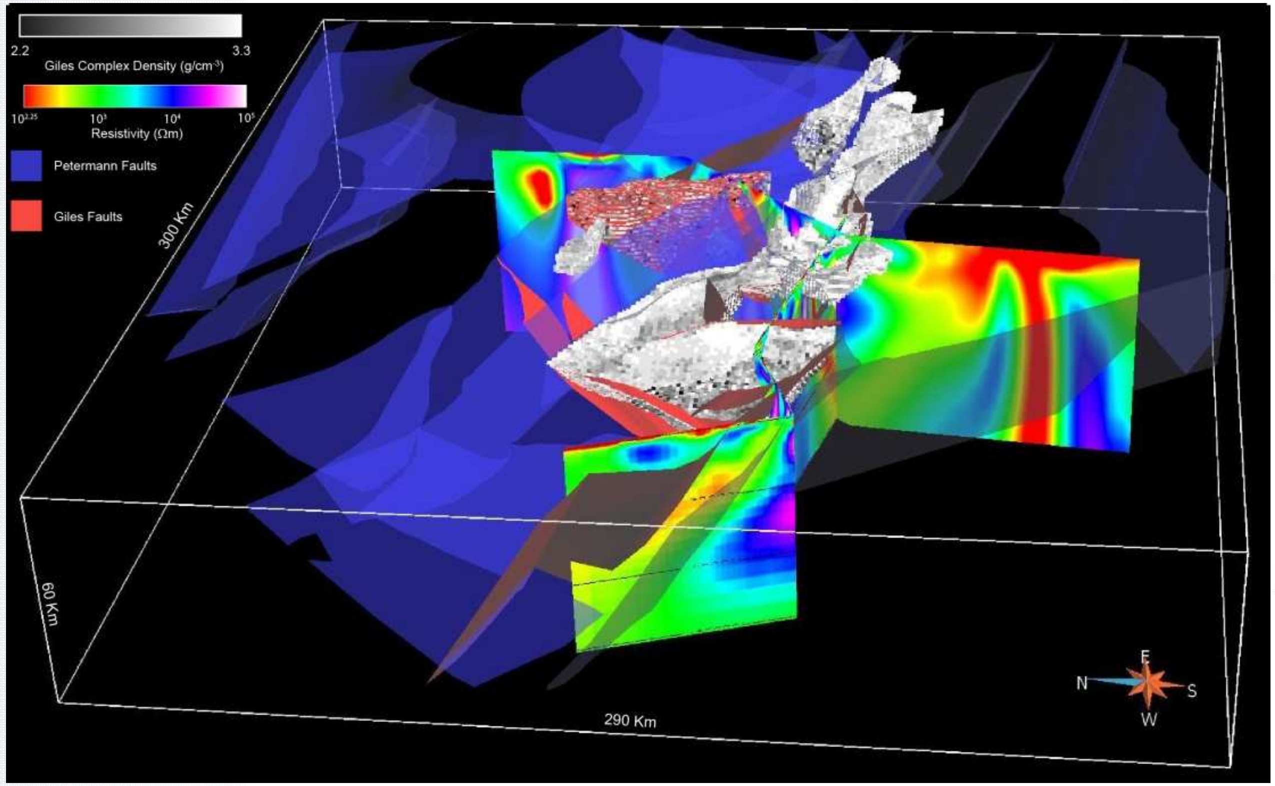
Four-dimensional architecture of the west Musgrave Province



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ROYALTIES FOR REGIONS
EXPLORATION INCENTIVE SCHEME

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Introduction

- Recent work in the west Musgrave Province characterised the 4-dimensional architecture of the province.
- A predominantly pre-seismic view of crustal architecture within the region.

Aims:

- To better understand the crustal architecture and structural evolution of the west Musgrave Province.
- To image spatial variations in prospectivity indicators
- To foster effective exploration targeting in this challenging greenfields region.

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Geological Overview

- The west Musgrave Province preserves several key periods of tectonic activity.

1. ~1900 Ma to 1350 Ma.
   - Several tectonic events preserved in the isotopic record (Kirkland et al., 2012)
   - Little knowledge of their architecture however

2. 1350 Ma to 1150 Ma.
   - Mt West and Musgrave Orogenies
   - Architecture preserved to some degree
   - Tectonic interpretation possible – but architecture ill-constrained (Smithies et al., 2011)

Geological Overview

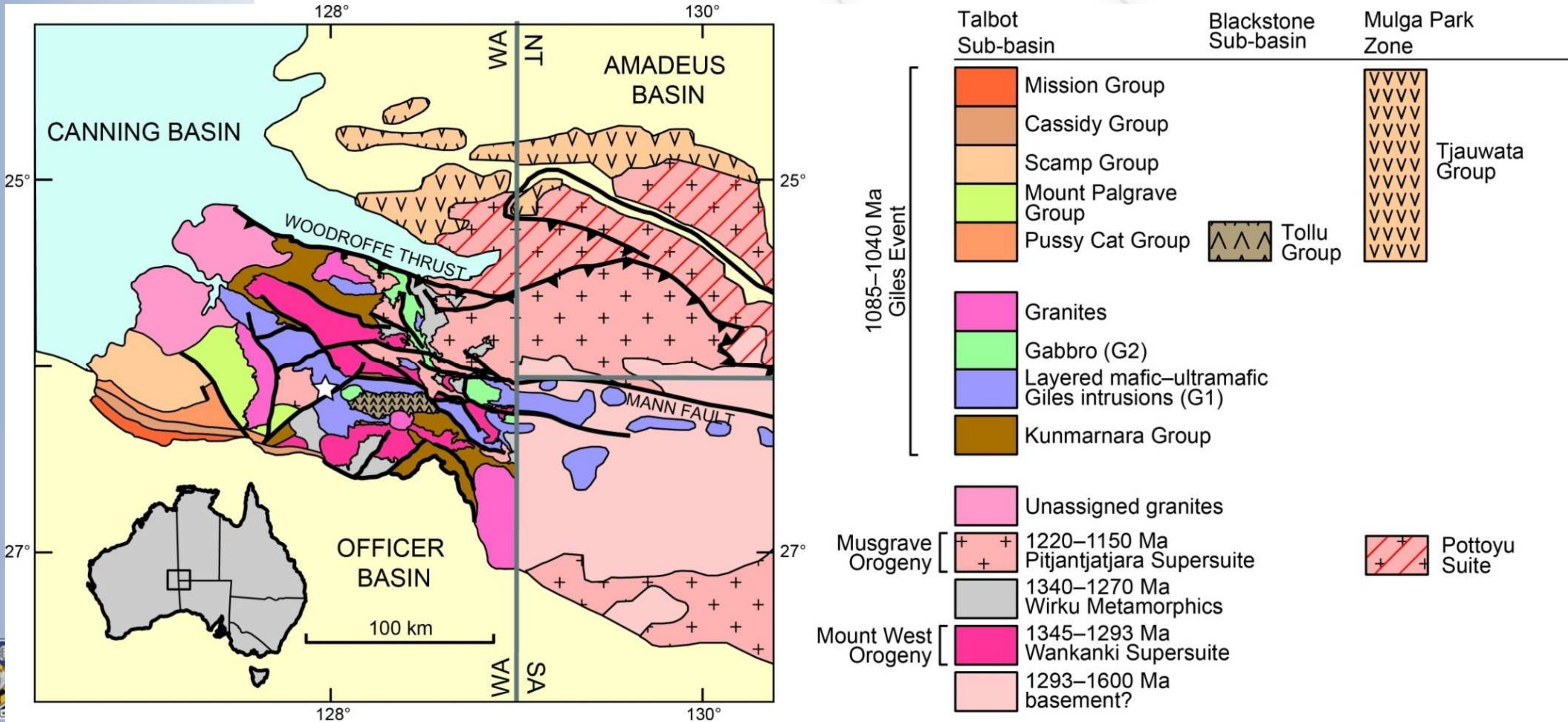
- The west Musgrave Province preserves several key periods of tectonic activity.

3. 1085 to 1040 Ma.
   - Ngaanyatjarra Rift/ Giles Event
   - Architecture exceptionally well preserved
   - Spectacular examples of Mesoproterozoic rift architecture (Evins et al., 2010; Aitken et al., 2013)

4. Ca. 700 Ma to 350 Ma.
   - Paterson,Petermann and Alice Springs Orogenies
   - Architecture well preserved (Raimondo et al., 2010)
   - High-grade nature and lack of magmatism makes tectonic interpretation difficult (Walsh et al., 2013)

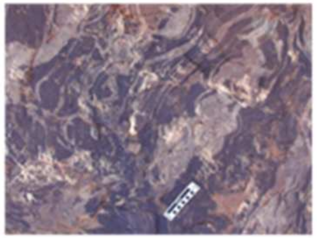
Geological Overview

- The basic architecture is evident in overview maps
- Challenge is to find the “devil in the detail” (Evins et al, 2010)



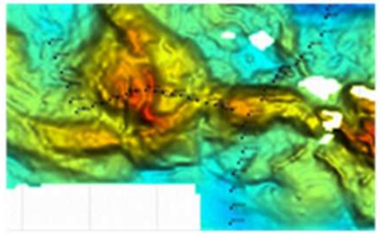
Methods and Approach

1. Geology



Smithies et al 2008

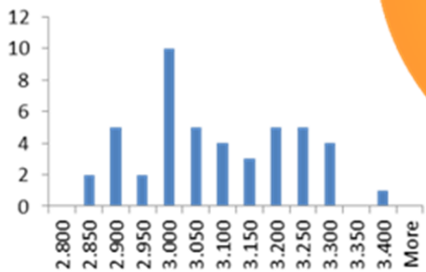
2. Potential fields



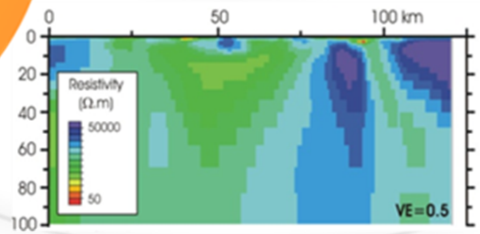
Integrated Analysis :

4D architecture model

Prospectivity Analysis



3. Petrophysical Data



4. Magnetotellurics

Analyse crustal-scale structure, and structural evolution

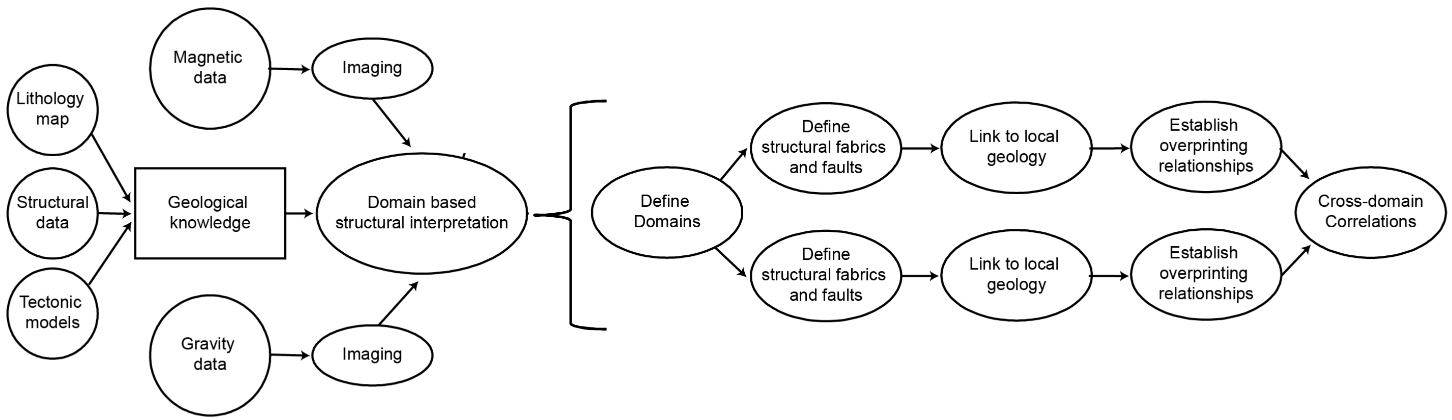
- Geologically constrained structural interpretations of aeromagnetic and gravity data
- Petrophysical databases (100s of samples)
- Constrained forward modelling and inversion (magnetics and gravity)
- MT data collection and modelling

