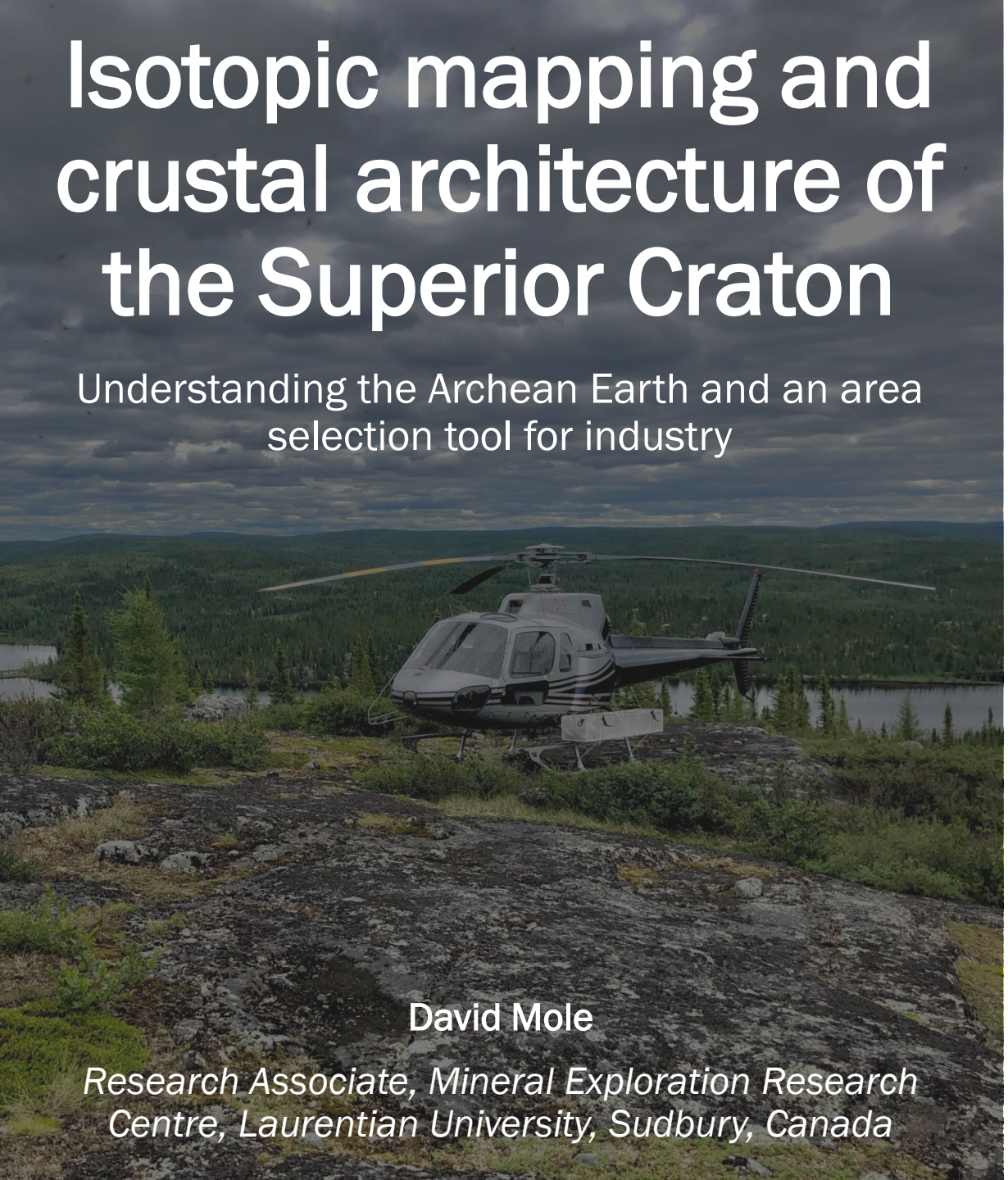
Isotopic mapping and crustal architecture of the Superior Craton

Understanding the Archean Earth and an area selection tool for industry



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CANADA FIRST RESEARCH EXCELLENCE FUND

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MERC Mineral Exploration Research Centre

Outline

- Motivation for the project
- Background and methodology
- Previous work
- Applying isotopic mapping to the Superior Craton – Progress so far
- Example from the Abitibi

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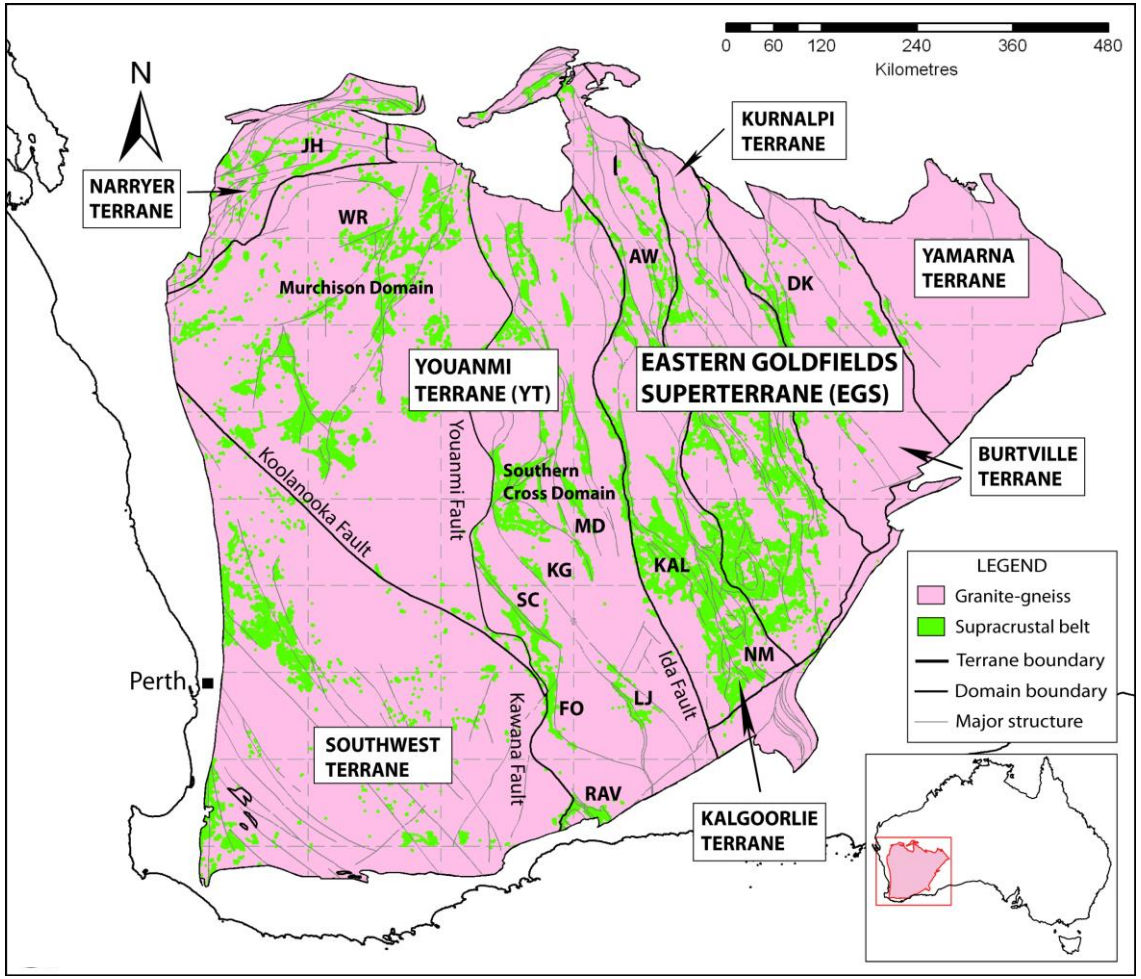
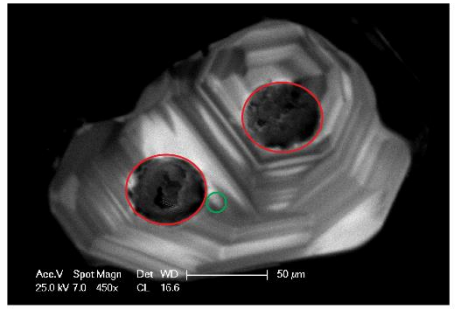
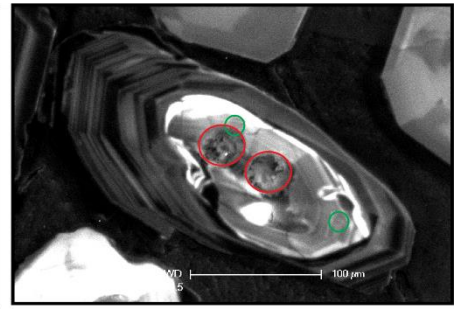
Some background information

