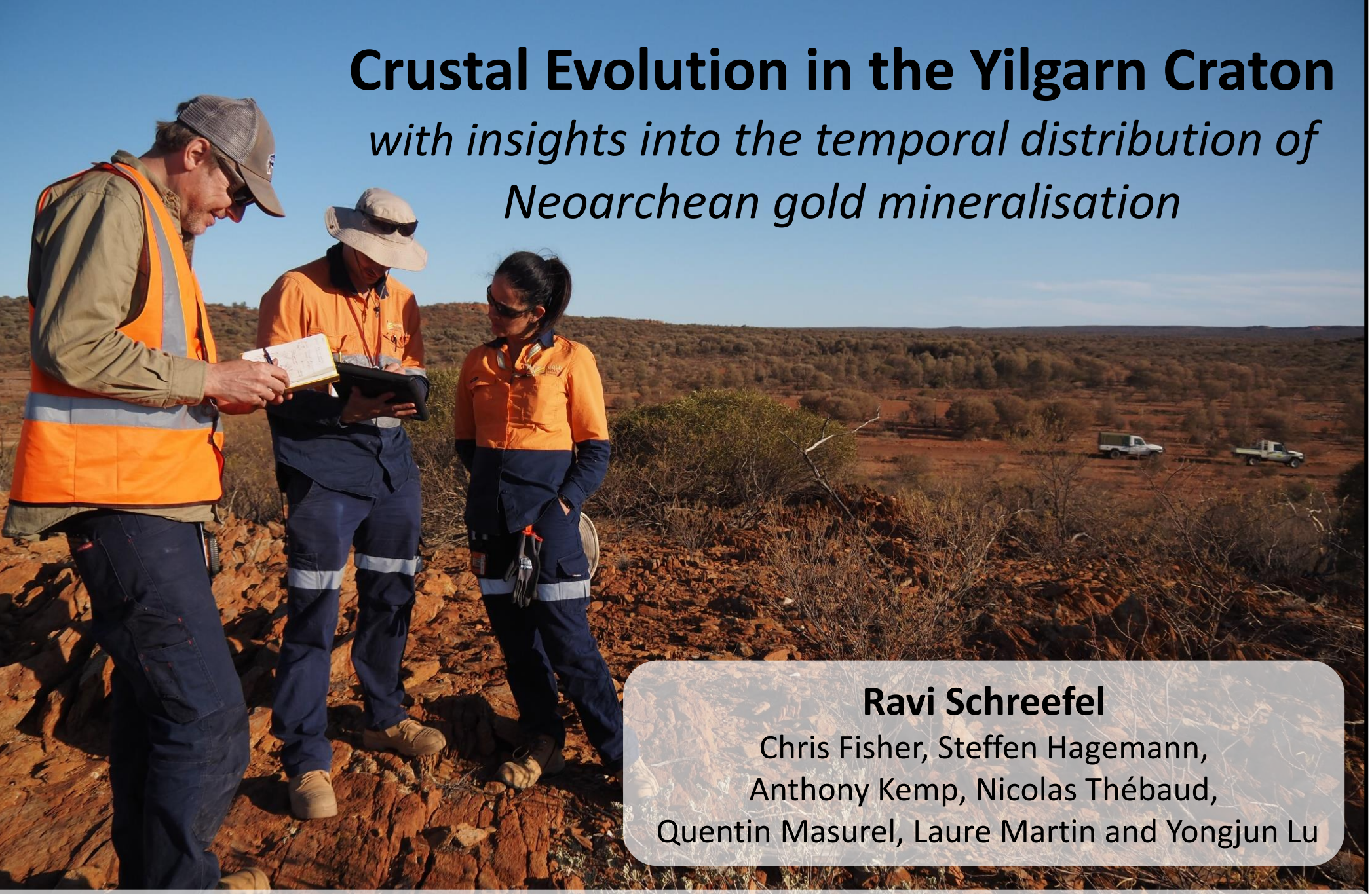
Crustal Evolution in the Yilgarn Craton

with insights into the temporal distribution of Neoarchean gold mineralisation



Ravi Schreefel

Chris Fisher, Steffen Hagemann,
Anthony Kemp, Nicolas Thébaud,
Quentin Masurel, Laure Martin and Yongjun Lu

Ziggy Monzogranite (Dorothy Hills Greenstone Belt, Yilgarn Craton) with Chris Fisher and Danielle Kelly

THE UNIVERSITY OF WESTERN AUSTRALIA

Centre for EXPLORATION TARGETING

YILGARN 2020

GOLD ROAD RESOURCES

Geological Survey of Western Australia

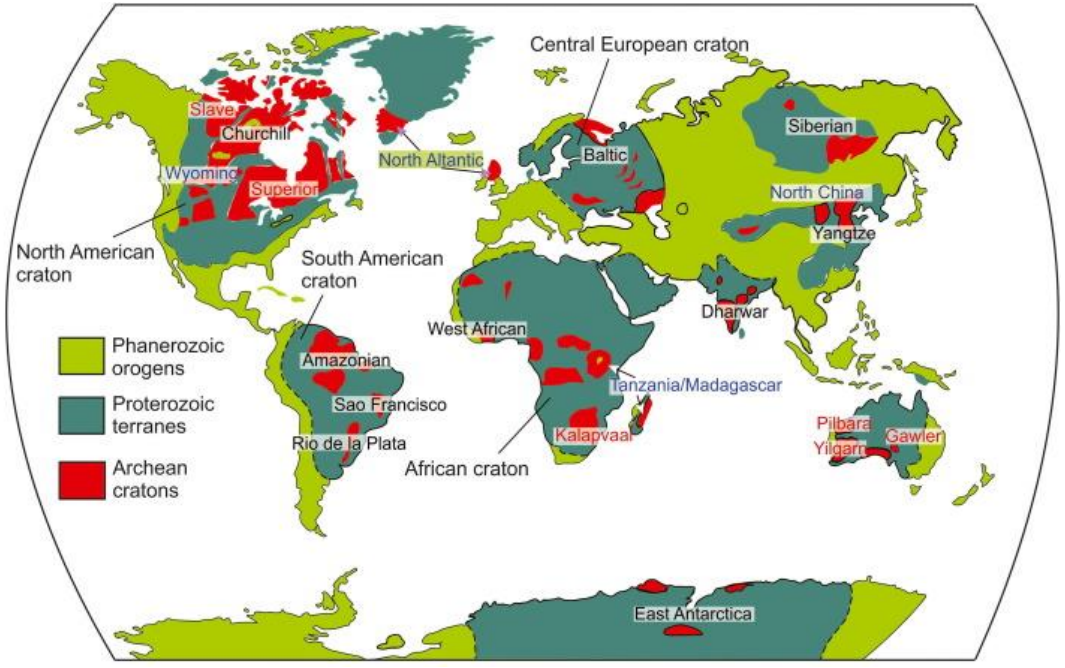
Archean cratons

- Only ~7% of the continental crust
- Significant gold-endowment during the **Neoarchean** (2700 – 2600 Ma)

→ **Can this endowment be correlated to crustal evolution?**

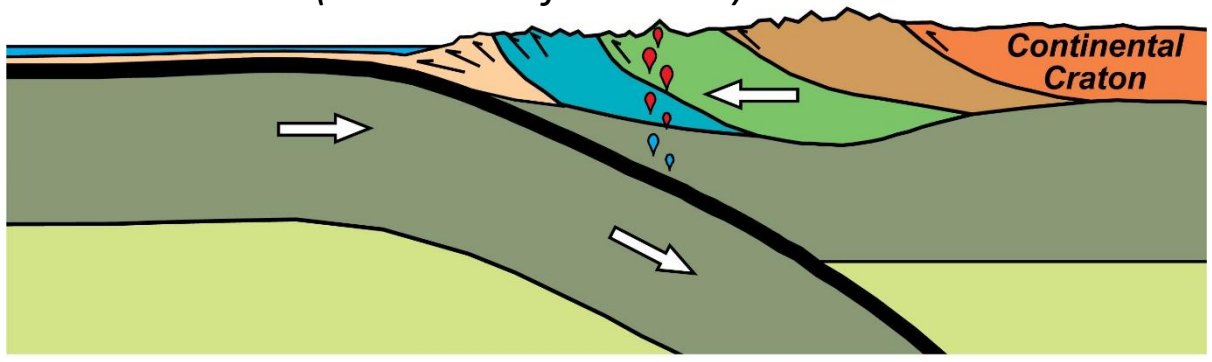
➢ Uncertainties in Archean **crustal growth** models

- Onset of plate tectonics (~subduction)



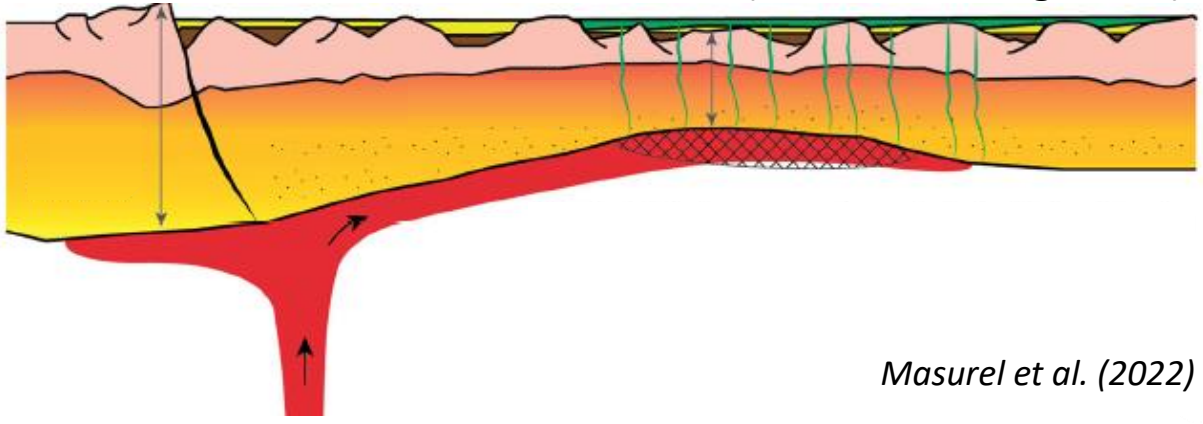
Groves and Santosh (2021)

Allochthonous *(accretion of terranes)*



Lillie (2005)

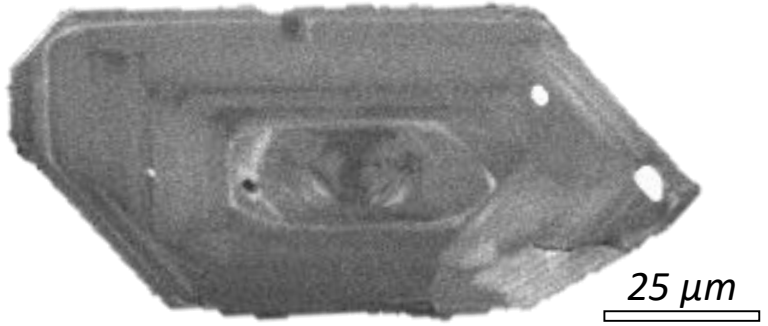
Autochthonous *(in-situ crustal growth)*



Masurel et al. (2022)

Overview

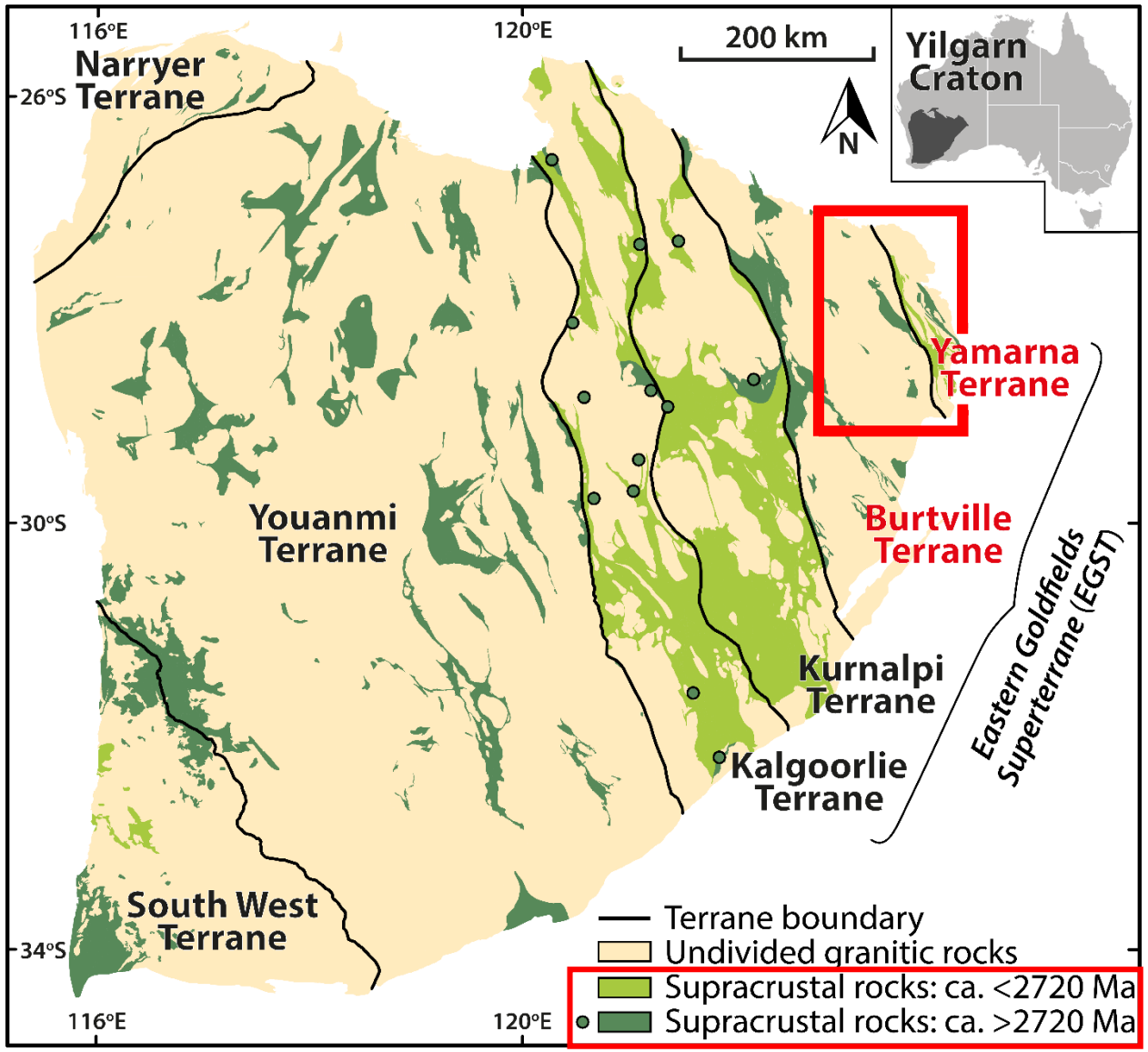
1. Crustal evolution in the **Yilgarn Craton**
   - Insights from the far-east region
   - Zircon petrochronology (U-Pb, Lu-Hf, O)
   - Crustal growth model
2. Secular geodynamic shift linked to the temporal distribution of **Neoarchean gold mineralisation?**
   - Yilgarn Craton, Australia
   - Superior Craton, Canada



