Australian Government
Geoscience Australia

Minerals @ GA Update Forum
2 September 1:00 – 5:00 Raggatt Theatre
Cnr Jerrabomberra Ave & Hindmarsh Drive, Symonston

Geoscience Australia is holding a free Minerals Open Afternoon at its Canberra Headquarters. Please join us to hear about our exciting new products and Geoscience Australia's UNCOVER projects being conducted across Australia.

RSVP's to Nicole.manning@ga.gov.au by 27th August

1.00 - The Minerals programme at GA: an UNCOVER overview

Theme 1. Cover

1.15 - Towards a national cover thickness map using data mining: a model-based predication of cover thickness

1.30 - Airborne electromagnetic (AEM) – cover thickness, cover character, advanced processing, interpretations and case study exemplars.

1.45 - Geophysics applied to variable cover: benchmarking multiple methods to known depths.

Theme 2. Architecture

2.00 - The magnetotelluric method to map near surface to deep lithosphere: case studies and new developments.

2.15 - The seismic database of Australia: a continent in cross section.

2.30 - Bringing it all together: The Australian Architecture Reference Model (AusARM)

2.45 - Refreshments

Theme 3. Geodynamics and mineral system evolution

3.00 - Australia through time: the U-Pb database of Australia, ASUD, GA's geochronology capability.

3.15 - Isotope geochemistry to map architecture and fertility: Sm-Nd, Pb and Hf.

3.30 - Mineral systems as an area selection method at the national and regional scales: examples of magmatic Ni-PGE, IOCG and salt lakes.

Theme 4. Footprints and toolkits

3.45 - Update in regional stratigraphic drilling projects: Stavely and Thomson.

4.00 - Lowering the entry level to big data and big compute: the Virtual Geophysical Laboratory and its future development.

4.15 - Data delivery and discoverability: Rock Properties, Geoscience Portal, GADDS.

4.30 - Discussion

Australian Government
Geoscience Australia

Minerals @GA: an UNCOVER overview

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Mineral Systems Branch Head

Australian Government
Geoscience Australia

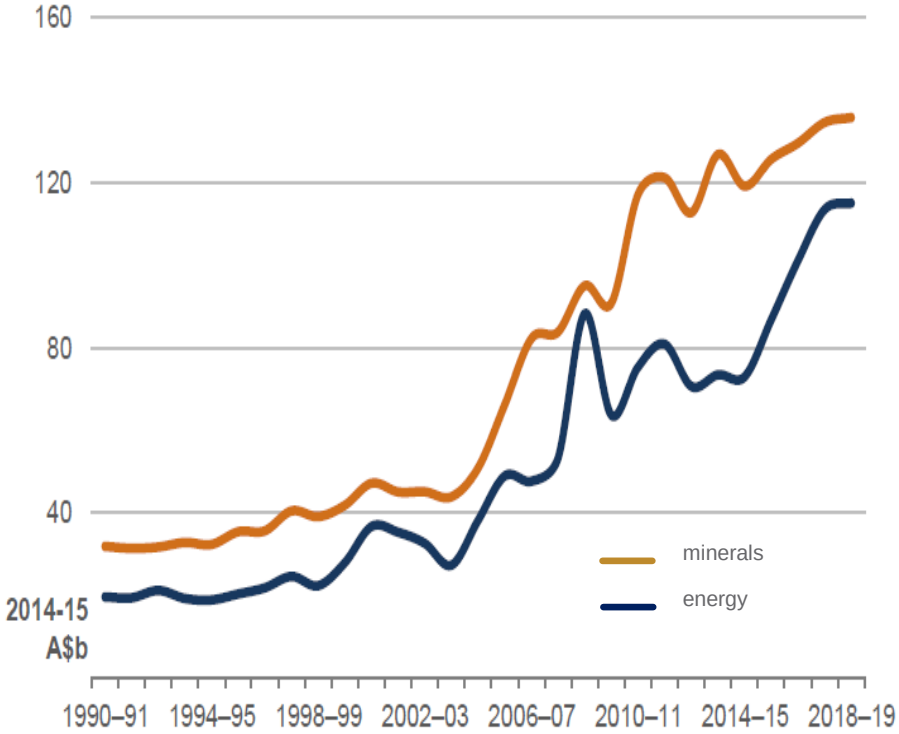
Minerals @GA: an UNCOVER overview

Richard.Blewett@ga.gov.au Mineral Systems Branch Head

GA’s minerals-related activities

- Pre-competitive minerals data acquisition, processing, interpretation and delivery
- Custodians national databases and maps (mineral resources, geology, geophysics, stratigraphy, geochemistry, geochronology)
- Work with states/NT across borders on seamless geoscience products
- Lead innovations nationally (eg. high-performance computing, data integration, 3-4D)
- Set standards for the service providers (eg. Geophysics), which benefits all users including industry
- Advice to Government
- Lead *Australia Minerals* to promote a minerals prospectus for ‘united Australia’ at international investment attraction meetings like China Mining, Prospectors & Developers Association Canada (PDAC)
- **But why do we do what we do?**

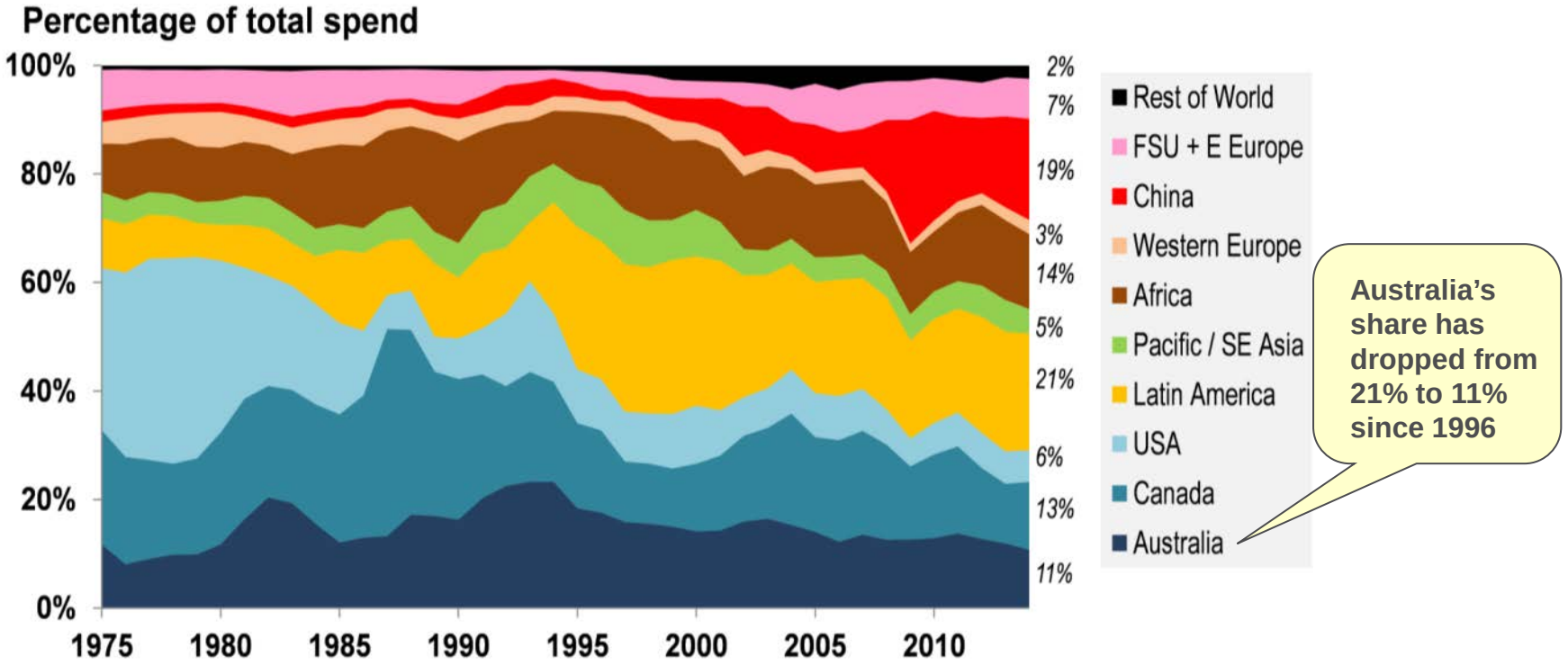
Minerals and energy export earnings



2013-14	$195 billion
	$124 billion – minerals
	$71 billion – energy
2014-15	$192 billion

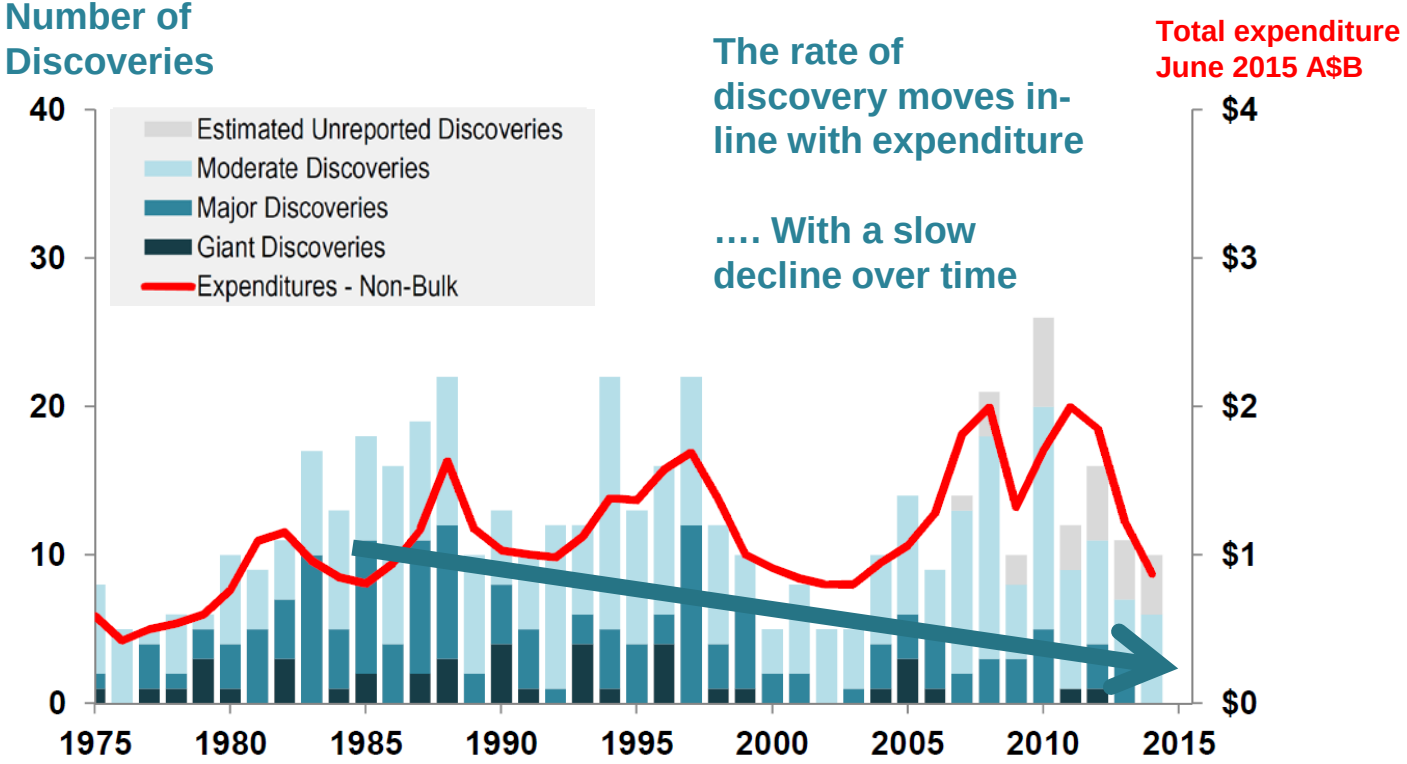
Sources: BREE, ABS

New discovery requires new exploration



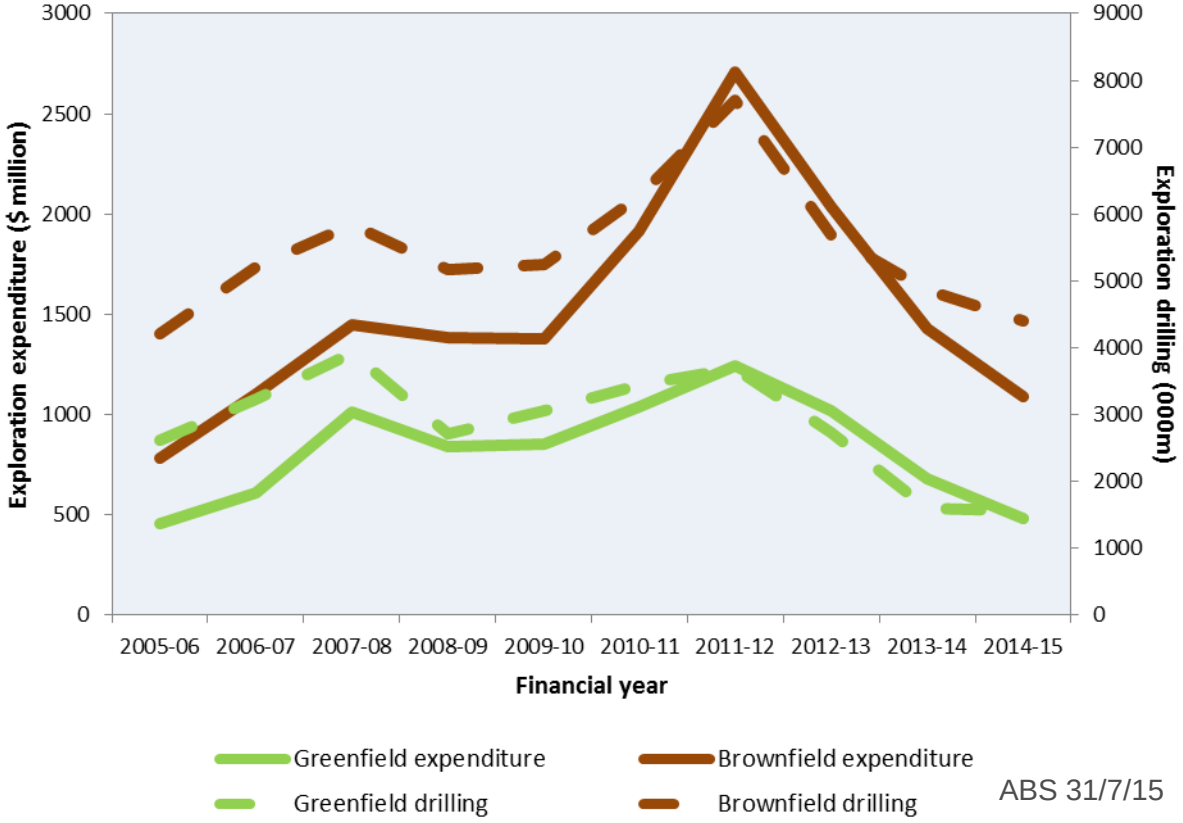
Source: MinEx Consulting estimates June 2015

Despite exploration increase, discoveries not followed



MinEx consulting June 2015

A worrying trend!



ABS 31/7/15

Mining exploration dips by 76pc in three years

Tess Ingram

Australian mining exploration expenditure hit a near-decade low of $381 million in the three months to March, down 76 per cent in three years.

The total national investment in exploration slumped 13.4 per cent during the March quarter, according to the seasonally adjusted data from the Australian Bureau of Statistics.

This is the lowest estimated total spend the bureau has reported since September 2006, when investment was $380 million. It is down more than 60 per cent from the high of $1 billion invested in the industry in March 2012.

During the quarter, Queensland led the decline across the states, down 32 per cent, or $31 million. Western Australia dropped $30 million, or 12 per cent, led by a substantial drop in iron ore expenditure.

modity was on coal exploration, down more than 44 per cent, or $34 million.

Industry experts have warned the reduction in exploration expenditure could be detrimental for the industry if maintained in the long term.

Earlier this year Association of Mining and Exploration Companies chief executive Simon Bennison highlighted the importance of continued exploration, given the long lead time between exploration and production. Mr Bennison said it often took companies seven to 10 years to progress from an initial exploration application to first production at a project.

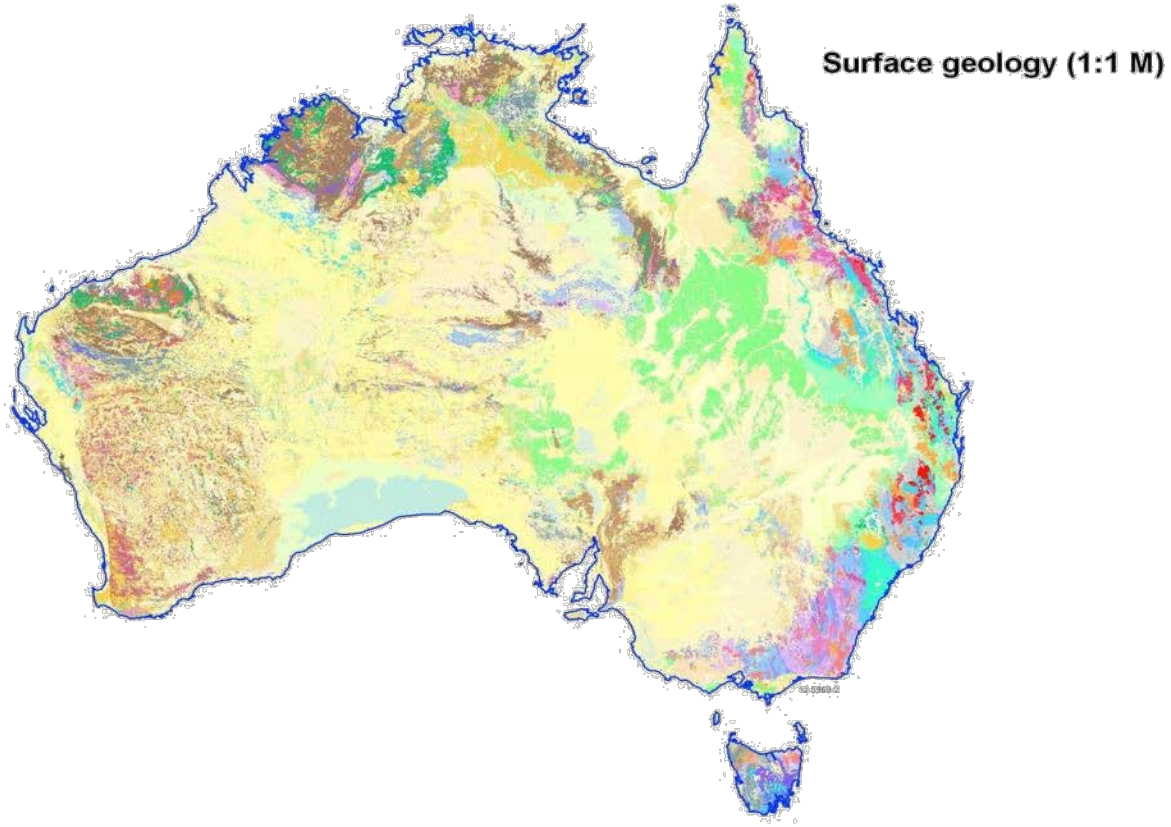
The downturn also has repercussions for contractors; some have been forced to diversify into other industries.

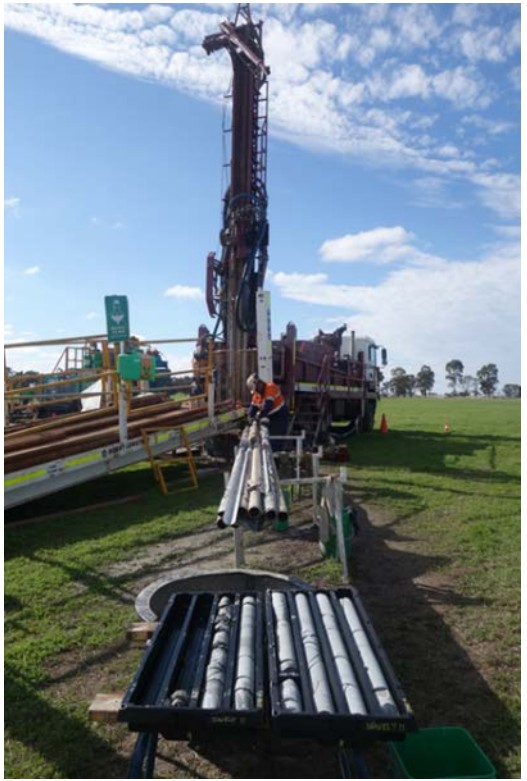
Grain farmer Dan Cooper told Fairfax Media in April he was using mineral exploration drills to search for

The exploration drillers are looking for work so they're heading to [agriculture].
Dan Cooper, grain farmer

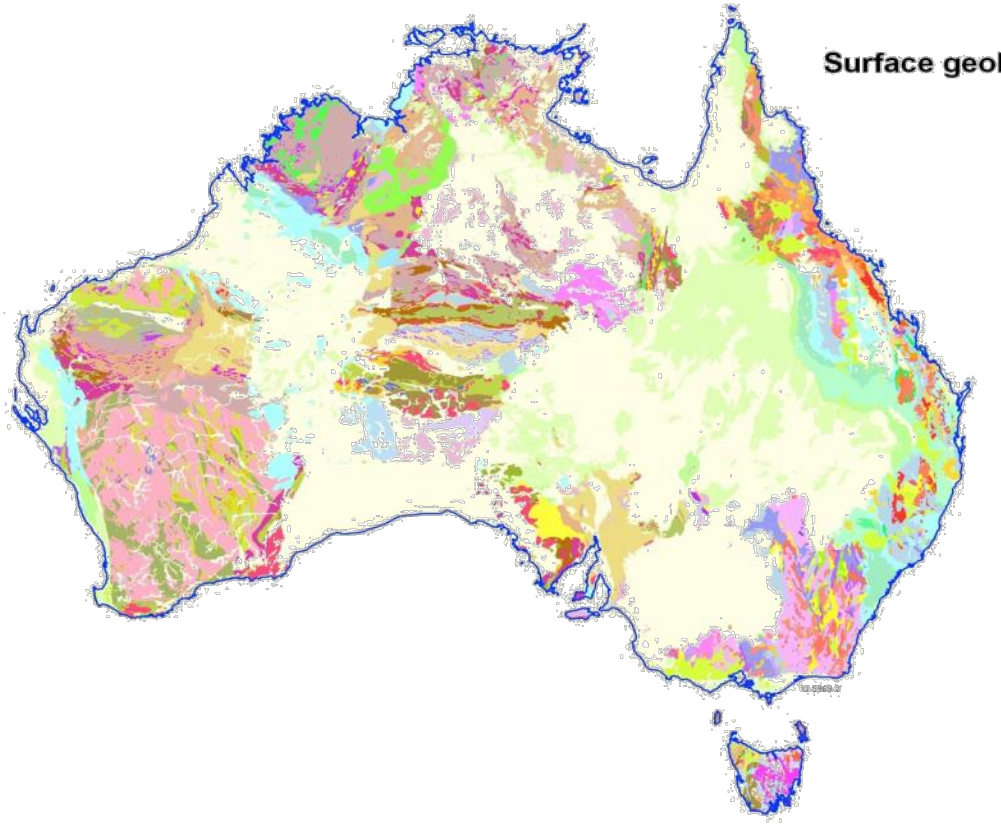
Australian Financial Review
2 June 2015

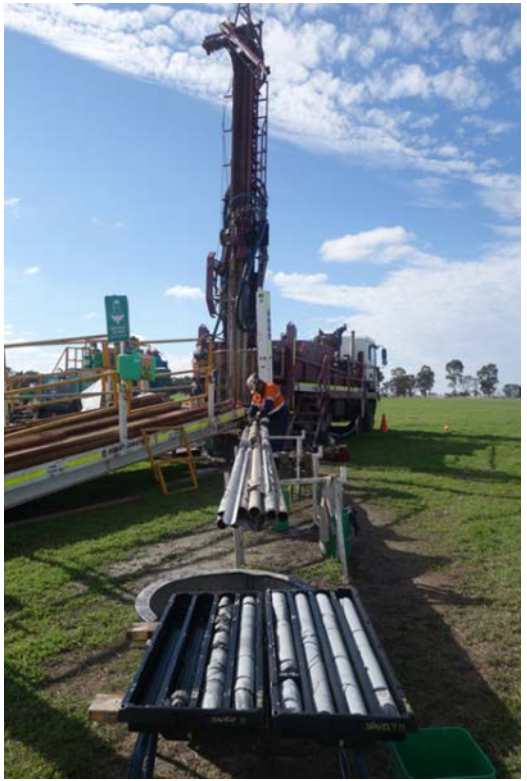
Australia’s undercover mineral potential





Australia’s undercover mineral potential





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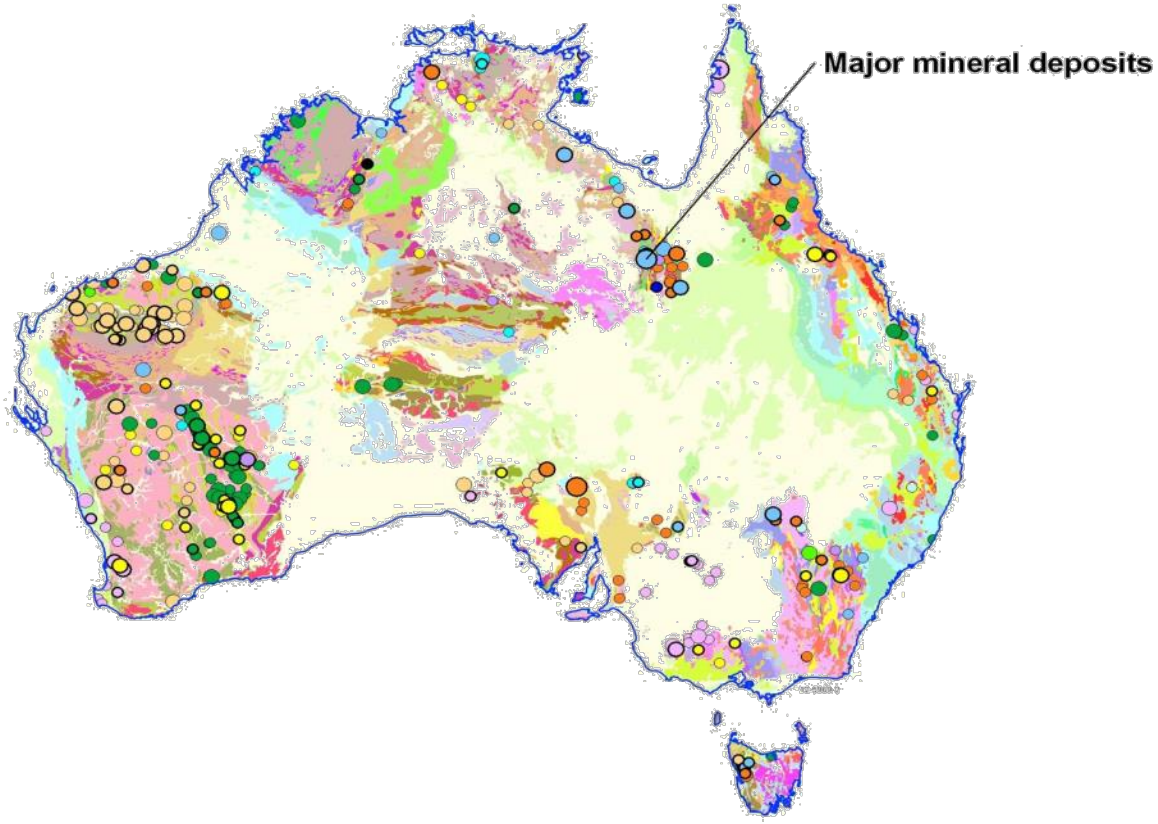

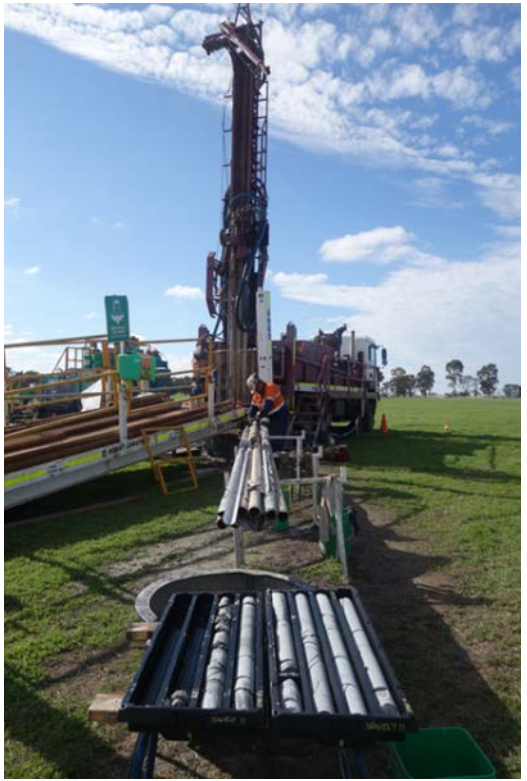

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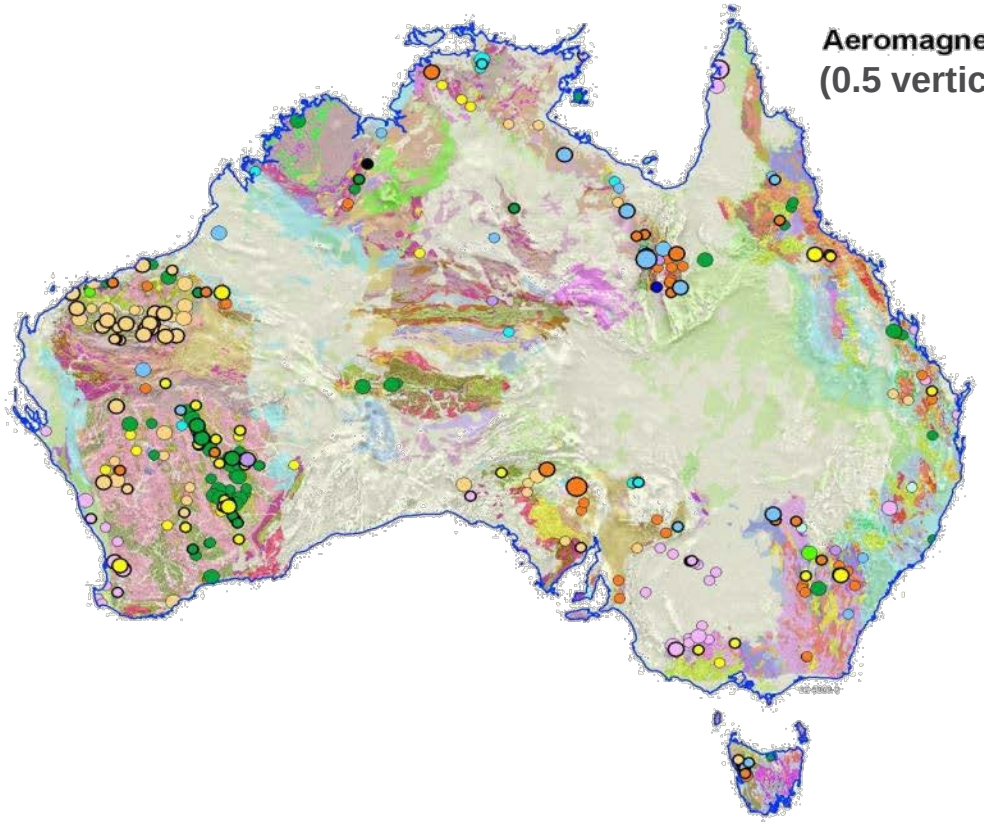
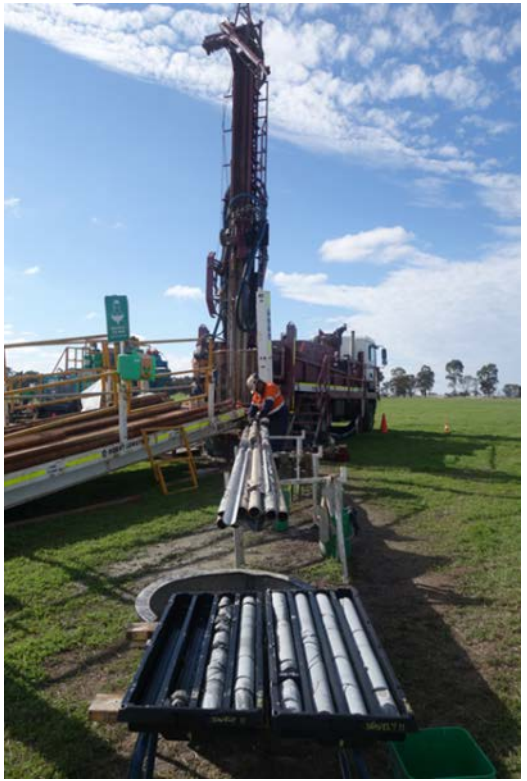


Aeromagnetics
(0.5 vertical derivative)



The challenge and the opportunity

- Continent is ~80% covered
- How to see through the cover?
- …… and seize the opportunity

Government response to the challenge and opportunity

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.

SCOPE OF THE STRATEGY

This National Mineral Exploration Strategy focuses on the acquisition and delivery of pre-competitive geoscience, applied geoscience research initiatives to assist exploring undercover and a mineral exploration investment attraction plan. Supporting activities associated with the strategy aimed at cross-jurisdictional collaboration on regulatory reform are also underway. The strategy will not address the financial challenges facing the minerals sector.

COAG Energy Council

UNCOVER
AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH

THE THREE ELEMENTS OF THE NATIONAL MINERAL EXPLORATION STRATEGY ARE:

- PRE-COMPETITIVE GEOSCIENCE INFORMATION
- MINERAL EXPLORATION INVESTMENT ATTRACTION PLAN
- NATIONAL GEOSCIENCE RESEARCH INITIATIVE

UNCOVER Initiative (www.uncoverminerals.org.au)

… an innovative, structured and nationally coordinated strategic venture that will bring competitive advantage to Australian mineral exploration …

Partners

- Mineral exploration industry
- METS industry
- GA, Geological surveys & CSIRO
- Research (Unis)

Science themes

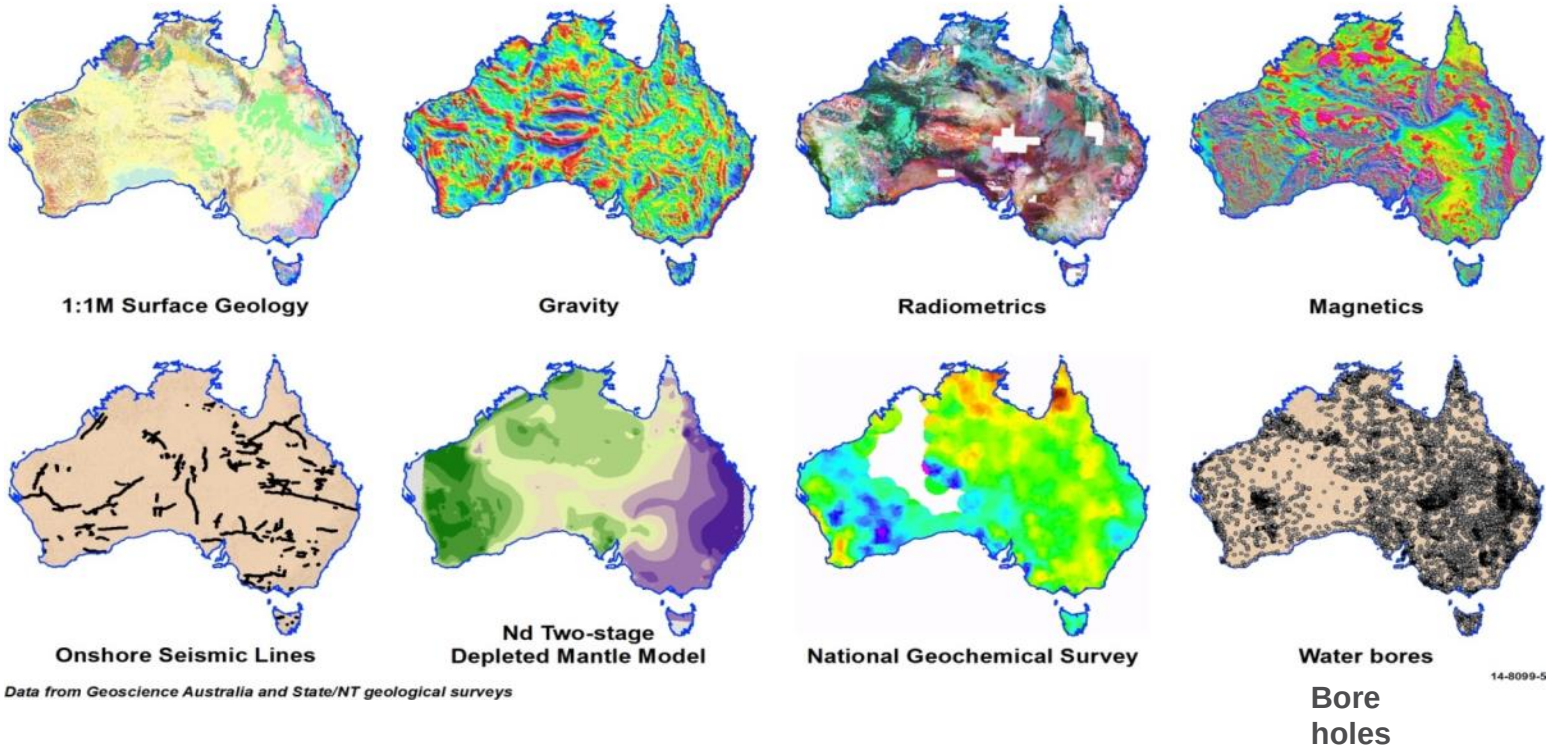
1. Cover
2. 3D architecture
3. Geodynamics & Mineral system evolution
4. Distal Footprints of ore bodies

UNCOVER Roadmap priorities

	Focus Area Themes	
Highest Priority	1.1	Understand type age, depth of cover. Compile and produce 3D Geological & Paleosurface Maps & Layers
	4.3	Characterise and mapping whole mineral system footprint signatures. Proximal to Distal through data compilation of Geology, Geochemistry & Geophysics
	4.1	Improve understanding and develop definitions of mineral systems across scales for different model/deposit types and commodities
	2.1	Compile and integrate models and data to build 3D architecture and composition of Australian whole lithosphere (mantle-crust-surface) from current data and knowledge
	1.8	Depth-to-basement and cover-characteristics, imaging from new targeted airborne National (20km) EM surveys.
	2.4	Acceleration and completion of national AusLamp long period MT (55km spacing) program

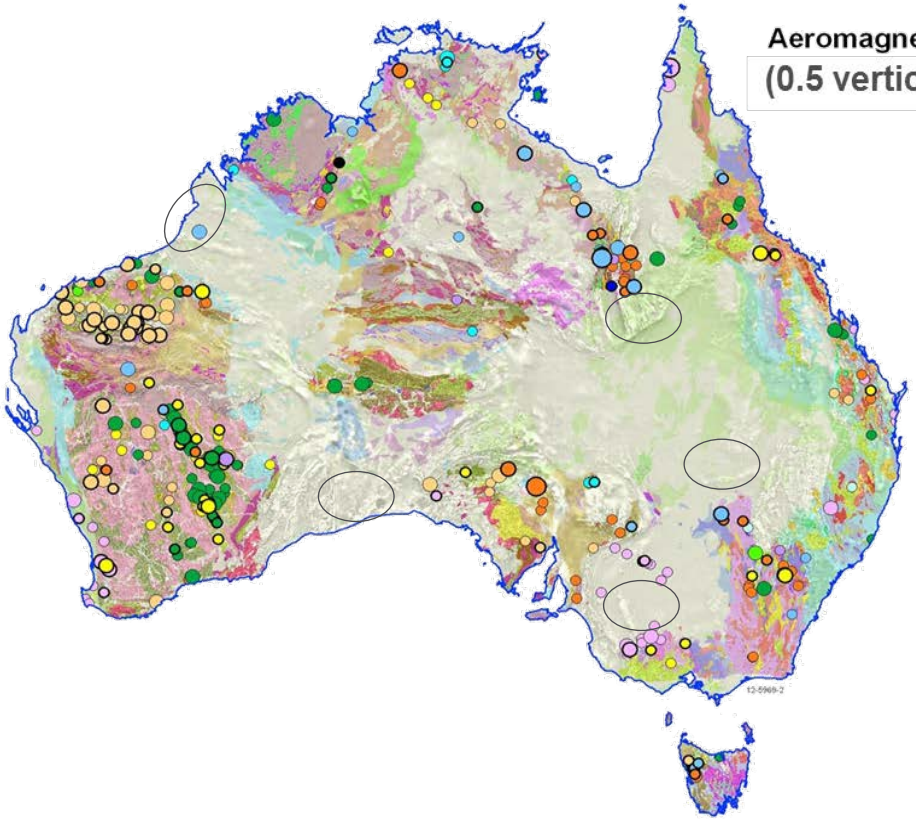
- List of the Highest priorities from the 45 Roadmap activities

Custodians of the national database



- quality-assured and delivered FREE incl. major investment from States/NT

Continuing to build on national maps



Precompetitive data program with collaborative projects with States/NT geological surveys:

- airborne magnetic-radiometric
- gravity
- AEM
- Seismic/MT transects
- AusLAMP
- Regional drilling (Thomson)
- Geochronology and stratigraphy

Greenfields focus of combined Government efforts

Continuing to build on national maps

Precompetitive data program with collaborative projects with States/NT geological surveys:

- airborne magnetic-radiometric
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- Regional drilling (Thomson)
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Greenfields focus of combined Government efforts

Theme 1: Cover

Science problem: ~80% of the continent is covered by post mineralisation material which poses a major exploration challenge and opportunity.

What is the thickness and character of cover at my drill site?

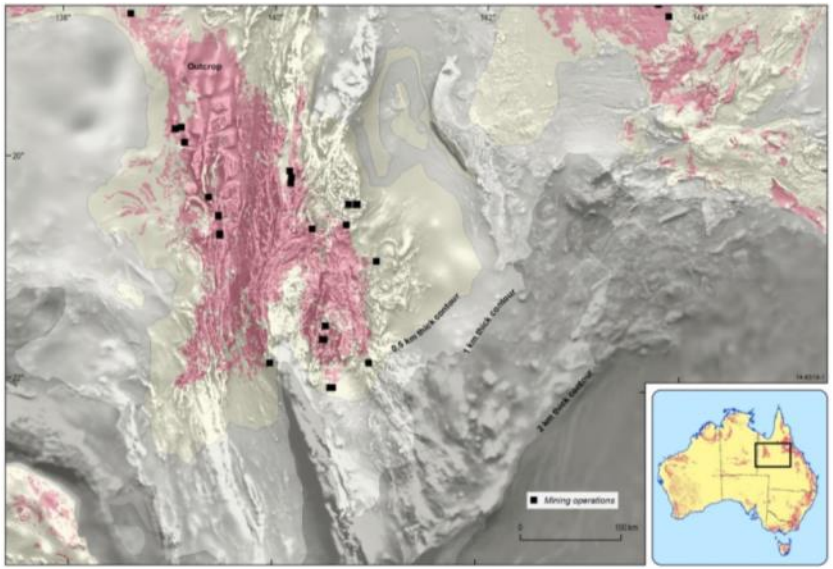
Solutions:

a) Harness legacy data

b) Benchmark methods of cover-thickness estimation

c) Develop new techniques of cover characterisation

d) New predictive maps



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Towards a national cover thickness map using data mining: a model-based predication of cover thickness

John Wilford, Karol Czarnota, Tony Meixner, Patrice de Caritat

John.Wilford@ga.gov.au

Cover characterisation

Drilling and associated lithological descriptions – points of truth?

A. Harness legacy data (drilling; remote sensing – geophysics)

B. Building national databases

C. Drill hole interpretation

D. Interpolation/modelling between drillholes – building surfaces.

Cover characterisation

Building point depth database and surfaces (national coverage)

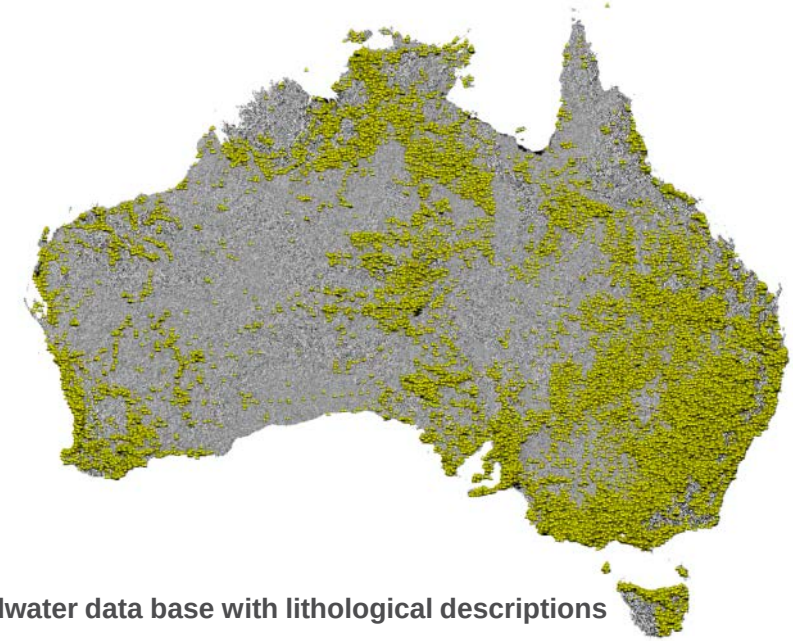
National prediction of Chronostratigraphic era

- Cenozoic
- Mesozoic
- Paleozoic
- Proterozoic (Neoproterozoic/ Meoproterozoic)
- Paleoproterozoic/Archean

Depth of oxidation

Harnessing legacy data – drillholes and remotely sensed depths

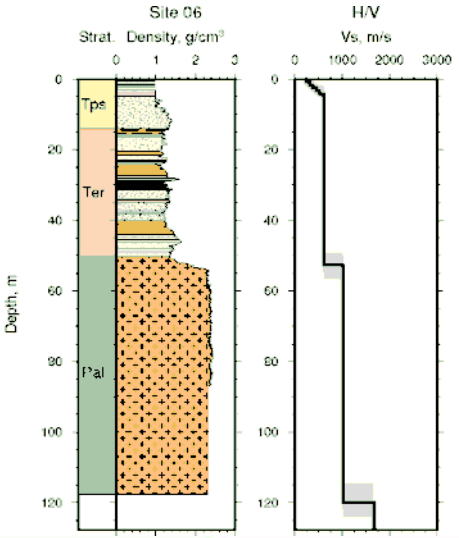
- Designing point-cloud database of cover-thickness estimates (borehole, seismic, magnetic, AEM, AMT, etc…) with chronostratigraphic attributes



Groundwater data base with lithological descriptions

- Bores (~365,000)
  98% < 200m

Remotely sensed

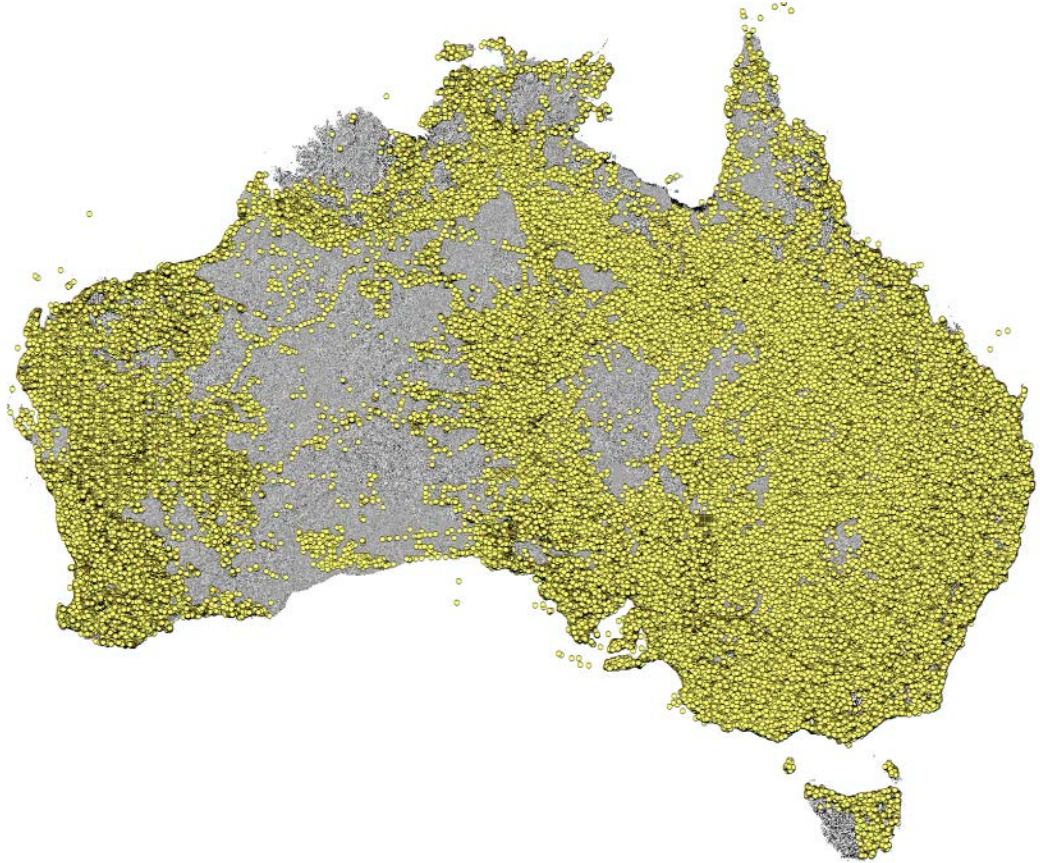


Data interpretation and assessing confidence

1. Drillhole descriptions poor and inconsistent; spatial inaccuracies prior to GPS < 1990.
2. Automatic lithology and lithology ‘like’ text matching.
3. Tagging drill depth descriptions that are at odds with our understanding of weathering and geomorphic processes or from other datasets (e.g. radiometrics; DEM, more reliable drilling).

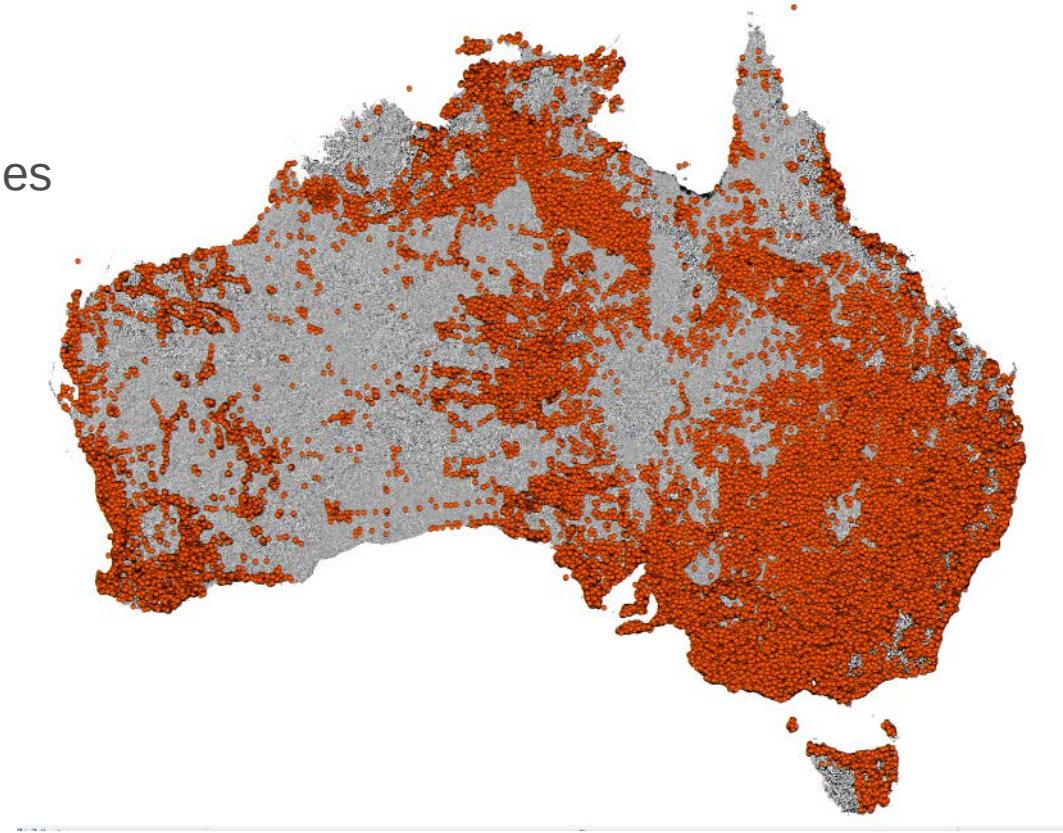
National Groundwater database

> 800 000 drill holes



National Groundwater database

~ 350 000 drill holes with lithology

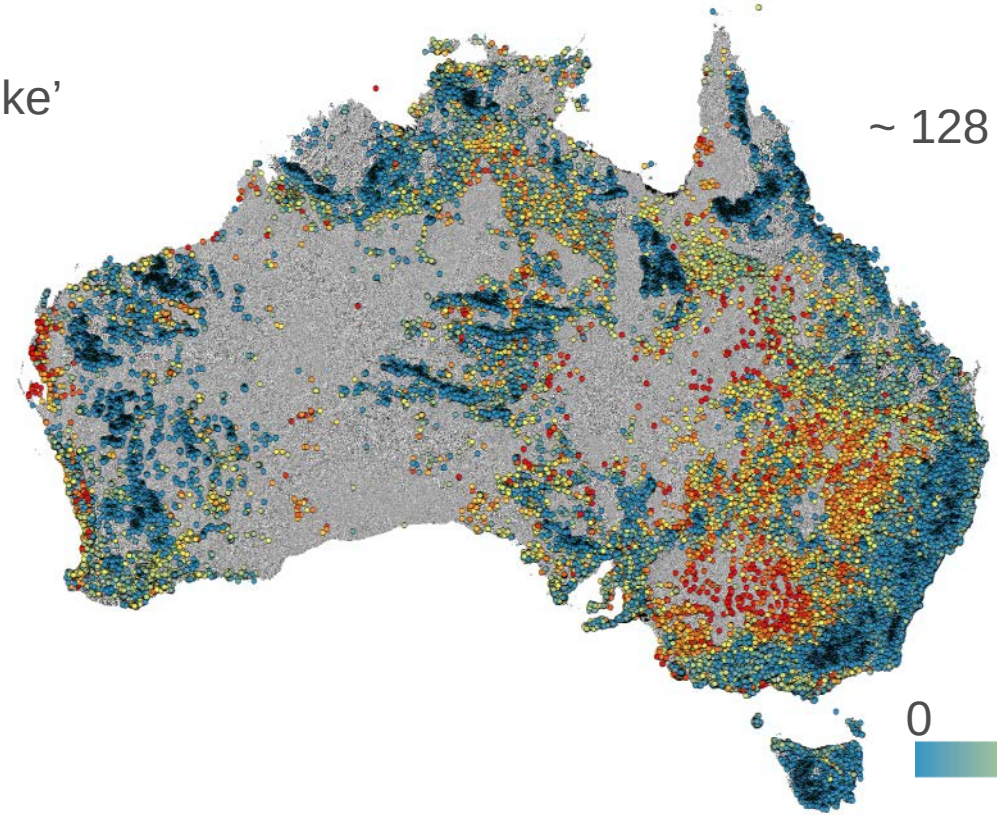


National Groundwater database

Lithology and lithology ‘like’ text matching

granod
granodi
granodio
granodioite
granodionite
granodior
granodiorate
granodiori
granodioriote
granodiorit
granodiorite
granodioritic
granodiort
granodiorte
granodiotite
granodorite
Granodylt

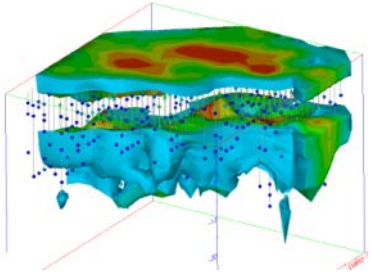
⇨ Bedrock depth

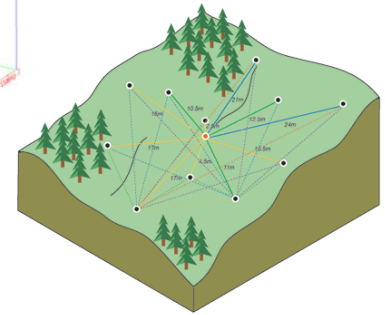


~ 128 000 drill holes

0 200m +

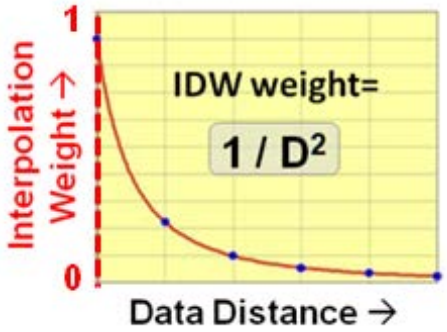
Points to surface predictions





1. Interpolation between points. Based on auto correlation between points – “nearby things are more alike than distant things” e.g. Inverse distance weighted (IDW) interpolation and kriging (variogram).

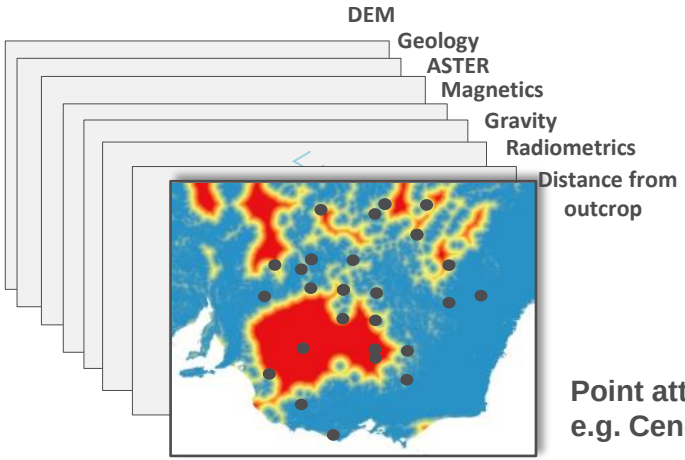
2. Covariate modelling supported by supplementary data using data mining techniques



Points to surface predictions using environmental correlation

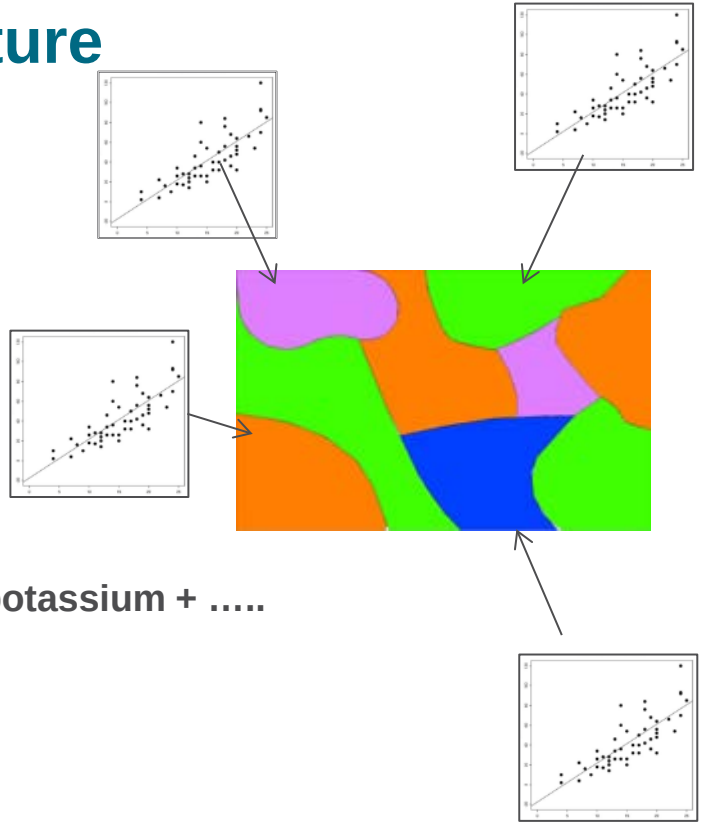
Environmental correlation uses covariates or predictive datasets coupled with statistical methods for correlation and regression to predict cover depth/geochemistry. Cubist data mining – consists of a decision-based classification tree with nested linear regression models (regression trees).

Covariate datasets



Point attribute
e.g. Cenozoic depth

Cubist model structure



1) If (conditional statement based on decision tree splits)

Distance from outcrop < 200m

and

Lithology = (p, q, r)

(2) Then (linear model)

Property = c_1 * magnetic intensity + c_2 * gravity + c_3 * gamma potassium + …..

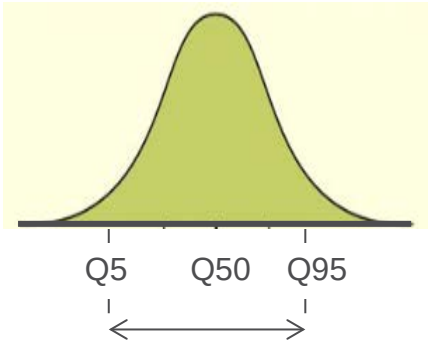
where a, c_1, c_2, c_3 are constants, p, q, and r are classes, and property = target variable.

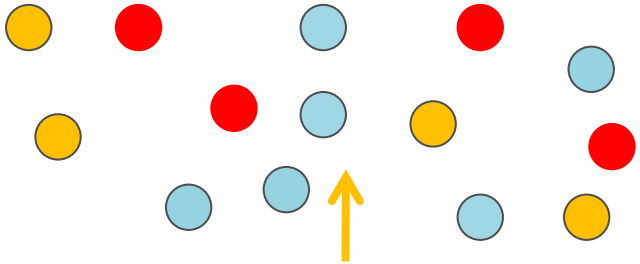
Cubist implementation

Sample stratification - bootstrapping (with sample replacement) or K-fold x-validation.

Sample stratification used to generate many model predictions from which median values are calculated and associated uncertainties.

Out of sample validation





Random sampling (model generation)

Cubist implementation

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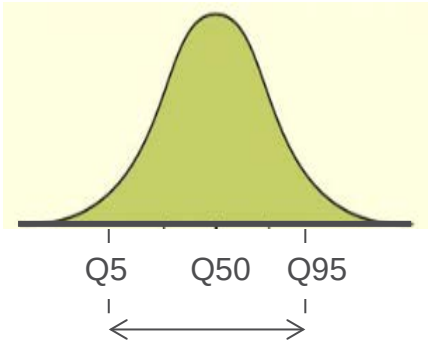
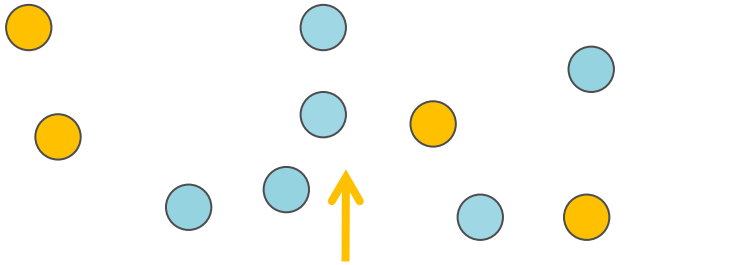
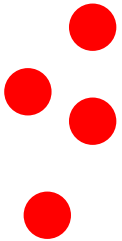


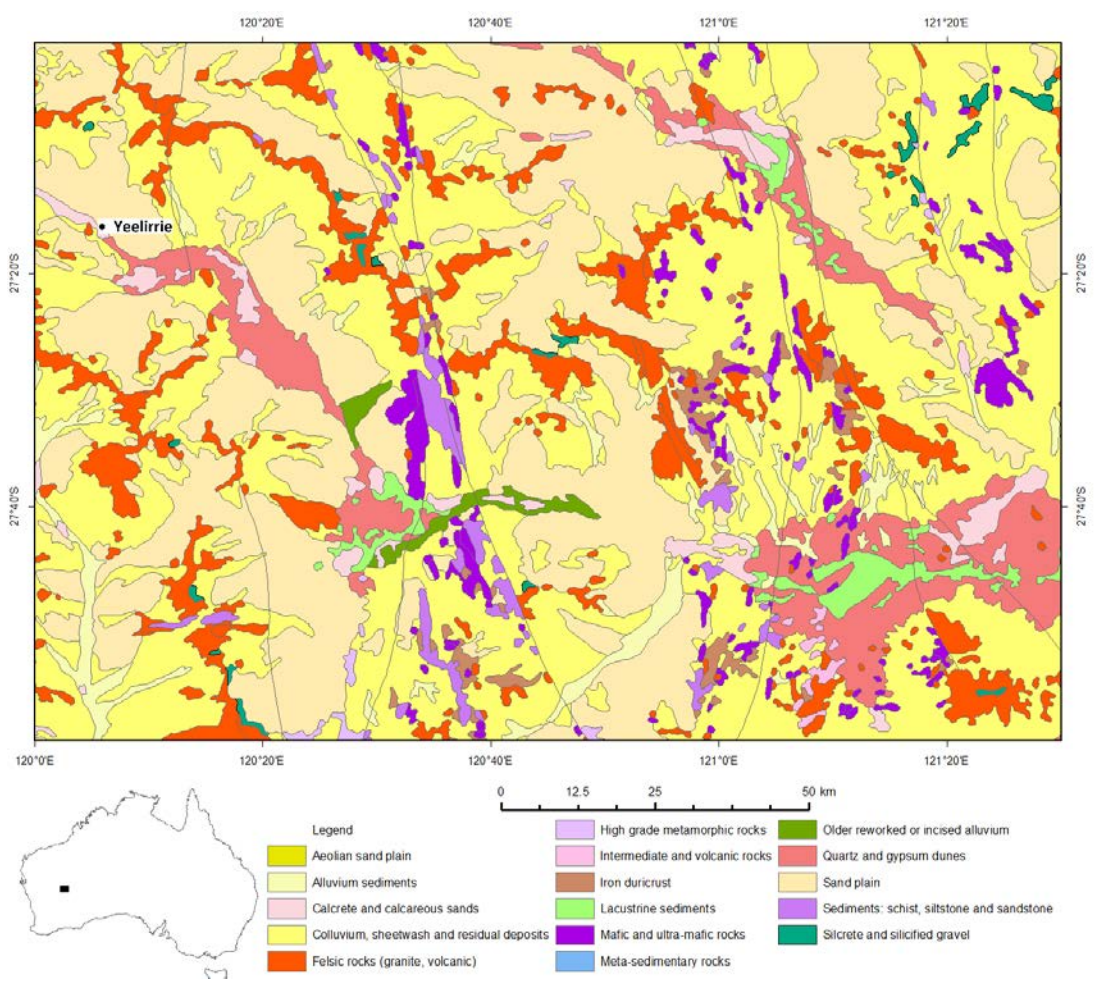


Random sampling (model generation)

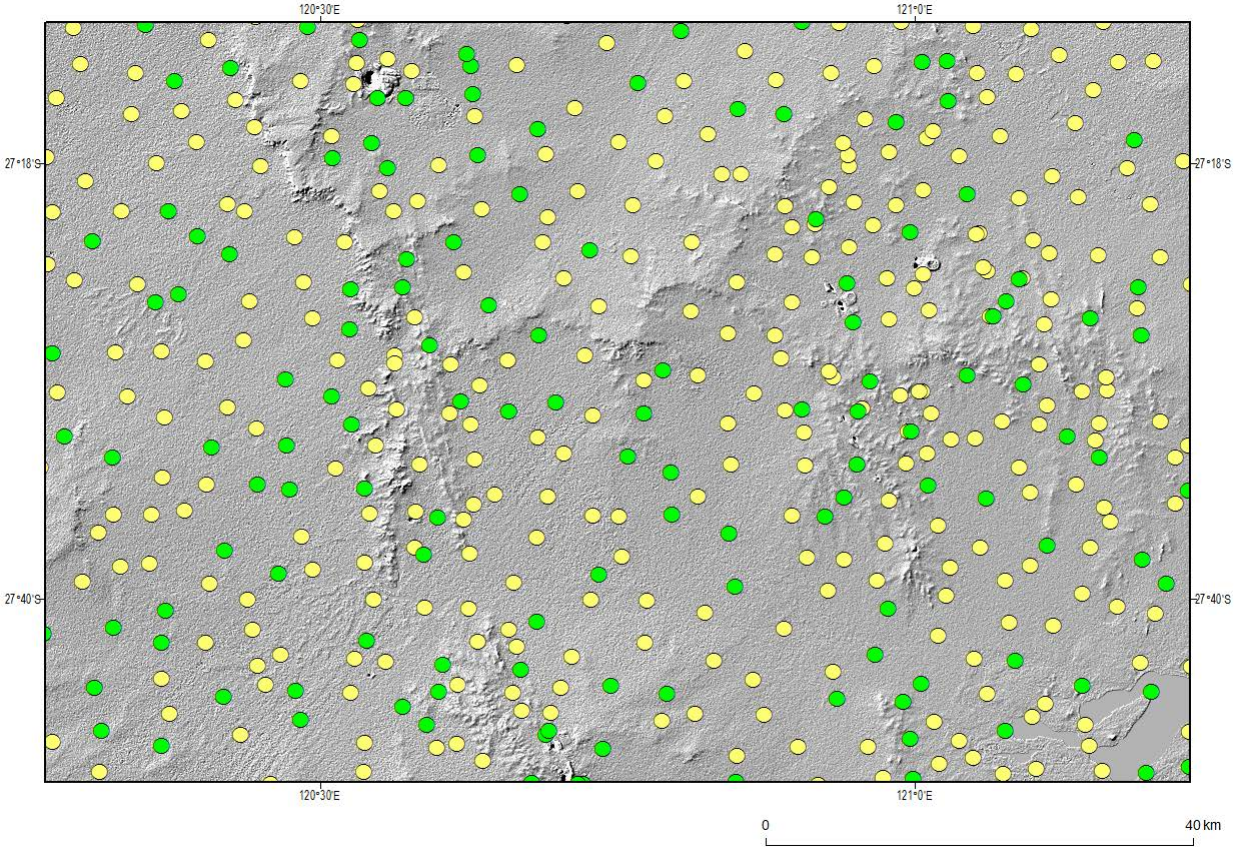
Out of sample validation



Modelling surface geochemistry



Sir Samuel 1:250 000 map sheet area

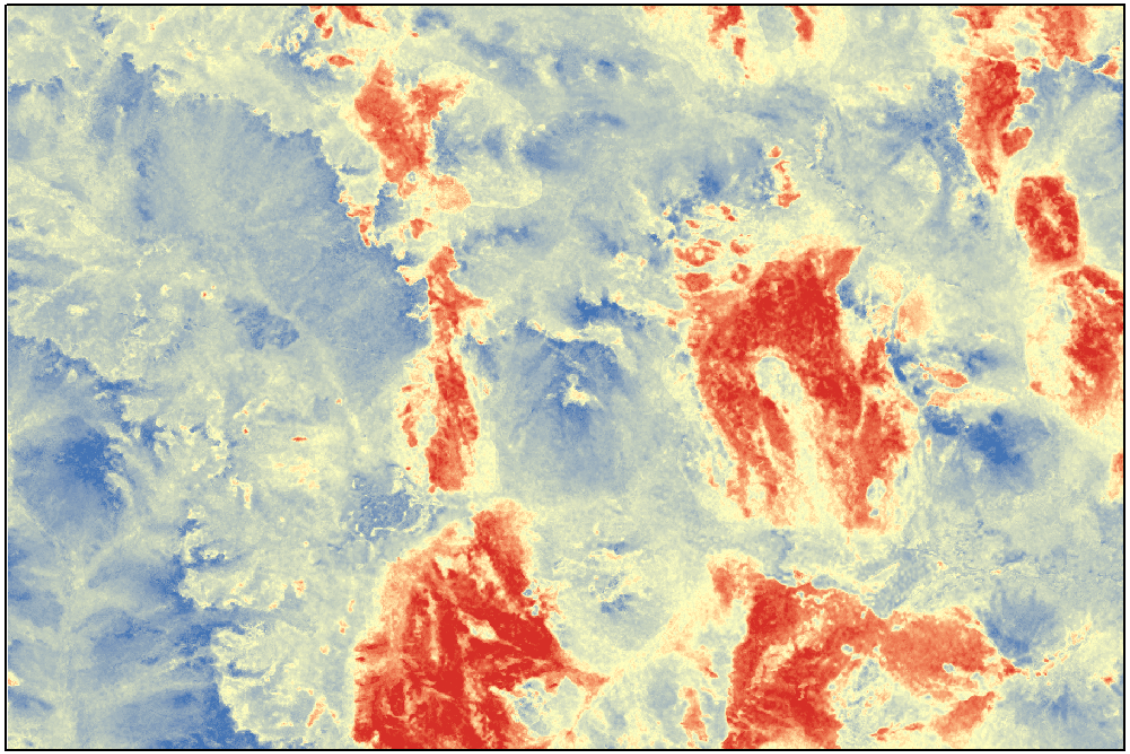


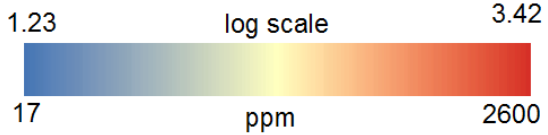
Geochemical Sample locations

Sir Samuel 1:250 000 map sheet area

Yellow = training (66%)
Green = validation (33%)

Cr concentration using environmental correlation

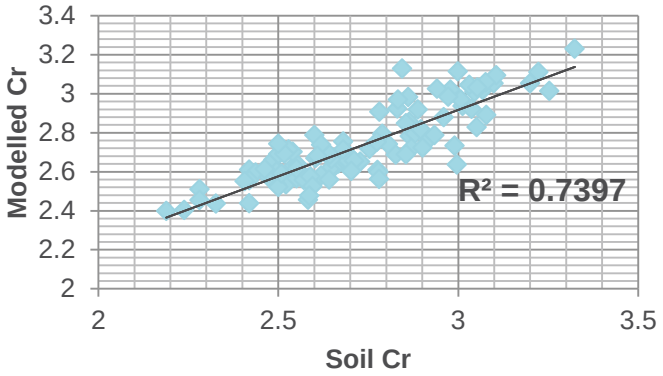


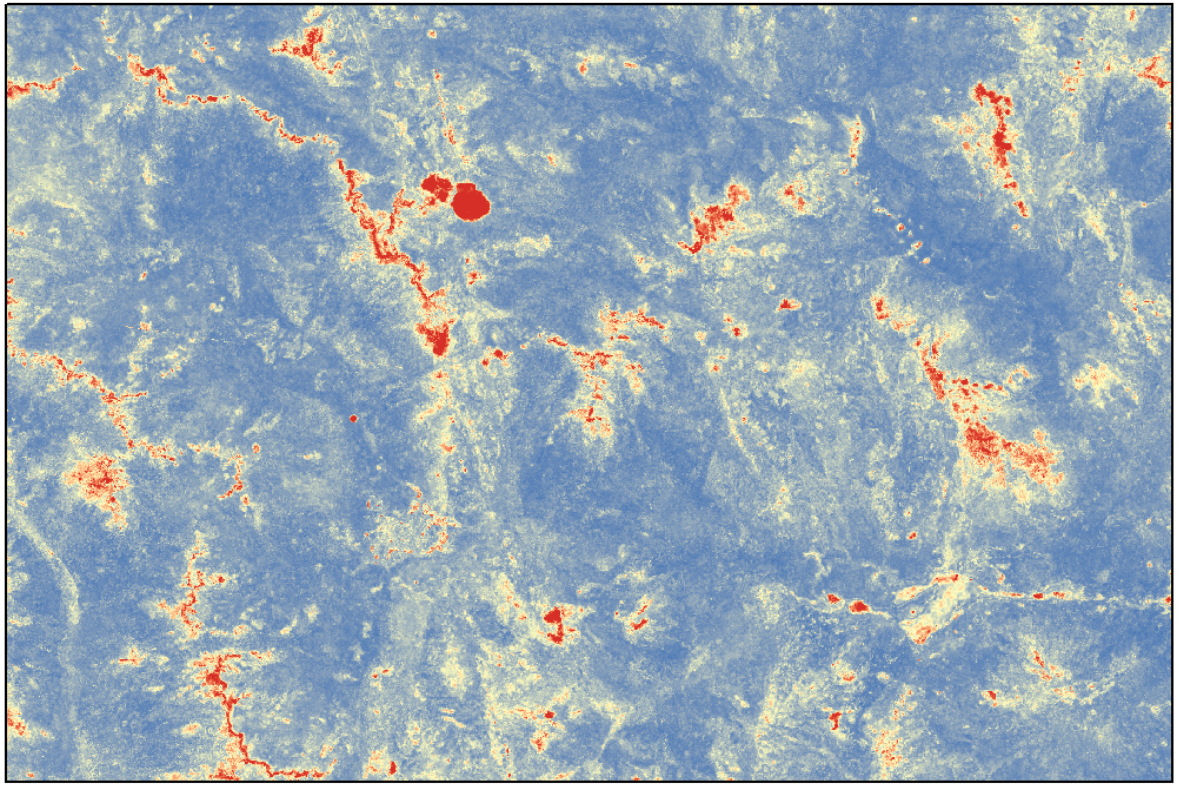


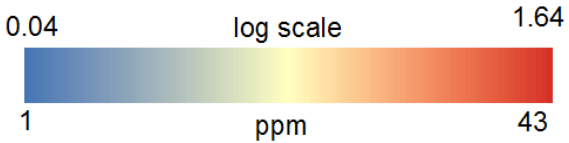
Important predictors

- Gamma-ray
- MODIS satellite
- Gravity
- Terrain
- Magnetics

Cr modelled vs soil geochemistry

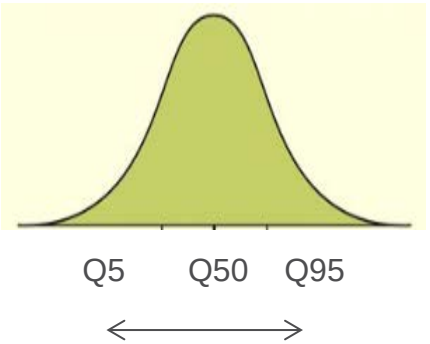




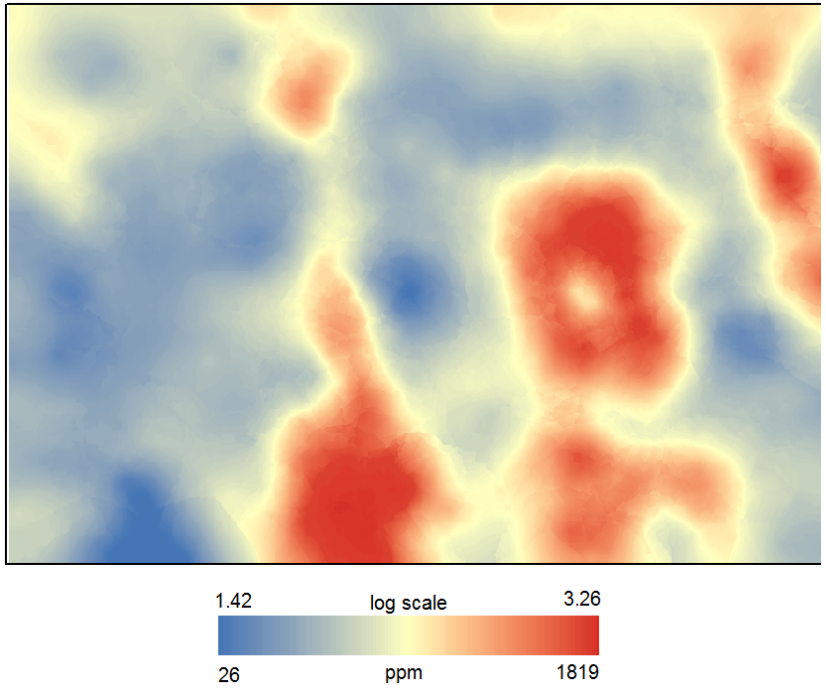


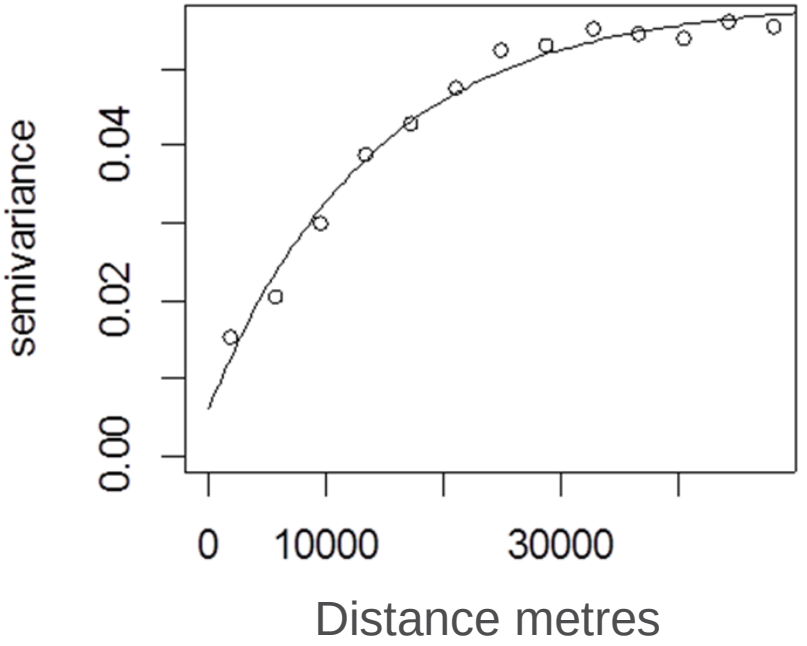
Cr prediction uncertainties

(Q95-Q5/Q50)



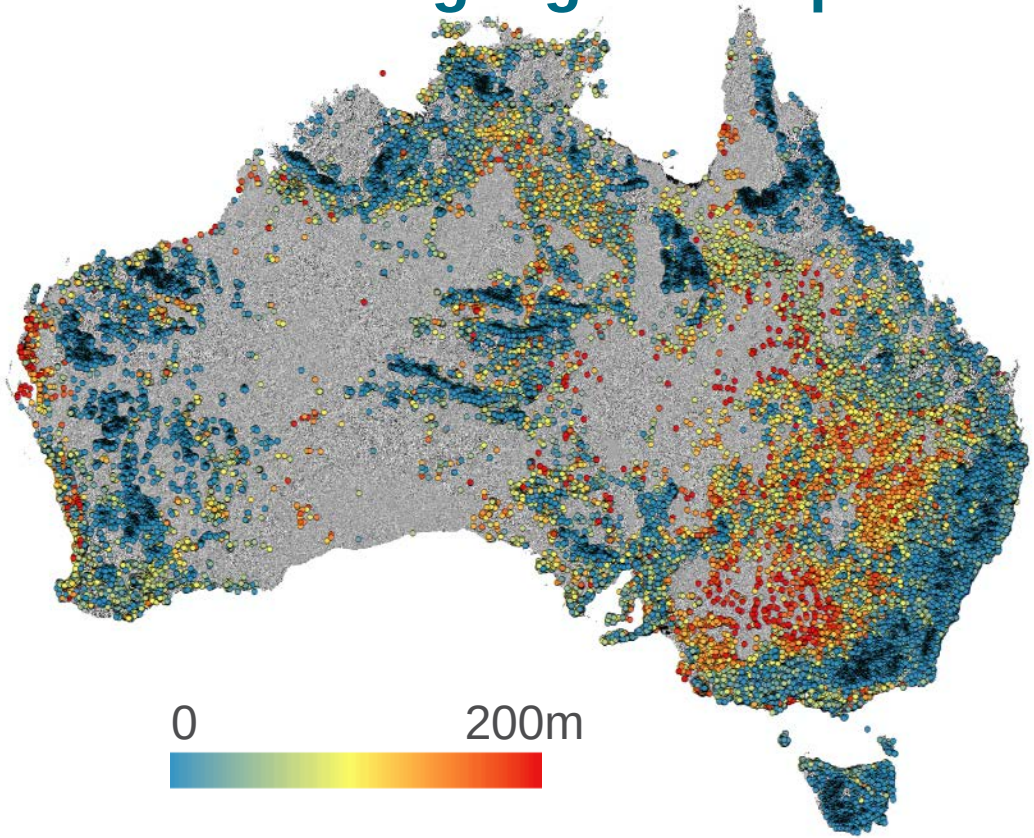
Kriged Cr concentration



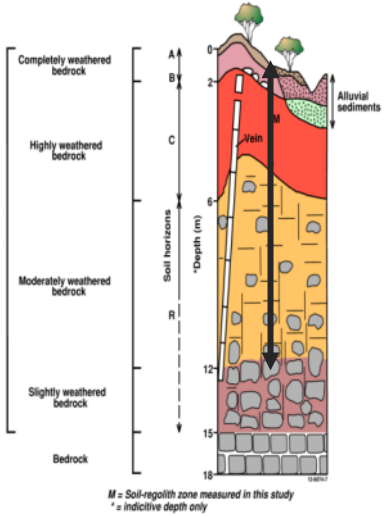


$R^2 = 0.70$

Modelling regolith depth



Lithology and lithology ‘like’ text matching



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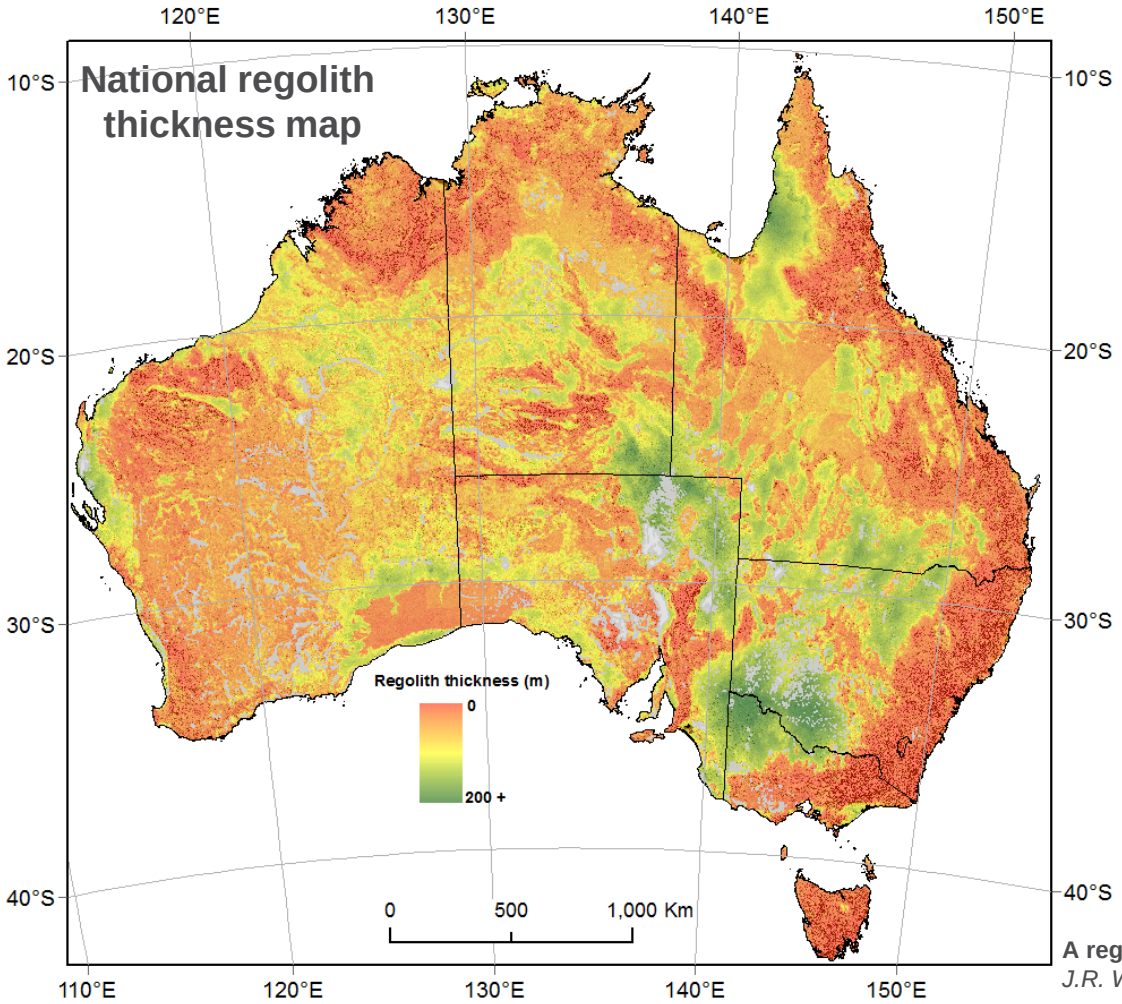
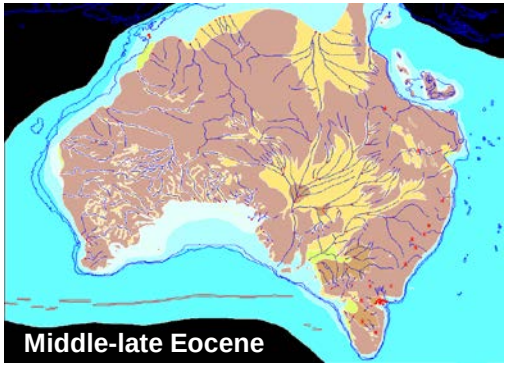
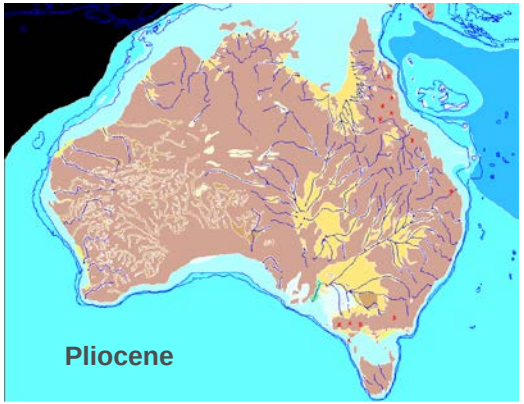


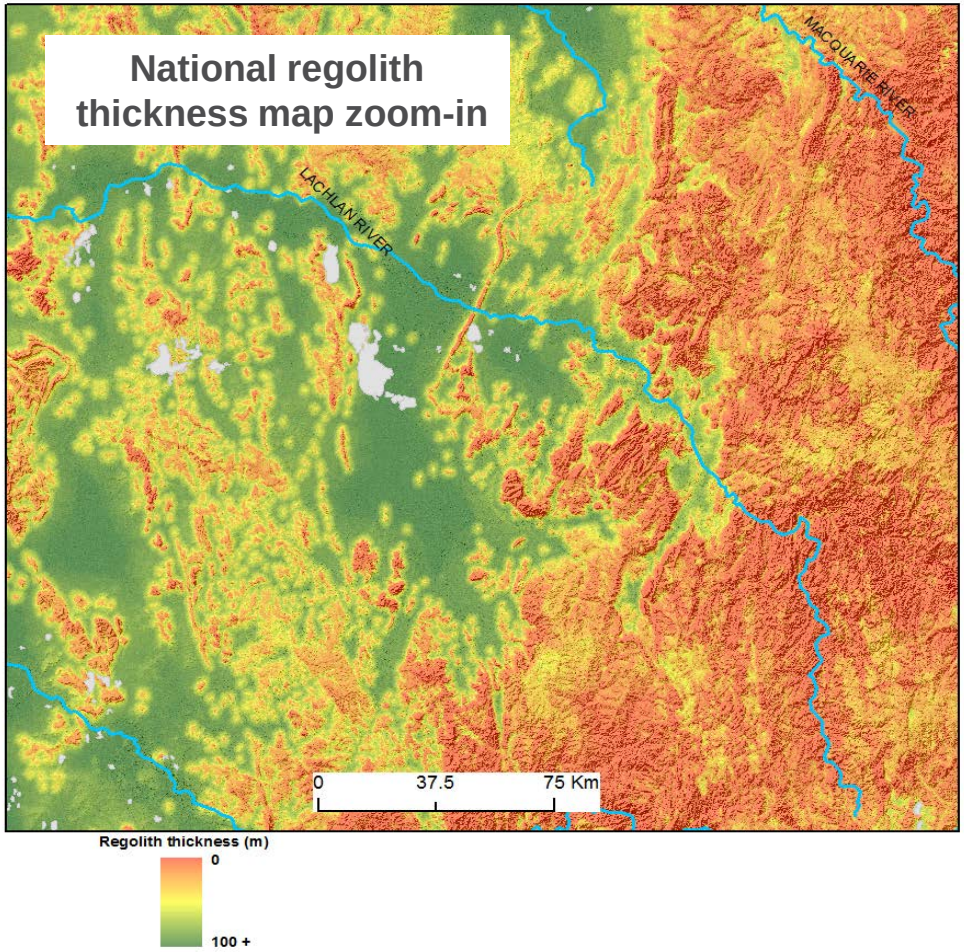
Cenozoic time periods



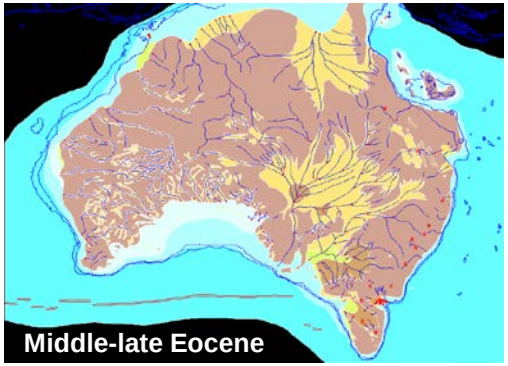


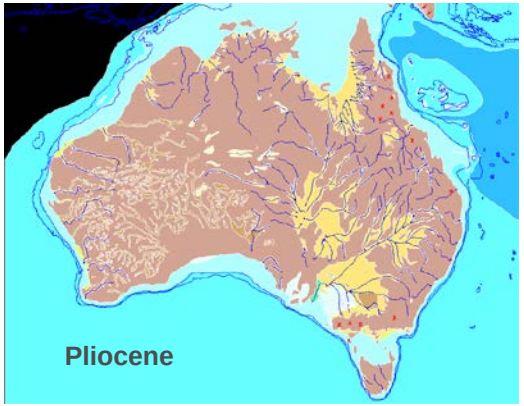
A regolith depth map of the Australian continent. In prep

J.R. Wilford, R Searle, M. Thomas, D. Pagendam, M.J. Grundy



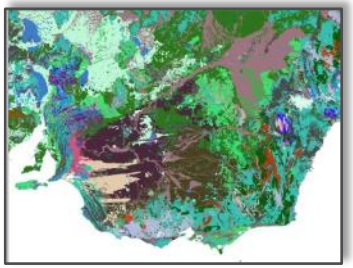
Cenozoic time periods



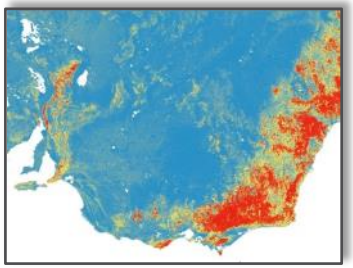


Predictive maps of cover thickness – Murray Basin

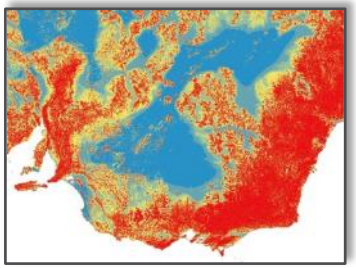
Surface geol.



