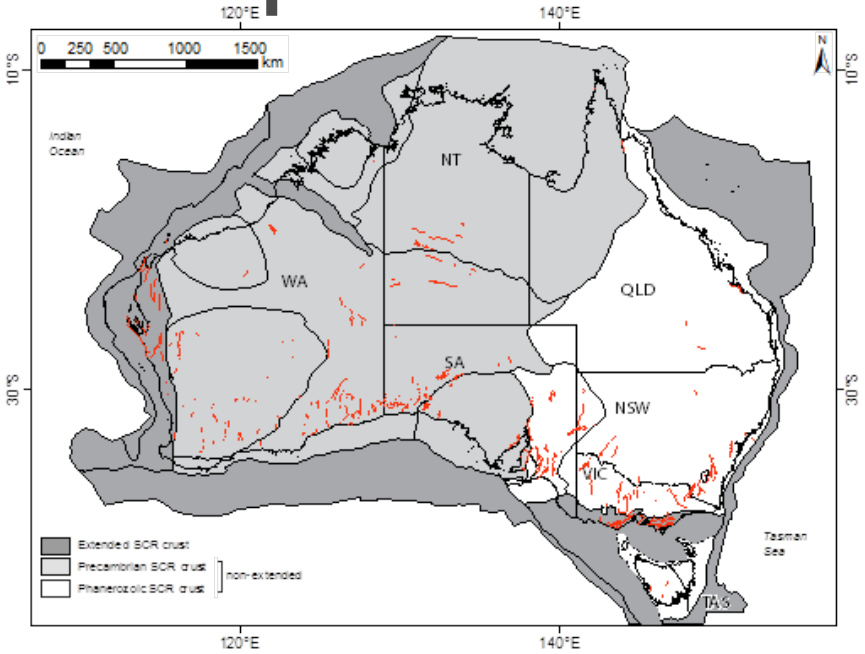
Australian Government
Geoscience Australia

Variation in earthquake surface rupture characteristics across intraplate Australia

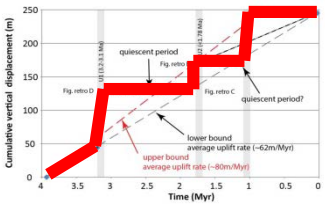
As they relate to fault displacement hazard assessment

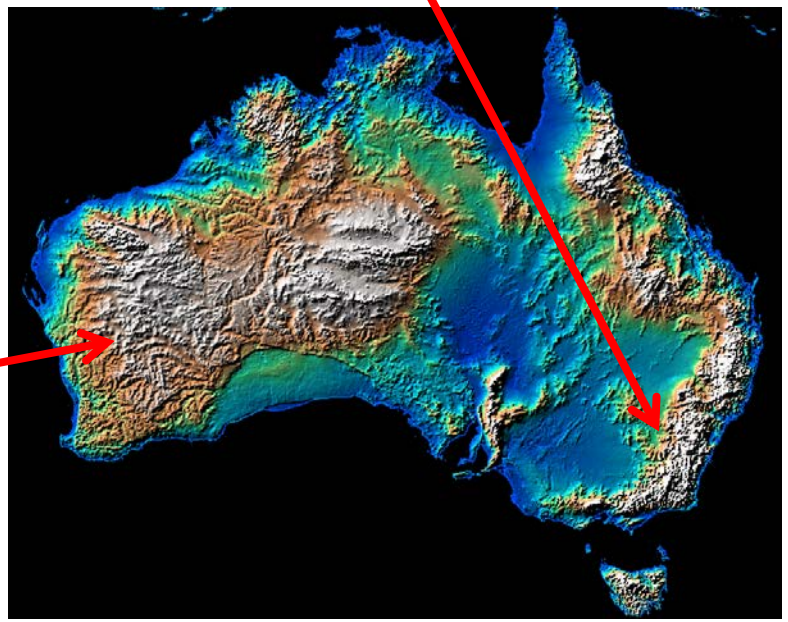


Dan Clark
Geoscience Australia
Community Safety Branch

FDHA - intraplate style

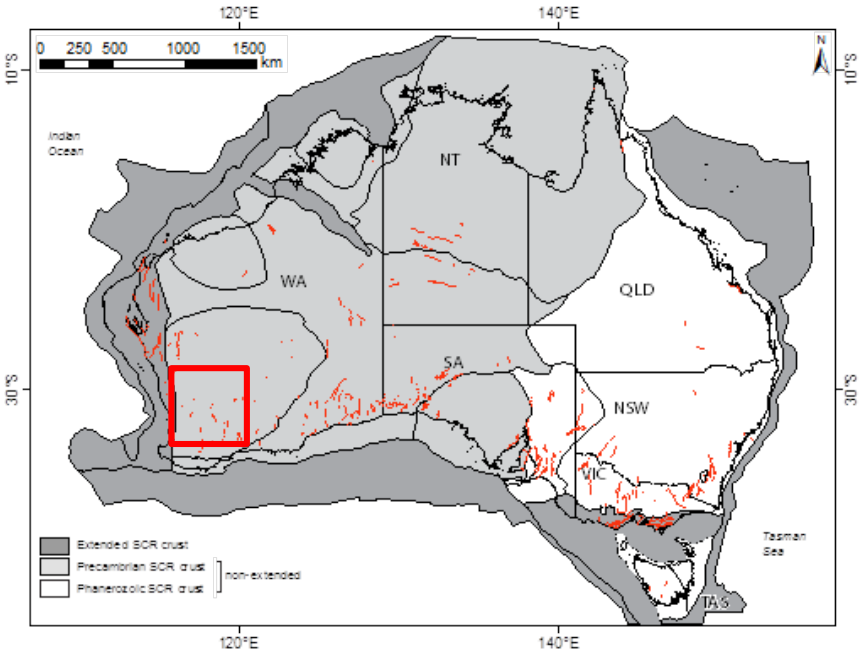
- Fault displacement hazard requires recurrence
- How should the term ‘recurrence’ be understood in the intraplate setting?
  - periodic
  - episodic
  - random
  - no recurrence, or ‘one-off’

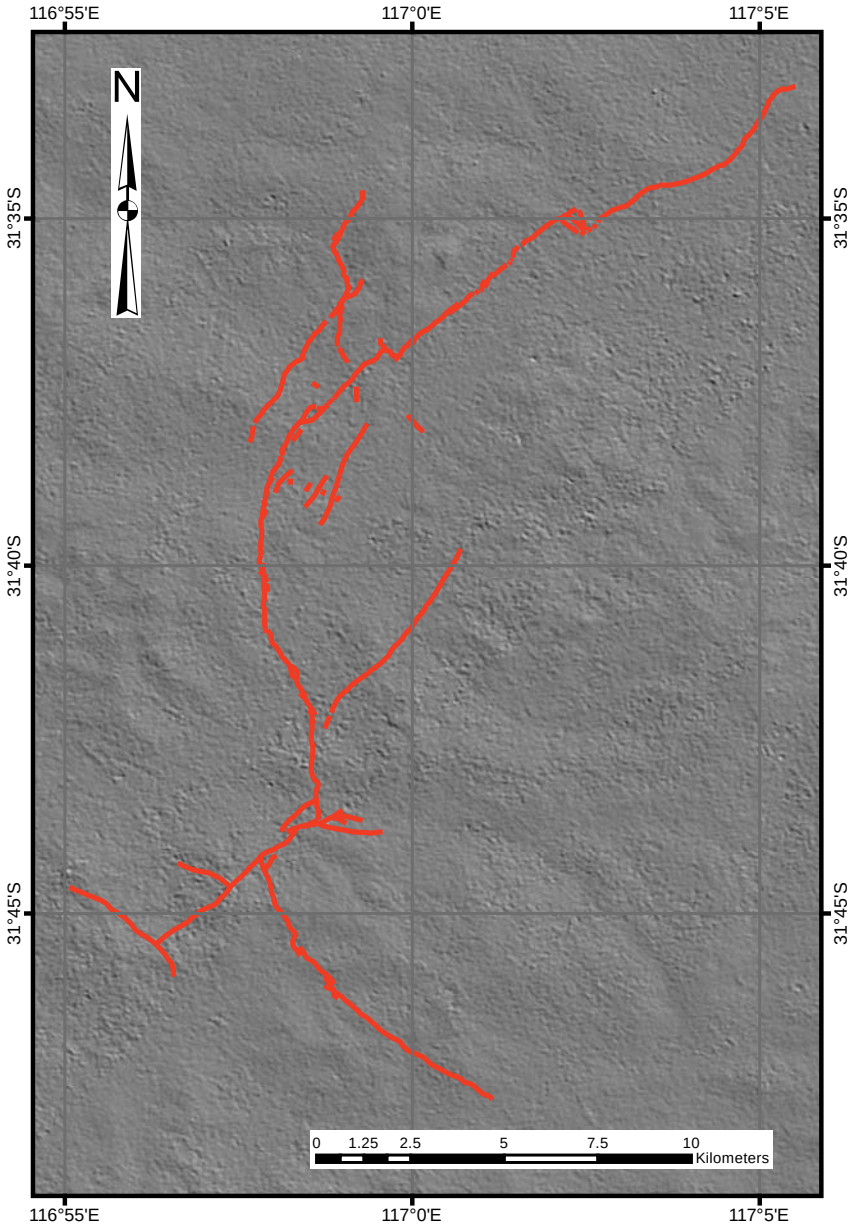




Cratonic domains

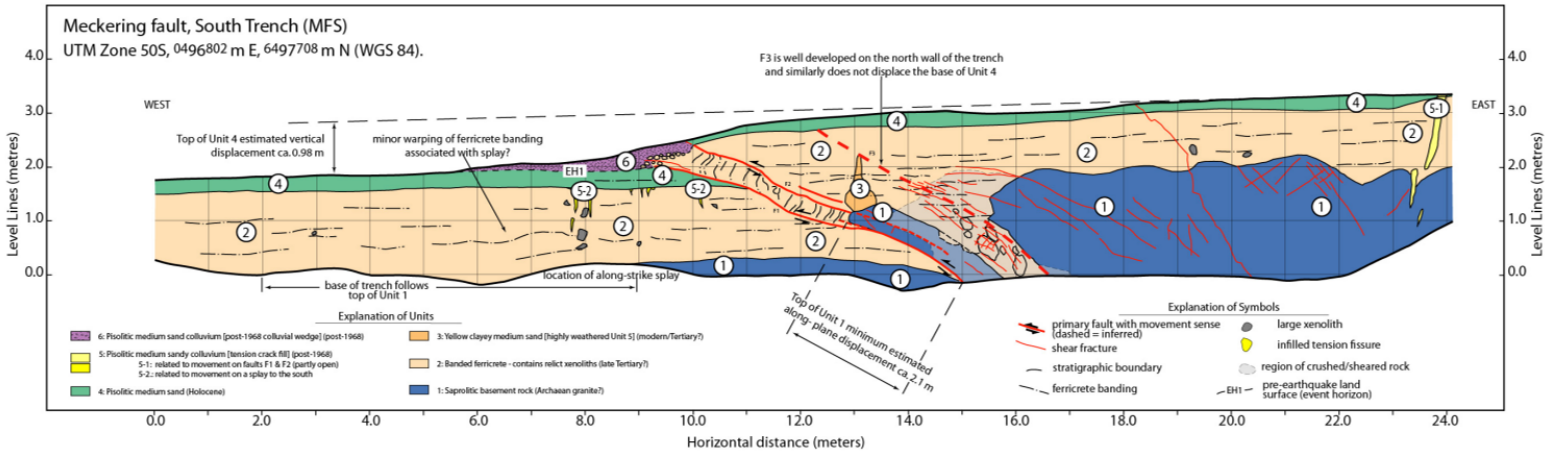
- short, complex scarps
- isolated
- little relief
- erosion rates 1-5 m/Myr