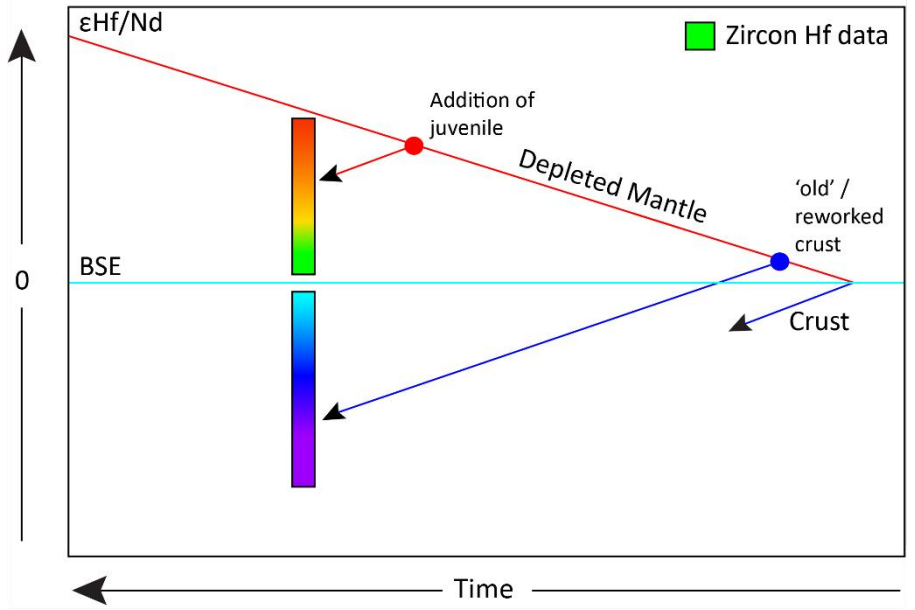
1. Geology of the Yilgarn Craton, Australia



2. The Lu-Hf / Sm-Nd isotopic system







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Motivation

- Imagine a large-scale exploration method that could identify a prospective area of 1000s of km^2 within a continent or craton >100,000s km^2 in size - 99% reduction in search space
- This would allow more efficient and effective area selection
- As well as a greater focus on the target area at the regional-belt-drilling scales
- What if this method could detect cryptic changes in the crust invisible to other tools?
- What if this method could cover an area the size of the south-east Superior Craton at the same cost as a 500 m diamond drill hole?

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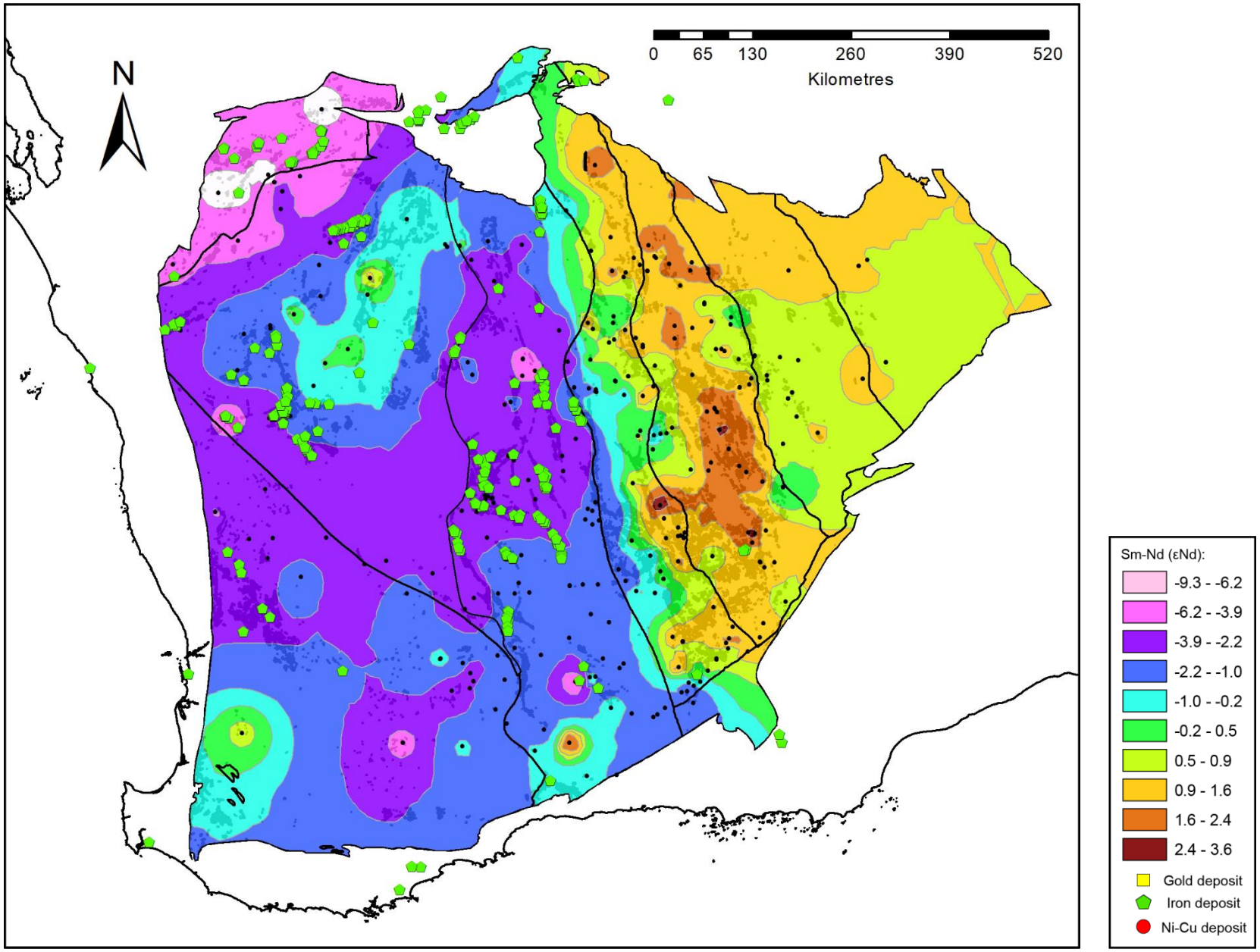
Motivation cont.

- **Isotopic mapping:**
  - Yilgarn granites show similar age ranges and geochemistry across the craton
  - How can we effectively understand spatial variations in crustal evolution?
- **Radiogenic isotopes:**
  - The spatial application of the Sm-Nd unveiled the cryptic architecture of the Yilgarn Craton
  - Apparent controls on multiple mineral systems
  - Later, the Lu-Hf system was used to look at architecture further back in time
- **The result?**
  - Crustal architecture has a first-order control on the location of major mineral systems
  - …and we have a way to image it



