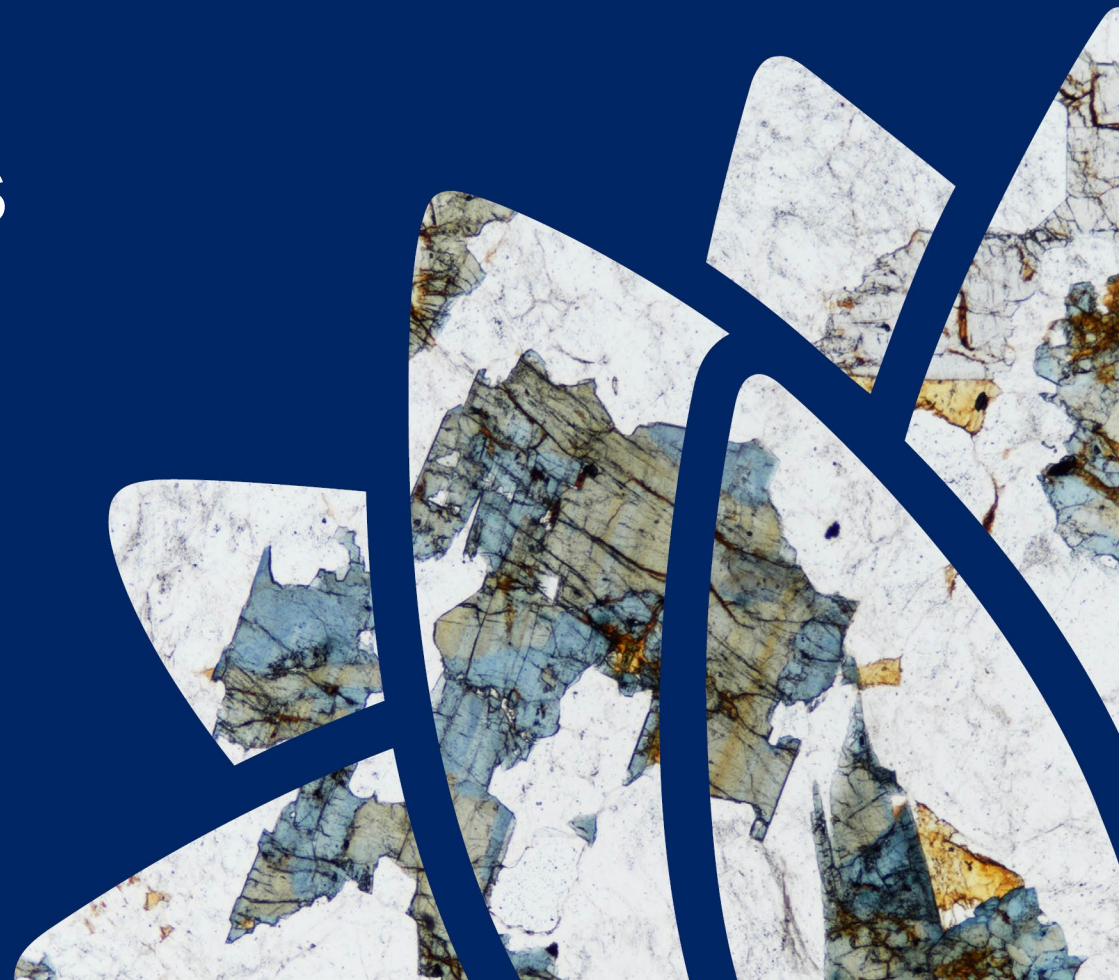
Mining, Exploration & Geoscience

NSW GOVERNMENT

New England Magmatic-Related Mineral Systems

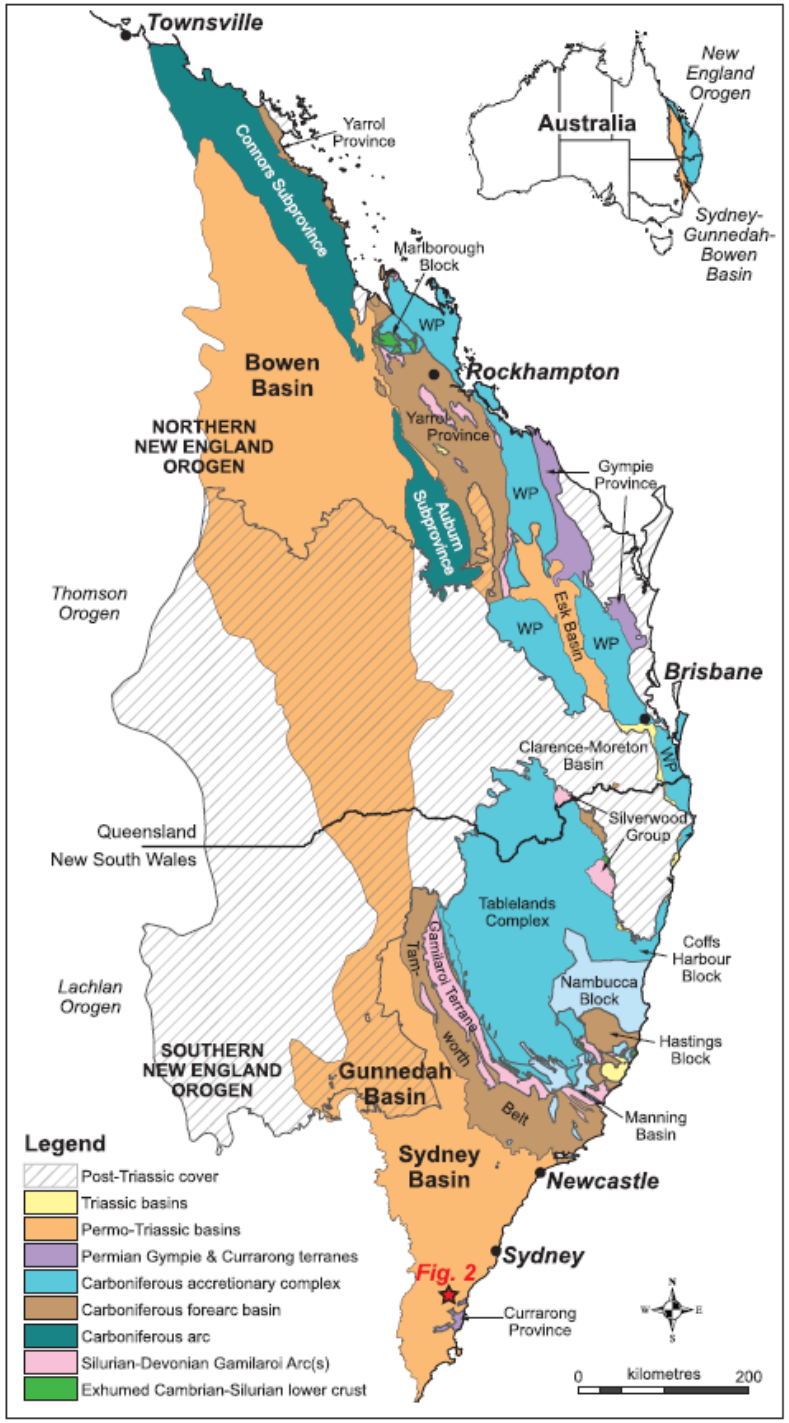
Phillip Blevin

13 May 2022



New England Orogen

- The New England Orogen (NEO) is the eastern-most (extant) orogen of the Tasmanides system, representing the culmination of a series of repeated extensional and compressional events commencing in the Cambrian.
- The NEO extends from Newcastle in New South Wales (NSW) to Townsville in Queensland. Bounded on the west by basins (Sydney–Gunnedah–Bowen); eastern portion has been rifted offshore.
- The bulk of the NEO comprises arc, forearc basin and accretionary sedimentary and igneous materials.
- Extensively intruded and overlain by Devonian (>375 Ma) to Cretaceous (~200 Ma) granites (*sensu lato*) and volcanic rocks.
- Younger magmatism in the Cenozoic ranges from basaltic to peralkaline in composition.
- Usually broken into the NNEO and the SNEO



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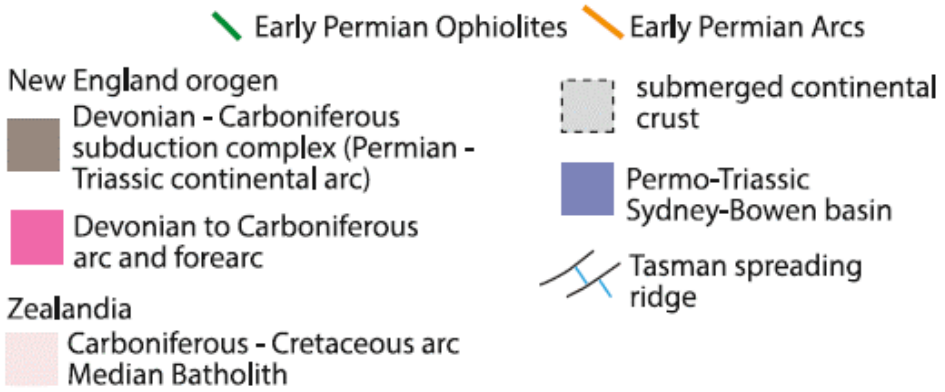
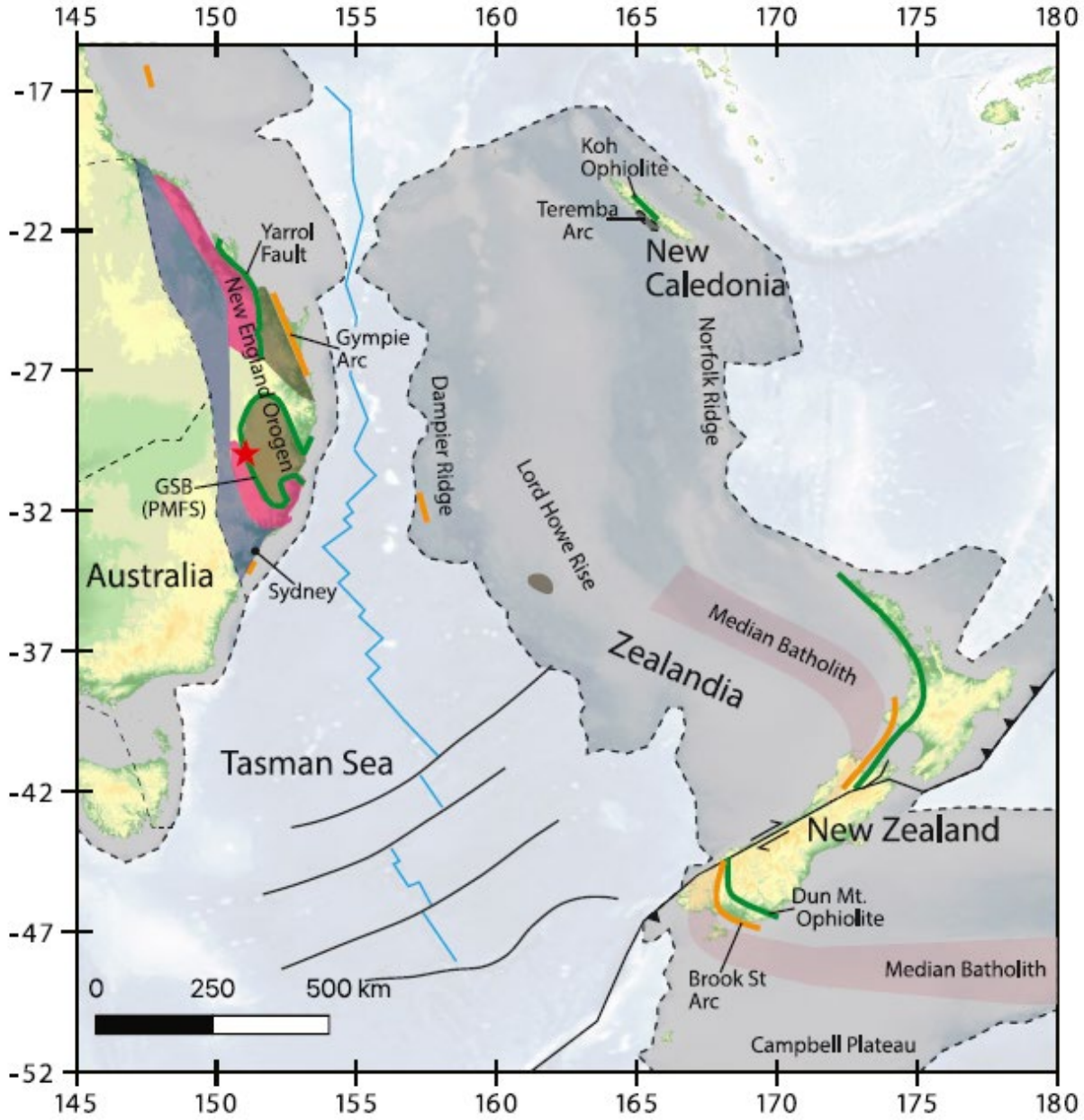
New England Orogen





Milan, et al, 2022. Geophysical Research Letters, 48, https://doi.org/10.1029/2020GL090293

New England Orogen

Transition from Lachlan/Thomson to NEO

1. Calliope-Gamilaroi Arc: >375 Ma, Silurian–Devonian

Compression: Cycle I

2. Currabubula-Connors Arc: ca 375–ca 305 Ma, Upper Devonian–Carboniferous

Extension and Relaxation: Cycle I

3. East Australian rift: ca 305–ca 280 Ma, Upper

Carboniferous–mid Permian

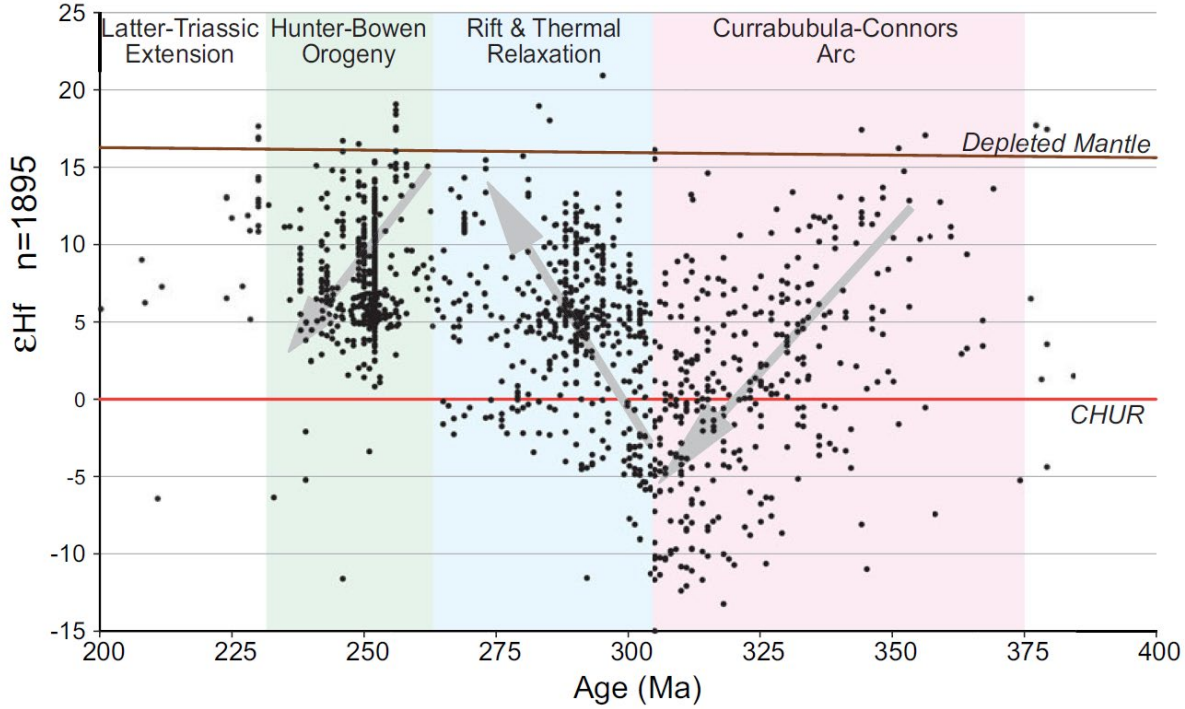
4. Thermal relaxation: ca 280–ca 265 Ma, mid–upper Permian

Compression: Cycle II

5. Hunter Bowen Orogeny: ca 265–ca 230 Ma, upper Permian–mid Triassic

Extension: Cycle II

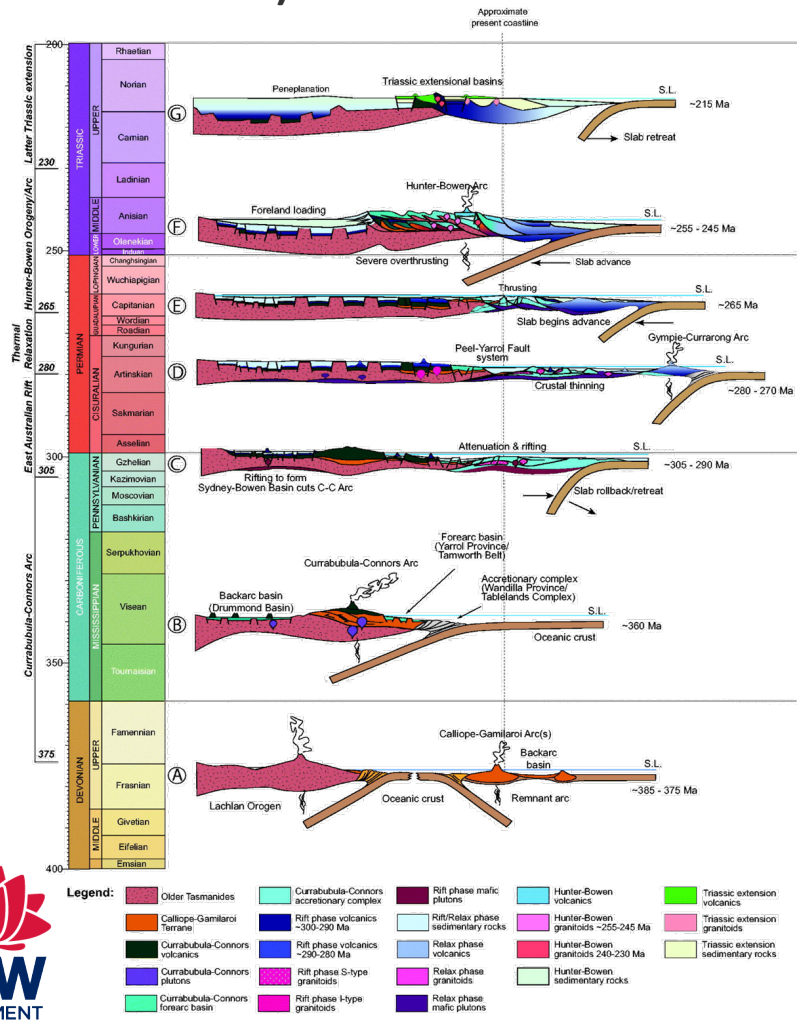
6. Triassic Extension: ca 230–ca 200Ma, mid Triassic–lowest Jurassic



eHf vs zircon age for zircons from the NEO. Data: Craven and Daczko (2017, 2018); Jessop (2017); Jeon et al. (2014); Kemp et al. (2009); Li et al. (2015); Murgulov et al. (2007); Phillips et al. (2011); Shaw, Flood and Pearson (2011); Tucker et al. (2016).

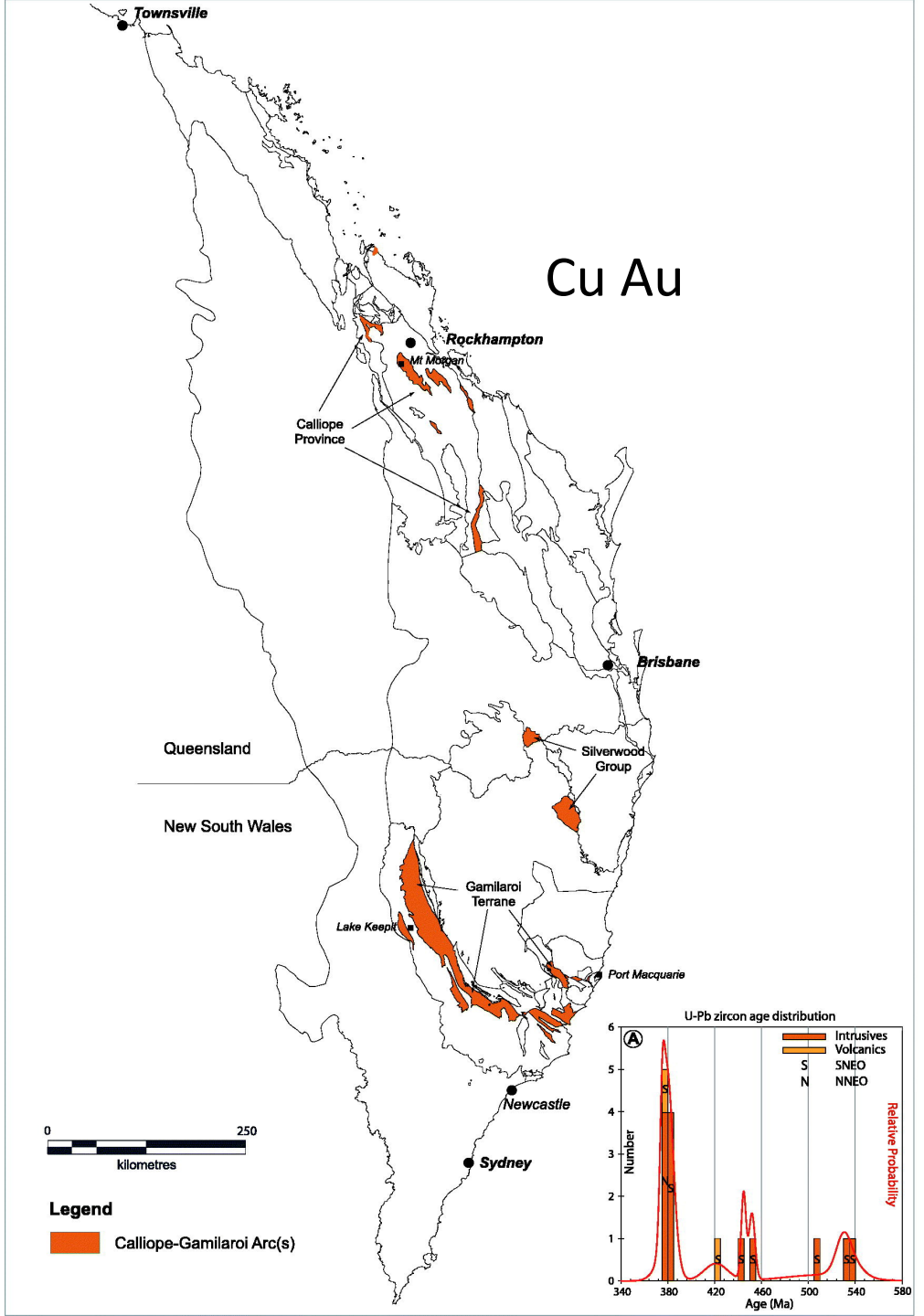
NEO - Evolution

Phase 1: Transition from Lachlan/Thomson Orogens: Calliope-Gamilaroi Oceanic Arc (>375 Ma, obducted Silurian-Devonian oceanic arc)



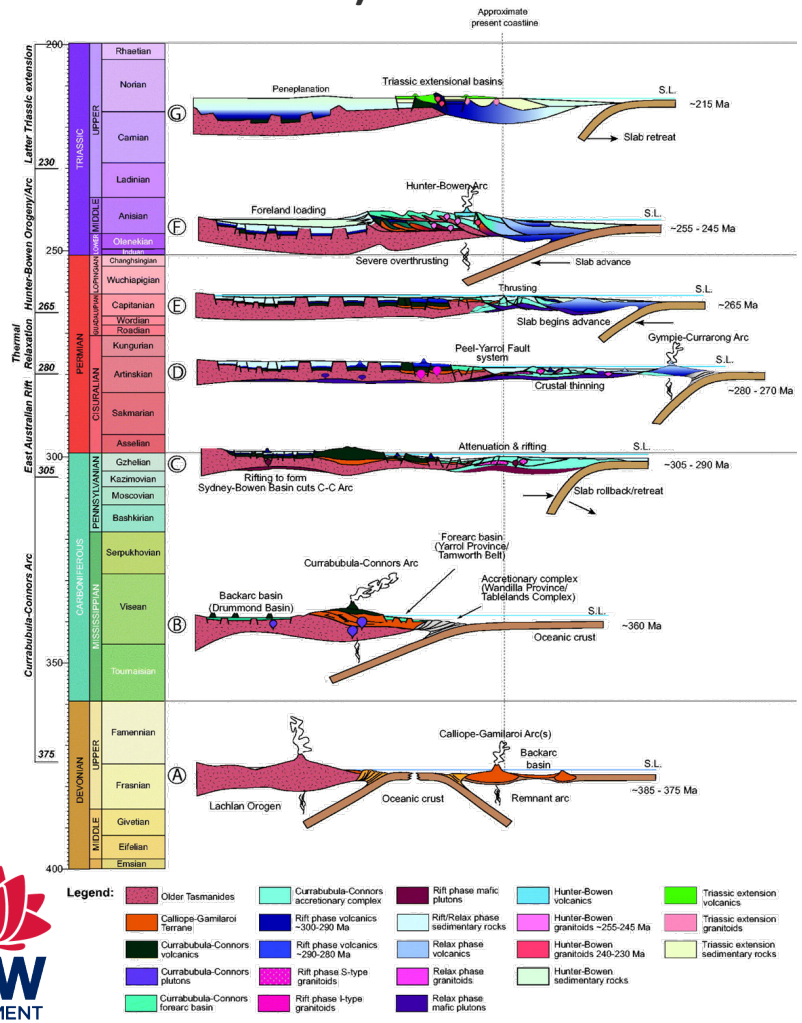
Mt Morgan Tonalite

Jessop et al., 2019

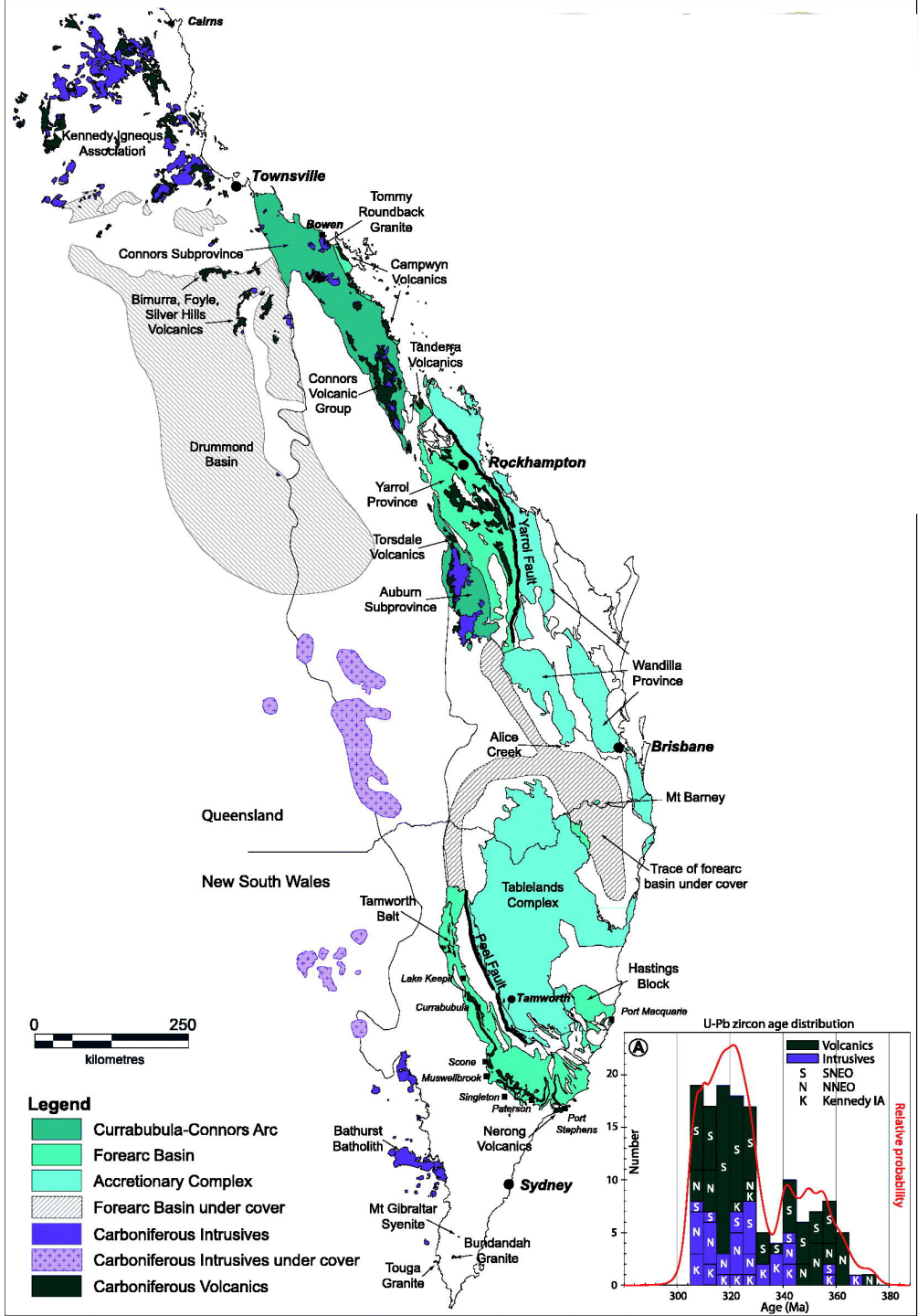


NEO - Evolution

Phase 2: Compression cycle I: Currabubula-Connors Arc (*ca* 375–305 Ma, upper Devonian – upper Carboniferous long-lived continental arc)



