Timing is everything

Applications of new dating methodologies to the mineral systems of NSW

Dr Phillip Blevin – Manager – Minerals, GSNSW

April 26th 2018

Contents

Minerals at the GSNSW

- Dr Phil Blevin – Manager
  - Dr Joel Fitzherbert (senior geoscientist)
  - Dr Peter Downes (senior geoscientist)
- NVCL - Londonderry
  - Dr David Tilley (senior geoscientist)
    - Peter Bukey (technical officer)
    - Troy Kelly (technical assistant)

Major Projects

- Nymagee – Cobar
- Hylogging
- Geochronology
- NEO metallogeny and granites
- Mineral potential mapping

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Metals in Time

- Aim to tie mineralisation to specific events, magmas.
- Help constrain paragenetic models and assist with exploration modelling.
- New dating techniques, using new minerals, are being developed which is resulting in a marked increase in precision and accuracy.

The Minerals Team would like to encourage collaboration with explorers and miners in NSW to better understand the timing and origins of metals and fluids in the state's mineral systems.

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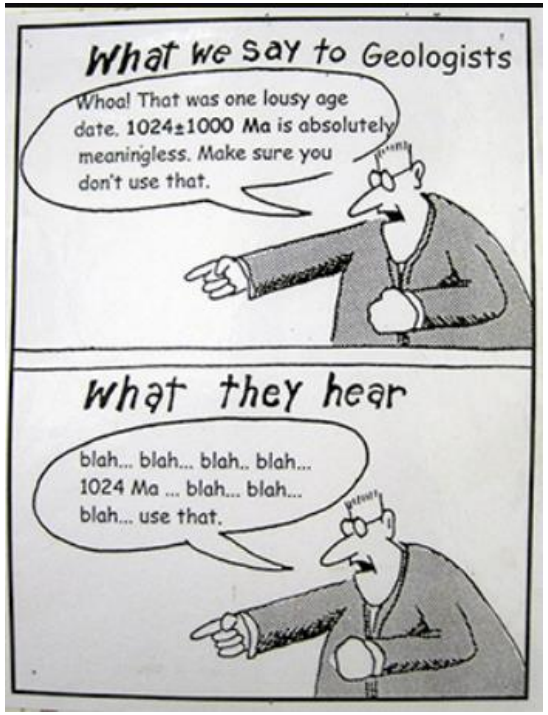
Dating techniques being employed

- U-Pb dating by SHRIMP, LA-ICPMS and CA-IDTIMS for:
  - zircon
  - cassiterite
  - allanite
  - titanite
  - apatite (problematic)
- Sm-Nd dating of scheelite and garnets
- Rb-Sr dating of biotites and scheelite
  - Rb-Sr can also be applied to chlorite-carbonate
- Re-Os on molybdenite. Arsenopyrite?
- Ar-Ar and K-Ar dating of hydrosilicates
  - musc, biotite, amphiboles



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CA-IDTIMS

- Chemical abrasion isotope dilution thermal ionization mass spectrometry (CA-TIMS or CA-IDTIMS)
  - Performed on single crystals
  - Crystals are etched by HF and HNO_3
  - Spiked with mixed ^{233}U-^{235}U-^{205}Pb tracer solution and dissolved
  - U and Pb recovered, loaded onto a Re filament, and measured on a TIMS giving a direct measurement

- CA-IDTIMS: ± 100,000 years at 400 million years and much better
- SHRIMP: ± 2,000,000 years at 400 million years

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CA-IDTIMS

Annealing and chemical abrasion

High temperature annealing (900°C) prepares zircon crystals for the chemical abrasion method, an efficient partial dissolution method for removing open-system intra-crystalline domains

Photo credit - https://earth.boisestate.edu/isotope/

CA-IDTIMS

Phoenix X62

The IGL hosts two thermal ionization mass spectrometers with state-of-the-art ion-counting and 10^12 ohm Faraday amplifiers: the new IsotopX Phoenix X62 and the upgraded IsotopX Isoprobe-T

Photo credit - https://earth.boisestate.edu/isotope/

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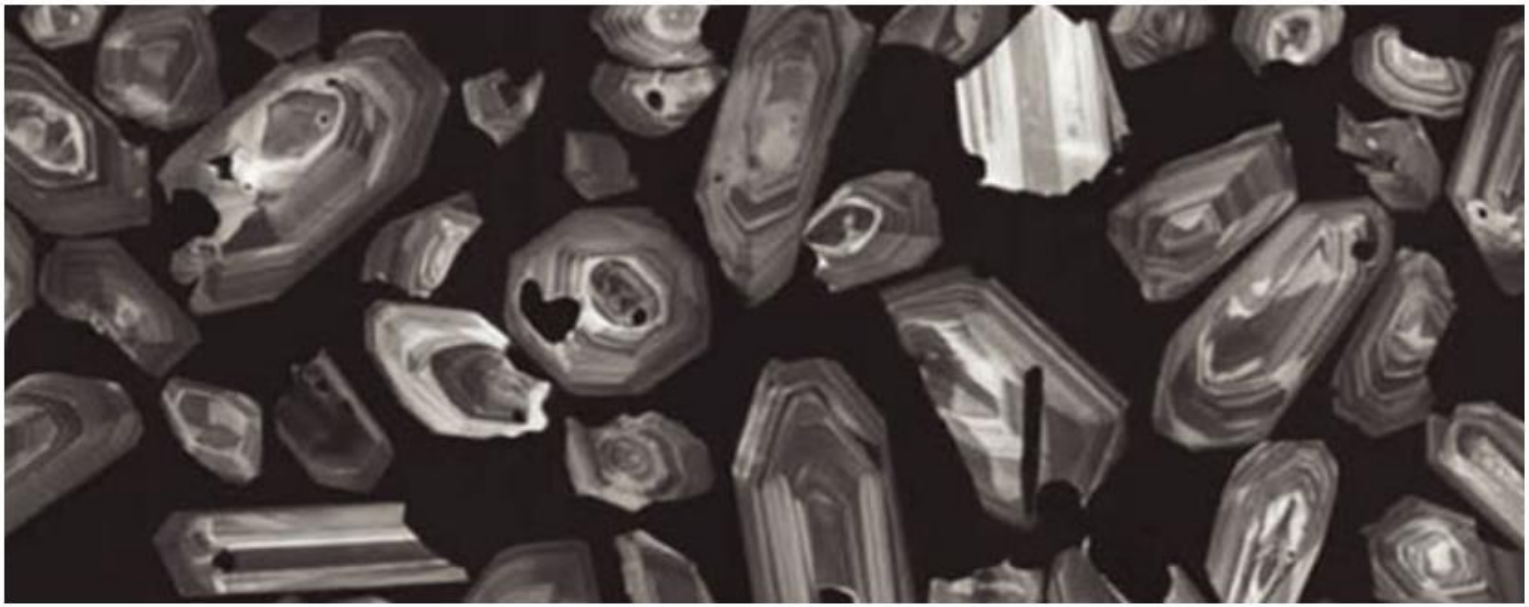
CA-IDTIMS – however...



Zircon cathodoluminescence (CL)

Zircon crystals are luminescent under electron beam bombardment, revealing internal growth patterns invisible to the naked eye

Photo credit - https://earth.boisestate.edu/isotope/

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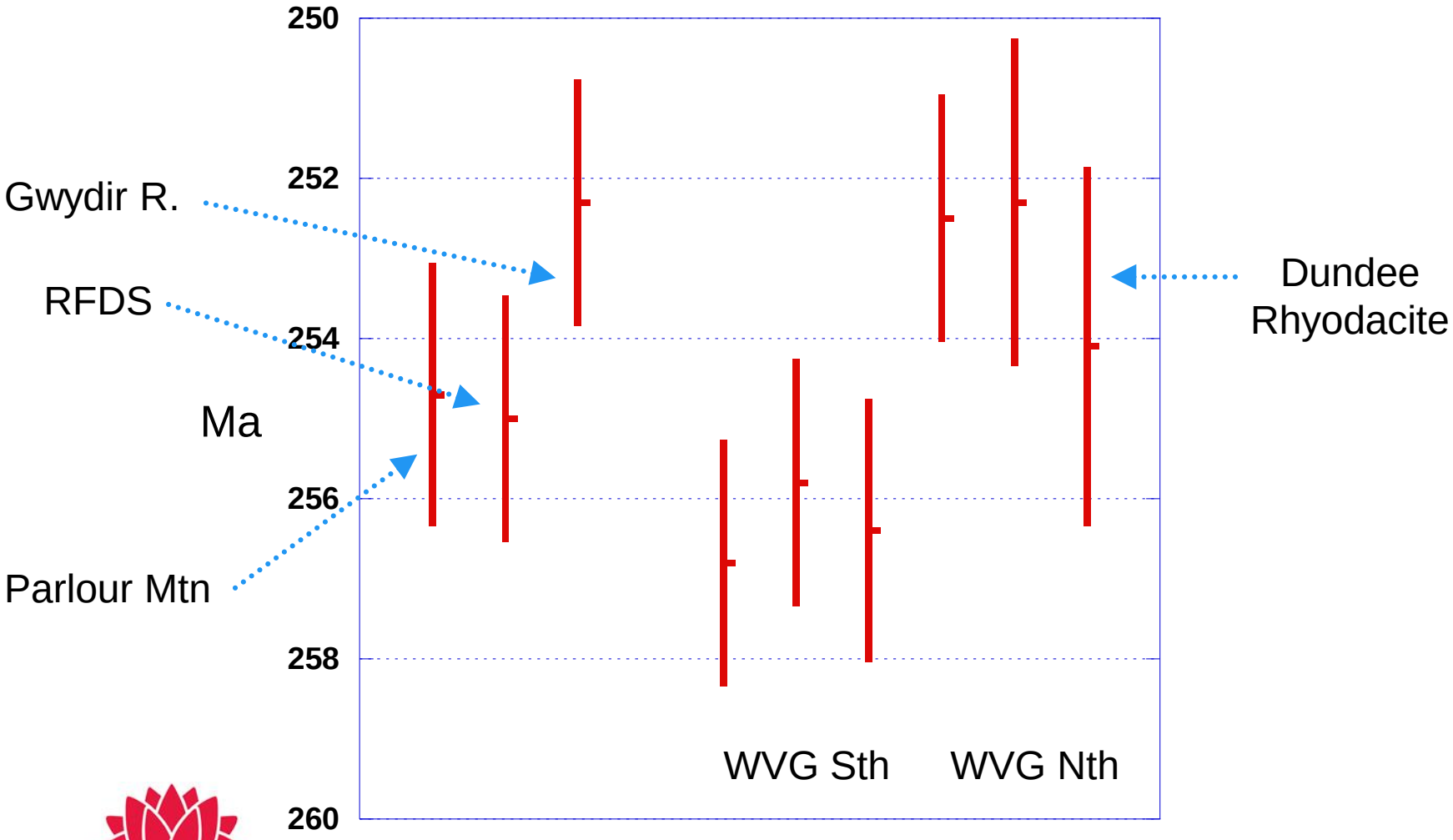
CA-IDTIMS: just how precise?



