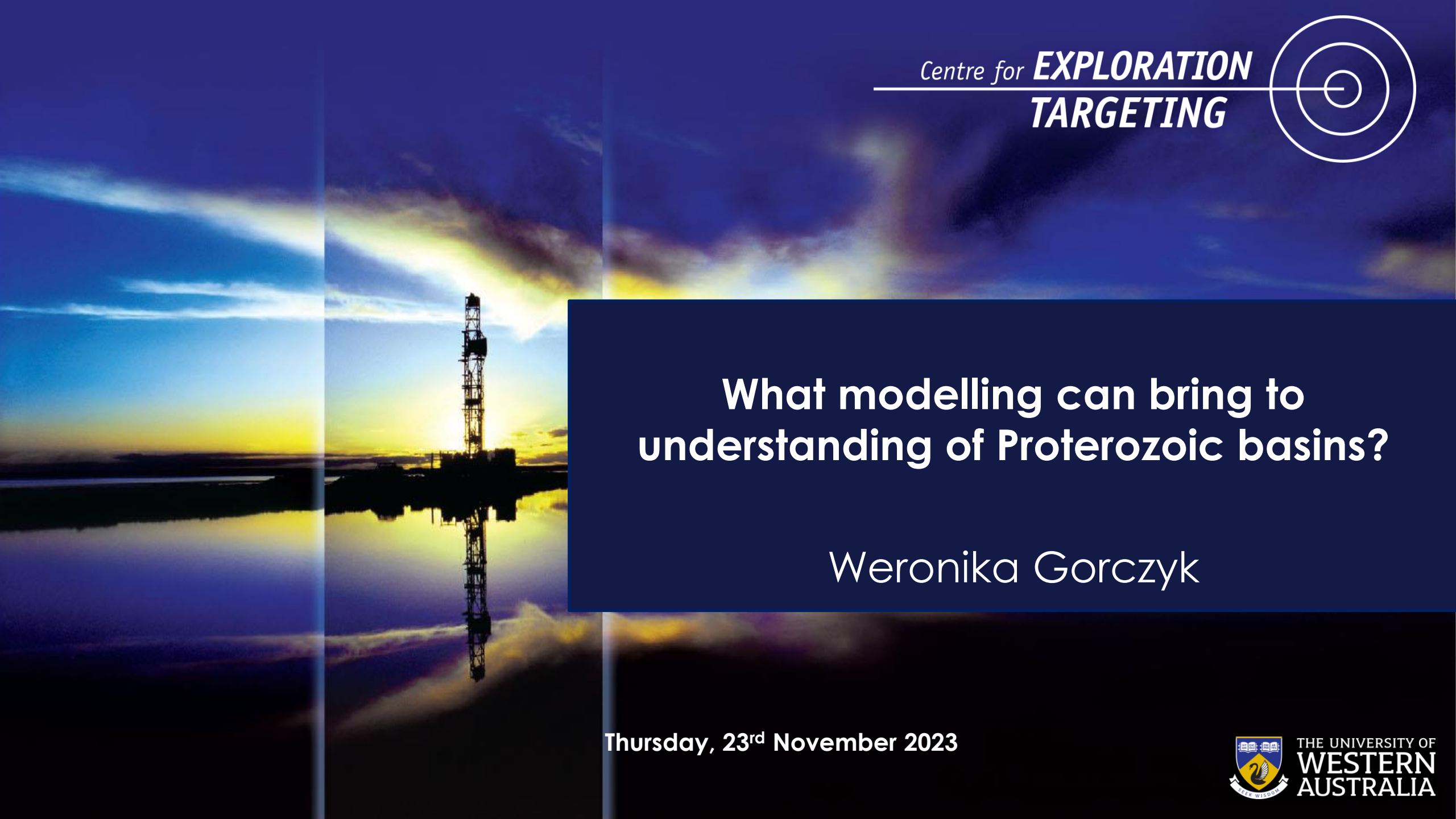

Centre for EXPLORATION TARGETING

What modelling can bring to understanding of Proterozoic basins?

Weronika Gorczyk

Thursday, 23rd November 2023

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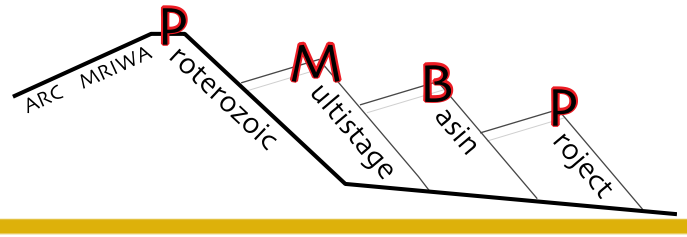

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ARC Linkage/MRIWA M554

Evolution of Proterozoic multistage rift basins

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MONASH University

CSIRO

THE UNIVERSITY OF SYDNEY

Geological Survey of Western Australia

mriwa
Minerals Research Institute of Western Australia

Australian Government
Australian Research Council

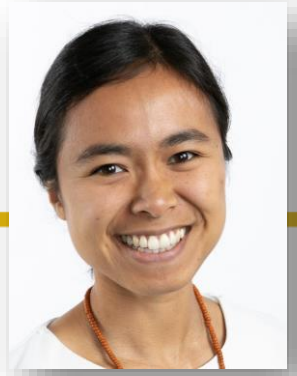
BHP
bhpbilliton

igo

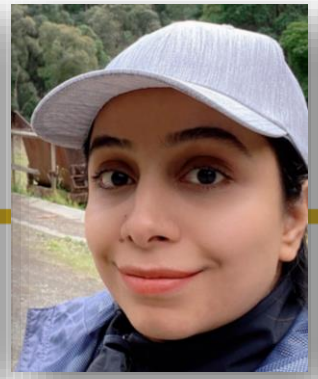
ANGLO AMERICAN

FMG Fortescue
The New Force in Iron Ore

FIRST QUANTUM MINERALS LTD.



Anindita Samsu



Fatemeh Amirpoorsaeed

Tristan Salles

Patrice Rey

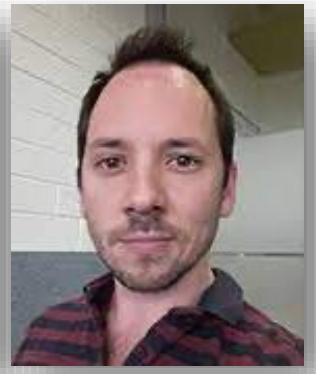
Alan Aitken

Sandy Cruden

Weronika Gorczyk

Polyanna Moro

Fariba Kohanpour



Julian Giordani

Youseph Ibrahim

Uchitha Nissanka Arachchige

Lu Li

Tolga Mercan

Joel Kumwenda

Mark Jessell

Olive

Susanne Schmid

Myra Keep

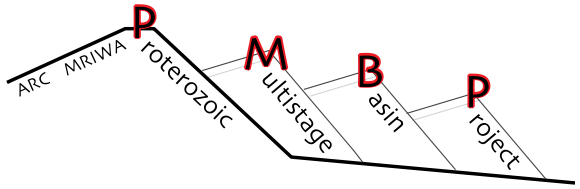
Simon Lang

Ian Tyler

Peter Betts

Sinan Ozaydin

Numerical modeling



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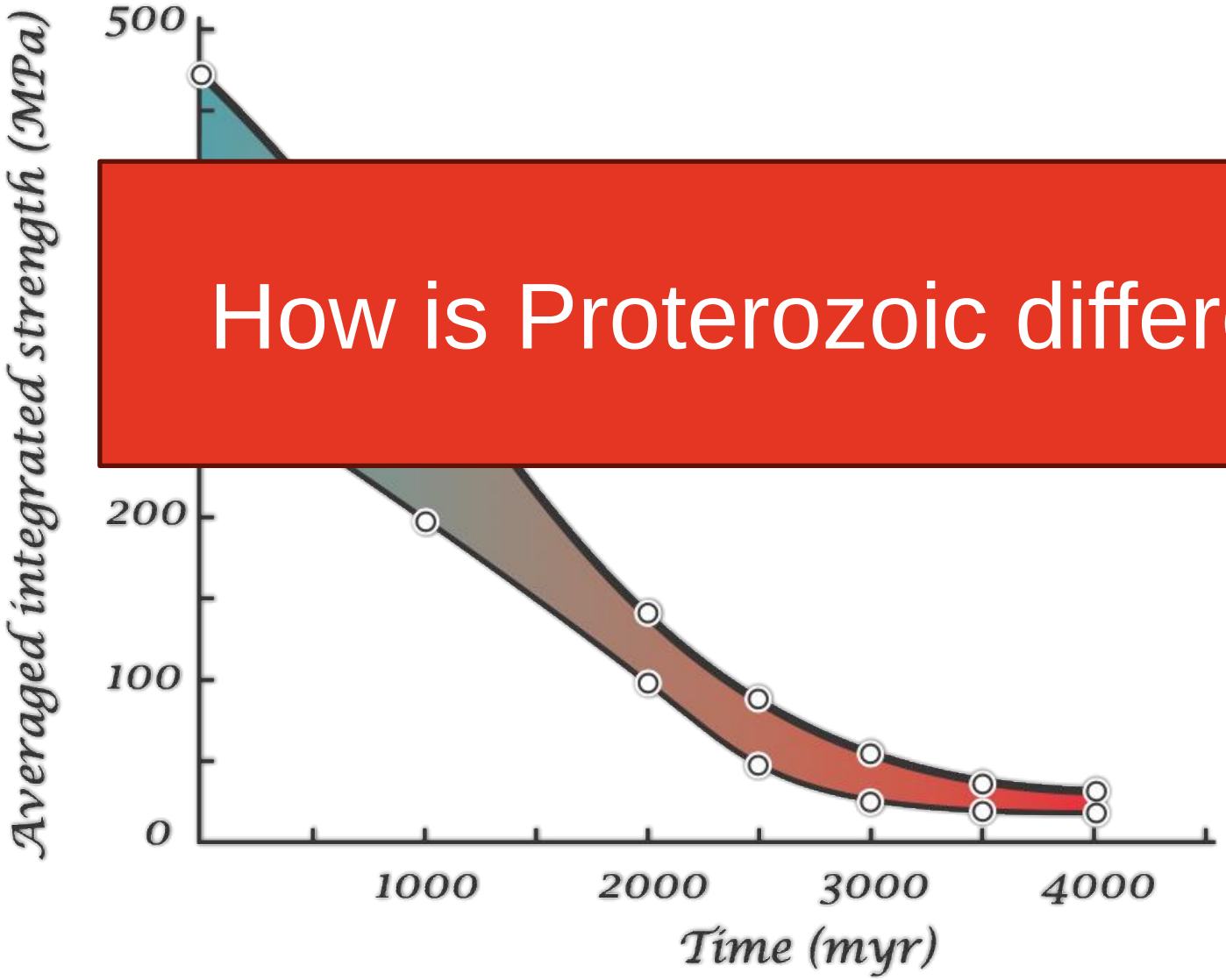
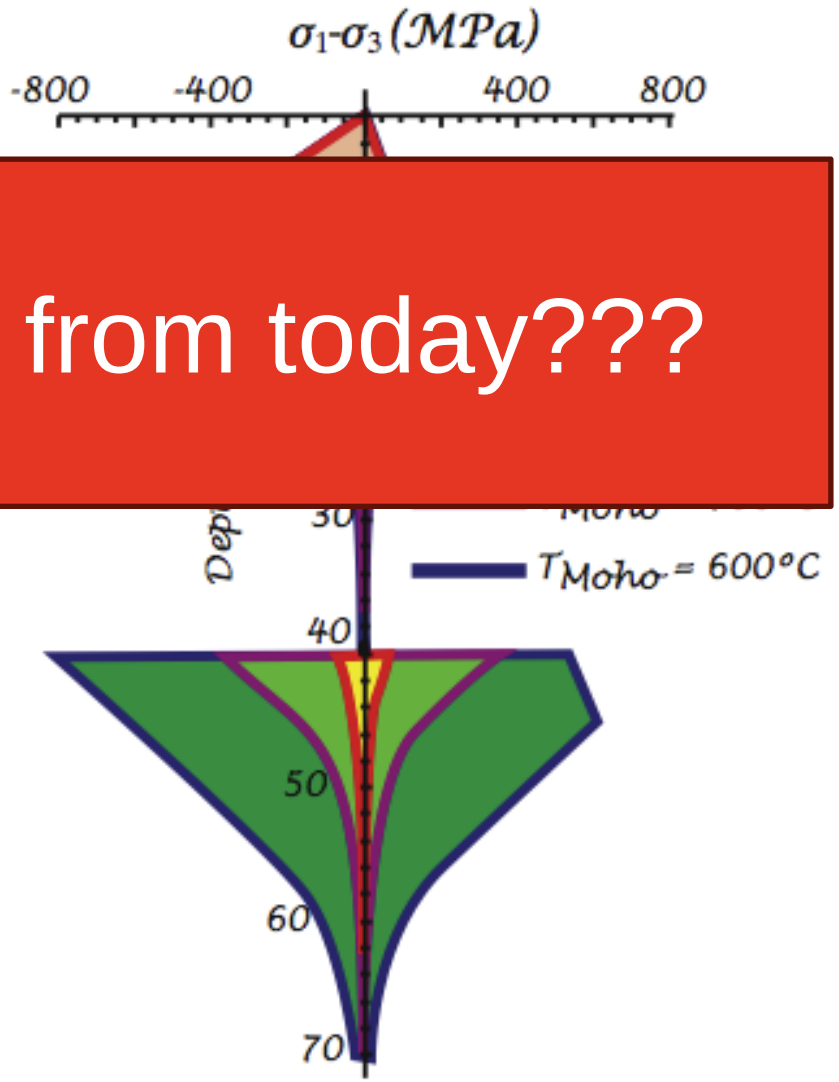
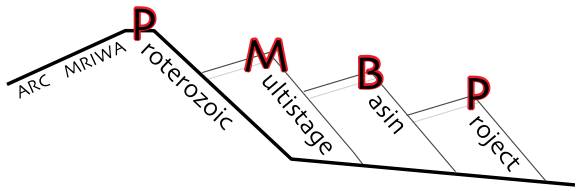




How is Proterozoic different from today???