I-type granites



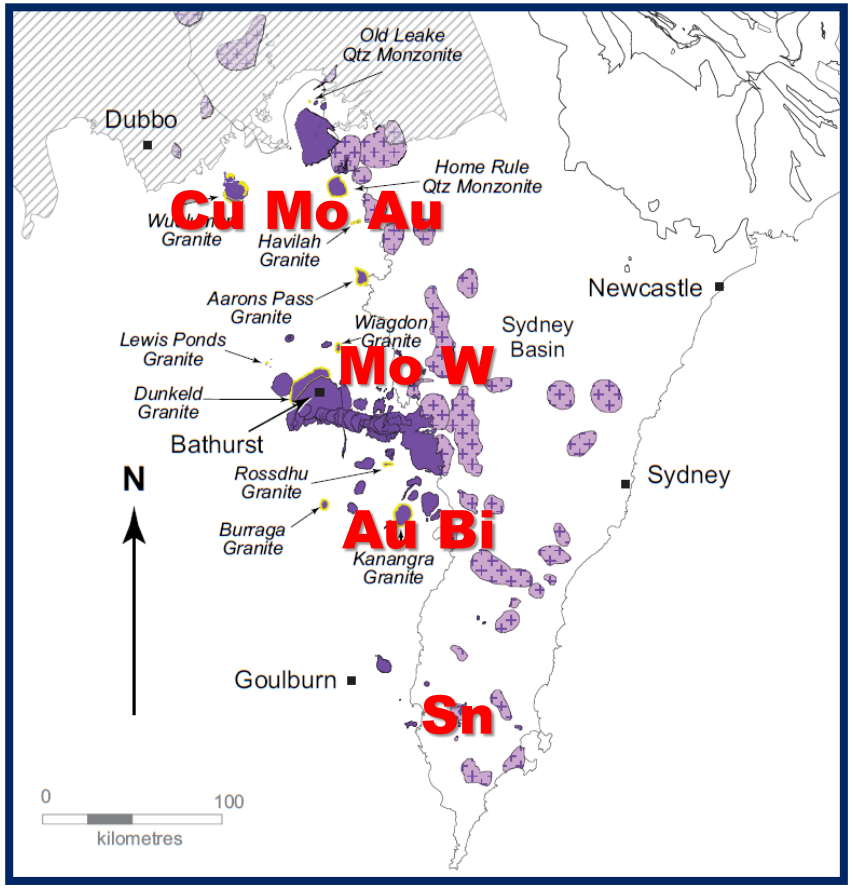
Jessop et al., 2019

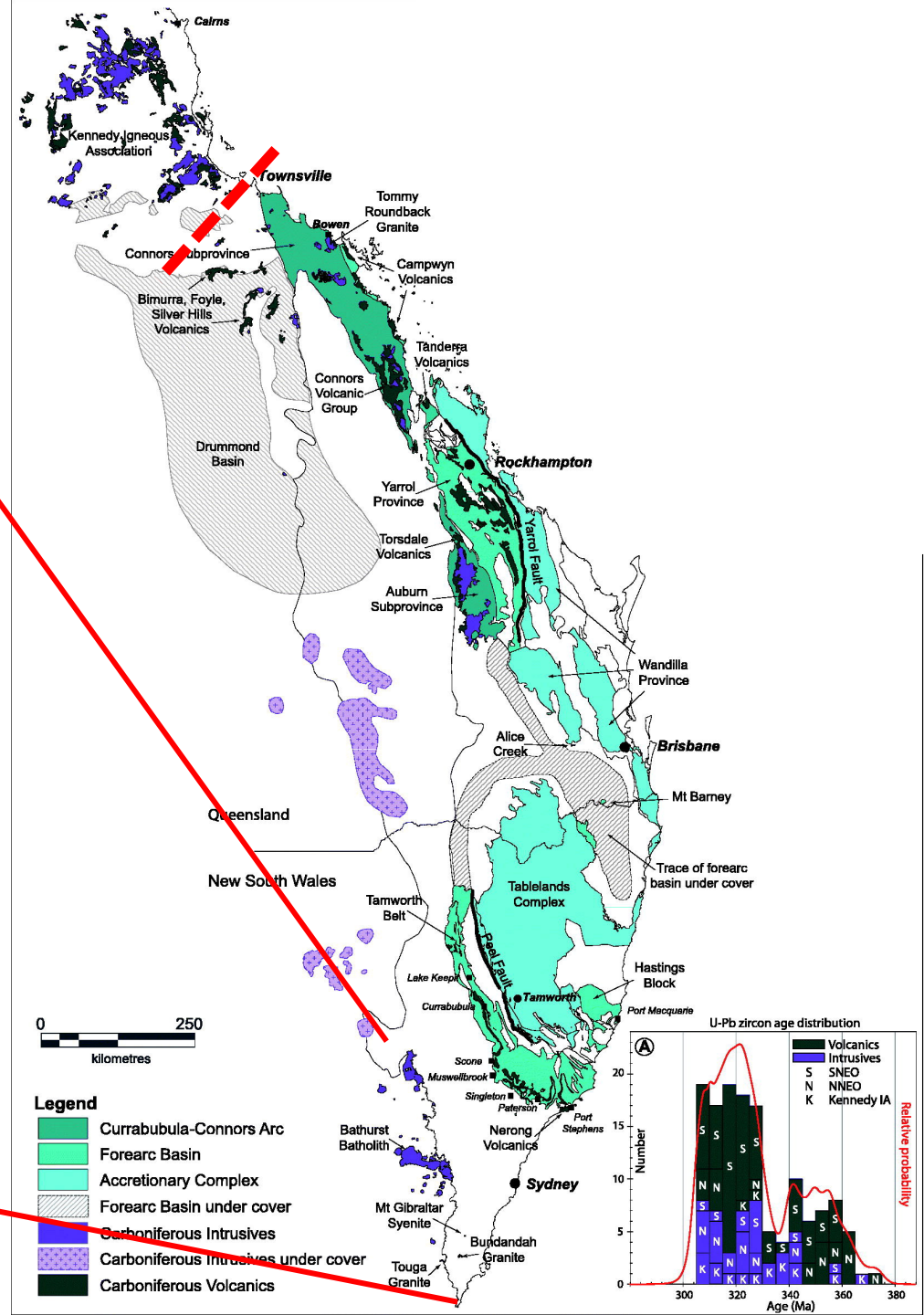
NEO - Evolution

Phase 2: Compression cycle I: Currabubula-Connors Arc (*ca* 375–305 Ma, upper Devonian – upper Carboniferous long-lived continental arc)

↑Lachlan zrc restite

↑$\delta^{18}O_{zrn}$

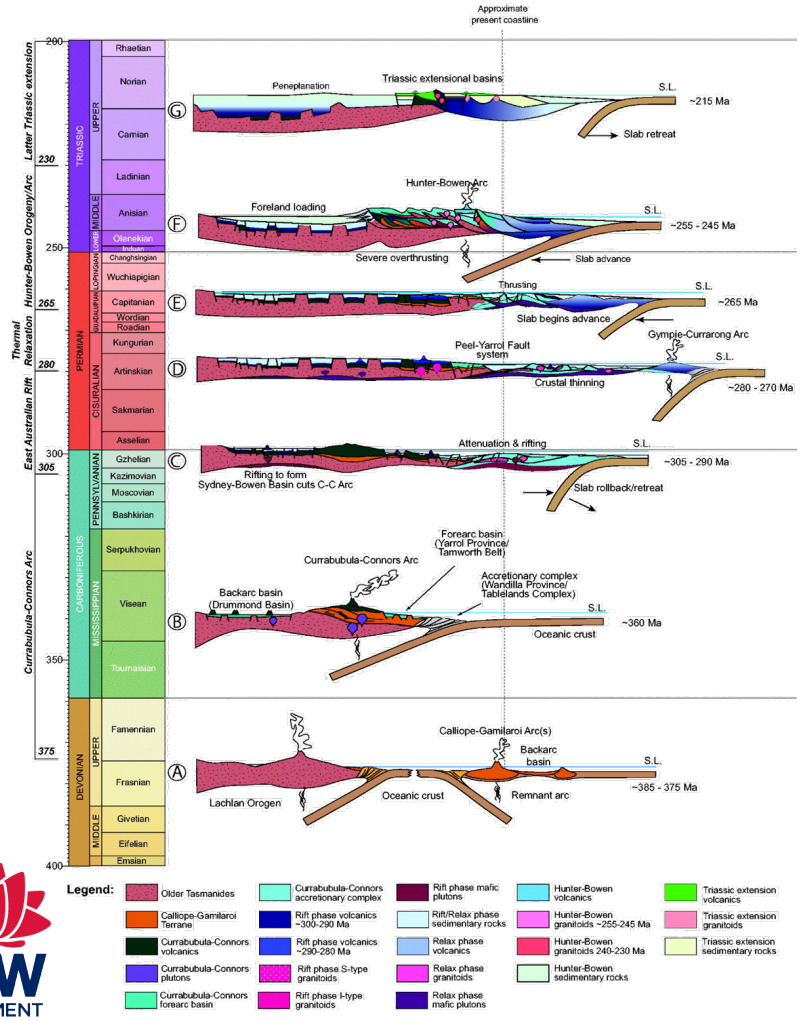




Jessop et al., 2019

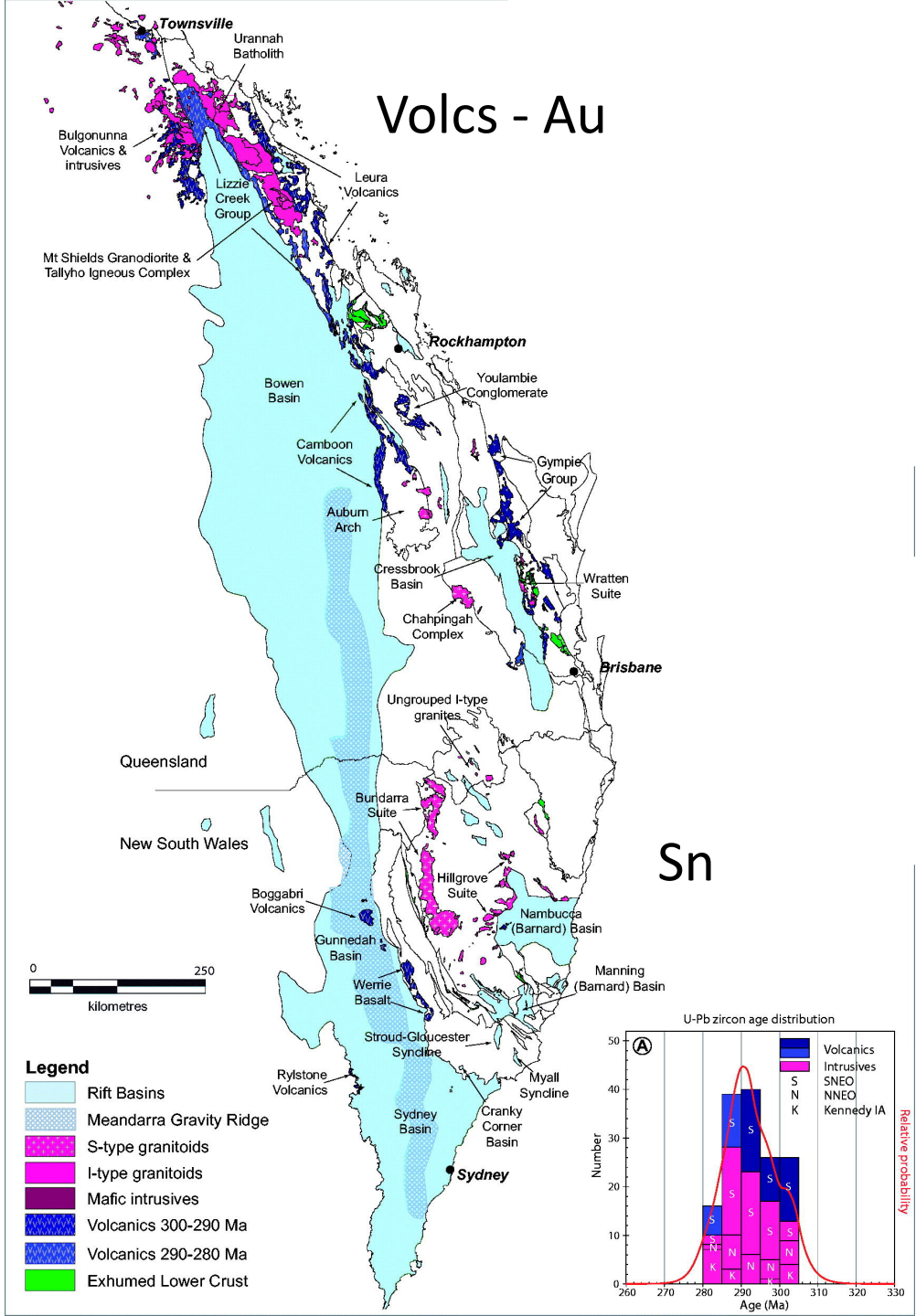
NEO - Evolution

Phase 3: Extension cycle I: East Australian rift (*ca* 305–280 Ma, uppermost Carboniferous–lower/Middle Permian)



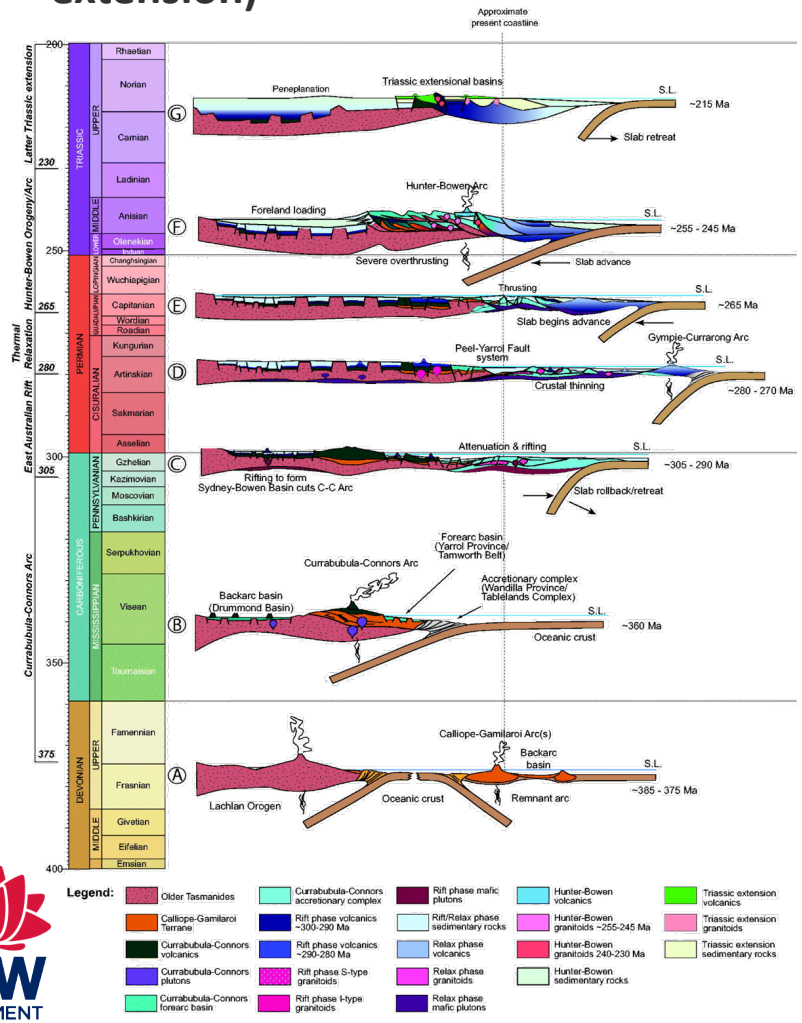
Gympie arc,
S- & I-types,
Bimodal volc'm

Jessop et al., 2019

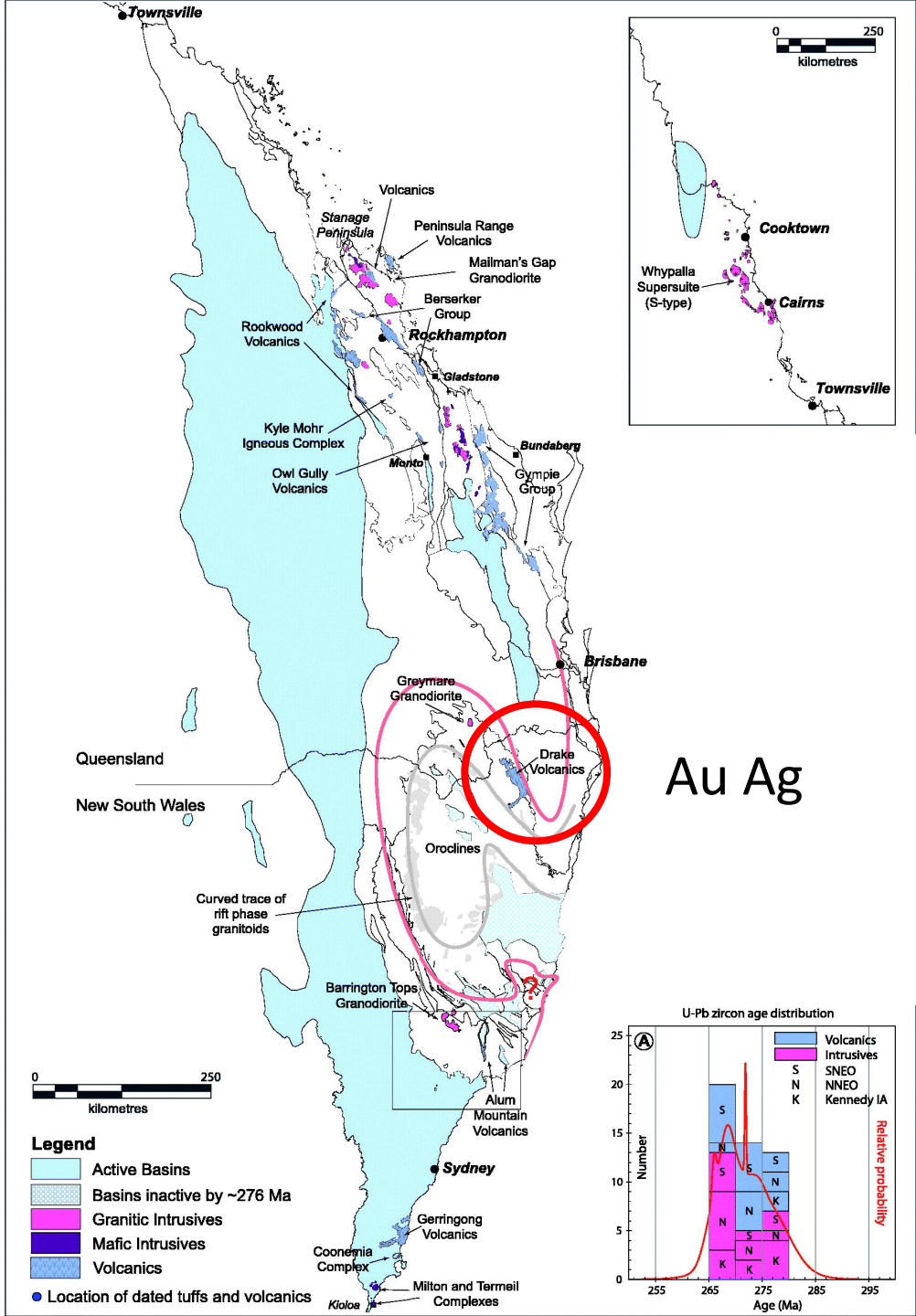


NEO - Evolution

Phase 4: Extension cycle I continued: thermal relaxation (ca 280–265 Ma, mid to upper Permian gravitational sagging and local extension)



Orocline, rollback

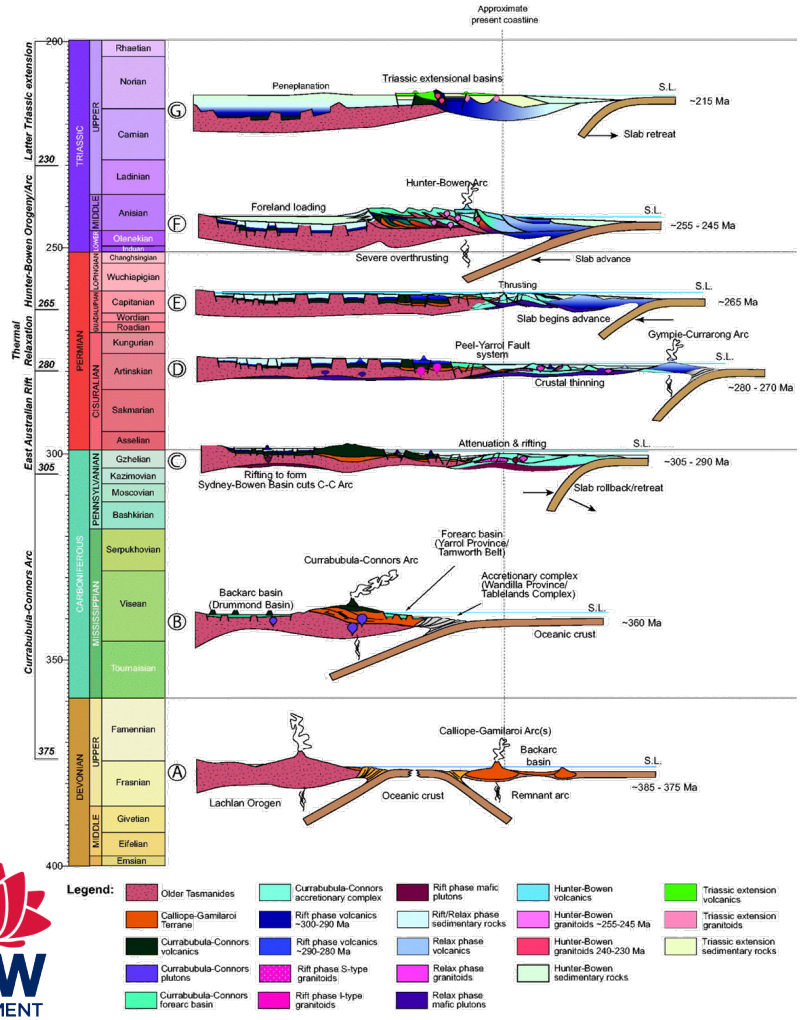


Au Ag

Jessop et al., 2019

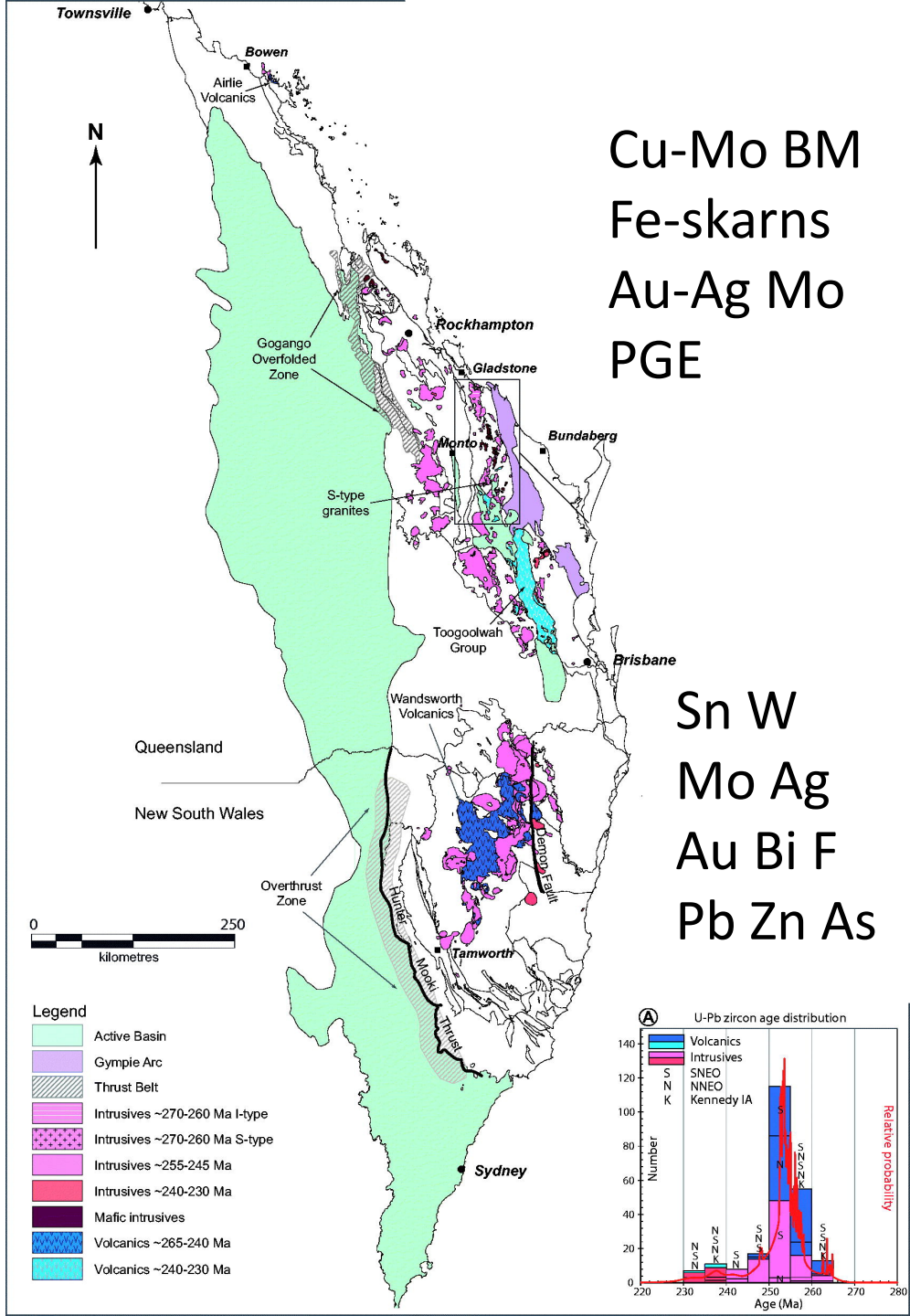
NEO - Evolution

Phase 5: Hunter-Bowen Orogeny and Arc (*ca* 265–230 Ma, late Permian–mid Triassic compressive continental arc)



SNEO I-types & volc;
NNEO I & S-types

Jessop et al., 2019

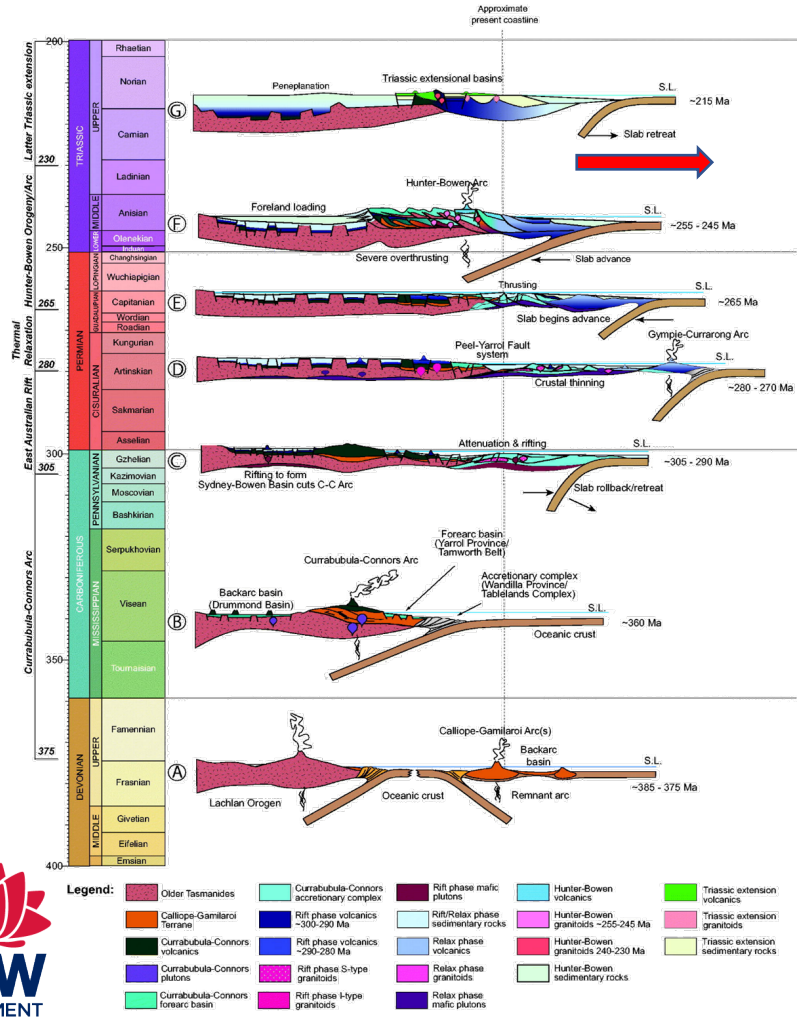


Cu-Mo BM
Fe-skarns
Au-Ag Mo
PGE

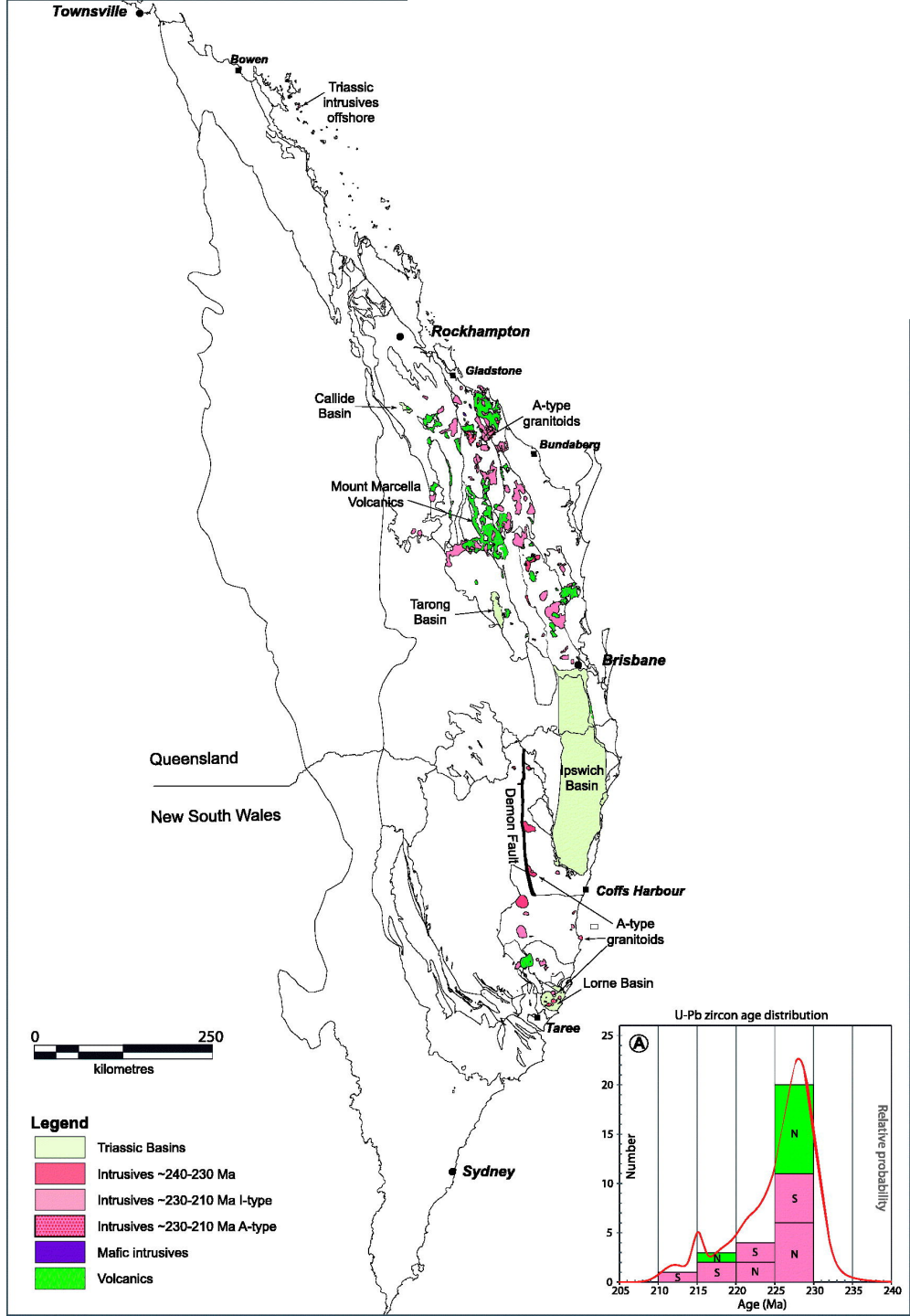
Sn W
Mo Ag
Au Bi F
Pb Zn As

NEO - Evolution

Phase 6: latter Triassic (ca 230–200 Ma, mid Triassic to lowest Jurassic extension)



