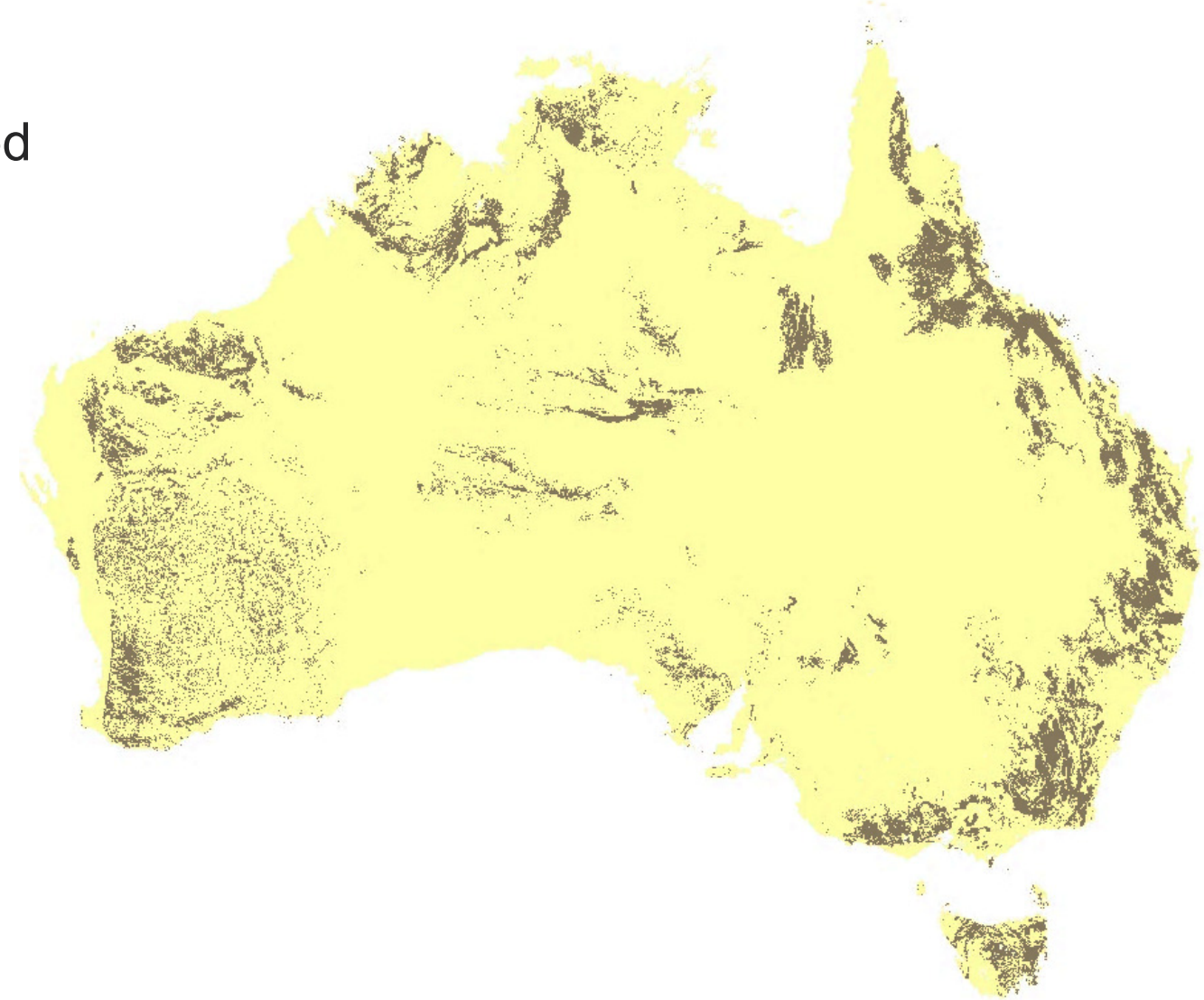
Australian Government
Geoscience Australia

Exploring undercover: building and testing geological models

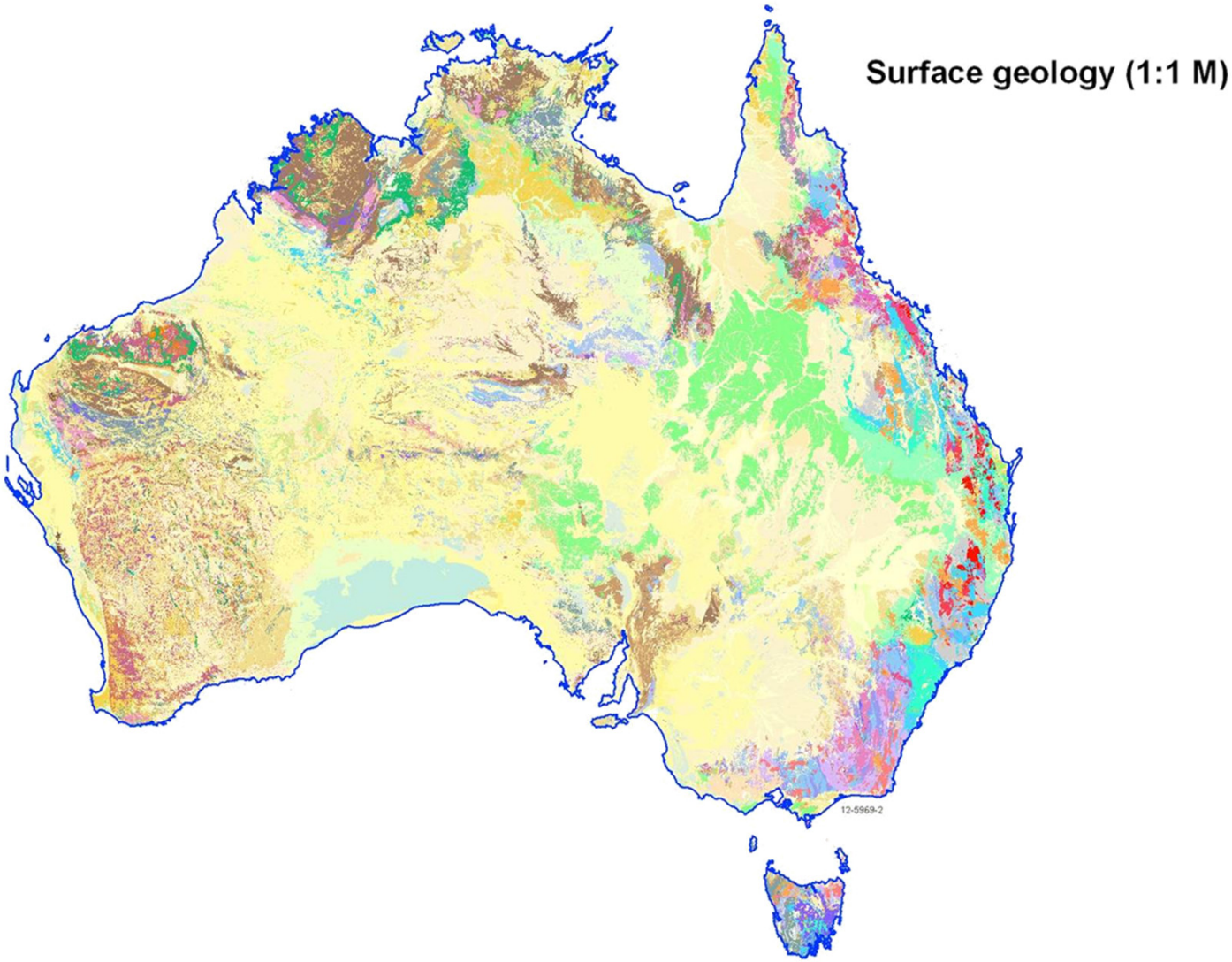
Andy Barnicoat
Chief of Minerals & Natural Hazards Division

Challenges and opportunities

- ~80% covered



Australia's undercover mineral potential



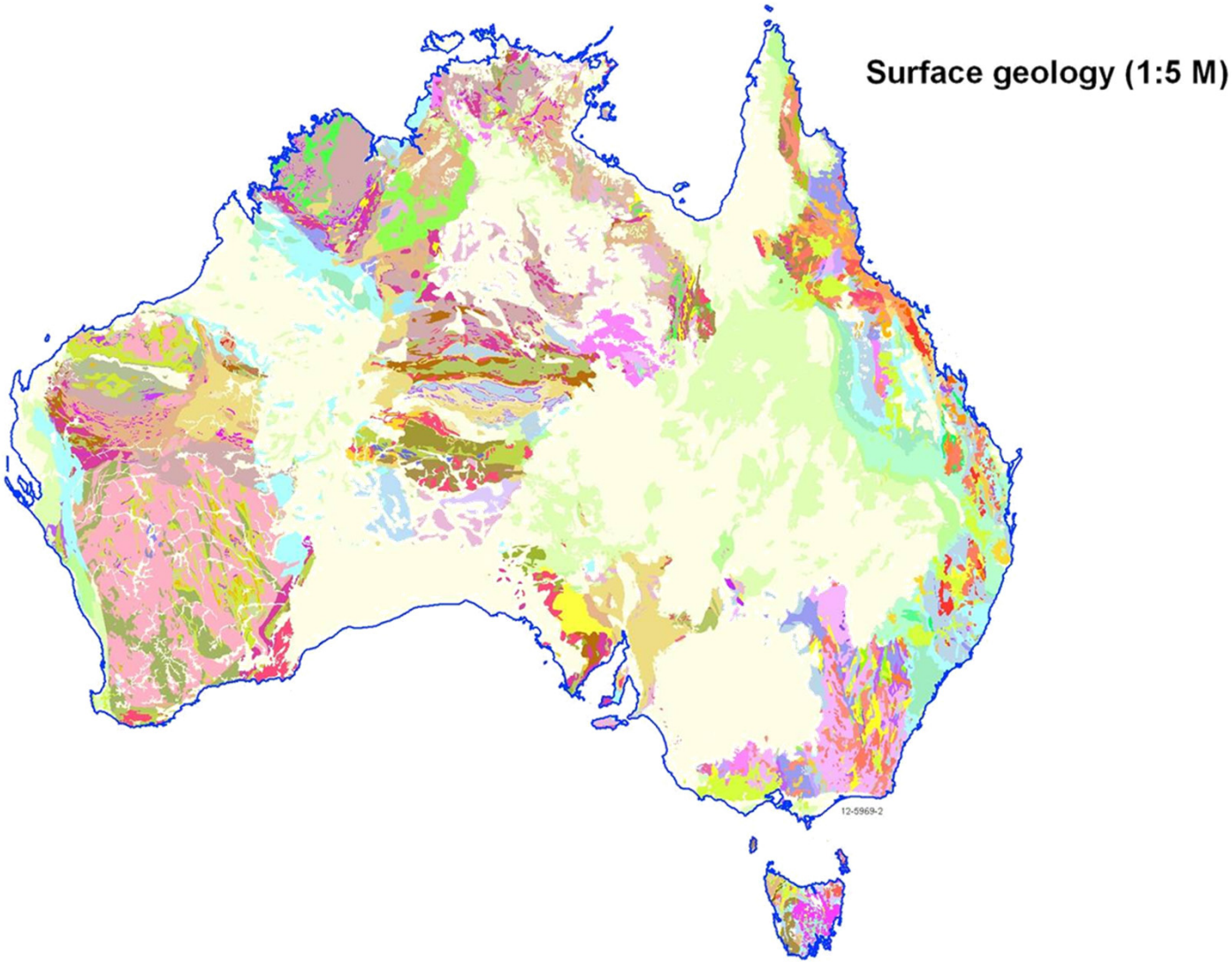
Australia's undercover mineral potential

Australia's potential for new discoveries. A common perception of Australia as 'mature' in relation to mineral exploration and discovery

Vast areas of basement rock are concealed by relatively thin transported cover, shown in yellows and pale browns in this image of the 1:1 million scale Surface Geology

Huge potential for discovery under and within this cover

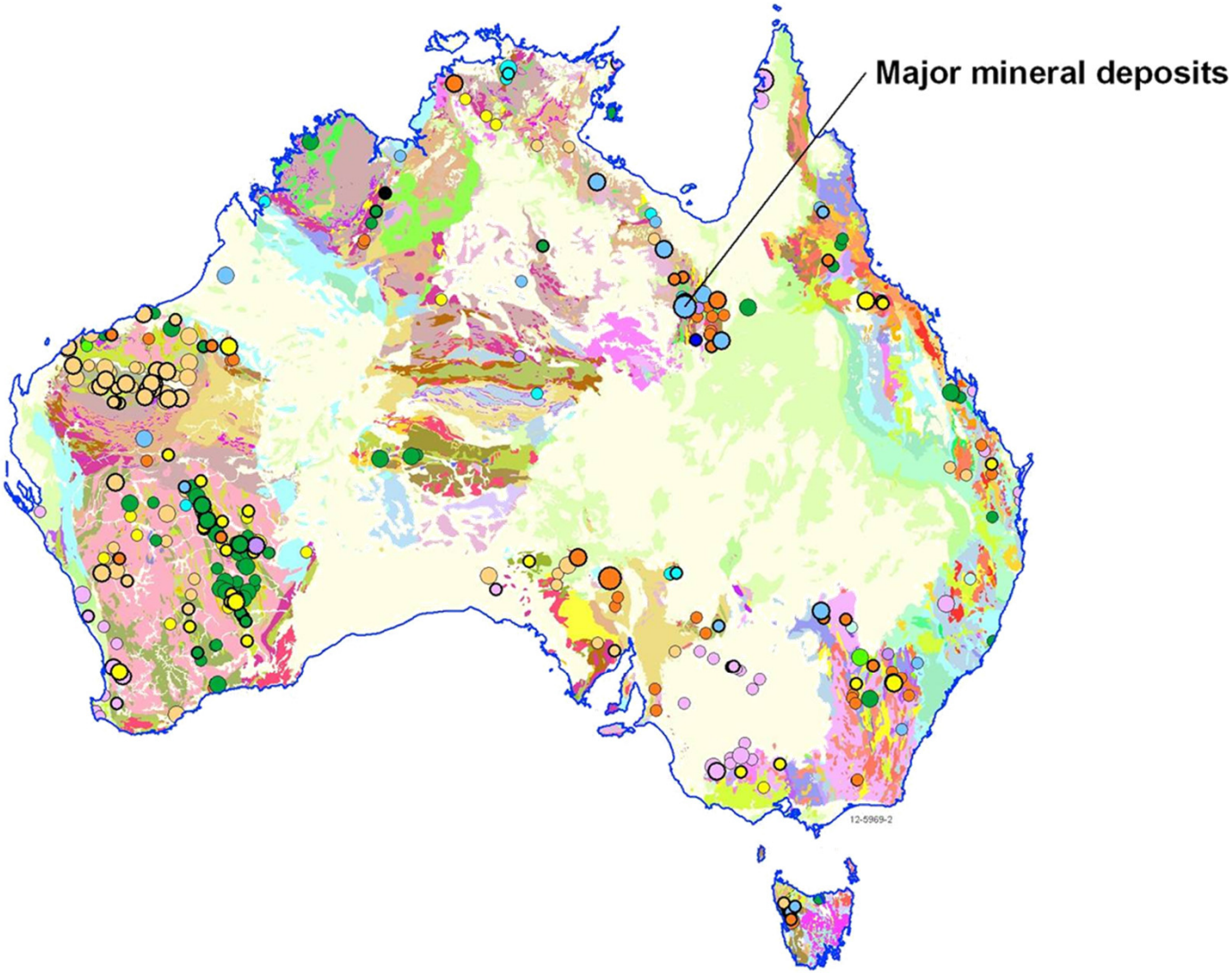
Australia's undercover mineral potential



Australia's undercover mineral potential

Generalised surface geology (from 1:5 million scale map) exaggerates the amount of outcrop but shows the extent of exposed geological provinces

