Application of innovative geochronology techniques in geoscience mapping and exploration

Professor Brent McInnes

John de Laeter Centre

Curtin University

22 February 2019

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

Build world-class analytical and characterisation infrastructure to support research excellence and foster end-user driven, collaborative programs		
Enabling Technology	**Research Excellence**	**Access & Optimisation**
Acquire & maintain world-class research technology	Attract & retain research academics & innovators	Attract & retain professional staff to optimise technology usage
Build integrated, purpose-built facilities	Develop new techniques & innovations	Facilitate access to academic, industry & government end-users

http://idlc.curtin.edu.au

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

https://jdlc.curtin.edu.au/2019-rates/

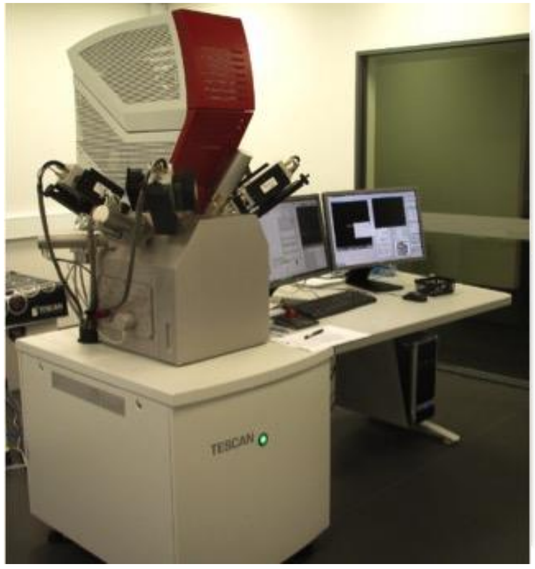
Application of innovative geochronology techniques in geoscience mapping and exploration: Examples

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)*

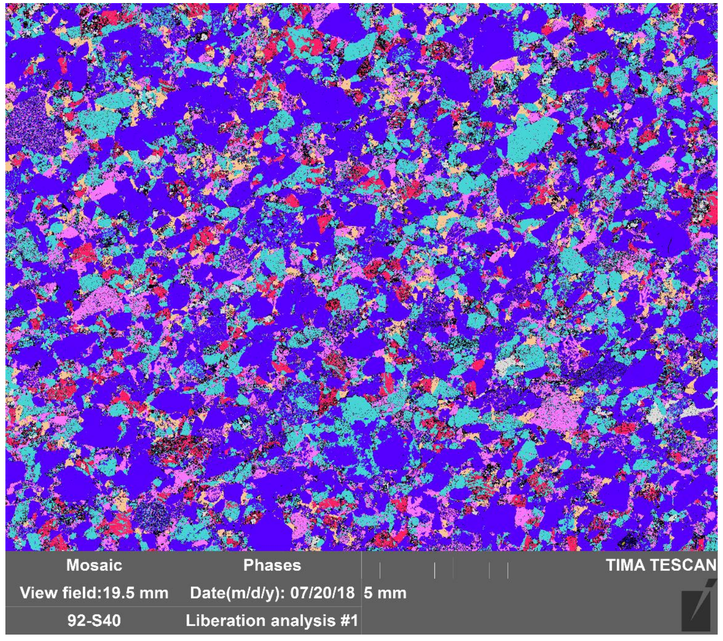
Mineralogy-based Analytical Workflow

Automated mineralogy Characterisation by *Tescan Integrated Mineral Analyser* (TIMA)

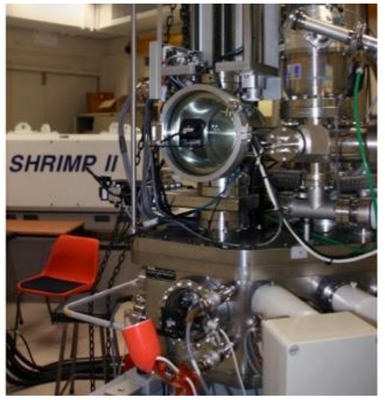
Only small rock chip samples required (grain mounts, thin sections or polished sections), to identify and target appropriate minerals for in situ analysis



TIMA
Digital Mineralogy Hub Facility



- 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



SHRIMP II B
Sensitive High Resolution Ion Micro Probe Facility (SHRIMP)

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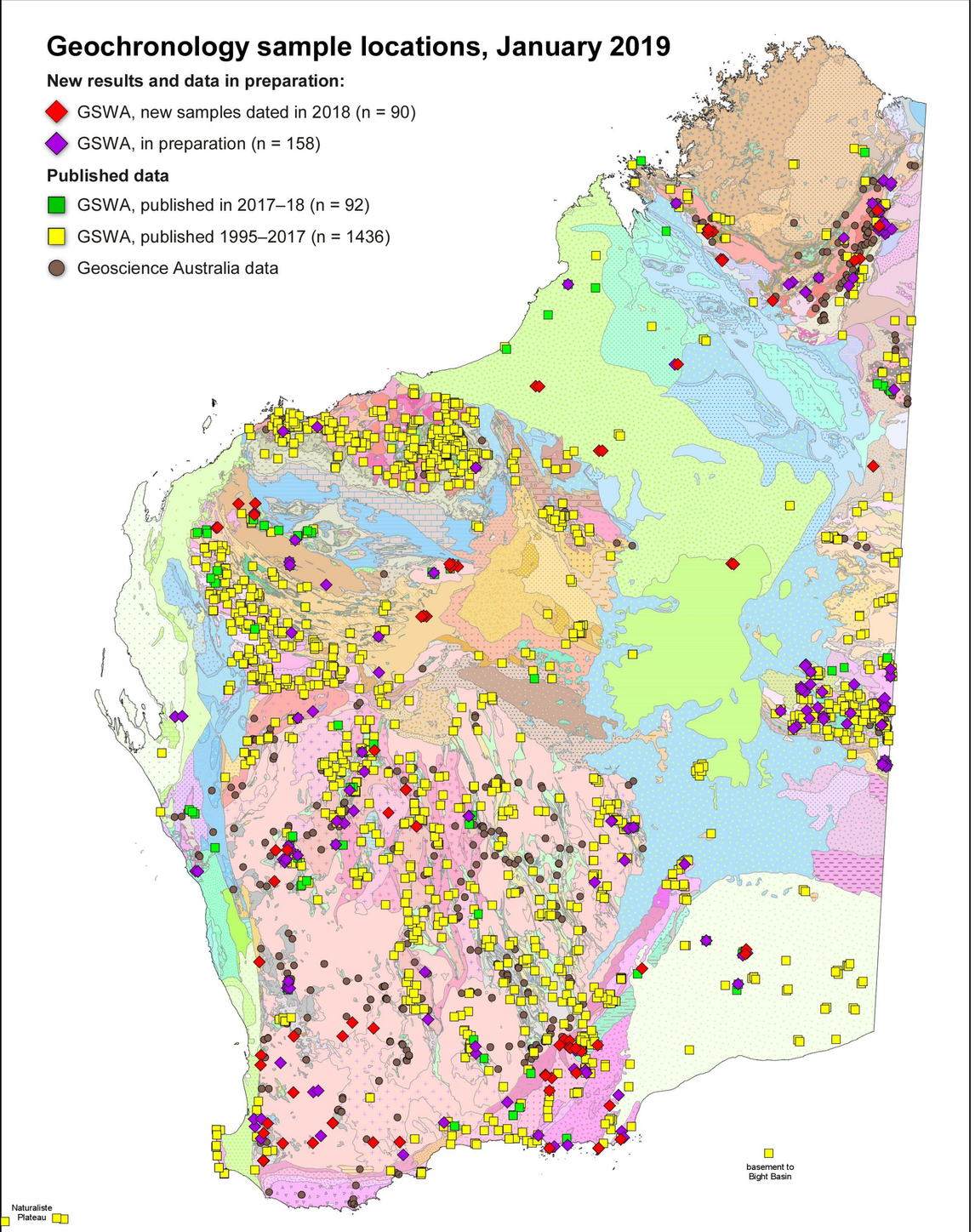
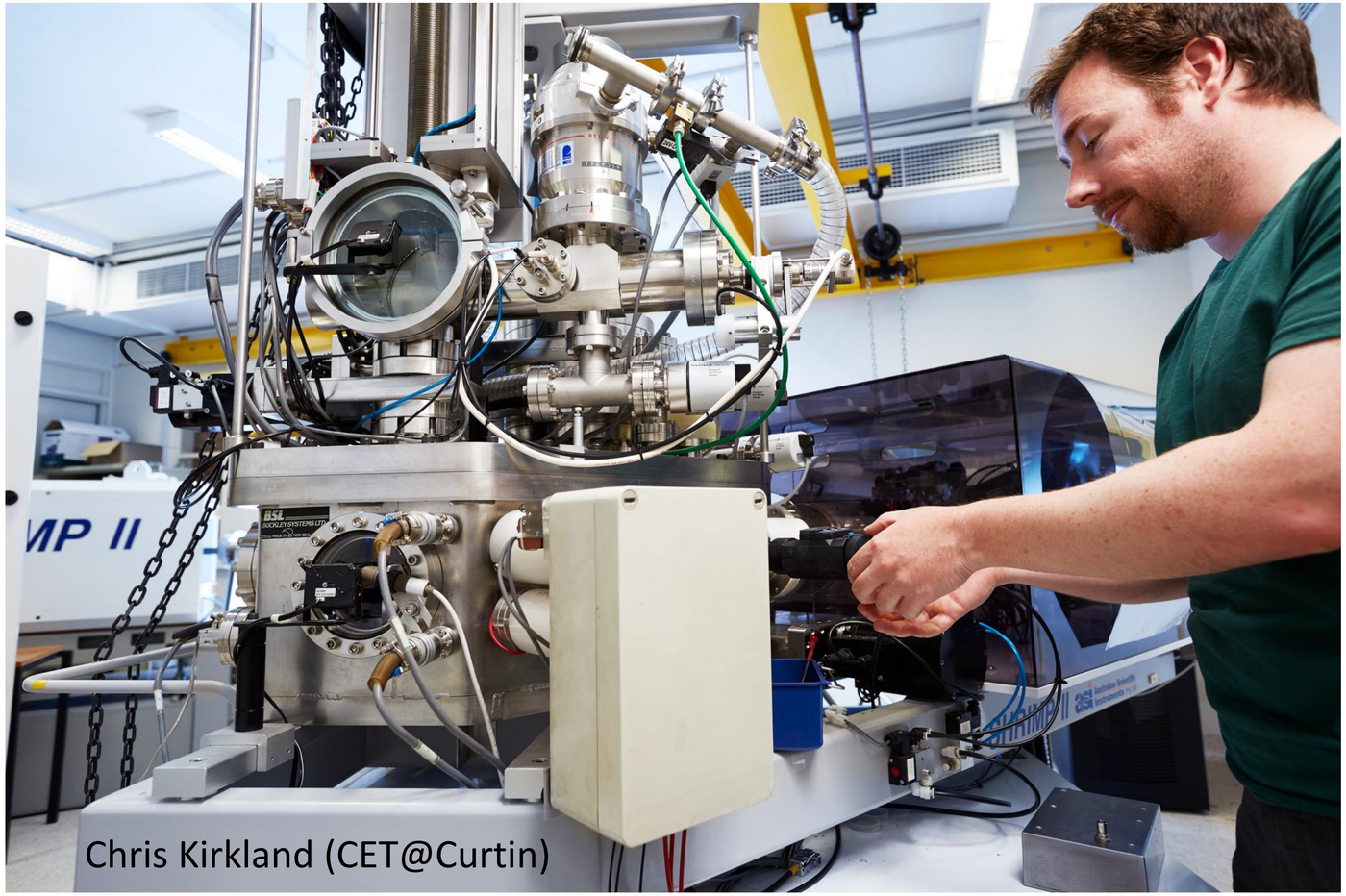


