

Scale-reduction MT studies to link deep source regions to deposit scales for IOCG and Au deposits in Australia

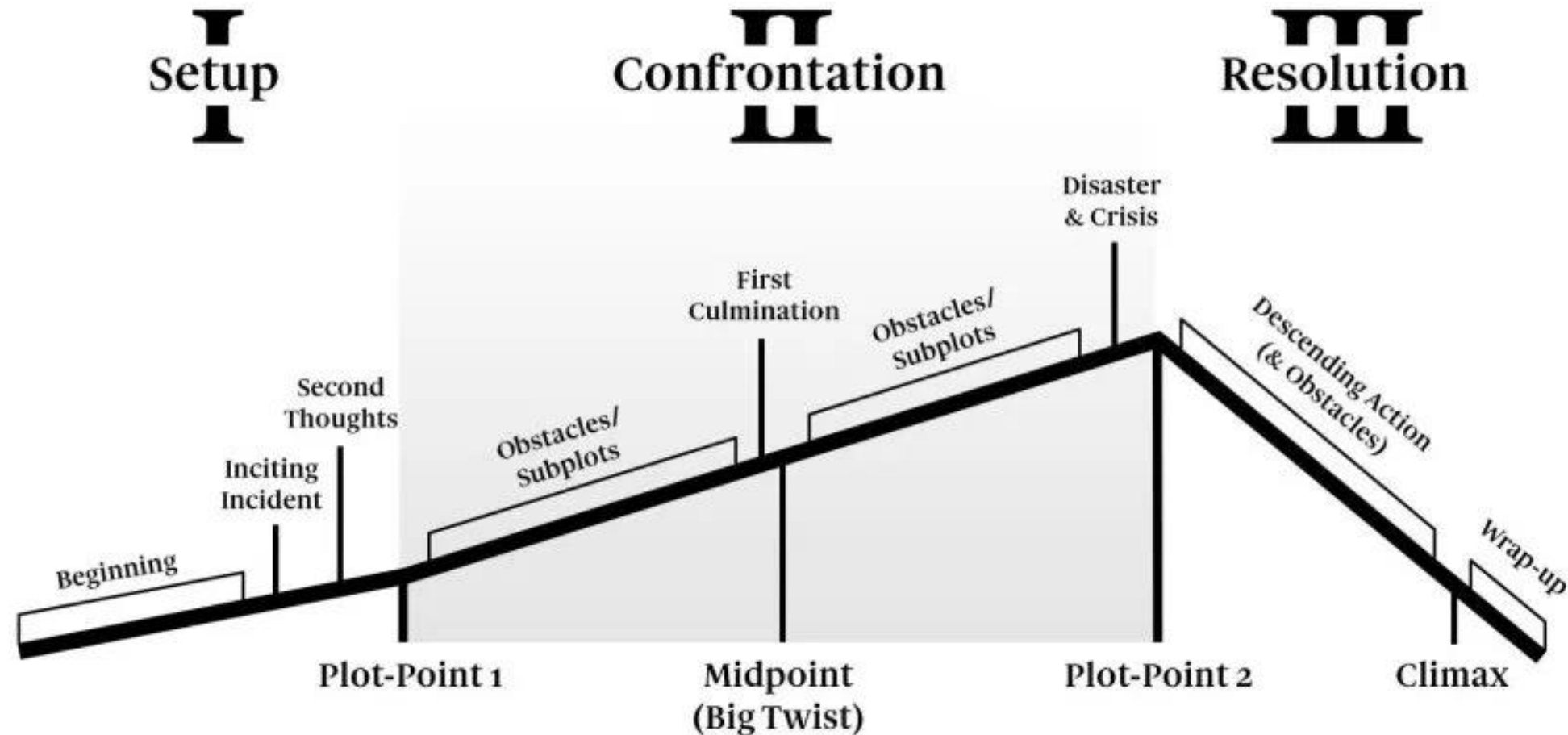
Graham Heinson¹, Ben Kay¹, Kate Robertson^{1,2}, Stephan Thiel^{1,2}

¹University of Adelaide; ²Geological Survey of South Australia



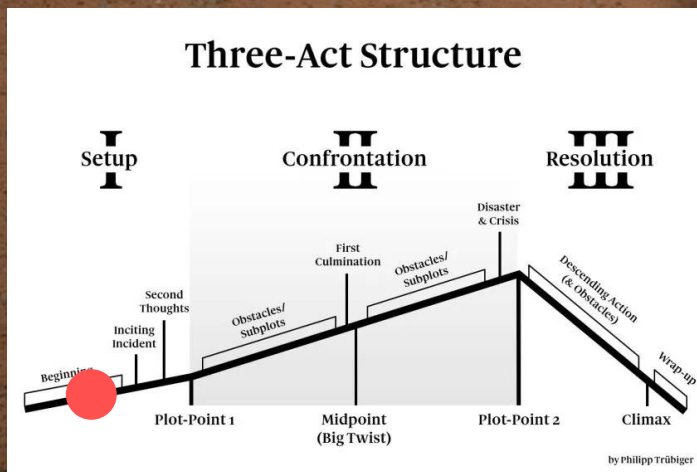
Government of South Australia
Department for Energy and Mining

Scale-reduction from deep source regions to deposit scales in Three Acts



Act I

Setup

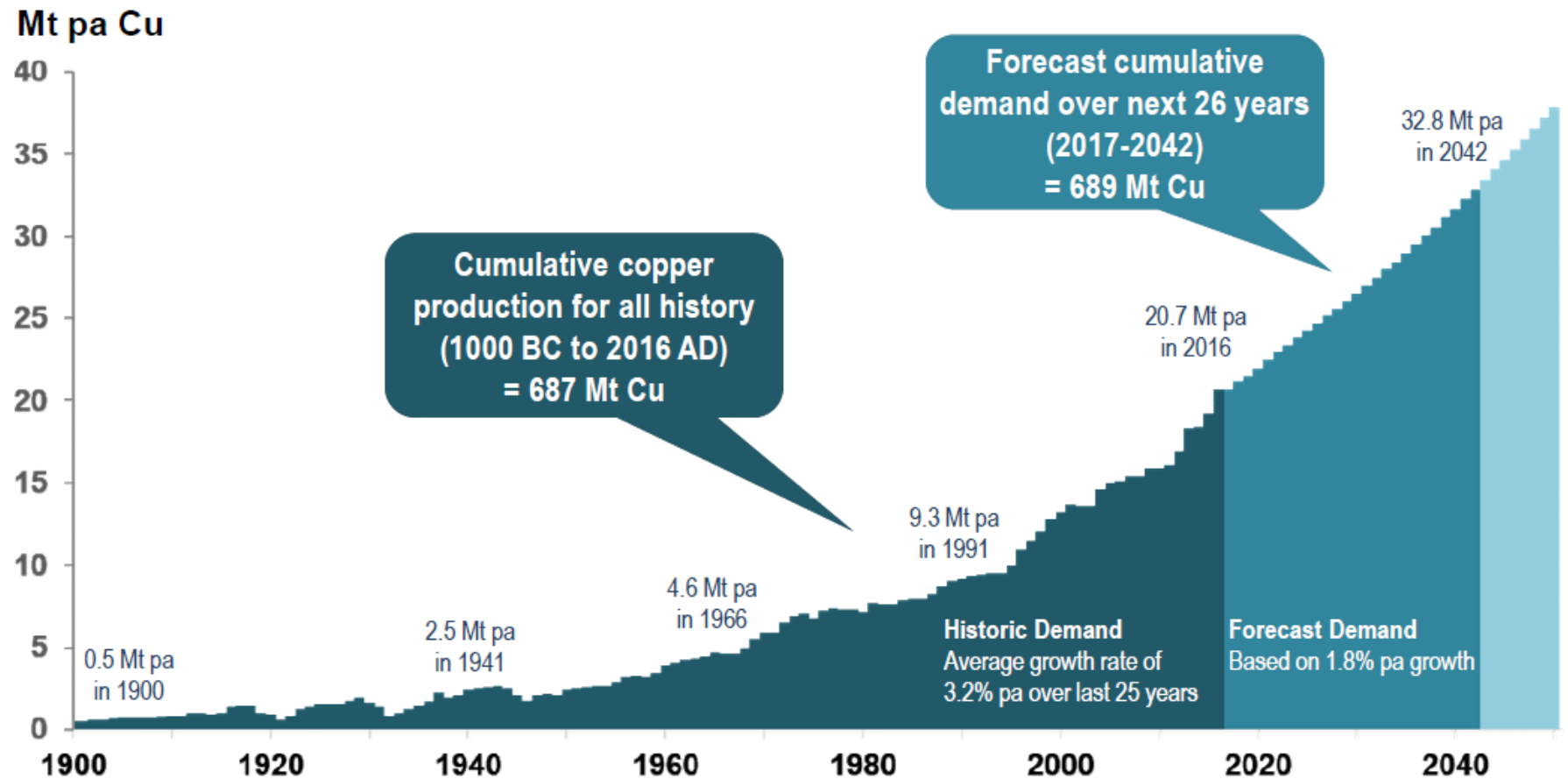


To convert UK's 31.5 million hydrocarbon vehicles to EVs requires 207,900 t Co, 264,600 t Li, 7,200 t of Nd and 2,362,500 t Cu.

Equivalent to twice current global production of Co (battery electrodes), an entire year's production of Nd (motor magnets) and three-quarters global production of Li (battery electrolyte)

World's demand for metals doubles every 20-30 years

Primary copper production for World: 1900-2050



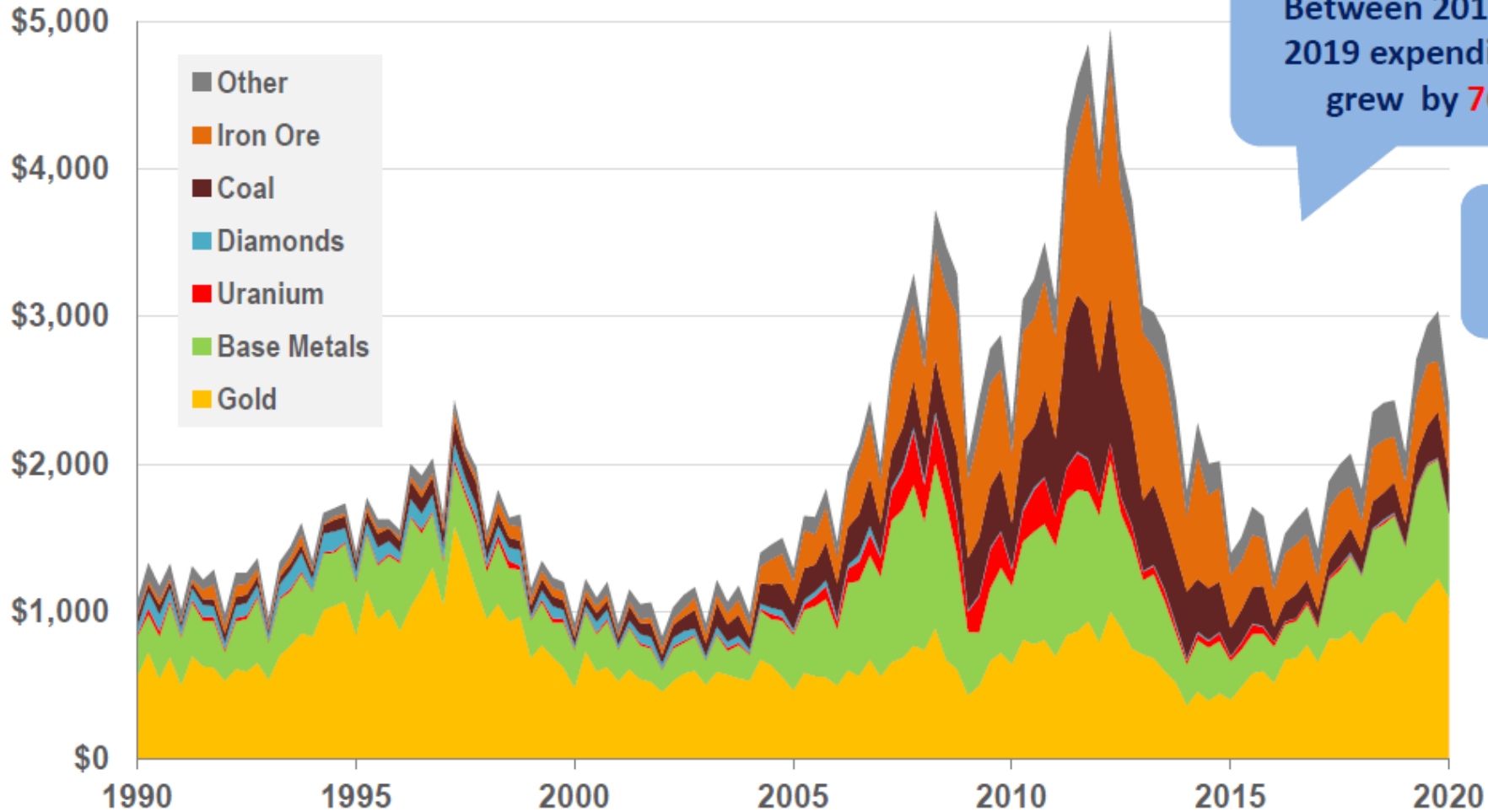
Over the next 26 years the world is going to mine more copper than what has been mined in all history.

Sources: Historical data from USGS and BREE March 2017

Exploration expenditures are going up ...

Australia : March 1990 to March 2020

June 2020 A\$m



Between 2016 and 2019 expenditures grew by **76%**

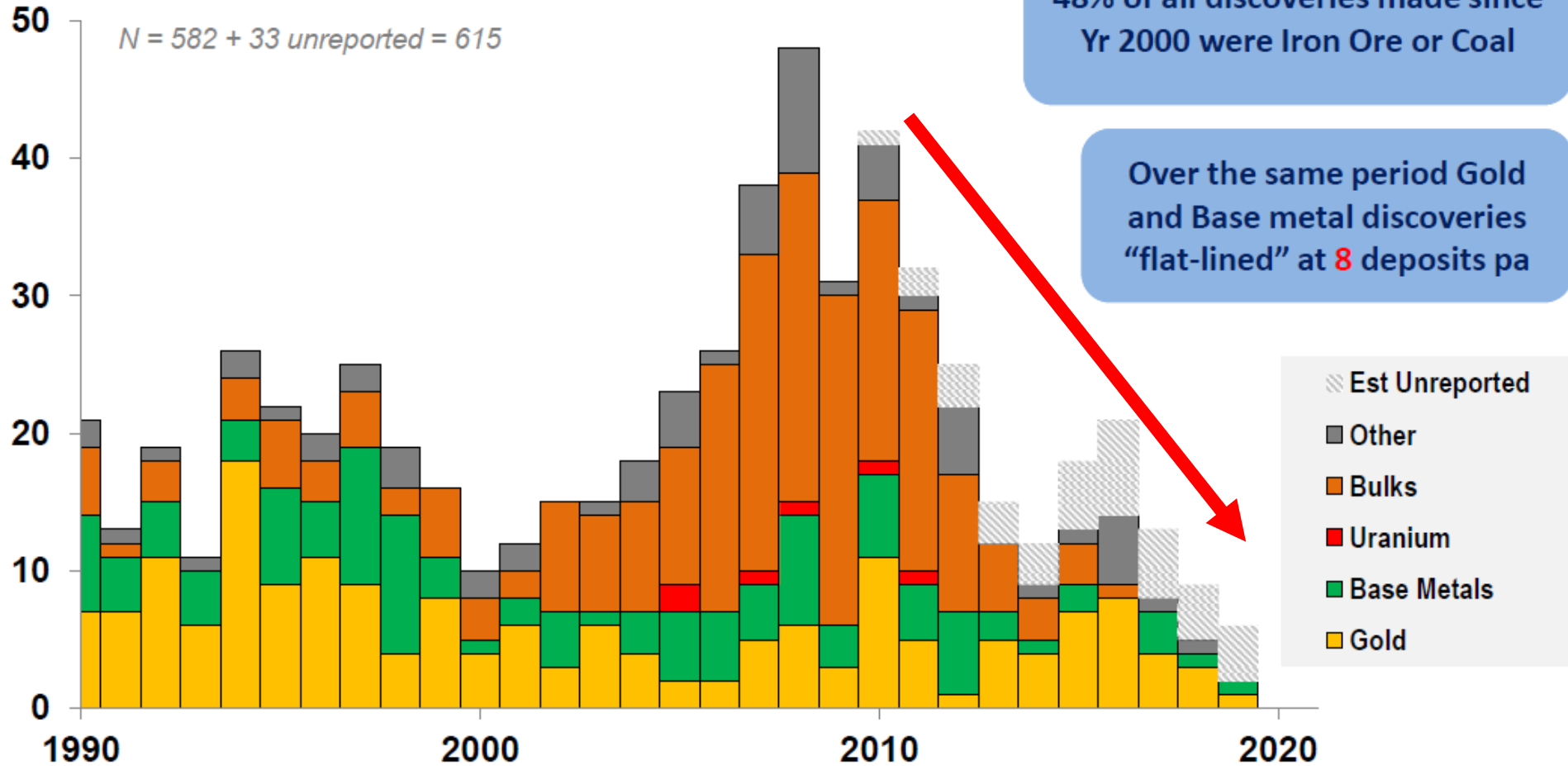
... but fell by **20%** in Q1 2020

Expenditures on gold and base metals are at a near all-time high

... but the number of discoveries is going down

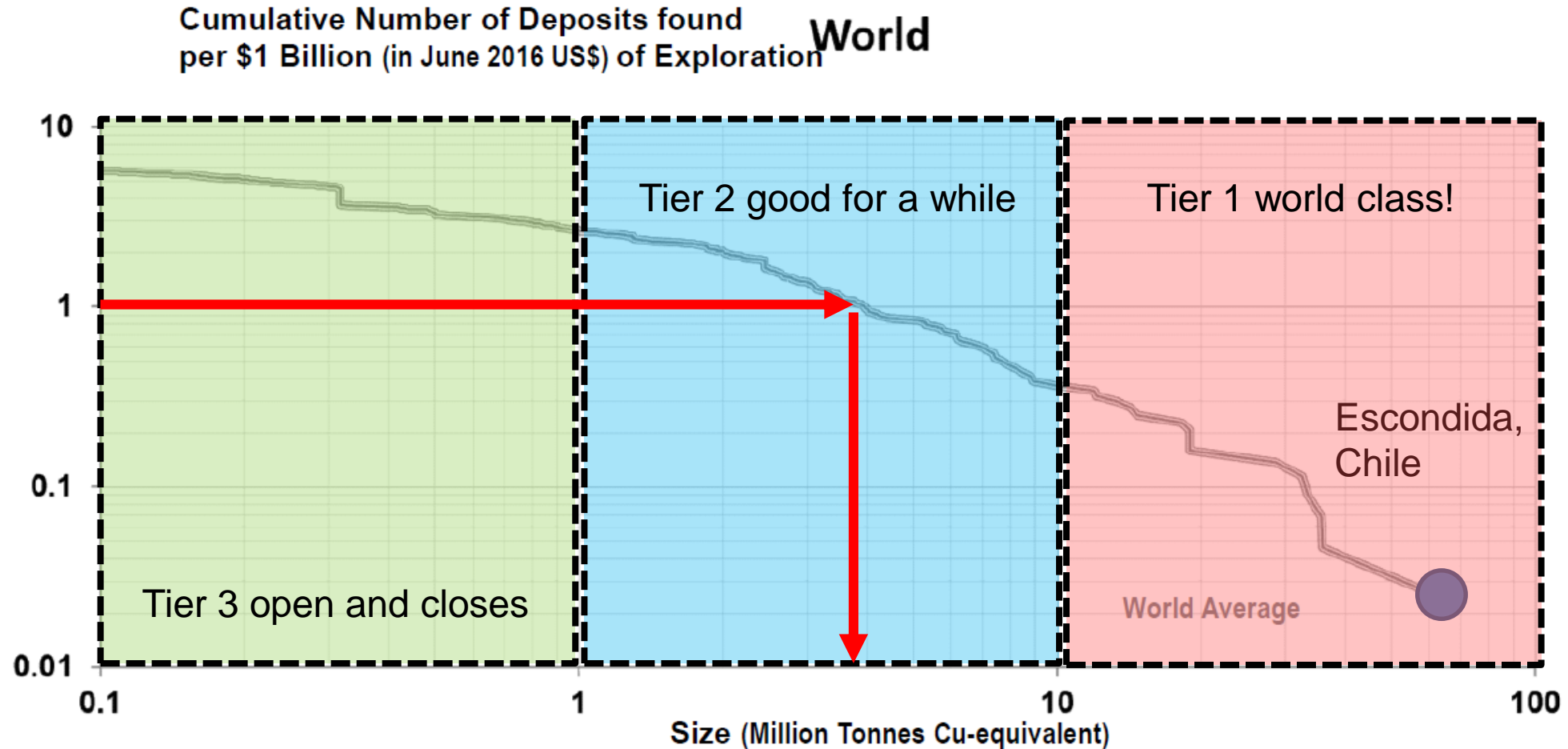
Number of significant discoveries in Australia : 1990-2019

Number of Discoveries



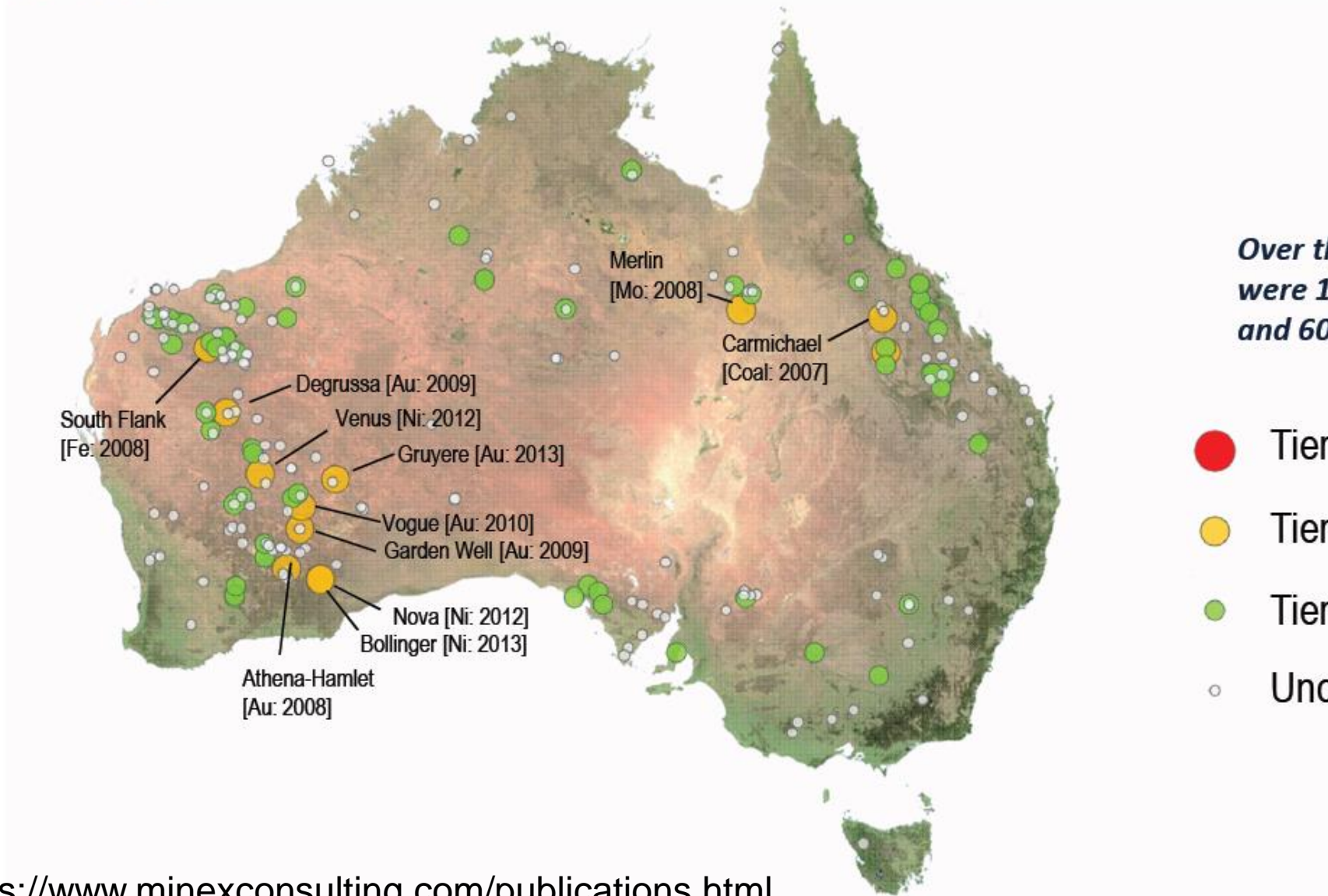
The cost of finding a given-sized copper deposit

