Australian Government
Geoscience Australia

Exploring for the Future
minerals | energy | groundwater

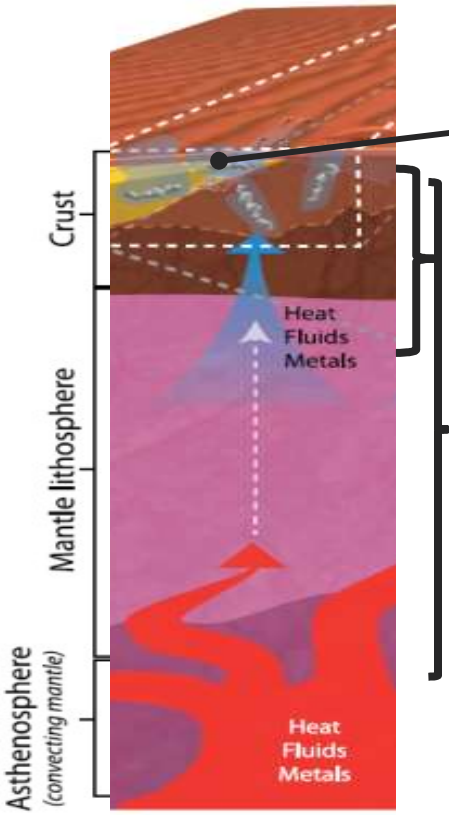
AusLAMP, AusARRAY and National Scale Datasets for Exploration

Marina Costelloe on behalf of the Mineral Systems Branch

Overview

- **AusLAMP MAPPING CONDUCTIVITY**
  Magnetotellurics (MT)
- **AusARRAY MAPPING SEISMIC VELOCITY**
  Passive Seismic (PS)
- **New national-scale Pb isotope dataset and maps**
- **NAGS Data Release 2 Au, Pd, and Pt.**
- **National pre-competitive databases: team effort**
- **Bare(st) earth satellite imagery**
- **Data delivery**

Magnetotellurics AND Passive Seismic



Cover-thickness:
Audio MT (pre-drilling)

Crustal architecture:
Broadband MT (regional survey)
Passive Seismic (regional survey)

Lithospheric architecture:
Long-period MT **(AusLAMP)**

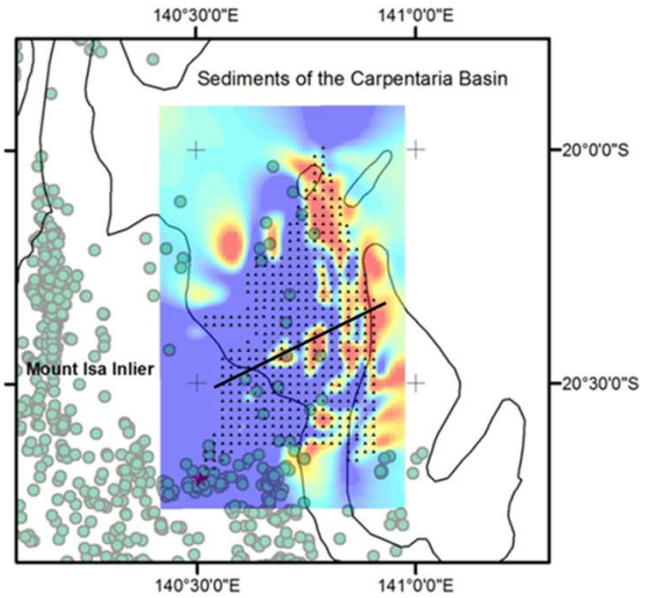
Mantle architecture:
Passive Seismic **(AusARRAY)**

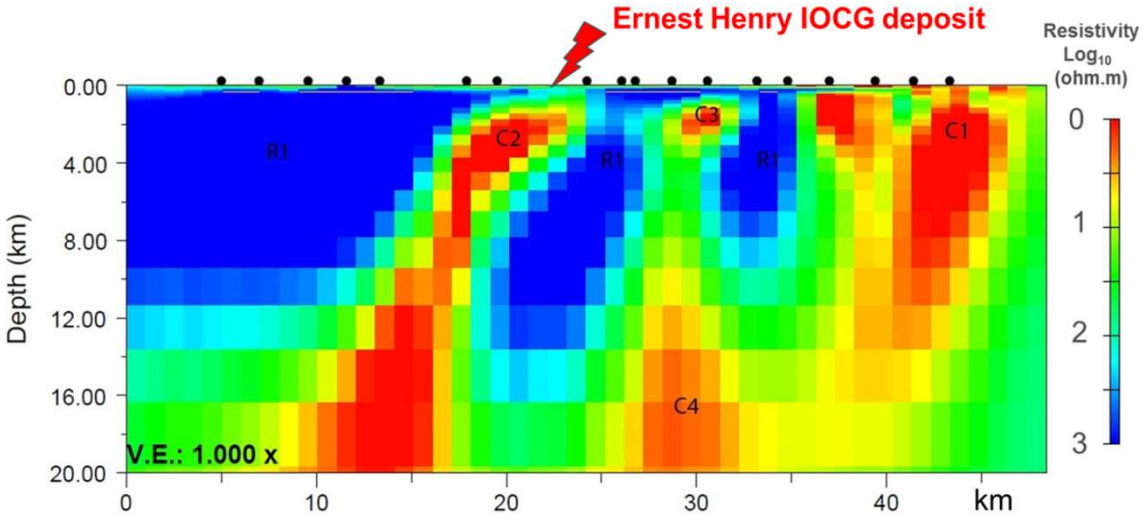
Mapping Architecture

- Architecture is a key component of a mineral system
- Identify the major structures in the crust and upper mantle
- Image entire mineral system “root” – Lithosphere
- Improving scientific understanding of geological processes and geodynamics.
- Provide important information for unlock potential mineral and energy resources through integration

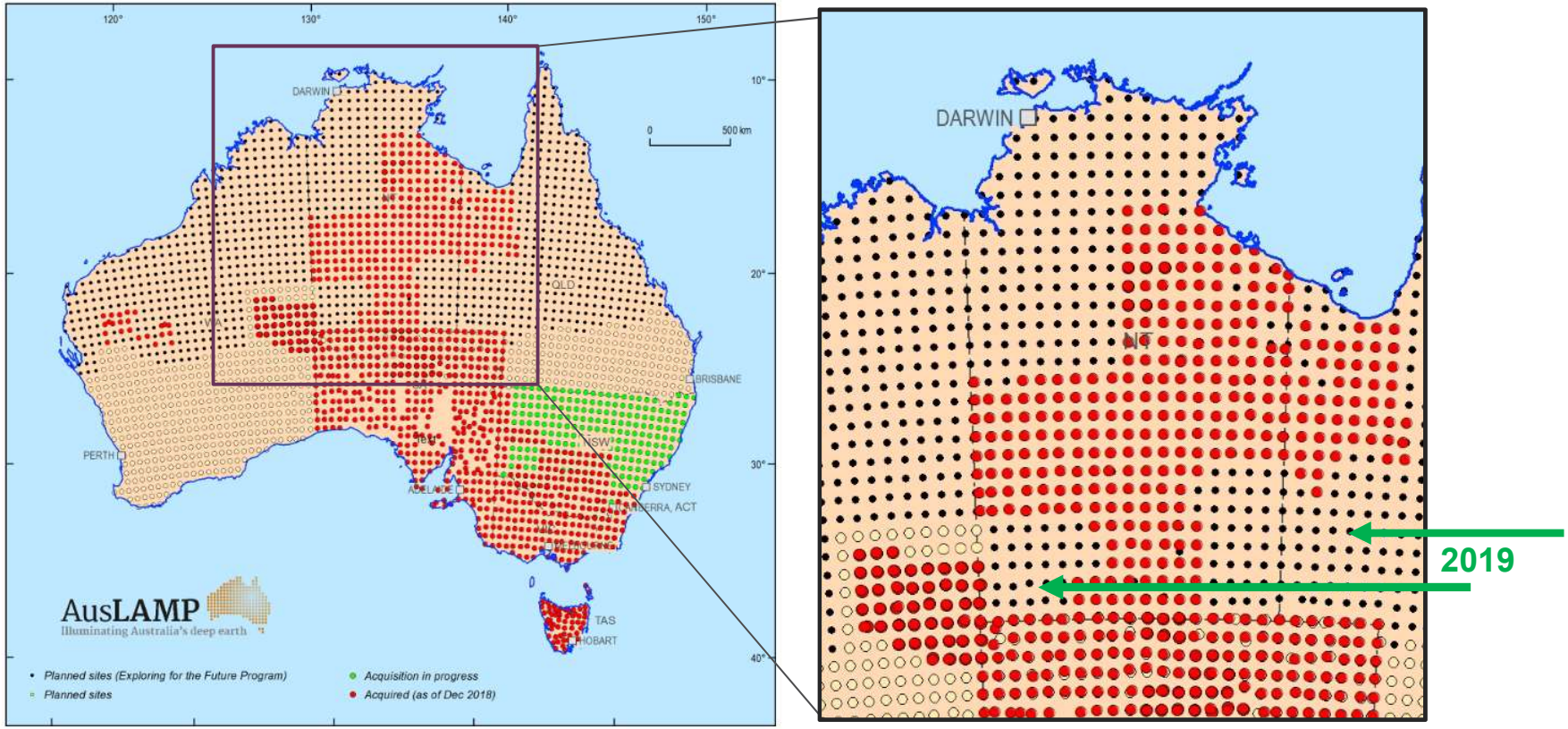
Conductivity - Magnetotellurics

Coincident conductivity anomalies and mineral deposits



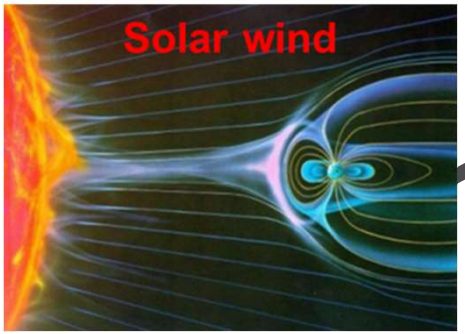


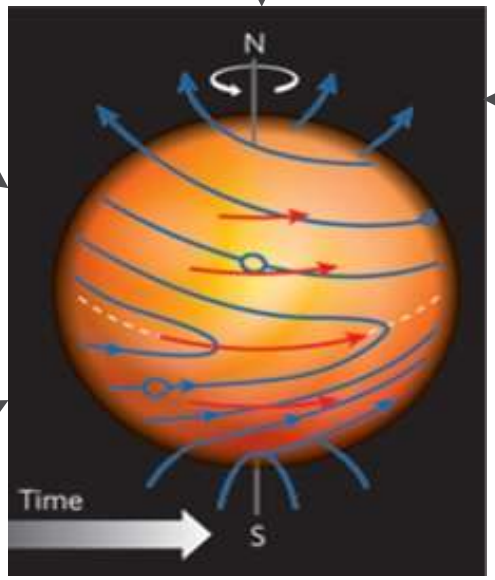
AusLAMP: National-scale Survey Progress Update



What is MT?

