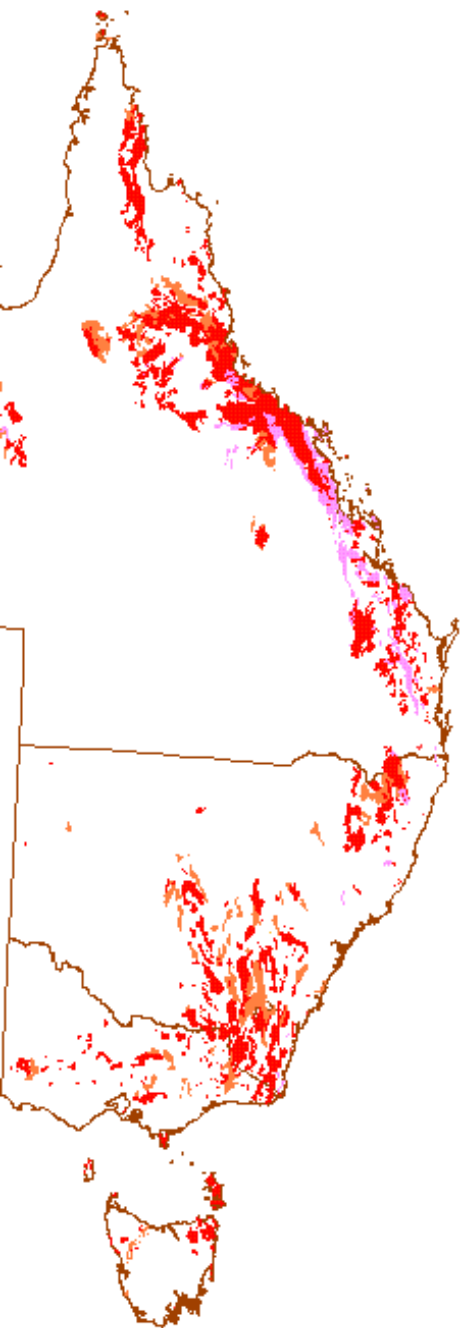


Eastern Australian granites: origins and metallogenesis

Phillip Blevin

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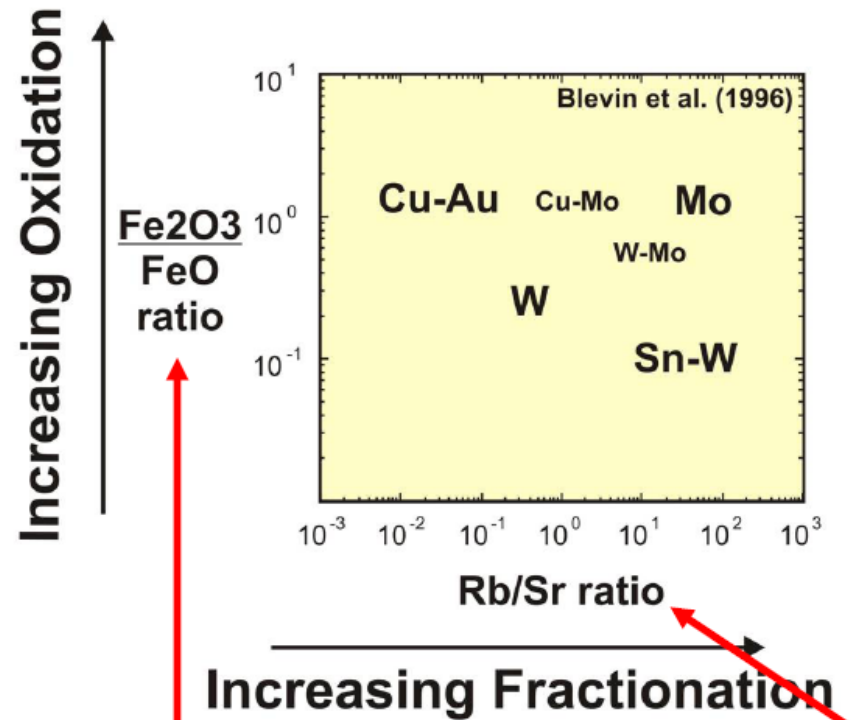
Granites



- Granites (s.l.) refer to a wide range of felsic plutonic rocks. They comprise a significant proportion of the continental crust.
- Granites redistribute significant amounts of material vertically within the crust, and may be responsible for the significant addition of new material to the crust.
- Most occur in areas where the continental crust has been thickened by orogeny, including continental arc subduction or collision of sialic masses, but granitic rocks can occur in many tectonic settings.
- The majority of granites are derived by crustal anatexis, but the mantle may also be involved. The mantle contribution may comprise heat and/or material.

Metallogenic Classification

- Compositional type (I, S, A)
- Differentiation processes.
- Degree of compositional evolution.
- Oxidation state.
- Physical parameters (level of emplacement, volatile content, T etc)

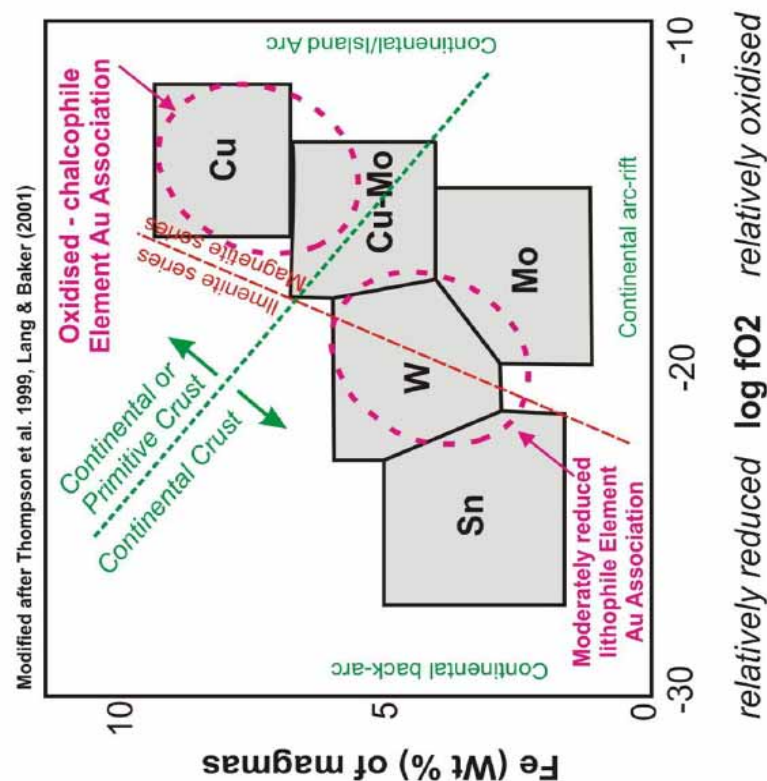
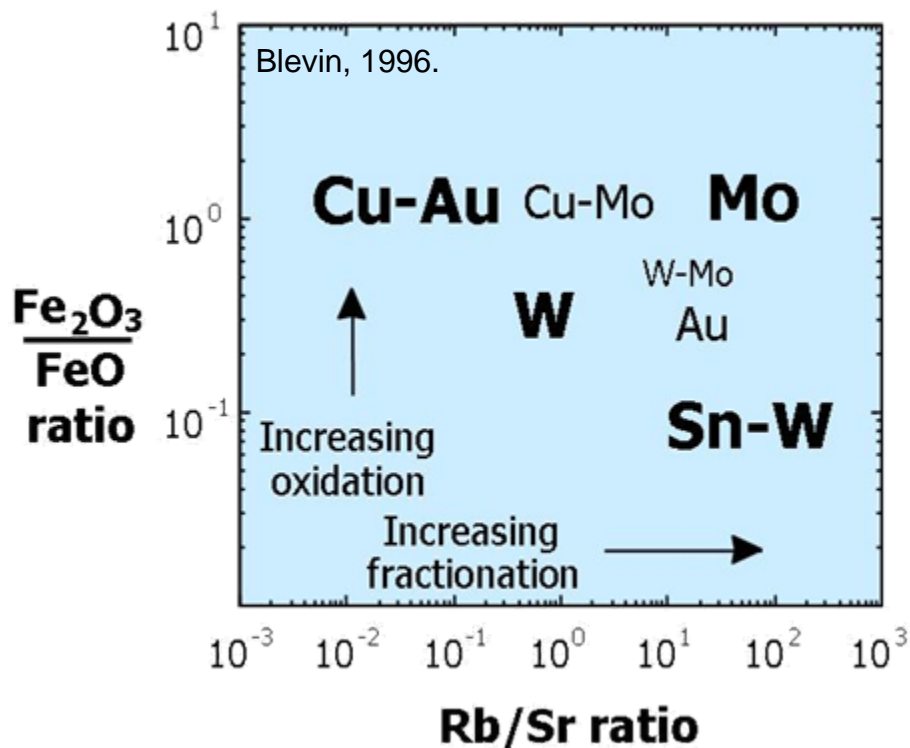


This scheme assigns metallogenic associations to granites.

Measure of
Oxidation

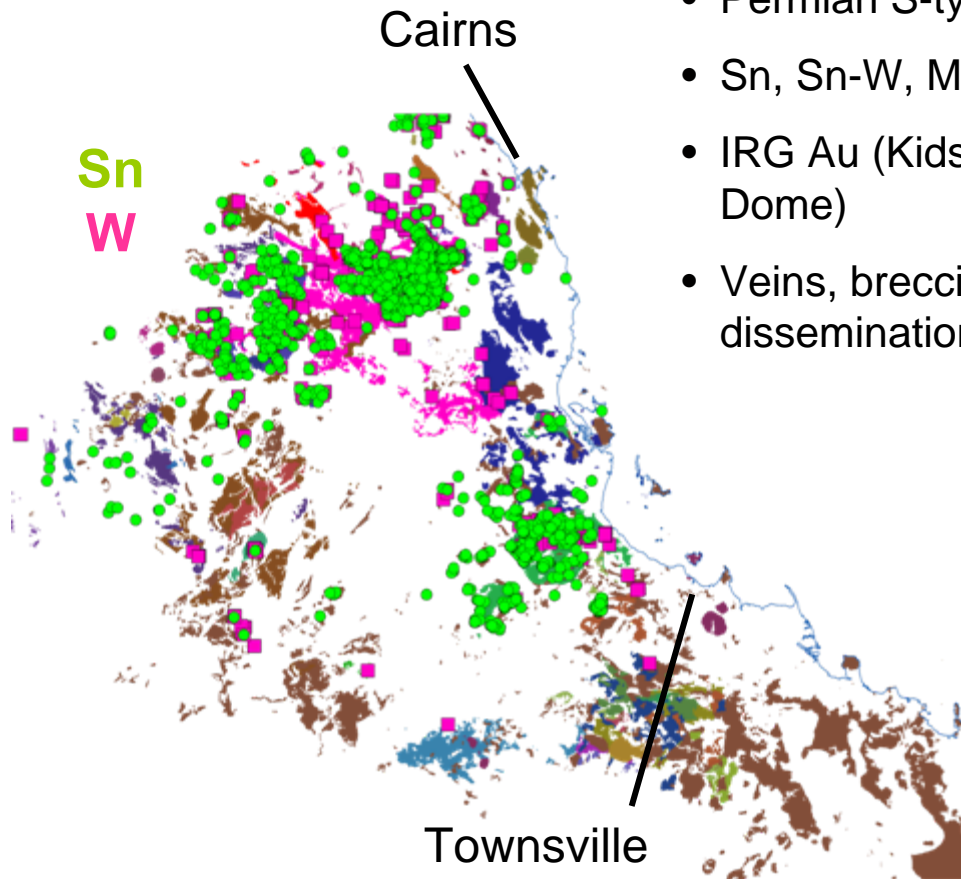
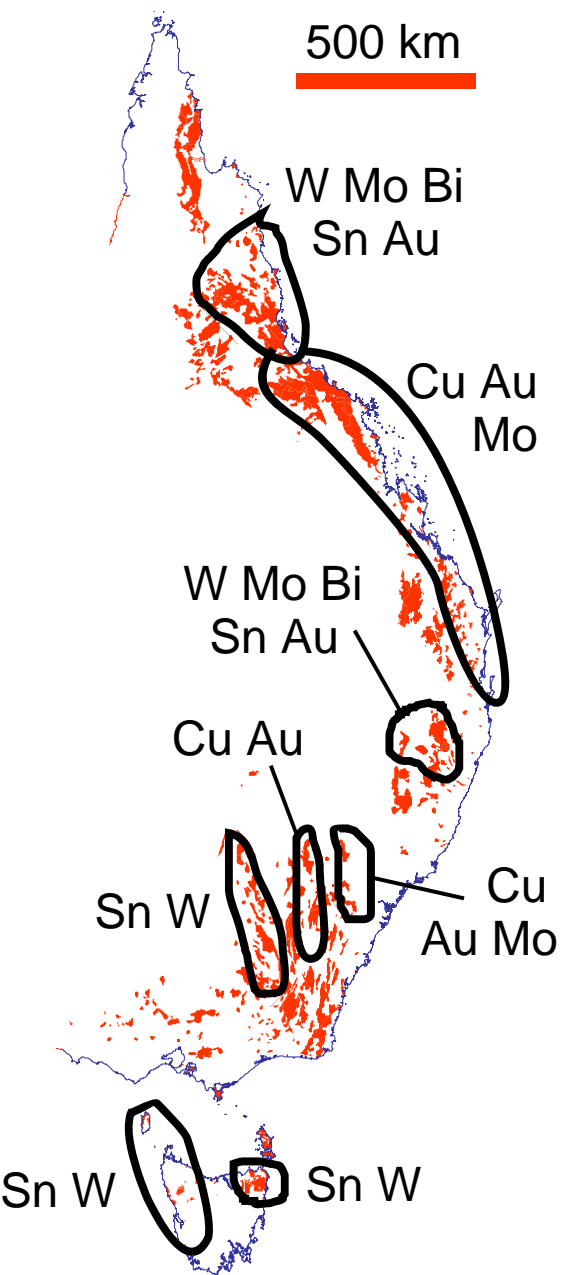
Measure of
compositional evolution

Igneous Metallogeny



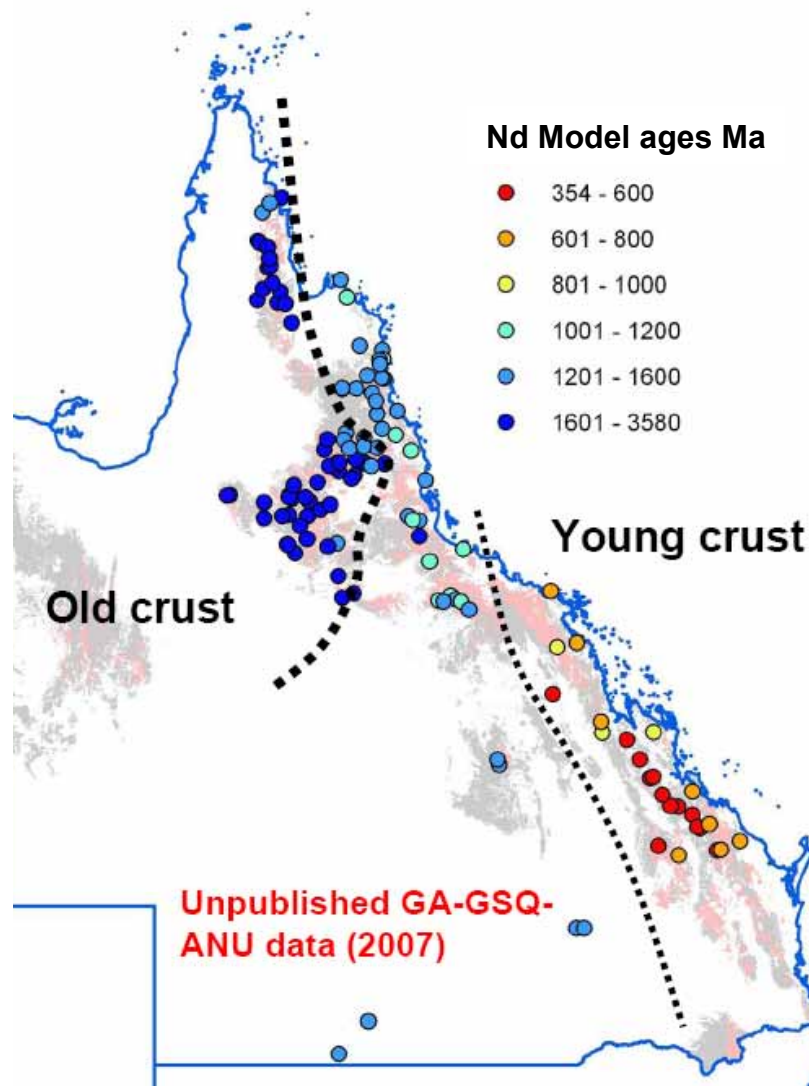
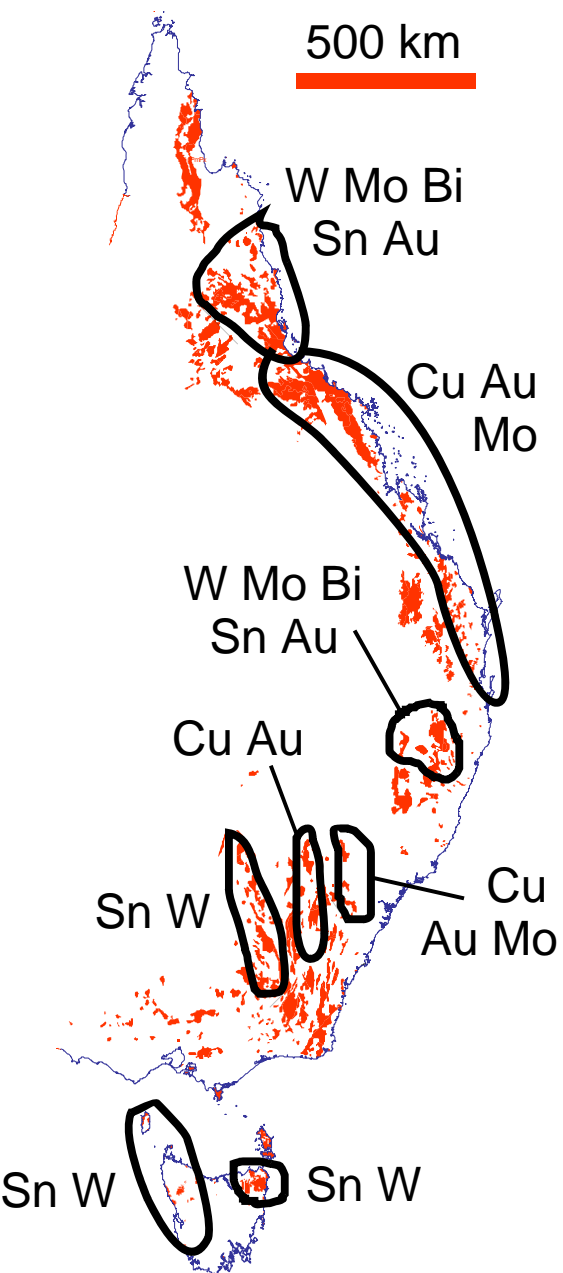
Thompson et al. (1999) also showed a similar relationship between commodity types & igneous parameters, and also added a tectonic overlay.

