Preliminary interpretation of deep seismic reflection line 10GA-CP1: crustal architecture of the northern Capricorn Orogen

Government of **Western Australia**
Department of **Mines and Petroleum**

by

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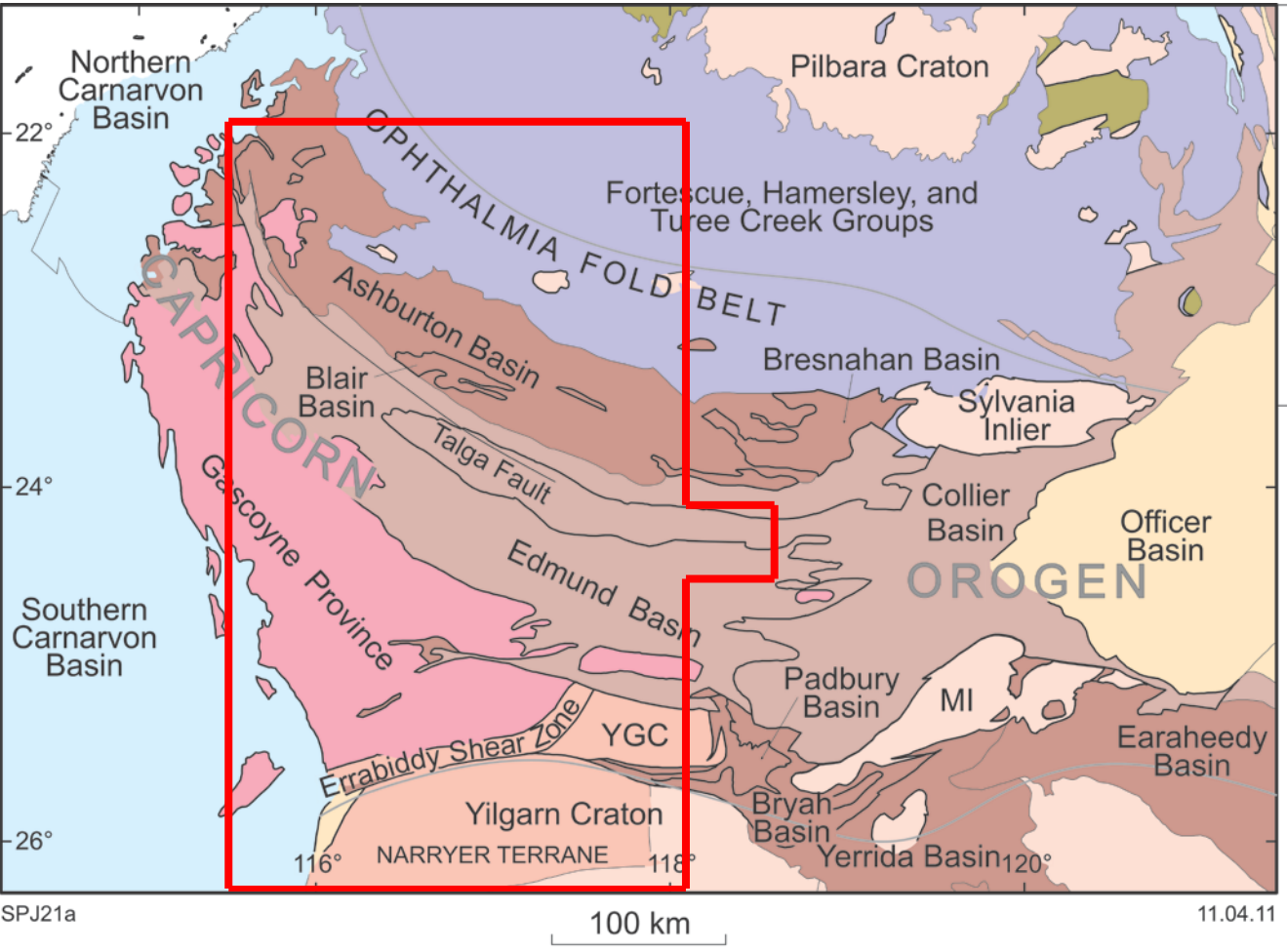
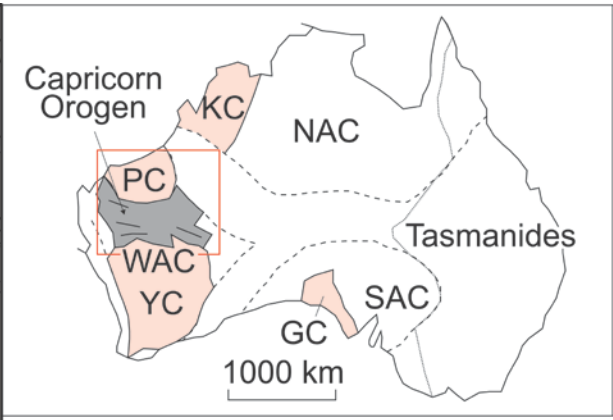
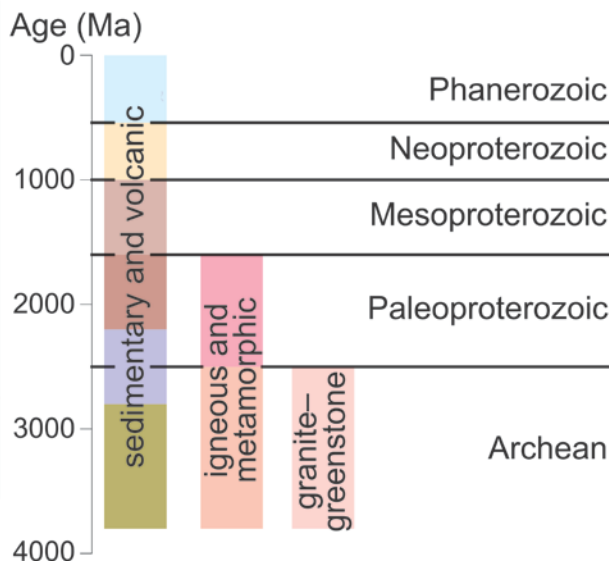
Talk outline

- Geology of the Capricorn Orogen: an introduction.
- Summary of northern Carpricorn Orogen geology.
- Preliminary interpretation of deep seismic reflection line 10GA-CP1: crustal architecture of the northern Capricorn Orogen.

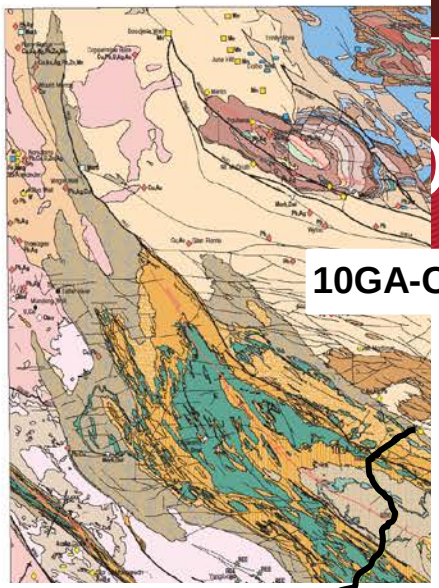
Capricorn Orogen







Orogen



10GA-CP1

10GA-CP2

10GA-CP3

Location of Deep Seismic Lines

Capricorn Orogen: Geological Evolution (1)

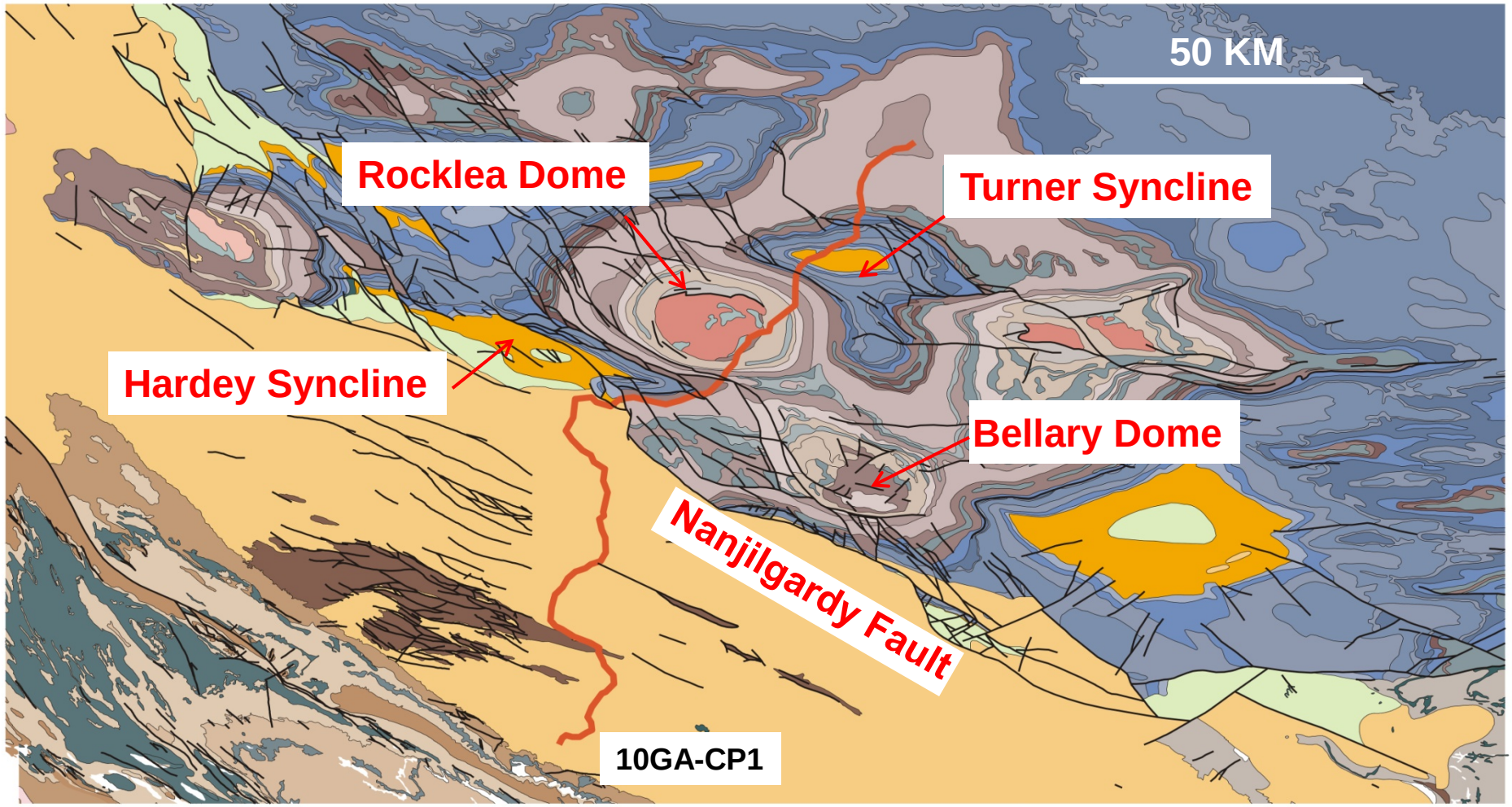
- Early intracratonic models:
  - e.g. Horwitz & Smith 1978; Gee, 1979
- Pilbara-Yilgarn collision models:
  - e.g. Muhling,1988; Tyler and Thorne, 1990; Myers, 1993.
- Recent work highlights complexity of the Capricorn Orogen.
  - e.g. Occhipinti et al. 2004; Rasmussen et al. 2005; Sheppard et al., 2005, 2010; Martin and Morris, 2010; Johnson et al. 2011 (and many more)
- Seven major orogenic events recognised:

Capricorn Orogen: Geological Evolution (2)

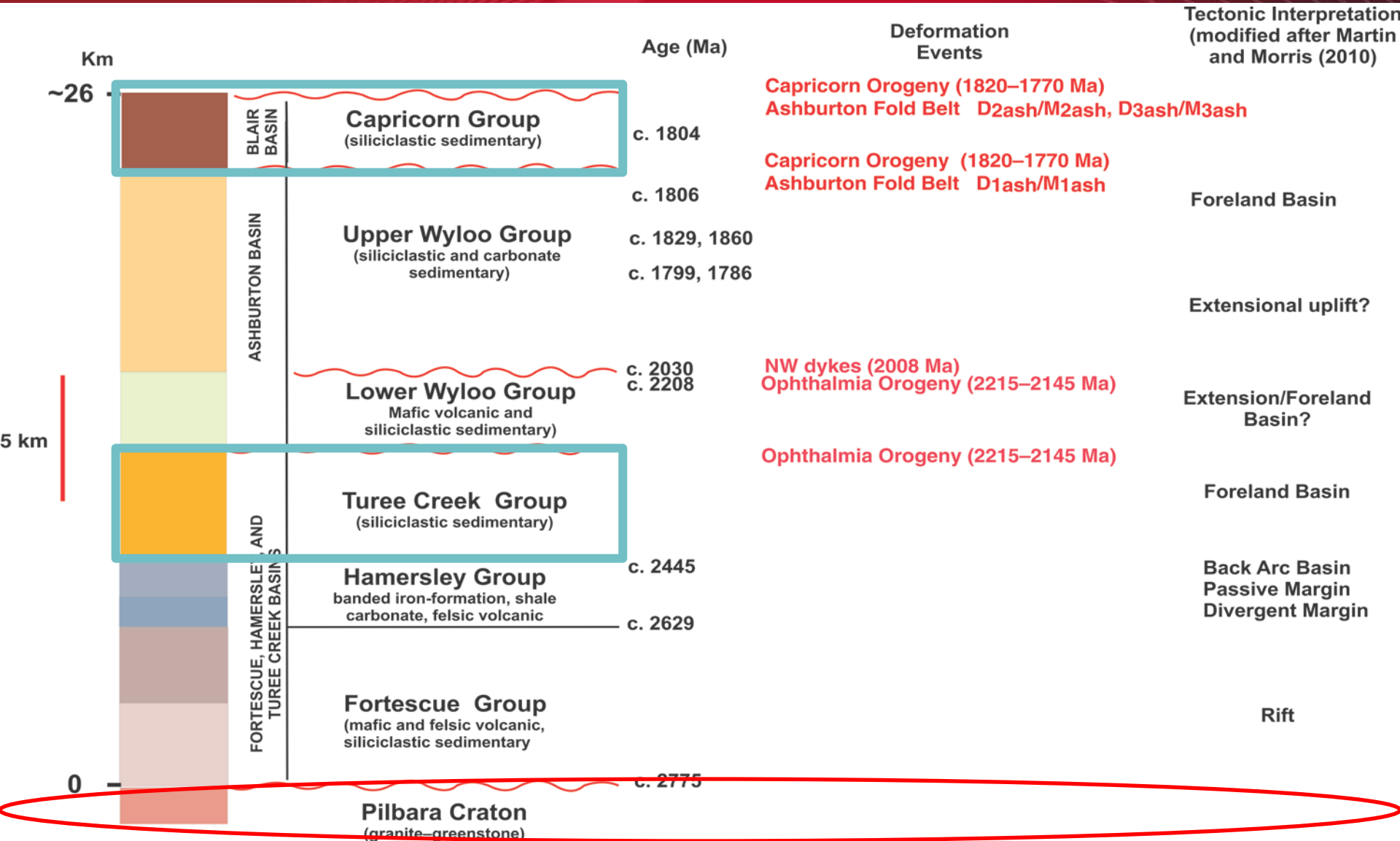
- **2215–2145 Ma Ophthalmian Orogeny,** — **Pilbara — Glenburgh Terrane (Gascoyne) collision**
- **2005–1950 Ma Glenburgh Orogeny,** — **Pilbara + Glenburgh Terrane — Yilgarn collision**
- **1820–1770 Ma Capricorn Orogeny,**
- **1680–1620 Ma Mangaroon Orogeny,**
- **1385–1200 Ma Mutherbukin tectonic event,**
- **1030–950 Ma Edmundian Orogeny**
- **c. 570 Ma Mulka Tectonic Event**