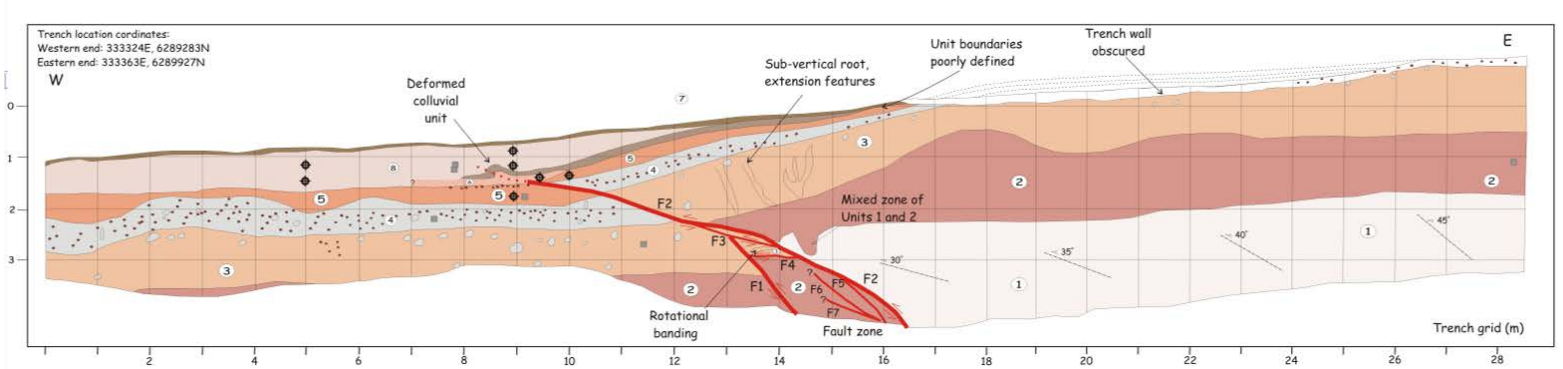


Cratonic Fault Characteristics

- 1-3 or 4 events in the last 100 kyr
- slip rate in last 100kyr ~0.01-0.03 mm/yr (10-30m/Myr)
- long term slip rate <0.001 mm/yr (<1m/Myr, so relief transient)



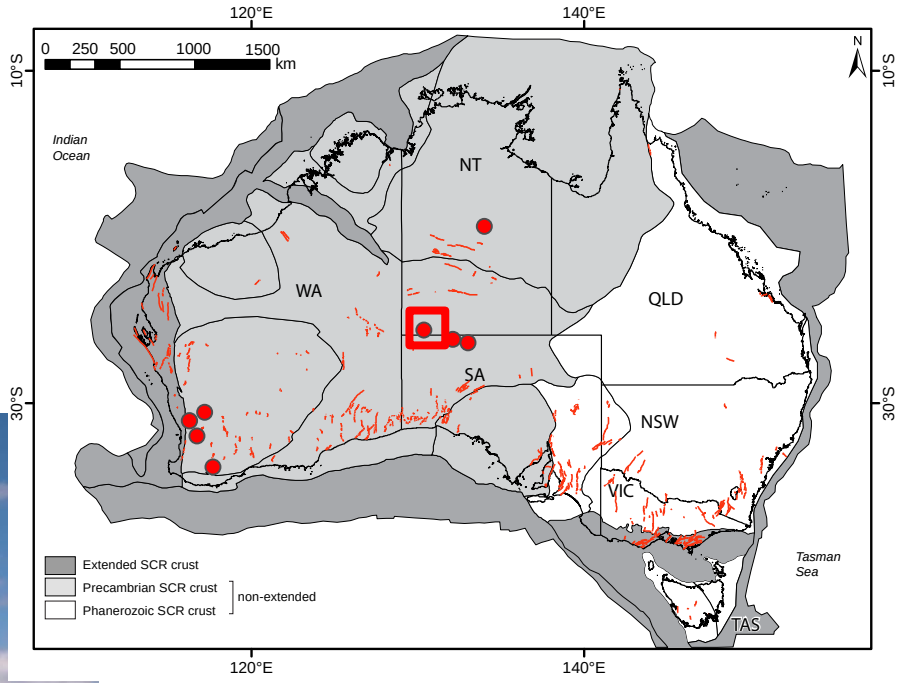
Meckering
1 event/
100kyr



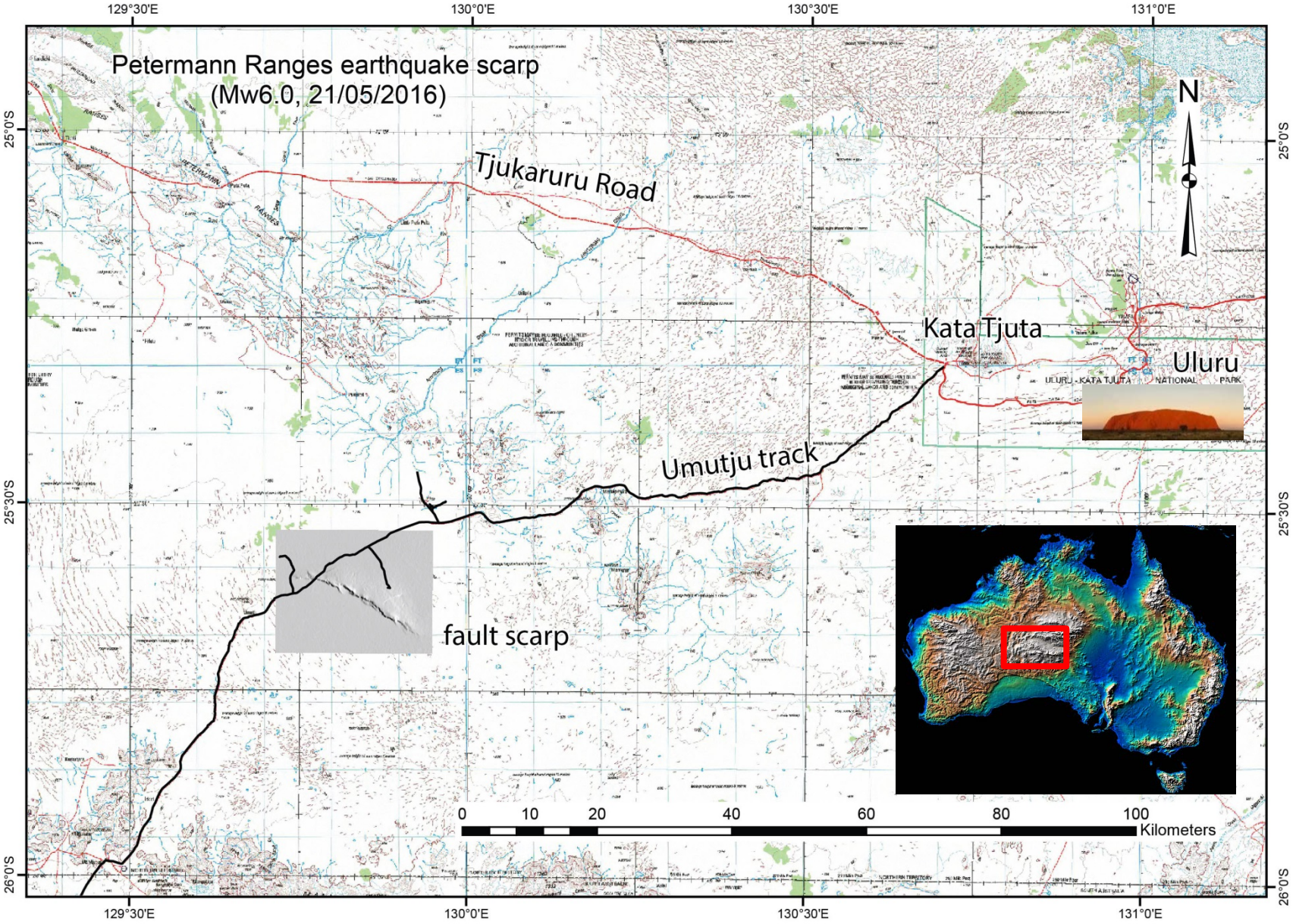
Lort River
3 events/
100kyr

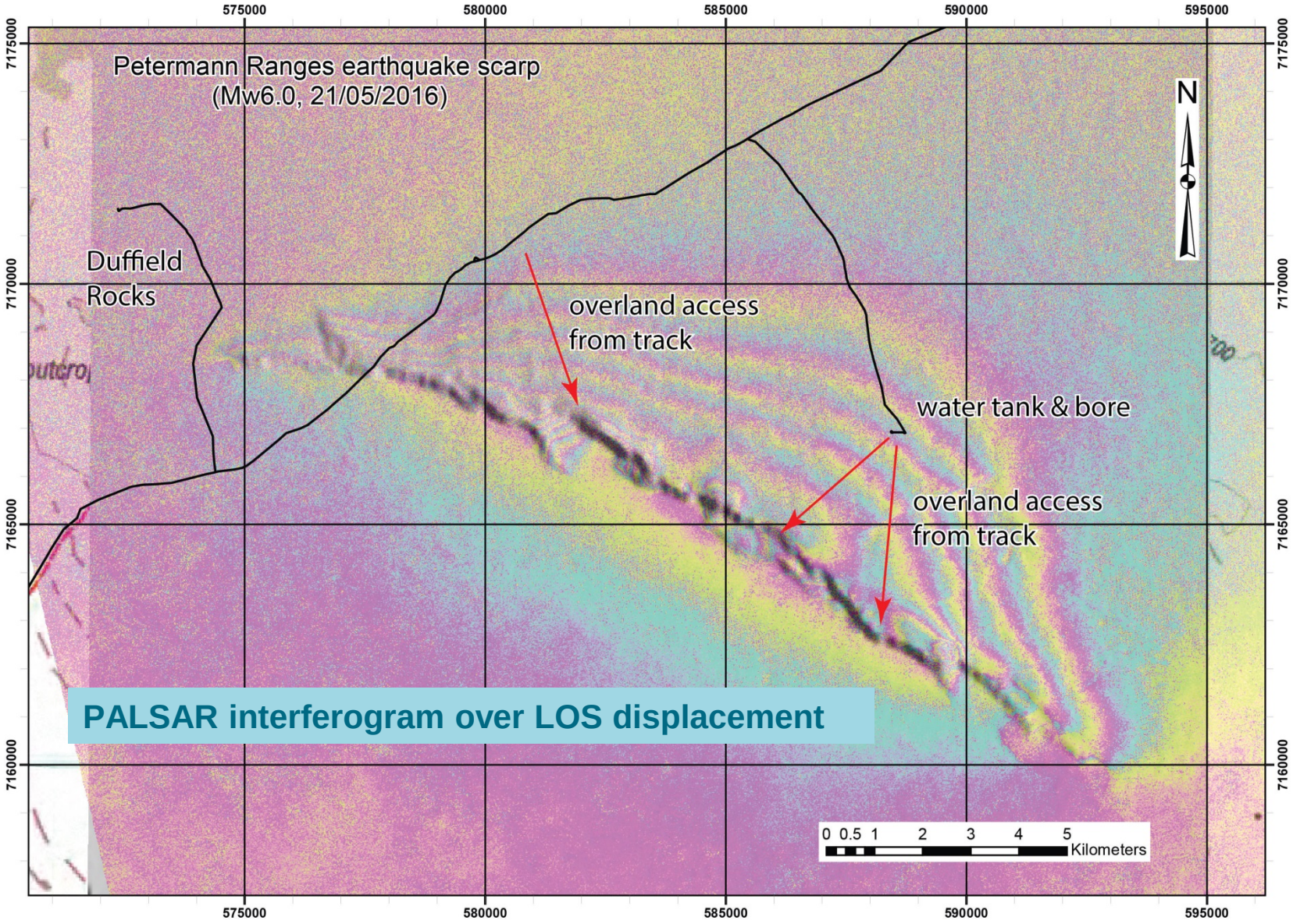
One-off ruptures in the cratonic domains?