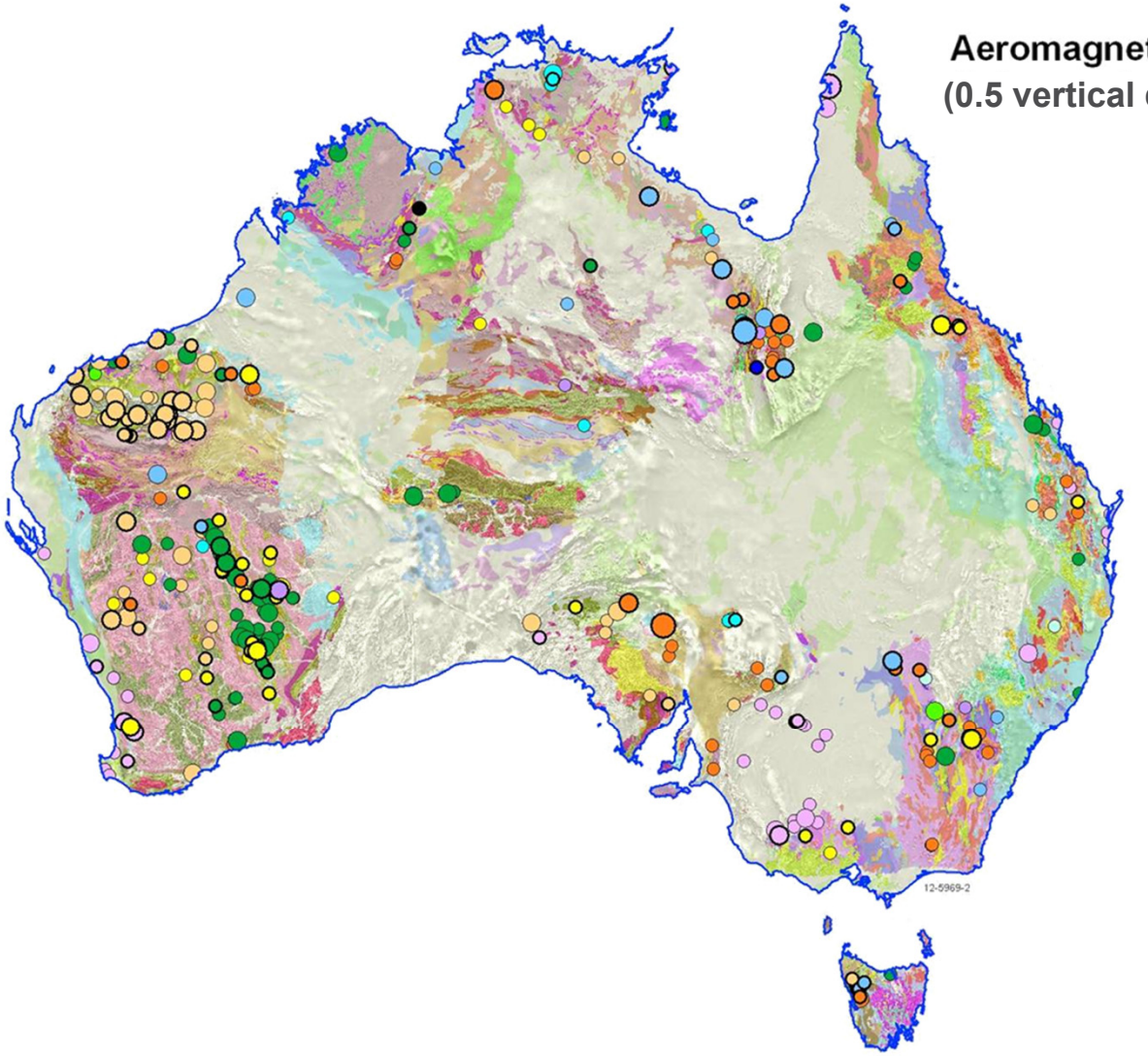
Australia's undercover mineral potential



Australia's undercover mineral potential

Major known mineral deposits (coloured dots) are clearly mostly located within areas of outcrop

Australia's undercover mineral potential



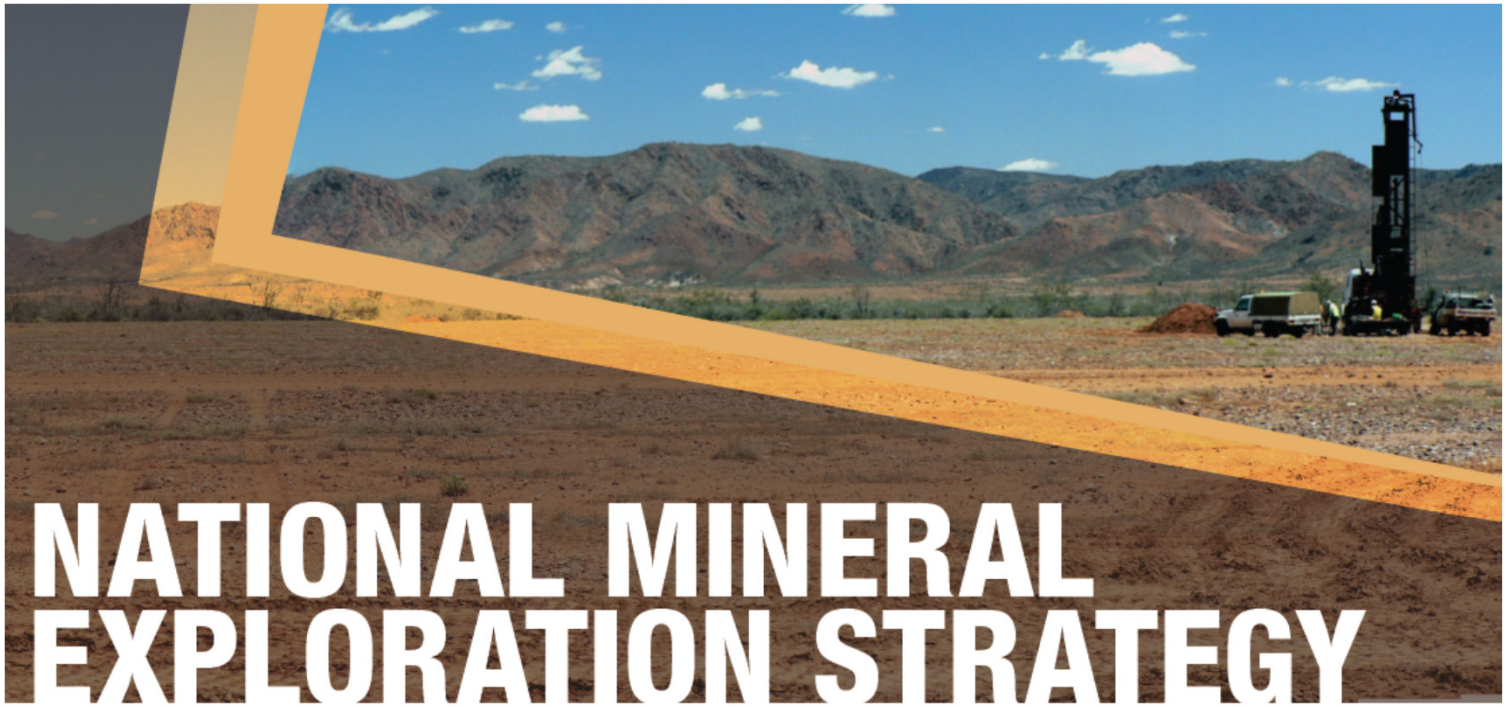
Australia's undercover mineral potential

When we superimposed the aeromagnetic data, shown as a greyscale transparency here, we can see that many of the well known and world class mineral provinces actually extend for considerable distances beneath the cover of transported sediments – good examples are south of Mt Isa, Albany-Fraser province, northern Gawler Craton.

Those areas of basement concealed by shallow cover represent major greenfields exploration opportunities

Australia is not as mature as commonly perceived!

Standing Council Energy & Resources (SCER) National Mineral Exploration Strategy (2012)



VISION:

Unlocking Australia's hidden resource potential.

MISSION:

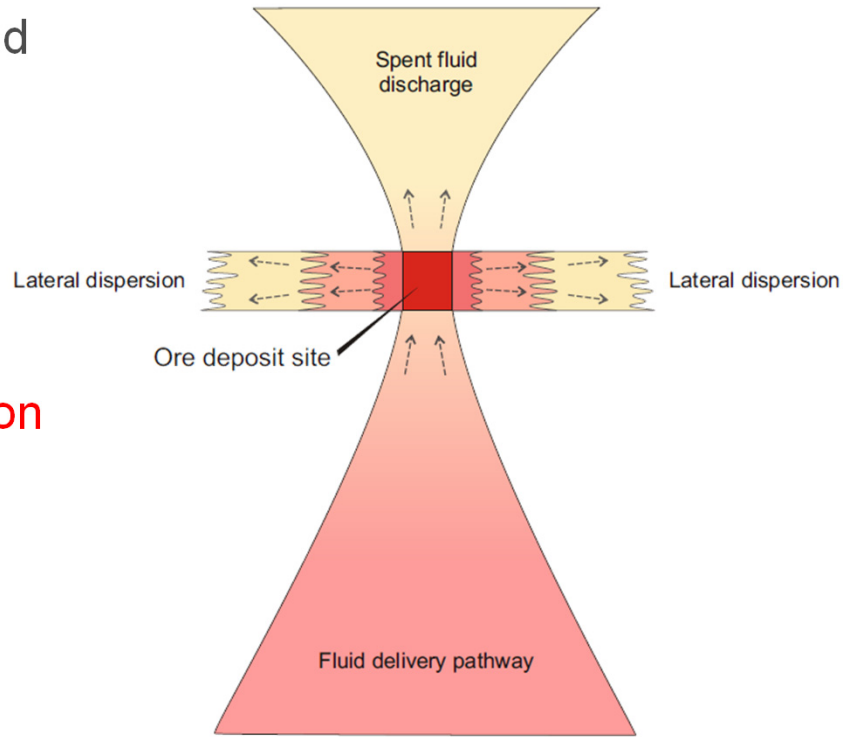
To address greenfield exploration challenges, stimulate new discoveries, ensure continuity of the pipeline of mineral resource investments, and the longevity of Australia's mineral resources industry.

UNCOVER vision

- nationally-coordinated and strategic people and sector network
- Science based on mineral systems concepts
- Four “themes” for research groups, Government surveys, service providers and explorers:

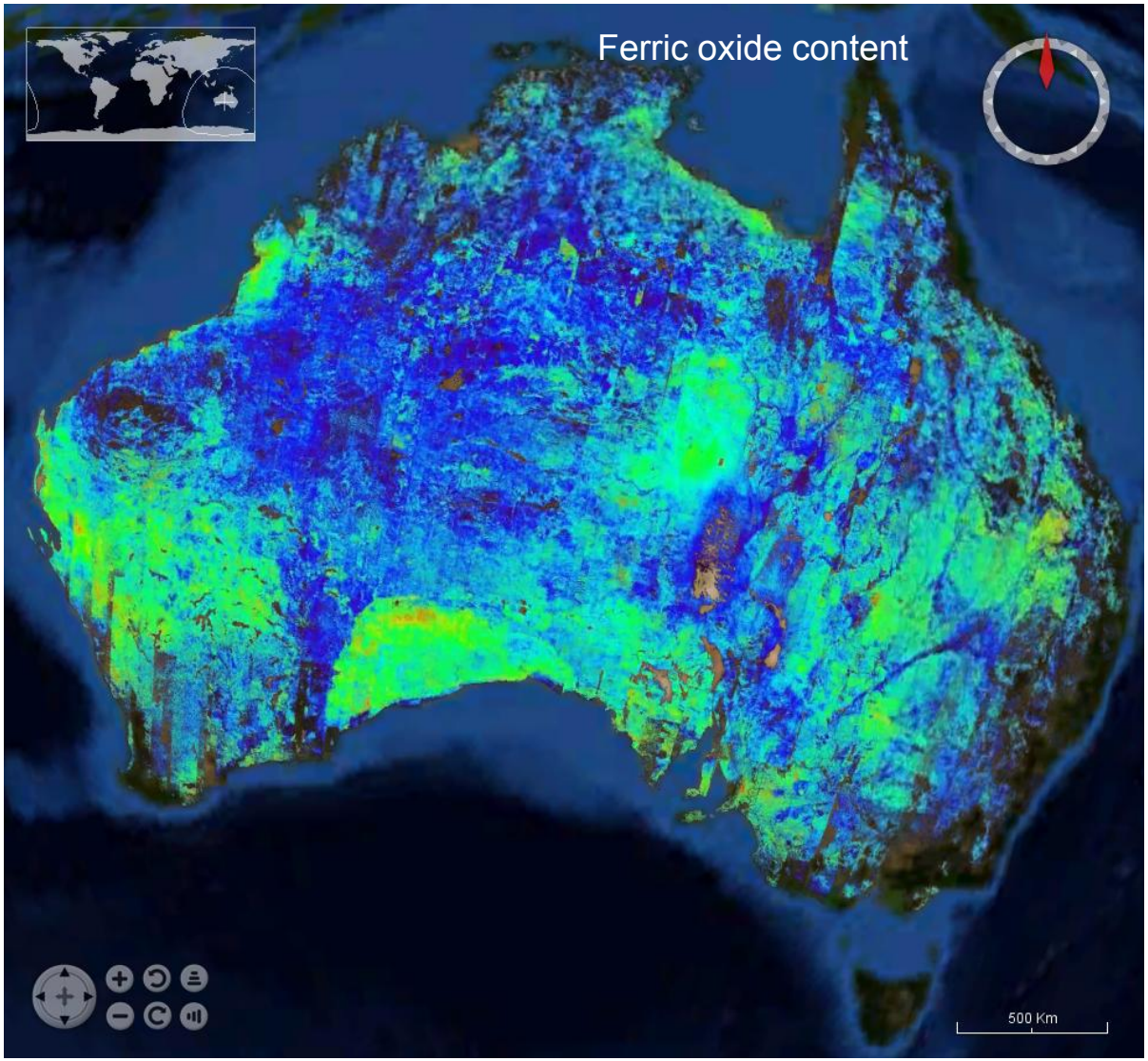
1. Character & depth of Australia’s cover
2. Investigating Australia’s lithospheric architecture
3. 4D geodynamic and metallogenic evolution of Australia
4. Characterising and detecting the distal footprints