Intracratonic reworking

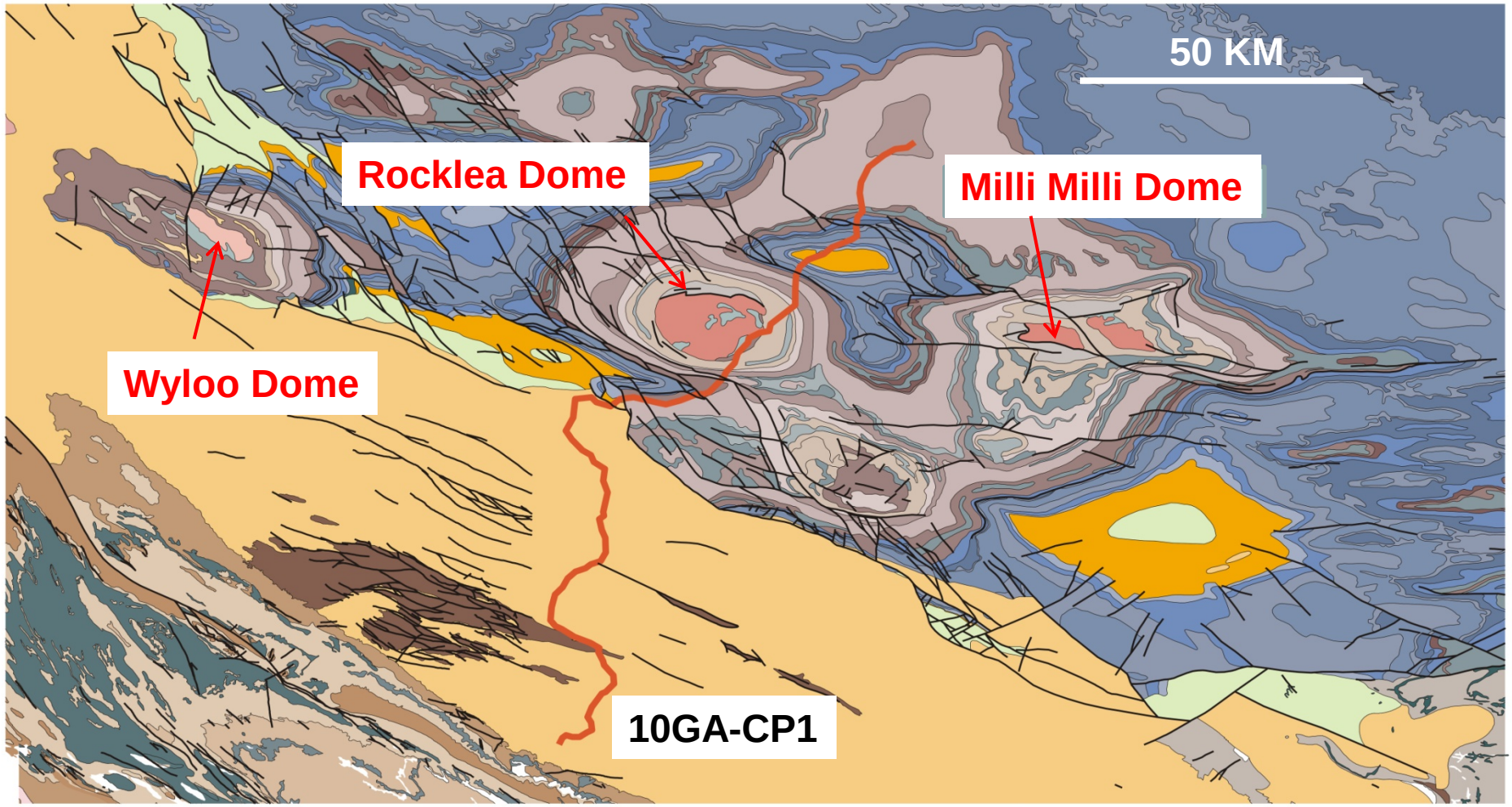
Northern Capricorn Orogen geology



Northern Capricorn Orogen: Generalized stratigraphy



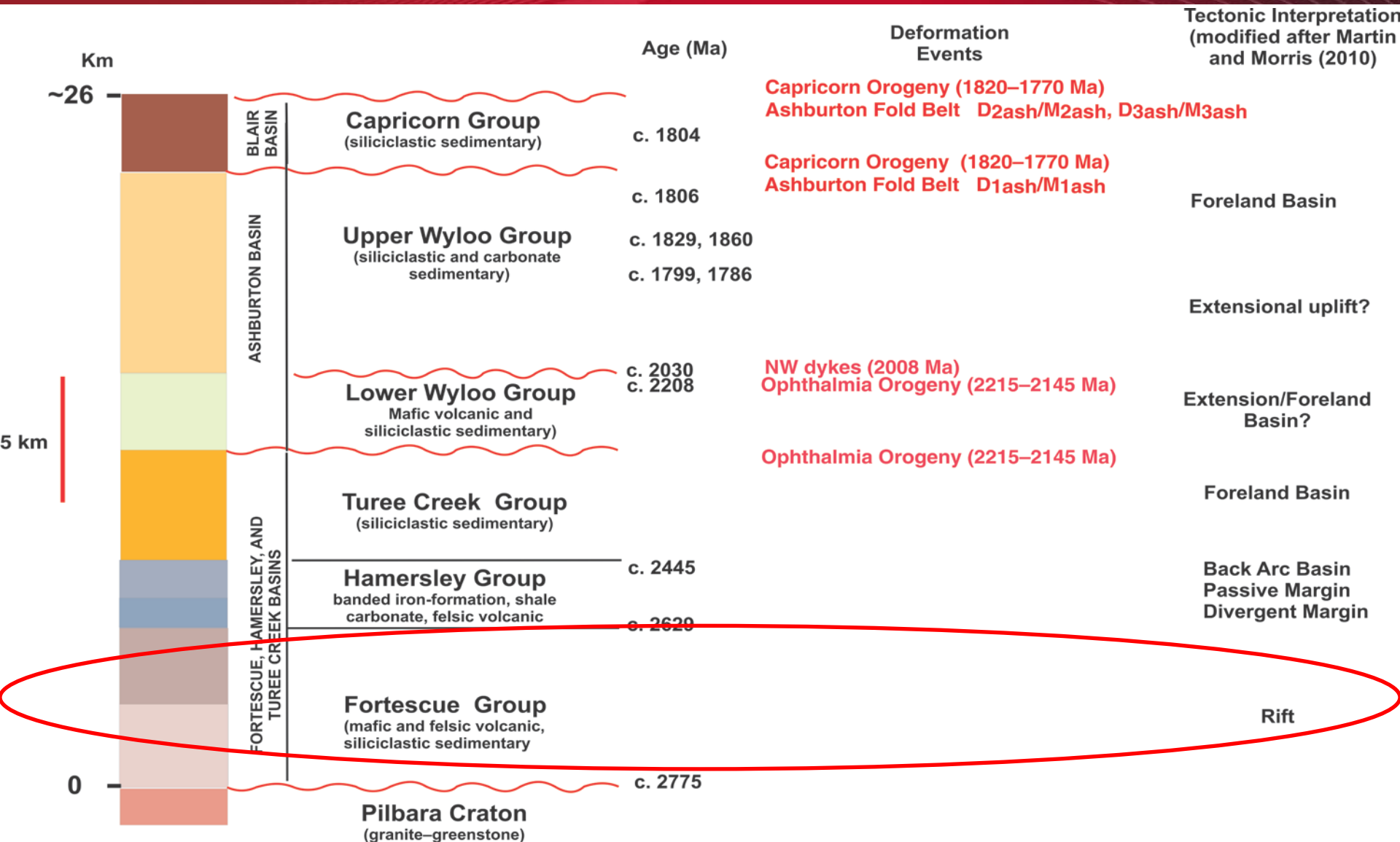
Pilbara Craton basement



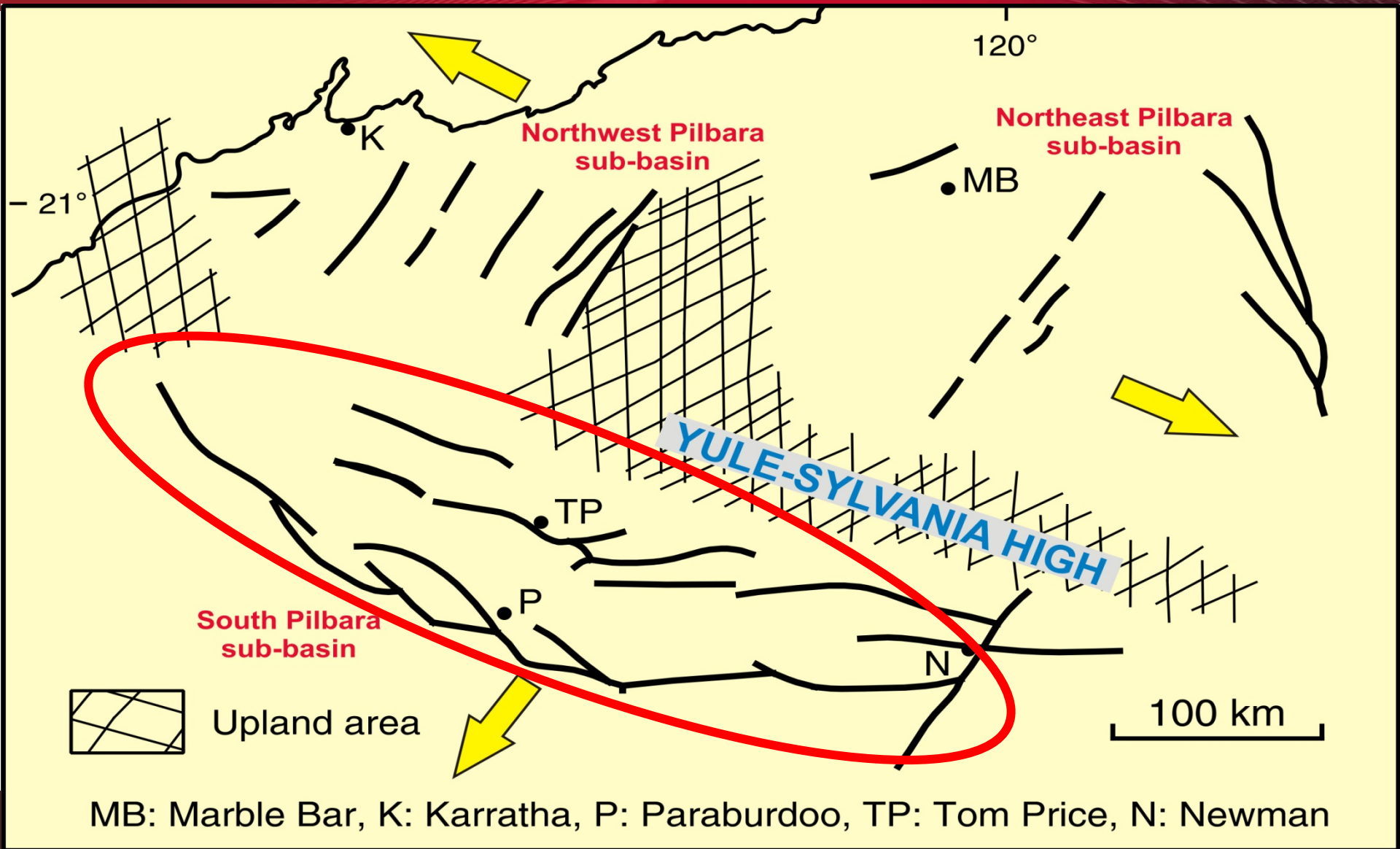
Southern Pilbara Craton basement (few details known)

- Greenstones:low-grade meta mafic volcanic and siliclastic sedimentary rocks.
- Granites mostly biotite monzogranite and minor pegmatite;locally intruded by pre-Fortescue Group metadolerite dykes.
- Granite-greenstone minimum age set by c. 2775 Ma age of overlying basal Fortescue Group.
- Maximum age unknown. Probably formed between 3800–2830 Ma.

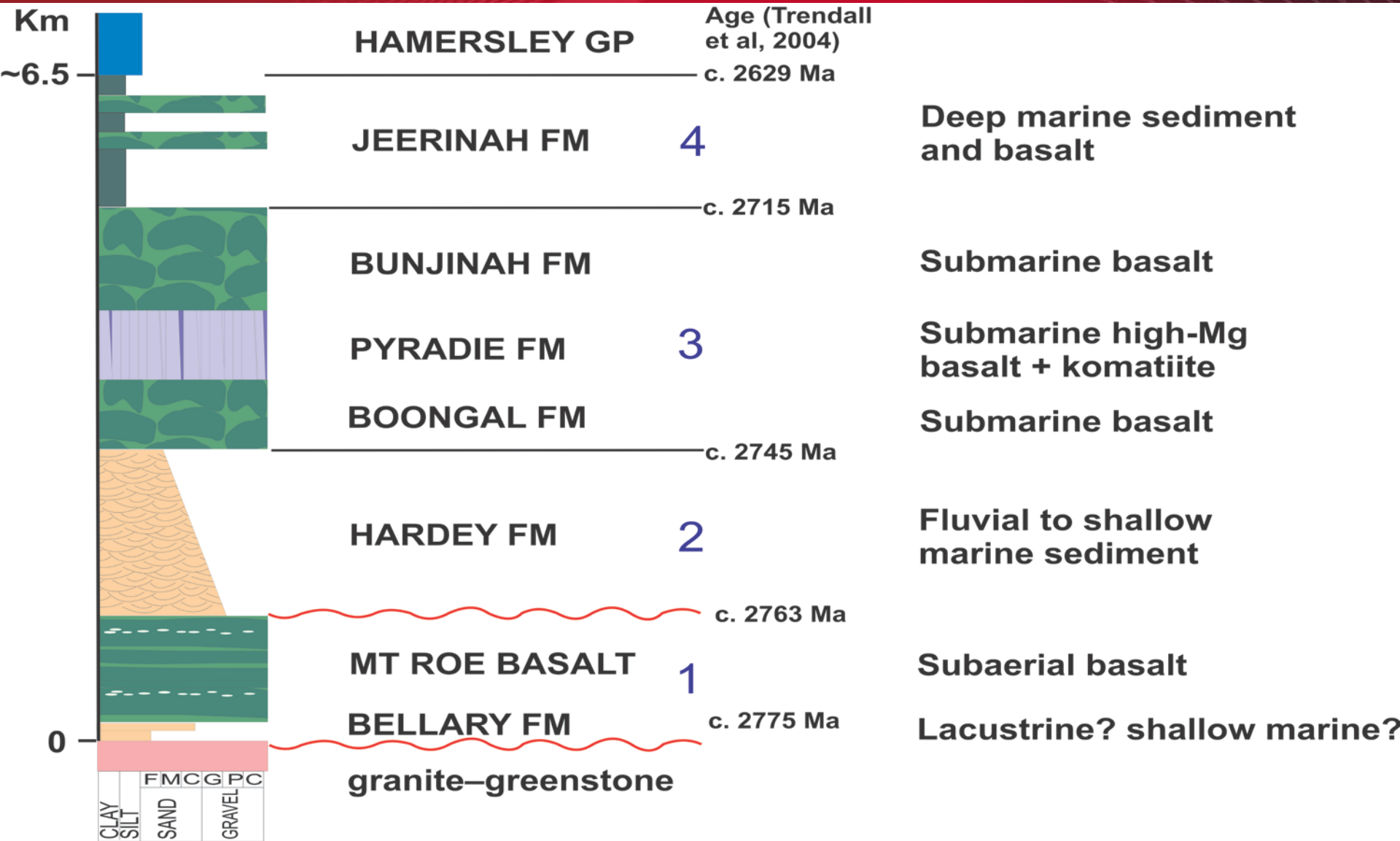
Northern Capricorn Orogen: Generalized stratigraphy



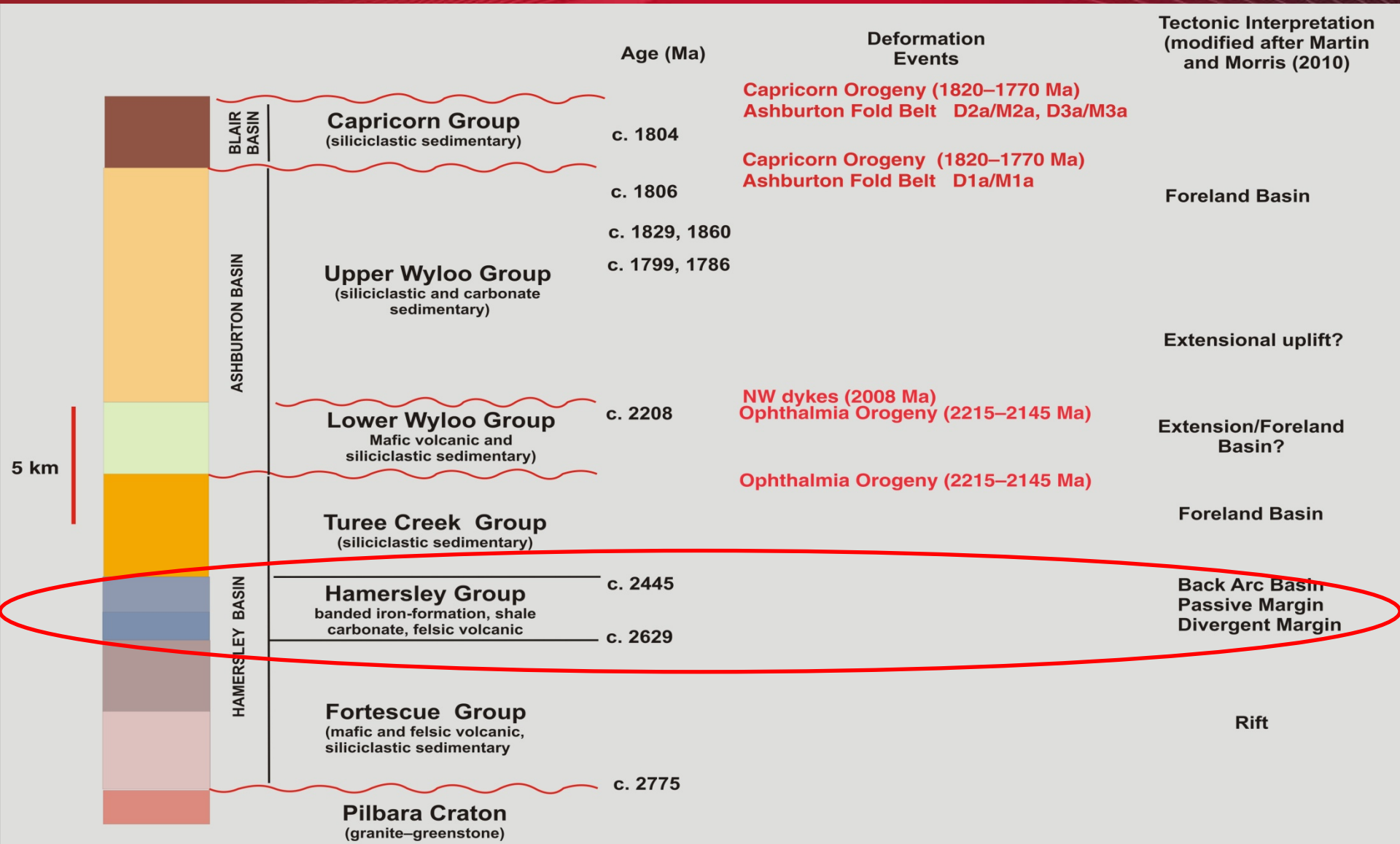
Fortescue Group – Pilbara Craton rifting (c. 2775 – c. 2630 Ma)



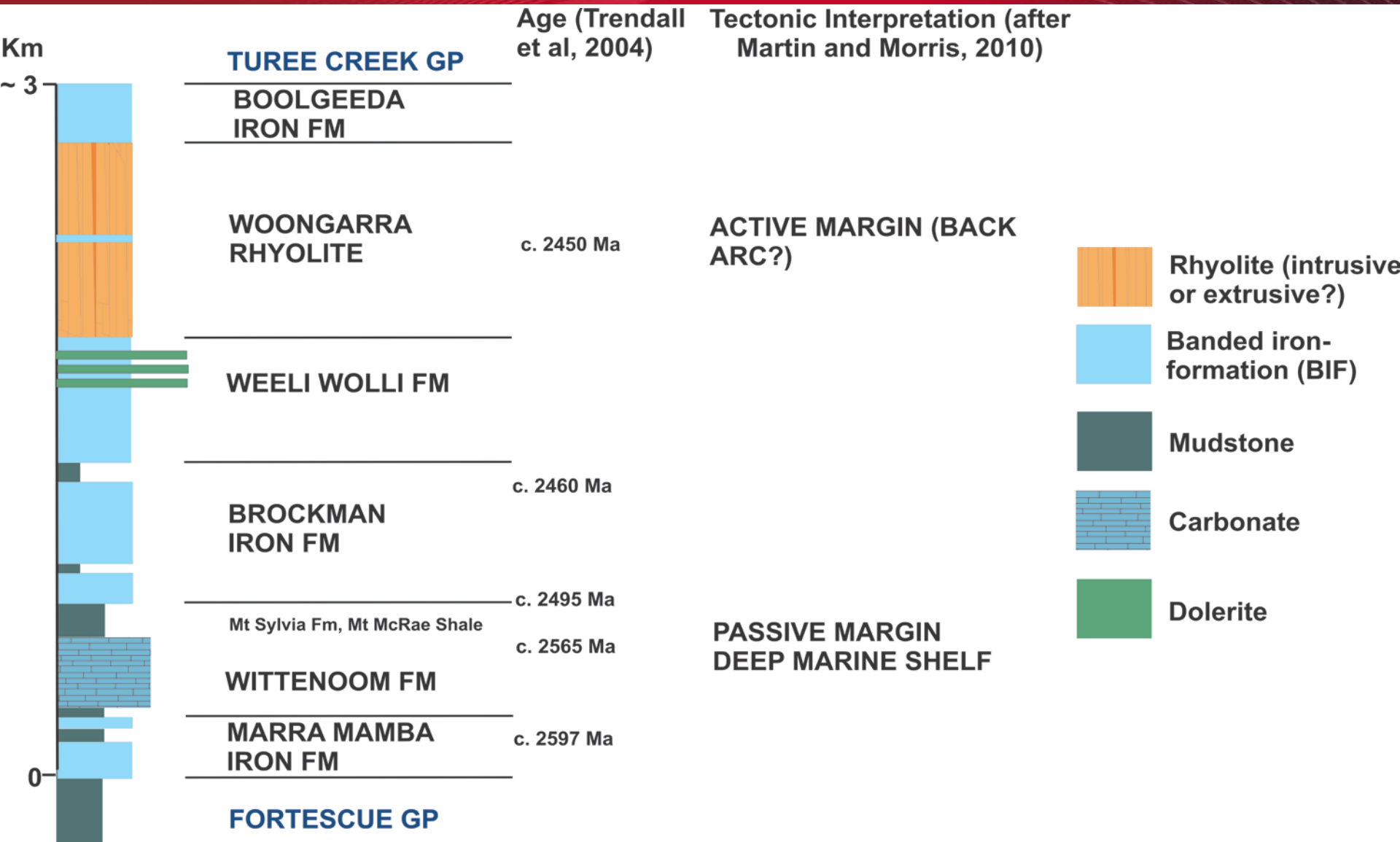
Fortescue Group rift stratigraphy (south Pilbara)