Sensitive High Resolution Ion MicroProbe (SHRIMP)



- *GSWA SHRIMP Records: >1500 since 1995*
- *Over 50 PhD graduates supported*

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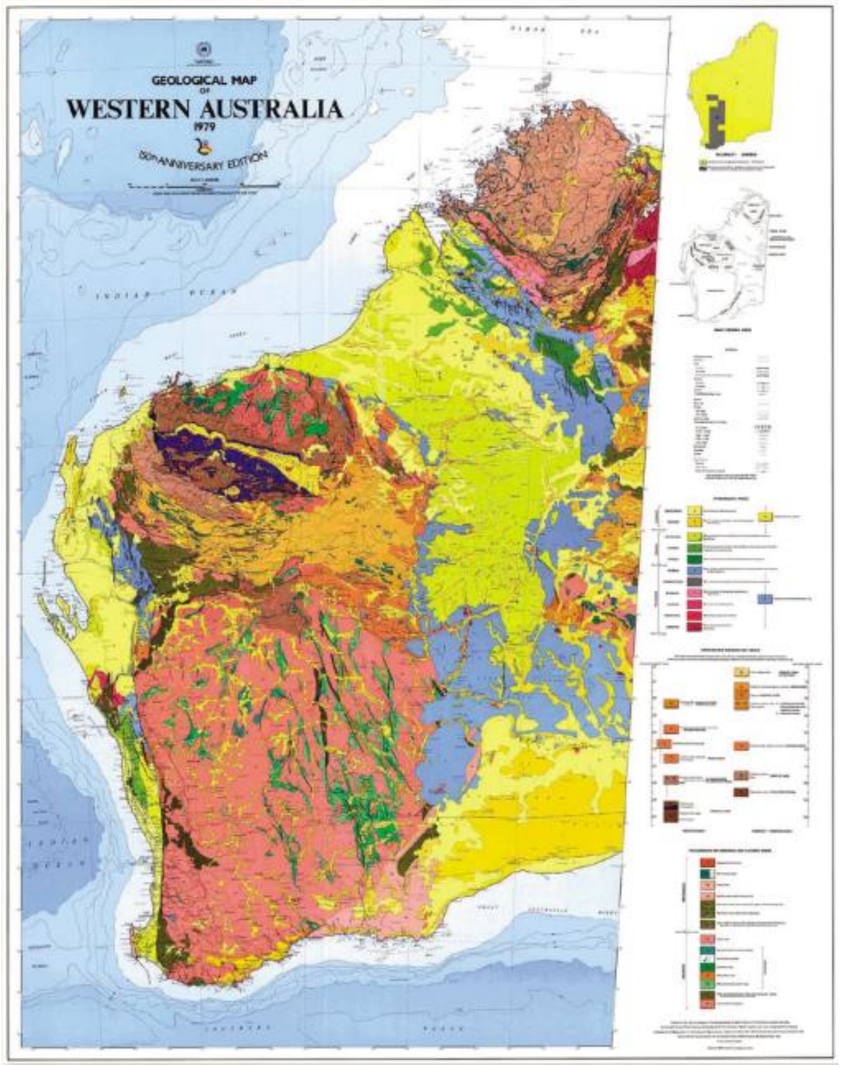
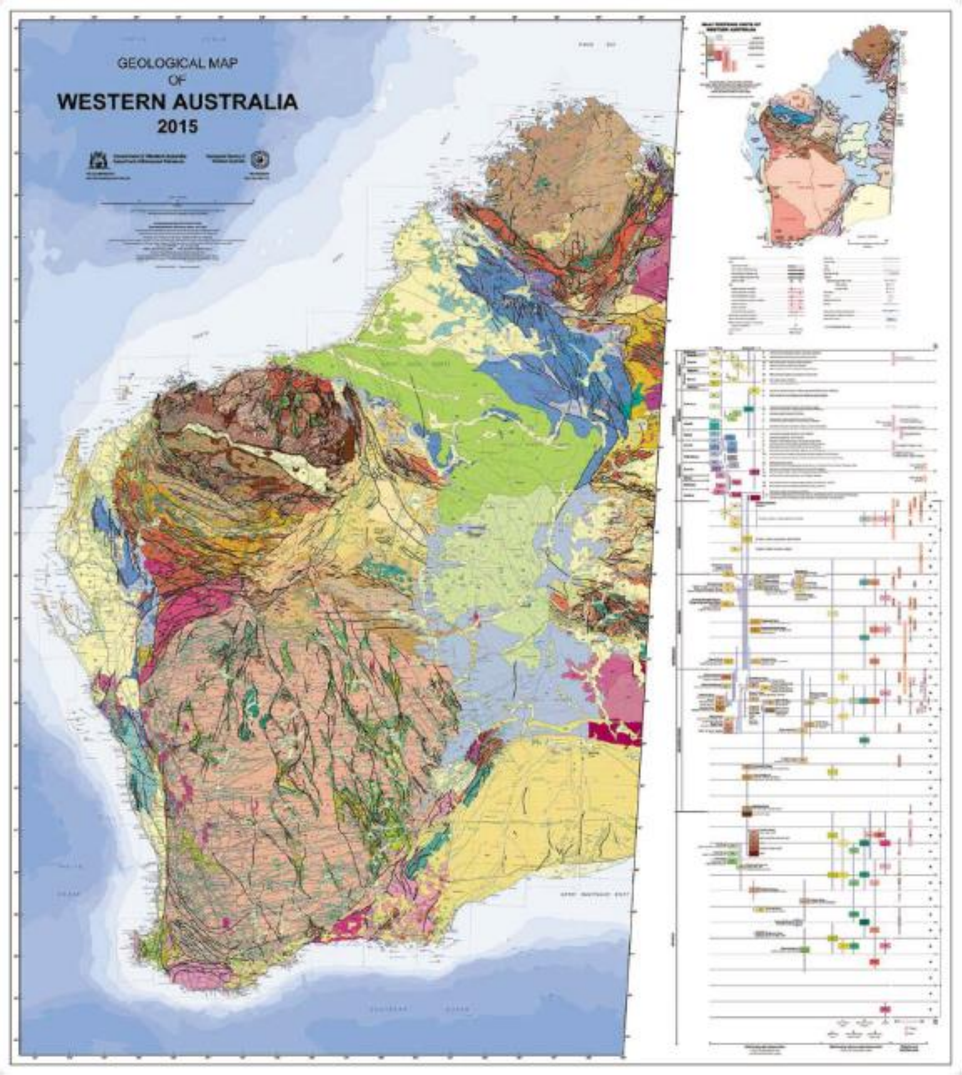
Impact of Isotope Geoscience on the Geological Map of Western Australia



