Application of innovative geochronology techniques in geoscience mapping and exploration

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John de Laeter Centre
Curtin University
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What is the John de Laeter Centre?

- Modern centralised research infrastructure facility at Curtin University
- Founded 1992 by Professor John de Laeter as Centre for Mass Spectrometry
  - Co-operation between Curtin, UWA and the Geological Survey of Western Australia
- 30 staff operating $35M in instrumentation across 15 laboratories
- Support applied research projects with mineral, petroleum and chemical industries

**JdLC Mission, Themes and Objectives**

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<thead>
<tr>
<th>Enabling Technology</th>
<th>Research Excellence</th>
<th>Access &amp; Optimisation</th>
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<tbody>
<tr>
<td>Acquire &amp; maintain world-class</td>
<td>Attract &amp; retain research academics &amp; innovators</td>
<td>Attract &amp; retain professional staff to optimise</td>
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<tr>
<td>world-class research technology</td>
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<td>technology usage</td>
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<td>Build integrated, purpose-built</td>
<td>Develop new techniques &amp; innovations</td>
<td>Facilitate access to academic, industry &amp;</td>
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<tr>
<td>facilities</td>
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<td>government end-users</td>
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Build world-class analytical and characterisation infrastructure to support research excellence and foster end-user driven, collaborative programs.
Facilities, Locations & Science Leaders

1. Ion Microprobe – A Kennedy
2. Microscopy - Z Quadir
3. Digital Mineralogy – M Aylmore
4. Thermal Ionization MS – S Tessalina
5. Noble Gas MS – F Jourdan
6. Laser MC-ICP-MS – N Evans
7. Materials Separation – A Kumara
8. Surface Analysis – JP Veder
9. Diffraction & Scattering – M Rowles
10. High P-T Synthesis – K Evans
11. Atom Probe – D Saxey
12. FIB/TOF - W Rickard
13. GeoHistory – M Danisik
14. TEM – K Merigot
15. TRACE/HR-ICP-MS – B Ware
JdLC: A “one-stop shop” for geoscientists

• Sample preparation
  • Selfrag UHV pulse fragmentation
  • Magnetic and heavy liquid separation
  • Polished mounts

• Sample characterisation
  • Automated mineralogy (TIMA)
  • XRD
  • Solution ICP-MS
  • Laser ablation chemical mapping
  • TOF-SIMS mapping
  • Atom probe analysis

• Geochronology and thermochronology
  • Re-Os (sulfides, black shales, bitumen)
  • $^{40}$Ar/$^{39}$Ar (K-bearing rocks and minerals)
  • U-Pb (zircon, monazite, titanite....)
    • SHRIMP and ELA-ICP-MS
  • U-He (zircon, apatite, Fe-oxides)
  • Rb-Sr (Rb-bearing minerals and shales)

• Isotope Analysis
  • Re-Os
  • Lu-Hf
  • Sm-Nd
  • Rb-Sr
  • Pb-Pb
  • Ag

Application of innovative geochronology techniques in geoscience mapping and exploration: Examples

1. SHRIMP U-Pb Age Geochronology
   • GSWA Geological Mapping - Zircon
   • Yilgarn Gold Metallogeny – Xenotime & Monazite
   • Regional Exploration - Cassiterite

2. Sulfide Geochronology (Re-Os)

3. Regolith Geochronology (U-He)
Mineralogy-based Analytical Workflow

Automated mineralogy Characterisation by Tescan Integrated Mineral Analyser (TIMA)

Only small rock chip samples required (grain mounts, thin sections or polished sections), to identify and target appropriate minerals for in situ analysis

- SHRIMP U-Pb (zircon, monazite, xenotime, etc.)
- Laser ablation ICP-MS U-Pb and (U-Th)/He (zircon, monazite, apatite, etc.)
- Laser ablation ICP Triple Quad (ICP-QQQ)-MS Rb-Sr dating of K-rich minerals (clays, micas & K-feldspar, etc.)
- Laser ablation MC-ICP-MS Lu-Hf isotope systematics of zircon

Laser ablation MC-ICP-MS Lu-Hf isotope systematics of zircon

Apatite
Sensitive High Resolution Ion MicroProbe (SHRIMP)

- GSWA SHRIMP Records: >1500 since 1995
- Over 50 PhD graduates supported
Impact of Isotope Geoscience on the Geological Map of Western Australia

SHRIMP data has been instrumental in transforming the geological map of WA.
Sensitive High Resolution Ion MicroProbe (SHRIMP)

25 years of operation! – December 14, 2018

January 16, 2019
Federal government announcement - Boosting performance of Australia’s world-class research facilities

John de Laeter (1993)
“Atomic machine a boon to science”

An enduring legacy of SHRIMP collaboration between the John de Laeter Centre and Centres for Global Metallogeny & Exploration Targeting

