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New Re–Os model age constraints on the timing of tungsten and copper mineralisation in the Warramunga Province

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Introduction

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- The Warramunga Province has had a long history of exploration for and production from Tennant Creek-style ironstone-hosted Au-Cu±Bi deposits
- The Warramunga Province is also prospective for intrusion related W±Cu mineralisation

- *Aims*
  - *What are the characteristics and timing of intrusion-related tungsten and copper mineralisation in the Warramunga Province?*
  - *Are there any relationships with Au–Cu–Bi mineralisation in the Tennant Creek mineral field?*
  - *Are there any similarities to mineralisation of similar style in the Davenport and Aileron provinces?*

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Regional Geology

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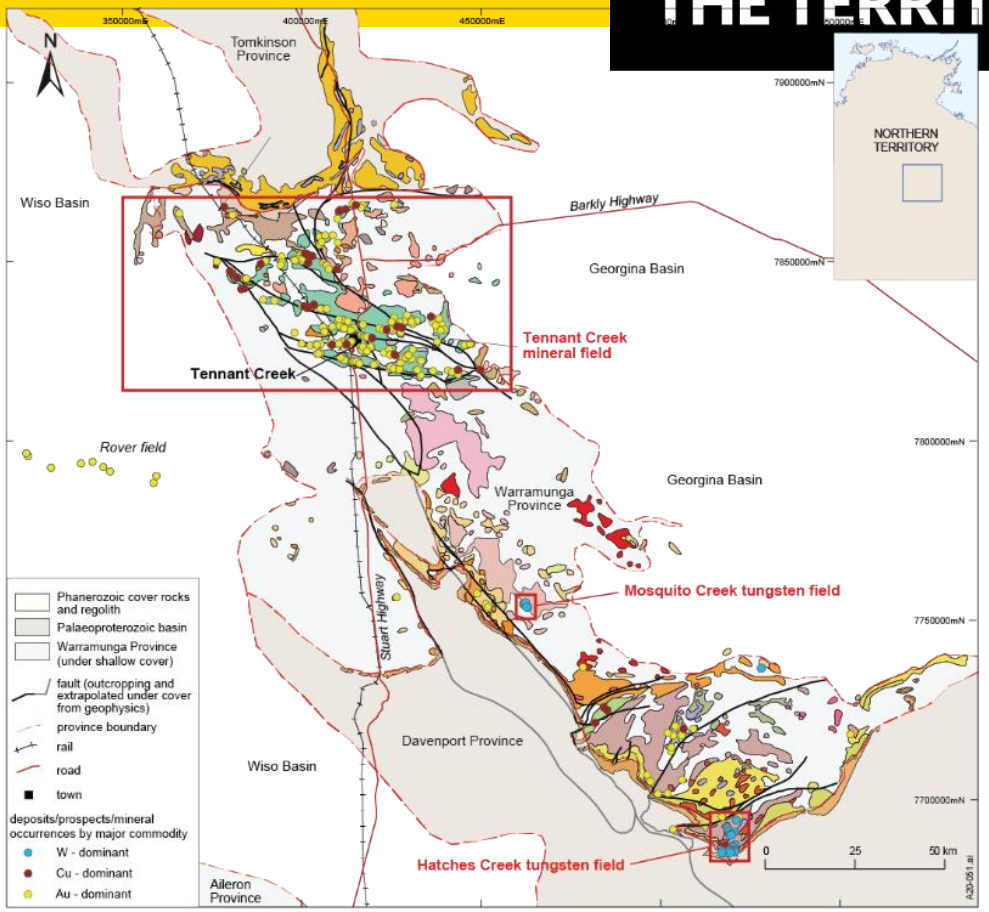
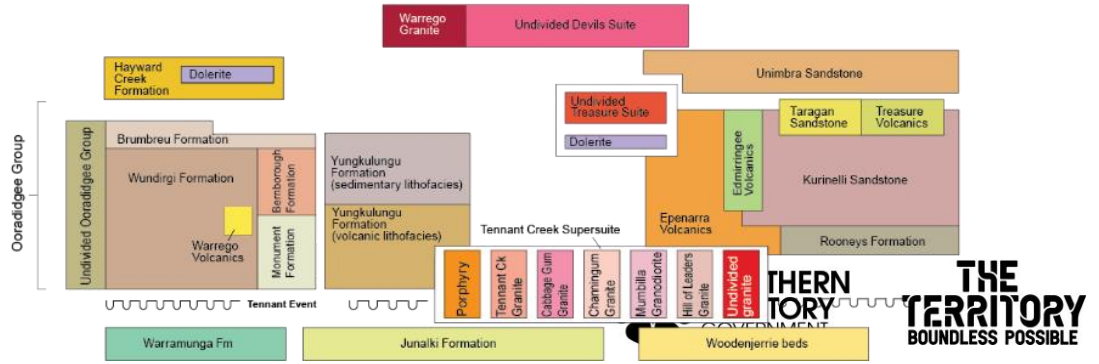
- Palaeoproterozoic basement terrane consisting of turbidite and volcano-sedimentary successions intruded by metaluminous and peraluminous bimodal igneous suites
- Polydeformed, low metamorphic grade
- >1.86 Ga sedimentary protoliths (Warramunga Formation and equivalents) deposited in a deep water setting, locally grading into shallow marine, host of mineralised ironstones
- syn-tectonic metaluminous felsic–mafic bimodal magmatism ca 1.85–1.84 Ga (Tennant Creek Supersuite), sub- to lower-greenschist facies metamorphism and west to locally southwest trending upright, tight–close folds and axial planar slaty cleavage
- Renewed clastic sedimentations and associated felsic and mafic volcanism from ca 1.84–1.82 Ga (Ooradidgee Group).
- syn-tectonic dominantly extrusive, felsic and mafic bimodal magmatism ca 1.82–1.81 Ga (Treasure Suite) associated with extensional tectonism
- Post-tectonic fractionated, peraluminous, dominantly felsic intrusive magmatism ca 1.72–1.71 Ga (Devils Suite)





