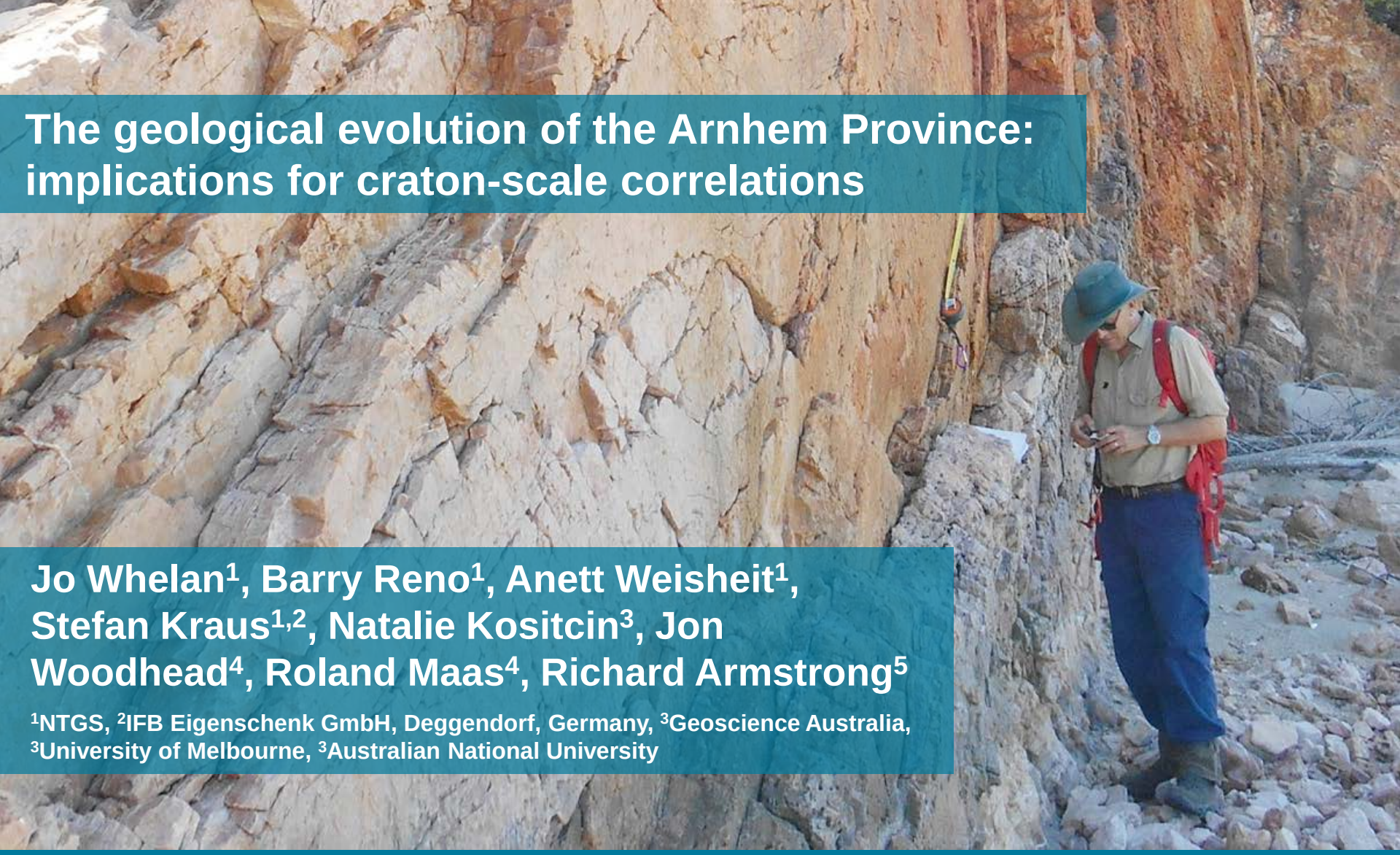

The geological evolution of the Arnhem Province: implications for craton-scale correlations

Jo Whelan[1], Barry Reno[1], Anett Weisheit[1], Stefan Kraus[1,2], Natalie Kositcin[3], Jon Woodhead[4], Roland Maas[4], Richard Armstrong[5]

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AUSTRALIA'S NORTHERN TERRITORY

