Multiply reactivated crustal-scale structures and a long lived counter-clockwise $P$–$T$ path: New insights into the 1.5 b.y. tectonothermal evolution of the eastern Arunta Region

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Regional geology of central Australia
1:100k maps and notes of JINKA and JERVOIS RANGE

Detailed versions of the maps are shown on the Arunta Region foyer poster
Geophysical Interpretation

TMI_RTP_TDR: Total Magnetic Intensity _ Reduced To Pole _ Tilt angle Derivative
brittle faults along contact between Aileron Province and Georgina Basin
shear zones along contact between Aileron and Irindina provinces
Geophysical Interpretation

- NNW-trending structures
- NNE-trending structures
- WNW-trending structure

- area of presented geological evolution

- Delny Shear Zone
- Bonya Hills
- Jervois Range
- Charlotte Fault
- Bonya Fault zone
- Jervois Fault zone
- Lucy Creek Fault

- DNEIPER
- JINKA
- HUCKITTA
- JERVOIS RANGE
- Bonya Fault zone
- Jervois Fault zone
- Lucy Creek Fault
Geological evolution in JERVOIS RANGE

At ca 1.79–1.78 Ga:

- **deposition** of oldest exposed rocks: pelites, sandstones, carbonates of Bonya Metamorphics (*maximum deposition ages ca 1.81–1.79 Ga)*

- **syndepositional bimodal magmatism** (*igneous crystallisation ages ca 1.79–1.78 Ga*)

- **syngenetic Cu-Ag(Pb-Zn)** massive sulfide mineralisation (*galena Pb model ages 1.79–1.77 Ga*)

- **first deformation event D₁**: extensional shear (*deformed xenoliths in mafic bodies*)
Geological evolution in JERVOIS RANGE

At ca 1.79–1.78 Ga:
- deposition of oldest exposed rocks: pelites, sandstones, carbonates of Bonya Metamorphics \((\text{maximum deposition ages ca 1.81–1.79 Ga})\)
- syndepositional bimodal magmatism \((\text{igneous crystallisation ages ca 1.79–1.78 Ga})\)
- syngenetic Cu-Ag(Pb-Zn) massive sulfide mineralisation \((\text{galena Pb model ages 1.79–1.77 Ga})\)
- first deformation event \(D_1\): extensional shear \((\text{deformed xenoliths in mafic bodies})\)

possible geological setting: \textbf{back-arc basin}

- extensional structures during \(D_1\)
- whole rock major and trace elements of bimodal rocks
- contact metamorphism: high-thermal gradient

![Diagram of geological evolution](image-url)
Geological evolution in JERVOIS RANGE

At ca 1.76 Ga:

- first recognised activity along the Delny Shear Zone with **normal, dip-slip movement** in proto-mylonites and mylonites in a Palaeoproterozoic orthogneiss

*proto-mylonite: dip-slip, S-down*

**dating of Monazite grown in proto-mylonite foliation**

by LA-ICP-MS *in situ* $^{207}\text{Pb}/^{206}\text{Pb}$

ca 1.76 Ga
Geological evolution in JERVOIS RANGE

At ca 1.76 Ga:

- first recognised activity along the Delny Shear Zone with **normal, dip-slip movement** in proto-mylonites and mylonites in a Palaeoproterozoic orthogneiss
- formation of the **main foliation S_2** during **extensional D_2** north of Delny Shear Zone; peak-T

S_2 = ca 1.76 Ga

Monazite LA-ICP-MS in *situ* \(^{207}\text{Pb}/^{206}\text{Pb}\)

X-ray map of K-concentration

S_2 foliated Cordierite-Andalusite meta-pelitic schist from Jervois Range

Peak Temperature 510-620°C at 0.1-0.3 GPa

melt-bearing fields (no melt observed)
Geological evolution in JERVOIS RANGE

At ca 1.76 Ga:

- first recognised activity along the Delny Shear Zone with normal, dip-slip movement in proto-mylonites and mylonites in a Palaeoproterozoic orthogneiss
- formation of the main foliation $S_2$ during extensional $D_2$ north of Delny Shear Zone
- normal, dextral movement along Jervois Fault zone forming extensional $S_3$ mylonites at ca 1.76 Ga

**S_2 testing hypothesis $S_3 = ca 1.76??? Ga:**

*in situ* Monazite dating under way!
Geological evolution in JERVOIS RANGE

At ca 1.76 Ga:

- first recognised activity along the Delny Shear Zone with **normal, dip-slip movement** in proto-mylonites and mylonites in a Palaeoproterozoic orthogneiss
- formation of the **main foliation S₂** during **extensional D₂** north of Delny Shear Zone
- **normal, dextral movement** along Jervois Fault zone forming **extensional S₃** mylonites at ca 1.76 Ga

→ **In this case**: contemporaneous **normal movement** along the **NNE (dextral)** and **NNW (sinistral)** trending structures (**conjugate set**)
In a (near-)isotropic rock volume at simple shears the **primary shear zone** forms 45° from the main stress directions $\sigma_1$ and $\sigma_3$. **Secondary shear structures** form in a certain angle to the primary shear zone.