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Timing of mineralisation

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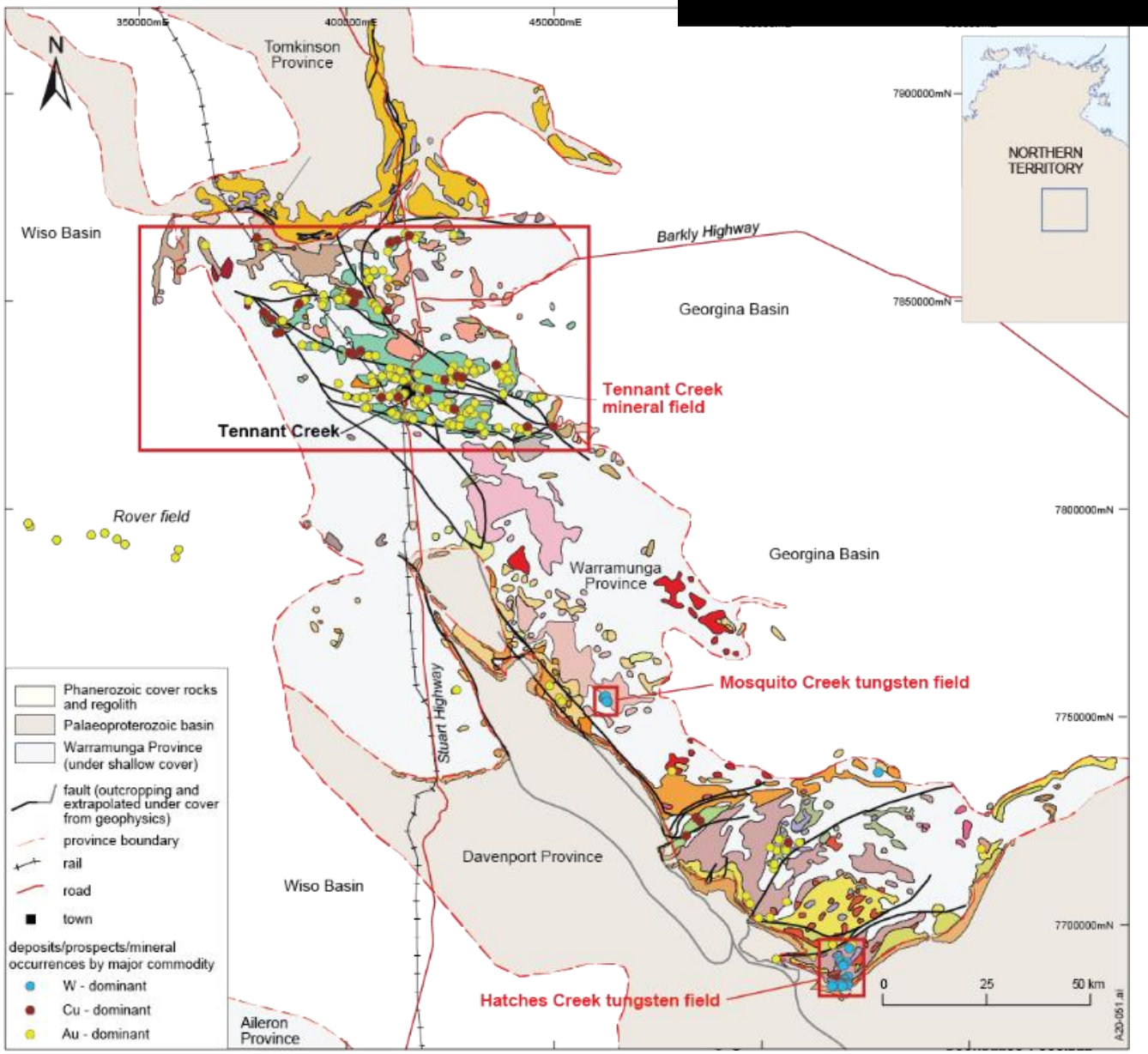
- Tennant Creek mineral field:
  - $^{40}Ar/^{39}Ar$ dating muscovite associated with Peko-type Au–Cu–Bi ironstone-hosted mineralisation in the Warramunga Formation yields ages of ca 1.85–1.83 Ga, coincident with Tennant Creek Supersuite magmatism (eg Fraser *et al* 2008)
  - *in situ* SHRIMP U–Pb–Th dating of monazite from Orlando and Navigator 6 yield ca 1.66–1.65 Ga ages interpreted to record hydrothermal fluid flow associated with mineralisation (Skirrow *et al* 2019)
- Mosquito Creek and Hatches Creek tungsten fields:
  - $^{40}Ar/^{39}Ar$ dating muscovite from selvages in the margins of tungsten mineralised quartz veins spatially associated with Devils Suite intrusions yields ages of ca 1.72–1.71 Ga (Fraser *et al* 2008)



Legend is on slide 3.

Intrusion-related tungsten and copper mineralisation

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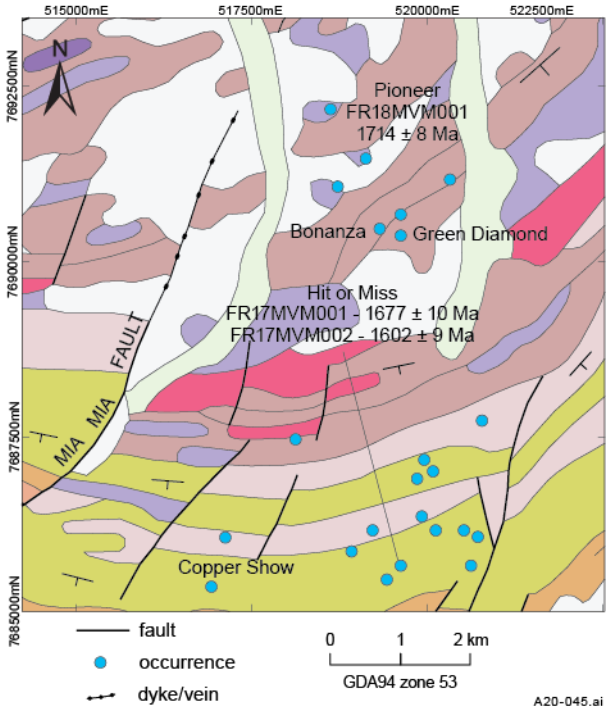
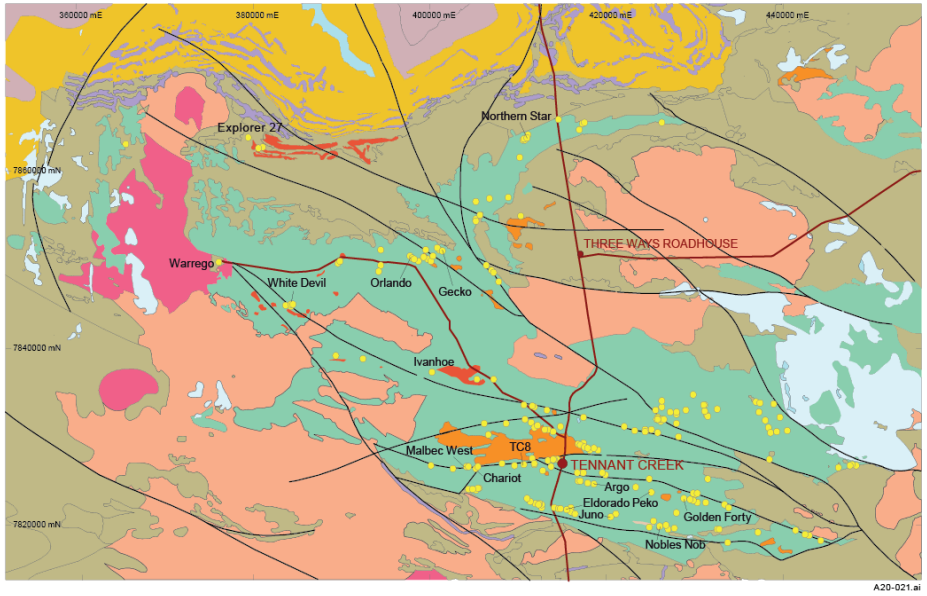
- Two styles of mineralisation:
  1. within quartz veins, and sheeted veins and dykes within Ooradidgee Group, Treasure Volcanics or Pedlar gabbro
  2. within sheared, greissenised granite
- Tungsten and copper are associated with molybdenite, tin, tantalum, bismuth and cobalt
- On the basis of field relationships (eg Donnellan 2013) and previous $^{40}Ar/^{39}Ar$ dating at least some of the W±Cu mineralisation can be linked to ca 1.72–1.71 Ga Devils Suite magmatism (Fraser *et al* 2008)
- The of Cu-Mo mineralisation in the Tennant Creek mineral field is unclear and at least some mineralisation in the Mosquito Creek tungsten is spatially associated with intrusions of the ca 1.85–1.84 Ga Tennant Creek Supersuite