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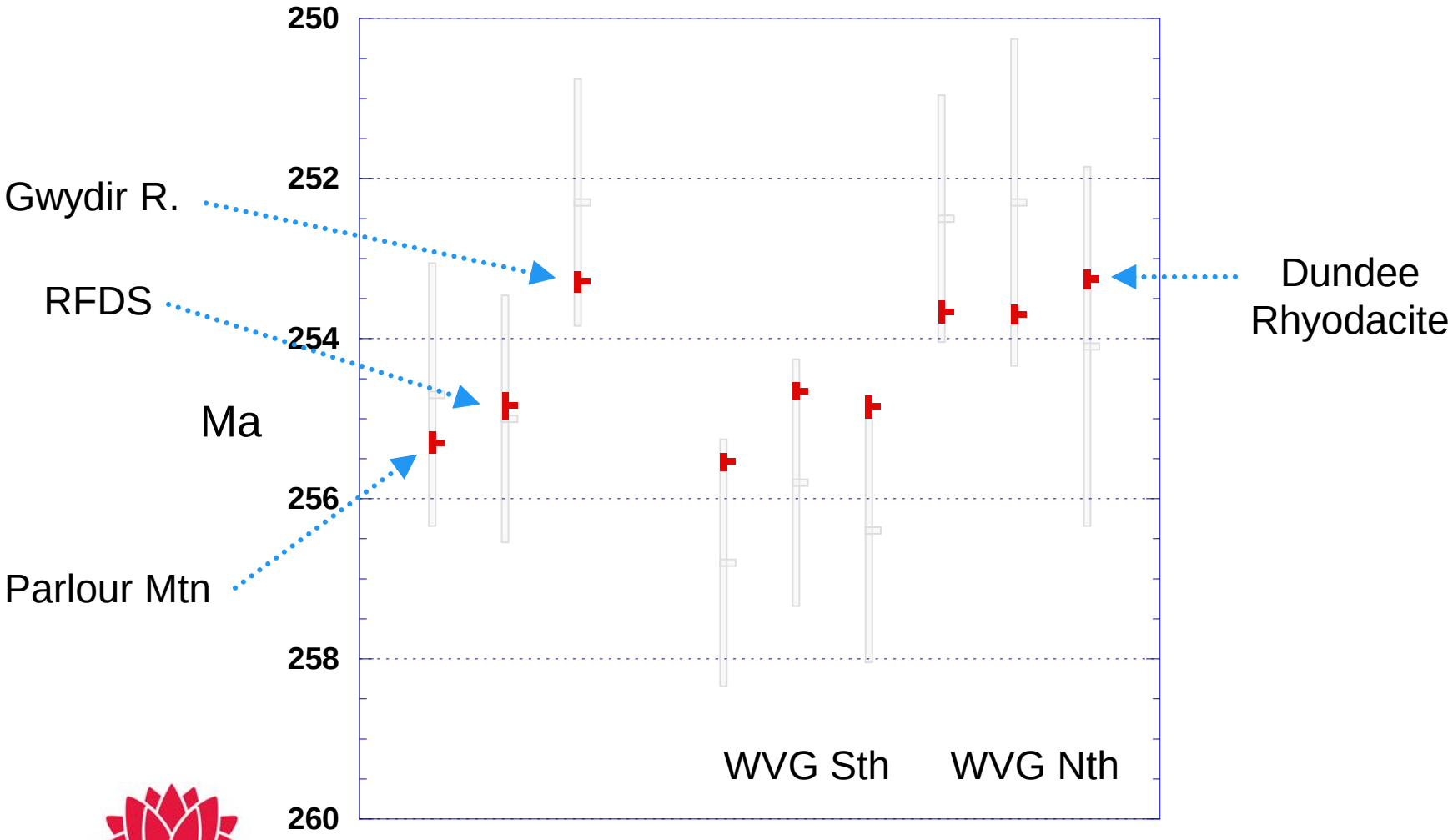

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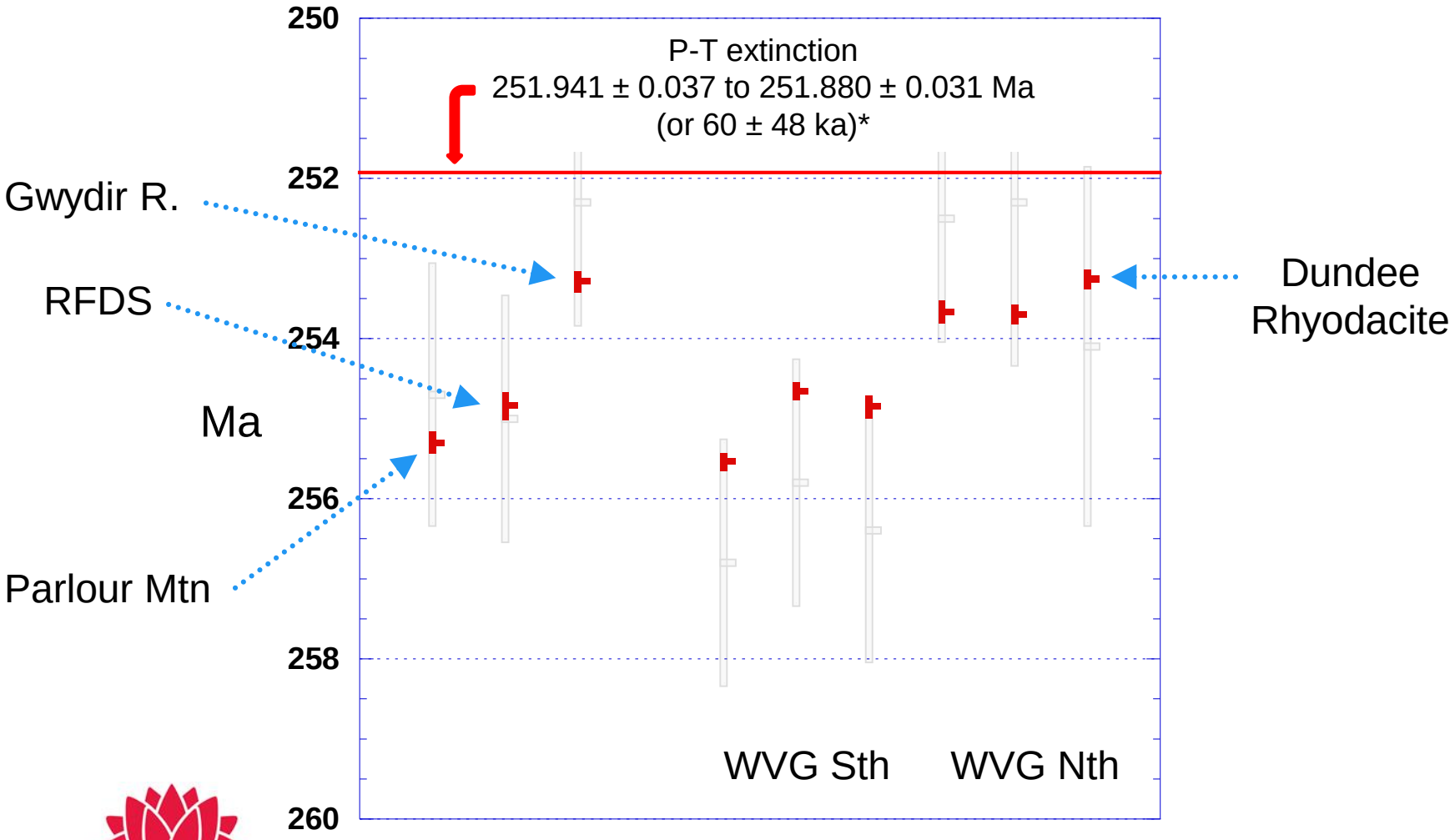
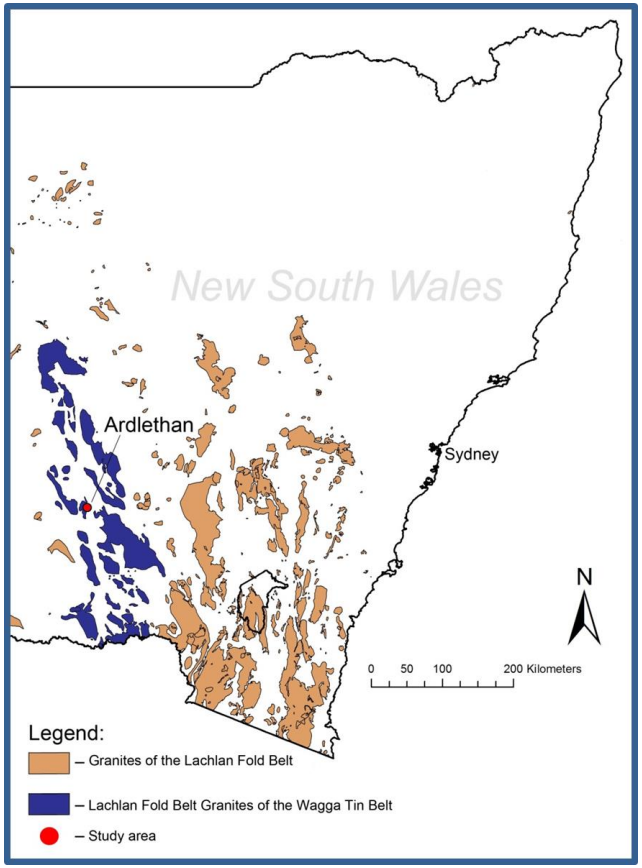
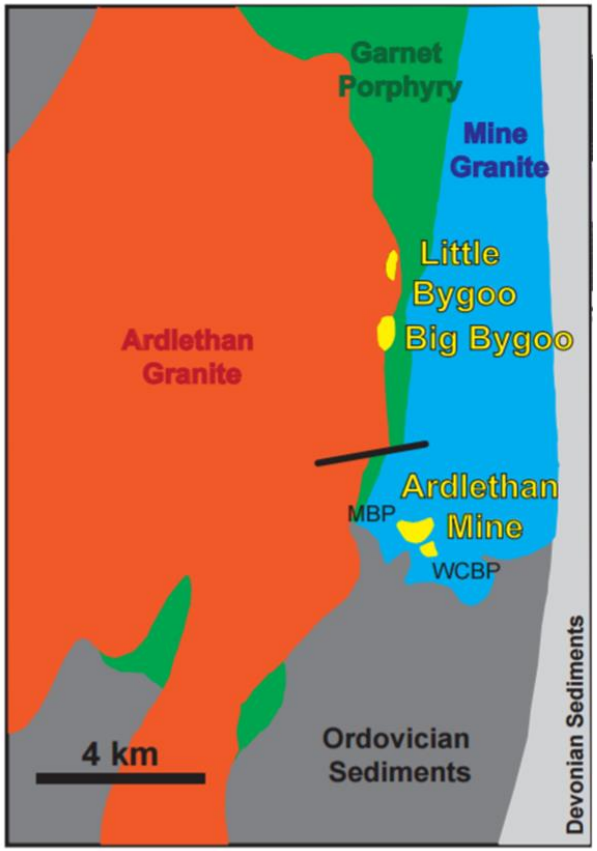


