Australian Government
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Implications of AEM for uranium in the Paterson area

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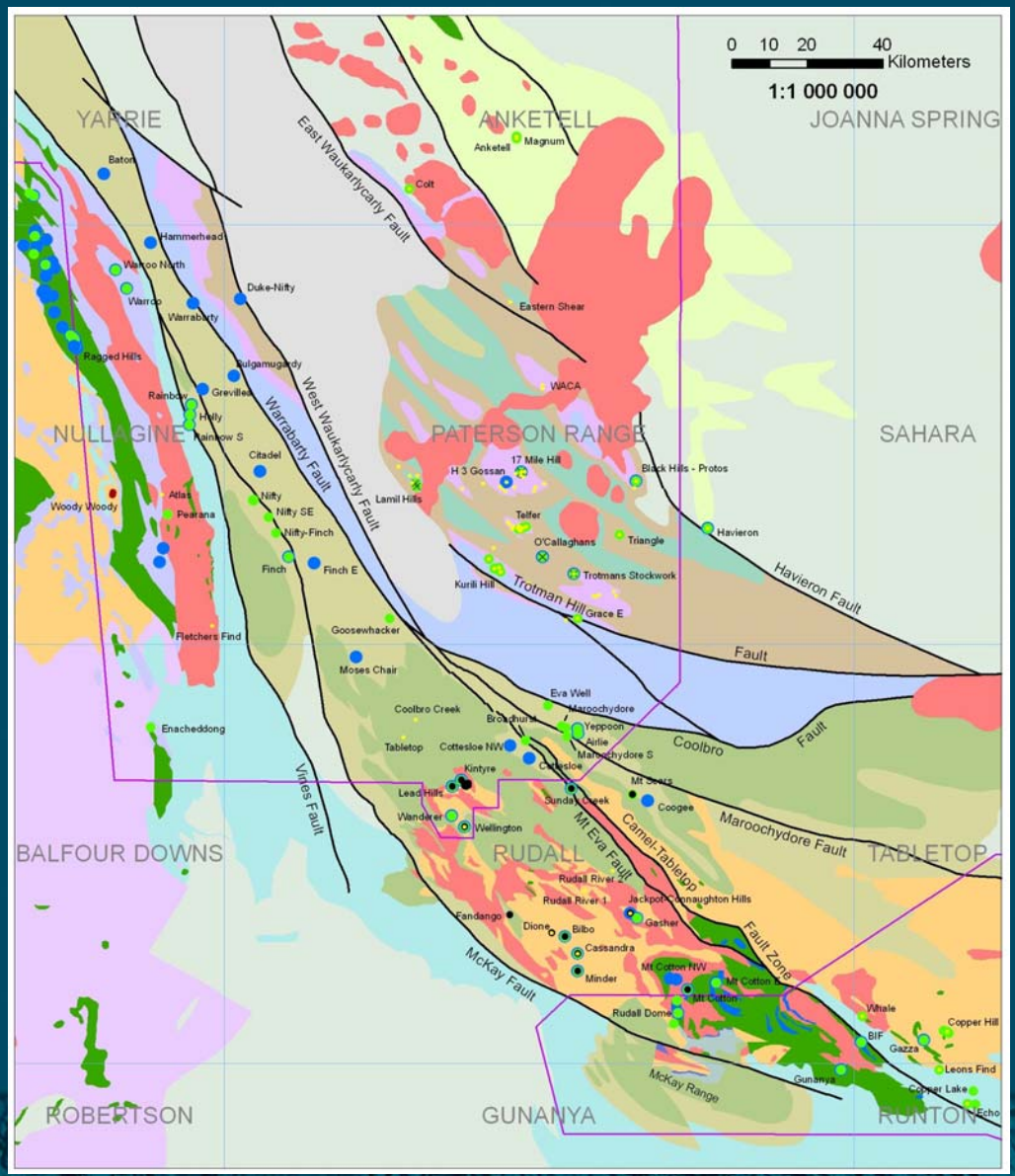
Outline of this presentation

- Miles mineral system :
  - late stage of Yeneena Basin development
  - initial inversion of Yeneena Basin during Miles Orogeny
- Implications of AEM for uranium in Paterson :
  - Unconformity related uranium mineral system
  - U-Cu mineral system associated with the Broadhurst-Coolbro contact
  - Sandstone-hosted uranium mineral system
  - Calcrete-hosted uranium mineral system

Mineral occurrences & deposits in Paterson



- Most known U in Rudall Complex (Coolbro-Rudall unconformity)
- Association of U with Cu-Pb-Zn
- Newly interpreted major faults:
  - East Waukarlycarly Fault
  - Havieron Fault
  - Trotman Hill Fault
  - West Waukarlycarly Fault
  - Coolbro Fault
  - Maroochydore Fault

New geochronology

~~~~~~~~~ Paterson Orogeny ~ 650 Ma ~~~~~~~~~~

~~~~~~~~~ Miles Orogeny ~ 810 Ma ~~~~~~~~~~

Tarcunyah Group

Lamil Group

Throssell Range Group

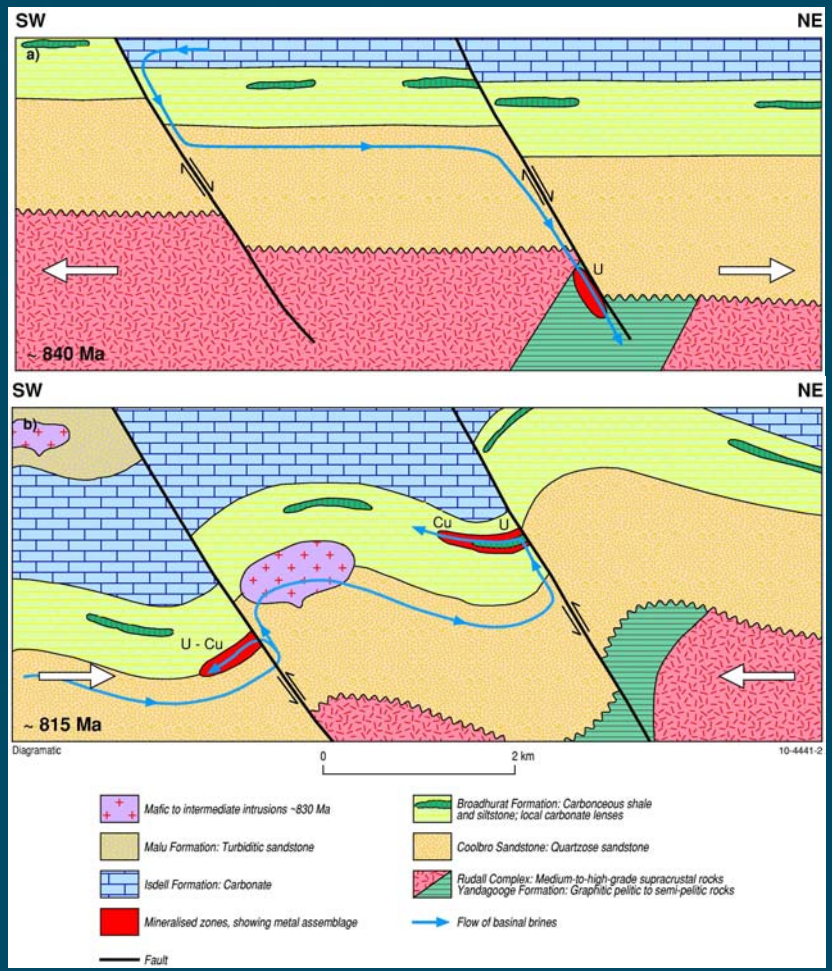
---------- ~ 860 Ma ----------

felsic intrusions @ 1590-1550 Ma

~~~~~~ Yapungku Orogeny ~ 1800-1760 Ma ~~~~~

Rudall Complex
~~~~~~

Miles mineral system



Two-event model:

840-830 Ma: late Yeneena Basin development

- extension - downward fluid movement
- basin thickness >10km
- basinal brines during diagenesis
- additional heat flow: mafic intrusions (835-835 Ma)
- trap rocks in basement →deposition of U, Cu-Zn-Pb, Au, and platinum group

830-810 Ma: initial inversion of Yeneena Basin

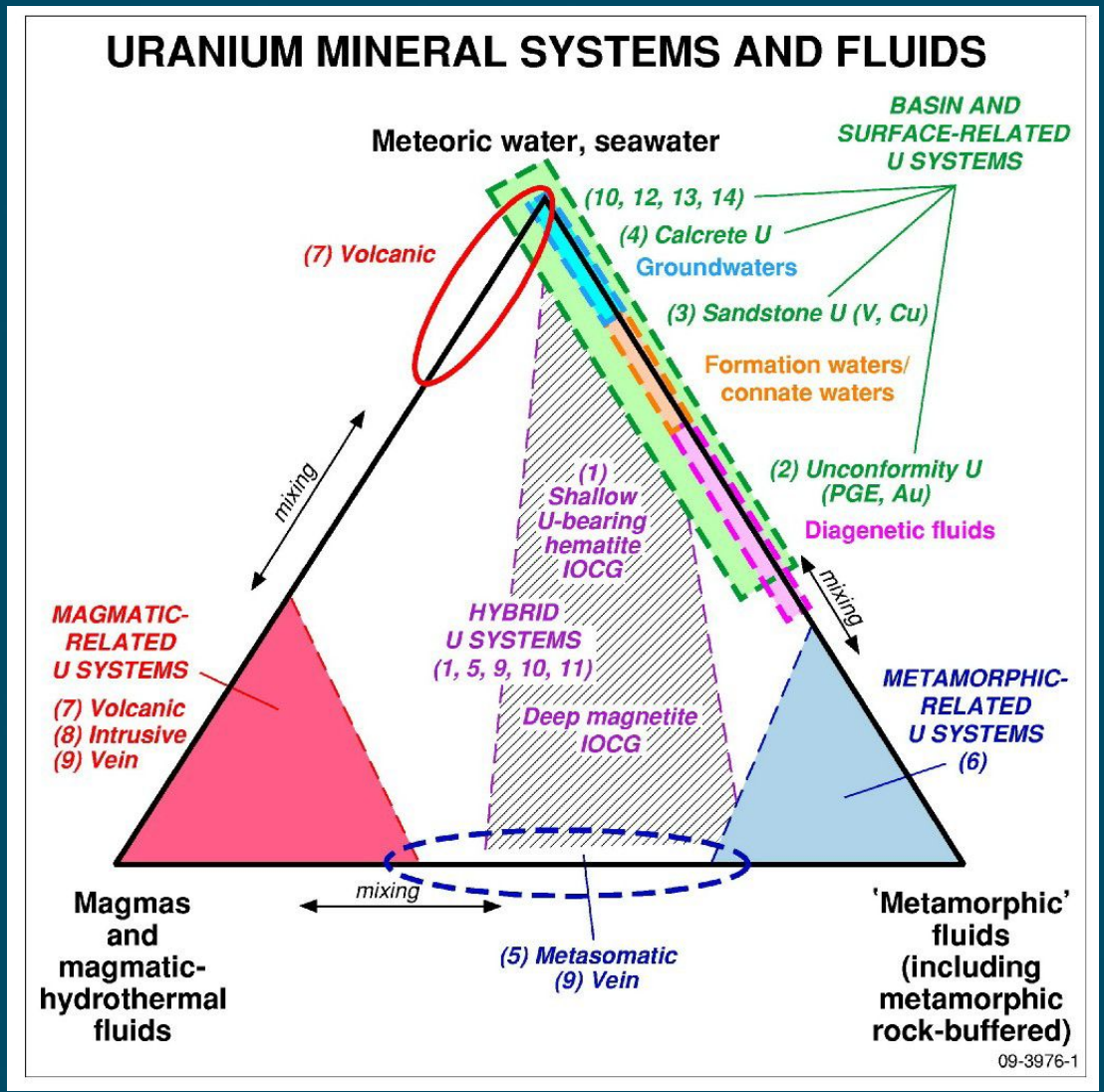
- normal faults during basin formation → thrusts, & folding
- upward fluid movement
- fluids interact with traps at the Coolbro-Broadhurst contact, or carbonaceous and carbonate-rich intervals at higher levels in Broadhurst Formation
- Cu, U and other metals, also as consequence of reduction
- enriched in Cu – ~830Ma mafic rocks as Cu sources

U, Cu & U-Cu-Zn-Pb mineral systems & zoning

- deposit scale
- regional scale

NEXT: U mineral systems in Paterson

Uranium mineral systems in Paterson



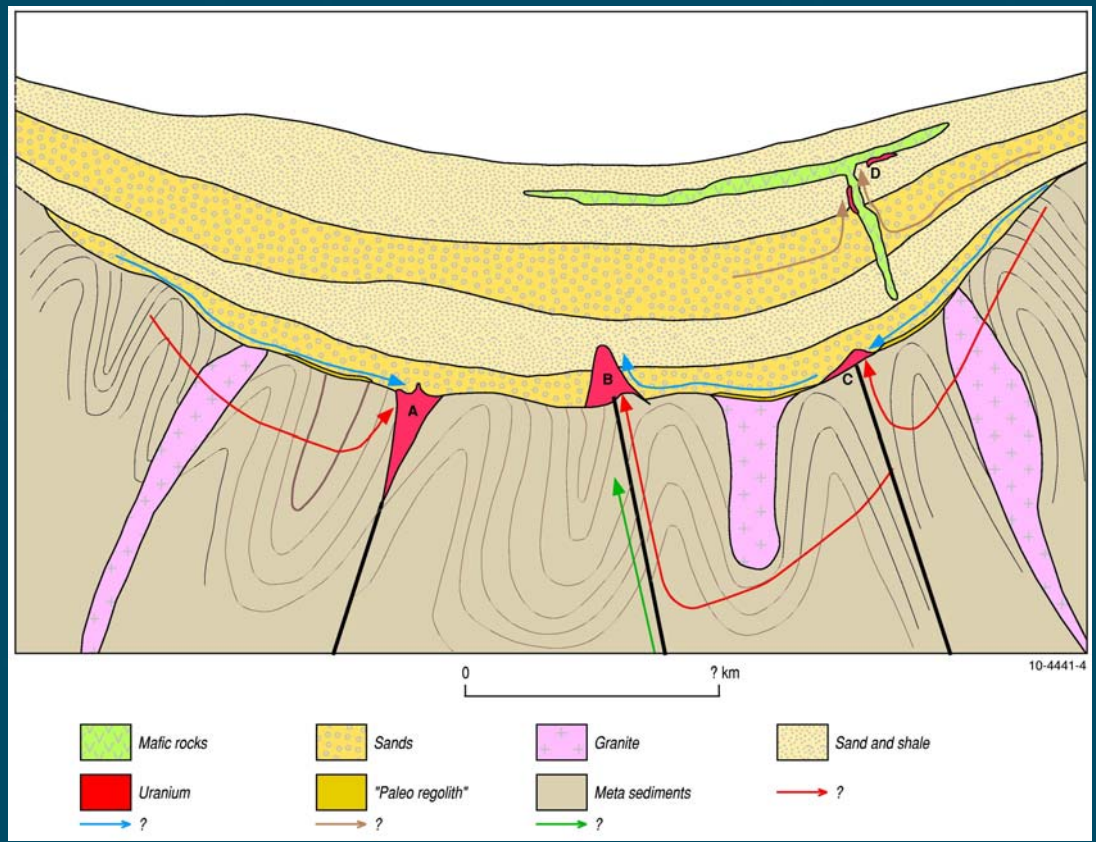
Basinal fluid related:

- Unconformity-related U
- Diagenetic fluid-related U-Cu
- Sandstone-hosed U
- Calcrete-hosted U

NEXT: U mineral systems in Paterson

after Skirrow et al. (2009)

Unconformity related uranium system



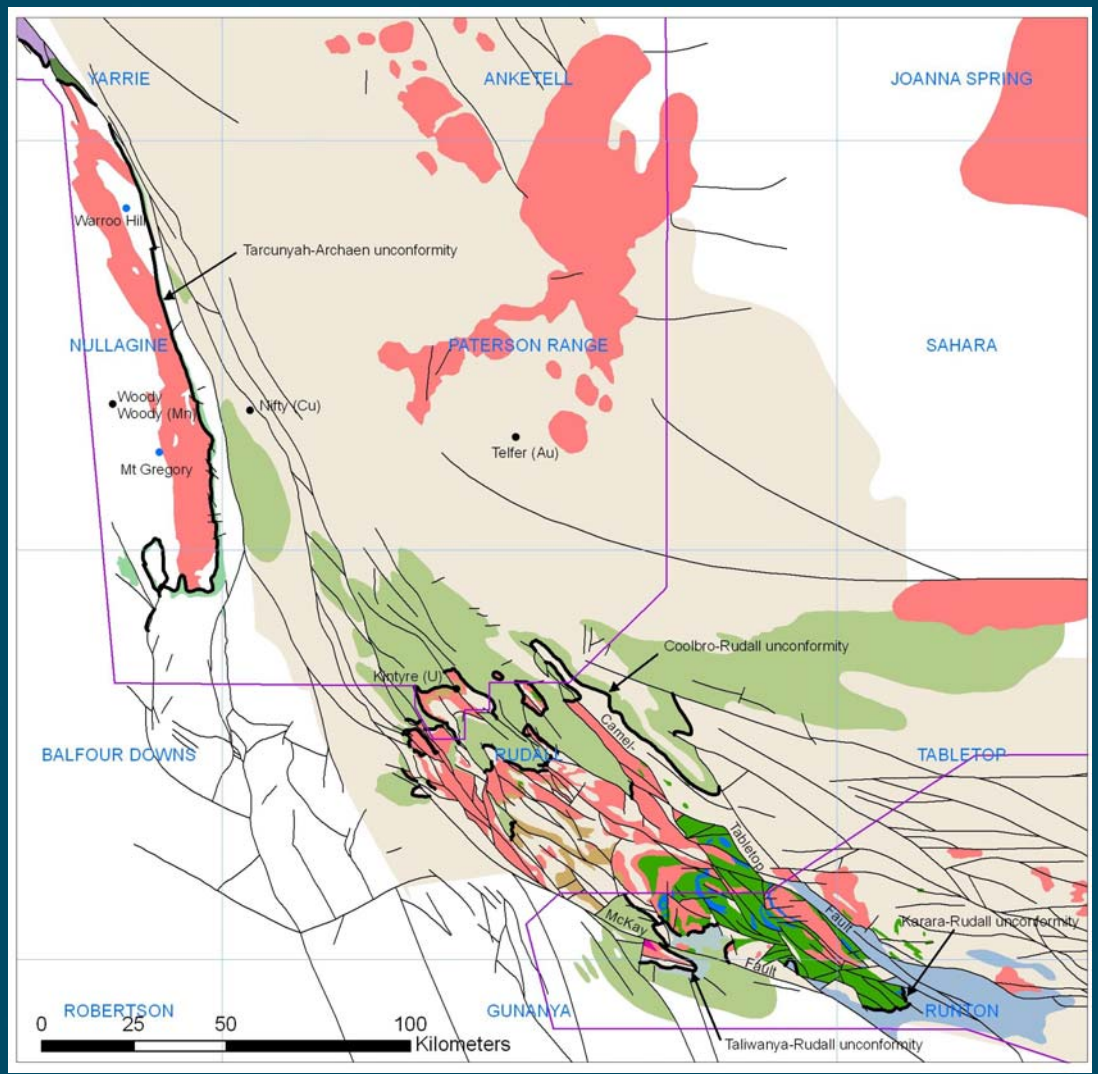
Critical components :

- unconformity
- uranium-rich source rocks
- thick (5-7km) fluviatile sandstone package
- reductants
- faults

closely associated with unconformity:

- spatially (with 100s m of unconformity)
- process (fluid movement along unconformity & faults)

Neoproterozoic unconformities in Paterson



Tarcunyah-Archean

- Eel Creek, Waroongunyah, & Googehnama Fms over Archean Pilbara Craton & Fortescue Basin

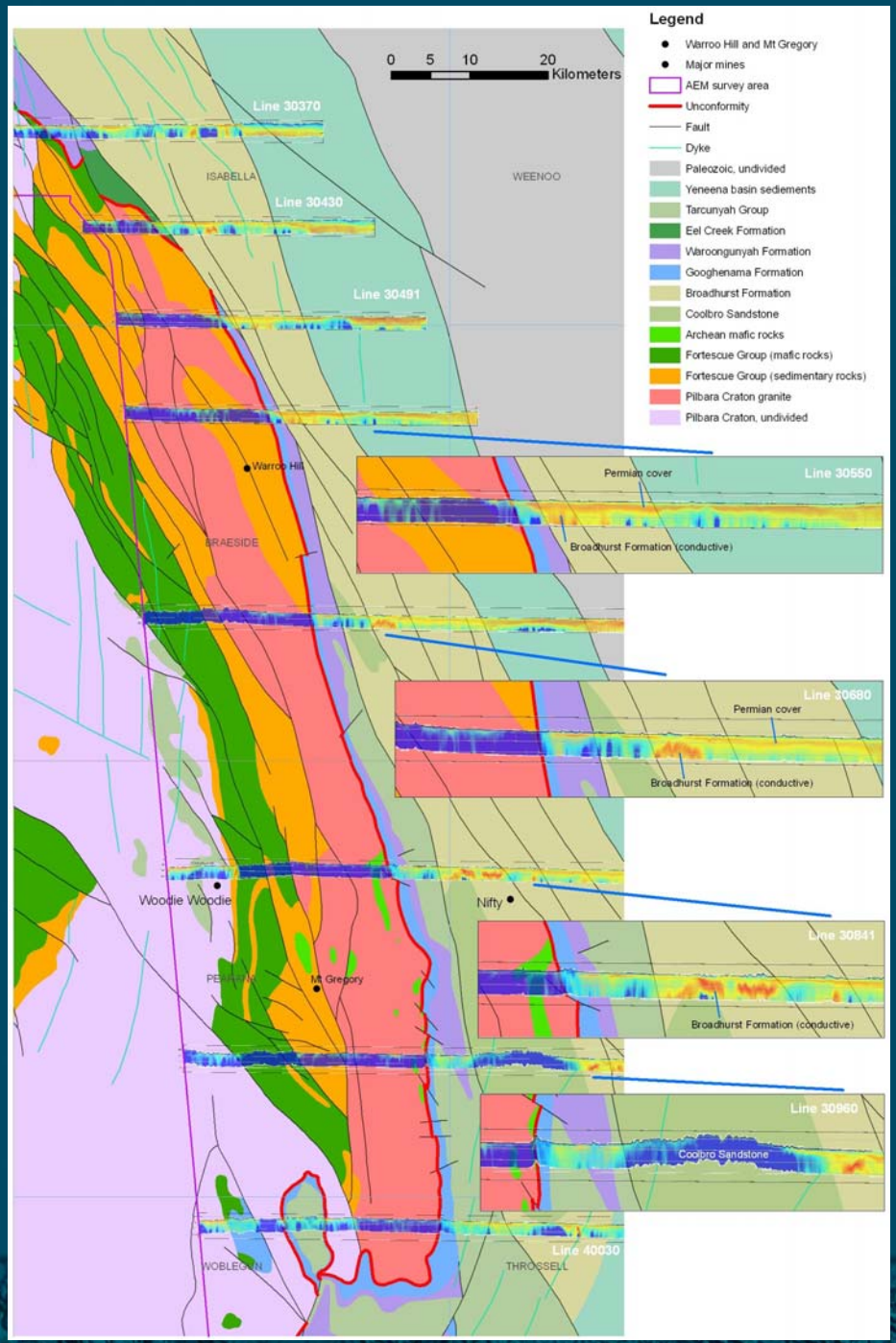
Yeneena-Rudall

- Coolbro Sandstone over Rudall Complex
- Coolbro Sandstone-Taliwanya Formation over Rudall Complex

Karara-Rudall

- Karara Formation over Rudall Complex

NEXT: Tarcunyah-Archean unconformity



Tarcunyah-Archean unconformity:

- Cover: Eel Creek, Waroongunyah & Googhenama Formations
- Basement: Fortescue Basin & Pilbara Craton

Googhenama-Archean unconformity:

- Mapped in surface & solid geology
- Depicted in AEM data

Googhenama Formation:

- Sandstone & conglomerate (contains locally derived granitic and gneissic clasts)

Uranium sources:

- Felsic igneous rocks in Pilbara Craton & Fortescue Basin

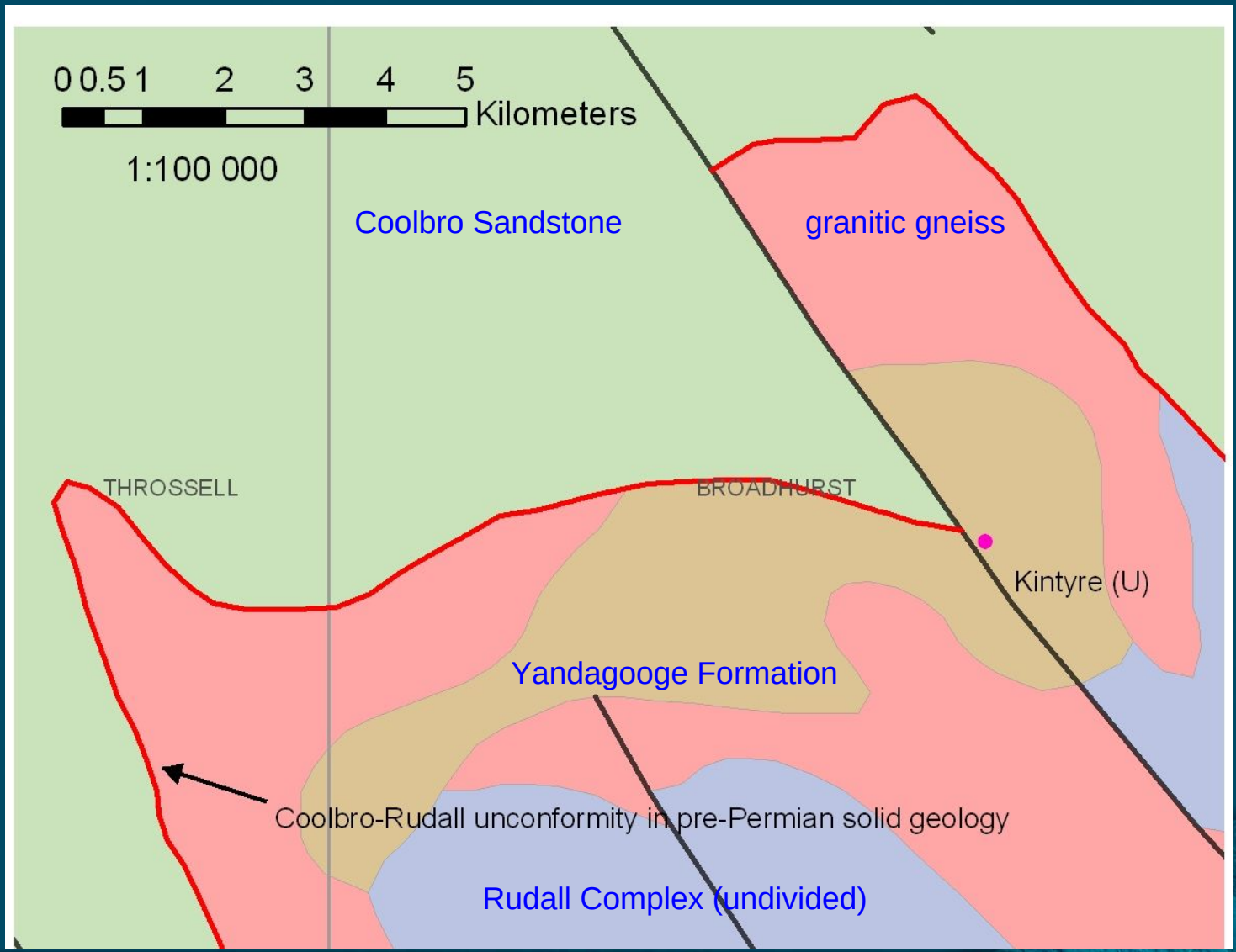
Trap rocks:

- Pelitic sediments & mafic rocks in Fortescue Group
- Mafic igneous rocks in Pilbara Craton