Size-Frequency distribution of primary copper deposits discovered: 1997-2016



Discoveries by Tier : 2007-2016

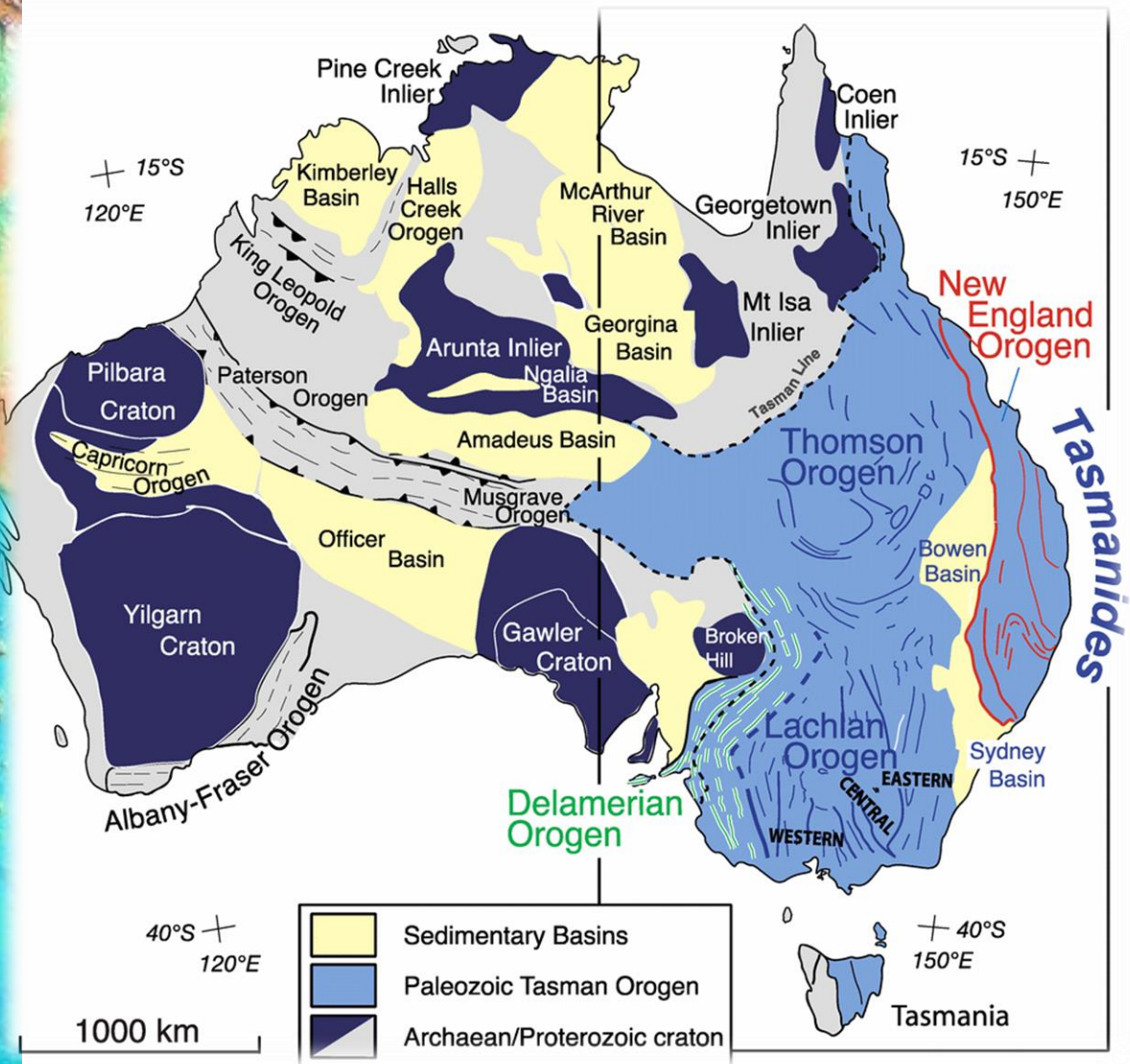
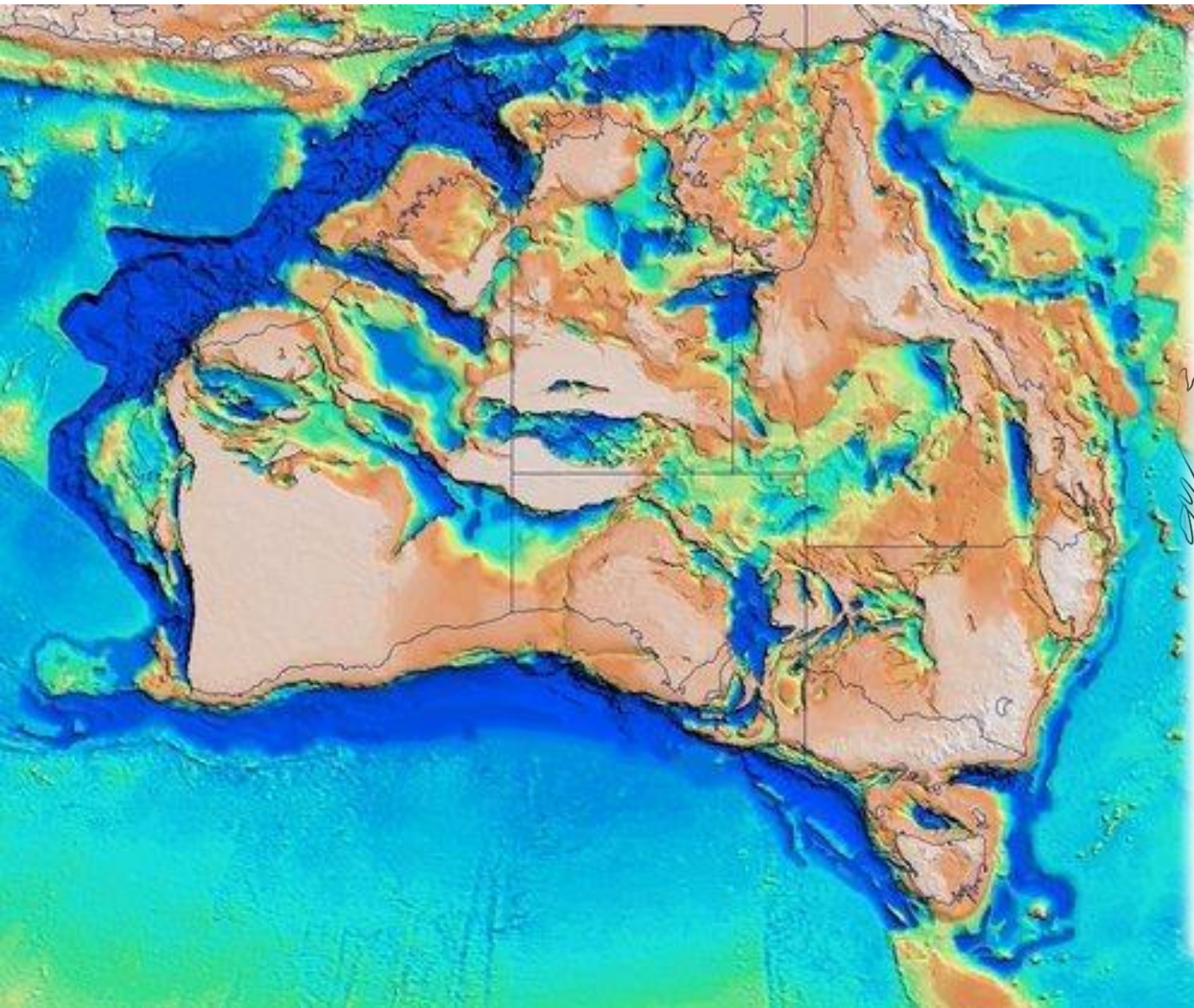
N = 226



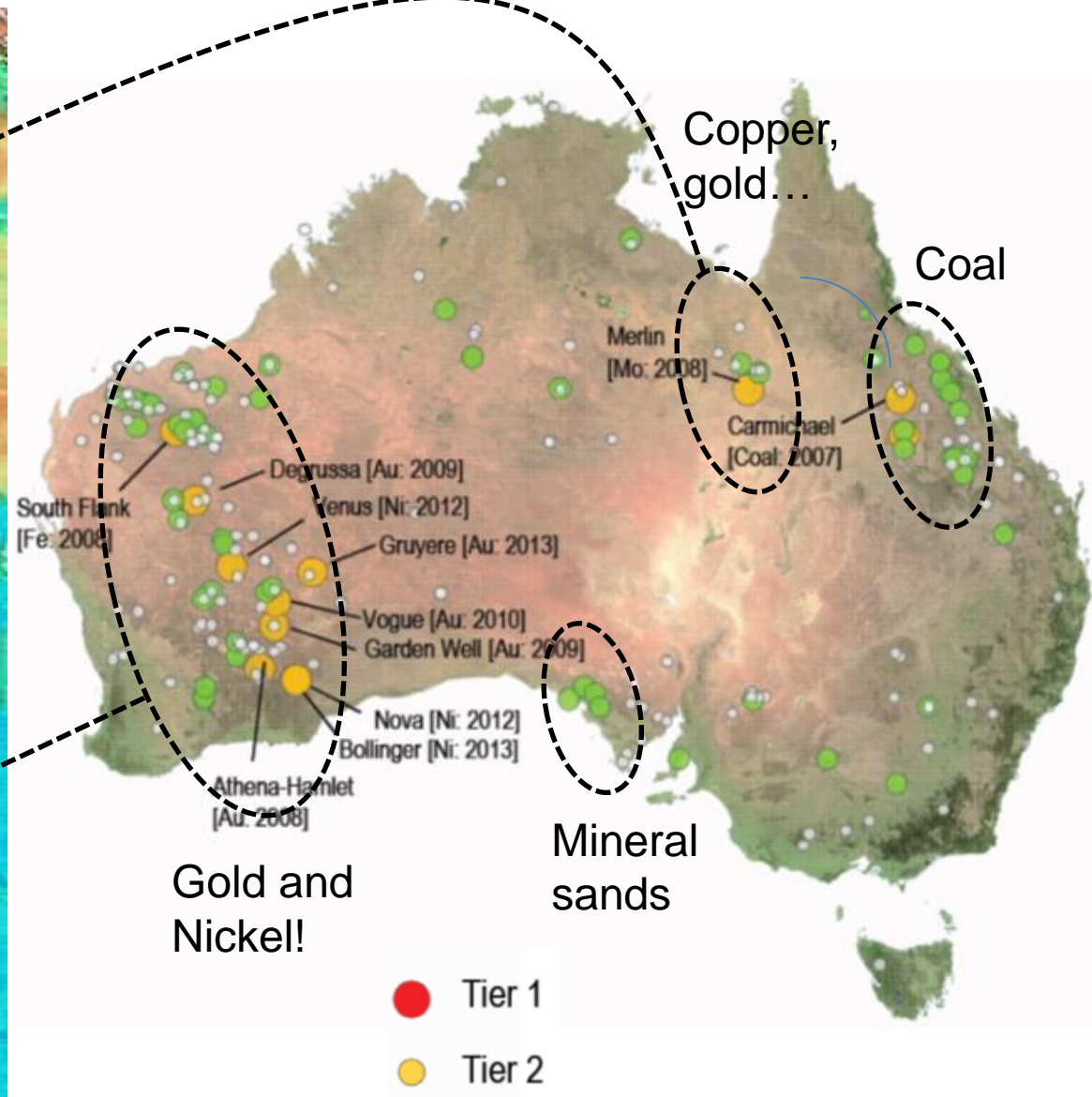
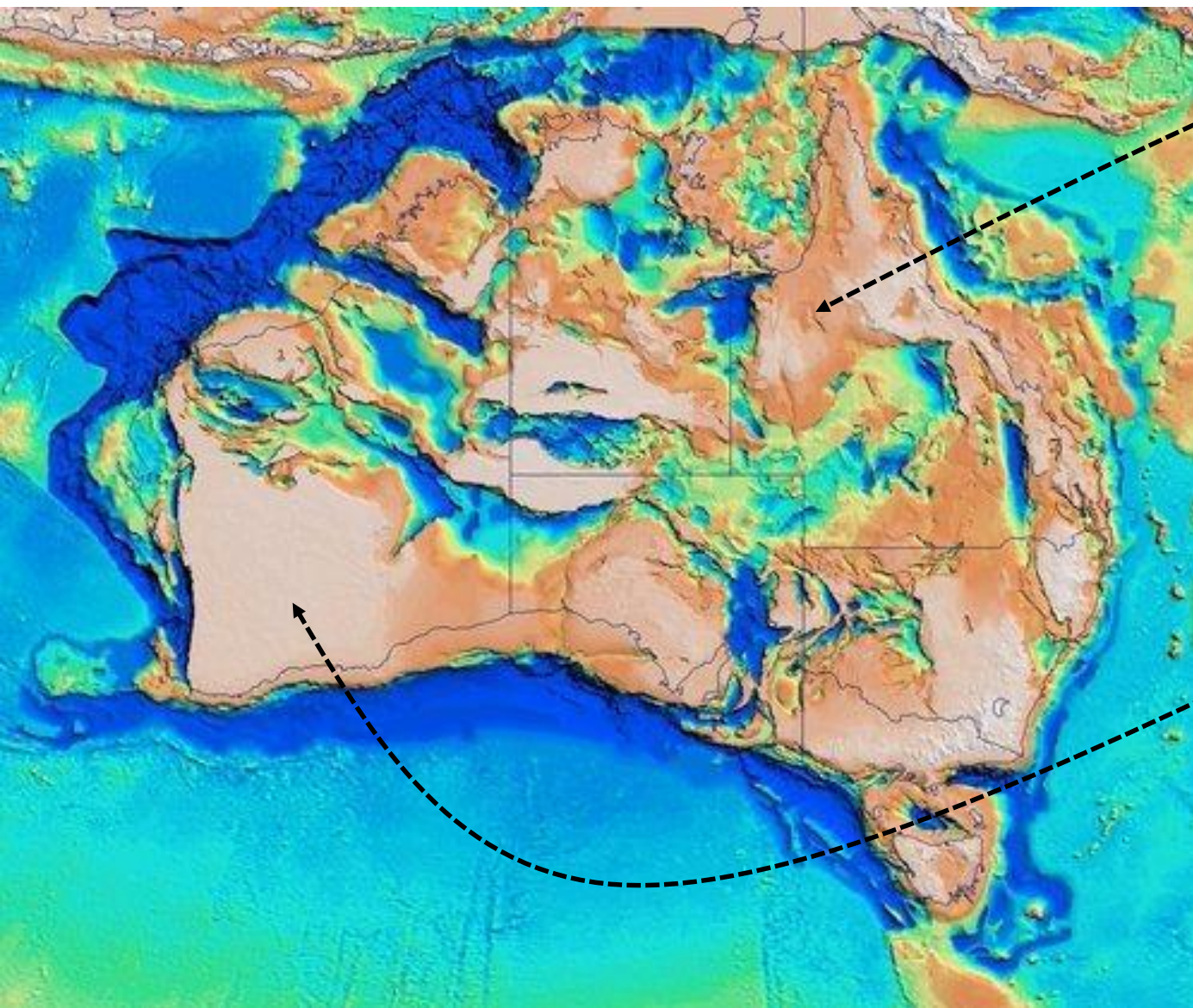
Over the same time there were 12 Tier 2 discoveries and 60 Tier 3 discoveries

- Tier 1
- Tier 2
- Tier 3
- Unclassified

Over the last decade no Tier 1 discoveries were made in Australia



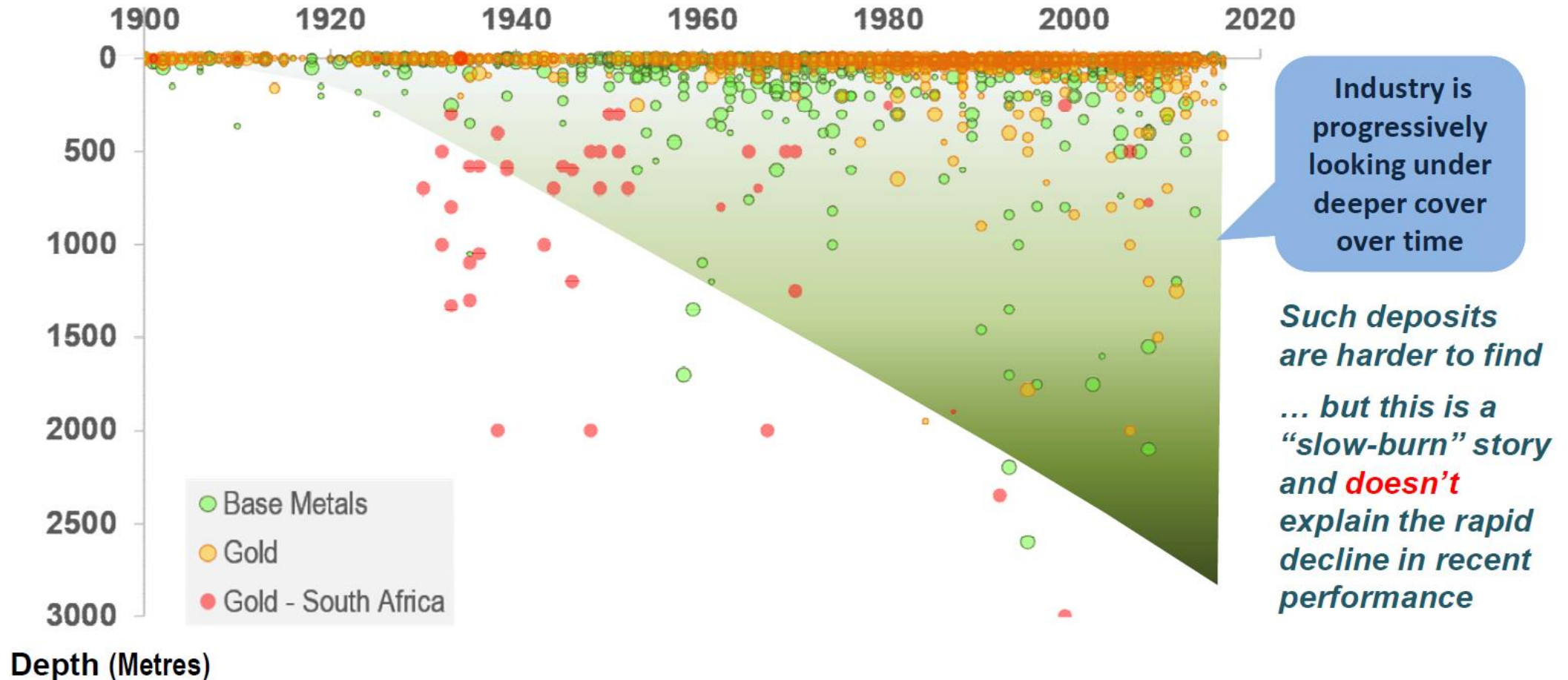
Discoveries by Tier : 2007-2016



- Tier 1
- Tier 2
- Tier 3

Depth of cover versus discovery year:

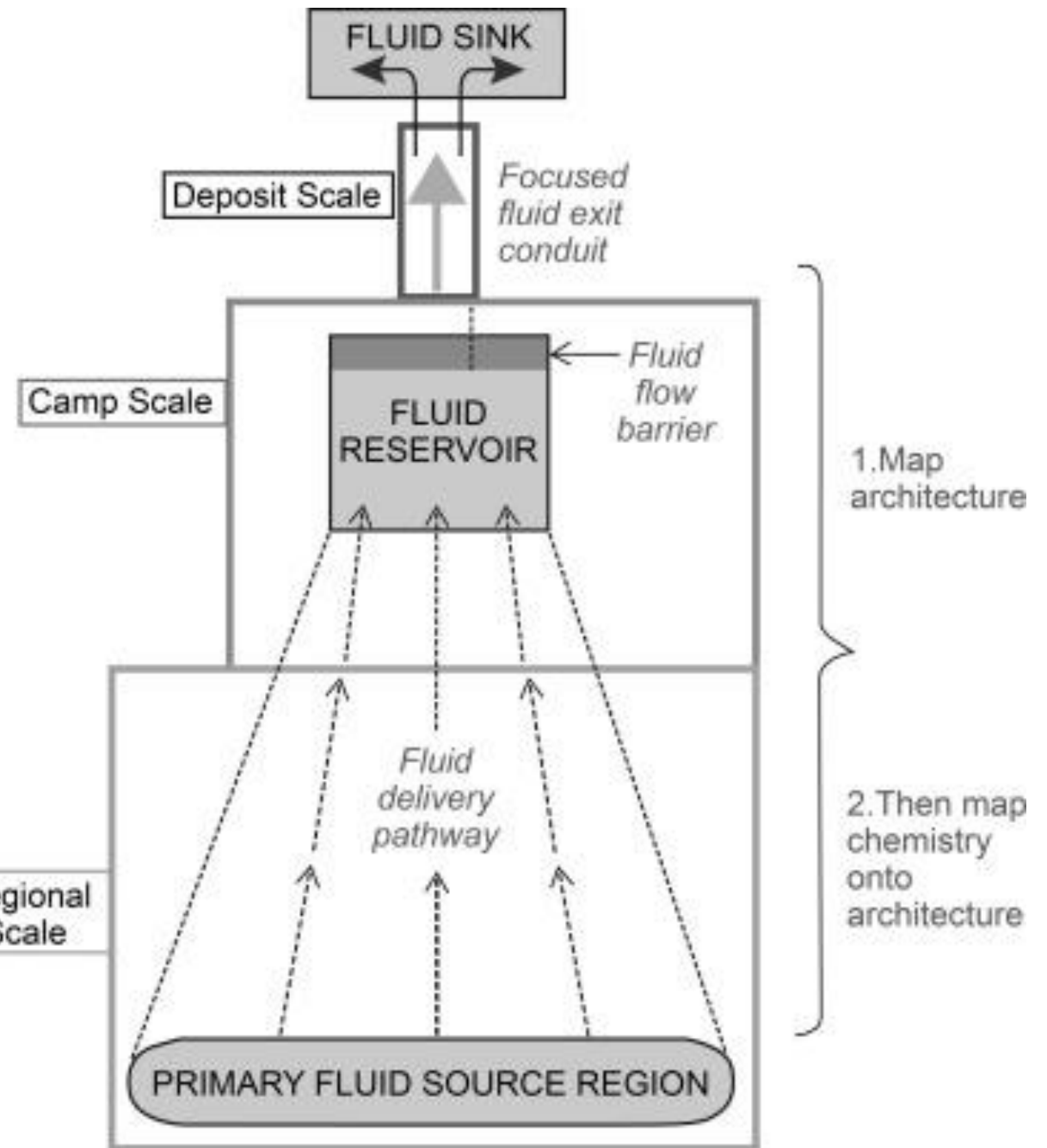
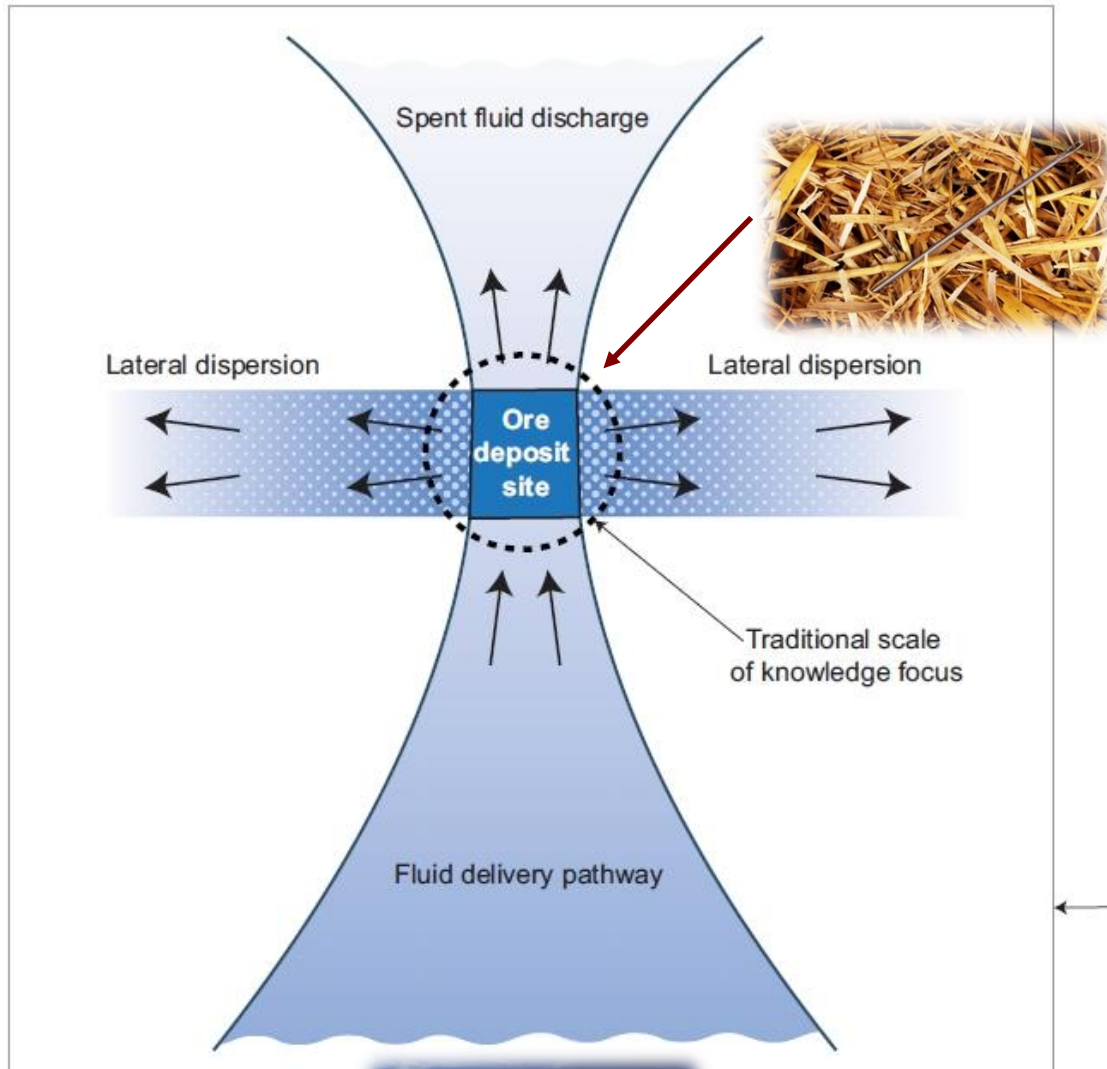
Gold and Base Metal discoveries in the World : 1900-2016



Size of the bubble refers to Moderate, Major and Giant discoveries
Analysis excludes Nickel laterites

Source: MinEx Consulting © March 2017

Needle in a Haystack....