Magneto-Tellurics

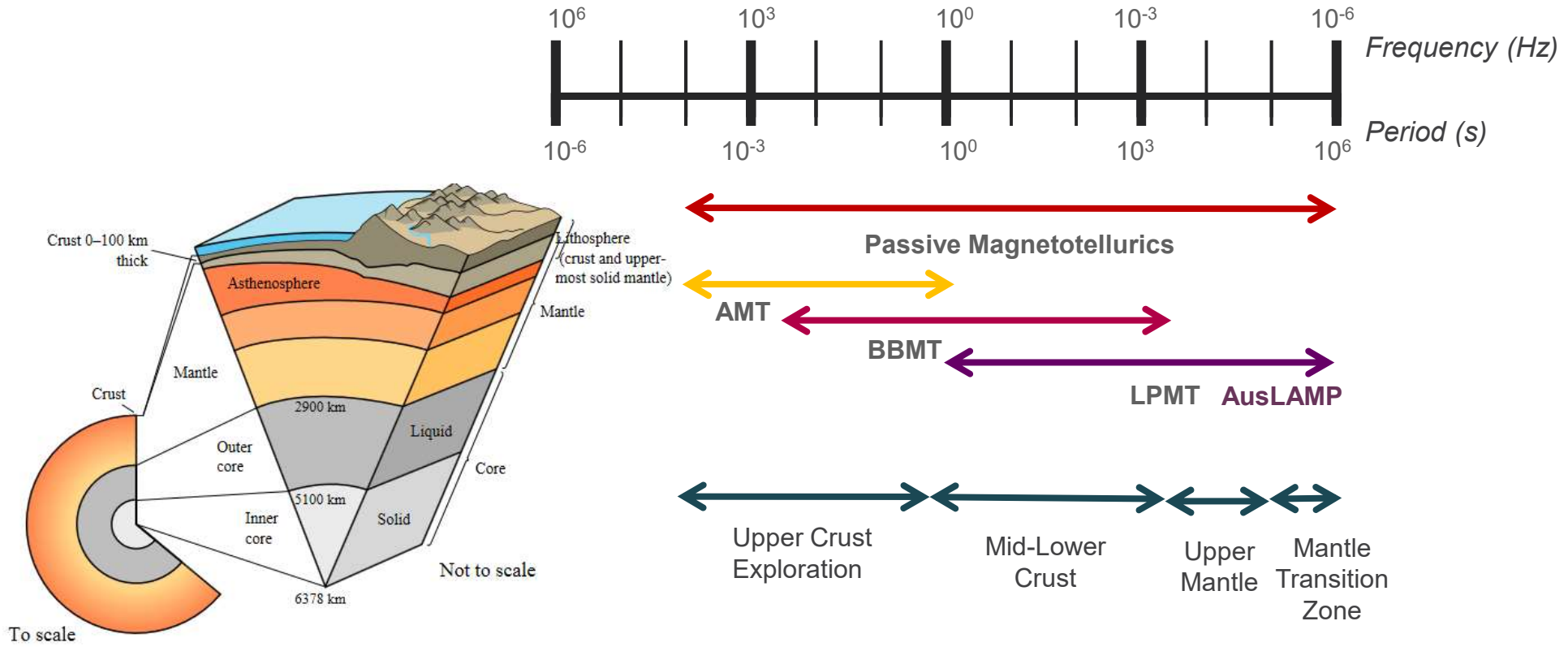




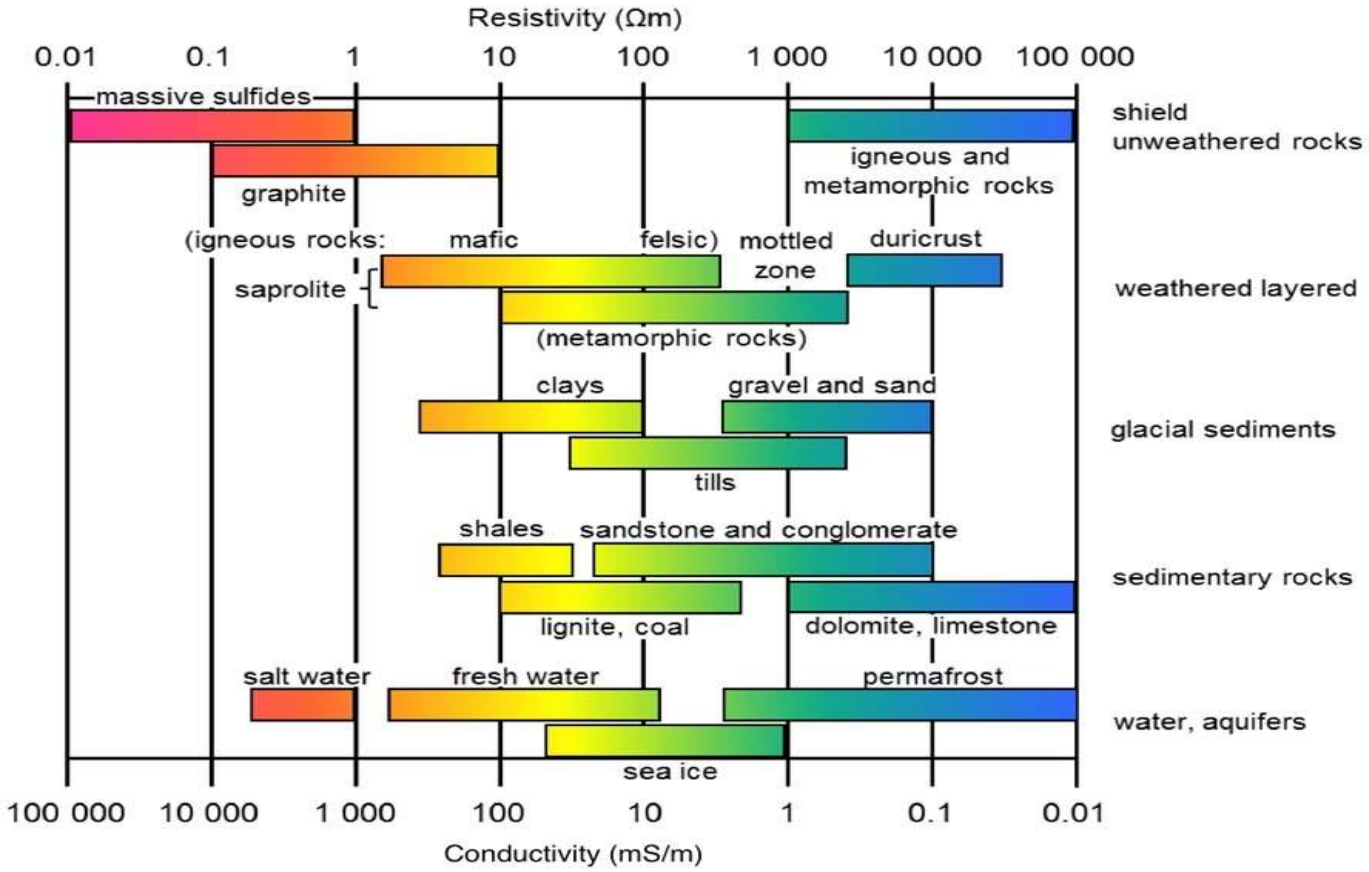
Measures time variations of electric and magnetic fields at the Earth‘s surface

Electrical conductivity /resistivity structure of the subsurface

The different type of MT mapping conductivity



Why measure MT - conductivity



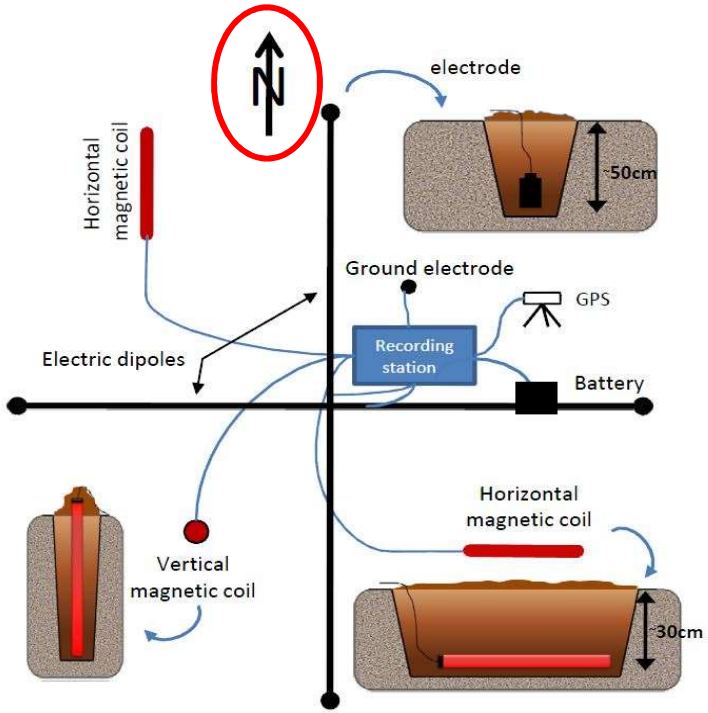
Palacky (1987)

Interpretations of conductivity anomalies

- aqueous fluids; partial melts; metallic compounds
- deformation; graphitic or sulfidic sedimentary rocks; faulting
- iron oxide – magnetite (breccia-hosted Ernest Henry IOCG)
- sulfides concentrating along fold hinges
- graphite precipitated from fluids along a fault zone
- conducting phases at grain boundaries – sulfides
- hydrogen and iron content in the crystal lattice
- saline-filled sedimentary rocks; mantle step
- asthenospheric upwelling; **concentrations at tectonic boundaries**

References:
Jones 1992; Ferguson et al. 1999; Becken et al. 2011; Myer et al. 201
Drummond et al. 1998; Lilley et al. 2003
Camfield and Gough 1977; Jones et al. 1997
Jones 1992
Heinson et al. (2018); Bastrakov et al. 2007
Thiel and Heinson (2013)
Lilley and Tammemagi 1972; Tammemagi and Lilley 1973;
Chamalaun 1985; White and Polatayko 1985;
Tammemagi and Lilley 1973; Gough et al. 1974; Robertson et al. 2016
Schäfer et al. 2011; Neska 2016

MT Data acquisition

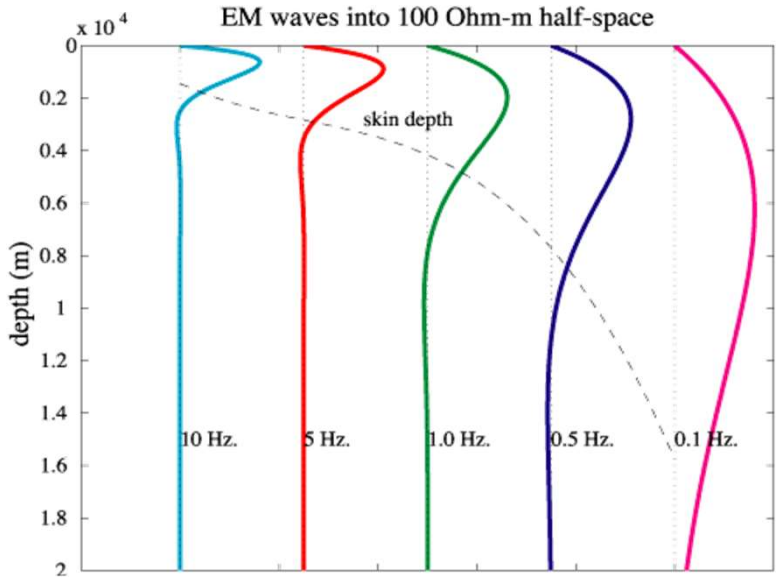


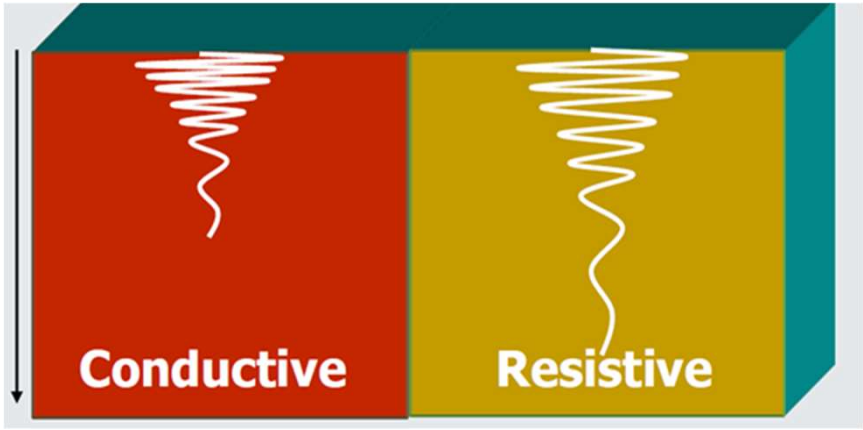
Schematic MT field layout, modified from Schmoldt (2011).

MT Skin Depth/Penetration Depth

$$\delta(\omega) = \left(\frac{2}{\sigma\mu\omega}\right)^{\frac{1}{2}} = \left(\frac{T\rho}{\pi\mu}\right)^{\frac{1}{2}} = 503\sqrt{\rho T}$$

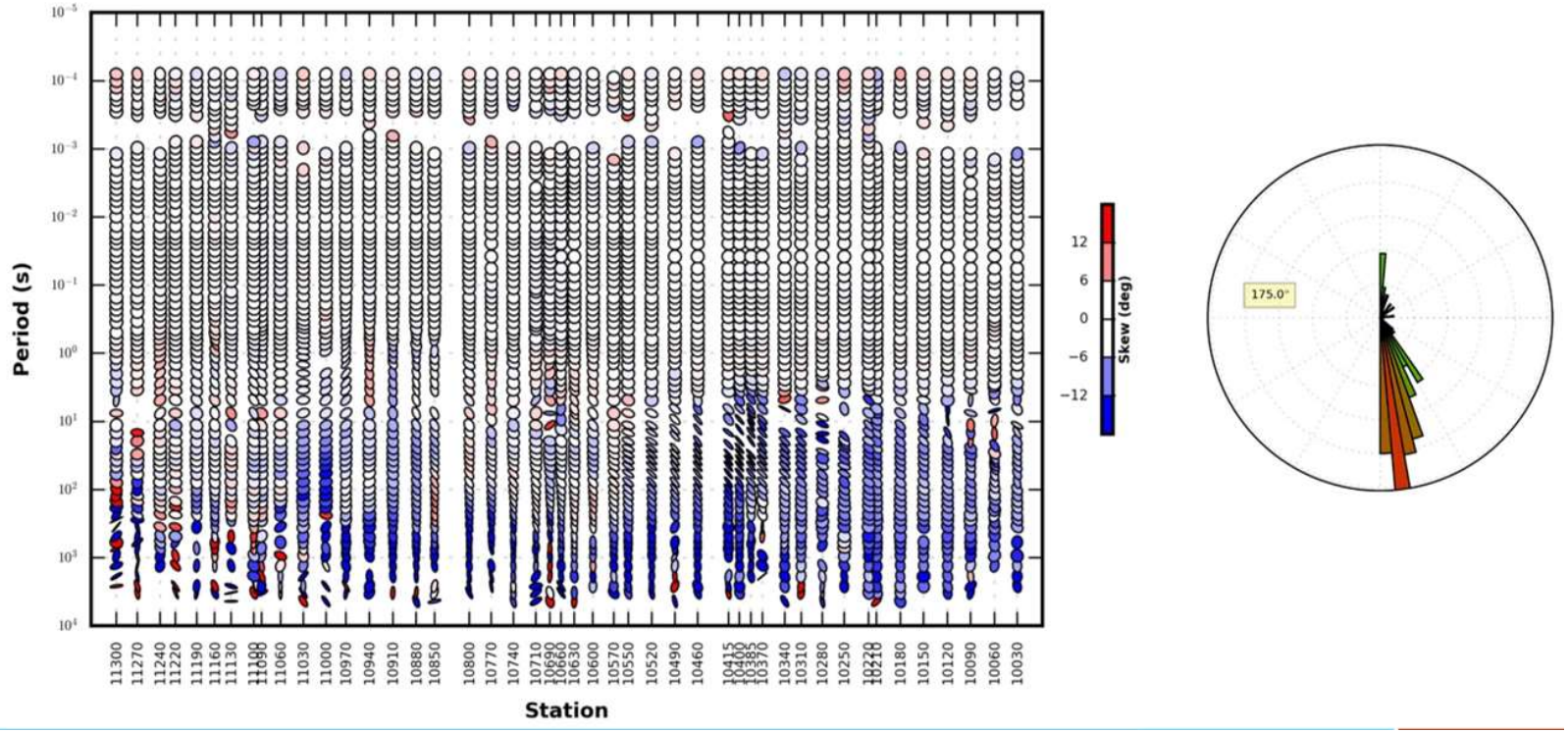
(Vozoff K,1972)