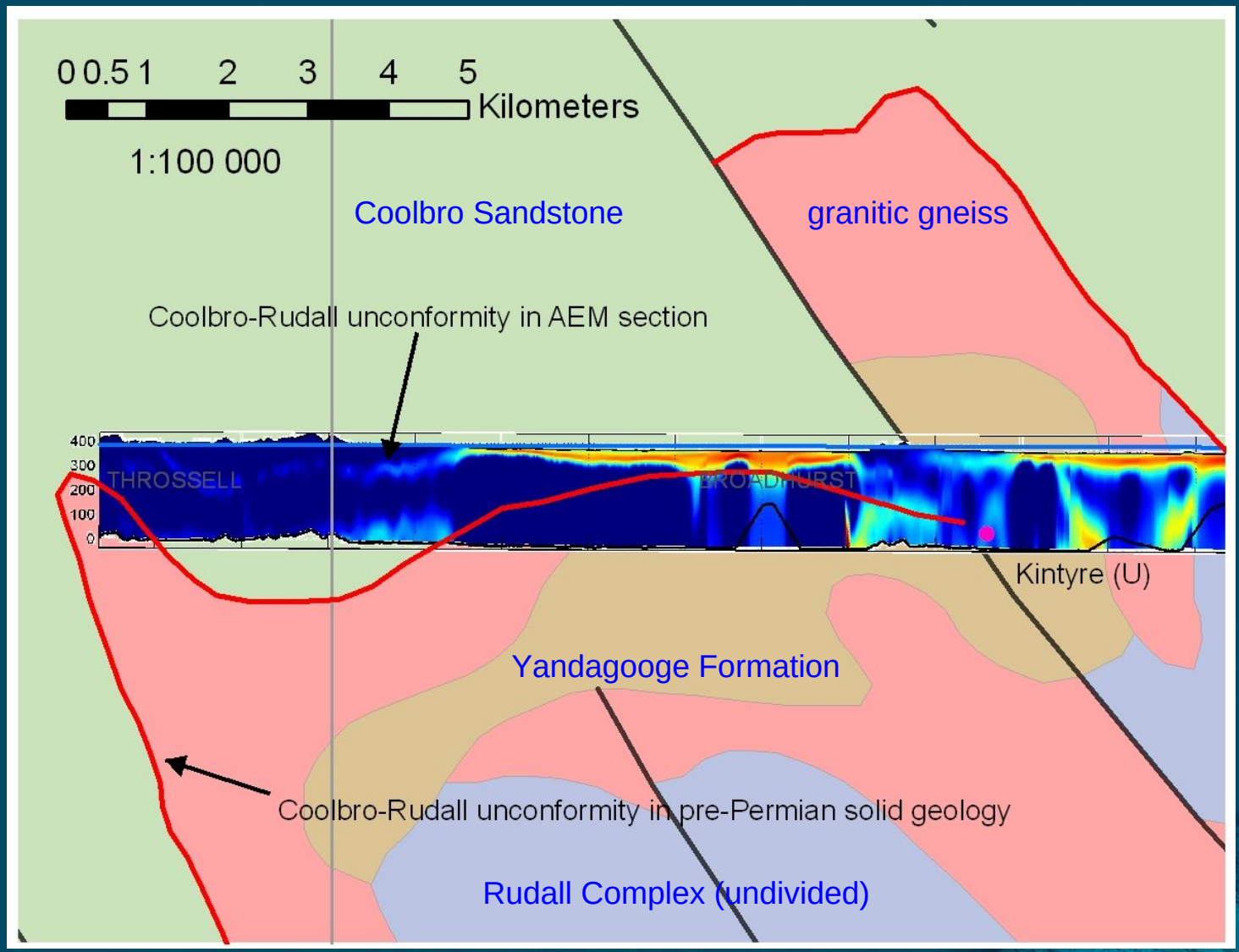
Moderate to high potential, moderate certainty

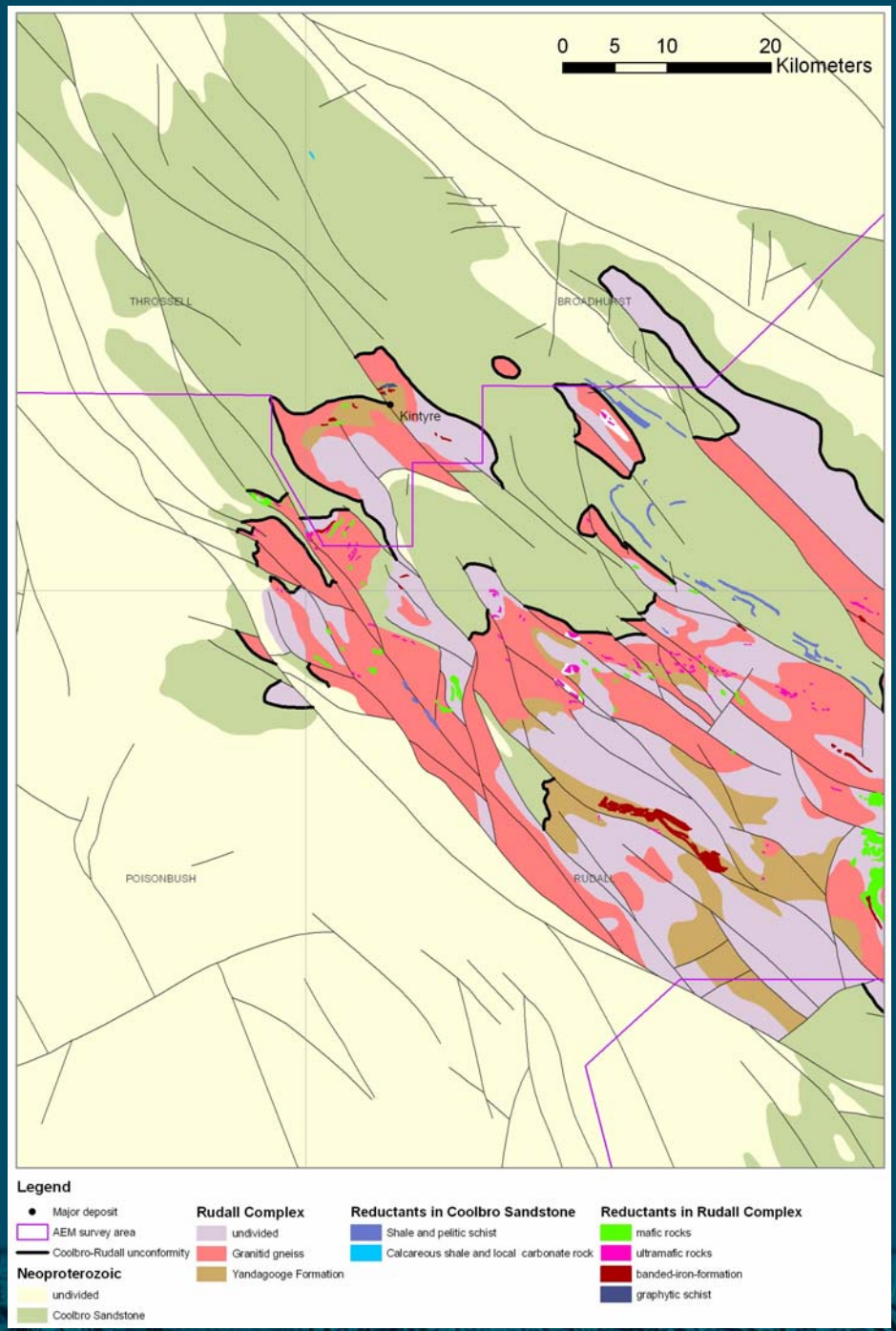
NEXT: Coolbro-Rudall unconformity

Coolbro / Rudall unconformity



Coolbro / Rudall unconformity

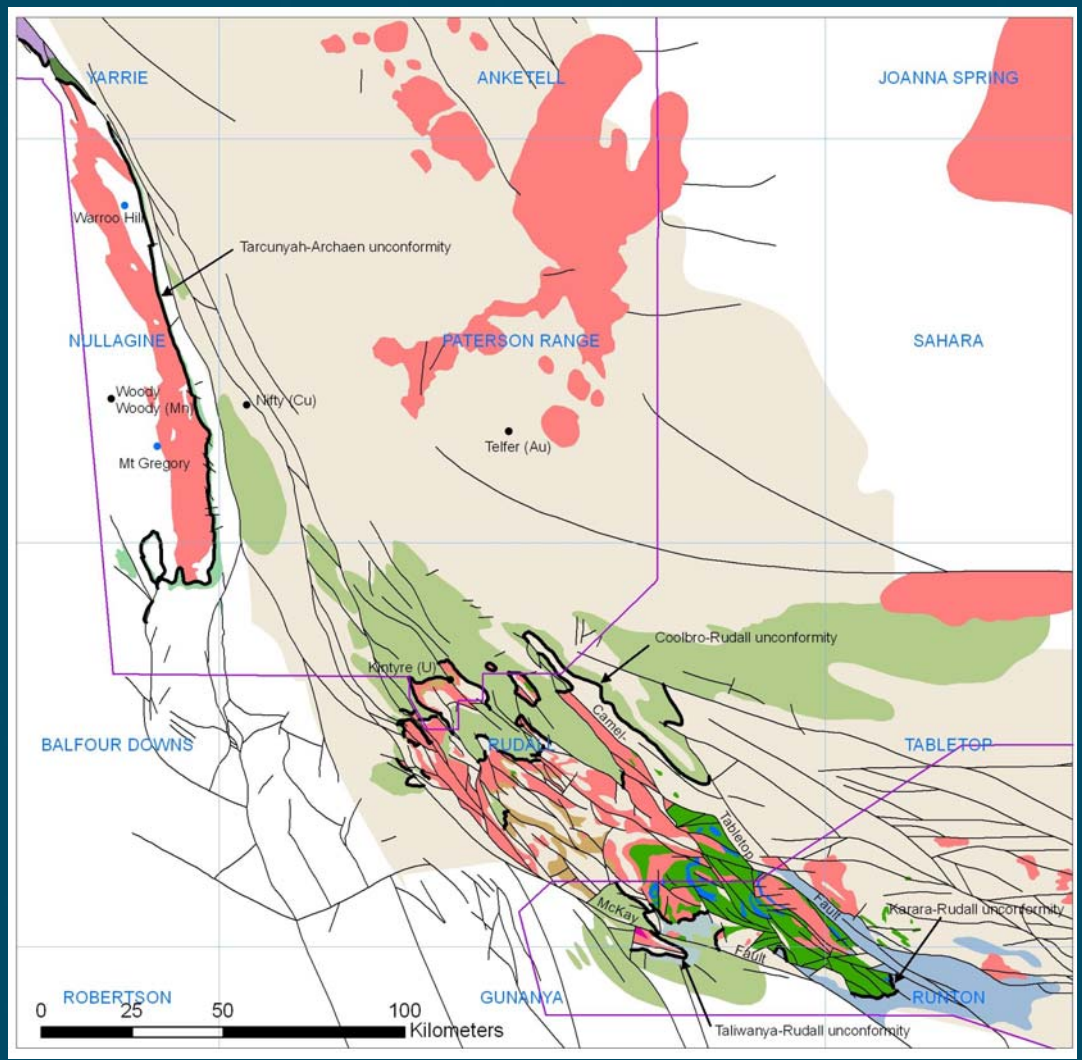




Trap rocks in Rudall Complex & Coolbro Sst

- In Rudall Complex
  - graphitic schist (Yandagooge Fm)
  - mafic & ultramafic rocks
  - BIFs
- In Coolbro Sandstone
  - shale and pelitic schist
  - calcareous shale

Coolbro / Rudall unconformity



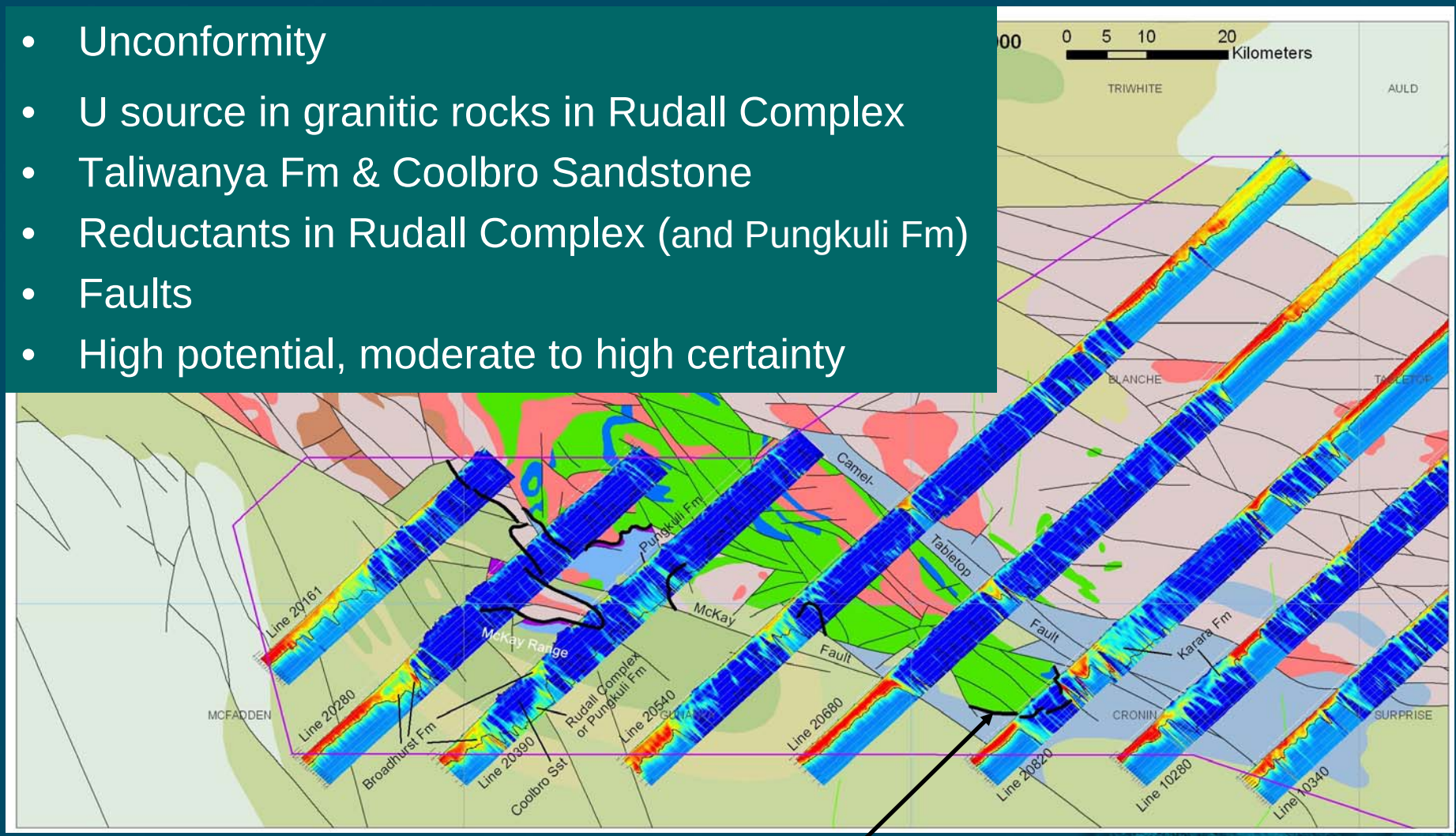
Coolbro / Rudall unconformity

- Unconformity
- U source in granitic rocks in Rudall Complex
- Coolbro Sandstone: fluviatile
- Reductants in Rudall Complex (and Coolbro Sandstone)
- Faults, particularly NNW thrusts
- High potential, high certainty

