Resolving the 4D geodynamic and metallogenic evolution of (west) Australia: towards better prediction.

J. Miller - **Centre for Exploration Targeting**

T. Campbell McCuaig - **Centre for Exploration Targeting**

N. Thébaud - **Centre for Exploration Targeting**

M. Dentith - **Centre for Exploration Targeting**

Jon Hronsky - **Western Mining Services / Centre for Exploration Targeting**

Centre for **EXPLORATION TARGETING**

UNCOVER
AUSTRALIAN EXPLORATION
GEOSCIENCE RESEARCH

Curtin University

THE UNIVERSITY OF
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National Resources Science Precinct (NRSP)

Centre for **EXPLORATION TARGETING**

Distal Footprints of Giant Ore Systems

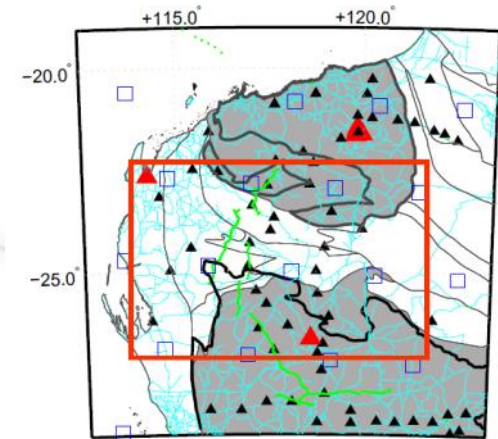**>$16M new initiative over Capricorn Orogen**

Rob Hough, Cam McCuaig, Steve Reddy, Ian Tyler, Dave Gray, Mike Dentith, Chris Clark, John Miller, Steve Barnes, Ravi Anand,, Marco Fiorentini, Tim Munday, Simon Johnston, Alan Aitken, Sandi Occhipinti, Vasek Metelka
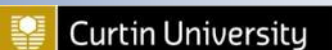
**Project Leader
Dr Rob Hough**

- $900K from Industry

- $4M Federal Government Science and Industry Endowment Fund

- $2.5M GSWA (AEM Survey)

- $2.6M MRIWA

- $6.3M from CSIRO/UWA/Curtin

**Project designed to Uncover vision
Funding agencies related to vision
NO one institution could do it all**

National Resources Science Precinct (NRSP)

Mineral System

Deposit

Regional

Global

Fluid Sink

Focused Fluid Exit Conduit

Fluid Reservoir

Fluid delivery pathway

Primary Fluid Source Region

Mineral Systems Research into different components
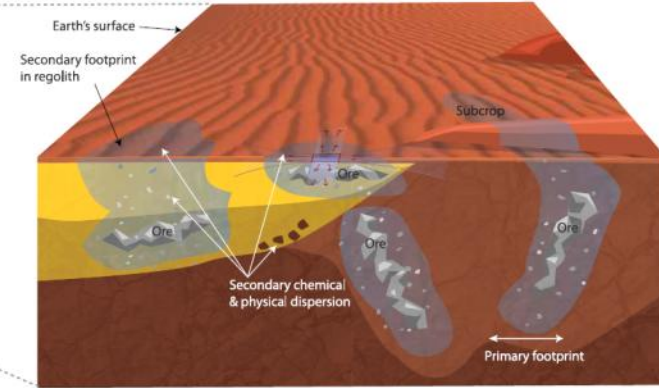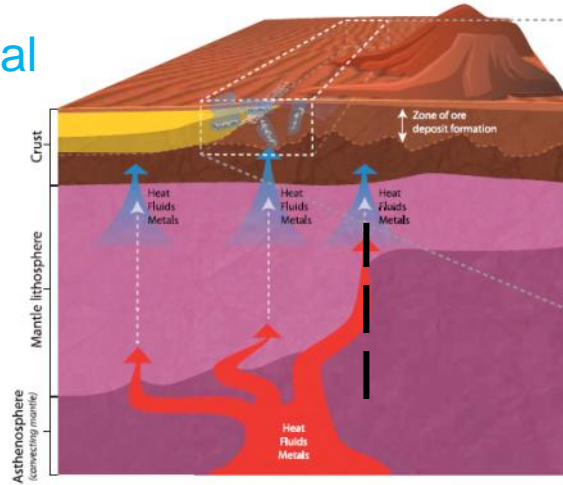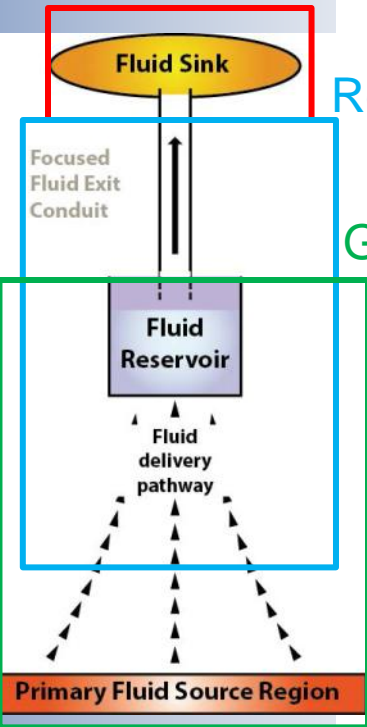
Need to predict location at global to regional scale
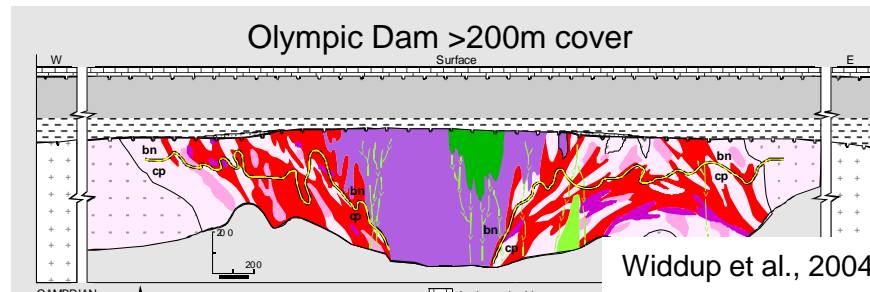To refine search space
"Are we in the right area?"
Can be done within a mineral systems framework.

Need to be able to detect deposit
1) Outcropping deposit
2) Sub-cropping and/or surface anomalism-ground water
3) Under cover or "blind"

Different detection methods
e.g. gossan, soil anomalies, ground water, geophysical anomalies

Olympic Dam >200m cover

Widdup et al., 2004

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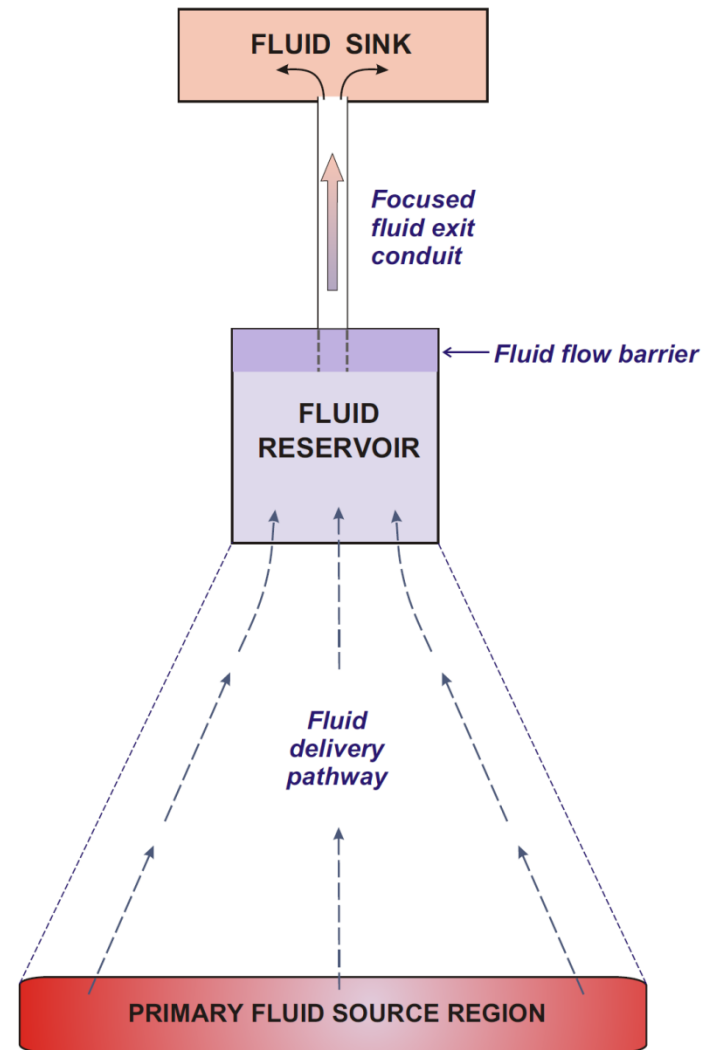
- Define the key *generic, unifying* process elements that govern ore-formation (at all scales)
- Map these elements **(essential for predictive targeting**)
- Develop frameworks for evaluating endowment potential of systems

Develop proxies for every component

**A PHYSICAL PROCESS BASED MINERAL SYSTEM MODEL TO UNDERTAKE RESEARCH**

Geodynamic/tectonic setting

- Geodynamic/ tectonic setting can provide a guide to likely deposit types, but doesn't always reduce search space

- Archean/ Paleoproterozoic uncertainty in geodynamics

- Long periods of reworking – timing of mineralisation critical !

- Exceptions to rule e.g. a giant Cu-Au deposit in sediments not in an obvious IOCG/ Porphyry Cu geodynamic setting.

- Role of previously enriched SCLM i.e. formation of world class deposits is a later geodynamic event tapping this

Courtesy David Groves
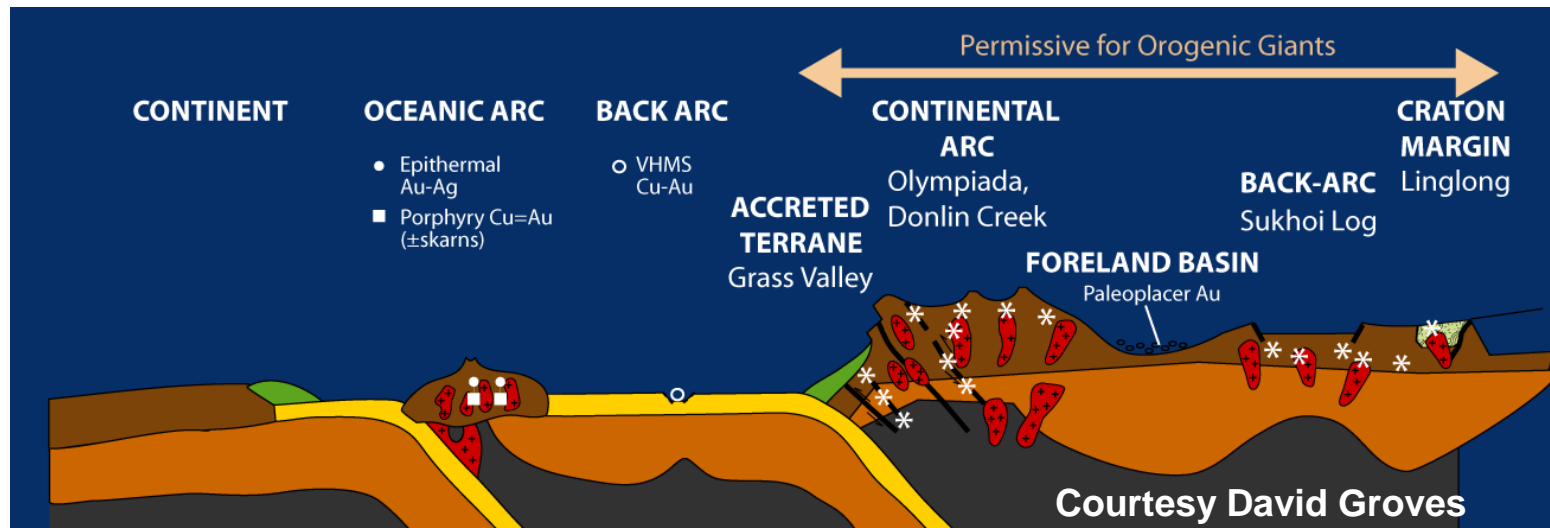
We must see beyond Deposit-Scale Complexity: major component of prediction is from larger scale


