

# Geochemical techniques for undercover exploration: The 'new geophysics'?

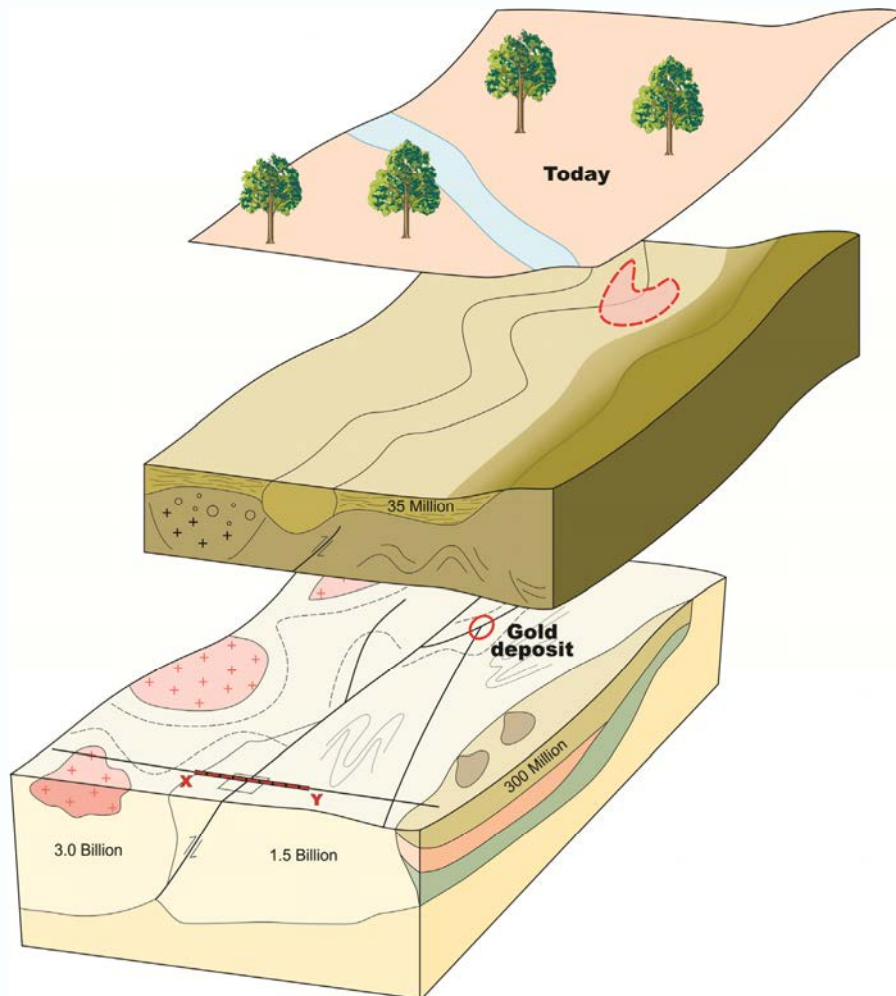
James S. Cleverley | Principal Geochemist

CSIRO EARTH SCIENCES & RESOURCE ENGINEERING – MINERALS DOWN UNDER  
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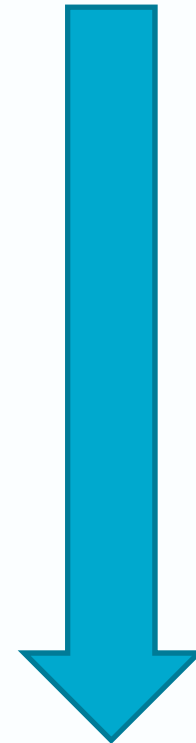




# The Exploration Challenge



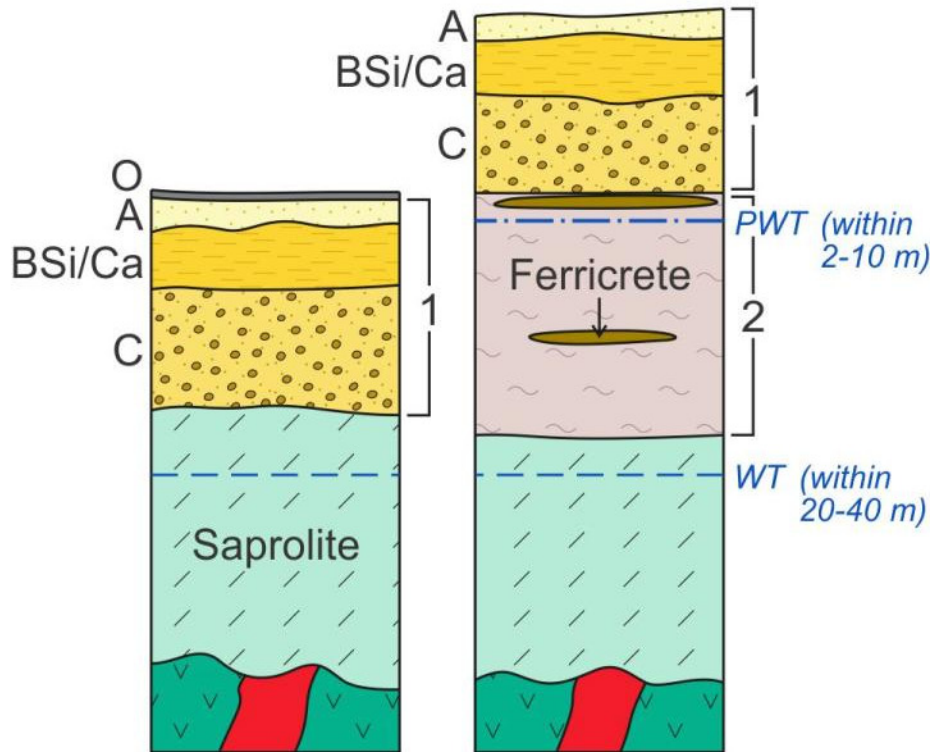
Deep Exploration Targeting



A New Search Space

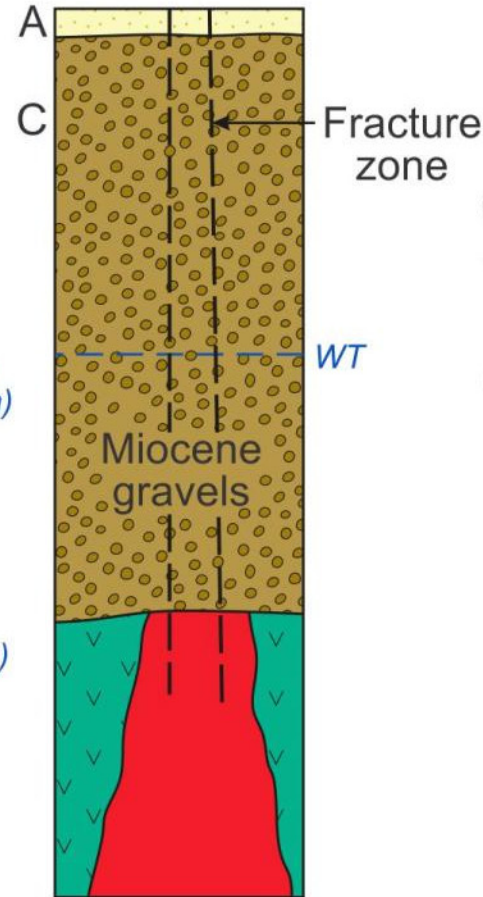
# Complex Cover Sequences

Arid, Australian environments



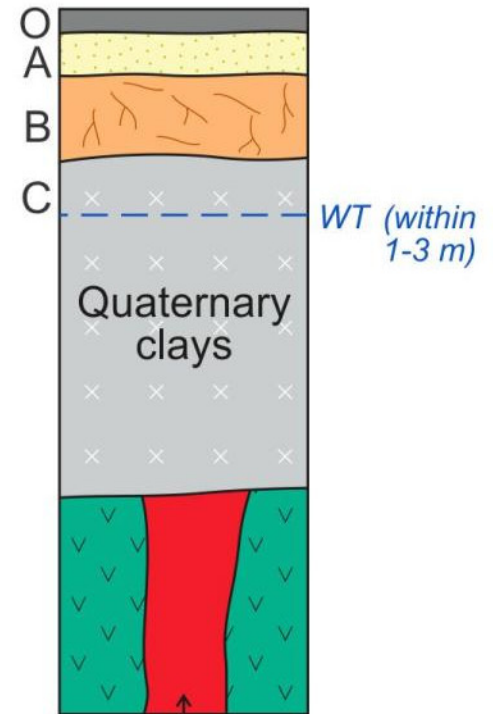
- 1 Quaternary colluvium and alluvium
- 2 Tertiary/Mesozoic sediments

Hyper arid, northern Chile environments



PWT = Palaeowater table  
WT = Current water table

Boreal, Canadian environments



Mineralisation

As a result of this complex history, we can have profiles which are quite distinct from other environments such as Chile and Canada. First, our cover is generally weathered and mature compared to Chile and Canada where much younger. Many regions are tectonically stable and have not experienced much neotectonic activity. Because of present arid climate, upper soil profile development is very poor and lack development of strong A and B horizons because of low leaching environments. We have silicified and calcareous B horizons. Because of palaeowater tables we may have ferricrete developed at redox front in some situations and may have experienced processes outlined by Cameron and others. We can take advantage of those processes.

# Mineral Systems and R&D

## The Why Question

**Why is the ore body there?**

### 6 Questions

1. Geodynamics
2. Architecture
3. Fluid reservoirs
4. Flow drivers & pathways
5. Deposition
6. Preservation

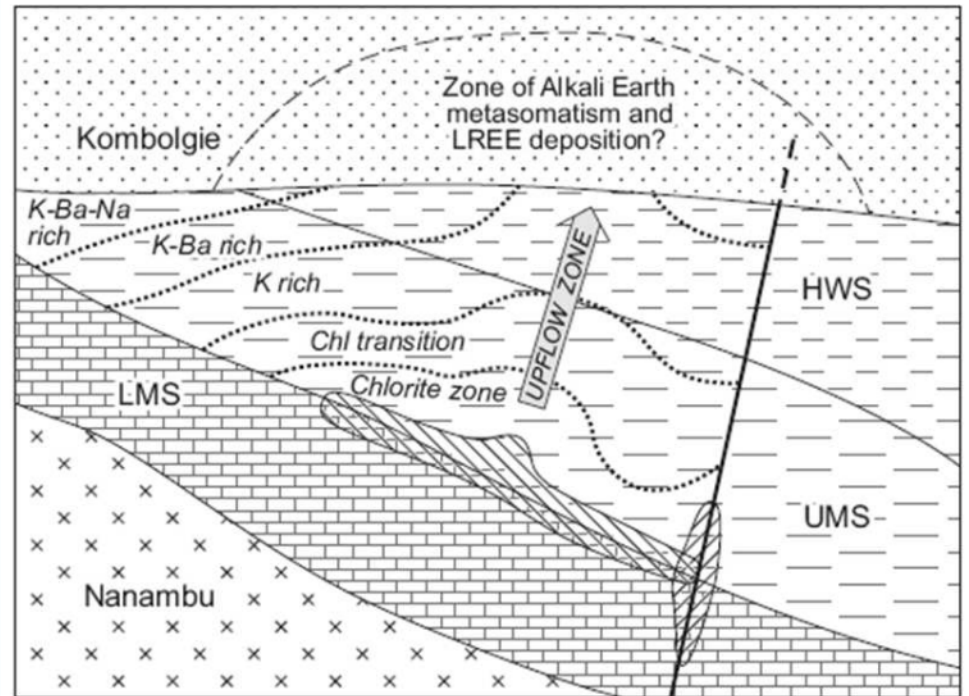
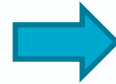
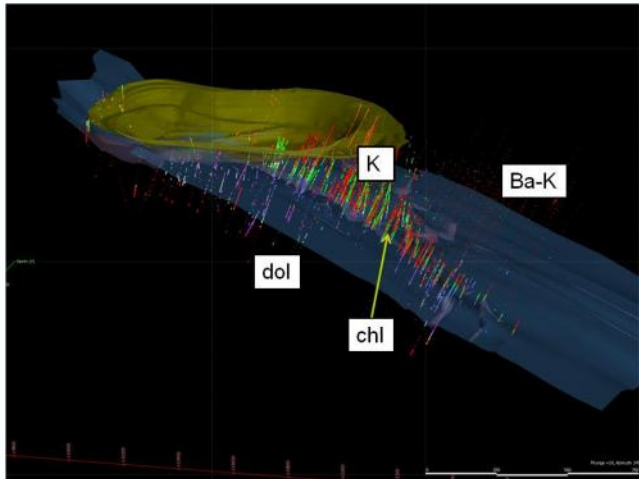
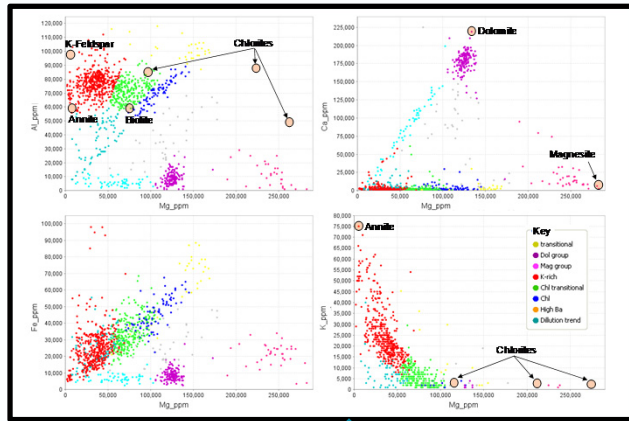
### Inputs from:

Data Integration  
New technology  
3D Analytics

## The Where Question

**Where is the next ore body?**

# Targeting Distal Footprints

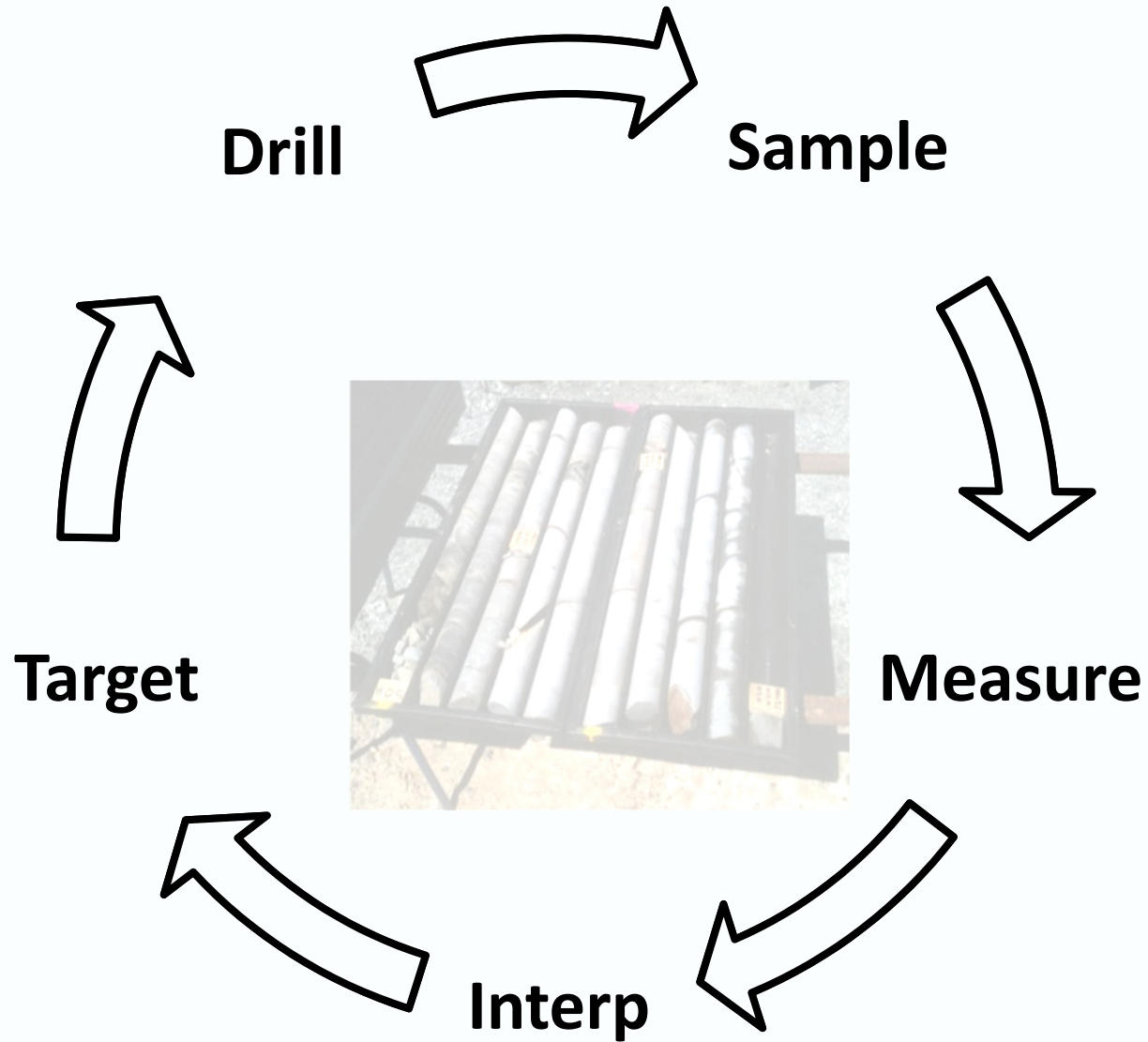


Fisher et al; 2013

**We don't have much to go on ...**

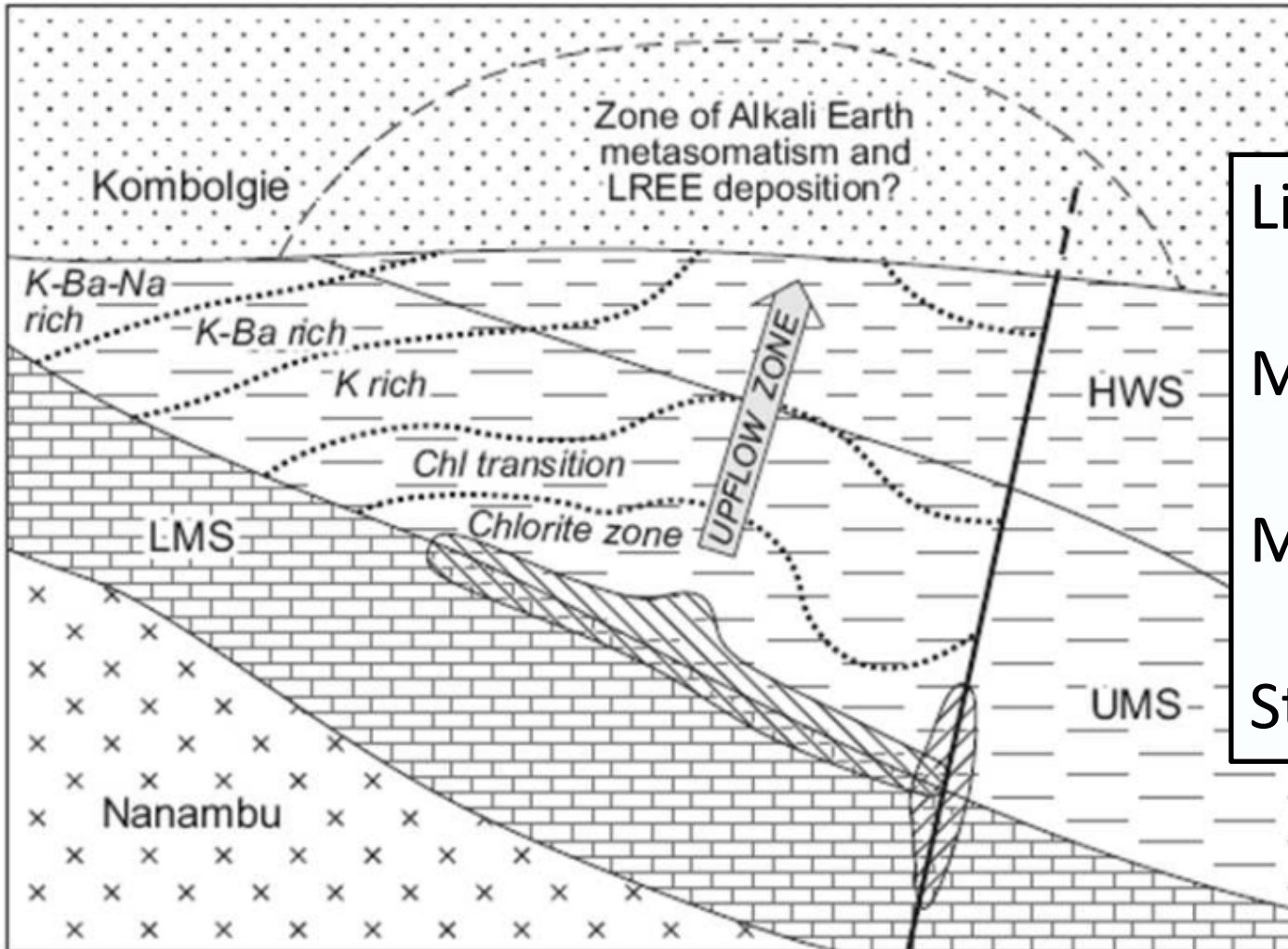


# The process can be slow



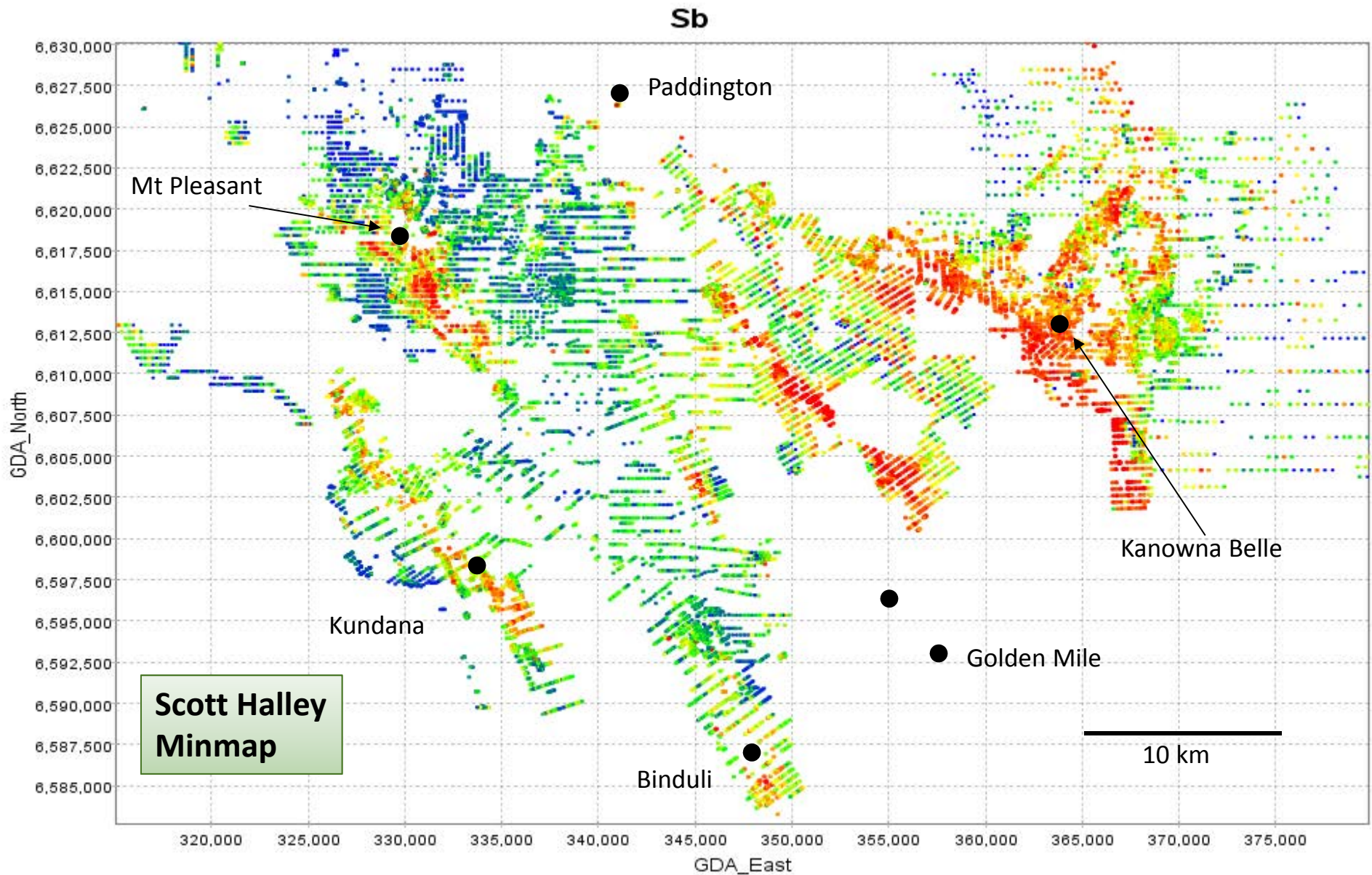
# What is the anatomy of a mineral system and how do we read its story?

# The Mineral System?



- Lithology
- Metamorphism
- Metasomatism
- Structure

# Map of TOFR in the Kalgoorlie District

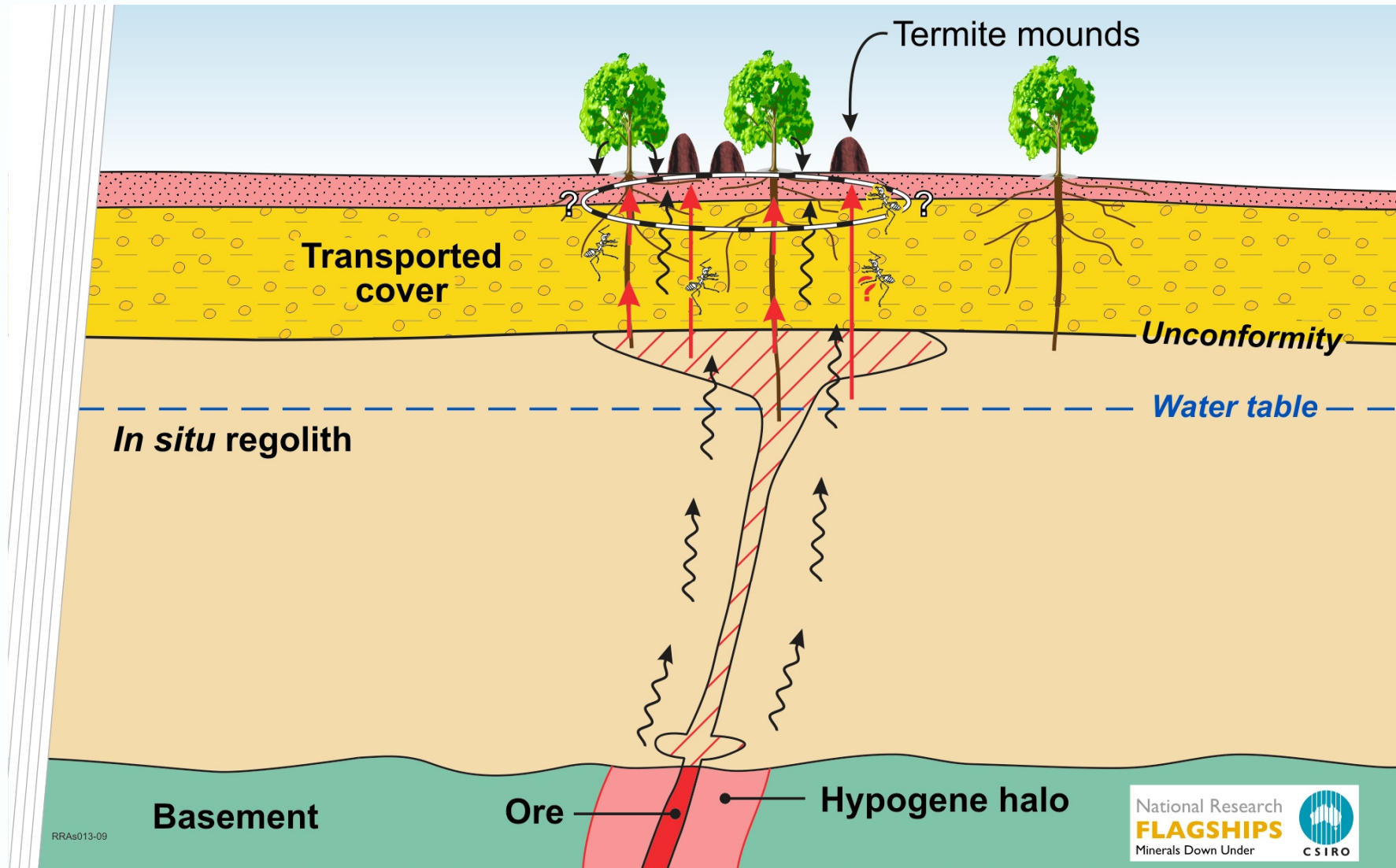


Reference; Halley S (2007) Mineral mapping - how it can help us explore in the Yilgarn Craton In: Bierlein FP, Knox-Robinson CM (eds) Proceedings of Geoconferences (WA) Inc Kalgoorlie '07 Conference. pp 143 -144.

This is a map of the antimony distribution based on analyses of end of hole RAB drill samples. Antimony substitutes into the lattice of pyrite, and it has a larger primary dispersion halo than any other pathfinder in Archean gold systems. Because it goes into a widely distributed mineral like pyrite, it has a remarkably regular distribution pattern. Note the scale of the anomalism. Sampling on a pattern of 2km by 2km would not have discovered the gold ore bodies, BUT it would have demonstrated that this was a mineralised segment of a greenstone belt. Broad-scale anomaly definition like this is an excellent way to discriminate between greenstone belts.



