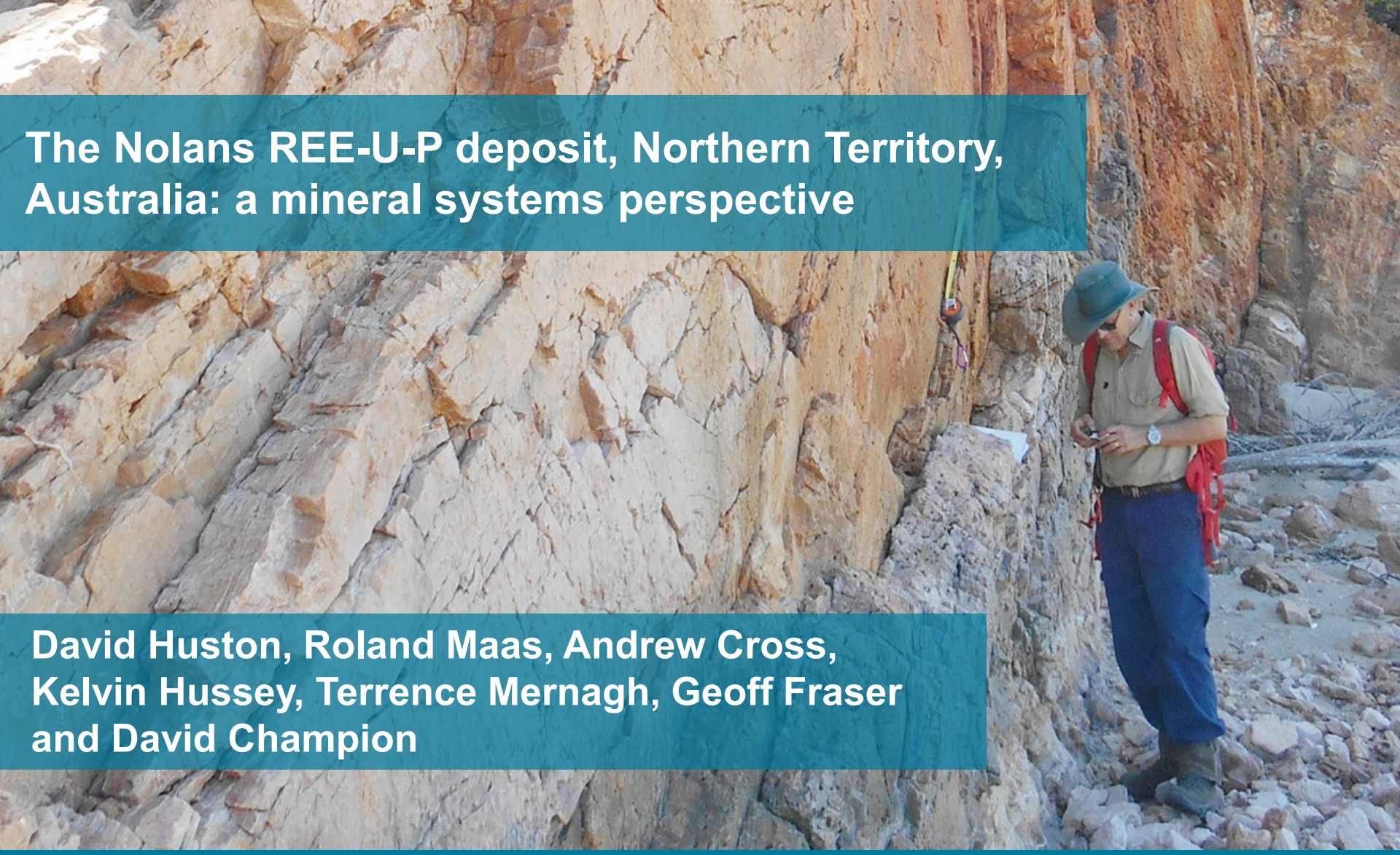
The Nolans REE-U-P deposit, Northern Territory, Australia: a mineral systems perspective



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AUSTRALIA'S NORTHERN TERRITORY

NORTHERN TERRITORY GEOLOGICAL SURVEY
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The Nolans REE-U-P deposit, Northern Territory, Australia: a mineral systems perspective

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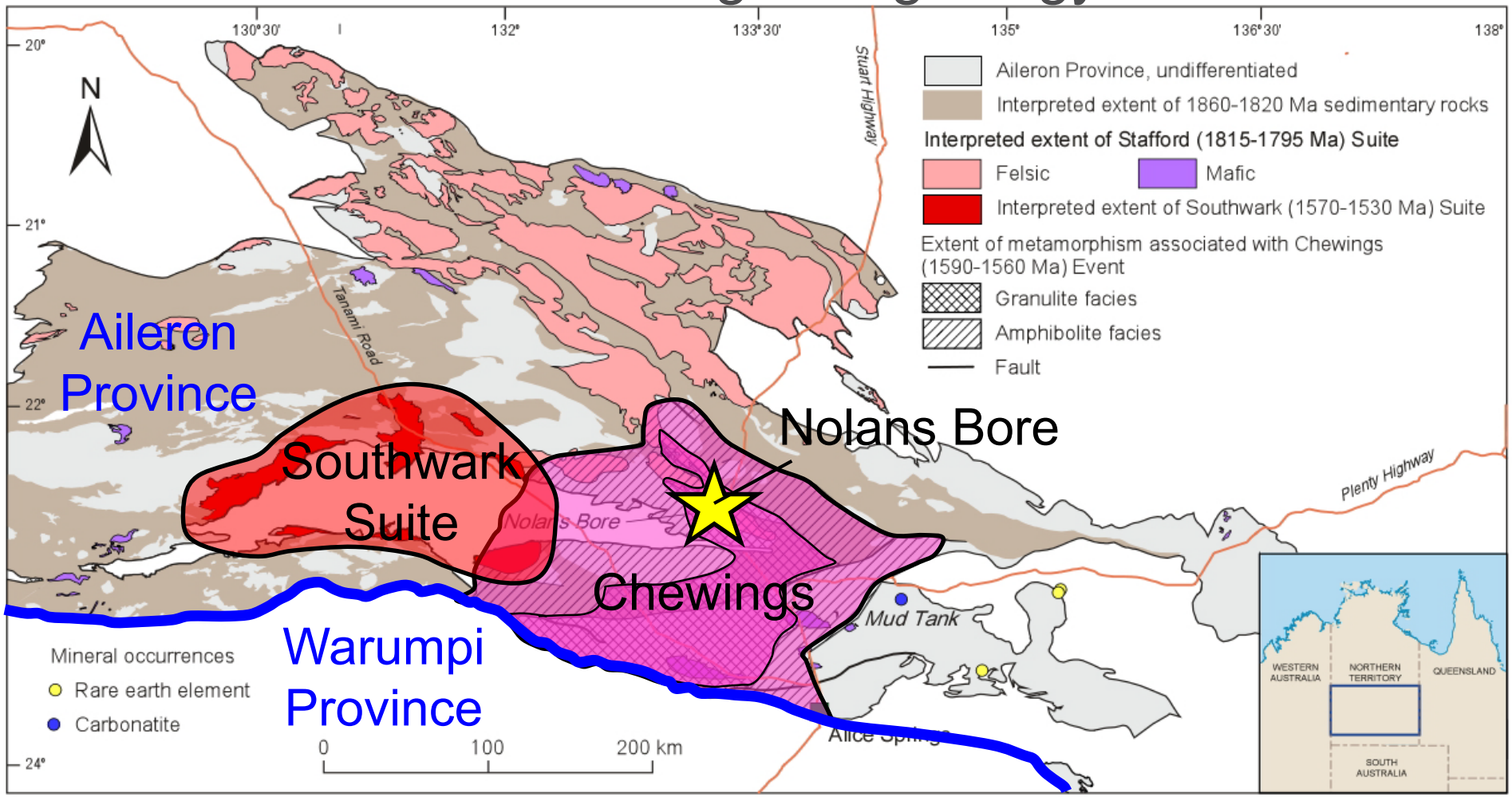
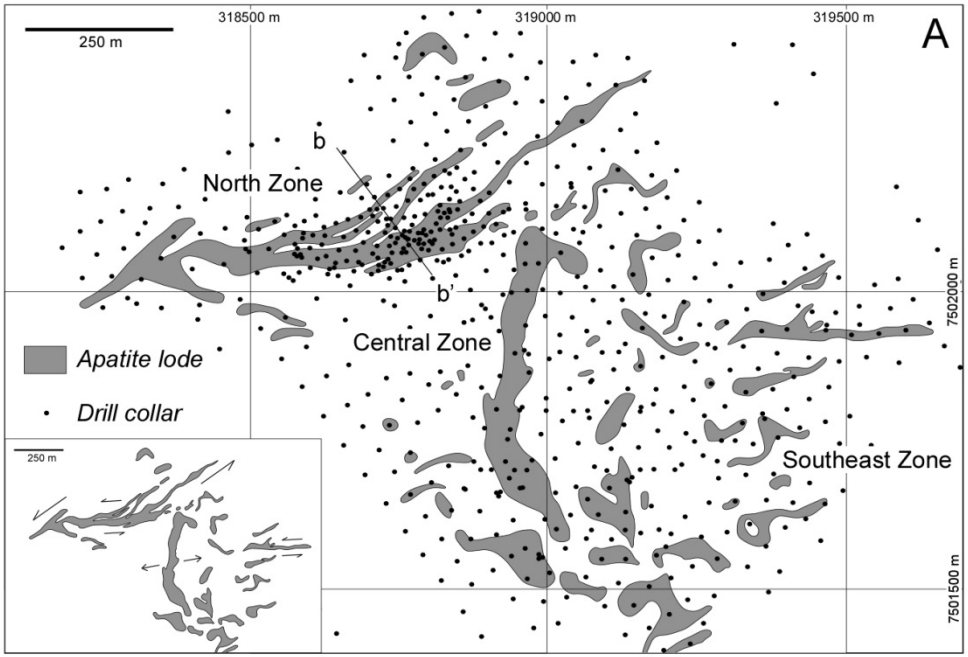
Nolans – regional geology

