

# Eucla basement results: implications for geodynamics and mineral prospectivity

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# Introduction



- Big topic – can't cover it all here but there's a healthy (rant) in the abstract volume
- Will continue with the Eucla-Gawler deep crustal seismic reflection and MT line with GSSA and GA (western Gawler section interpretation release December 10th; full line at AESC June 2016)
- Significant amount of data and knowledge gained from the stratigraphic drilling program
- A resource for future work



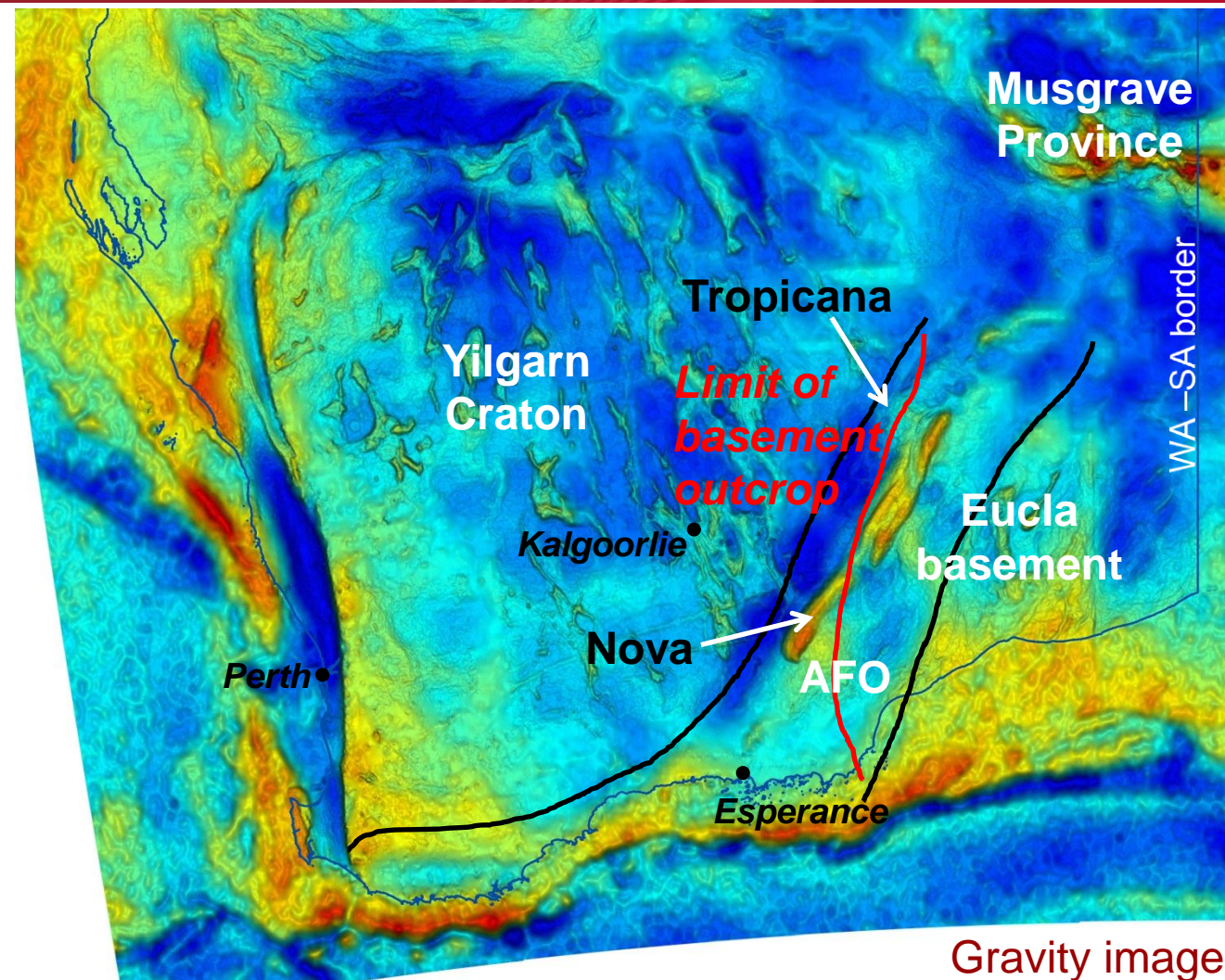
# Introduction



- In this talk we integrate the available data and interpretations from the cores, and speculate on potential geodynamic settings
- Relationship of alteration footprints – seems to be a common Cu theme throughout - significance?
- Address how the results and knowledge gained improves our understanding of the evolution of the Albany–Fraser Orogen
- Implications for links to the Musgrave Province and the Gawler Craton

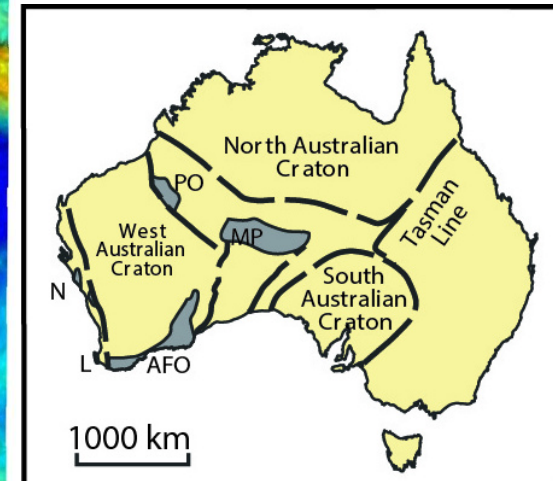


# Albany-Fraser Orogen (AFO) and Eucla basement connections



Gravity image

AFO is part of the West Australian Craton



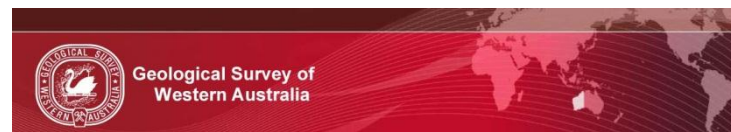
AFO tells the story of modification of the southern and southeastern Yilgarn Craton margin.

How does it link to the Musgrave Province, or the Gawler Craton in SA?

# Eucla basement – what is it?



- In 2011 we said “To understand the Proterozoic evolution of the Albany-Fraser Orogen we need to see further east – we don’t as yet understand what we are dealing with”



## ALBANY-FRASER FIELDTRIPS

The Geological Survey of Western Australia is offering two fieldtrips in September 2011 to examine the relationship of the Albany-Fraser Orogen to the Yilgarn Craton margin.

Both trips will be self-drive, self-cater, tag-along style. Note that bush camping and long driving distances will be necessary. The trips will run back to back with a night in Kalgoorlie inbetween. Participants may choose to do just one trip or both.

### Trip 1.

#### Highlights of Albany-Fraser geology

##### *Esperance to the Transline*

**Leaders:**  
*Catherine Spaggiari and Chris Kirkland*

Meet in Esperance on September 11th. Outcrop visits September 12th to 15th, finishing in Kalgoorlie. The fieldtrip will cover all major lithotectonic units of the orogen, including Archean, Paleoproterozoic and Mesoproterozoic components, and look at structural, geophysical, geochronological and geochemical aspects.

### Trip 2.

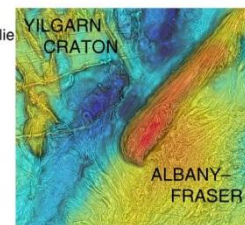
#### Tropicana in a regional context

##### *Tropicana area*

**Leaders:**  
*Catherine Spaggiari, Chris Kirkland, and Mark Doyle (AngloGold Ashanti)*

September 16th: Depart Kalgoorlie for Tropicana. Tropicana JV manager AngloGold Ashanti will co-lead this trip and provide an opportunity to view mineralisation and host rocks in drill core at Tropicana. We will also examine the surrounding regional geology. We will be driving back to Kalgoorlie on September 21st.

For more information and to express interest please email Catherine Spaggiari at: [catherine.spaggiari@dmp.wa.gov.au](mailto:catherine.spaggiari@dmp.wa.gov.au) or phone 9222 3491. The number of vehicles may have to be limited.