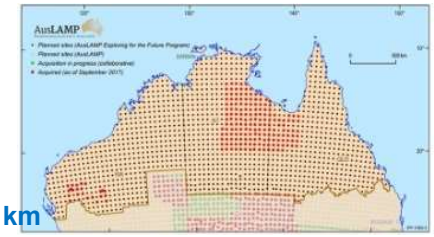


MT Phase tensor – dimensionality and directionality

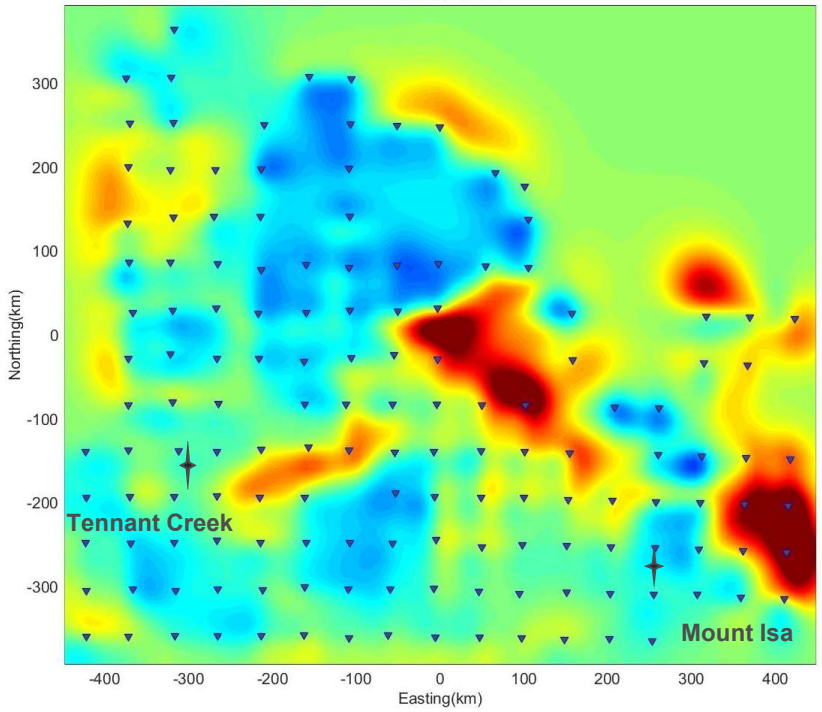
MT Phase tensor pseudo-section



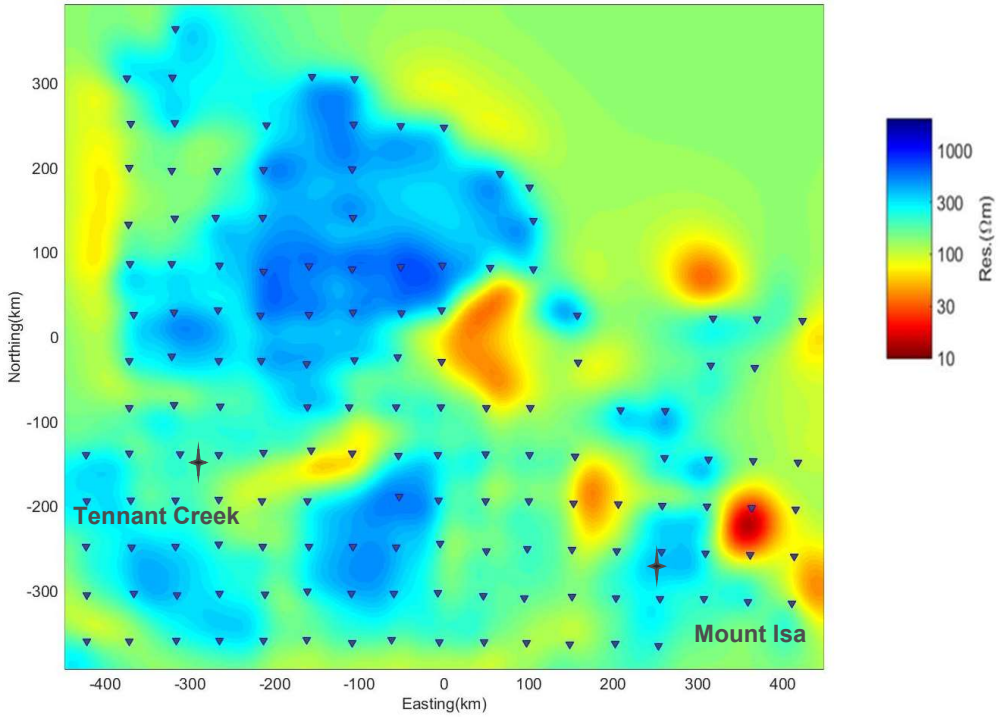
EFTF-AusLAMP: crustal architecture
Northern Territory – Queensland Border



