Distal Footprints of large ore systems – the challenge of exploring through cover and the role of AEM

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CESRE / Minerals Down Under Flagship
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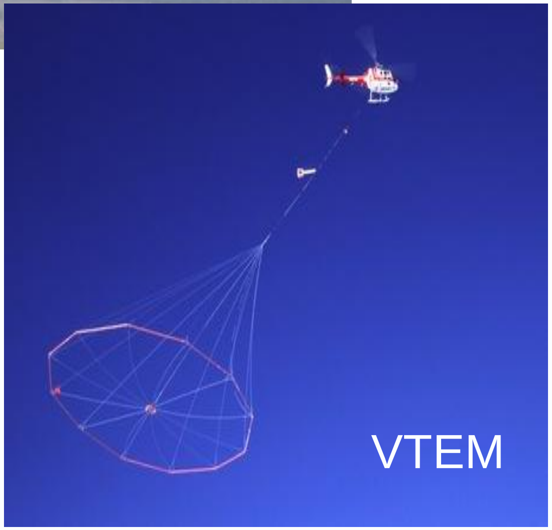
ASEG-WA AEM Workshop

A slide of AEM Systems......we have used.....



UNCOVER

AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH

SEARCHING THE DEEP EARTH

A VISION FOR EXPLORATION GEOSCIENCE IN AUSTRALIA

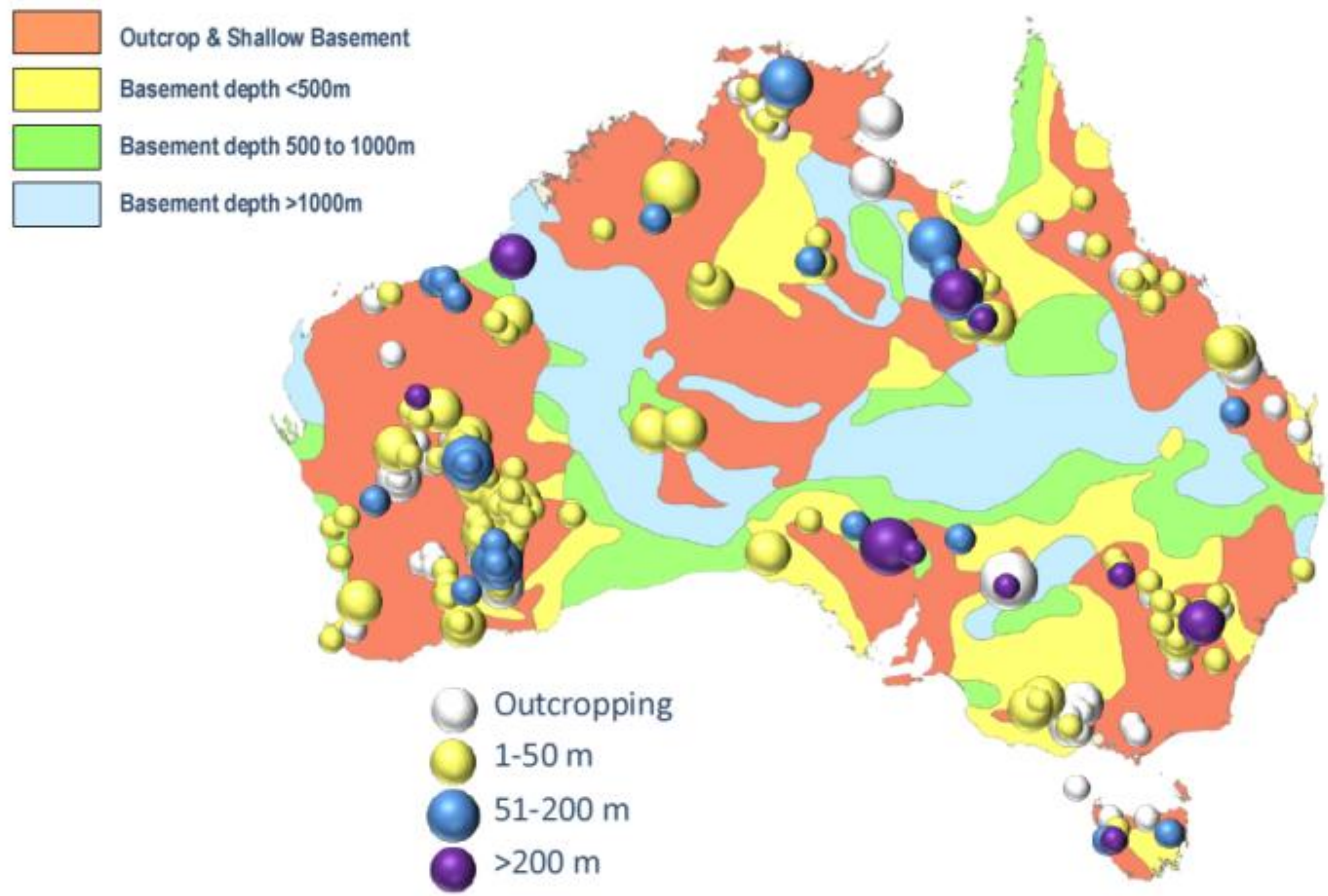
Prepared by UNCOVER under the aegis of the Australian Academy of Science

Exploration Challenge for Australia

1. Over the last century, exploration success for new economic mineral deposits in Australia has declined sharply.
2. Our economy is reliant on mineral discoveries dating well back into the 20th century.
3. These deposits are being depleted much faster than the discovery rate for new deposits.
4. The decline in exploration success is, in large part, due to the difficulty in exploring what lies beneath the regolith and sedimentary basins that cover approximately 80 per cent of Australia
5. We need improved predictive and detection capabilities for searching under cover to build investment confidence

Source: Searching the deep earth *A vision for exploration geoscience in Australia; 2012*

Cover – the Australian challenge

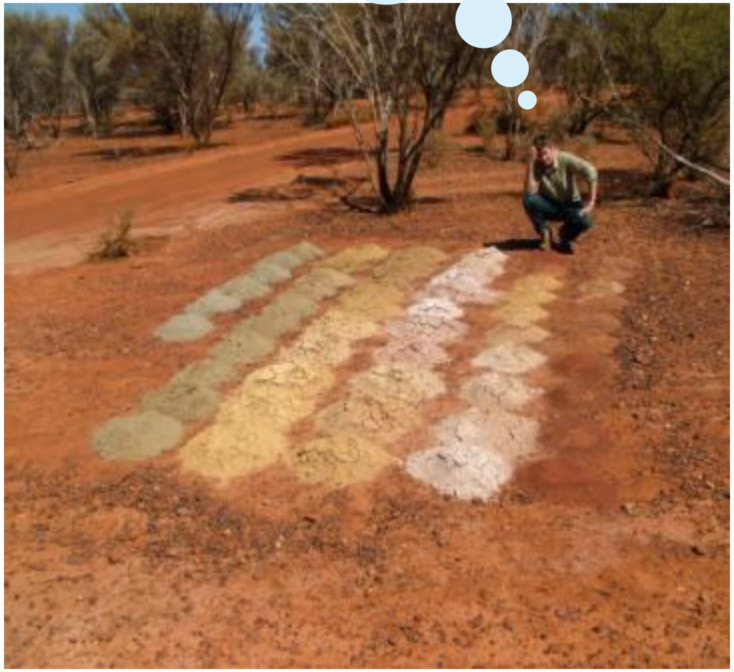


Note: Major defined as >1 moz Au, >1mt Cu, > 100kt Ni or equivalent
Excludes Bulk Minerals such as Coal, Bauxite and Iron Ore

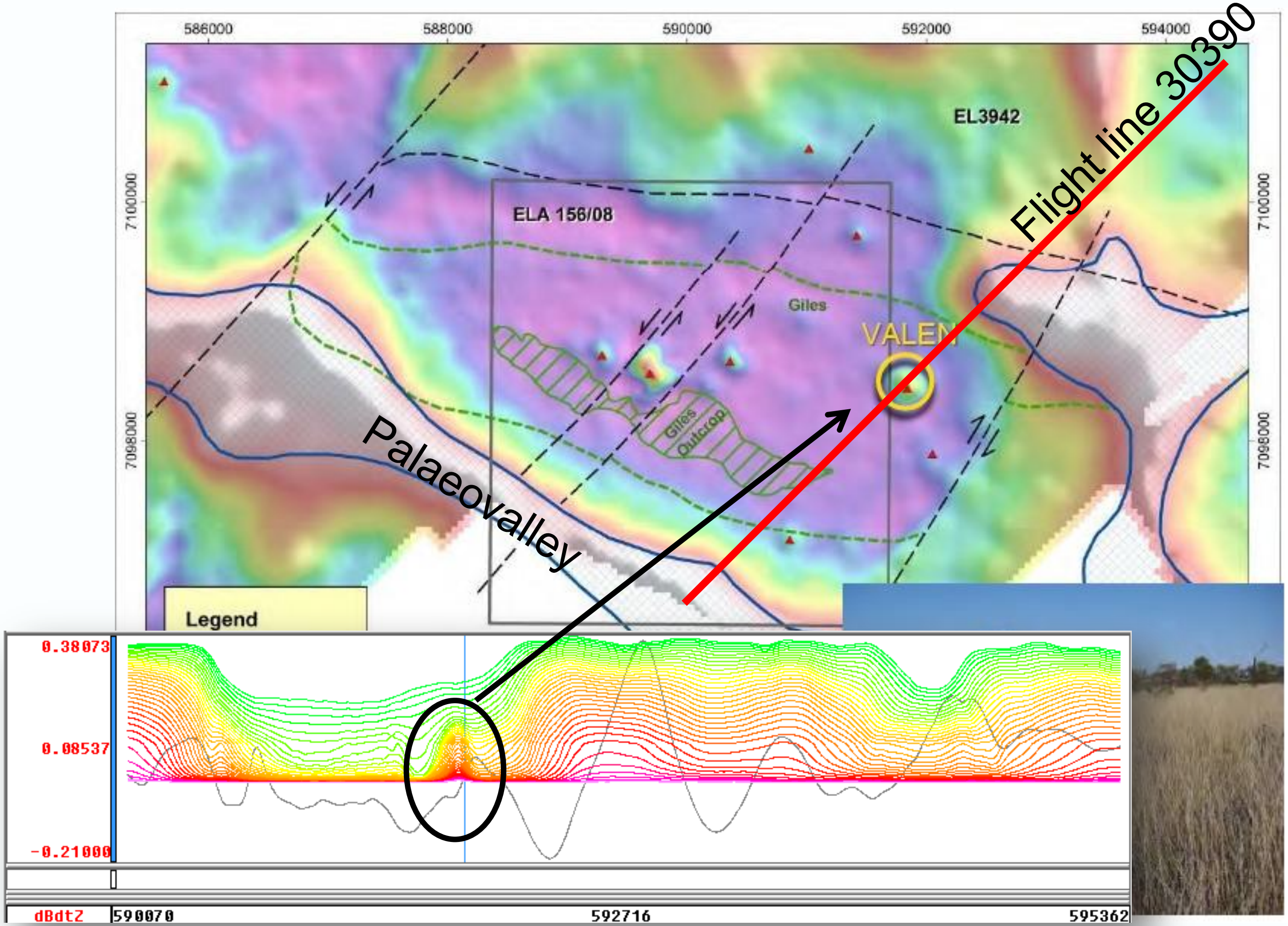
Sources: MinEx Consulting August 2010
Geoscience Australia

Regolith – in-situ and transported

Ships! ?
.....Where
is the rock?



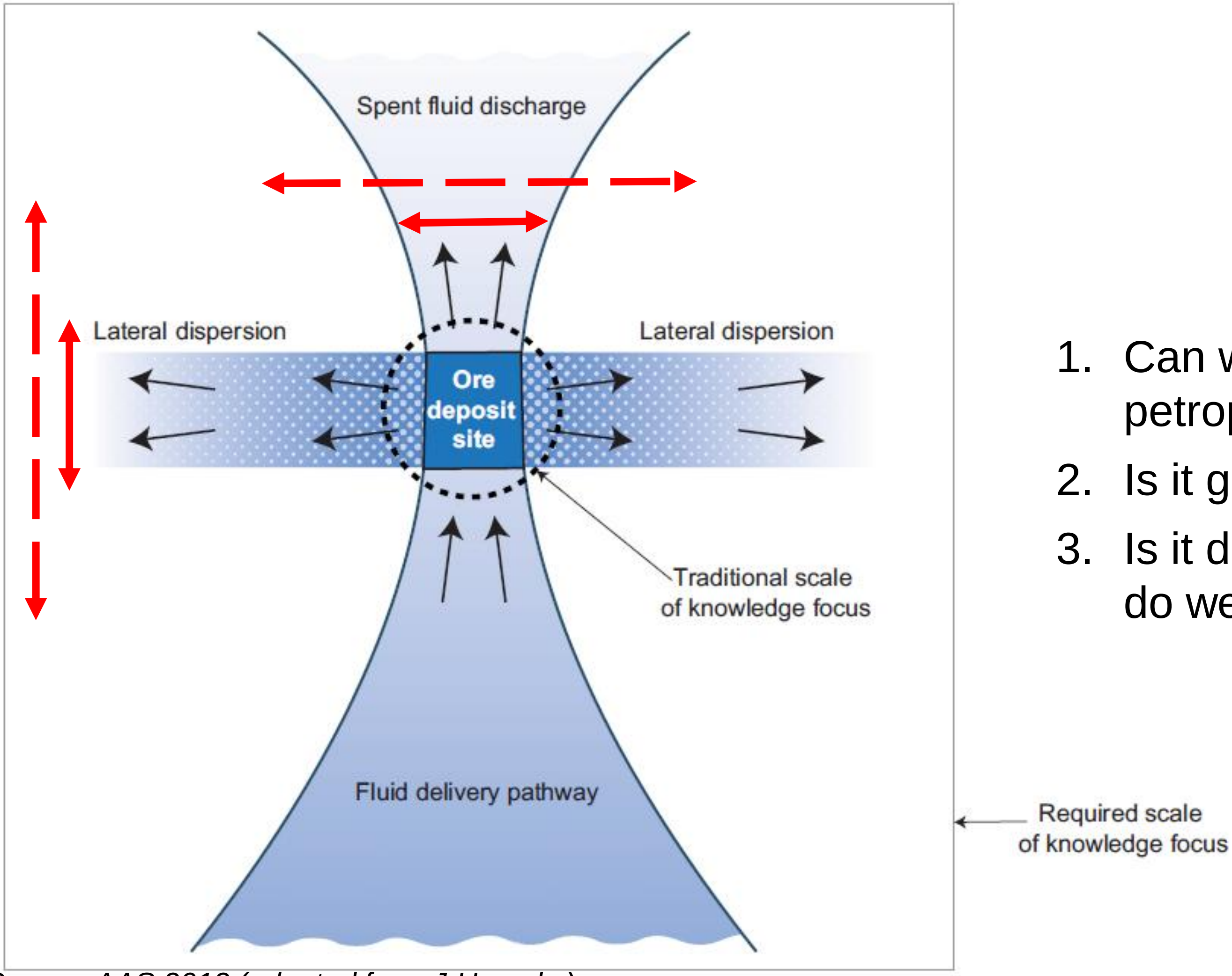
AEM late time anomalies



- VTEM Late time channel
- Late time anomaly

  i. Follow it up with ground EM,
  ii. Model it
  iii. Drill it…..

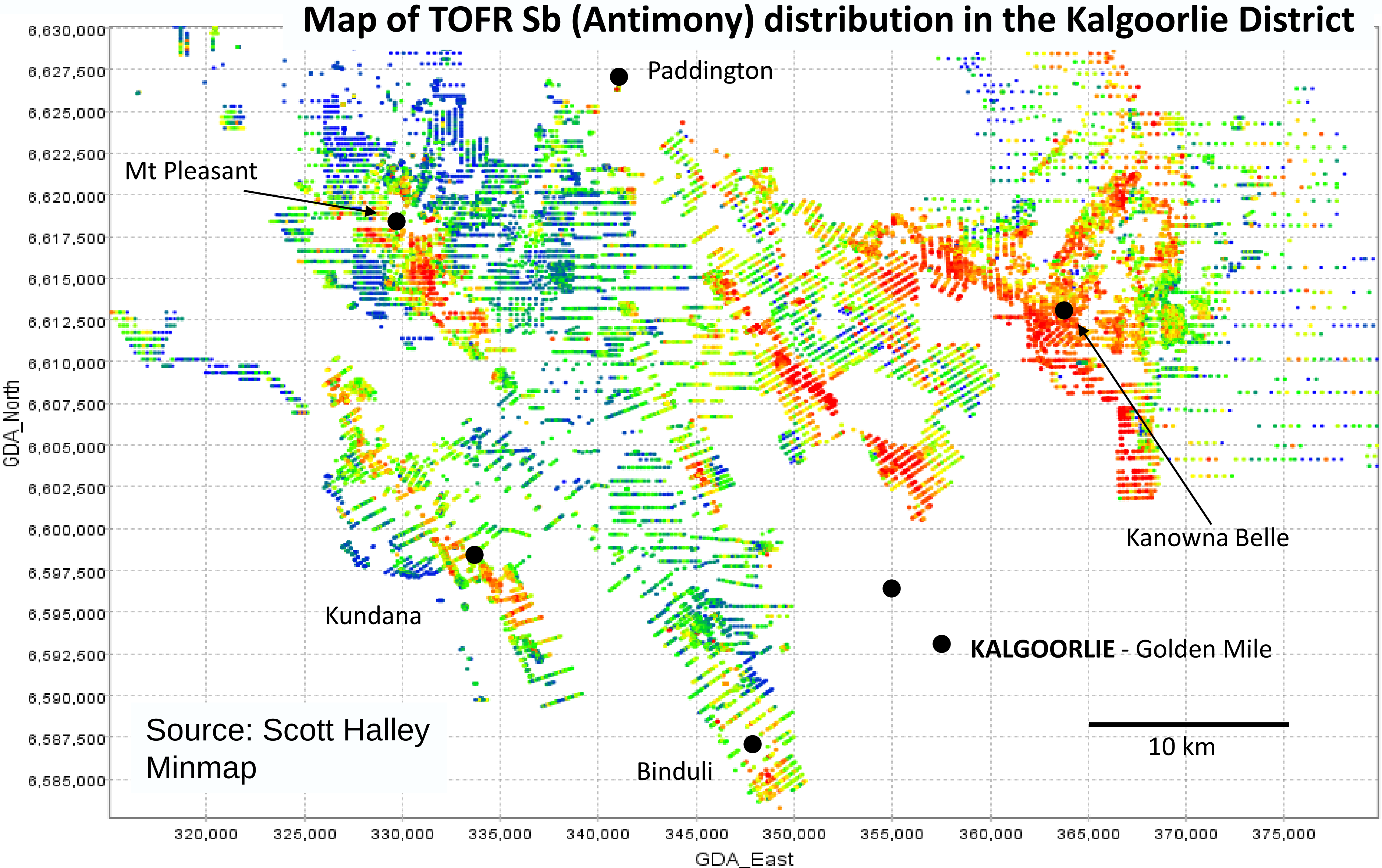
Expand our search footprint



Source: AAS 2012 (adapted from J Hronsky)

1. Can we see a larger petrophysical footprint?
2. Is it gradational?
3. Is it detectable and what do we need to detect it?