Corbett 2004
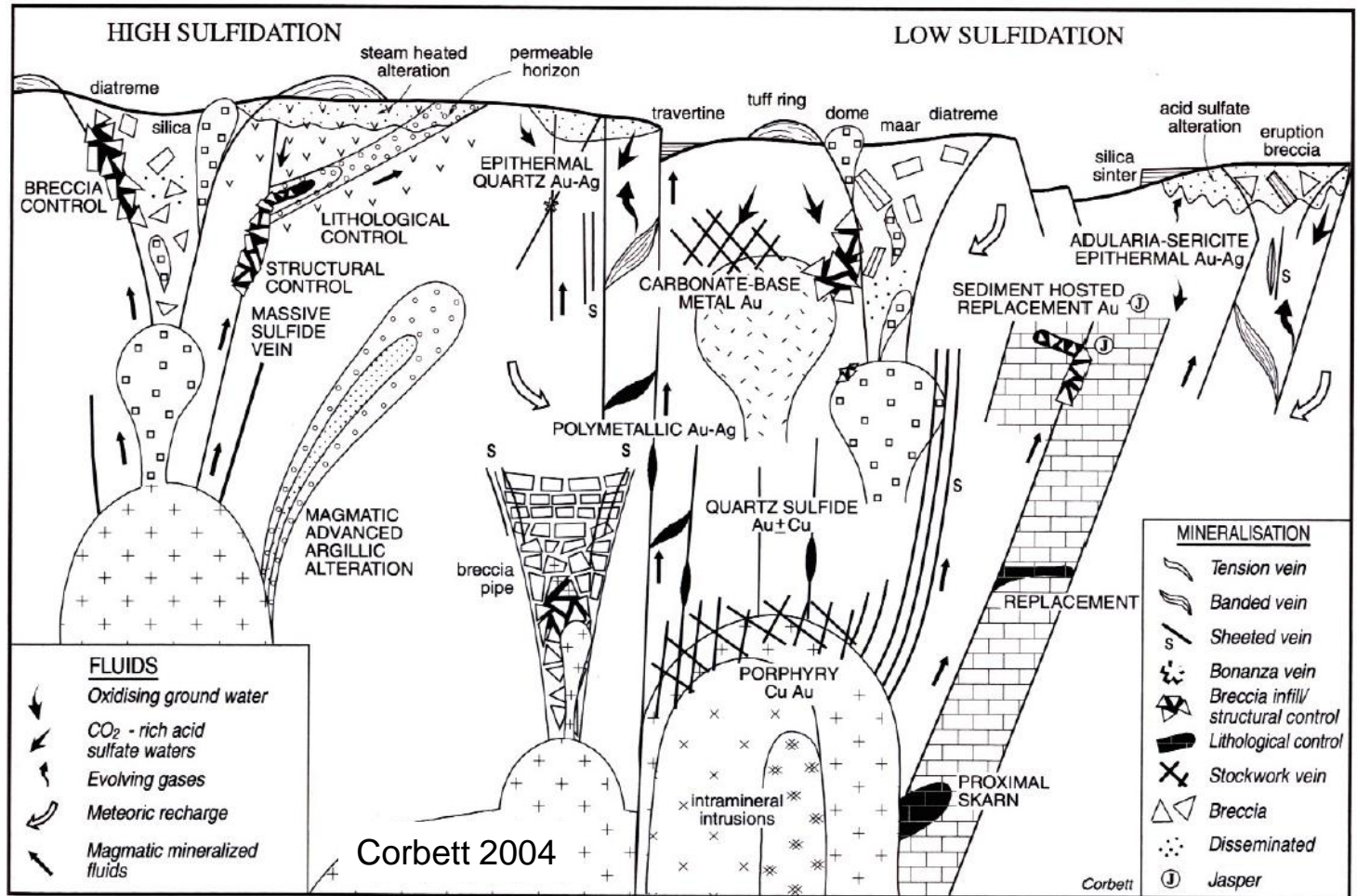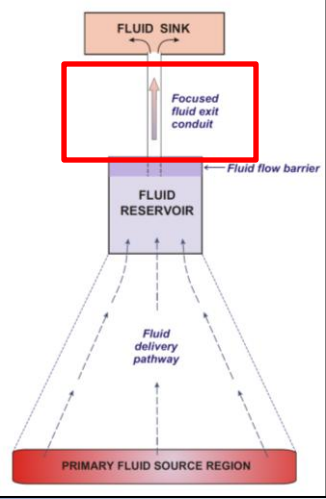
Deep Structure and Prospectivity

"At the scale of the Yilgarn Craton … the gold deposits … and nickel sulphide deposits … the major architecture controlling these systems are lithospheric in nature adjacent to paleocraton margins" (McCuaig et al, 2010, Ore Geology Reviews)……..

Yilgarn Geodynamic/ Tectonic model ? Ask Nicolas Thebaud and Richard Blewett over coffee.

"The location of magmatic Ni-Cu-PGE sulfide deposits is related to lithospheric architecture …. At crustal levels, this relationship is manifest by a close proximity to craton and paleocraton margins" (Begg et al. 2010, Economic Geology)
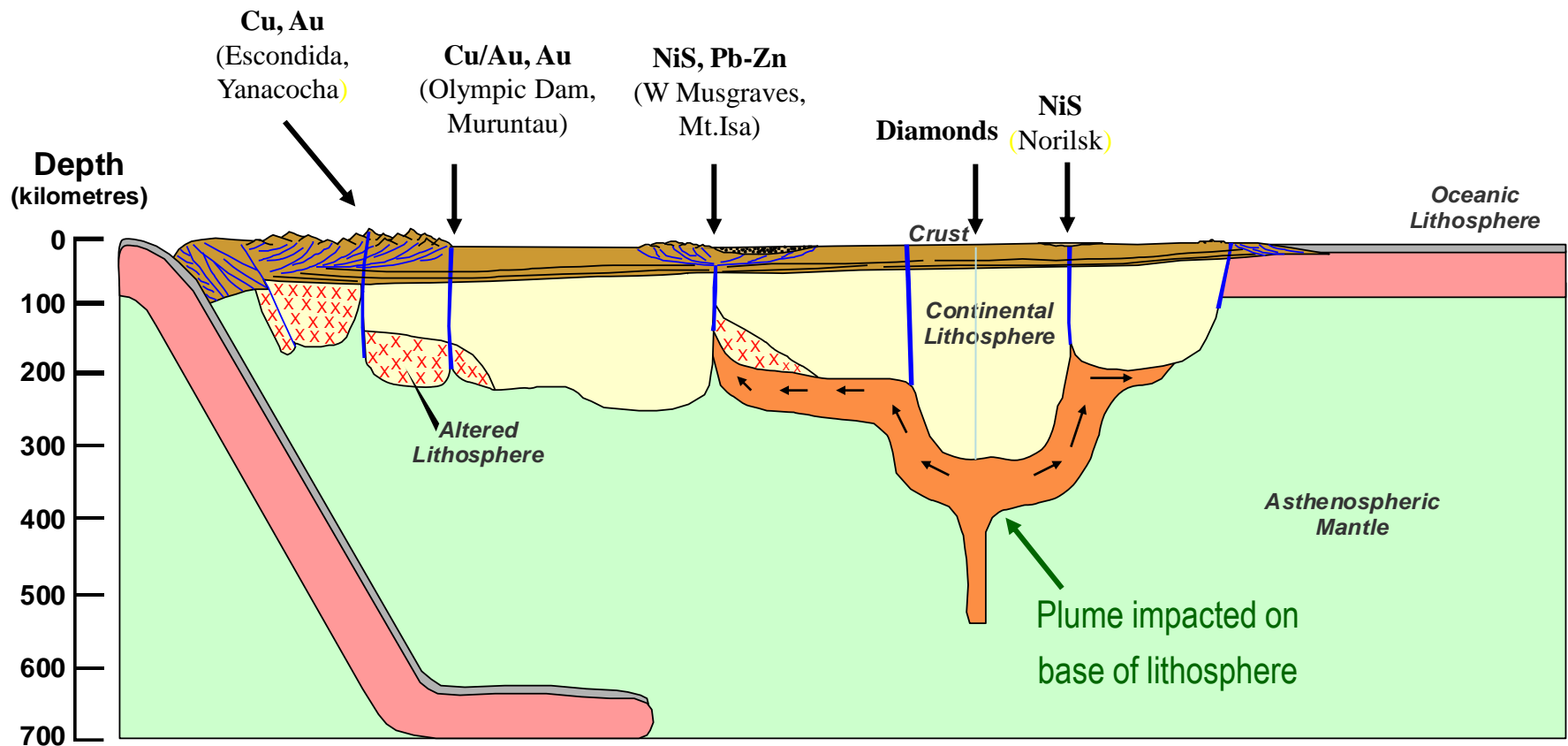
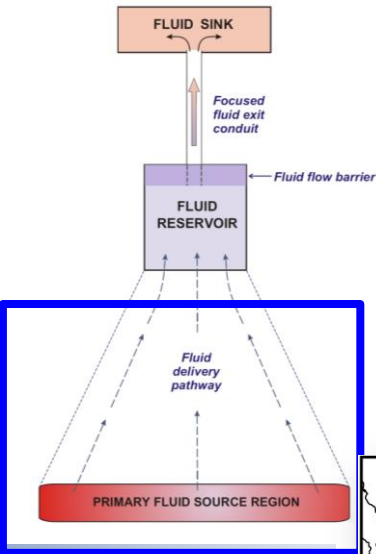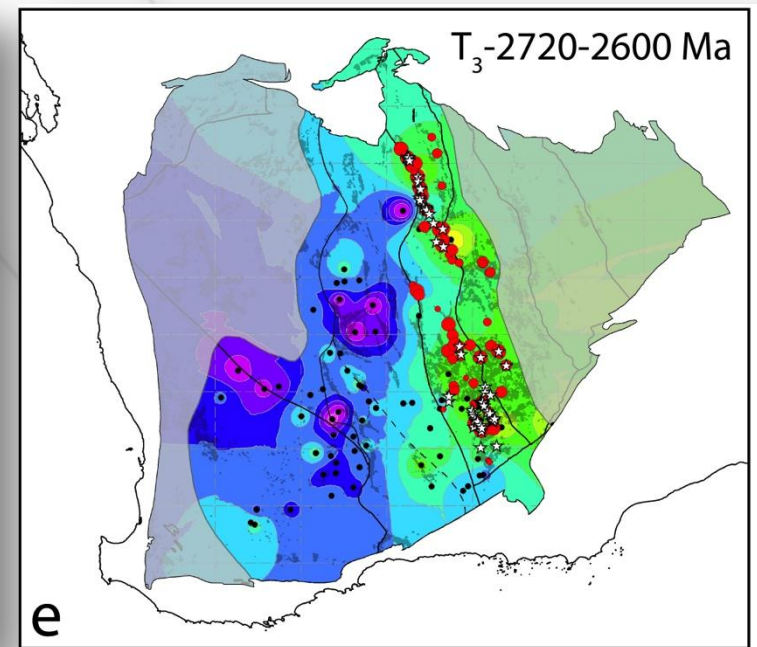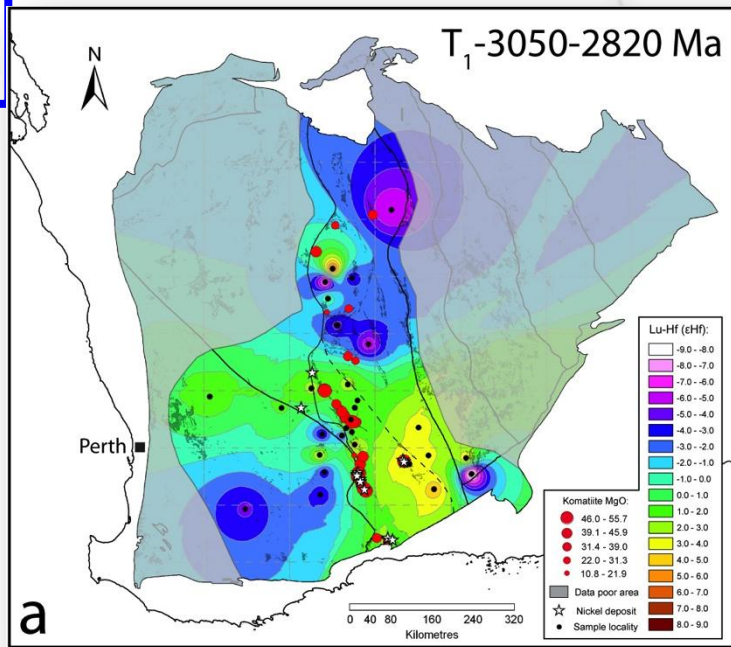# Isotopic mapping in Lhasa Terrane, Tibet
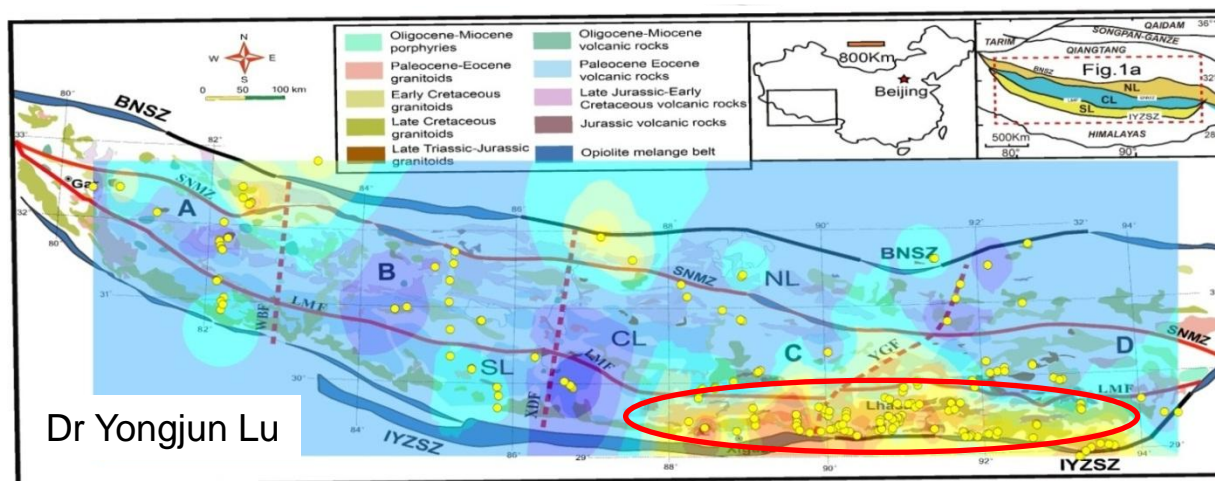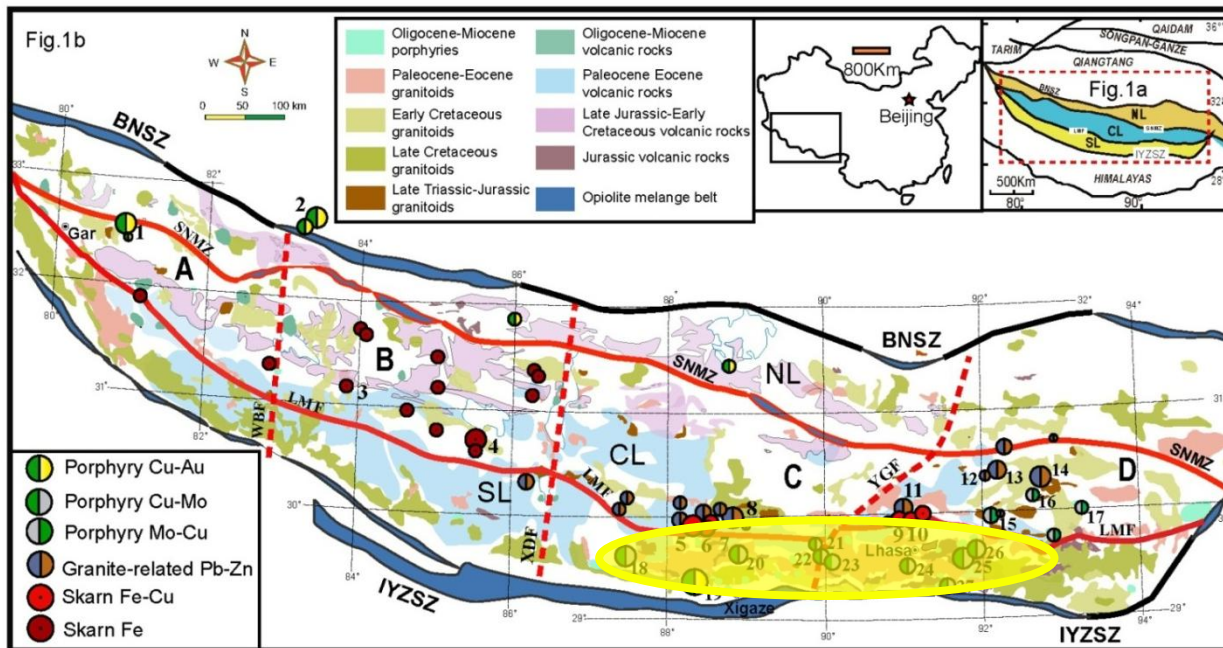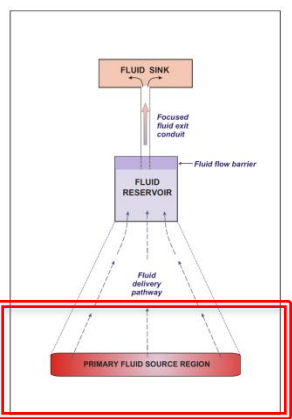
Dr Yongjun Lu