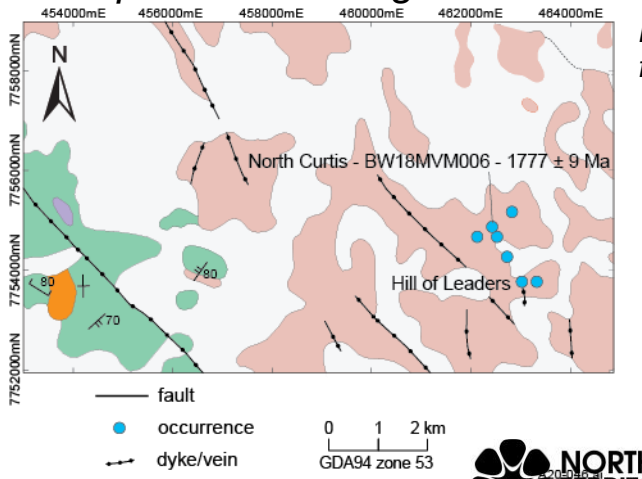
Hatches Creek tungsten field



Tennant Creek mineral field



Mosquito Creek tungsten field



Legend and locations for maps are on slide 3.

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New Re–Os molybdenite dating

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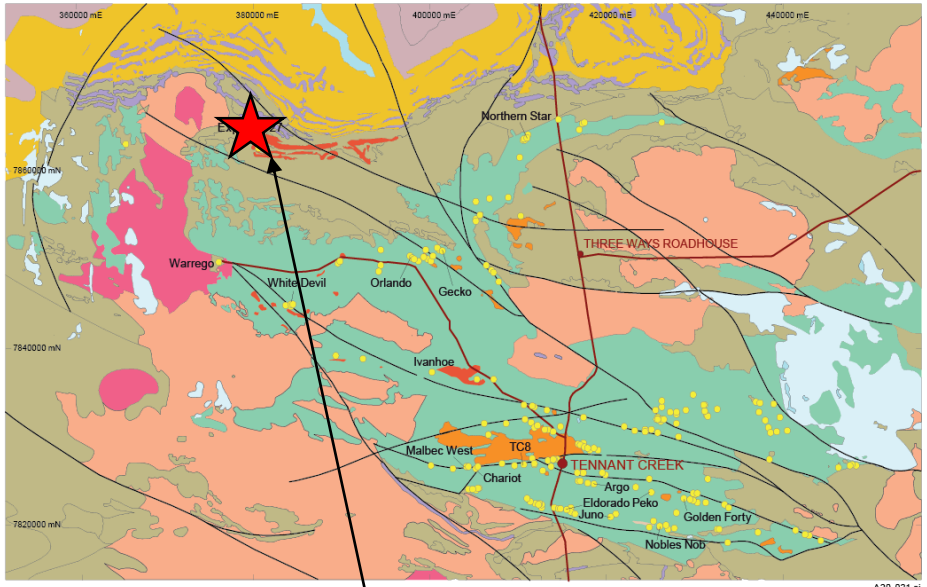
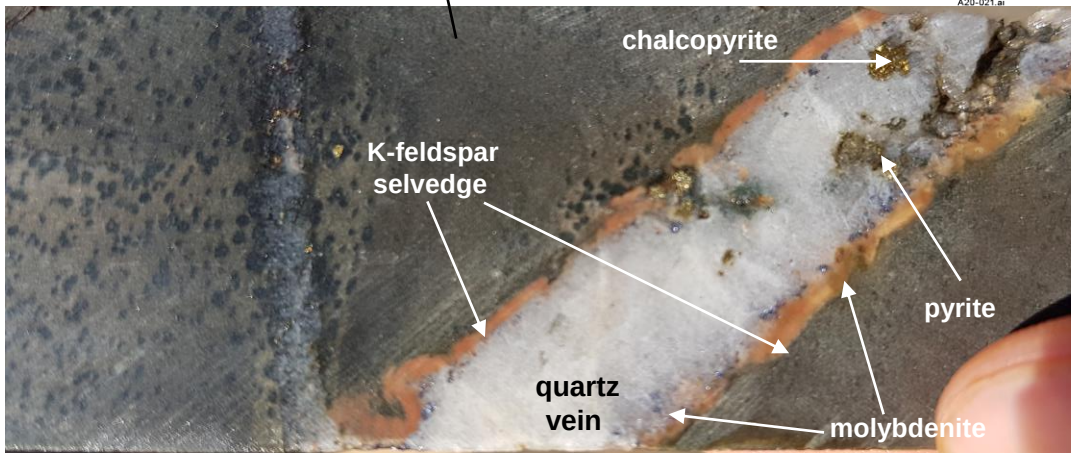
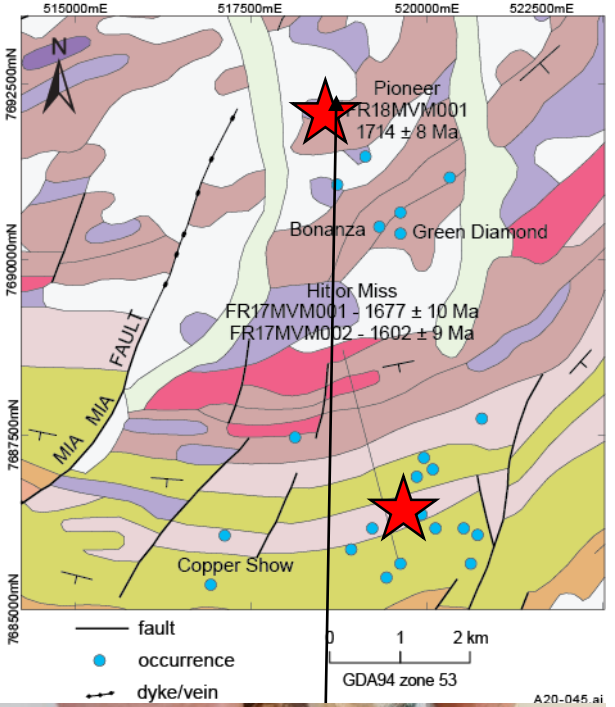
Tennant Creek mineral field

