



Government of Western Australia  
Department of Mines, Industry Regulation and Safety

EXPLORATION  
INCENTIVE  
SCHEME



# The Future of Mineral Exploration Geoscience at GSWA: EIS 4 and MinExCRC

Klaus Gessner, Ian Tyler, CE Hall, CV Spaggiari,  
TJ Beardsmore, P Duuring, SP Johnson,  
RH Smithies, MTD Wingate

# Plan of talk

- Exploration Geoscience in Australia
- Exploration Geoscience: GSWA Activities
- Exploration Incentive Scheme Phase 4 (EIS 4)
- Mineral Exploration Cooperative Research Centre (MinEx CRC)

# Plan of talk

- Exploration Geoscience in Australia
- Exploration Geoscience: GSWA Activities
- Exploration Incentive Scheme Phase 4 (EIS 4)
- Mineral Exploration Cooperative Research Centre (MinEx CRC)

# The future of mineral exploration geoscience in Australia

- Mineral Systems approach
- Characterize the cover
  - Confidently explore beneath the cover
- Lithospheric architecture
  - Identify fluid pathways through the crust — link to mantle reservoirs
- 4D geodynamic evolution and metallogenesis
  - Identify tectonic settings and associated mineral deposits through time and space
  - Improve predictive ore deposit targeting
- Characterizing and detecting the distal footprints of ore deposits
  - Multiscale compilation and integration of geology, geophysics and geochemistry datasets
  - Understanding deposit models and commodities in mineral systems
- Data Strategy
  - Collect, integrate and make available additional pre-competitive geoscience data

# Good news from recent announcements...

## Bipartisan support by the Coalition and Labor will help our resource sector dig deeper for Australia's secure future

The peak body for Australia's 8,000 geoscientists — the Australian Geoscience Council (AGC) — has strongly welcomed commitments from both the Coalition Government and Australian Labor Party to boost support for the exploration of 'next generation' hidden mineral deposits in Australia.

“While Australia is endowed with significant mineral resources and the resources sector contributes massively to our economy, the 'easy to find' minerals of past decades have largely been discovered and exploited”

**AGC President, Dr Bill Shaw.**

Australian Geoscience Council Inc.

The Council of Earth Science Societies in Australia



# The future of mineral exploration geoscience in Australia



Australian Government  
Department of Industry,  
Innovation and Science



*“... recommendations on how Australia’s resources sector can remain globally competitive and sustainable.”*

## Resources 2030 Taskforce

*Australian resources—  
providing prosperity for  
future generations*



NATIONAL COMMITTEE FOR EARTH SCIENCES | AUSTRALIAN ACADEMY OF SCIENCE | OCTOBER 2018

## Our Planet, Australia’s Future

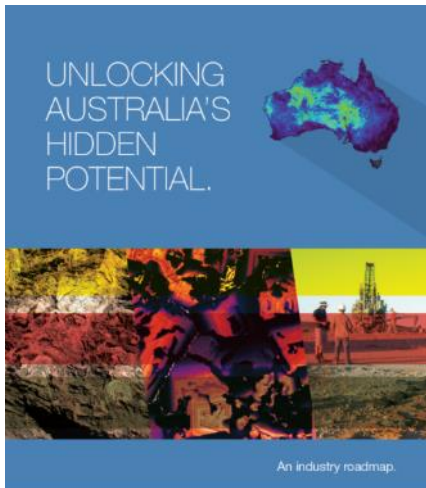
A decade of transition in Geoscience  
A decadal plan for Australian Geoscience  
2018–27

*“... future research to impact positively on Australian life: improving the safety, security and well-being of Australians while contributing positively to the nation’s prosperity and management of environmental challenges.”*

# The future of mineral exploration geoscience in Australia

## Unlocking Australia's hidden potential. An Industry Roadmap

1. *Characterizing Australia's cover*
2. *Investigating Australia's lithospheric architecture*
3. *Resolving the 4D geodynamic and metallogenic evolution of Australia*
4. *Characterizing and detecting distal footprints of mineralization*

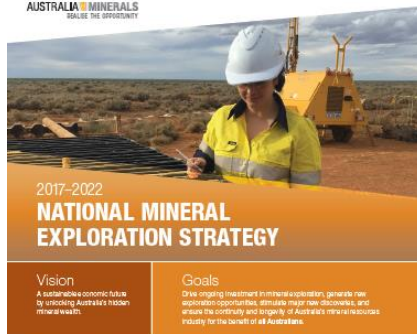


Creating value through collaboration

UNCOVER AUSTRALIA

## National Mineral Exploration Strategy

AUSTRALIA MINERALS  
REALISE THE OPPORTUNITY



### Vision

A sustainable economic future by unlocking Australia's hidden mineral wealth

### Goals

To set ongoing investment in mineral exploration, generate new exploration opportunities, stimulate major new discoveries, and increase the continuity and capacity of Australia's mineral resources industry for the benefit of all Australians.

### BENEFIT OF MINERALS TO THE NATIONAL ECONOMY

The mineral resources sector plays a vital role in Australia's ongoing economic prosperity. The sector dominates the nation's export earnings, provides substantial direct and indirect employment and investment in regional and Indigenous communities, supports downstream and service industries, and delivers essential services to governments.

In 2015-16, mining directly contributed around 8 per cent of Australia's GDP, employed more than 620 000 people and generated 80 per cent of the nation's export earnings.

Estimates produced by Deloitte Access Economics suggest that the gross value added from mining and METS activities was \$133.2 billion in 2015-16, indirect contribution for the same period estimated to have added \$10.6 billion to the economy and over 850 000 jobs.

The combined direct and indirect contribution of minerals in 2015-16 was \$133.8 billion, which is 10 per cent of the national economy, and 1.14 million jobs, comprising 10 per cent of full-time employment<sup>1</sup>.

### SCOPE OF THE STRATEGY

The National Mineral Exploration Strategy will address the technical risk and the science and technology of mineral discovery required to unlock the potential of under-explored regions of Australia. The Strategy was endorsed by the Critical Energy Council, will be delivered by the Governance Working Group (GWG), which comprises the Commonwealth, state and territory governments of mineral resources. The Strategy will be delivered in partnership with the resources industry, the research community, and the services sector. The Strategy includes a programme to attract increased investment into the Australian exploration sector but does not address the financial or regulatory challenges facing mineral exploration.

*"... promote Australia to be the preferred destination for investment in exploration, and to advocate opportunities in covered greenfield areas."*

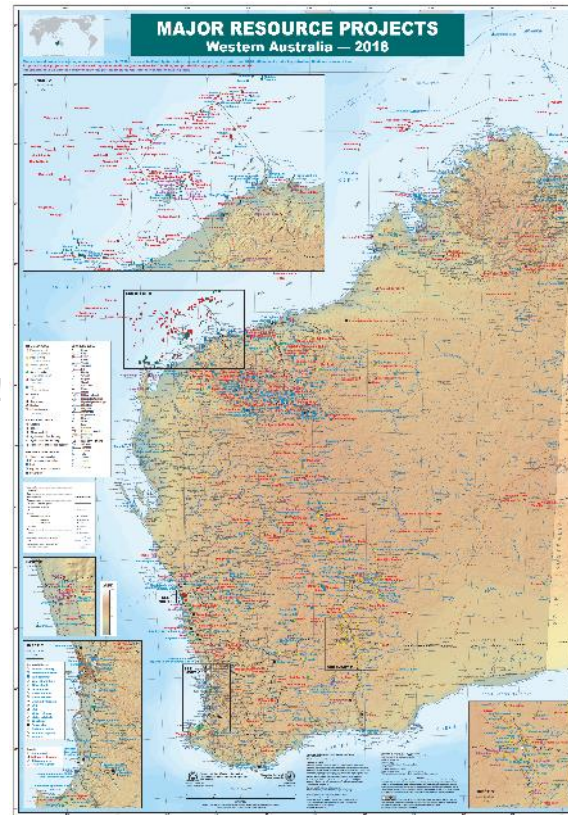
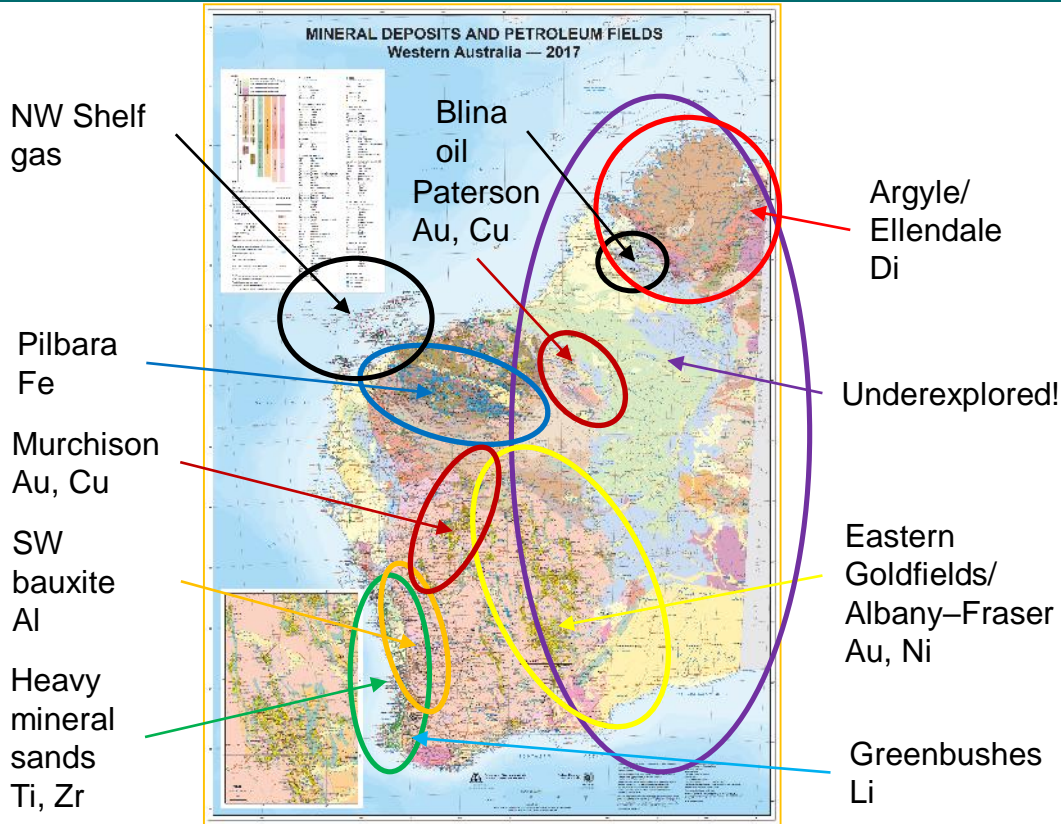
AUSTRALIA MINERALS  
REALISE THE OPPORTUNITY

