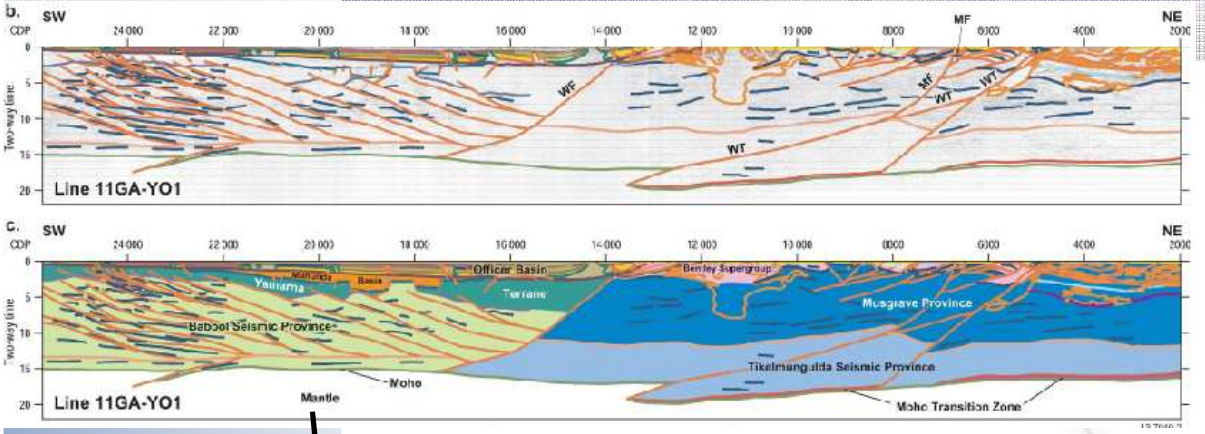
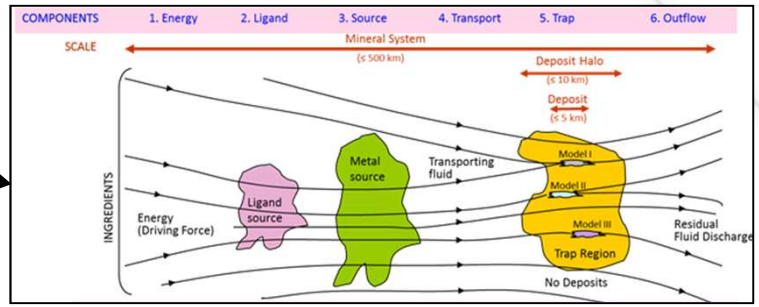
Yilgarn-Officer-Musgrave (11GA-YO1): implications for mineral systems





After Wyborn et al. (1994)

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ROYALTIES FOR REGIONS
EXPLORATION INCENTIVE SCHEME

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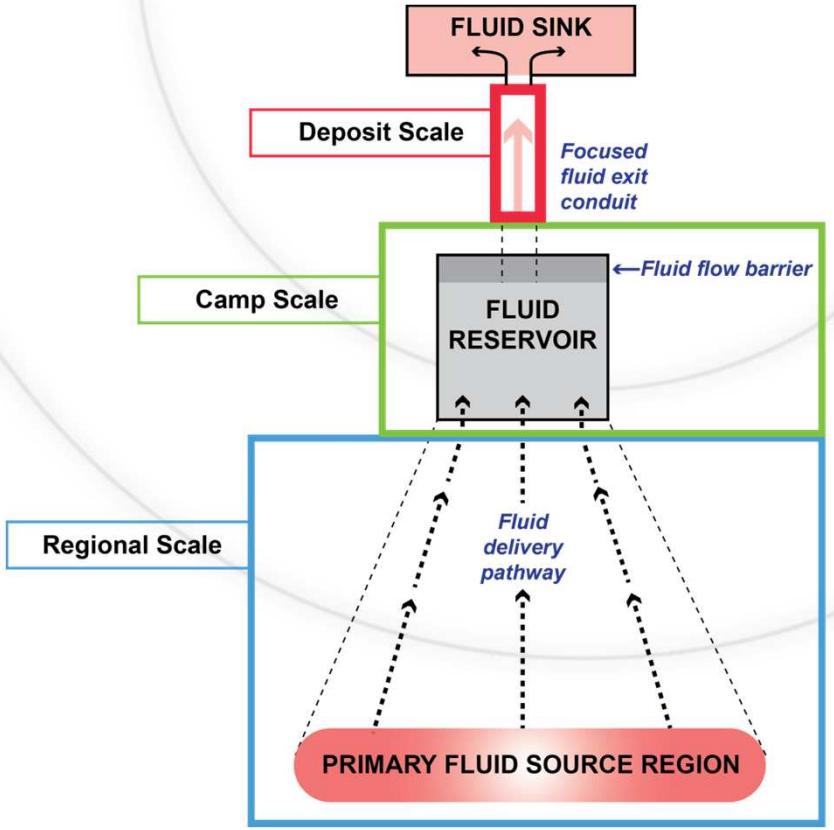
Introduction

- Deep seismic reflection data provide knowledge of crustal structure, a crucial component of many mineral systems.
- YOM traverses several regions with significant potential for mineral resources - but little development due to difficult exploration.
- Improved targeting is necessary to aid exploration in this vast greenfields region.
- Here we will review the potential implications of the newly imaged crustal structure for several mineral systems.



www.science.org.au/policy/documents/uncover-report.pdf

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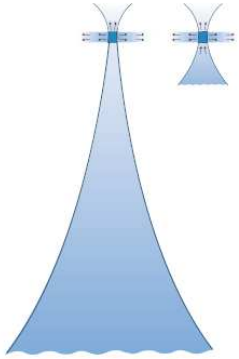
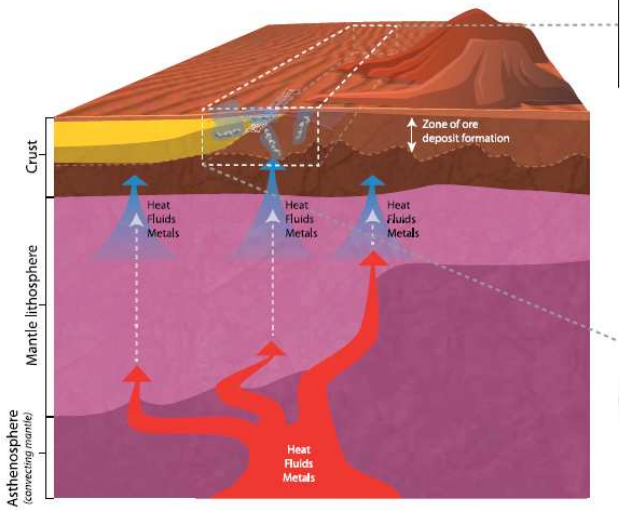
A holistic view of Mineral Systems

Pmd*CRC – 5 Questions

1) Geodynamic evolution;
2) Lithospheric architecture;
3) Sources and reservoirs of fluids and metals;
4) Fluid pathways and drivers;
5) Transport and metal depositional processes

6) Preservation.





www.science.org.au/policy/documents/uncover-report.pdf

Key challenges include (McCuaig et al., 2010):

1 – Identifying proxies for system components.

2 – Applying these at the right scale.

3 – Making the transition from prediction to detection.

	Source	Active Pathway	Fluid Throttle (physical)	Deposition (chemical)
District	**Critical** • Geodynamic setting • Major metallogenic epoch	• Lithospheric architecture • Long-lived features • Paleocraton margins	Large scale damage zones	
Camp	**Important** • P-T windows • Magma series	•4D structure model •Crustal architecture	• Small-scale damage zones • Complexity • Broad permeability barriers	• Alteration • Metal anomalism • Chemical gradients
Prospect	**Less relevant**	• Large scale damage zones	• Small-scale damage zones • Competency contrasts • Kinematic framework	• Alteration • Metal anomalism • Chemical gradients

McCuaig et al. (2010)

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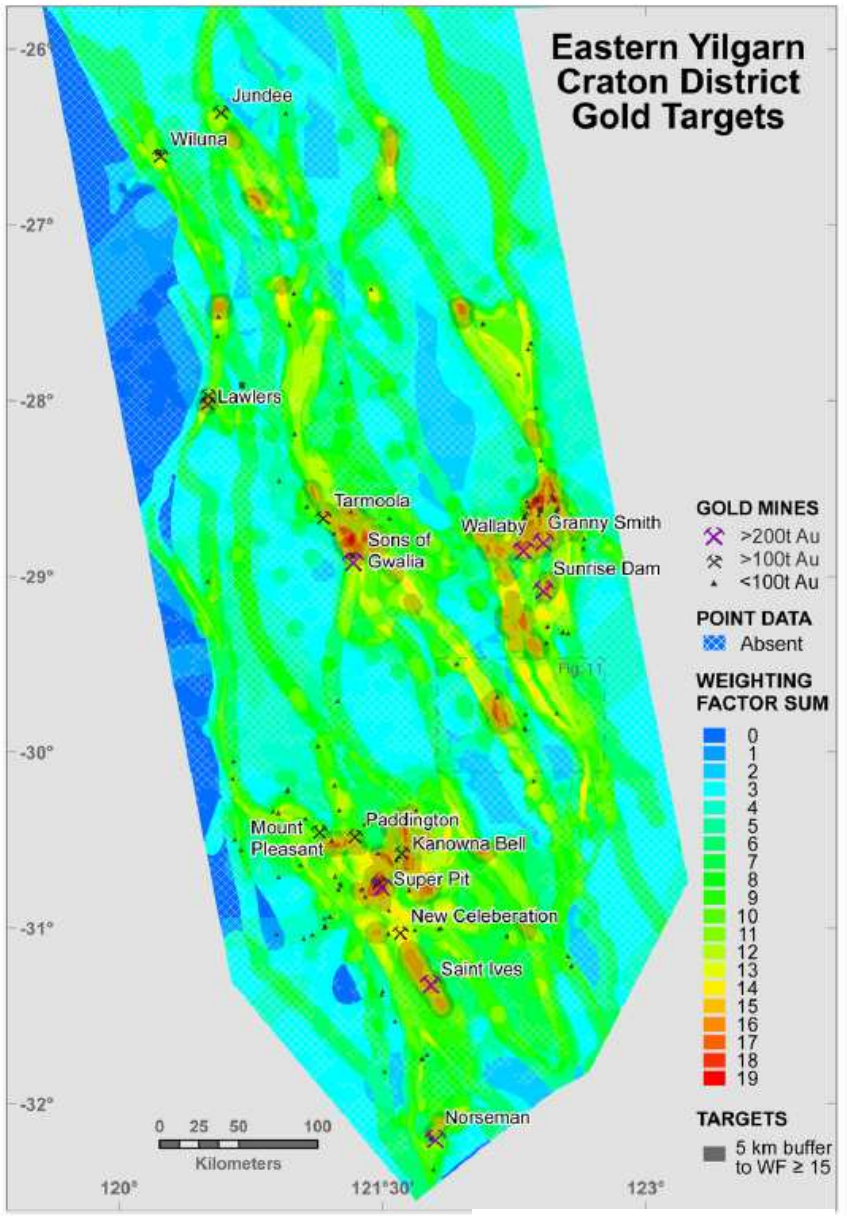
Yilgarn Mineral Systems – Orogenic Gold

Archean Orogenic Gold

- Relatively well-studied system for Kalgoorlie and eastern Kurnalpi Terrane (Czarnota et al., 2010)
- Little knowledge of system for the Yamarna Terrane

Key Factors:

- Crustal isotopic age – most well endowed regions are intermediate in age – 3.0-2.9 Ga Sm-Nd
- Crustal-scale fault networks are important pathways
- Second- and third-order structures are important for deposition
- Domes provide an additional structural focus