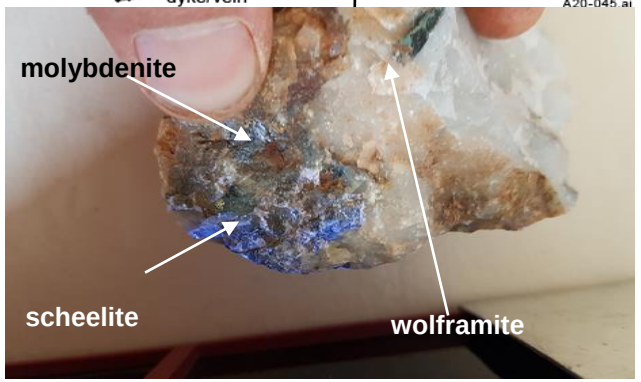




Drill core from Explorer 27 prospect showing the context of molybdenite and copper Mineralisation cross cutting Wundirgi Formation of the Ooradidgee Group

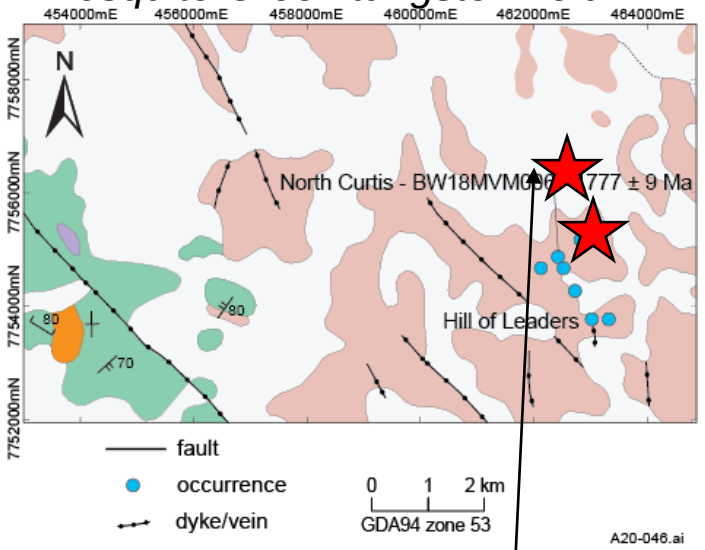
Hatches Creek tungsten field





Intergrown molybdenite and scheelite from Pioneer deposit

Mosquito Creek tungsten field



Molybdenite-bearing chips from North Curtis

★ *Molybdenite sample location for Re–Os dating. Legend and locations for maps are on slide 3.*

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New Re–Os molybdenite model ages

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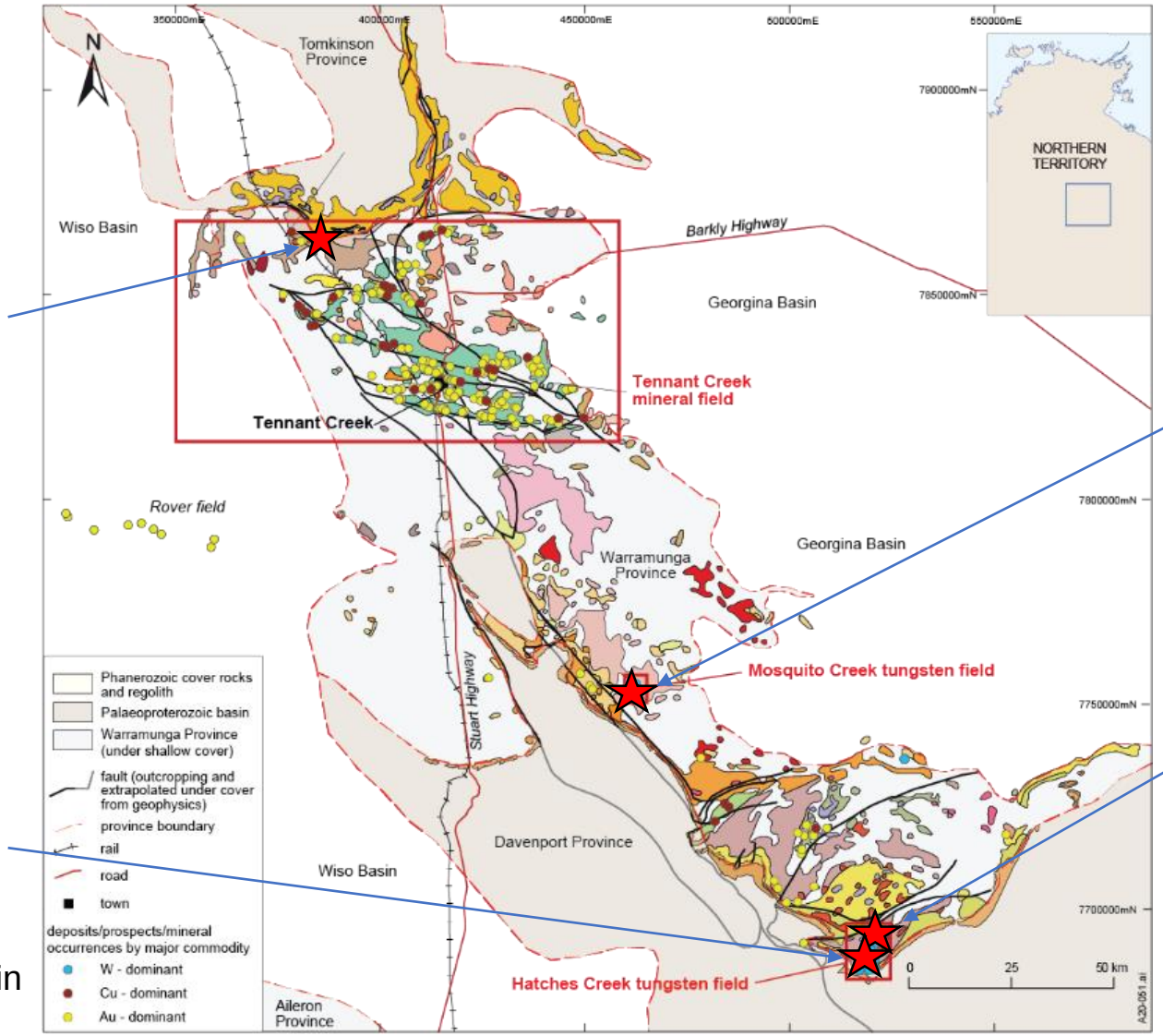
Tennant Creek mineral field
Explorer 27
Sample: TC18MVM001
Context: chalcopyrite–molybdenite-bearing quartz vein
Chemistry: Re 6.84 ppm, Os 124.2 ppb
Model age: **1711 ± 8 Ma**