# The role of Government geoscience in the 21st Century

- Australia perceived as mature exploration space:
  - Declining discovery rate with near surface, easily found and exploited ore bodies already discovered and mined
- Government Precompetitive Geoscience datasets change that perception while reducing risk for explorers
  - Encourage exploration in under-explored, remote Greenfields regions
    - Crustal architecture
    - Geodynamic setting and geological history (4D)
  - Explore to economic basement through cover of thick regolith and thin sedimentary basin margins
  - Expand and enhance pre-competitive geoscience datasets and increase access to them
    - Modelling, 3D visualization and big data analytics



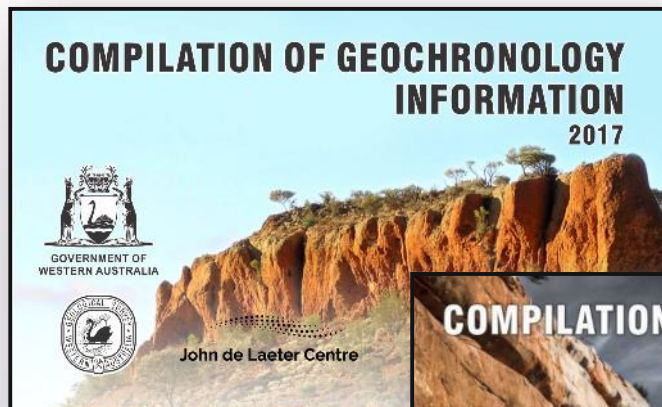
# WA: mineral and petroleum endowment



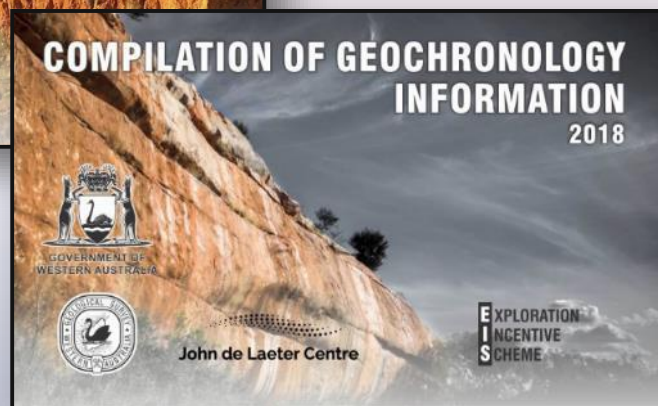
# Plan of talk

- Exploration Geoscience in Australia
- **Exploration Geoscience: GSWA Activities**
- Exploration Incentive Scheme Phase 4 (EIS 4)
- Mineral Exploration Cooperative Research Centre (MinEx CRC)

# Geochronology Record series



2016–17:  
**90**

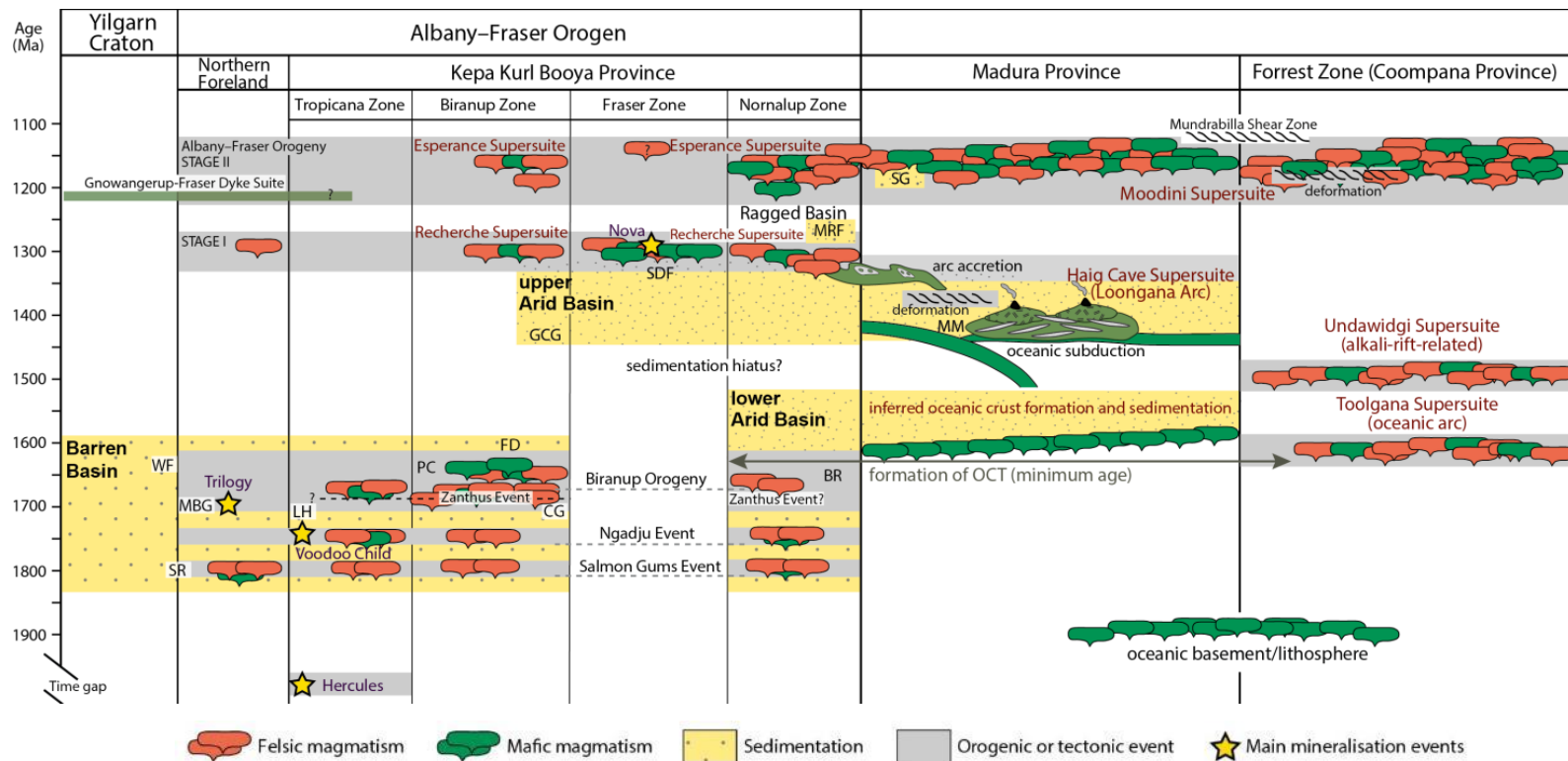


2017–18:  
**92**

1995–2018: **1551**

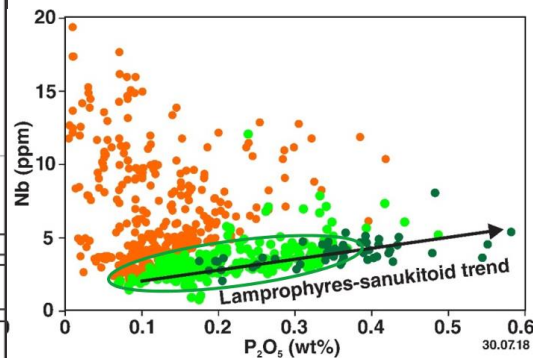
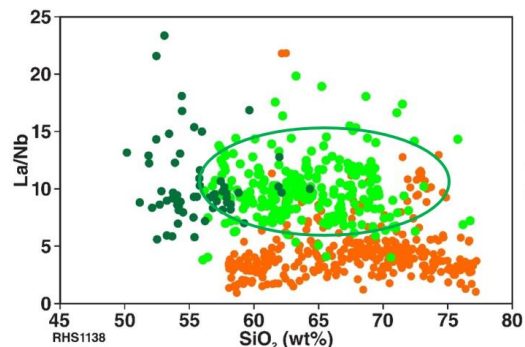
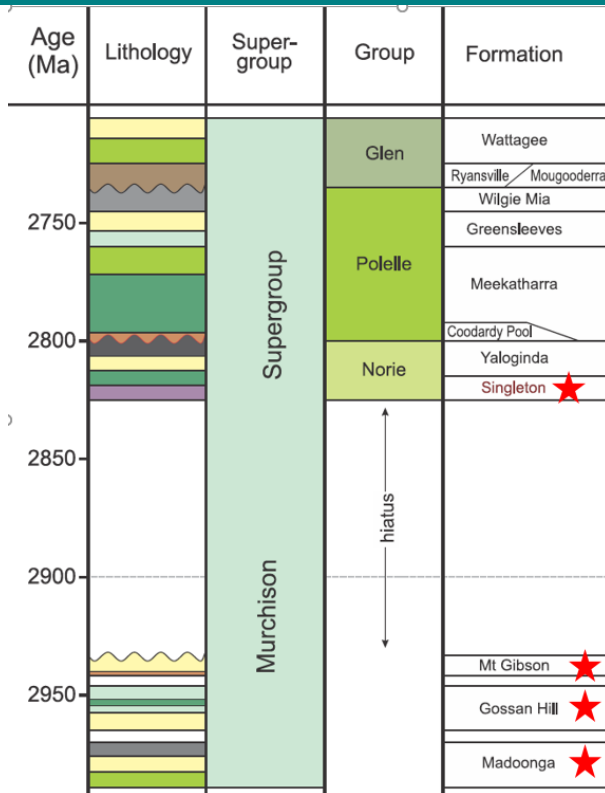
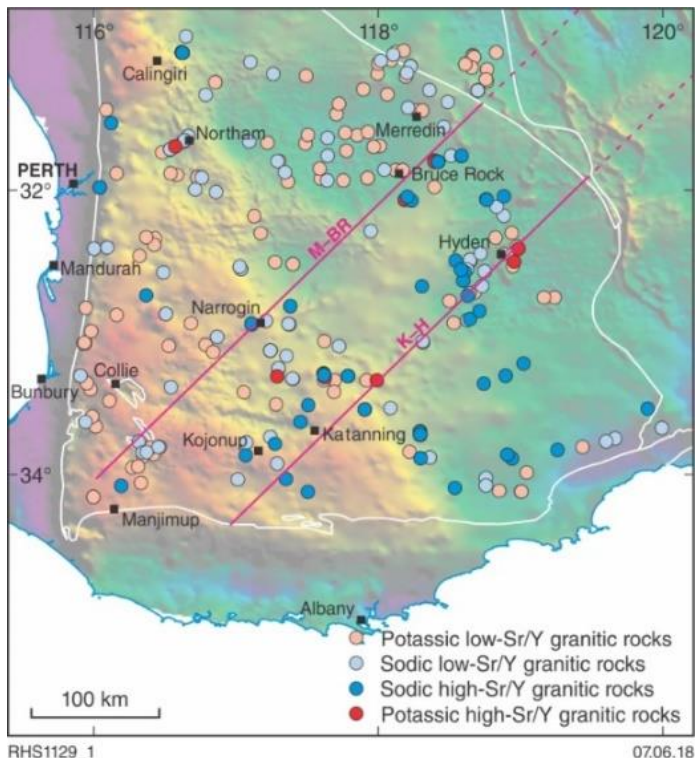