Mole *et al.* (2013) *Geol. Soc. London Spec. Pub.*

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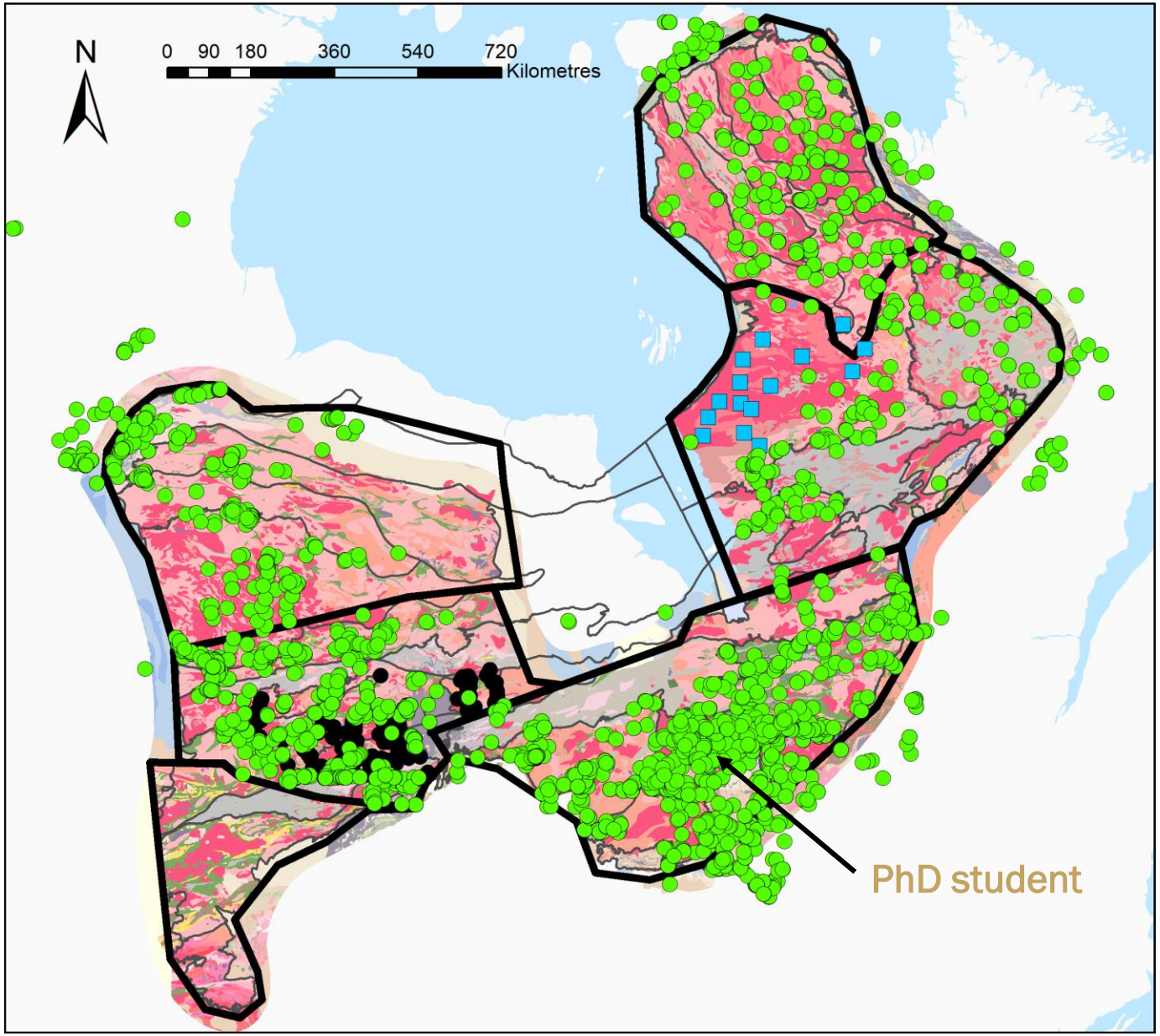
Methodology

- **Sample acquisition:**
  - Build database of U-Pb zircon samples for target area
  - Divide craton into quadrants
  - Collect sub-samples from existing material (~200 per region)
  - Perform fieldwork in under-sampled areas
- **Data Collection:**
  - Zircons mounted at LU
  - Imaging and O-isotopes collected at UoA
  - Lu-Hf isotopic data collected in-situ from zircons via Neptune LA-ICP-MS at LU
  - U-Pb geochronology and zircon trace element data also collected
- **Process and map data:**
  - Reduce data and map
  - Produce time-slices



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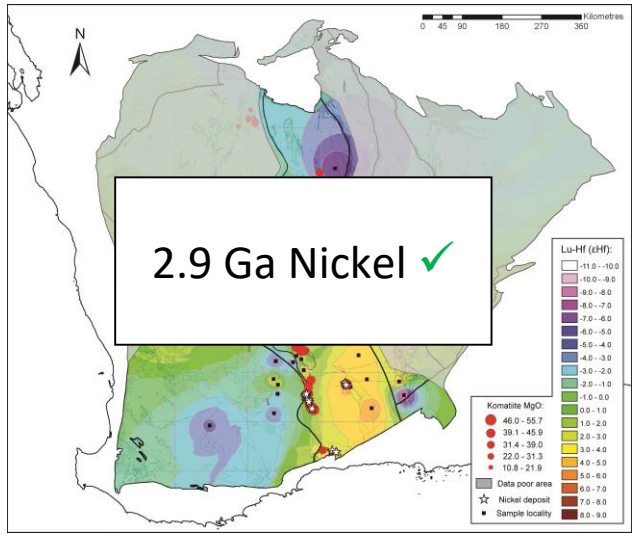
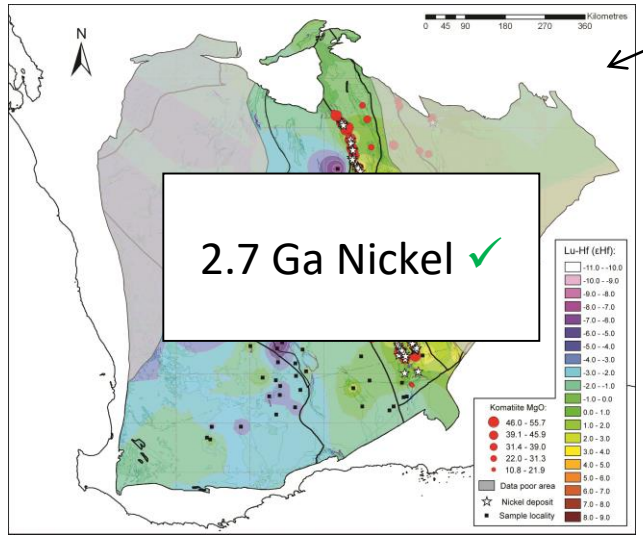
Methodology – Time-slice mapping

- Hf-isotope data is grouped by U-Pb age into ‘time-slices’
- Produces ‘snap-shots’ of crustal architecture – used together these image craton evolution
- This was used to investigate nickel mineralisation at 2.9 and 2.7 Ga in the Yilgarn Craton:

Lu-Hf → In-situ technique on zircons → Zircons are 3.6-2.6 Ga → Can group Hf data into ‘time-slices’