Methods and Approach

Aeromagnetic Interpretation:

Domain-based structurally focused method

- Local events defined on the basis of local overprinting relationships
- Grouped into regional tectonic events based on:
    1. stratigraphic position
    2. consistent overprinting relationships
    3. deformation style/magnetic character
    4. orientation

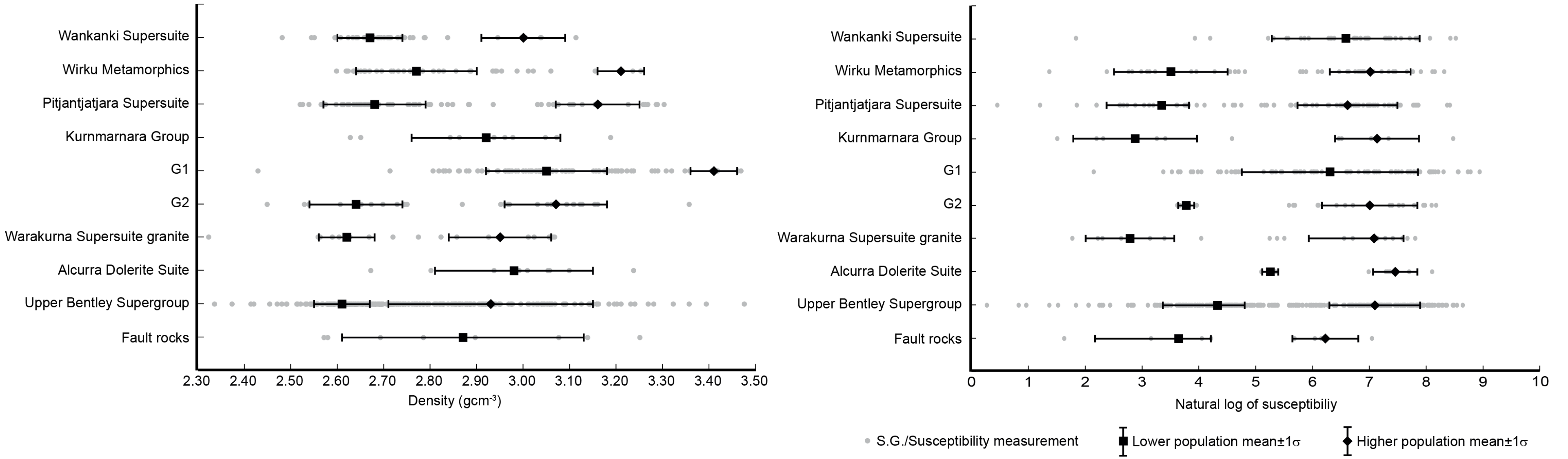


Methods and Approach

Combined 2D gravity and magnetic modelling:

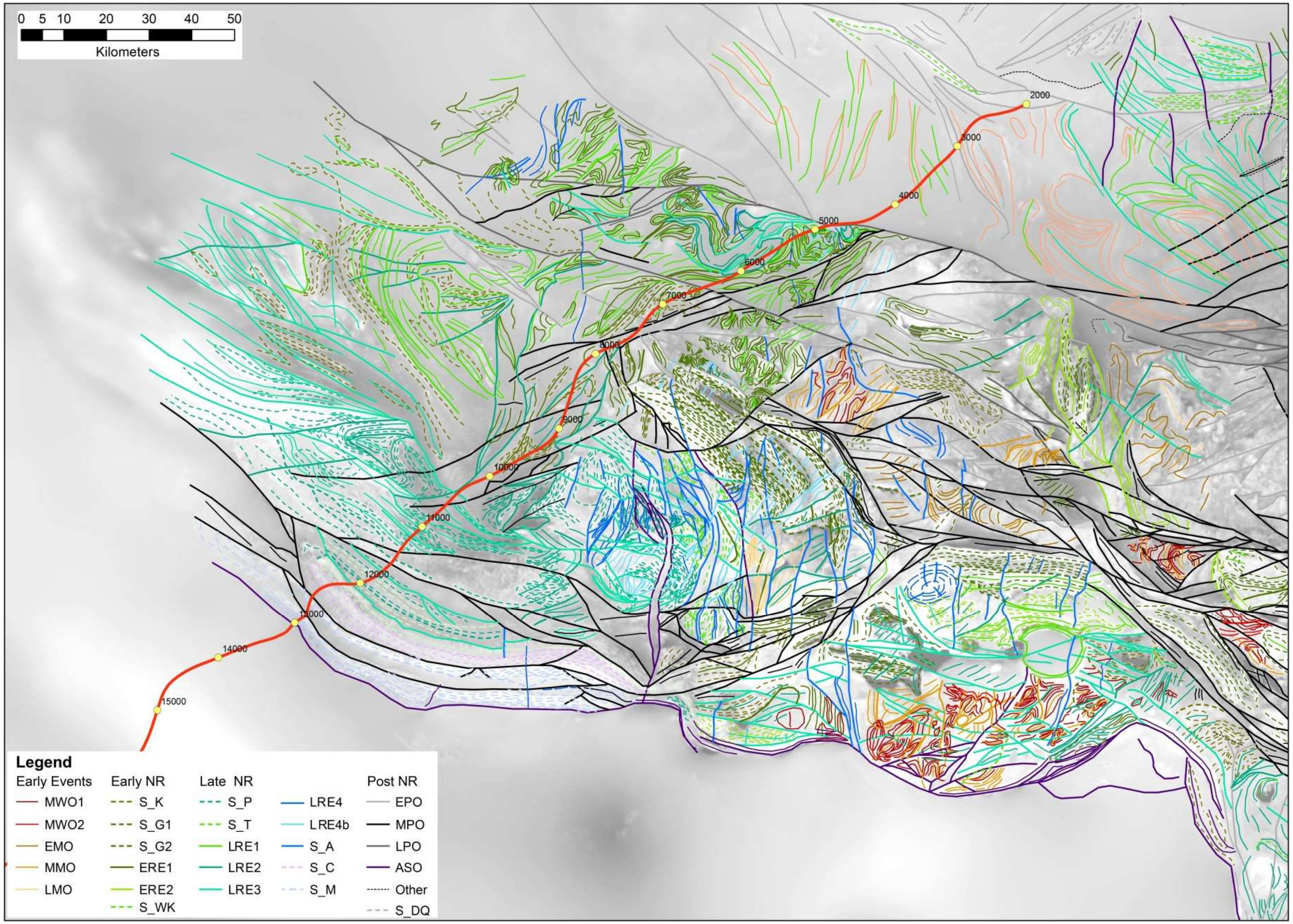
Structural-tectonic method

- Geometry initially derived from geological principles
- Petrophysical constraint from 666 samples (see below)
- Final model can be considered a geophysically acceptable geological cross section
    - i.e. not all features are required by grav and mag data



Tectonic Architecture of the WMP

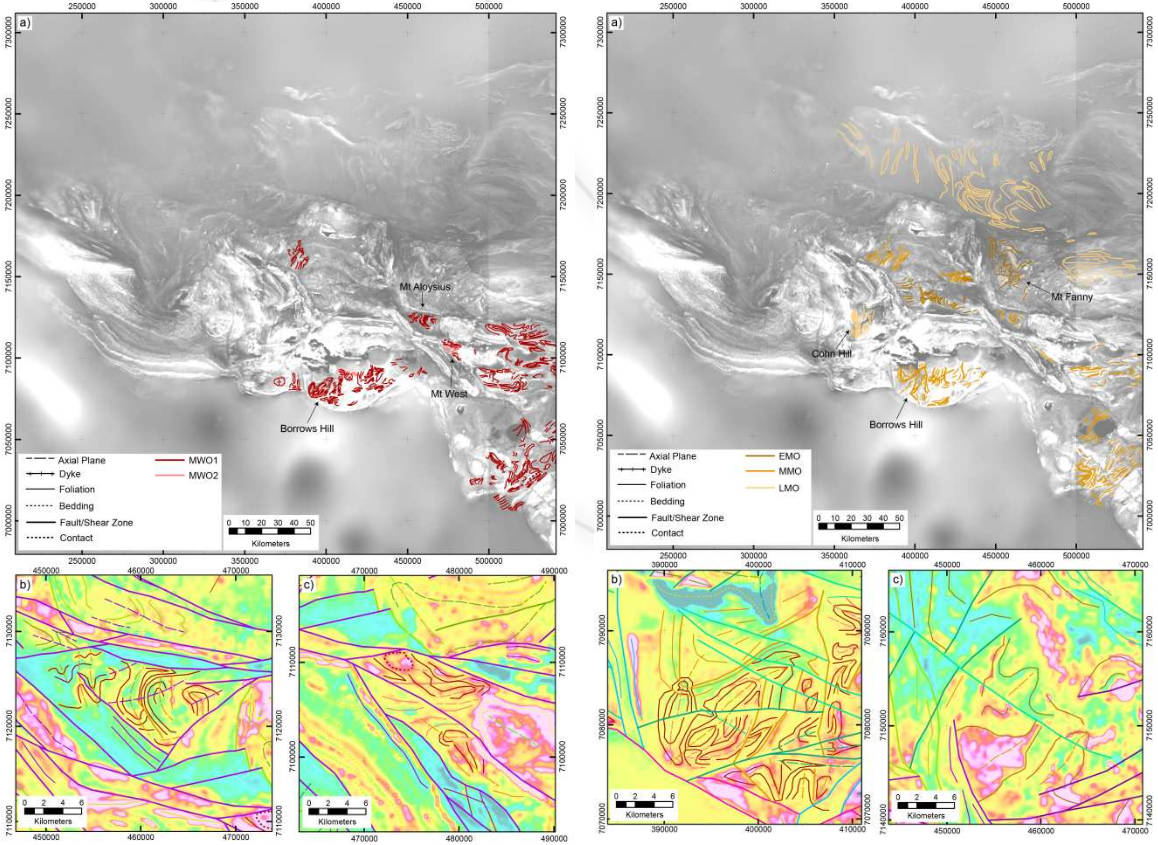
- Interpretation Overview



Tectonic Architecture of the WMP

Mt West & Musgrave Orogeny

- Architecture preserved in several inliers
- MWO > complexly deformed early fabrics
- MO structure more consistent > typically NW-SE close folding
- Perhaps not especially reflective of overall tectonic system