CONDUCTIVITY AT Depth at 10 km

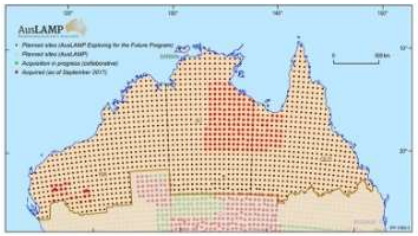


CONDUCTIVTIY Depth at 20 km

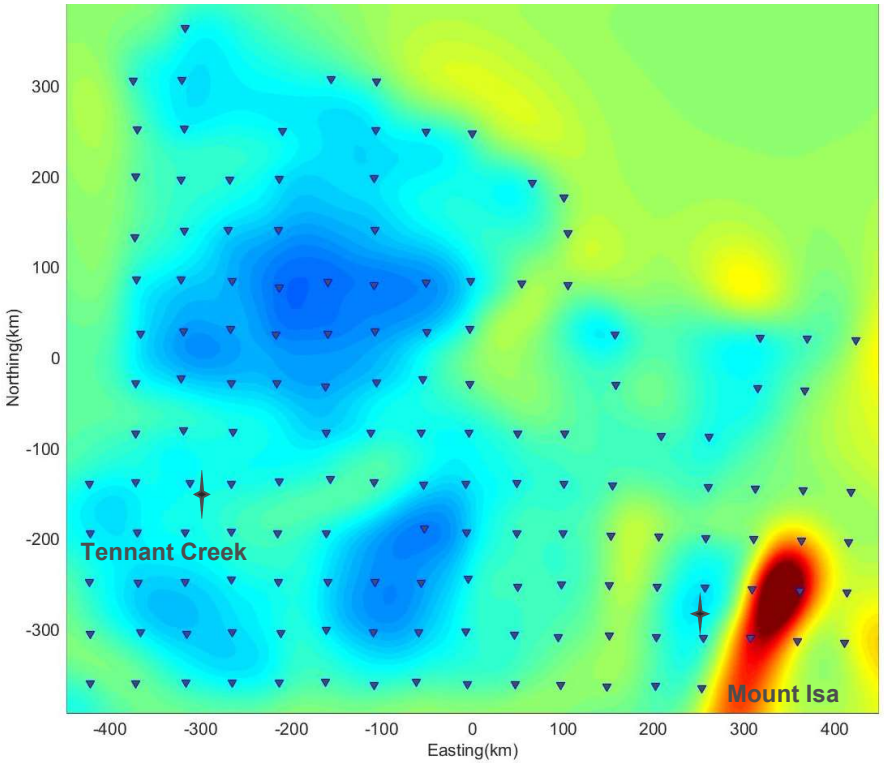


EFTF-AusLAMP: mantle architecture

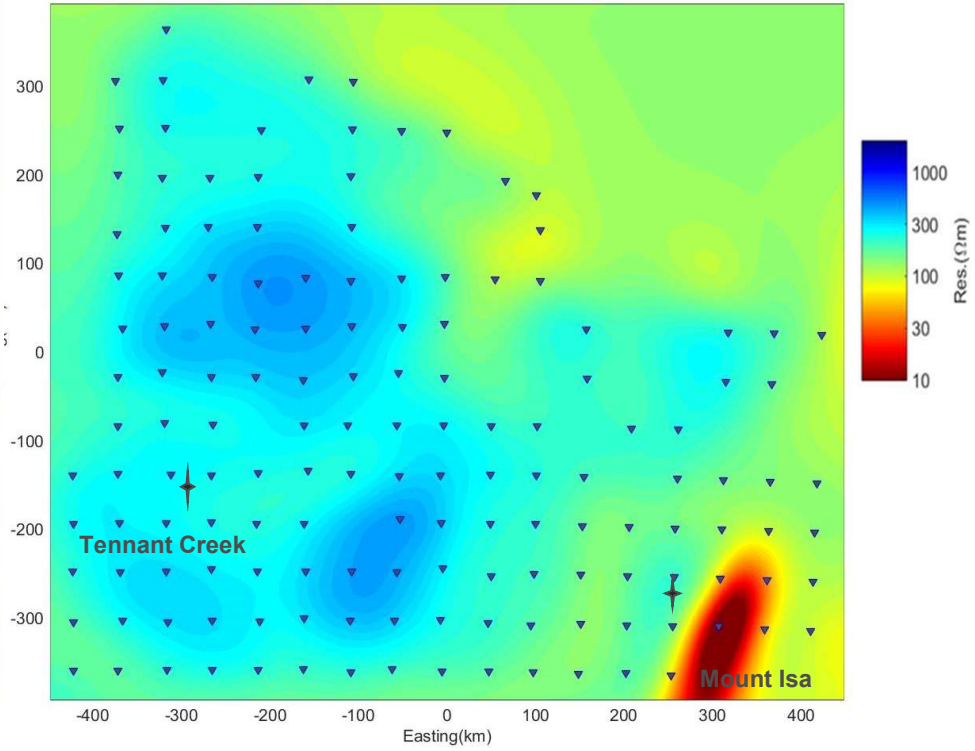
Northern Territory – Queensland Border



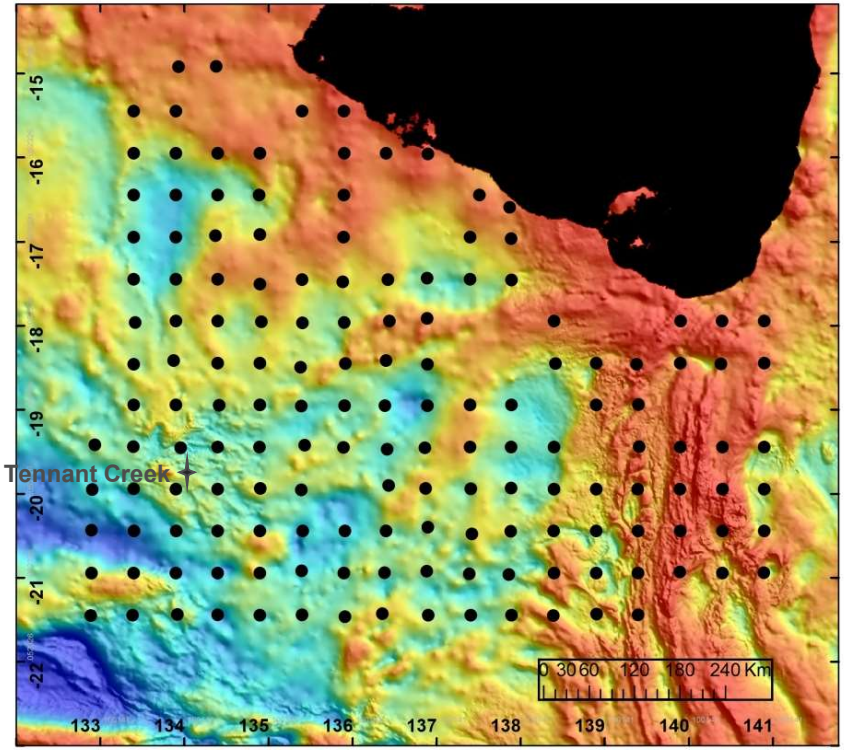
CONDUCTIVITY Depth at 40 km



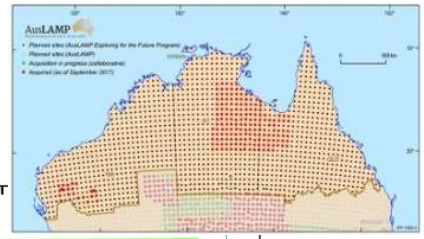
CONDUCTIVITY Depth at 60 km

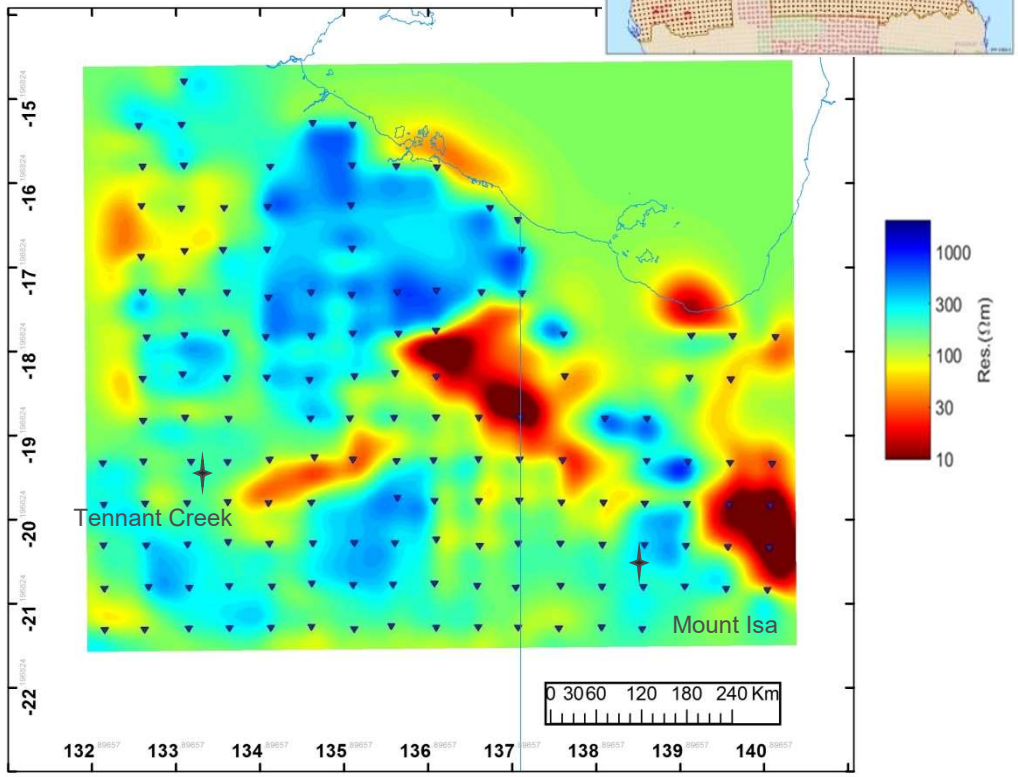


EFTF-AusLAMP and Bouguer gravity
Northern Territory – Queensland Border



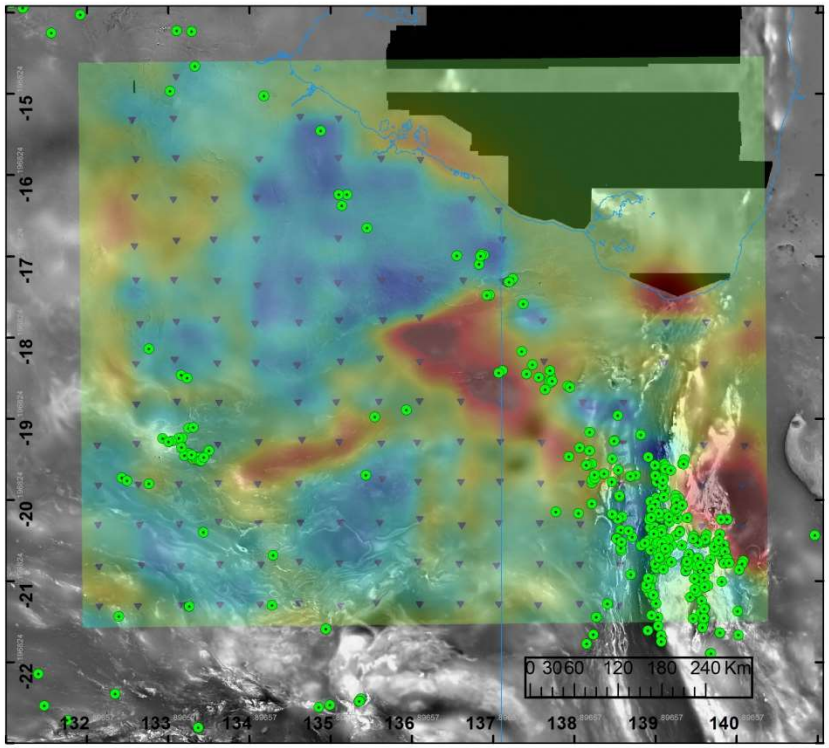
Bouguer Gravity

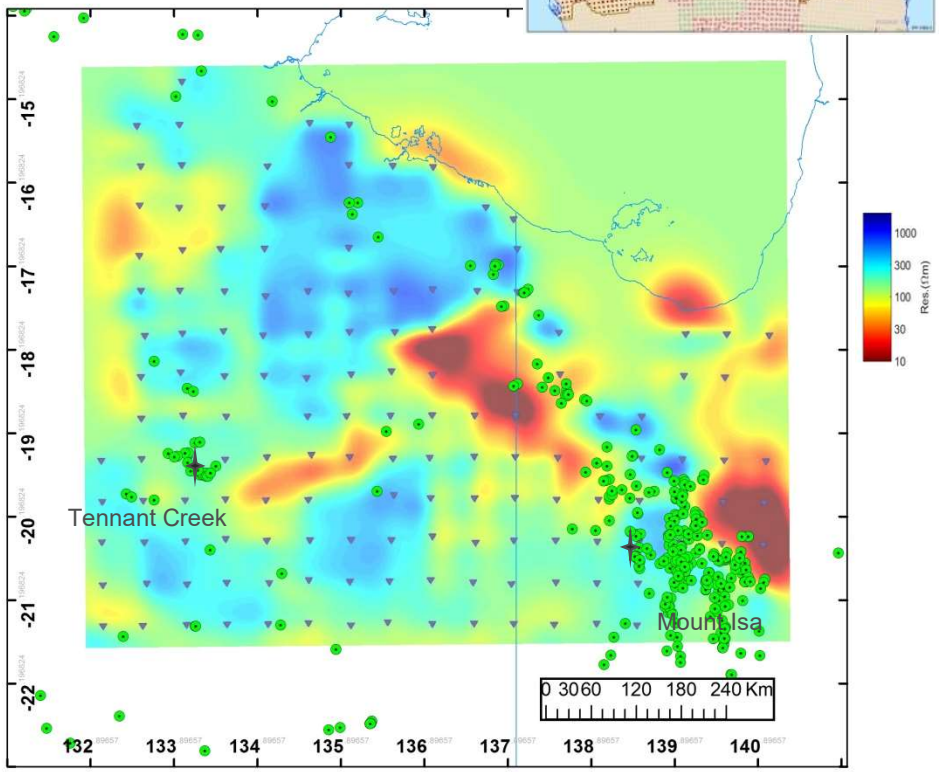




CONDUCTIVITY AT Depth at 10 km

EFTF-AusLAMP and mineral occurrence Gradients/Edges





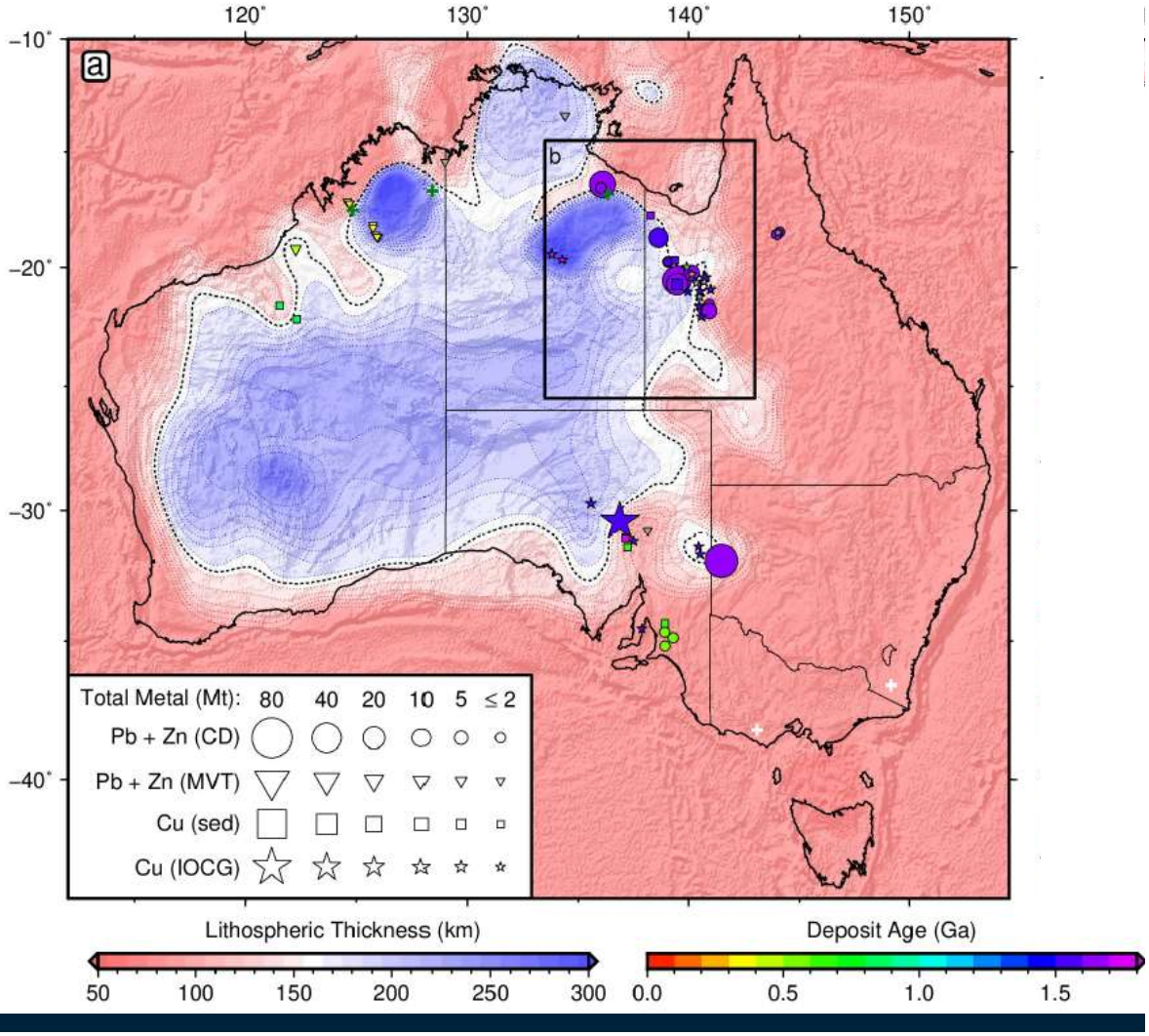
AusARRAY

Collecting Passive Seismic Data

Seismic tomography highlighting

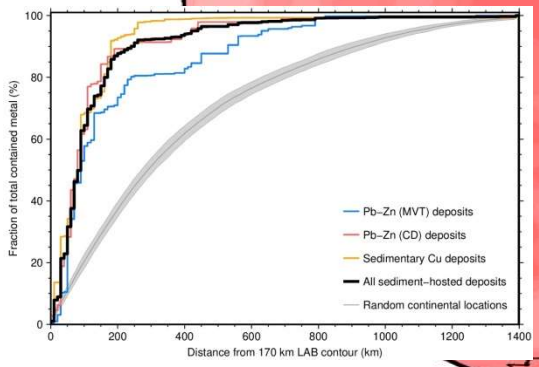
- new prospective regions
- exploration targets
- distribution of sediment-hosted and Fe-oxide-Cu-Au base metal deposits as a function of *lithospheric thickness* in Australia

supplied by Karol Czarnota



Lithospheric gradients: a global control – incredible

Czarnota et al, 2018 (AGU)



Age (Ga)

0.0 0.5 1.0 1.5 2.0

Lithospheric Thickness (km)

50 100 150 200 250 300

Total Ore (Mt):

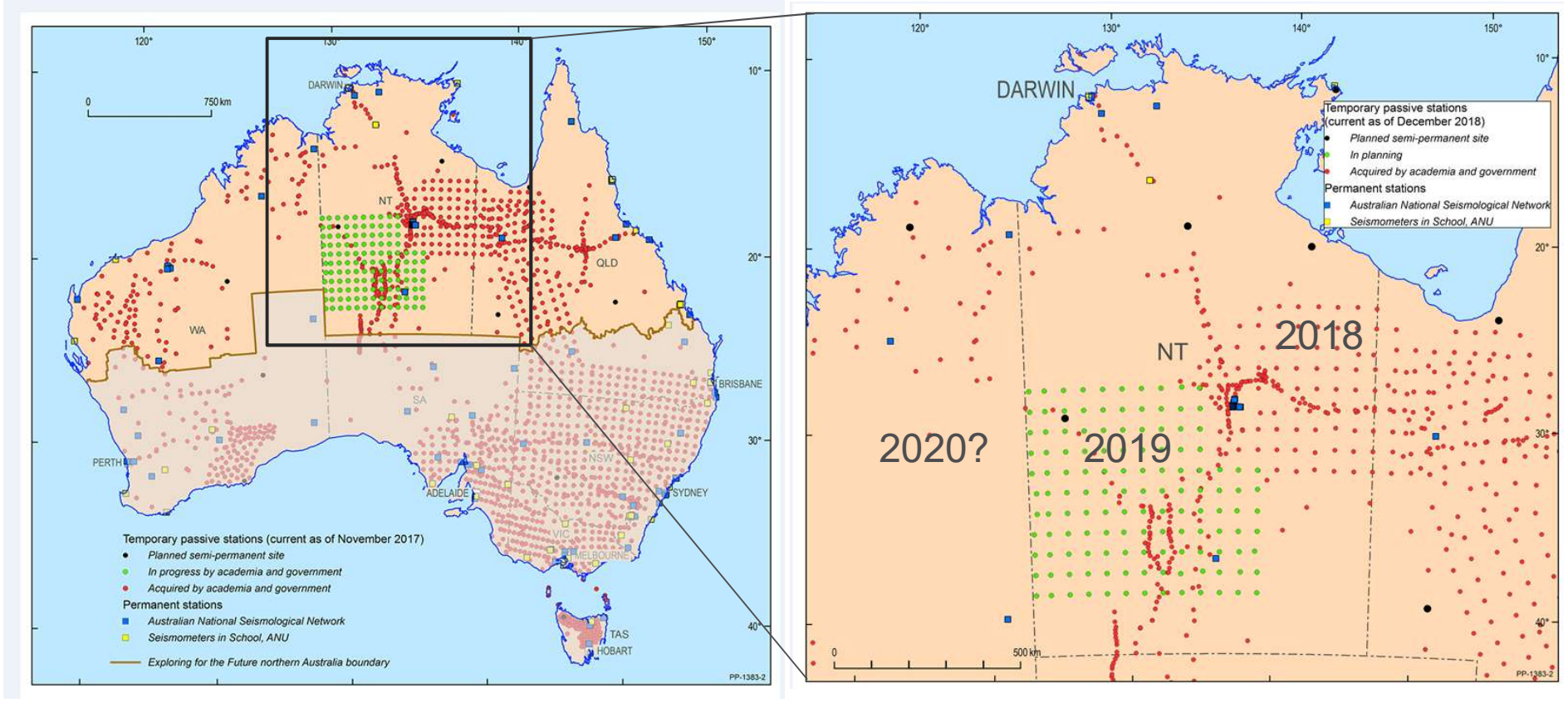
80 40 20 10 5 ≤ 2

Pb + Zn (CD)