(Far) North Queensland



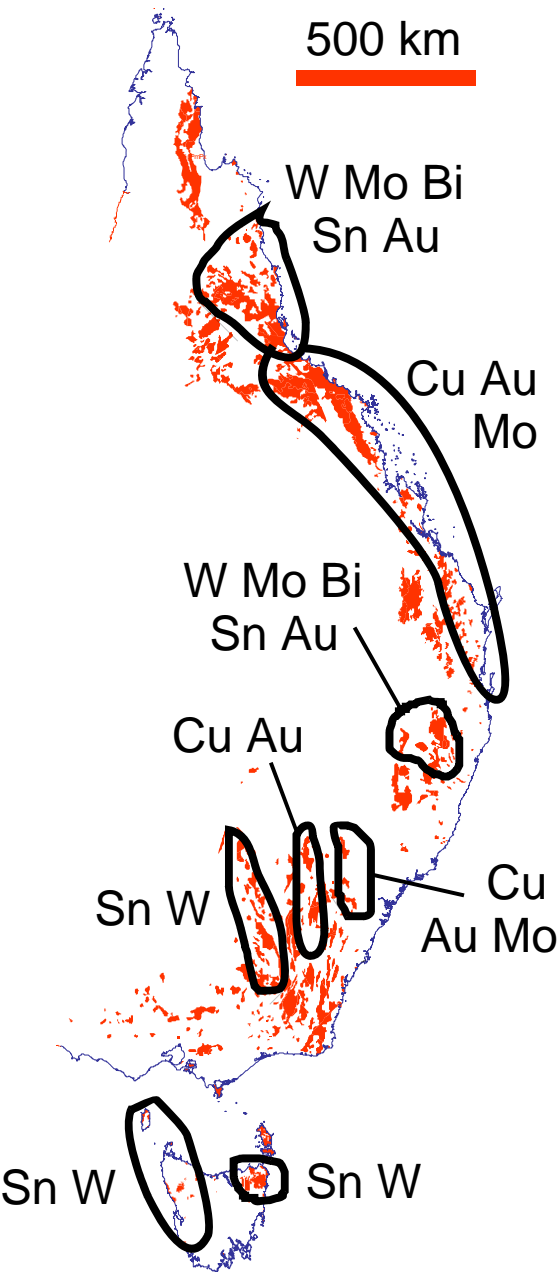
- Carboniferous I-types
- Permian S-type (Cooktown)
- Sn, Sn-W, Mo and W-Mo-Bi
- IRG Au (Kidston, Red Dome)
- Veins, breccias, greisens, dissemination, porphyries

Very sharp southern boundary to Sn and W deposits



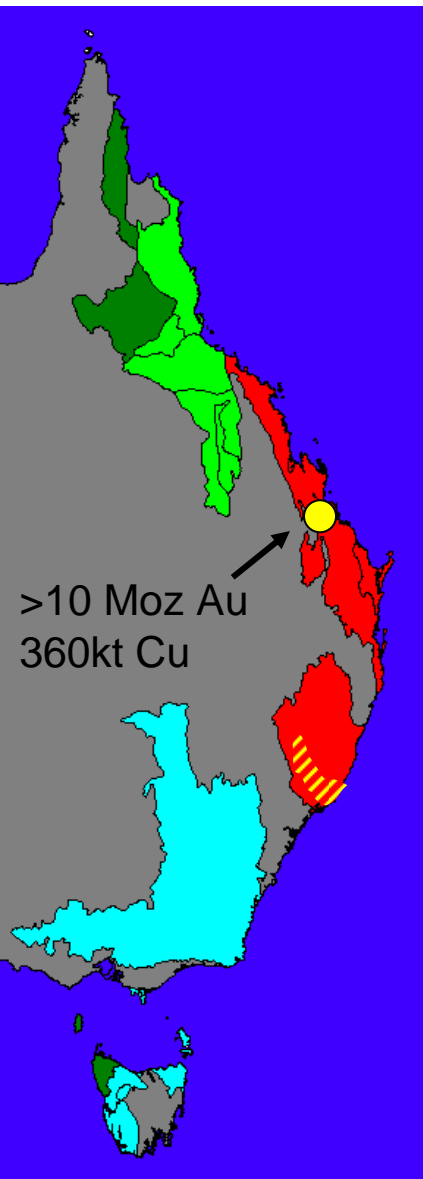
Champion, 2007

Qld Porphyry Cu-Mo



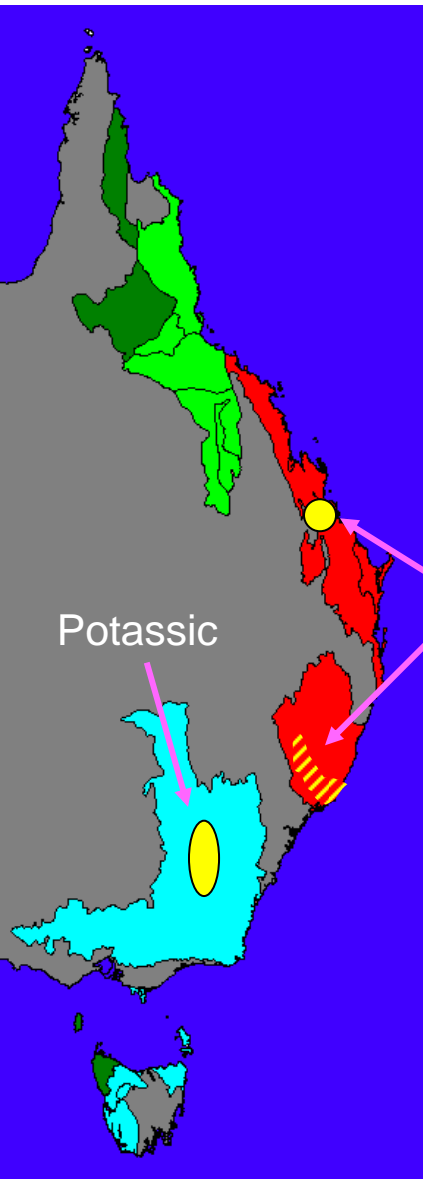
- Among the oldest around the Pacific (Macquarie Arc are older).
- Classic porphyry style alteration, mineralisation, breccias etc.
- The province is “shifted” metallogenically towards porphyry Cu-Mo and even Mo (Anduramba). Doesn’t preclude Au on periphery and epithermals.
- Grade tonnage unusual.
- Silver tends to be subdued on our side of the Pacific compared to the Americas.

- Middle - Late Devonian (380 Ma)
- Mid-Carboniferous – Early Permian (330-280 Ma)
- Late Permian – Late Triassic (275-205 Ma)
- Early Cretaceous (145-90 Ma)
- Mount Morgan Tonalite Complex formed in an oceanic island arc by dehydration melting of low-K basaltic andesite with subsequent fractionation. Similar to arc tonalites in New Britain etc.
- Au-Cu orebody is essentially synchronous with MMTC and associated compositionally similar volcanics.

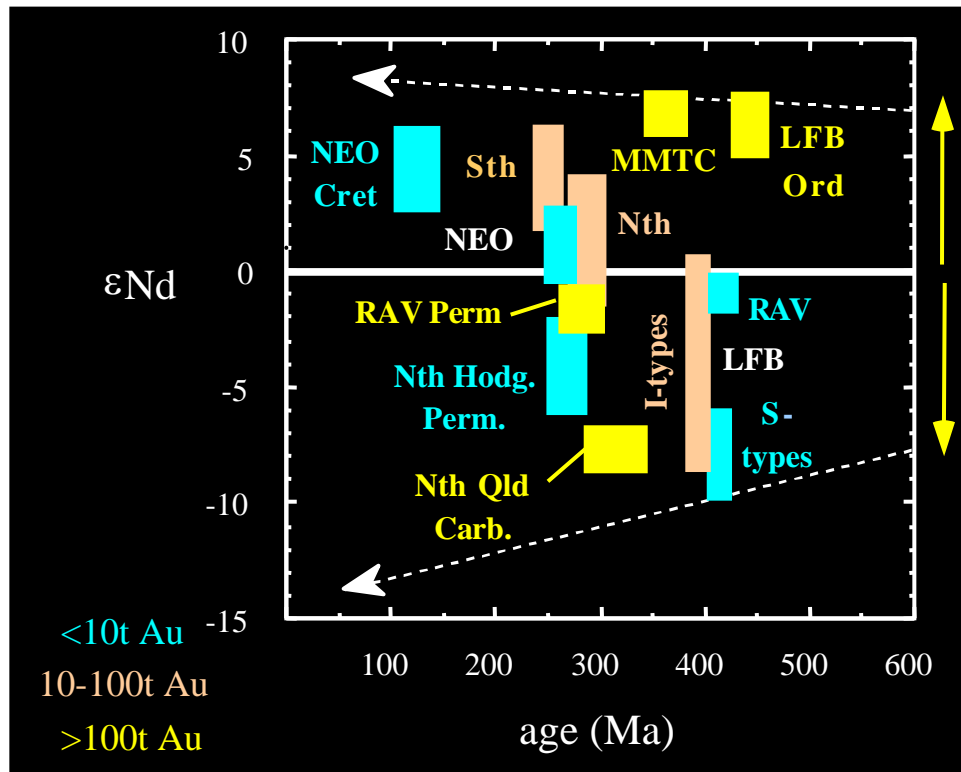
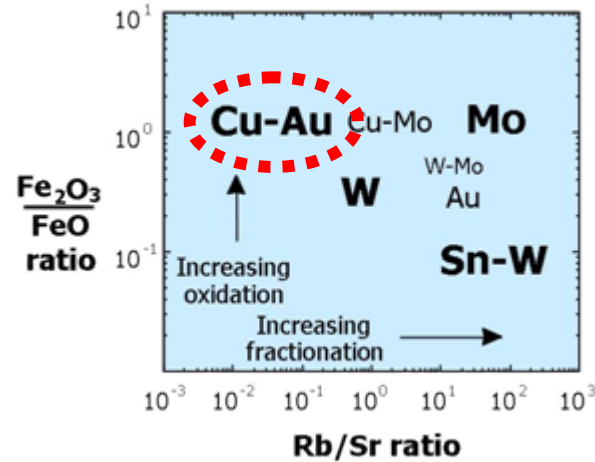


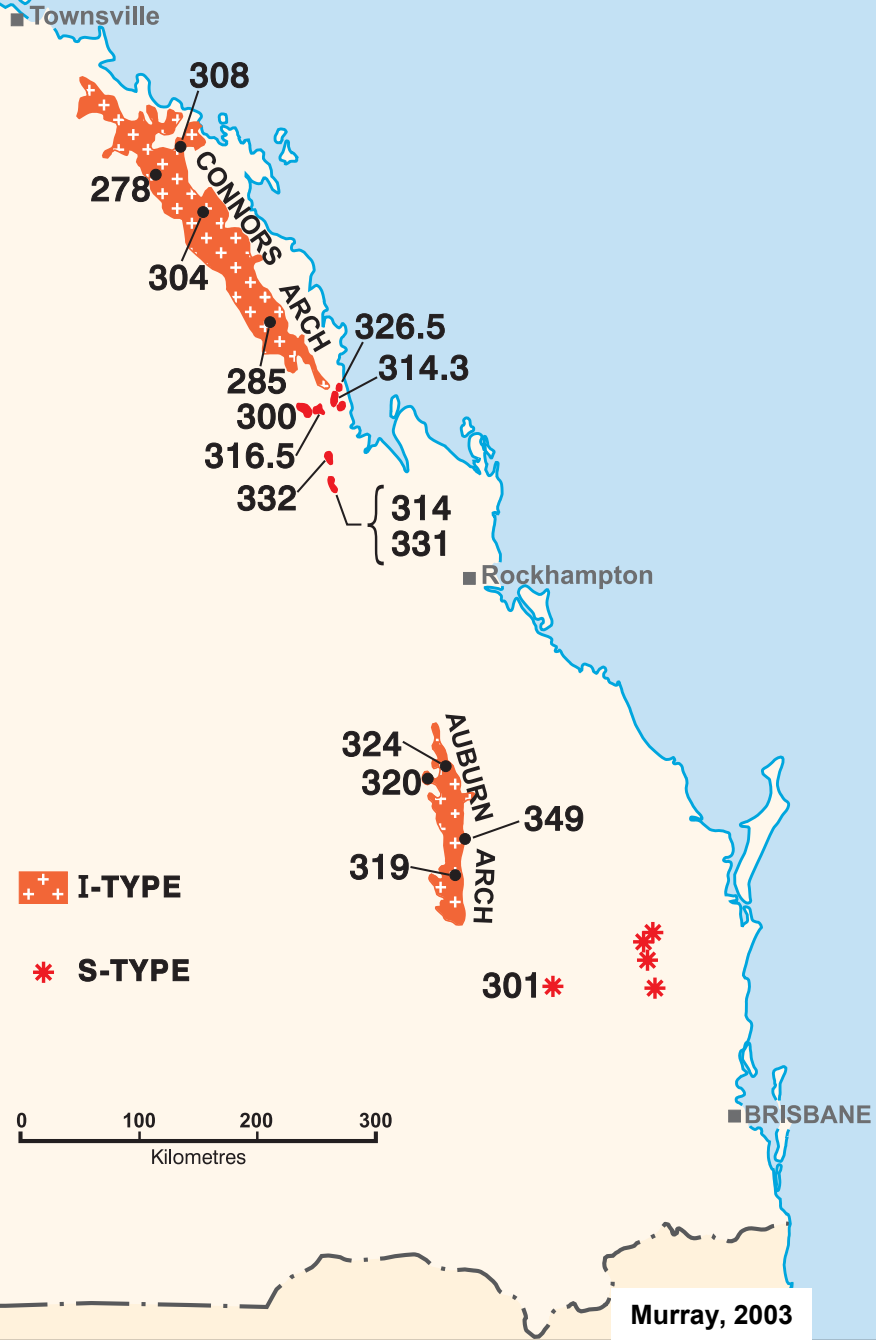
Mount Morgan, 1991

Mount Morgan and Macquarie Arc – similar where it matters



Sodic



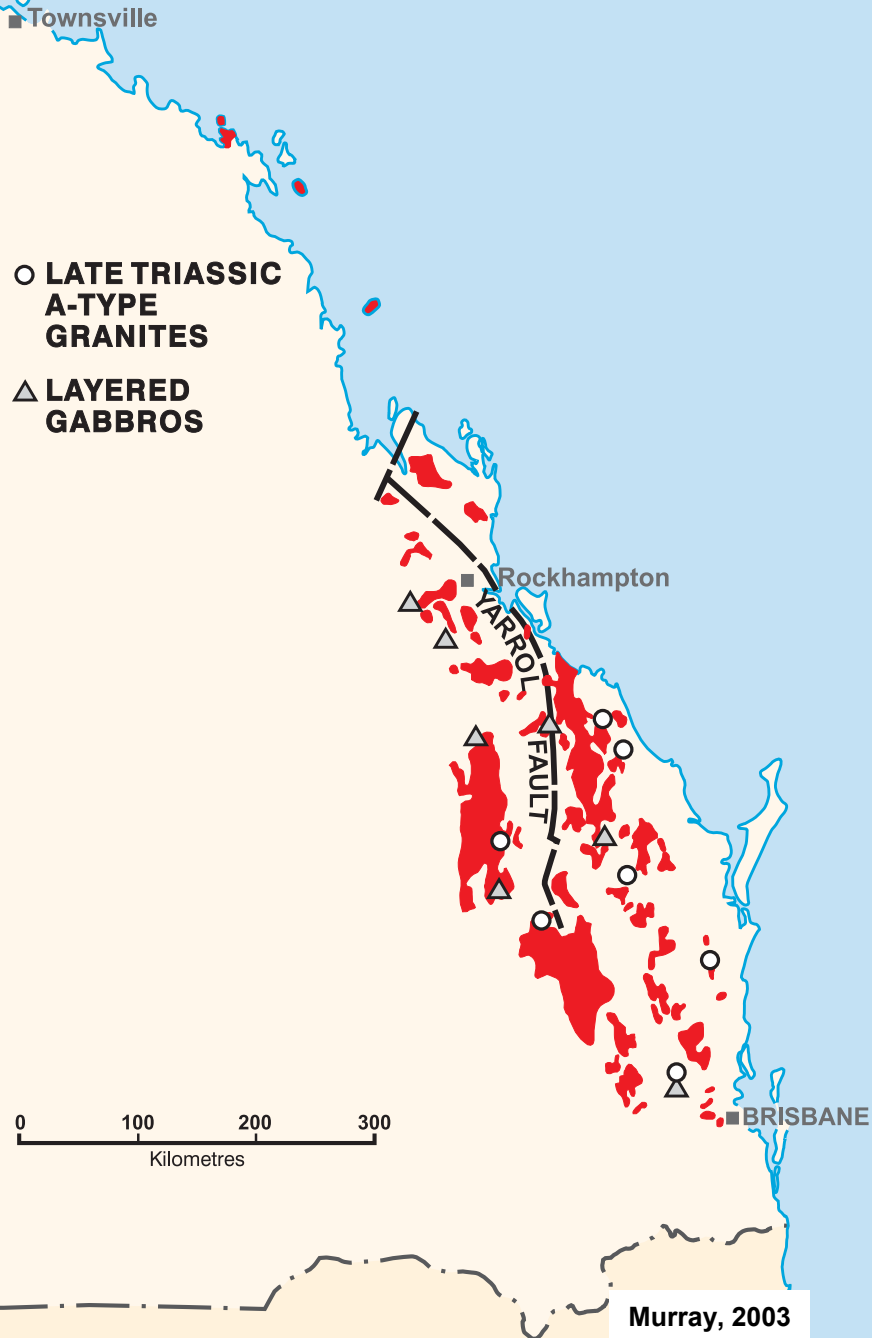


- Middle - Late Devonian (380 Ma)
- Mid-Carboniferous – Early Permian (330-280 Ma)
- Late Permian – Late Triassic (275-205 Ma)
- Early Cretaceous (145-90 Ma)

MID-CARBONIFEROUS TO EARLY PERMIAN

- Granites of the northern Connors Arch (Urannah Batholith) are younger than those of the Auburn Arch and southern Connors Arch and isotopically a little more evolved.
- Compositionally similar to that of Late Permian to Late Triassic granites.
- Granites represent the transition from subduction (Auburn Arch and southern Connors Arch) to extension (northern Connors Arch).
- Only minor mineralisation.