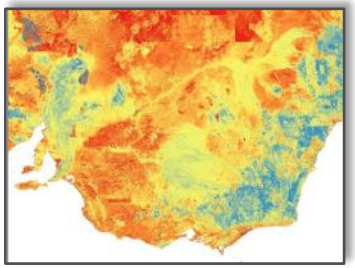
Topo. relief



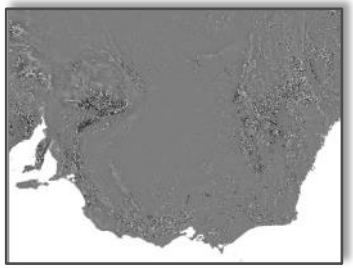
Valley flatness index



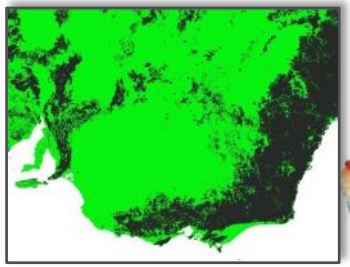
Weathering intensity



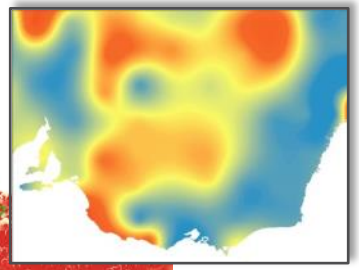
RTP TMI

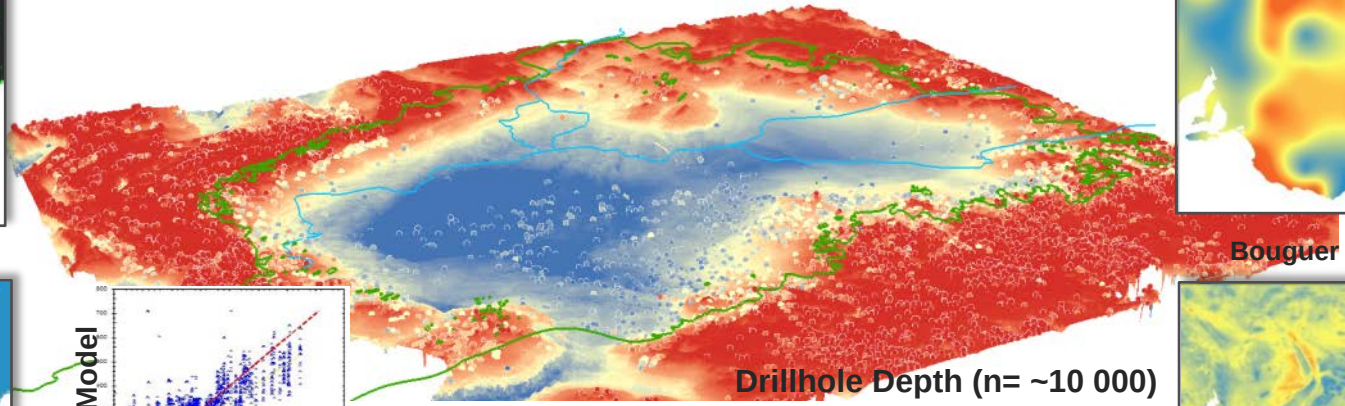


Cenozoic geology

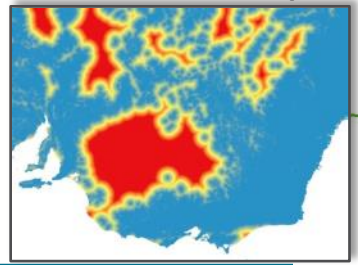


Filtered tilt est.





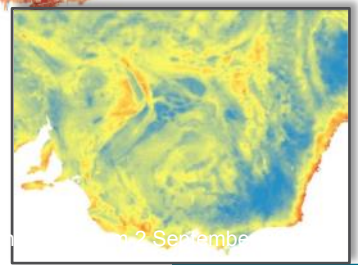
Distance from outcrop



Drillhole Depth (n= ~10 000)

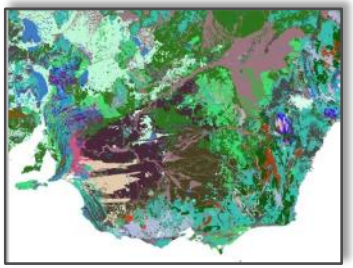
0 650 m

Bouguer gravity

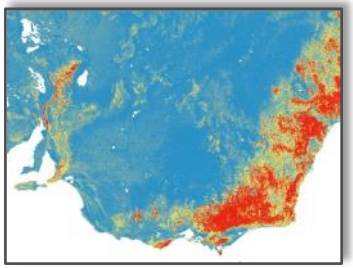


Predictive maps of cover thickness – Murray Basin

Surface geol.



Topo. relief



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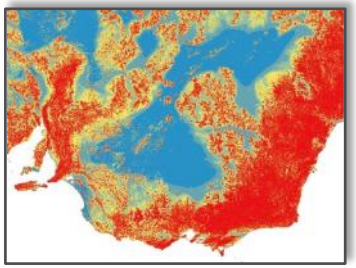
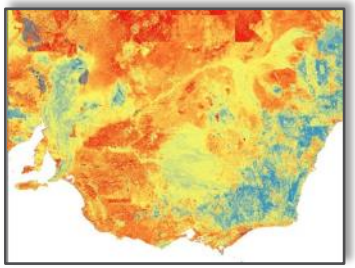
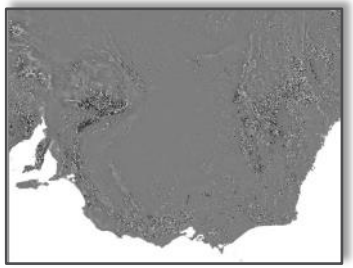


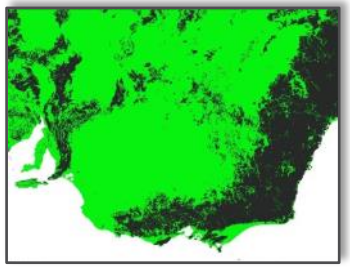
Weathering intensity



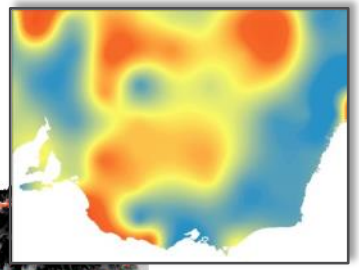
RTP TMI

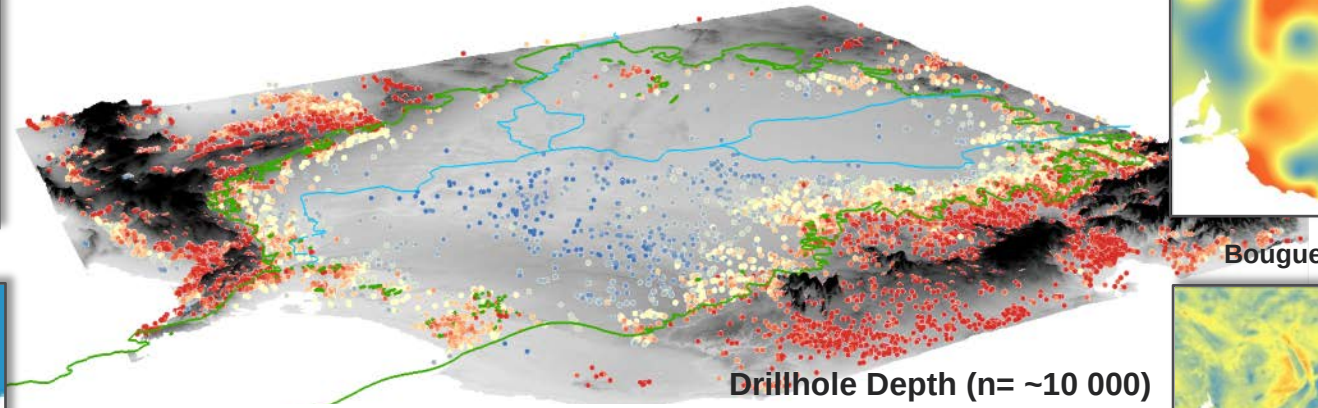


Cenozoic geology

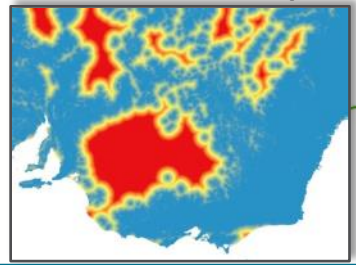


Filtered tilt est.

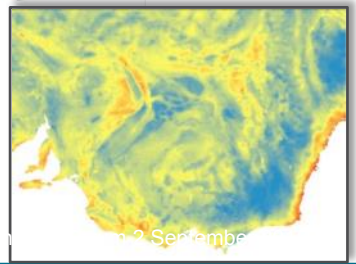




Distance from outcrop



Bouguer gravity

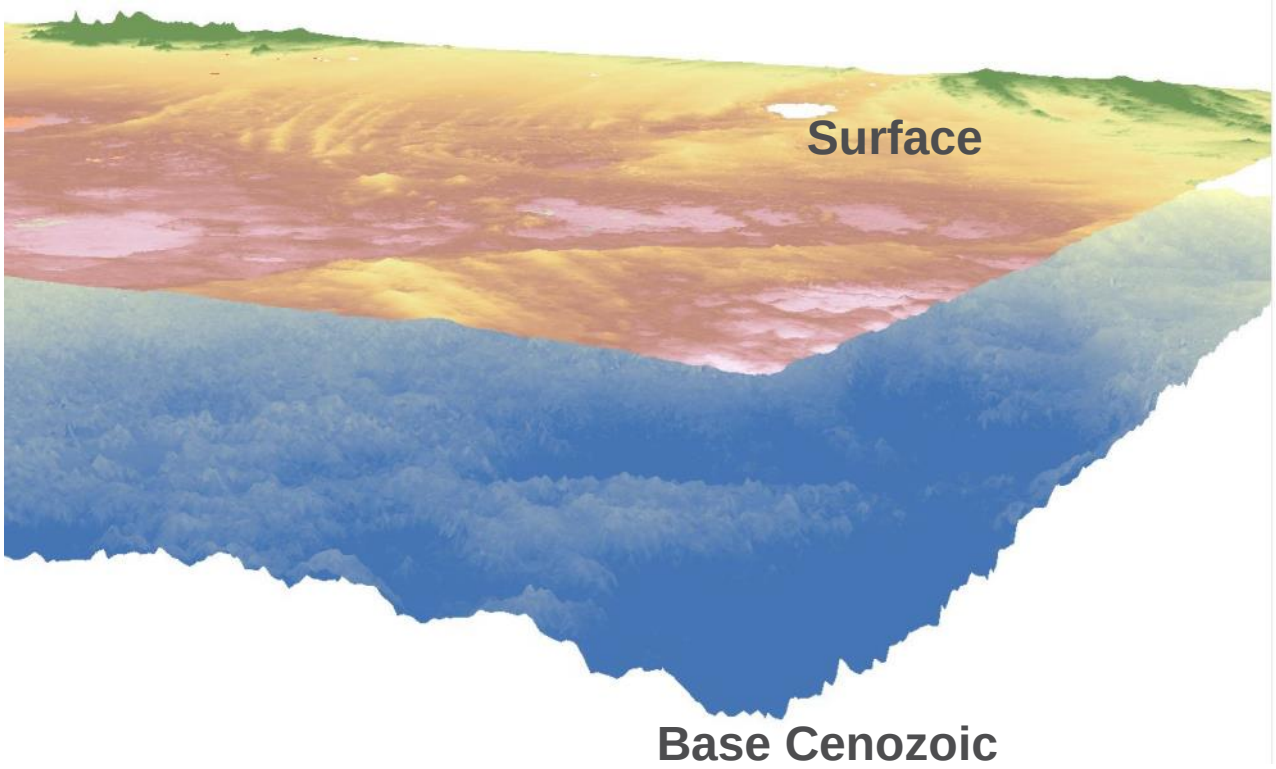


200km

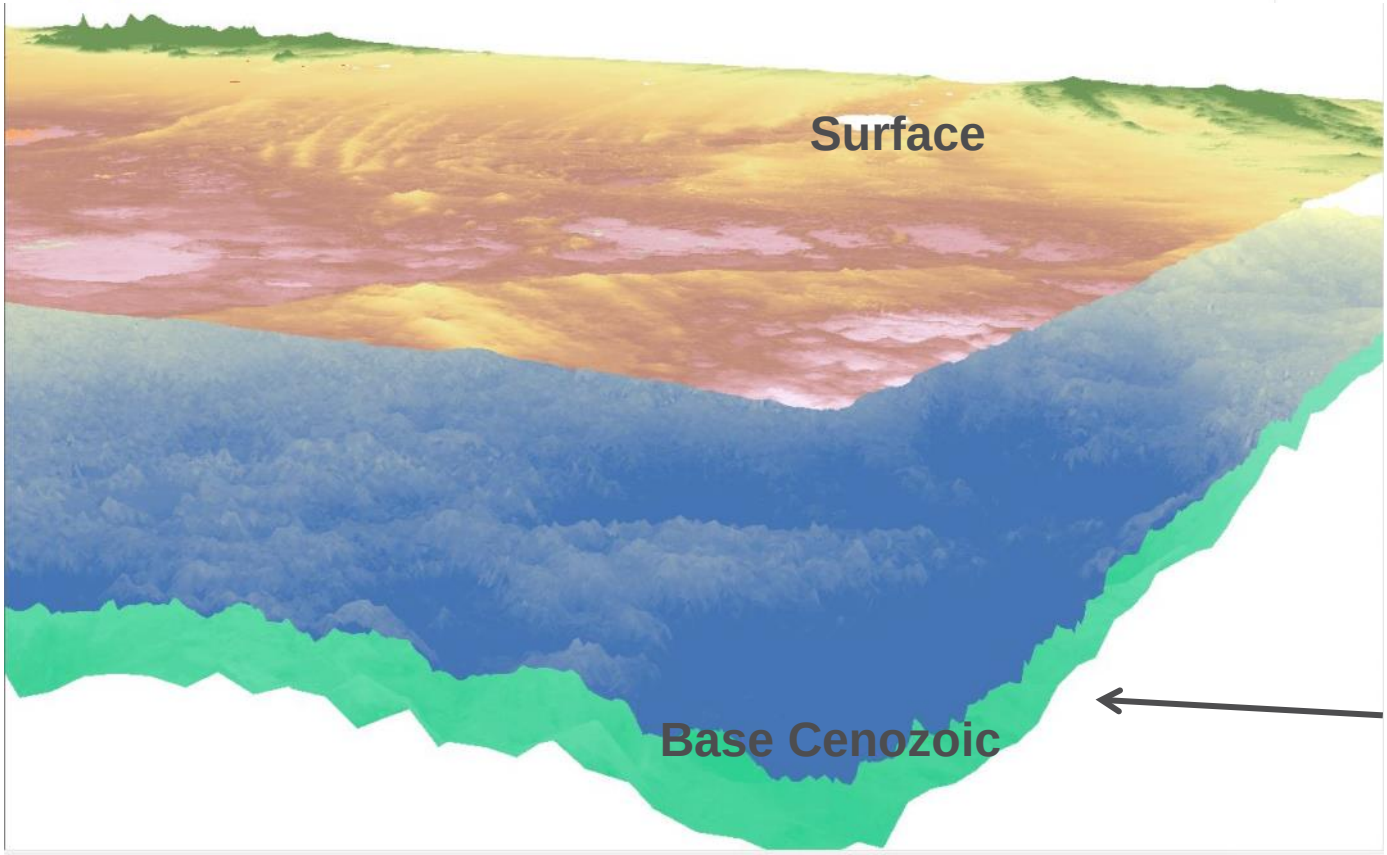
Drillhole Depth (n= ~10 000)

0 650 m

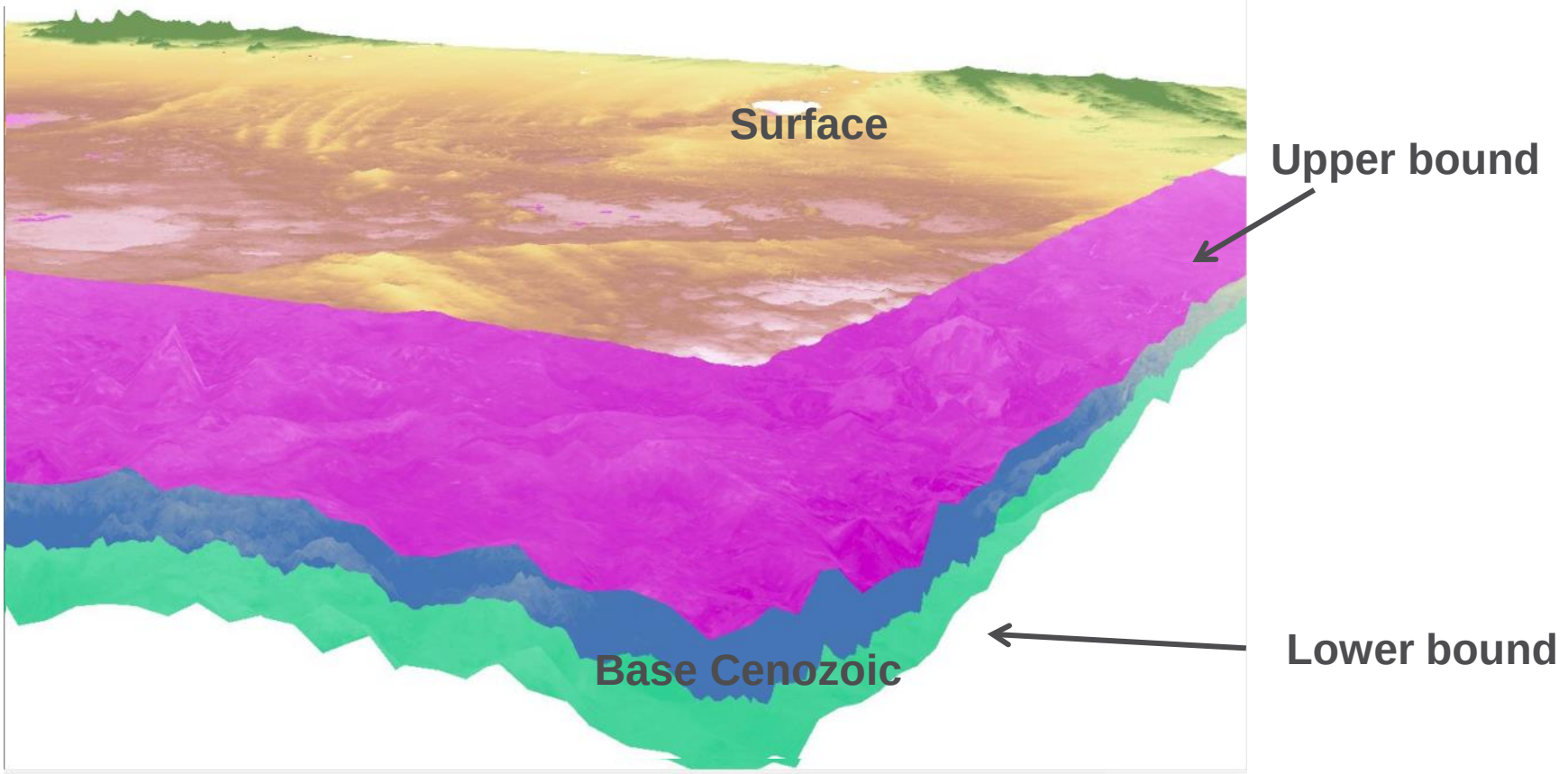
Cenozoic depth boundary with uncertainties - Murray Basin



Cenozoic depth boundary with uncertainties - Murray Basin

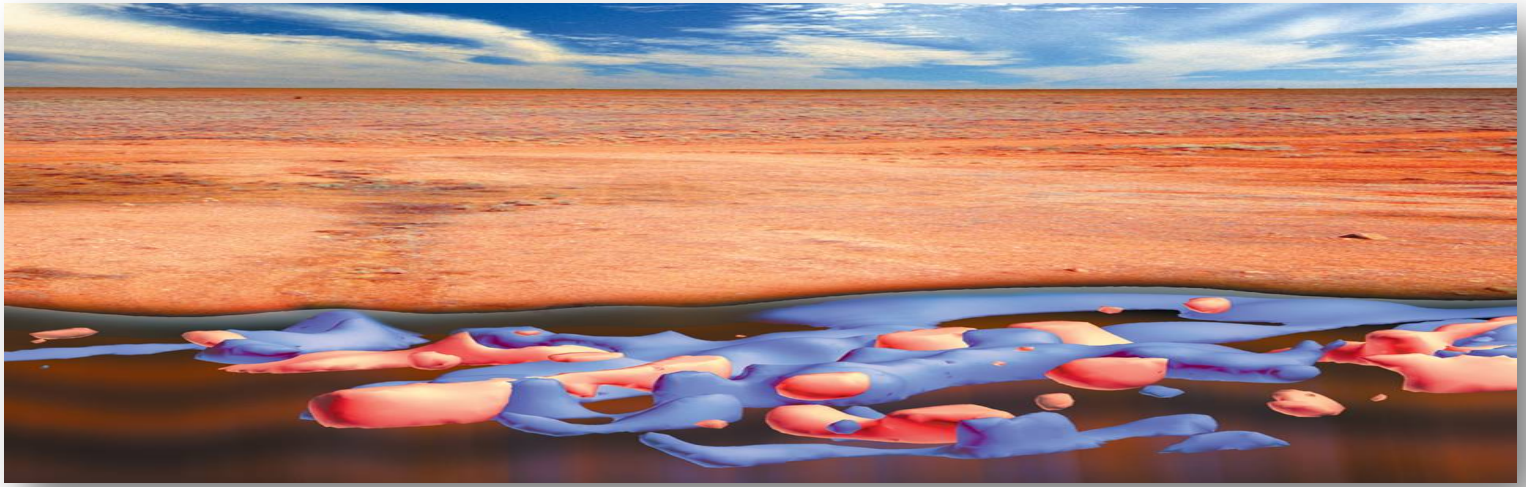


Cenozoic depth boundary with uncertainties - Murray Basin



Conclusions

- Compiling legacy data (drilling; remote sensing – geophysics)
- Building robust databases of primary depth estimates (with degrees of confidence)
- Developing and testing different techniques to generate predictive maps of cover thickness and surface geochemistry (with uncertainties).



Mapping Geology with Airborne Electromagnetics

- Introduction
- AEM Systems
- AEM at GA
- AEM discoveries
- GA AEM Impacts
- GA AEM Innovations

AEM

Characterises the depth and nature of cover

Characterise and detect distal footprints of ore deposits

One geologist's cover is another geologist's basement

"Cover" and "basement" depend on the commodity sought

Todays examples are only a few from GA's AEM survey work

Highlighting some of the science outcomes and industry impacts

AEM systems on the Geoscience Australia Deed

SPECTREM

GPX

TEMPEST

CGG

SKYTEM

SkyTEM Australia

VTEM

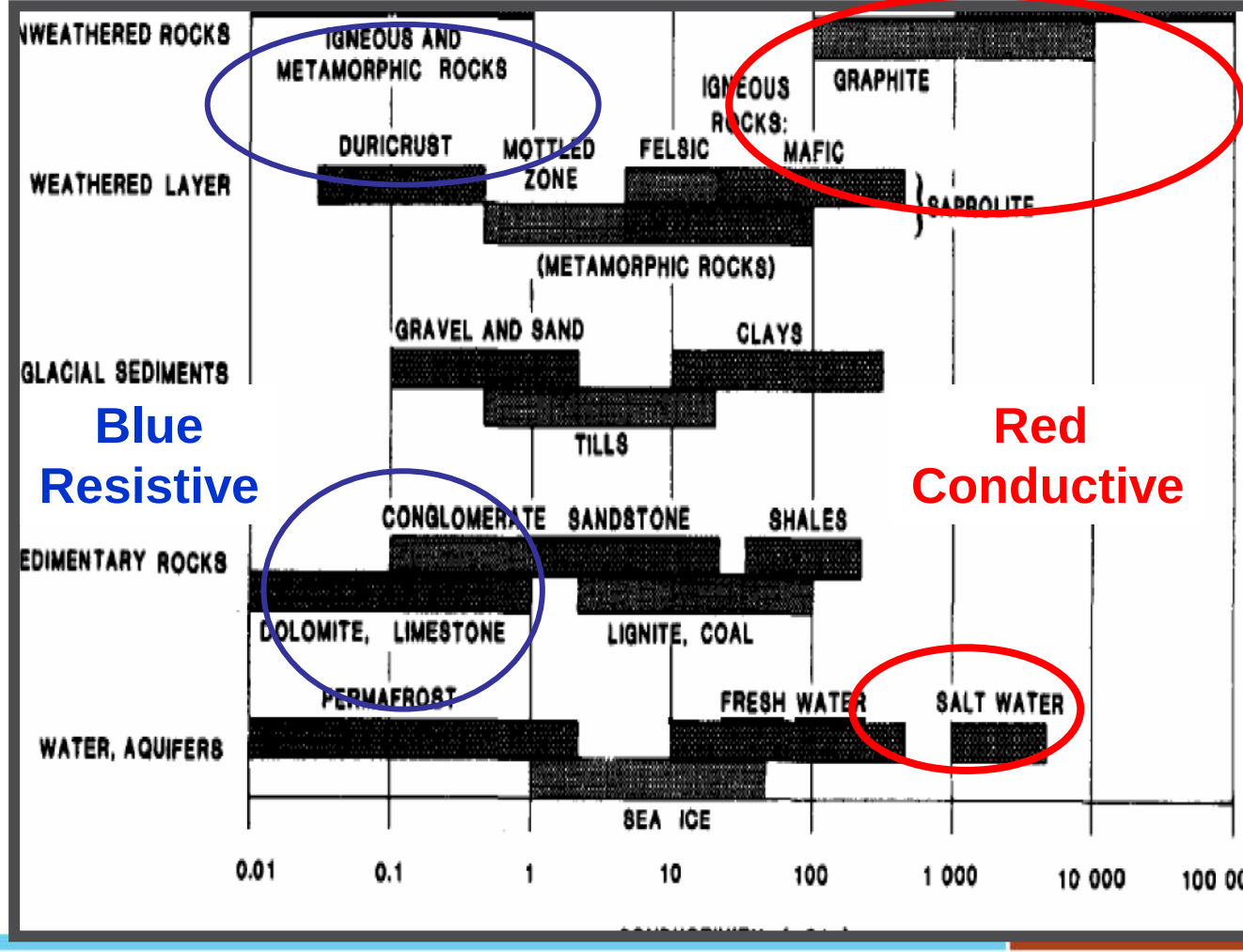
Geotech Airborne Surveys

AEM 1.01

Typical ranges of electrical conductivities for common earth materials

Conductivity contrasts can help us map under-cover geology

Palacky (1993)



Government funded AEM surveys

G.A. AEM surveys

Pine Creek: 2008-2009
Area: 73,700 km^2
Line km: 29,900

Frome: 2010
Area: 95,450 km^2
Line km: 32,317
10% of SA

Southern Thomson: 2014
Area: 16,000 km^2
Line km: 4,200

Paterson: 2007-2008
Area: 47,600 km^2
Line km: 28,200

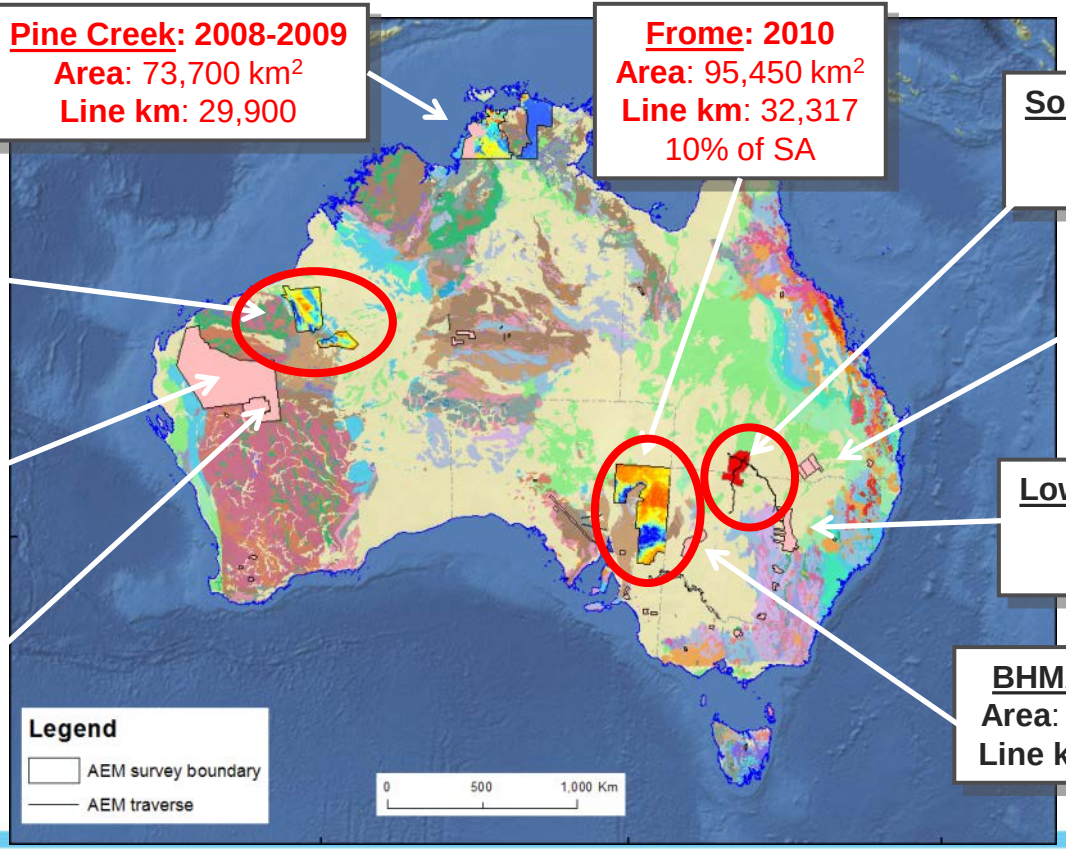
Lower Balonne: 2001
Area: 8,880 km^2
Line km: 28,882

WA Govt
Capricorn: 2013-2014
Area: 146,300 km^2
Line km: 30,123

Lower Macquarie: 2007
Area: 13,000 km^2
Line km: 35,189

WA Govt
Bryah Basin: 2012
Area: 146,300 km^2
Line km: 2,025

BHMAR: 2009
Area: 7,541 km^2
Line km: 31,834



AEM at Geoscience Australia

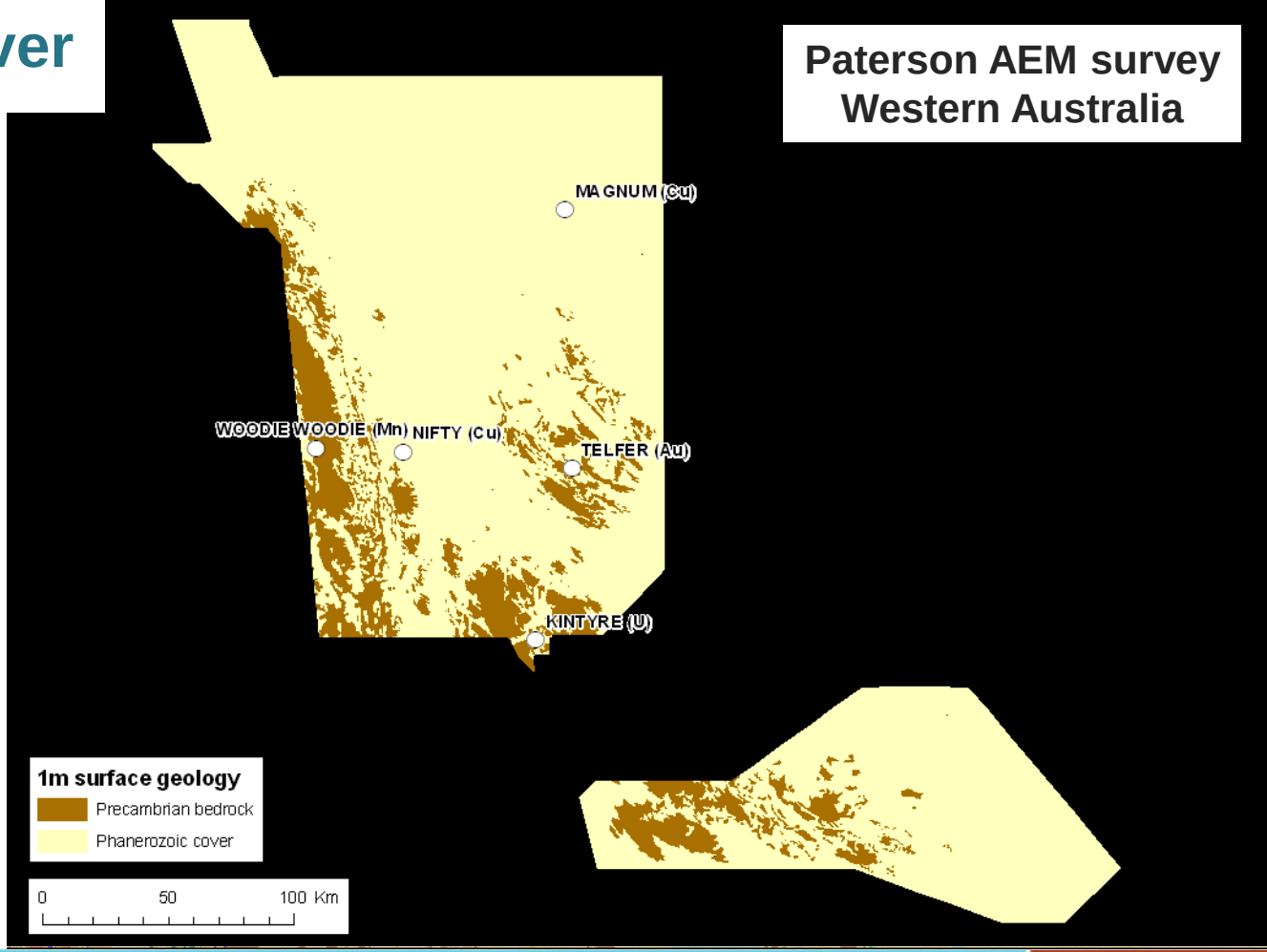
- Precompetitive AEM released
- Very large regional surveys
- Risk reduction
- Increased/new investment – surveys paid for themselves
- Good quality – archived – re-useable
- Value add product development
- Value add expert interpretation

Mapping under cover

84% cover in the AEM survey area

Lateral continuity of conductivity patterns with mapped surface geology

- Extensions of geology under cover
- Potential rock types under cover



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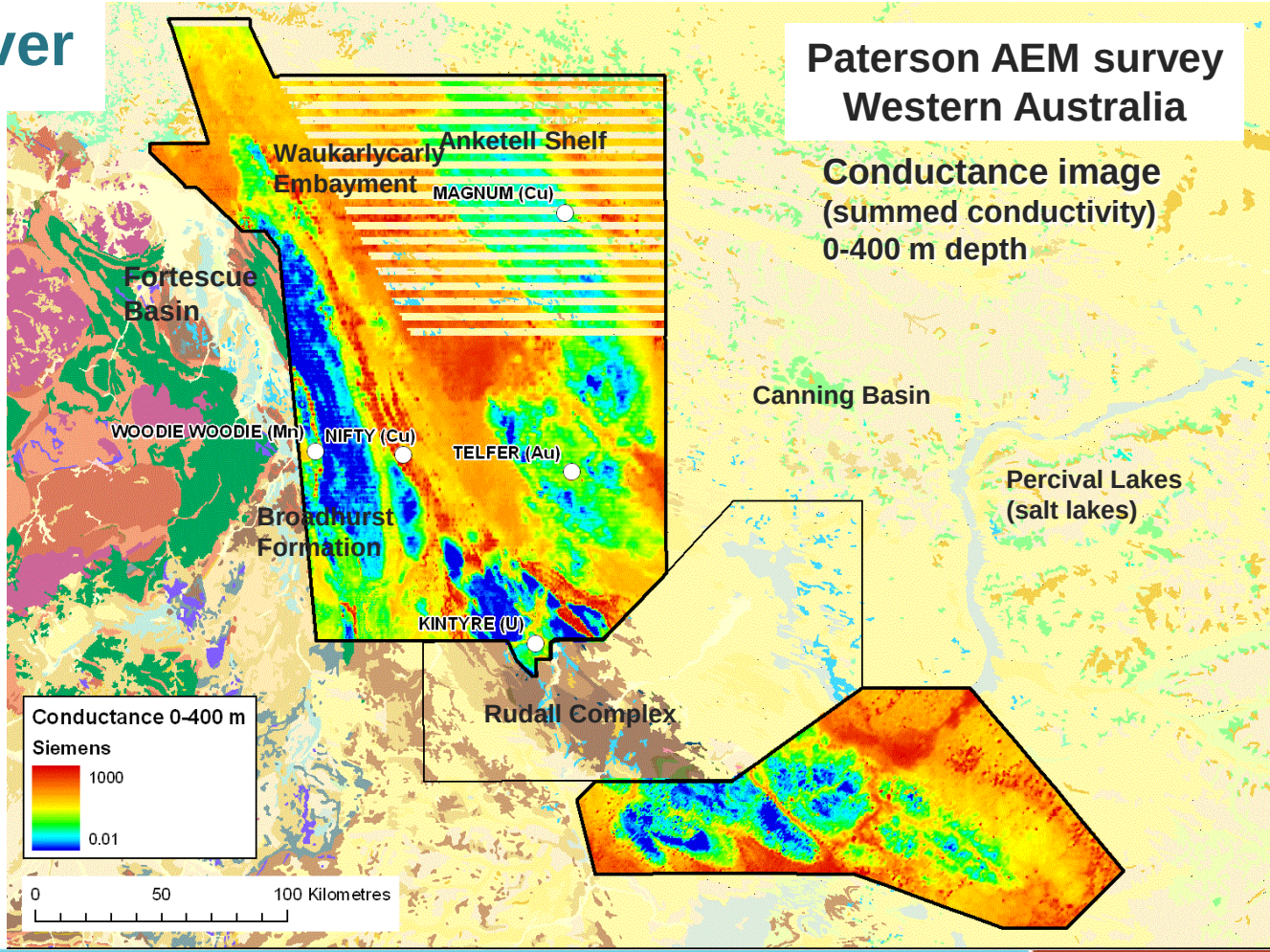
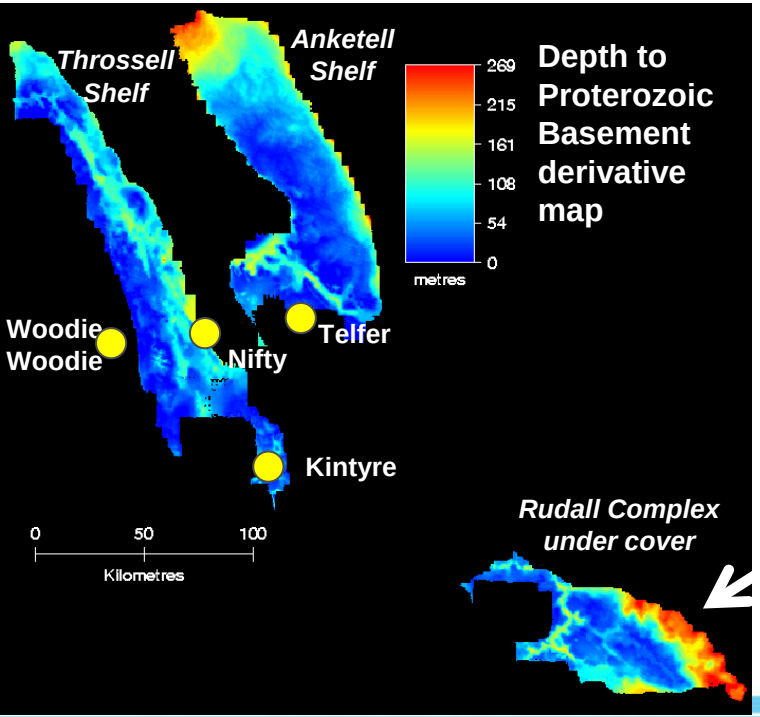
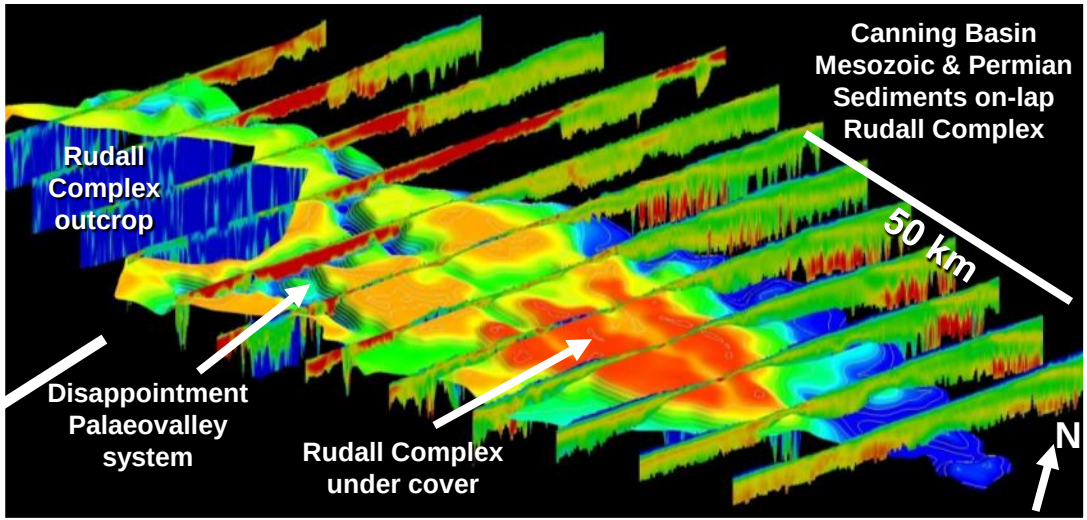


"Just tell us how thick the cover is!"

Excellent results in mapping regional cover thickness and extent of under-cover high-prospectivity terrains – Paterson W.A.

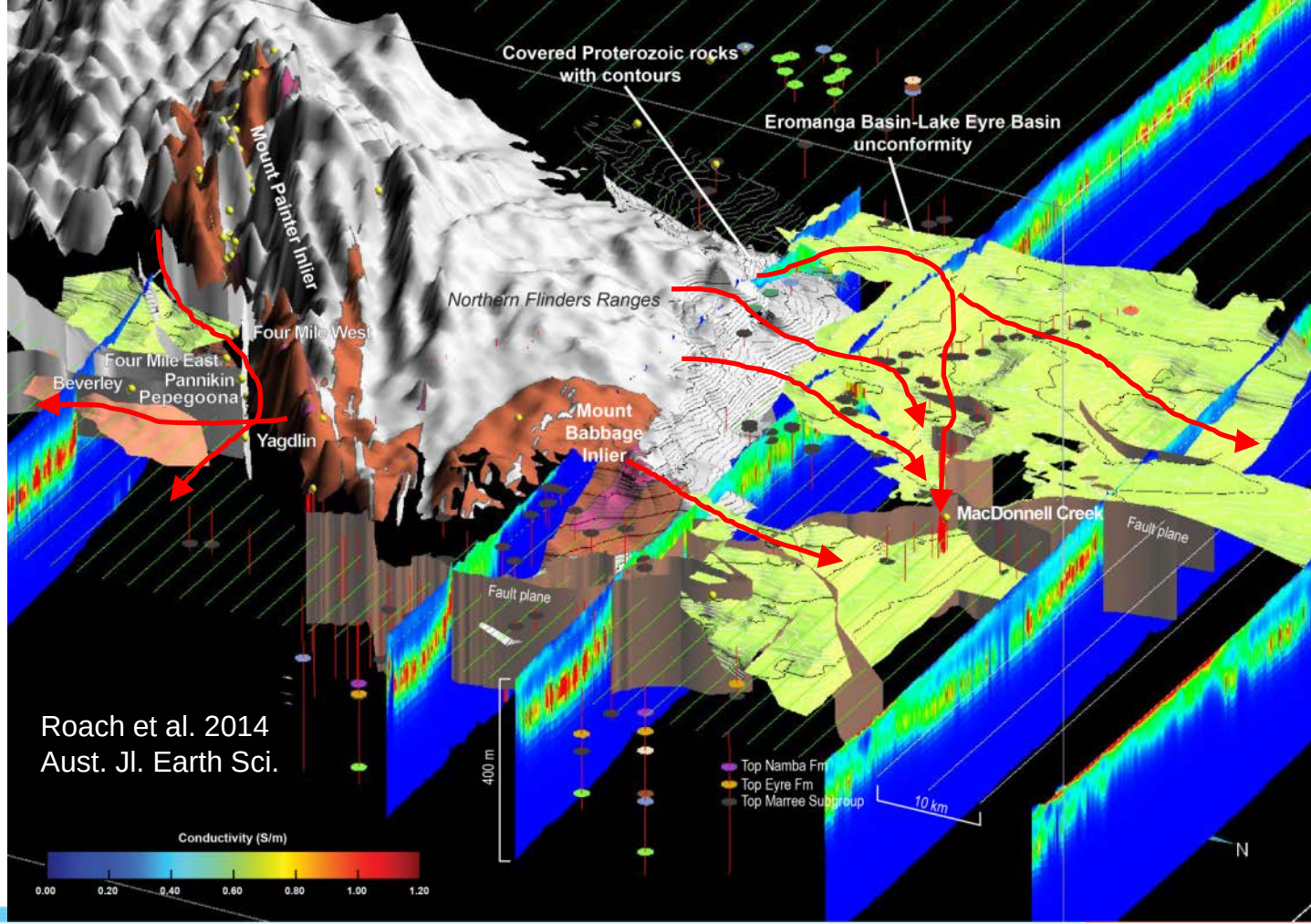




Mapping under cover Frome S.A.

Mapping the sources, transport pathways and sinks of uranium in the northern Flinders Ranges

Tectonic controls on preservation of uranium traps



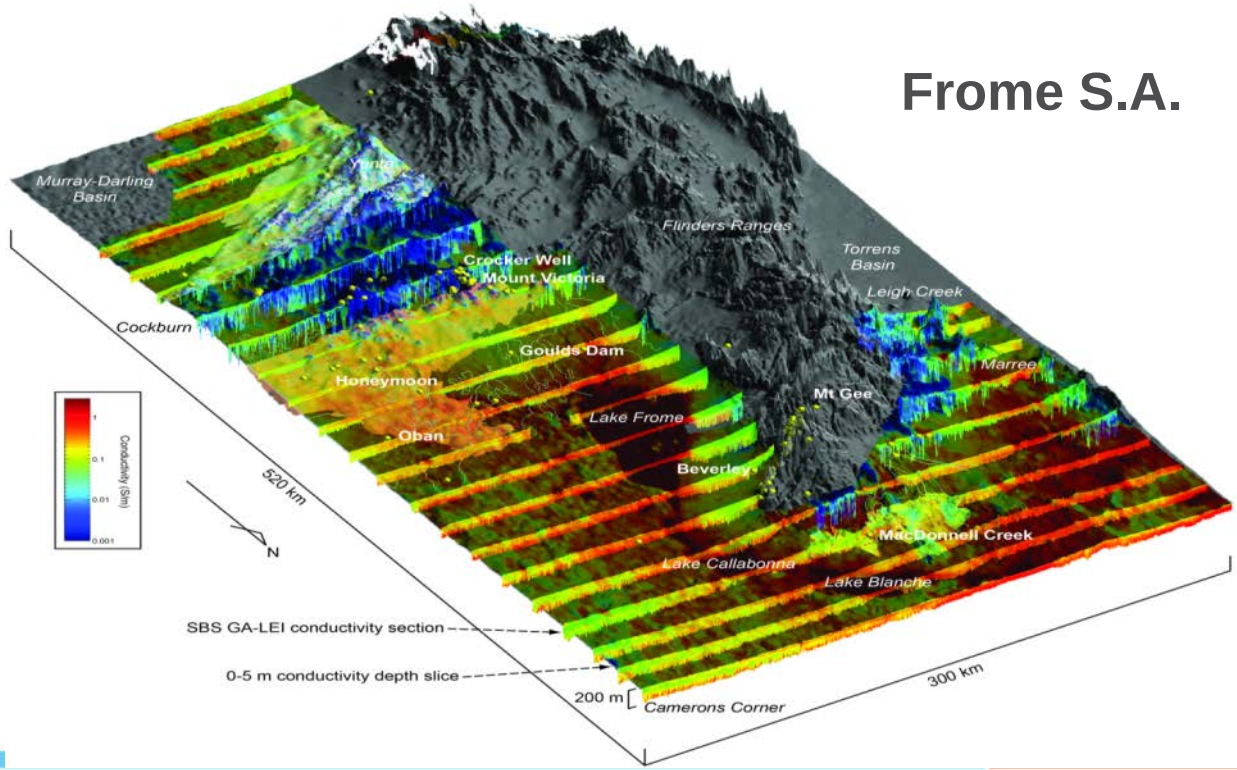
GA AEM Impacts: Regional Mapping

Regional understanding of U systems and their settings

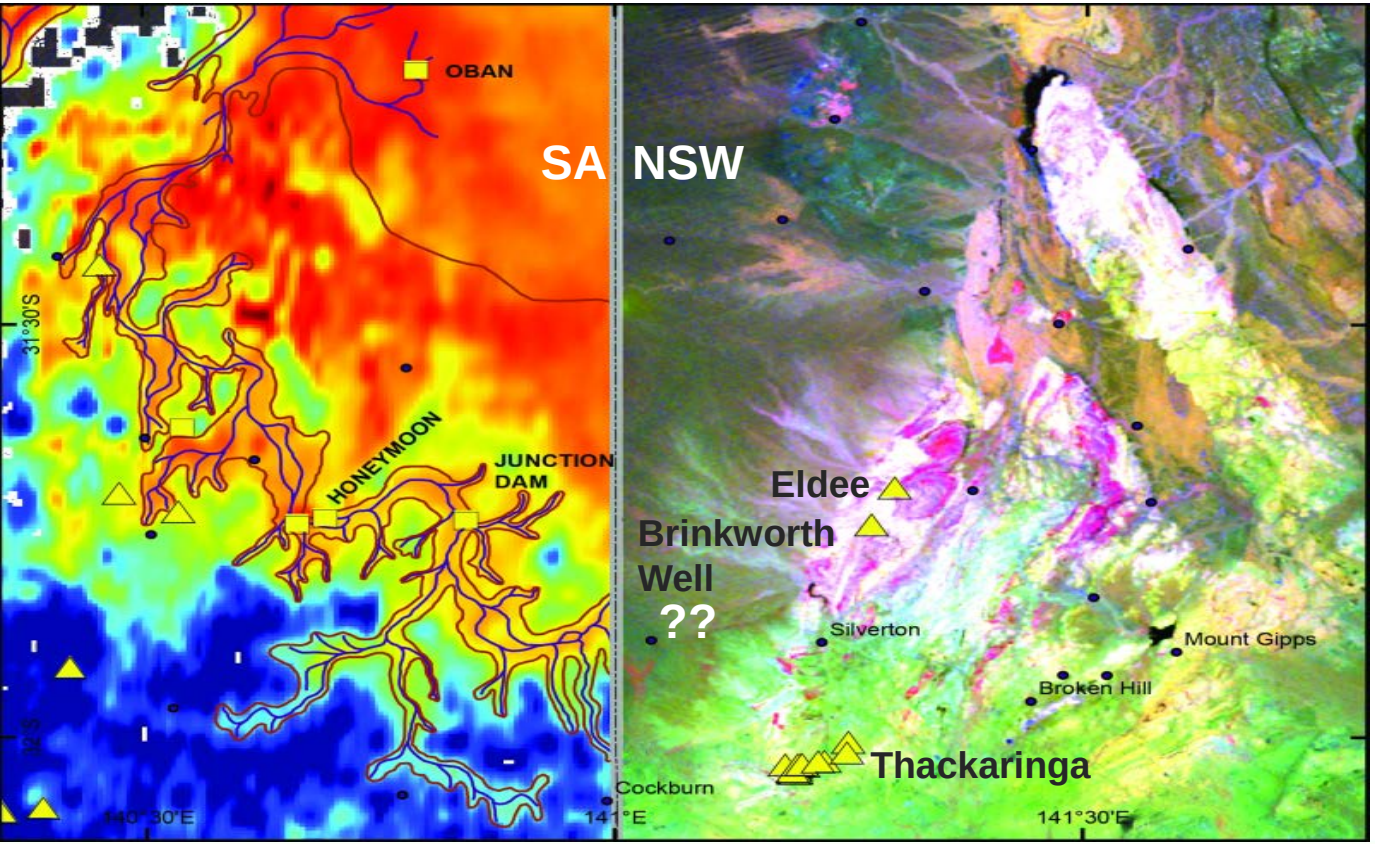
Model palaeosurfaces

More precise depth
to target information

Map alteration zones

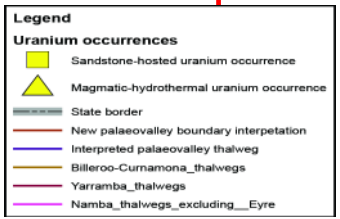


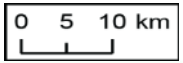
Where does that palaeovalley go?



Remapped

- Yarramba Palaeovalley
- Billeroo-Curnamona
- Lake Namba
- Uranium Prospectivity





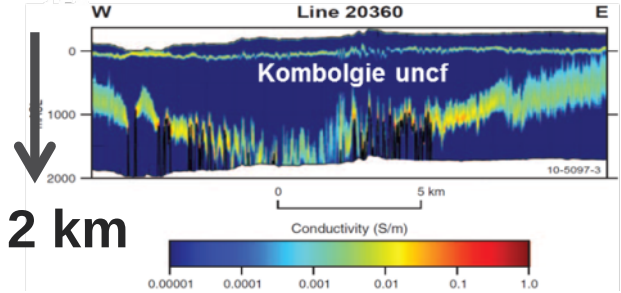
GA AEM Impacts: Under Cover

Mapping cover thickness in search of NEW targets

- United Uranium
- Outback Metals
- Uranium Exploration Australia
- Territory Uranium (Green Ant)

New discovery: Thunderball uranium prospect (Thundellara Exploration)

VTEM Kombolgie Survey



2 km

The AEM interpretation in Figure 3, coupled with the coherent geochemical anomaly depicted in Figure 2, make this target an excellent resource development priority for the start of TUC's busy exploration season.

*Reference: Lally, J.H., & Bajwah, Z., 2006; *Uranium Deposits of the Northern Territory, Report 20*, August 2006, Northern Territory Geological Survey; Northern Territory Government.

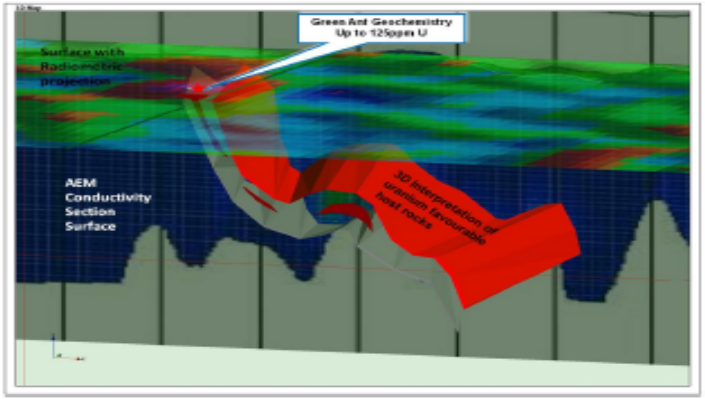
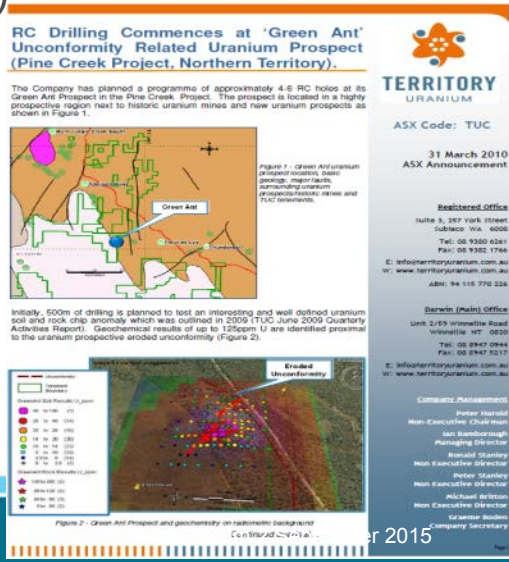


Figure 3– 3D interpretation of uranium favourable host rocks beneath the Green Ant Prospect. Information used for drill targeting.

Territory Uranium Company Ltd ASX Announcement 11 March 2010


RC Drilling Commences at 'Green Ant' Unconformity Related Uranium Prospect (Pine Creek Project, Northern Territory).

The Company has planned a programme of approximately 4-6 RC holes at its Green Ant Prospect in the Pine Creek Project. The prospect is located in a highly prospective region next to historic uranium mines and new uranium prospects as shown in Figure 1.

Green Ant

Figure 1 - Green Ant uranium prospect location, basic geology, major faults, surrounding uranium prospects/historic mines and TUC tenements.

Initially, 500m of drilling is planned to test an interesting and well defined uranium soil and rock chip anomaly which was outlined in 2009 (TUC June 2009 Quarterly Activities Report). Geochemical results of up to 125ppm U are identified proximal to the uranium prospective eroded unconformity (Figure 2).

Eroded Unconformity

Figure 2 - Green Ant Prospect and geochemistry on radiometric background

TERRITORY URANIUM

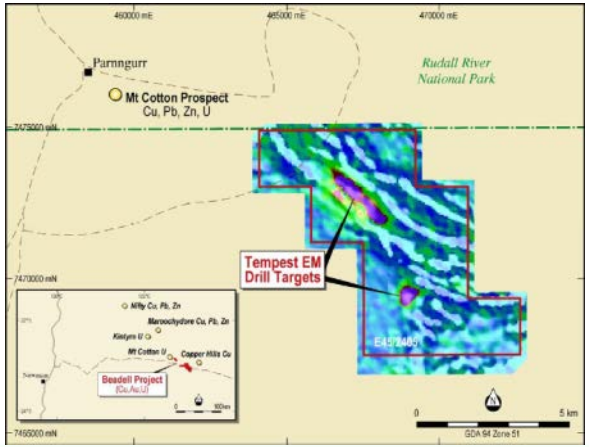
ASX Code: TUC

31 March 2010
ASX Announcement

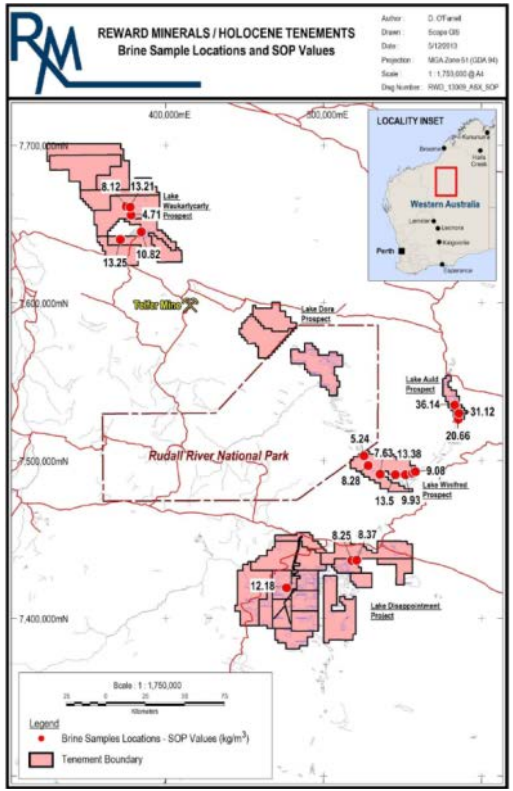
GA AEM Impacts: Discoveries

Target generation:

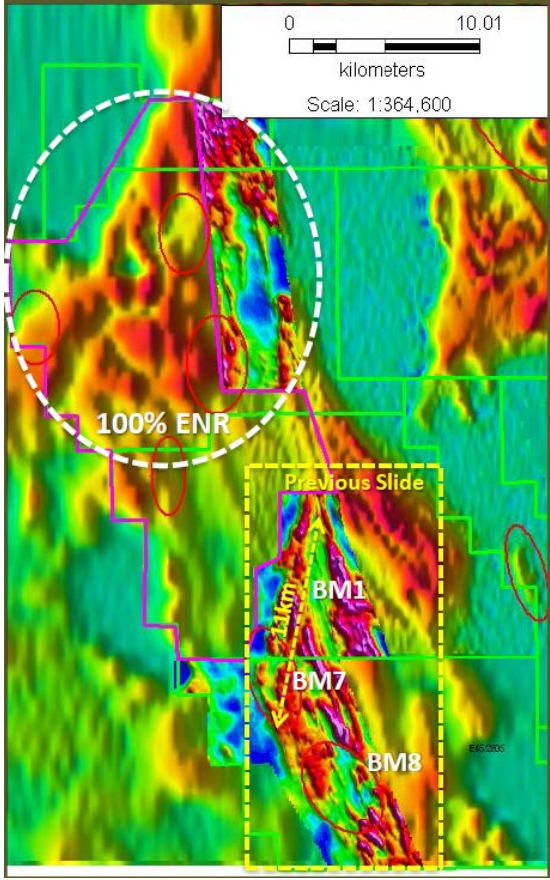
- Yeneena Cu-Co, Mn, Cu-Zn
- Beadell Cu-Pb-Zn-Au
- Further U, Cu-U mineral systems around Kintyre
- Salt lakes potash



GA TEMPEST AEM image, **Beadell Cu** prospect. Cauldron Energy Ltd ASX announcement 1 Nov 2010

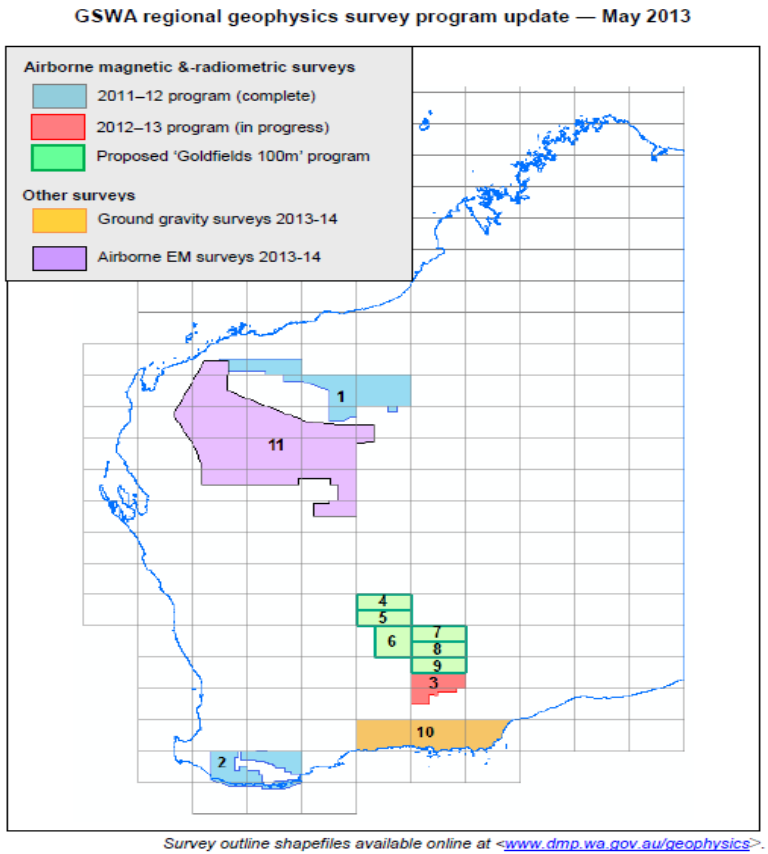


Reward Minerals Ltd **potash** tenements



GA TEMPEST and VTEM AEM image, **Yeneena Cu prospect**. Encounter Resources Ltd, RIU Sydney 14 May 2013

GA AEM Impacts: Government Investments

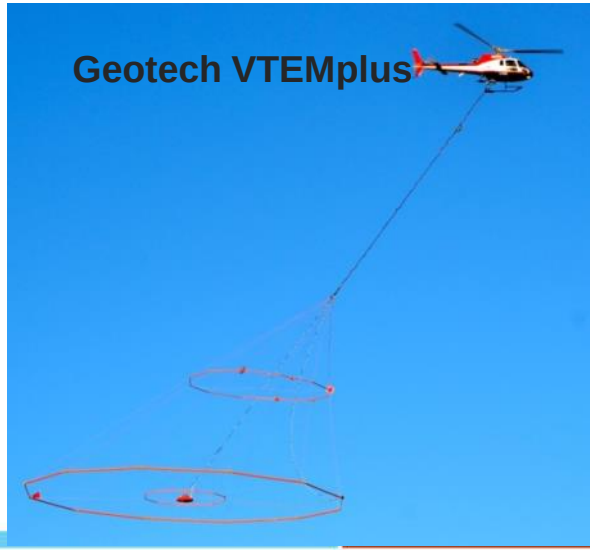


- Bryah Basin 2012 (GSWA)
- Capricorn Orogen 2014 (GSWA)
- Mt Isa AEM (GSQ)
- Water for Food Initiative
- Musgraves (GSSA)
- Spike in co-funding AEM (NTGS)

Equivalent investment by Industry
- infill geophysical surveys
- logging
- drilling
- mapping

GA AEM Impacts: AEM industry

- Influencing system development
- Increasing the scope of AEM beyond “traditional uses”
- Improving technical specifications
- Demonstrate mapping techniques
- Consultants selling value add prospect scale analysis
- Introducing new inversion algorithms (NCI, VGL)

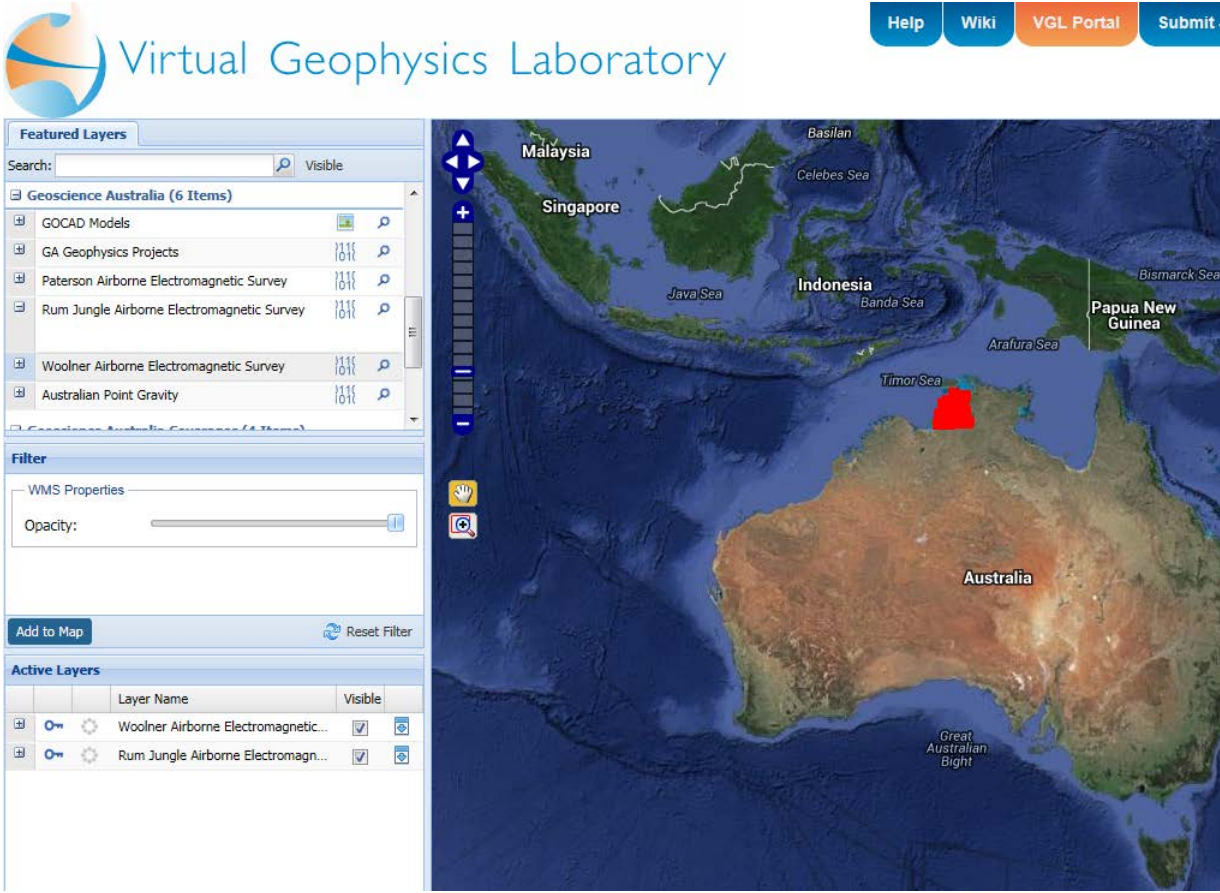


GA AEM Innovation:

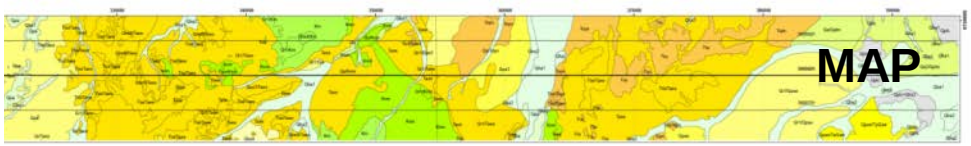
Computational Science

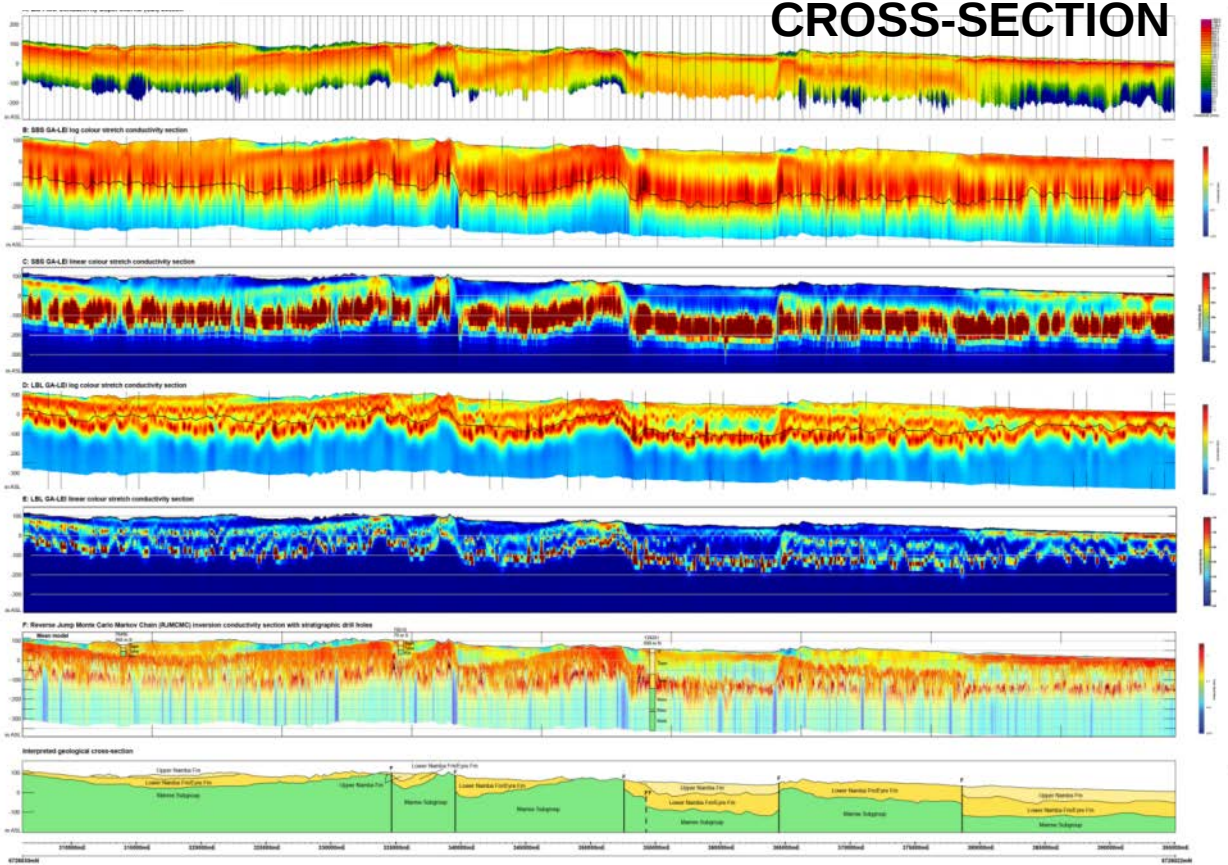
NCI
NATIONAL COMPUTATIONAL INFRASTRUCTURE

github
SOCIAL CODING



GA AEM Innovation: Inversions





Conclusions

Regional AEM data bridge the gap between where outcrop stops and where other geophysical models start

AEM data join the dots between sparse drillholes

AEM data can model the all-important basement-cover interface

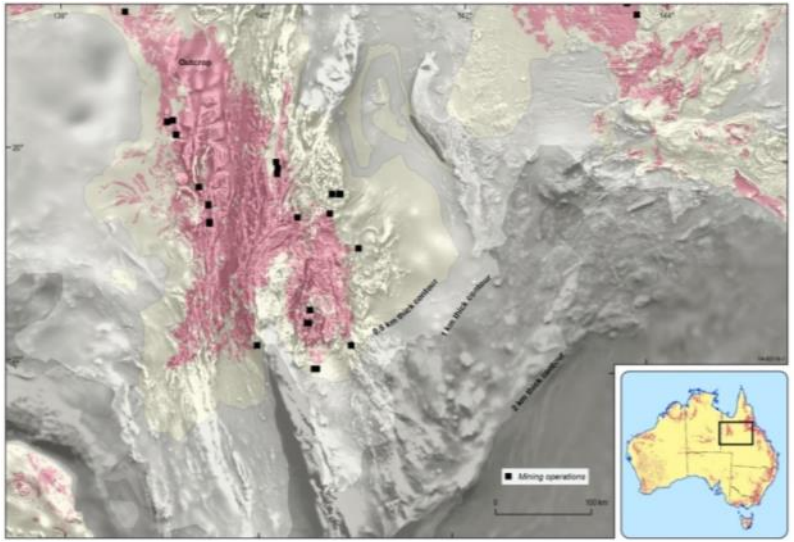
AEM data are ideally suited to exploration in the top ~300 m of the Earth's surface; explorable depths within easy reach of current drilling technology

Regional AEM data reduce exploration risk and stimulate investment by government and industry

SPECTREM Athol Franz

Australian Government
Geoscience Australia

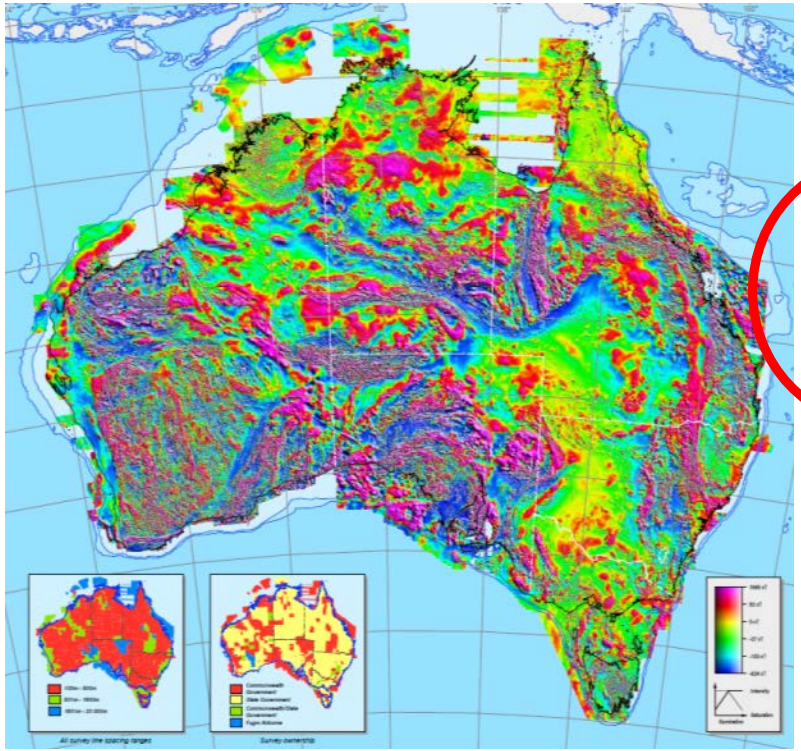
Geophysics applied to variable cover: benchmarking multiple methods to known depths



Tony Meixner, Aki Nakamura, Karol Czarnota, Alexei Gorbatov, Sarlae McAlpine, James Goodwin and Malcolm Nicoll

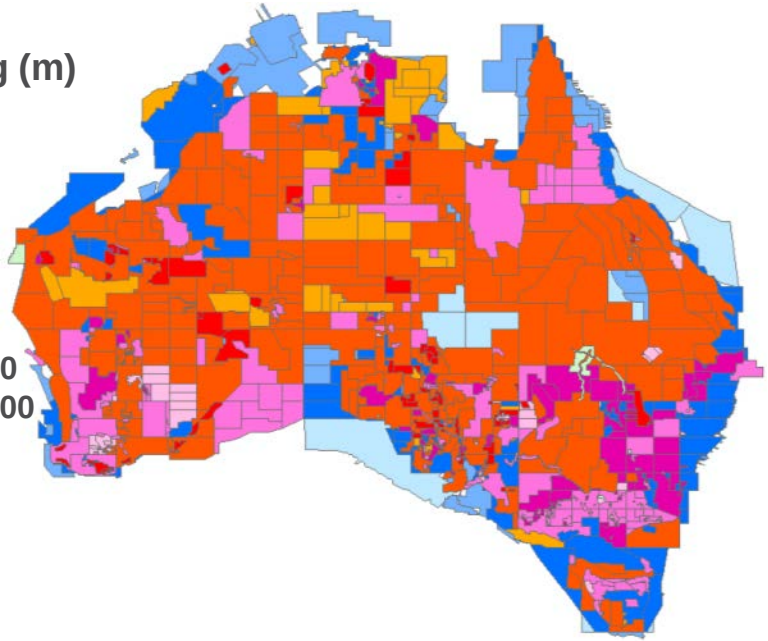
tony.meixner@ga.gov.au

Magnetic anomaly map of Australia

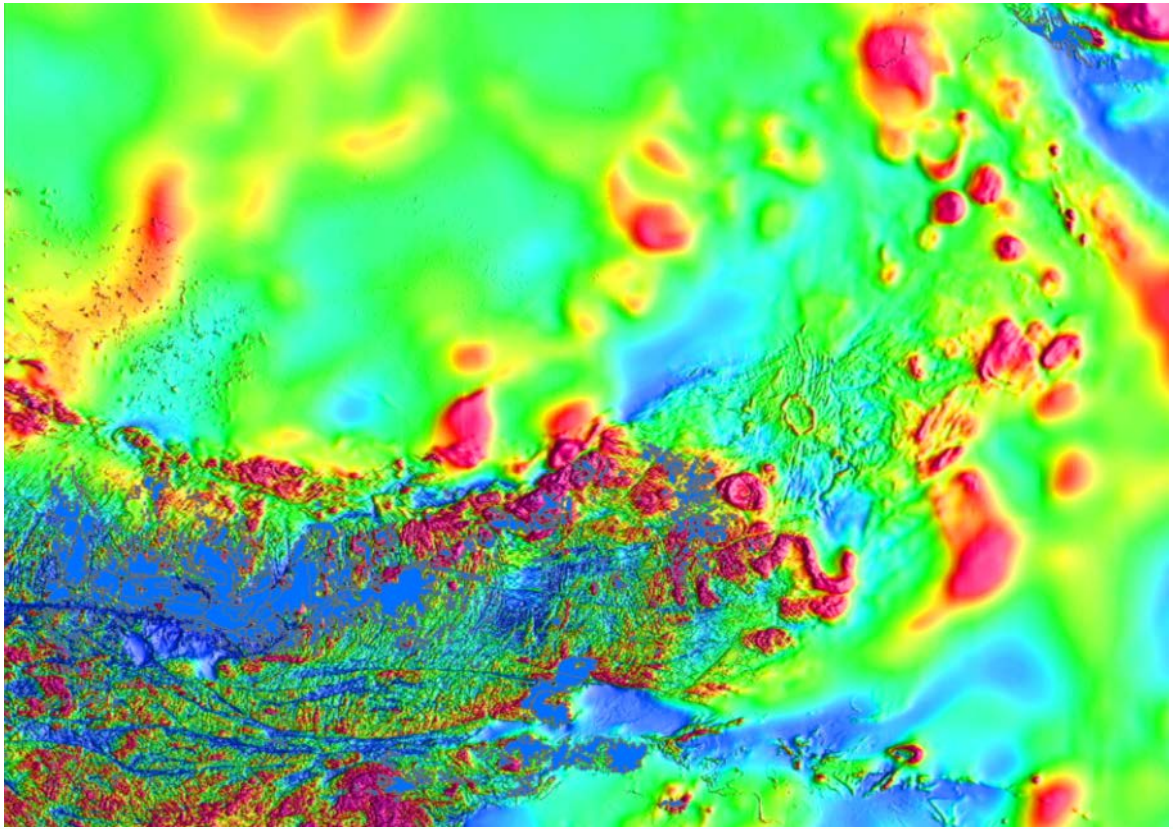


Line spacing (m)

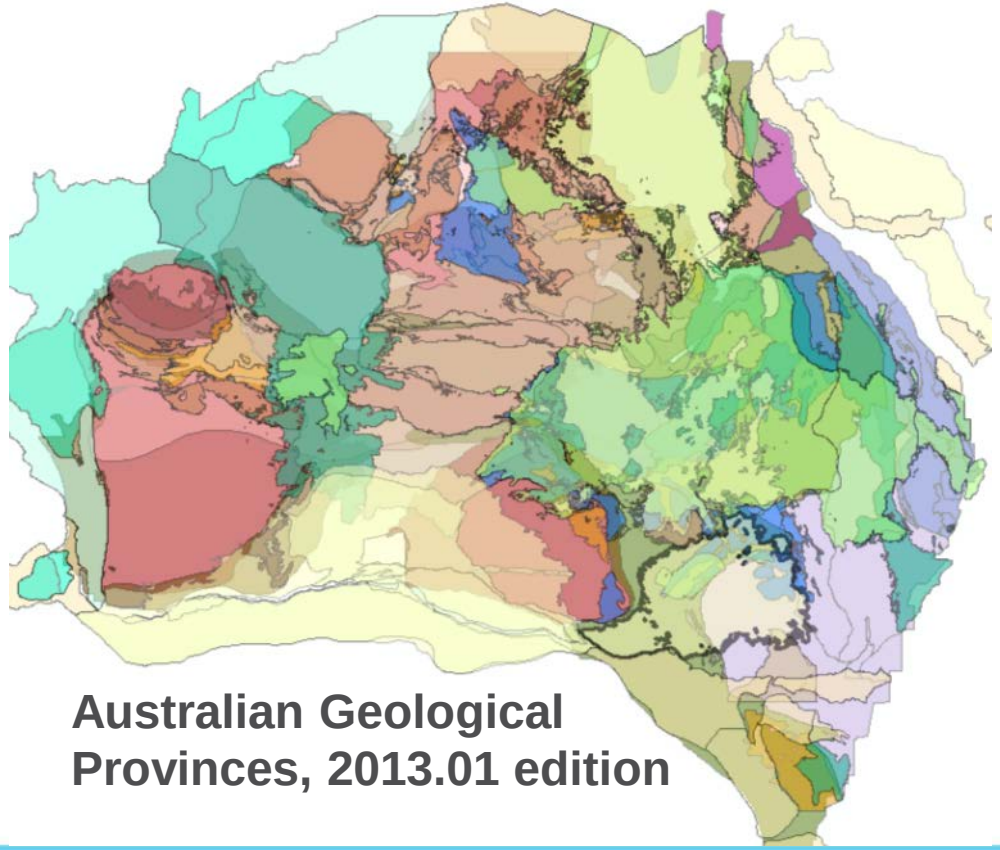
- 100
- 150, 200
- 250
- 300
- 400
- 500
- 600 to < 2000
- 2000 to < 4000
- >= 4000



Magnetic anomaly attenuation with depth



Benchmarking magnetic methods against drill-holes

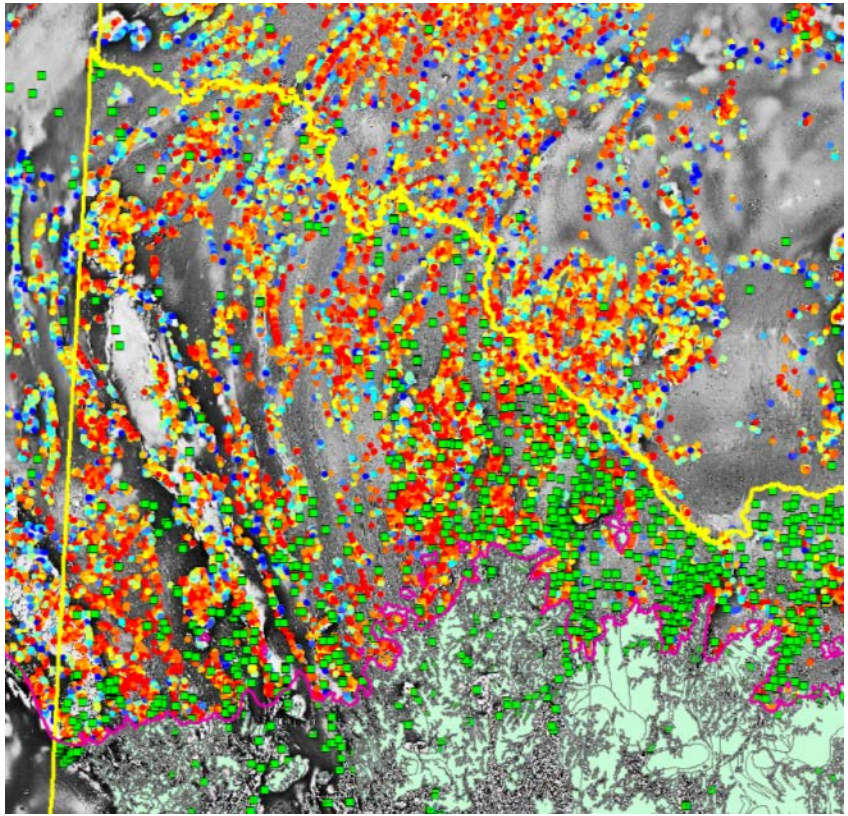


Australian Geological Provinces, 2013.01 edition

Depth to magnetic source method

- Targeted Inversion Modelling
- Naudy method
- Tilt depth
- Euler deconvolution
- (Spectral method)