- All historic surface ruptures occurred in unanticipated locations
- All in Cratonic Domains



May 21st 2016 Mw6.1 Petermann Ranges earthquake scarp



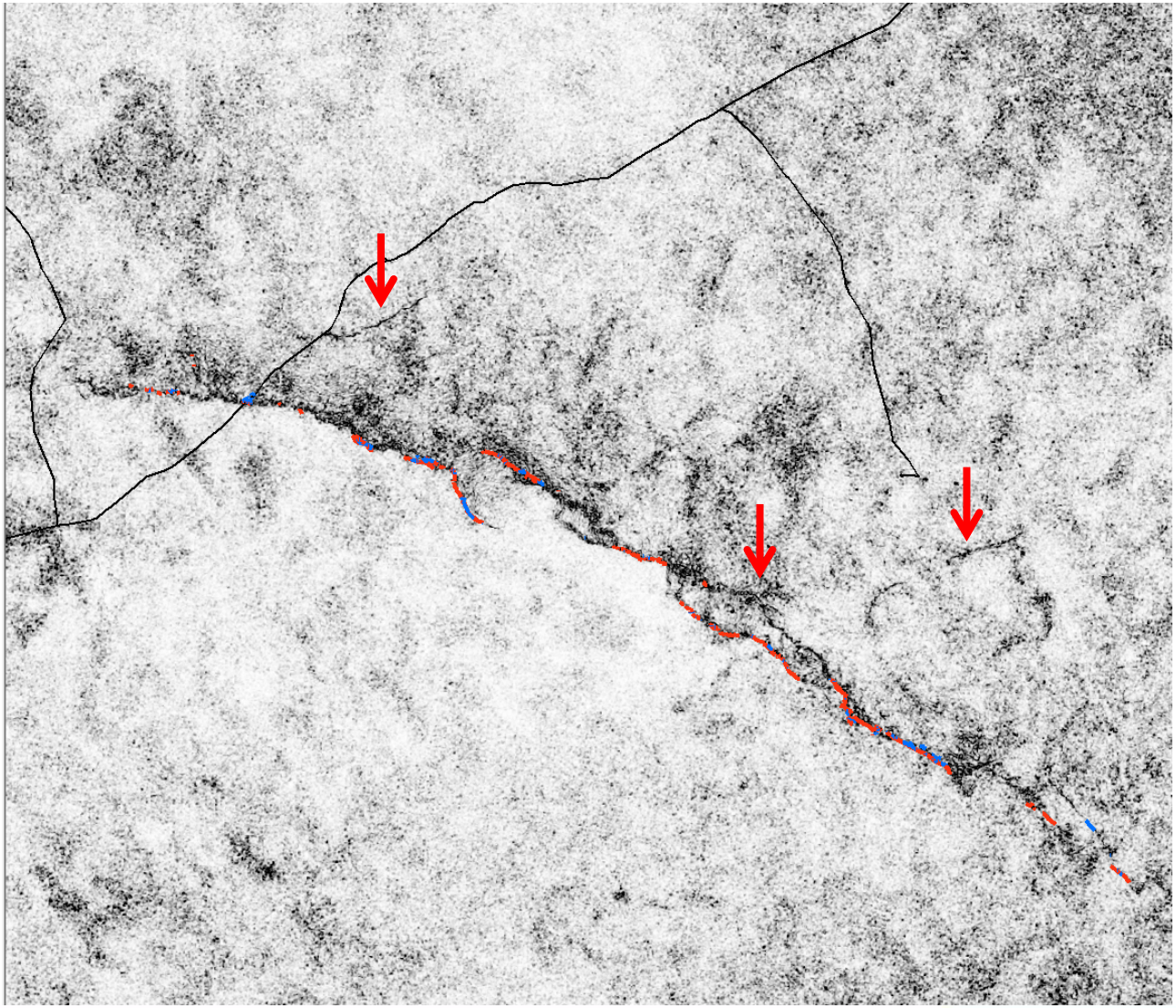


PALSAR interferogram over LOS displacement

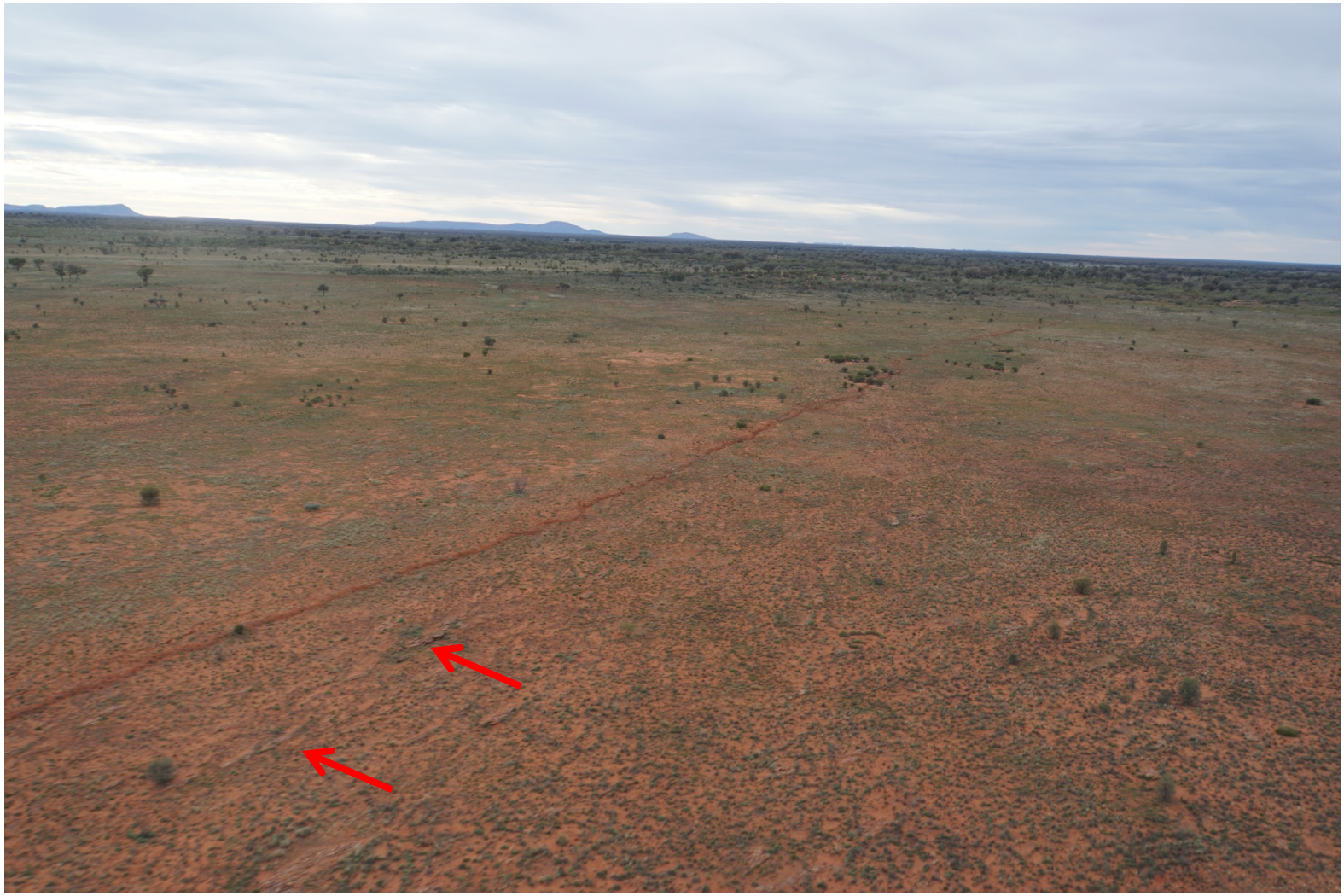
INSAR filtered coherence image

Shows exactly where displacement hazard was

Not only where we mapped a scarp



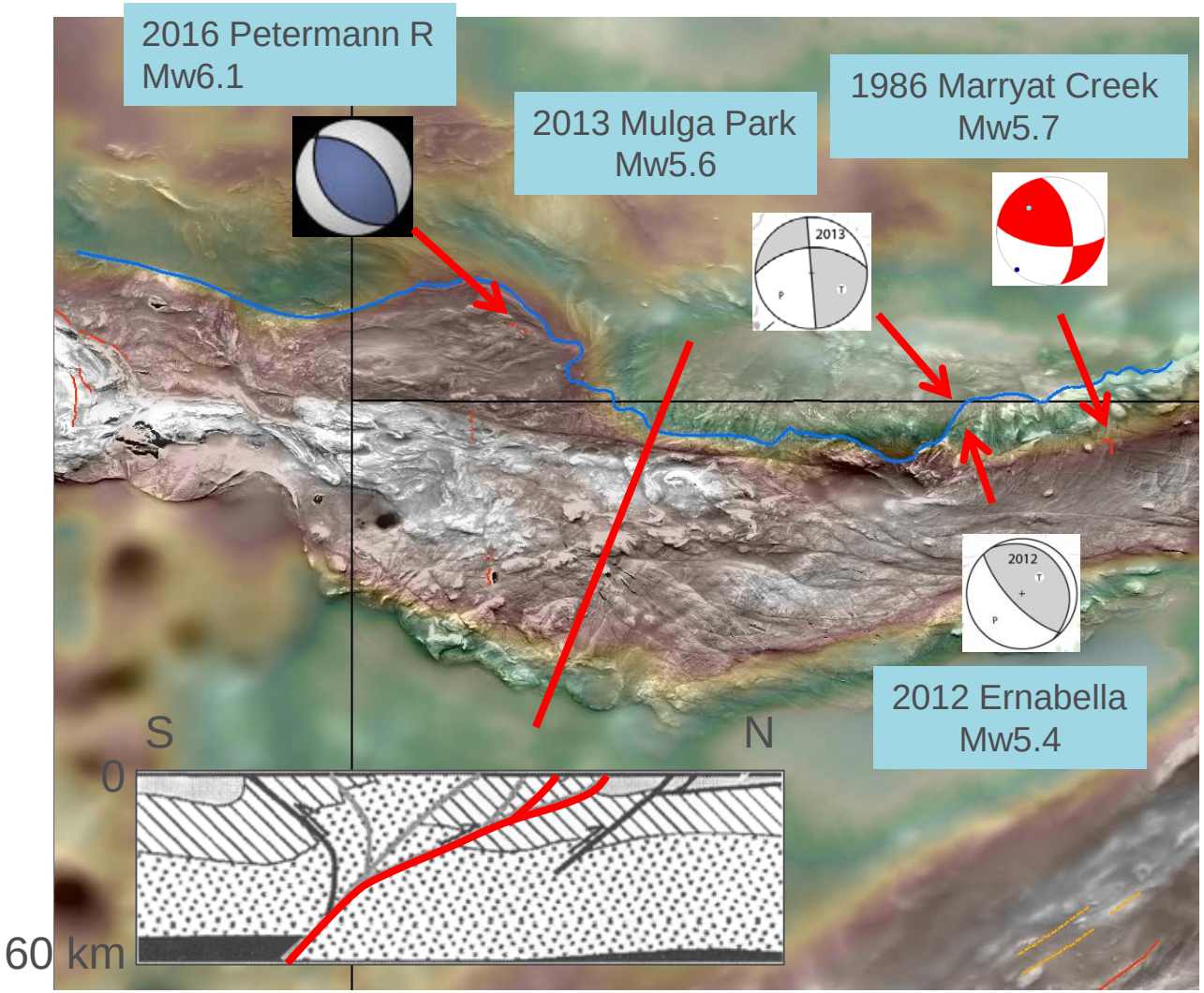
Recurrence? Note bedrock in footwall



Bedrock in the footwall = no recurrence

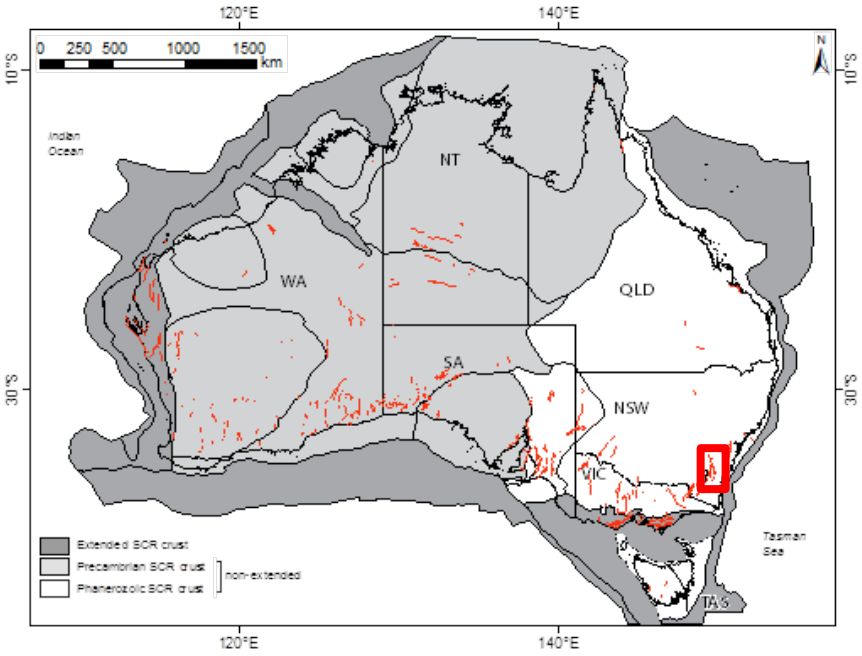
Spatially distributed recurrence?