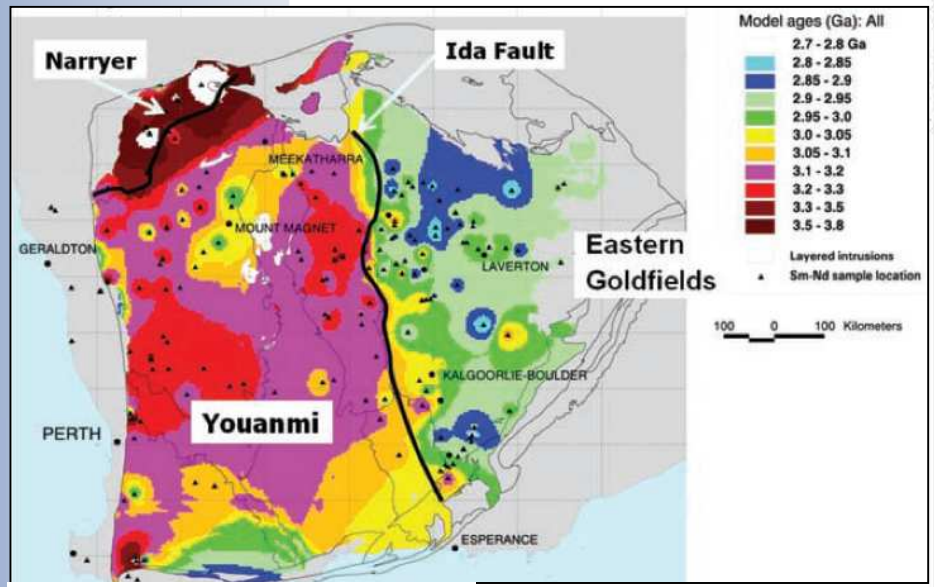


Czarnota et al. (2010)

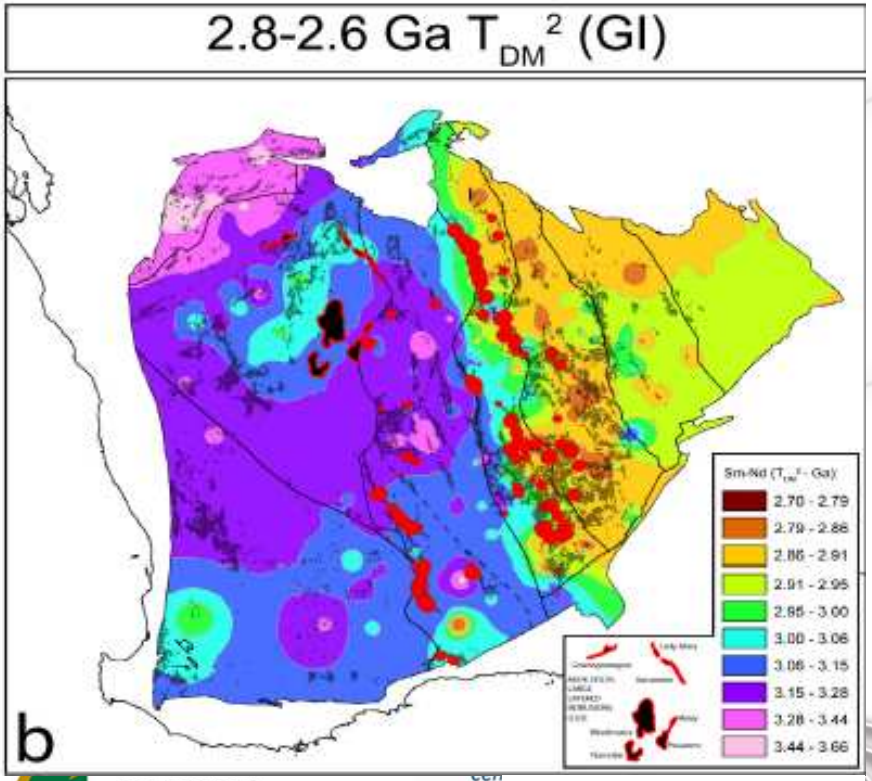
Yilgarn Mineral Systems – Orogenic Gold

Key Factor: Crustal isotopic age – most well endowed regions are intermediate in age – 3.0-2.9 Ga (Sm-Nd T_{DM})

- Very sparse Sm-Nd isotopic data suggest that the Yamarna Terrane may be of intermediate age (2.95-2.9 Ga) (Champion and Cassidy, 2007; Mole et al., 2010)



Champion and Cassidy (2007)



Mole et al. (2010)

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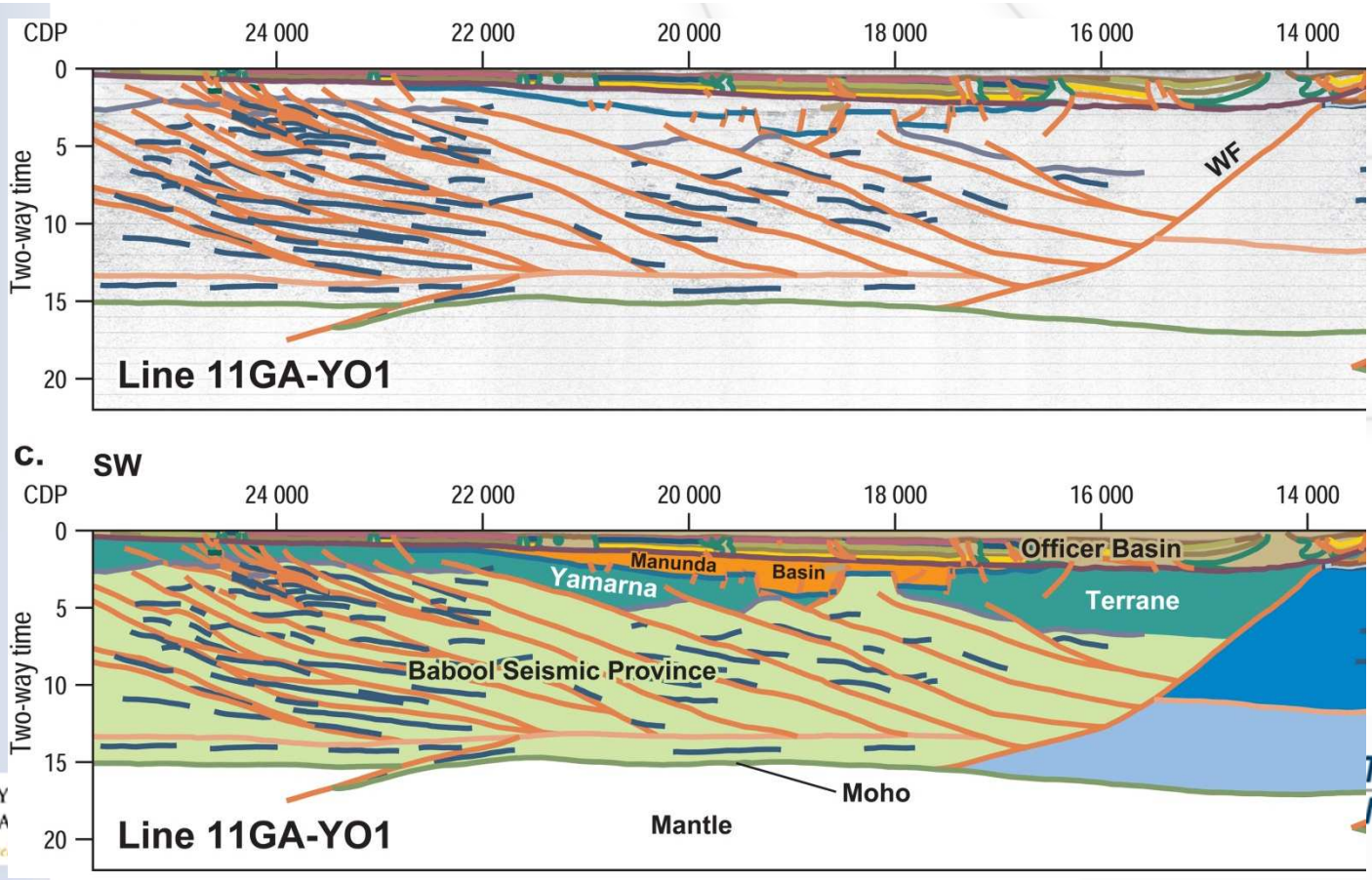
Yilgarn Mineral Systems – Orogenic Gold

Key Factor: Crustal-scale fault networks are important pathways

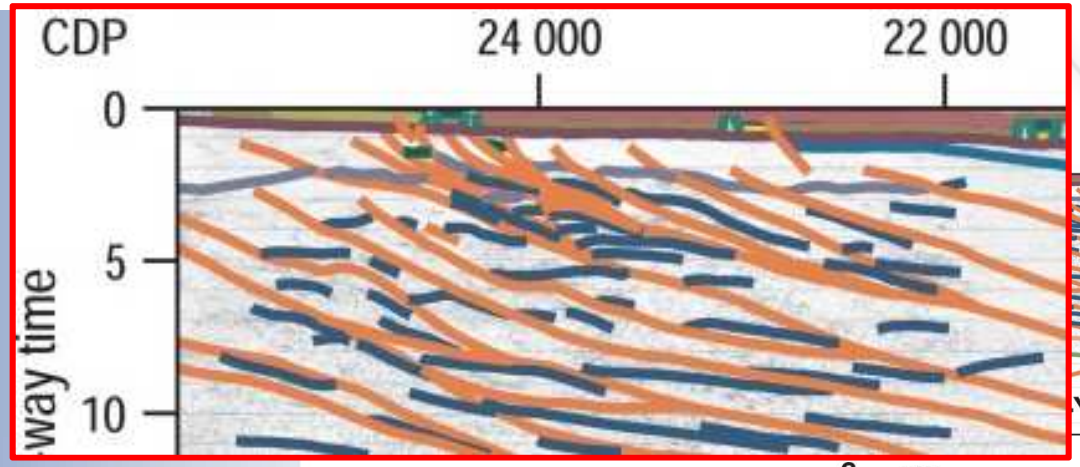
- YOM Images several northeast-dipping crustal-scale shear zone systems, although none offset the Moho.
- Offsets to the Yamarna Terrane/Babool Seismic Province and S-C geometry may suggest bulk normal offset, later inverted (Korsch et al., this volume)

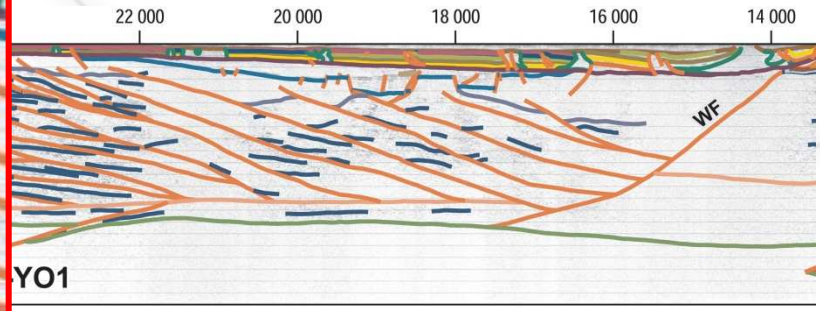


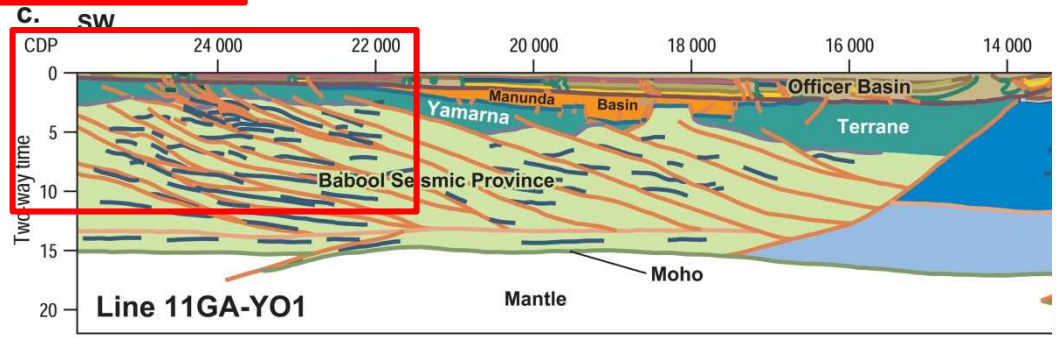
Yilgarn Mineral Systems – Orogenic Gold

Key Factor: Second- and third-order structures are important for deposition

- The western end (CDPS 22000-25000) is associated with a broad damage zone
- Other faults may also have these features – depth + seismic quality limit imaging capability







