

Australian Government  
Geoscience Australia

Resourcing Australia's  
Prosperity

# An Integrated FAIR modelling approach to map Australia's subsurface

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S. C. T. Wong<sup>1</sup>, J. Vizy<sup>1</sup>, N. Rollet<sup>1</sup> and many more

<sup>1</sup>Geoscience Australia, <sup>2</sup>Monash University



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# Acknowledgement of Country

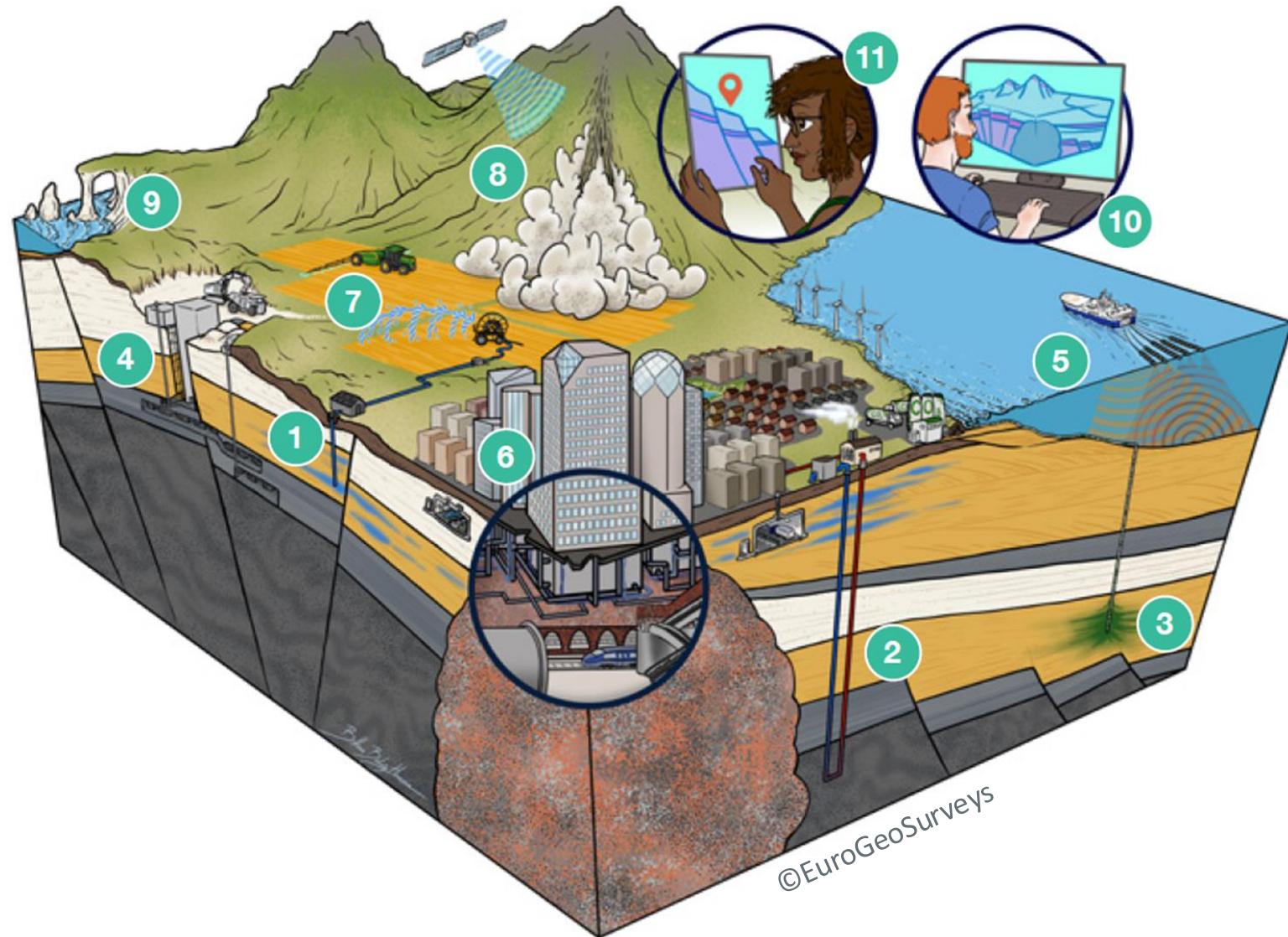
Geoscience Australia acknowledges the traditional owners and custodians of Country throughout Australia and acknowledges their continuing connection to land, waters and community. We pay our respects to the people, the cultures and the elders past and present.

Image: Caterpillar Tracks: Artwork by Roseanne Kemarre Ellis on Geoscience Australia's Alice Springs antenna

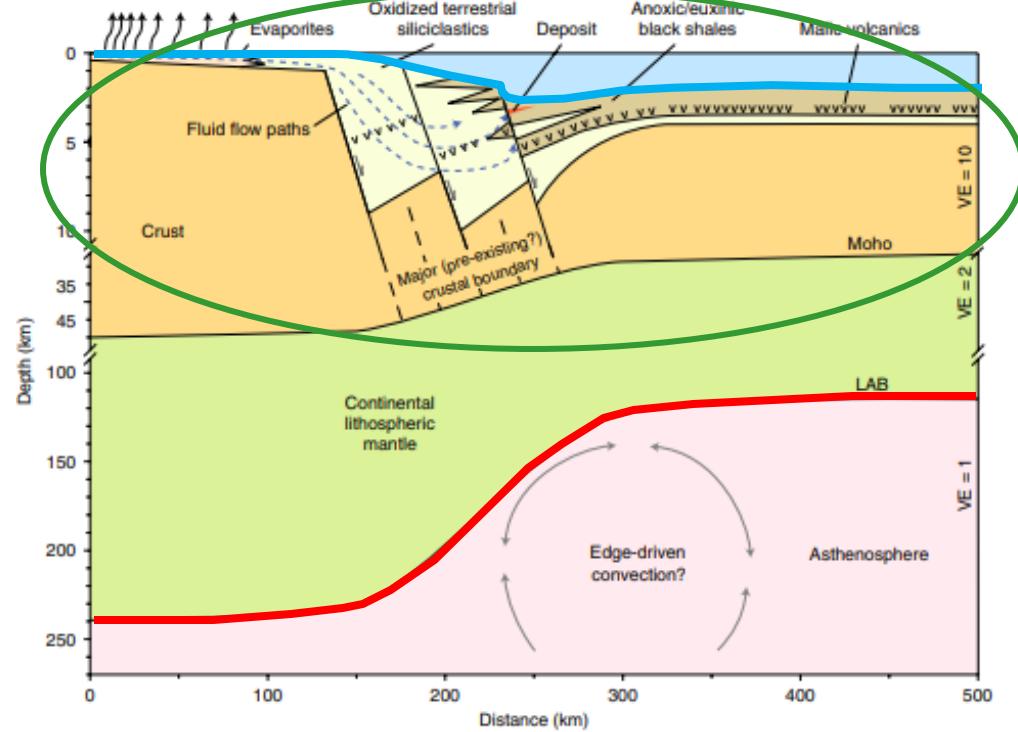


# Managing competing land-uses – Increased subsurface knowledge

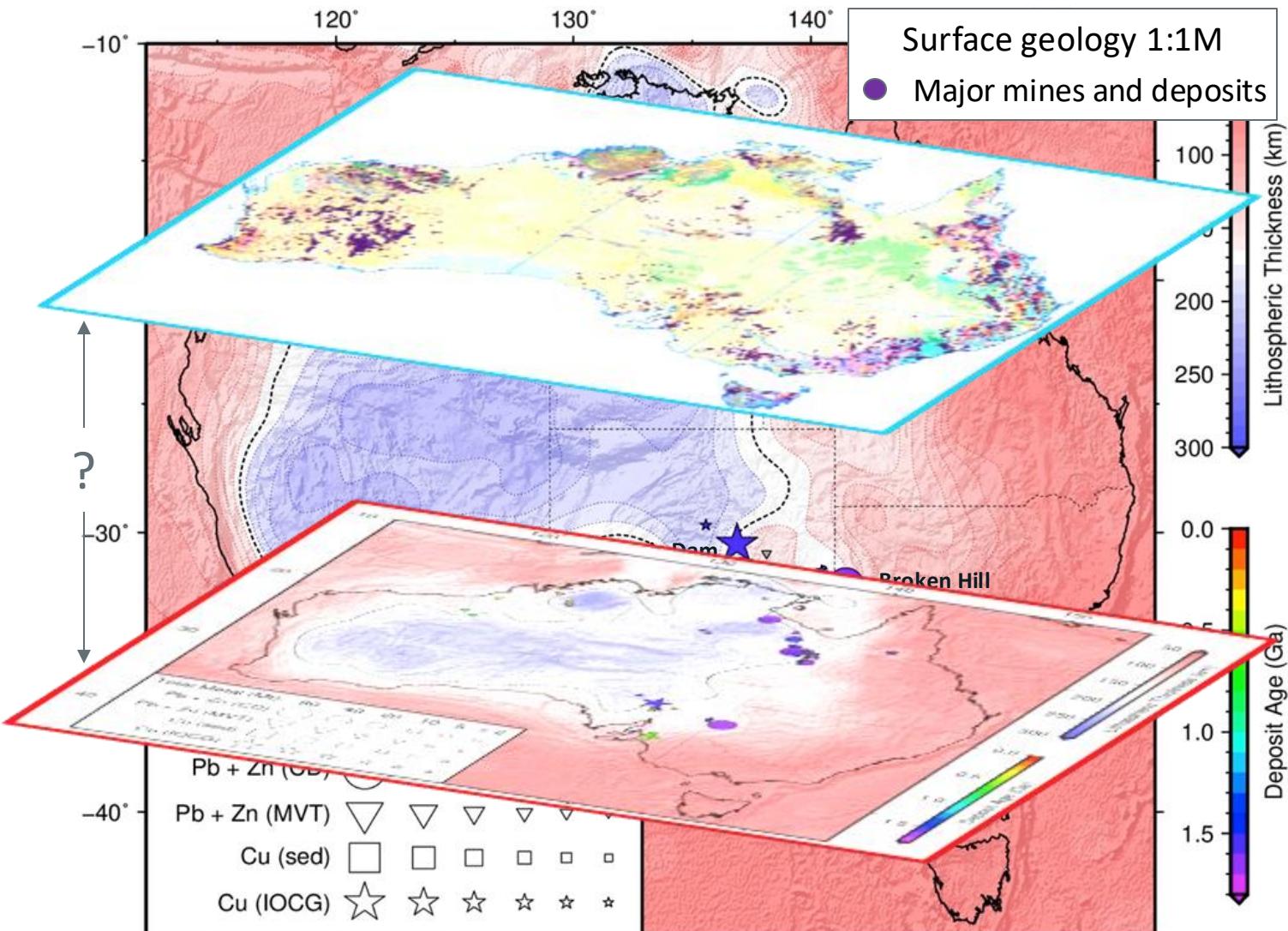
- 1 Groundwater
- 2 Renewable Energy
- 3 Geological storage space, e.g. CO<sub>2</sub>, salt caverns, Hydrogen
- 4 Minerals, incl. critical minerals
- 5 Civil engineering, e.g. wind farms, green cities, infrastructure
- 6 Agriculture
- 7 Hazard risk
- 8 Geoheritage
- 9 Mapping and modelling
- 10 Spatial information