Blocks where porphyry Cu deposits cluster

Evaluating the lithospheric architecture of the Archean Yilgarn Craton in space and **time: Craton boundaries weren't always static**

Dr David Mole

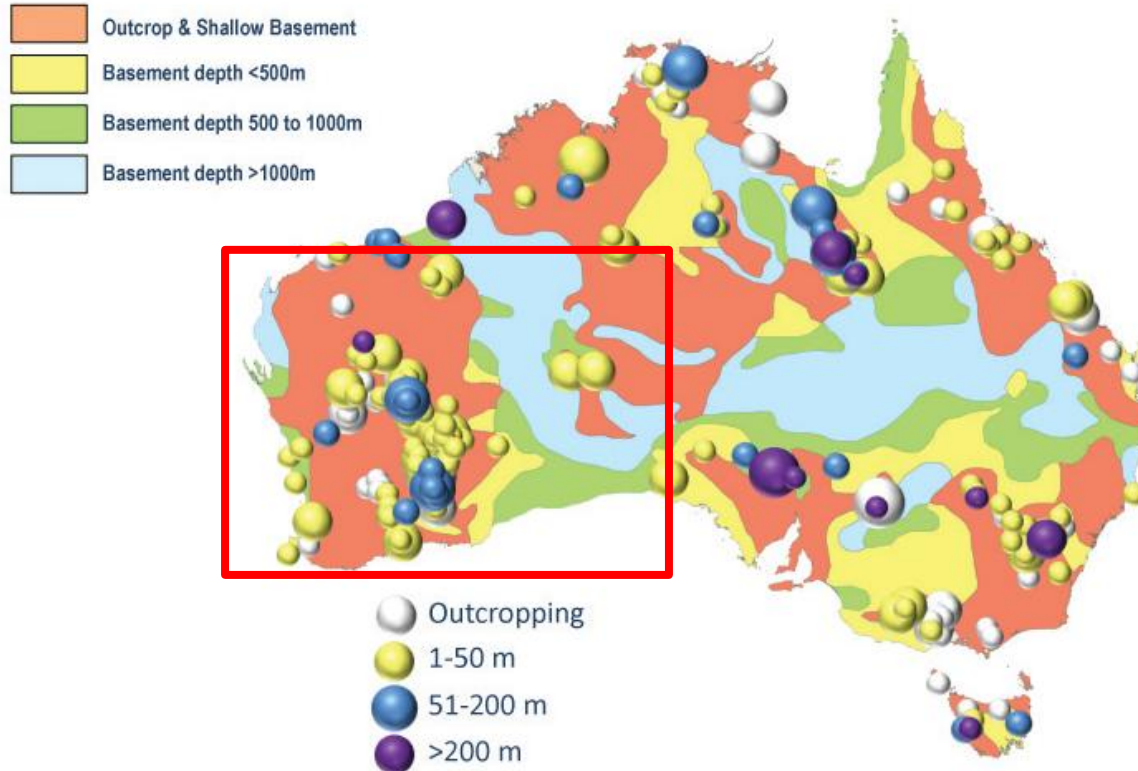**Understanding timing of mineralization and coincident architecture critical**

Mole et al., 2013

Australia's cover challenge

Major mineral deposits in Australia
Depth of cover

Legend — Depth of cover:
- Outcrop & Shallow Basement
- Basement depth <500m
- Basement depth 500 to 1000m
- Basement depth >1000m

Legend — Deposit symbols:
- Outcropping
- 1-50 m
- 51-200 m
- >200 m

Major defined as >1Moz Au, >1Mt Cu, >100Kt Ni or equiv.

Excludes bulk commodities Bauxite, Coal, Iron Ore

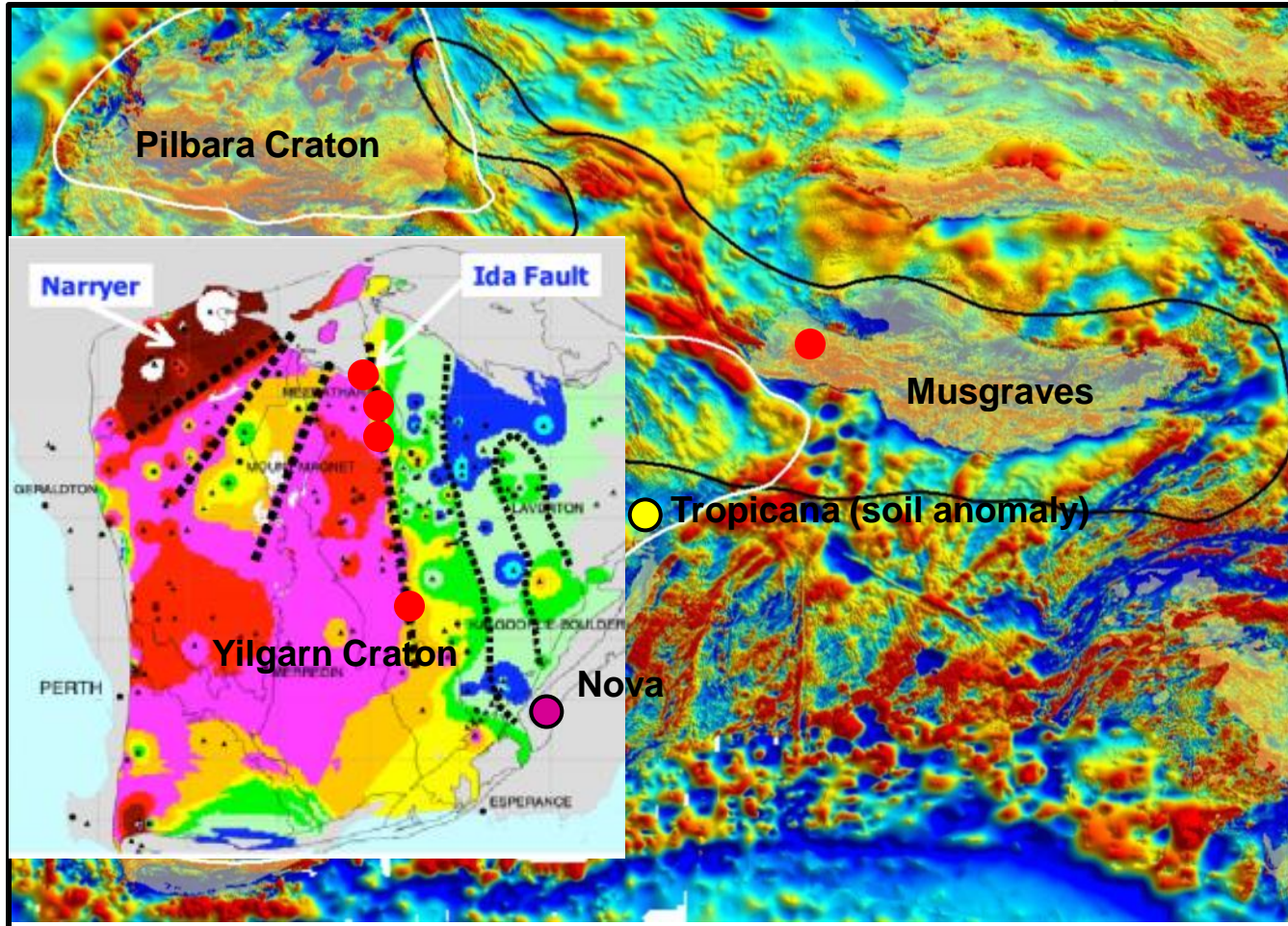Sources: MinEx Consulting © August 2010
Geoscience Australia

~80% of landmass (7.5M km^2) under cover

Both challenge and opportunity!