Yilgarn Craton

- **3730 – 2600 Ma**: successive mantle extraction and crustal reworking events
- **Geological framework**: 7 terranes
  (Cassidy et al. 2006; GSWA Record)
  - West: 'older' greenstone belts (**>2720 Ma**)
  - East: 'younger' greenstone belts (**<2720 Ma**)
    - Except the Burtville Terrane

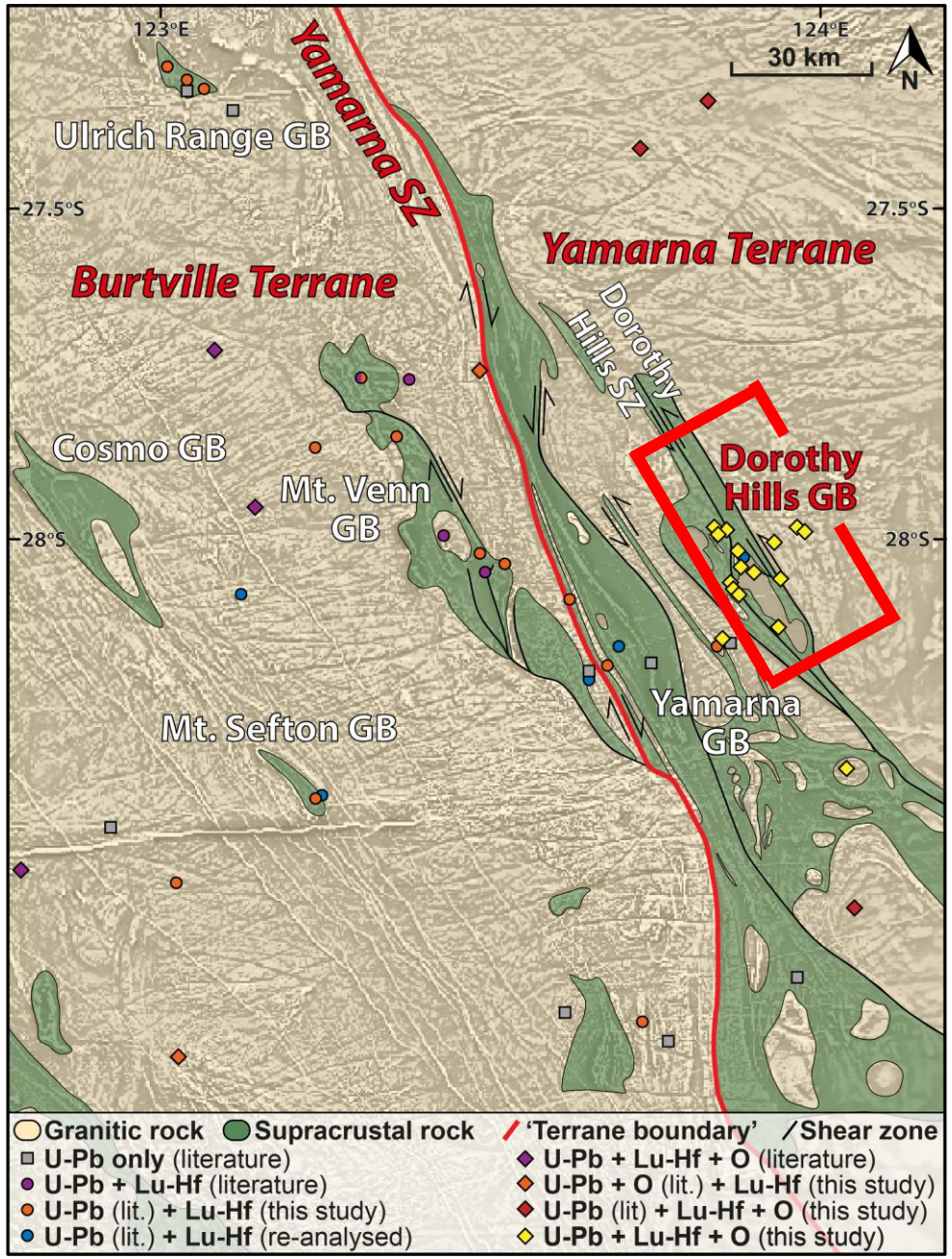
  - Recent advances in terrane boundaries:
    - **Yamarna Terrane** defined
      (Pawley et al. 2012; AJES)
    - South West Terrane border relocated
      (De Gromard et al. 2021; GSWA Record)



Modified after Witt et al. (2020; Min. Dep.) and Masurel et al. (2022; AJES)

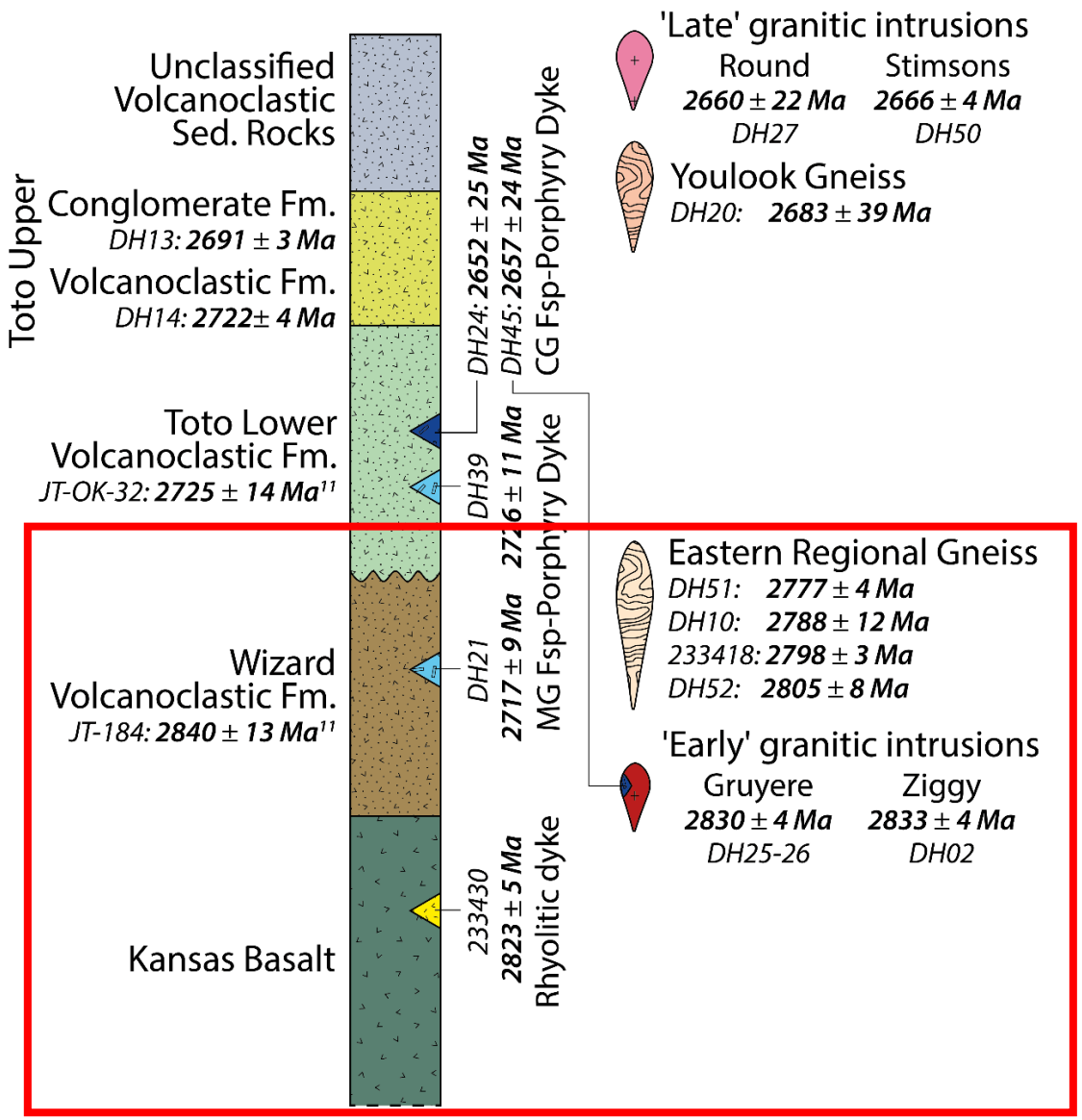
Burtville and Yamarna terranes

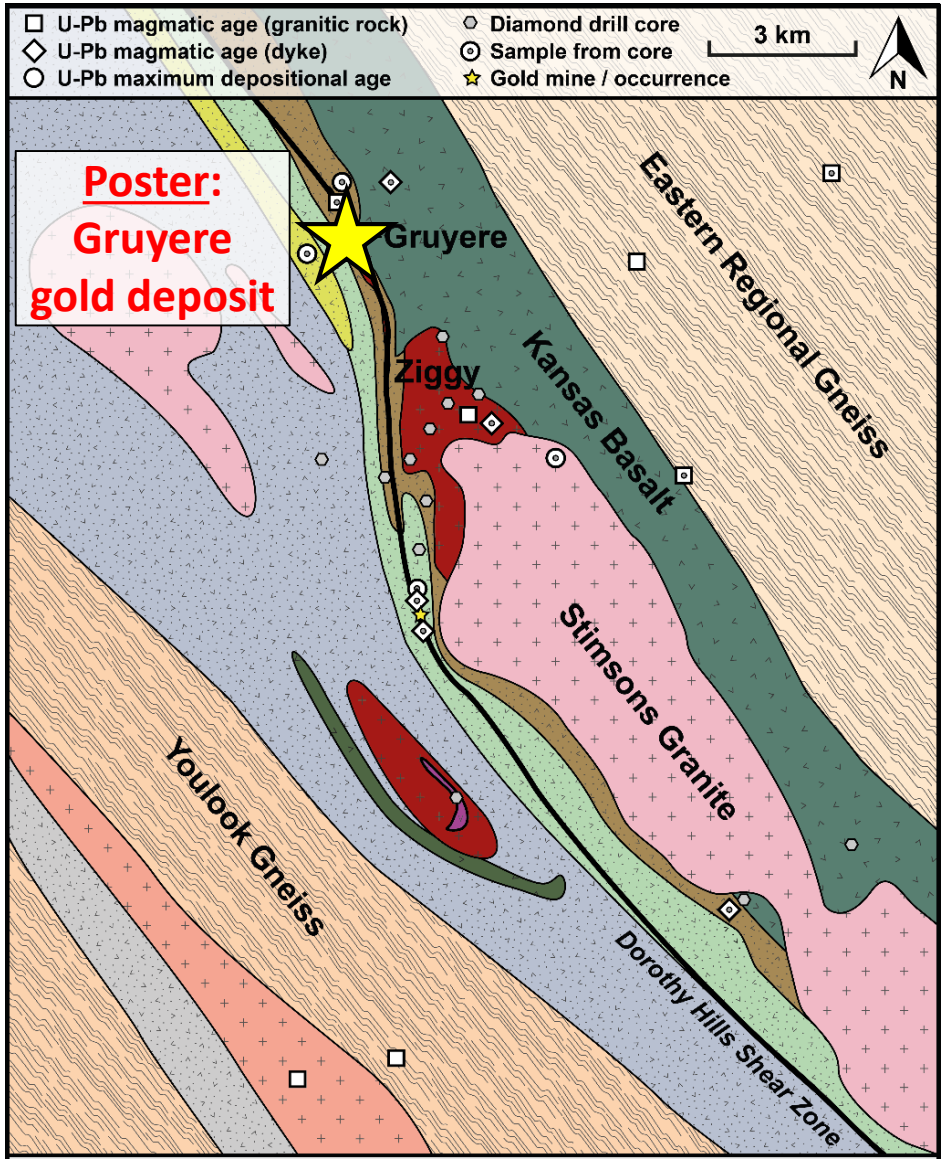
- Greenstone belts separated and intruded by granitic gneisses and granites
- **Yamarna Shear Zone** *(Pawley et al., 2012)*
  - **Burtville Terrane**: *"distinctively older greenstones in the west"* (>2735 Ma)
  - **Yamarna Terrane**: *"only youngest magmatic event in the east"* (<2715 Ma)
- Terrane division largely based on geochronology
  - Limited data from the **Dorothy Hills Greenstone Belt**
  - Limited regional zircon petrochronology (e.g. Hf-O)



Modified after Pawley et al. (2012)