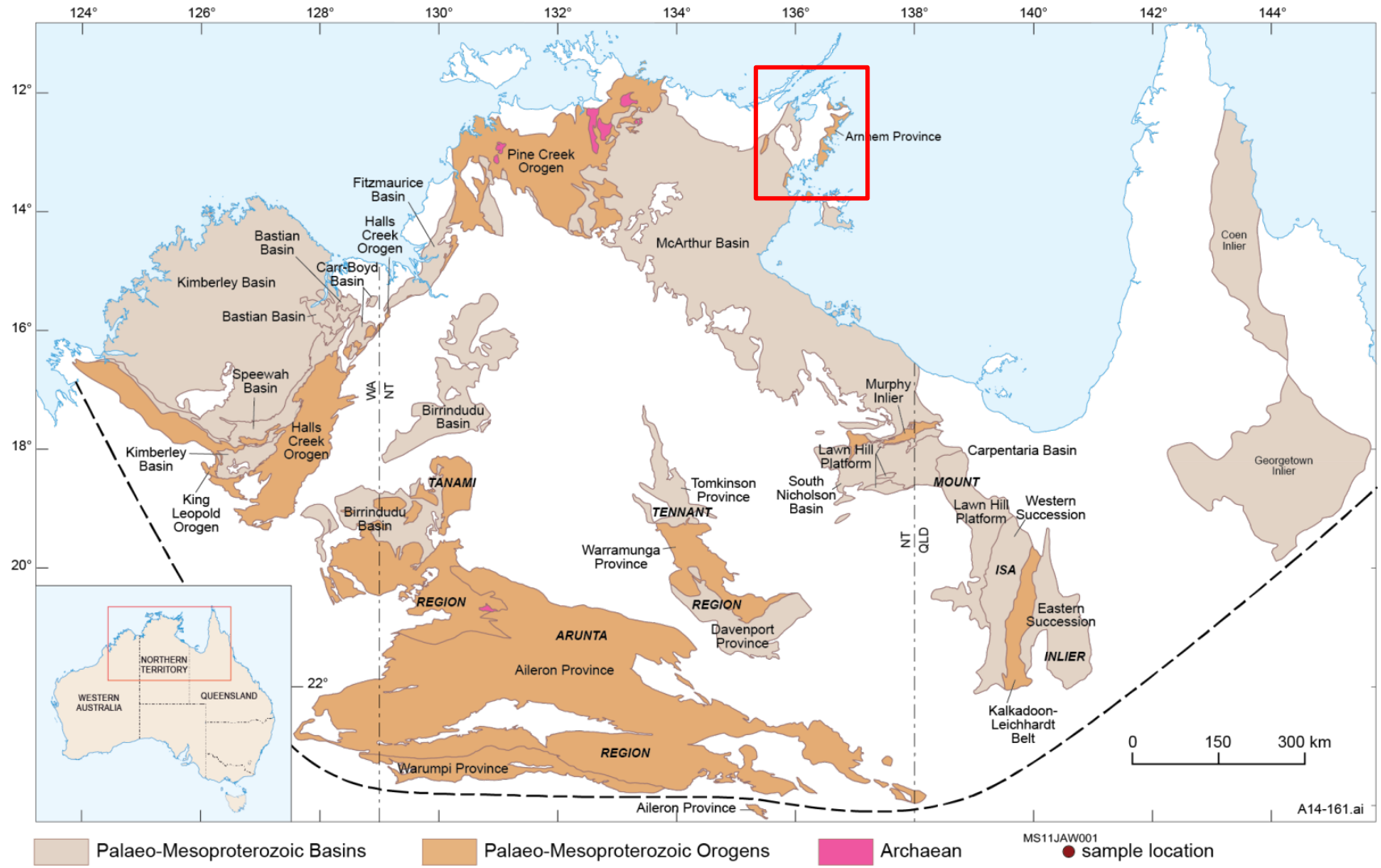
NORTHERN TERRITORY GEOLOGICAL SURVEY

AGES2017

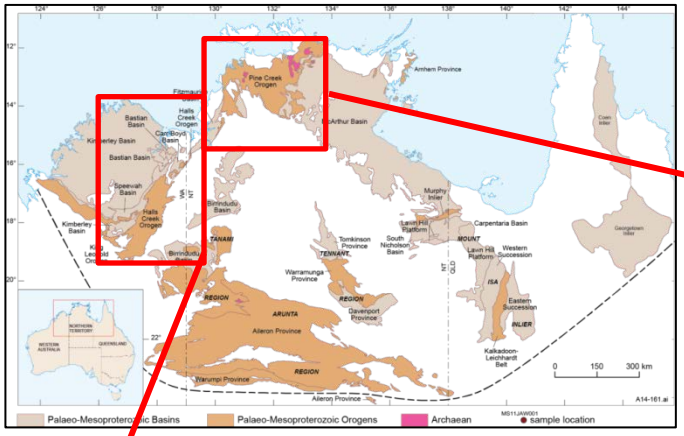
ANNUAL GEOSCIENCE EXPLORATION SEMINAR

Alice Springs, 28–29 March 2017, Northern Territory

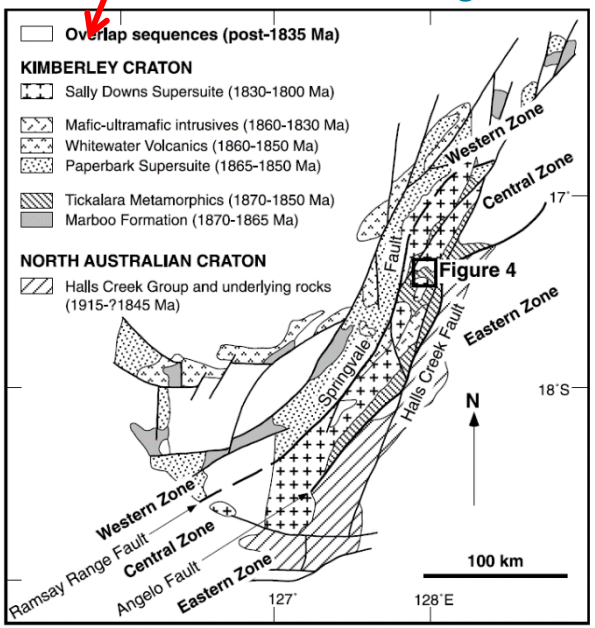
North Australian Craton



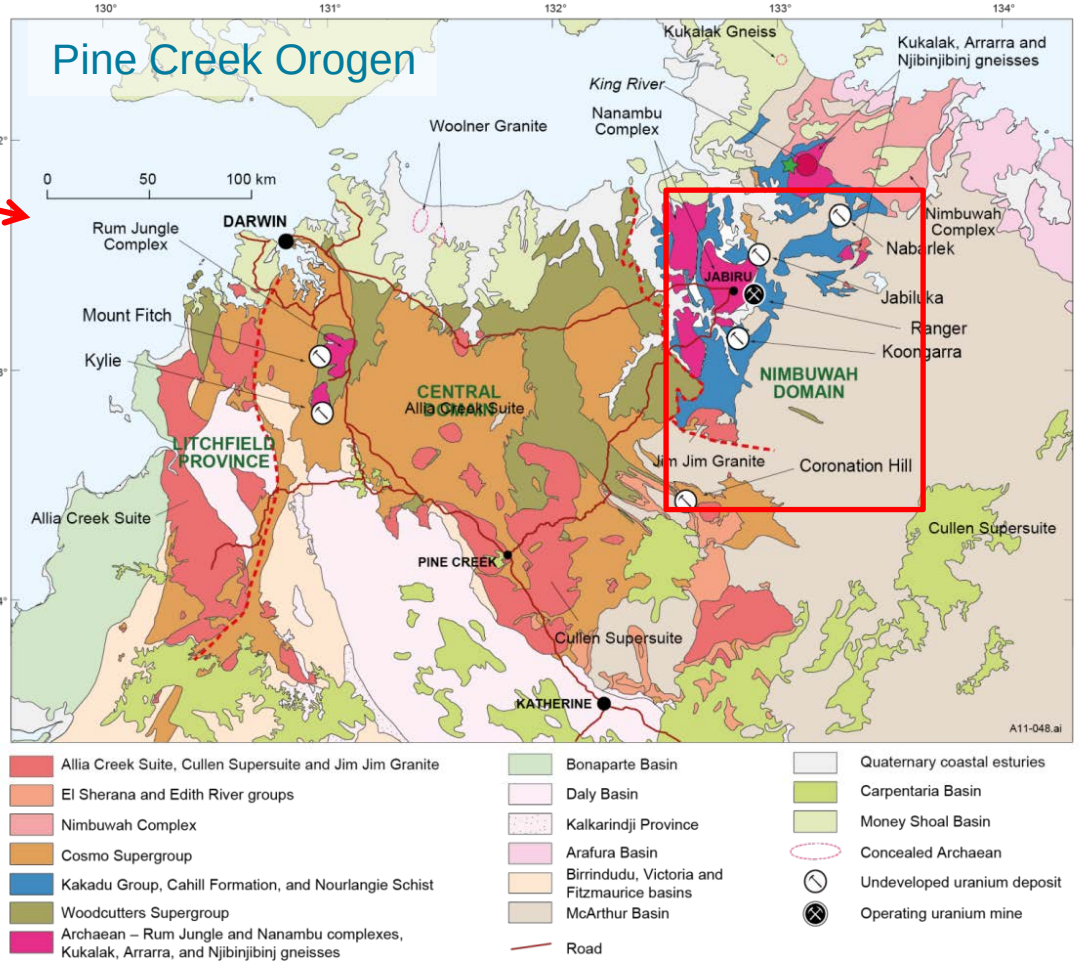
Arnhem Province in the context of NAC



Halls Creek Orogen

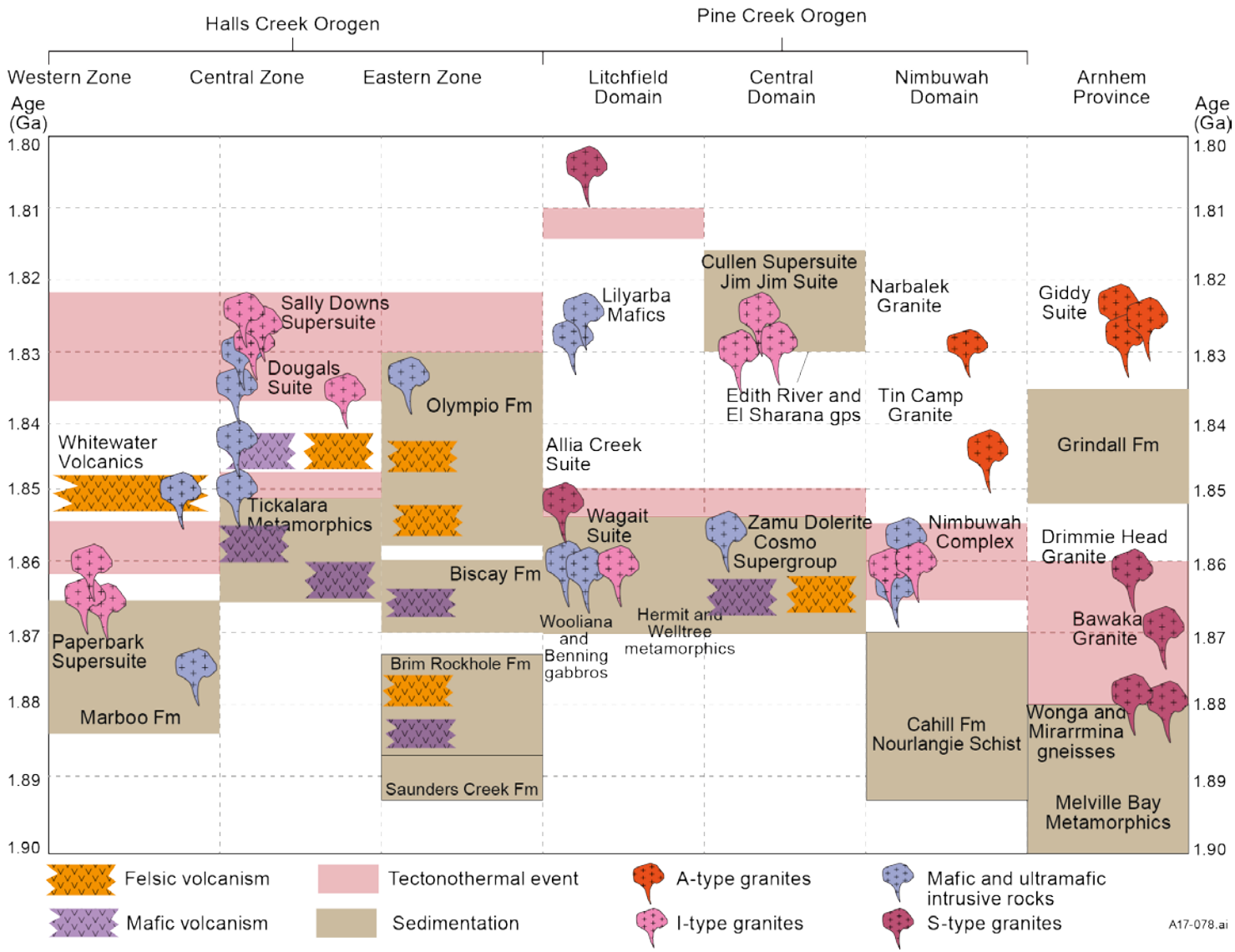


Bodorkos *et al* 1999

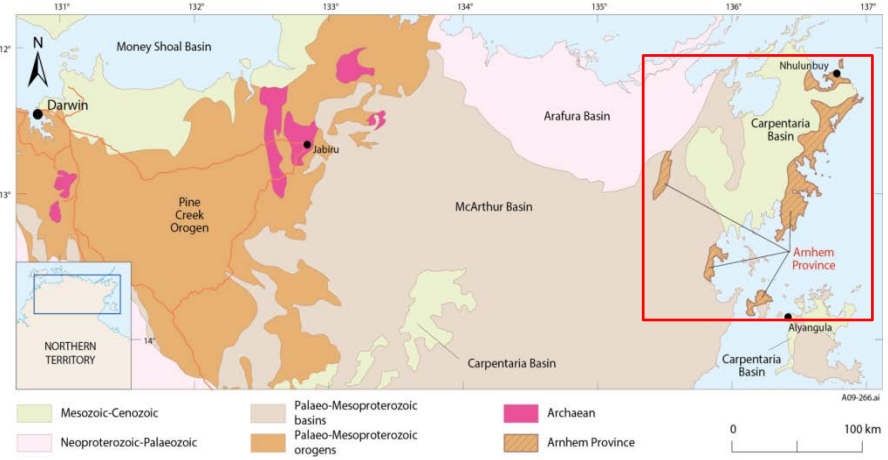


- Similarities in the timing of geological events
- Marked differences in the nature of these events

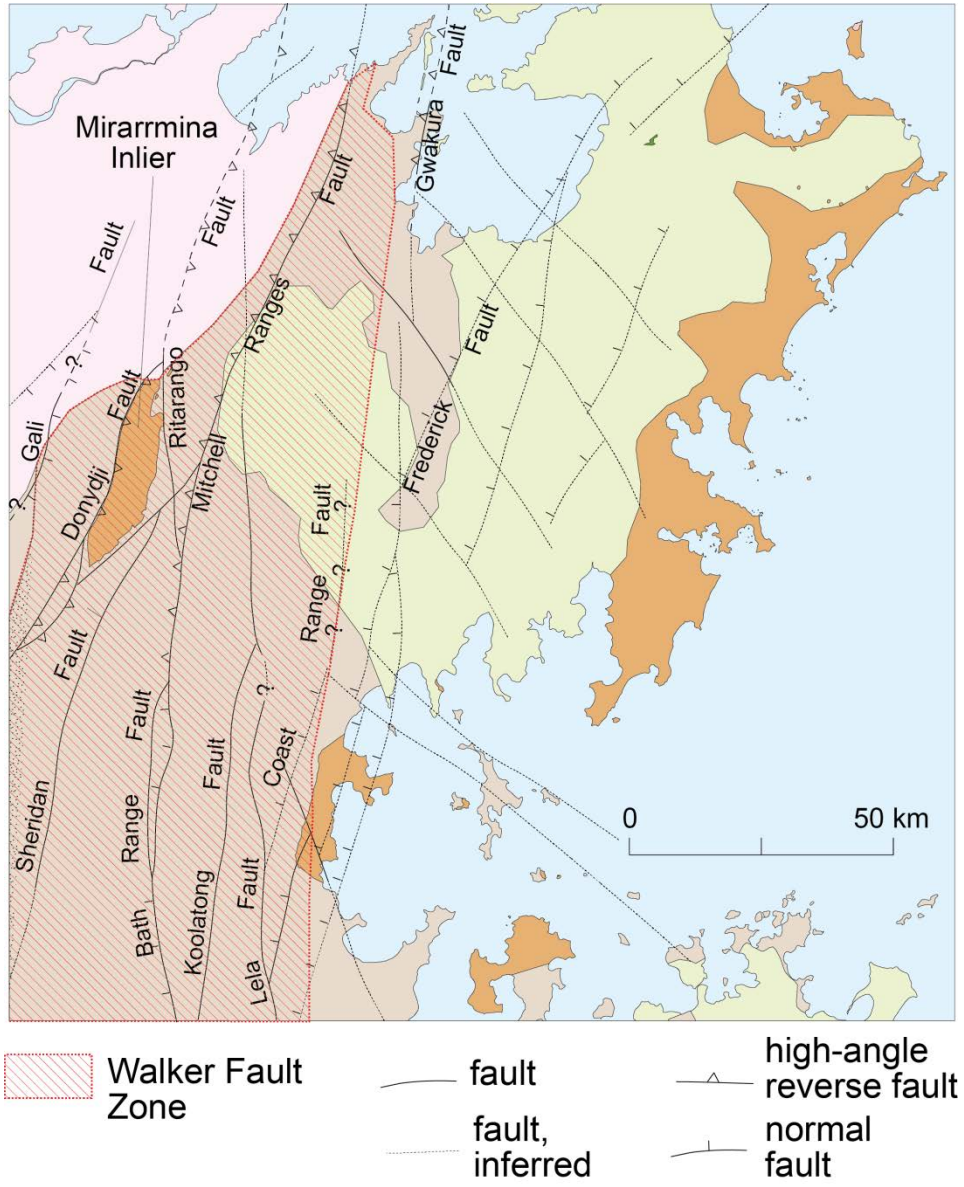
Geological evolution of the NAC ca 1.90–1.80 Ga