# Geodynamic setting and history





# Lithochemochemistry: Yilgarn Craton



# State metamorphic map

Document the thermal history of State

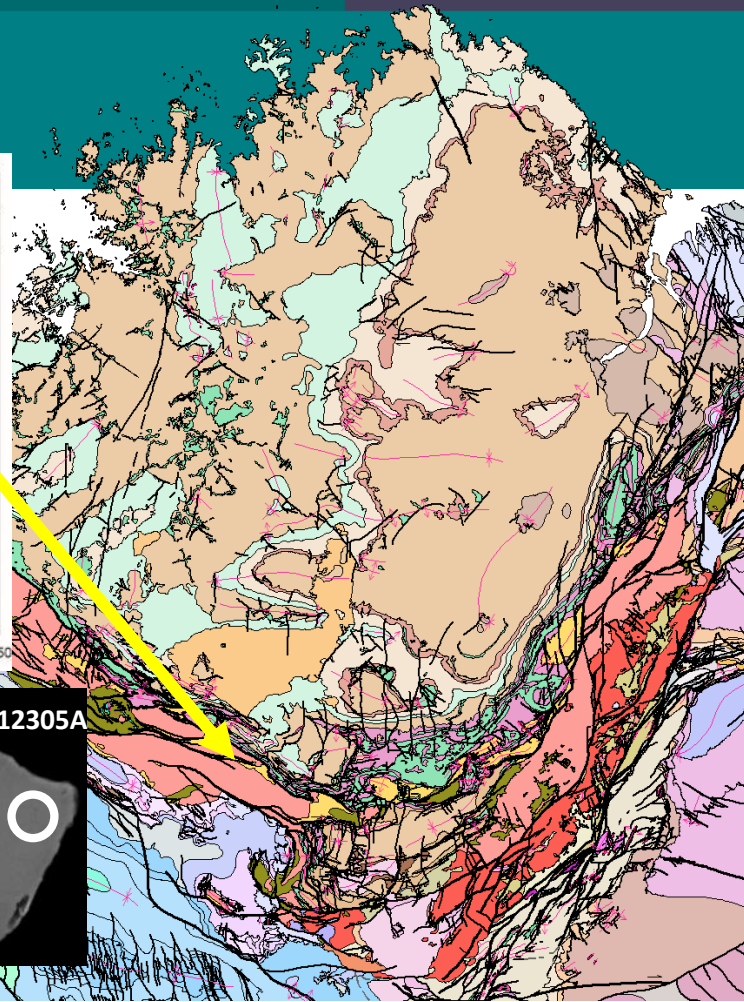
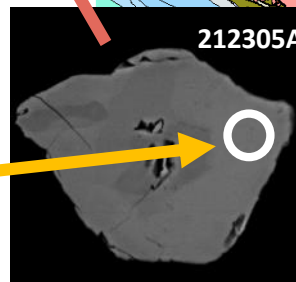
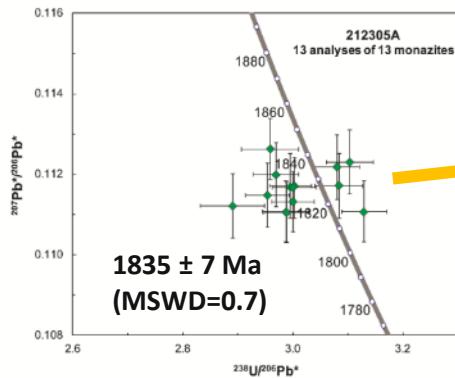
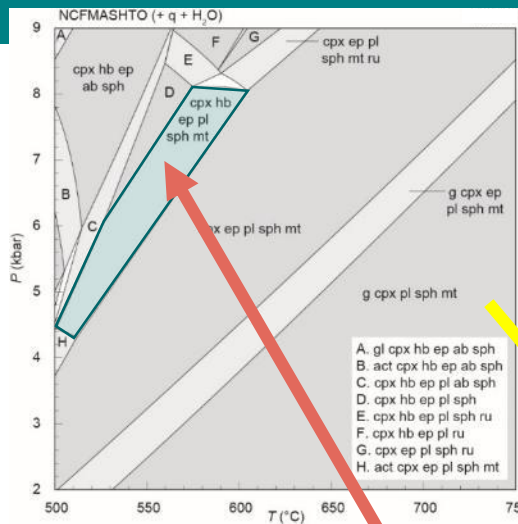
Combine petrographic and thermobarometric data (PT pseudosections) with in-situ LA-ICPMS phosphate dating to constrain timing of metamorphic events (PTt)

## Existing data:

- Capricorn Orogen
- Musgrave Province
- West Kimberley
- Yilgarn Craton (Goscombe data)

## New data:

- Pinjarra Orogen
- SW Terrane
- Paterson Orogen
- Yamarna Terrane





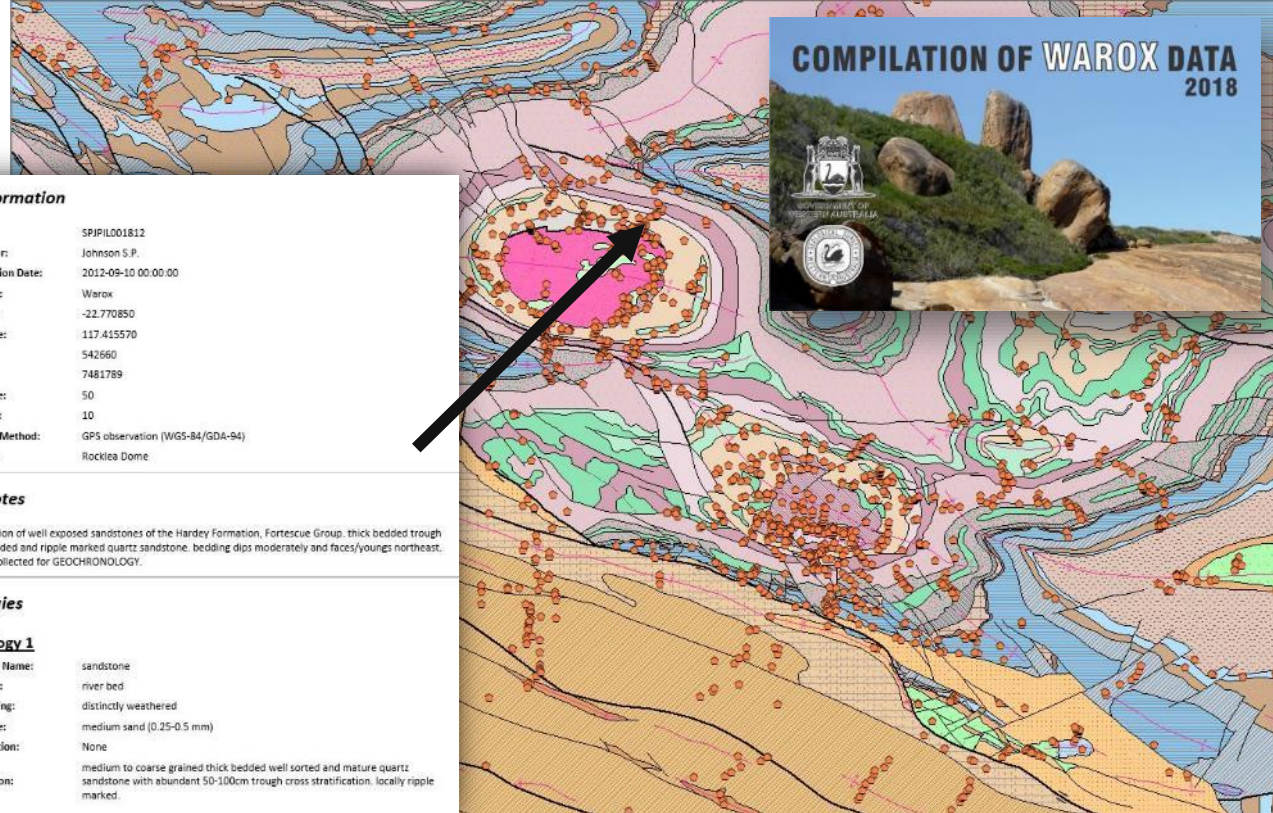
# Statewide WAROX field observations, 2018



Detailed field notes now available through ArcMap

Sites from 2017–2018 field season now available

- 240 000+ sites
- 130 000+ linear and planar structural measurements



### Site Information

Site Id: SPIPIL001812  
Originator: Johnson S.P.  
Observation Date: 2012-09-10 00:00:00  
Site Type: Warox  
Latitude: -22.770850  
Longitude: 117.415570  
East: 542660  
North: 7481789  
Mga Zone: 50  
Accuracy: 10  
Location Method: GPS observation (WGS-84/GDA-94)  
Location: Rocklea Dome

### Field Notes

river section of well exposed sandstones of the Hardey Formation, Fortescue Group. thick bedded trough cross beddes and ripple marked quartz sandstone. bedding dips moderately and faces/youngs northeast. sample collected for GEOCHRONOLOGY.