Dorothy Hills Greenstone Belt

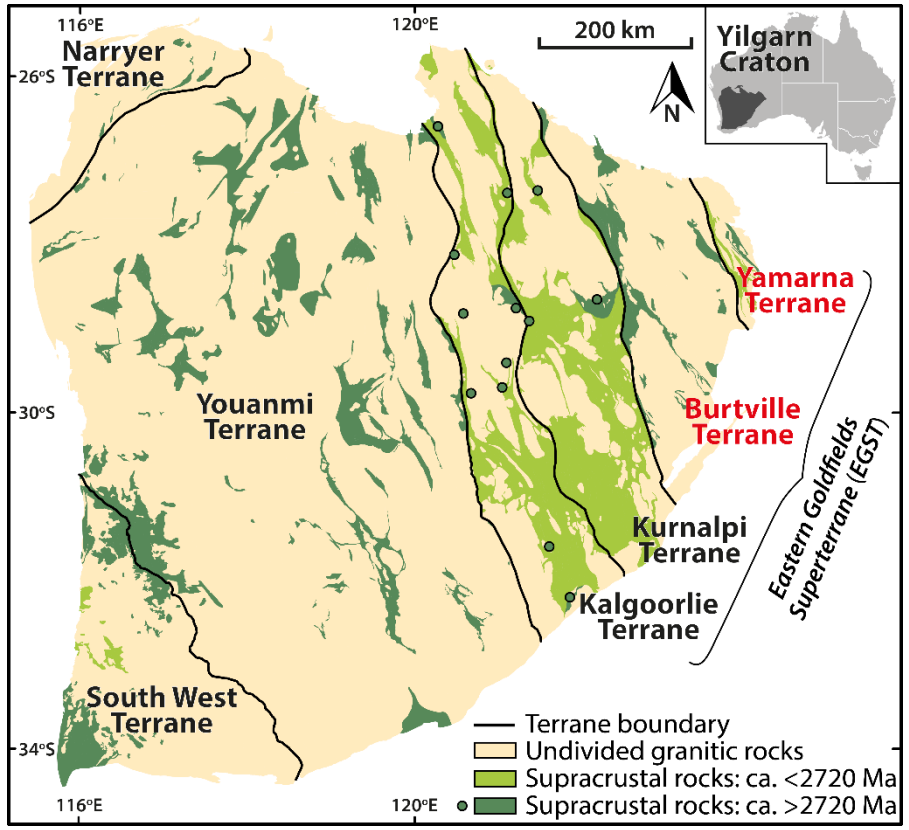




[11] *Tunjic (2019) / Gold Road Resources*

Eastern Goldfields correlation

- Yamarna Terrane:
  - Yamarna Greenstone Belt: <2720 Ma
  - **Dorothy Hills GB**: **2840 – 2775 Ma**
- Burtville Terrane: >2735 Ma
- Kalgoorlie and Kurnalpi terranes: <2720 Ma



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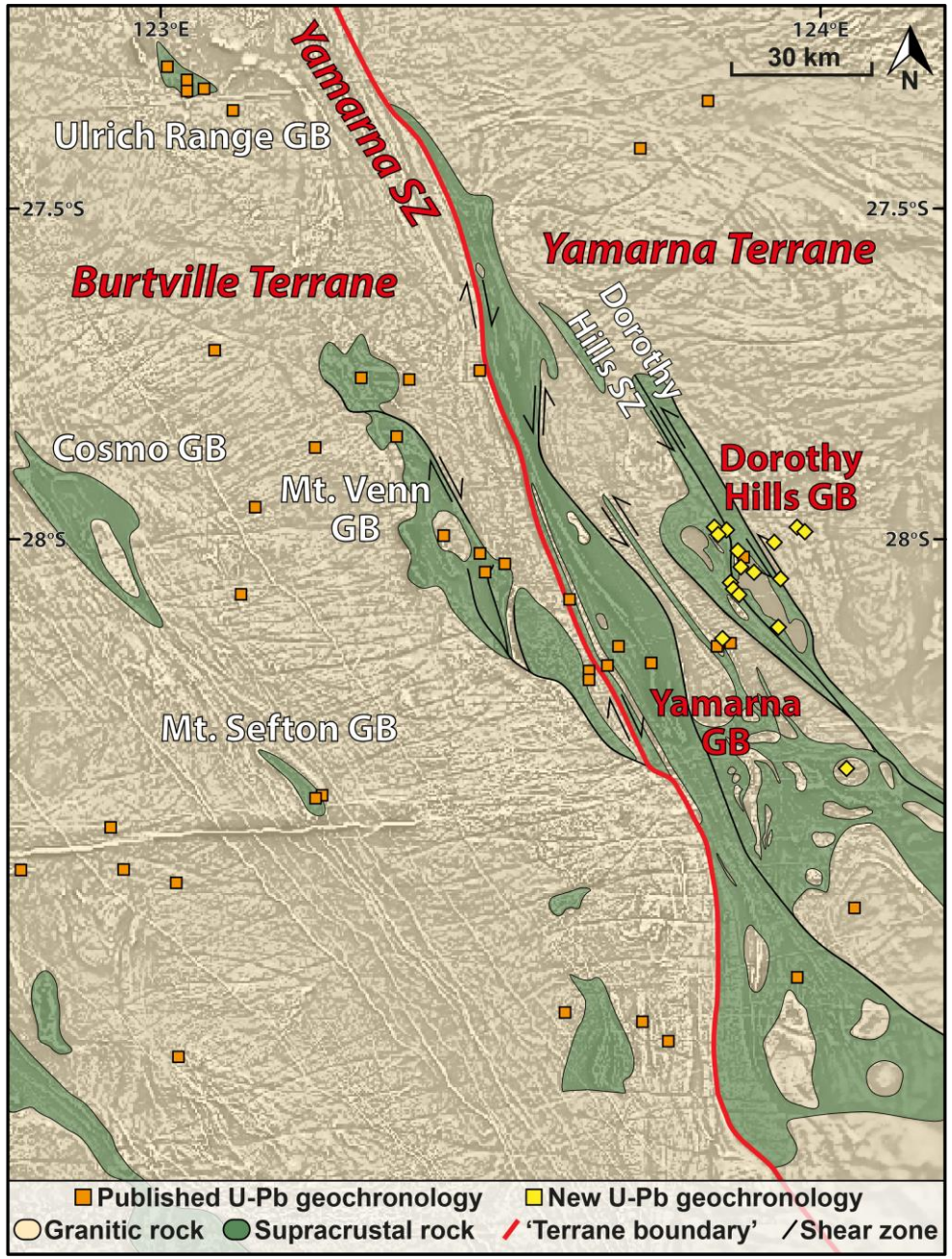
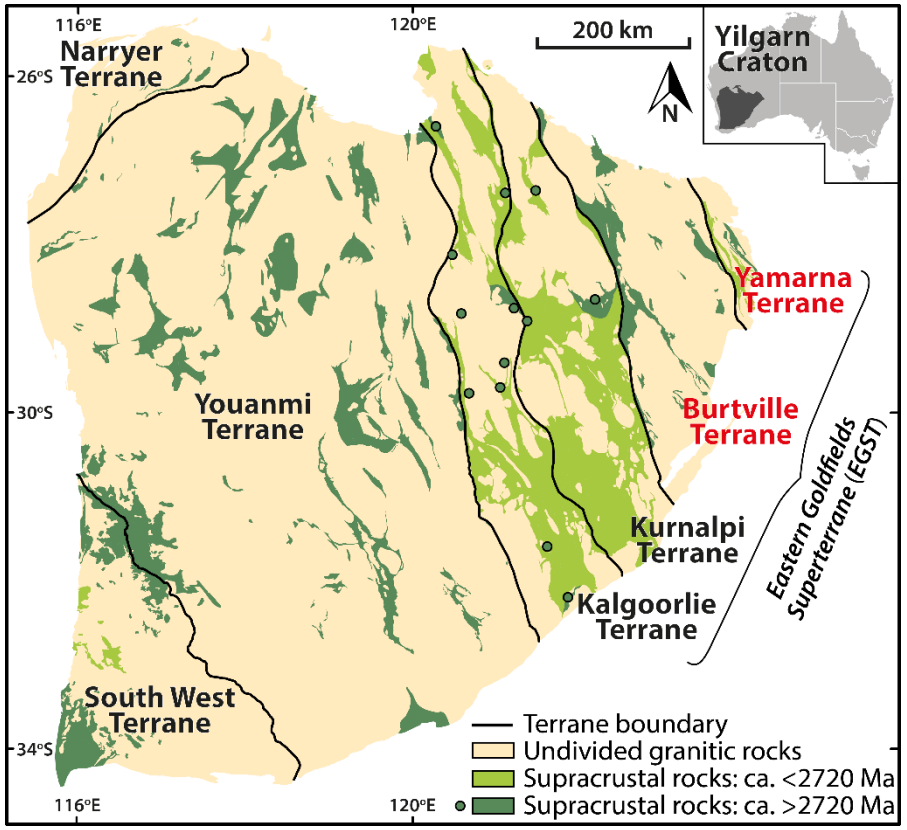


Modified after Pawley et al. (2012)

Regional zircon petrochronology

1. Zircon lutetium-hafnium isotopes
2. Zircon oxygen isotopes



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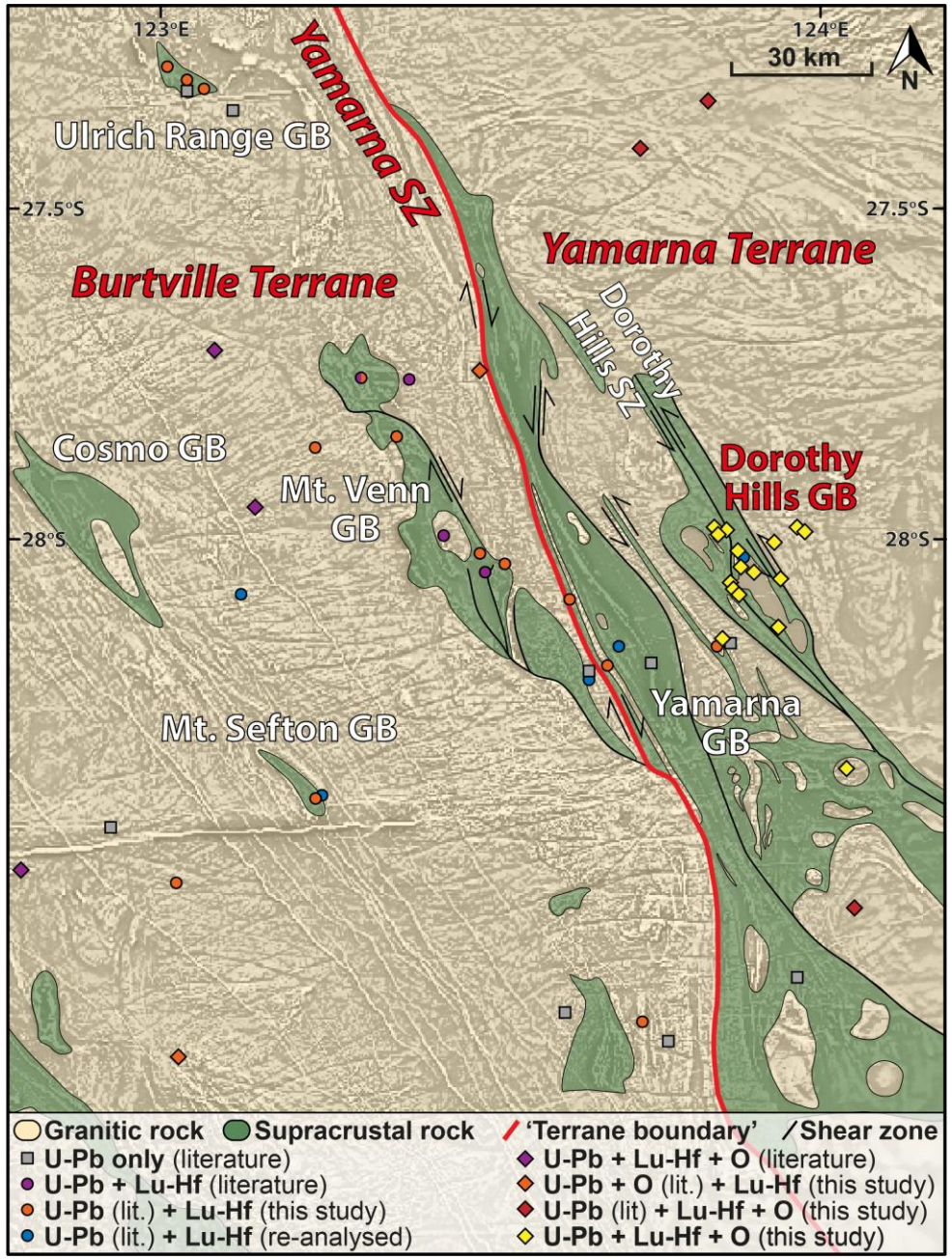
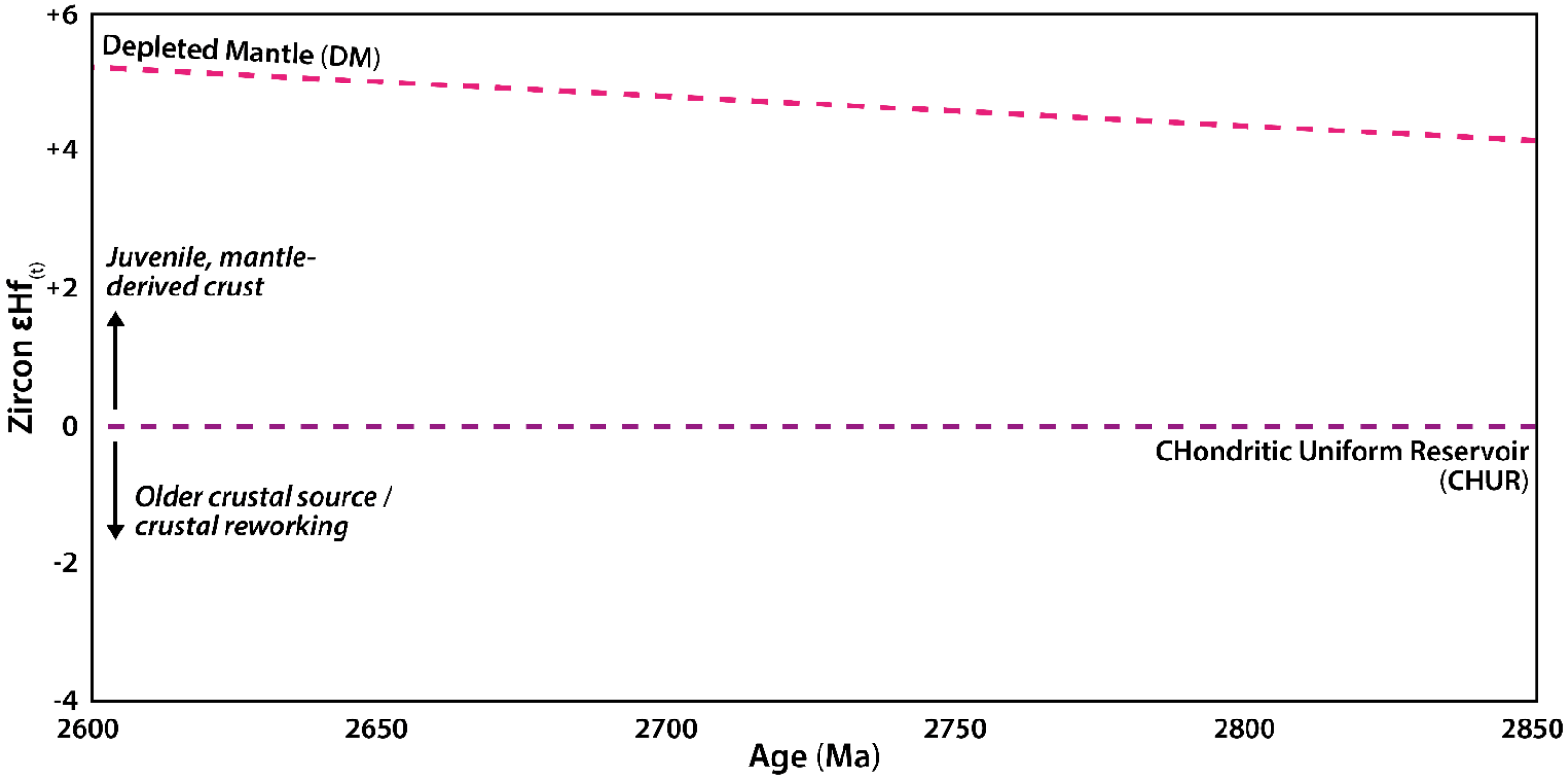