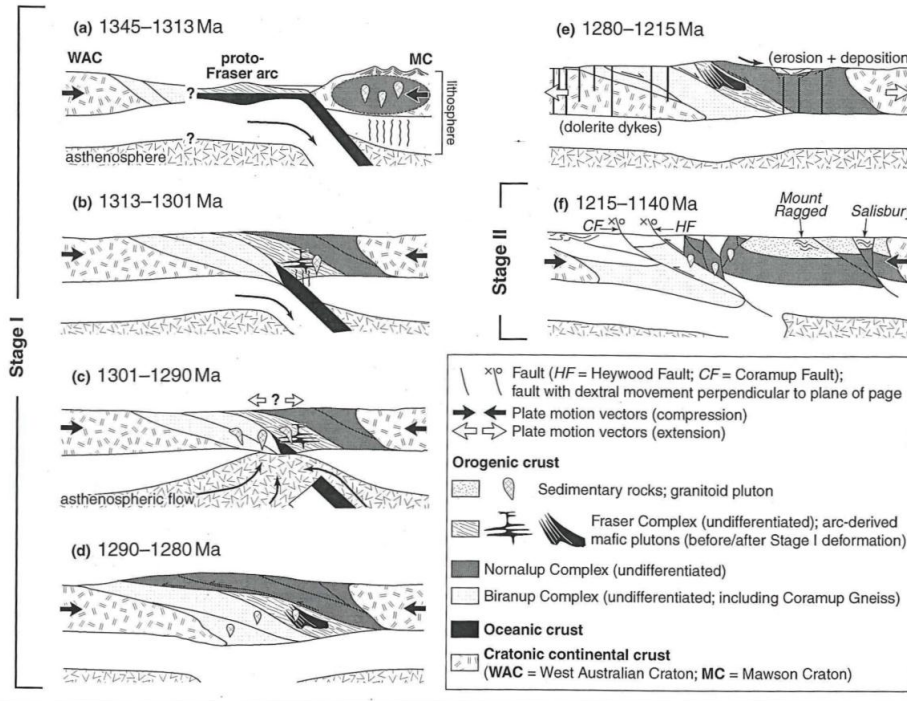


# Previous work – focus was on Mesoproterozoic ‘the Grenville’

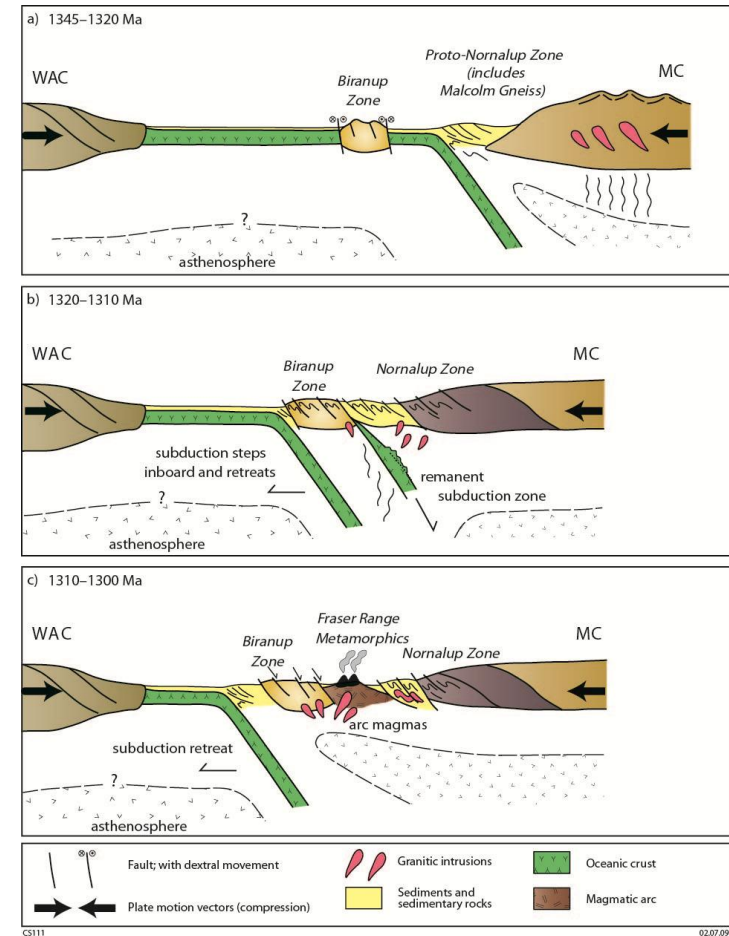


- Southern Yilgarn Craton margin was passive in the Paleoproterozoic
- Interpretations and models based on Mesoproterozoic accretion and collision

724 S. BODORKOS & D. J. CLARK



Bodorkos and Clark, JMG, 2004

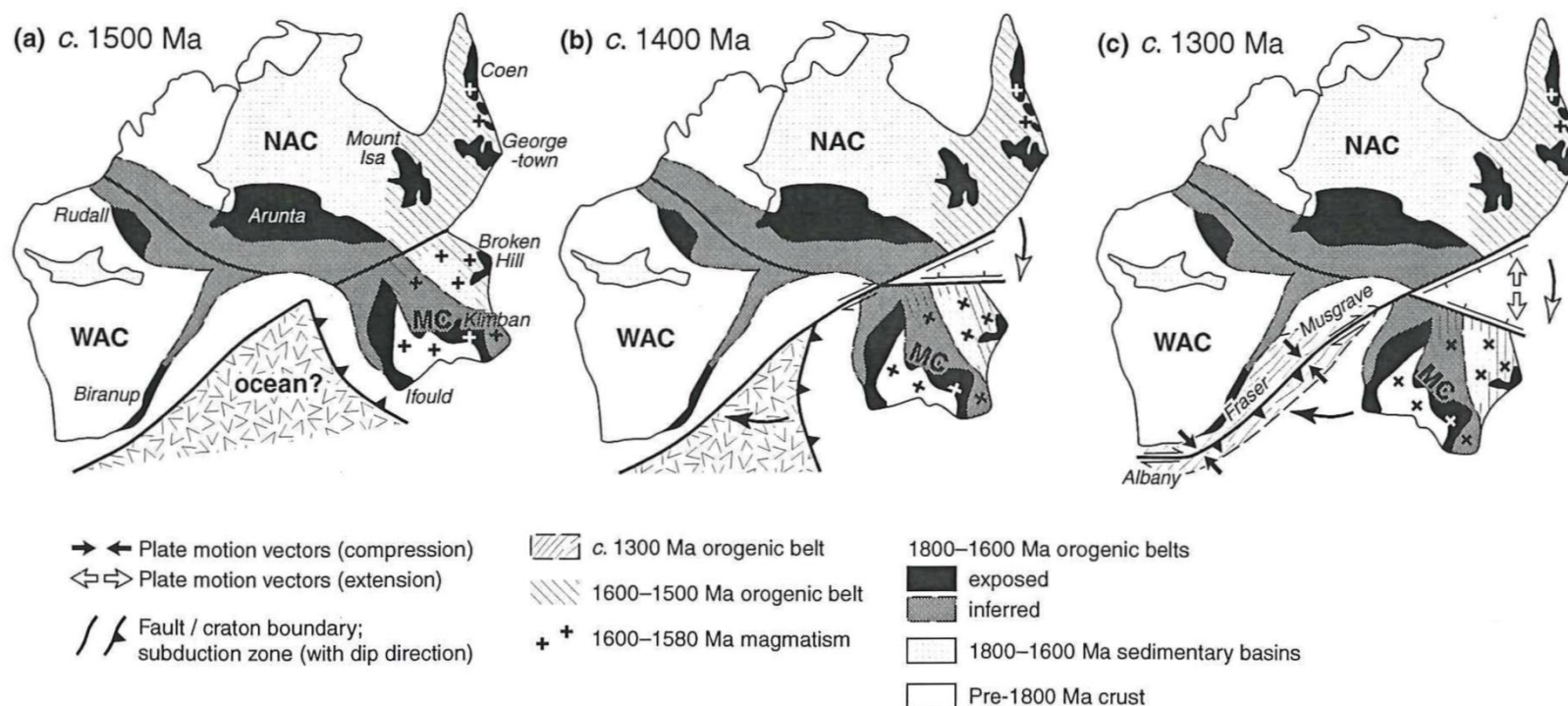


Spaggiari et al., 2009

# Previous work



## One major event in two stages: the Mesoproterozoic Albany-Fraser Orogeny



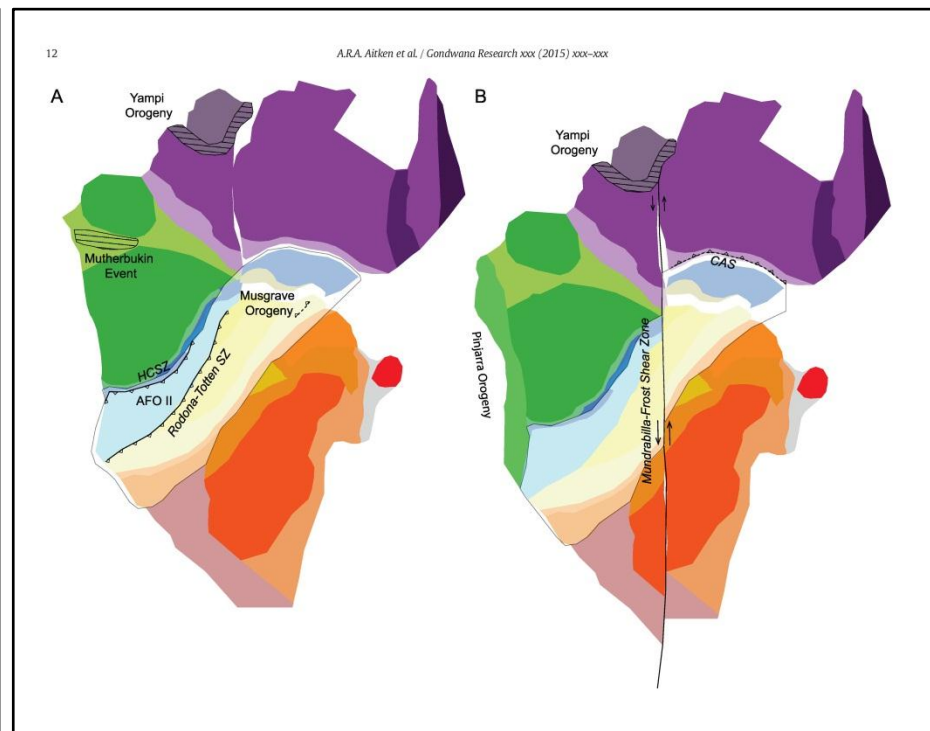
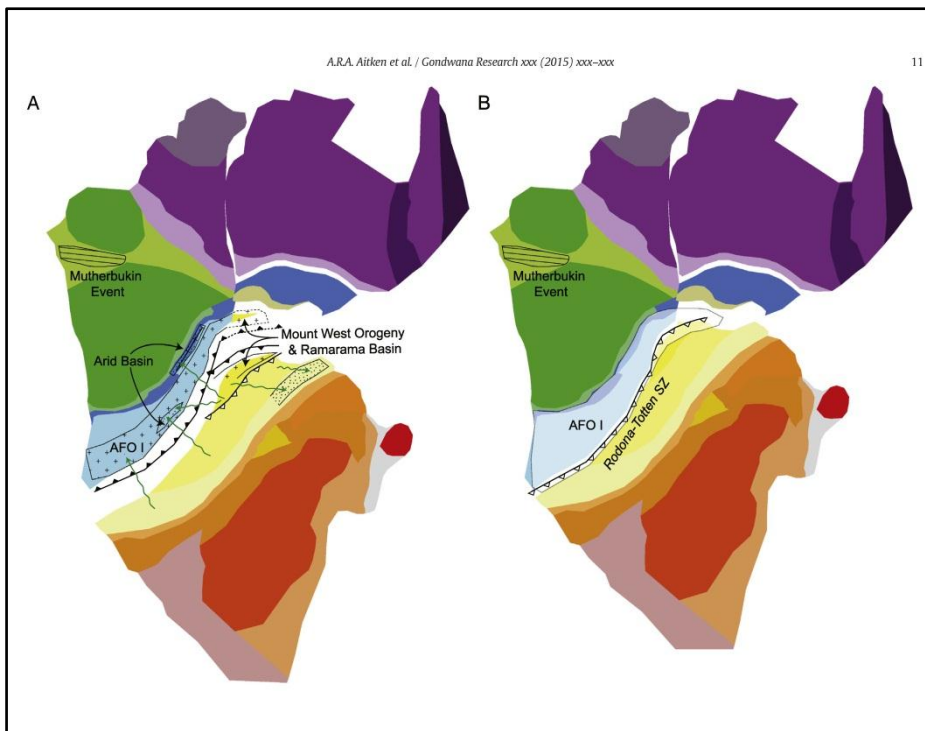
Bodorkos and Clark, JMG, 2004