# An ability to assess resource potential in Australia



**LAB: Lithosphere-Asthenosphere Boundary**



Hoggard et al. 2020 *Nature Geoscience*



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# Resourcing Australia's Prosperity initiative

—  
**\$3.4b over 35  
years**



Australian economy



Concentrated markets



Information



Net zero transition

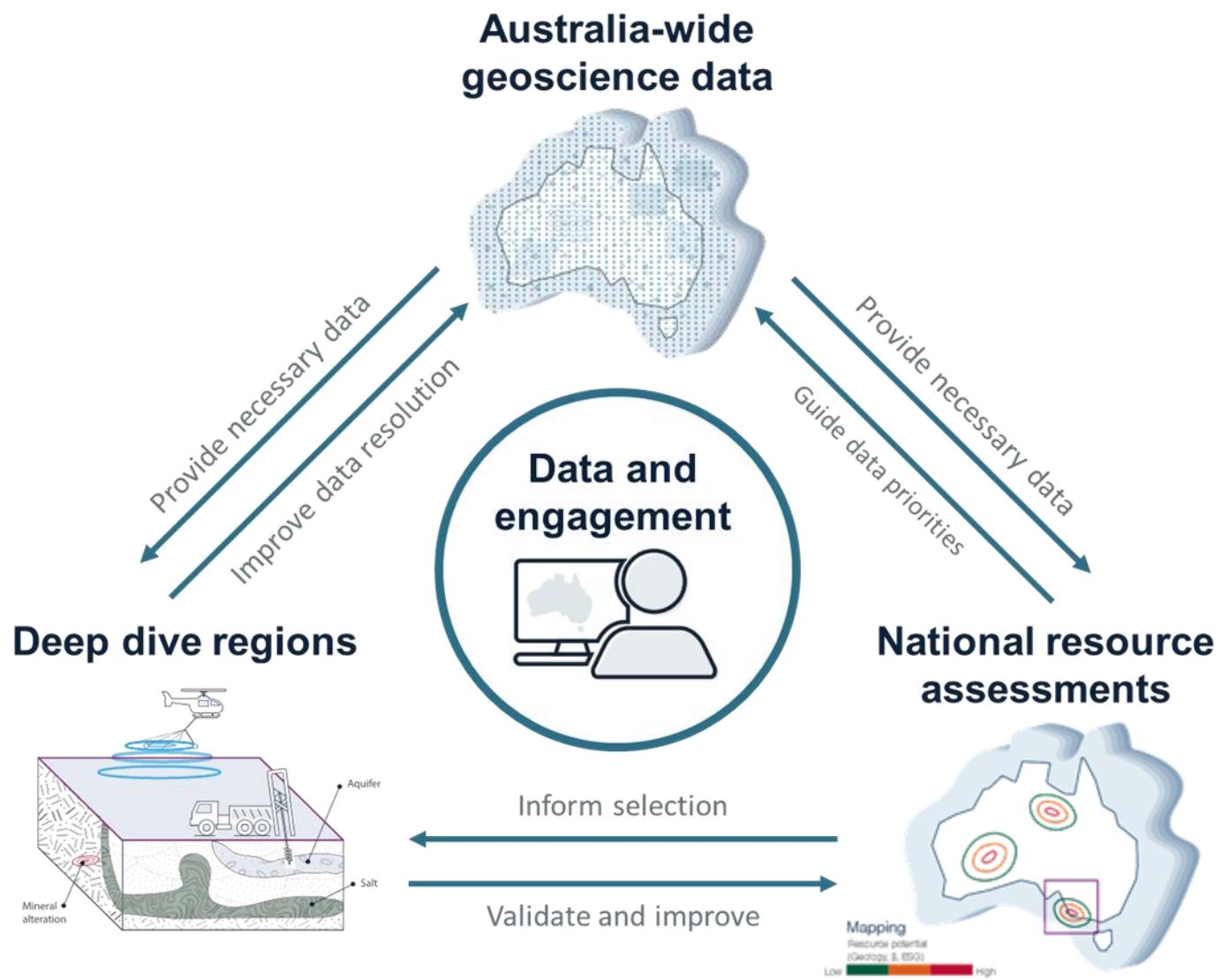


Geopolitics



First Nations

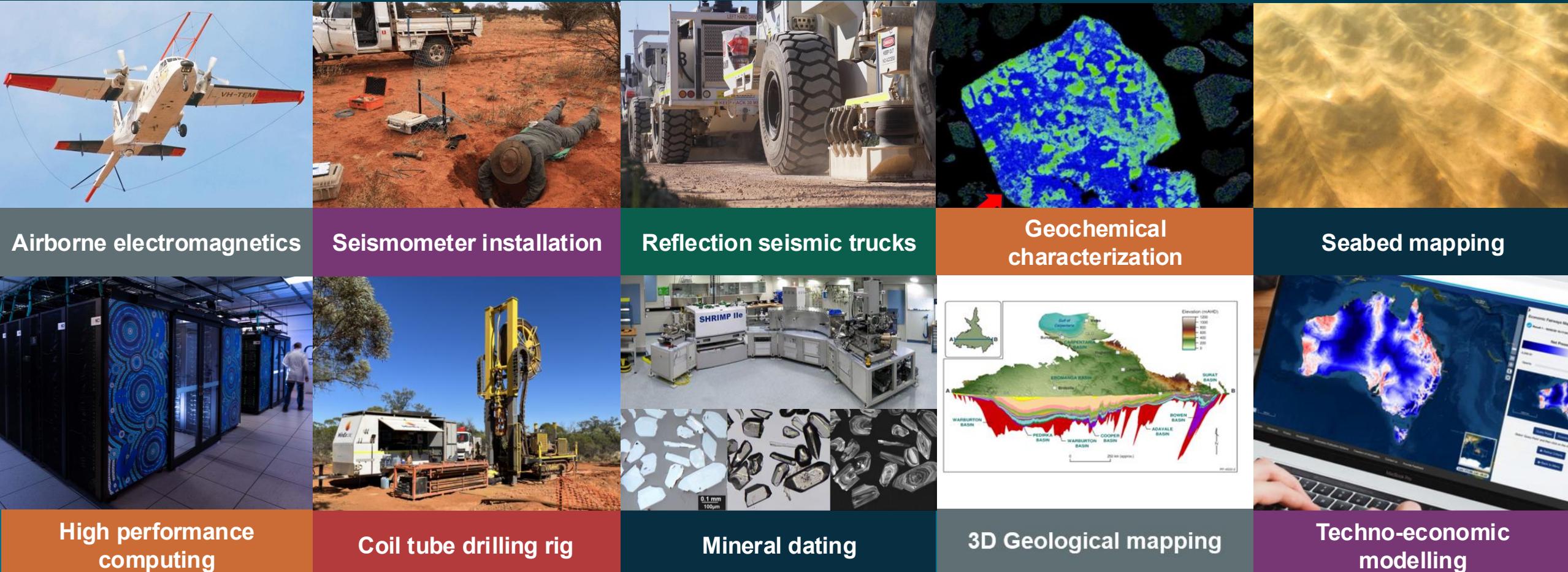
## 4 integrated components



## 4 key objectives

1. Improved quality and completeness of national geophysical, geochemical and geological data and products
2. Map minerals, energy and groundwater resources that will underpin Australia's resource future and support decision-making
3. Investigate 12 deep dive regions onshore, with multi-commodity assessment
4. Deliver data, information and tools that inform decision making by government, industry and communities

# Australia-wide geoscience data: Examples of our data collection and analysis



# An Integrated FAIR modelling approach to map Australia's subsurface

## WHAT?

- What is the **distribution in space and time** of the stratigraphic units of interest, e.g. Prospective for minerals, energy, groundwater? Geological storage locations? What are their physical and chemical properties?
- How can we map and **quantify uncertainties**, e.g. footprints of mineralised systems? New generation of datasets to map continuous variation of properties?

## HOW?

- **Data space:** What data type, format and metadata do we need to facilitate interoperability?
- **Tools:** adoption of digital technologies, e.g. artificial intelligence and machine learning methodologies, open-source modelling software and visualisation platforms.