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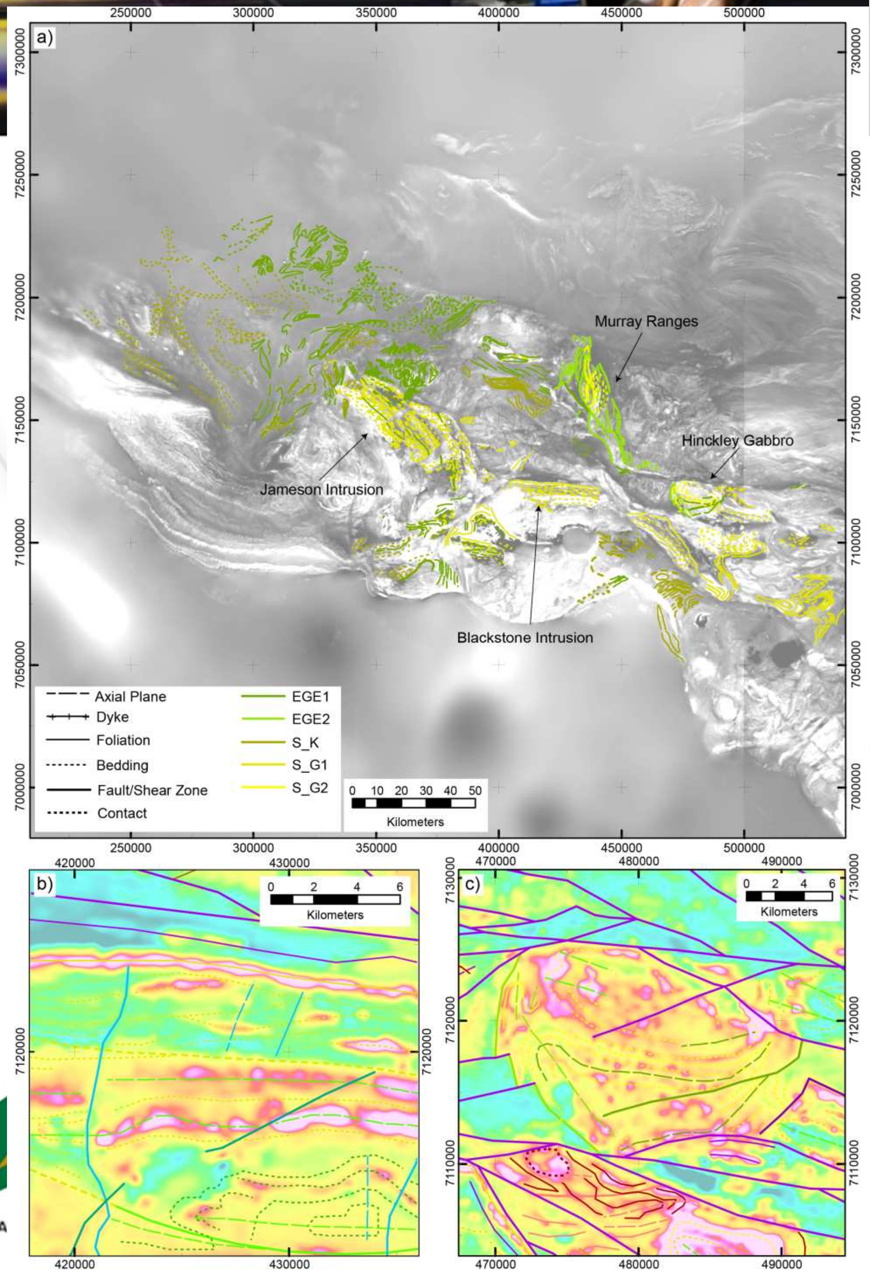
Tectonic Architecture of the WMP

Early Ngaanyatjarra Rift 1082-1072 Ma

- Intrusion-related structures dominate
  - Intra-intrusion structures
  - Multiple phases of intrusion
  - Pluton-country rock interactions
  - Giles-Suite – lopolith geometry
  - Bounded by “growth faults”

- Later large-scale syn-magmatic shear zone
  - Murray Range/Hinckley Gabbro
  - Sinistral transpression (Evins et al, 2010)
  - West dipping



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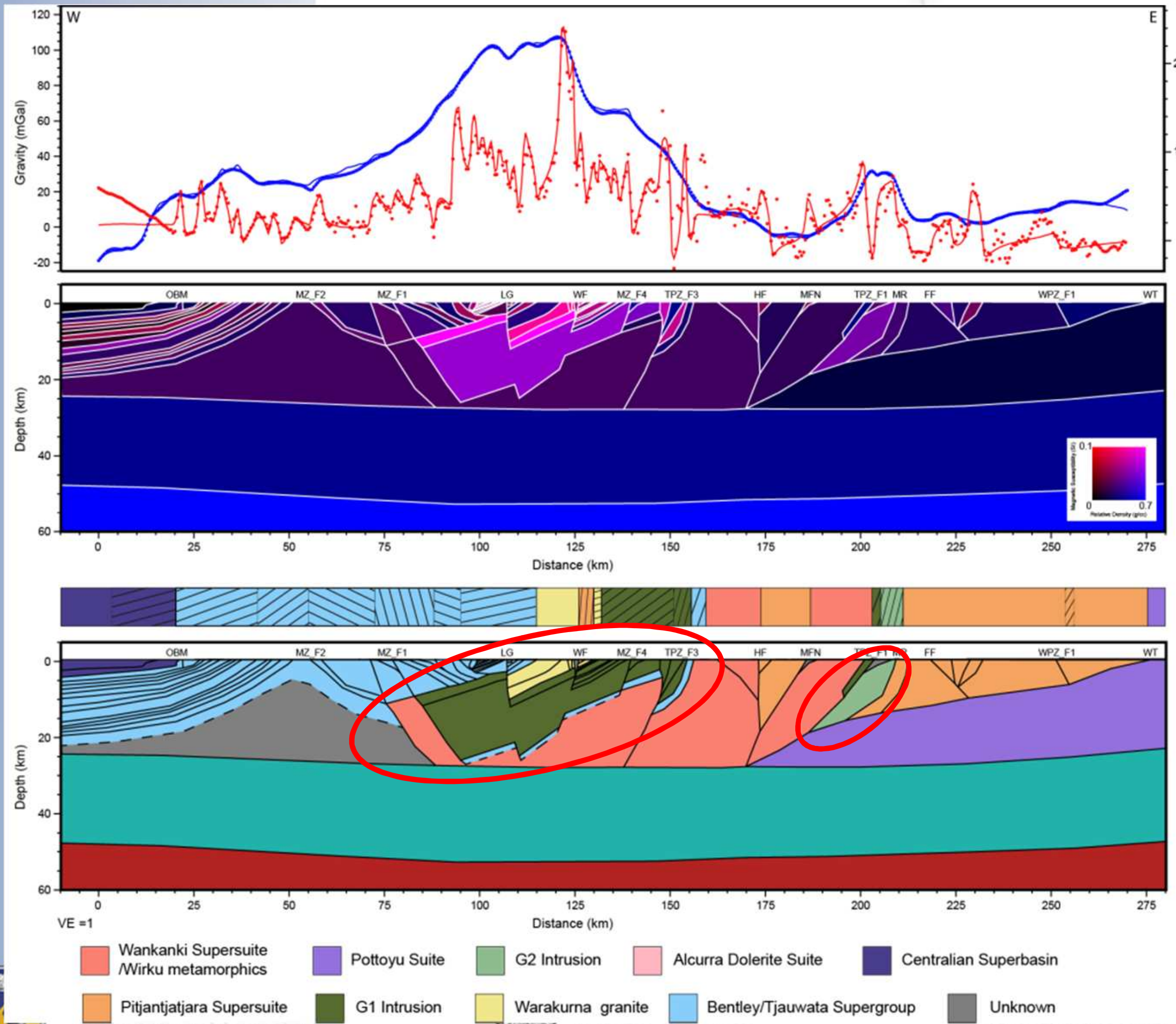
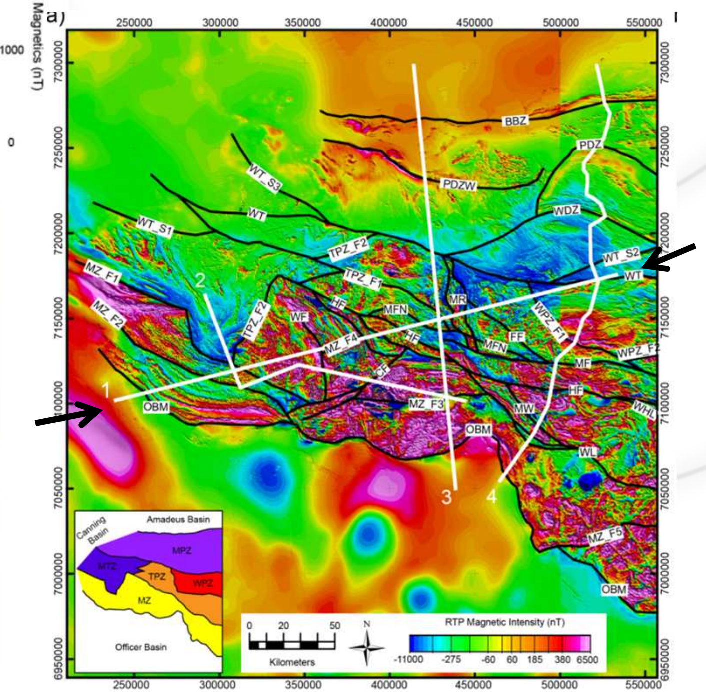
Tectonic Architecture of the WMP

Early Ngaanyatjarra Rift (1082-1072 Ma)





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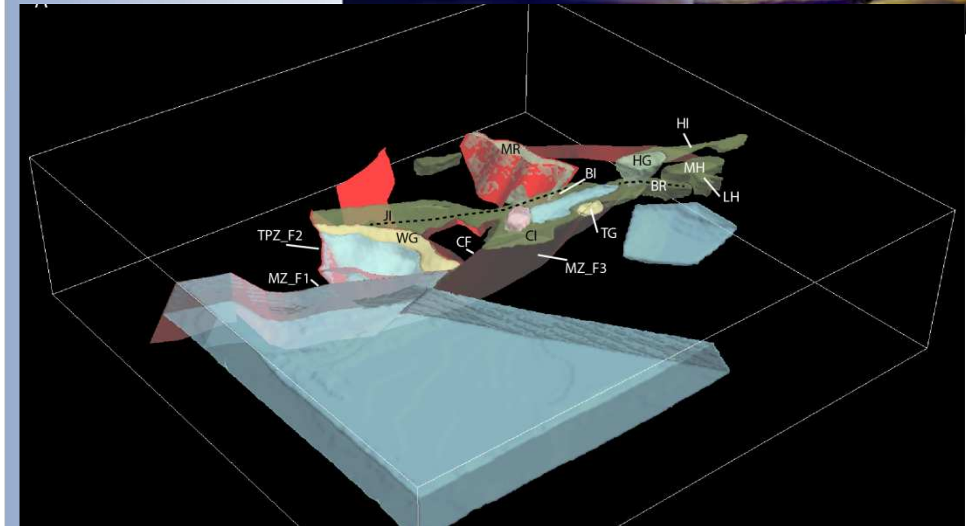
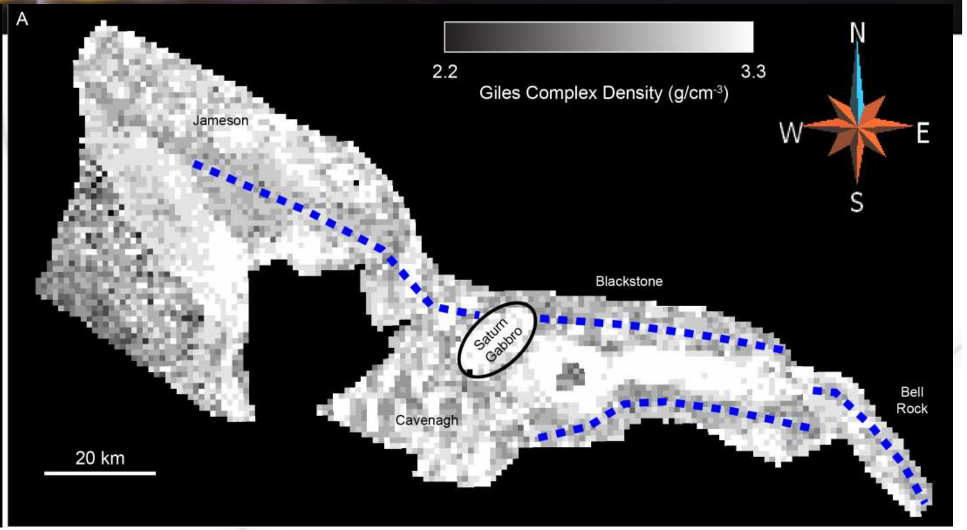
Tectonic Architecture of the WMP





- Overall, shallowly dipping layering parallels the Bentley Supergroup - lopoliths
- Giles Suite 1 mega-intrusion emplaced into this layering along an ESE axis – 31,100 km^3 preserved volume.
- Bounded to south and probably west by syn-emplacement "growth faults"
- Single low-density troctolite layer exists throughout