UNCOVER
AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH



Character & depth of Australia's cover

Modelling cover character: ASTER

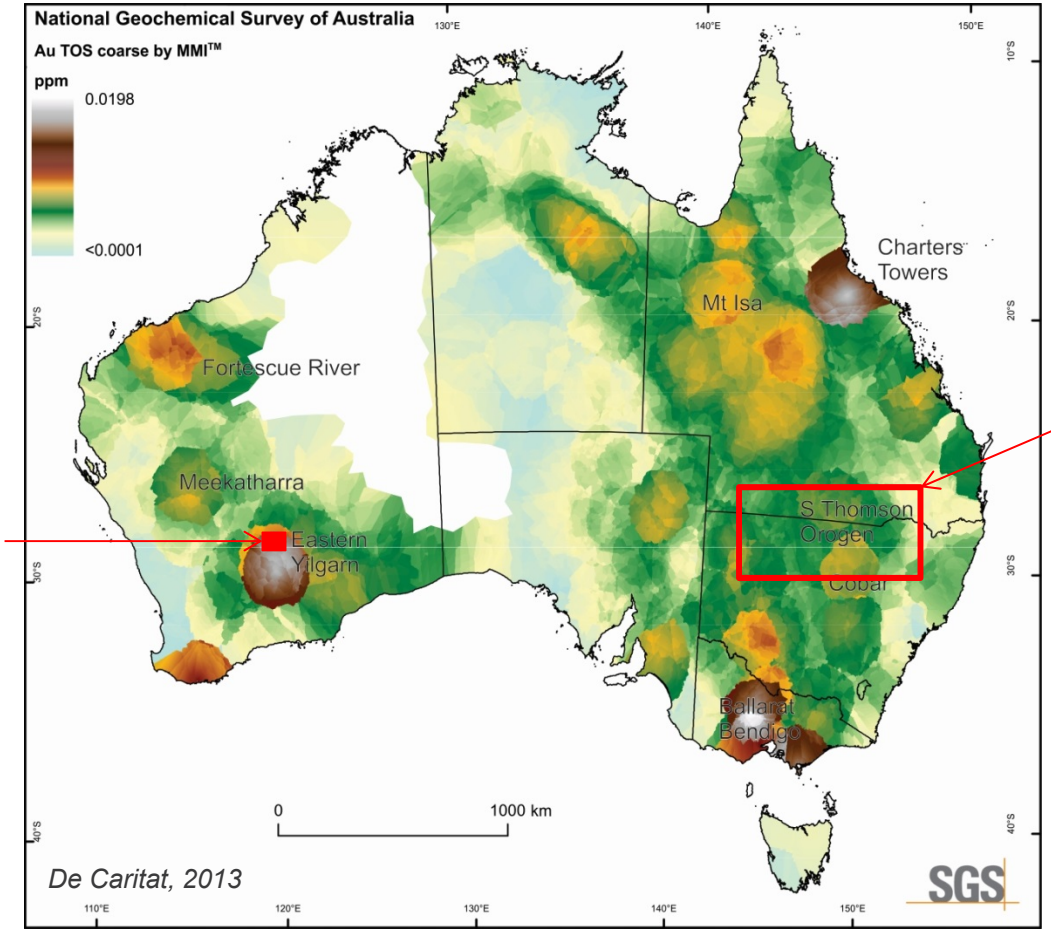


Cudahy et al.,

Modelling cover character: national geochemistry

Mobile metal ion Au analysis from coarse fraction

Next slide



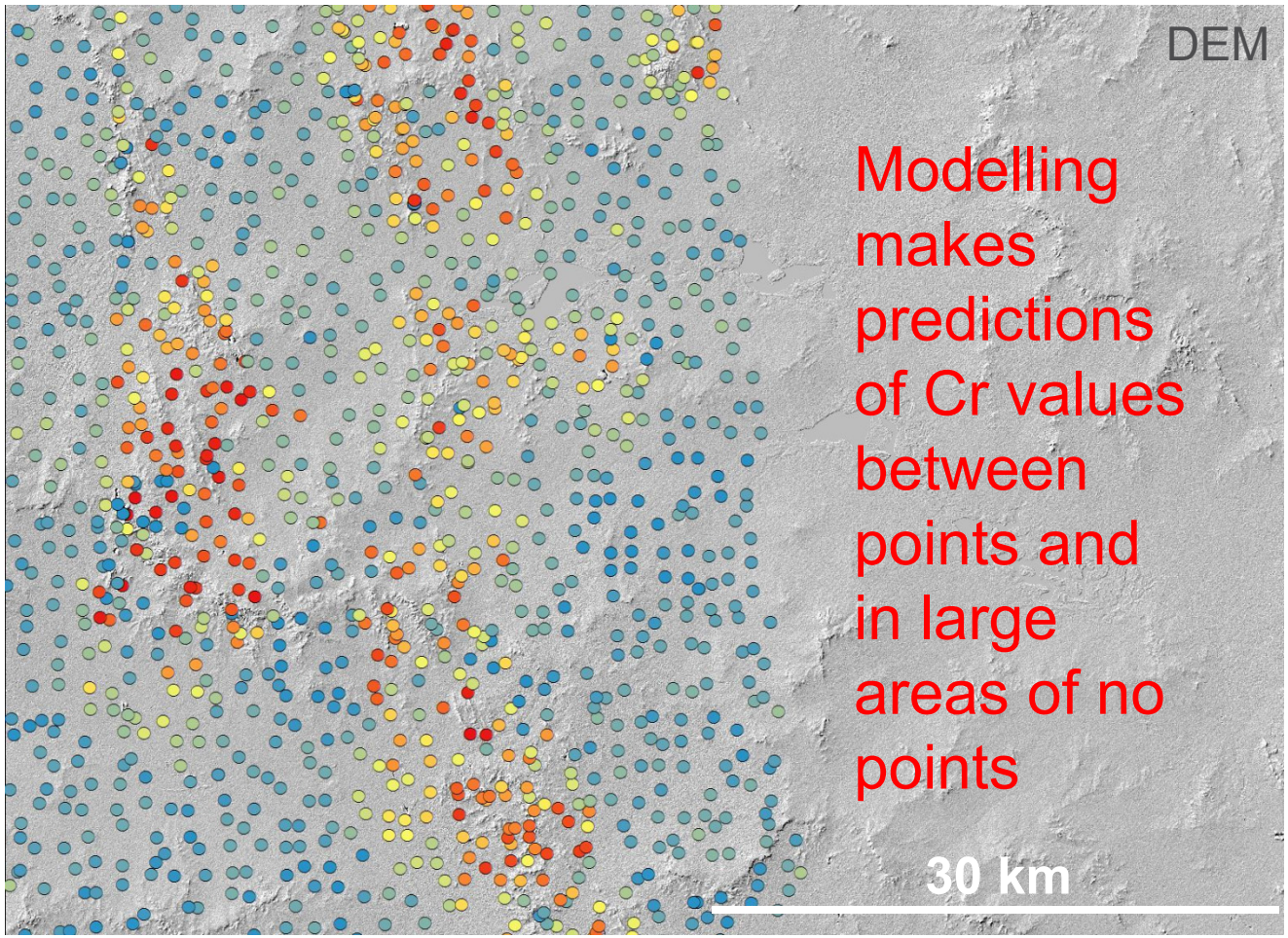
Testing the NGSA with infill ME geochemistry in southern Thomson (2013–14)

Several known gold-rich regions (eg Kalgoorlie, Charters Towers, Ballarat) show up as anomalous in gold in the surface regolith material. Other gold anomalies elsewhere may be pointers to undiscovered gold enrichment in the basement

de Caritat, 2013

Modelling cover character: regolith geochemistry

Regional regolith geochemistry GSWA (Paul Morris)



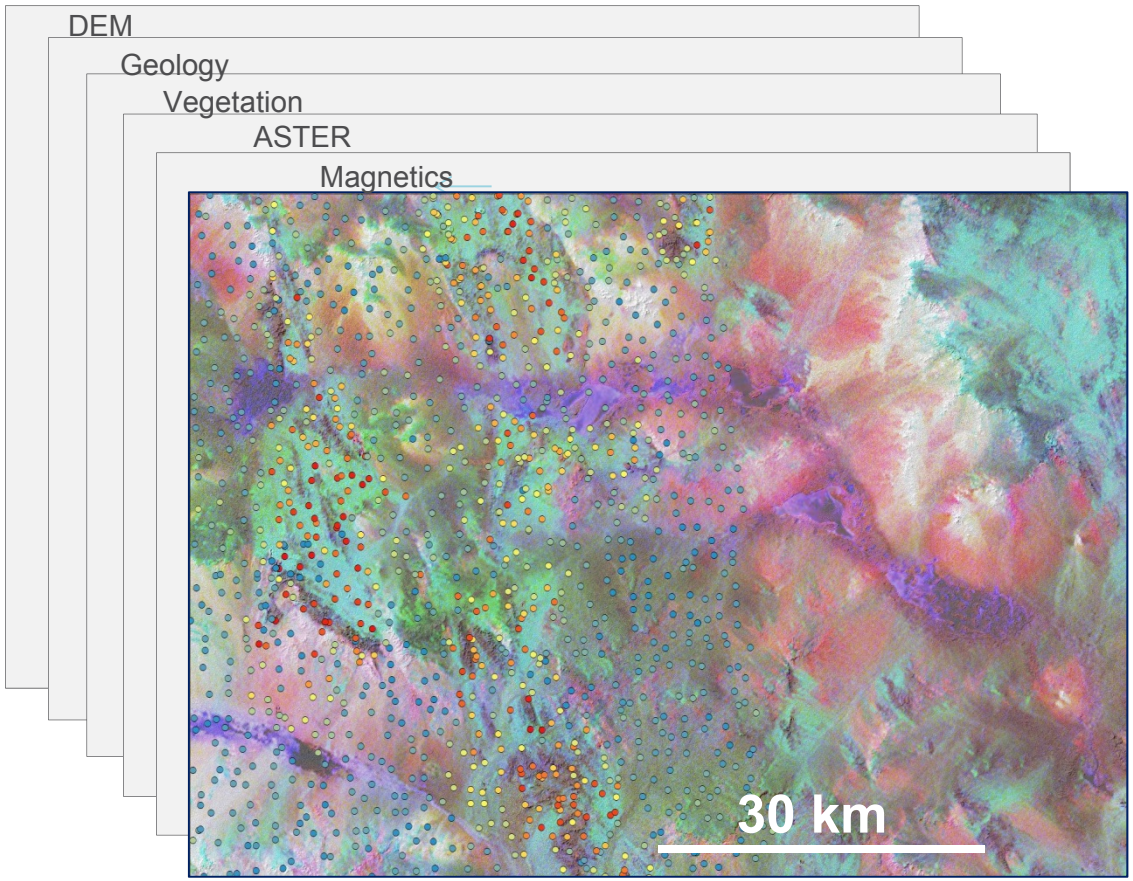
Cr ppm

800

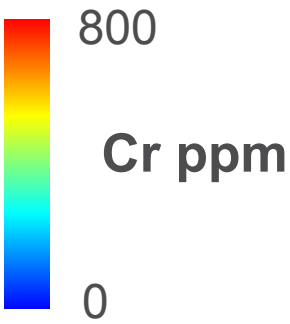
0

J Wilford

Modelling cover character: regolith geochemistry

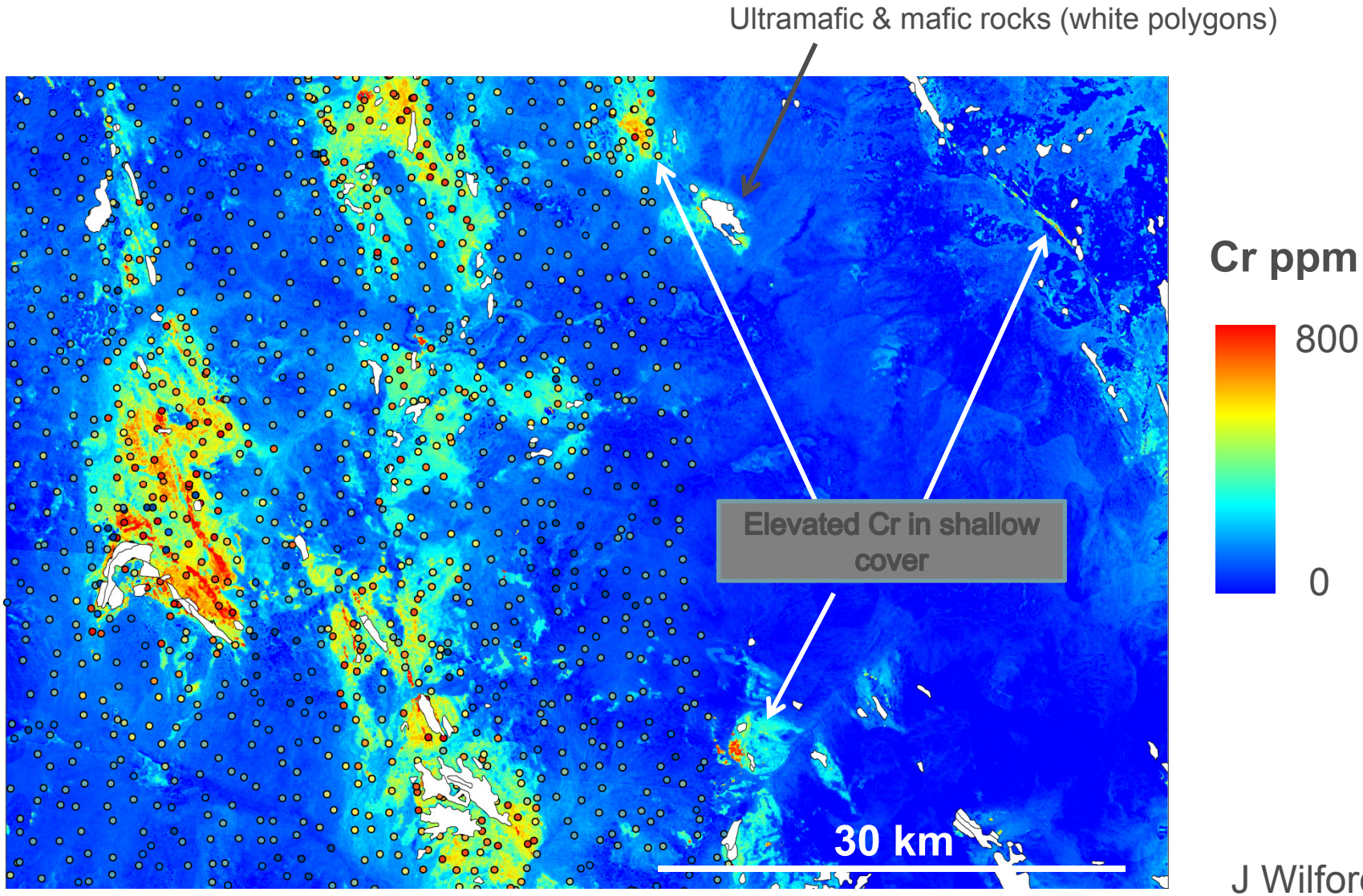


Modelling is <u>not</u> interpolation between points but a <u>model prediction</u> based on multivariate correlation



J Wilford

Modelling cover character: regolith geochemistry



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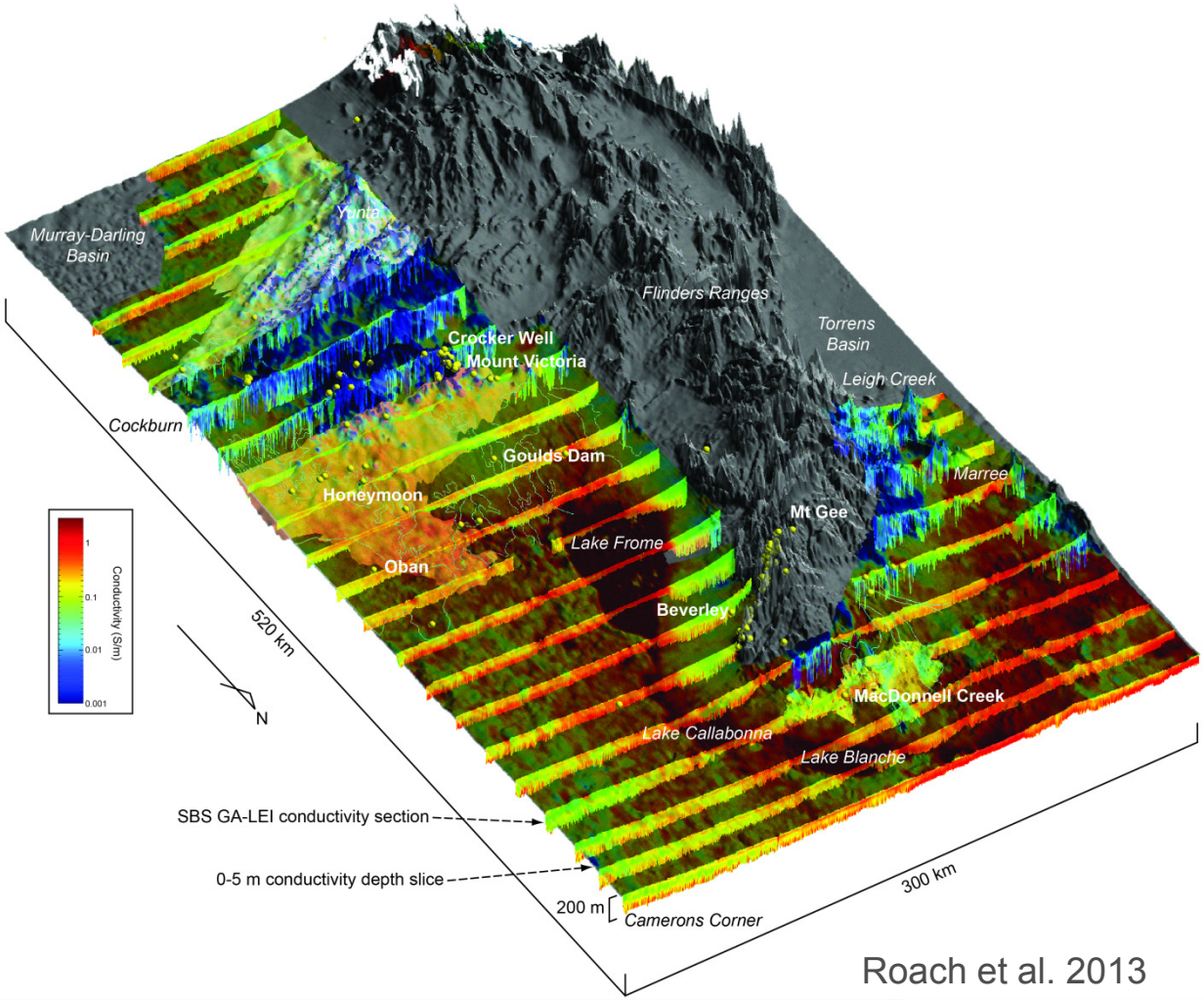
Depth of Cover: AEM valuable tool

- Model palaeosurfaces
- More precise depth to target information
- Map alteration zones



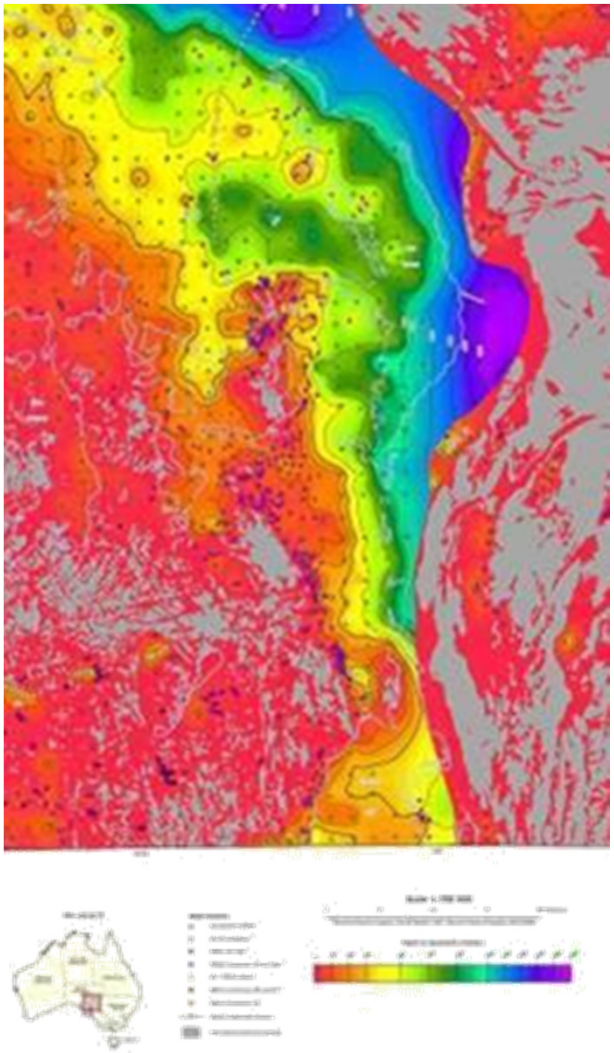
Roach et al. 2013

Depth of Cover: AEM valuable tool

3D mode of the entire Frome AEM survey showing combined depth to resistive basement models in the NW Murray-Darling Basin, Benagerie Ridge at Honeymoon and the northern Flinders Ranges at MacDonnell Creek. The model combines the digital elevation model (DEM), conductivity sections and a depth slice to highlight the ability of AEM to map cover in 3D over a wide region. This model appears on the front cover of the Frome AEM Survey GA Record.