I- & A-types

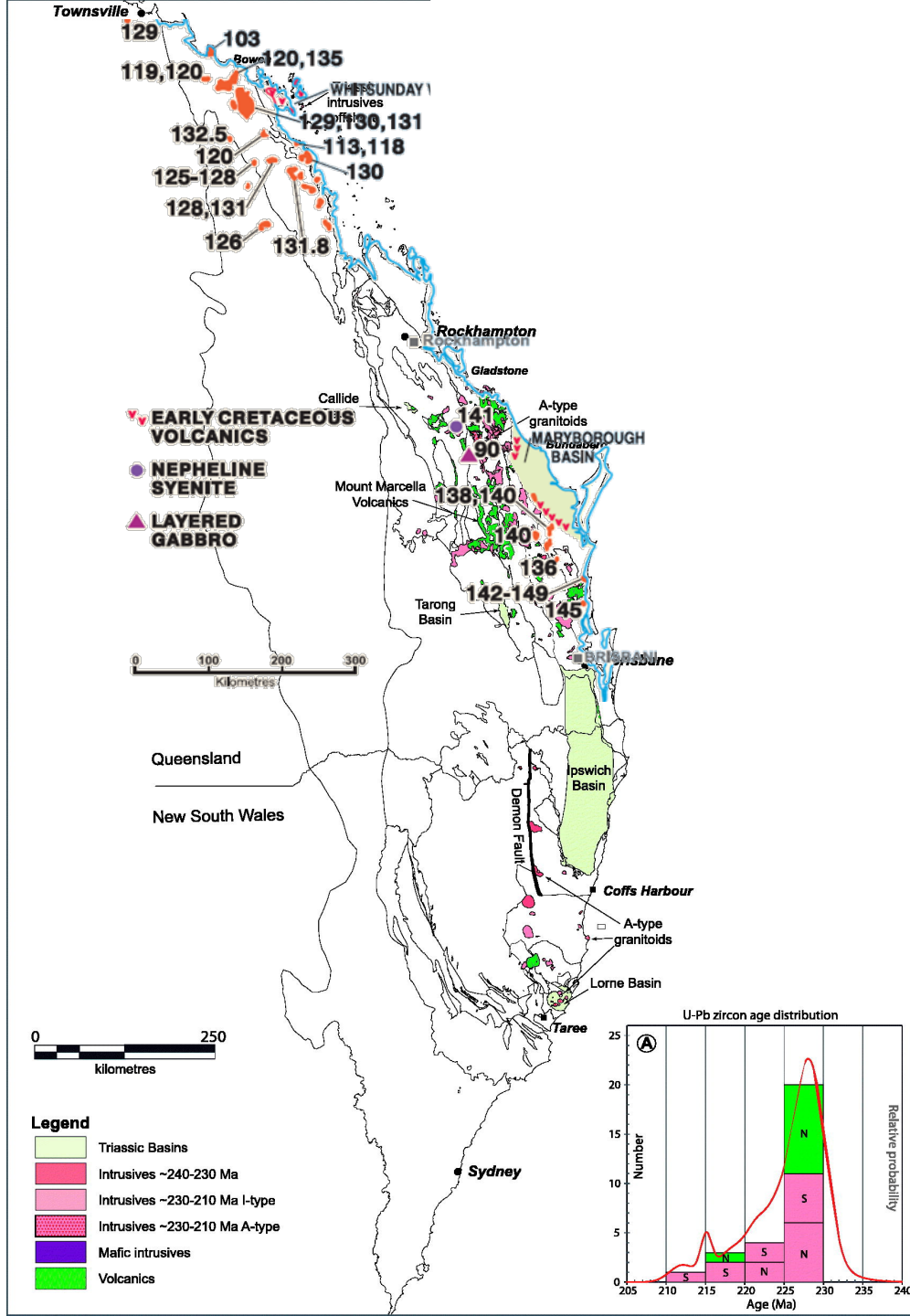


Jessop et al., 2019

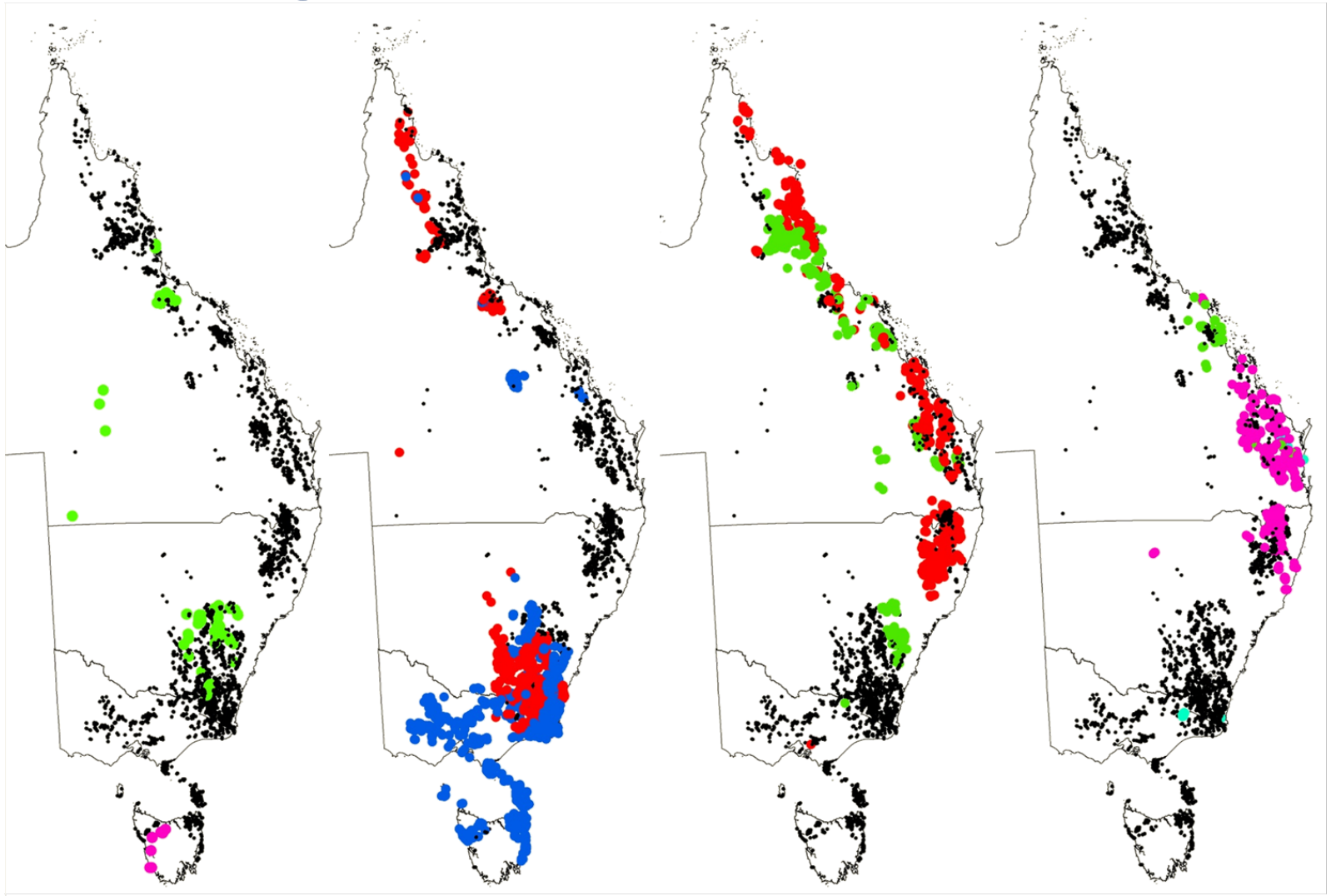
NEO - Evolution

Cretaceous magmatism

- Rare Jurassic age dates
- Cretaceous volcanism (137–109 Ma) and plutons (142–117 Ma). Small group just north of Gympie.
- Only remnants of subsequent tectonic cycles recorded on the mainland.
- They reinforce the expansion–contraction differences between the NNEO and SNEO.
- Significant overprinting of orogenic phases in the NNEO that is not seen in the south. Echoed in the location and timing of metamorphism within the orogen (Jessop, 2017).
- Cu-Mo porphyry
- Mesothermal vein gold deposits (Normanby)
- Mafic systems



Magmatic ages



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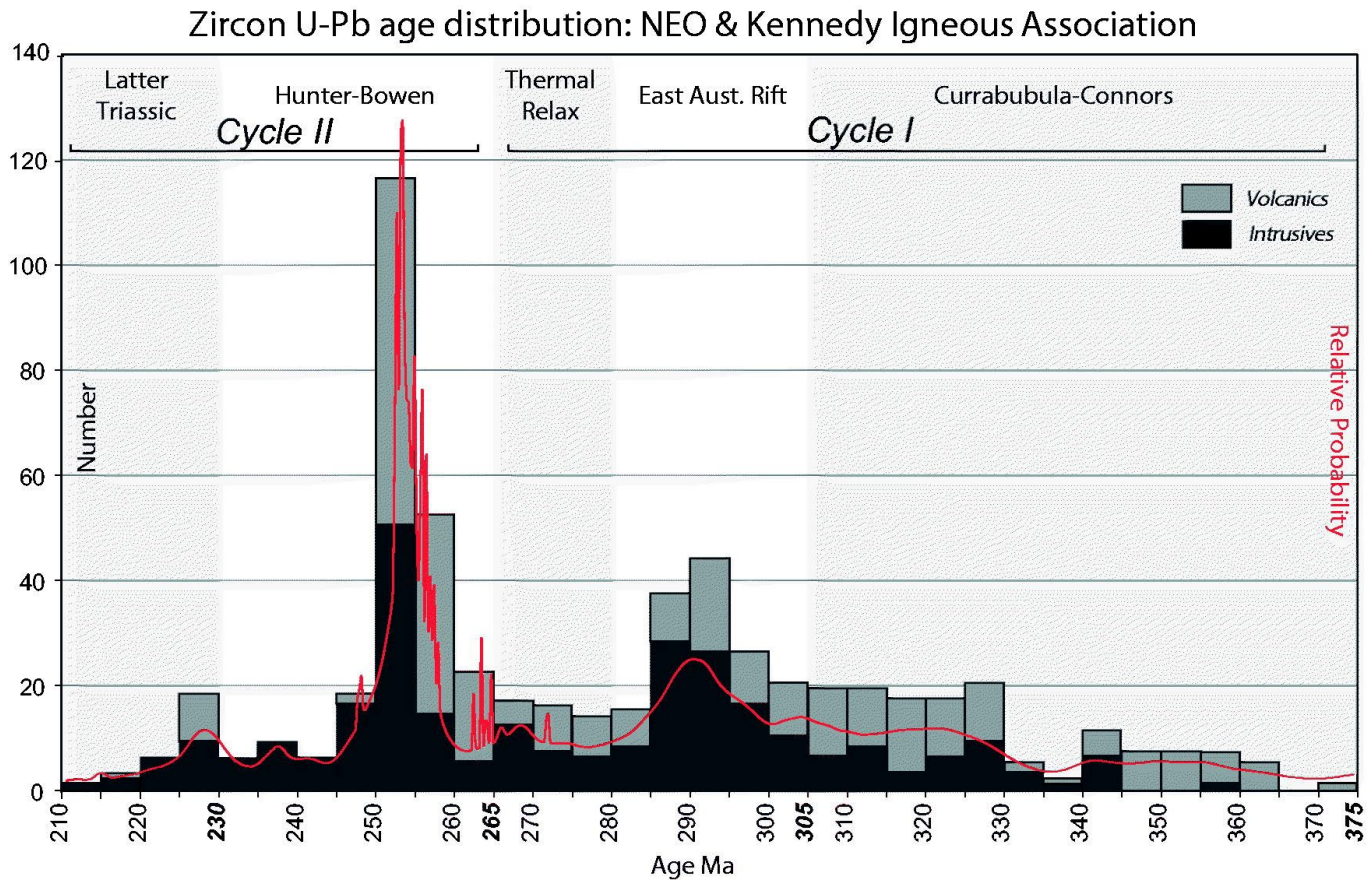
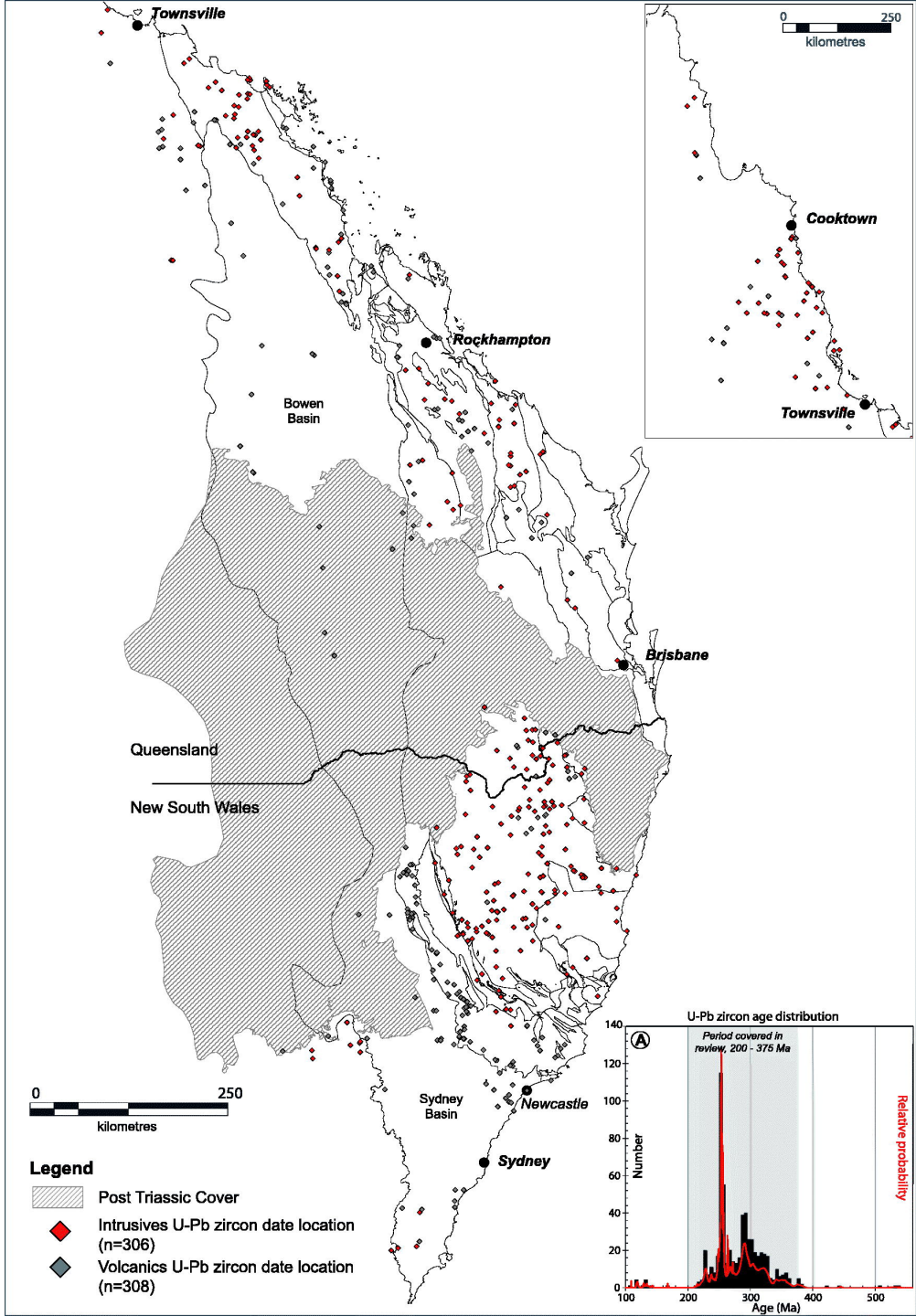
New England Orogen





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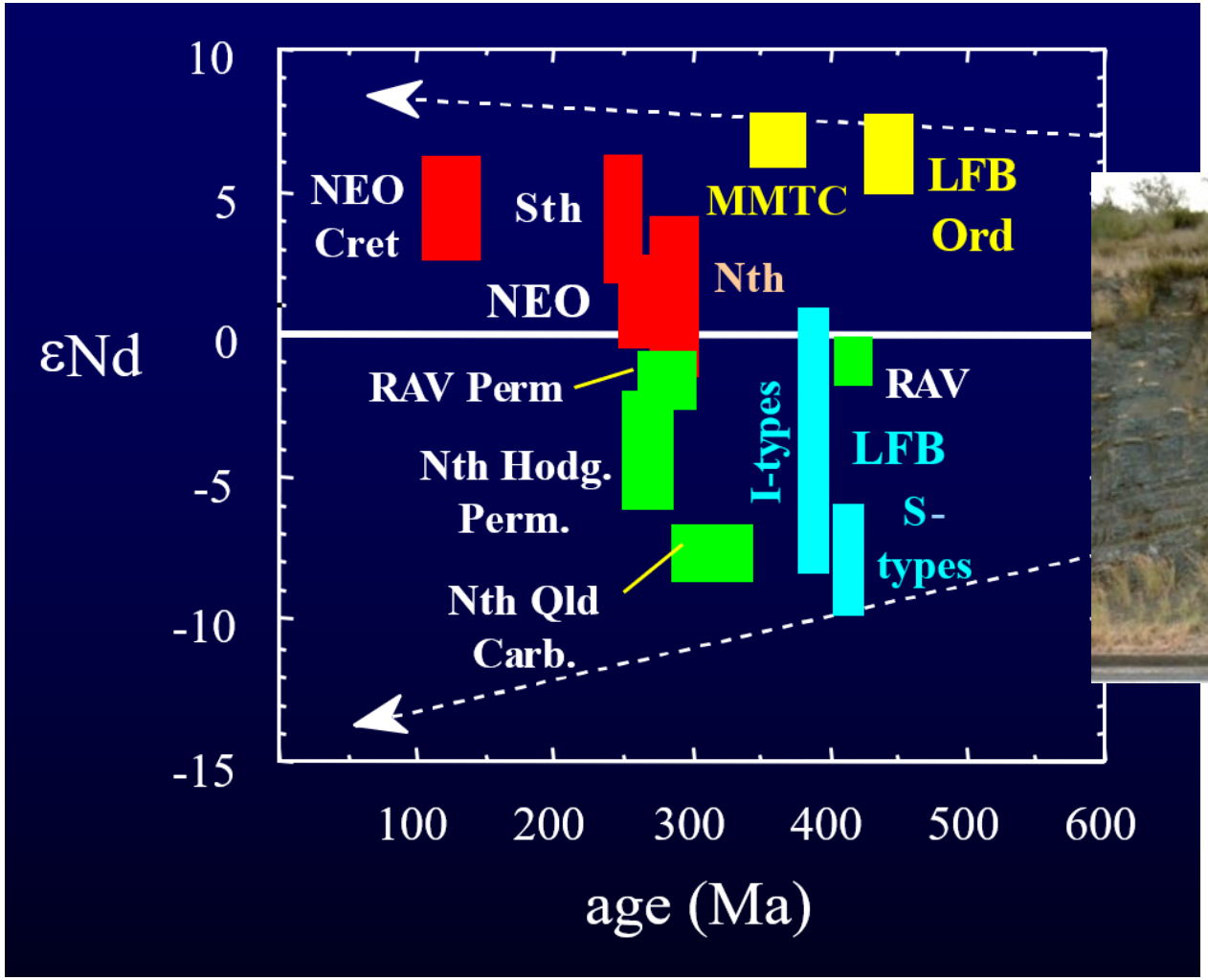
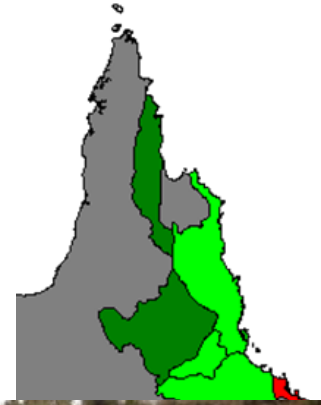
Isotopic evolution





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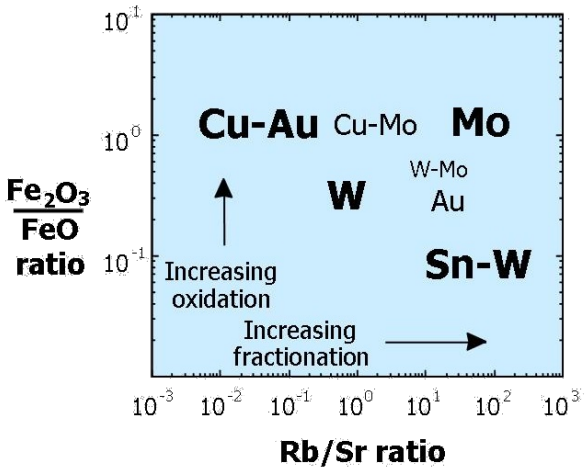
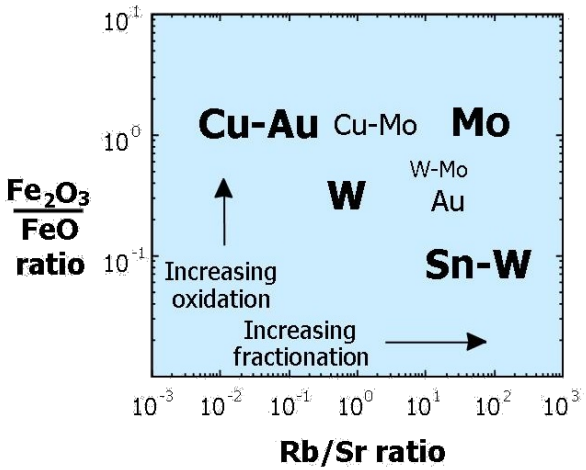
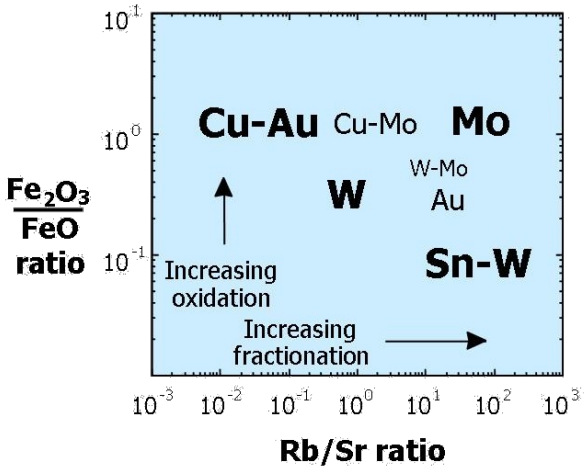
Fertility

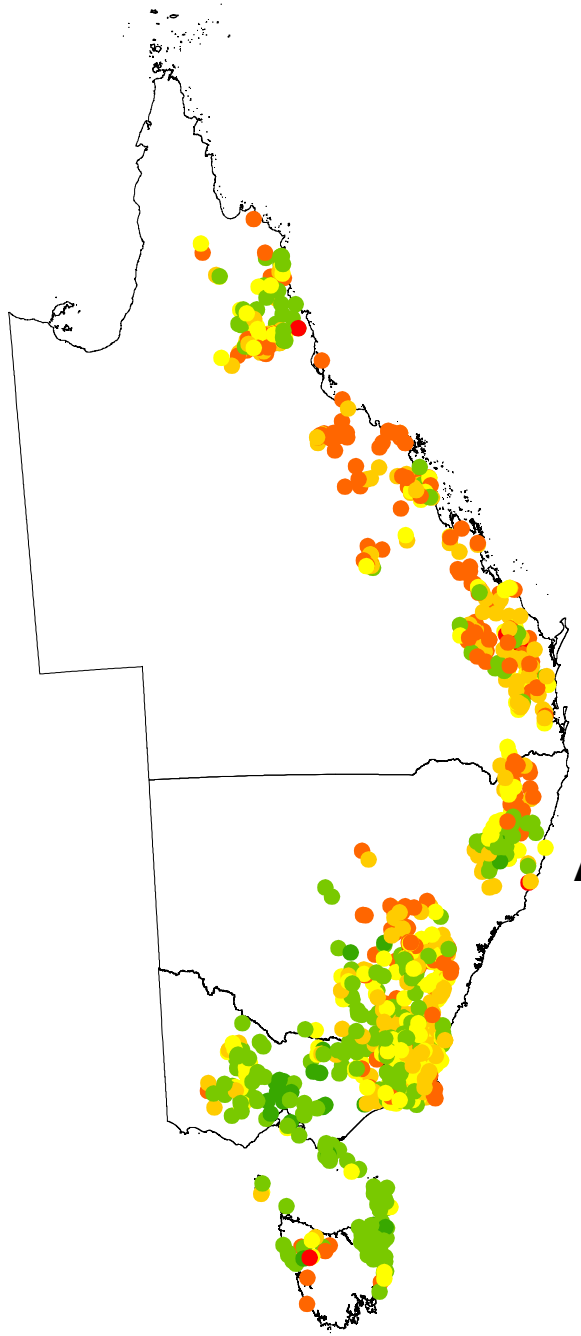

10^{1}
10^{0}
10^{-1}
$\frac{Fe_2O_3}{FeO}$ ratio
Cu-Au
Cu-Mo
Mo
W-Mo
W
Au
Sn-W
Increasing oxidation
Increasing fractionation
10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1} 10^{2} 10^{3}
Rb/Sr ratio

Fertility


Cu-Au
Cu-Mo
Mo
W-Mo
W
Au
Sn-W
Increasing oxidation
Increasing fractionation
$\frac{Fe_2O_3}{FeO}$ ratio
Rb/Sr ratio

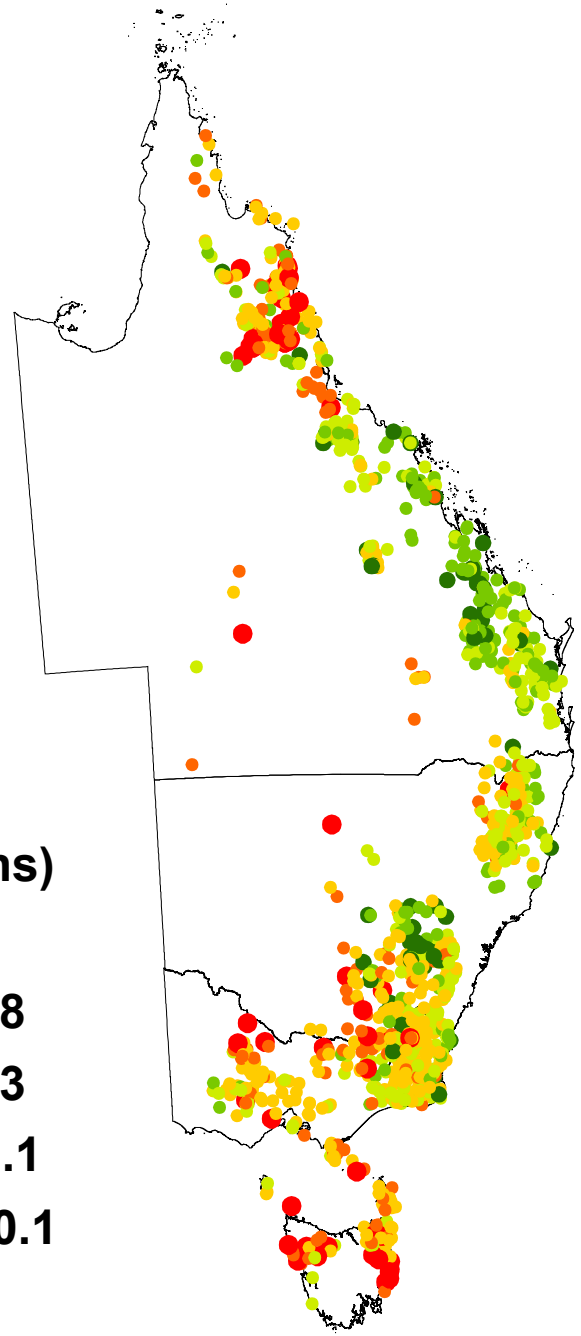
Fertility





Δ Ox (plutons)

- >0.8
- 0.3 - 0.8
- 0.1 - 0.3
- -0.1 - 0.1
- -0.7 - -0.1
- < -0.7



K/Rb (plutons)