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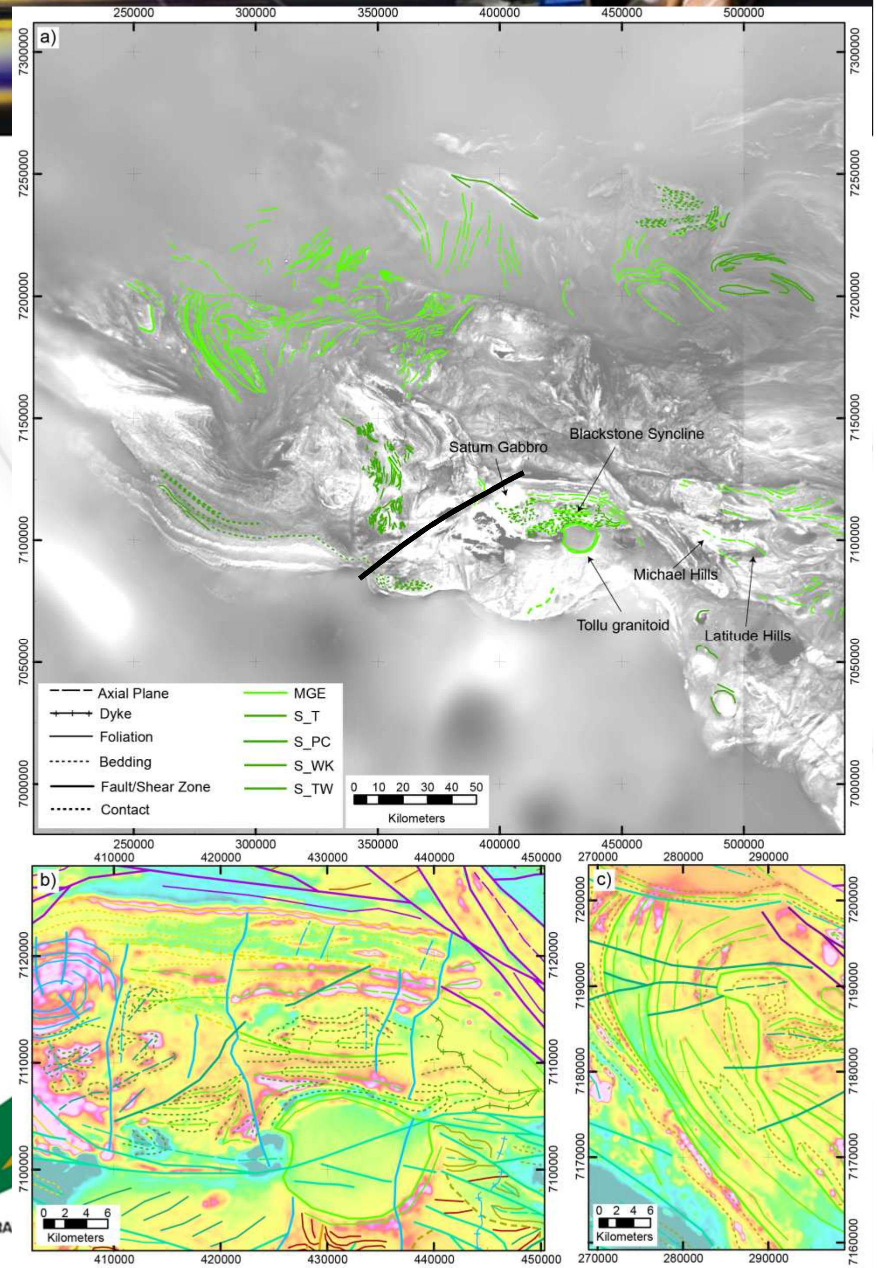
Tectonic Architecture of the WMP

Late Ngaanyatjarra Rift 1 (1075 -1064 Ma)

- N-S shortening
  - SE of Cavenagh Fault only
  - Blackstone Syncline formed
- Folding in Mitika Zone and Mulga Park Zone
  - Uncertain age (post-Kunmarnara, pre-Alcurra)
  - Uncertain kinematics – broadly NE-SW shortening
  - May not be directly related



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Tectonic Architecture of the WMP

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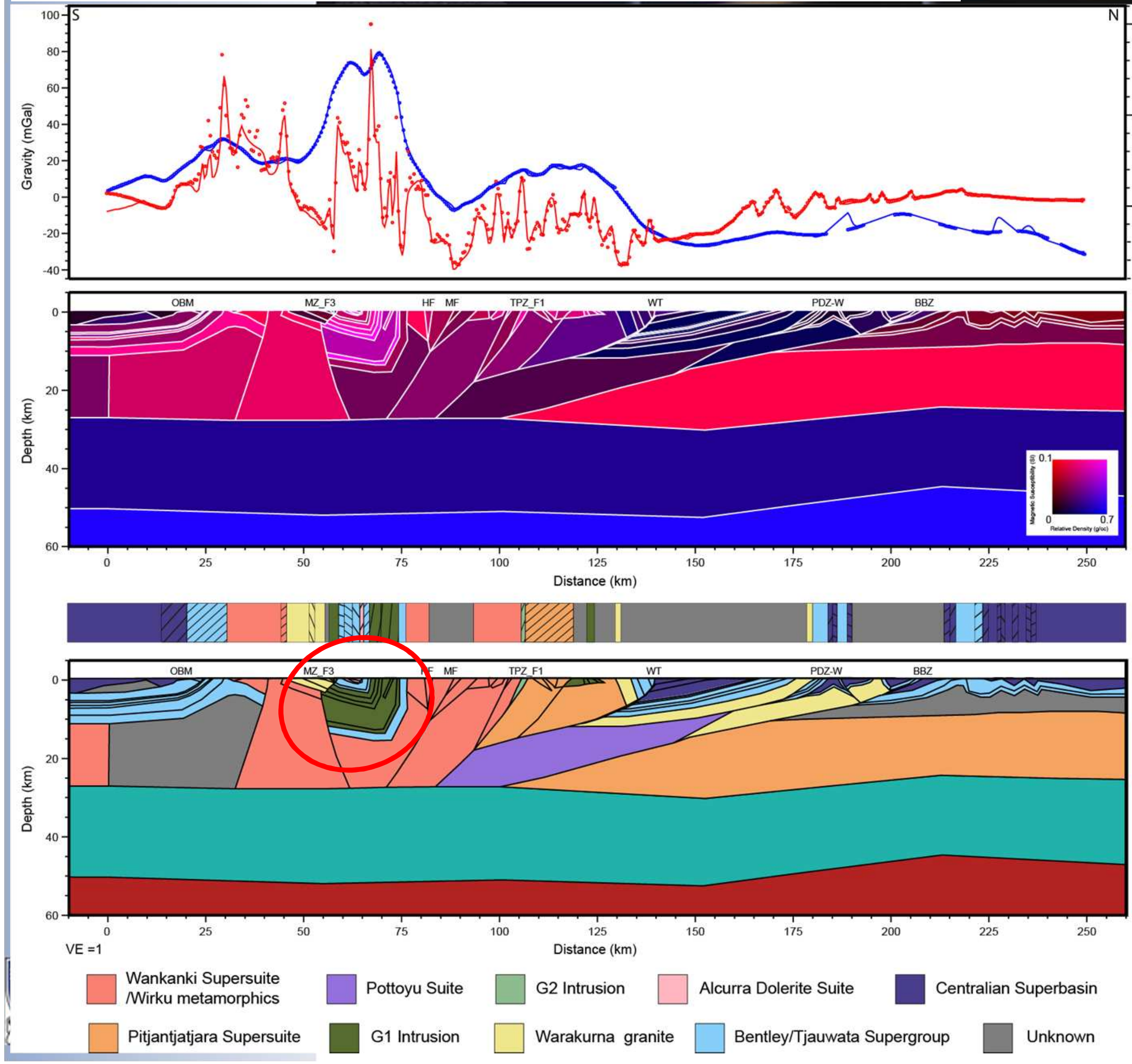

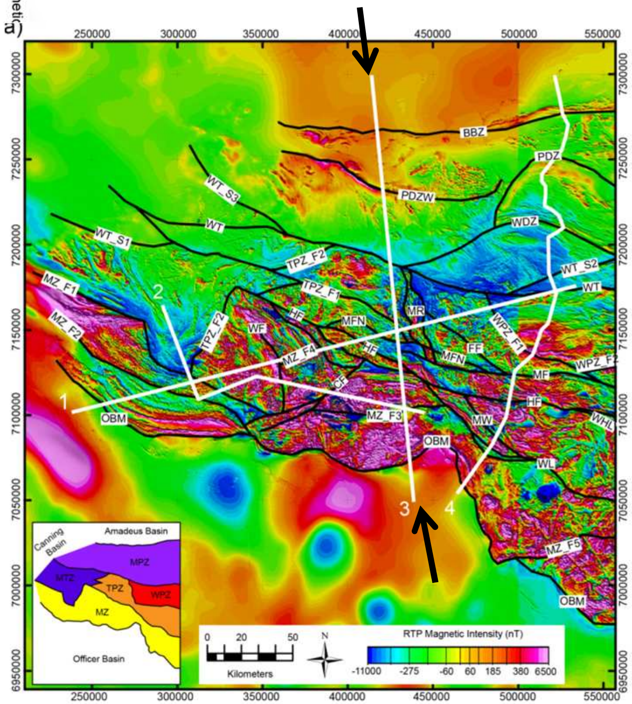

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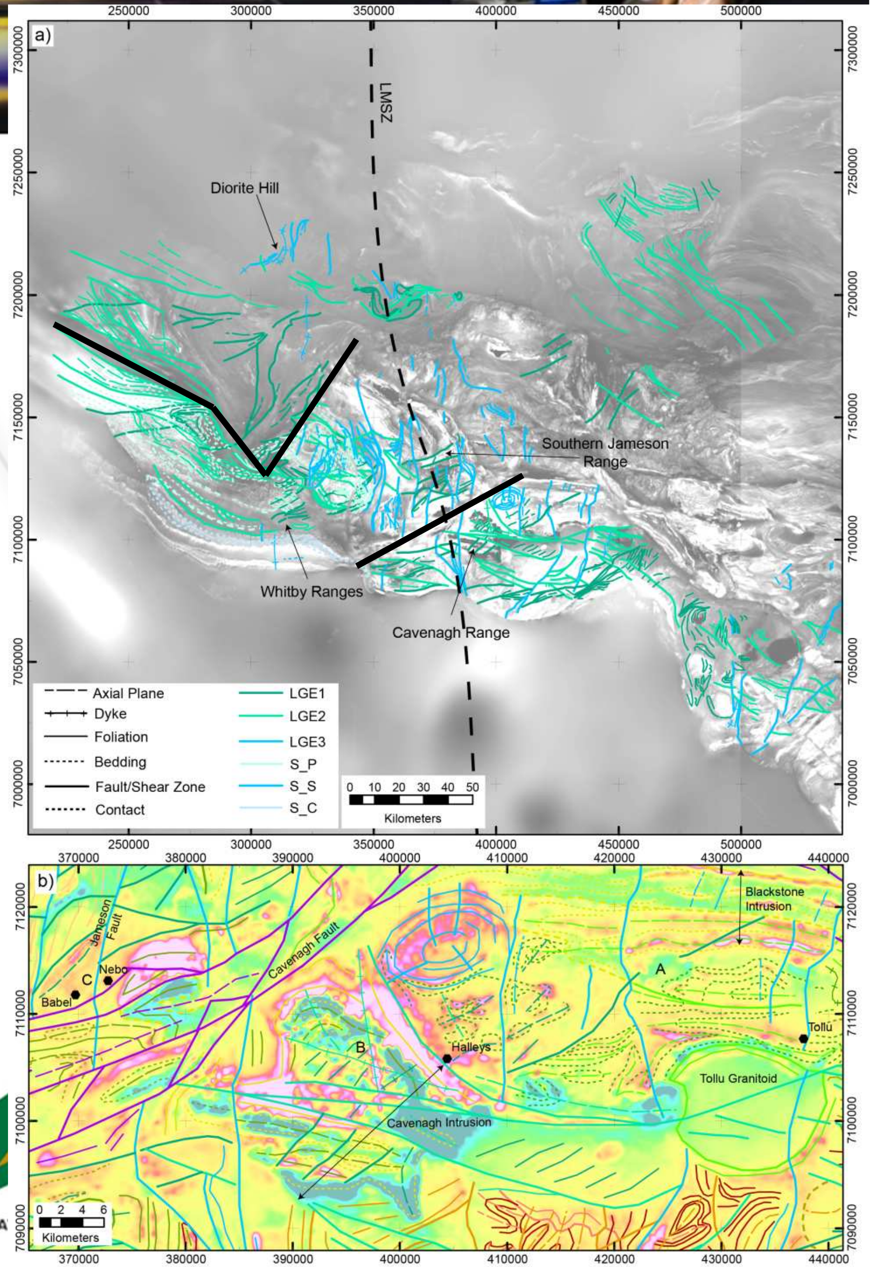
Tectonic Architecture of the WMP

Late Ngaanyatjarra Rift 2, 3 & 4
(1075-1060 Ma)

- NW-SE extension
  - Talbot Basin deepened between Cavenagh Fault and TPZ_F2 Fault
- NW-SE shortening
  - N-S Sinistral and ESE-WNW dextral Conjugate Faults
  - Talbot Basin partially inverted
  - Nebo Babel overturned and then cut by N-S Jameson Fault (Seat et al, 2011)?