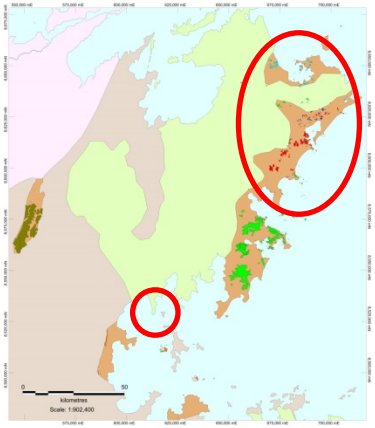
Geological setting

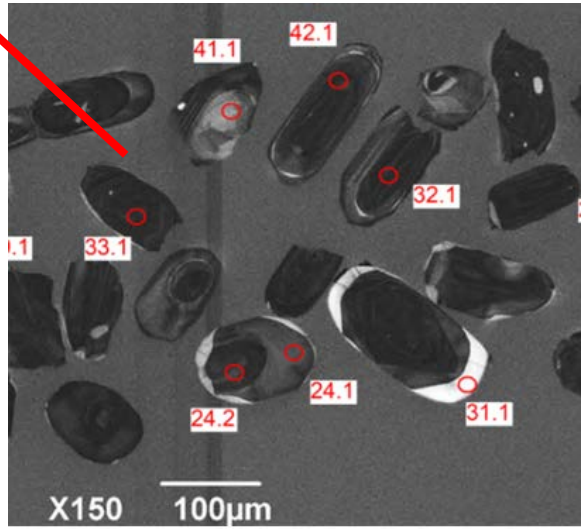


- Previous studies 1:250 000 mapping
- New 1:100 000 scale mapping to understand the geology and resource potential
- Basement to the McArthur Basin
- Links with mineral endowed Pine Creek Orogen



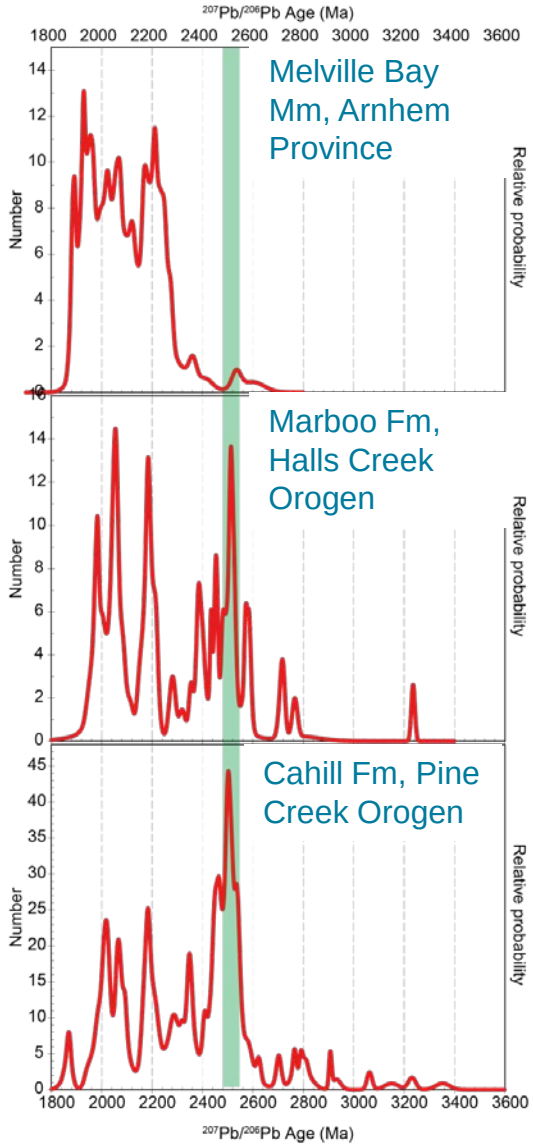
ca 1.90–1.88 Ga sedimentation

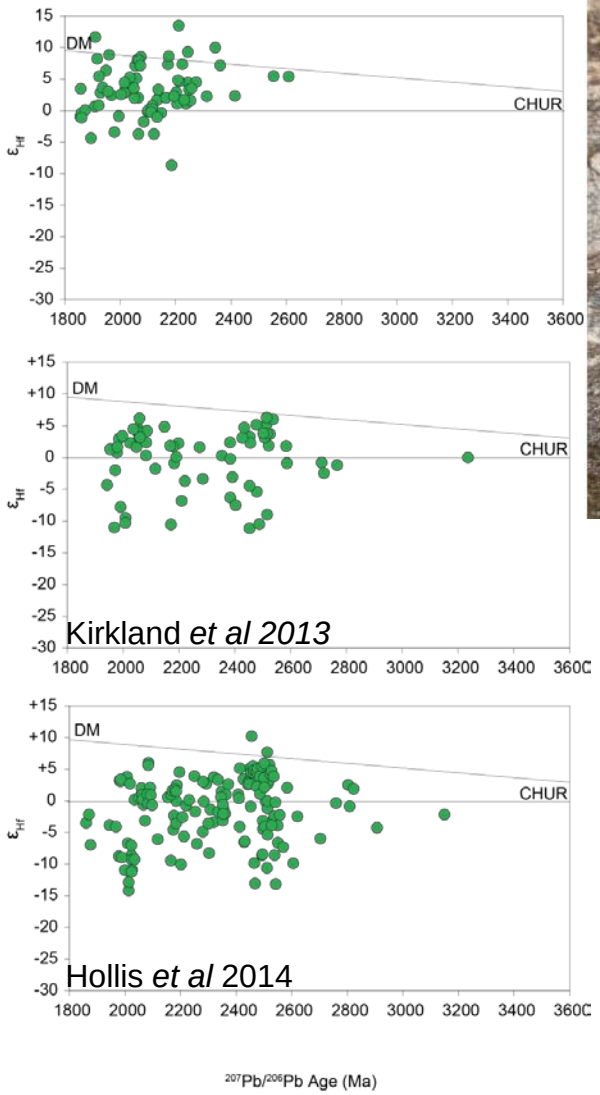




- Deposition of siliciclastic and carbonate protoliths to the Melville Bay Metamorphics
- Shallow water environment
- Youngest detrital zircon component ca 1.90 Ga
- Oldest metamorphic zircon component ca 1.88 Ga

NAC correlations: ca 1.90–1.88 Ga sedimentation

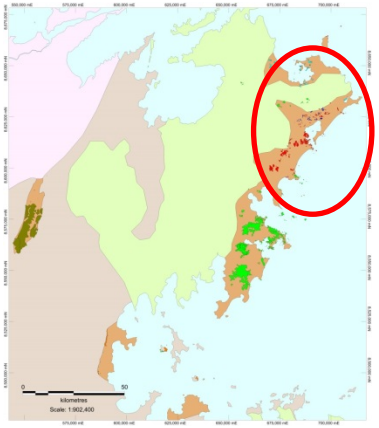


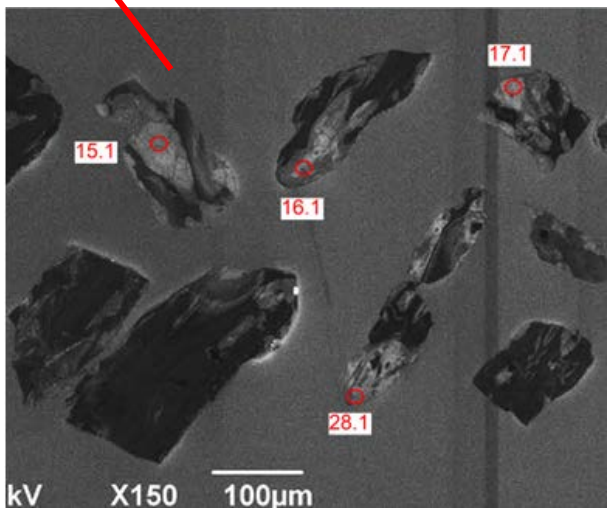


- Similar provenance to Cahill Fm and Nourlangie Schist
- Dominated by input from ca 2.50–1.90 Ga sources
- Reduced influence of Neoarchaean sources
- No known exposed Neoarchaean basement in the Arnhem Province

ca 1.88–1.86 Ga metamorphic cycle: heat source

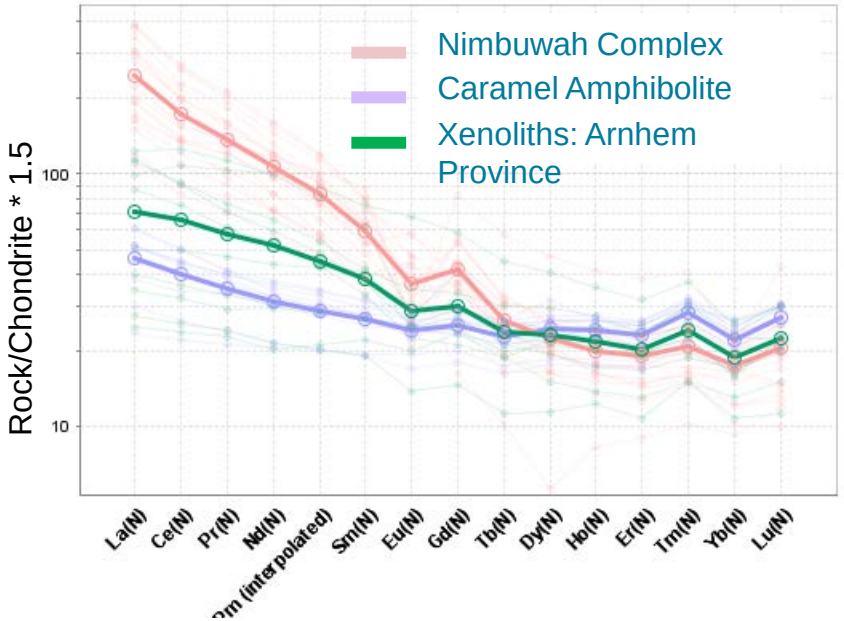
- Thinned crust, influx of mafic magma into lower crust?
- High-thermal-gradient environment
- Rare mafic xenoliths: gabbro, diorite
- Minimum zircon crystallisation age ca 1.88 Ga (Kositcin *et al* in prep)