Modified after Pawley et al. (2012)

Zircon Lu-Hf isotopes – Yamarna-Burtville

- Positive εHf: mantle-derived magmatic additions without significant reworking of older crust
- Negative εHf: magmatic additions with infracrustal reworking



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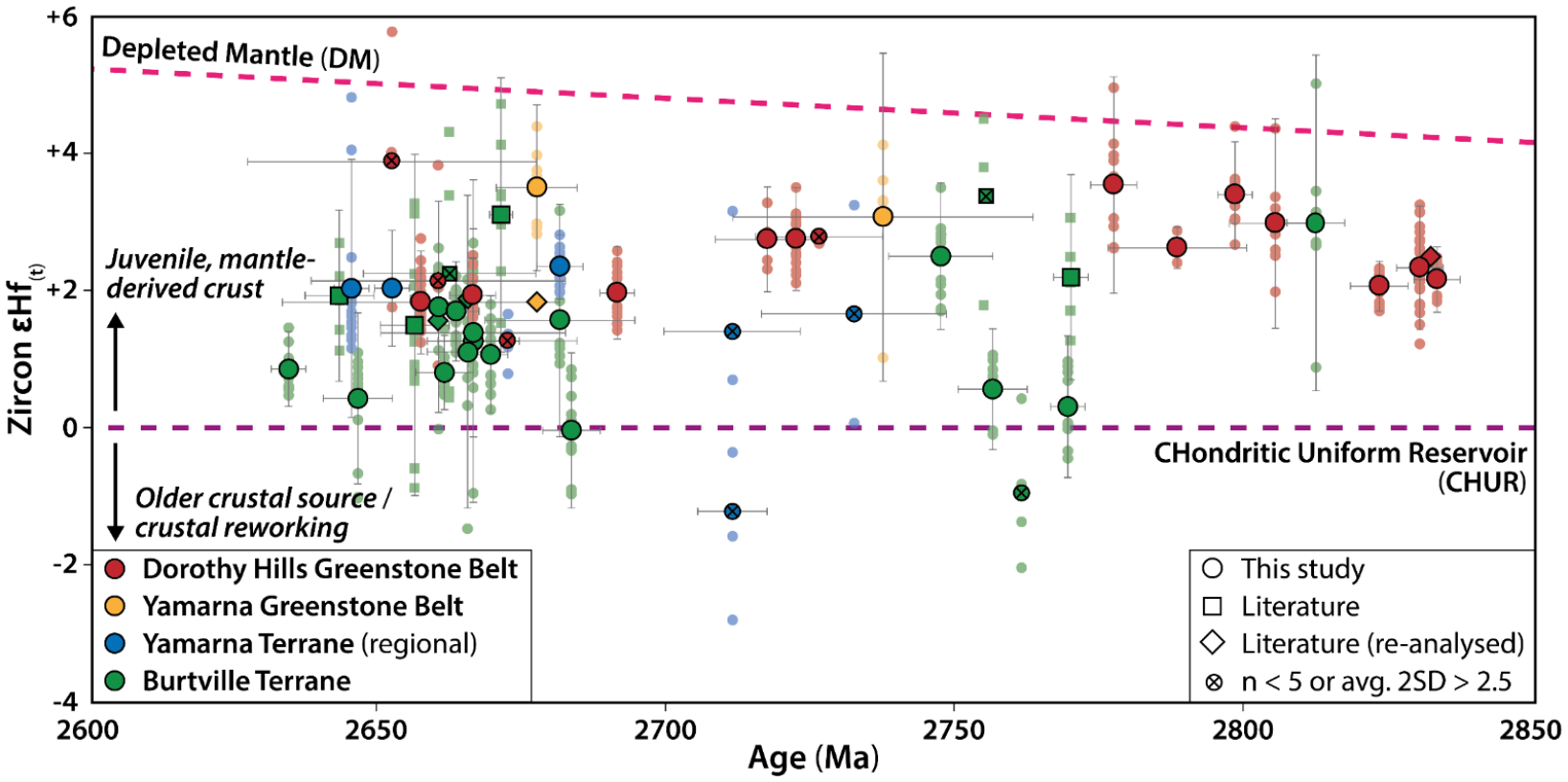
➢ **Yamarna-Burtville**: near continuous, mildly super-chondritic (positive) εHf evolution

→ sustained, mantle-derived magmatic additions



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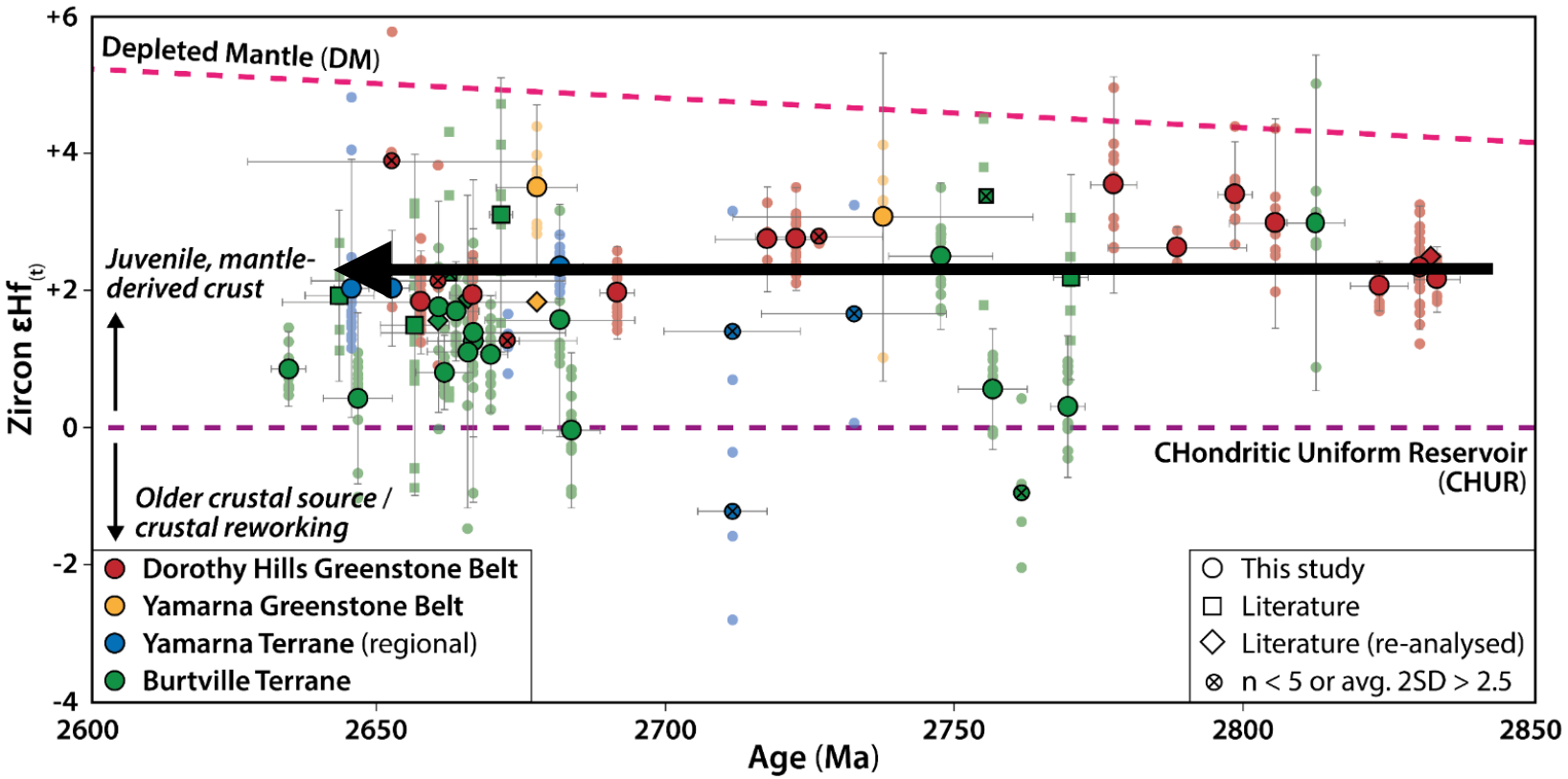

Zircon Lu-Hf isotopes – Yilgarn Craton

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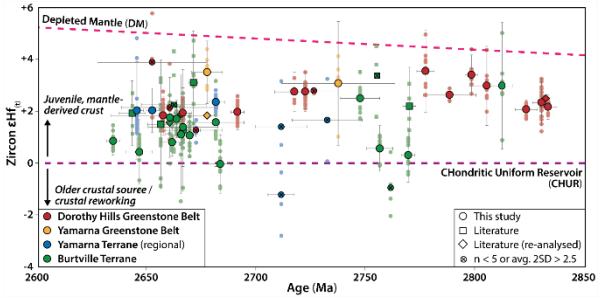
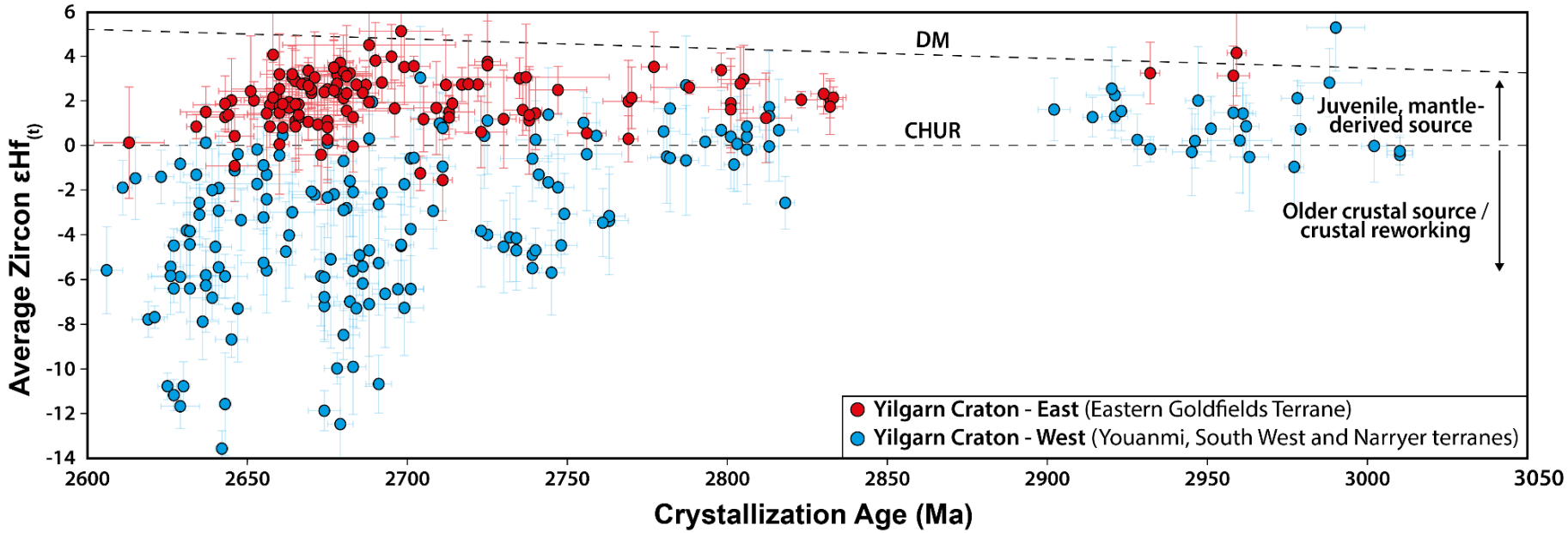
- **Western Yilgarn** (Youanmi, South West, Narryer): decrease to unradiogenic εHf (from ca. 2820 Ma)
  → magmatic additions with infracrustal reworking (thicker, older crust)

Yamarna-Burtville



Yilgarn-wide



Literature data from Ivanic et al. (2012), Wyche et al. (2012), Mole et al. (2014), Isaac (2015), Mole et al. (2019), McDivitt (2021), Rowe (2021), and Lu et al. (2022)