# Previous work



1400–1290 Ma

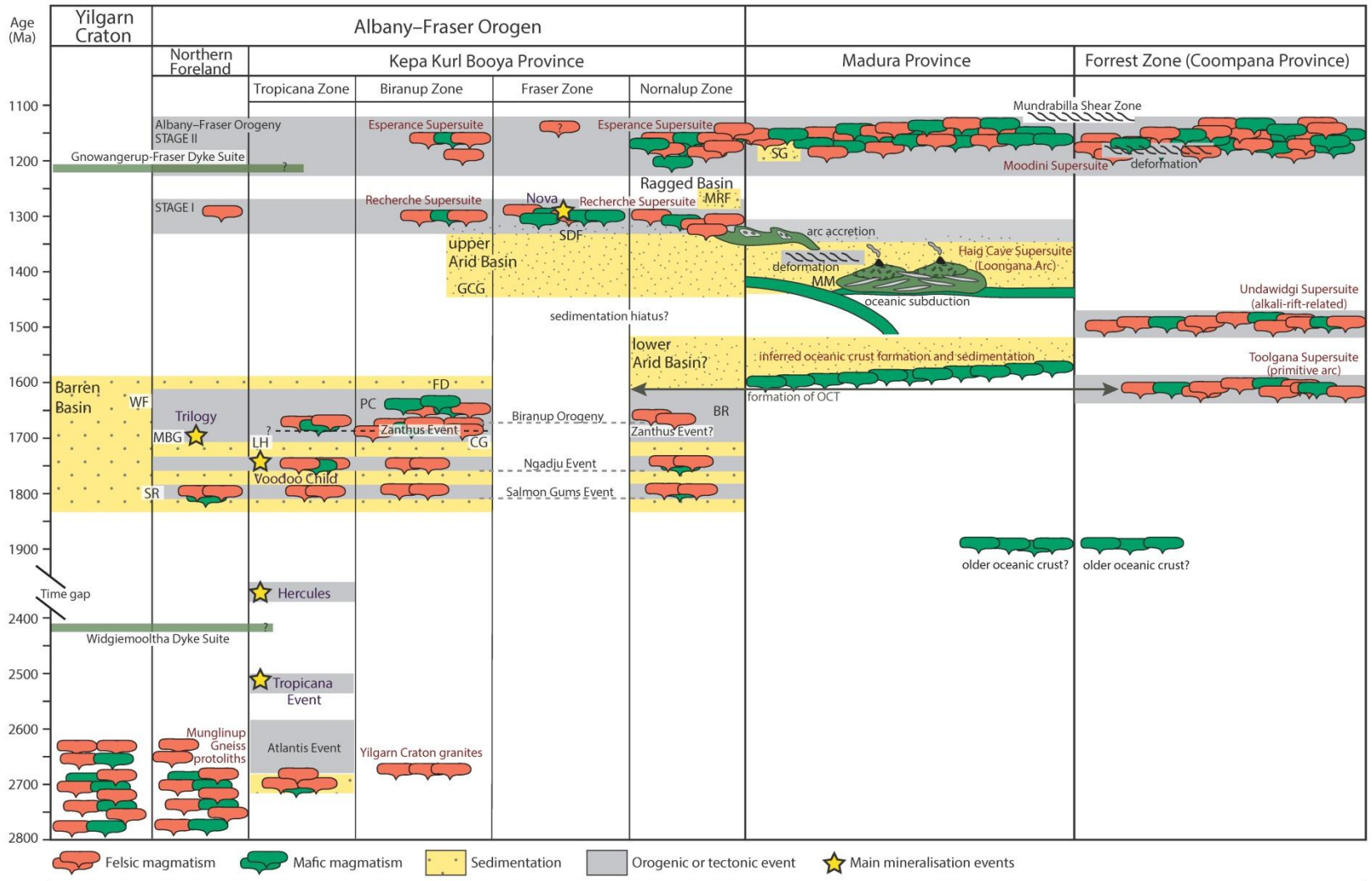
1260–1130 Ma



Aitken et al., Gondwana Research, 2015



# Time-space diagram



# 2000–1600 Ma



## **Madura Province and Forrest Zone:**

- Juvenile crustal basement (geochemistry and isotopes; 2.0–1.9 Ga) – probably similar for Musgrave Province – how much Coompana?
- Tap deep mantle sources
- Extension and juvenile crust formation the dominant processes
- c. 1600 Ma Toolgana Supersuite (Forrest Zone) – interpreted primitive arc; near primary melt of subduction-modified mantle and lower crust
- **Subduction- or arc-related mineral prospectivity?**
- **Presence of Cu in chlorite-epidote-sericite alteration**
- Toolgana Supersuite possibly linked to c. 1611 Ma St Peters Suite arc magmatism in South Australia (Swain et al., 2008)
  
- Orogenic processes in the Gawler Craton (talk to the South Australians)
- Major crustal evolution in the Albany–Fraser Orogen; continental rift or back-arc setting 1800–1600 Ma (includes Biranup Orogeny)

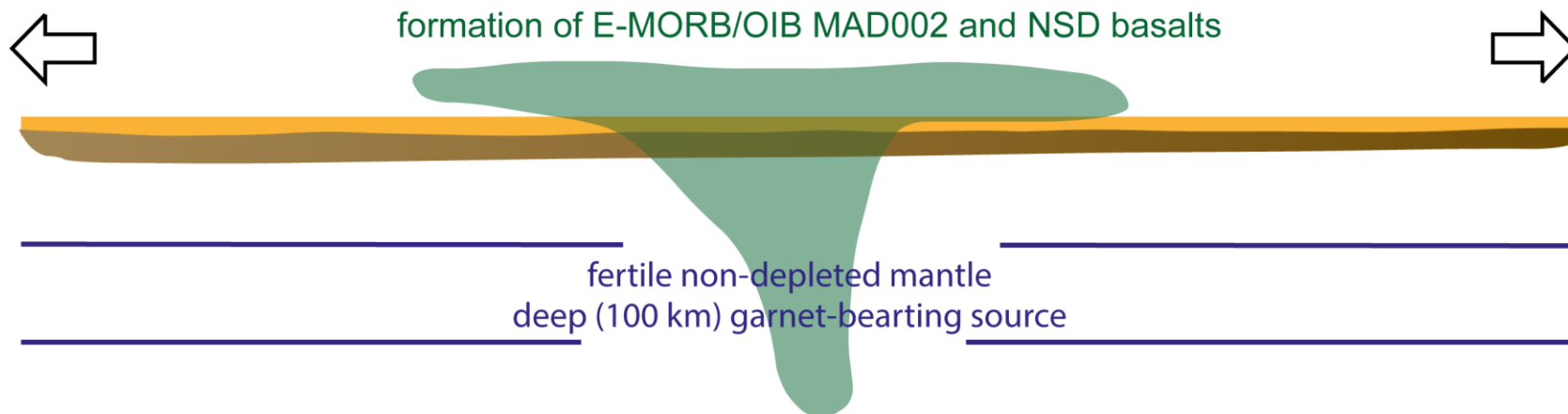
# 2000–1600 Ma



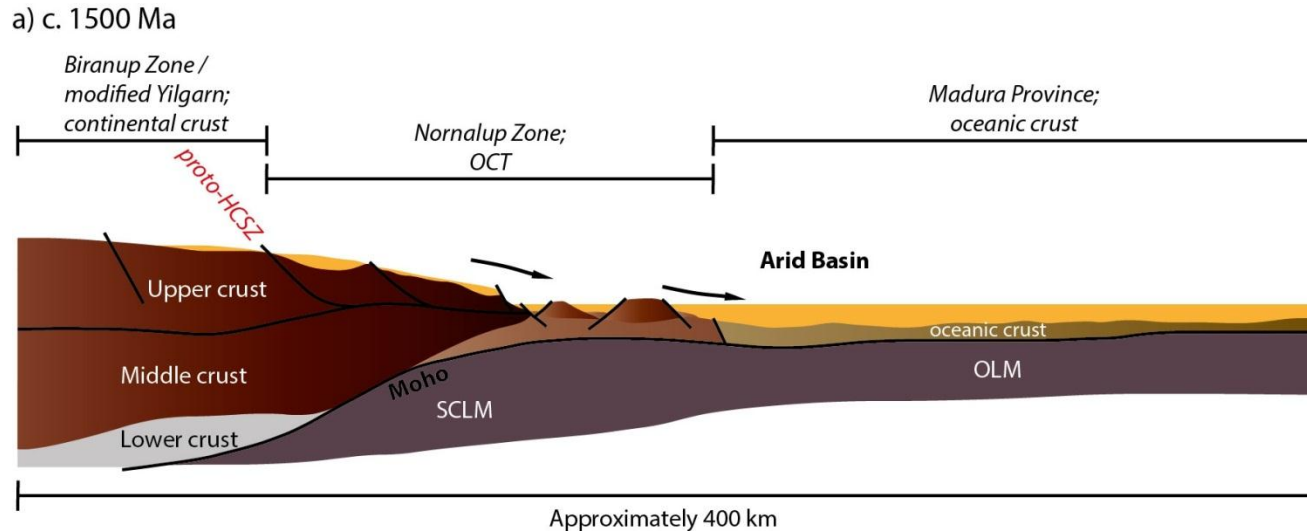
## Madura Province, and possibly eastern Nornalup Zone:

- Basaltic rocks encountered in MAD002 and NSD co-funded core (E-MORB/OIB) – proto-oceanic crust interpreted as part of this OCT phase
- Lithospheric extension on the continent edge, probably c. 1600 Ma (but could be earlier), certainly before c. 1450 Ma
- **Potential for VMS-style or exhalative deposits?**
- **Cu in MAD002**

lithospheric extension: continental rift or ocean-continent transition



# 1600 to 1500 Ma: Tectonic quiescence in the Albany–Fraser Orogen

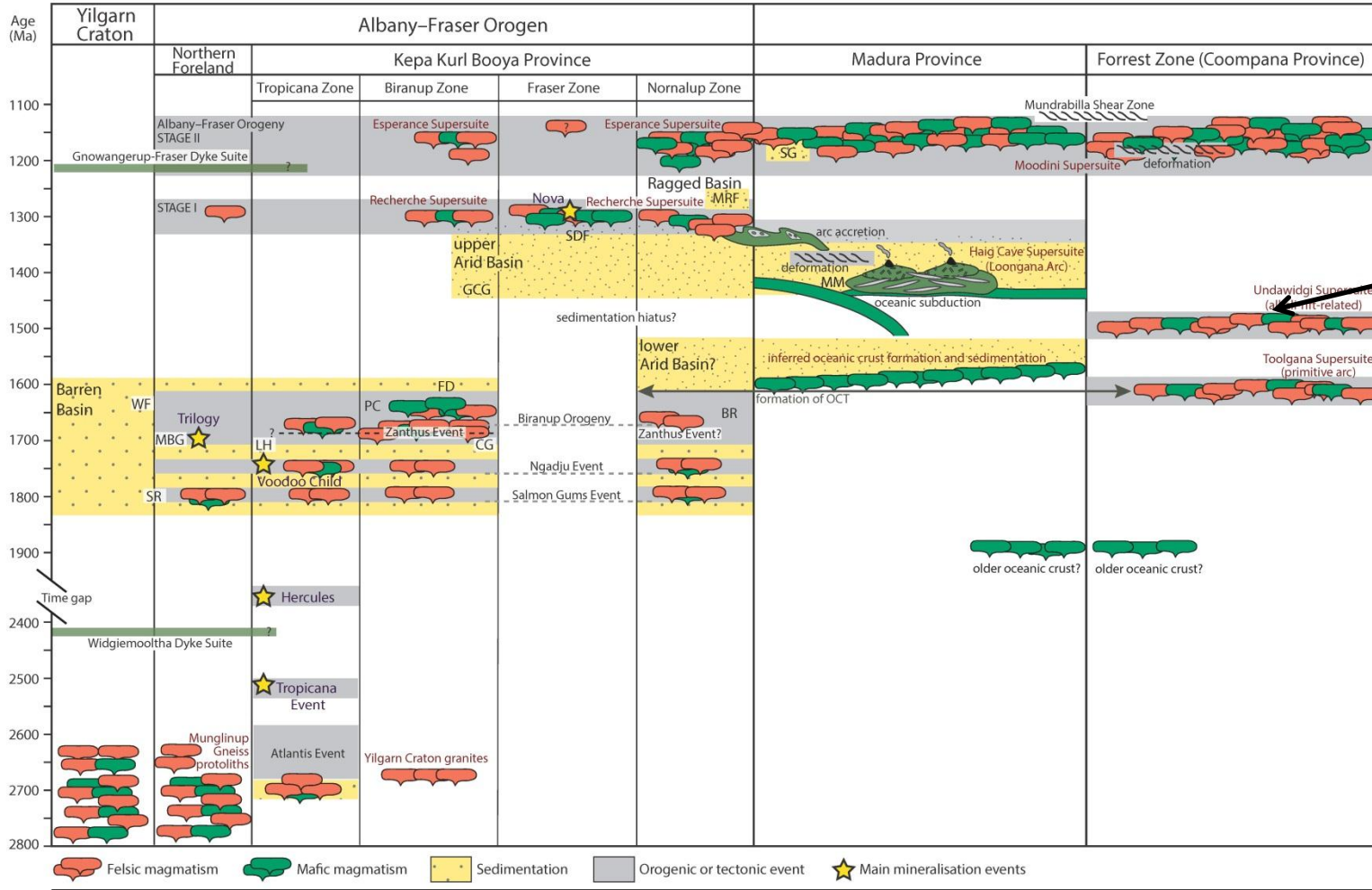


Initiation of the Arid Basin as a marginal basin:

- The Arid Basin lay outboard of the Yilgarn Craton and Biranup Zone, with the Nornalup Zone as an ocean–continent transition (OCT).

(Spaggiari et al., 2014; GSWA Report 133).

# 1500–1450 Ma



Undawidgi Supersuite is the main activity identified so far

# 1500–1450 Ma



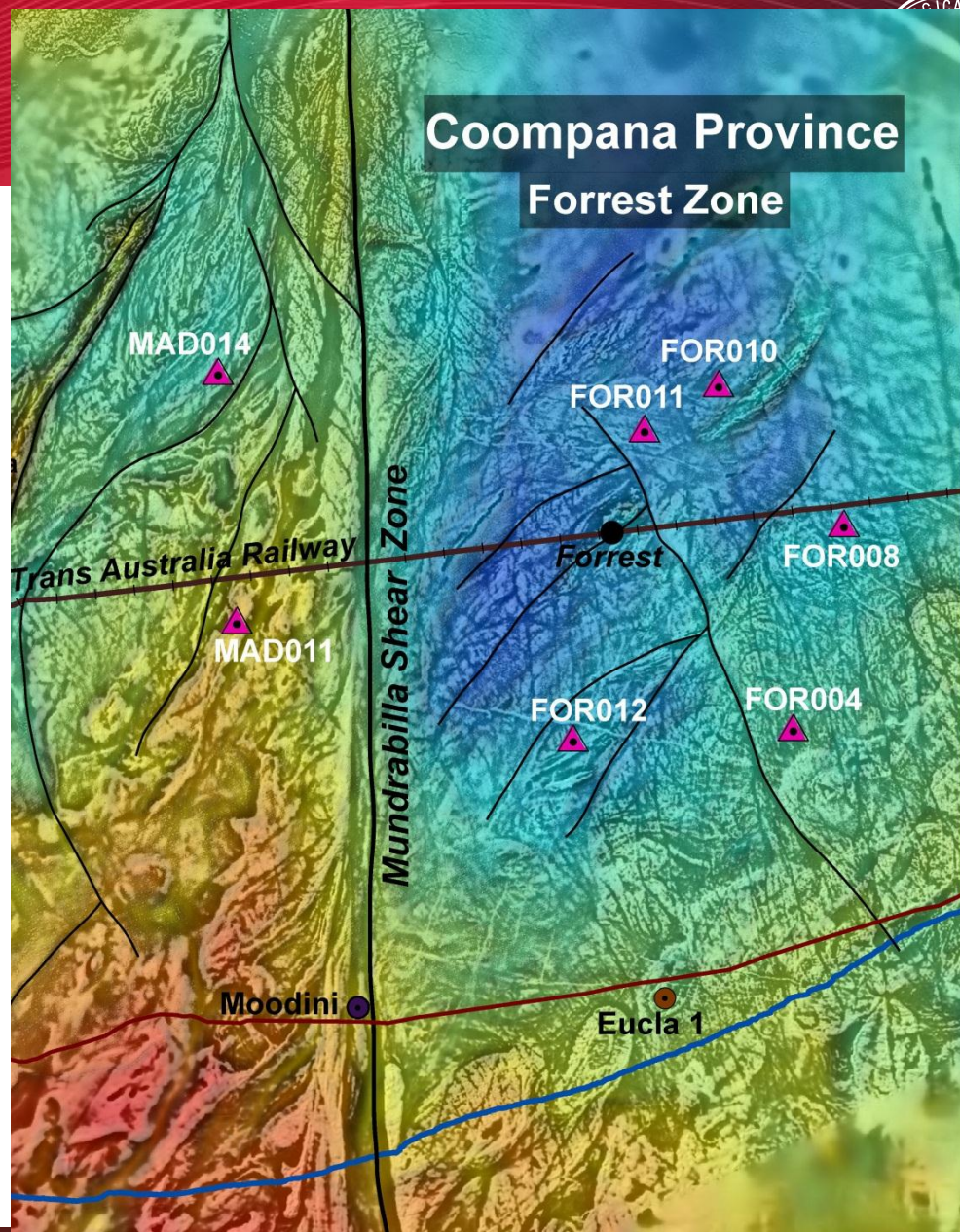
## **Forrest Zone:**

- c. 1500 Ma Undawidgi Supersuite: granitic rocks, possibly bi-modal volcanics
- Interpreted as melting of lower mafic crust and introduction of a mantle component
- Recycled c. 1600 Ma Toolgana Supersuite
- Interpreted high-K, rift-related suite
- Extension and juvenile crust formation the dominant processes again
- **Potential for VMS-style mineral prospectivity?**
- **Presence of Cu in chlorite-epidote-sericite alteration**
- **Alkali-rich, magnetite-bearing high level intrusives / volcanics possibly formed from melting alkali-metasomatised subduction-related crust - IOCG potential?**
- Undawidgi Supersuite probably linked to c. 1500 Ma granite gneiss in Mallabie 1 (Wade et al., 2007) – widespread rifting