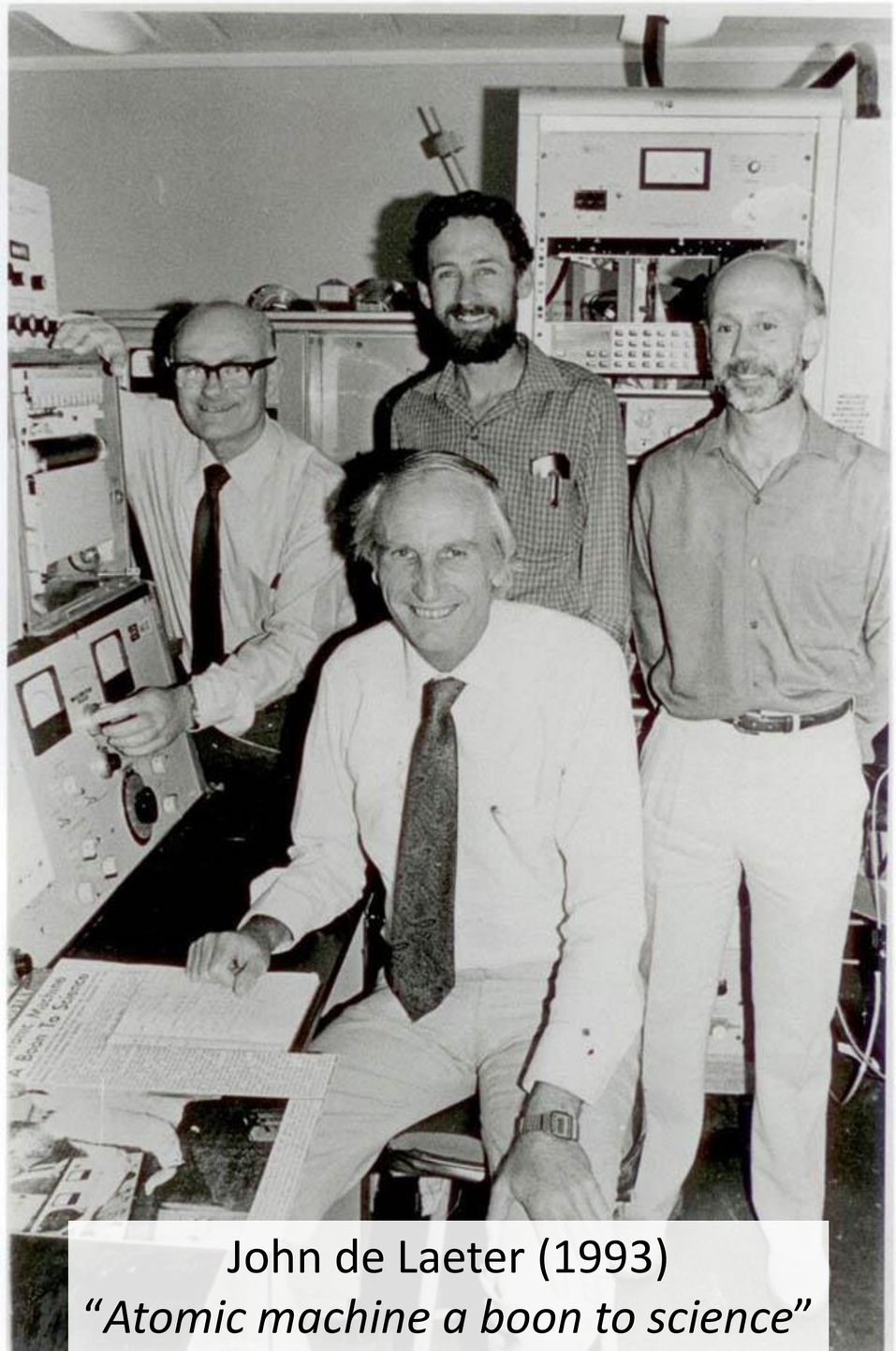
1979



2015

SHRIMP data has been *instrumental* in transforming the geological map of WA

Sensitive High Resolution Ion MicroProbe (SHRIMP)



John de Laeter (1993)

"Atomic machine a boon to science"

25 years of operation! – December 14, 2018

January 16, 2019

Federal government announcement - *Boosting performance of Australia's world-class research facilities*

AuScope

NCRIS National Research Infrastructure for Australia
An Australian Government Initiative

$5,000,000

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Top 50 Words in JdLC-linked Research Publications (1992-2018)

Exploration Keywords

- Gold
- Deposit
- Orogeny
- Timing
- Mineralisation
- Yilgarn

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

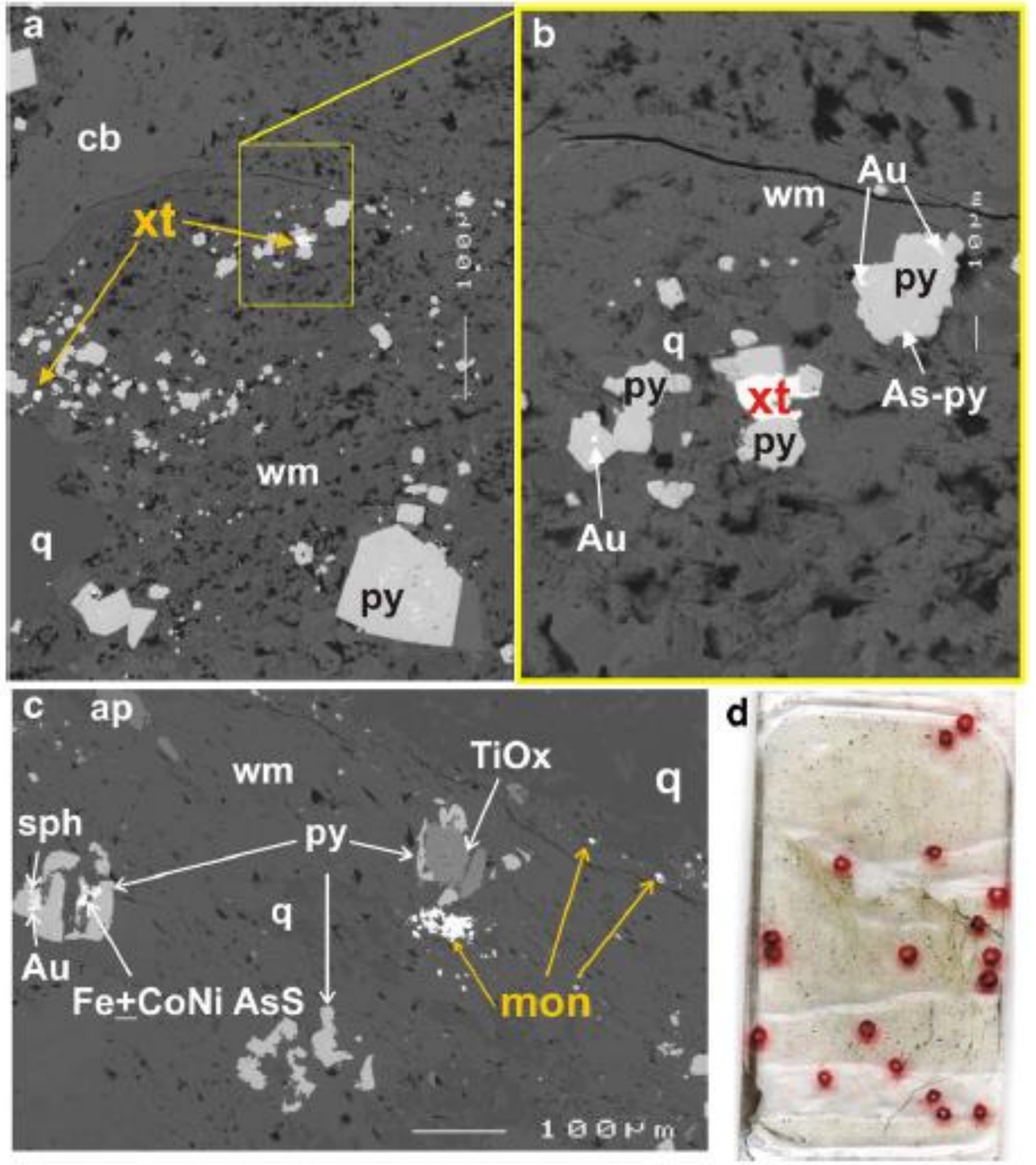
Centre for EXPLORATION TARGETING | John de Laeter Centre | Curtin University

SHRIMP U-Pb geochronology of Yilgarn orogenic gold deposits using REE-phosphates

Workflow:

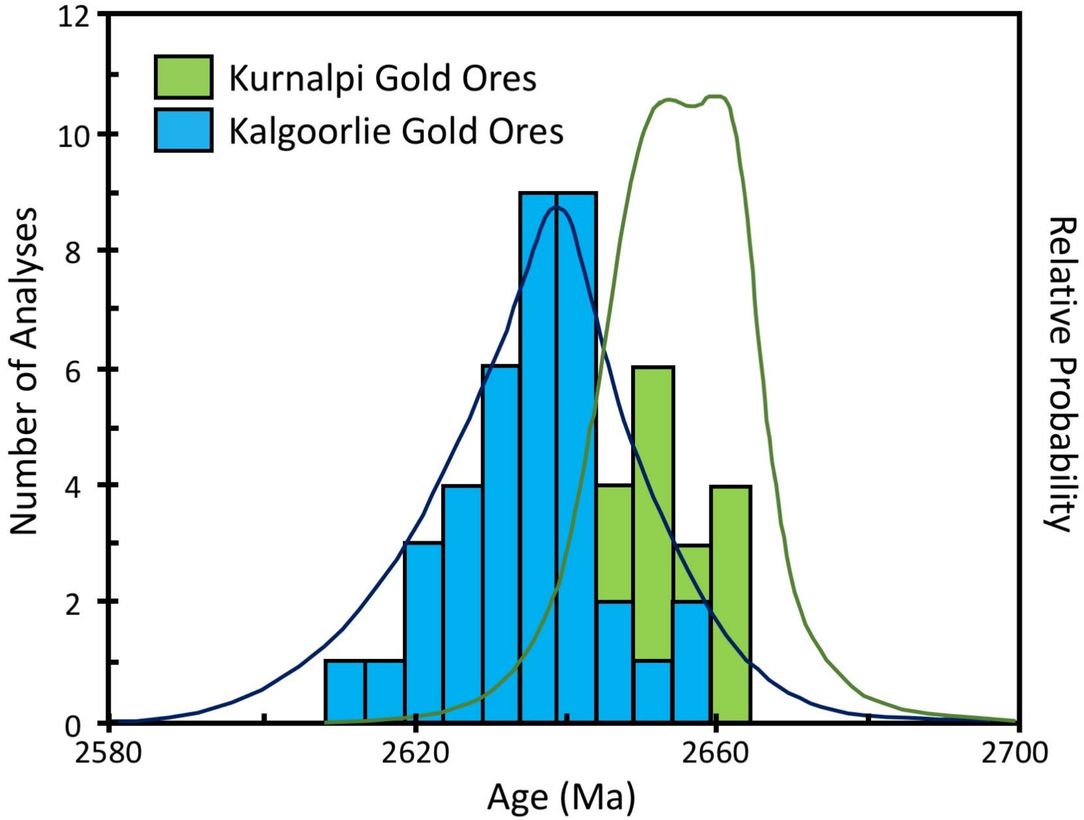
1. Identify monazite and xenotime in polished thin sections of high-grade gold ores
2. Drill out and prepare a composite mount
3. Verify paragenetic relationship between gold and phosphate minerals using SEM/TIMA
4. Determine age of phosphate minerals using SHRIMP U-Pb dating techniques

Vielreicher et al, 2015. *Mineralium Deposita*.

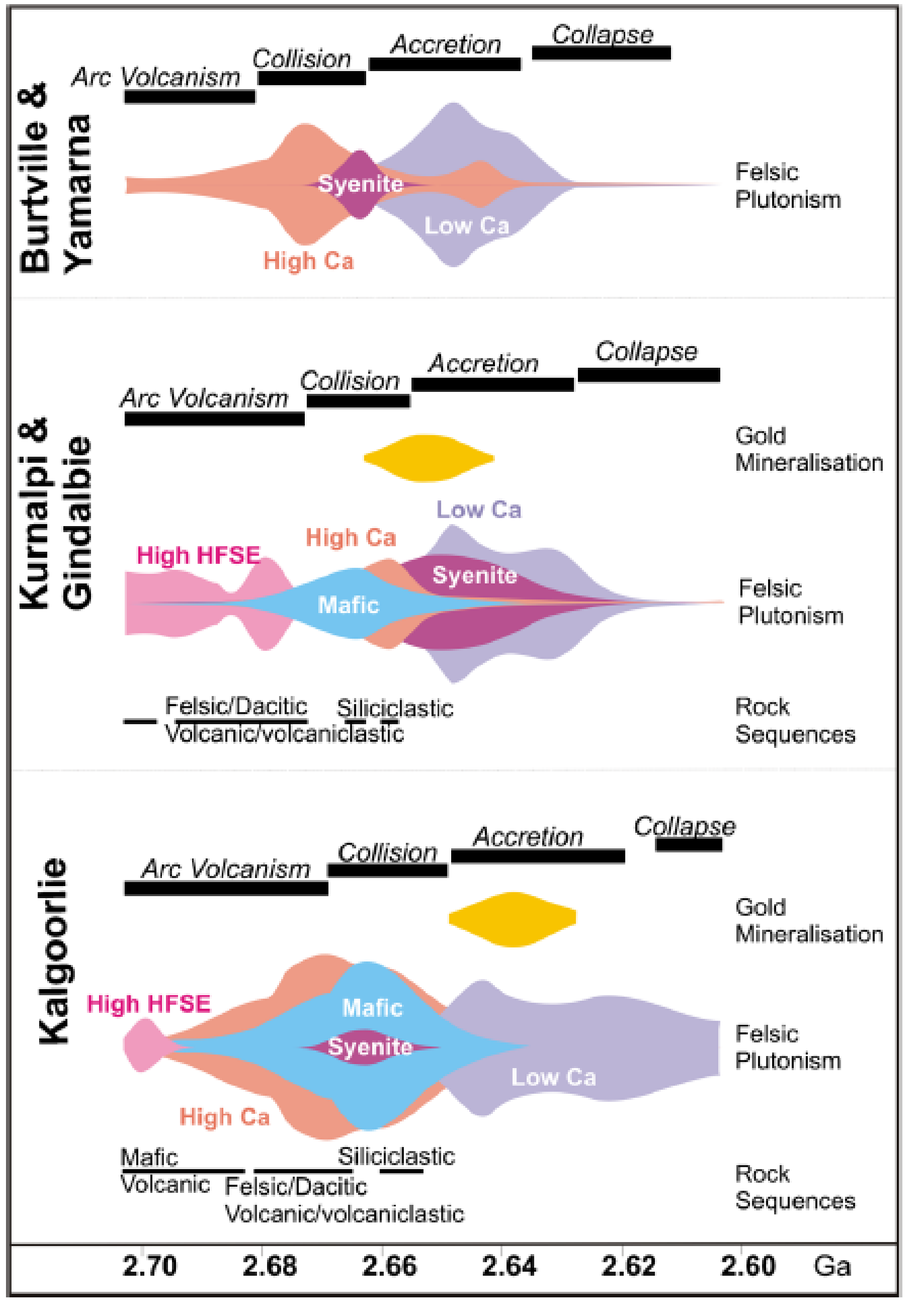


Tectonic reconstruction of Eastern Goldfields

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



Vielreicher et al, 2015. *Mineralium Deposita*.



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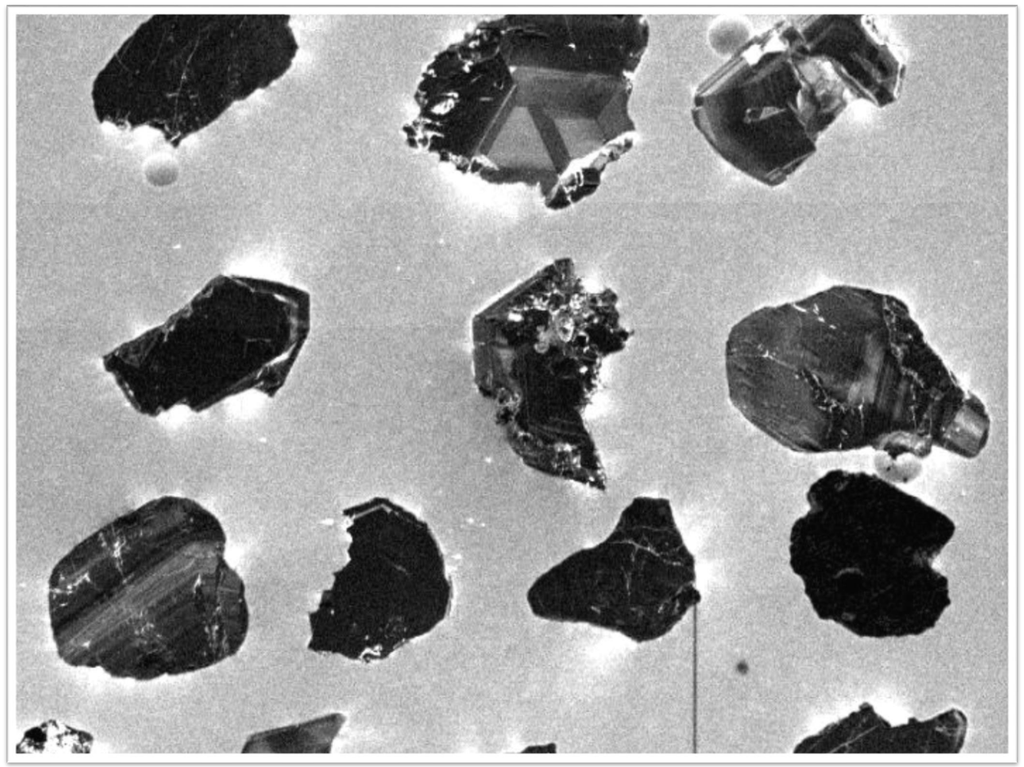
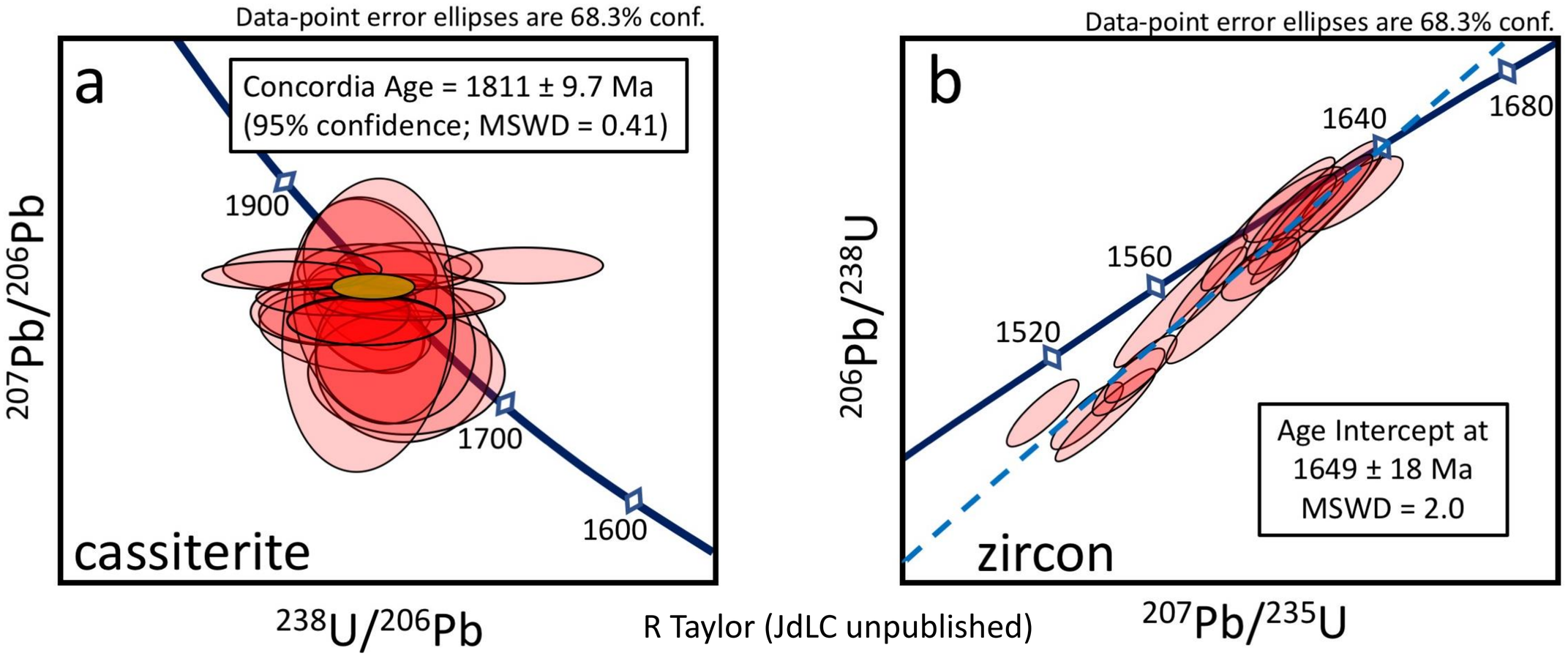
Regional Exploration – Cassiterite Geochronology