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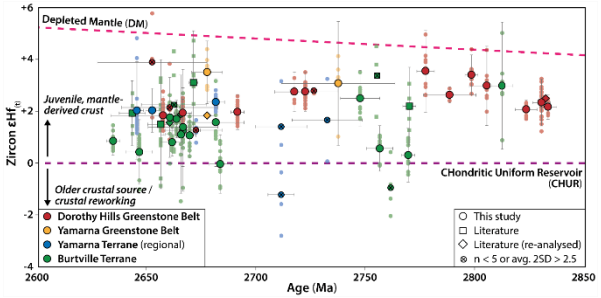

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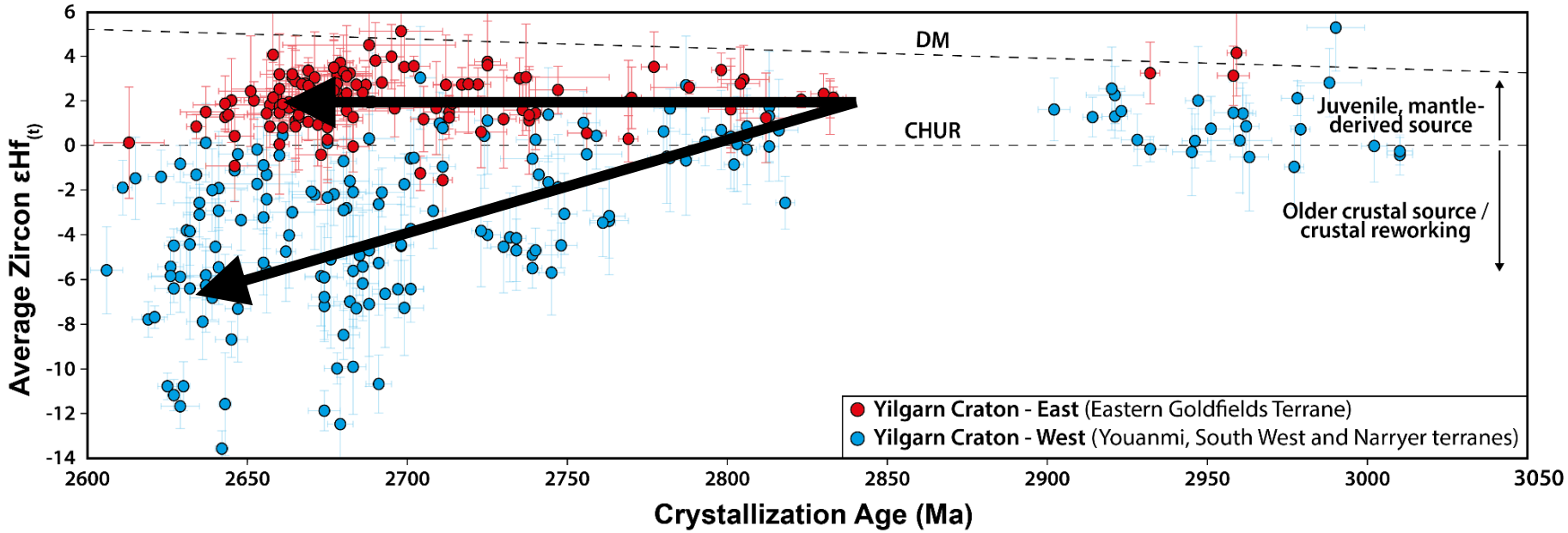

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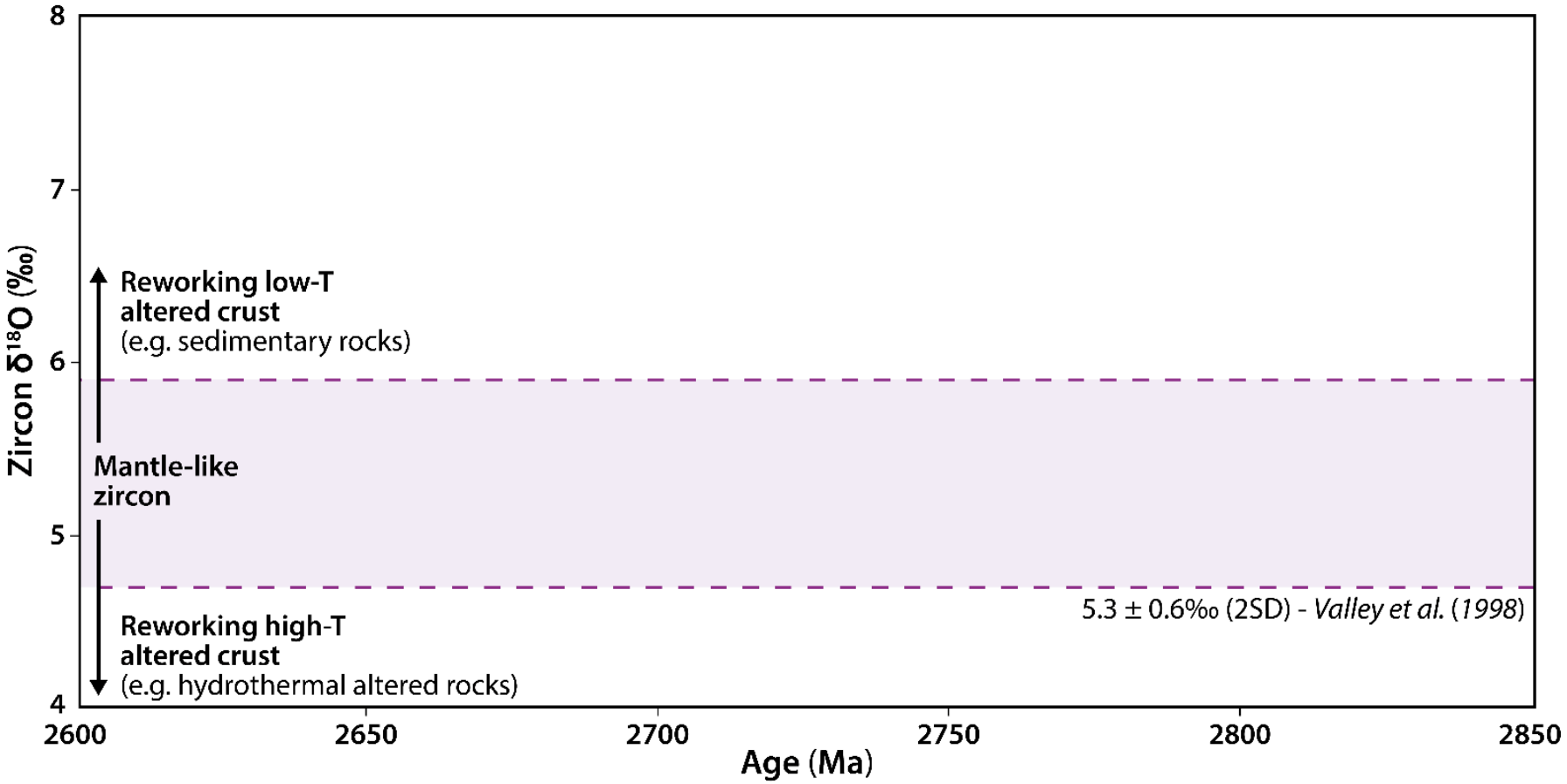
Zircon O isotopes – Yamarna-Burtville

- $\delta^{18}O$ (5.3 ± 0.6‰): zircon derived from mantle-equilibrated magmas



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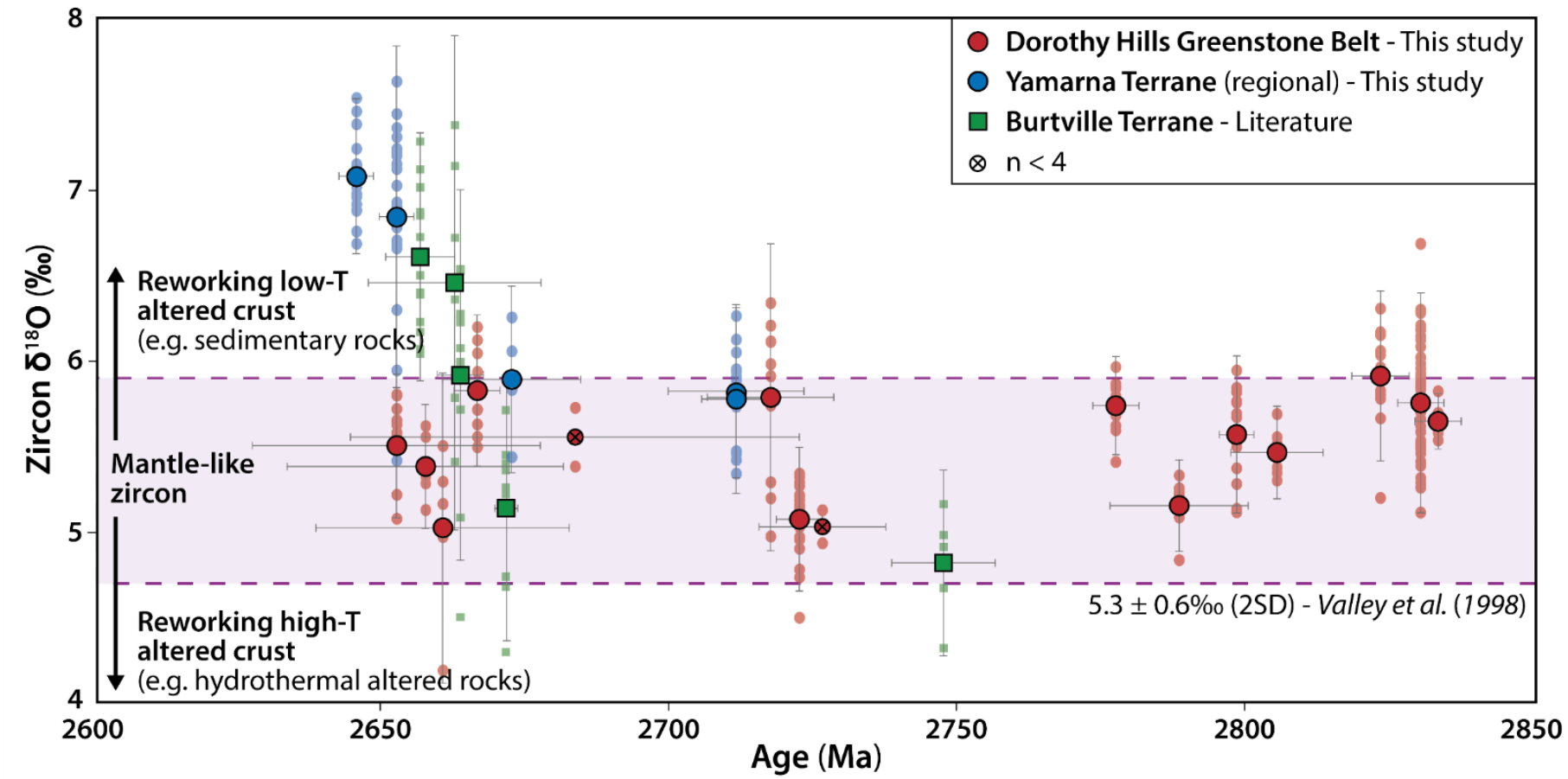

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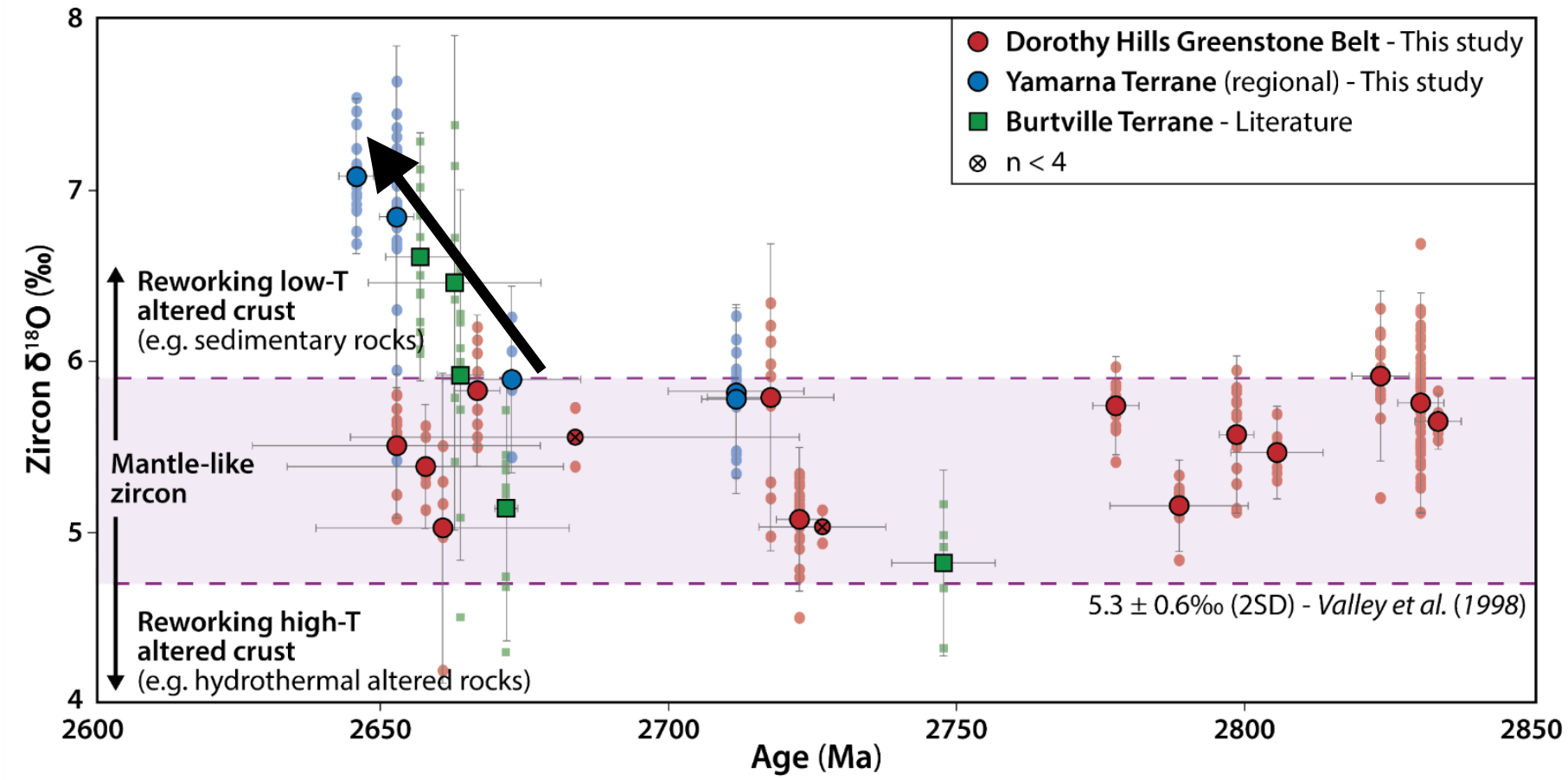
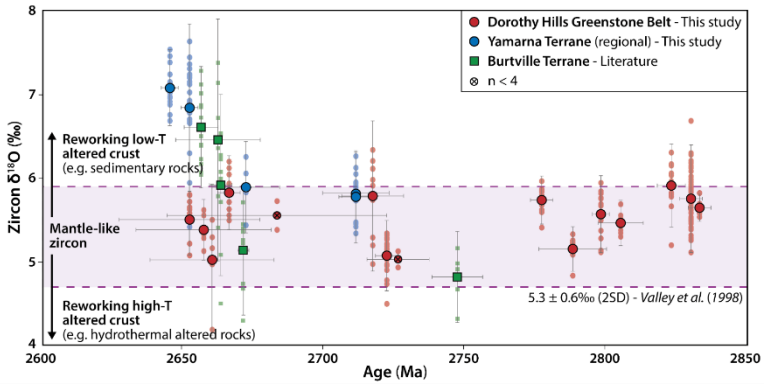