*: Burgess et al, 2014

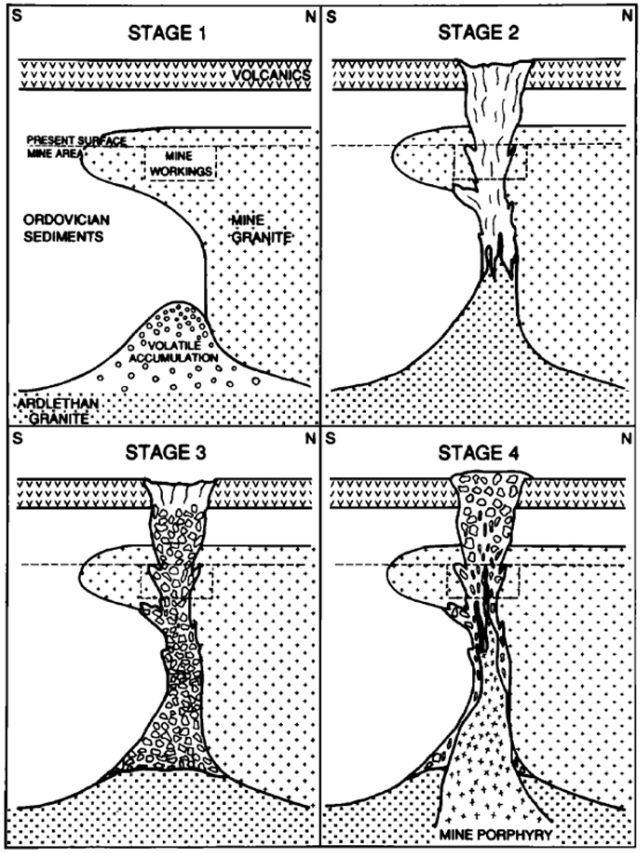
Ardlethan – original rock relationships





After Ren et al., 1994

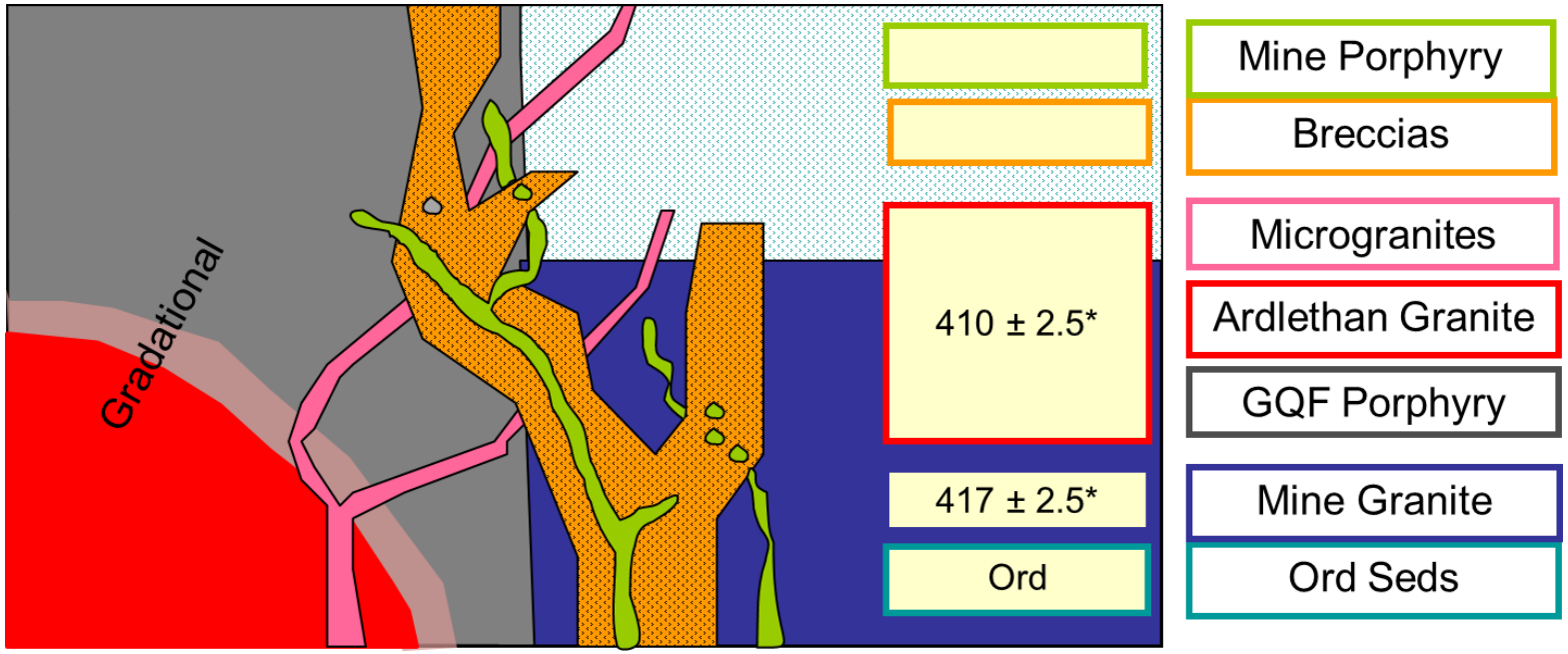
Ardlethan – original rock relationships



- Stage 1: Volatile accumulation
- Stage 2: Explosive brecciation
- Stage 3: Collapse
- Stage 4: Resurgent magmatism emplacement of Mine Porphyry

After Ren et al., 1994

Ardlethan – original rock relationships



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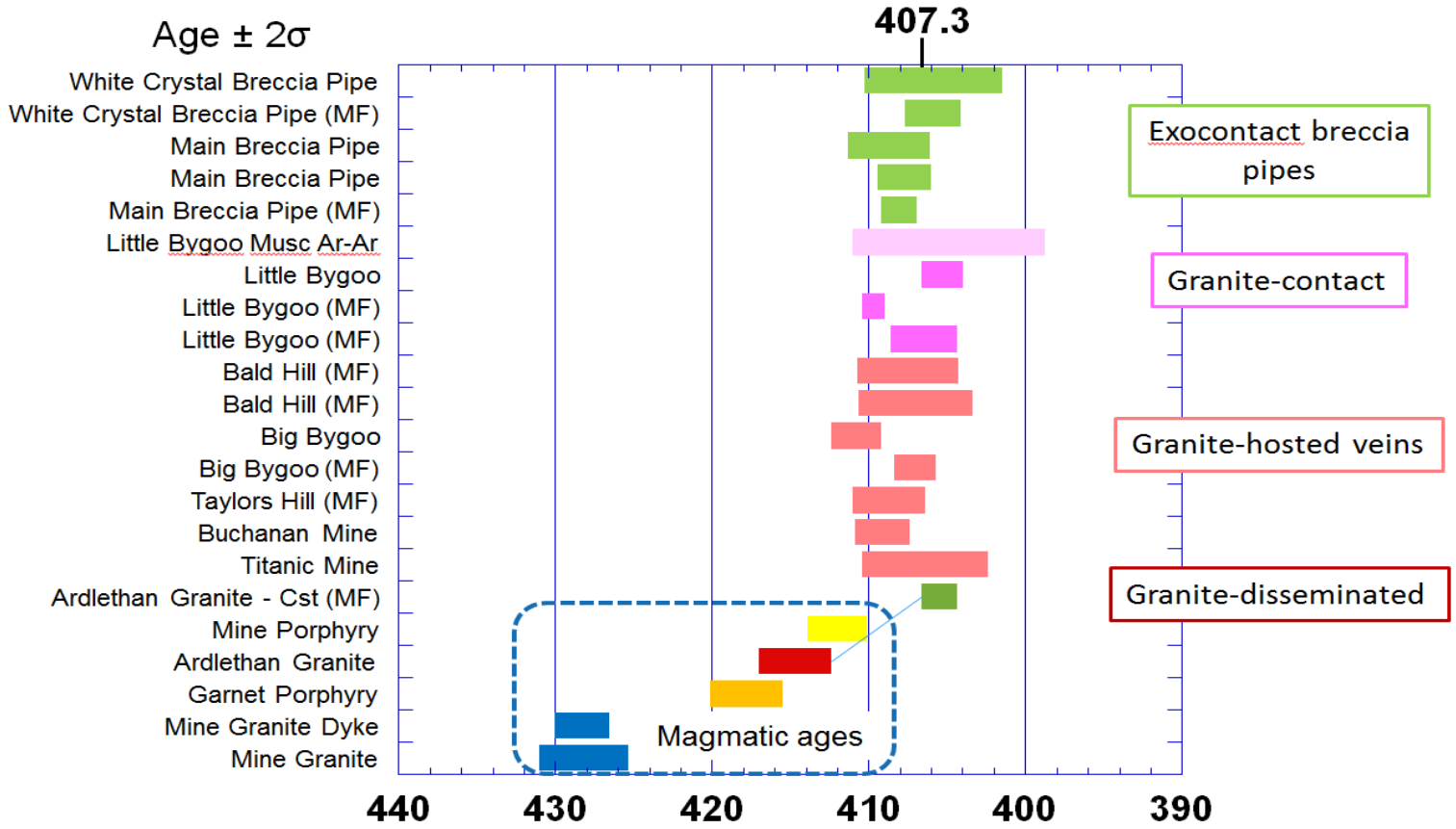
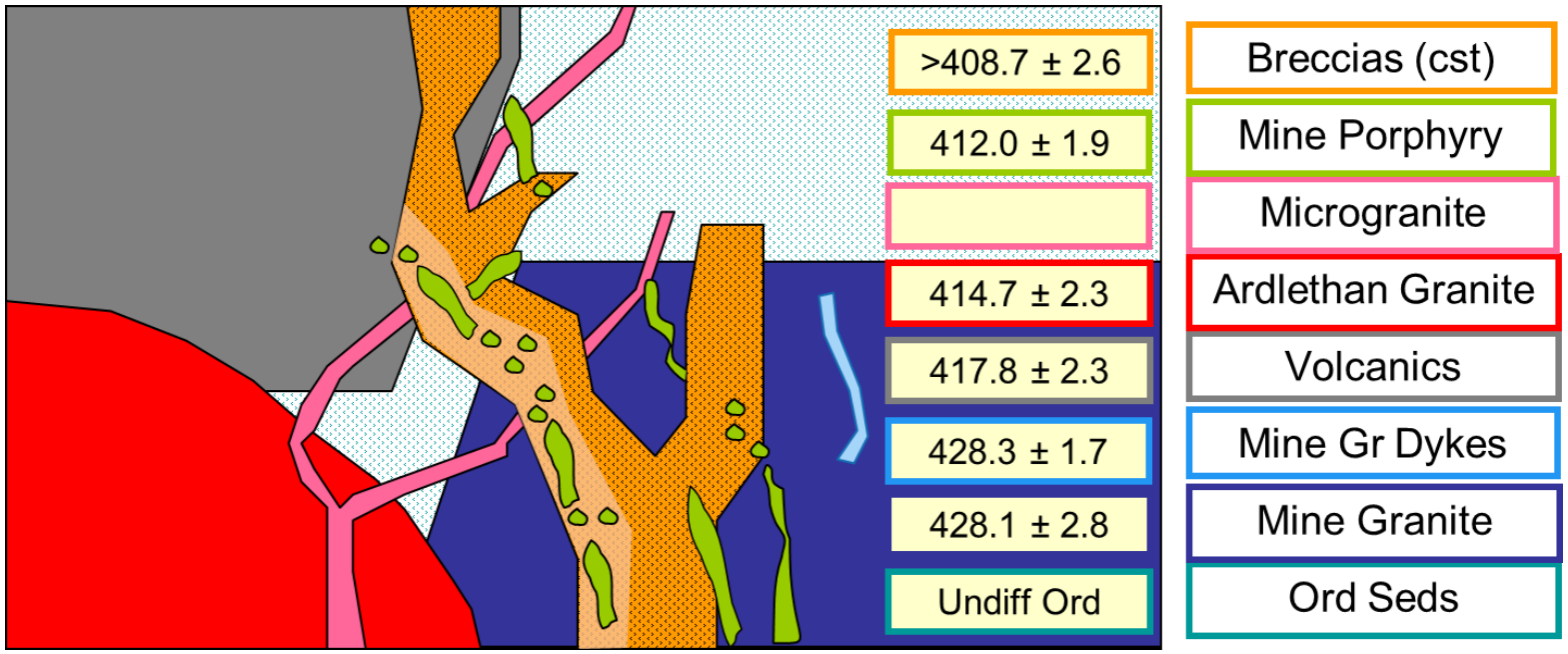
Cassiterite U-Pb LAICPMS dating