- 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?

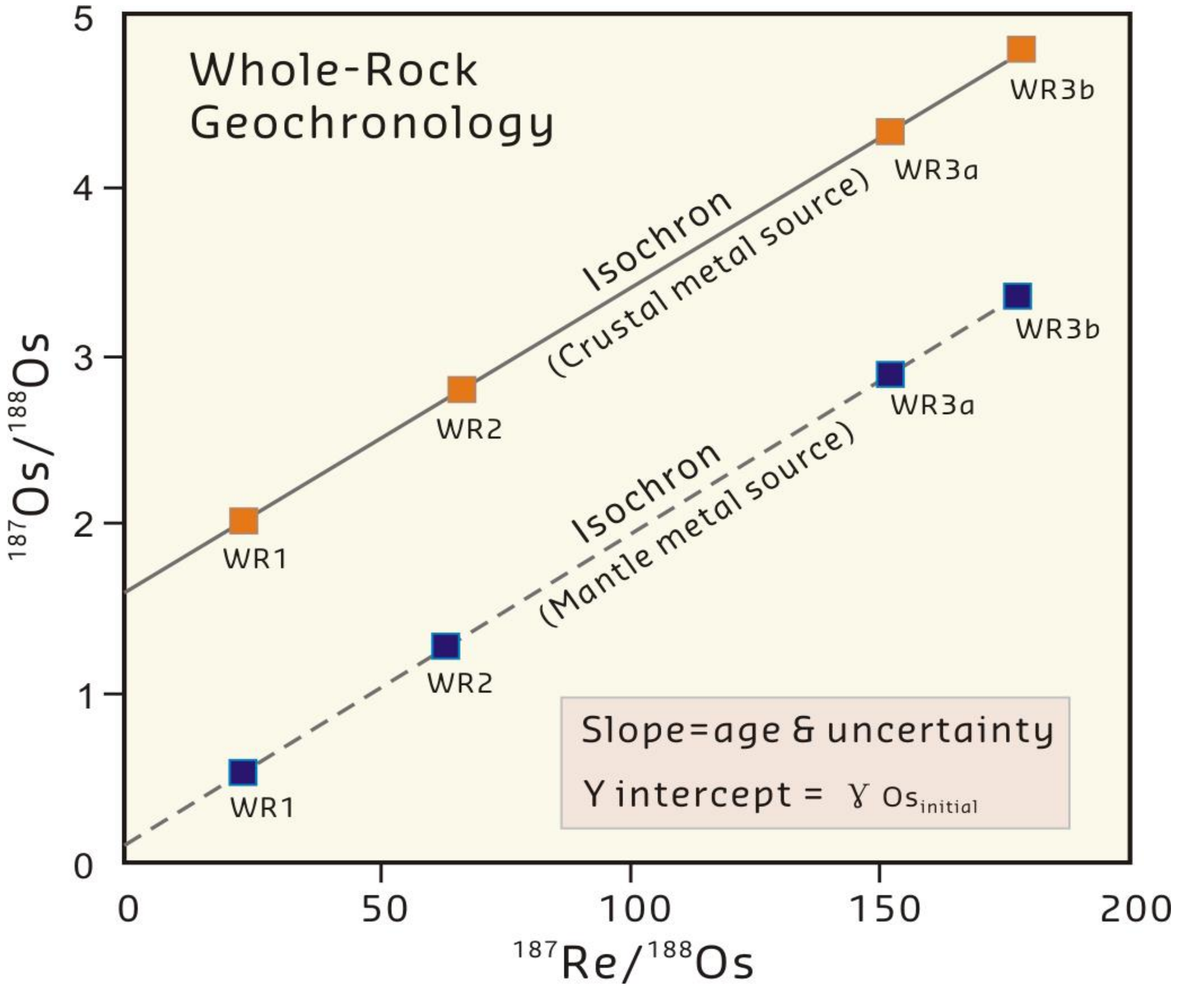
Regional Exploration – Cassiterite Results



R Taylor (JdLC unpublished)

- 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



Re-Os isochron diagram
(McInnes et al. 2008, AJES 55, 967-981)

Geochronology – direct dating of ores and black shales formation

Fingerprinting of ores or black shales provides provenance information based on initial $^{187}Os/^{188}Os$ 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