3050-2820 Ma



2720-2600 Ma

RESULT: We can image crustal evolution in action

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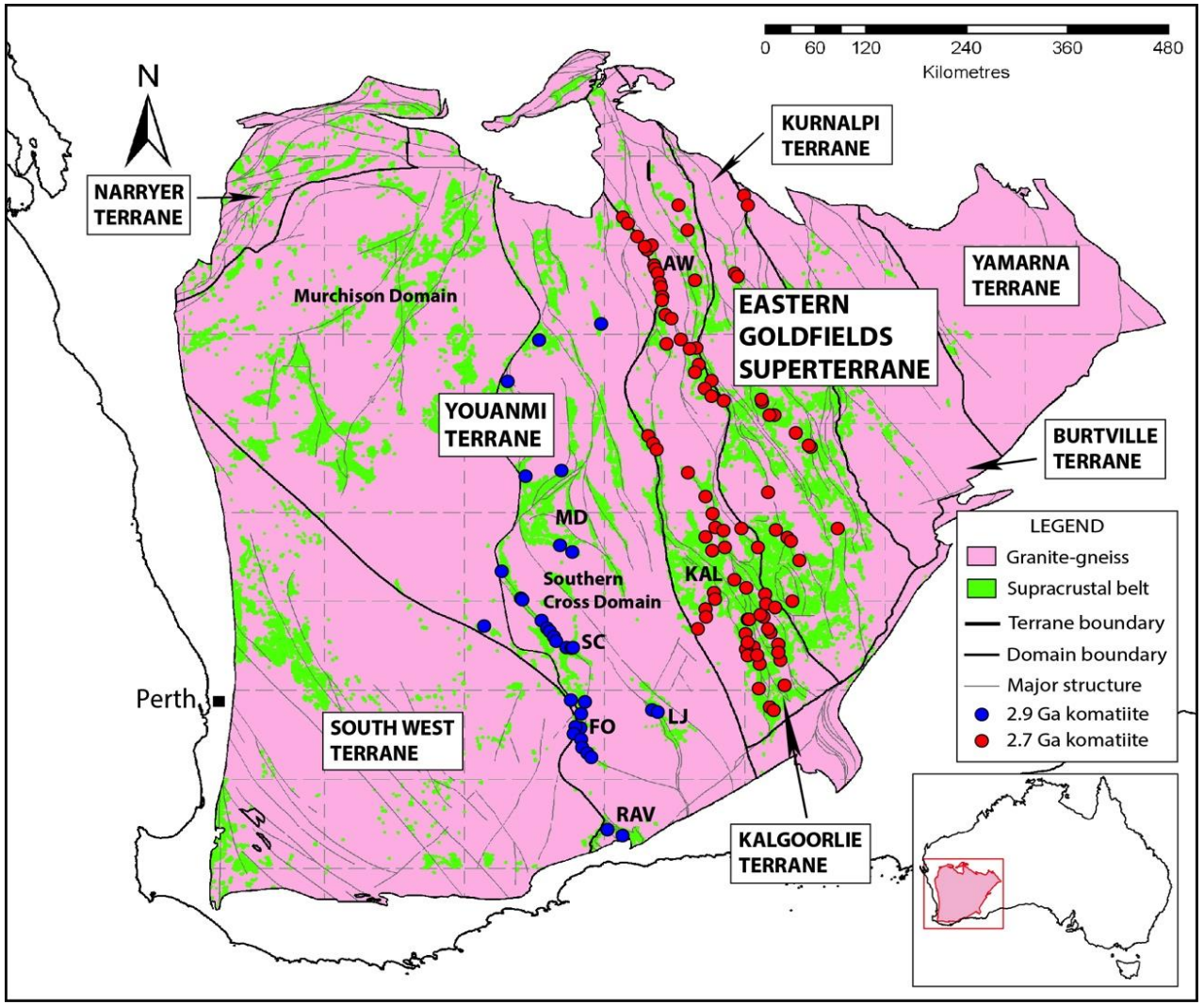
Previous work



Problem:

What controls the localisation of 2.9 and 2.7 Ga komatiite-hosted nickel systems in the Yilgarn Craton, Western Australia?

Can isotopic mapping help?

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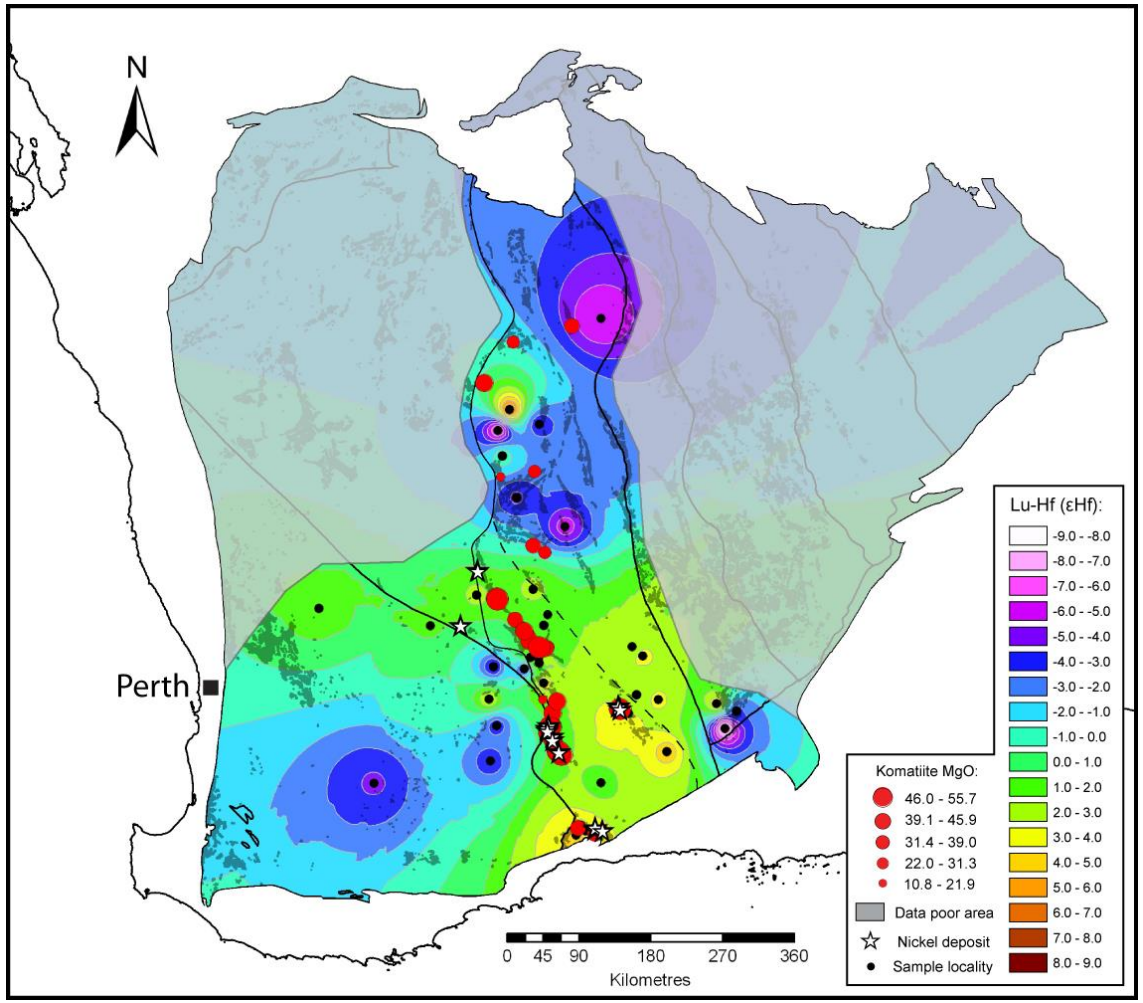
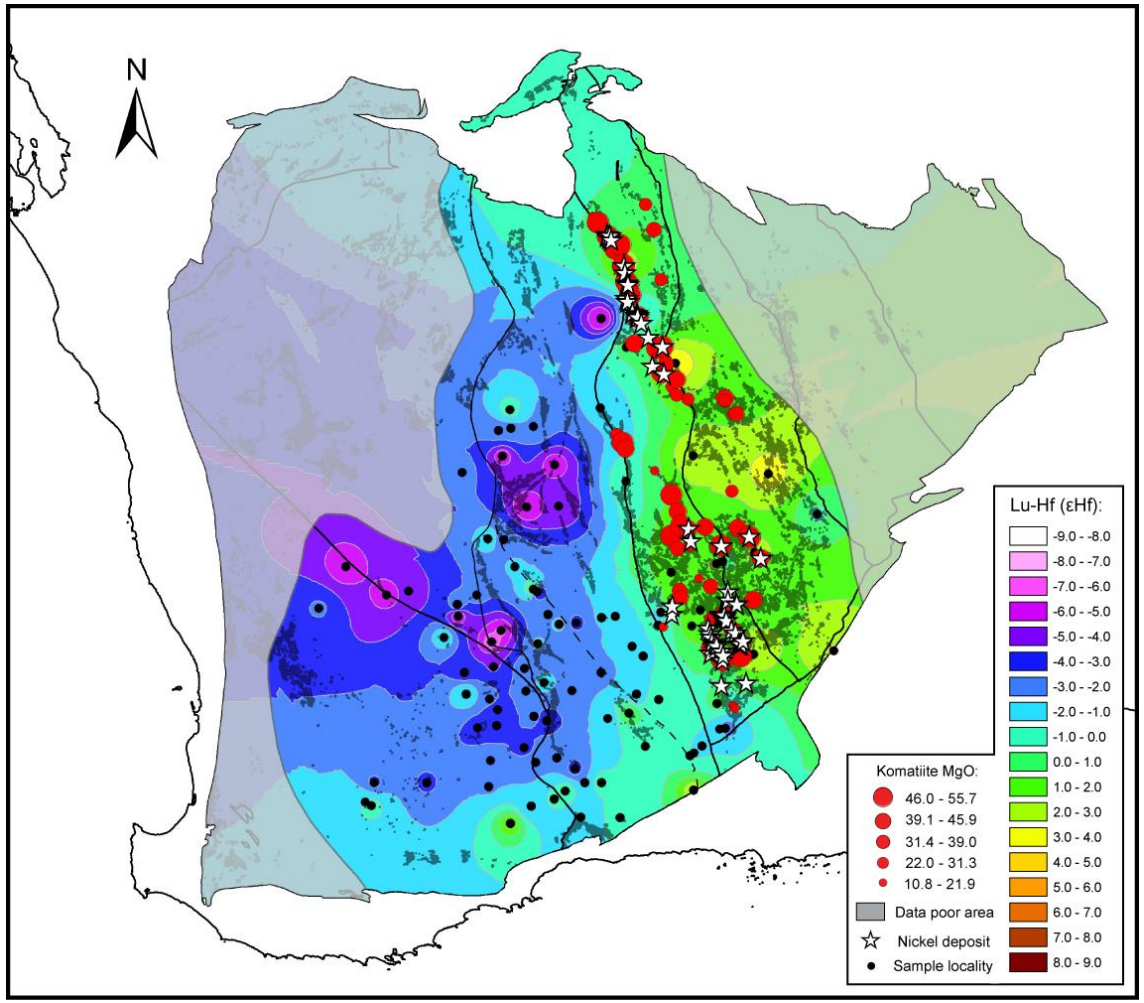
Previous work