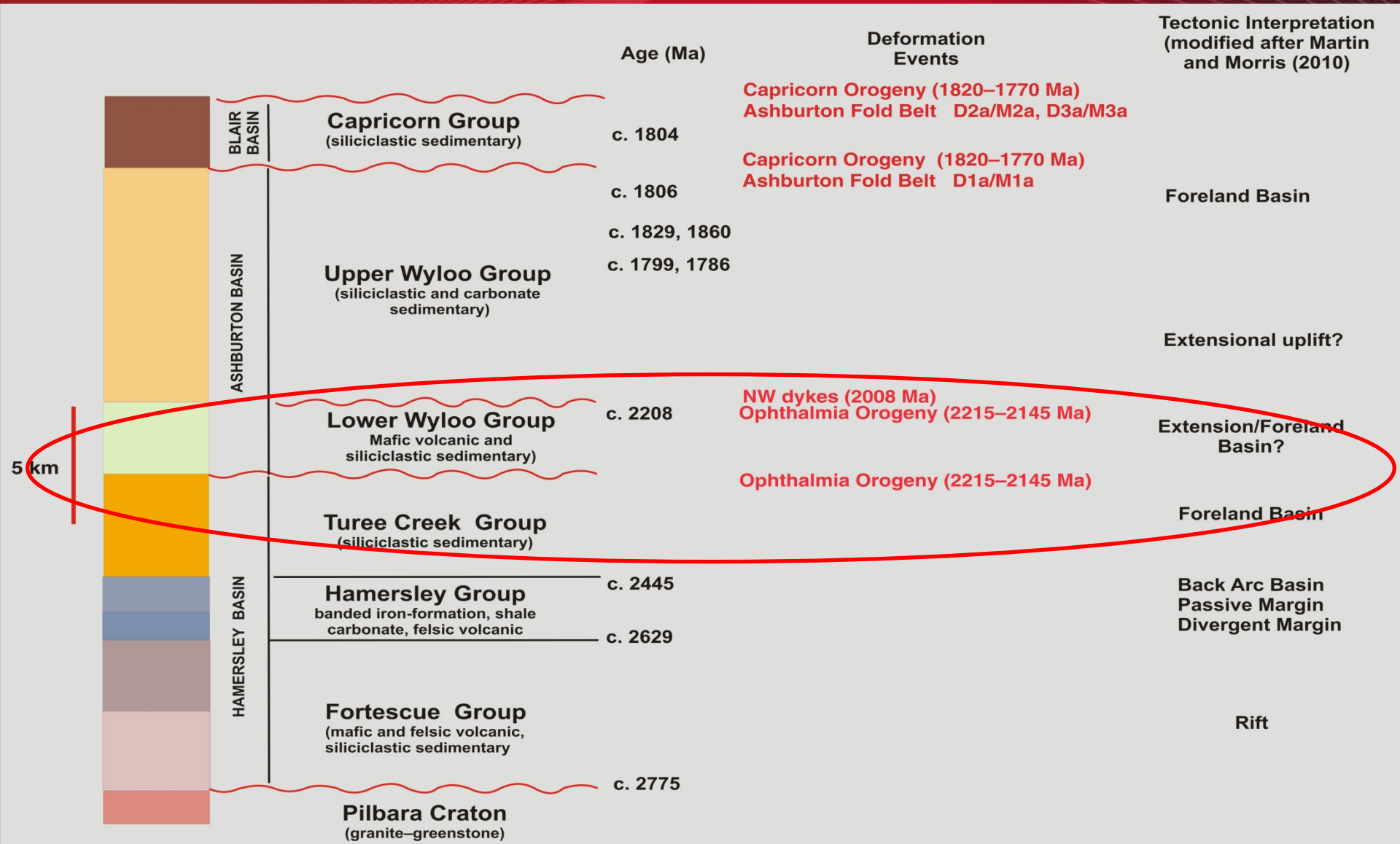
Northern Capricorn Orogen: Generalized stratigraphy



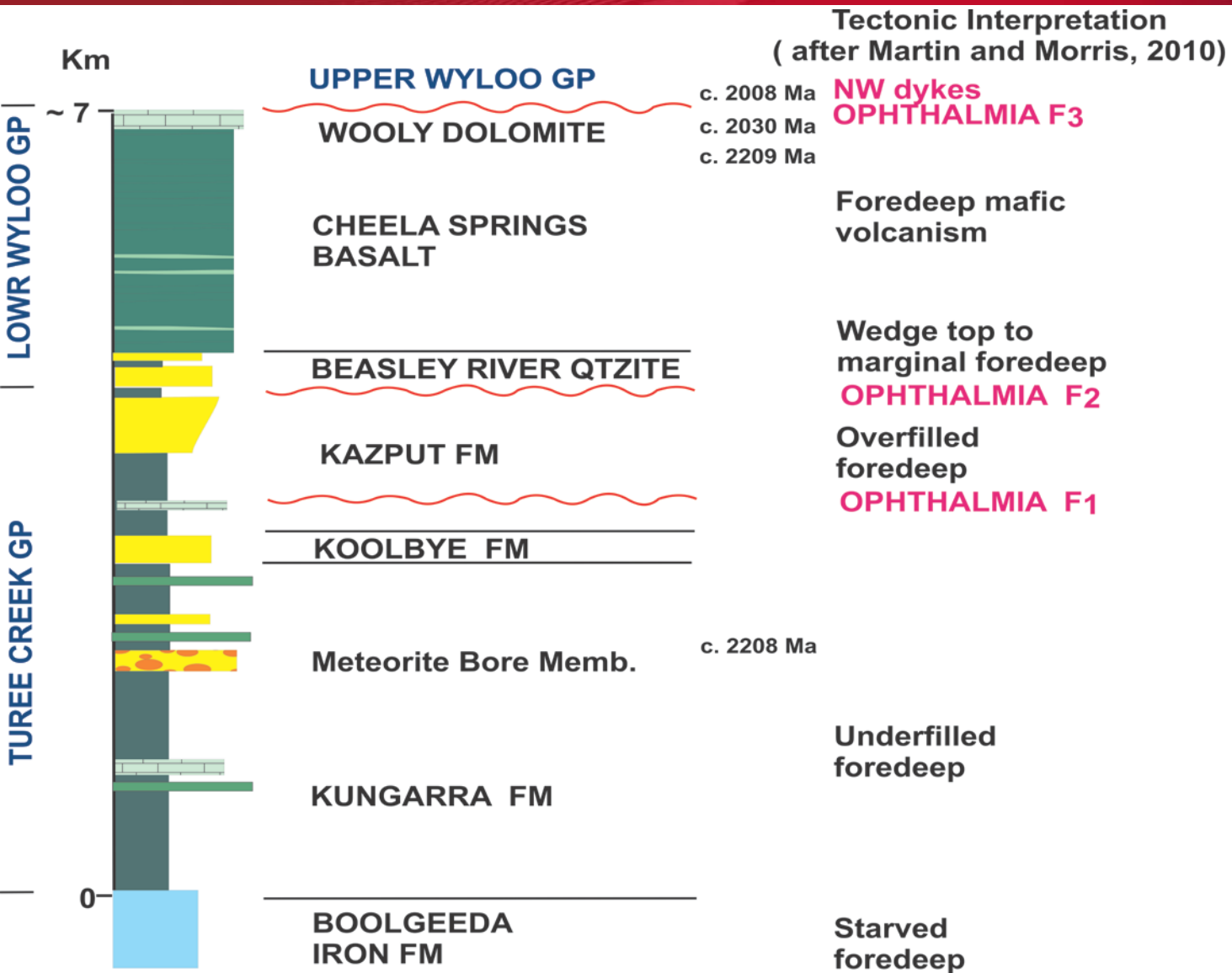
Hamersley Group: passive to active margin sedimentation and volcanism