UNCOVER
AUSTRALIAN EXPLORATION
GEOSCIENCE RESEARCH

Cratonic architecture – a whole lithospheric approach, can target key boundaries via geophysical data and isotopic mapping (latter requires physical samples)
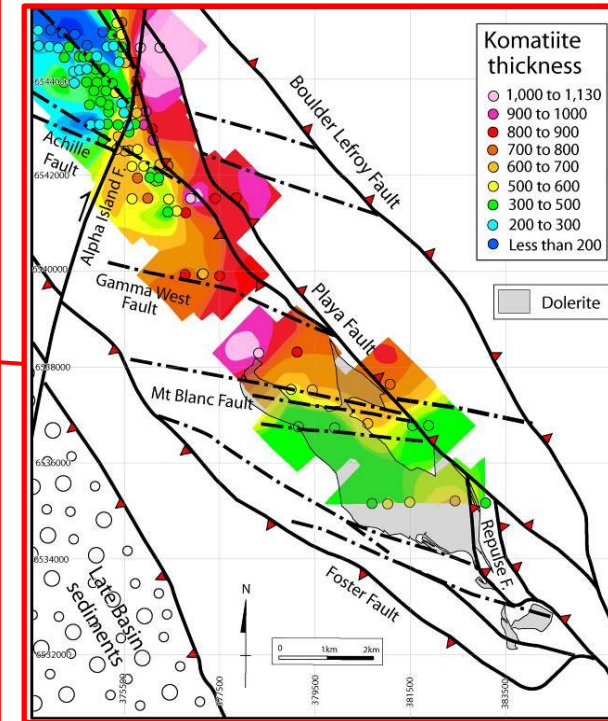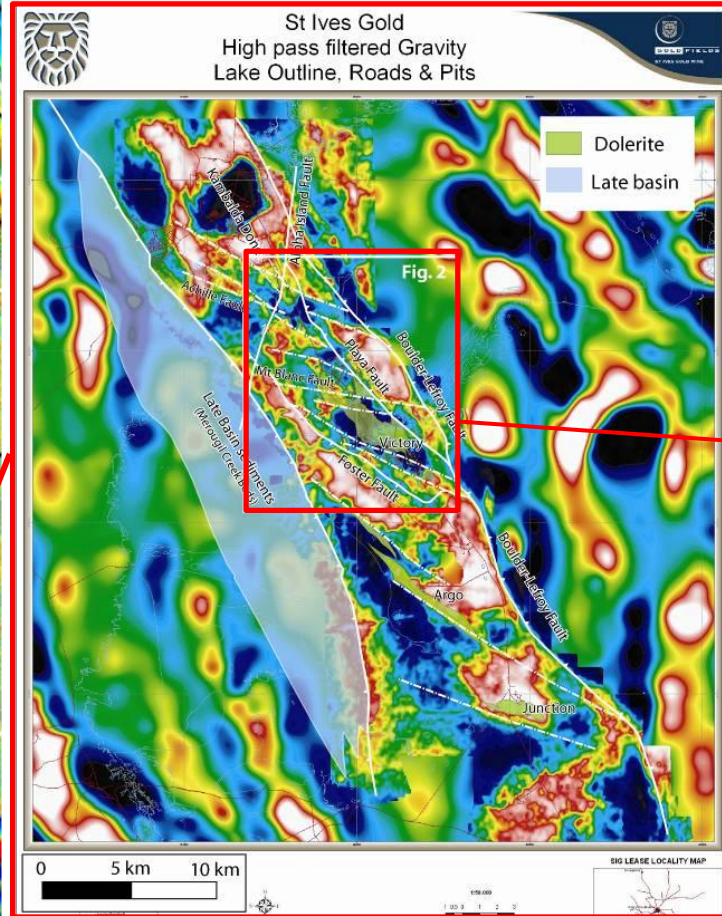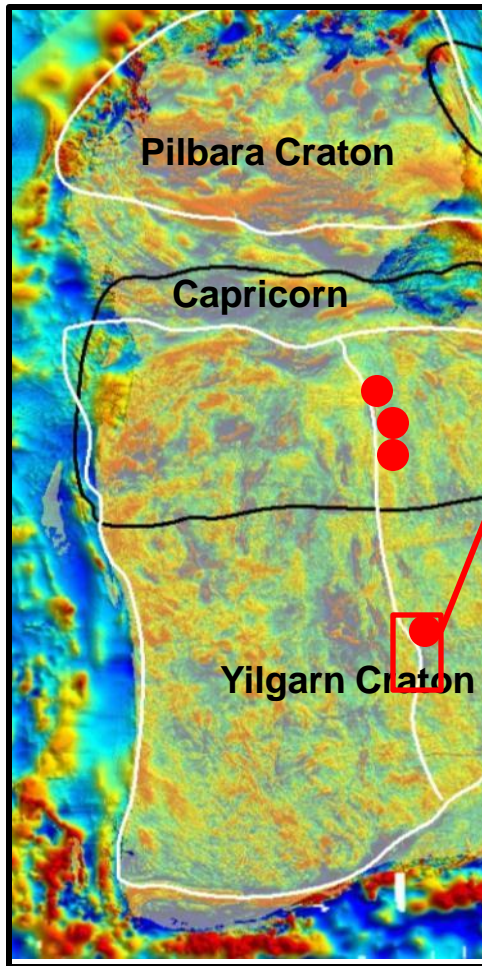

Craton margins

● Tier 1 NiS deposits

○ Tropicana Au

○ Nova NiS deposit

Pilbara Craton

Narryer

Ida Fault

Musgraves

Tropicana (soil anomaly)

Yilgarn Craton

Nova

GERALDTON

PERTH

MOUNT MAGNET

LAVERTON

KALGOORLIE-BOULDER

MERREDIN

ESPERANCE

Granitoid Nd™ after Cassidy and Champion 2007

Centre for EXPLORATION TARGETING

Australian Government
Geoscience Australia

Cratonic architecture – can target key boundaries
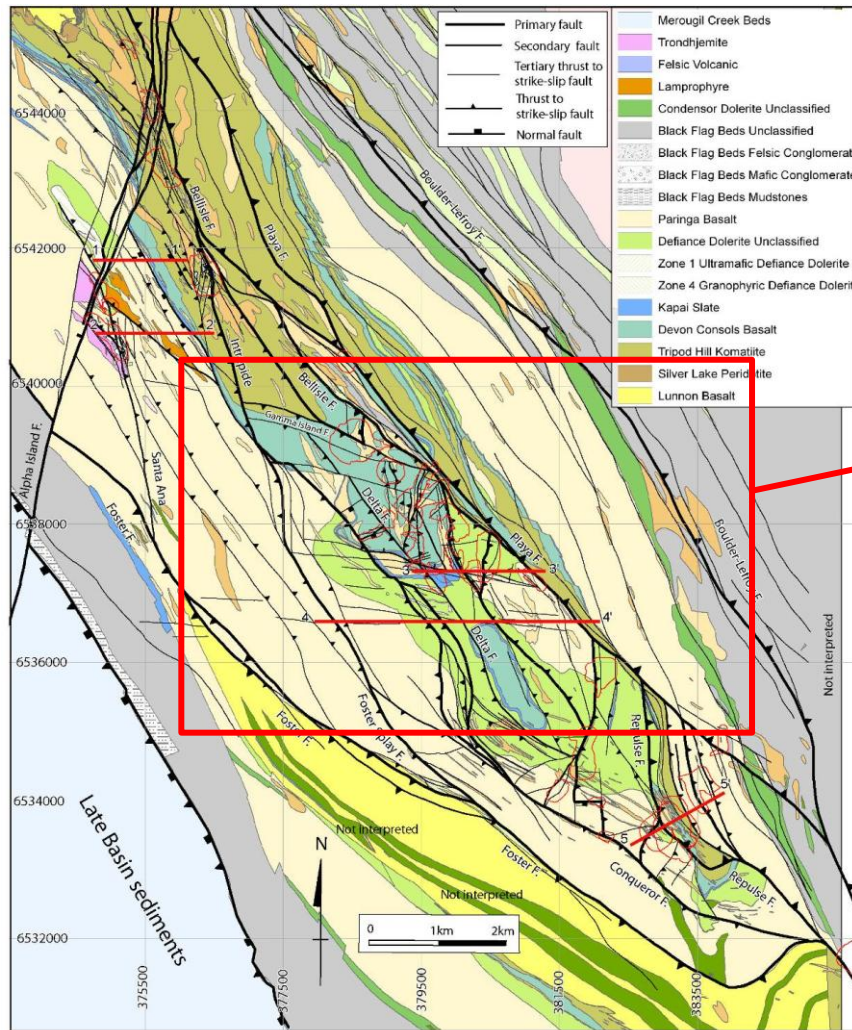## BUT what about the next scale down??????

Connors 2002

Need to integrate across scales
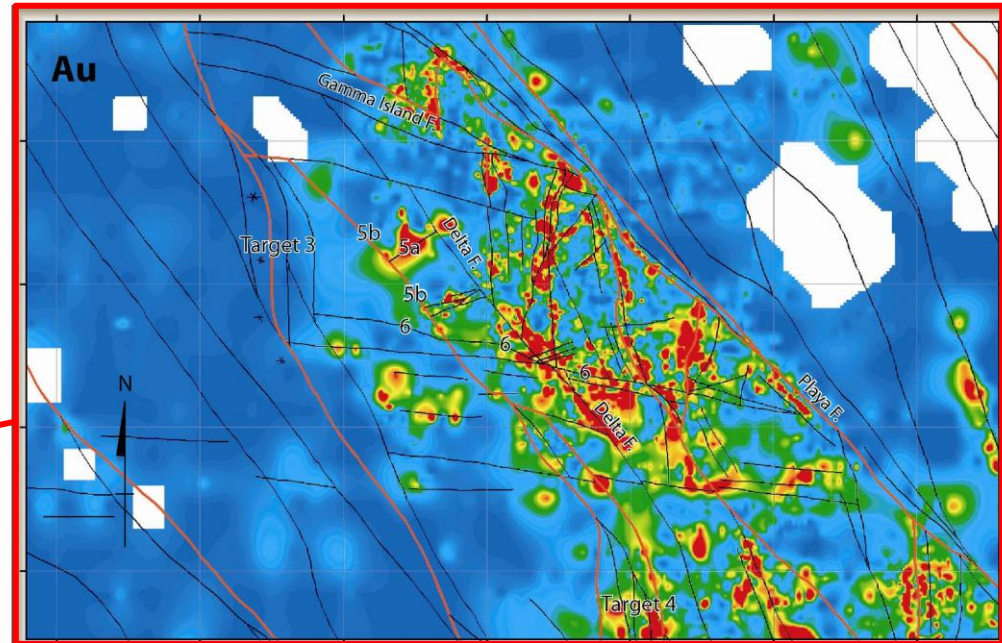**Early syn-rift architecture links to later Au**