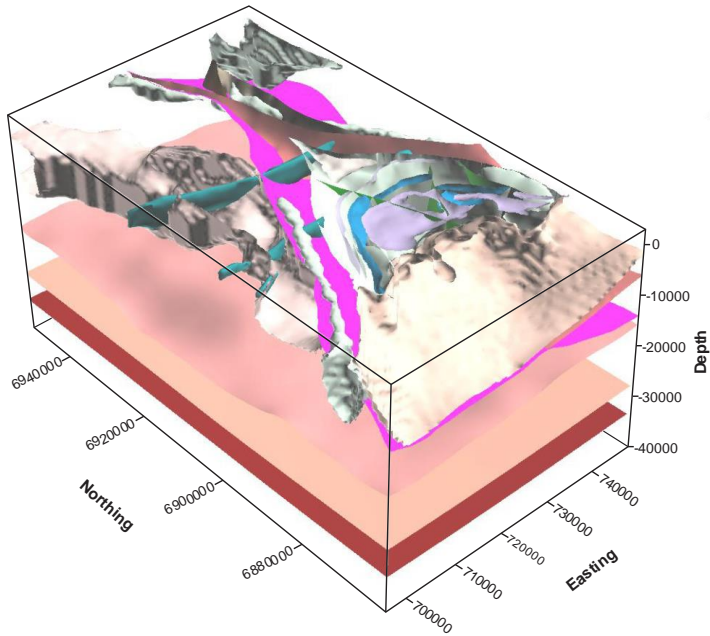
### Lithologies

#### Lithology 1

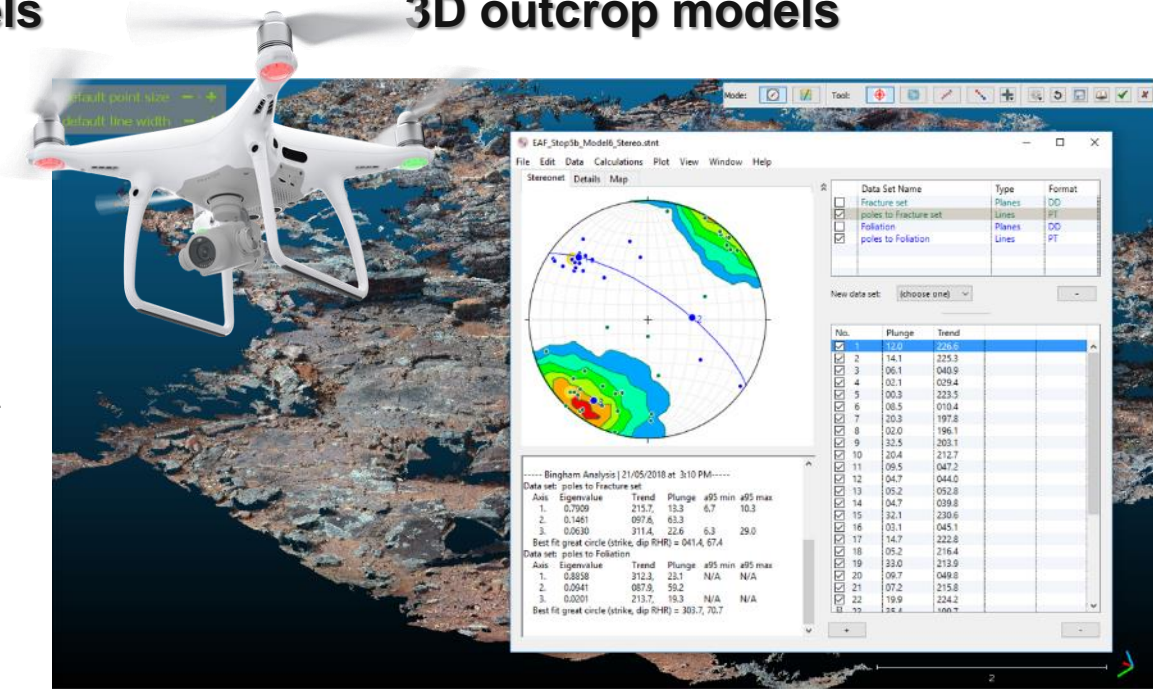
Lithology Name: sandstone  
Exposure: river bed  
Weathering: distinctly weathered  
Grain Size: medium sand (0.25-0.5 mm)  
Composition: None  
Description: medium to coarse grained thick bedded well sorted and mature quartz sandstone with abundant 50-100cm trough cross stratification. locally ripple marked.

# 3D Geomodels

## Regional-scale 3D crustal models



## 3D outcrop models

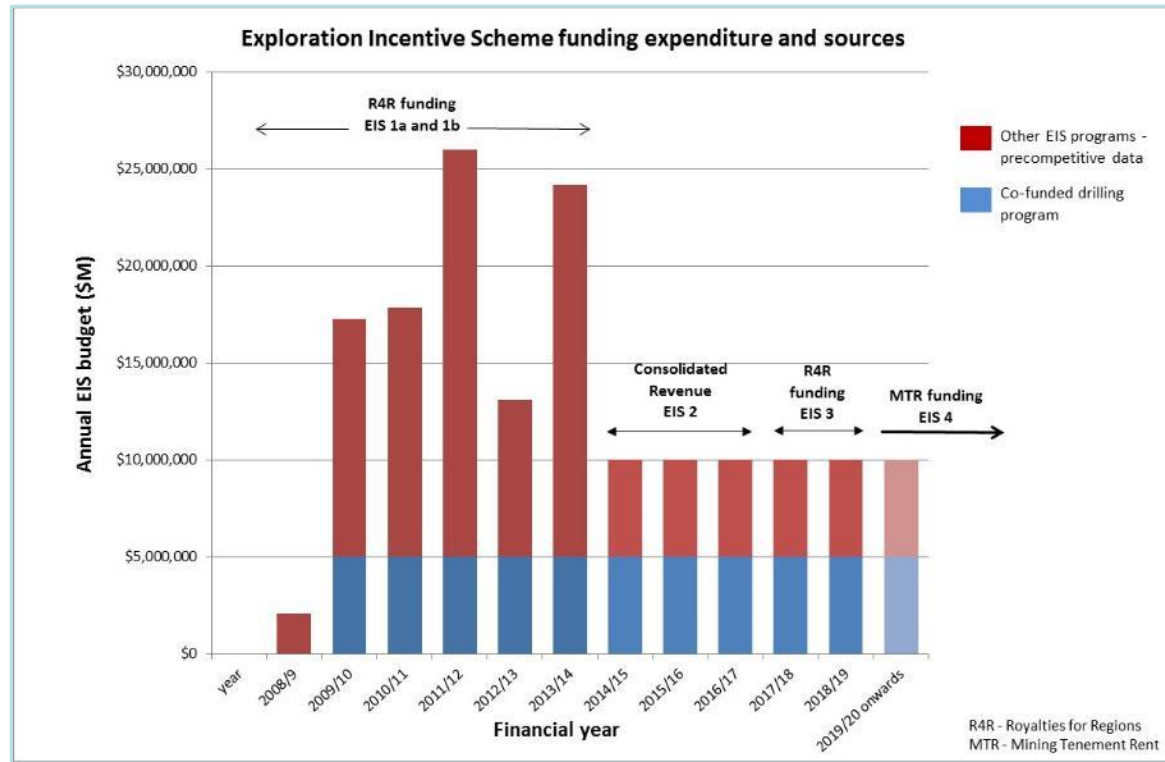




# Plan of talk

- Exploration Geoscience in Australia
- Exploration Geoscience: GSWA Activities
- **Exploration Incentive Scheme Phase 4 (EIS 4)**
- Mineral Exploration Cooperative Research Centre (MinEx CRC)

# Exploration Incentive Scheme funding



# EIS 4 – programs (5)

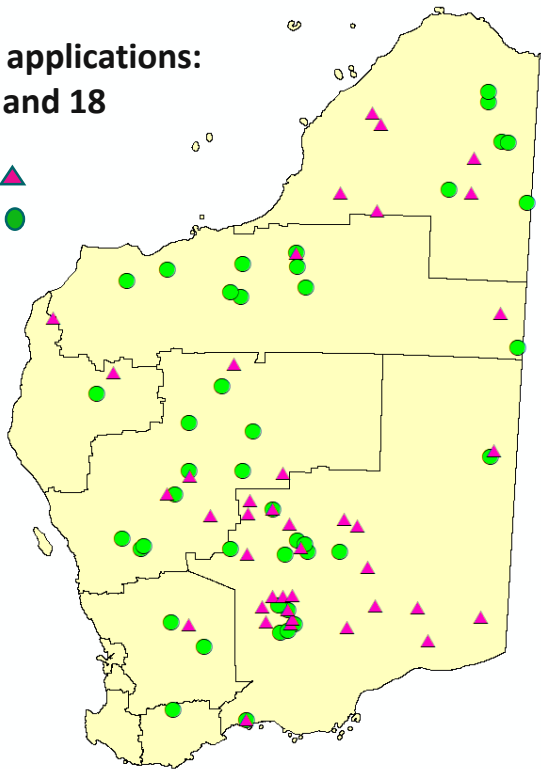
- **Program 1: Innovative Drilling (\$5 million)**
  - Government-Industry co-funded exploration drilling
  - Stratigraphic and mineral potential drilling using new technologies
- **Program 2: Geophysical Surveys**
  - Airborne gravity surveys
  - Airborne electromagnetic surveys (AEM)
  - 2D deep crustal seismic data
  - Passive seismic data
  - Magnetotelluric (MT) data
- **Program 3: Encouraging exploration through cover**
  - Drilling decision support and targeting
  - Depth of cover and its interfaces
- **Program 4: 3D prospectivity mapping**
  - Basement geology and evolution
  - Mineral systems analysis
- **Program 5: promoting strategic research with industry**
  - MRIWA (\$350,000/annum)