# Shallow cover techniques



# Techniques in the profile



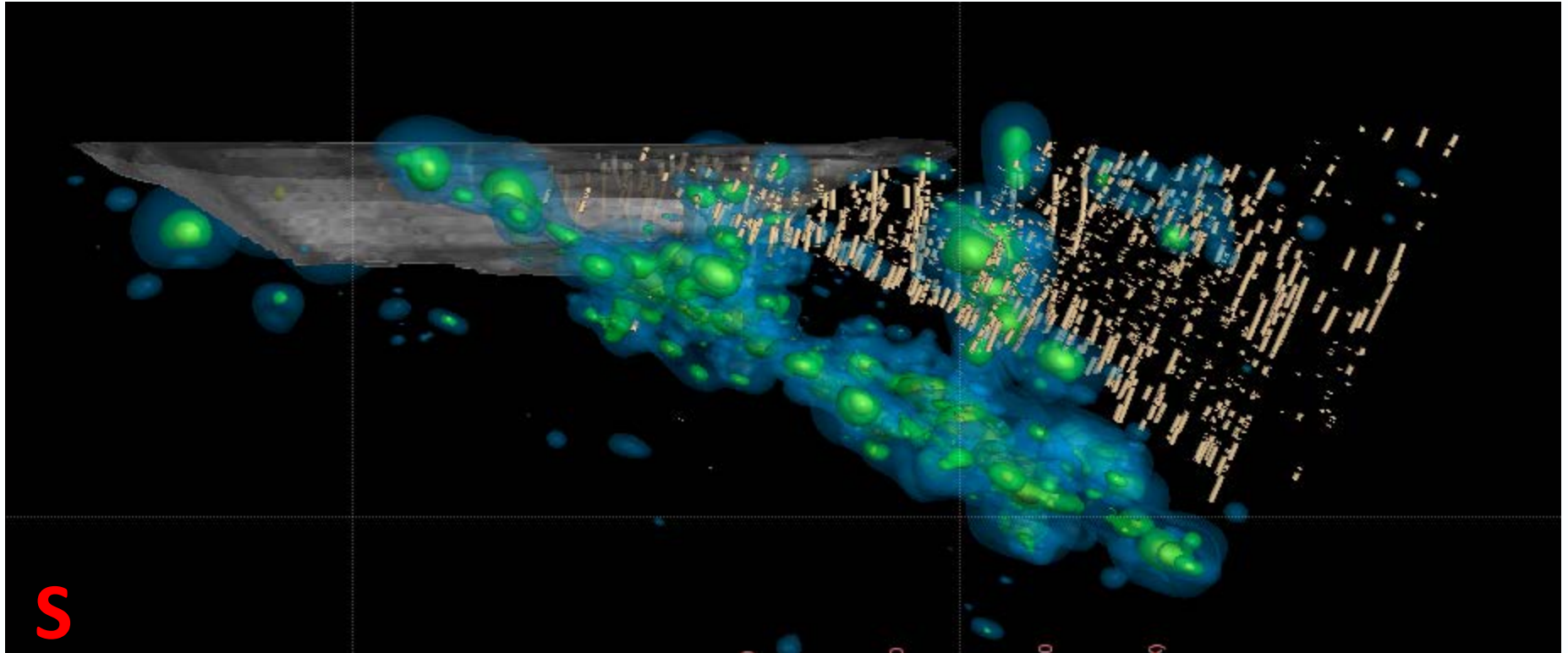
< 50 meters – Gas, hydrogeochem, biogeochem (trees/shrubs)

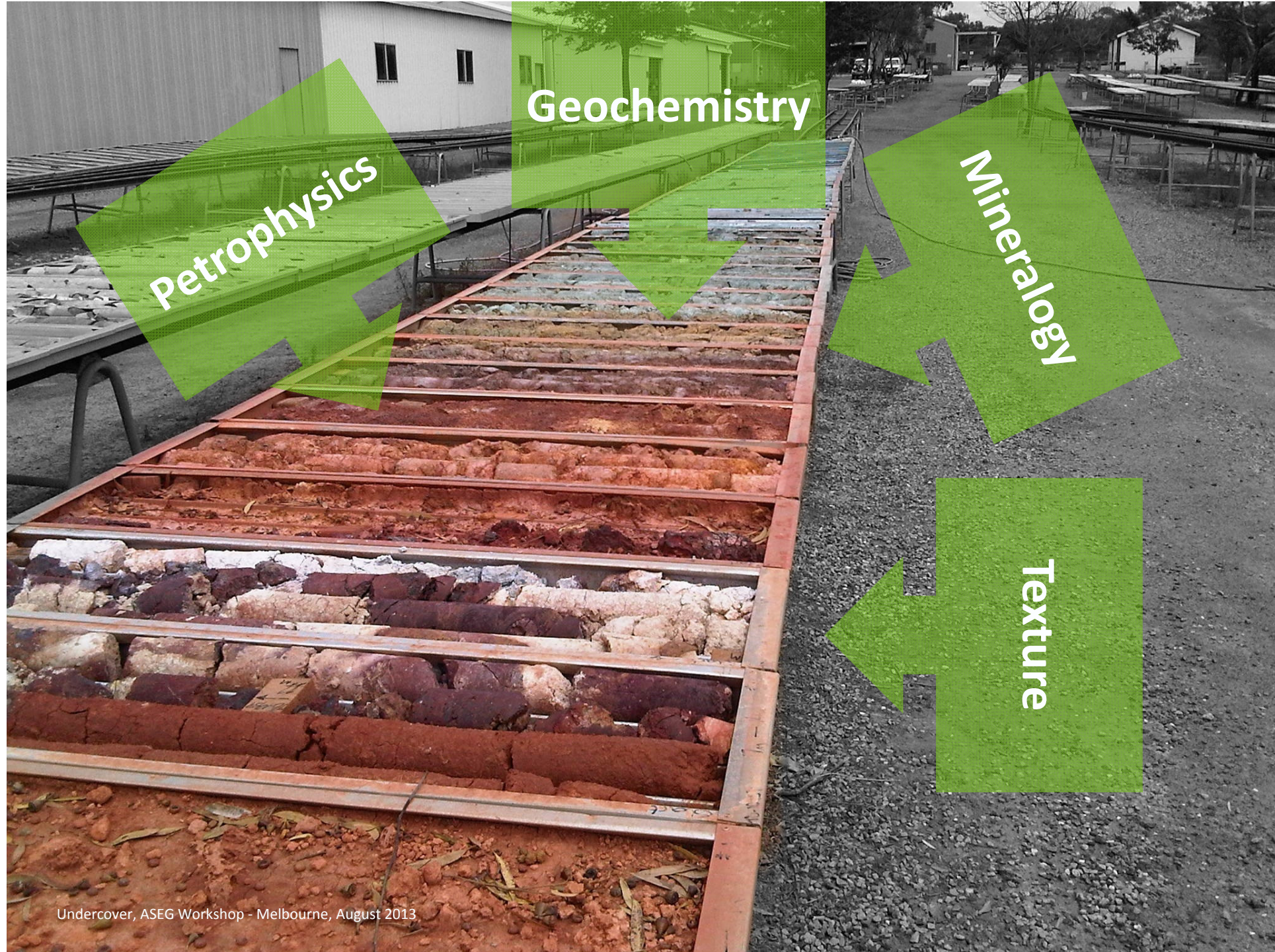
> 50-100 meters - Hydrogeochemistry

Immobile geochem/mineralogy  
Resistate mineral chemistry

Whole rock geochem/mineralogy  
Mineral chemistry

# Geochemistry extends into 3D





Petrophysics

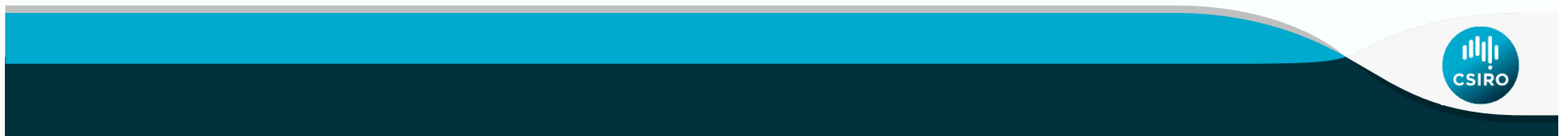
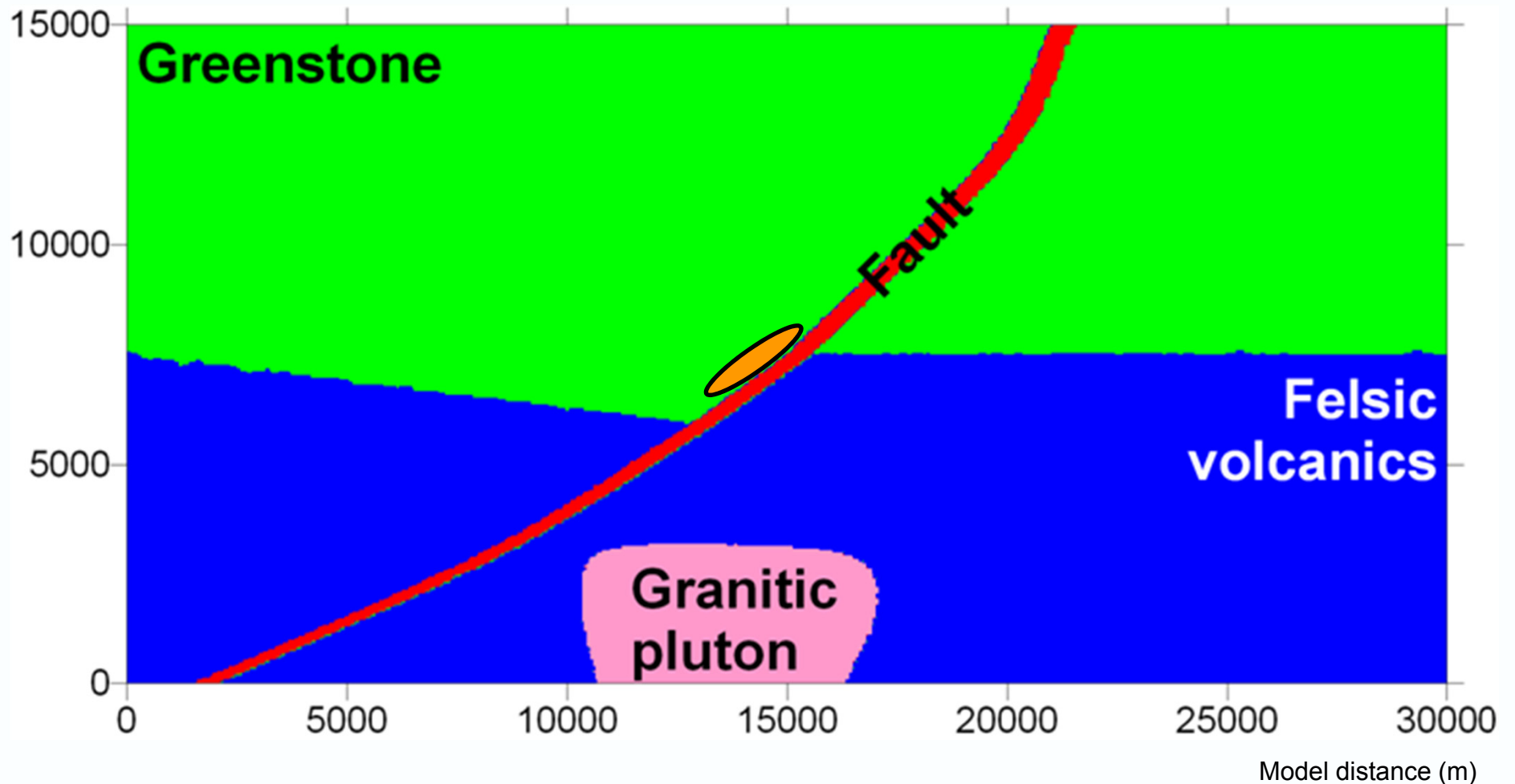
Geochemistry

Mineralogy

Texture

# Modelling the coupled approach

# Model & simulating geological history

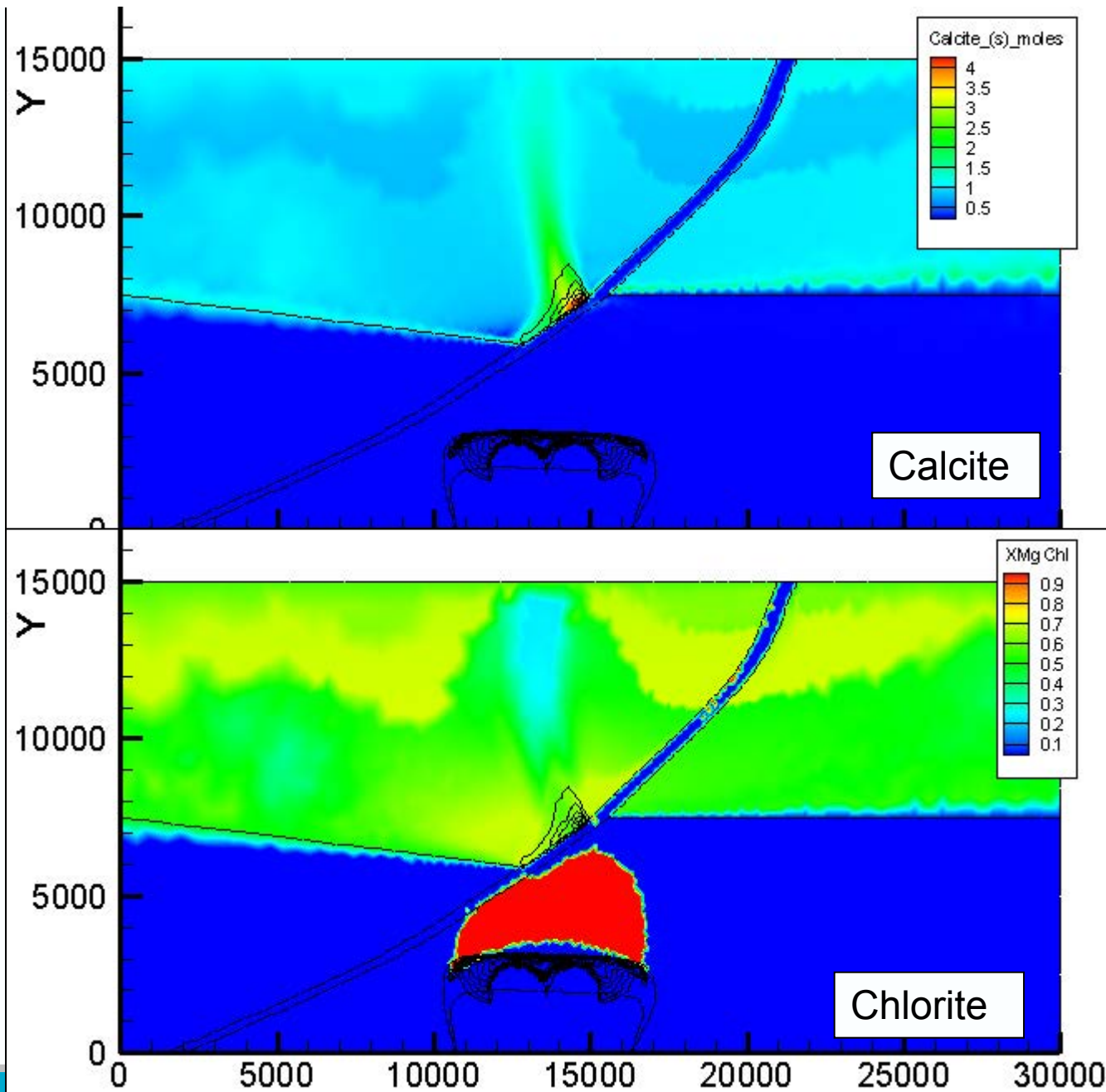


The listric fault model (see Cleverley et al., 2006) is a model of fluids being expelled from a cooling granite pluton. These fluids travel up the fault, depositing gold at the region of the orange oval. There are also convection cells set up in the greenstones and also the felsic volcanics.

