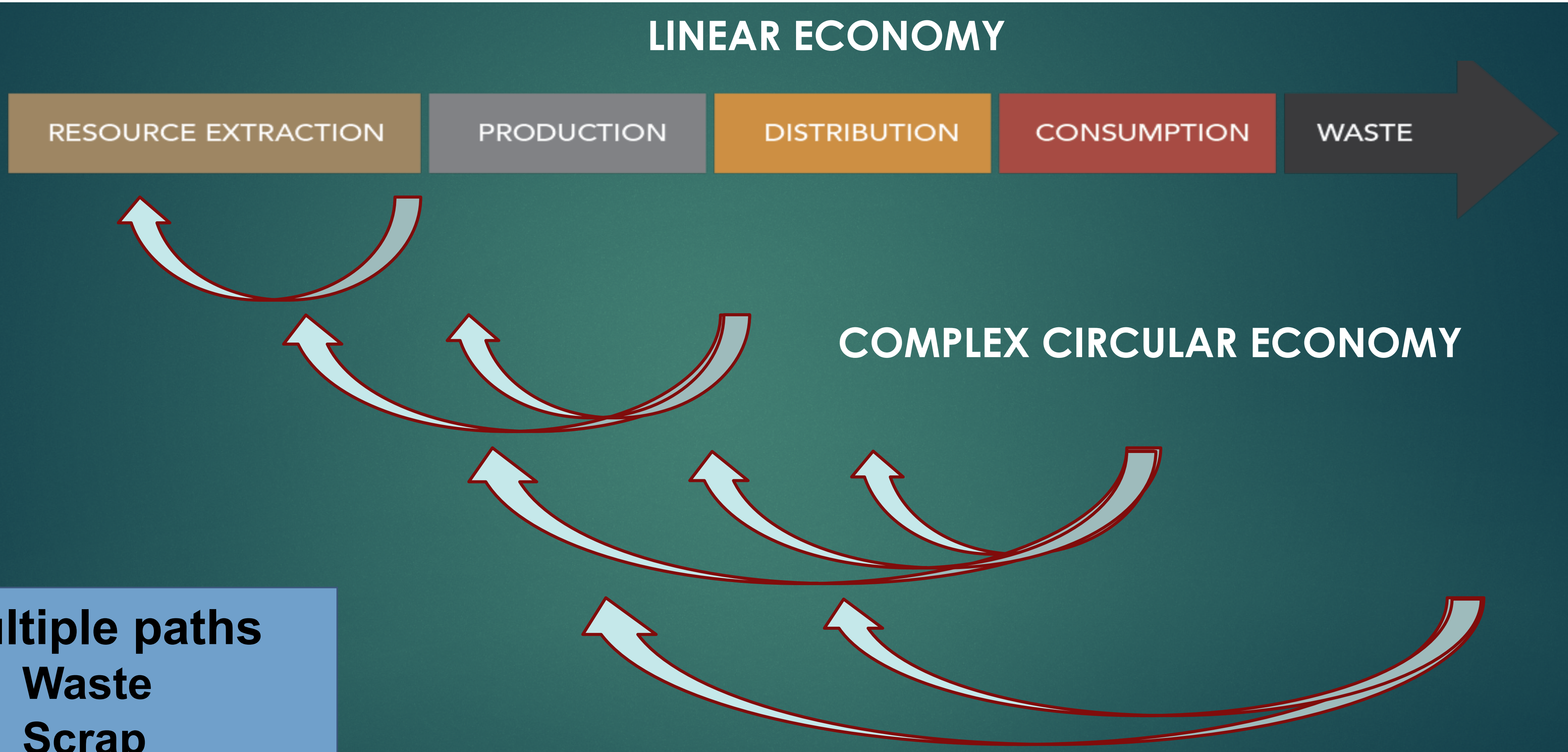
Facilitated by landscape-scale data

- Landscape scale data
  - 3D geology
  - Surface and biosphere
  - Culture and heritage
  - Human activity