Numerical modeling



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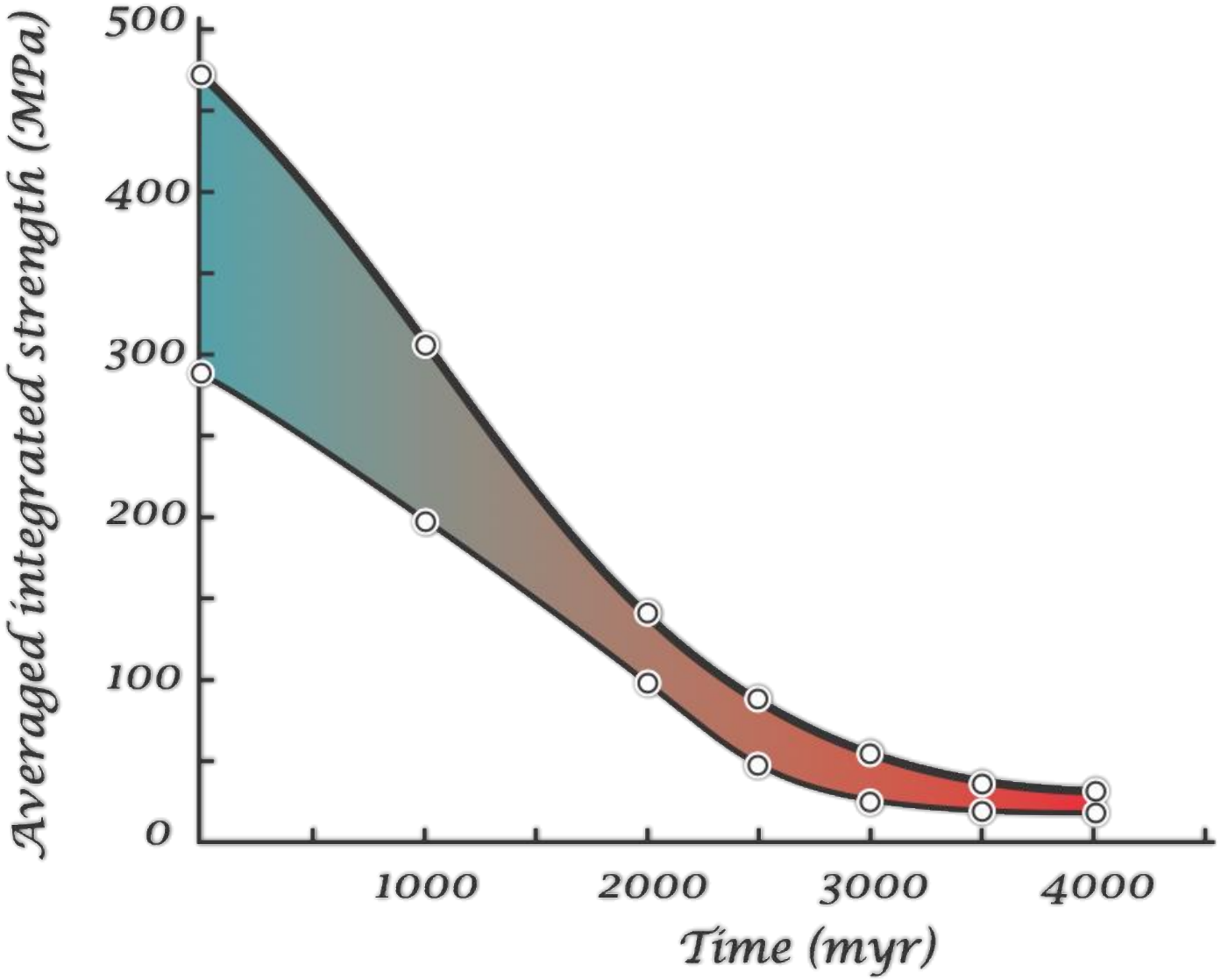
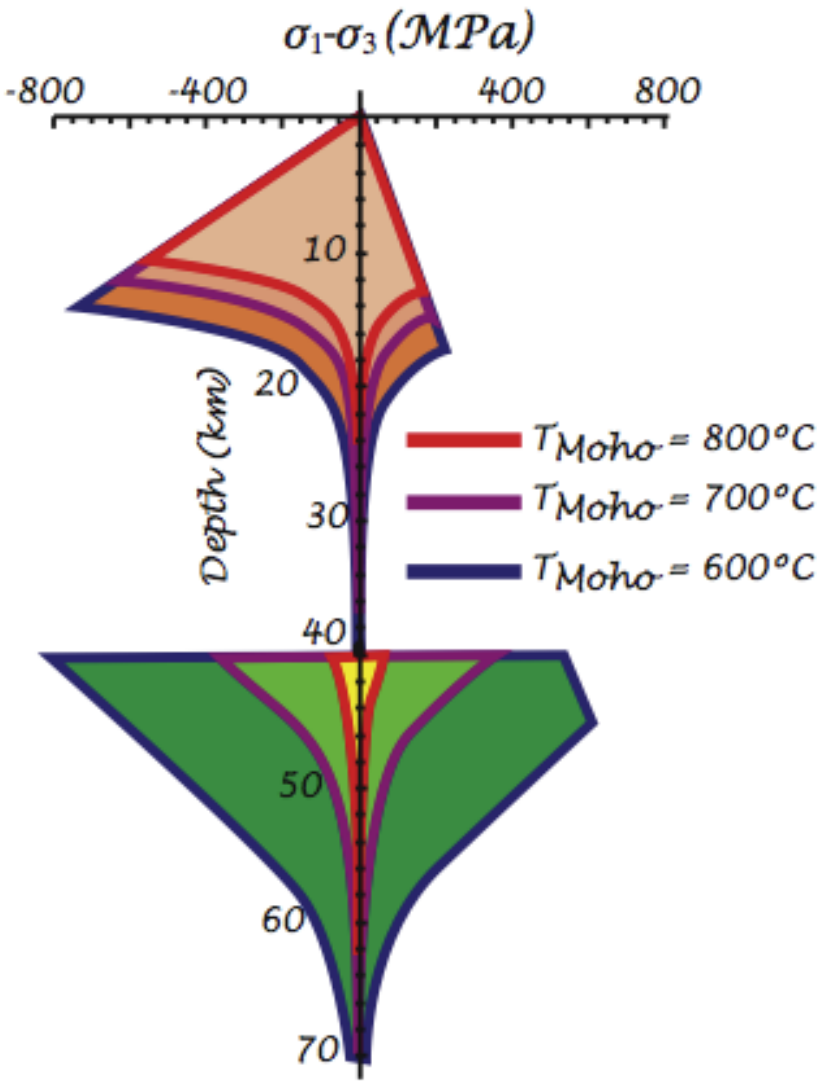
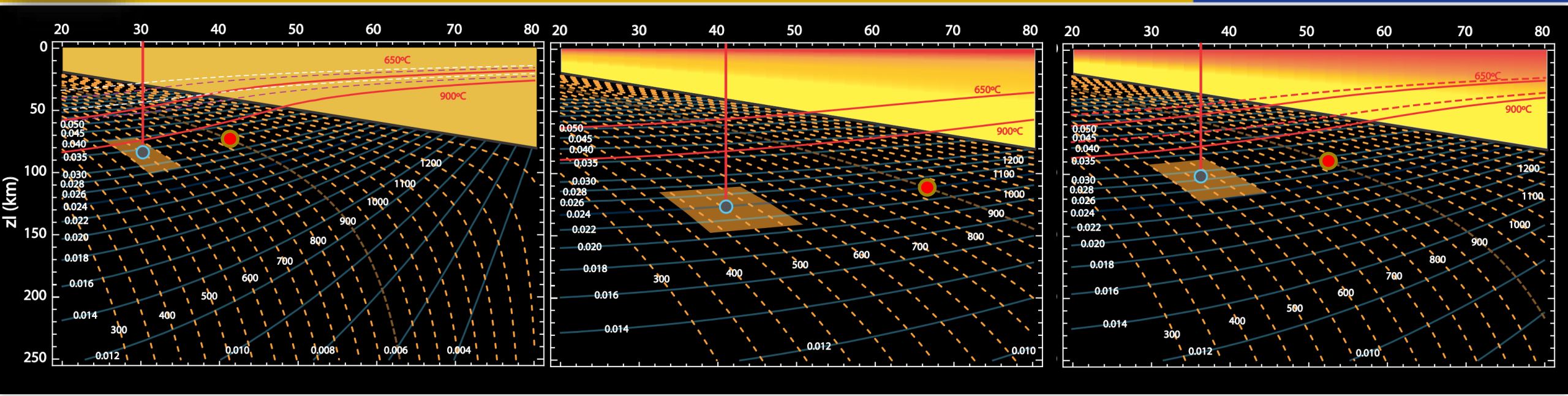




Numerical modeling



Bulk crust @ 2 Ga

- Continental crust = 30 km
  TMoho = 620ºC
  Mantle heat flow = 0.034 mW/m^2
- Continental crust = 41 km
  TMoho = 900ºC
  Mantle heat flow = 0.034 mW/m^2

Bulk crust @ 1 Ga

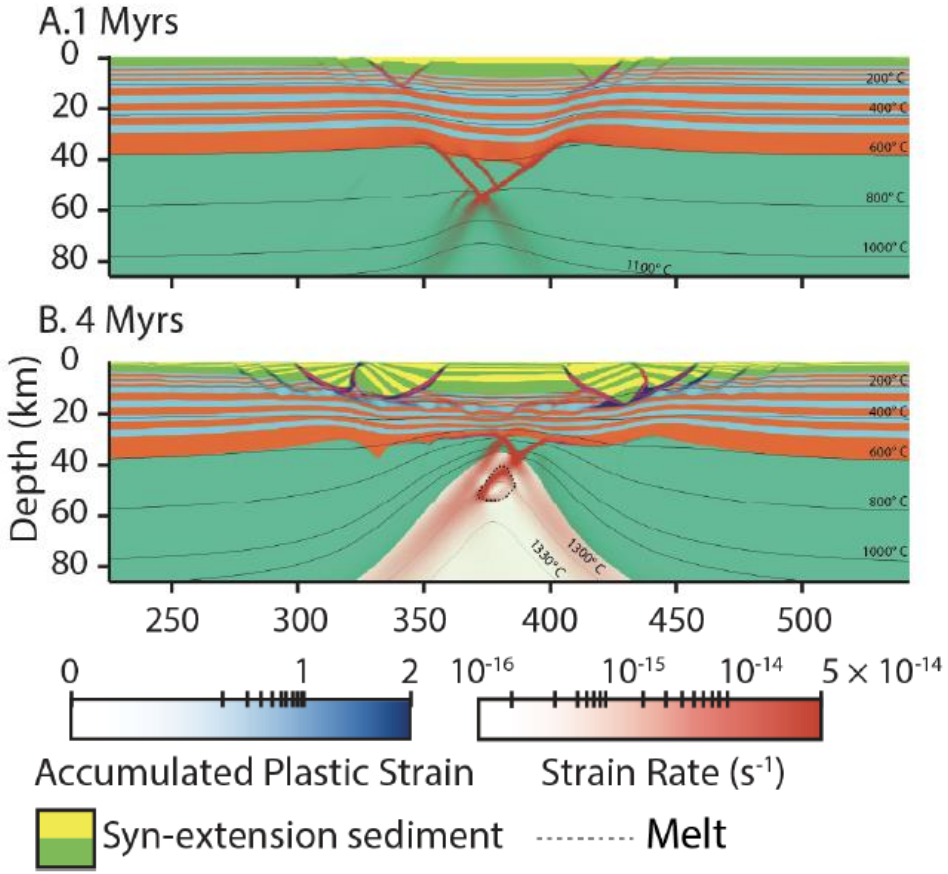
- Continental crust = 36 km
  TMoho = 575ºC
  Mantle heat flow = 0.028 mW/m^2
- Continental crust = 52 km
  TMoho = 900ºC
  Mantle heat flow = 0.028 mW/m^2

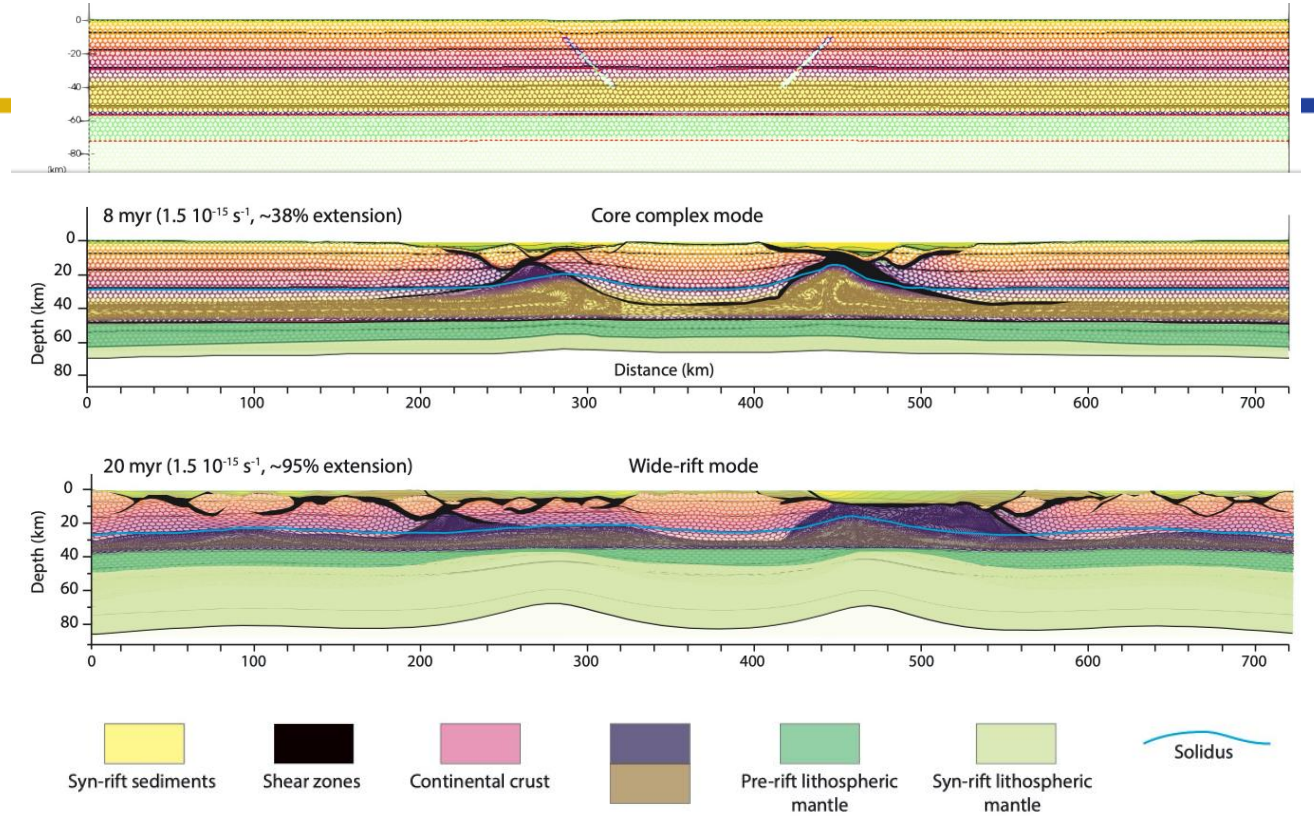
Bulk crust @ today

- Continental crust = 41 km
  TMoho = 490ºC
  Mantle heat flow = 0.024 mW/m^2
- Continental crust = 67 km
  TMoho = 900ºC
  Mantle heat flow = 0.024 mW/m^2

Numerical modeling

T_{moho} < 650°C narrow rift is the default mode of continental extension



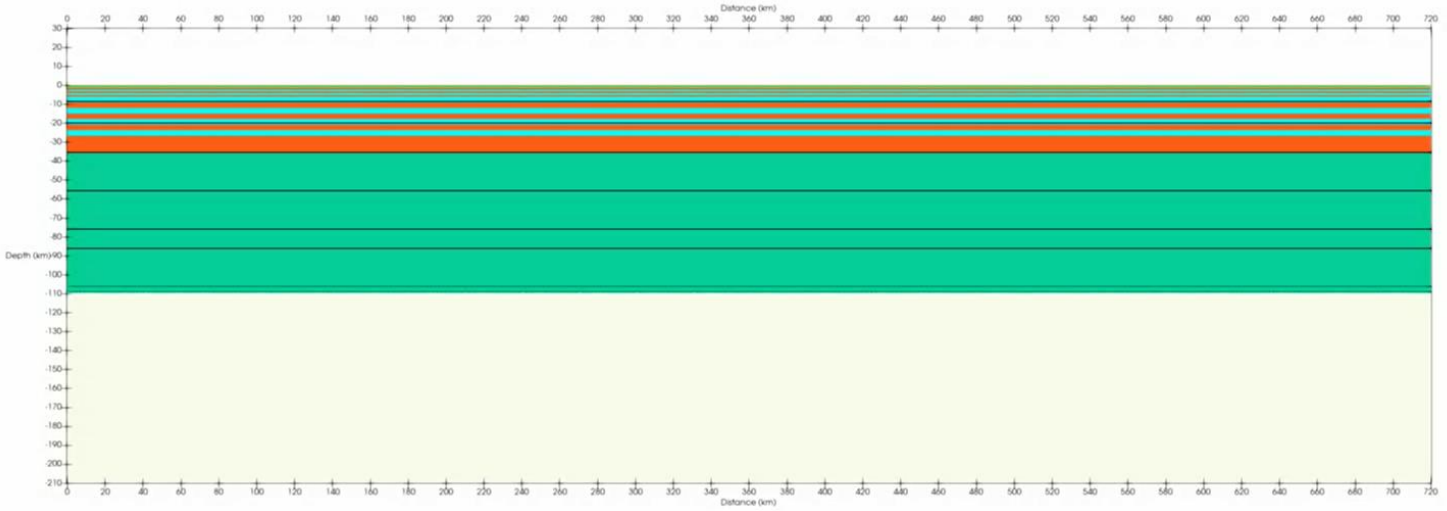


T_{moho} > 650°C multiple modes of riffing

Extension of hot crust leads to a long period of wide rift/cooling and embrittlement followed by a shorter period of narrow rift leading to breakup

0.00 Ma

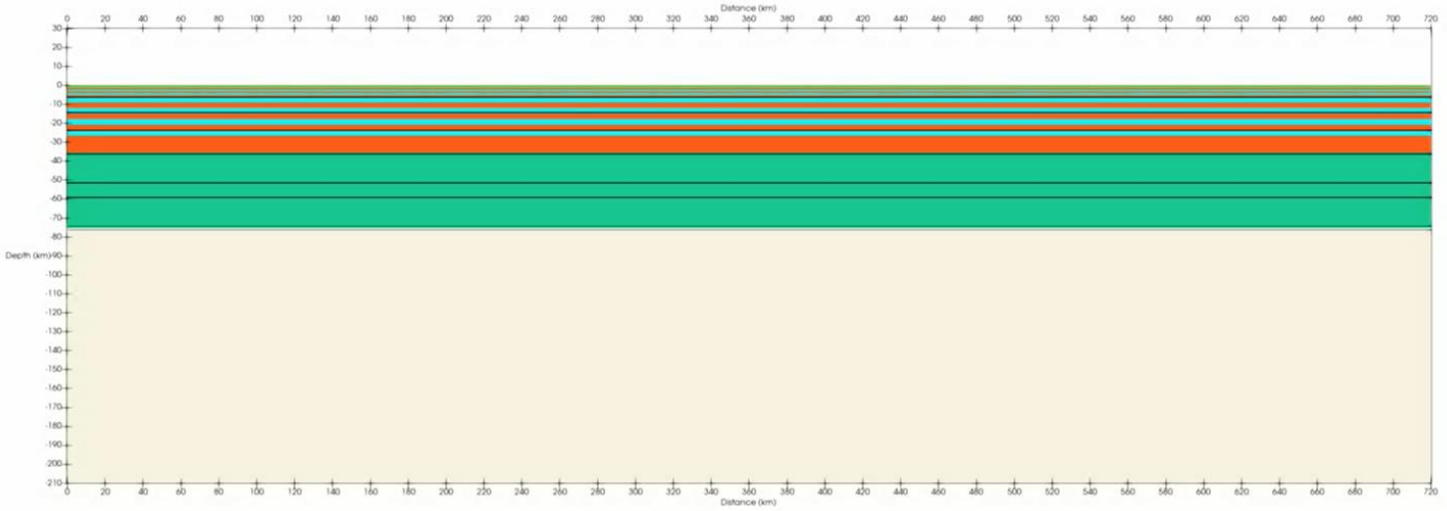
Narrow rift, inverted



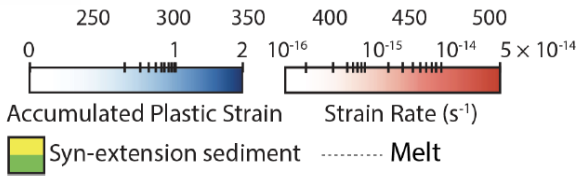
T_{moho} < 650°C
Strong strain partitioning between upper and lower crust during inversion