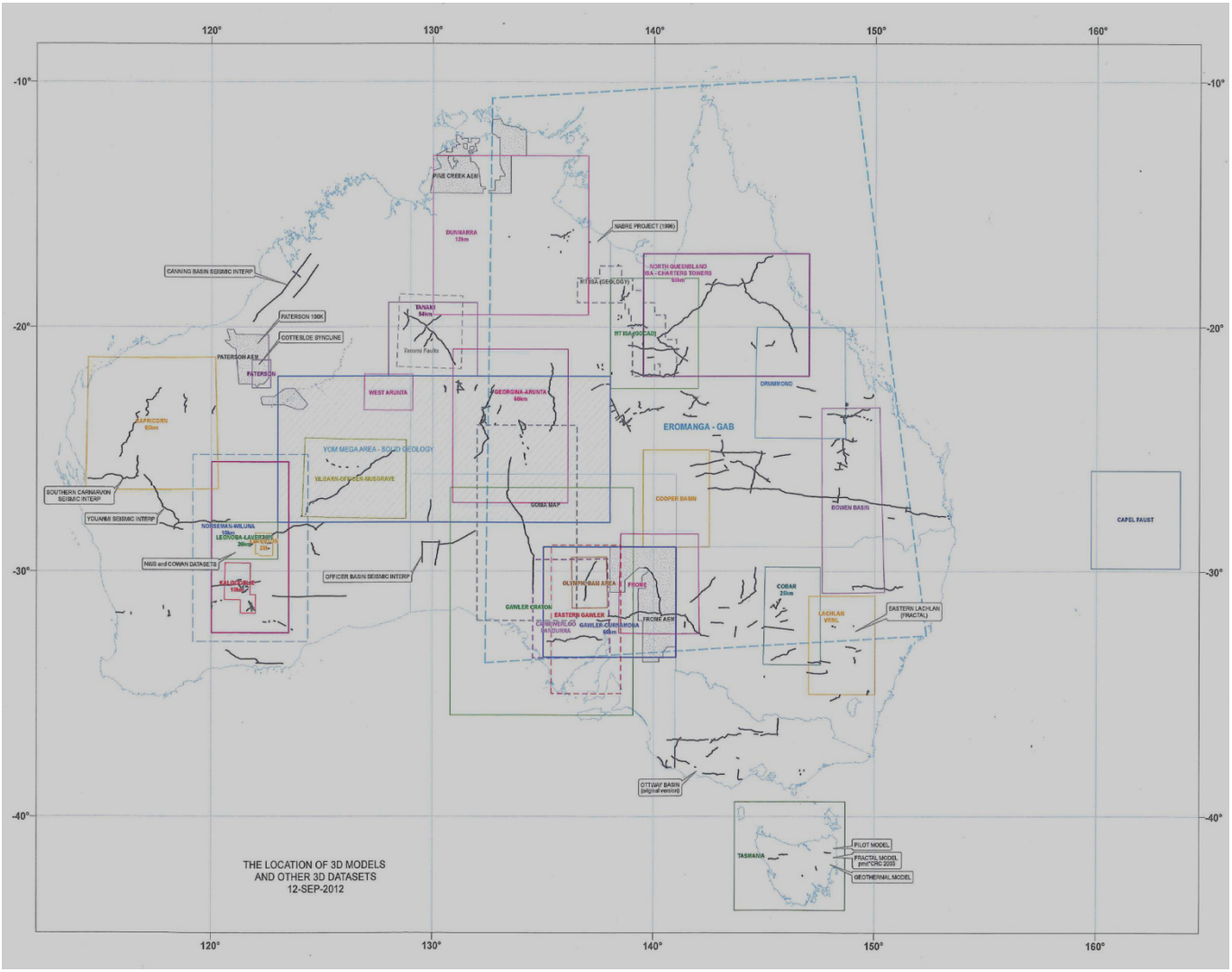
Depth of cover

- Cover depth predictions difficult
- Range of magnetic methods with mixed terrane-specific success
- Possible national AEM survey (like AWAGS)?
  - good for <500 m regions
- Terrane-specific experiments needed with shallow MT, seismic, plus potential fields
  - What works best and how much?
  - What scale?
- UNCOVER workshop to tackle the depth challenge



Meixner, 2010

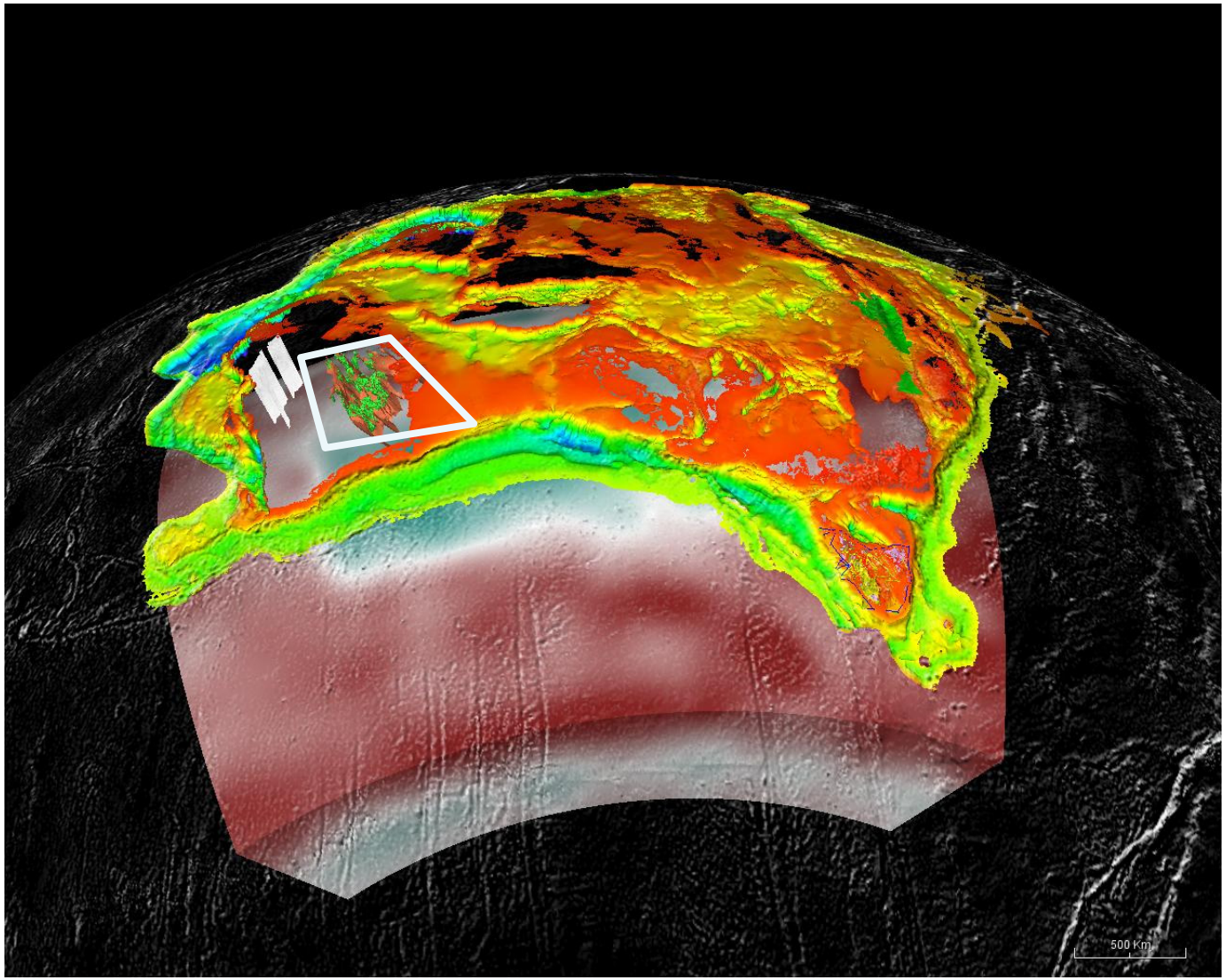
Looking a bit deeper: towards a 3D map of Australia



GA working on harmonising and integrating these 25 regional and provincial maps into a national 3D geological map/model

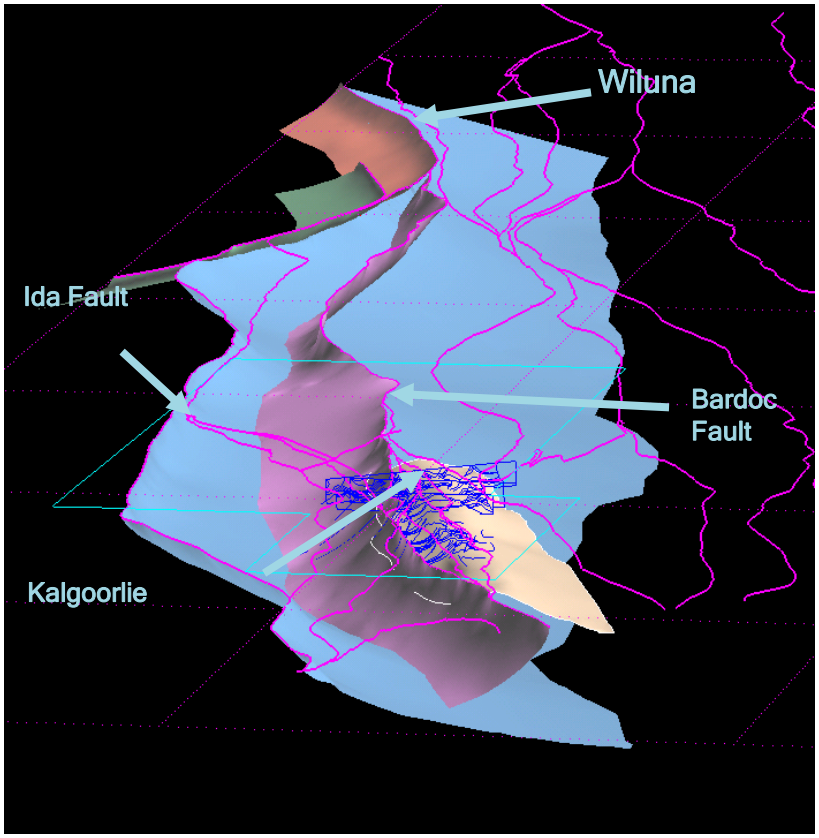
T Brennan

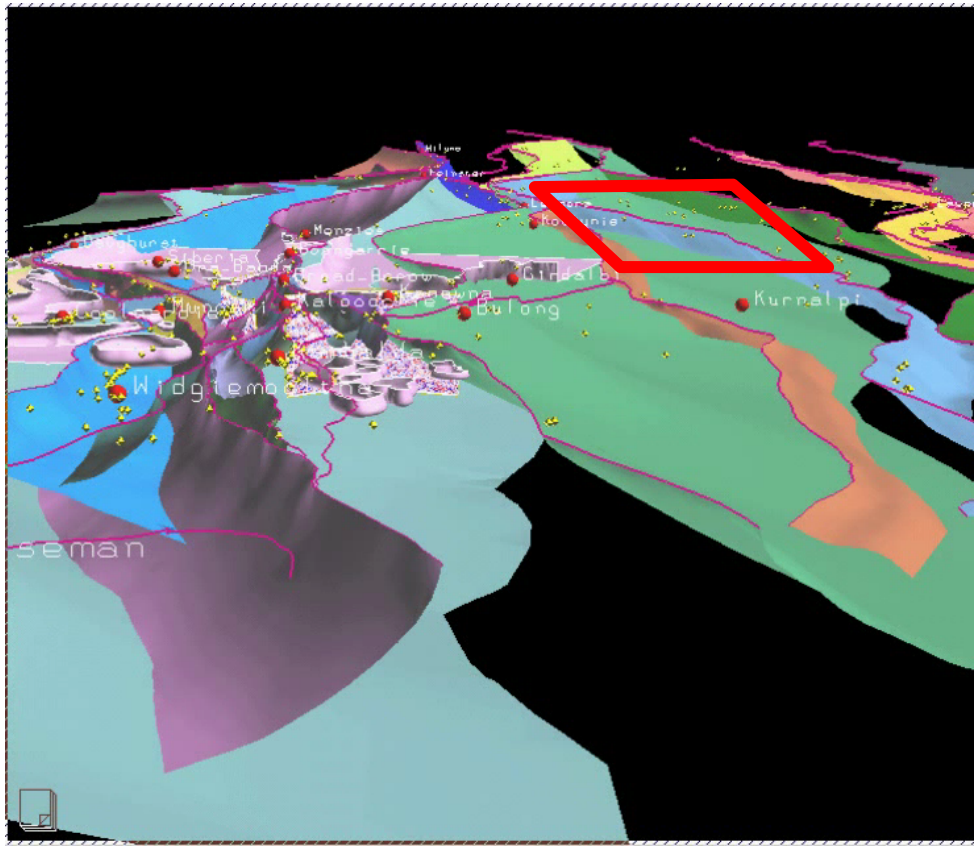
Building continental-scale 3D models/maps