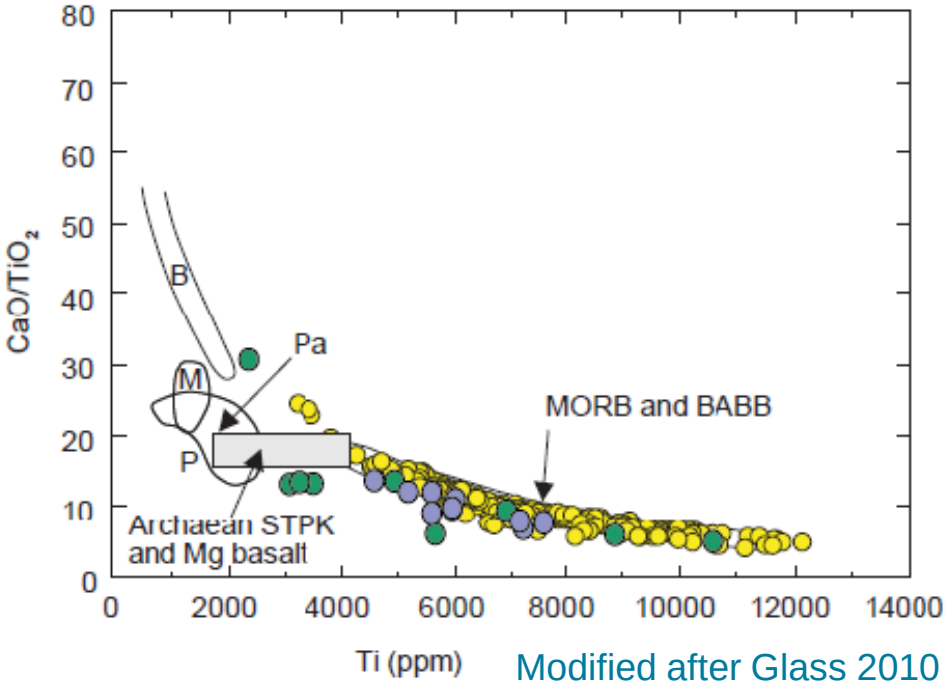




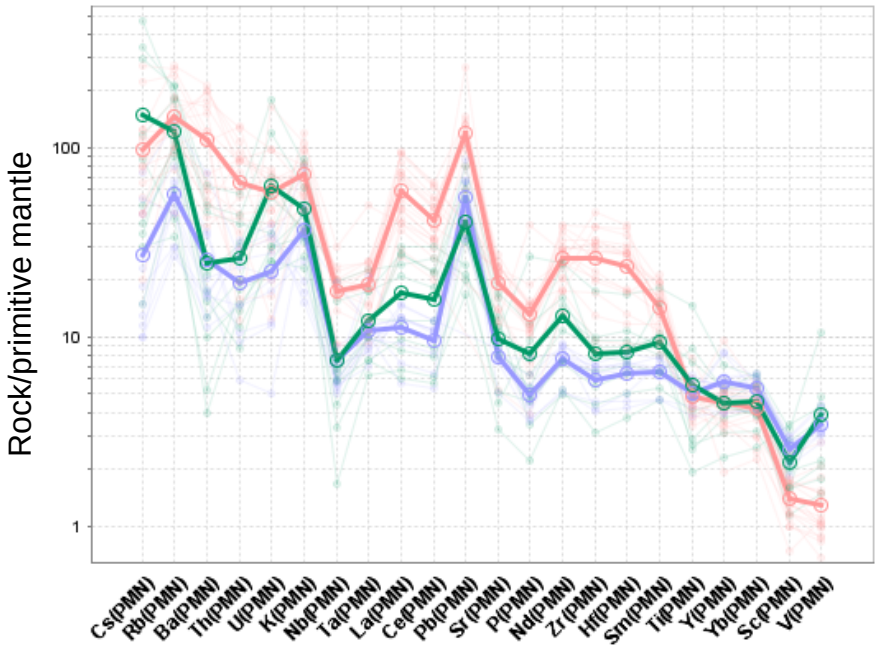
NAC correlations: mafic geochemistry

- Similar to Caramel Amphibolite which occurs as rafts in the Cahill Formation
- Distinct from mafic rocks of the Nimbuwah Complex
- Geochemical similarities to back-arc-basin basalts

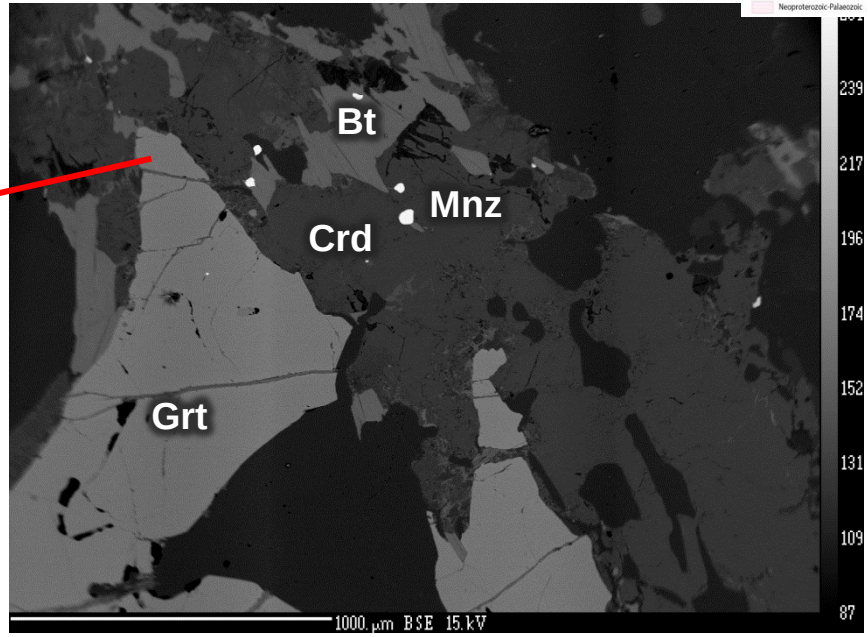


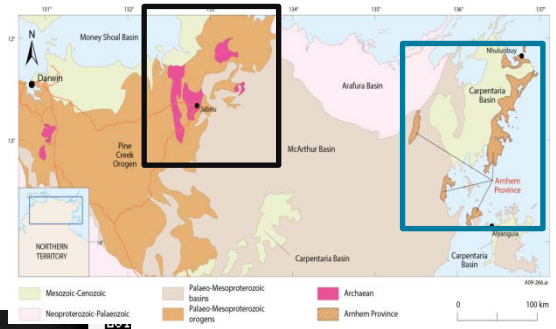


Modified after Glass 2010



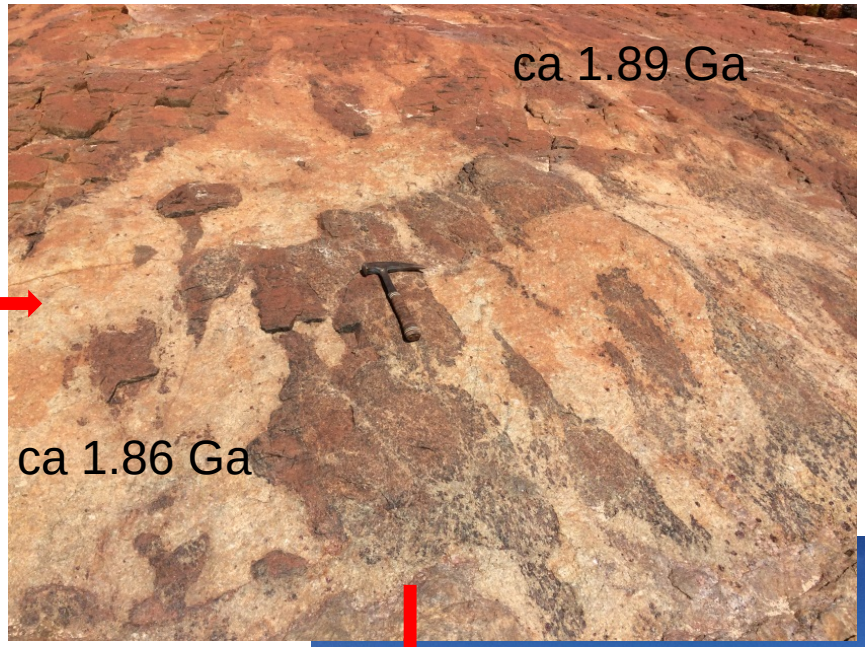
ca 1.88–1.85 Ga metamorphic cycle

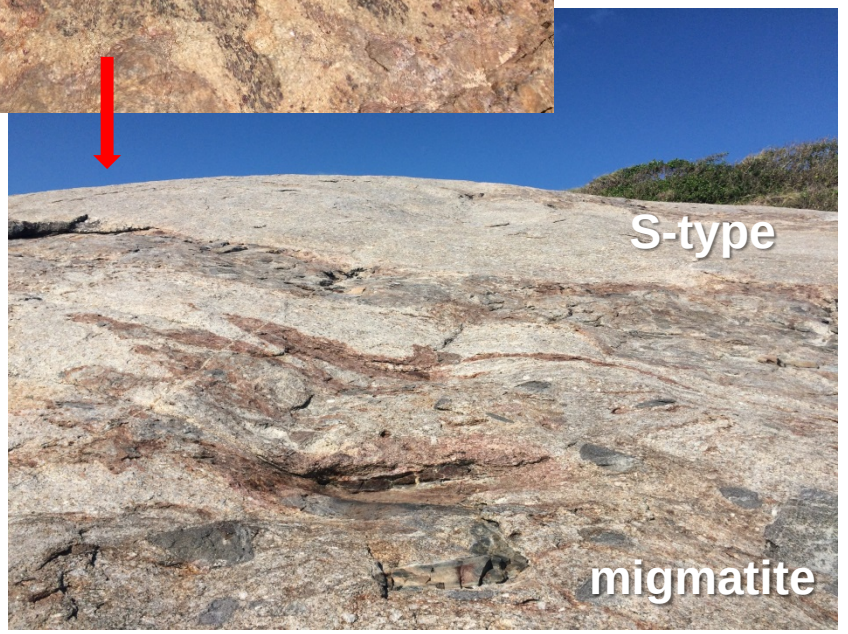




- **Arnhem Province** - granulite-facies metamorphism, clockwise *P–T* evolution beginning at ca 1.88 Ga and continuing to at least 1.85 Ga.
  - Peak recorded *P–T* 0.8 GPa, >825°C by ca 1.87 Ga followed by cooling and decompression to 0.4 Gpa, ~750°C by ca 1.85 Ga
- **Nimbuwah Domain (PCO)** – amphibolite-facies *P–T* conditions of ≥ 0.92 GPa and ~650°C collisional orogenesis