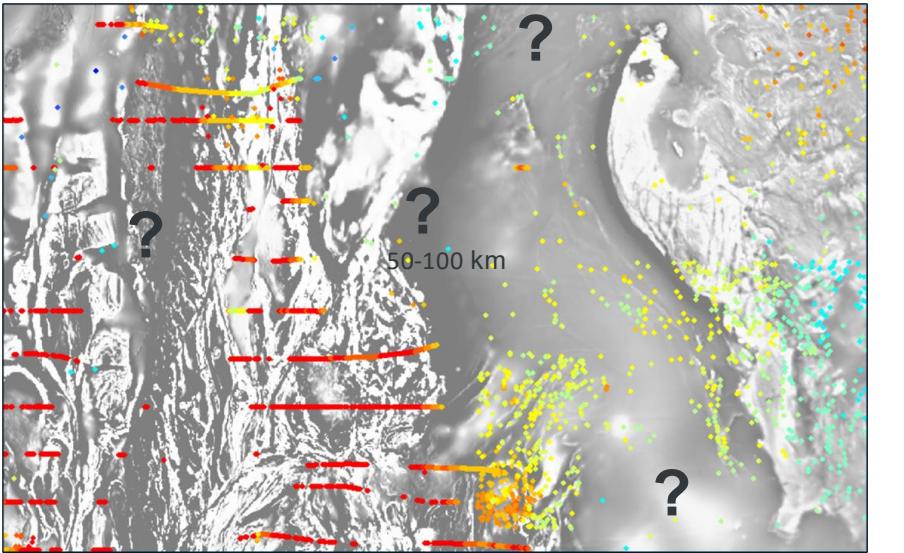
# Challenges

Scale: national = continental

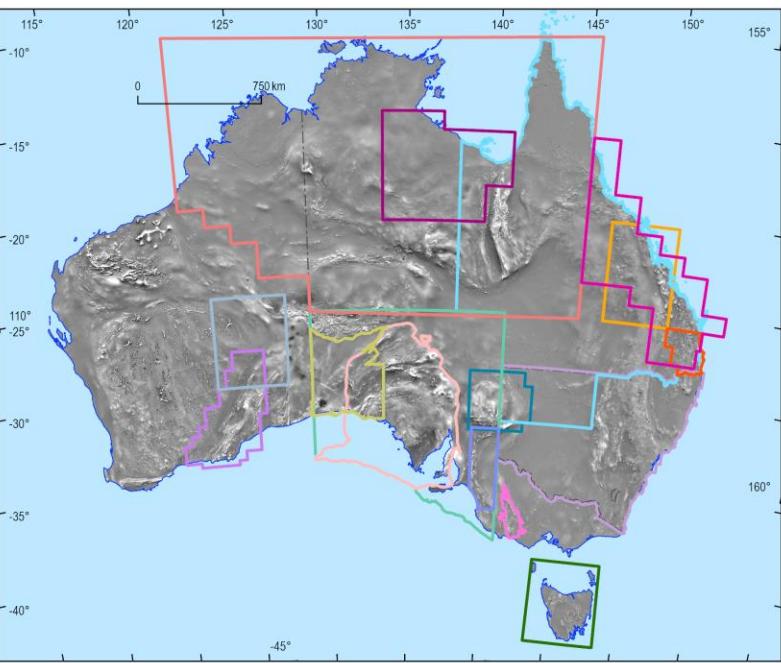
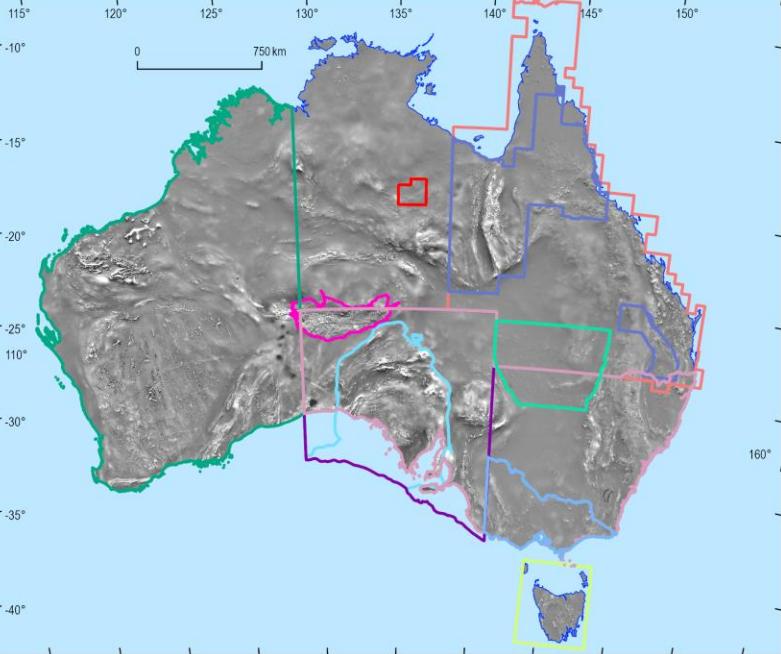
Available datasets vary in **quality and coverage**:

- *Not internally consistent national scale*
- *Heterogenous and sparse datasets*
- *Multiple sources with conflicting interpretations*

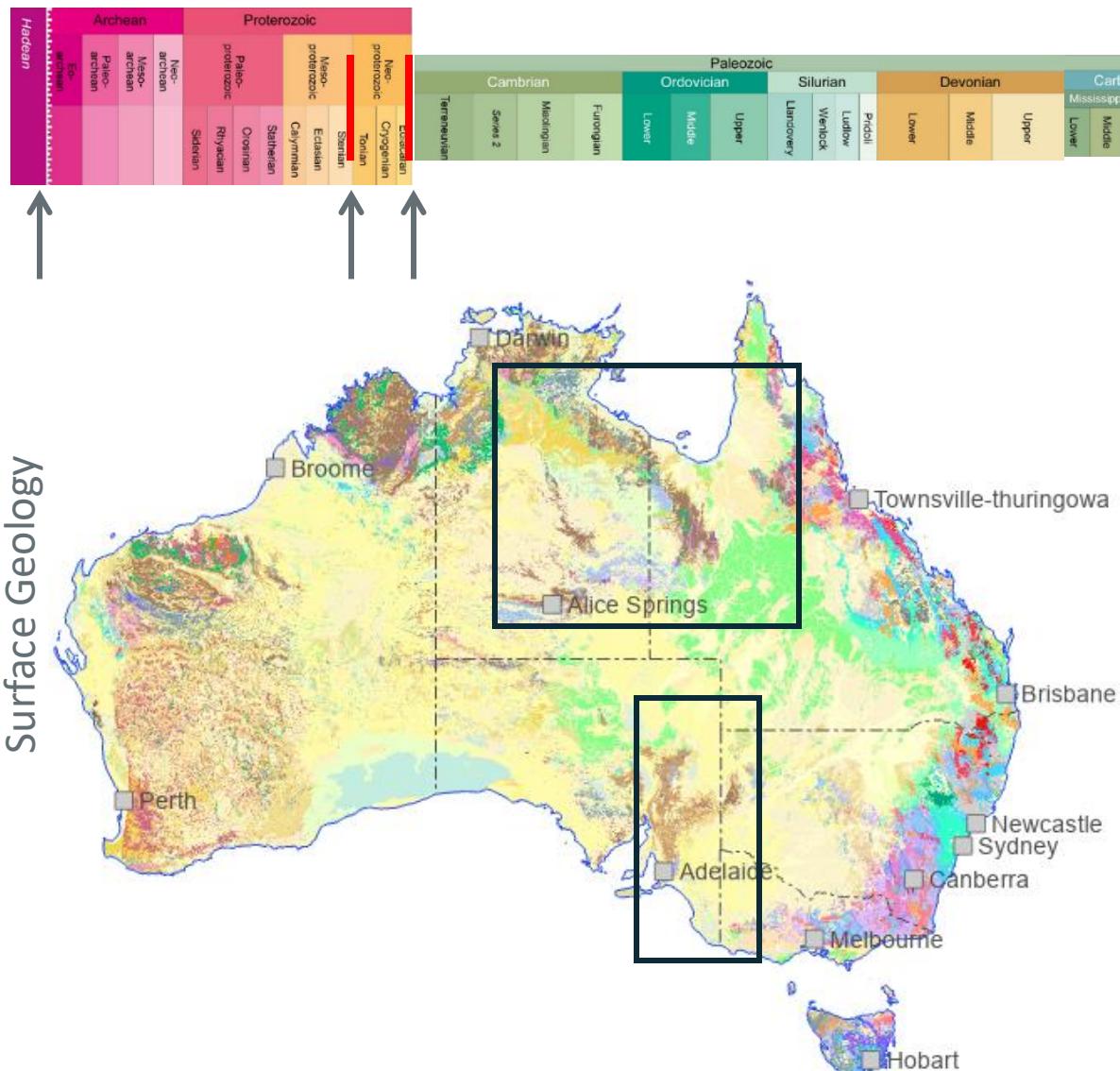
Scalable modelling tools



- Purdy et al. (2018)
- Callaway et al. (2014)
- Lui (2018)
- Clark et al. (2021)
- GSPA (2020)
- Schofield et al. (2013)
- Cowley (2006)
- Cowley et al. (2020)
- GSQ (2018)
- GSQ (2022)
- Seymour and Calver (1995)
- Stewart et al. (2020)
- GSPA (2021)
- GSPA (2020)
- Wise et al. (2018)
- Pawley and Wilson (2019)
- Wise (2020)
- Katona et al. (2021)
- GSQ (2020)
- Liu and Zhang (2014)
- Healy et al. (2008)
- Colquhoun et al. (2021)
- Cayley et al. (2018)
- GSSA et al. (31)
- Bombardier et al. (2023)
- Stewart (2018)
- Stewart (2024)