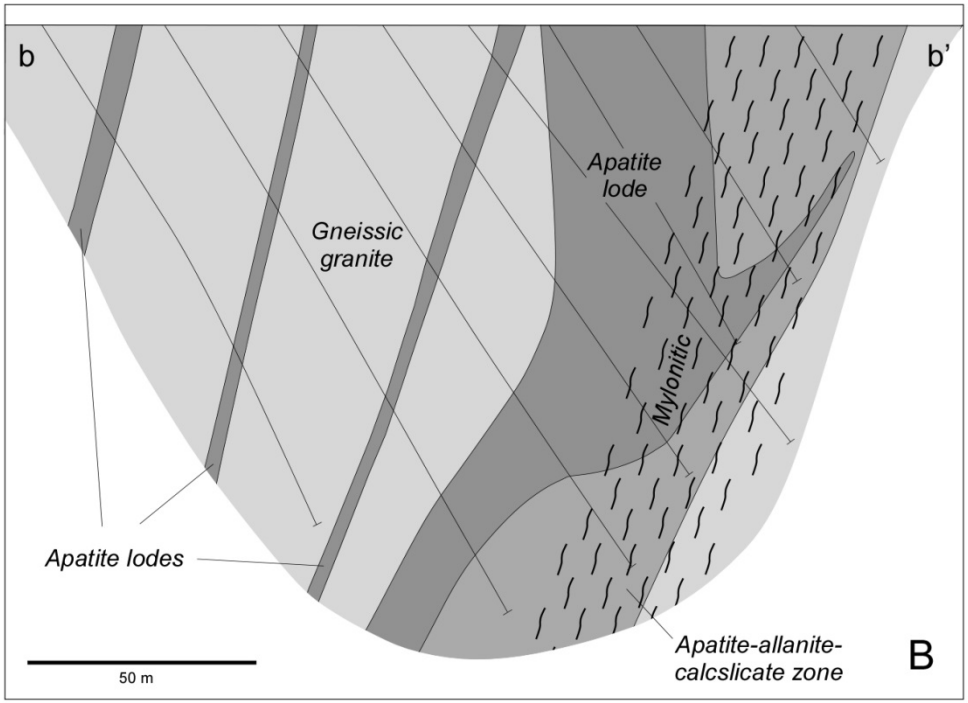


- Located north of major suture
- Nearby 1570-1530 Ma granitic magmatism

- Associated with 1590-1550 Ma, high T-low P metamorphism
- Affected by 450-300 Ma Alice Springs Orogeny

Nolans – deposit geology



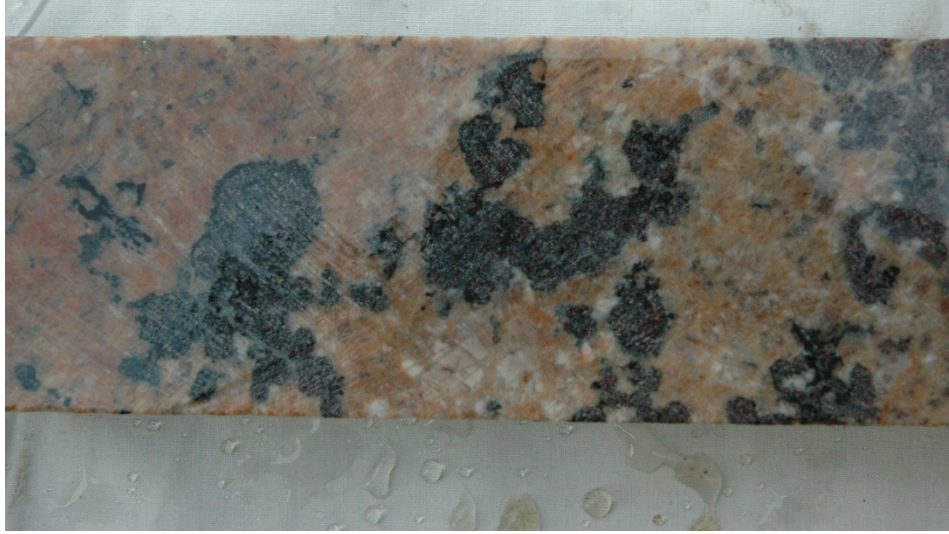


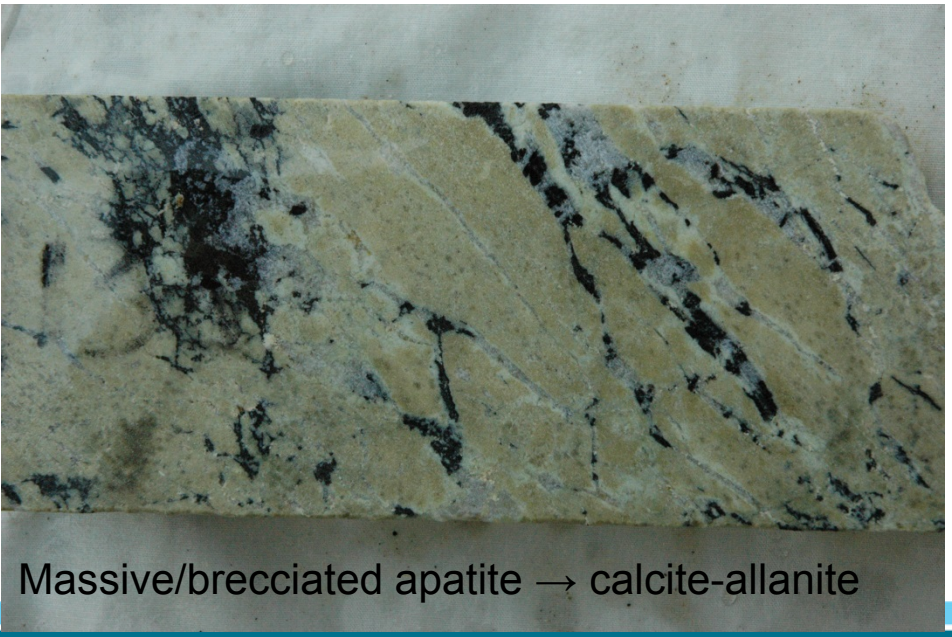
- Global resource: 56 Mt @ 2.6% TREO, 190 ppm U_3O_8 and 12% P_2O_5
- Averages ~2500 ppm Th
- Extends over 3.5 km × 2 km area
- Three zones
  - North
  - Central
  - Southeast
- North Zone
  - Hosted by granitic gneiss
  - ENE-striking, N-dipping apatite veins
  - Individual veins to 70-m-thick
  - Largely primary position
- Central Zone – extensively remobilised (Schoneveld et al, 2015)

Nolans – hosts and ores

Granite gneiss (~1806 Ma; Collins and Williams, 1995)

Pegmatite (1550 ± 6 Ma; this study)





Massive/brecciated apatite → calcite-allanite

Diopside-garnet altered wall rock

Nolans – conditions of mineralisation (?)