U-Pb zircon SHRIMP and cassiterite LAICPMS dating



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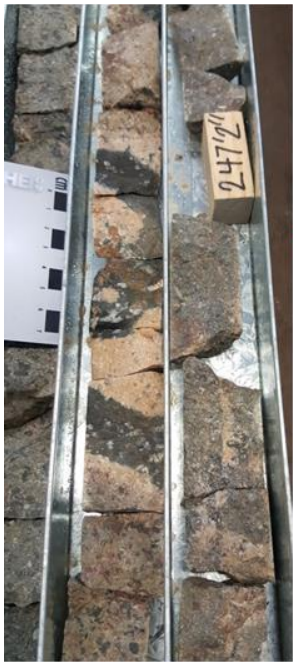
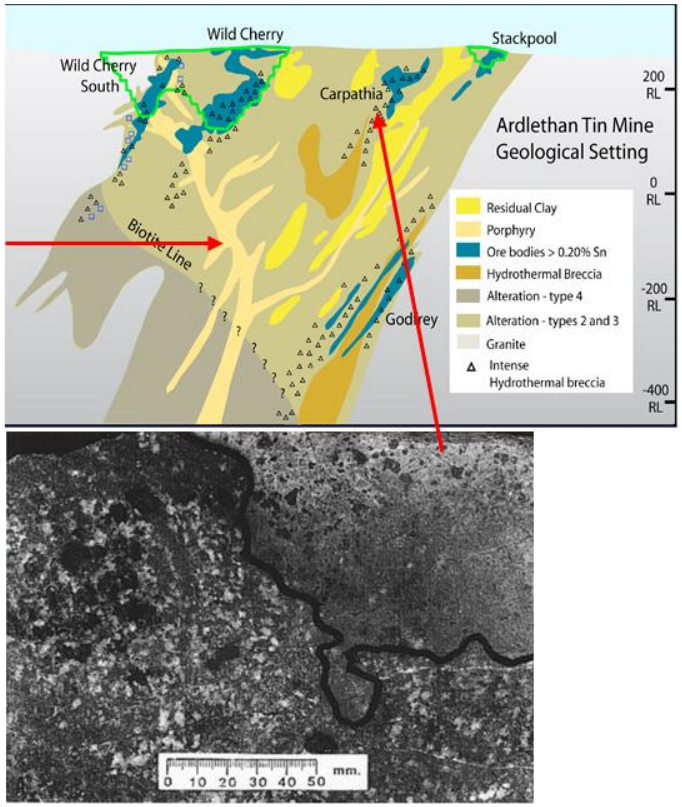
The “mine porphyry” problem





Ren et al., 1994

- Porphyry appears to predate and post date breccias.
- No apparent petrographic or chemical differences.
- Is it the orebringer?
- Porphyry is not genetically related to the Ardlethan Granite.

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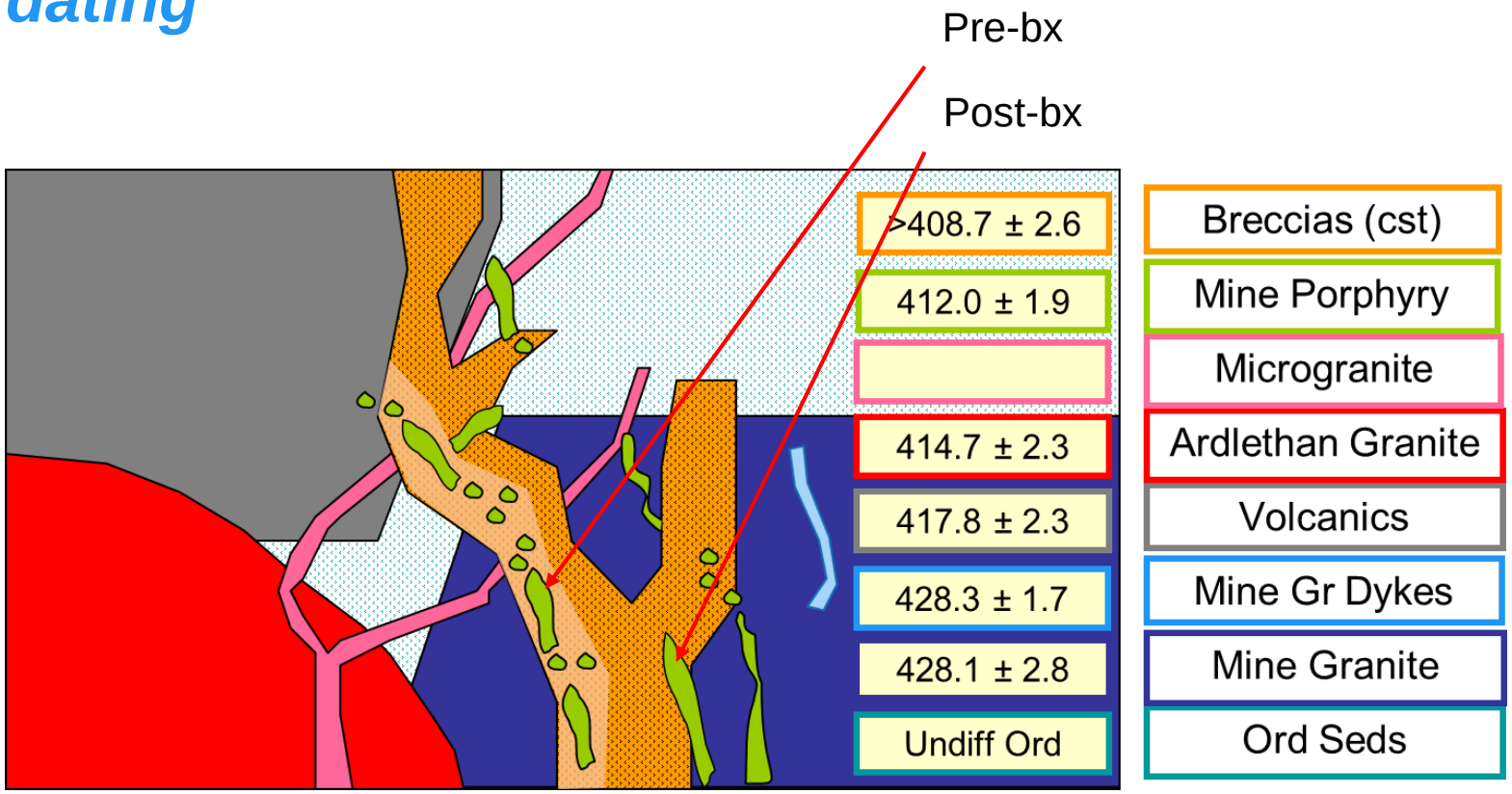
U-Pb zircon SHRIMP and cassiterite LAICPMS dating