Benchmarking: Magnetic tilt-depth estimates against drill-holes

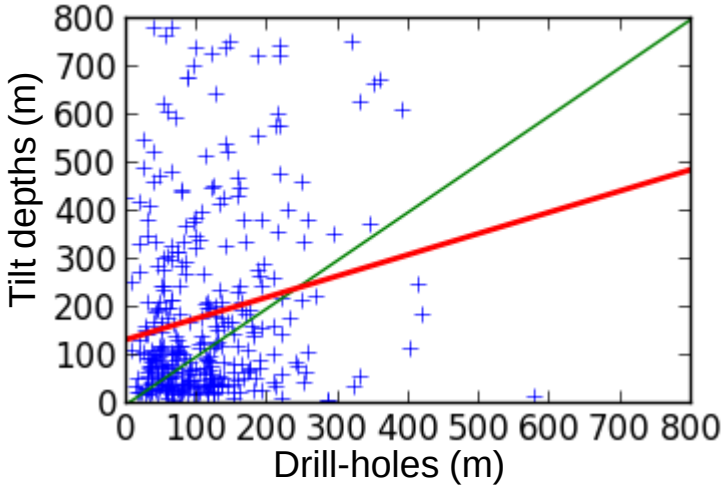


Basement intersecting Drill-holes

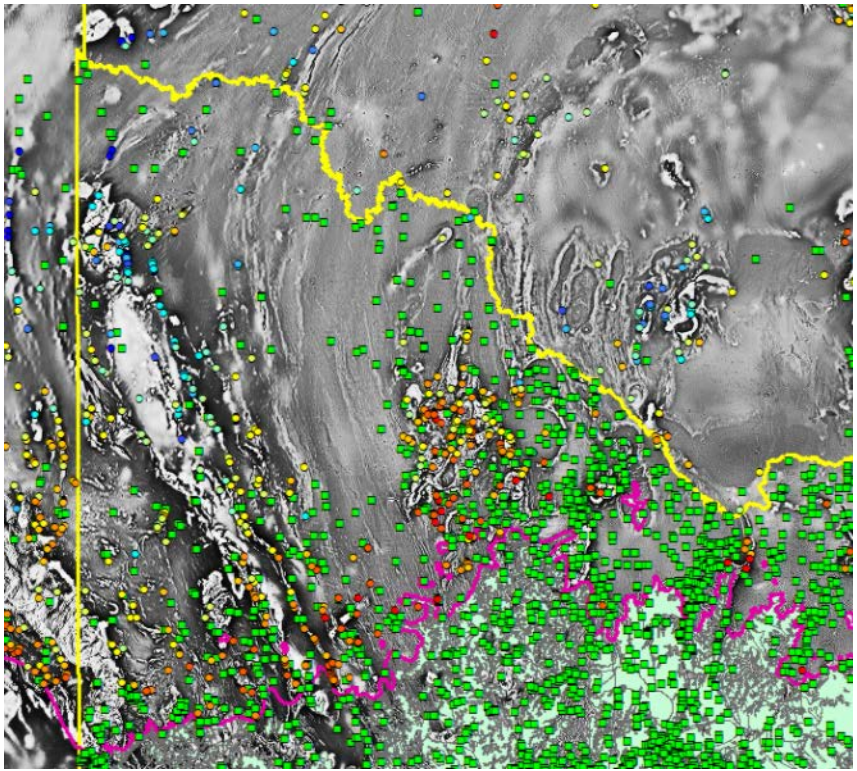
Tilt depths

- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650

Highly automated method:
$R^2 = 0.04$



Benchmarking: Naudy depth estimates against drill-holes

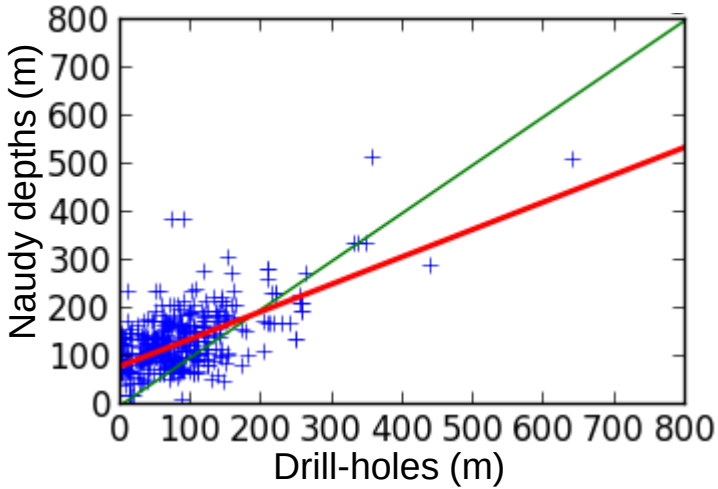


Basement intersecting Drill-holes

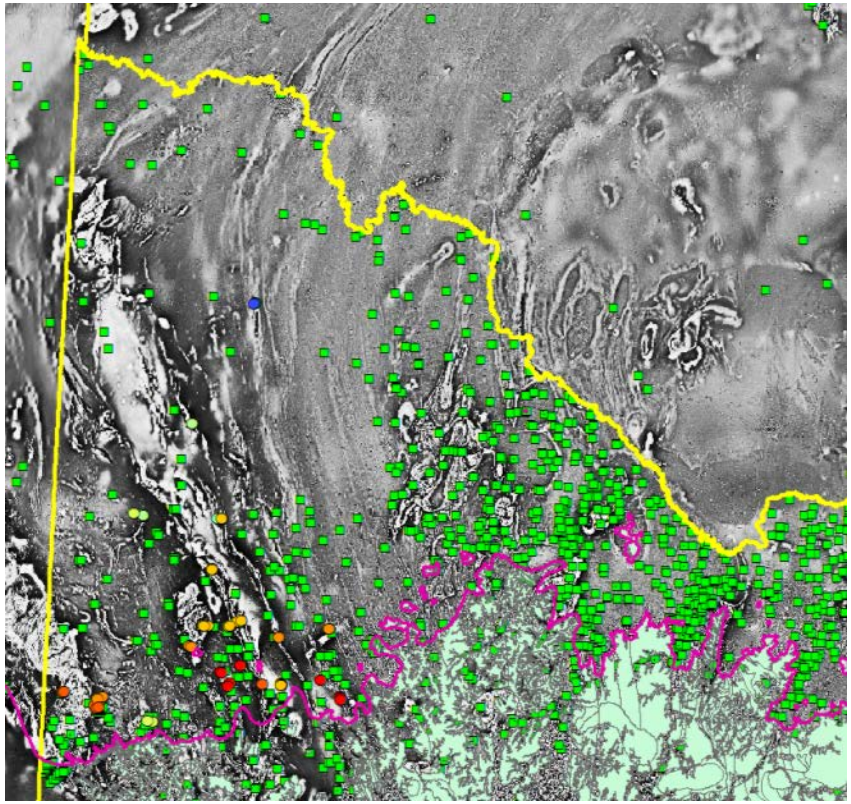
Naudy depths

- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650

moderately automated method:
$R^2 = 0.42$



Benchmarking: Targeted inversion modelling against drill-holes

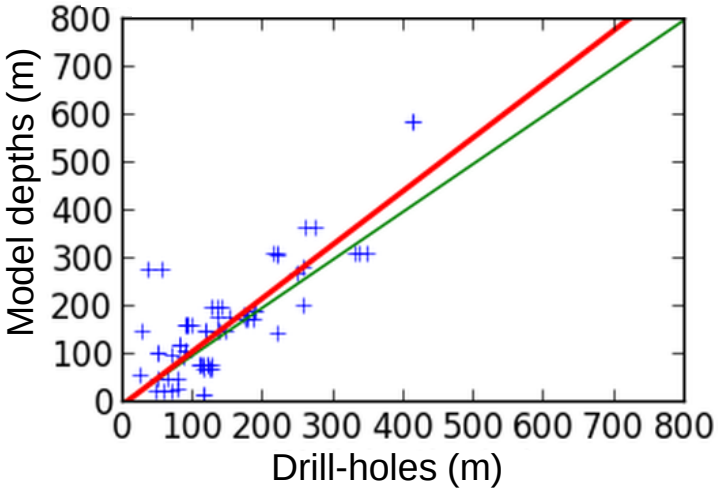


Basement intersecting Drill-holes

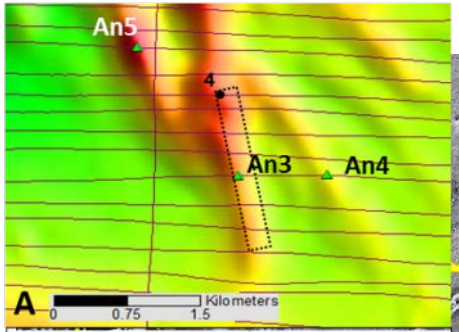
Model depths

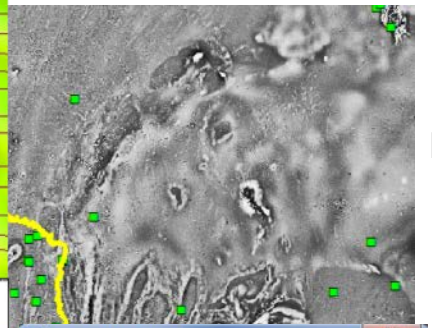
- 0 - 50
- 51 - 100
- 101 - 150
- 151 - 200
- 201 - 250
- 251 - 300
- 301 - 350
- 351 - 400
- 401 - 450
- 451 - 500
- 501 - 550
- 551 - 600
- 601 - 650

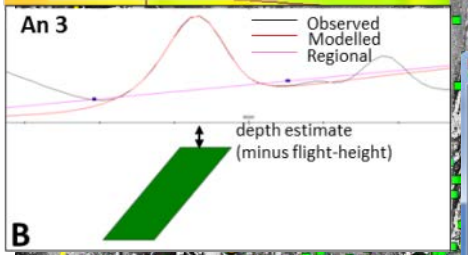
Hands on method:
$R^2 = 0.68$

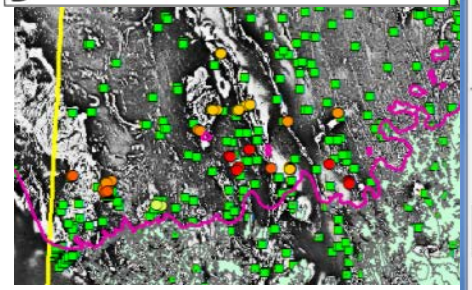


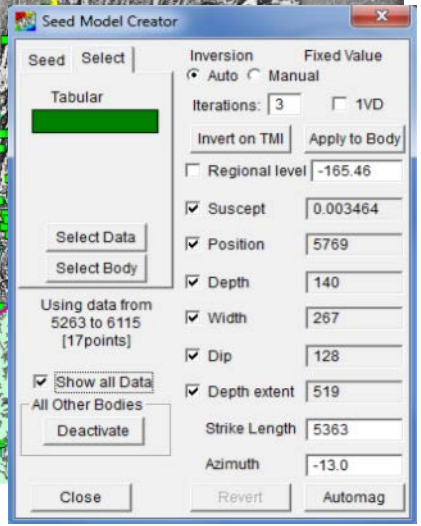
Benchmarking: Targeted inversion modelling against drill-holes











Basement intersecting Drill-holes

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- 501 - 550
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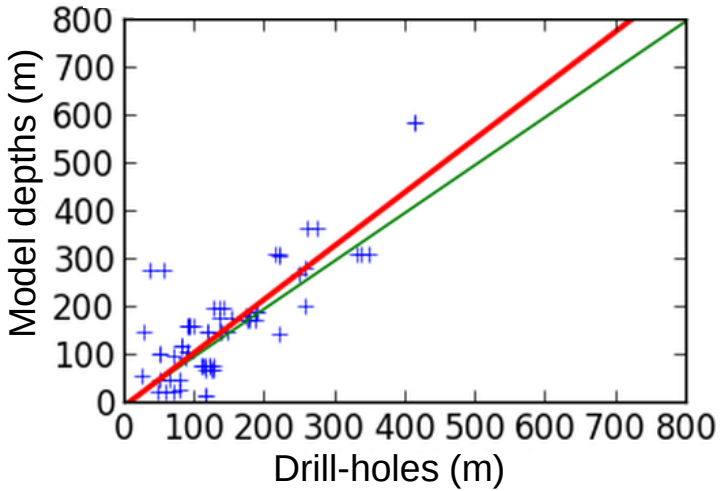
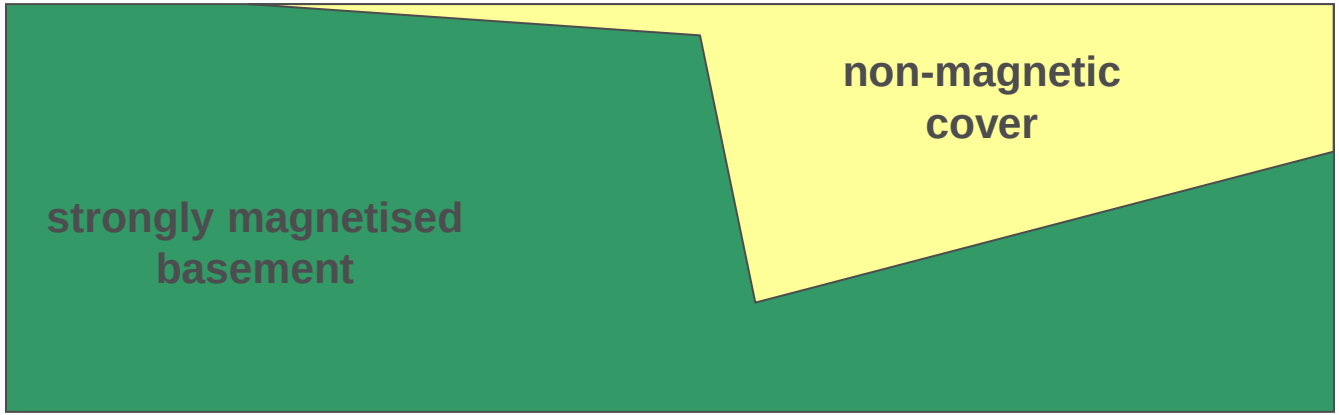
- 601 - 650

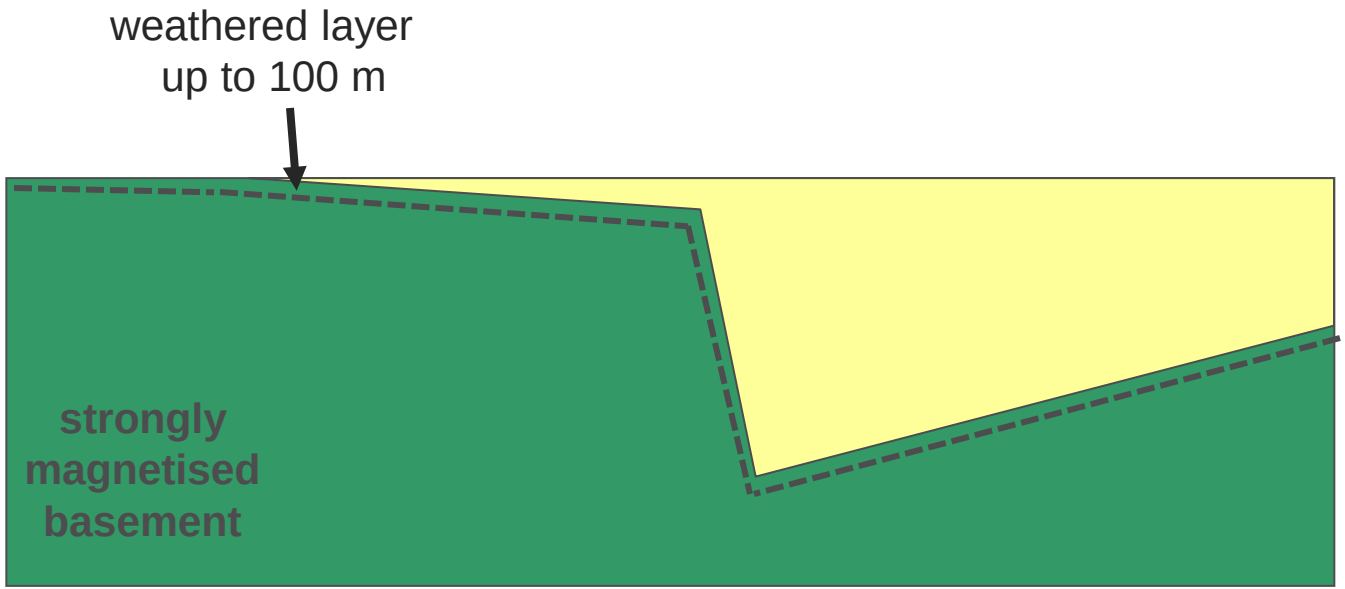
Hands on method:
$R^2 = 0.68$



Geological attributing



Geological attributing



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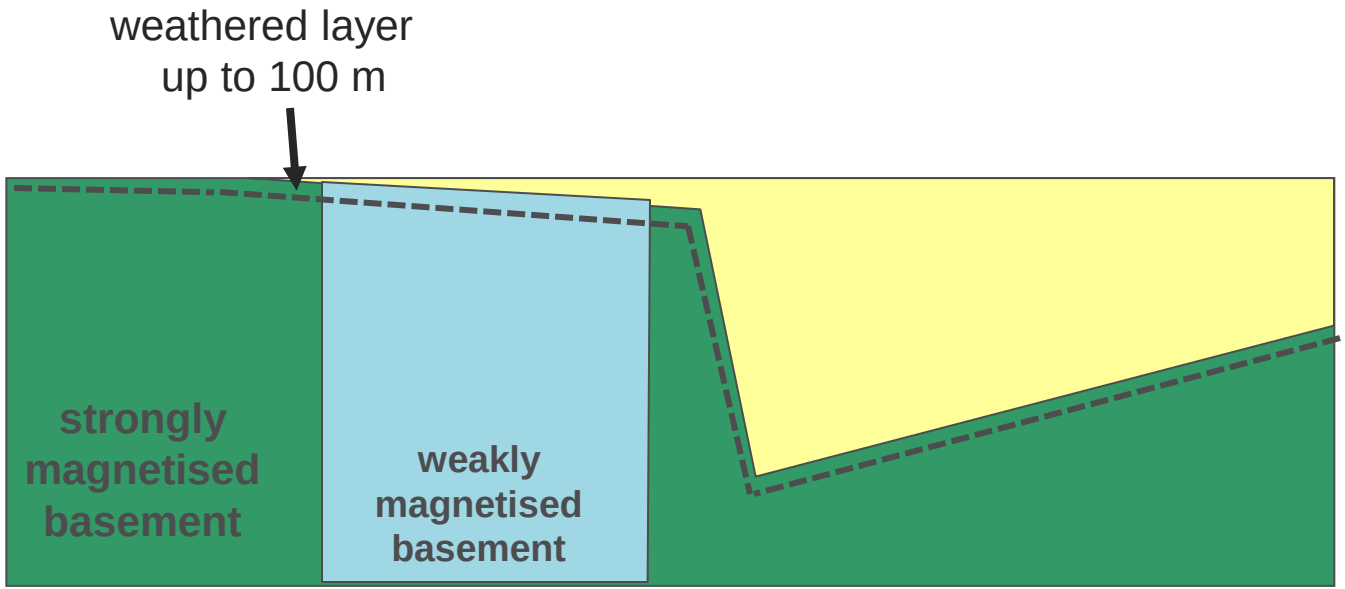
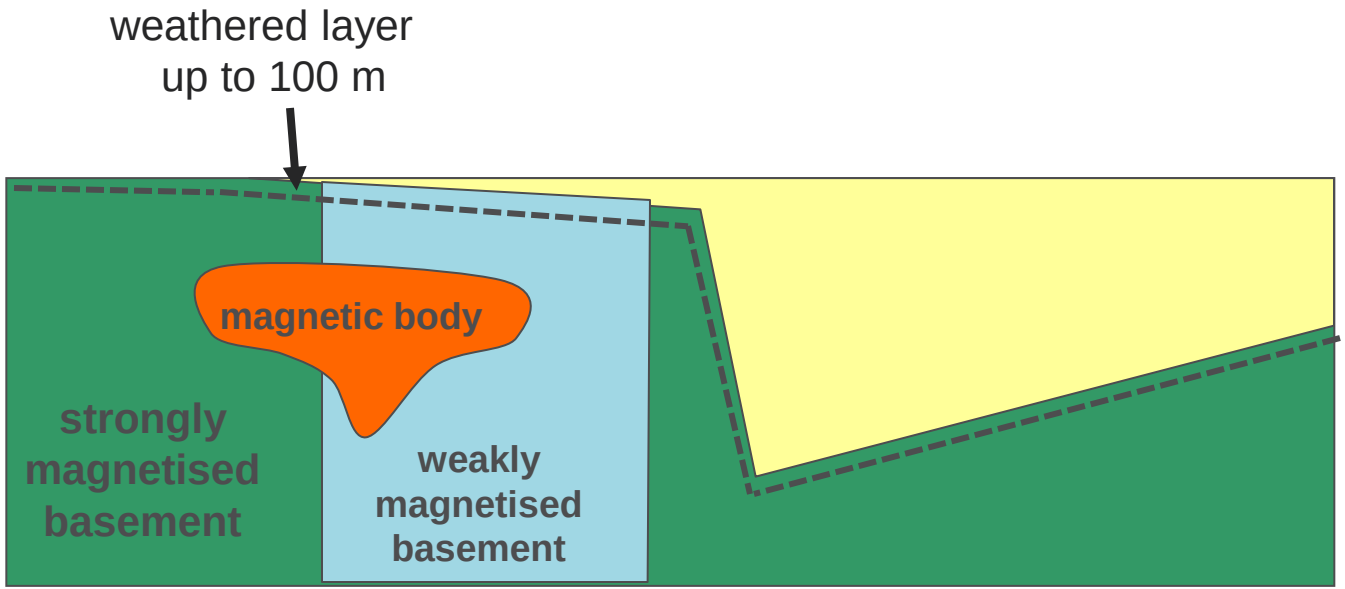
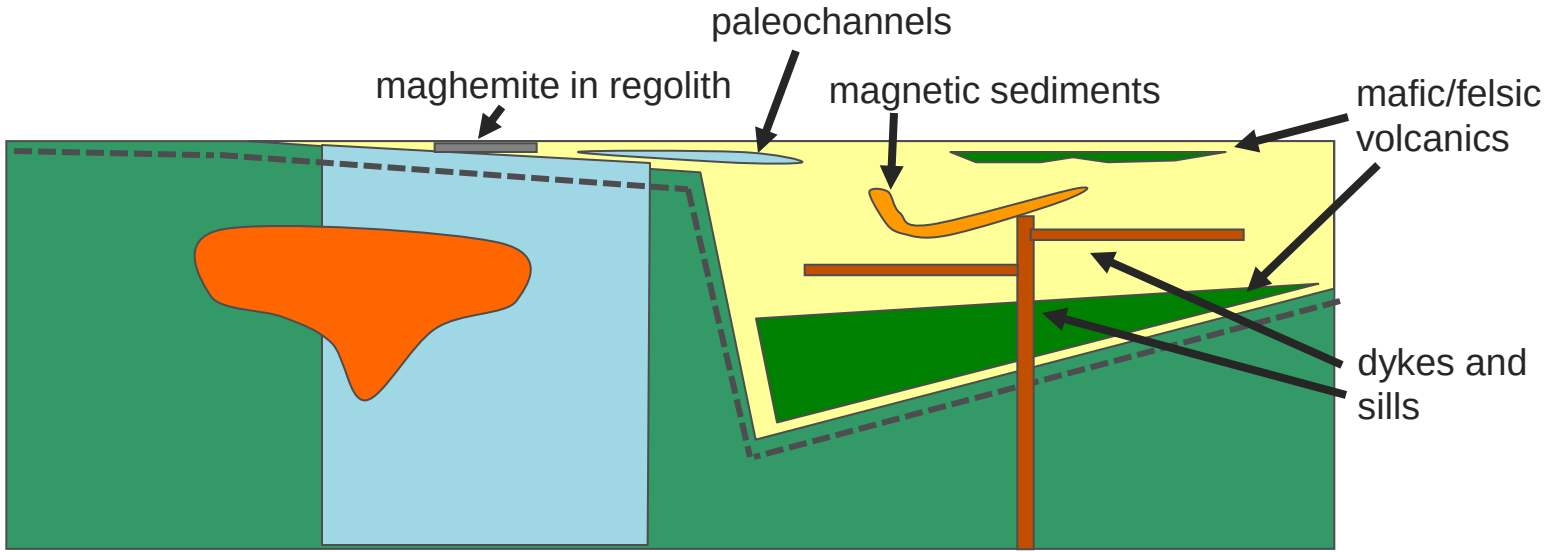


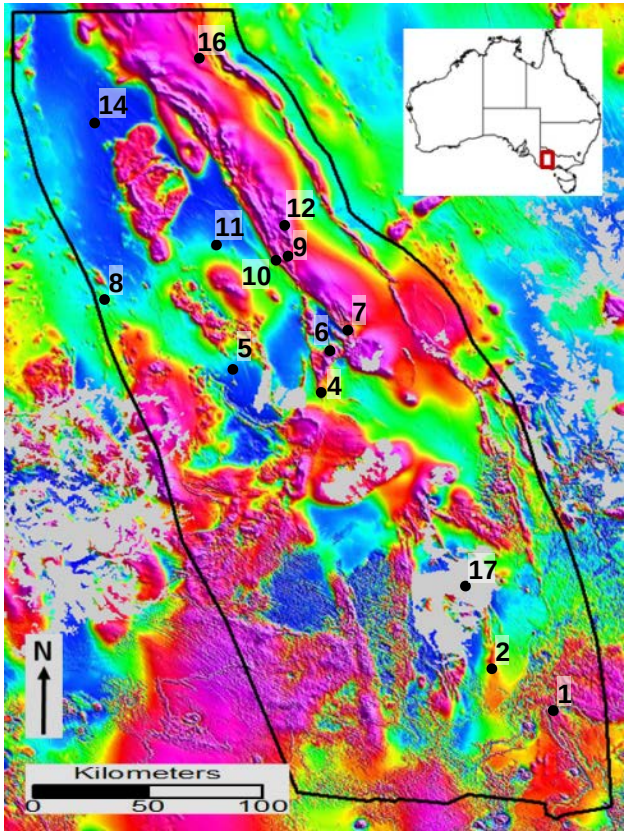
Geological attributing



Geological attributing



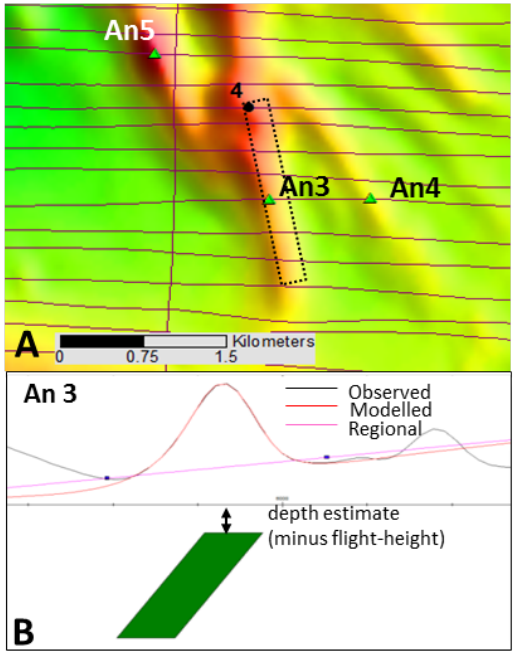
Stavely drilling project: pre-drilling geophysics

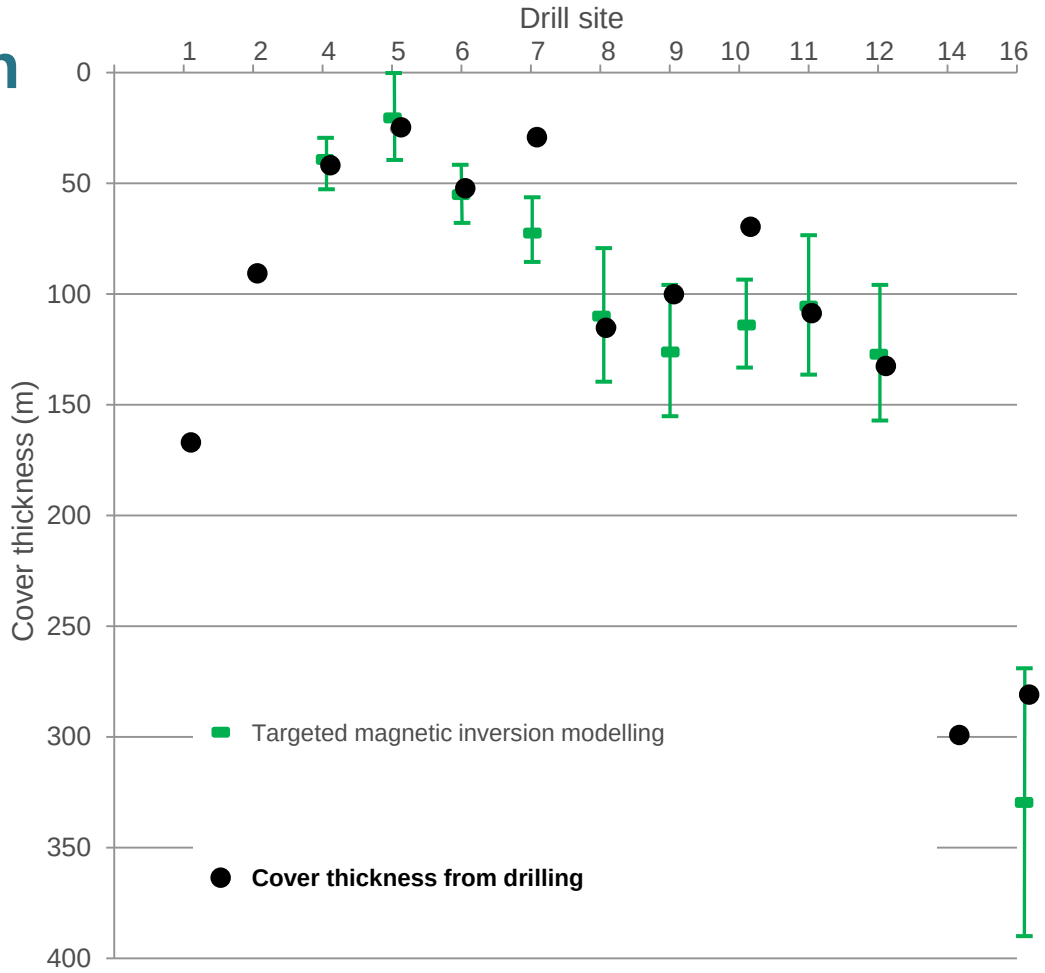


Objectives:

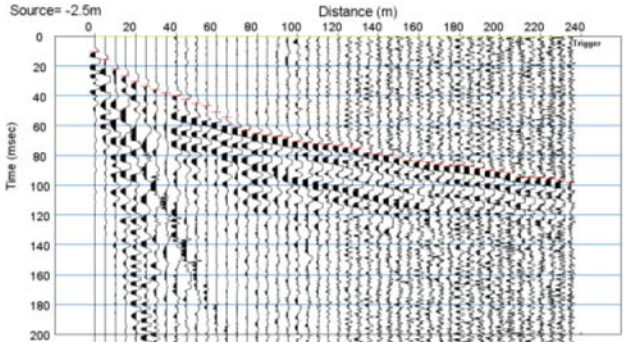
1. Estimate cover thickness – reduce the risk of drilling
2. Investigate a range of geophysical techniques – to provide a ‘tool kit’ for the explorer to delineate cover thickness in greenfield regions.

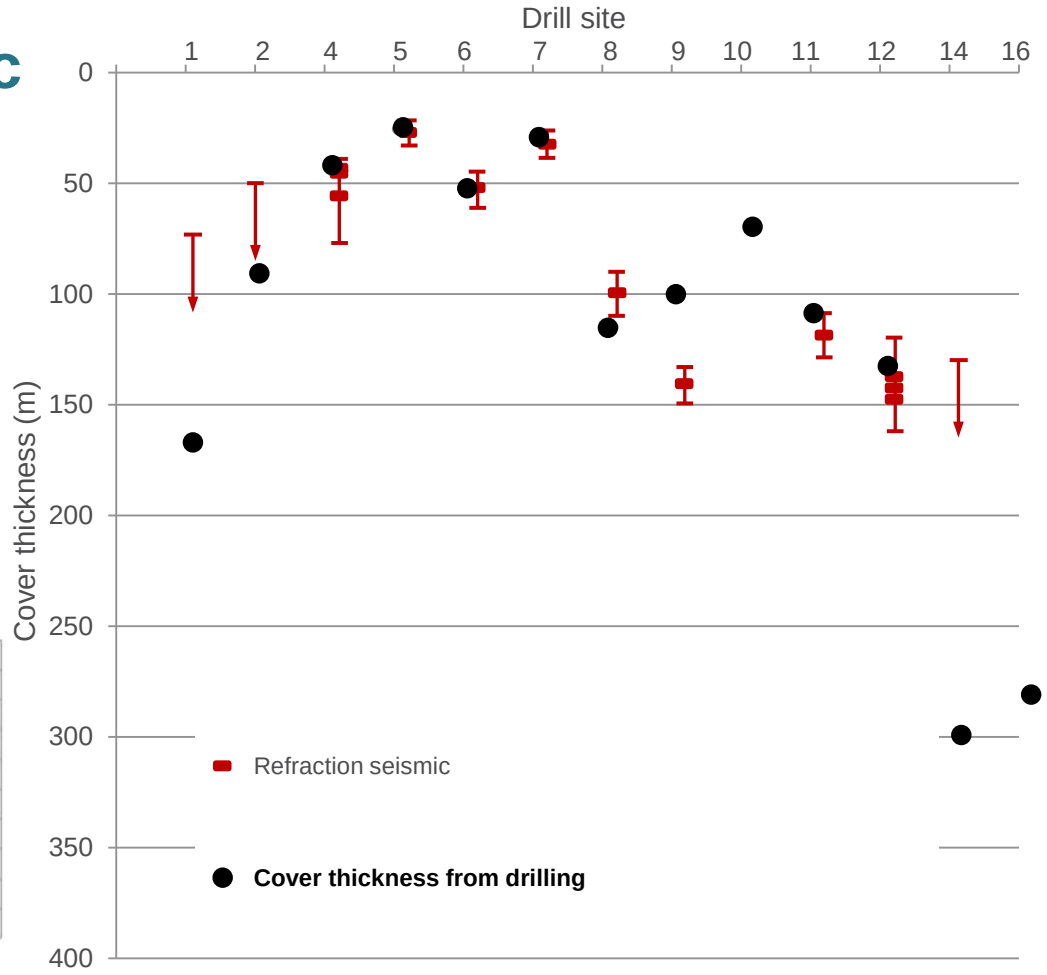
Targeted Inversion Modelling



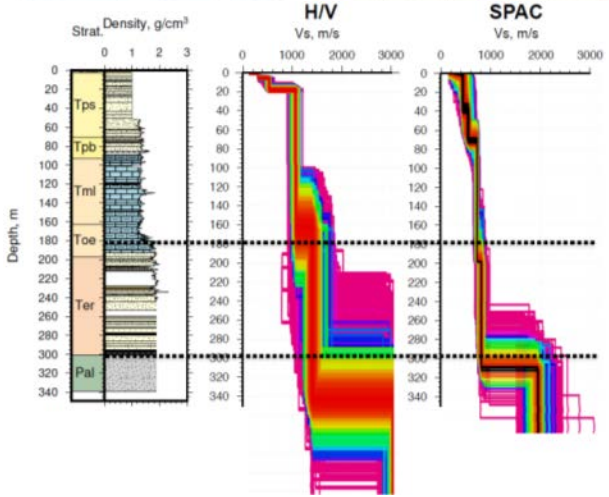


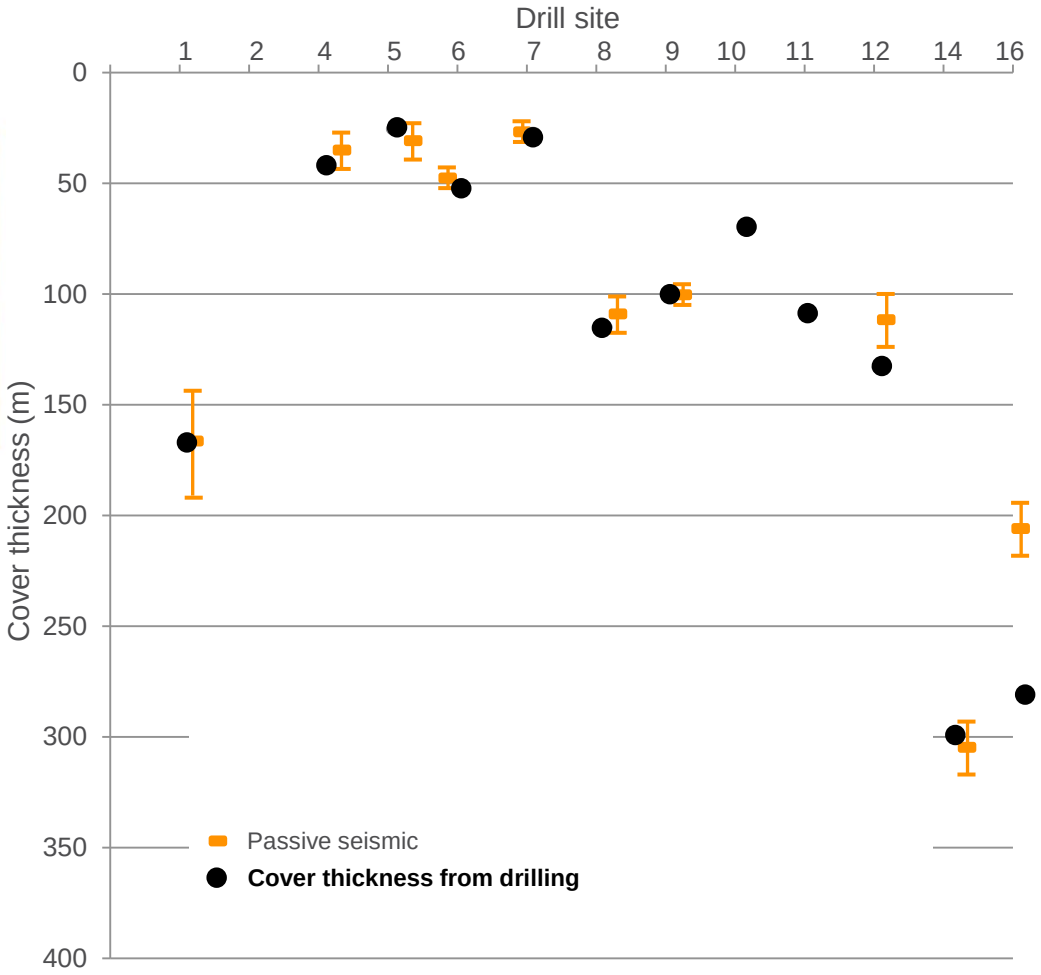
Refraction seismic





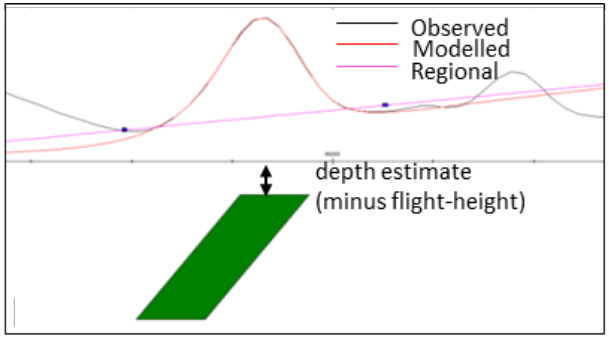
Passive seismic

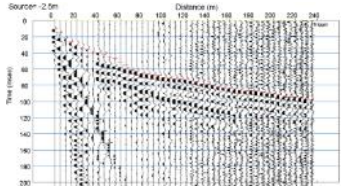


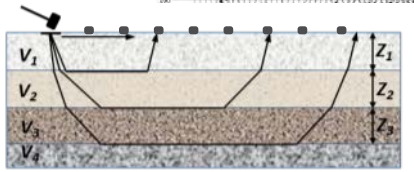


Conclusions

- Depth to magnetic source methods can provide cover thickness estimation across most of Australia
- Grid based methods produce low reliability results - flight-line based methods produce higher reliability results
- Magnetic depth estimates must be geologically attributed
- If need to know cover thickness accurately (e.g. prior to drilling) use local scale geophysical acquisition (refraction seismic, passive seismic, electrical resistivity, audio magnetotellurics)



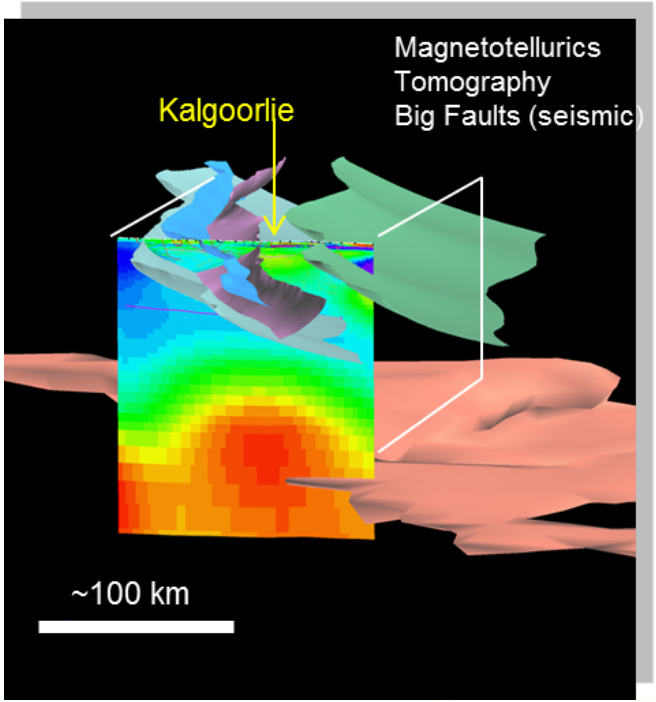




Theme 2: 3D architecture

Science problem: World class mineral deposits result from efficient focussing of metal, fluid and energy through the lithosphere into the upper crust.

What is the architectural record of these fluxes, especially under cover?



Solutions:

a) Map the lithospheric architecture

b) Define the crustal architecture

c) Integrate towards national 3D model

Australian Government
Geoscience Australia

Magnetotellurics:

Illuminating Australia's deep earth using all natural sources of electrical data

Jingming Duan, Leijung Wang, Millicent Crowe, Sarah Buckerfield, Tristan Kemp, *Richard Chopping*
richard.chopping@ga.gov.au

Talk outline

What is MT

How it relates to other electrical methods

Geoscience Australia's MT work, with examples

- Transects to complement seismic sections
- AMT augmenting AEM
- AusLAMP: Illuminating Australia's deep earth

Wrapping up – what about vectors to mineralisation?

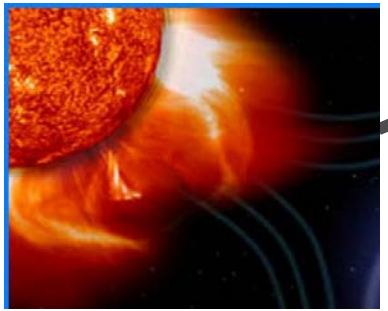
AusLAMP
Illuminating Australia's deep earth

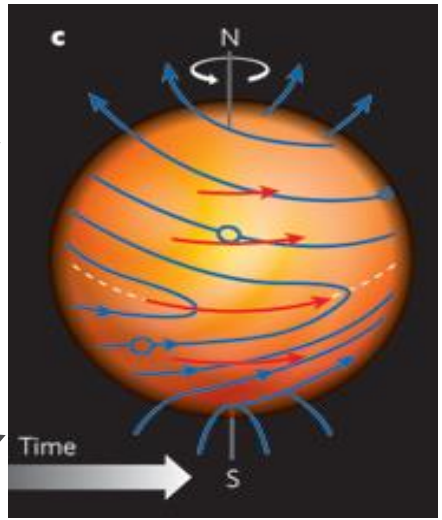
What is MT: the source of signals

THE INPUT

1. Lightning

2. Solar wind





Black box - Earth

>1 Hz from Spherics, generated by world-wide thunderstorms

F > 1Hz

F < 1Hz

<1 Hz from Earth's magnetic field variations with solar wind interactions

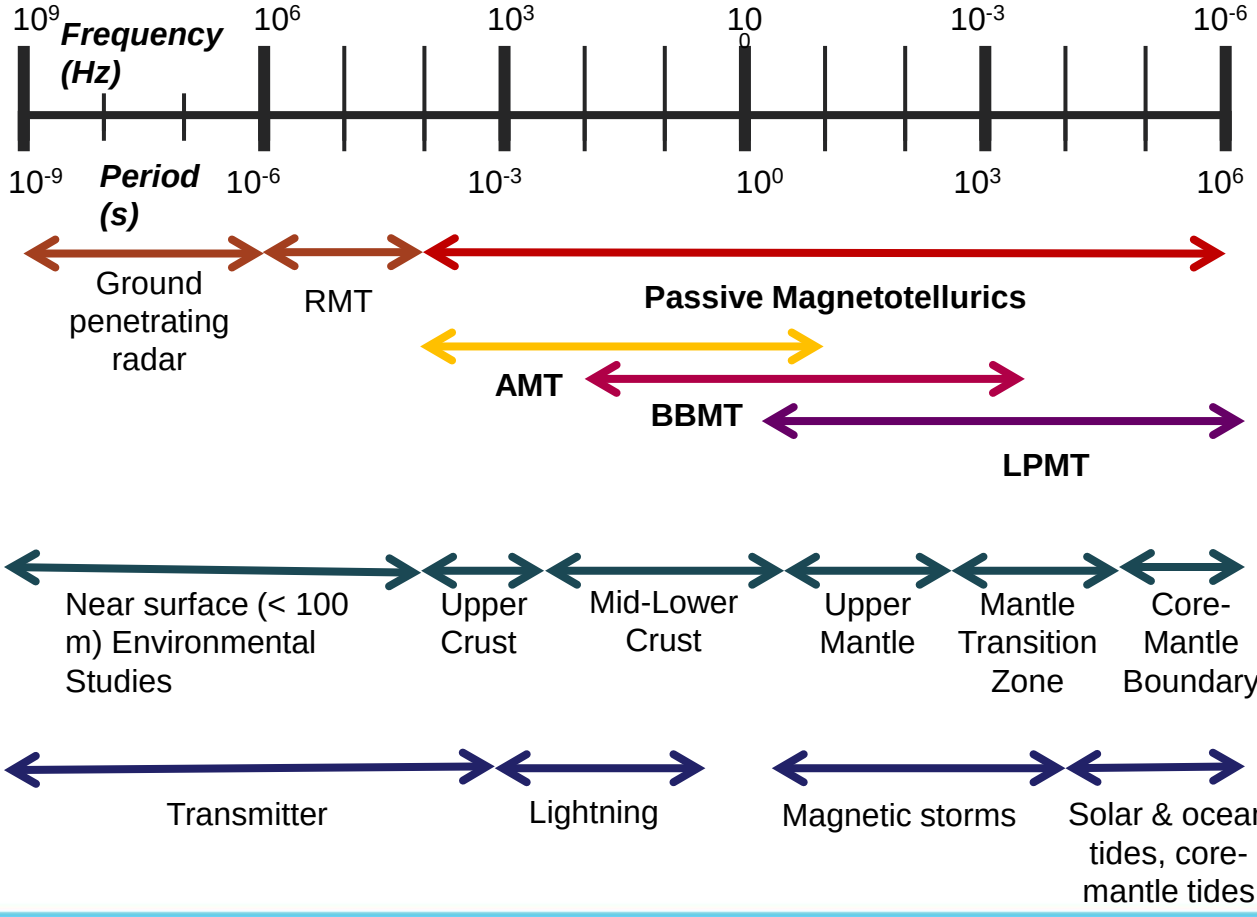
Measure time variations of electric (E) and magnetic (H) fields at the Earth's surface.

MT DATA

Objective: derive the geoelectric structures and relate it to geological structures and tectonics

THE OUTPUT

What is MT: the different flavours



Frequency Period

Techniques

RMT: Radiomagnetotellurics

AMT: Audiomagnetotellurics

BBMT: Broadband magnetotellurics

LPMT: Long-period magnetotellurics

Areas of investigation

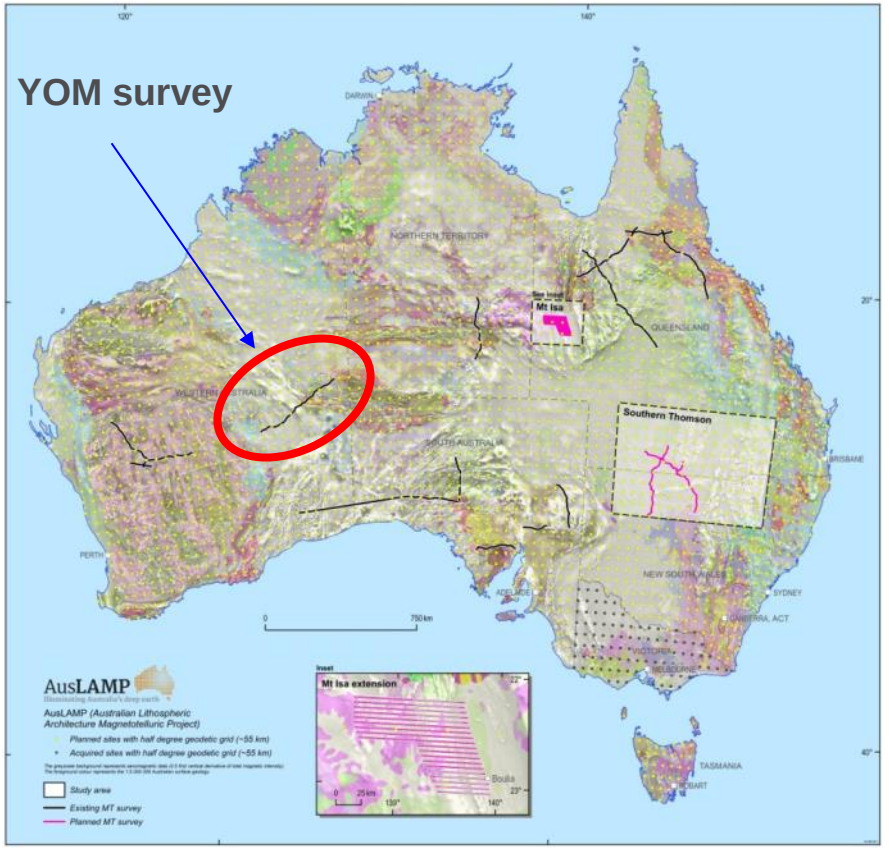
Signal sources

Geoscience Australia's MT program

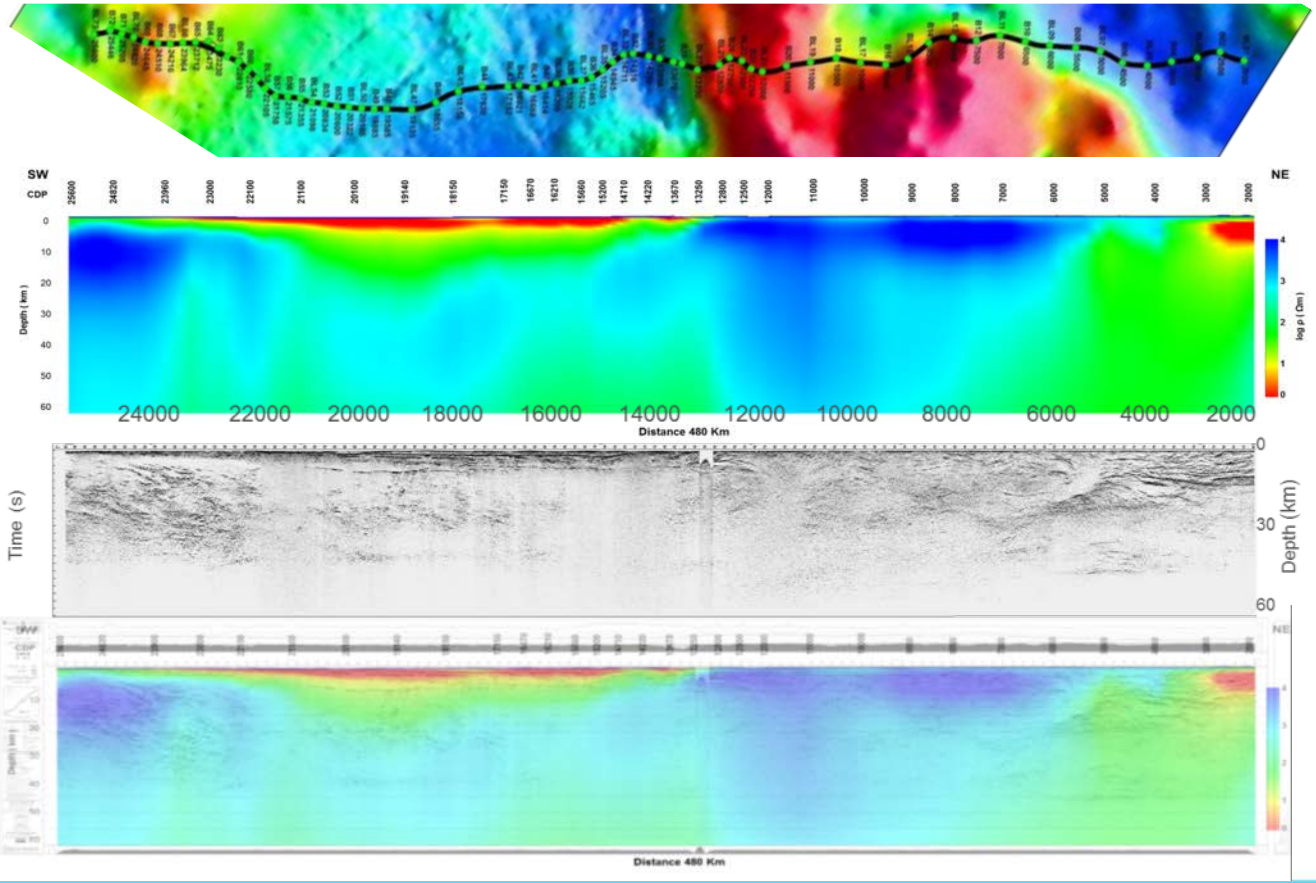
- Large-scale regional and national MT surveys to investigate crustal and lithospheric architectures in Australia
- 16 regional surveys (more than 3000 sites) across potential mineral provinces and frontier sedimentary basins
- The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP) is a collaborative national survey for acquiring LPMT data at approximately 2800 sites with a ~50 km grid spacing

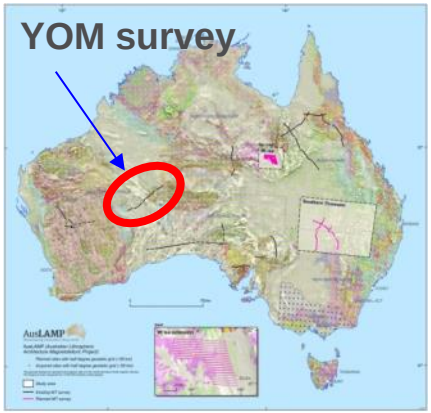
MT complementing deep reflection seismic transects

- Yilgarn Craton, western Officer Basin and western Musgrave Province (YOM) MT survey results released to public in 2013
- 73 broadband (BBMT) and 31 long-period (LPMT) sites
- These MT data complement other datasets

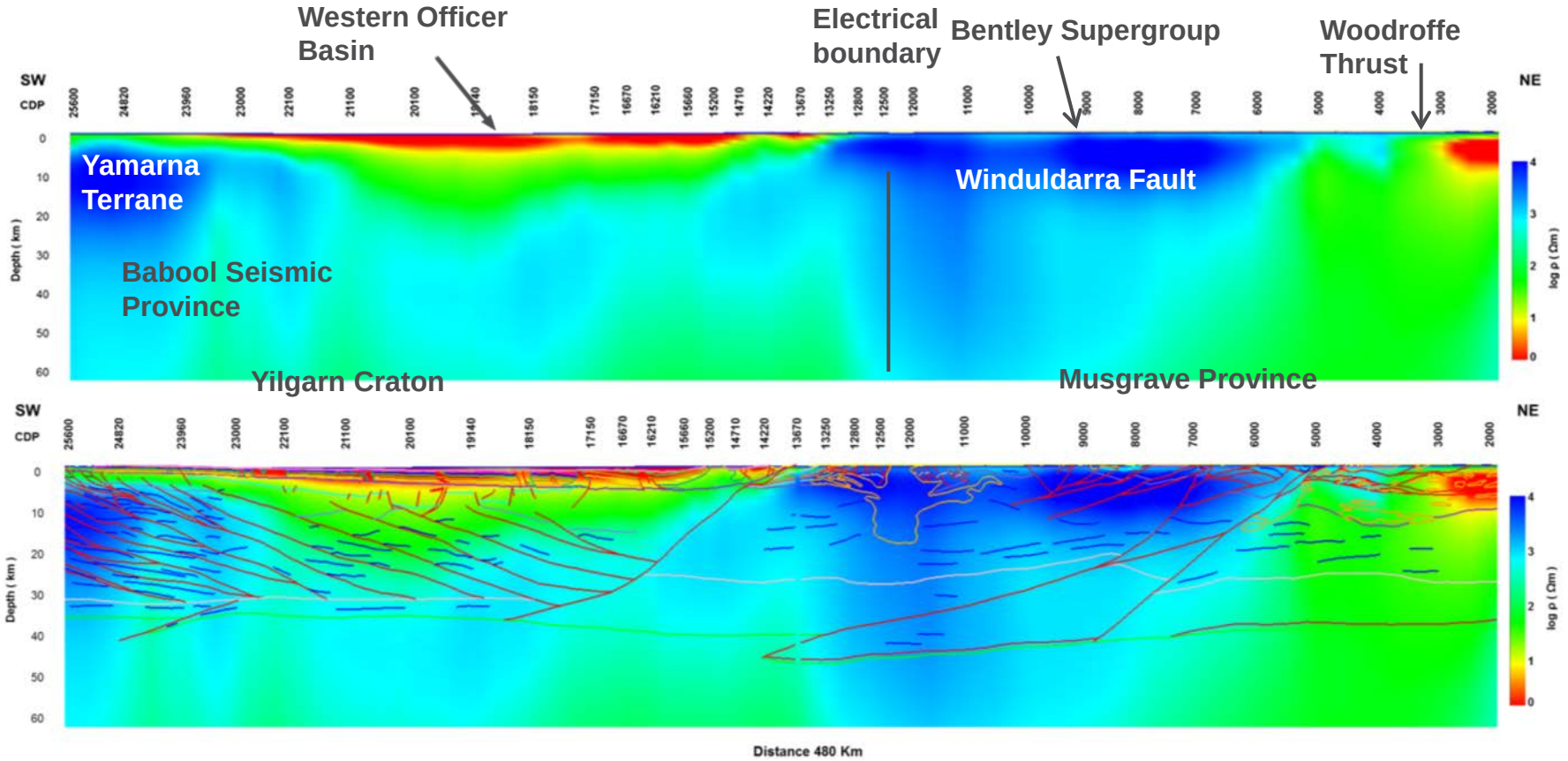


MT complementing deep reflection seismic transects

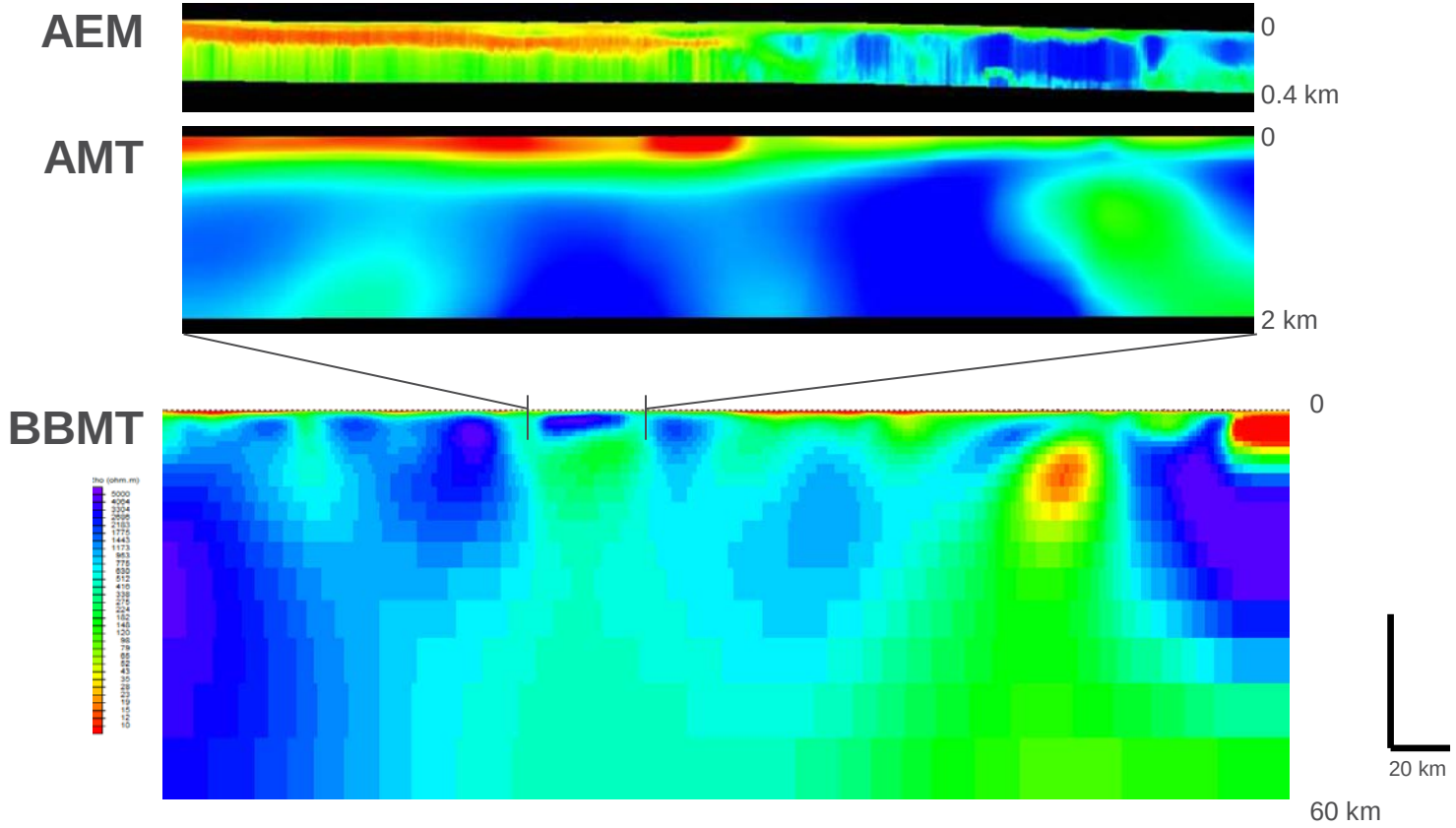




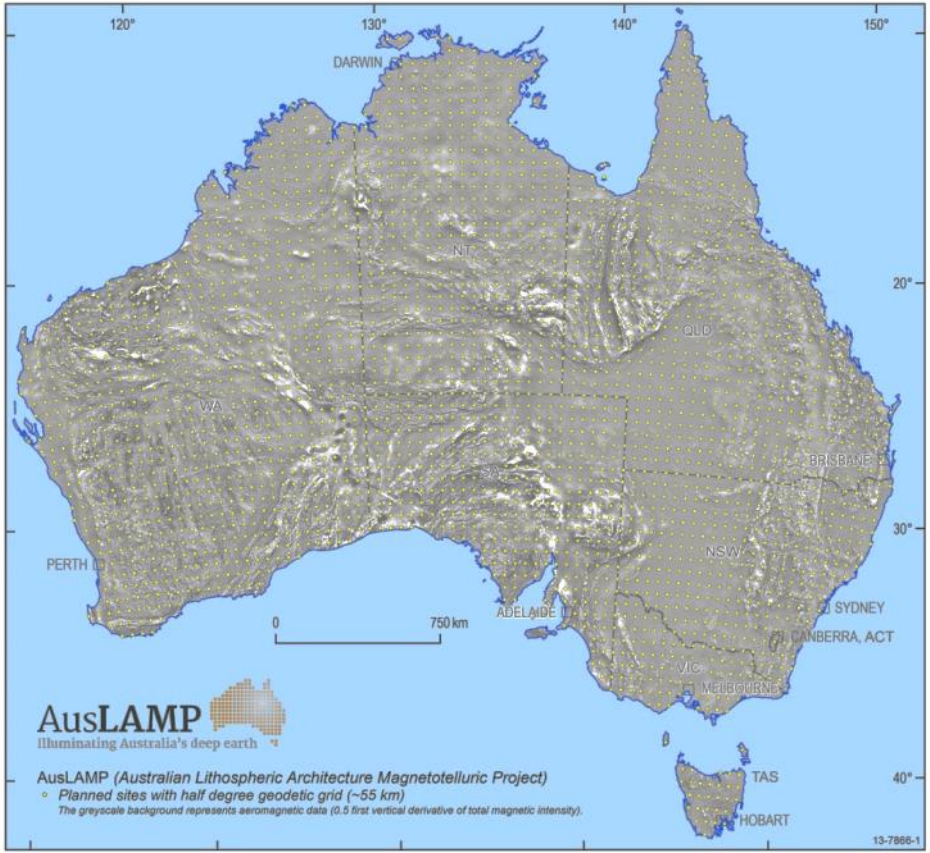
MT complementing deep seismic transects



MT to augment AEM



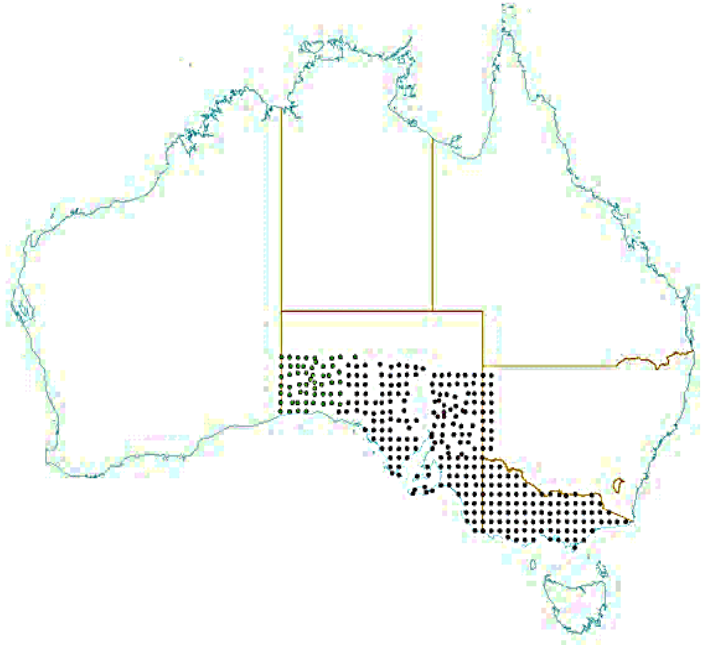
AusLAMP



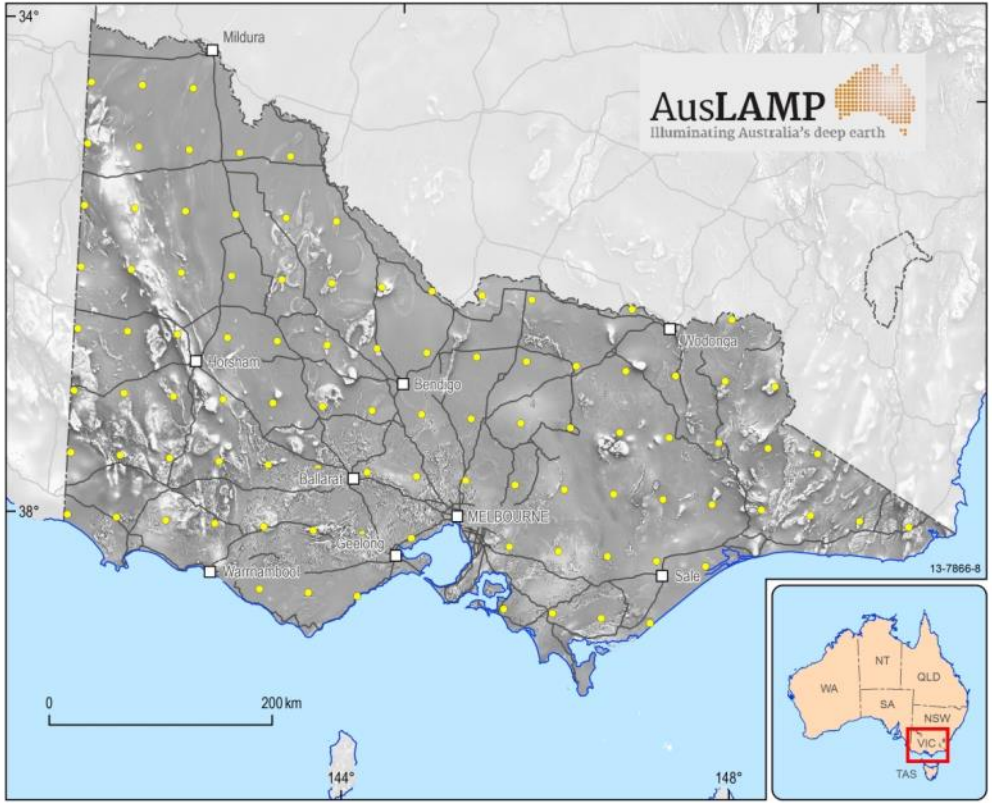
The Australian Lithospheric Architecture Magnetotelluric Project (AusLAMP), aims specifically to illuminate Australia's deep electrical structure

LPMT ~2800 sites with a ~50 km grid spacing

AusLAMP-VIC is the first survey for the project.

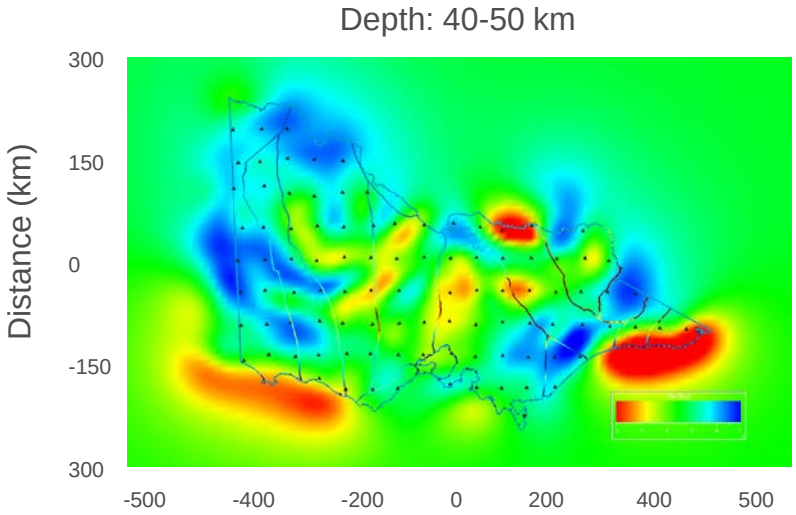


AusLAMP: Victoria

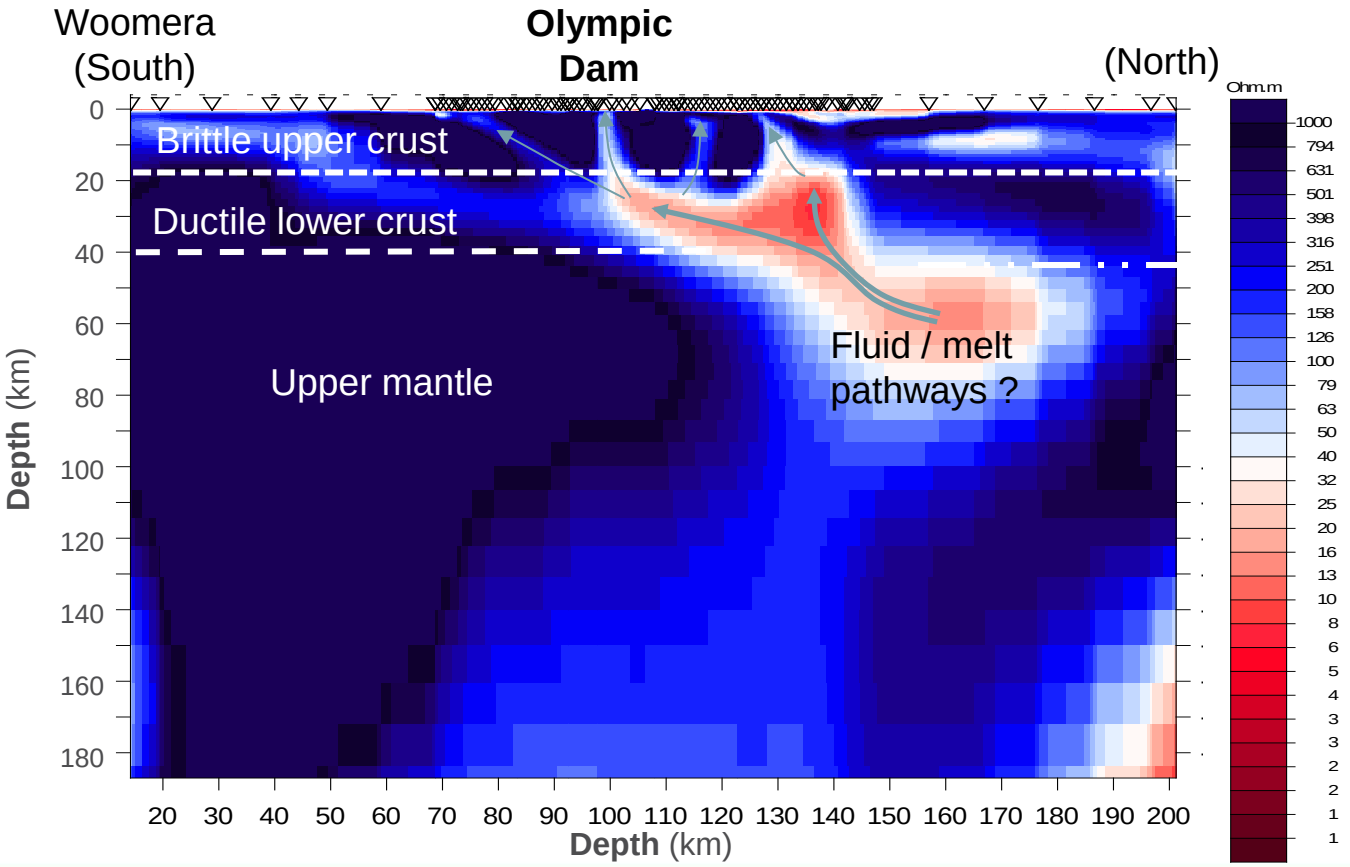


AusLAMP *(Australian Lithospheric Architecture Magnetotelluric Project)*
Planned sites with half degree geodetic grid (~55 km)
The greyscale background represents aeromagnetic data (0.5 first vertical derivative of total magnetic intensity).

- 7 months for data acquisition
- 4 months for data processing
- Data analysis and modelling are in progress
- Data release due very shortly!



MT and mineralisation…



Example from Graham Heinson, University of Adelaide

High resolution LPMT across the Stuart Shelf

Highlights alteration pathways in the lithosphere beneath Olympic Dam

Although the LPMT deployments for AusLAMP cannot reach this resolution in the upper crust, they can resolve the broad scale features that are indicative of mineralised terranes

GA MT work program 2015-2016

AusLAMP is our priority going forwards for the broadest scale electrical structures across Australia

Working with states to acquire more regional scale broadband data as required, e.g. Cloncurry and Southern Thompson regions

Working with research organisations on further developments to processing and modelling

- Standards for MT products
- Better utilisation of high-performance computing for MT

Web based delivery of data and model products

In short: lots of stuff to do, lots of good stuff to come from it!

Conclusions

MT adds considerable knowledge to the structure of Australia

MT results are directly comparable with other datasets

Our final unknown property is conductivity

AusLAMP well underway with Victoria and 50% of SA completed (70% by EoY)

Potential to map structures unobserved in other datasets

Contact us for further info: richard.chopping@ga.gov.au or magnetotelluric@ga.gov.au

Australian Government
Geoscience Australia

The seismic database of Australia: A continent in cross section

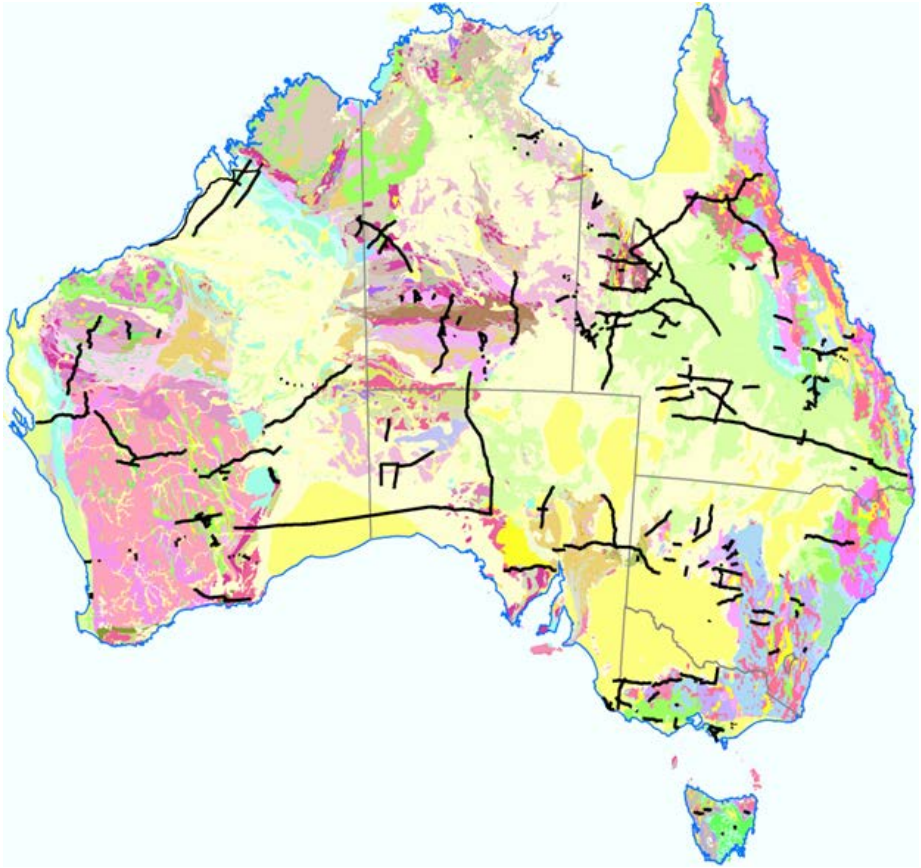
Onshore Seismic and MT Section

Ross.Costello@ga.gov.au

The Deep Crustal Seismic Data

Deep Crustal Seismic (Refraction and Reflection) since 1950's

Digital recording of Reflection Seismic Lines collected by BMR/AGSO/GA in collaboration with state geological surveys
1976 – 2015



Surveys

Deep Crustal

Reflection Seismic

Lines

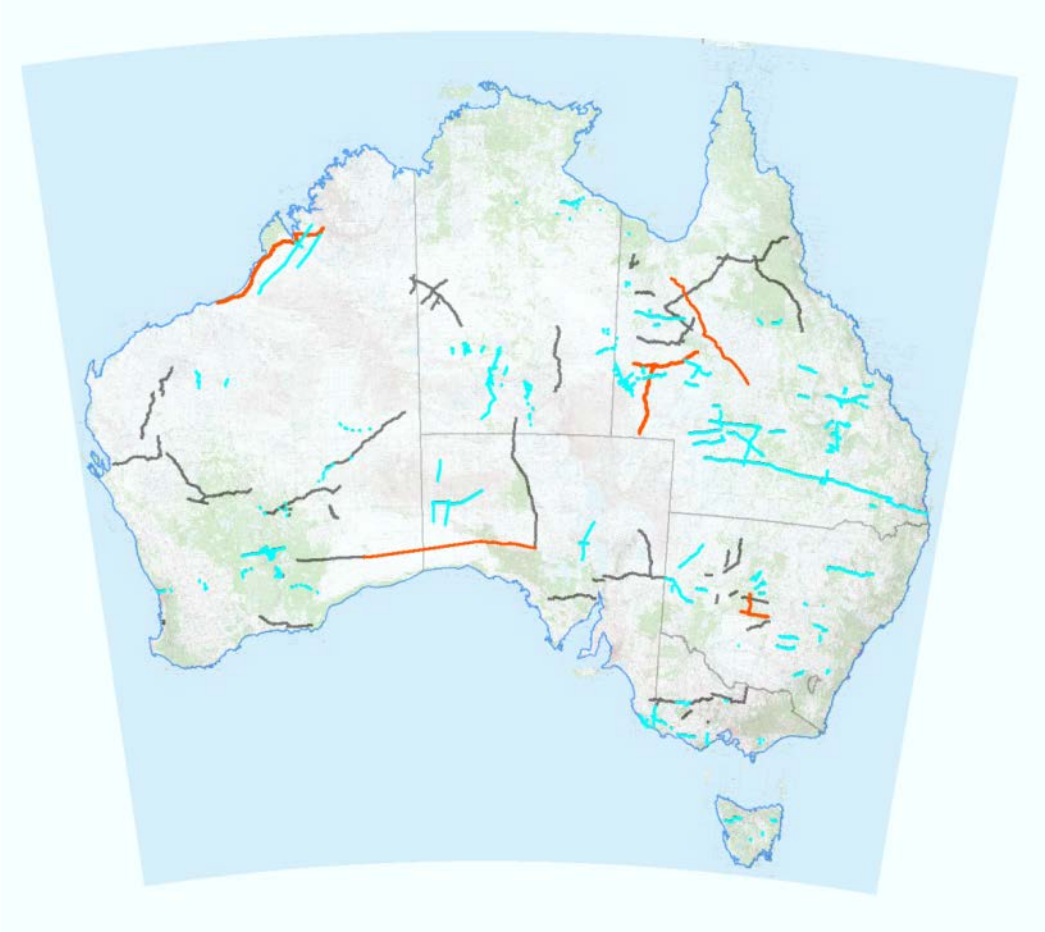
Explosives

1976-1999

Vibroseis

1999-2013

2013-2015



Surveys

Deep Crustal Reflection Seismic

Energy Source

Pre 1999 – Explosives

Georgina Basin 1977

Eastern Lachlan 1997

Surveys

Deep Crustal Reflection Seismic

Energy Source

From 1999 – Vibroseis

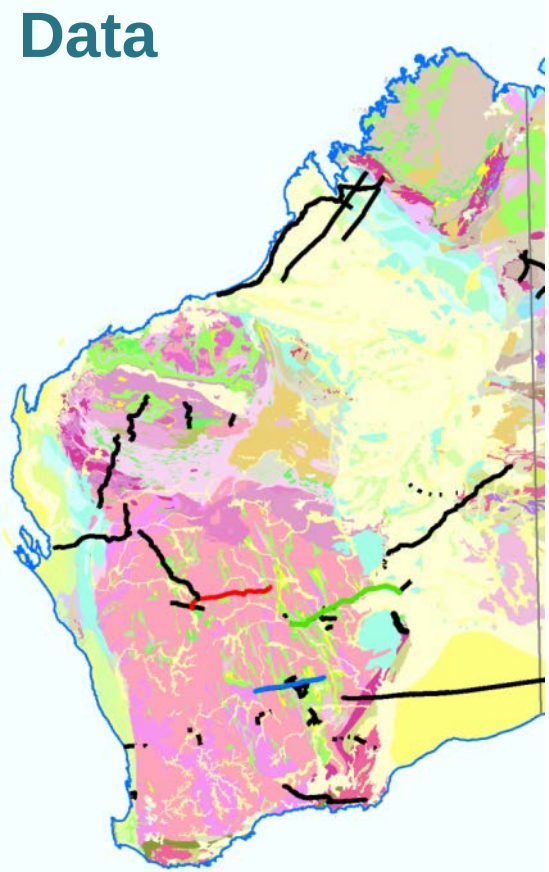
The Deep Crustal Seismic Data

Progress of acquisition and processing

BMR91-EGF1 (explosives)

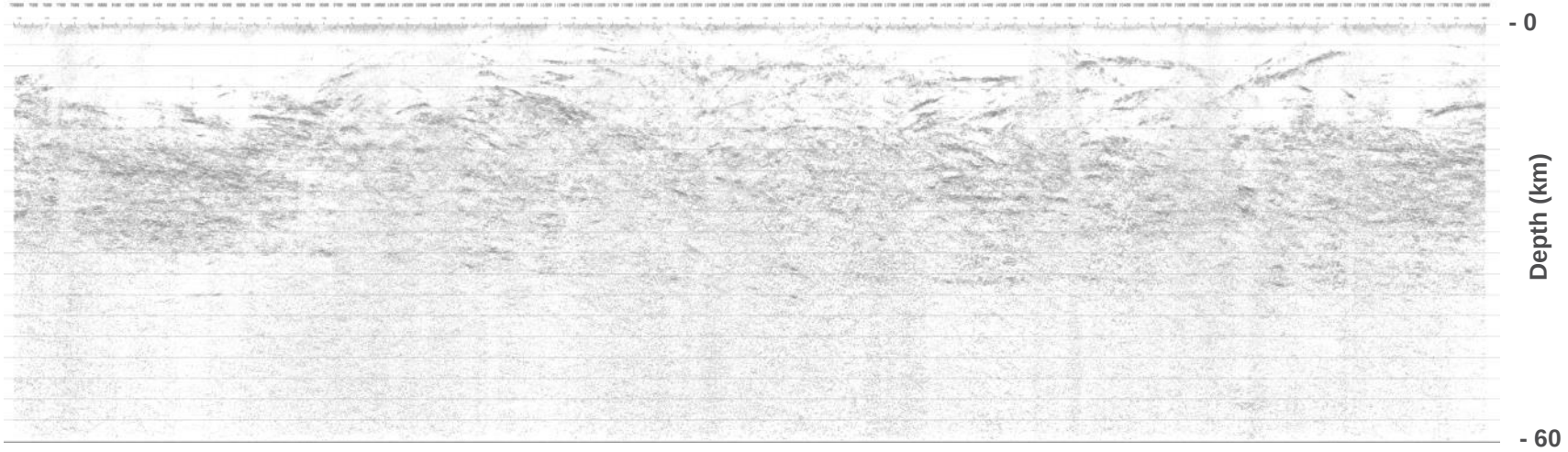
01AGS-NY1 (vibroseis)

10GA-YU2 (vibroseis)