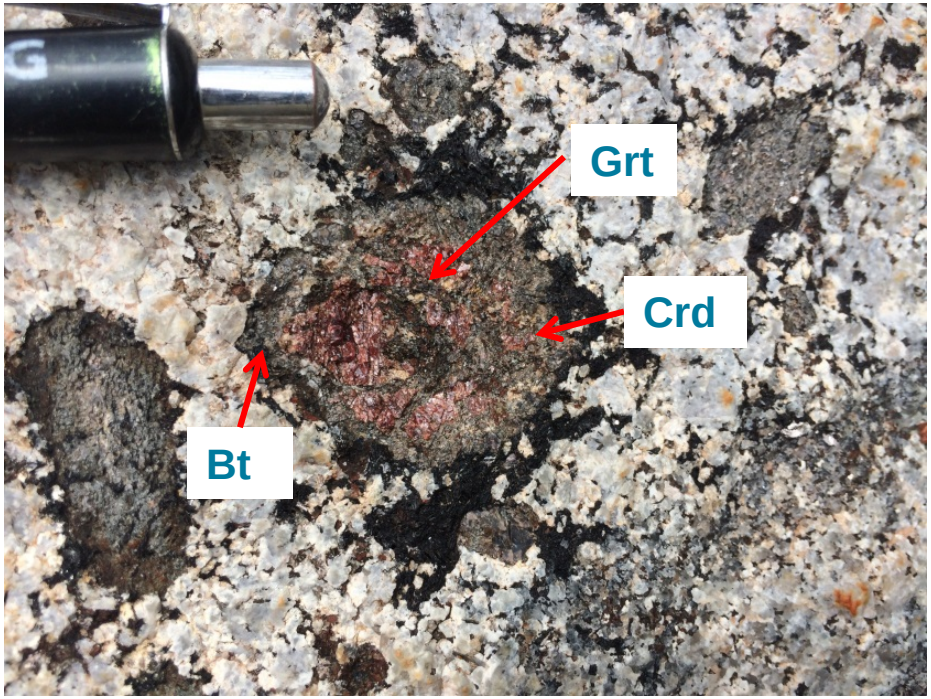
Migmatites: source of S-type magmas

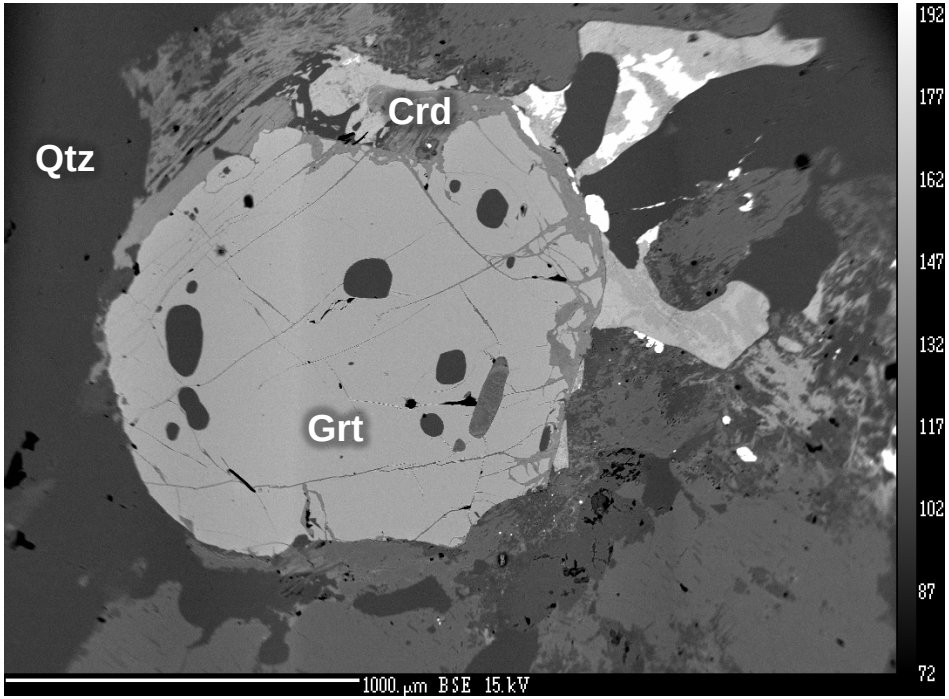




- Migmatite formation, melt migration and pooling
- Field relationships indicate a migmatite source = Melville Bay Metamorphics

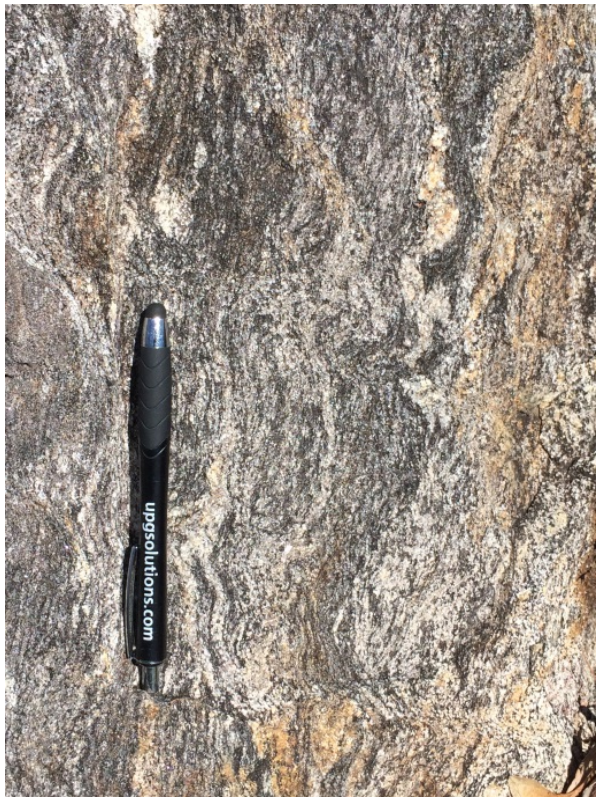
Migmatites: source of S-type magmas

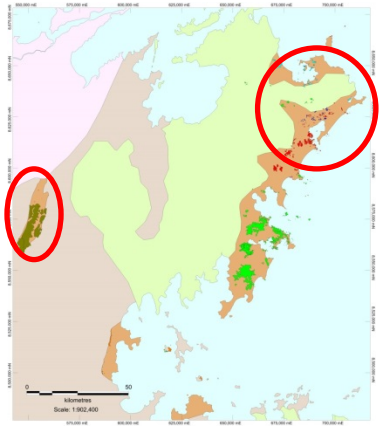


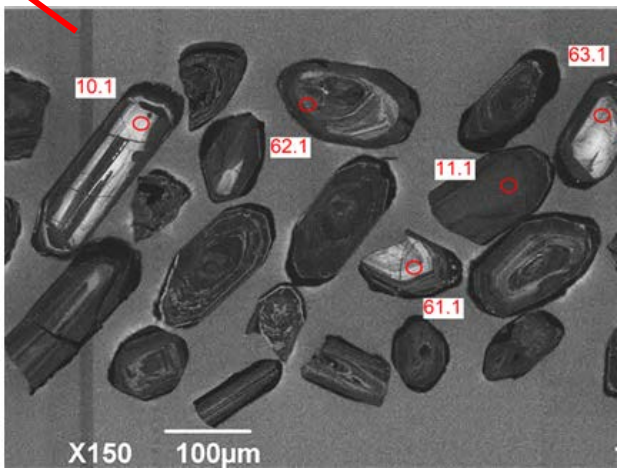


- Garnet chemically and petrographically identical in Melville Bay Metamorphics and S-type granites = peritectic phases entrained during melt extraction
- Metamorphic monazite and zircon in the Melville Bay Metamorphics is indistinguishable from age of magmatic and metamorphic zircon in the S-type granites

ca 1.88 Ga S-type magmatism

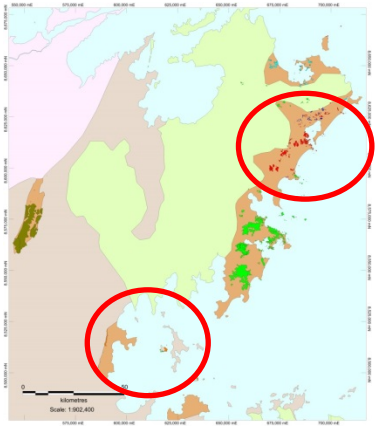


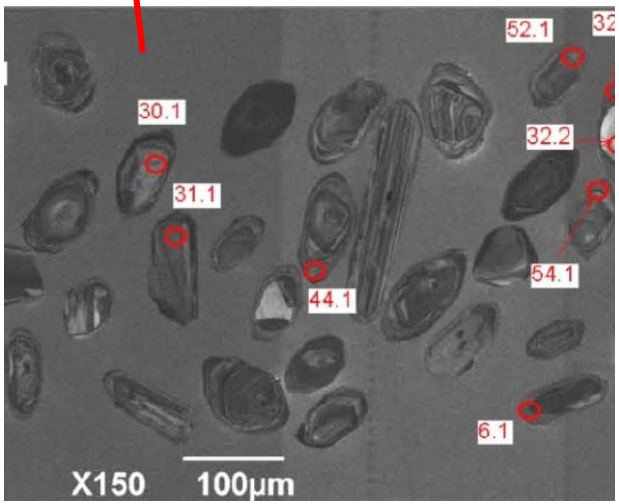




- Grt–Crd–Bi±Sill granitic gneisses
- Rare xenoliths: quartzite
- No new metamorphic zircon growth
- Zircon crystallisation ca 1.88 Ga (Kositcin *et al* in prep)
- Monazite crystallisation ca 1.88 Ga and 1.87 Ga (Reno *et al* in prep)