Modified after Murray, 2003

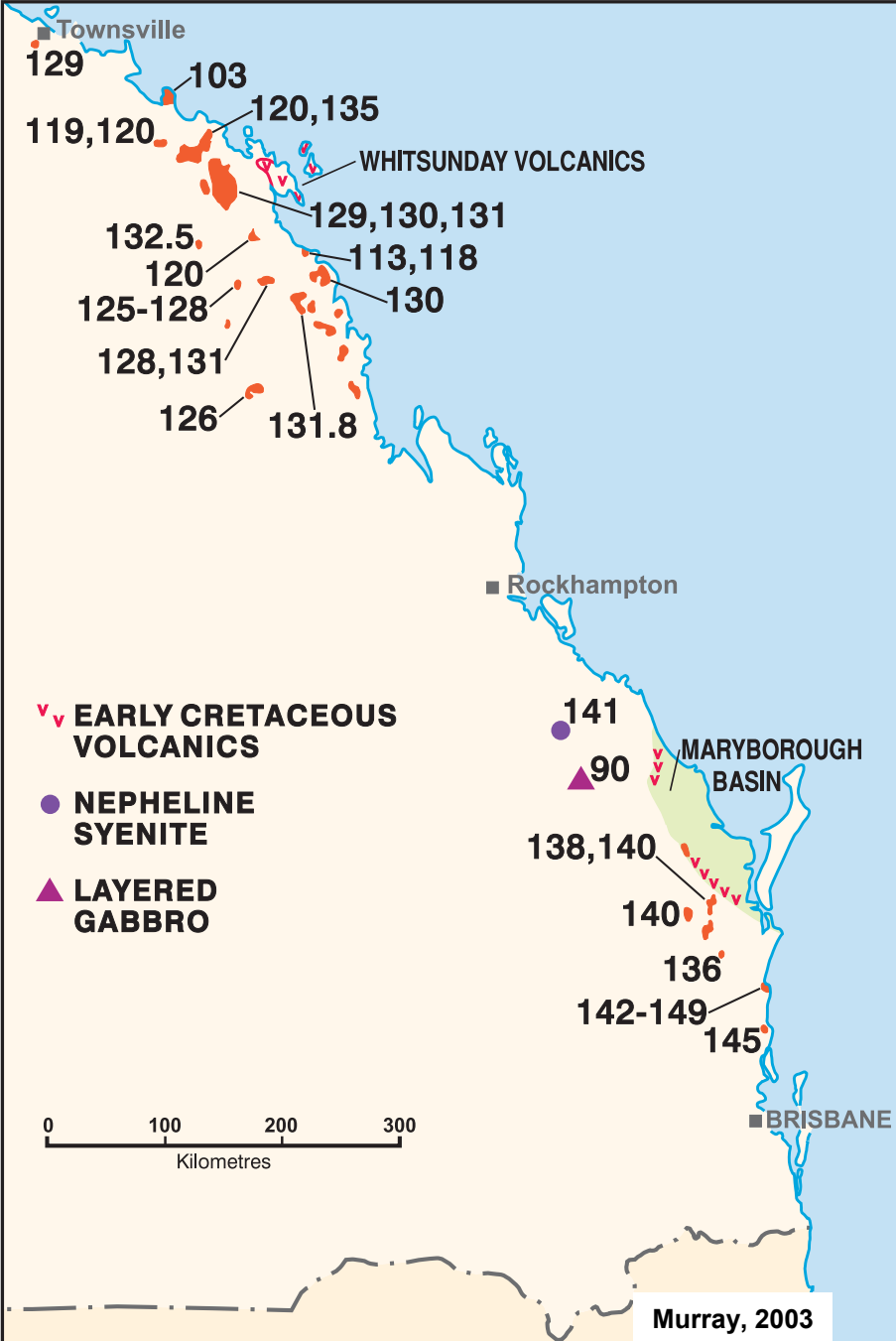


- Middle - Late Devonian (380 Ma)
- Mid-Carboniferous – Early Permian (330-280 Ma)
- Late Permian – Late Triassic (275-205 Ma)
- Early Cretaceous (145-90 Ma)

LATE PERMIAN TO LATE TRIASSIC

- Similar range of compositions to New England Batholith, but proportions differ. Late Triassic now recognised in sNEO.
- No systematic compositional trends with time except for several Late Triassic A-type granites.
- Subduction, changing to extensional magmatism in the Late Triassic due to slab rollback (Murray, 2003).
- Age range of intrusions overlaps with Hunter-Bowen Orogeny.
- Associated with a wide range of mineral deposit styles.

Modified after Murray, 2003

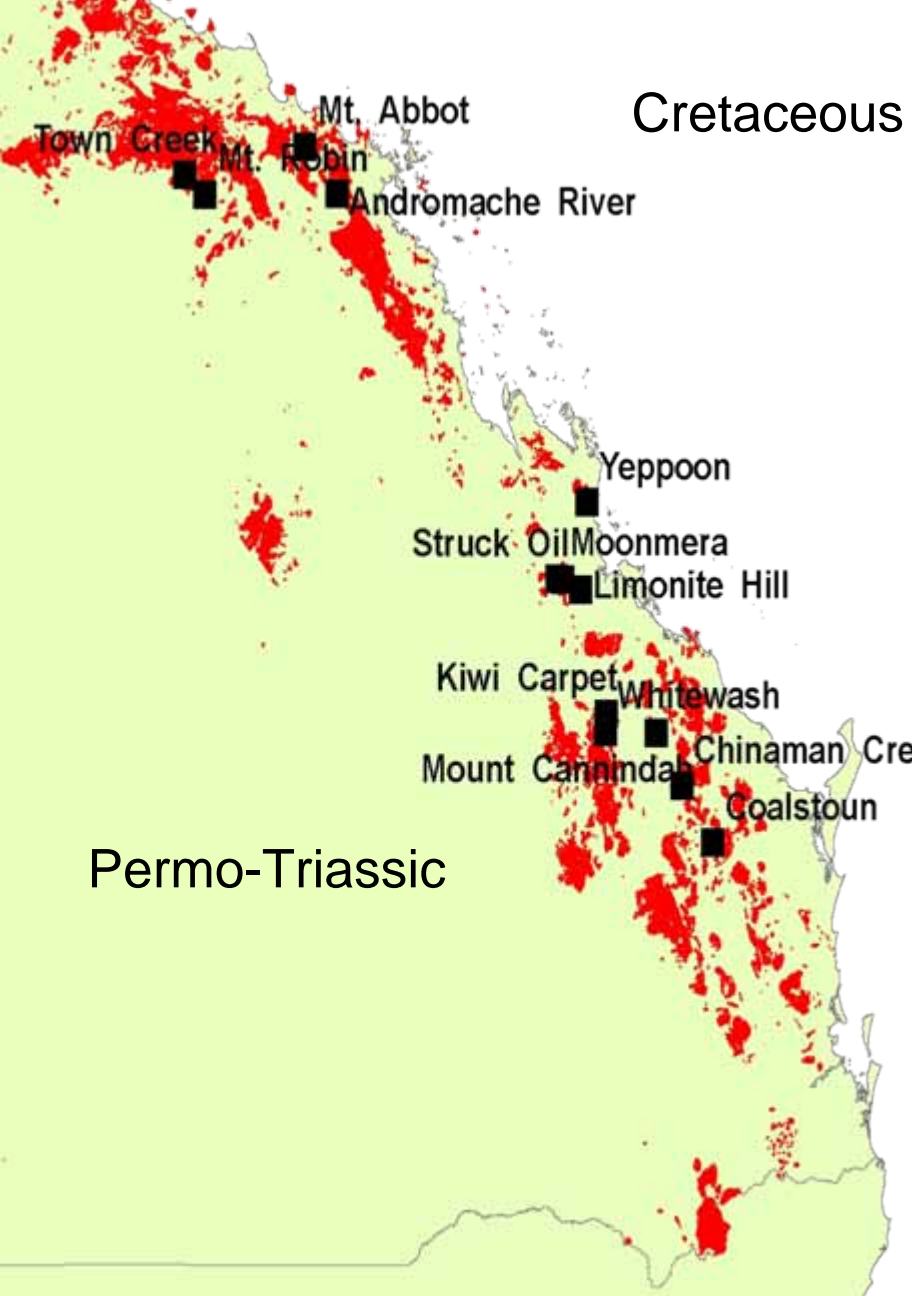


- Middle - Late Devonian (380 Ma)
- Mid-Carboniferous – Early Permian (330-280 Ma)
- Late Permian – Late Triassic (275-205 Ma)
- Early Cretaceous (145-90 Ma)

EARLY CRETACEOUS

- Similar range of compositions to the Carboniferous to Triassic granites, but bimodal distribution.
- Isotopically unevolved.
- Extensional environment favoured, but subduction contribution to older intrusions cannot be ruled out
- Associated with Cu-Mo porphyry and Au vein style deposits

Modified after Murray, 2003



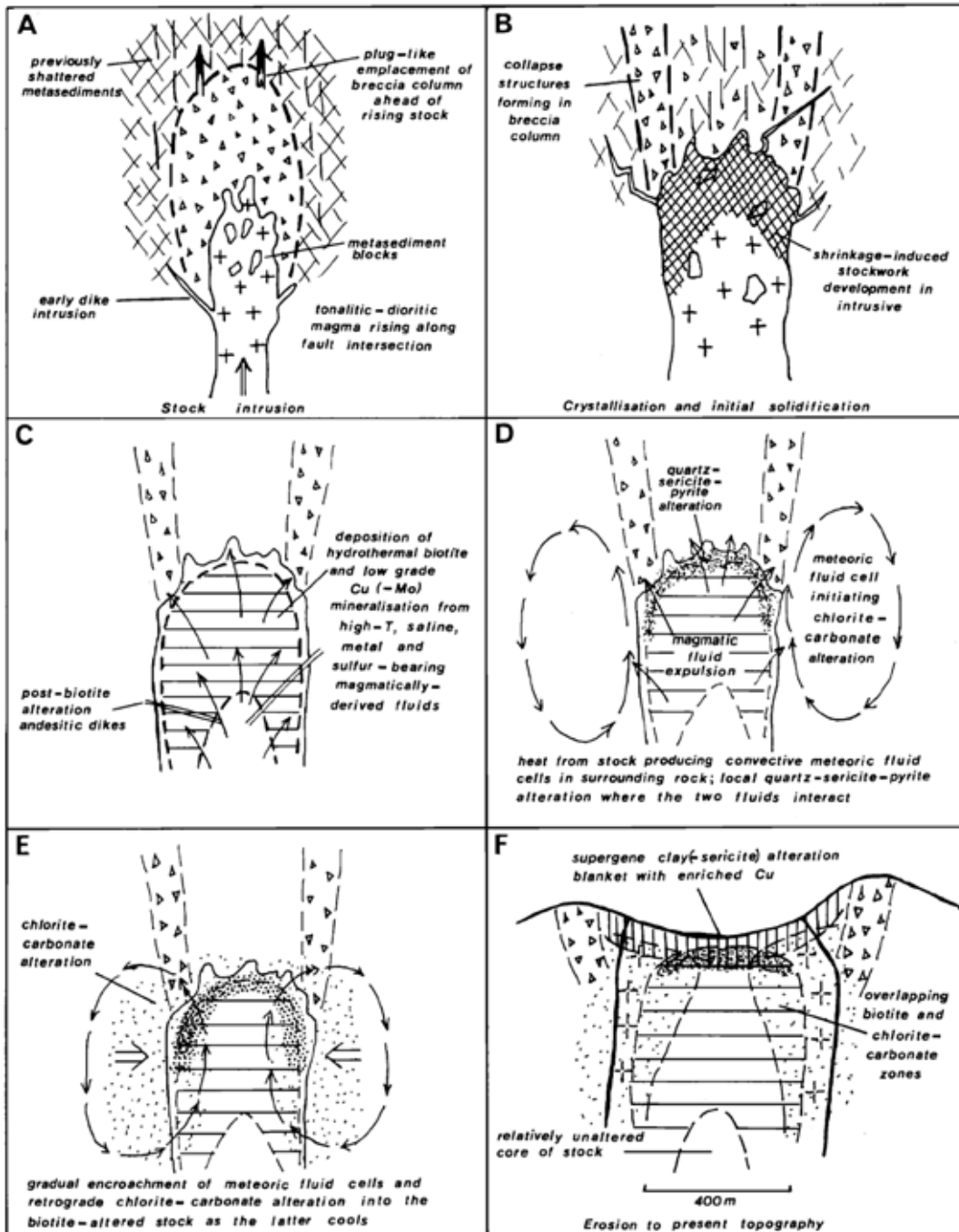
Cretaceous

Permo-Triassic

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

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

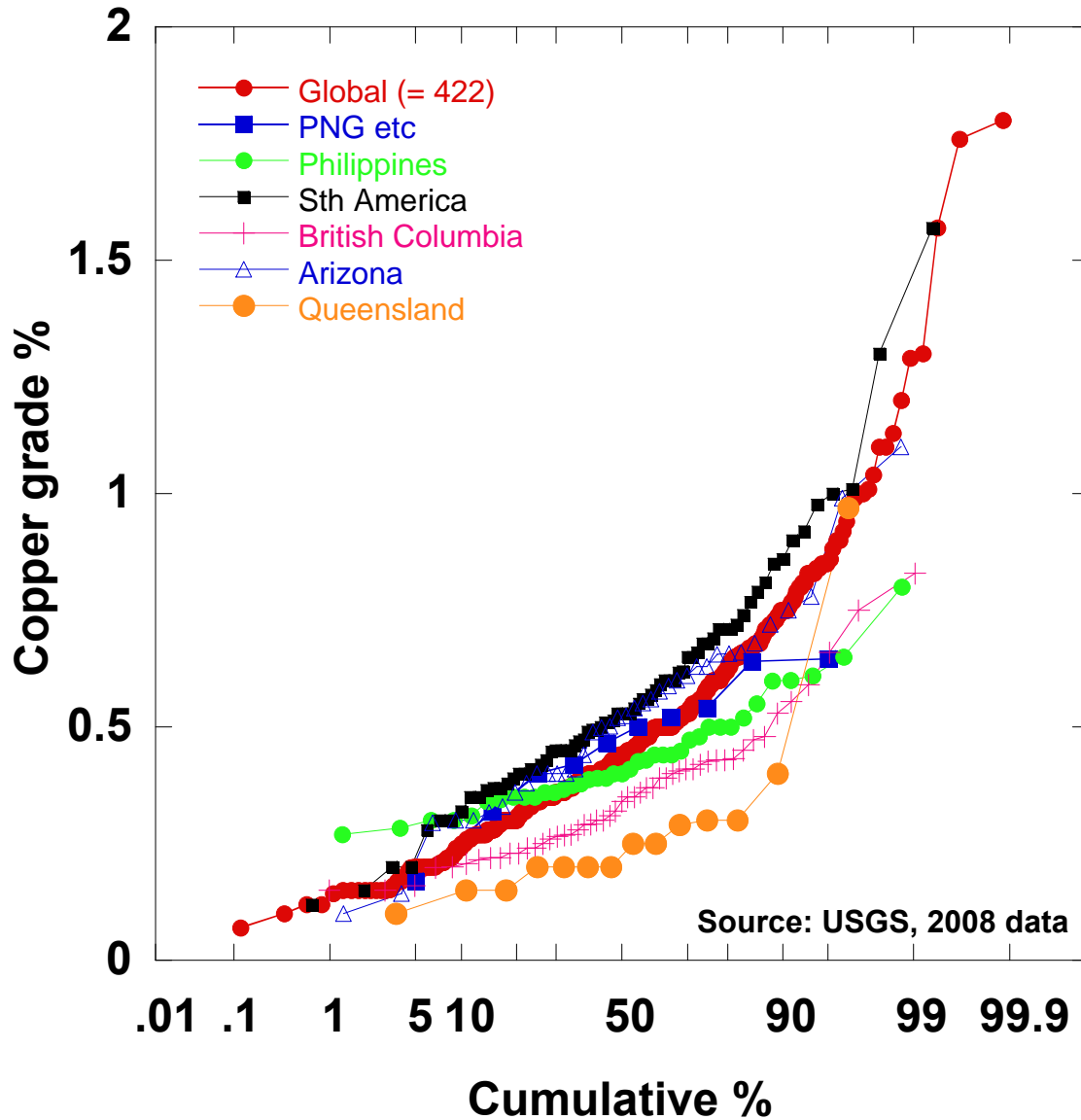


Queensland systems show typical textures, alteration and internal evolution.

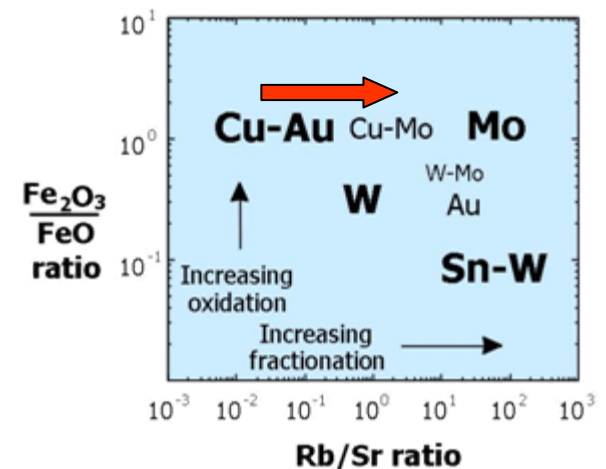
- Biotite, phyllic, propylitic, mt destructive etc alteration types.
- Veins, breccias
- Multiphase events
- Oxidised magmatic-meteoric hydrothermal systems

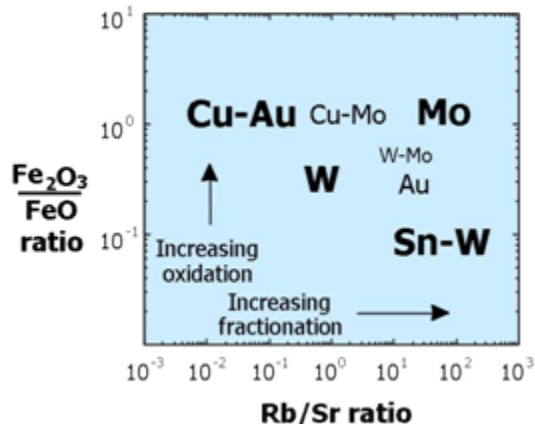
Coalstoun Porphyry Copper Prospect
Ashley et al., 1978, Econ Geol

Cu grade distributions for porphyry Cu deposits

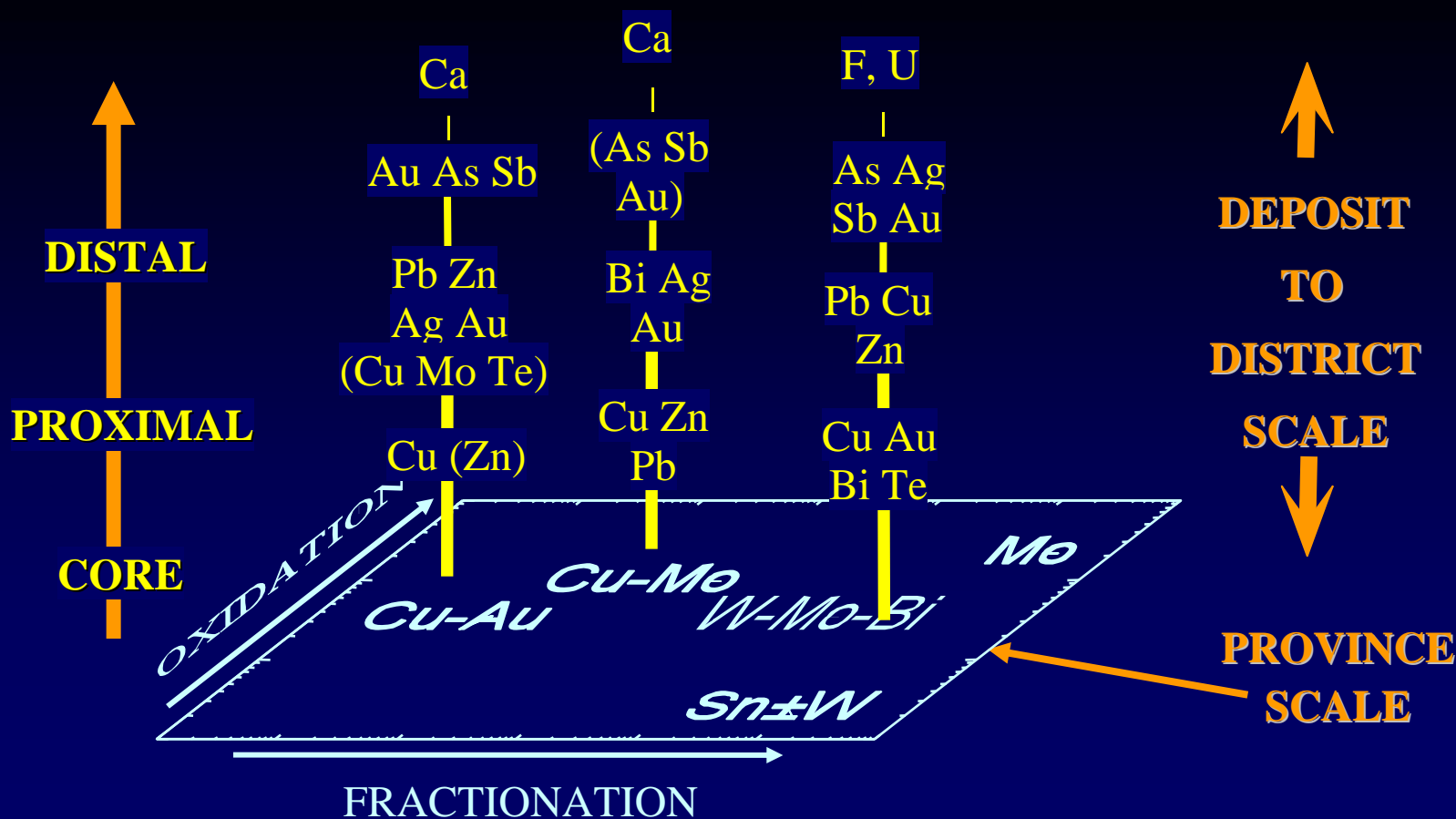


- Cu grade distributions are similar for most provinces. Queensland rather exceptional.