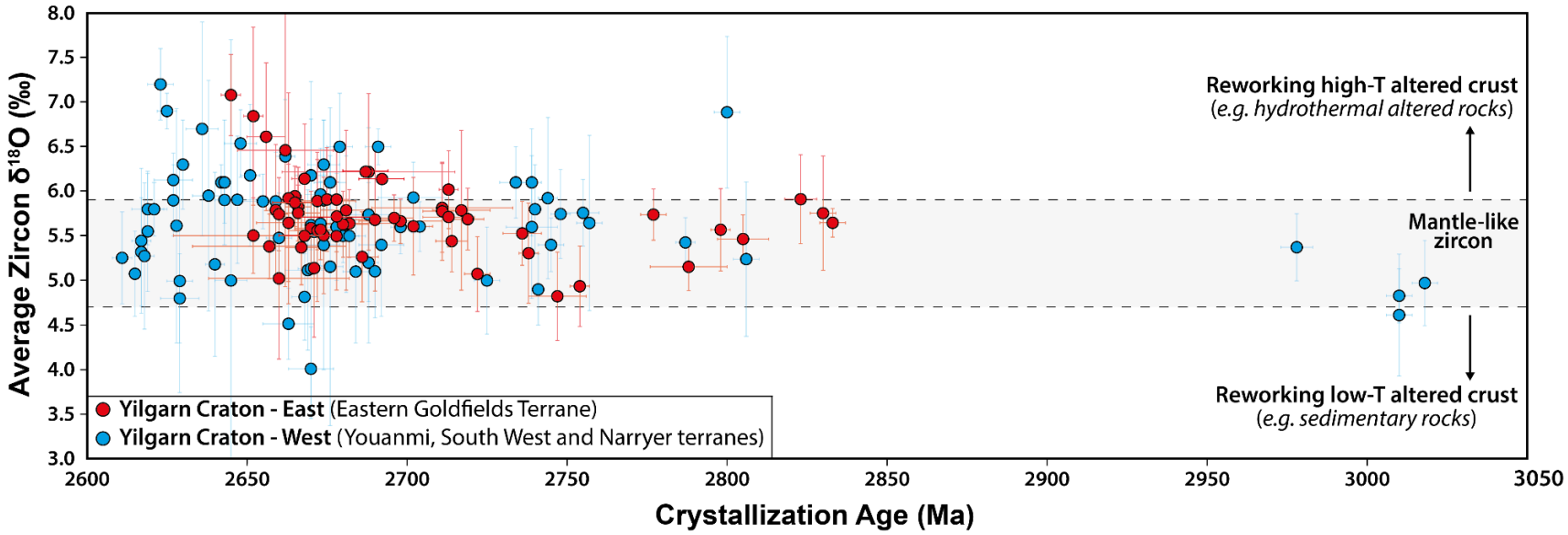
Zircon O isotopes – Yilgarn Craton

- **Yilgarn**: mantle-like until ca. **2680 Ma**, after which there is a rise to higher values ($\delta^{18}O$: >6‰)
- **Distinct transition**: recording onset of significant supracrustal reworking?
  - Subduction or lower crustal foundering (delamination; dripping)? → **geodynamic shift?**

Yamarna-Burtville



Yilgarn-wide



Literature data from Lu et al. (2021), Smithies et al. (2021.), McDivitt (2021), Rowe (2021), Johnson et al. (2022), and Lu et al. (2022a), and Lu et al. (2022b)

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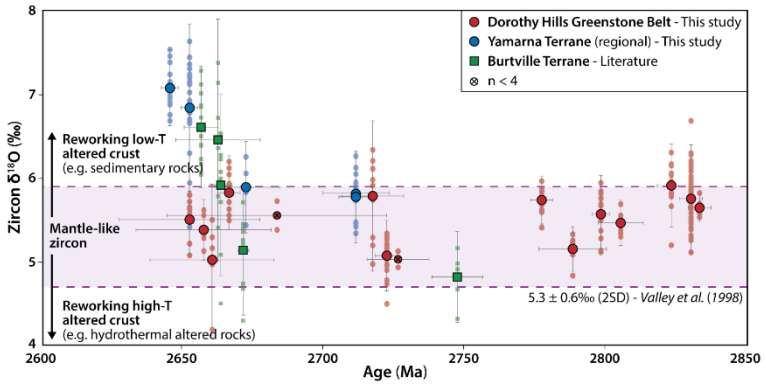
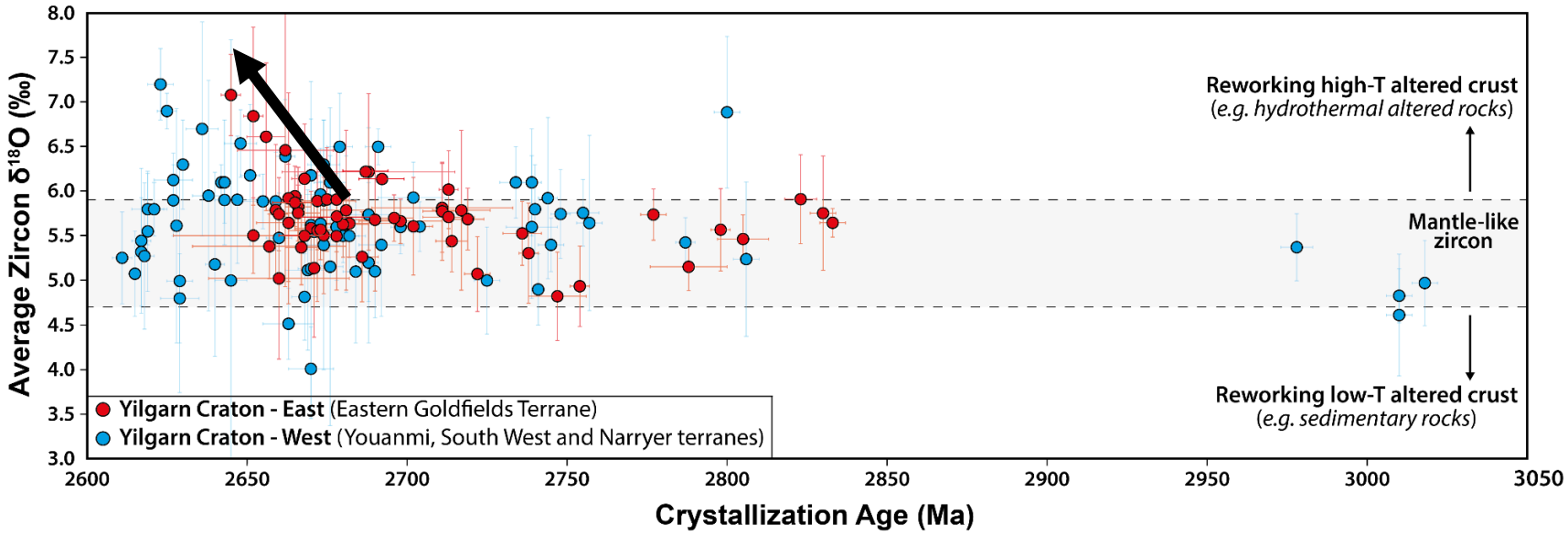


Yilgarn-wide



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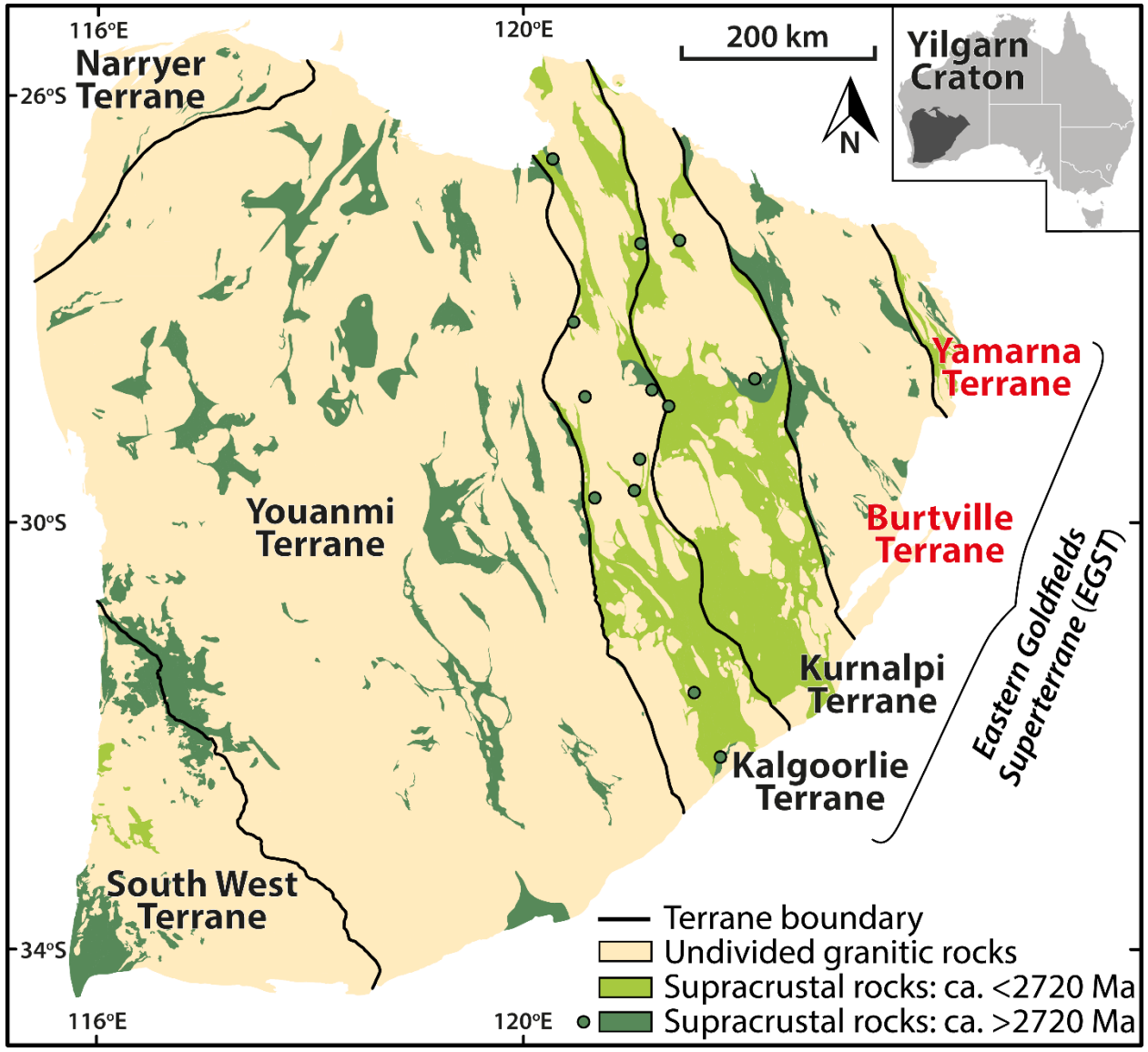
Zircon petrochronology correlations

- **Mesoarchean**: geochronological and isotopic similarities between:
  - Dorothy Hills Greenstone Belt (Yamarna Terrane)
  - Burtville Terrane
  - Youanmi Terrane

  → **Shared Mesoarchean history**

- **Neoarchean**: dissimilar Hf, but comparable O trends Eastern Goldfields and Western Yilgarn

  → Different emplacement processes but simultaneous change in nature of magma source?