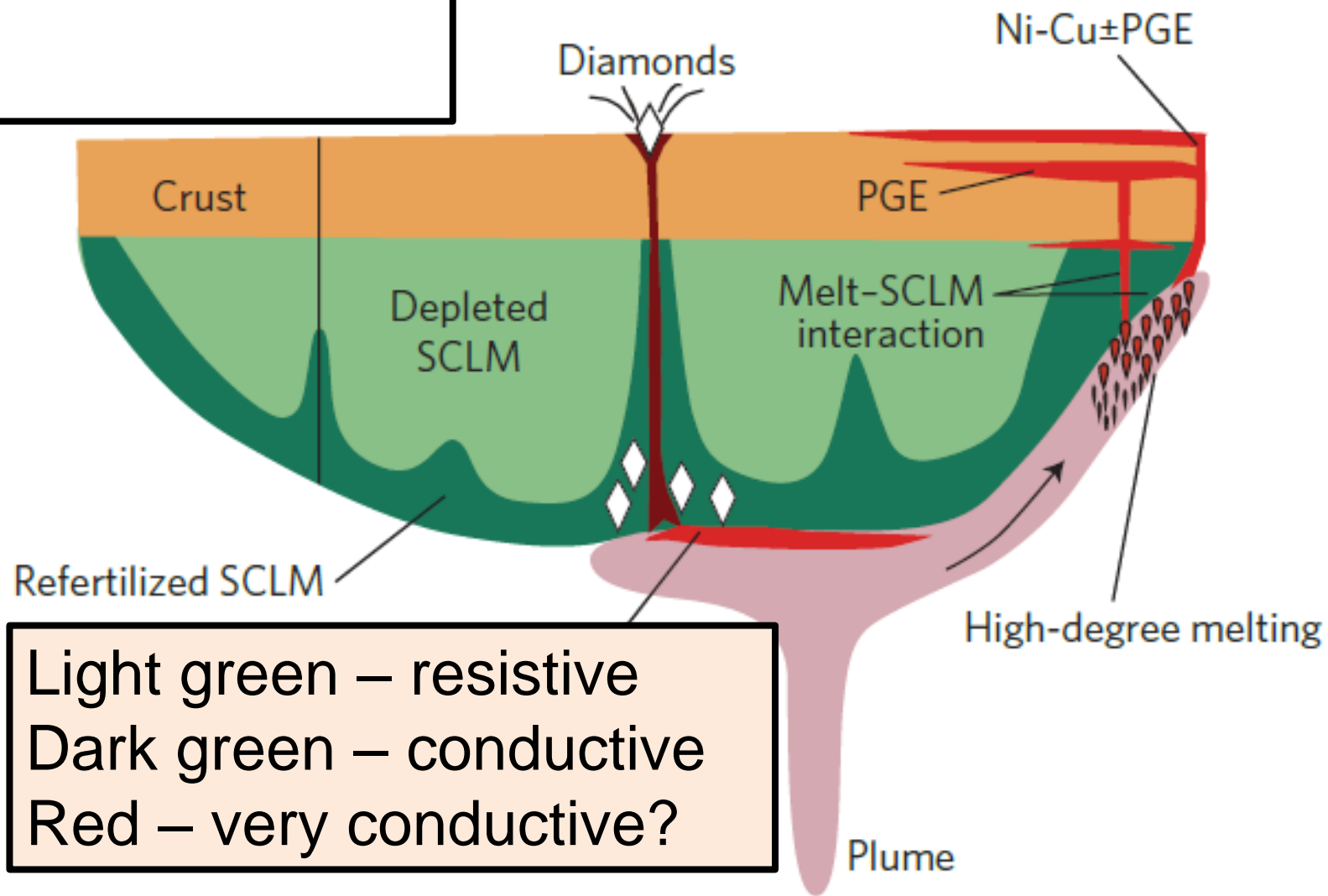
(Hronsky, 2014)

(McCuaig & Hronsky, 2014)

Continental-root control on the genesis of magmatic ore deposits

W. L. Griffin^{1*}, G. C. Begg^{1,2} and Suzanne Y. O'Reilly¹

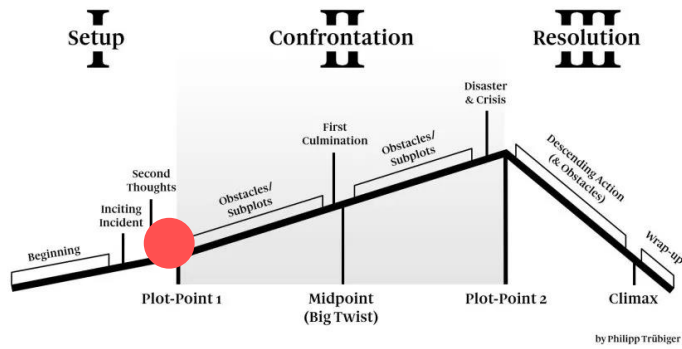
*“..we argue that the sub-continental lithospheric mantle may actually contain ore-forming elements that could be entrained by ascending magmas....We therefore suggest that models for ore genesis and exploration **need to incorporate the entire lithosphere to be effective**”*



Maybe we need to find the haystack first...

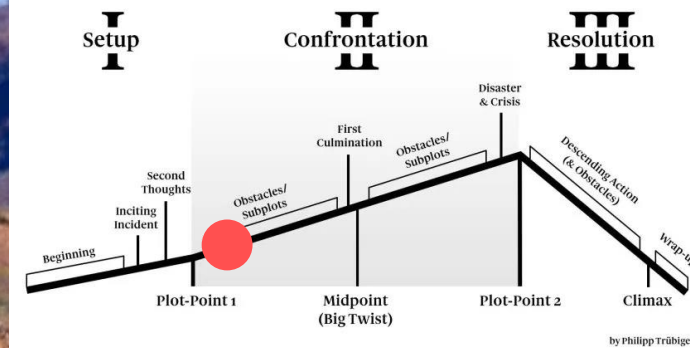


Three-Act Structure



Act II

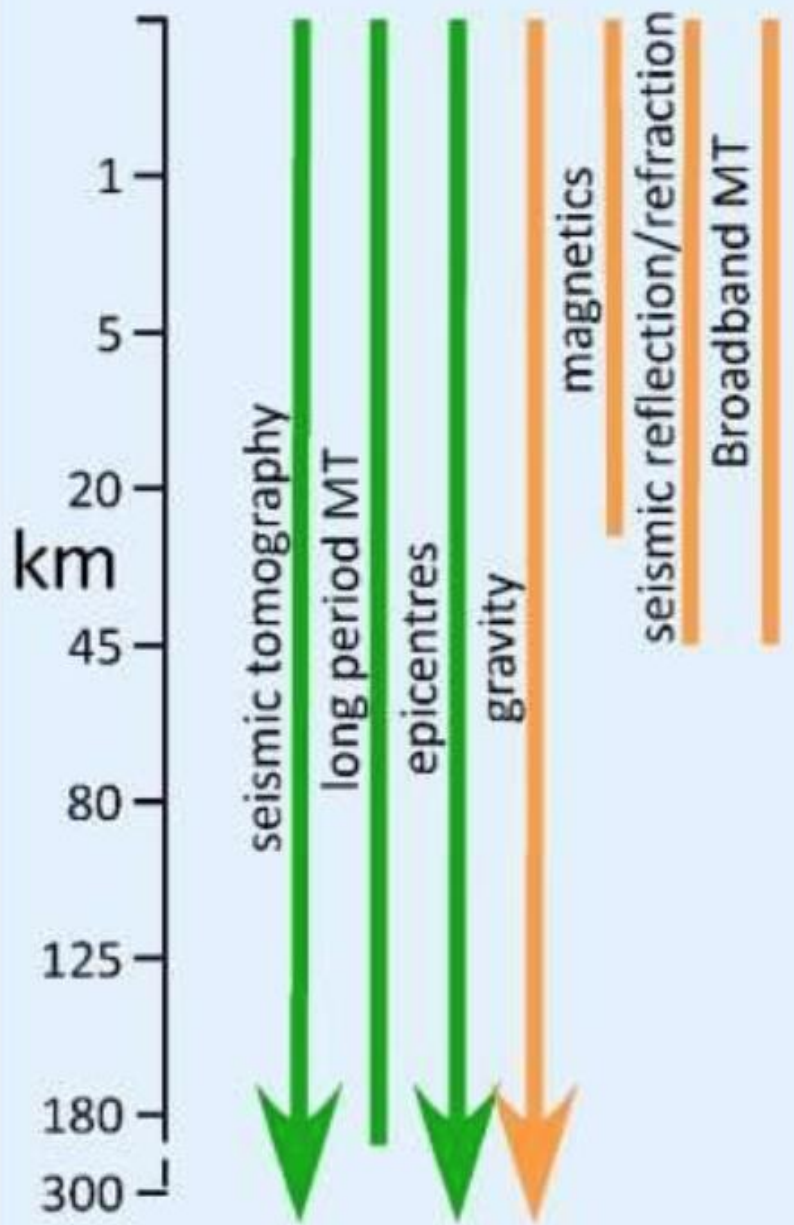
Three-Act Structure



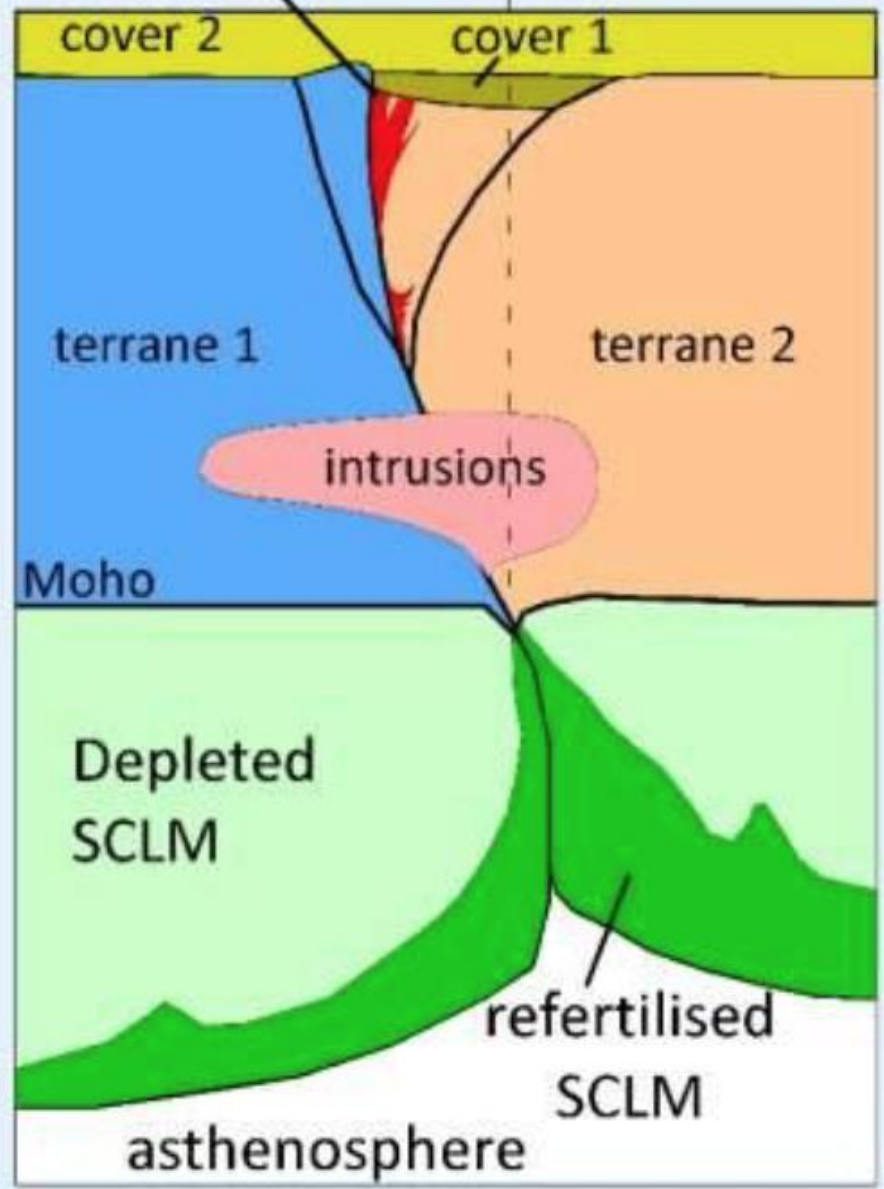
Confrontation

Photo: Jarred Lloyd

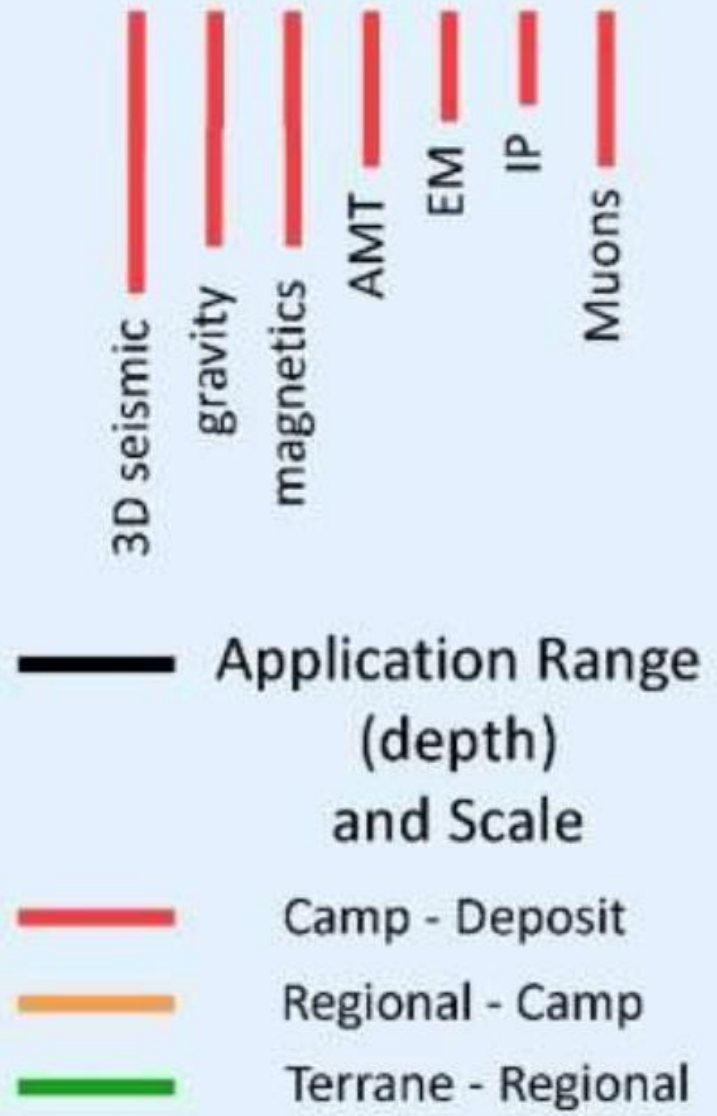
Architecture



mineralisation <40km



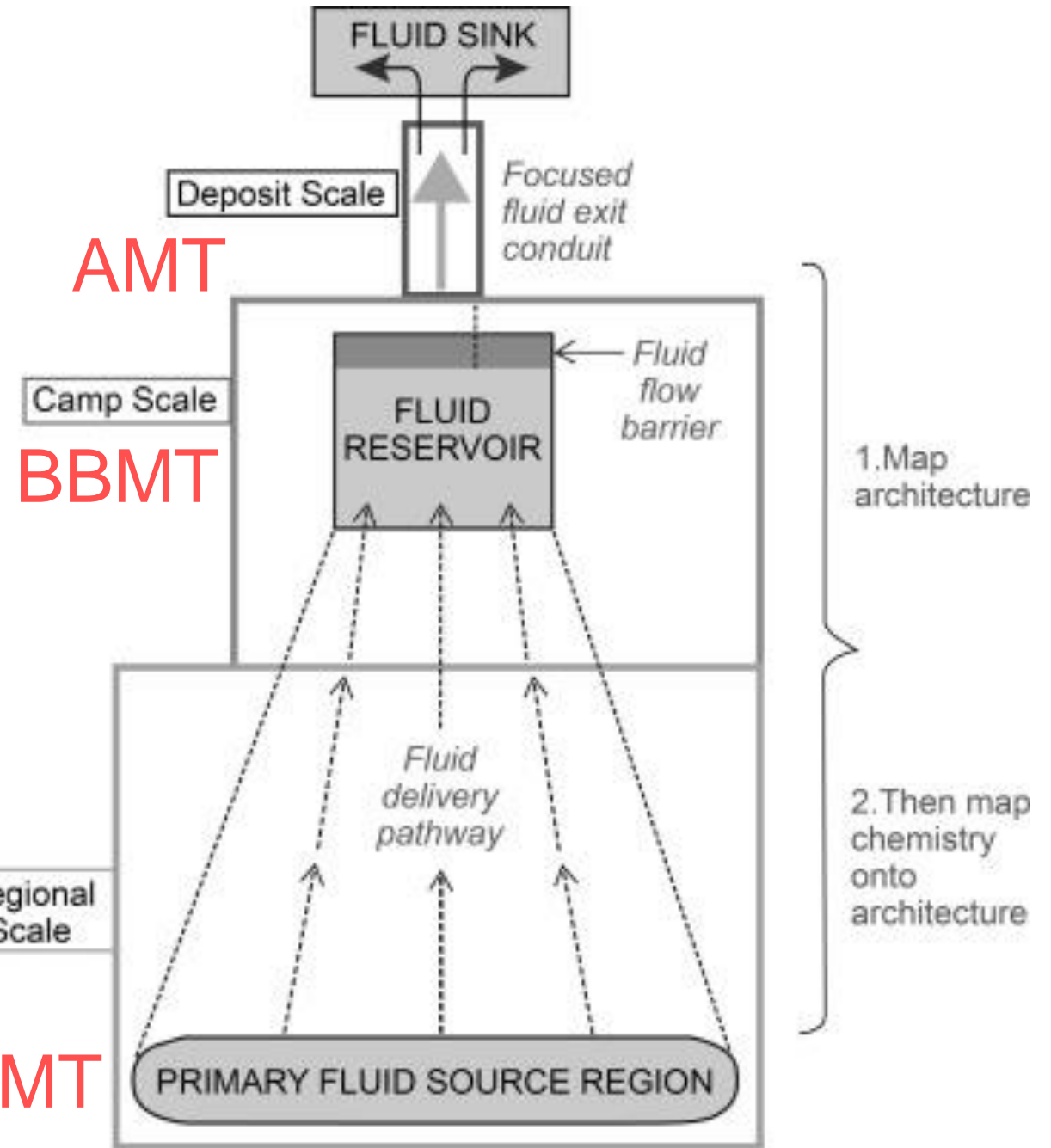
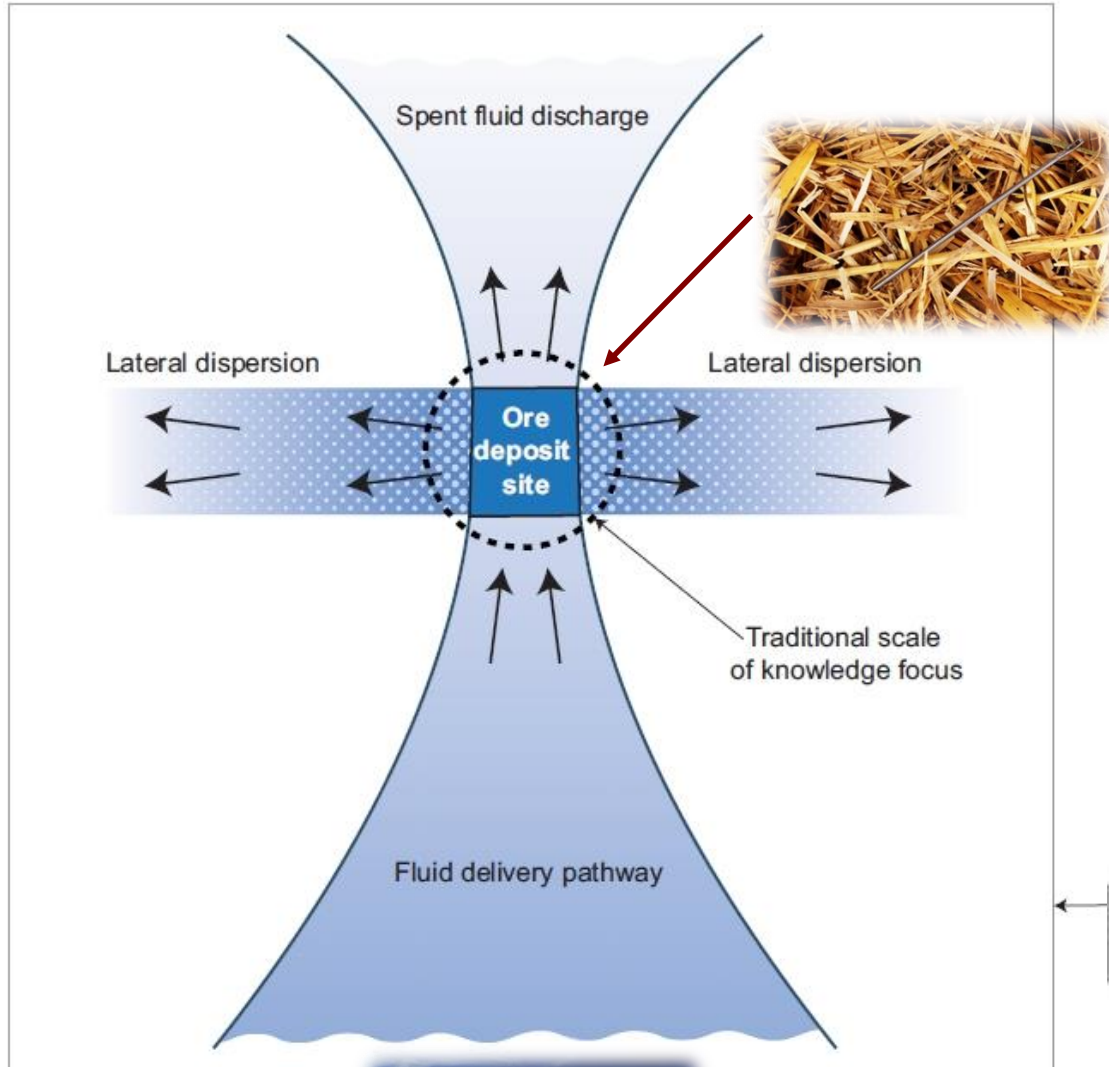
Detection



Not to Scale

(Begg, 2015)

Needle in a Haystack....



AMT

BBMT

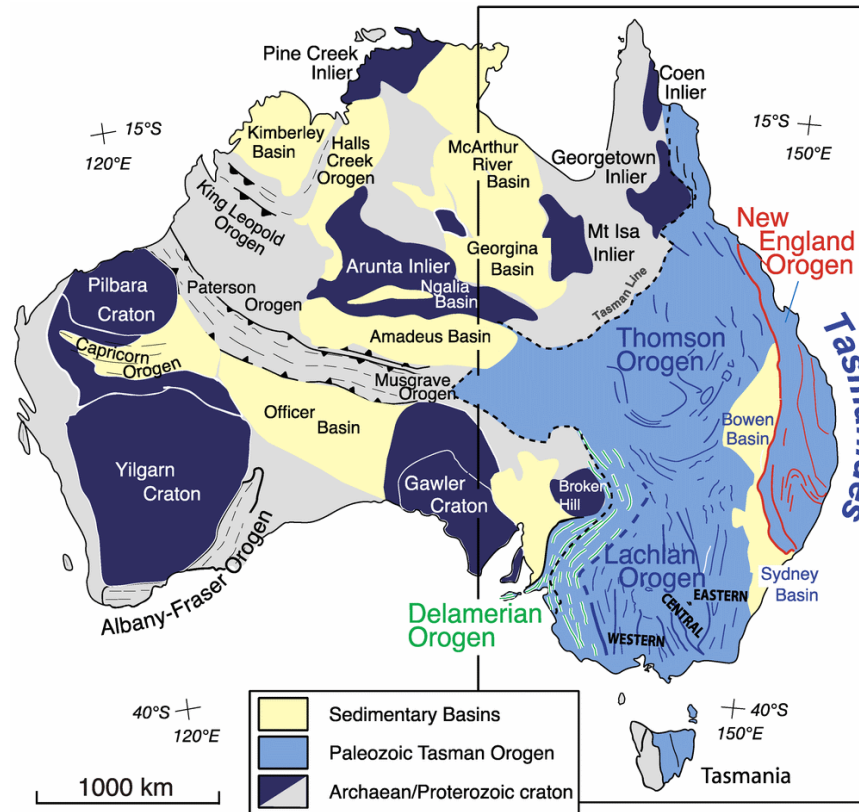
LPMT

(Hronsky, 2014)

(McCuaig & Hronsky, 2014)

AusLAMP – Australian Lithospheric Architecture Magnetotelluric Project

Program to map the Australian lithosphere 20 – 200 km depth
~55 km sites (0.5°)
Long-period MT three-week deployments
~3000 sites! (12 years!)



(Foster and Goscombe, 2013)

Progress as of 2020!