0.00 Ma

Wide rift, inverted

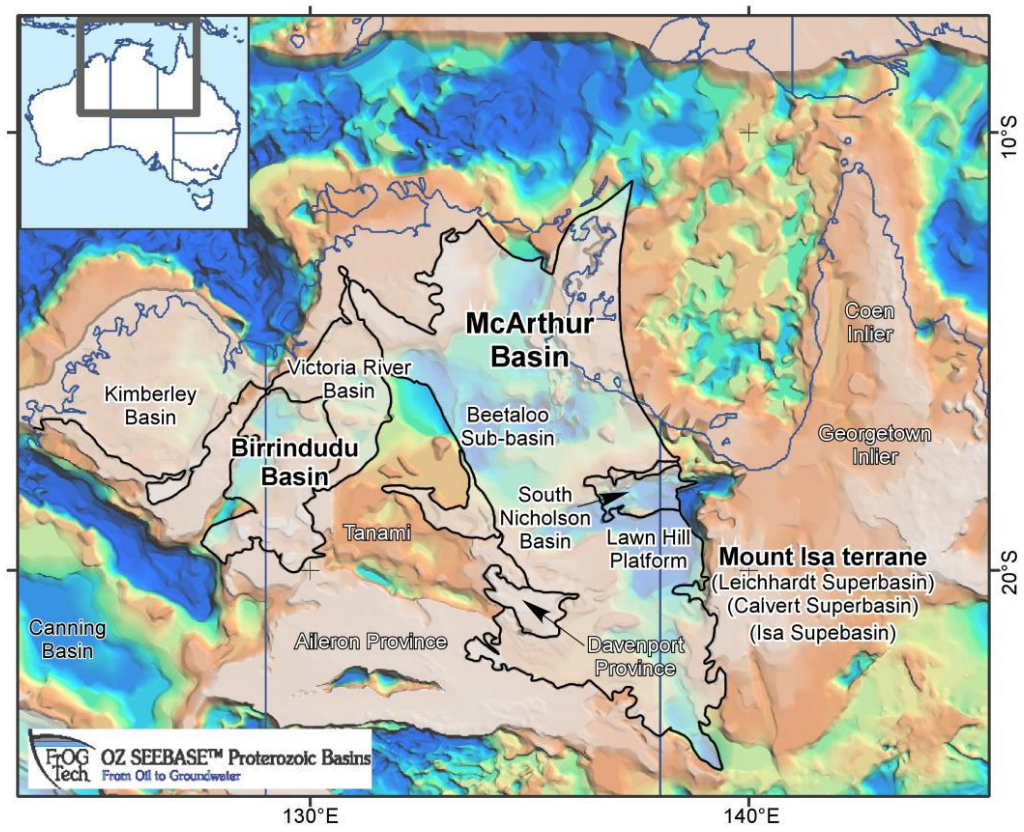


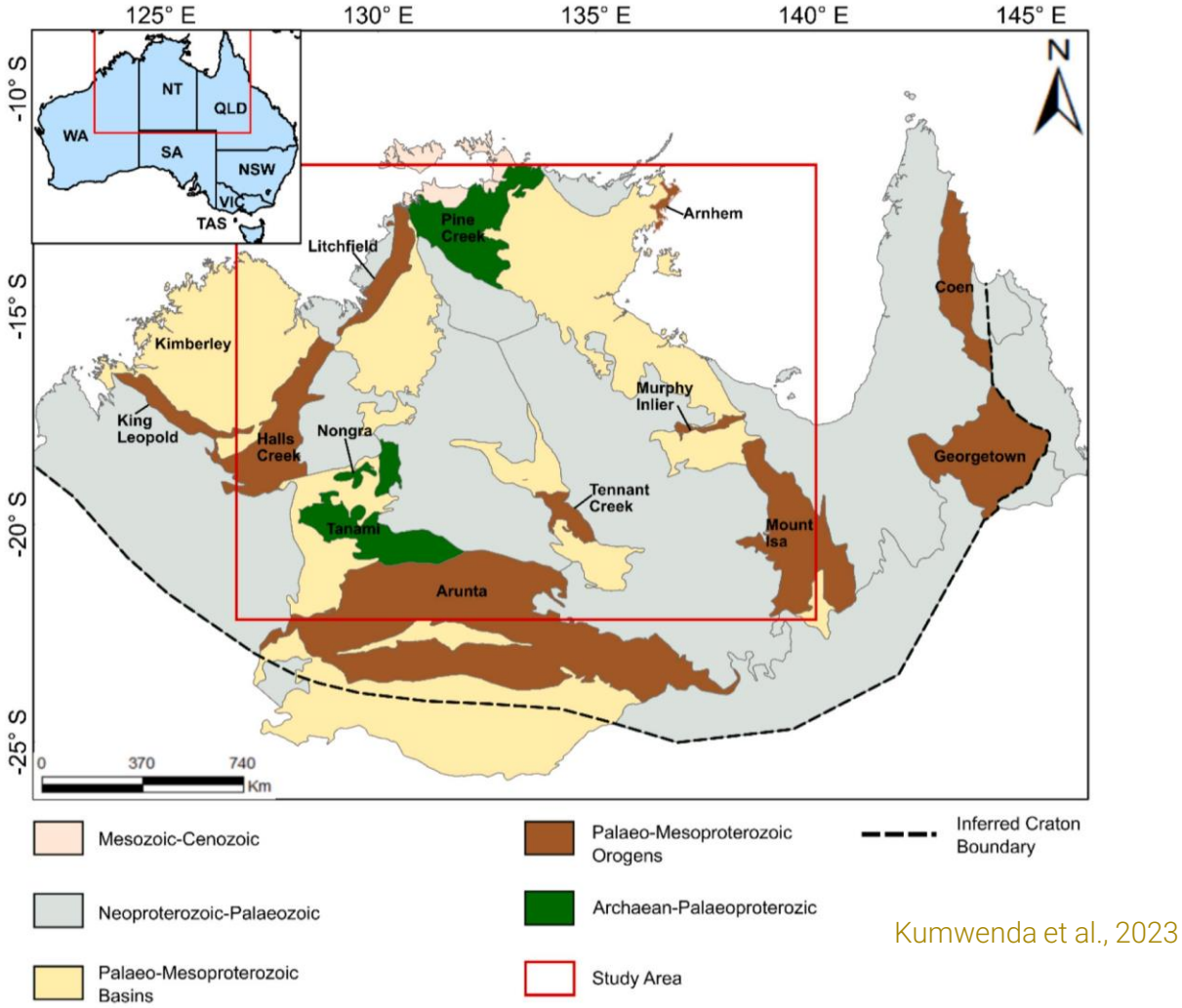
T_{moho} > 650°C
Little strain partitioning between upper and lower crust during inversion



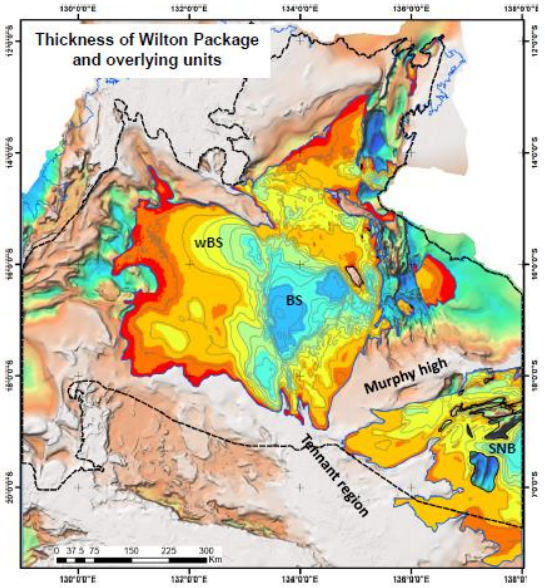
8 myr of extension followed by 8 myr of inversion

North Australian Craton



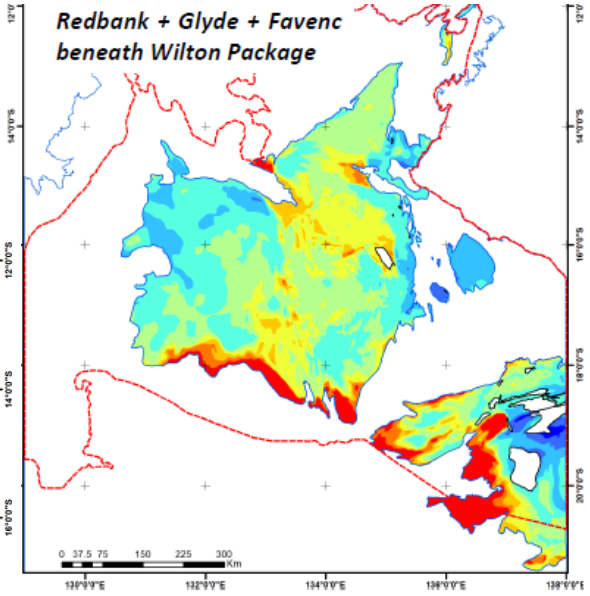


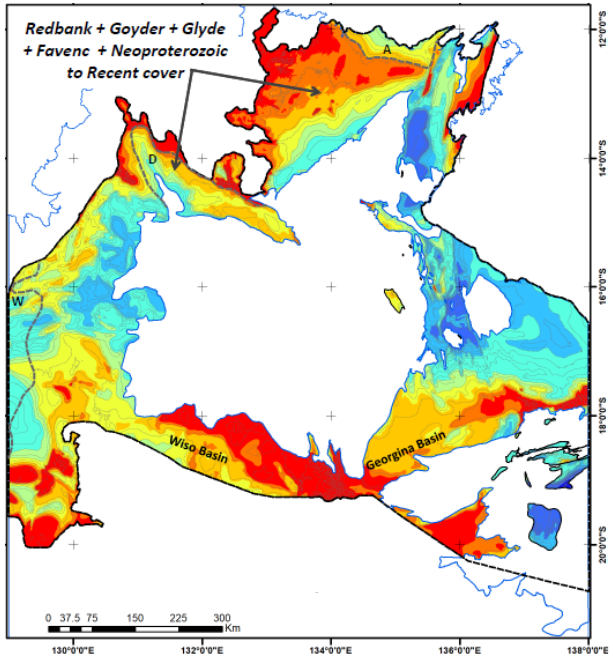
Kumwenda et al., 2023



Sediment
Thickness metres

- 28 - 279
- 280 - 648
- 649 - 1,189
- 1,190 - 1,981
- 1,982 - 3,142
- 3,143 - 4,844
- 4,845 - 7,338
- 7,339 - 10,993
- 10,994 - 16,351





The four stacked basin systems of the McArthur Basin have been separated into several sedimentary packages (Rawlings, 1999).

Each package is separated by a major unconformity, which can be associated with a major basin inversion event.

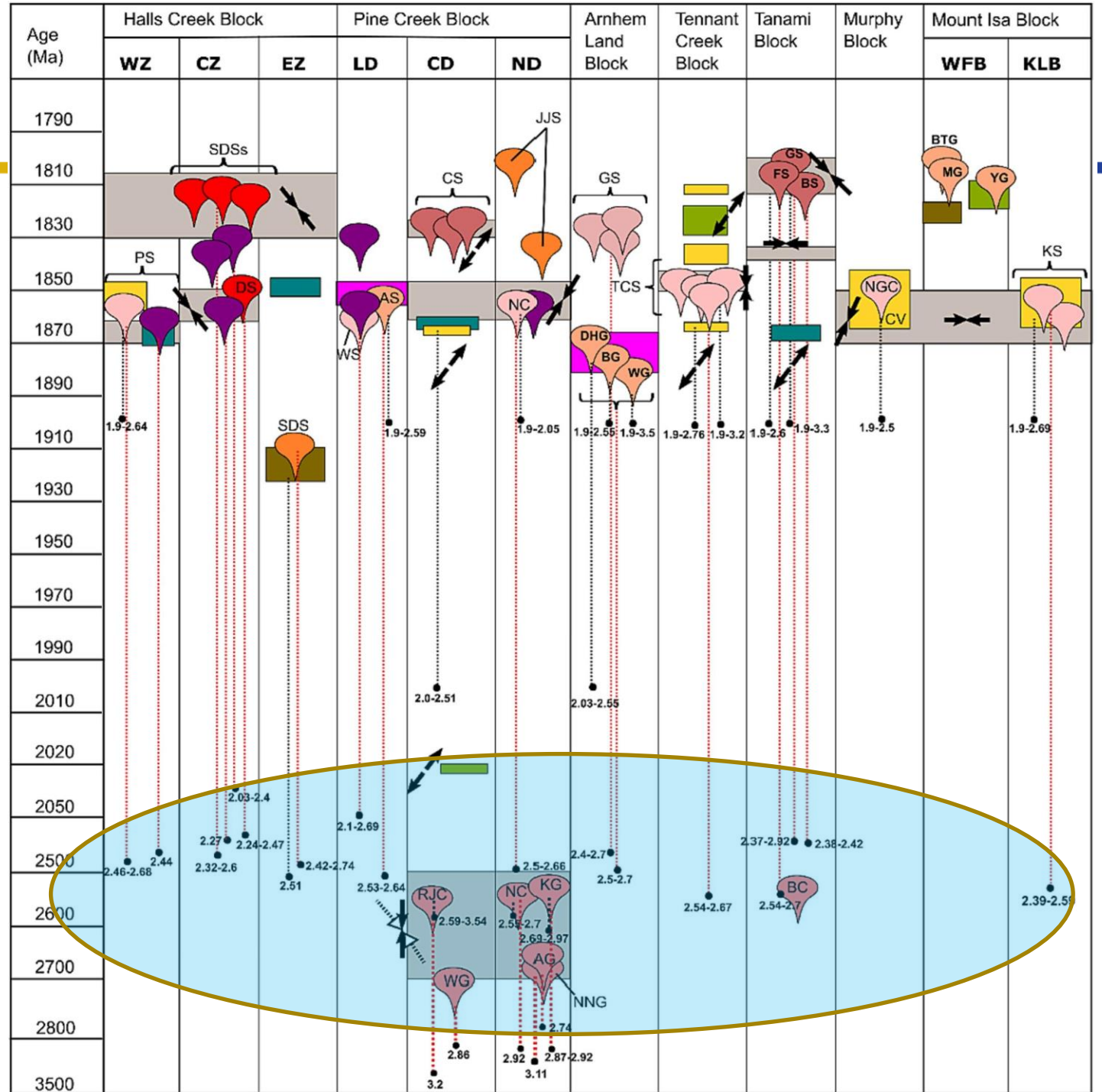
The sedimentary packages are:

- **Redbank Package:** includes the Katherine River Group, Tawallah Group (McArthur Basin), and Tomkinson Creek Group (Tennant Creek Block). *1815-1710 Ma*
- **Goyder Package:** includes the Parsons Range Group. *1710 - 1670 Ma*
- **Glyde Package:** includes the McArthur Group, Habgood Group, Balma Group (McArthur Basin), Limbunya Group (Birrindudu Basin), Namerinni Group (Tennant Creek Block). *1670-1600 Ma*
- **Favenc Package:** includes Nathan Group, Mount Rigg Group (McArthur Basin), Wattie Group, and Bullita Group (Birrindudu Basin). *1600-1570 Ma*
- **Wilton Package:** includes Roper Group (McArthur Basin) and Renner Group (Tennant Creek Block). *1500- 1400 Ma*

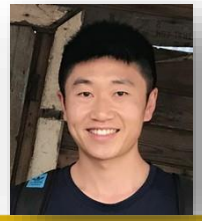
Pre- McArthur Basin events in NAC

- Mafic-Ultramafic intrusions
- Fayalite -biotite-bearing granite
- Biotite-bearing granite and leucogranite
- Fractionated biotite-(hornblende)-bearing granite, granodiorite, monzogranite and leucogranite
- Biotite-hornblende-bearing tonalite, quartz diorite, trondhjemite and minor gabbro
- Peraluminous leucogranite
- Unfractionated biotite-hornblende-bearing high-K, granodiorite, monzogranite, syenogranite and minor tonalite
- Fractionated biotite-hornblende-bearing, high-K granodiorite, monzogranite, and syenogranite

- Extension direction
- Shortening direction
- Tectonic/ Orogenic events
- Metamorphic events
- Nd Model ages
- U-Pb Inherited zircon ages
- Felsic volcanism
- Mafic volcanism
- Dolerite & Gabbro
- Bimodal Volcanism



Kumwenda et al., 2023



Link mantle properties from geophysics

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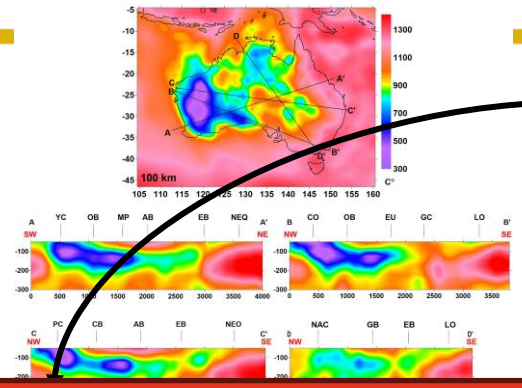
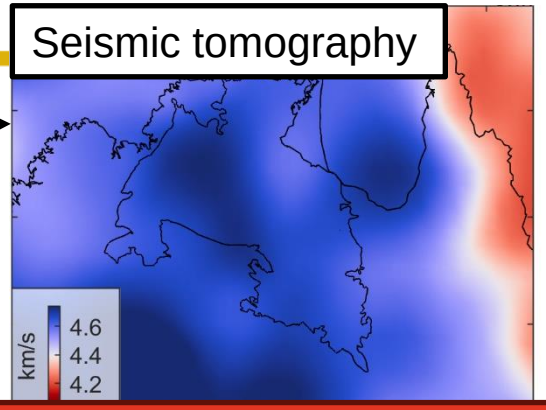
Temperature/ Composition

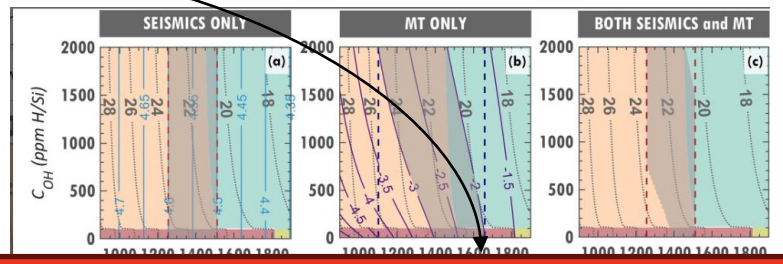


Tesauro et al., 2020

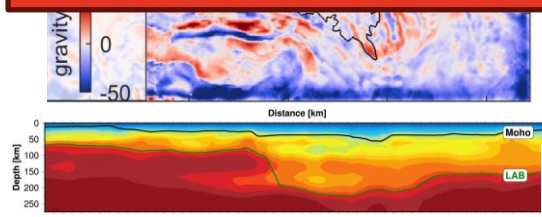
Seismic tomography



Temperature/Water content

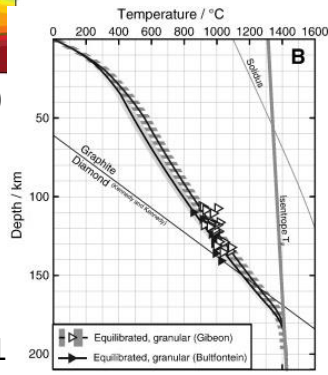


Do pre-existing structures shape the development of the McArthur basin?