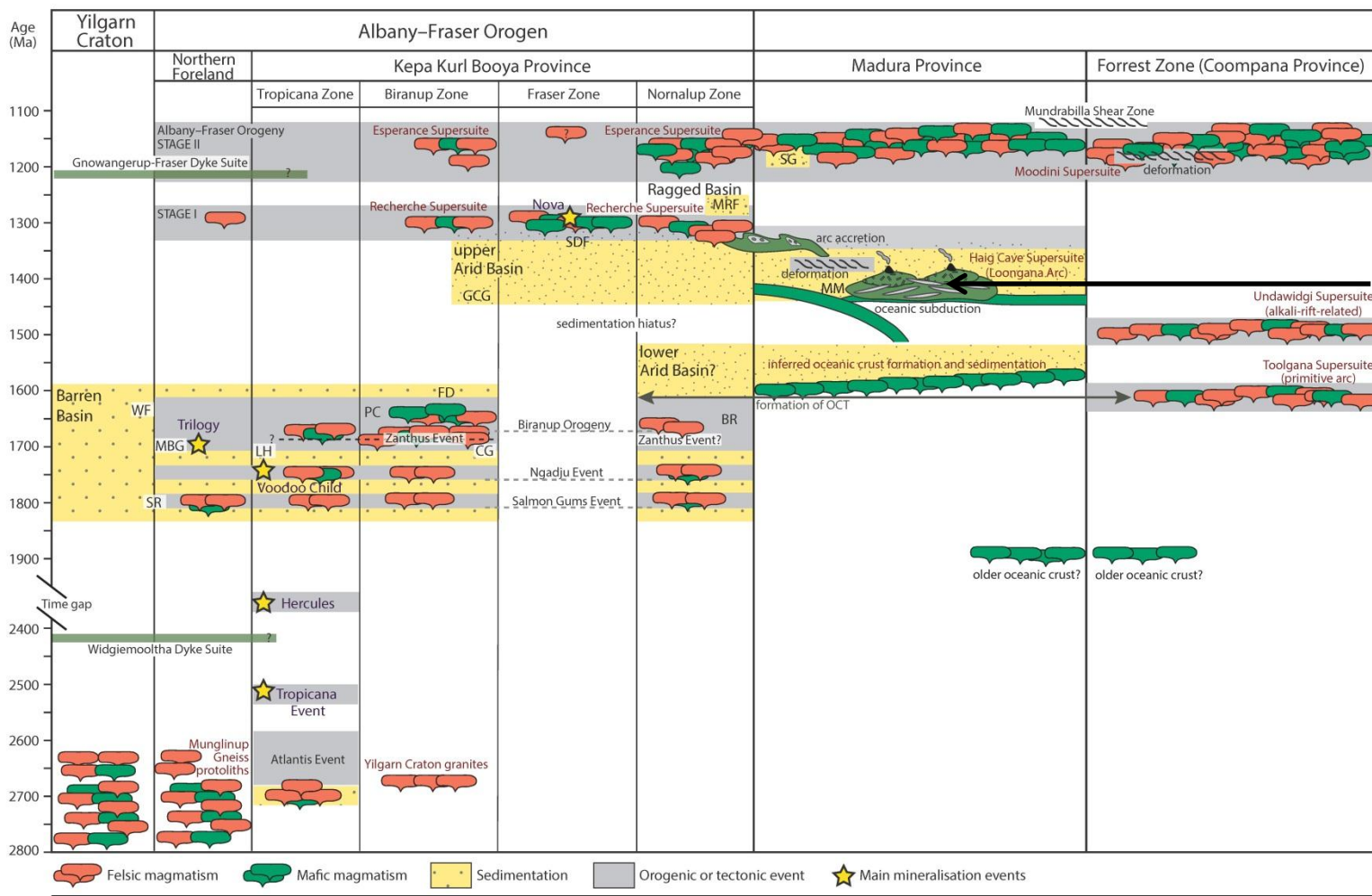
# 1500–1450 Ma

## Forrest Zone:

- Potential for a large structure between Undawidgi Supersuite in the northwest and Toolgana Supersuite in the southeast
- Mylonites in FOR012 (Undawidgi), top NW kinematics in FOR008 (Toolgana)
- **Prospective?**
- Will see what the seismic shows....



# 1450–1330 Ma



Loongana Arc is the main activity identified so far



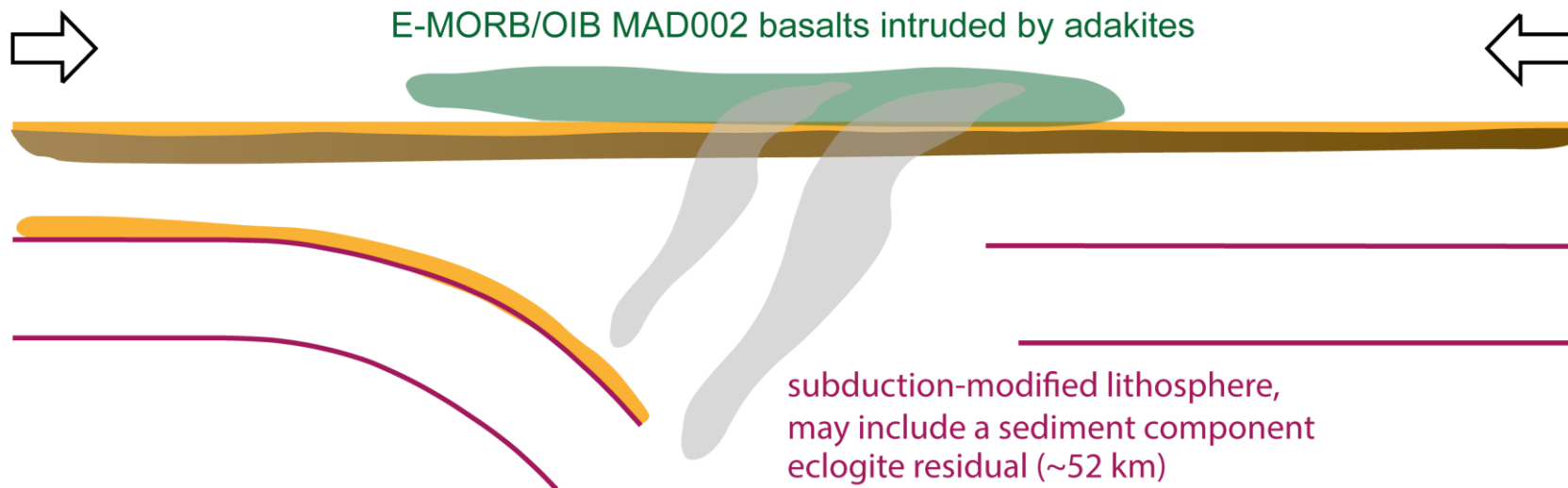
# 1450–1330 Ma



## Madura Province:

- c. 1400 Ma Loongana Arc (Haig Cave Supersuite)
  - Interpreted as an oceanic arc; east-dipping subduction (uncontaminated)
  - Interpretation supported by the presence of c. 1389 Ma adakites in MAD002 – subduction-modified source required (not melts of E-MORB)
- **Potential for subduction-related PGEs and Ni**

Deep source melting, potentially during deformation



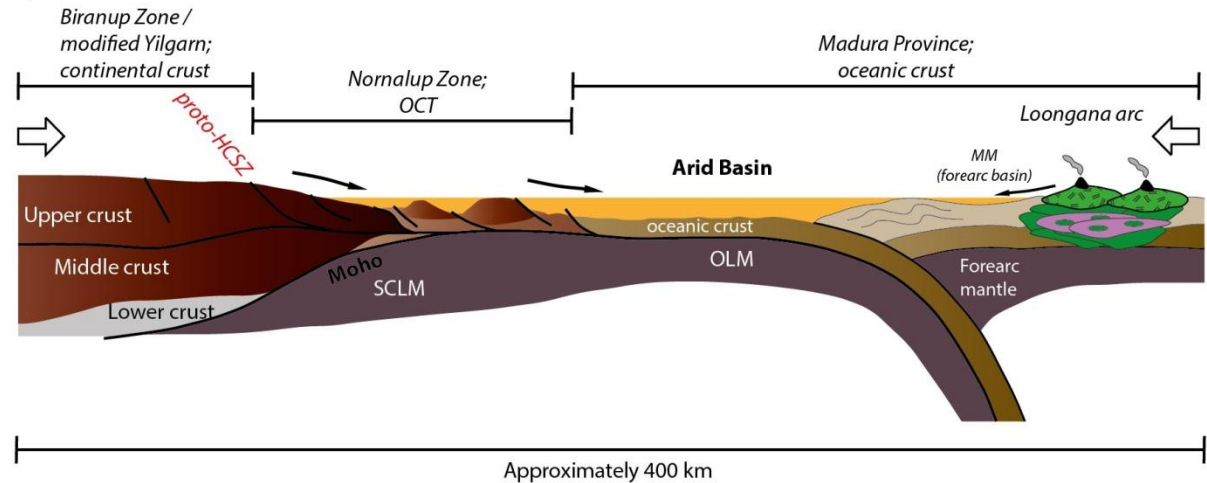
# Madura Province: c. 1400 Ma Loongana oceanic-arc



Change to convergent setting and development of the Loongana oceanic magmatic-arc at c. 1400 Ma.