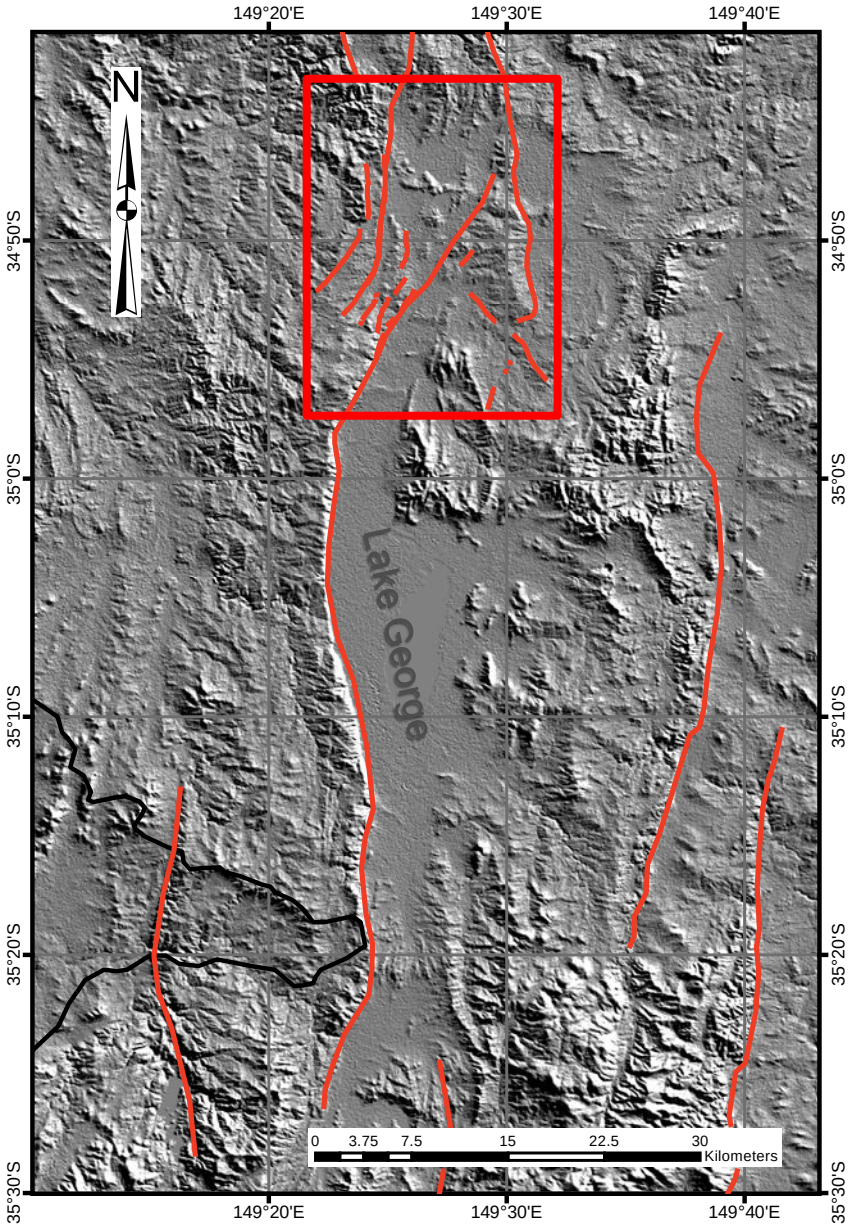
Events localised to the Woodroffe Thrust, a major Proterozoic to Cambrian intraplate fault system



Less ~~Non~~-cratonic

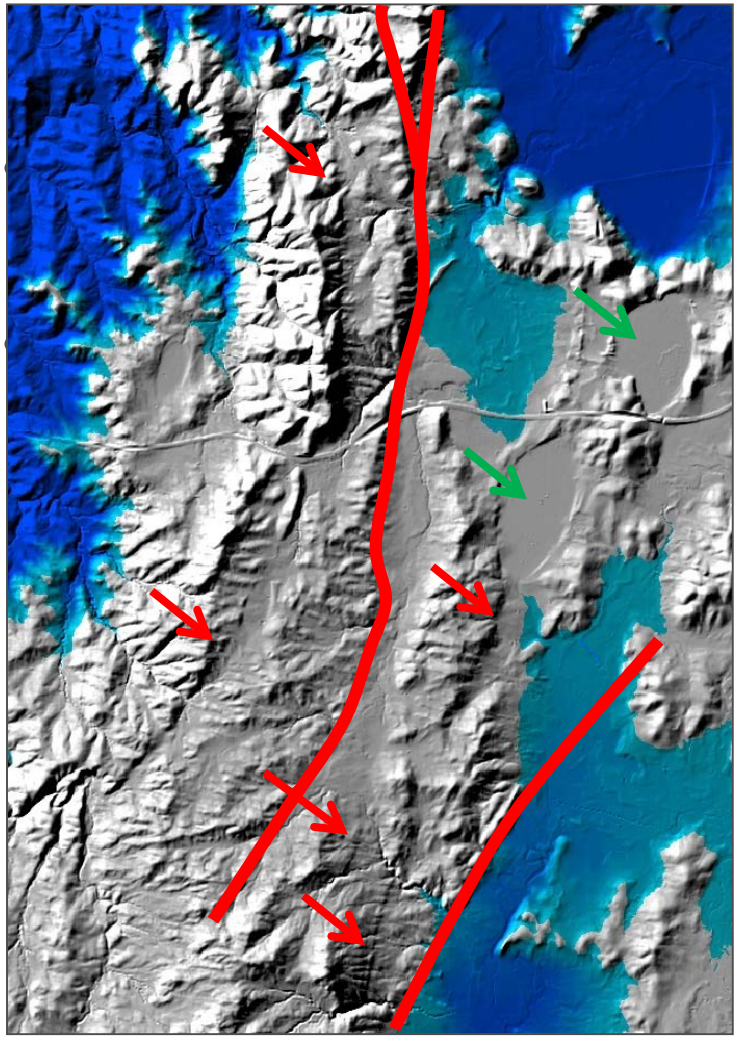
- no historic surface ruptures
- longer, linear, connected scarps
- significant relief = recurrence
- erosion rates 30-50 m/Myr



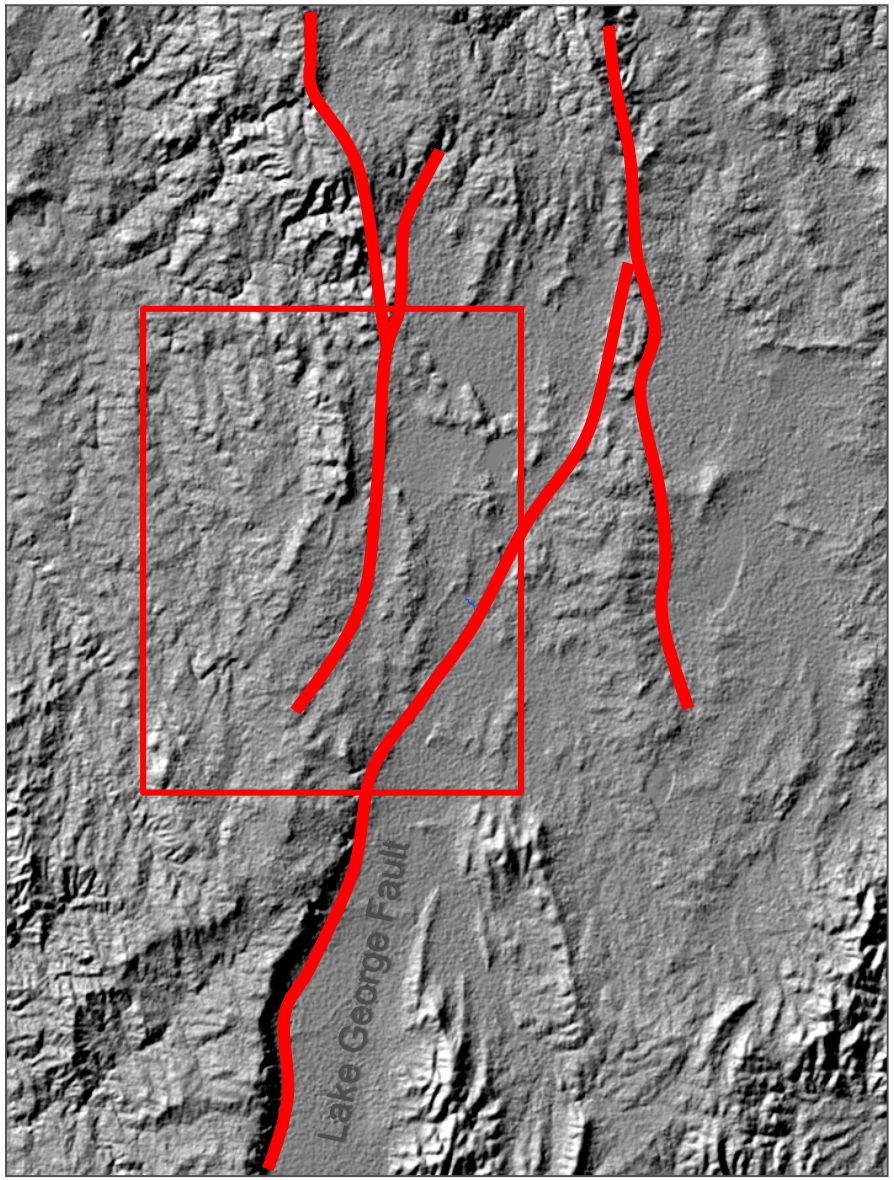


Complex linkages

LiDaR



SRTM

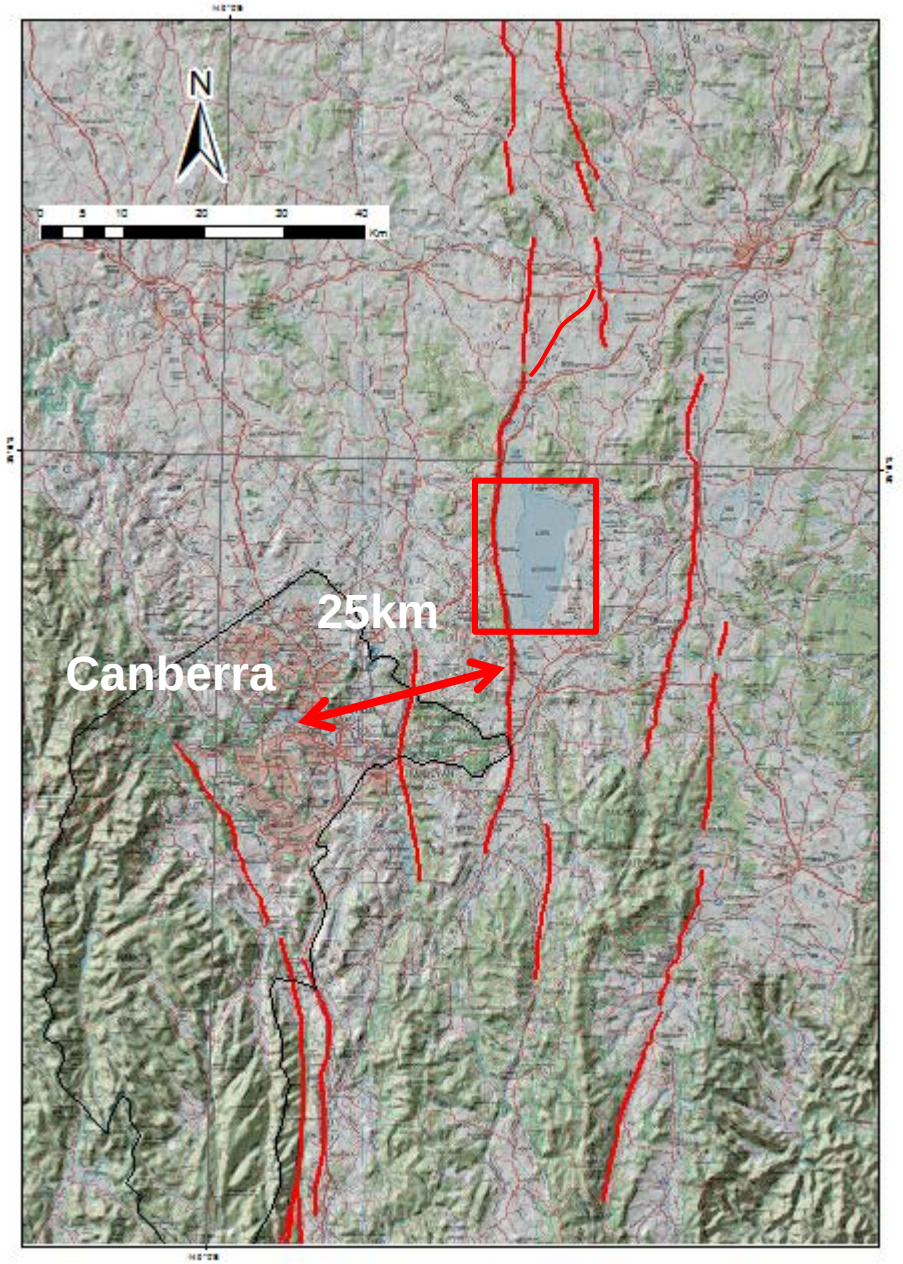


Recurrence in the non-cratonic domains?