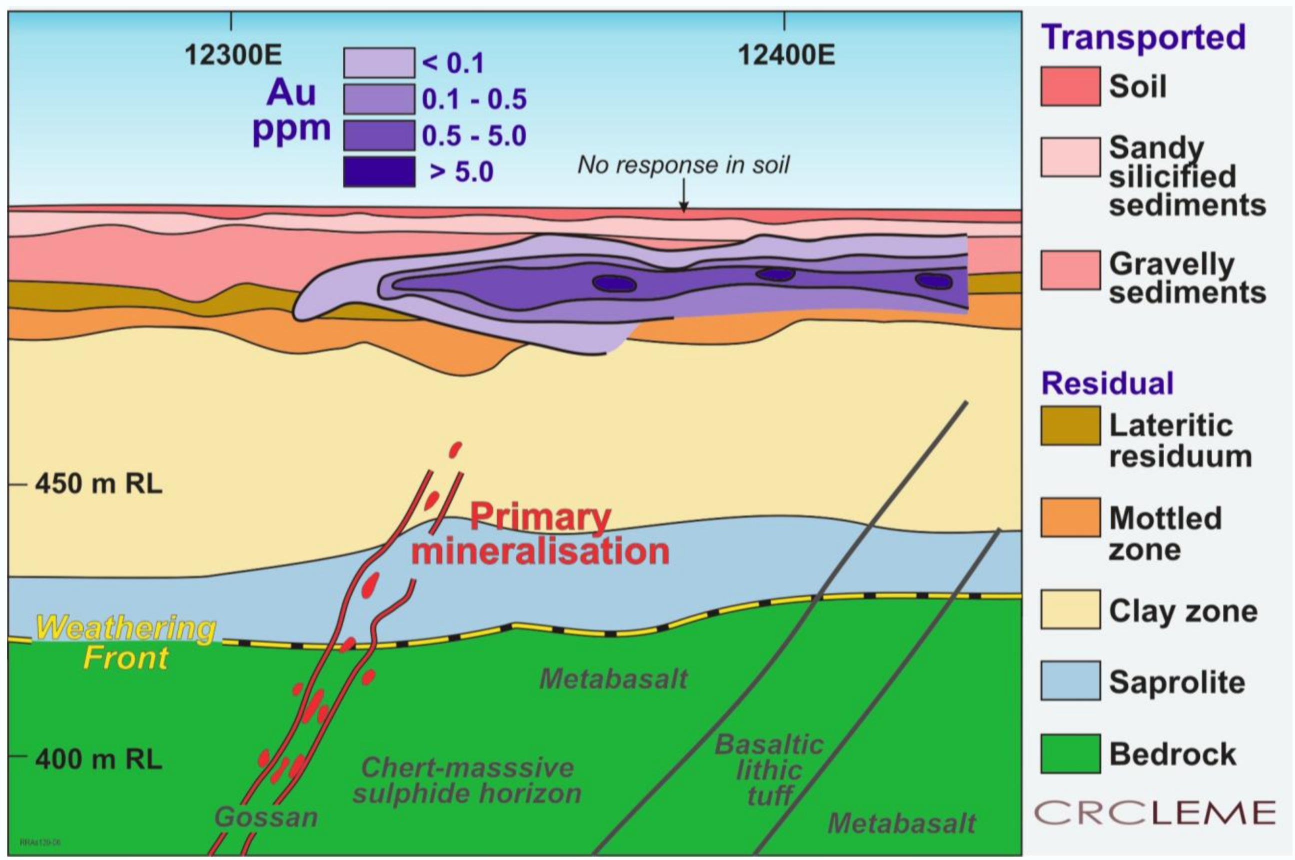
Geochemical/Mineralogical footprints – is there a petrophysical one?



Cover issues

1. At a minimum, cover represents a barrier that masks the detectable signature of mineral systems……but it can act as:

a valuable dispersal medium in a mineral system, expanding the potential geographic footprint of a buried resource

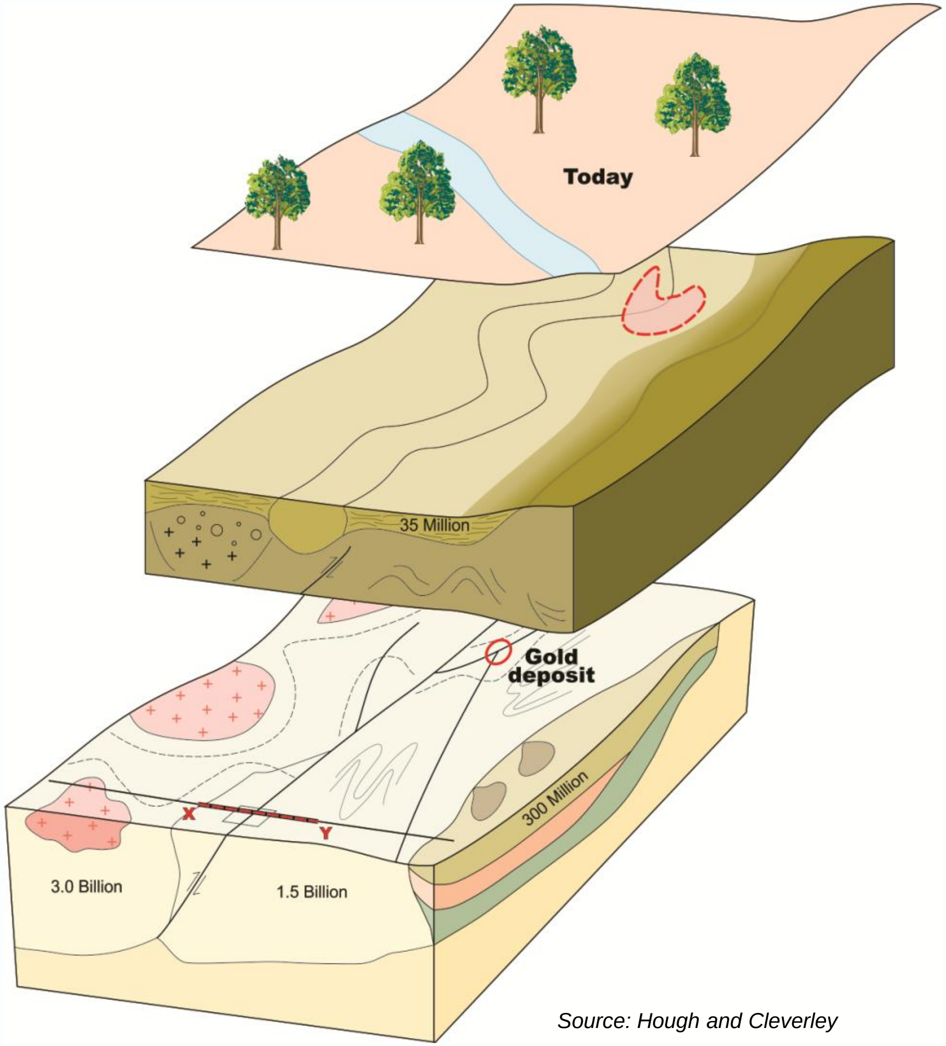


Cover issues (cont.)

Needs:

Targeted characterisation of

- *depth,*
- *physical, mineralogical and chemical nature*
- *geometry & variability of cover*
- *the processes that formed modified it (age etc)*



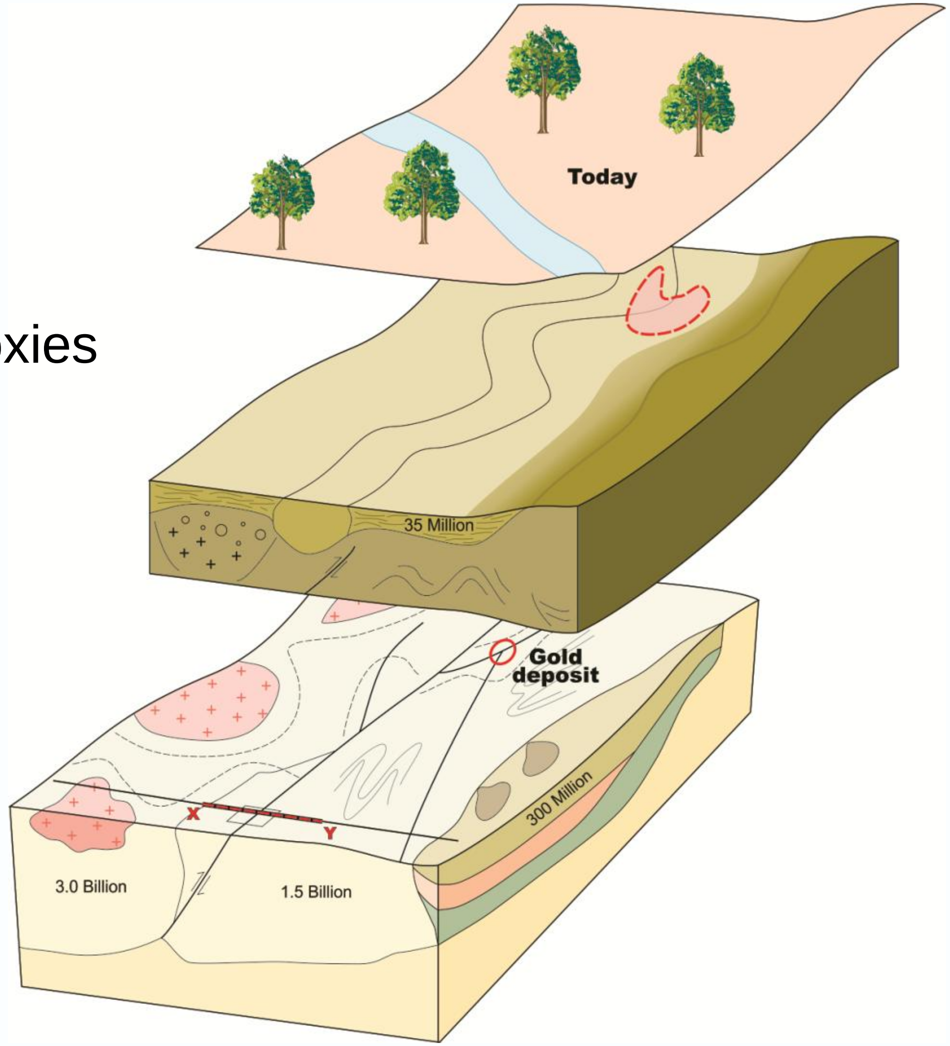
Source: Hough and Cleverley

AEM and Cover

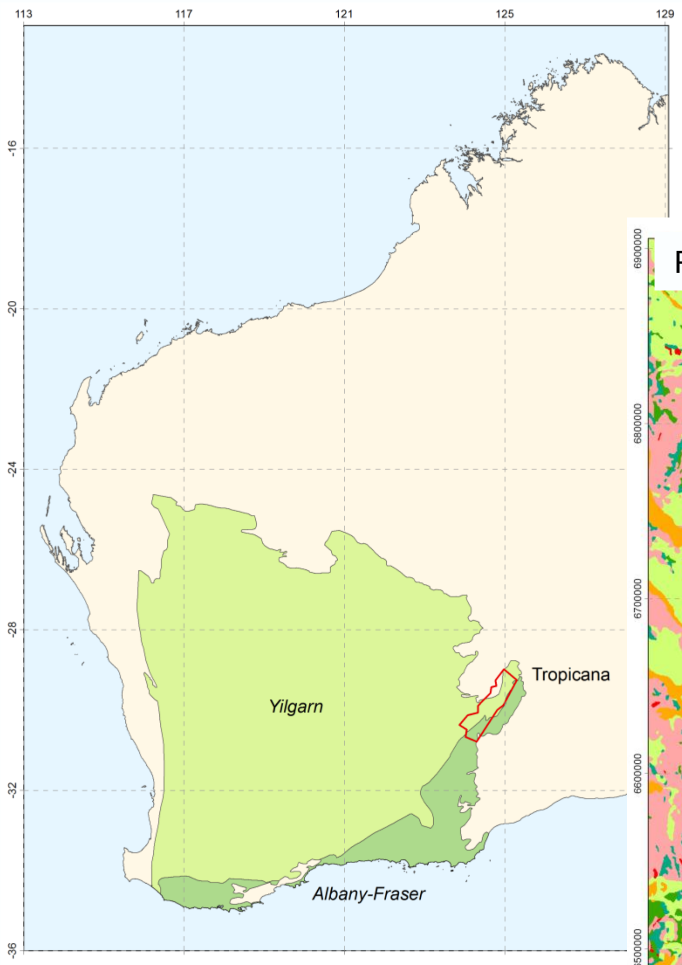
Deep Exploration Targeting

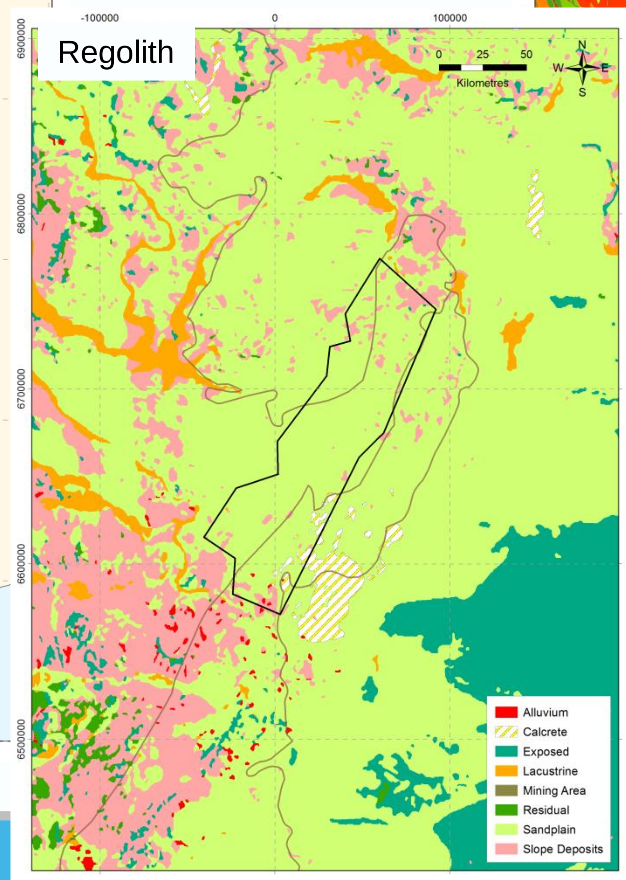
Spatial proxies
- *Thickness*
- *Variability*

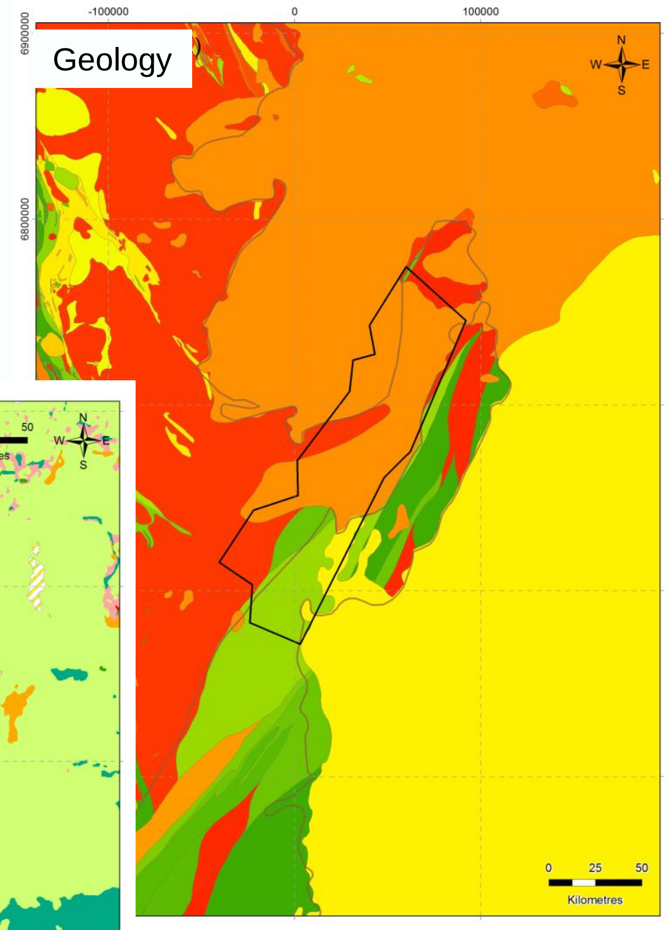
A New Search Space



How does the cover vary?