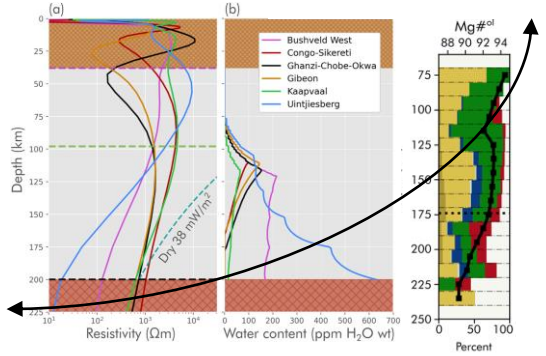
Pappa et al., 2020

Hoggard et al., 2020



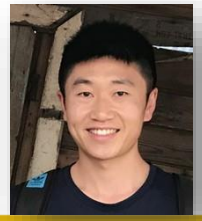
Mather et al., 2011

Xenolith



Özaydın et al., 2022

Temperature/ Composition/ Water content



Link mantle properties from geophysics

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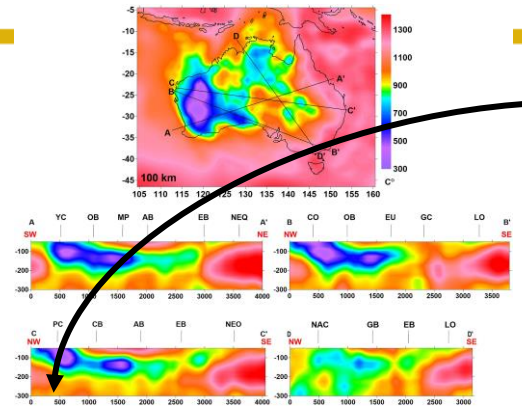
Temperature/ Composition



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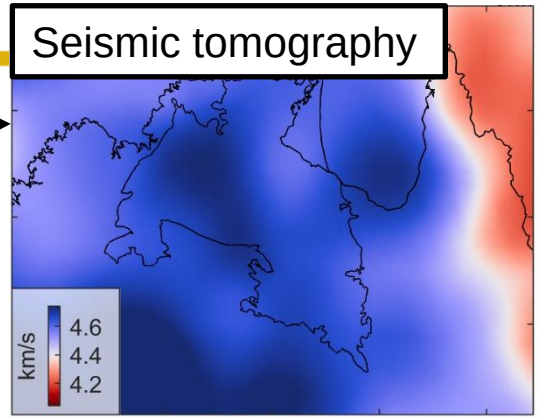
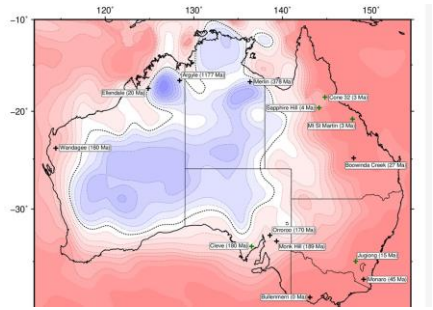
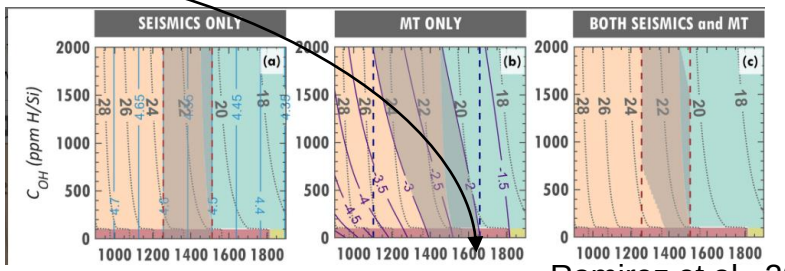




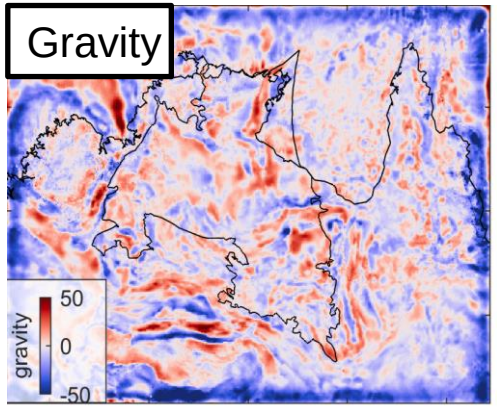
Hoggard et al., 2020

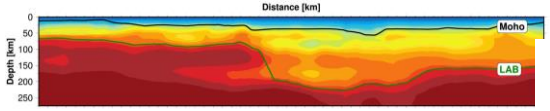
Temperature/Water content



Ramirez et al., 2022

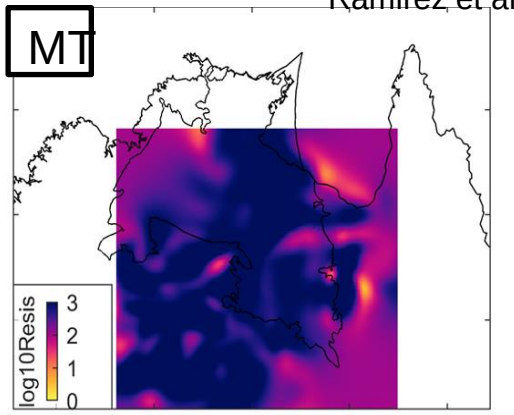
Gravity

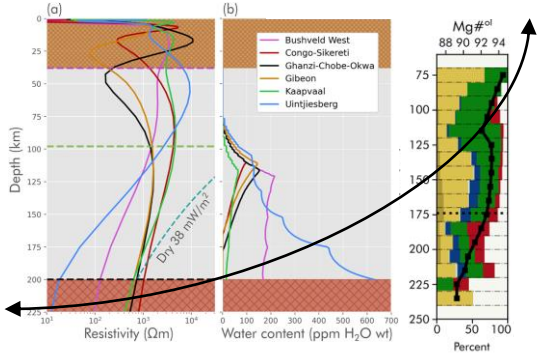




Pappa et al., 2020

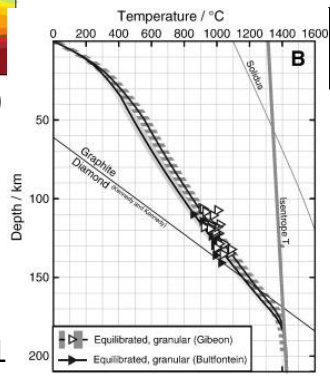
MT





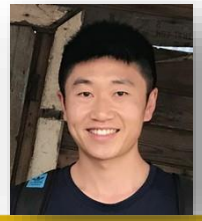
Özaydın et al., 2022

Xenolith



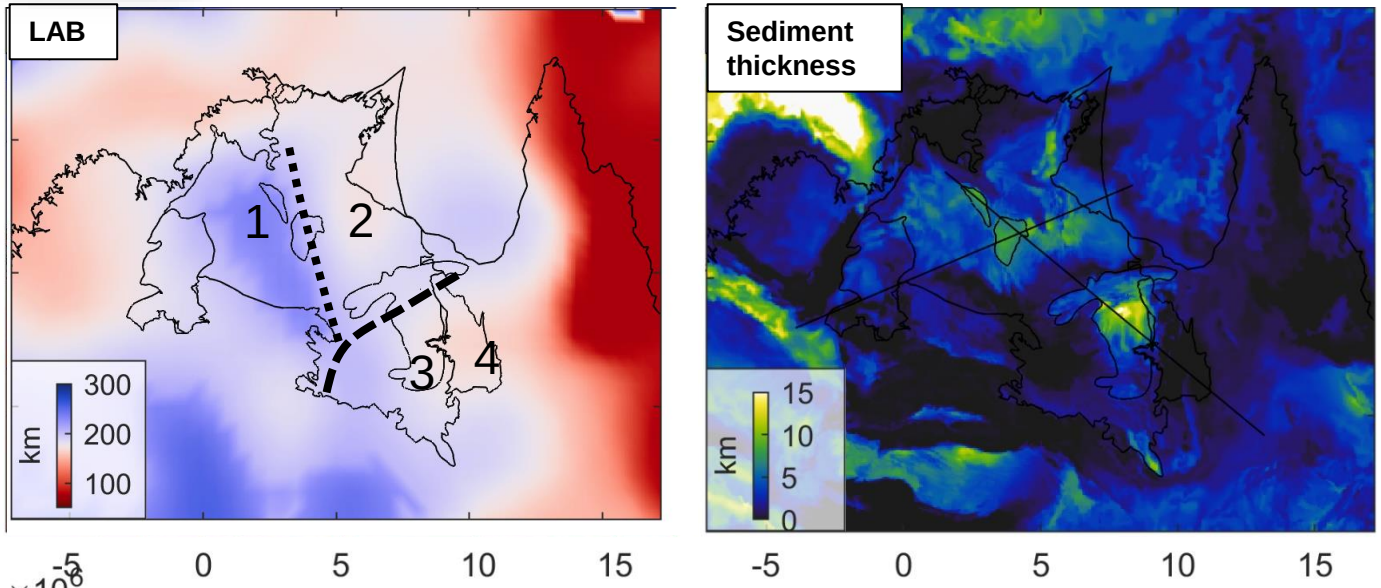
Mather et al., 2011

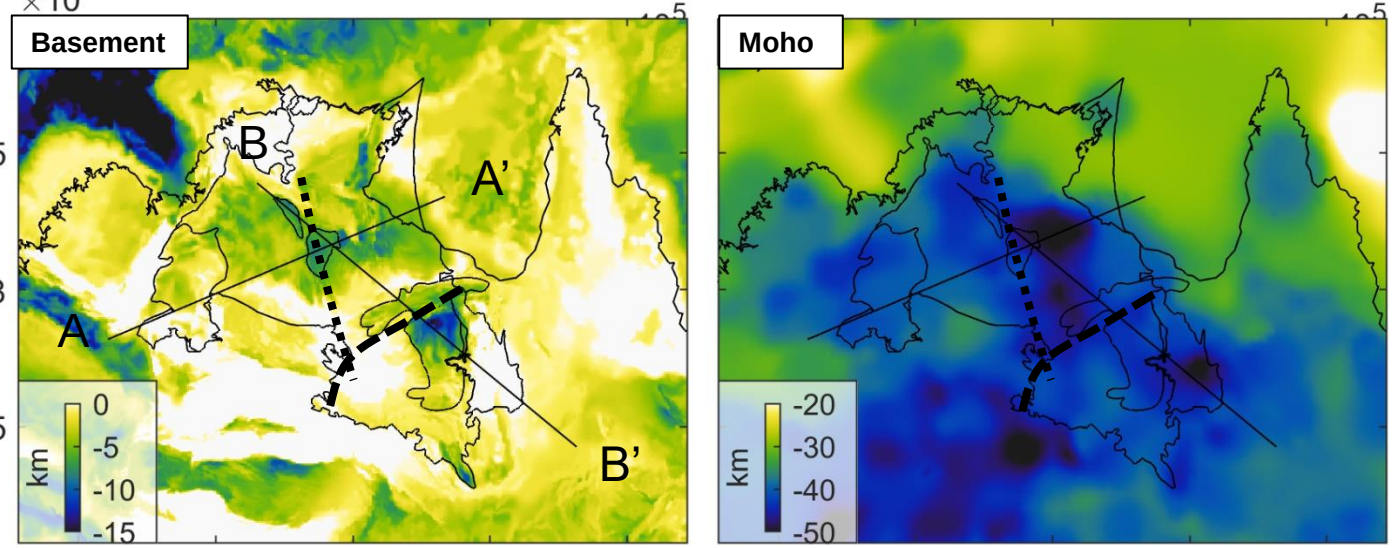
Temperature/ Composition/ Water content

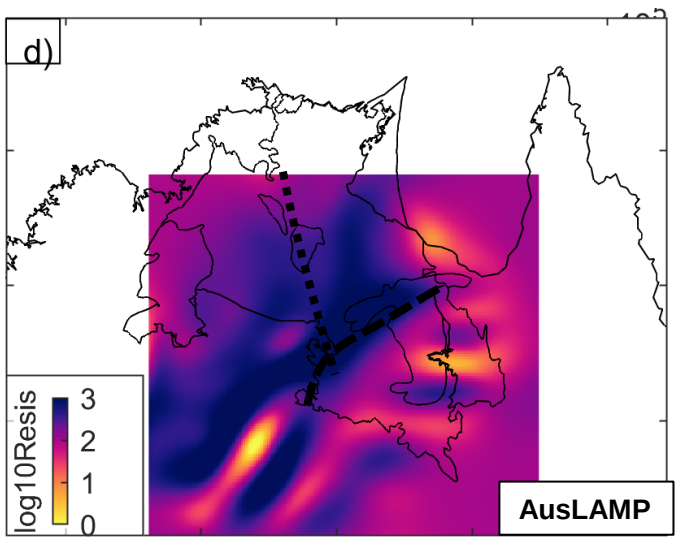


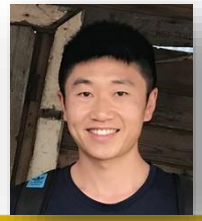
Geophysical modeling

Domain	1	2	3	4
Basin name	**Birrindudu, WBS**	McArthur (EBS?)	South Nicolson	Mount Isa
Sediment thickness	Thin(<5 km)	Thick(>5km)	Thick (>5km up to 13 km)	Very thin(<1km)
Moho	Shallow (40 -42 km)	Deep (45 - 50 km)	Shallow (40 - 44 km)	Deep (45 - 50 km)
LAB	Deep (>220km)	Shallow (170 km)	Shallow (170 km)	Shallow (160 km)
Mantle Temperature	Low	High	High	High
Resistivity	Medium (No data)	Low	High	High
Surface Heat flow	High at edge of basin High WBS (86 mW/m^2)	High McArthur Low EBS (60 mW/m^2)	Low (56 mW/m^2)	High (75 – 95 mW/m^2)