NEXT: Taliwanya-Coolbro / Rudall unconformity

Taliwanya-Coolbro / Rudall unconformity

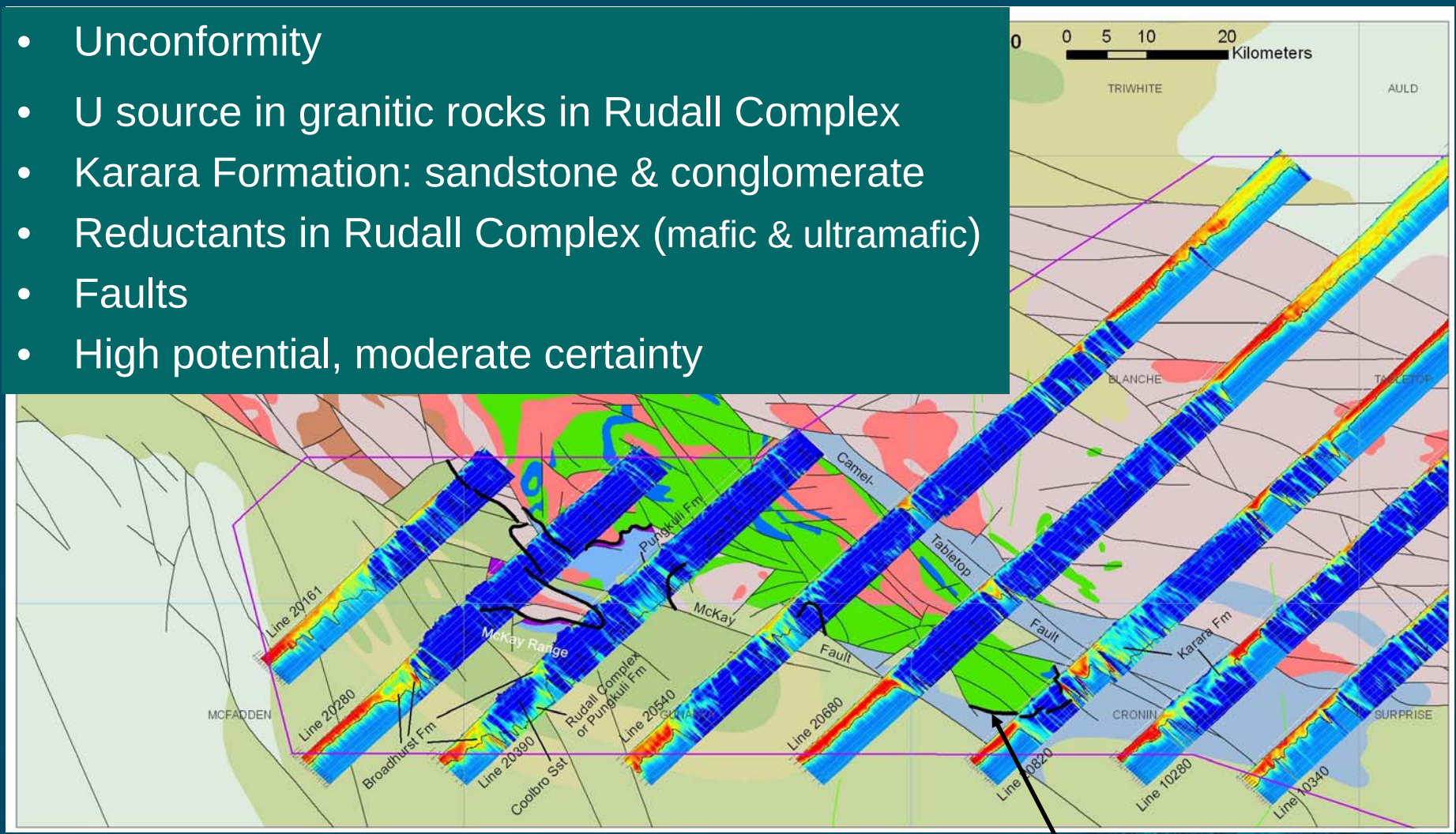
- Unconformity
- U source in granitic rocks in Rudall Complex
- Taliwanya Fm & Coolbro Sandstone
- Reductants in Rudall Complex (and Pungkuli Fm)
- Faults
- High potential, moderate to high certainty



NEXT: Karara / Rudall unconformity

Karara / Rudall unconformity

- Unconformity
- U source in granitic rocks in Rudall Complex
- Karara Formation: sandstone & conglomerate
- Reductants in Rudall Complex (mafic & ultramafic)
- Faults
- High potential, moderate certainty

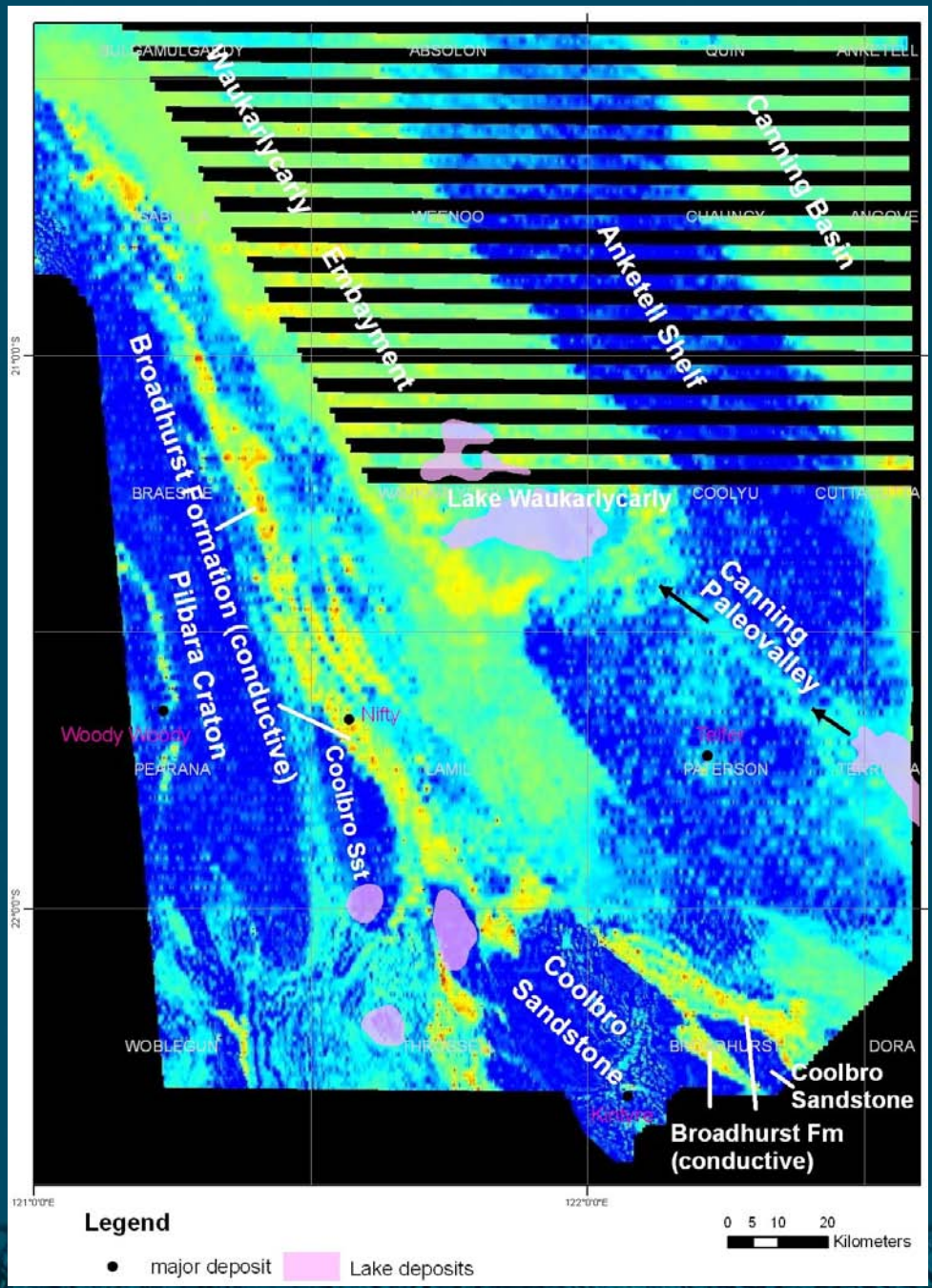


NEXT: U-Cu with Broadhurst - Coolbro contact

U-Cu mineral system associated with the Broadhurst-Coolbro contact

- Assessment of potential :
  - Broadhurst-Coolbro contact (solid geology)
  - Reduced parts of Broadhurst Formation
    - conductive zone (AEM data)
  - Fluid pathways (surface and solid geology)
  - Indications of alteration and deposition of uranium (surface geology mapping & remotely sensed data)
    - iron-oxide alteration zone
    - sericite composition from ASTER data