M Nicoll

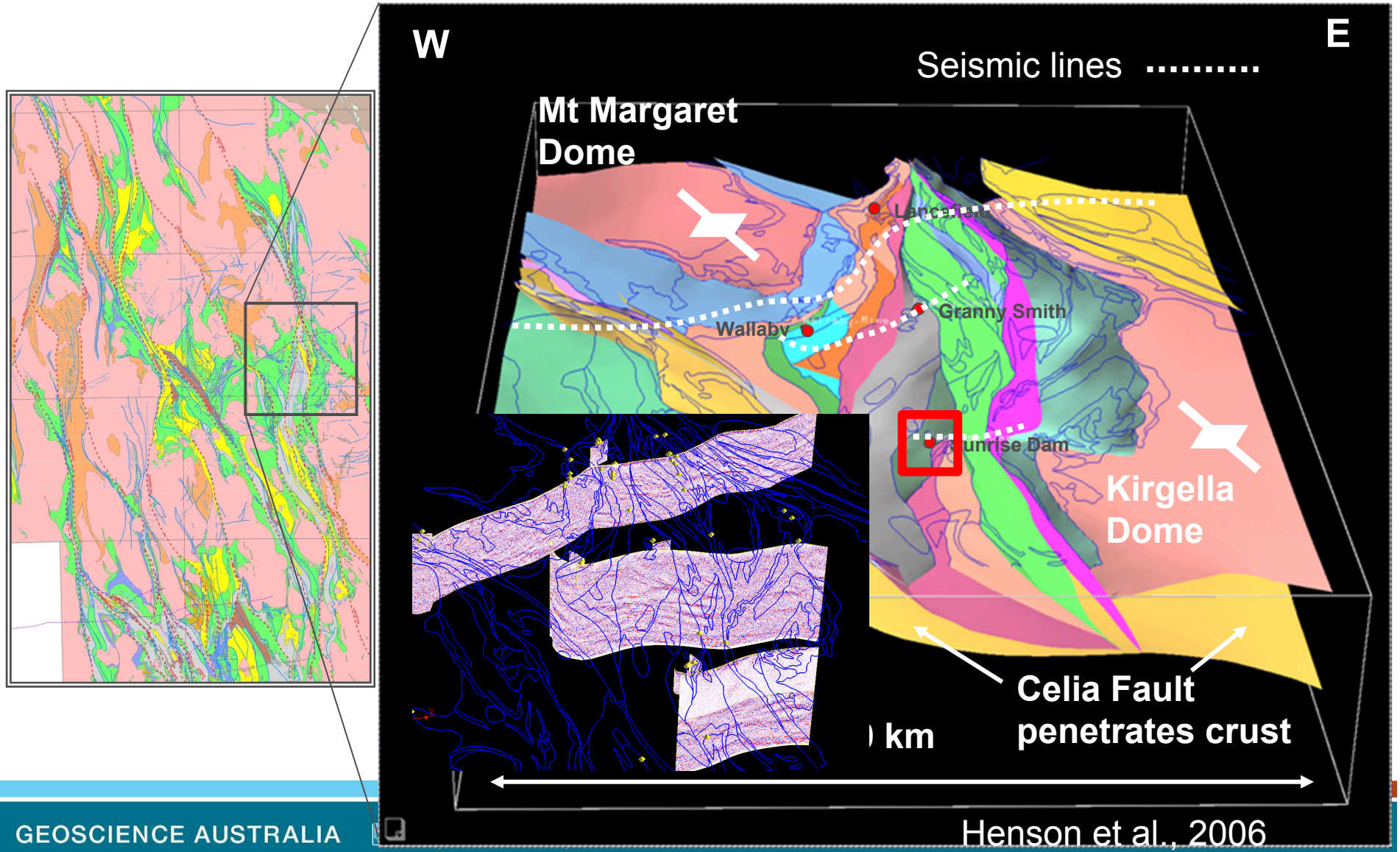
Building province-scale 3D models/maps



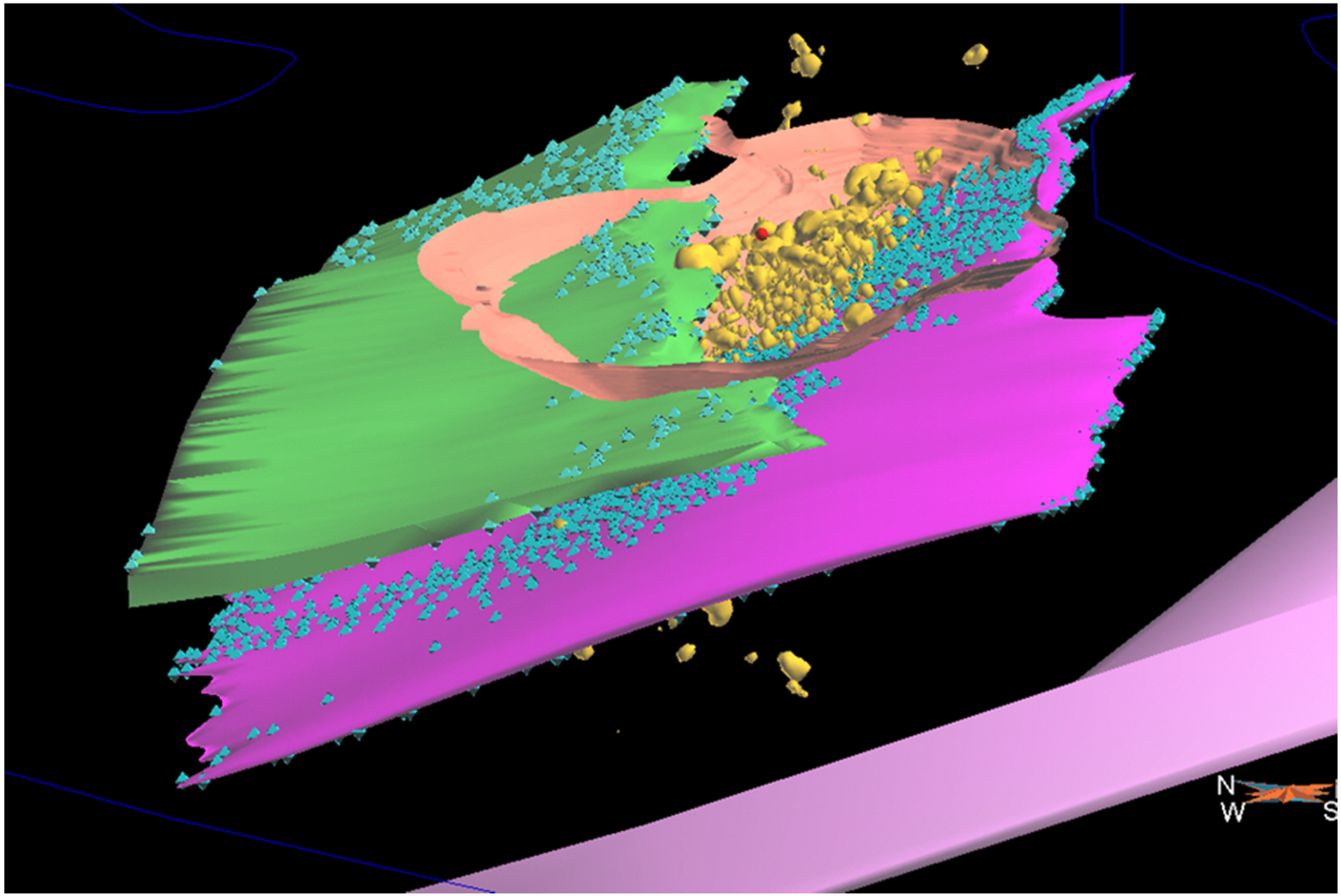


Henson et al., 2006

Building camp-scale 3D models/maps



Building deposit-scale 3D models/maps



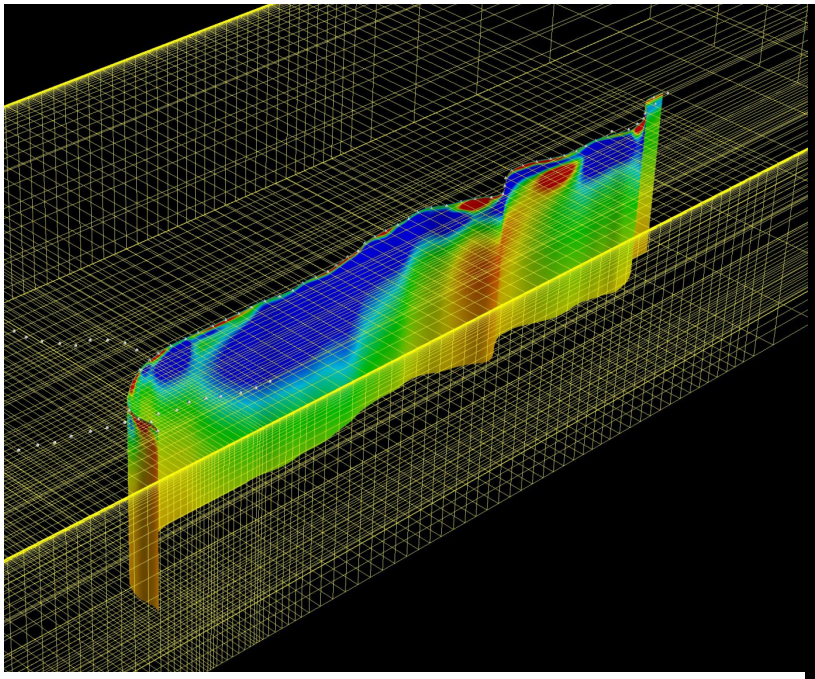
AnglogoldAshanti

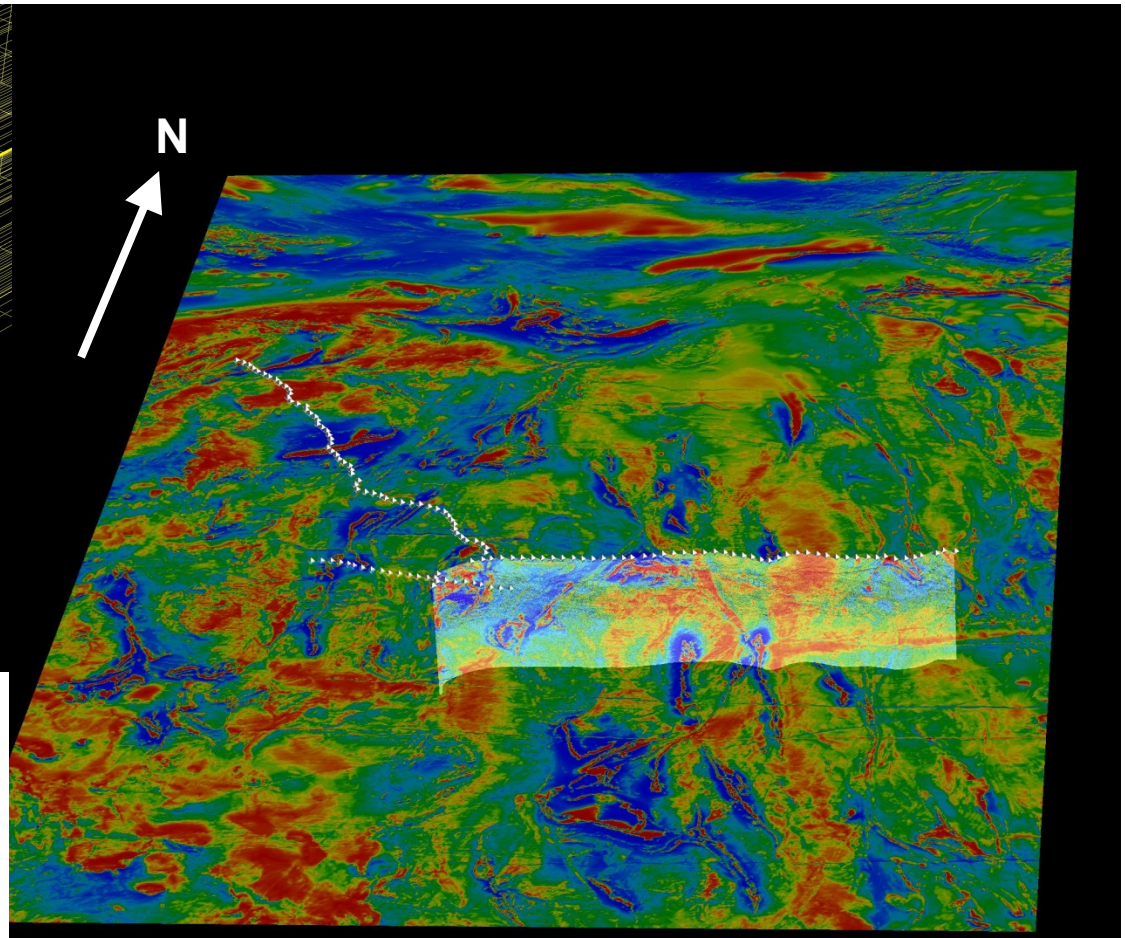
Building deposit-scale 3D models/maps

This slide shows the calibration of the grade shells (generated by John Miller in Leapfrog) and favourably oriented regions on the Sunrise Shear (blue spheres). The correlation is very good and deeper extensions that are favourably oriented are highlighted down dip and along strike. Unrealised potential?

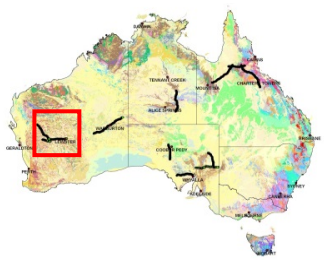
AnglogoldAshanti

Model building advances: 3D inversion codes on NCI



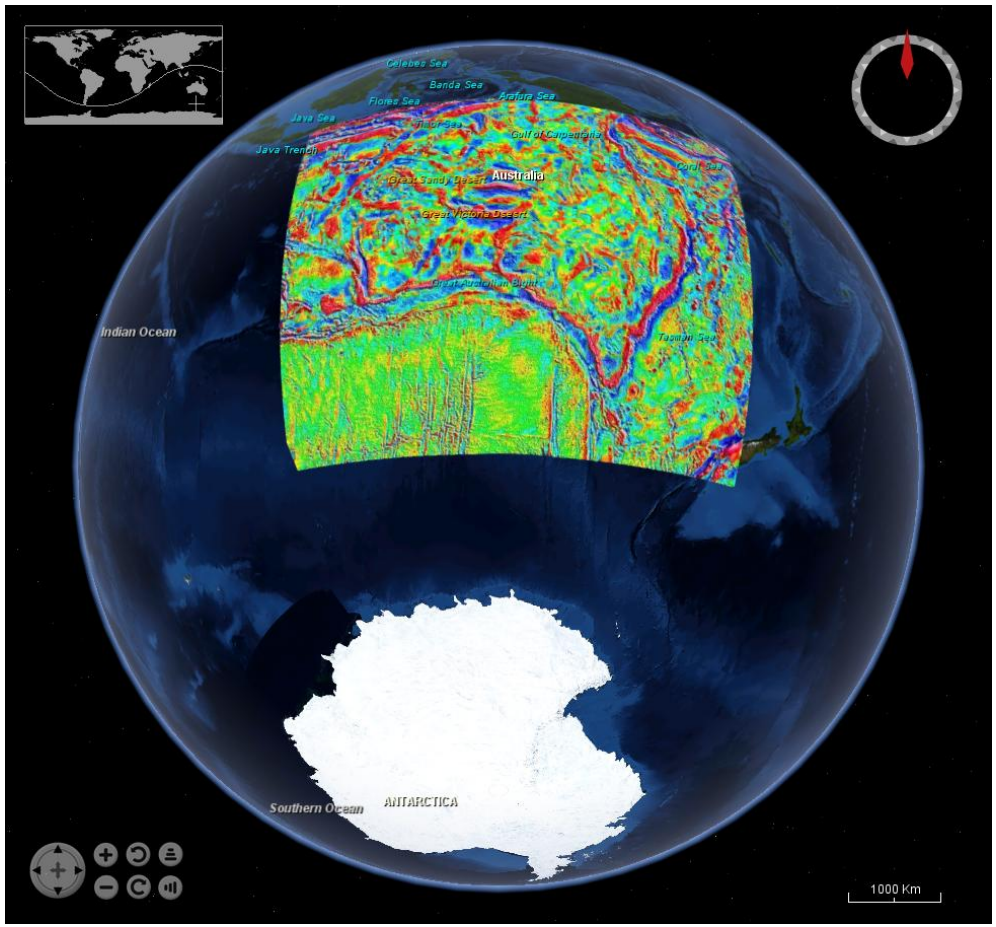


TMI magnetics image *Milligan et al, 2013*
YU2 seismic section
Broadband MT stations