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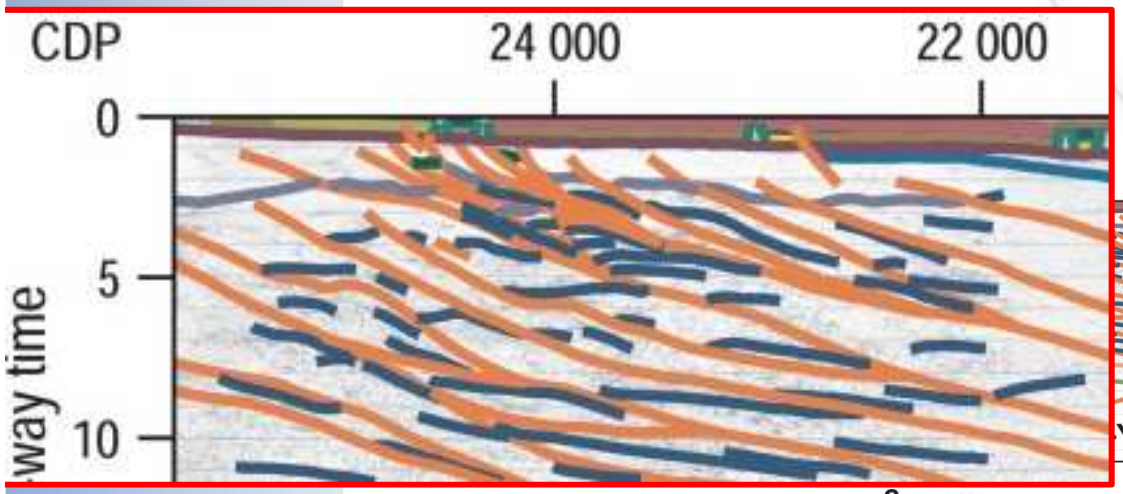
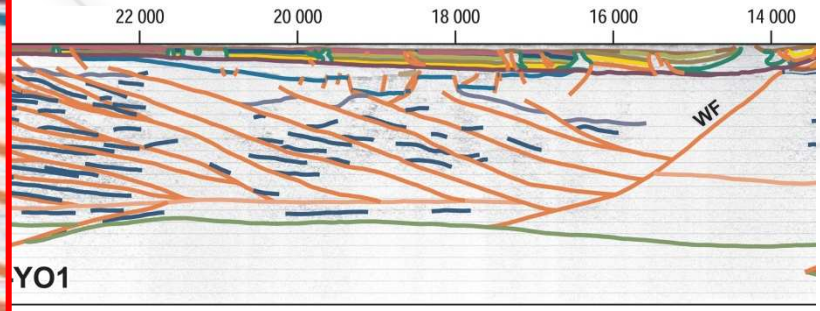
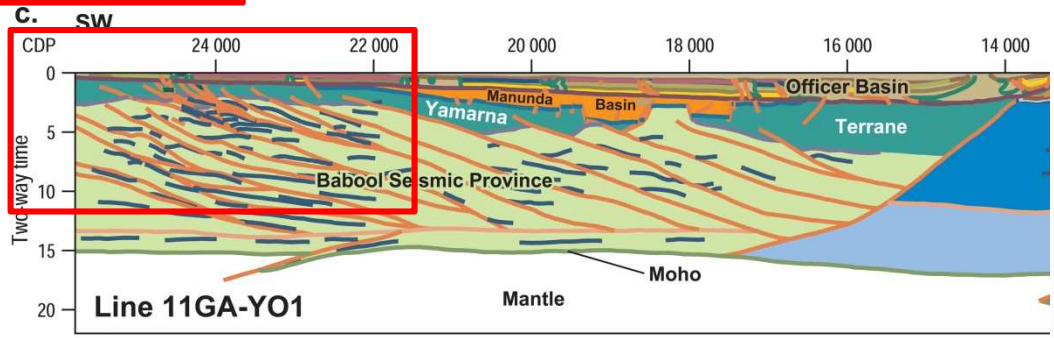
Yilgarn Mineral Systems – Orogenic Gold

Key Factor: Domes provide an additional structural focus

- The western end (CDPS 22000-25000) is also associated with a broad structural high
- Several smaller anticlines exist within the damage zone







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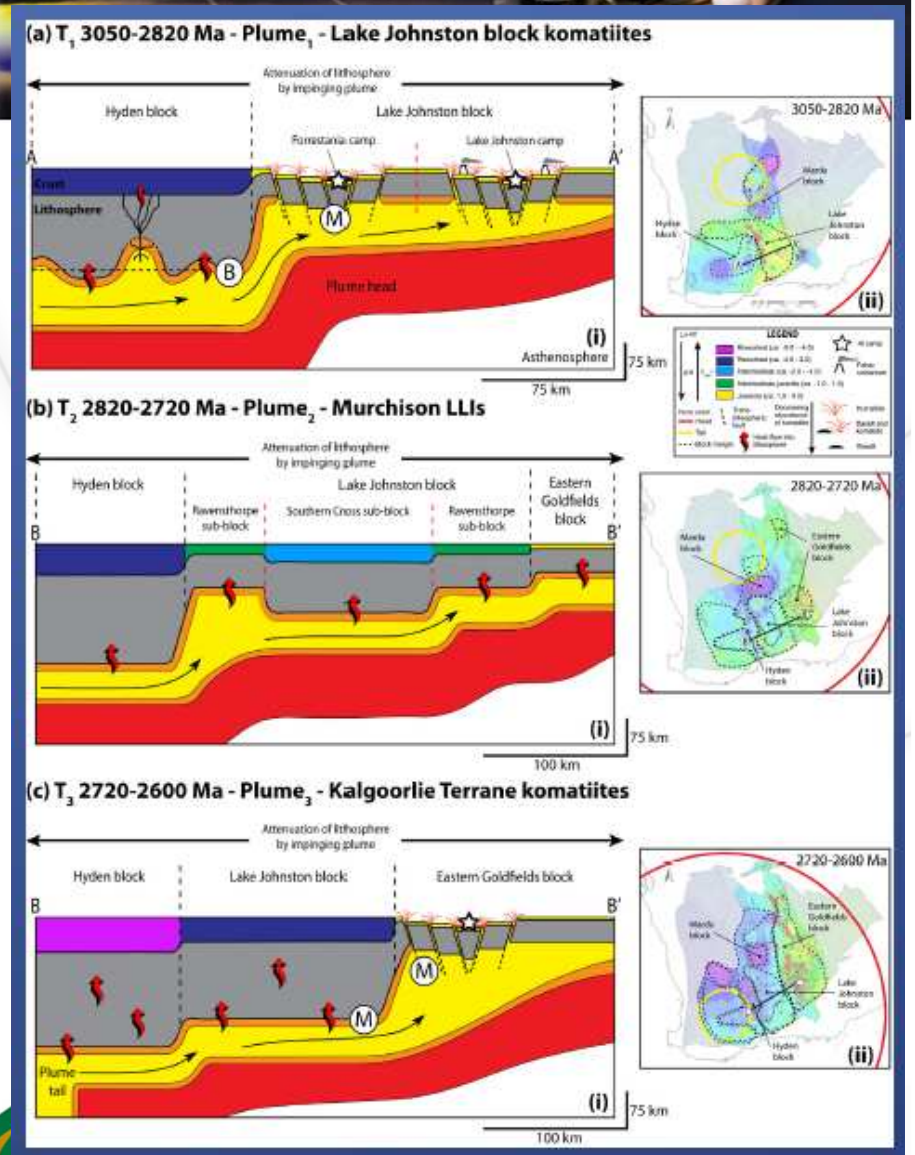
Yilgarn Mineral Systems - Komatiite Nickel

Komatiite Related Nickel

- Relatively well-studied system for Kalgoorlie Terrane (Barnes & Fiorentini, 2012)
- Relatively few greenstone belts in the Yamarna Terrane

Key Factors:

- Lithospheric Architecture – magma funnelled towards lithospheric discontinuities (Mole et al., 2012)
- Sustained high-magma flux rate
- Translithospheric pathways
- Sulphur Saturation – crustal assimilation or otherwise



Mole et al. (2010)

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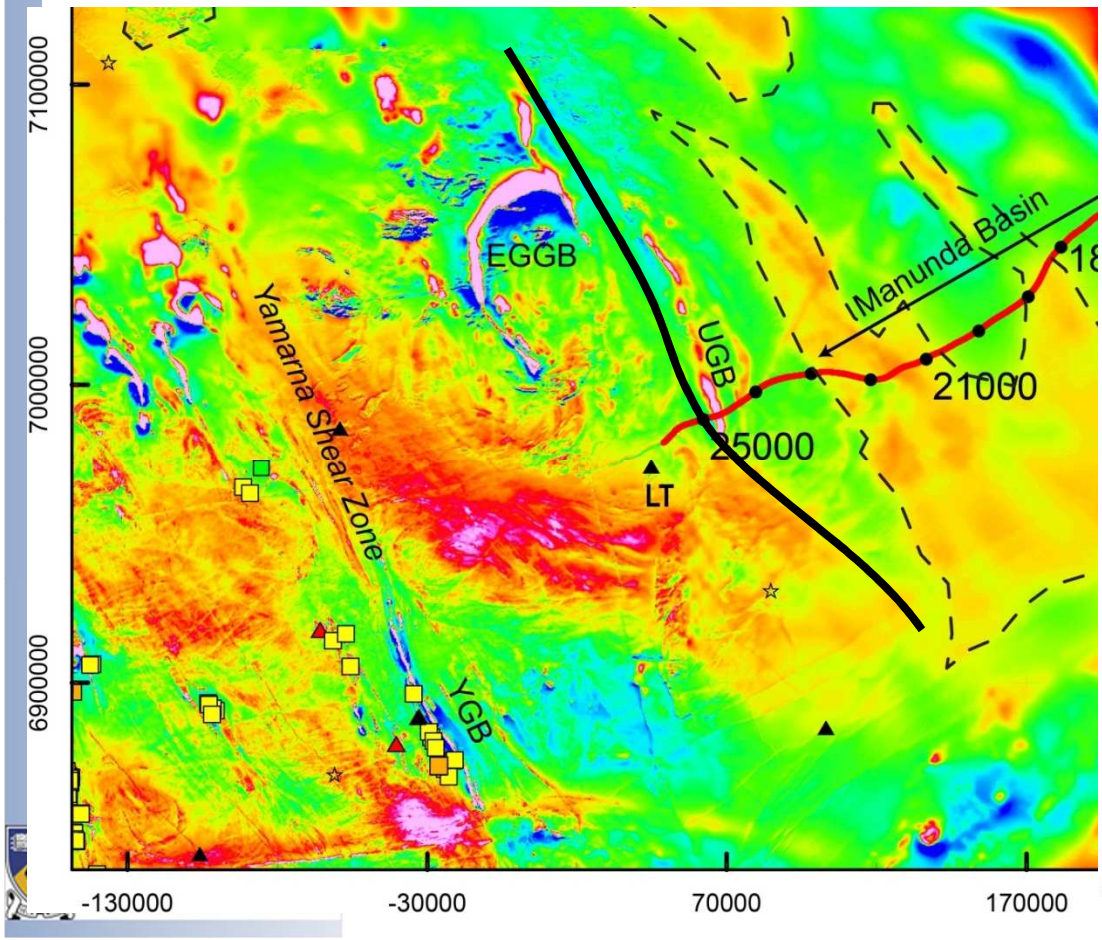
Yilgarn Mineral Systems - Komatiite Nickel