The Lake George fault scarp and basin:

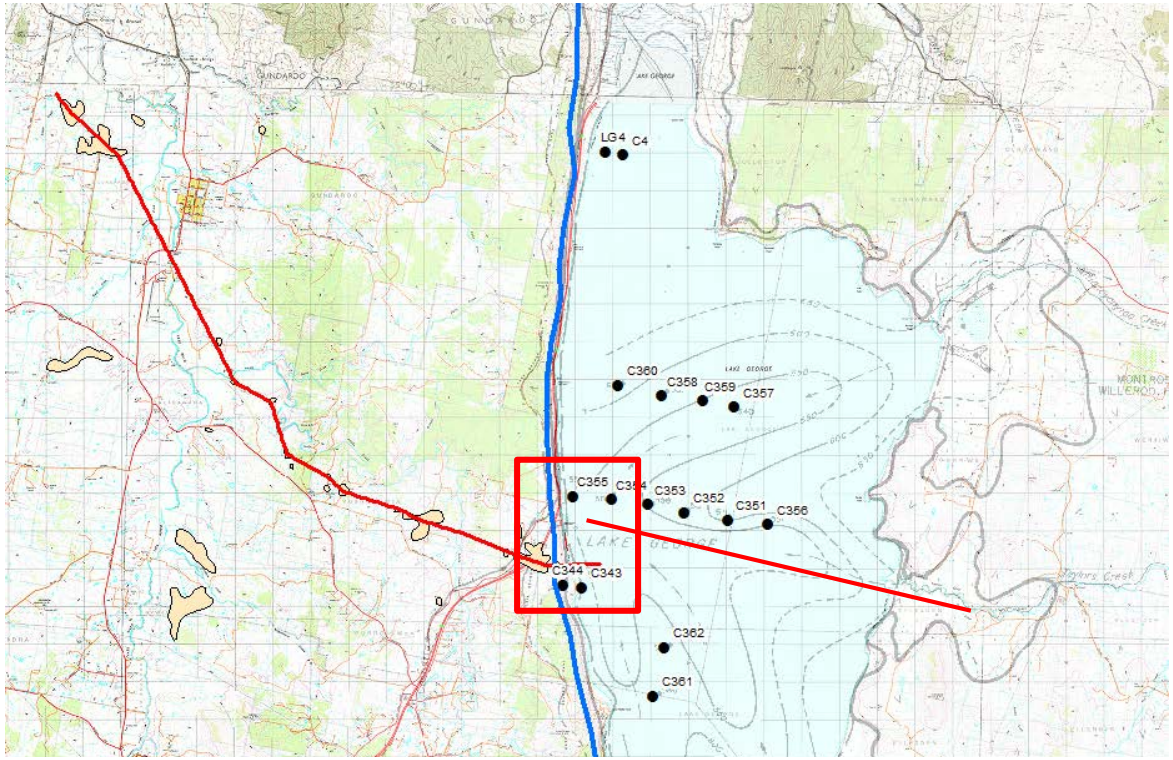
Ponds west flowing drainage

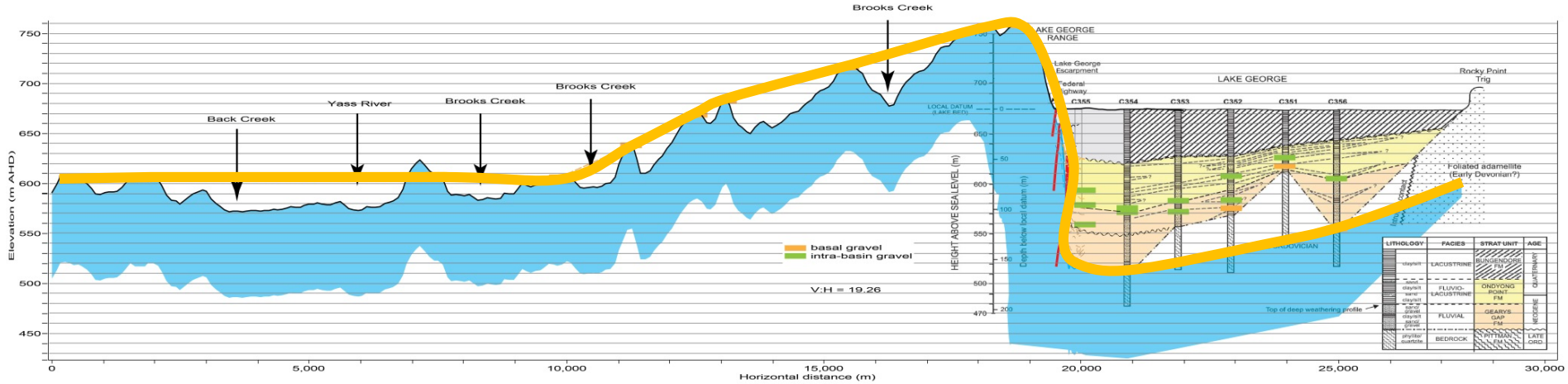
150 m thick sedimentary section



Basin <*ca.* 4 Myr

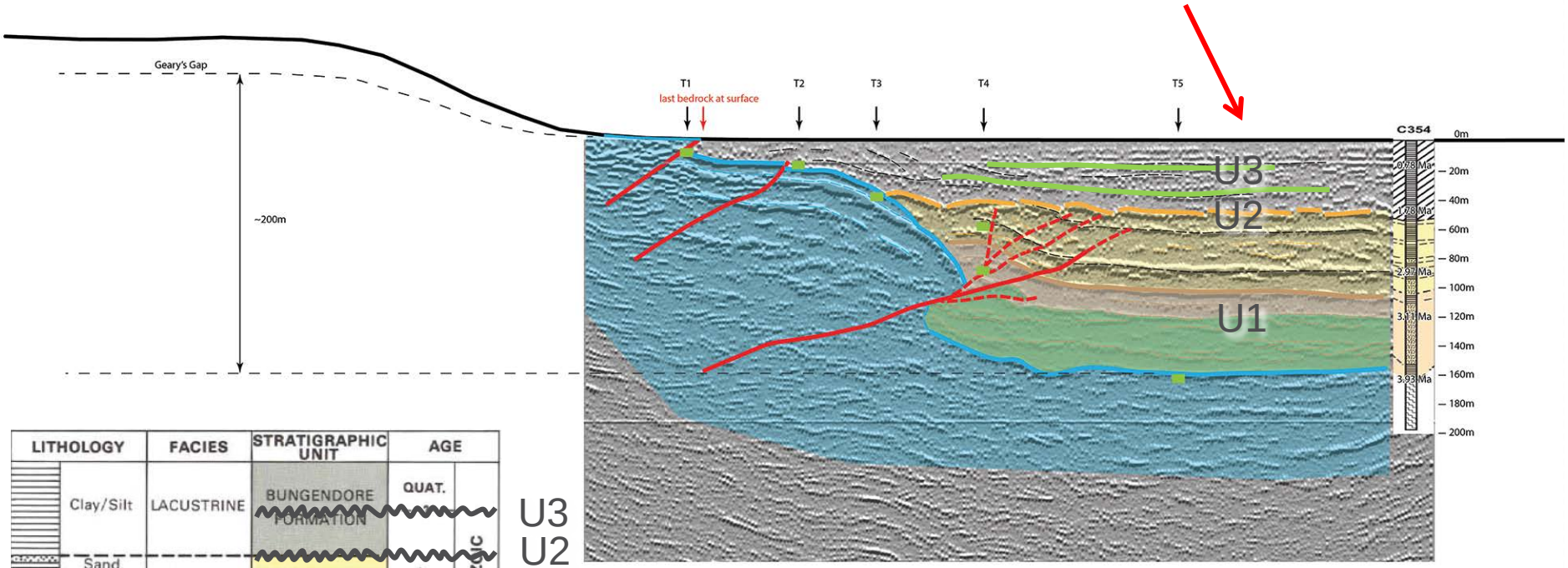
- Paleo-channel gravels extend from basin onto the hanging wall
- 250 m of <ca. 4 Myr vertical separation





Shallow seismic reflection data and interpretation

Angular unconformities with parallel strata in between



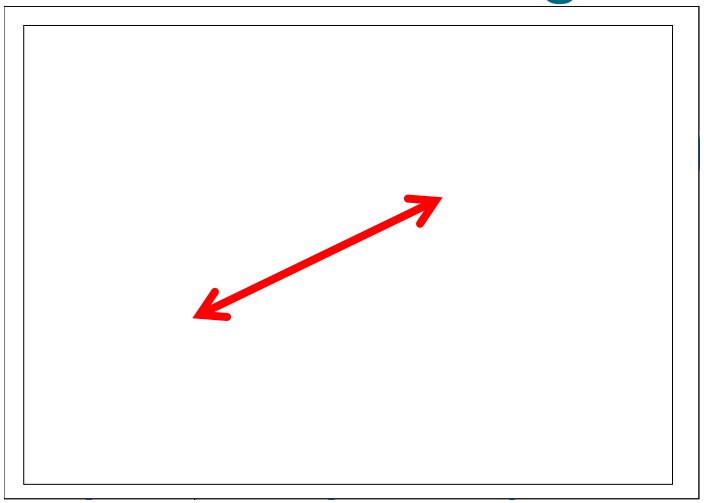
LITHOLOGY	FACIES	STRATIGRAPHIC UNIT	AGE	
Clay/Silt	LACUSTRINE	BUNGENDORE FORMATION	QUAT.	
Sand Clay/Silt Sand Clay/Silt	FLUVIO-LACUSTRINE	ONDYONG PT FORMATION	TERTIARY	CAINOZOIC
Gravel/ sand/ silty clay	FLUVIAL	GEARYS GAP FORMATION		
Phyllite/ Quartzite	BEDROCK	PITTMAN FORMATION	LATE ORD.	PALAEOZOIC

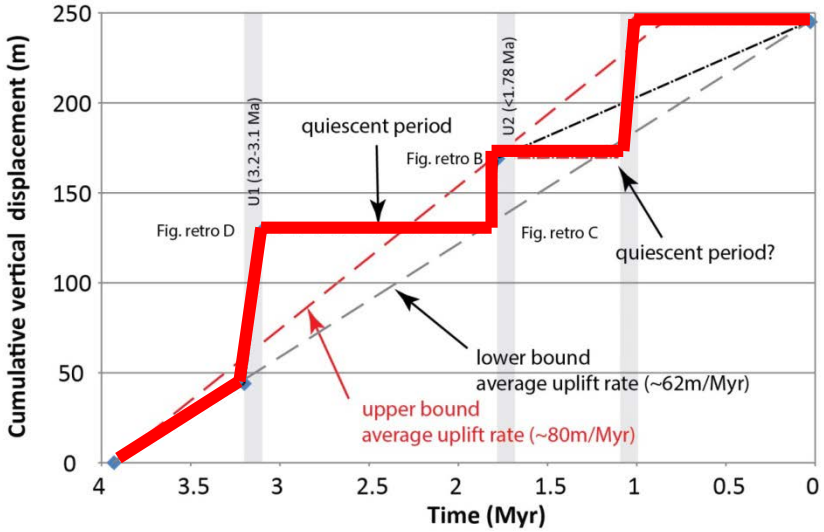
U3
U2
U1

V:H =1

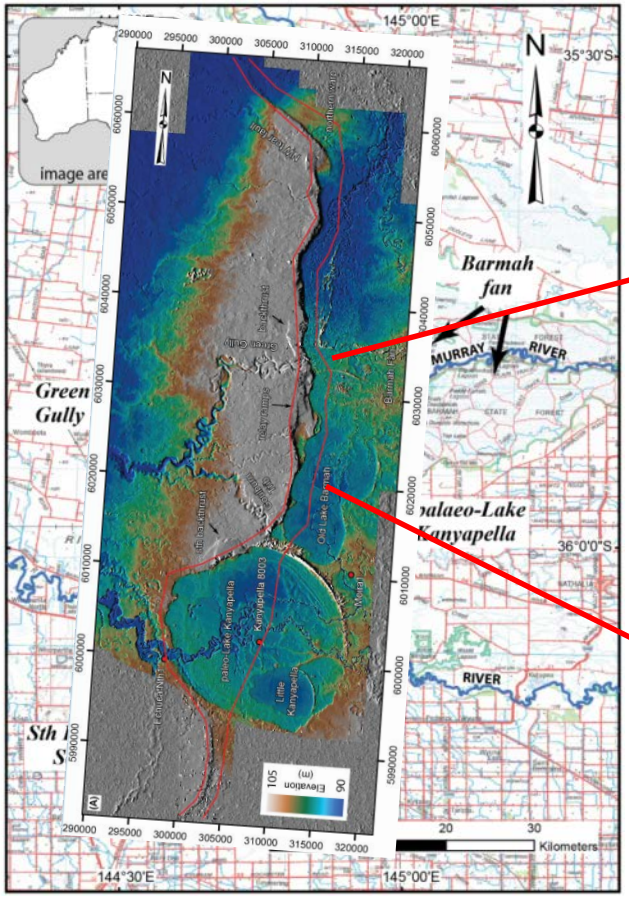
Contributions to seismic hazard understanding