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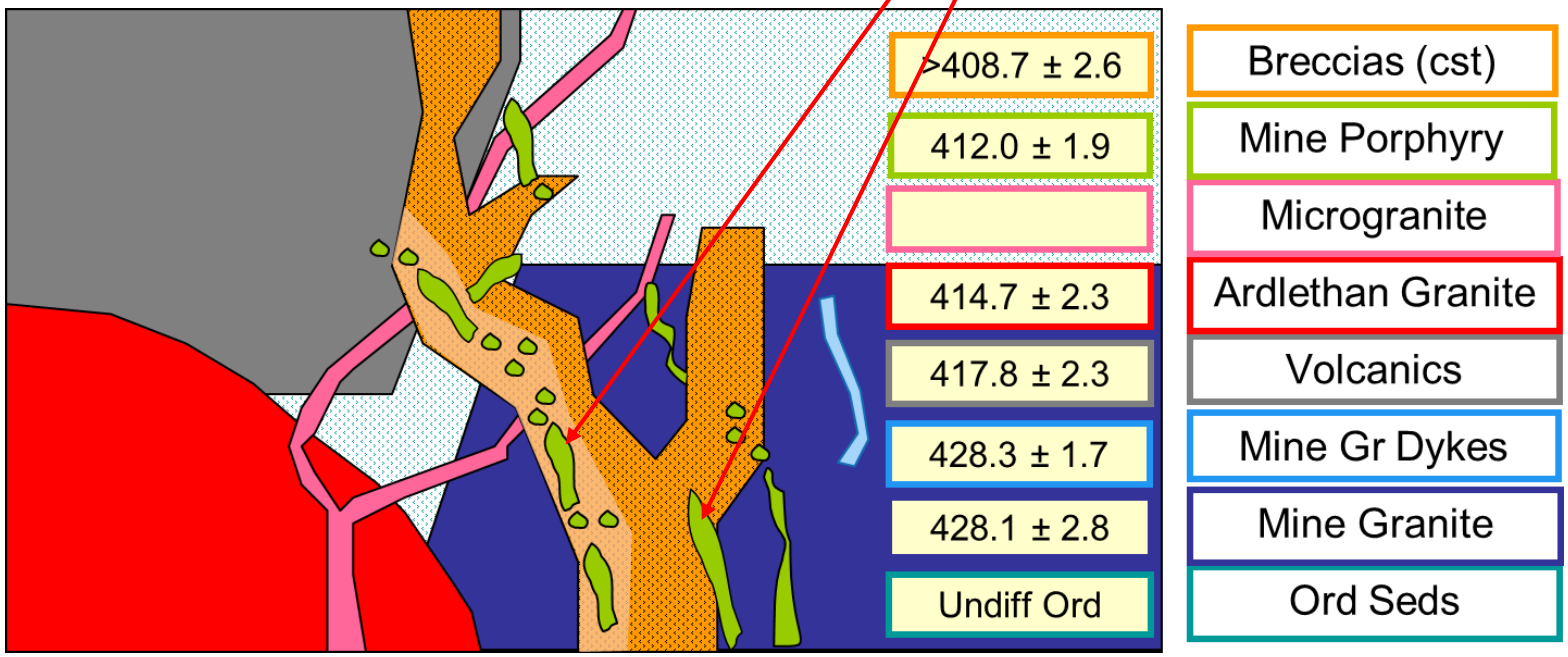
U-Pb zircon SHRIMP and cassiterite LAICPMS dating

Pre-bx = 414.28 ± 0.13 Ma

Post-bx = 414.27 ± 0.11 Ma



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Hera – skarn-like systems in Cobar Basin

Never deeply buried

- anchizone basin (250°C) with very local zones up to ?500°C

Carbonate-bearing stratigraphy

Strongly reduced, low XCO_2 Pb–Zn-skarn

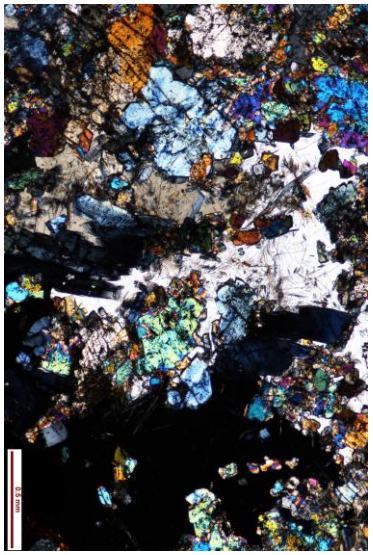
- sub-calcic garnet
- zoisite–anorthite-rich skarn = low XCO_2
- Mn-enriched calc-silicate mineralogy

No direct link to intrusive rocks

- but, high heat flow, skarn development
- H–O–S isotopes consistent with magmatic input
- distal parts to a ?large magmatic hydrothermal system

Complex paragenesis/multiphase mineralisation

- skarn Pb–Zn mineralisation
- Au mineralisation
- foliation development and thrusting



Garnet–pyroxene–zoisite–anorthite skarn, cross-polarised light

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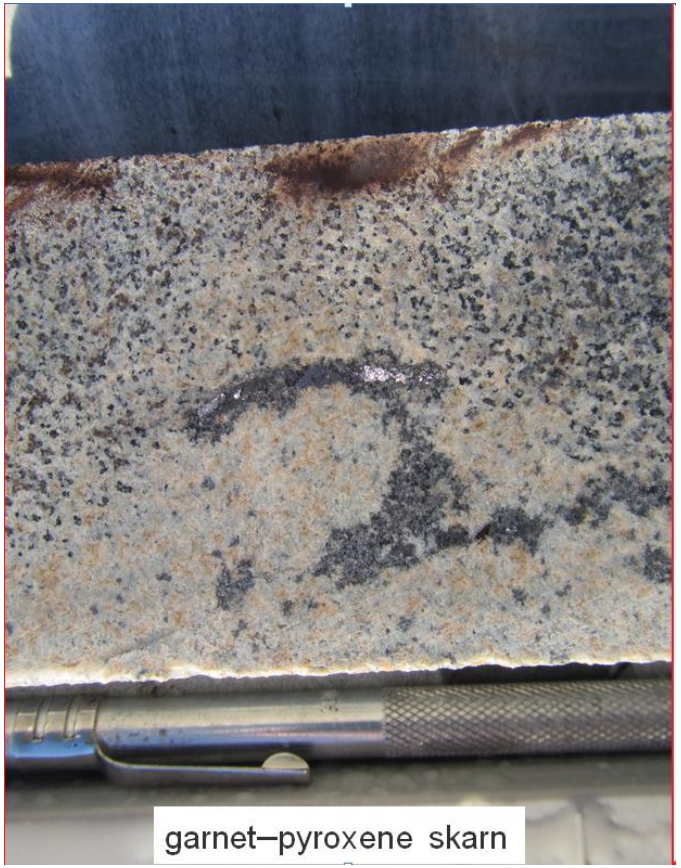
Thanks to Joel Fitzherbert, GSNSW)

Early garnet-scheelite dating at Hera

- Sm-Nd dating of early garnet-scheelite veins = 426 ± 26 Ma
- Very low LREE contents
- Age is consistent with Devonian I-type magmatism
- Scheelite has no Rb so gives initial Sr isotope results
- Biotite is also present so scheelite-biotite Rb-Sr will be used.



From Joel Fitzherbert, GSNSW)

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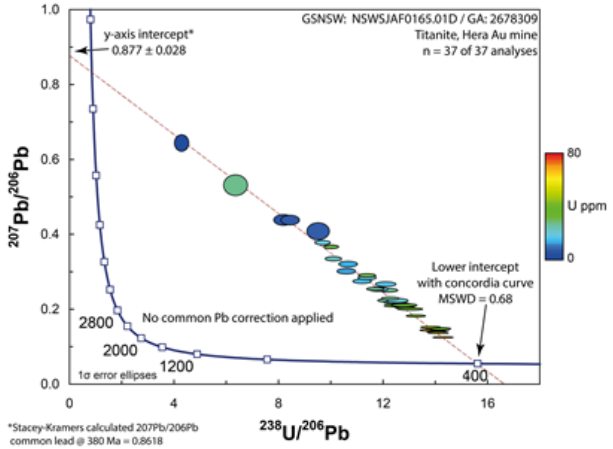
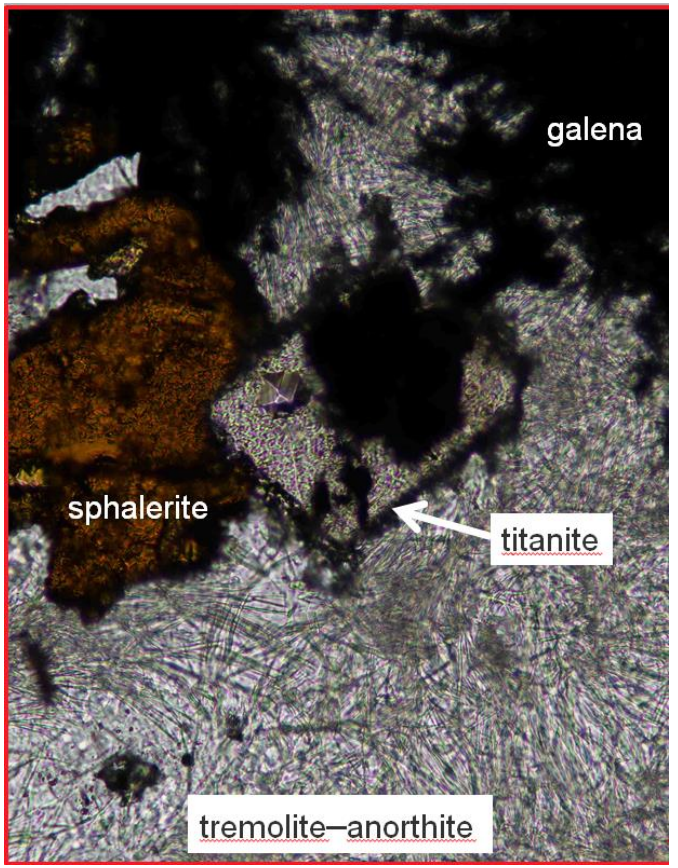
Titanite dating by SHRIMP & ID-TIMS at Hera

Au mineralisation post dates Pb-Zn skarn

Titanite U–Pb c. 400 Ma



Preliminary results – do not quote



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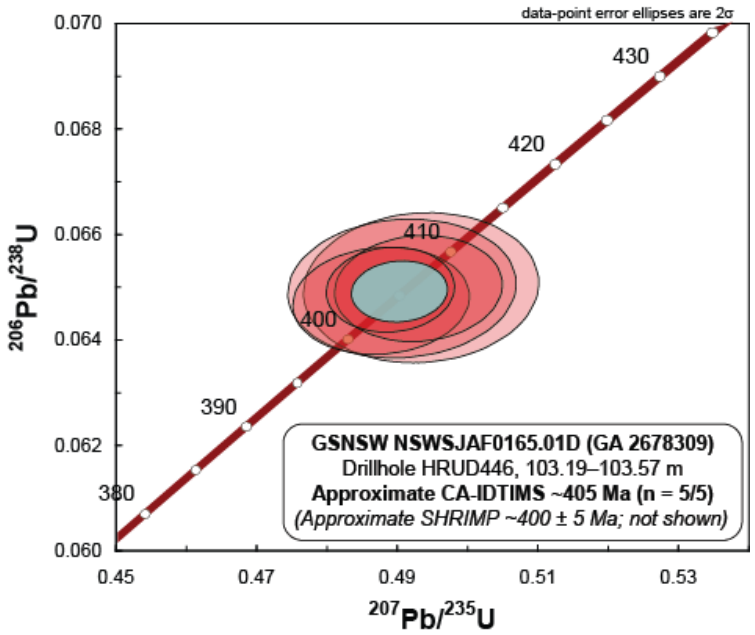
Titanite dating by SHRIMP & ID-TIMS at Hera