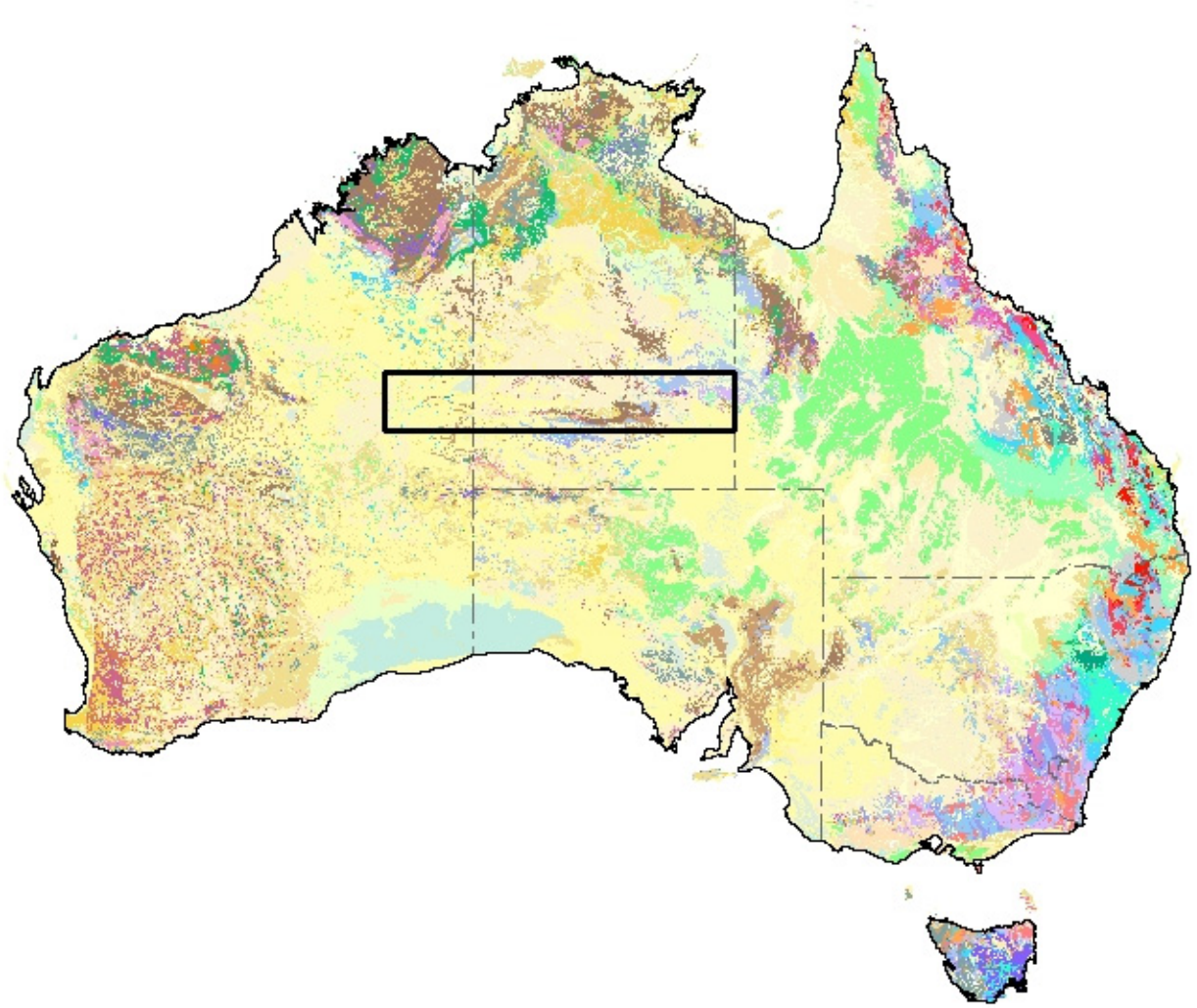
Milligan et al., 2013

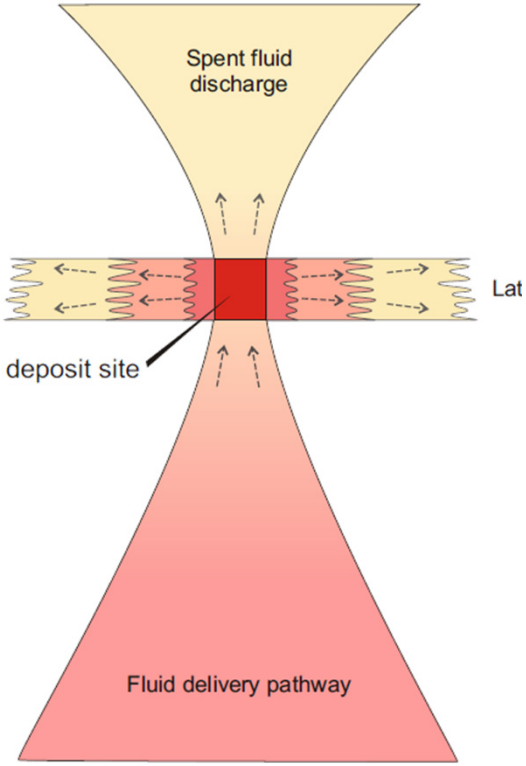
Model building advances: 3D inversion in spherical on NCI



- Continental Scale 3D density model of crust
- Australian national Gravity database + satellite data
- in true spherical co-ordinate space

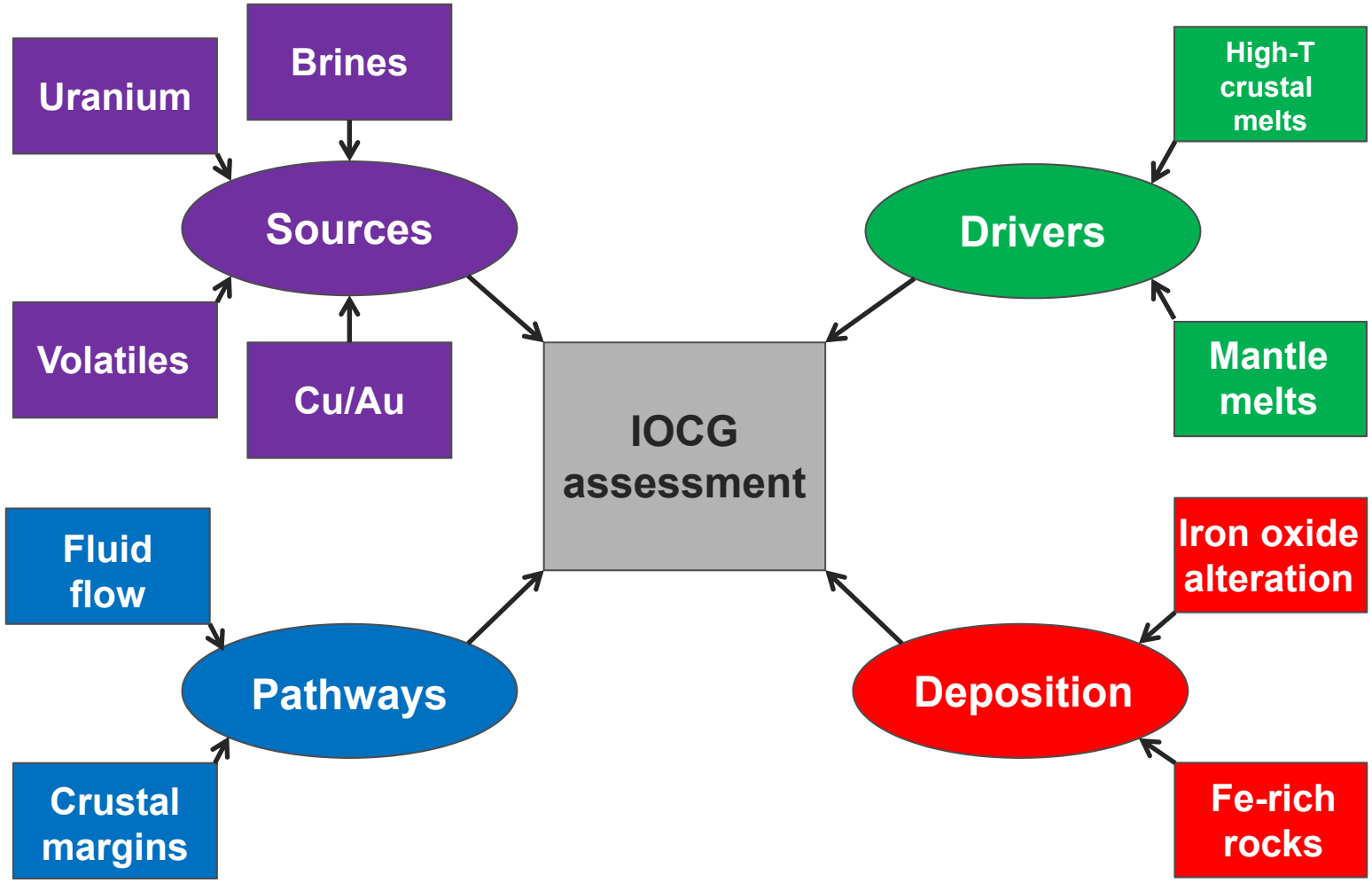
Building a mineral systems model





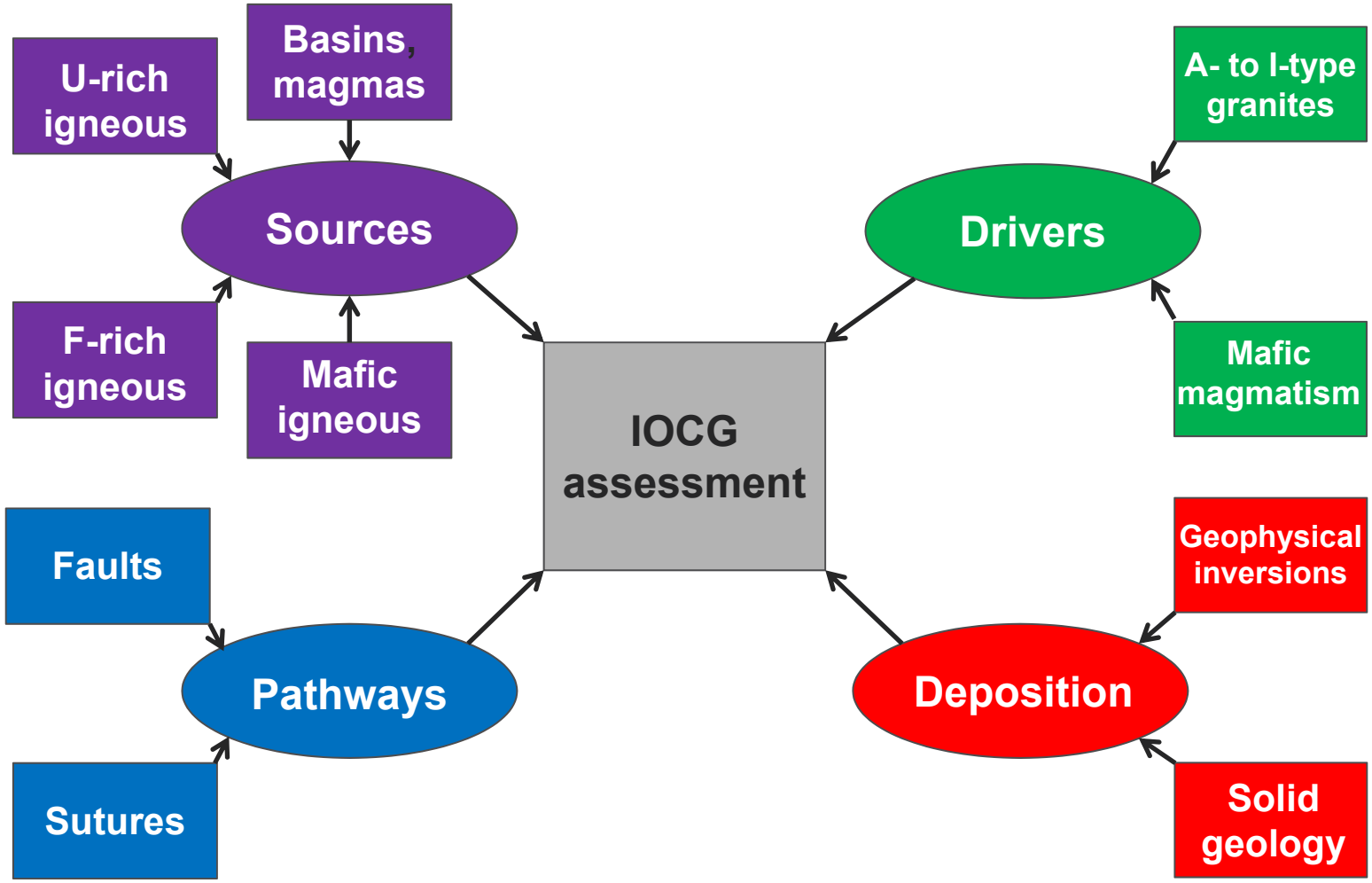
Schofield, 2013

IOCG conceptual criteria



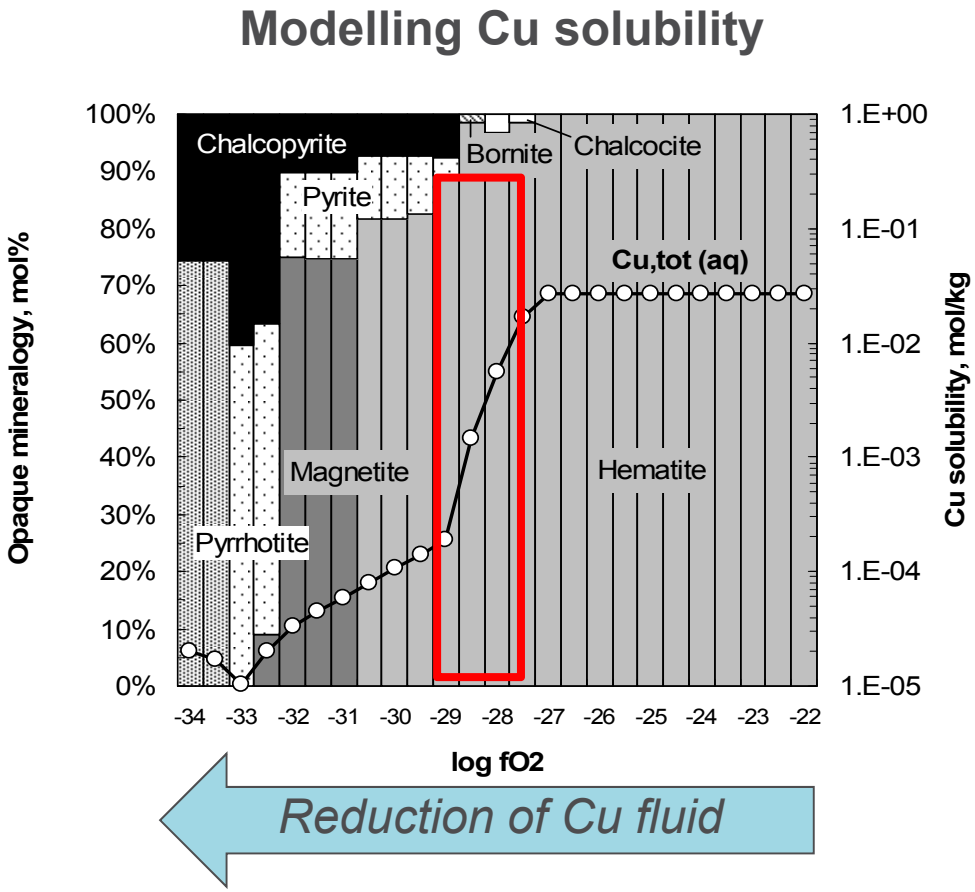
Schofield, 2013

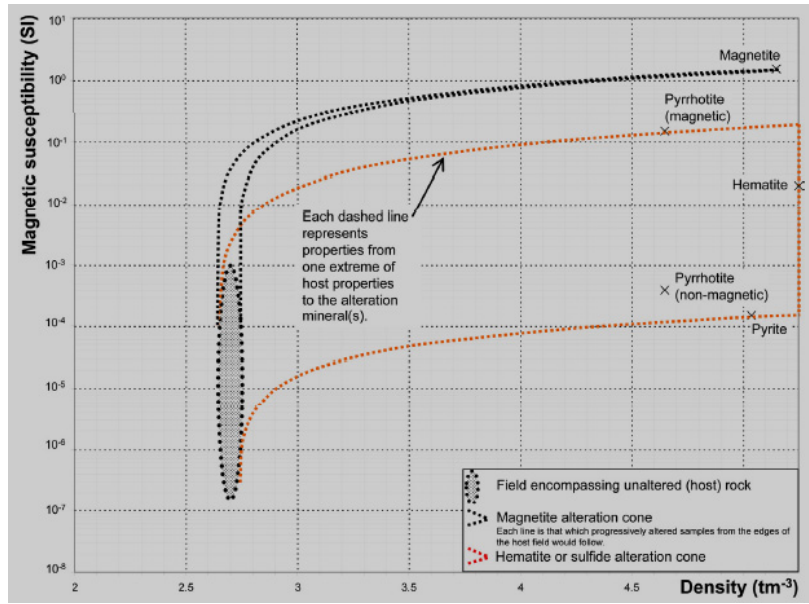
IOCG mappable criteria



Schofield, 2013

Integrating geochemical modelling





From Huston et al., 2012

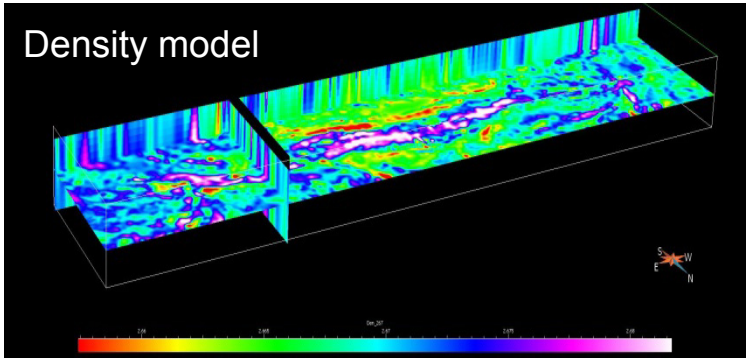
Cu deposited near magnetite-hematite gradient

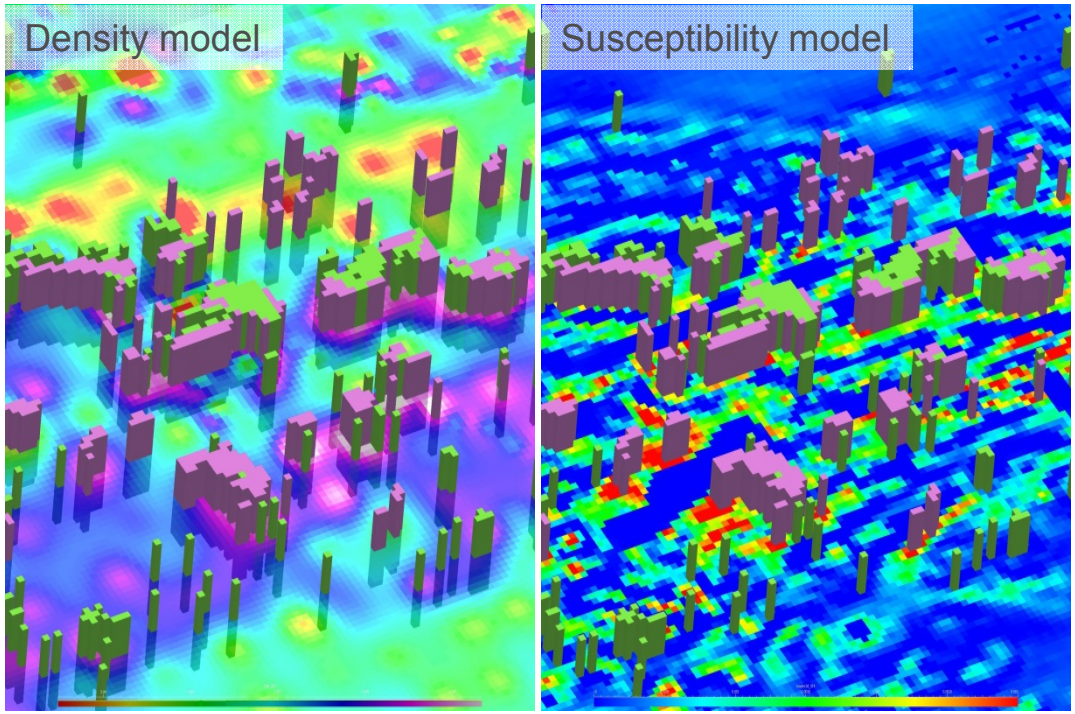
- **Map magnetite-hematite gradient in susceptibility (mag) & density (gravity) space**
- **Take into map space via 3D inversion of mag and gravity**

Integrating geochemical modelling

A water-rock interaction model for Cu and Au precipitation in IOCG systems. Copper precipitates by reduction of a copper-gold-bearing oxidized (hematite-stable) fluid infiltrating a magnetite-bearing assemblage. The slide shows a dramatic drop in copper solubility and development of best copper grades next to the hematite-magnetite alteration interface. The example is provided for 300oC but the principle would upply outside of this temperature range.