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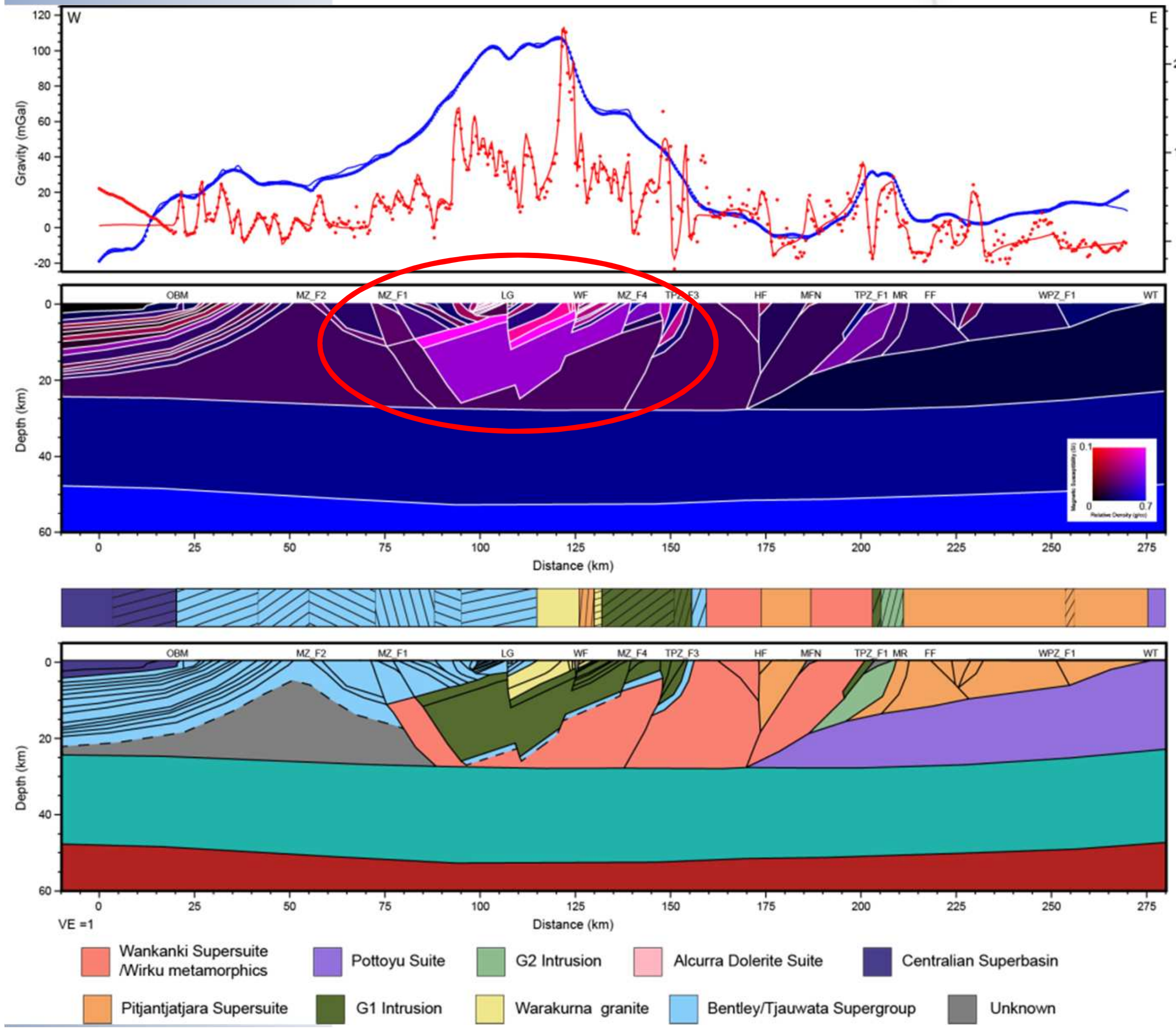
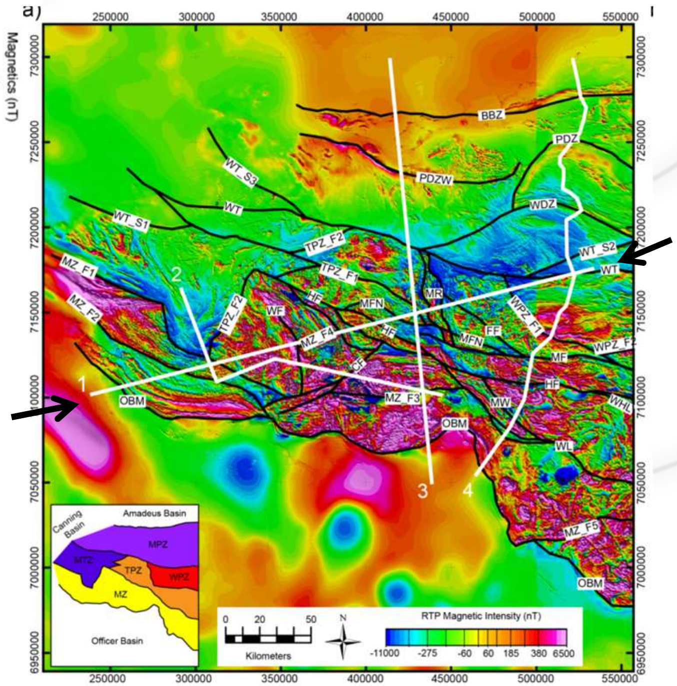
Late Ngaanyatjarra Rift 2, 3 & 4 (1075-1060 Ma)





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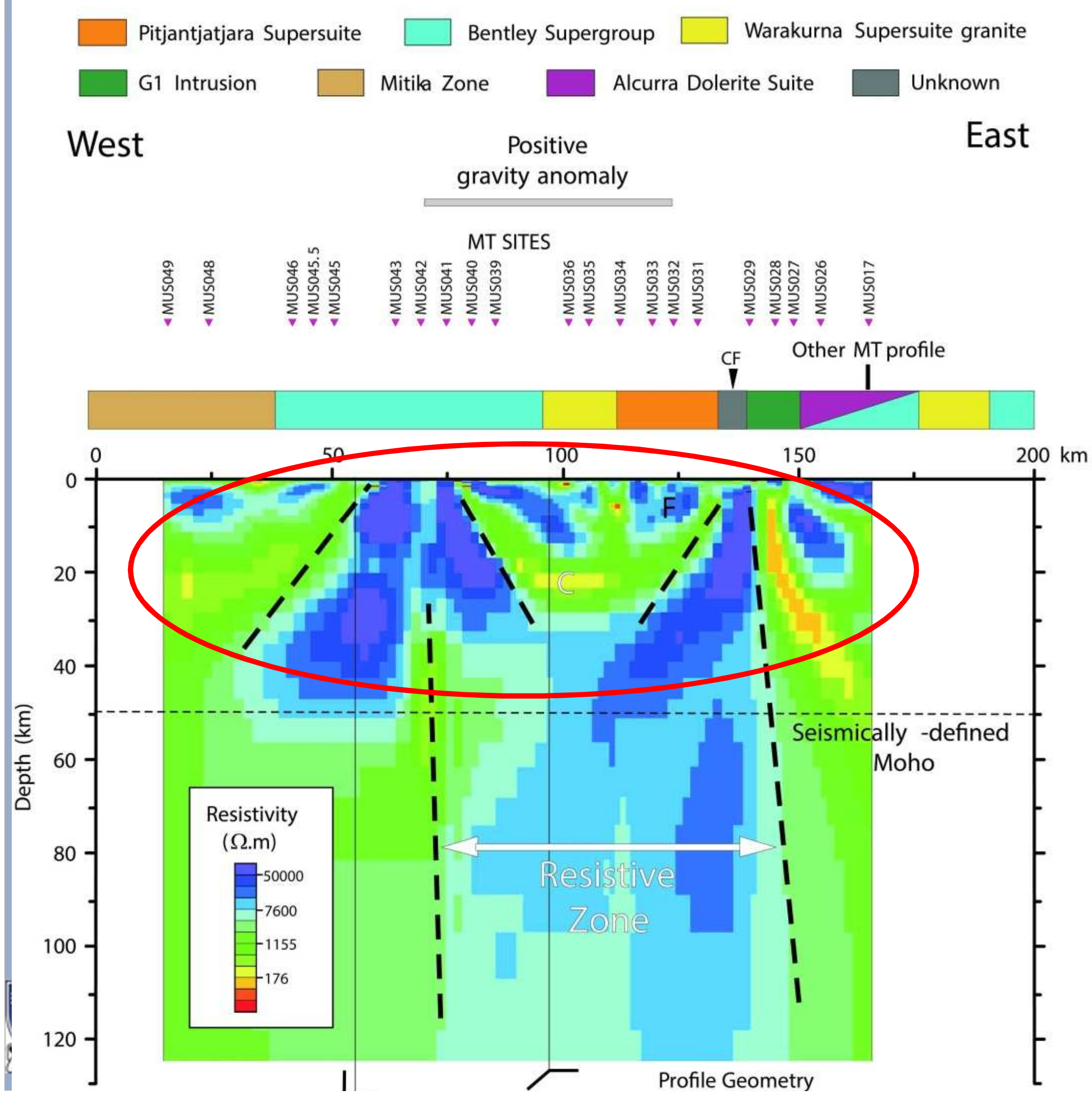
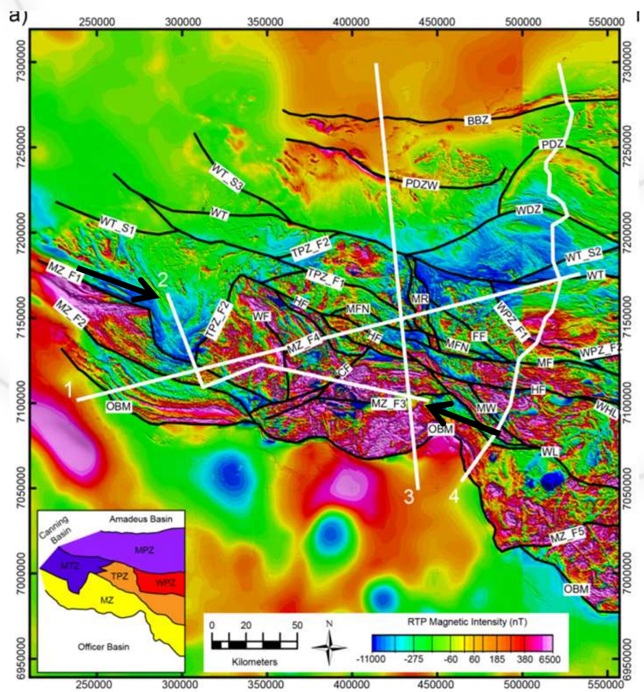
Tectonic Architecture of the WMP

Late Ngaanyatjarra Rift 2, 3 & 4 (1075-1060 Ma)