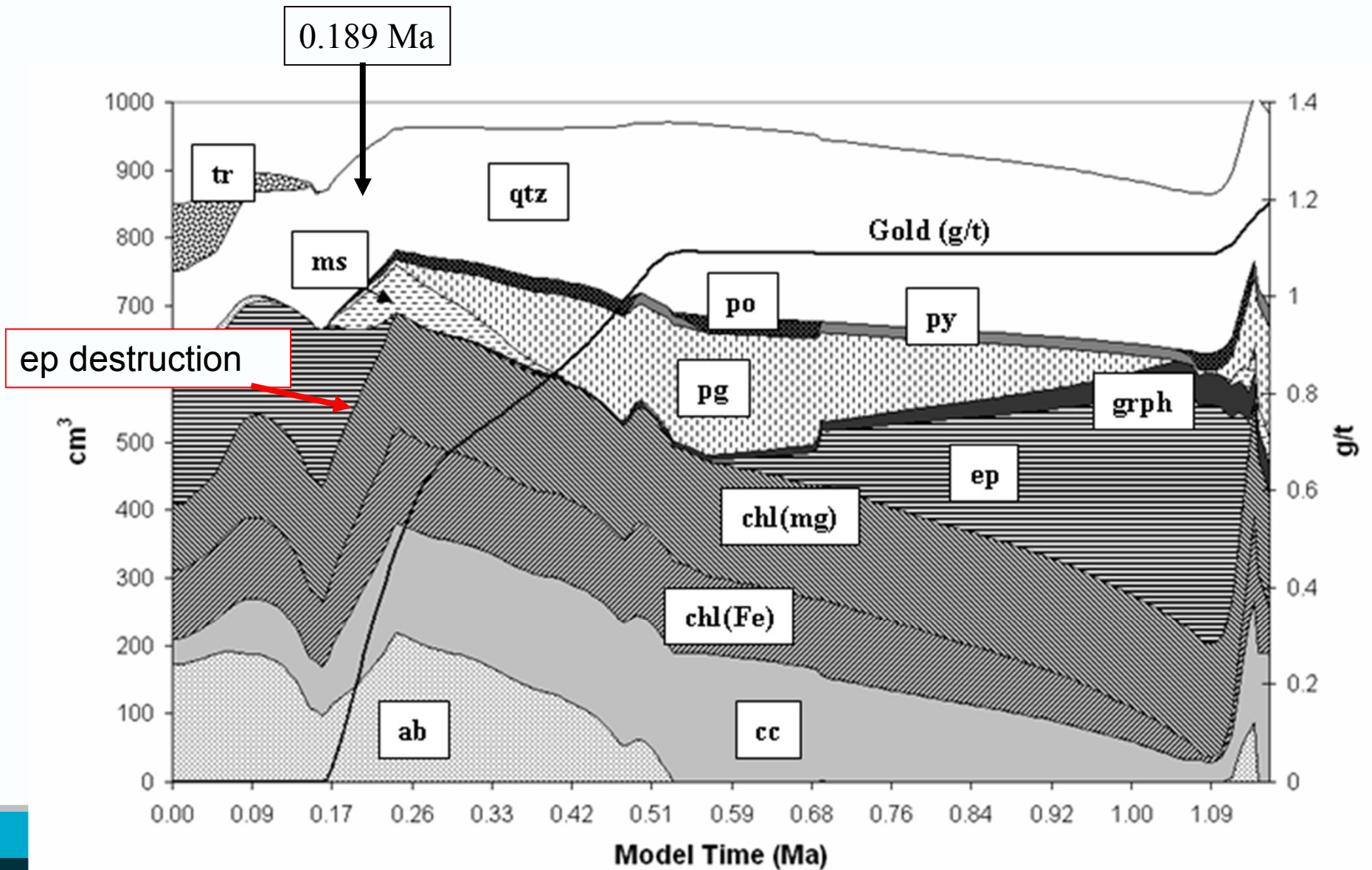
Cleverley, J. S., Hornby, P. & Poulet, T. (2006). *pmd\*RT: Combined fluid, heat and chemical modelling and its application to Yilgarn geology*. In Barnicoat, A. C. & Korsch, R. J. (Eds.) *Predictive Mineral Discovery Cooperative Research Centre - Extended Abstracts from the April 2006 Conference*. Geoscience Australia, Record 2006/07.



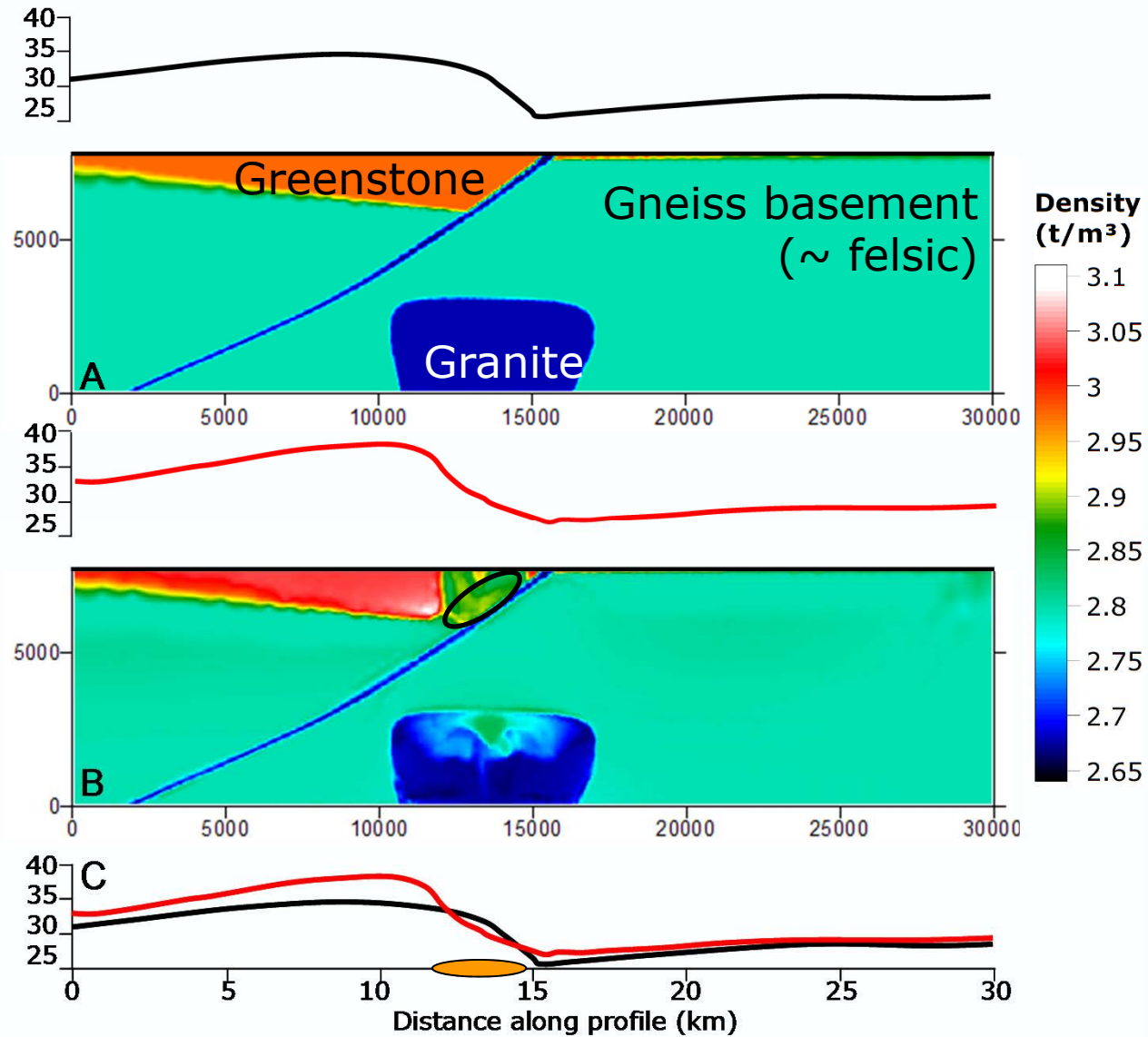
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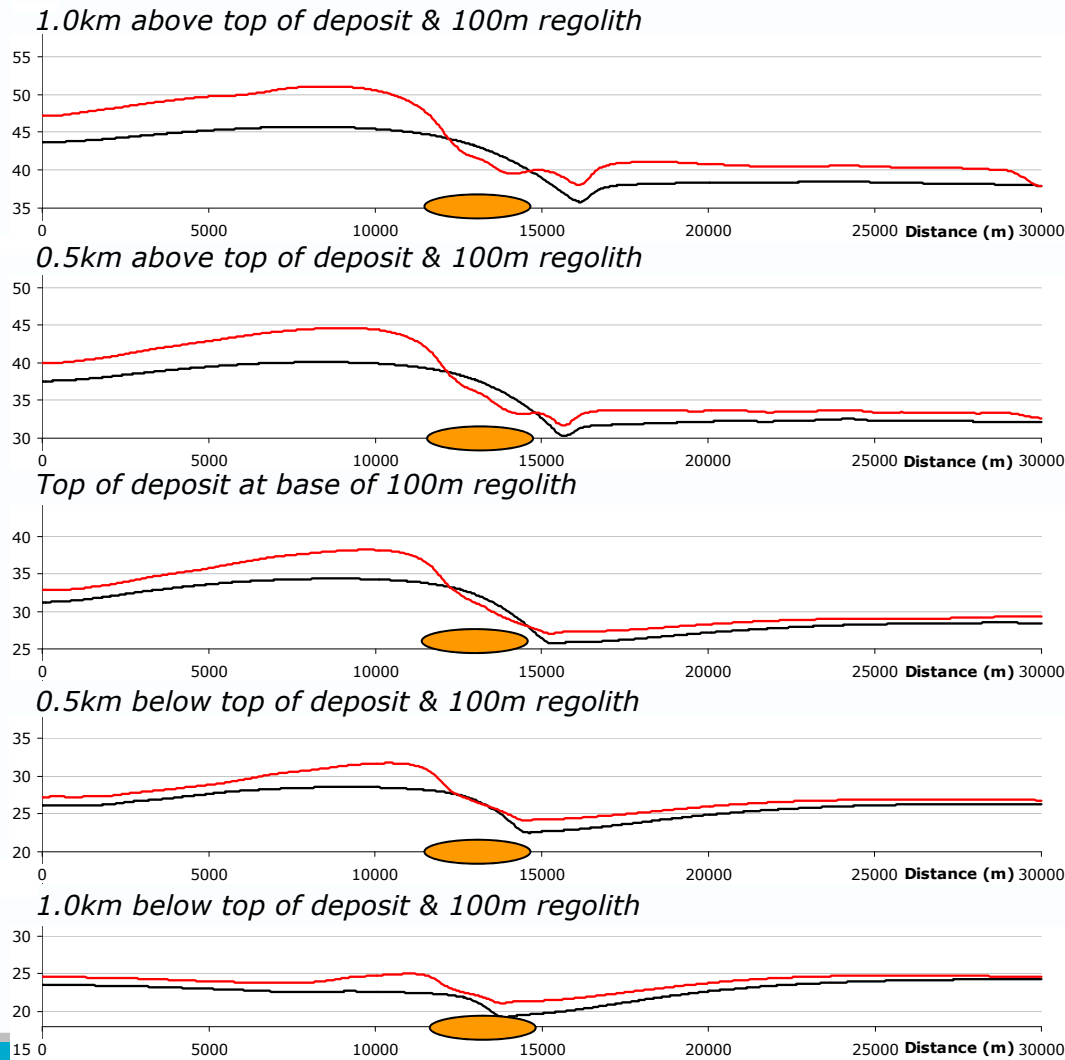
# A mineral system also evolves in time



# Gravity response from this model



# Gravity response with extra 'cover'



**Deposit buried**

**Deposit crops out**

**Deposit is eroded**

# Technology is driving a new way of thinking ....



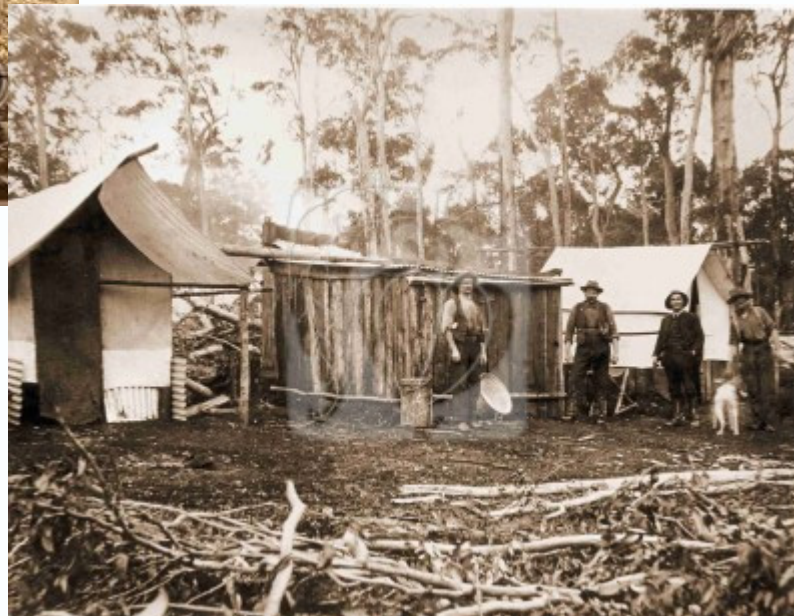
www.dilbert.com  
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# Regional Prospecting ... 1850



# Regional Prospecting ... 2012

## Stream Sediment



Standard sampling kit:

- 2 sieves (2mm and 150 $\mu$ m)
- 1 fibre glass pan; 1 wooden pan
- sample bags
- 1 funnel
- 1 trenching tool
- rubber gauntlets.



Sediment is dug from beneath the oxidised layer in the centre of the stream channel and sequentially sieved through coarse (2mm) and fine (150 $\mu$ m) mesh. The fine fraction is collected in a fibre glass pan and left to settle for 20 minutes.

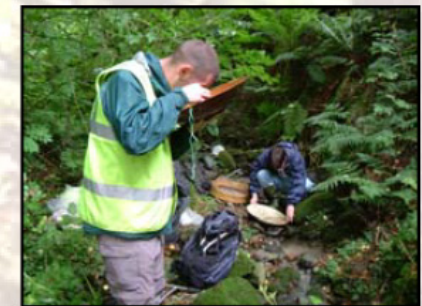


After settlement excess water is carefully drained off. The sediment is homogenised and transferred to a Kraft sample bag.



The samples are air dried until plastic in consistency, before being dispatched to Keyworth for freeze drying and sample preparation.