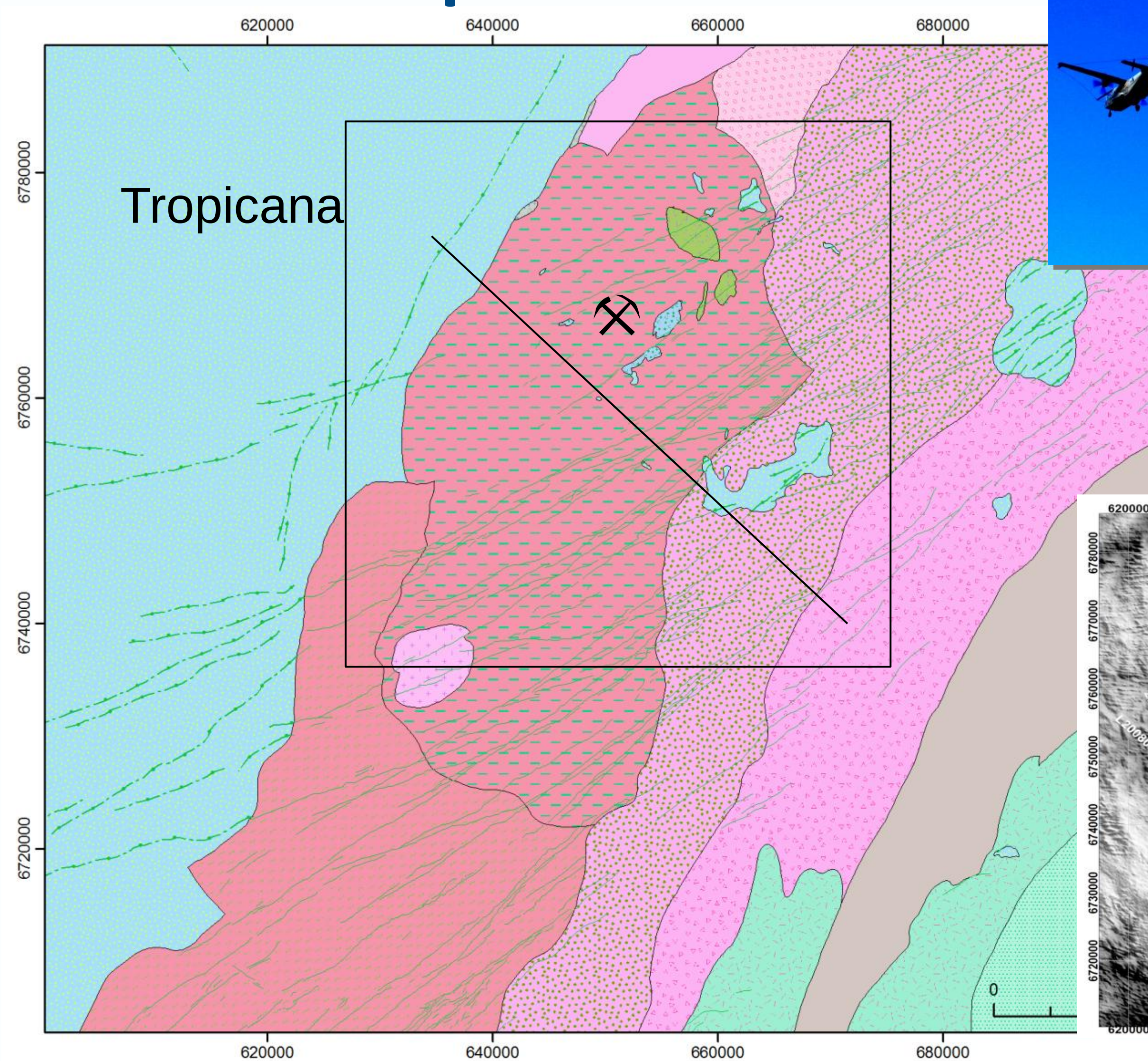




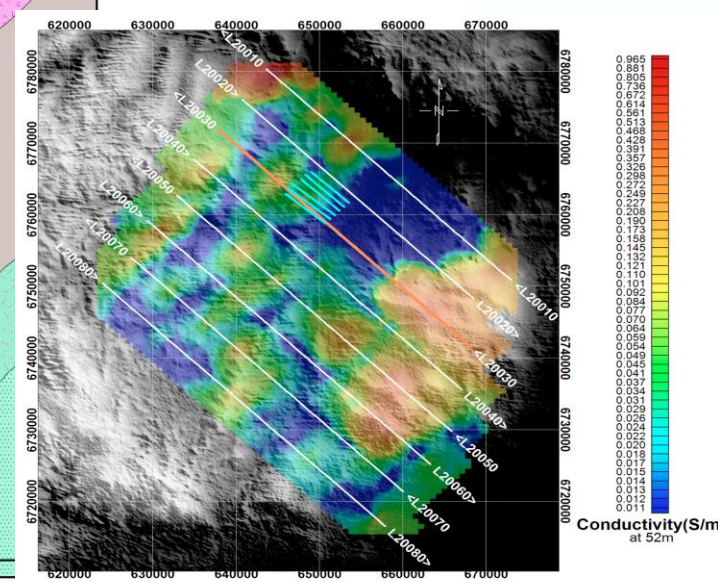


On the ground

Bedrock – Tropicana Area

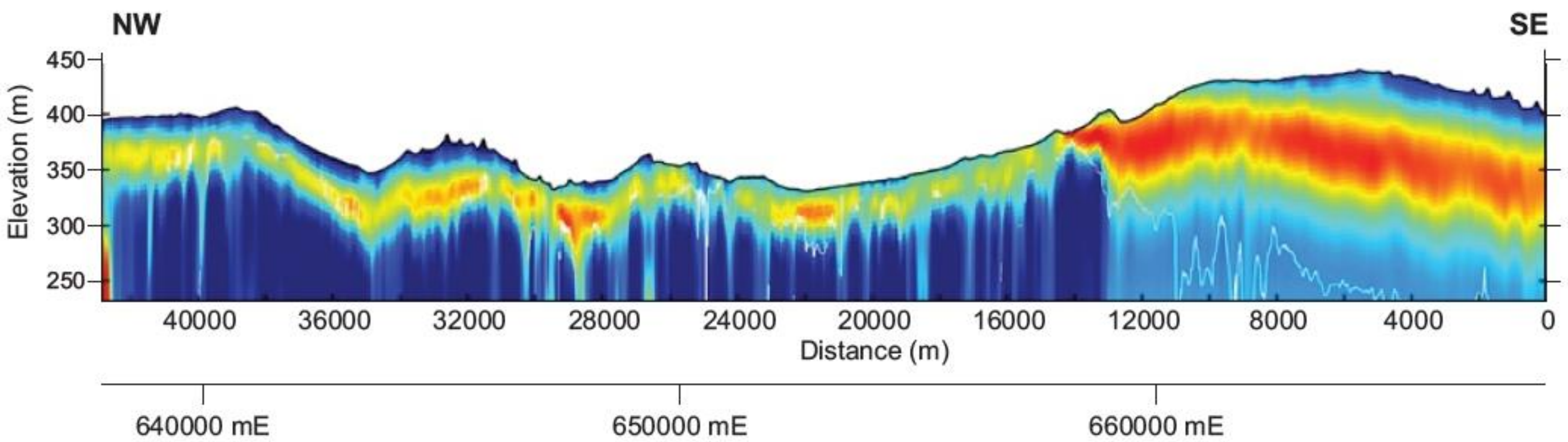


TEMPEST AEM data

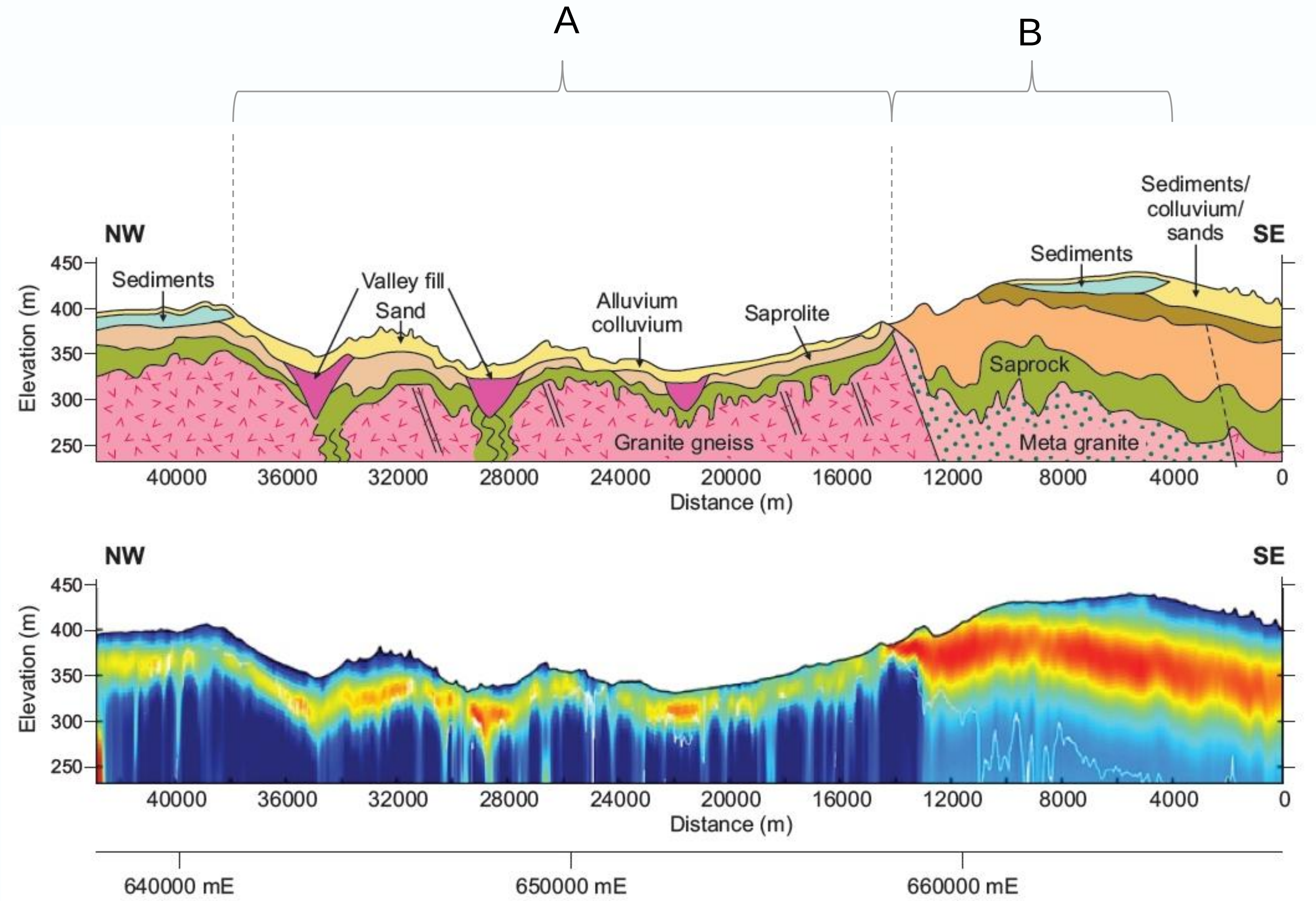


Working Though Cover

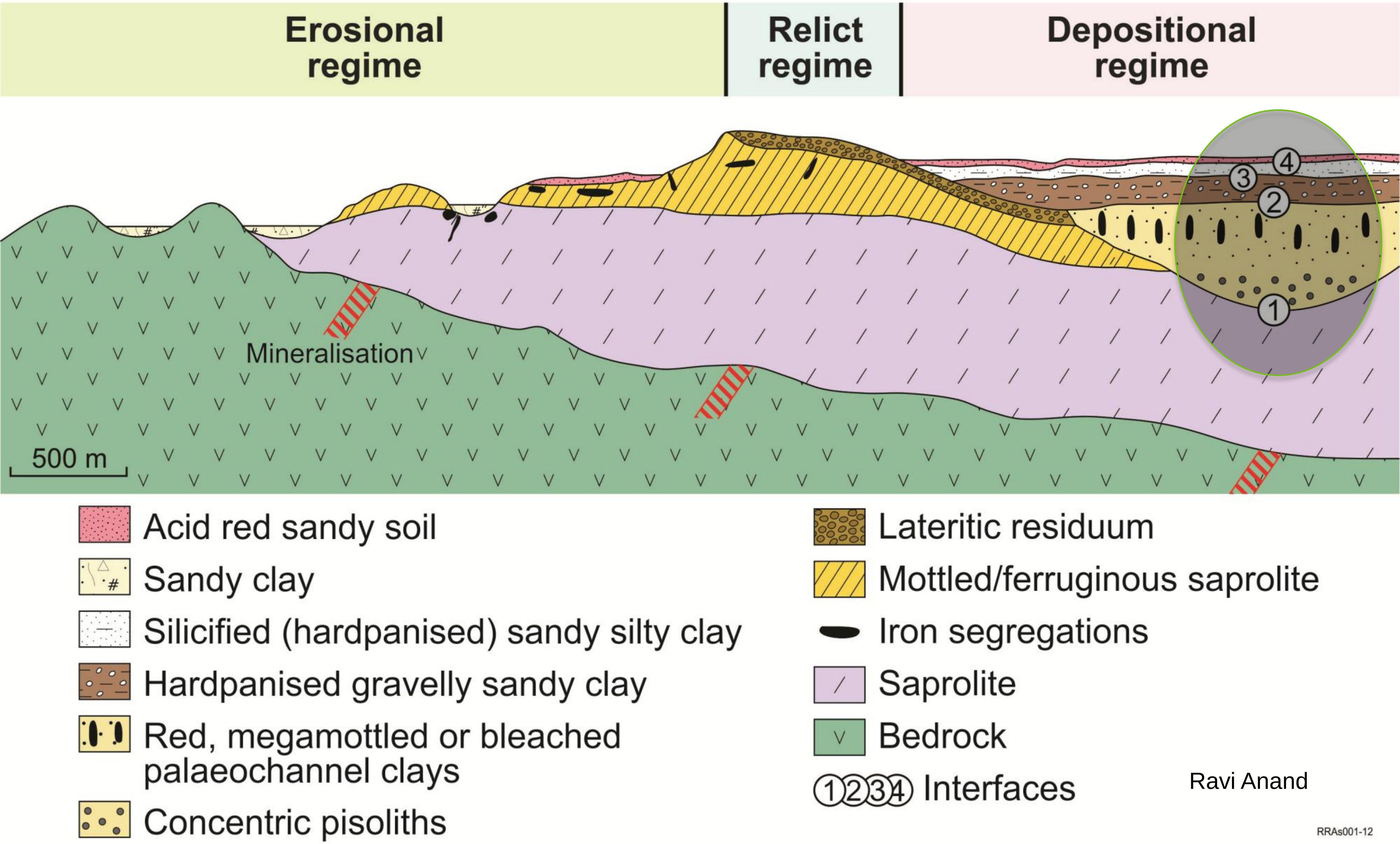
- A 1D SBS inversion



Mapping and Working with Regolith Complexity

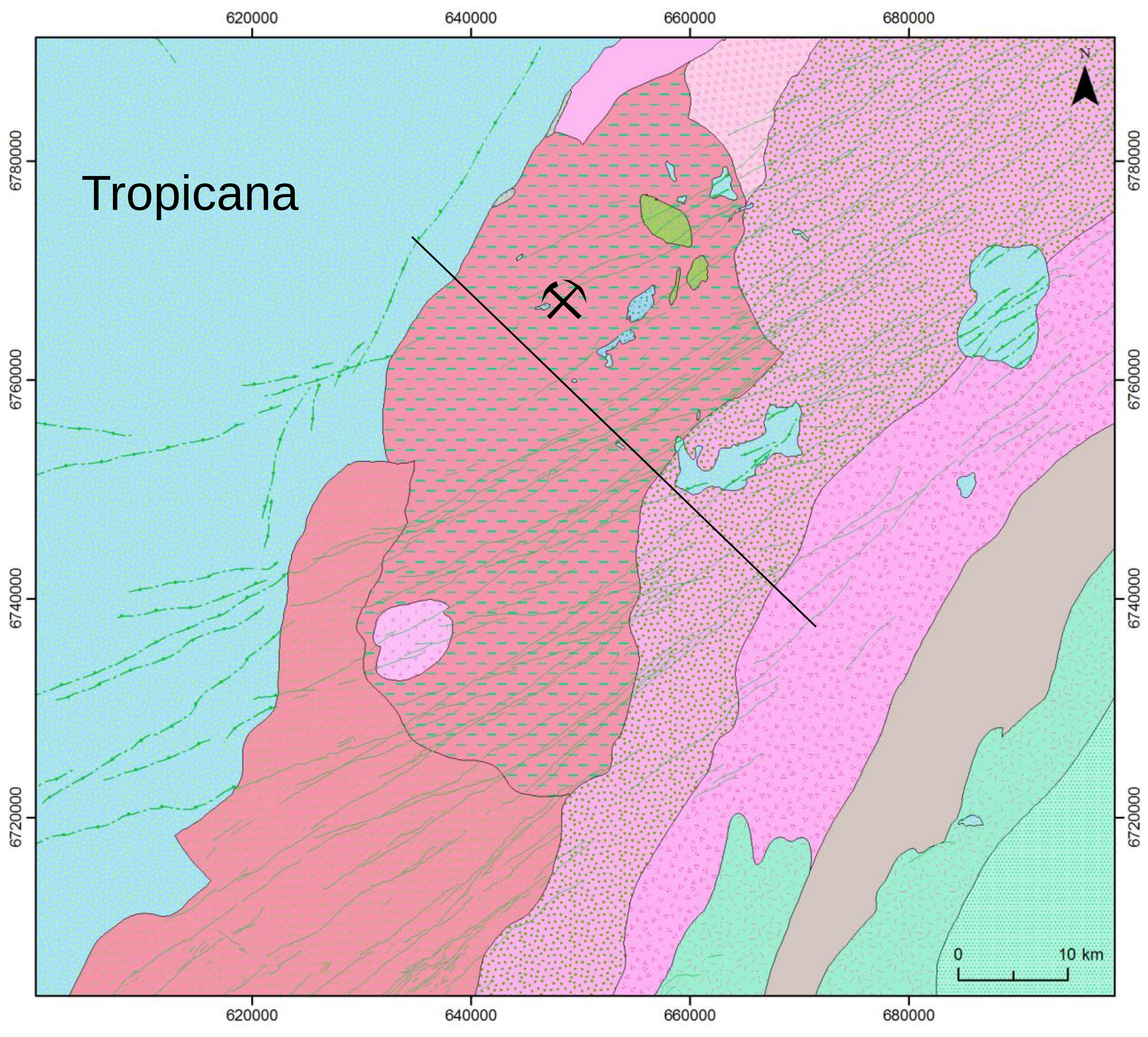


Exploration in various regolith settings

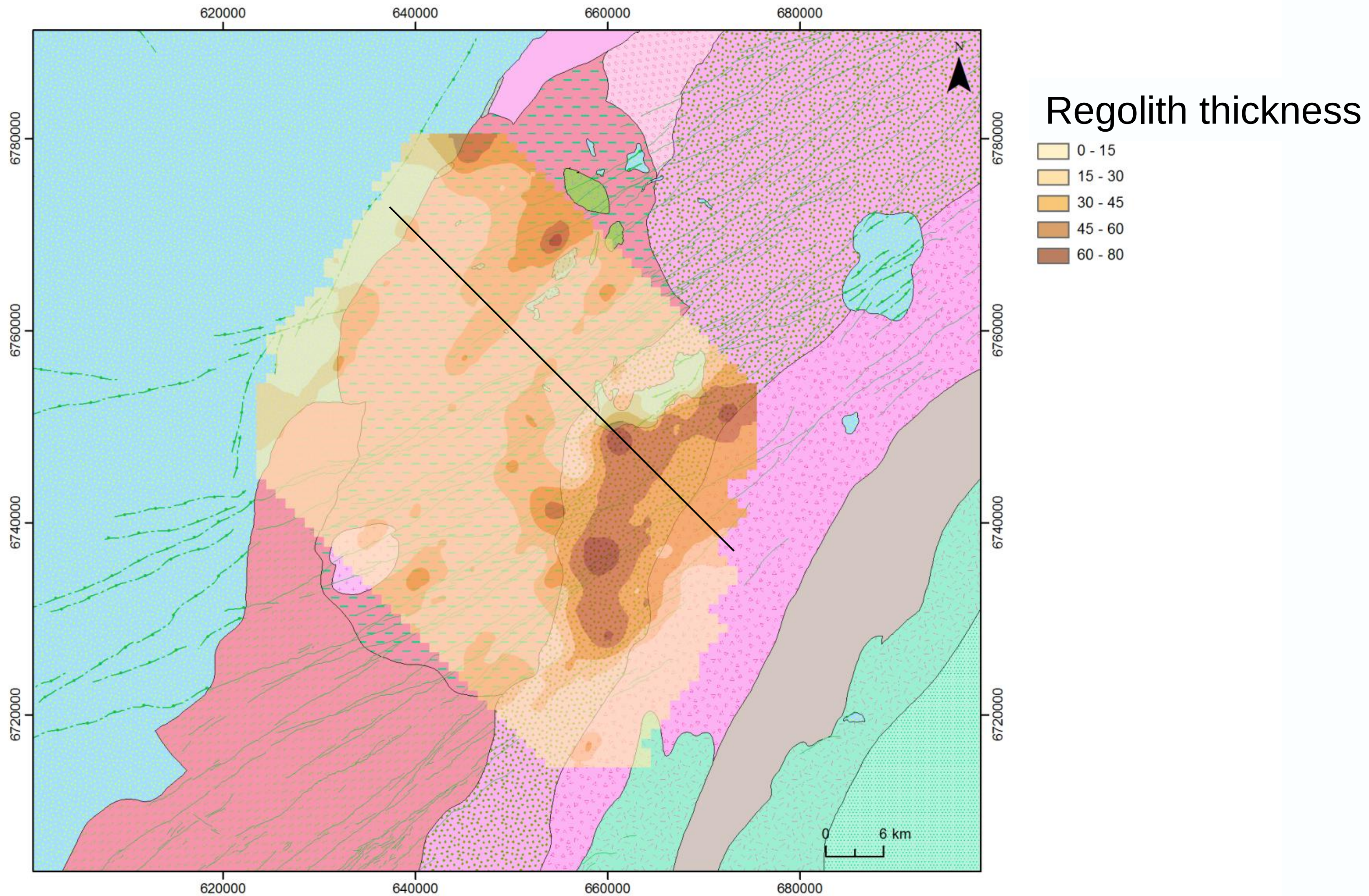


Ravi Anand

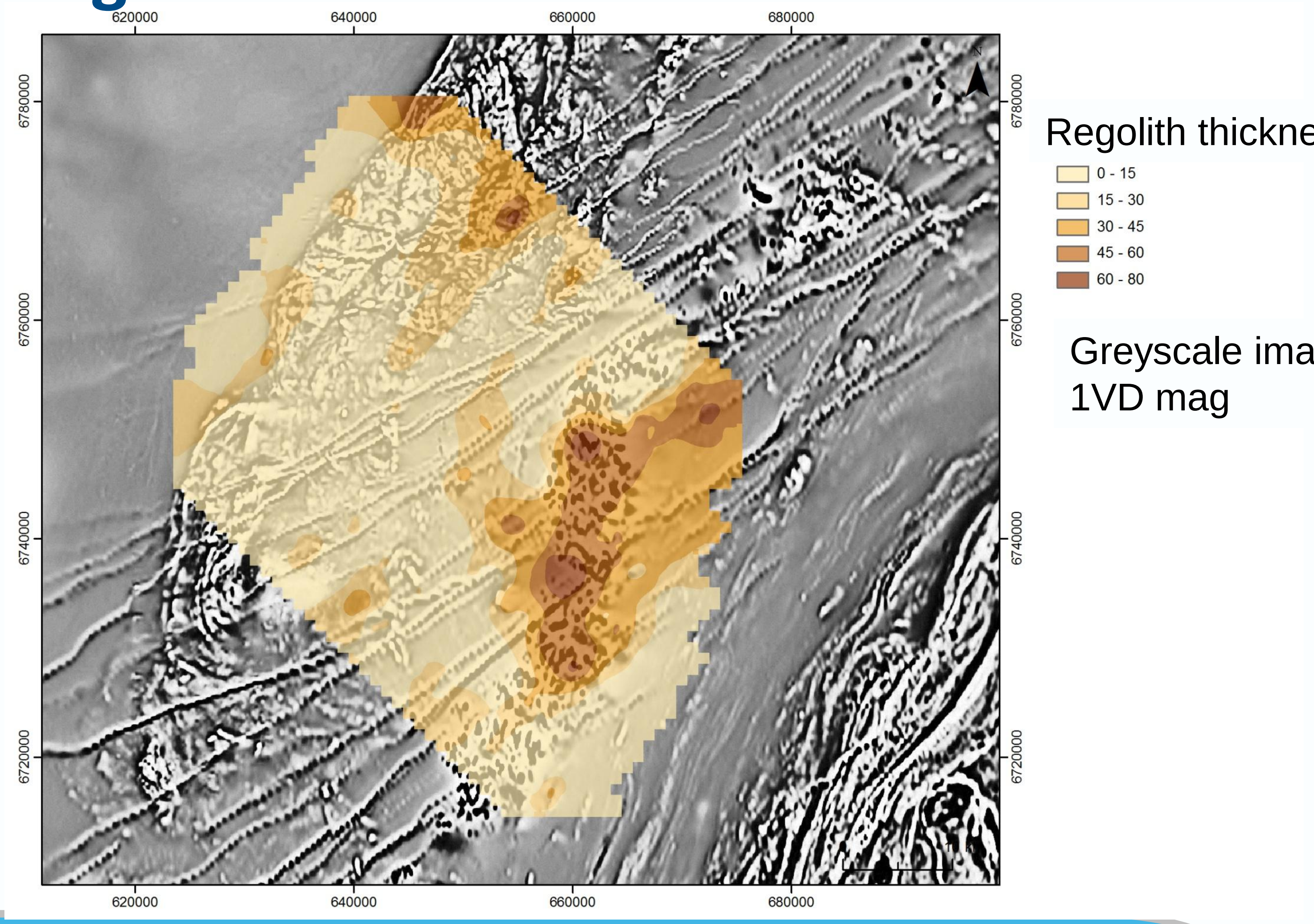
Bedrock – Tropicana Area



Spatial Proxy - Regolith Thickness



Regolith Thickness & Lithostructure

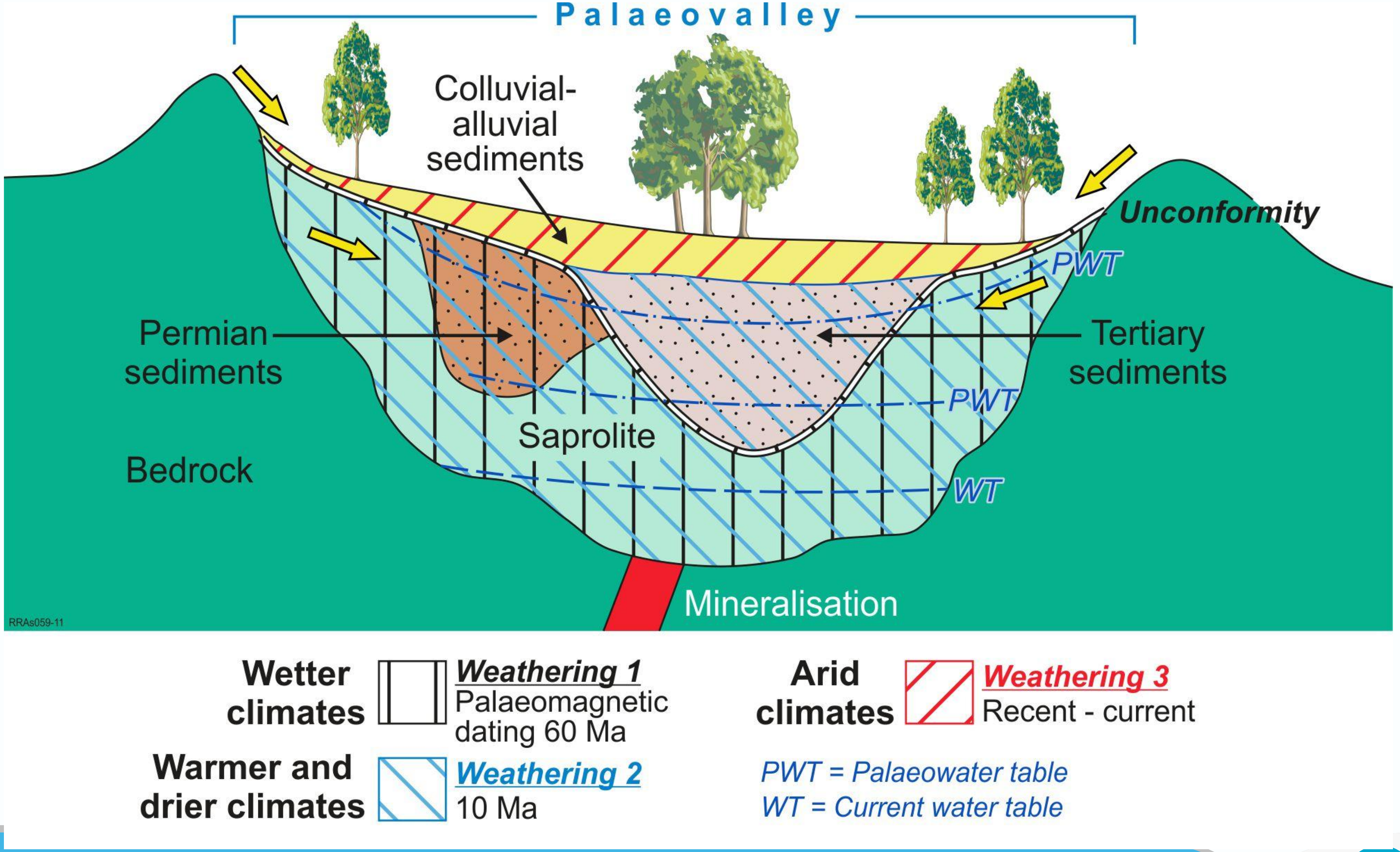


Greyscale image:
1VD mag

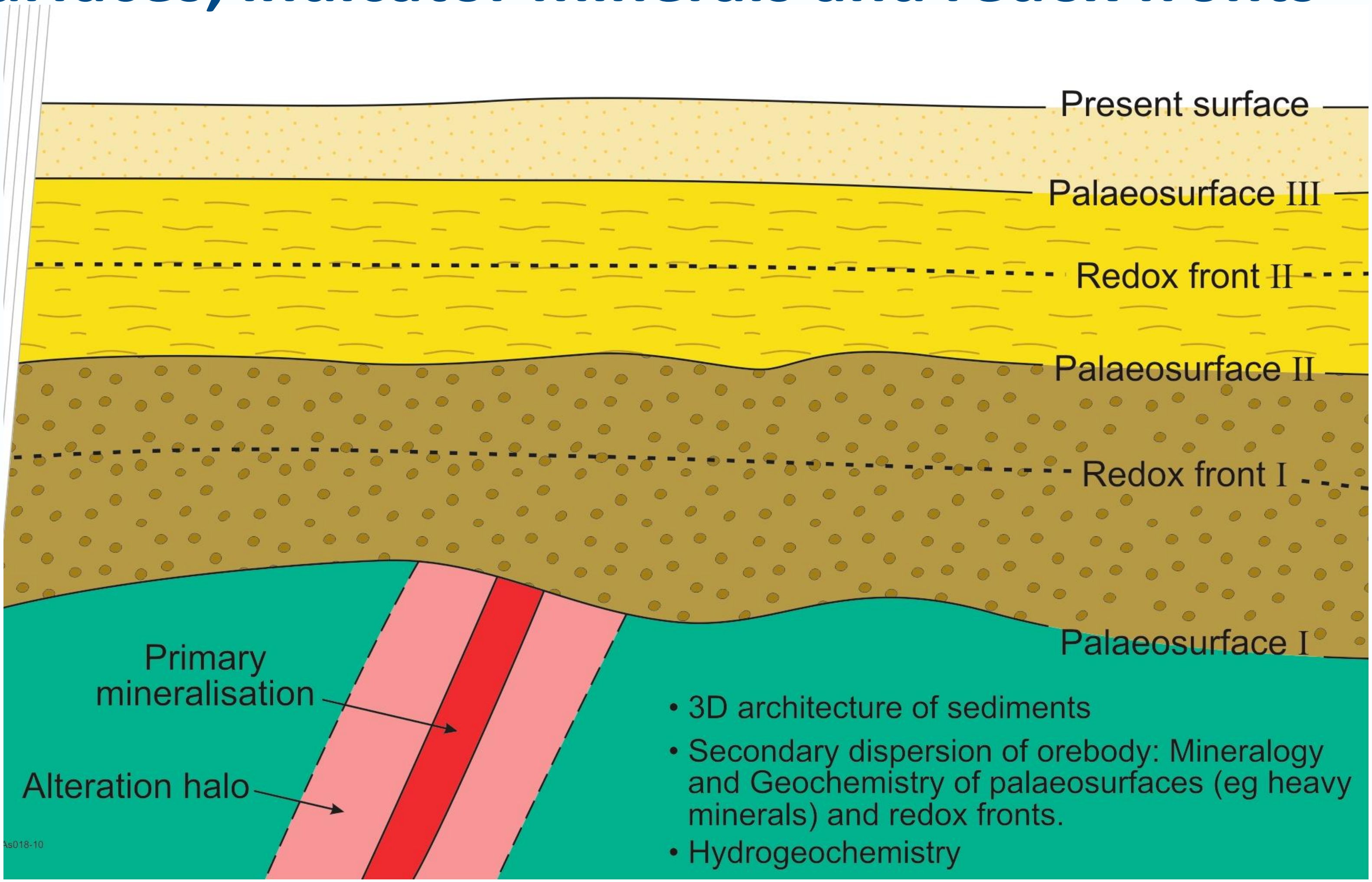