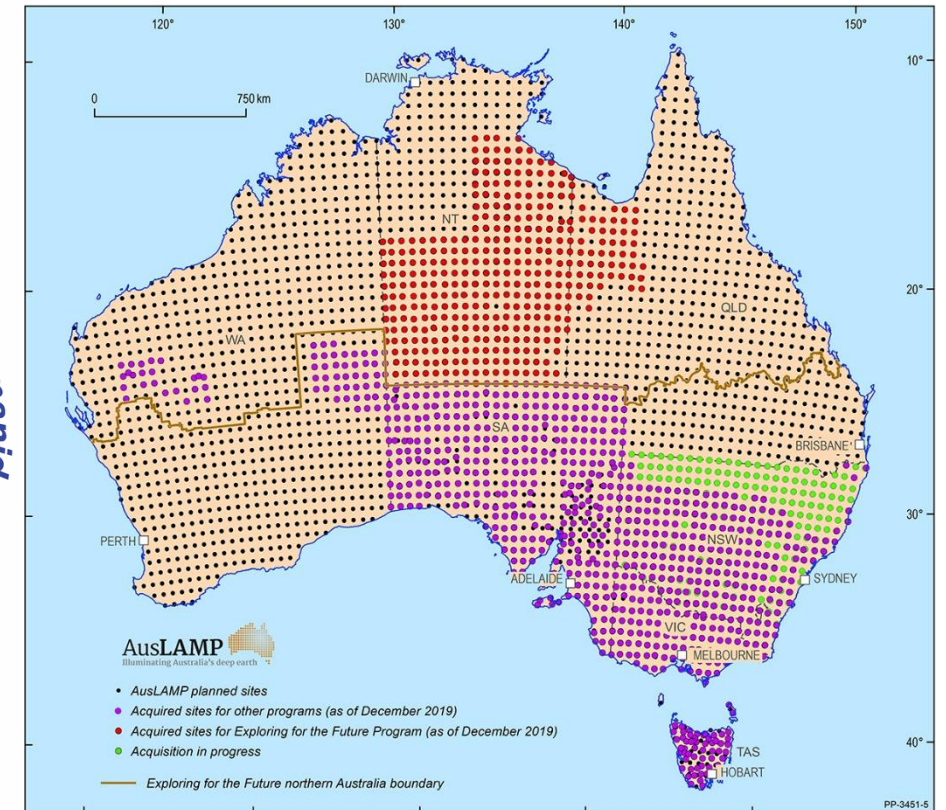
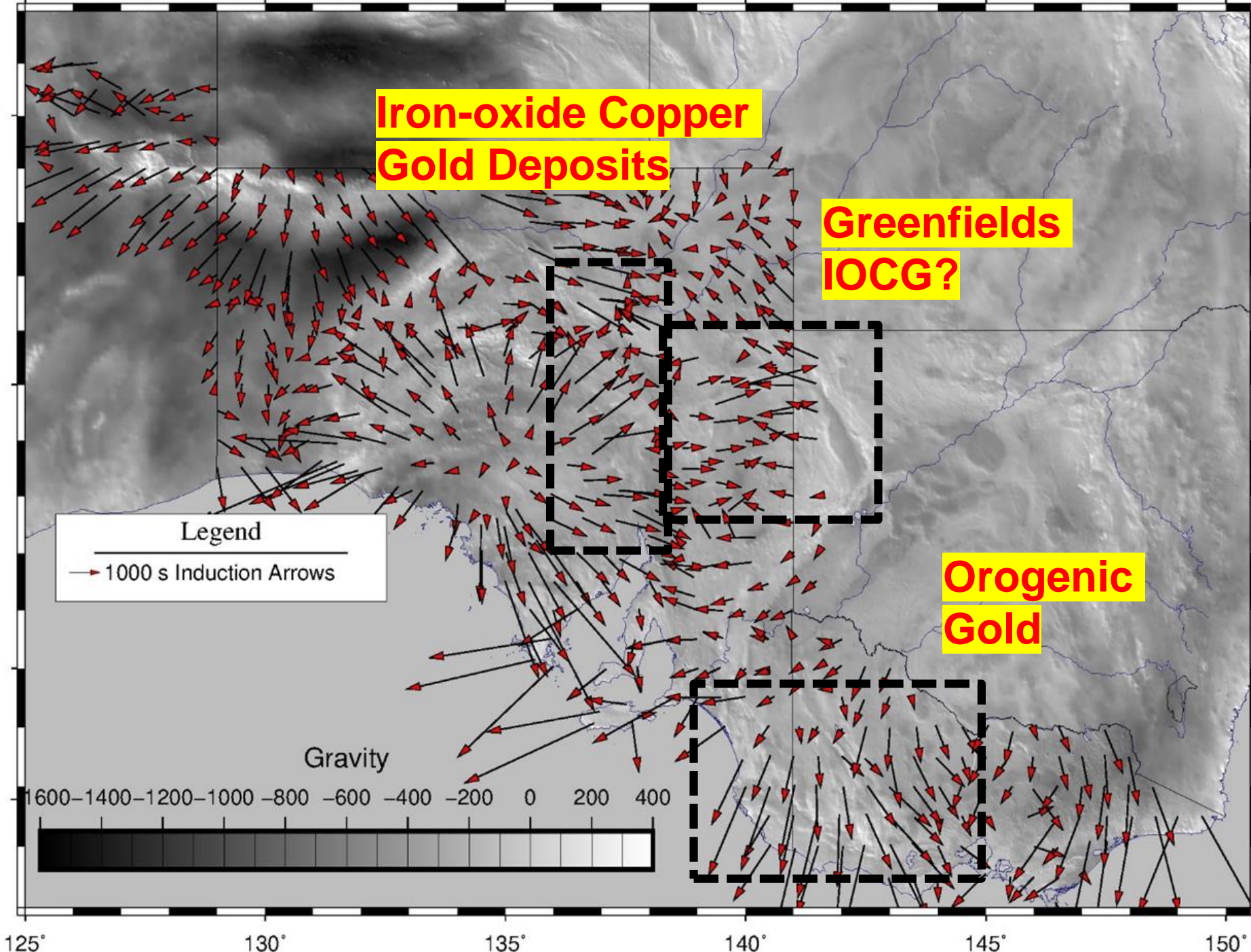


Image: Geoscience Australia

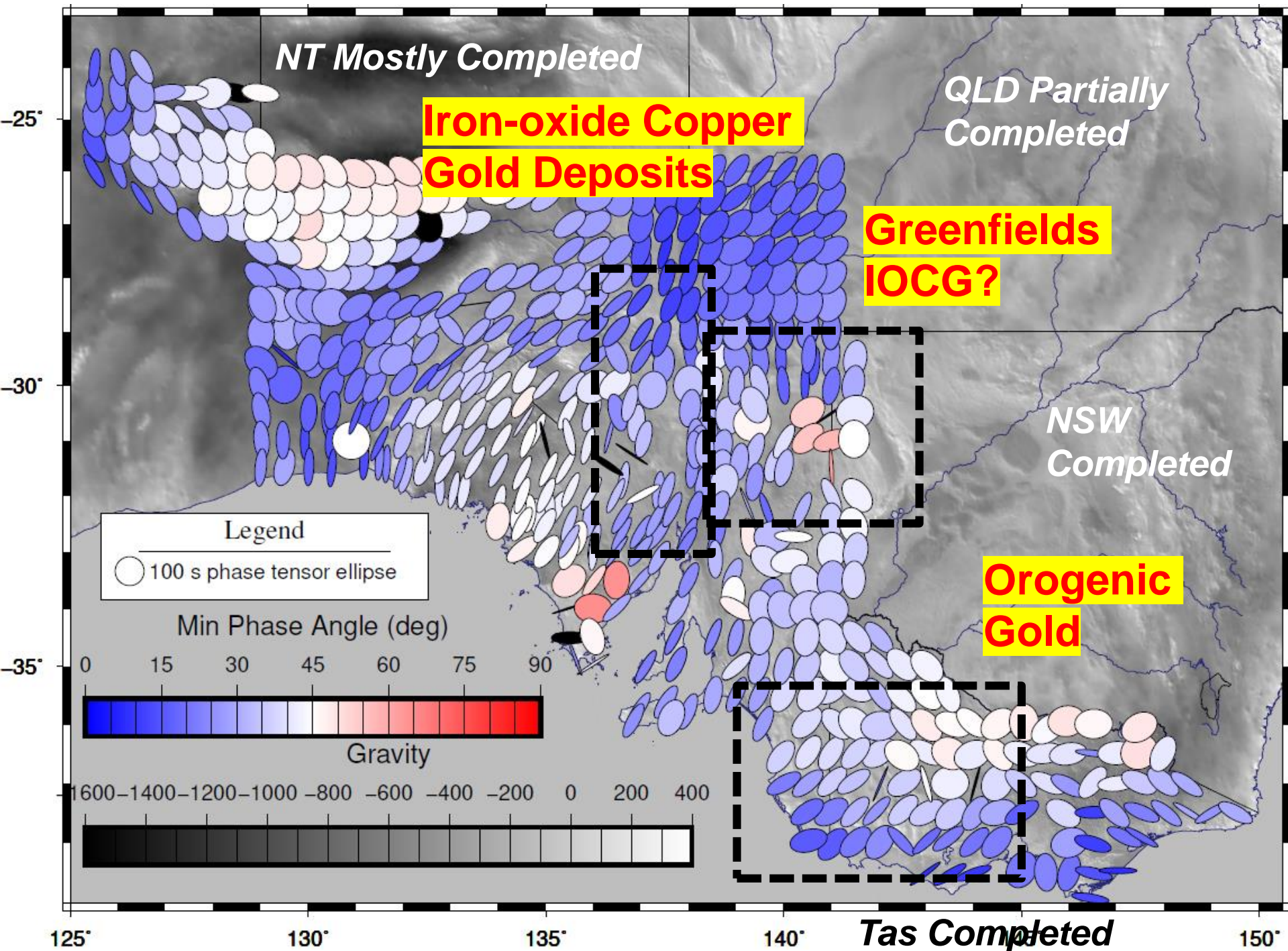


Induction arrows

Point away from resistive regions and towards conductive regions.

Length of arrow ~ magnitude of resistivity gradient

(Image: Kate Robertson)



Phase tensors

Ellipticity is a measure of electric current density orientation

Circular – ~1D
 Ellipse – 2D or 3D

Colour infill shows change of resistivity with depth

Blue – more resistive with depth

Red – more conductive with depth

(Image: Kate Robertson)

Sub plot: Long-Period MT arrays

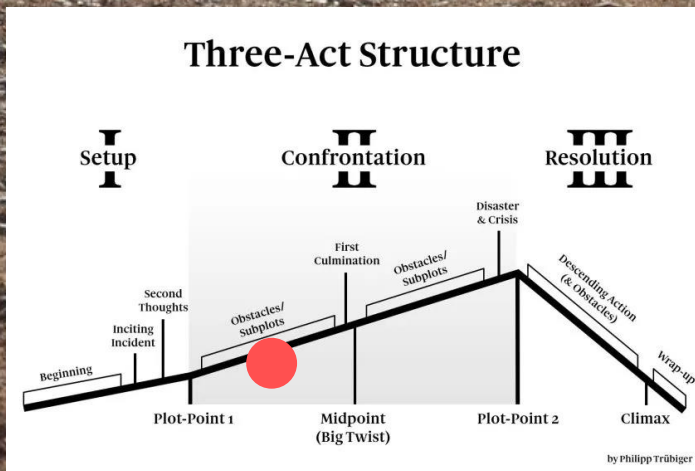
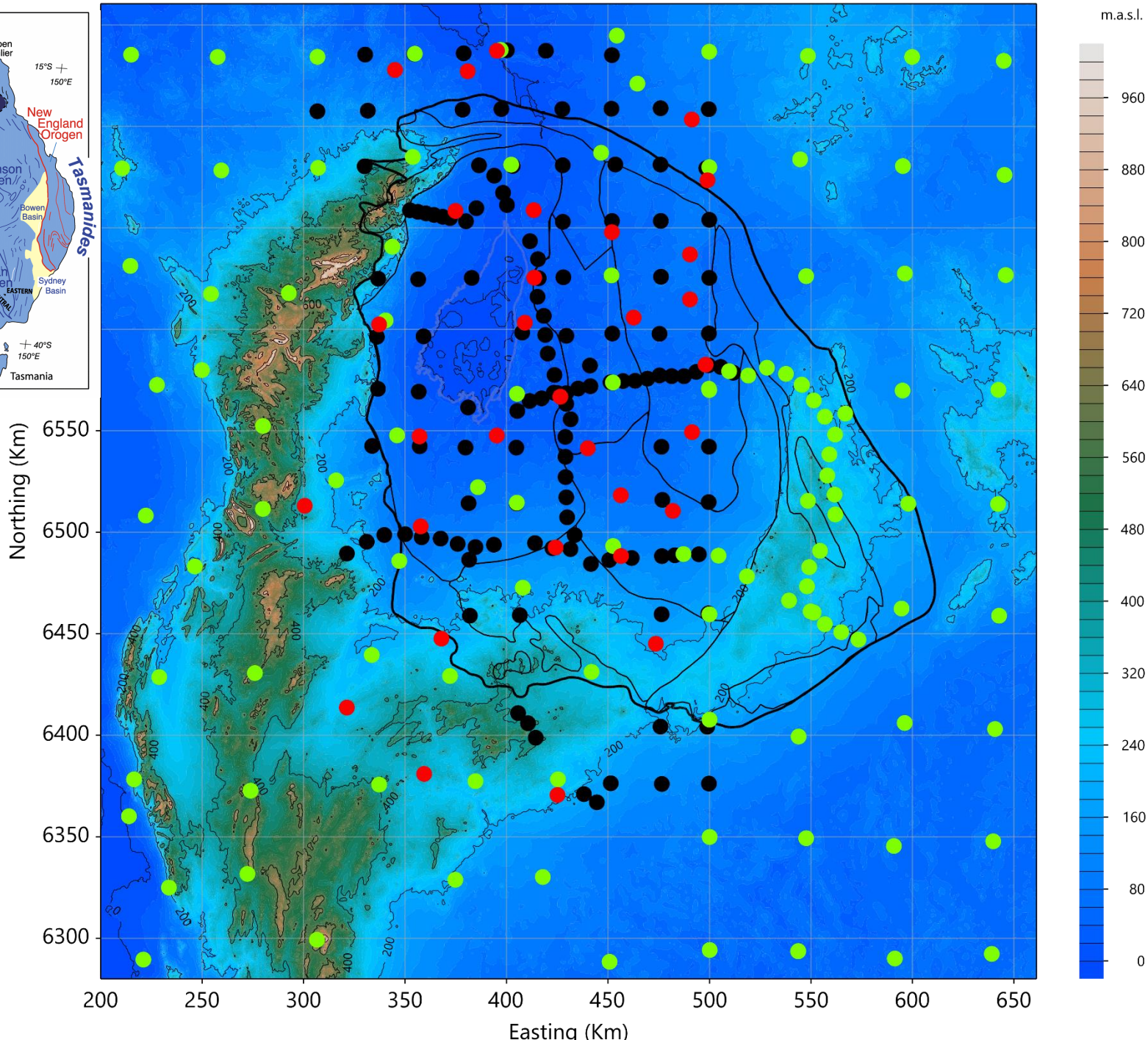
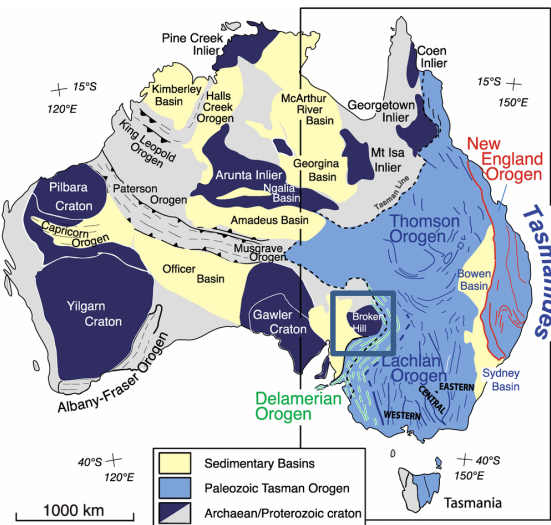
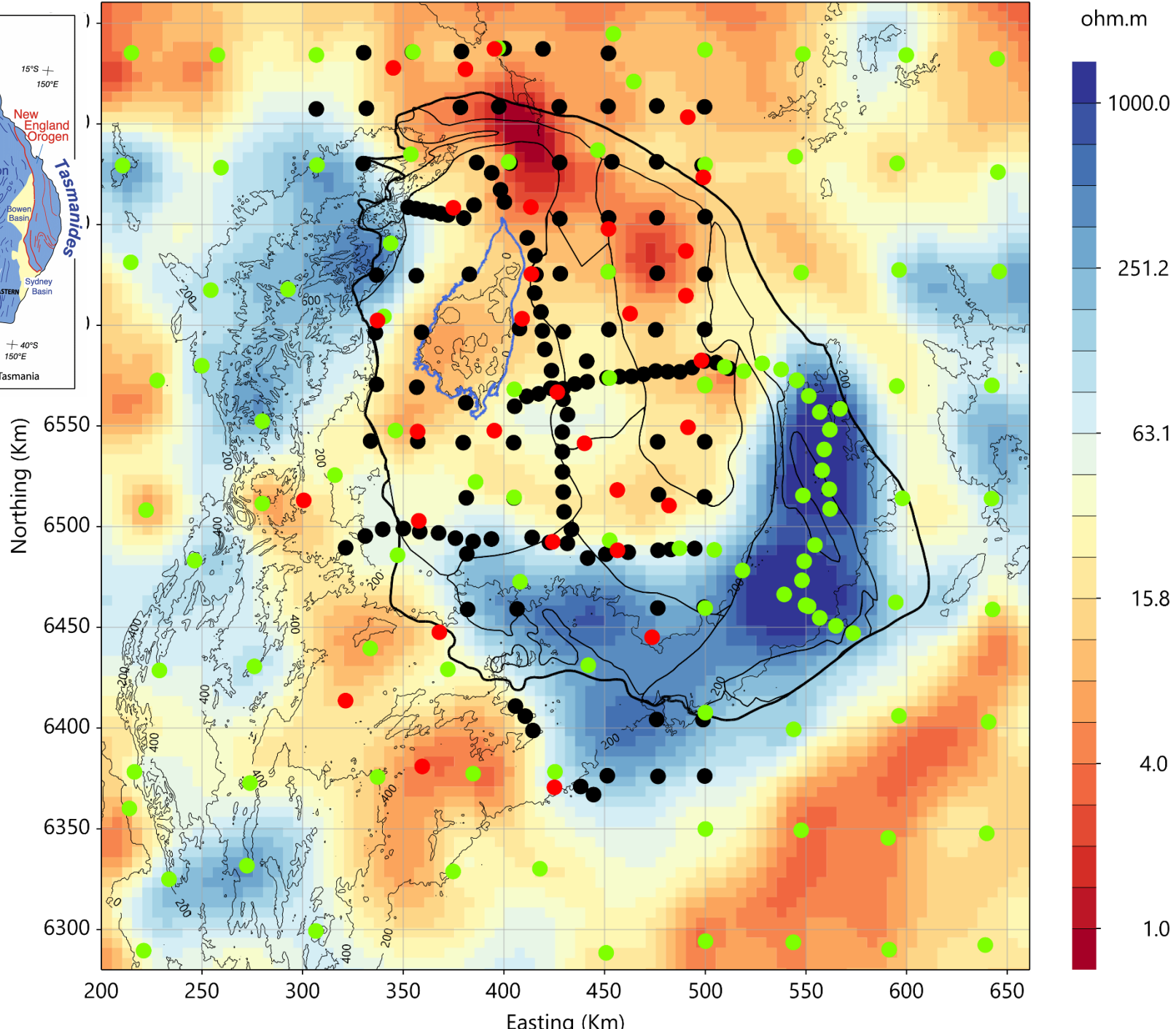
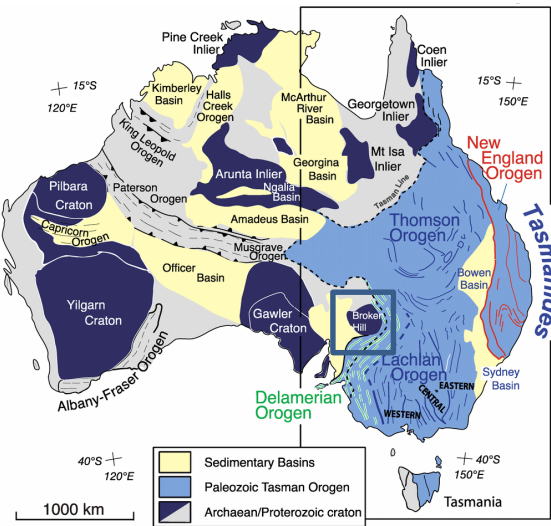


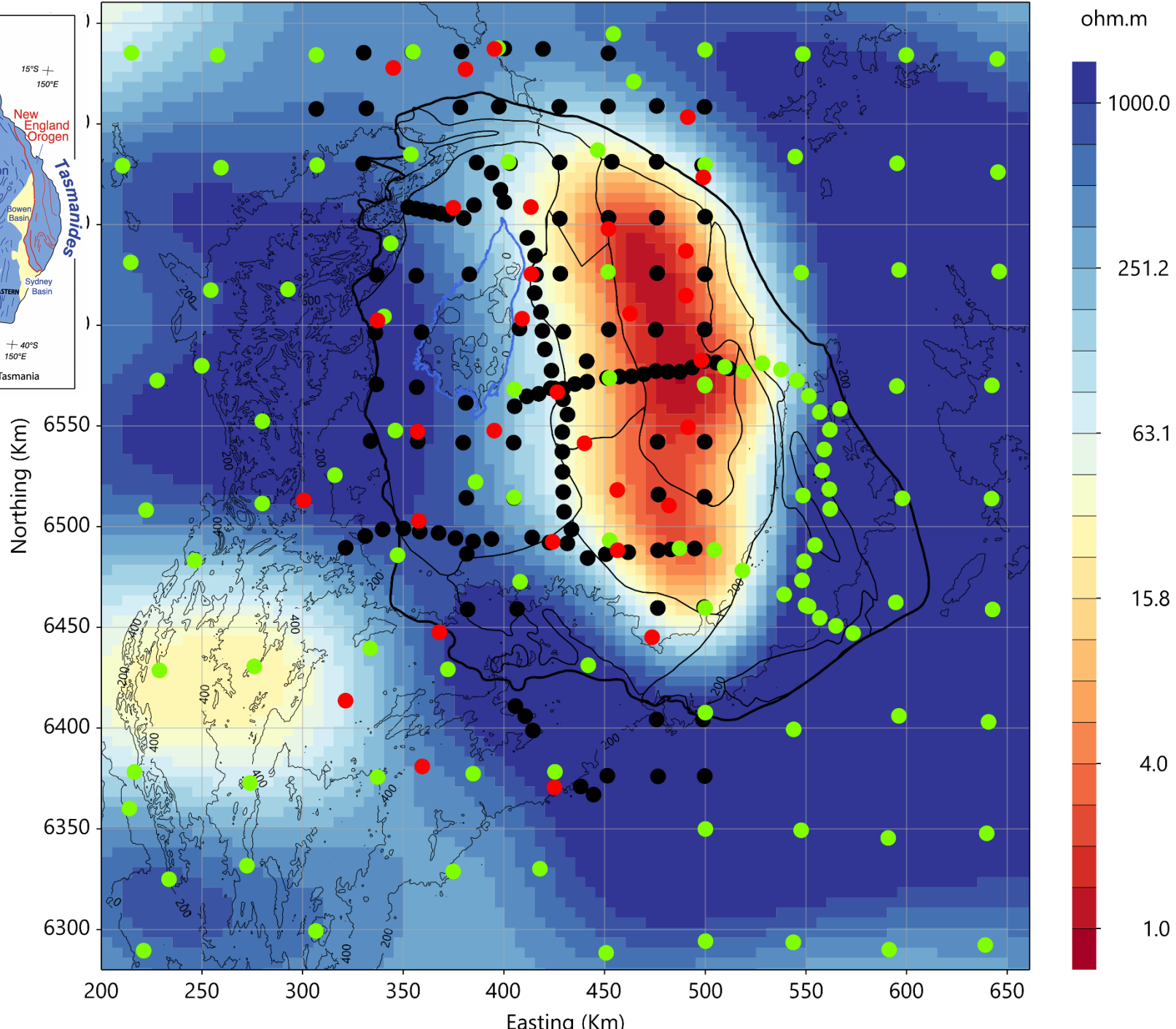
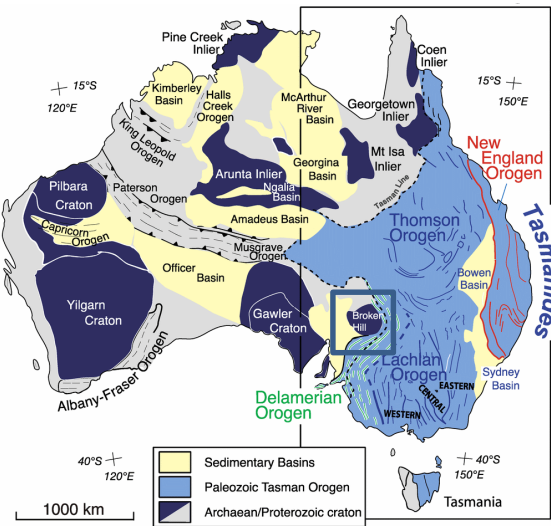
Photo: Jarred Lloyd

MT Sites and topography

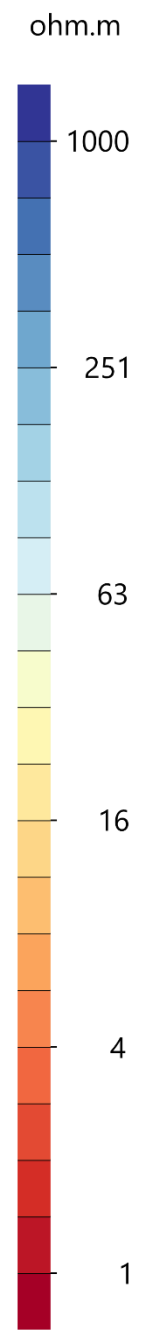
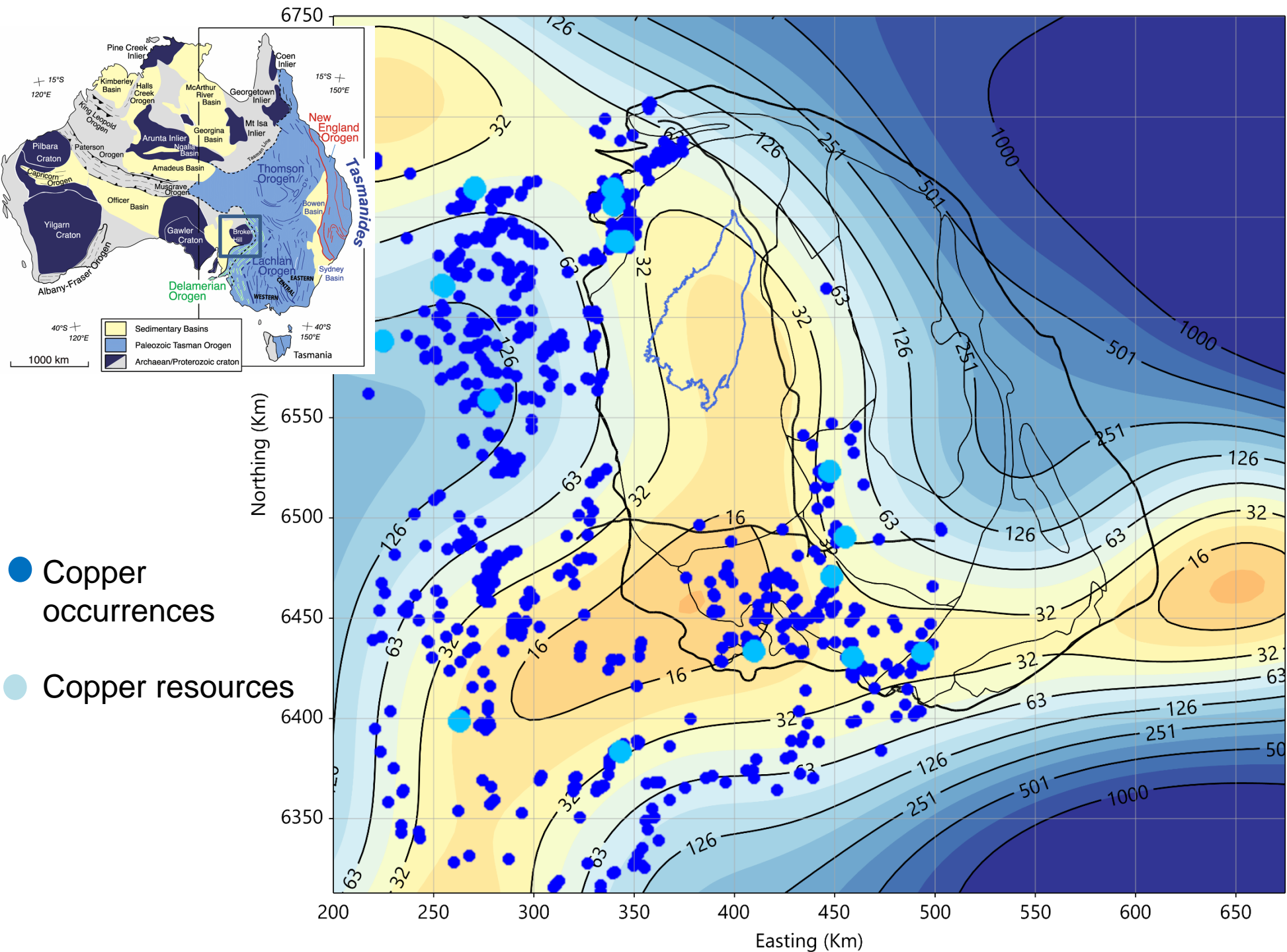