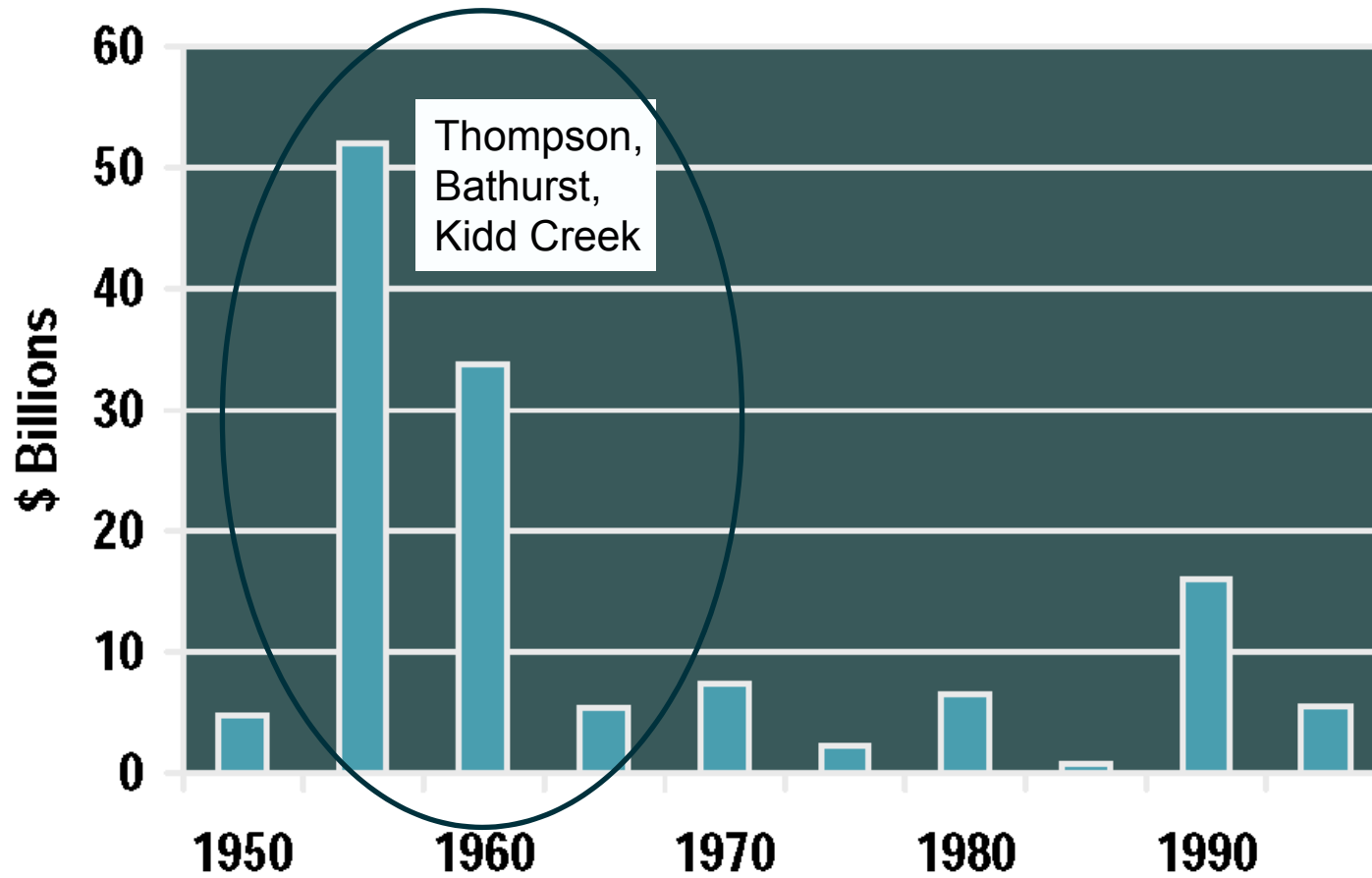
The excess <2mm +150 $\mu$ m fraction is washed, shaken and panned to provide a heavy mineral concentrate. This is carefully examined in the field for minerals of economic interest and contaminants. Samples are retained in the NGD/C, Keyworth



BGS G-Base Project

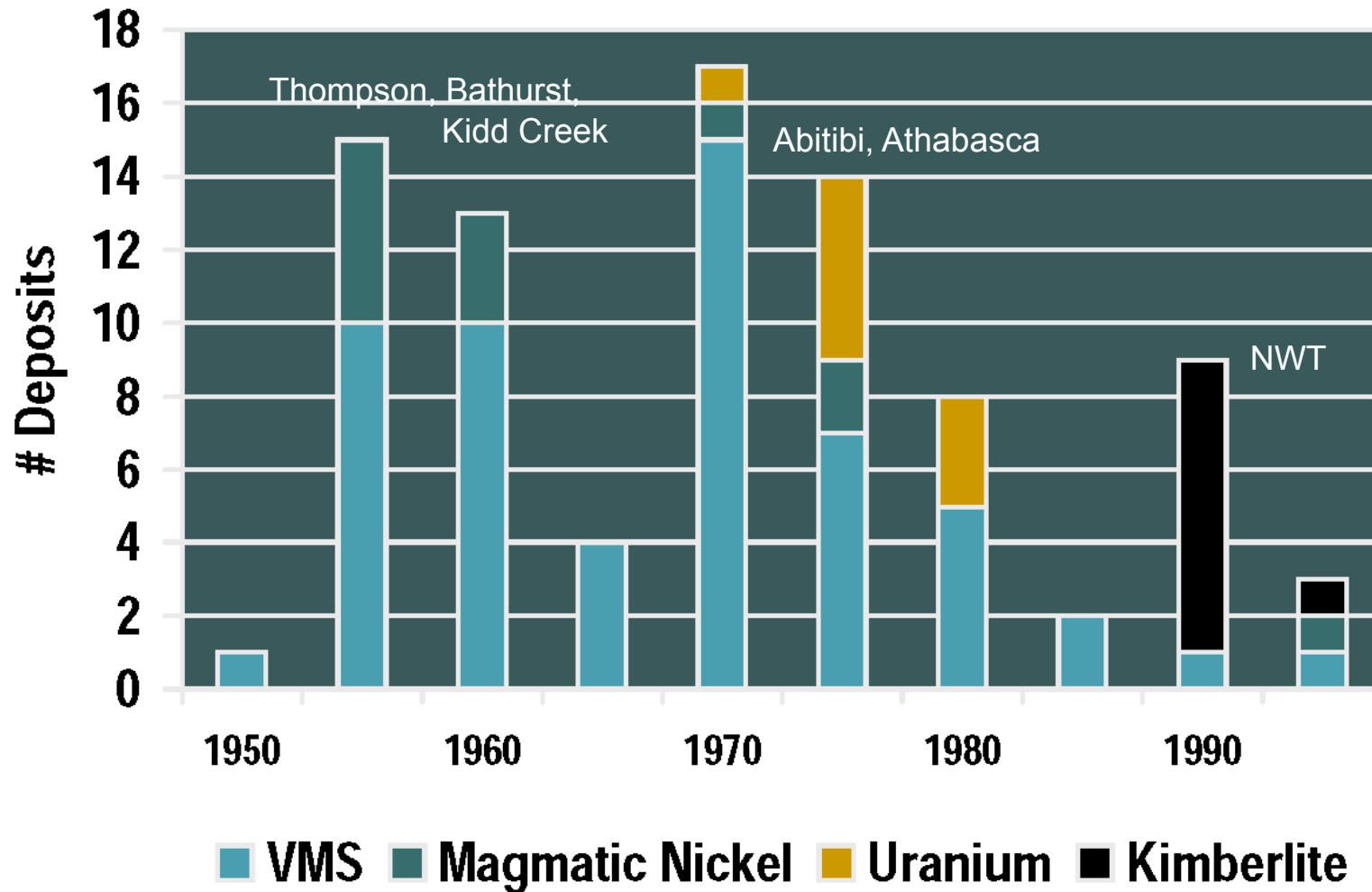


# The Story of AEM



Source: (Witherly, 2000)