- >400
- 250 - 400
- 200 - 250
- 150 - 200
- 100 - 150
- 33 - 100

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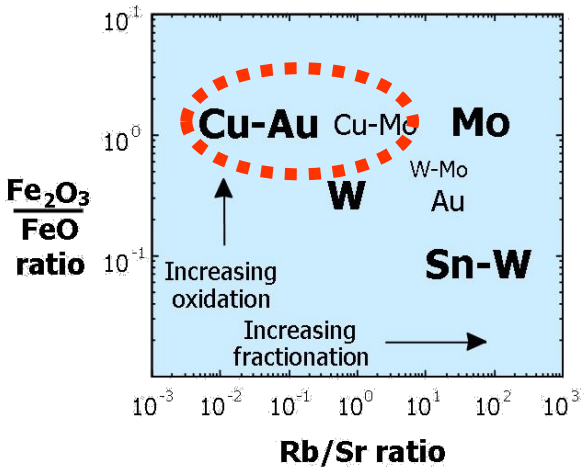
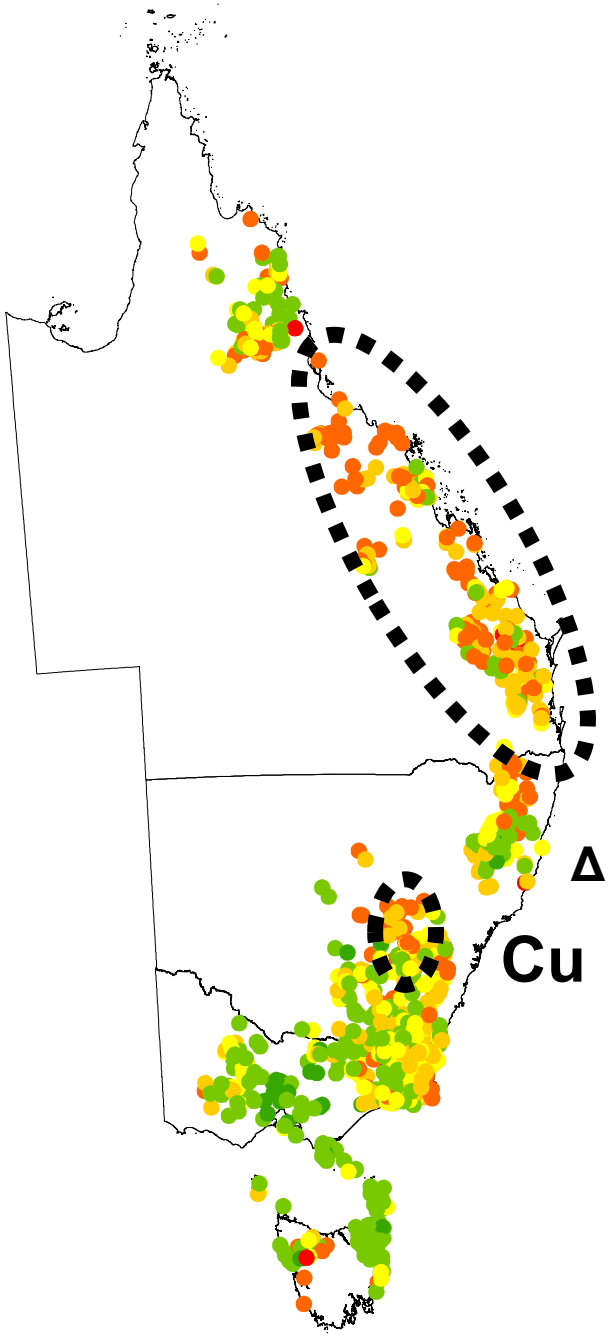
Cu-Au,-Mo





Δ Ox (plutons)

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- 0.3 - 0.8
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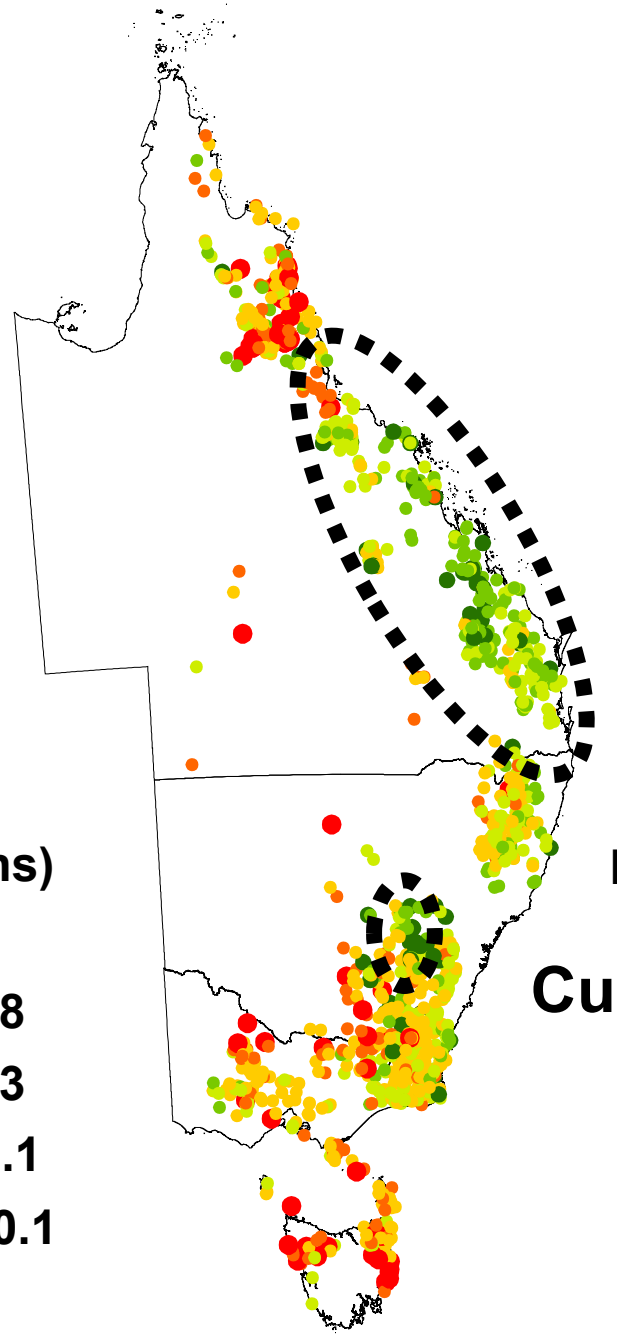

K/Rb (plutons)

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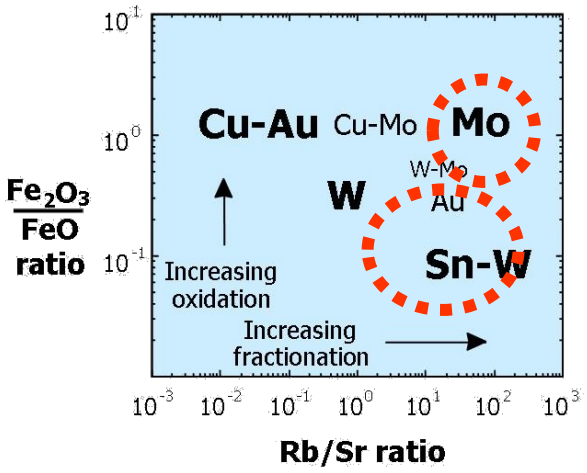
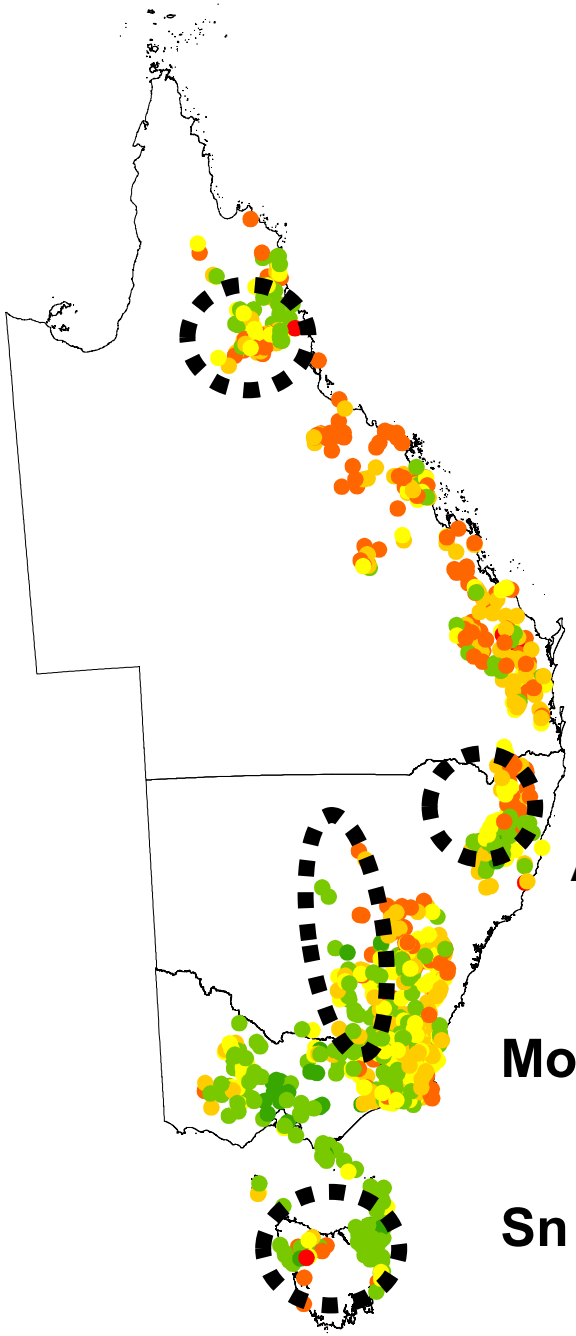
Sn W, Mo



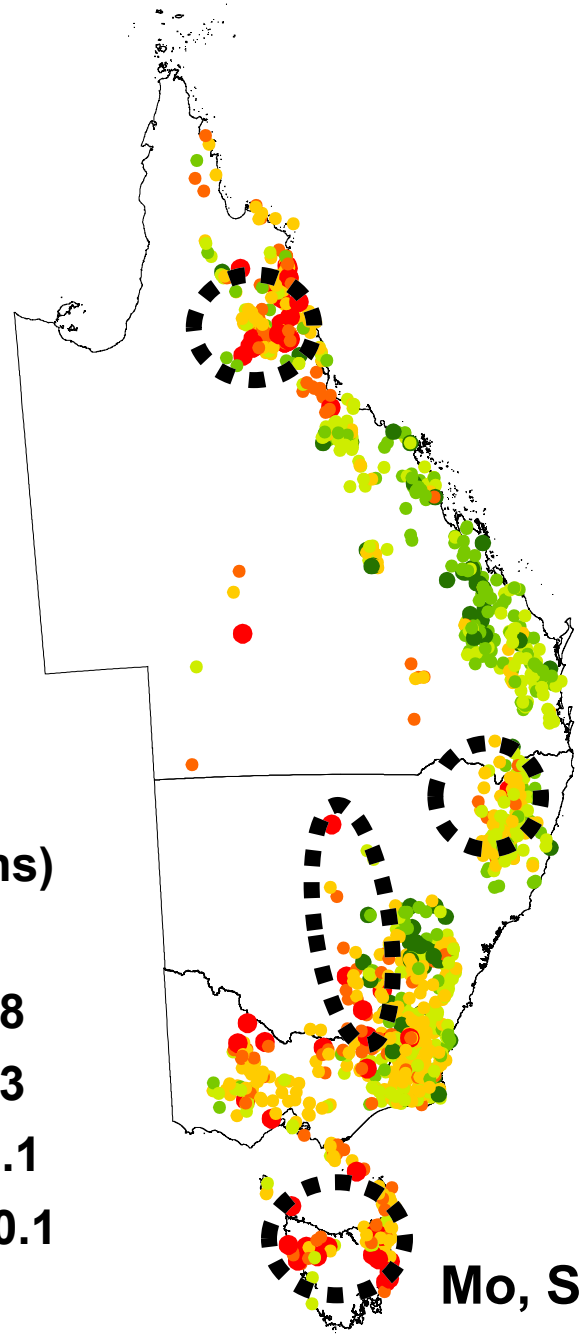


Mo

Sn

Δ Ox (plutons)

- >0.8
- 0.3 - 0.8
- 0.1 - 0.3
- -0.1 - 0.1
- -0.7 - -0.1
- < -0.7



Mo, Sn

K/Rb (plutons)

- >400
- 250 - 400
- 200 - 250
- 150 - 200
- 100 - 150
- 33 - 100

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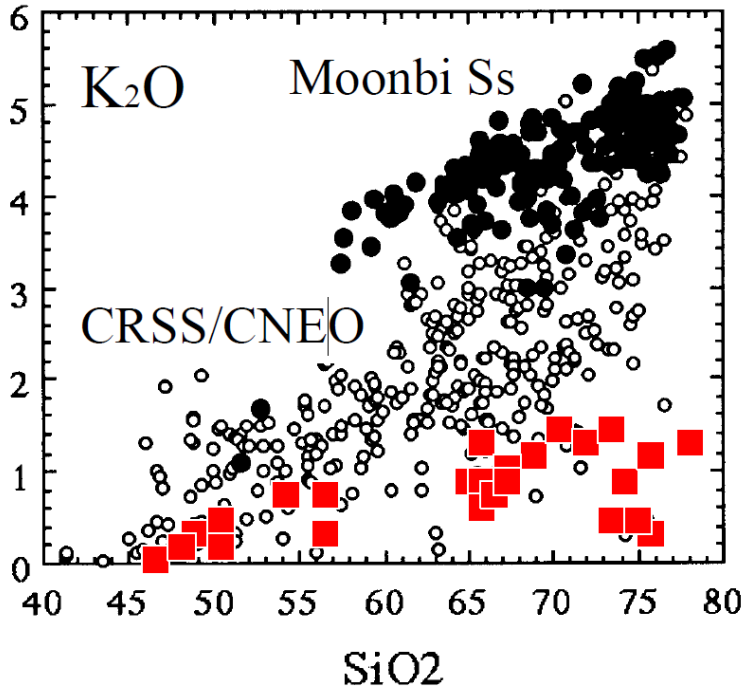
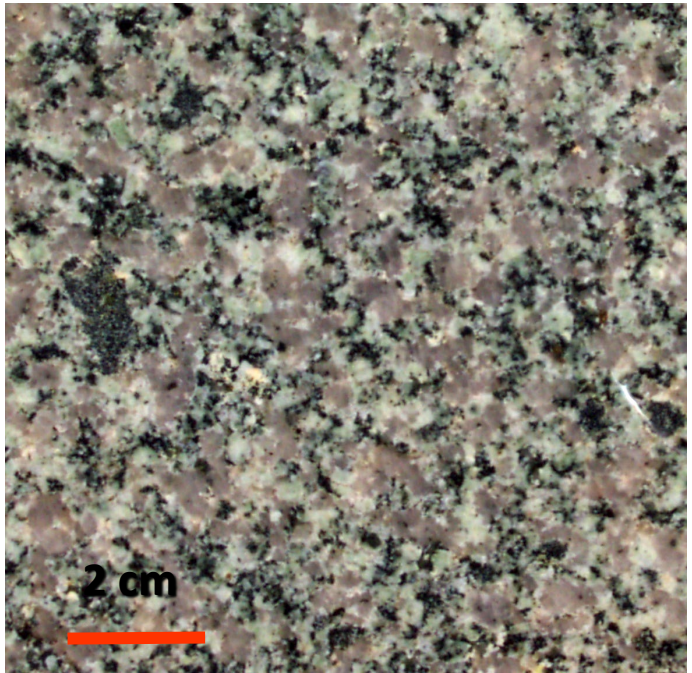
NNEO – Mount Morgan





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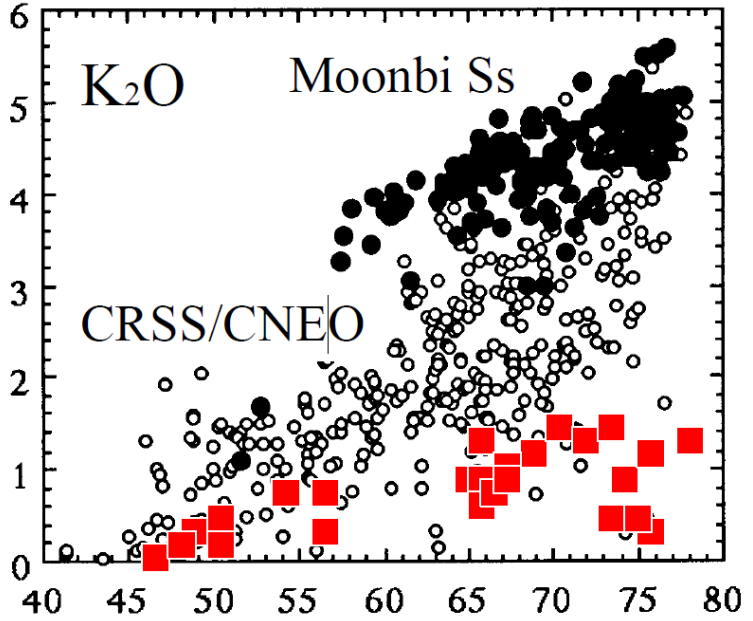
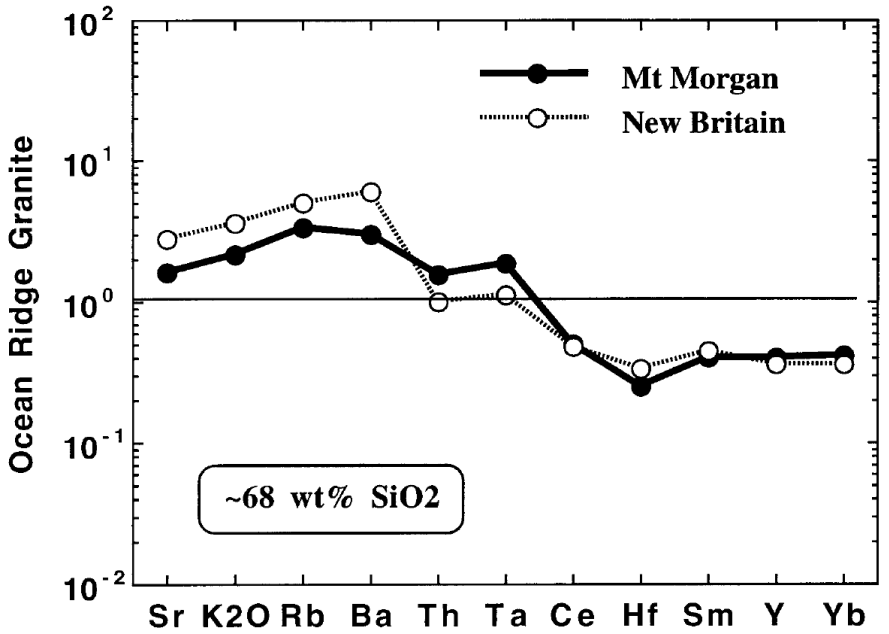
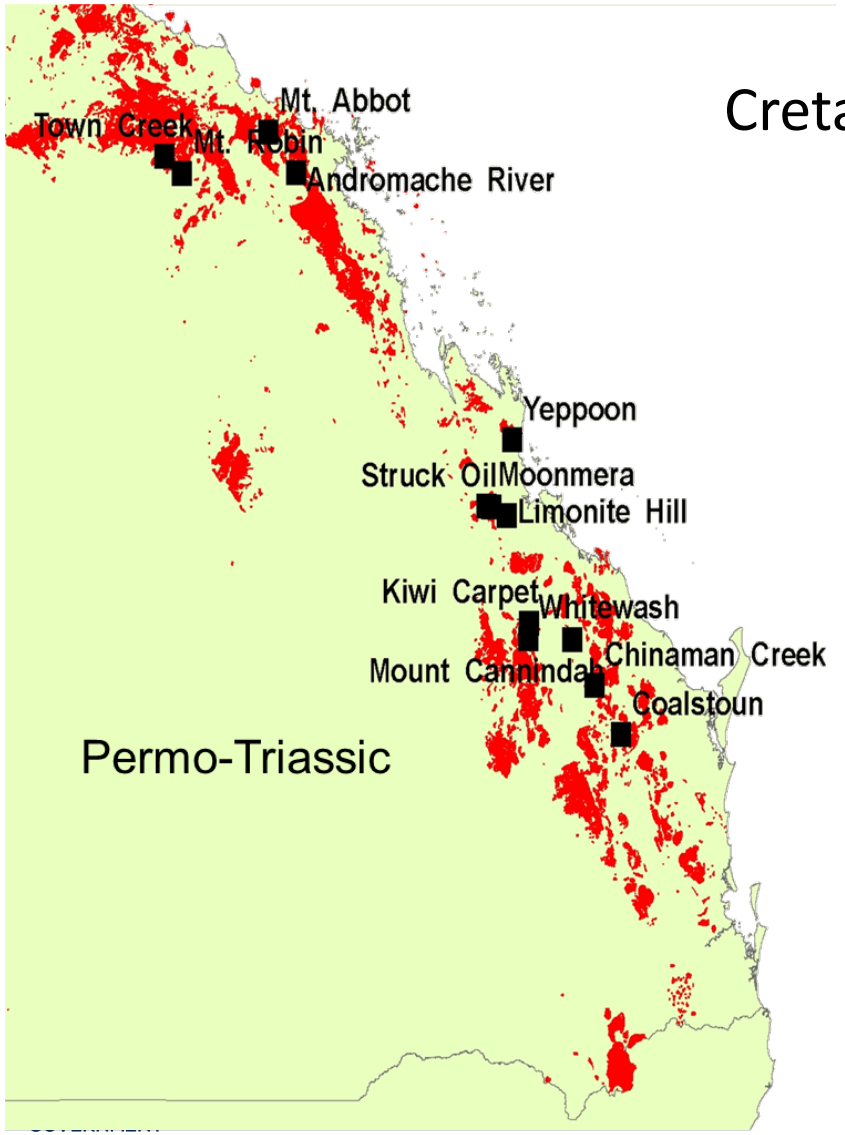
NNEO – Mount Morgan





NNEO - porphyry Cu systems

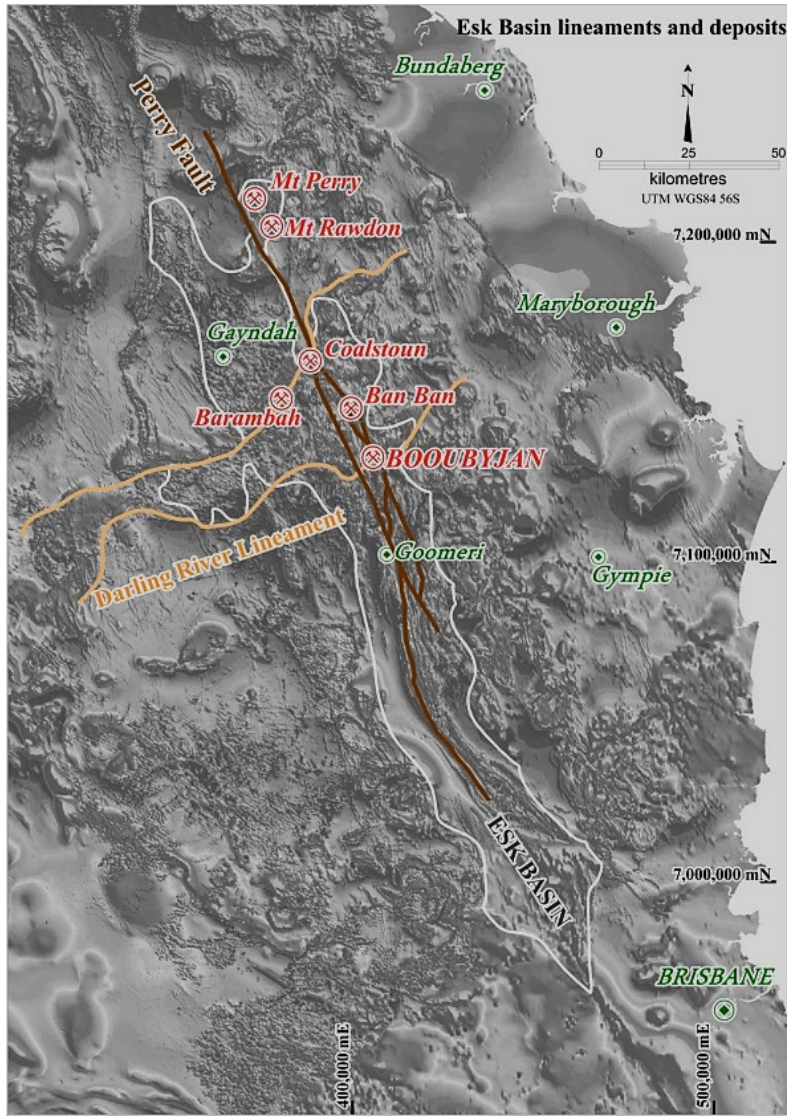


Name	tonnes	Cu %	Mo %
Andromache River	20,000,000	0.25	
Coalstoun	85,000,000	0.29	
Kiwi Carpet	200,000,000	0.15	
Mount Abbot	200,000,000	0.15	
Chinaman Creek	200,000,000	0.20	
Mount Leslie*	20,000,000	0.20	
Struck Oil	100,000,000	0.20	
Yeppoon	50,000,000	0.30	0.010
Whitewash	71,500,000	0.10	0.034
Mount Cannindah	7,430,000	0.97	0.000
Anduramba (Mo)	31,600,000	0	0.060