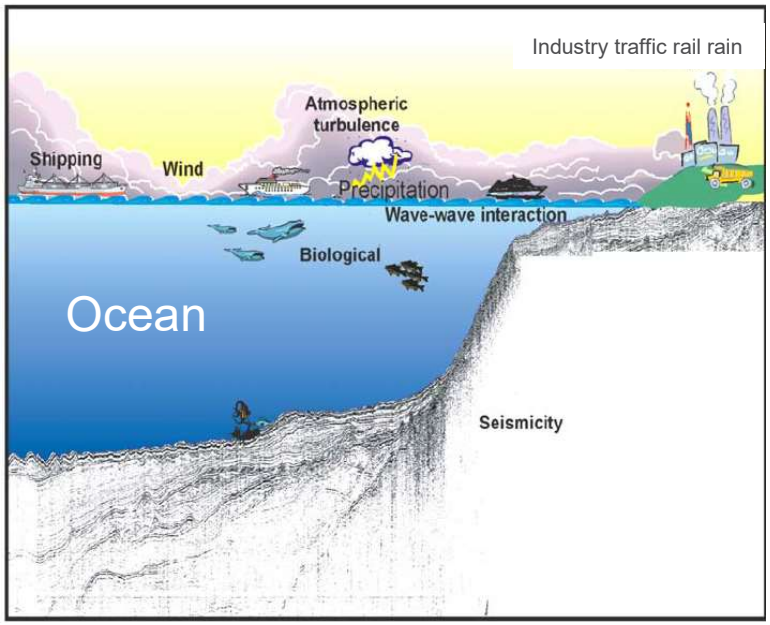
Pb + Zn (MVT)

Cu (sed)

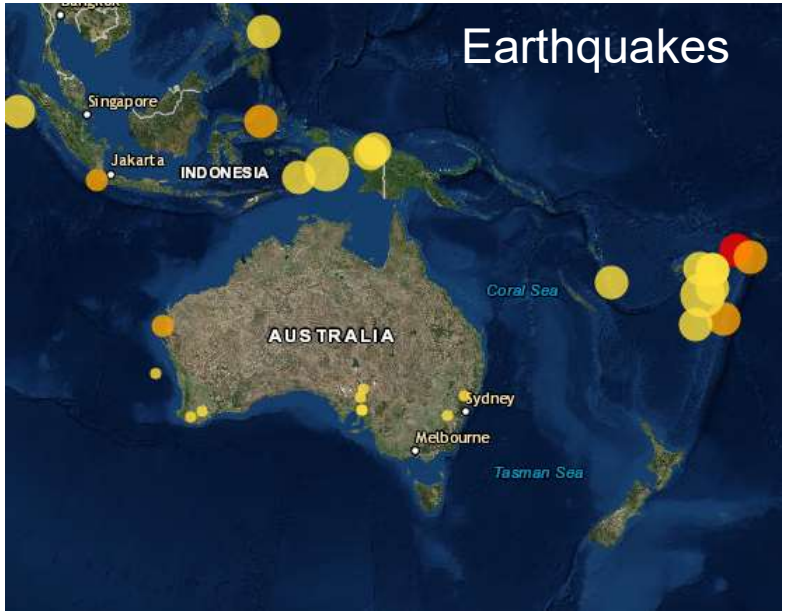
AusARRAY – Passive Seismic



Passive Seismic Energy Sources



Akal, Tuncay et. al. (2008).



https://earthquakes.ga.gov.au/

AusArray Passive Seismic Stations

Temporal (array of 120 sites)

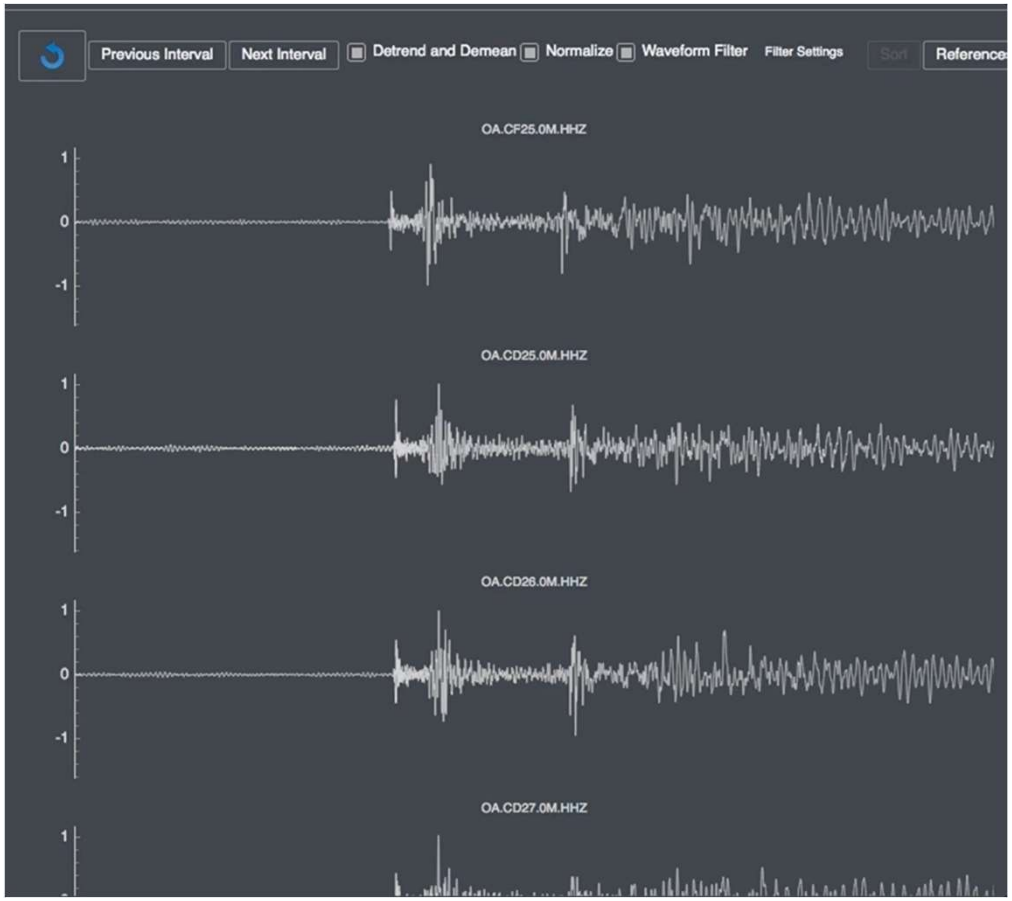
Semi-permanent

Seismic Waveforms

Magnitude 6.4, Depth: 98km,

SOUTH OF FIJI ISLANDS

Excellent data quality, comparable to permanent station quality



PASSIVE SEISMIC QA-QC

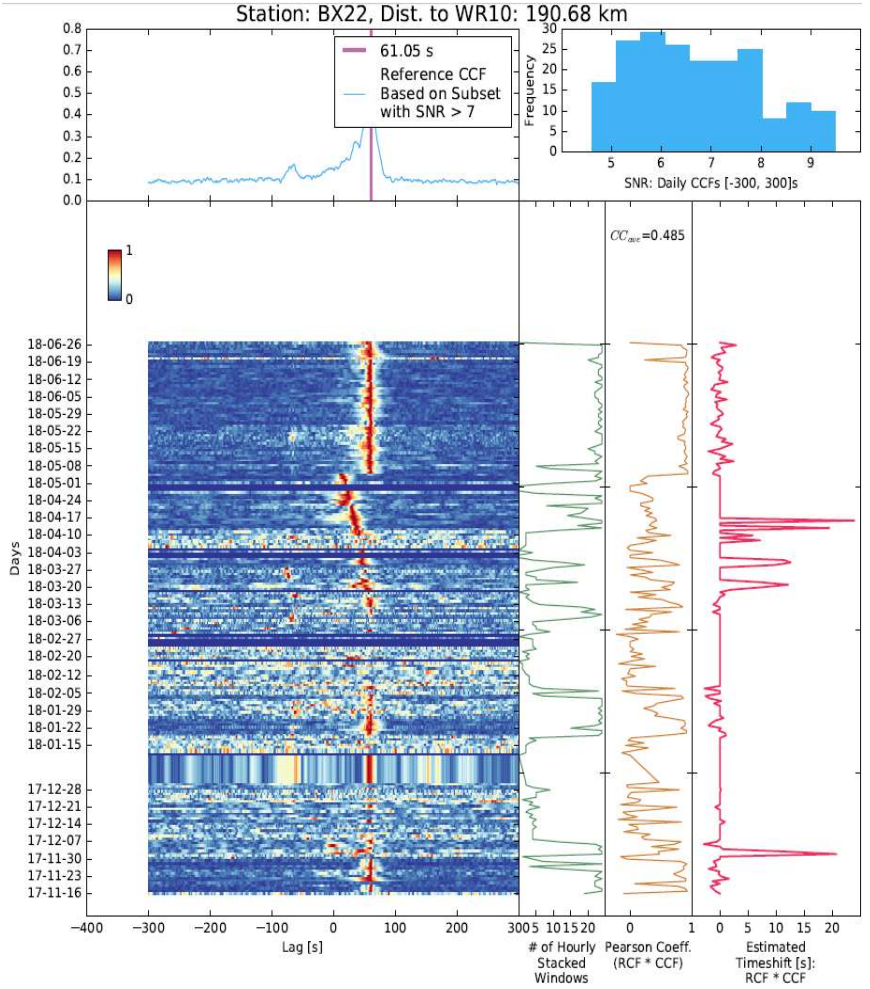
AusARRAY 1 collected Nov 2018

New semi automated code

New efficient procedures

Using international and national data

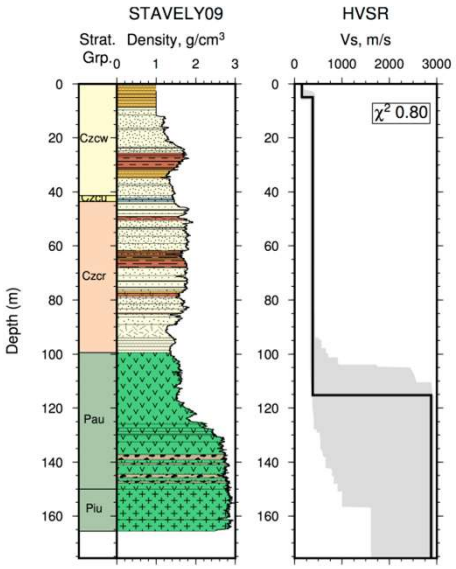
e.g. GPS Clock analysis and other noise



Products

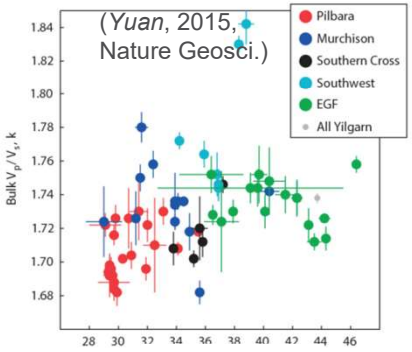
1. Cover-thickness beneath each station

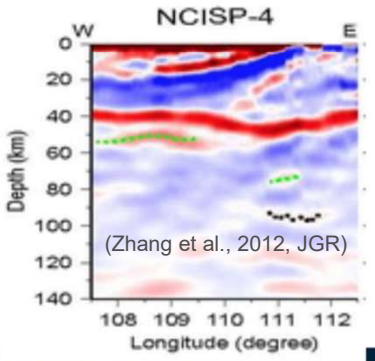
[HVSR analysis]



2. Crustal structure beneath each station

[H-k stacking, CCP stacking & inversion of receiver functions]

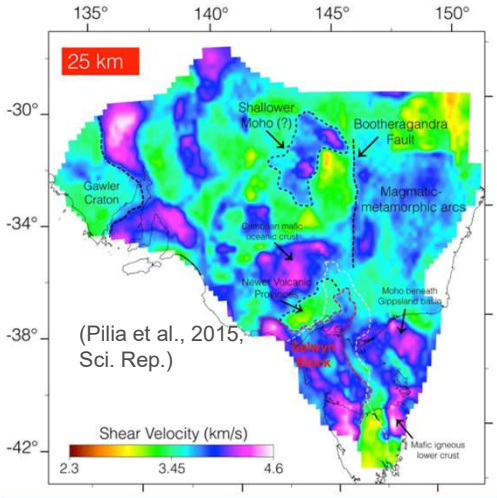




3. Crustal volumetric velocity

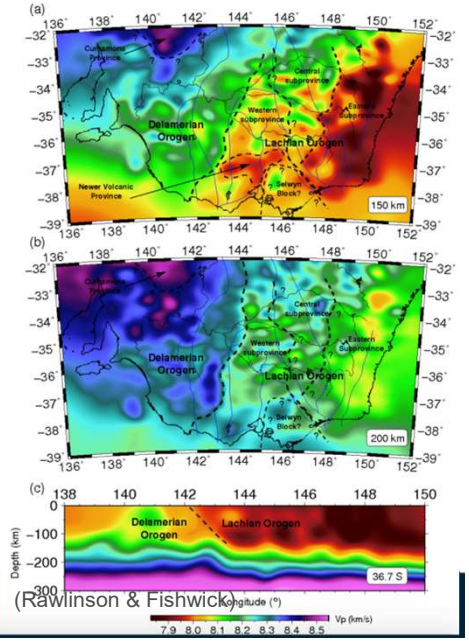
[Ambient noise tomography, and full waveform inversion]

- Aim to resolve features < 10 km wide between 1–30 km deep.