Northern Capricorn Orogen: Generalized stratigraphy

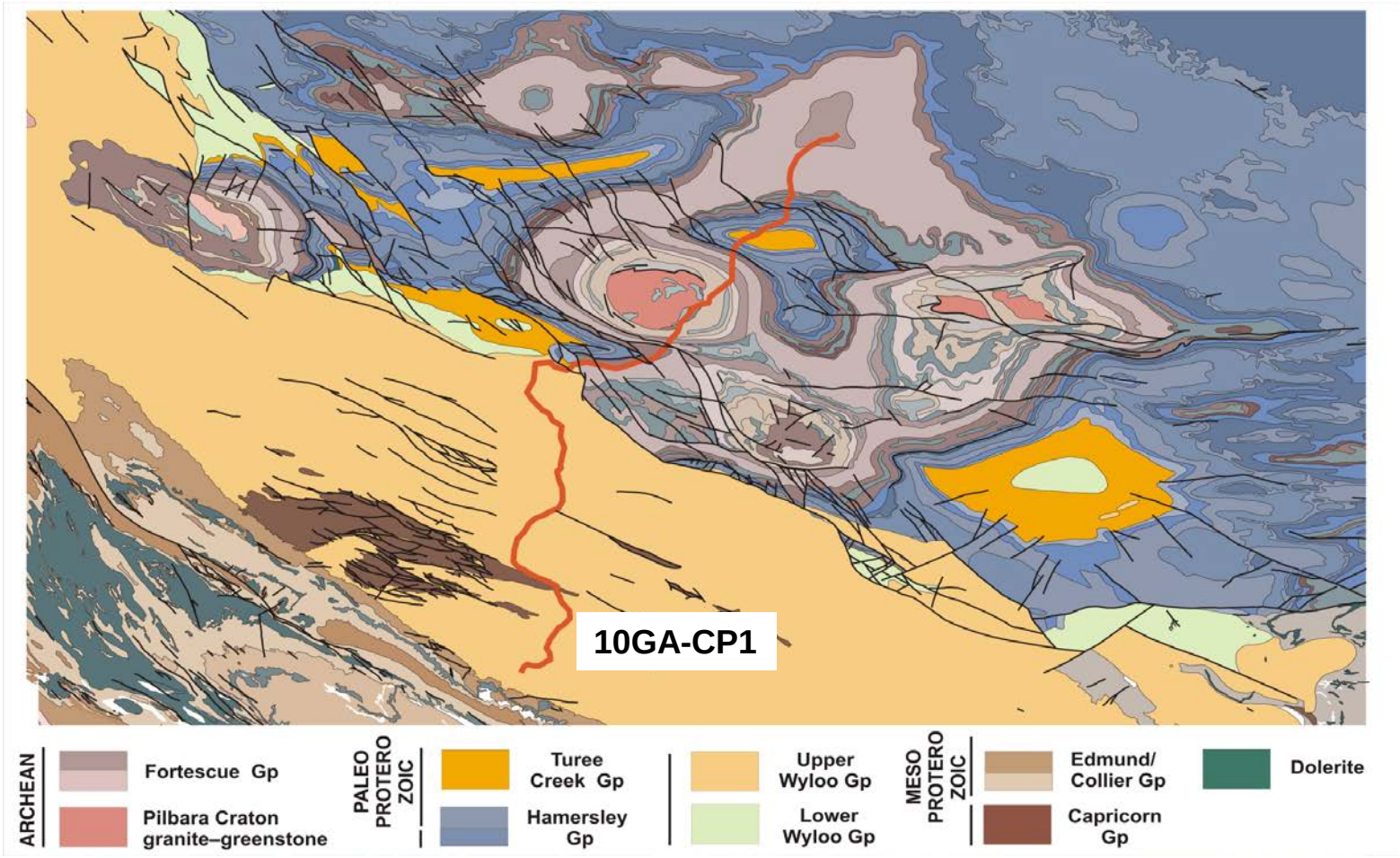


Turee Creek and lower Wyloo Groups: foreland basin deposition and volcanism

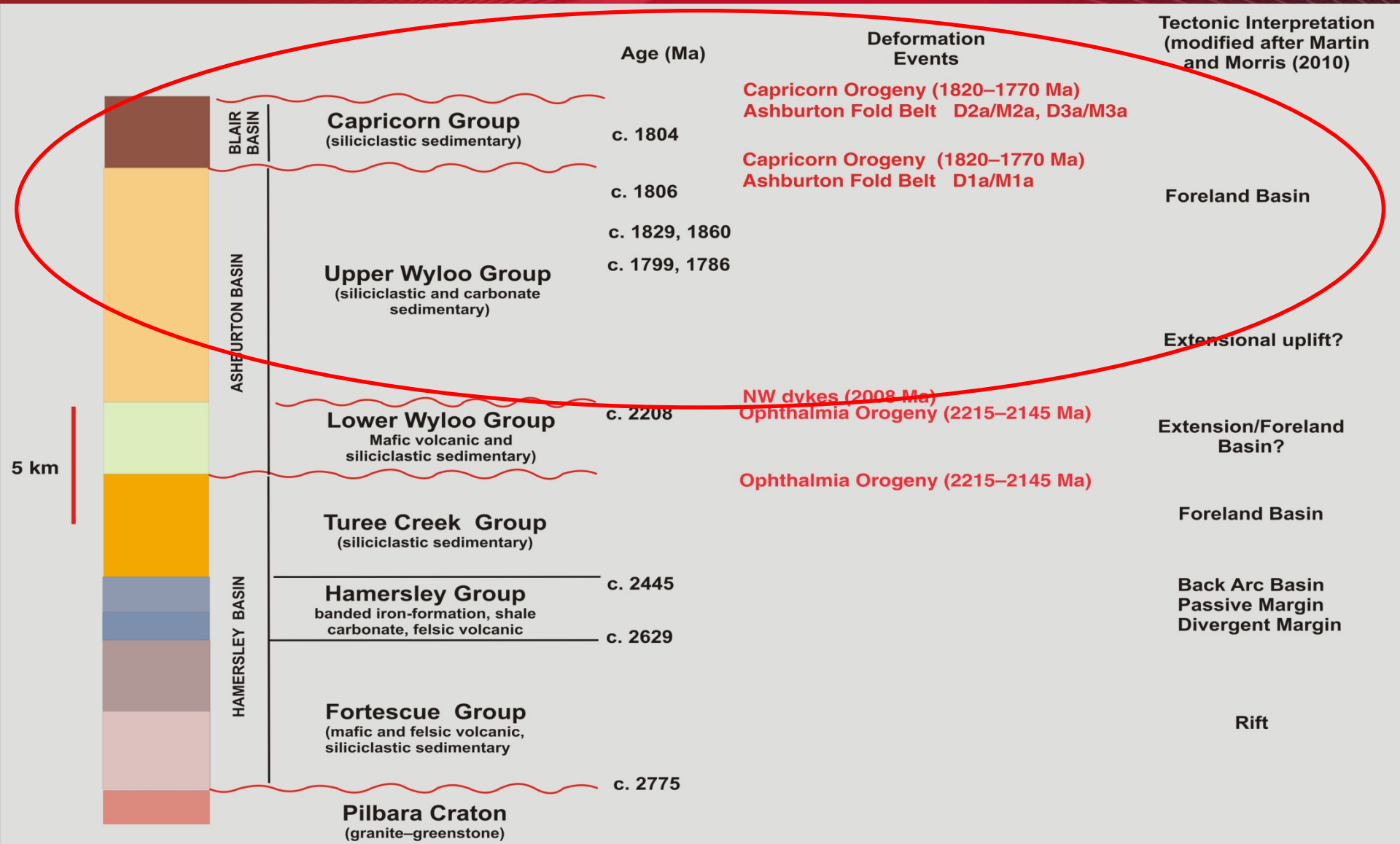


Geochronology:
Martin et al., 1998;
Müller et al., 2005

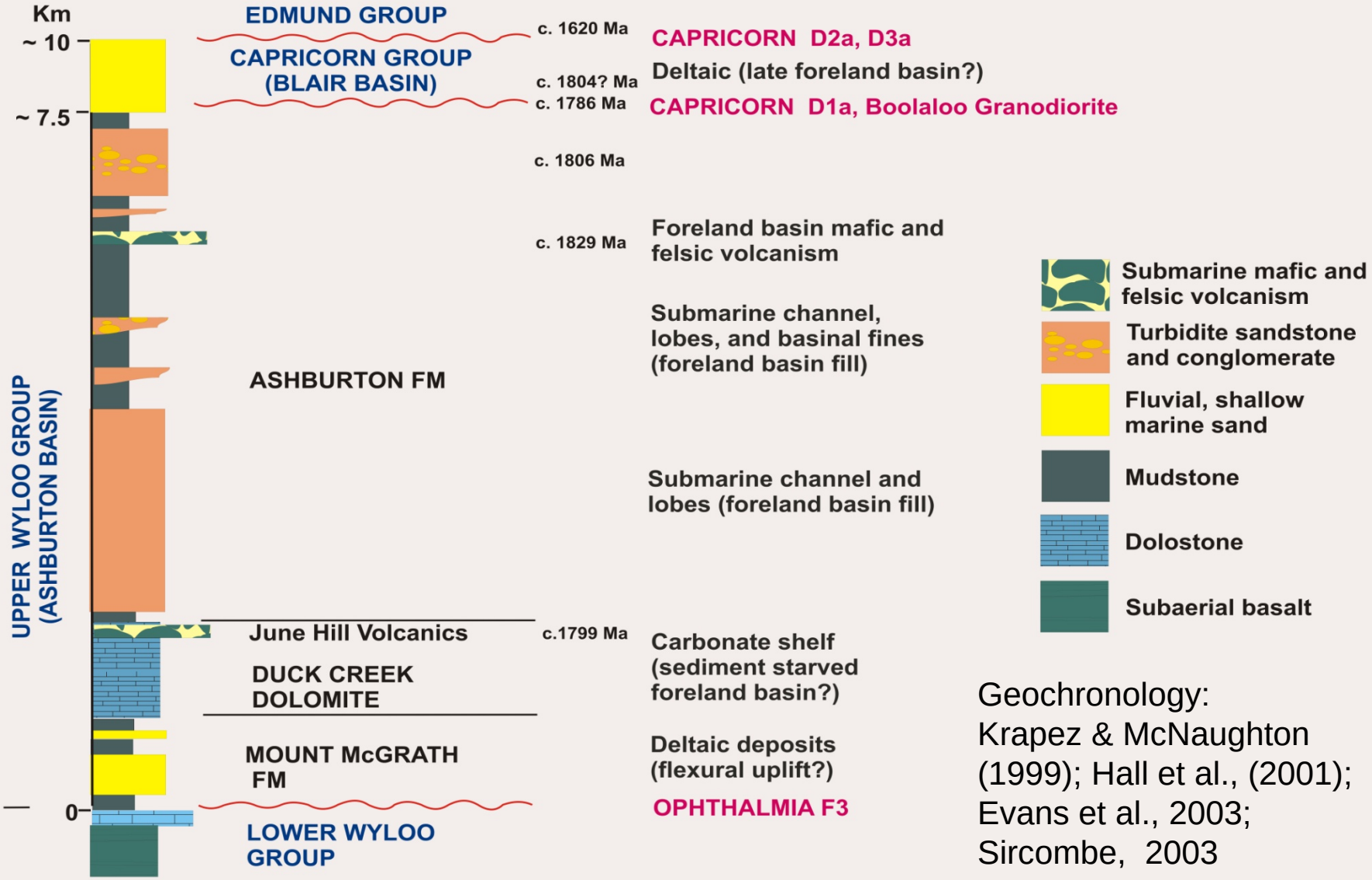
Turee Creek and Lower Wyloo Groups



Northern Capricorn Orogen: Generalized stratigraphy

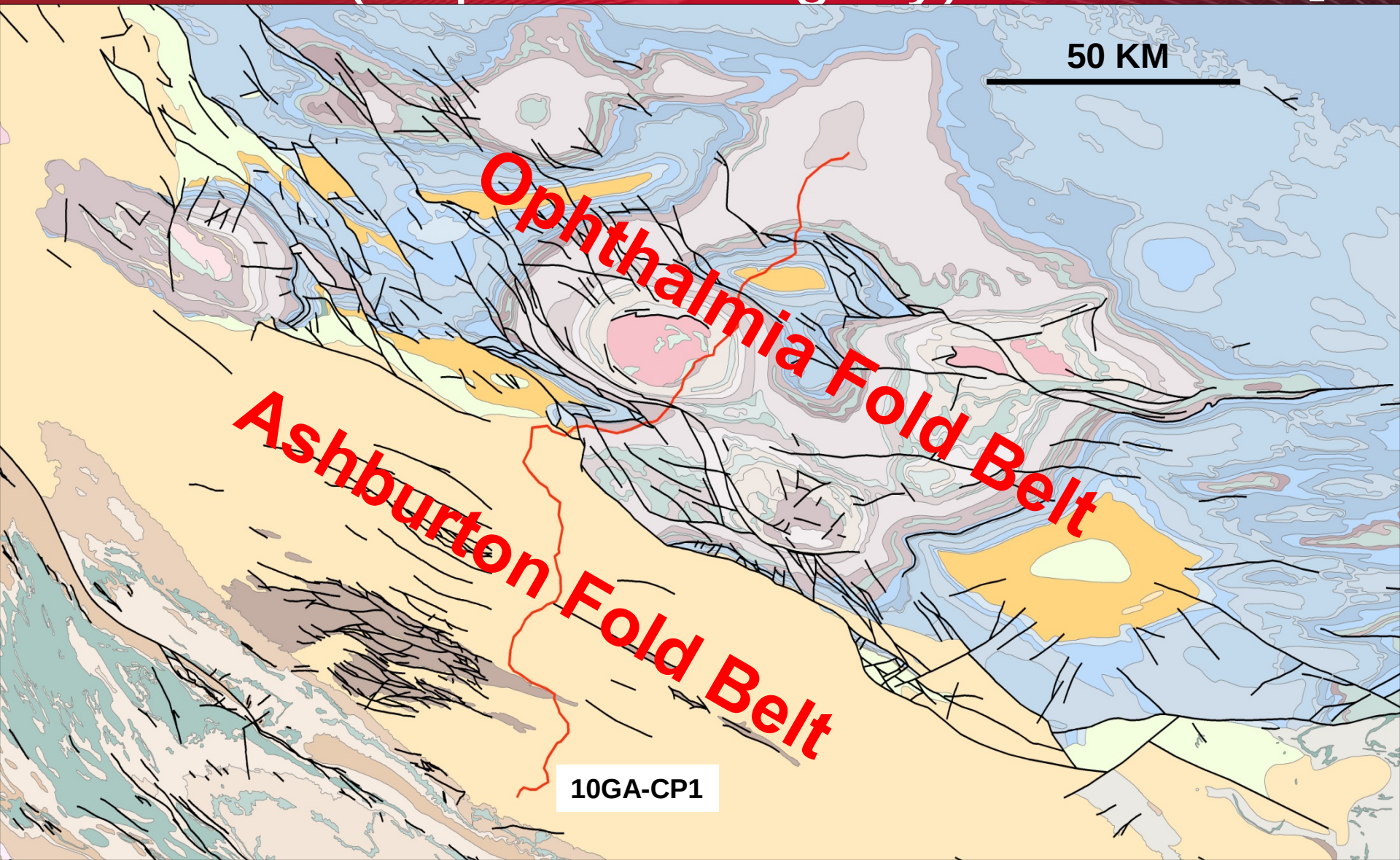


Upper Wyloo and Capricorn Groups: more foreland basin sedimentation?



Geochronology: Krapez & McNaughton (1999); Hall et al., (2001); Evans et al., 2003; Sircombe, 2003

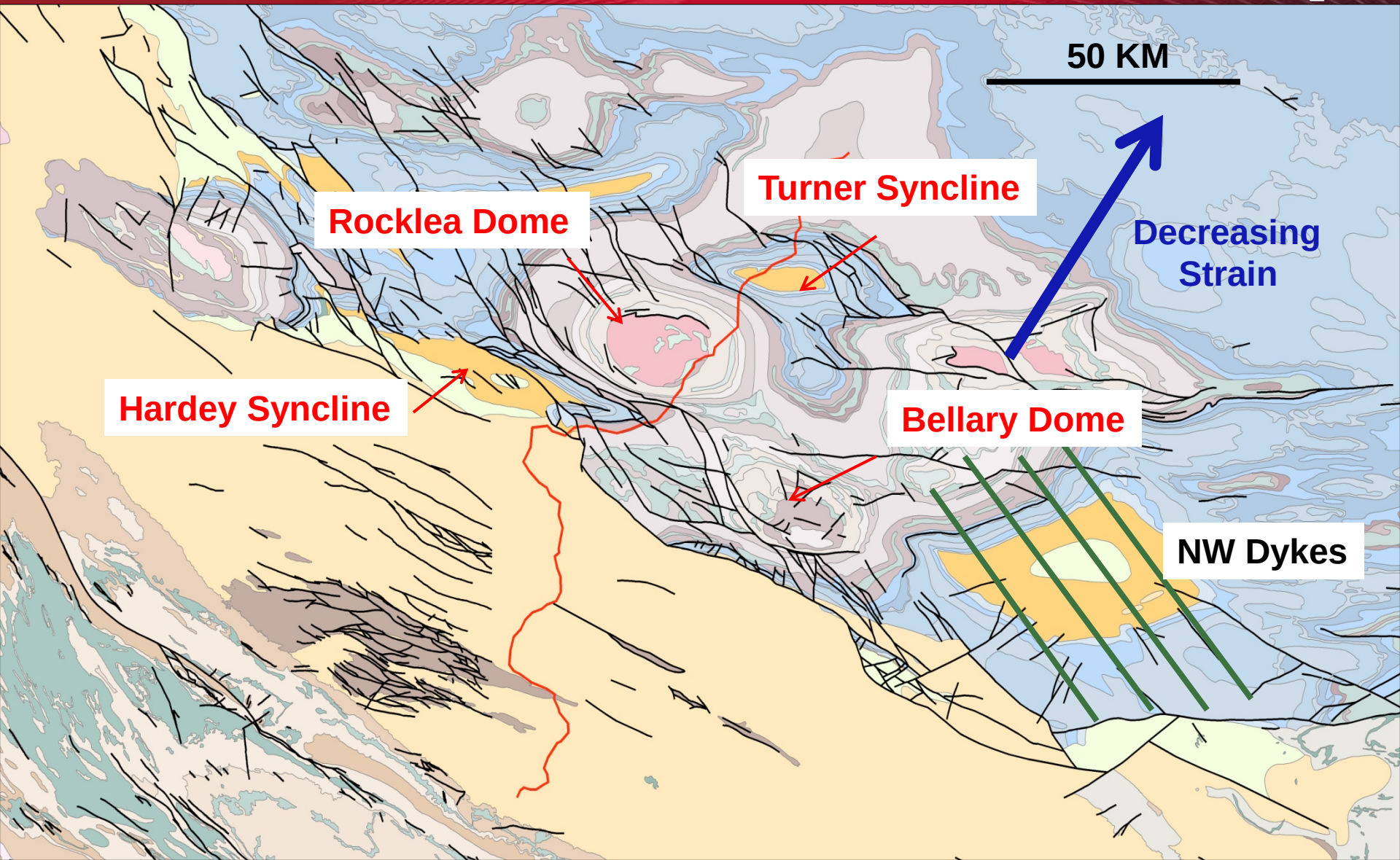
Deformation history: Ophthalmia and Ashburton (Capricorn Orogeny) Fold Belts



Ophthalmia Fold Belt

- Affects very low grade supracrustal rocks, up to and including the lower Wyloo Group
- Comprises three pre- and one post- lower Wyloo Group events.
- Dated 2215 – 2145 Ma (Rasmussen et al 2005).
- Results in regional scale, en-echelon, open to tight, upright structures e.g. Hardey Syncline, Turner Syncline, Rocklea Dome.
- Cut by NW dykes and overprinted by Ashburton Fold Belt structures

Ophthalmia Fold Belt

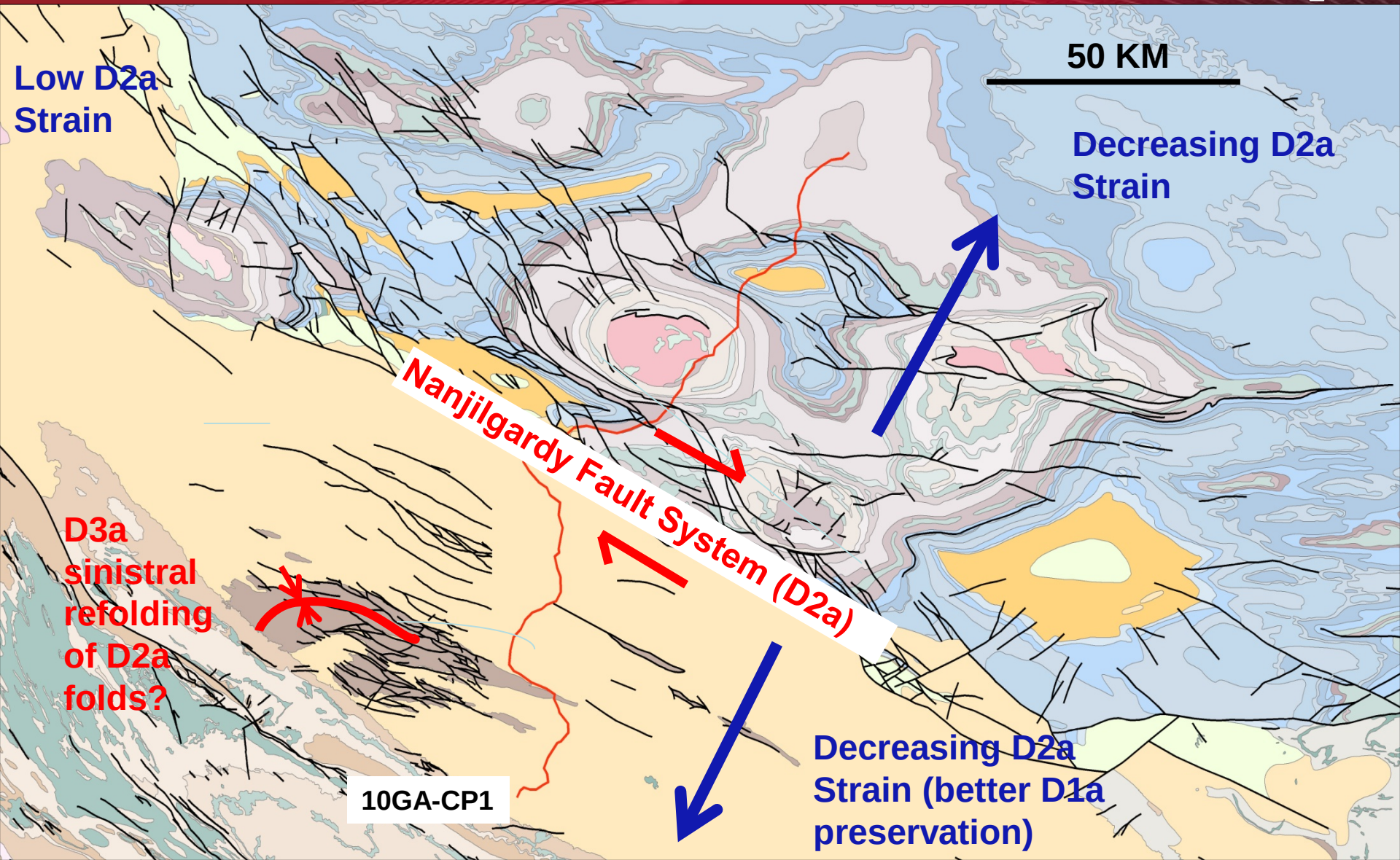


Ashburton Fold Belt structures

- Affects stratigraphy up to and including the Capricorn Group
- Overprints Ophthalmia Fold Belt structures
- Comprises one pre- Capricorn Group (D1a) and two post Capricorn Group – pre- Edmund Group events (D2a, D3a)
- D1a between 1806 – 1786 Ma
- D2a between 1786–1738 Ma
- D3a between 1738–1620 Ma

Geochronology: Krapez & McNaughton (1999); Sener et al., (2005)

Ashburton Fold Belt: structural summary



Ashburton Fold Belt D1a/M1a

- Widespread S1a foliation in low strain areas,
- rare F1a folds, some recumbent
- marked angular unconformity between Ashburton Fm and Capricorn Group,
- quartz-chlorite-muscovite(sericite) in pelitic and psammitic rocks.
- quartz–muscovite–biotite–cordierite–andalusite –garnet schist in west.

Ashburton Fold Belt D2a/M2a: dextral transpression

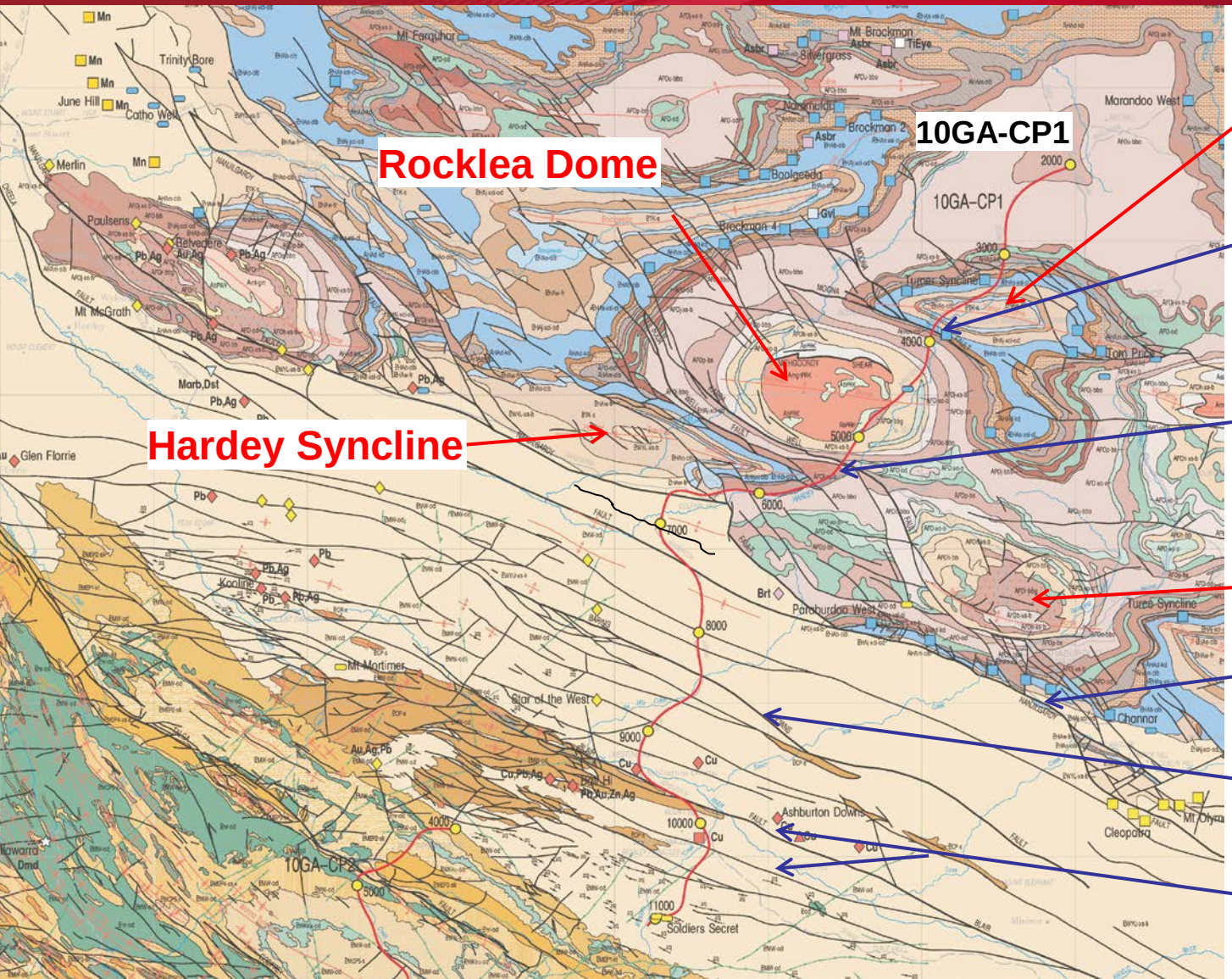
- Dextral strike slip faults (includes Nanjilgardy)
- Open to tight, non-cylindrical, upright folds,trend west to northwest,
- axial planes dip steeply to the southwest or northeast.
- S2a generally a penetrative slaty cleavage in the east and a crenulation cleavage in the west
- Low-grade retrogression of biotite to chlorite and andalusite to sericite,
- growth of porphyroblastic muscovite.

Capricorn Seismic Line 10GA-CP1: Preliminary Interpretation

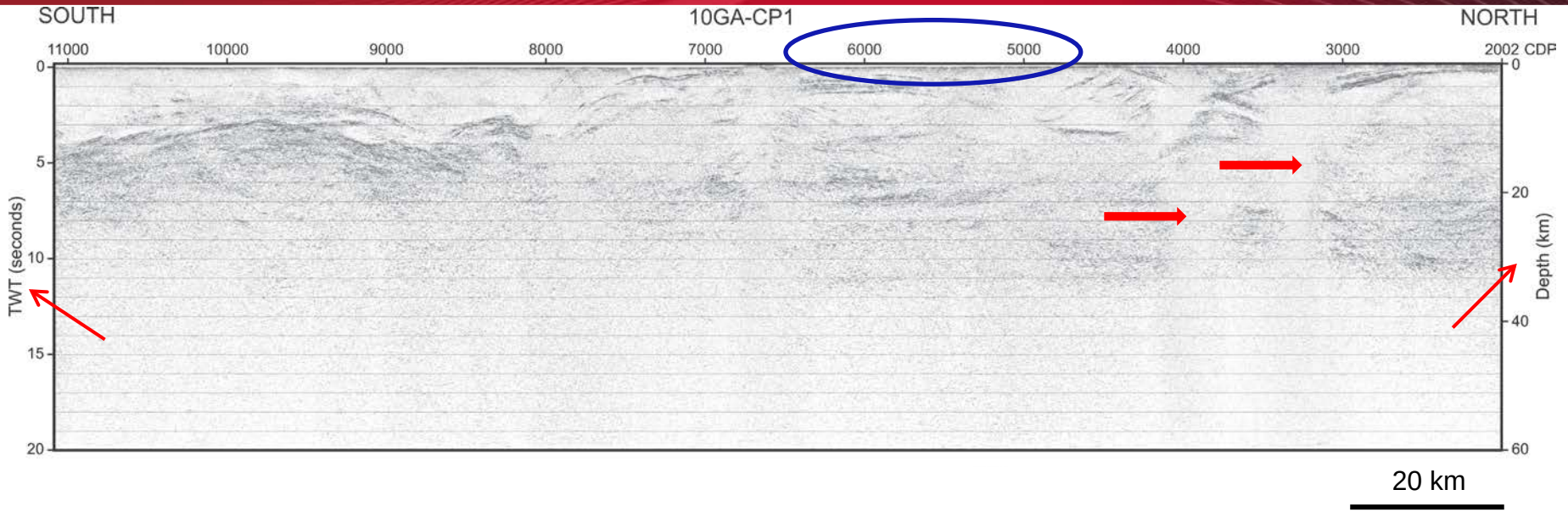
Seismic Line 10GA-CP1: major objectives

- character of major faults (e.g. Nanjilgardy) that mark the boundary between the Pilbara Craton and the Ashburton Basin,
- nature of reactivated Fortescue Group growth faults in the southern Pilbara,
- deep crustal structure of the northern Capricorn Orogen.
- crustal architecture of the Ashburton Basin – is it consistent with current tectonic models for the Orogen?