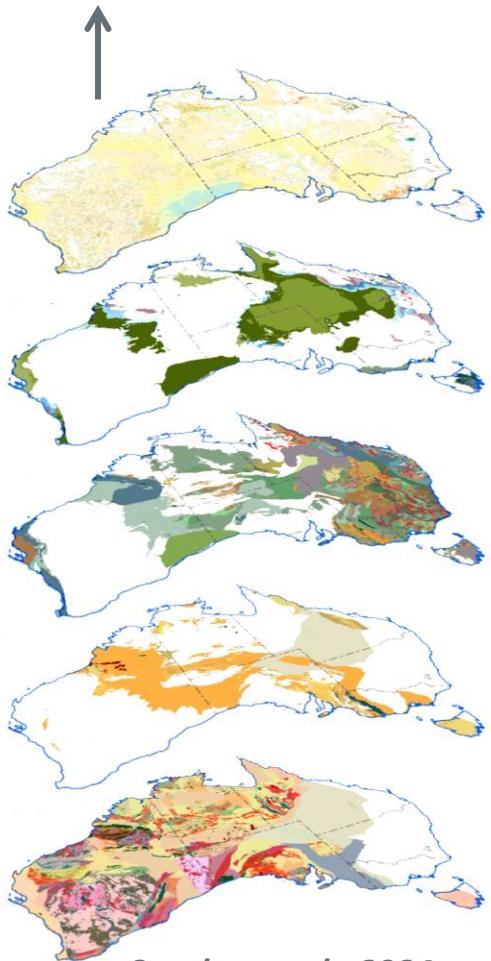


# Multi-layered chronostratigraphic mapping – First step toward a Digital Twin



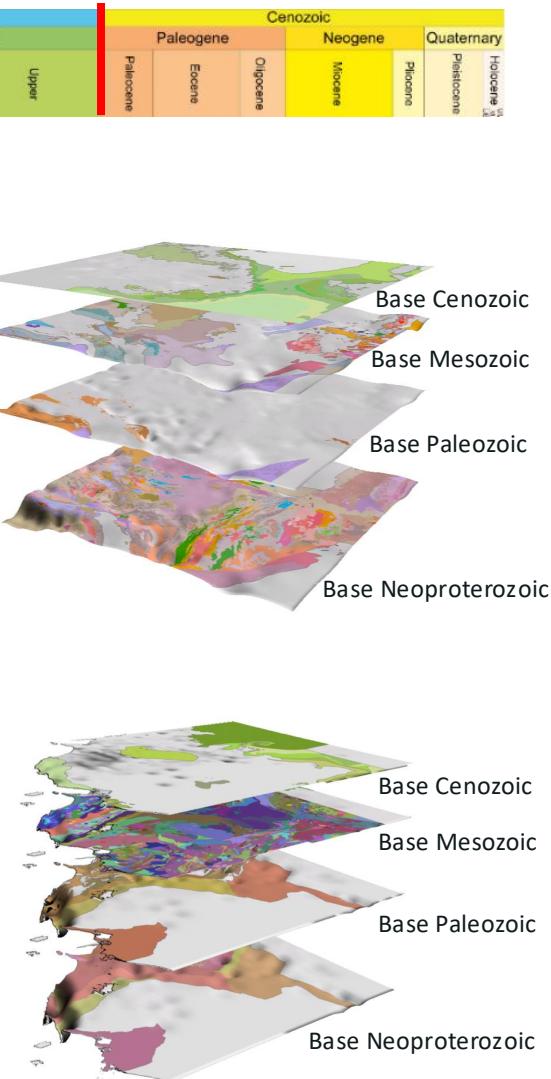
Raymond et al., 2012

## Layered Geology



Sanchez et al., 2024

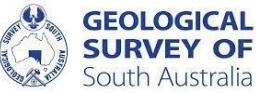
## 3D Geology



Bonnardot et al., 2020; 2024



# Layered Geology Map of Australia



GEOLOGICAL  
SURVEY OF  
South Australia



Queensland  
Government  
Australia



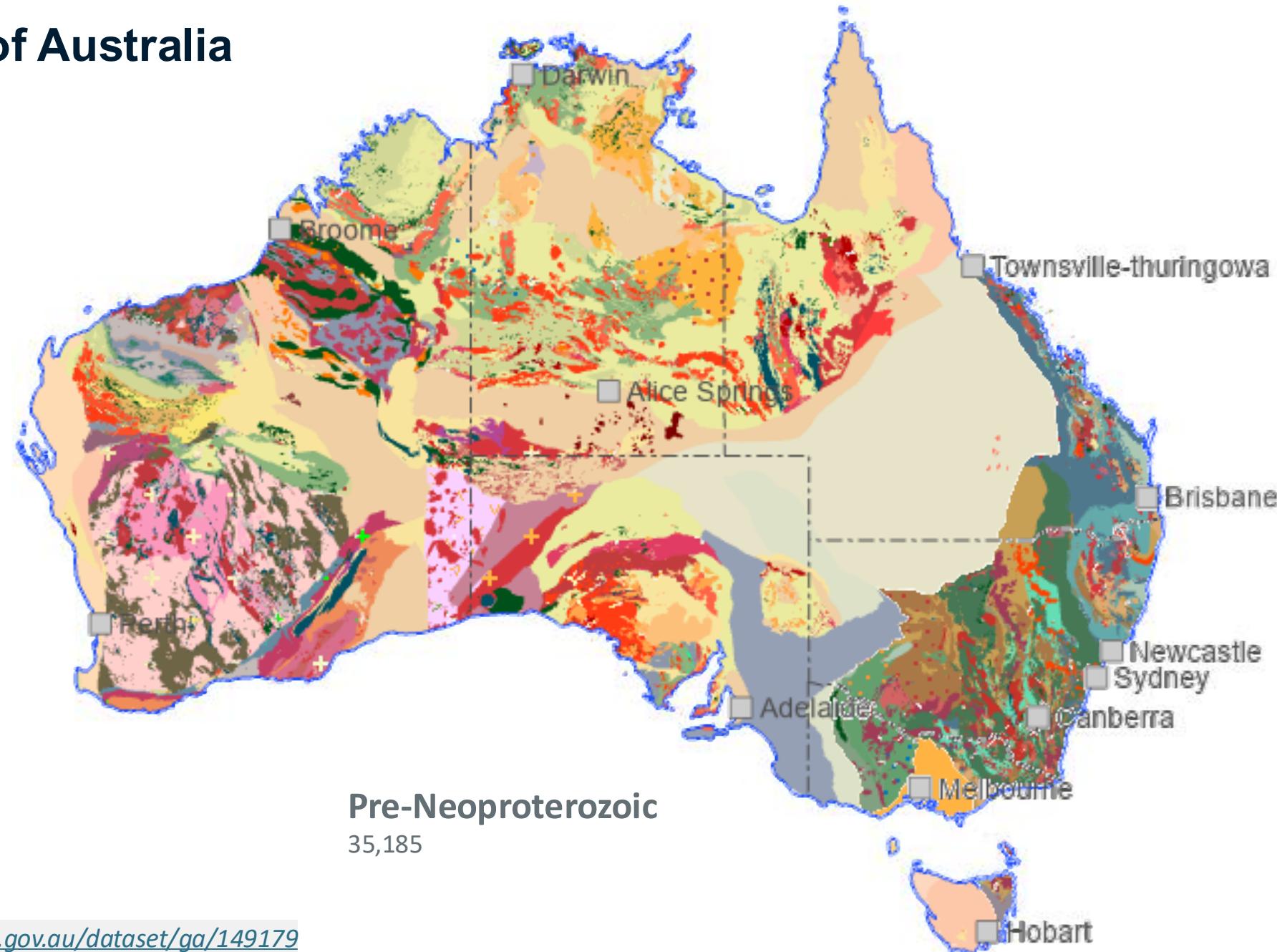
AUSTRALIA'S  
NORTHERN  
TERRITORY



Geological Survey of  
Western Australia



- Optimal use at 1:1M scale
- ~185,000 polygons
- ~7600 geological units



Sanchez et al., 2024. <http://pid.geoscience.gov.au/dataset/ga/149179>



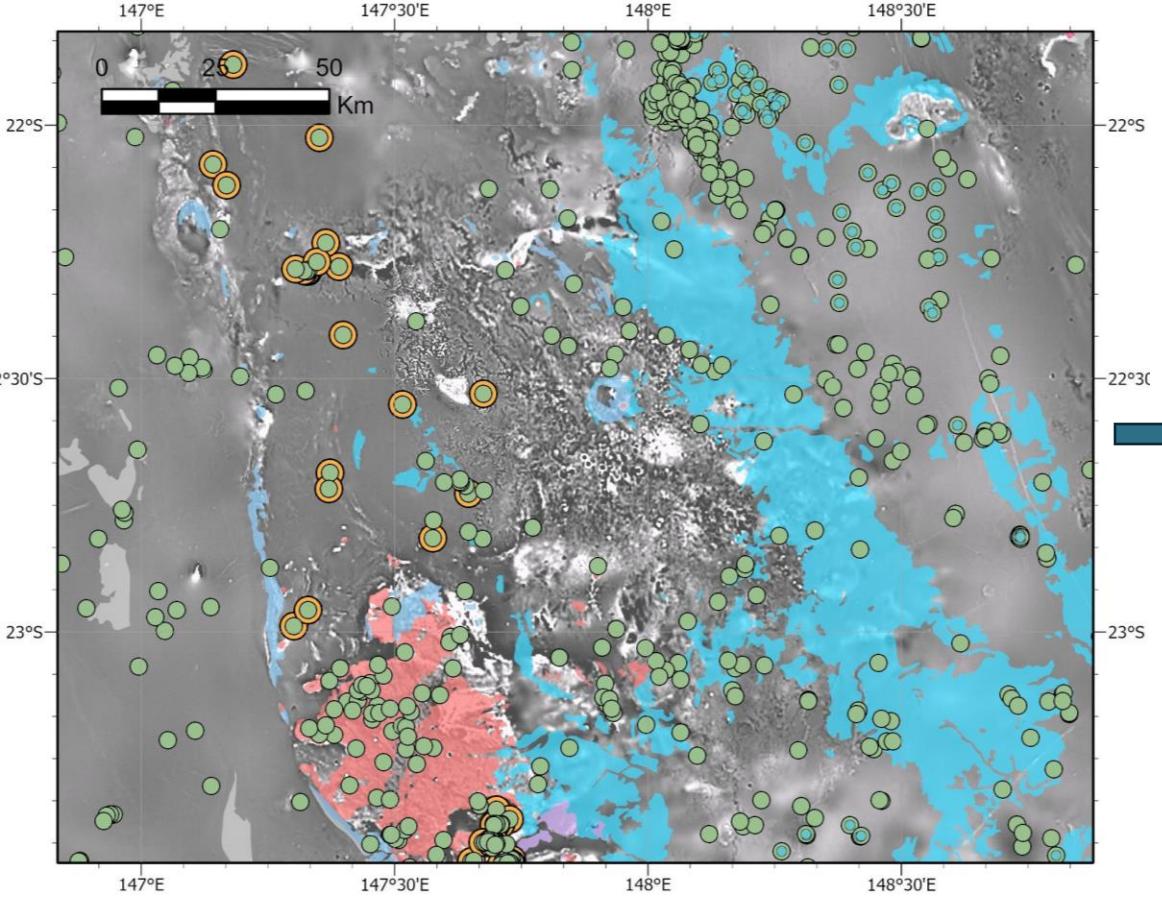
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# Layered Geology Map of Australia – Integrated workflow