Sample: TC18MVM002
Context: chalcopyrite–molybdenite-bearing quartz vein
Chemistry: Re 1.30 ppm, Os 23.8 ppb
Model age: **1718 ± 8 Ma**

Hatches Creek tungsten field
Hit or Miss
Sample: FR17MVM001
Context: scheelite–molybdenite–chalcopyrite-bearing quartz vein
Chemistry: Re 1.01 ppm, Os 17.97 ppb
Model age: **1677 ± 10 Ma**

Sample: FR17MVM002
Context: molybdenite-bearing quartz vein
Chemistry: Re 1.83 ppm, Os 31.10 ppb
Model age: **1602 ± 9 Ma**



★ **Re–Os molybdenite model age (this study)**

Mosquito Creek tungsten field
North Curtis
Sample: BW18MVM006
Context: molybdenite–scheelite–wolframite-bearing quartz vein
Chemistry: Re 2.26 ppm, Os 42.66 ppb
Model age: **1777 ± 9 Ma**

Hatches Creek tungsten field
Pioneer
Sample: FR18MVM001
Context: molybdenite–scheelite-bearing quartz vein
Chemistry: Re 1.62 ppm, Os 42.66 ppb
Model age: **1714 ± 8 Ma**

Interpretation of new data

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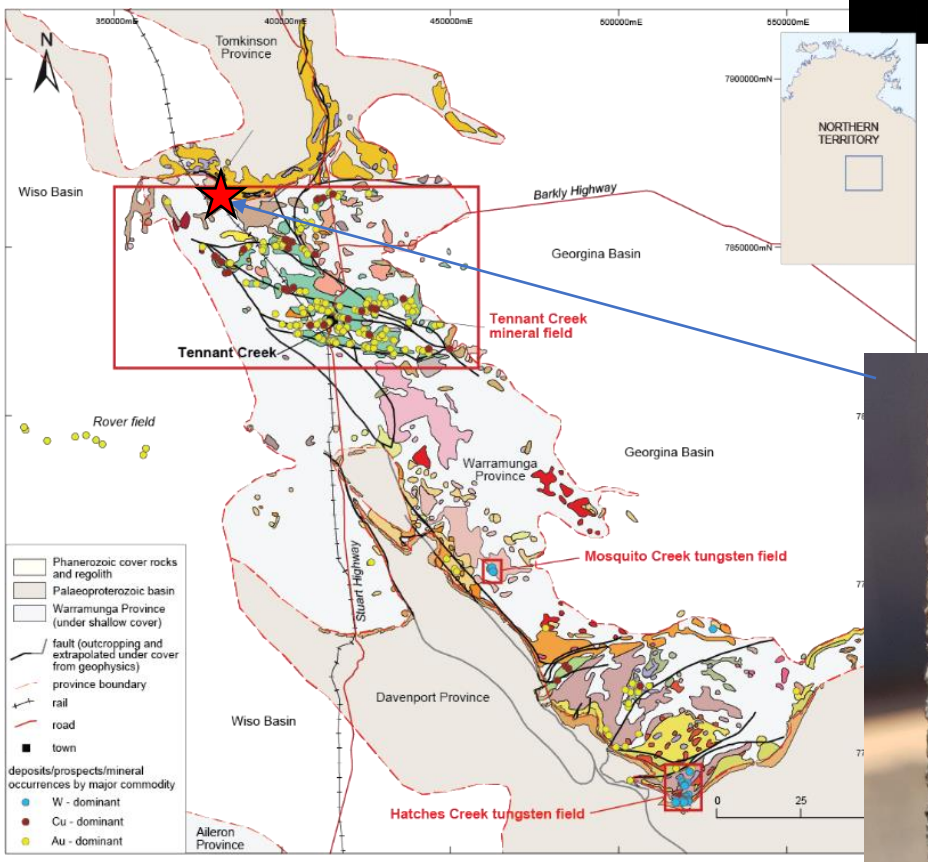
Tennant Creek mineral field

- Molybdenite is characterised by low Re concentrations, consistent with a felsic magmatic source
- ca 1.72–1.71 Ga Re–Os model ages are interpreted to record the timing of copper and molybdenite mineralisation hosted in quartz veins at Explorer 27
- Warrego Granite is the closest intrusion, new SHRIMP U–Pb zircon dating yields a $^{207}Pb/^{206}Pb$ crystallisation age of 1711 ± 10 Ma (Huston *et al* 2020)
- New Re–Os model ages indicate an episode of Cu mineralisation younger than irontstone-hosted Au-Cu-Bi mineralisation (cf Fraser *et al* 2008, Skirrow *et al* 2019)



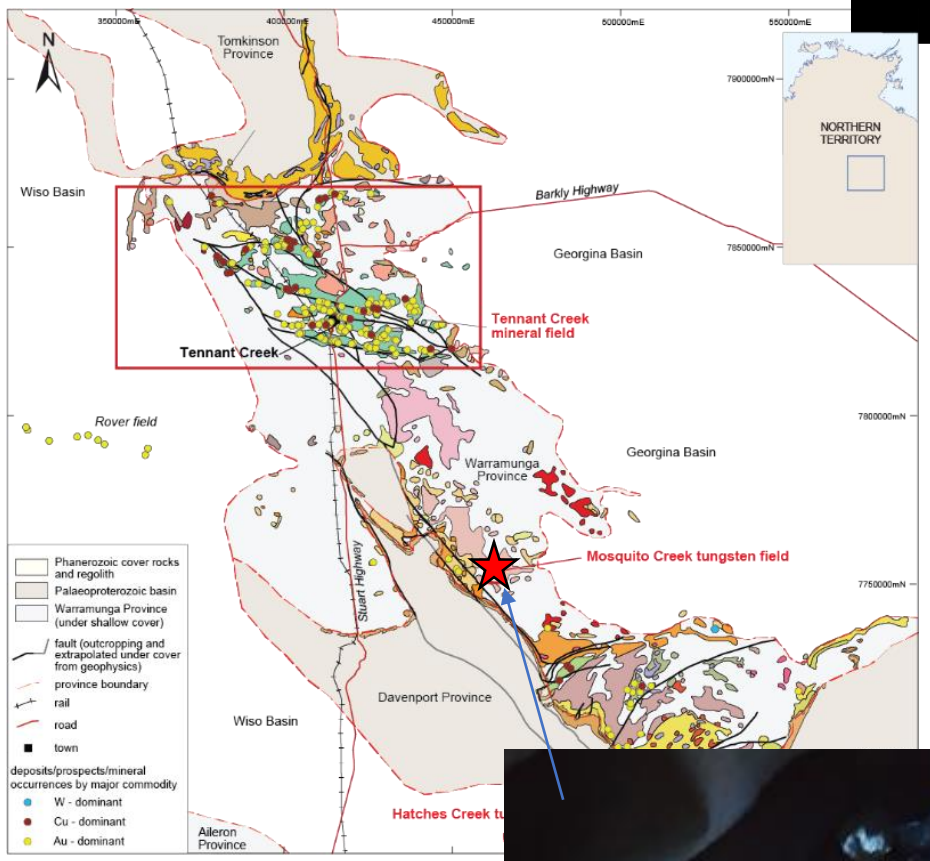
Drill core from Explorer 27 prospect, Tennant Creek mineral field