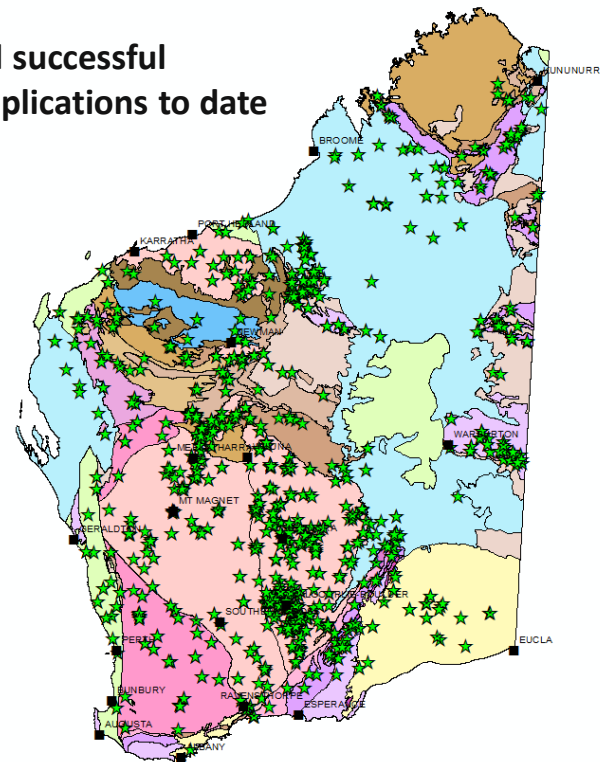
# Program 1: Co-funded Drilling

Successful applications:  
rounds 17 and 18

Round 18 ▲  
Round 17 ●



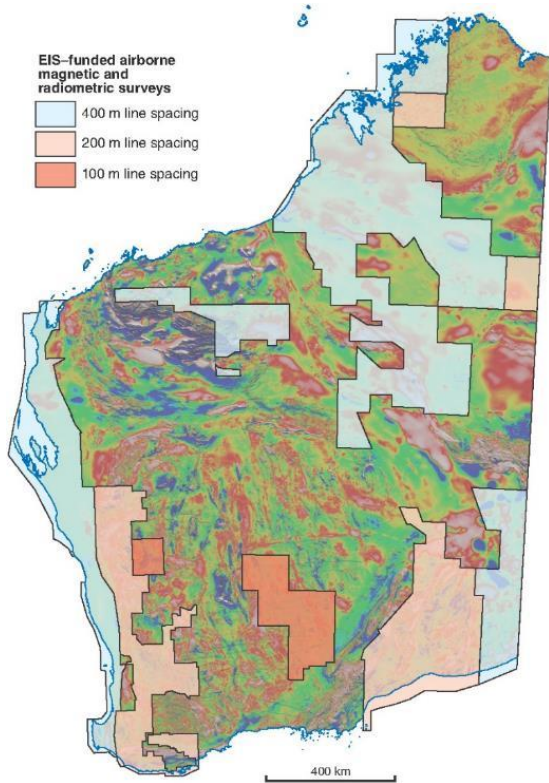
All successful  
applications to date



# Program 2: Geophysical Surveys

## Magnetics and radiometrics

AEM



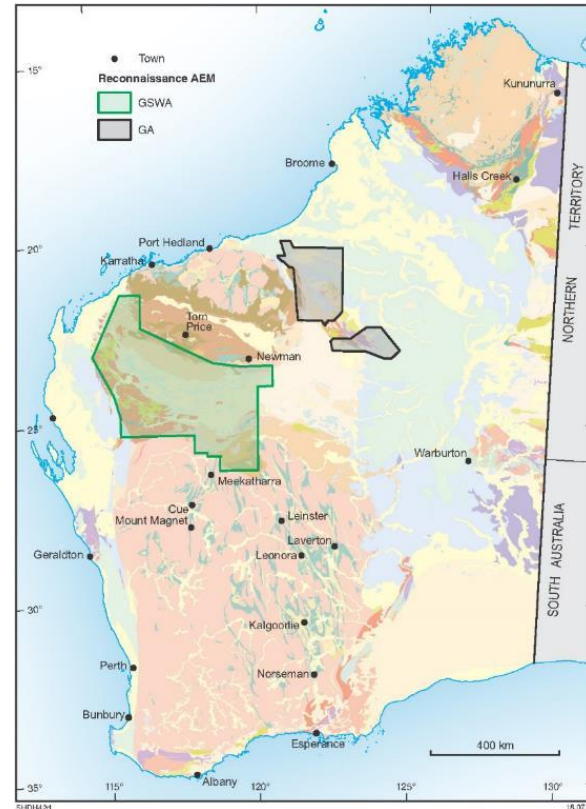
SHDH40b

18.07.18



Australian Government  
Geoscience Australia

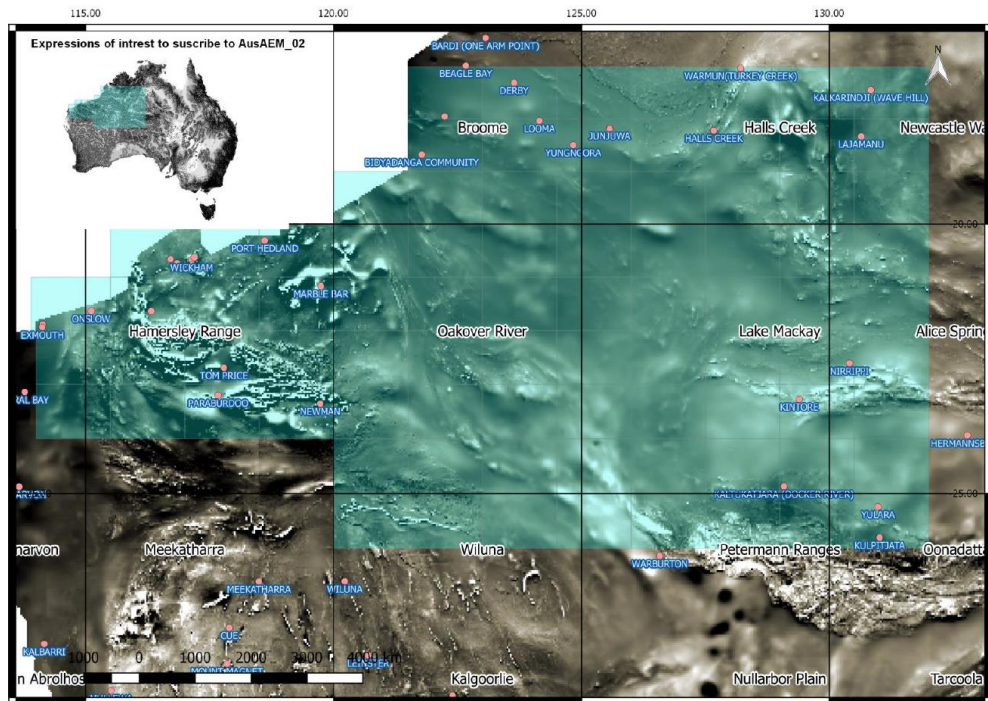
**E**XPLORATION  
**I**NCENTIVE  
**S**HEME



SHDH42d

18.07.18

# AEM – March to Sept 2019



20 kilometre line spacing

Western Australia and Northern Territory Government agencies, in collaboration with Geoscience Australia, is conducting a series of airborne electromagnetic (AEM) surveys **in 2019** as part of the *Exploring for the Future* geoscience program.



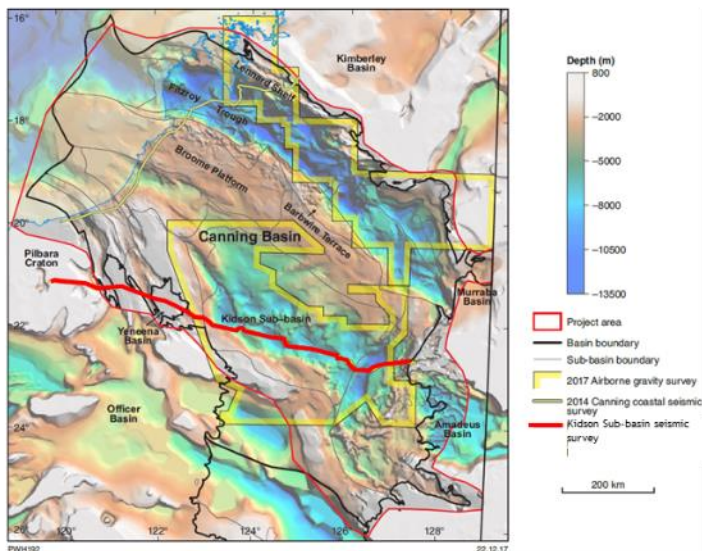


# Energy Geoscience and Carbon Strategy

## Canning Basin – Kidson Sub-basin Seismic Survey

- Kidson Sub-basin deep crustal **Seismic Survey**, co-funded by GA as part of Exploring for the Future and DMIRS Exploration Incentive Scheme

Acquisition of 872 km between 17 June & 7 August 2018. Release of data at APPEA 2019