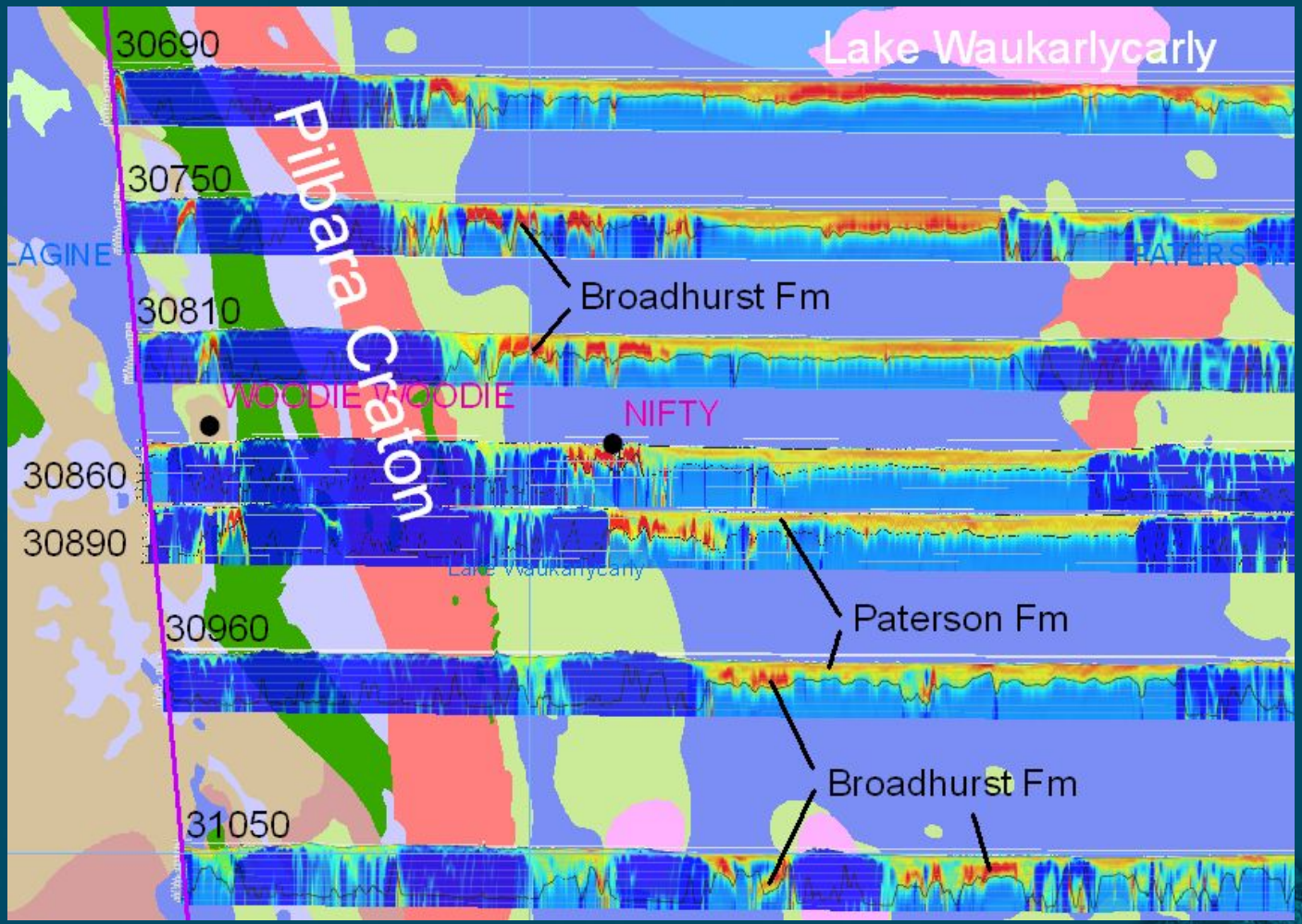
→ Much work to be done



Broadhurst Formation

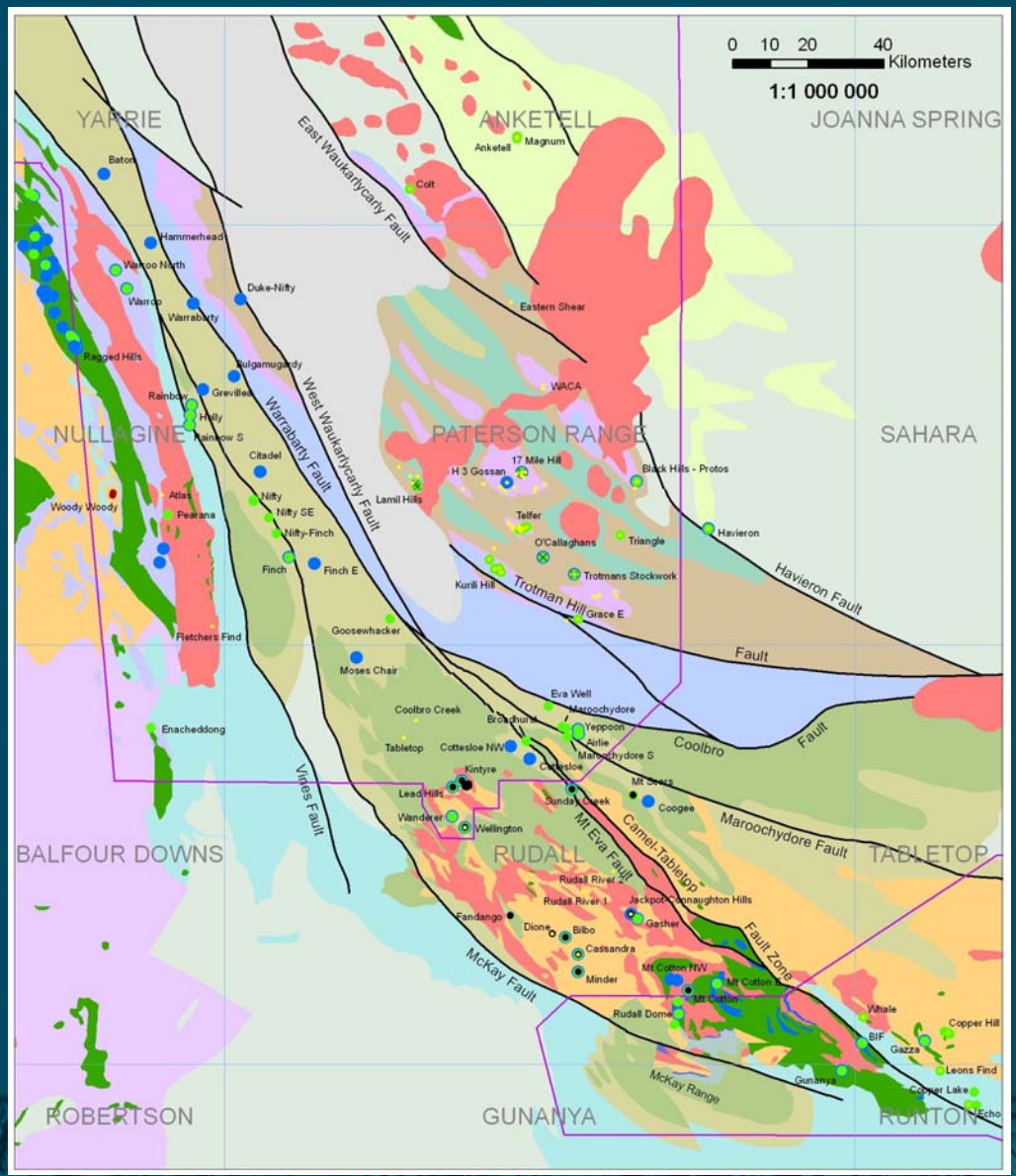
- Parts very conductive
  - carbonaceous & sulfidic shale
  - up to 10% pyrite & pyrrhotite near base of unit, distinctive magnetic signature (Hickman & Clarke 1993)
- At Maroochydore
  - 70 Siemens/m in mineralised horizon & footwall carbonaceous shale (Reed 1996)
  - Map subsurface host sequence & structure
- Map regionally

Conductive Broadhurst Formation



Lakes and selected AEM sections over pre-Mesozoic solid geology

U-Cu mineral system associated with the Broadhurst-Coolbro contact

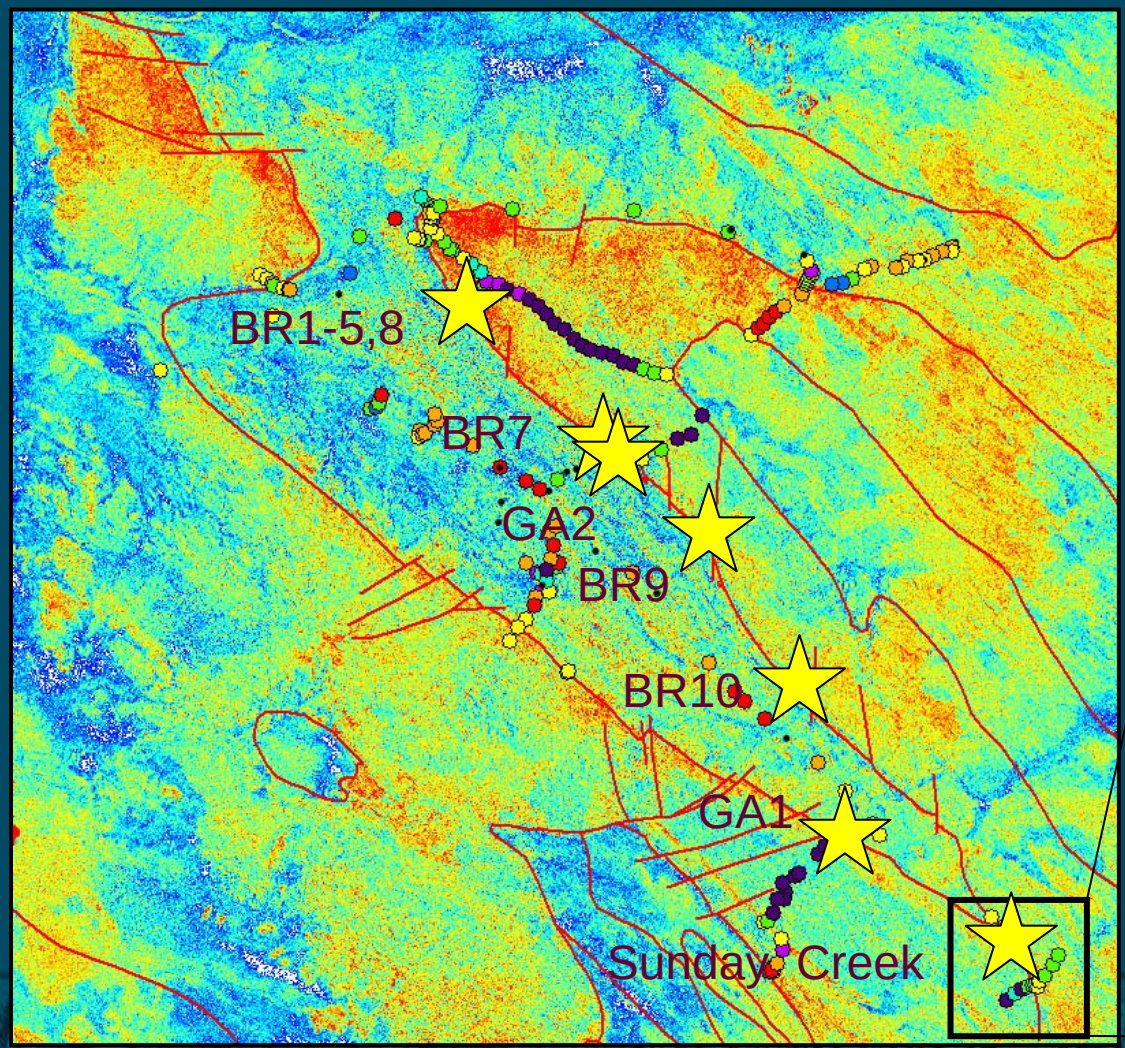


- Known mostly in two areas
  - Maroochydore and Broadhurst-Sunday Creek
  - Rainbow-Nifty-Finch
- Near major crustal scale faults
  - Coolbro Fault
  - Maroochydore Fault
  - Mt Eva and Camel-Tabletop Fault Zone
  - McKay Fault
  - Vine Fault
- Potential in other areas?

Muscovite ASTER minerals index map with Pima samples overlay

unpublished results from Czarnota et al.

★ uranium prospect

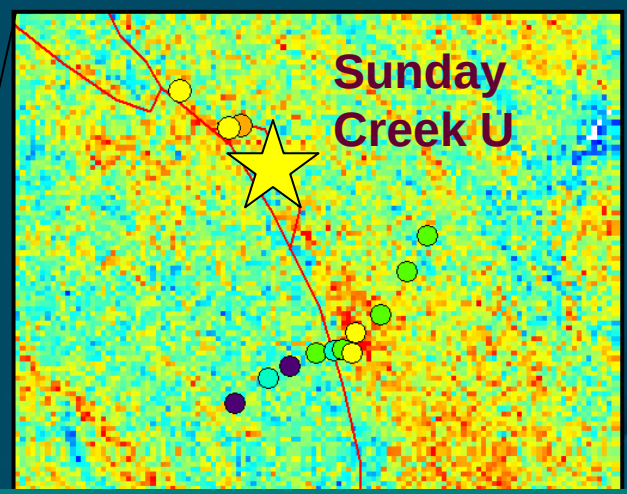


AlOH absorption feature wavelength (nm)

Muscovite

- 2201 - 2206
- 2206 - 2208
- 2208 - 2210
- 2210 - 2212
- 2212 - 2214
- 2214 - 2216
- 2216 - 2218
- 2218 - 2221

Phengite



Alteration mapping from ASTER data

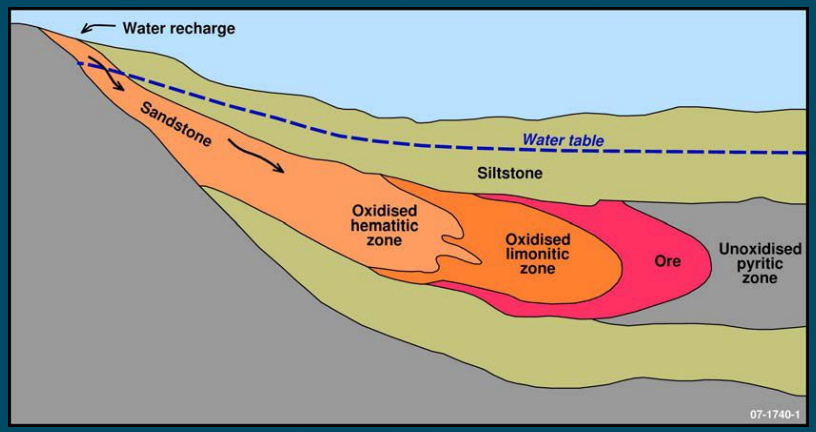
- Muscovite alteration at Broadhurst-Coolbro contact
- Fluid pathway in up part of Coolbro Sst
- Evidence for Miles mineral system

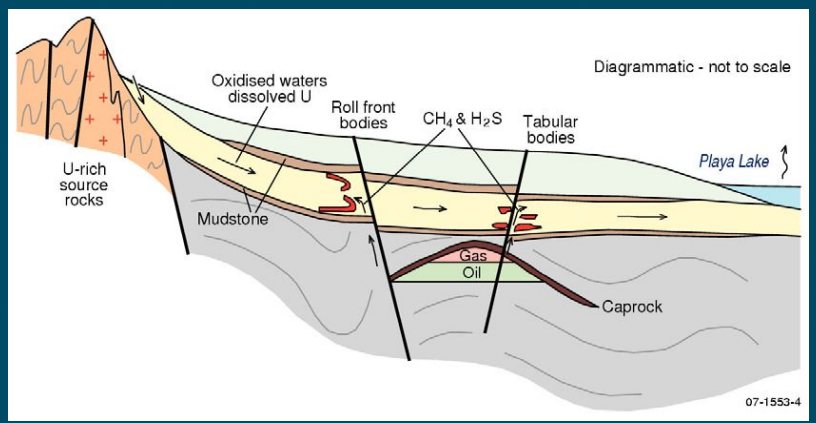
NEXT: sandstone-hosted U

Sandstone-hosted U mineral system

- Two types:
  - Confined aquifers: roll-front & tabular types
  - Paleochannels: basal channel type
- Continental fluvial or marginal marine (mixed fluvial-marine) sediments

Sandstone-hosted U mineral system

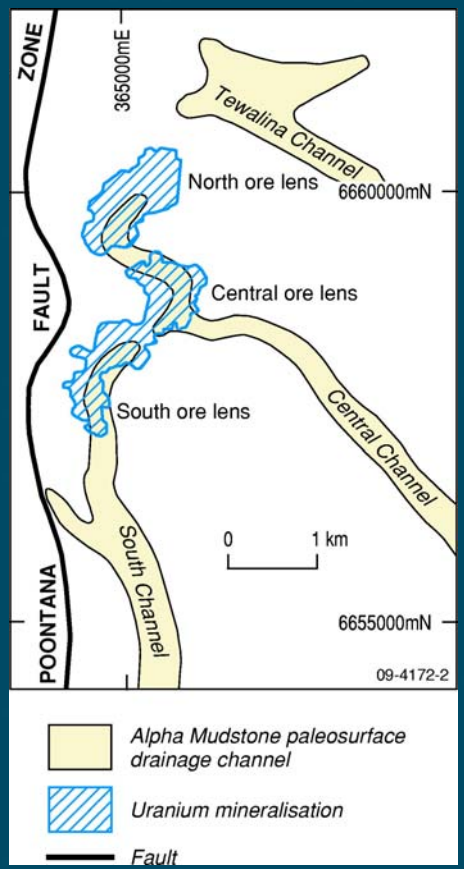




after Jaireth et al. (2008)

- Confined aquifers :
  - roll-front & tabular types
    - roll front deposit: e.g., new discovery by Heathgate Resources, west of Beverley, SA
  - Single fluid or two fluids
- Uranium transported in oxidised shallow-level ground water → deposited due to reduction by *in situ* organic materials (plant debris, amorphous humate, marine algae) or other reductants (sulfides, Fe^{+2}-bearing silicates and oxides) or mobile reductants (hydrocarbons and/or H_2S) reductants
- Similar chemistry for paleochannel type but U transported in surface water

Sandstone-hosted U mineral system



Paleochannels: basal channel type

- meandering bends of main channel
- confluence of main channel with tributary channels

