Timing is everything
Applications of new dating methodologies to the mineral systems of NSW

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Contents

1. Minerals program at the GSNSW
2. Metals in Time
3. Some new techniques and results
4. Other work by the Minerals Team
Minerals at the GSNSW

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  o Dr Joel Fitzherbert (senior geoscientist)
  o Dr Peter Downes (senior geoscientist)

• NVCL - Londonderry
  o 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
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.
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
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 HNO₃
  - 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
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/
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 Isocprobe-T

Photo credit - https://earth.boisestate.edu/isotope/
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/
CA-IDTIMS: just how precise?
CA-IDTIMS: just how precise?

Gwydir R.
RFDS
Ma
Parlour Mtn

Dundee Rhyodacite

WVG Sth
WVG Nth

CA - IDTIMS: just how precise?
CA-IDTIMS: just how precise?

P-T extinction
251.941 ± 0.037 to 251.880 ± 0.031 Ma
(or 60 ± 48 ka)*

*: 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
Cassiterite U-Pb LAICPMS dating

Age ± 2σ

White Crystal Breccia Pipe
White Crystal Breccia Pipe (MF)
Main Breccia Pipe
Main Breccia Pipe
Main Breccia Pipe (MF)
Little Bygoo Musc Ar-Ar
Little Bygoo
Little Bygoo (MF)
Little Bygoo (MF)
Bald Hill (MF)
Bald Hill (MF)
Big Bygoo
Big Bygoo (MF)
Taylors Hill (MF)
Buchanan Mine
Titanic Mine
Ardlethan Granite - Cst (MF)
Mine Porphyry
Ardlethan Granite
Garnet Porphyry
Mine Granite Dyke
Mine Granite

Exocontact breccia pipes
Granite-contact
Granite-hosted veins
Granite-disseminated

Magmatic ages
U-Pb zircon SHRIMP and cassiterite LAICPMS dating
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.

**The “mine porphyry” problem**

Ren et al., 1994
U-Pb zircon SHRIMP and cassiterite LAICPMS dating

- Pre-bx:
  - >408.7 ± 2.6
  - 412.0 ± 1.9
  - 414.7 ± 2.3
  - 417.8 ± 2.3
  - 428.3 ± 1.7
  - 428.1 ± 2.8
  - Undiff Ord

- Post-bx:
  - Breccias (cst)
  - Mine Porphyry
  - Microgranite
  - Ardlethan Granite
  - Volcanics
  - Mine Gr Dykes
  - Mine Granite
  - Ord Seds
**U-Pb zircon SHRIMP and cassiterite LAICPMS dating**

Pre-\(bx\) = 414.28 ± 0.13 Ma

Post-\(bx\) = 414.27 ± 0.11 Ma

Sample Data:

- Breccias (cst)
- Mine Porphyry
- Microgranite
- Ardlethan Granite
- Volcanics
- Mine Gr Dykes
- Mine Granite
- Ord Seds
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Sample Ages:

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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 XCO₂ Pb–Zn-skarn
- sub-calcic garnet
- zoisite–anorthite-rich skarn = low XCO₂
- 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

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)
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

From Joel Fitzherbert, GSNSW)
Titanite dating by SHRIMP & ID-TIMS at Hera

CA-IDTIMS of titanite

Preliminary results – do not quote

From Joel Fitzherbert, GSNSW)
Titanite dating by SHRIMP & ID-TIMS at Hera

Foliation development and late thrusting
Titanite U–Pb 383.9 ± 2.2 Ma

Preliminary results – do not quote

From Joel Fitzherbert, GSNSW)
Accessories by SHRIMP & ID-TIMS - comments

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

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

From Joel Fitzherbert, GSNSW)
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
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.
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.
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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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.
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.

Mineral potential mapping
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- example: competency contrasts
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- example: fault bends
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
And don’t forget HyLogger!