2.9 Ga Hf time-slice



2.7 Ga Hf time-slice

Mole *et al.* (2014) *PNAS*

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Previous work

Asthenosphere

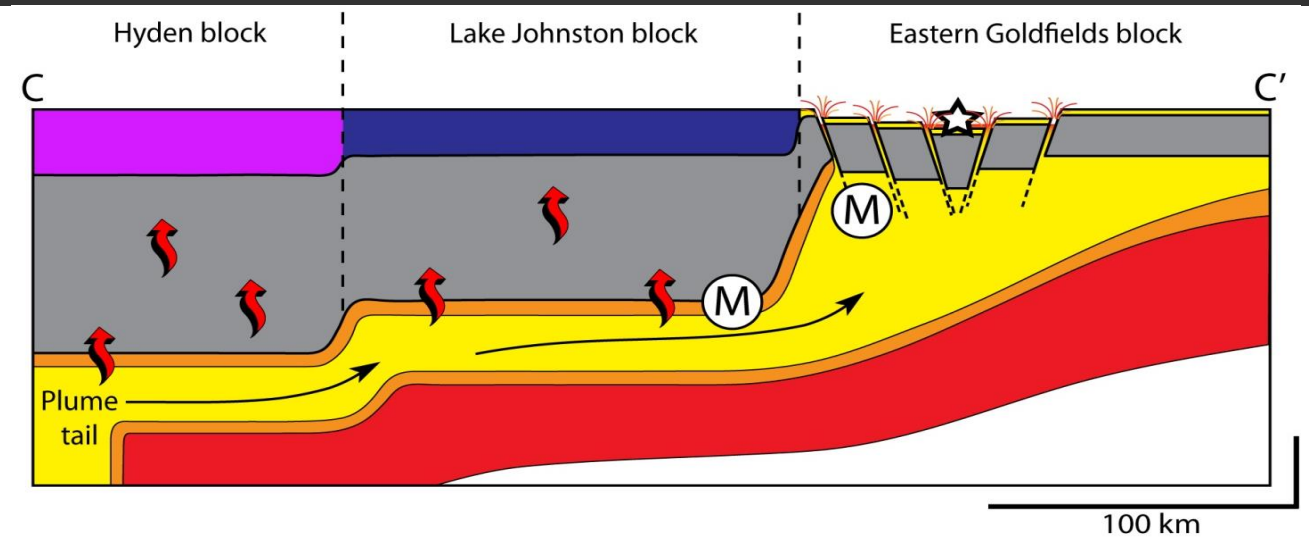
Mantle lithosphere

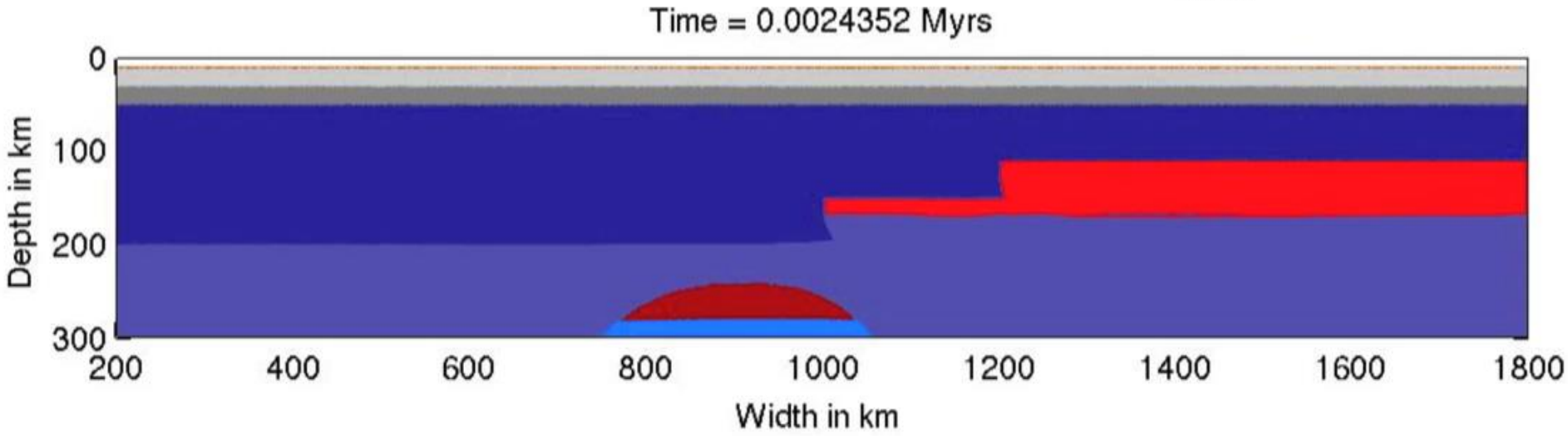
Adiabatic melting of plume head

Adiabatic melting of asthenosphere

Melts extracted from plume head

Melts extracted from asthenosphere





Gorczyk *et al.* (2017) *Tectonophysics*

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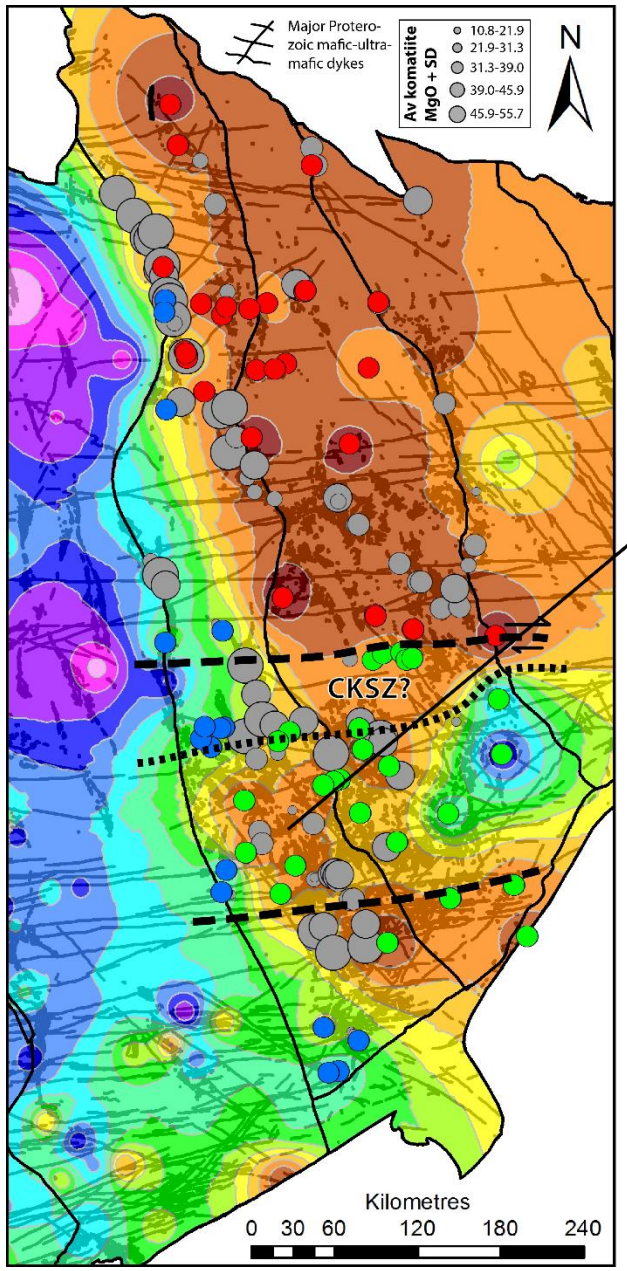
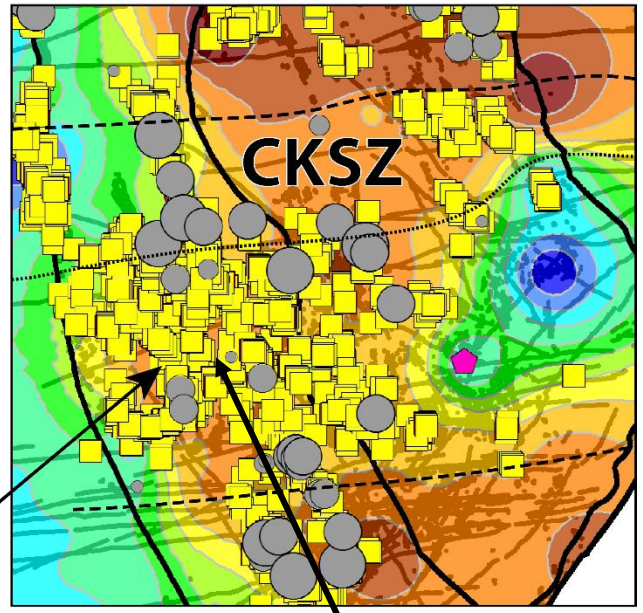
Architectural complexity?

- World-class Au Camp:
  - Golden Mile (Kalgoorlie) has produced >60 Moz of Au
  - This camp occurs at a ‘kink’ in the Kalgoorlie-Kurnalpi rift zone (KKR)