Key Factor: Lithospheric Architecture – magma funnelled towards lithospheric discontinuities

- Greenstone Belts are the most basic expression of this
- Also requires lithospheric-scale discontinuity to allow for rapid ascent



The Ernest Giles Greenstone Belt has lithological similarities with greenstone belts in the Murchison Domain (Greatland Gold, 2010)

The unnamed greenstone belt may be similar to the EGGB – emplaced along, and/or offset by the major shear zone

The UGB is not clearly imaged in the new seismic or magnetotelluric data

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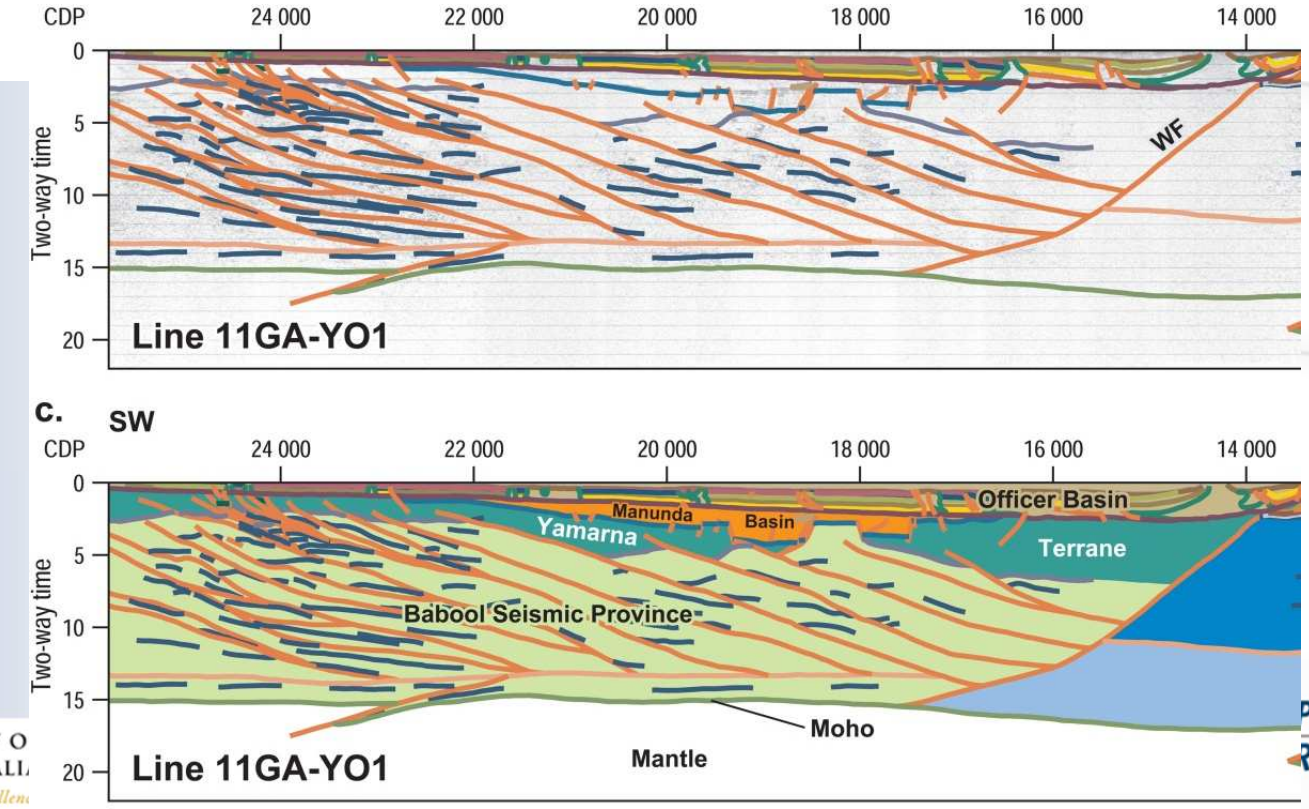
Yilgarn Mineral Systems - Komatiite Nickel

Key Factor: Translithospheric pathways

- The same faults previously mentioned may represent crustal pathways
- Lithospheric pathways are unclear
  - The Yilgarn Craton Margin is proximal at ca. CDP 14000
  - Seismic and MT Differences in the Babool Seismic Province either side of major shear zones (Korsch et al., this volume) – lithospheric boundaries?



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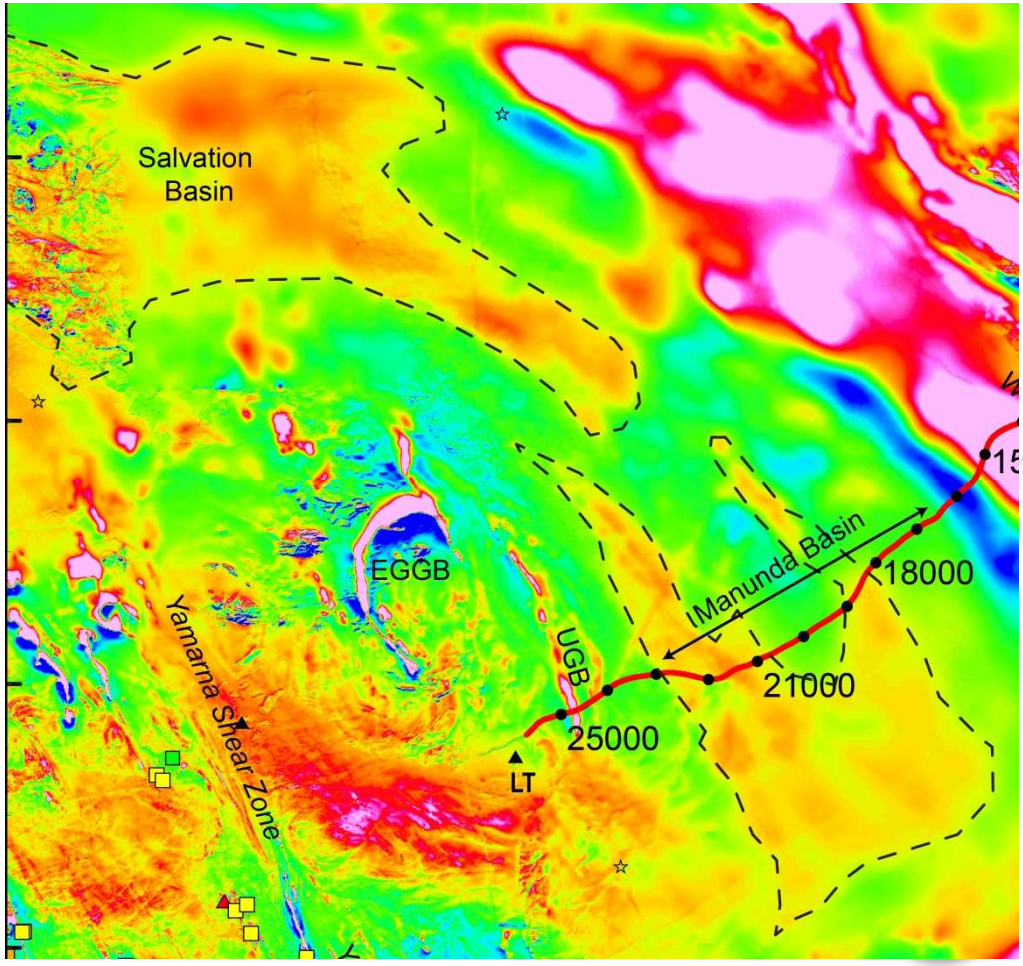
The Manunda Basin

The depth of the Mesoproterozoic Manunda Basin on the section is probably prohibitive for economic exploration.

A correlation with the Salvation and/or Collier Basin is most likely.

- The magnetic features may represent Warakurna-LIP sills
- Equivalent to the Glenayle Dolerite?
- The Glenayle Dolerite hosts no known deposits

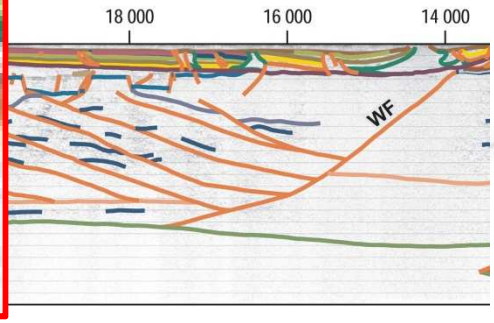


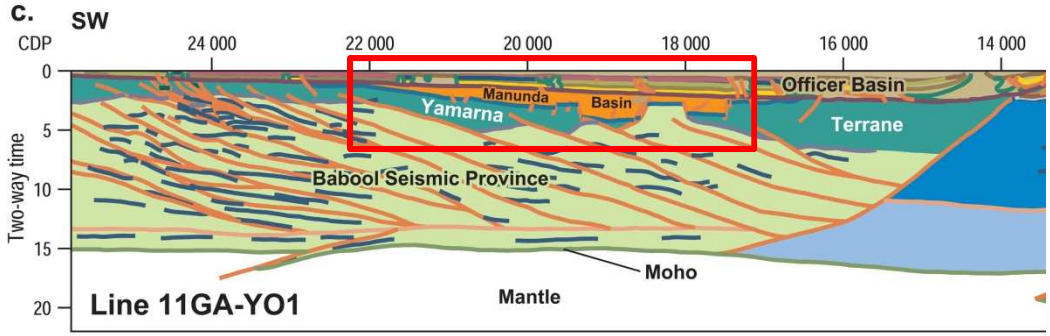
The Manunda Basin

The Collier Basin hosts several shear hosted base metal (Cu) occurences/prospects (at Ilgarari and Kumarina) and manganese

The Manunda Basin may potentially contain equivalents of the relevant formations

VE=2





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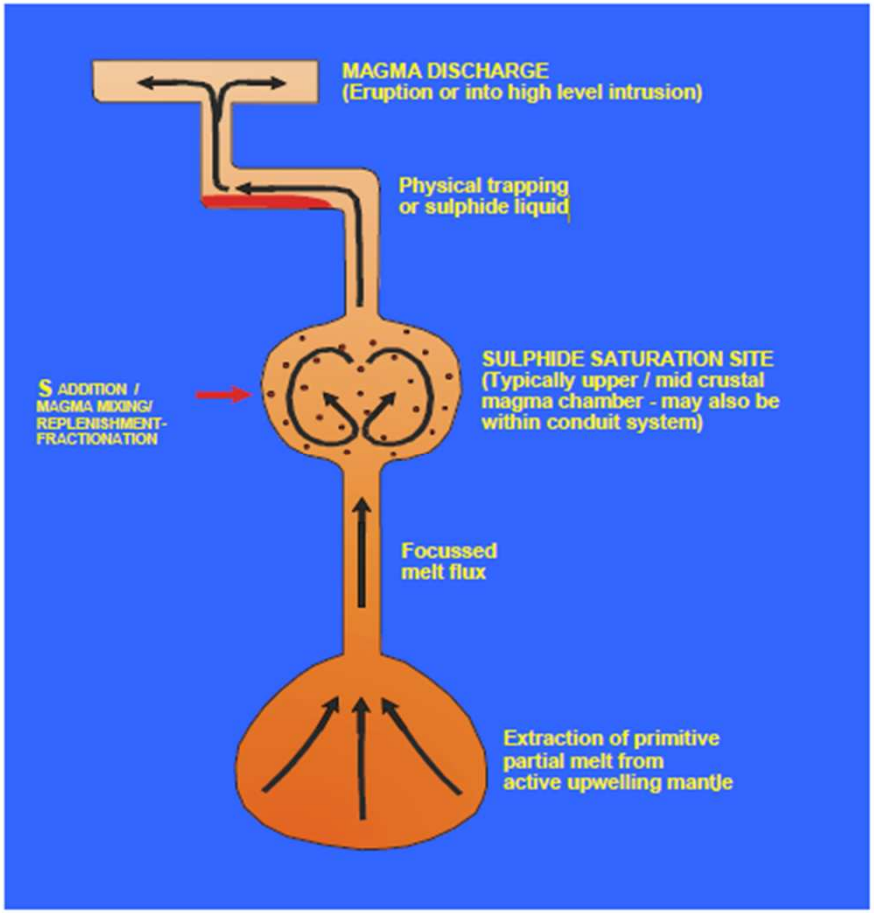
West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Orthomagmatic Nickel-Cu-PGE