1000 m below sea level

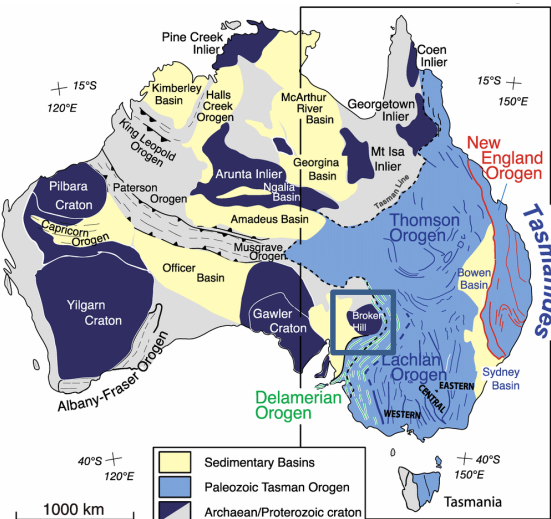


10 km below sea level

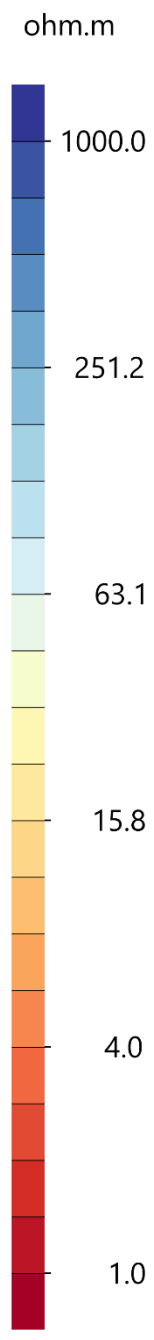
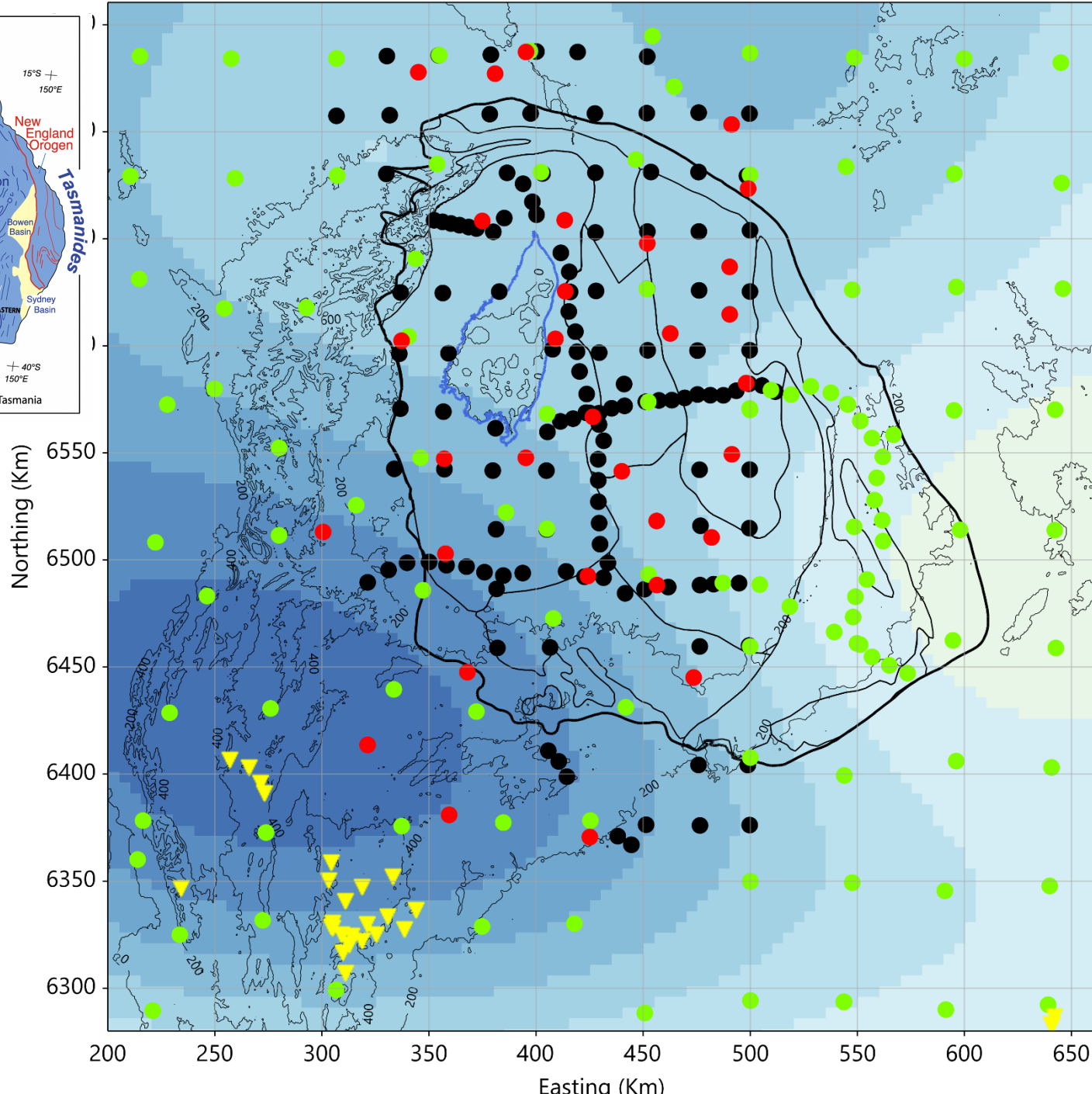


30 km below sea level

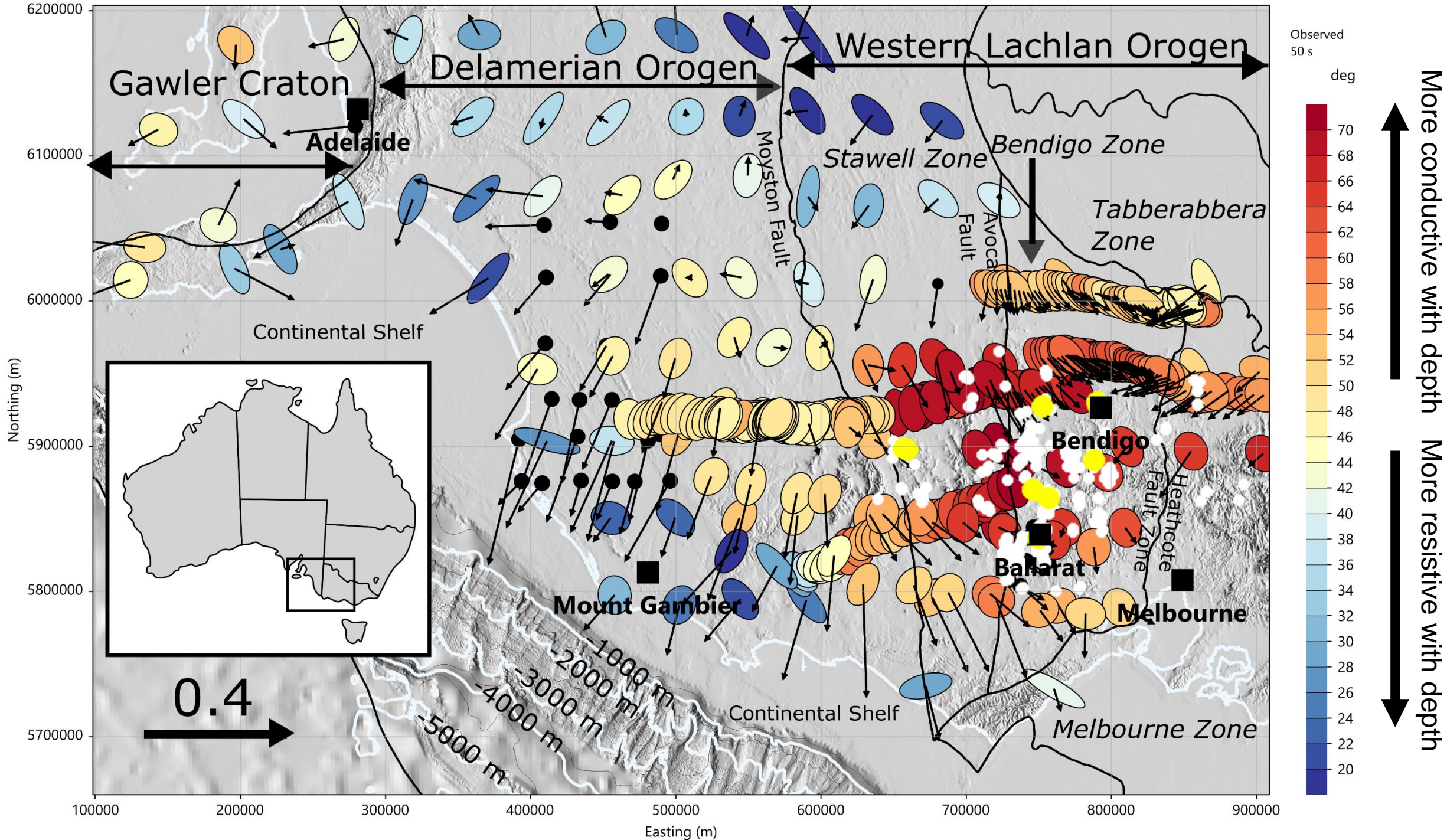
- Copper occurrences
- Copper resources

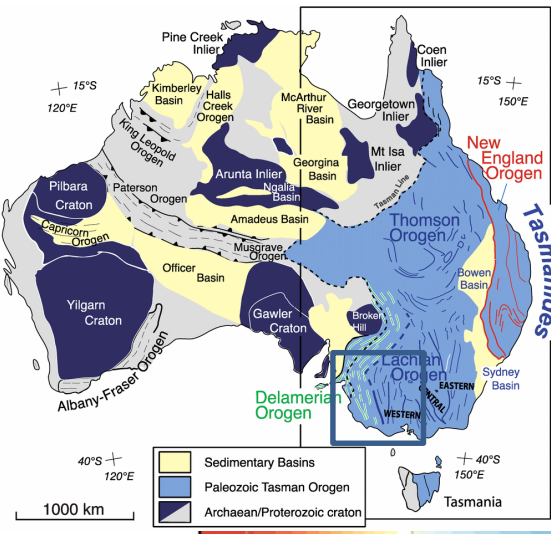


 Diamonds

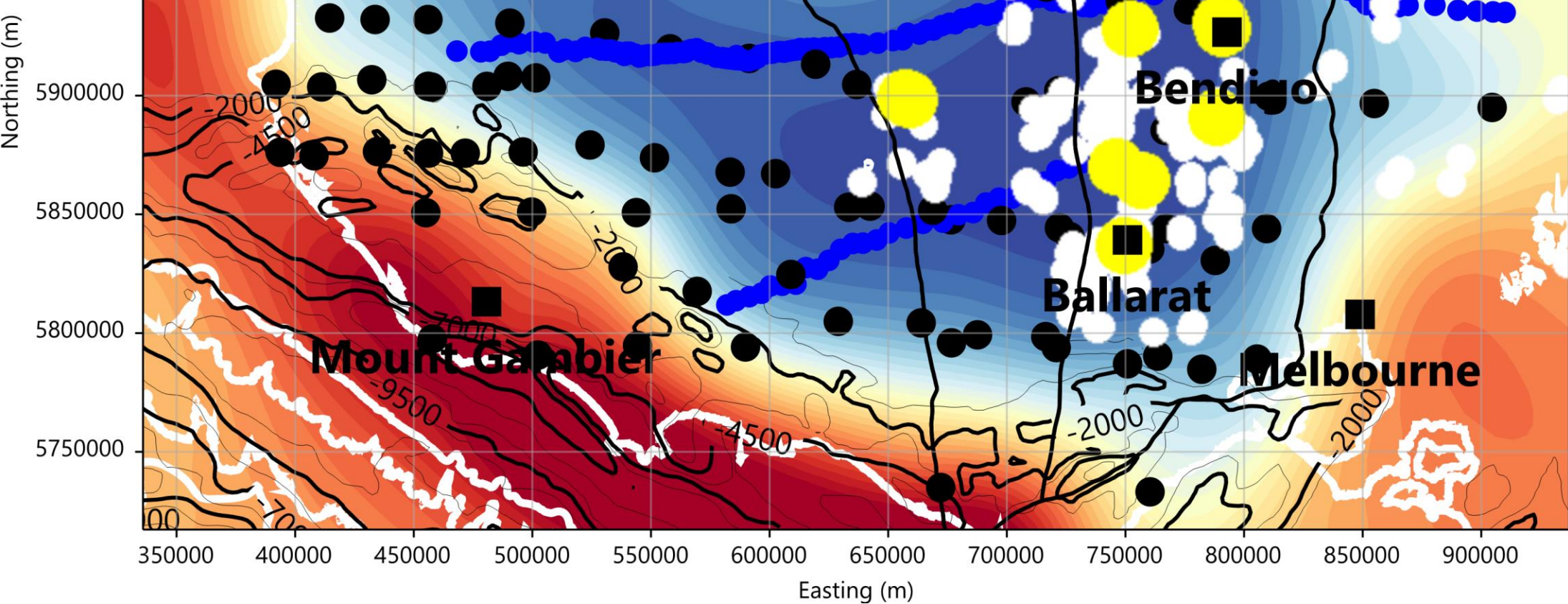
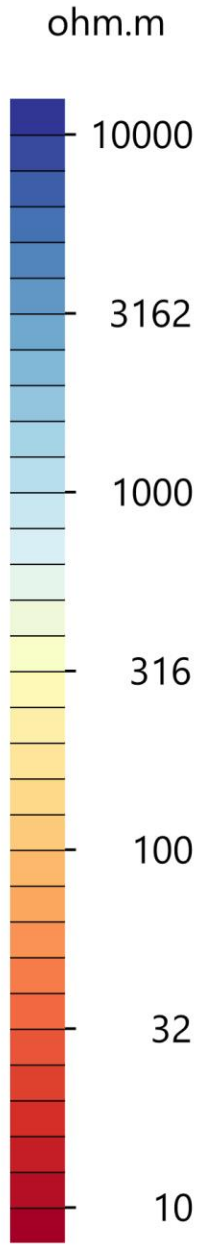


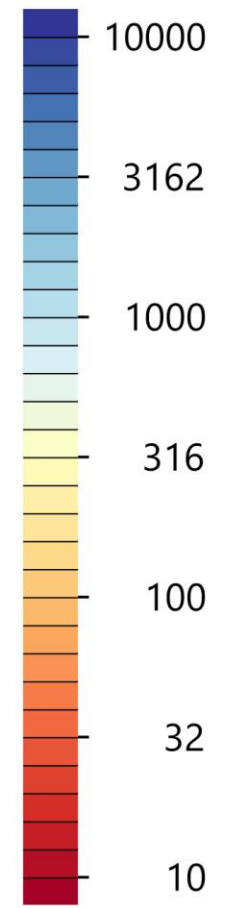
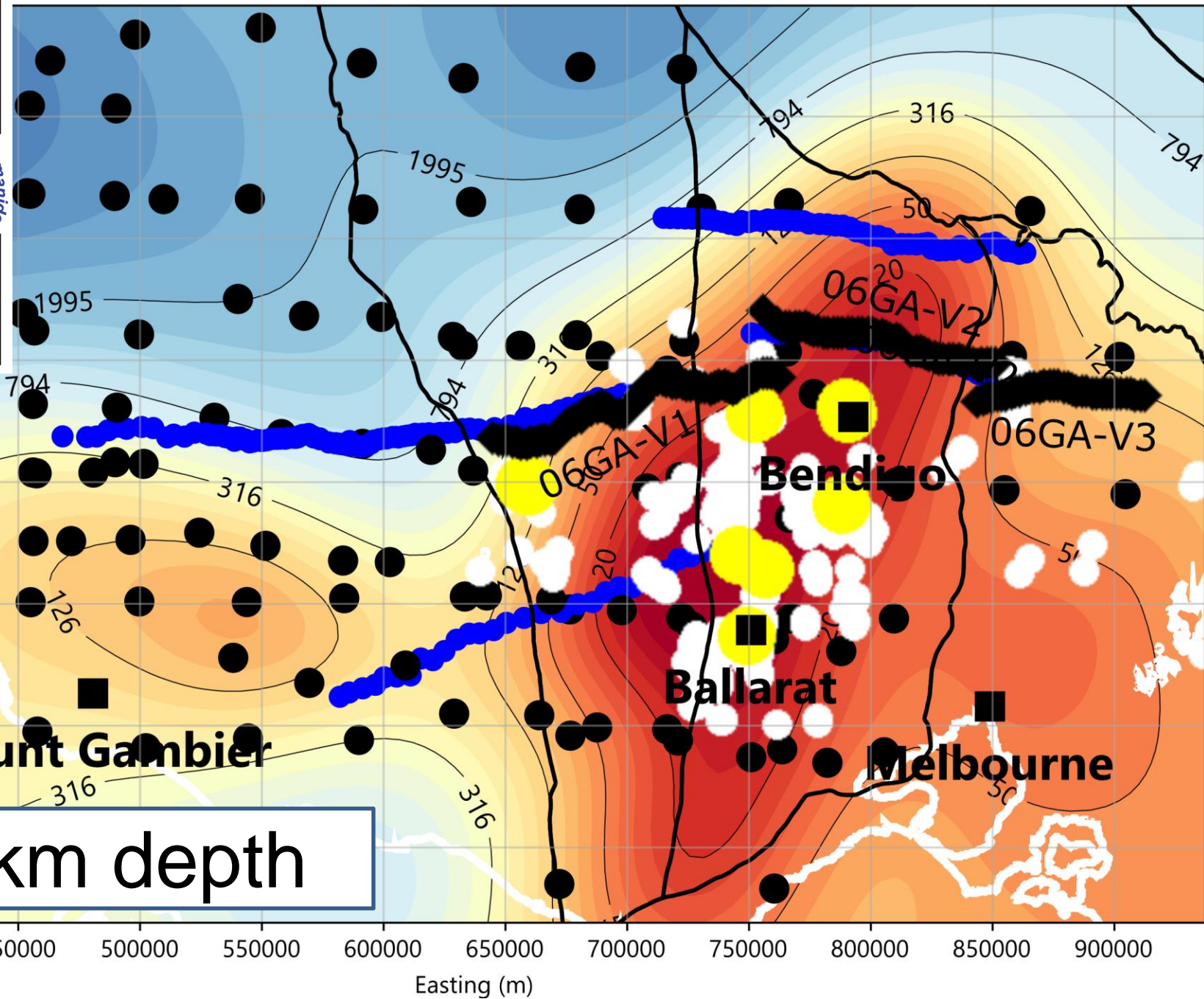
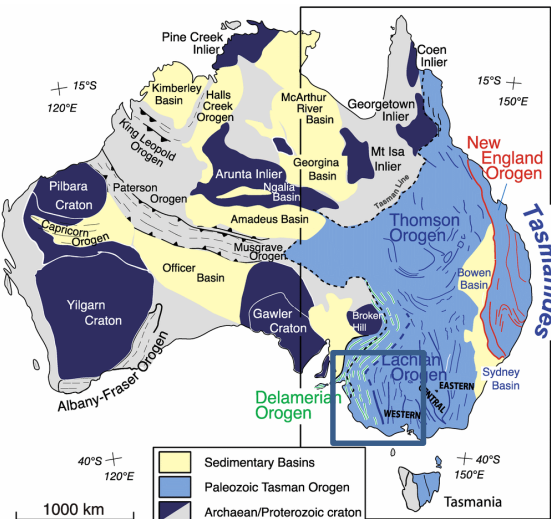
150 km below sea level

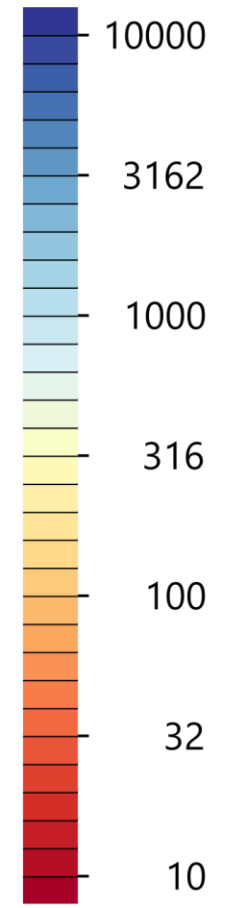
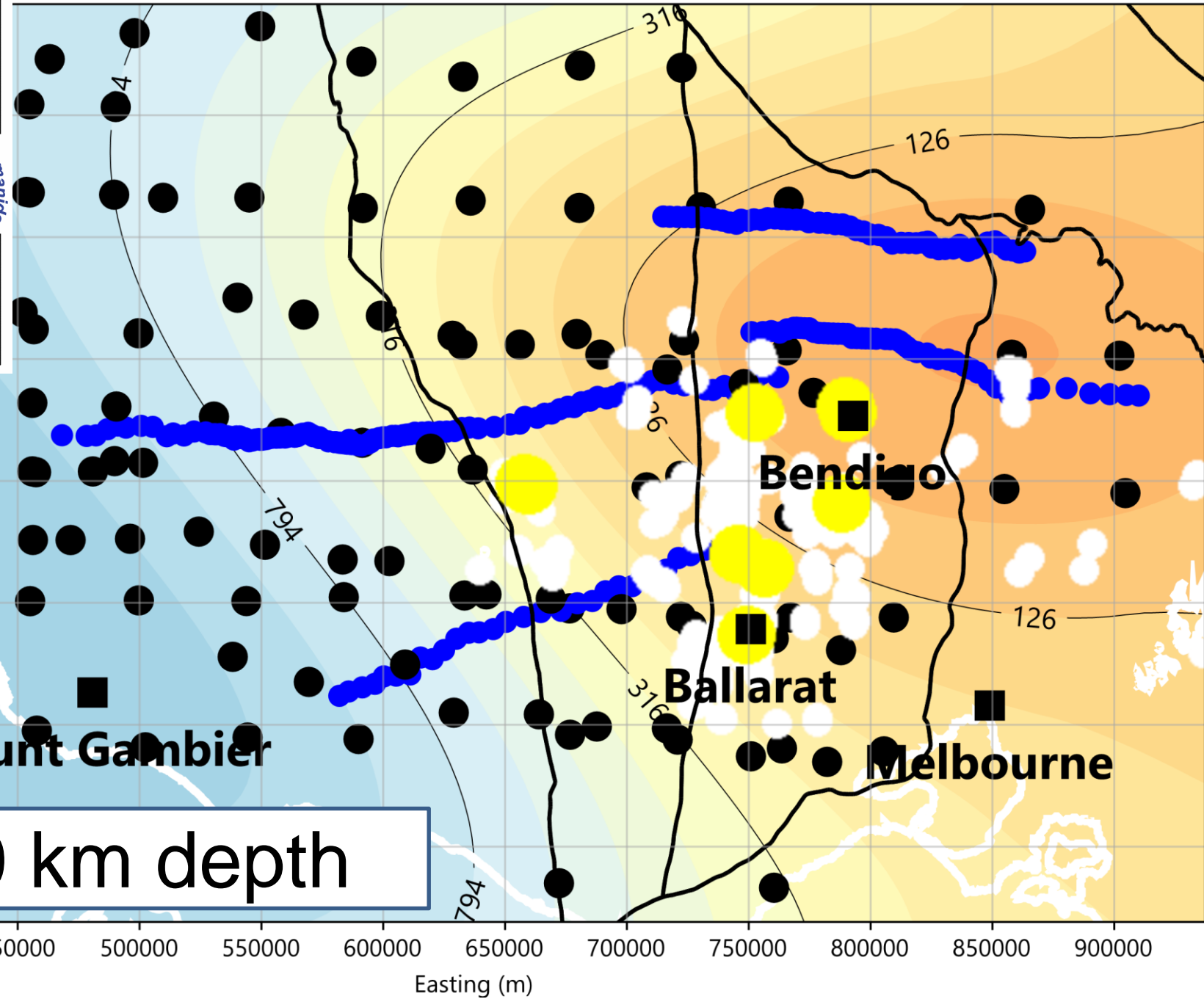
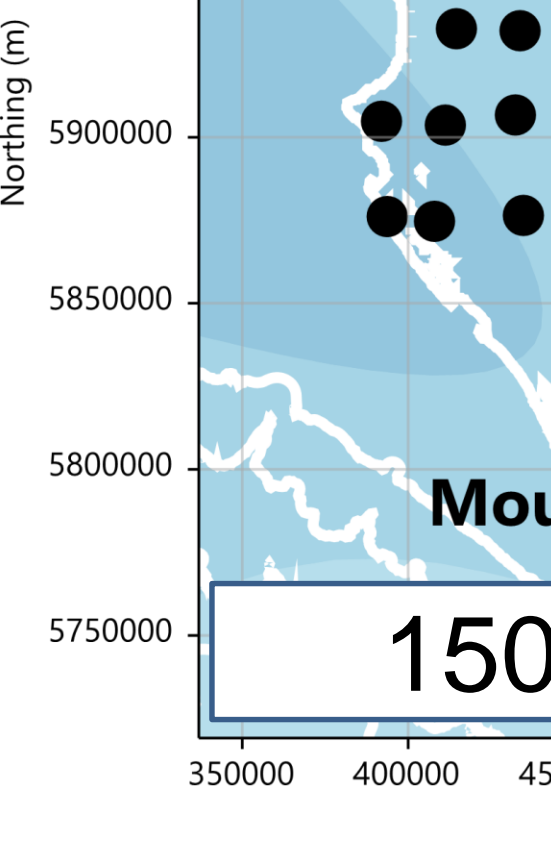
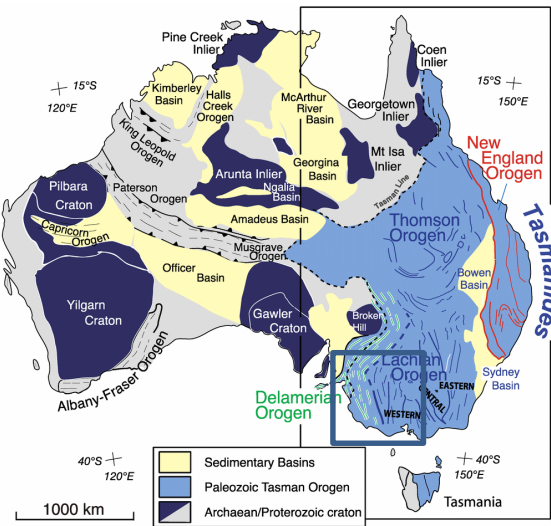