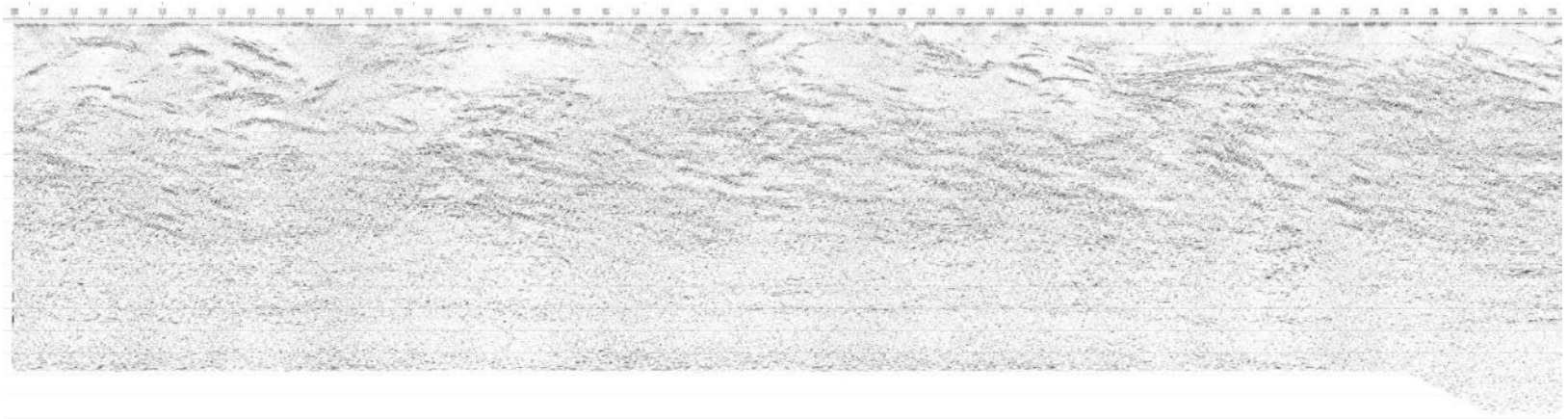
Surveys

BMR91-EGF1 96 Channels



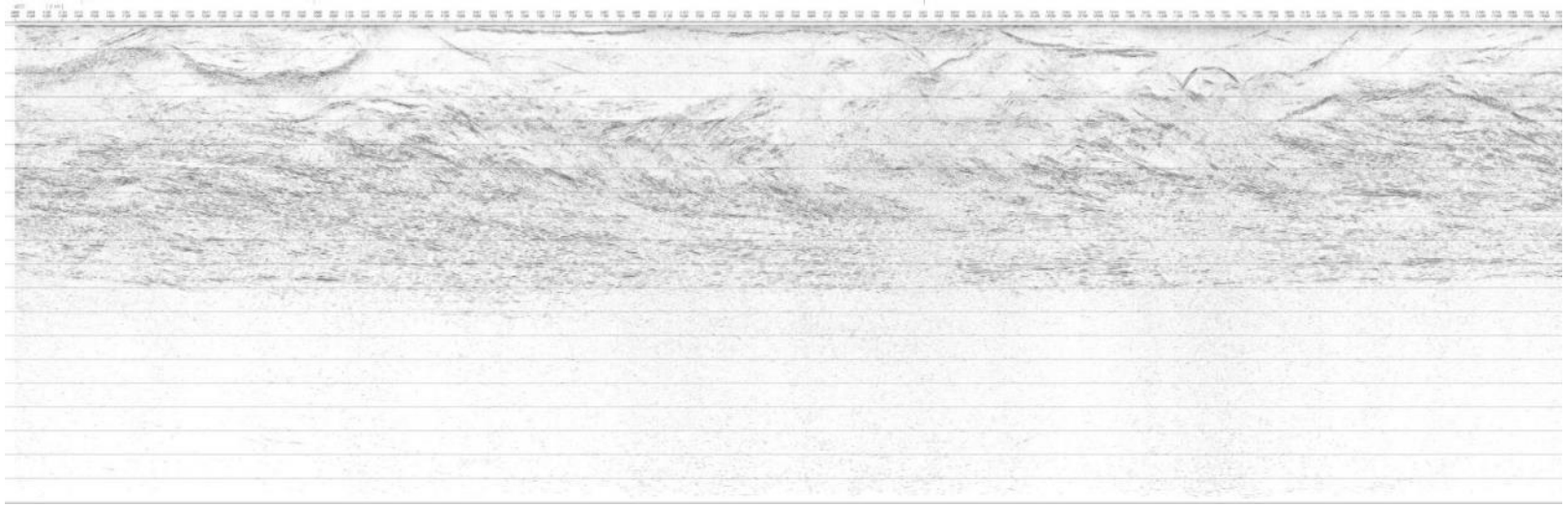
Surveys

01AGS-NY1 240 Channels



Surveys

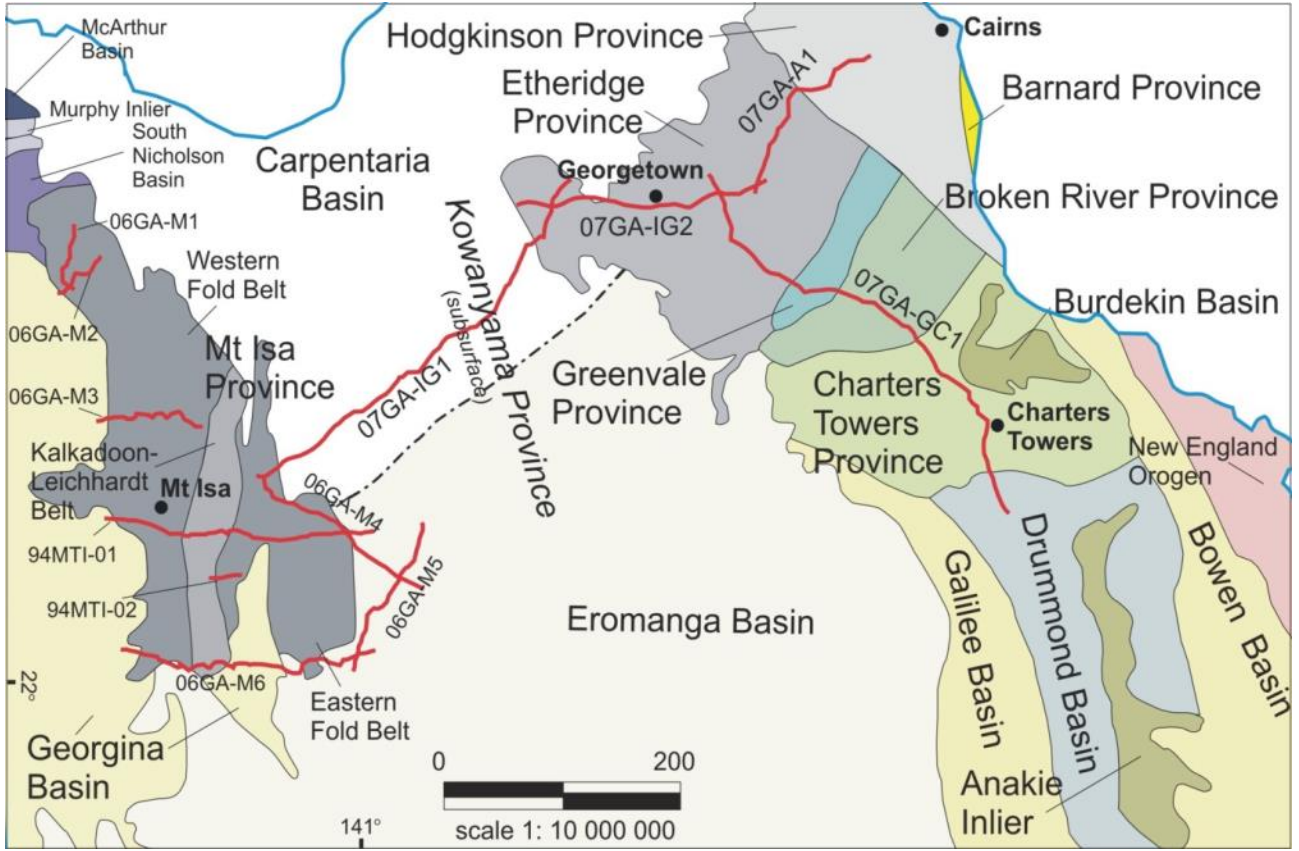
10GA-YU2 300 Channels



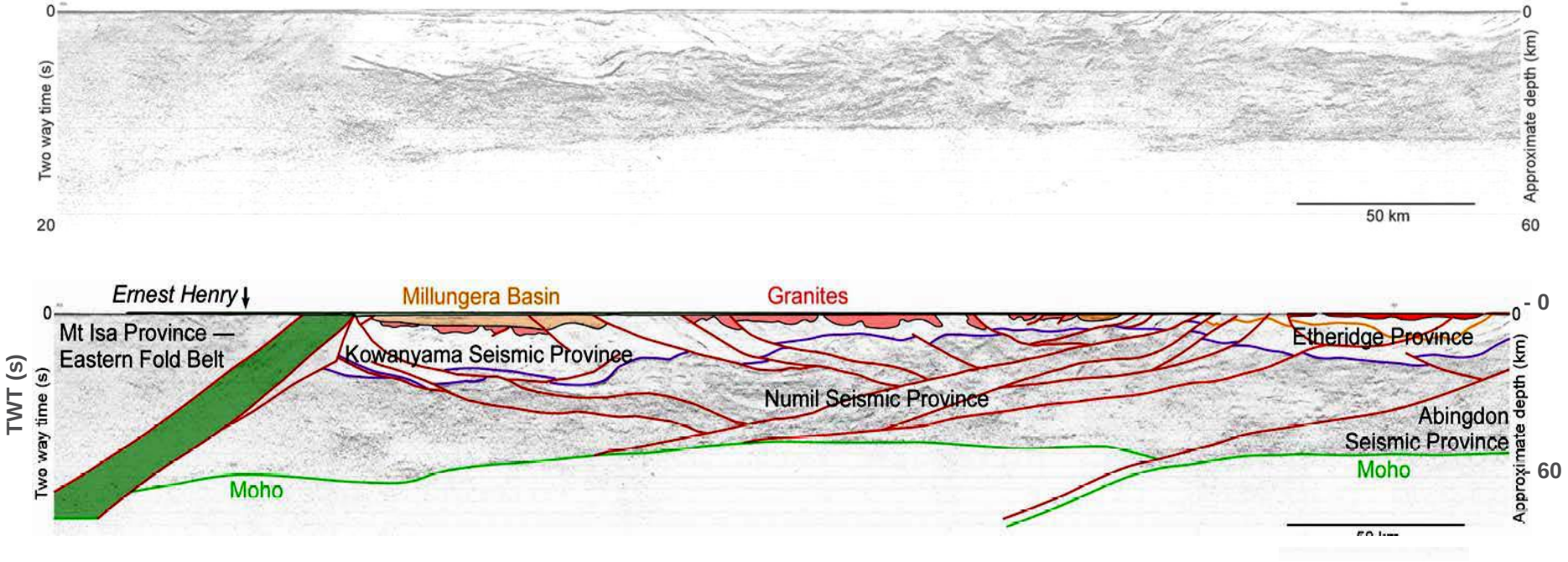
Surveys

07GA-IG1

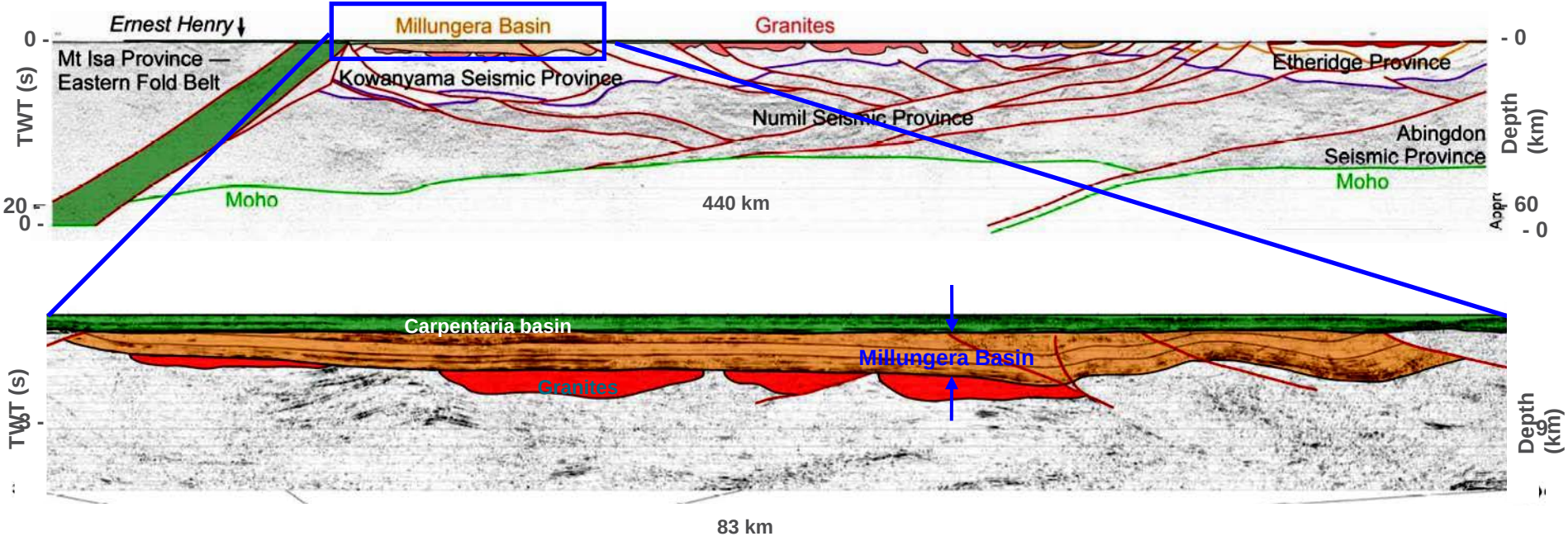
GA/GSQ



Survey Isa-Georgetown 07GA-IG1



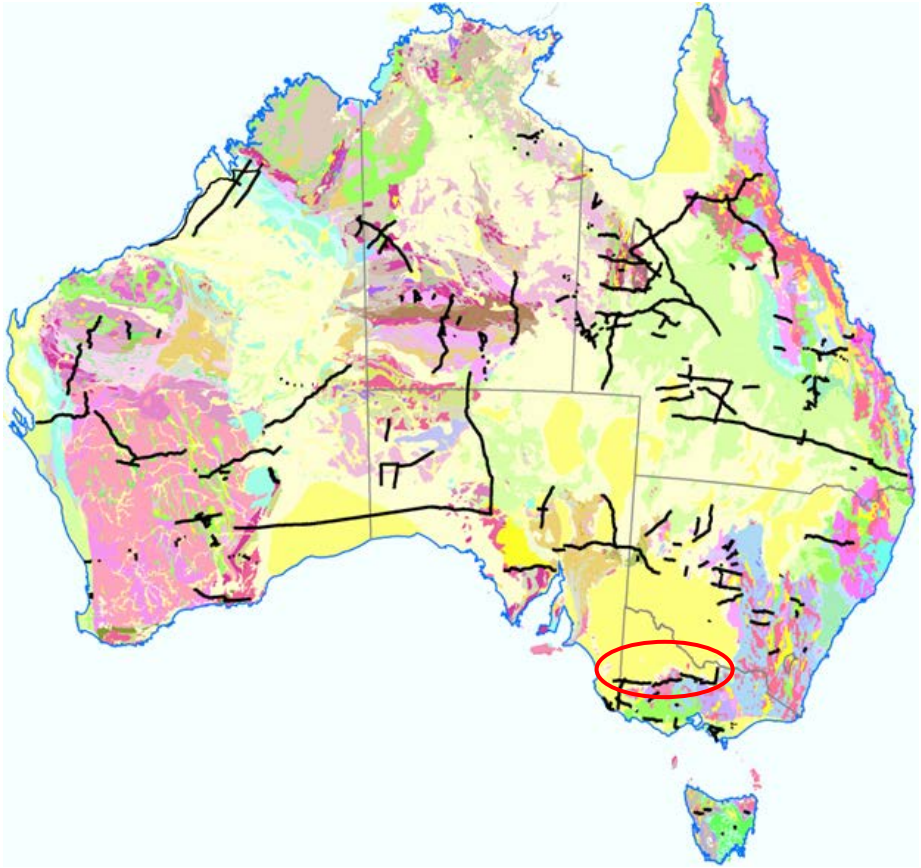
Survey Isa-Georgetown 07GA-IG1



The Deep Crustal Seismic Data

2006 Central Victoria Survey

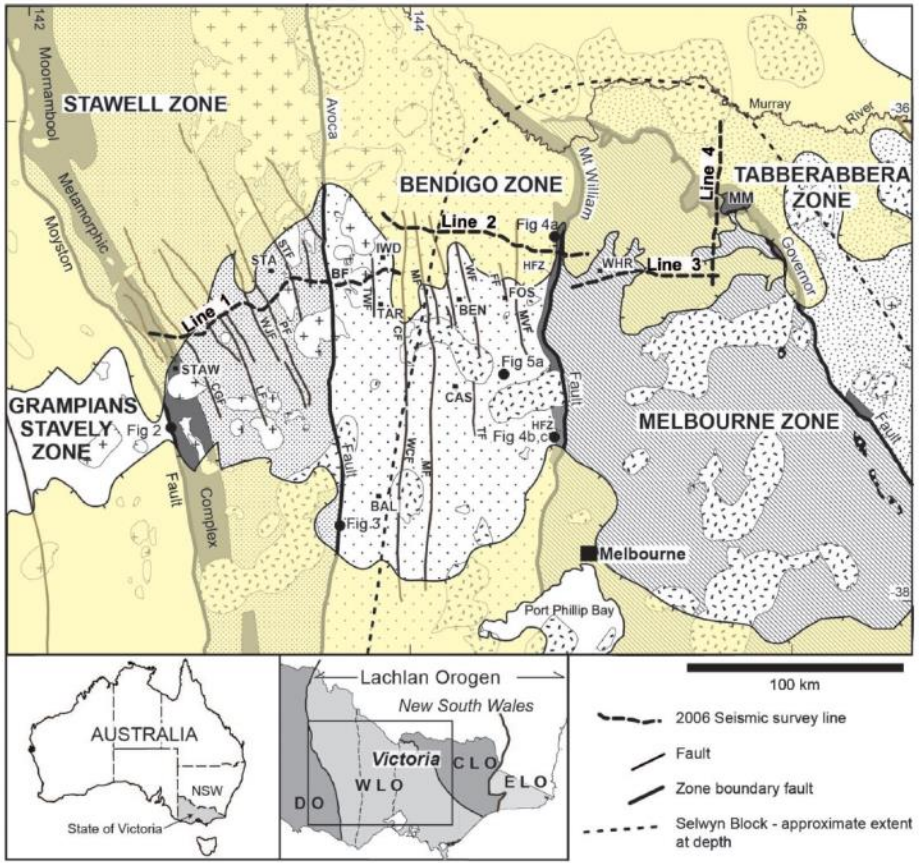
GA/GSV



The Deep Crustal Seismic Data

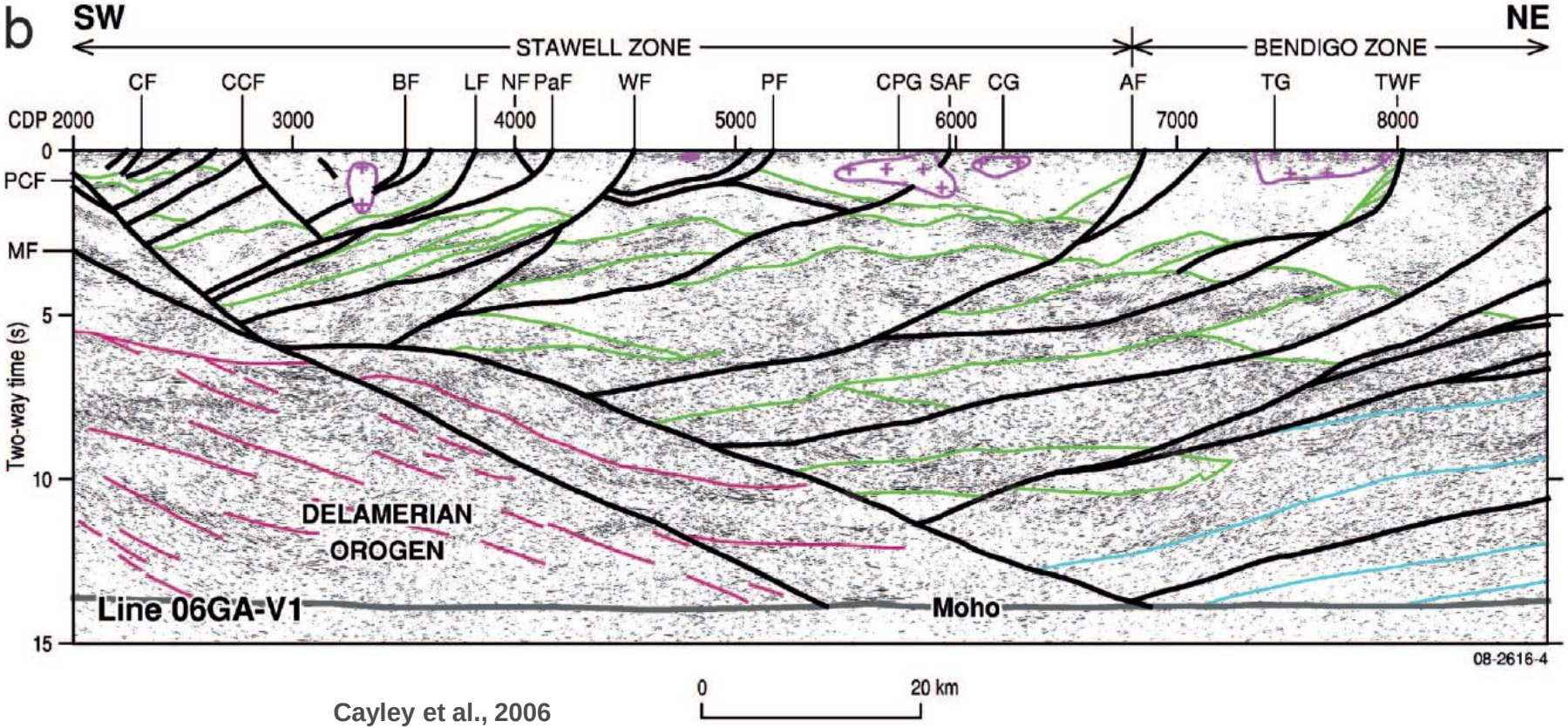
2006 Central Victoria Survey

GA/GSV



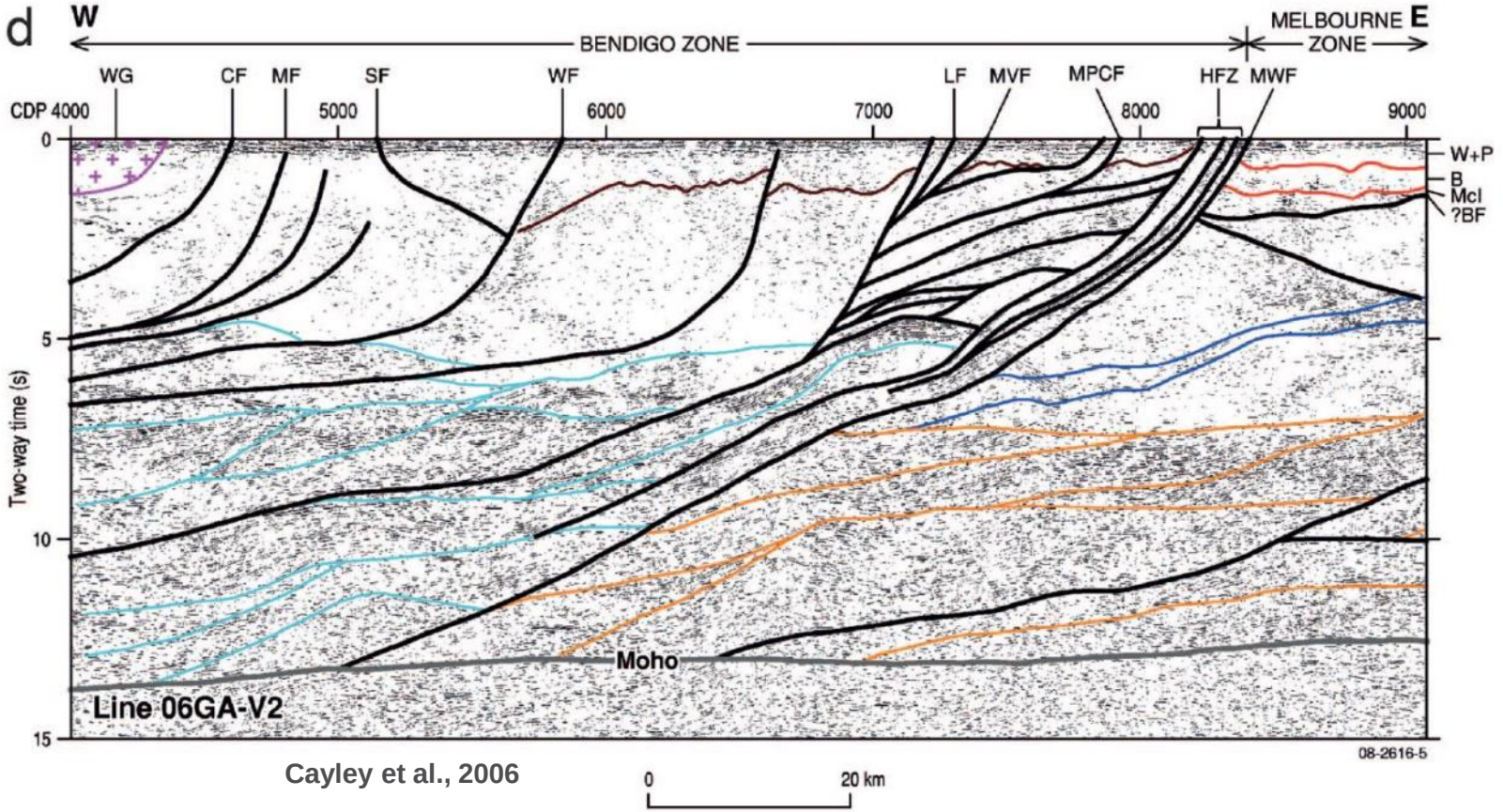
Cayley et al., 2006

The Deep Crustal Seismic Data



Cayley et al., 2006

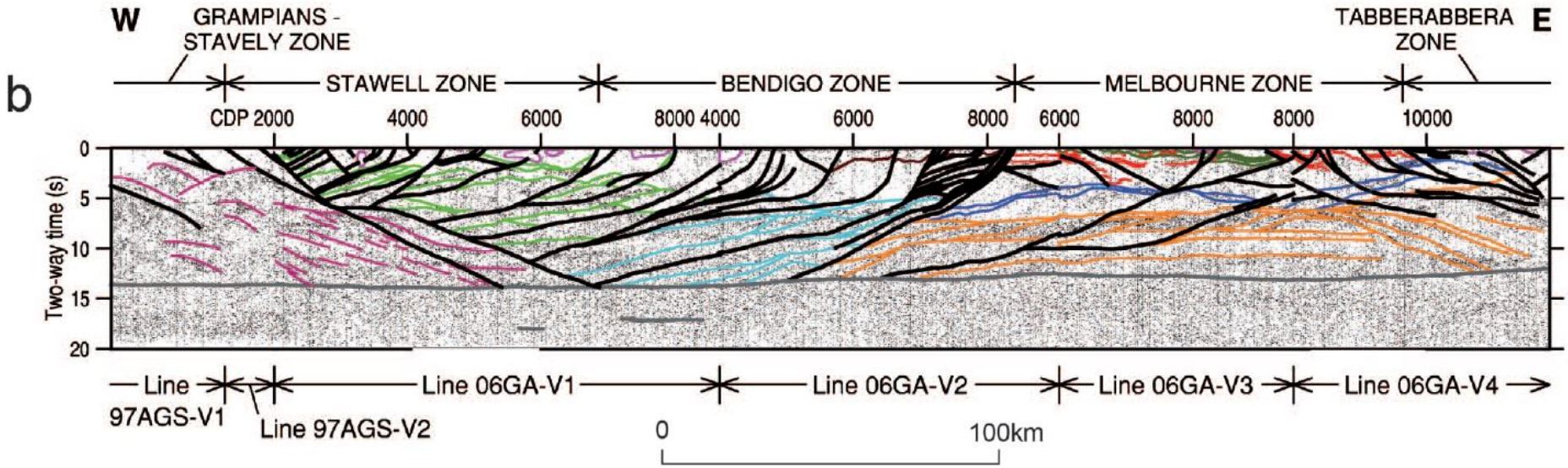
The Deep Crustal Seismic Data



Cayley et al., 2006

The Deep Crustal Seismic Data

2006 Central Victoria Survey



Cayley et al., 2006

The Deep Crustal Seismic Data – Recent Surveys

SA (Eucla-Gawler)
GA/DMITRE

Collected 2013/14
374 km @ 20 seconds

Release September 2015

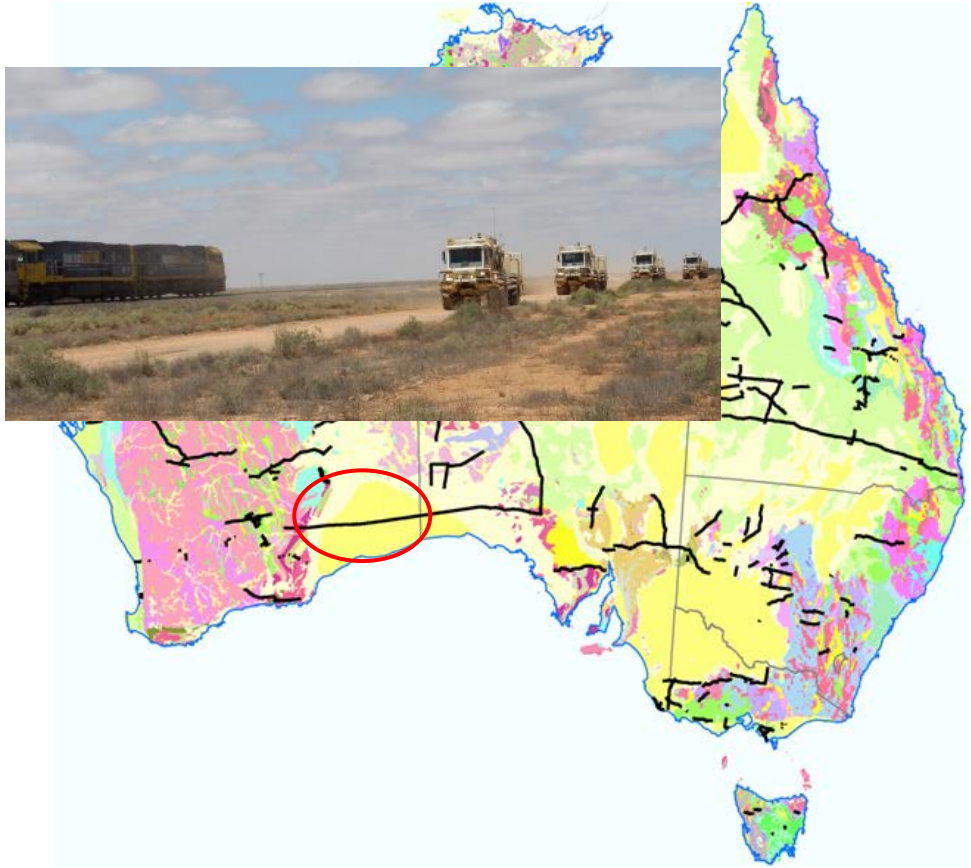
The Deep Crustal Seismic Data – Recent Surveys

WA (Eucla-Gawler)
GA/GSWA

Collected 2013/14
460 km @ 20 seconds

Image beneath Eucla Basin – relation between Yilgarn/Albany-Fraser/Gawler

Release June 2016



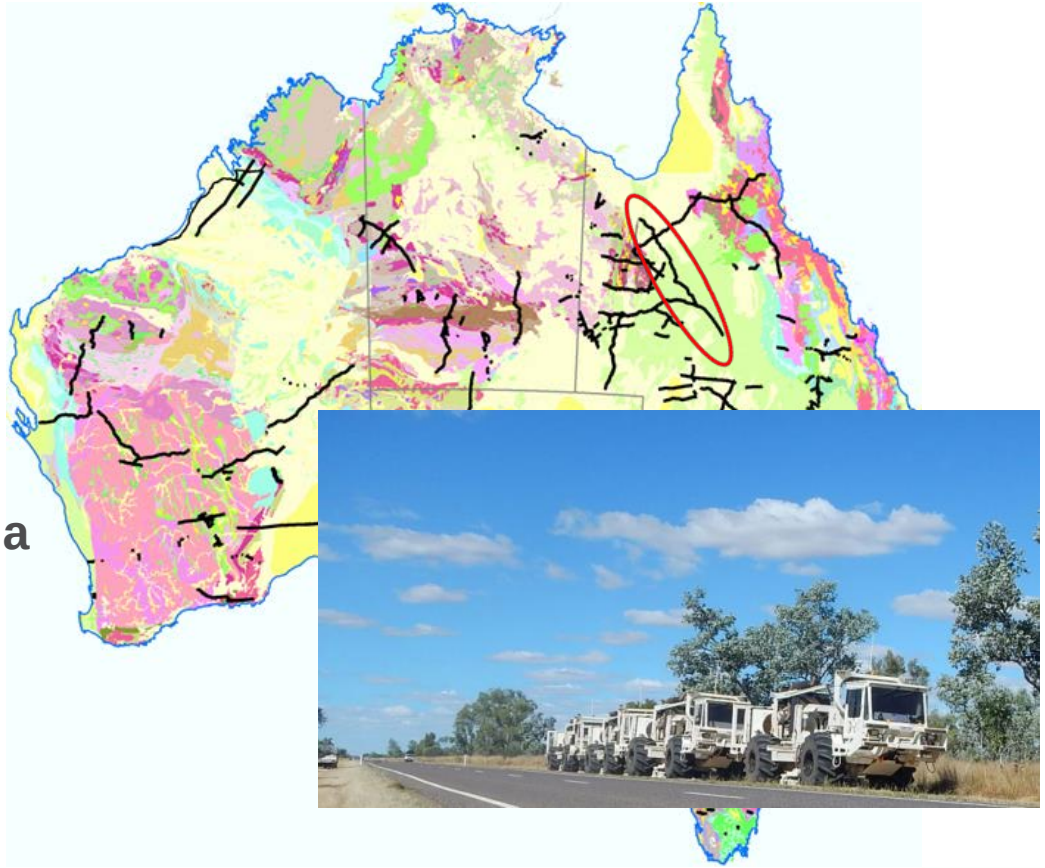
The Deep Crustal Seismic Data

Southeastern Mt Isa
GA/GSQ

Collected 2014
670 km @ 20 seconds

Cork Fault
Relation to overlying basins
Millungera, Galilee, Eromanga

Release September 2015



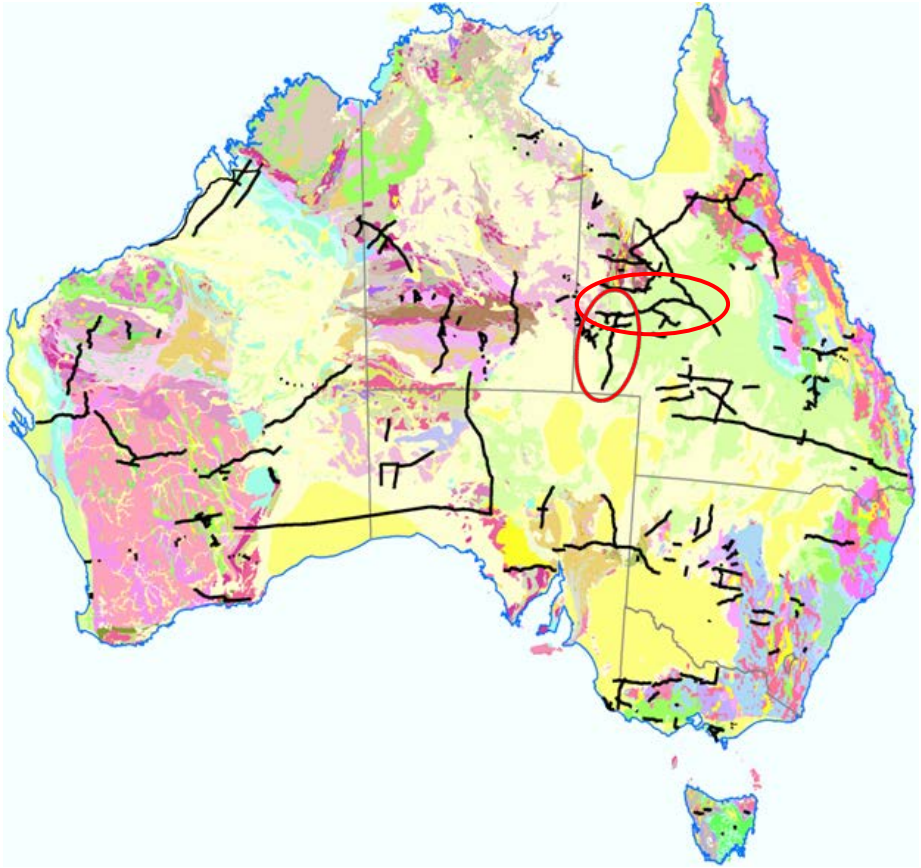
The Deep Crustal Seismic Data

Boulia and Boulia Extension
GA/GSQ

Collected 2015
847 km @ 20 seconds

Cork Fault
Mount Isa Inlier
Thomson Orogen
Galilee, Eromanga Basins

Release September 2015
Early 2016 (processed)



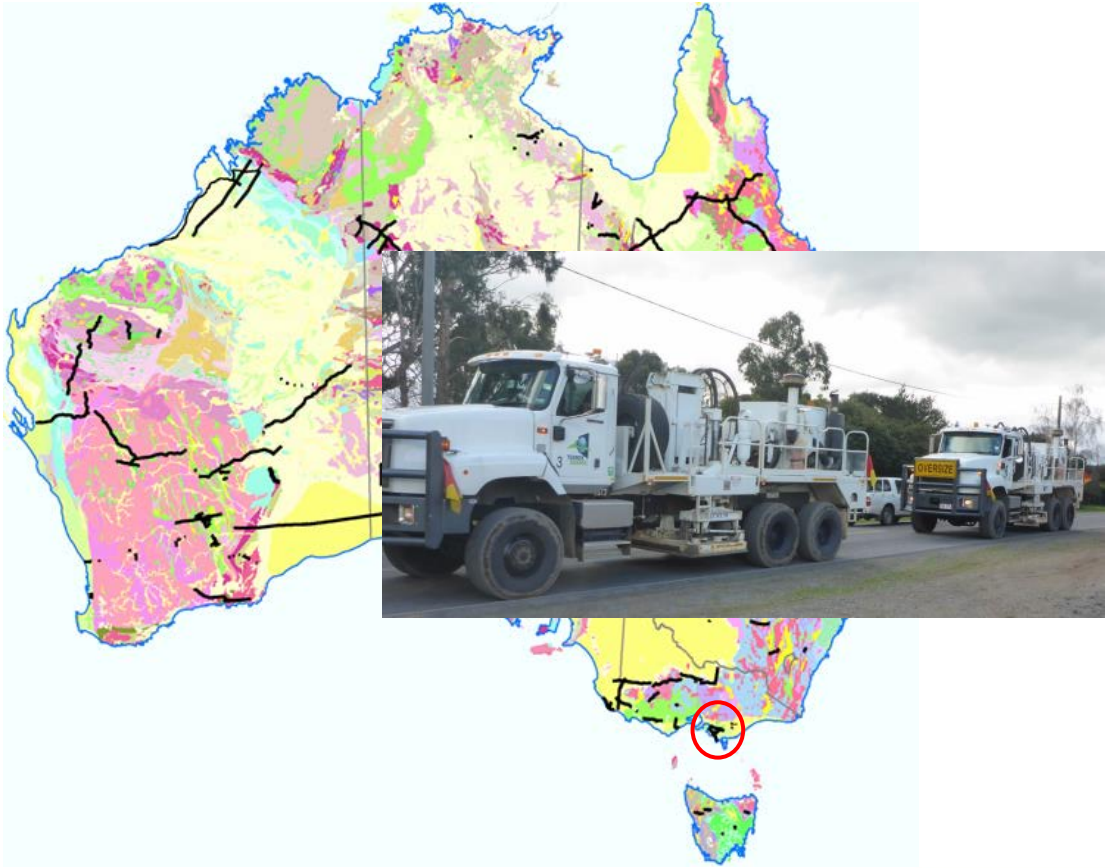
The Deep Crustal Seismic Data

South Gippsland
GA/GSV

Collected 2015
203 km @16 seconds

Geometry of Strzelecki Group,
Gippsland Basin
Architecture of Basement

Release Early 2016



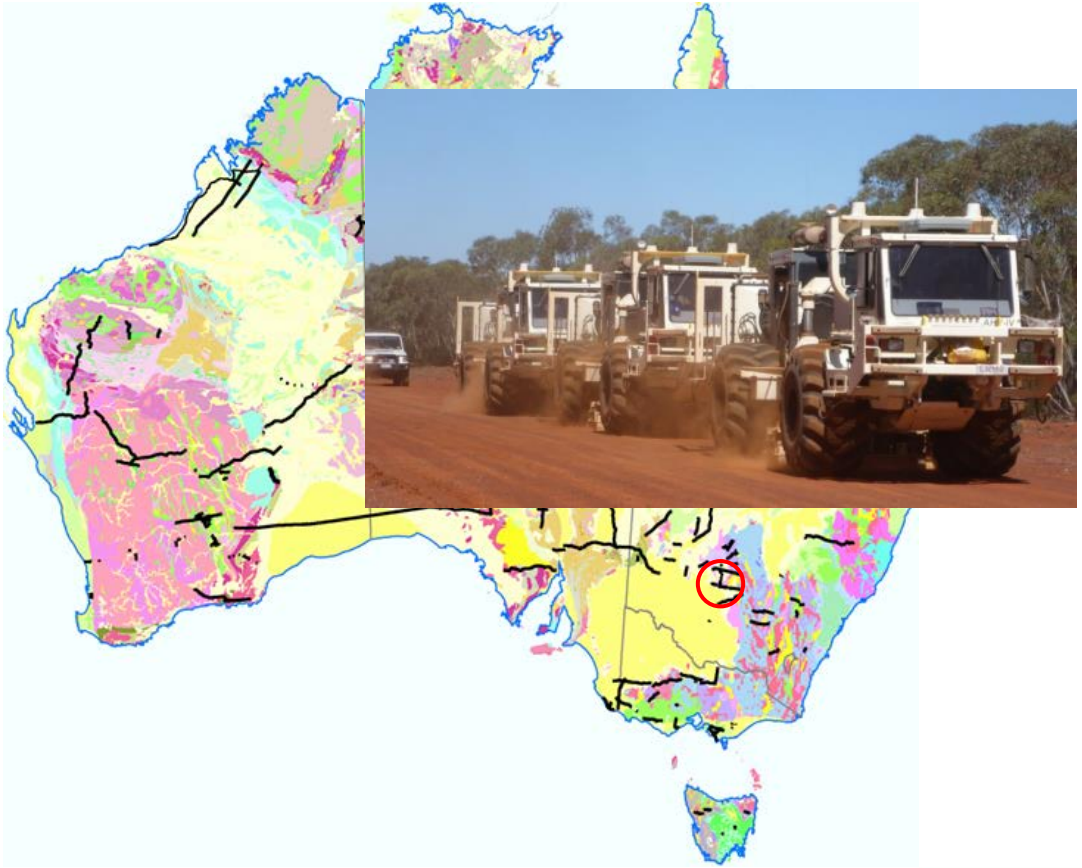
The Deep Crustal Seismic Data

Yathong Trough
GA/GSNSW

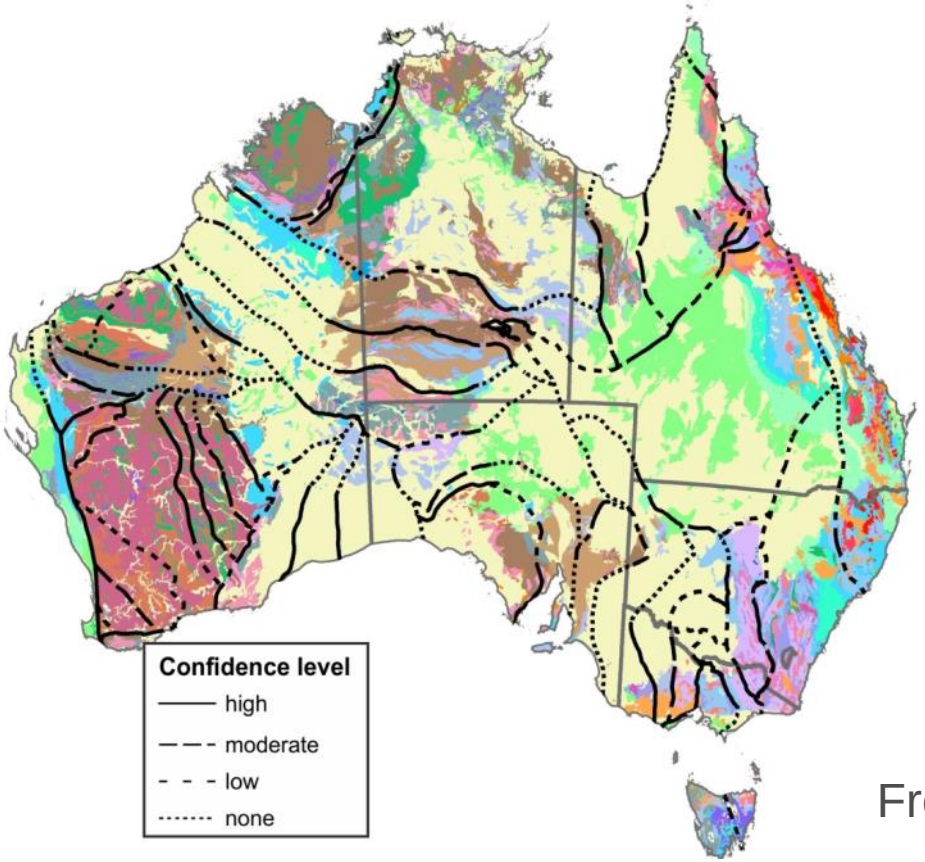
Collected 2013
230 km @ 22 seconds

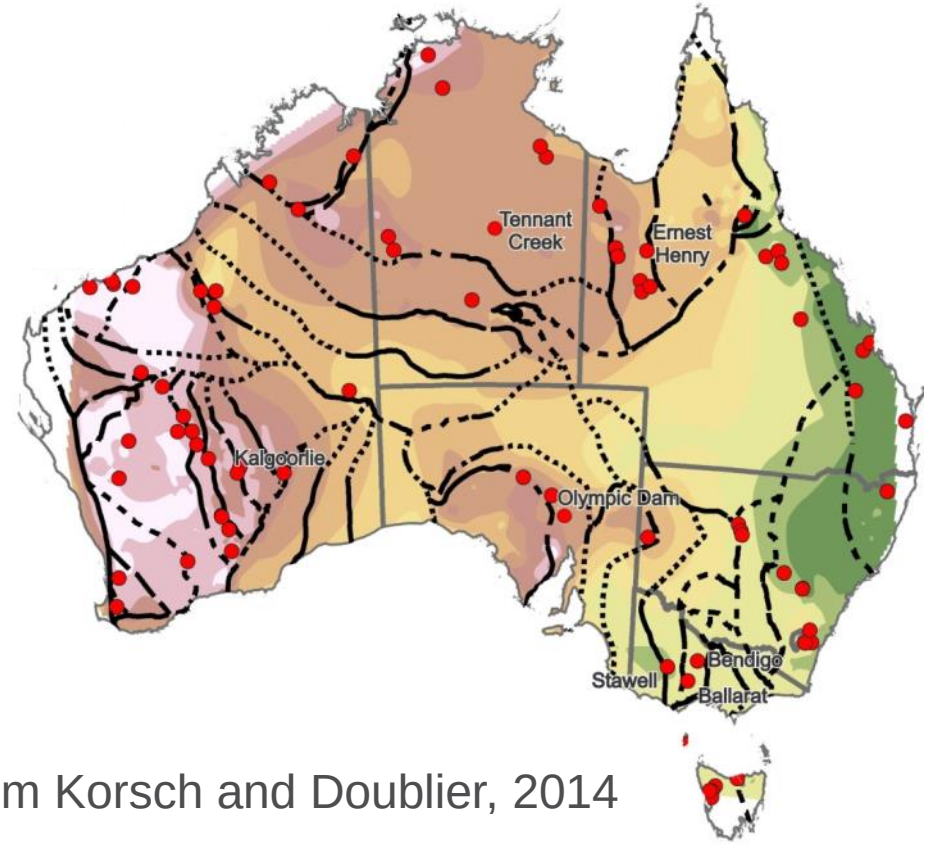
Geometry of Yathong Trough part of the Darling Basin

Release 2015



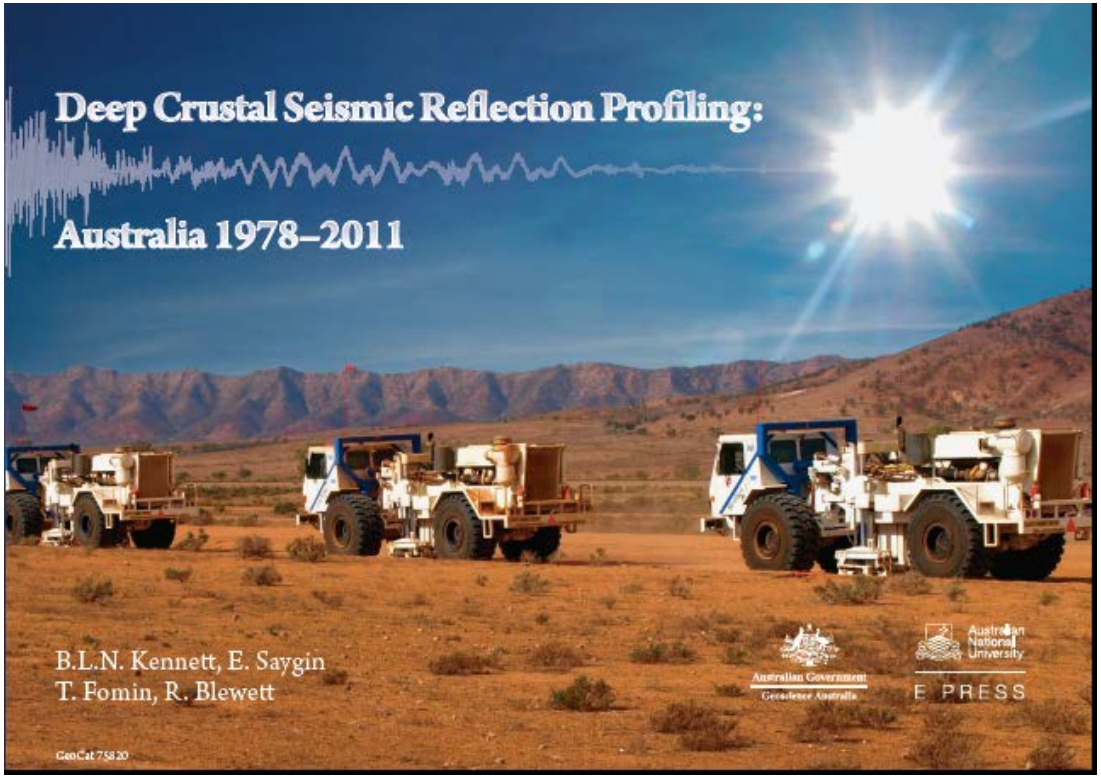
The Deep Crustal Seismic Data

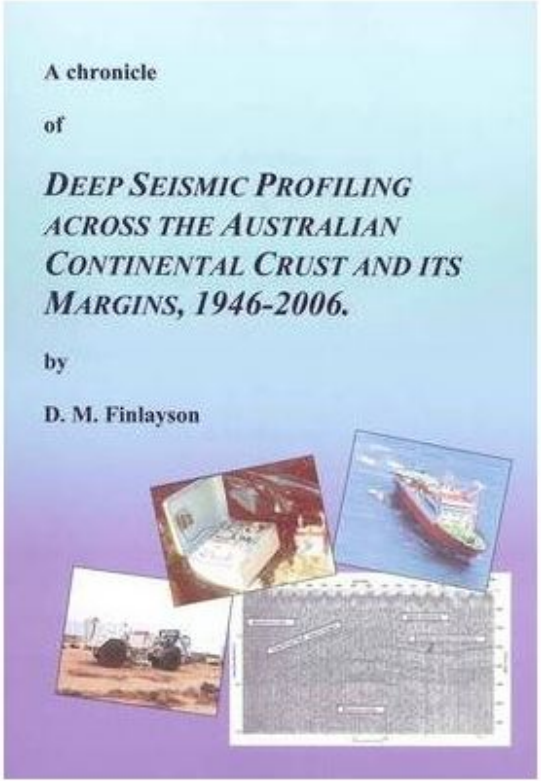




From Korsch and Doublier, 2014

The Deep Crustal Seismic Data





http://press.anu.edu.au/?p=249881

Conclusions

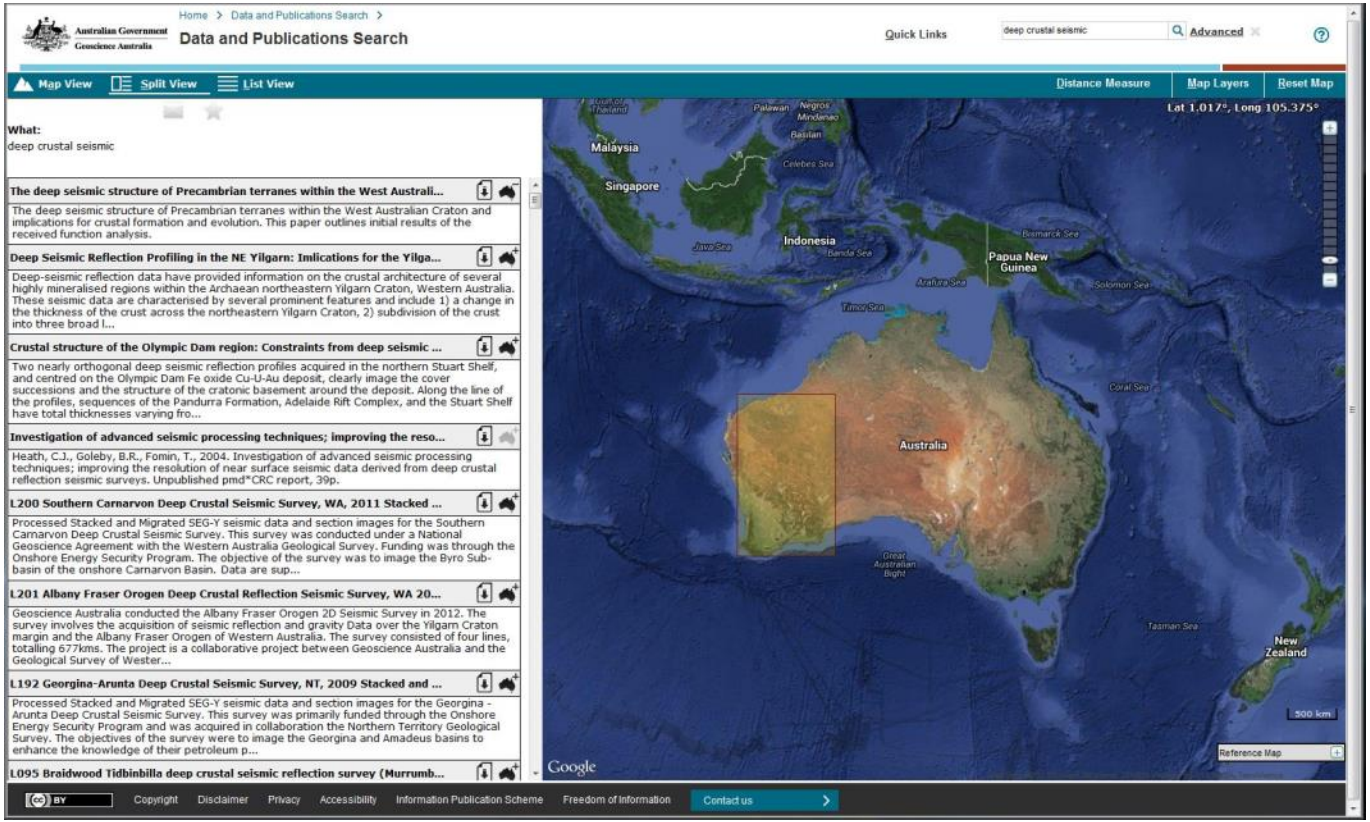
Deep crustal seismic can

- Image major crustal boundaries and faults
- Indicate potential fluid flow pathways
- Image under cover

Processed data and images available from GA website

http://www.ga.gov.au/about/what-we-do/projects/minerals/current/seismic

Data

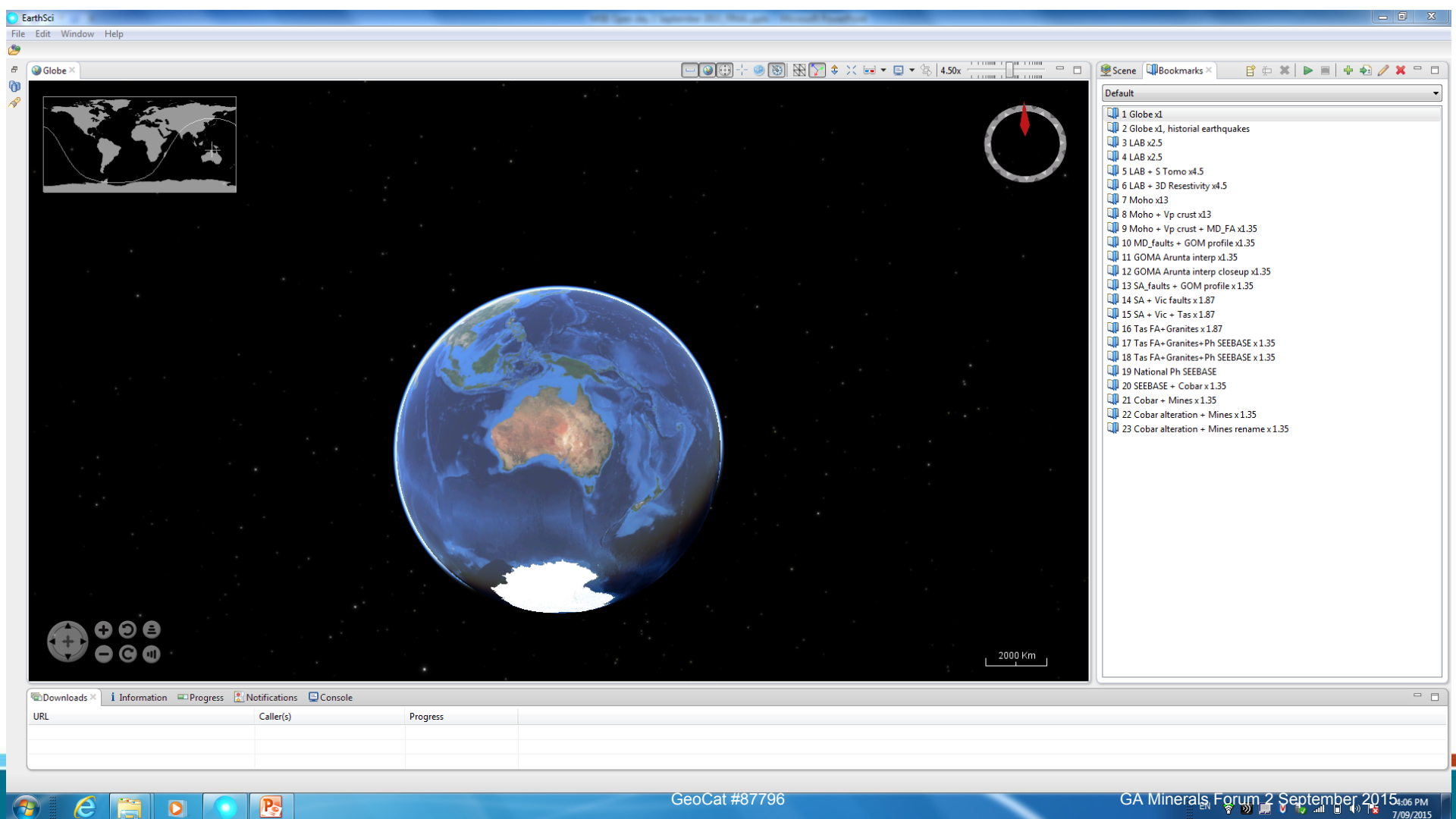


http://www.ga.gov.au/search/index.html#/

Australian Government
Geoscience Australia

Bringing it all together: The Australian Architecture Reference Model (AusARM)

Malcolm Nicoll, *Karol Czarnota* Karol.Czarnota@ga.gov.au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File Edit Window Help
Globe
4.50x
Scene
Bookmarks
Default
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2 Globe x1, historial earthquakes
3 LAB x2.5
4 LAB x2.5
5 LAB + S Tomo x4.5
6 LAB + 3D Resestivity x4.5
7 Moho x13
8 Moho + Vp crust x13
9 Moho + Vp crust + MD_FA x1.35
10 MD_faults + GOM profile x1.35
11 GOMA Arunta interp x1.35
12 GOMA Arunta interp closeup x1.35
13 SA_faults + GOM profile x 1.35
14 SA + Vic faults x 1.87
15 SA + Vic + Tas x 1.87
16 Tas FA+ Granites x 1.87
17 Tas FA+Granites+Ph SEEBASE x 1.35
18 Tas FA+Granites+Ph SEEBASE x 1.35
19 National Ph SEEBASE
20 SEEBASE + Cobar x 1.35
21 Cobar + Mines x 1.35
22 Cobar alteration + Mines x 1.35
23 Cobar alteration + Mines rename x 1.35
2000 Km
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GA Minerals Forum 2 September 2015
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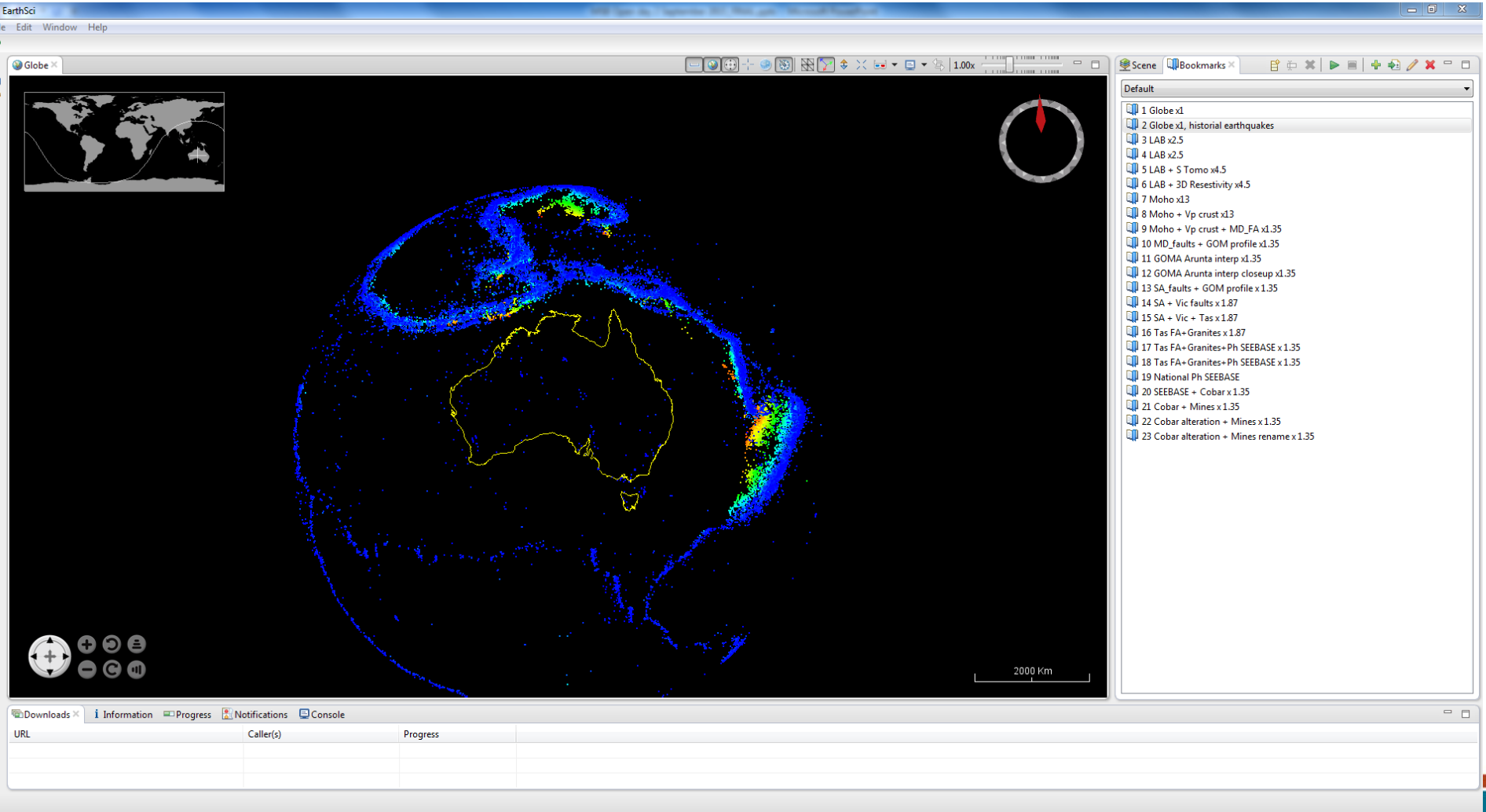
7/09/2015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17 Tas FA+Granites+Ph SEEBASE x 1.35
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19 National Ph SEEBASE
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21 Cobar + Mines x 1.35
22 Cobar alteration + Mines x 1.35
23 Cobar alteration + Mines rename x 1.35
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Downloads
Information
Progress
Notifications
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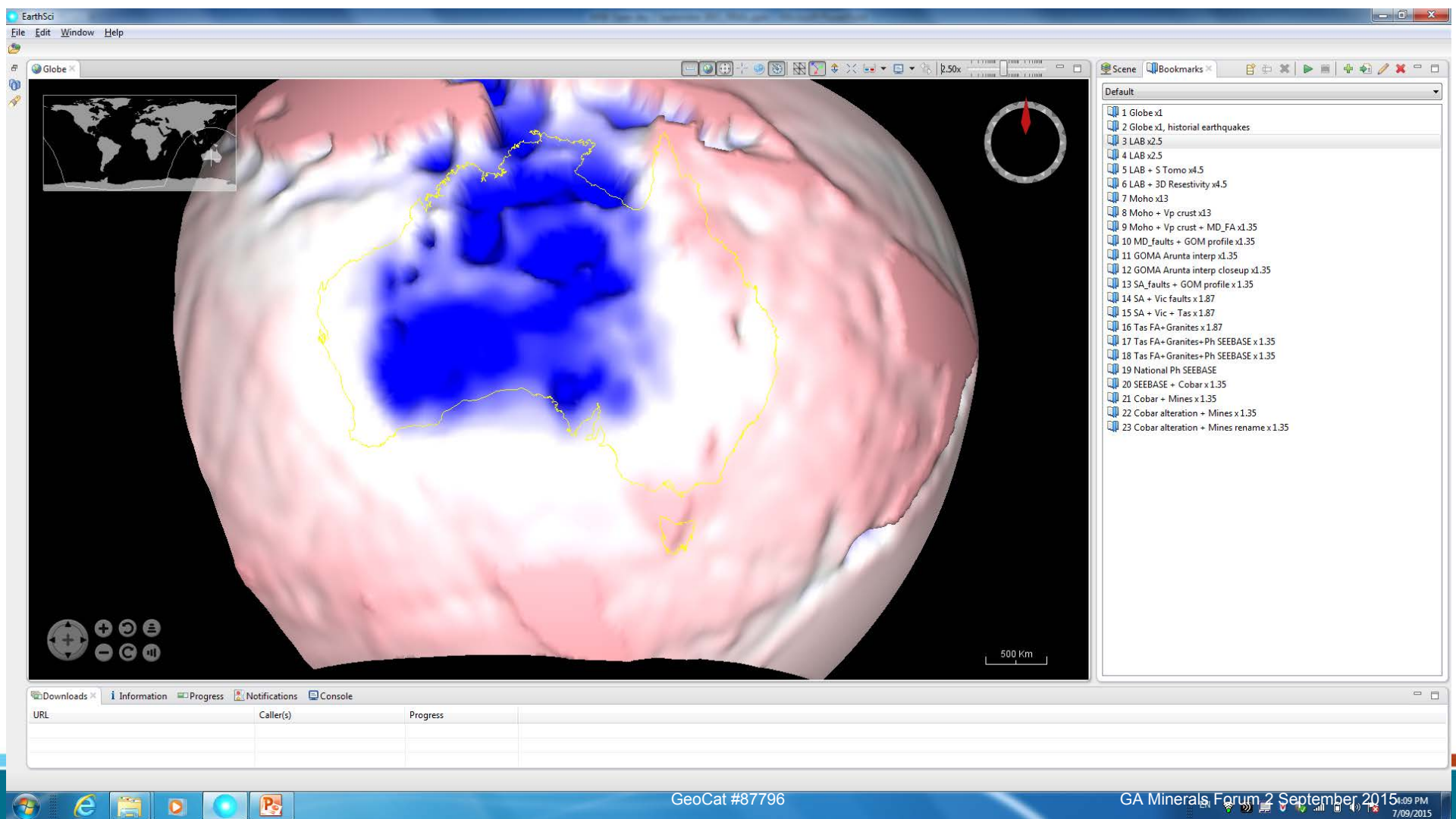
Caller(s)
Progress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2 Globe x1, historial earthquakes
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16 Tas FA+Granites x 1.87
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19 National Ph SEEBASE
20 SEEBASE + Cobar x 1.35
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GA Minerals Forum 2 September 2015
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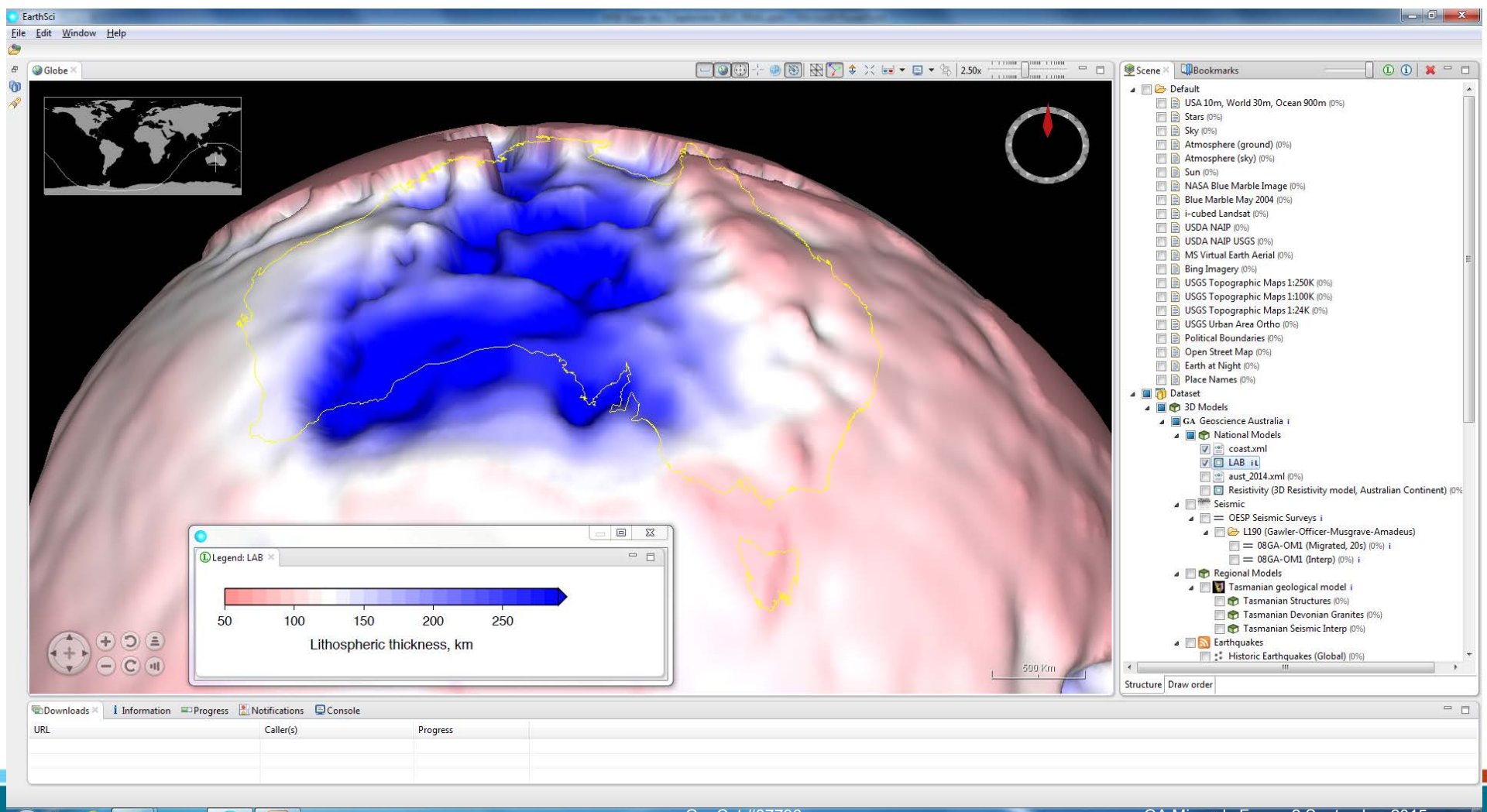
7/09/2015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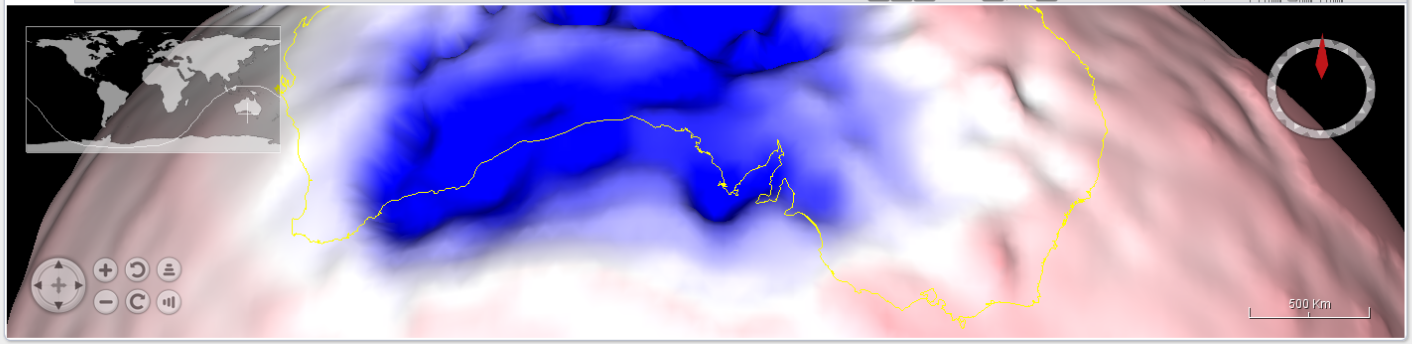
File Edit Window Help
Globe
2.50x
Scene
Bookmarks
Default
USA 10m, World 30m, Ocean 900m (0%)
Stars (0%)
Sky (0%)
Atmosphere (ground) (0%)
Atmosphere (sky) (0%)
Sun (0%)
NASA Blue Marble Image (0%)
Blue Marble May 2004 (0%)
i-cubed Landsat (0%)
USDA NAIP (0%)
USDA NAIP USGS (0%)
MS Virtual Earth Aerial (0%)
Bing Imagery (0%)
USGS Topographic Maps 1:250K (0%)
USGS Topographic Maps 1:100K (0%)
USGS Topographic Maps 1:24K (0%)
USGS Urban Area Ortho (0%)
Political Boundaries (0%)
Open Street Map (0%)
Earth at Night (0%)
Place Names (0%)
Dataset
3D Models
GA Geoscience Australia
National Models
coast.xml
LAB
aust_2014.xml (0%)
Resistivity (3D Resistivity model, Australian Continent) (0%)
Seismic
OESP Seismic Surveys
L190 (Gawler-Officer-Musgrave-Amadeus)
08GA-OM1 (Migrated, 20s) (0%)
08GA-OM1 (Interp) (0%)
Regional Models
Tasmanian geological model
Tasmanian Structures (0%)
Tasmanian Devonian Granites (0%)
Tasmanian Seismic Interp (0%)
Earthquakes
Historic Earthquakes (Global) (0%)
Structure
Draw order
Legend: LAB
50
100
150
200
250
Lithospheric thickness, km
500 Km
Downloads
Information
Progress
Notifications
Console
URL
Caller(s)
Progress
GeoCat #87796
GA Minerals Forum 2 September 2015
4:10 PM
7/09/2015

EarthSci

File Edit Window Help

Globe



Scene Bookmarks

Default
USA 10m, World 30m, Ocean 900m (0%)
Stars (0%)
Sky (0%)
Atmosphere (ground) (0%)
Atmosphere (sky) (0%)
Sun (0%)
NASA Blue Marble Image (0%)
Blue Marble May 2004 (0%)
i-cubed Landsat (0%)
USDA NAIP (0%)
USDA NAIP USGS (0%)
MS Virtual Earth Aerial (0%)
Bing Imagery (0%)
USGS Topographic Maps 1:250K (0%)
USGS Topographic Maps 1:100K (0%)

Structure Draw order

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Australian lithosphere–asthenosphere boundary

Australian lithosphere–asthenosphere boundary from Czarnota et al. (2014) based on a surface wave tomography model by Fishwick and Rawlinson (2012) using parametrisation by Priestley and McKenzie (2006).

References

Czarnota, K., G. G. Roberts, N. J. White, and S. Fishwick (2014), Spatial and temporal patterns of Australian dynamic topography from River Profile Modeling, Journal of Geophysical Research: Solid Earth, 119(2), 1384-1424, doi:10.1002/2013JB010436.
http://onlinelibrary.wiley.com/doi/10.1002/2013JB010436/full Fishwick, S., and N. Rawlinson (2012), 3-D structure of the Australian lithosphere from evolving seismic datasets, Australian Journal of Earth Sciences, 59(6), 809-826. Priestley, K., and D. McKenzie (2006), The thermal structure of the lithosphere from shear wave velocities, Earth and Planetary Science Letters, 244(1-2), 285-301.