Some observations....Tropicana

1. Regolith (particularly saprolite) is conductive...
2. Regolith modelled reasonably well as a 1D body (at scale of AEM resolution)
3. Can map thickness and spatial variability based on conductive response – spatial proxies
4. Spatial character and relationships with basement

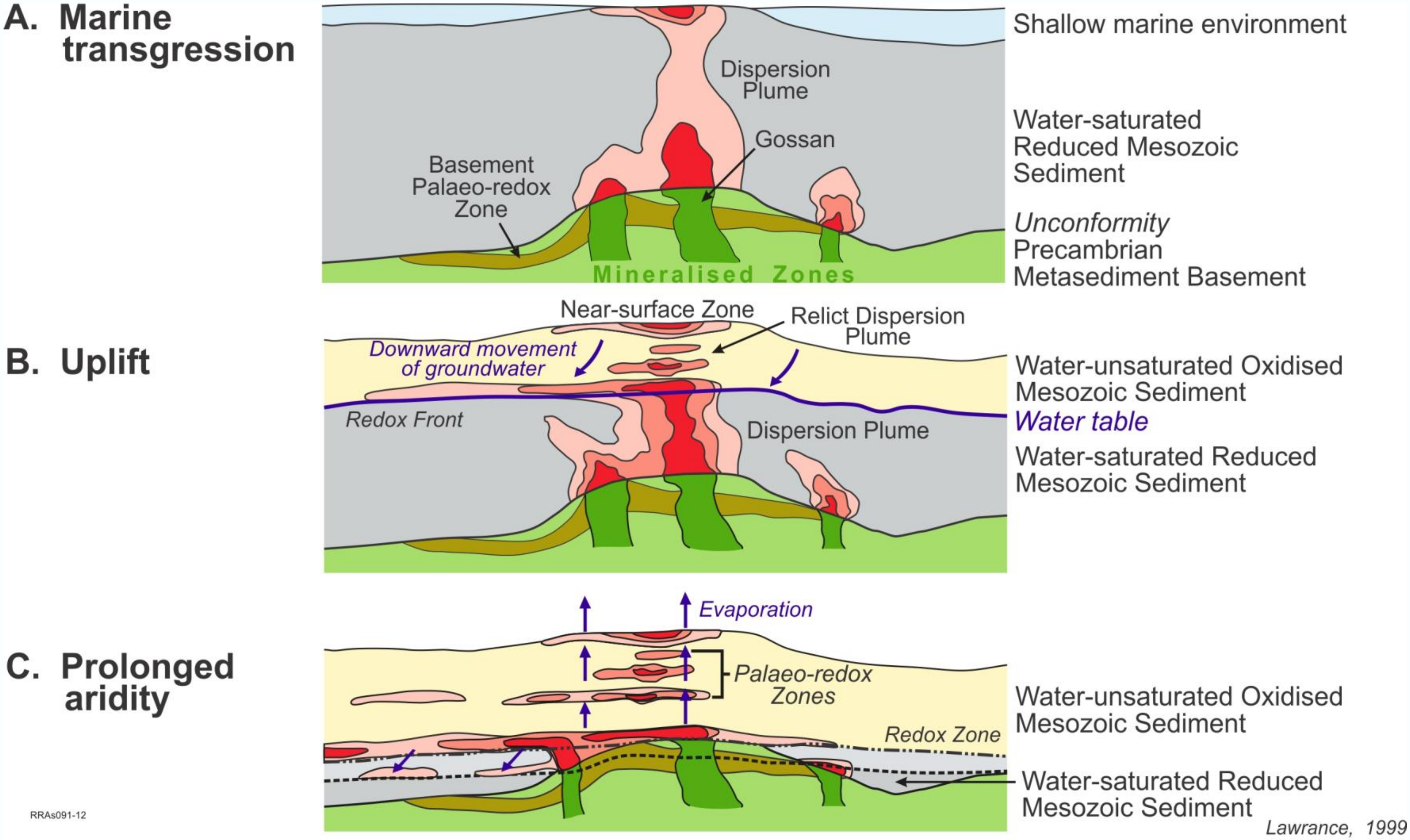
Anomaly detection in arid, old complex landscapes of Australia



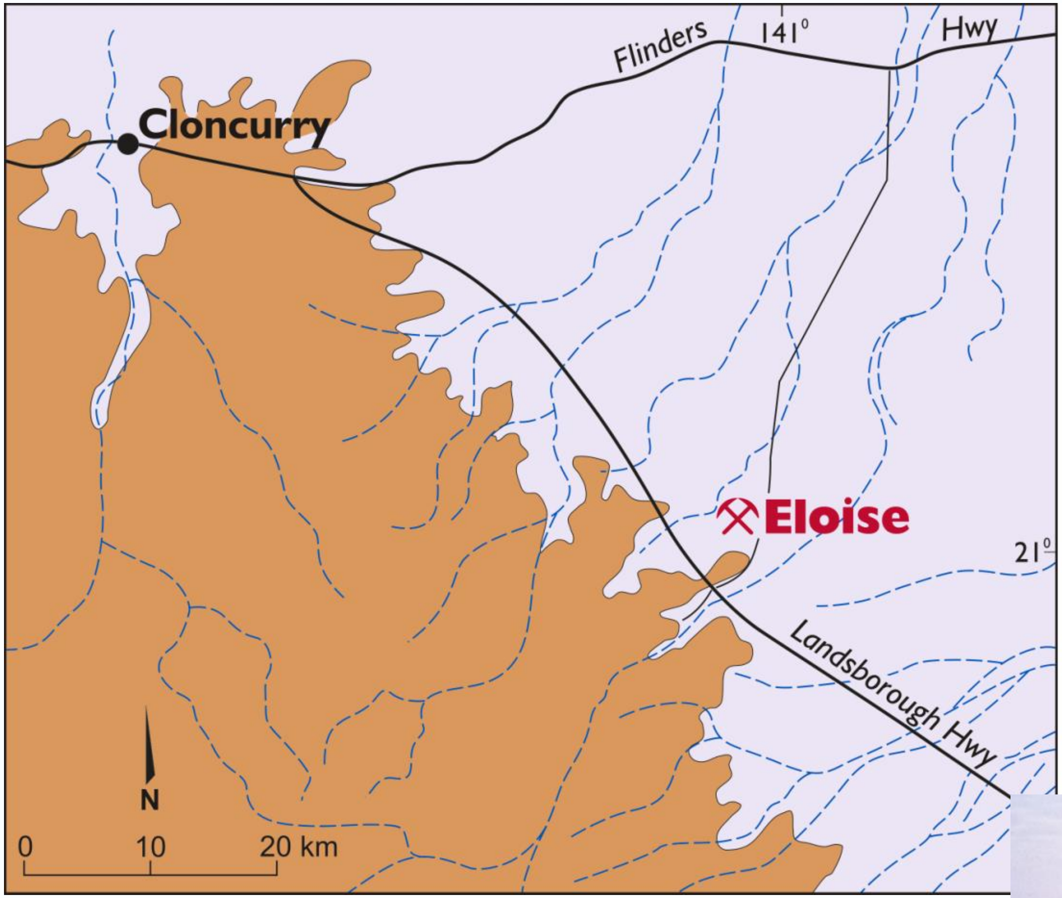
Exploration in areas of deep cover using palaeo-surfaces, indicator minerals and redox fronts

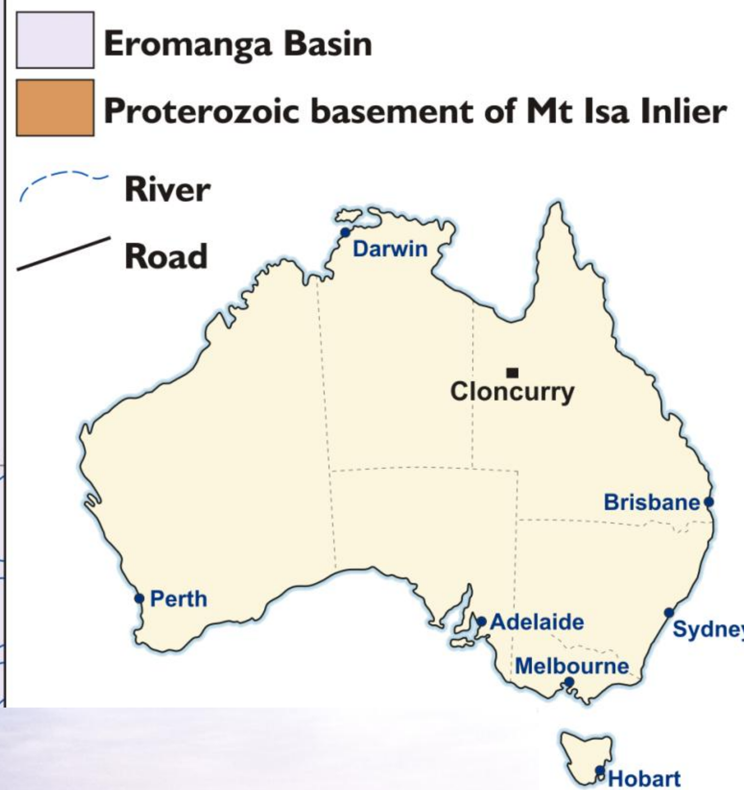


Formation of anomaly at palaeo-redox fronts: Osborne Cu-Au deposit



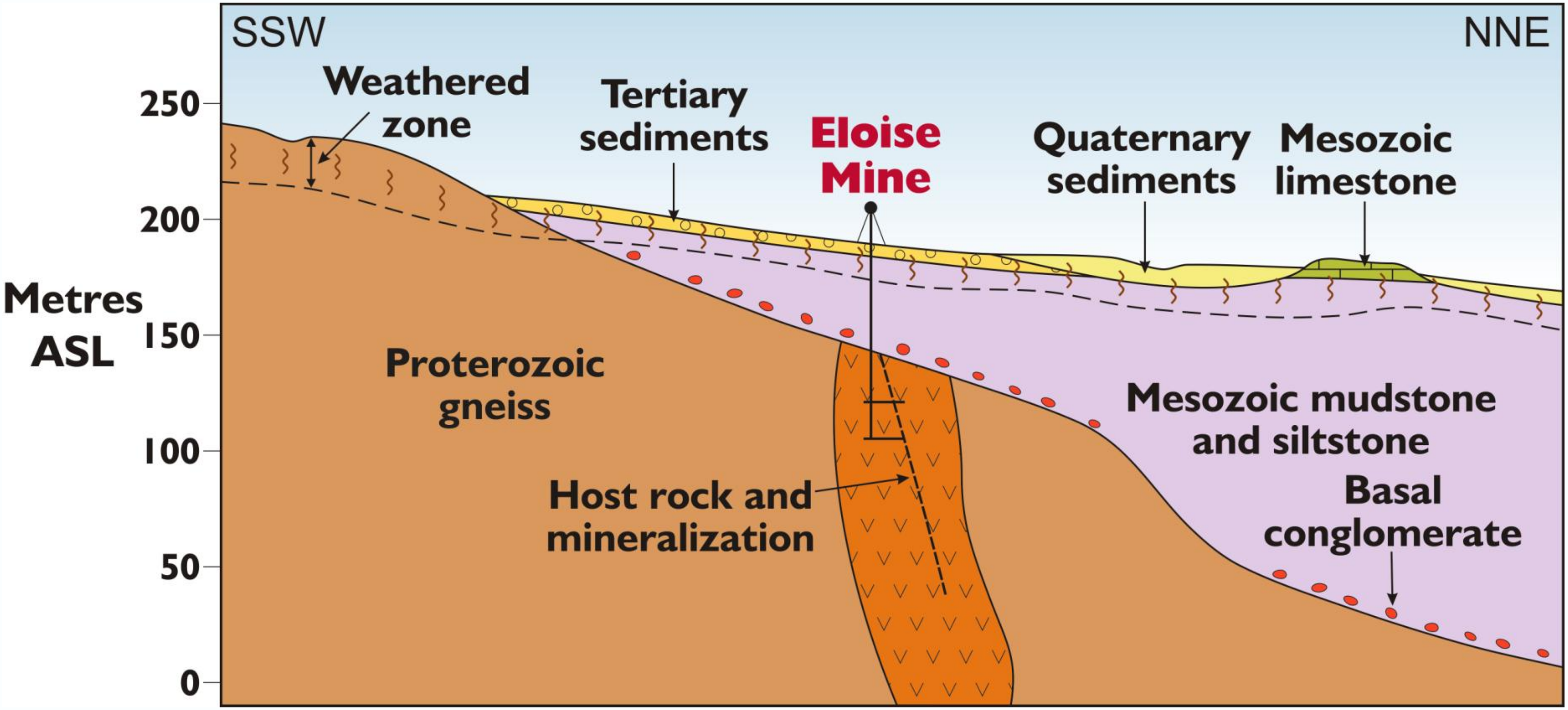
Areas of deep cover: Eloise (Cu-Au) deposit