## Magnetics, surface geology, boreholes



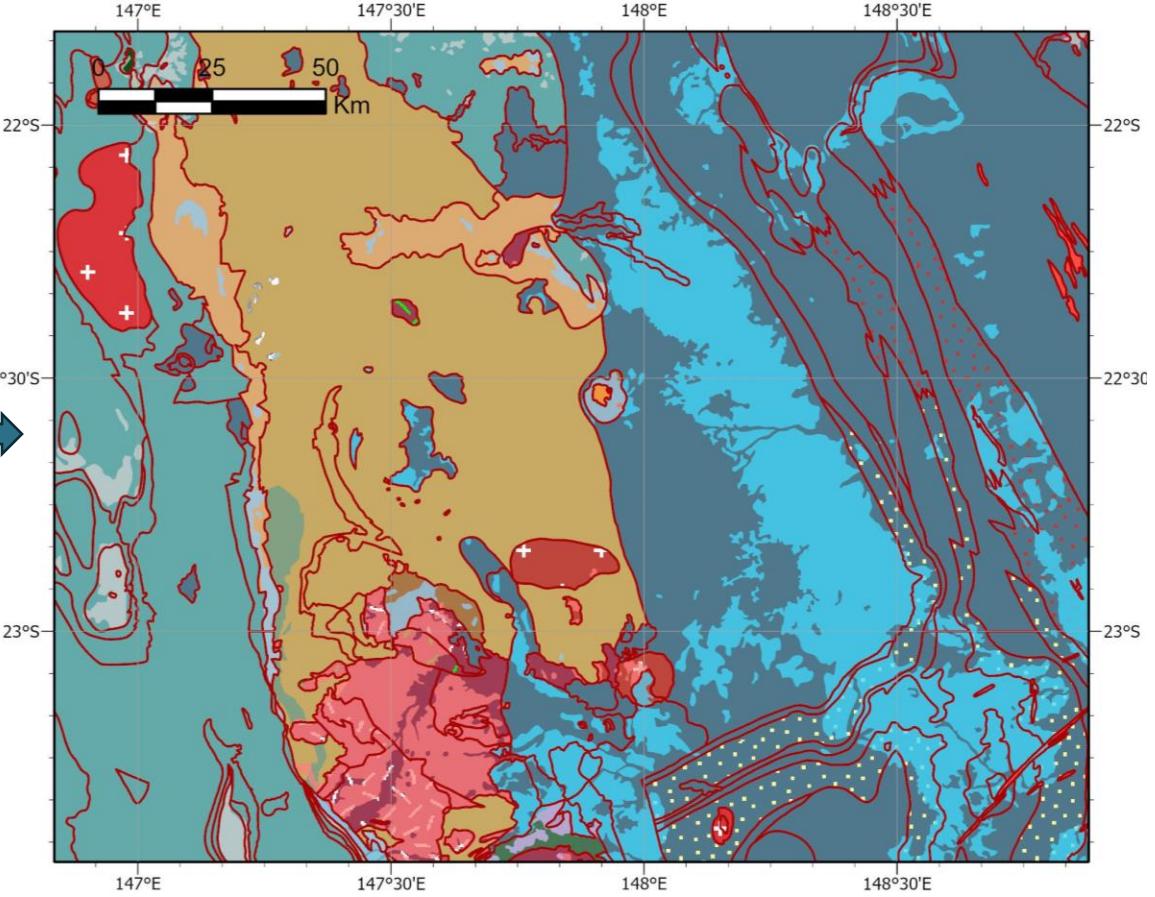
Borehole

- Mesozoic
- Paleozoic
- Neoproterozoic

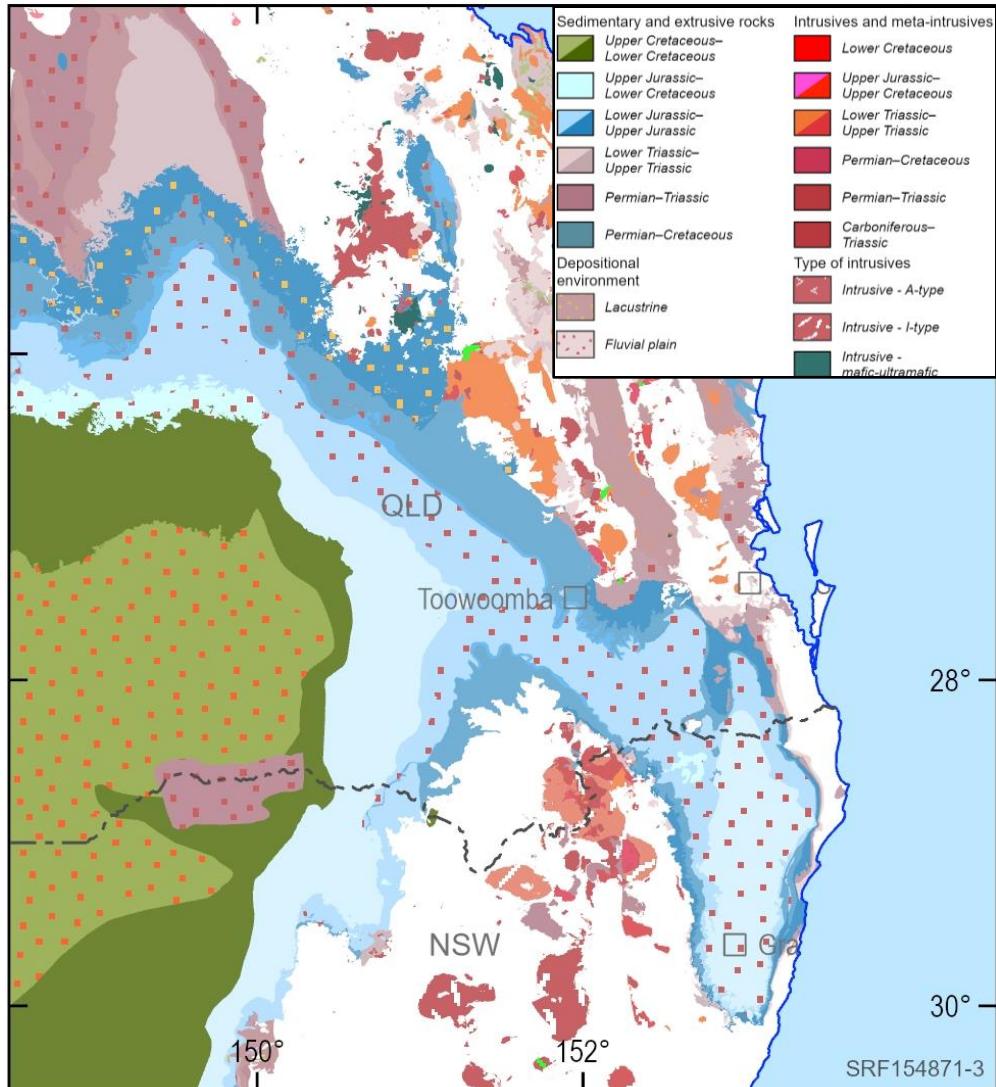
Surface geology - Paleozoic stratigraphy

|                            |                          |
|----------------------------|--------------------------|
| ● Permian                  | ● Devonian-Carboniferous |
| ● Carboniferous            | ● Devonian               |
| ● Carboniferous, intrusive |                          |

## Geological interpretation



# Australian Stratigraphic Unit Database - ASUD



- Layered geology linked to the Australian Stratigraphic Unit Database (ASUD) through Stratigraphic number
- Provides up-to-date information on the chronostratigraphy and lithostratigraphy of geological units
- ~780 units were specifically created for the layered geology map

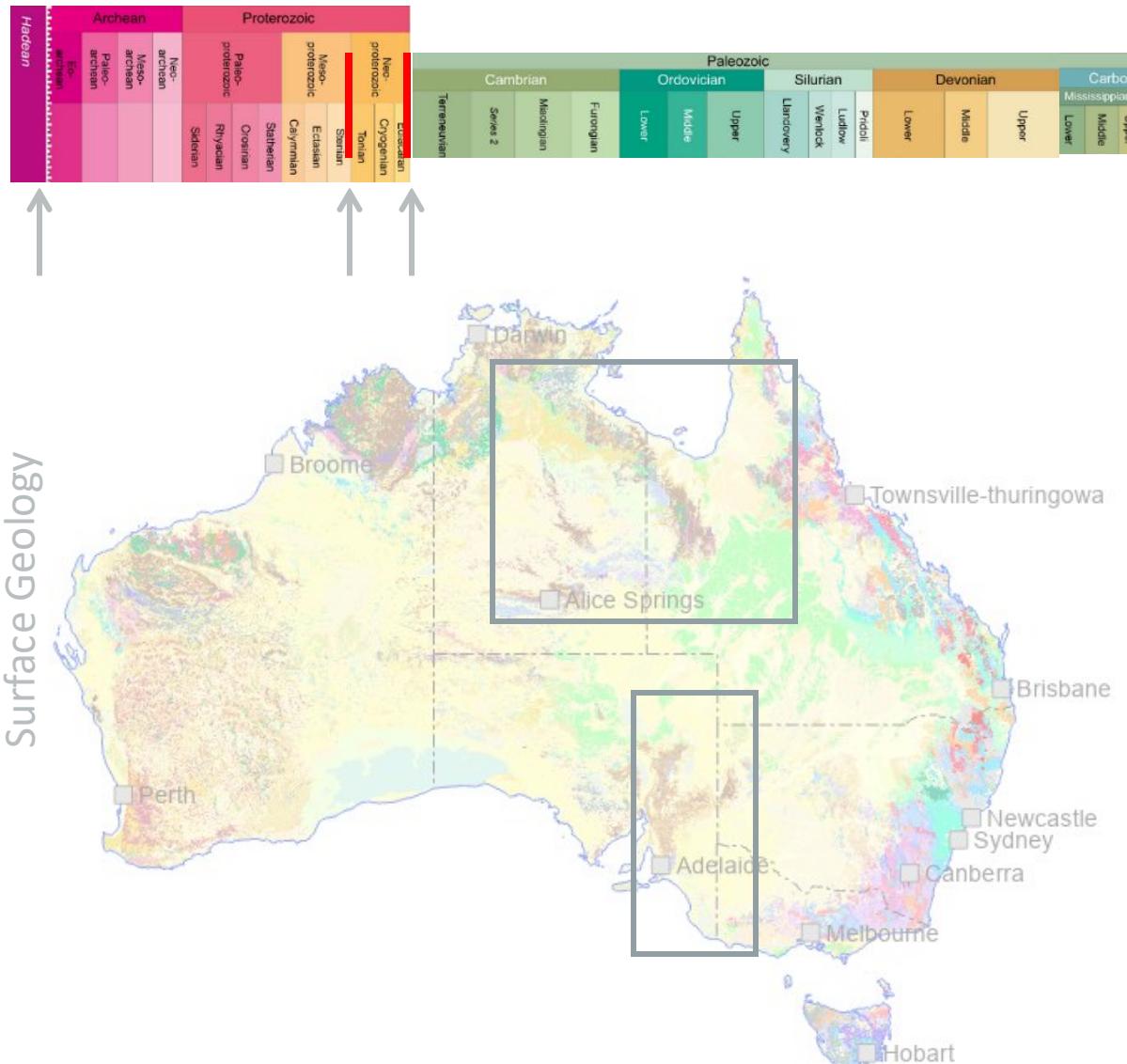
## KEY FIELD ATTRIBUTES

- Stratigraphic age
- Lithology

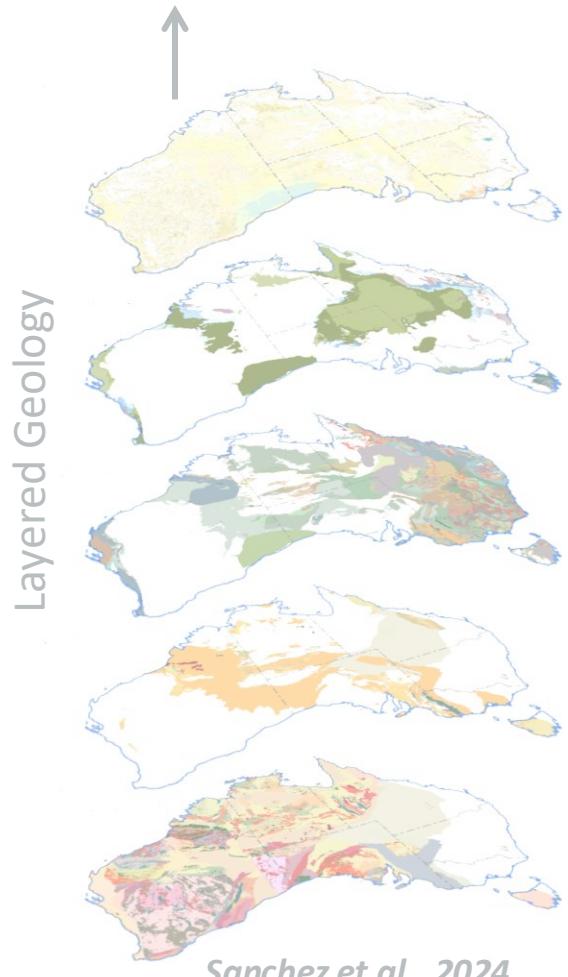
Geoscience Australia & Australian Stratigraphy Commission, 2024. <http://www.ga.gov.au/data-pubs/datastandards/stratigraphic-units>



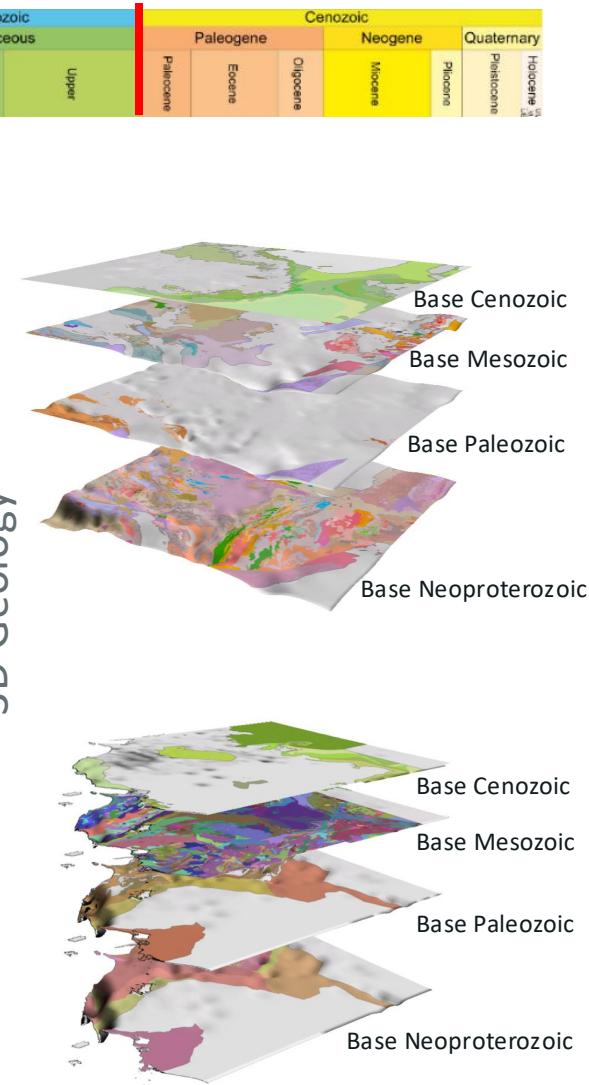
# Multi-layered chronostratigraphic mapping – First step toward a Digital Twin