- Relatively well-studied system globally
- Focus on Nebo-Babel
- PGE potential also in Bushveld-scale layered intrusions

Key Factors:

- High degree of mantle partial melting
- Dynamic crustal-scale fluid pathways
- Sulphur Saturation – crustal assimilation or otherwise
- Trapping within magma conduits

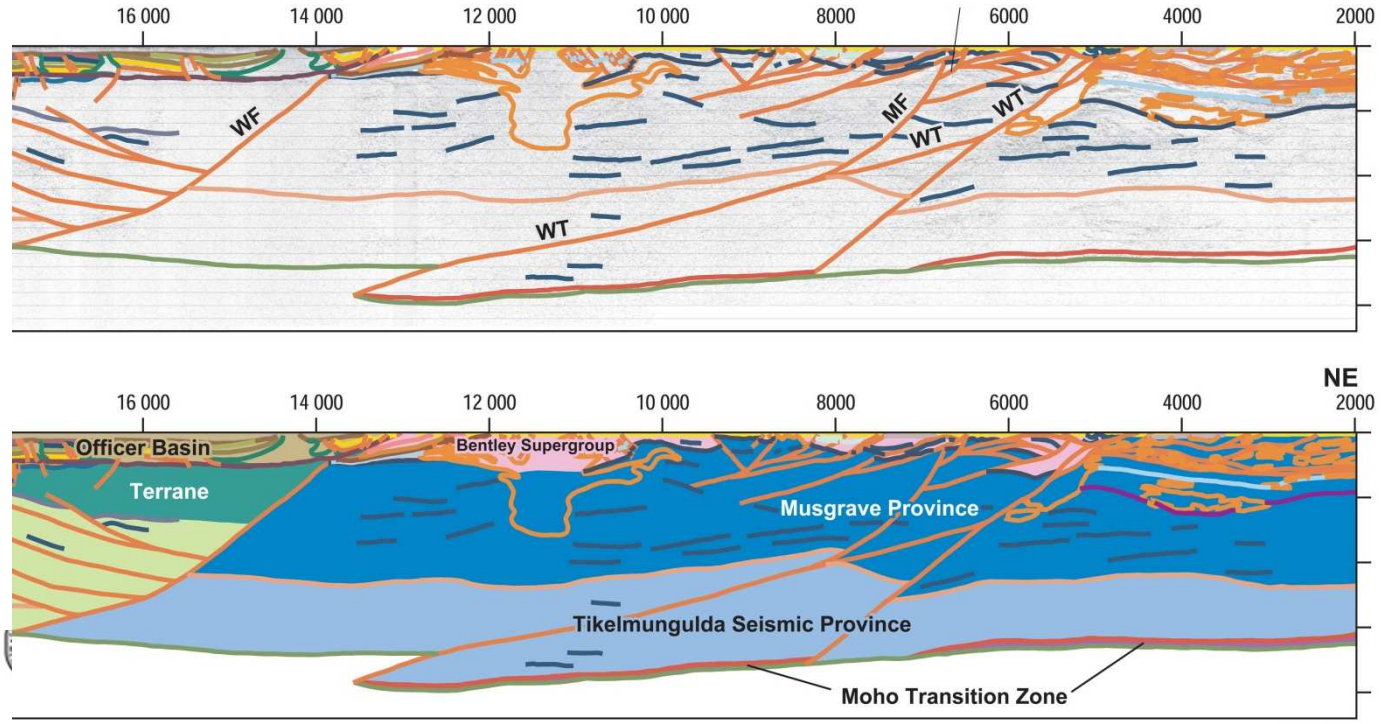


Hronsky (2007)

West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Key Factor: High degree of mantle partial melting

- The enormous amount of magmatism coupled with static geodynamics requires an enormous **amount** of upper-mantle melting.
- Tikelmungulda Seismic Province may indicate the extent and intensity of magmatism, may also provide a S source in the lower crust.
- Nebo-Babel parent magmas represent 5-10% partial melting (Godel et al, 2011).



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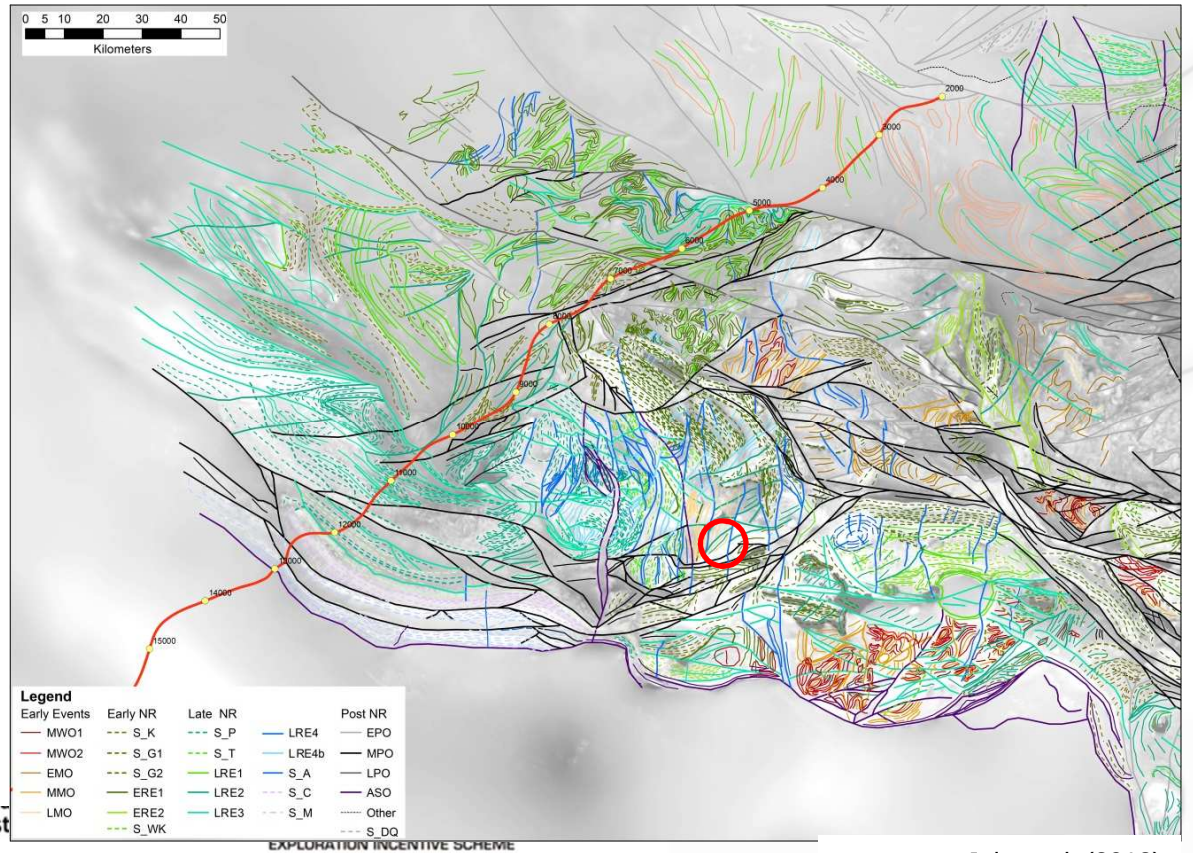
West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Key Factor: Dynamic crustal-scale fluid pathways

- Several crustal-scale fault zones may be important in this system
  - Cavenagh Fault, Mt West Fault (neither crossed by YOM)
  - Lasseter Shear Zone (cryptic deep lithospheric fault, crossed between CDP 6000-8000)
  - Other late-Giles Event faults

- These faults show changing kinematics during late-Giles Events



Joly et al. (2013)

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West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Nebo Babel

located in the hanging wall of the northwest dipping Cavenagh Fault, 2.5 km from the near-surface trace, aligned with the fault

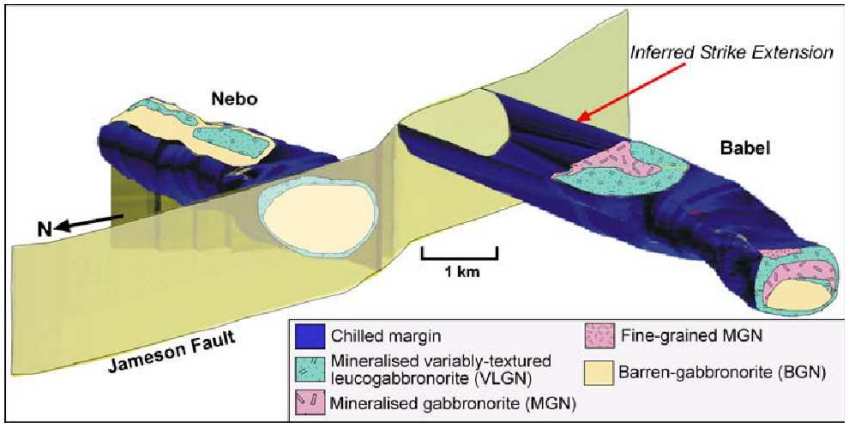
The region experienced several late-Giles Event movements (Aitken et al., 2013a), all within analytical error of Nebo-Babel emplacement:

D1 – Cavenagh Fault - 10 km passive sinistral strike-slip under ~ SW-NE compression to SE

D2 – Cavenagh Fault - Several kilometres normal movement under ~ NW-SE tension

D3 – Jameson Fault – ~2 km sinistral strike-slip under ~ NW-SE compression or NE-SW tension

Possibly reverse movement on Cavenagh Fault immediately prior



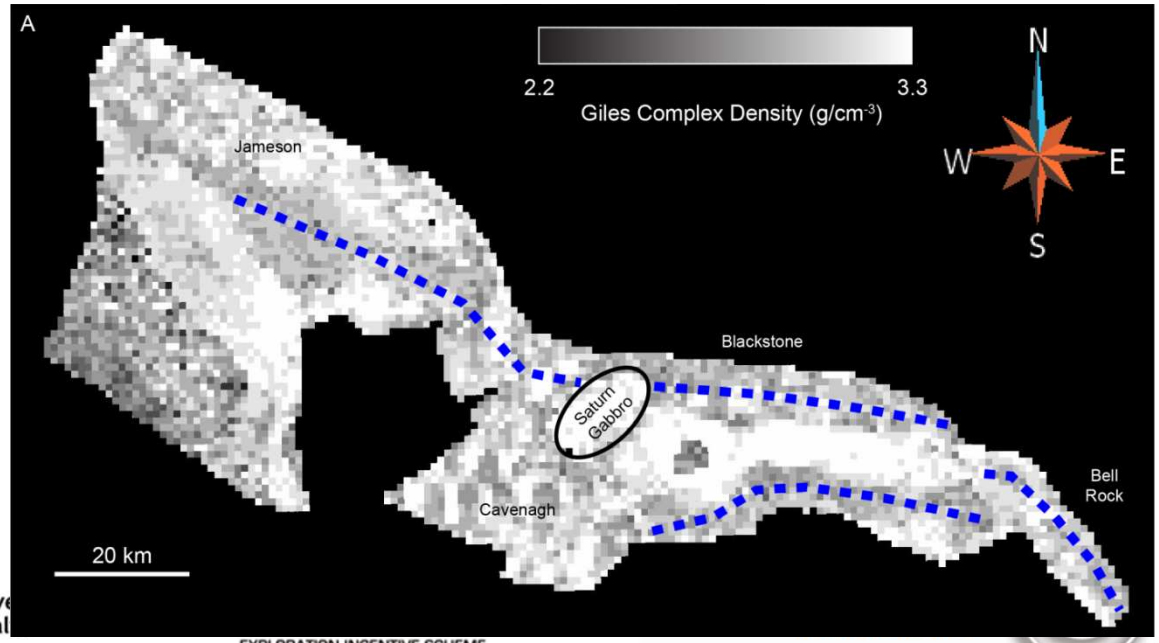
Seat et al. (2007)