Interpretation of new data

RESOURCING THE TERRITORY

Mosquito Creek tungsten field

- Molybdenite is characterised by low Re concentrations, consistent with a felsic magmatic source
- ca 1.77 Ga Re–Os model age tentatively interpreted to record the timing of molybdenite, scheelite and wolframite mineralisation associated with quartz veining in greisenised granite at North Curtis prospect
- Hill of Leaders Granite is the closest intrusion, new SHRIMP U–Pb zircon dating yields a $^{207}Pb/^{206}Pb$ crystallisation age of 1846 ± 3 Ma (Maidment *et al* 2006)
- No direct link to a known period of felsic magmatism in the Warramunga Province
- Significance remains to be tested



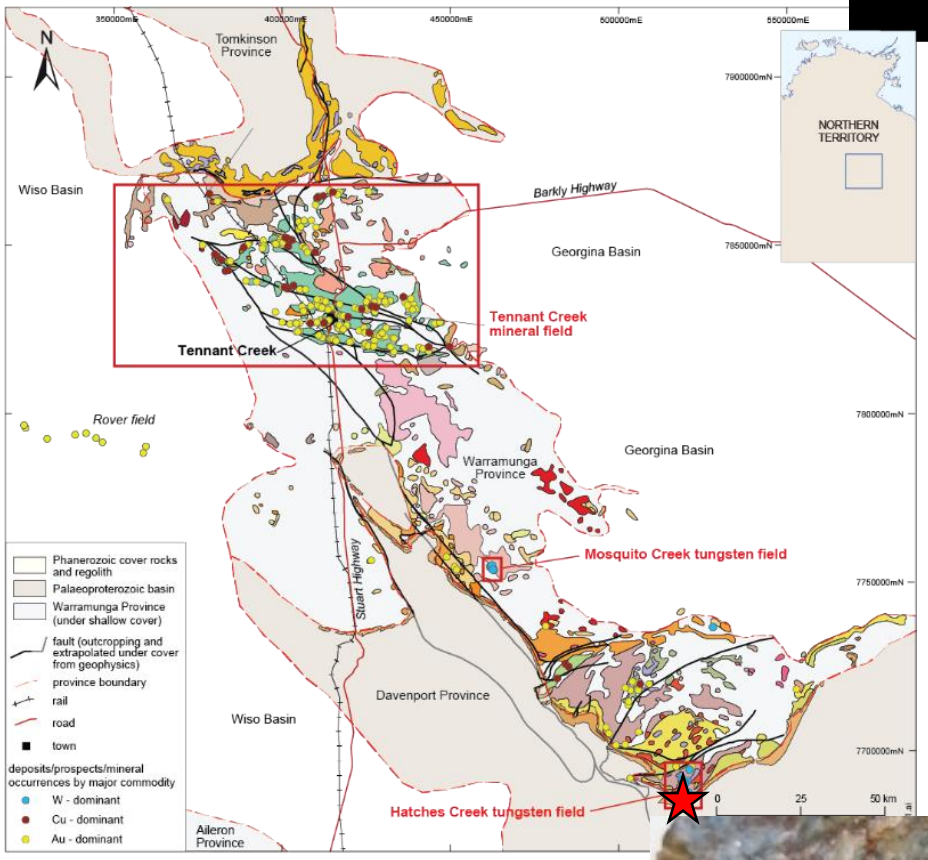
Molybdenite and scheelite with quartz chips under UV light from North Curtis prospect

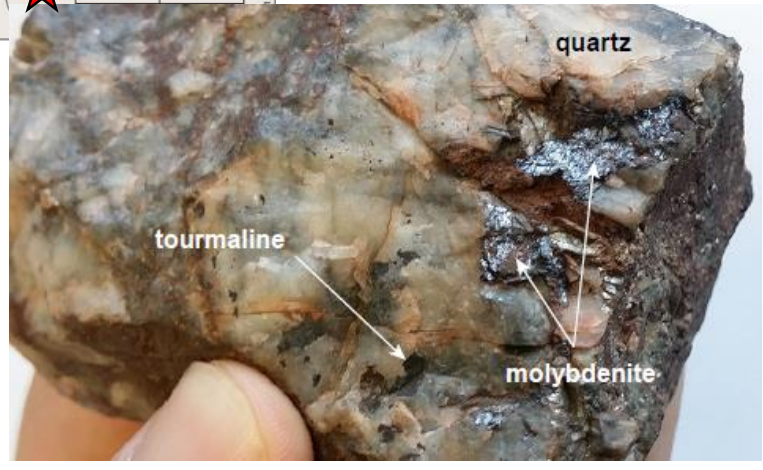
Interpretation of new data

RESOURCING THE TERRITORY

Hatches Creek tungsten field

- Molybdenite is characterised by low Re concentrations, consistent with a felsic magmatic source
- New Re–Os model ages indicated at least two phases of tungsten mineralisation
- ca 1.71 Ga for molybdenite, scheelite and wolframite mineralisation associated with quartz veins cross cutting Pedlar Gabbro at the Pioneer deposit interpreted to record timing of mineralisation associated with proximal Devils Suite magmatism
- ca 1.68 Ga and ca 1.60 Ga for Hit or Miss deposit, no direct relationship to known felsic magmatism
- ca 1.68 Ga is interpreted to record timing of tungsten and copper mineralisation and is broadly similar to new constraints on the timing of Au–Cu mineralisation at Gecko, Orlando and Navigator 6 (Tennant Creek mineral field; McInnes *et al* 2008, Skirrow *et al* 2019)
- Multiple mineralising (remobilisation?) events, significance of the younger ages remains to be tested





Molybdenite-bearing quartz vein from the Hit or Miss deposit

Constraints on the timing of mineralisation in the Warramunga Province

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- ca 1.85 Ga Au-Cu-Bi (Argo, Juno, Nobels Nob)
- ca 1.77 Ga W±Cu (North Curtis)
- ca 1.72–1.71 Ga Cu±Au (Explorer 27) and W±Cu (Pioneer, Bonanza, Green Diamond, Copper Show)
- ca 1.67–1.66 Ga Cu-Au (Gecko, Navigator 6, Orlando East) and W±Cu (Hit or Miss)