CA-IDTIMS of titanite



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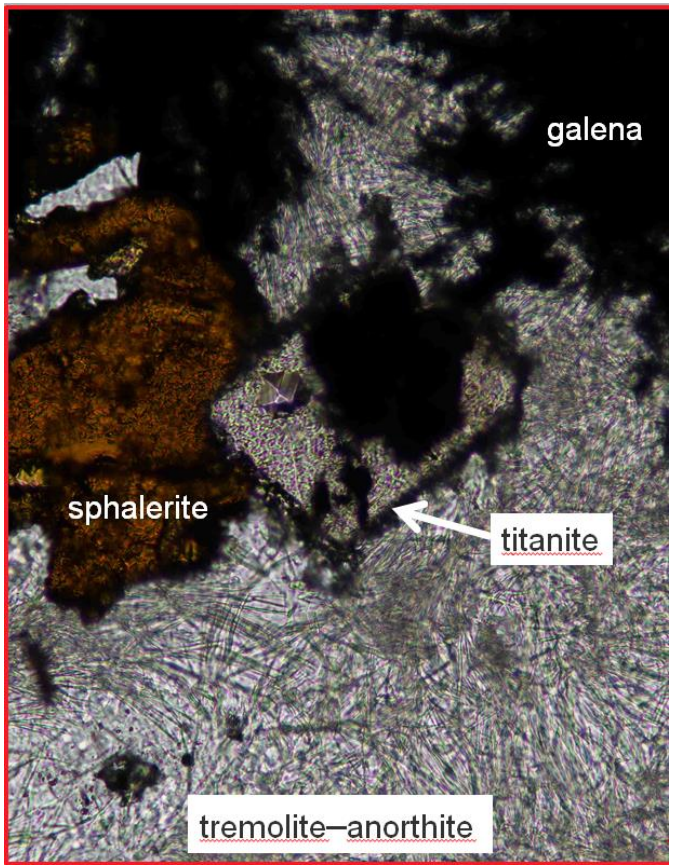


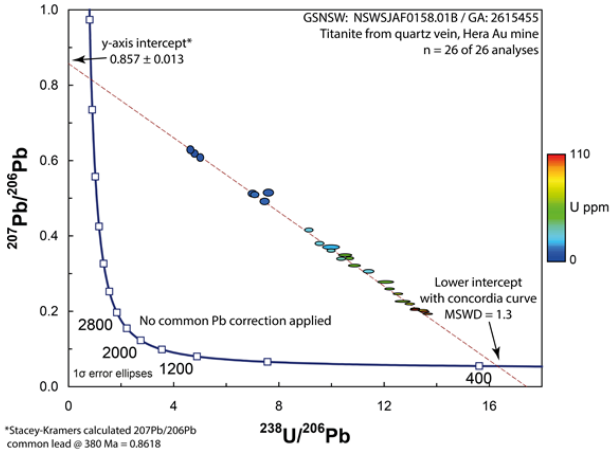
From Joel Fitzherbert, GSNSW)

NSW GOVERNMENT

Titanite dating by SHRIMP & ID-TIMS at Hera

Foliation development and late thrusting

Titanite U–Pb 383.9 ± 2.2 Ma



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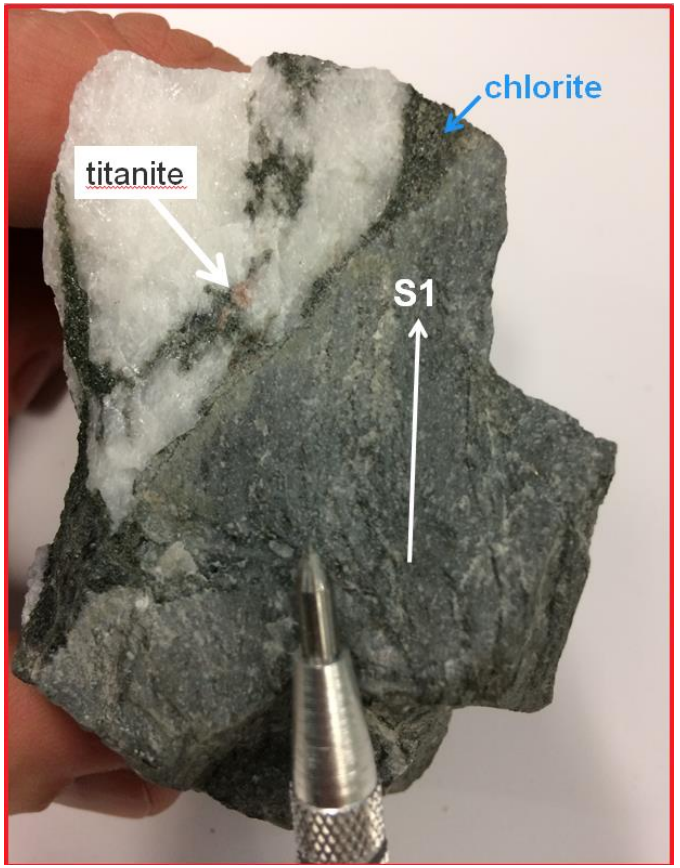

From Joel Fitzherbert, GSNSW)

Accessories by SHRIMP & ID-TIMS - comments

- CA-IDTIMS of titanite
  - surprisingly, precision is only marginally better than SHRIMP.
  - titanite very common at Cobar and elsewhere.

- Rutile, xenotime, allanite, cassiterite can be dated.
  - allanite by LA-ICPMS
  - rutile probably by TIMS – orientation effects using SHRIMP
  - cassiterite better by LA-ICPMS

From Joel Fitzherbert, GSNSW)

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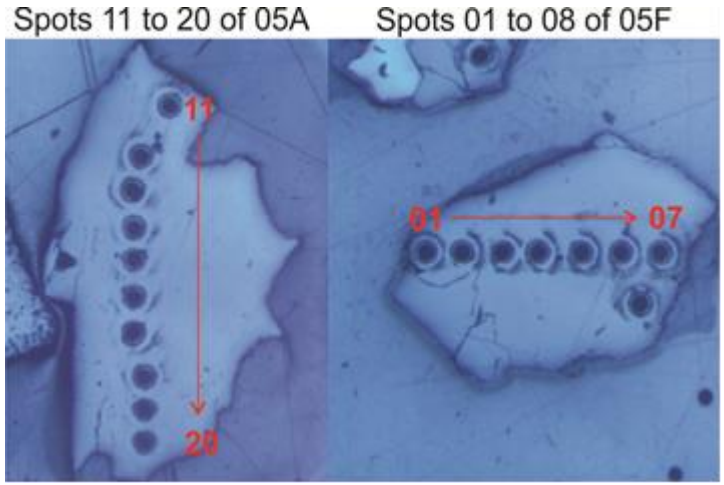
Trace element studies - scheelite



- Scheelite contains REE, Sr, Nb, Mo, Cu, Mn that can be used as a petrogenetic tracer.
- Can also be used for stable O, and radiogenic Nd-Sm and Rb-Sr studies.
- Preliminary studies in NSW indicate that scheelite is useful in understanding the origin of some deposits.
- Study being undertaken at JCUNQ

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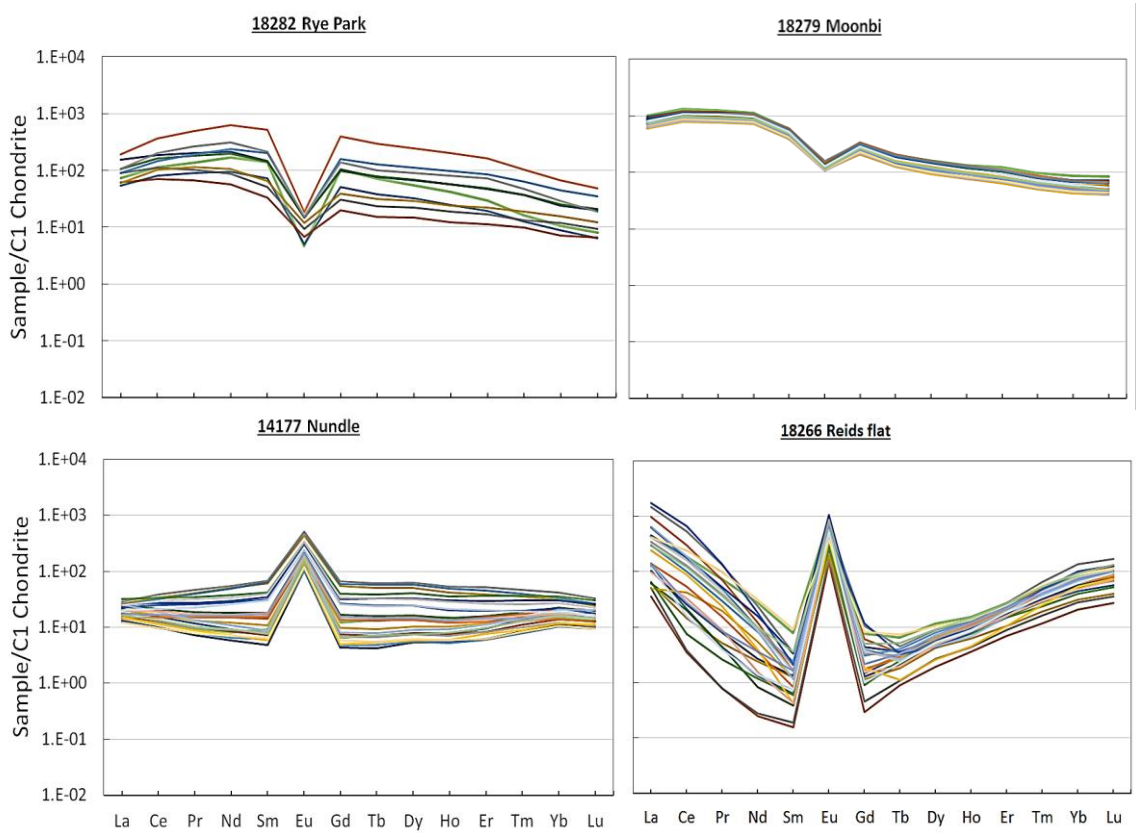
Trace element studies - scheelite



Trace element studies - scheelite

- Moonbi scheelite (pictured) has very high Mo, Y and Nb.
- Hera scheelite, and all orogenic scheelites, have very low Nb and Mo (reduced).
- Hera consistent with “orogenic” fluid source at least as far as metal sources.