West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Key Factor: Early Rift Architecture and PGEs

- Bushveld-scale intrusions
  - Wingellina Ni laterite, also elevated PGE levels
  - Vanadiferous titanomagnetite in Jameson

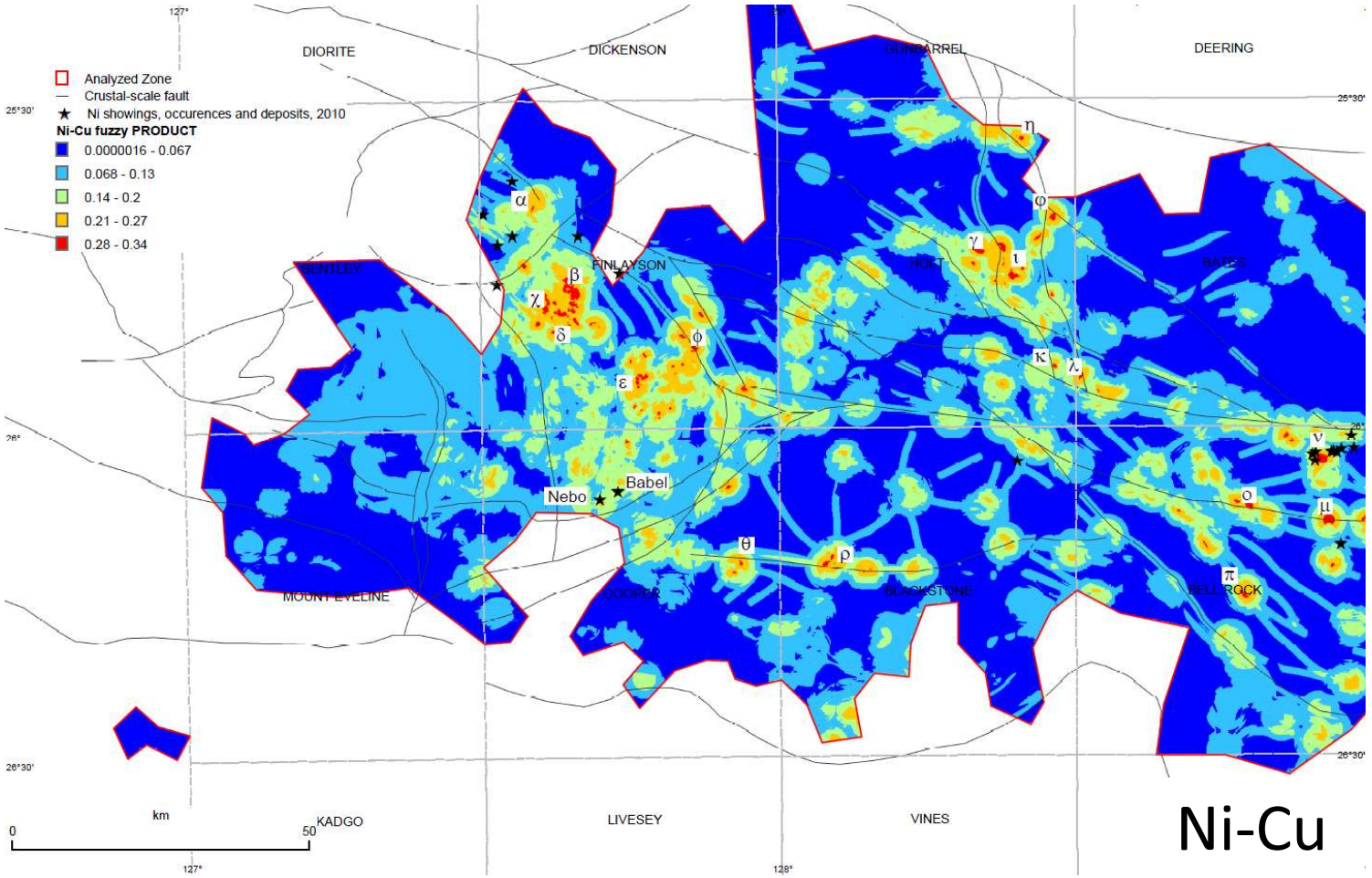
- Similarities in cumulate stratigraphy with the Bushveld Complex and Great Dyke are promising (Maier et al, in prep)



Aitken et al. (2013b)

West Musgrave Mineral Systems - Giles Event magmatic Ni-Cu-PGE

Joly et al (2013) analysed the mineral potential of the west Musgrave Province for several commodities using a knowledge driven mineral systems approach.



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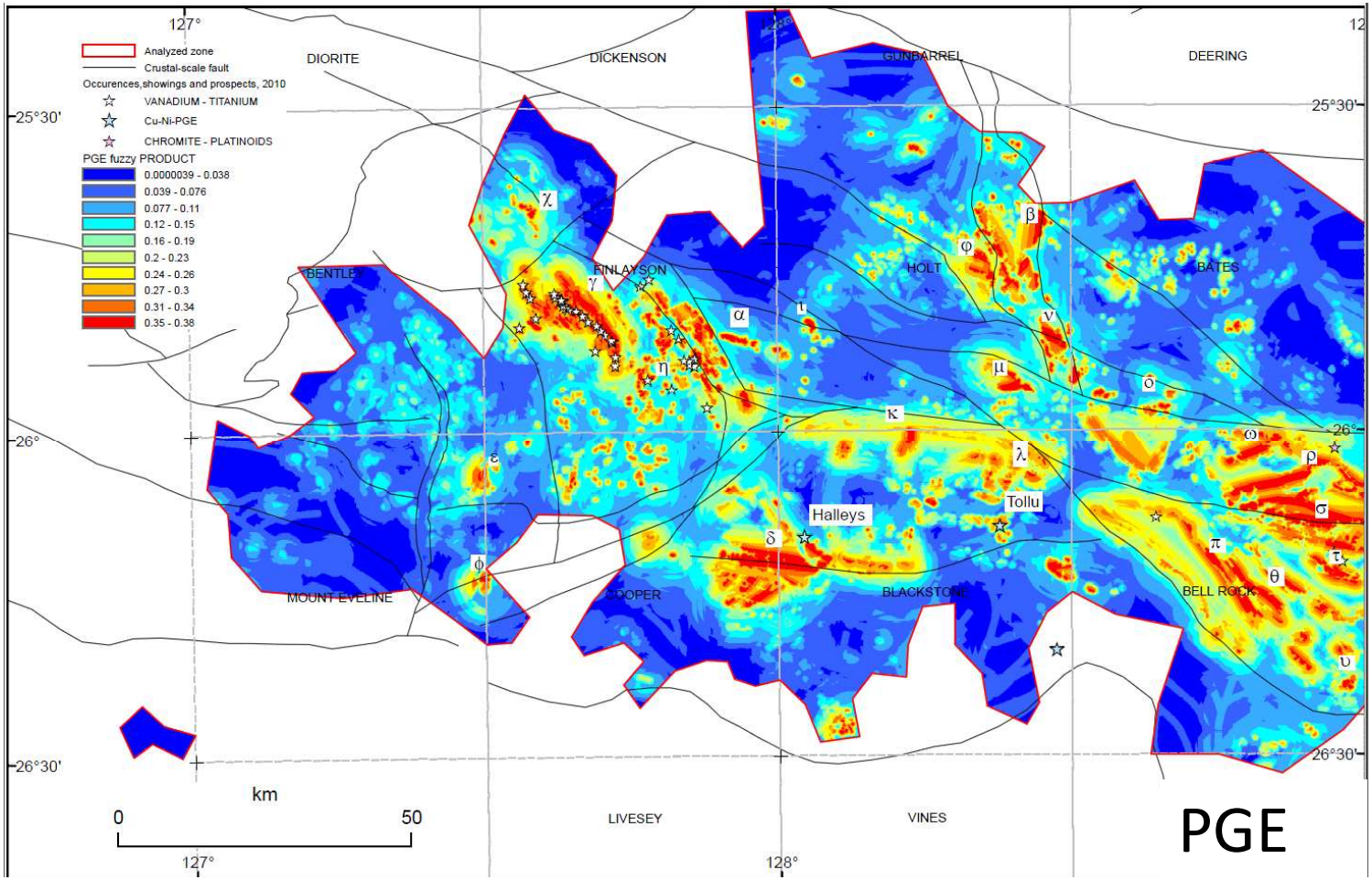

PGE

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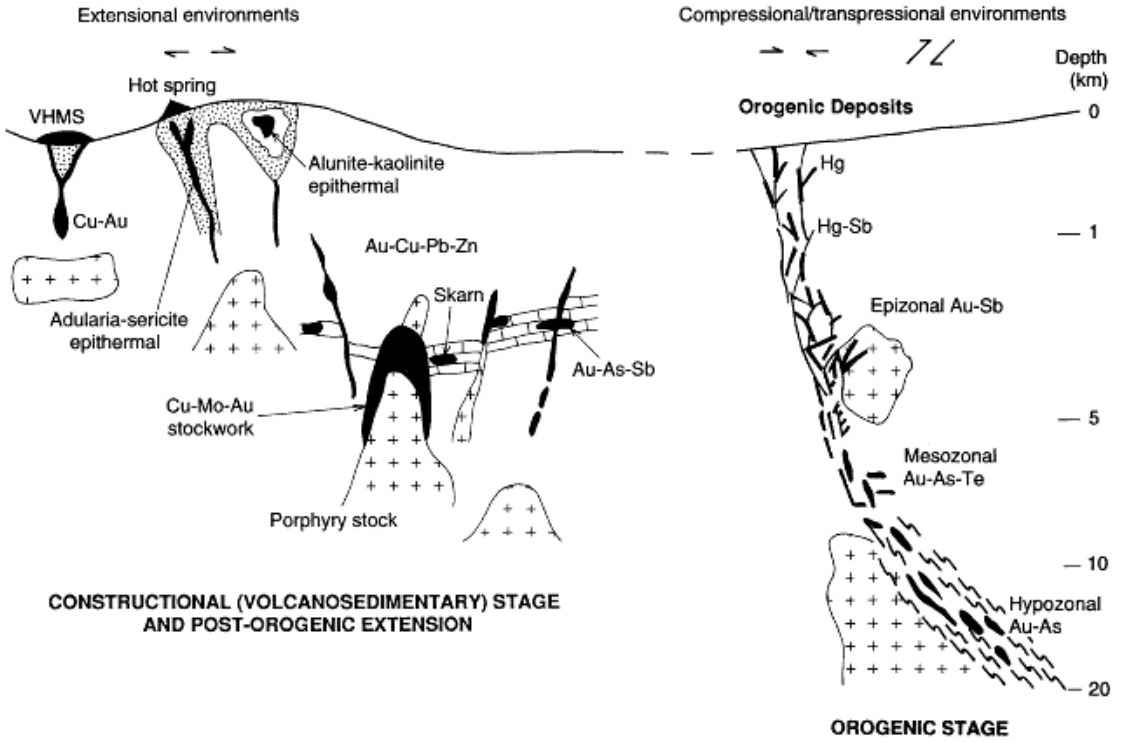
West Musgrave Mineral Systems – Hydrothermal Au & Base metals in Bentley Supergroup