- Architectural complexity:
  - This area of the rift is offset to the west
  - This offset may be controlled by transform faults
  - Ancient transform faults destroyed by late granites?
  - Proterozoic dykes are focused where faults may have occurred
  - Komatiites are also offset
  - Controlled by ‘backstop’ of older crust?

Did these features localise fluids, structures, and magmas, encouraging mineralisation?





60 Moz Au

Mole *et al.* (2019) *ESR submitted*

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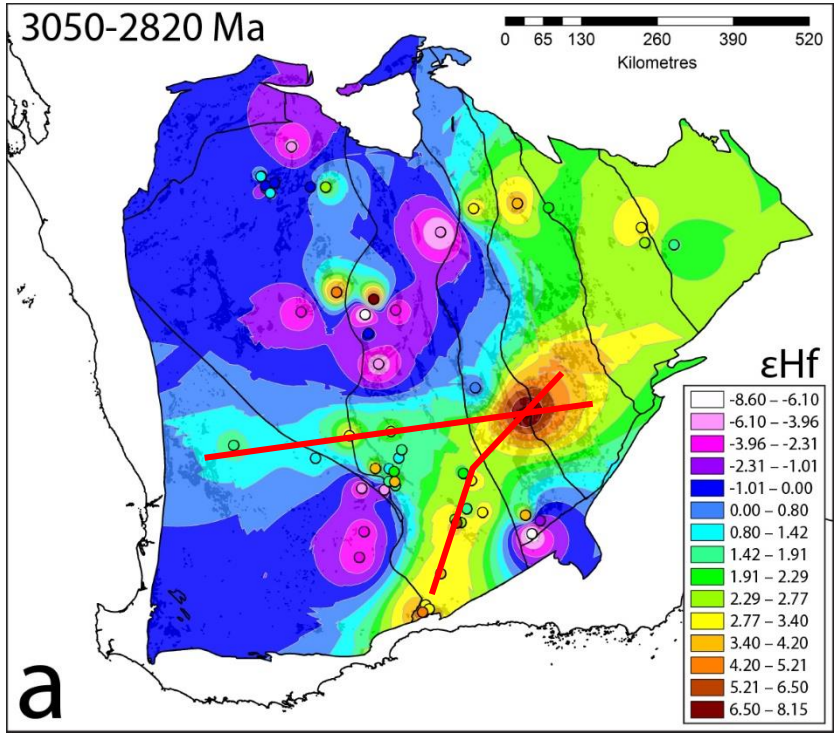
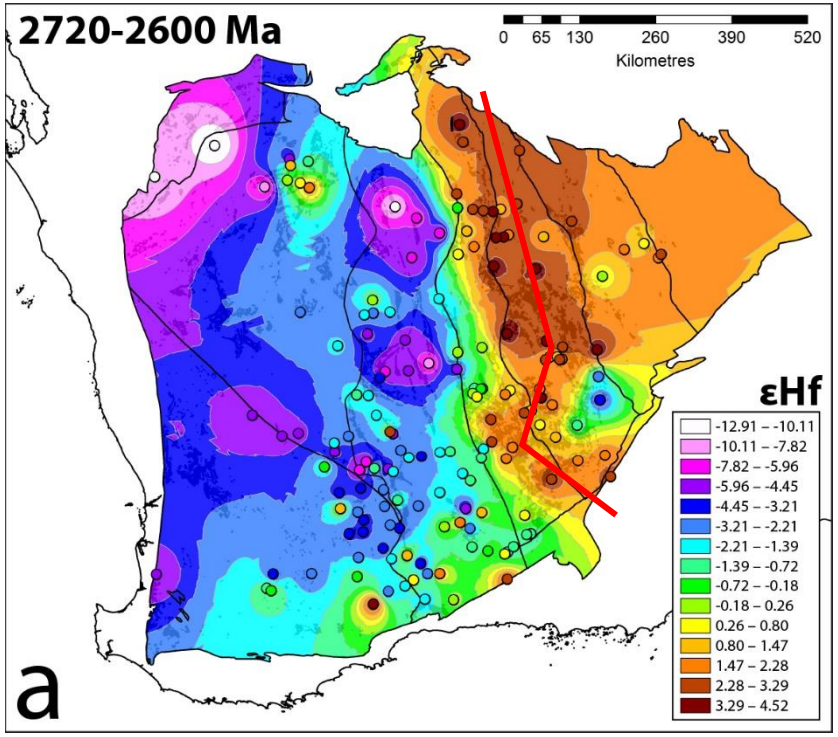
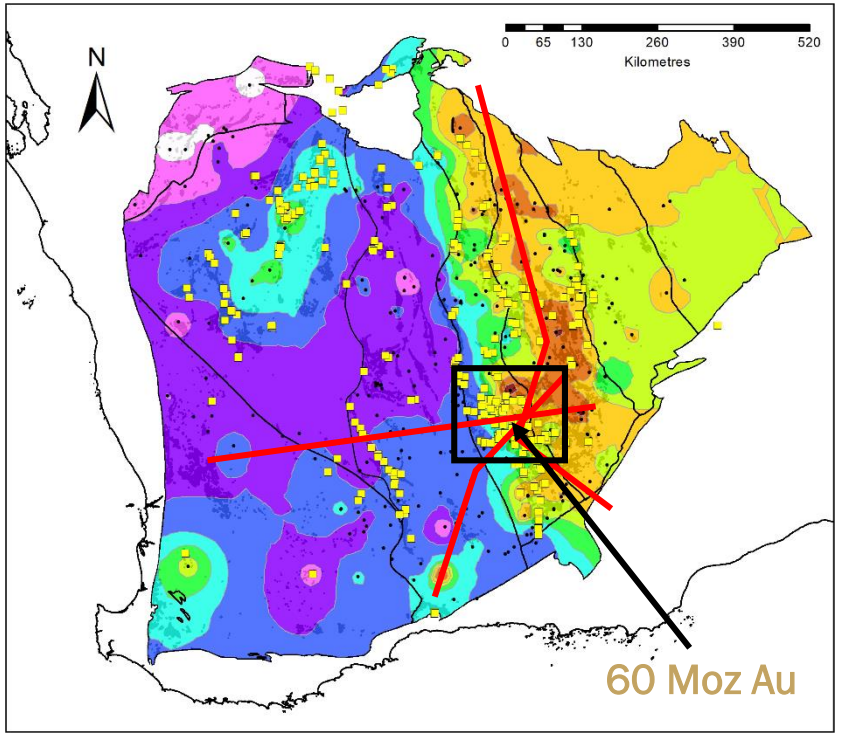
Identification of major rifts and long-term architectural set-up