Northern Capricorn Orogen: major structural elements



Seismic Line 10GA-CP1: uninterpreted data

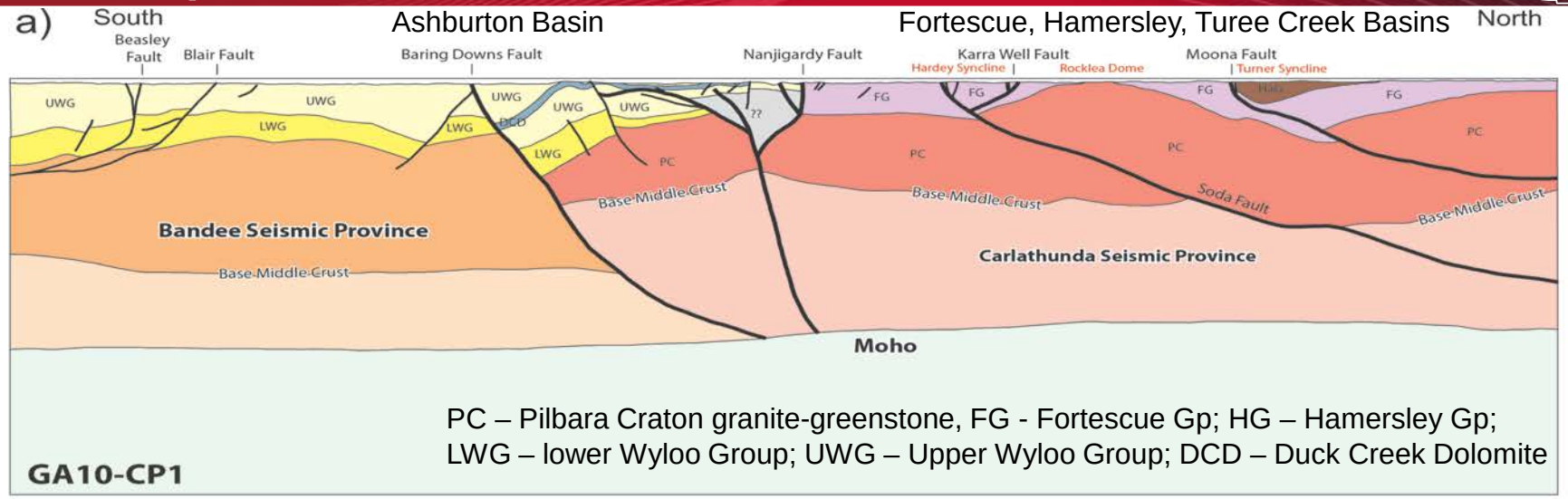


Migrated seismic section for 10GA-CP1,northern Capricorn Orogen (north to right)

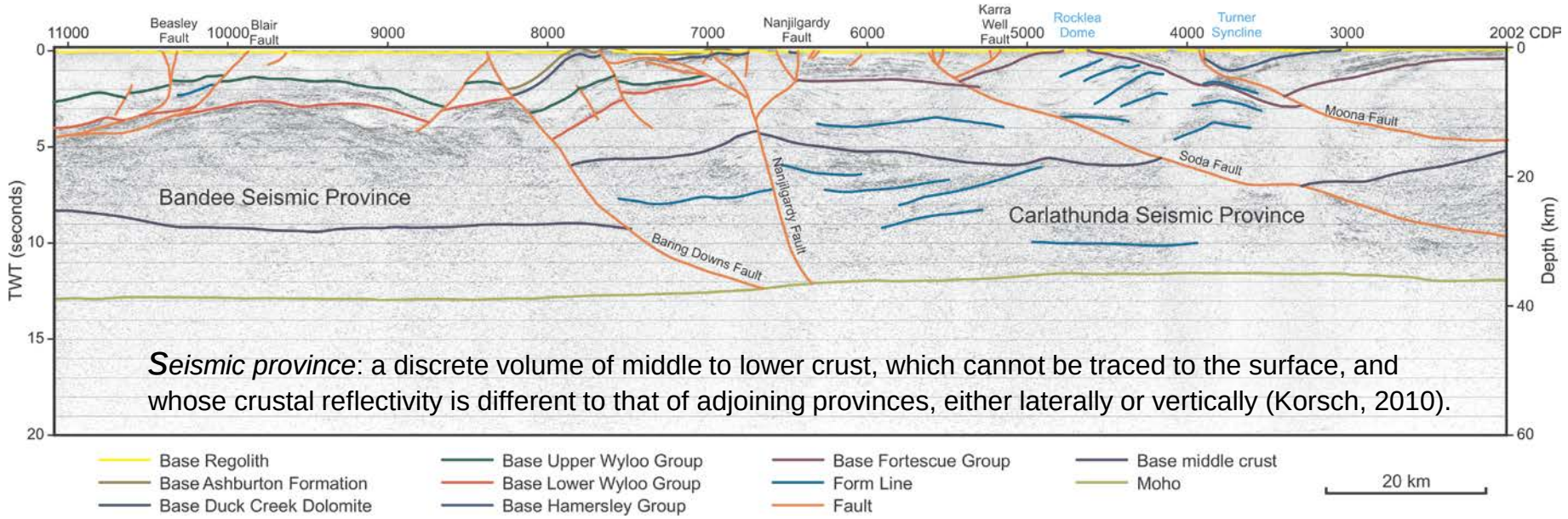
- **Vertical scale equal to the horizontal scale (assuming a crustal velocity of 6000 m $s^{-1)}$. One sec Two Way Travel time (TWT) ~3 km**

- **Common Depth Point (CDP) location are shown along the surface (100CDP = 2km).**

Seismic Line 10GA-CP1: preliminary interpretation

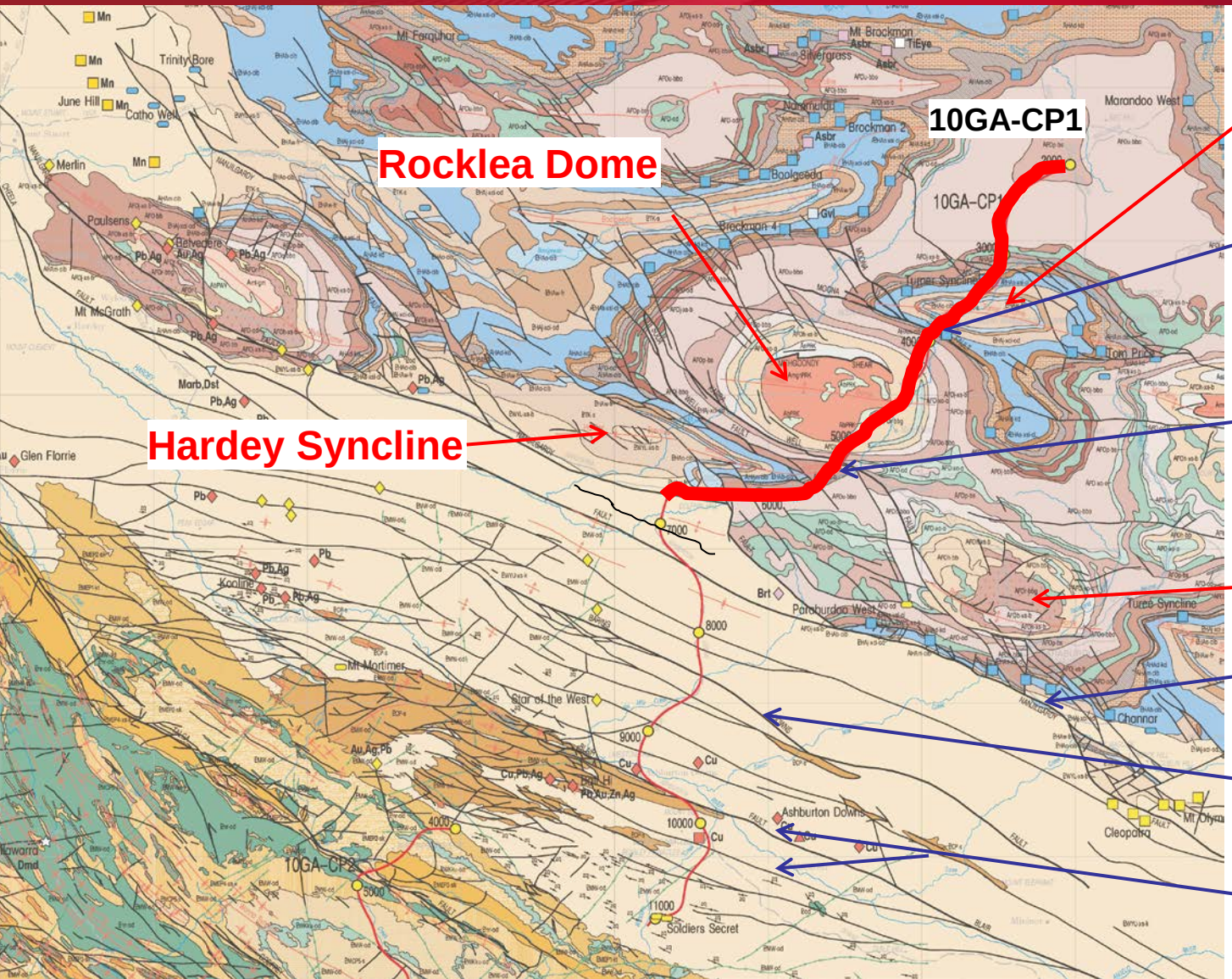


PC – Pilbara Craton granite-greenstone, FG - Fortescue Gp; HG – Hamersley Gp; LWG – lower Wyloo Group; UWG – Upper Wyloo Group; DCD – Duck Creek Dolomite

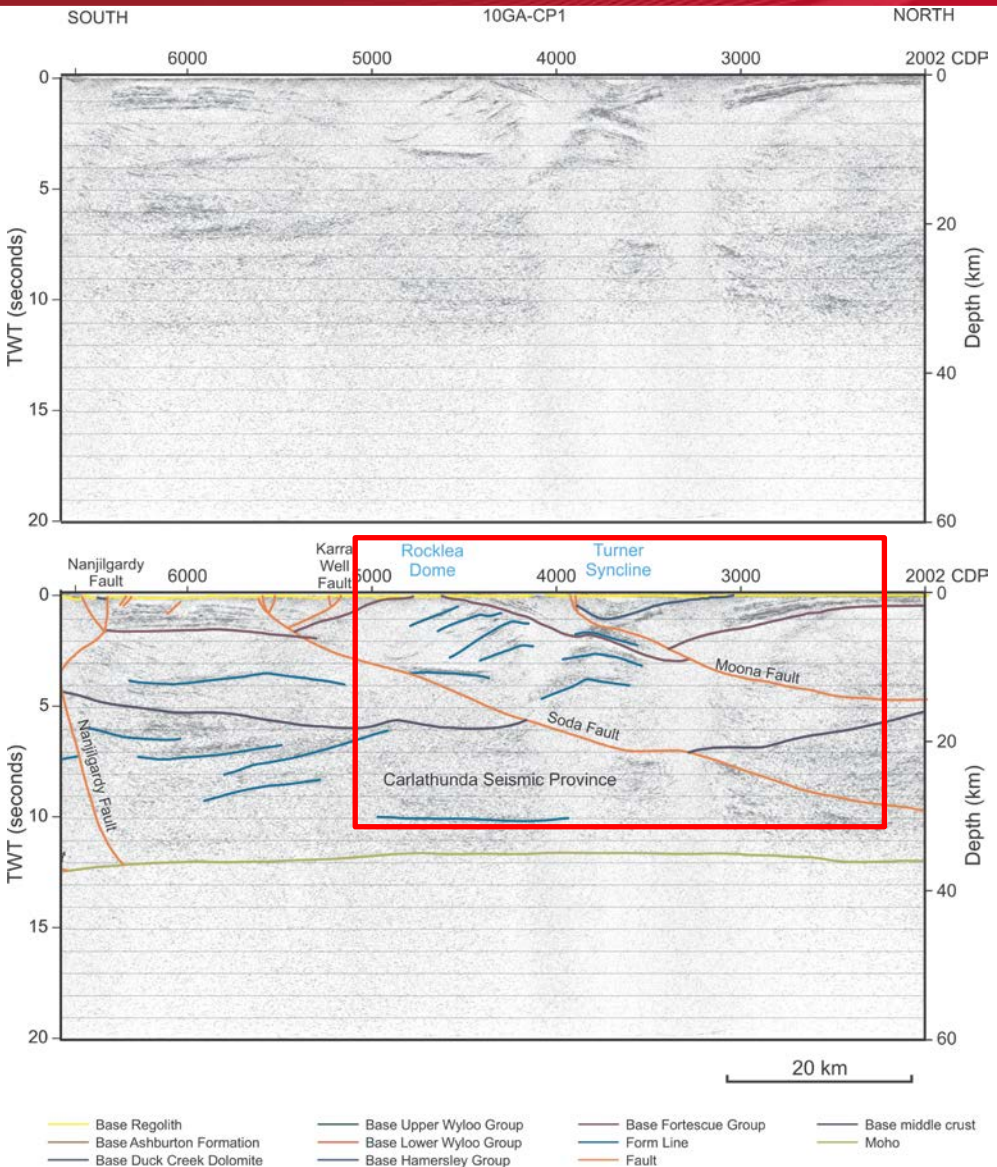


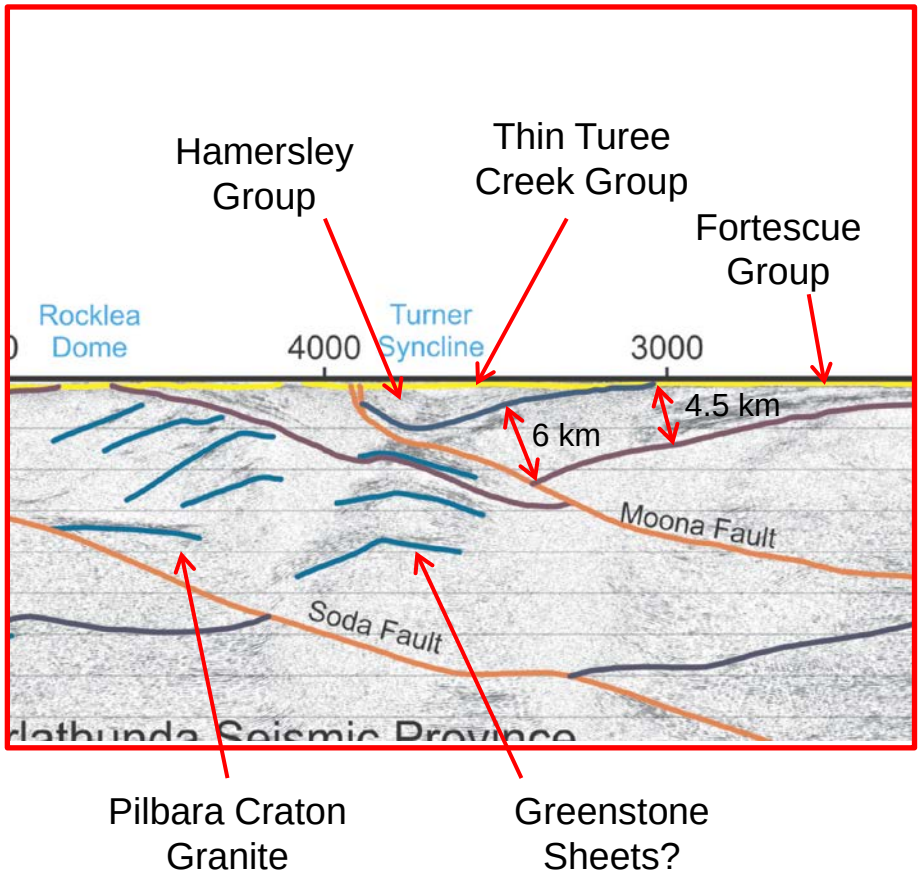
Seismic province: a discrete volume of middle to lower crust, which cannot be traced to the surface, and whose crustal reflectivity is different to that of adjoining provinces, either laterally or vertically (Korsch, 2010).