Geophysical-Geochemical modeling

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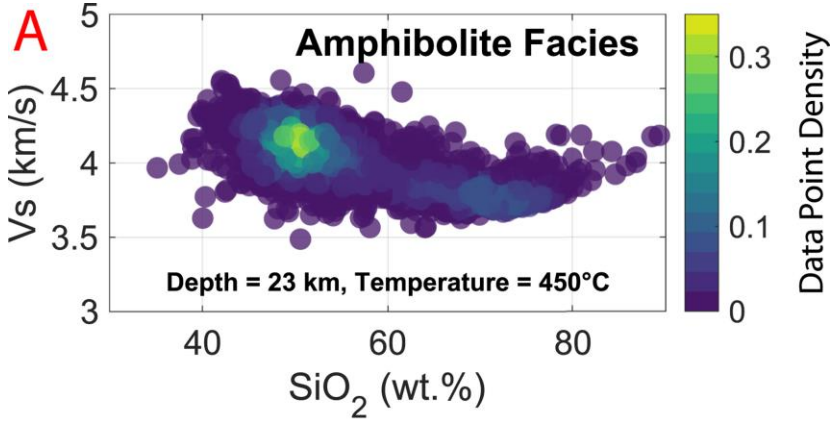
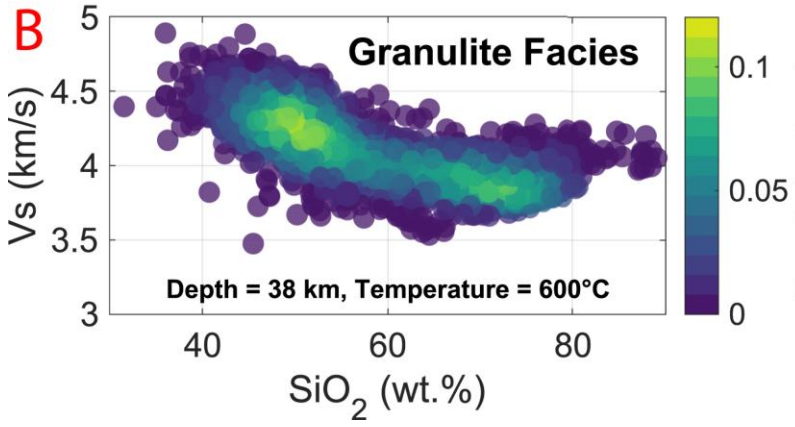
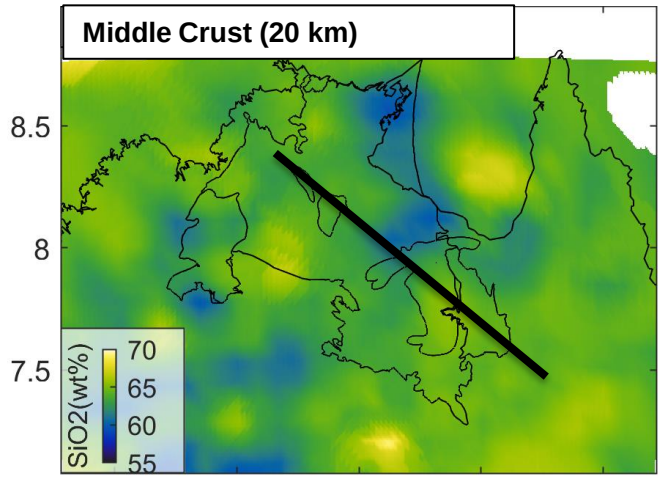
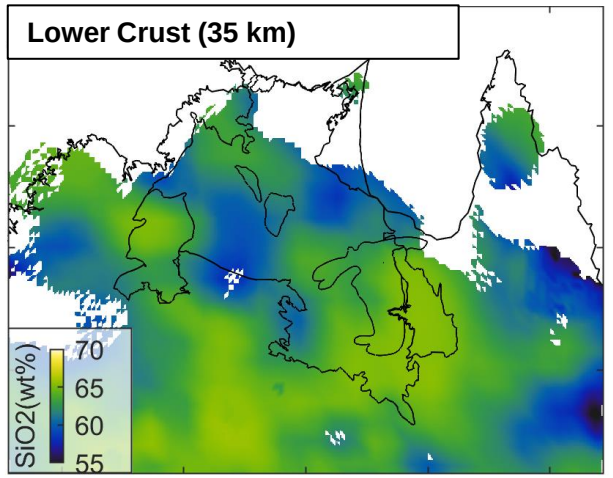
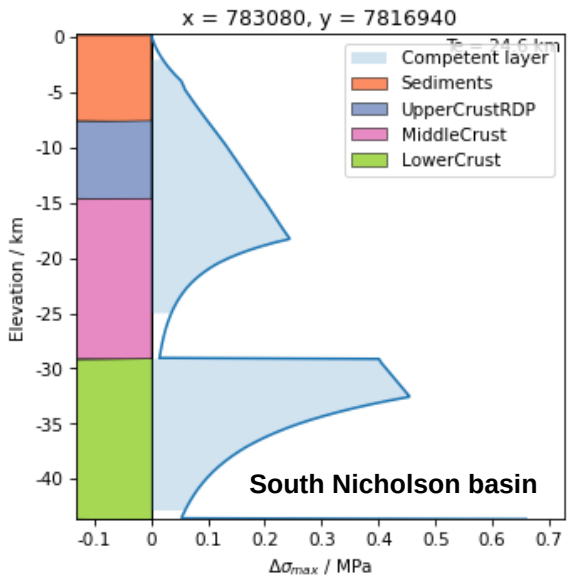


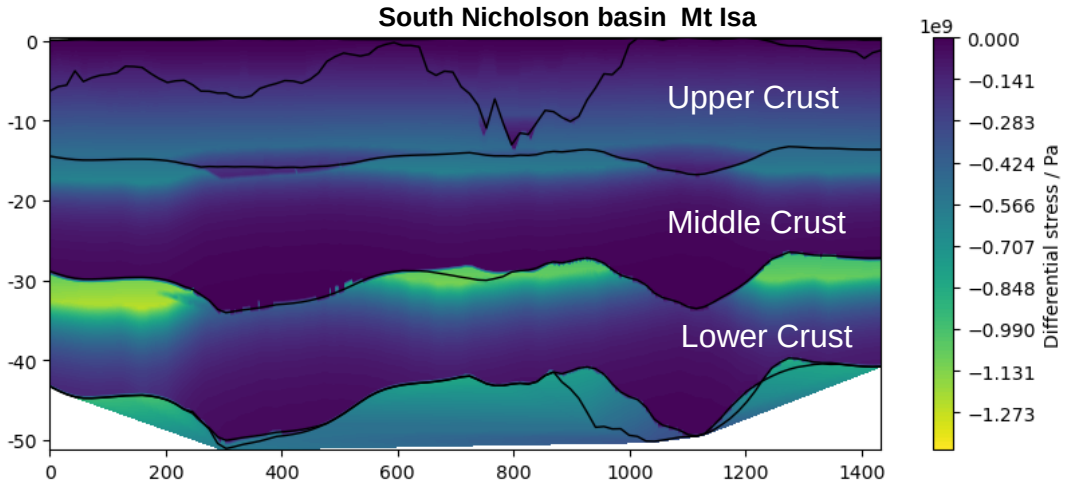


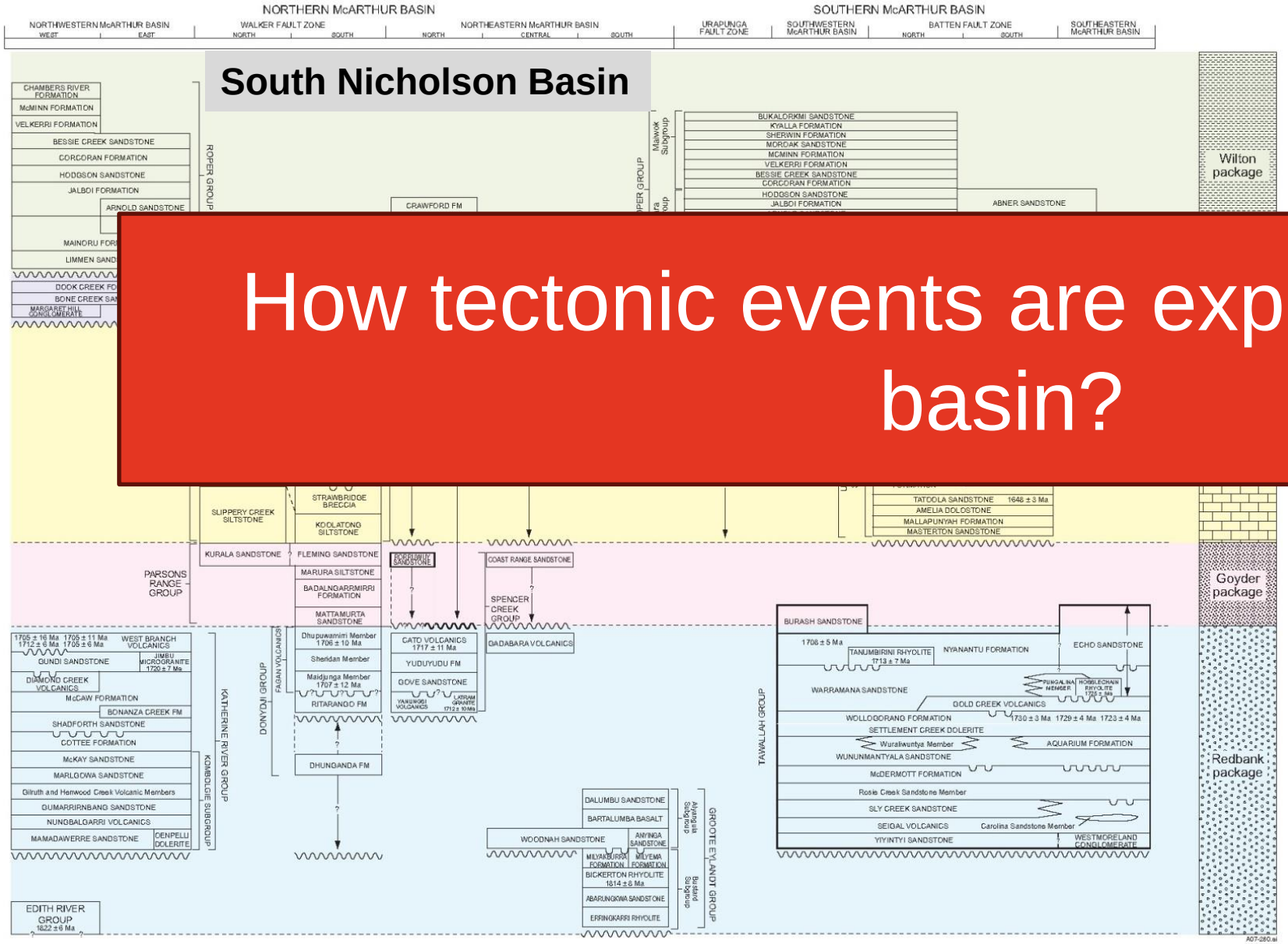
Sammon et al., 2021











Wilton Package: *?1500-? 1400 Ma*

Glyde Package: *?1670-1600 Ma*

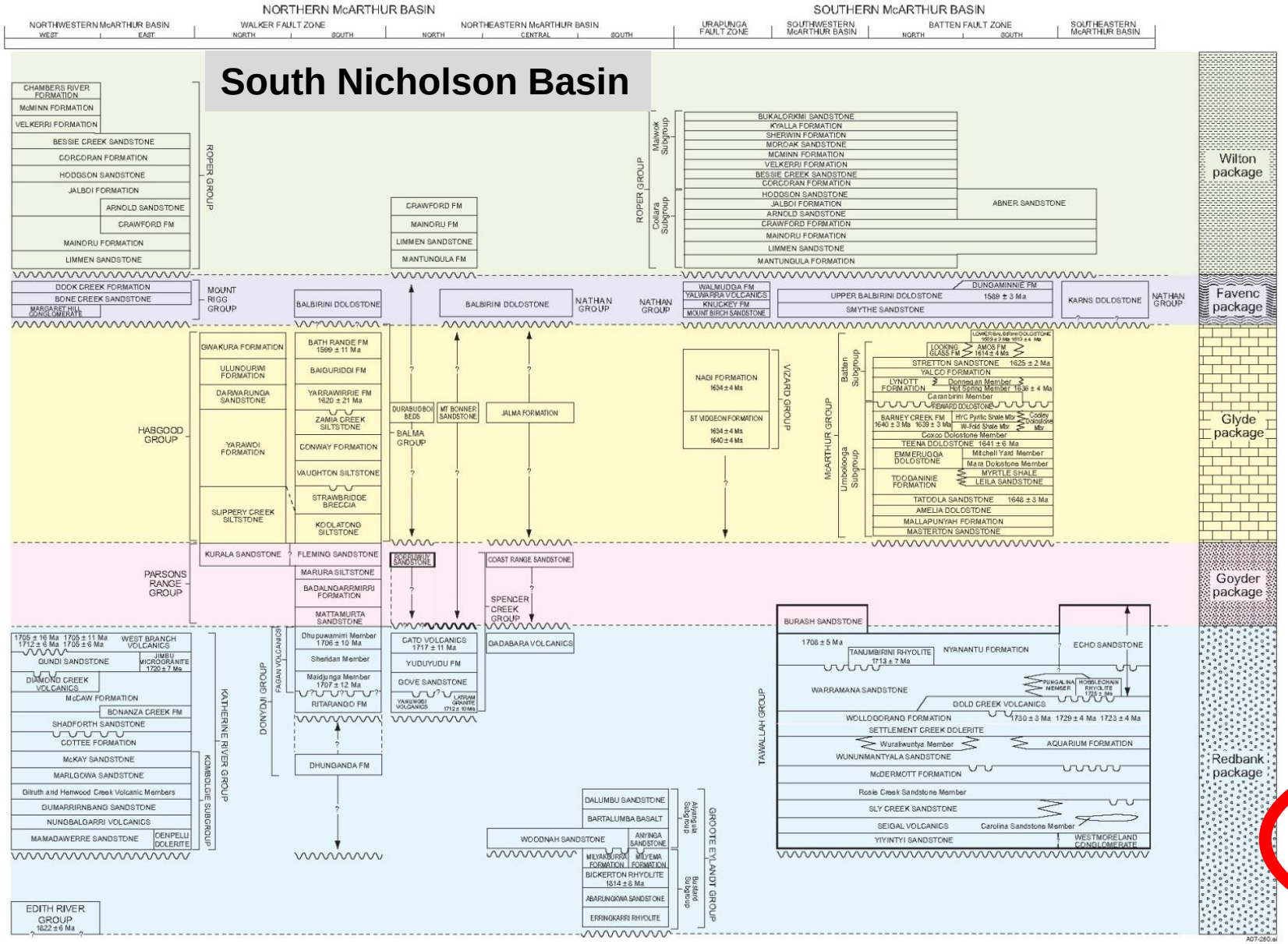
Calvert Superbasin

Goyder Package: *-1710-?1670 Ma*

Leichhardt Superbasin

Redbank Package: *-1815-1710 Ma*

Basins of the North Australian Craton



Wilton Package:*?1500-? 1400 Ma*

Favenc Package:*-1600-?1570 Ma*

Isa Superbasin

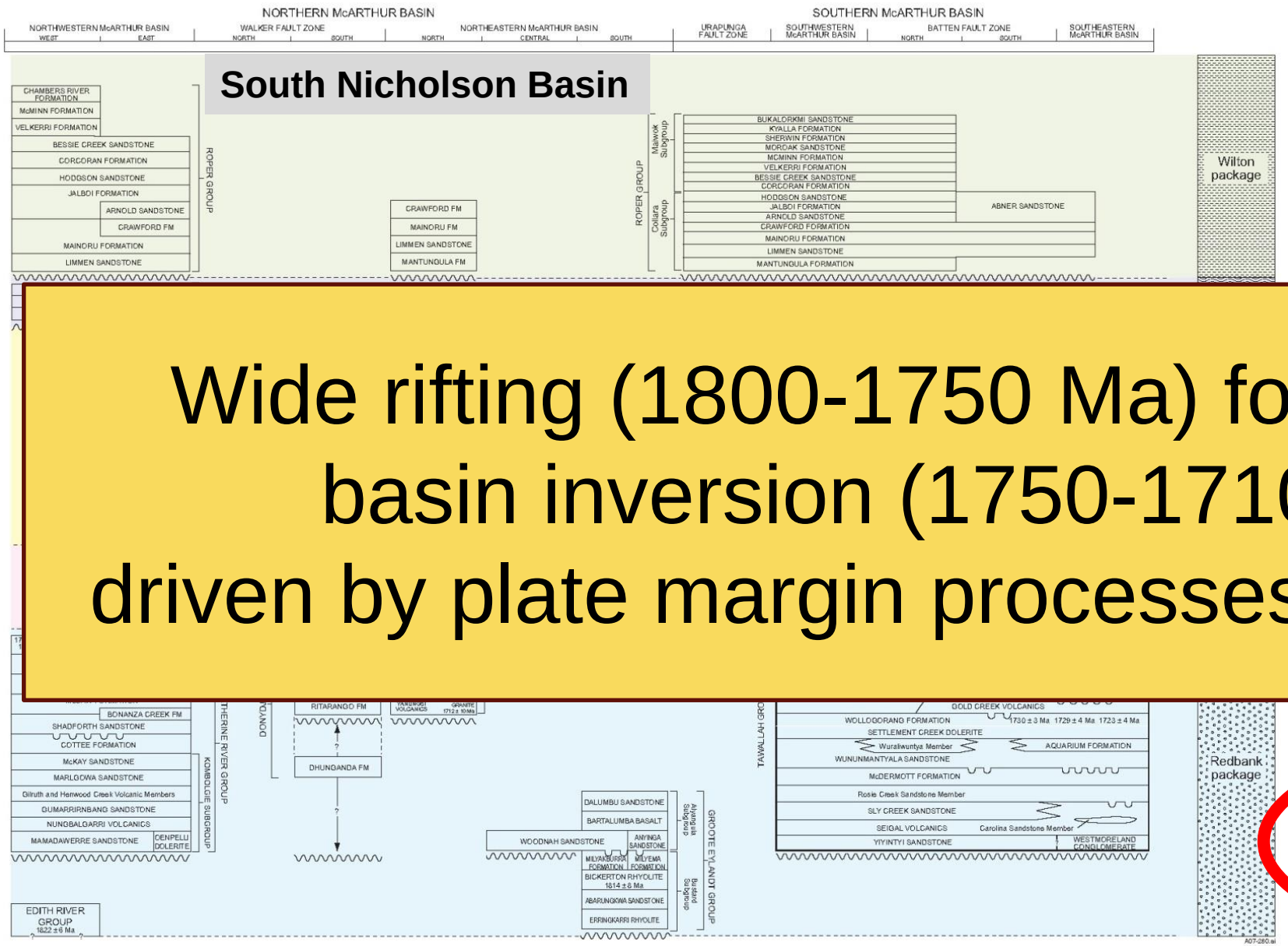
Glyde Package: *?1670-1600 Ma*

Calvert Superbasin

Goyder Package: *-1710-?1670 Ma*

Leichhardt Superbasin

Redbank Package: *-1815-1710 Ma*



Wide rifting (1800-1750 Ma) followed by basin inversion (1750-1710 Ma) driven by plate margin processes to the east