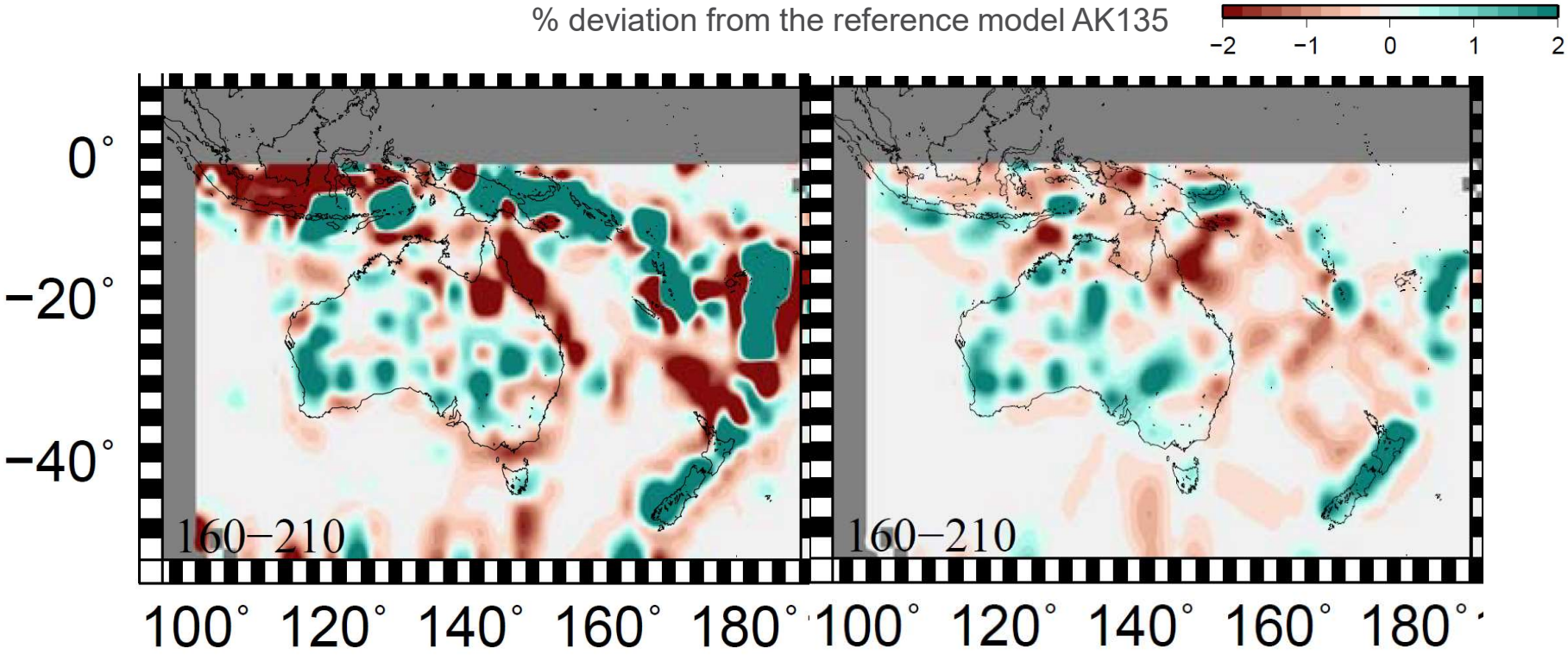


4. Lithospheric mantle volumetric velocity & lithosphere-asthenosphere boundary

[Teleseismic tomography, full waveform inversion]



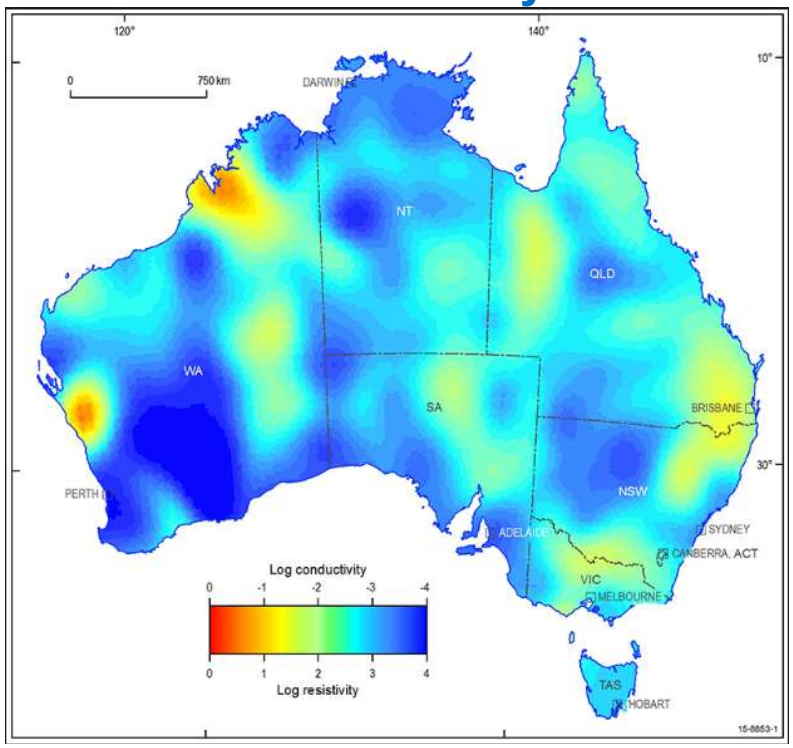
Preliminary P and S-wave Seismic Tomography



P and S-wave tomography of the Australian lithosphere at the depth range of 160-210 km

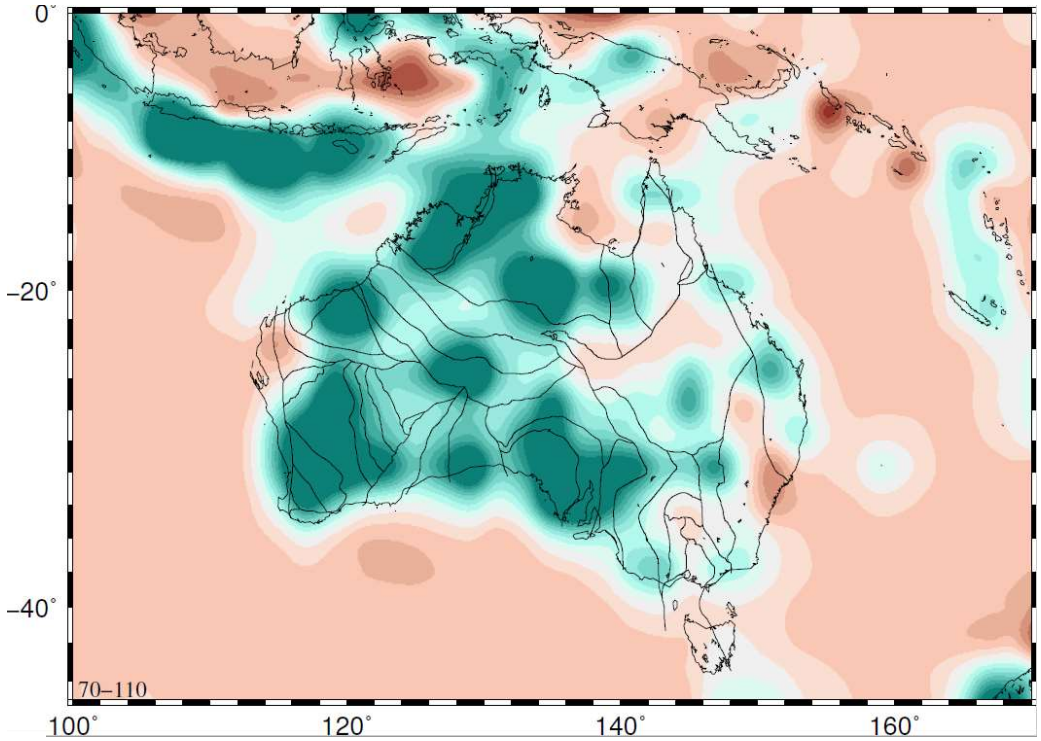
National Scale - Framework

Conductivity 112 km



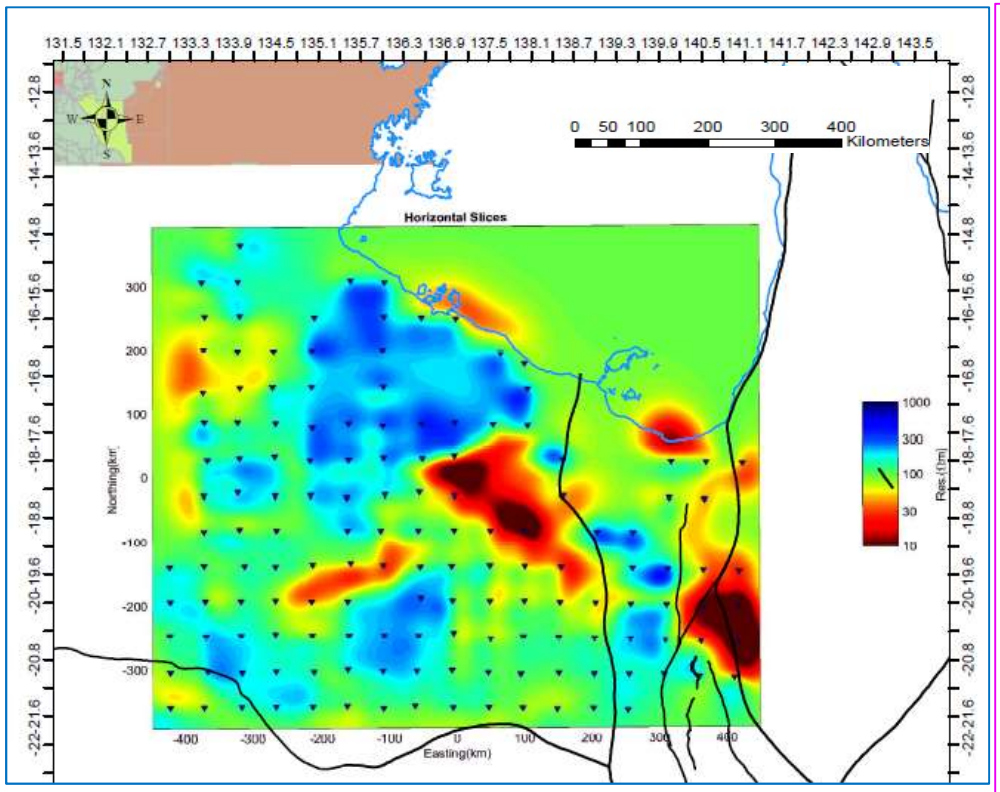
3D **conductivity** **model** *using* ***very wide spaced*** *geomagnetic network* *(Wang et al 2014)*

Seismic Velocity Tomography 70-110 km

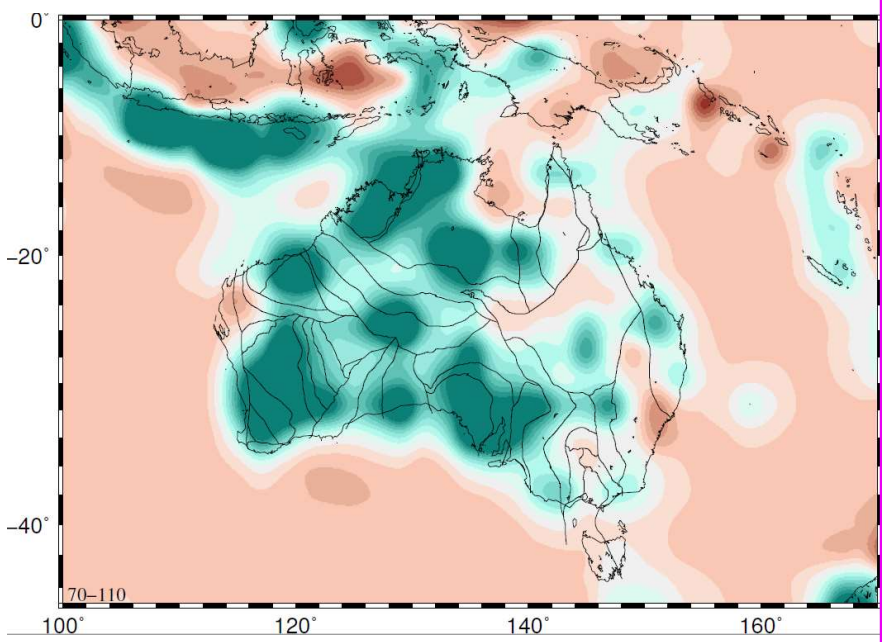


Preliminary **P-wave model** using **very wide spaced** earthquake **seismic** network (Image A.Gorbatov)

Northern Territory Scale – Regional Assessment



Preliminary TISA AusLAMP Conductivity



Imagine the improvement in resolution when we use AusARRAY 1 Data

AusLAMP
Magnetotellurics
Conductivity

AusARRAY
Passive Seismic
Seismic Velocity

Significant up take in industry of both techniques

New data standards

New Open Source Code

New discoveries (particularly using MT in South Australia)