Northern Capricorn Orogen: major structural elements

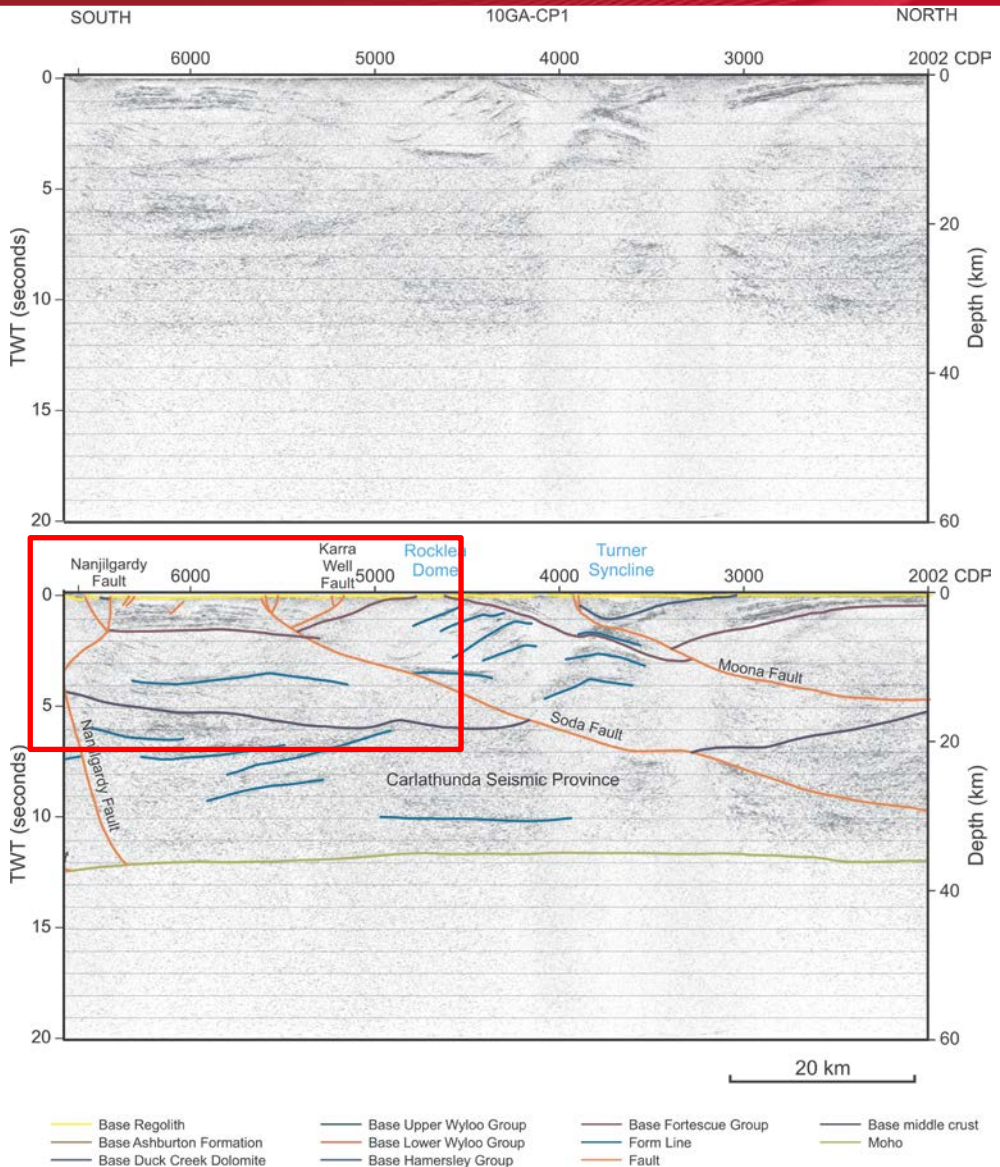


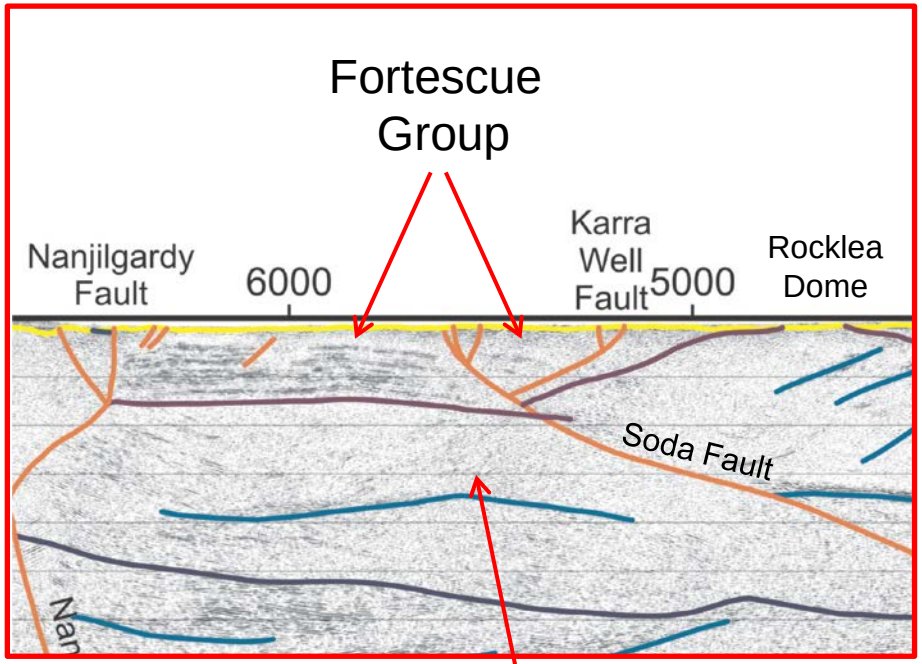
Turner Syncline —Rocklea Dome: preliminary interpretation



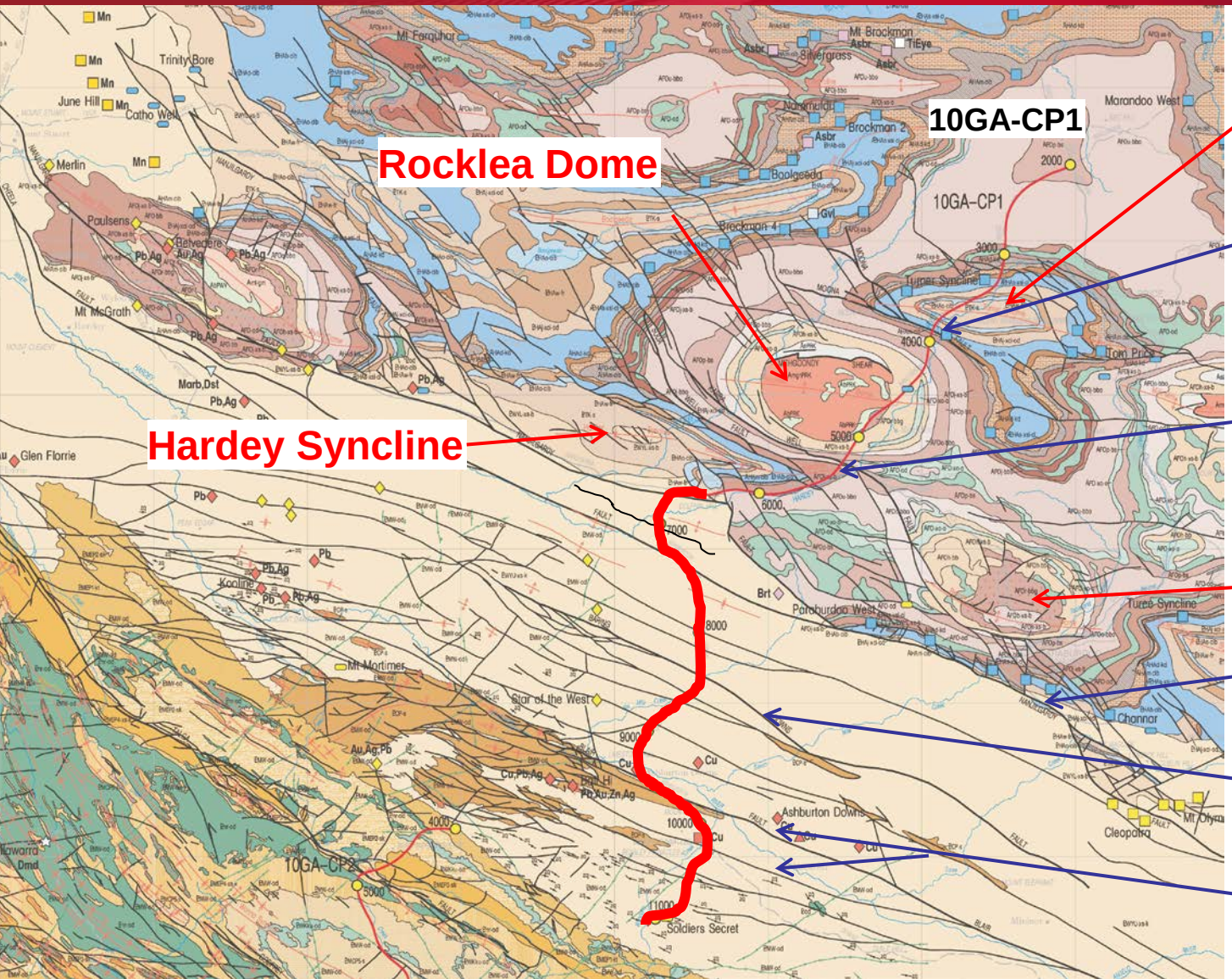


Rocklea Dome to Nanjilgardy Fault: preliminary interpretation

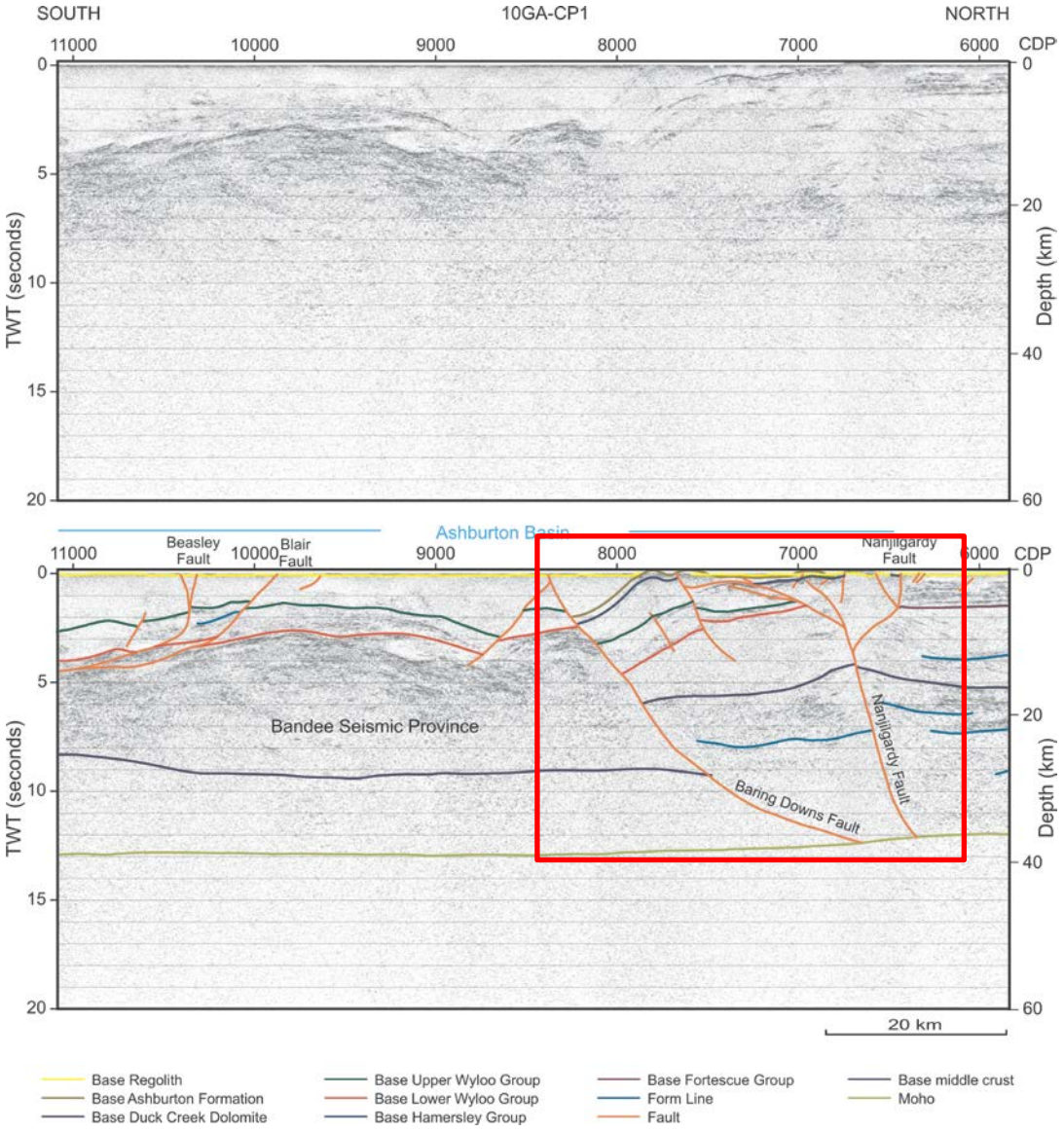


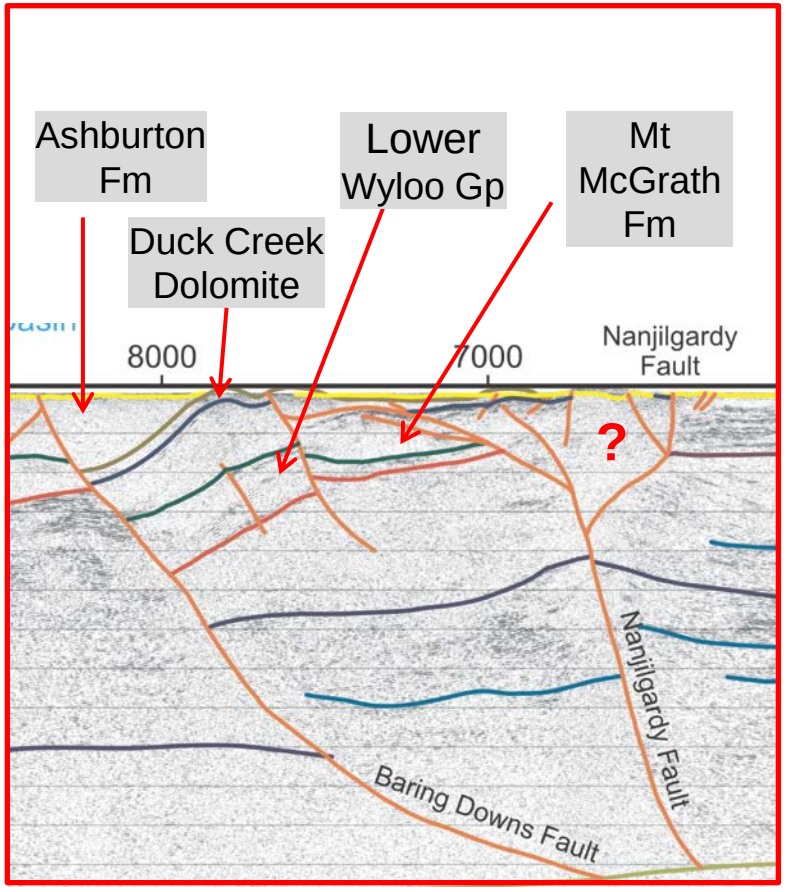


Northern Capricorn Orogen: major structural elements

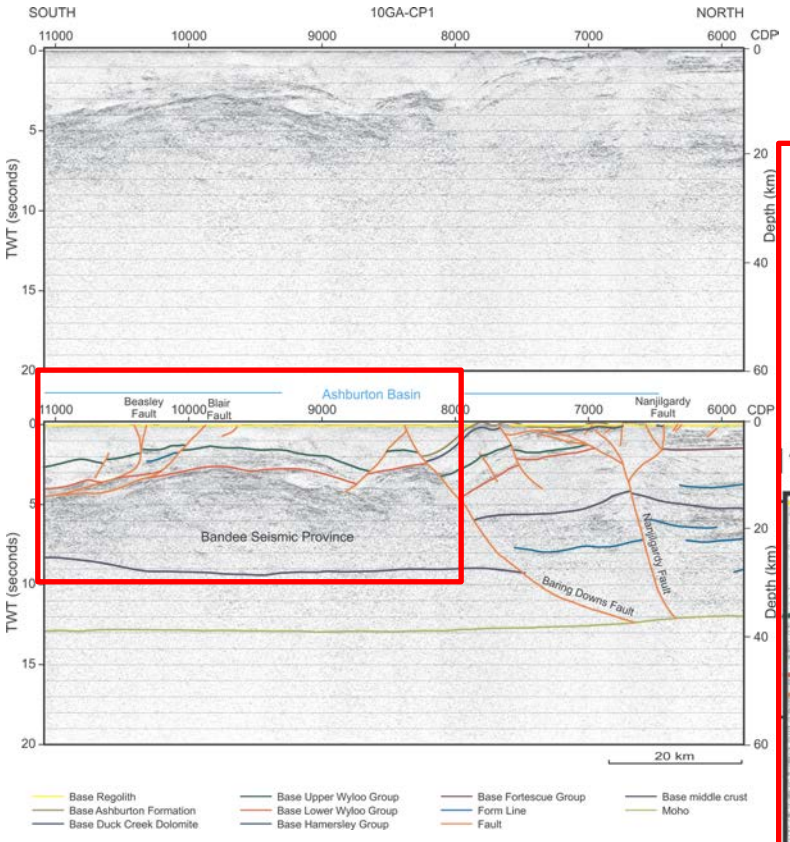


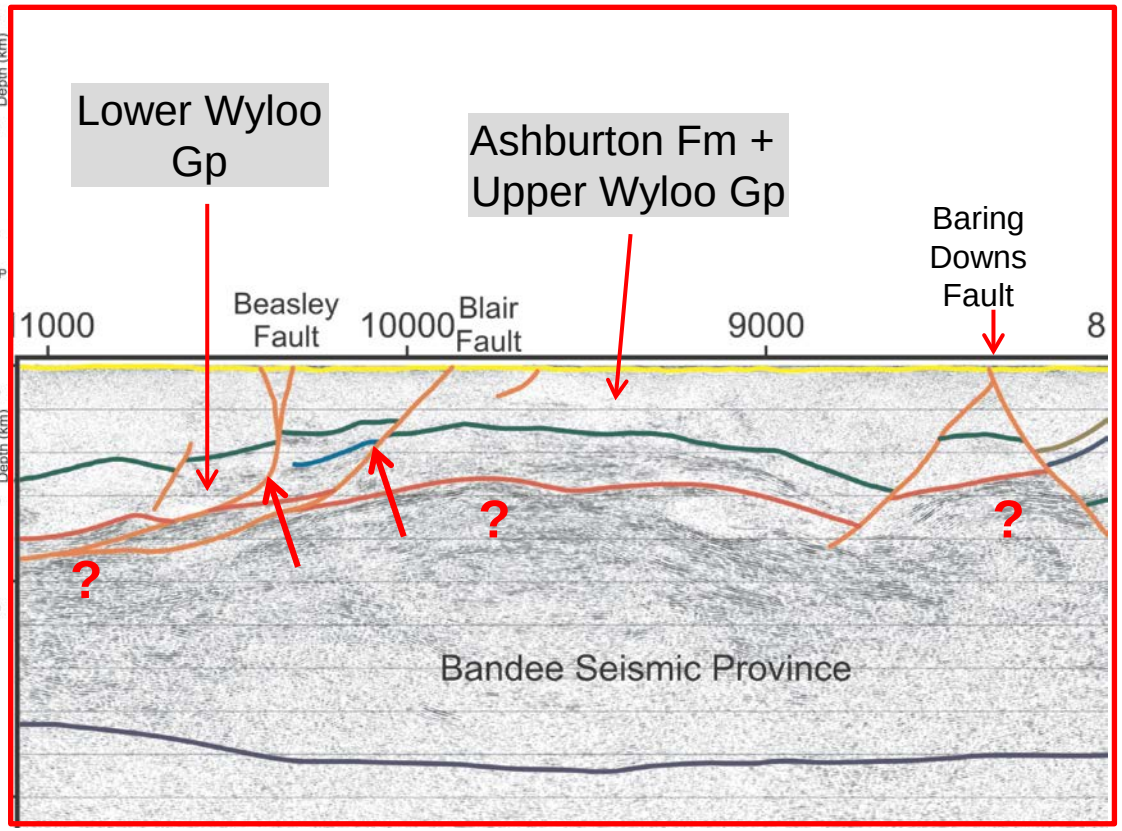
Nanjilgardy Fault to Baring Downs Fault: preliminary interpretation





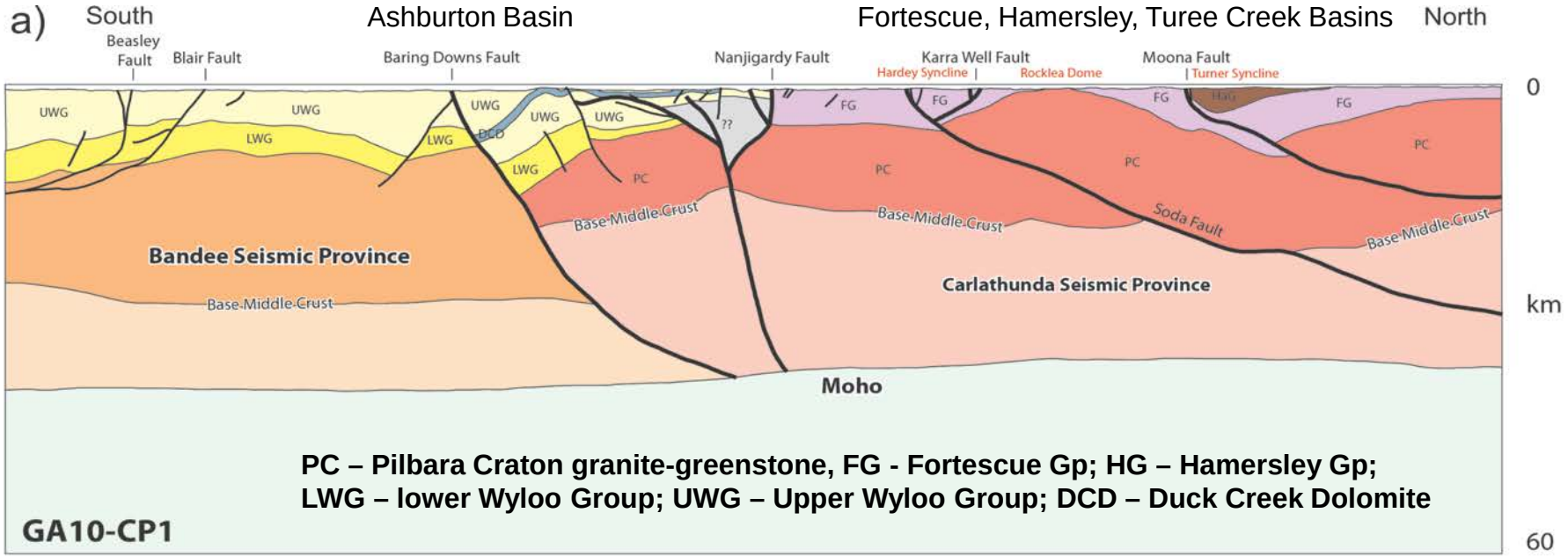
Baring Downs Fault to southern end of 10GA-CP1: preliminary interpretation