+ Ag, Au, Re sweeteners

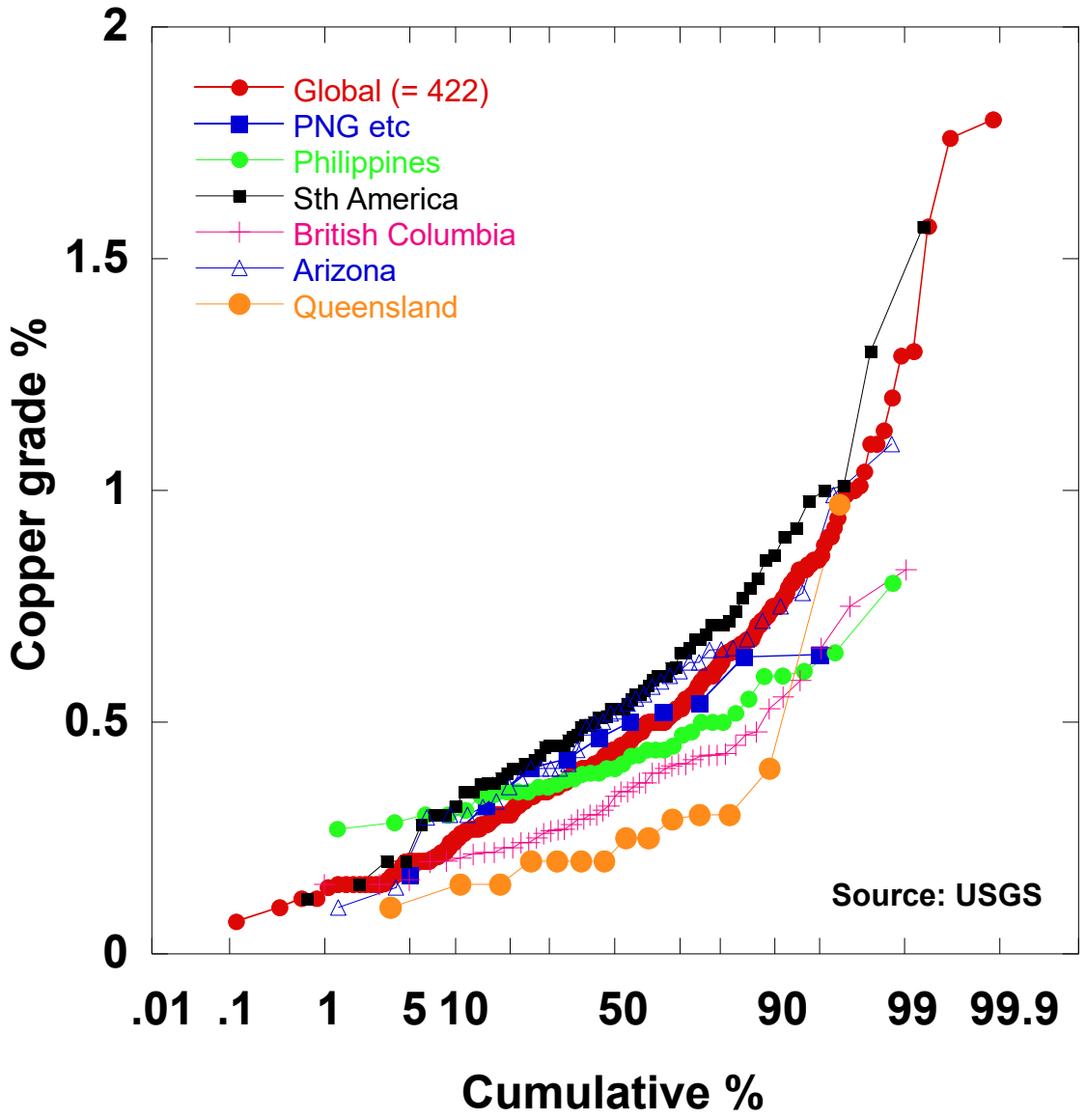
*** = Copper Dome**

Sources: USGS, Horton (1978), Aussie Q Resources website



Veracruz et al., 2015

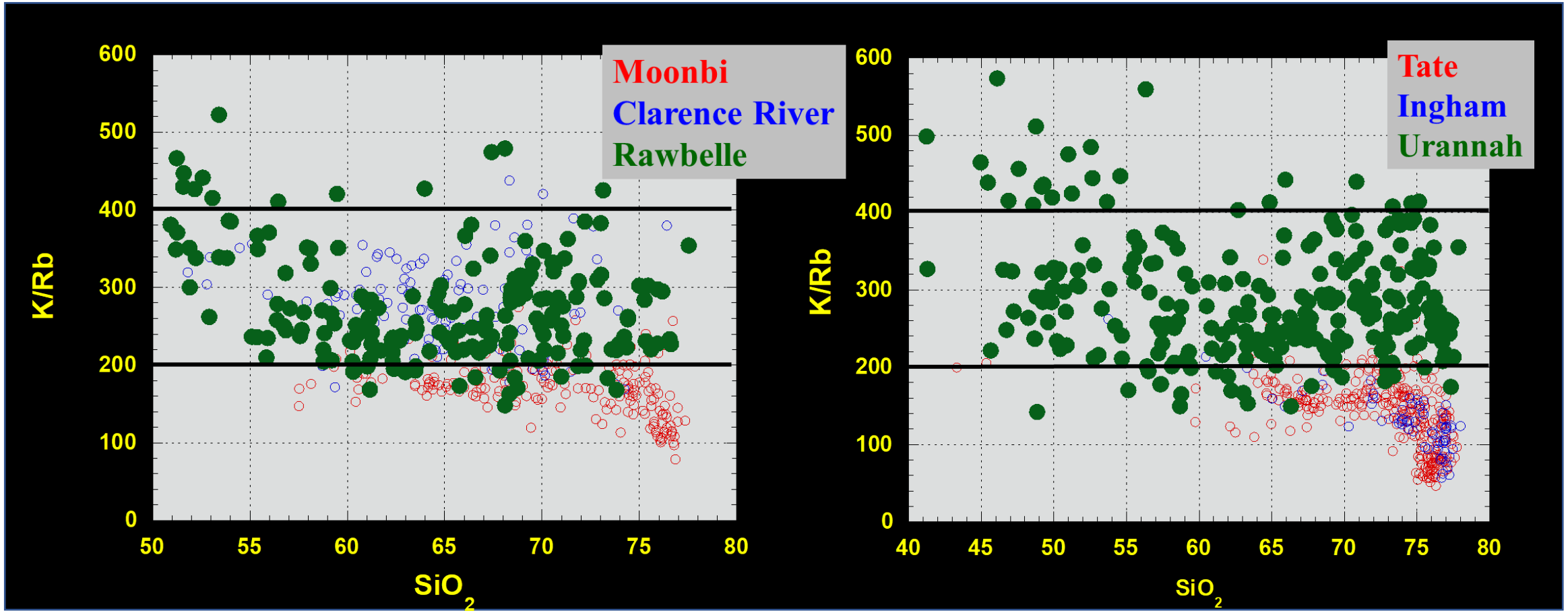
NNEO - porphyry Cu systems



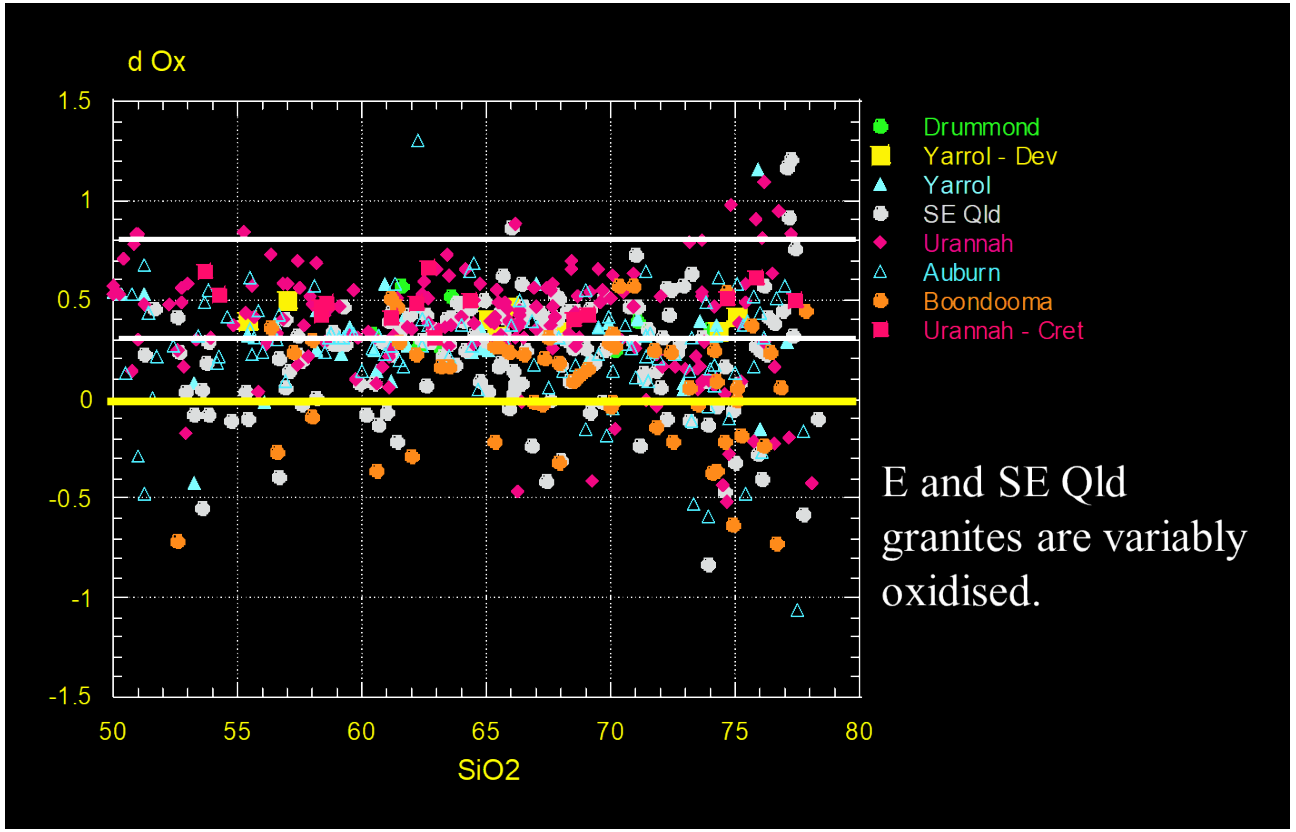
- Cu grade distributions are similar for most provinces.
- Queensland are rather low.

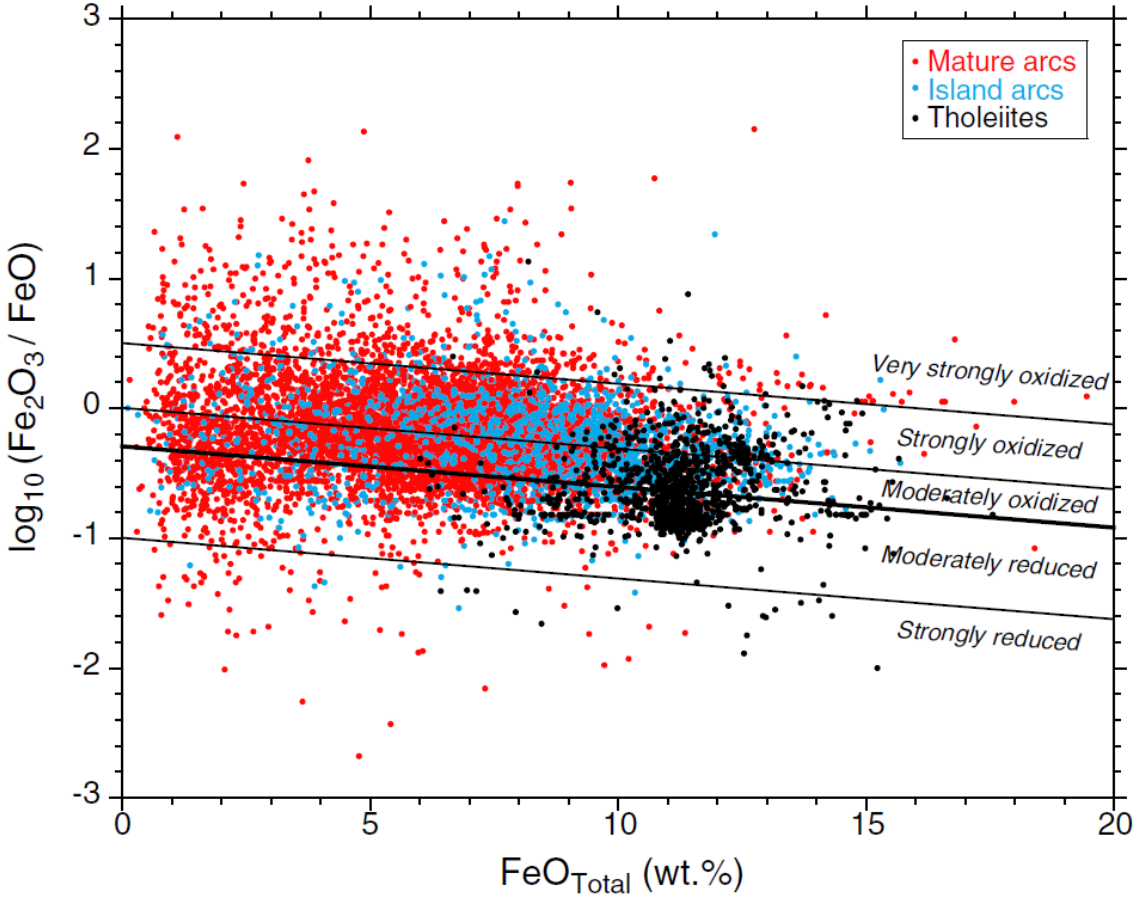
NSW GOVERNMENT

NNEO - Compositional character



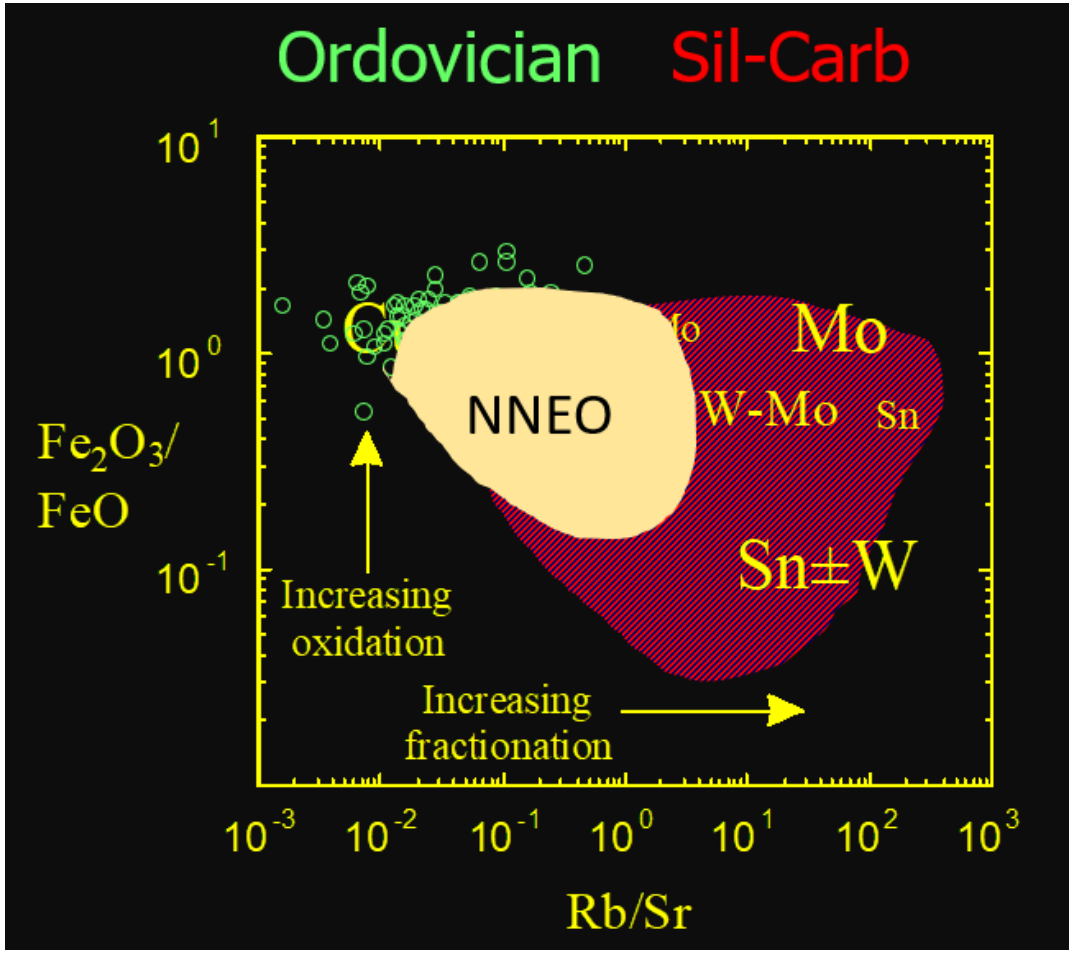
NNEO – relative oxidation state

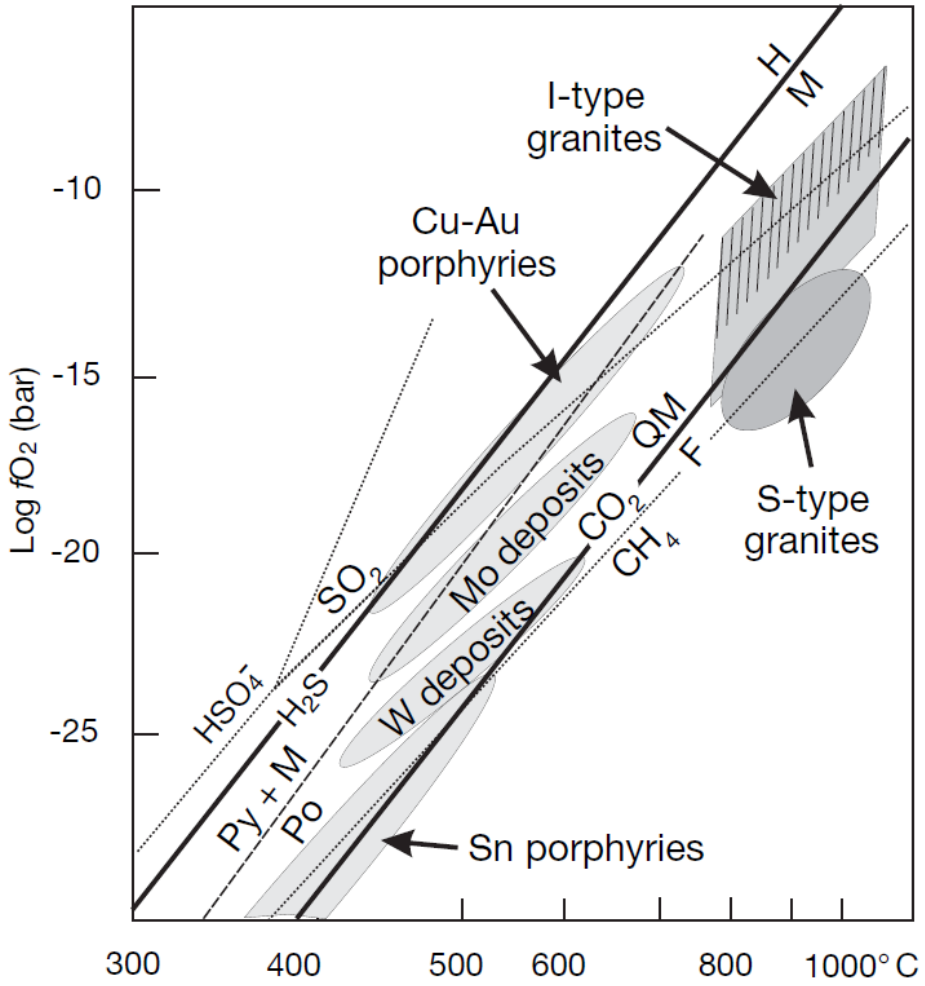




Richards, 2015 after Blevin, 2004

NNEO – relative oxidation state

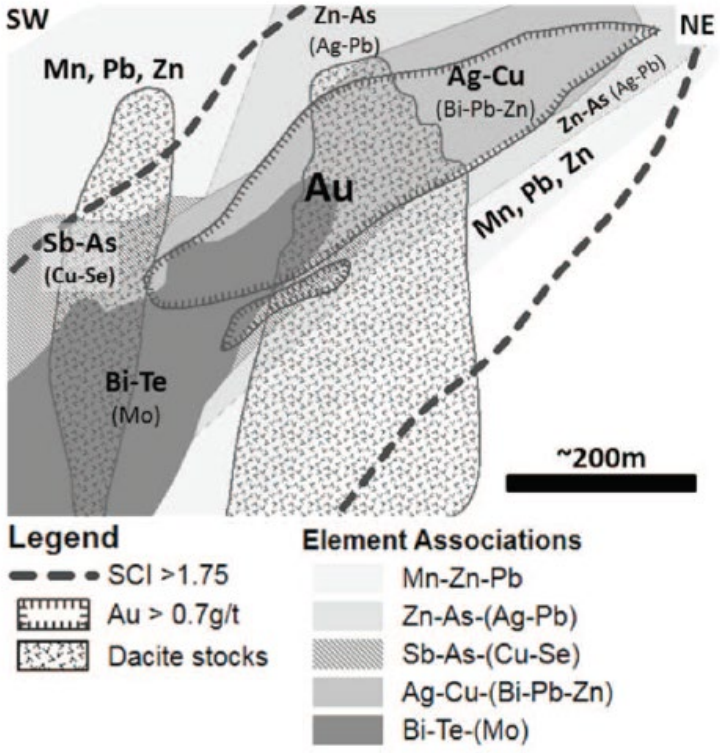


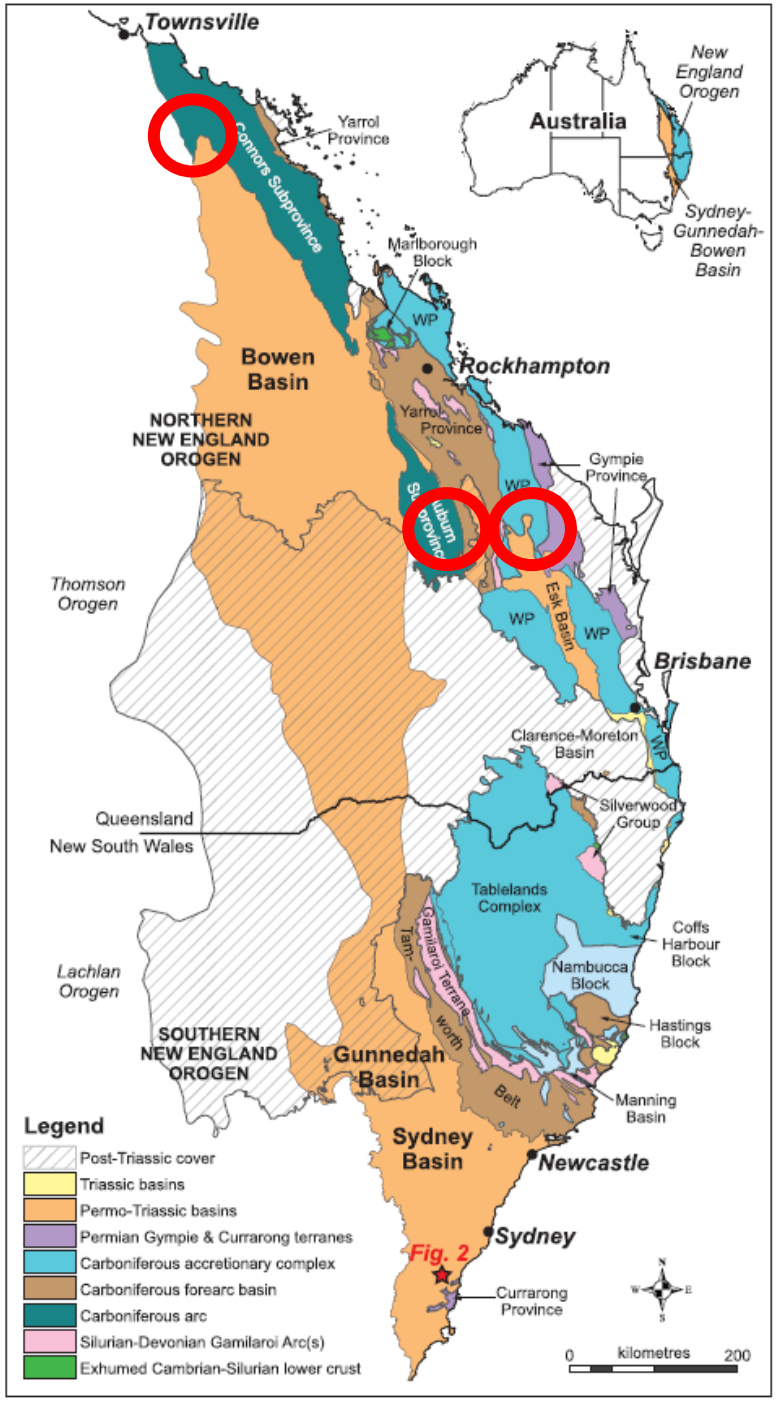


NNEO – Epithermal Systems

- Cracow
  - Conners-Auburn Arc
  - 2.5 Moz Au
  - Repeated reactivation
- Mount Carlton
  - 284 Ma
  - HS to IS characteristics
  - Au-Ag-Cu
- Mount Rawdon
  - Hosted in Triassic volcanics
  - ~50 Mt @ 0.73 Au g/t
  - Interpreted as an epizonal intrusion-related gold deposit (Howard, 2017)

Mount Rawdon





Pike et al., 2017
Dugale & Howard, 2017

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NNEO – Epithermal Systems

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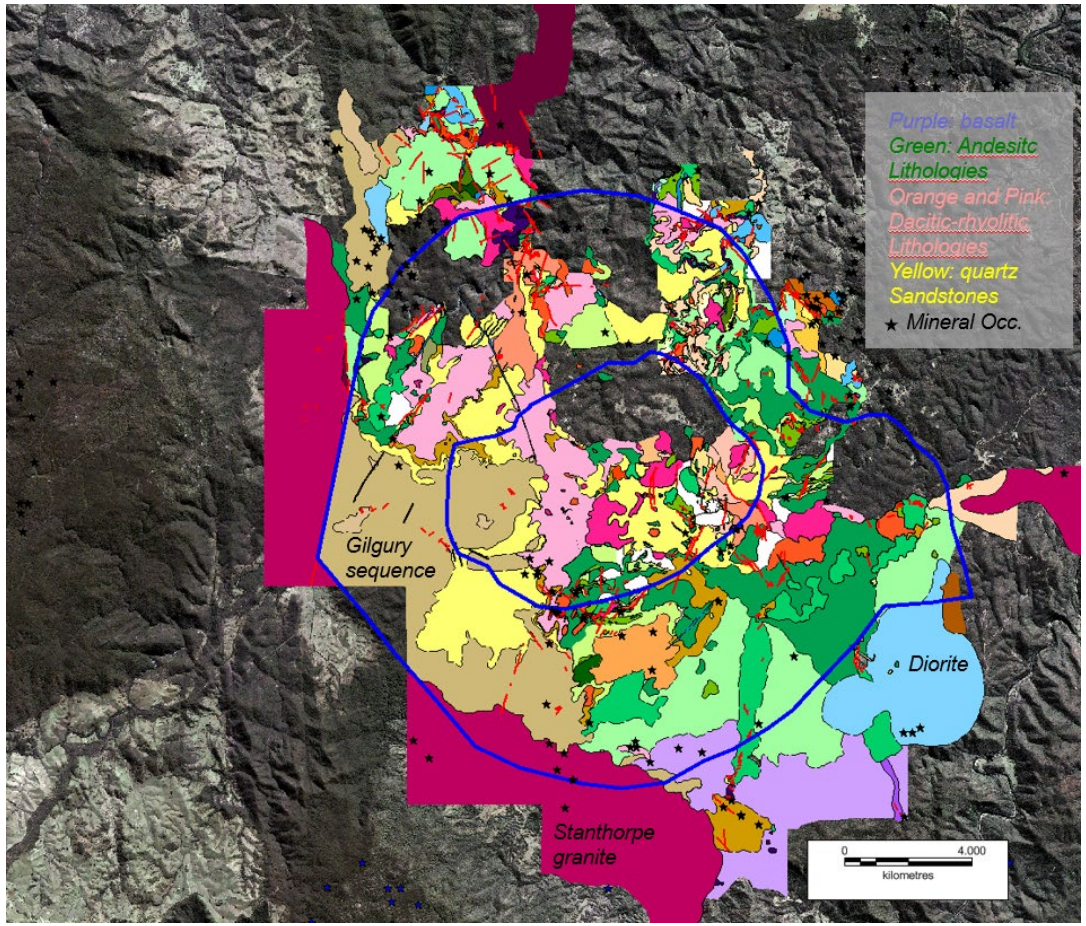
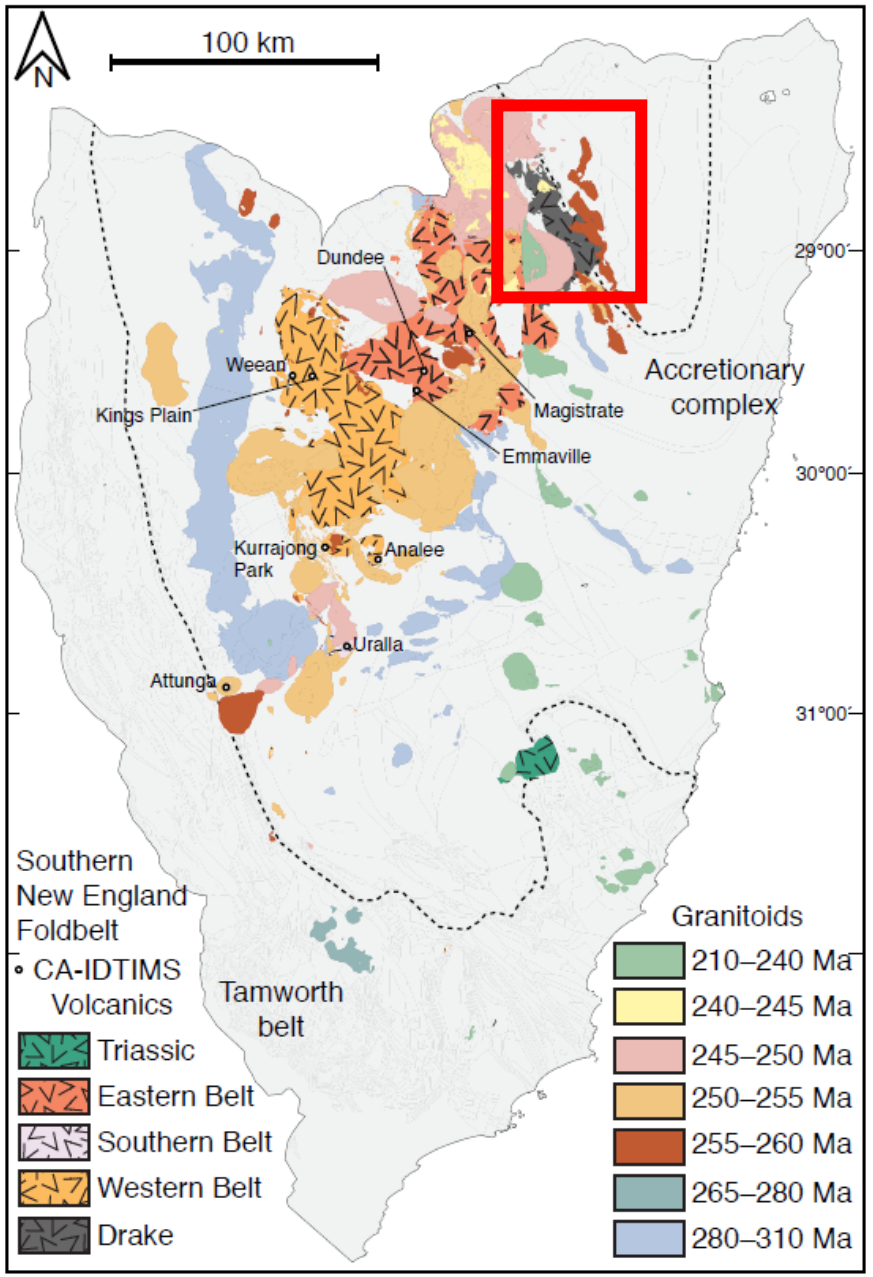
SNEO: Drake Volcanics

- Drake Volcanics are older, and substantially more primitive
- Subaqueous caldera complex
- Work of Grace Cuming





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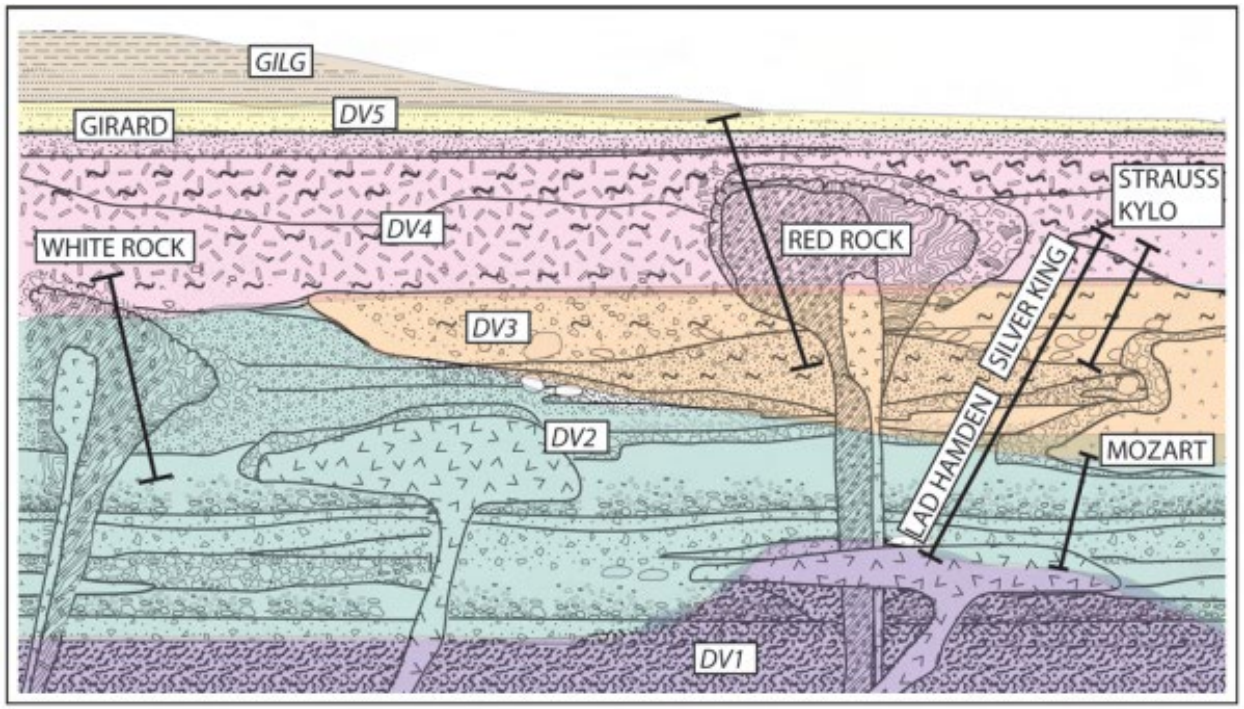
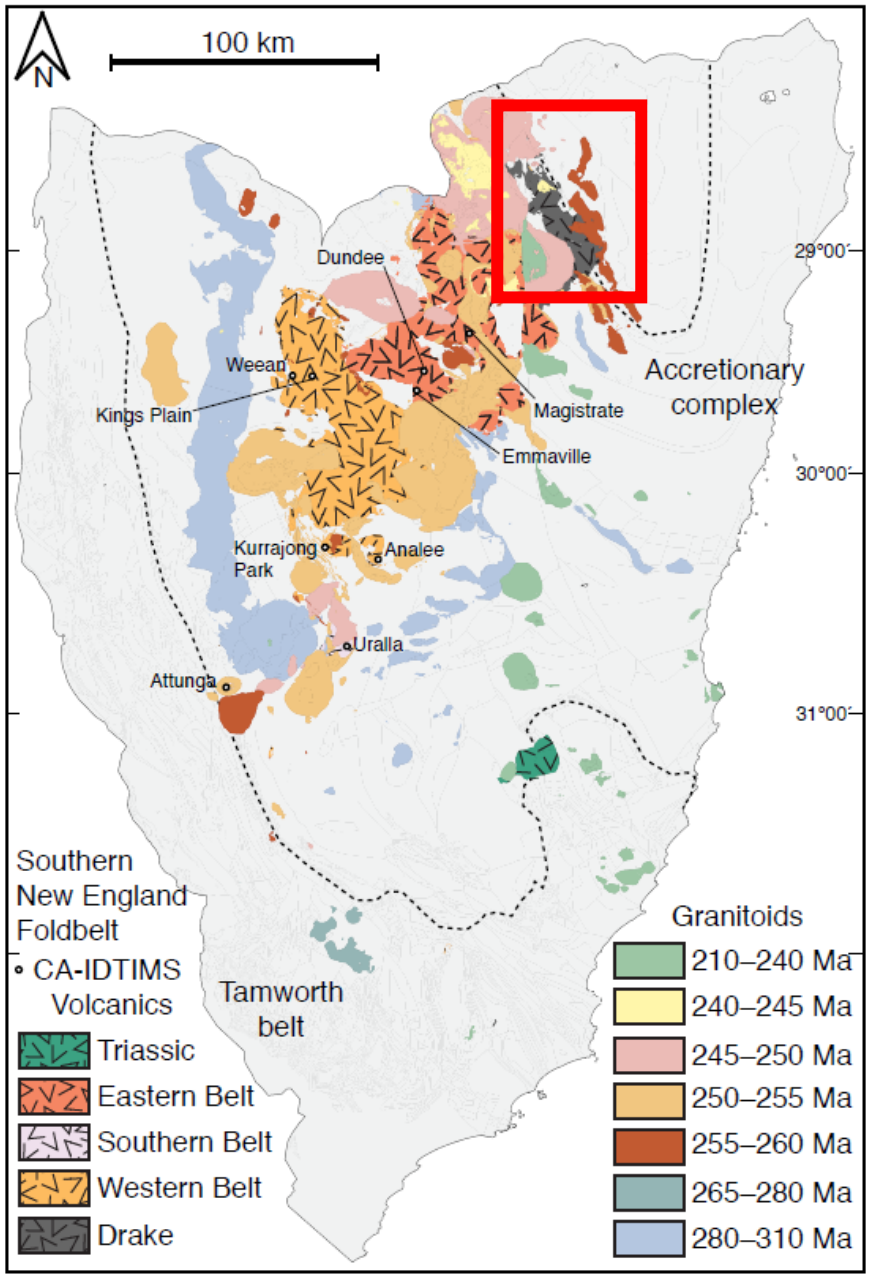
SNEO: Drake Volcanics

- Drake Volcanics are older, and substantially more primitive.
- Subaqueous caldera complex.
- Red Rock: 265.3 ± 1.4 Ma from the Red Rock locality.
- White Rock: 265.3 ± 1.5 Ma for the White Rock locality.
- Mid section sill: 264.4 ± 2.5 Ma sill.