# Canning passive seismic projects

- In collaboration with Macquarie University, and the Institute of Geology and Geophysics at the Chinese Academy of Sciences
- Along line of 14GA-CC1 + 11 OBS
- Pilbara Craton, across Canning Basin, across King Leopold Orogen into Kimberley Craton
- Along western part of Kidson line



IGG-CAS – Macquarie offshore 'sister'-project

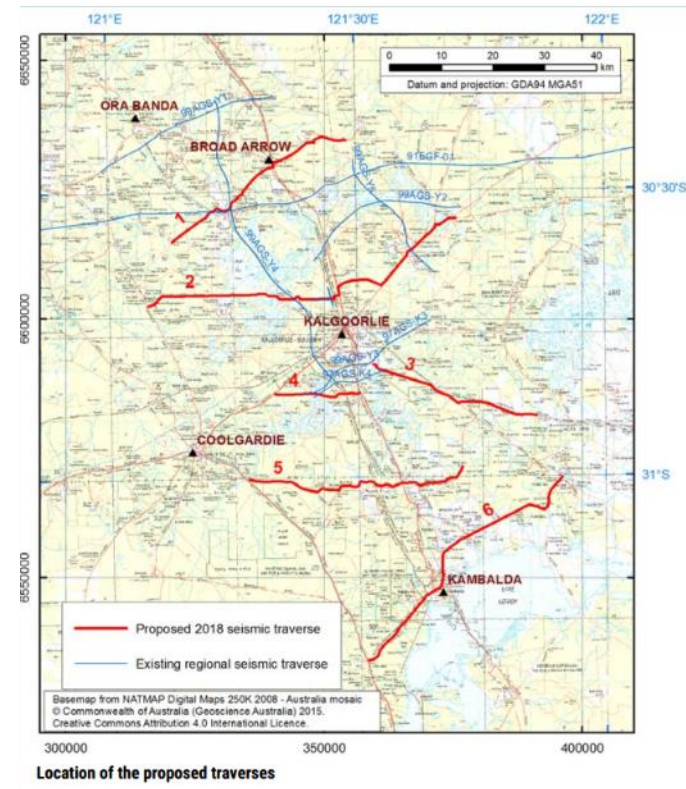




# 2019: Shining a light on the Eastern Goldfields

- Active and passive source seismic surveys, MT, high-res gravity and aeromagnetics
  - Mapping structure at depth
- Structural mapping from micro- to lithosphere scale
  - Understanding crustal deformation processes

**E**XPLORATION  
**I**NCENTIVE  
**S**HEME

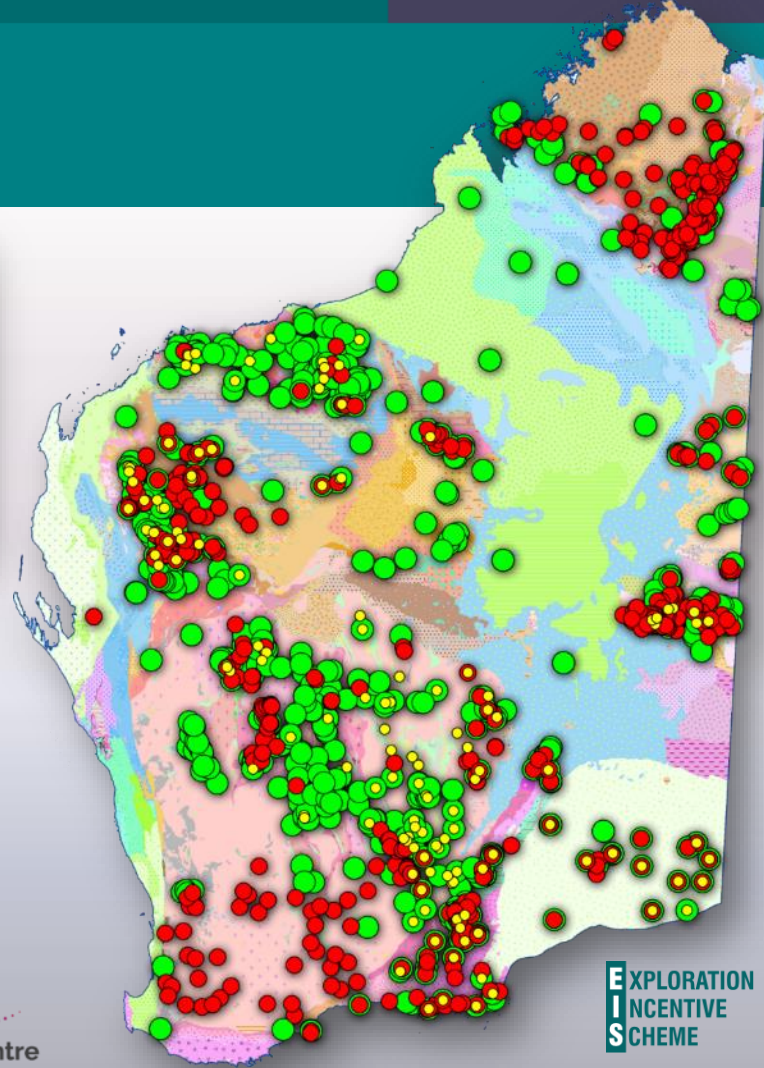


# Isotope measurements

<b>E</b> XPLO <b>I</b> NCENTIVE <b>S</b> HEME	<b>year</b>	<b>whole-rock Sm–Nd</b>	<b>zircon Lu–Hf</b>	<b>zircon oxygen</b>
	2016-17	96	53	52
	2017-18	93	76	56
	<b>total under EIS</b>	<b>793</b>	<b>756</b>	<b>156</b>

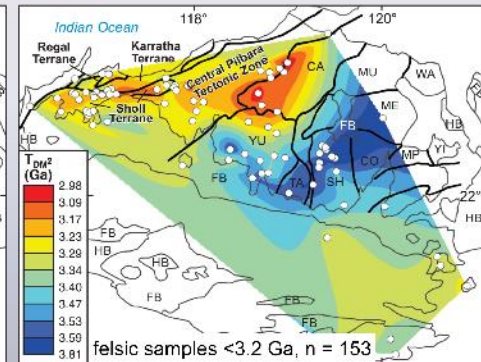
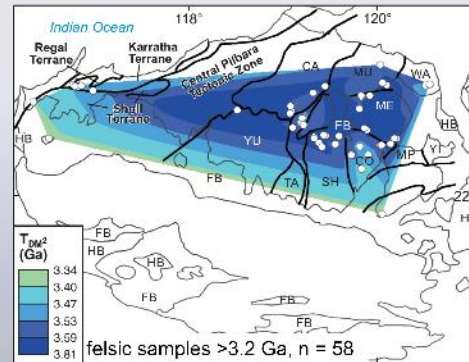
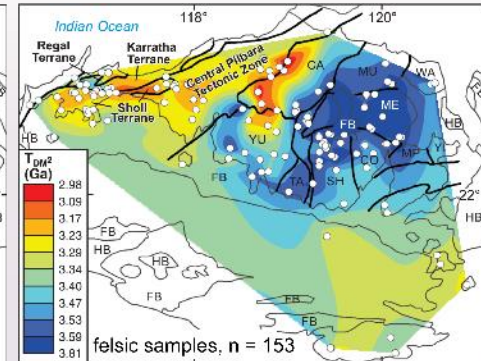
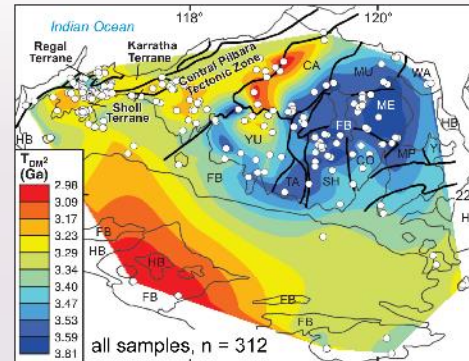
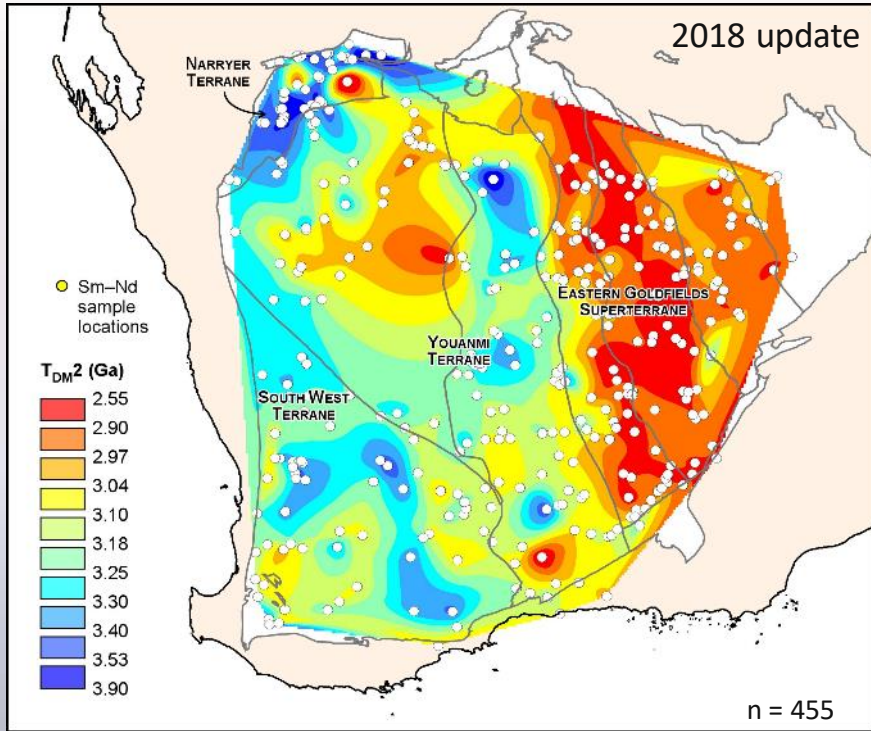
Efforts to target obvious gaps in coverage, e.g. Nd in South West Terrane, coordinated with geochemistry and trace element studies