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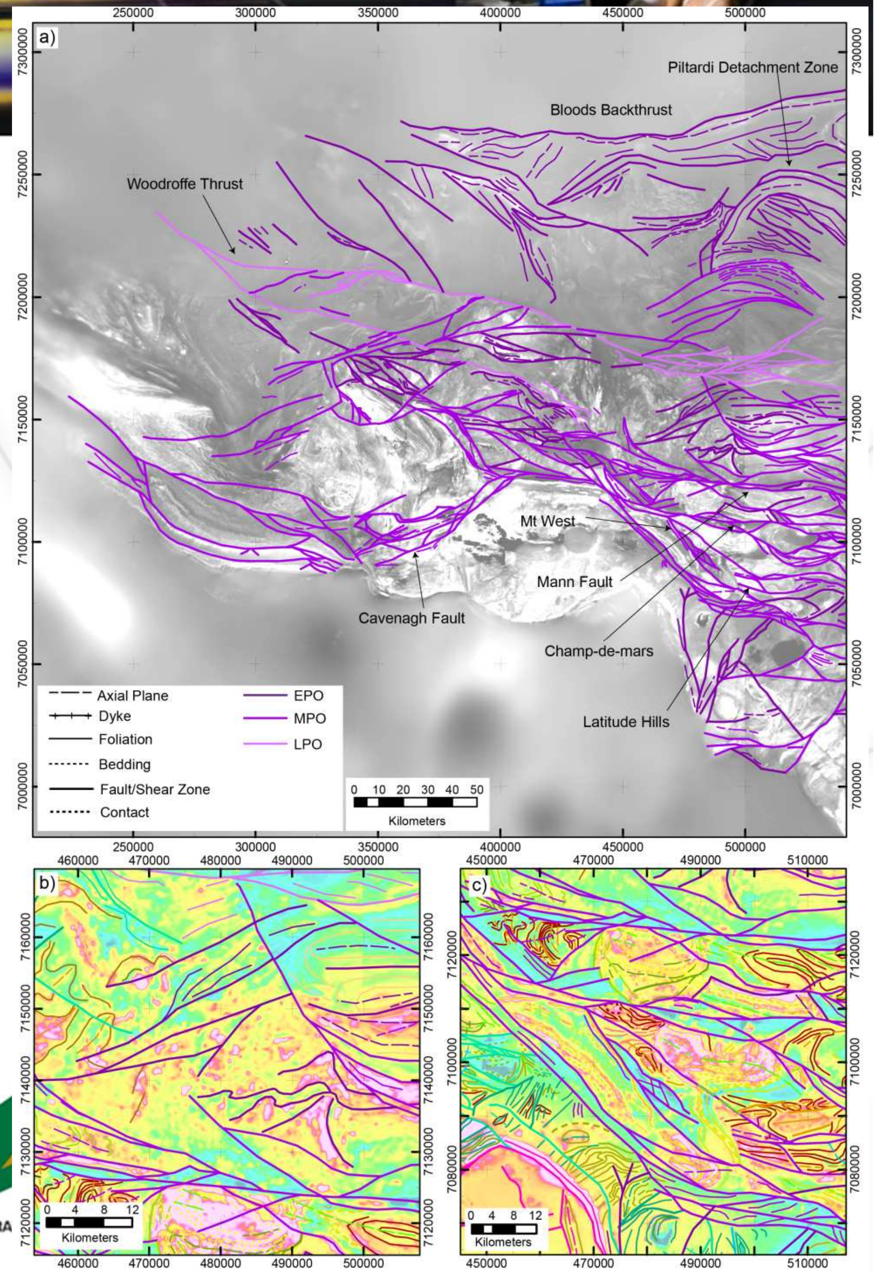
Tectonic Architecture of the WMP

Inferred Petermann Orogeny (580-530 Ma)

- Foreland: Shallow dipping thrusts
  - PDZ is an early (580-560 Ma) mutliply thrusted and folded duplex structure (Flottmann et al., 2005; Edgoose et al., 2004)
  - Woodroffe Thrust is a relatively late major thrust, ca. 20km of throw (ca. 540 Ma - Maboko et al., 1992)
  - Shortening reduces considerably to the west

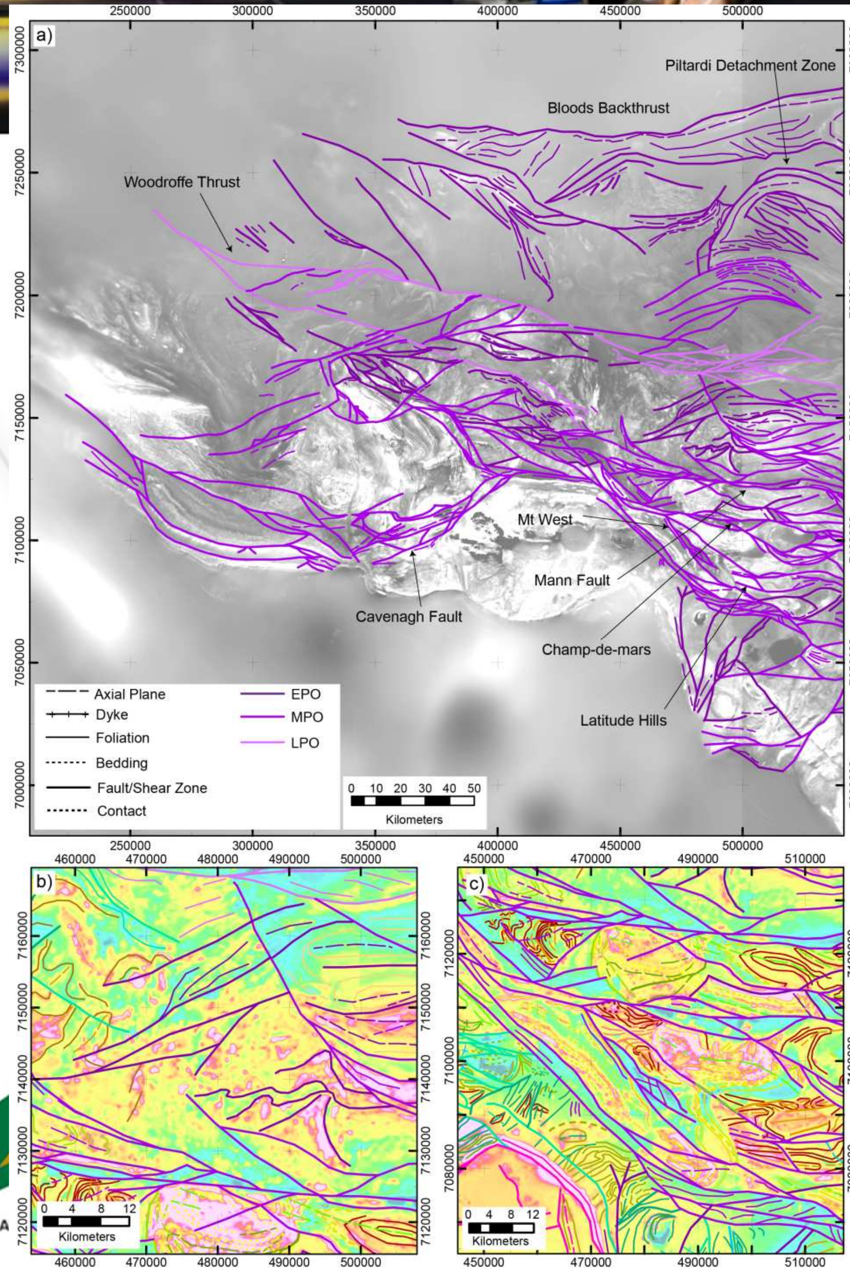
- Walpa Pulka Zone: lower crustal flow
  - NE-directed flow within lower-crustal channel (Raimondo et al., 2009)



Tectonic Architecture of the WMP

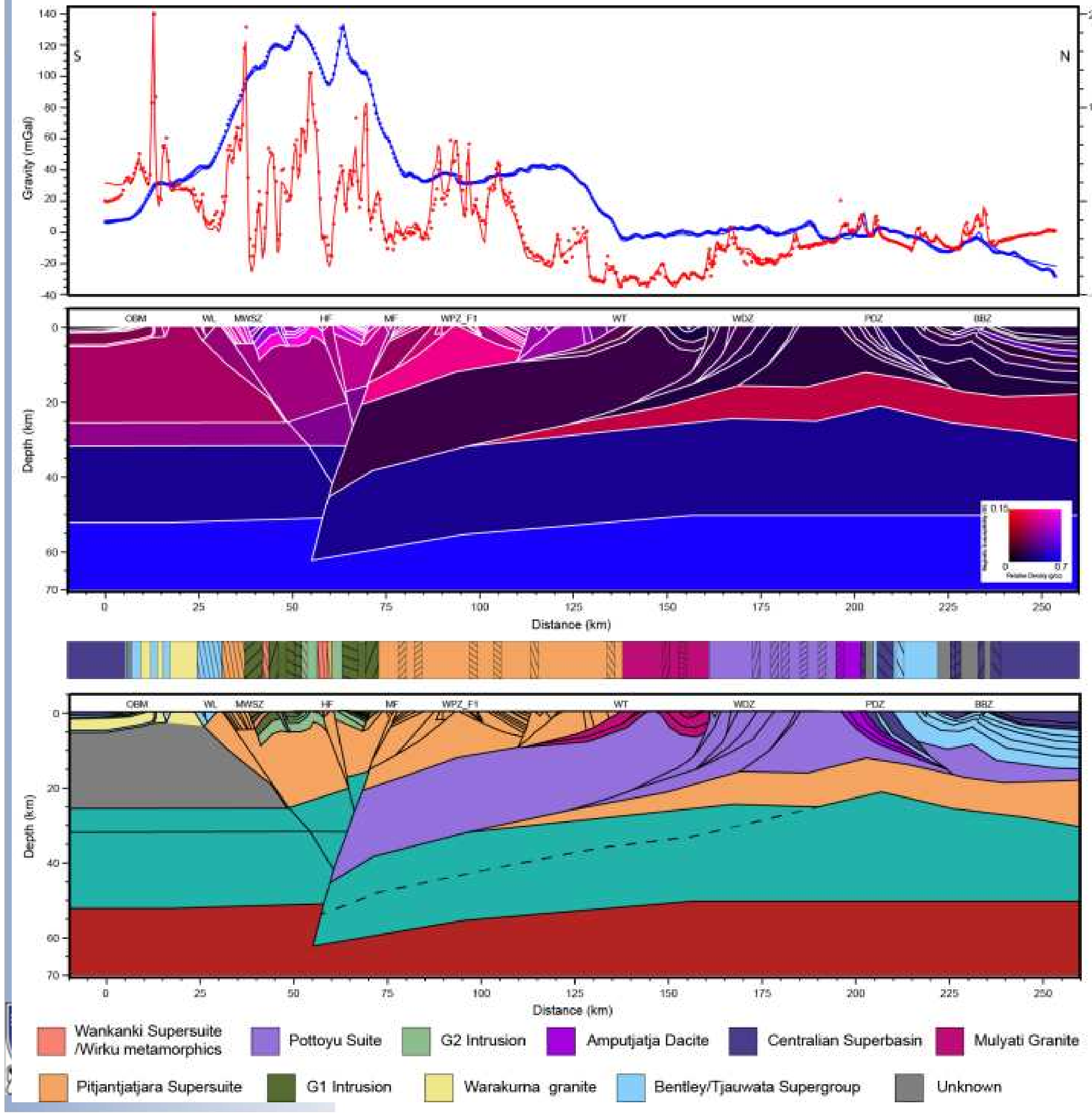
Inferred Petermann Orogeny (580-530 Ma)

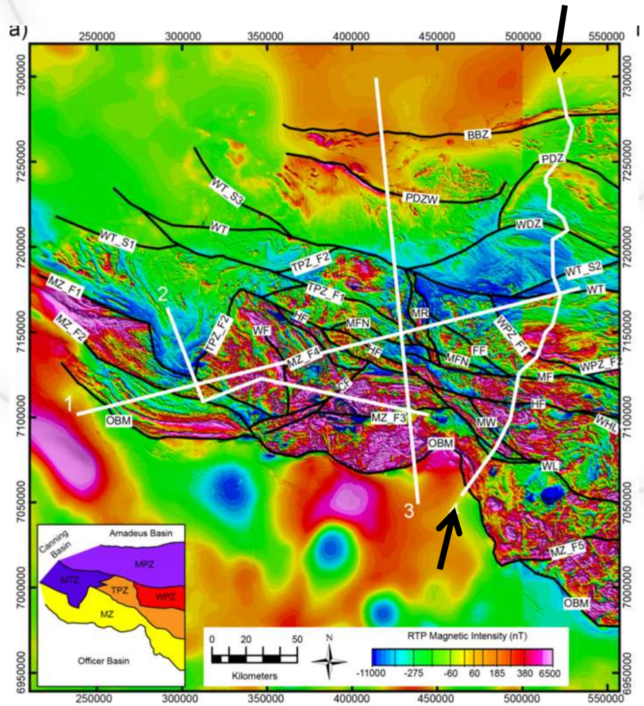
- Hinterland: Anastomosing Network of shear zones
  - Kinematics indicate ~ N-S shortening
  - Number and magnitude of shear Zones reduces considerably to the southwest – e.g. Cavenagh has 4 km sinistral offset post-NR
  - Possibly some other events preserved – e.g.
    - ca. 720 Ma Areyonga Movement
    - ca. 630 Ma Paterson Orogeny
    - ca. 450-350 Ma Alice Springs Orogeny