Cross and Blevin, 2010
Waltenberg et al., 2016





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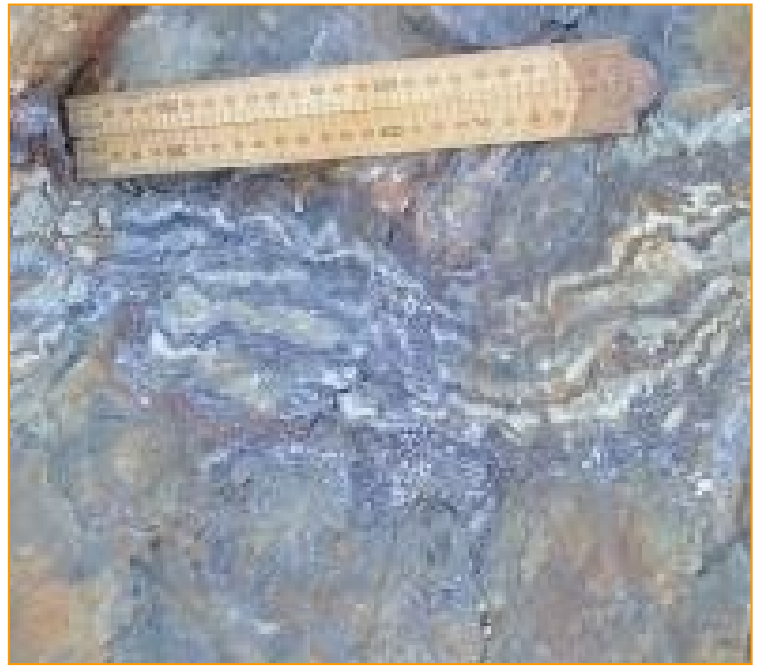
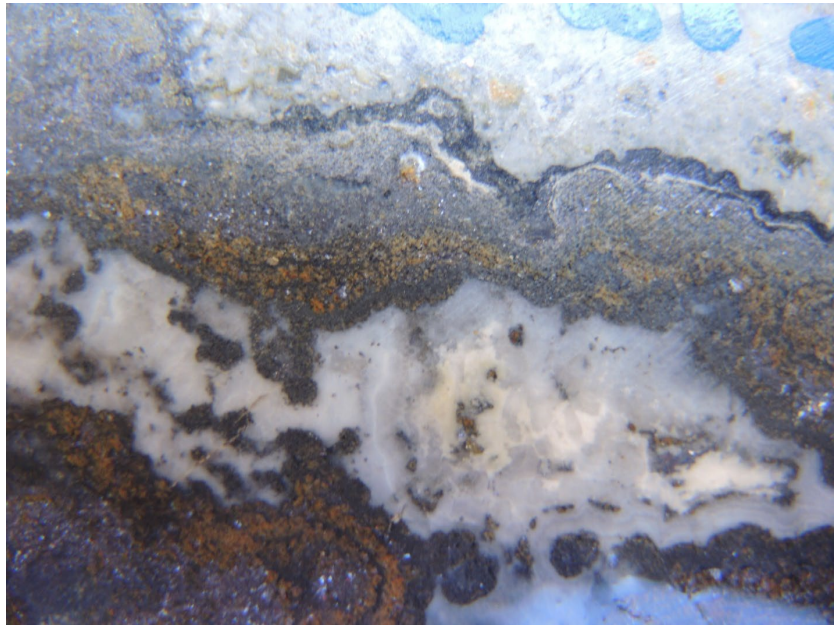
SNEO: Drake Volcanics





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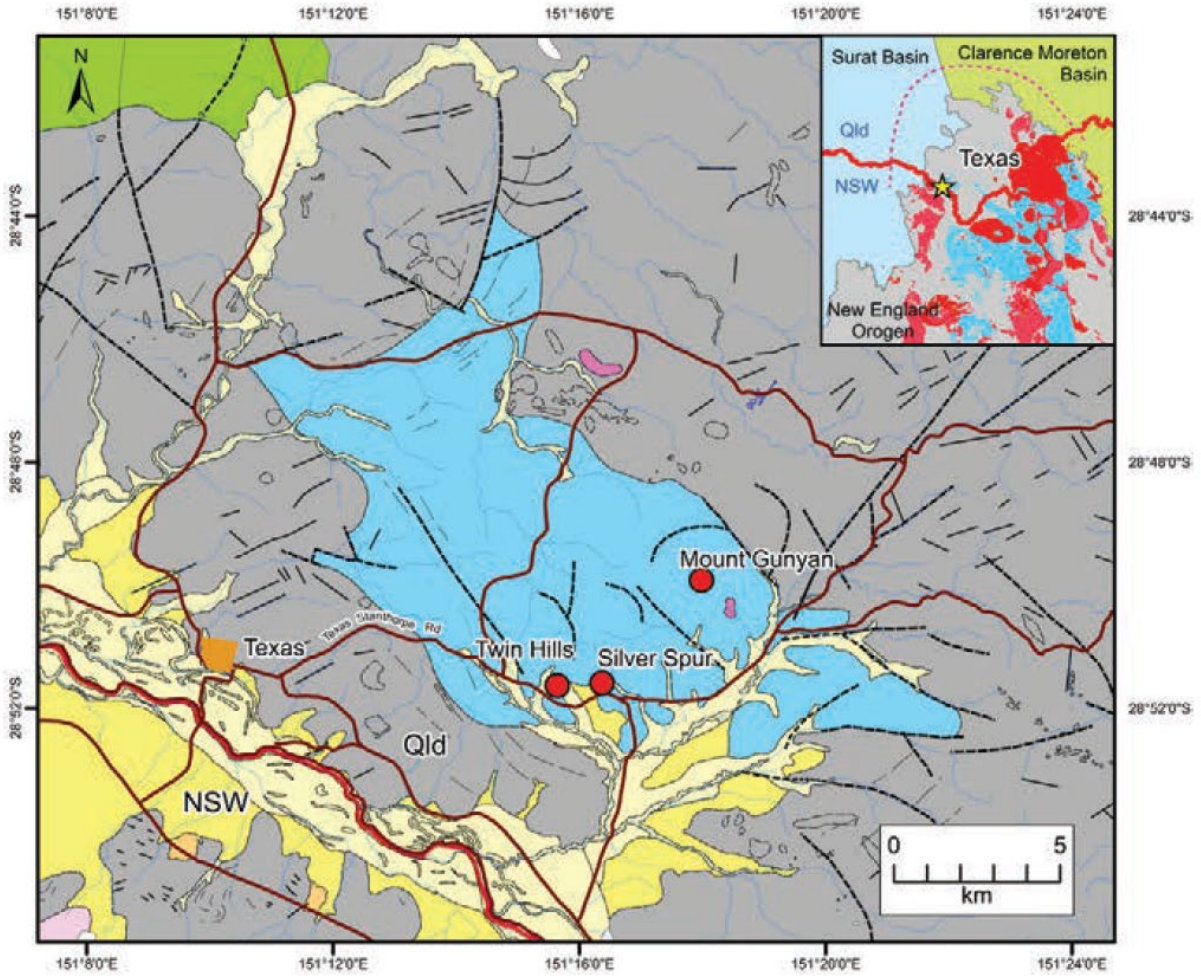
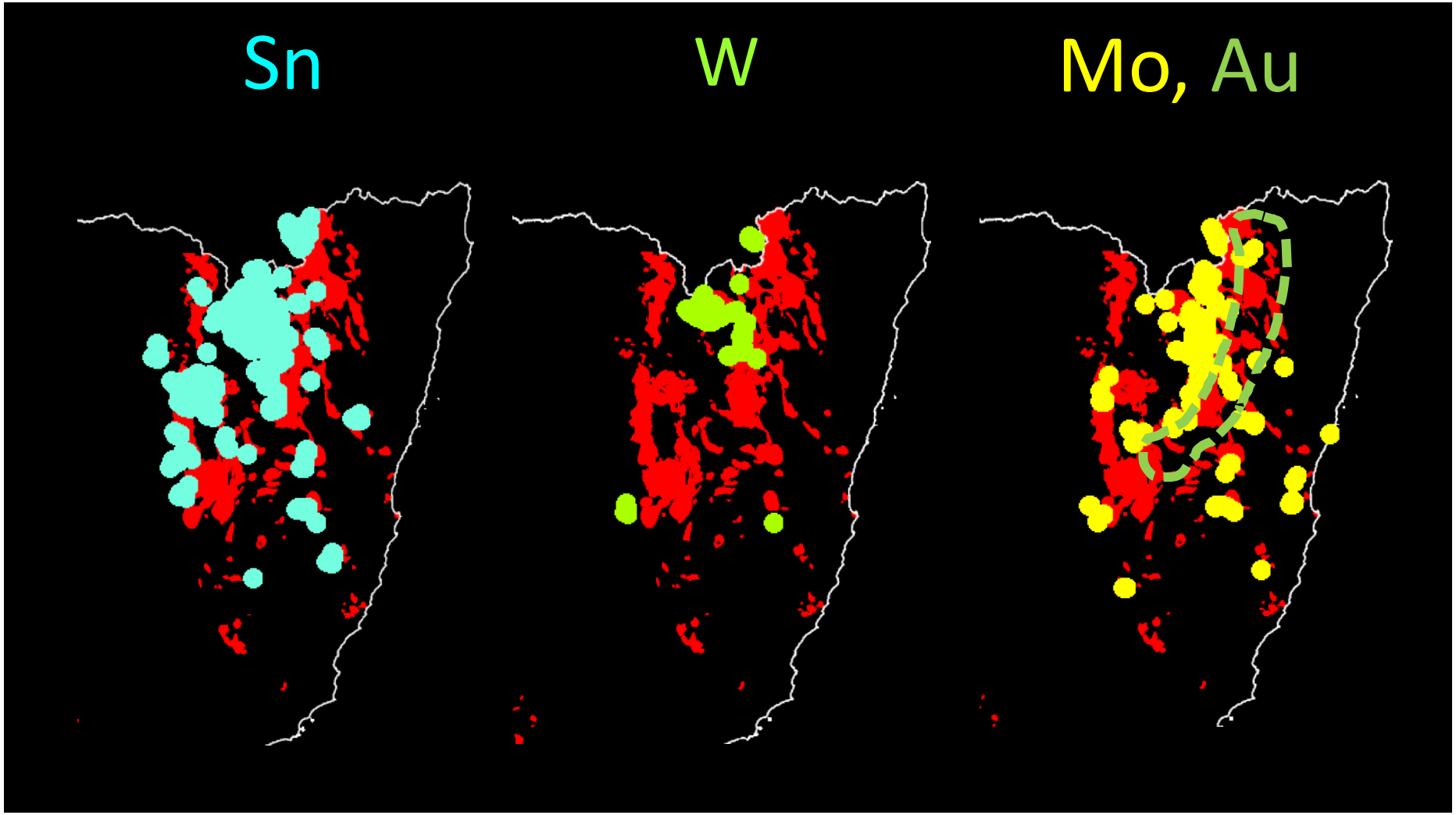
SNEO – Epithermal Ag

- Twin Hill, Mount Gunyan and Silver Spur
- Contained within the Early Permian Silver Spur Basin
- Not related to host volcanics but to younger magmatism
- **Ag also in granite deposits**



Halloran et al., 2017

SNEO – Igneous Metallogeny



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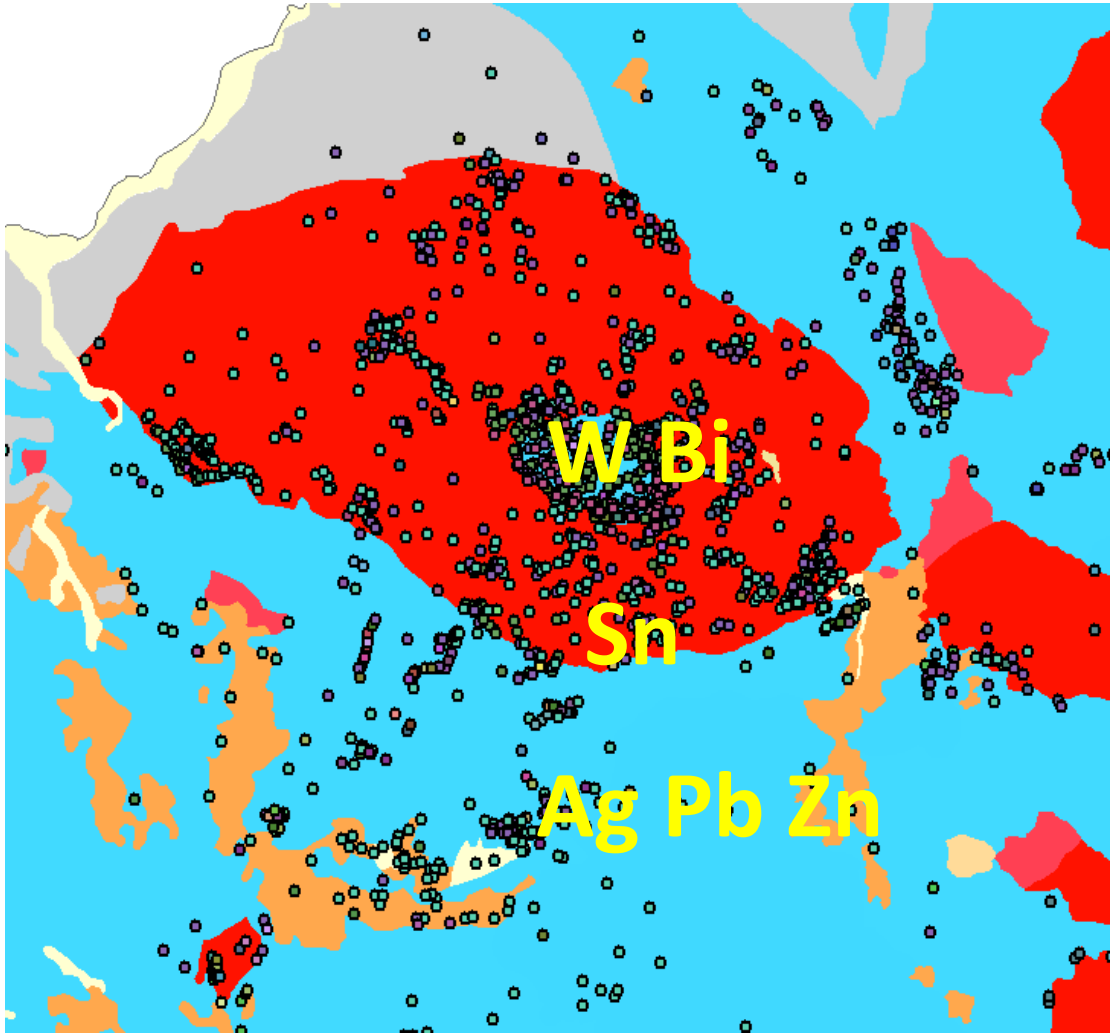
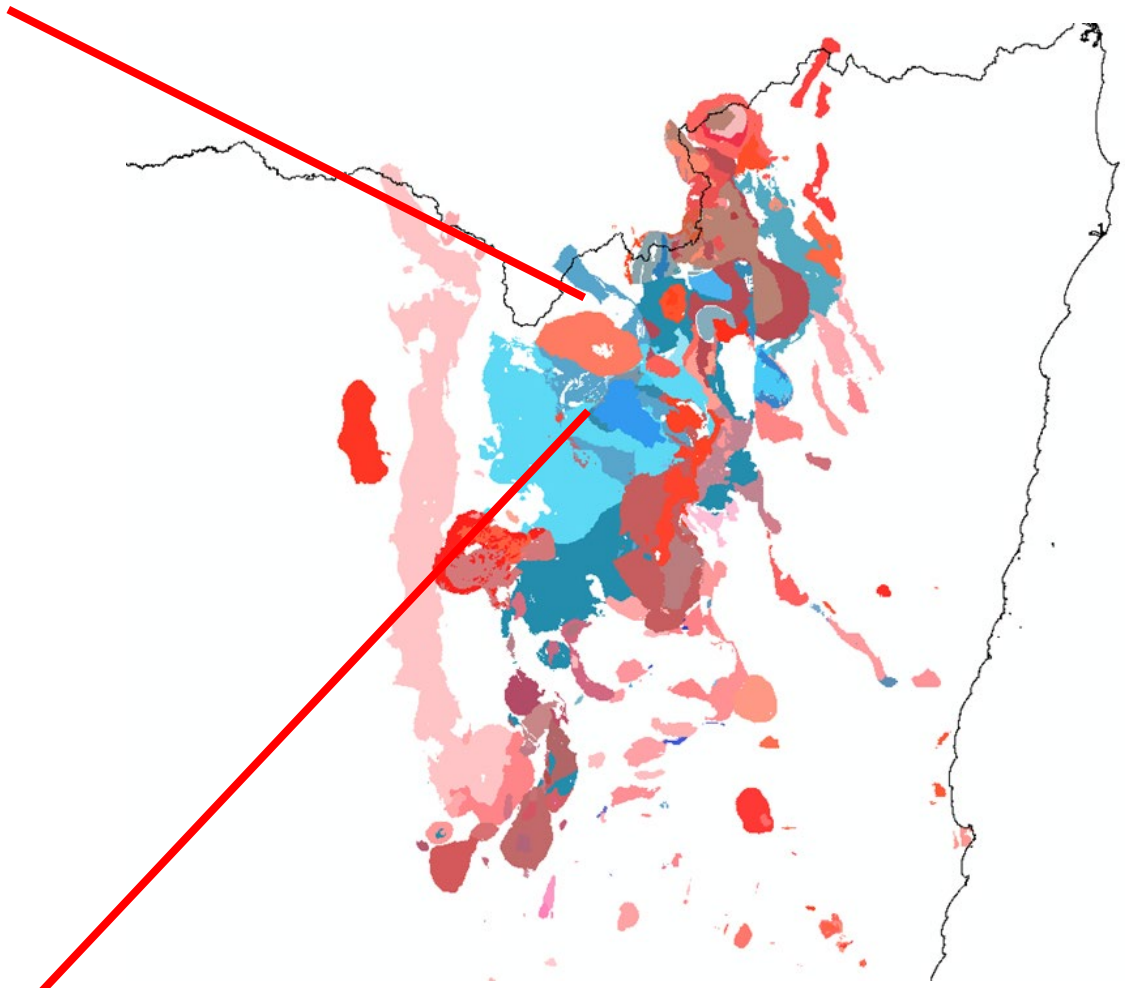
SNEO: Mole Granite





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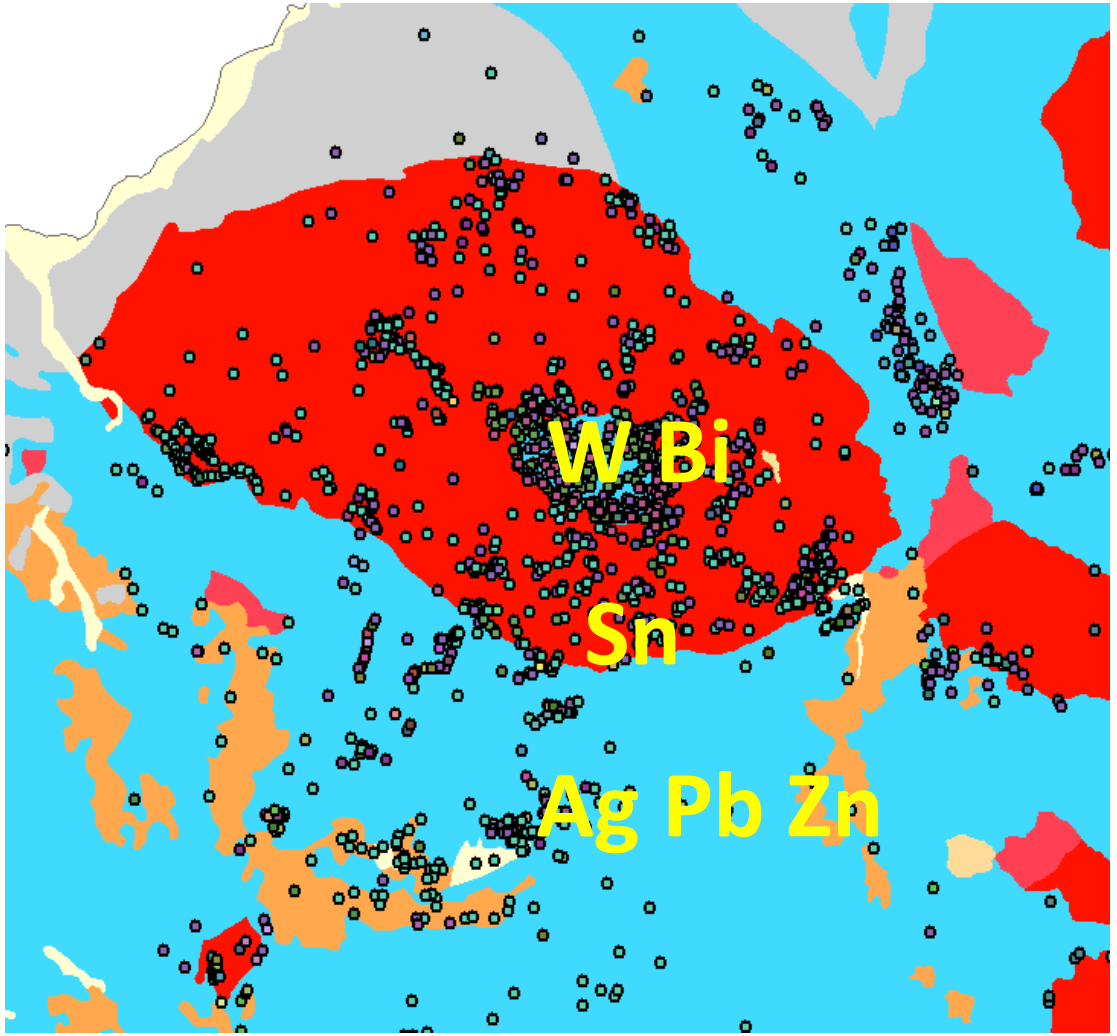
SNEO – Igneous metallogeny



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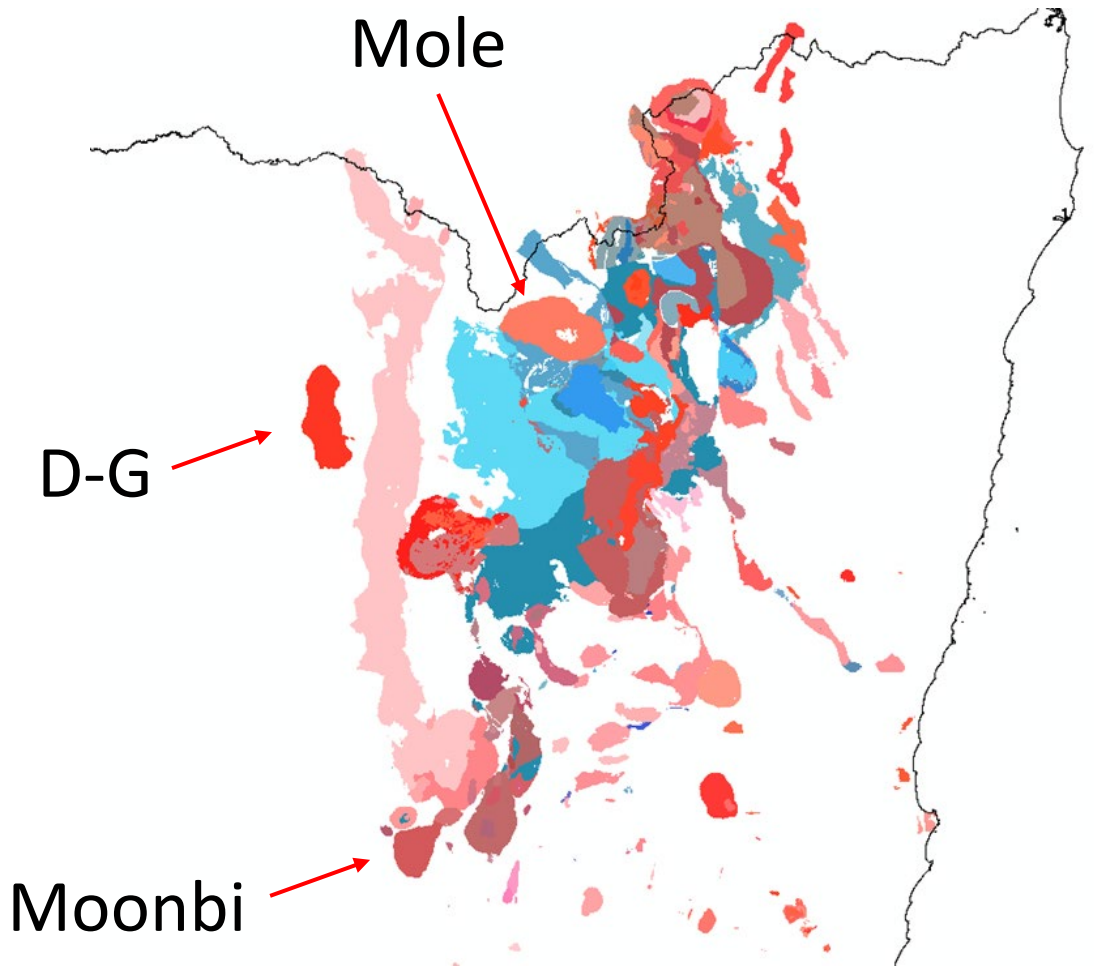
SNEO: Mole - good, different

$\delta^{18}O_{zrn}$

• **CRSS, Drake Volcanics:**	**5.9 to 6.8, 5.2**	**Ag Au Cu**
• **Leucogranites:**	**6.7 to 7.2**	**Mo Bi Au**
• **Moonbi SS:**	**6.9 to 7.8**	**W Mo**
• **Mole**	**8.1**	**Sn W Ag As**
• **S-types:**	**10.0 to 11.5**	**Sn**
• **Dumboy-Gragin**	**8.0**	**Sn As**

- The Mole Granite is distinct in terms of source.
- It is not an extreme fractionate of other I-types.
- Explains higher B, Li, F and reduced character.
- Dumboy-Gragin has similar characteristics