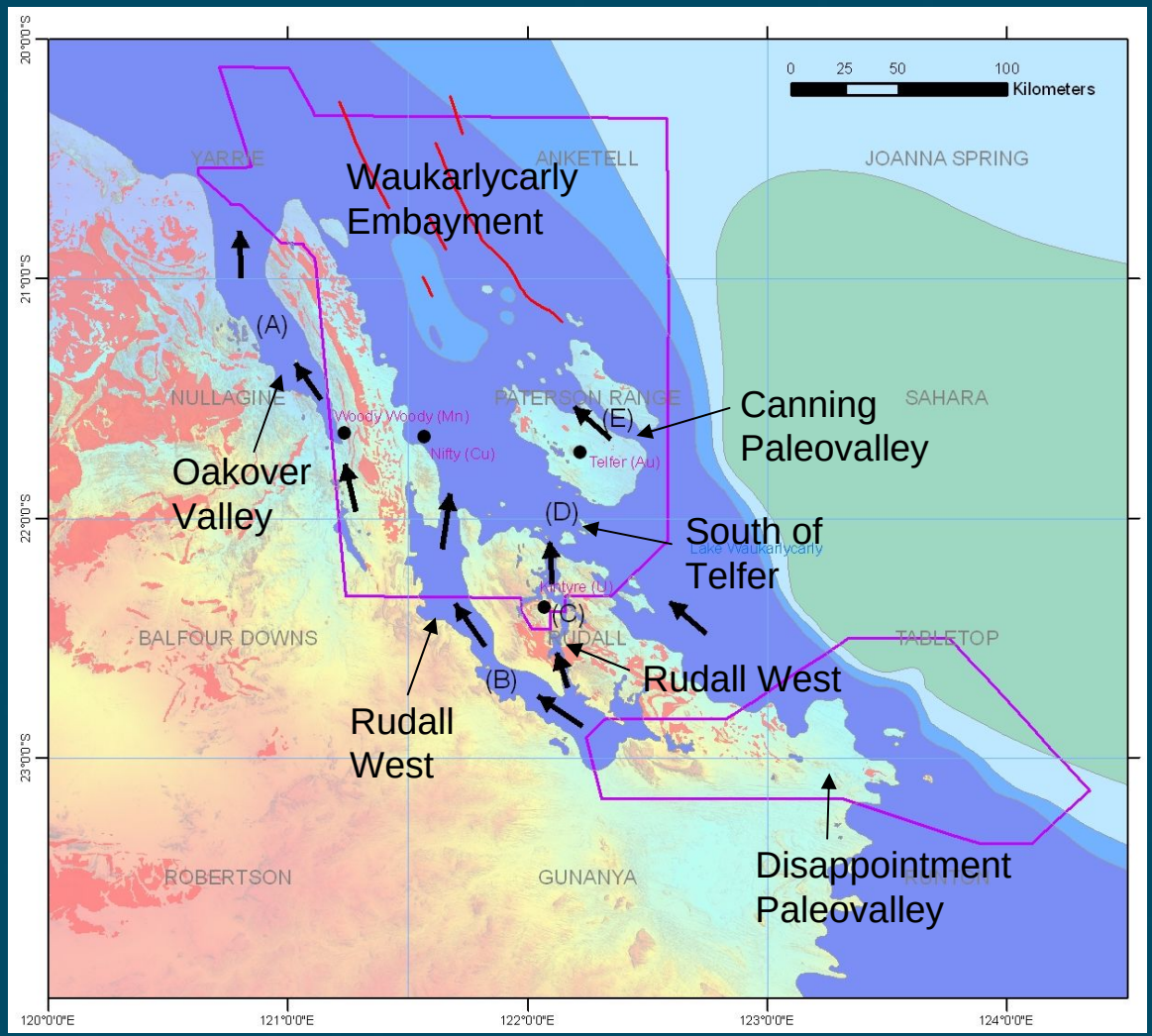
Beverley Hill (after Jaireth et al. 2010)

Sandstone-hosted U mineral system

Possibilities in Paterson:

- Permian-recent paleovalleys / paleochannels: moderate to high potential
- Mesozoic: low potential – lack of uranium rich source rocks
- Permian: moderate potential
- Neoproterozoic: low potential – lack of plant derived organic materials

Permian solid geology with glacial flow directions



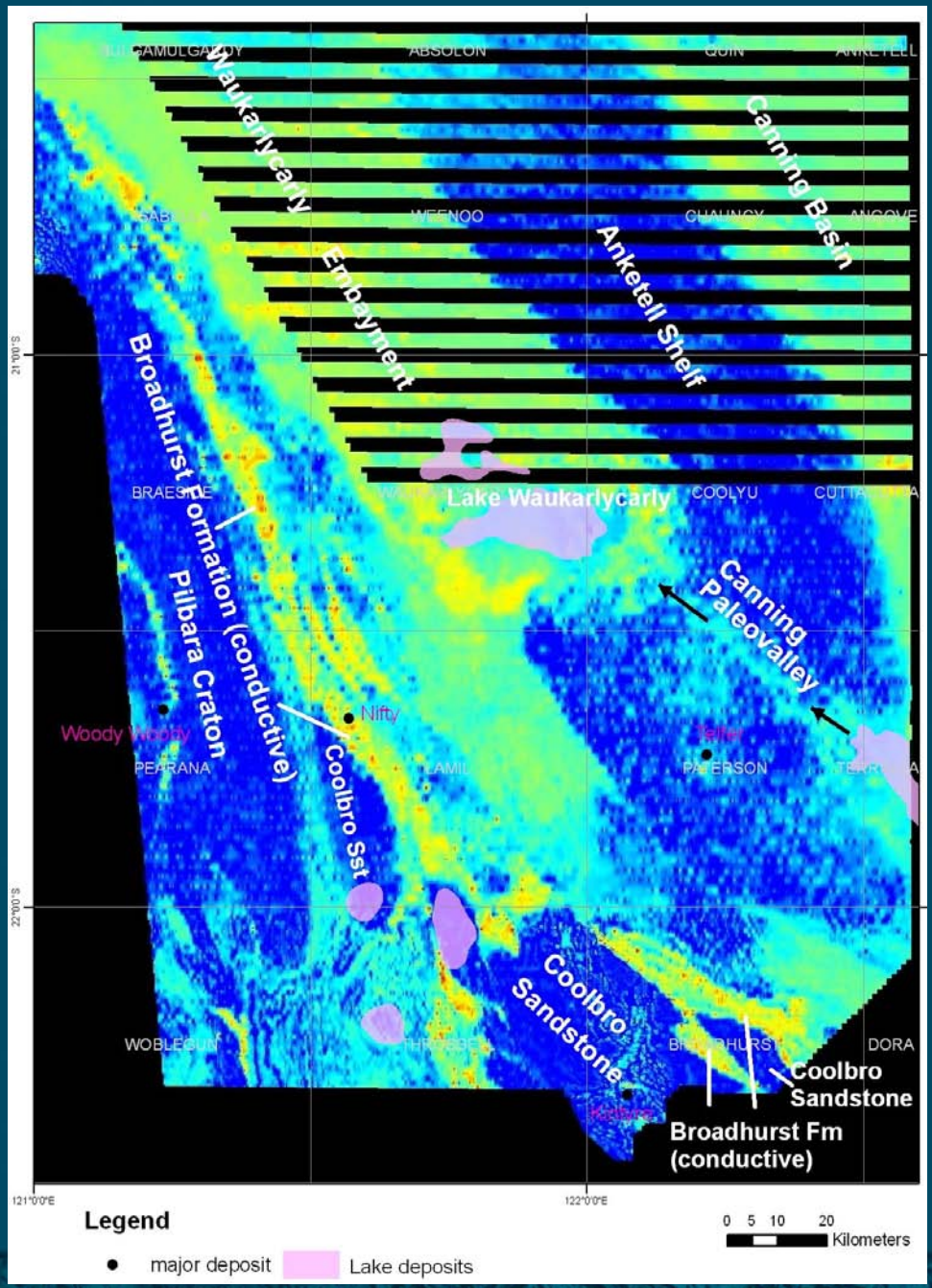
labelled: Permian paleovalleys

Paterson Formation:

- fluvioglacial sequence
- lack of info on reductants: *in situ* organic materials or other reductants
- potential of mobile reductants: e.g., hydrocarbons

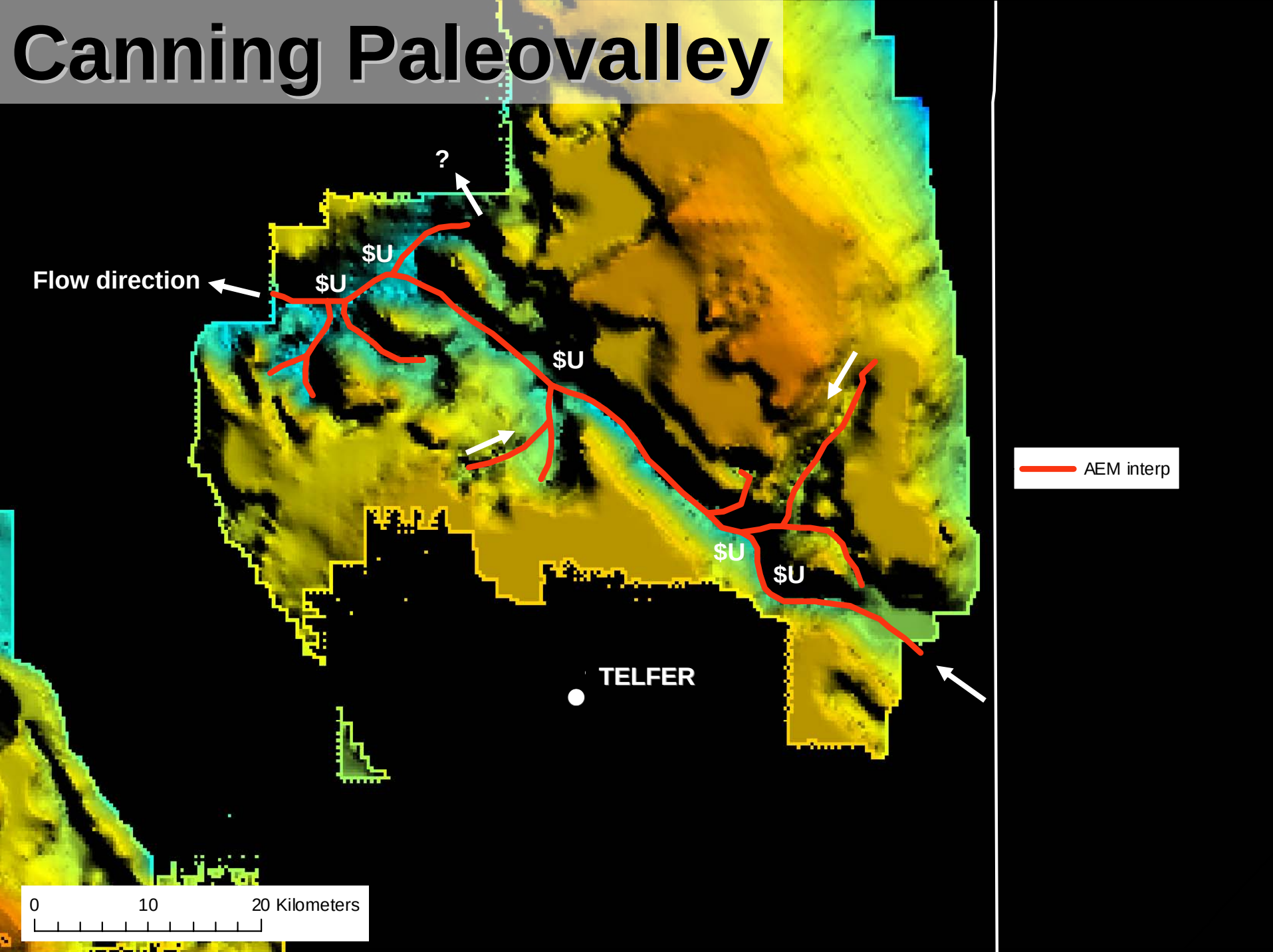
Paleovalleys :

- Oakover Valley (A)
- Rudall West (B)
- Rudall Central (C)
- South of Telfer (D)
- Canning Paleovalley (E)
- Disappointment Paleovalley
- Waukarlycarly Embayment