Tectonic Architecture of the WMP

- Inferred Petermann Orogeny (580-530 Ma)





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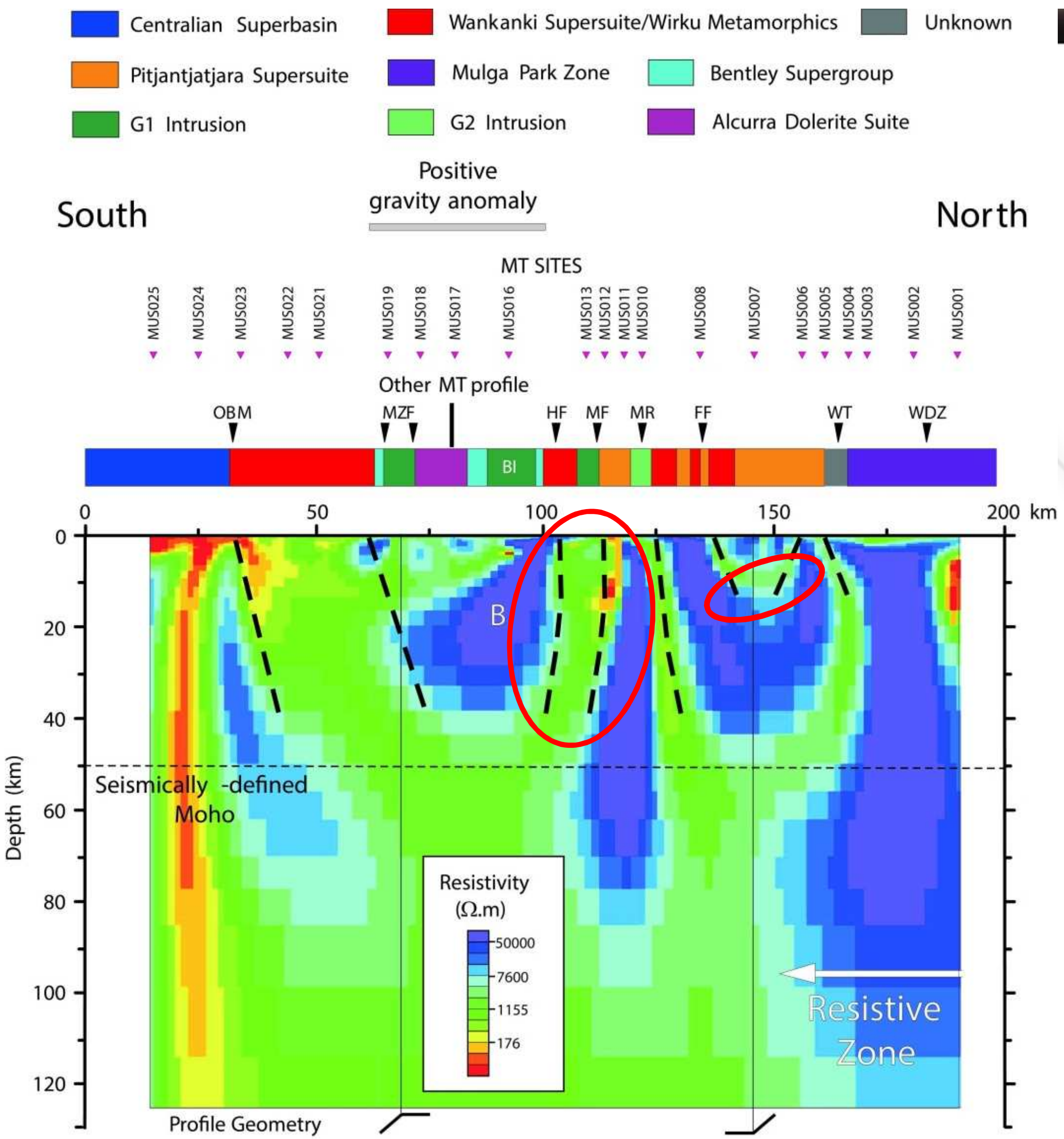
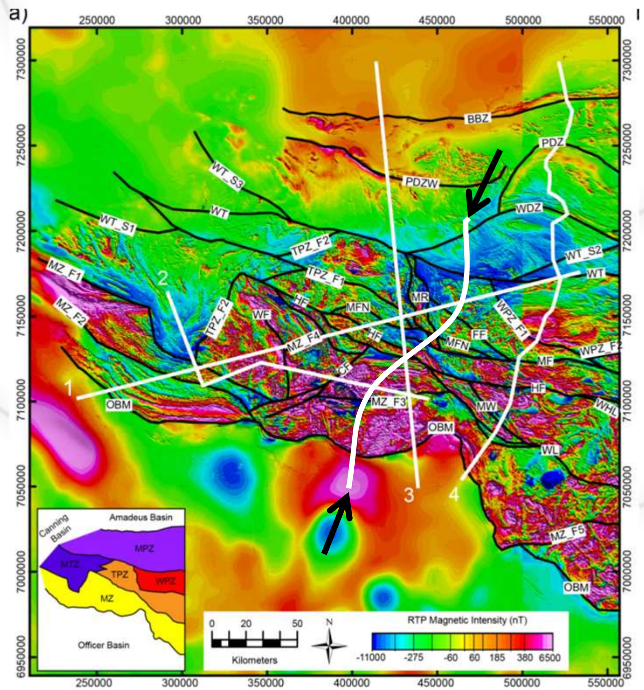
Tectonic Architecture of the WMP

- Inferred Petermann Orogeny (580-530 Ma)





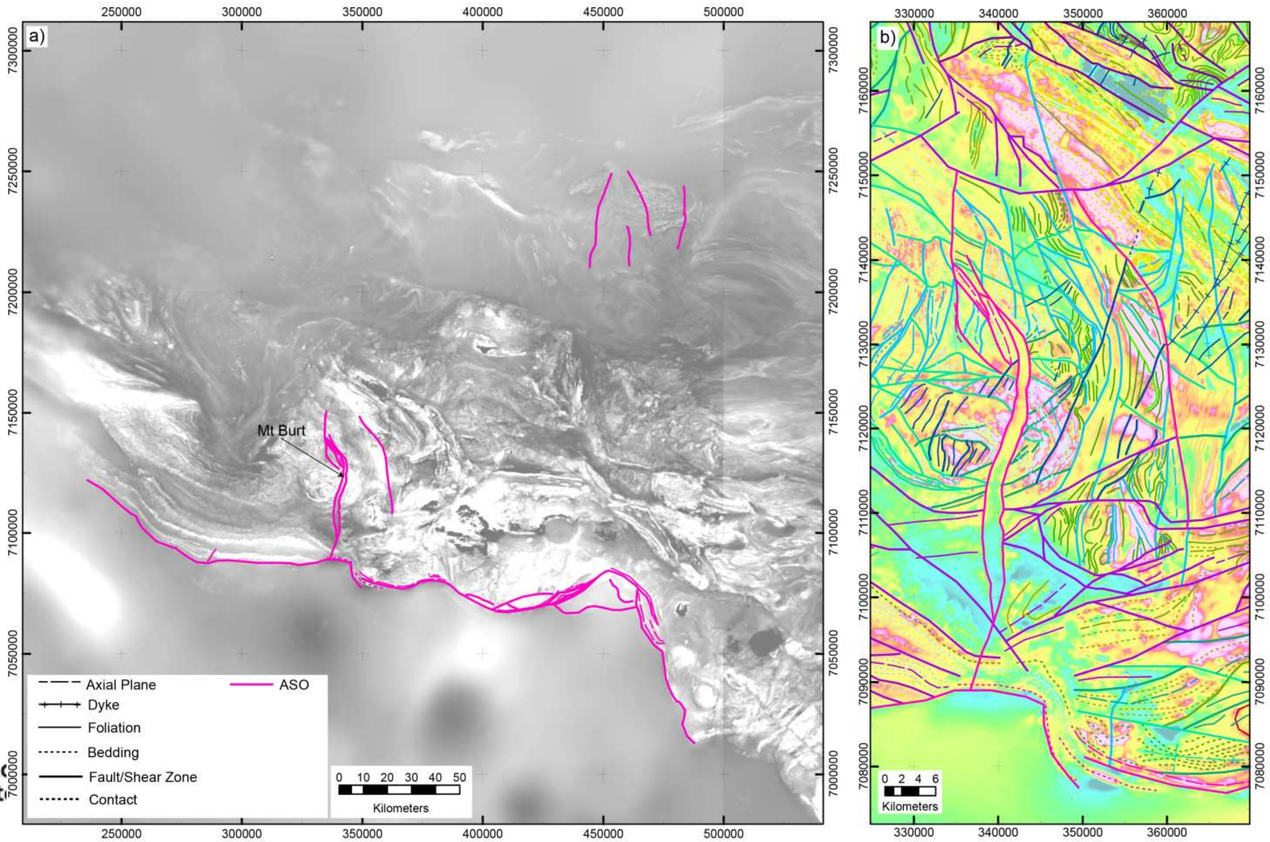
Mann Fault and Hinckley Fault steeply dipping crustal scale features

WT not obvious, except perhaps truncation

Tectonic Architecture of the WMP

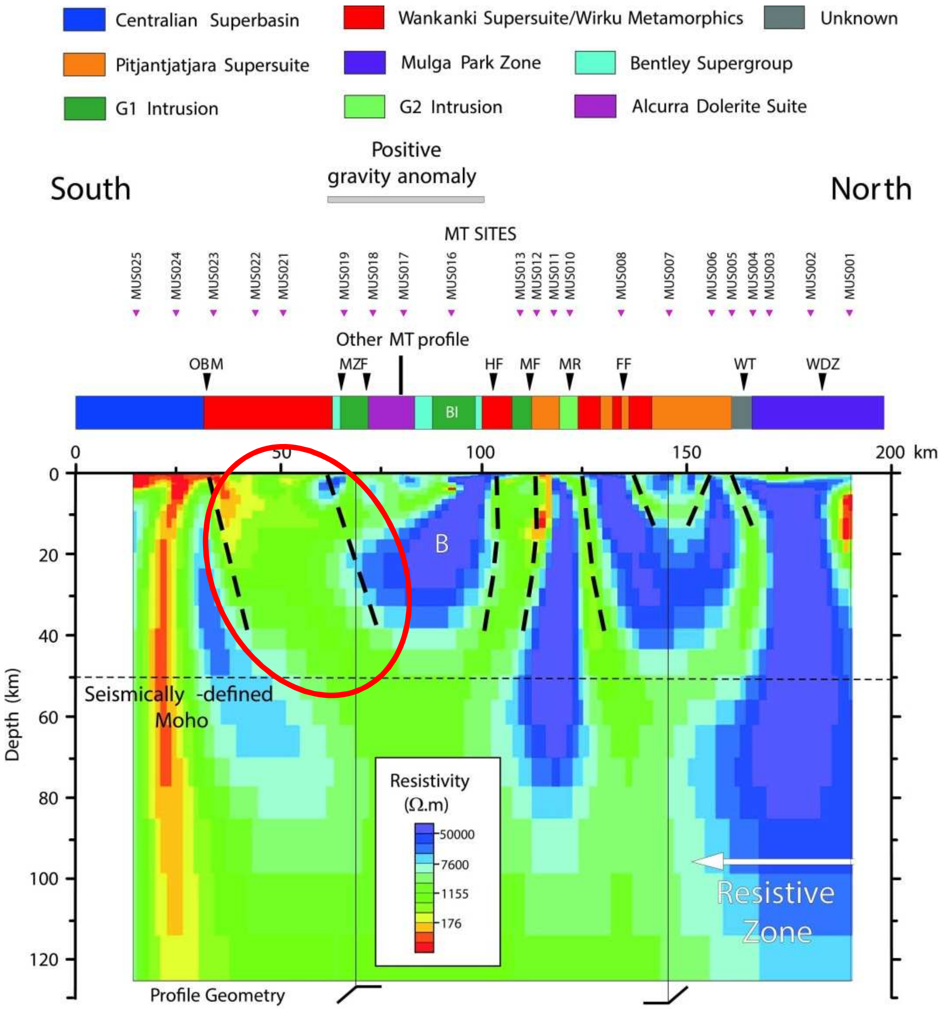
Inferred Alice Springs Orogeny (450-350 Ma