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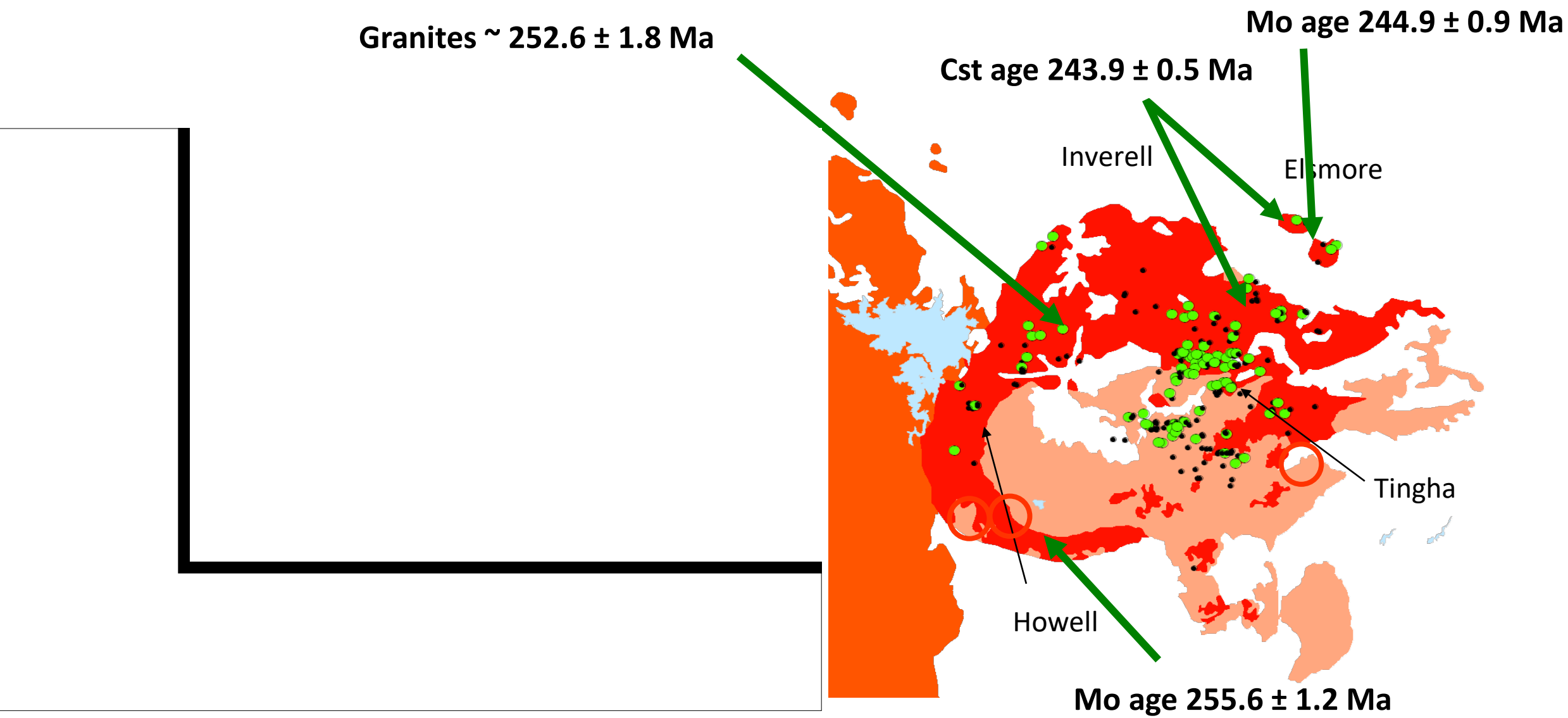
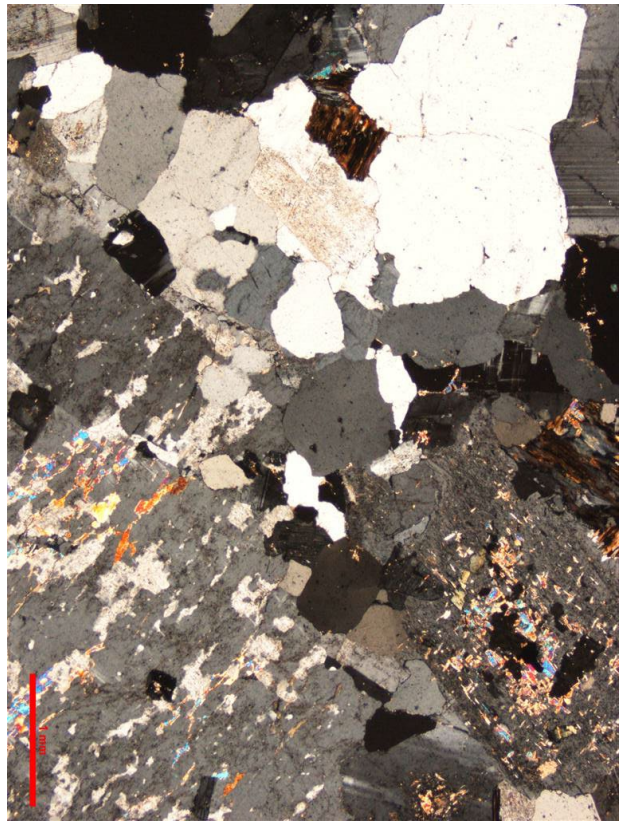
SNEO – Understanding Sn (Ag, In)

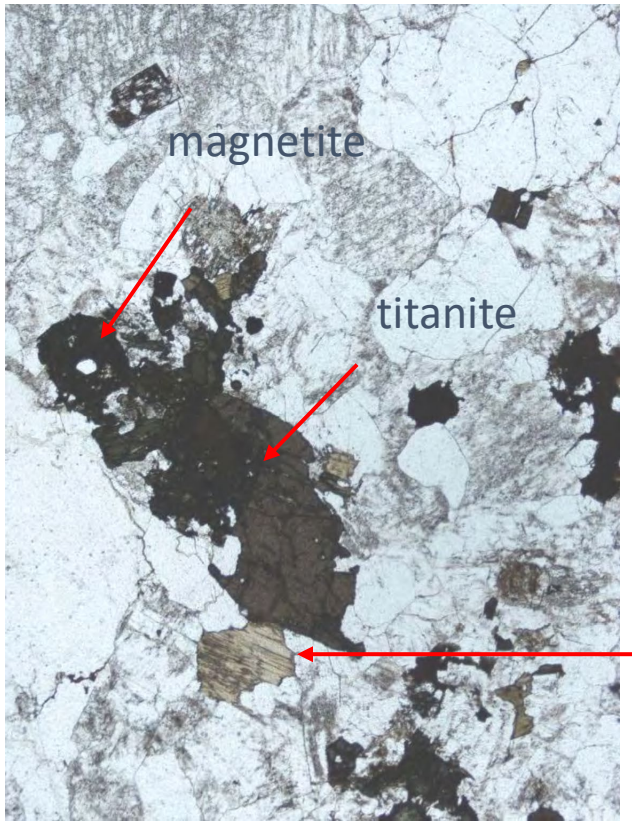


Pick the tin granite

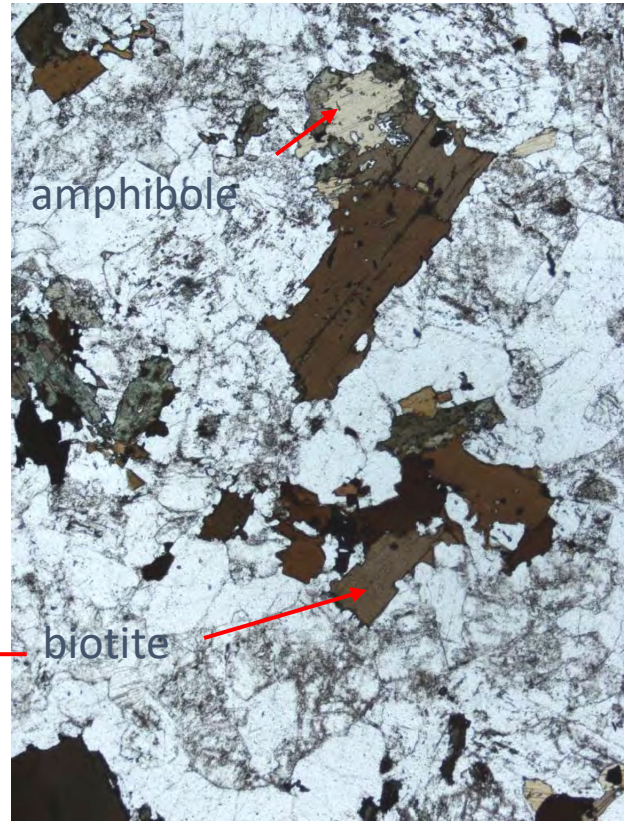
FOV = 7 mm



Elsmore



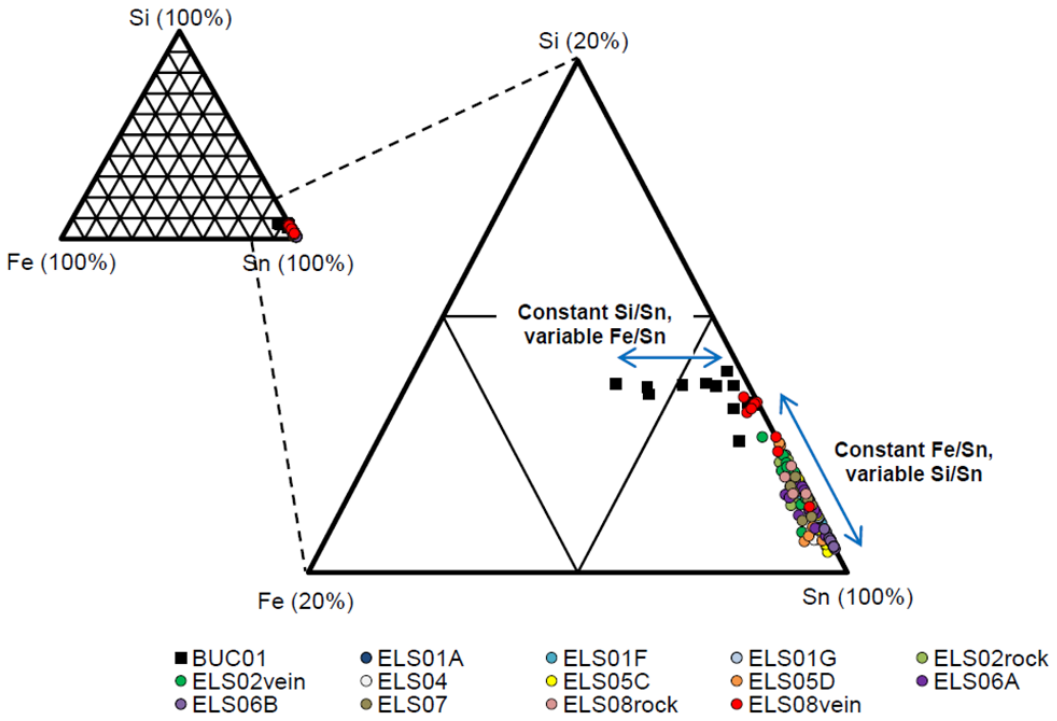
Gilgai

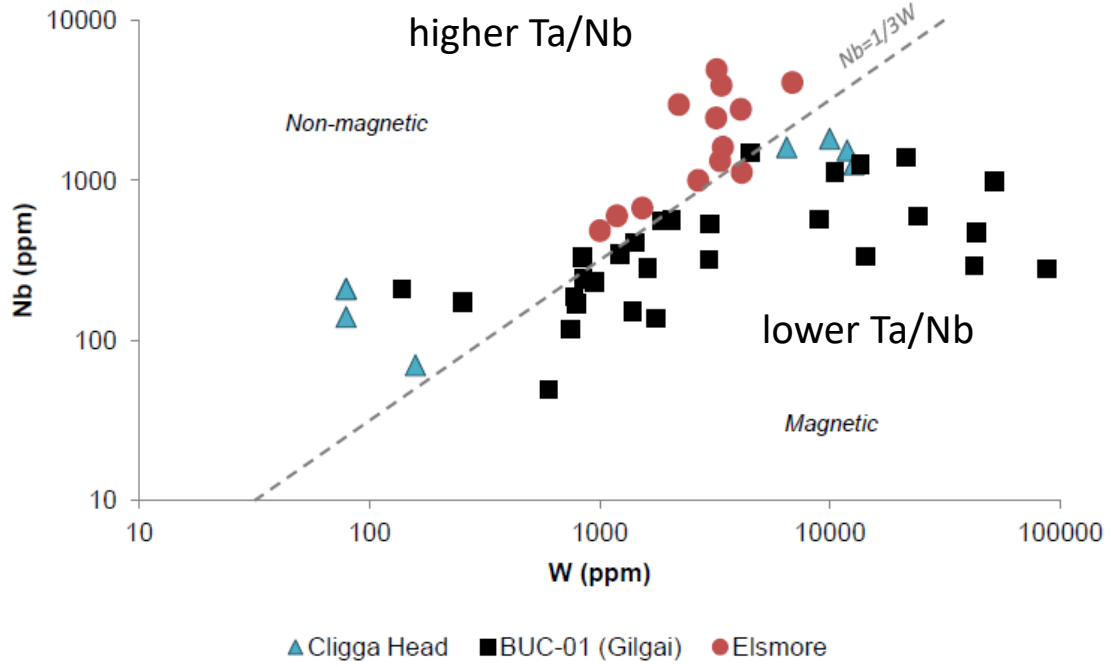


Tingha

Magnetic cassiterite

Site occupancies for Sn, Si and Fe in cassiterite samples from Tingha–Gilgai. Note the occurrence of two chemically distinct populations with opposing compositional vectors.

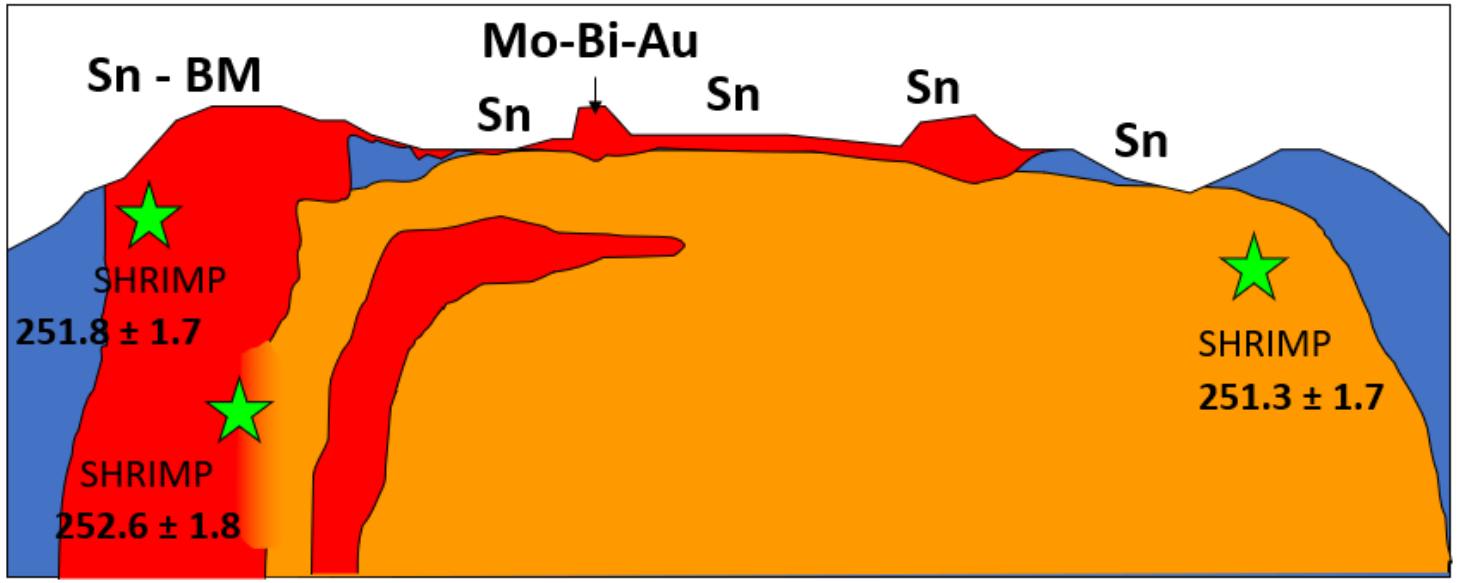


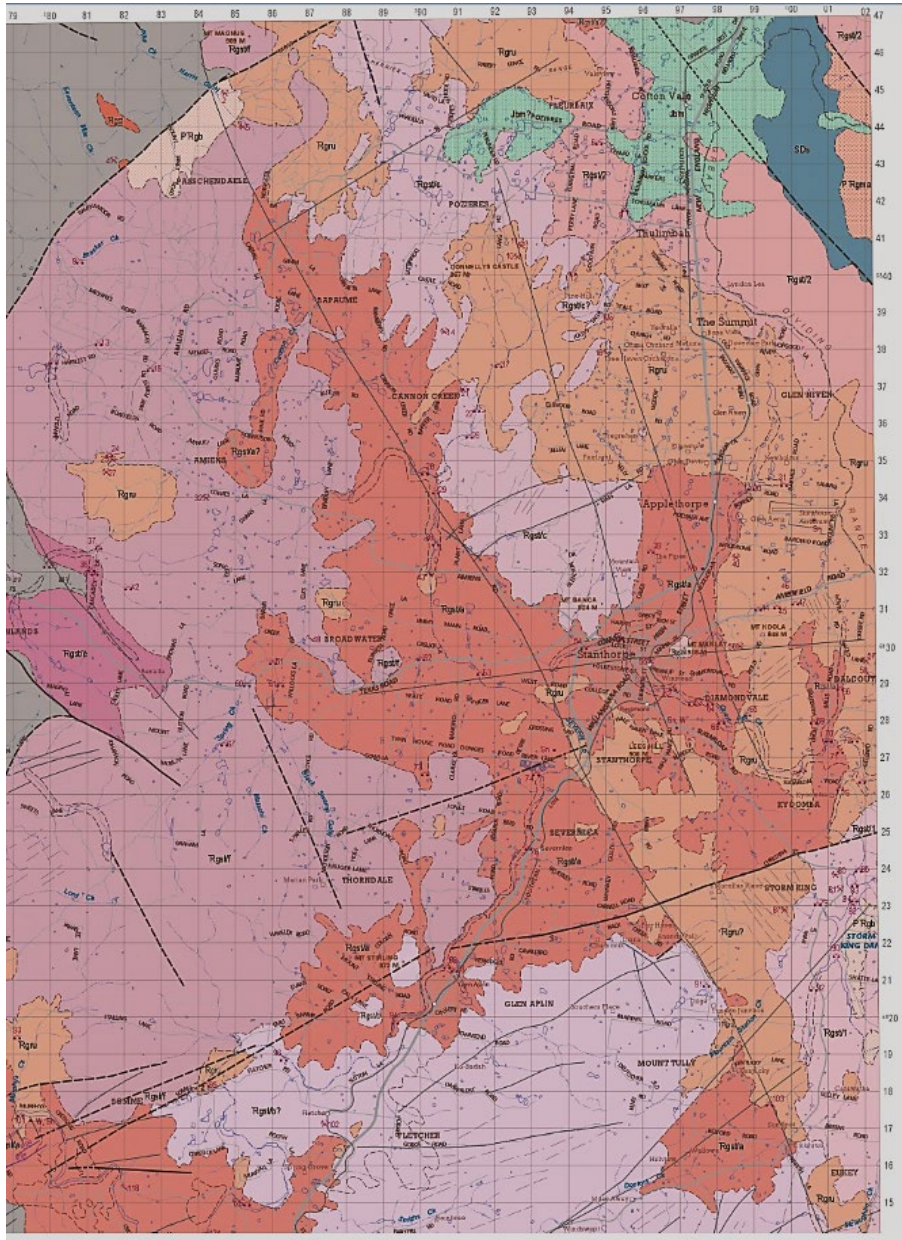


Nb/W ratio defines a potential compositional threshold of Nb=1/3W differentiating between magnetic and non-magnetic cassiterites from Cligga Head, Elsmore and Gilgai.

SNEO: The granite - volcanic connection

Tingha – Gilgai System





Queensland Government

STANTHORPE
BASEMENT GEOLOGY
SHEET 9240
COMPILATION MAP

The geology on this map depicts data from the current MinesOnline geodatabase release.
Compiled on 30 August 2018

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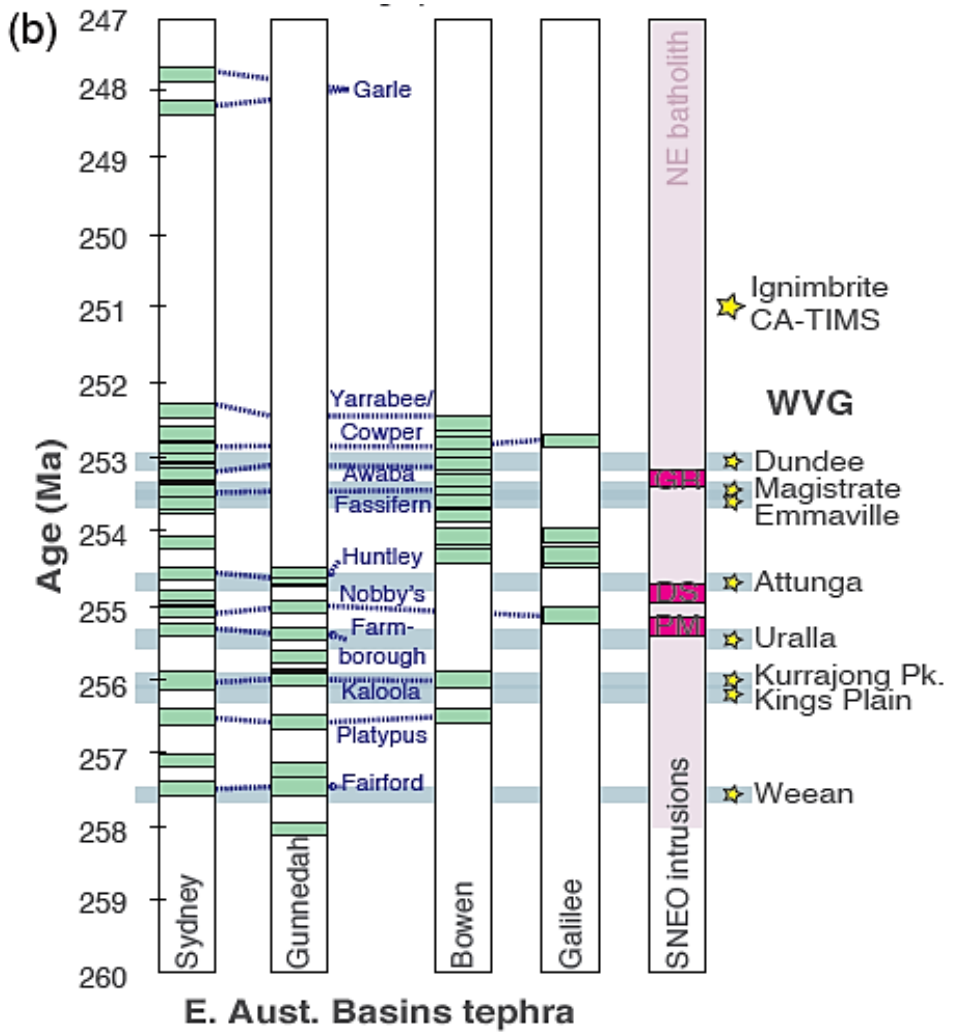
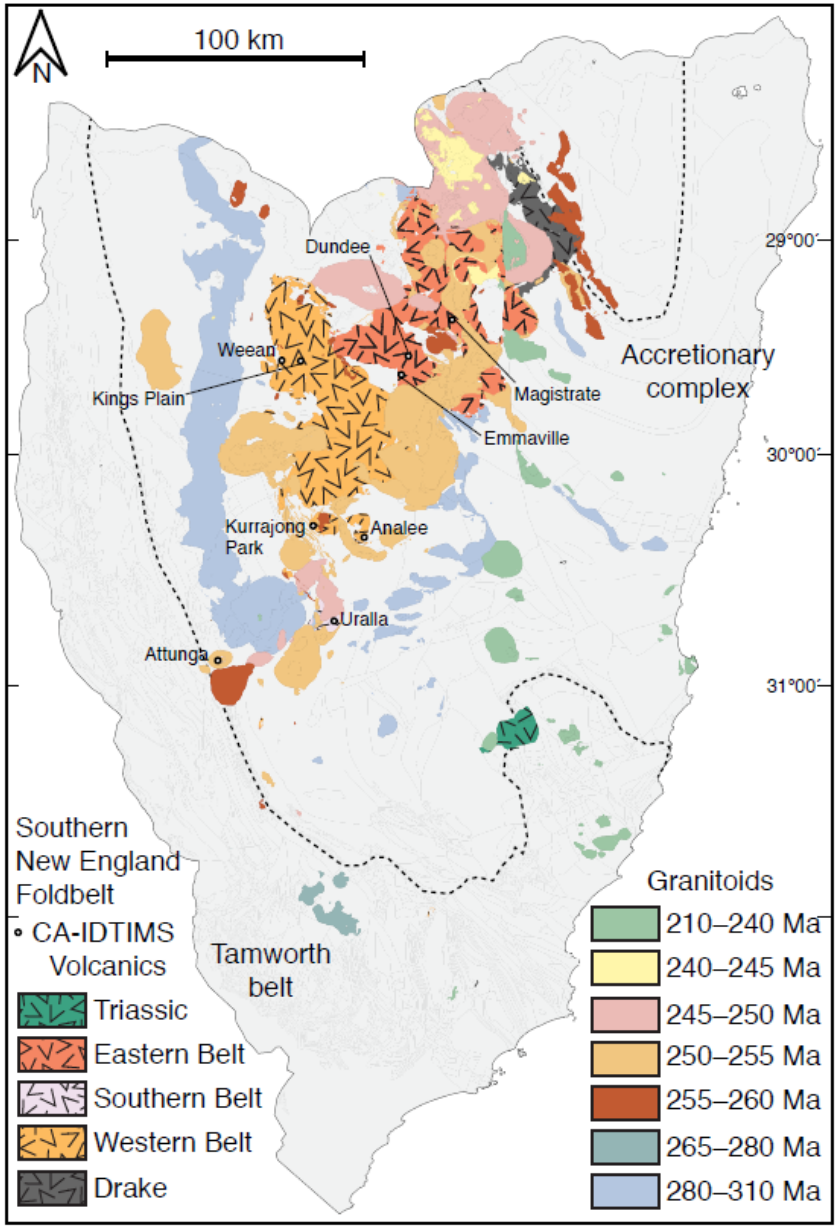
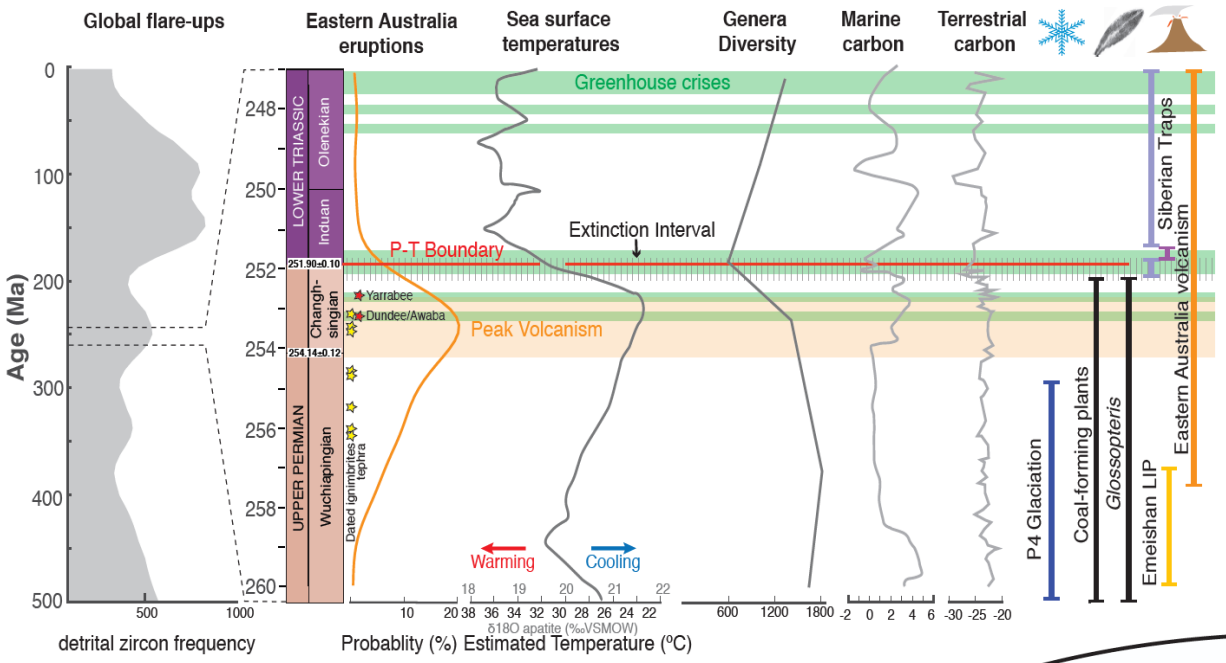
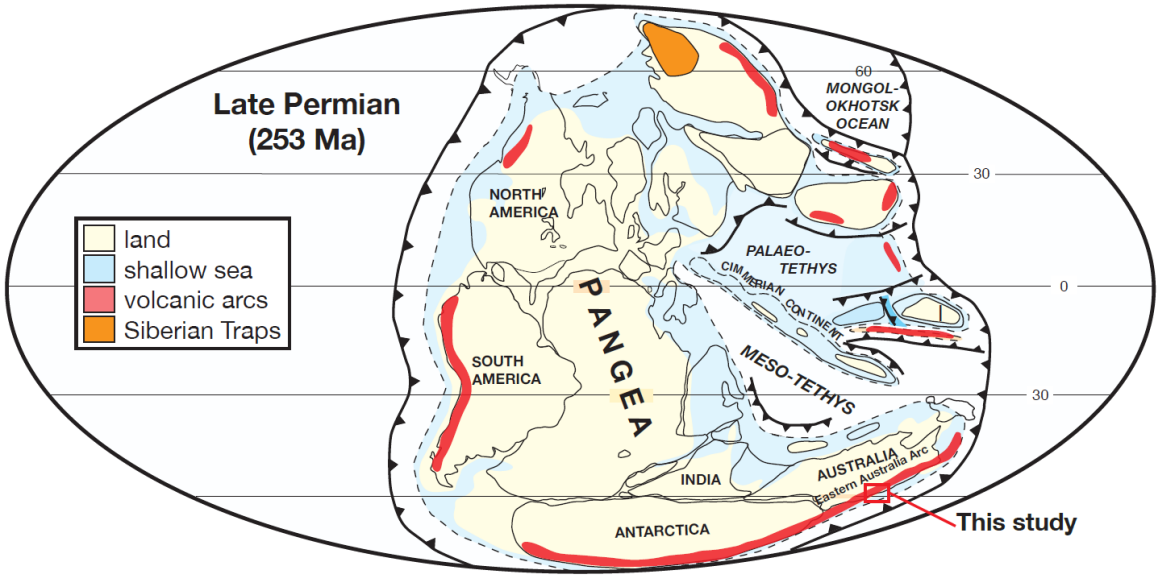
SNEO: The granite - volcanic connection