## Albany-Fraser Orogen

b) c. 1410 Ma

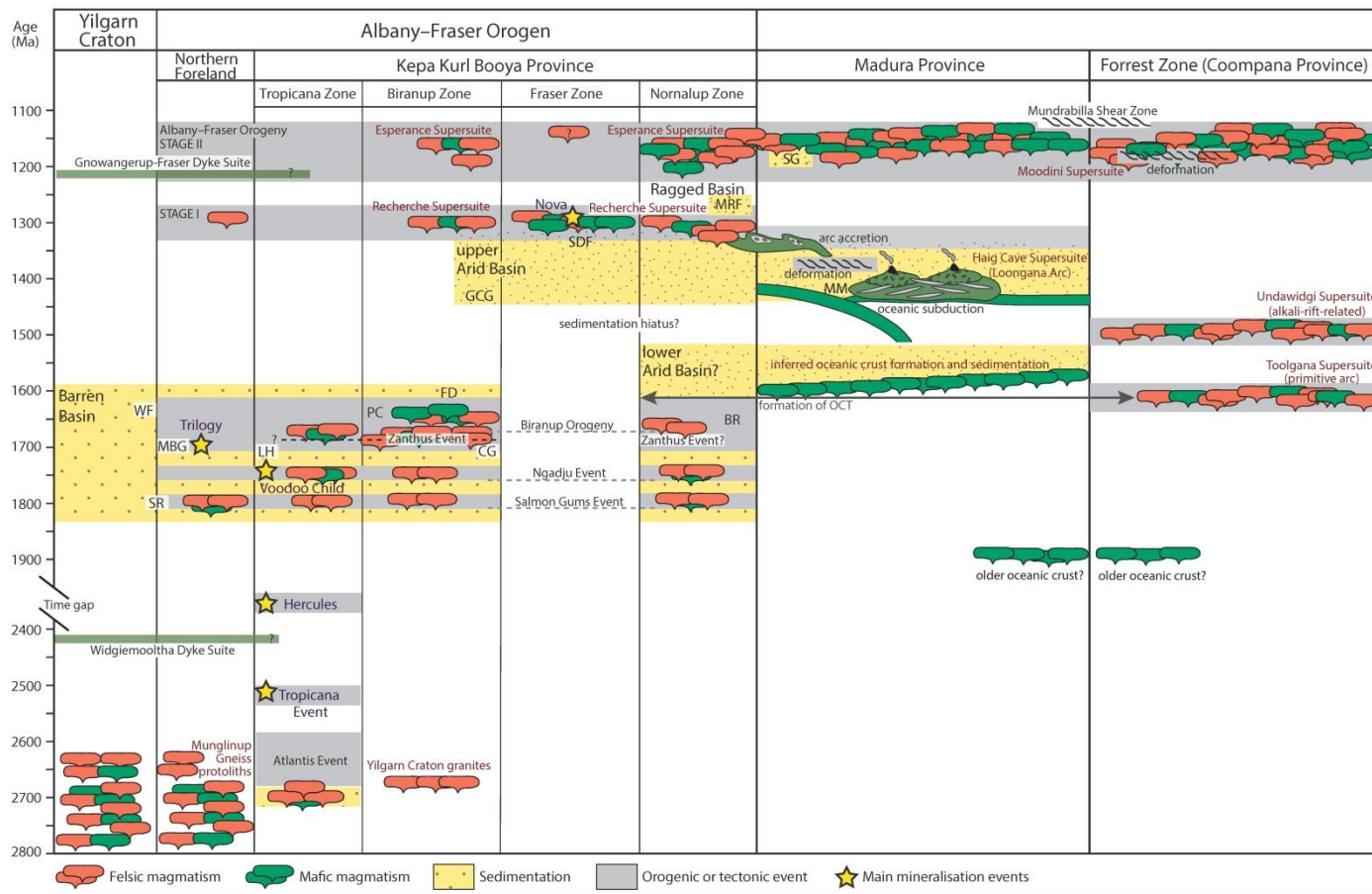


Malcolm Metamorphics (Point Malcolm) are interpreted fore-arc basin sediments, interlayered with N-MORB basalt; similar to Burkin prospect.

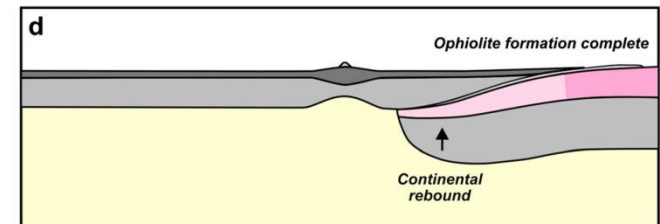
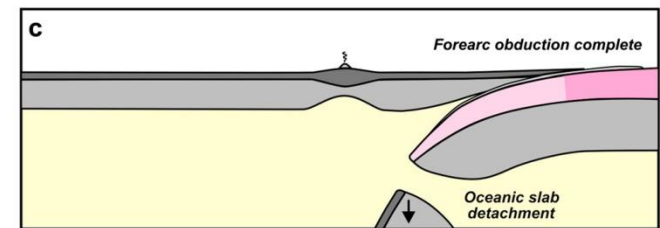
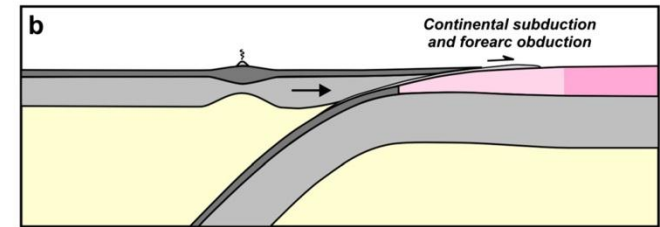
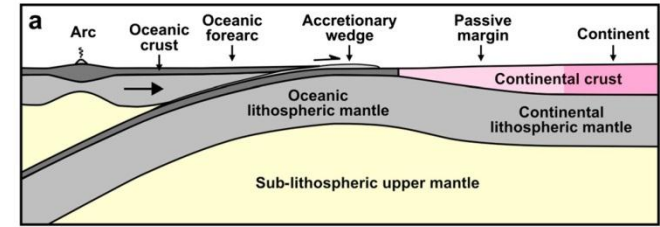
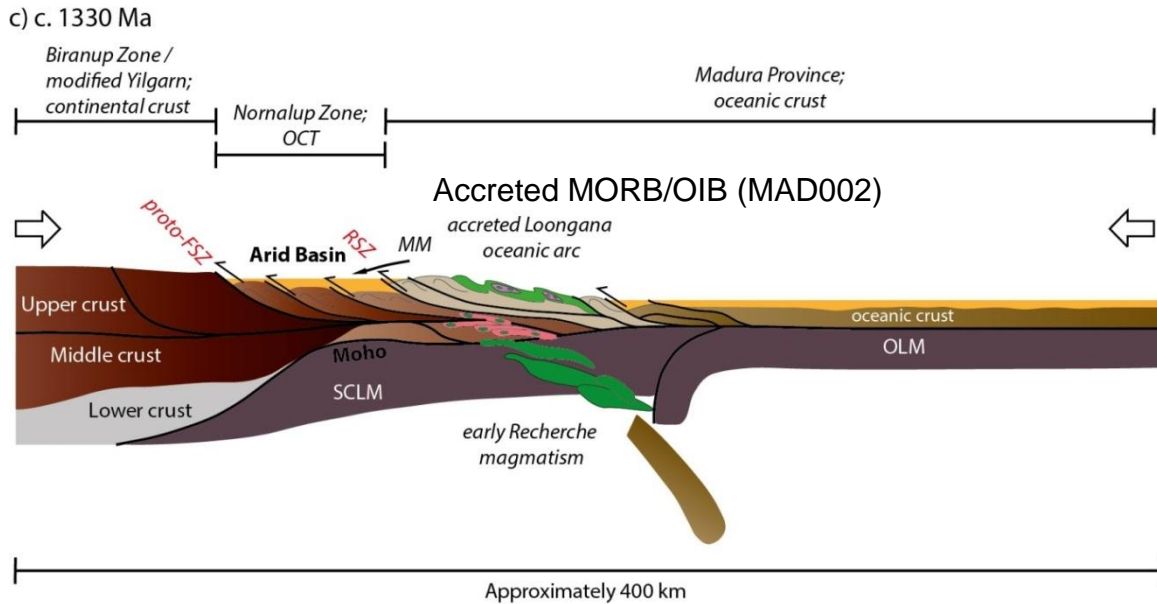
# No 1330–1260 Ma rocks in Madura or Forrest?



Stage I Albany–Fraser Orogeny restricted to craton edge – accretion only – doesn't appear to be continental collision



# c. 1330 Ma oceanic-arc accretion – Rodona Shear Zone – ophiolite complex



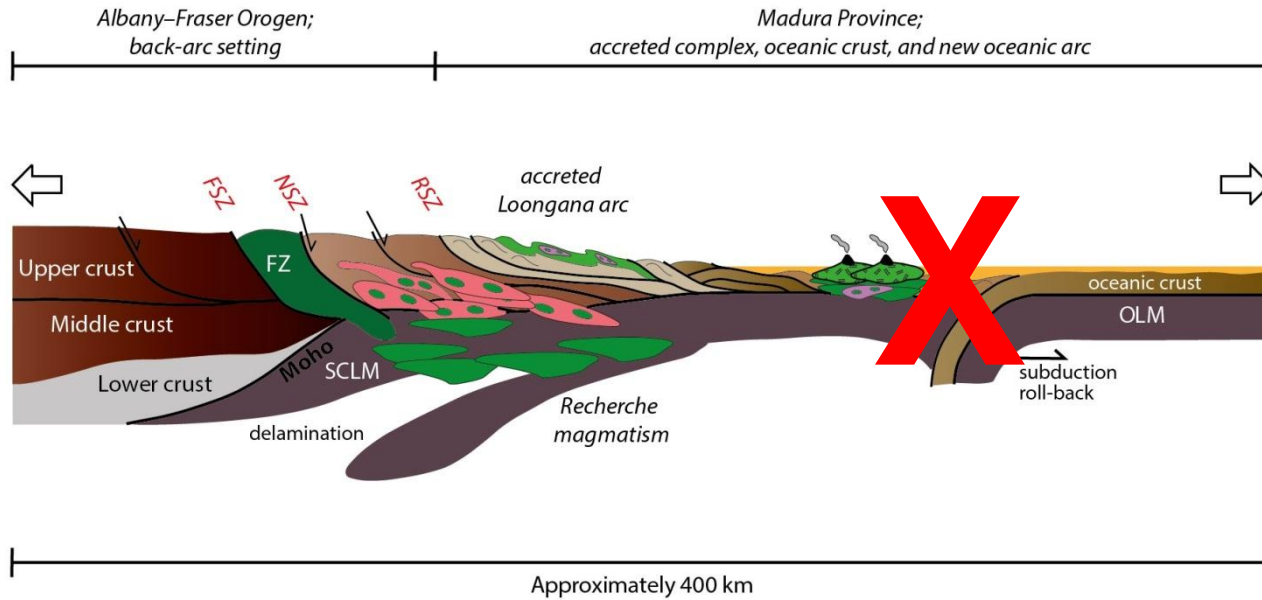
- Oceanic -arc accretion and slab detachment triggers the onset of Stage I of the Albany-Fraser Orogeny, and early Recherche Supersuite magmatism.
- Sediments transferred from the Loongana oceanic-arc and its environs to the Arid Basin (foreland basin component).