Plan and design development

- Maximize "value" for all
- Minimize cumulative impact

Waste Management in a Circular Economy



Multiple paths

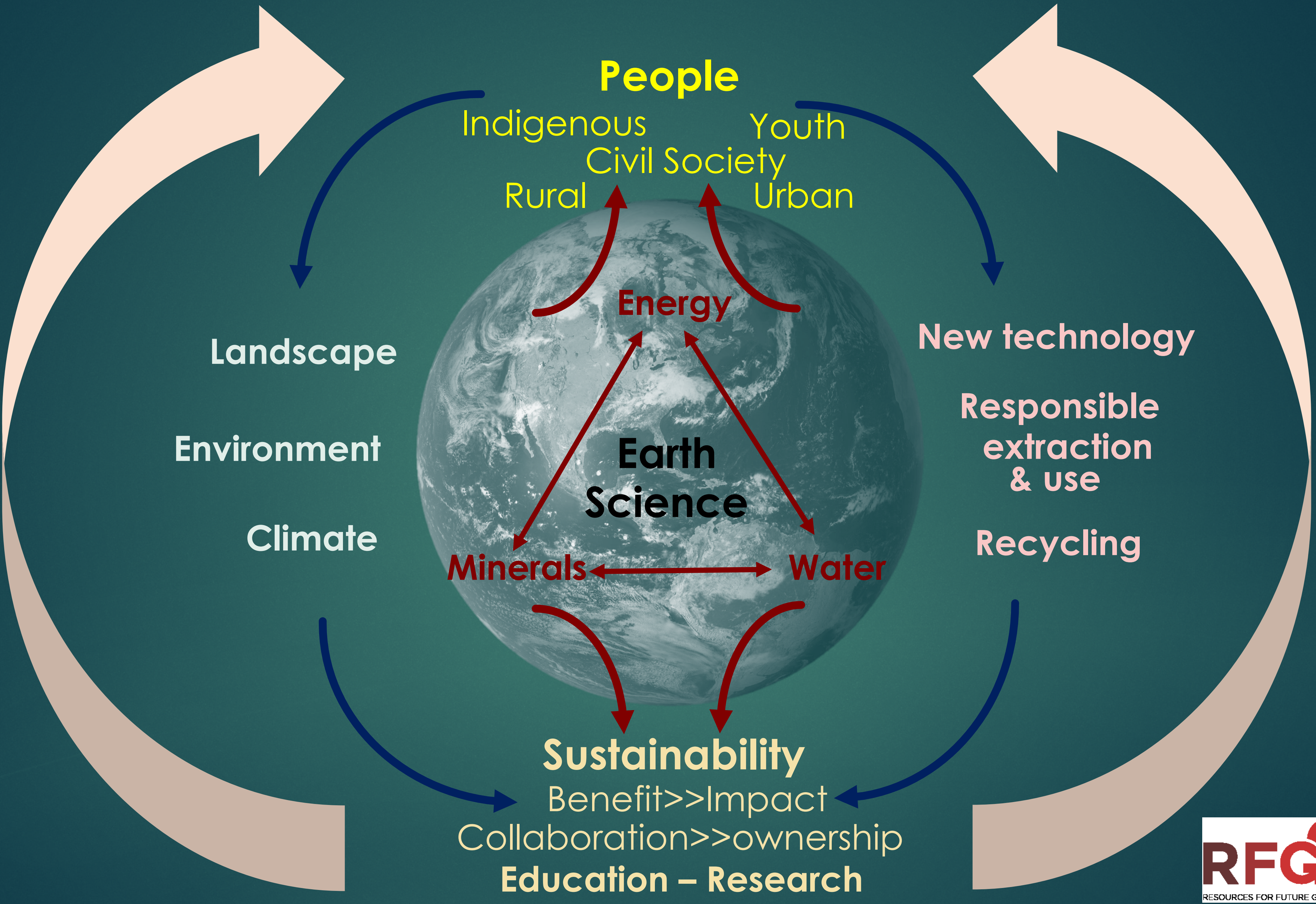
- **Waste**
- **Scrap**
- **Products**

Recycling record

- Lead
  - 99% of lead acid batteries recycled – developed world; >50% globally
- Aluminum
  - 30-85% total recycling globally
- Steel
  - 40% of global market from recycling
- Copper
  - Recycled scrap (old and new): ~30% of global market
- Zinc
  - Limited to batteries and some galvanized steel
- E-waste: precious and specialty metals
  - Limited – phones, computers, flat screens, solar panels….

Conclusions

- Demand for metals will continue
  - Watch for "peak demand"
- Short-medium term solutions – "mine of the future"
  - New discoveries of quality deposits
  - Responsible mines: clean, efficient – reduced, managed and reused waste
  - Transparent and collaborative partnerships
- Integration with products and consumers
- Driving towards the circular economy



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