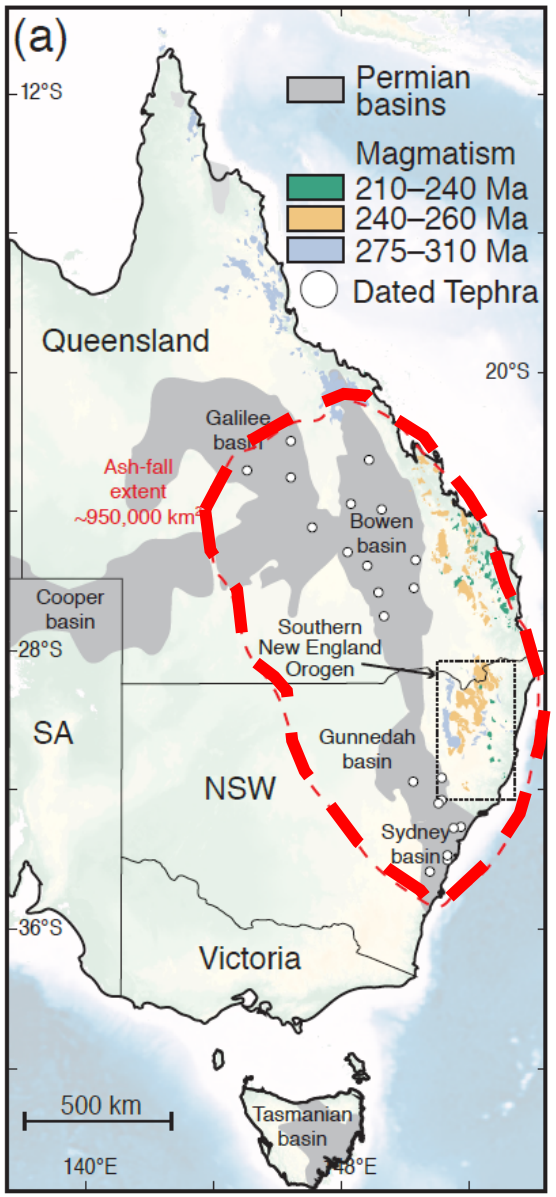




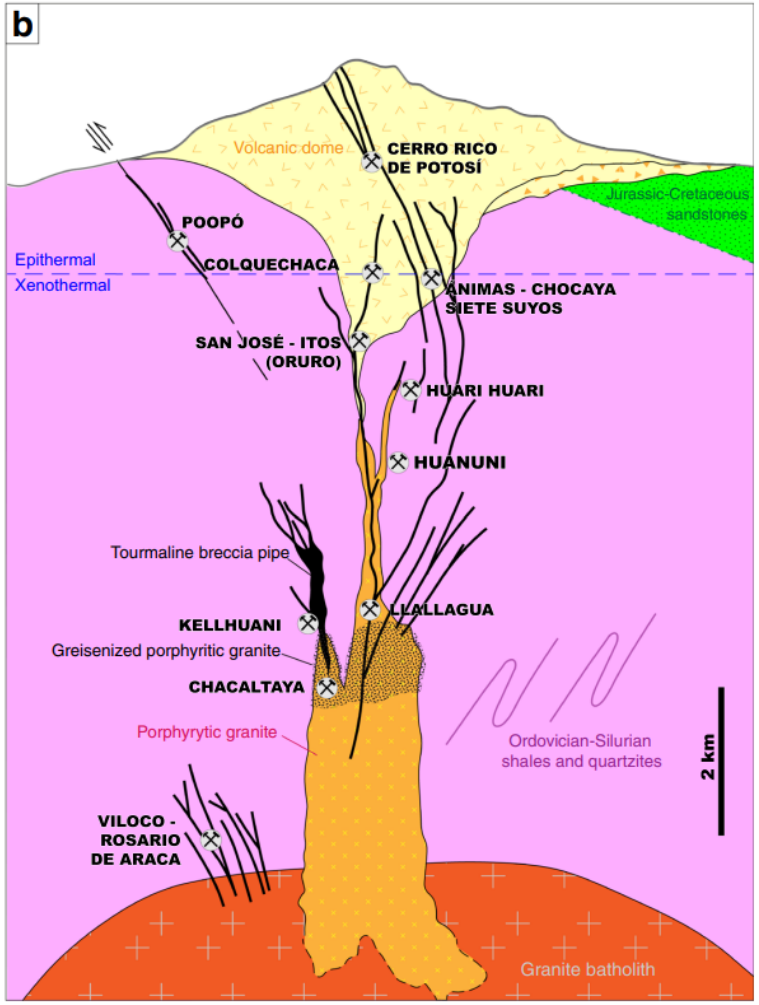
SNEO: The granite - volcanic connection

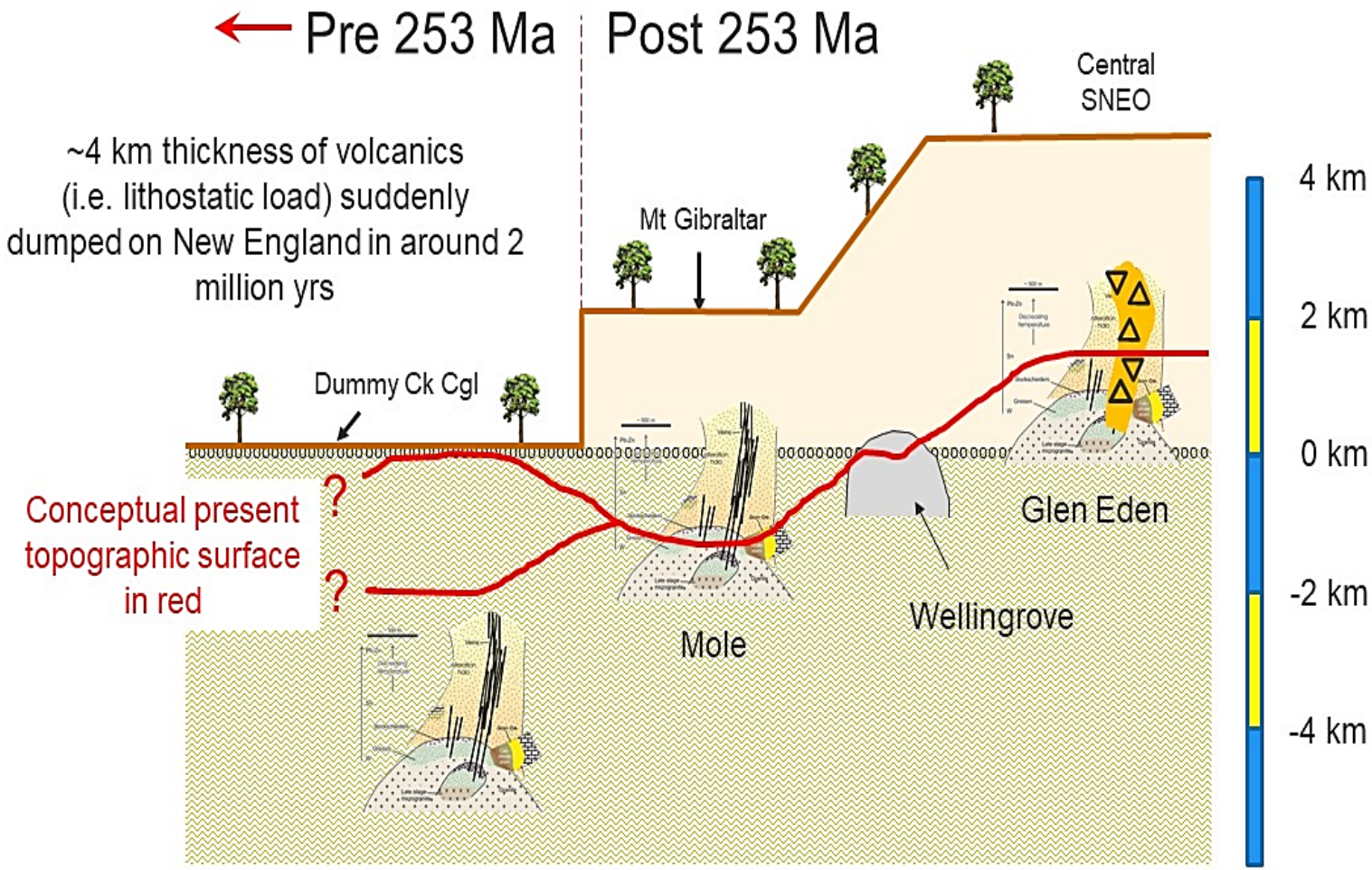






Porphyry Sn - Glen Eden





Gemmrich et al, 2021.

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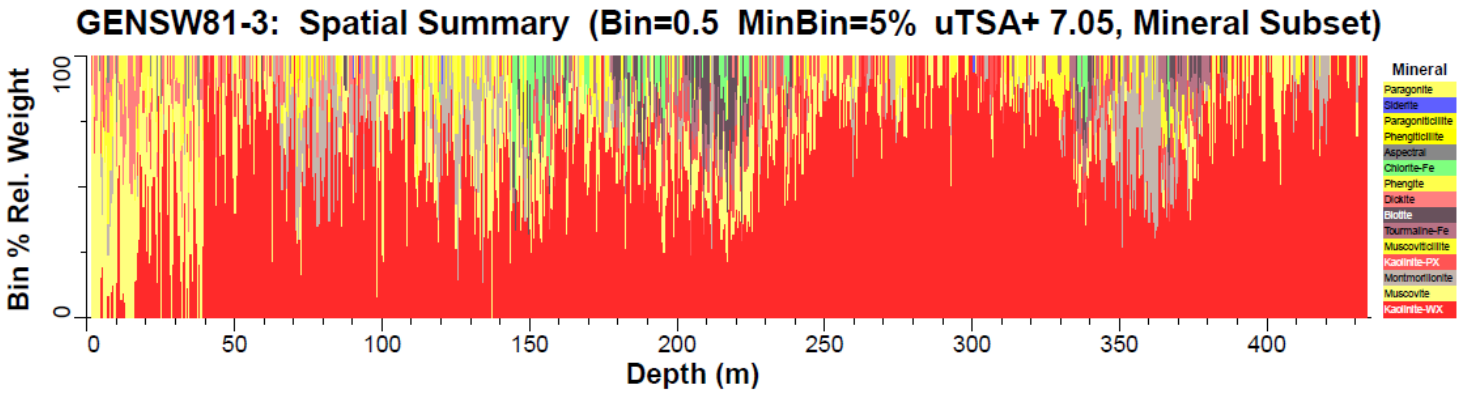
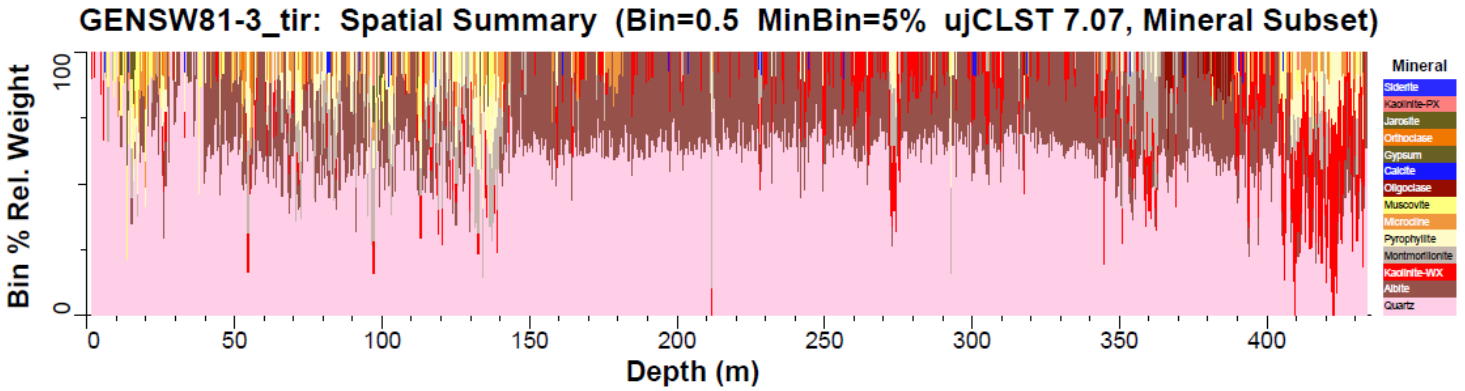
Porphyry Sn - Glen Eden

- Breccia hosted Sn-W-Mo-Bi deposit
- Microporphyry intrusions = 243.8 Ma (CA-IDTIMS).
- Similar to that of the Ruby Creek and the Brassington ring dyke (SE of Tenterfield).





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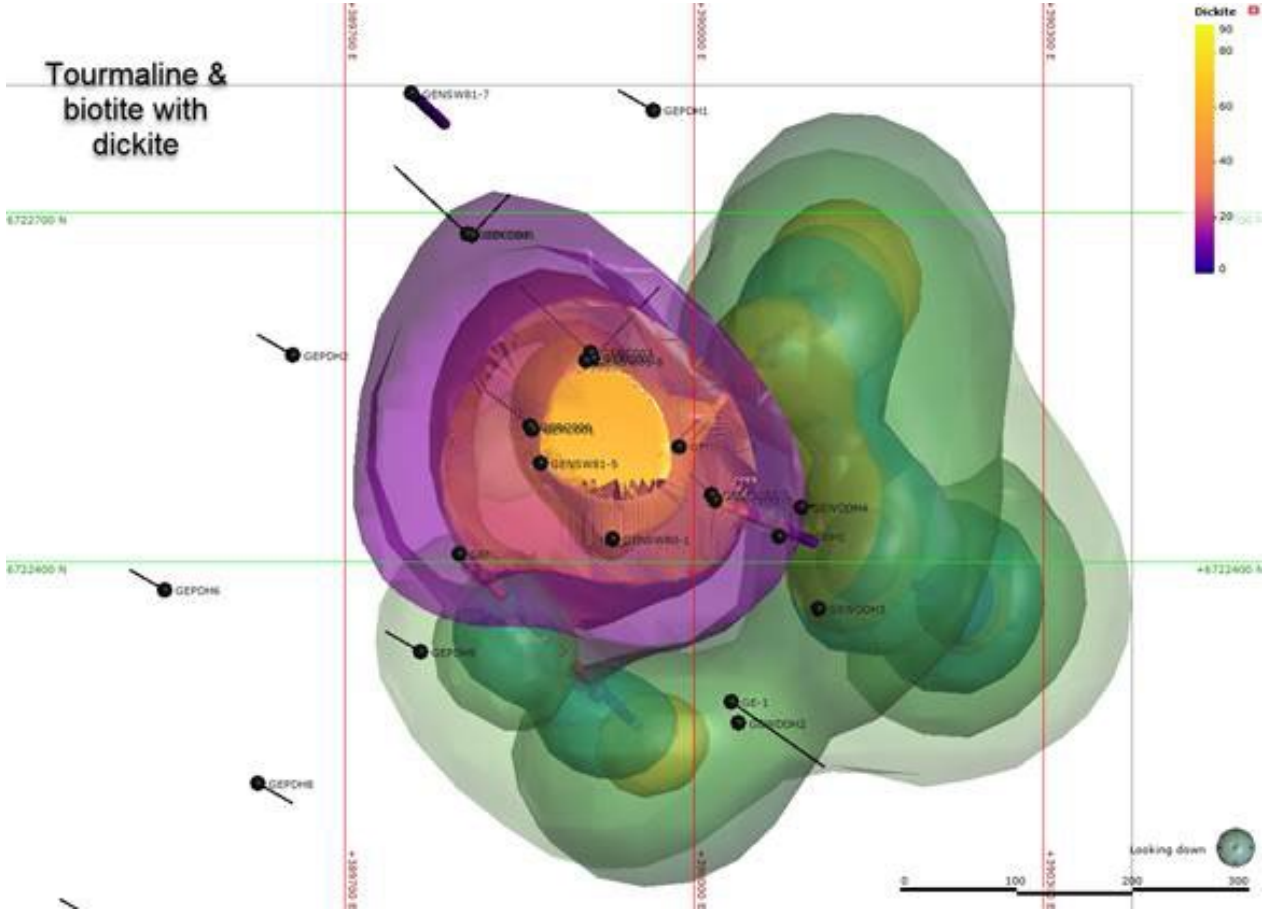
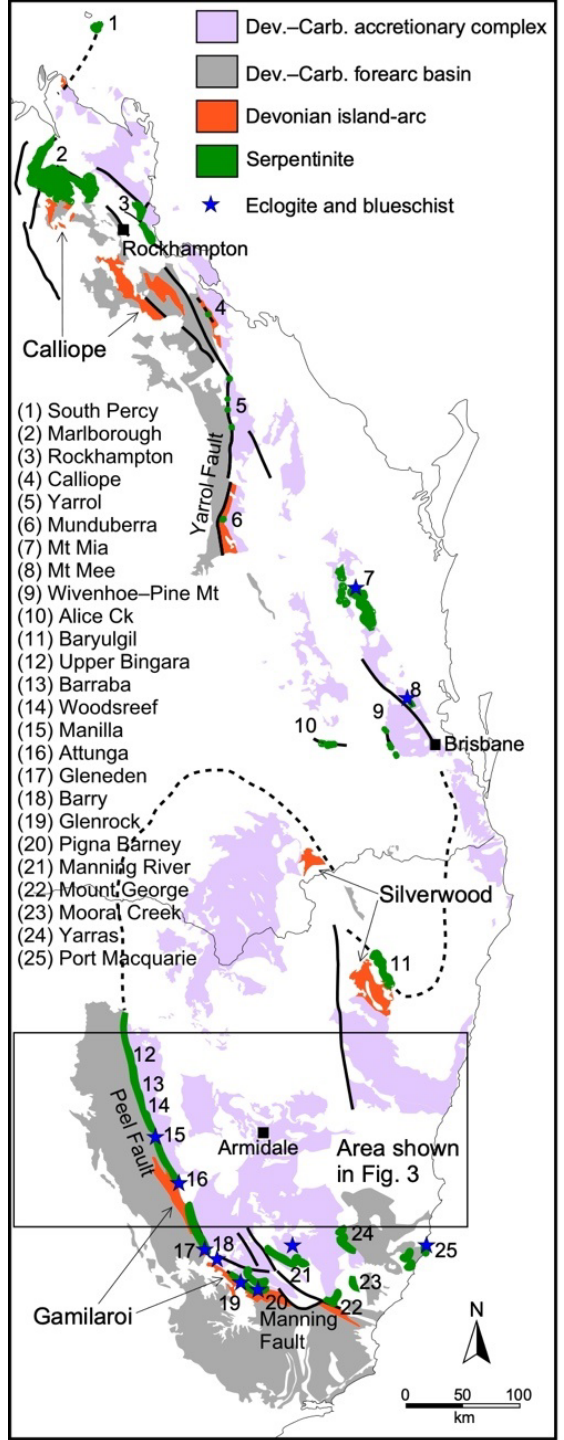
Porphyry Sn - Glen Eden



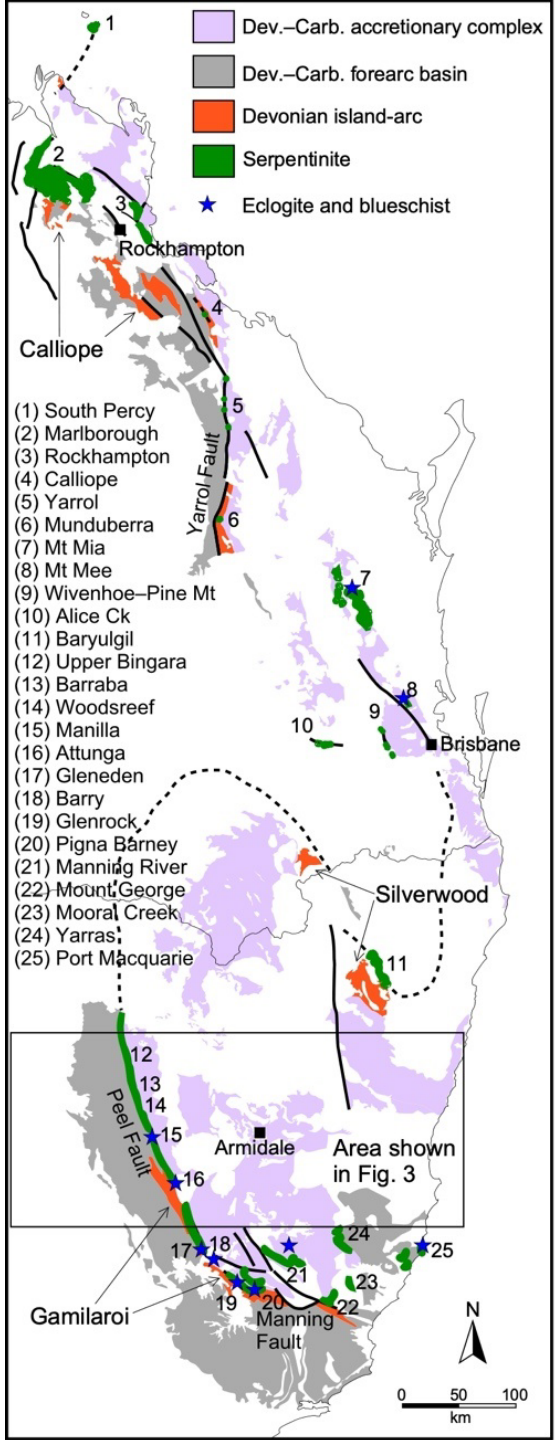
E. Australian Ophiolite Belt (EAOB)

- Within the New England Orogen (NEO)
- Most ultramafic and high-pressure (HP) rocks occur along a narrow belt coinciding with major fault systems (Yarrol, Peel, Manning) that separate Devonian–Carboniferous forearc basin units from accretionary complex units of similar age.
- Evidence of an earlier (Cambrian–Ordovician) history of subduction processes
  - late Neoproterozoic–Cambrian ages of ophiolitic material
  - Ordovician HP metamorphic ages
- Early Permian ophiolite ages (Barraba, Percy)
- Devonian oceanic terranes (Calliope, Silverwood, Gamilaroi)
  - Accreted after ocean closure?



E. Australian Ophiolite Belt (EAOB)

- Exhumed mantle wedge serpentinites in accretionary prism (no ophiolite)
- Subduction complex melange scraped off the downgoing plate (orogenesis without collision)
- Ophiolitic suture (closure of an intervening ocean and terrane accretion)



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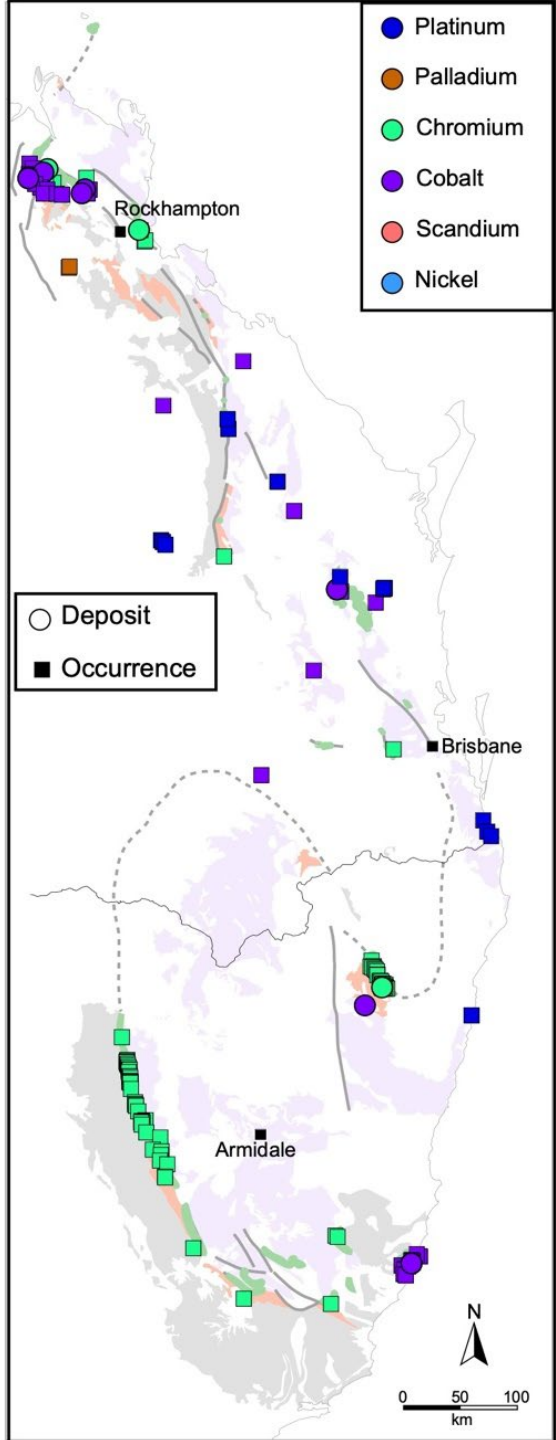
Critical metals in the EAOB

57.30 Mt of proved and probable ore reserves grading 0.58% nickel, 0.10% cobalt, and 33 parts per million (ppm) of scandium. HULEATT, M. B. 2019



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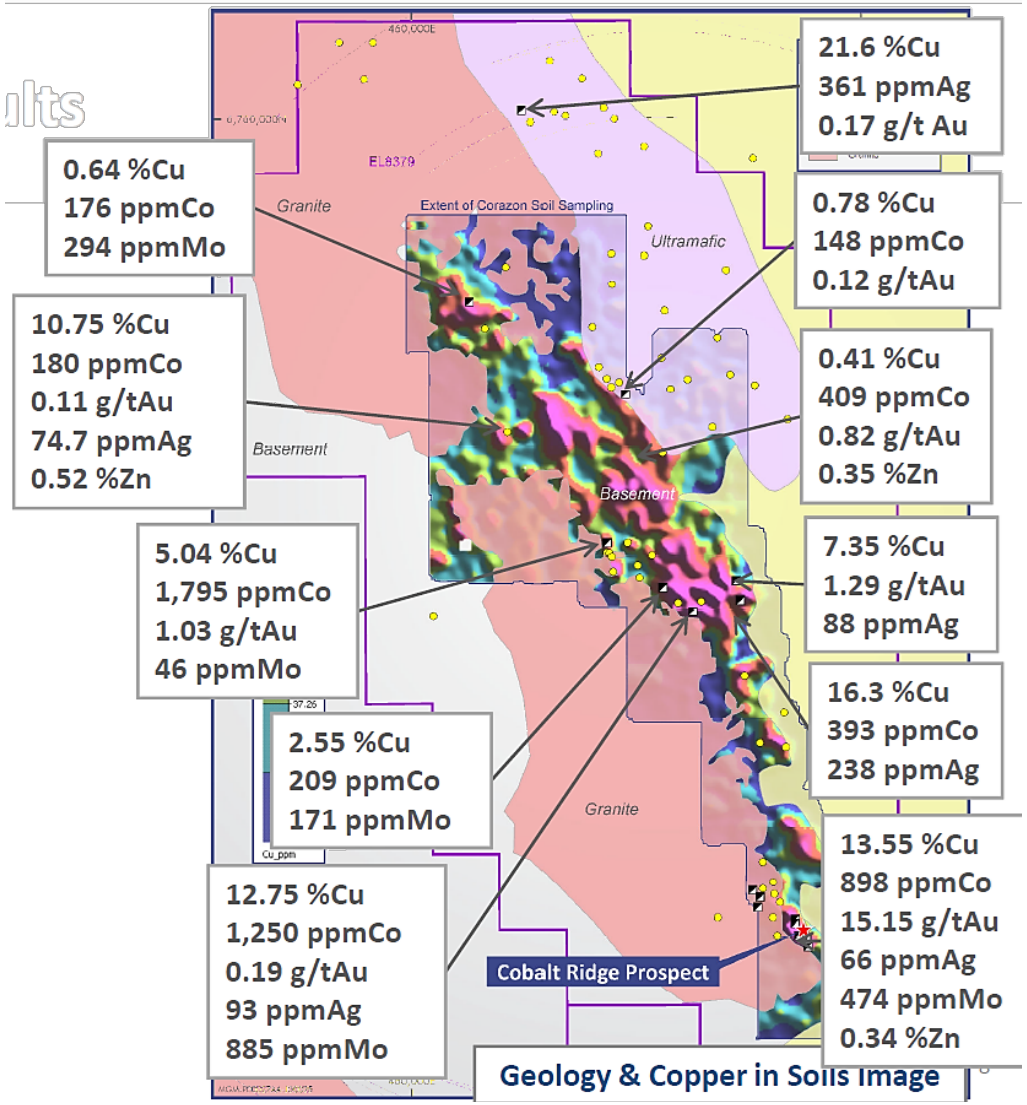
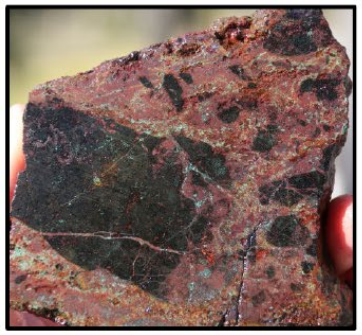
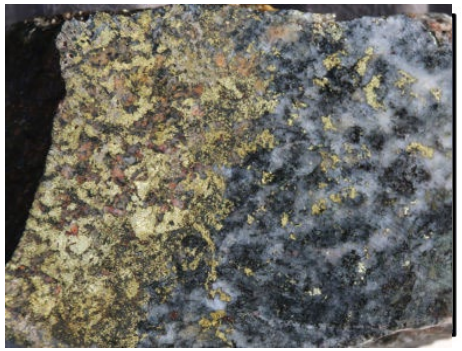
Co at Gordonbrook



- Pyrite
- Chalcopyrite
- Arsenopyrite
- Pyrrhotite
- Cobaltite
- Gold
- Tourmaline





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Summary

- The NEO is a classic orogenic system with all the appropriate bits.
- Magmatism has been extensive through its history from the arc, through plutonism and volcanism in the accretionary complexes, and post orogenic volcanism.
- Diverse metallogeny arraigned primarily longitudinally down the orogen rather than laterally across it although such a zonation appears to be present in the SNEO.
- Good opportunity for exploring the volcanic-plutonic connection for epizonal Au, Ag and Sn-polymetallic mineralisation.

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