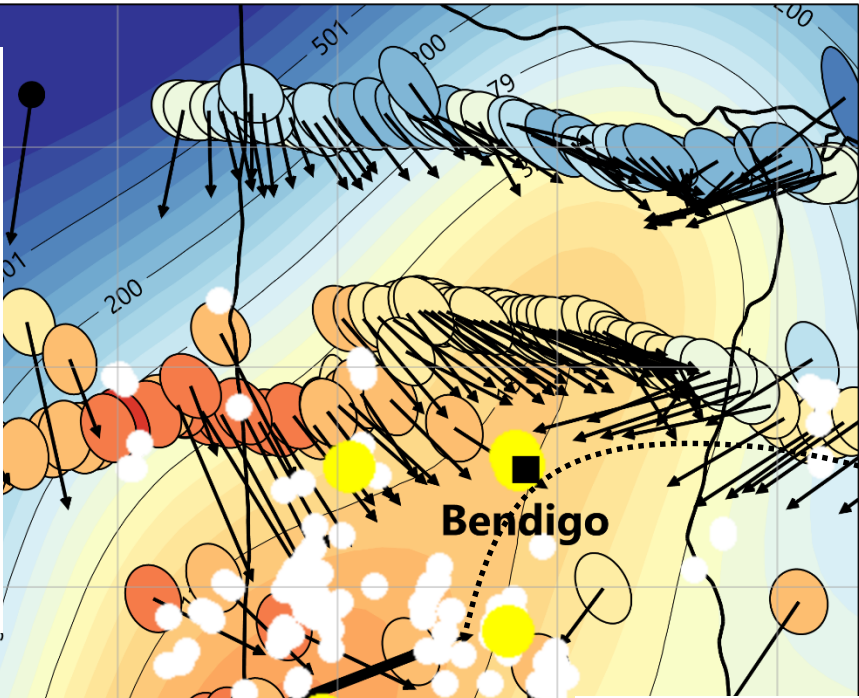
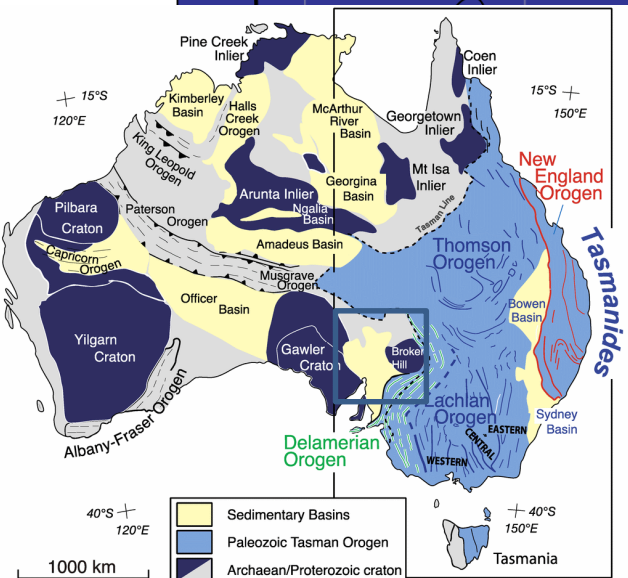


5 km depth

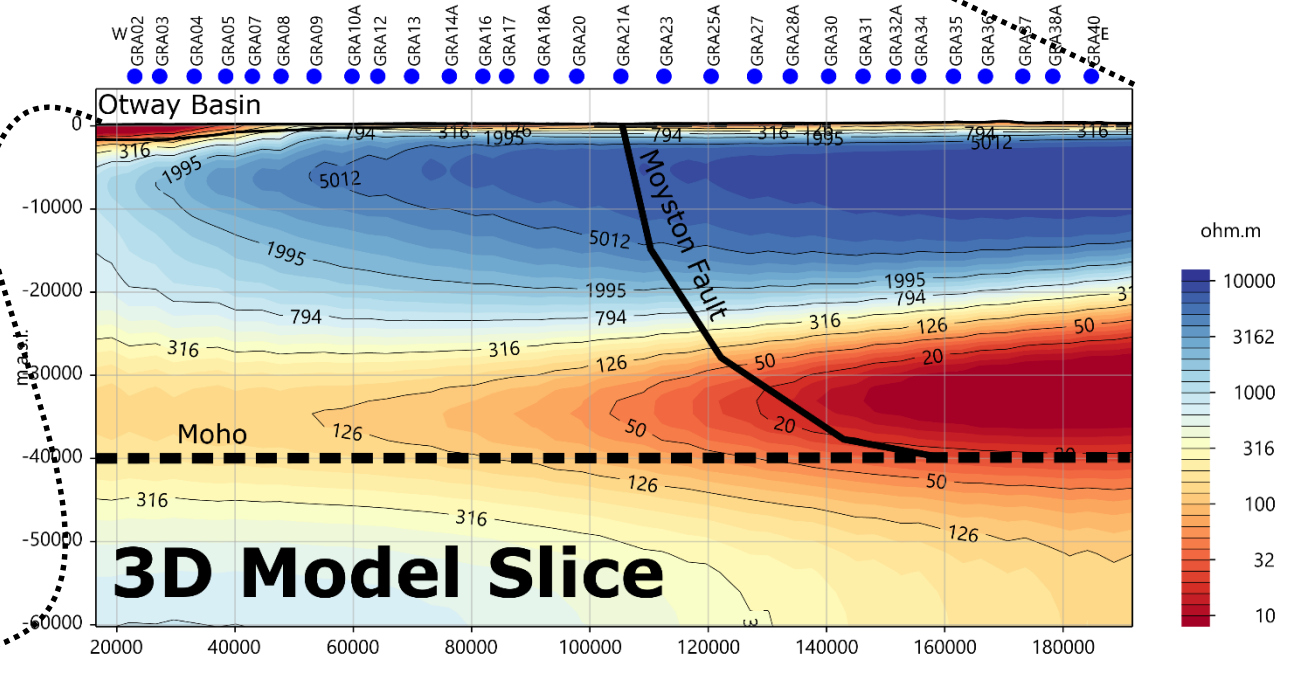
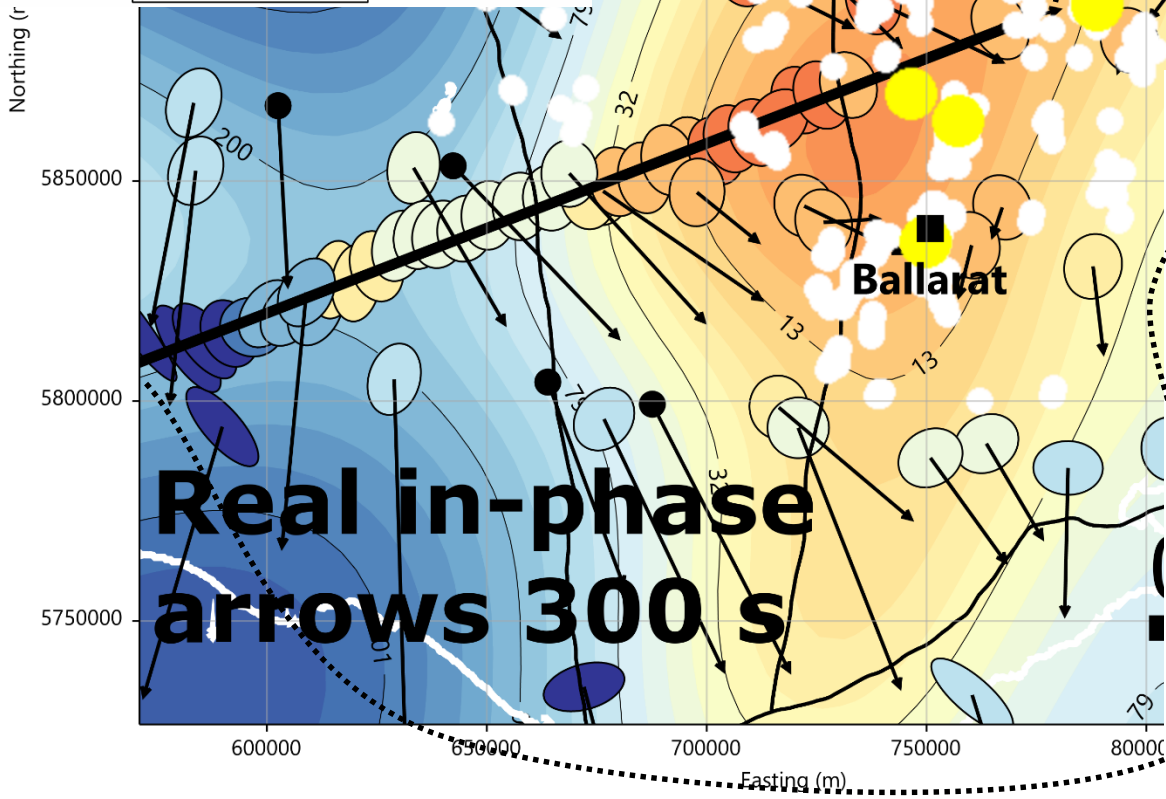






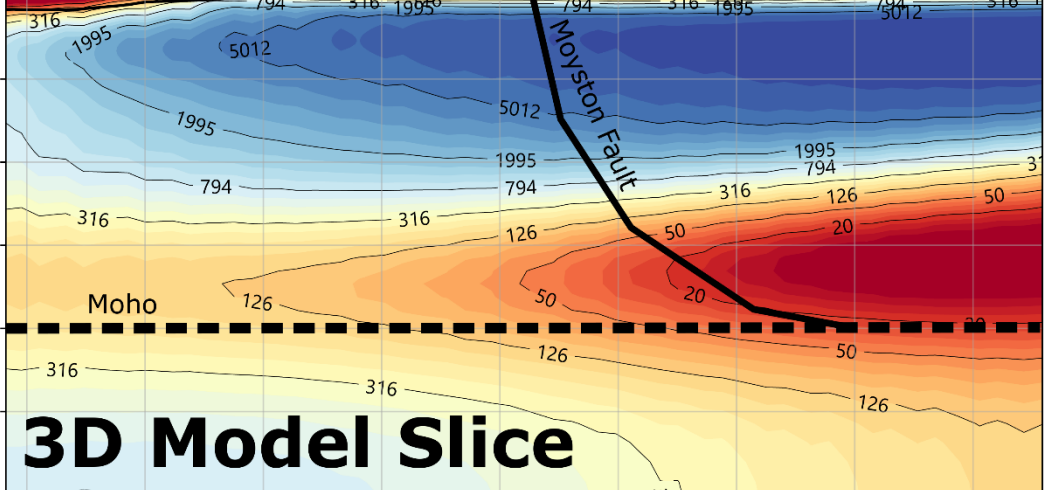


30 km slice



- W
- GRA02
- GRA03
- GRA04
- GRA05
- GRA07
- GRA08
- GRA09
- GRA10A
- GRA12
- GRA13
- GRA14A
- GRA16
- GRA17
- GRA18A
- GRA20
- GRA21A
- GRA23
- GRA25A
- GRA27
- GRA28A
- GRA30
- GRA31
- GRA32A
- GRA34
- GRA35
- GRA36
- GRA37
- GRA38A
- GRA40
- Et

Otway Basin



3D Model Slice

Sub plot: Broadband Transects

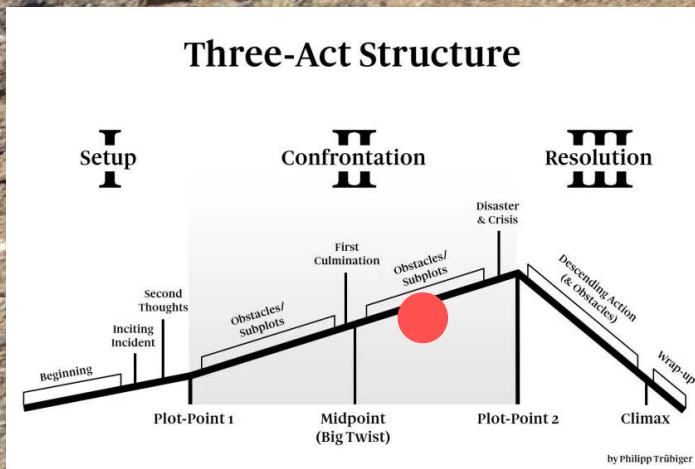
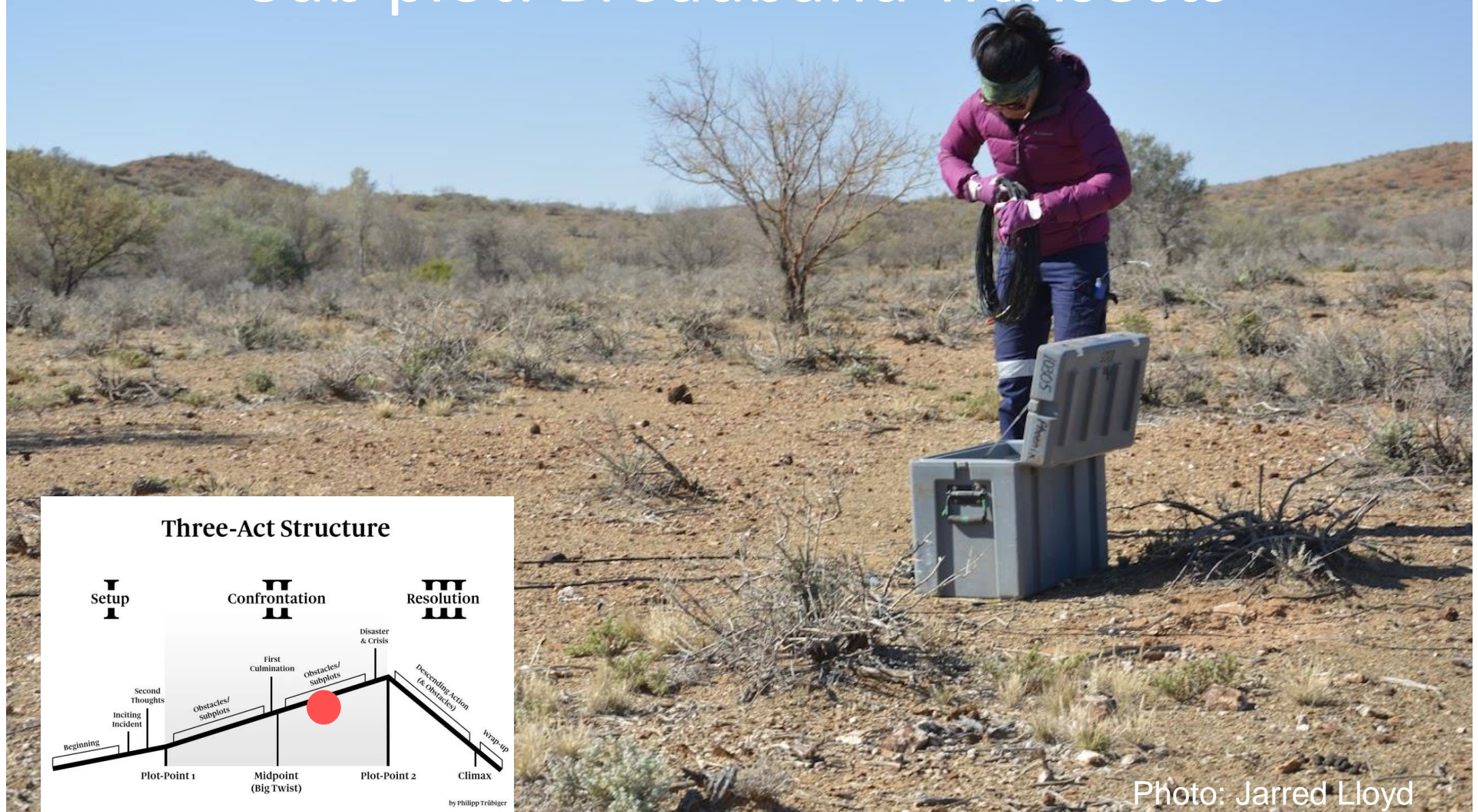
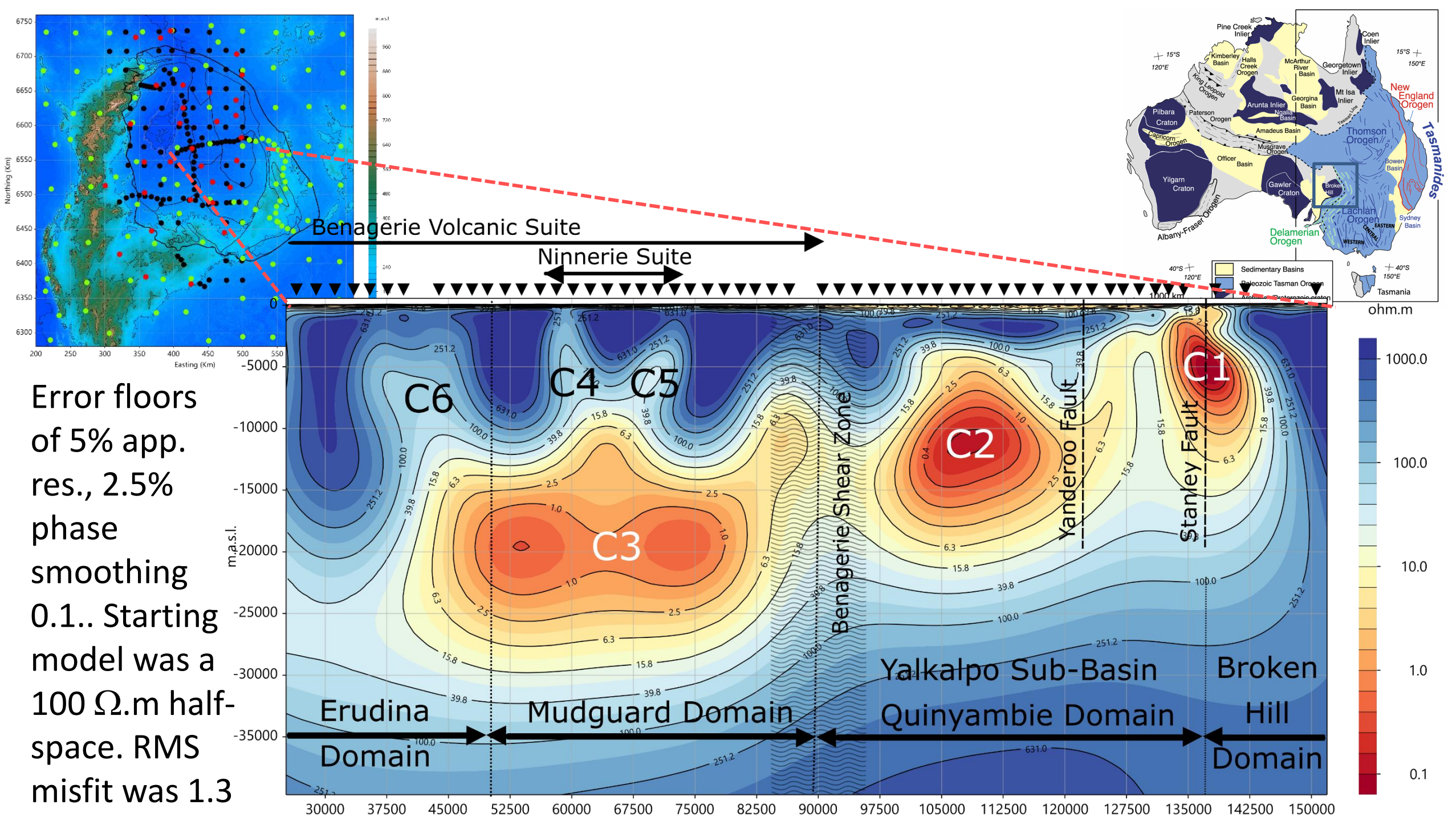
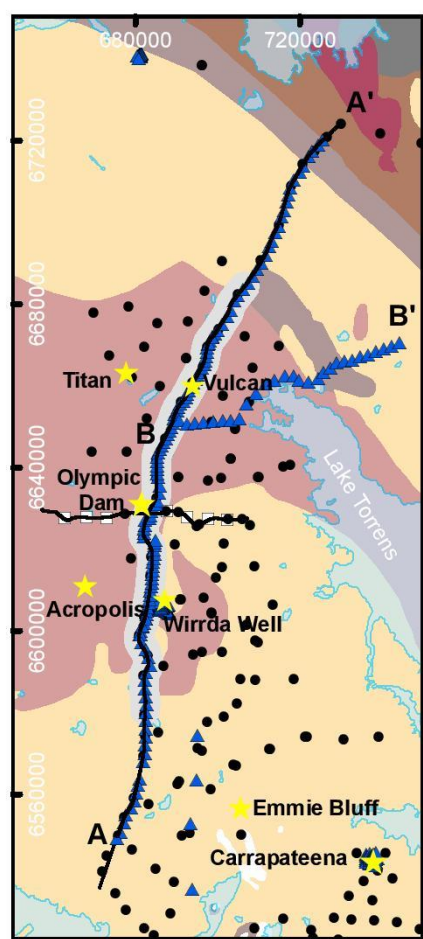


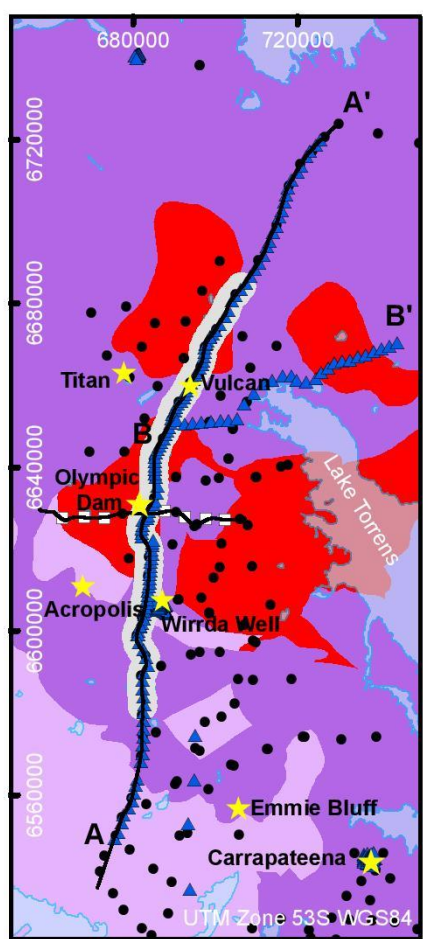
Photo: Jarred Lloyd



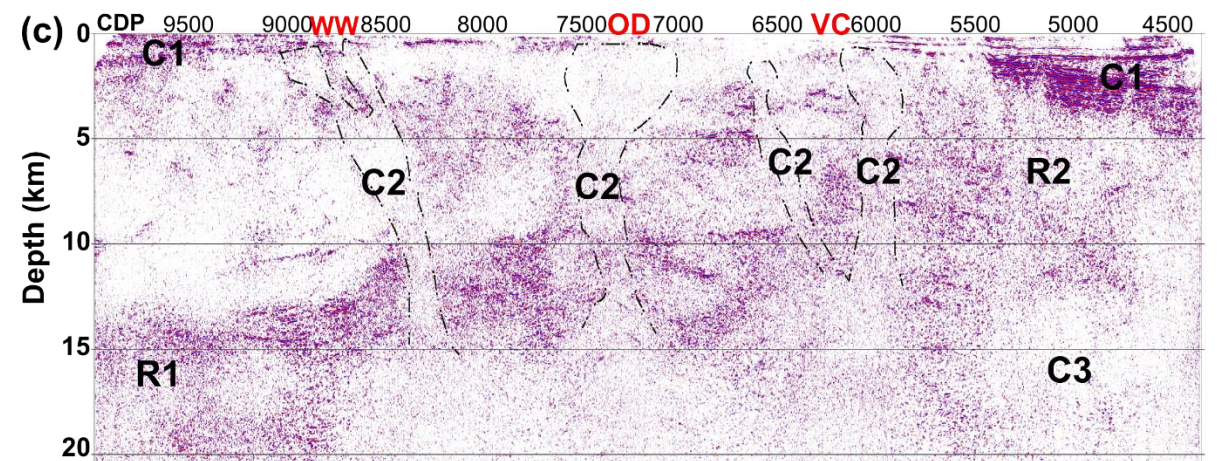
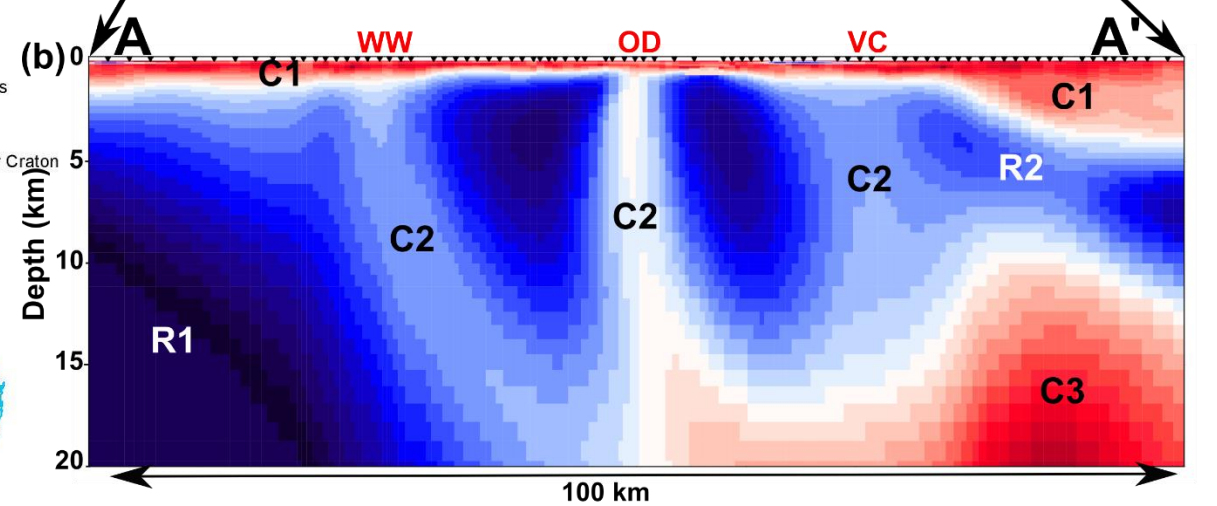
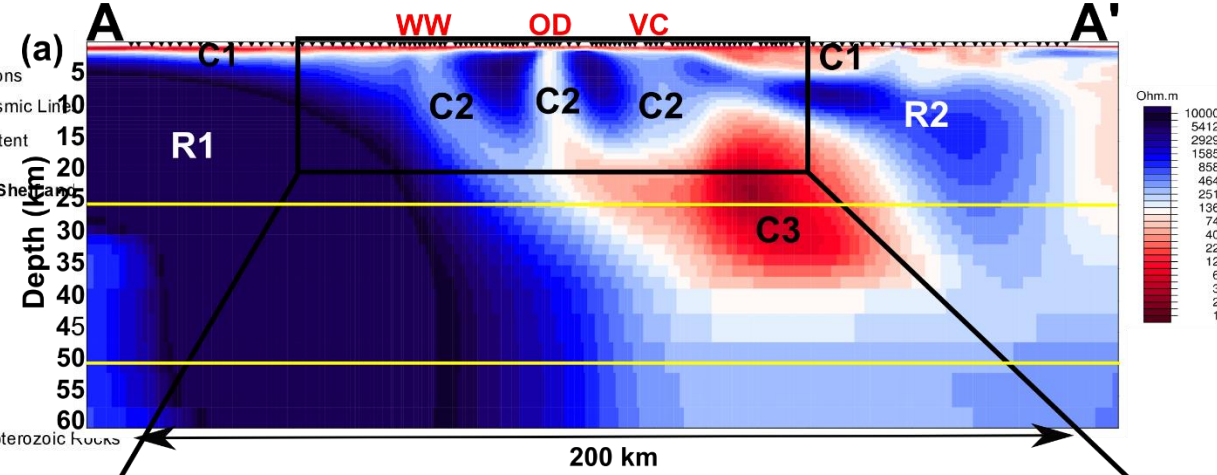
Error floors of 5% app. res., 2.5% phase smoothing 0.1.. Starting model was a 100 Ω .m half-space. RMS misfit was 1.3