Hydrothermal systems in Bentley Supergroup

- Handpump (Au) recently ignited interest
- Established Cu & Pb-Zn prospects
- Local system not well known

Key Factors:

- Source of heat and fluids
- crustal-scale and local fluid pathways
- structural complexity
- preservation

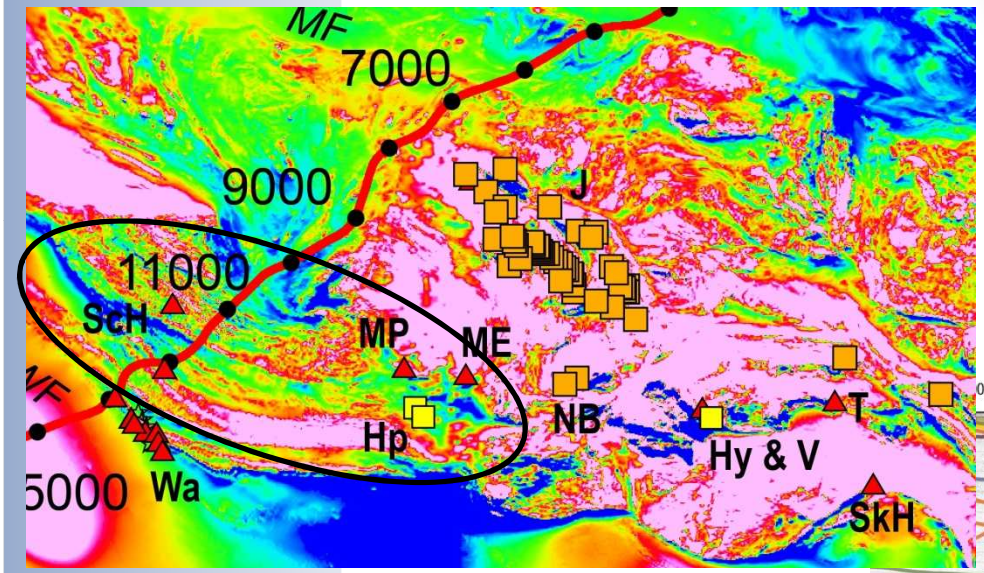


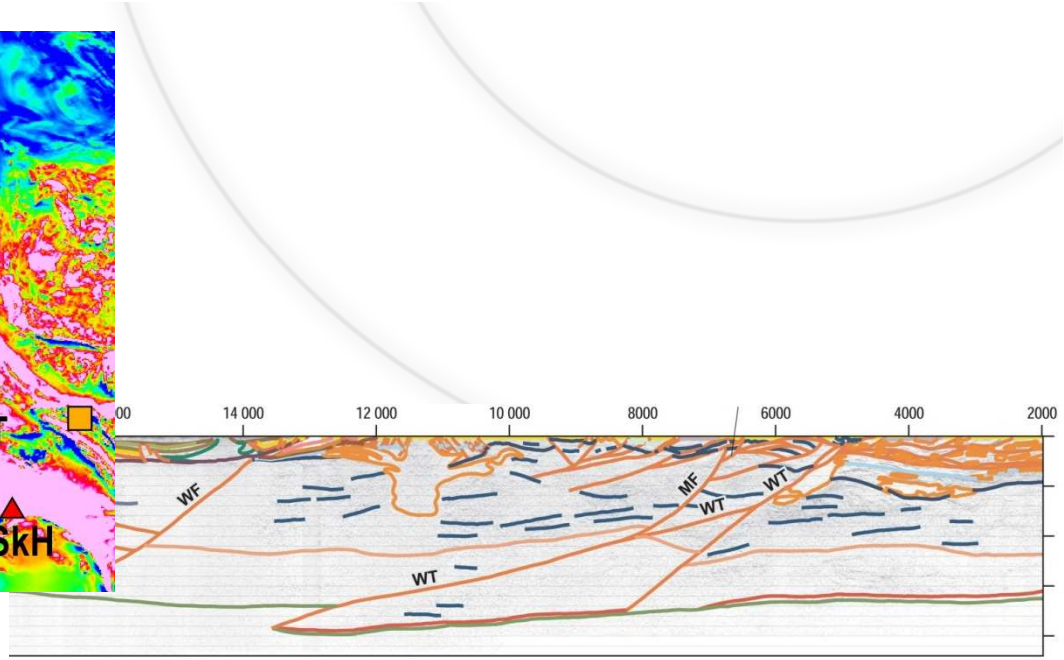
Groves et al. (1998)

West Musgrave Mineral Systems – Hydrothermal Au & Base metals in Bentley Supergroup

Key Factor: Source of heat and fluids

- Intrusion of Warakurna Supersuite into the Bentley Supergroup
- Evidence of widespread hydrothermal alteration





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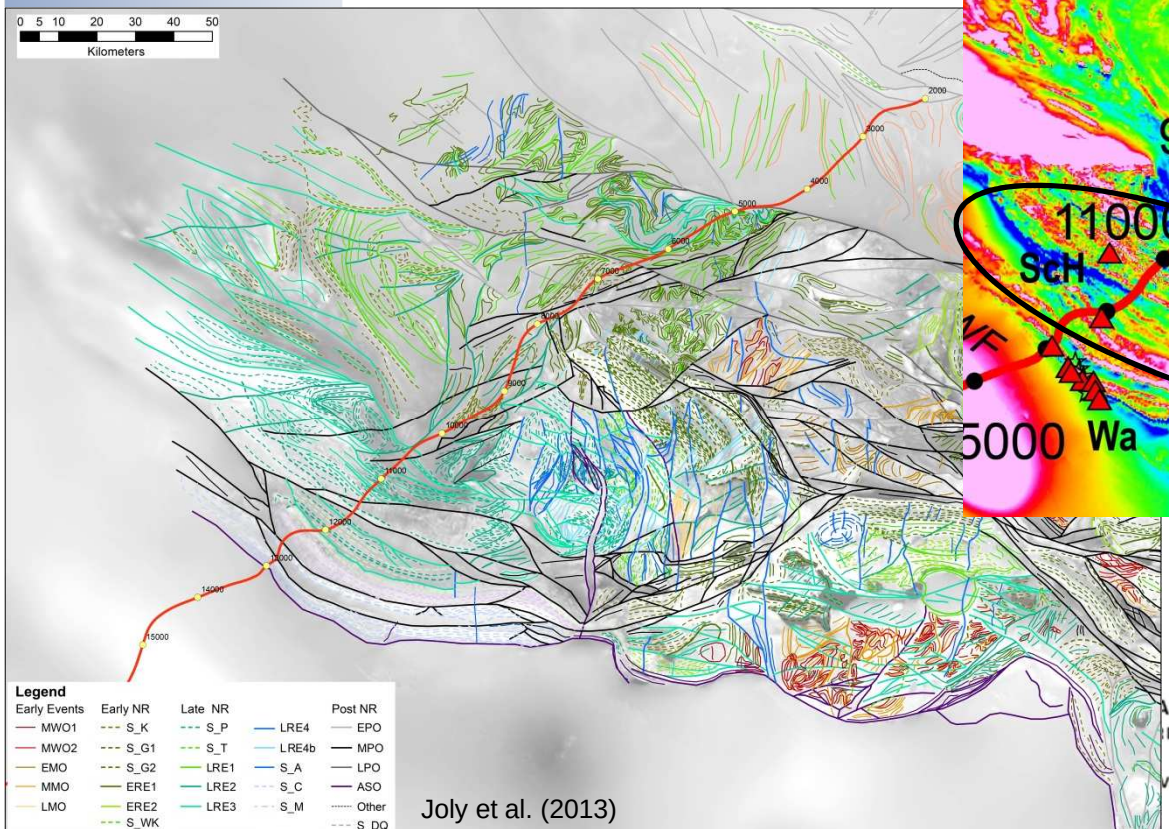
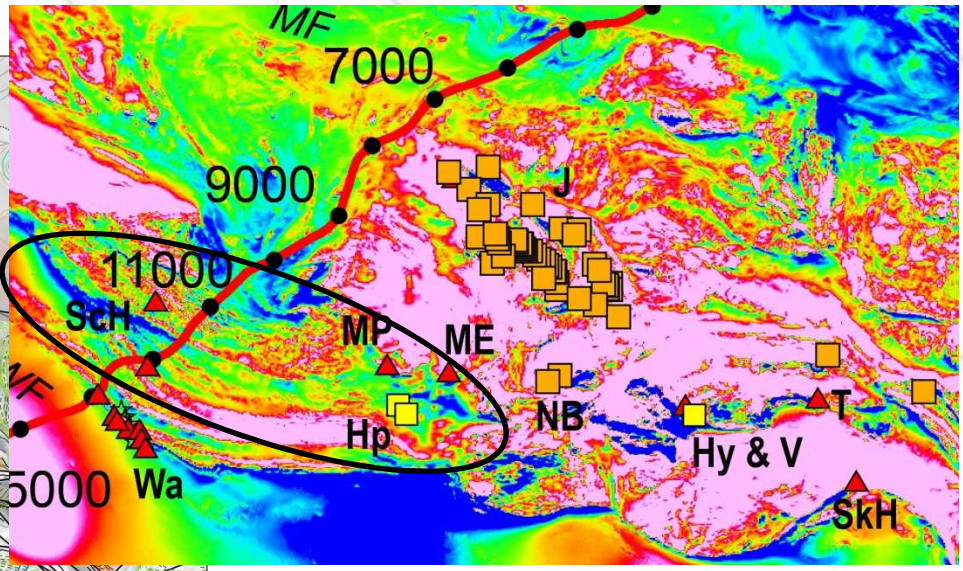
West Musgrave Mineral Systems – Hydrothermal Au & Base metals in Bentley Supergroup

Key Factor: crustal-scale and local fluid pathways; structural complexity

- Region dominated by late-Giles event architecture
- Reactivation of early rift architecture
- Reactivated again during later events (Areyonga/Petermann/ASO)



Joly et al. (2013)