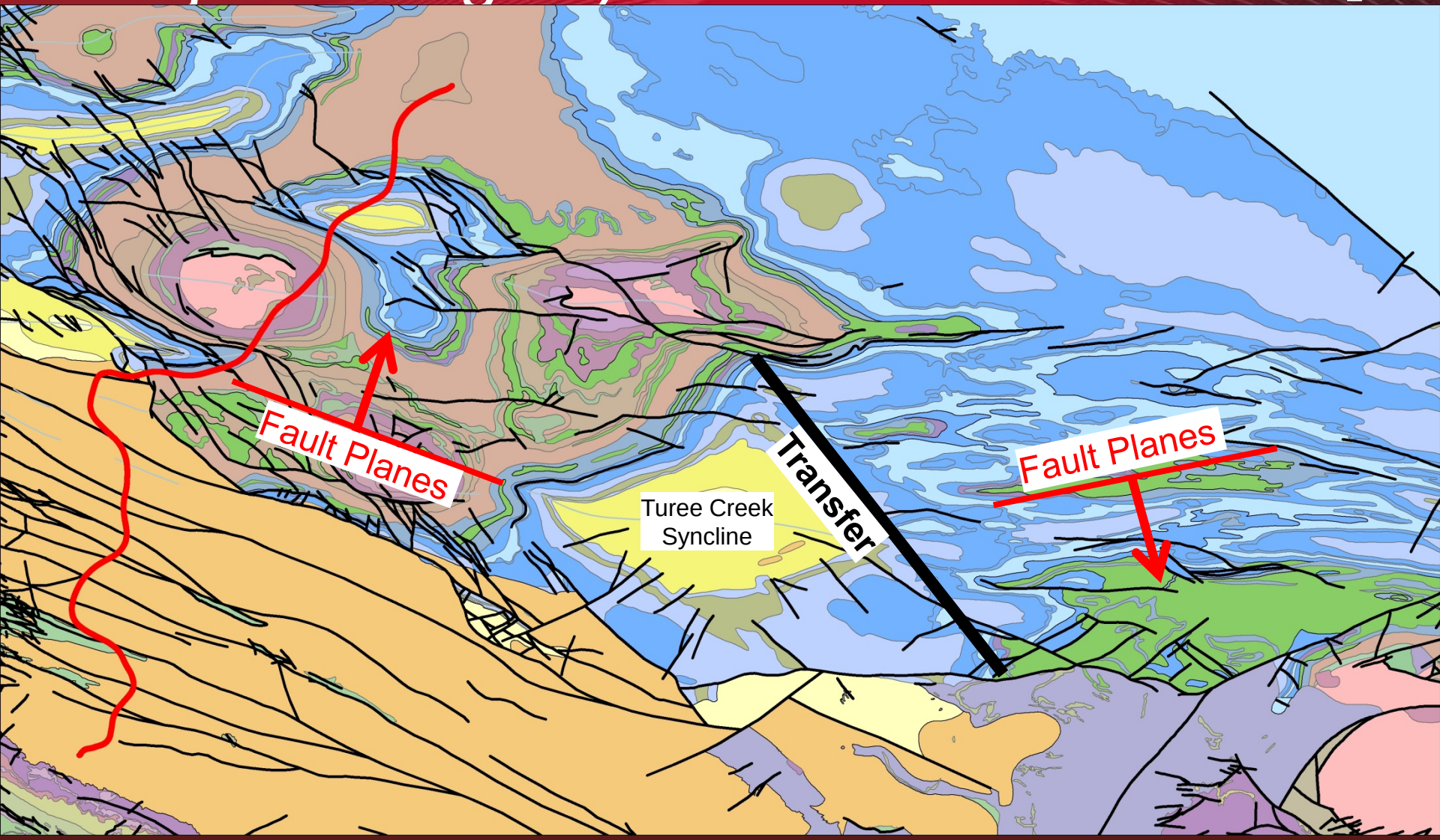


Seismic Line 10GA-CP1: summary of major findings 1)

- Major faults at the boundary between the Pilbara Craton and the Ashburton Basin are steep to listric, northward dipping – mantle tapping.
- Reactivated Fortescue Group growth faults are listric, northward dipping.



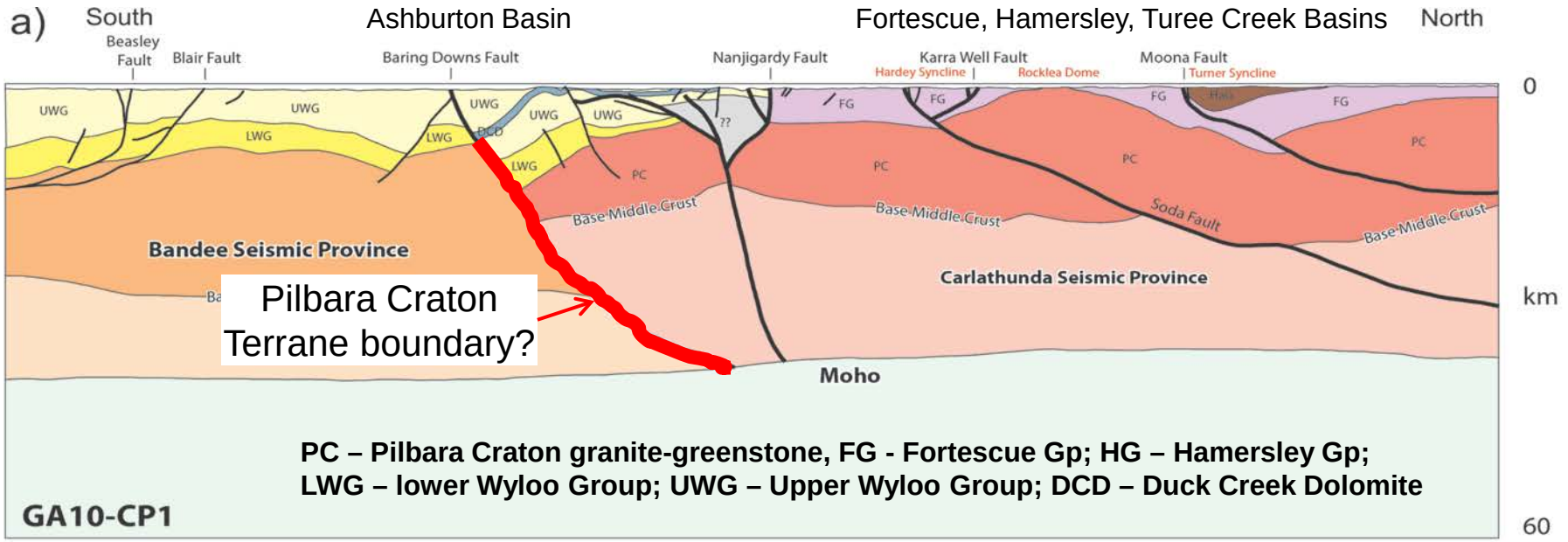
Seismic Line 10GA-CP1: summary of major findings 1)



Seismic Line 10GA-CP1: summary of major findings

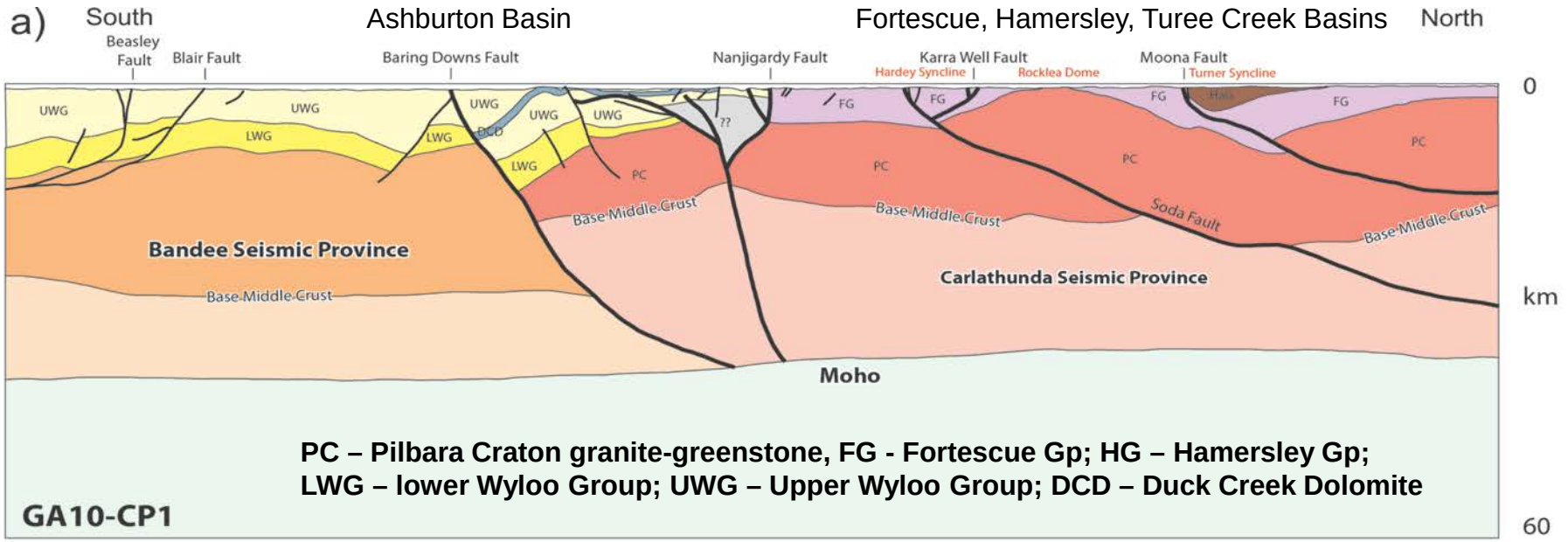
Deep crustal structure of the northern Capricorn Orogen:

Is the Baring Downs Fault a reactivated Pilbara Craton terrane suture?



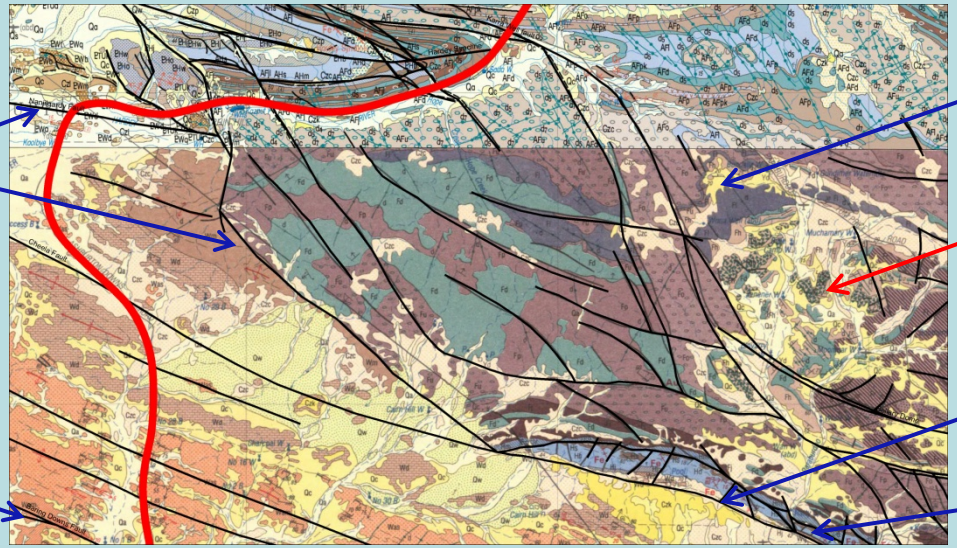
Seismic Line 10GA-CP1: summary of major findings

- crustal architecture of the Ashburton Basin – is it consistent with accepted tectonic models for the Orogen?



Interpreting Line 10GA-CP1: additional geological/geophysical constraints 1

1:250k Geology



Nanjilgardy Fault

Baring Downs Fault

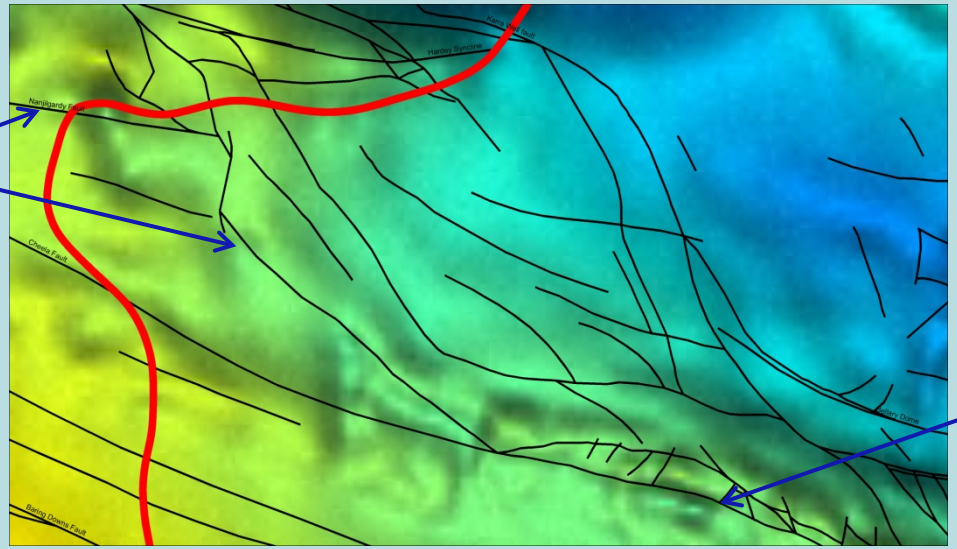
Fortescue Group (>6 km)