Wilton Package: *?1500-? 1400 Ma*

Ma

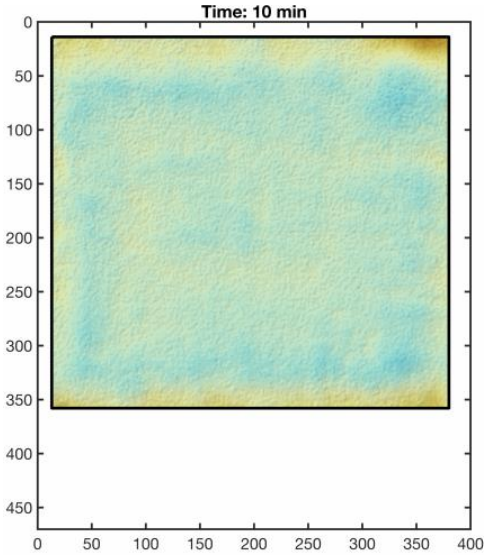
Ma

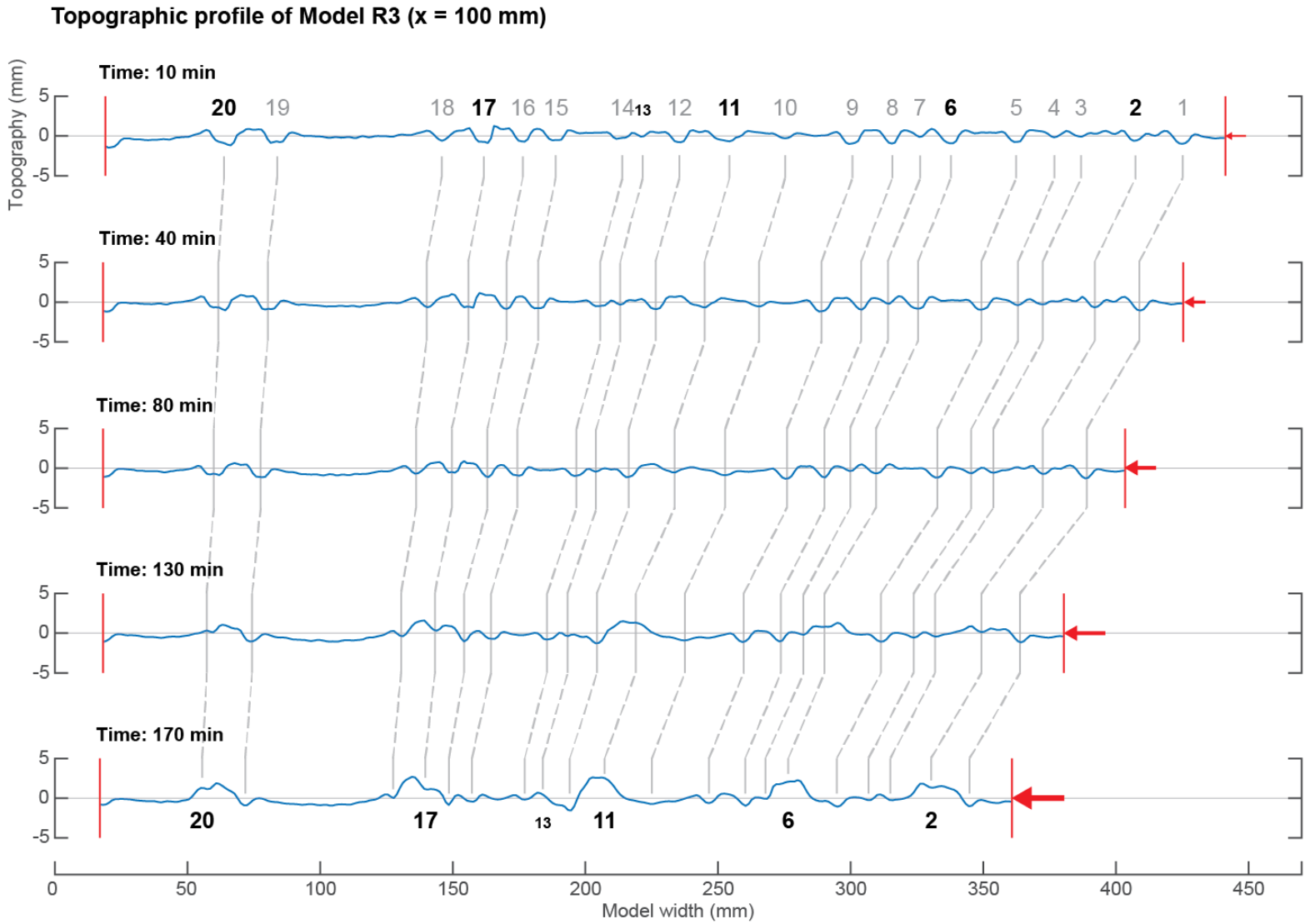
70 Ma

Leichhardt Superbasin

Redbank Package: *-1815-1710 Ma*

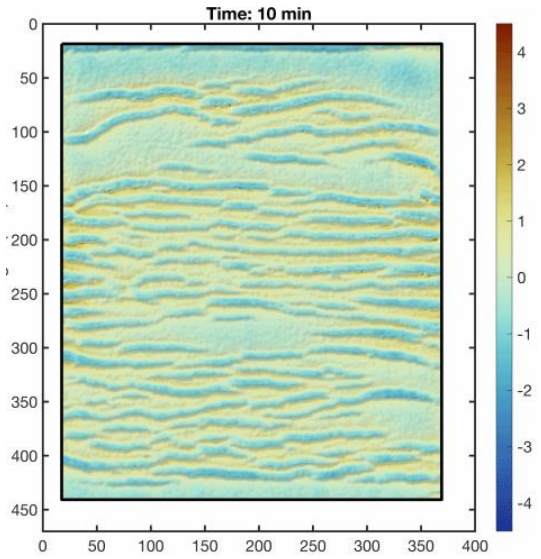
Analogue modeling

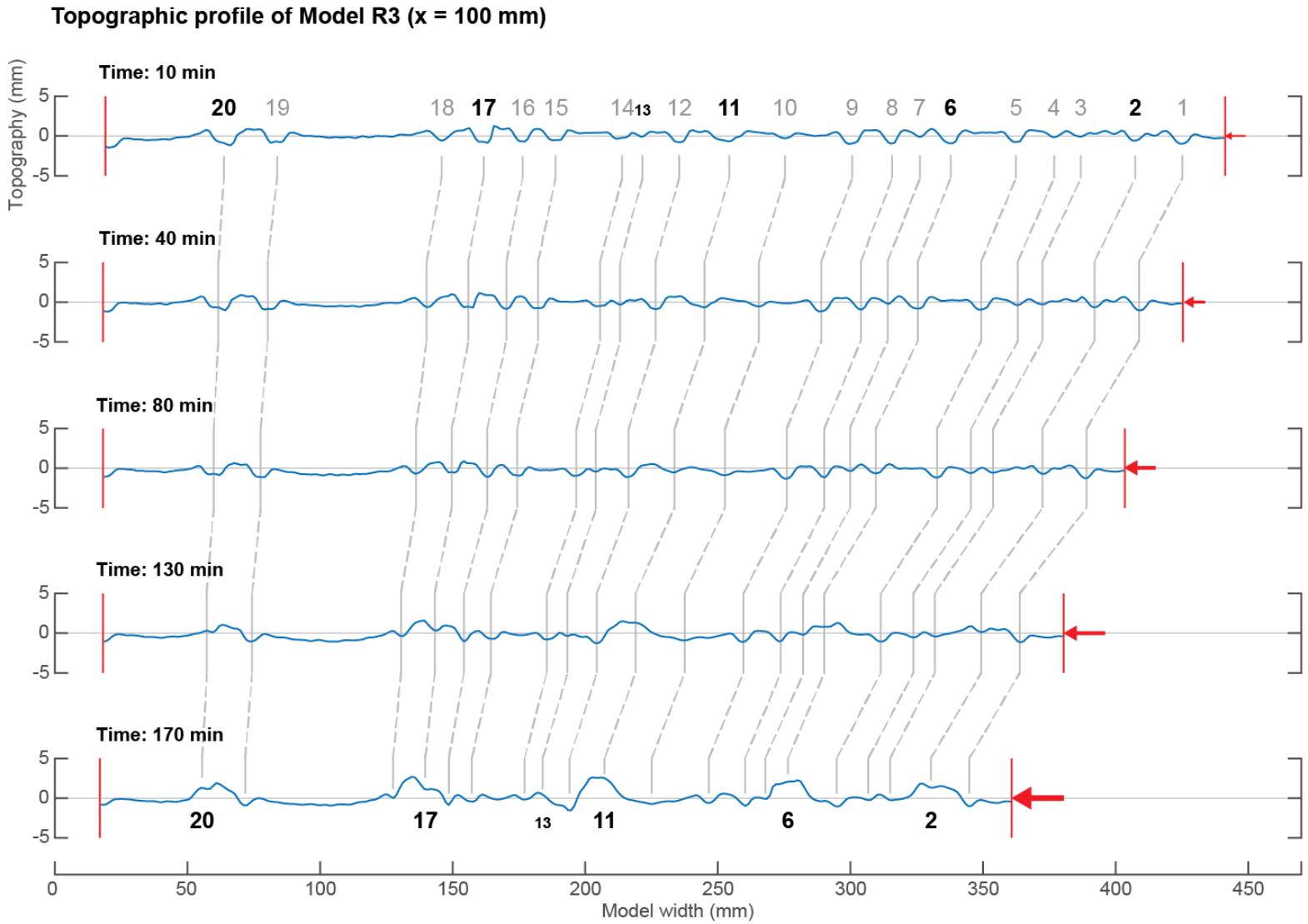




Decreasing displacement & velocity gradient

Analogue modeling

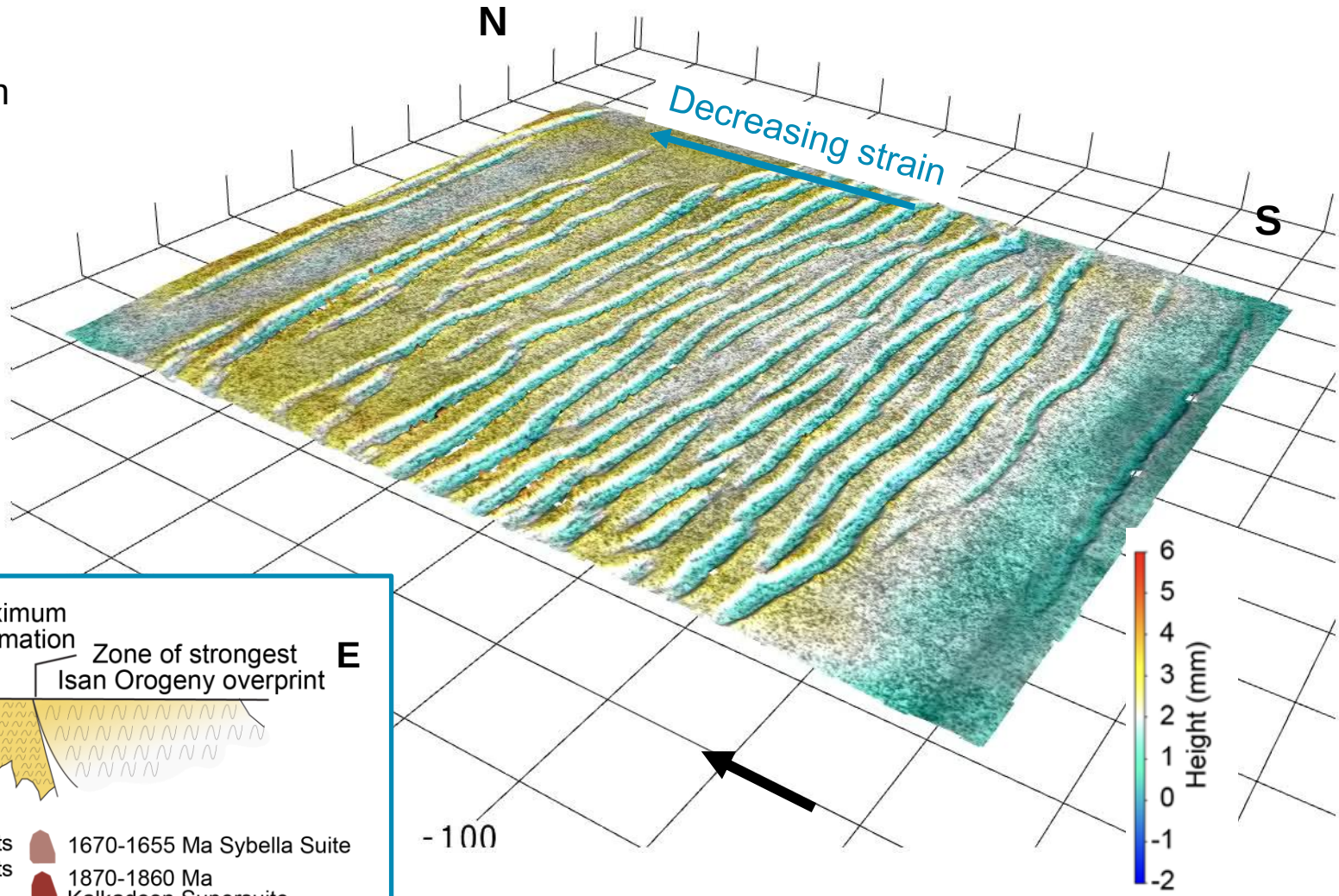




Decreasing displacement & velocity gradient

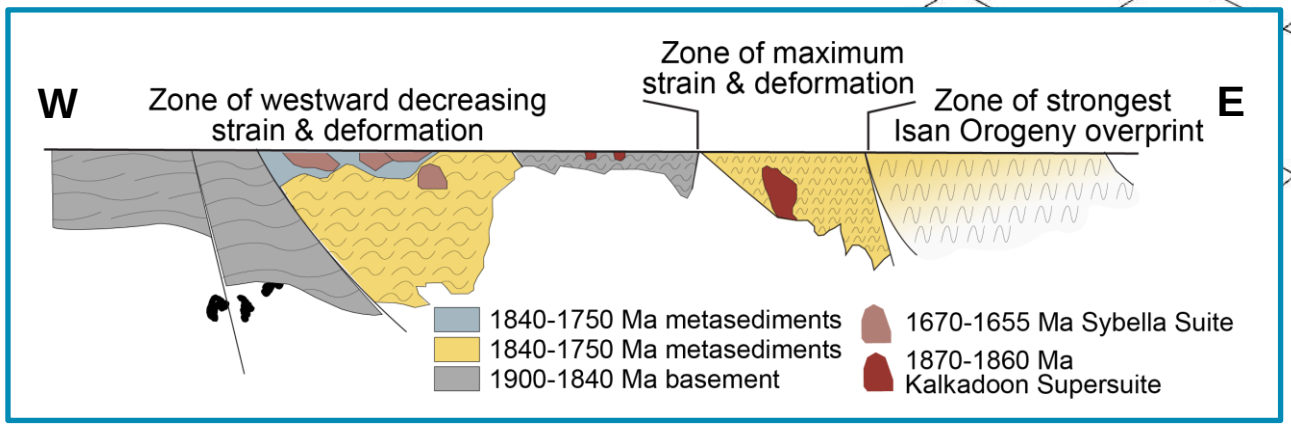
Observations from analogue models

- Closer spacing between basins in the south