New agreements in progress for Lu–Hf and oxygen isotope measurements





# Updated isotope maps of the Yilgarn and Pilbara Cratons

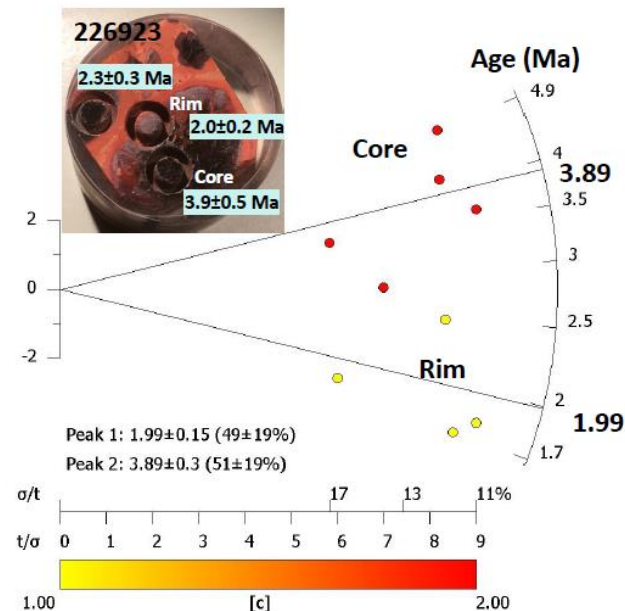


Sm-Nd two-stage model age maps for the Yilgarn Craton (Lu et al., in progress), and for the Pilbara Craton (Gardiner et al. 2018, GSWA Report 181, and Gardiner et al. 2017, Precambrian Research, v. 297, p. 56–76)

# Program 3: Encouraging exploration through cover

## (U–Th)/He geochronological analysis of secondary iron oxides in weathering systems

- Collaborative project with the John de Laeter Centre at Curtin University
- To determine if the age of ferruginous duricrust varies significantly on a regional scale, and how this relates to landscape evolution and past climatic conditions
- Combined with regolith mapping and geophysical analysis these data and their interpretations will help detect the distribution of key horizons in the cover



*Radial plot of (U–Th)/He dates (in Ma) for the rim and core of a large pisolite (pisolitic duricrust sample #226923)*

# Program 4: 3D prospectivity mapping – New ARC Linkage Project

- Australian Research Council LP170100985 “Enabling 3D stochastic geological modelling” (Laurent Ailleres et al.)
- ARC funding \$711,000 for 2018–2021
- Monash University-led international consortium for reducing risk for Resources Industry by developing 3D stochastic modelling

**E**XPLORATION  
**I**NCENTIVE  
**S**HEME

**Loop**

MONASH University  
THE UNIVERSITY OF WESTERN AUSTRALIA  
Australian Government Australian Research Council  
MinEx CRC

**3D Geology Modelling and Inversion PhD Scholarships & Fixed-term positions**

**Project Background - Loop**

The **Loop consortium**, founded as a **GeoEcology** initiative, with geosurvey and Australian Research Council support, brings together geological surveys and research institutions in Australia, Canada, France, Germany and the UK to found a new Open Source initiative to build the next generation of 3D geological modelling tools. In parallel the Australian Government recently announced the formation of a new \$21M industry & government funded Cooperative Research Centre (the [Linkage Centre](#)) focused on 3D drilling for discovery and definition of mineral deposits.

We invite technically-minded students to apply for scholarships to work with us at The University of Western Australia (UWA), Monash University (MU) and the Geological Survey of Canada (GSC) on a series of challenging PhD scholarships and research projects related to the implementation and testing of this new platform and related novel methodologies.

**Fixed term positions are or will be available for:**

- Scientific Programmer (MU, UWA)
- Software Architect (MU)
- 3D implicit geological modelling method development (GSC)
- Knowledge representation and reasoning for 3D geological modeling (GSC)

**Specific PhD topics include, but are not limited to:**

- Structural geological modelling as a probabilistic problem (MU)
- Topology of Geology in 2D & 3D as a 3D generalising constraint (UWA)
- Optimal drilling schemes in uncertain terrain (UWA)
- Multiscale 3D geological modelling from drill hole data (MU and UWA)
- Data fusion methodologies for geology-geophysics inversion (UWA)
- 3D geological modelling using the Loop Platform (MU & UWA)

**Further information**

For details of the various scholarships and job positions, please visit <http://loop3d.org>

**Process to apply**

To apply for PhD projects please email [monash18071@earthworks.jobs.com](mailto:monash18071@earthworks.jobs.com) with:

- Resume/CV
- Cover letter addressing your research interests, qualifications and experience relevant to the position specifying your one page summary of your research interests.

Applicants for fixed term positions should email for more information on the application process.

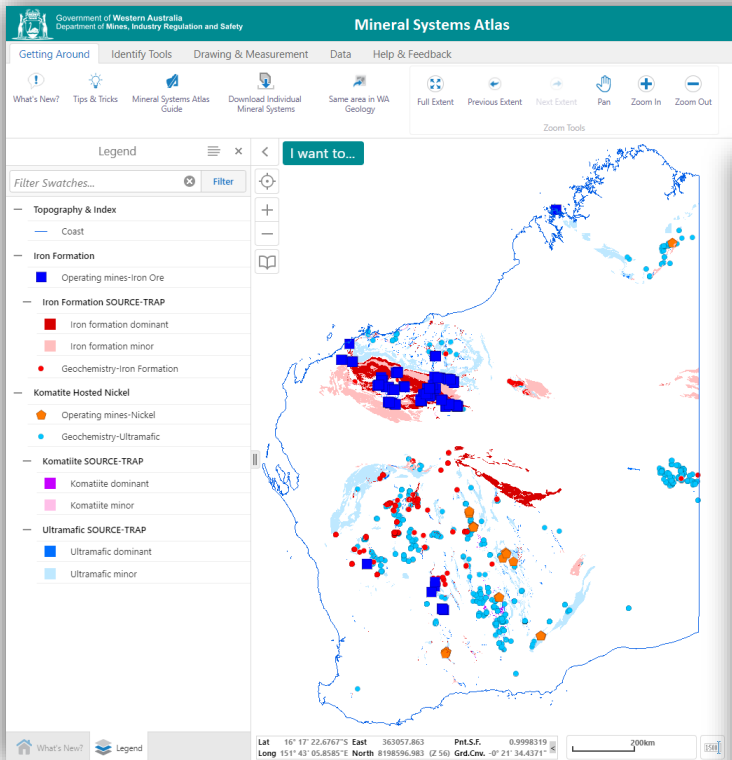
published: 08 July 2018 Please mention EARTHWORKS when responding to this advertisement.

[find us on facebook](#) [23228148](#) [follow us on twitter](#)

LOOP advert on Earthworks.com

# Program 4: 3D prospectivity mapping – Mineral Systems Atlas

EXPLORATION  
INCENTIVE  
SCHEME



Home

Find Mineral Systems by Process

Find Mineral Systems by Commodity

Mineral Systems

Contact Us

## Welcome to the Mineral Systems Atlas Guide

- What is the Mineral Systems Atlas?
- Mineral Systems Analysis
- The Atlas Interface
- The Atlas Guide
- What's New?
- Acknowledgments

[Open Mineral Systems Atlas](#)

### What is the Mineral Systems Atlas?

The **Mineral Systems Atlas** is an interactive GIS-based platform that collates and delivers map-based geoscience data layers filtered to be specifically relevant to understanding and exploring for mineral deposits in Western Australia. **Atlas** content is systematically defined by applying the mineral systems concept advocated by Wyborn et al (1994) and McCuaig et al. (2010). The premise of this concept is that mineral deposits will only form and remain preserved where there has been a spatial and temporal coincidence of critical earth processes (geodynamic setting; lithosphere architecture; fluid, ligand and ore component reservoir(s); fluid flow drivers and pathways; depositional mechanisms; post-depositional processes), and that the occurrence of these critical processes might be recognized from mappable geological features expected to result from them. It is these geological features ("targeting elements" or "geological proxies") that can potentially be extracted as digital map layers from geoscience datasets, and that may be subsequently used in GIS-based prospectivity studies.

The **Mineral Systems Atlas** is by its very nature a continuous work in progress. The modular and hierarchical design of its online platform and user guide will readily permit the addition of new mineral systems and new geological proxy layers as these progressively become available. Users are encouraged to learn about the latest releases of data/layers, and other additions to the **Atlas**, by viewing the What's New? present in the interface and the **Guide**.

### Mineral Systems Analysis

Different mineral systems (as defined by Fraser et al., 2007) are analysed to define the mappable geological proxies for critical mineralizing processes. Such analyses draw on in-house knowledge, existing literature, and collaborations with subject-matter experts. Structured queries are then used to extract relevant data from one or more state-wide GSWA geoscience databases, for those proxies that can be practically produced. These queries operate directly on, and are dynamically linked to, primary GSWA geoscience data sources. No new data are acquired or created, although some information may be reformatted to meet the internal requirements of particular map layers. Furthermore, the queries are scheduled to automatically update the derived proxy map layers whenever new data are added to the primary databases. Users may therefore be confident that the data layers portrayed in the **Mineral Systems Atlas** are always current.