ca. 2.9 Ga architecture



ca. 2.7 Ga architecture



ca. 2640 Ma – Au mineralisation

Suggests pre-existing events and architecture important for world-class regions

Mole *et al.* (2019) *ESR submitted*

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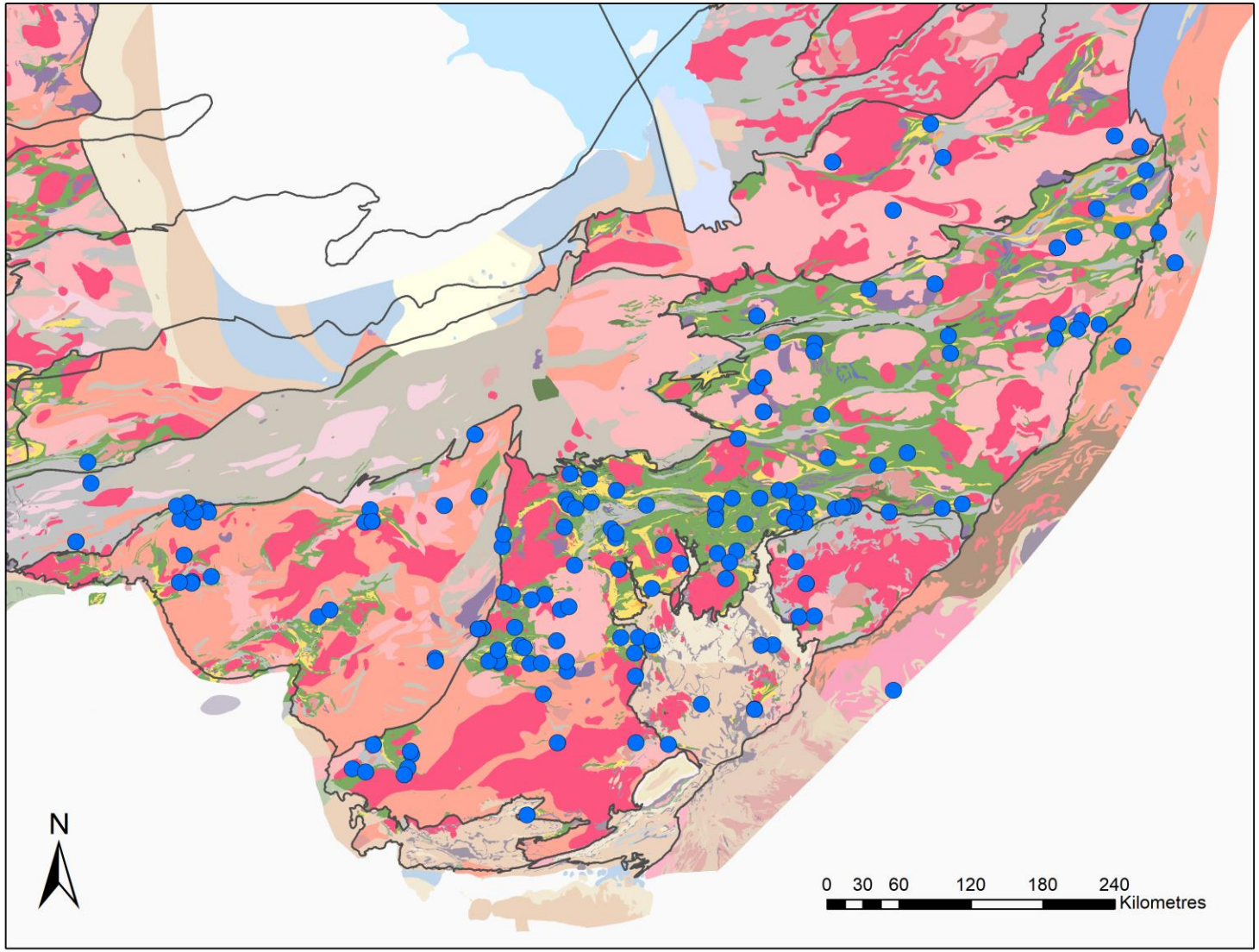
Superior Craton: Progress so far

- **Building the capability:**
  - Installation of laser ablation lab ✓
  - Superior Geochronology Database **[ONGOING]**
  - Building the analytical protocol with UoA ✓
- **Data Collection:**
  - 300 samples selected from >3000 ✓
  - 165 available for analysis ✓
  - O-isotopes collected at UoA ✓
  - U-Pb-Hf-TE data collected at LU ✓
- **Process and map data:**
  - Reduction of >9000 analyses **[ONGOING]**
  - Data collation for interpretation **[APR2019]**
  - Map production **[MAY2019]**