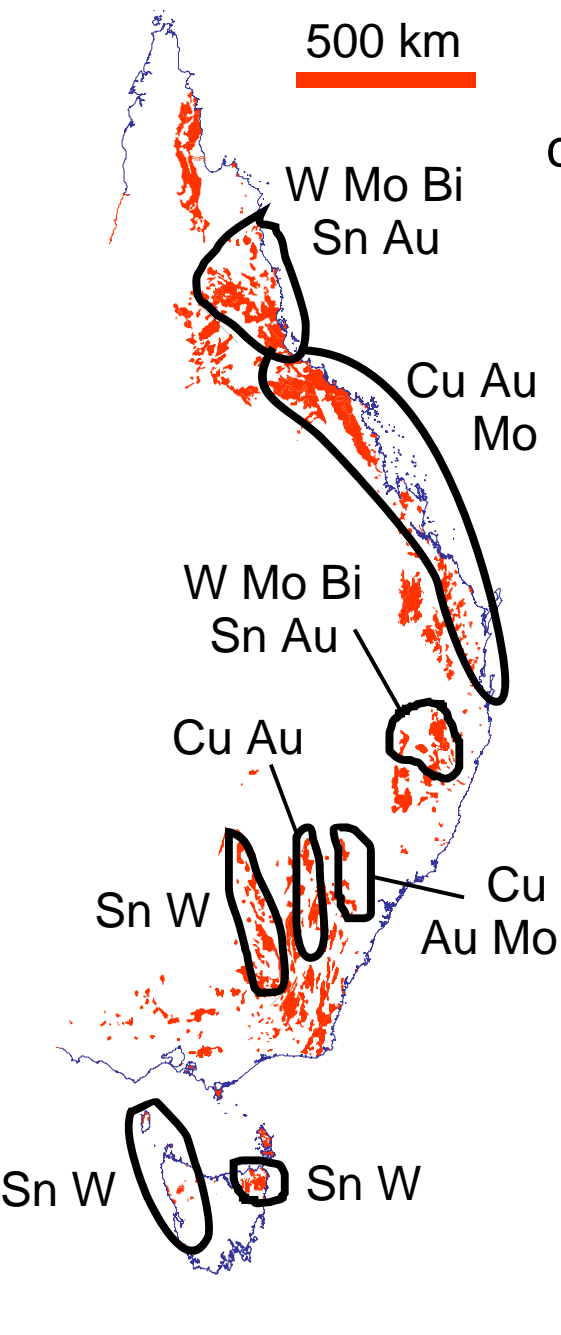




Gold location in zoned systems

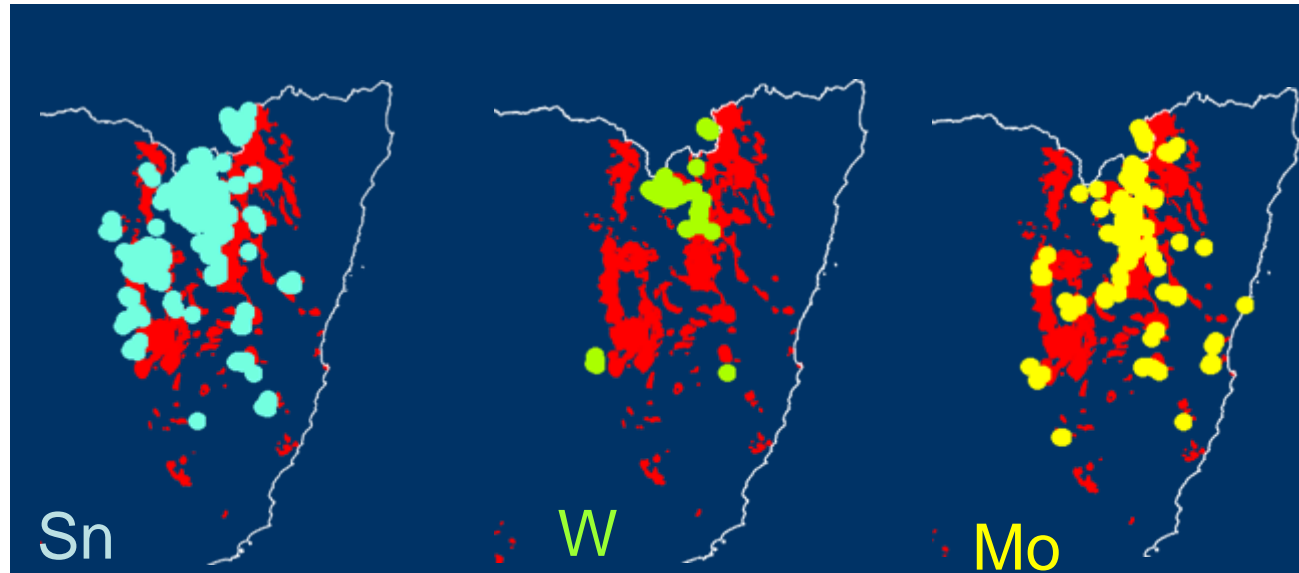


Metallogeny of the southern NEO contrasts utterly with that of the northern NEO.



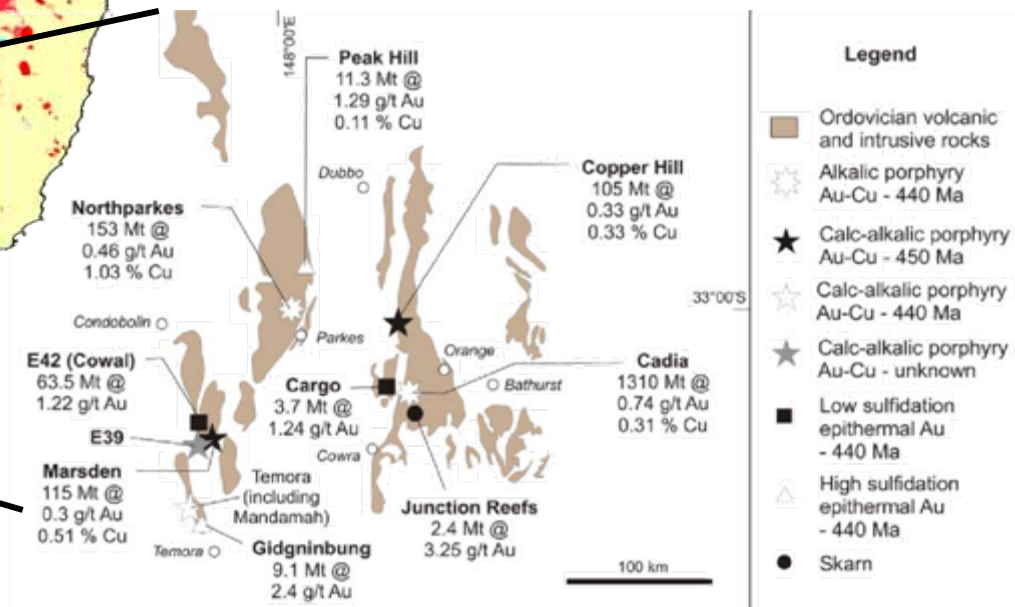
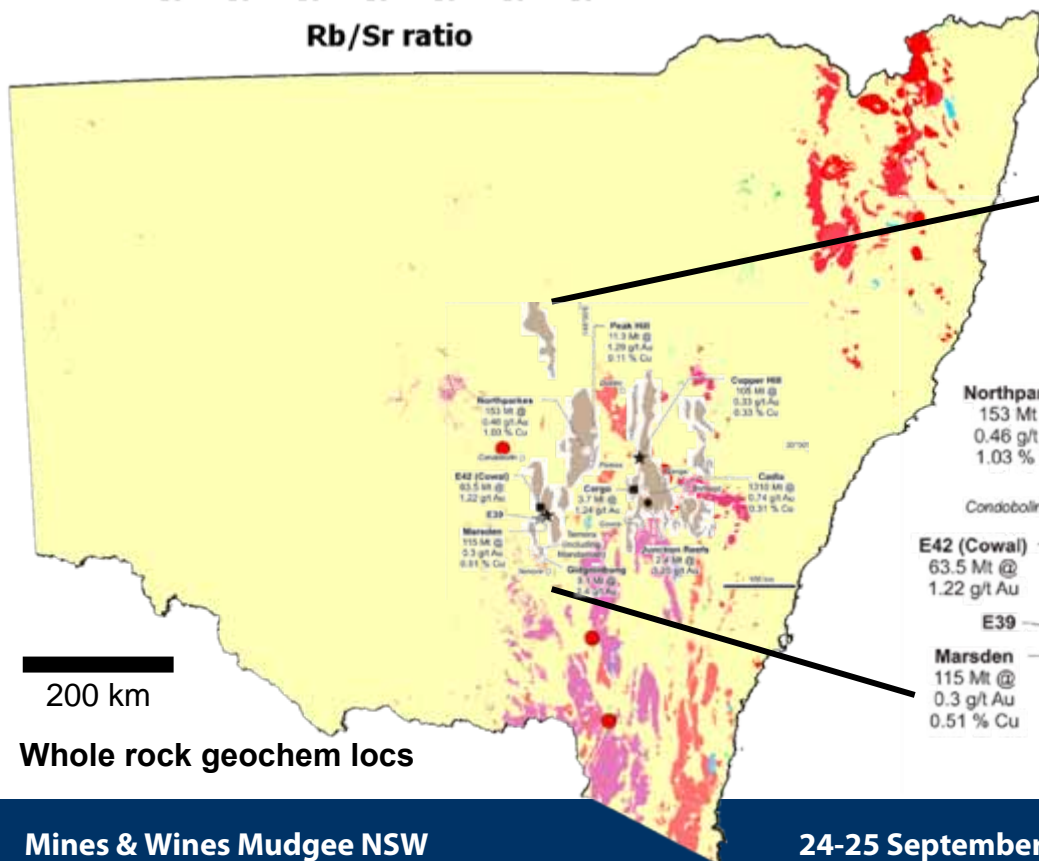
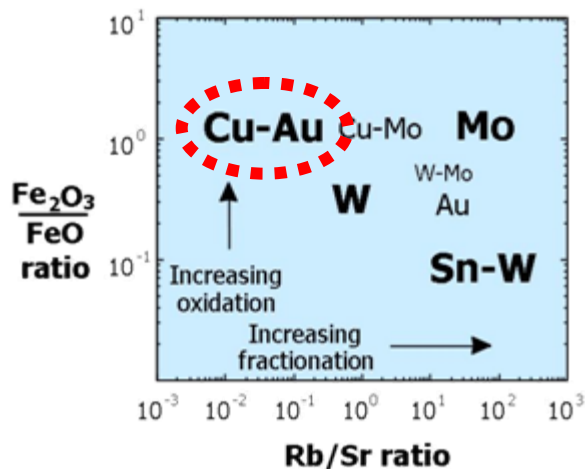
sNEO granites have:

- higher K
- more fractionated
- more S-types

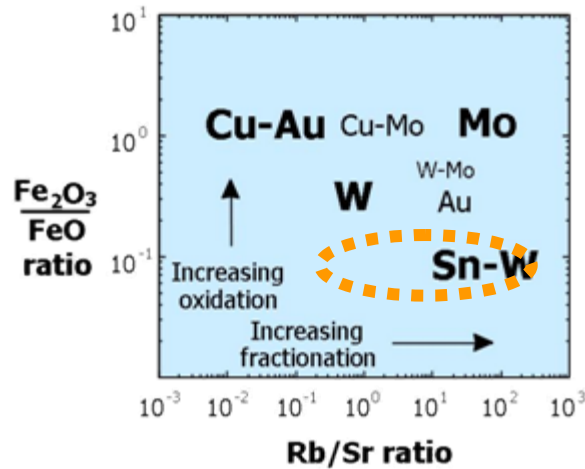


Ordovician System

- Mantle sourced
- Med-high-K and shoshonites
- Porphyry dominant
- Fertile for Cu-Au and Au

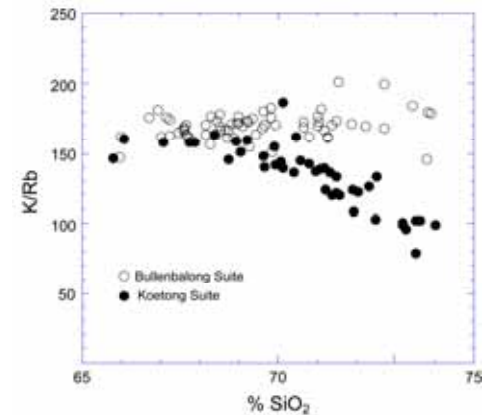
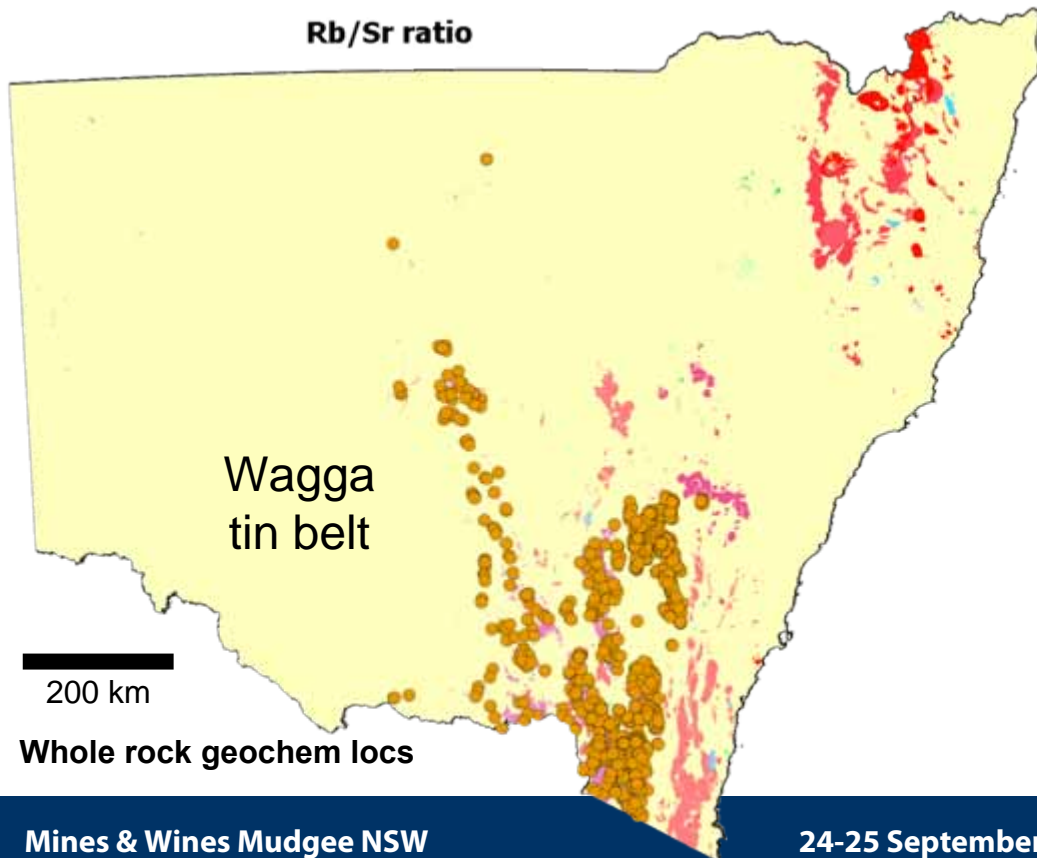


Silurian System

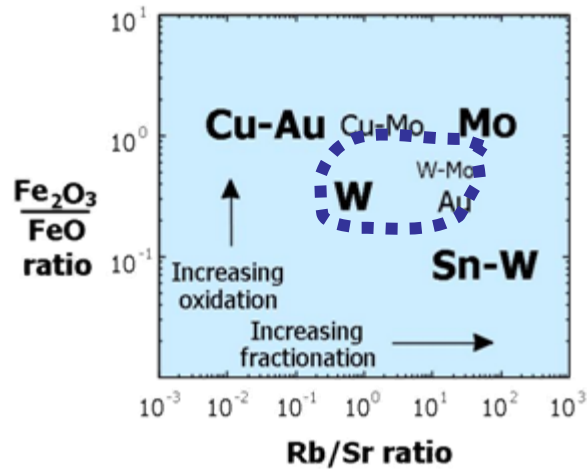


- S-types > I-types
- Distinct Supersuites
- Overwhelmingly crustal
- Fertile for Sn-W, Nb-Ta