New Integration

- targeting near surface deposits as well as large crustal features

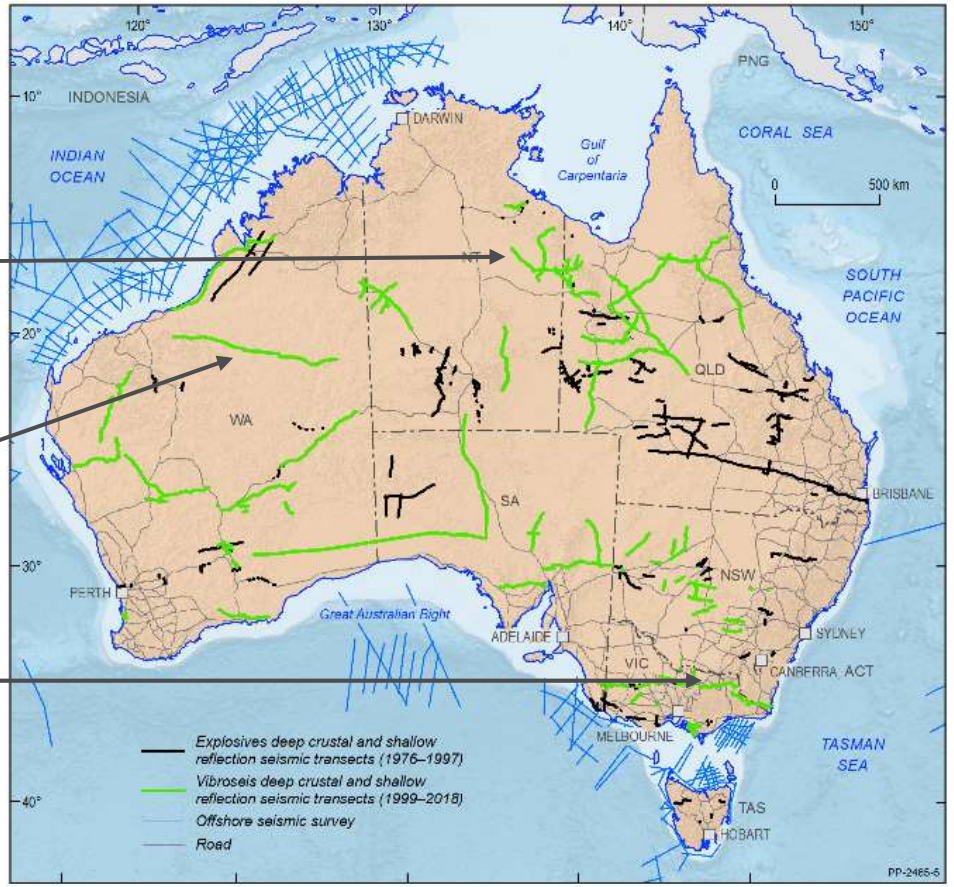
But WAIT there is more…

New seismic transects

South Nicholson 1102 km
GA and NTGS, GSQ
Completed Aug 2017
Released

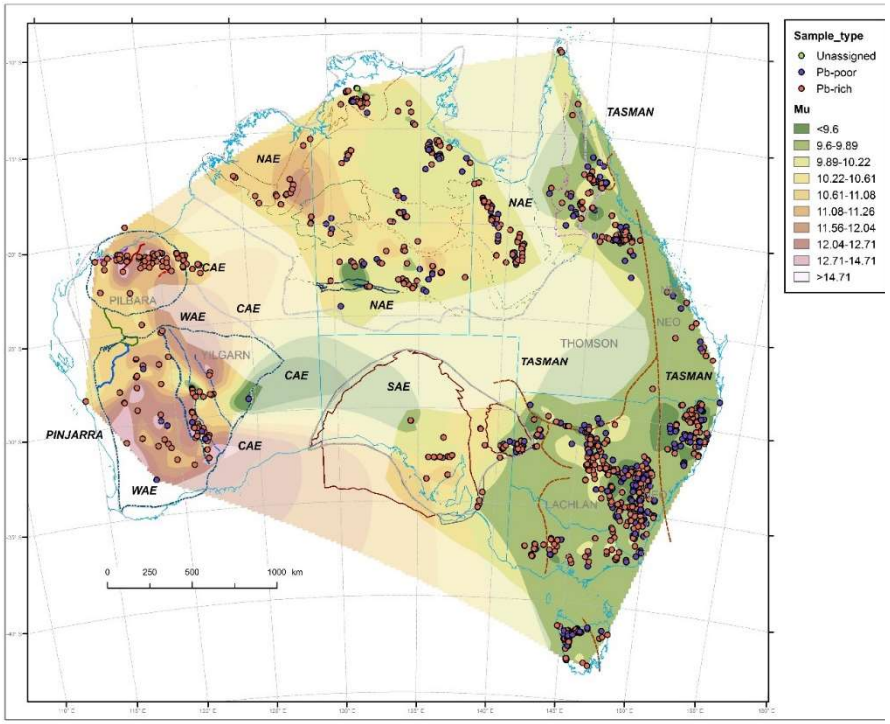
Kidson sub-basin 872 km
GA and GSWA
Completed Aug 2018
Release- Mid 2019

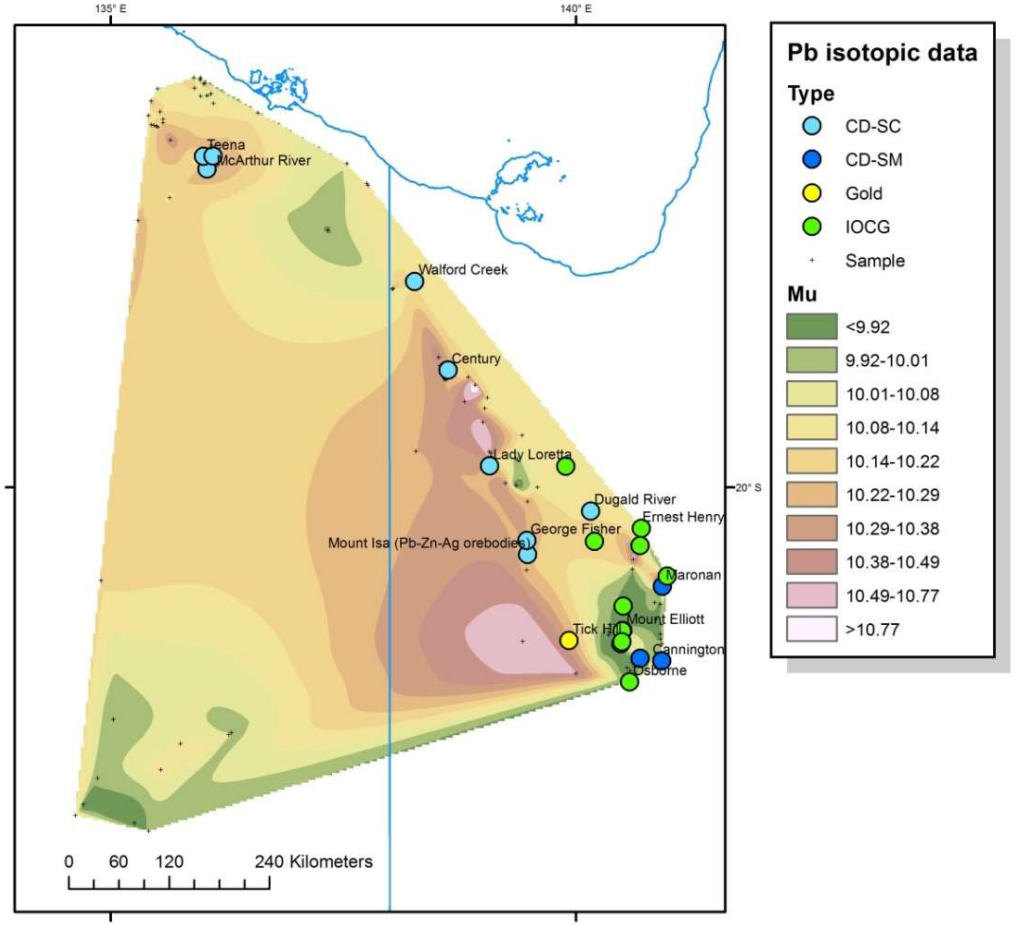
Southeast Lachlan 629 km
GA and GSV, GSNSW, AuScope
Completed 2018
Release- late 2019



For more information: http://www.ga.gov.au/about/projects/resources/seismic

New national-scale Pb isotope dataset and maps





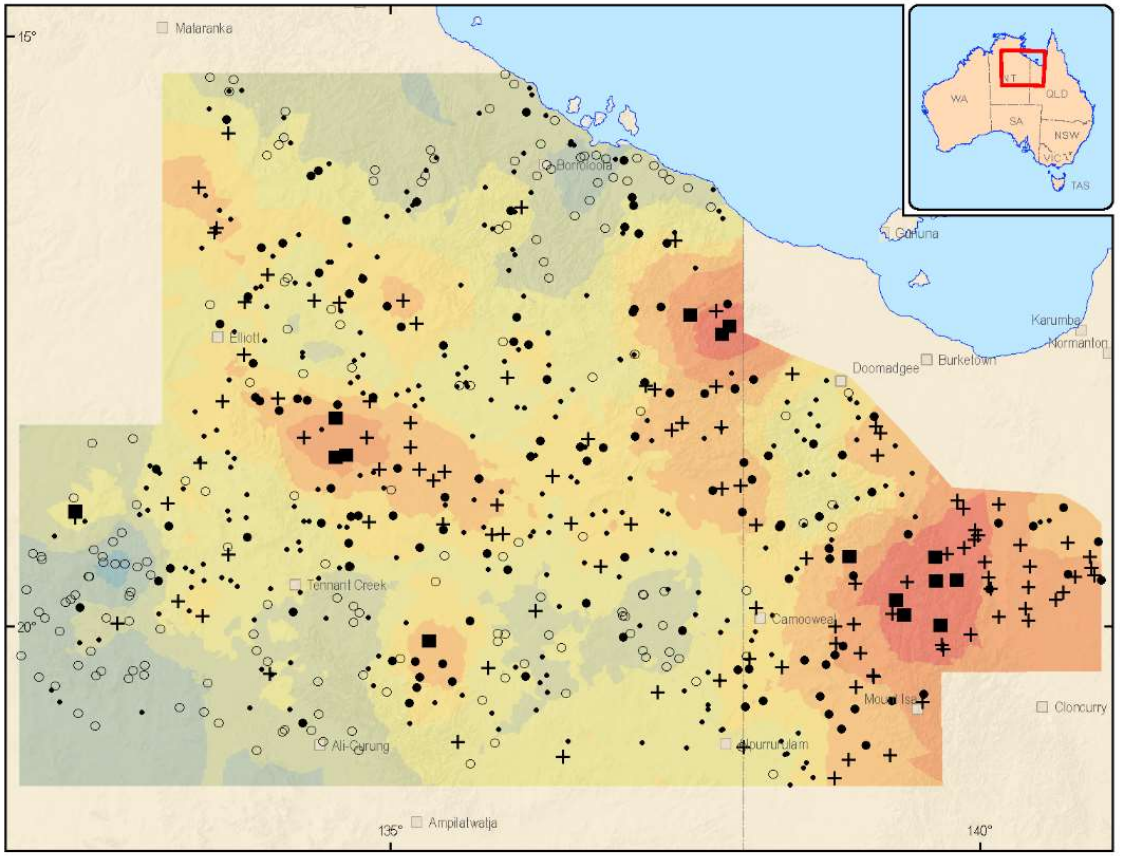
David Huston et al.

GA 2019/001 Released this week

NAGS Data Release 2 Au, Pd, and Pt.

Data released this week

Philip Main Et Al. 2019-002



Australian Government Geoscience Australia

Exploring for the Future
minerals | energy | groundwater

NORTHERN TERRITORY GOVERNMENT

Queensland Government

Tennant—Isa study area: Northern Australia Geochemical Survey

Top Outlet Sediment
0-10 cm
Fraction: <75 µm
Preparation: FA Digestion
Analysis: ICP-MS
N: 690