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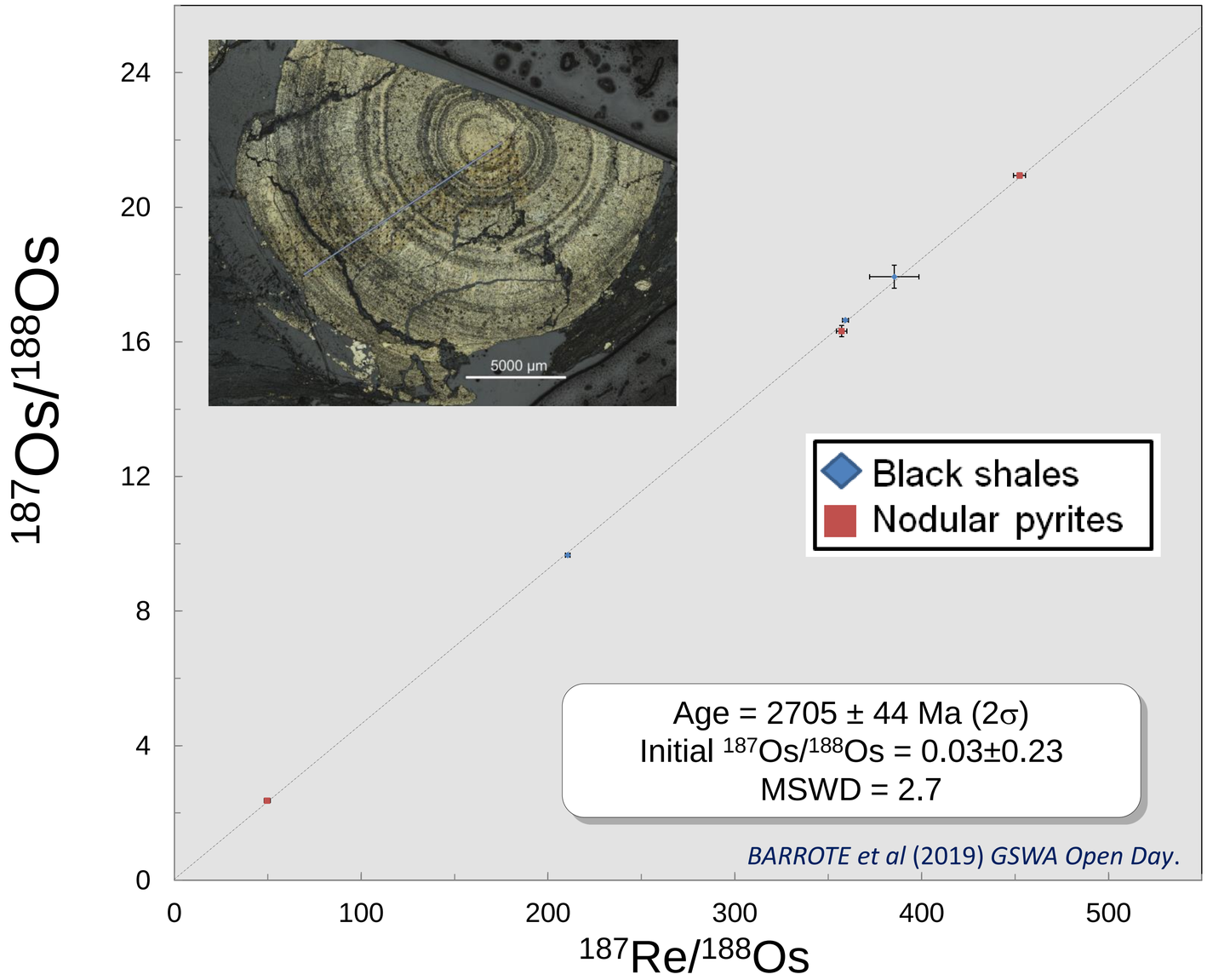
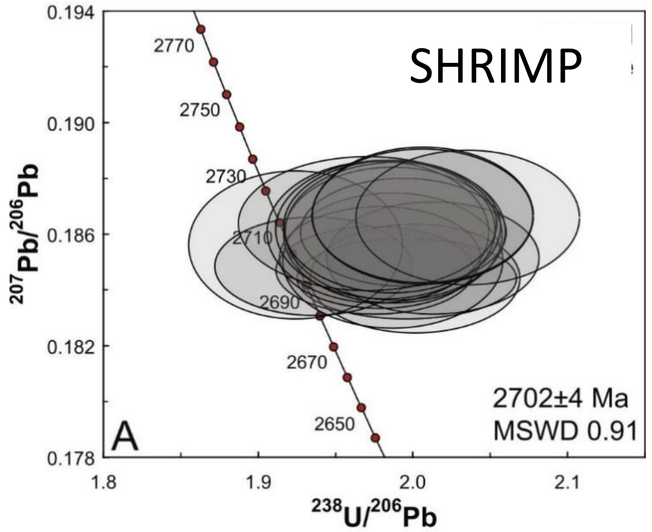
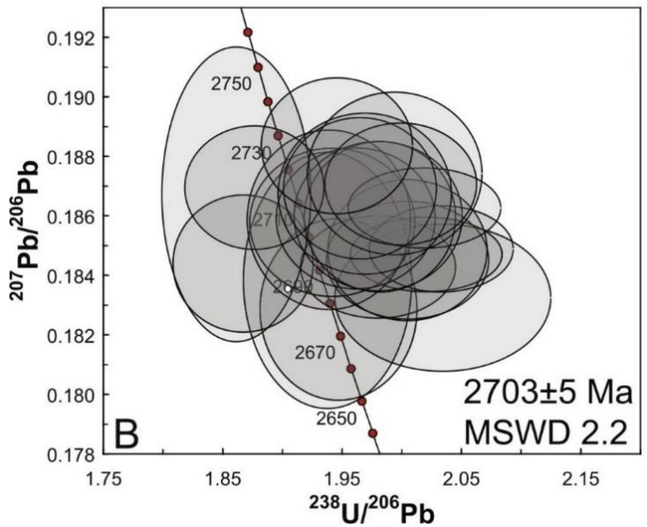
Re-Os geochronology of WA ore deposits: Shale-hosted mineralisation



Underlying volcanics





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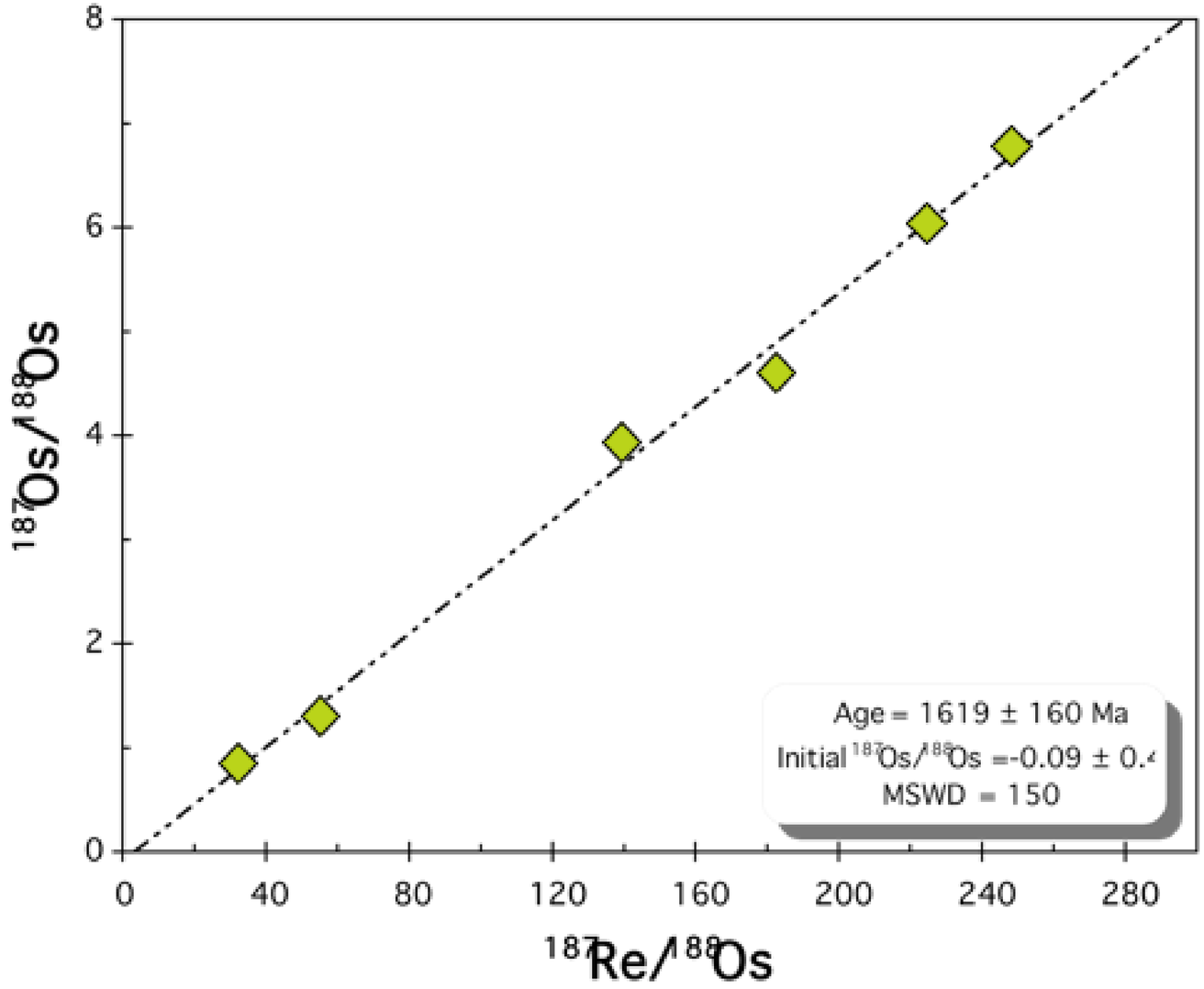
Callie Au Deposit, Tanami Belt: Re-Os Results
Vein Sulfides (po, cpy, py)



Australian Journal of Earth Sciences (2008) **55**, (967–981)

Re–Os geochronology and isotope systematics of the Tanami, Tennant Creek and Olympic Dam Cu–Au deposits