# Evolving technology



Discoveries by Deposit Style

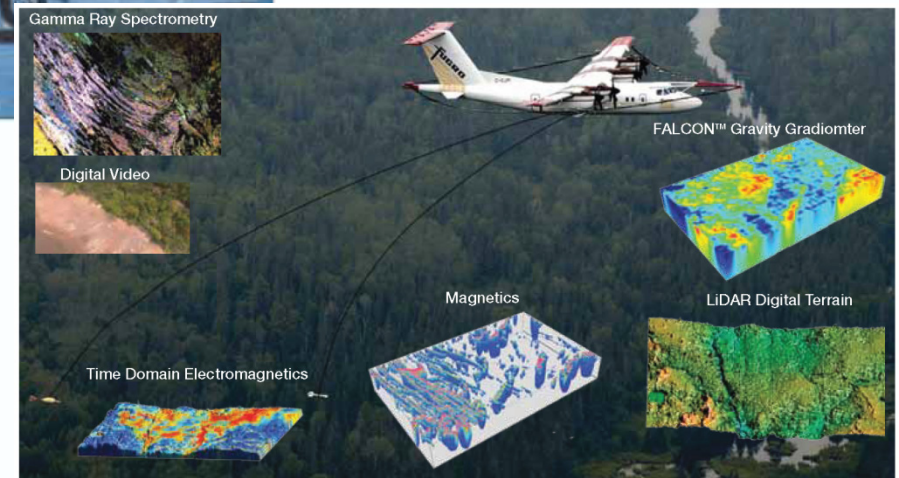
Source: Witherly, 2000



# AEM evolution to platform technology



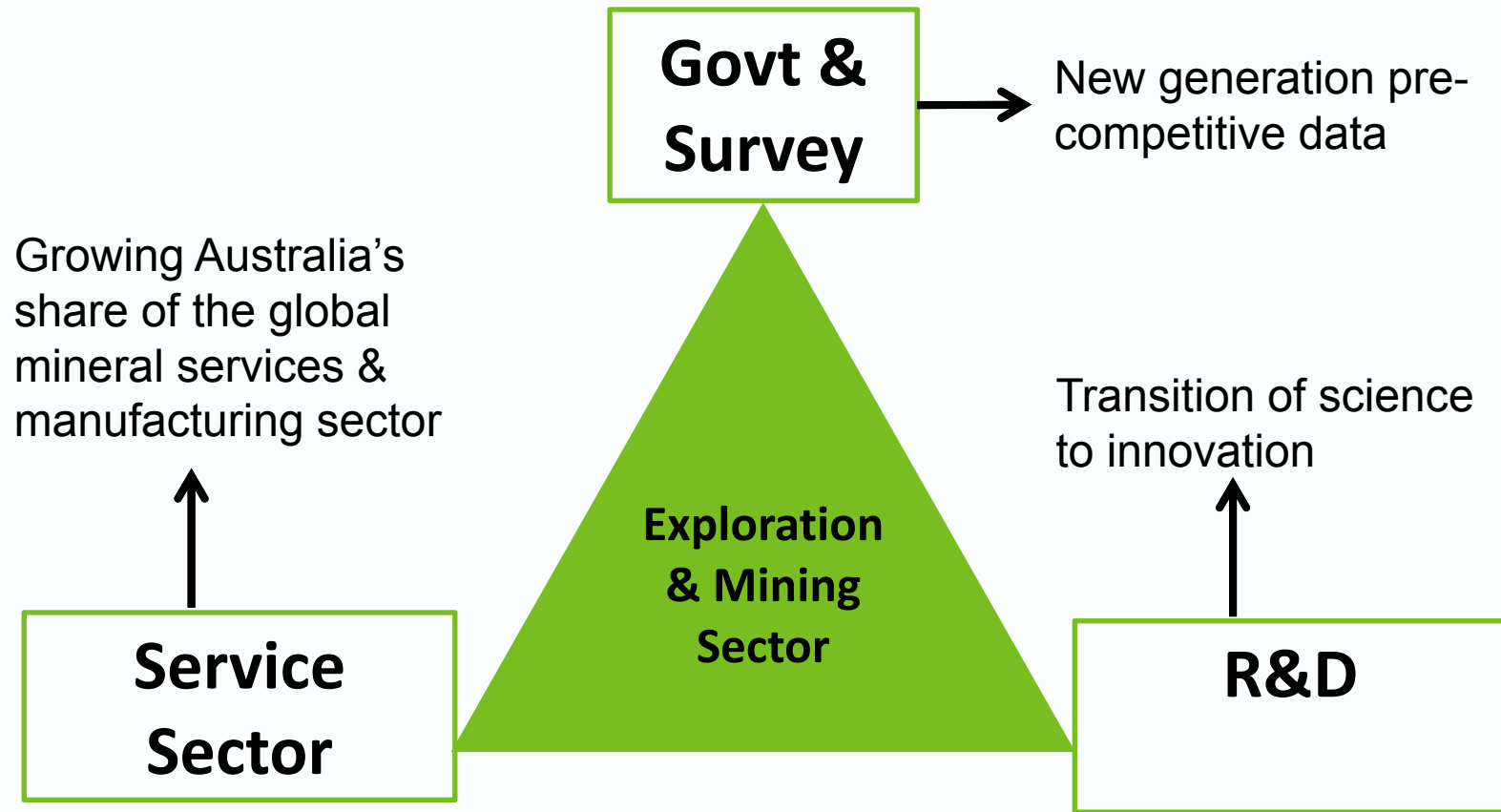
...and now



# The REx Platform



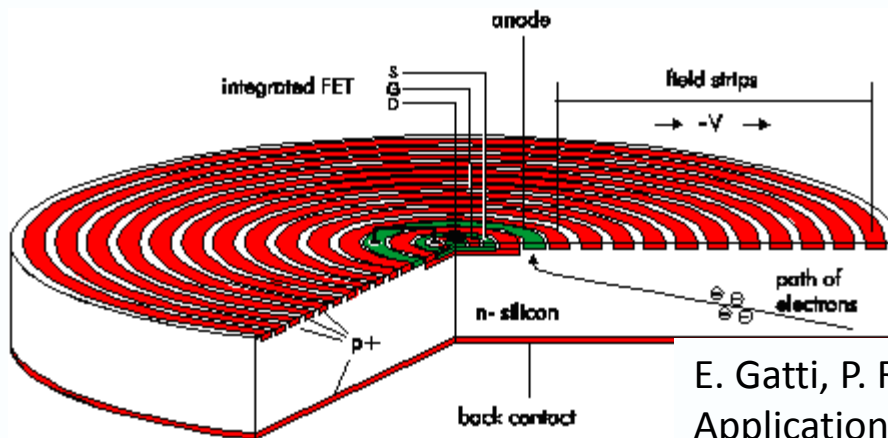
# Unlocking Innovation



# X-Ray Detector Revolution

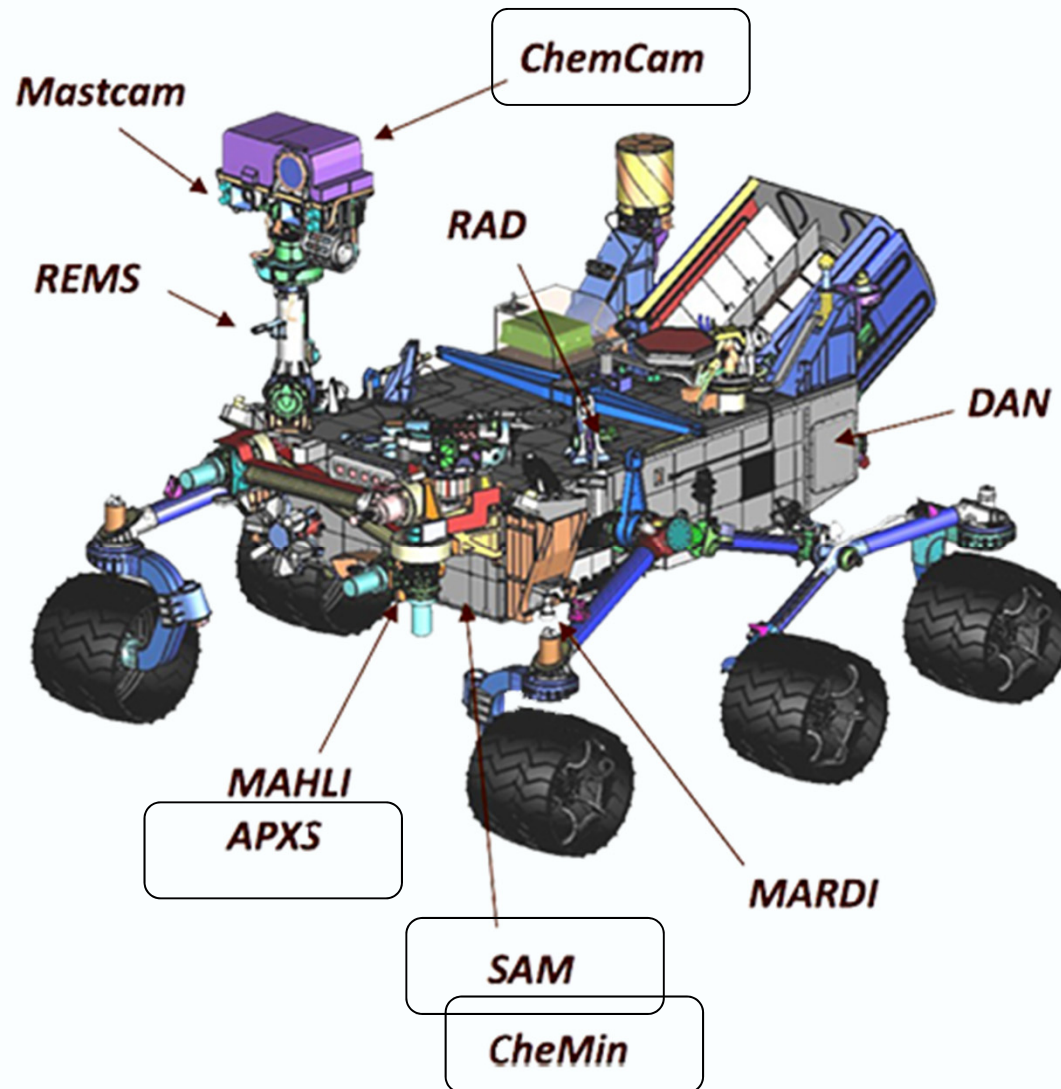


- High count rates
- High energy resolution (e.g. 140 eV)
- Peltier cooling

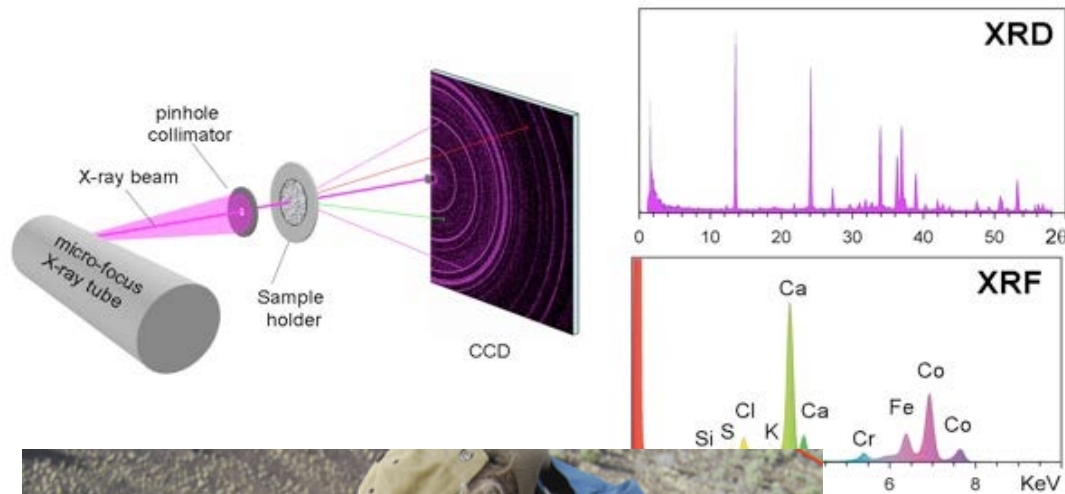


E. Gatti, P. Rehak, Semiconductor Drift Chamber - An Application of a Novel Charge Transport Scheme, Nucl. Instr. and Meth. A 225, 1984, pp. 608-614.

# Curiosity technology



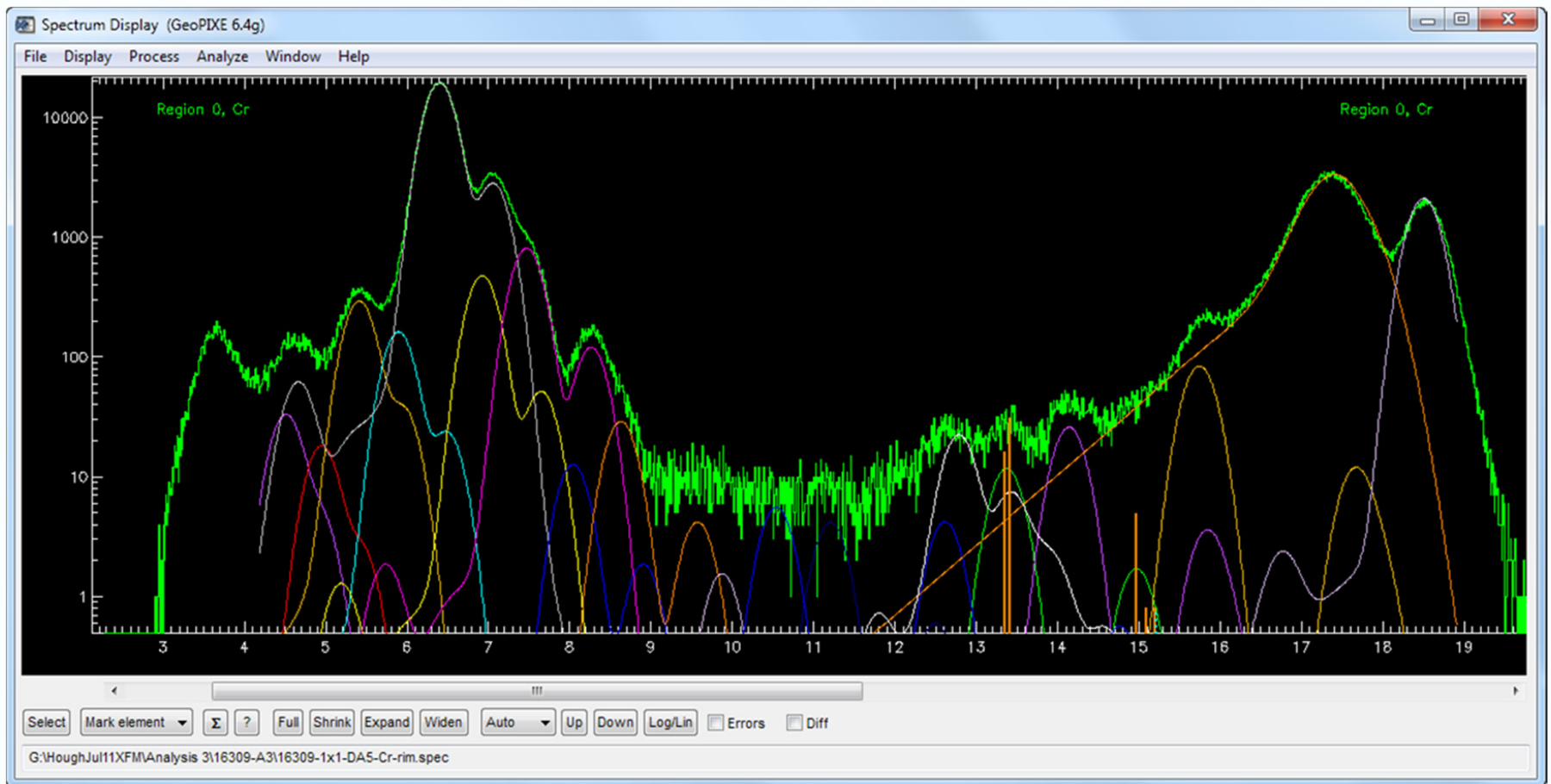
# CheMin applied to mineral exploration



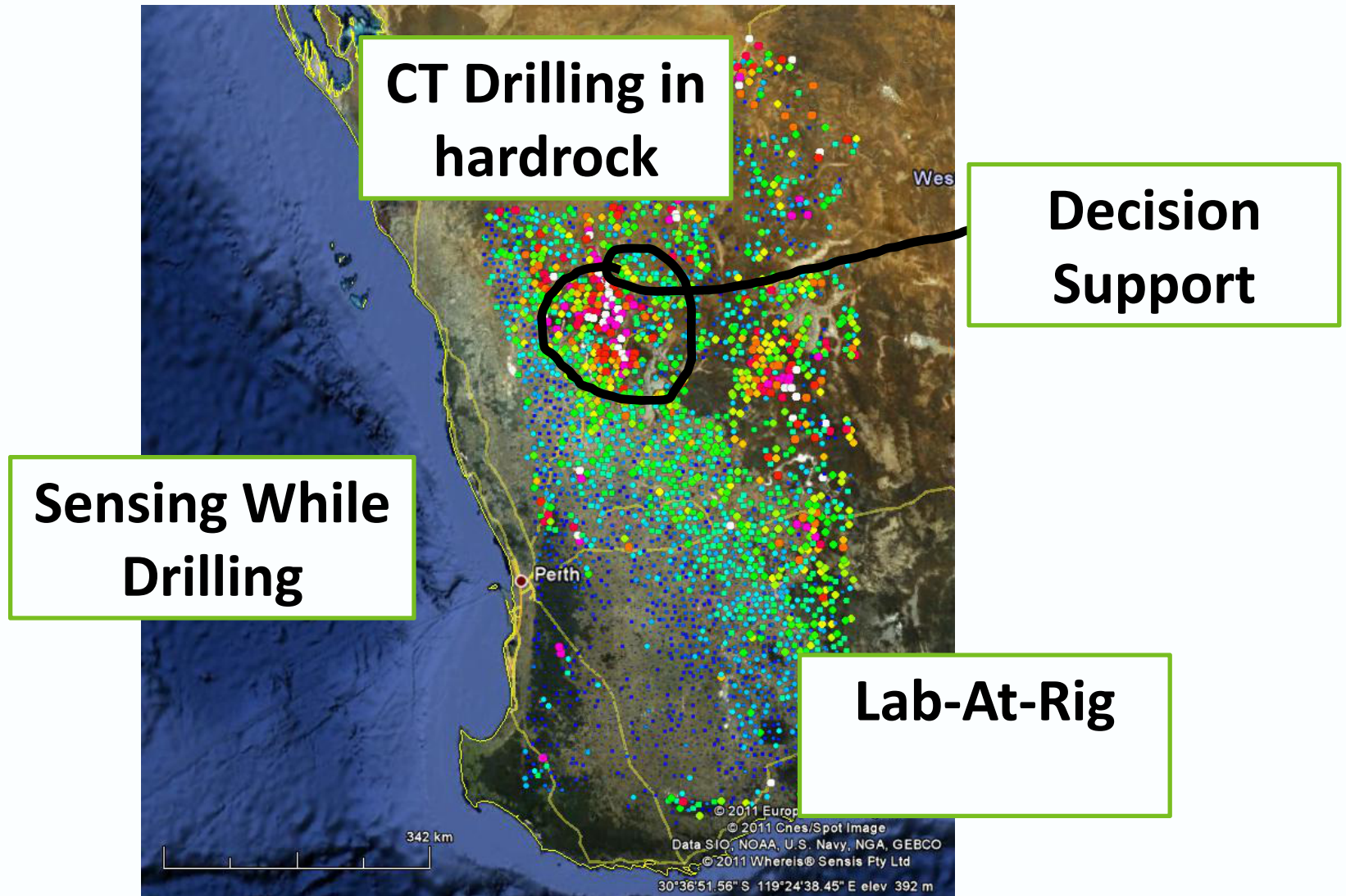
**OLYMPUS**<sup>®</sup>



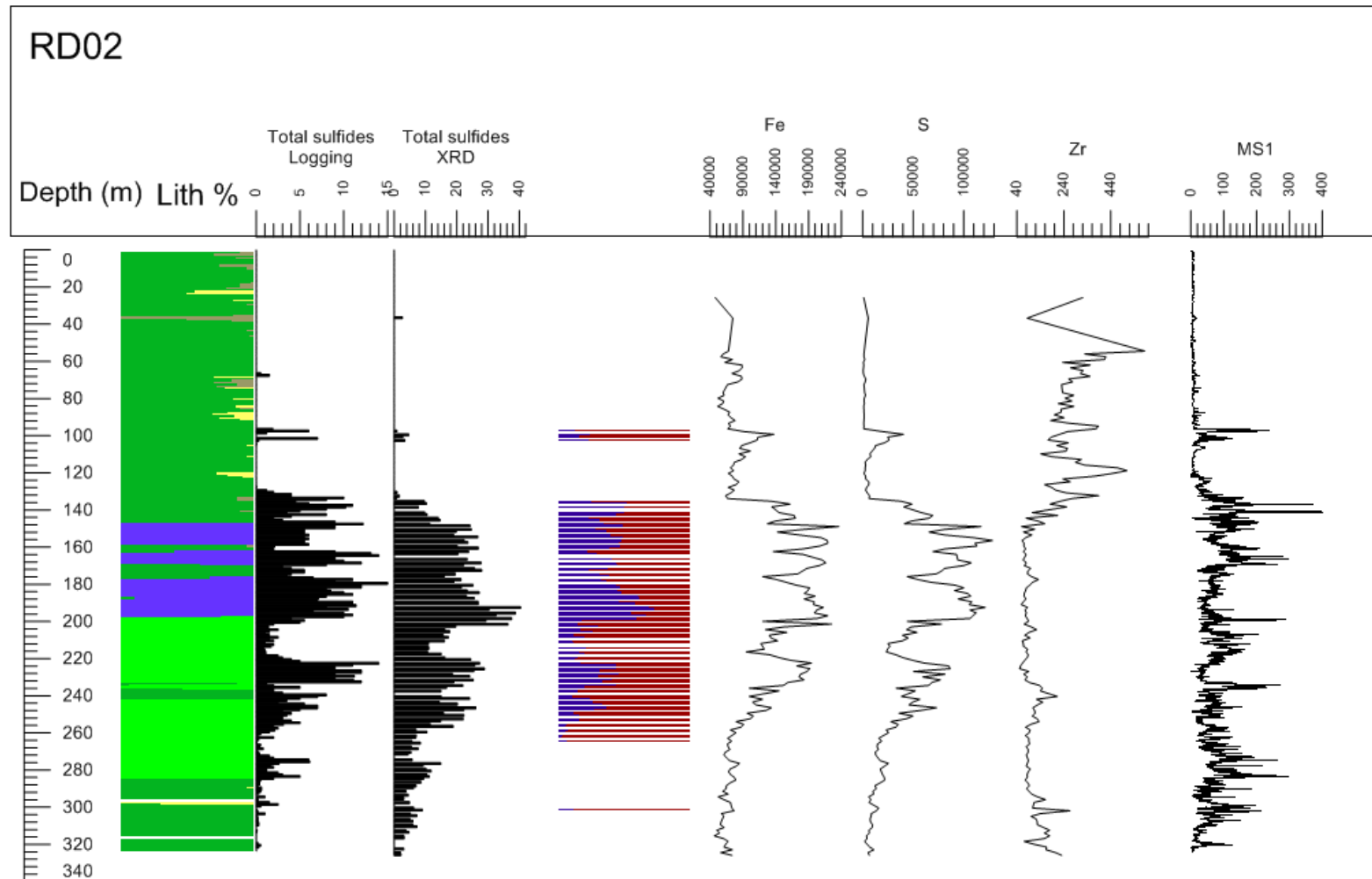
# Biggest challenges in processing ..