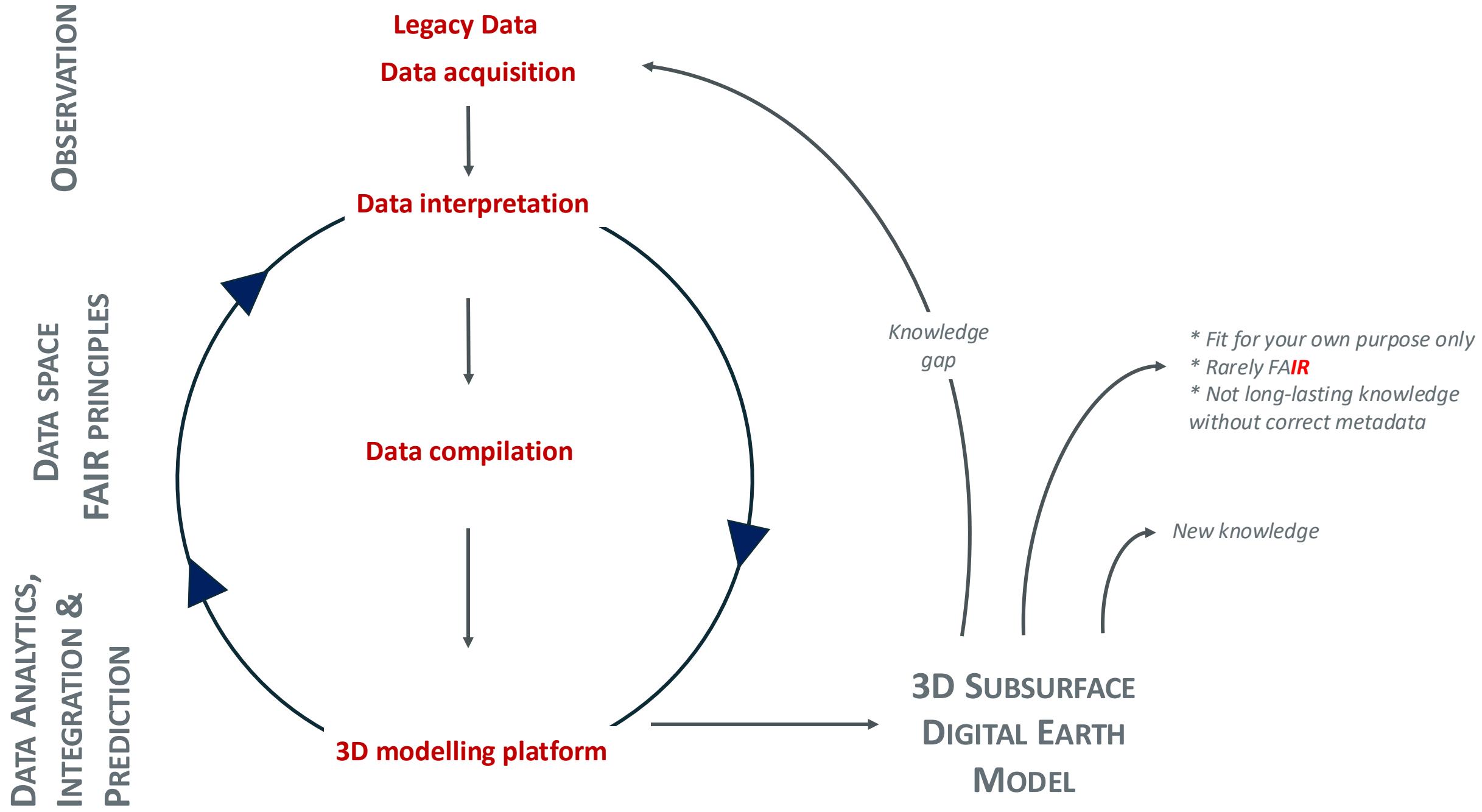
*Raymond et al., 2012*



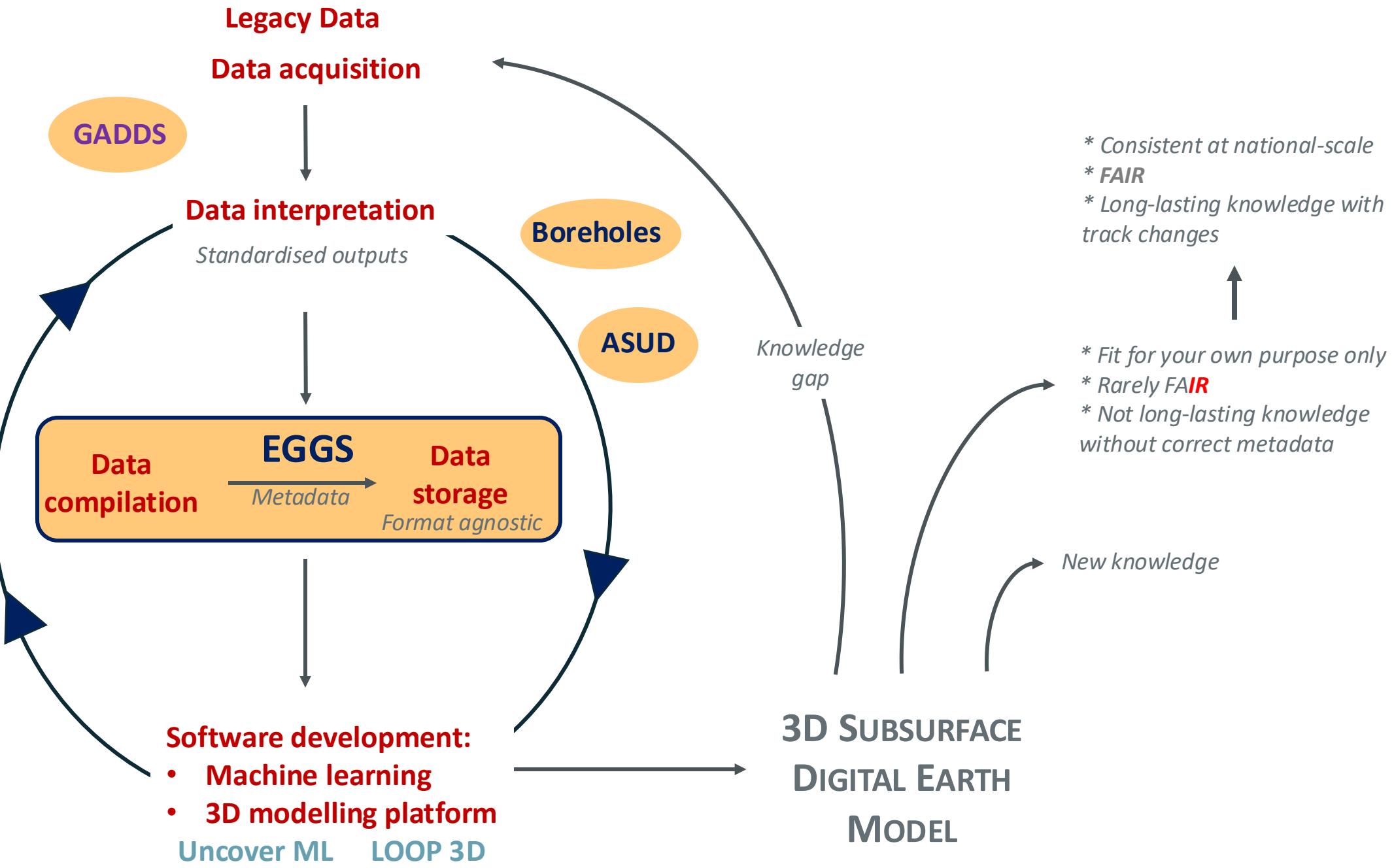
*Sanchez et al., 2024*



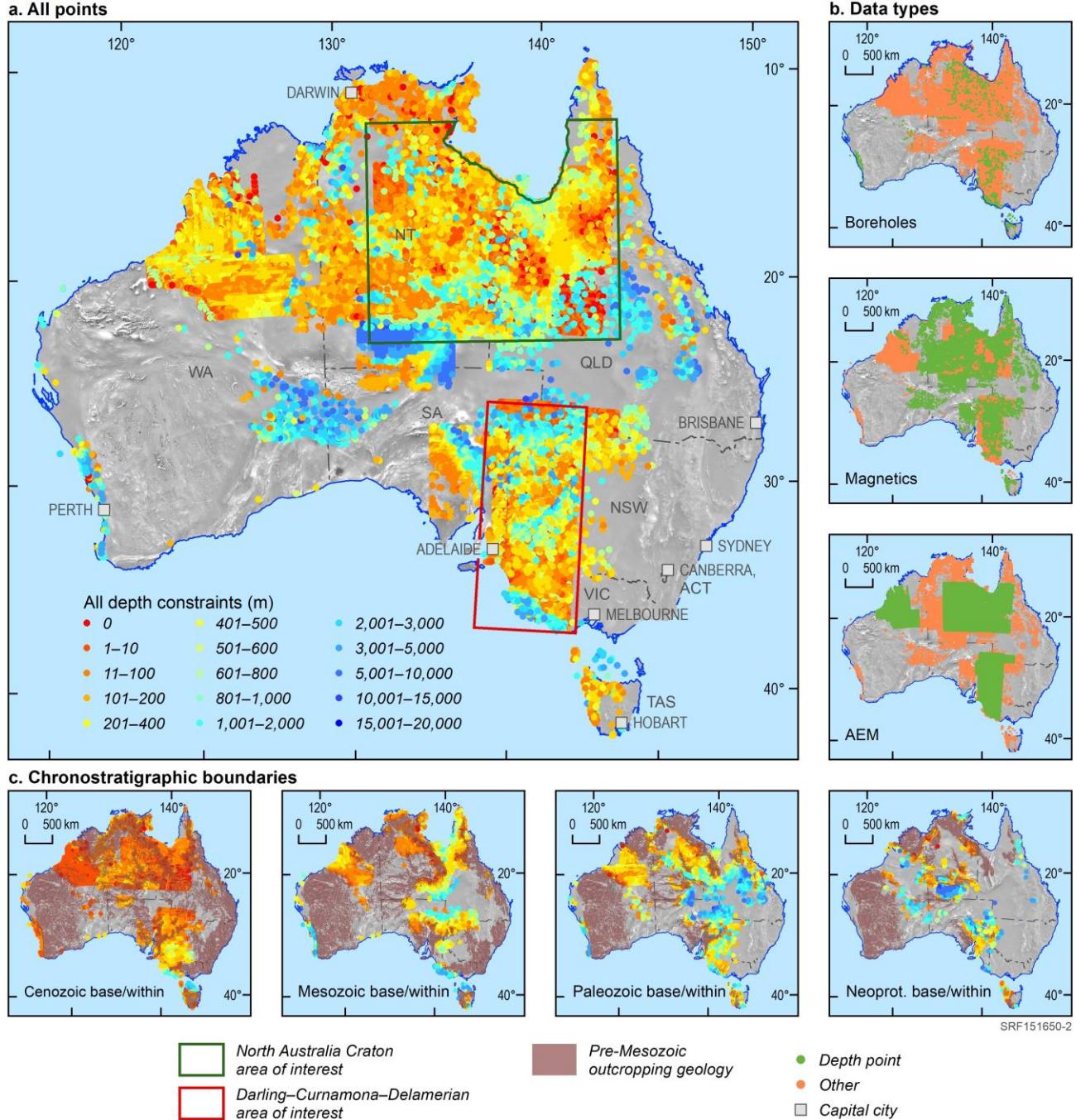
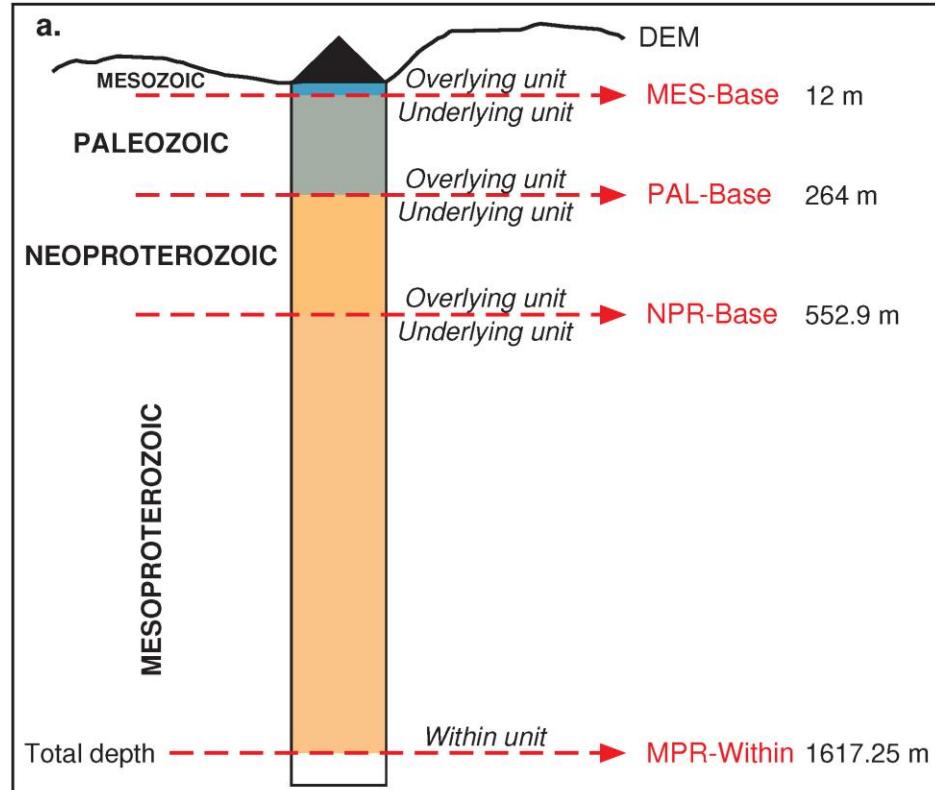
Bonnardot et al., 2020; 2024