Explorer 27: 1711 ± 8 Ma, 1718 ± 8 Ma

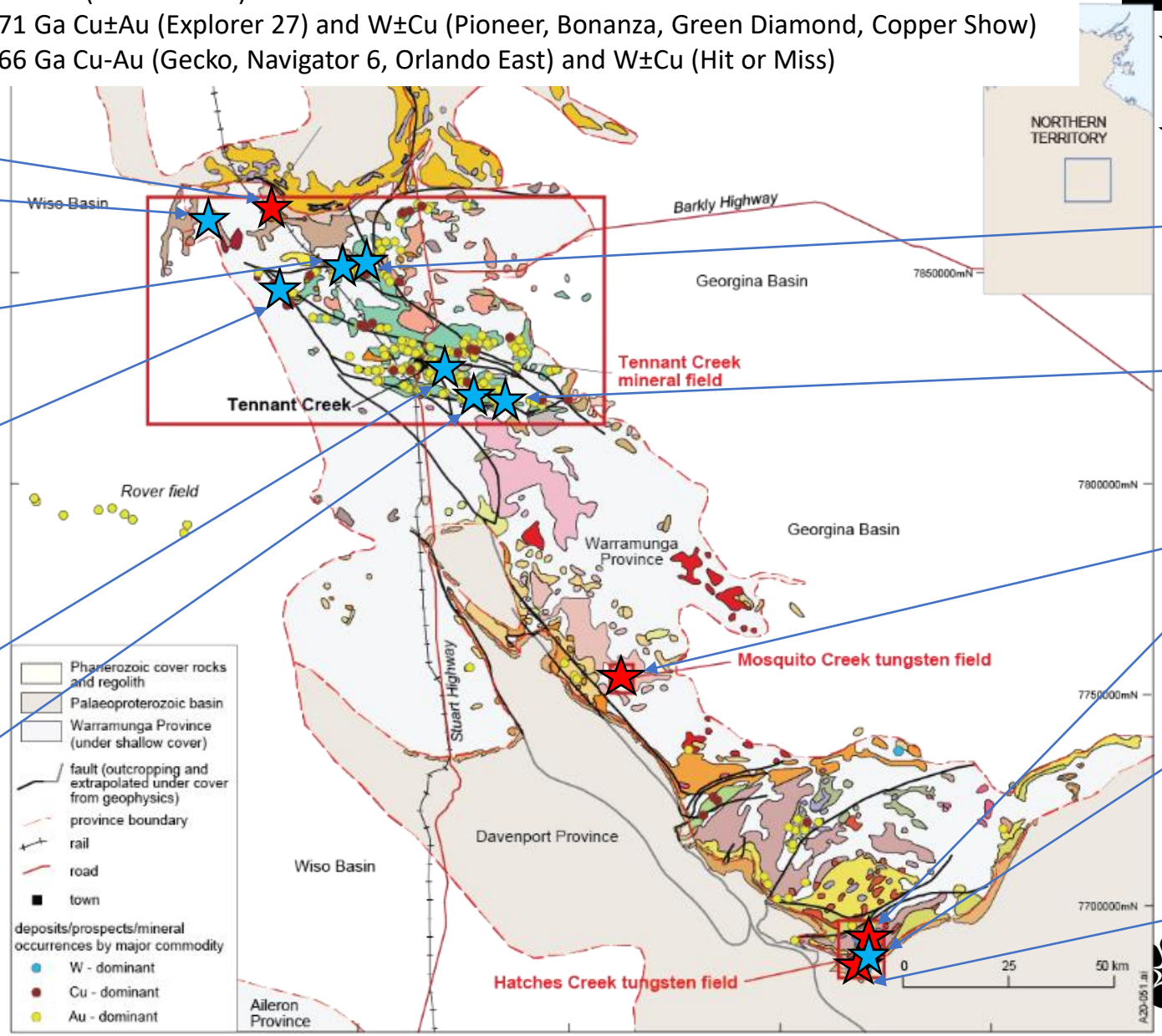
Warrego: K–Ar muscovite, 1716 ± 36 Ma (contact metamorphism; Compston and McDougall 1994)

Navigator 6: *in situ* SHRIMP U–Pb–Th monazite, 1659 ± 15 Ma (hydrothermal Mnz associated with mineralisation; Skirrow *et al 2019*)

Orlando East: *in situ* SHRIMP U–Pb–Th monazite, 1659 ± 13 Ma (hydrothermal Mnz associated with mineralisation; Skirrow *et al 2019*)

Argo: $^{40}Ar/^{39}Ar$ muscovite, 1850 ± 4 Ma (Au-Cu mineralisation; Fraser *et al* 2008)

Juno: $^{40}Ar/^{39}Ar$ muscovite, 1848 ± 4 Ma, 1851 ± 4 Ma (Au-Cu-Bi mineralisation; Fraser *et al* 2008)



Re–Os molybdenite model age (this study)

Location of samples dated in previous chronologic studies

Gecko: Re–Os whole rock isochron, 1665 ± 65 Ma (Au-Cu mineralisation; McInnes *et al* 2008)

Nobels Nob: $^{40}Ar/^{39}Ar$ muscovite, 1847 ± 4 Ma, 1848 ± 4 Ma (Au-Cu mineralisation; Fraser *et al* 2008)

North Curtis: 1777 ± 9 Ma

Pioneer: 1714 ± 8 Ma

Bonanza: $^{40}Ar/^{39}Ar$ muscovite, 1715 ± 6 Ma; Green Diamond: $^{40}Ar/^{39}Ar$ muscovite 1717 ± 5 Ma; Copper Show: $^{40}Ar/^{39}Ar$ muscovite, 1711 ± 6 Ma (W mineralisation; Fraser *et al* 2008)