Exploration Keywords
- Gold
- Deposit
- Orogeny
- Timing
- Mineralisation
- Yilgarn
SHRIMP U-Pb geochronology of Yilgarn orogenic gold deposits using REE-phosphates

Workflow:
1. Identify monazite and xenotime in polished thin sections of high-grade gold ores
2. Drill out and prepare a composite mount
3. Verify paragenetic relationship between gold and phosphate minerals using SEM/TIMA
4. Determine age of phosphate minerals using SHRIMP U-Pb dating techniques

Tectonic reconstruction of Eastern Goldfields

Ages based on SHRIMP U-Pb geochronology of granites-greenstones (mostly zircon) and orogenic gold (mostly monazite-xenotime)

Regional exploration by heavy mineral sampling detected >500 cassiterite grains
Where they of igneous origin?
Can U-Pb dating determine whether they are temporally linked to adjacent granites?
**Regional Exploration – Cassiterite Results**

- Detrital SnO$_2$ (1811 Ma) is **160 million years older** than adjacent granite; **no temporal link**
- Report filed 2 years later; company grid-drilled the adjacent granite (>100 holes & 7 km drill)
- “[absence] of key pathfinders...diminished the chance of having an economic Sn deposit”
MRIWA 446: Re-Os geochronology of WA ore deposits

Geochronology – direct dating of ores and black shales formation

Fingerprinting of ores or black shales provides provenance information based on initial $^{187}\text{Os}/^{188}\text{Os}$ ratio from an isochron

Poster Session
- Pb-Os systematics of native gold
  - Svetlana Tessalina et al
- Re-Os dating of massive sulphide deposits
  - Vitor Barrote et al

Re-Os isochron diagram
(McInnes et al. 2008, AJES 55, 967-981)
Re-Os geochronology of WA ore deposits: Shale-hosted mineralisation

Underlying volcanics

Age = 2705 ± 44 Ma (2σ)
Initial $^{187}$Os/$^{188}$Os = 0.03±0.23
MSWD = 2.7

Mesothermal Au deposits have low Re concentrations requiring ppt sensitivity.

Age determination via isochron is possible but precision demands cutting edge laboratories.

Implications at Callie are that mineralisation is post granite emplacement (1810 Ma).

Source of gold is not the crust!
Dating of Regolith Materials

- A thick layer of regolith ‘blankets’ the Australian surface
- Result of continual weathering for 10’s to 100’s of million years??
- Regolith deposits provide a time-integrated record of weathering processes
- Weathering linked to wetter climate, so understanding the absolute timing of regolith formation is important in better understanding the Australian climate record
- **Dating of metal anomalies in regolith materials could potentially be used to provide explorers with vectors to source of primary metals**
TIMA Mineral Mapping

Boddington
Fragmental duricrust

Primary phases
- Hematite/Maghemite
- Gibbsite + Fe oxides
- Gibbsite + Kaolinite + Fe-oxides
- Quartz
- Gibbsite
- Kaolinite Fe-oxides
- Kaolinite
- Mixed Al + Ti + Fe
- Gibbsite + Kaolinite
- Muscovite
- Ilmenite
- Unclassified
- The rest

Mosaic
- View field: 9.00 mm
- Date (m/d/y): 06/06/17
- 2 mm

226970-1
- Liberation analysis #2

Martin Wells
Boddington regolith (U-Th)/He age distribution

- Late-Miocene/Pliocene age for Boddington duricrust
- Comparable to age of regolith materials from the Darling range (Pidgeon et al., 2004)

(U-Th)/He-dates (Ma) for all BGM duricrust samples. Each coloured bar represents individual replicate measurements; ‘size’ (height) is measurement error ($\pm 1 \sigma$).
Low Temperature Oxide Ores: Paleoalluvial Robe River Fe Deposits, WA

Hematite-goethite assemblages

- 9.4 ± 0.5 Ma
- 11.6 ± 3 Ma
- 18.3 ± 3.5 Ma
Other JdLC Works at GSWA Open Day

- Prok Vasilyev
  - Webb diamond exploration: a geochemical thermodynamic approach
- Martin Wells
  - Wolf V-Zn project, Pilbara
- Mark Aylmore
  - MRIWA M532 Lithium characterisation in WA battery metal deposits
- Bryant Ware
  - Ar-Ar geochronology of mafic dykes
Summary

• The John de Laeter Centre is a ”one-stop shop” for mineralogy, geochemistry and geochronology services.
• Over 25 years of innovative development and application of research techniques for academia, government and industry.
• Proud to have GSWA as a core partner
• Come visit the labs or contact us to discuss your projects!
• Contact Brent McInnes
  • b.mcinnnes@curtin.edu.au
  • Twitter: @JDLCentre
  • http://jdlc.curtin.edu.au
Thank you

Make tomorrow better.