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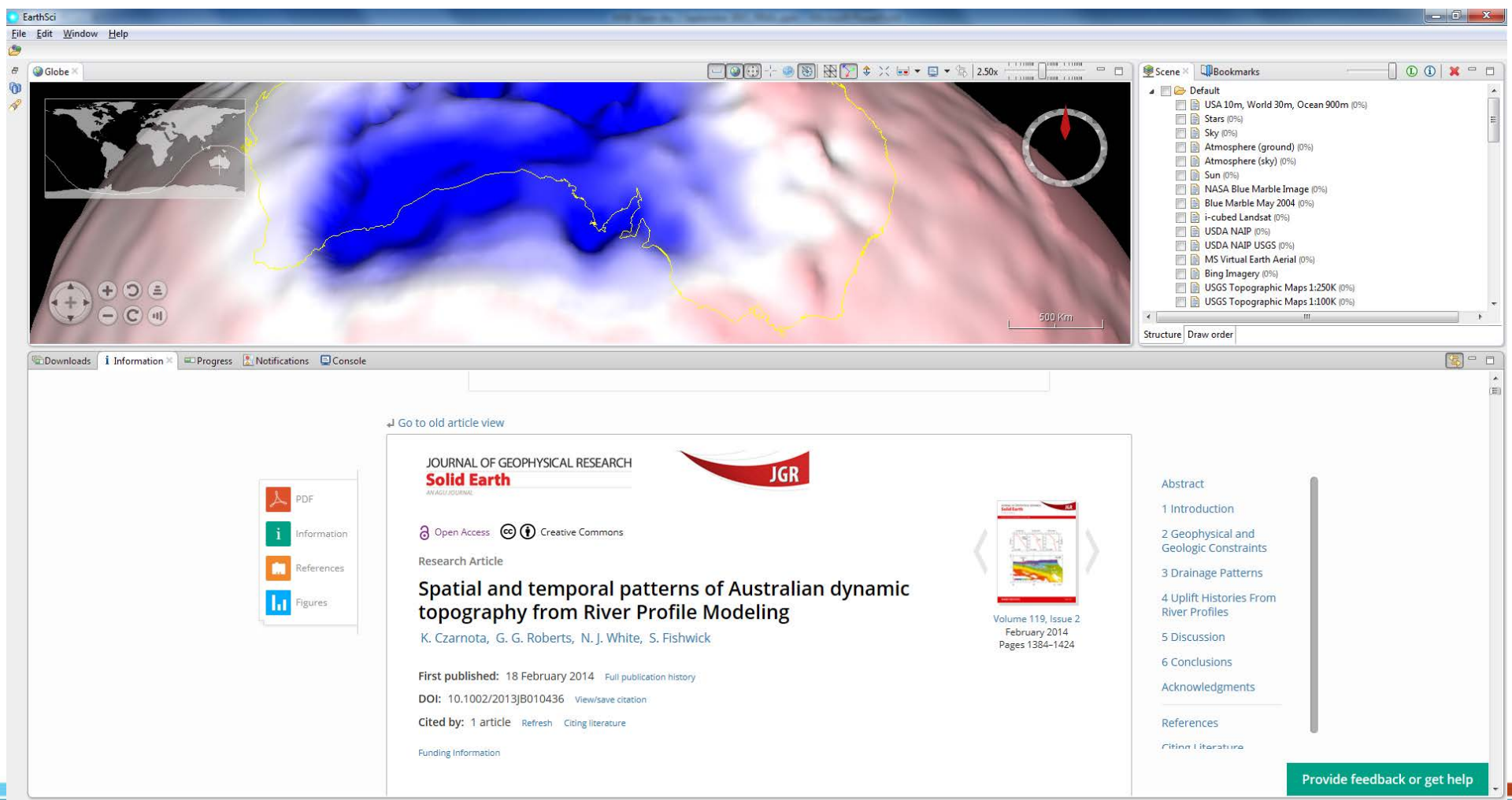
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K. Czarnota, G. G. Roberts, N. J. White, S. Fishwick
First published: 18 February 2014 Full publication history
DOI: 10.1002/2013JB010436 View/save citation
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Volume 119, Issue 2
February 2014
Pages 1384–1424
Abstract
1 Introduction
2 Geophysical and Geologic Constraints
3 Drainage Patterns
4 Uplift Histories From River Profiles
5 Discussion
6 Conclusions
Acknowledgments
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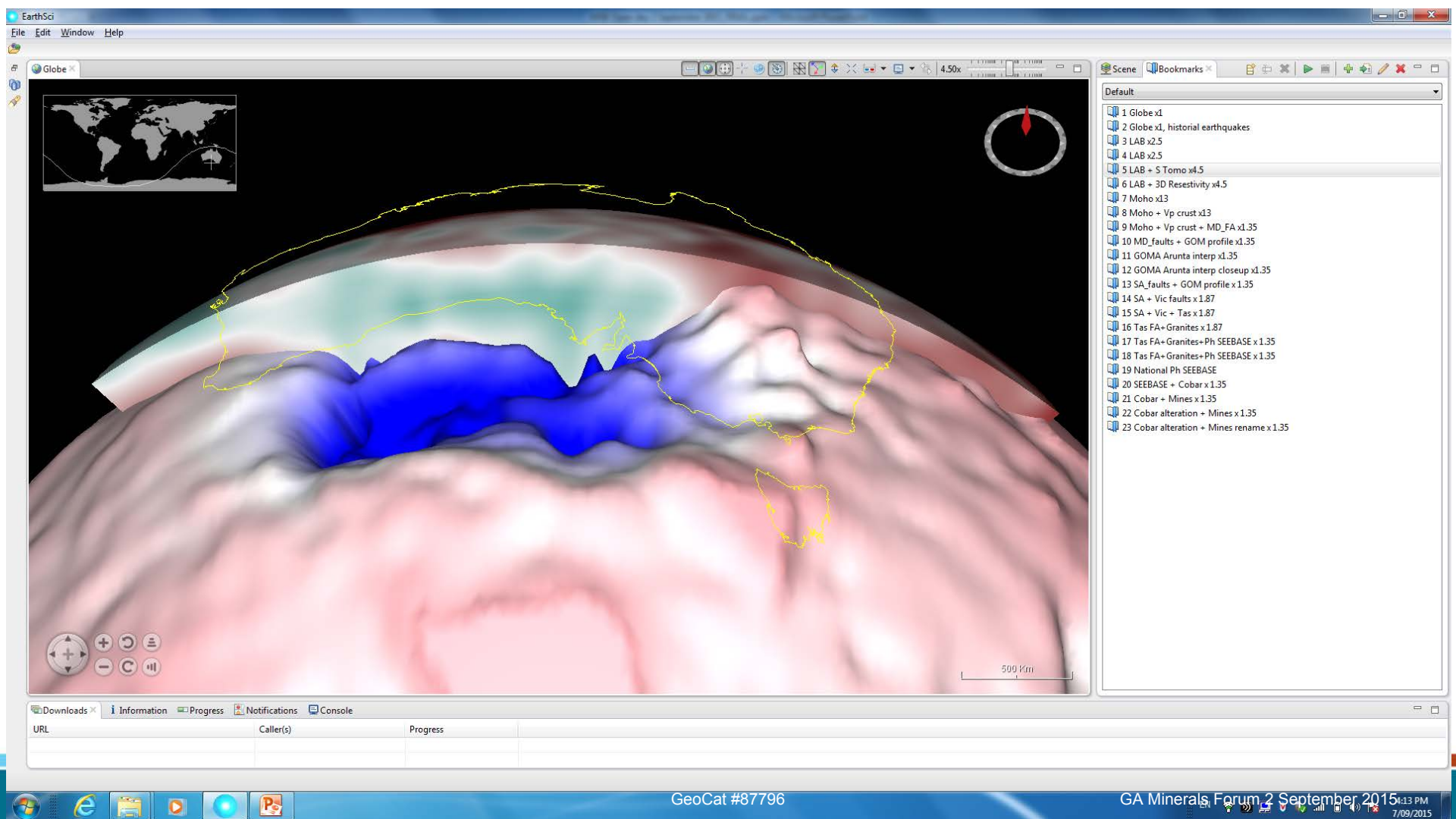
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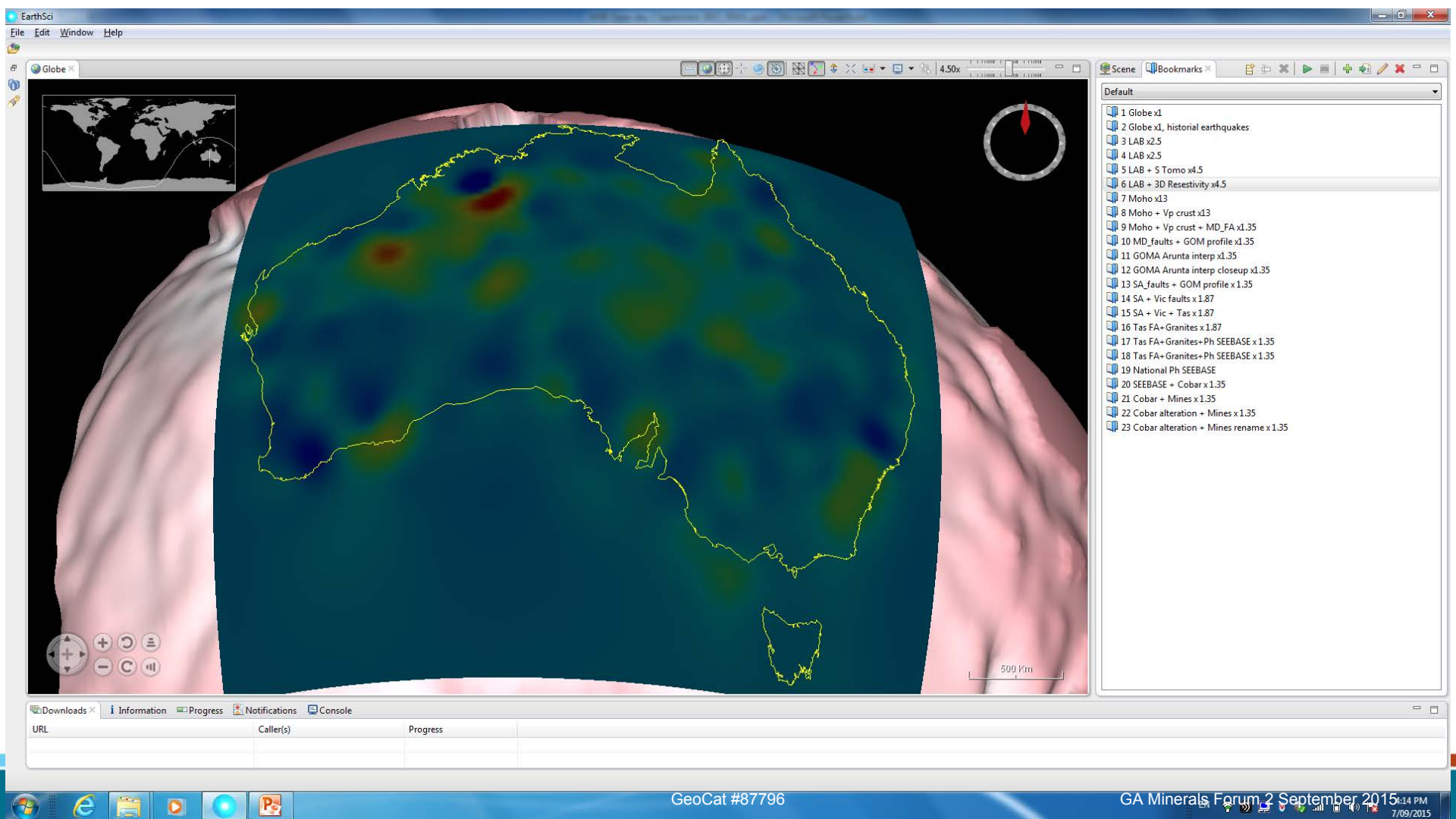
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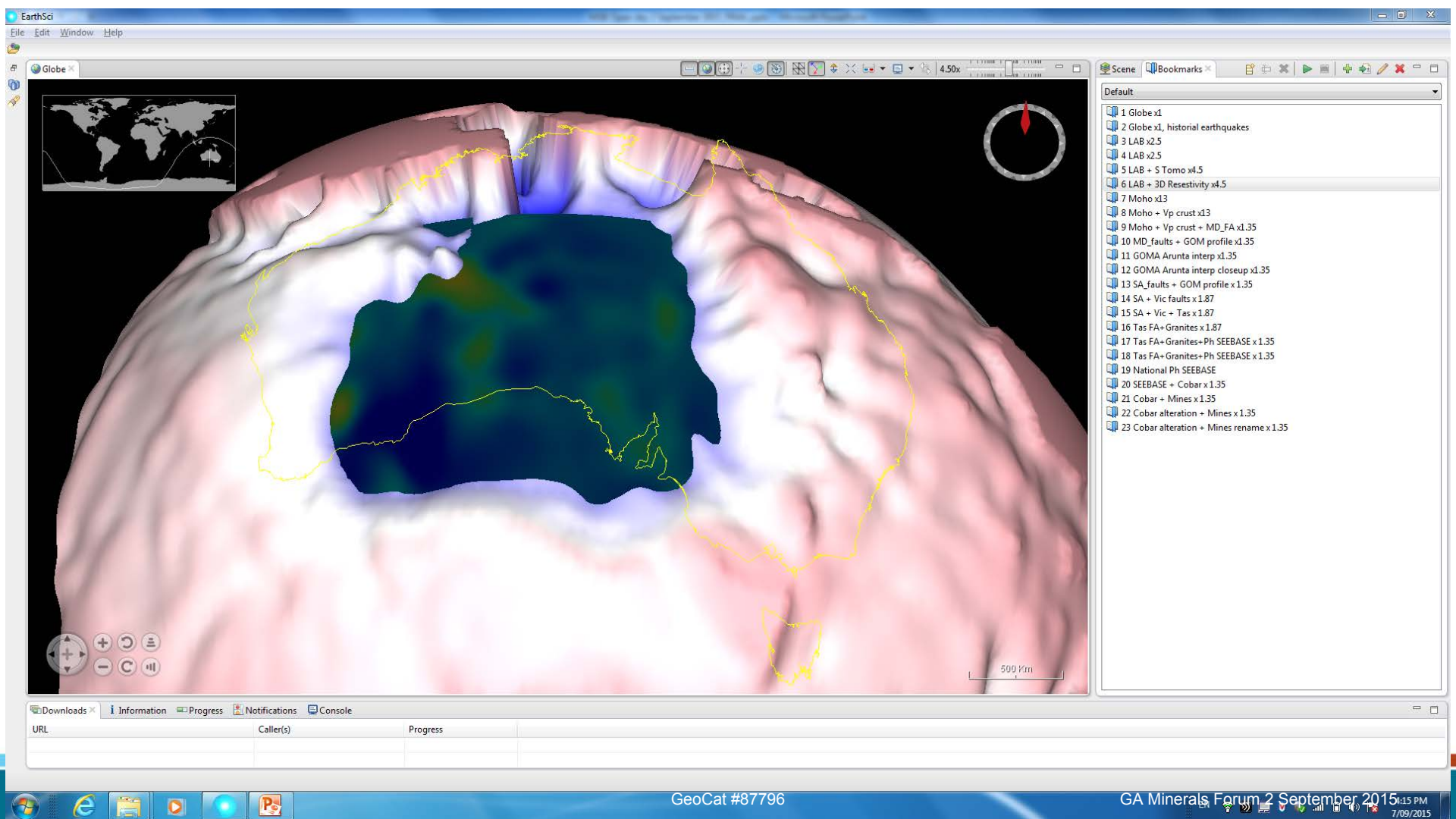
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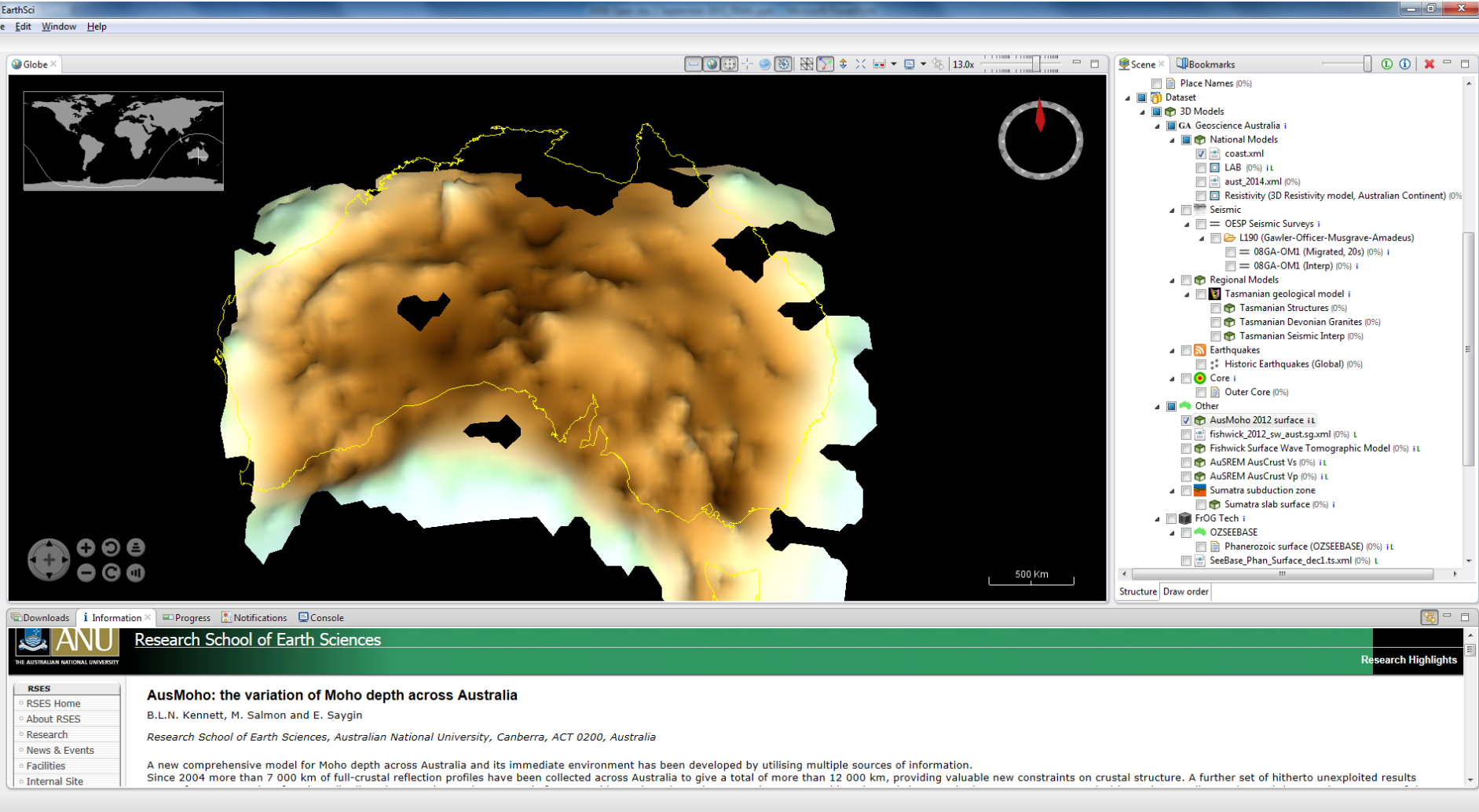
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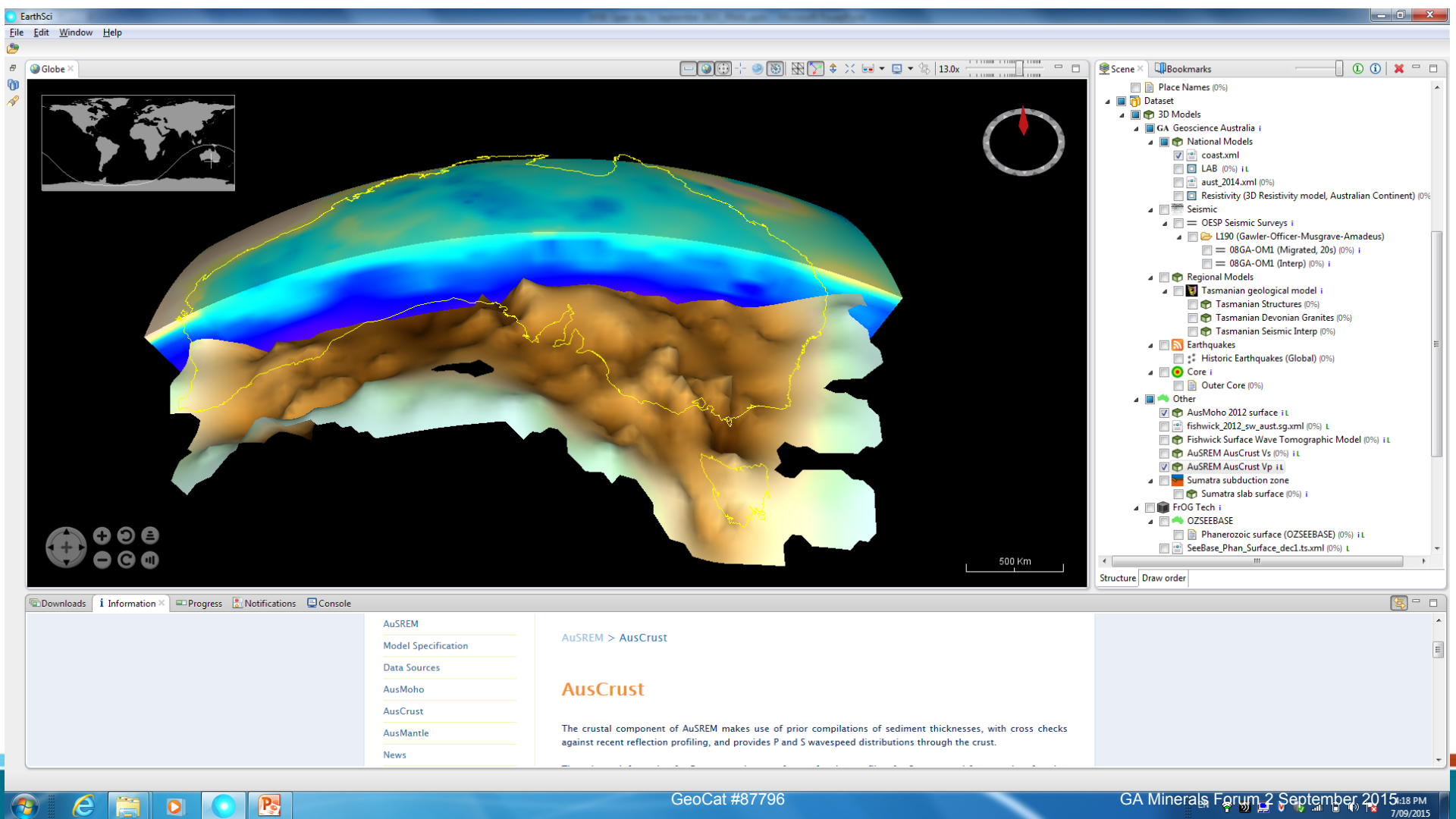
AusMoho: the variation of Moho depth across Australia
B.L.N. Kennett, M. Salmon and E. Saygin
Research School of Earth Sciences, Australian National University, Canberra, ACT 0200, Australia
A new comprehensive model for Moho depth across Australia and its immediate environment has been developed by utilising multiple sources of information.
Since 2004 more than 7 000 km of full-crustal reflection profiles have been collected across Australia to give a total of more than 12 000 km, providing valuable new constraints on crustal structure. A further set of hitherto unexploited results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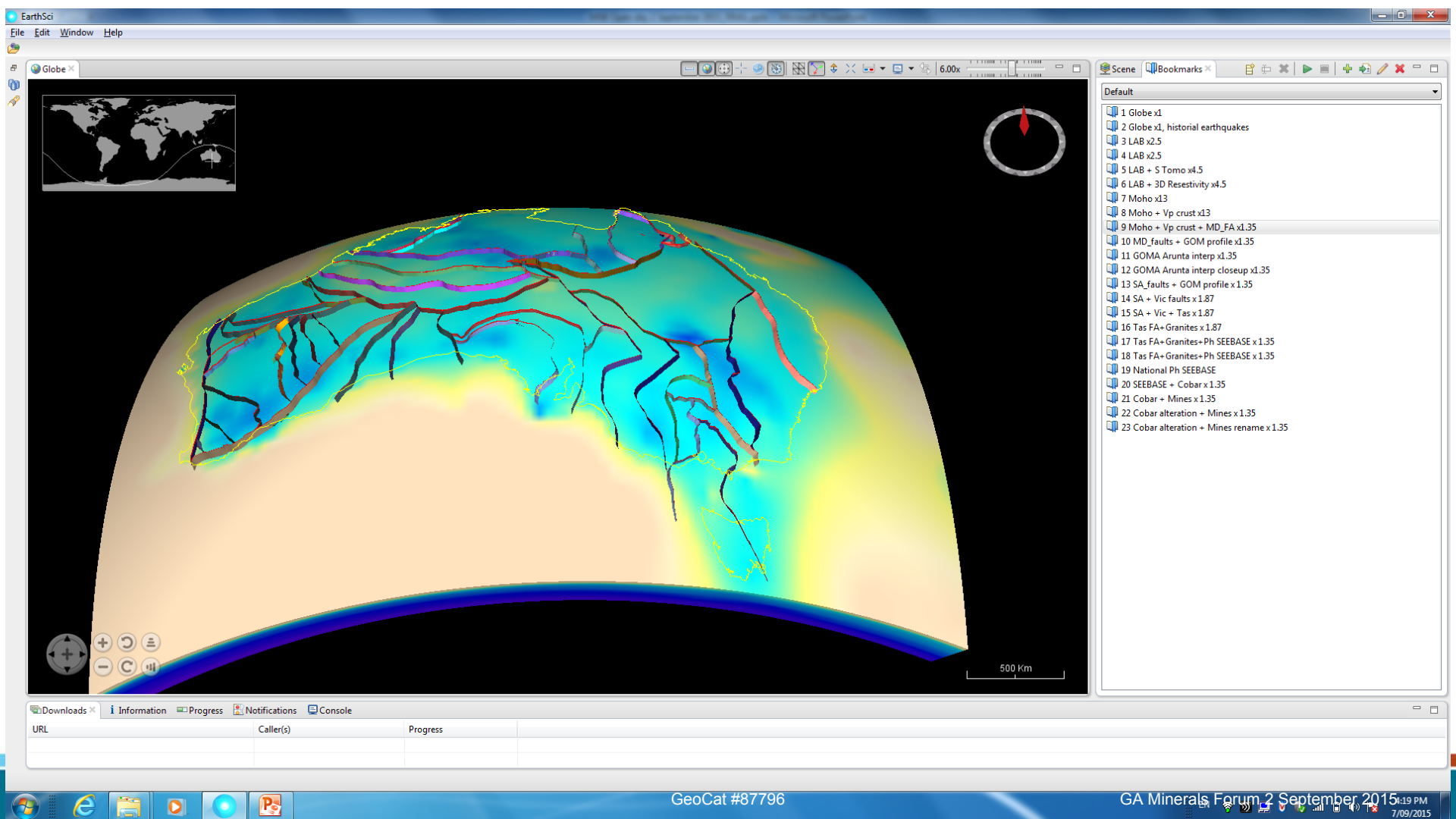
The crustal component of AuSREM makes use of prior compilations of sediment thicknesses, with cross checks against recent reflection profiling, and provides P and S wavespeed distributions through the crust.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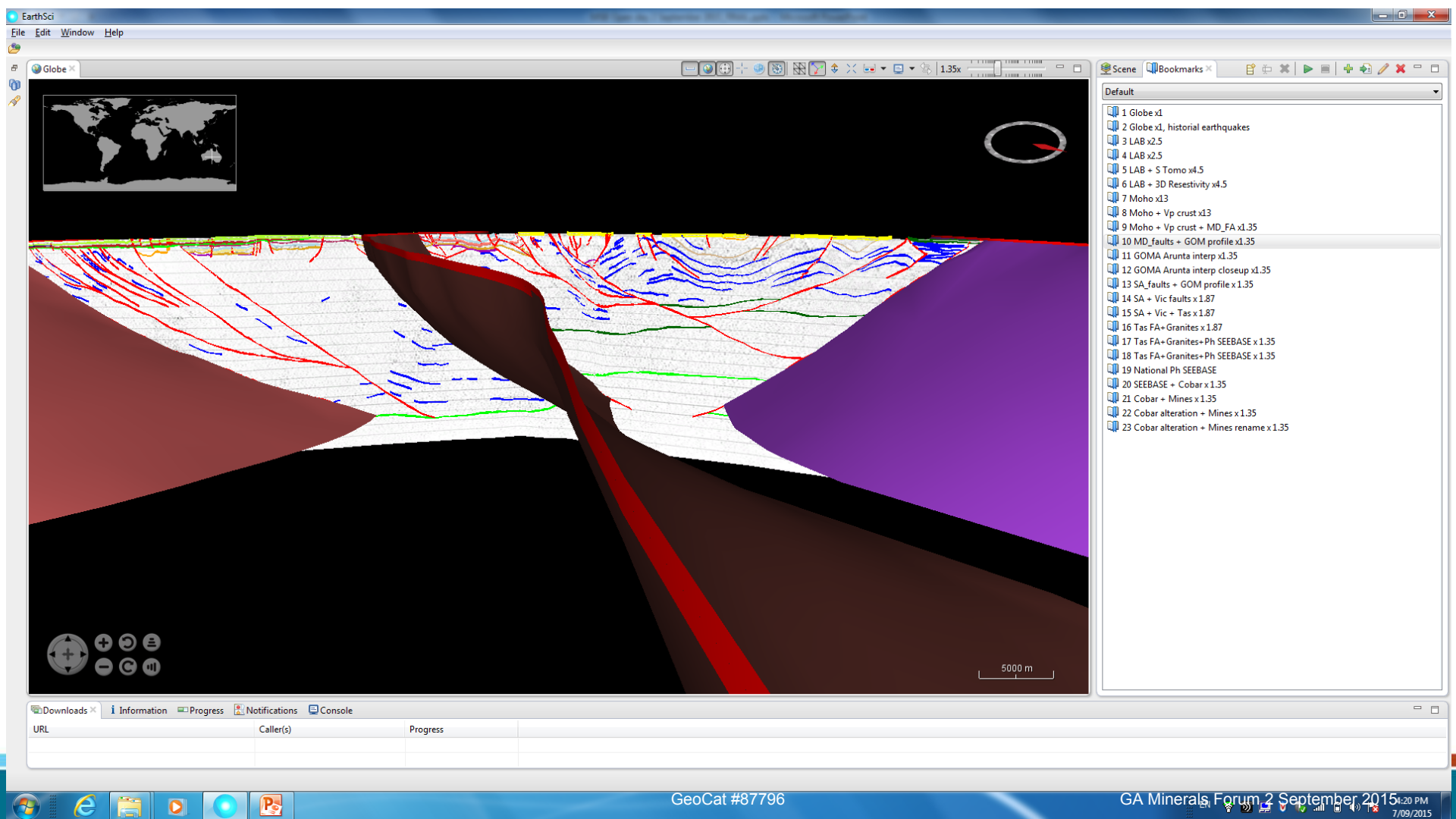
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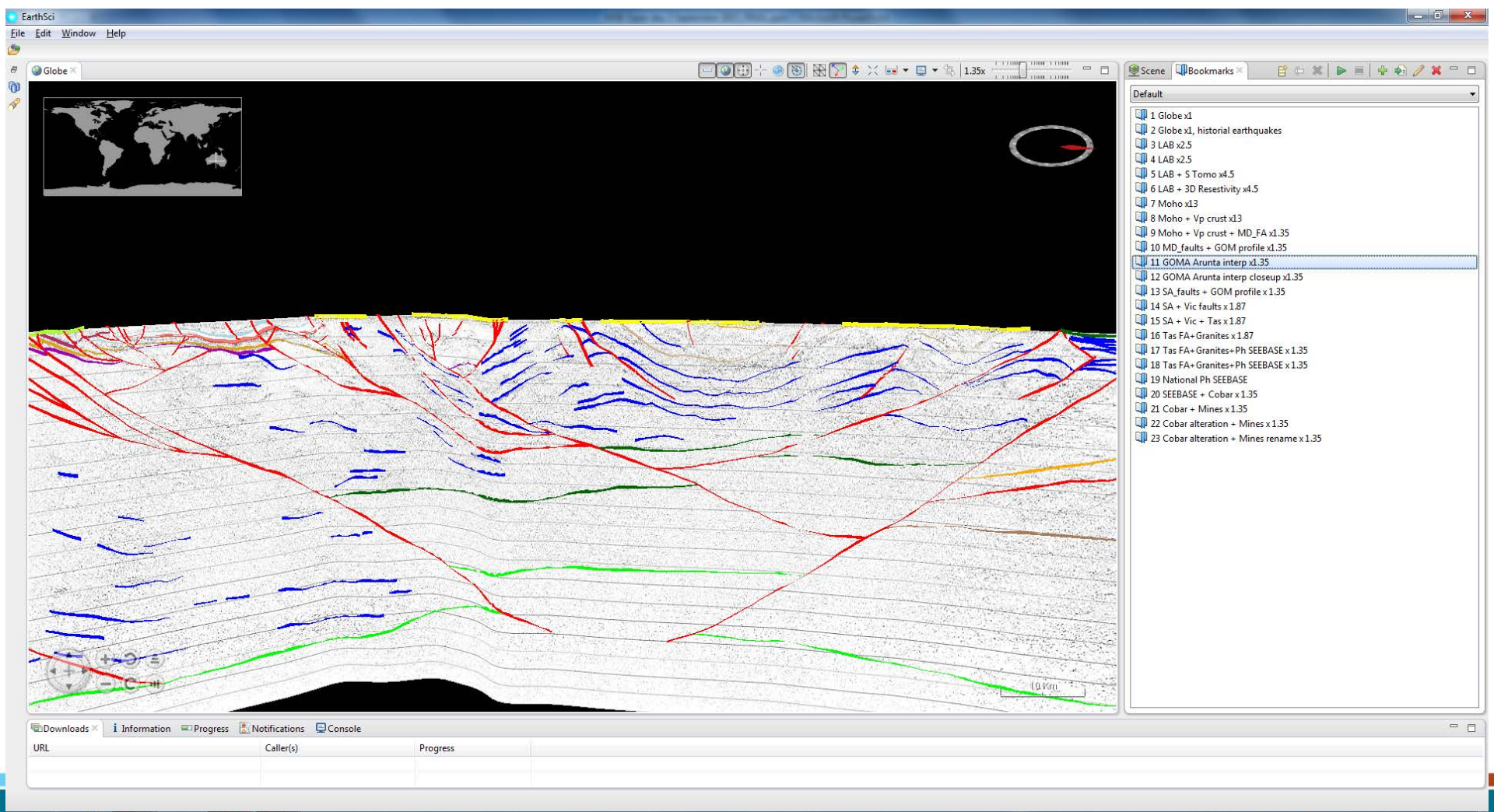
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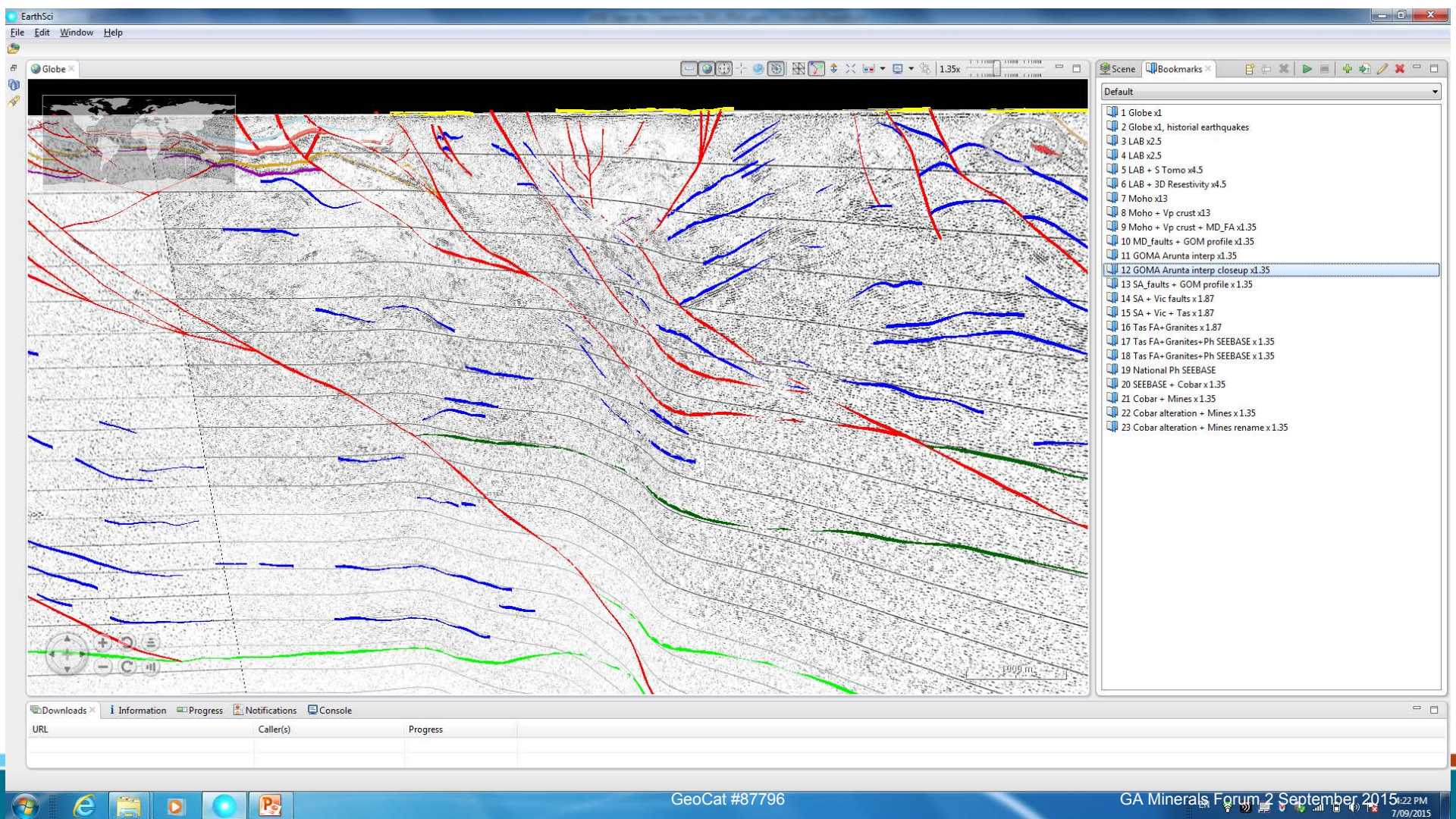
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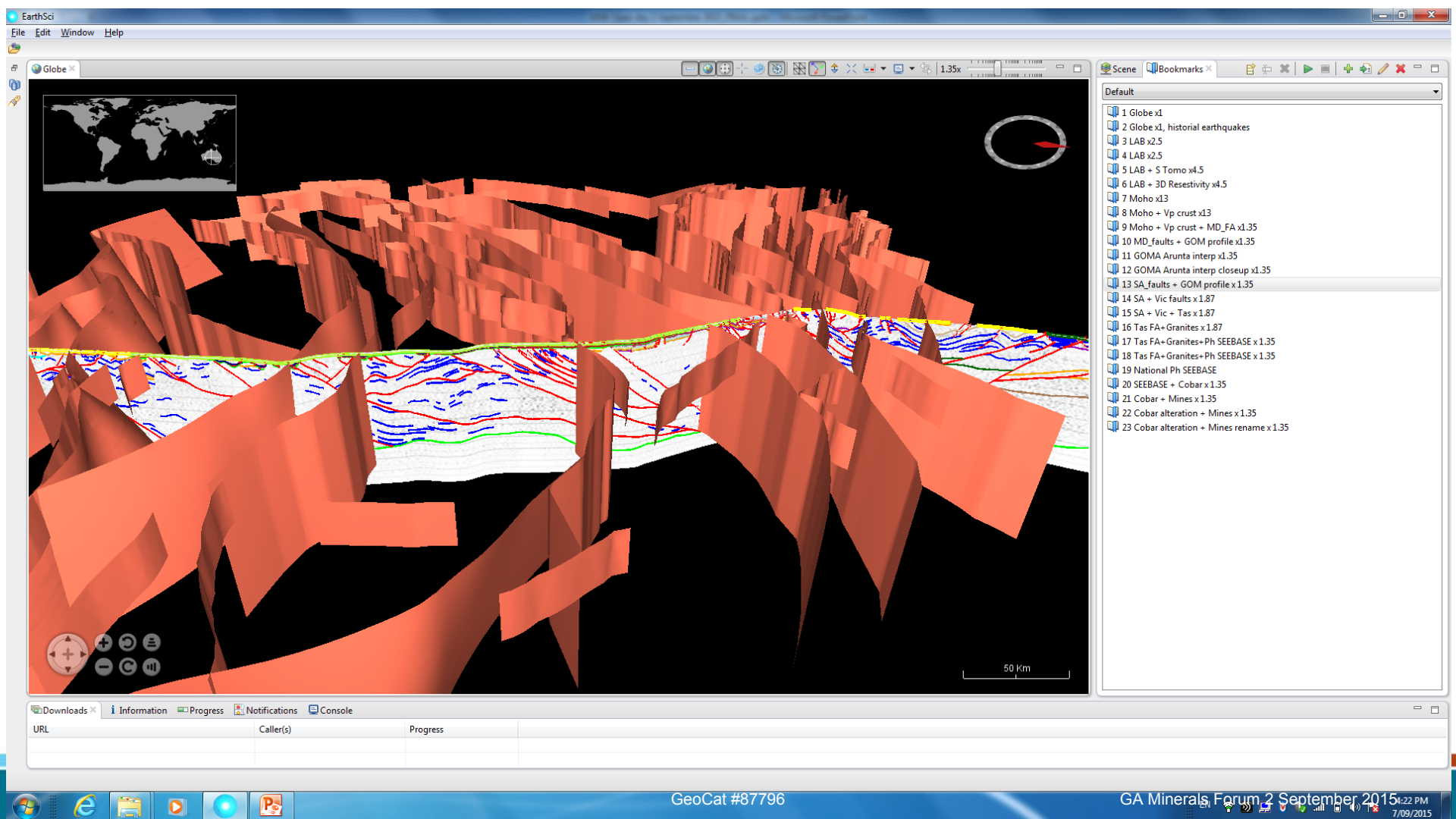
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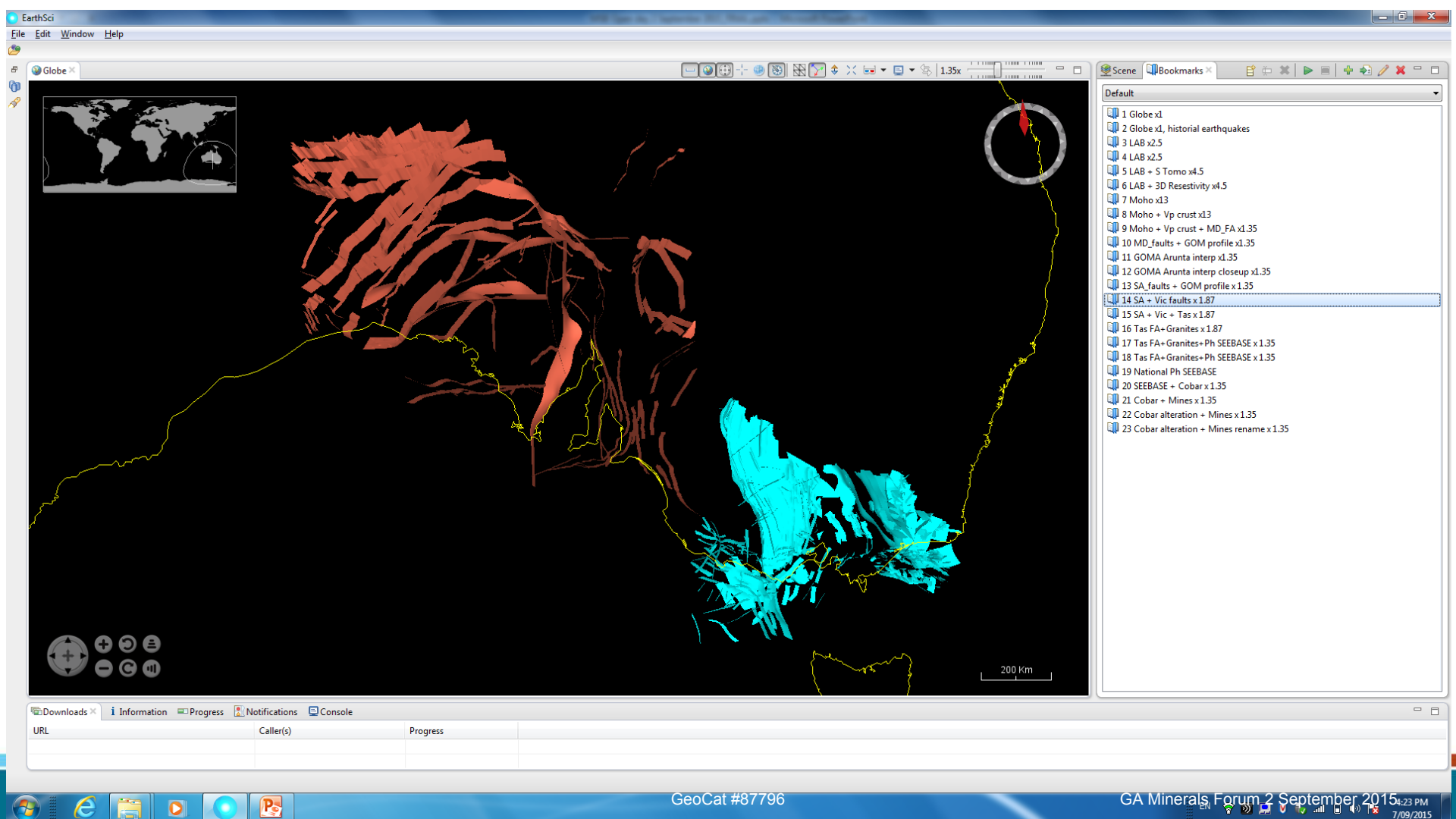
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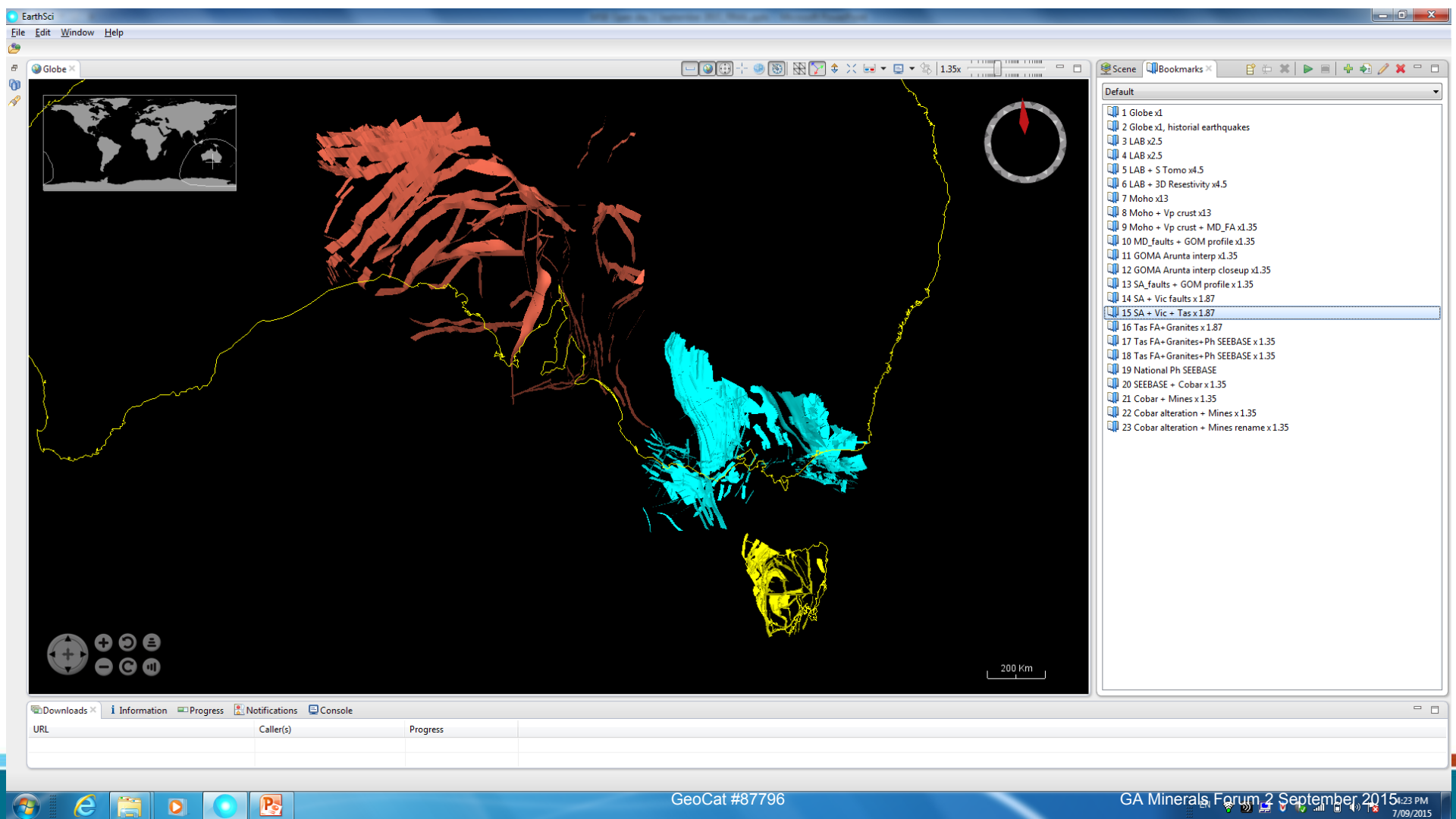
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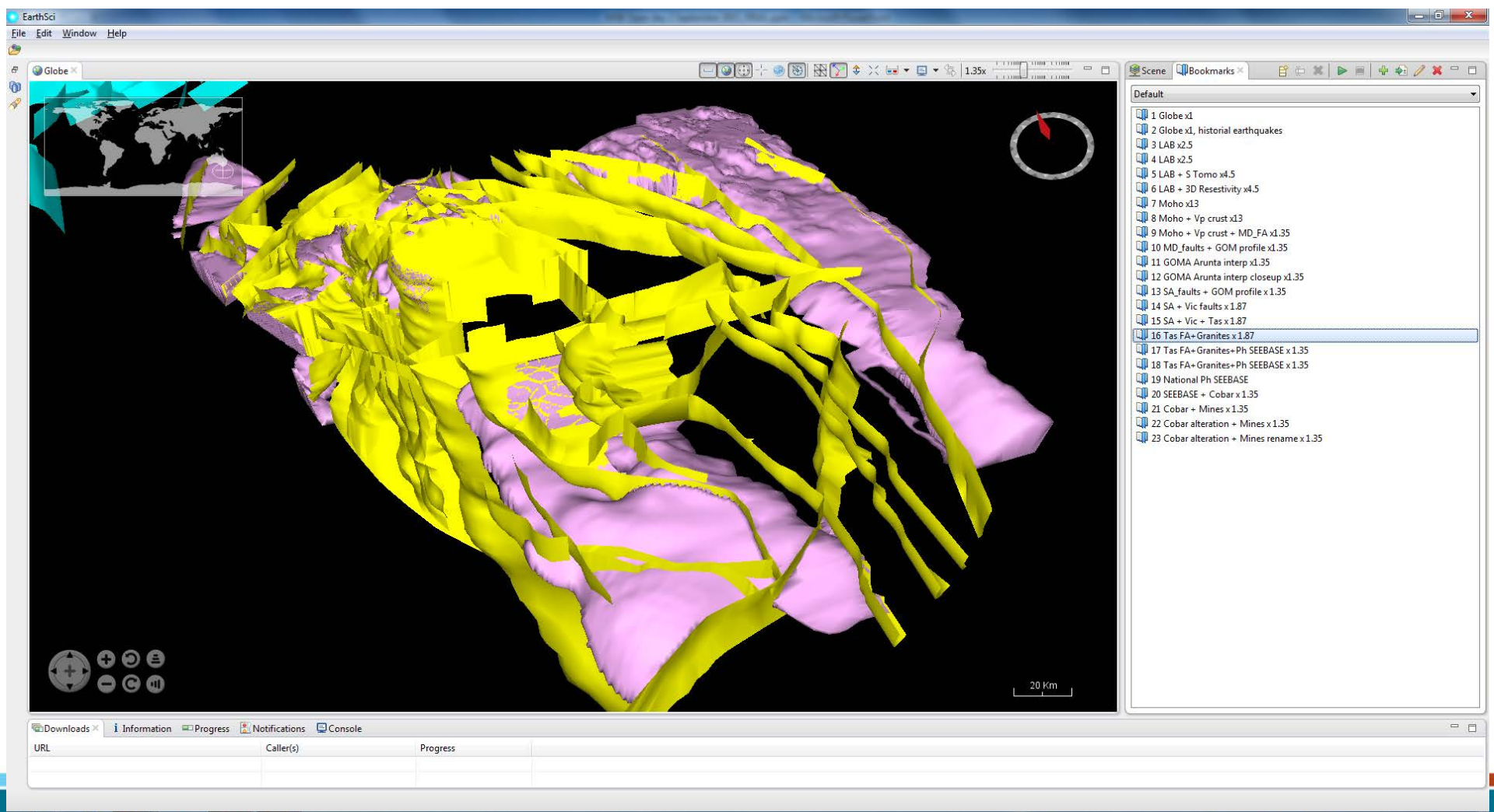
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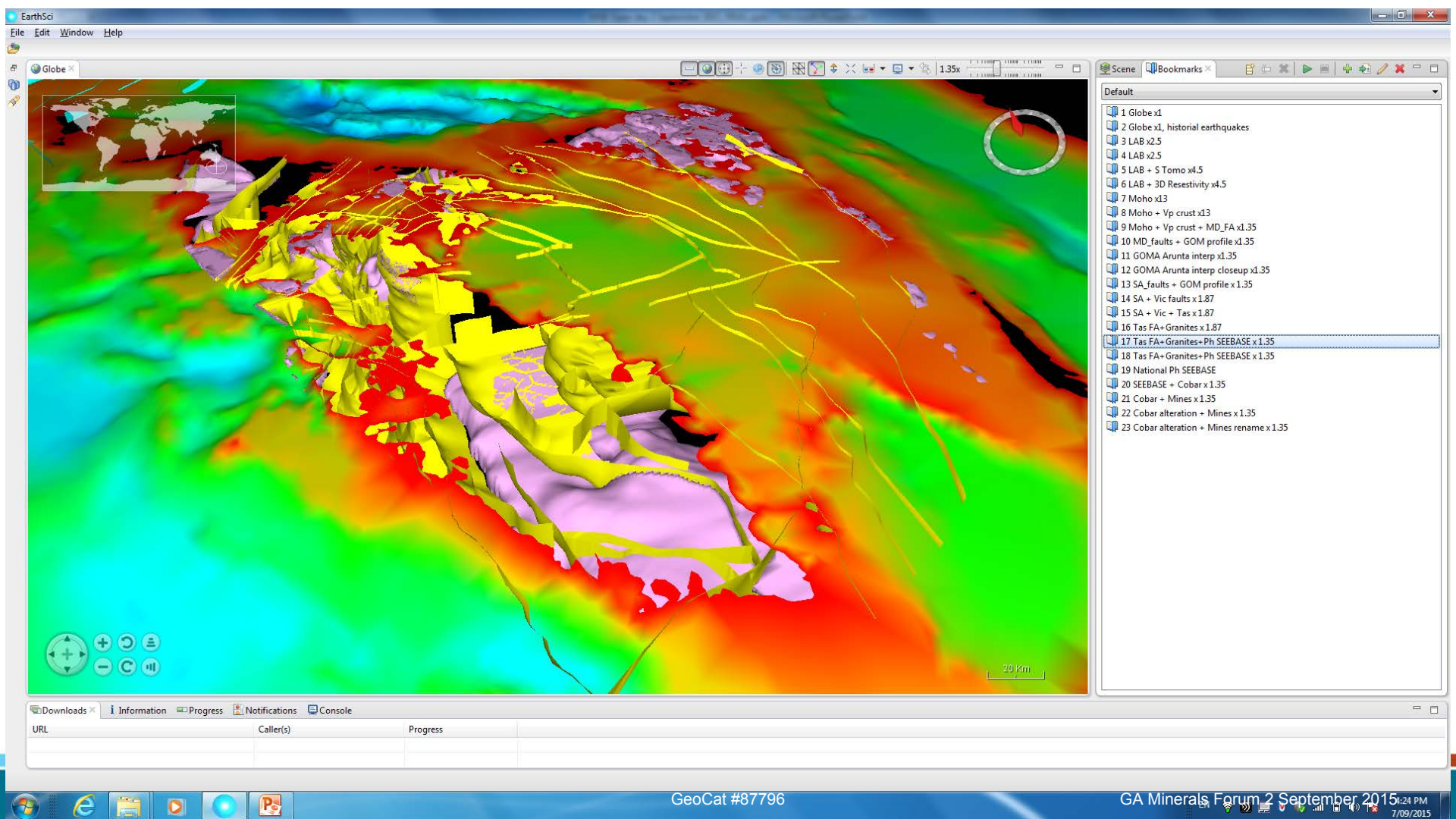
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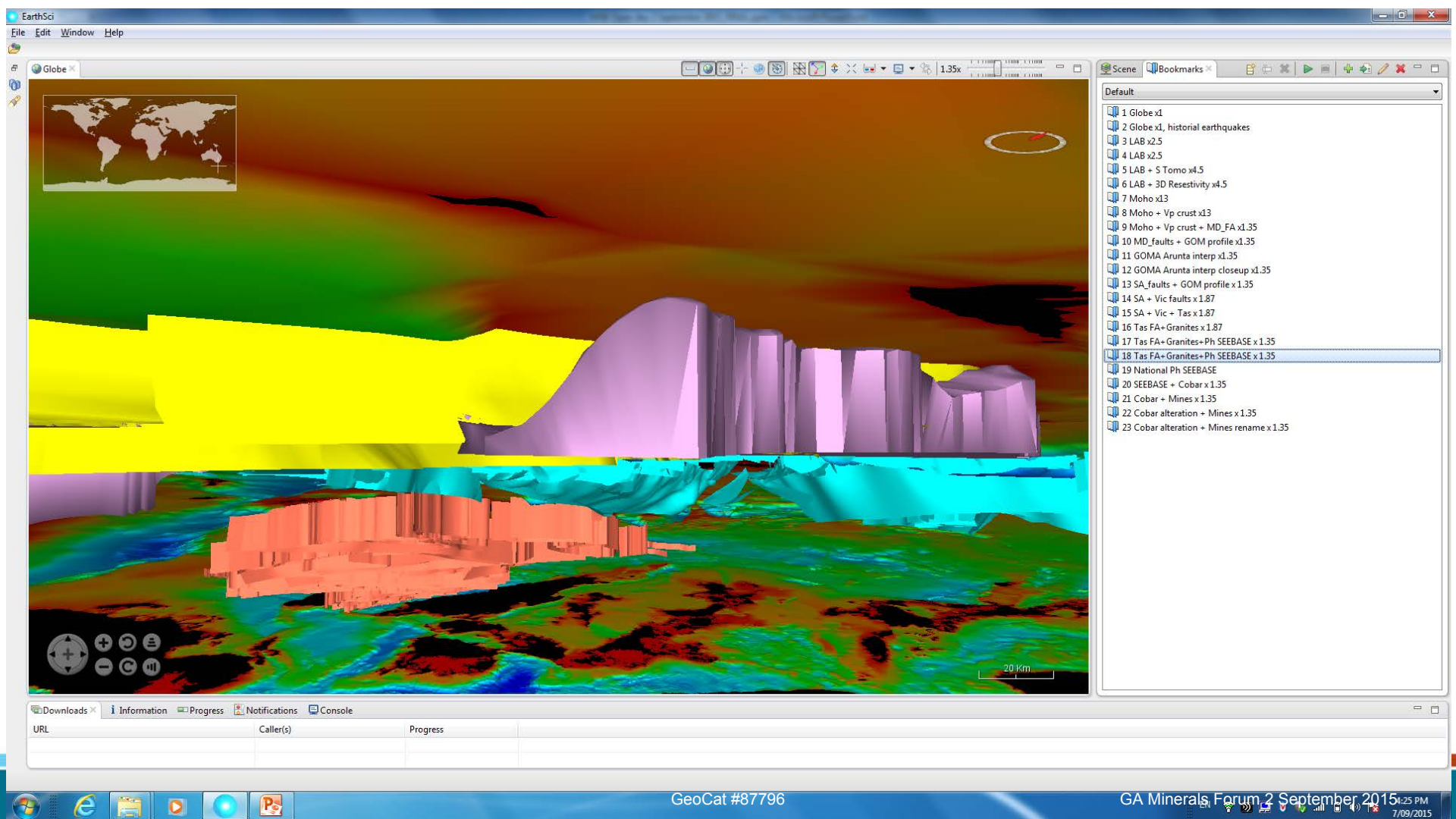
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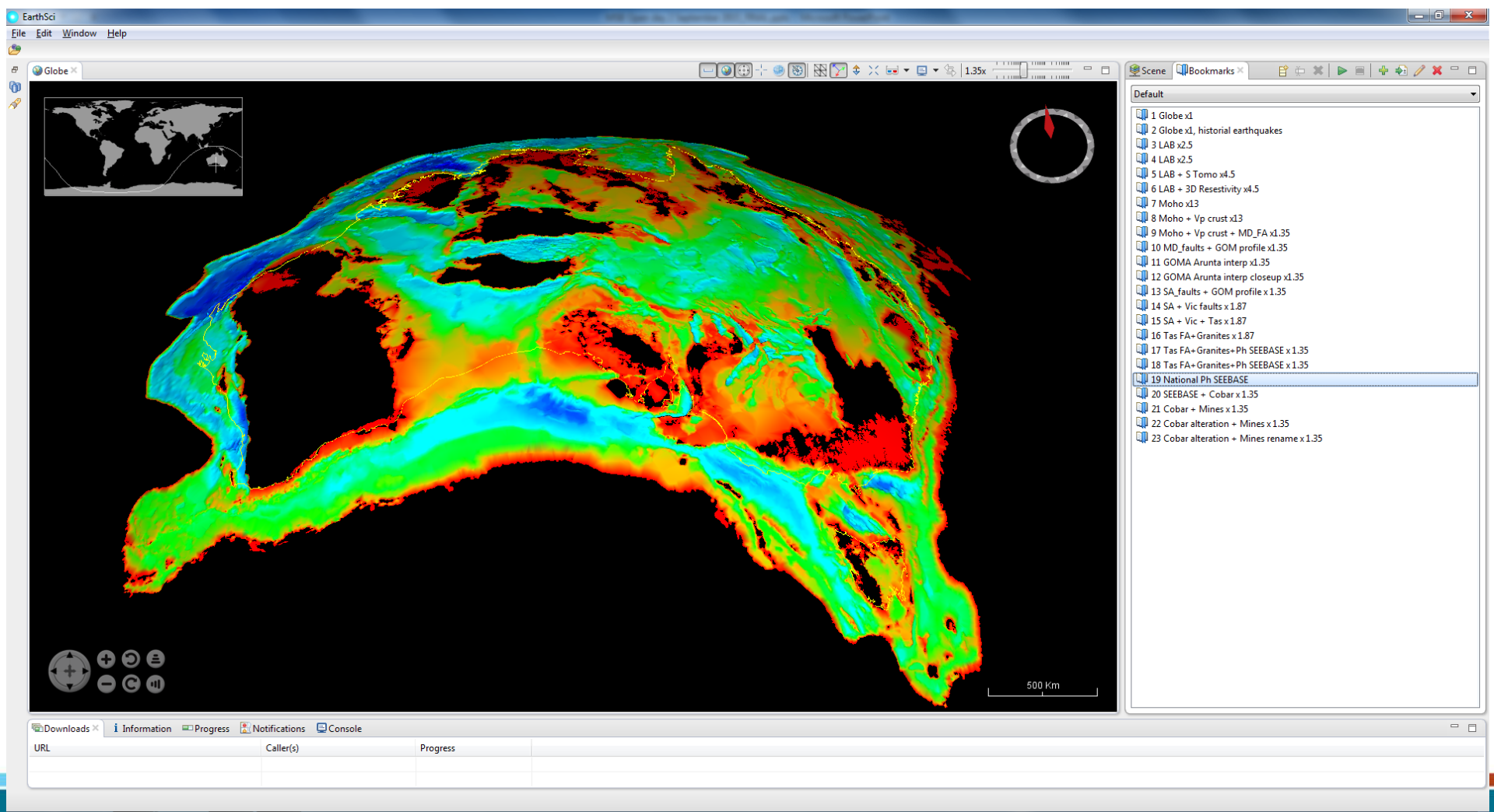
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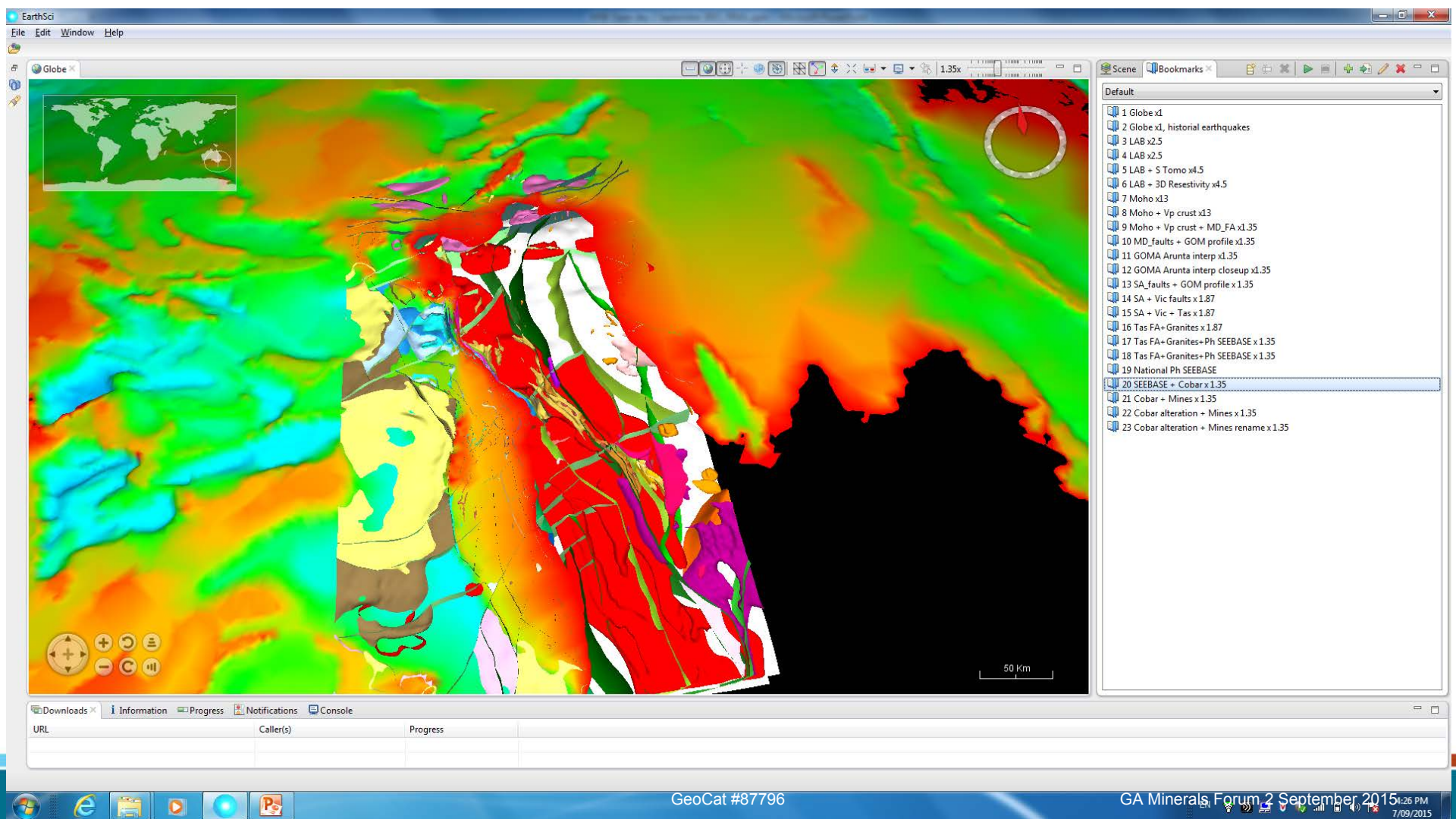
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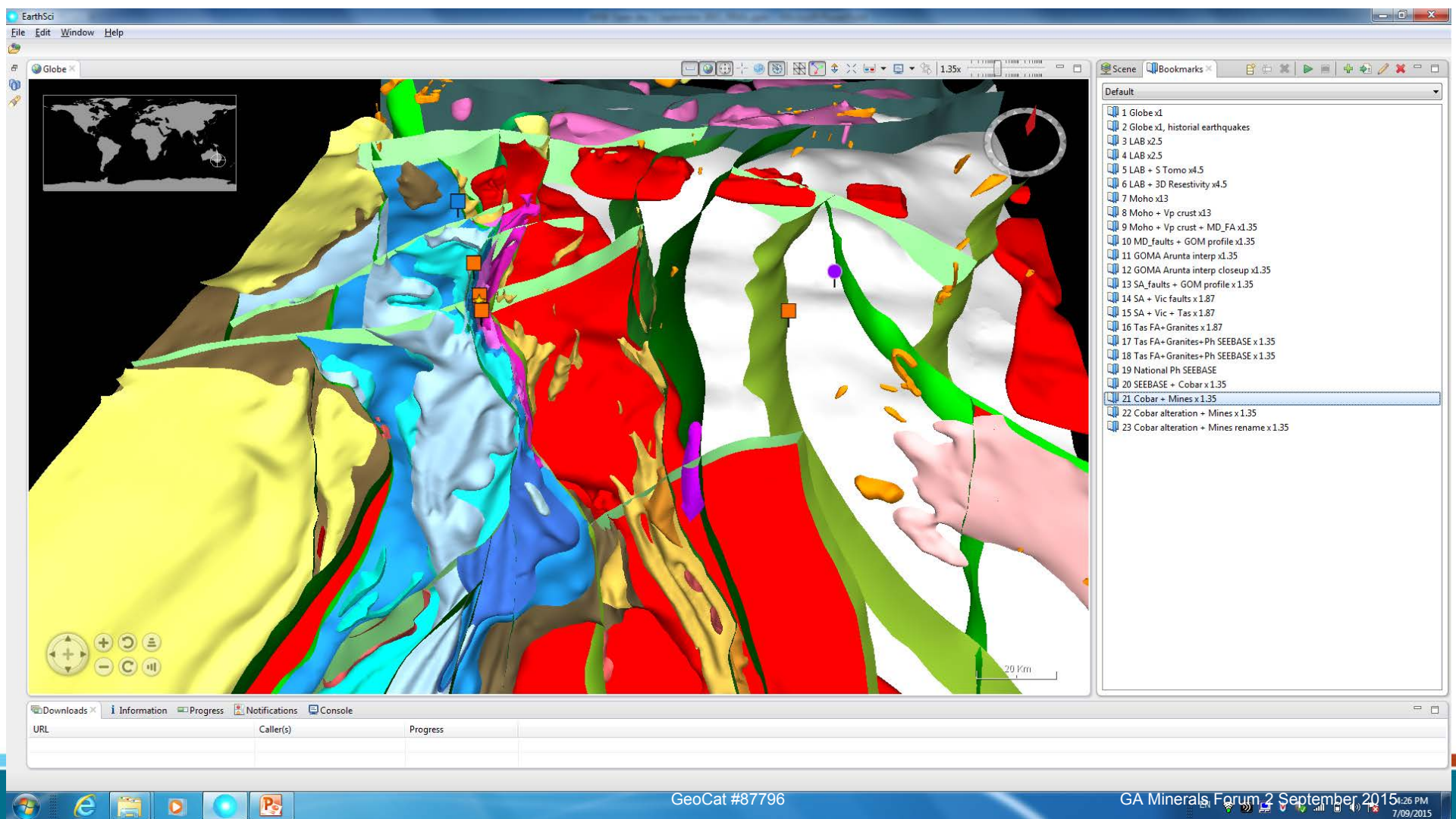
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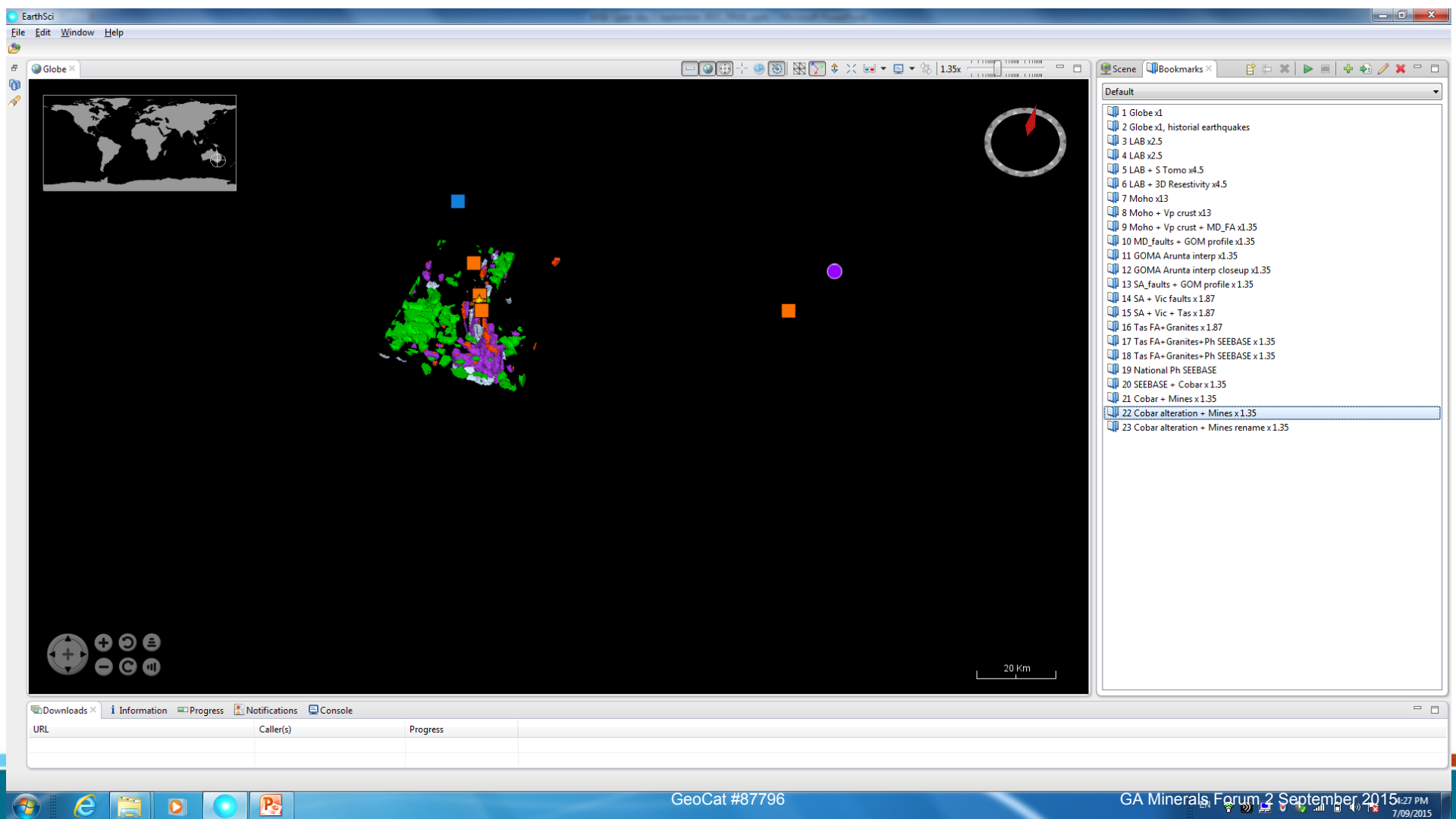
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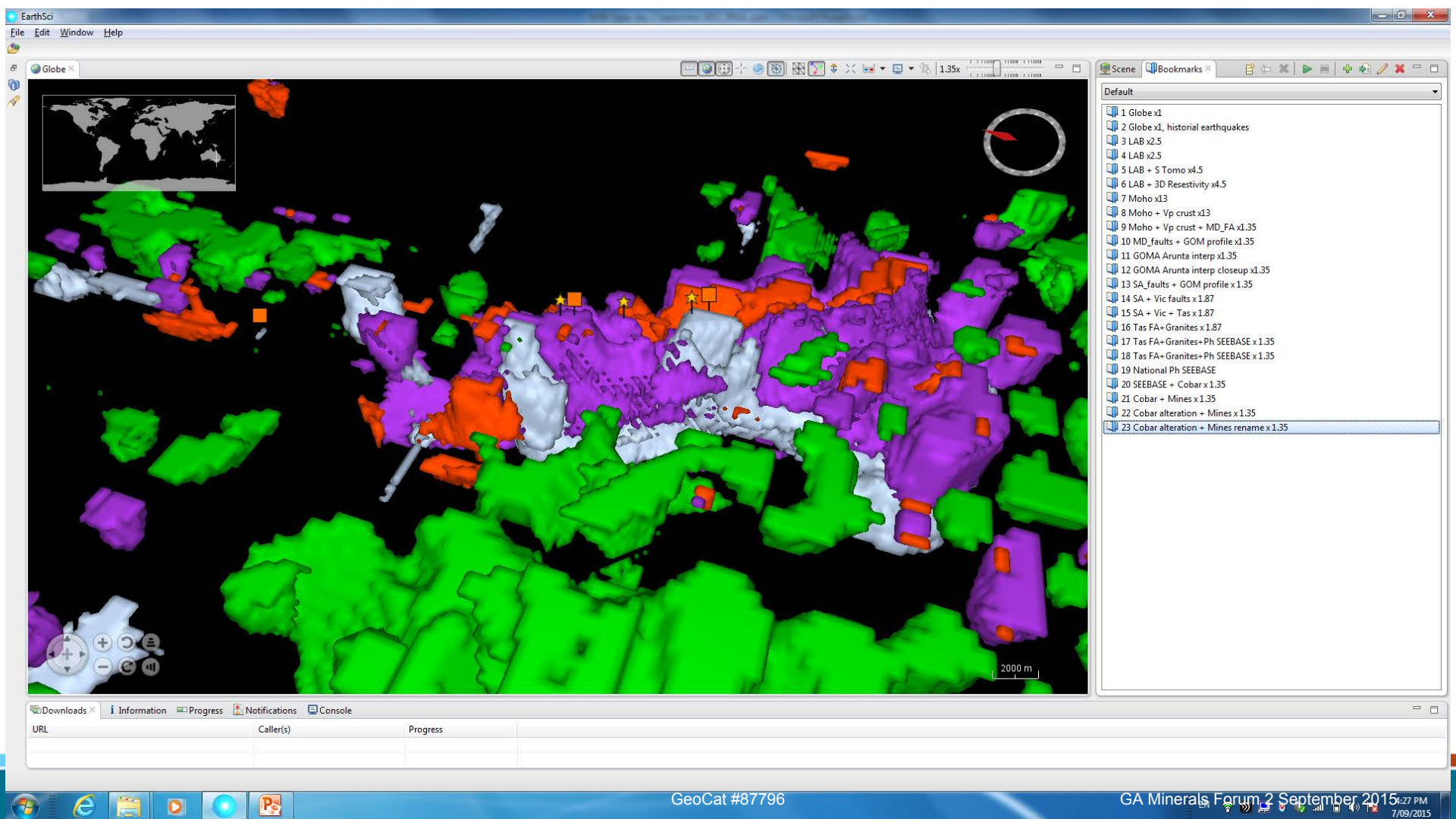
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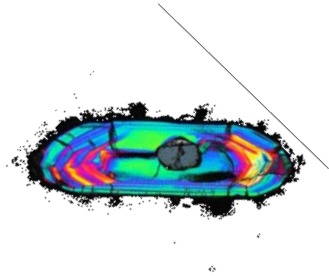
Theme 3: Geodynamics & mineral system evolution

Science problem: Most major ore deposits formed during specific time periods, linked to stages in supercontinent cycles.

Australia is endowed with a >3.8 billion year rock record, but where are the favourably-aged rocks hosting mineral deposits?



Solutions:

a) New determinations of geological ages (stratigraphy, rocks, events, mineral deposits, etc)

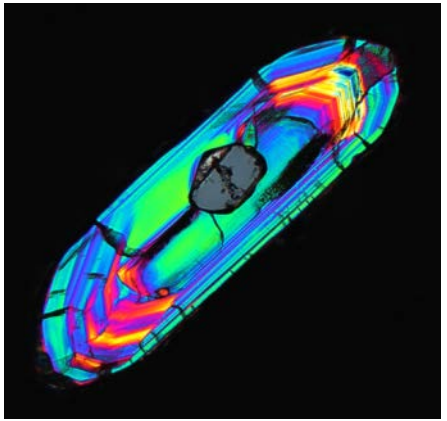
b) Translating theory into practical maps for exploration area selection

c) Assessments of Australia's mineral potential, greenfields and under cover

Australian Government
Geoscience Australia

Australian geology through time:

The Australian Stratigraphic Units Database (ASUD)
GA's geochronology capability and program

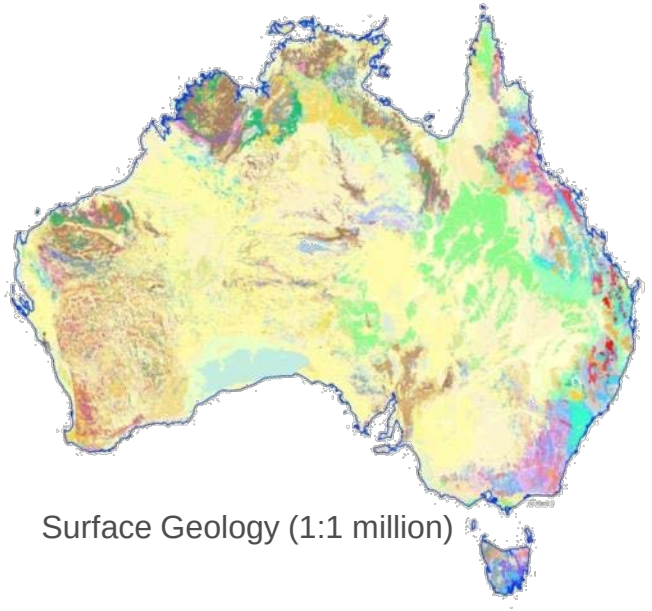


Geoff.Fraser@ga.gov.au

Geochronology & Stratigraphy Section
Mineral Systems Branch, Resources Division

The Australian Stratigraphic Units Database (ASUD)

- >14,000 geological units
- names
- lithologies
- relationships
- ages
- references



Surface Geology (1:1 million)

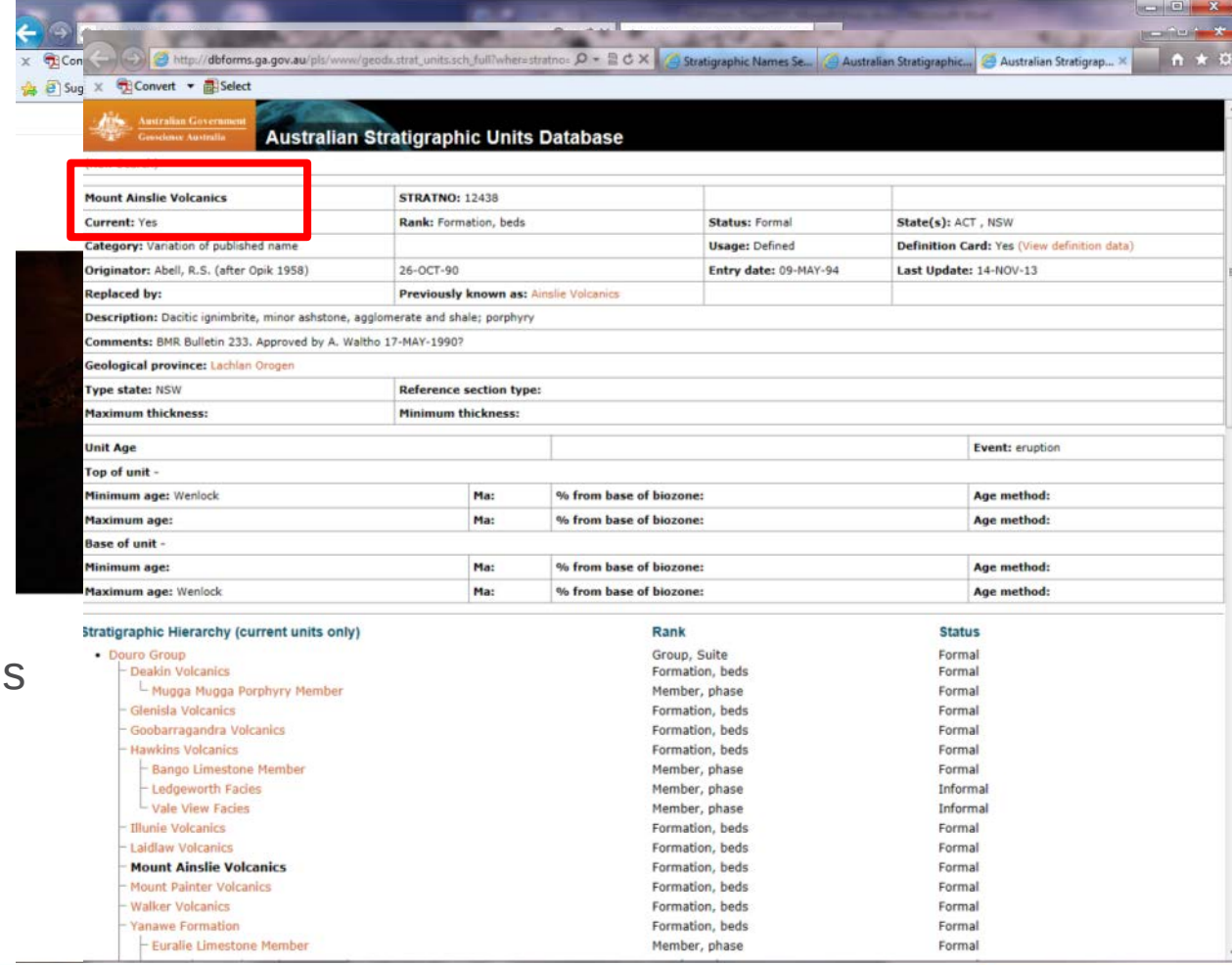
Australian Stratigraphic Units Database (ASUD)

- where to find it?
- ga.gov.au

- stratigraphic unit searches

But that's not all…

- name reservation forms
- unit definition forms
- guides to stratigraphic nomenclature (incl. igneous units)



Geoscience Australia's geochronology program:

- **core capability is in-house SHRIMP laboratory**
- **other in-house expertise (but not in-house analytical facilities):**
  ID-TIMS U-Pb, Ar-Ar, K-Ar, Re-Os, (Nd, Pb, O, Hf)

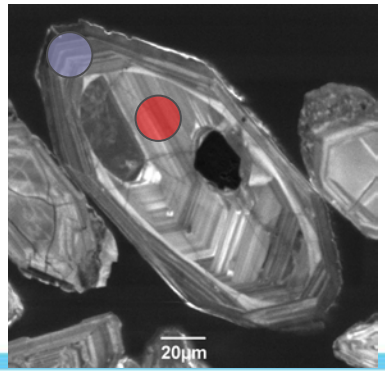
Geological Events we can (and do) date:

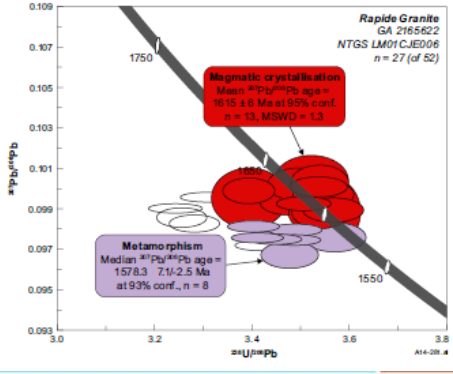
- Igneous
- Metamorphic
- Fluid alteration/mineralisation
- Sediment provenance
- Geological timescale calibration

SHRIMP

- U-Pb zircon (monazite, titanite)
- ~120 samples per year
- supporting GA projects
- ongoing collaborations with:
  - NTGS
  - GSQ
  - GSNSW
  - GSSA
  - GSV

Big instrument …> 5 metres
Small targets… ~300 micron zircon grains

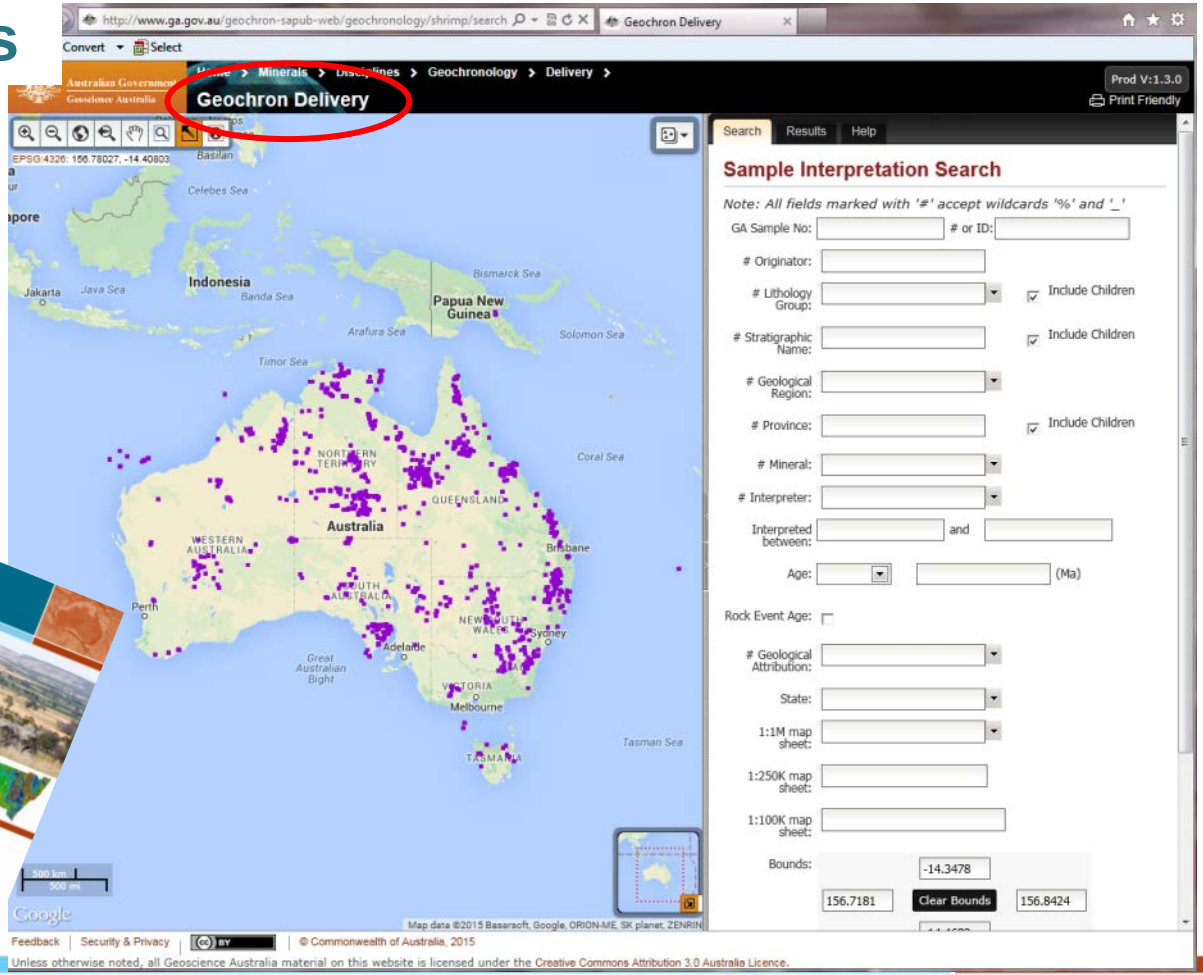




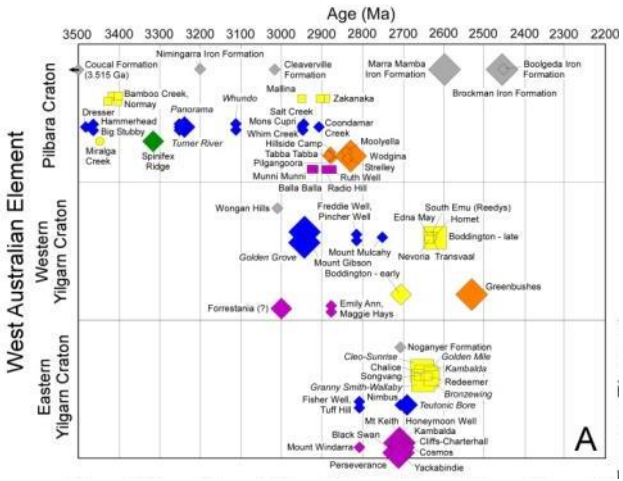
Mineral Separation & Sample Preparation

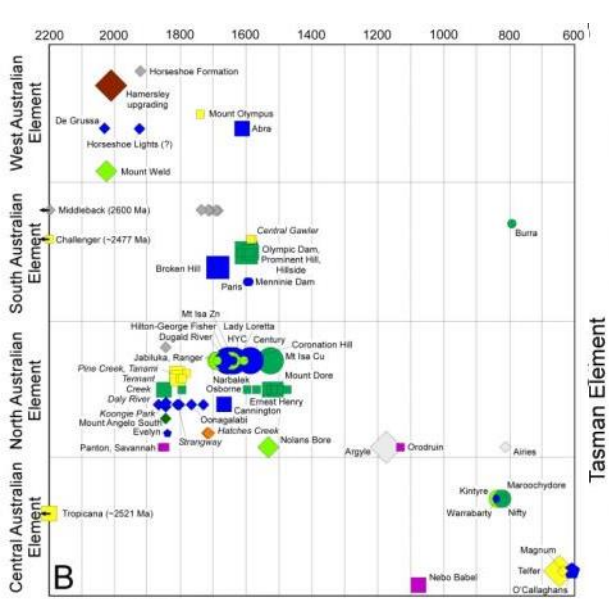
Geochronology results

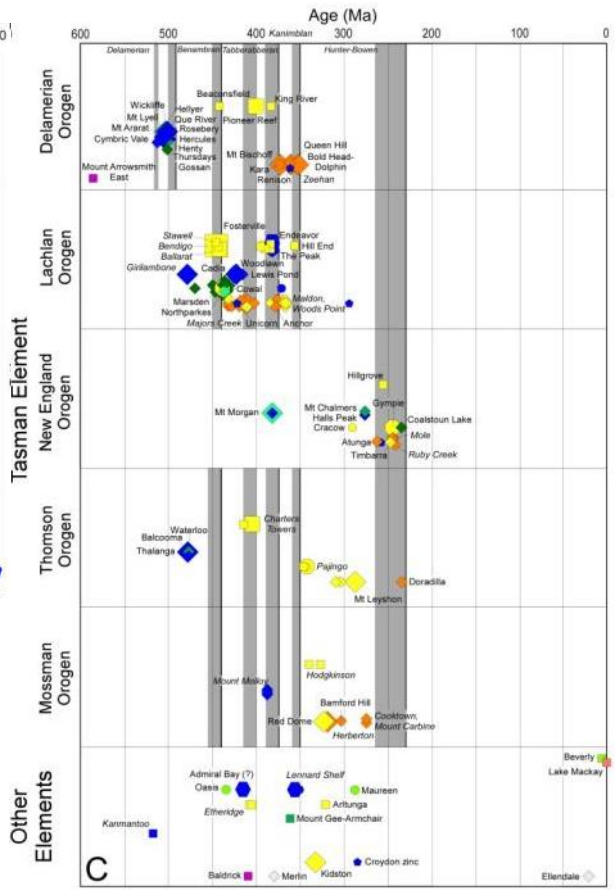
- Geological reports
- Journal papers
- Online data delivery
  - >1300 samples from GA laboratory



Datasets: ages of Australian ore deposits – a new synthesis







Convergent margins

Initial stage: subduction
- Komatiite-associated Ni-Cu-PGE
- VHMS Zn-Pb-Cu; high sulphidation Cu-Au
- Porphyry Cu-AuMo; calc-alkaline and alkaline
- Epithermal Au, Ag-Pb-Zn

Final stage: post-orogenic extension
- Iron ore enrichment
- Iron-oxide Cu-Au(U)
- Granite-related Zn-W-Cu-Sn
- Granite-related Sn-Ta, Mo-W
- intrusion-related Au

Intermediate stage: orogenesis
- Mississippi Valley-type Zn-Pb
- Epigenetic Cu-Au; Zn-Pb-Ag
- Orogenic Au

Intraplate
- Sandstone-hosted U; surficial U-V
- Salt-lake hosted K
- Orthomagmatic Ni-Cu, PGE and V-Ti-Fe

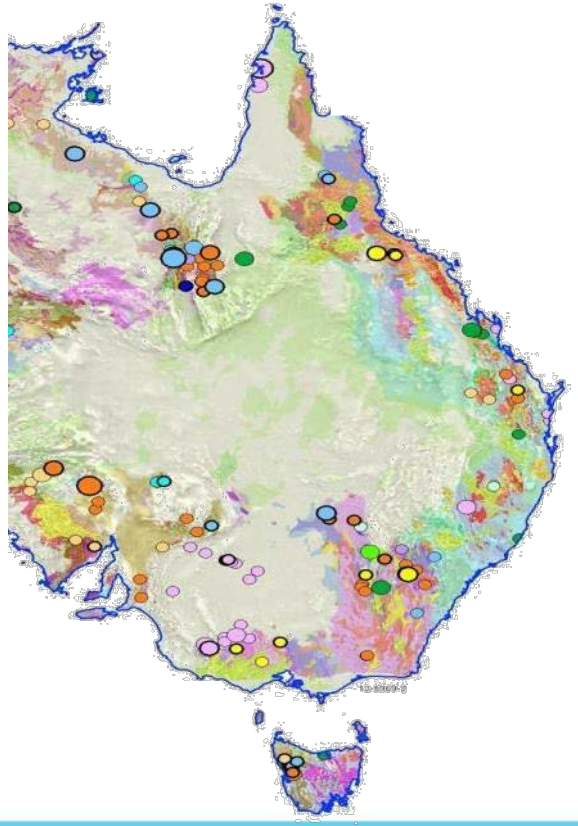
Divergent margins

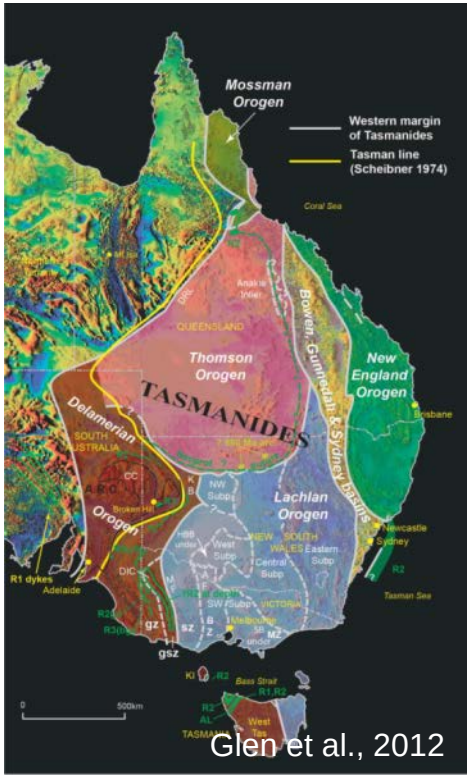
Initial stage: initiation and rifting
- Diamond
- Alkaline-related REE-P-Th-U
- Siliciclastic-mafic Zn-Pb-Ag

Final stage: basin sag, passive margins and inversion
- Shale-hosted Cu
- Unconformity-related U
- Banded-iron formation (undifferentiated)
- Siliclastic-carbonate Zn-Pb-Ag

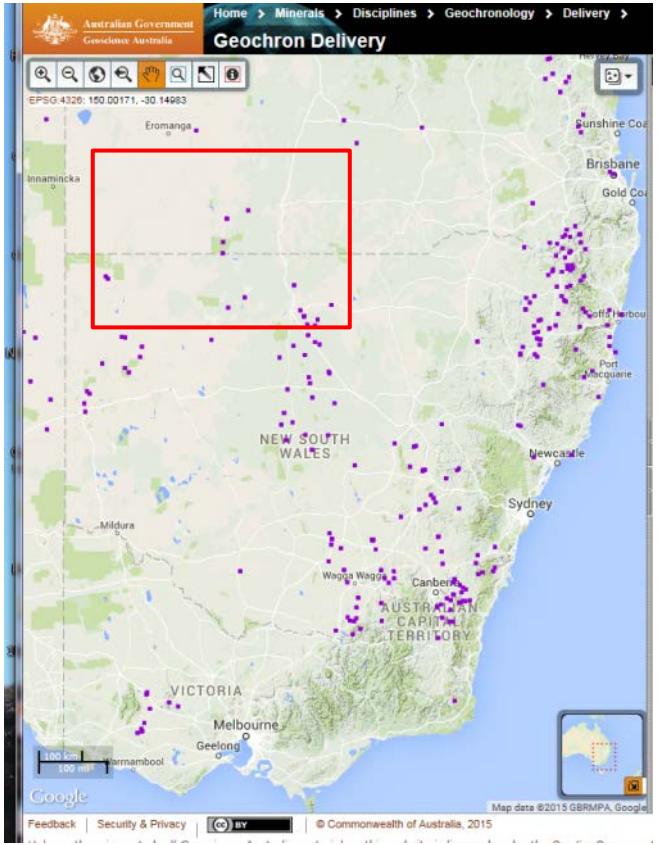
(from Huston et al., in press)

Work in progress: southern Thomson Orogen





Glen et al., 2012

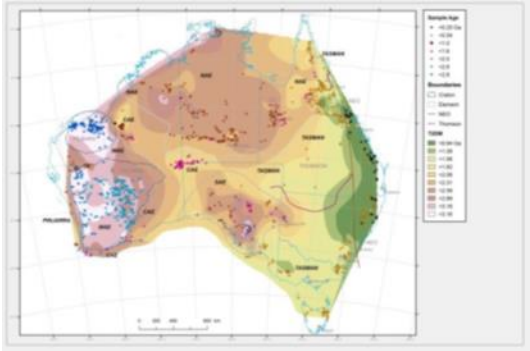


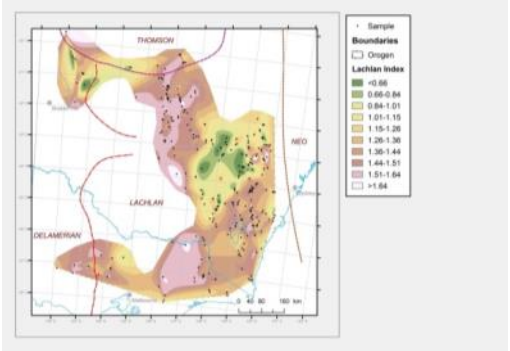
Contact us…..

stratnames@ga.gov.au
geochronology@ga.gov.au

Australian Government
Geoscience Australia

Isotope geochemistry: a tool to map crustal architecture and fertility

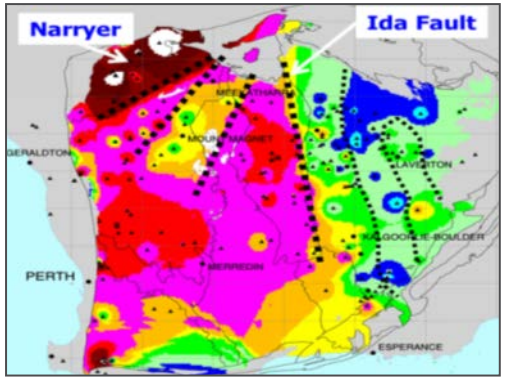




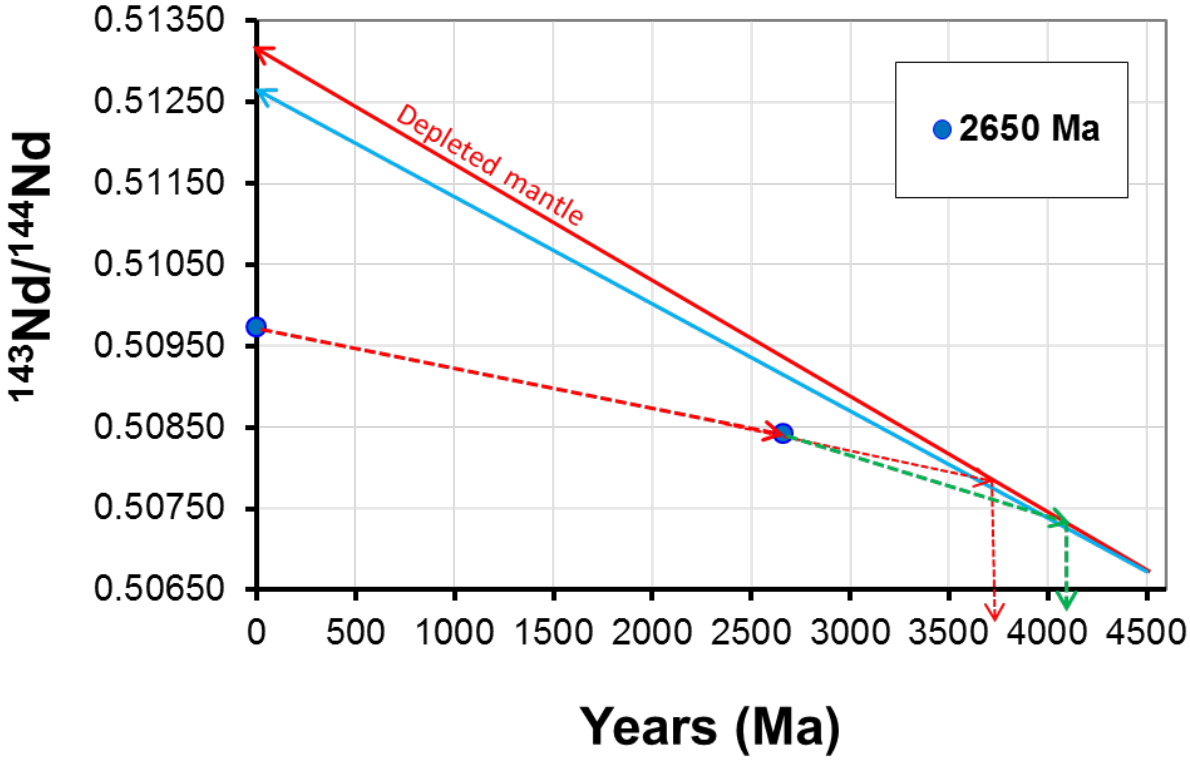
Kathryn Waltenberg, David Champion, David Huston
Kathryn.Waltenberg@ga.gov.au

4D metallogenic evolution: big boundaries in Sm-Nd and Pb

Yilgarn T_{DM} map



Champion & Cassidy, 2004



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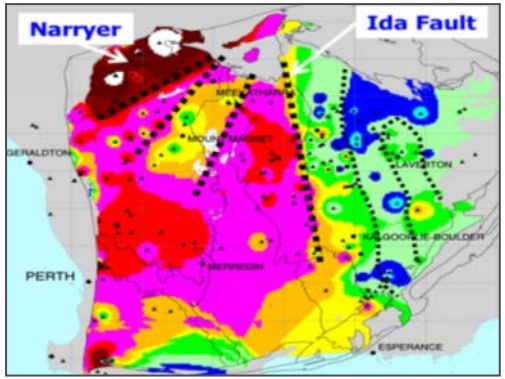

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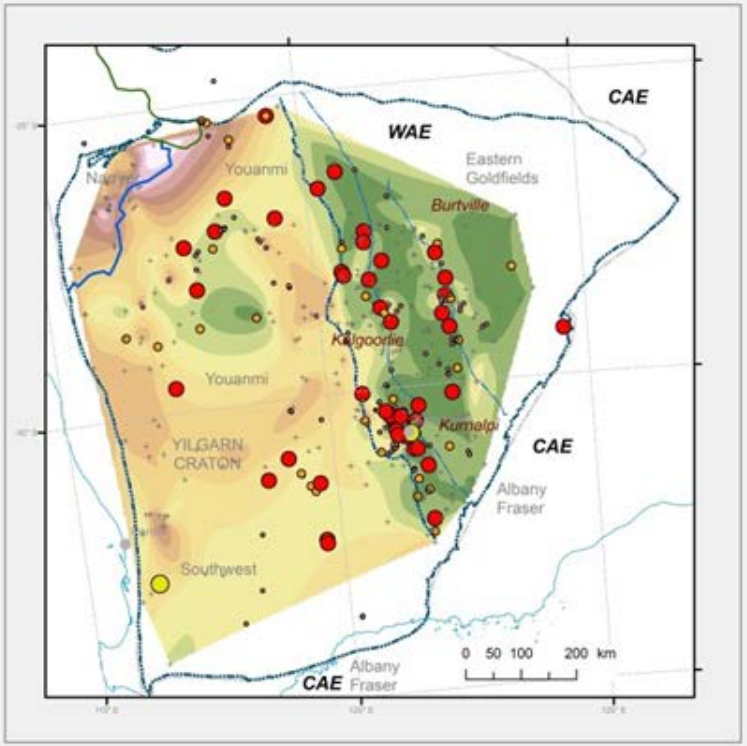
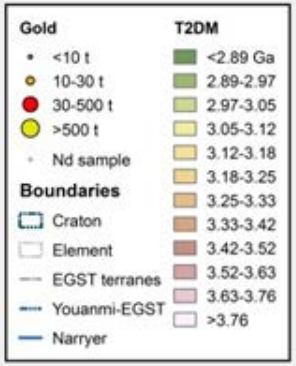




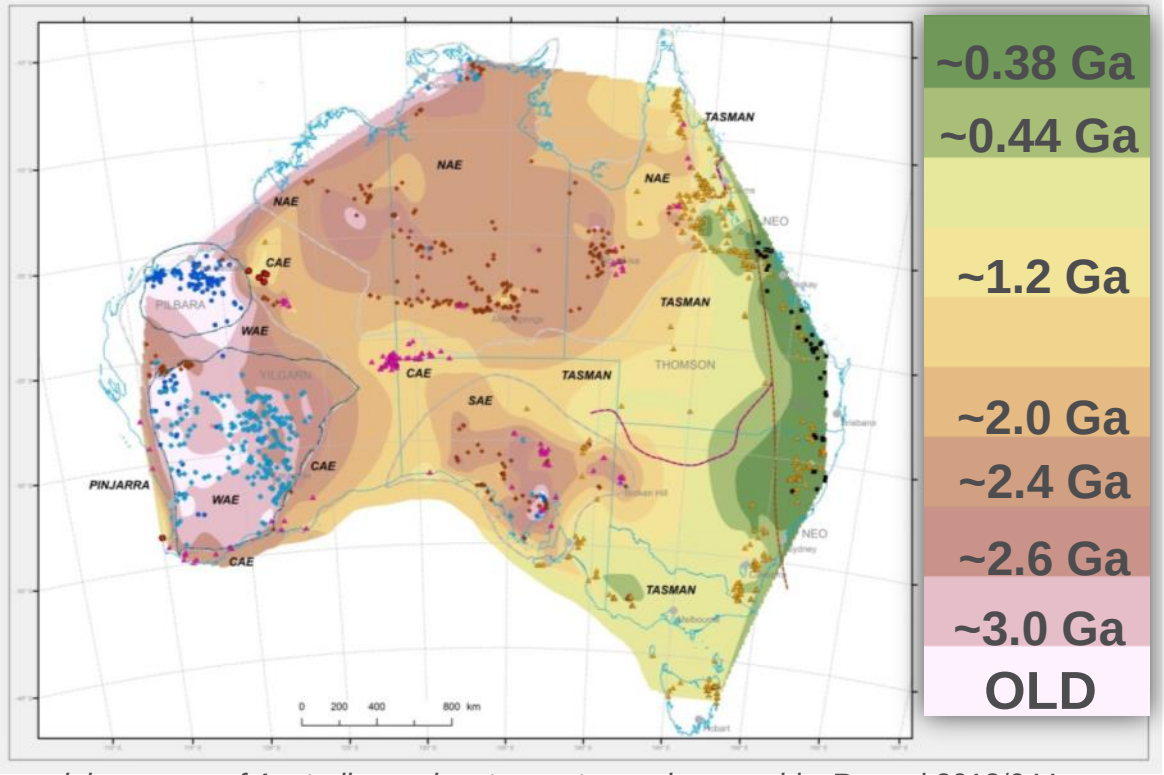
Champion et al 2013

Sm-Nd model age map of Australia

- Look ‘through’ the granite to date its source
- ~Timing of crust ‘extraction’ from mantle