Hit or Miss: 1677 ± 10 Ma, 1602 ± 9 Ma

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Implications

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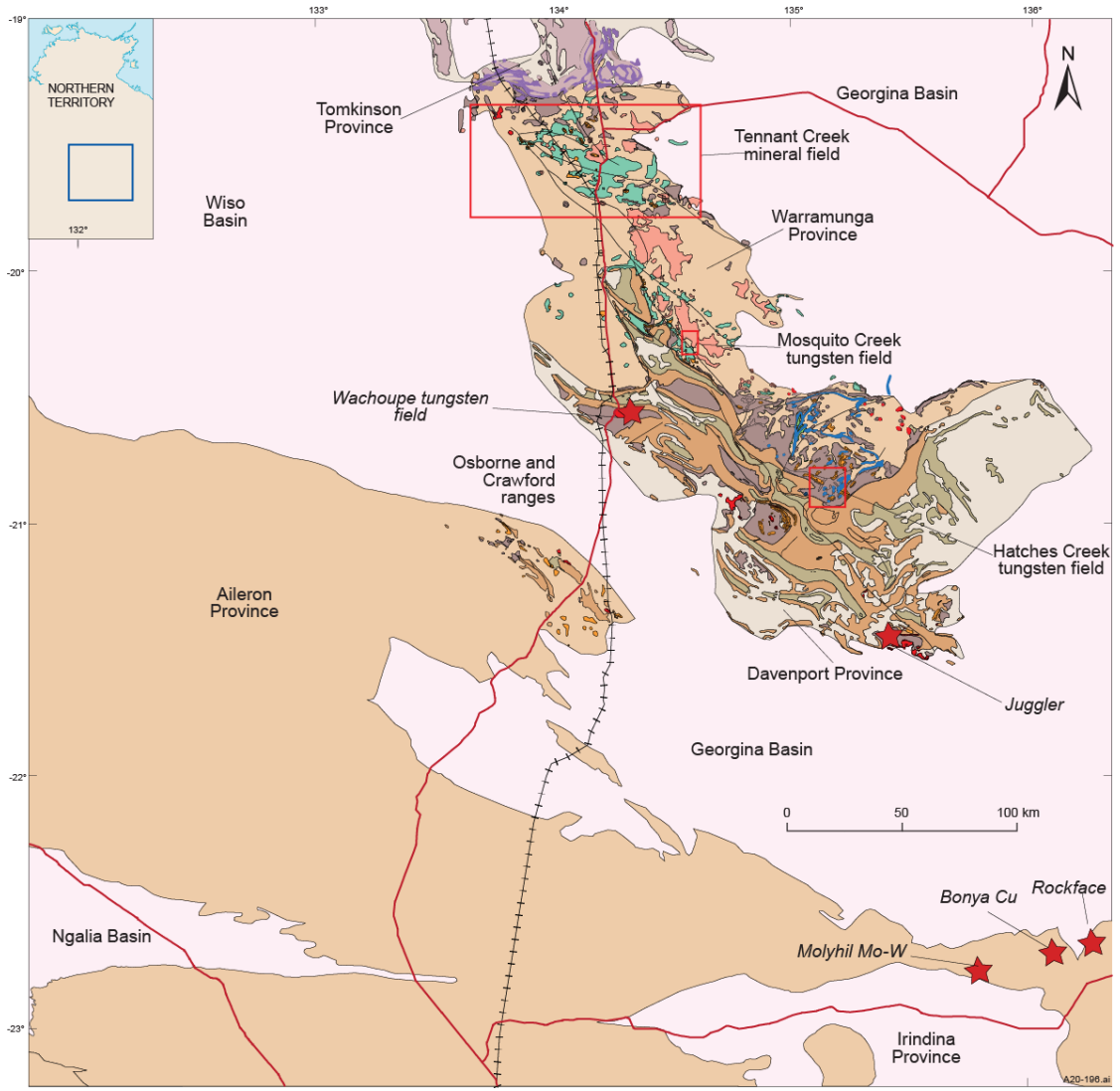
- New Re–Os model ages indicate 3 mineralising (remobilisation) events:
  - Mosquito Creek tungsten field: ca 1.77 Ga
  - Tennant Creek mineral field and Hatches Creek tungsten field: ca 1.72–1.71 Ga
  - Hatches Creek tungsten field: ca 1.67 Ma
- Ca 1.72–1.71 Ga W ± Cu mineralisation associated with fractionated, peraluminous granite suites is widespread across southern and central North Australian Craton and include:
  - Davenport Province: Juggler prospect associated with Elkedra Granite (Devils Suite; Fraser *et al* 2008, Page 1996)
  - Aileron Province:
    - Molyhil deposit associated with Marshall Granite (McGloin and Weisheit in review)
    - Bonya Cu deposit associated with Samarkand Pegmatite (McGloin and Weisheit in review)
    - Rockface deposit associated with Samarkand Pegmatite (McGloin and Weisheit in review)
- Multiple chronometers (monazite Skirrow *et al* 2019; whole rock Re–Os isochron McInnes *et al* 2008; molybdenite this study) indicate evidence for fluid flow associated with mineralisation between ca 1.68–1.6 Ga in the Warramunga Province. The significance of these ages on a regional-scale requires further testing



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Questions?

Contact

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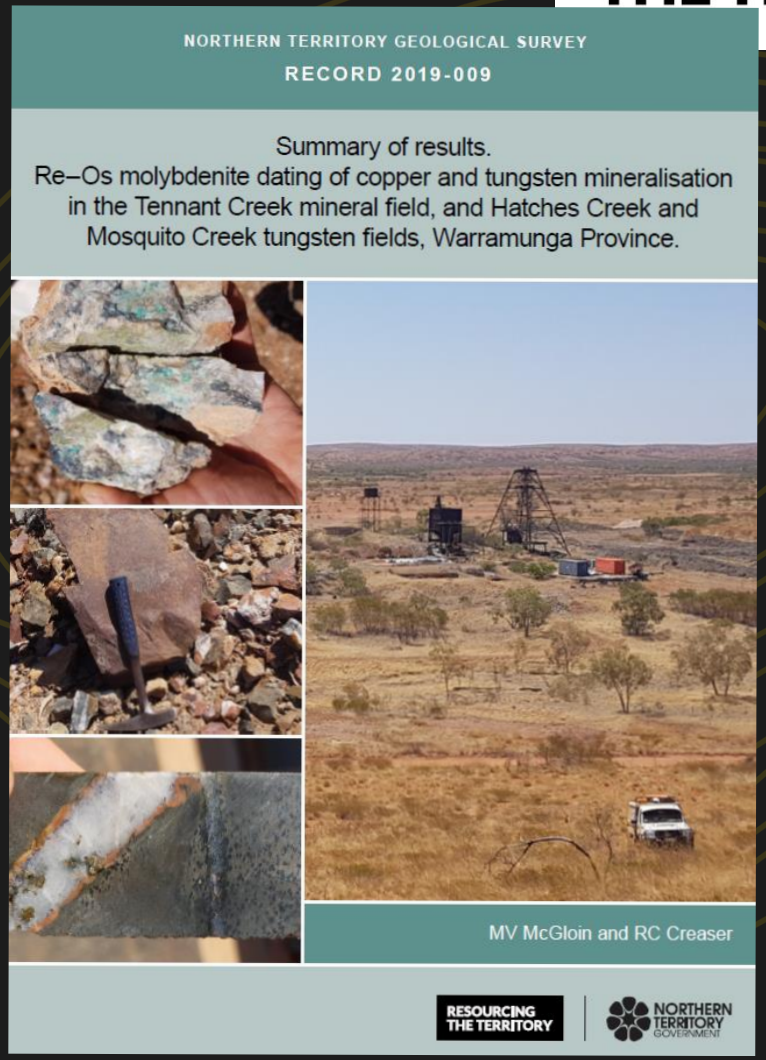

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