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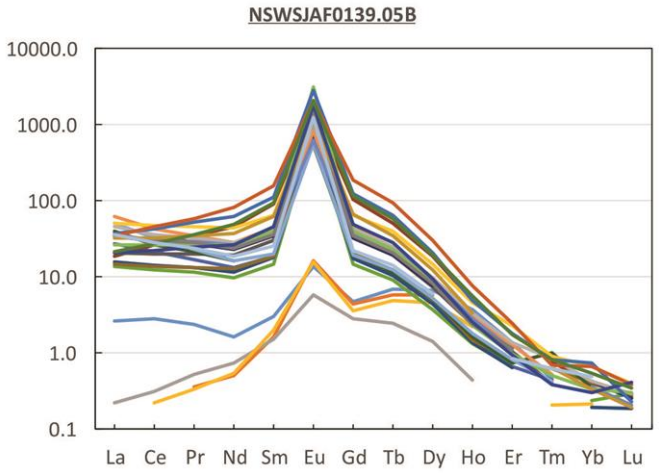
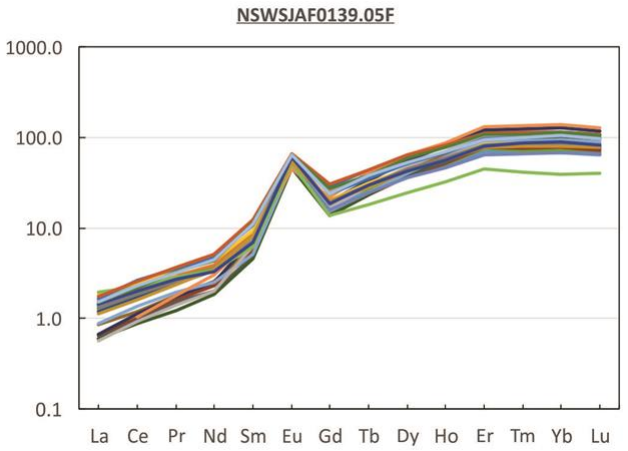
Trace element studies – Hera scheelite

- Scheelite acts as a passive monitor for REE.
- REE being stripped from a starved fluid (not replenished).
- Indicates ppt'n from reduced fluid.
- W and REE derived from breakdown of Fe-Ti minerals in basin shed from S-type granites.
- Presence of scheelite does not imply direct magmatic origin or input.





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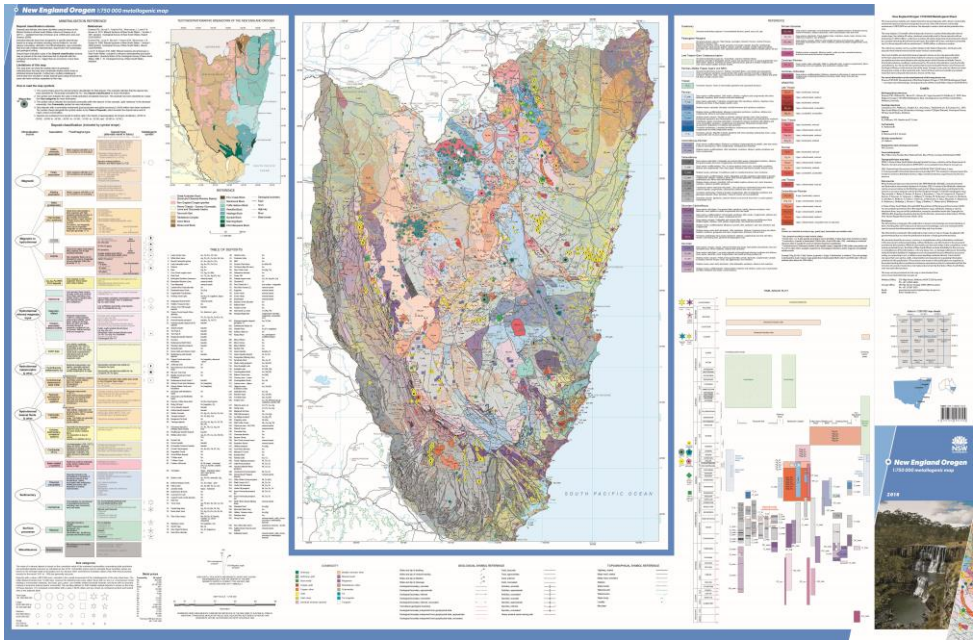
New England metallogenic map



- New England Orogen only - adjacent basins excluded
- Covers 12 x 250K map sheets
- Final map at 1:750,000 scale
- Metallic & related industrial deposits only
- Displaying rock units according to fertility, reactivity & depositional environment.

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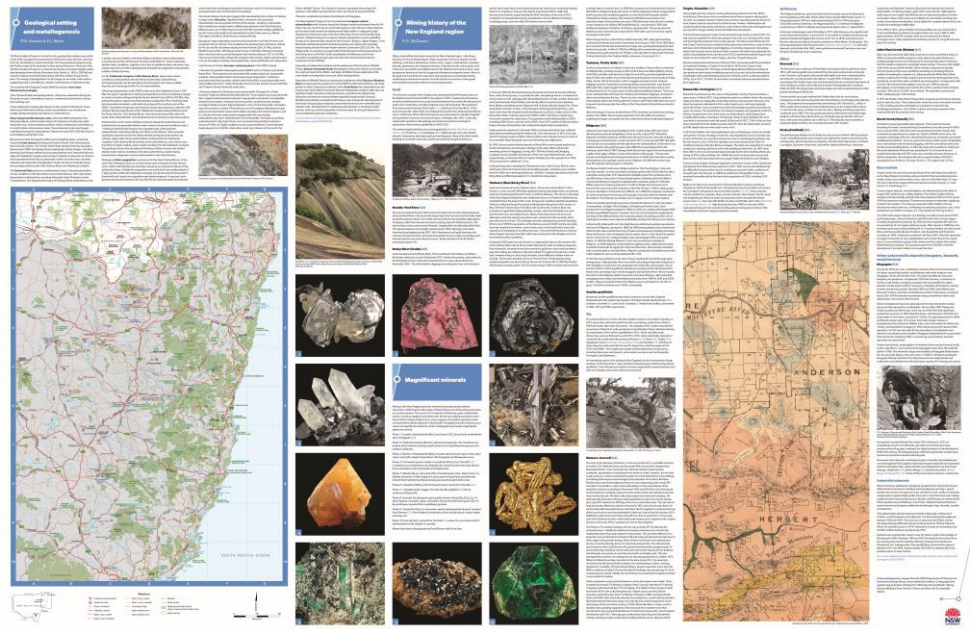

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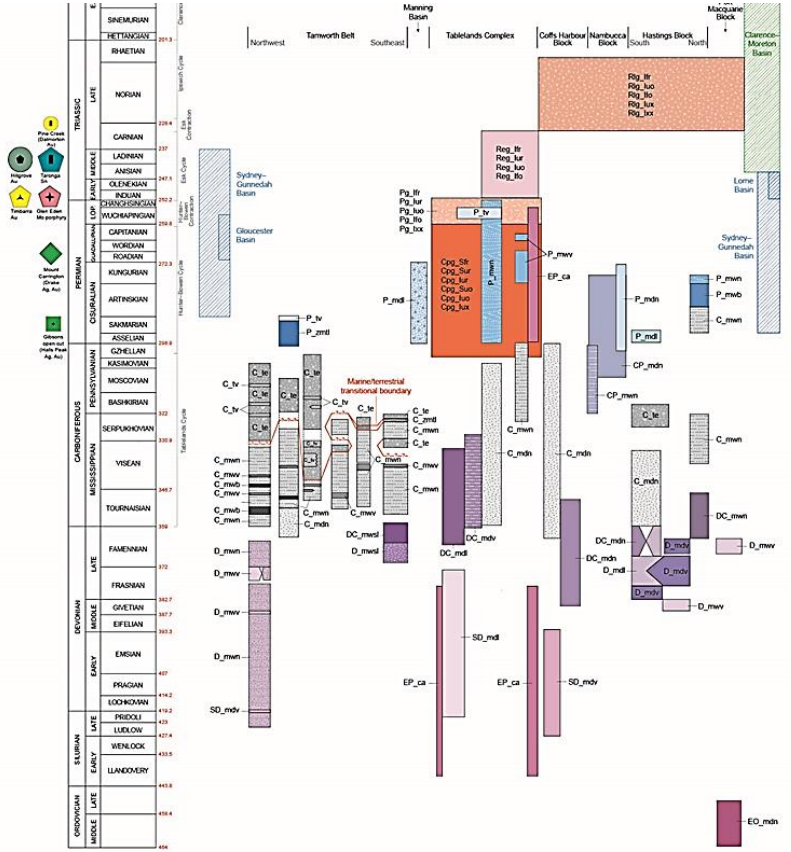

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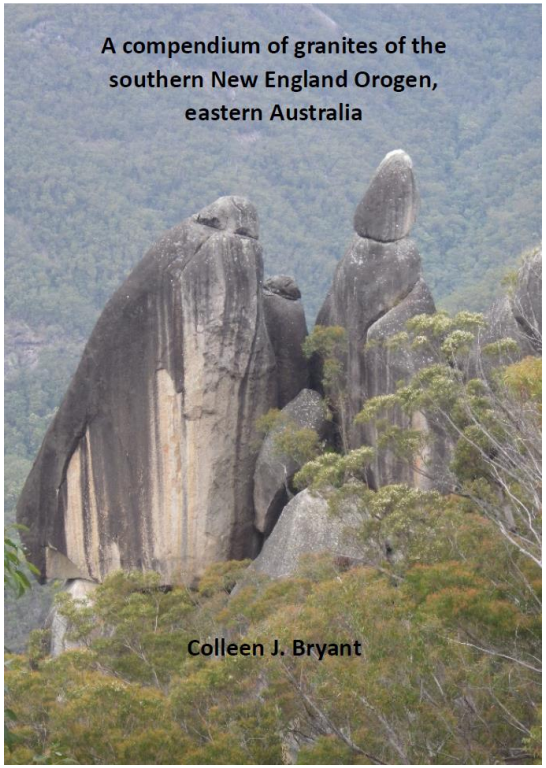
New England Orogen granites



- GSNSW DIGS Report GS2017/0408
- The most comprehensive overhaul of the NEO granites since the early 1980s.
- Updates stratigraphic nomenclature, unit definitions & descriptions of 300+ granites.
- 1,153 pages, 1,240 references
- Will underpin ongoing metallogenic and petrogenetic studies.

A summarised version with age dating data is in preparation as a NSWGS Quarterly Note.