OBSERVATION  
DATA SPACE  
FAIR PRINCIPLES  
DATA ANALYTICS,  
INTEGRATION &  
PREDICTION



# Estimates of Geological and Geophysical Surfaces database (EGGS)



<https://portal.ga.gov.au/>

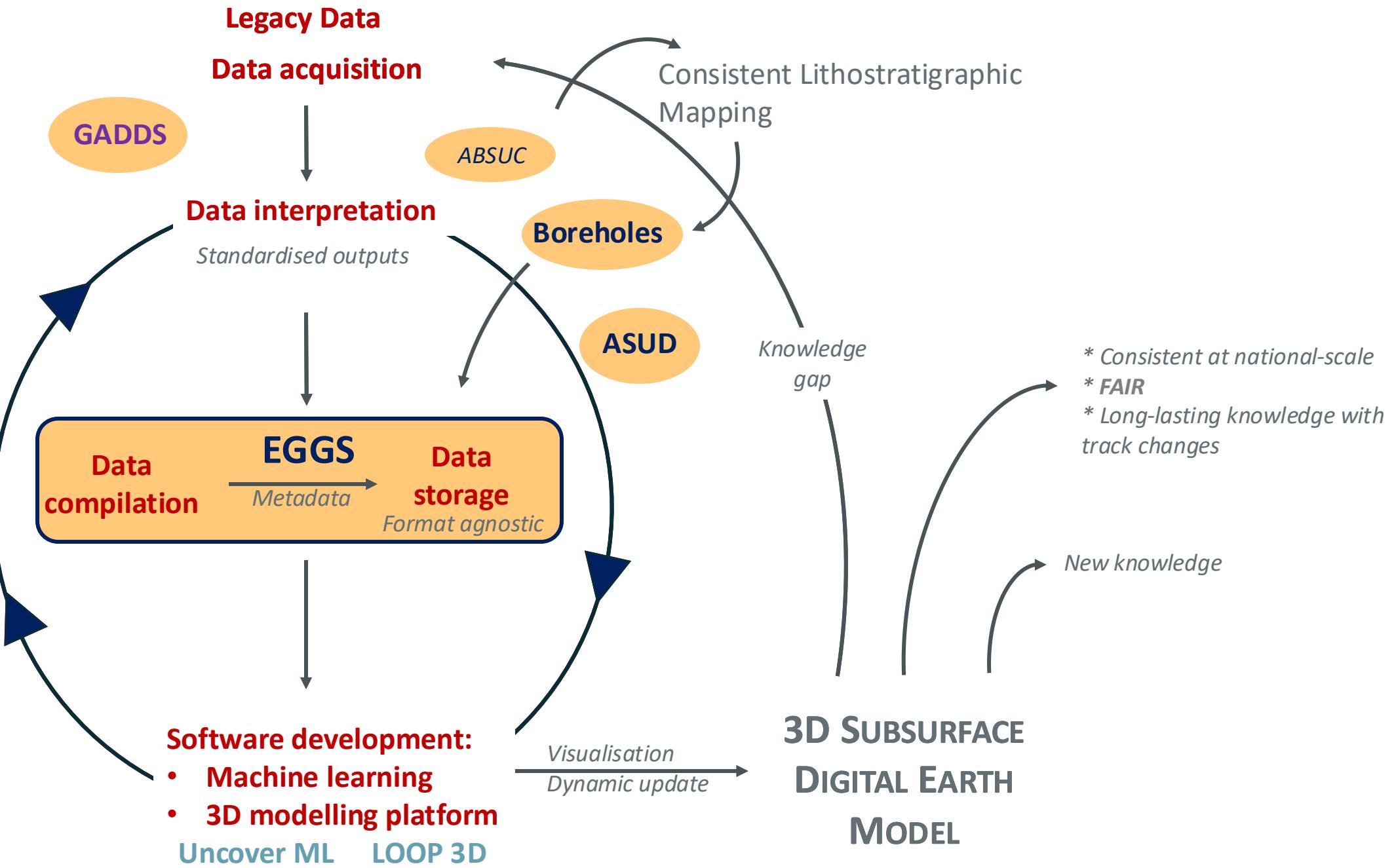


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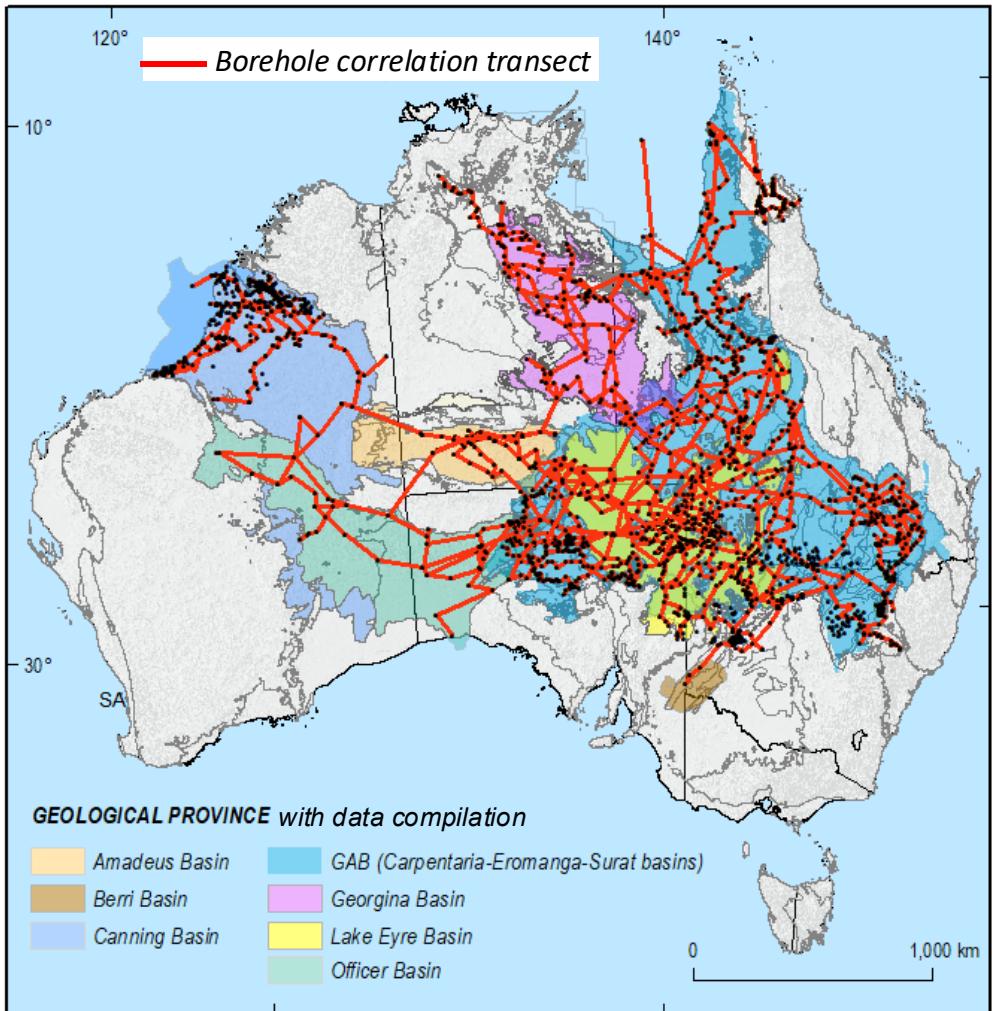
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OBSERVATION  
DATA SPACE  
FAIR PRINCIPLES  
DATA ANALYTICS,  
INTEGRATION &  
PREDICTION