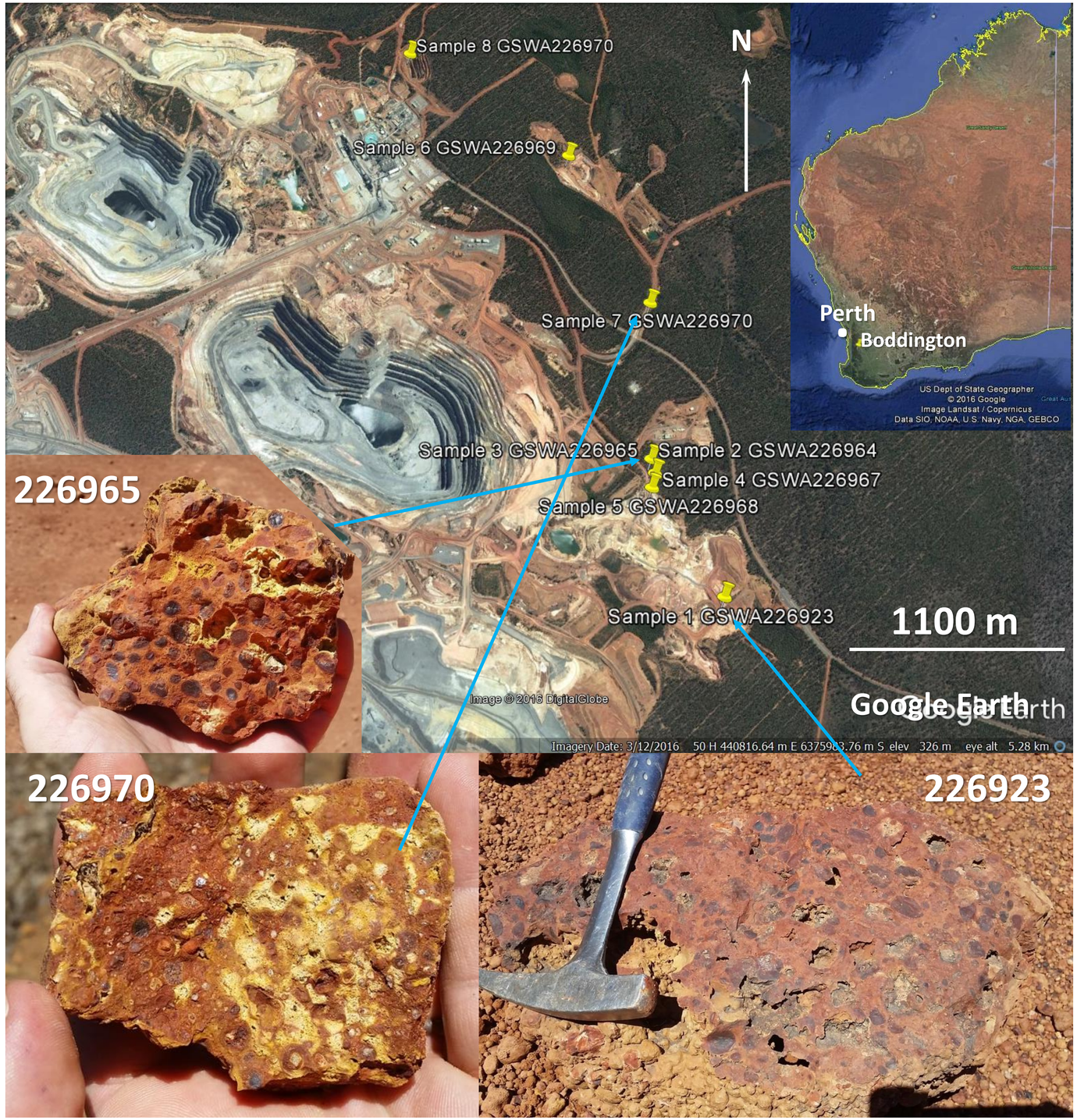
B. I. A. McINNES[1]*, R. R. KEAYS[2], D. D. LAMBERT[3], J. HELLSTROM[4] AND J. S. ALLWOOD[5]

[1]*CSIRO Exploration & Mining, PO Box 1130, Bentley, WA 6102, Australia.*
[2]*School of Geosciences, PO Box 28E, Monash University, Vic. 3800, Australia.*
[3]*US National Science Foundation, Arlington, VA 22230, USA.*
[4]*School of Earth Sciences, University of Melbourne, Vic. 3010, Australia.*
[5]*Geomodelling Ltd, 56 Adelaide Street, Petone, Lower Hutt, New Zealand.*

- 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

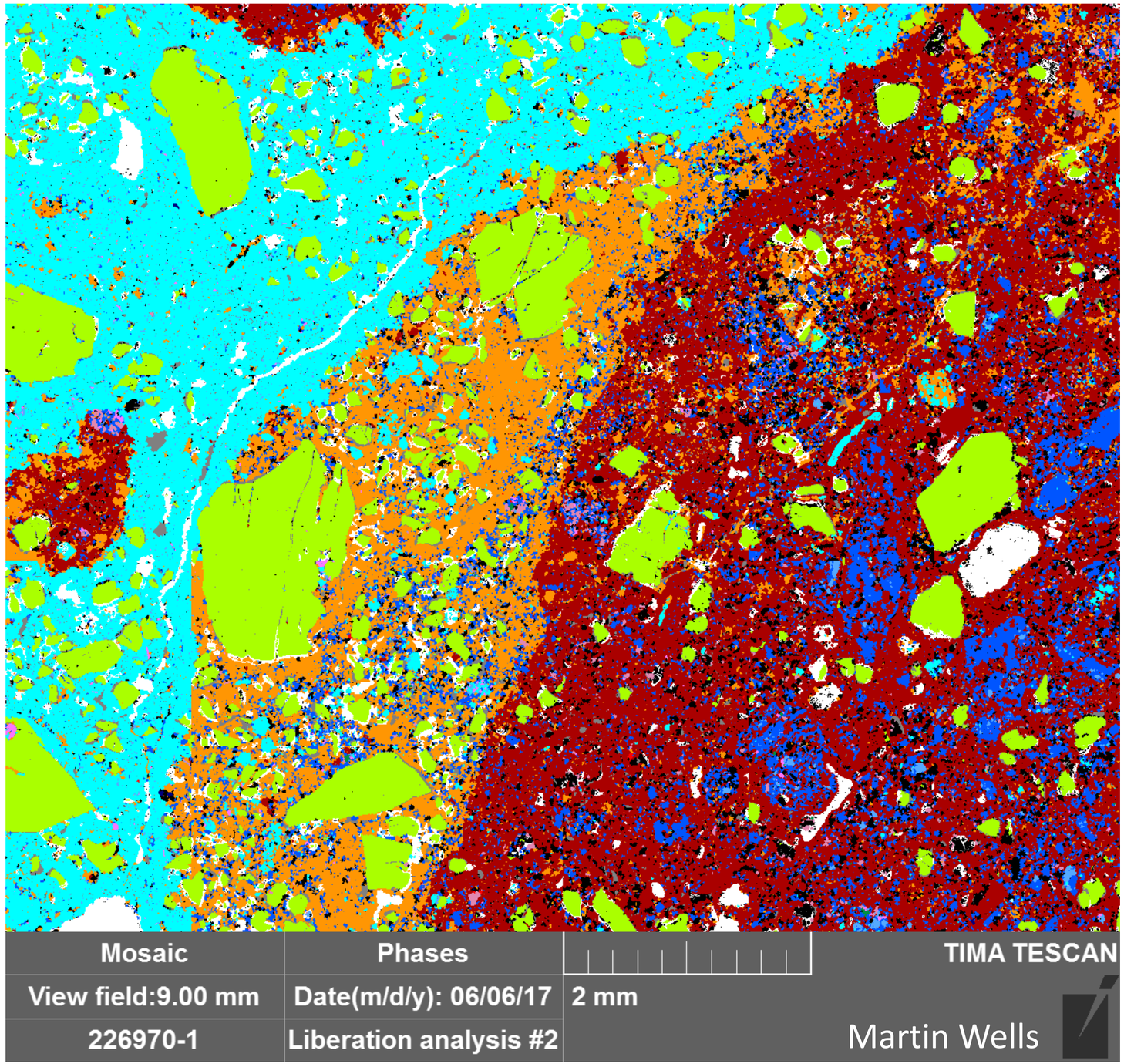


TIMA Mineral Mapping

Boddington
Fragmental duricrust

Primary phases

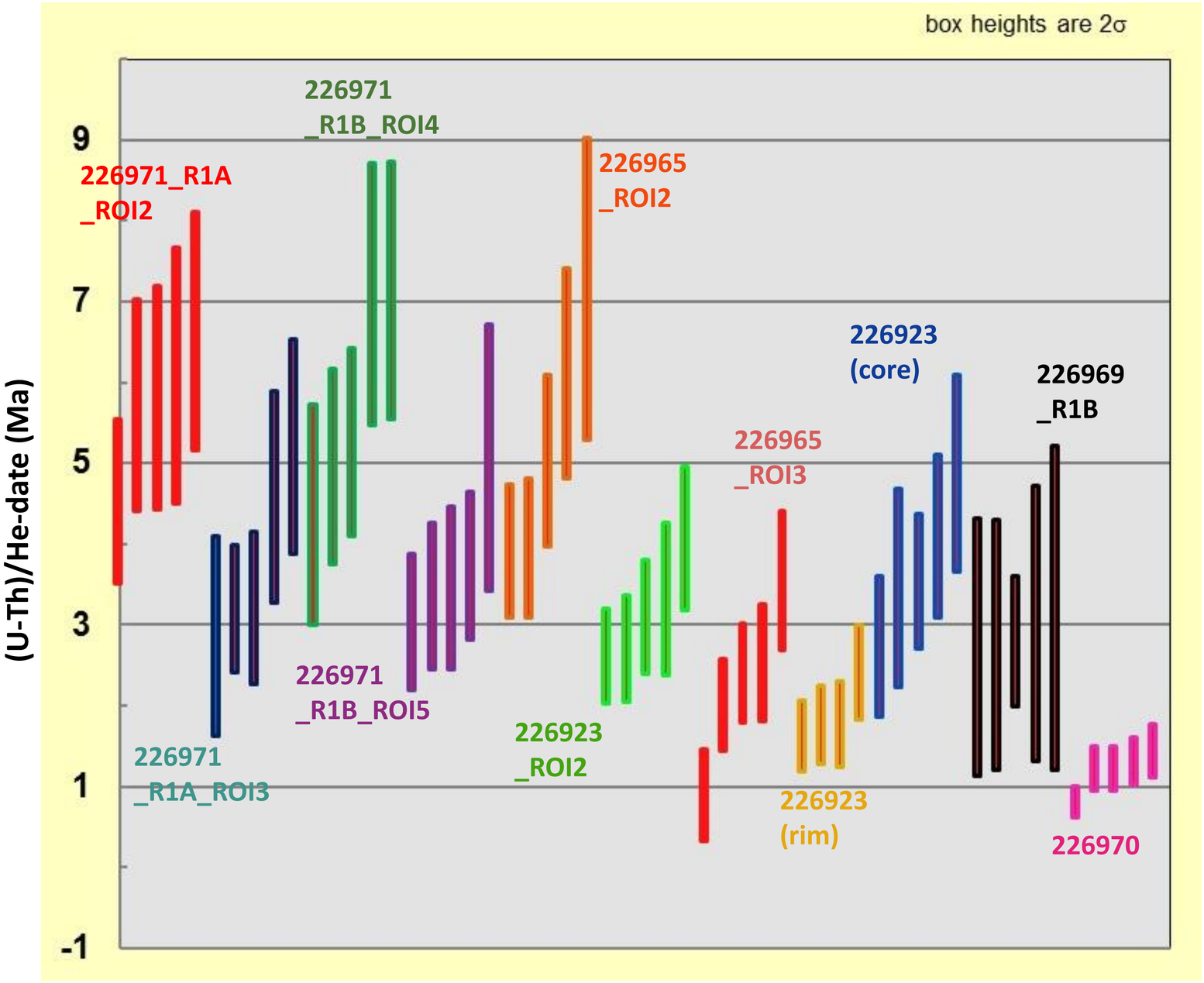
- Hematite/Maghemite
- Gibbsite+Fe oxides
- Gibbsite+Kaolinite+Fe-oxides
- Quartz
- Gibbsite
- Kaolinite_Fe-oxides
- Kaolinite
- Mixed Al+Ti+Fe
- Gibbsite+Kaolinite
- Muscovite
- Ilmenite
- Unclassified
- The rest