In case of, **for example**, dextral transtension the **Delny Shear Zone** formed as the primary structure and the **NNE** and **NNW** trending structures could have formed in the same stress field. Differences in angles are due to **anisotropy** in the crust, and not ideal strike-slip case. Normal movement dominates, the stress field must have been **extensional**.
Geological evolution in JERVOIS RANGE

Palaeoproterozoic:

In case of normal movement along primary and secondary structures in the Palaeoproterozoic: how did that influence the counter-clockwise $P–T$ path in hanging wall rocks?

Andalusite-Cordierite-Sillimanite meta-pelitic schist from Jervois Range

**Peak Temperature**

600-670°C at 0.2-0.3 GPa

melt-bearing fields (no melt observed)

Andalusite-Cordierite-Sillimanite meta-pelitic schist from Bonya Hills

**Peak Temperature**

510-620°C at 0.1-0.3 GPa

melt-bearing fields (no melt observed)
generic Palaeoproterozoic $P\text{-}T\text{-}t$ in central JERVOIS RANGE

- deposition in an active back-arc basin
- extensional $D_1$
- bimodal magmatism
- Cu-Ag(Pb-Zn) mineralisation

→ high-$T$ / low-$P$ metamorphism

ca 1.79–1.78 Ga
generic Palaeoproterozoic $P$–$T$–$t$ in central JERVOIS RANGE

ca 1.78–1.77 Ga
- intrusion of granitic melts from lower crustal levels: I-type and calc-alkaline
→ partly arc-like and intra-plate signature
- later deformed by $S_2$

Pressure

Temperature

ca 1.79–1.78 Ga

Surface

$S_2$
generic Palaeoproterozoic $P–T–t$ in central JERVOIS RANGE

- ca 1.76 Ga
  - thermal weakening
  - progressive deformation, extensional $D_2$
  - main foliation $S_2$, peak-$T$

- ca 1780–1770 Ma

- ca 1.79–1.78 Ga
generic Palaeoproterozoic $P\text{--}T\text{--}t$ in central JERVOIS RANGE

- strain localisation
- normal movements along primary and possibly secondary shear zones $D_3$
- granite intrusions: I-type and calc-alkaline
  \[ \rightarrow \text{peak}-P \text{ in hanging walls} \]
generic Palaeoproterozoic $P-T-t$ in central JERVOIS RANGE

c. 1.73–1.71 Ga
- cooling
- post-deformational granitic melt intrusion: I-type and S-type
- epigenetic W-Mo and Cu mineralisation, granitic fluids, leaching of Cu from mafic intrusions, concentrating in existing structures

c. 1.76–1.74 Ga

c. 1.76 Ga

c. 1.78–1.77 Ga

c. 1.79–1.78 Ga
generic Palaeoproterozoic $P–T–t–D$ in central JERVOIS RANGE

progressive deformation
extensional stressfield
normal shearing:
increasing $P$ of rocks in hanging wall

drawn extensional structures
possibly growth/ graben faults
Neoproterozoic re-activation as graben faults

basement at surface
deposition of lower Georgina Basin rift sediments in grabens
angular unconformity
tilted unconformity/palaeosurface
deformed basement

Neoproterozoic Georgina Basin siltstone (Mt Cornish Formation)

based on Greene, 2010, Tectonics, 29
Palaeozoic re-activation during Alice Springs Orogeny

Primary shear and secondary fault activity during sinistral transpression

after Coulang, 2014, ETH Zürich, script “Strike-slip faults” sinistral
Summary

- **main structures** found in HUCKITTA may partly have their **origin** during Palaeoproterozoic extension, progressive deformation and strain localisation.

- **normal movements** along these structures had a **direct influence on the** Palaeoproterozoic $P-T$ path of rocks in the hanging walls.

- The ca 100 my lasting **counter-clockwise $P-T$ path** was also influenced by heat input of continuous **magmatic intrusion of arc-like and intra-plate geochemical signature**.

- **Syngenetic base metal** mineralisation occurred during **deposition** of the host sediments and bimodal magmatism in a back-arc basin, later **epigenetic W-Mo and Cu** mineralisation related to **granitic fluids during cooling** of host rocks.

- **Reactivation** of structures occurred during Neoproterozoic extension, possibly during the **Larapinta Event extension** and during **compression in the Alice Springs Orogeny**.