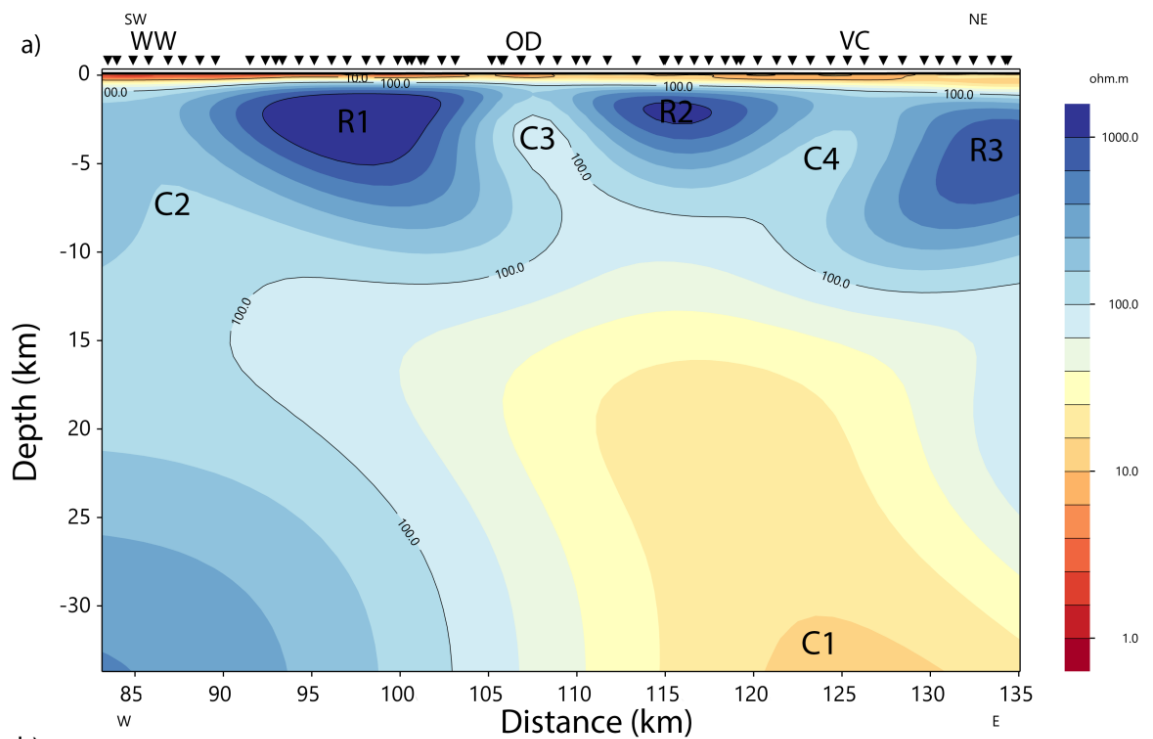
Cambrian-Neoproterozoic Cover



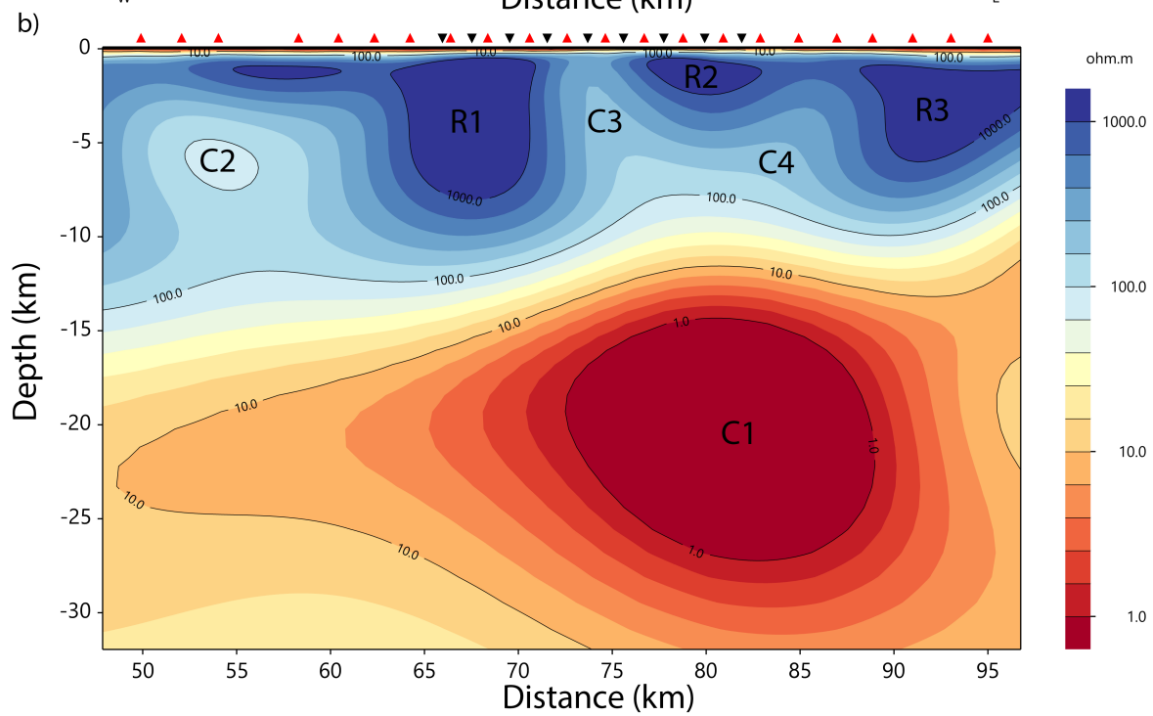
Crystalline Basement Cover



Olympic Dam line
(2021 Geotools
model)



Curnamona line
(2021 Geotools
model)

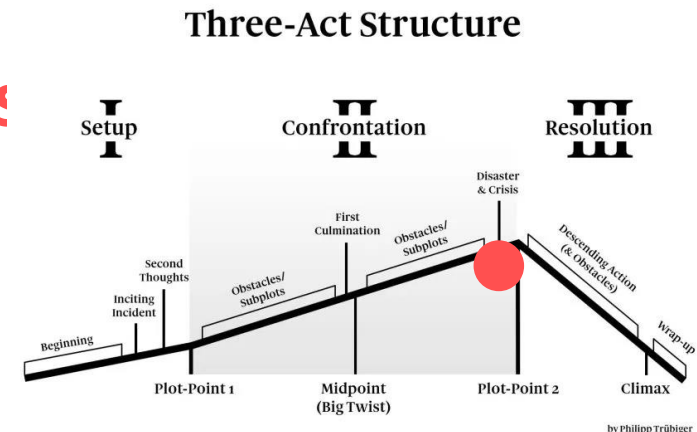


Same vertical and
horizontal scale

Thank you Emily
Lewis for this figure

Scale reduction?

- Long-period arrays maps regions of low-resistivity in lower crust that have spatial correlation with deposits
- Broadband transects appear to map discrete ‘pathways’ of low resistivity between lower crust and upper crust
- AMT grids map structural hosting of deposits in upper crust
- **BUT: what does this mean in terms of fluids, chemistry, temperature, melts, metal provenance and preservation?**



Act III

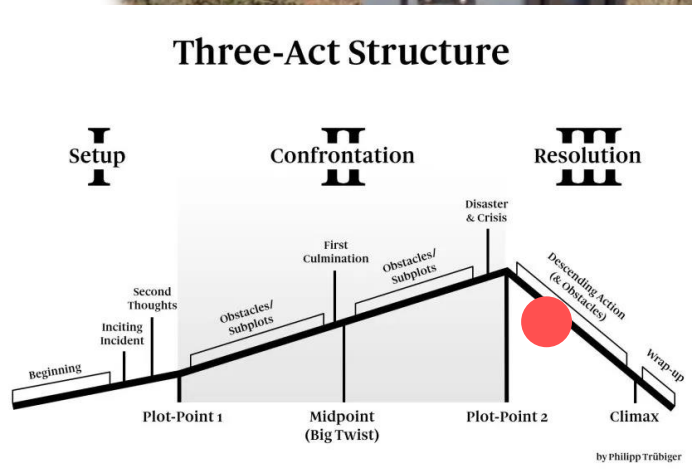
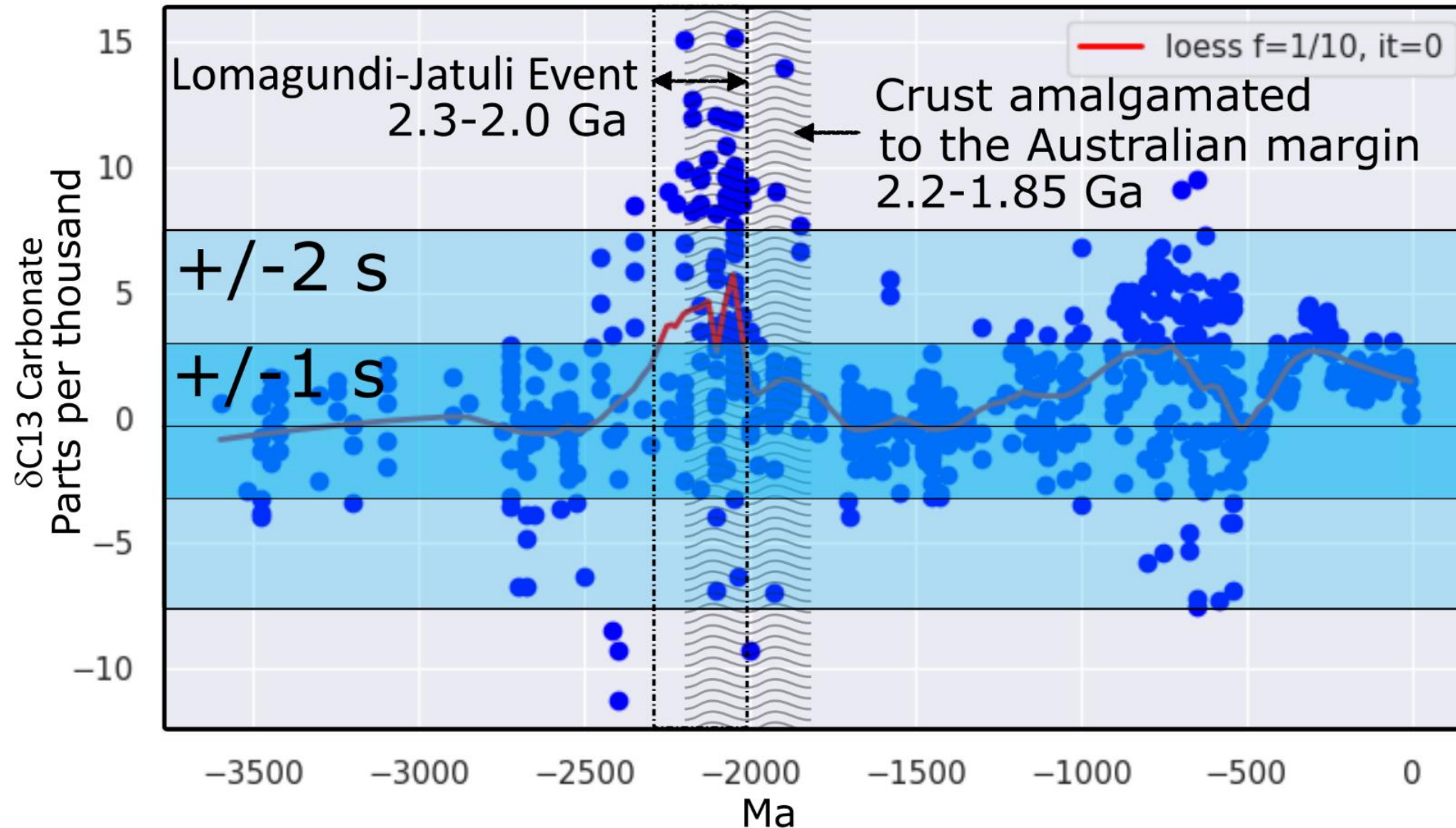


Photo: Jarred Lloyd

Resolution

Lomagundi-Jatuli Event ~2300–2000 Ma



Great oxidation event: Significant \uparrow in organic C relative to CO_2^-

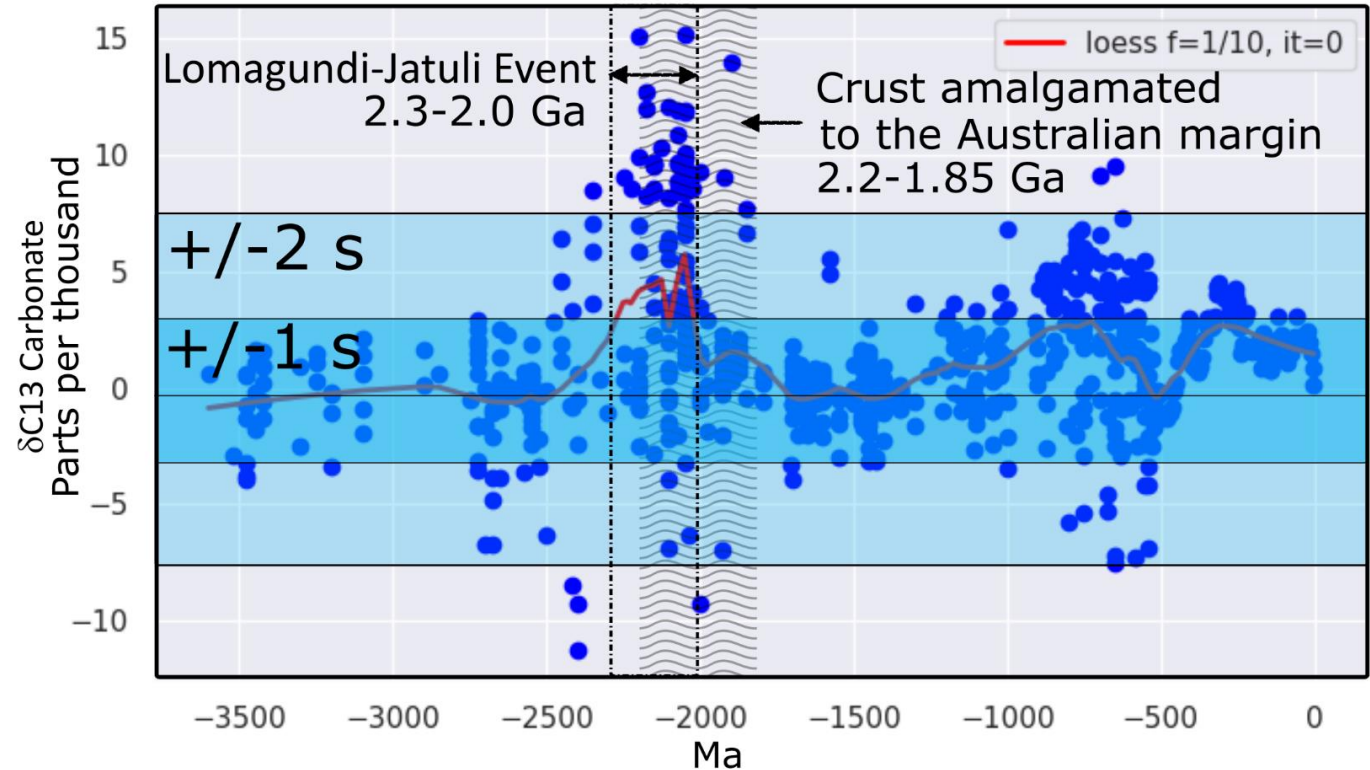
(Mand et al., 2020
Eguchi et al., 2020)

Lomagundi-Jatuli Event ~2300–2000 Ma

Lomagundi-Jatuli Event

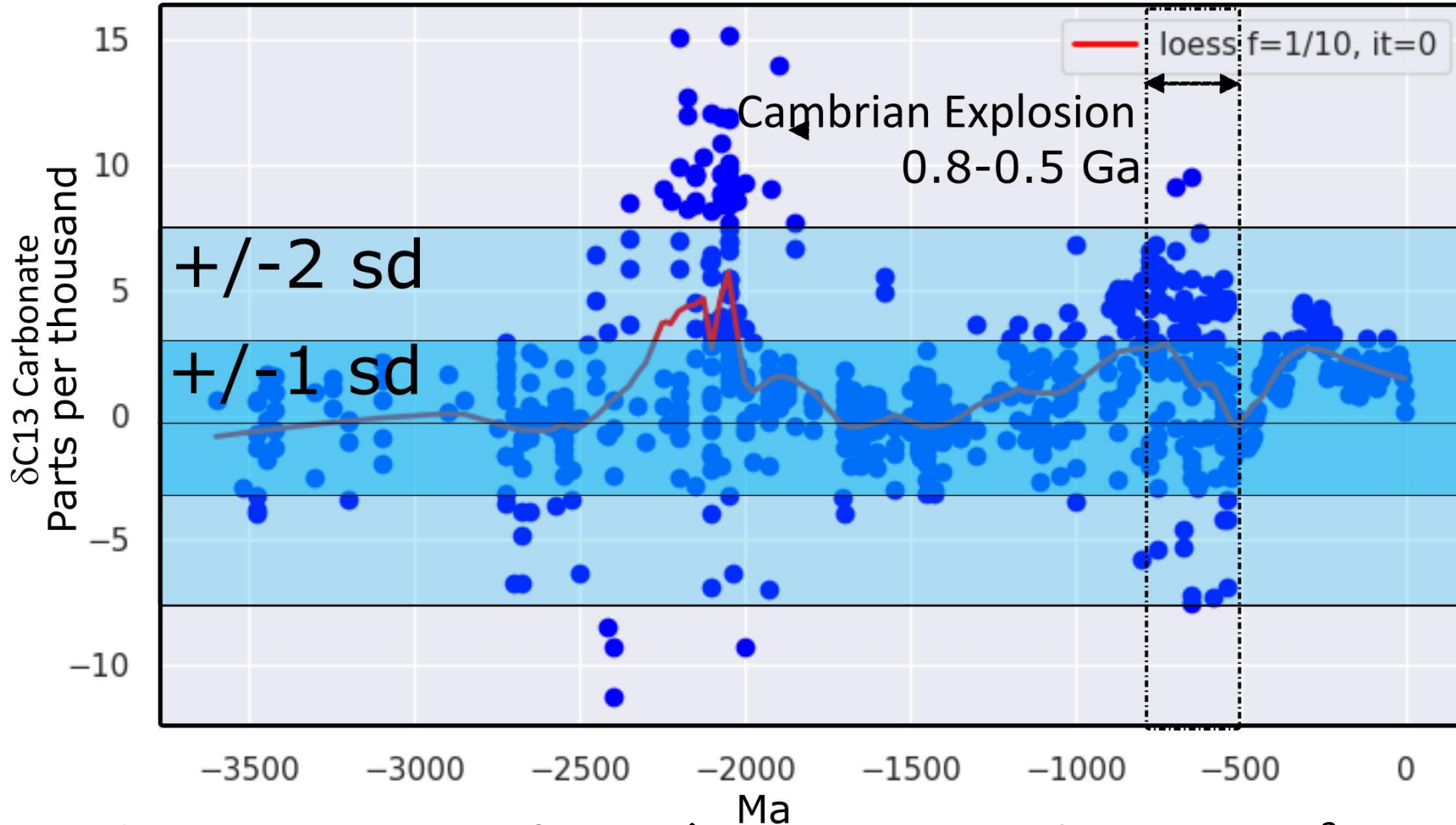
~2300–2000 Ma: C isotope ratios of carbonates increased by ~10‰ and O increased rapidly

Significant increase in the fraction of C buried as organic C relative to carbon buried as carbonate CO_3^{2-}