Fluid inclusions

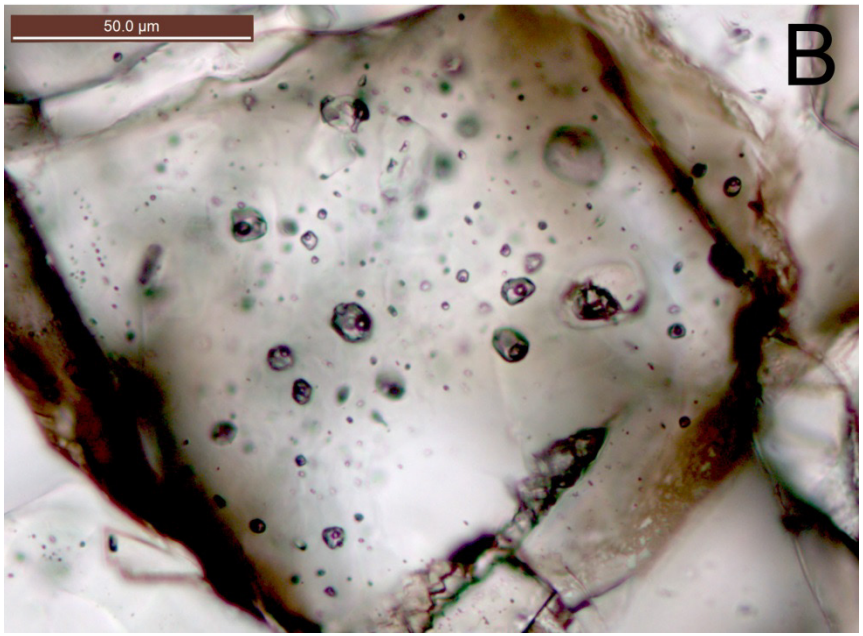
- Mostly multiphase (liquid-NaCl-other solids)
- T_h: 200-350°C
- T_m (NaCl): 156-246°C (23-36 eq wt % NaCl)

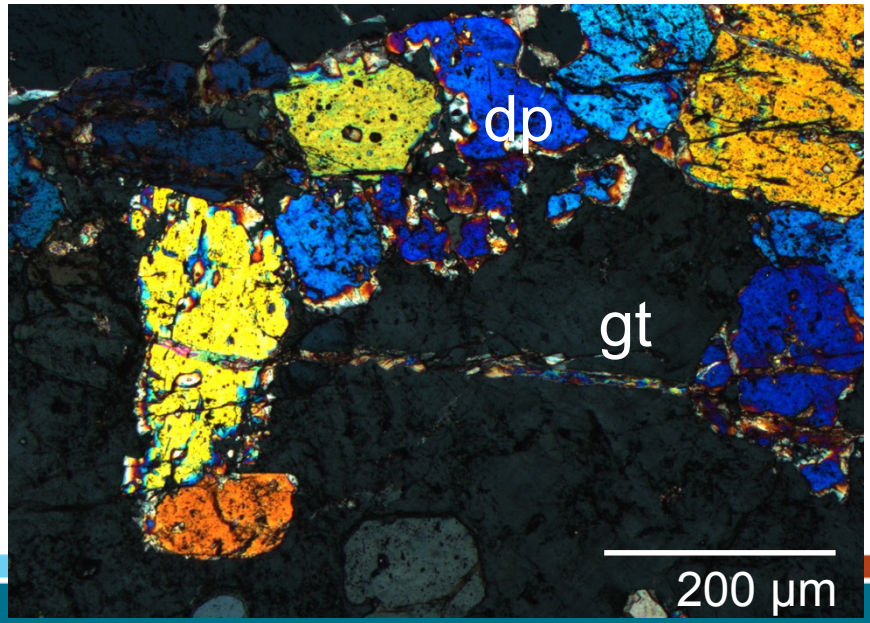
Oxygen isotopes

- $\Delta^{18}O_{dp\text{-}gt}$ = 0.6‰ (two pairs)
- T ~ 410°C
- $\delta^{18}O_{fluid}$ ~ 7-8‰

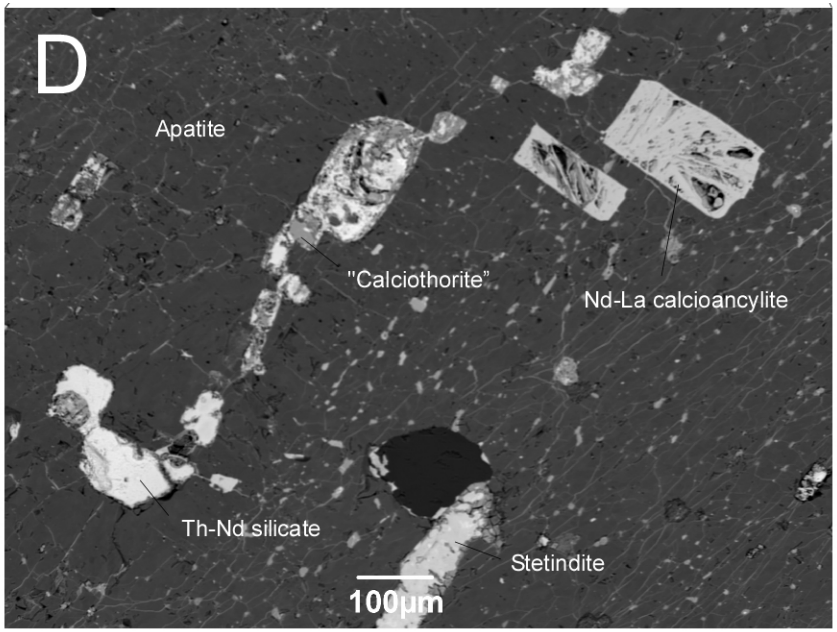
$\Rightarrow$ P ~ 100-370 (mostly 130-200) MPa