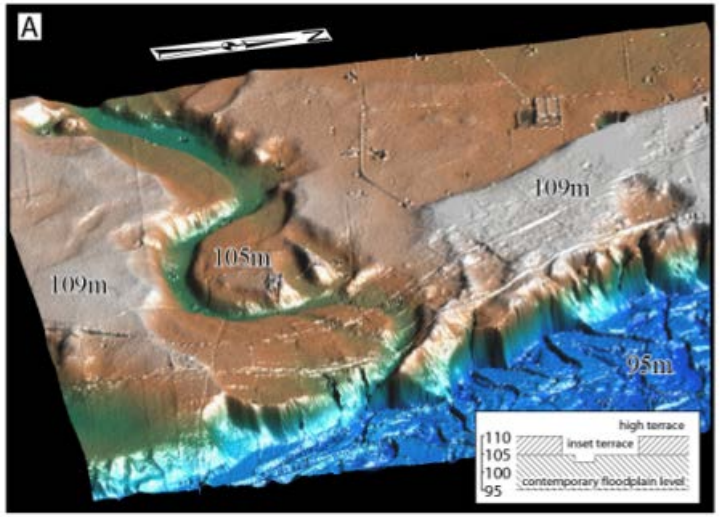
- Characteristic magnitude
  - 75 km long fault
    ~ Mw7.4
    60-80 m/Myr uplift rate
    <25km from Canberra
- Episodic recurrence
  - ~0.78 - 1.3 Myr quiescent periods separating active periods involving 40-70 m of uplift
  - Recurrence in an active period not yet known

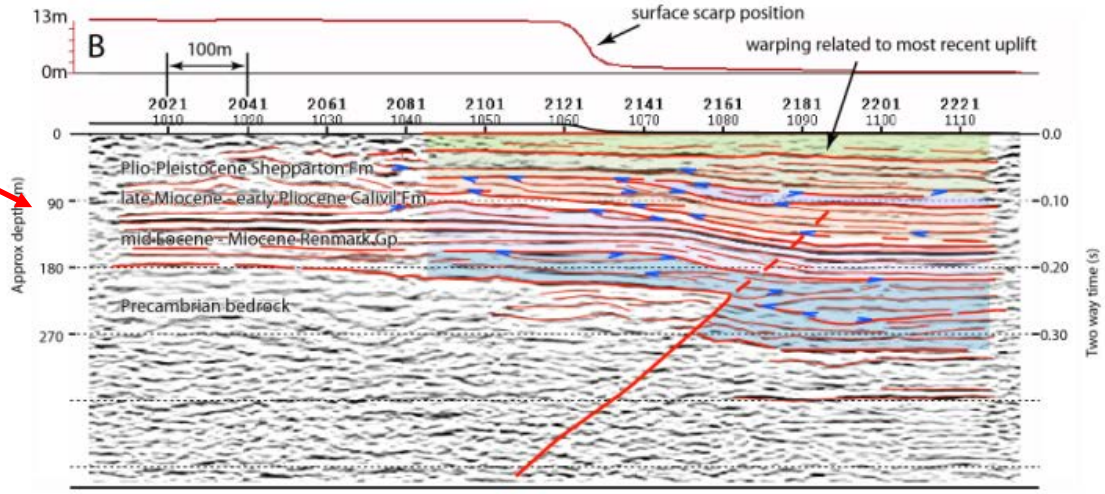




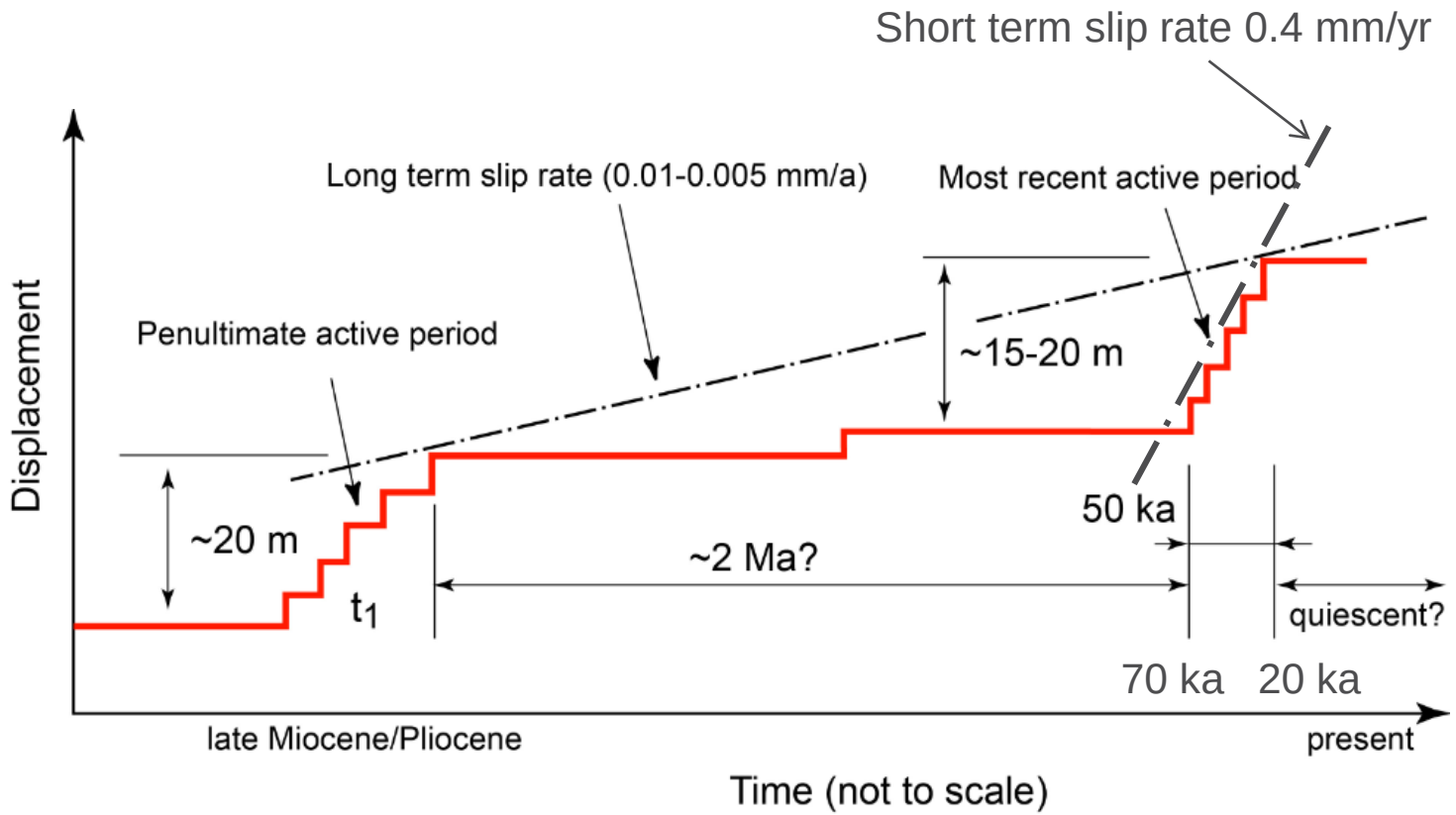
Recurrence in an active period? the Cadell scarp, NSW/Victoria







Clustered Cadell Fault rupture behaviour

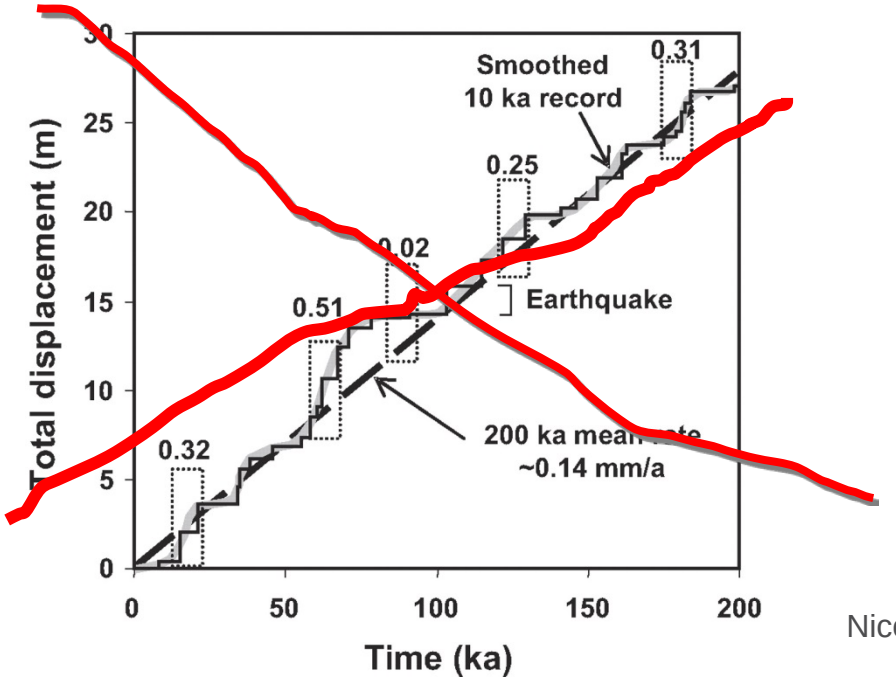


Clark *et al.* (2015) GSL Special Publication doi: 10.1144/SP432.2

Short term slip rate 400 m/Myr!
Recurrence for M7.4 ~ 8kyr on average

Plate margin recurrence/slip model

- Fairly regular build up of elastic strain and release as earthquakes
- Long term slip rates provide a reasonable estimate of activity at shorter time frames (i.e. for seismic hazard purposes)



not suitable for intraplate?

Nicol et al. 2009 Geology 10, 911-914

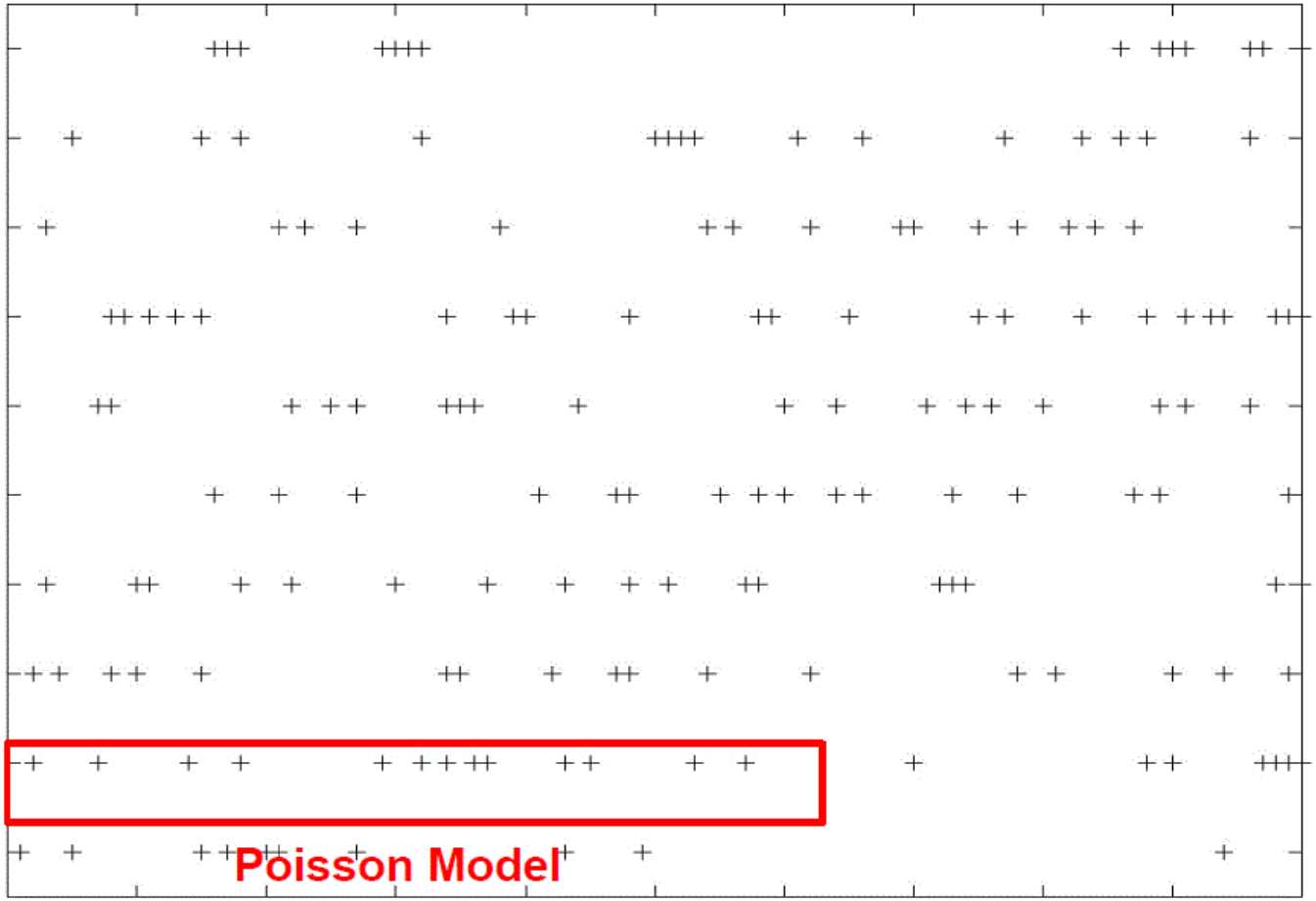
Random recurrence?