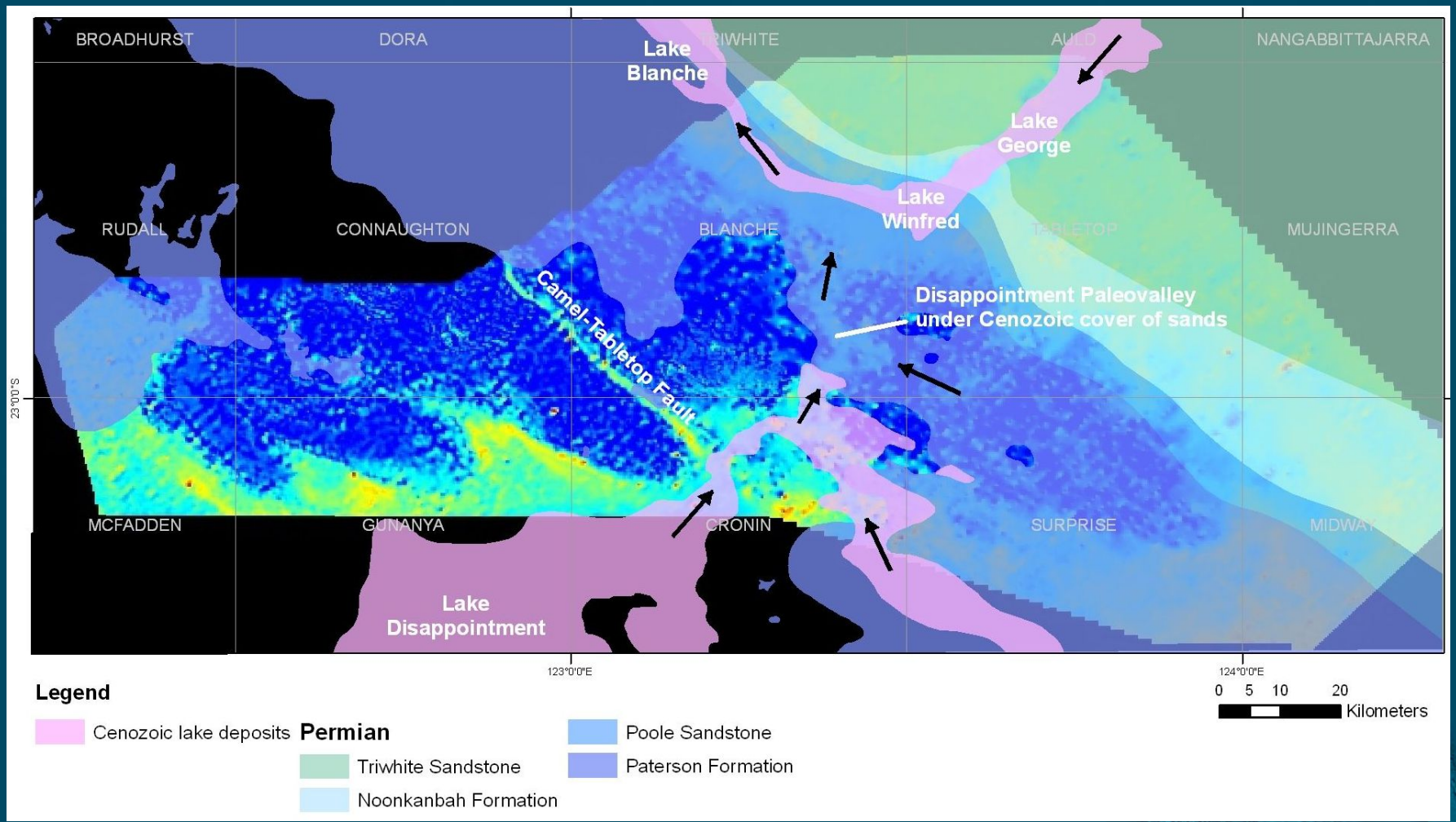


AEM depth slice image at 200m in Paterson North

- Waukarlycarly Embayment
- Canning Paleovalley

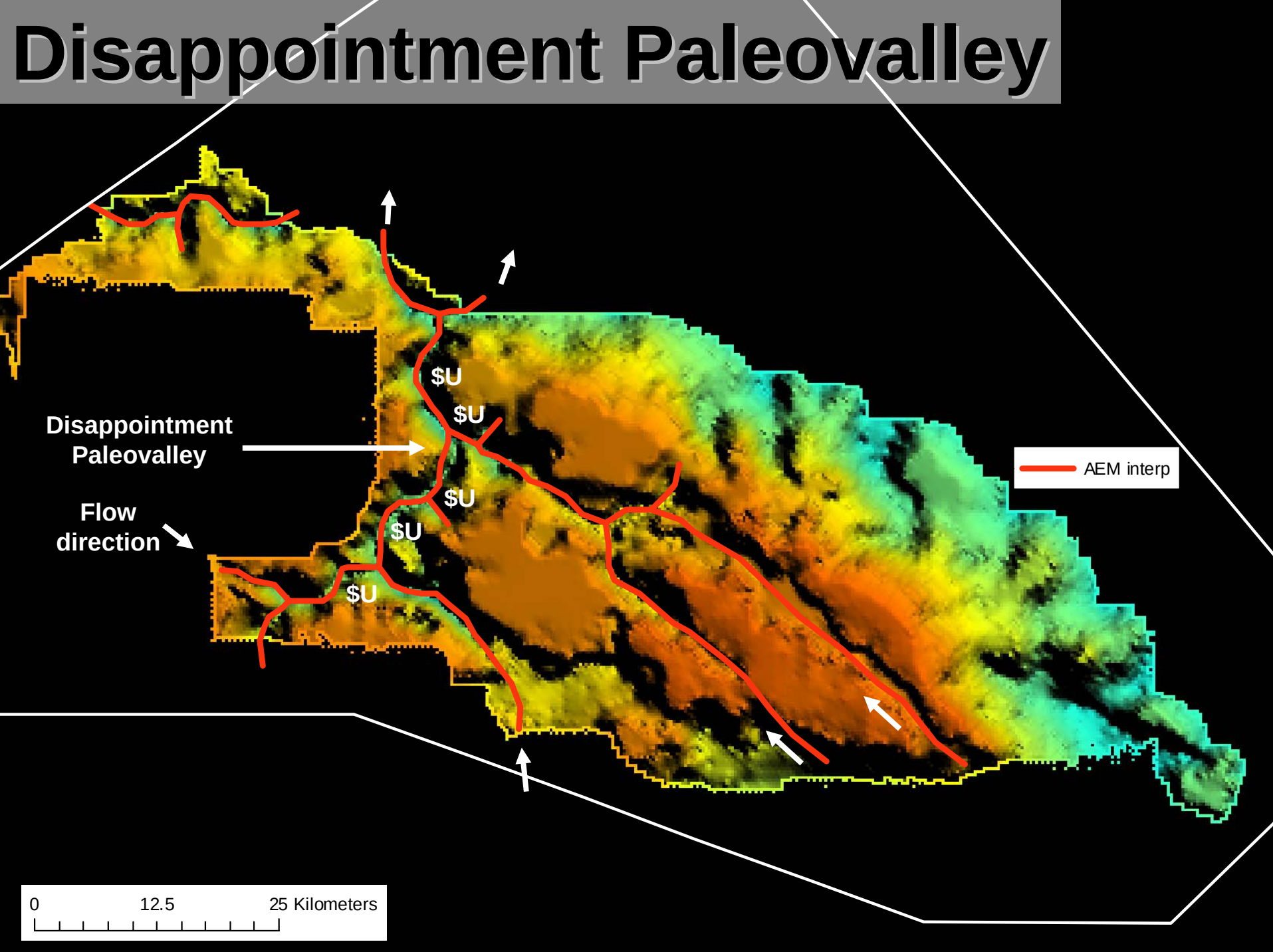

Canning Paleovalley
?
Flow direction
$U
$U
$U
$U
$U
TELFER
AEM interp
0
10
20 Kilometers

Paleovalley-type sandstone-hosted uranium mineral system --- Disappointment Paleovalley

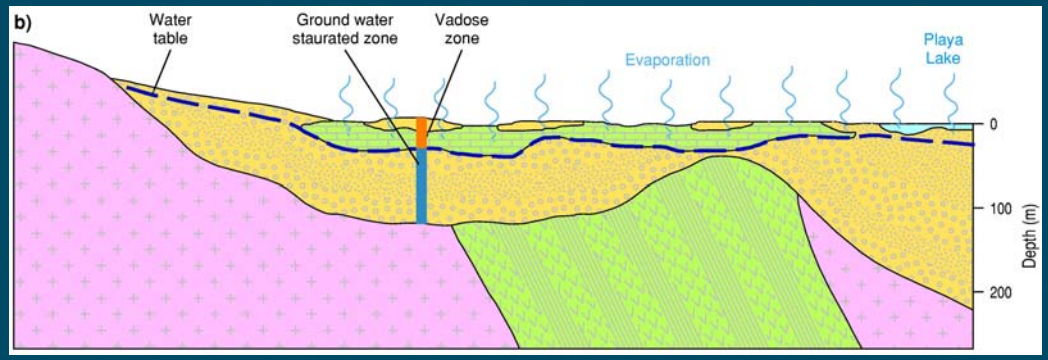


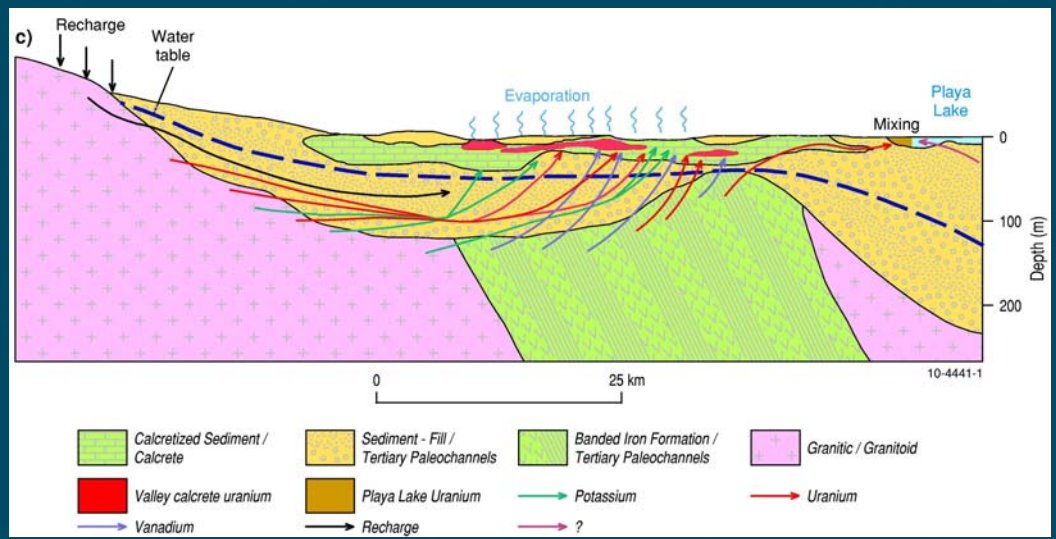
AEM depth slice image at 200m of Paterson South survey area

Disappointment Paleovalley



Calcrete-hosted U mineral system





Schematic diagrams showing stages in the formation of calcrete-hosted uranium deposits (modified after Thomas 2007)

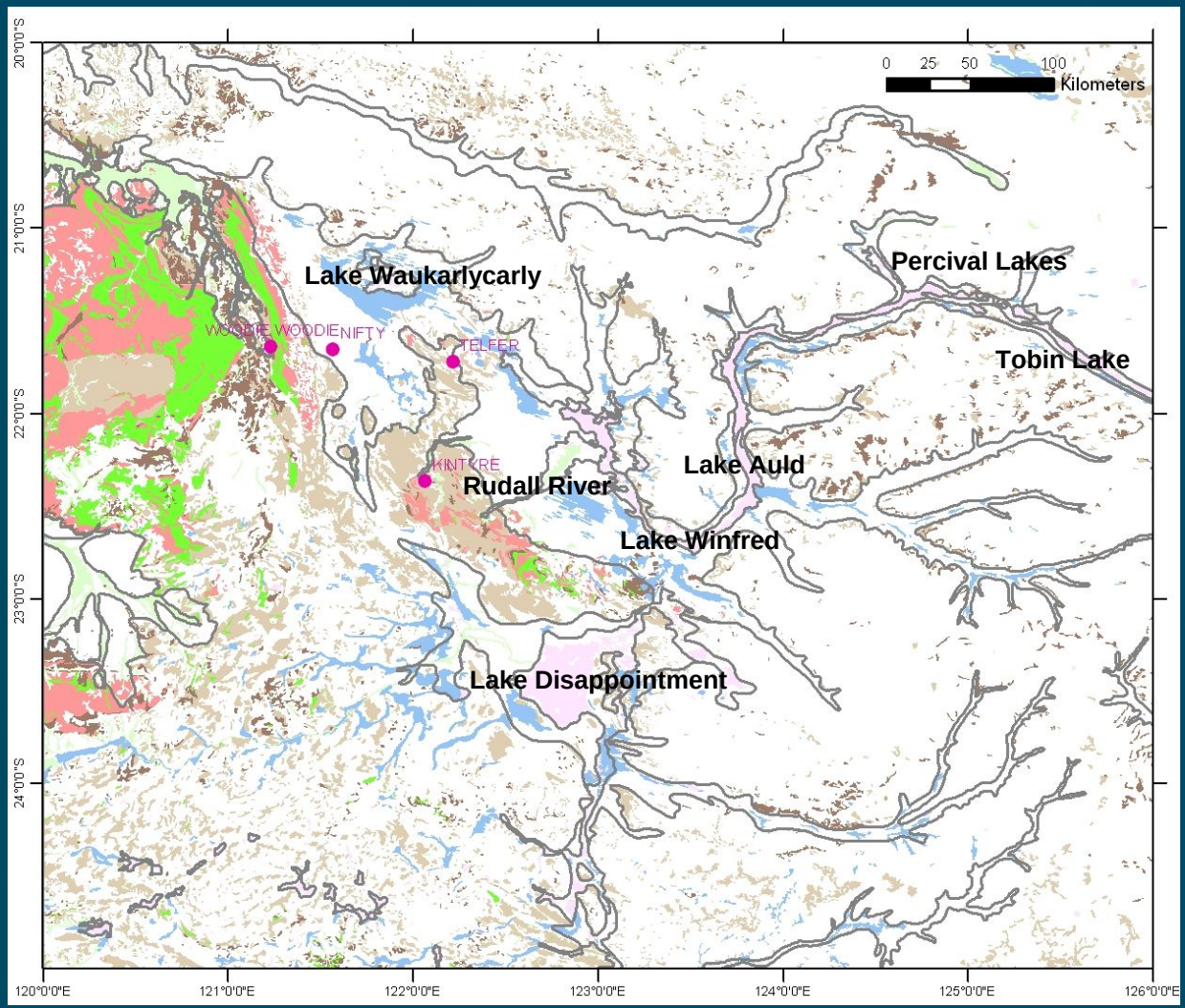
- Carnotite: $K(U^{+6}O_2)(V^{+5}O_4).xH_2O$
- K & U leached from felsic rocks and V from mafic and Fe-rich sediments
- Calcrete-hosted U in 3 stages:
  - fill of coarse sediments
  - evaporation → calcrete, which acts as aquifer
  - seasonal fluctuation of water table a/with evaporation → increase concentration of K, V & U → precipitation of carnotite, or, mixing of valley ground water with more saline lake waters (higher in K & Ca)

Calcrete-hosted U mineral system

Essential components:

- source rocks of uranium
- source rocks of vanadium
- drainage system with recharge and discharge areas (e.g., playa lake)
- paleovalleys / paleochannels with calcrete

Calcrete-hosted U mineral system



U & V sources, calcrete, & drainage systems with flow directions in the Paterson area

Potential areas in Paterson:

- Lake Waukarlycarly
- Lake Disappointment W
- Lake Disappointment SE
- Lake Winfred
- Lake Auld – Percival Lakes – Tobin Lake
- Rudall River

Essential components

- source rocks of uranium
- source rocks of vanadium
- drainage system with recharge and discharge areas (e.g., playa lake)
- paleovalleys / paleochannels with calcrete