Pd

Maximum: 5.8 mg/kg

Upper Fence: 2.08 mg/kg

75%: 0.8 mg/kg

Median: 0.6 mg/kg

25%: 0.42 mg/kg

Lower Fence: NA

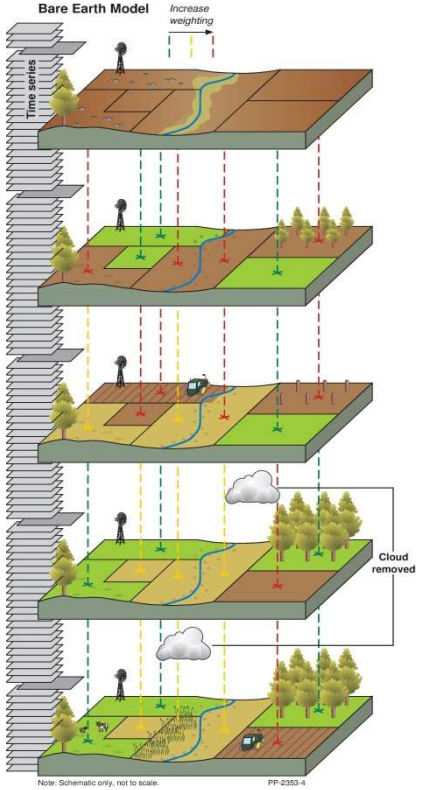
Minimum 0.2 mg/kg

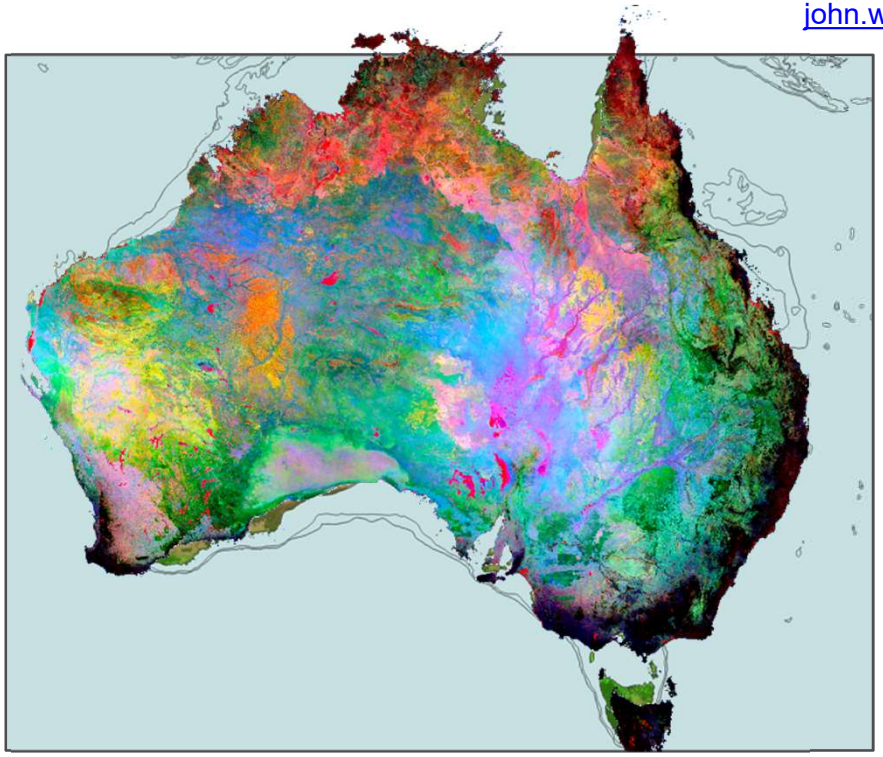
0 250 km

http://www.ga.gov.au/eftf/minerals/fis/nags

Bare(st) earth satellite imagery to enhance geology

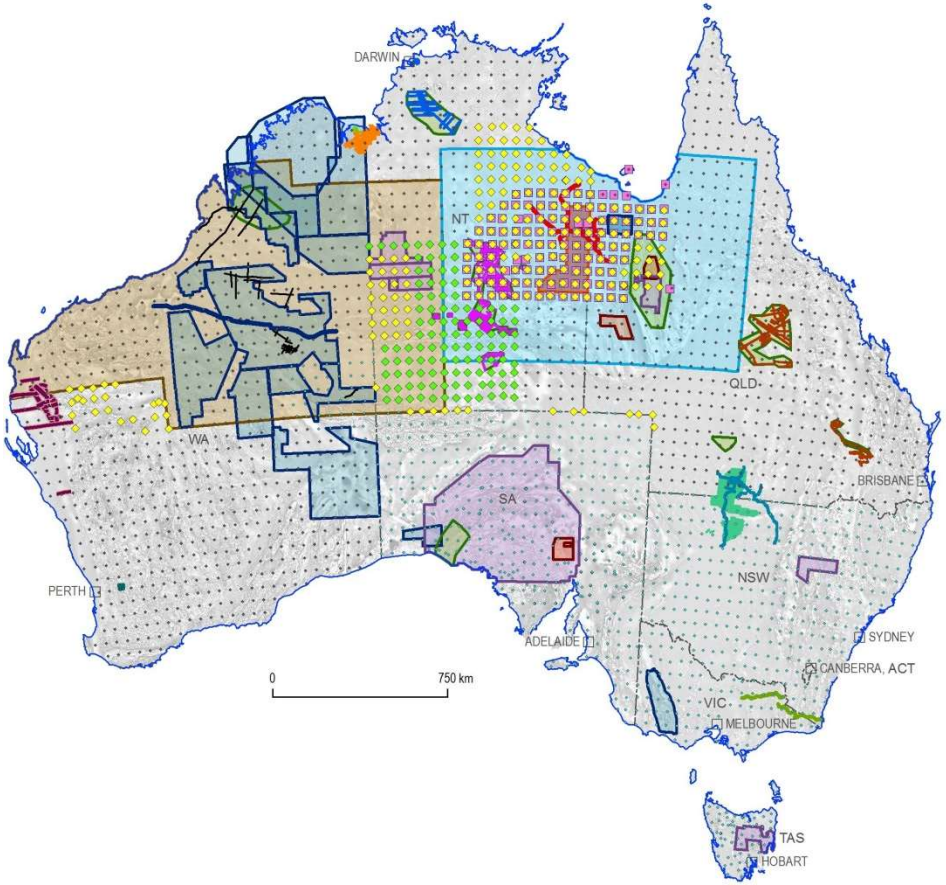
dale.roberts@anu,ed.au
john.wilford@ga.gov.au





Landsat-8 Barest Earth mosaic, shown in False Colour
Sentinel 2: Red = clays, Green = Fe, Blue = silica

National pre-competitive datasets: team effort



***Exploring for the Future*, February 2019**

- *AusAEM 2017–2018 completed survey*
- *AusAEM 2019 proposed survey*
- *Gravity survey, South Nicholson Basin, released October 2017*
- *Seismic reflection survey, South Nicholson Basin, released March 2018*
- *AEM survey, Surat and Galilee basins*
- *AEM survey, East Kimberley*
- *AEM survey, Northern Stuart Corridor*
- *AEM survey, Southern Stuart Corridor*
- *Seismic reflection survey, Kidson Sub-basin*
- *Reprocessed seismic reflection survey, Canning Basin*
- *Reprocessed seismic reflection survey, Carnarvon Basin*
- *Reprocessed seismic reflection data, East Kimberley*
- *AusARRAY survey, Mount Isa to Tennant Creek*
- *EFTF AusLAMP survey, completed*
- *EFTF AusLAMP survey, southwest Alice Springs, in progress*

Geophysical Acquisition Programs, current activities

- *Airborne magnetic and radiometric survey*
- *Gravity survey*
- *Airborne electromagnetic survey*
- *Magnetotelluric survey*
- *Airborne test site*
- *AEM survey, Thomson*
- *Gravity survey, Thomson*
- *Seismic reflection survey, Lachlan*
- *AusLAMP survey, completed and in progress*
- *AusLAMP survey, planned*

NOTE: The greyscale background represents aeromagnetic data (0.5 first vertical derivative of total magnetic intensity).

PP-2798-2

Australian Government
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AUSTRALIA'S NORTHERN TERRITORY

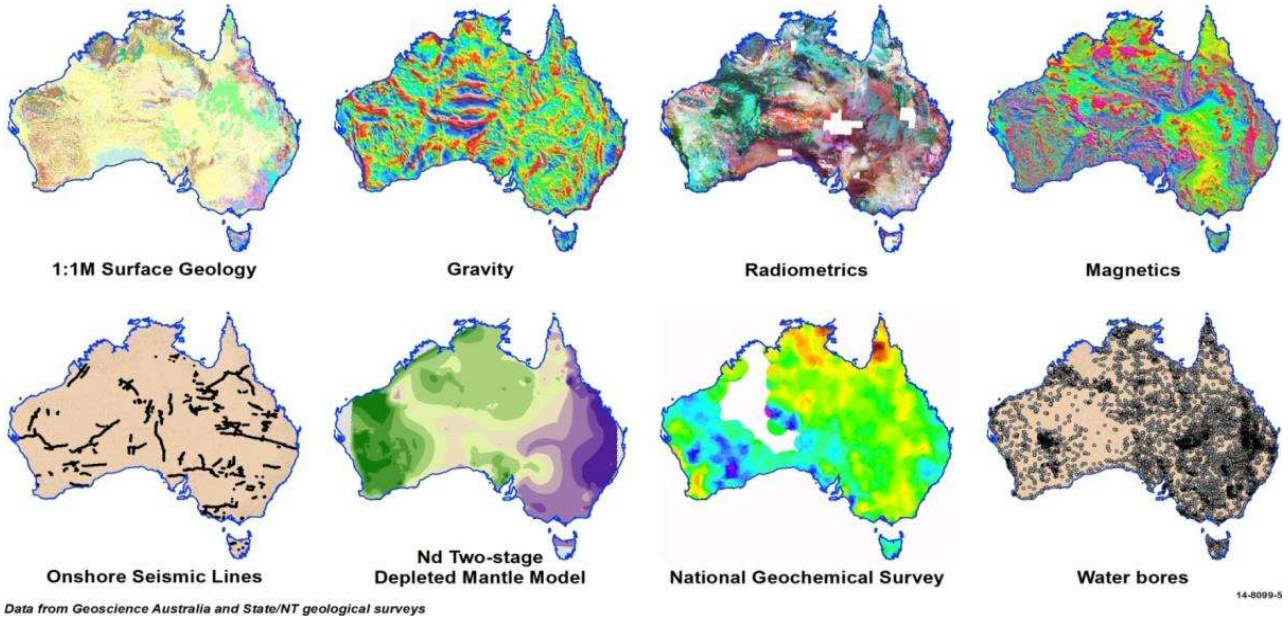
Queensland Government

GSWA 2018

NSW GOVERNMENT

Tasmanian Government

National pre-competitive datasets: team effort

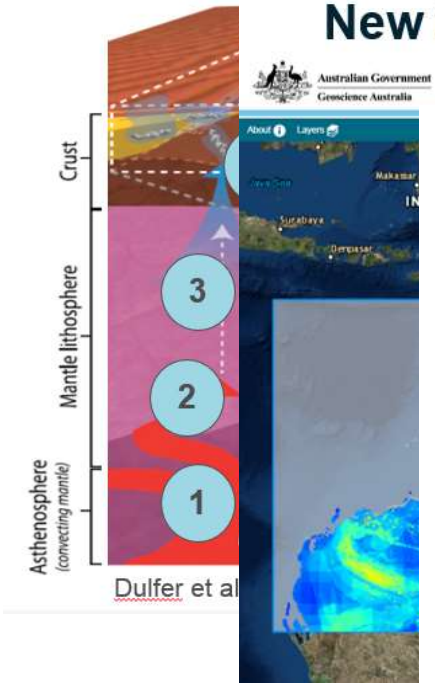


- Australia's national geoscientific data is quality-assured and delivered FREE
- Historical exploration data is open file so subsequent exploration can build on prior work

New methods to deliver the data

Bringing all together: national mineral potential mapping

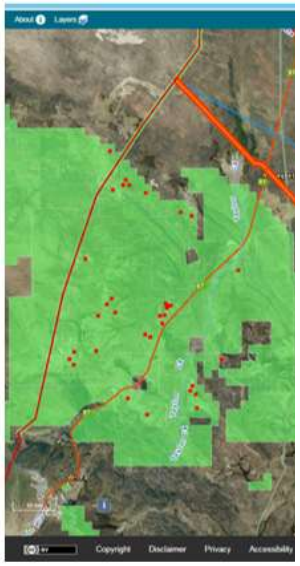
New tools: mineral potential mapping on the fly



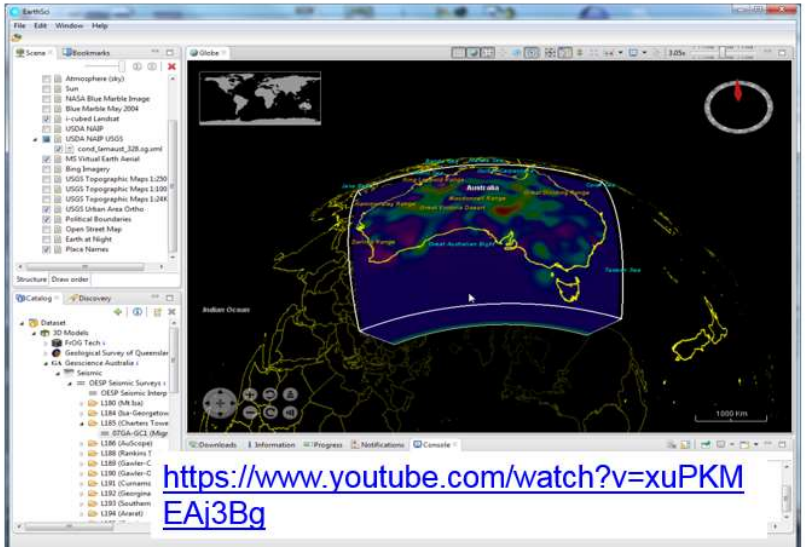
Australian Government Geoscience Australia

Exploring for the Future (Nonprod)

New tools: economic and social impact decision support



New tool: Earth*Sci* to visualise, integrate and deliver



- GA-developed 2D and 3D visualisation tool
- supports integration & visualisation wide range data types
- runs on normal PCs & Macs with reasonable graphics card

https://www.youtube.com/watch?v=xuPKMEAj3Bg

malcolm.nicoll@ga.gov.au

Acknowledgements and Thanks

I acknowledge the traditional owners of the land we are meeting on today. Further I take this opportunity to acknowledge the traditional owners of the land where we have conducted work recently, and thank those communities for guidance and assistance in relation to the land.

I pay my respects to all Elders, both past and present, and to any of their family with us today.

Acknowledgements

Thank you

Marina Costelloe
Marina.Costelloe@ga.gov.au

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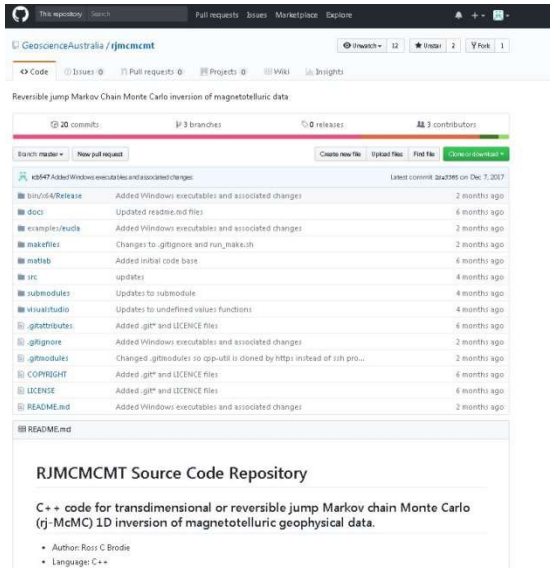
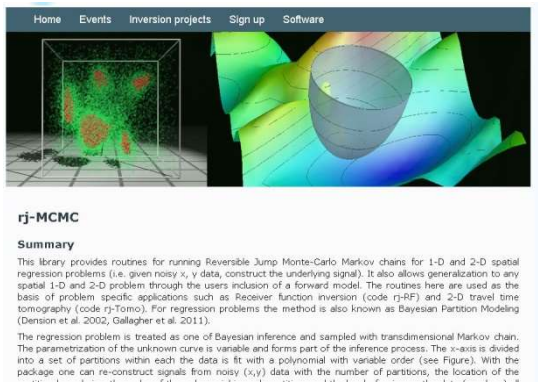
Exploring for the Future
minerals | energy | groundwater

Open source code

- Freely available on GitHub repository
  - https://github.com/GeoscienceAustralia/rjmcmcmt
- C++ source code developed at Geoscience Australia
  - Linux and Windows
  - Standard C++11 compliant compilers
- MPI enabled for parallel multi-chain execution
- Contains usage examples
- Makes use of open source RJMCMC engine on iEarth
  - Developed at the RSES, ANU
  - http://www.iearth.org.au/codes/rj-MCMC





P waves win the race (fast)
S Waves Damage