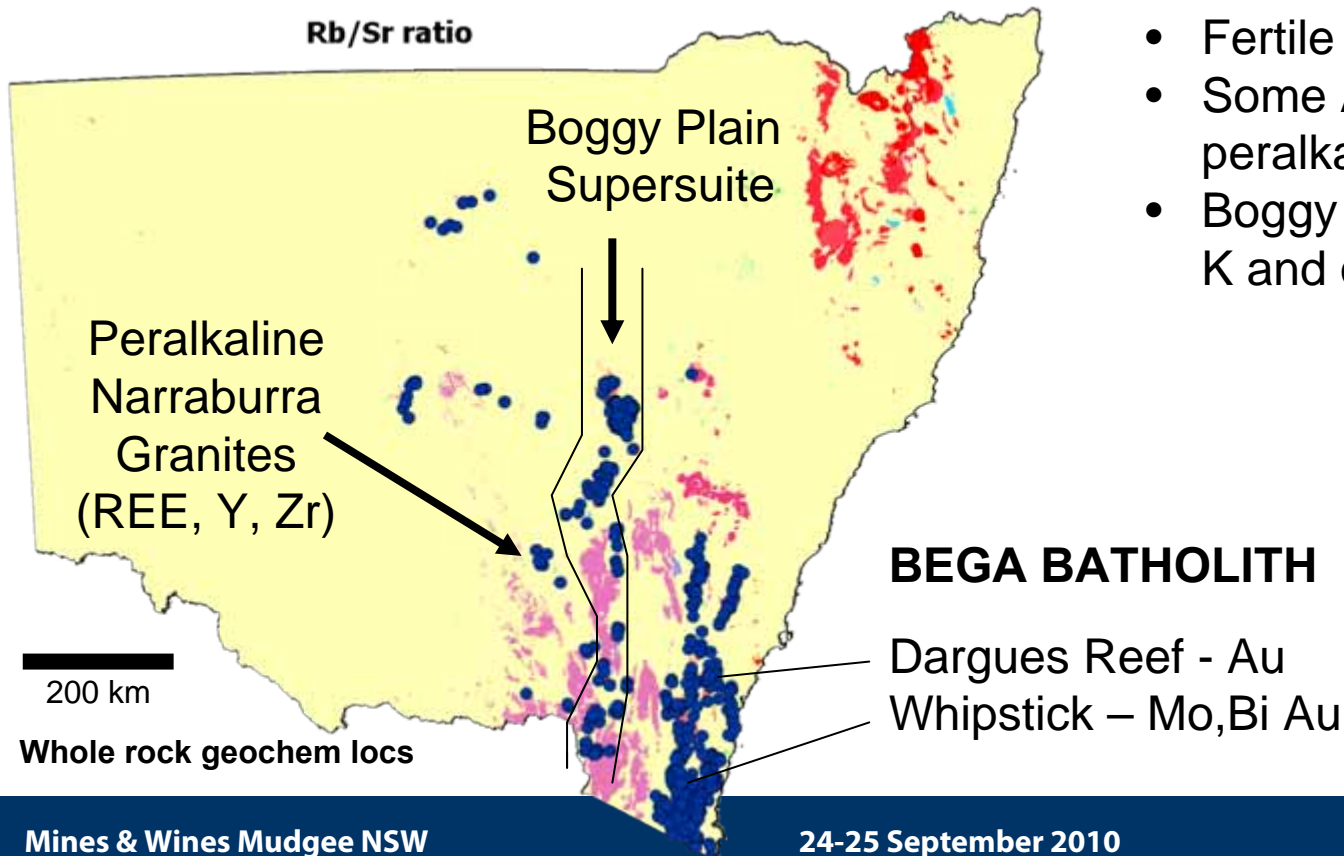
- Wagga tin belt associated with distinct Koetong Supersuite.
- Ardlethan deposit clearly younger.



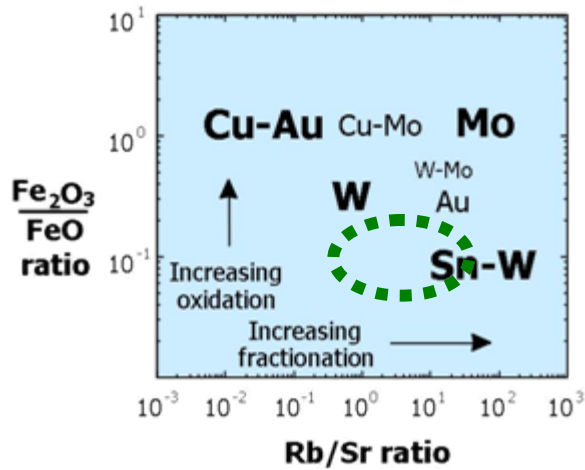
Devonian System



- I-types and A-types
- Compositionally more evolved than Ordovician
- Evolved away from Por. Cu-Au.
- Fertile for IR Au, Mo, W
- Some A-types and peralkaline.
- Boggy Plain distinct with high-K and oxidised.

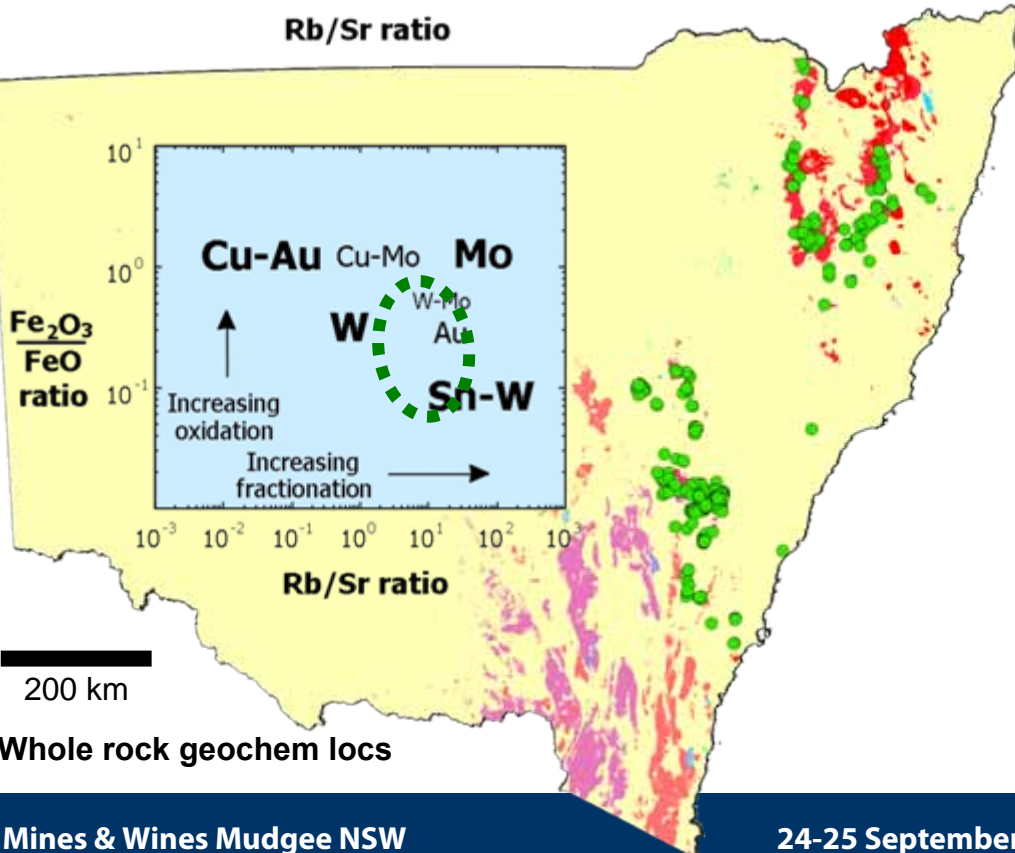


Carboniferous System



NEW ENGLAND

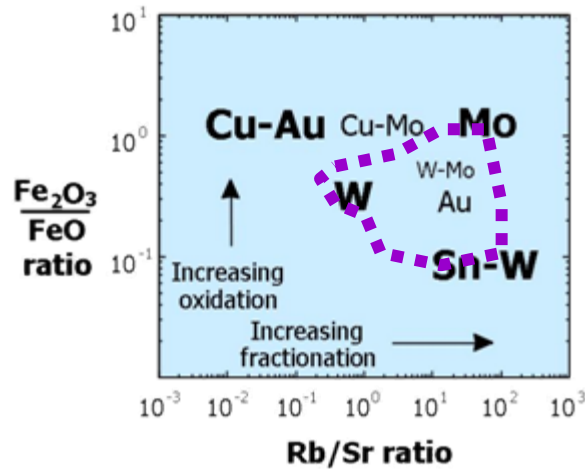
- S-type – earliest Permian
- Two supersuites, one mineralised (Sn).
- Na rich for S-types, isotopically juvenile.



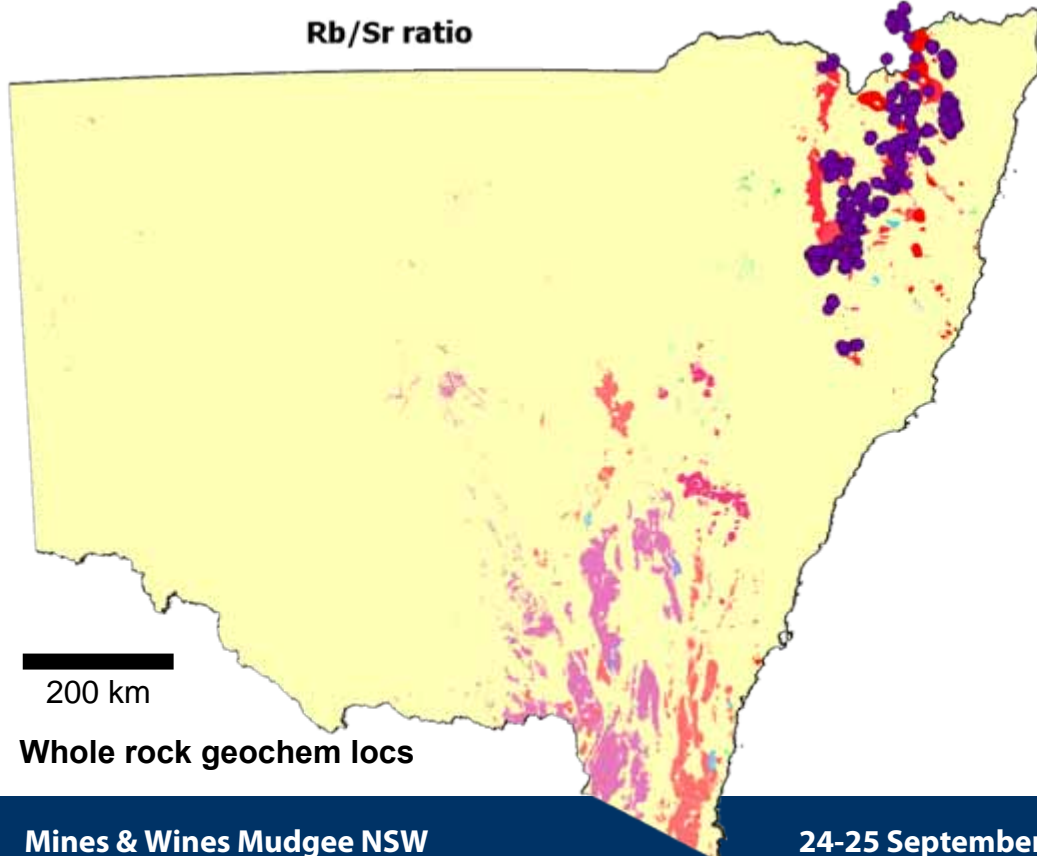
LACHLAN

- I-types, high K and Sr
- Pink feldspars common.
- Metallogenically diverse
- Fertile for IR Au, Mo, W, Sn

Permian System



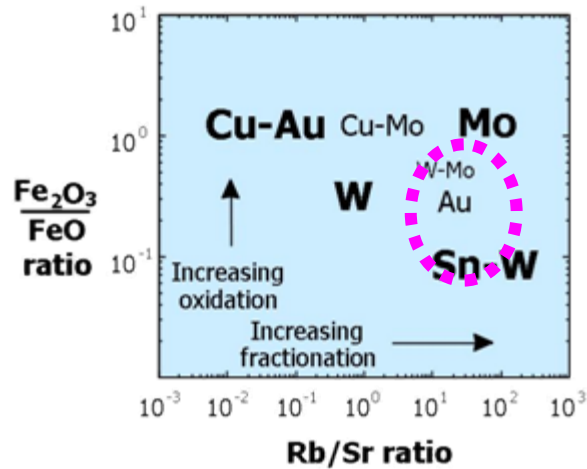
- I-types
- Compositionally evolved.
- Several supersuites from low-medium to high-K.
- Fertile for Au, Mo, W
- Similarities with Lachlan Carboniferous
- Former Triassic Sn granites now known to be Permian.



Deposits include:

- Attunga (W-Mo-Au-Cu)
- Conrad Howells (Ag-In-Sn)
- ?Kingsgate (Mo-Bi)

Triassic System

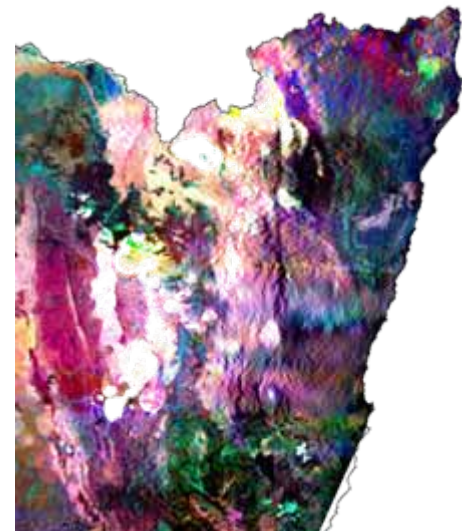


- I-types and A-types
- Moderately to strongly evolved.
- Includes Doradilla
- Fertile for IR Au, Mo, W, Sn
- Mole, Timbarra

Ruby Creek

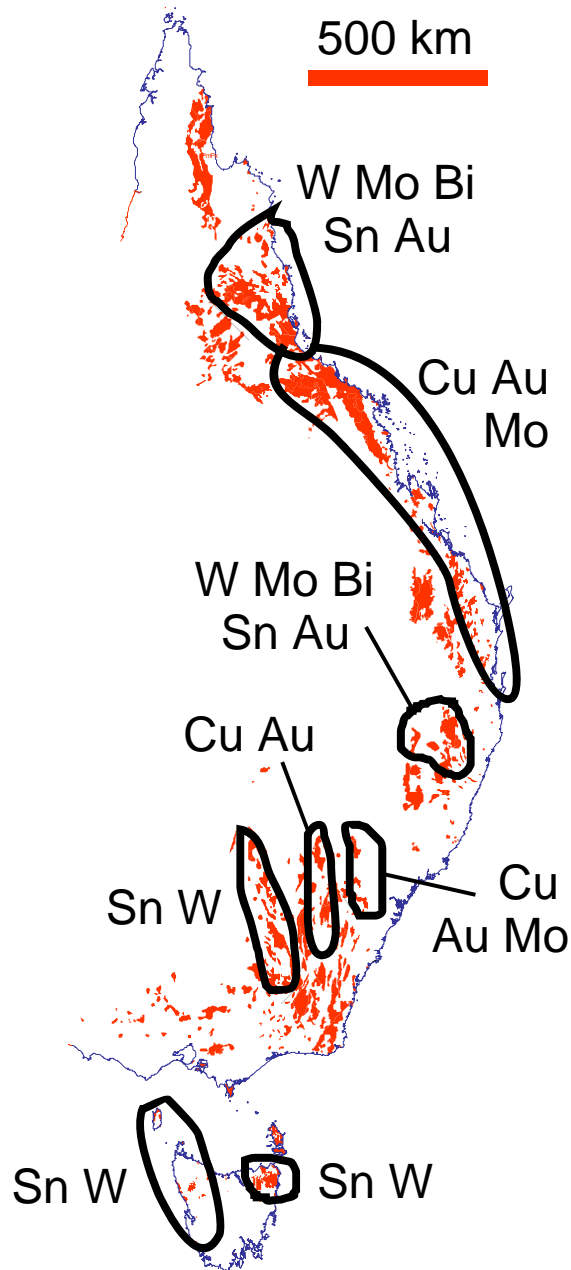
Mole

Doradilla
Sn skarns, and Ni



200 km

Whole rock geochem locs



A diverse metallogeny along and across “strike”

- Simple explanation in terms of oxidation and compositional character of associated igneous rocks.
- These can be presented graphically or spatially from geochem data. Extensive sets of high quality data are becoming available.
- Strong regionality is evident, indicative of extensive source regions and controls on compositions etc. They are not “point sources”

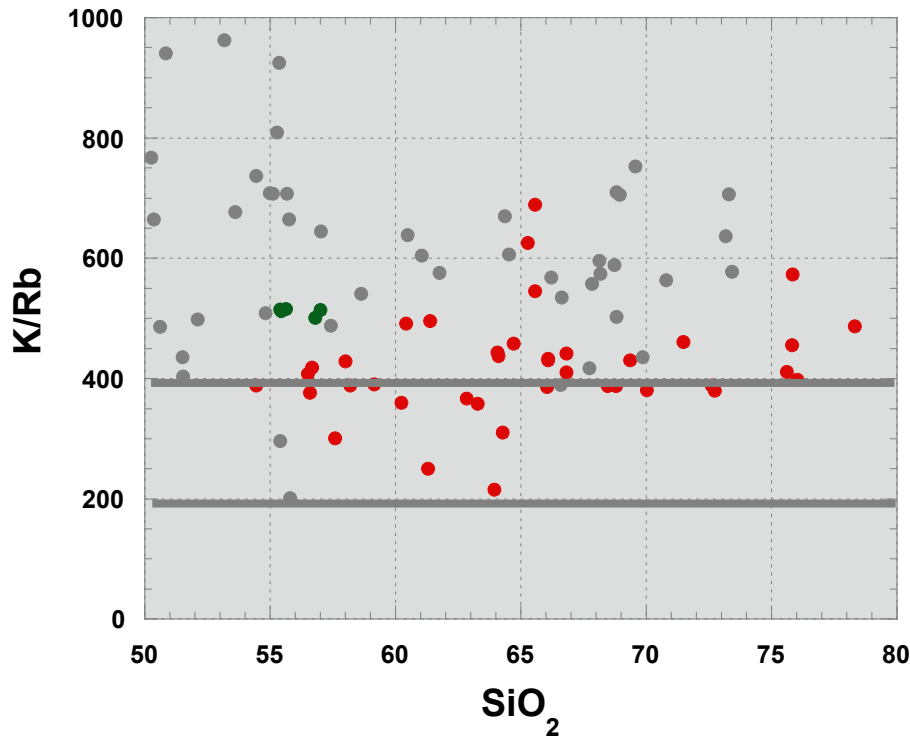
Victoria:

- NSW belts follow through in the east
- Prominent reduced I-types in centre
- Delamerian granites to the west

Tasmania – Sn-W and W (+ IRG) dominate, but Au/Cu in Cambrian.