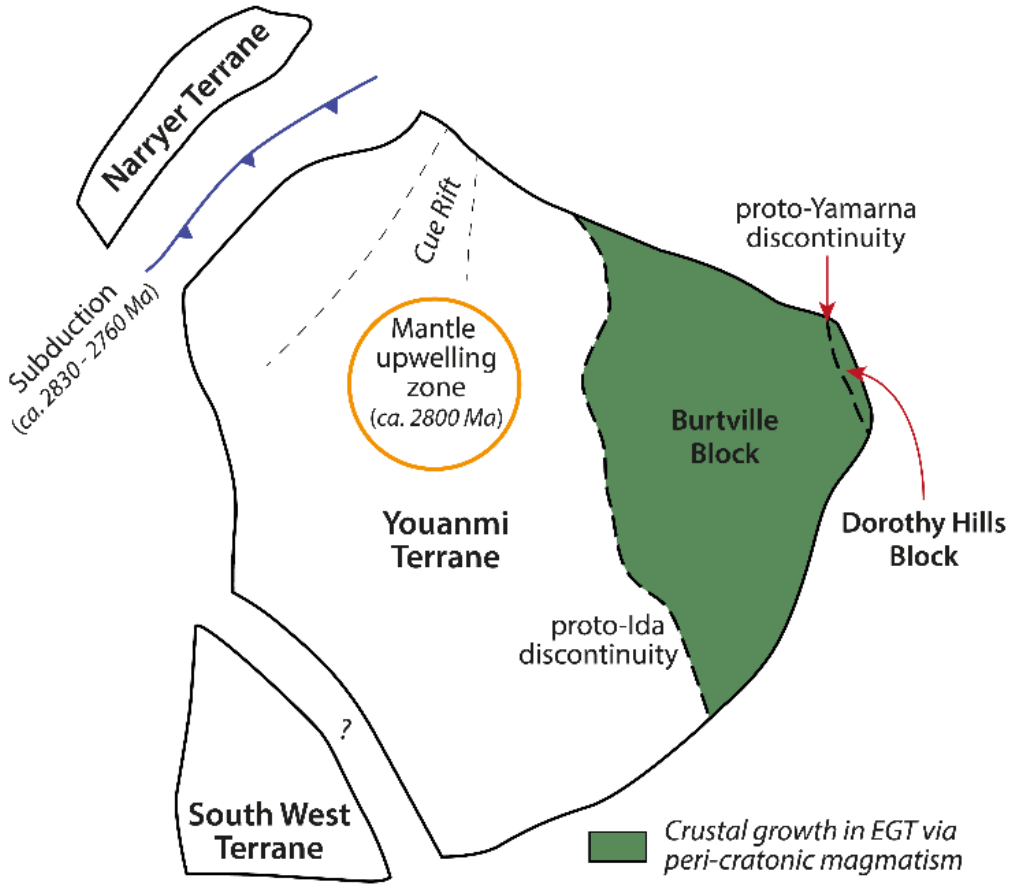


Modified after Witt et al. (2020) and Masurel et al. (2022)

Eastern Yilgarn Craton: autochthonous crustal growth model

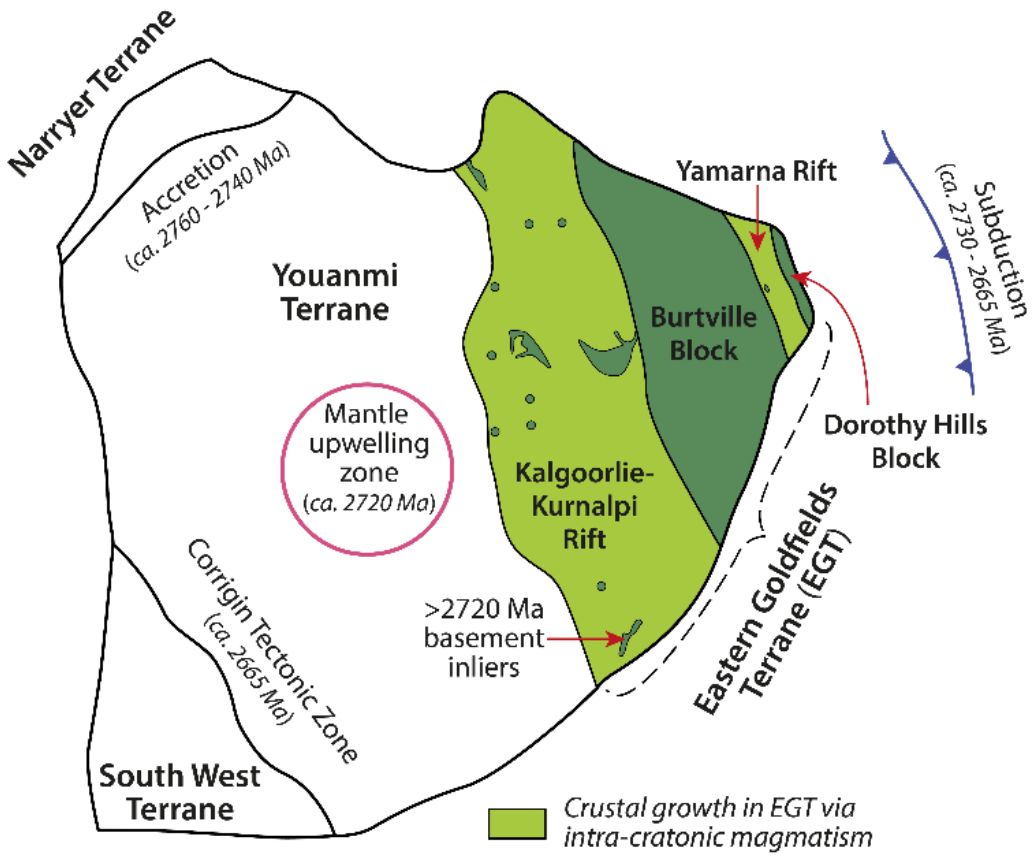
>2720 Ma: Craton-margin magmatism

Burtville and Dorothy Hills 'Blocks'



<2720 Ma: Intra-cratonic magmatism

Kalgoorlie-Kurnalpi and Yamarna 'Rifts'



Metallogenesis and zircon petrochronology

Can this crustal evolution be linked to the Neoarchean gold endowment?

What initiated this significant gold mineralisation?

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Crustal architecture of the south-east Superior Craton and controls on mineral systems

D.R. Mole [a,b,c,*], B.M. Frieman [a], P.C. Thurston [a], J.H. Marsh [a], T.R.C. Jørgensen [a], R.A. Stern [d], L.A.J. Martin [e], Y.J. Lu [b,f], H.L. Gibson [a]

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Crustal architecture and its controls on mineralisation in the North China Craton

Changming Wang[a,b,*], Leon Bagas[c], Jun Deng[a], Mengmeng Dong[a]

minerals

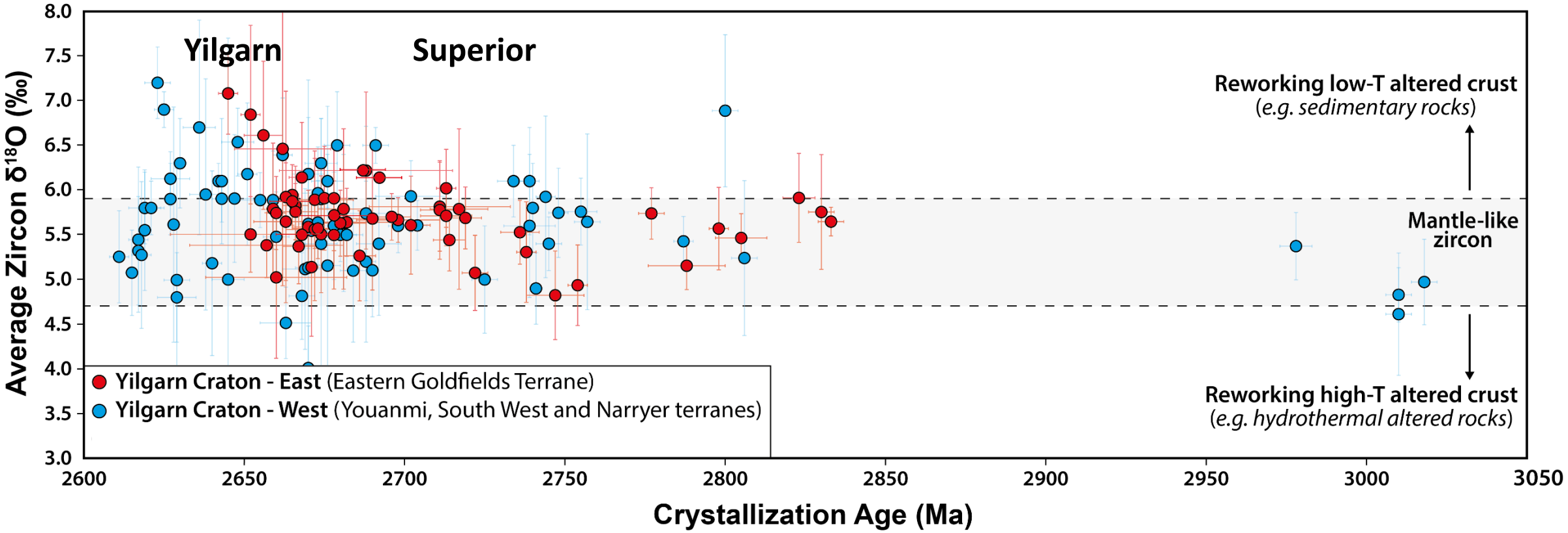
Article

Linking Gold Systems to the Crust-Mantle Evolution of Archean Crust in Central Brazil

Jessica Bogossian *, Anthony I. S. Kemp and Steffen G. Hagemann

Change in zircon O isotopes

- Significant supracrustal reworking → geodynamic shift or result of cratonisation?
  - Yilgarn Craton: **2680 Ma** → subduction or lower crustal foundering (delamination; dripping)?



Literature: A) Yilgarn: Lu et al. (2021), Smithies et al. (2021), McDivitt (2021), Rowe (2021), Johnson et al. (2022), and Lu et al. (2022), Lu et al. (2022);
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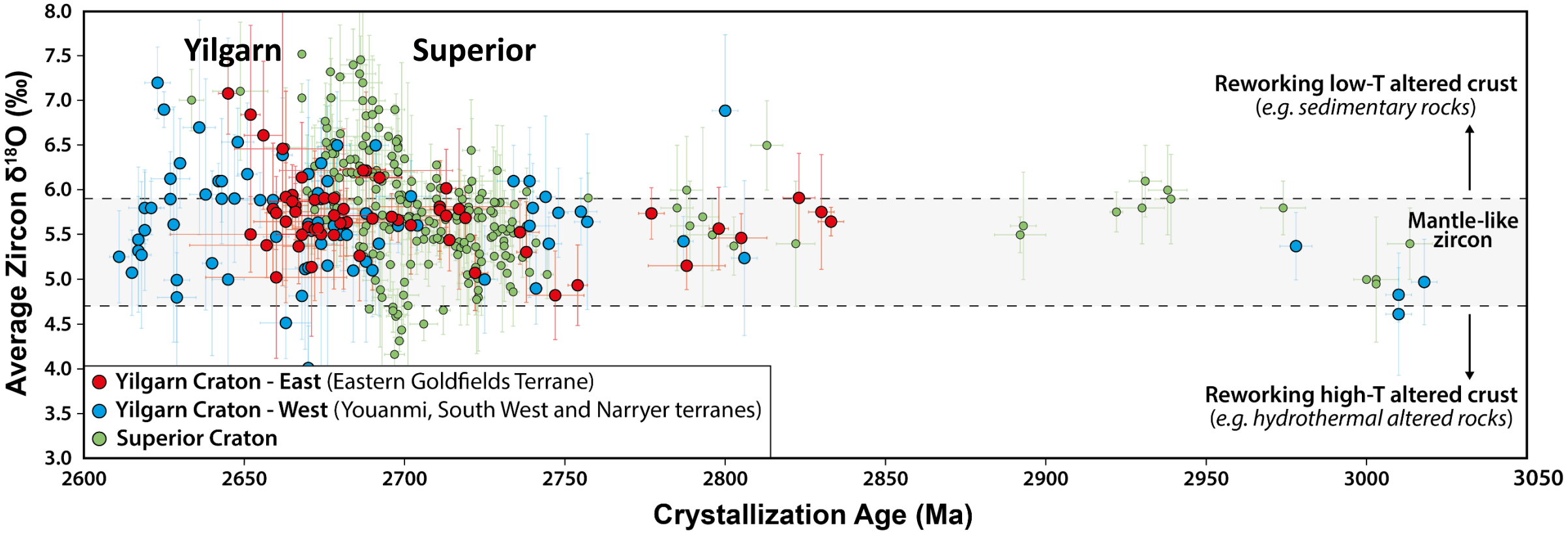

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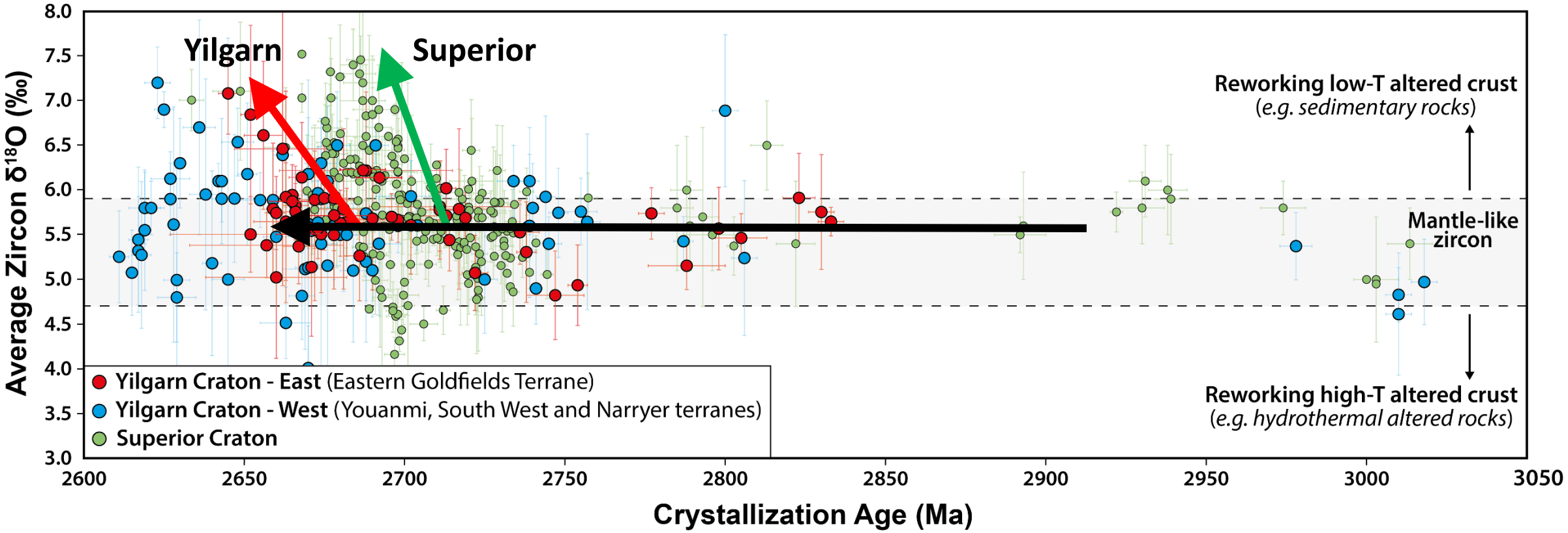