# Program 5: Promoting strategic research with industry



**MRIWA ... is a State Government organisation who:**

- Undertakes, procures or manages minerals research project
- Confers and collaborates on matters relating to minerals research
- Promotes awareness of and foster public interest in matters relating to minerals research
- Fosters academic activities

All to the benefit of Western Australia

## Contact

Nicole Roocke  
Dr Anil Subramanya  
Dr Charmaine de Witt

Phone  
[+61 8 6180 4340](tel:+61861804340)

Email  
[enquiries@mriwa.wa.gov.au](mailto:enquiries@mriwa.wa.gov.au)



# Plan of talk

- Exploration Geoscience in Australia
- Exploration Geoscience: GSWA Activities
- Exploration Incentive Scheme Phase 4 (EIS 4)
- **Mineral Exploration Cooperative Research Centre (MinEx CRC)**



# MinEx Cooperative Research Centre (CRC)



## Program 1

### Drilling technologies:

More productive, safer and environmentally friendly drilling methods

#### Project 1 Drilling Optimisation



#### Project 2 Coiled tubing drilling for definition of mineral deposits

## Program 2

### Data from drilling:

New technologies for collecting data while drilling

#### Project 3 *Real-time downhole assay*

#### Project 4 *Petrophysical logging while drilling*

#### Project 5 *Seismic in the drilling workflow*

#### Project 6 *Automated 3D modelling*

## Program 3

### National Drilling Initiative:

Exploration data on never-before sampled rocks that are hidden but prospective for minerals

#### Project 7 *Maximizing the value of data and drilling through cover*

#### Project 8 *Geological architecture and evolution*

#### Project 9 *Targeting mineral systems in covered terranes*

# The National Drilling Initiative and GSWA



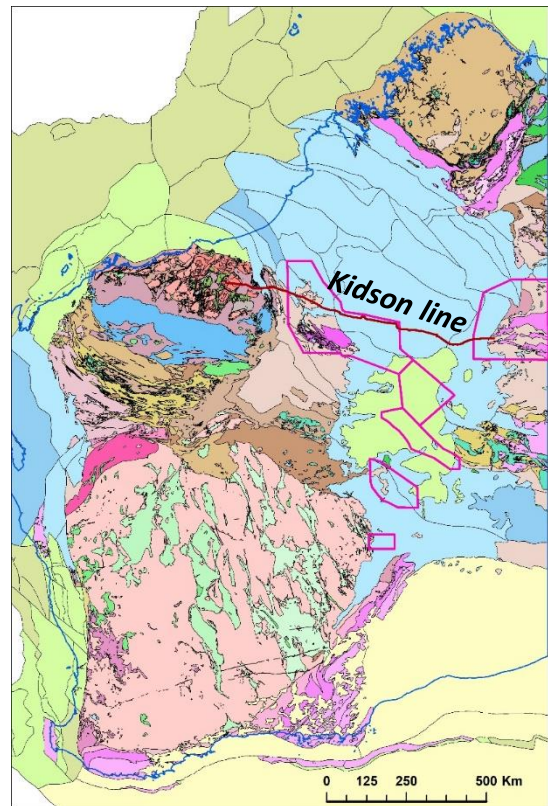
## Proposed GSWA NDI areas situated within the Gap and planned activities:

- NDI areas shown by the pink polygons – actual drilling areas to be determined
- Geophysical data interpretation and compilation of interpreted bedrock geology at various scales and time slices (regional areas / link to state datasets; both through GSWA work and MinEx Program 3)
- Coordinated with basin studies (Basins Group)
- Analysis of legacy drillcores (both through GSWA work and MinEx Project 8)
- Regolith and depth-to-basement mapping (Geoscience Mapping Through Cover Section / focussed on NDI areas)
- Field mapping of exposed areas

EXPLORATION  
INCENTIVE  
SCHEME



MinEx CRC



# The Gap – mineral occurrences

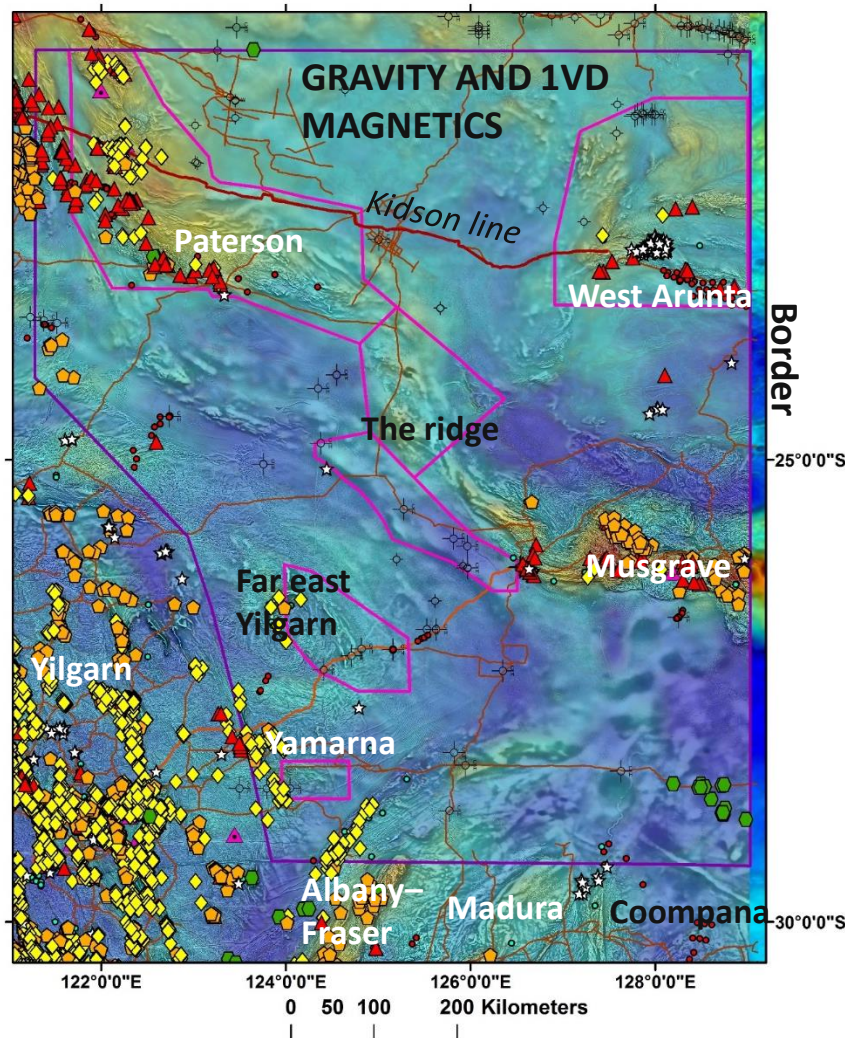
## Broad research questions:

- What types of ore deposits are likely to be present and what do we need to do to detect them?
- How could known deposits and mineral occurrences help answer this?
- How can we use cover, geophysical data and sparse drillcores to detect and map mineral occurrences to aid exploration?
- In order to do the above, we need a better understanding of the background geology of the cover and basement, and the links between tectonic entities
- How can we use cover, geophysical data and sparse drillcores to map cover and basement?



MinEx CRC

*Image shows Minedex database mineral occurrences: base metals (red triangles), gold (yellow diamonds), steel alloys (orange symbols), specialty metals (green), diamonds (white stars)*





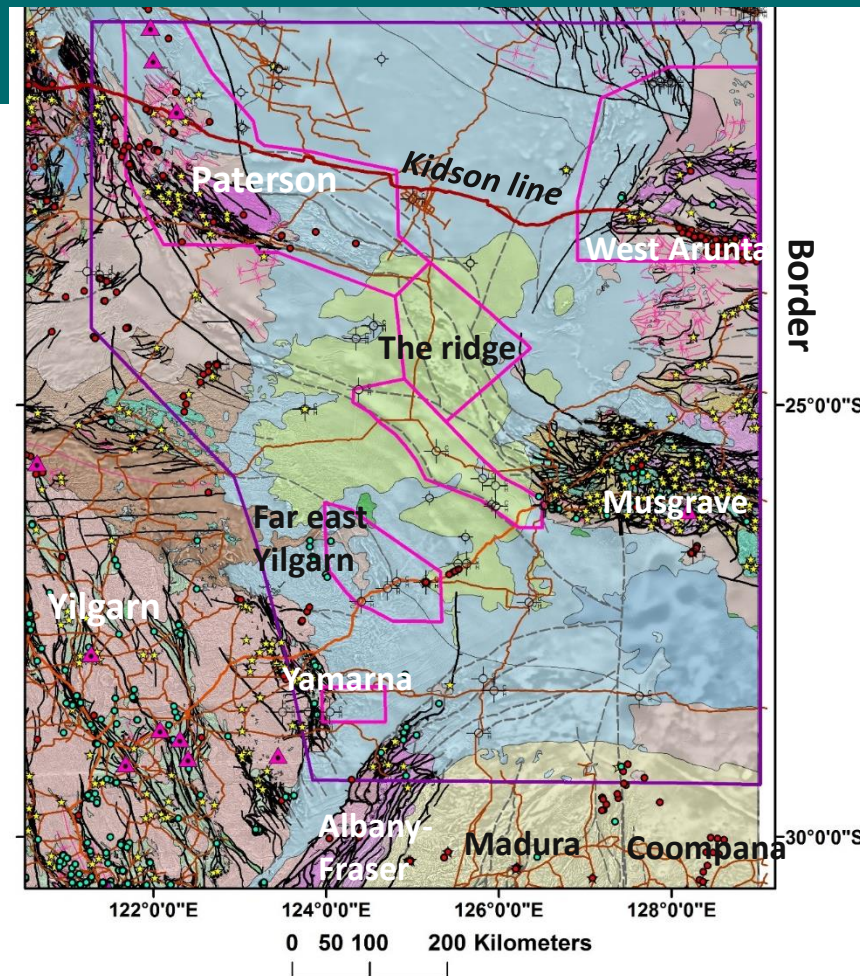
# The Gap – major boundaries

- 1:500k structures (dashed lines) demonstrate poor understanding of how the basement tectonic units link up
- Very sparse information from drillholes, and need for more lateral coverage
- Knowledge from existing and future mapping of the ‘edges’ is crucial
- New data, tools, methods and data analytics developed through the NDI projects are great opportunities to progress our understanding



MinEx CRC

*Image shows 1:500 k State layers, existing drillholes and petroleum wells in WA core library, and GSWA geochronology (yellow stars)*



# GSWA: aligned with national research strategies and collaborating with Industry, Government and Academia...

**Capricorn**  
DISTAL FOOTPRINTS

  
John de Laeter Centre



Centre for **EXPLORATION TARGETING**



THE UNIVERSITY OF  
WESTERN AUSTRALIA



Australian Government  
Australian Research Council