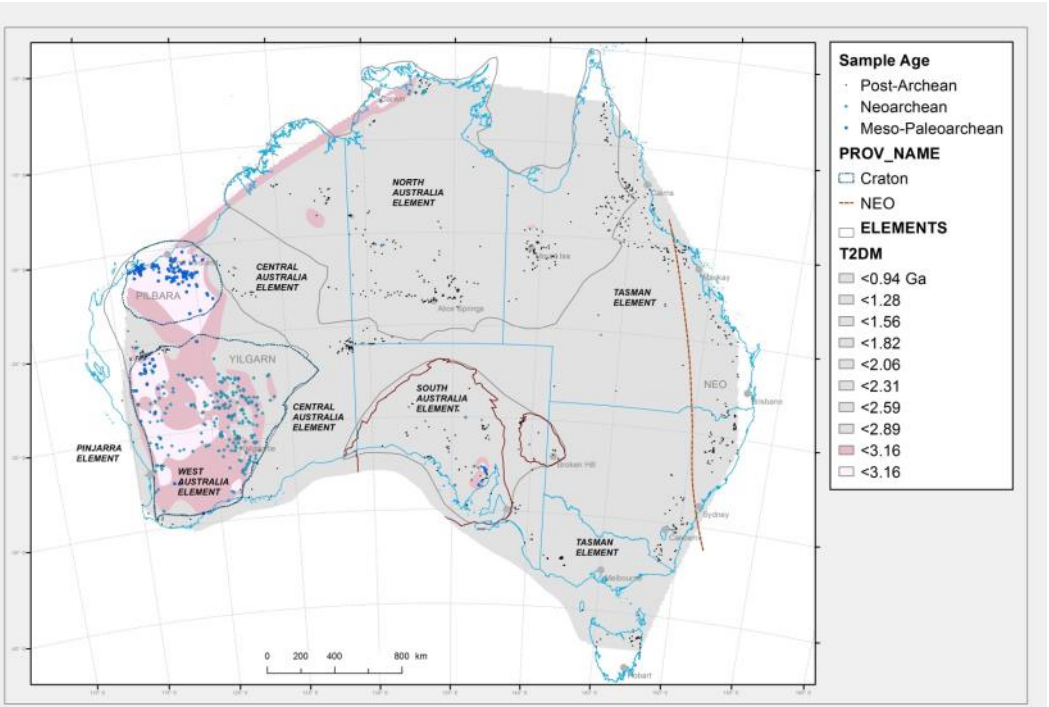
Model ages:

- Approximation of the bulk age of the crust
- Best used in relative terms and at regional scales



Champion, D.C., 2013. *Neodymium depleted mantle model age map of Australia: explanatory notes and user guide*. Record 2013/044. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2013.044

Sm-Nd model age map of Australia: building a continent



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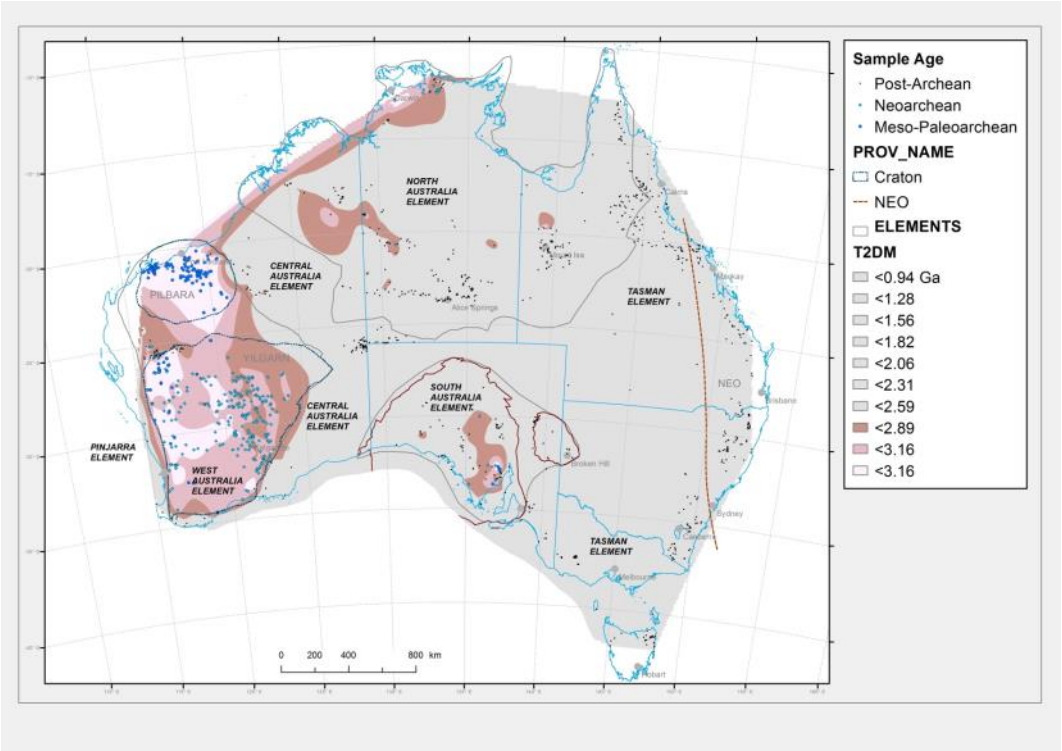

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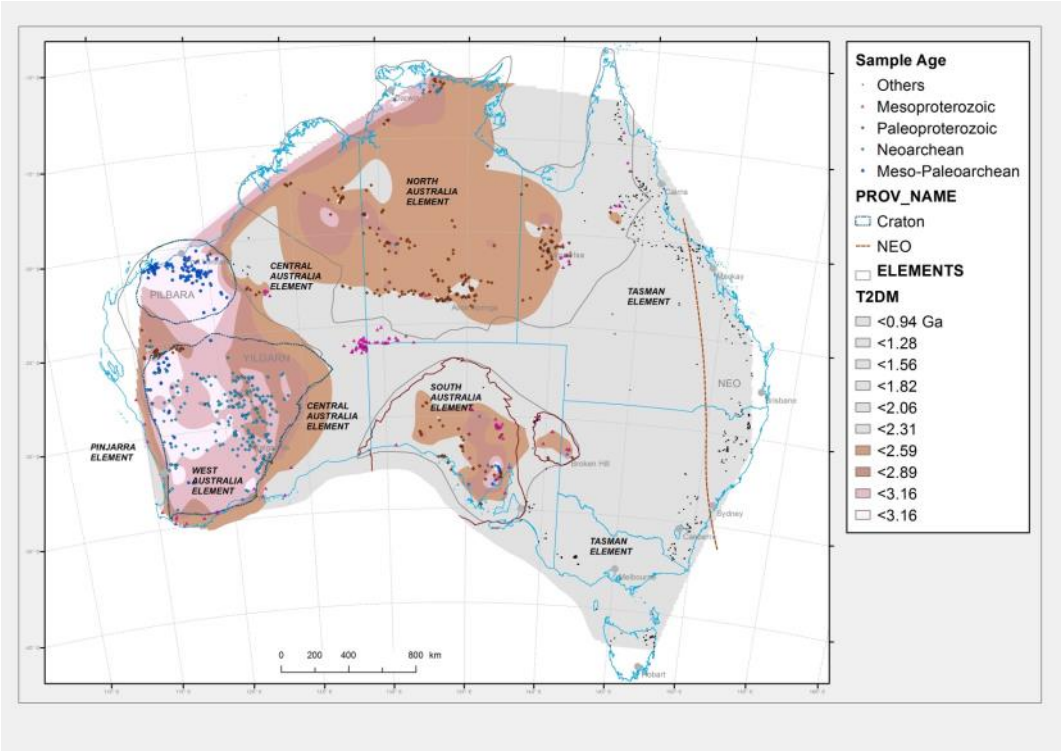

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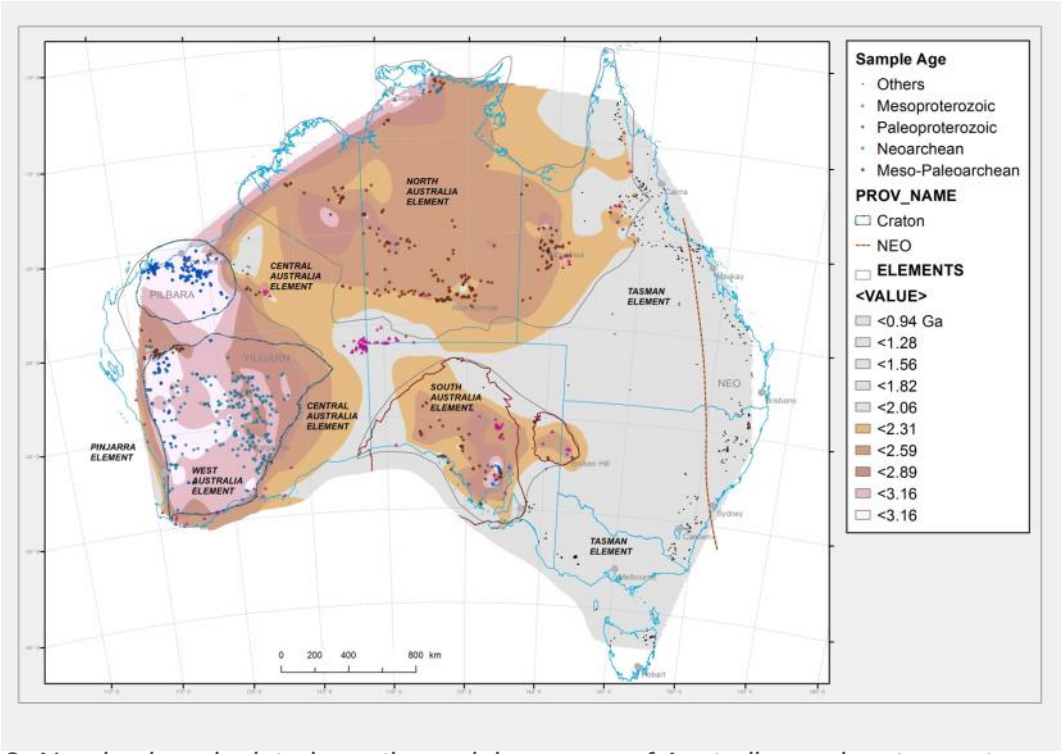

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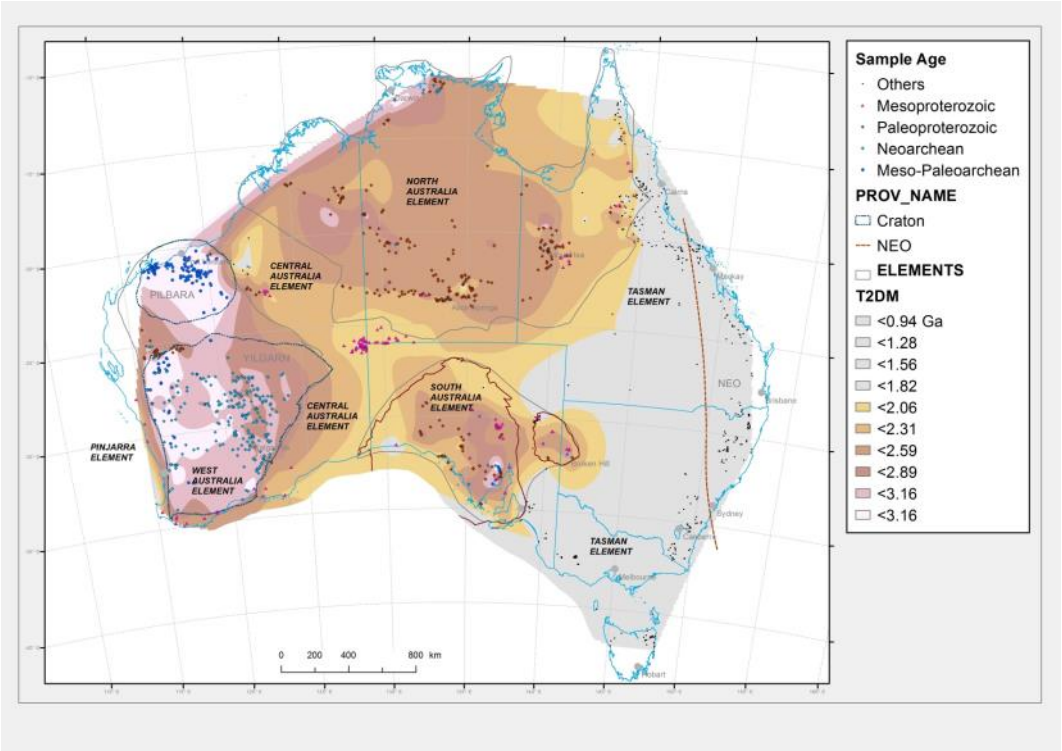

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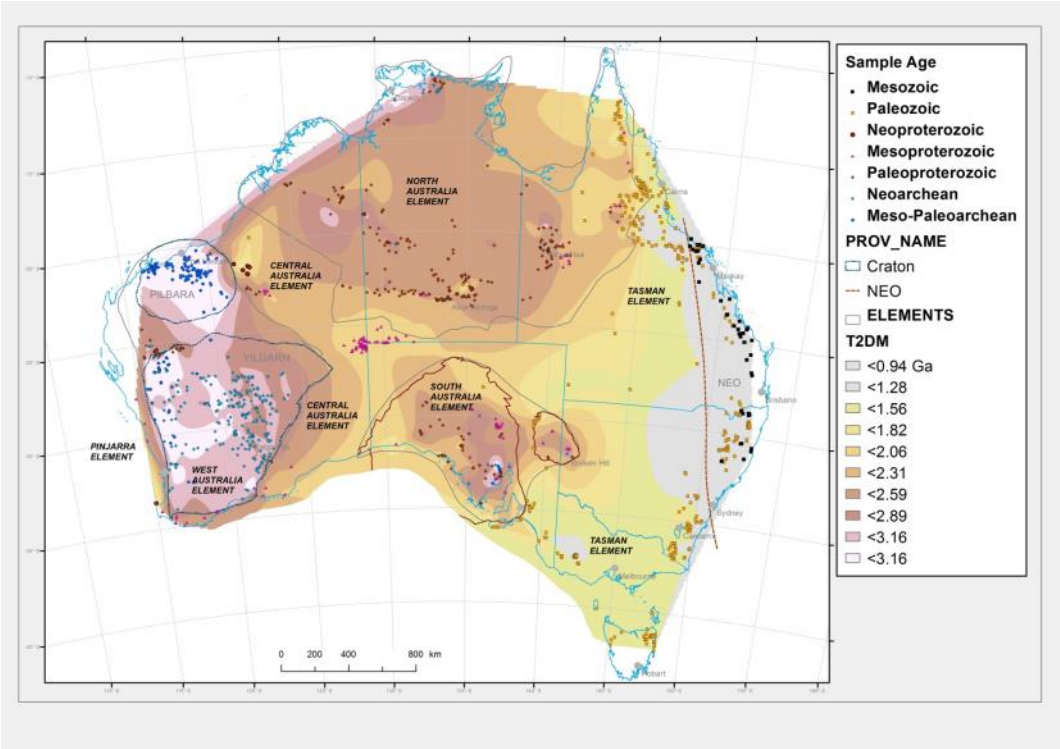
Sm-Nd model age map of Australia: building a continent



~0.38 Ga
~0.44 Ga
~1.2 Ga
~2.0 Ga
~2.4 Ga
~2.6 Ga
~3.0 Ga
OLD

Champion, D.C., 2013. *Neodymium depleted mantle model age map of Australia: explanatory notes and user guide*. Record 2013/044. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2013.044

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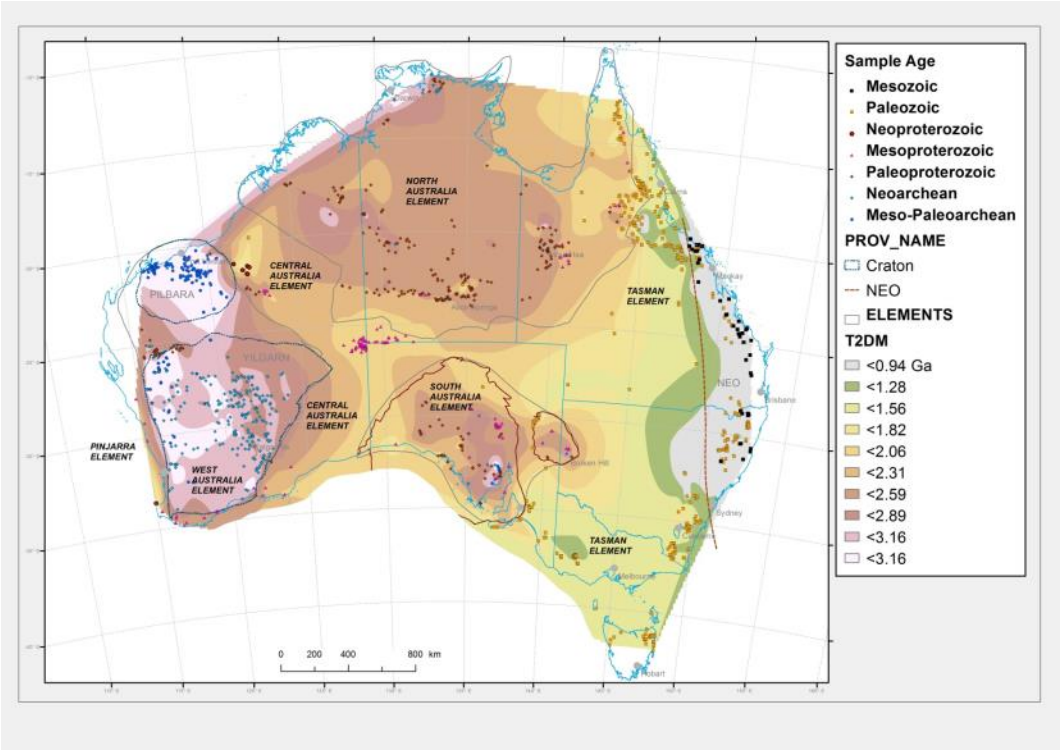

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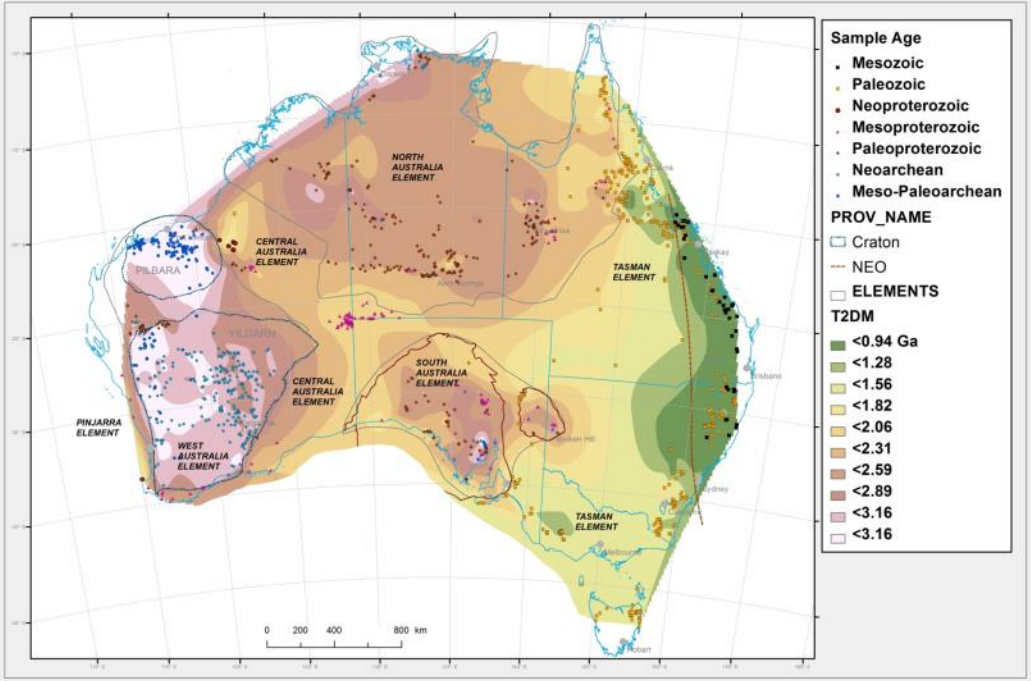

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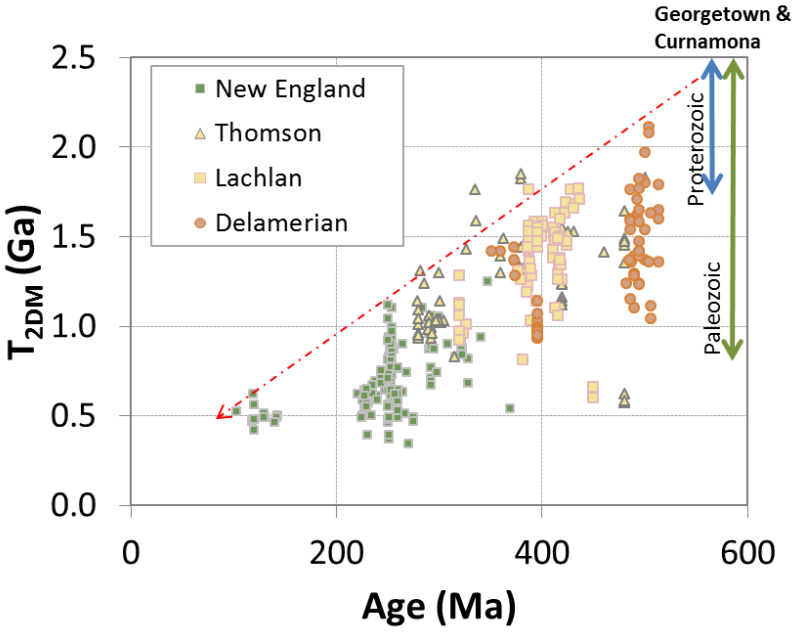
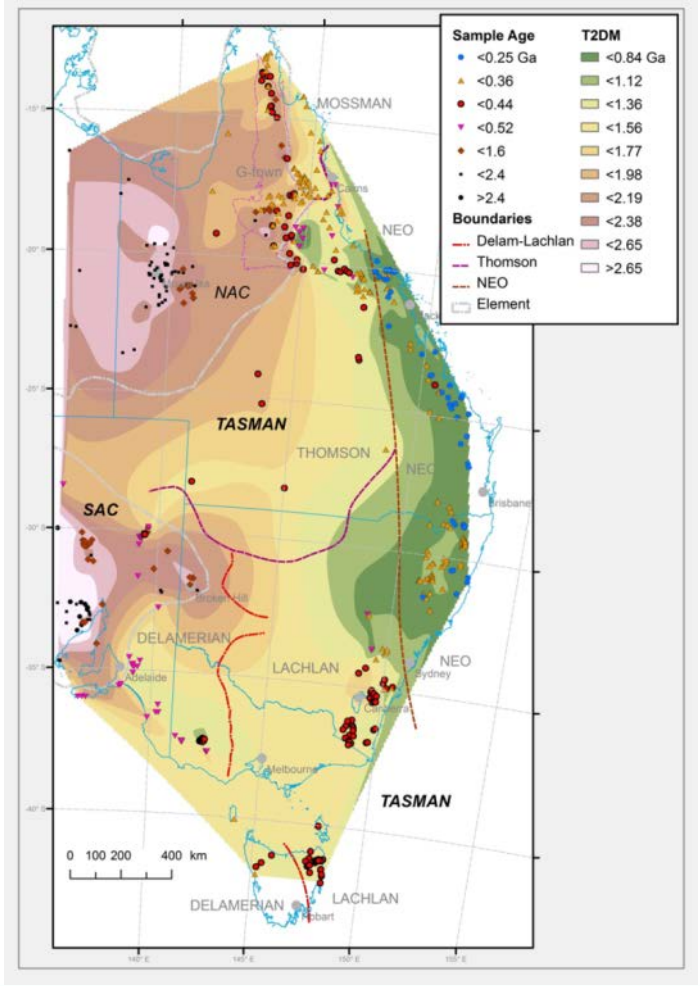
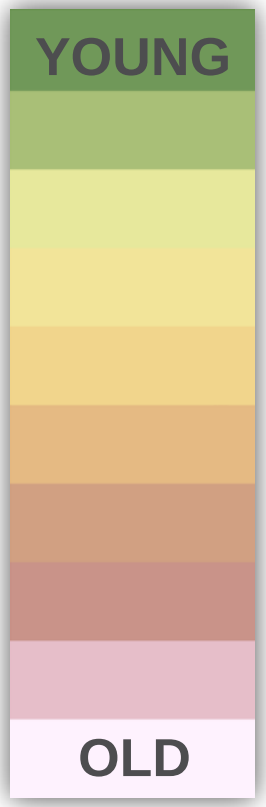
Sm-Nd: Eastern Australia







Lead (Pb) isotopes

- Similar concept to Sm-Nd, but utilises Pb-rich, U-free minerals (e.g. galena, feldspar)
- Best when the age of the system is independently known
- Pb isotopes in feldspar can represent bulk-crust/mantle composition through time
- Pb isotopes in galena provide direct information about crust/mantle input during mineralisation events


Rob Lavinsky, iRocks.com

Lead isotopes in Lachlan: $^{206}Pb/^{204}Pb$ vs $^{207}Pb/^{204}Pb$

- Similar concept to Sm-Nd, but utilises Pb-rich, U-free minerals (e.g. galena, feldspar)
- Best when the age of the system is independently known
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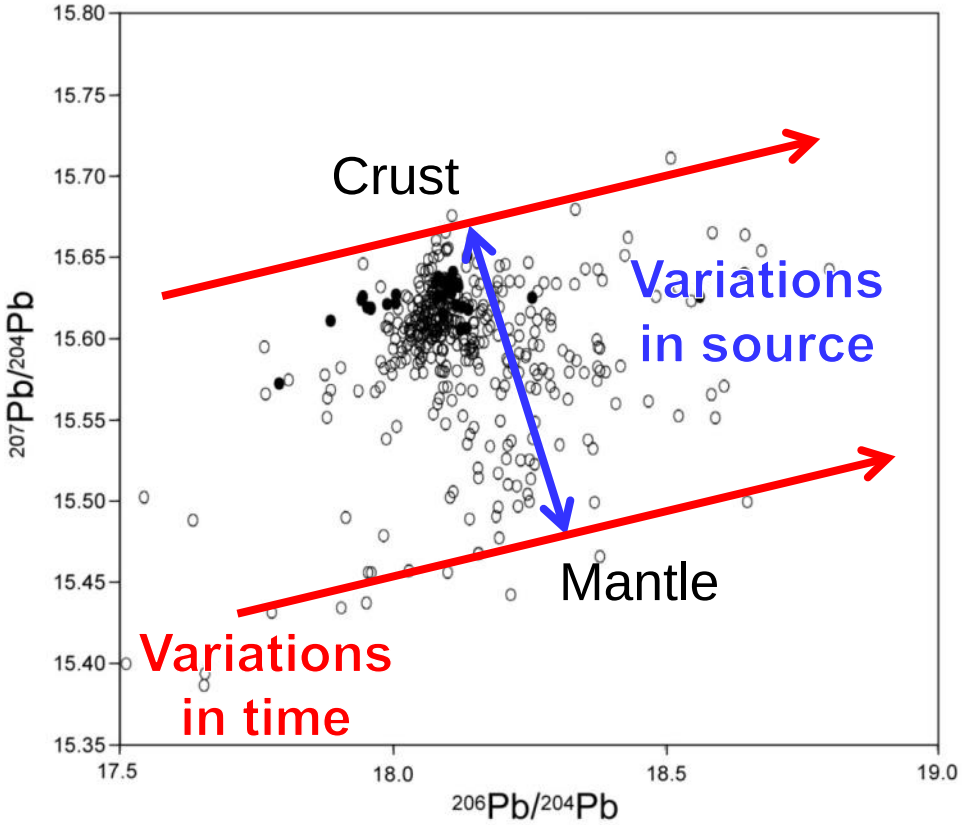


Lead isotopes in Lachlan: mineralising processes

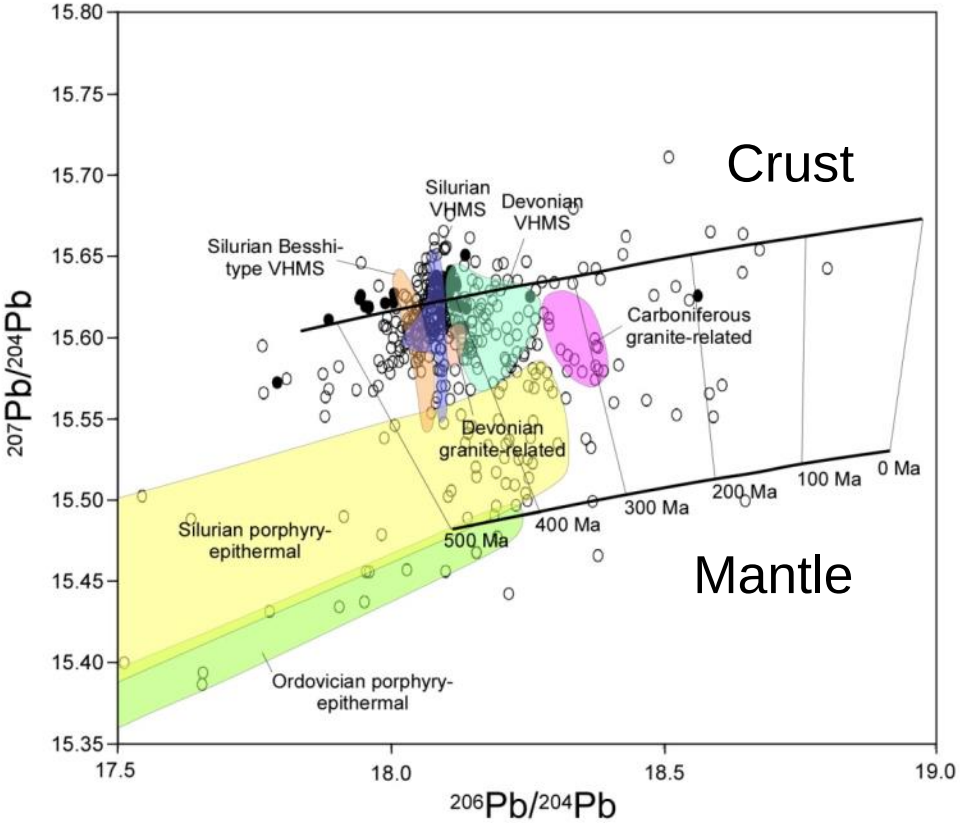
Different mineralising processes generate different Pb-isotope signatures

Crustal:

VHMS

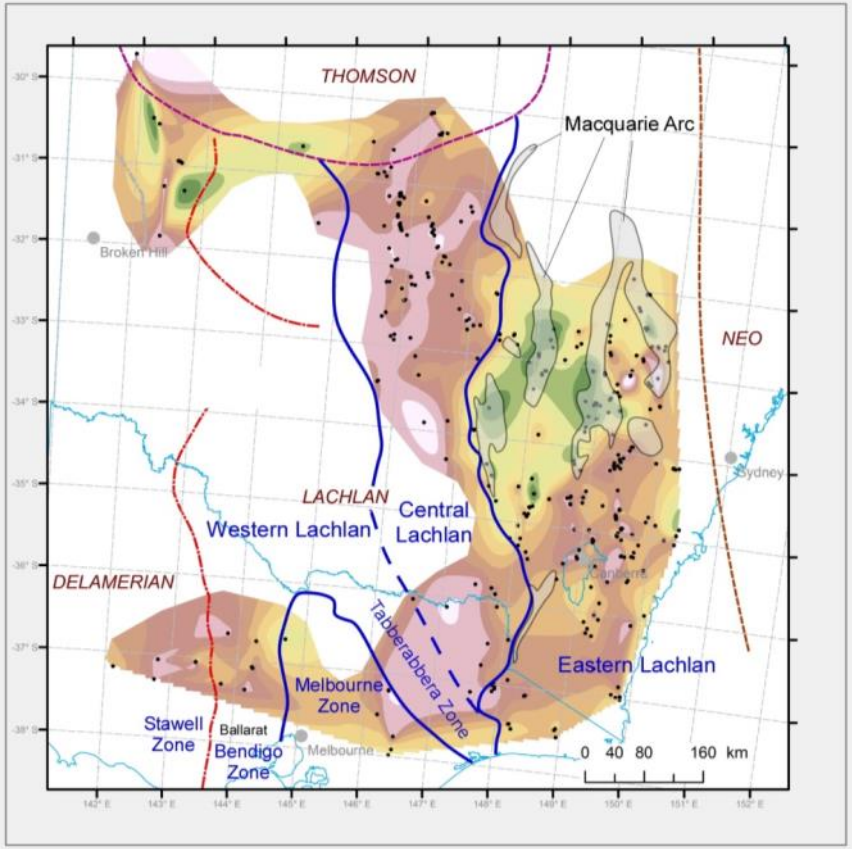
Mantle:

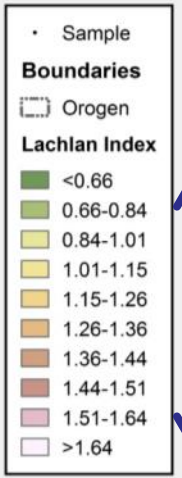
Porphyry-epithermal



Fields and evolution curves from Carr et al. (1995)

Lead isotopes in Lachlan: Lachlan Lead Index





Juvenile

Evolved

Strong correlations between isotope signatures and subprovince boundaries

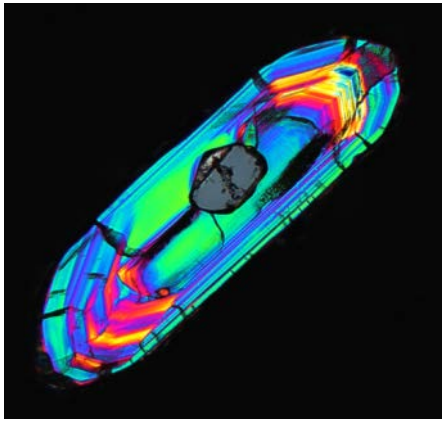
Huston, D.L., et al., in press. Metallogenesis and geodynamics of the Lachlan Orogen: New (and old) insights from spatial and temporal variations in lead isotopes. *Ore Geology Reviews*. http://dx.doi.org/10.1016/j.oregeorev.2015.07.005

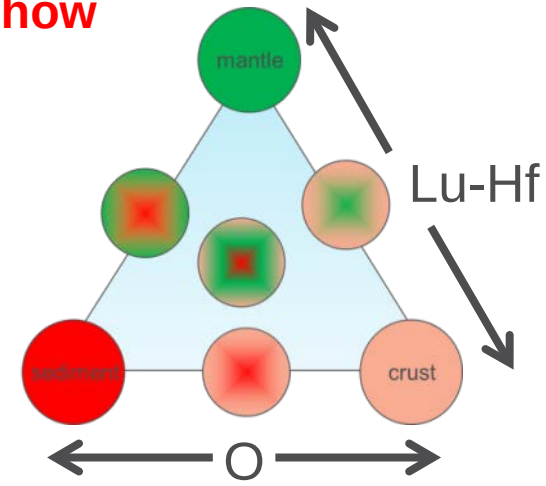
Lu-Hf and O isotopes

Zircons lock in Hf-isotope composition at time of crystallisation

O-isotopes record metasomatism (e.g. during subduction)

U–Pb + **Lu-Hf** + **O** = **when** + (from) **where** + (maybe) **how**





Hf-isotope data: compilation and database

Existing literature:

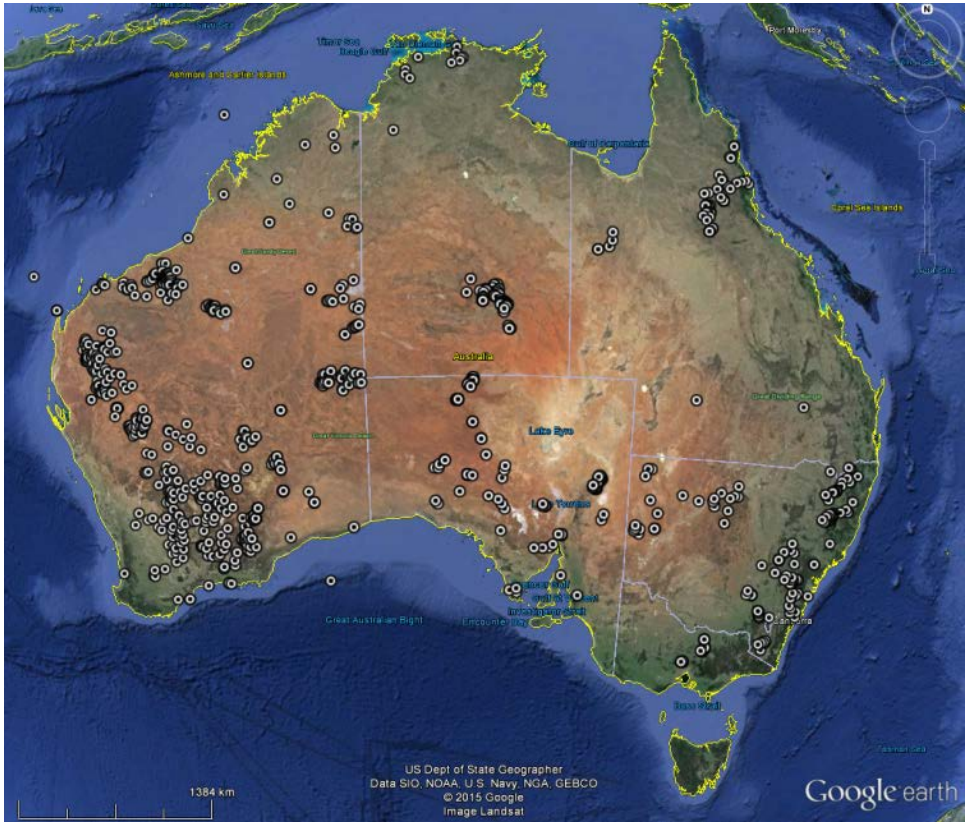
>17 000 analyses

>1200 samples

>150 publications

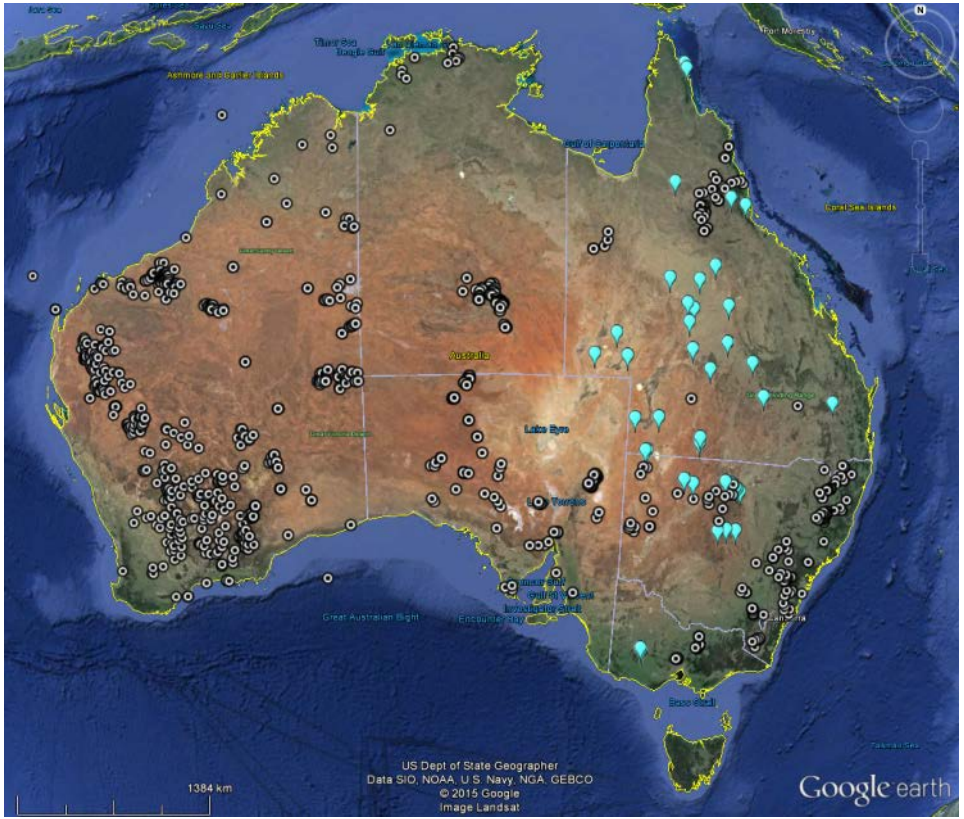
Only 75% of samples properly located!

Database to store both Lu-Hf and O isotope data: long-term project



Hf-isotope data: new work (GA and State partners)

- Stavely Region, in support of Stavely drilling program with GSV
- In Queensland, collaboration with GSQ
- Thomson-Lachlan boundary, in support of southern Thomson drilling program with GSNSW and GSQ



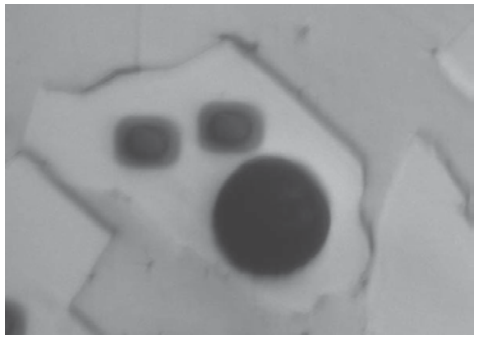
Hf + O isotopes across Thomson–Lachlan boundary

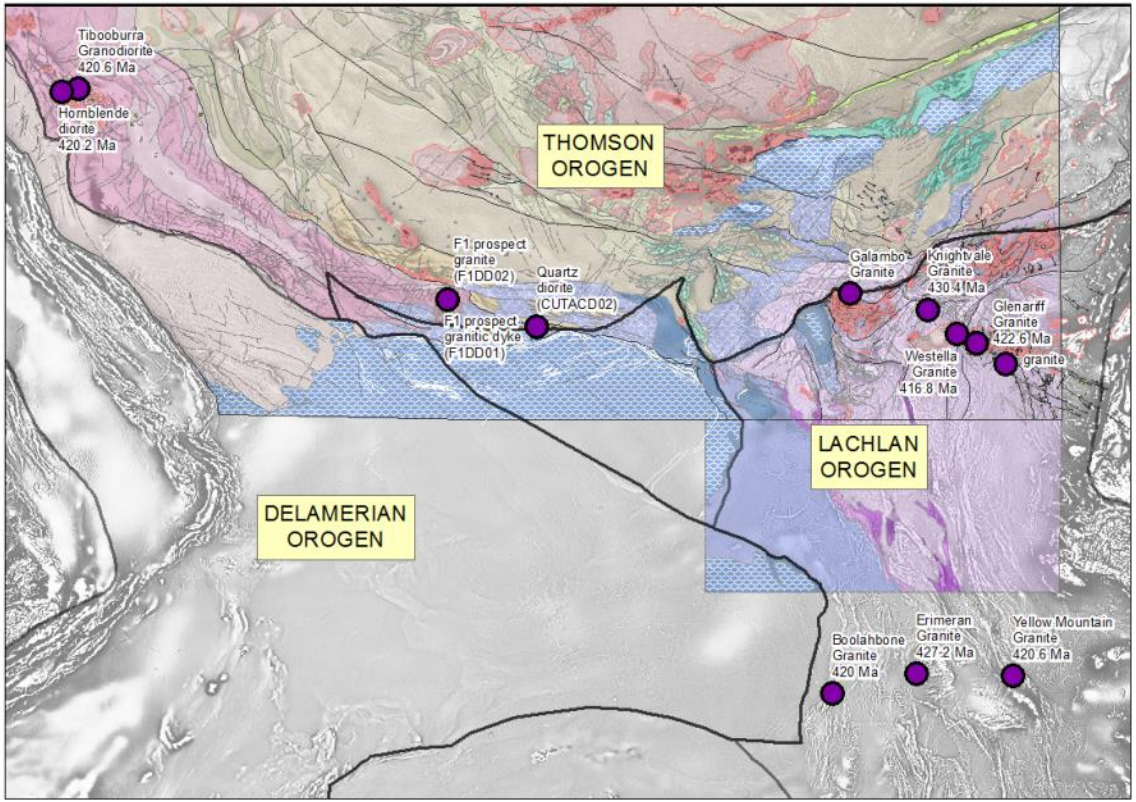
New isotopic information from archived collections

Existing SHRIMP U-Pb

+ SHRIMP O-isotopes

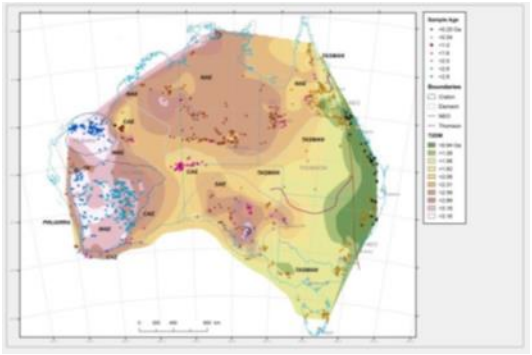
+ MC-ICP-MS Hf-isotopes

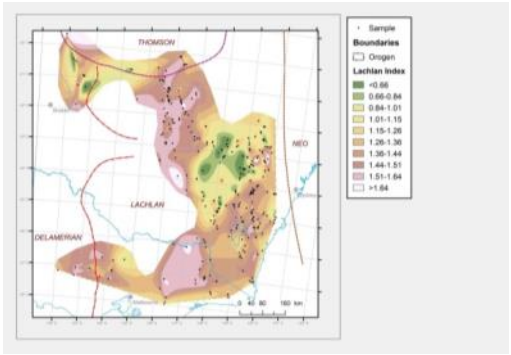




Contacts

- Sm-Nd isotopes: David Champion David.Champion@ga.gov.au
- Pb isotopes: David Huston David.Huston@ga.gov.au
- Lu-Hf + O isotopes: Kathryn Waltenberg Kathryn.Waltenberg@ga.gov.au





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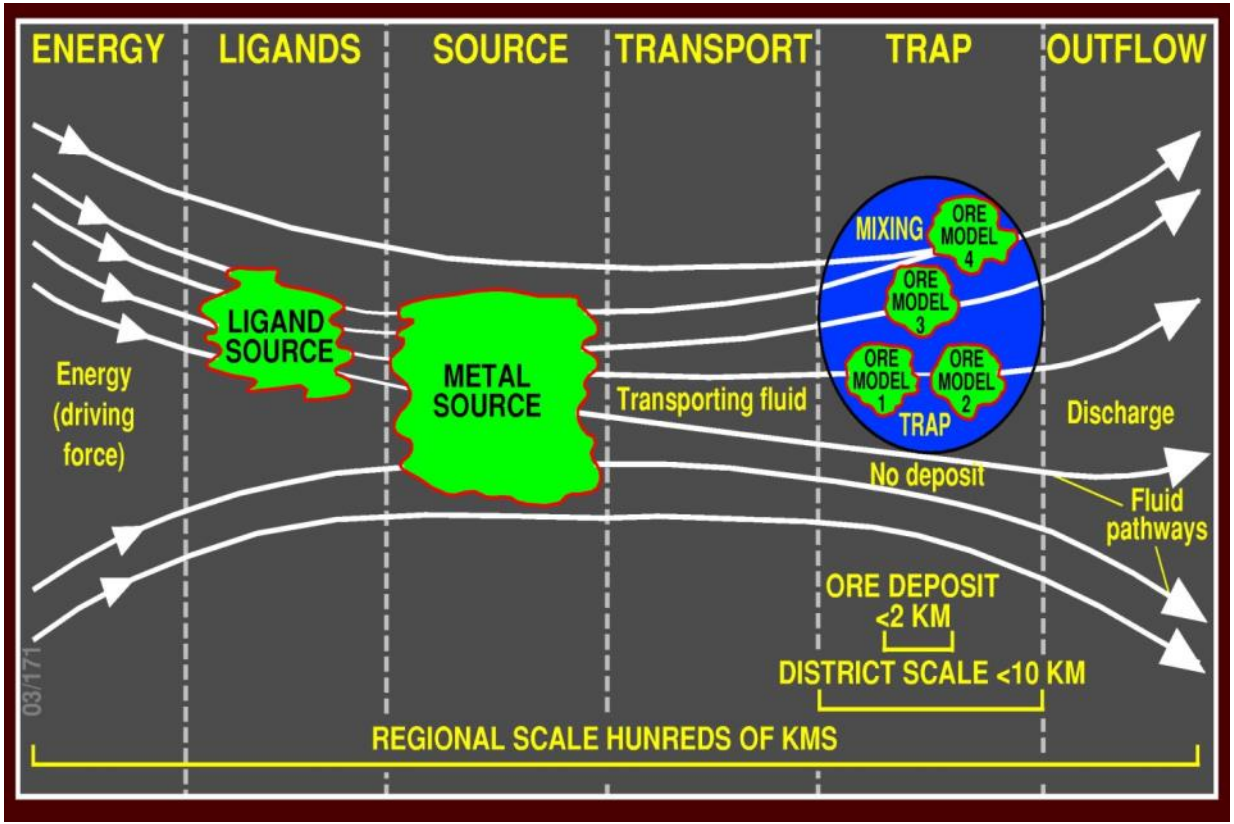
Australian Government
Geoscience Australia

Mineral systems as an area selection method at the regional and national scales: examples of IOCG and magmatic Ni-Cu-PGE systems

R Skirrow, H Dulfer, J Thorne, D Champion, A Schofield, DL Huston*
*David.Huston@ga.gov.au

Mineral systems – the beginnings



Wyborn et al. (1994)

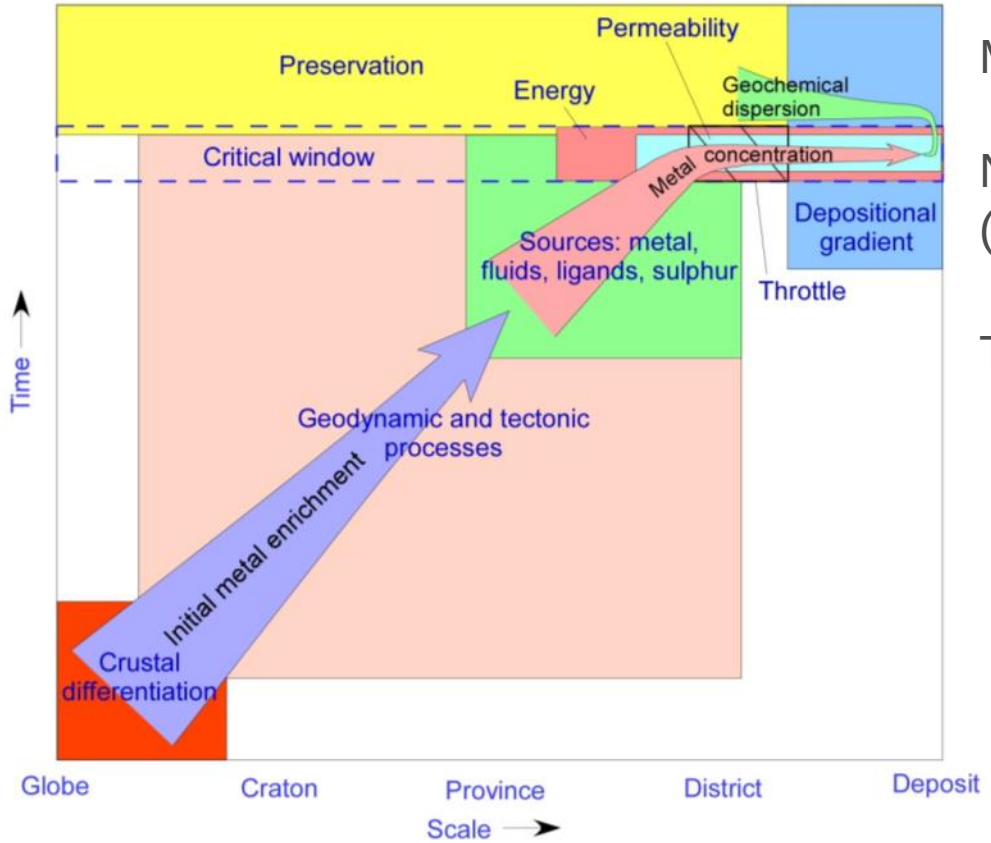
Modelled after petroleum system concept (developed in 1970s)

Source – transport – trap

Mineral system is much larger than ore deposit

Mineral system concept can be predictive

Mineral systems – evolution of a concept

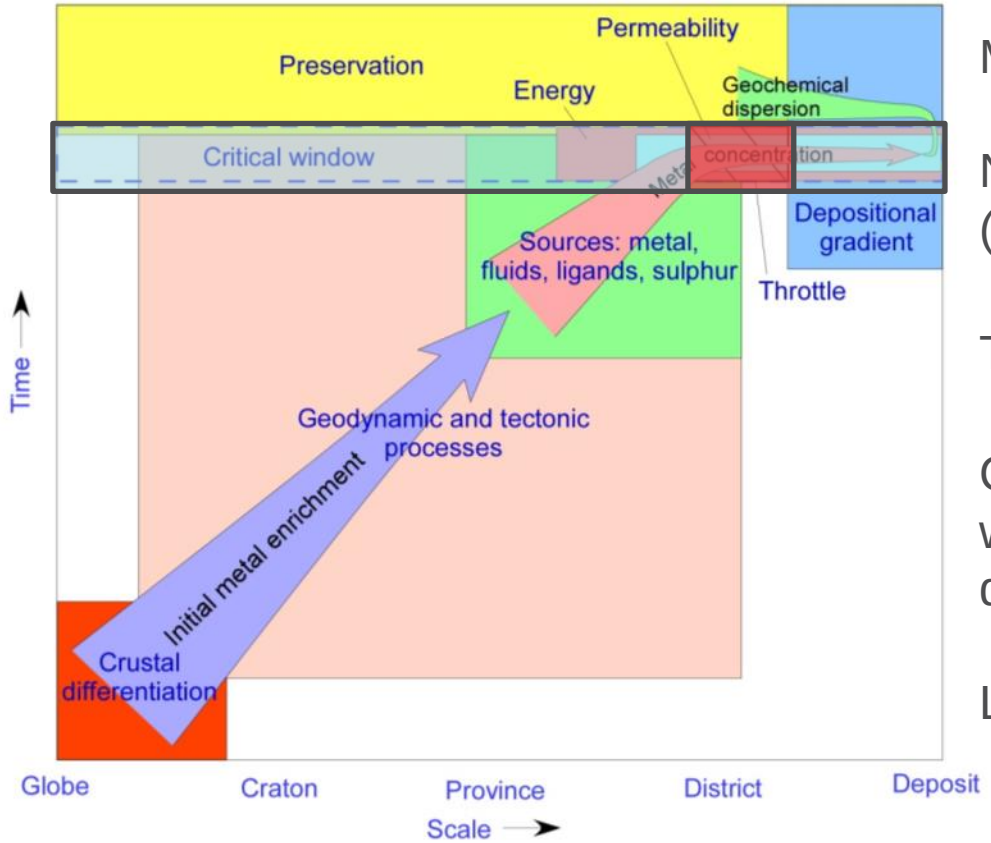


Mineral system concept has evolved

Number of different versions around (GA, UWA and consultants)

Time component recognised

Mineral systems – evolution of a concept



Mineral system concept has evolved

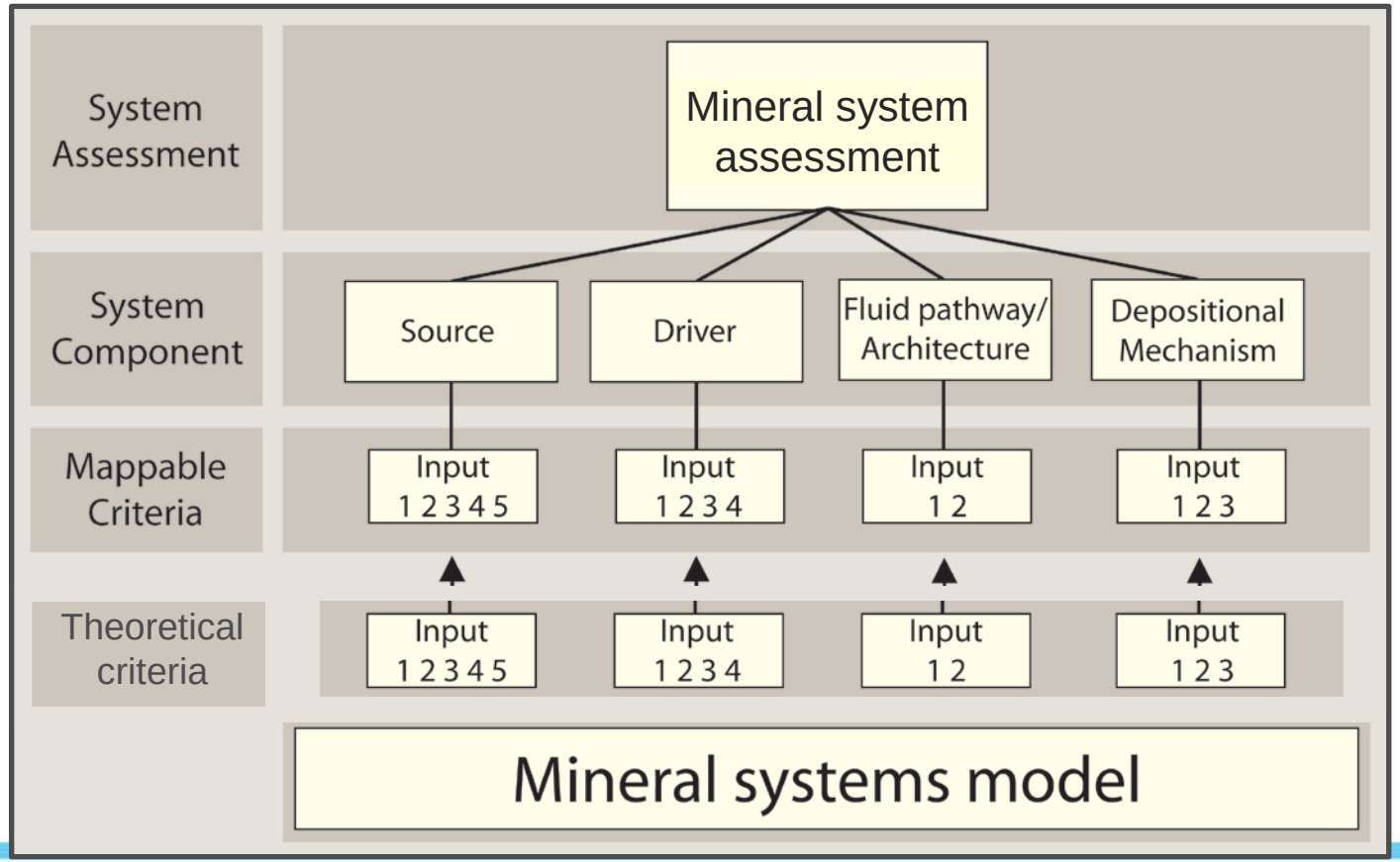
Number of different versions around (GA, UWA and consultants)

Time component recognised

Concepts of trigger (in time - critical window) and throttles (in space) developed

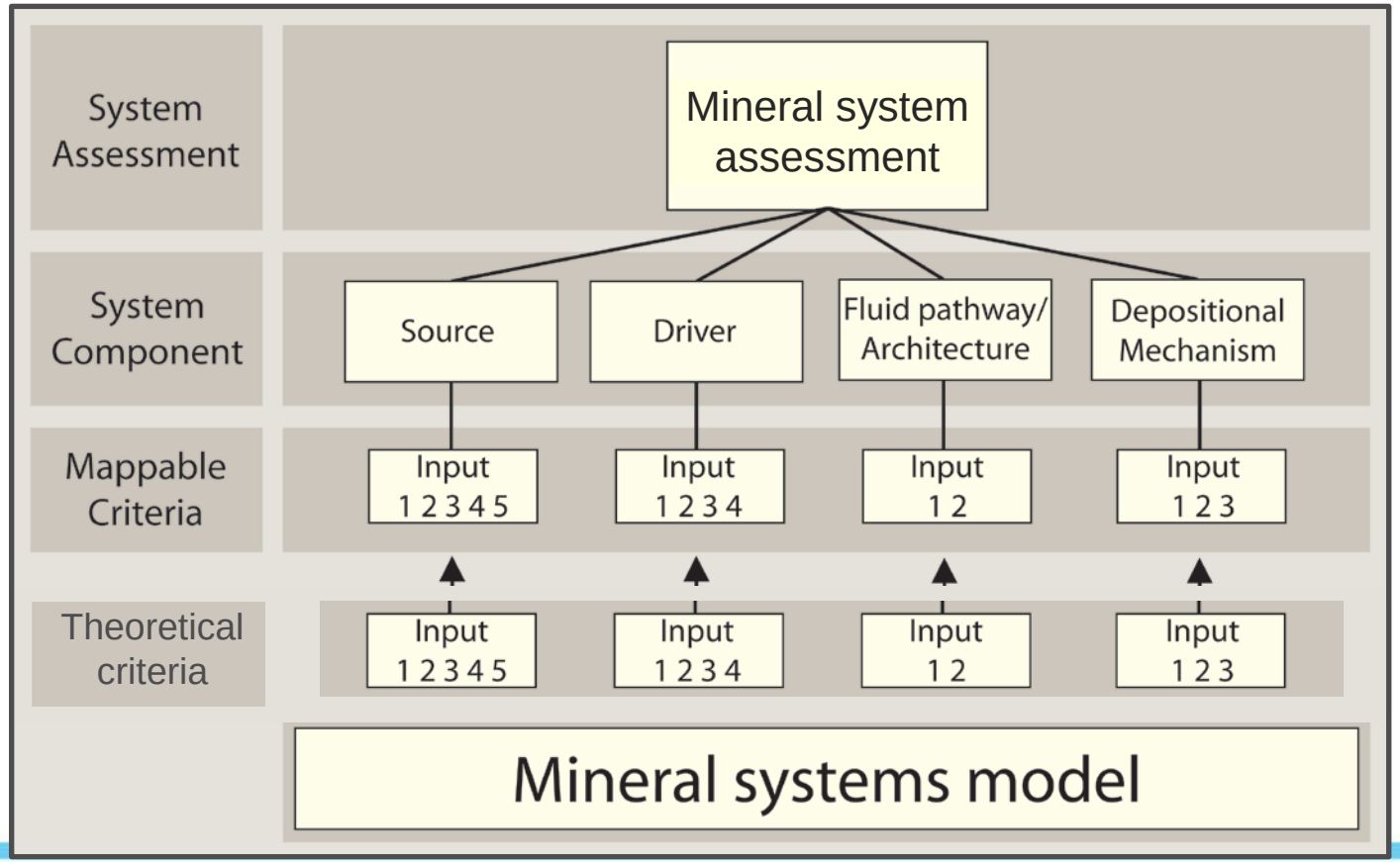
Linkages to tectonic systems

GA's methodology of mineral potential mapping



Workflow

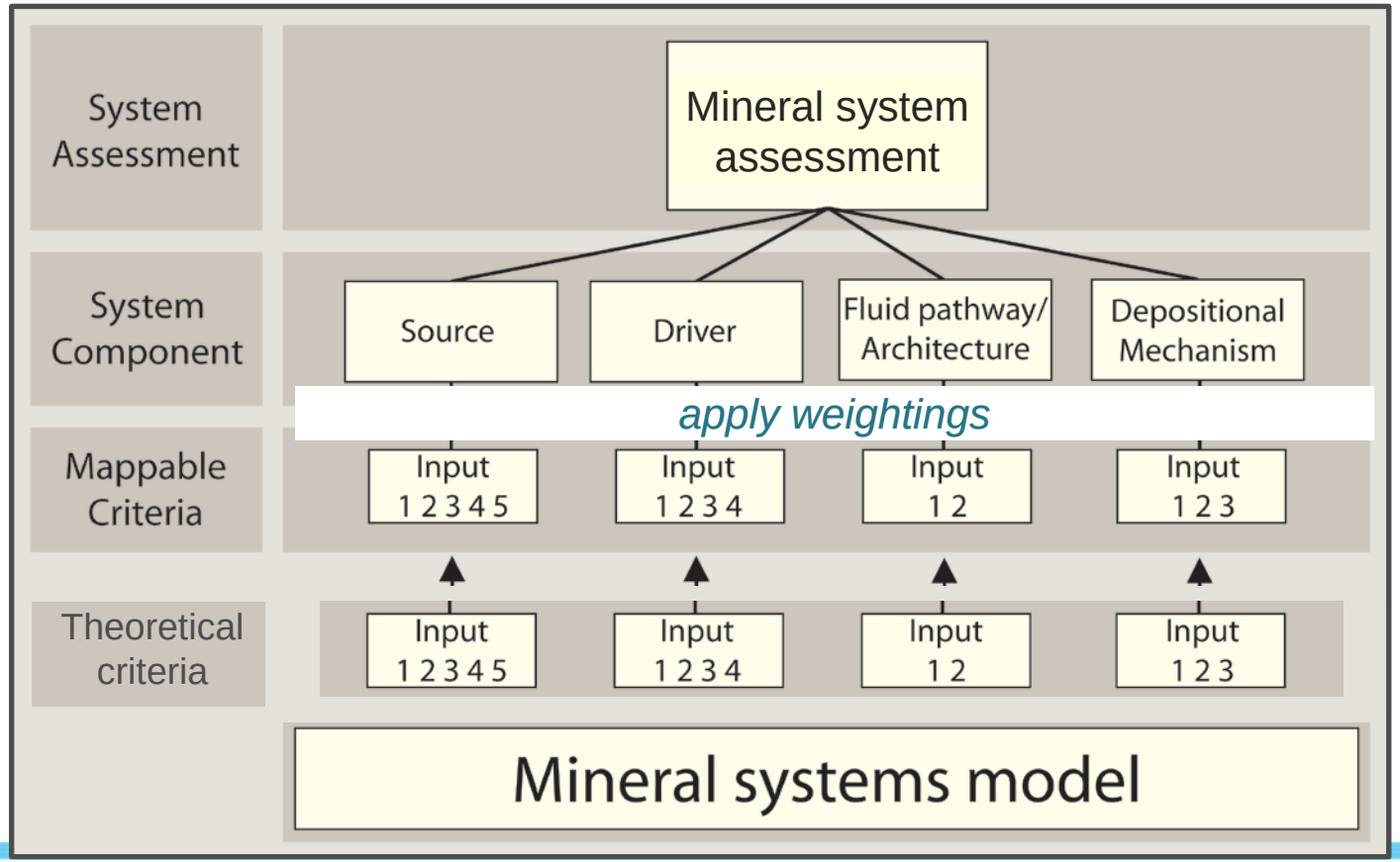
GA's methodology of mineral potential mapping



Convert theoretical into measurable

Workflow

GA's methodology of mineral potential mapping

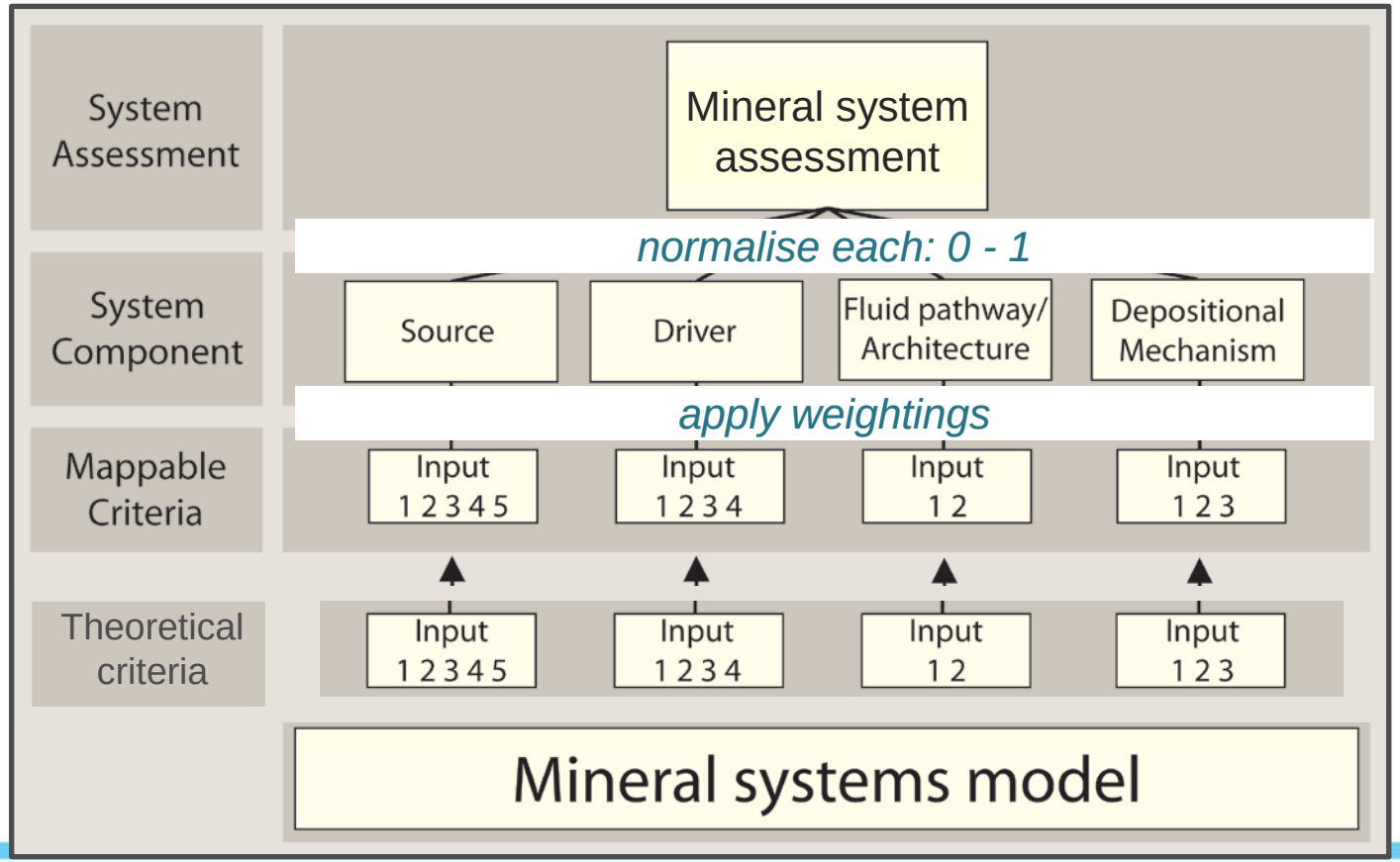


Decide importance

Convert theoretical into measurable

Workflow

GA's methodology of mineral potential mapping



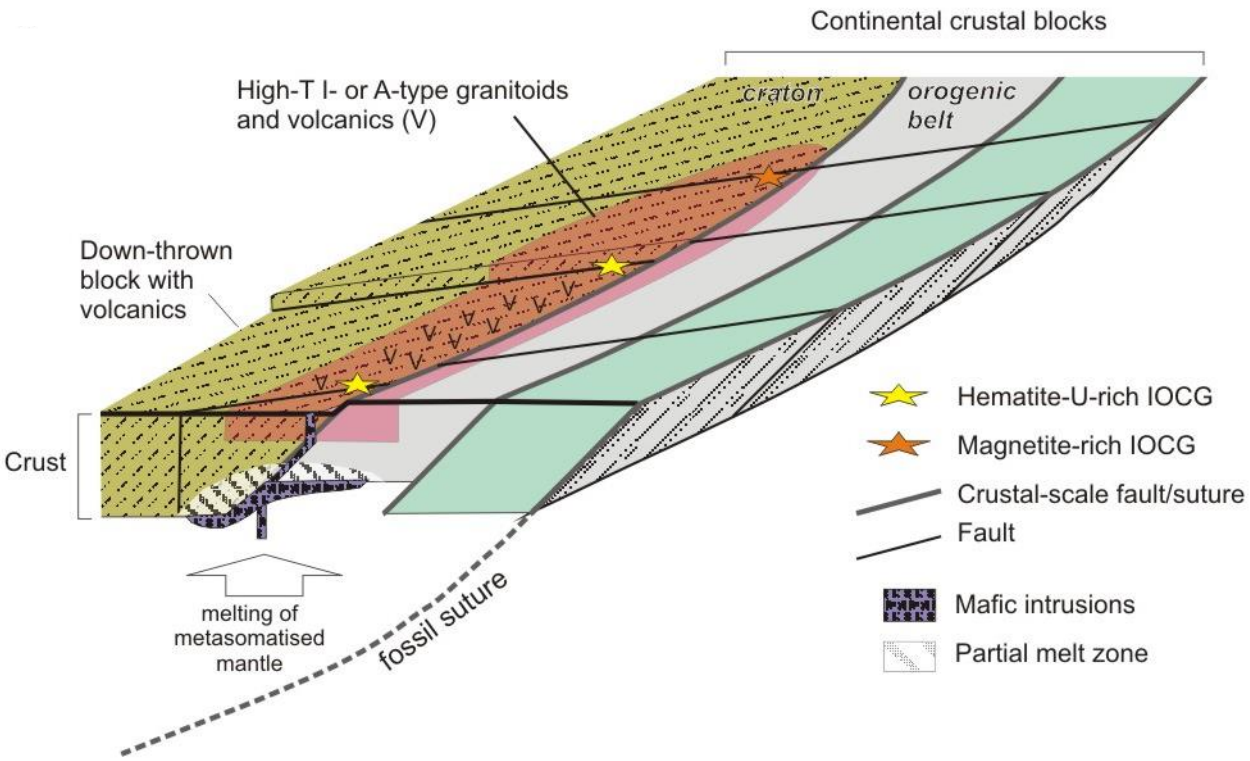
Combine components

Decide importance

Convert theoretical into measurable

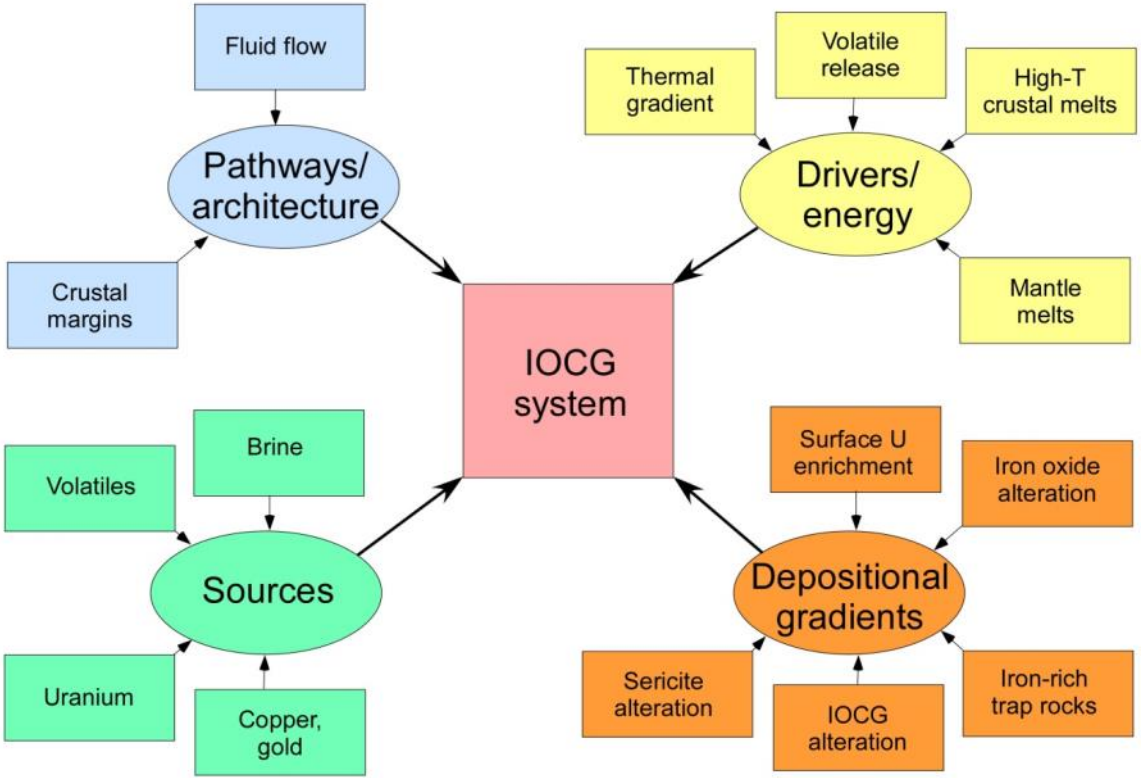
Workflow

IOCG deposits – system model

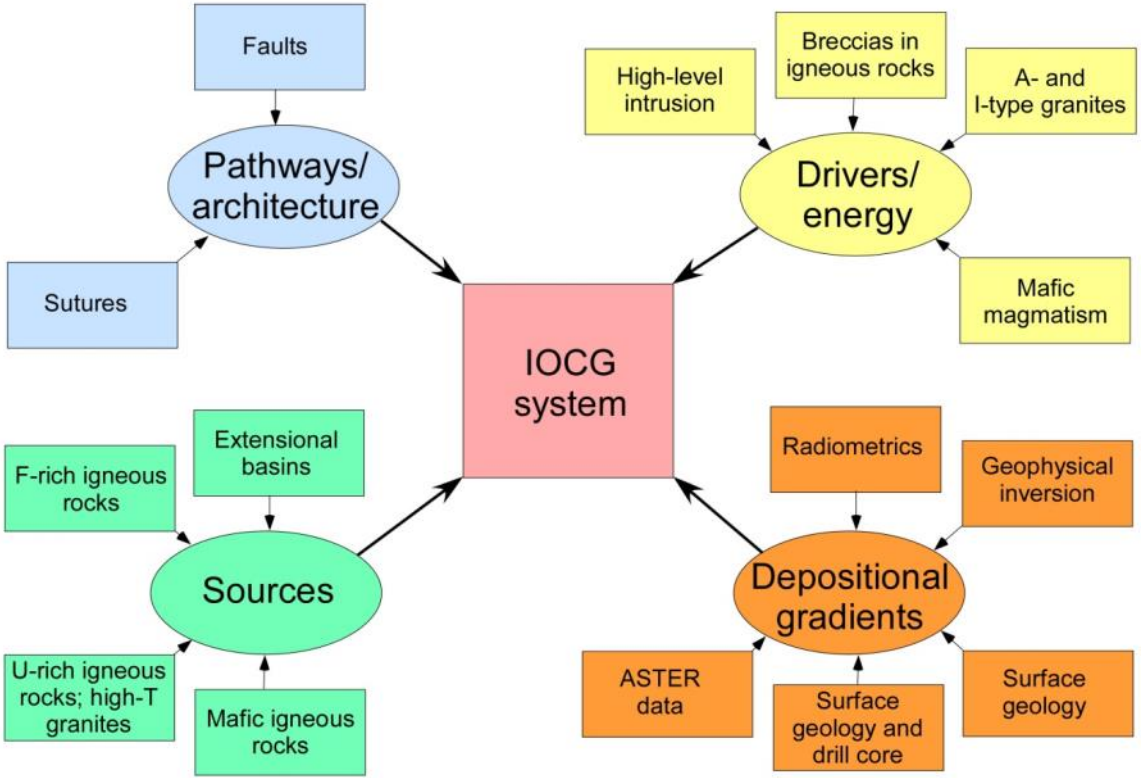


- Associated with sutures
- Associated with extension following contraction
- Associated with cross structures
- Related to high-T crustal magmatic rocks
- High level intrusive rocks
- Regional and local alteration: Fe, Na-Ca, K

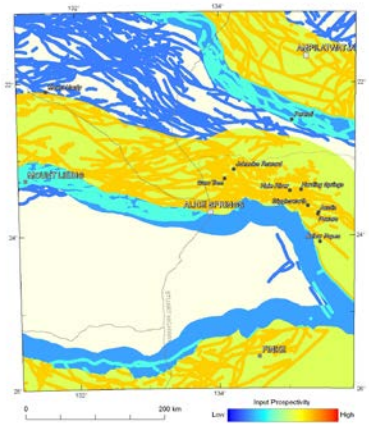
Arunta IOCG potential – theoretical criteria



Arunta IOCG potential – mappable criteria



IOCG deposits in Arunta – results



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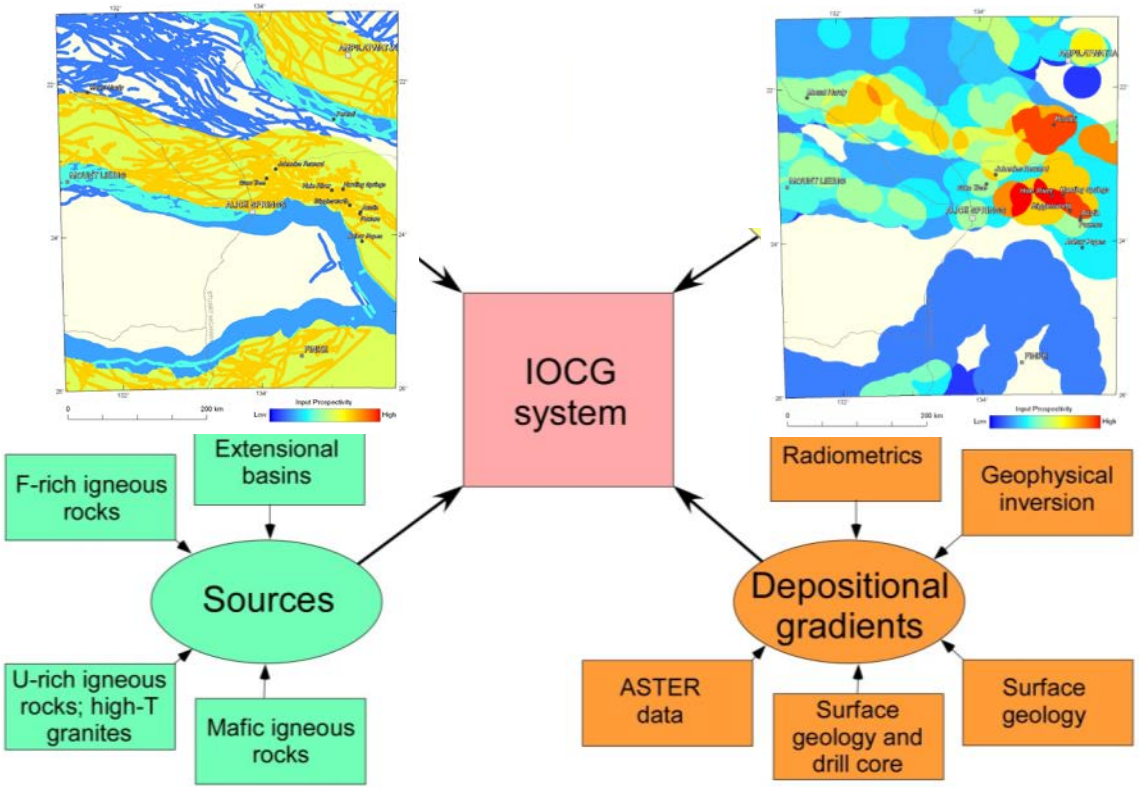

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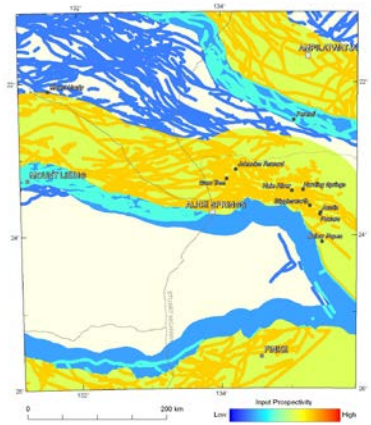
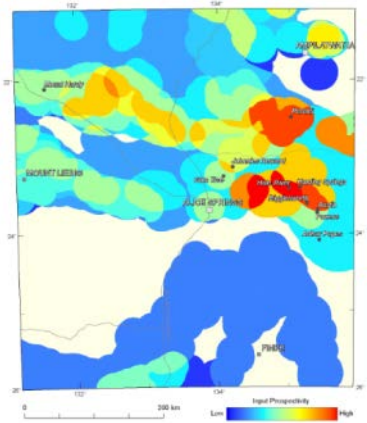
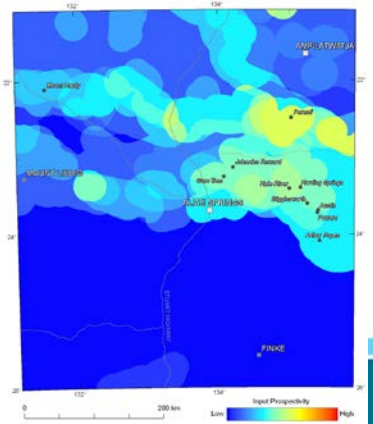
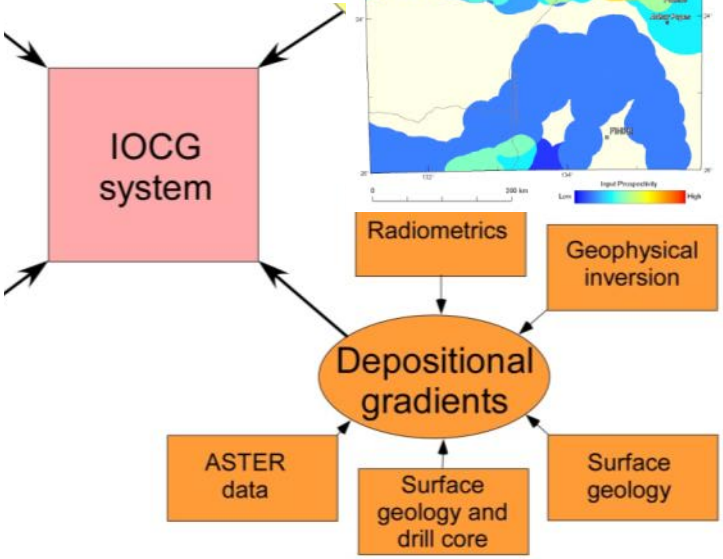
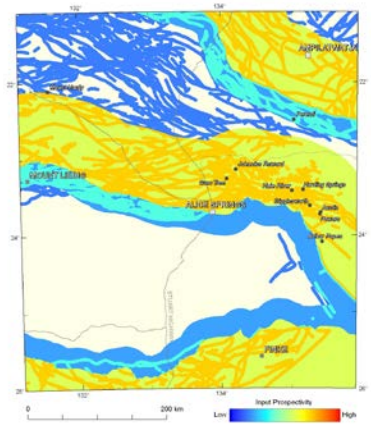


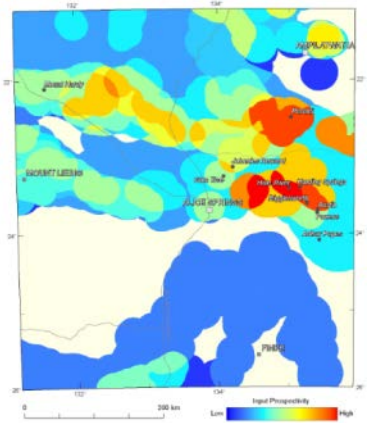




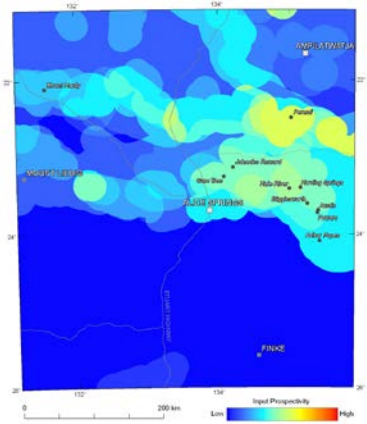


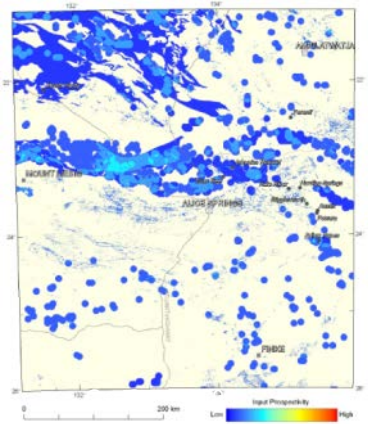
IOCG deposits in Arunta – results



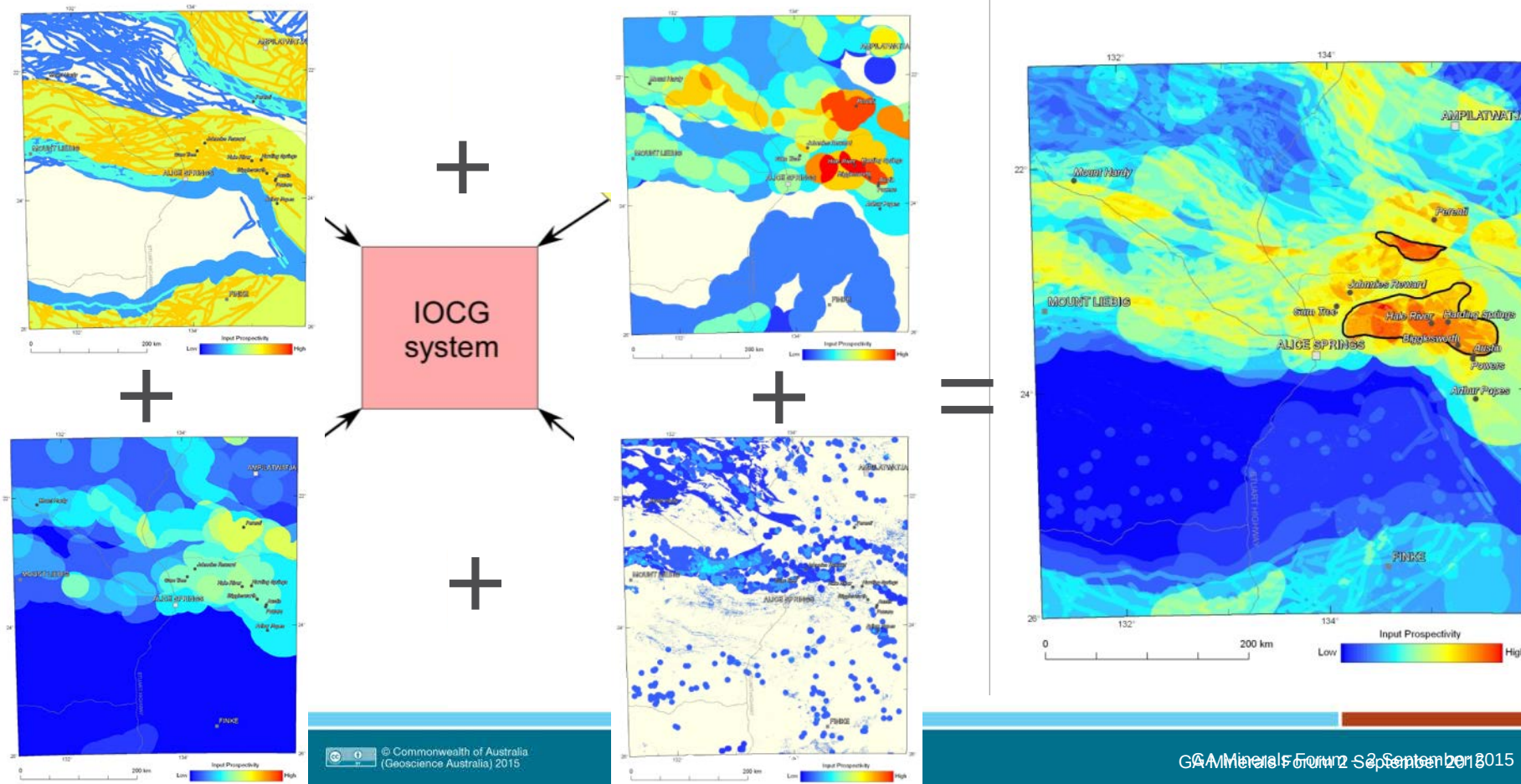


IOCG system

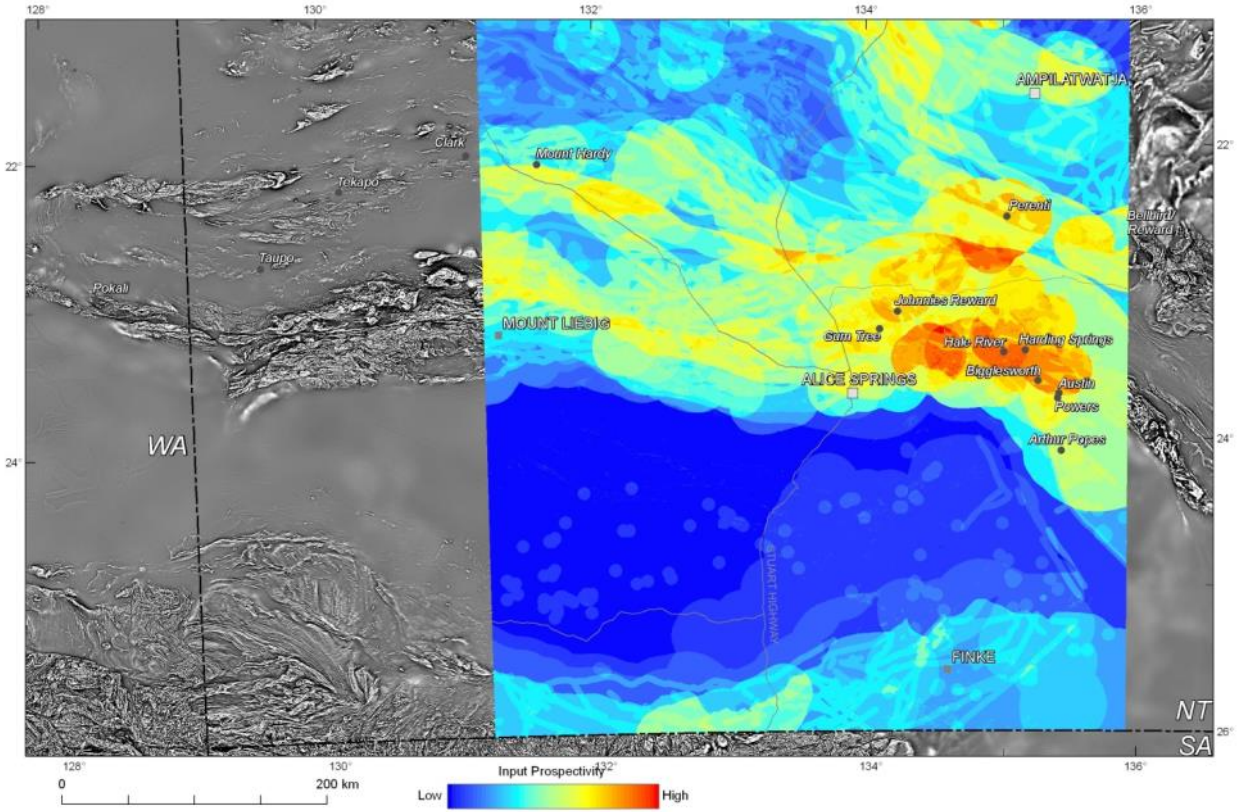




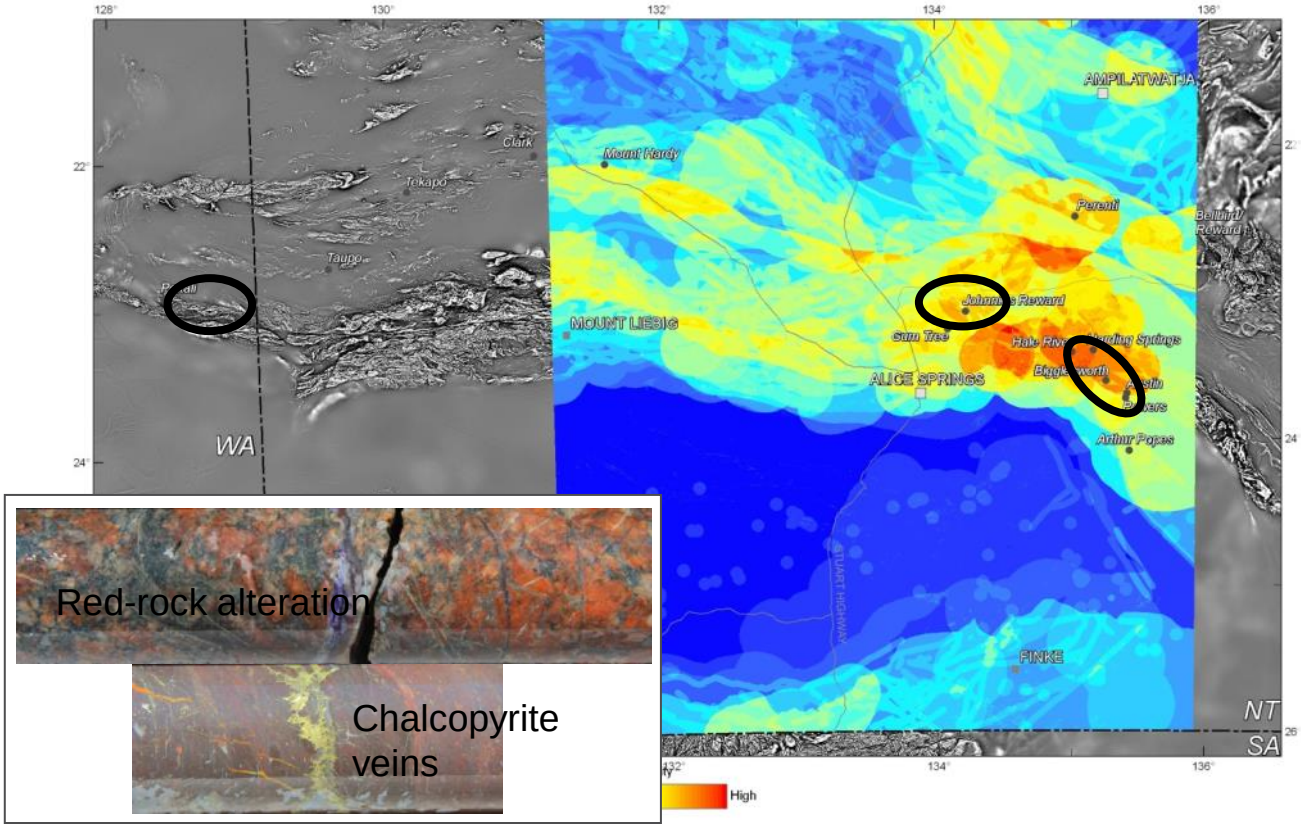
IOCG deposits in Arunta – results



IOCG deposits in Arunta – final results



IOCG deposits in Arunta – final results



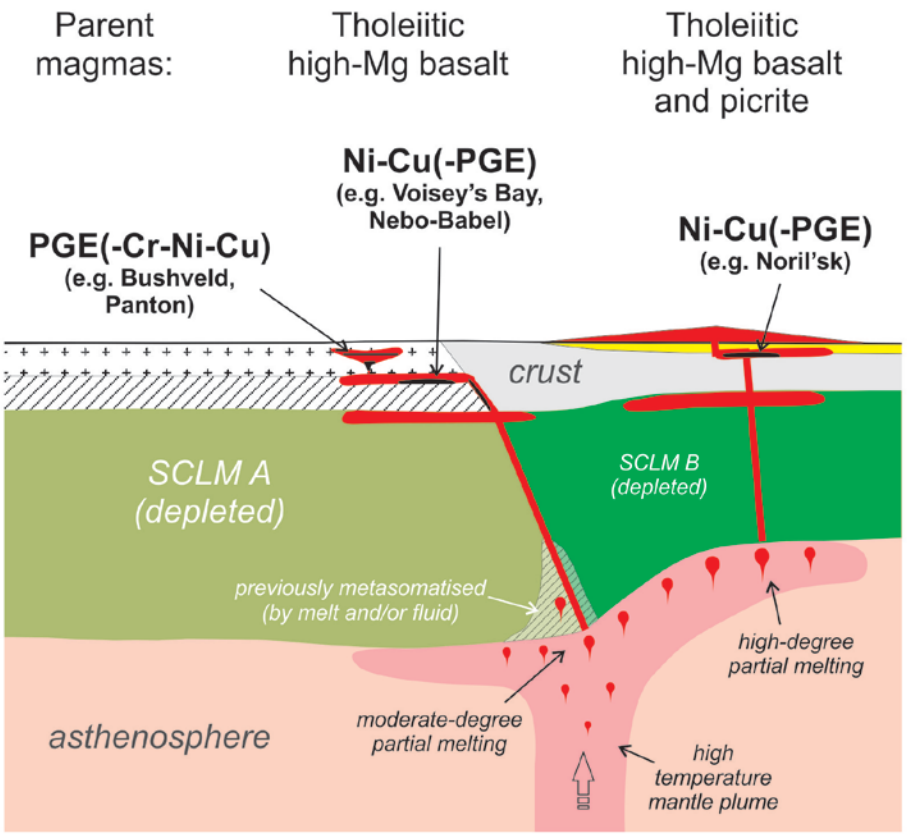
78m @ 0.26% Cu (Ashburton Minerals ASX release, 19 July 2012)

34m @ 3.83 g/t Au, 0.44% Cu (Transol ASX release, 26 July 2012)

Extensive hematite-fluorite alteration (Whelan et al., 2012)

Rock chip results of up to 4.5% Cu, 0.2 g/t Au, 2.3 g/t Ag (Mithril Resources ASX release, 29-11-2011)

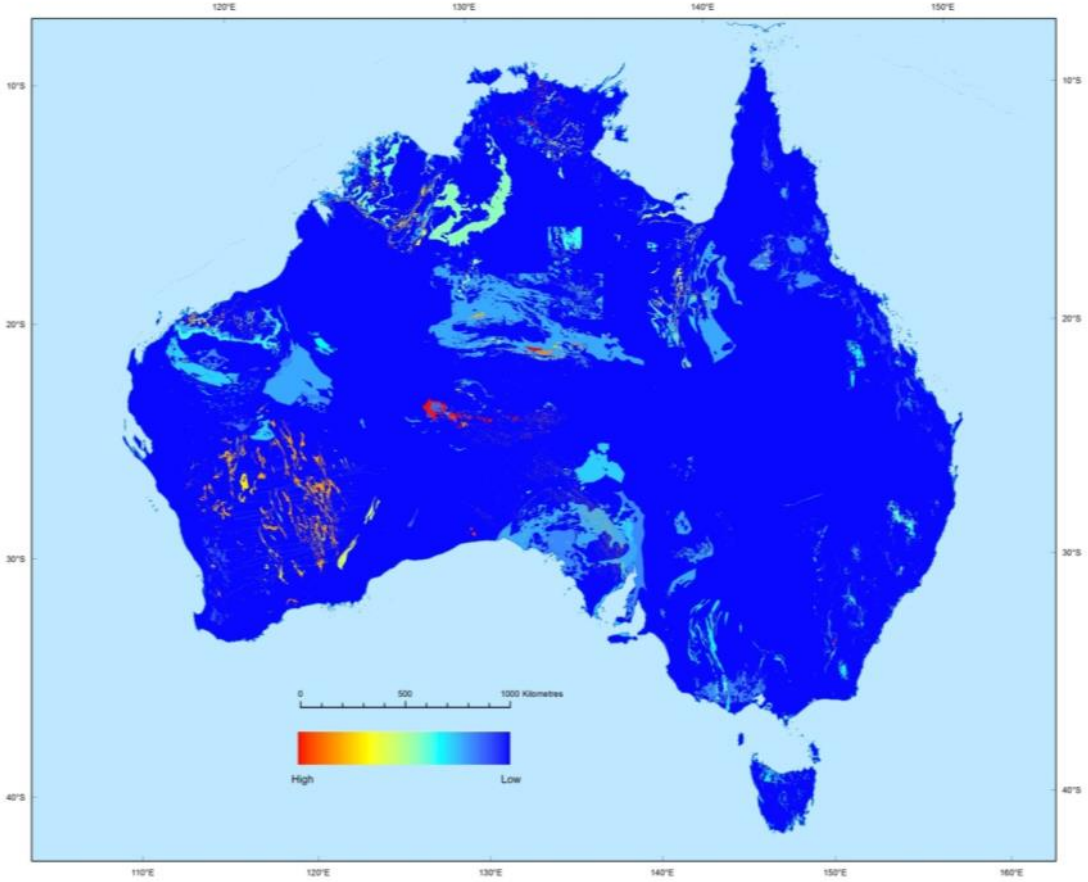
National magmatic Ni-Cu-PGE – system model



- Plume ascends through the mantle
- Moderate to high degree partial melting
- Melt travels along trans-crustal and trans-lithospheric weaknesses
- Nickel sulphide ore formation at mid- to upper-crustal levels due to sulphur saturation

Source: Naldrett (2004), Arndt et al. (2005) Barnes and Lightfoot (2005), Hoatson et al. (2006), Begg et al. (2010) Schulz et al. (2010), Griffin et al. (2013) and Arndt (2013).