Mosaic	Phases		TIMA TESCAN
View field:9.00 mm	Date(m/d/y): 06/06/17	2 mm	
226970-1	Liberation analysis #2		Martin Wells

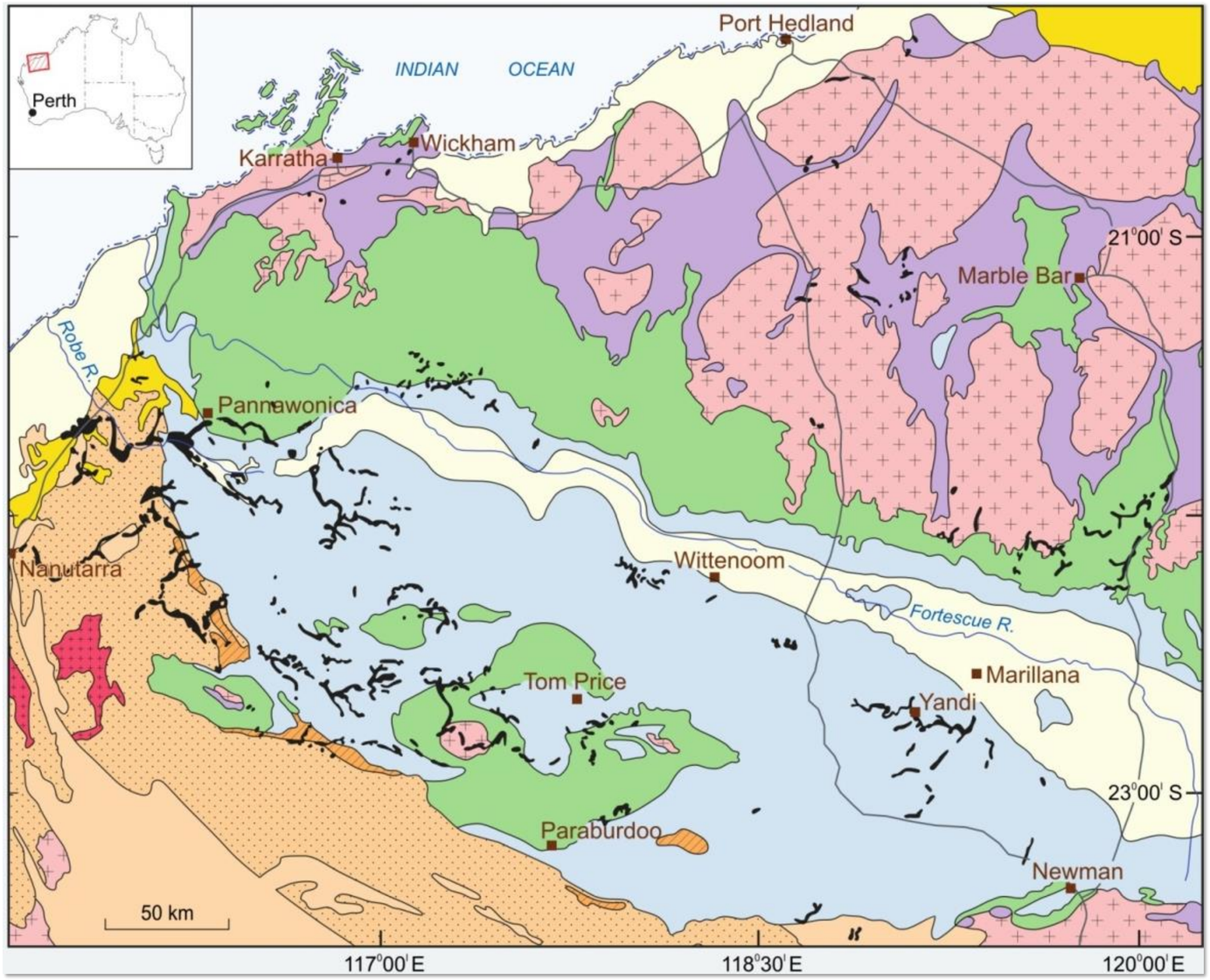
Boddington regolith (U-Th)/He age distribution

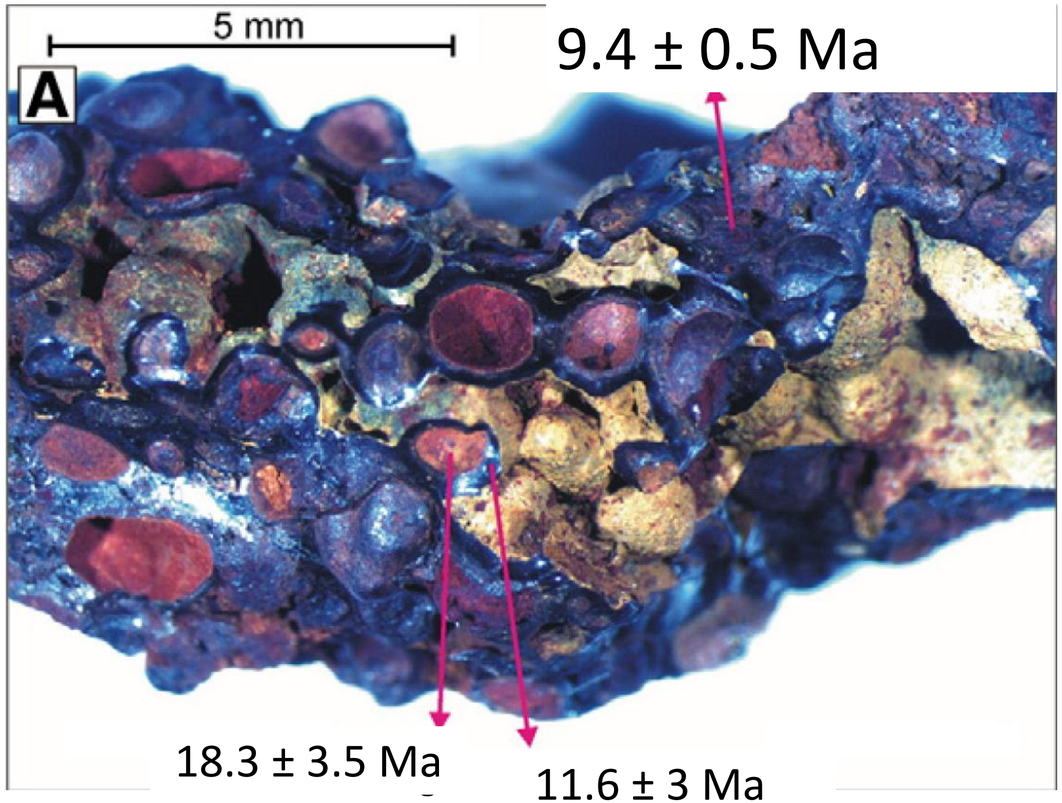
- Late-Miocene/Pliocene age for Boddington duricrust
- Comparable to age of regolith materials from the Darling range (Pidgeon et al., 2004)



(U-Th)/He-dates (Ma) for all BGM duricrust samples. Each coloured bar represents individual replicate measurements; 'size' (height) is measurement error (± 1 σ).z

Low Temperature Oxide Ores: Paleoalluvial Robe River Fe Deposits, WA





Chemical Geology 354 (2013) 150–162

Contents lists available at SciVerse ScienceDirect

Chemical Geology

journal homepage: www.elsevier.com/locate/chemgeo

(U–Th)/He chronology of the Robe River channel iron deposits, Hamersley Province, Western Australia

Martin Danišík [a,b,*], Noreen J. Evans [a,c], Erick R. Ramanaidou [c], Brad J. McDonald [a,c], Celia Mayers [c], Brent I.A. McInnes [a,c]

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.mcinnes@curtin.edu.au
  - Twitter: @JDLCentre
  - http://jdlc.curtin.edu.au

Thank you

Make tomorrow better.