Random distribution of 15 events

For example number of M7 earthquakes in 100,000 years

Could very easily be interpreted as Episodic or Periodic or Random

Care is needed when inferring a pattern



Periodic with variable COV (McCalpin 2013)

increasing aperiodicity parameter

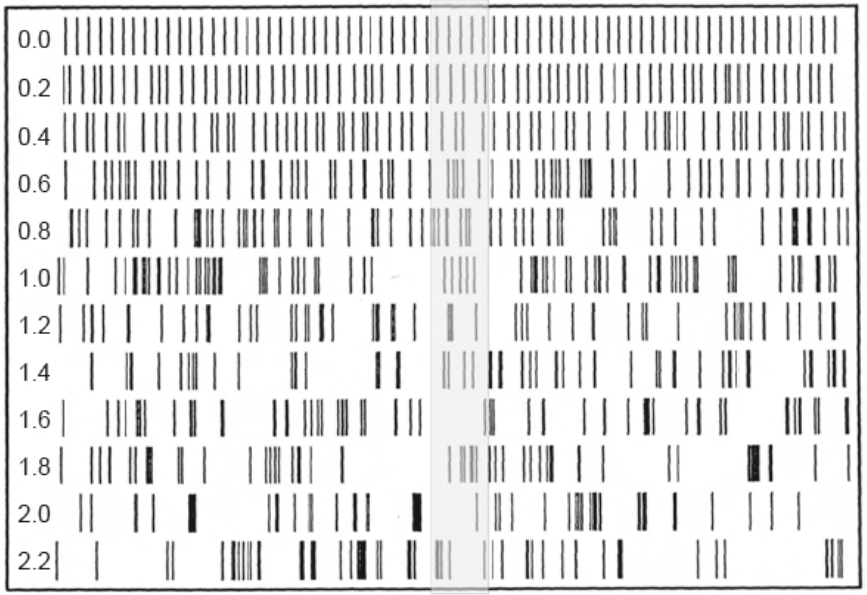


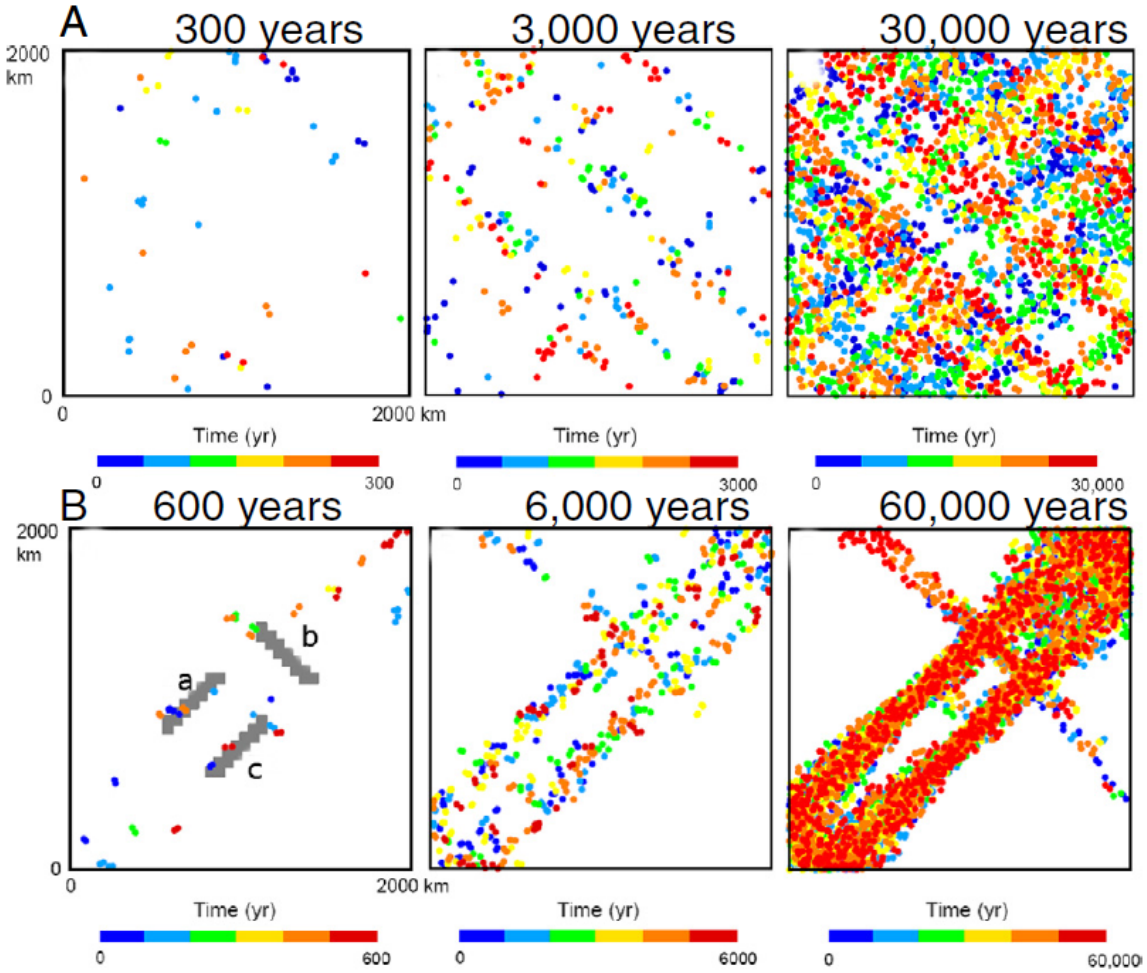
Figure 9.30: Visualization of the effect of the aperiodicity parameter η on the recurrence of earthquakes. Each row represents an earthquake history with time increasing to the right. The short vertical lines in each row represent 50 characteristic earthquakes drawn from a Weibull distribution of identical mean recurrence time, but with the aperiodicity parameter (equivalent to the coefficient of variation) increasing from 0 (top row) to 2.2 (bottom row). An aperiodicity of 0.0 represents perfectly periodic recurrence. As the aperiodicity parameter increases, the time series become less regular and more aperiodic or "temporally clustered." The gray rectangle represents an arbitrary time window that captures five earthquakes on average (about 10% of the earthquake history), and represents a typical detailed paleoseismic field study. Note that this short time window can be representative of the entire earthquake history, or unrepresentative, or somewhere in-between. Adapted from Ward (1992).

Omori's Law? (Liu *et al.* 2016, Calais *et al.* 2016)

Long lived 'stress pool': strain accumulation and release rates disparate.

Craton?

Non-Craton?



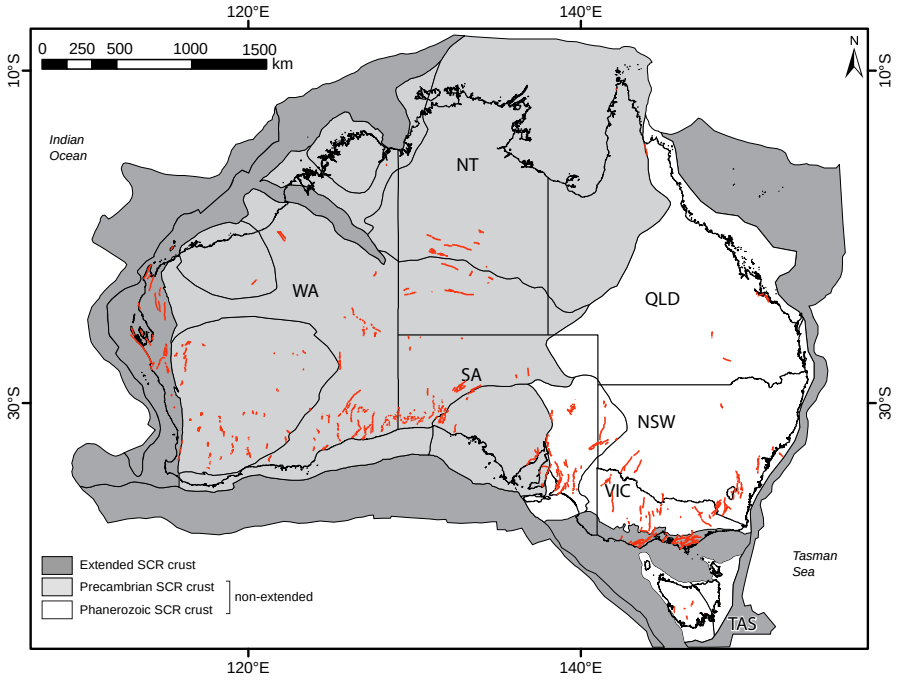
Fault displacement hazard: summary

CRATONIC (Archaean and non-reactivated Proterozoic): N/A?

- often complex rupture geometry and trace complexity
- recurrence not in a meaningful time frame for hazard?

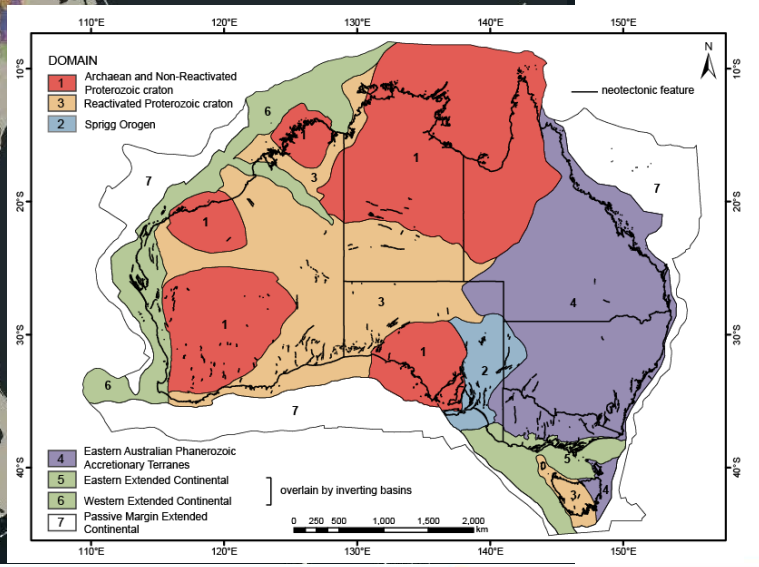
NON CRATONIC and EXTENDED

- little known about rupture geometry and trace complexity
- potential for recurrence
- recurrence in an active period drives hazard



Global Crustal Analogues

- Archaean and Proterozoic core of Nth America similar to non-extended cratonic (Precambrian) SCR crust
- Phanerozoic foldbelts (incl. Cheraw/Meers faults) similar to non-extended non-cratonic SCR crust
- Passive margins (Charleston source zone) and aulacogens (Reelfoot, Sth Oklahoma, Ottawa, Saguenay, Charlevoix) similar to elements of extended non-cratonic SCR crust



Australian Government
Geoscience Australia

Thankyou for your attention!