New structural interpretation with solid geology
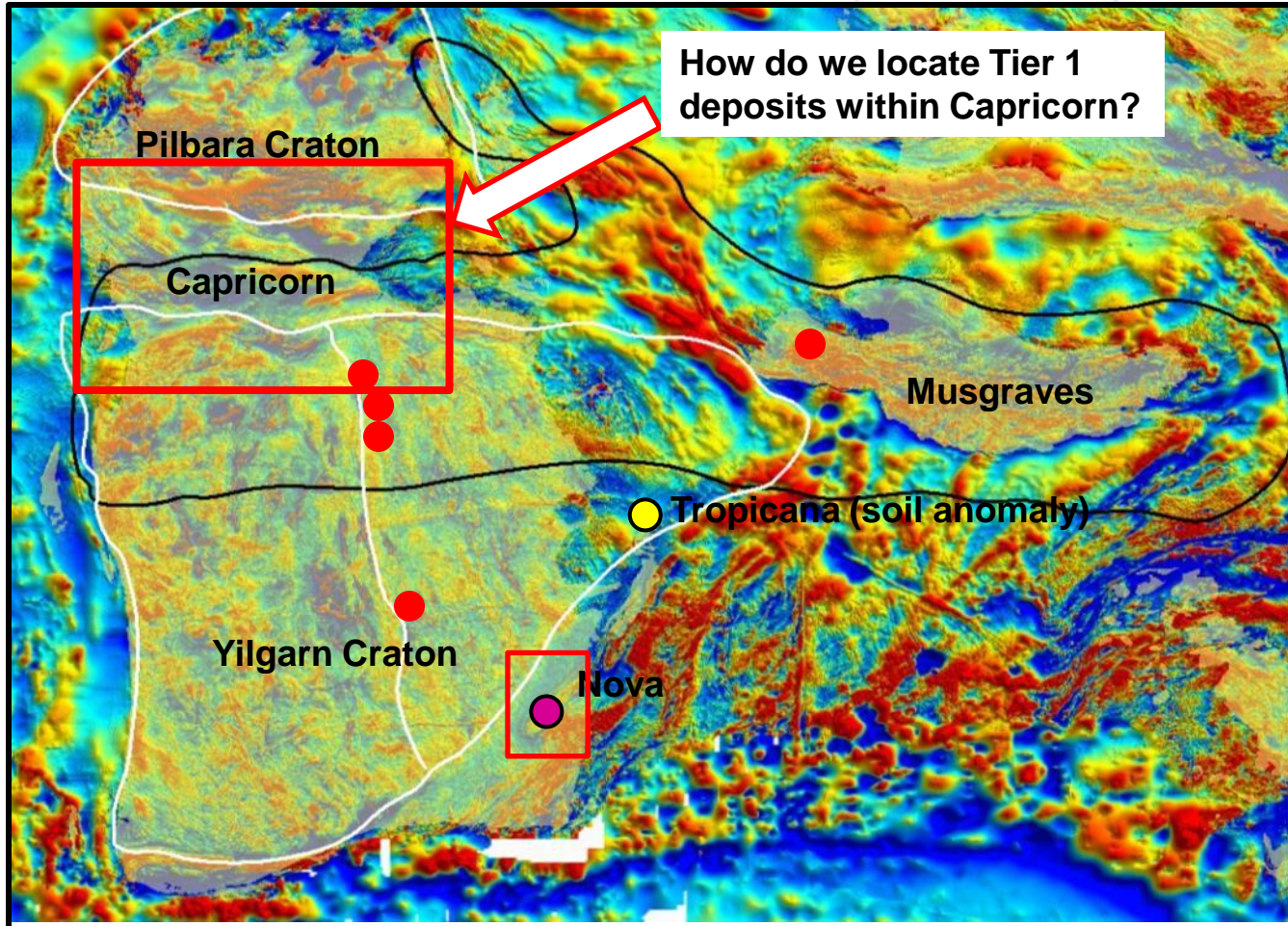

Miller et al., 2010

New structural interpretation with gold flitch and targets (lead to exploration success!)

Cratonic architecture – can target key boundaries
BUT what about the next scale down??????

How do we locate Tier 1 deposits within Capricorn?

Pilbara Craton

Capricorn

Musgraves

Tropicana (soil anomaly)

Yilgarn Craton

Nova

Craton margins

● Tier 1 NiS deposits

○ Tropicana Au

● Nova NiS deposit

Granitoid Nd_TM after Cassidy and Champion 2007
Yilgarn Au after Robert et al. (2005)

Centre for **EXPLORATION TARGETING**
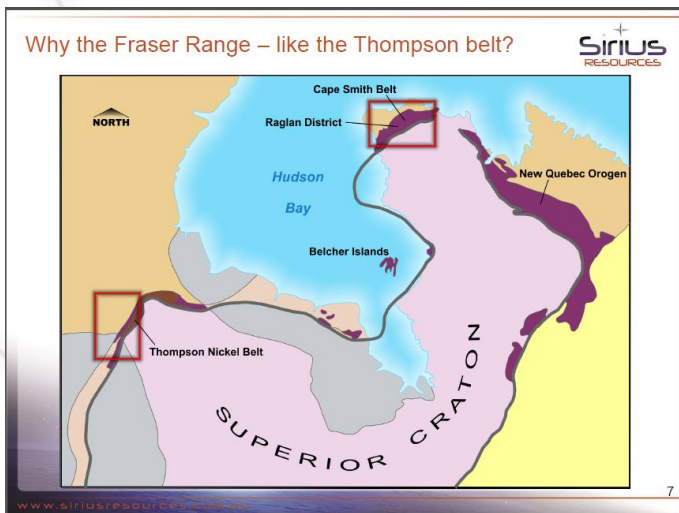
Australian Government
Geoscience Australia
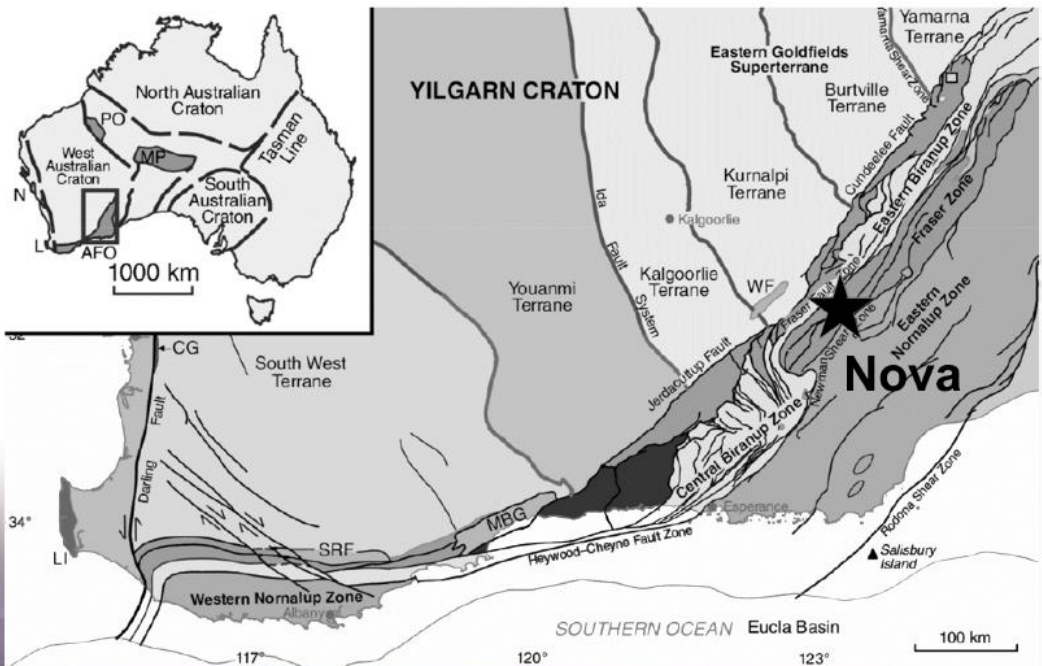
The psychology of exploration:
those that talk about it, those that back it and those that do it

Mark Bennett, Sirius Resources, CET Discovery Day, February 2014

- Serendipity (e.g., Skylab!)
- Metallogenic model = Thompson Ni Belt (note Trans Hudson Orogeny also has VMS)
- Release of GSWA data = regional geophysical data and geochemical sampling
- A WA Government co-funded drillhole
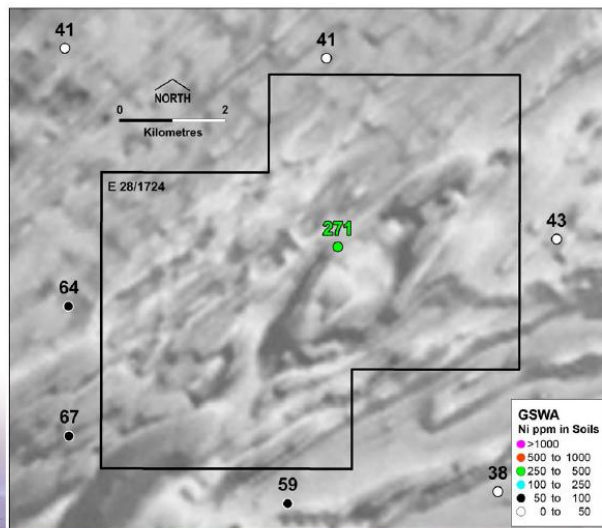- Tenacious exploration

The psychology of exploration:
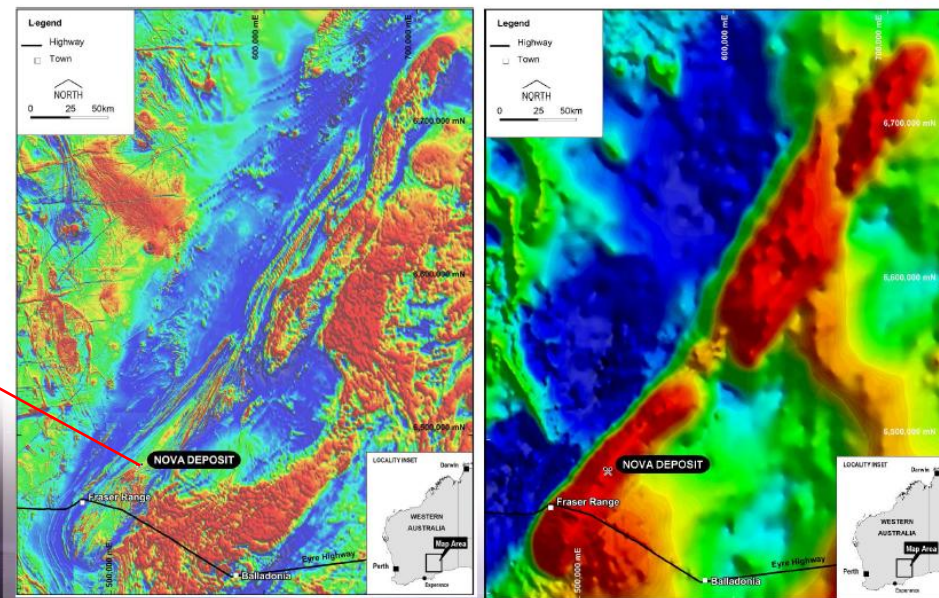## those that talk about it, those that back it and those that do it
Mark Bennett, Sirius Resources, CET Discovery Day, February 2014

- Release of GSWA data = regional geophysical data and geochemical sampling
- A WA Government co-funded drill hole
- Tenacious exploration – the "eye" was first target to be drilled

Major role of GSWA data sets in discovery.
What new data do we need for new discoveries?

The birth of supercontinents
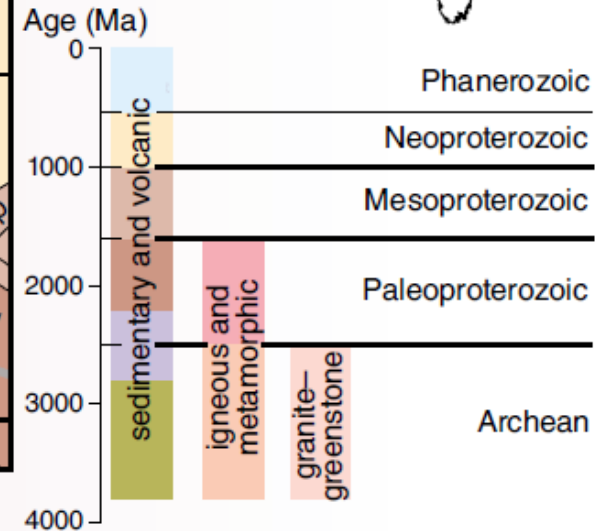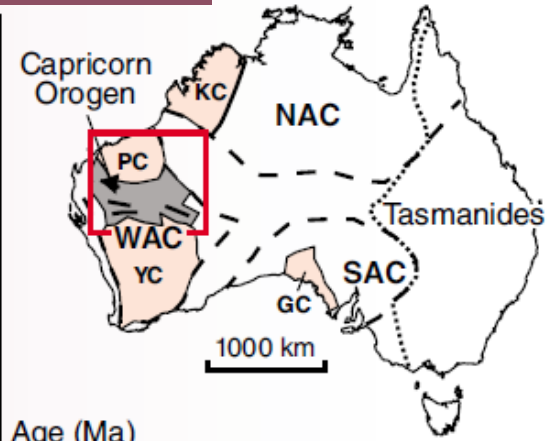### and the Proterozoic assembly of Western Australia