Anand and Robertson, 2011

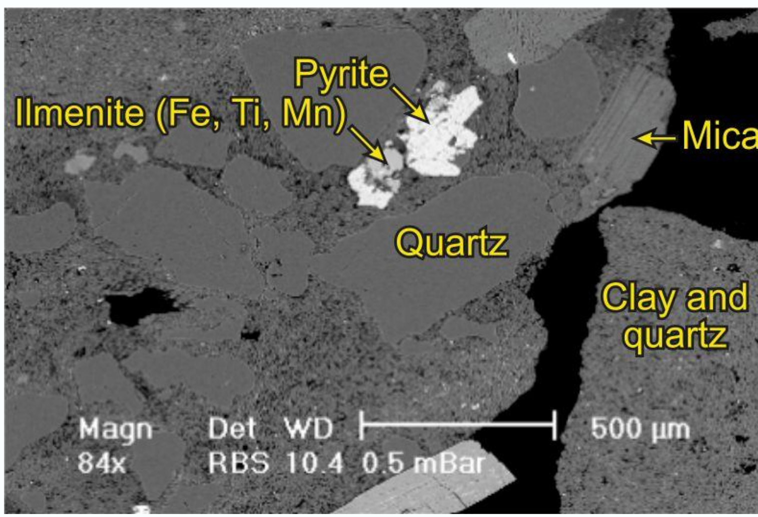
Cover cross section: Eloise deposit

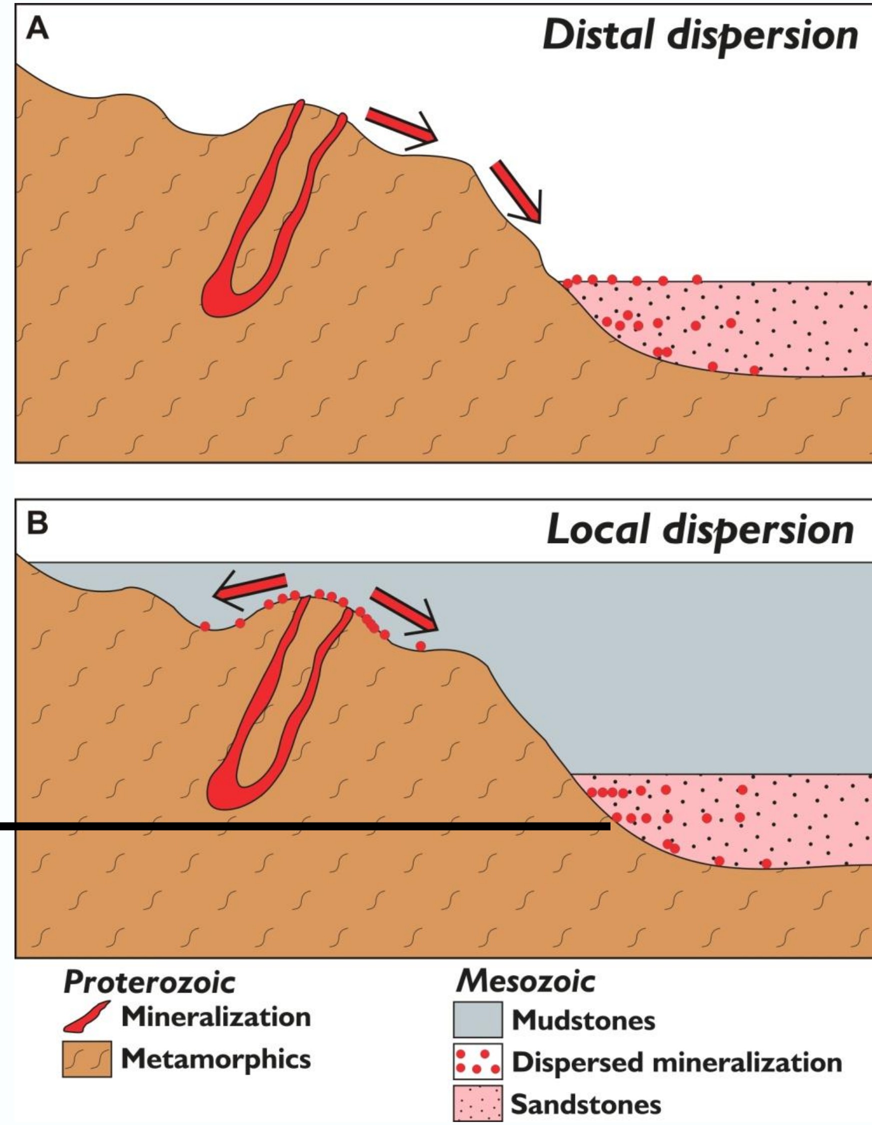


Anand and Robertson 2011

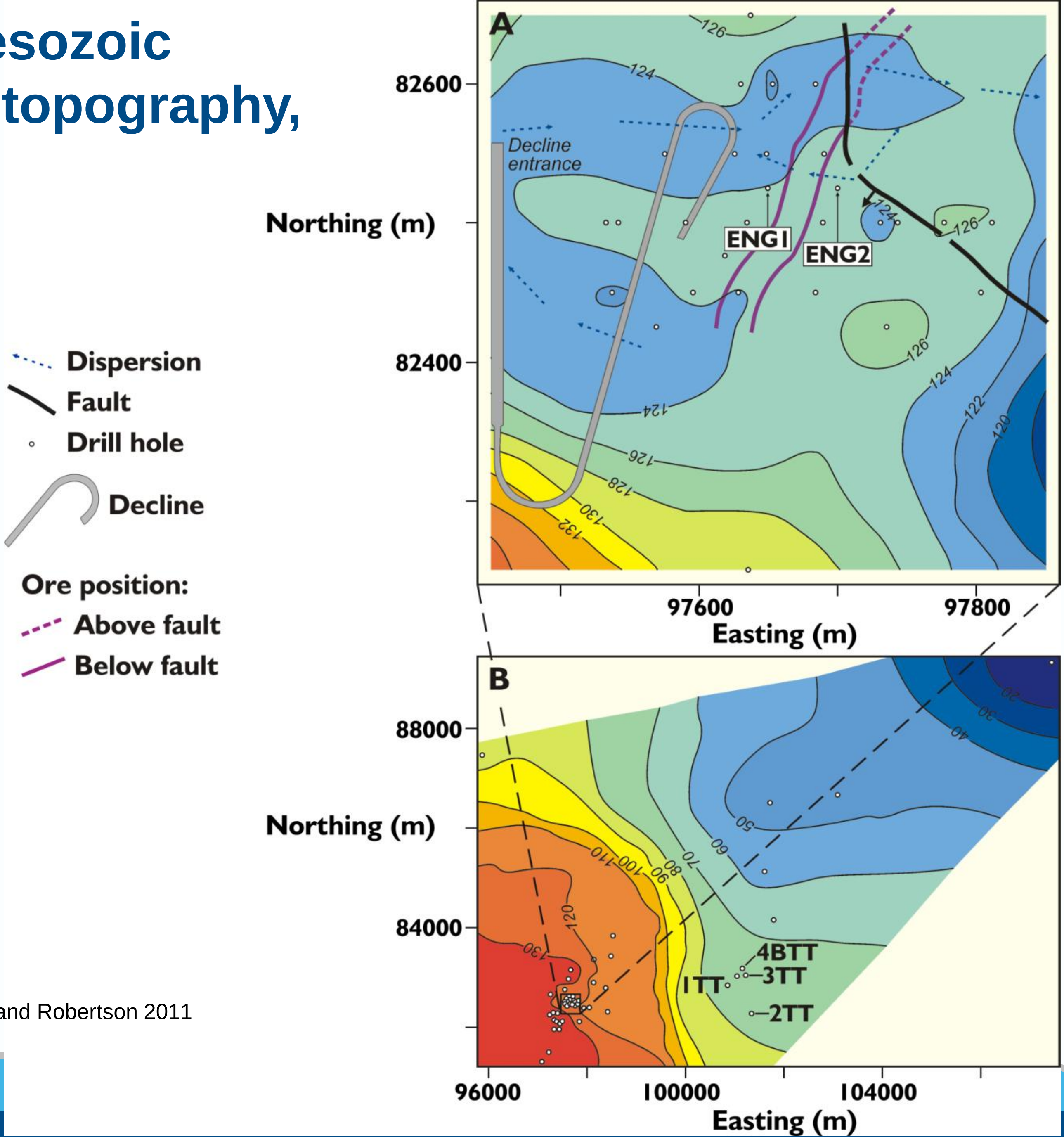
Formation of anomaly at interface by mechanical processes, Eloise Cu-Au deposit

- Mineralisation: pyrite, chalcopyrite
- Fresh Mesozoic cover up to 70 m thick over fresh Proterozoic bedrock
- Dispersion both local and distal (up to 3 km) by mechanical processes





Pre-Mesozoic Palaeotopography, Eloise

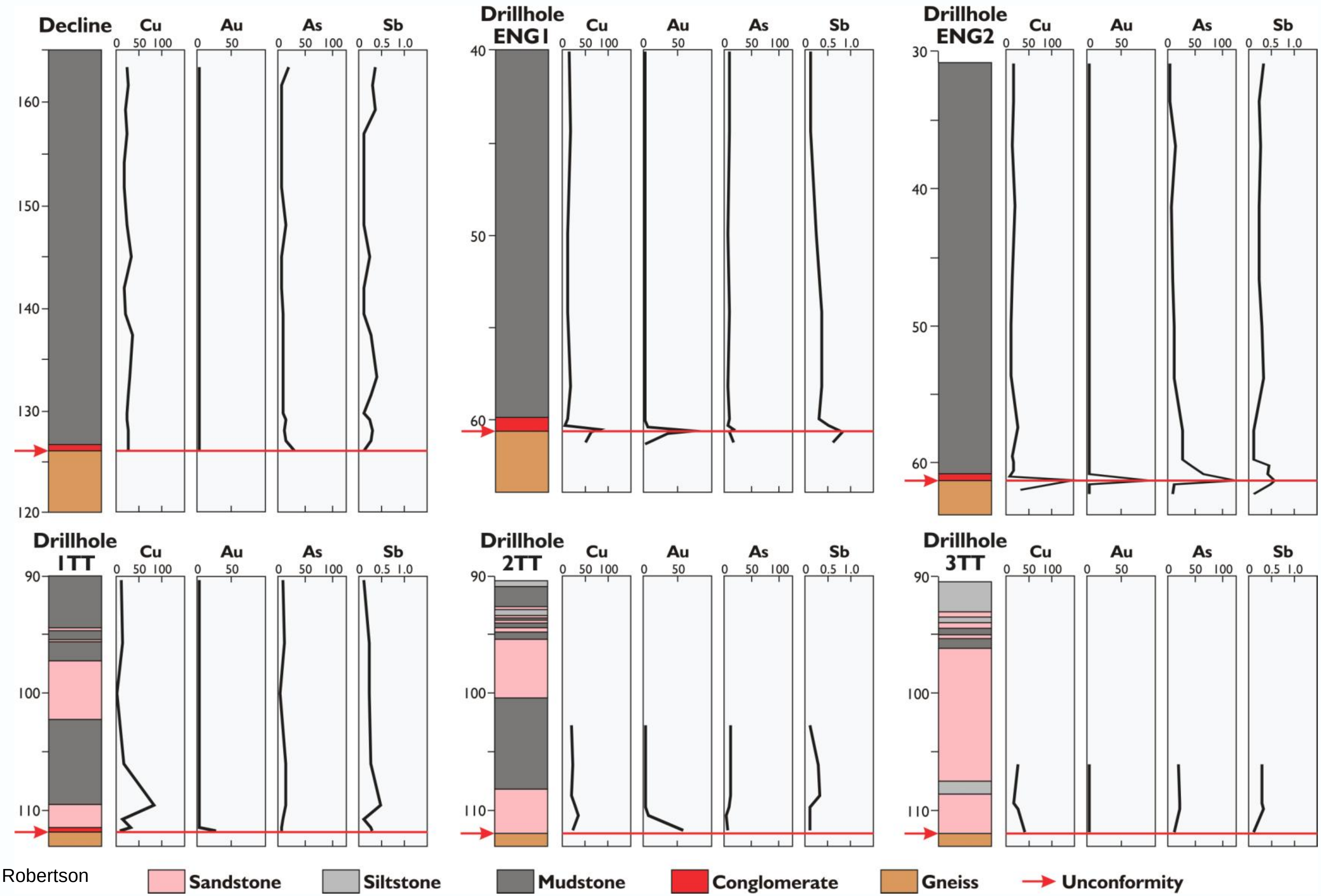


Near mine

Distal

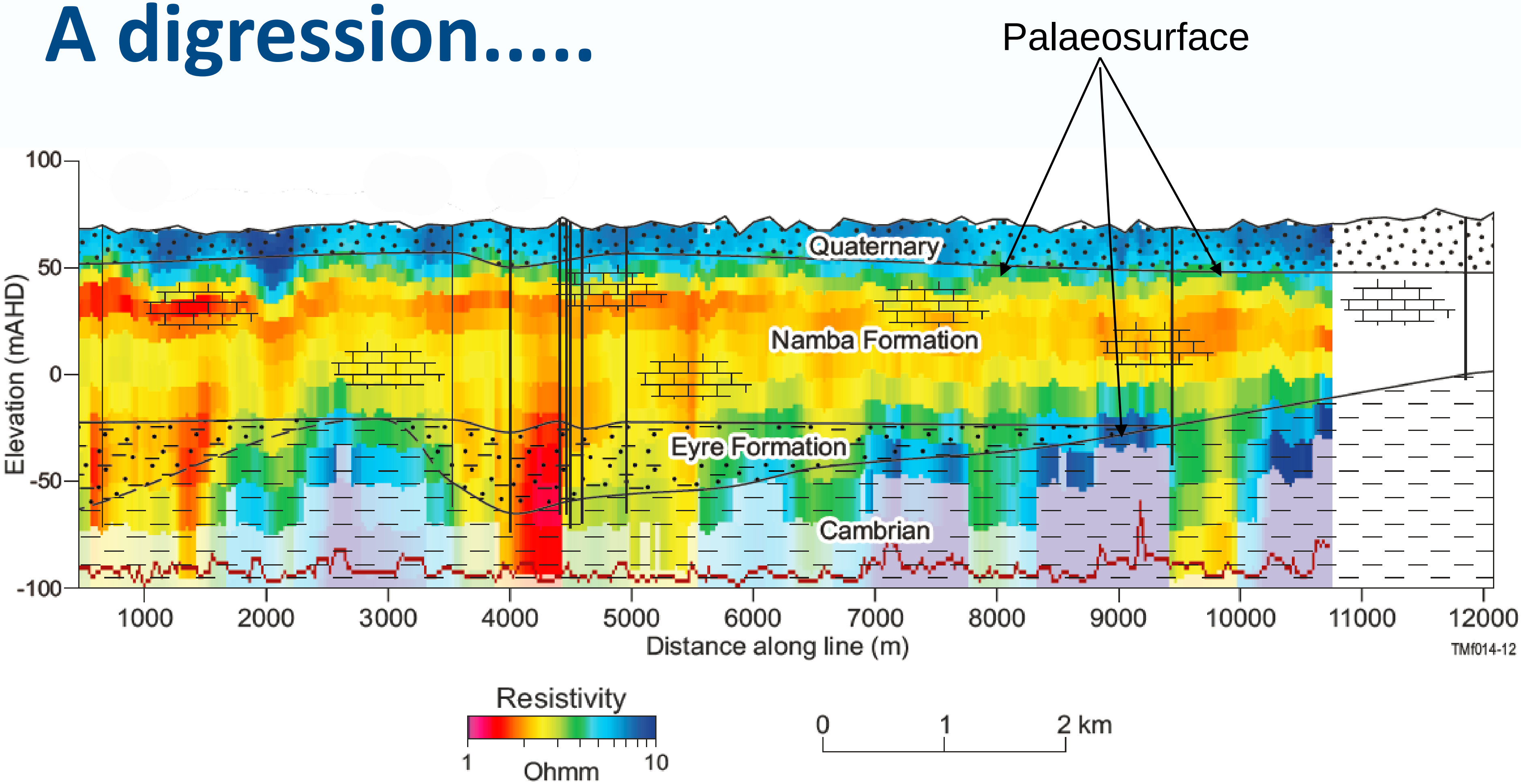
Anand and Robertson 2011

Geochemistry of drill holes, Eloise deposit



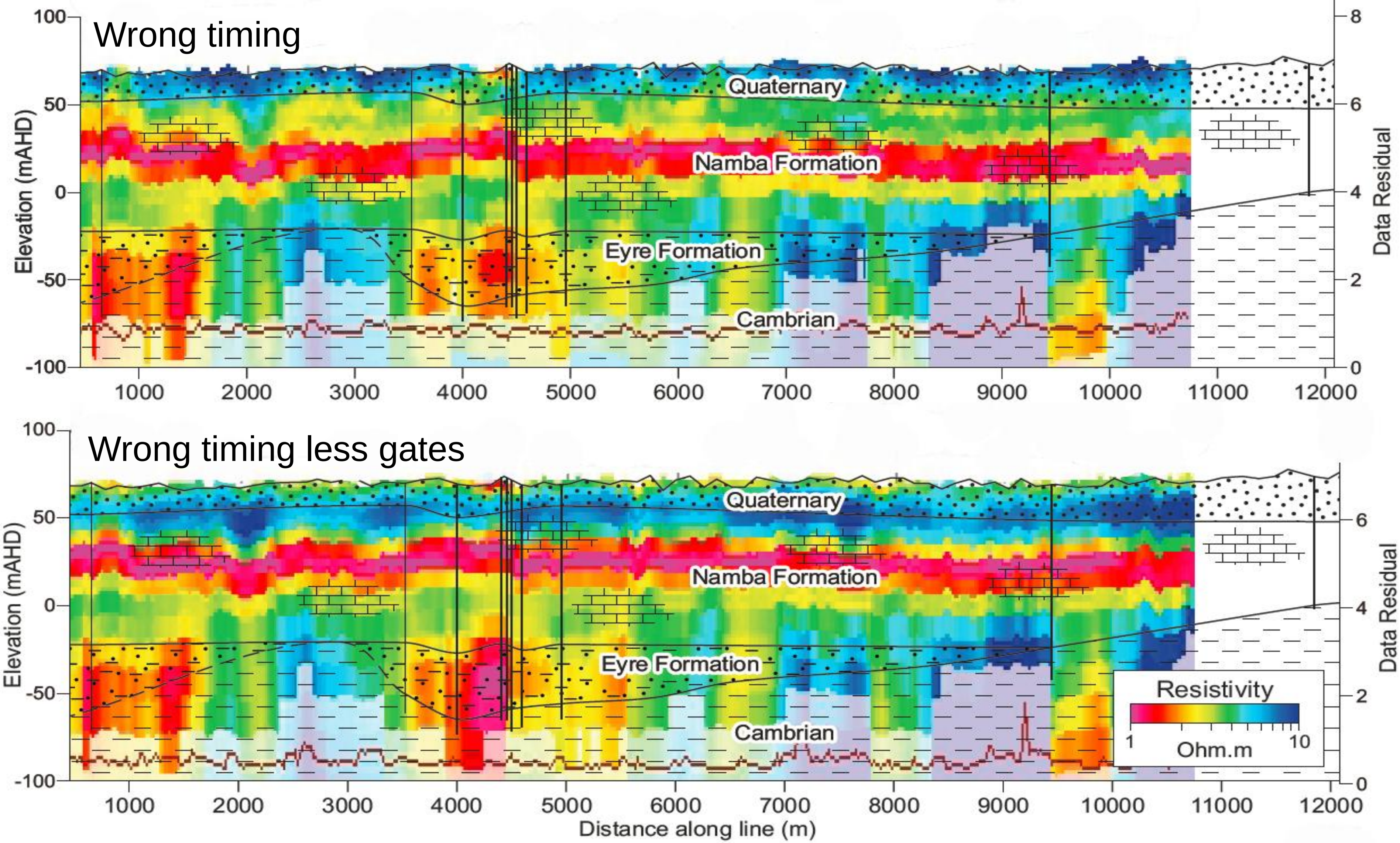
Anand and Robertson

A digression.....