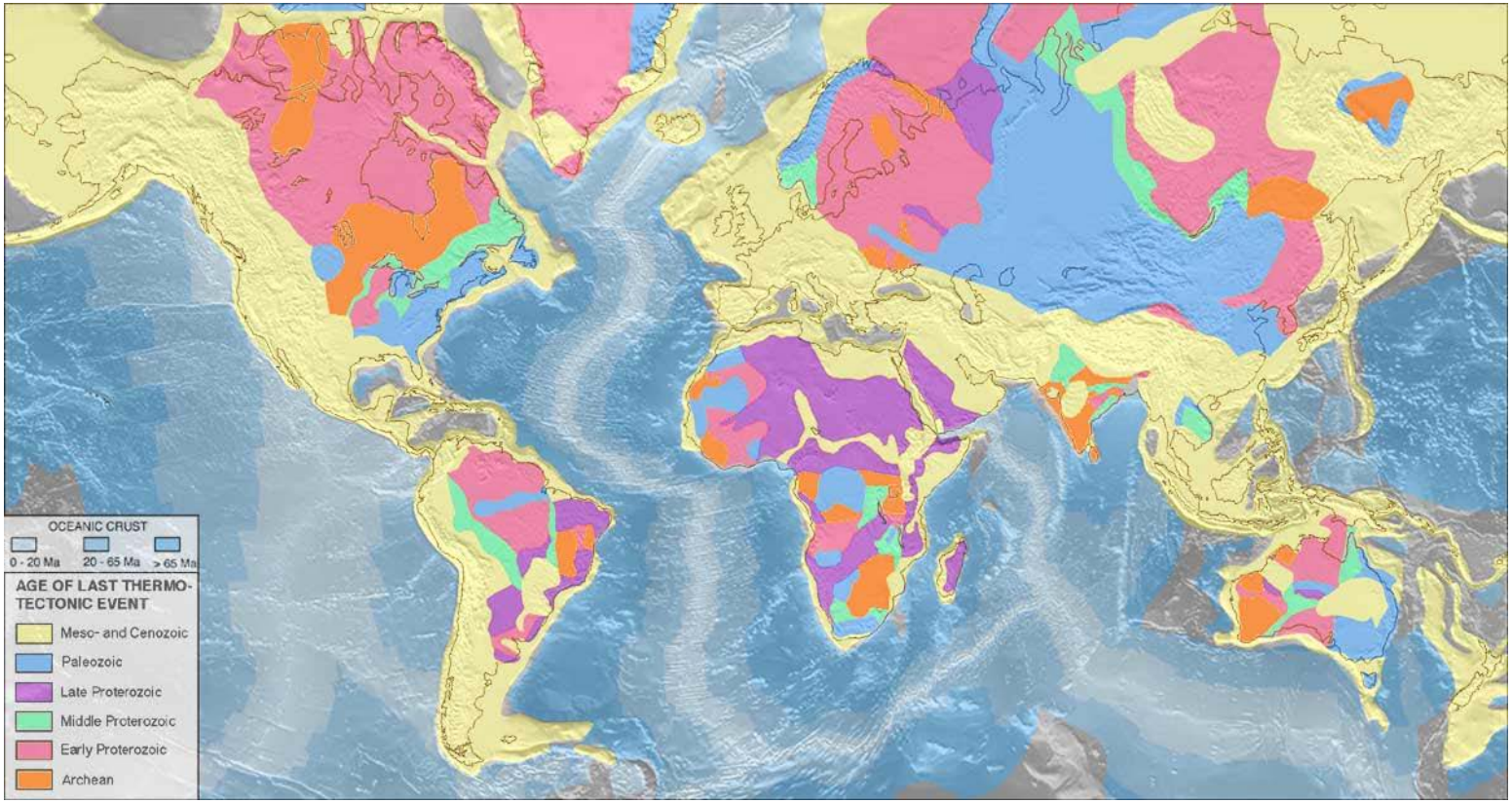
Phone: +61 2 6249 9111

Web: www.ga.gov.au

Email: clientservices@ga.gov.au

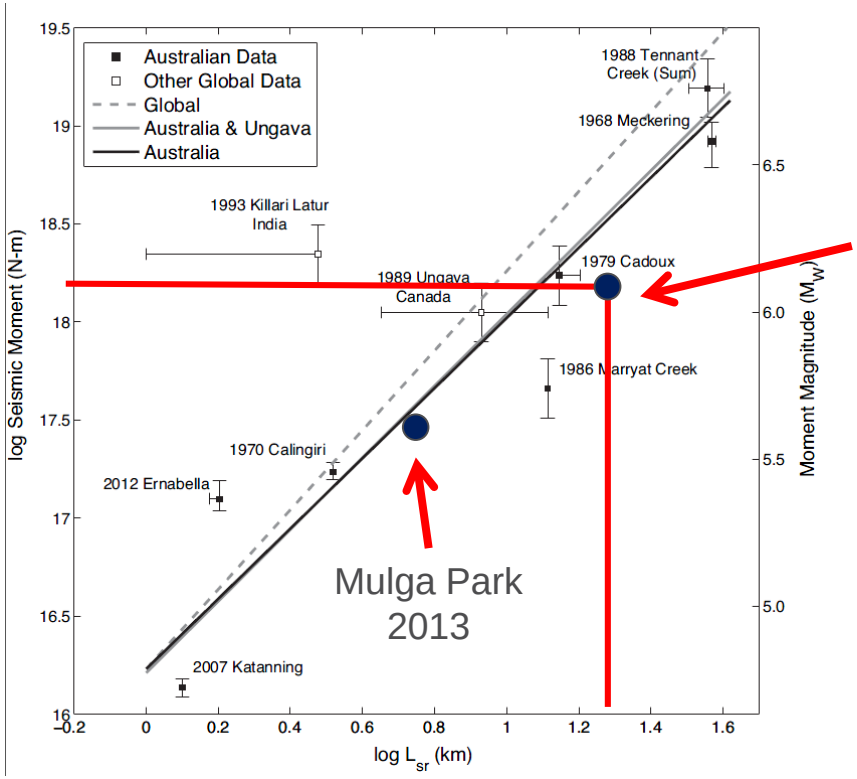
Address: Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston ACT 2609

Postal Address: GPO Box 378, Canberra ACT 2601



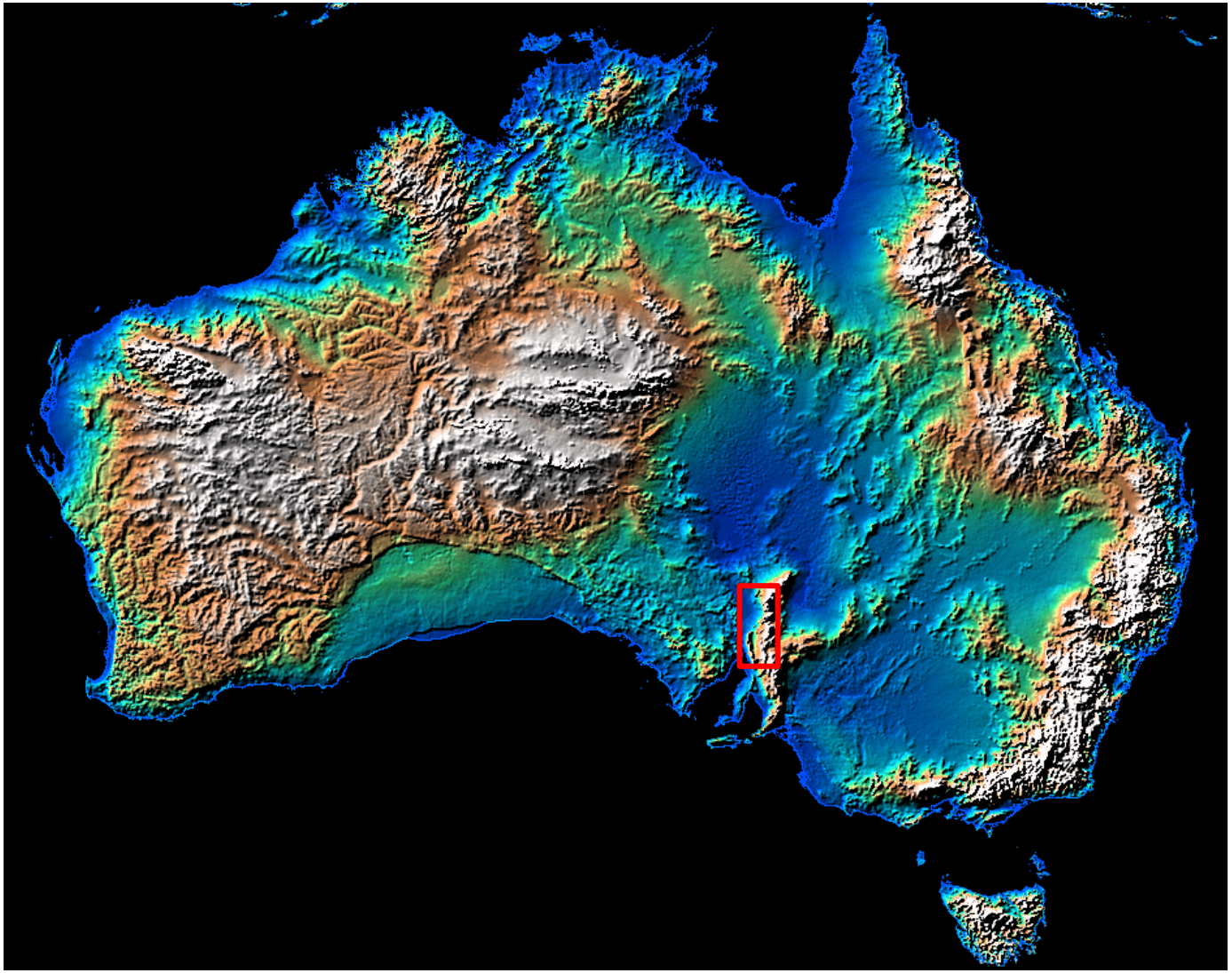
Scaling Relations

A little longer than we might predict from Clark et al (2014).



Petermann R 2016

Future low to intermediate radioactive waste repository



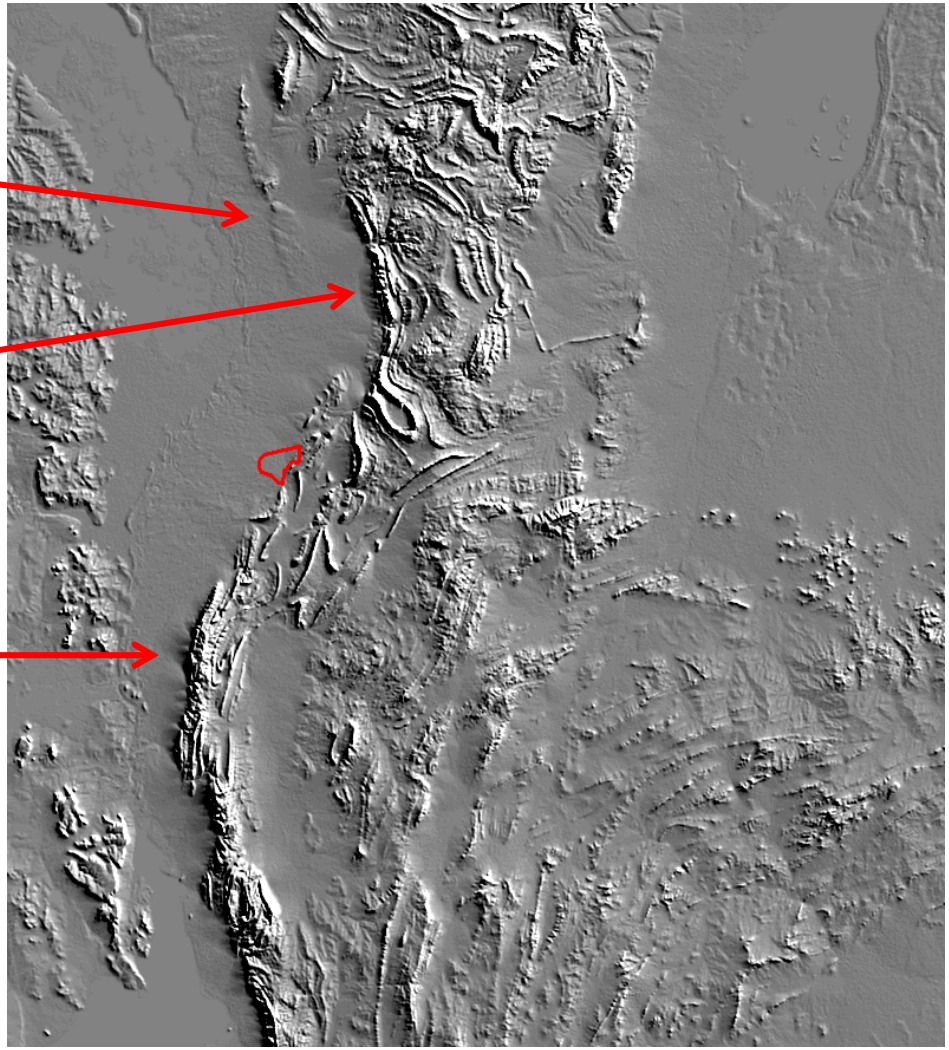
Western Boundary of the Flinders Ranges

Ediacara scarp
unknown activity

Un named scarp
unknown activity

Wilkatana Fault
15m of slip in 60 kyr
0.25 mm/yr

(Quigley *et al.* 2006)



More oblique to stress field, so moderate relief

Displacement of creek bed conglomerate