by

Simon P Johnson

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

Geological Survey of **Western Australia**

Curtin University

THE UNIVERSITY OF WESTERN AUSTRALIA
Achieve International Excellence

Centre for **EXPLORATION TARGETING**

The birth of supercontinents
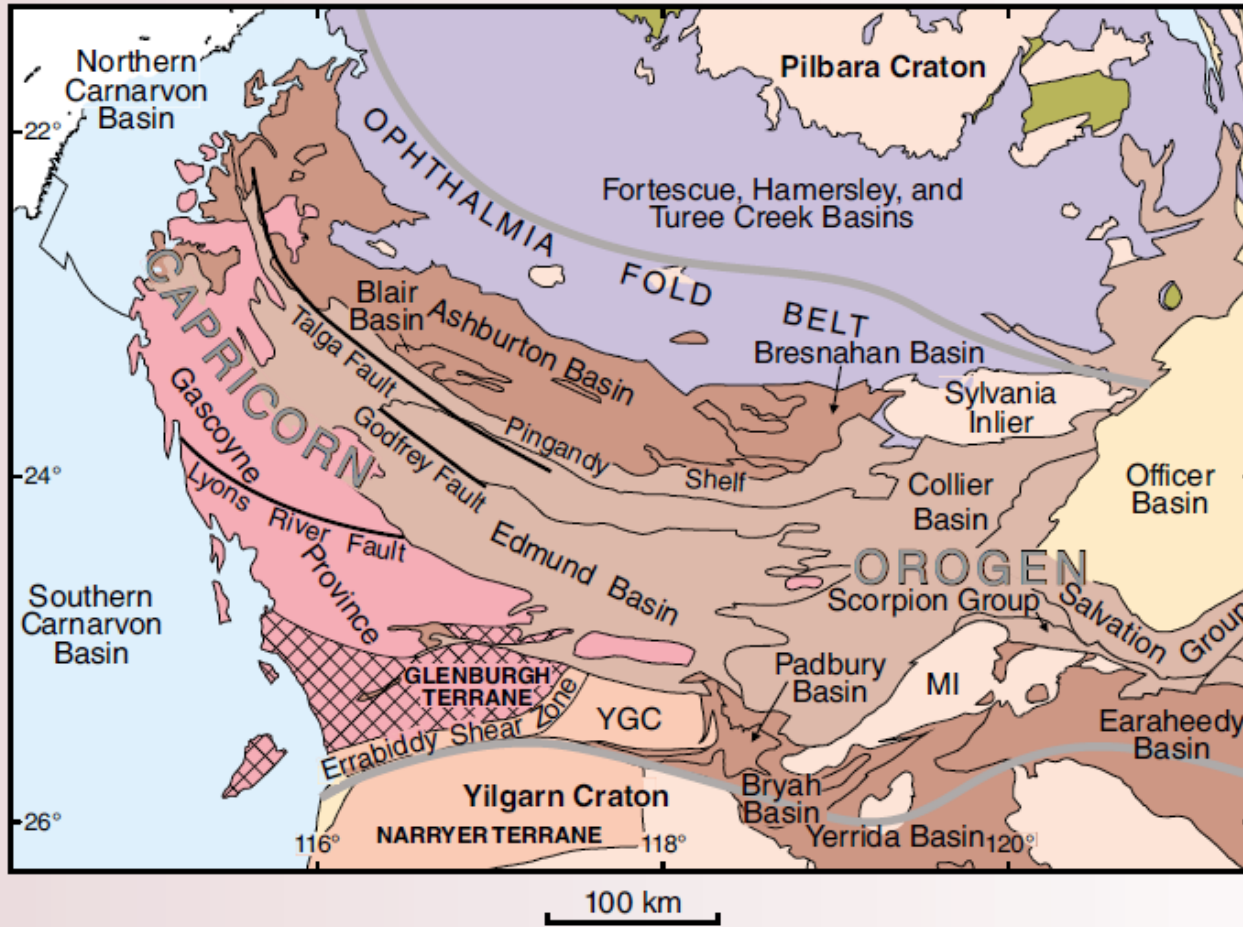## and the Proterozoic assembly of Western Australia

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Geological Survey of Western Australia
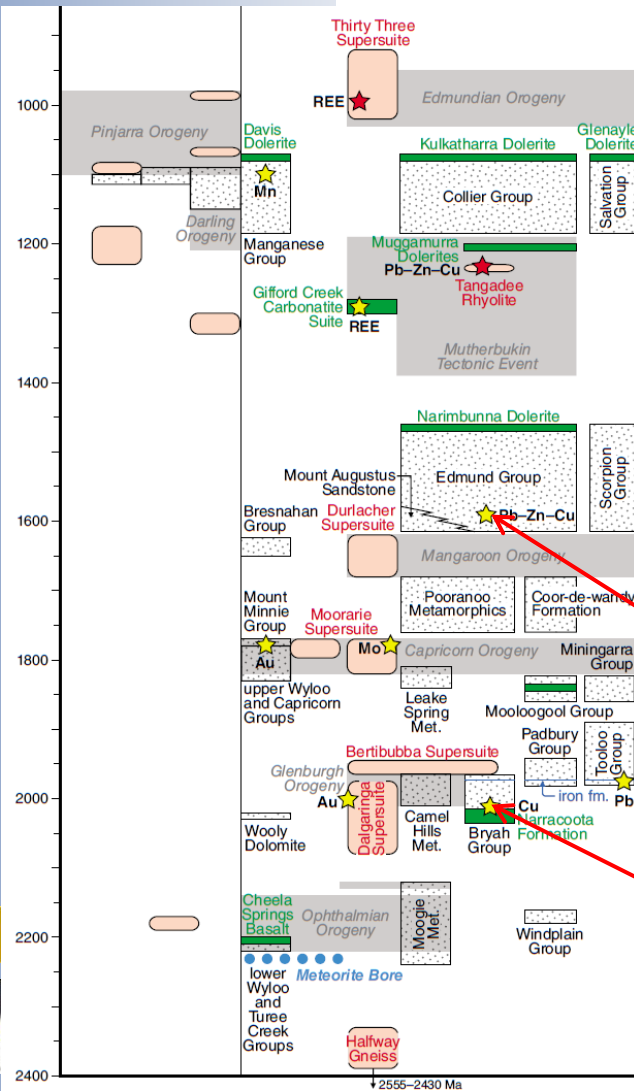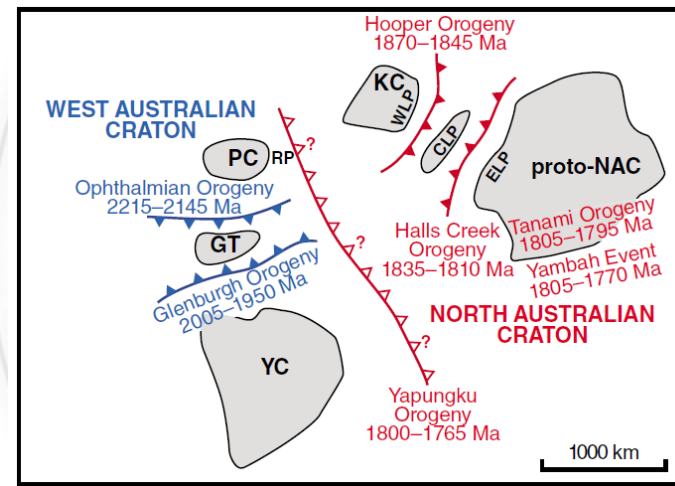
- Complex and long lived (2.2-1.0 Ga)
- Cratons ca. 2.5 (GT, plus Lu-Hf data = 2.6 to 2.7 Ga, exotic) and older PC, YC
- Multiple types of mineral deposits forming at different times

Abra deposit (Pb/Ag plus Cu/Au resources), no surface expression, exploration via geophysical targeting

Degrussa (Cu/Au, VMS)

Centre for **EXPLORATION TARGETING**
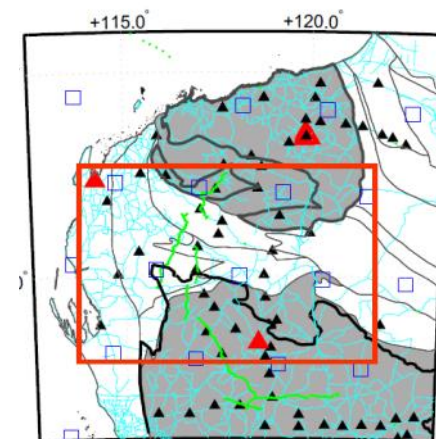
Distal Footprints of Giant Ore Systems

>$16M new initiative over Capricorn Orogen

- Multi-scale project to define distal footprints of ore systems under cover and how to detect them in complex weathered terrains
- Integrate regional- and lithospheric-scale datasets with prospect-scale focused studies to determine and develop scale-dependent criteria for the recognition of distal footprints
- Regolith, ground water geochemistry, new mapping, geochemistry, geophysical data acquisition, modelling and geochronology
- Focus on integration and mineral systems
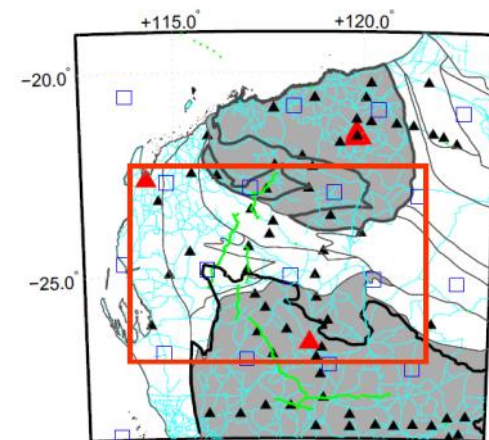
Project Leader
Dr Rob Hough

Distal Footprints of Giant Ore Systems

>$16M new initiative over Capricorn Orogen

Rob Hough, Cam McCuaig, Steve Reddy, Ian Tyler, Dave Gray, Mike Dentith, Chris Clark, John Miller, Steve Barnes, Ravi Anand, Marco Fiorentini, Tim Munday, Simon Johnston, Alan Aitken, Sandi Occhipinti, Vasek Metelka

- $900K from Industry
- $4M Federal Government Science and Industry Endowment Fund
- $2.5M GSWA (AEM Survey)
- $2.6M MRIWA
- $6.3M from CSIRO/UWA/Curtin
- CSIRO/UWA/Curtin: 9 Dedicated post-doctoral researchers
- 8 PhD students plus 2 MSc students
- ARRC as the key central location linking the team

Project designed to Uncover vision
Funding agencies related to vision
NO one institution could do it all

Project Leader
Dr Rob Hough

National Resources Science Precinct (NRSP)

Distal Footprints of Giant Ore Systems
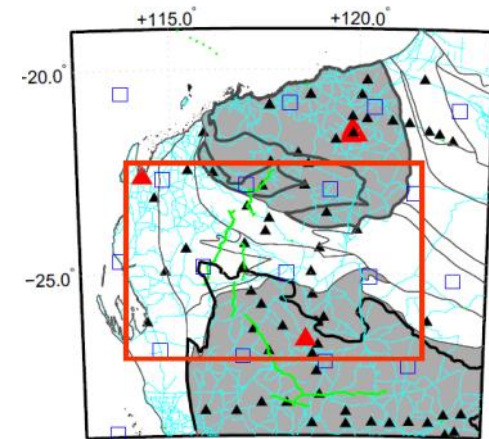
>$16M new initiative over Capricorn Orogen

How to effectively map a region approximately 500km by 500km extending to down to 250 km depth? Need a cost effective and complementary ways of mapping physical property changes to map architecture and cover.