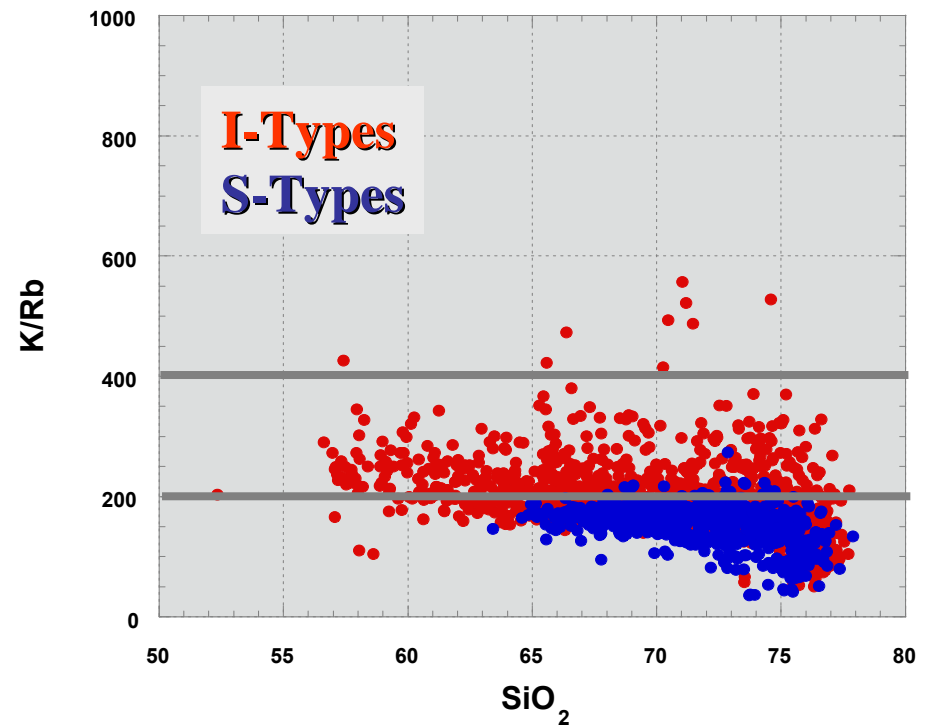
K/Rb – a very useful indicator of compositional evolution, or “remoteness from mantle”

Intrusives from island arcs



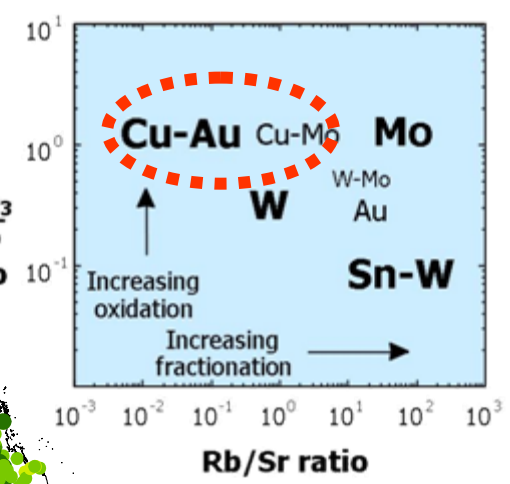
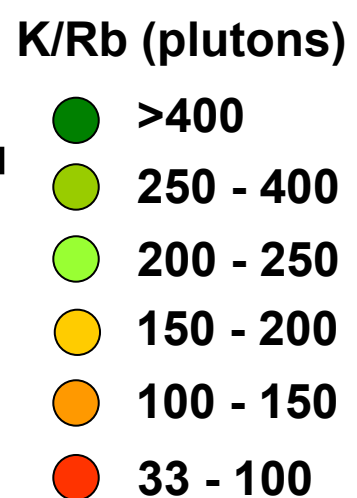
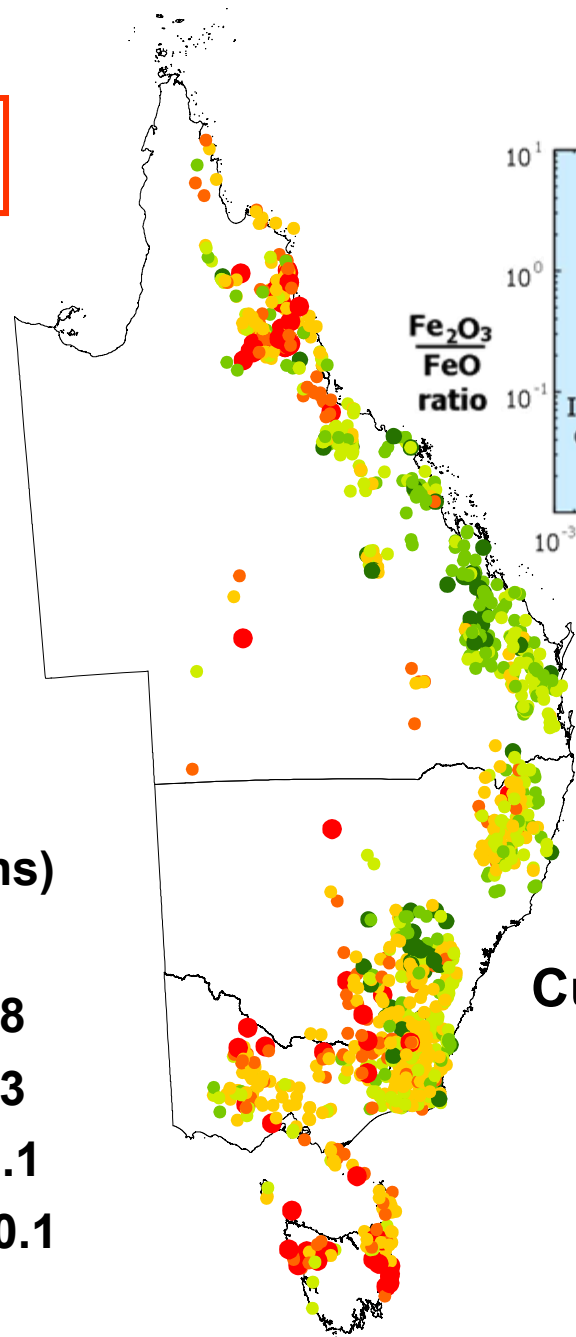
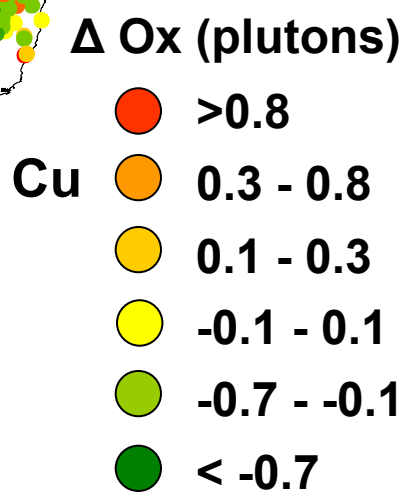
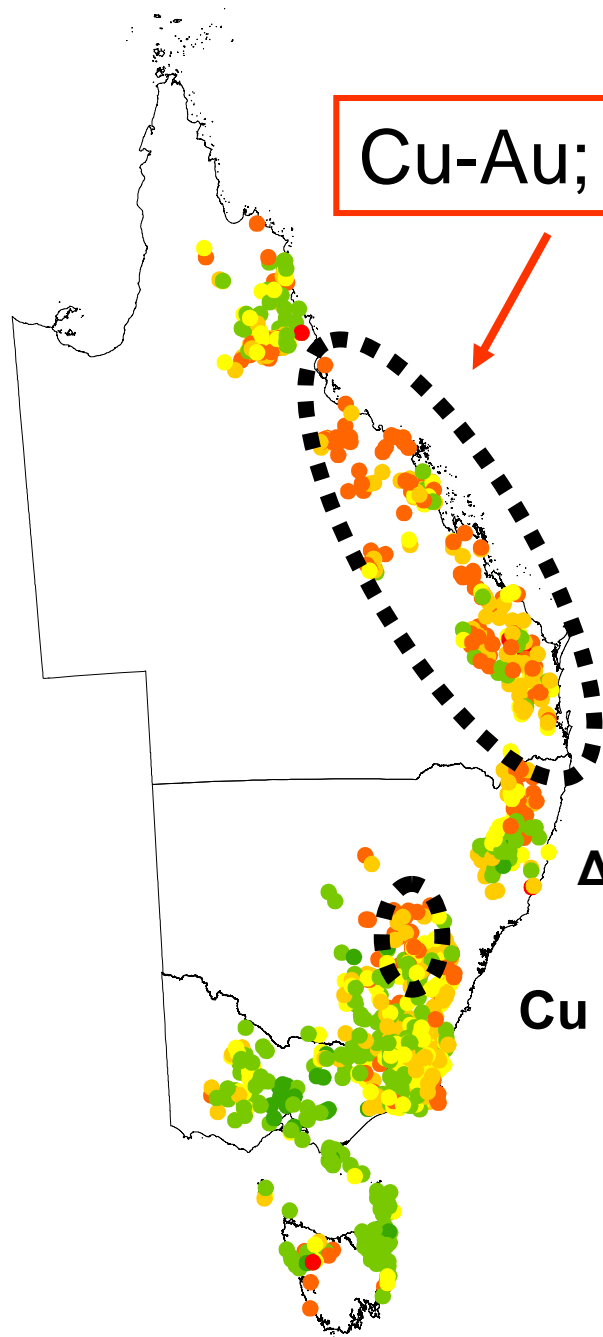
New Britain, **Marianas**, **Lau Basin**

Lachlan Orogen granites

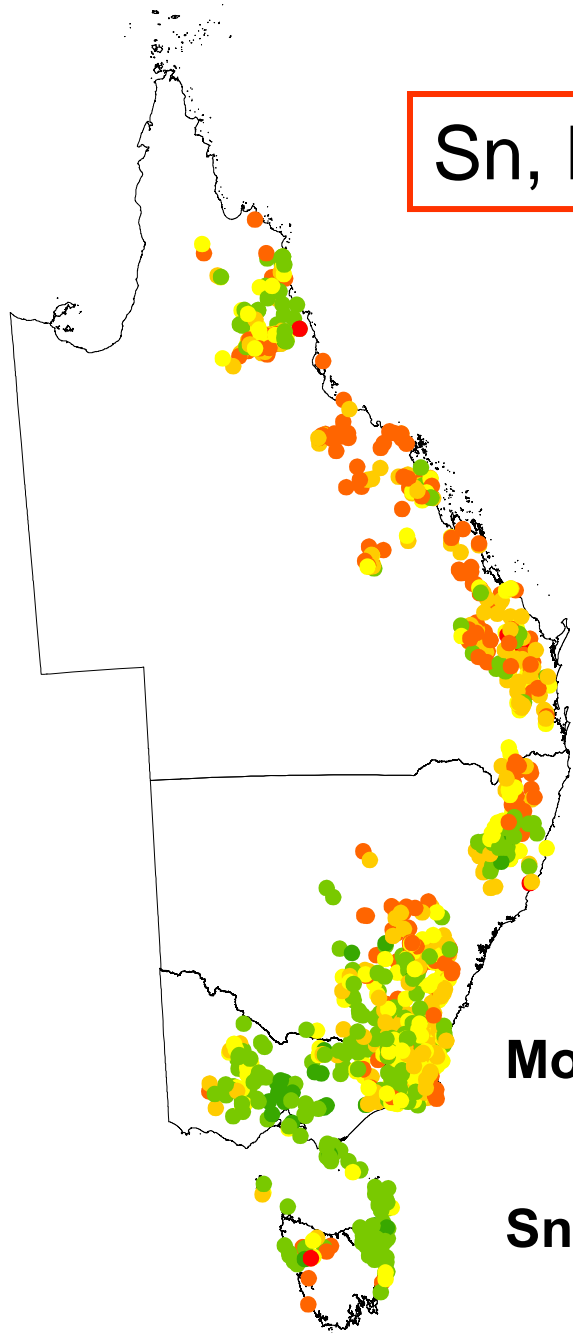


Data sources: GEOROC, Whalen, B. W. Chappell

Cu-Au; Cu-Mo



Sn, Mo, W

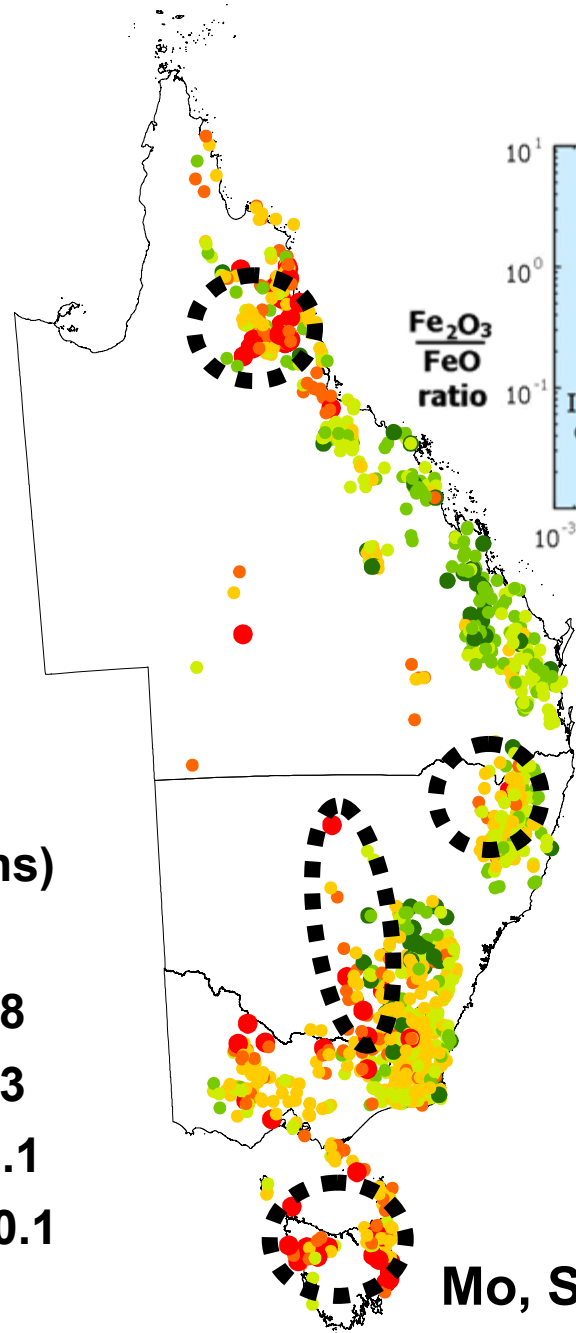


ΔOx (plutons)

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

Mo

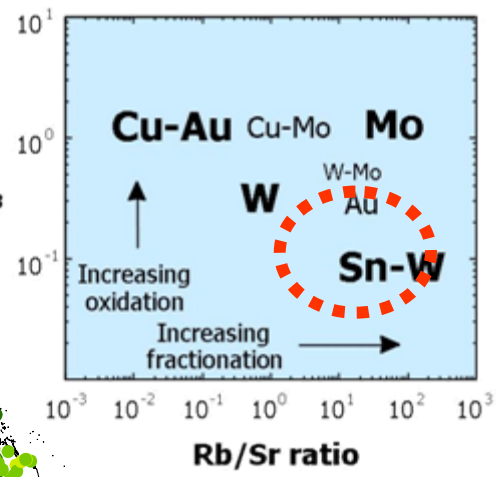
Sn



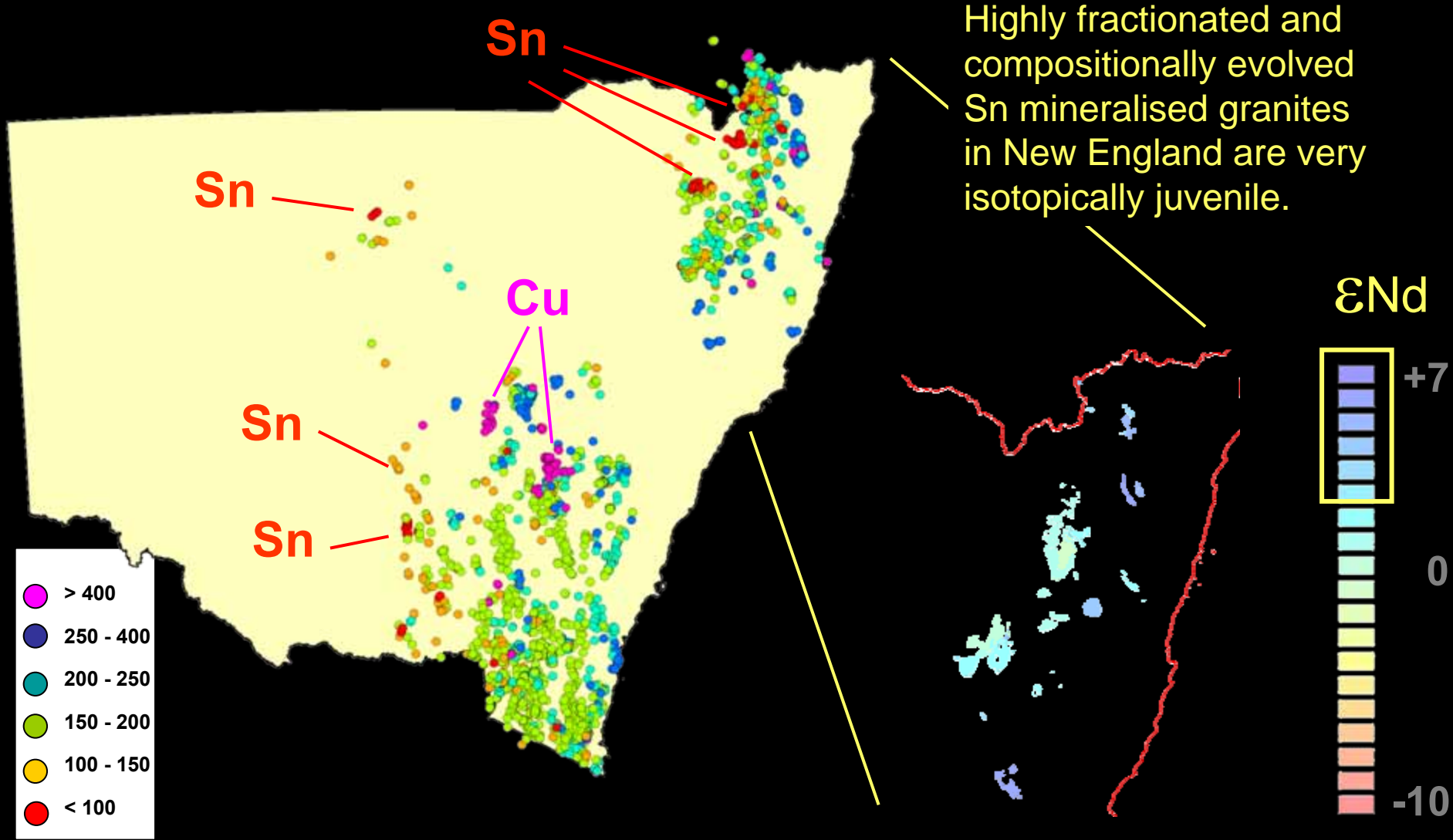
K/Rb (plutons)