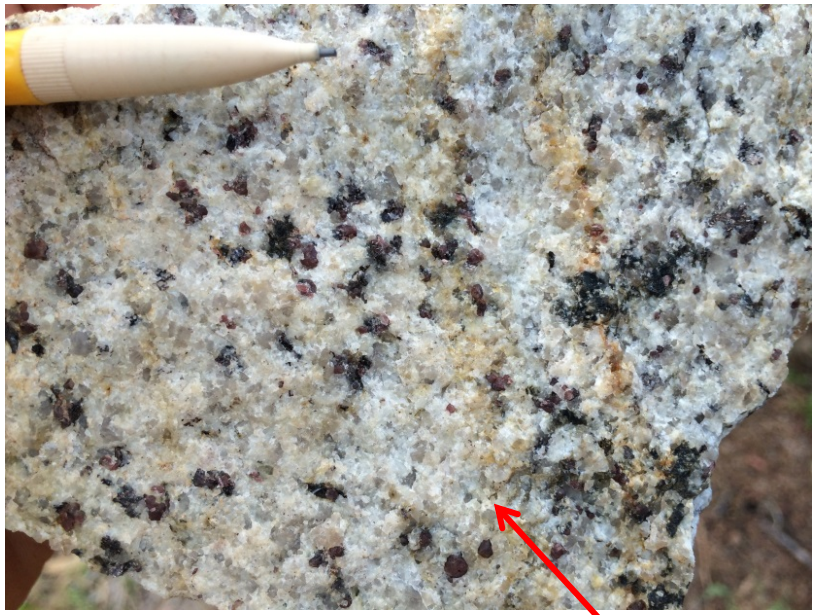
ca 1.87 Ga S-type magmatism

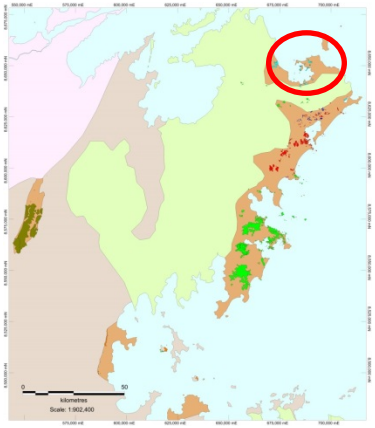


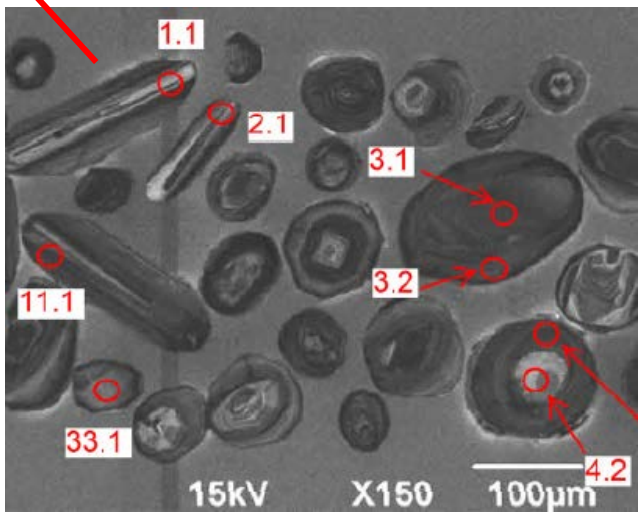


- Grt–Crd–Bi±Sill variably foliated granite
- Abundant xenoliths: quartzite, schist, gneiss, calc-silicate rock, marble, meta-mafic and meta-ultramafic rocks
- Zircon crystallisation ca 1.87 Ga (Kositcin *et al* 2015)

ca 1.86 Ga S-type magmatism

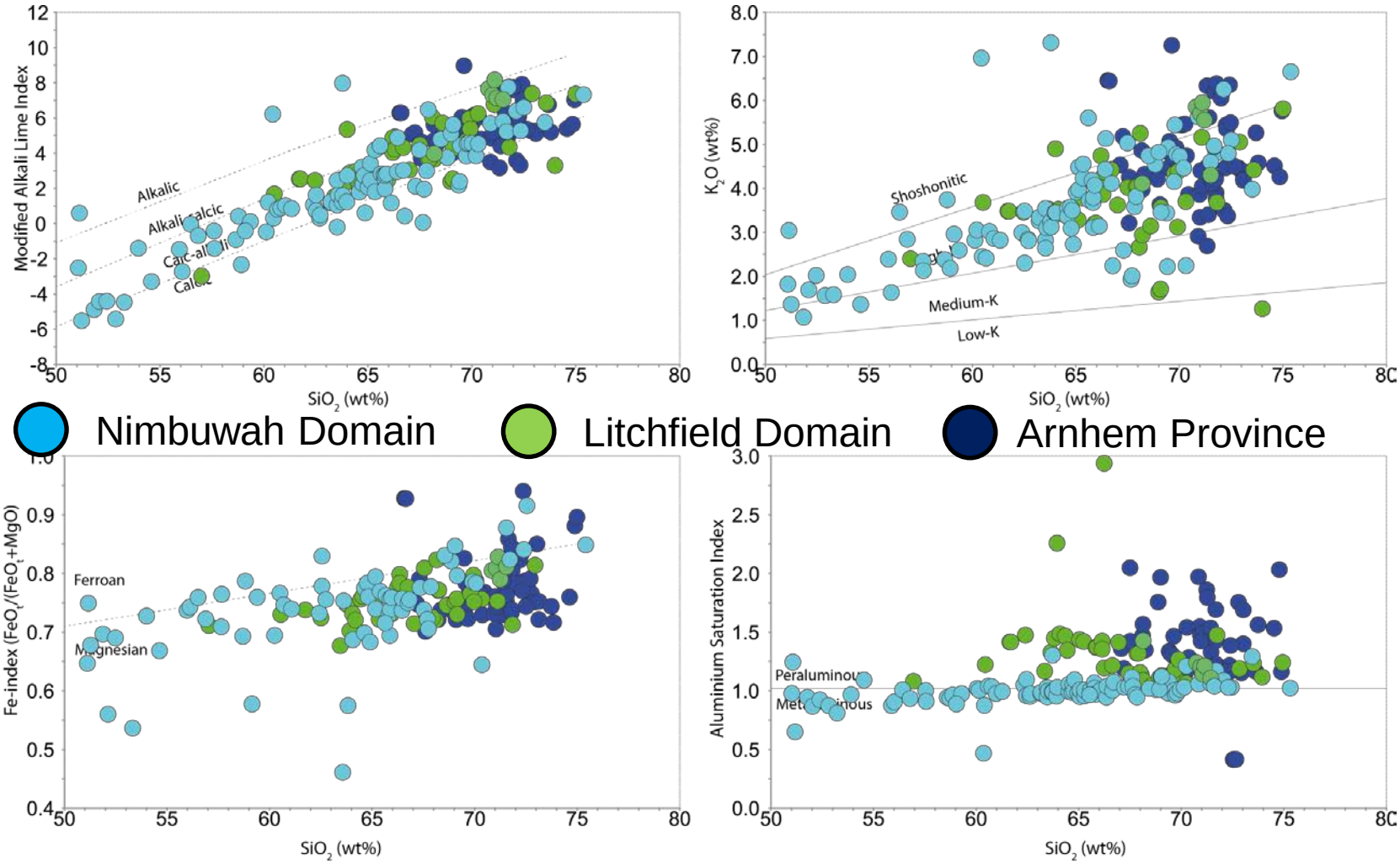






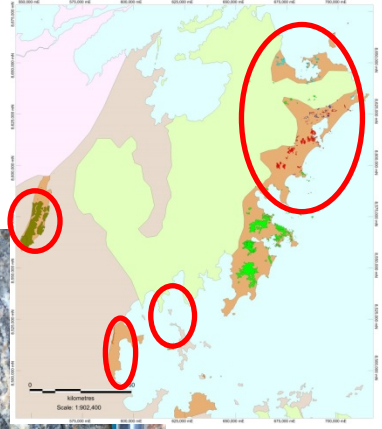
- Grt–Crd–Bi variably foliated granite and leucogranite
- Xenoliths: quartzite, schist, gneiss, calc-silicate rock, marble
- Zircon crystallisation ca 1.86 Ga (Kositcin *et al* 2015)

NAC correlations: ca 1.87–1.86 Ga magmatism



- Nimbuwah Domain (PCO) – I-type cordilleran bimodal intrusions
- Arnhem Province – S-type felsic intrusions

ca 1.88–1.86 Ga deformation



- Contemporaneous metamorphism, localised strain, variable across the province
- $S_{0/1}$ - steep to sub-vertical NE-dipping, anastomosing compositional layering (Melville Bay Metamorphics)

ca 1.88–1.86 Ga deformation

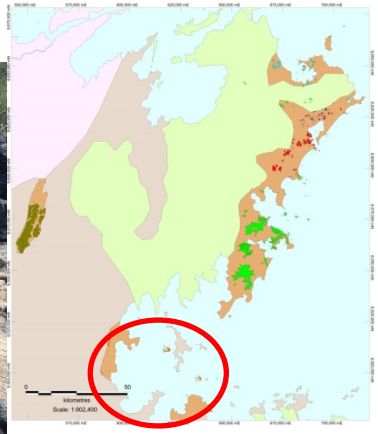
Arnhem Province

- S_2 – rare asymmetric folds, steep to subvertical NW–NE-dipping axial planar foliation (Melville Bay Metamorphics) and main foliation (S-type granites)
- Early melt phase - pooling in hinge zones of asymetric folds
- Late melt phase leucocratic dykes cross-cutting asymetric folds supersolidus phase of metamorphism outlasted deformation

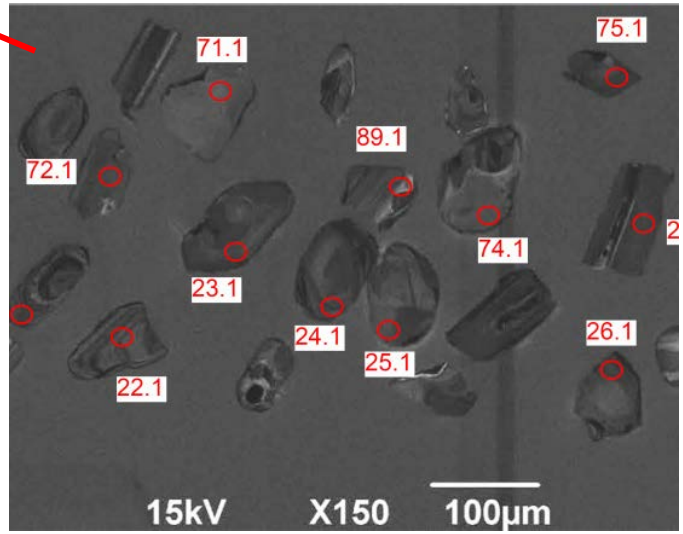
Nimbuwah Domain (PCO)

- Crustal thickening and west-directed thrusting and folding

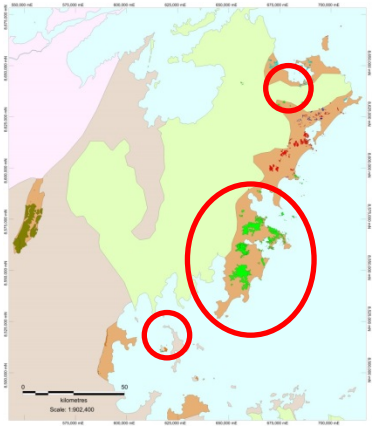
Geological evolution: ca 1.85–1.83 Ga sedimentation

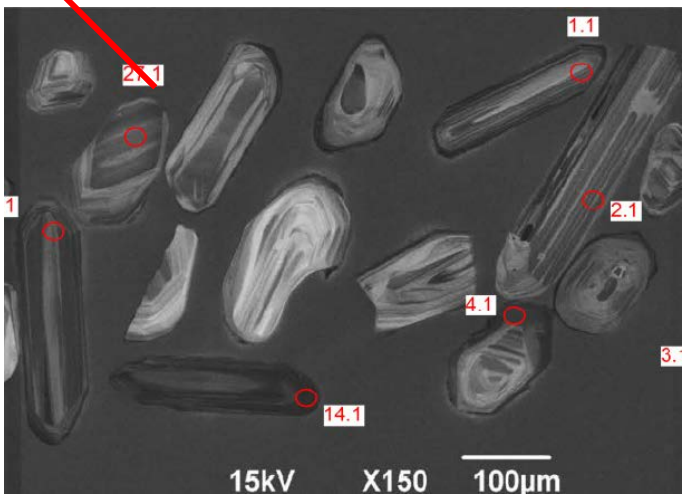


- Deposition of siliciclastic sediments – Grindall Formation
- Unconformable on Melville Bay Metamorphics and S-type granites, intruded by younger suite of granites
- Zircon max. dep. ages ca 1.93 Ga and ca 1.99 Ga
- Field relationships constrain timing of deposition to between ca 1.85–1.83 Ga