For SIEF project = AEM, Passive seismic, MT. Existing potential field data, active seismic
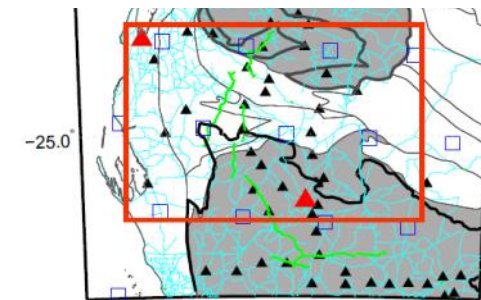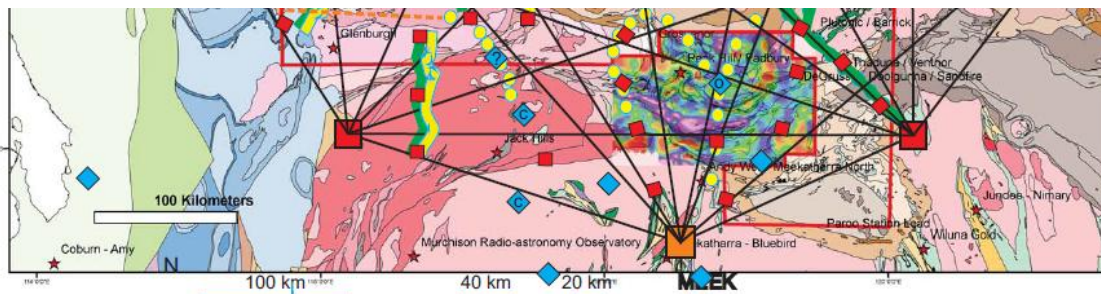
Project Leader Dr Rob Hough

Distal Footprints of Giant Ore Systems

>$15M new initiative over Capricorn Orogen
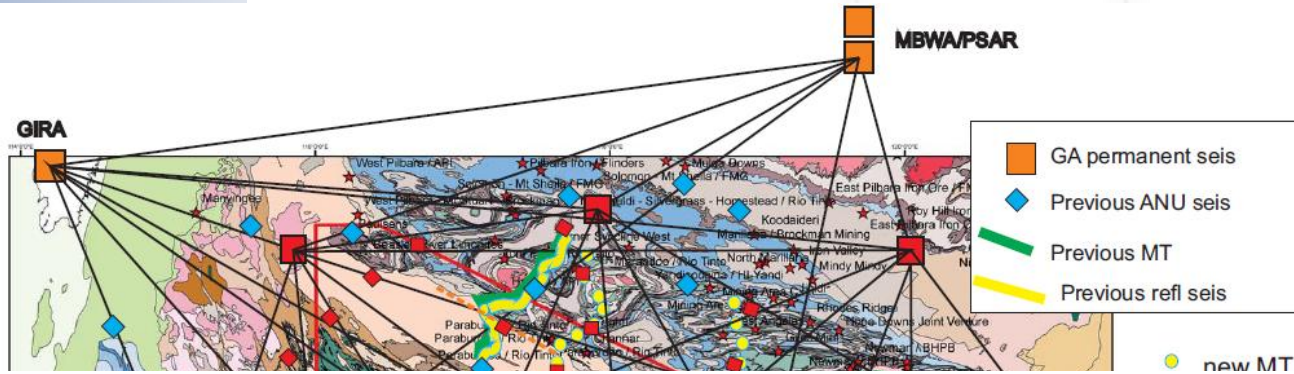
**Project Leader
Dr Rob Hough**

Even better precompetitive data sets integrated with multi-disciplinary, multi-scale, multi-institutional research. Collaboration of Industry, Government and Academia.

Passive Seismic

GSWA, Huaiyu Yuan, Brian Kennett

- Record natural seismic energy of the Earth
  - ☺ Much cheaper than active source methods
  - ☹ Much lower resolution
- Ambient noise tomography
  - Deployment is for months
  - Correlate background noise between pairs of stations
  - Derive shear-wave speed on line between them
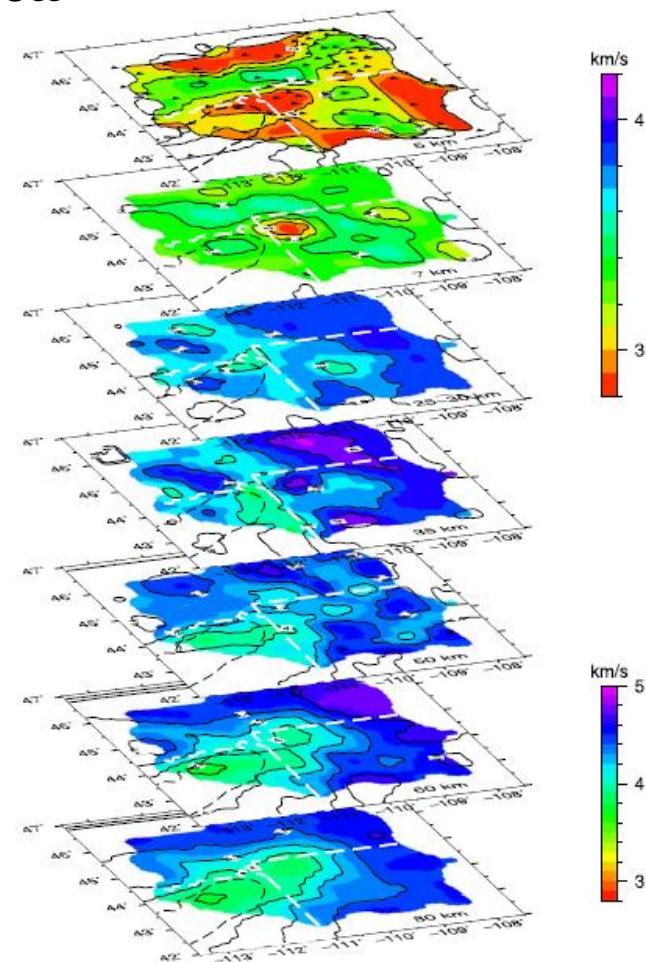
Stachnik et al. 2008

Zircon Geochemistry
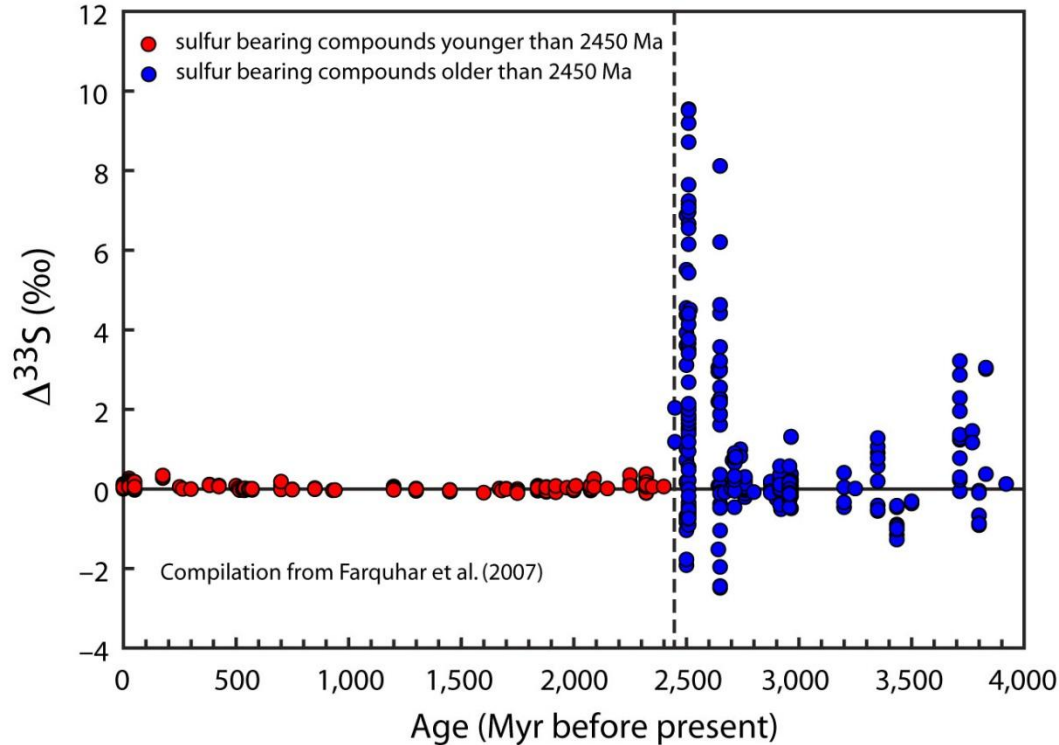
Steve Reddy, Chris Clark

- **Existing Capricorn data**
  - **U-Pb (geochronology)**

- **Planned Capricorn zircon data**
  - **U-Pb (geochronology)**
  - **Trace elements geochemistry (e.g. Ti for Temperature)**
  - **REE (LREE vs HREE)**
  - **Hf isotope data (crustal residence time)**
  - **O data (crust vs mantle sources)**

Multiple sulfur isotope record

Marco Fiorentini

Compilation from Farquhar et al. (2007)

Mass-independent fractionation is a chemically-conservative tracer.
For the Proterozoic Capricorn Orogen we will be able to detect if, and where, there is an Archean link to system – will tie with new geophysical data (MT, passive seismic)
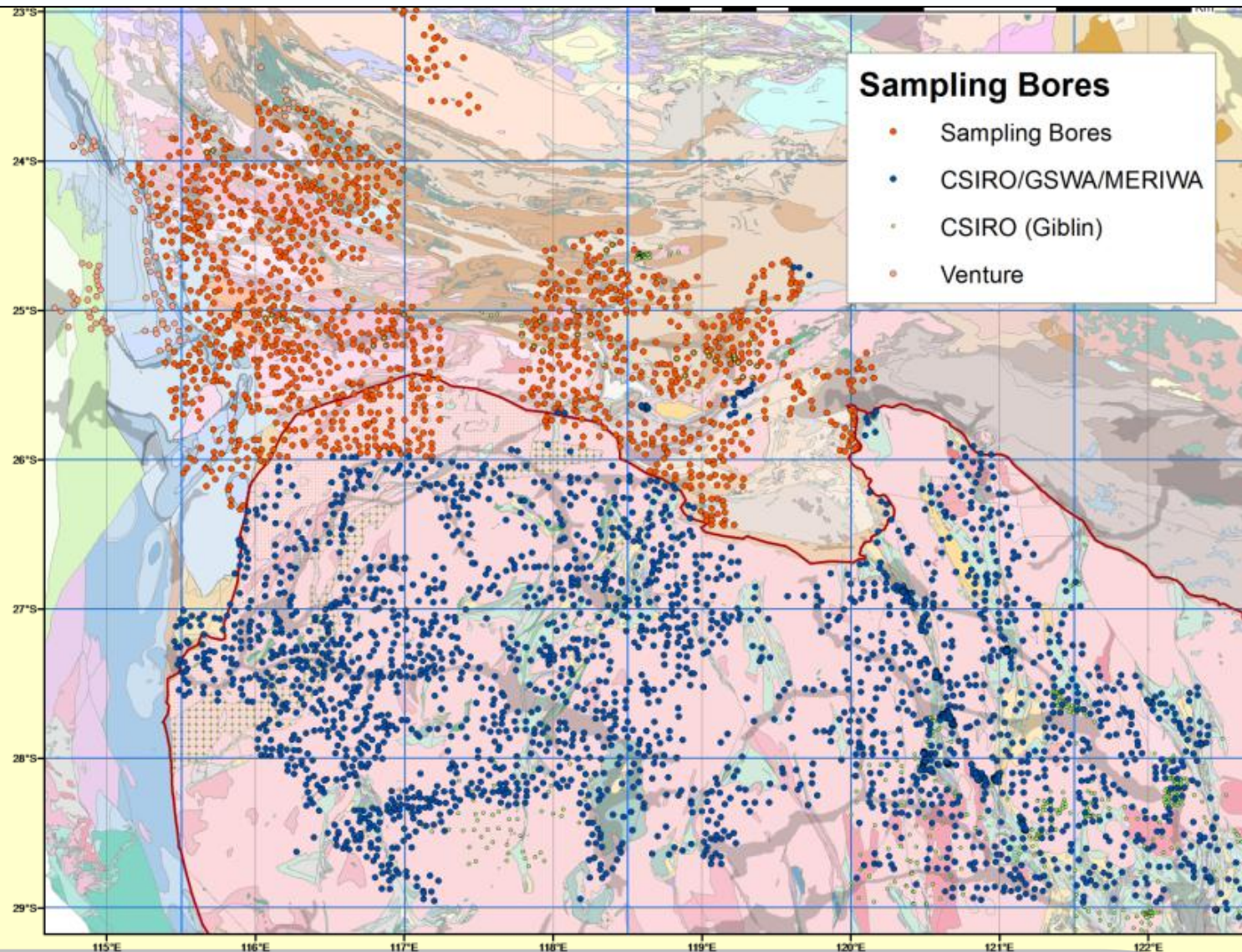
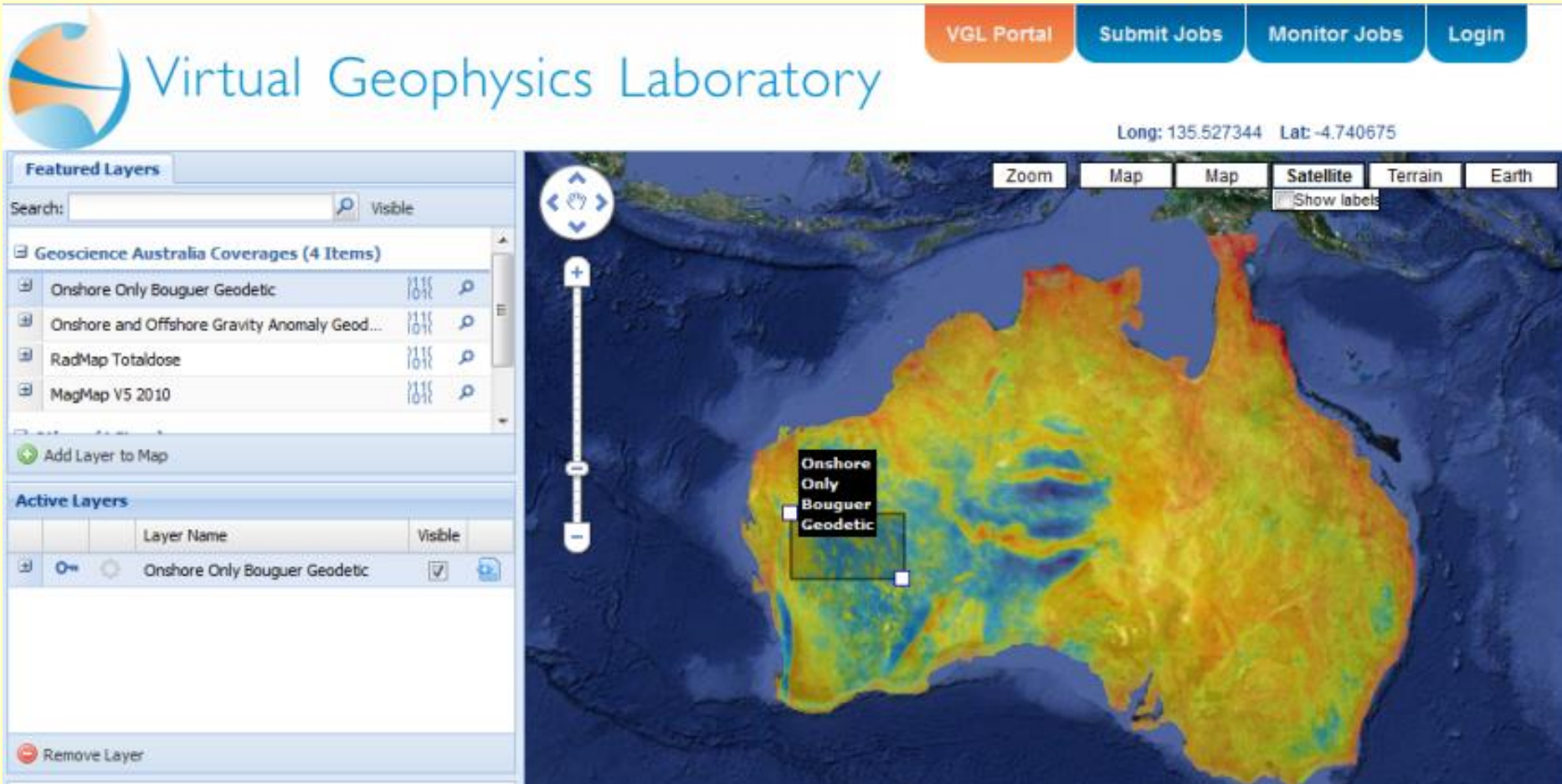# Comparisons with GSWA soil geochemistry, and geophysics