(Spaggiari et al., 2014; GSWA Report 133).

Edwards et al., 2015, *Tectonics*, 34, 1494–1515.

# Stage I Albany–Fraser Orogeny at c. 1300 Ma

d) c. 1300 Ma

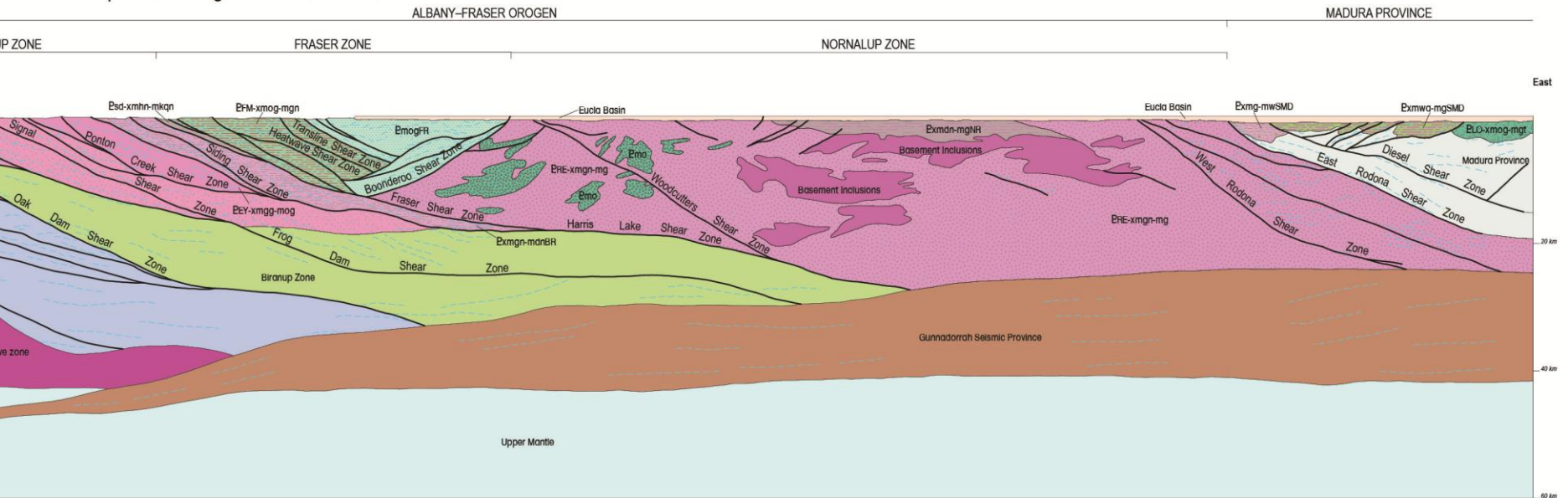


- Renewed subduction dips west beneath the easternmost extent of the orogen and accreted portion of the Madura Province, forming a new oceanic-arc and adjacent back-arc setting.
  - Roll-back leads to extension of the back-arc and formation of the Fraser Zone; continued Recherche Supersuite magmatism.
- (Spaggiari et al., 2014; GSWA Report 133).

# Stage I Albany–Fraser Orogeny at c. 1300 Ma

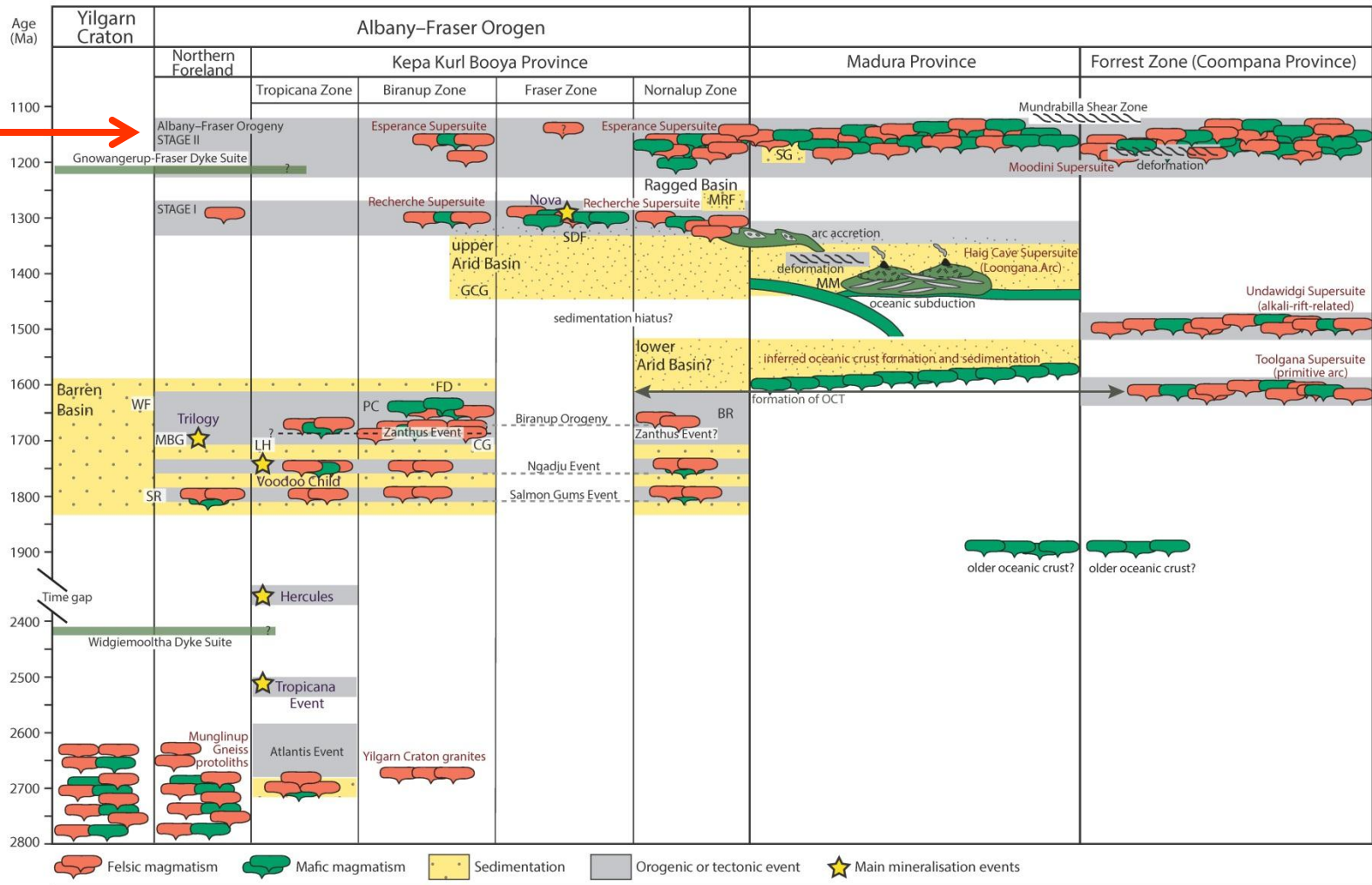
- Intrusion of the Fraser Zone gabbros at c. 1300 Ma – Ni-Cu prospectivity
- Link to formation of the Rodona Shear Zone?
- Is the Madura Province linked to the Ni source?
- Is the eastern Nornalup Zone just as prospective?

Interpreted Geological Cross Sections



Seismic line GA12-AF3; GSWA Record 2014/6

# 1200–1100 Ma – the Massive Event

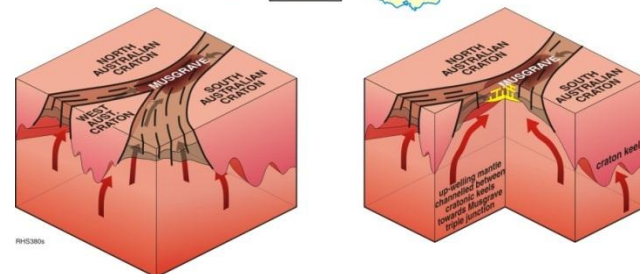
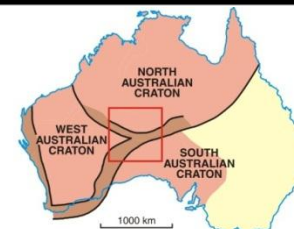
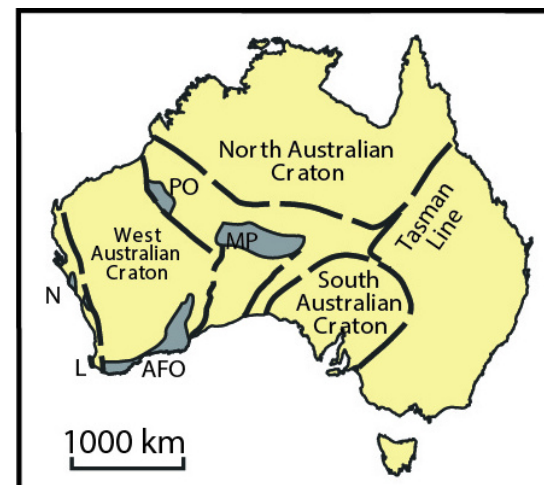