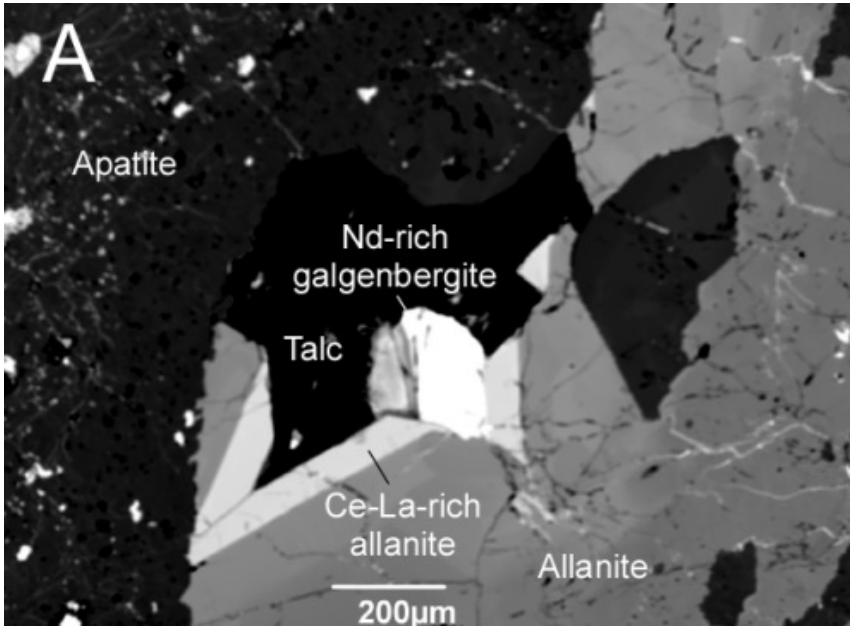
- Depth ~ 3.8-14 km

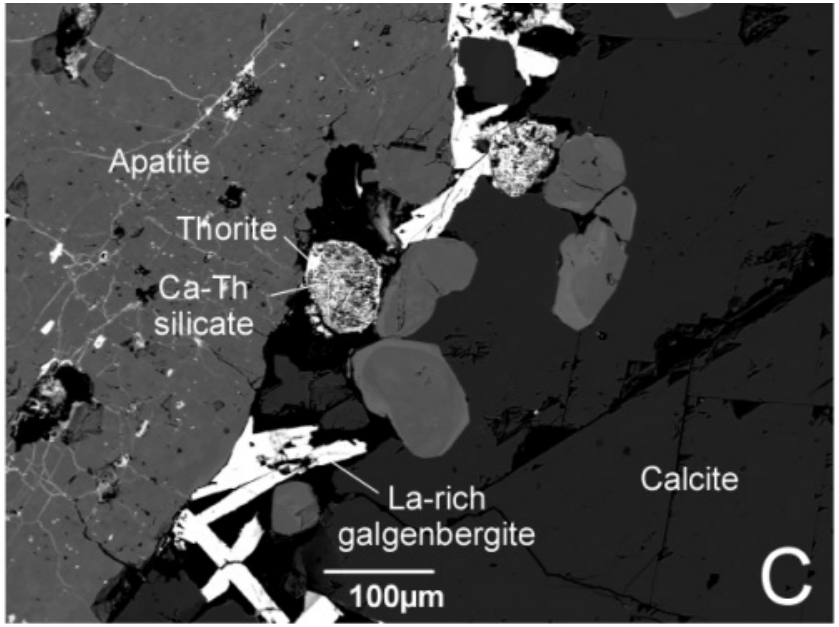


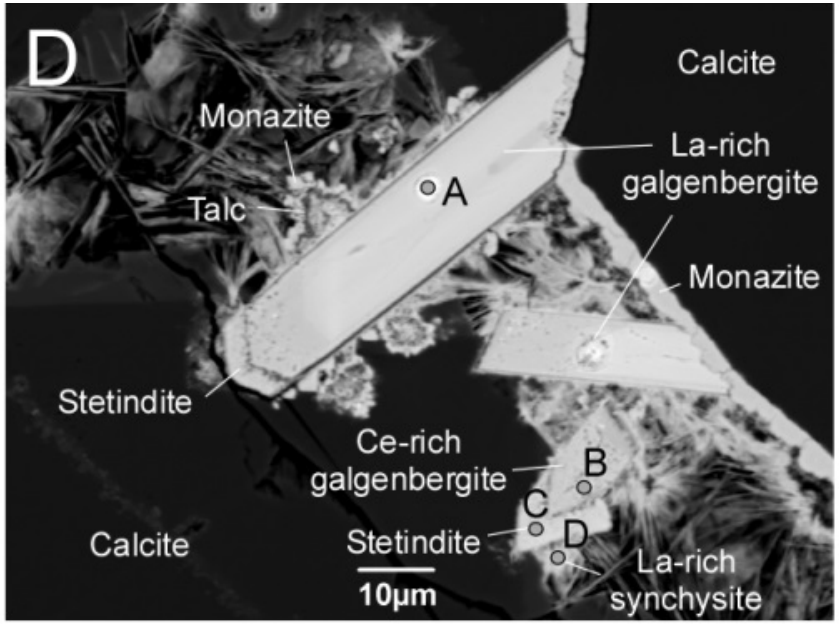


Nolans – ore textures

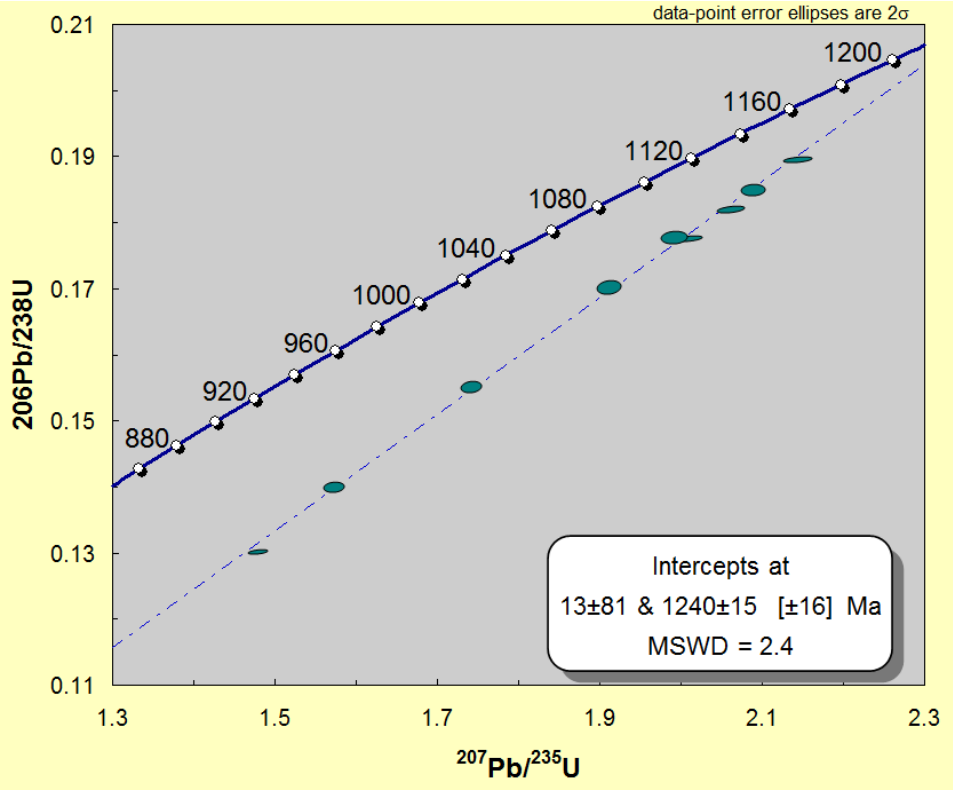


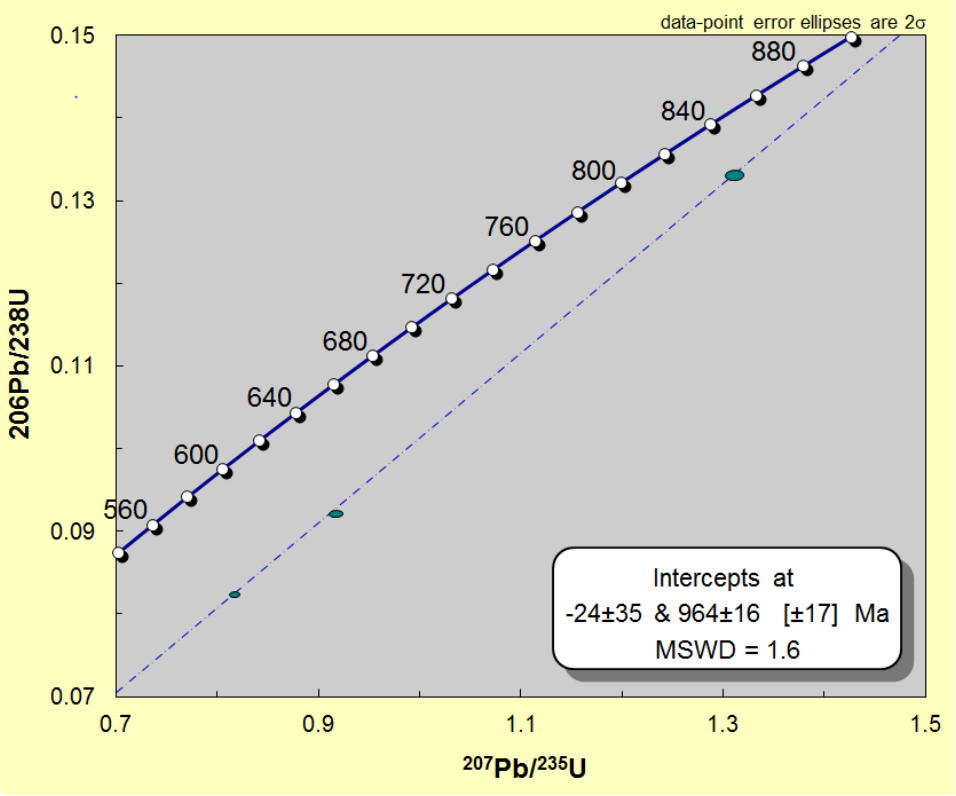






Nolans – age of mineralisation

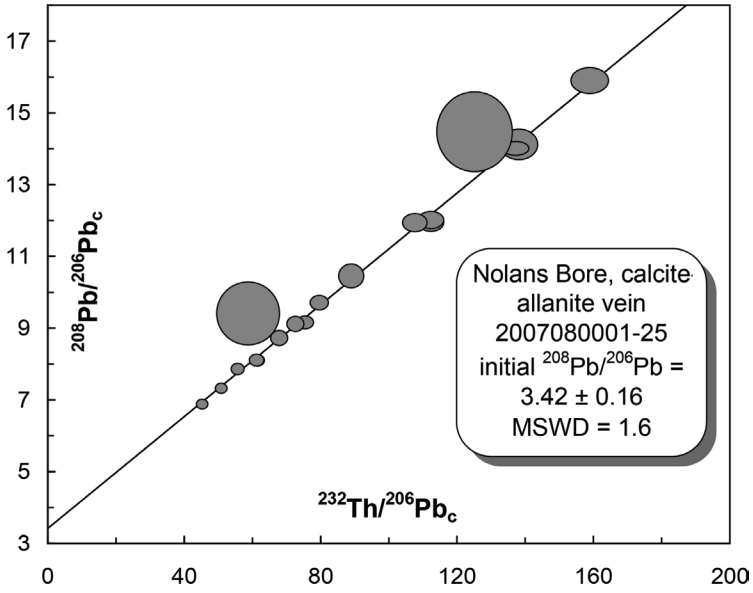




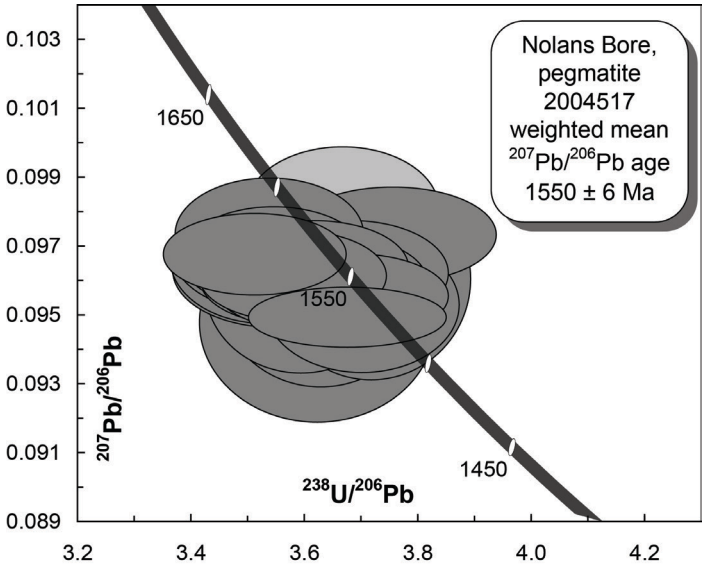
- Initial results (discordia) indicated an age of 1240 ± 15 Ma (apatite U-Pb)
- Analysis of second sample indicated an age of 964 ± 16 Ma