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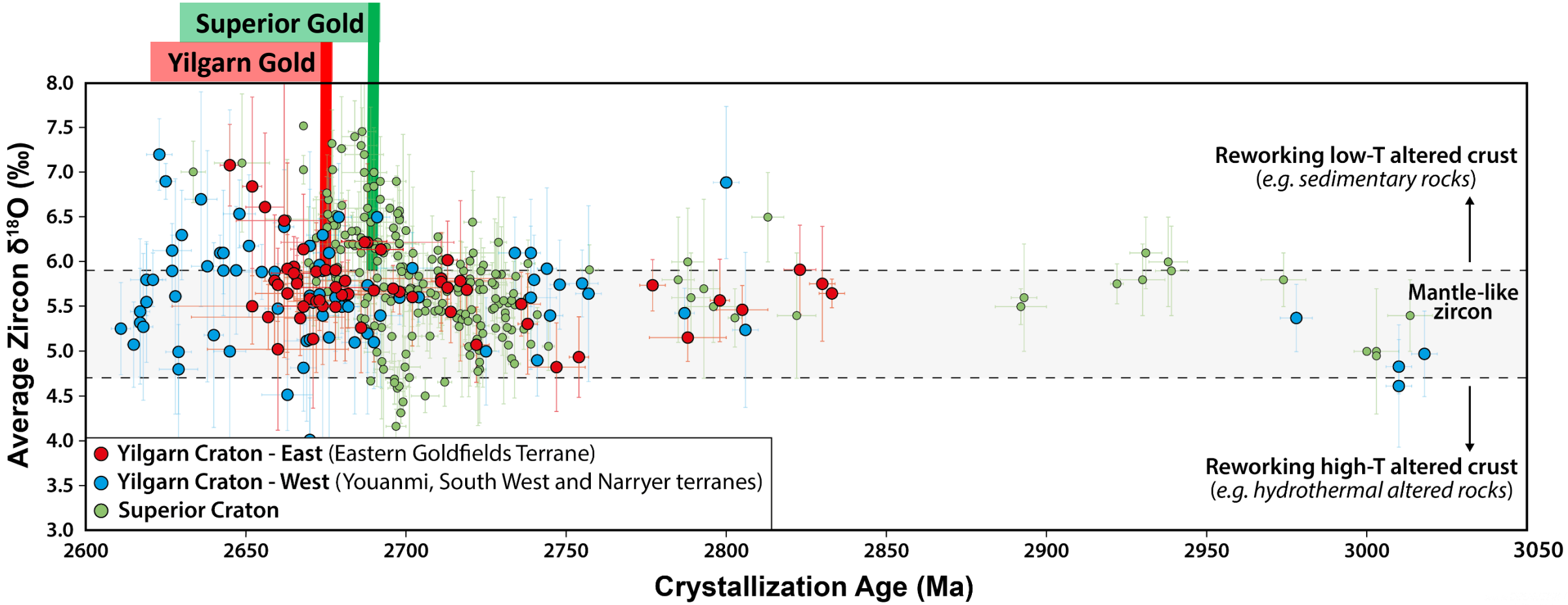
Temporal distribution of gold mineralisation

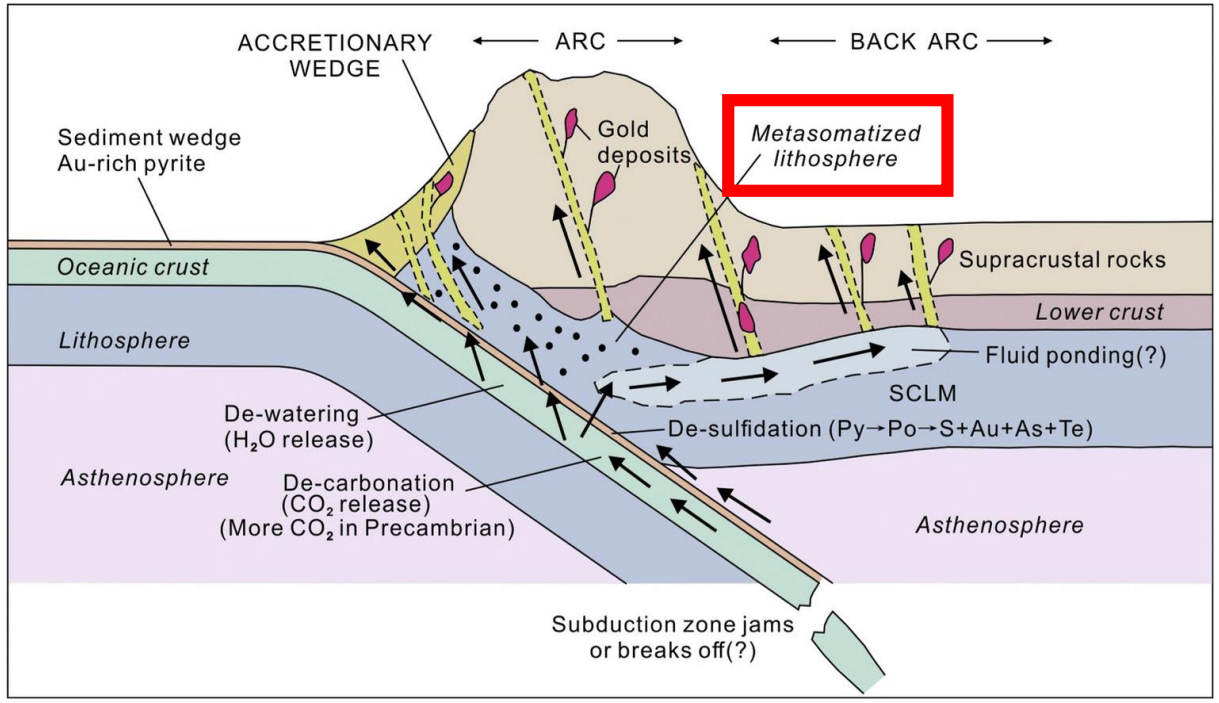
- **Shift in O-isotopes is in both cratons followed by major gold mineralisation events:**
- **Yilgarn Craton**: shift at ca. 2680 Ma → gold mineralisation: ca. 2675 Ma
- **Superior Craton**: shift at ca. 2705 Ma → gold mineralisation: ca. 2695 Ma
  - Also present in the West African Craton and Amazonian Craton – *(results in preparation by WAXI and SAXI teams)*



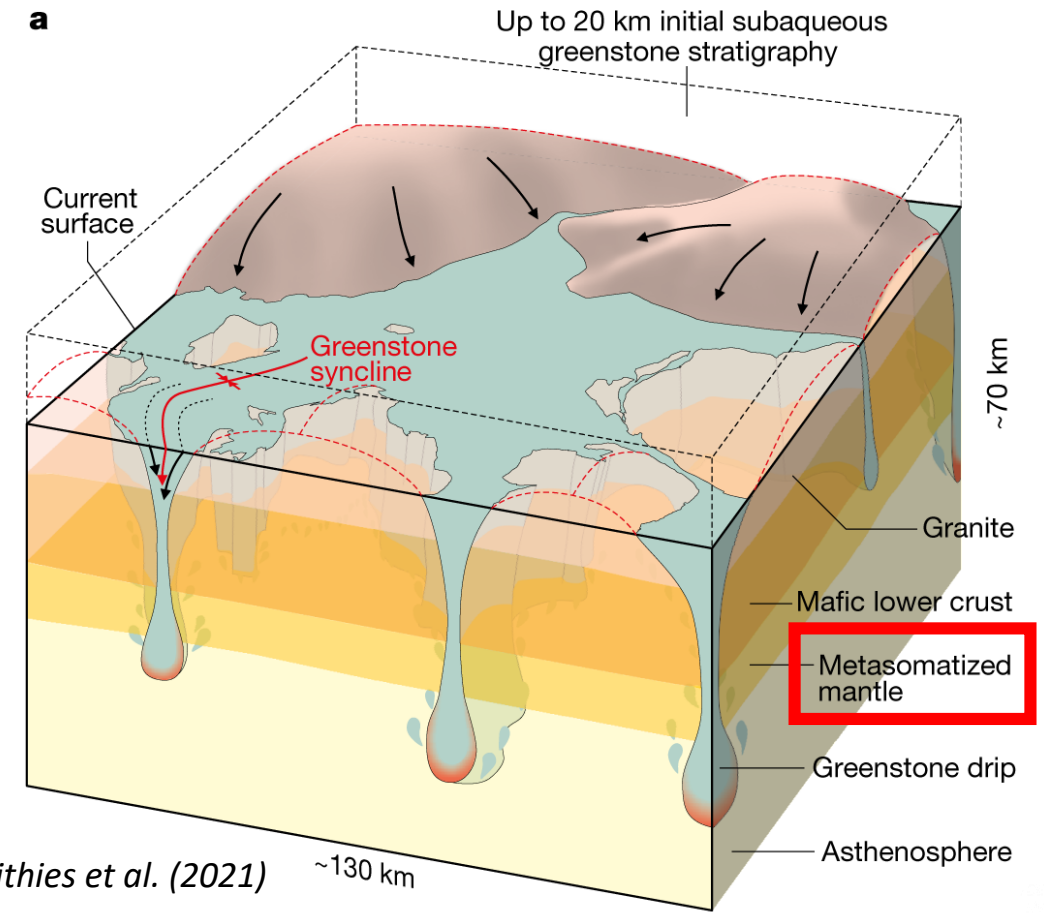
Archean geodynamics and gold mineralisation

Did a geodynamic shift preceded significant Neoarchean gold mineralisation?

- The onset of <u>significant</u> subduction?
- Lower crustal foundering (delamination, dripping)?
- Result of cratonisation?



Groves et al. (2020)



Smithies et al. (2021)

Conclusions

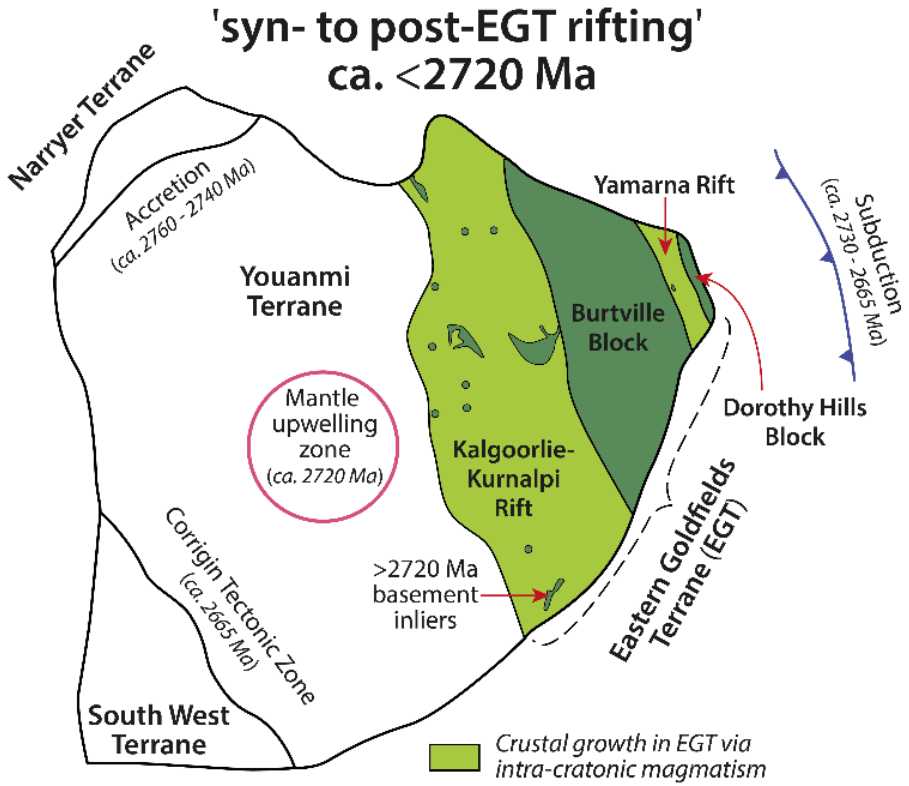
1. A relatively old (2840 – 2775 Ma) crustal block exists at the eastern edge of the Yilgarn Craton

2. Eastern Goldfields Terrane formed via **sustained, autochthonous crustal growth**
   - **Dorothy Hills and Burtville blocks**: craton-margin magmatism
   - **Yamarna and Kalgoorlie-Kurnalpi rifts**: intra-cratonic magmatism

3. **Neoarchean geodynamic shift** in Archean cratons may have resulted in the major gold endowment

Exploration Targeting

- Identification of cratonic and intra-cratonic <u>margins</u>
- Gold mineralisation towards the end of cratonic cycles → <u>older and younger regions</u> are both prospective!
  (see also Gruyere gold deposit poster)



THE UNIVERSITY OF WESTERN AUSTRALIA

Centre for EXPLORATION TARGETING

YILGARN 2020

GOLD ROAD RESOURCES

GOLD FIELDS

Evolution MINING

BHP

NORTHERN STAR RESOURCES LIMITED

Creasy Group

mriwa Minerals Research Institute of Western Australia

QUT

Geological Survey of Western Australia

Yilgarn Craton – updated nomenclature

Four major terranes:

- Narryer Terrane
- Youanmi Terrane
- South West Terrane
- **Eastern Goldfields Terrane**
  - **Burtville and Dorothy Hills blocks** (>2720 Ma)
  - **Kalgoorlie-Kurnalpi and Yamarna rifts** (<2720 Ma)