Integrating geochemical modelling in 3D space





Hematite: green; magnetite: pink

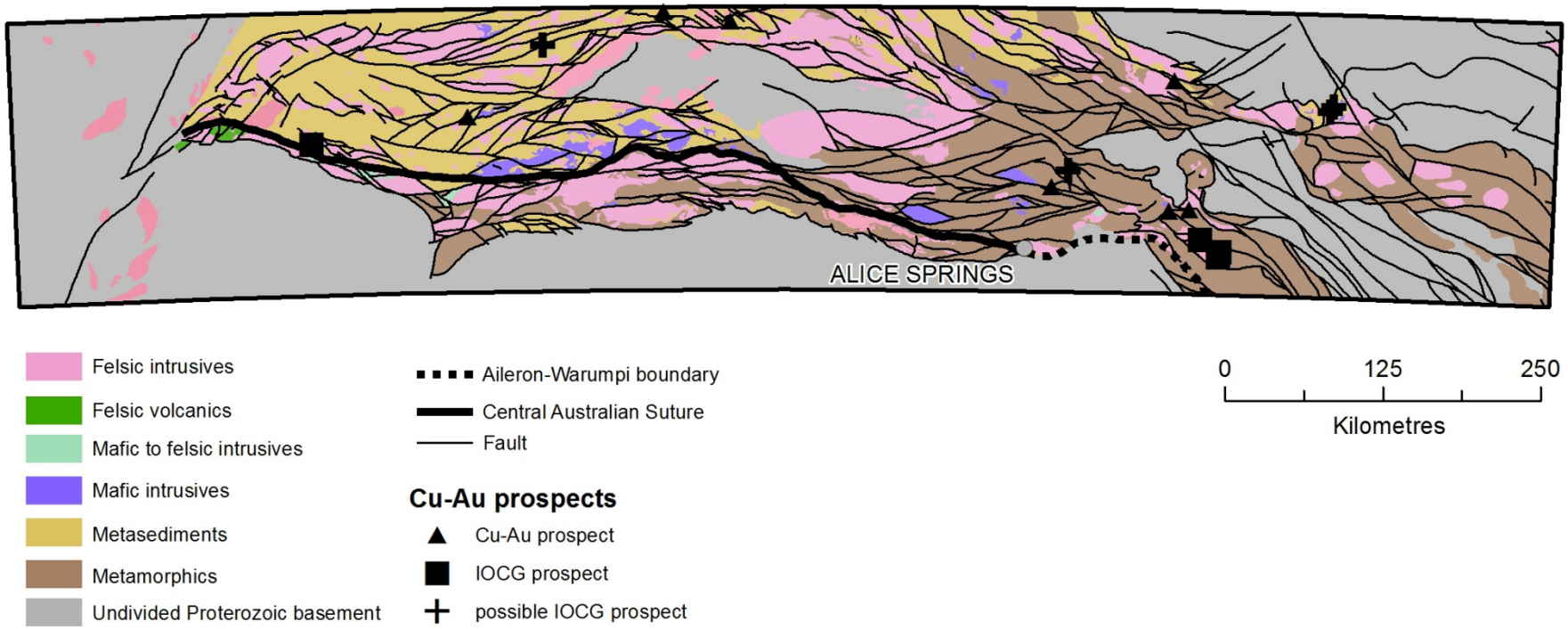
- 3D magnetic and gravity inversions volumes hematite & magnetite alteration
- Filtered by geology to minimise lithological influences
- Favourable gradient near magnetite to hematite mapped in 3D
- Take result into spatial model analysis

Integrating geochemical modelling in 3D space

- First step: perform 3D magnetic and gravity inversions to derive density and magnetic susceptibility models for the study area
- Cross-plots of density vs susceptibility generated
  - Filtered using solid geology to minimise lithological influences (e.g., don't want mafic rocks coming up consistently as mgt)
- From this, volumes of potential mgt or hem alteration are identified, from which we identify the transition from mgt to hem as the most favourable

Building a geological (architecture) model

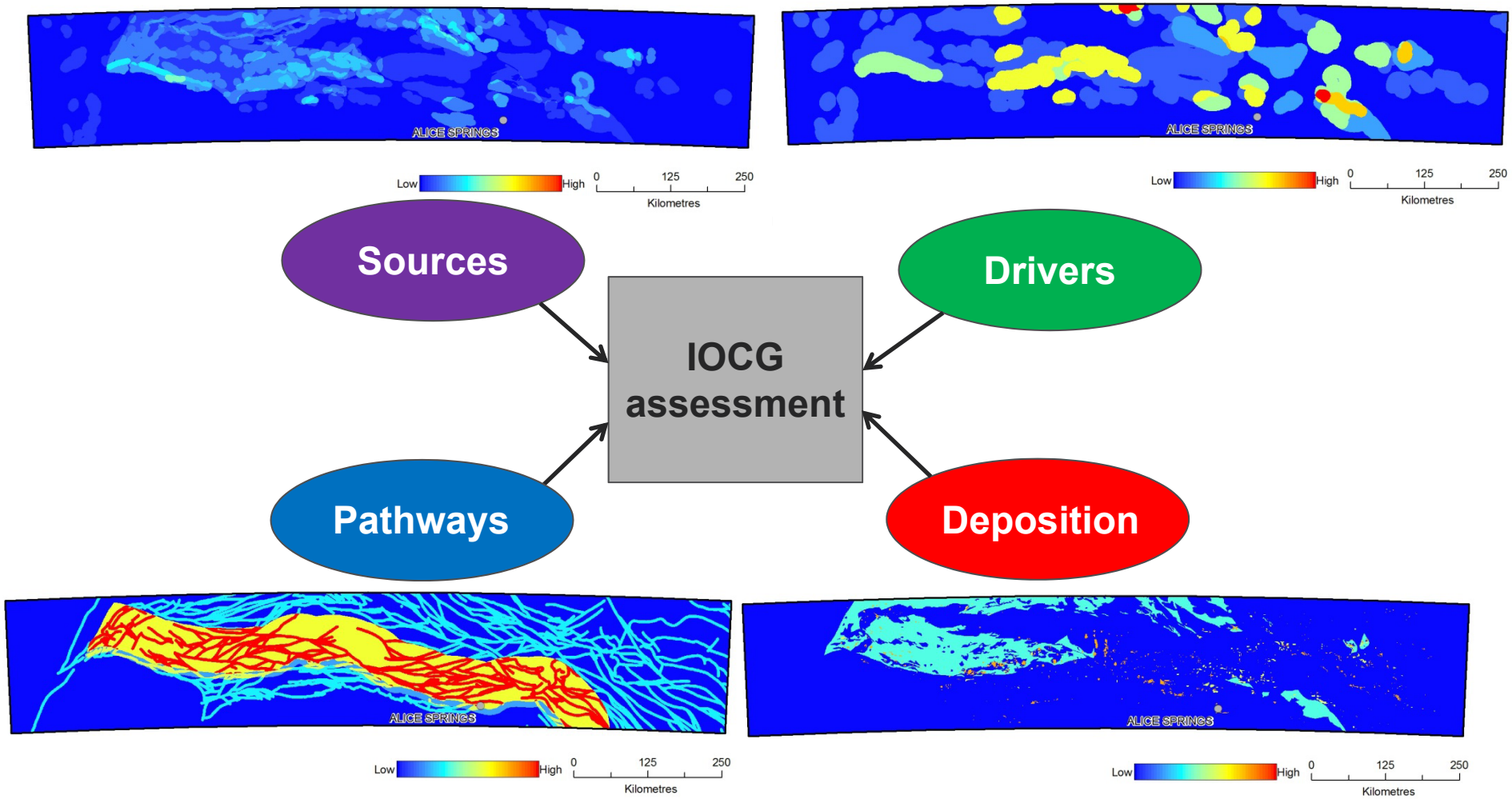
Southern Aileron Province



Reliable ‘solid geology’ (architecture) maps vital

Schofield, 2013

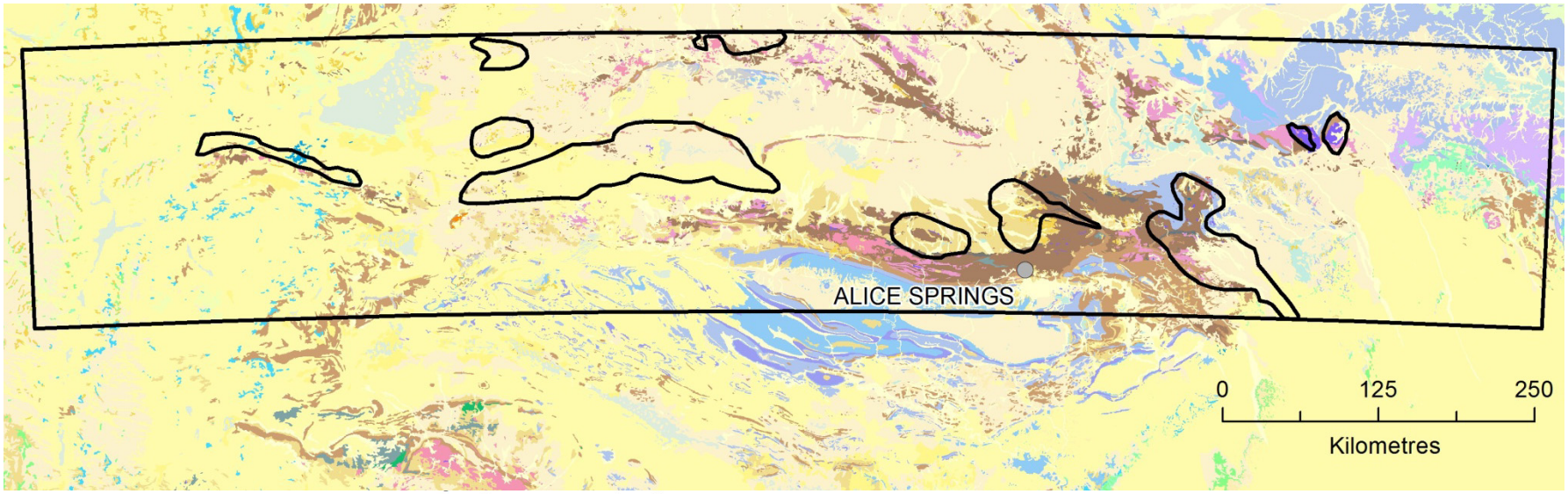
Building a mineral system model



Schofield, 2013

Building a testable hypothesis

Aileron IOCG potential



Schofield, 2013

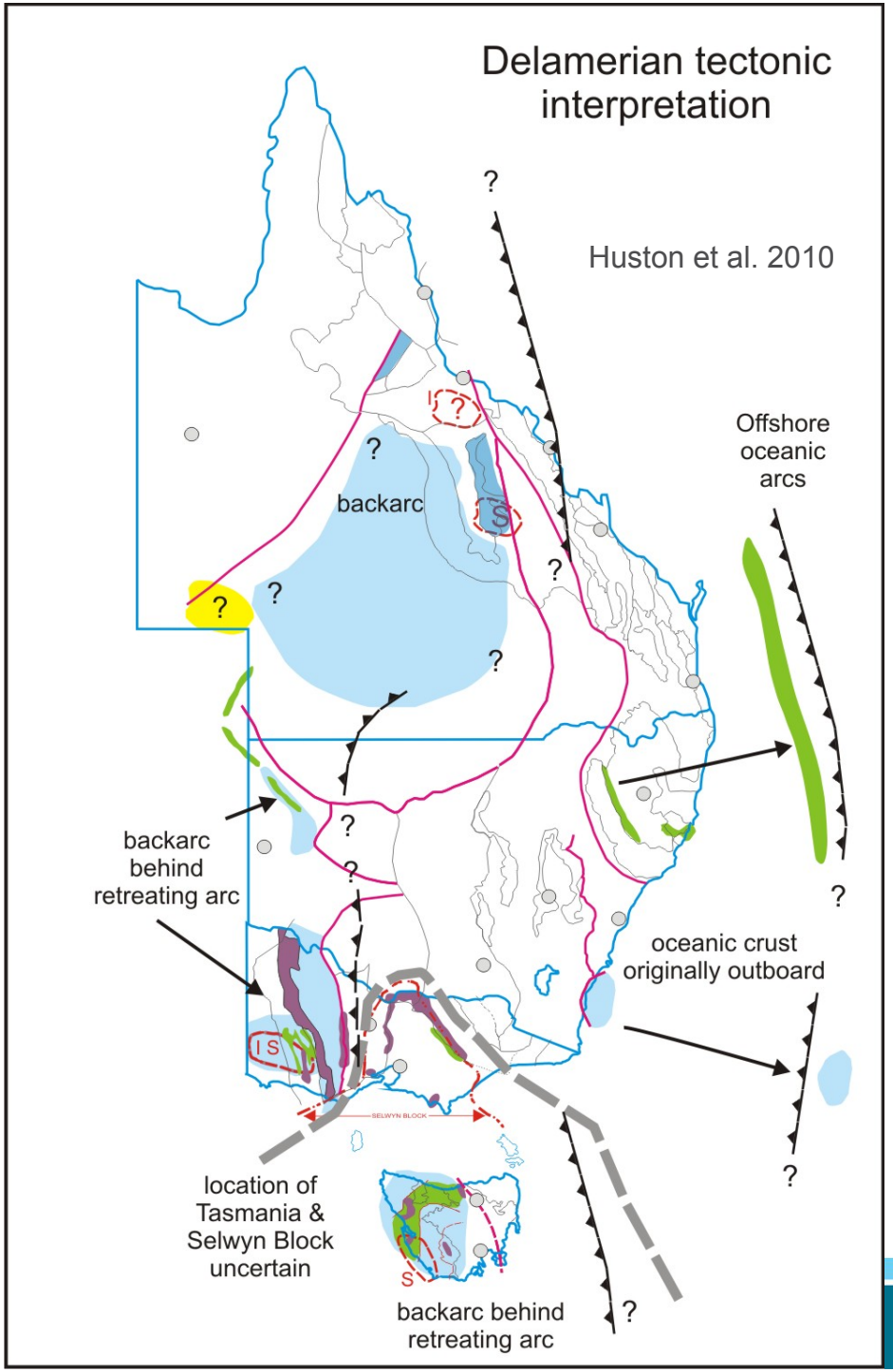
Testing the geological–mineral system models: regional-scale pre-competitive drilling

Considerations for area selection:

- Mineral systems potential
- Relatively poorly known geology
- Greenfields – make a material difference
- Potential to collaborate (co-invest)
- Suitable access and infrastructure