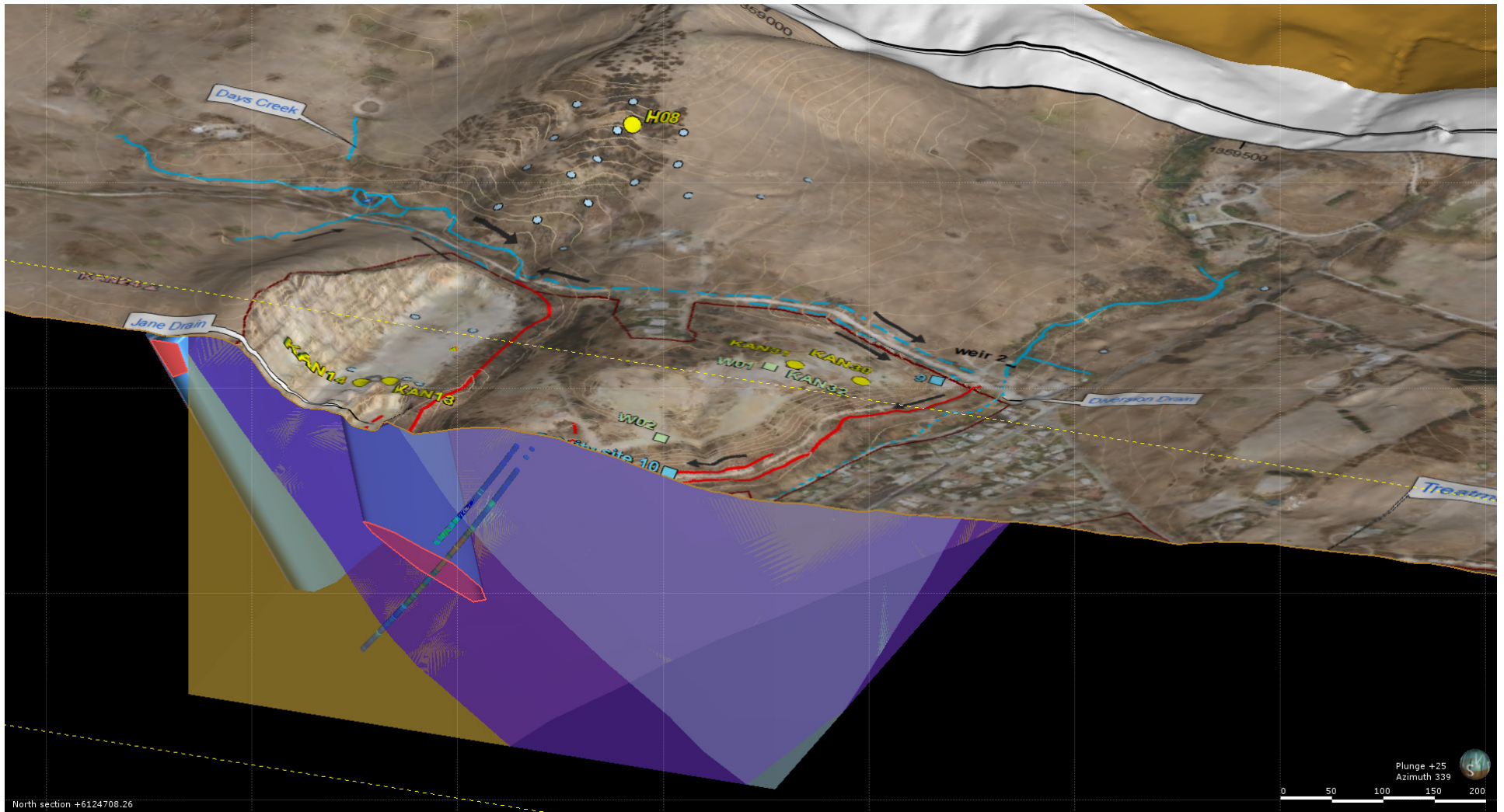
# Deep Exploration Technology CRC



# Real time integrated data while drilling



# The Dynamic 3D Geology Model

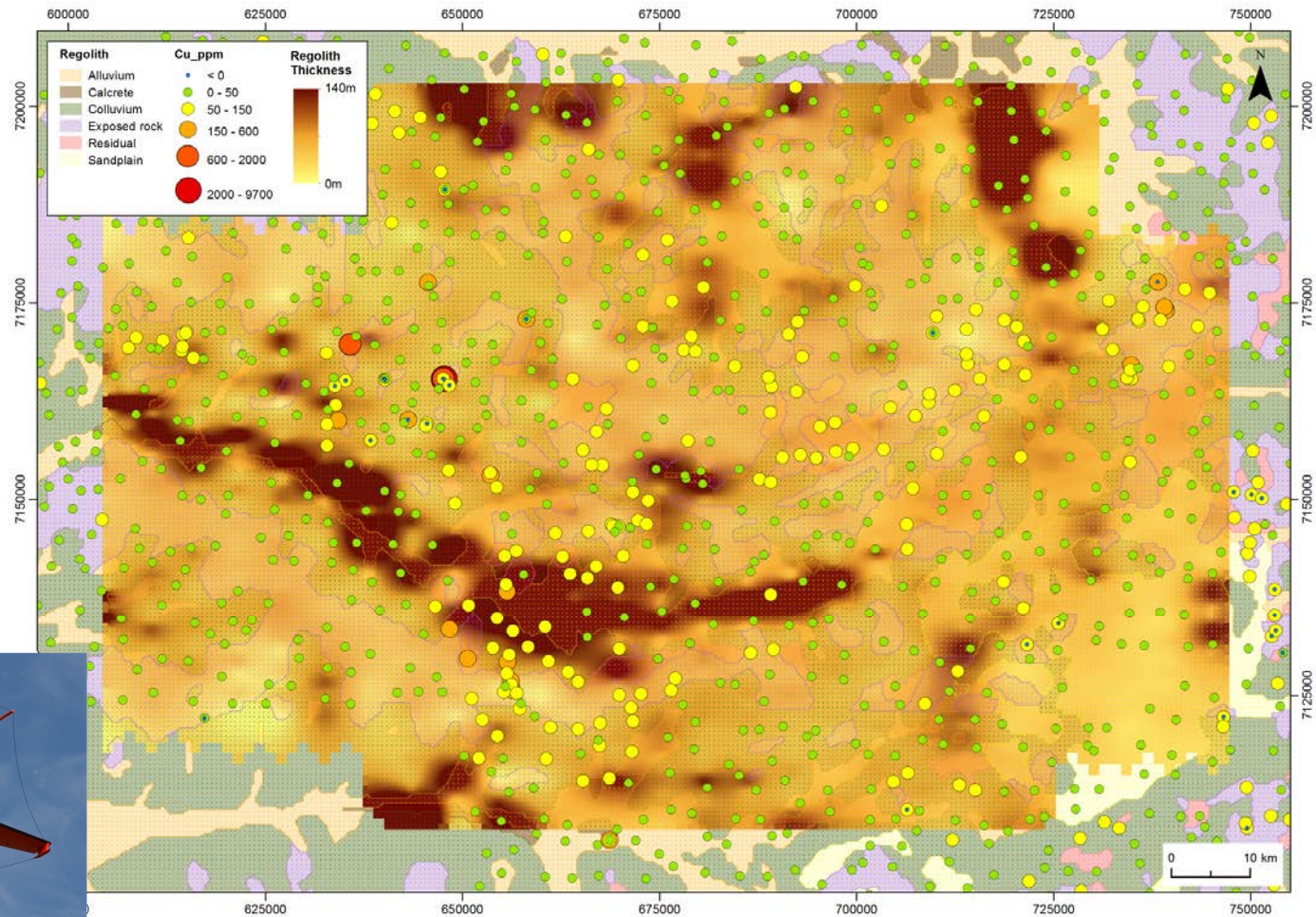


North section +6124700.26

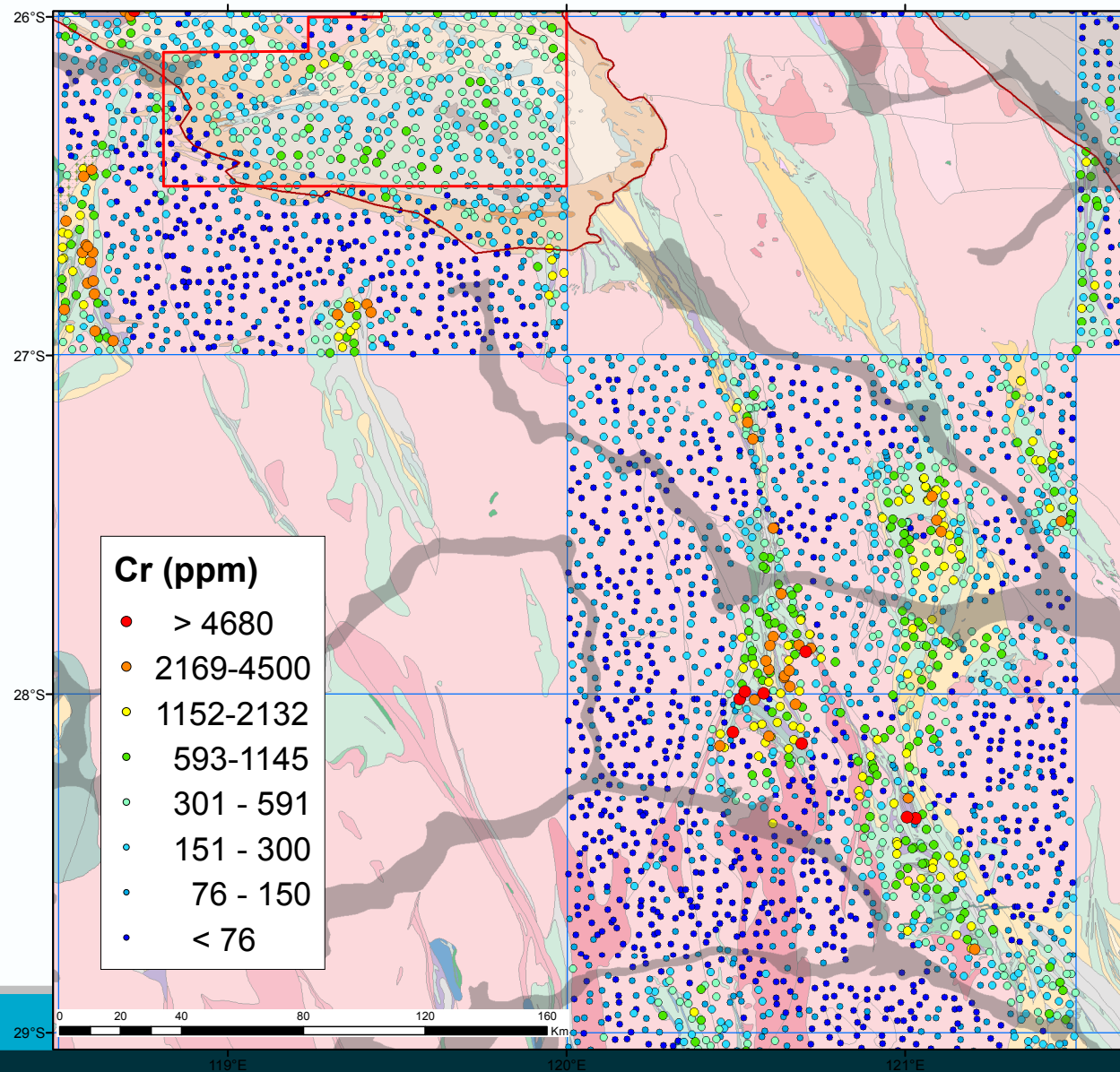
# A window on the future?



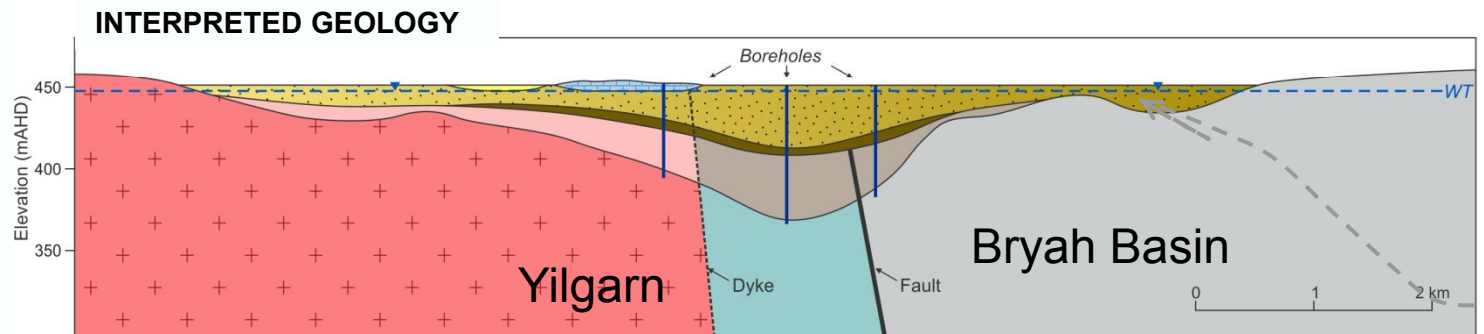
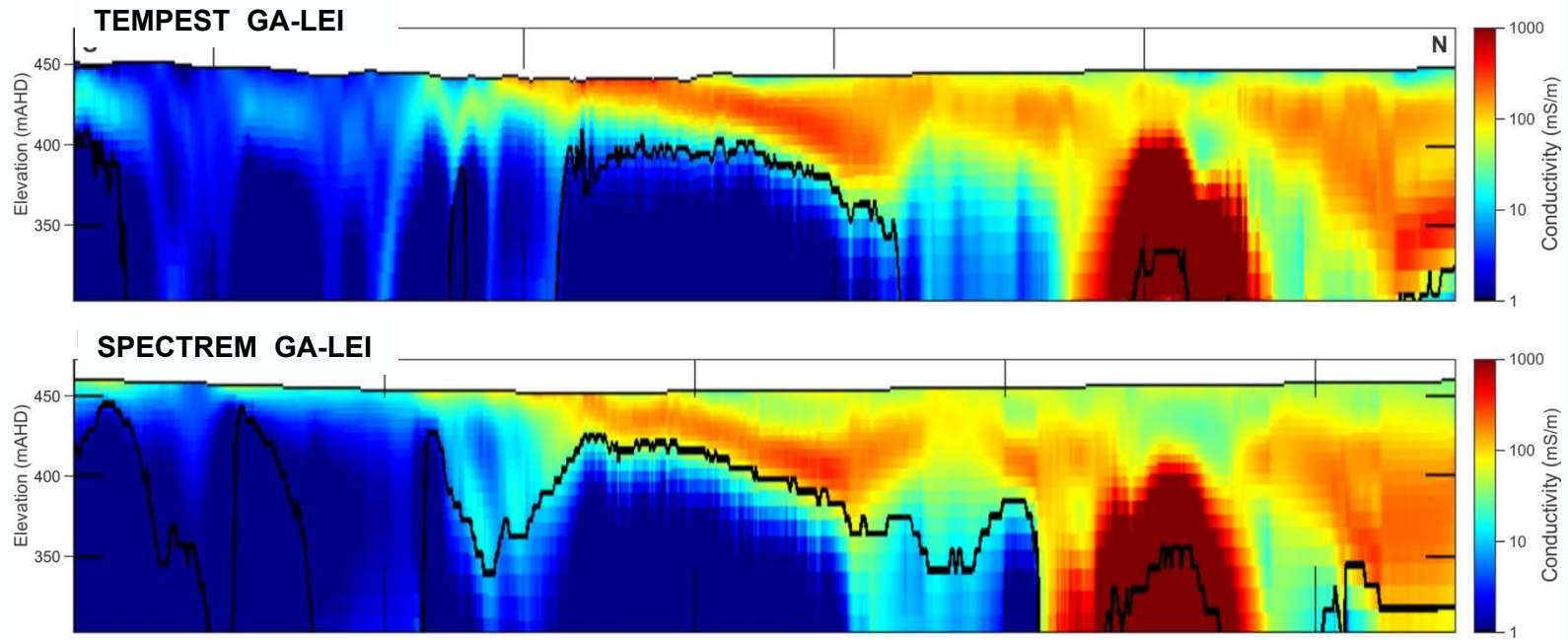
# Linking geophysics and geochemistry