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

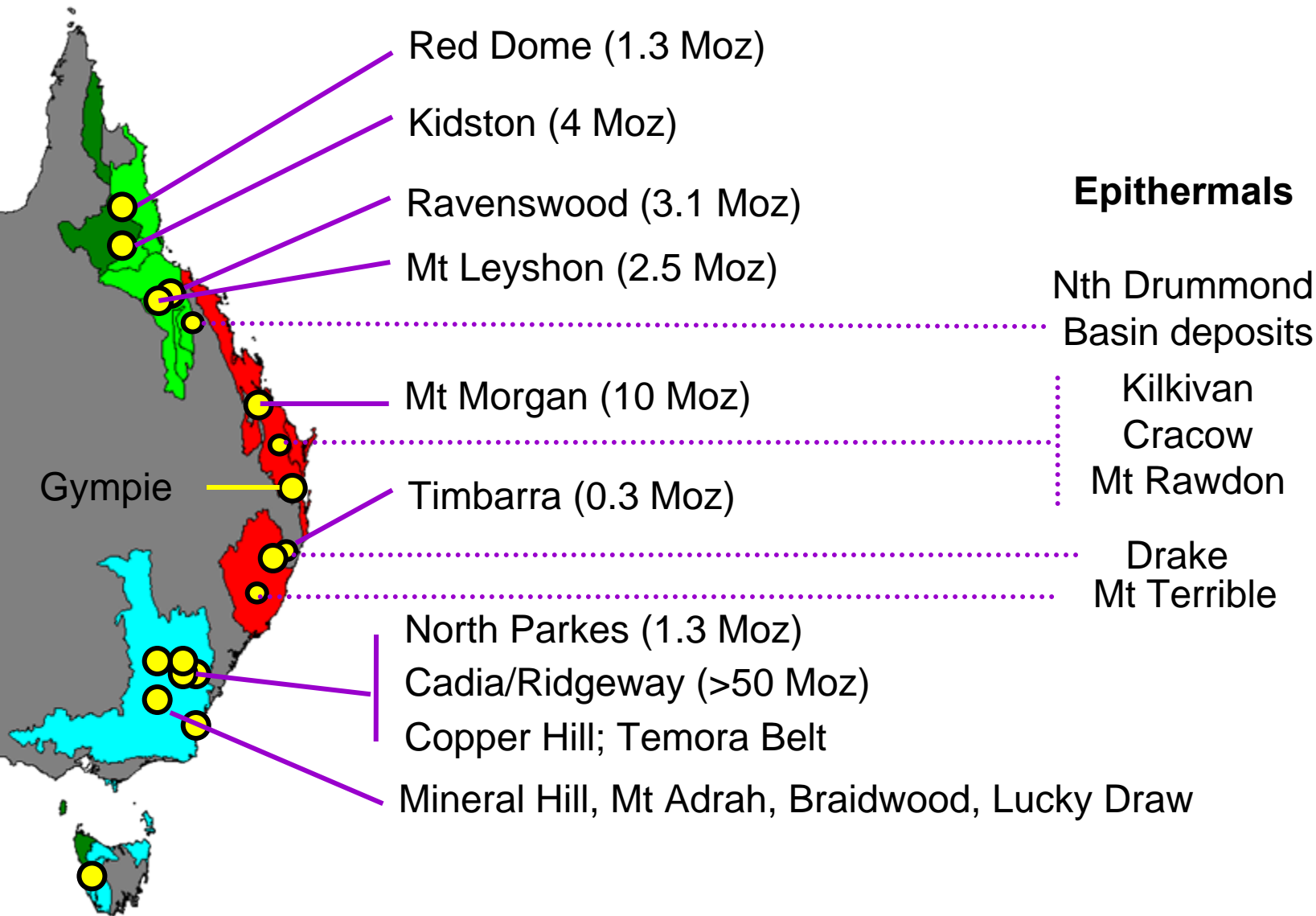
Mo, Sn



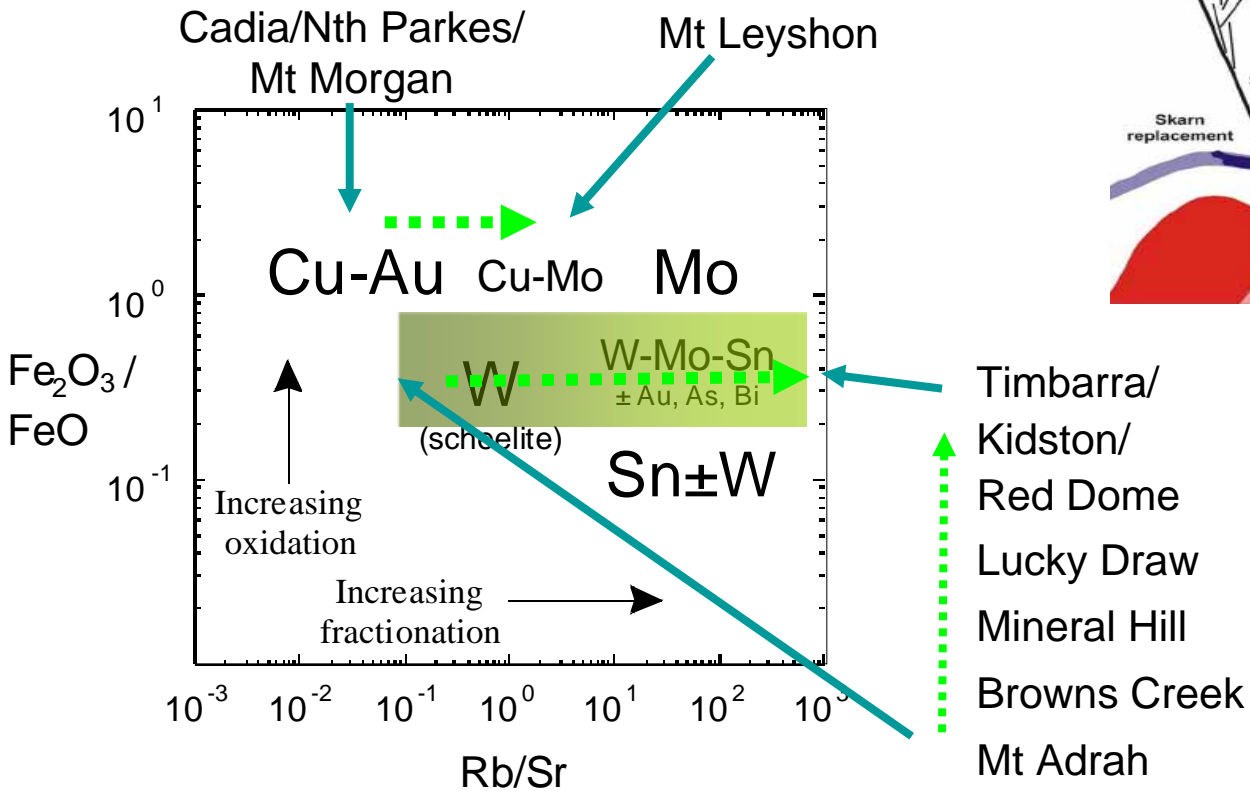
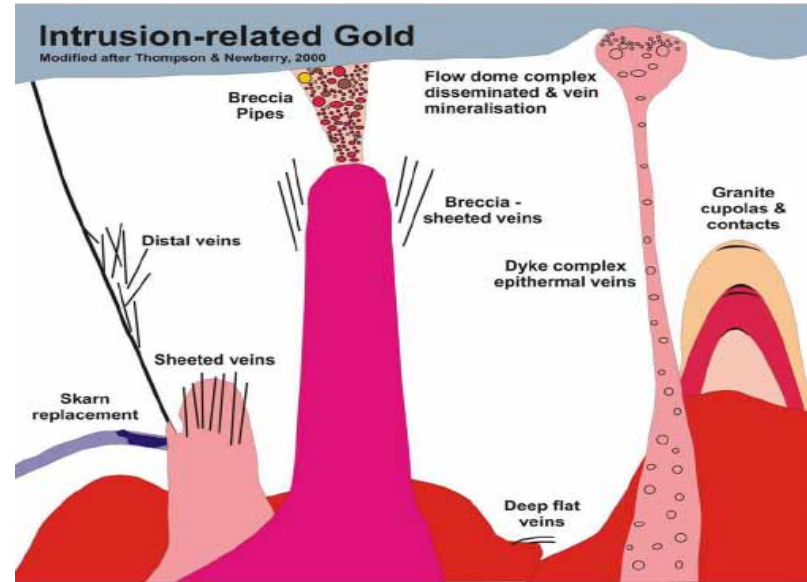
The disconnect between compositional & isotopic evolution



Igneous Gold



Strongly oxidised vs weakly oxidised IRGD



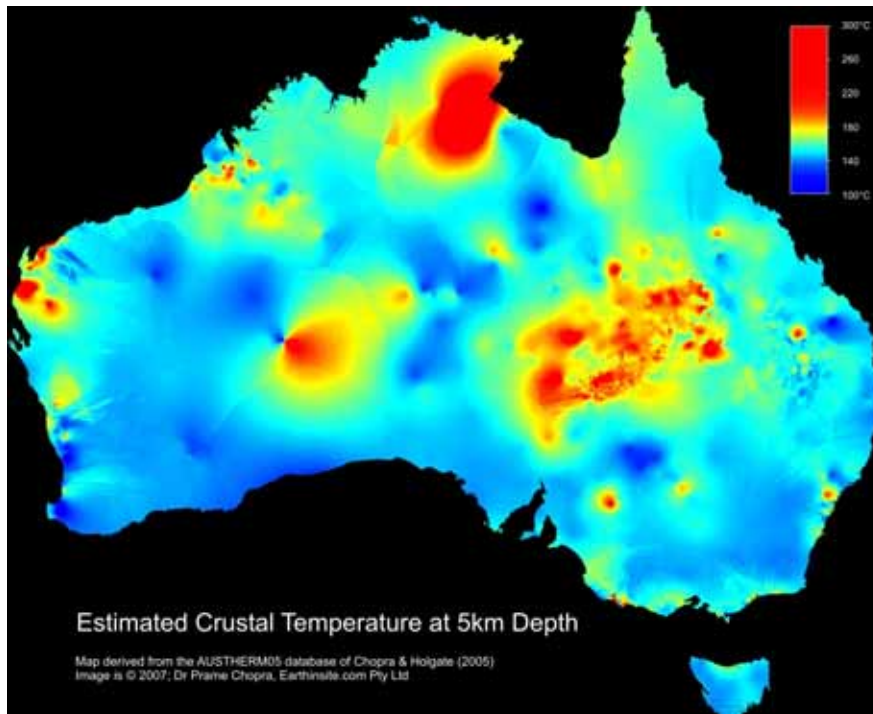
Sn-W-Mo provinces preferred

Granite Heat Potential

The heat production (A) of a rock is given by:

$$A = 0.01 * \rho * (3.48 * K\% + 2.56 * Th_{ppm} + 9.52 * U_{ppm})$$

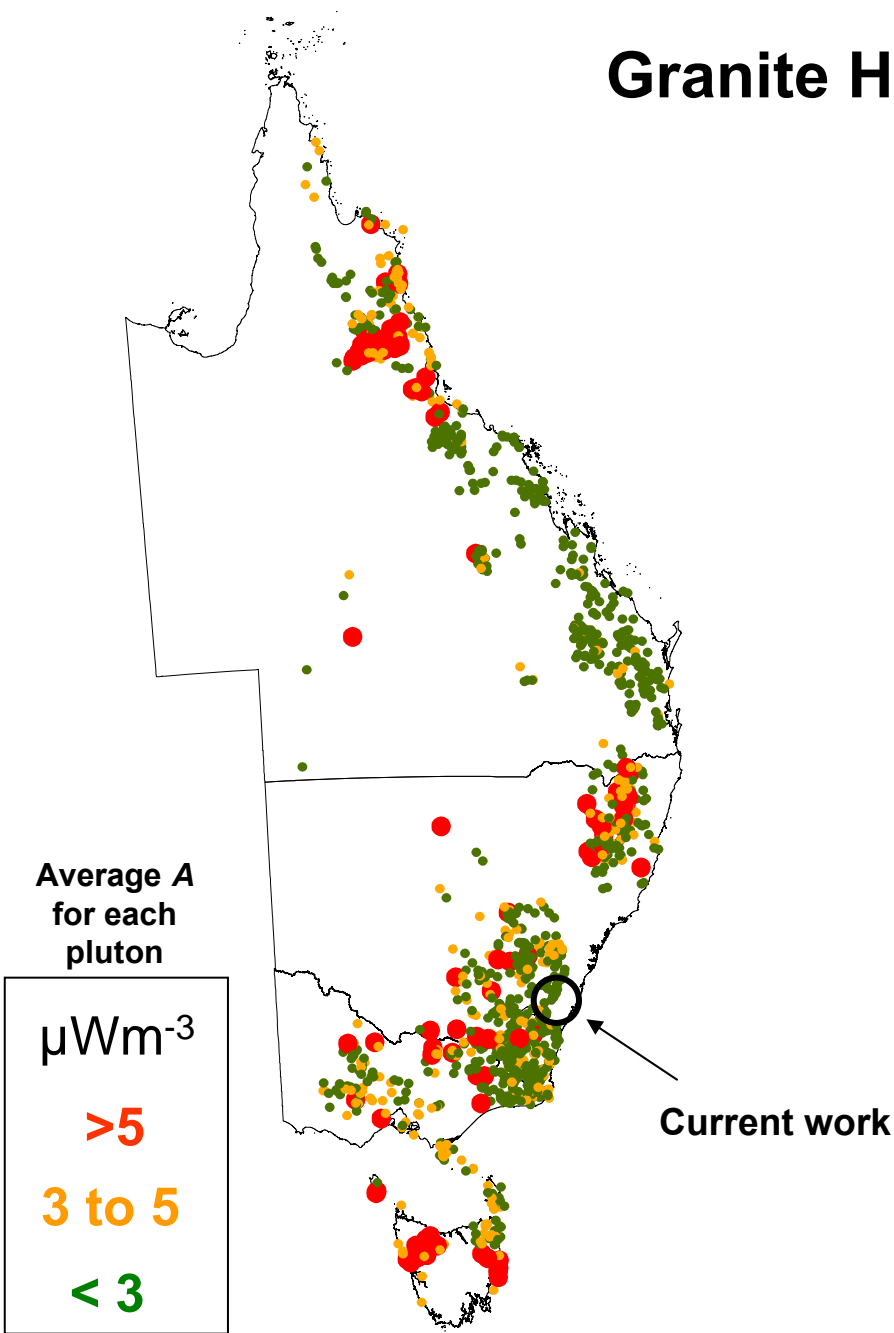
where ρ is density in tonnes/m³ (or SG) and A is $\mu\text{W}/\text{m}^3$



HPE are concentrated in granites but with variable abundances. Typically the most felsic (light-coloured) granites have heat productions (A) of about $3 \mu\text{W}/\text{m}^3$ – less felsic granites have lower values.

Some granites have higher heat production, those greater than $5 \mu\text{W}/\text{m}^3$ the High Heat Producing (HHP) granites. 12.7% of the more than 8000 granites that B. W. Chappell analysed from eastern Australia are HHP.

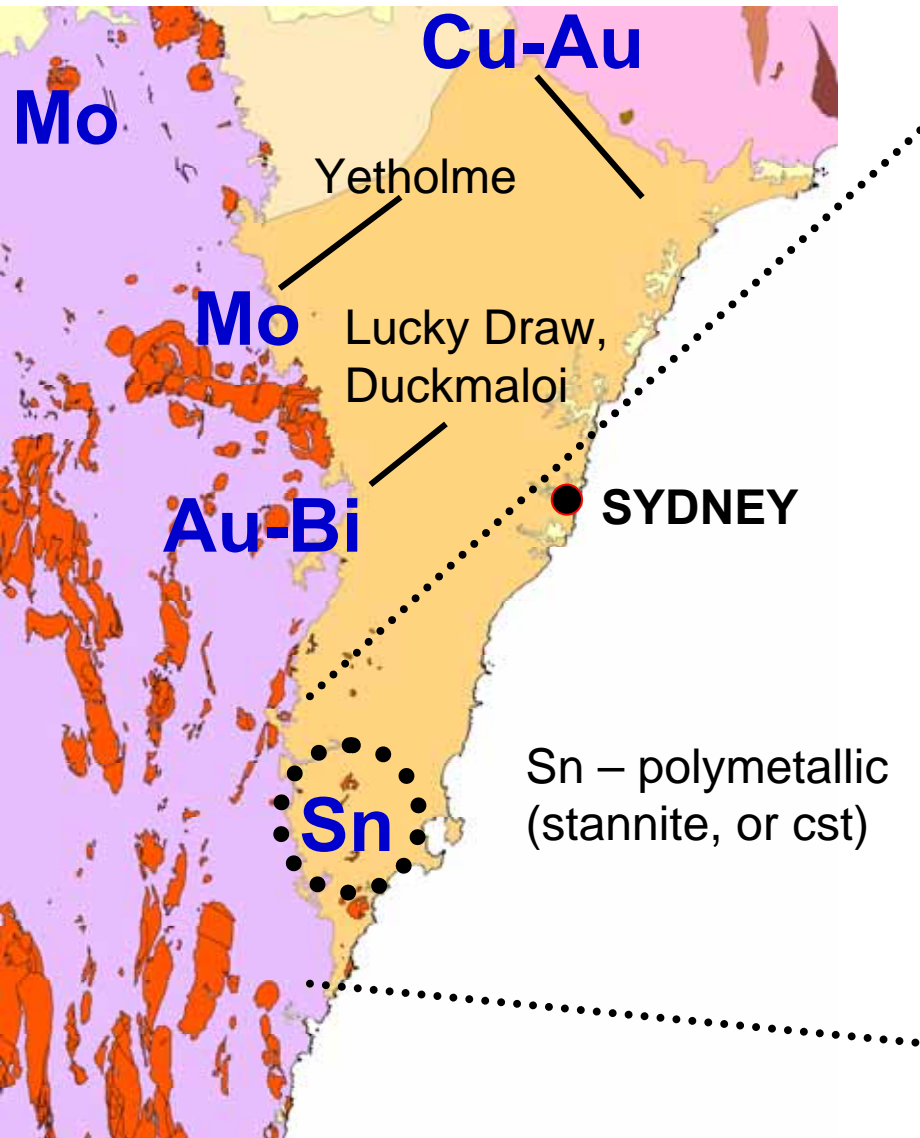
Granite Heat Potential



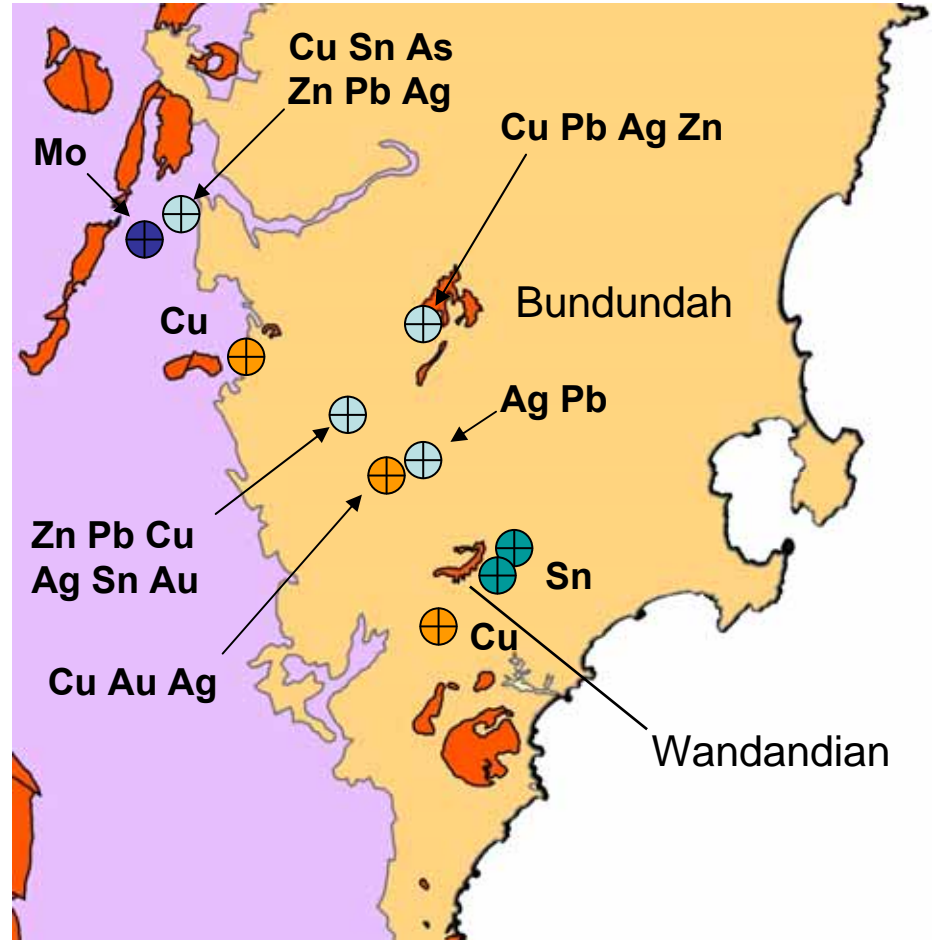
- Strong regionality.
- Associated with fractionated granites (Sn, W, Mo).
- Many near (and under) basins.
- No simple correlation with setting or isotopic evolution.