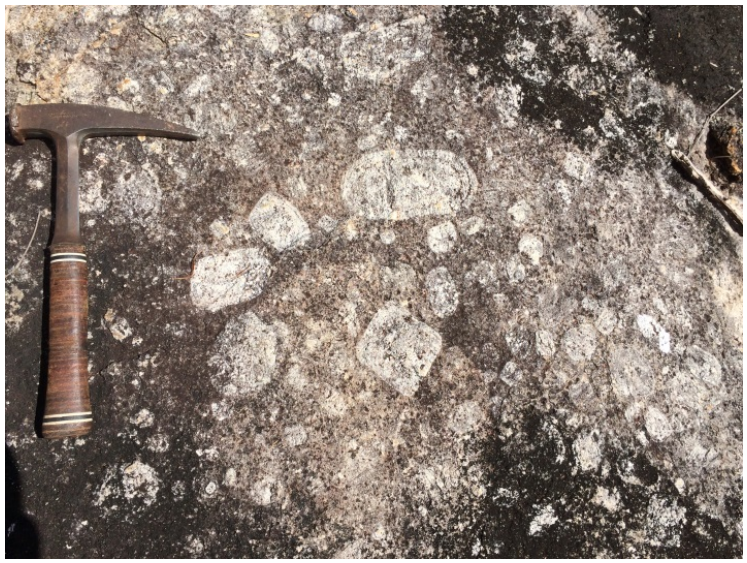
ca 1.83–1.82 Ga A-type magmatism

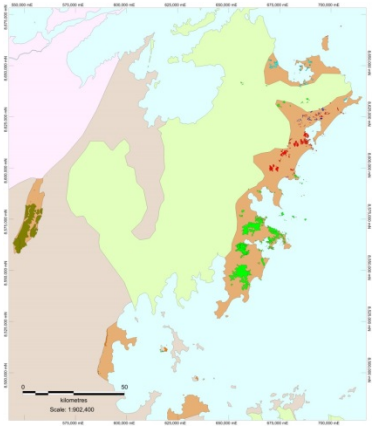




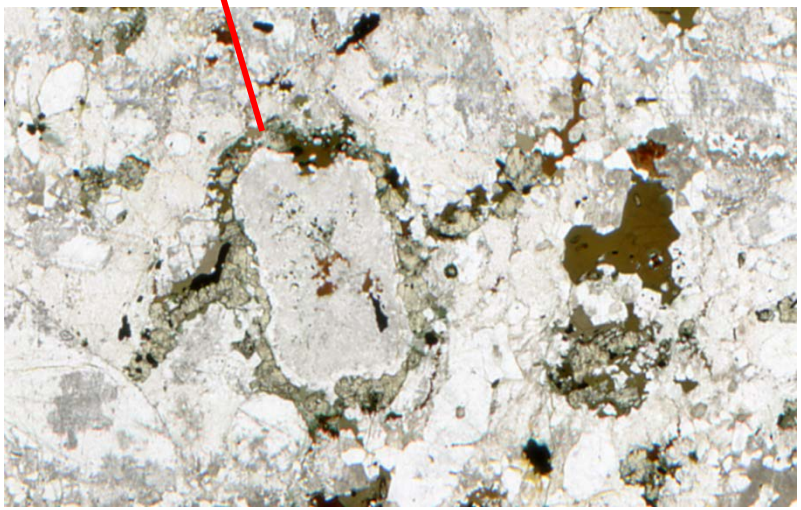
- Intrude all other stratigraphic units
- Fayalite–biotite±clinopyroxene granite
- Magmatic zircon crystallisation ca 1.83–1.82 Ga
  (Kositcin *et al* 2015, Whelan *et al* in prep)

ca 1.83–1.82 Ga A-type magmatism

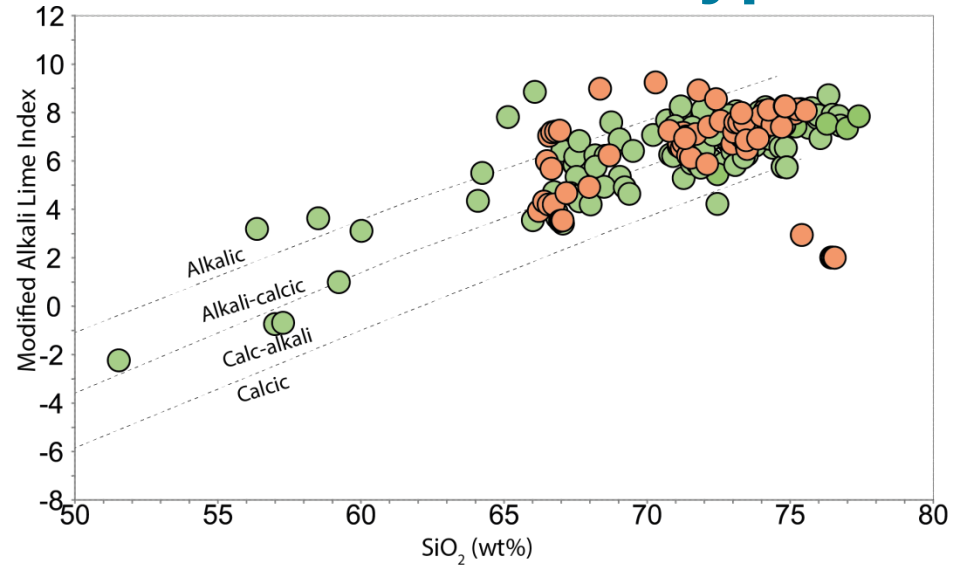


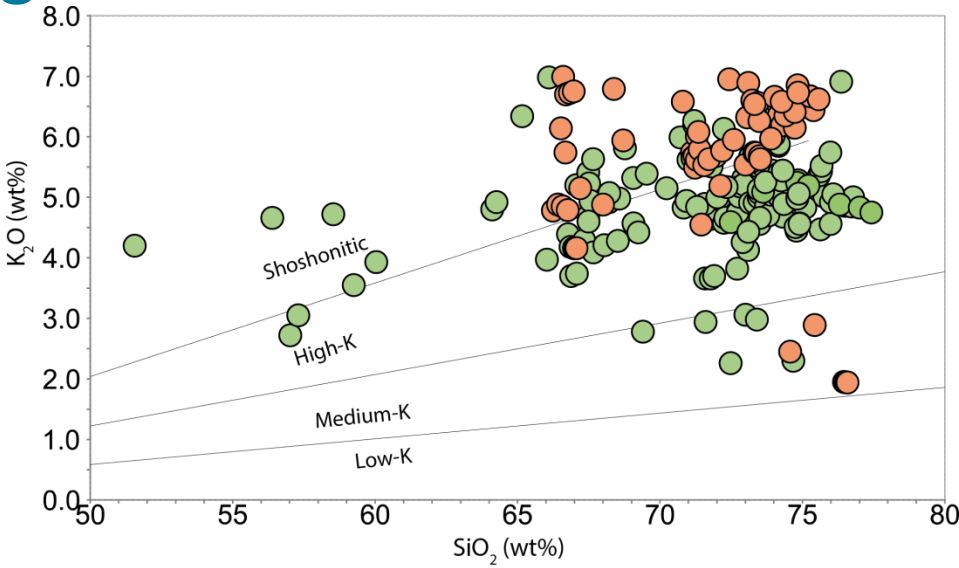


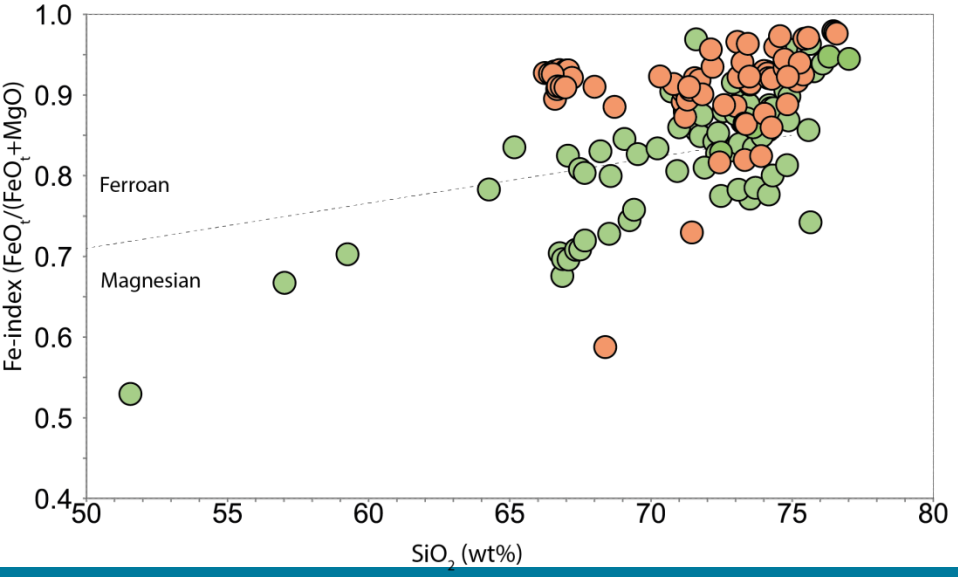
- Fayalite = late crystallising phase
- Miarolitic cavities, compositionally zoned K-feldspar in matrix of intergrown micrographic quartz and K-feldspar = high level emplacement