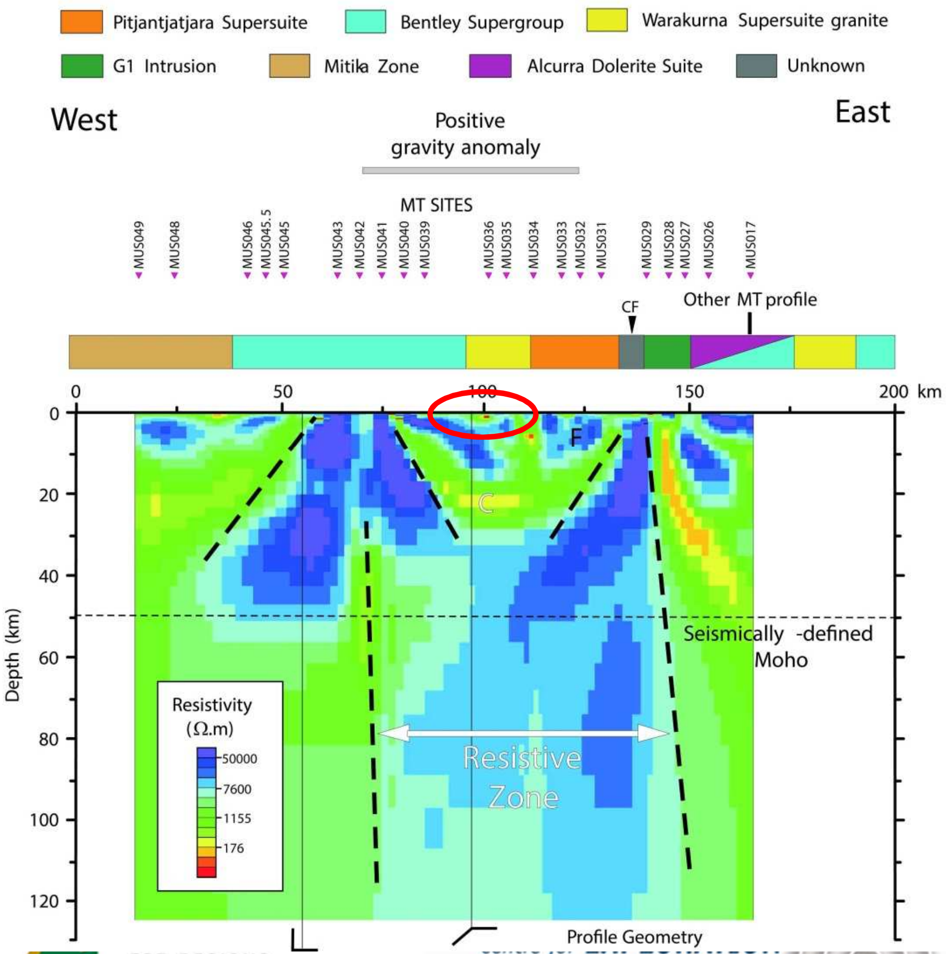
- Thrusting at southern margin (Lindsay and Leven, 1996) – only to the east of the Lassetter Shear Zone?
- N-S graben like feature developed - ~1 km deep, minimal strike-slip offset



Tectonic Architecture of the WMP

Inferred Alice Springs Orogeny (450 -350 Ma)





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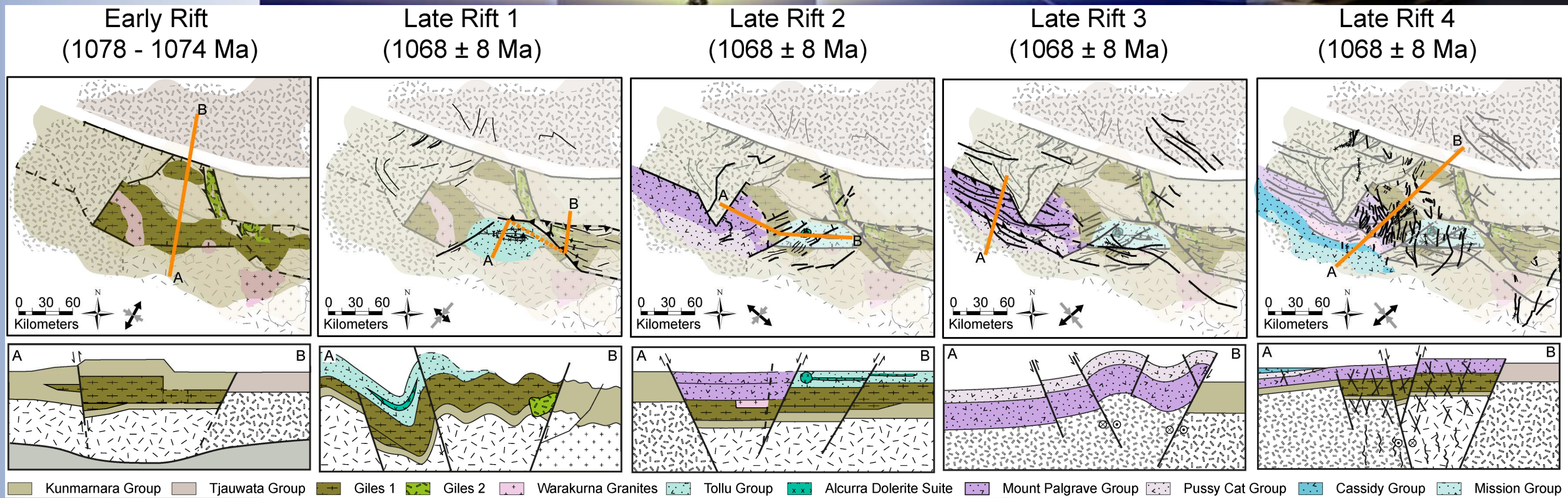
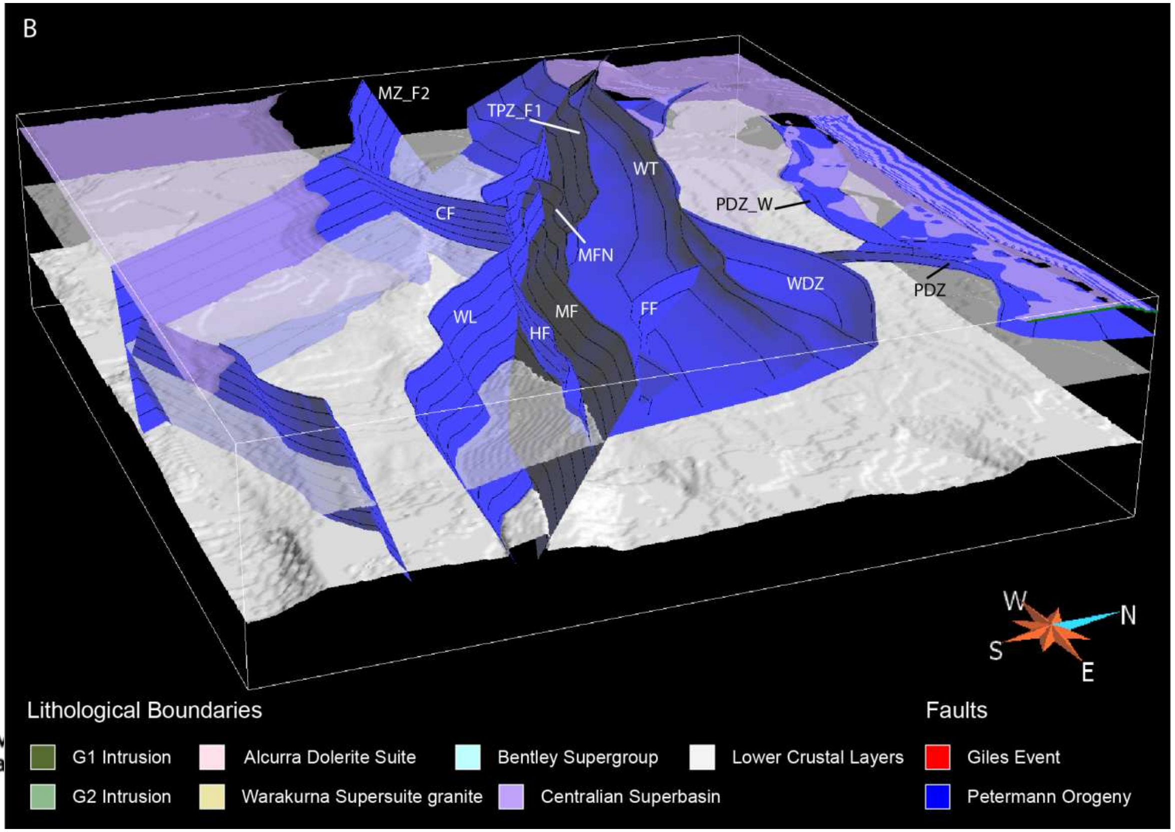
Summary – Ngaanyatjarra Rift/Giles Event



- Magmatism dominated > 20+ km thick pile emplaced in upper crust
- Crust thickened by ca. 15 km
- Fairly complex series of deformation events > net extension quite small in upper crust, shortening dominates in places
- Very-rapid tectonic switching in late rift evolution > local response to magmatism (Aitken et al. 2013)?

Summary – Petermann Orogeny

- Foreland Faults/SZs shallowly dipping – several tens of kilometres shortening on PDZ. Less in the west.
- Walpa Pulka Zone also dominated by shallowly south dipping shear zones
- Hinterland dominated by steep tranpressional faults
- Faults become shallower dipping in the west
- PO faults become less numerous to the southwest
- Also less offset observed on faults



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Acknowledgements

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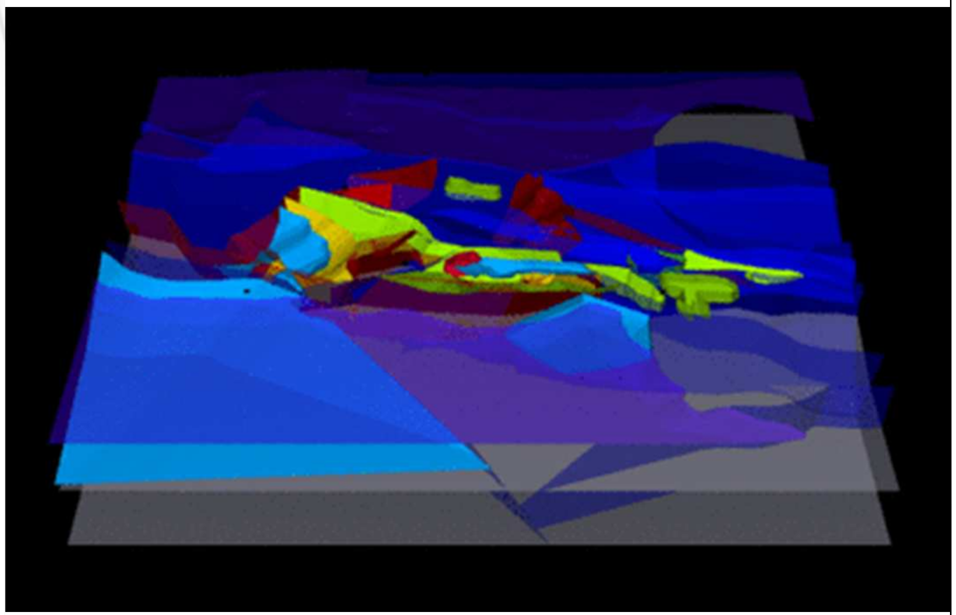

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