Bellary Dome

Nanjilgardy Fault

Faulted Hamersley Group

Bouger Gravity



Nanjilgardy Fault

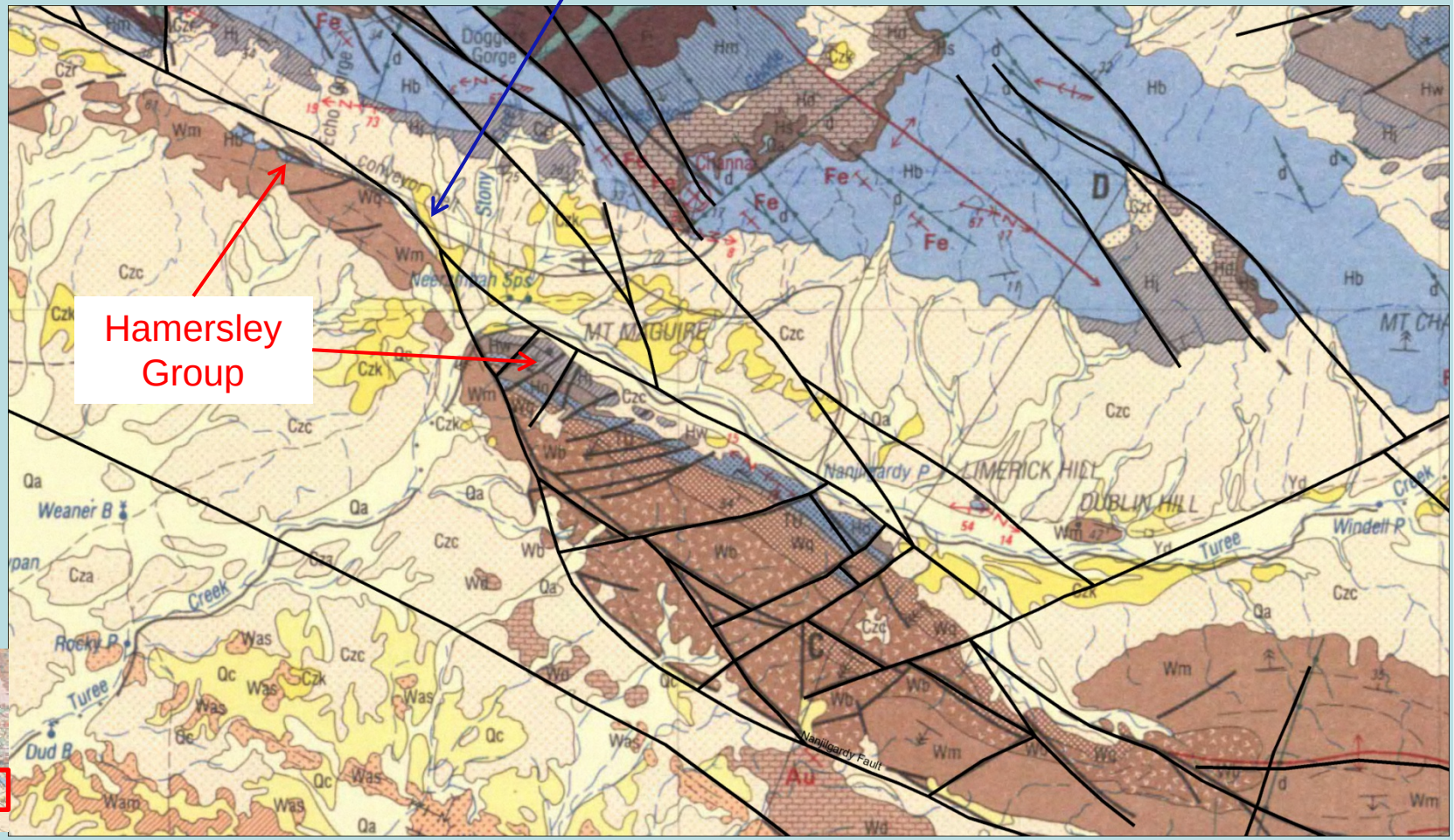
Nanjilgardy Fault

Interpreting Line 10GA-CP1: additional geological/geophysical constraints 2

Turee Creek 1:250k Geology

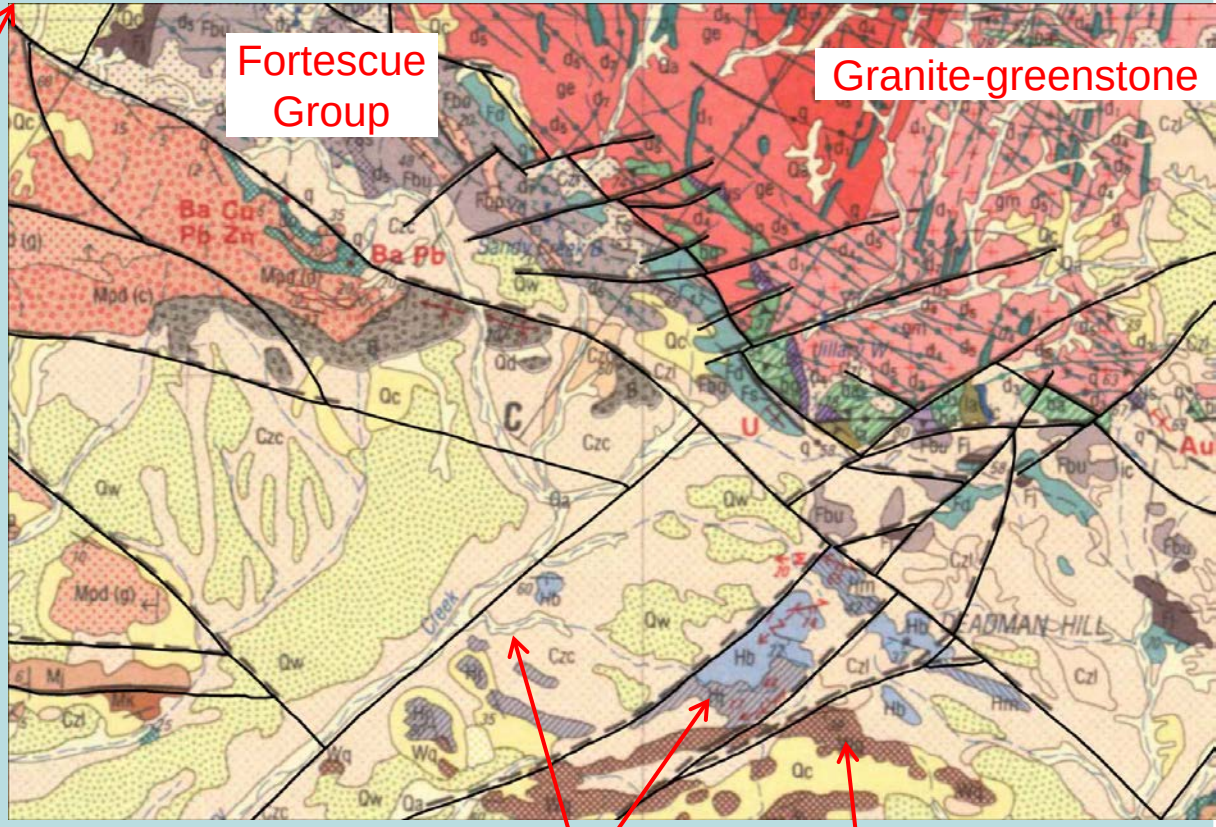
Nanjilgardy Fault

Hamersley Group

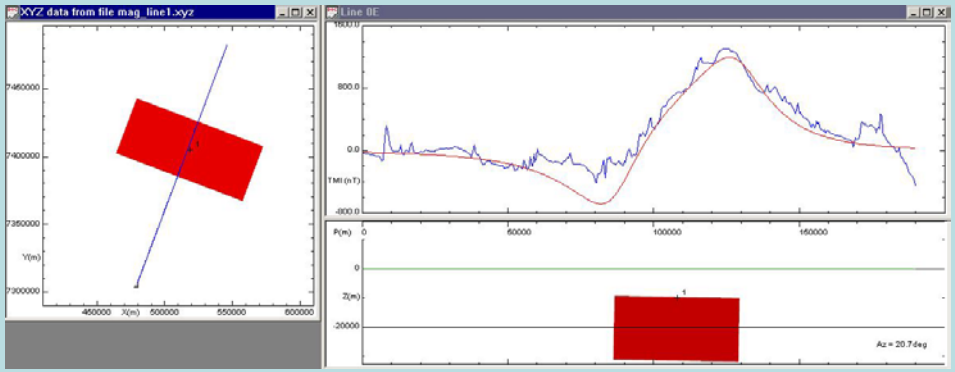


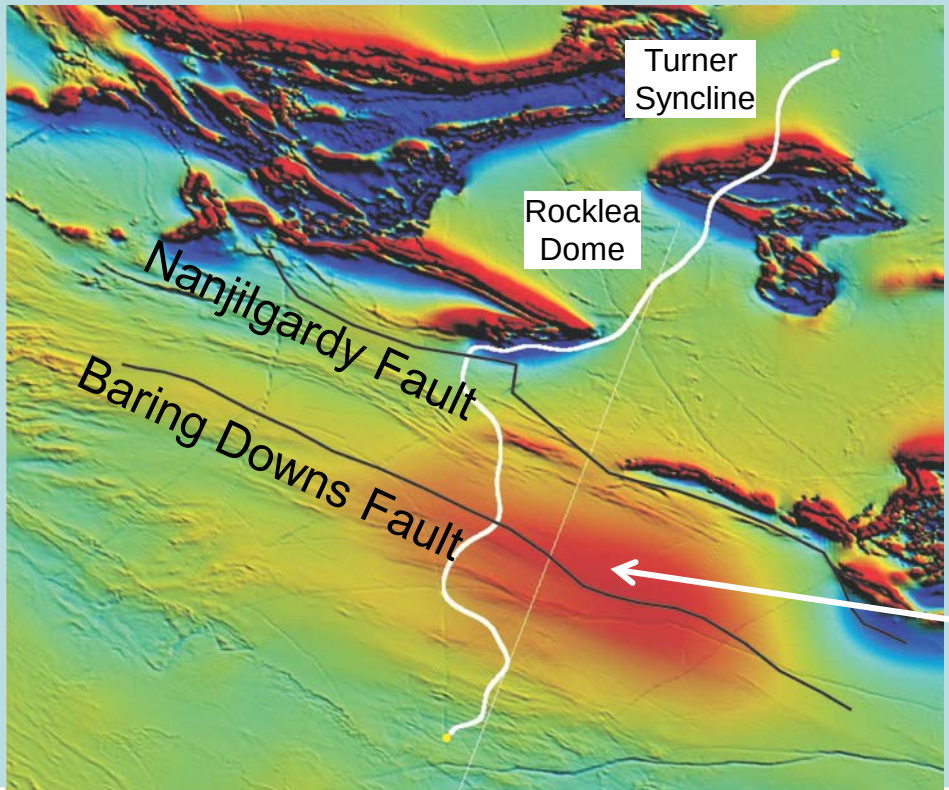
Interpreting Line 10GA-CP1: additional geological/geophysical constraints 3

Newman 1:250k Geology



Interpreting Line 10GA-CP1: additional geological/geophysical constraints 4





Magnetic Modelling

- Aeromagnetic anomaly could be caused by a very strongly magnetic unit such as the Hamersley Group (susceptibility = 0.13 SI), occurring at a depth of ~9.5 to10 km.
- modelled depth is similar to the 8 to 11 km, expected for the Hamersley Group based on position of the base of the lower Wyloo Group on the seismic section.

Deep-seated source, below strongly deformed and dismembered Ashburton Formation ie > 4.5 km depth.

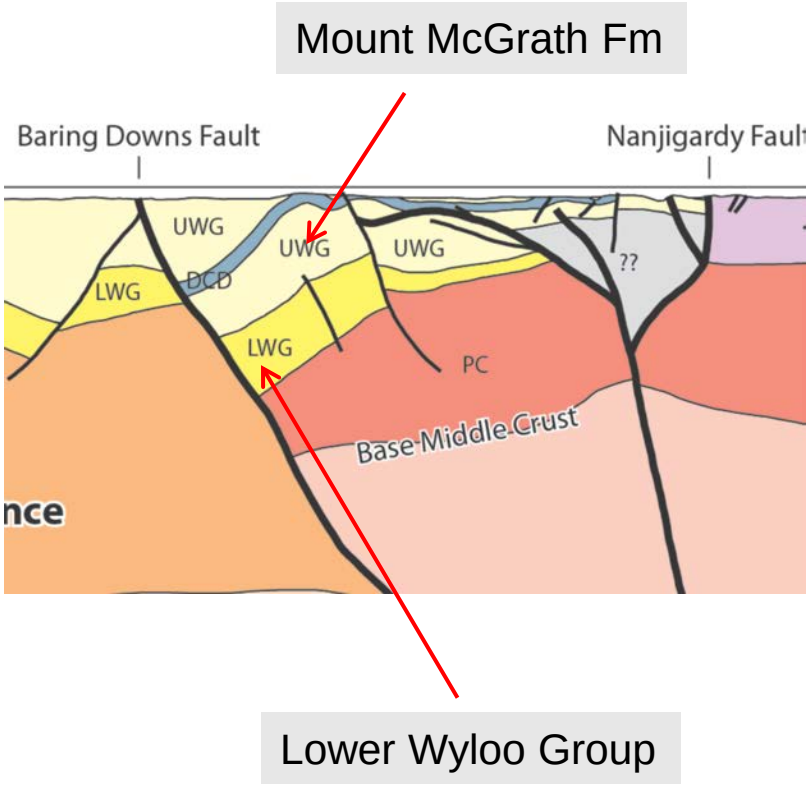
Interpreting Line 10GA-CP1: additional geological/geophysical constraints 5

- Magnetotelluric data (Heinsen et al., 2011) indicates the presence a conductive layer at depth beneath the Ashburton Basin.
- There are no clues in the Fortescue and Hamersley Group stratigraphy to suggest proximity to a southern basin margin at the Nanjilgardy Fault.
- Paleocurrent and provenance data suggest the Hamersley Group was distally exposed to the south of the present-day Pilbara margin during deposition of the middle to upper Turee Creek Group.

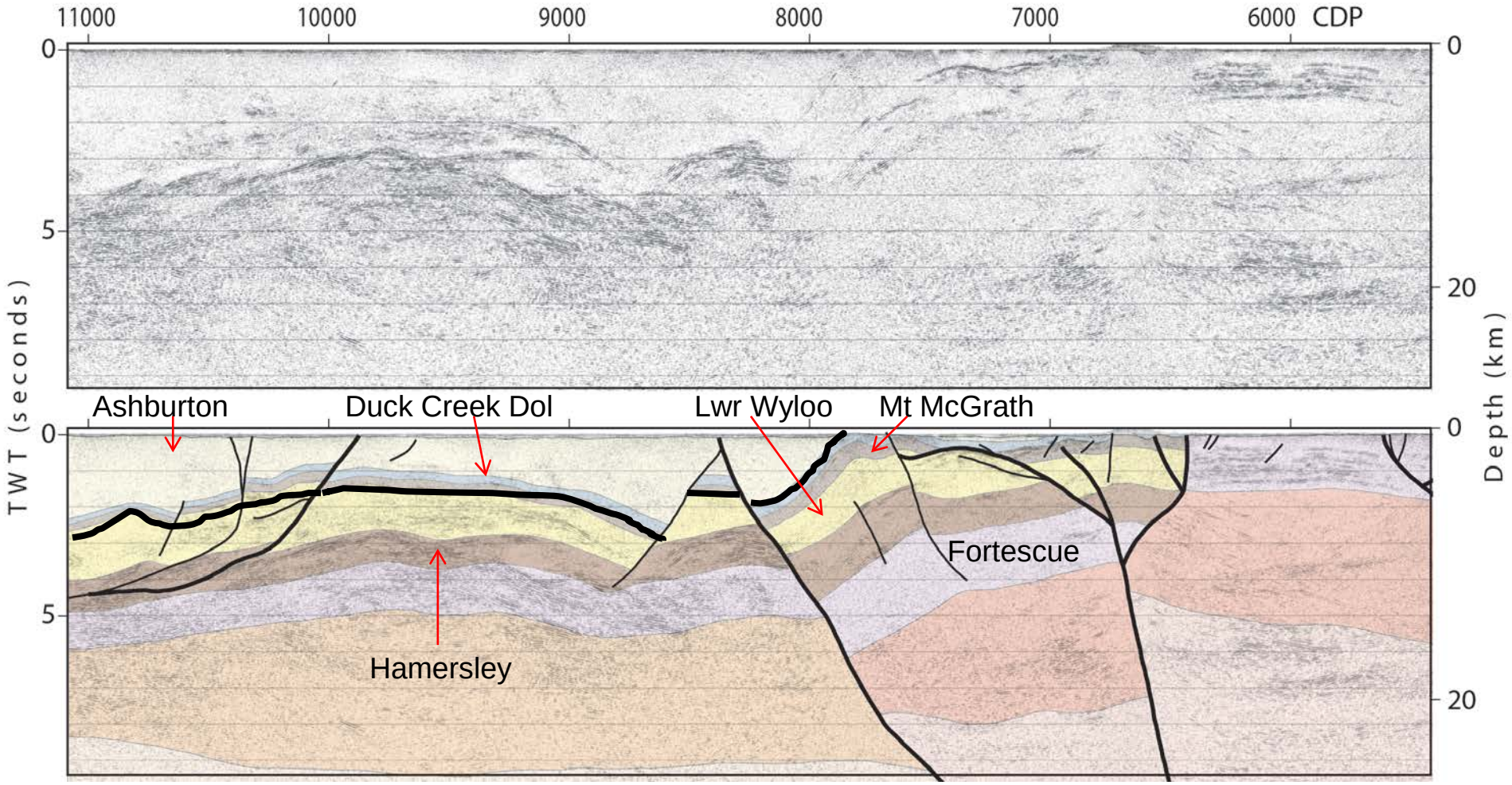
Interpreting Line 10GA-CP1: additional geological/geophysical constraints 6

Also:

- Seismic interpretation shows both lower Wyloo Group and Mount McGrath Fm changing in thickness from about c. 1 to 4 km between the Nanjilgardy and Baring Downs Faults.This doesn't match outcrop data which indicates consistent thicknesses of ~ 3 km and ~1.2 km for the lower Wyloo Group and Mount McGrath Fm respectively.



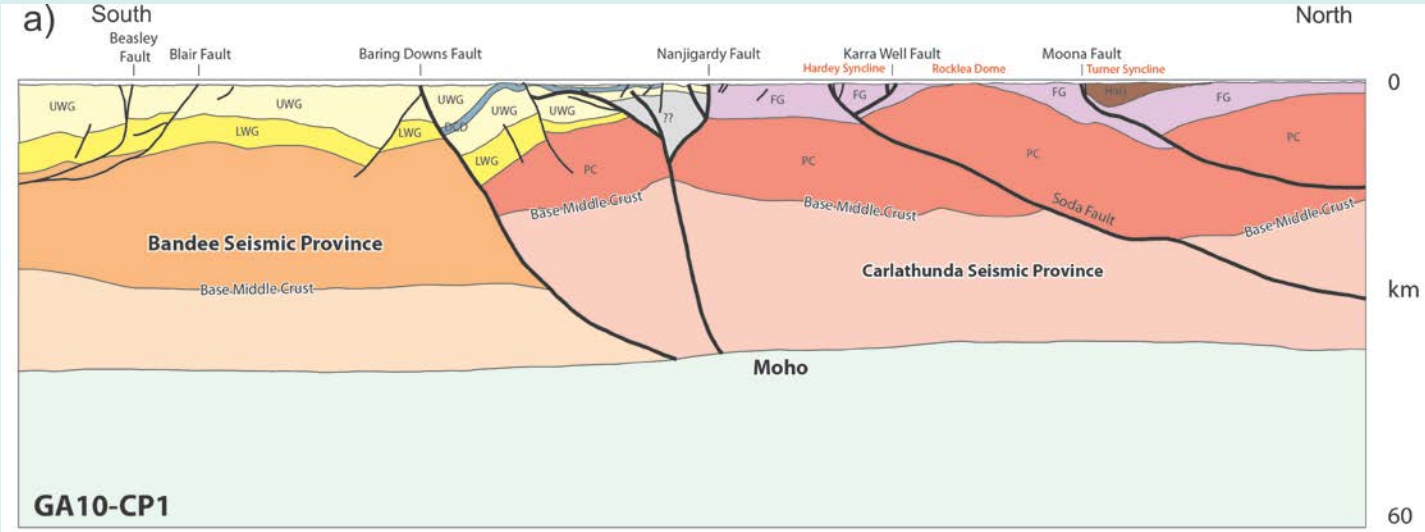
Seismic Line 10GA-CP1: alternative interpretation south of Nanjilgardy Fault

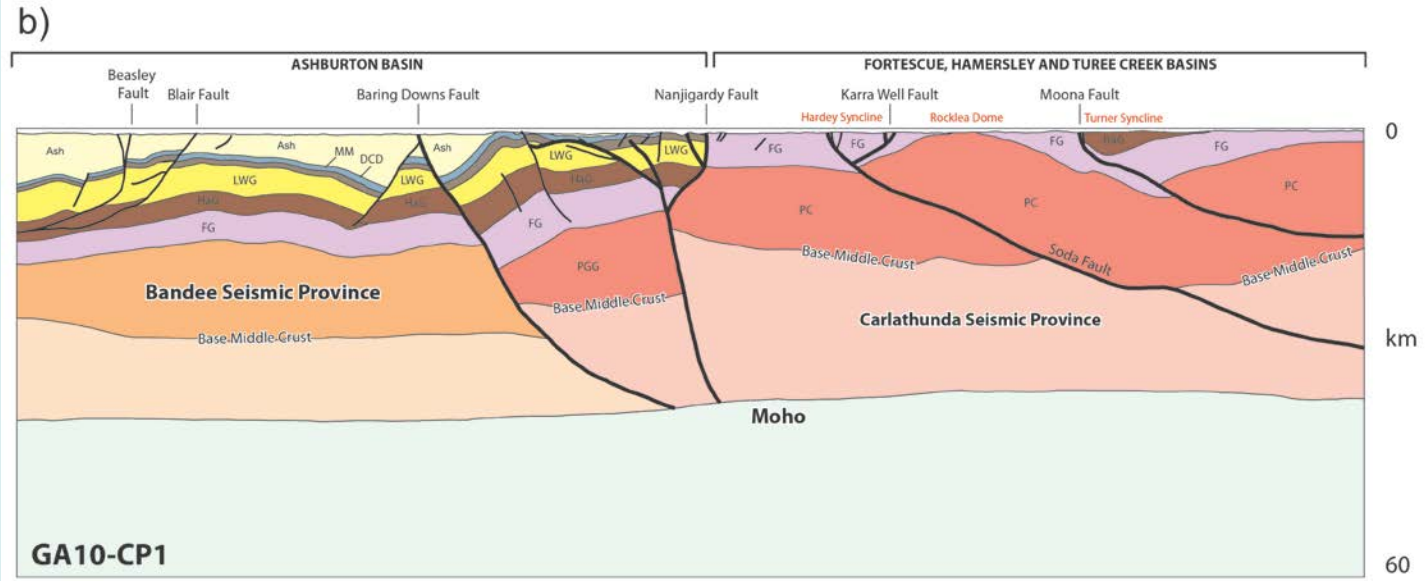


Seismic Line 10GA-CP1: preliminary interpretations

Preliminary interpretation 10GA-CP1

Alternative preliminary interpretation 10GA-CP1





Conclusions

Seismic line 10GA-CP1 is a major advance in our understanding of the northern Capricorn Orogen. It shows:

- Nature of major, mantle-tapping faults e.g. Nanjilgardy and Baring Downs Faults, that mark the boundary between the Pilbara Craton and the Ashburton Basin,
- northward-dipping, reactivated Fortescue Group growth faults in the southern Pilbara,
- deep crustal structure of the northern Capricorn Orogen, with the recognition of the Carlathunda and Bandee Seismic Provinces.

Conclusions — 2

- highlighted the crustal architecture beneath the Ashburton Basin, showing a change in fault orientation from north-dipping in the north to south-dipping in the south,
- the interpretation process is ongoing, particularly with regard to the supracrustal stratigraphy south of the Nanjilgardy Fault.