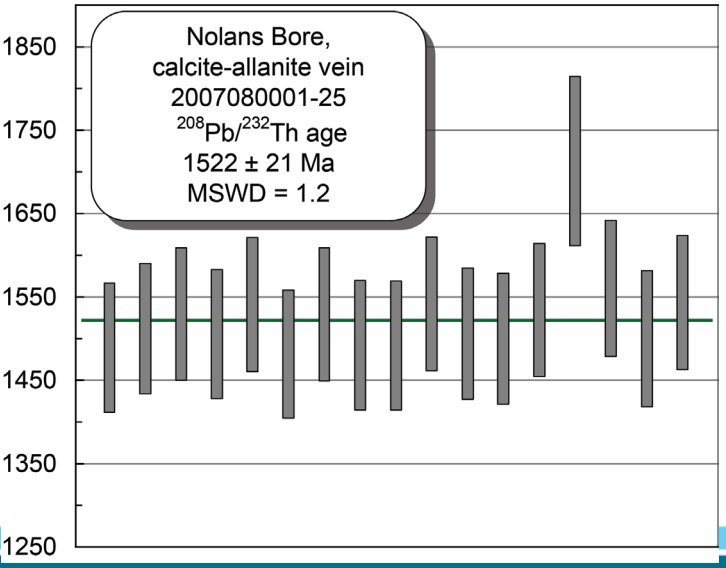
WTF?

Nolans – age of mineralisation (???)



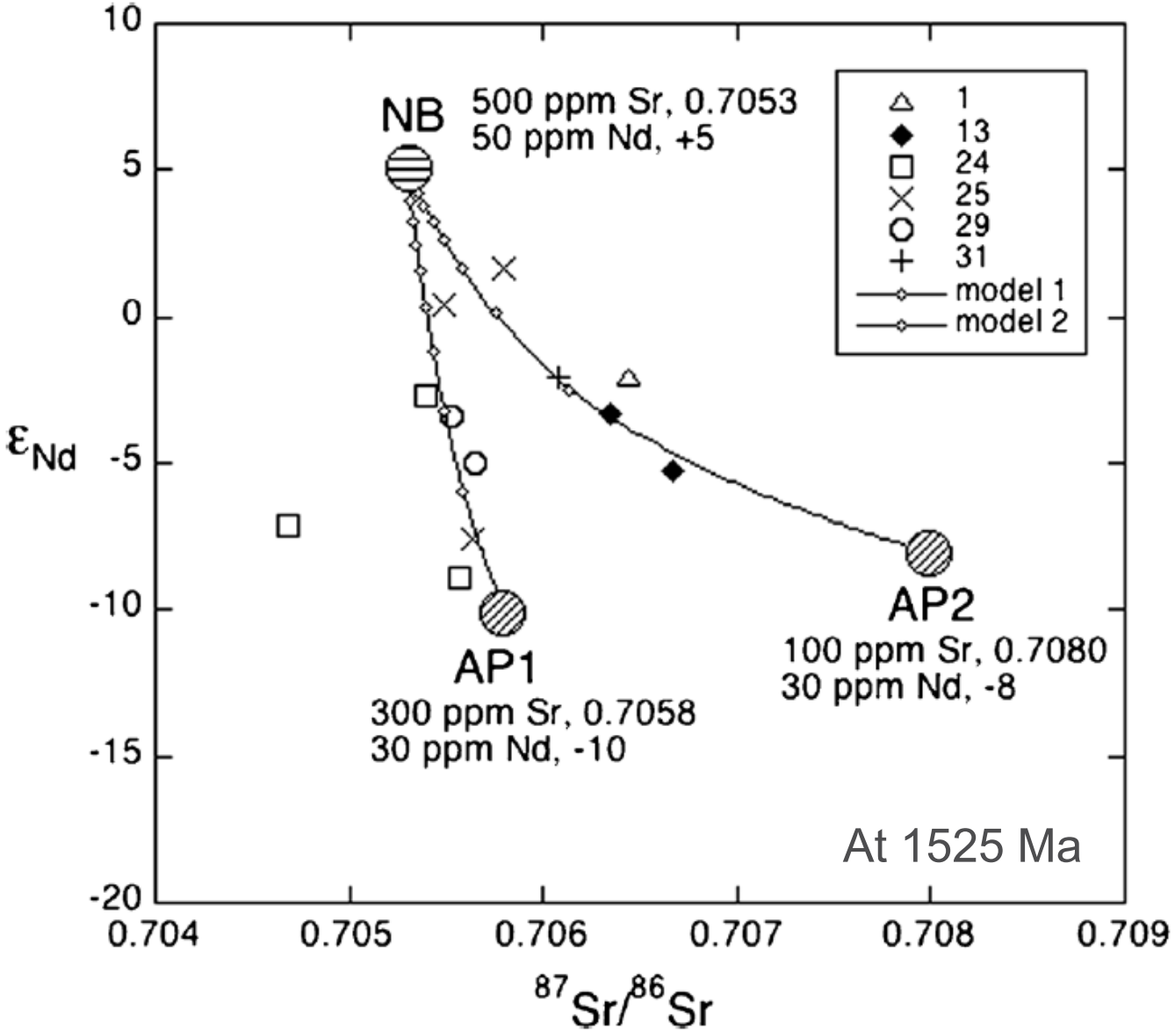
- Pegmatite U-Pb monazite age → 1550 ± 6 Ma





- Allanite Th-Pb age → 1522 ± 21 Ma
- Nd-Sm isochron ages → 1443 ± 14 Ma and 967 ± 20 Ma
- ^{40}Ar-^{39}Ar ages → ~370 Ma and ~345 Ma
- Age of mineralisation: ~1550 Ma, ~1522 Ma, ~1443 Ma, ~1240 Ma, ~965 Ma (×2), ~370 Ma or ~345 Ma (take your pick)
- Most likely age: 1550-1522 Ma