- Higher strain in the south



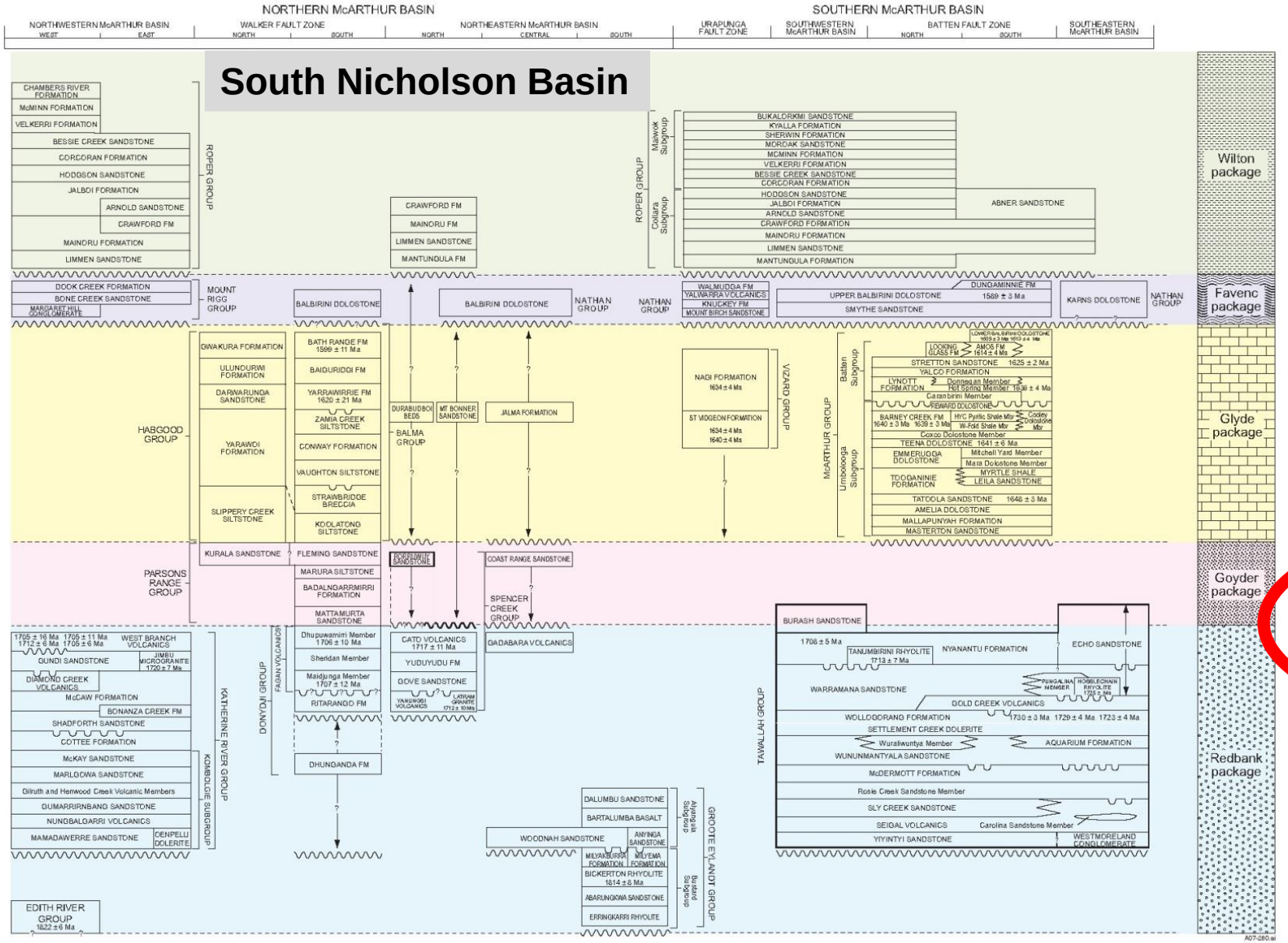
Cross section through Mt Isa Terrane

Extension & shortening driven by plate boundary processes to the east



← Decreasing strain

Basins of the North Australian Craton



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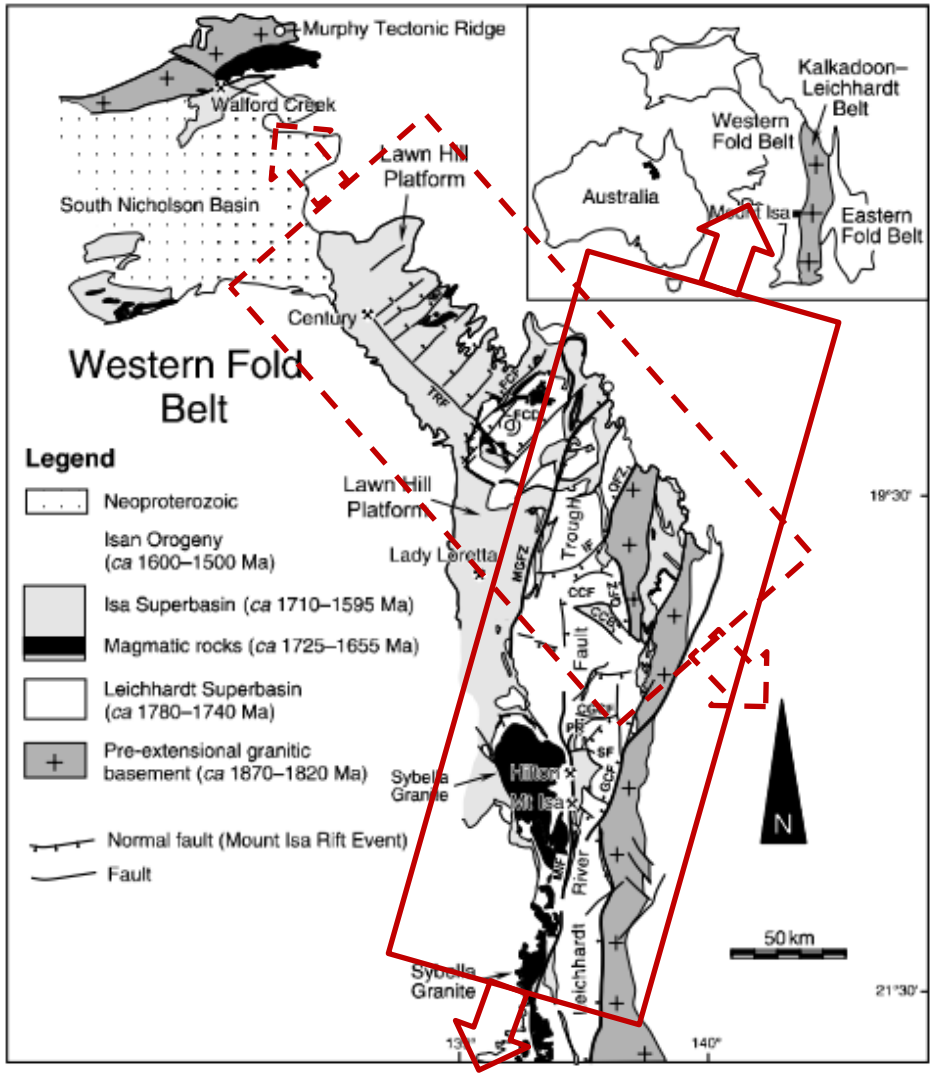
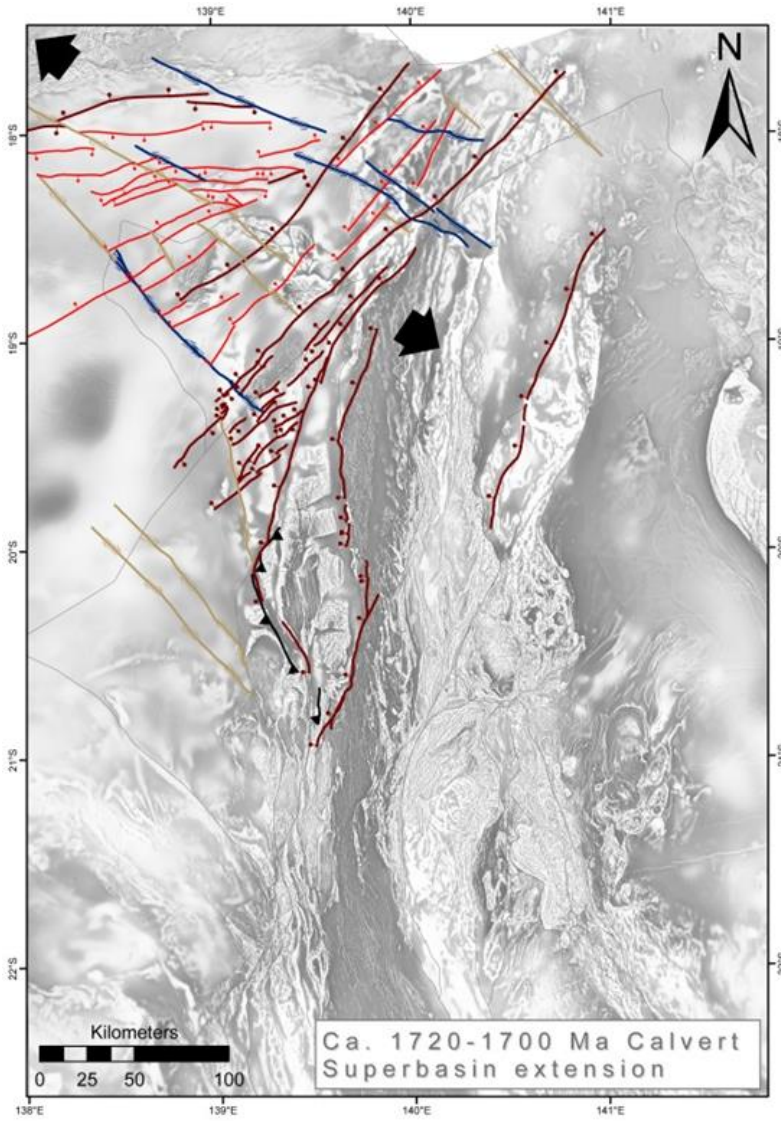
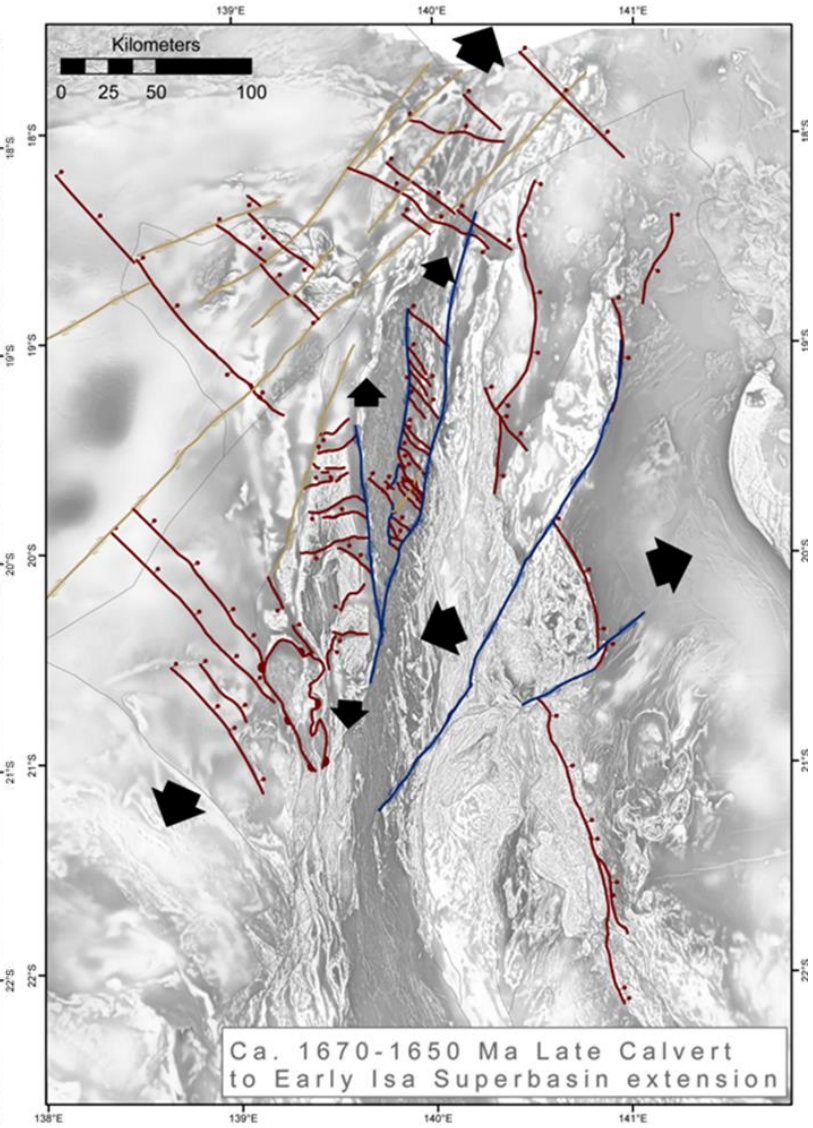
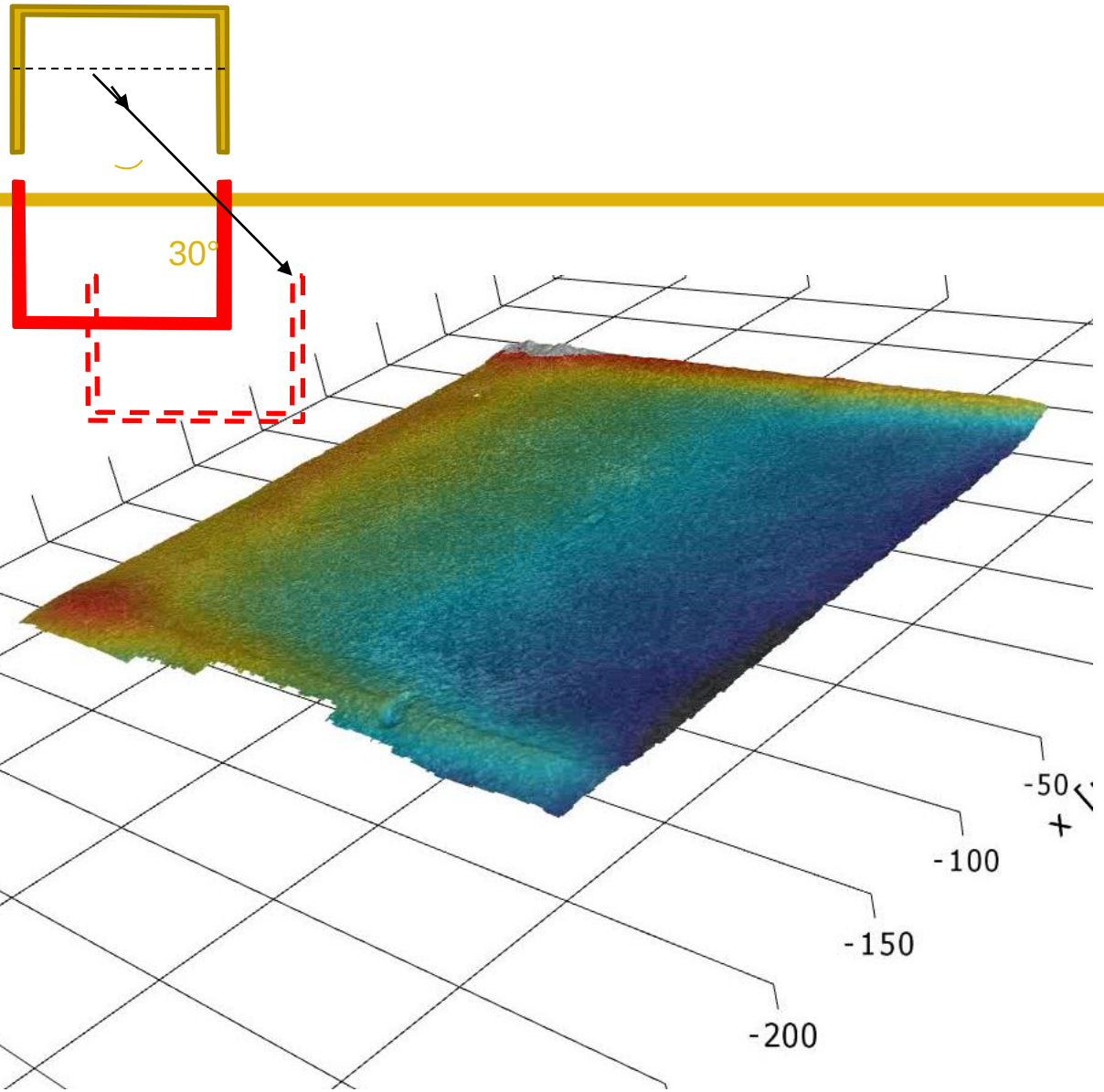
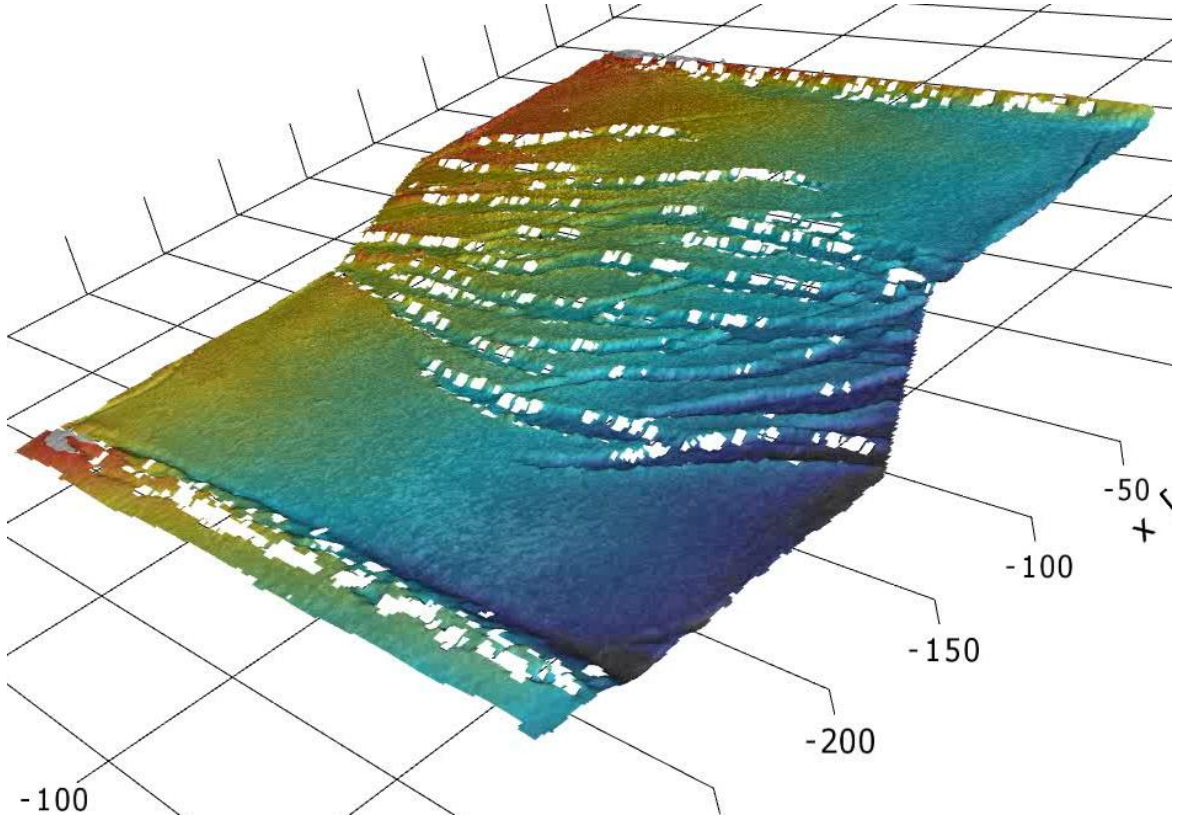








Phase: Extension



Phase: Inversion

Model Height (Topography)