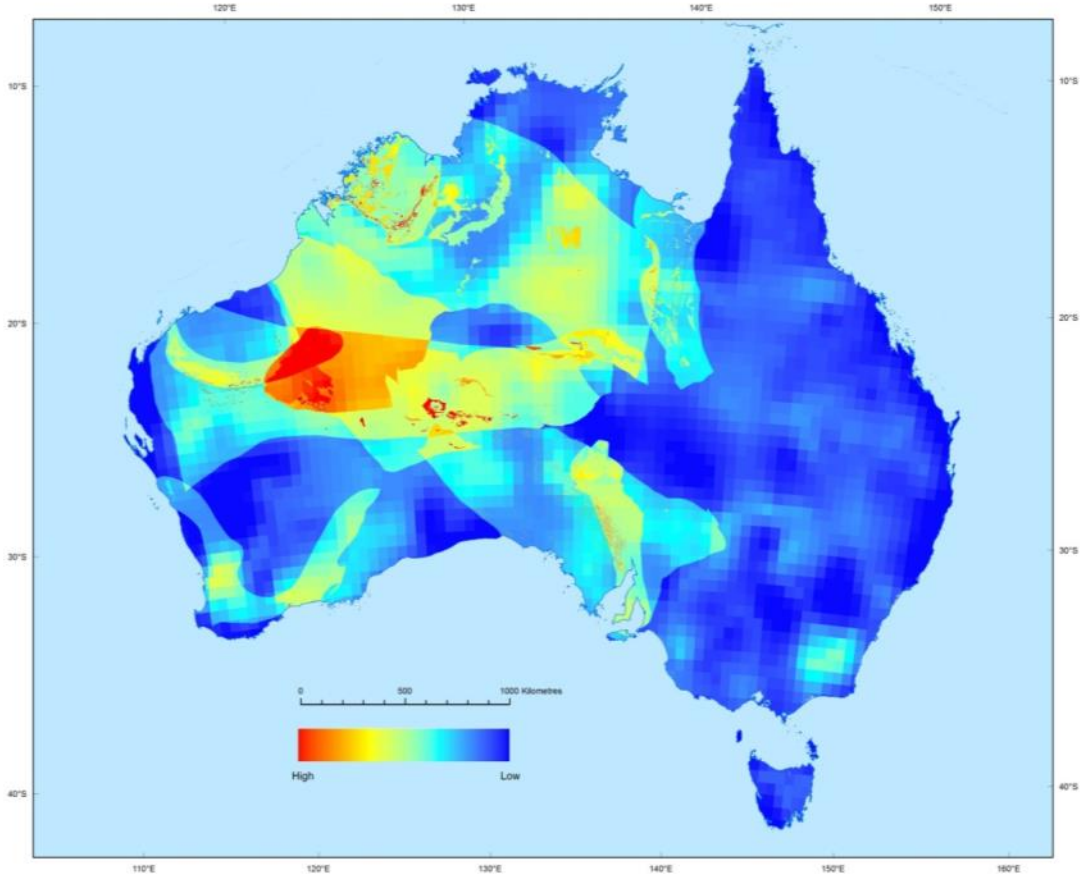
National magmatic Ni-PGE – sources



Datasets used

- Distribution of mafic and ultramafic rocks (MUM synthesis and OZchem)
- Distribution of tholeiitic rocks (OZchem)
- High Ni-Cu-PGE abundances in mafic-ultramafic rocks (OZchem)

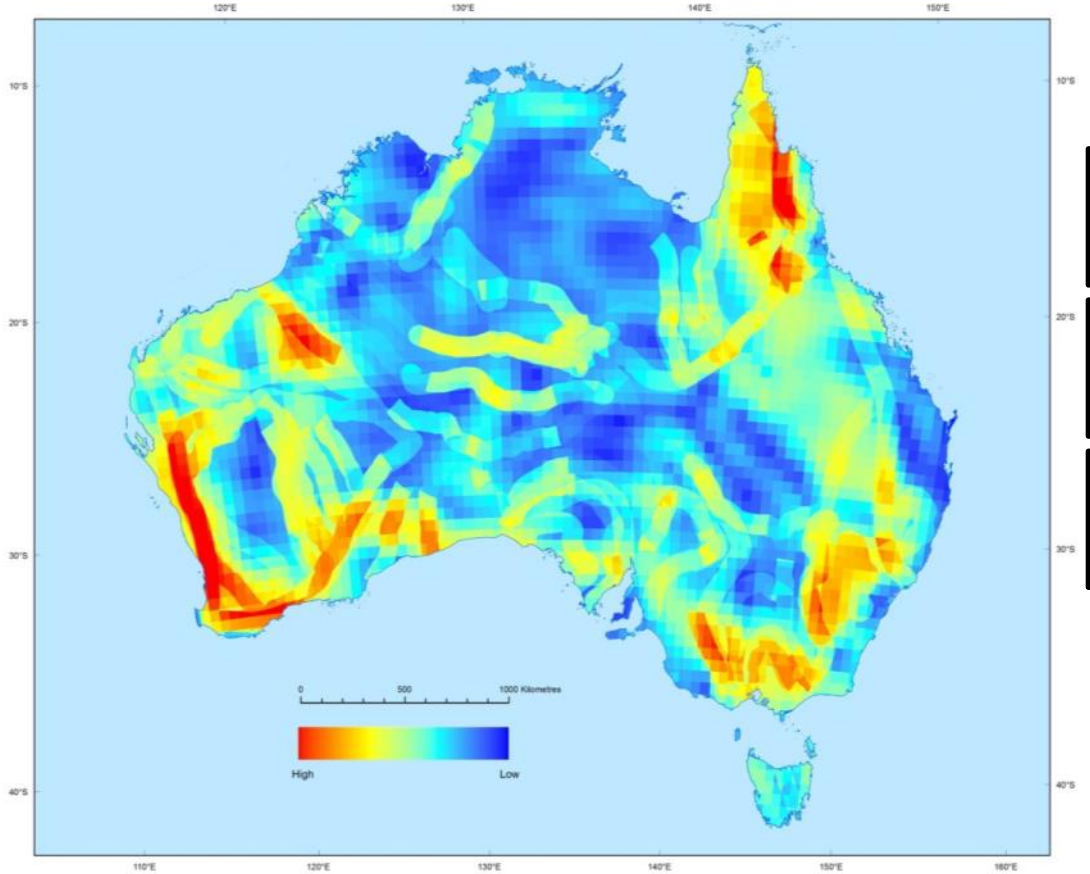
National magmatic Ni-PGE – driver



Datasets used

- Distribution of Proterozoic large igneous provinces (from MUM synthesis)
- Thickness of mafic rocks in the crust (from seismic velocity data)

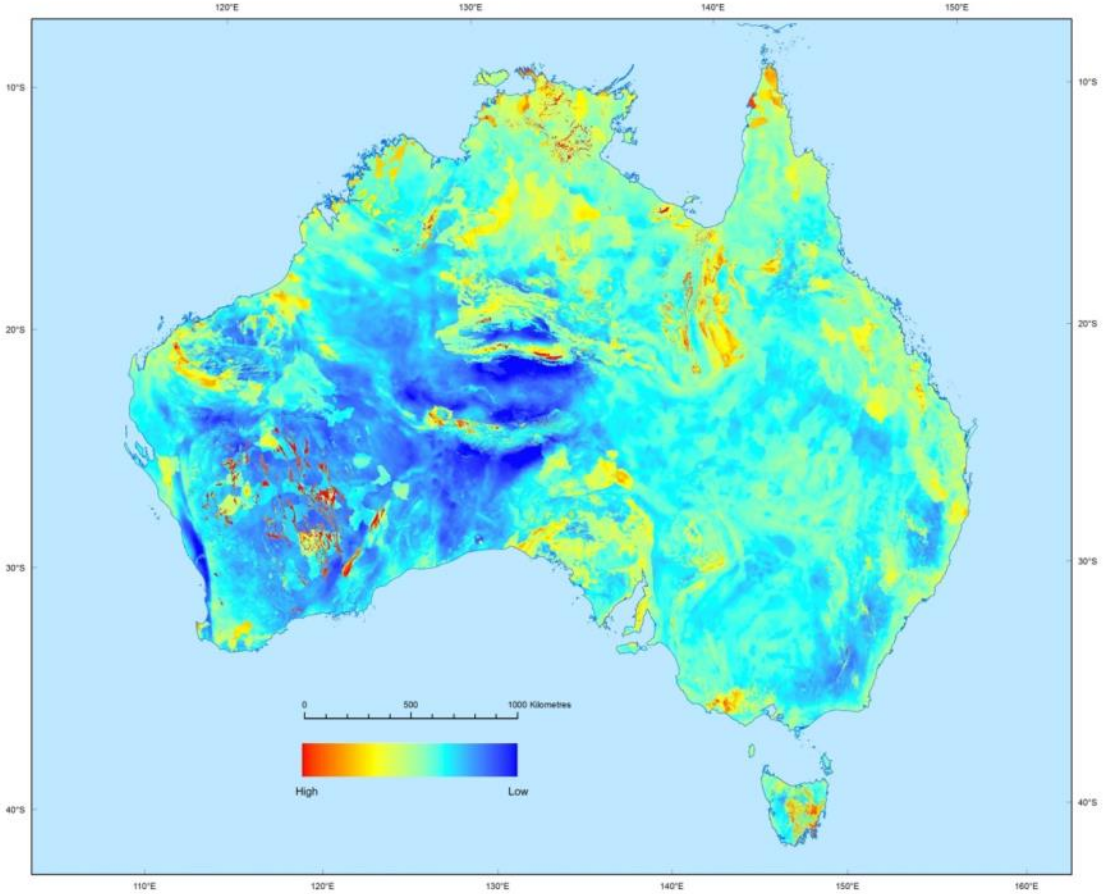
National magmatic Ni-PGE – pathway/architecture



Datasets used

- Seismic velocity tomography (AusREM)
- Crustal boundaries from seismic data
- Crustal boundaries from radiogenic (Sm-Nd) data

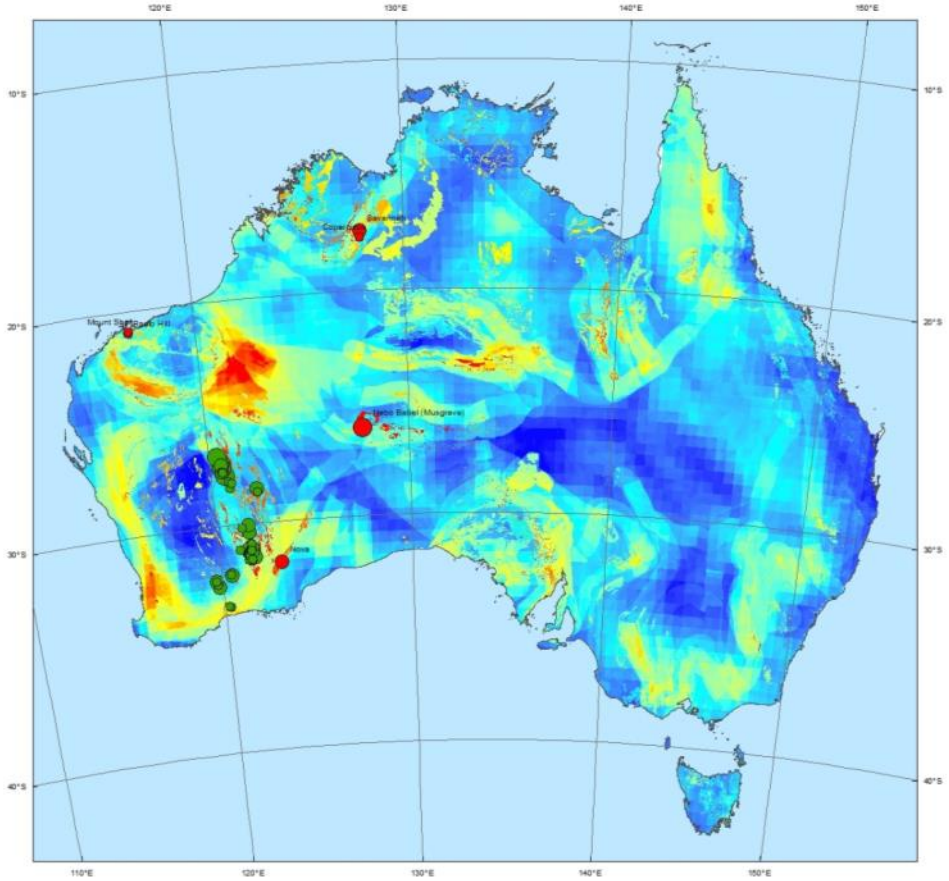
National magmatic Ni-PGE – deposition



Datasets used

- Local Ni, Cu and PGE depletion (OZchem)
- Sulphur saturation – high S (OZchem)
- Erosional dispersion of magmatic Ni-Cu (NGSA)
- Mineral occurrence locations (MINLOC)
- Presence of shallow mafic-ultramafic bodies (gravity and aeromagnetic data)

National magmatic Ni-PGE – final assessment



- Maps the location of known tholeiitic deposits (and komatiitic deposits also)
- Identifies new areas

Komatiitic

Tholeiitic intrusion hosted

High Low

Conclusions and the future

- GA has developed a robust, repeatable methodology for mineral potential analysis based on the mineral system paradigm
- This methodology works at both the national and province scale
- The methodology has been used for a number of different mineral system types
- The methodology effectively identifies the location of known deposits (not used in analysis)
- The datasets used at the national and province scales are very different, reflecting the importance of different essential ingredients
- Results will influence GA’s upcoming program of regional drilling

Theme 4: distal footprints & toolkits

Science problem: Ore deposits are small, and are often under cover.

How do we see the larger signals (footprints) of mineral systems to reduce risk in selected regions?

Solutions:

a) Collect new data to map prospective fairways under cover (drilling)

b) Maximise the knowledge: develop new exploration toolkits at a range of scales

c) Deliver products including data

Australian Government
Geoscience Australia

Regional stratigraphic drilling projects: Stavely and Southern Thomson

Anthony Schofield (anthony.schofield@ga.gov.au)
Ian Roach (ian.roach@ga.gov.au)

Why regional drilling projects?

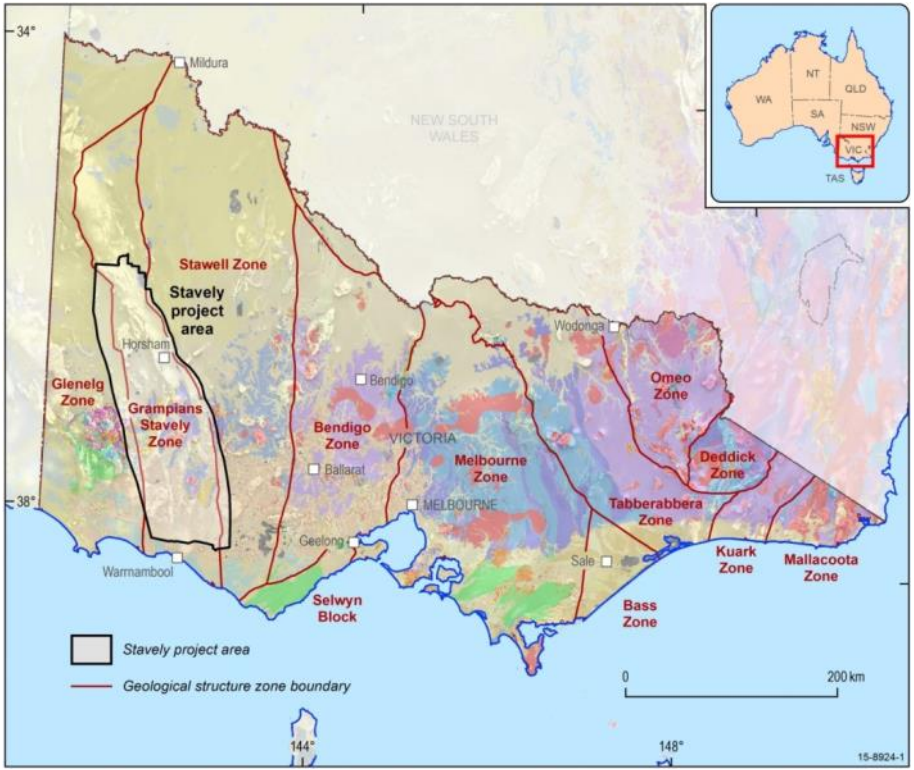
To lead the discovery of a new mineral province(s) in under cover Australia through:

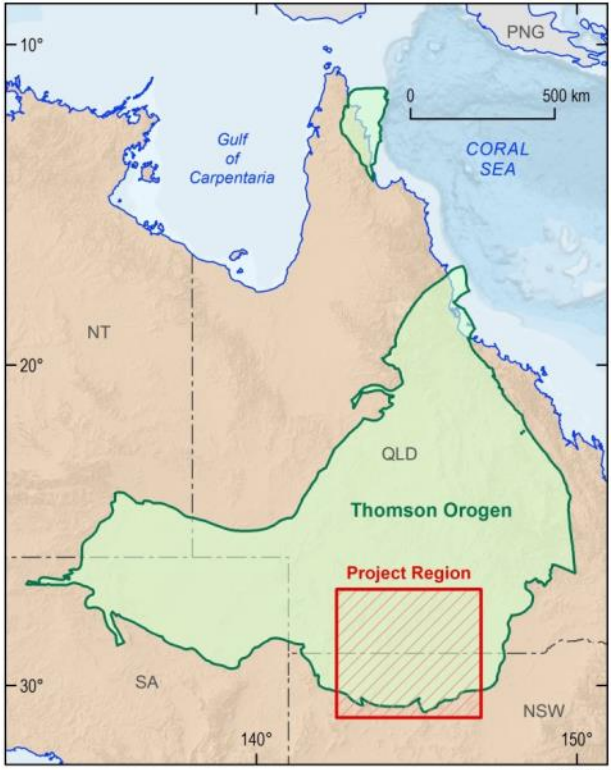
1) Development of **tool kits** which help explorers **determine the thickness and nature of cover** materials in a range of geological environments

2) **Collection and integration** of a range of **datasets and samples**

→ improved understanding of the regional geology and mineral systems in under cover areas

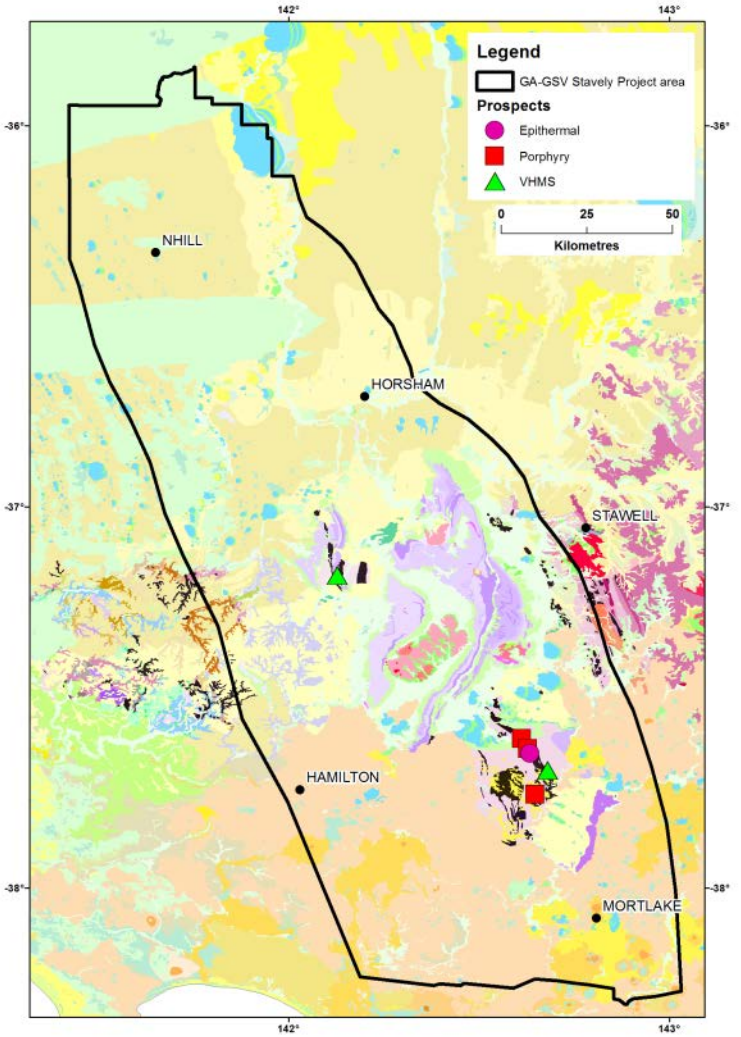
Regional drilling projects at Geoscience Australia





Stavely Project

- Geoscience Australia-Geological Survey of Victoria collaborative project
- Porphyry-epithermal and VHMS potential within largely buried Cambrian Arc package (Stavely Arc)
- Pre-competitive stratigraphic drilling of prospective rock packages with DET CRC
- New data acquisition



UNCOVER AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH

Australian Government
Geoscience Australia

DEEP EXPLORATION TECHNOLOGIES CRC
Uncovering the future

Stavely Project

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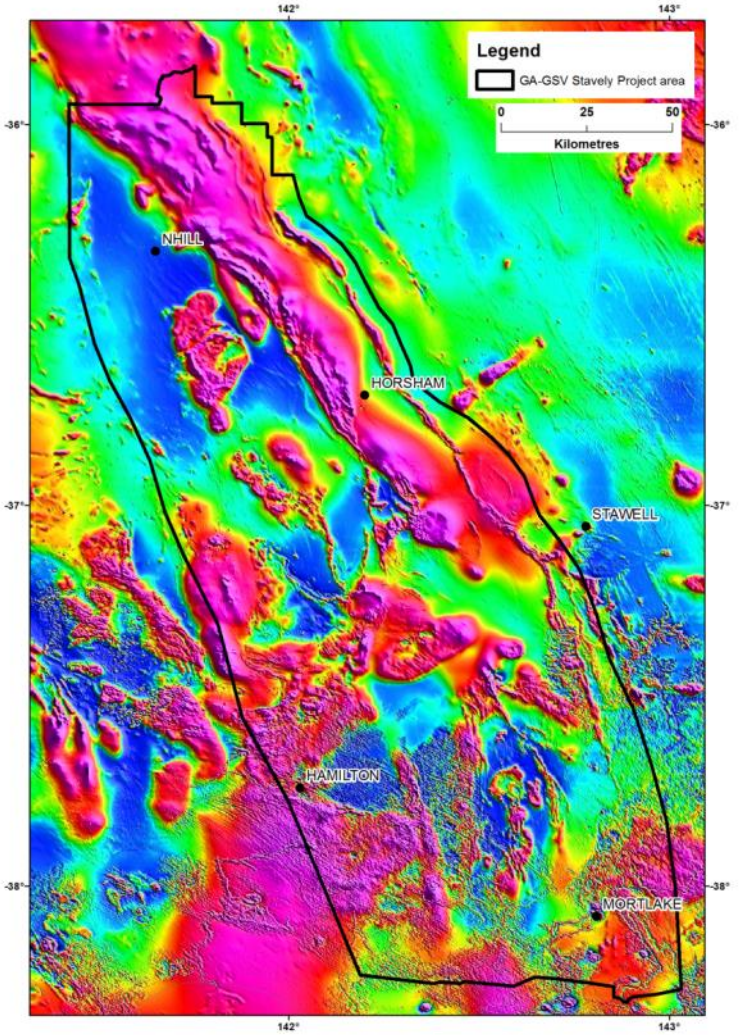


UNCOVER AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH

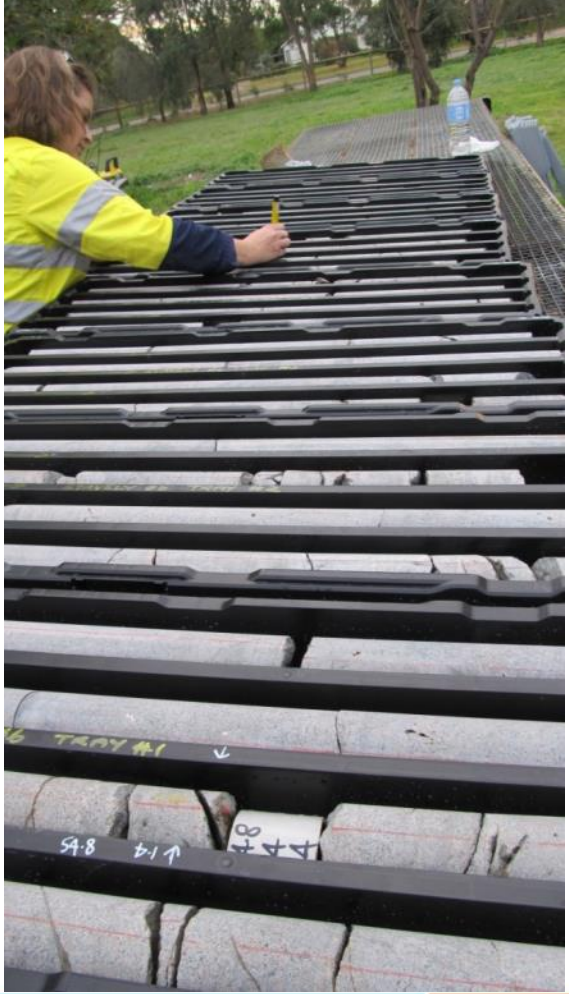
Australian Government
Geoscience Australia

DEEP EXPLORATION TECHNOLOGIES CRC
Uncovering the future

Drilling in the Stavely region

14 fully-cored stratigraphic drill holes

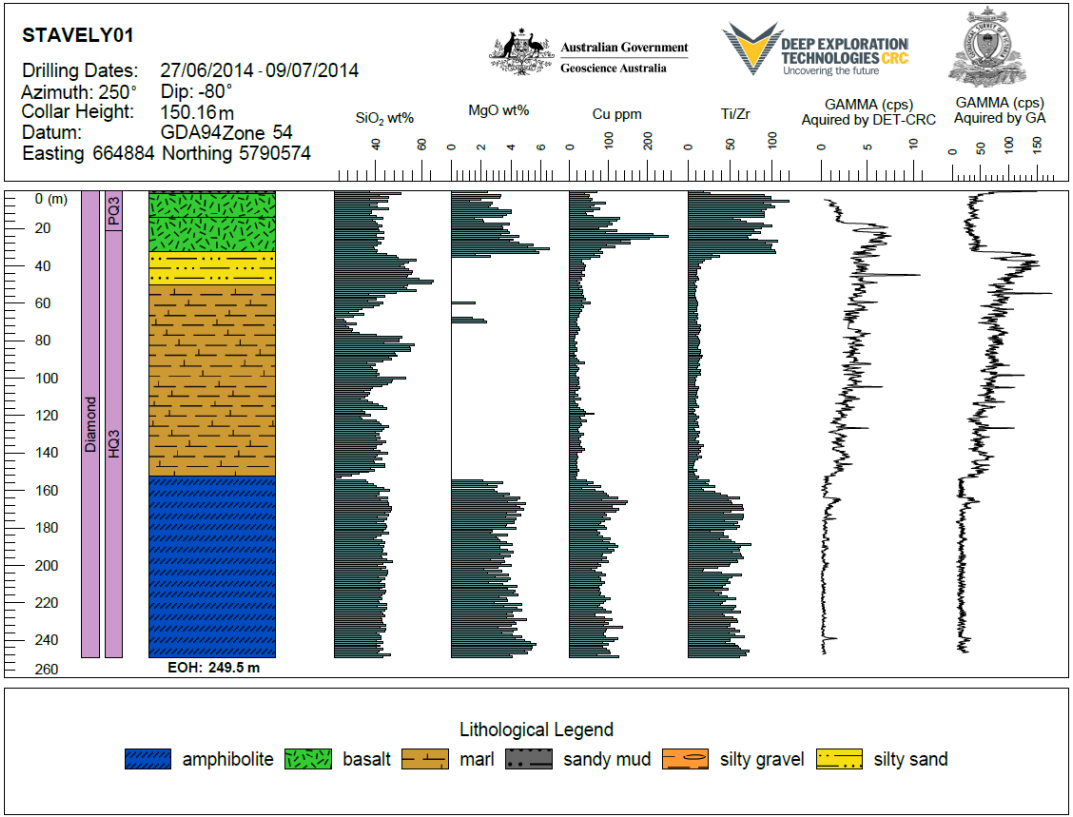
- April-September 2014
- 2708 m total (1152 m sonic, 1556 m diamond)
- Included deepest sonic hole drilled in Australia (212 m)
- Prospective arc rocks intersected
- Cover depths relatively shallow (typically <150 m)



Deploying new drilling technologies

DET CRC technologies deployed during drilling

- Lab-at-Rig® (geochemistry)
- AutoSonde™ (geophysics)
- Helps detect lithological changes and distal signatures of mineral systems

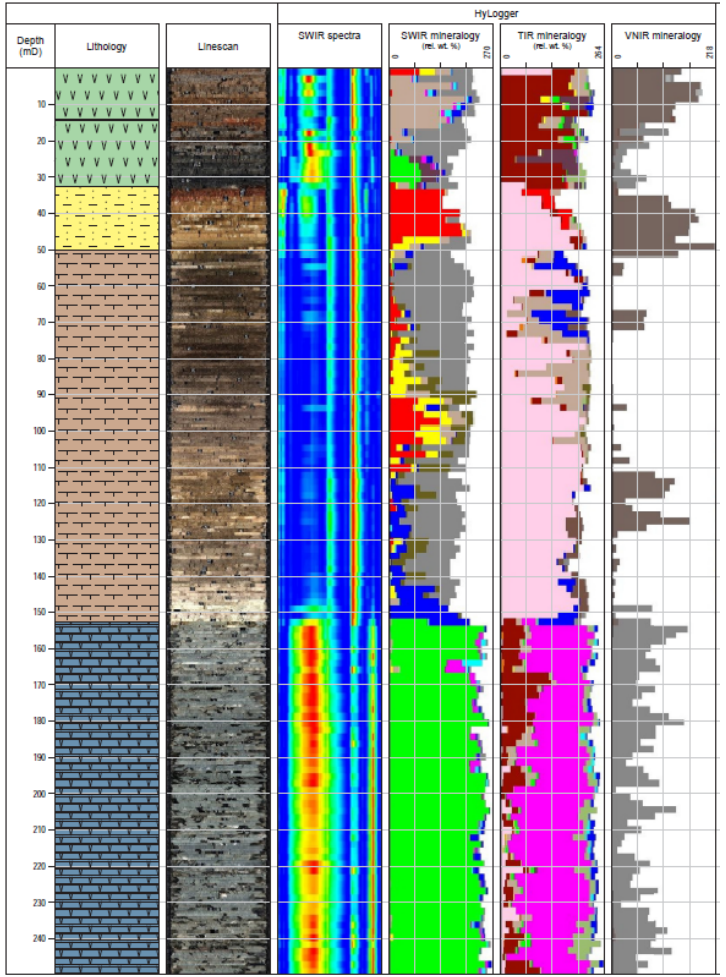


New data acquisition

Newly-acquired data helping to understand the geology and mineral systems potential of the Stavely Arc

- Down-hole geophysics
- Rock properties
- HyLogger™ hyperspectral data
- Whole rock geochemistry and isotope analysis
- Geochronology

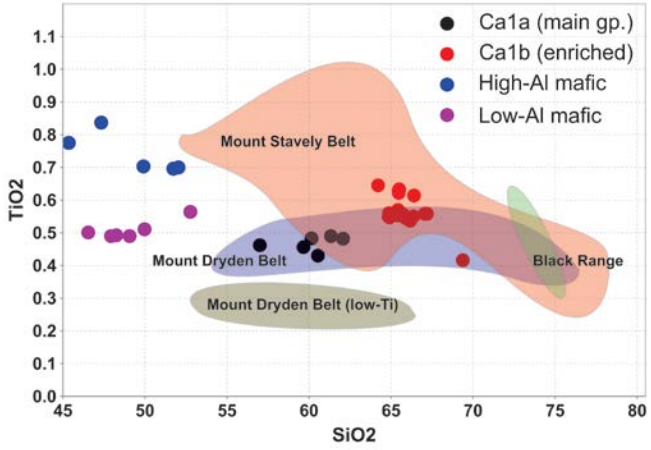
Partnerships with AuScope, University of Melbourne, GSSA, ANU, UTAS

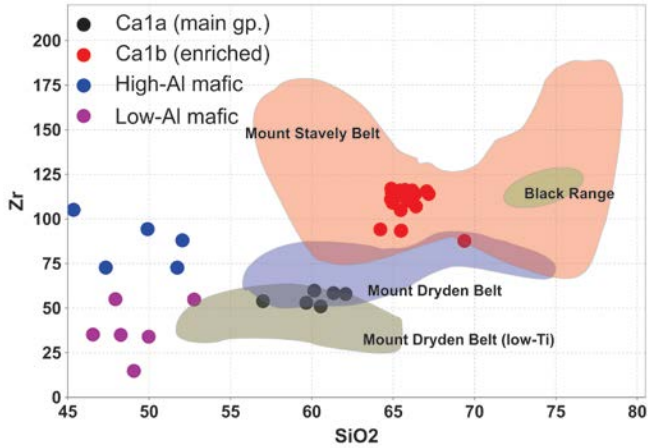


Mapping drilling results to outcrop

New geochemical data expanding the prospective fairway in the Stavely Arc

- Groups identified in drilling correlate with outcropping belts with known prospectivity
- Results consistent with a mature arc setting





Stavely Project delivery

Field data released July 2015

Upcoming releases:

- HyLogger™ hyperspectral data
- Lithological logs
- Petrophysical data
- Geochronology and geochemistry

Regional synthesis and Explorer's Guide to be delivered in early 2016

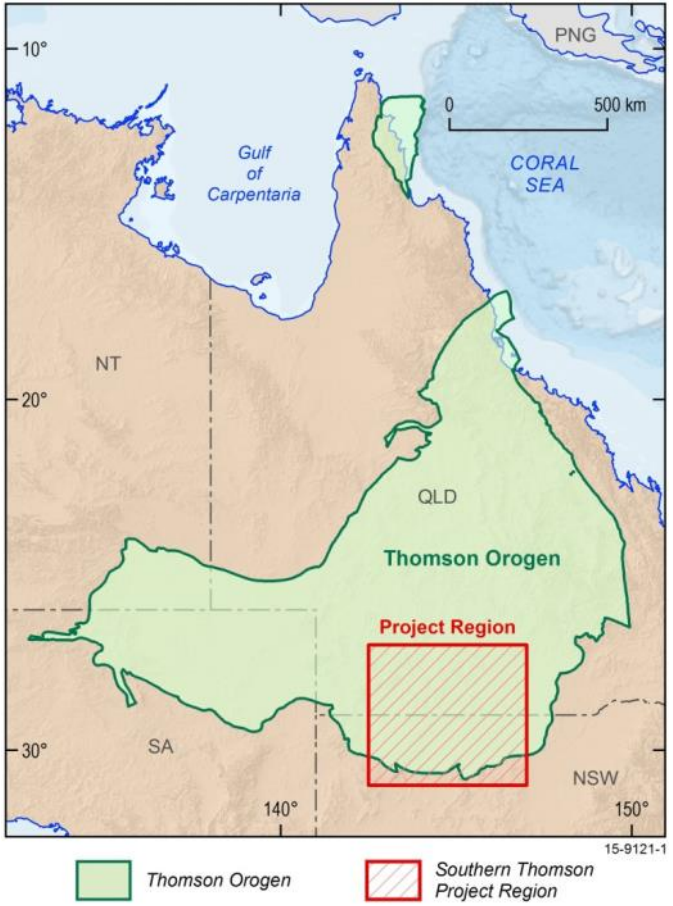
The Southern Thomson Project

The southern Thomson Orogen is a frontier area:

- << 1% outcrop, Mesozoic and Cenozoic cover
- Poor geological knowledge
- Poor mineral potential understanding

The southern Thomson Project:

- Joint project between GA, GSNSW and GSQ
- New geophysical, geochemical and geochronological data acquisition
- Drilling campaign in 2015/16 to test solid geology and mineral potential models



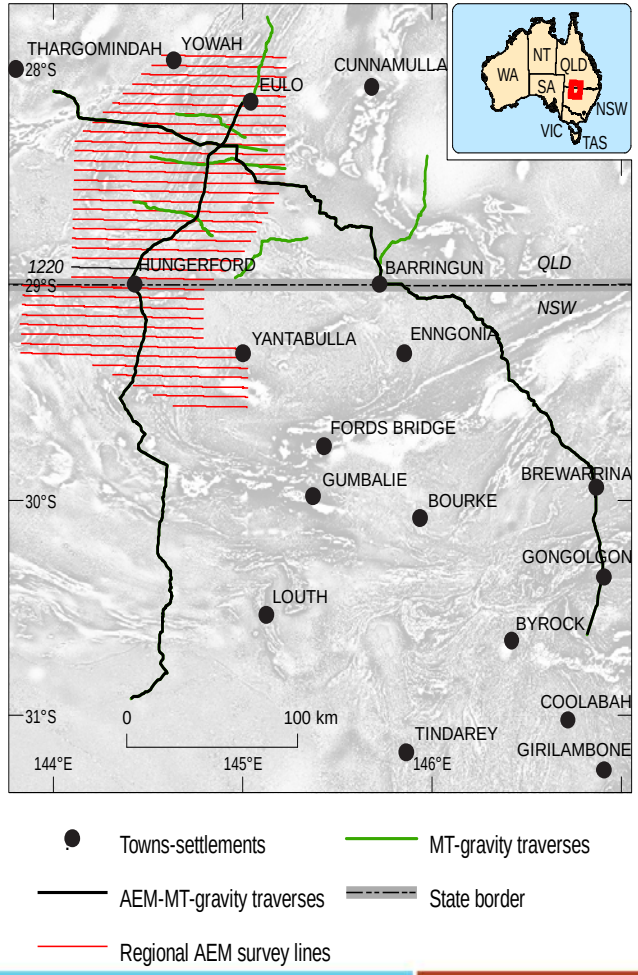
New geophysical data acquisition

Program of airborne and ground geophysical data acquisition:

- Airborne electromagnetics (released 2014 via GA website)
- Gravity traverses (released 2014 via GADDS)
- Broadband and audio magnetotelluric traverses
- Site-specific ground geophysics to support drilling program

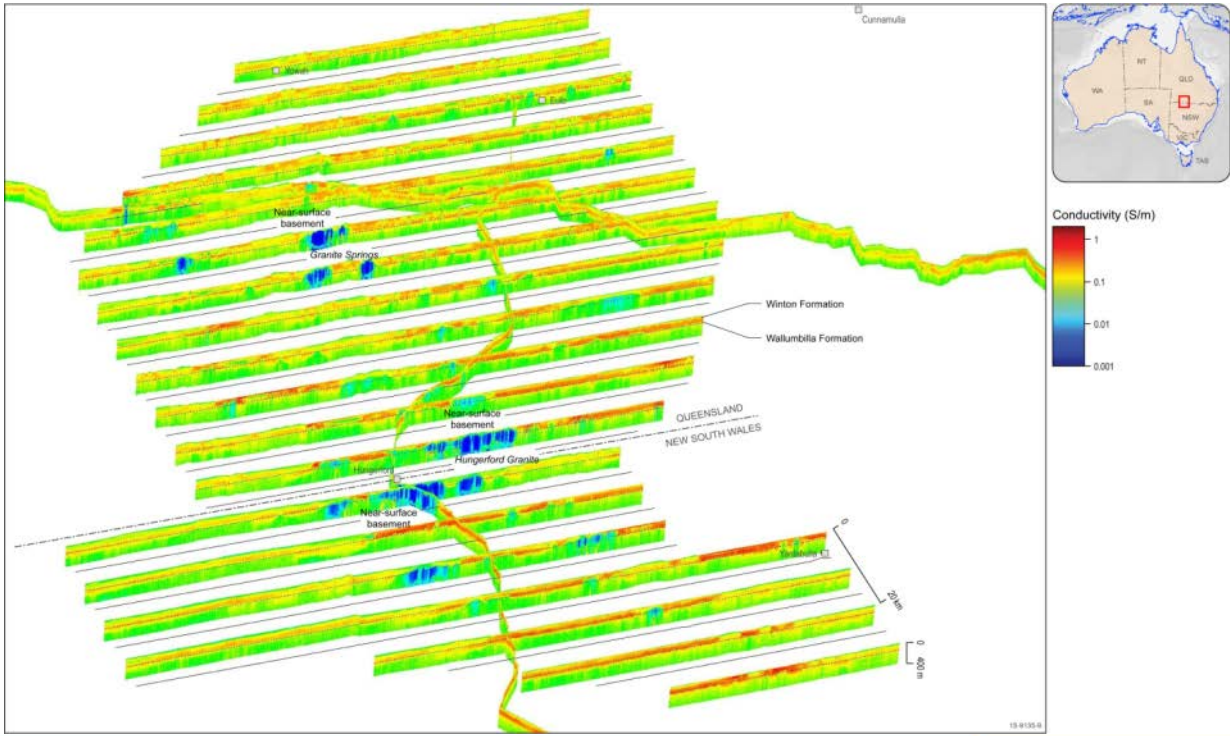
New data acquisition to support:

- Depth To Basement (DTB) mapping
- Under-cover geological mapping
- Model boundary between Thomson/Lachlan orogens
- Drill site targeting



AEM survey

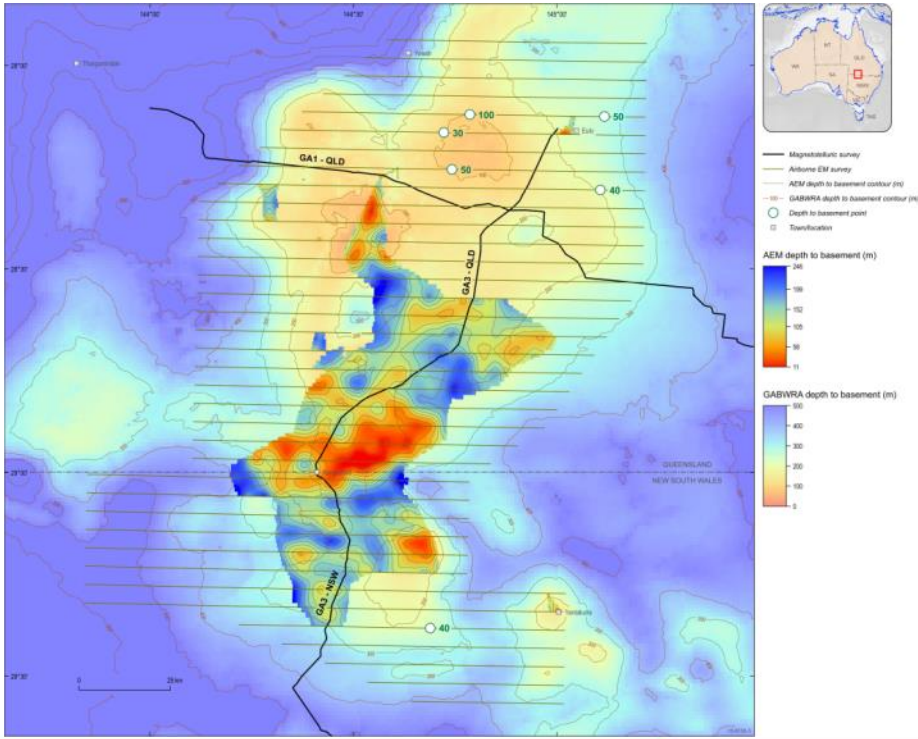
Flown 25 March-5 May 2014 using Geotech Ltd VTEM$_{plus}$® system



AEM survey

Flown 25 March-5 May 2014 using Geotech Ltd VTEM$_{plus}$® system

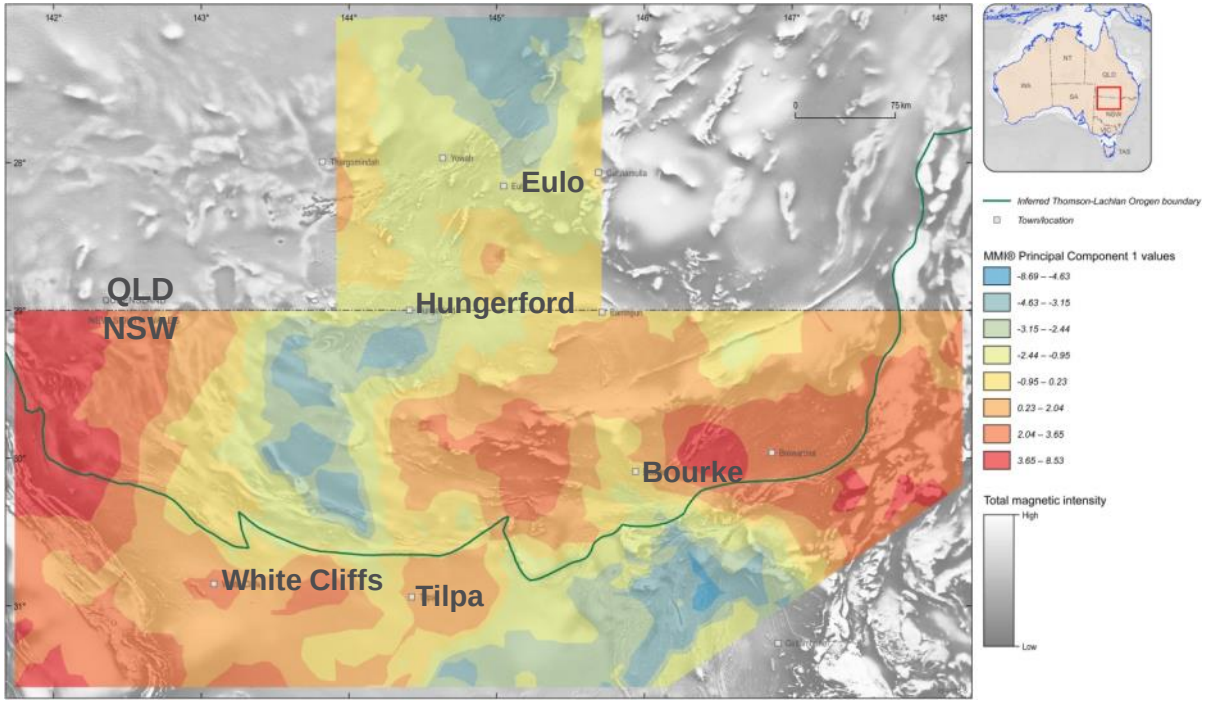
- Successfully map > 3440 km^2 of under-cover Eulo Ridge
- Map extensive electrically resistive basement terrains under cover
- Map unrecognised basement ‘islands’ under shallow cover
- High resolution hydrostratigraphic mapping
- Introduce new inversion algorithm
- Highlight the benefit of correct system selection by forward modelling



Regolith geochemistry

Mobile Metallic Ion® Principal Component 1 results of drainage catchment outlet sediments:

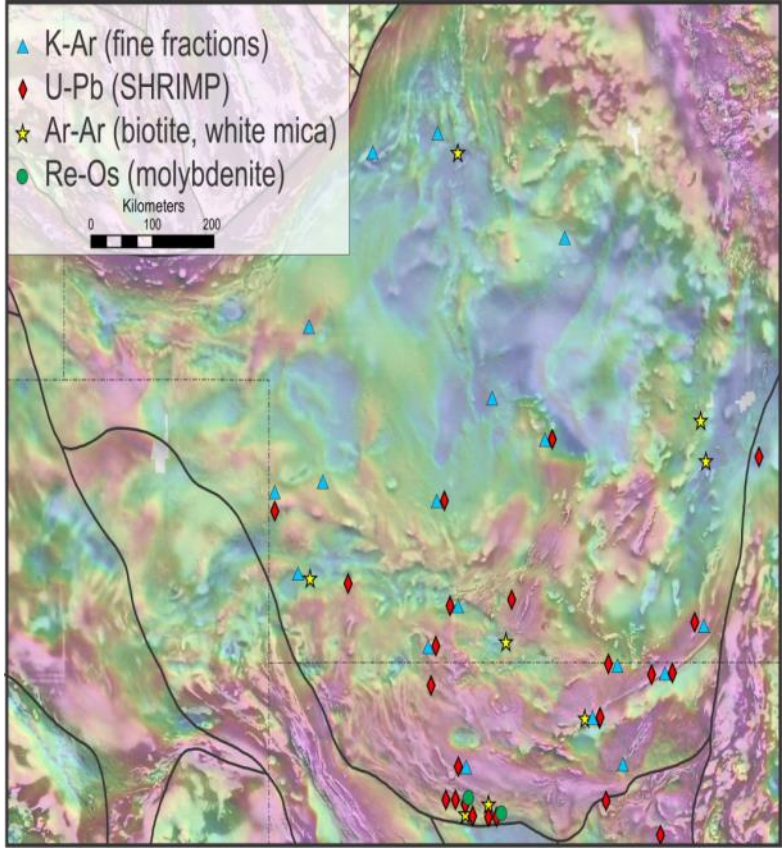
- Kriged MMI® PC1 map
- Cool colours – REEs associated with resistate minerals
- Warm colours – Ca, Sr, Mg, Cu, Au, Mo, Ni associated with calcrete and potential mineralisation



Geochronology

New data on magmatic, metamorphic and mineralisation ages:

- Builds on recent NGA geochronology in NSW and QLD
- New U-Pb SHRIMP mounts from industry drill core: magmatic ages
- New Ar-Ar, K-Ar ages, XRD on mineral separates for age of metamorphism on Culgoa Lineament
- New S & Pb isotopic data on mineralisation
- Release ages as a new GA Record on southern Thomson-northern Lachlan 2015



New isotopic age samples

Conclusions

Pre-competitive drilling aims to:

- Understand and develop new solid geology products
- Assess regional prospectivity
- Reduce exploration risk
- Encourage the discovery of a new minerals province

Drilling in the Stavely region uncovering prospective arc rocks

The southern Thomson Orogen is a true greenfields area. Drilling to commence in 2015

Australian Government
Geoscience Australia

Lowering the Entry Level to Big Data & Big Compute:

The Virtual Geophysics Laboratory and its future development

Carina Kemp, *James Goodwin*, Murray Richardson and Richard Chopping
james.goodwin@ga.gov.au

Big Data

There is an estimated 3 Petabytes of publically funded geoscience data in Australia, and the majority of this data is held by Geoscience Australia.

In terms of geophysics this includes nationwide datasets of:

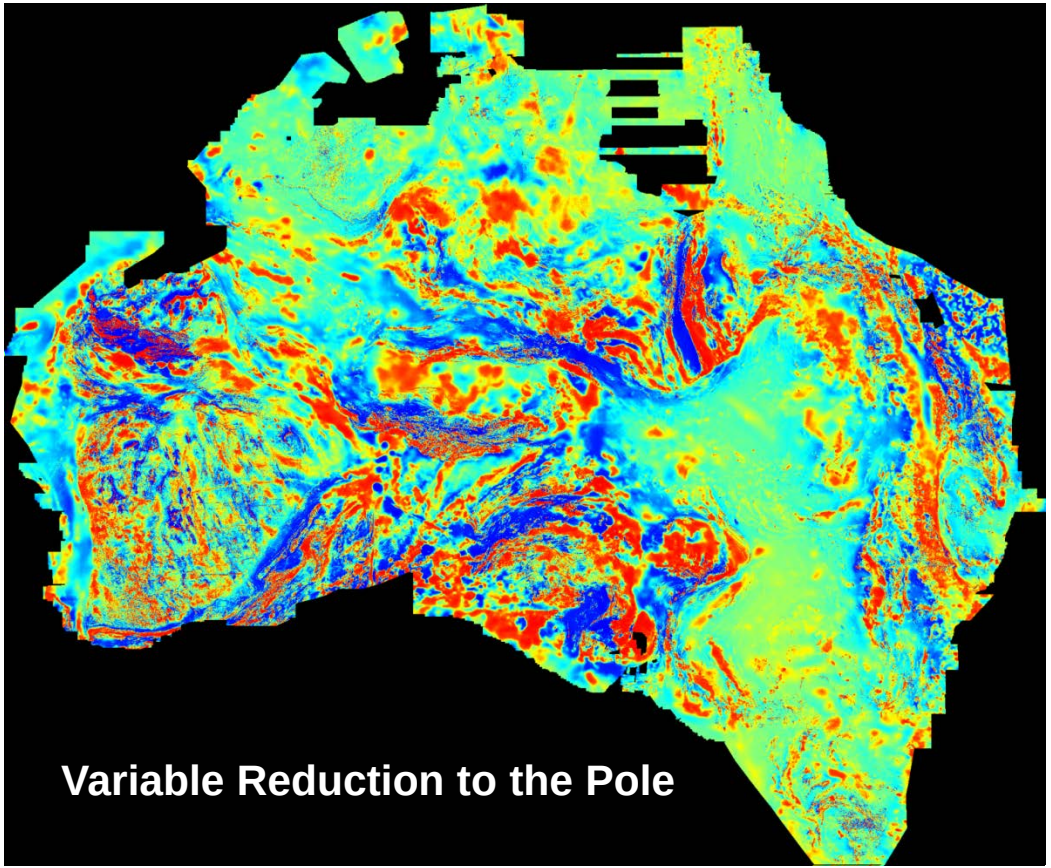
- Gravity
- Magnetics
- Radiometrics
- Seismic
- Magnetotellurics
- Airborne Electromagnetics (AEM)
- Satellite derived data

Big Compute: National Computational Infrastructure

RAIJIN

- 57,472 computer cores
- > 10 petabytes Research Data Storage Infrastructure (RDSI)
- Peak performance of 1.2 PFlops
- Ranked 38th most powerful computer system in the world
- Virtual labs (VLs)

Magnetic Anomaly Map of Australia 2015



- 80 × 80 m cell size
- Variable Reduction to the Pole produced using GA codes.
- Only possible using the NCI

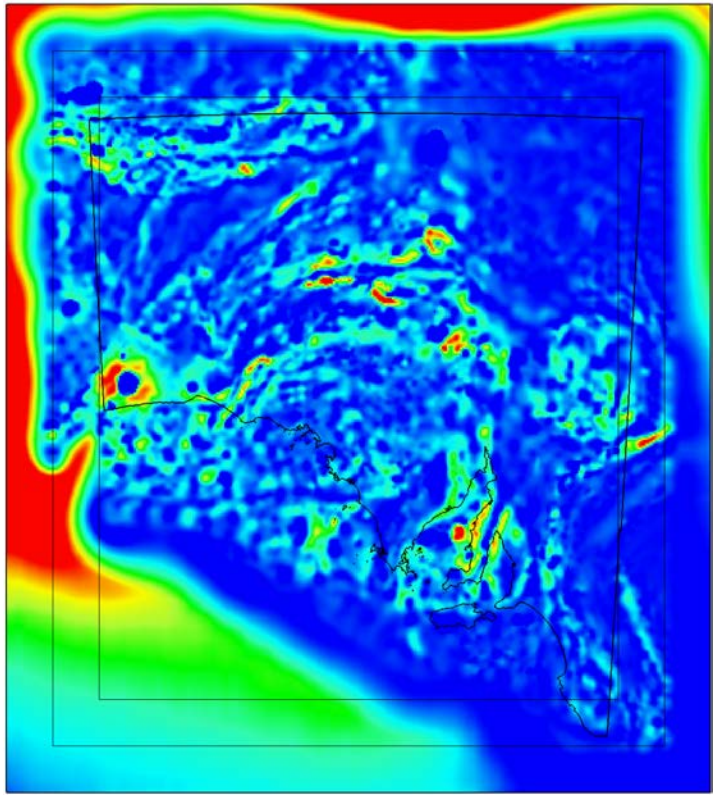
Magnetic Inversion Model – Gawler Craton, S.A.

1500 km x 1700 km
(4 km cell size)

~ 8 Million cells total

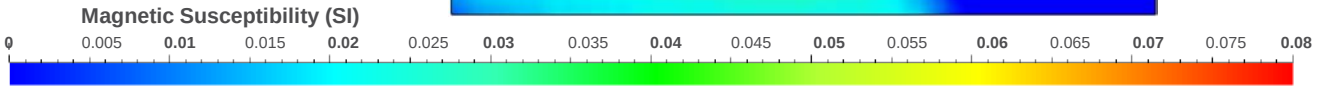
Inversion result
took 9 hours to run
using 128 CPU

Only possible using the
NCI



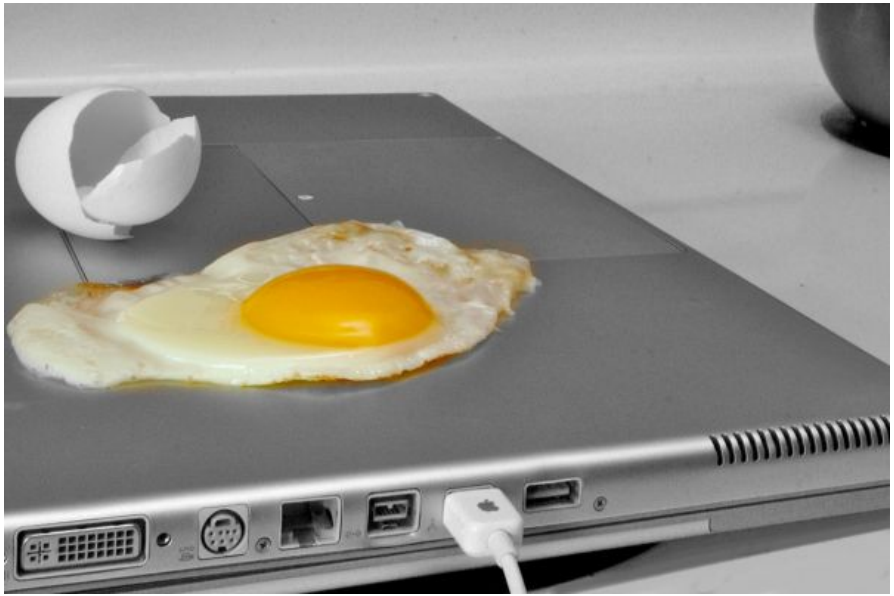
Horizontal Section
Z = -10,000 mRL

Results courtesy of the Geological Survey of South Australia (Simon van der Weilen et al.)

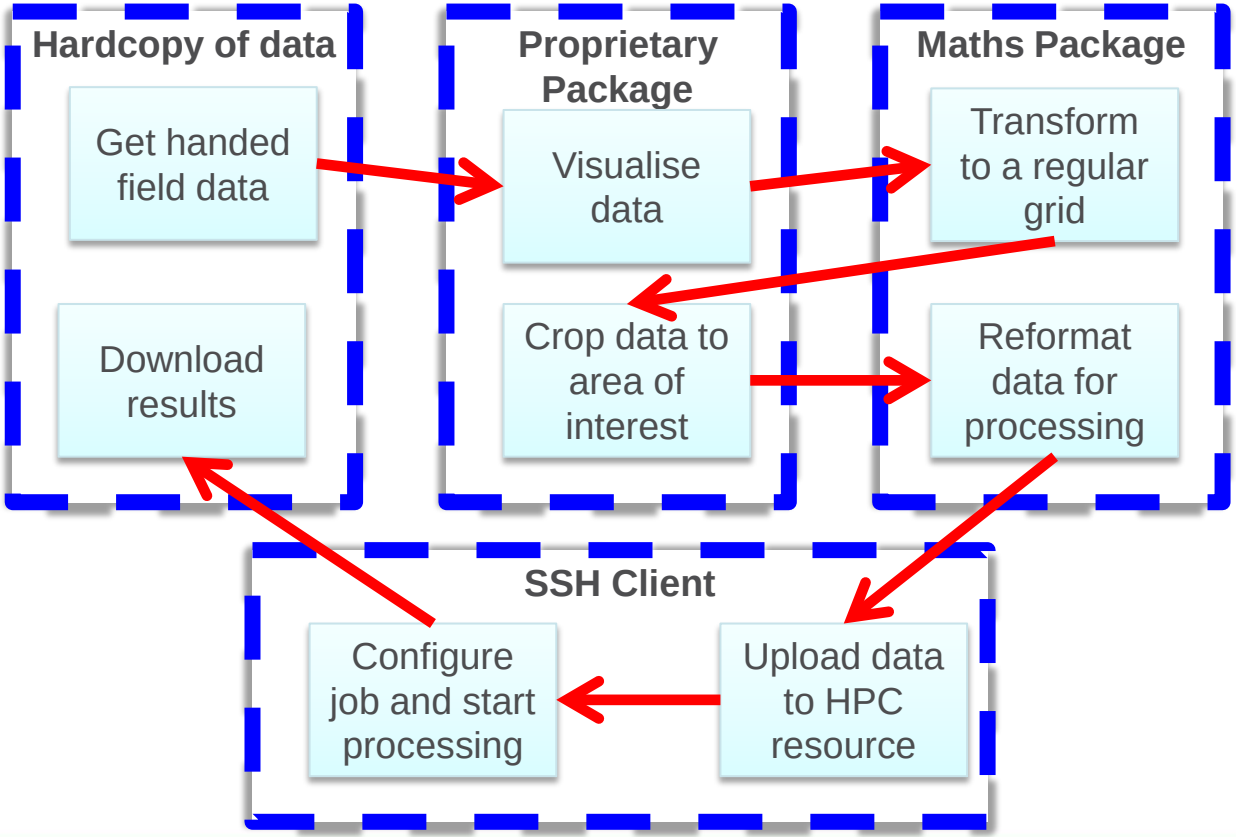


What is the problem?

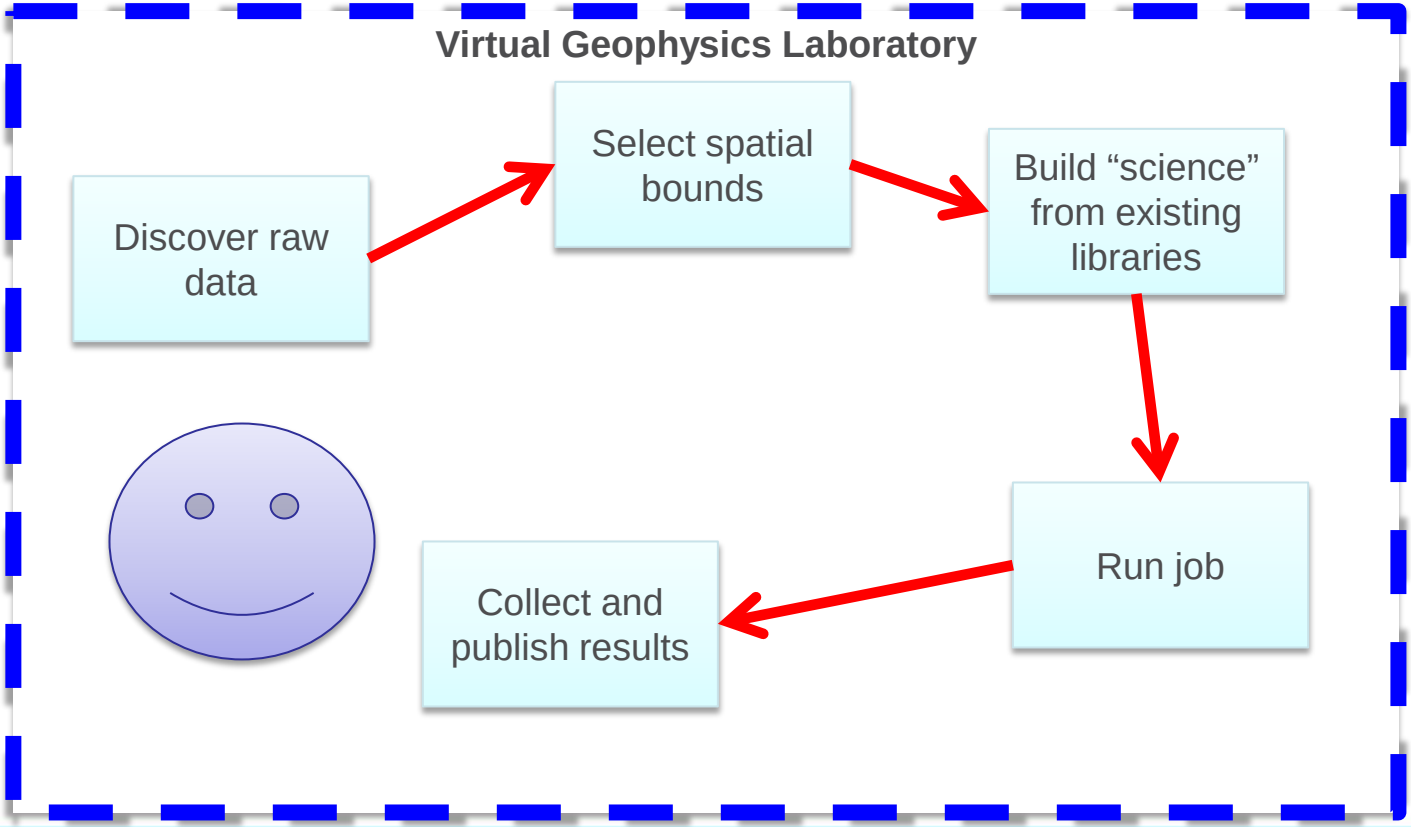
- Access to Big Data
- Access to Big Compute
- Complex geophysical scientific workflows



From this..

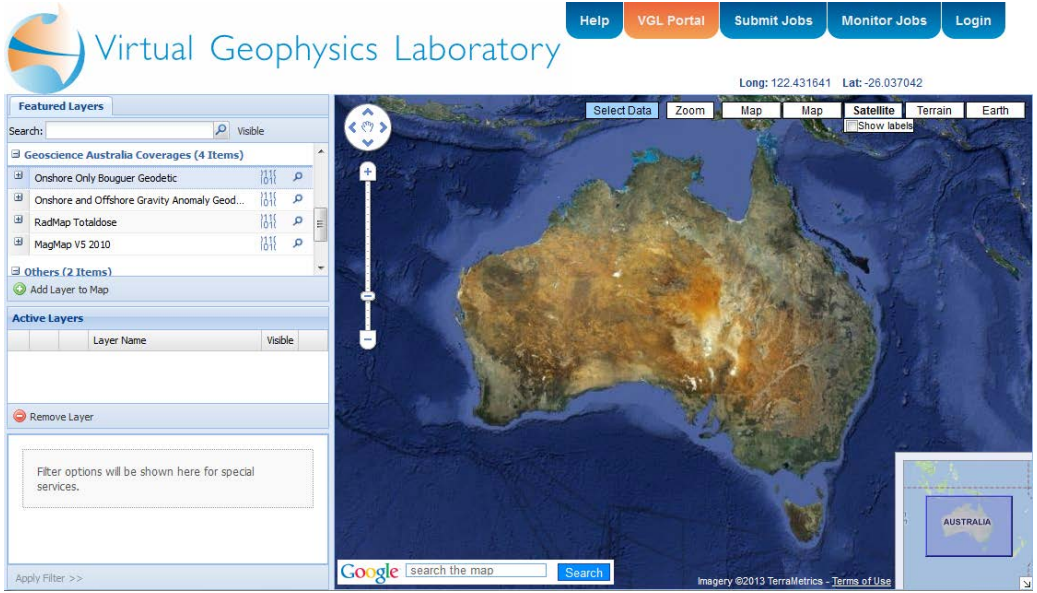


…to this: A Virtual Laboratory in the Cloud.



The Virtual Geophysics Laboratory

Contributing to the high performance computing evolution



http://vgl.auscope.org

Currently open for all for research and beta testing ..

Funded by:

nectar

collaboration

CSIRO

NCI

NATIONAL COMPUTATIONAL INFRASTRUCTURE

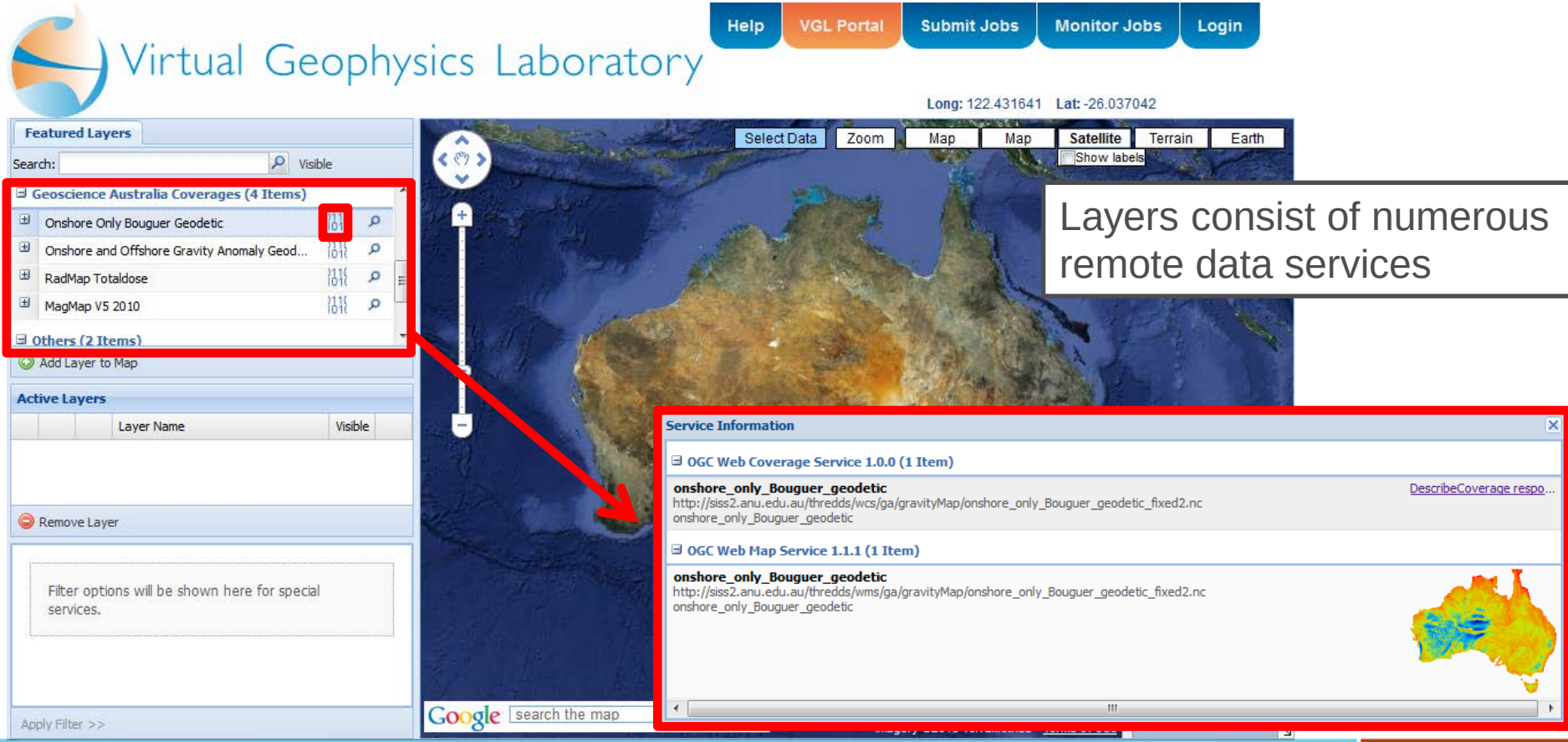
Australian Government

Geoscience Australia

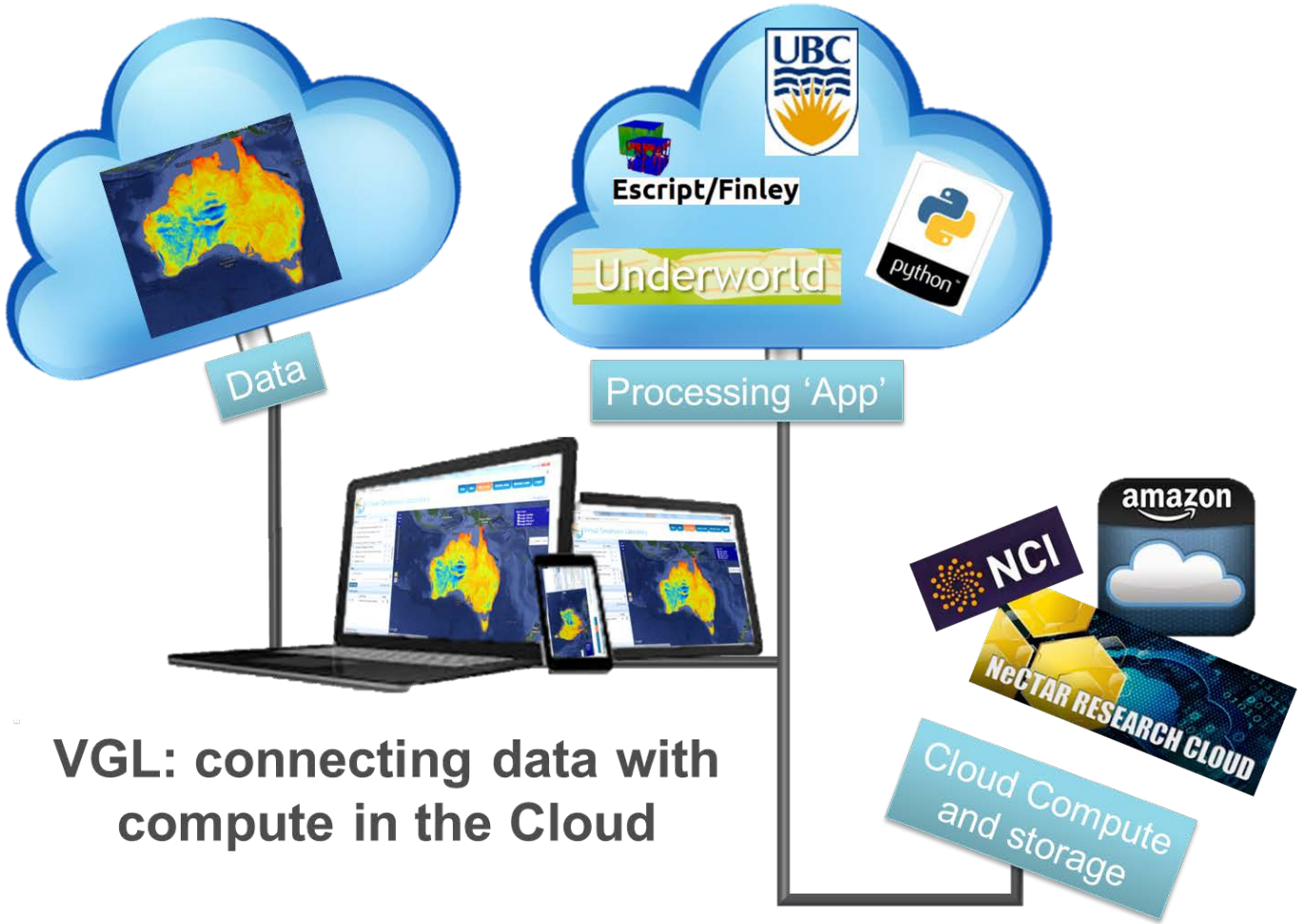
This is what VGL looks like.

Layers consist of numerous remote data services

This is what VGL looks like.



Layers consist of numerous remote data services



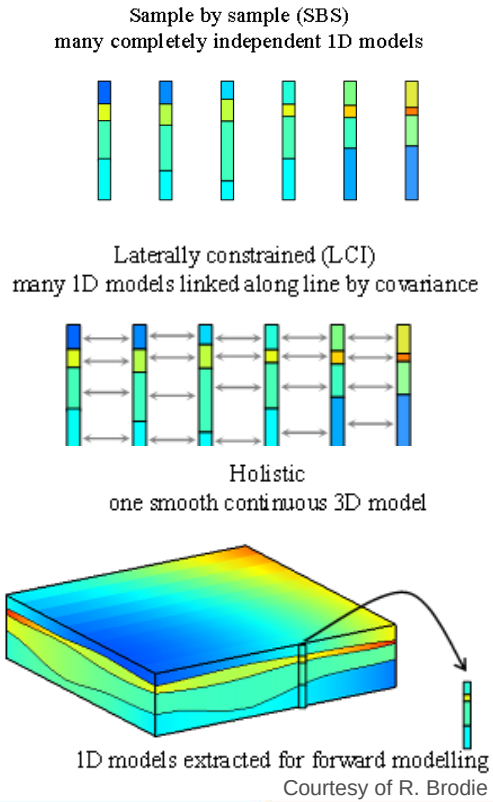
VGL: connecting data with compute in the Cloud

Key Virtual Geophysical Laboratory features

- Access to precompetitive **geophysical data** online
- Access to **cloud computing** and **storage**
- Access to geophysical data **workflows** (‘apps’)
- Capture **Metadata**
  - (ISO 19115) ‘provenance record’ enabling transparency of the results.
  - Share your results and search for other published results.

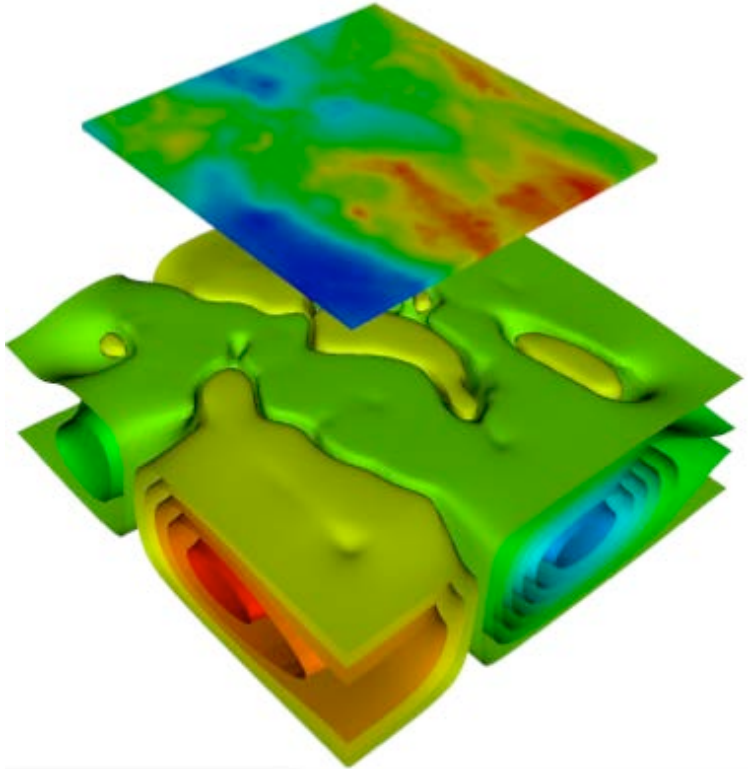
Airborne Electromagnetics (AEM) Inversion

- All codes developed at GA in platform independent C++
- Our inversions code is based on layered earths (1D not 3D)
- Deterministic Gradient Based
  - GALEISBS - sample by sample
    - our main production algorithm
  - GALEILBL - line by line
    - used occasionally
  - HOLISTIC - survey at a time
    - frequency domain only
- Codes released via VGL and open source

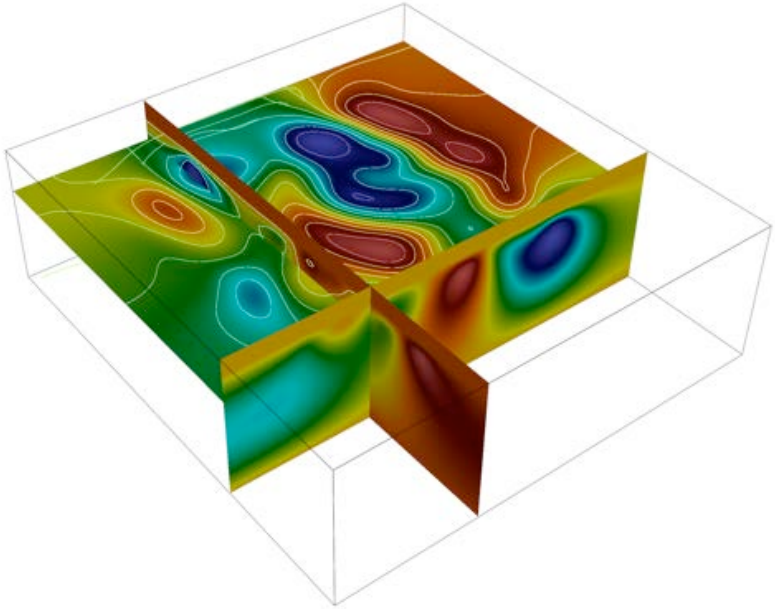


Courtesy of R. Brodie

A VGL Result: escript.downunder



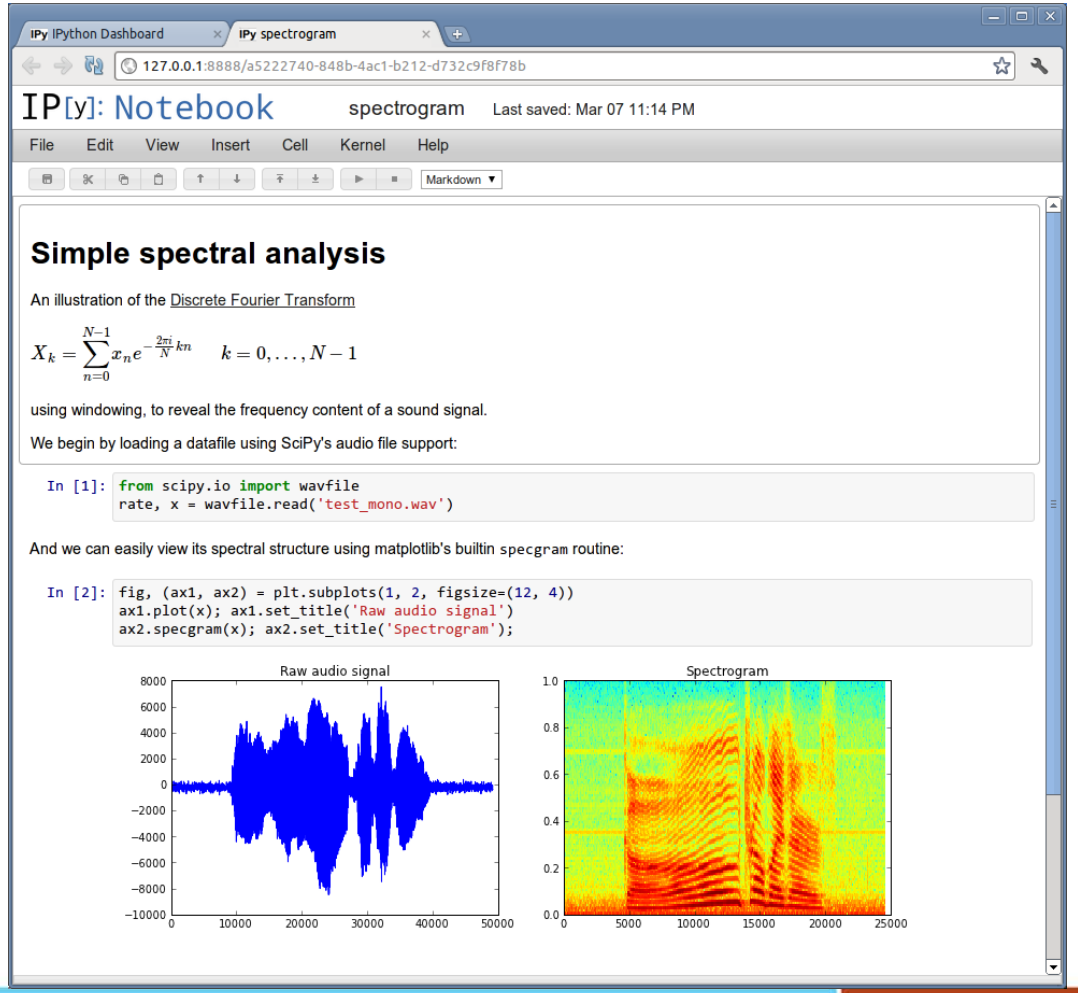
Inversion of gravity anomaly data



Joint inversion of gravity and magnetic data.~ 100km by 100km by 30km depth showing magnetic susceptibility variation.