New zircon UPb-Hf-O-TE dataset for Abitibi area

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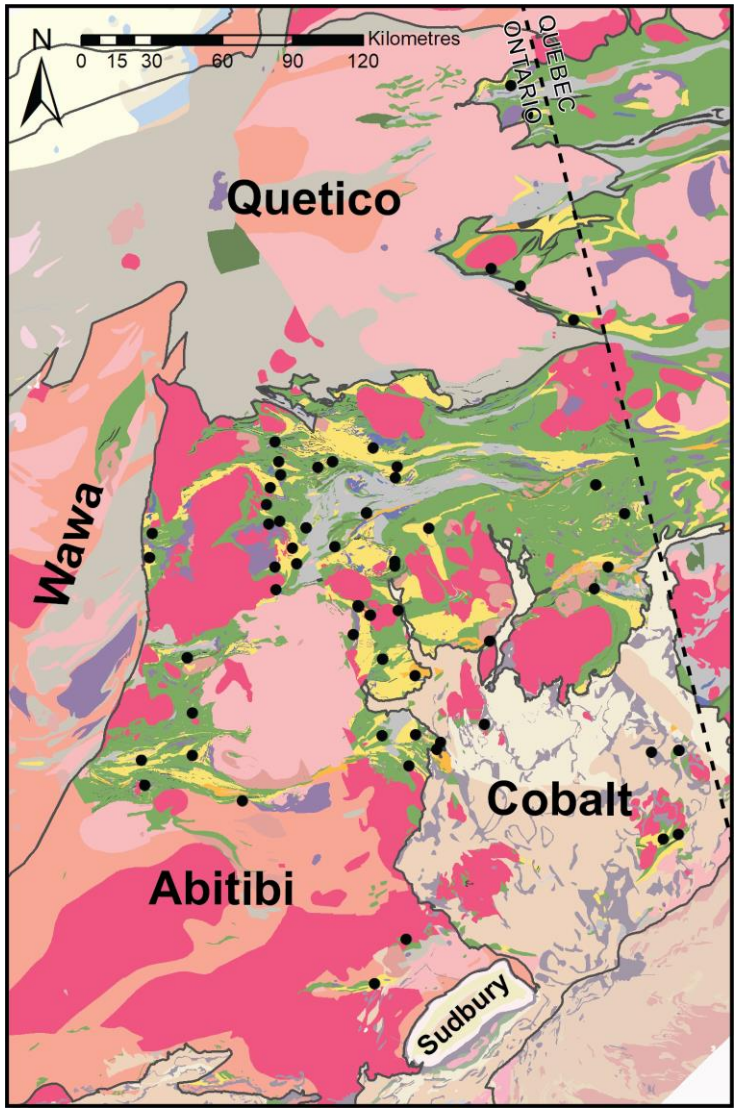
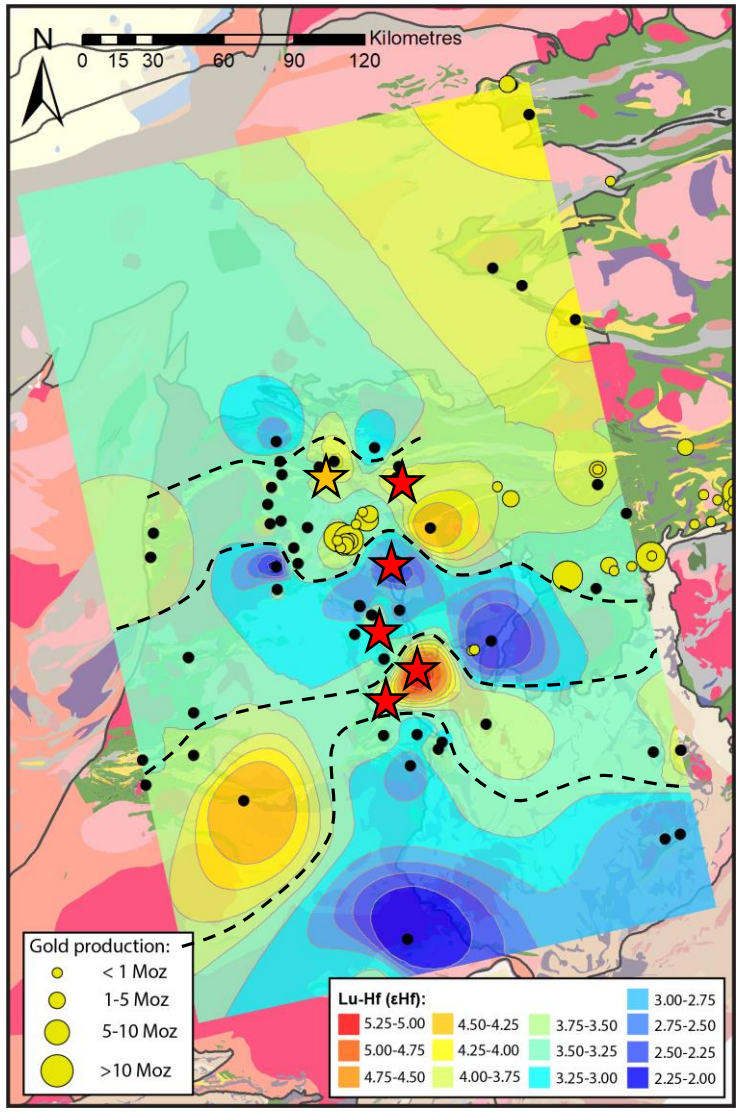
Preliminary results





- Small variations in εHf may be important
- Rough east-west isotopic zones identified
- Interpreted east-west crustal features:
  - 2740-2680 Ma rift architecture?
  - Edge of crustal overturns?
  - Volcanic arc/back-arc complexes?
- Au and VMS mineral deposits show and affinity for the most juvenile regions
- VMS prefer thinner crust, greater heat-flow; Au at margins – reactivated normal faults from rifts?
- Komatiitic Ni-Cu-PGE systems in both regions – related to older architecture?

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Summary

- Based on studies from other areas, this work has the potential to unlock a new level of understanding for the Superior Craton
- It will also provide a valuable large-scale area selection tool for exploration activities
- Time-slicing will allow us to image the evolution of the Superior spatially, documenting the phases in which the craton formed, and which were prospective
- Current activities are focused on the Abitibi-Wawa, moving to the SW Superior later in 2019, and the rest of the craton in 2020-2021
- In addition, a PhD student focused on the SE Superior will look to develop a high-resolution version of these Hf maps, as well integrating S-isotope information
- This project has the potential to explain large-scale endowment trends, as well as open new avenues in understanding the Archean Earth

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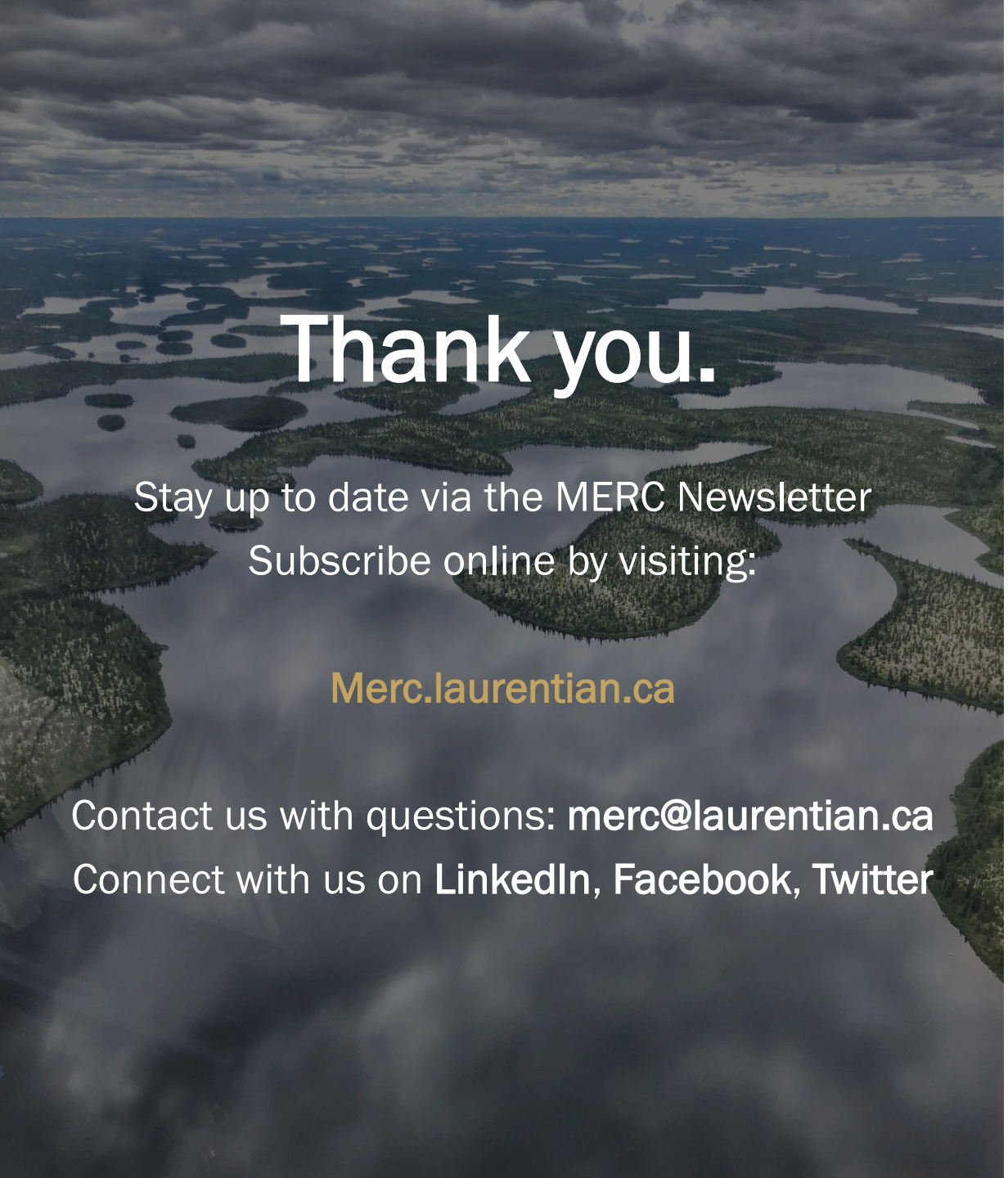

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