Smooth 19 layer inversion
HeliTDEM system

Beware: Getting the parameters right....



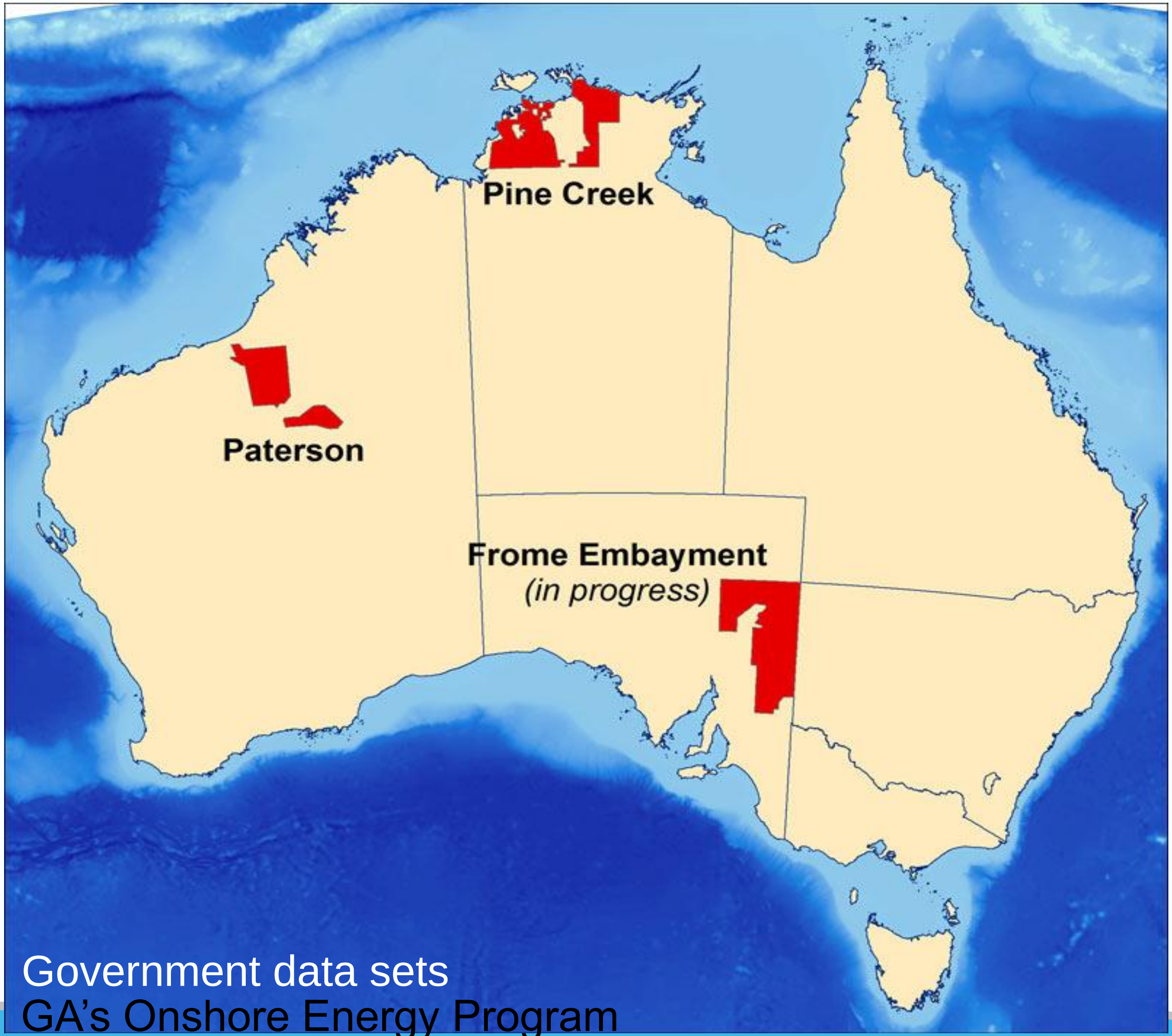
Characterising and detecting the distal footprints of ore deposits

- Exploration is an exercise in sequential volume reduction
  - *an understanding of the multiscale expressions of ore deposits and their entire mineralising systems;*
  - *The basic data, derivative products and tools required to detect mineral systems at the appropriate scales; and*
  - *knowledge of the regional background is critical*

Characterising and detecting the distal footprints of ore deposits

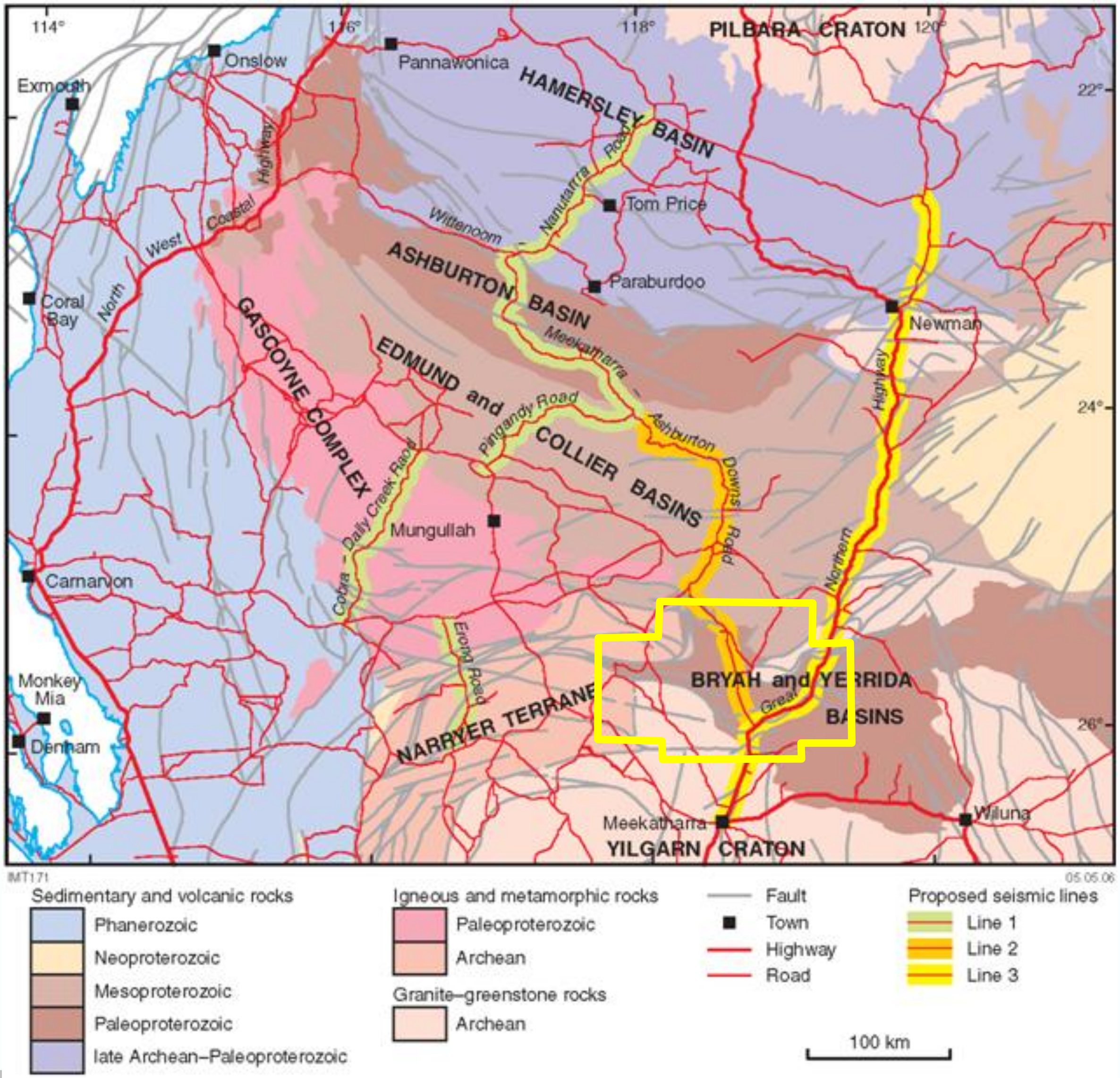
- Research opportunity
  - Integrate ore deposit characterisation and proximal to distal footprints for ore deposit types at regional to continent scales,
  - Understand footprints of mineral systems that may be much more subtle than the highly anomalous deposits residing within.

Regional AEM – Context & Opportunity



Government data sets
GA's Onshore Energy Program

Distal Footprints – Bryah Basin, WA

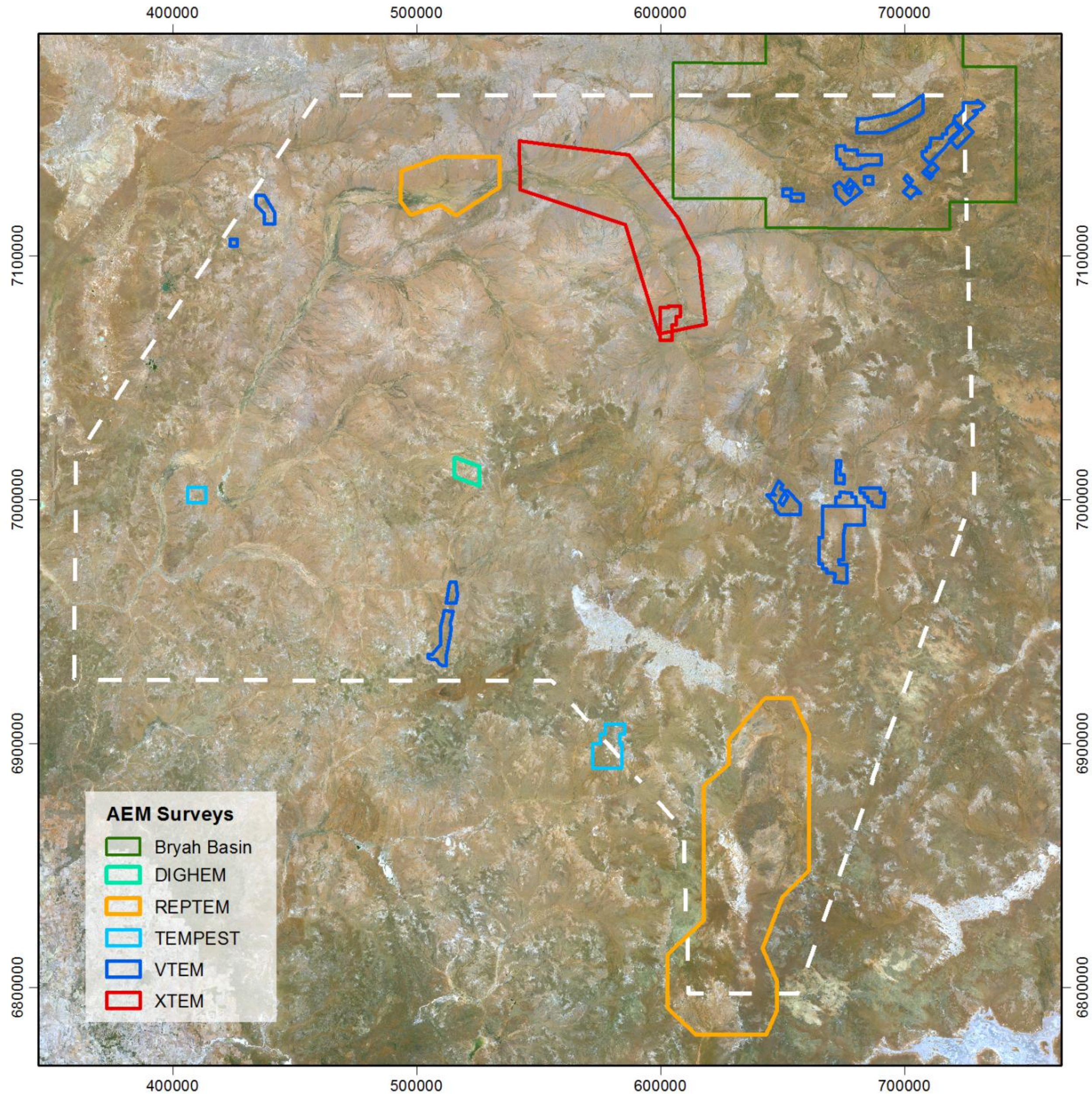


Prior AEM Surveys

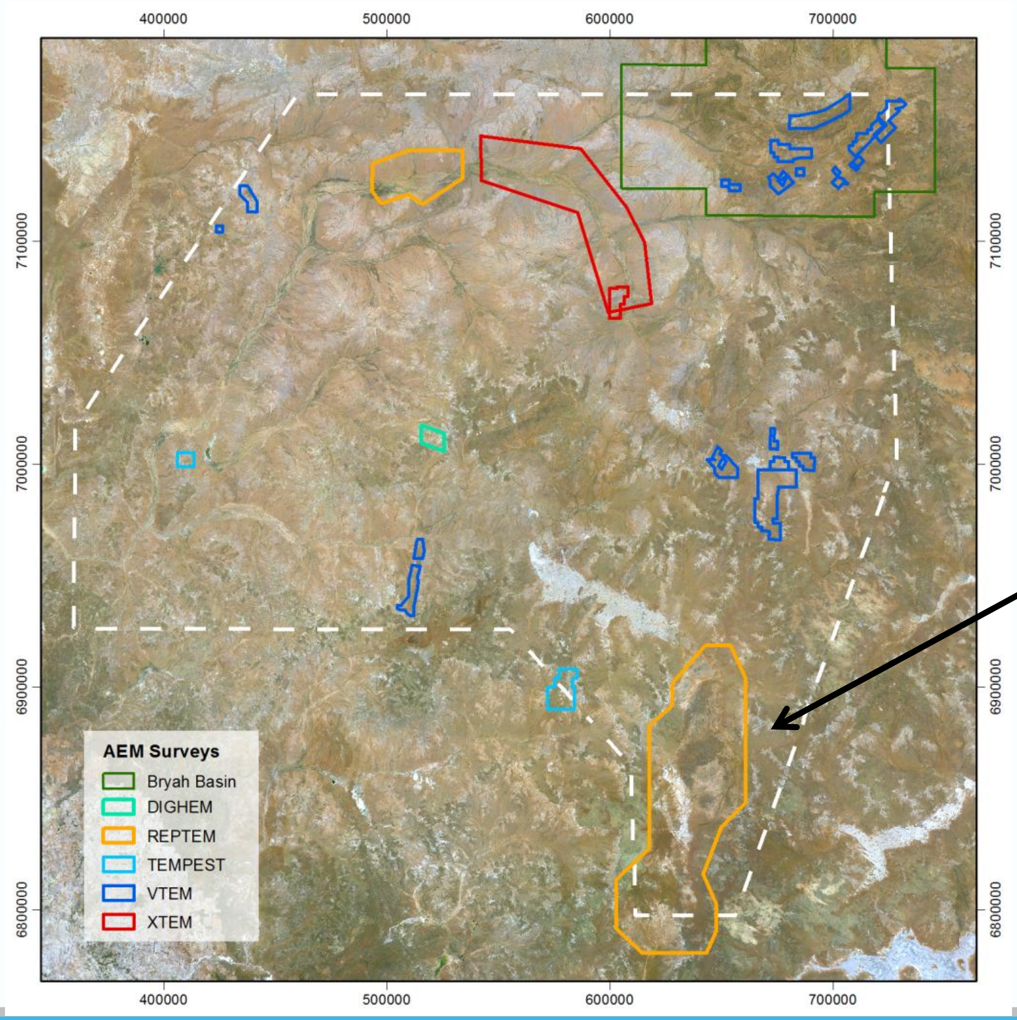
Targeting base metals, gold, diamonds, uranium & groundwater…

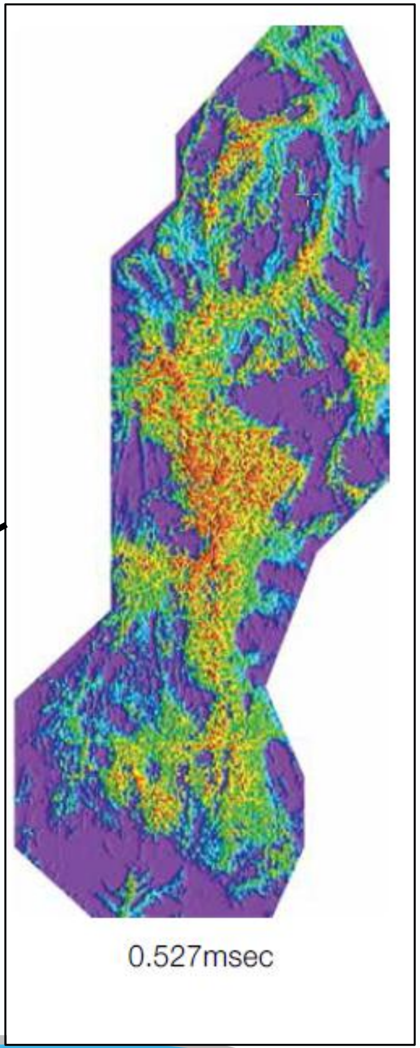
AEM Systems:

- REPTEM
- XTEM
- VTEM
- DIGHEM
- TEMPEST

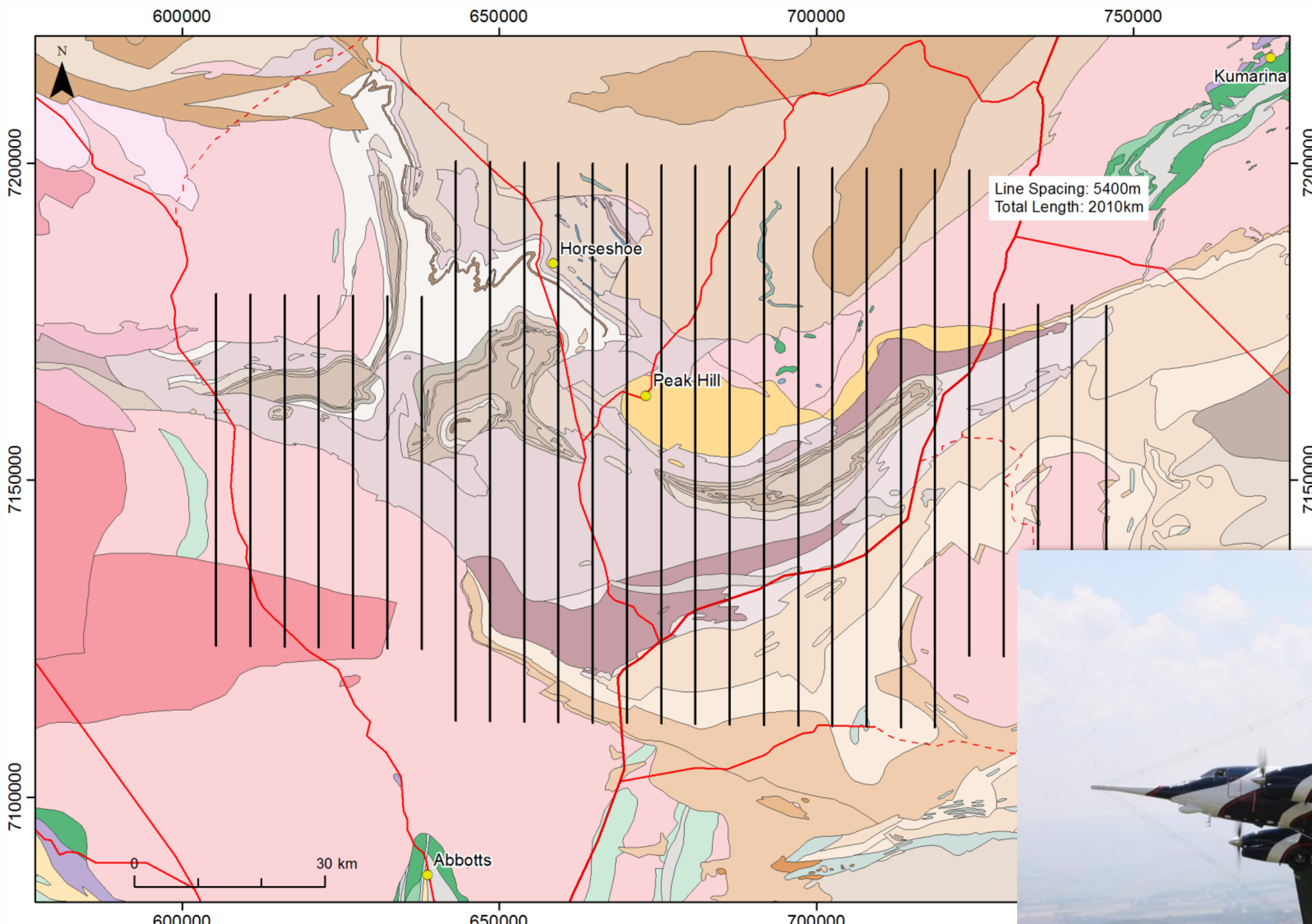


Larger surveys offer opportunity to look at





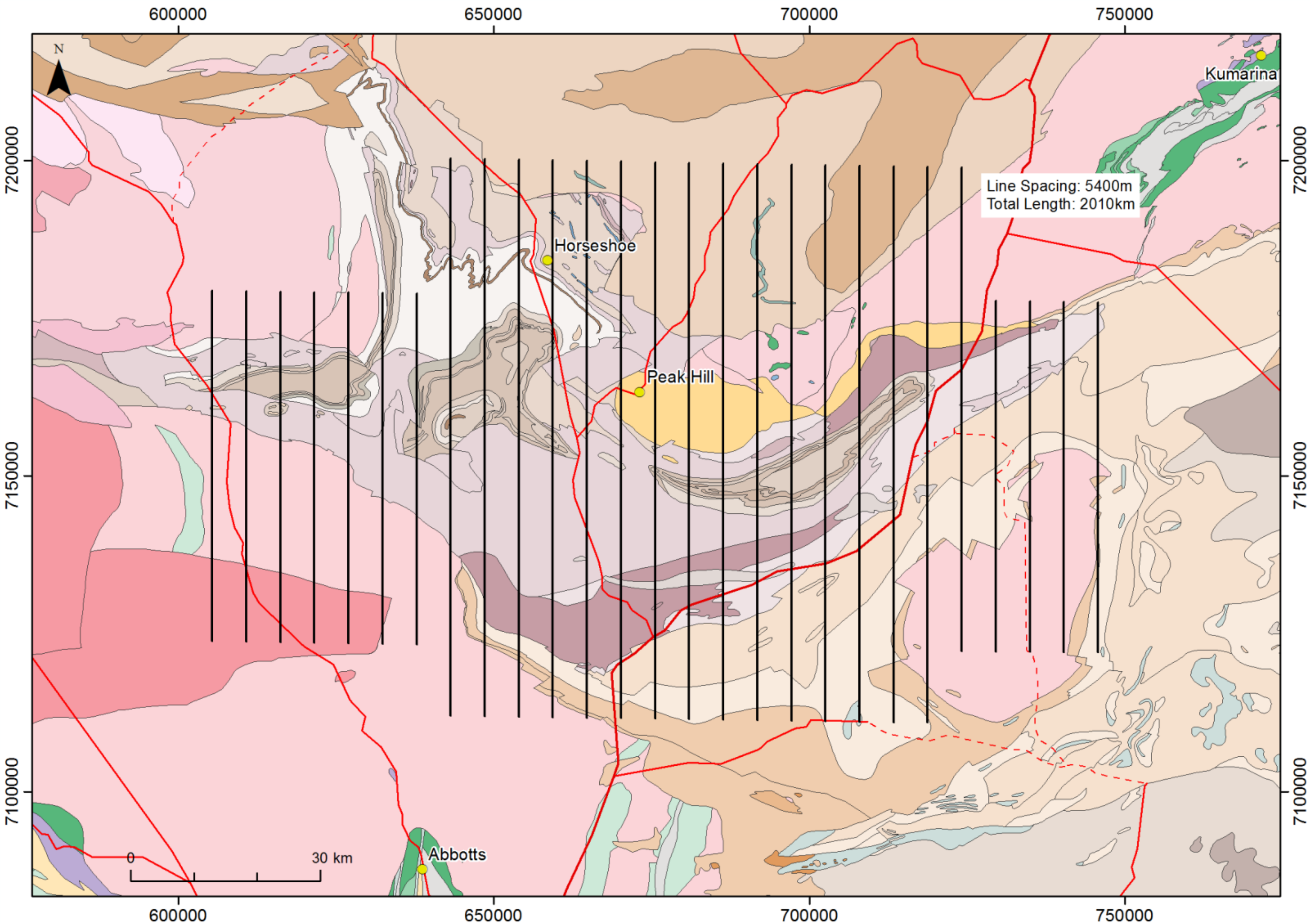
Distal Footprints – WA



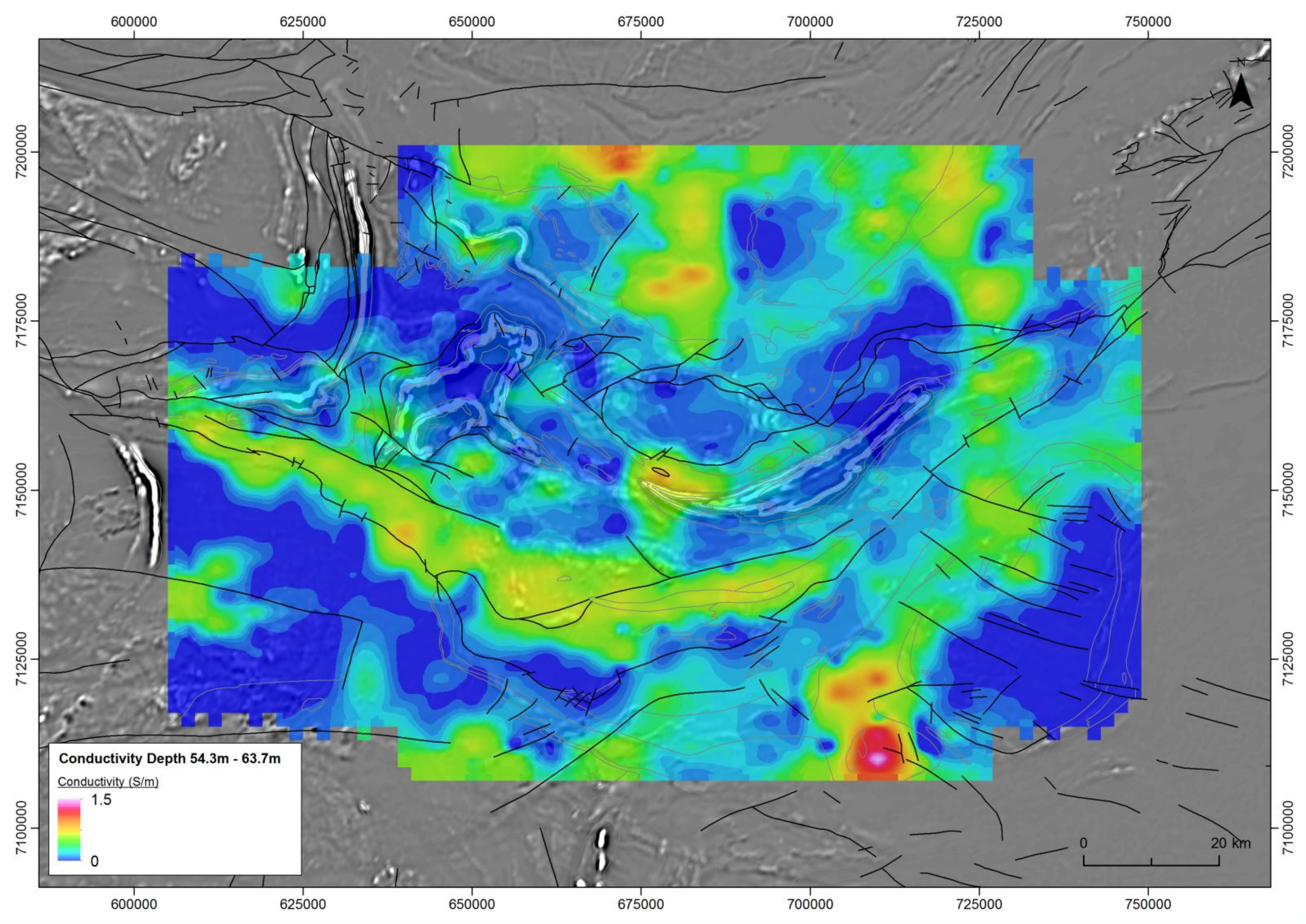
Government of **Western Australia**
Department of **Mines and Petroleum**

CSIRO

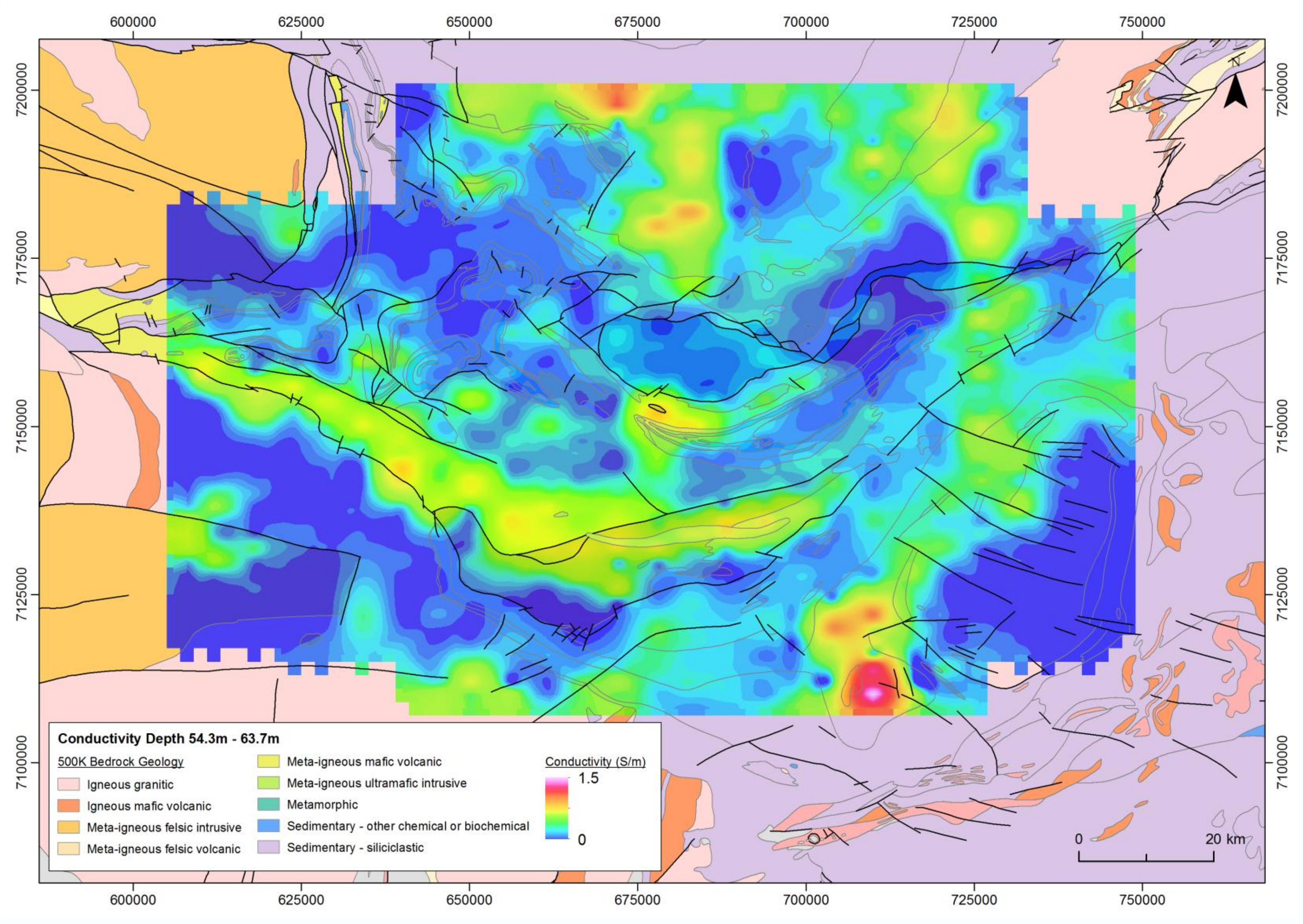
Palaeoproterozoic Basins, Northern WA



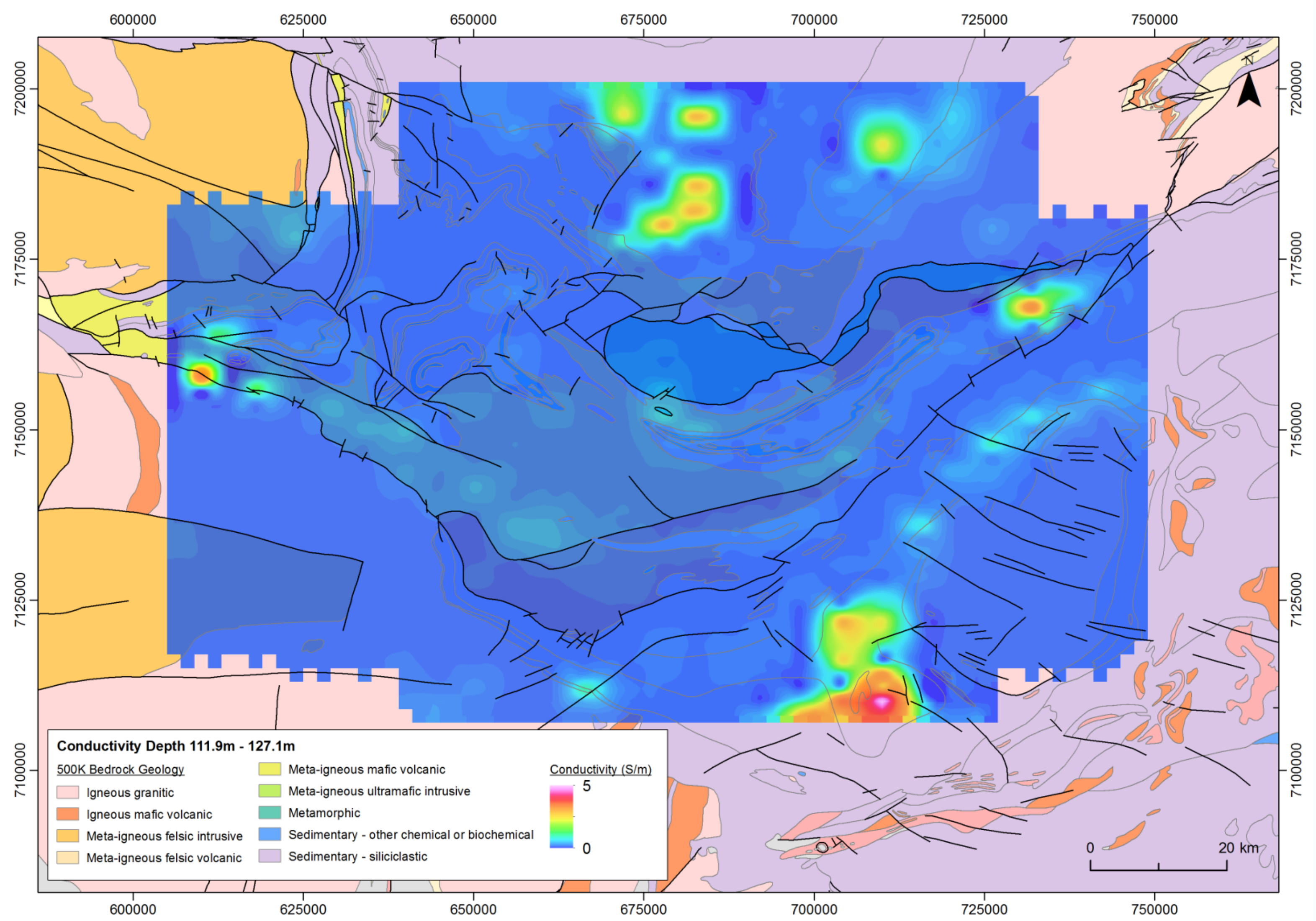
1D inverted Interval Conductivity – 54-64m BGL