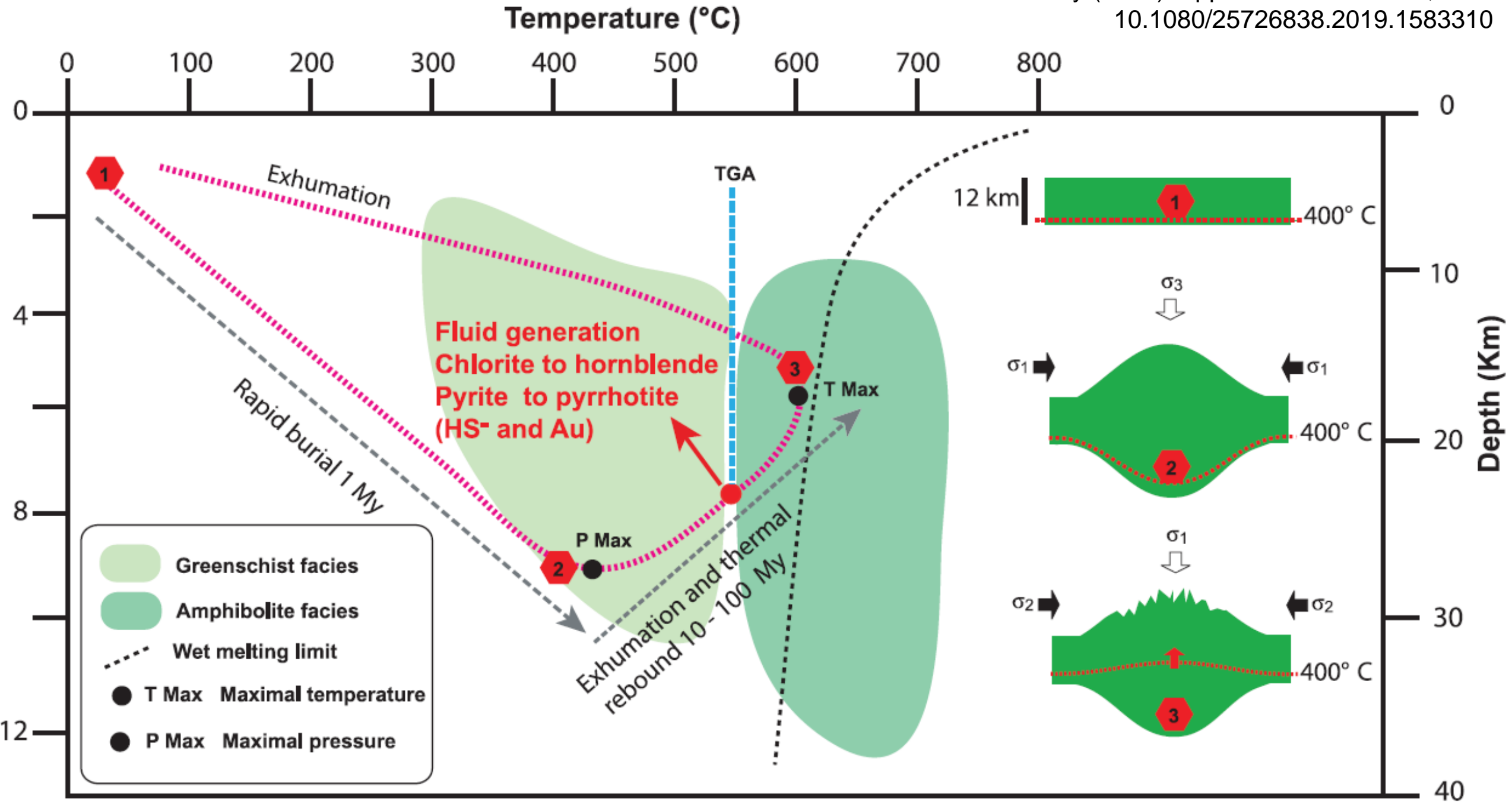


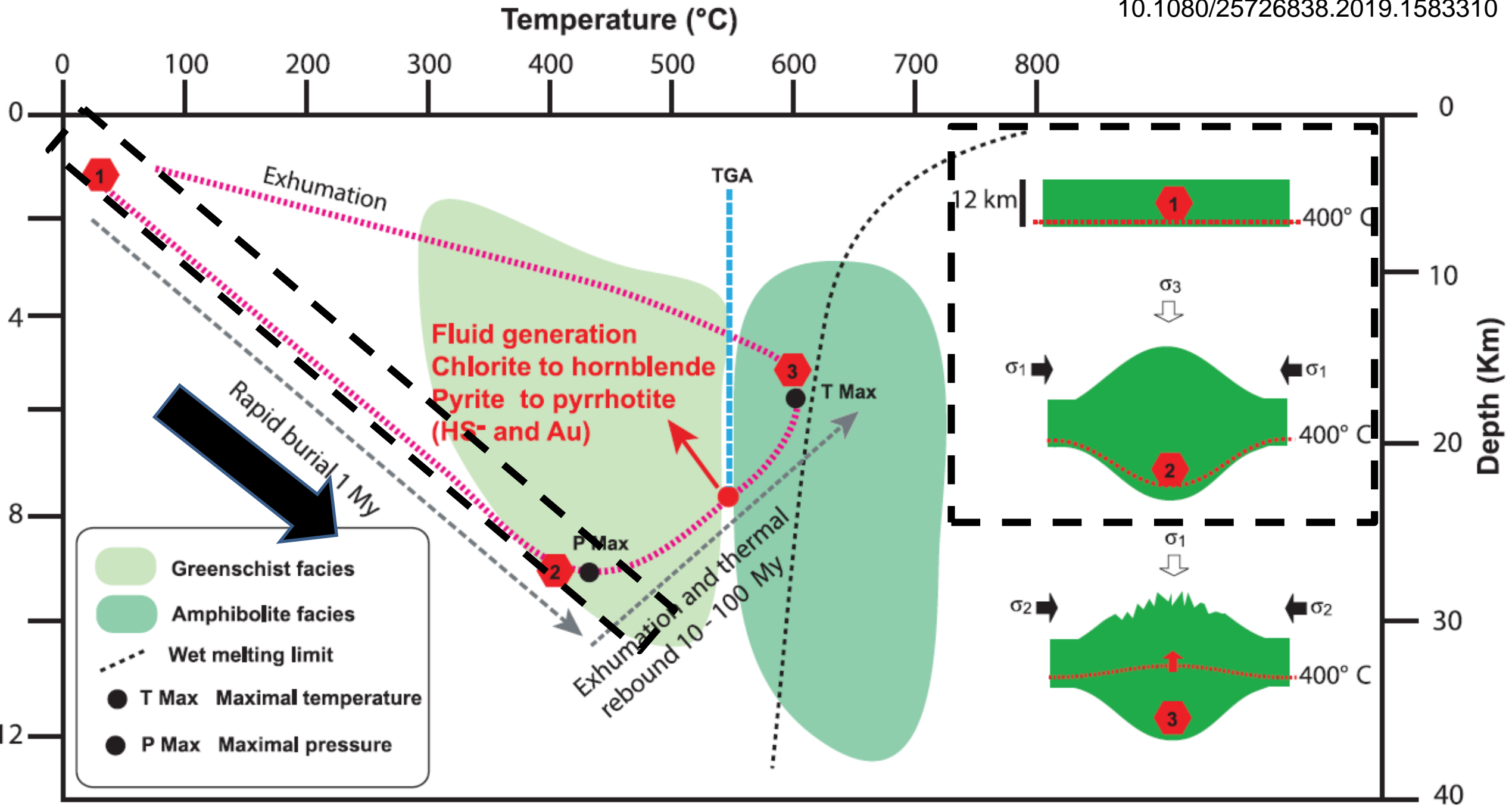
Increased amount of organic C in marine sediments increased $\delta^{13}\text{C}$ of carbonates (ratio of stable isotopes $^{13}\text{C} : ^{12}\text{C}$ in parts per thousand) because organic matter preferentially incorporates ^{12}C , leaving the carbonate-forming C reservoir enriched in ^{13}C

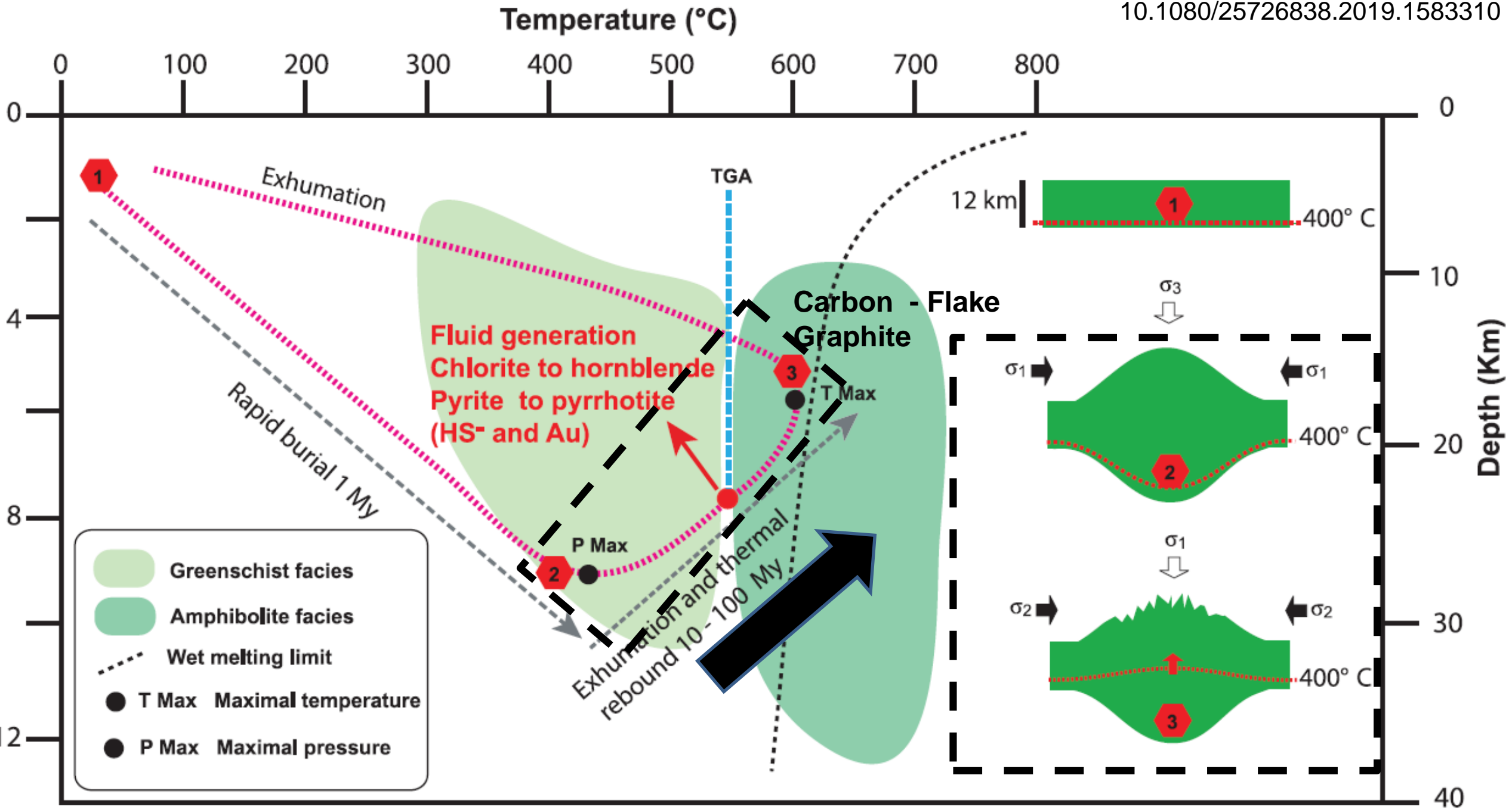
Cambrian Explosion Event ~800-500 Ma

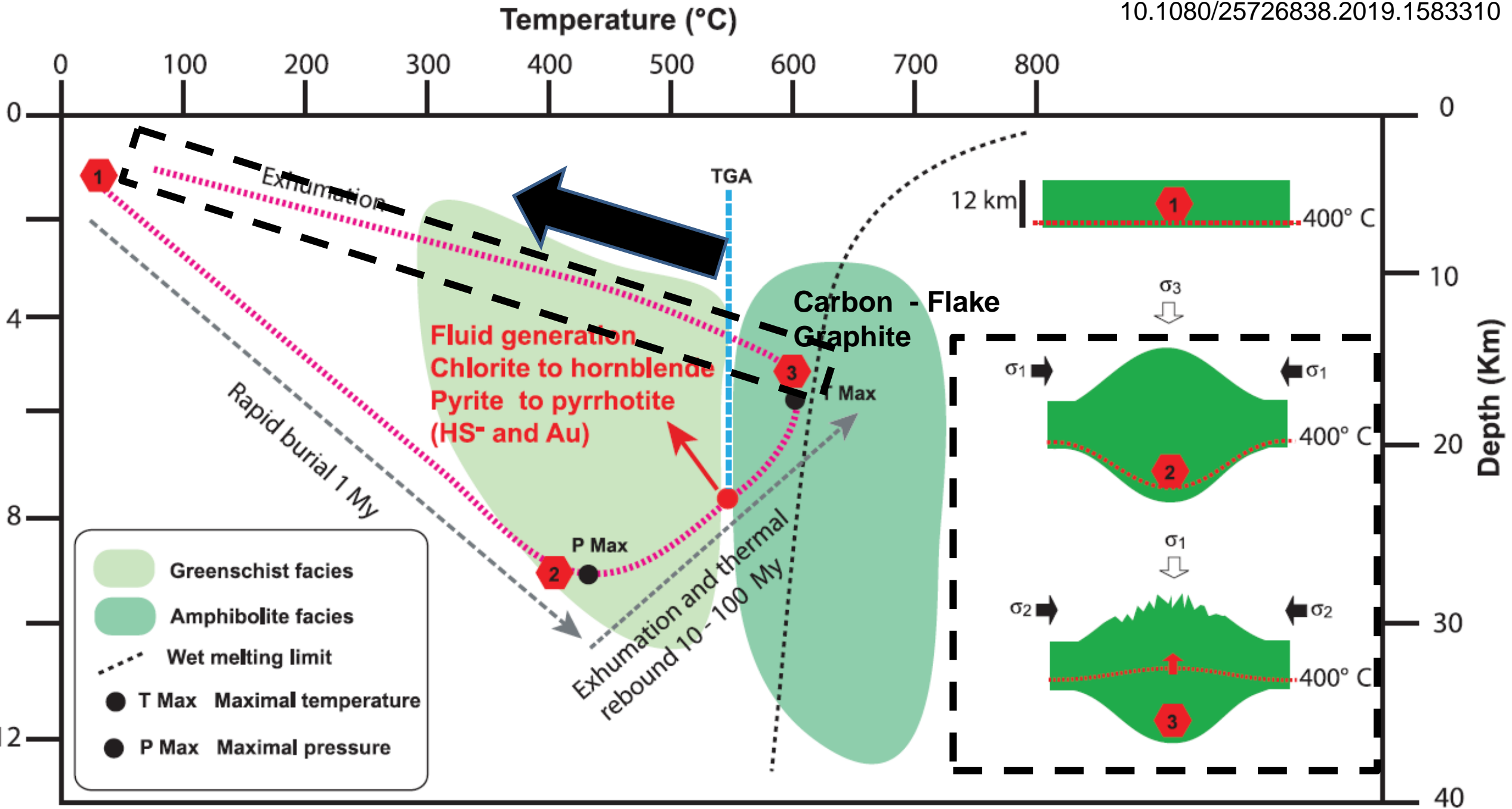


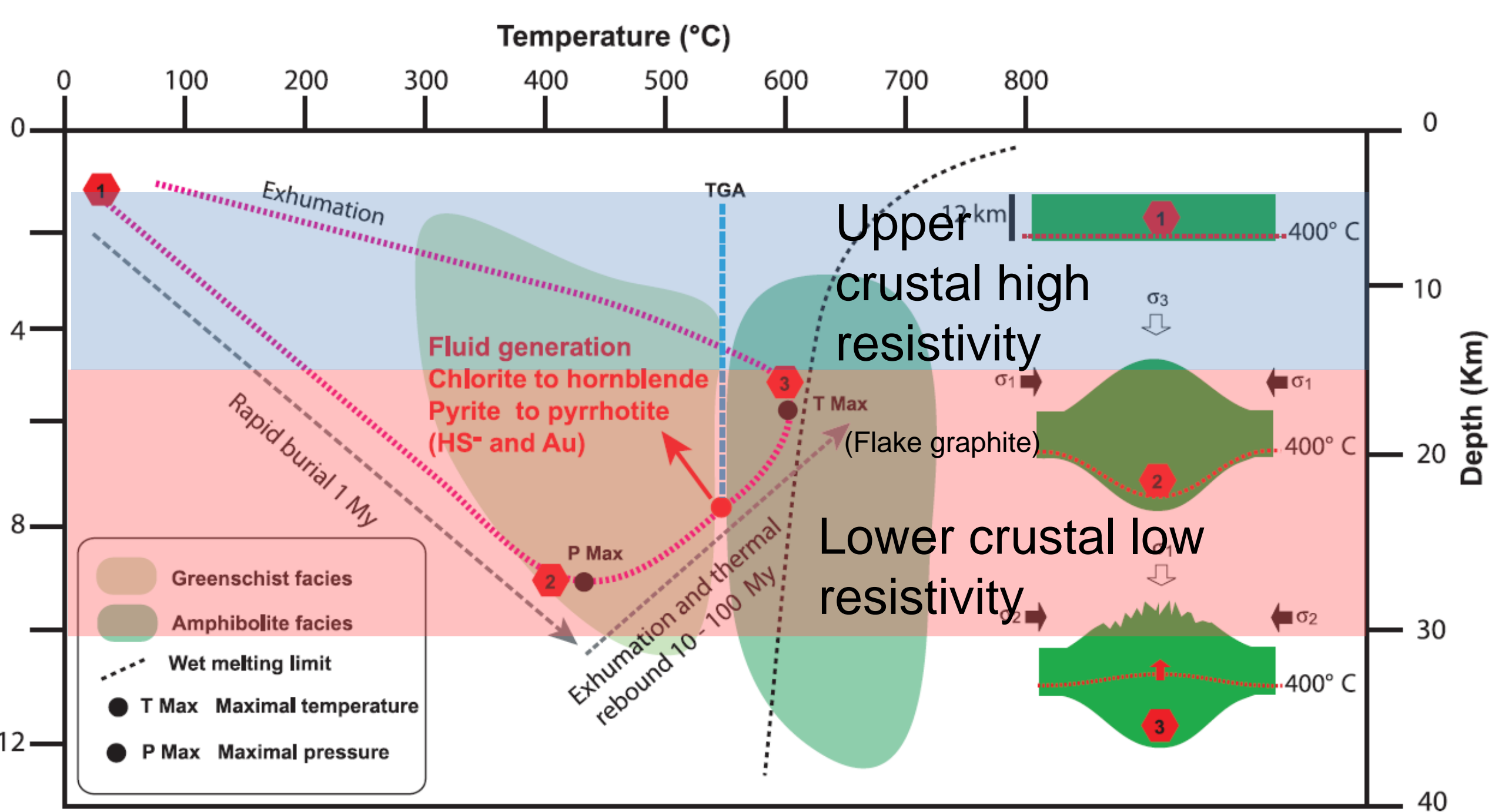
Great oxidation event: Significant \uparrow in organic C relative to CO_2^-











Act III

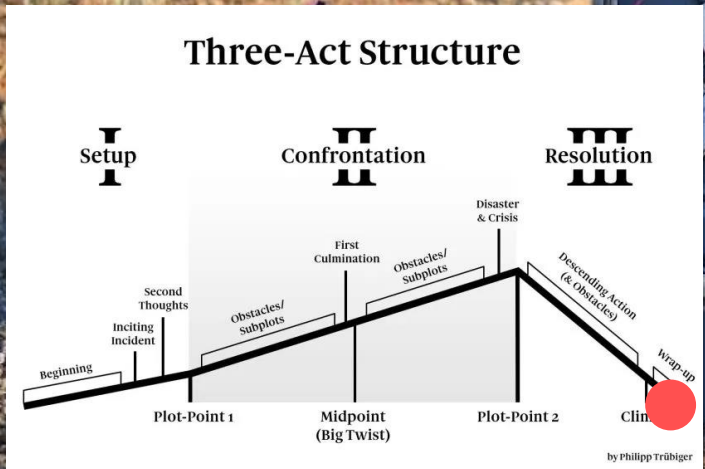


Photo: Jarred Lloyd

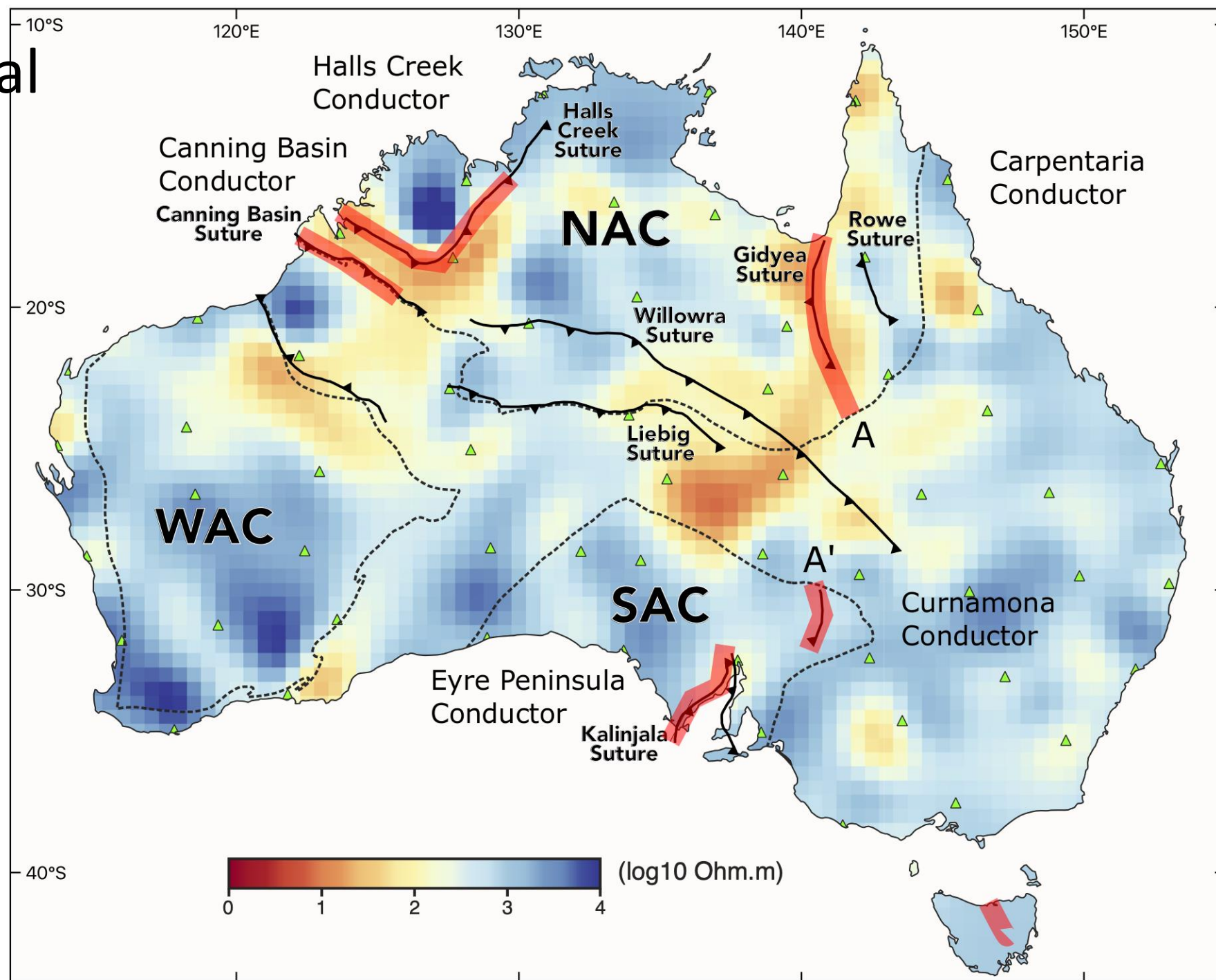
Climax

Australian electrical structure

Linear crustal conductors > 100 km and resistivities < 1 Ω .m (red lines)

Black solid lines show Paleoproterozoic sutures

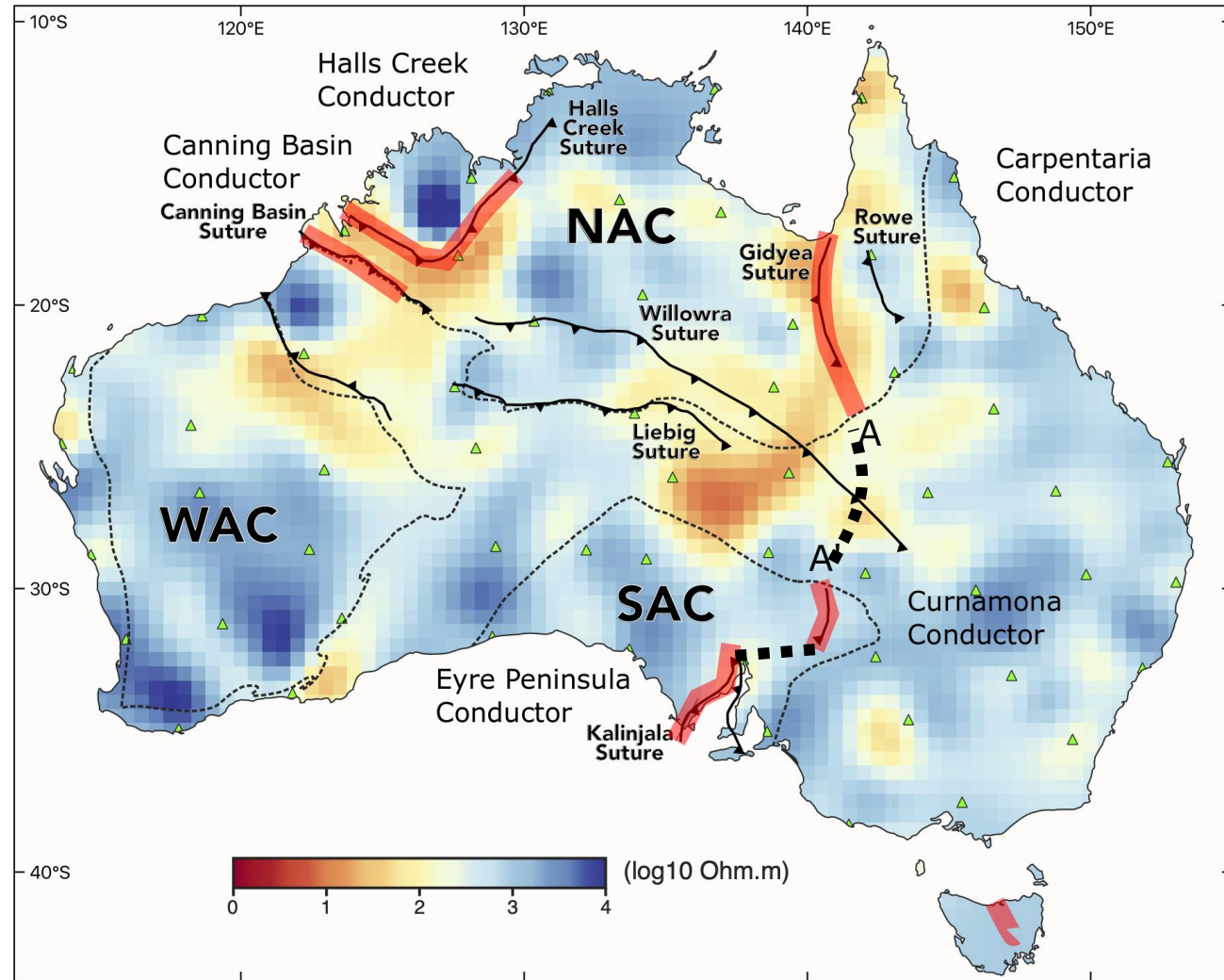
Background images shows electrical resistivity model of Australia at 36 km depth



Paleoproterozoic accretion

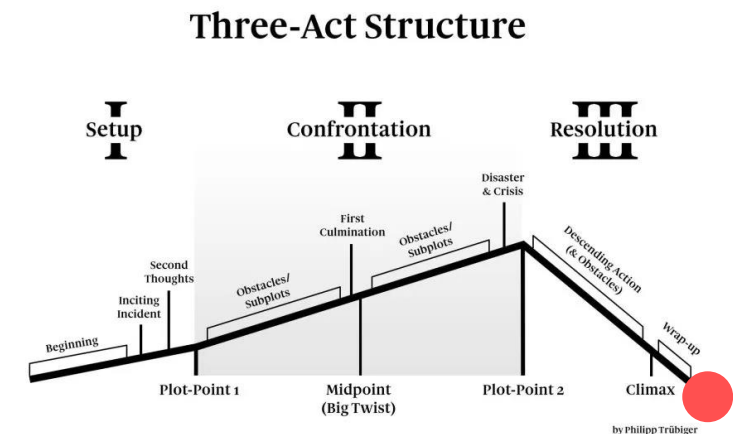
Betts et al. (2016) suggest sutures along margins of Mount Isa Province (Gidyea Suture), the Curnamona Province and the Kalinjala Shear Zone formed a contiguous boundary

Rapid accretion of several micro ribbon continents commenced 2200 Ma to 1850 Ma along eastern margin of proto-Australia while it was in the Nuna supercontinent



And so....

- Spatial mapping of lower crust conductors show significant correlation with surface economic mineral concentrations
- Transect slices suggest that a spatial connection marked as a low-resistivity pathway between deposits and lower crust
- Thermal and fluid processes that transport metals can be related to enhanced conduction methods
- **We need many more examples for known mineral deposits**



Finding mineral deposits
may turn out to be an
excellent way of
discovering a low-resistivity
lower crustal anomaly.....

Thank You

- Data were collected over three decades by many institutions. So, too many people to thank in a slide, you know who you are.



FOSSICKERS IN THE CREEK, NERRENA.