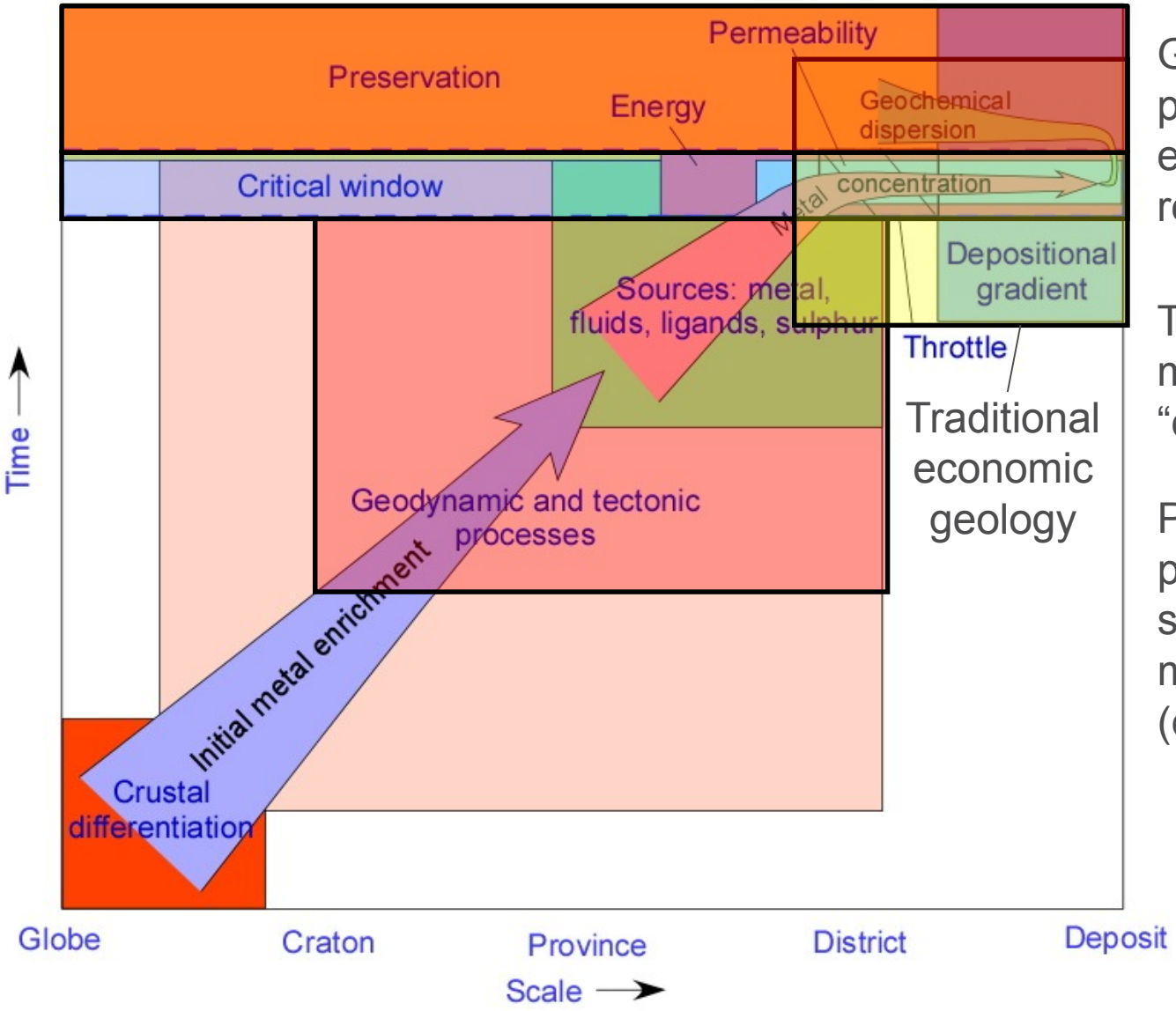
Nolans – source of metals



ε_{Nd} – $^{87}Sr/^{86}Sr_i$ variations can explained by three component mixing:

- Nolans ore fluid (NB: ε_{Nd} ~ 5, $^{87}Sr/^{86}Sr_i$ ~ 0.5035)
- Older, juvenile crustal source (AP1)
- Older, more evolved crustal source (AP2)

Mineral systems

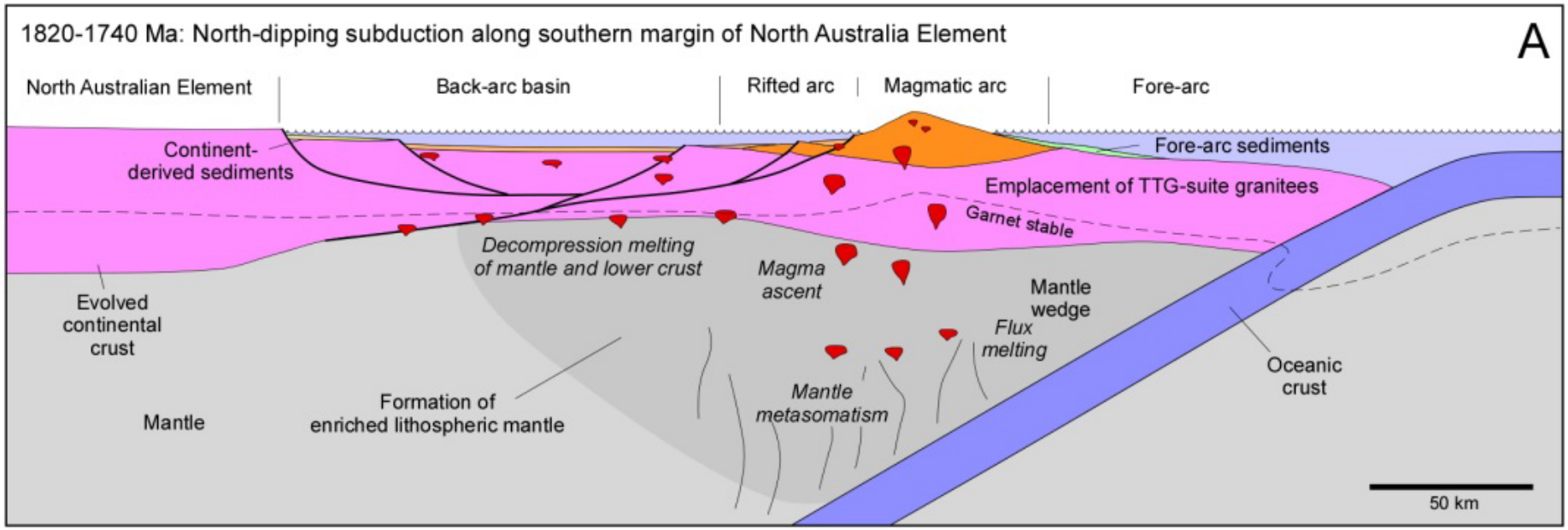


Geodynamic and tectonic processes concentrate elements to form source regions

Tectonic events trigger mineralising events (the "critical window")