$$A = 0.01 \cdot \rho \cdot (3.48 \cdot K\% + 2.56 \cdot \text{Thppm} + 9.52 \cdot \text{Uppm})$$

Mineralisation



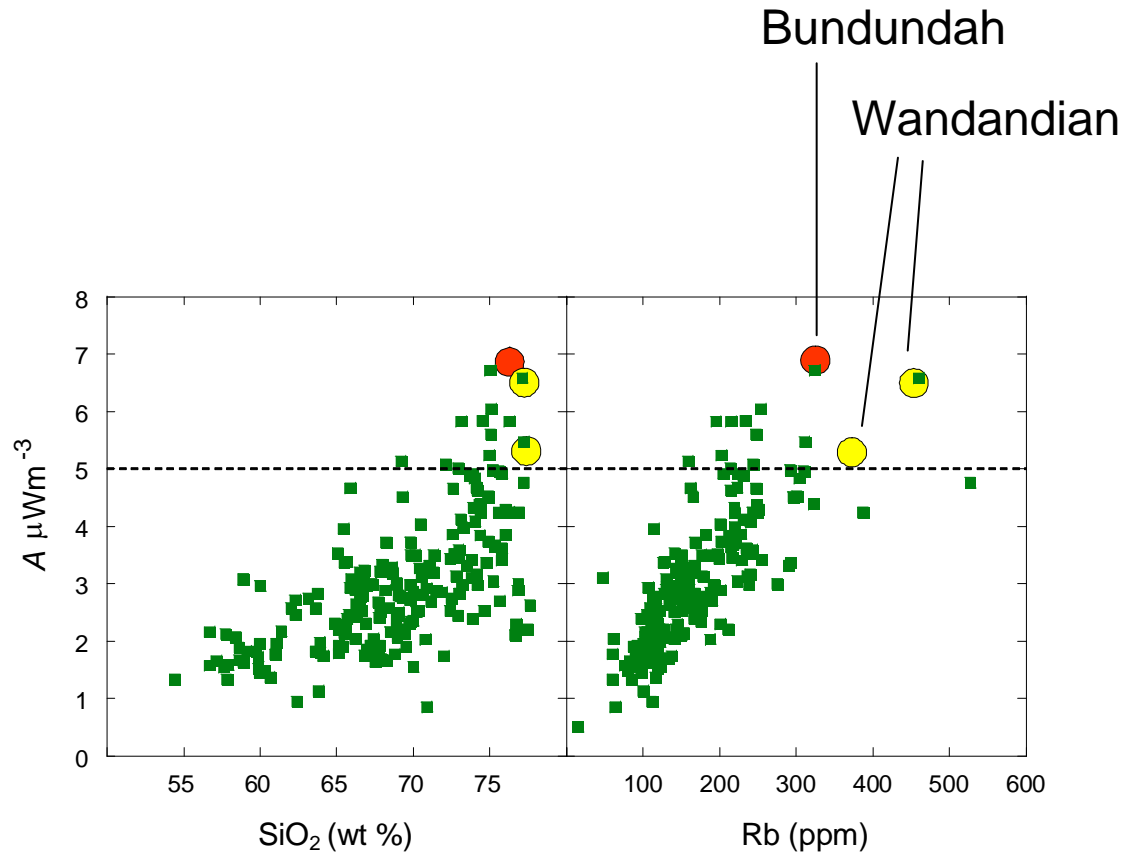
Possible Carboniferous mineral deposits



Sb, Bi & As are common accessories

Carboniferous Granites

Southern basin granites are very high heat generating.....



Carboniferous Granites



Exploration under cover

- Not all Carboniferous granites are magnetic. Some are reduced. Highly fractionated granites also have low magnetic susceptibilities.
- Gravity will be crucial.

Airborne magnetic image (RTP) of Bathurst Batholith

Cassiterite dating (RSES)

Highly successful

- New England
- Wagga Belt
- Curnamona

Zircon Forensics (JCU)

(U-Pb, Lu-Hf, O, REE)

- Mac Arc intrusions
- New England regional
- Tingha-Gilgai system

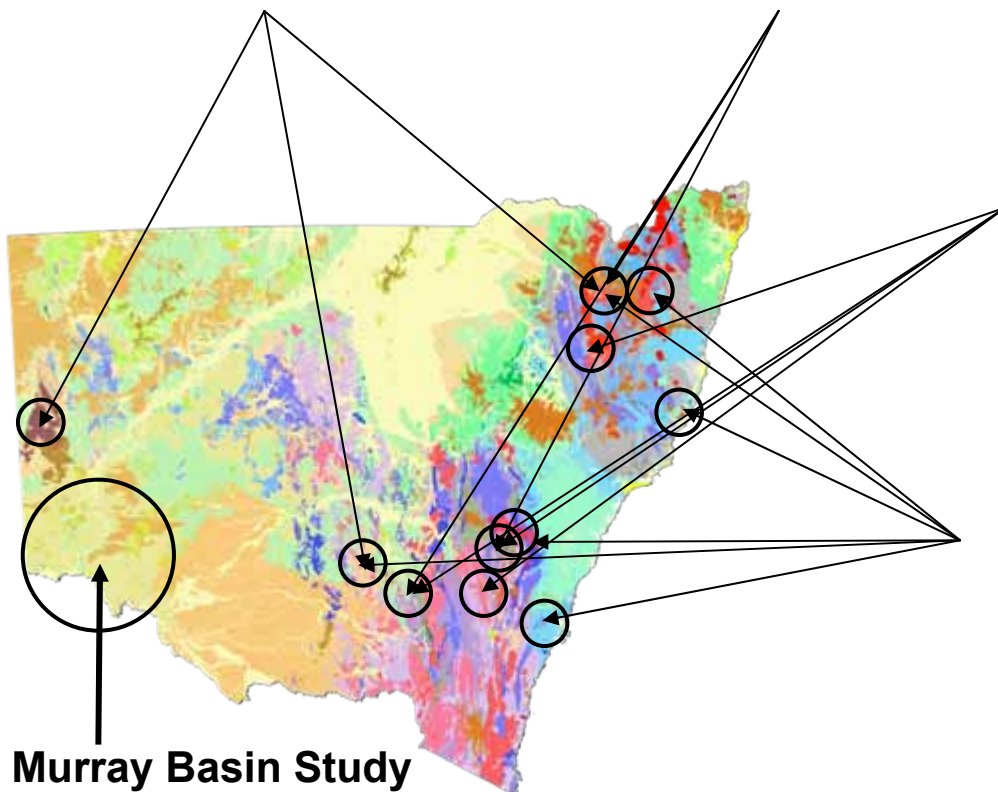
**Integrated dating to
define timing of
magmatism, alteration
and metal deposition.**

Re-Os dating (RSES)

- Mac Arc: Temora belt, Cargo, Tallwood
- New England: Kingsgate, Conrad, Attunga
- Lachlan: Rye Park

SHRIMP dating

- Coastal New England (GA)
- Tingha-Inverell (GA)
- Wagga Belt Sn (GA)
- Lachlan Carboniferous (ANU - PhD)



Murray Basin Study

Cassiterite dating – excellent results

**Great Britain Mine,
Emmaville: 242 ± 3 Ma**

Other Great Britain ages (Kleeman, Plimer and others):
244 ± 2 Ma by whole rock K-Ar of selvage.

Taronga stockwork: 245 ± 3 Ma

Other Taronga ages (Kleeman, Plimer and others):

244 ± 2 Whole rock K-Ar on selvage

247 ± 2 Muscovite K-Ar

246 ± 2 Muscovite - whole rock Rb-Sr

245 ± 1 Muscovite Ar-Ar

246 ± 2 Muscovite Ar-Ar

Elsmore Greisen: 242 ± 2 Ma!

Same age as Mole, much younger than Gilgai

ARC proposal: industry contributions welcome!

Ardlethan

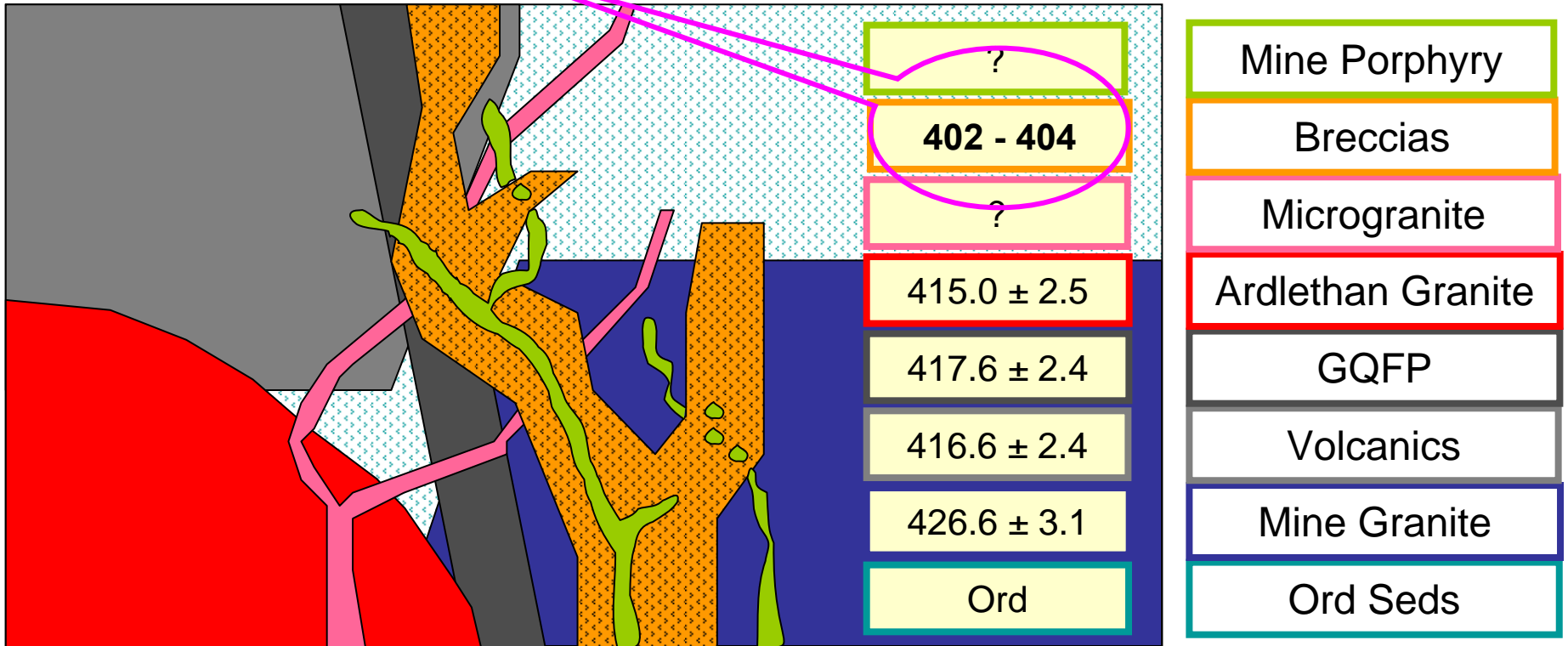
Burrandana also much younger

404.9 ± 2.3 Ma

402 ± 2 Ma

GEMOC U-Pb zircon

U-Pb cassiterite age



MINERALISATION REFERENCE

This is a draft reference guide for the Mineralisation Reference. It is intended to provide a consistent framework for the Mineralisation Reference. It is not intended to be a definitive guide and should be used in conjunction with the Mineralisation Reference. The Mineralisation Reference is a complex system of classification and is subject to change. It is intended to provide a consistent framework for the Mineralisation Reference. It is not intended to be a definitive guide and should be used in conjunction with the Mineralisation Reference.

Table with 4 columns: Mineralisation Reference, Description, and other classification details. It lists various mineralisation types such as Iron, Copper, and Gold, with their respective symbols and colors.

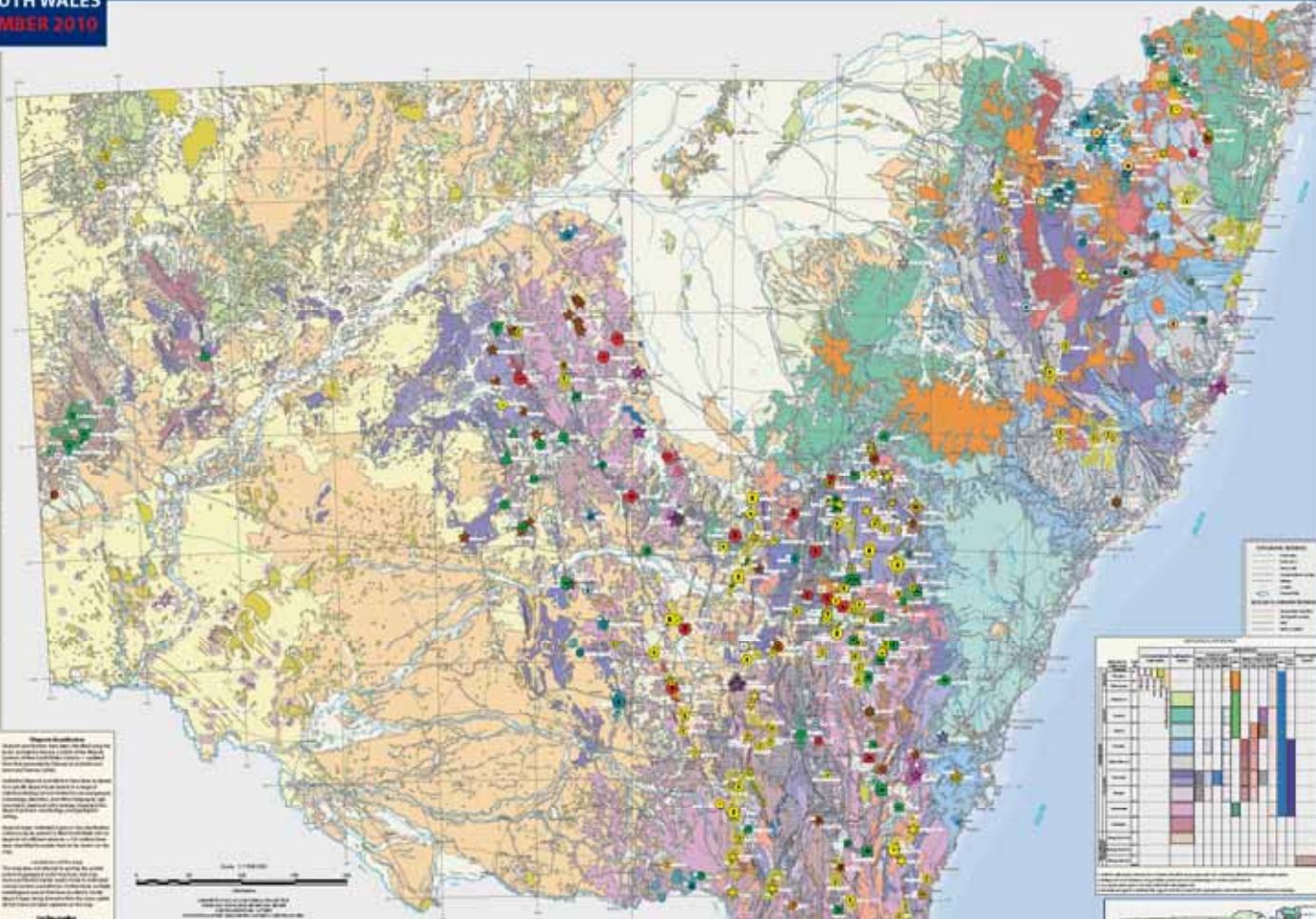


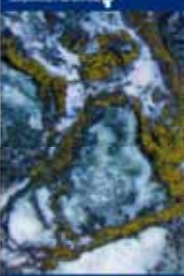
Table with 8 columns: Name, Location, State, and other details. It lists numerous mineralisation sites across New South Wales, including names like 'Ironstone', 'Copper', and 'Gold', along with their geographic coordinates and administrative boundaries.

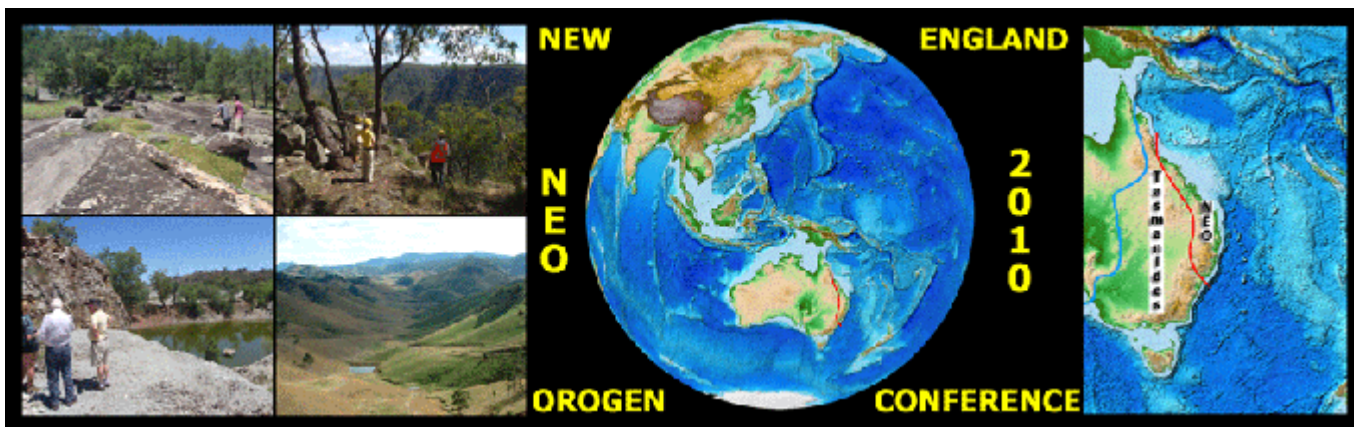


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METALLOGENIC MAP OF NEW SOUTH WALES
1:1 500 000





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