Obliquity: 30°

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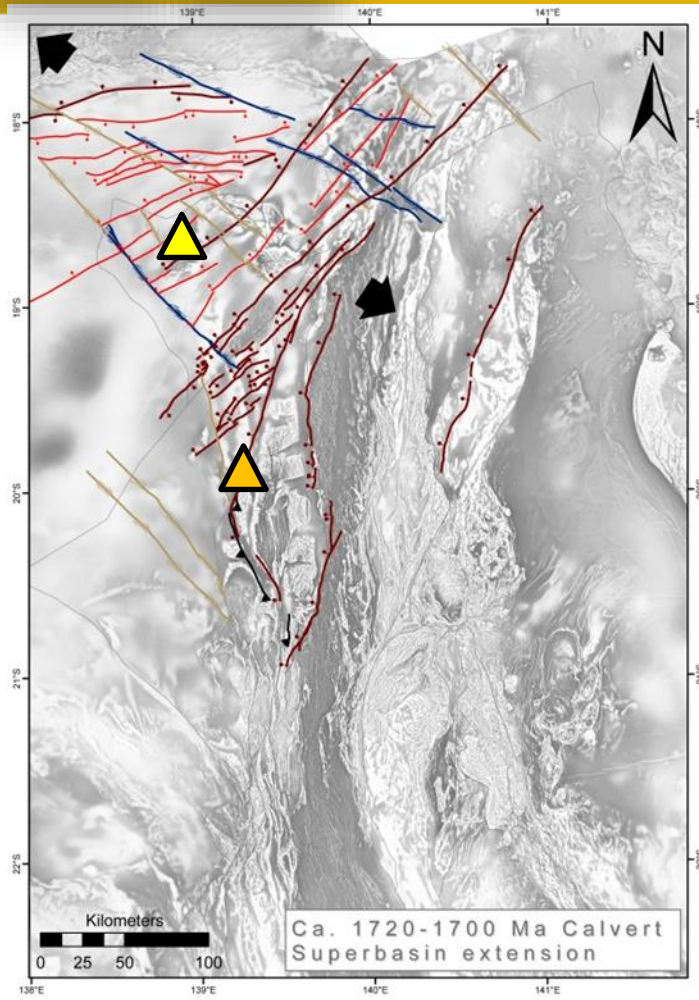
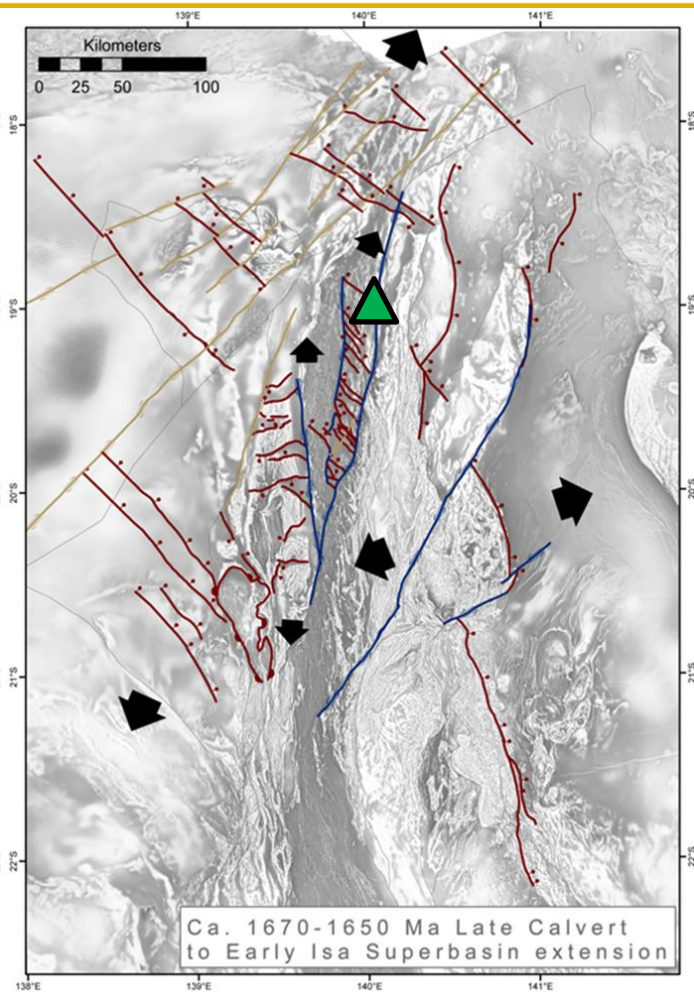
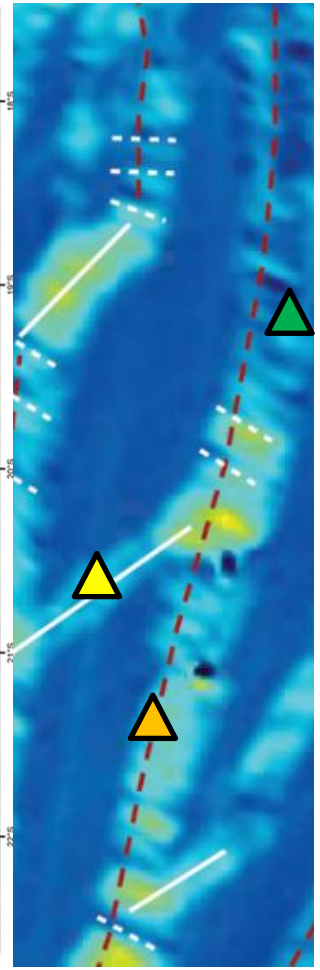
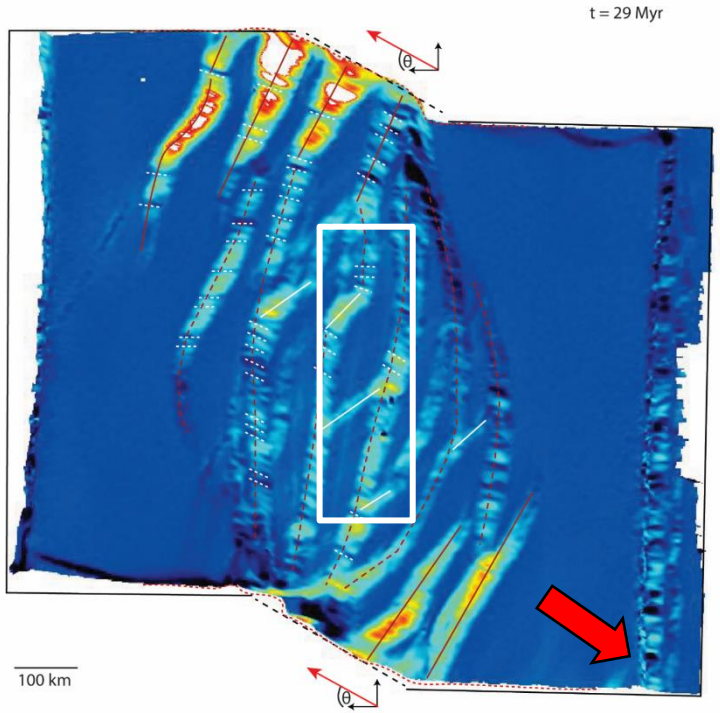








No requirement for two separate orthogonal events

Basin architecture at Calvert and Early Isa times could be explained an oblique dextral extensional kinematic regime

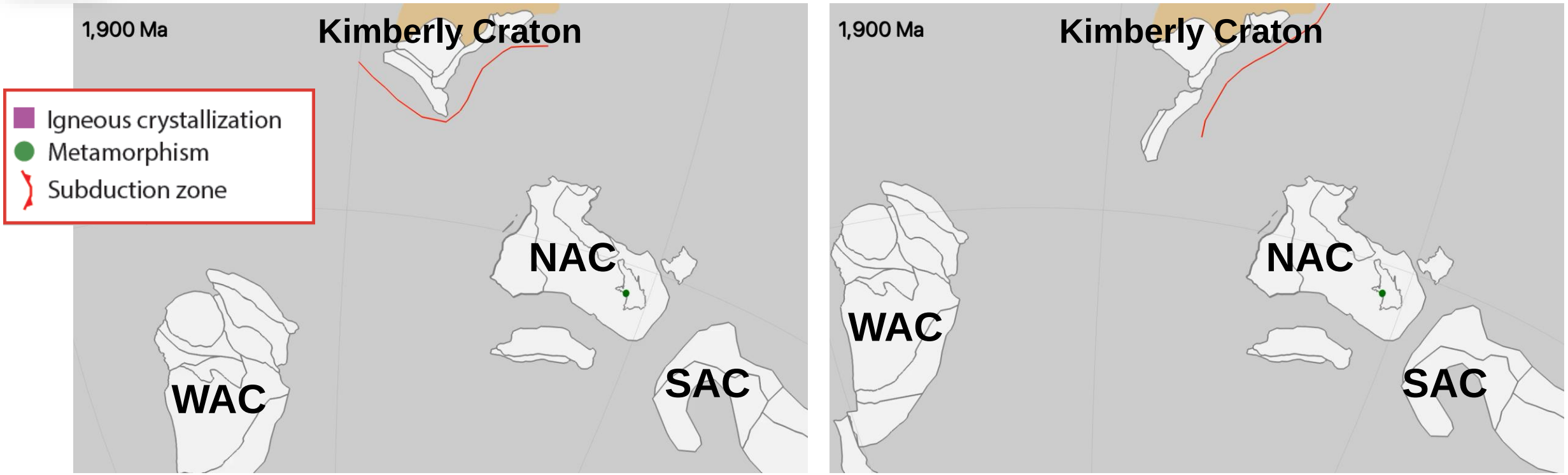
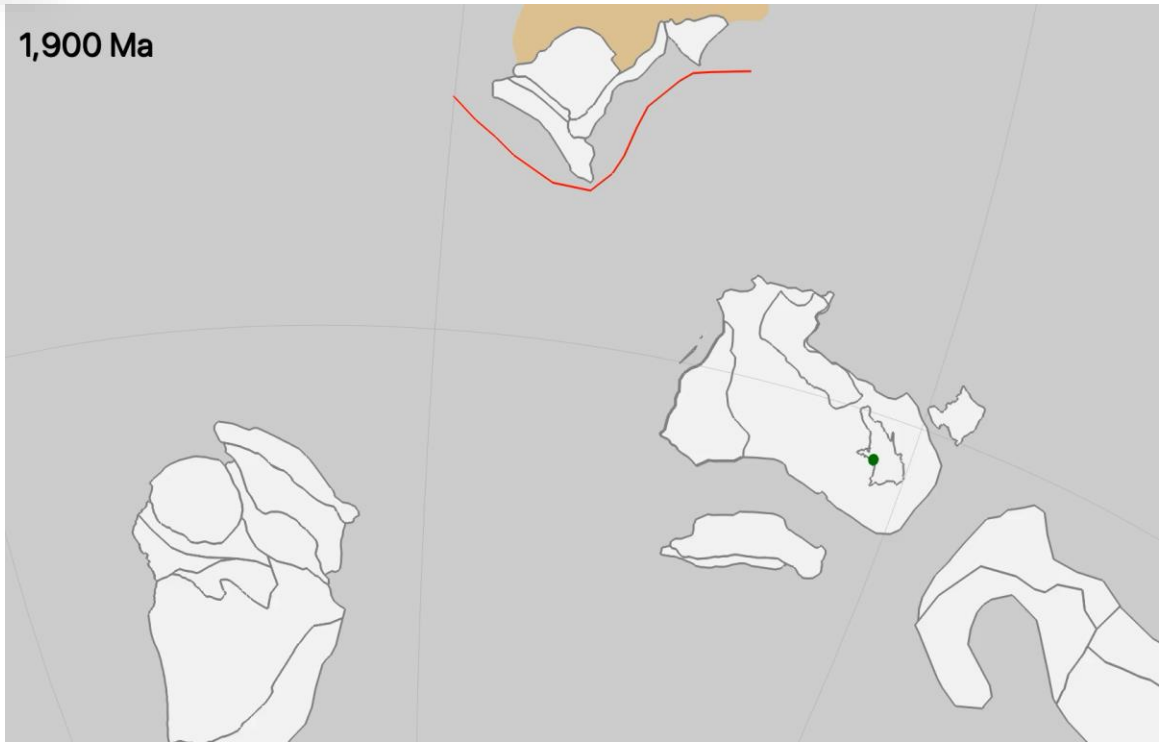


Plate tectonic reconstruction of Australian craton assembly gives an insight to potential far-field forces require for basin formation



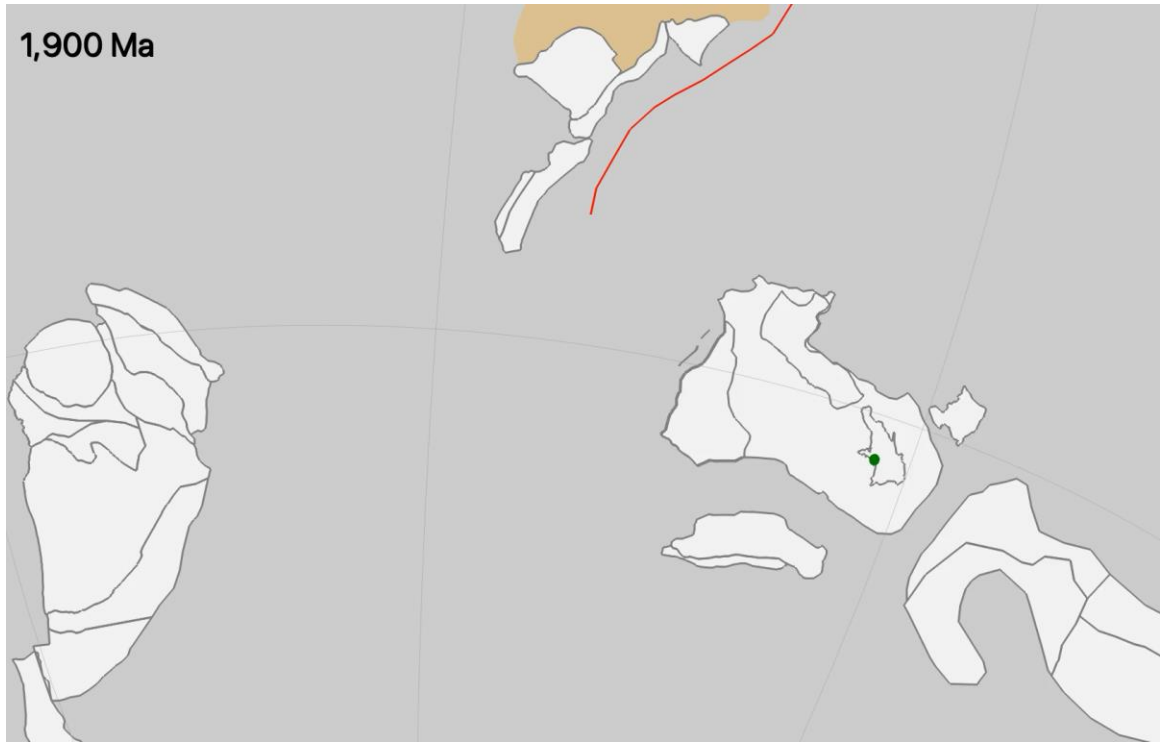


Plate tectonic reconstruction of Australian craton assembly gives an insight to potential far-field forces require for basin formation

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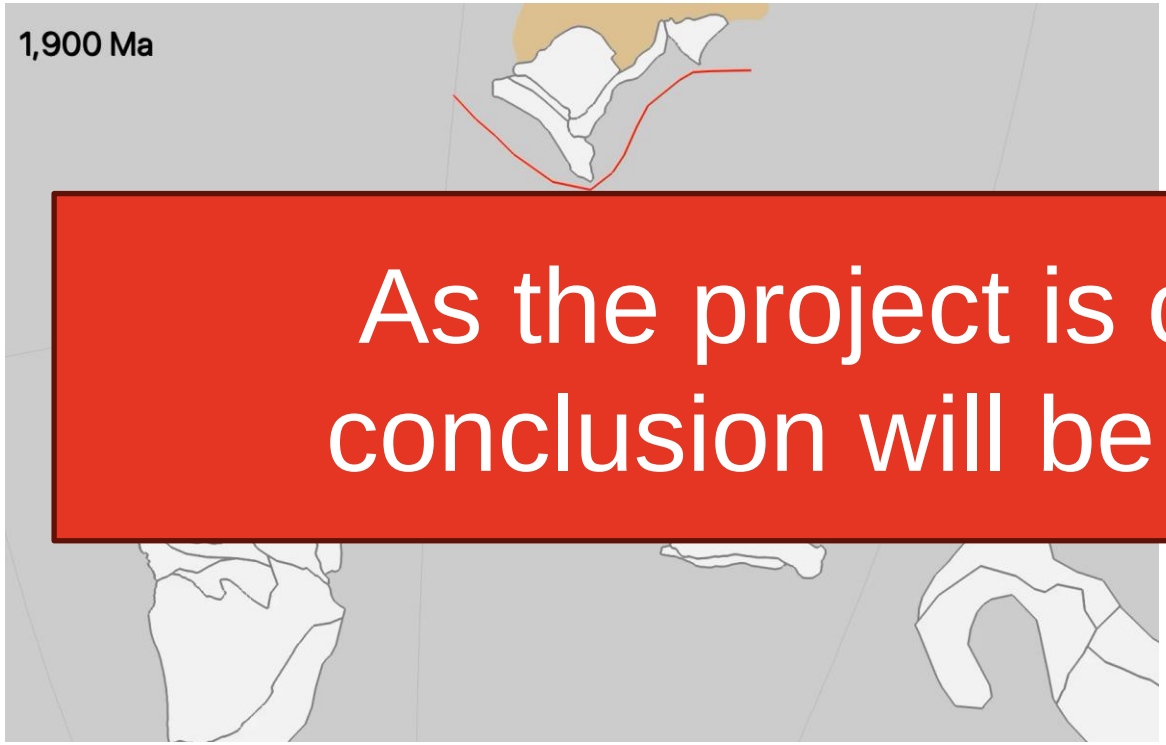

As the project is ongoing, therefore conclusion will be available in a year

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UNDERSTANDING THE LARGE-SCALE PROCESES DRIVING THE SUBSIDENCE AND INVERSION OF PROTEROZOIC BASINS PROVIDE FIST ORDER TOOLS FOR EXPLORATION.