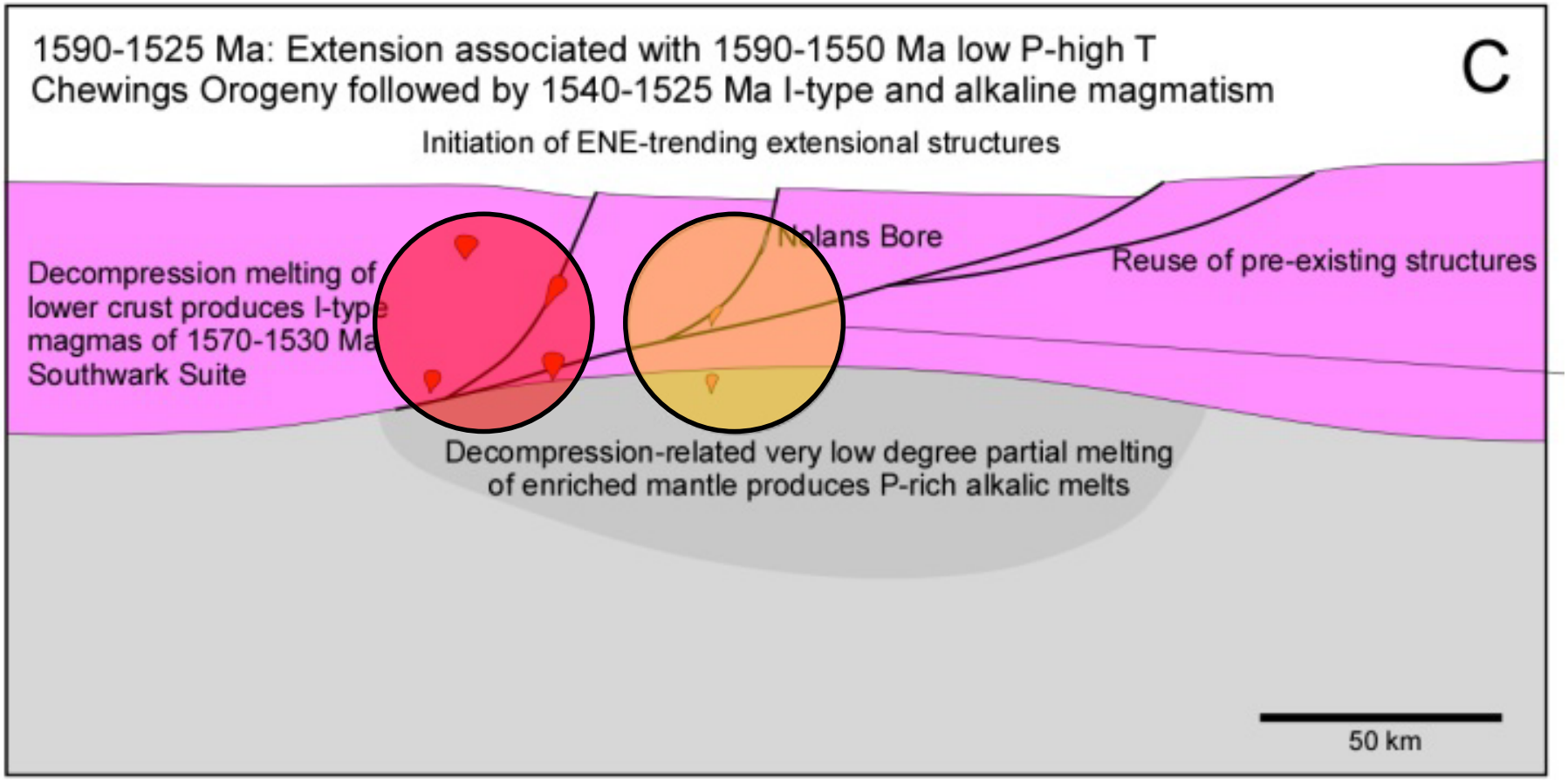
Post-depositional processes can substantially change mineral deposits (especially at Nolans Bore)

Nolans mineral system – formation of metal source and architecture



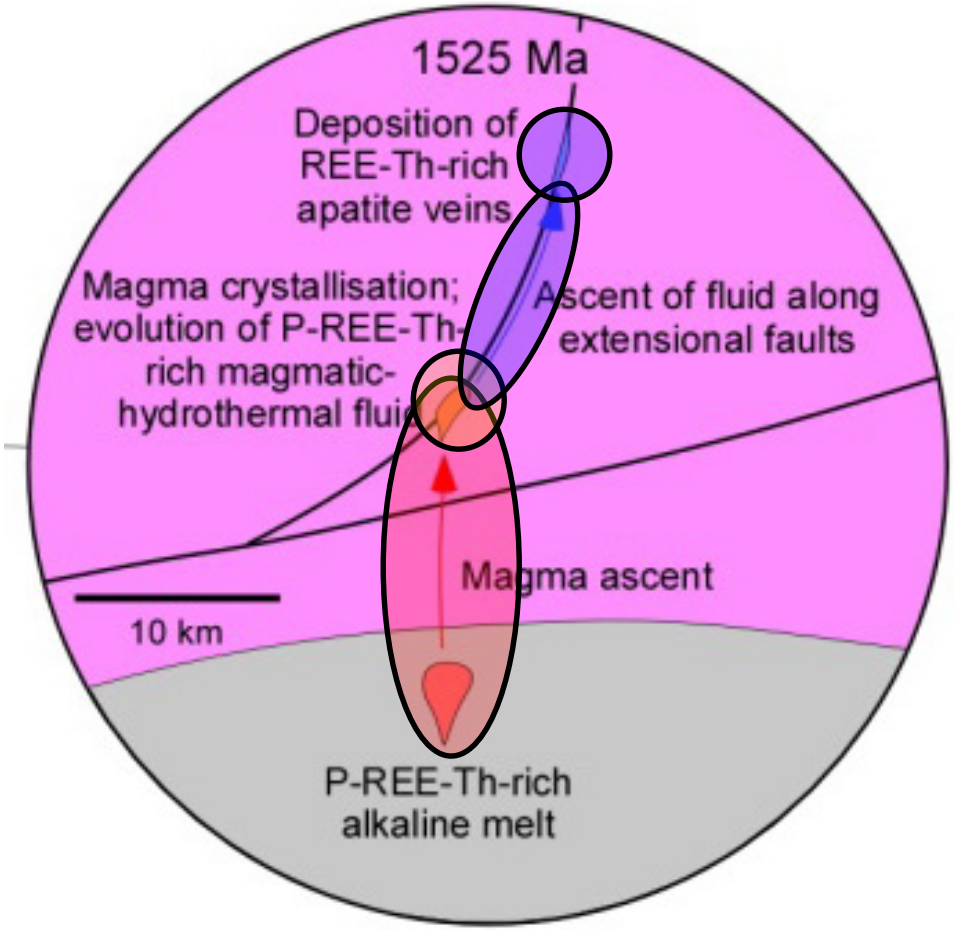
- Nolans Bore located ~150 km north of southern margin of Aileron Province
- This margin interpreted as site of north dipping subduction from 1820 to 1740 Ma (CAT granite suite (Zhao and McCuloch, 1995); VHMS deposits)
- Convergence and associated subduction enriched mantle and produced back-arc basin → metal source and architecture used during ~1550-1520 Ma Nolans event (and later Teapot (1130 Ma) and Mud Tank (730 Ma) alkaline events)
- Cratonised during Strangway (1740-1690 Ma) and Leibig (1640-1635 Ma) Orogenies

Nolans mineral system – extraction from source



- Post-orogenic relaxation at end of 1590-1550 Ma low P-high T Chewings Orogeny reactivated architecture and caused very low degree partial melting of pre-existing metasomatised mantle to produce P- and REE-enriched melts
- Lower crust melting caused by heat flux produced I-type magmas of 1550-1530 Ma Southwark Suite

Nolans mineral system – mineralisation



- P-REE-U-Th-rich alkaline melts ascend into mid-crust, utilising reactivated structures
- In mid-crust, magmatic immiscibility and/or crystallisation produce P-REE-U-Th-rich magmas/magmatic hydrothermal fluids
- Fluids move into upper crust along reactivated structures
- Apatite deposited by decrease in temperature and/or pressure or reaction with wall rocks