The iPython Notebook

Interactive computational environment that provides a platform for reproducible results.



The High Performance Computing Evolution

Virtual Laboratories remove the technical barriers

- Open access to data,
- Open access to scientific workflows
- Open access to and transparency in the scientific results.

More Information on VGL can be found at:

https://www.nectar.org.au/virtual-geophysics-laboratory

ANVGL coming soon.

VGL is free for research use:

http://vgl.auscope.org

Phone: +61 2 6249 9228

Web: www.ga.gov.au

Email: carina.kemp@ga.gov.au; richard.chopping@ga.gov.au; james.goodwin@ga.gov.au

Address: Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston ACT 2609

Postal Address: GPO Box 378, Canberra ACT 2601

Australian Government
Geoscience Australia

Advances in Geoscience Information Access

Ollie Raymond oliver.raymond@ga.gov.au

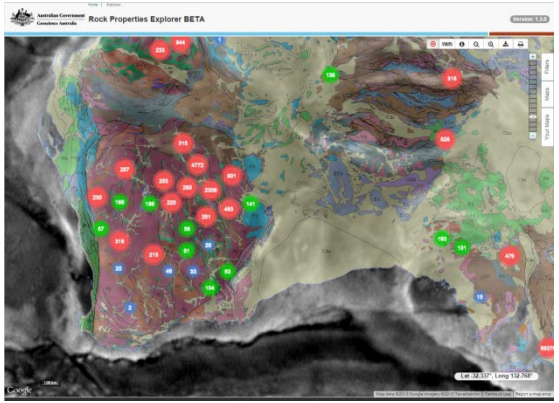
Advances in Geoscience Information Access

Data as Web Services

- What is an OGC Web Service?

OGC®
Making location count.
www.opengeospatial.org

GA Geological Data as Web Services



Australian Geoscience Information Network

- Geoscience Portal redevelopment
- GADDS redevelopment

Geoscience Data Standards and Australia's Role

- GA and GGIC

geoscience.gov.au

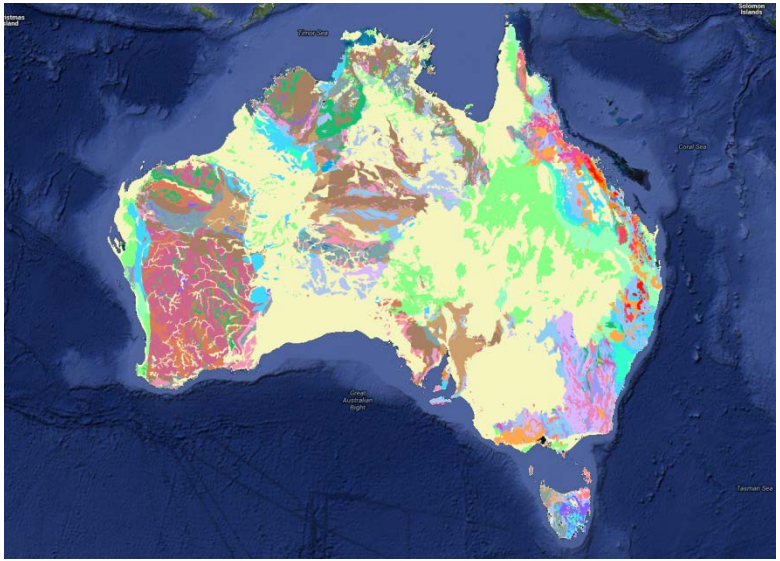
MineralTenementML

Data as Web Services

What are “OGC Web Services”?

Maps and data broadcast over the internet , like streaming TV, using international standard protocols developed by the Open Geospatial Consortium (OGC).

- **WMS (Web Map Service)**
- **WFS (Web Feature Service)**
- **WCS (Web Coverage Service)**



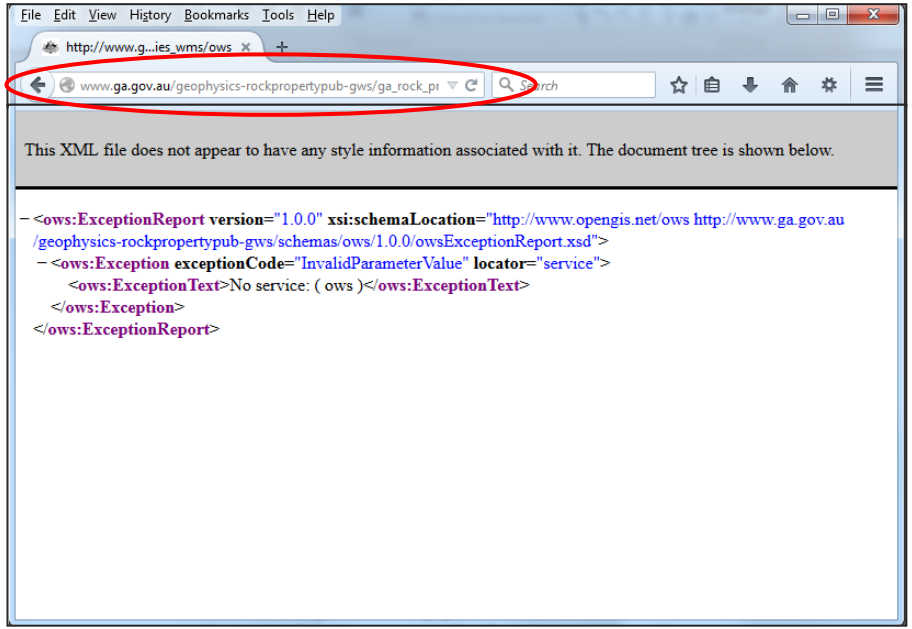
Data as Web Services

What are “OGC Web Services”?

- Web services are accessed via a URL “endpoint”

e.g: http://www.ga.gov.au/geophysics-rockpropertypub-gws/ga_rock_properties_wms/ows

- the endpoint URL will not resolve in a standard browser address bar!



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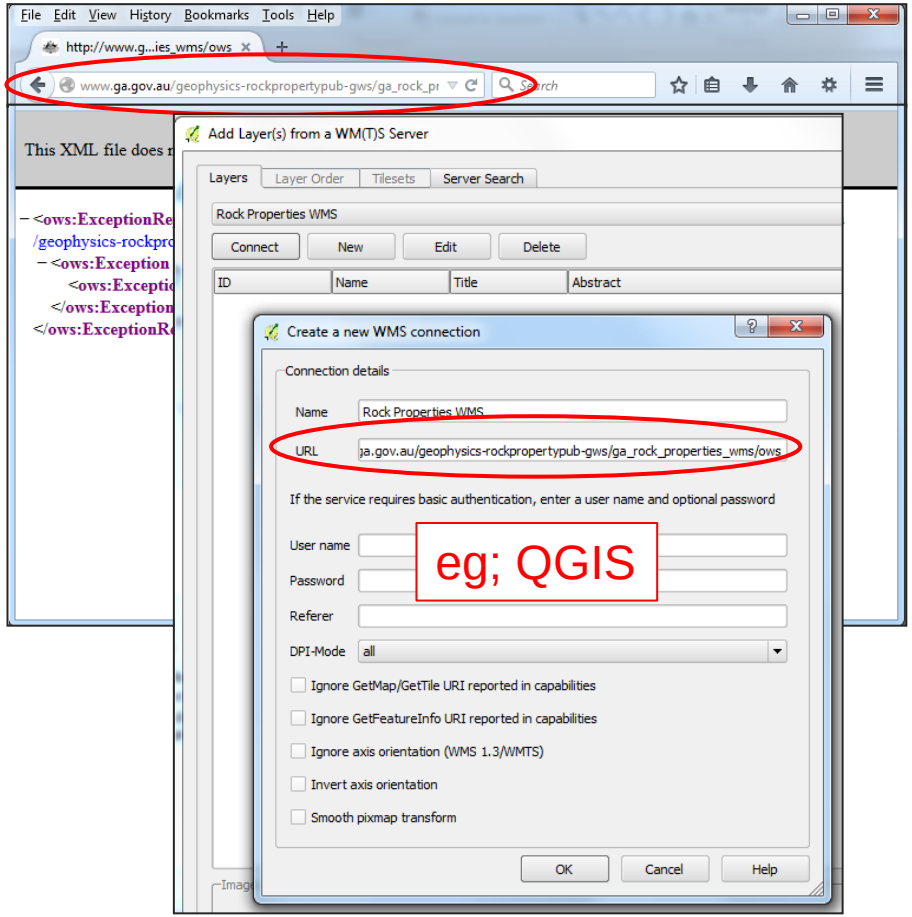
e.g: http://www.ga.gov.au/geophysics-rockpropertypub-gws/ga_rock_properties_wms/ows

- the endpoint URL will not resolve in a standard browser address bar!
- the URL is consumed by GIS applications, web portals, and other analytical applications built to consume OGC web services

- GA website has instructions for using web services in some common GIS applications

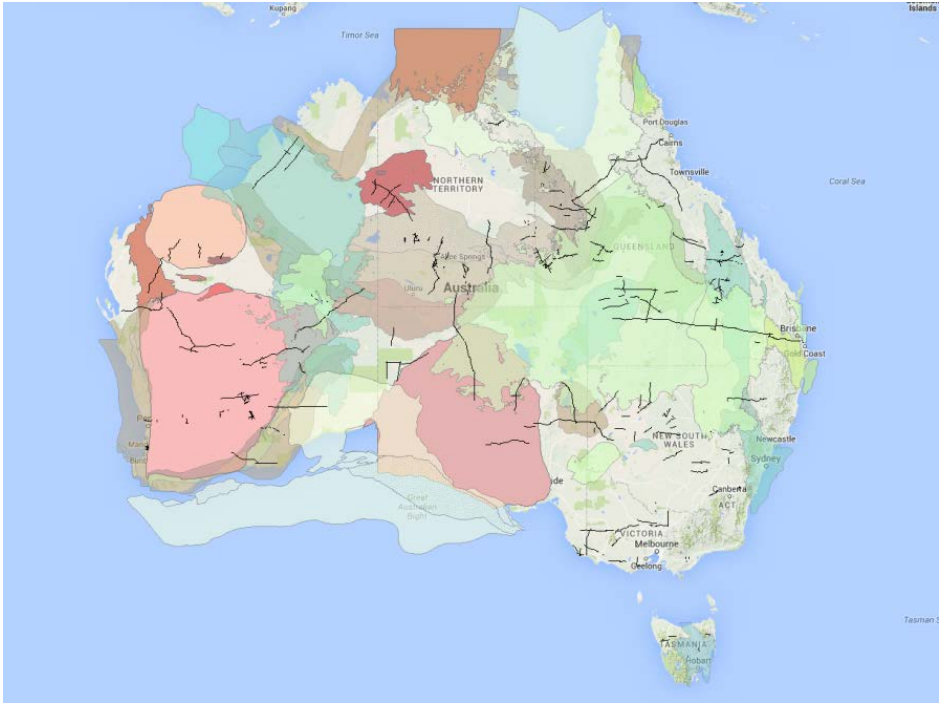
http://www.ga.gov.au/data-pubs/web-services#heading-2



Data as Web Services

WMS (Web Map Service)

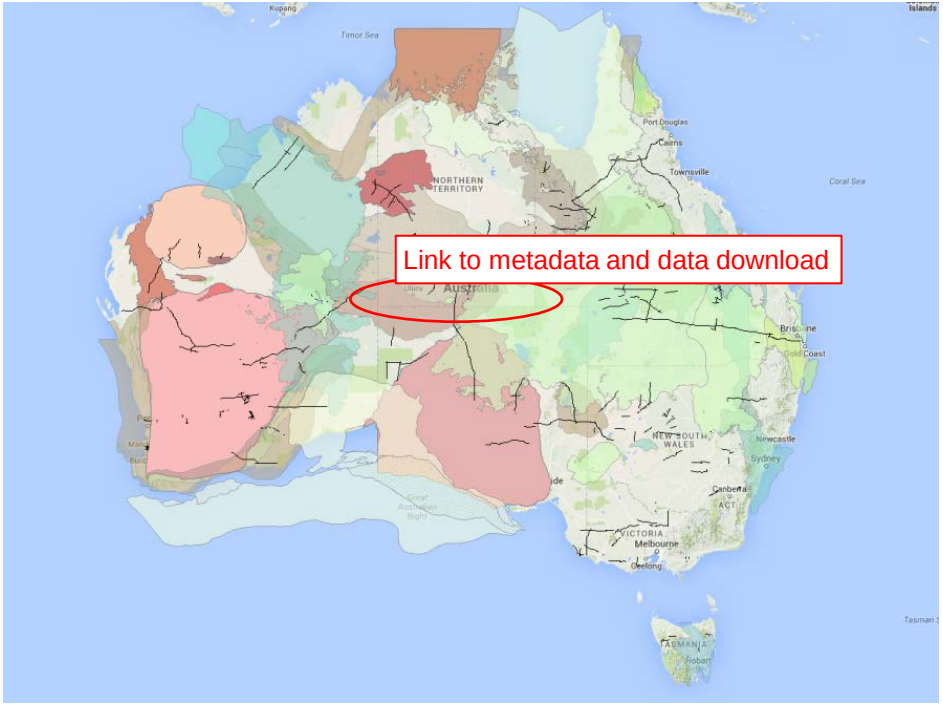
- delivers map data as an image



Data as Web Services

WMS (Web Map Service)

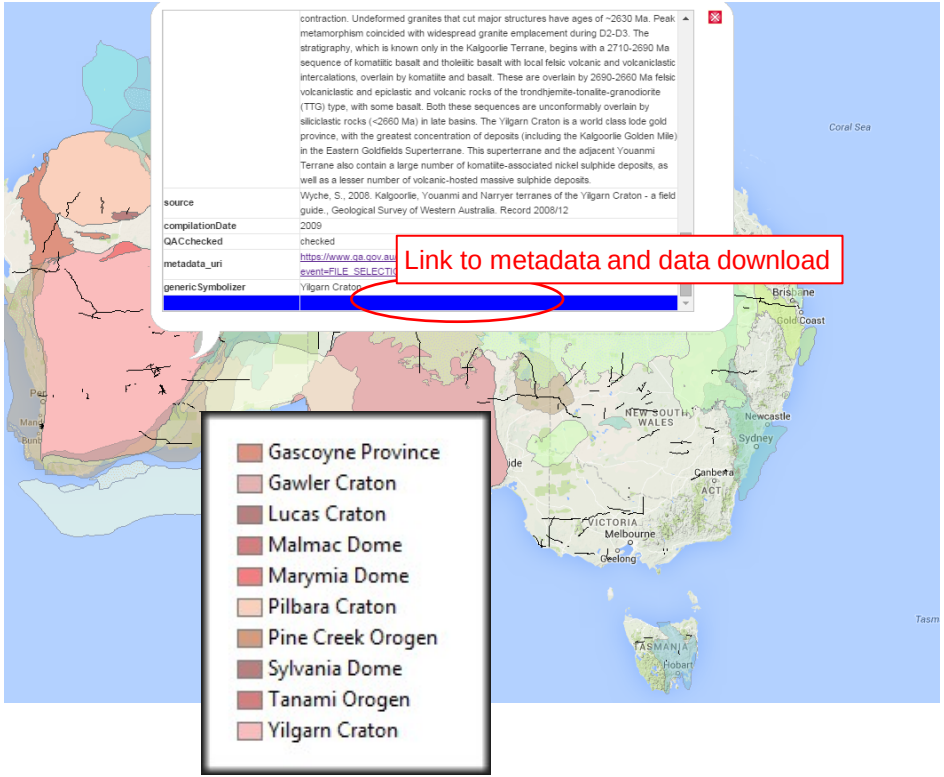
- delivers map data as an image
- they can be queried online



Data as Web Services

WMS (Web Map Service)

- delivers map data as an image
- they can be queried online
- the data behind the WMS can be accessed if a link is provided in the WMS to a downloadable file
- typically, symbolisation/legend is delivered with the WMS map
- WMS maps are primarily used as queryable backdrops in your GIS analysis

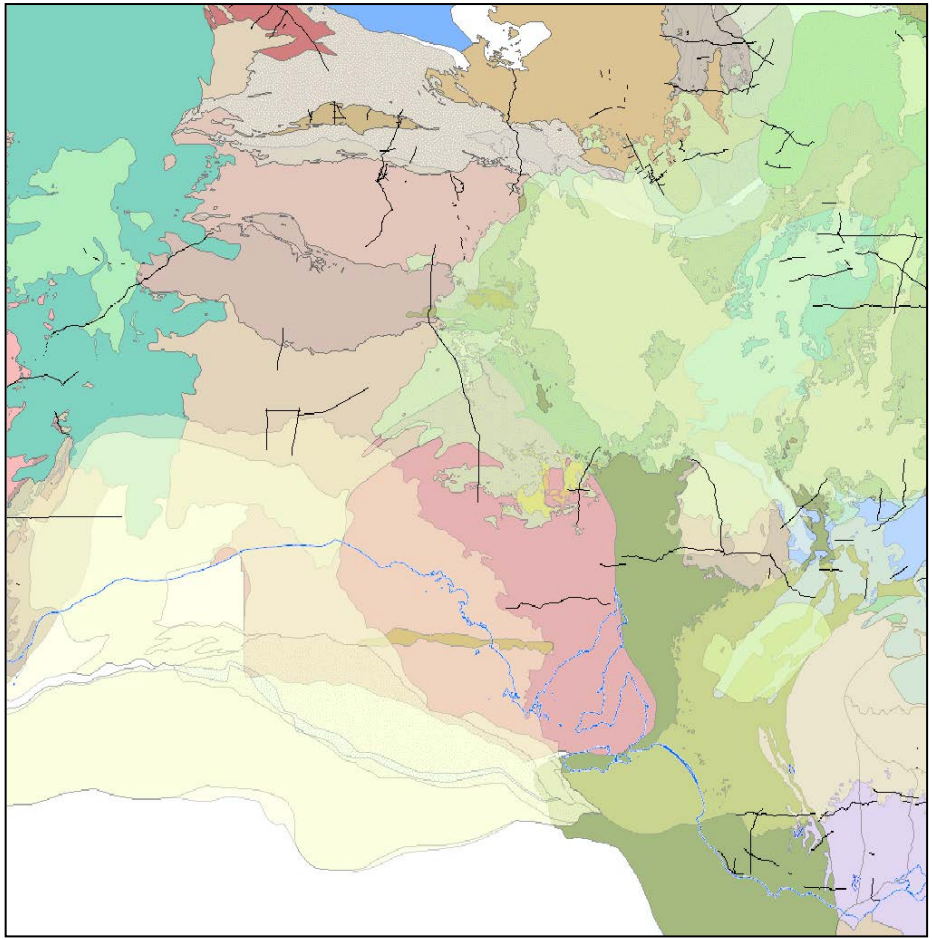


Data as Web Services

An example of a GA WMS,

GA's Onshore Seismic Surveys WMS

i. a map of survey locations,



Data as Web Services

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i. a map of survey locations,

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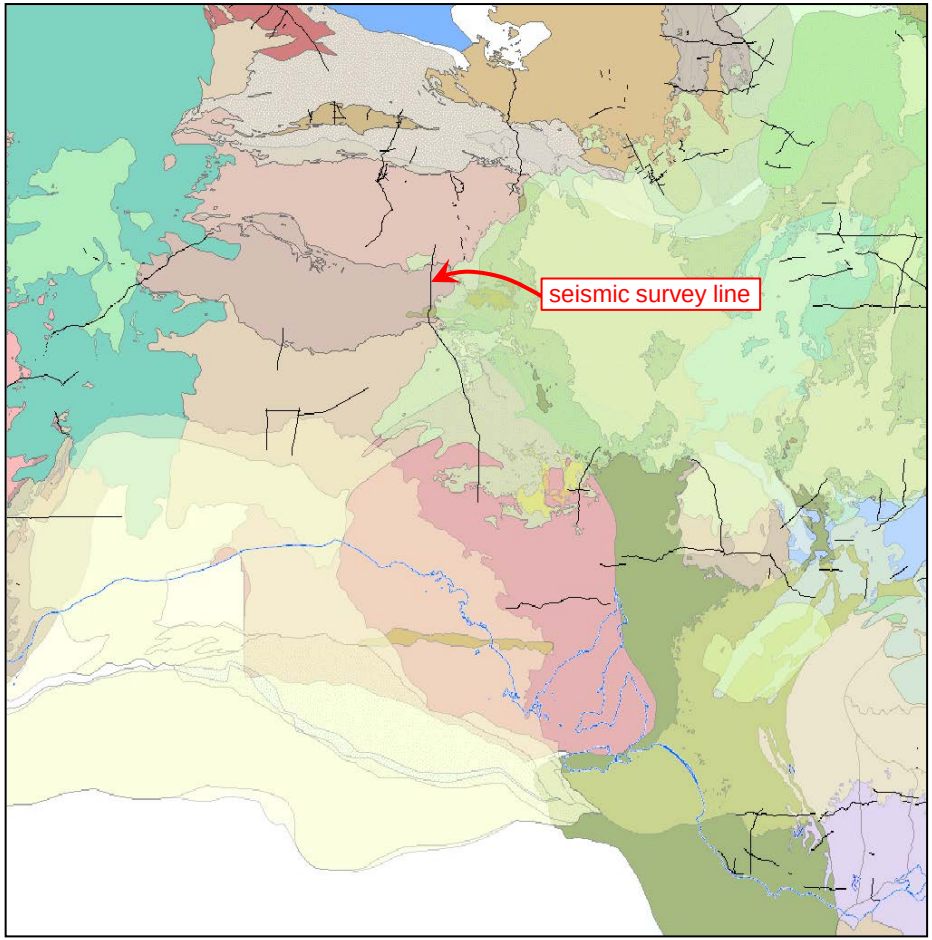
ii. a link to the seismic data



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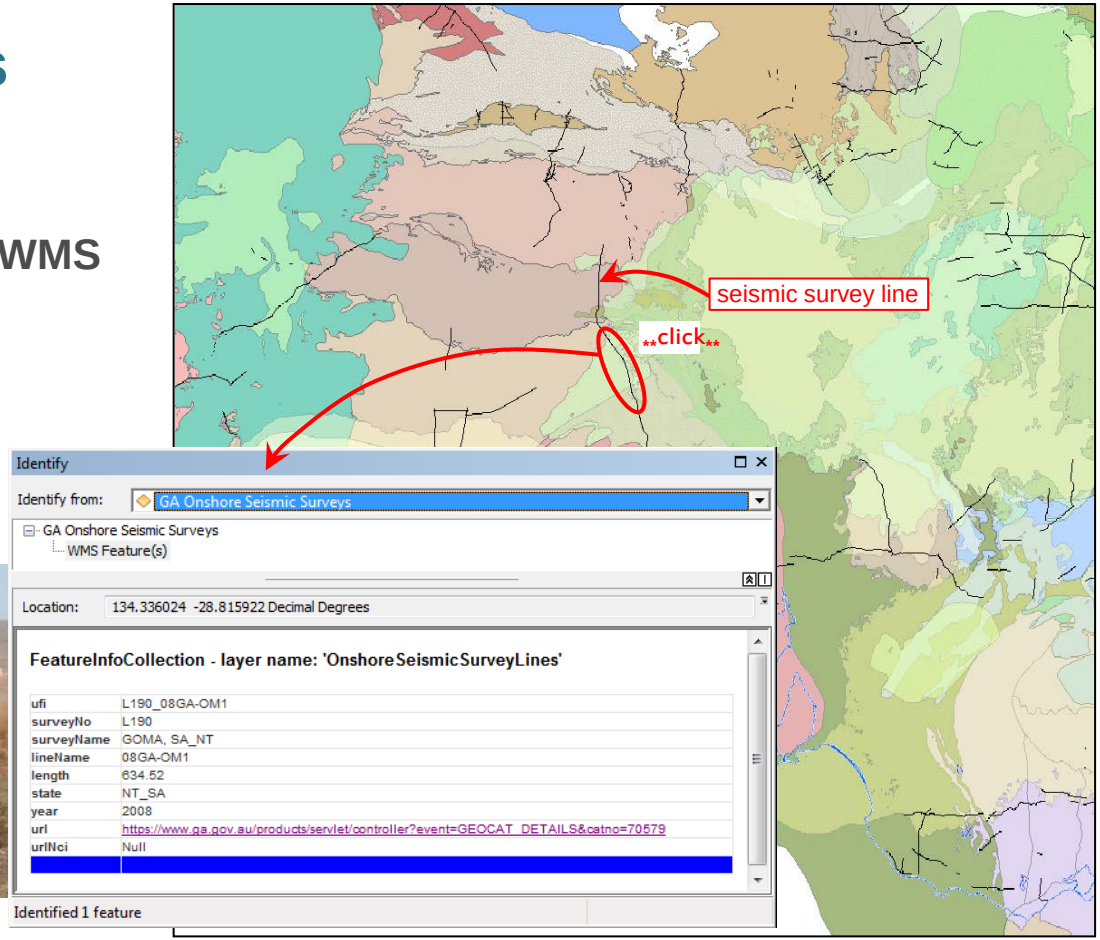

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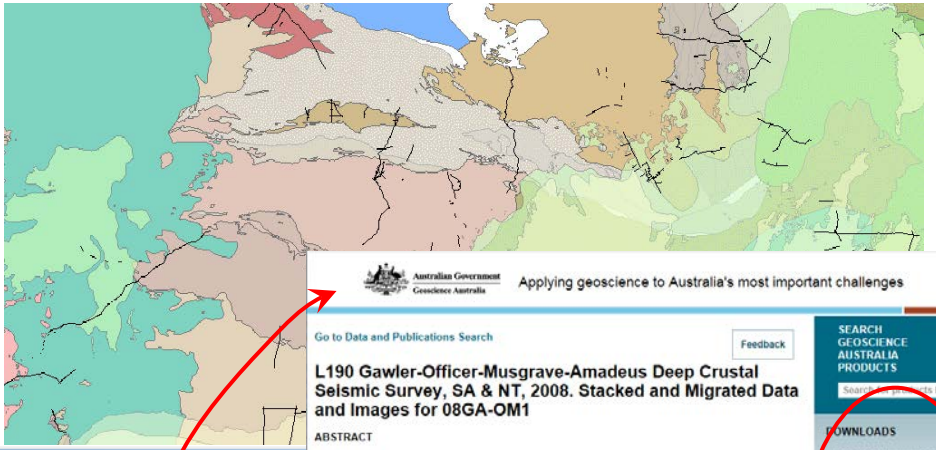

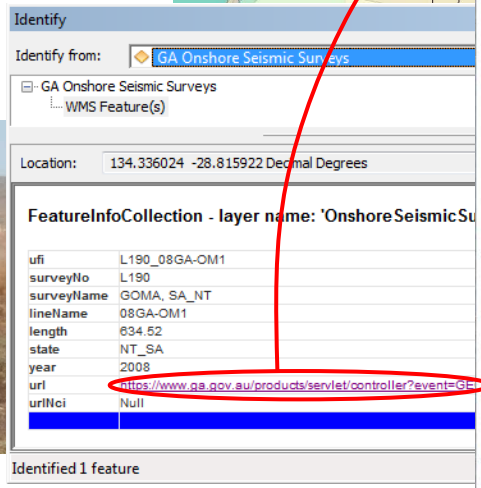

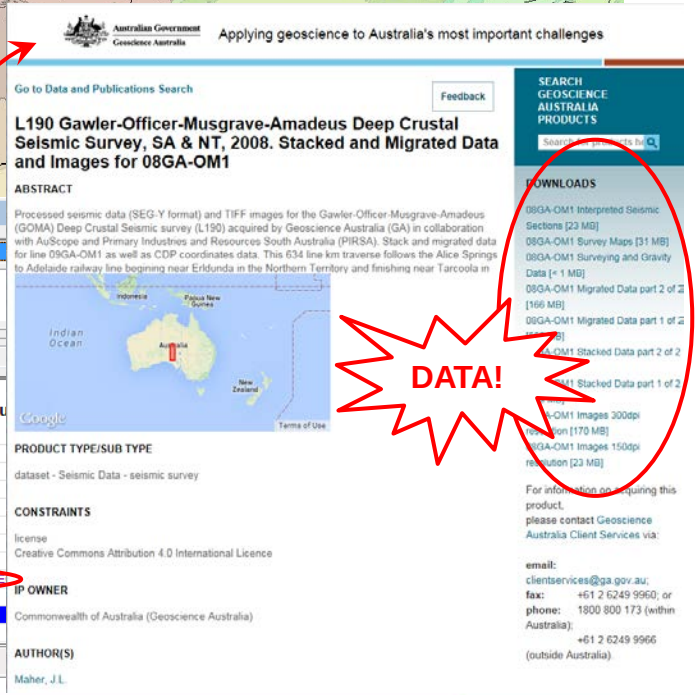

Data as Web Services

WFS (Web Feature Service)

- streams data as XML

```
<mt:MineralTenement
    xmlns:mt="http://xmlns.geoscience.gov.au/mineraltenementml/1.0"
    xmlns:xlink="http://www.w3.org/1999/xlink"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xmlns:gml="http://www.opengis.net/gml"
    xsi:schemaLocation="http://xmlns.geoscience.gov.au/mineraltenementml/1.0
                        http://schemas.geoscience.gov.au/MineralTenementML/1.0/mineral
    <mt:identifier>http://data.myagency.gov.au/resource/feature/mya/mineraltenement/12
    <mt:name>EL63/2015</mt:name>
    <mt:tenementType>exploration licence</mt:tenementType>
    <mt:commodity>Gold and other precious metals</mt:commodity>
    <mt:owner>Geo Exploration Pty Ltd</mt:owner>
    <mt:status>pending</mt:status>
    <mt:area>27.5 sq kms</mt:area>
    <mt:applicationDate>2014-11-19</mt:applicationDate>
    <mt:grantDate>2015-01-08</mt:grantDate>
    <mt:expireDate>2017-01-07</mt:expireDate>
    <mt:fileID>24281m23</mt:fileID>
    <mt:genericSymbolizer/>
    <mt:tenementType_uri>http://resource.geoscience.gov.au/classifier/ggic/tenement-ty
    <mt:status_uri>http://resource.geoscience.gov.au/classifier/ggic/tenement-status/p
    <mt:jurisdiction_uri>http://www.myagency.gov.au/</mt:jurisdiction_uri>
    <mt:shape>
        <gml:Polygon srsDimension="2" srsName="http://www.opengis.net/def/crs/EPSG/0/4
            <gml:exterior>
                <gml:LinearRing srsDimension="2">
                    <gml:posList>145.278660993645 -41.85236731493909
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                        145.306965906809 -41.87937754399609
                        145.336680620719 -41.87941383898959
                        145.278660993645 -41.85236731493909</gml:posList>
                </gml:LinearRing>
            </gml:exterior>
        </gml:Polygon>
    </mt:shape>
</mt:MineralTenement>
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Data as Web Services

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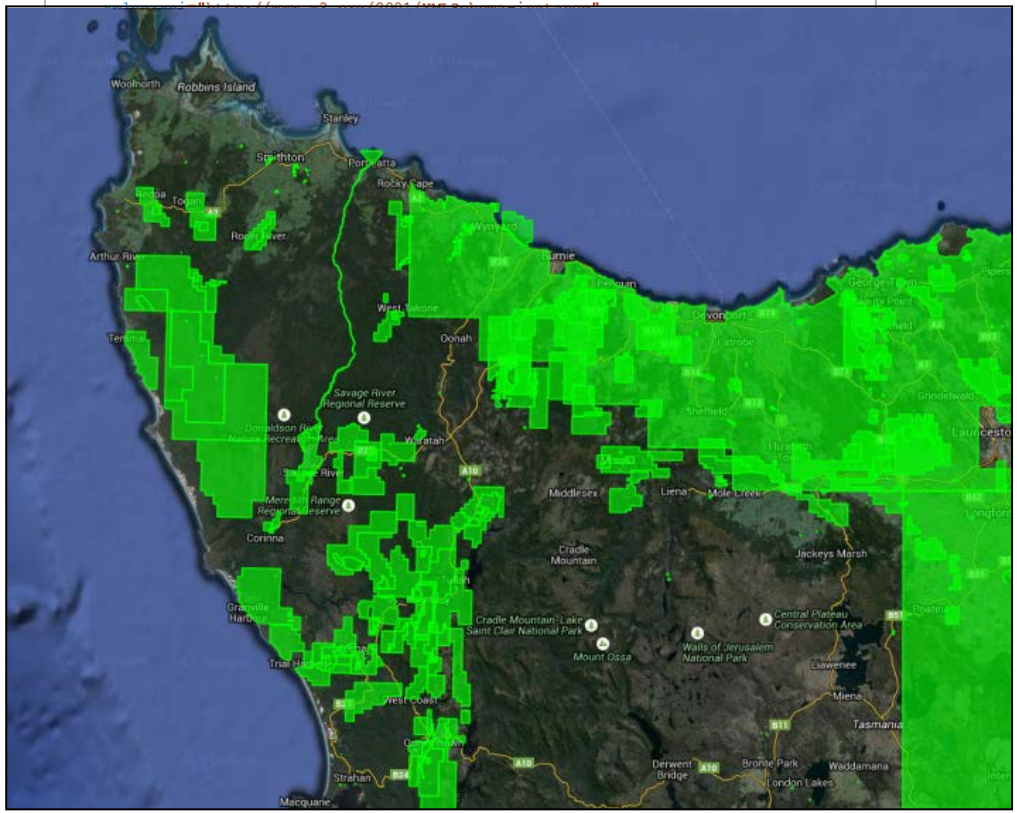

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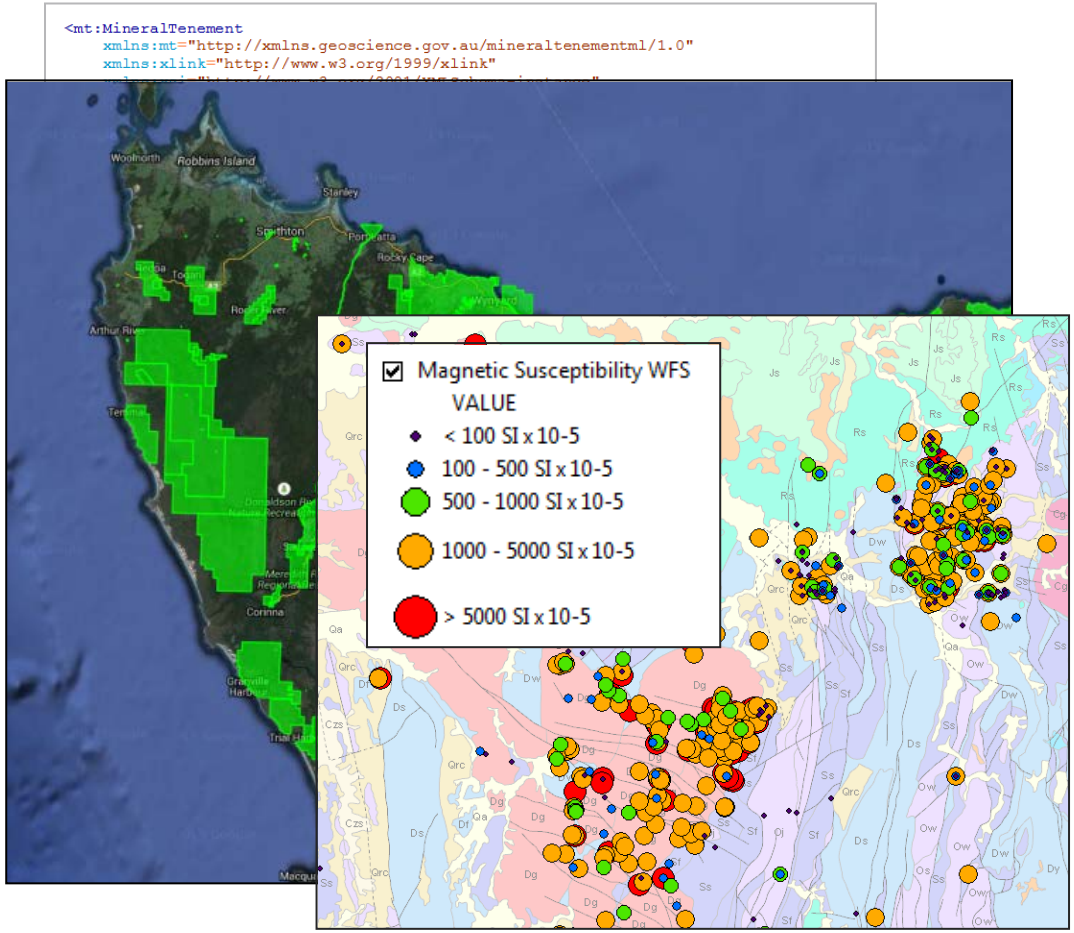

Data as Web Services

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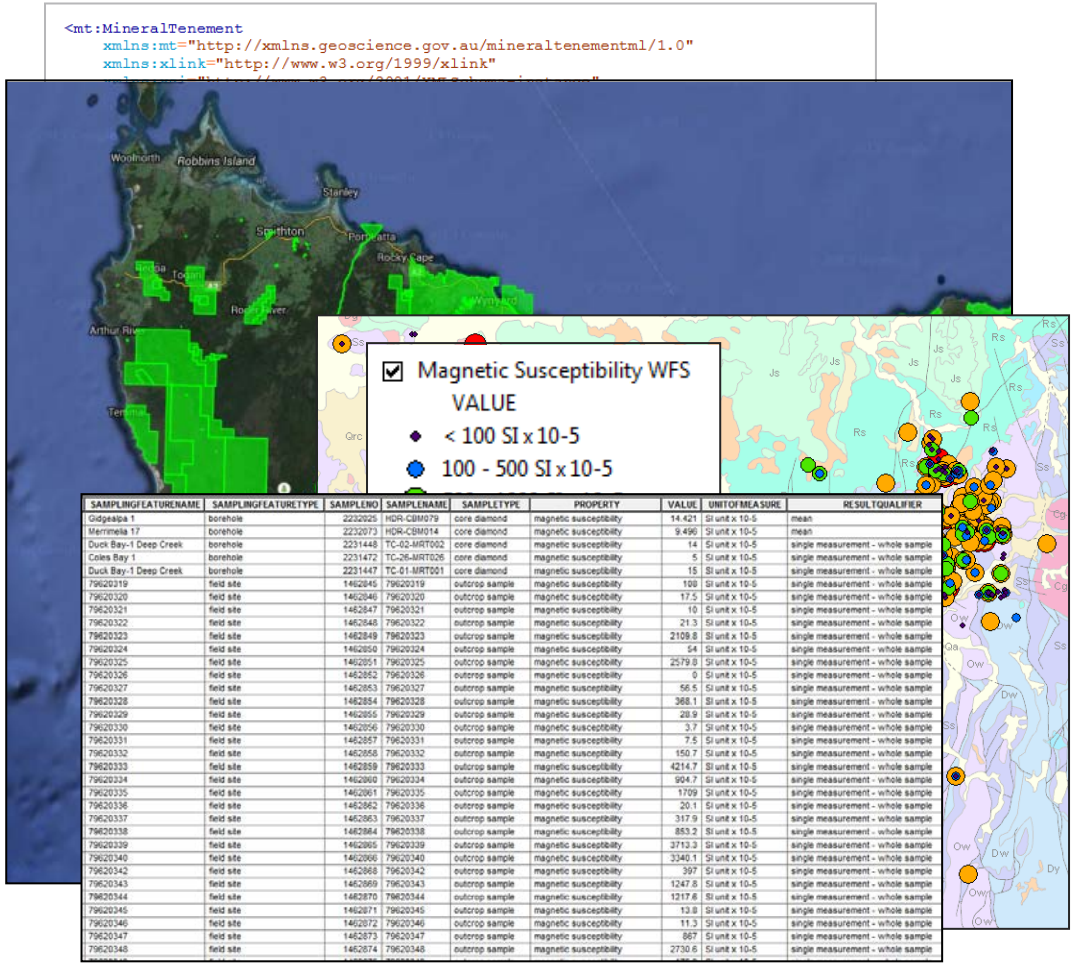
- or, it can be consumed on-the-fly by analytical and modelling applications
- or, it can be downloaded in various formats to your local PC (eg, CSV, shapefile, gdb)



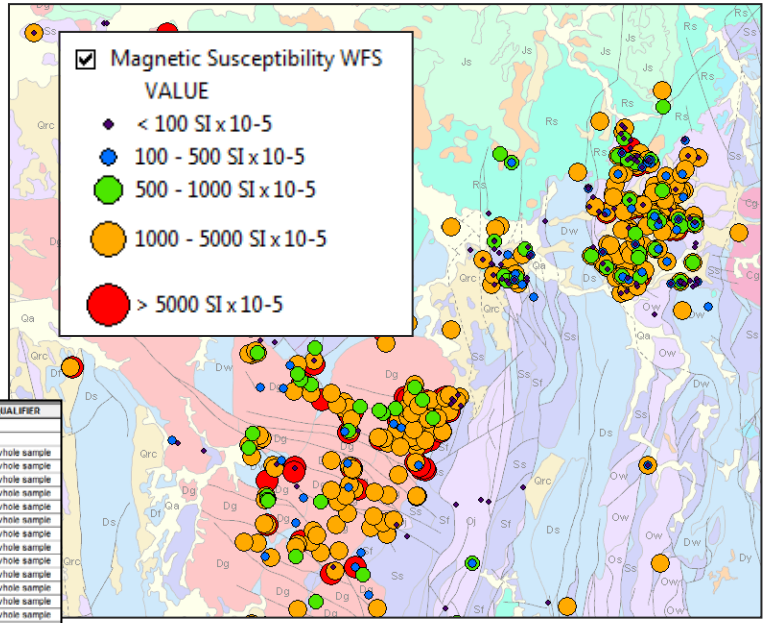
SAMPLINGFEATURENAME	SAMPLINGFEATURETYPE	SAMPLENO	SAMPLENAME	SAMPLETYPE	PROPERTY	VALUE	UNITOFMEASURE	RESULTQUALIFIER
Gidgealpa 1	borehole	2232025	HDR-CBM079	core diamond	magnetic susceptibility	14.421	SI unit x 10-5	mean
Merrimelia 17	borehole	2232073	HDR-CBM014	core diamond	magnetic susceptibility	9.496	SI unit x 10-5	mean
Duck Bay-1 Deep Creek	borehole	2231448	TC-02-MRT002	core diamond	magnetic susceptibility	14	SI unit x 10-5	single measurement - whole sample
Coles Bay 1	borehole	2231472	TC-26-MRT026	core diamond	magnetic susceptibility	5	SI unit x 10-5	single measurement - whole sample
Duck Bay-1 Deep Creek	borehole	2231447	TC-01-MRT001	core diamond	magnetic susceptibility	15	SI unit x 10-5	single measurement - whole sample
79620319	field site	1462845	79620319	outcrop sample	magnetic susceptibility	100	SI unit x 10-5	single measurement - whole sample
79620320	field site	1462846	79620320	outcrop sample	magnetic susceptibility	17.5	SI unit x 10-5	single measurement - whole sample
79620321	field site	1462847	79620321	outcrop sample	magnetic susceptibility	10	SI unit x 10-5	single measurement - whole sample
79620322	field site	1462848	79620322	outcrop sample	magnetic susceptibility	21.3	SI unit x 10-5	single measurement - whole sample
79620323	field site	1462849	79620323	outcrop sample	magnetic susceptibility	2109.8	SI unit x 10-5	single measurement - whole sample
79620324	field site	1462850	79620324	outcrop sample	magnetic susceptibility	54	SI unit x 10-5	single measurement - whole sample
79620325	field site	1462851	79620325	outcrop sample	magnetic susceptibility	2579.8	SI unit x 10-5	single measurement - whole sample
79620326	field site	1462852	79620326	outcrop sample	magnetic susceptibility	0	SI unit x 10-5	single measurement - whole sample
79620327	field site	1462853	79620327	outcrop sample	magnetic susceptibility	56.5	SI unit x 10-5	single measurement - whole sample
79620328	field site	1462854	79620328	outcrop sample	magnetic susceptibility	368.1	SI unit x 10-5	single measurement - whole sample
79620329	field site	1462855	79620329	outcrop sample	magnetic susceptibility	28.9	SI unit x 10-5	single measurement - whole sample
79620330	field site	1462856	79620330	outcrop sample	magnetic susceptibility	3.7	SI unit x 10-5	single measurement - whole sample
79620331	field site	1462857	79620331	outcrop sample	magnetic susceptibility	7.5	SI unit x 10-5	single measurement - whole sample
79620332	field site	1462858	79620332	outcrop sample	magnetic susceptibility	150.7	SI unit x 10-5	single measurement - whole sample
79620333	field site	1462859	79620333	outcrop sample	magnetic susceptibility	4214.7	SI unit x 10-5	single measurement - whole sample
79620334	field site	1462860	79620334	outcrop sample	magnetic susceptibility	904.7	SI unit x 10-5	single measurement - whole sample
79620335	field site	1462861	79620335	outcrop sample	magnetic susceptibility	1709	SI unit x 10-5	single measurement - whole sample
79620336	field site	1462862	79620336	outcrop sample	magnetic susceptibility	20.1	SI unit x 10-5	single measurement - whole sample
79620337	field site	1462863	79620337	outcrop sample	magnetic susceptibility	317.9	SI unit x 10-5	single measurement - whole sample
79620338	field site	1462864	79620338	outcrop sample	magnetic susceptibility	853.2	SI unit x 10-5	single measurement - whole sample
79620339	field site	1462865	79620339	outcrop sample	magnetic susceptibility	3713.3	SI unit x 10-5	single measurement - whole sample
79620340	field site	1462866	79620340	outcrop sample	magnetic susceptibility	3340.1	SI unit x 10-5	single measurement - whole sample
79620342	field site	1462868	79620342	outcrop sample	magnetic susceptibility	397	SI unit x 10-5	single measurement - whole sample
79620343	field site	1462869	79620343	outcrop sample	magnetic susceptibility	1247.8	SI unit x 10-5	single measurement - whole sample
79620344	field site	1462870	79620344	outcrop sample	magnetic susceptibility	1217.6	SI unit x 10-5	single measurement - whole sample
79620345	field site	1462871	79620345	outcrop sample	magnetic susceptibility	13.8	SI unit x 10-5	single measurement - whole sample
79620346	field site	1462872	79620346	outcrop sample	magnetic susceptibility	11.3	SI unit x 10-5	single measurement - whole sample
79620347	field site	1462873	79620347	outcrop sample	magnetic susceptibility	867	SI unit x 10-5	single measurement - whole sample
79620348	field site	1462874	79620348	outcrop sample	magnetic susceptibility	2730.6	SI unit x 10-5	single measurement - whole sample

Data as Web Services

WFS (Web Feature Service)

Geoscience Australia's Rock Properties

http://www.ga.gov.au/explorer-web/rock-properties.html



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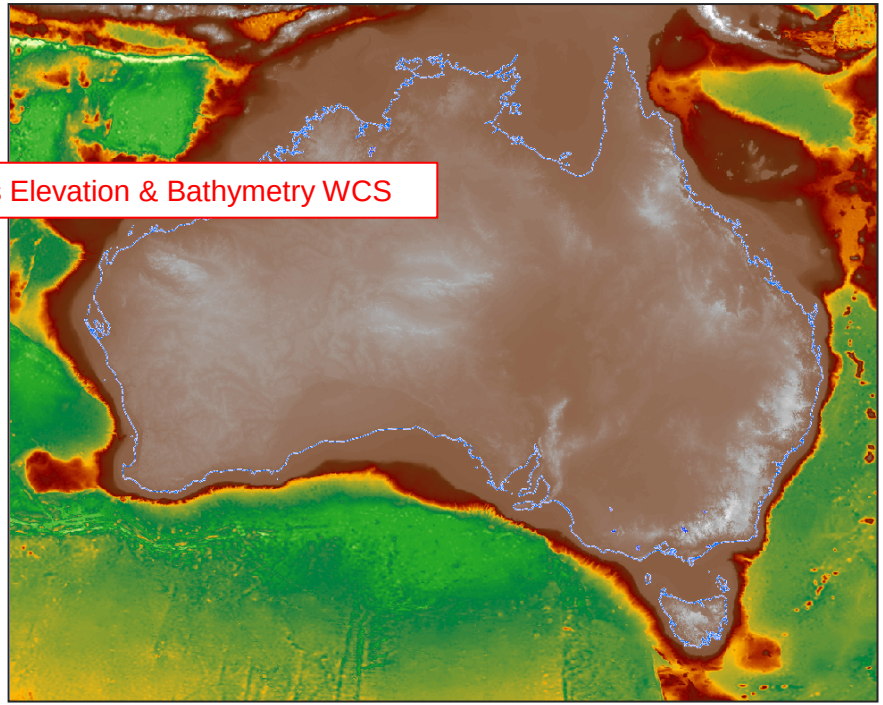
Data as Web Services

WCS (Web Coverage Service)

- delivers gridded (raster) data
- delivers the real data values, not just RGB pixel values



Data as Web Services

WCS (Web Coverage Service)

- delivers gridded (raster) data
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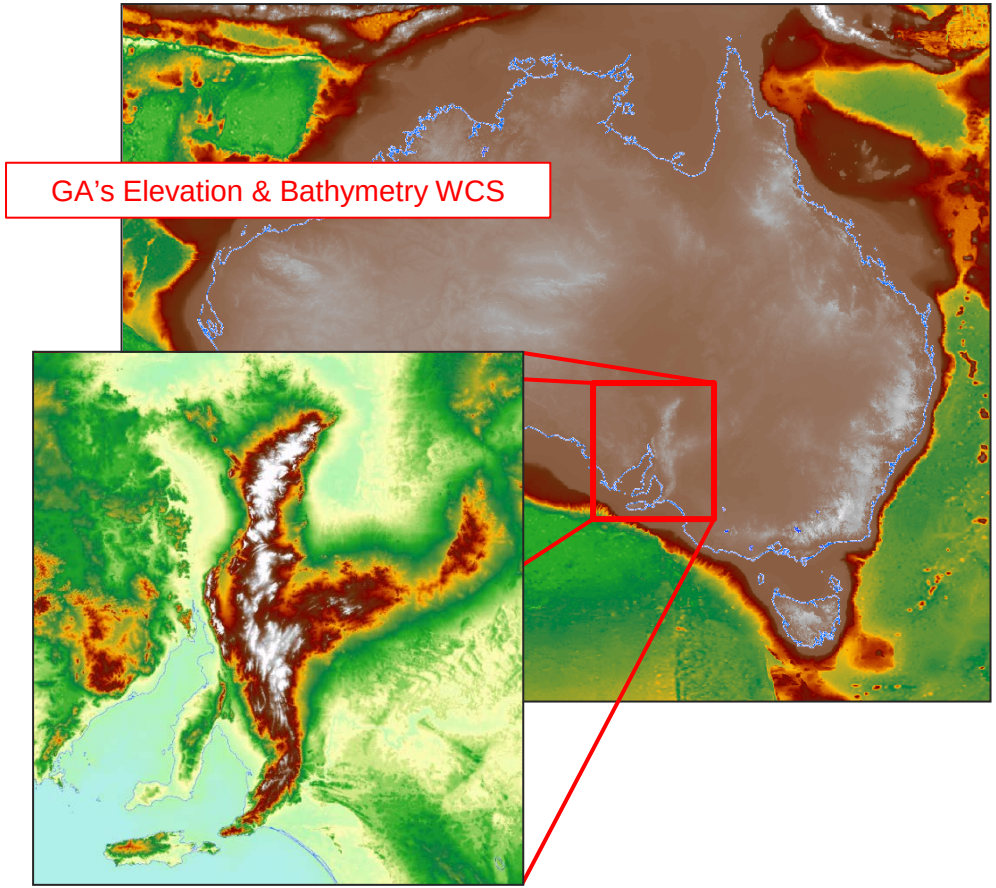
- data can be queried and consumed for data processing online
- data can be re-stretched by your mapping application
- can be downloaded in various formats (eg, NetCDF, geoTIFF)



Data as Web Services

Geoscience Australia Web Services

- Surface Geology of Australia (1:2.5M & 1:1M) - WMS
- Geological Provinces - WMS
- National Geophysical Grids - WMS
- Onshore Seismic Surveys - WMS
- Rock Properties - WMS & WFS
- Elevation and Bathymetry - WMS & WCS
- Topography and Infrastructure - WMS & WFS

…and over 100 more - just type “web services” into the GA website search tool

Geoscience Portal redevelopment

www.geoscience.gov.au

- owned by all Australian geological surveys
- hosted by Geoscience Australia

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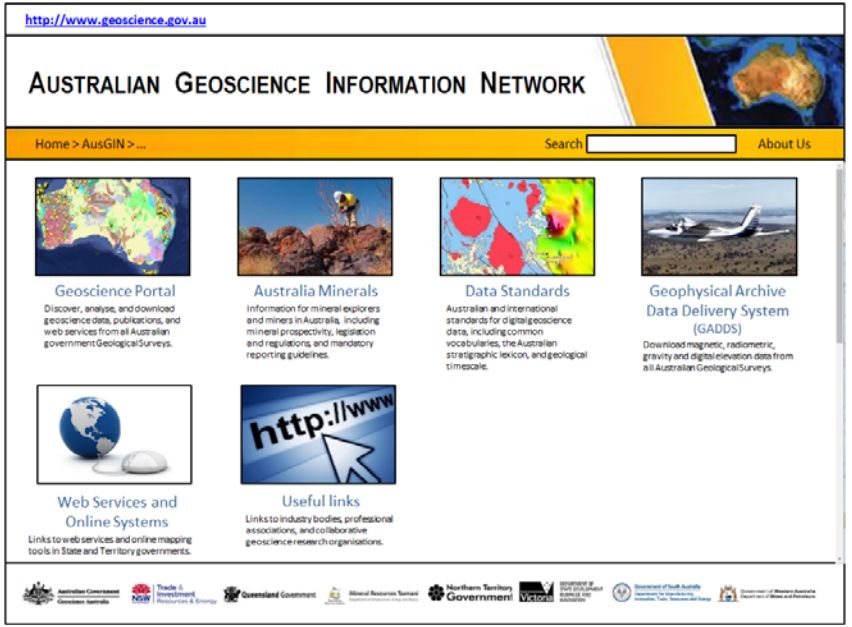

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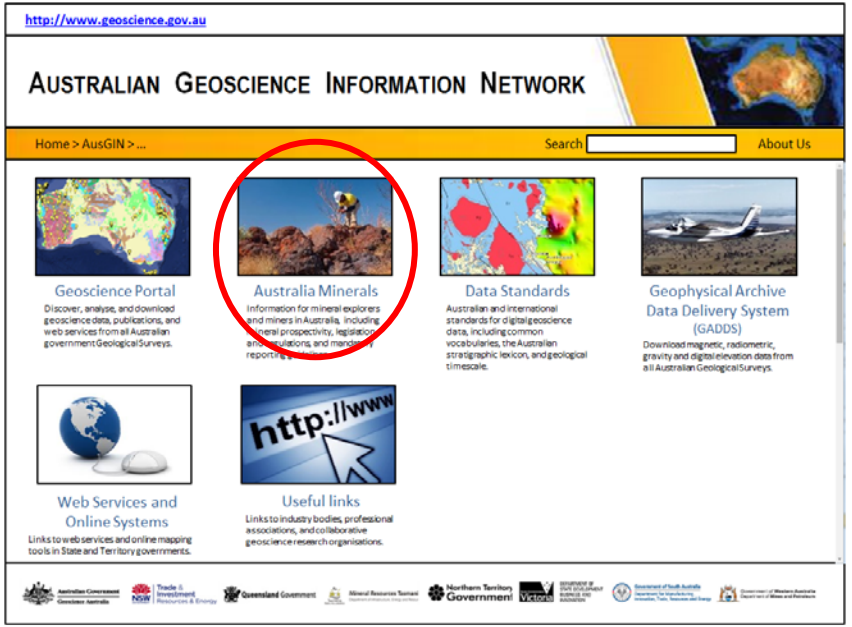

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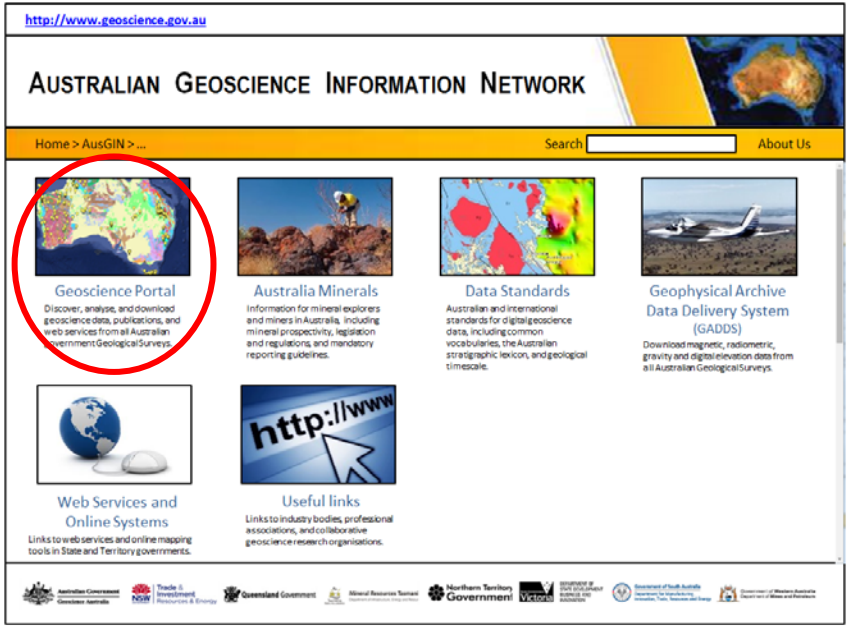
  - a single data portal for access to all government geoscience information



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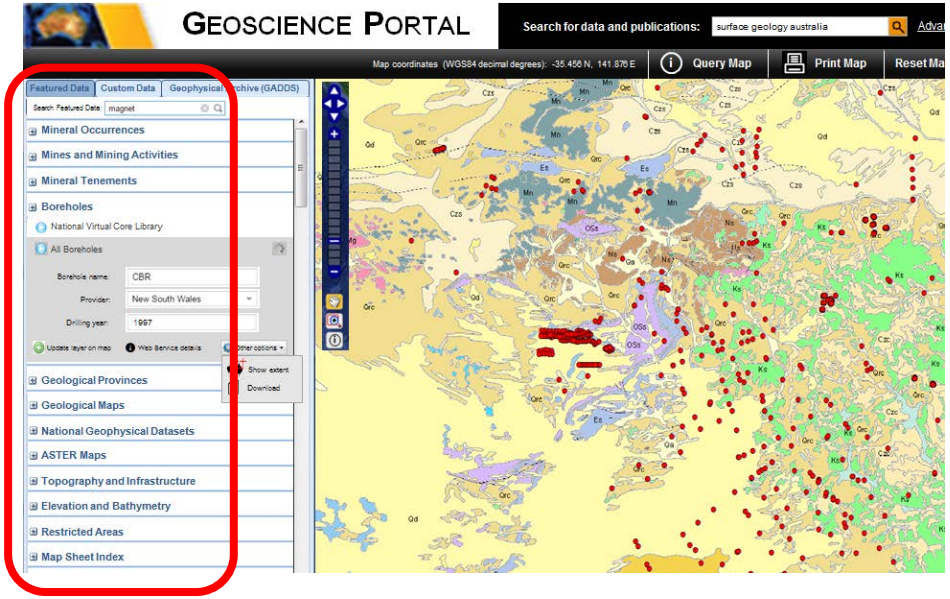
- featured web services for mineral explorers
    - mines and mineral occurrences
    - mineral tenements
    - boreholes



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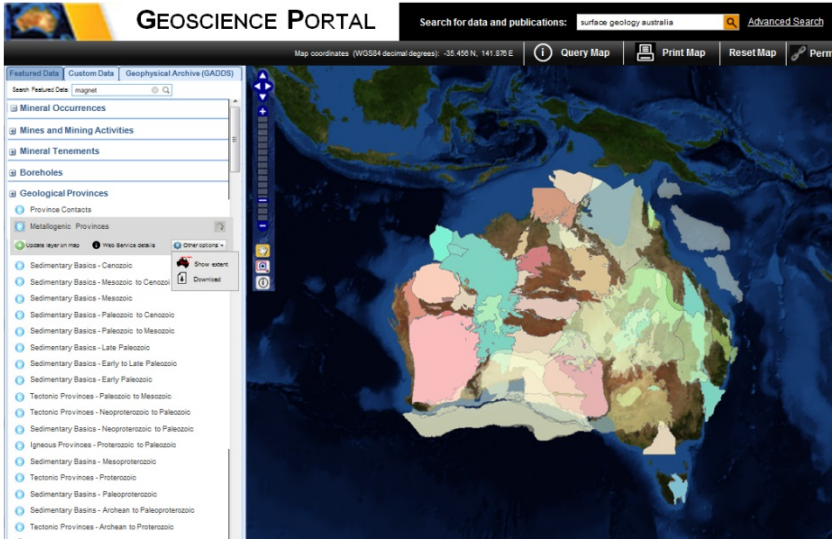

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  - restricted access areas, and more…
- sourced from all Australian geological surveys
- query and download data layers

Geoscience Portal redevelopment

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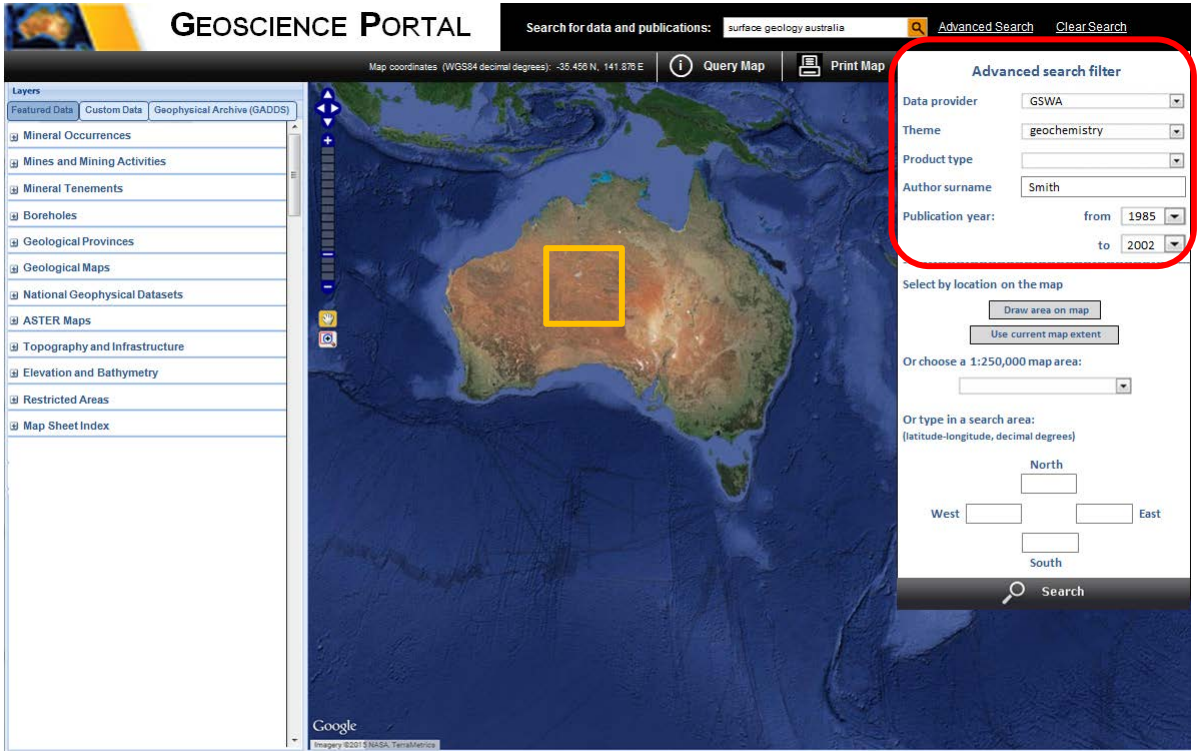
  - search data and publication catalogs from all State, Territory and Commonwealth geological surveys



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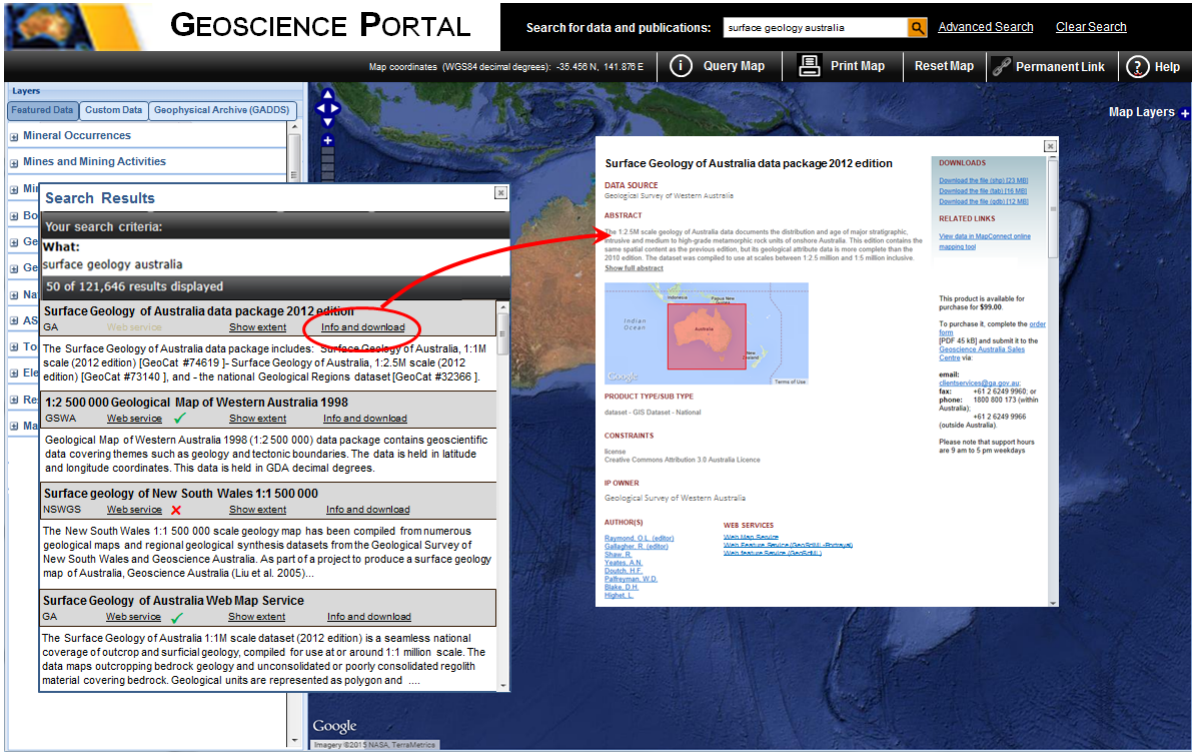

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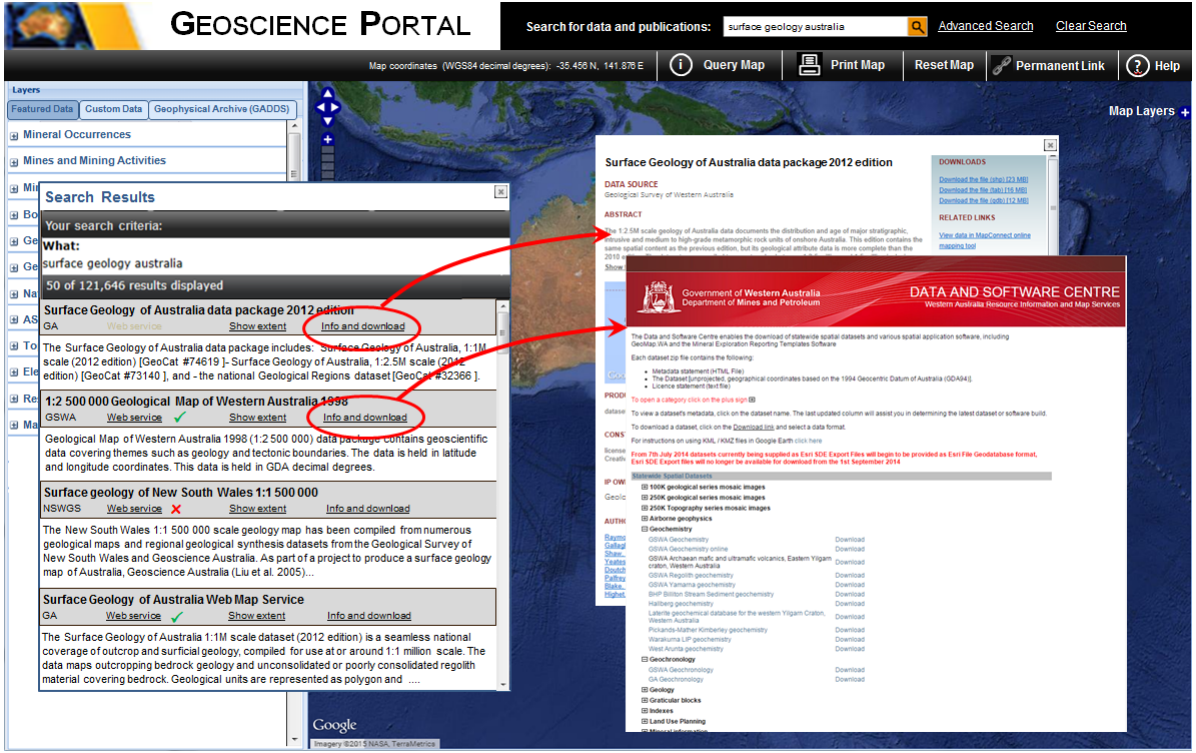

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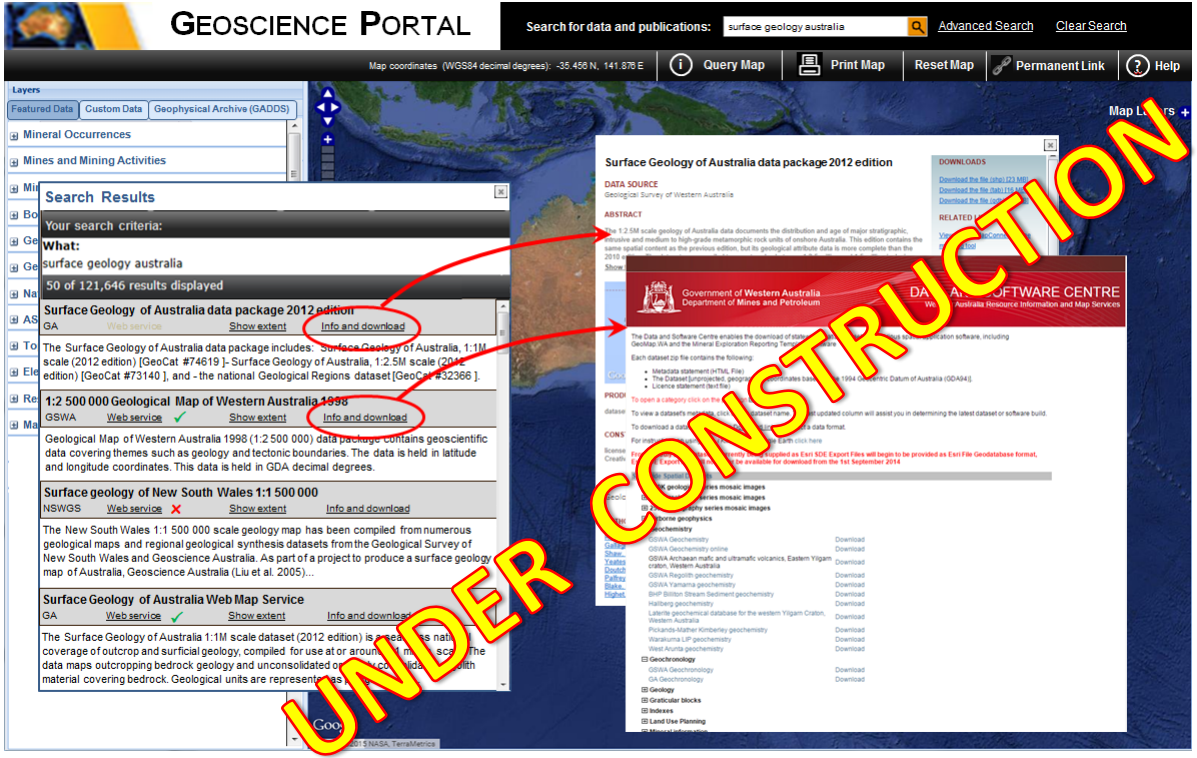
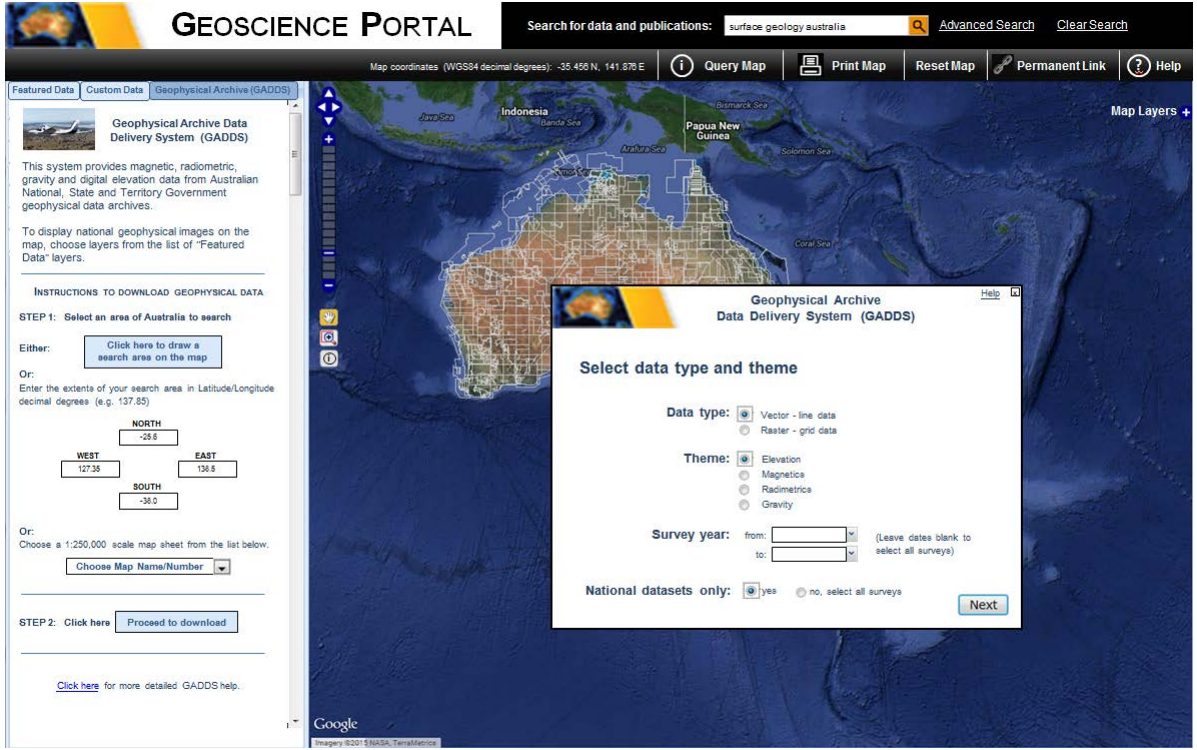
  - search data and publication catalogs from all State, Territory and Commonwealth geological surveys
  - download data and publications via links to the geological surveys' data repositories



Geoscience Portal redevelopment

- **GADDS**
  - a refit into the new Geoscience Portal
  - ability to download recently acquired AEM data
  - ability to filter surveys by year



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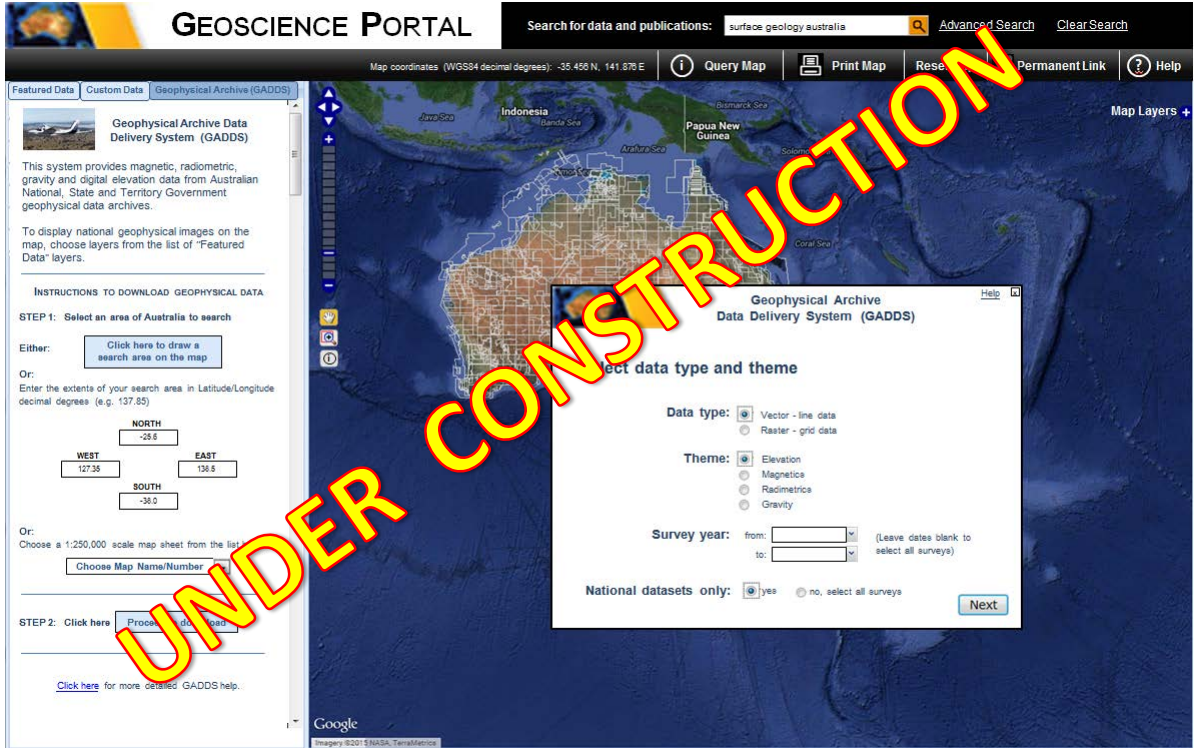


Geoscience Data Standards

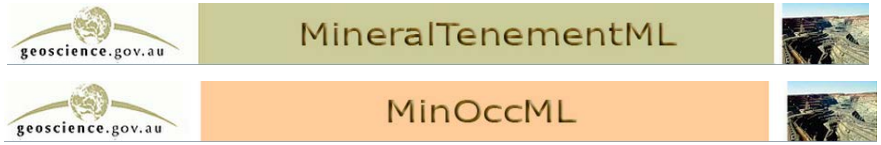
Standard Vocabularies

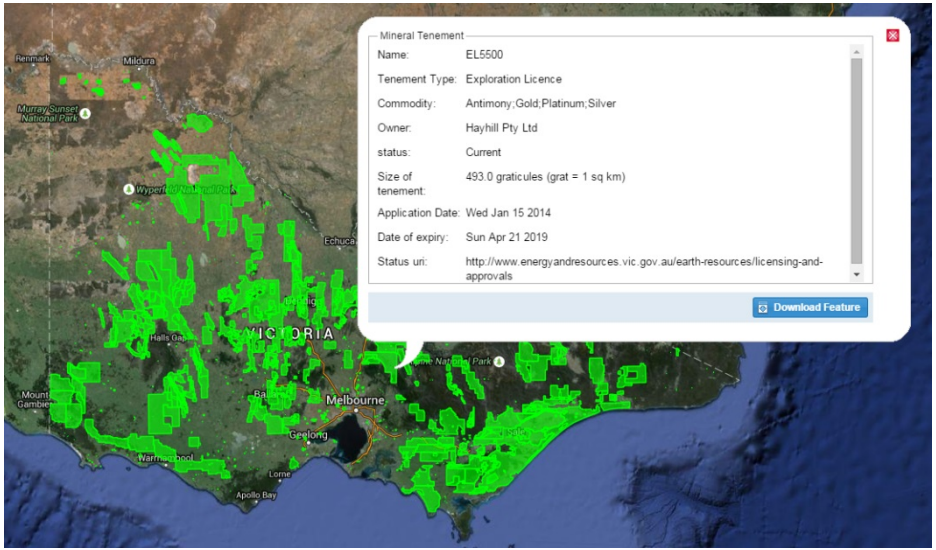
- GA is currently building a vocabulary service to deliver all of its standard geoscience vocabularies on the web
  - will be freely available for use by the geoscience community
  - GA will also serve agreed vocabularies developed by the AUS/NZ Government Geoscience Information Committee (GGIC)
    - eg, standard terminology for describing mineral tenements
- GGIC members also represent Australia and NZ on the IUGS Geoscience Terminology Working Group and ensure that Australasian vocabulary needs are met by global standards
  - IUGS vocabularies online - http://resource.geosciml.org

Geoscience Data Standards

Data Transfer Standards

- In Australia, GGIC recently published WFS/WMS data transfer standards for mineral tenements and mineral occurrences
  - currently being tested to deliver data in the AuScope Portal
  - best practice use of these standards is still being refined in the Australian geological surveys
  - the way of the future for delivery of mineral tenement, mineral occurrence, mine, and borehole data





Geoscience Data Standards

Data Transfer Standards

- Internationally, Geoscience Australia currently chairs the GeoSciML Standards Working Group, and the OneGeology Executive Board
    - considerable Australian influence on global standard data structures, and in the promotion of best practice in geoscience data delivery
    - there is still some way to go to get global data standards implemented as normal practice in all of the Geological Survey agencies

Conclusions

- Geoscience Australia (and all the other Australian Geological Surveys) are moving towards publishing all of their fundamental geoscience data as standard web services
- GA publishes over 100 web services of geological, geographic, and other spatial data
- Virtually all GIS applications (both free and costly) can now consume web services
  - at least WMS and simple WFS services
- The redeveloped Geoscience Portal will greatly enhance the ability of the geological community to find, analyse, and download government geoscience data

Australian Government
Geoscience Australia

Minerals @GA: Impacts

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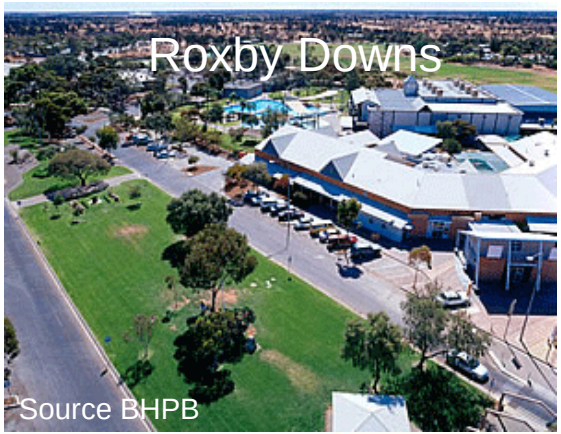
Mineral Systems Branch Head

Impact of GA pre-competitive work: operating mine

In the 1960s and early 70s GA collected magnetics, gravity and geochemistry data across the remote Stuart Shelf of South Australia

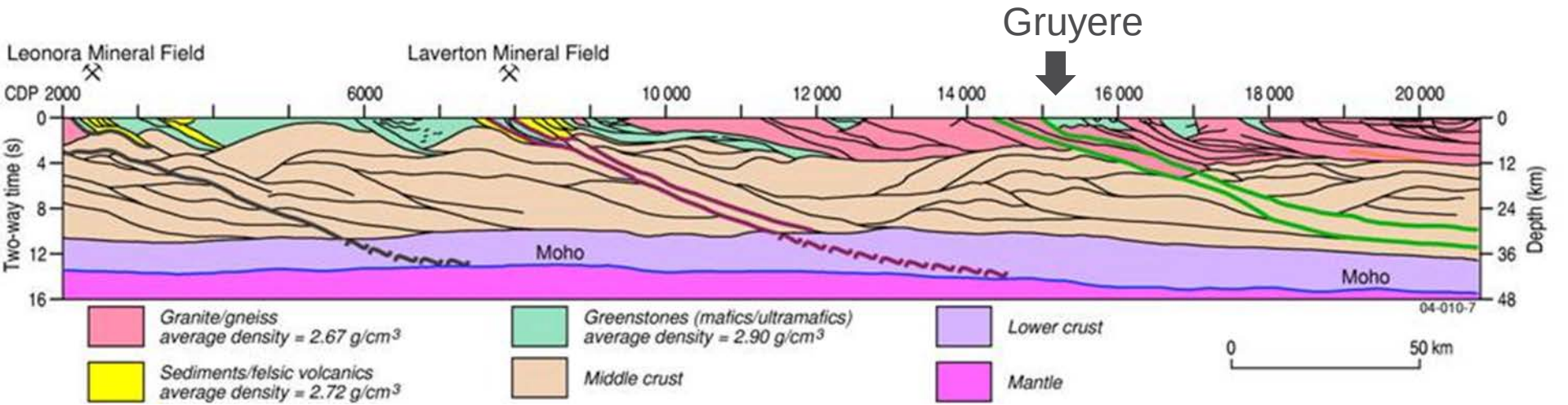
In 1975–6 Western Mining Corporation discovered Olympic Dam by using the precompetitive data, resulting in a $1T in ground value of U, Cu, Au and Rare Earths



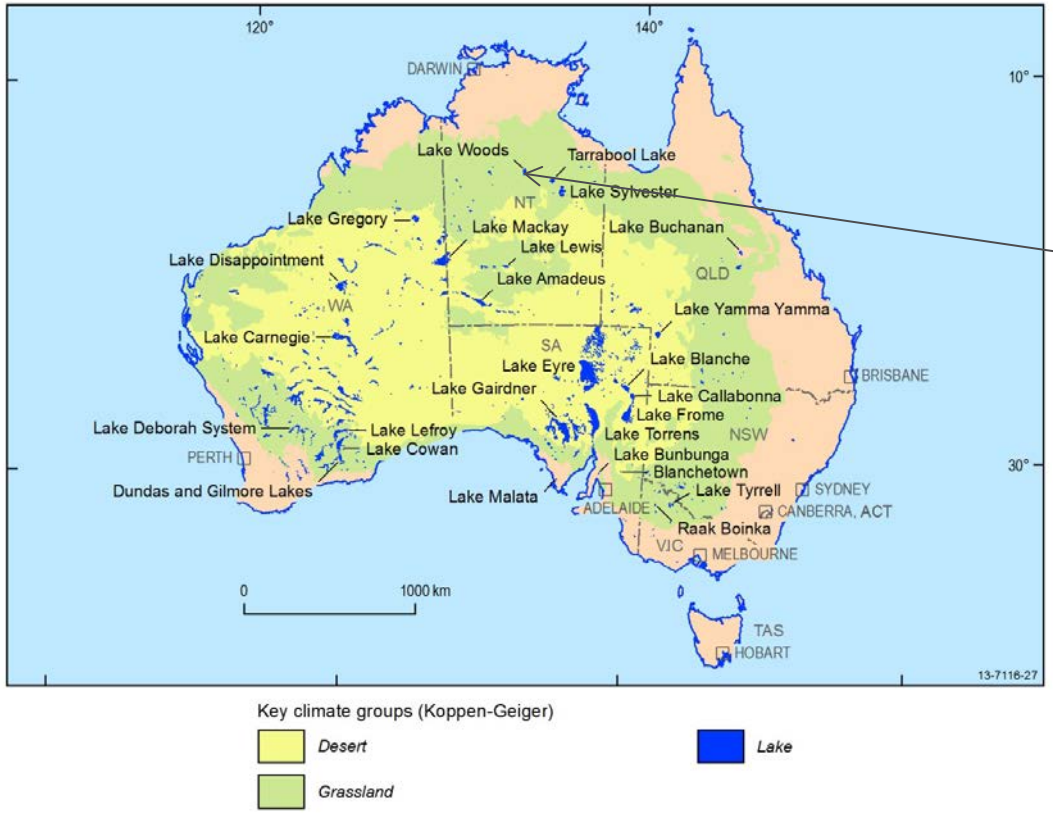
Impact of GA pre-competitive work: new discovery

In 2001 GA collected seismic data (below) and predicted this belt as prospective for new world-class gold deposits

In 2014 Gold Road Resources discovered the Gruyere gold deposit in the Yamarna Belt, which is a 5+ Million oz greenfields discovery in WA's Eastern Goldfields



Impact of GA pre-competitive work: new provinces



In 2013, GA delivered a national assessment of salt lake potential for K, Li, U, B.

Lake Woods (NT) was one region predicted as being prospective for potash (K)

In 2014–15 Frontline Resources took up potash exploration tenements on the basis of these predictions and data

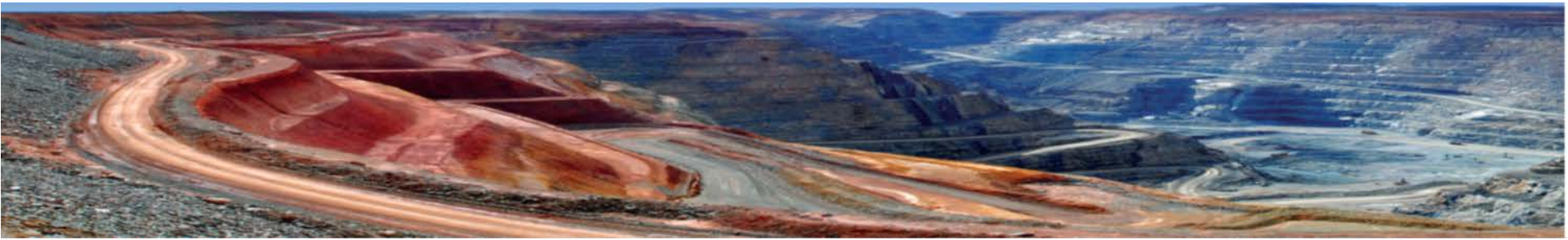
Two pertinent quotes

There are two basic ways a nation can derive more wealth from mining:

1) tax existing mines; and/or

2) discover new mines

Alan Trench MiningNewsnet.com 2015



Mineral industry users of geoscience data are almost unanimous in their view that government geoscience increases exploration efficiency and effectiveness …

J.M. Duke, Prospectors and Developers Association of Canada, 2010