# False negatives – transported cover



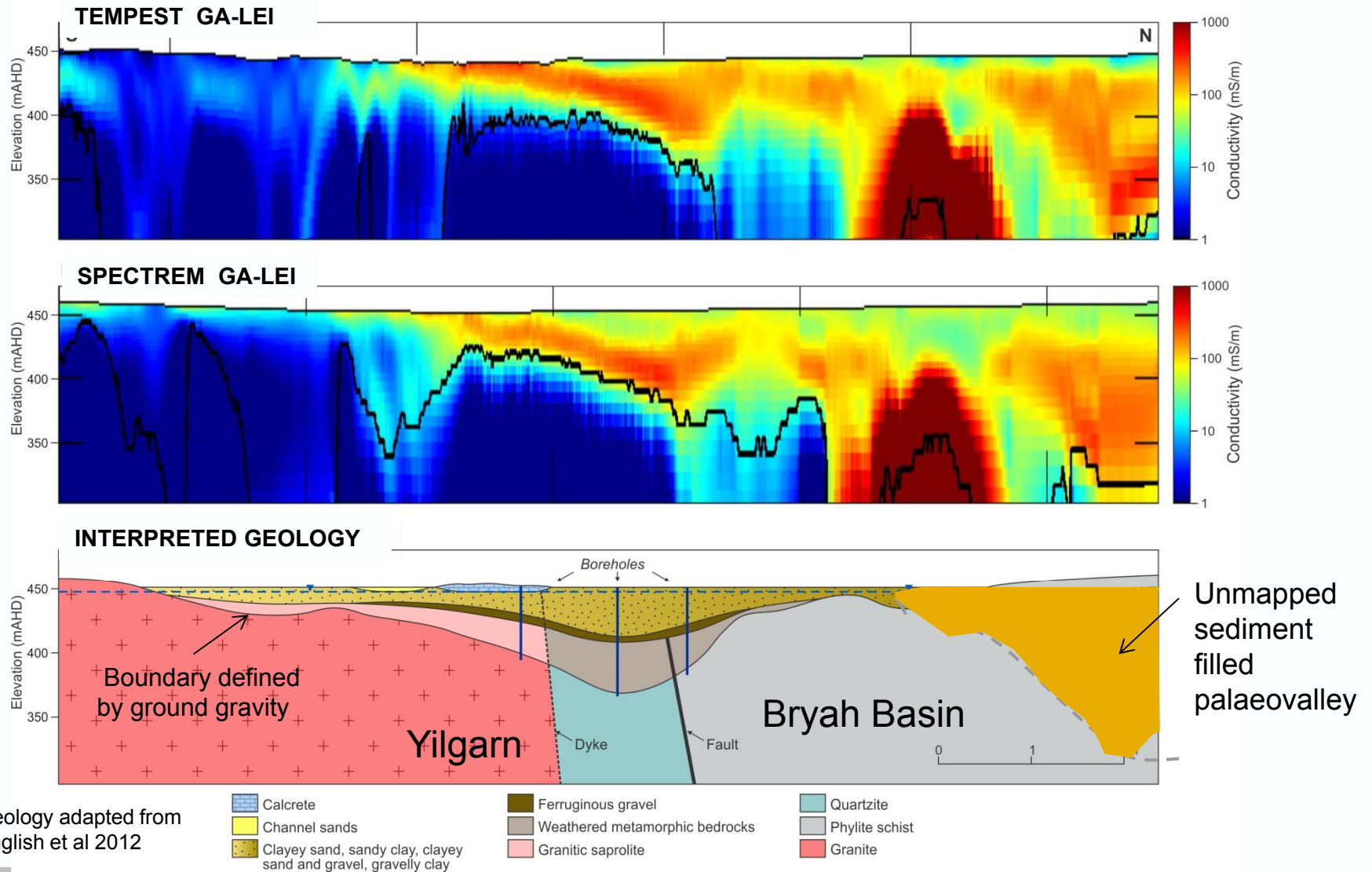
# Characterisation of Cover



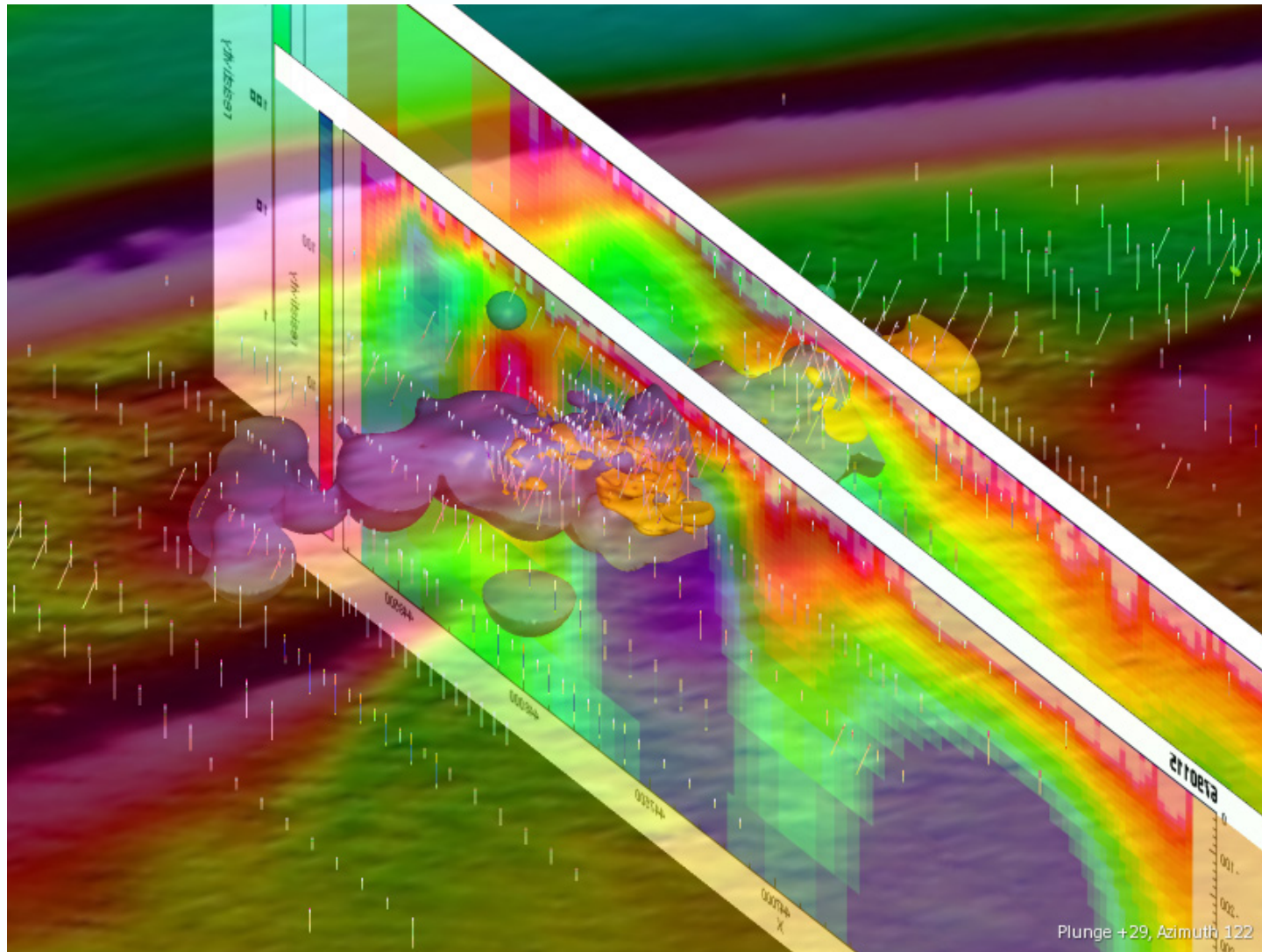
Geology adapted from English et al 2012

- |  |                                |                 |
|--|--------------------------------|-----------------|
| Calcrete   | Ferruginous gravel             | Quartzite       |
| Channel sands  | Weathered metamorphic bedrocks | Phyllite schist |
| Clayey sand, sandy clay, clayey sand and gravel, gravelly clay | Granitic saprolite             | Granite         |

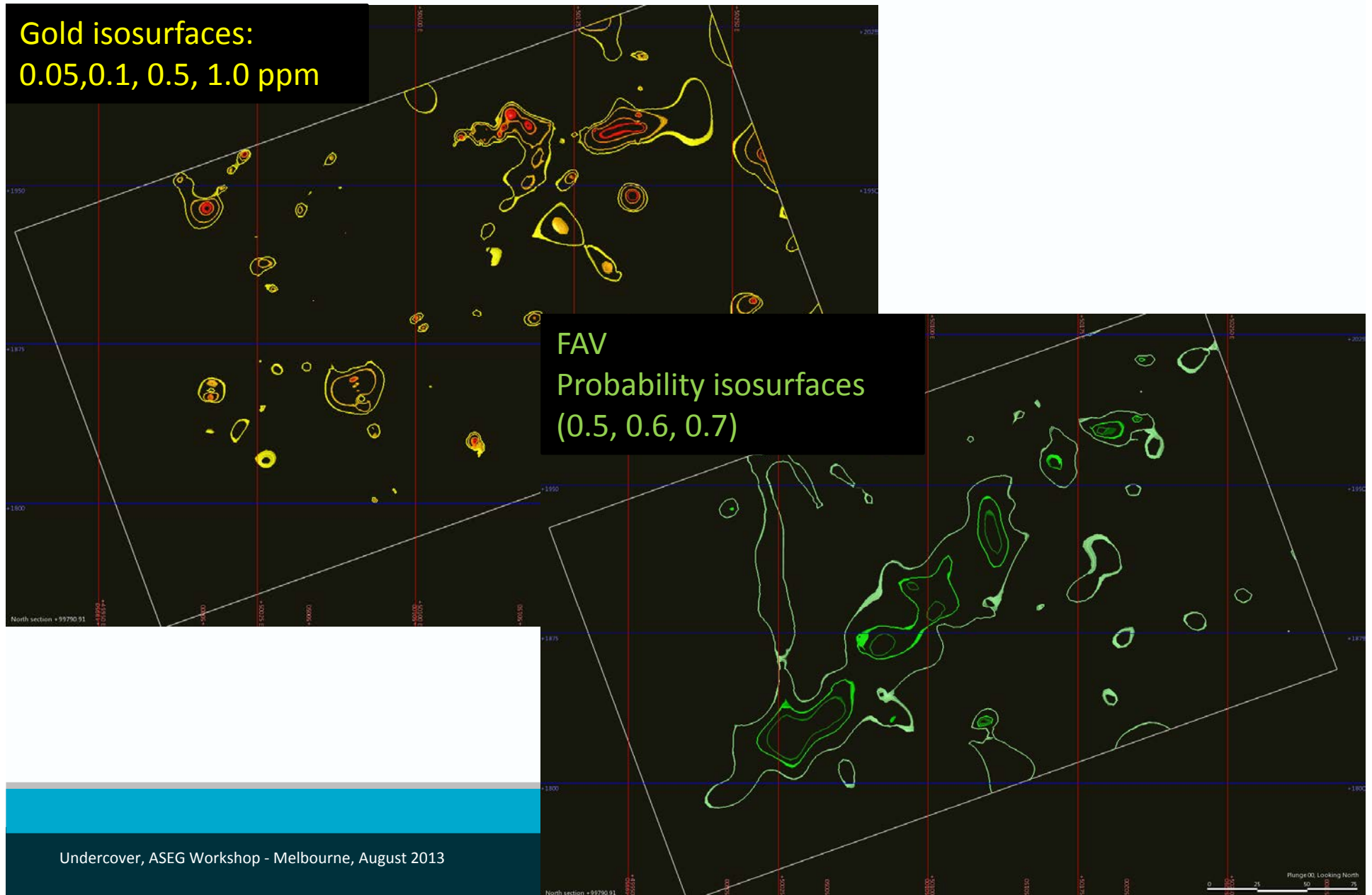
# Characterisation of Cover



# Integration of data in 3D

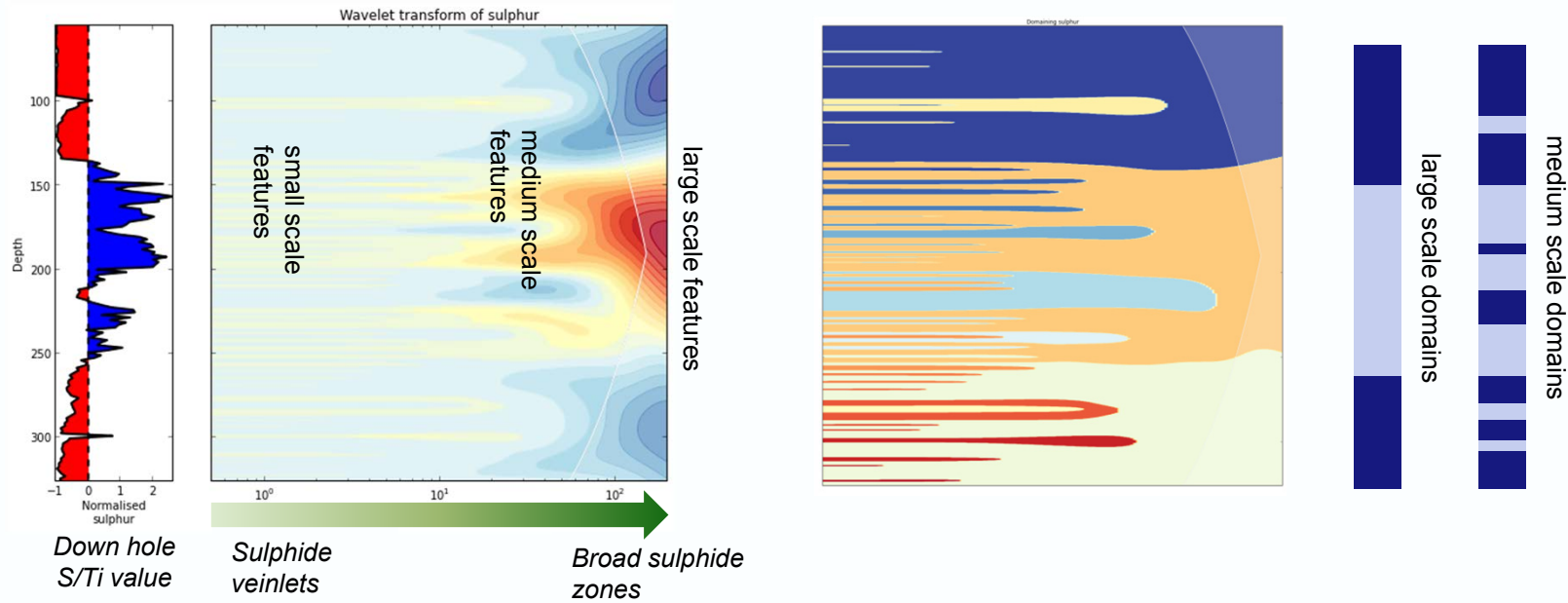


# 3D spatial understanding and quantification



# Large geochemical/mineralogical datasets will require new approaches to support decision making

S/Ti from pXRF during drilling



1. Lab quality, real-time geochemistry and mineralogy while drilling
  - Geochemistry and Mineralogy like a wire line log
  
2. Coupled sensor systems and processing will drive the future
  - Light elements
  - Low DL components
  
3. Data platform analytics

# This talk includes many ideas from others ....

Richard Chopping, Tim Munday, Richard Hillis, Dave Lawie, Aaron Baensch, Rob Hough, Dave Gray, Andy Barnicoat, John Walshe, Greg Hall, Scott Halley, Lesley Wyborne, Rob Woodcock, Richard Blewett, Ravi Anand, Louise Fisher, Yulia Uvarova, June Hill, The Cure and Lee Harris

Thank You