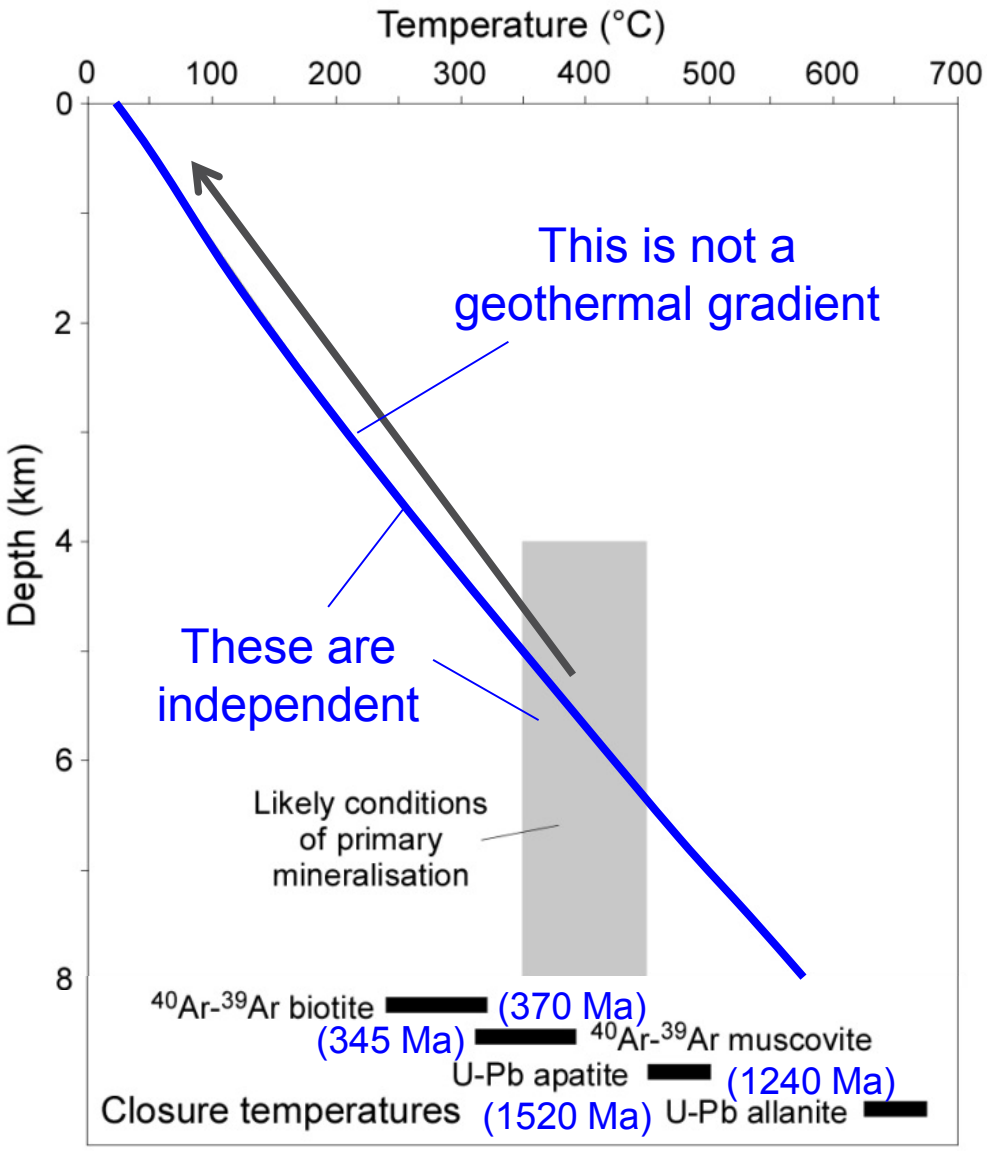
Conclusions (from Beyer, 2017)

- *Discrete zones of biotite-rich schist in two unrelated granites*
- *Geochronological and geochemical data implies genetic relationship between schists and their host granite*
- *New mineral growth in schists at ca 1575 Ma indicates regional metasomatism during the Chewings Orogeny*
- *Schists enriched in F-U-REE-metals compared to host granite*

  => schists represent zones of metasomatised granite
- *Metasomatism driven by fluids derived from a Mesoproterozoic alkaline (phosphatic) source*

Evidence for a regional late-Chewings REE-U-F mineralising event in central Aileron Province

Nolans mineral system – post-deposition changes



High Th (2500 ppm) and U (157 ppm) → 270 mW/m^3 radiogenic heat production (vs ~5 mW/m^3 for "normal" granite)

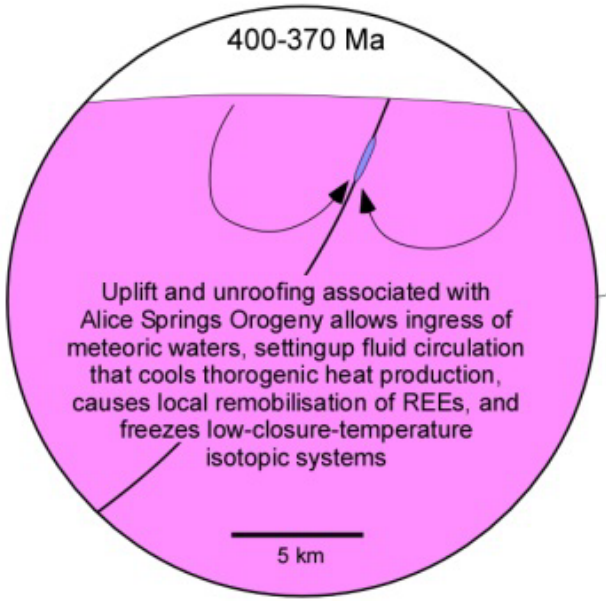
⇒ Local highly elevated thermal gradient associated with Nolans Bore

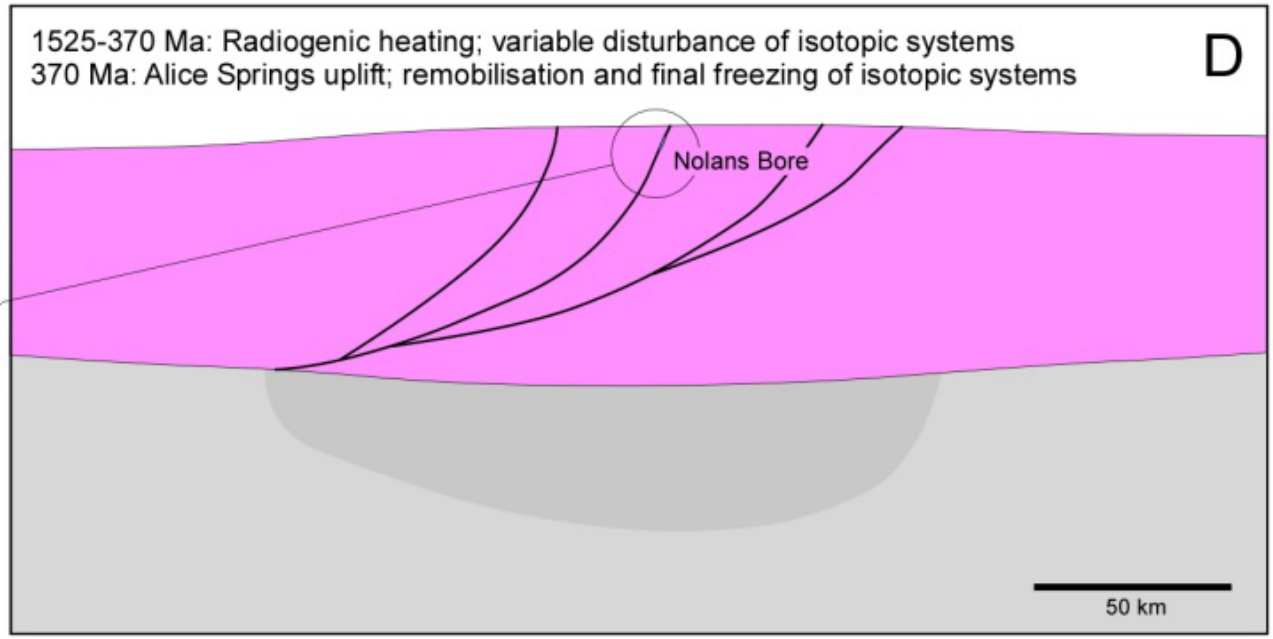
Thermal modelling indicates T ~340°C at 5 km depth (i.e. likely depth of mineralisation); decreasing at shallower depths

⇒ High radiogenic-driven temperatures would have been maintained until unroofing (during Alice Springs Orogeny – 450-300 Ma)

Lower closure temperature isotopic systems yield younger ages → *extensive isotopic re-equilibration due to high Th (and U) concentrations*

Nolans mineral system – post-deposition changes





- Between ~1520 and ~450 Ma, southern Aileron Province was quiescent
- Alice Springs orogenesis produced several periods of uplift (450-440 Ma Rodingan, 390-380 Ma Pertnjara, 365-355 Ma Brewer and 340-320 Ma Eclipse)
- This cooled the Nolans “reactor”, freezing in isotopic ages
- This also allowed ingress of meteoric waters, causing extensive remobilisation (e.g., Central Zone – Schoneveld et al., 2015)
- Recent supergene enrichment has caused local enrichment

Conclusions

- The Nolans deposit is the product of a mineral system that extended over 1.8 billion years
- Subduction at 1820-1740 Ma enriched mantle, producing a source that was tapped at 1550-1520 Ma
- Nolans mineralising event formed near end of low P-high T Chewings Orogeny
- It involved low degree partial melting of enriched mantle, ascent of P-REE-Th melt and evolution of magmatic-hydrothermal fluid
- Mineralisation occurred at depth of ~5 km from ~400°C, saline fluids (??)
- Post mineralisation radiogenic heating has extensively disturbed isotopic systems, yielding anomalously young apparent ages → *implications for geochronology of other U- and/or Th-rich systems*
- Ingress of meteoric waters during Alice Springs Orogeny caused extensive remobilisation in Central Zone (Schoneveld et al., 2015)
- DON'T be dogmatic about Nolans – it will make a fool of you

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Thank you

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