Calcrete-hosted U mineral system

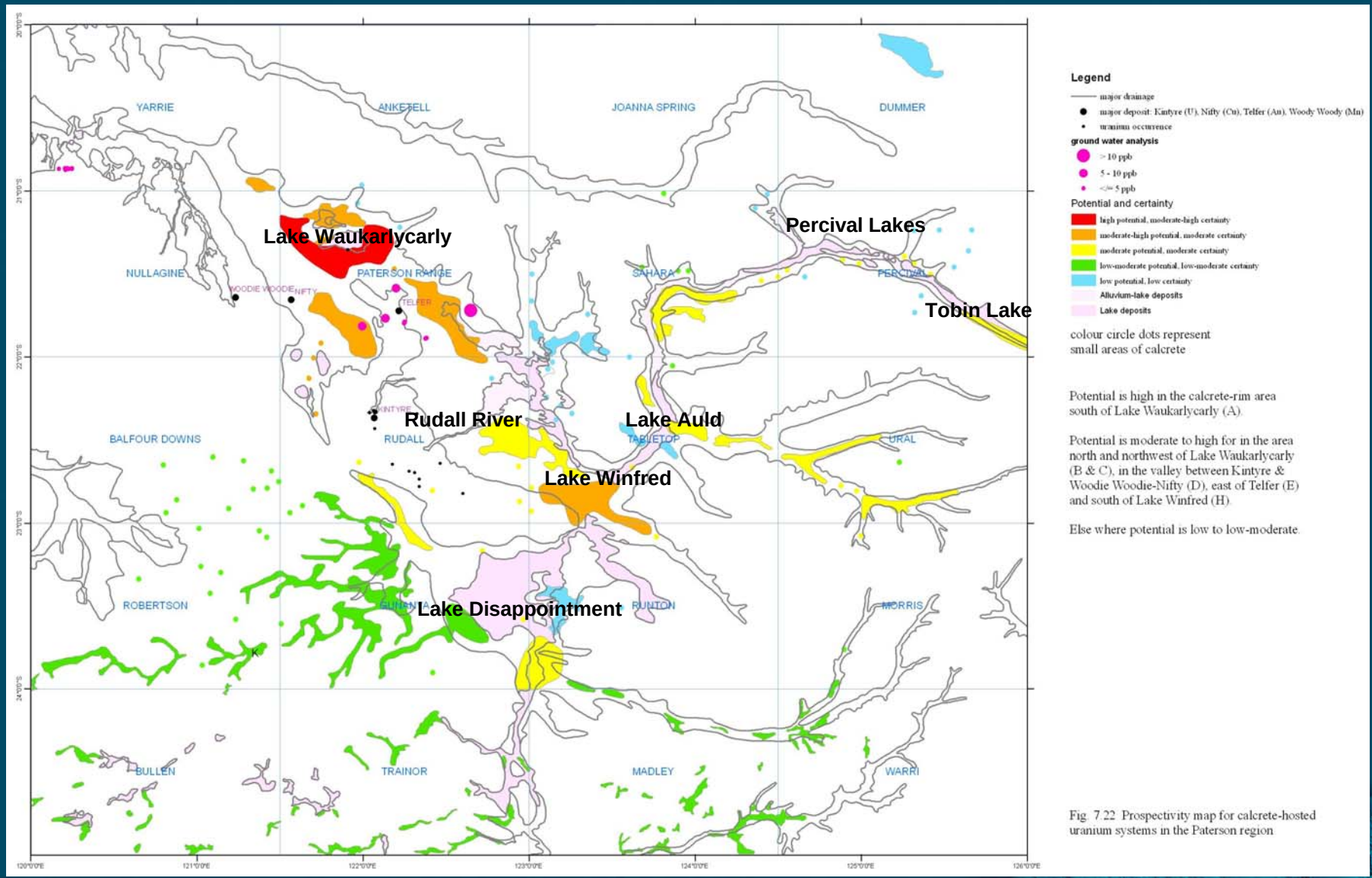
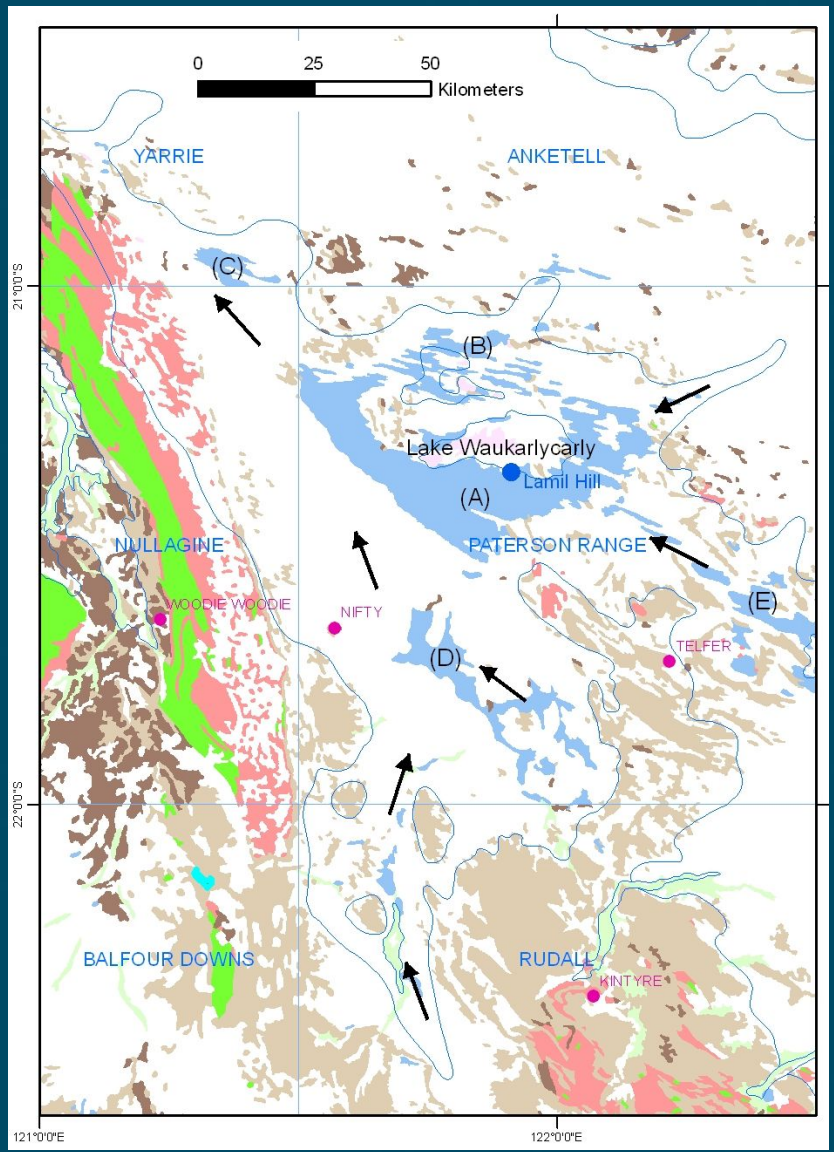


Fig. 7.22 Prospectivity map for calcrete-hosted uranium systems in the Paterson region

Prospectively map (potential and certainty)

Calcrete-U system: Lake Waukarlycarly



- U sources:
  - Pilbara Craton
  - Rudall Complex
  - Mt Crofton granite suite
- V sources:
  - Pilbara Craton
  - Rudall Complex
- Drainage systems:
  - Canning Paleovalley

    (Percival Paleovalley system)
  - Between Nifty, Telfer & Kin tyre
- Calcrete: rim around lake & in paleovalleys
- Moderate to high potential
- Lamil Hill U prospect

Calcrete-hosted U mineral system

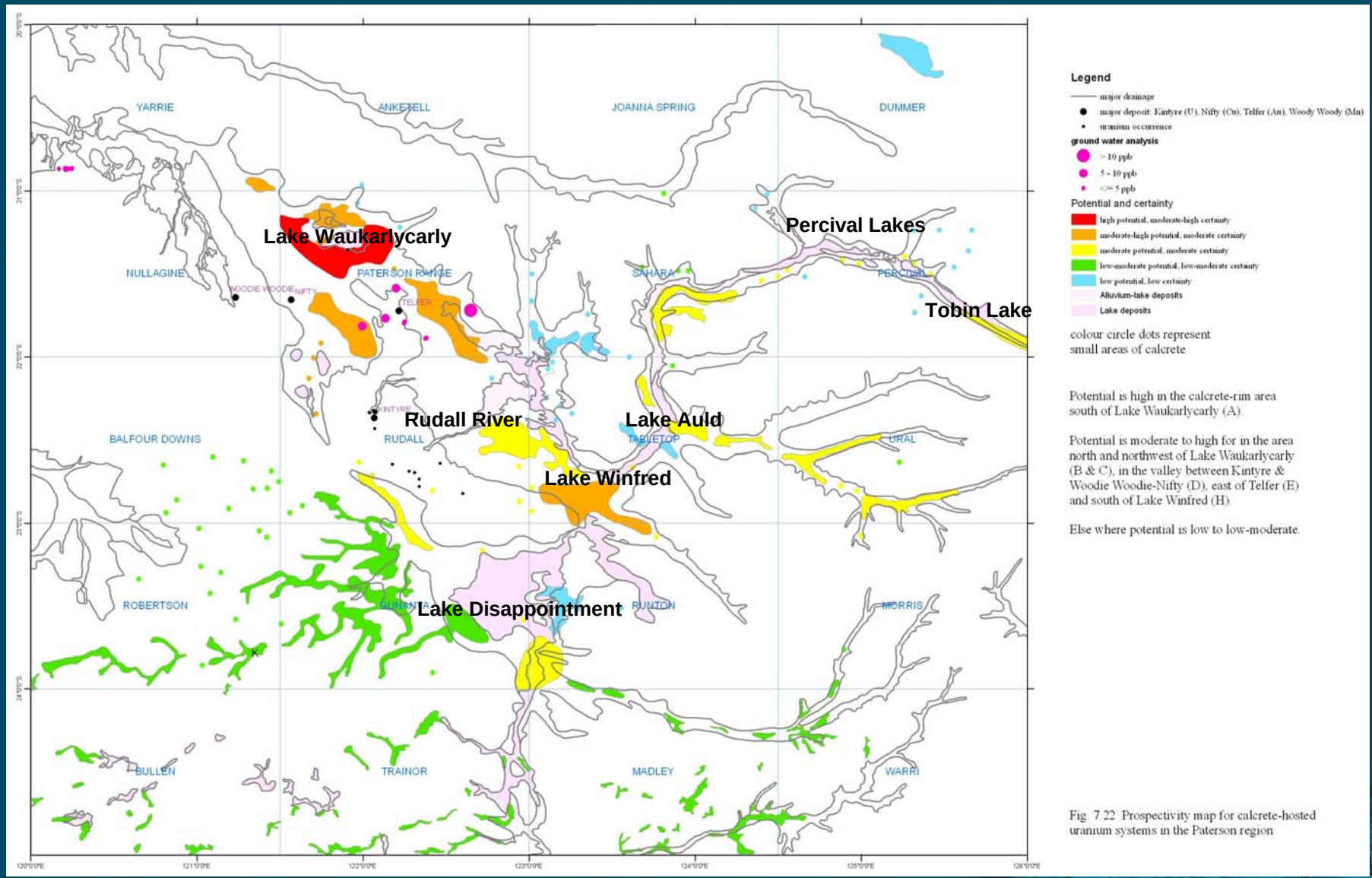


Fig. 7.22 Prospectivity map for calcrete-hosted uranium systems in the Paterson region

Prospectively map (potential and certainty)

Calcrete-hosted uranium mineral system – Disappointment Paleovalley

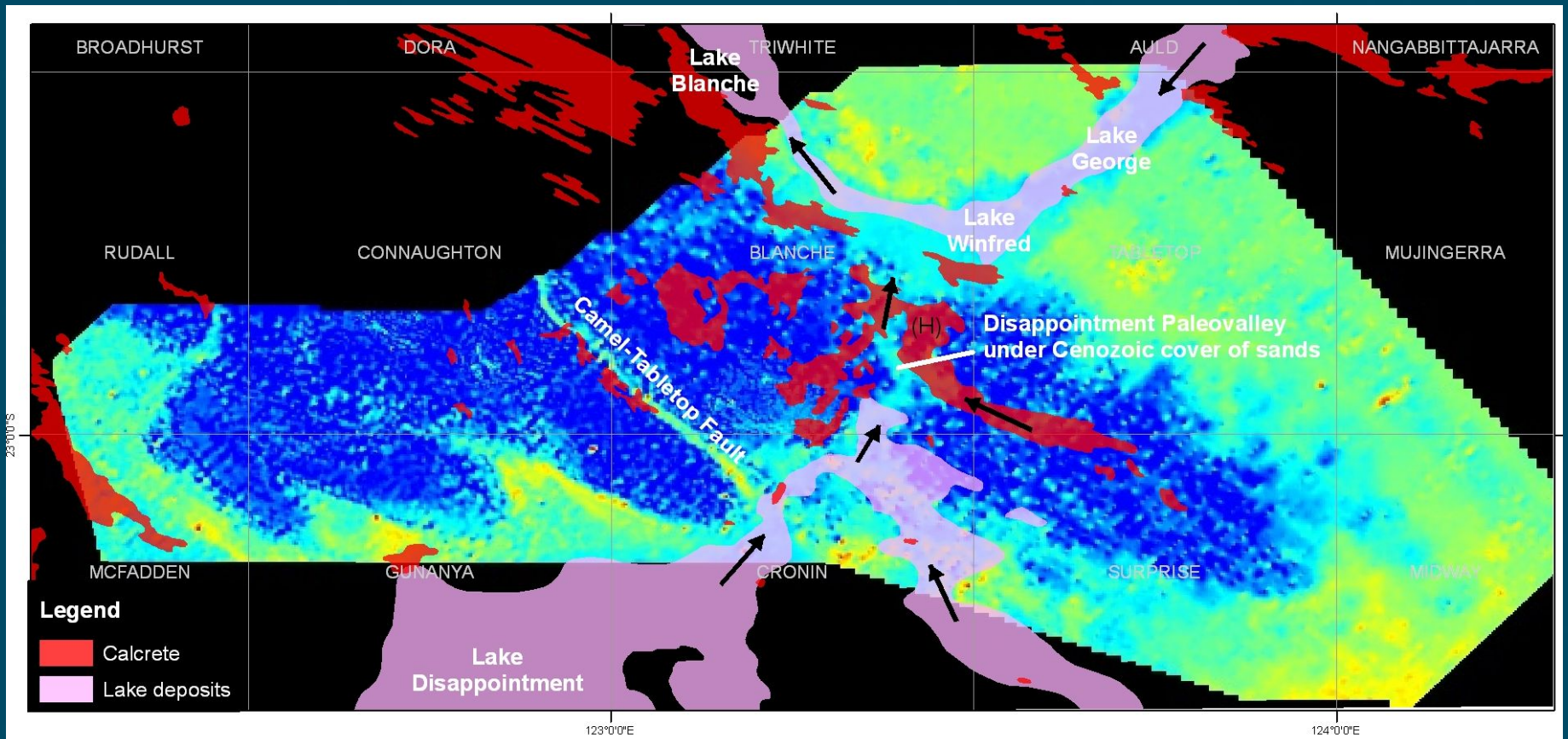


Fig. 7.20 Calcrete and lakes over AEM depth slice image at 200m of the south Paterson survey area
1:100 000 map tiles shown in grey line and text
(calcrete and current lakes' polygons are displayed at 25% transparency. note colour change in overlayed areas)

← Water flow direction (surface and groundwater)

AEM depth slice image at 200m of the South Paterson Survey area

NEXT: Conclusions

Conclusions

- Regional AEM data :
  - assist uranium potential assessment
- Potential for uranium mineral systems
  - unconformity-related
    - Tarcunyah-Archean unconformity
    - Yeneena-Rudall unconformity
    - Karara-Rudall unconformity
  - stratiform U-Cu with the Broadhurst-Coolbro contact
  - sandstone-hosted U
    - Paterson Formation
    - Permian and younger paleovalleys/paleochannels
  - calcrete-hosted U
    - Lake Waukarlycarly, east & west of Telfer, Lake Winfred