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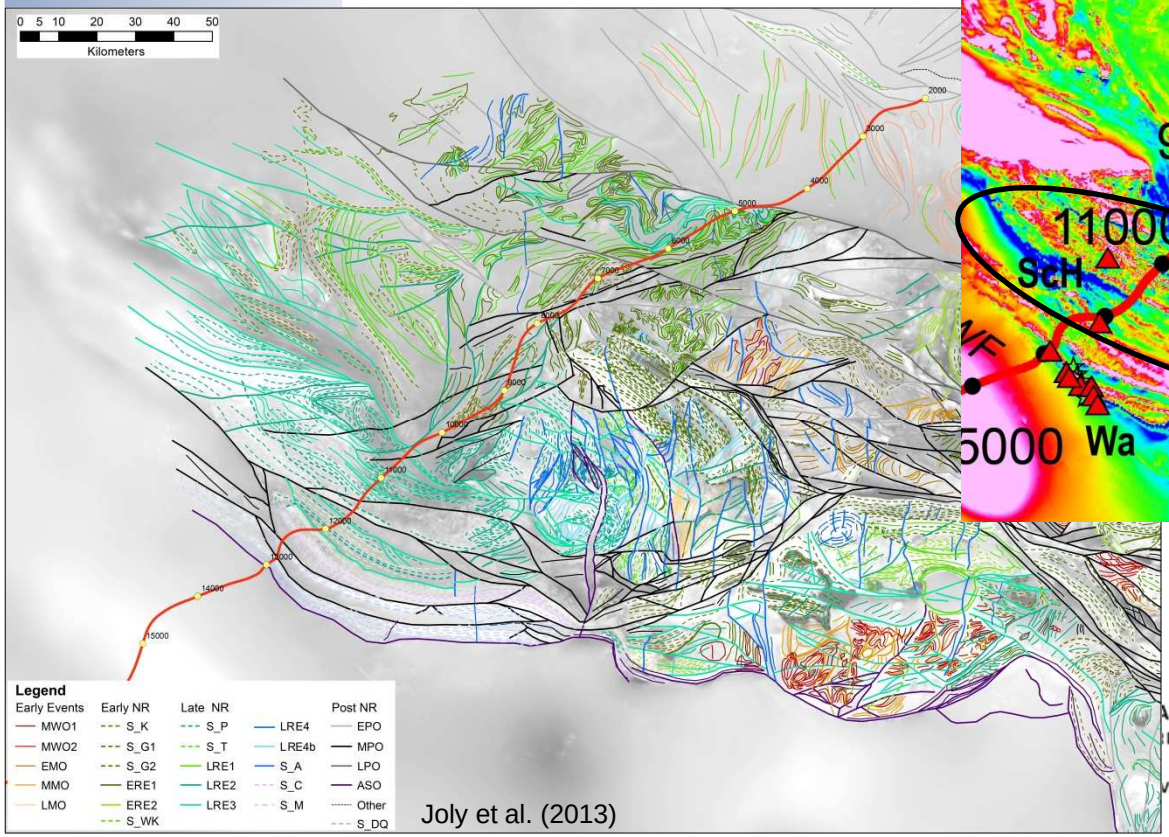
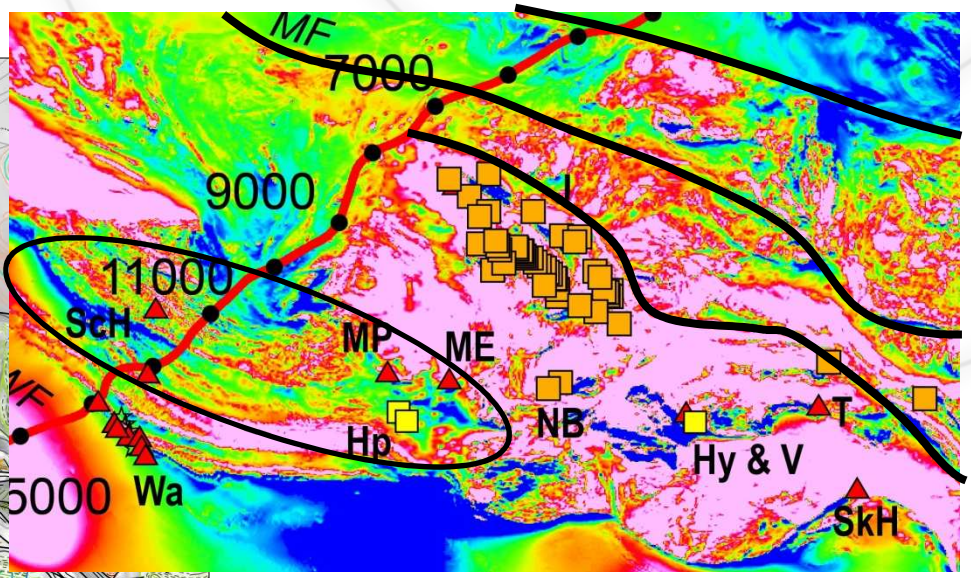
West Musgrave Mineral Systems – Hydrothermal Au & Base metals in Bentley Supergroup

Key Factor: Preservation

- SW west Musgrave Province has been near the surface since ca. 1080 Ma
- NE west Musgrave Province was at ~8-14 kbar at ca. 550 Ma
- Preservation less likely to NE (until Woodroffe Thrust)



Joly et al. (2013)



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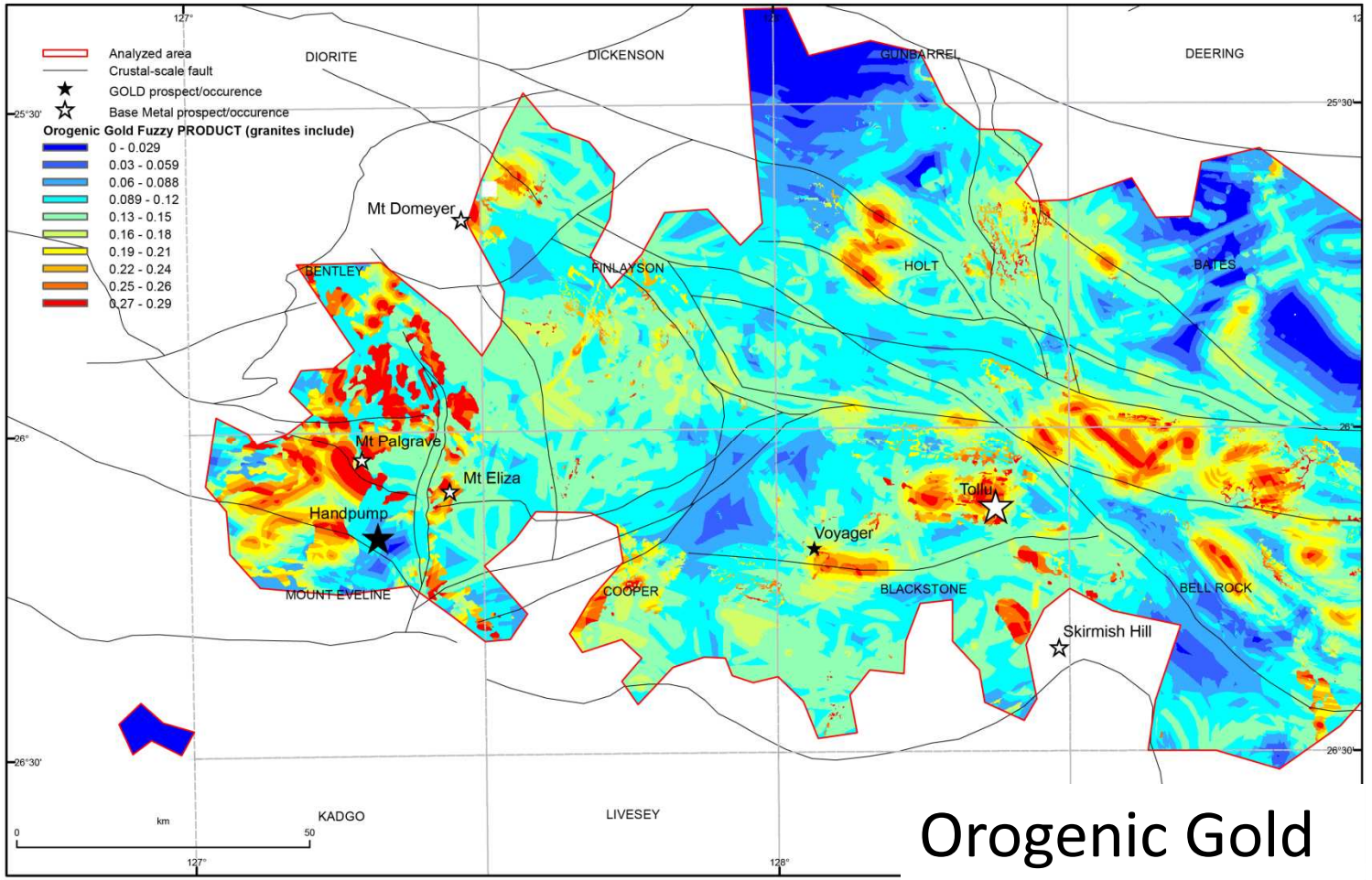

Orogenic Gold

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West Musgrave Mineral Systems – IOCG

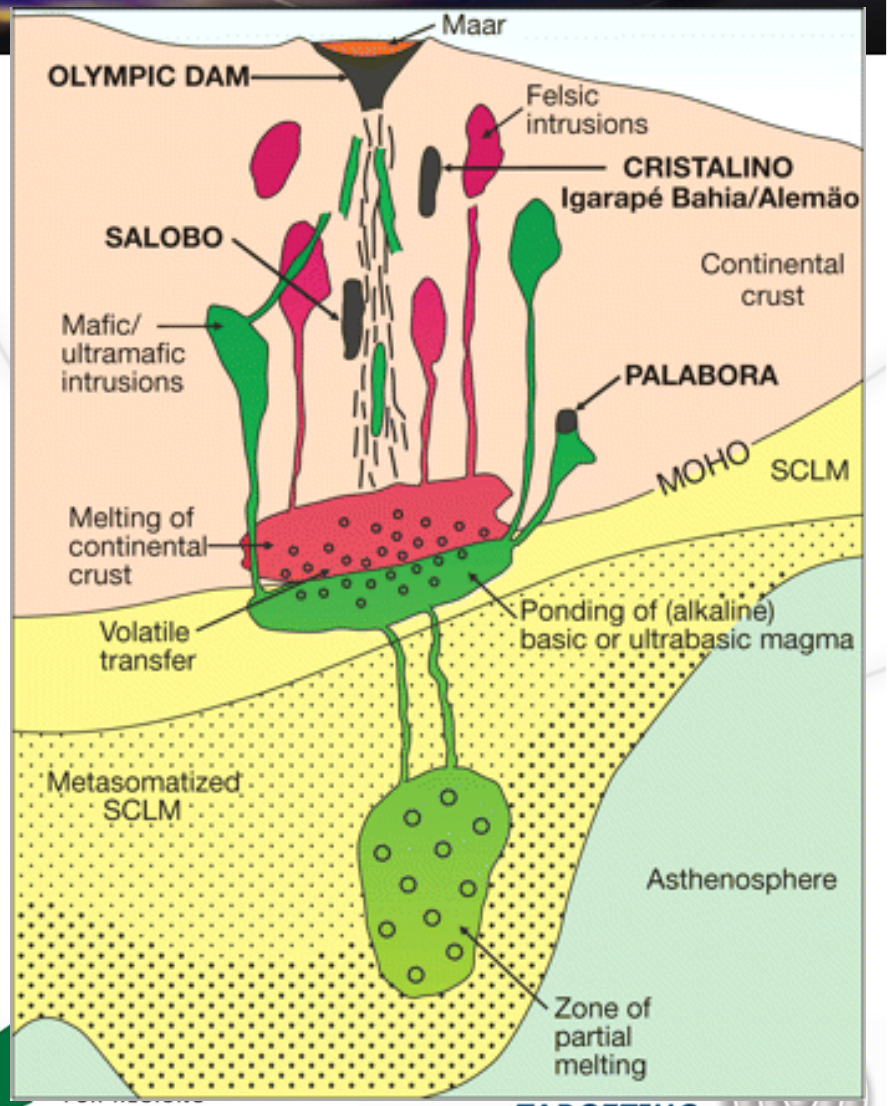
IOCG

Grouping of fairly diverse deposits

- Conceptually, the WMP has the ingredients
- No demonstrated examples

Key Factors:

- Craton margin
  - Winduldurra Fault
  - Paleo-collision zone (Mt West Orogeny)
- Huge thermal events> abundant A-type magmatism
  - Pitjantjatjara Supersuite
  - Warakurna Supersuite
- Many crustal scale fault zones



Groves et al, (2010)

Summary

YOM has traversed some of the least explored regions in WA. New insights include:

- Imaged major crustal structures within and beneath the Yamarna Terrane of the Yilgarn Craton and the west Musgrave Province
- Some of these are lithospheric-scale boundaries, esp the Winduldarra Fault
- Imaged the relatively thick Yilgarn crust (45 km) and very thick crust (50-60 km) beneath the west Musgrave Province.
- Imaged the existence of mid-lower crustal provinces – The Babool Seismic Province and the Tikelmungulda Seismic Province
- The latter may be indicative of the magnitude of the magmatic events that characterised this region in the late Mesoproterozoic
- Identified basin geometries for several large basins, including the Talbot sub-basin of the Bentley Supergroup
- The Bentley Supergroup contains many intrusive granitic bodies, potentially important for hydrothermal mineralisation

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