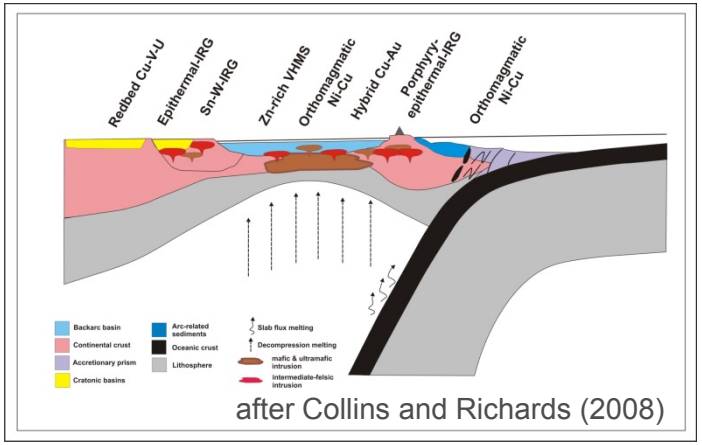
Some drilling parameters:

- Depth to target limit at <500 m.
- ~ 5–15 holes within ~ 1:250,000 map sheet area (~150 km x 115 km); or
- ~ 300 km long transect

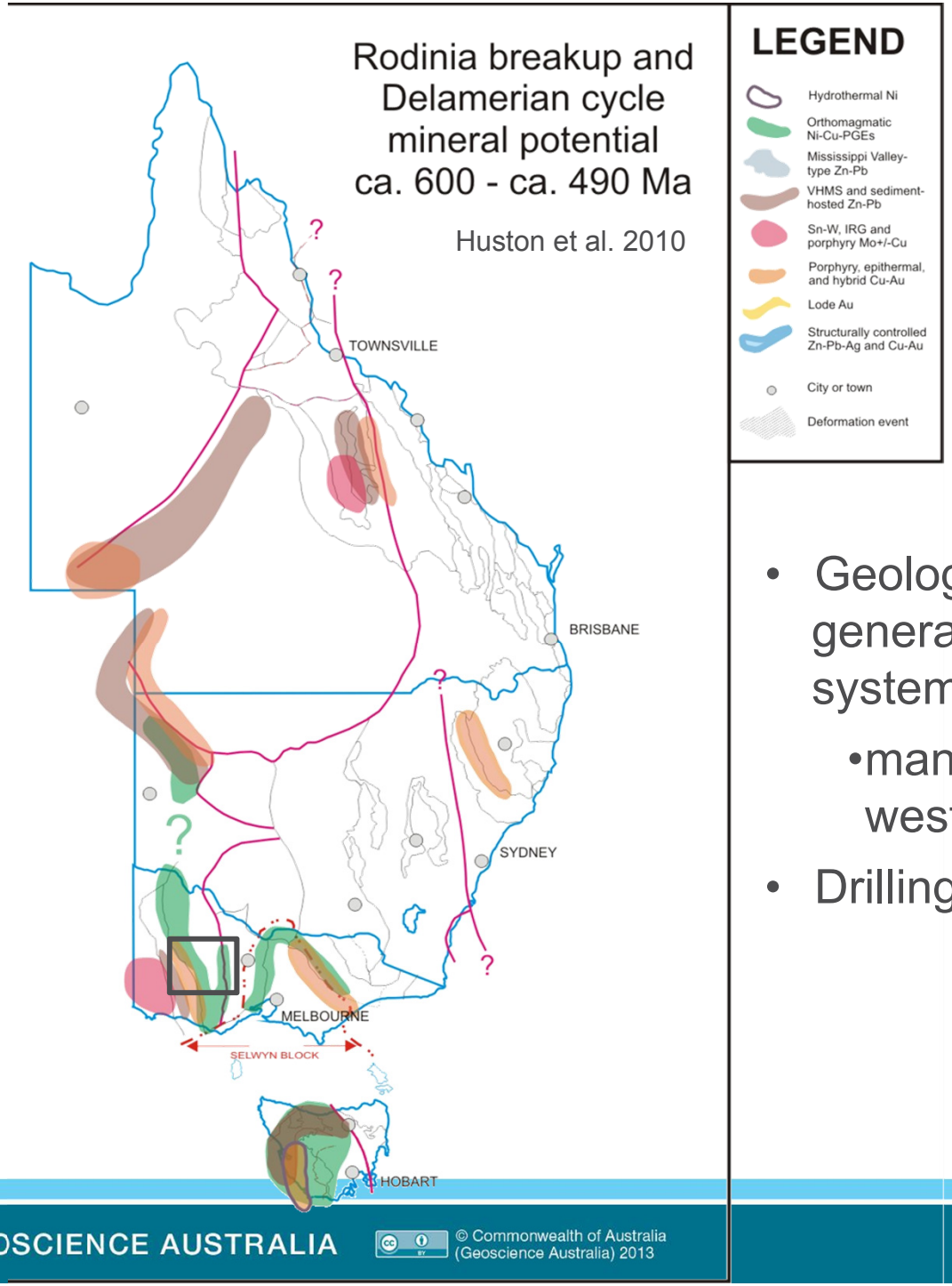


Delamarian (600–490 Ma)

- Margin of Proterozoic Australia with interpreted west-dipping subduction
  - •Began with Rodinia break-up
  - •Ended with Delamerian Orogeny (ca. 520-490 Ma)
- Extensive felsic and mafic volcanics and associated sediments
- Deep marine turbiditic sediments
- Restricted granites



after Collins and Richards (2008)

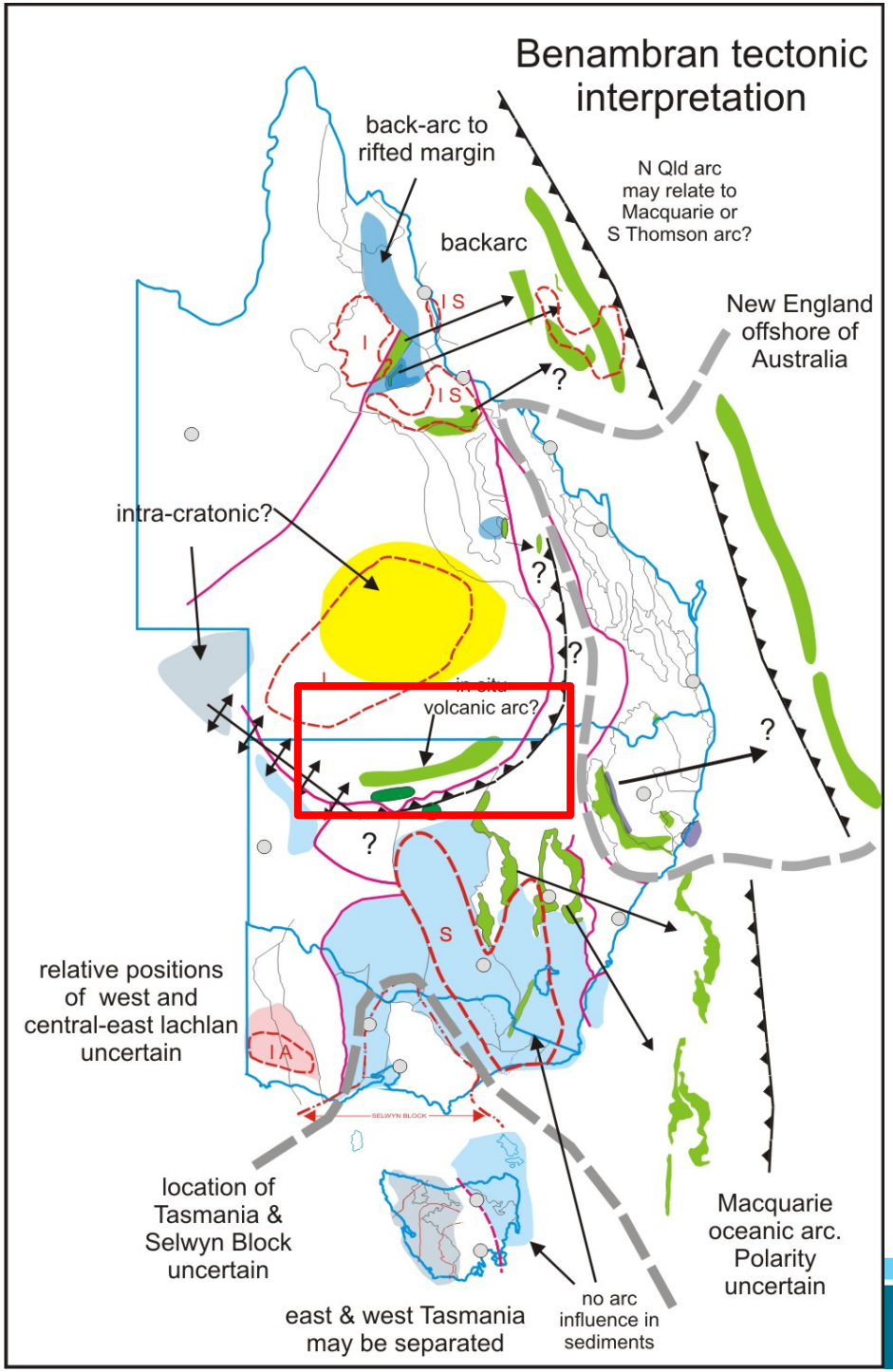


Delamarian (600–490 Ma)

- Geological model building generates a range of mineral system concepts
  - many under shallow cover e.g., western Victoria
- Drilling to test geological models

Pre-competitive drilling project 1

- Victoria drilling project (2013–15)
  - geophysical data acquisition
  - **Drilling in < 12 months**
  - 10+ diamond holes
  - Develop our workflows for sample handling and analysis
  - Partnership of GA, GSV and DET CRC
  - DET CRC research projects access (e.g. carbon fibre rods, new downhole tools, lab at rig)



Benambran Cycle (490-430 Ma)

- Widespread non-volcanic deep water sediments, and
- Calc-alkaline to shoshonitic magmatic arcs
- Ended with Benambran Orogeny (ca. 450-430 Ma)
- Subduction environment, complex configuration, modified by subsequent tectonism
- Geological model building generate a range of mineral system opportunities
- E.g., Southern Thomson
- Drilling to test geological models

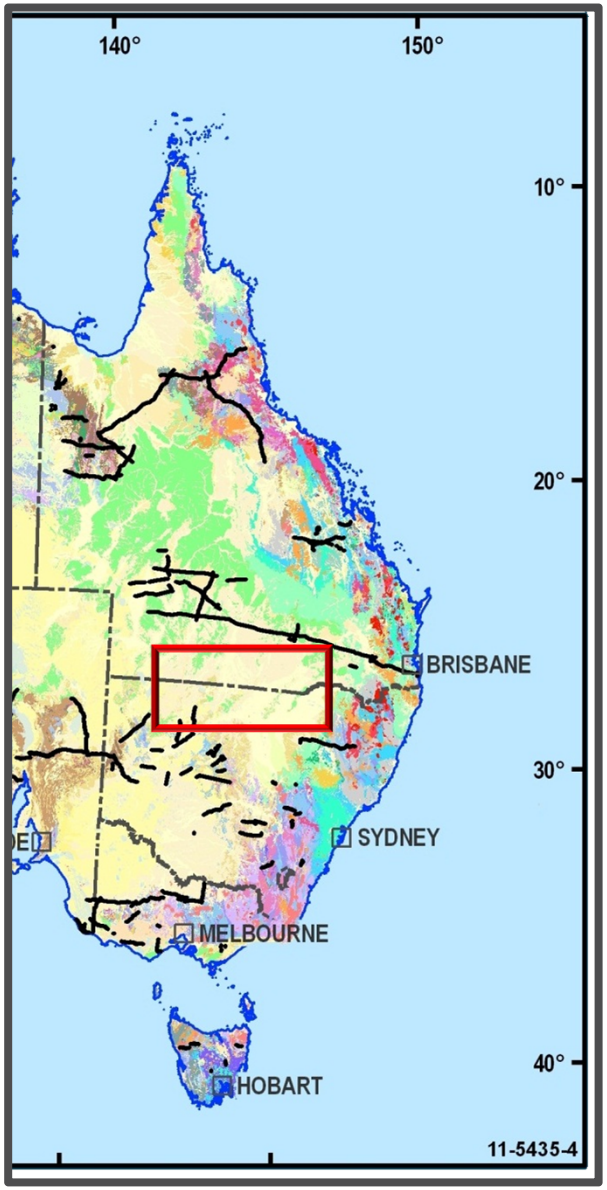
Pre-competitive drilling project 2

- Southern Thomson Orogen drilling project (2013–16)
  - GA–GSQ–GSNSW project

    Scoping and compilation (GA-GSQ-GSNSW data harmonisation)

    Define problem and select drill sites

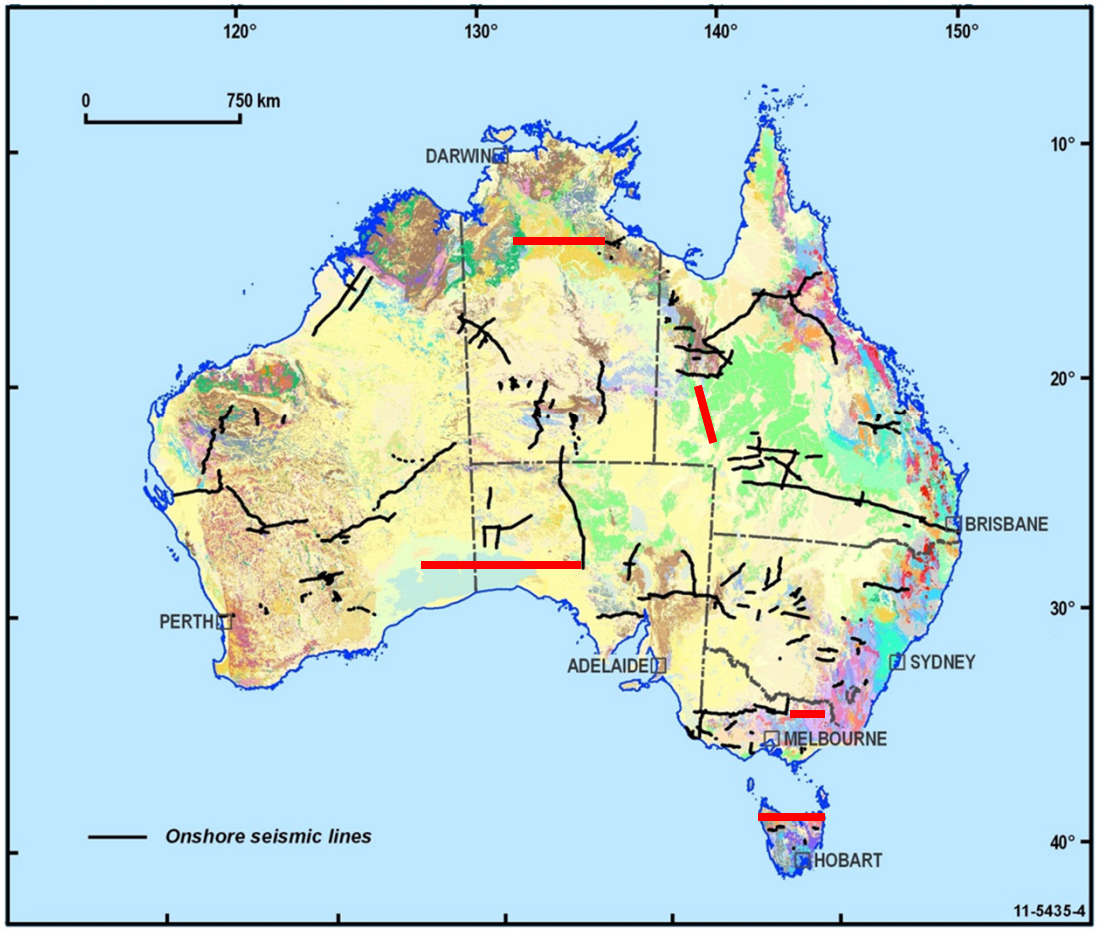
    Depth and character of cover (2013–14)
    - broad-spaced AEM survey
    - pre-drilling MT or passive seismic survey
    - pre-competitive surface geochemical survey
  - Drilling in 2014–15
  - Much to still scope on this project



…possible regional drilling in the out years?

Possible future areas include:

- Carpentaria Basin in NT seismic/MT and drilling
- Southern Isa in Qld seismic/MT and drilling
- Eucla to northwest Gawler in SA drilling
- Ideas in from Vic, Tas to consider



Australia Minerals: ‘open at depth’ for business under cover

- Vast undercover opportunities
  - extensions to known provinces
  - true greenfields
- World-class precompetitive data holdings, which are FREE
- Highly skilled knowledge base in terms of:
  - technology to manipulate & interrogate data
  - geology of Australia
- Networks both physical and intellectual
- Supportive government at all levels
- Skilled explorers to Australian conditions

Thank you

Dr Andy Barnicoat andrew.barnicoat@ga.gov.au

Chief: Minerals and Natural Hazards Division

Geoscience Australia