# 1200–1100 Ma – the Massive Event



## Everywhere except the Gawler?

- Esperance Supersuite (AFO), Moodini Supersuite, Pitjantjatjara Supersuite (Musgrave)
- Each supersuite reflects the crust it melts
- Massive high-T, melting event – juvenile high-KFe magmas
- Suggests ocean not completely destroyed by craton convergence – still no collision?
- Albany-Fraser and Gawler separated by Madura Province (ophiolite complex) and Coompana Province – all of it?
- Moodini Supersuite specialised high-T, A-type magmas.
- Compositionally different in the Madura Province and Forrest Zone (shoshonitic)



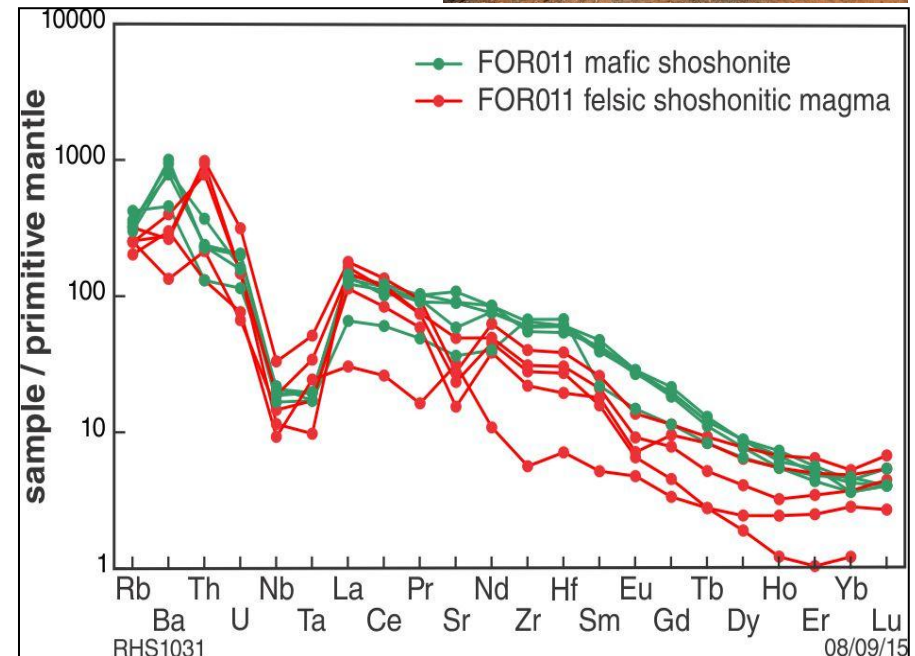


# Moodini Supersuite



## Bottle Corner Shoshonite

- Dy/Yb ratios are initially high in the mafic magmas (green) but decrease rapidly with increasing silica suggesting a strong role for hornblende fractionation, but Eu-anomalies are typically not developed.
- This suggests the magmas undergo early water saturation. These rocks show close compositional similarities with Cu-Au mineralised shoshonites in the Early Silurian Macquarie Arc (NSW)

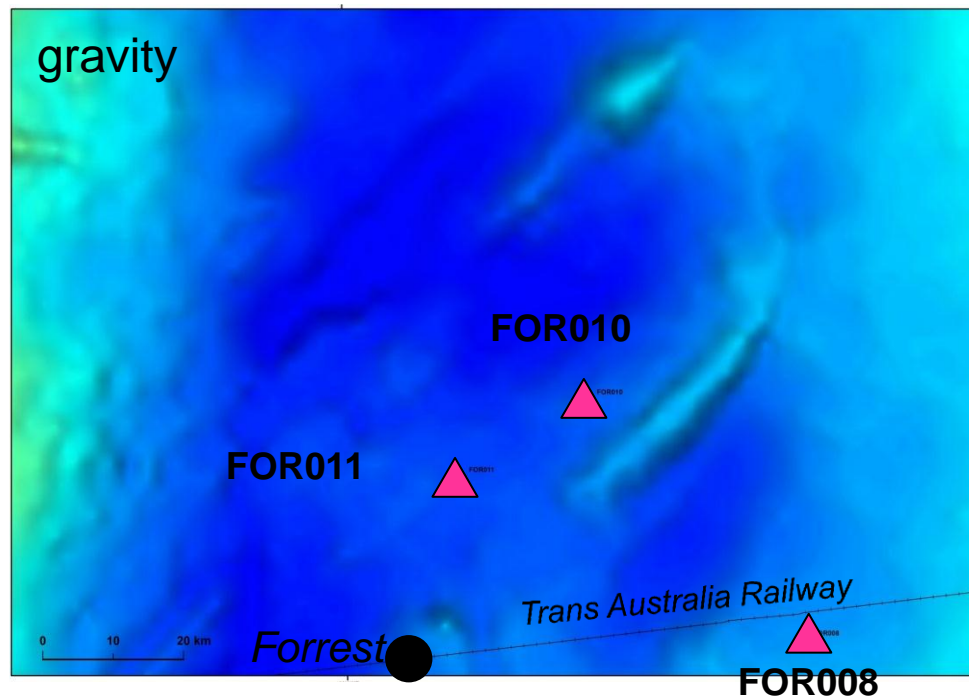


# Moodini Supersuite



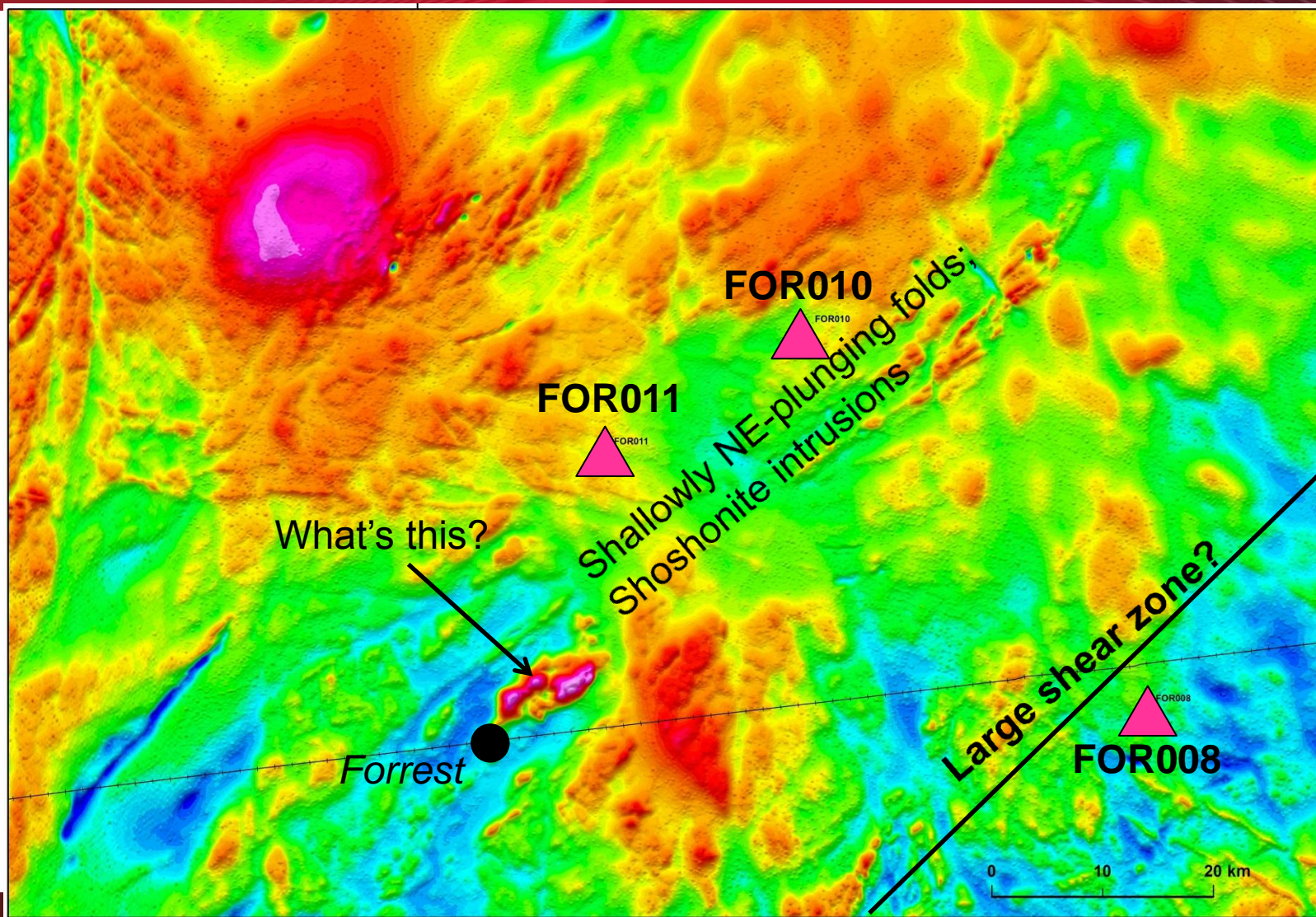
## Bottle Corner Shoshonite

- Shows compositional attributes potentially indicative of magmas with Cu and Cu-Au potential
- **Intrusion-related Cu-Au?**
- Late Si-rich shoshonites are significantly altered, and contain pyrite-chalcopyrite-rare galena



- Appear to be especially prevalent in the northern Forrest Zone, which has shallower basement, and a sealed airport!

# FOR011 and FOR010 drill sites; RTP magnetics



# Exploration under the Nullarbor is challenging



Seize the moment and bring home the silverware!



## Go Hawks!