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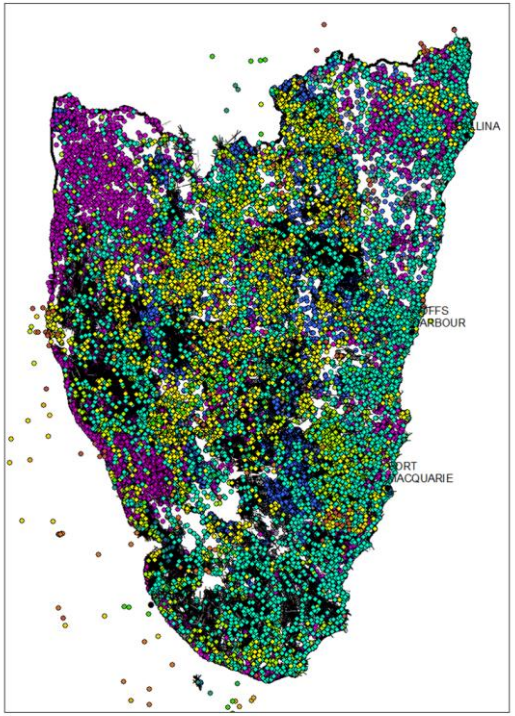
Mineral potential mapping

GSNSW is embarking on a statewide mineral potential mapping project that will:

- have results which can trigger land-use referrals
- replace the ‘potential’ layer in the current Mineral Resource Audit mapping
- includes spatial analysis
- identify economic potential for key mineral systems
- predictive maps are an excellent summary of spatial and point data.



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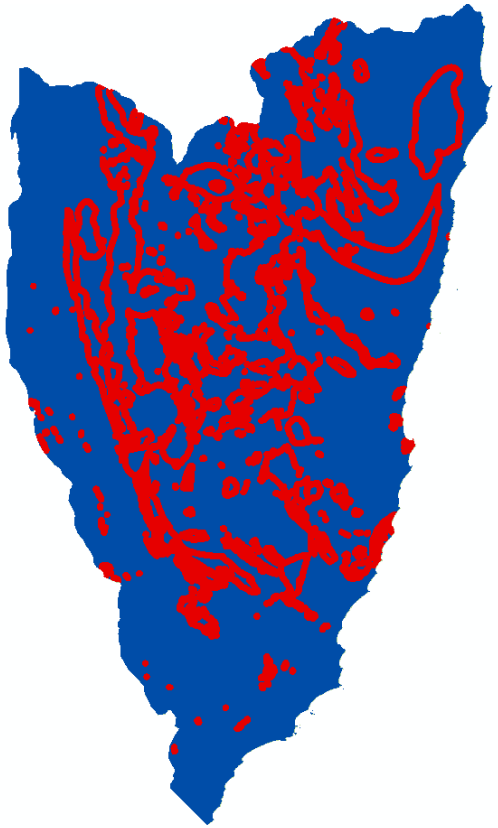
- predictive maps are an excellent summary of spatial and point data.
- example: competency contrasts



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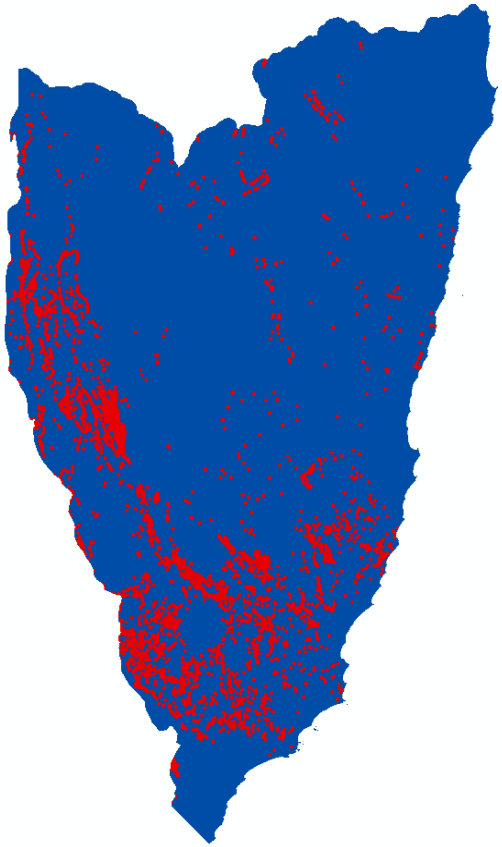
- example: fault bends



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Mineral system models - NEO

1. **Intrusion-related tin-tungsten** (IR Sn-W)

   GS2017/0617

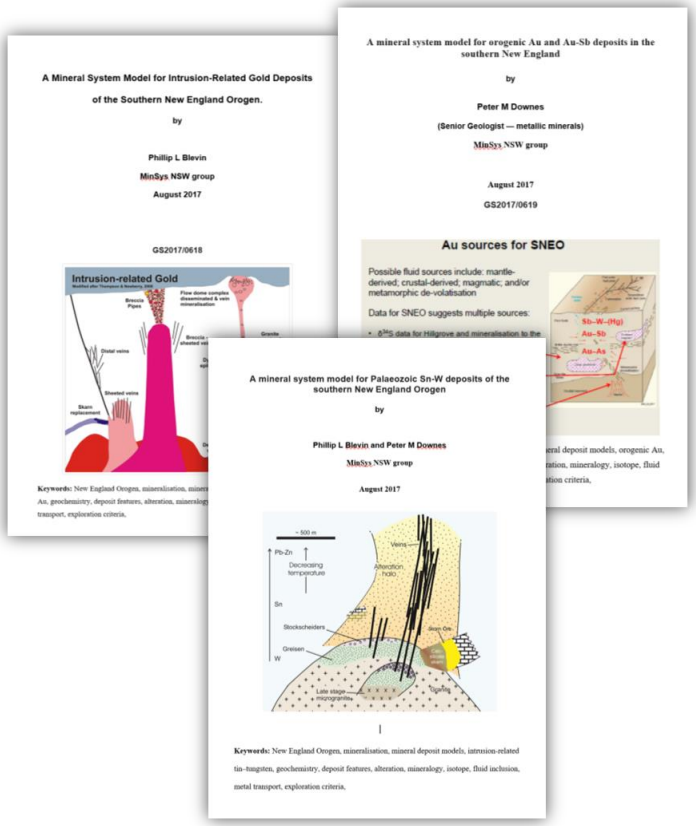
2. **Intrusion-related gold** (IR Au)

   GS2017/0618

3. **Orogenic gold-antimony** (orogenic Au-Sb)

   GS2017/0619

Will be rolled out over the state with the mineral potential mapping



Mineral system models – others to follow

- Zone 54
  - Broken Hill type Ag-Pb-Zn
  - Grassmere VAMS/orogenic
  - Fe Ox (Copper Blow)
  - Orogenic Au
- East Lachlan
  - Orogenic Hill End Au
  - Orogenic BM
  - Silurian basin VAMS
  - IR Au Mo Cu Sn (Carboniferous)
- Others currently in development
  - Ordovician PCG
  - Skarns

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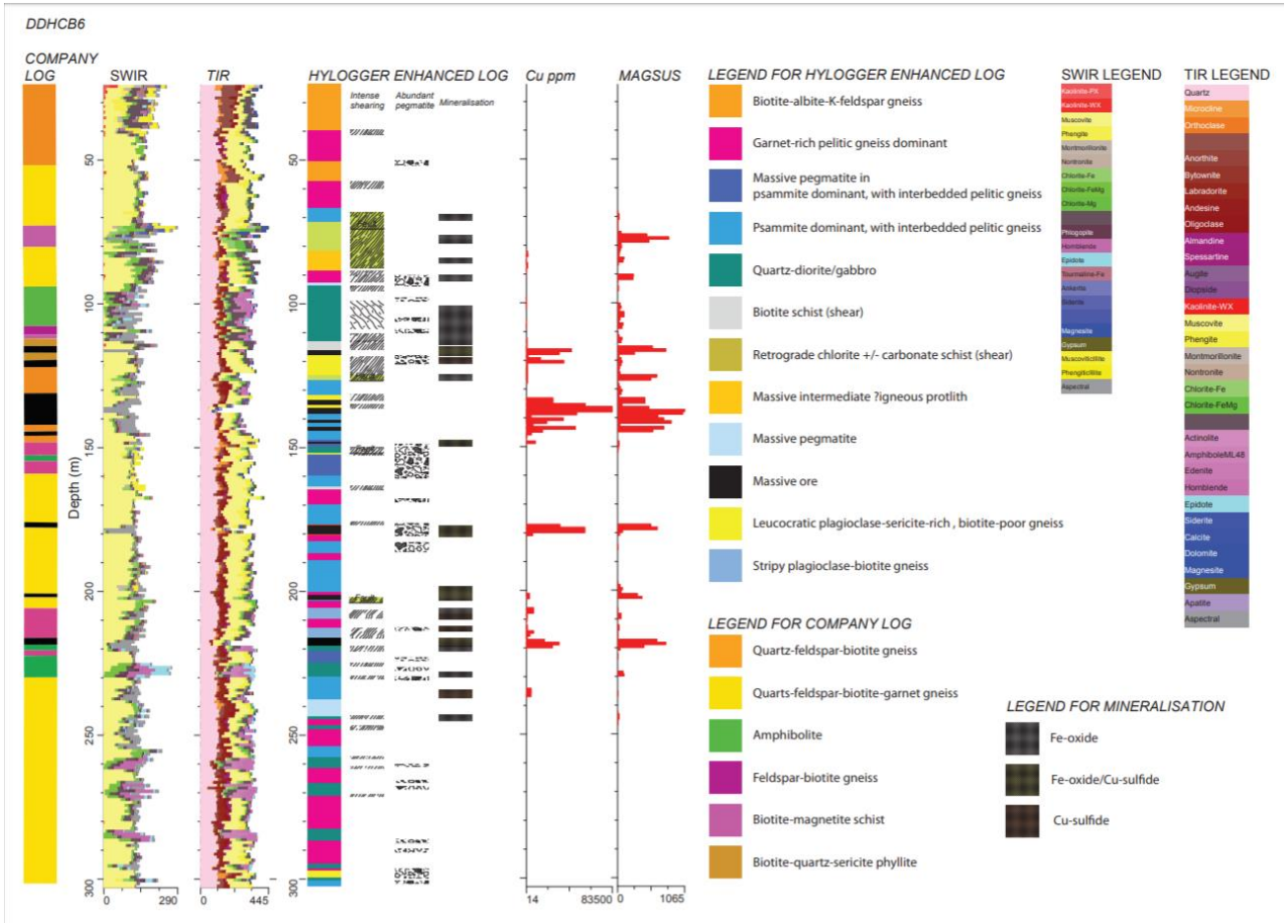
And don't forget HyLogger!



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Dr Phillip Blevin

phil.blevin@planning.nsw.gov.au

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