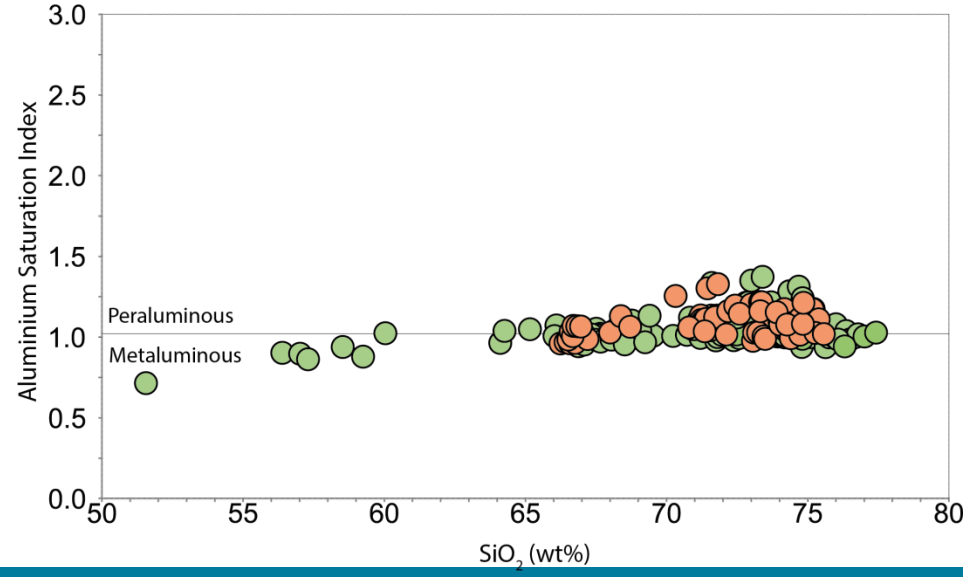


ca 1.83–1.82 Ga A-type magmatism

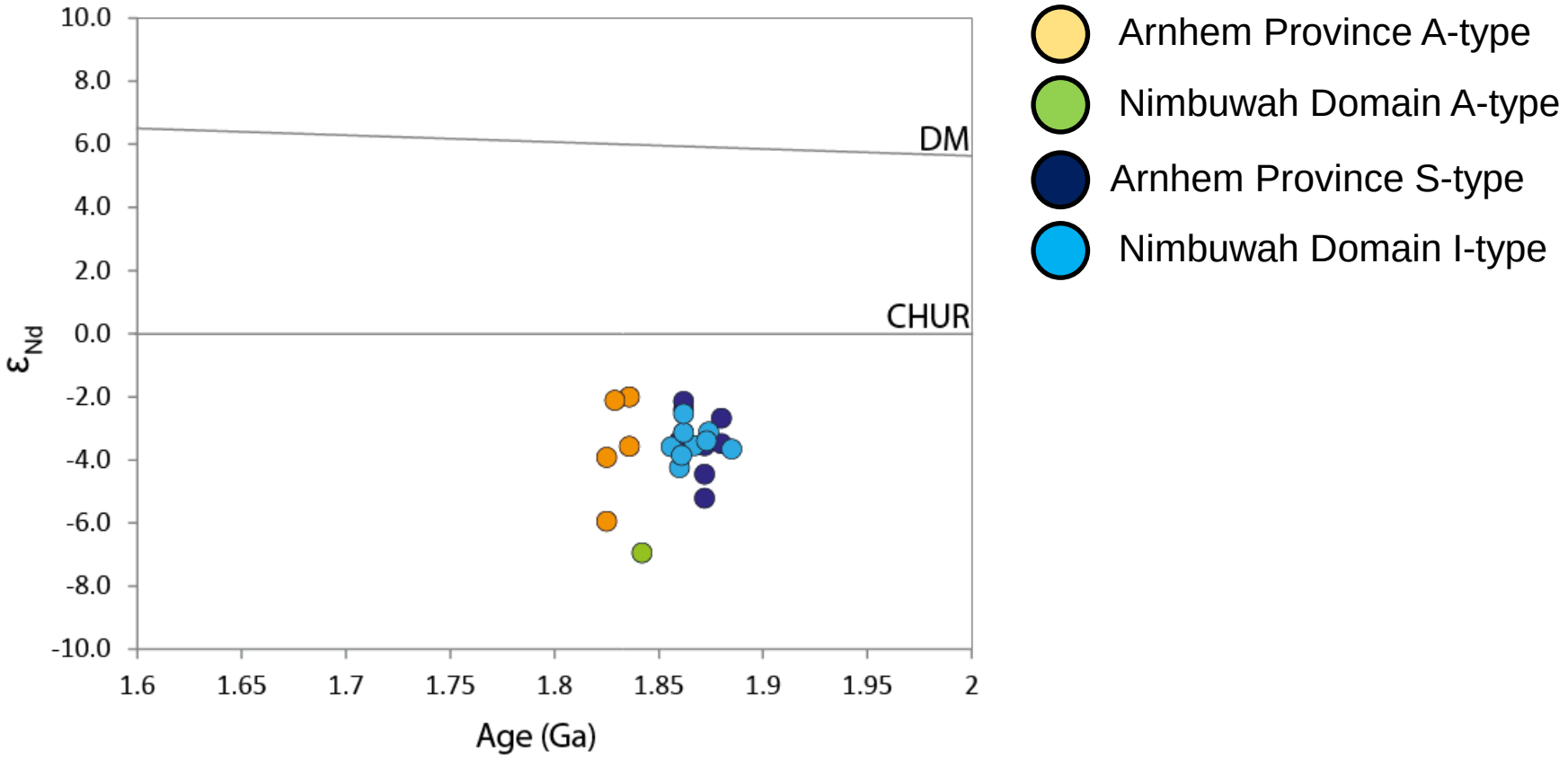








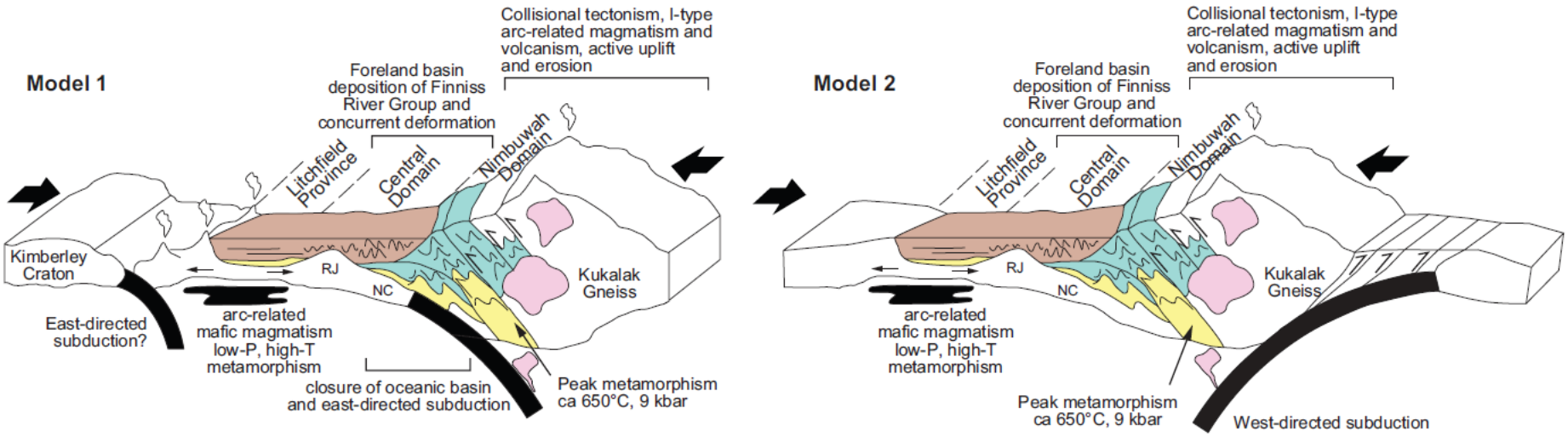
Nd isotopes



- Nd-model ages for all granites range from 2.47–2.70 Ga
- S- I- and A-types have similar Nd isotope signatures
- No major crustal boundaries between the Nimbuwah Domain and Arnhem Province

Tectonic Setting

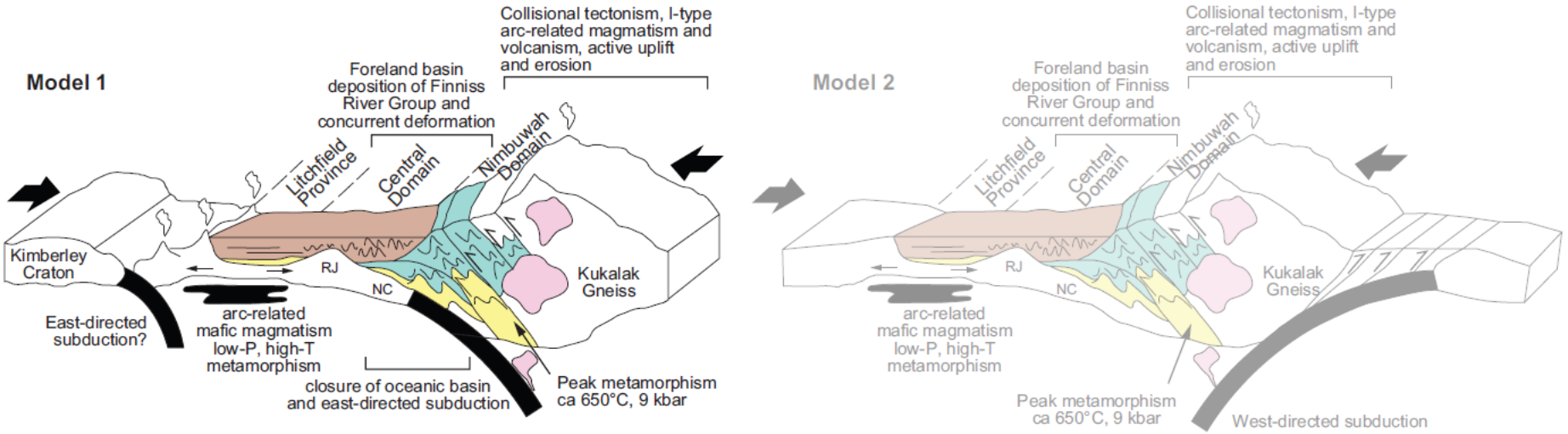
Hollis and Glass 2012



- ca 1.88–1.85 Ga high thermal gradient metamorphism and rare evidence for back arc basin-related mafic magmatism in the **Arnhem Province**
- ca 1.87–1.86 Ga cordilleran I-type magmatism in the **Nimbuwah Domain**
- ca 1.86 Ga island arc related mafic magmatism in the **Litchfield Province** and Central Zone of the **Halls Creek Orogen**

Tectonic Setting

Hollis and Glass 2012



- Arnhem Province located in a back arc basin to evolving plate margin located to the west
- Nimbuwah Domain preserves evidence for collisional orogenesis relating to collision from the west
- A-type granites in Nimbuwah Domain and Arnhem Province reflect magmatism in an intraplate setting following the cessation of orogenesis

Key Findings

- The timing of geological events in the Arnhem Province, Pine Creek and Halls Creek Orogens is similar, the nature of these events is distinct.
- The Melville Bay Metamorphics can be correlated with the Cahill Formation and Nourlangie Schist and Marboo Formation
- In the **Arnhem Province** metamorphism was initiated by crustal thinning, intrusion of mafic magmas into the lower crust (rare xenoliths) and resulted in high thermal gradient metamorphism, migmatite formation, melt migration and S-type magmatism.
- In the **Nimbuwah Domain** metamorphism was initiated by collisional orogenesis causing crustal thickening, west-directed thrusting and folding and higher pressure, lower temperature PT conditions than observed in the Arnhem Province and the intrusion of I-type cordilleran plutons
- Taken together these observations suggest a model in which the Arnhem Province is located in a barc-arc-basin to an evolving plate margin located to the west