CaO (%)

- > 6.5
- 3.5 - 6.5
- 1.8 - 3.5
- 1.2 - 1.8
- 0.8 - 1.2
- 0.5 - 0.8
- 0.3 - 0.5
- < 0.3
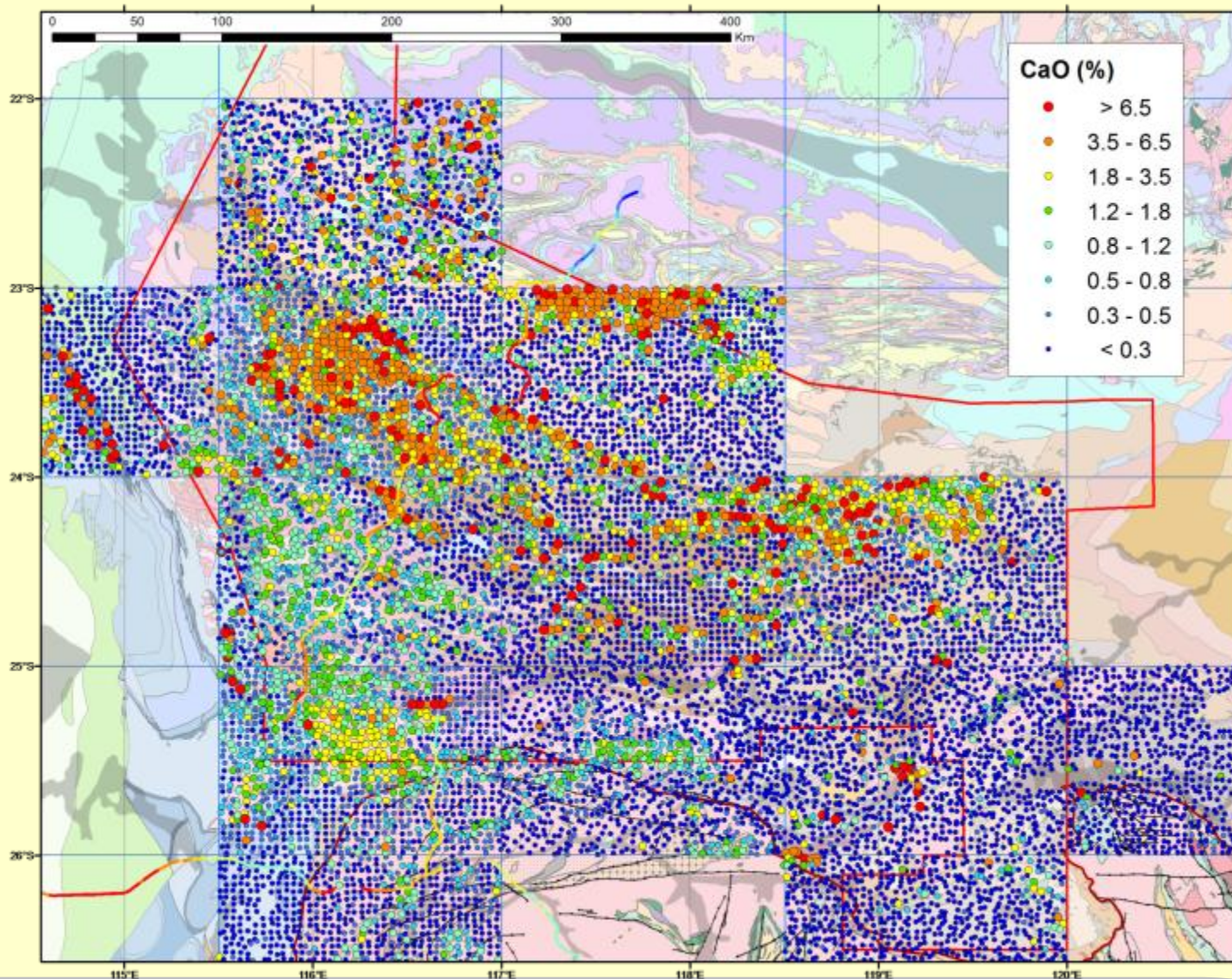
**Ravi Anand,
David Gray
GSWA**

Planned Capricorn and northern Yilgarn Groundwater Sampling

Data Portal – funded component of project
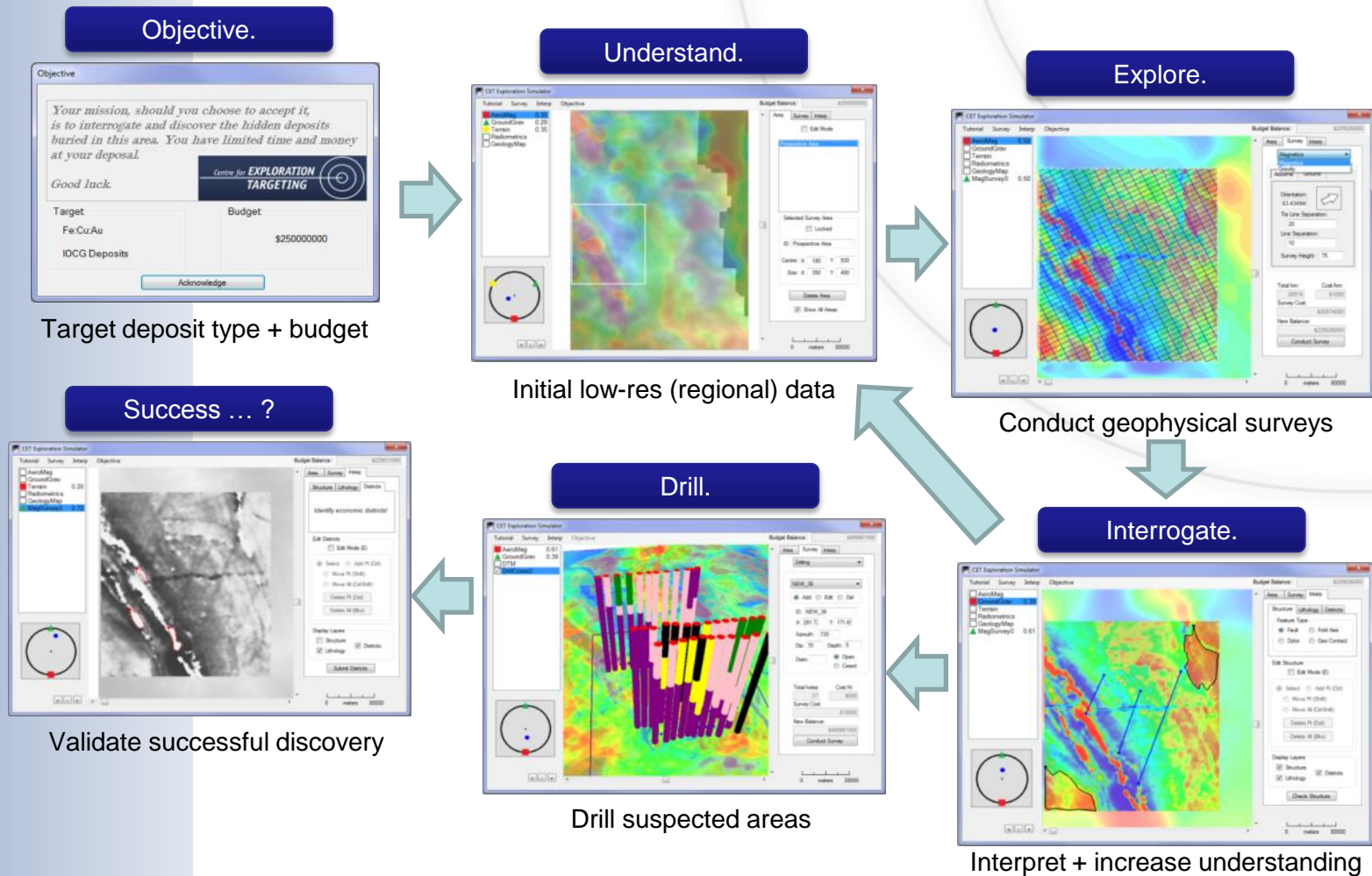
CET Exploration Simulator

Researchers: **Jason Wong**, Eun-Jung Holden, Peter Kovesi, Cam McCuaig, Jon Hronsky, Mark Jessell

Need to teach how to better explore and acquire right data sets – link to risk and value ($)

Objective.

Target deposit type + budget

Understand.

Initial low-res (regional) data

Explore.

Conduct geophysical surveys

Success … ?

Validate successful discovery

Drill.

Drill suspected areas

Interrogate.

Interpret + increase understanding

Take home messages

- Ore deposit formation is a multi-scale phenomenon requiring a multi-scale (and multi-disciplinary) research and exploration focus

  → Data integration and acquisition of new critical data at right scale

- Mineral system approach also focuses on answering the question of "Where?" ore deposits form and also "How?"

  → Architecture is key at large scale!

- Integrated multi-disciplinary, multi-scale, multi-institutional research

- Need true collaboration of Industry, Government and Academia – DISTAL FOOTPRINTS PROJECT IS AN EXAMPLE IN SPIRIT OF UNCOVER – NO ONE GROUP COULD DO IT