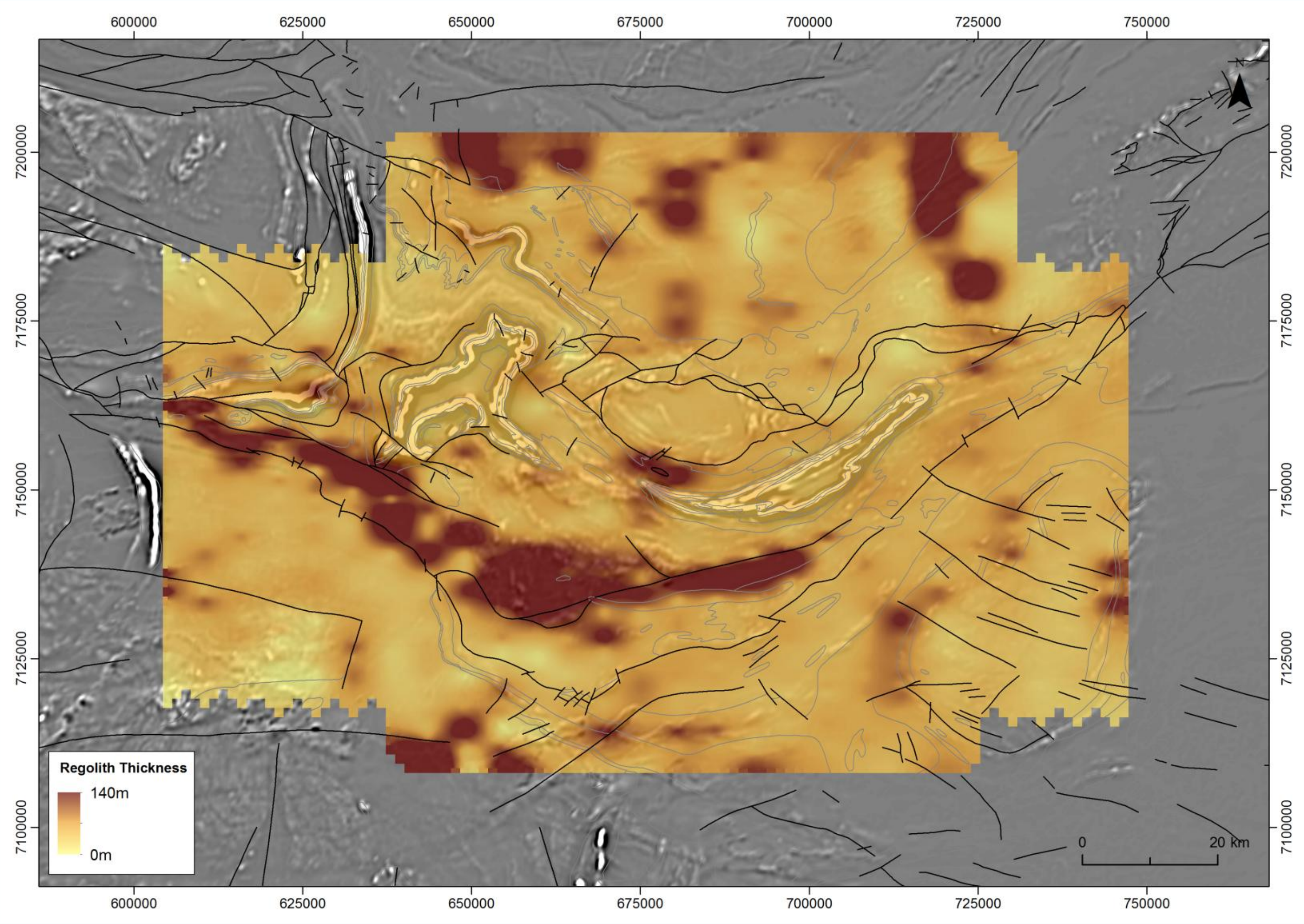
1D inverted Interval Conductivity – 54-64m BGL



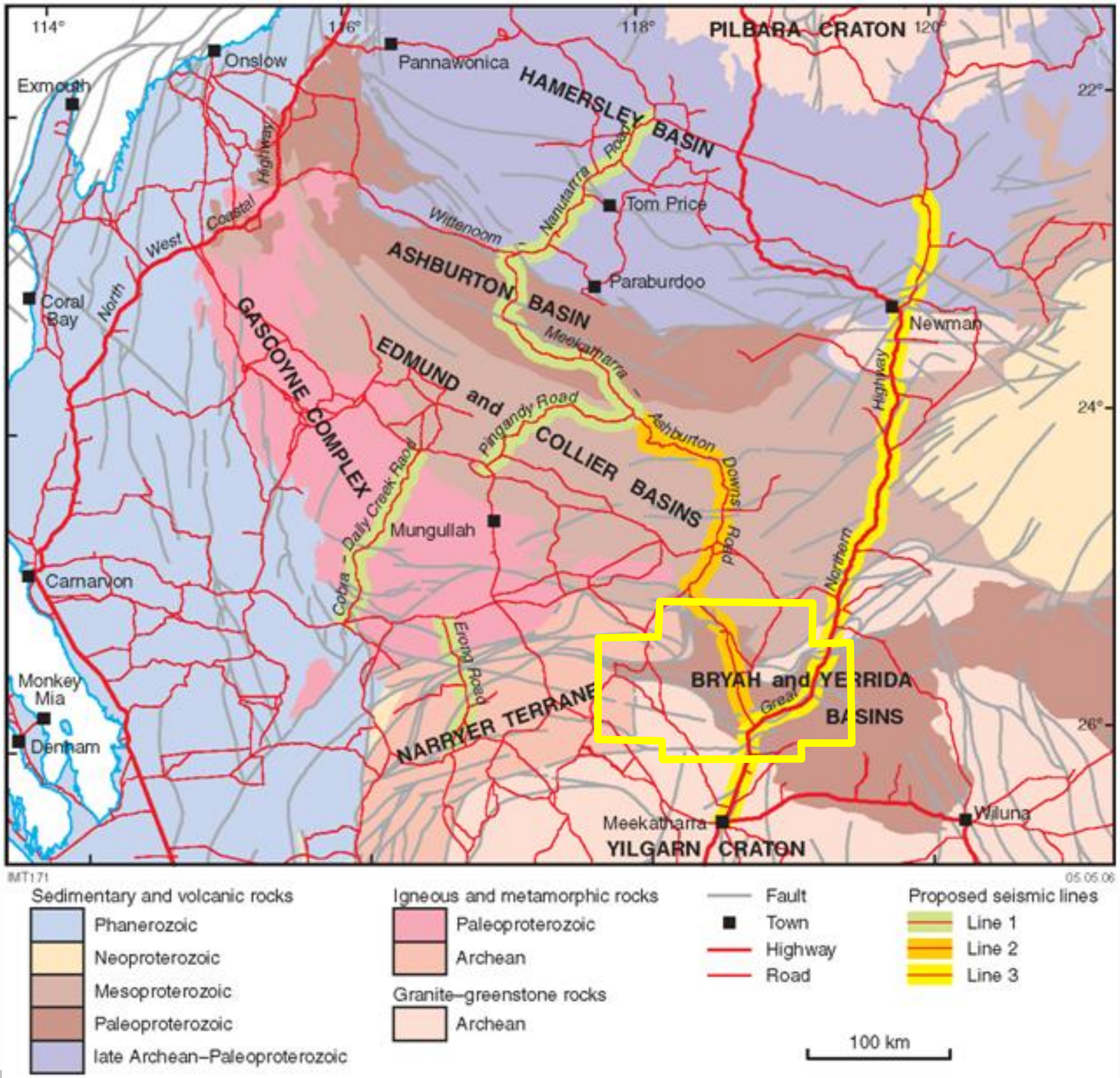
1D inverted Interval Conductivity – 110-130m BGL



Regional Scale map of cover thickness

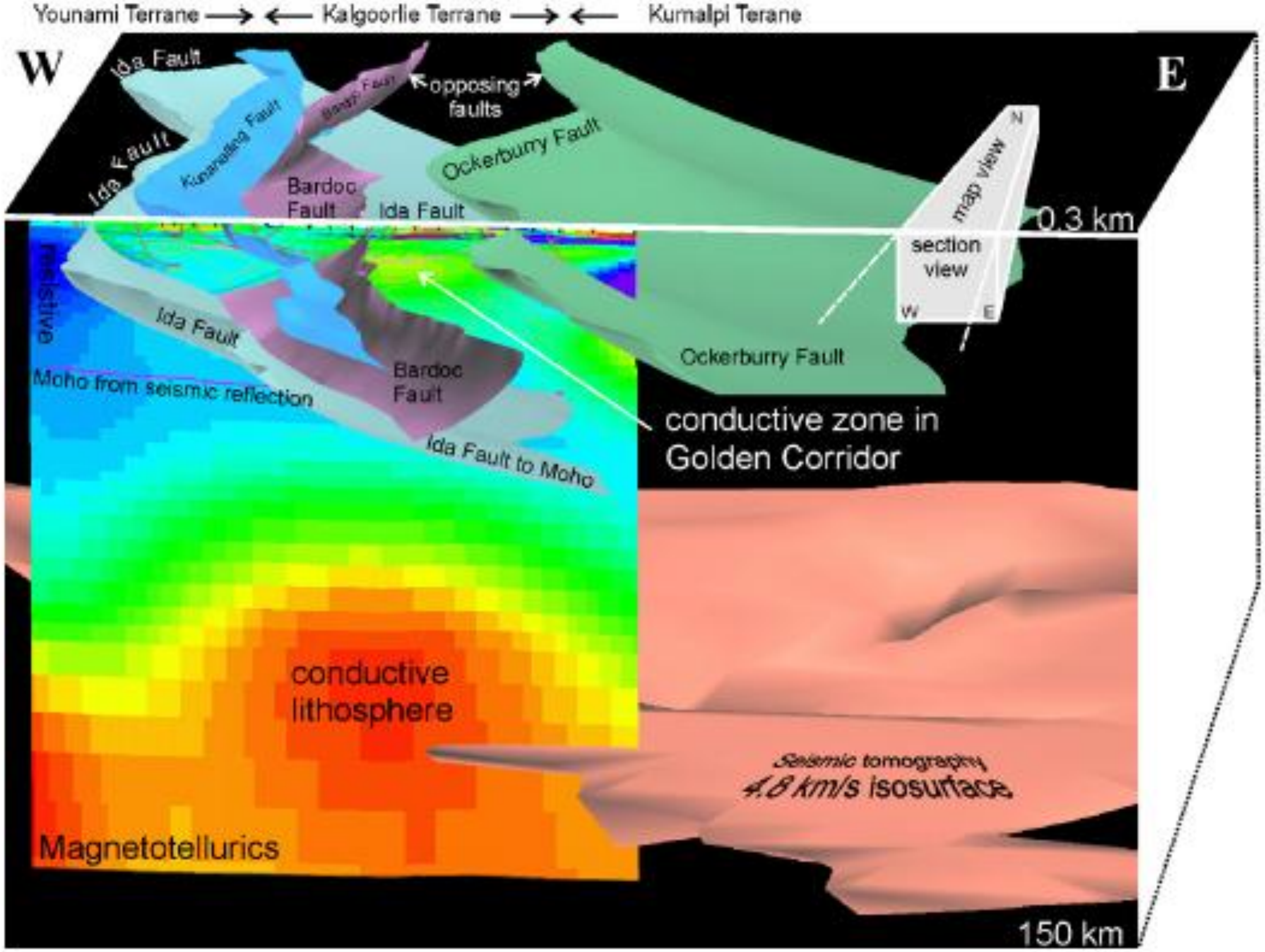


Regional EM



114°
116°
118°
120°
22°
24°
26°
PILBARA CRATON
HAMERSLEY BASIN
ASHBURTON BASIN
GASCOYNE COMPLEX
EDMUND and COLLIER BASINS
BRYAH and YERRIDA BASINS
NARRYER TERRANE
YILGARN CRATON
Onslow
Exmouth
Pannawonica
Tom Price
Paraburdoo
Newman
Coral Bay
Mungullah
Carnarvon
Monkey Mia
Denham
Meekatharra
Wiluna
North West Coastal Highway
Wittenoom
Nanutarra Road
Meekatharra - Ashburton Downs Road
Pingandy Road
Cobra - Dally Creek Road
Errabiddy Road
Great Northern Highway
IMT171
05.05.06
Sedimentary and volcanic rocks
Phanerozoic
Neoproterozoic
Mesoproterozoic
Paleoproterozoic
late Archean–Paleoproterozoic
Igneous and metamorphic rocks
Paleoproterozoic
Archean
Granite–greenstone rocks
Archean
Fault
Town
Highway
Road
Proposed seismic lines
Line 1
Line 2
Line 3
100 km

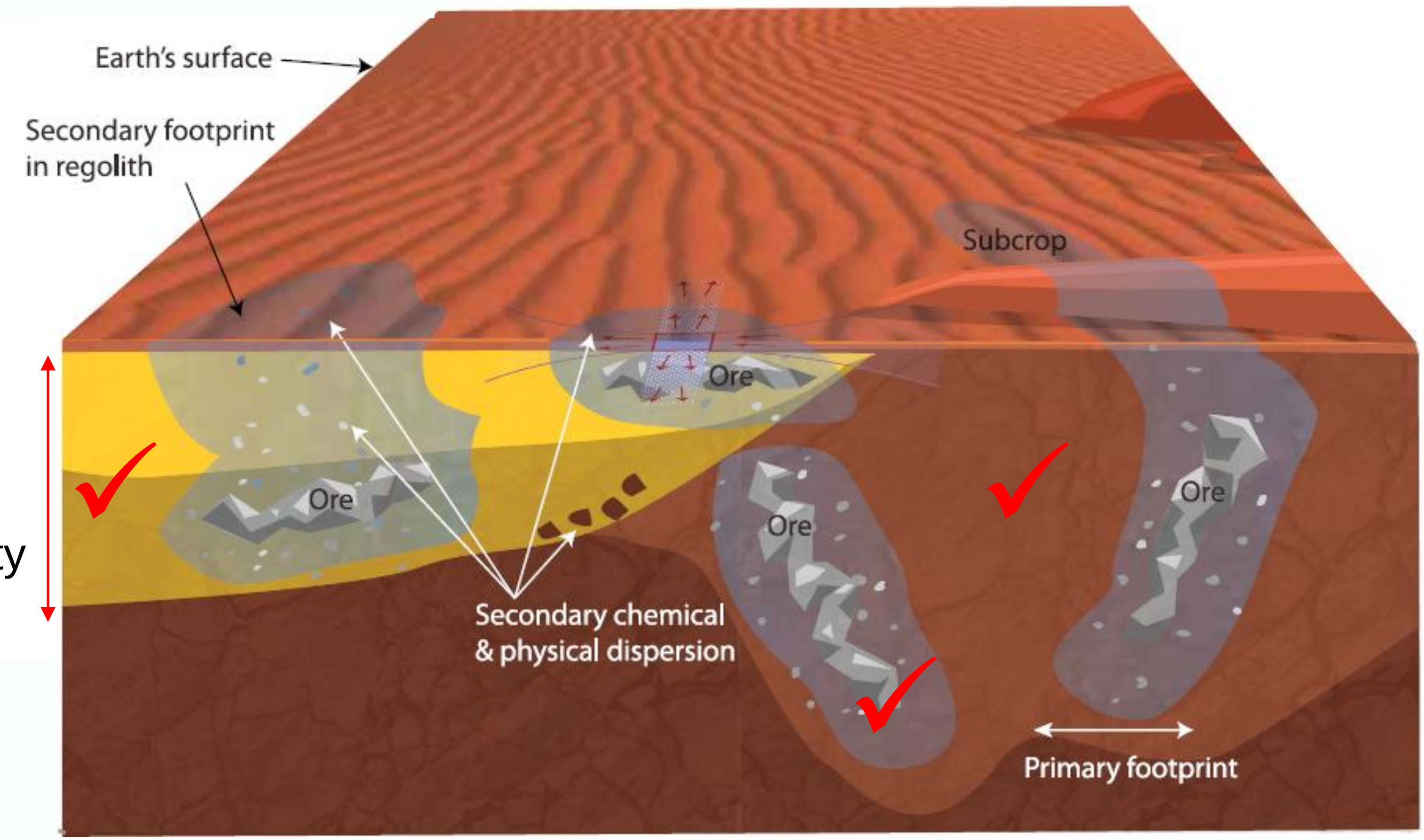
Near surface with MT – mineral system



Blewett et al 2010

How does AEM fit ?

Regolith thickness and variability



Adapted from: Searching the deep earth *A vision for exploration geoscience in Australia; 2012*

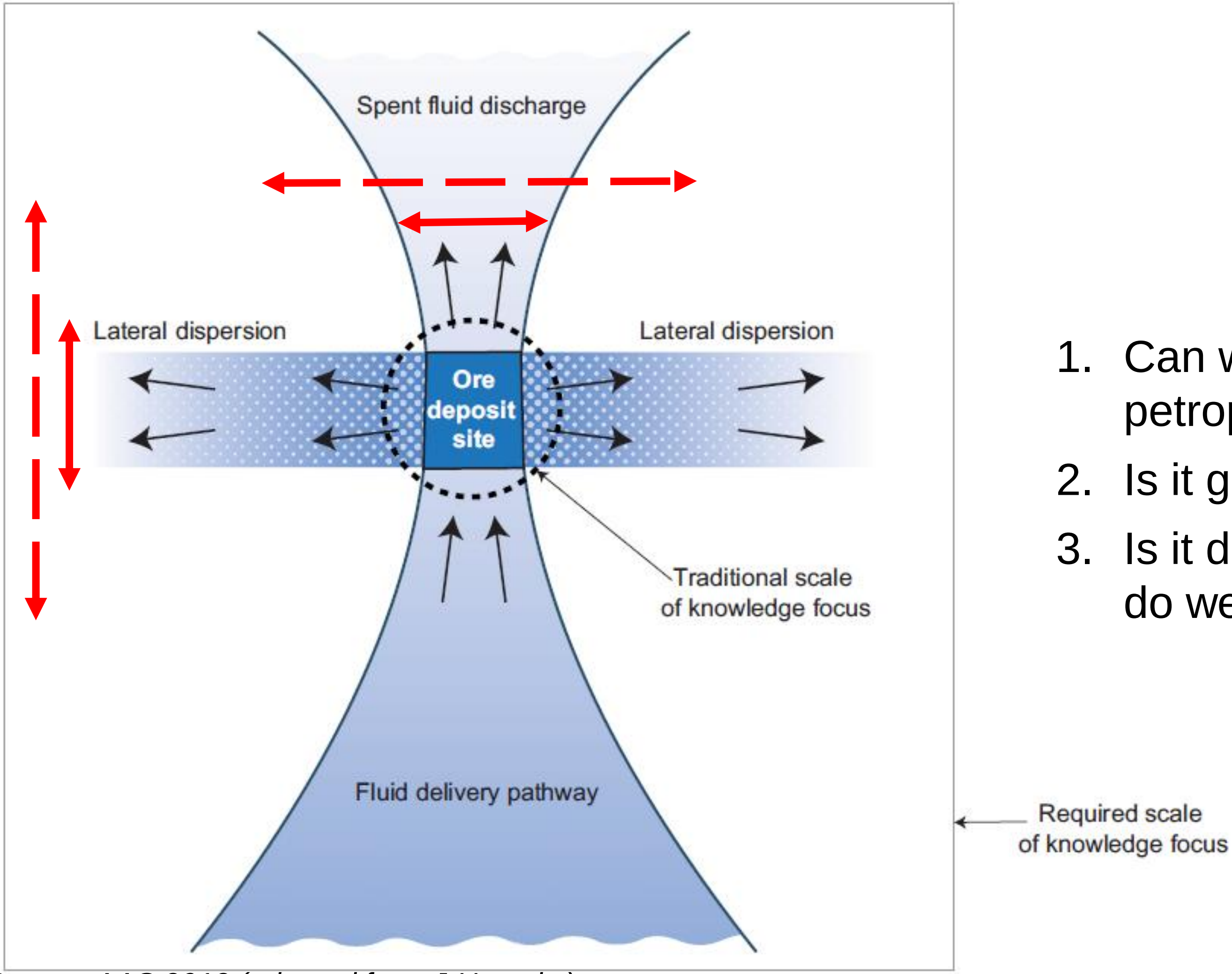
Regional AEM: Opportunities

1. Regolith Thickness and when studied in detail – variability within the regolith (are these palaeo discontinuities/horizons to sample geochemically etc etc).
2. Regolith discontinuities – do they reflect changing patterns of alteration etc ?
3. Opportunity to think about joint inversion with other regional geophysical data sets – common earth properties and, by implication, variations in that – significance for exploration through cover.
4. Opportunity for integrated geochemical/geophysical investigations with regolith character and variability in 3D involved – as distinct from 1D (surface approaches) used in past.

Challenge for all explorers/contractors

- AEM offers much more than just direct targeting for drilling (the common approach). Regional coverage – processed carefully(!) offers significant new opportunities to identify new exploration targets based on enhanced geological (weathering) understanding, targets that may not be necessarily conductive. But....
  - *Need greater S:N*
  - *More power to see deep but not at expense of sensitivity (make sure we have lots of gates/channels)*
  - *Bandwidth important – need to see near surface (top 50m) as well as deep 150m +*

Expand our search footprint



Source: *AAS 2012 (adapted from J Hronsky)*

1. Can we see a larger petrophysical footprint?
2. Is it gradational?
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Search Footprints - Geophysics

1. A key advance will be the recognition of unique datasets or proxies to map the various facets of a mineral system, from
   - metal and fluid source,
   - to pathways,
   - depositional sites and
   - fluid exit conduits.
2. To achieve this, we require more comprehensive data on *low-level* geochemical, thermal or geophysical anomalies.
3. In exploring under post-mineralisation cover where direct geochemical techniques may be challenged, translating mineral system characteristics to mappable geophysical parameters will be a major requirement

Thank You

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