# Stratigraphic correlations across basins and jurisdictional borders

Revise time-space relationships

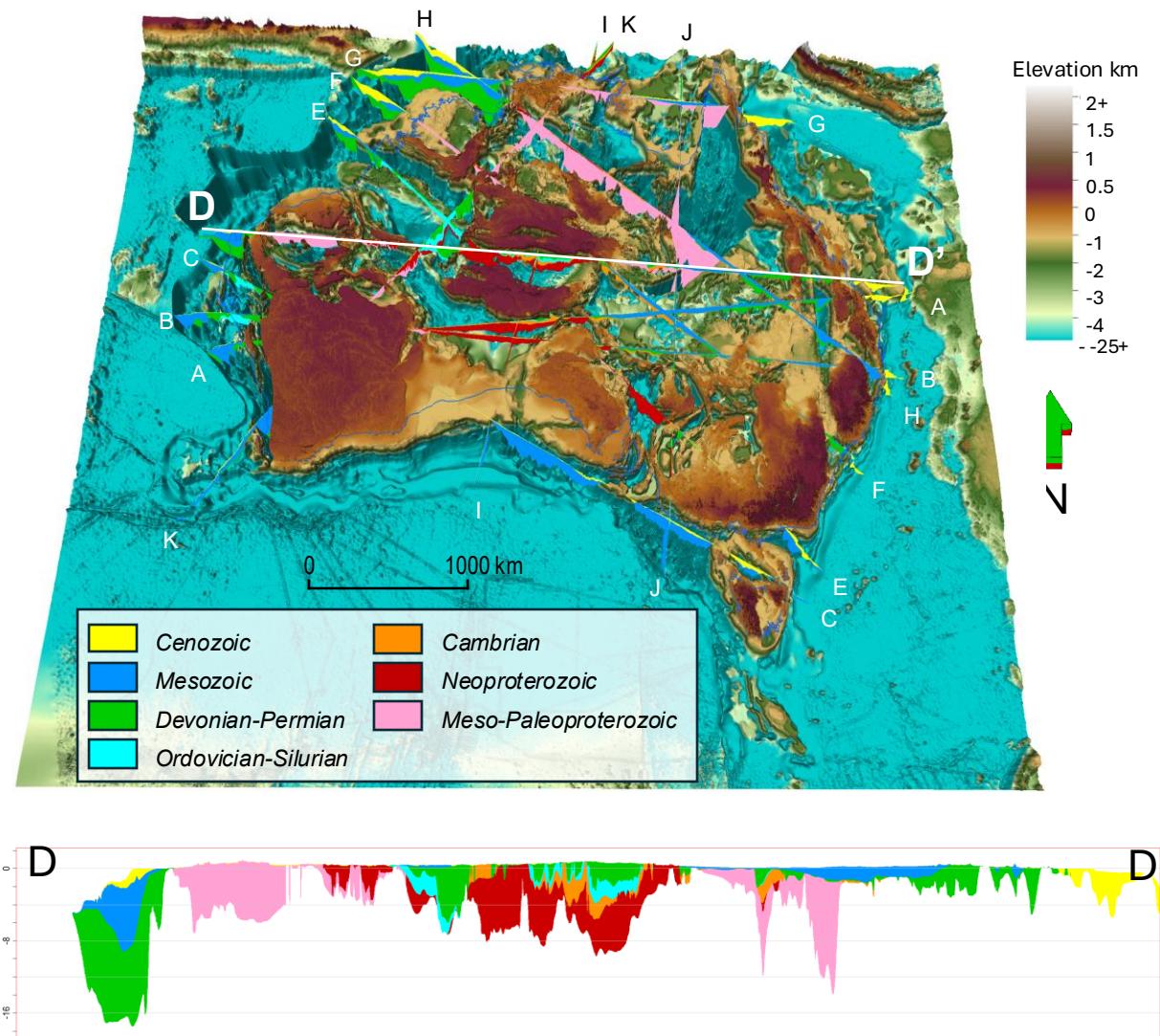


Norton & Rollet 2022, 2023, 2024

<https://dx.doi.org/10.11636/Record.2022.002>

<https://dx.doi.org/10.26186/147243>

<https://dx.doi.org/10.26186/149317>



Rollet et al., 2024

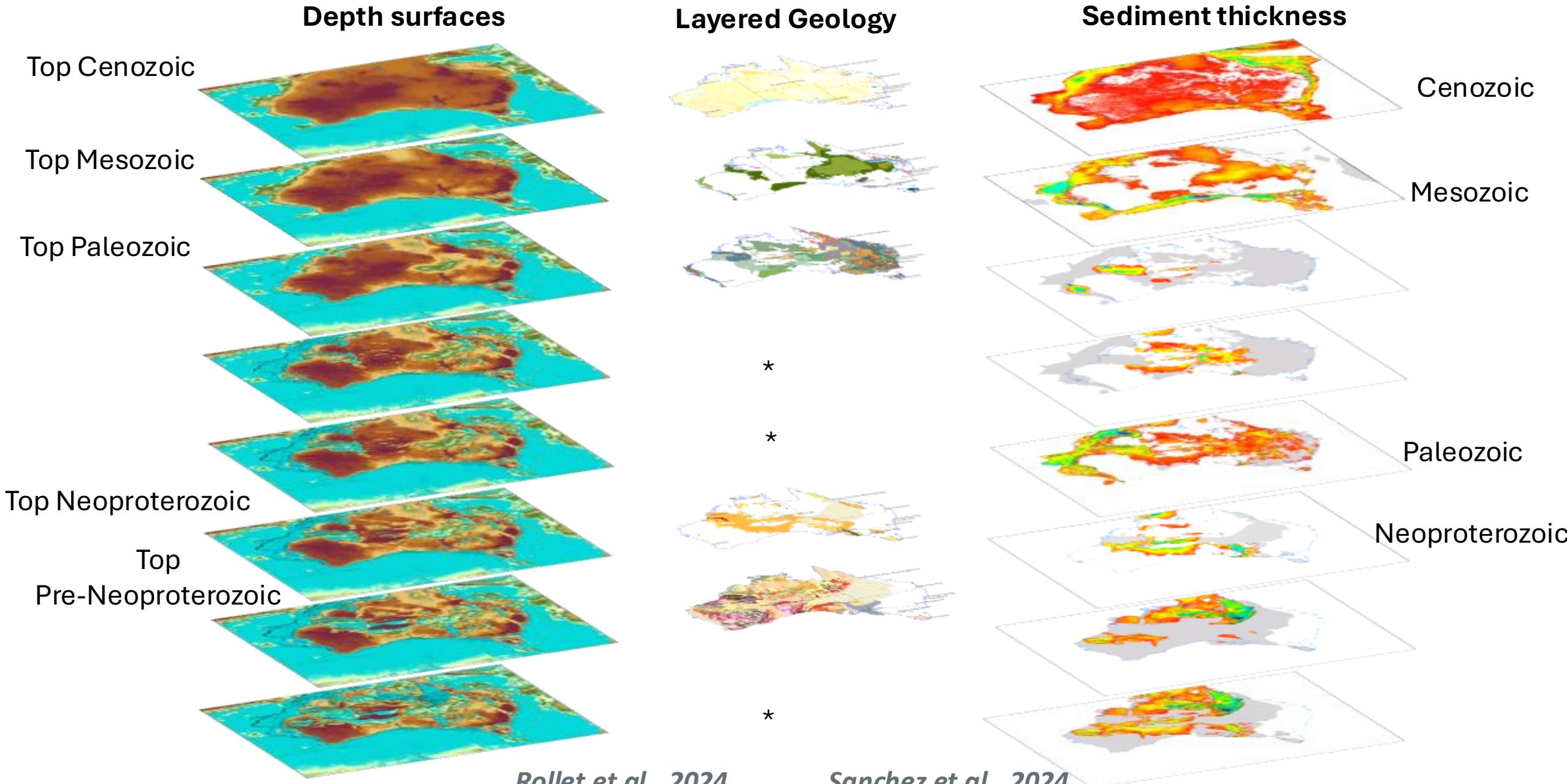


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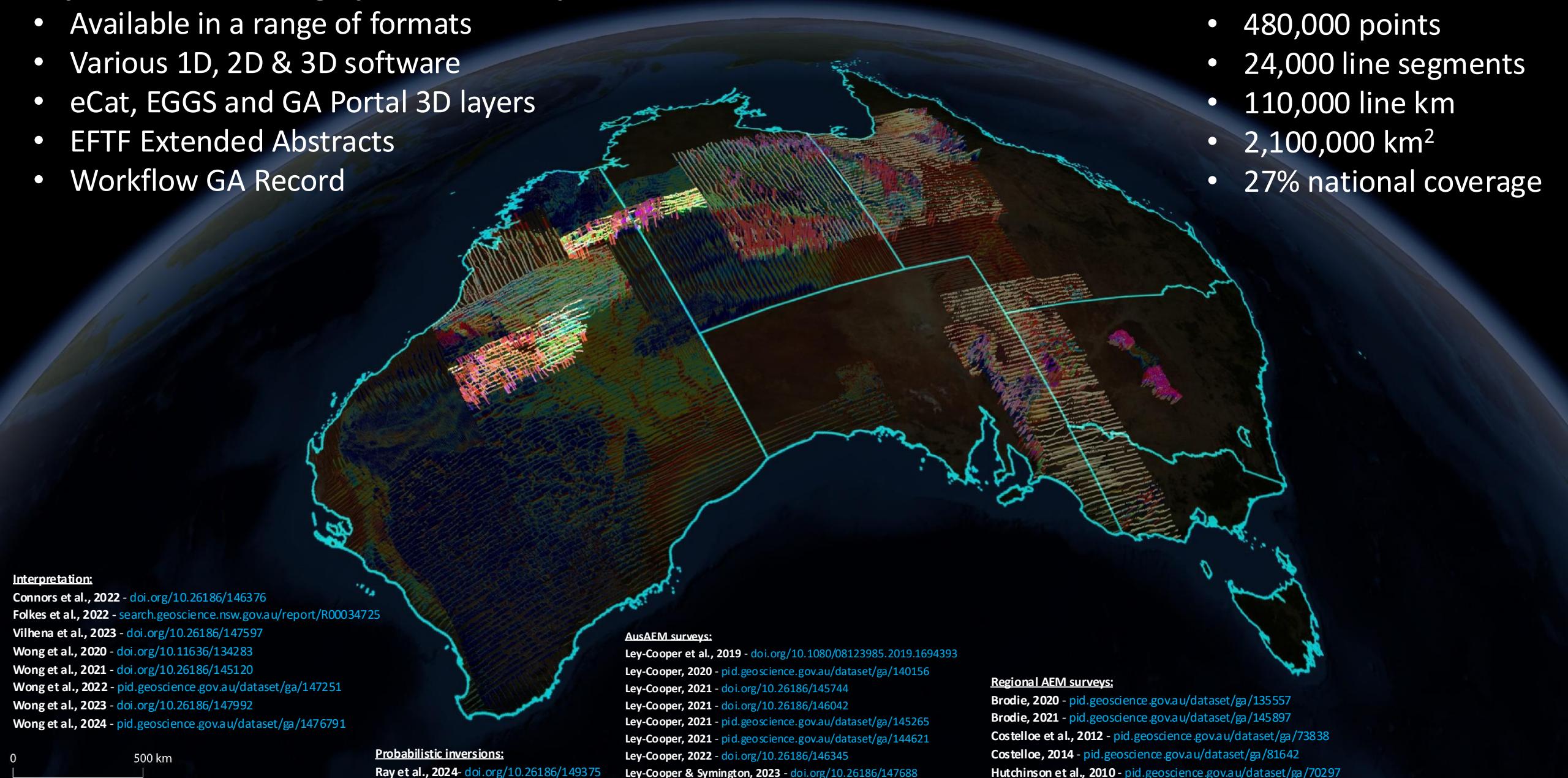
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# Advancing Nationwide Stratigraphic model

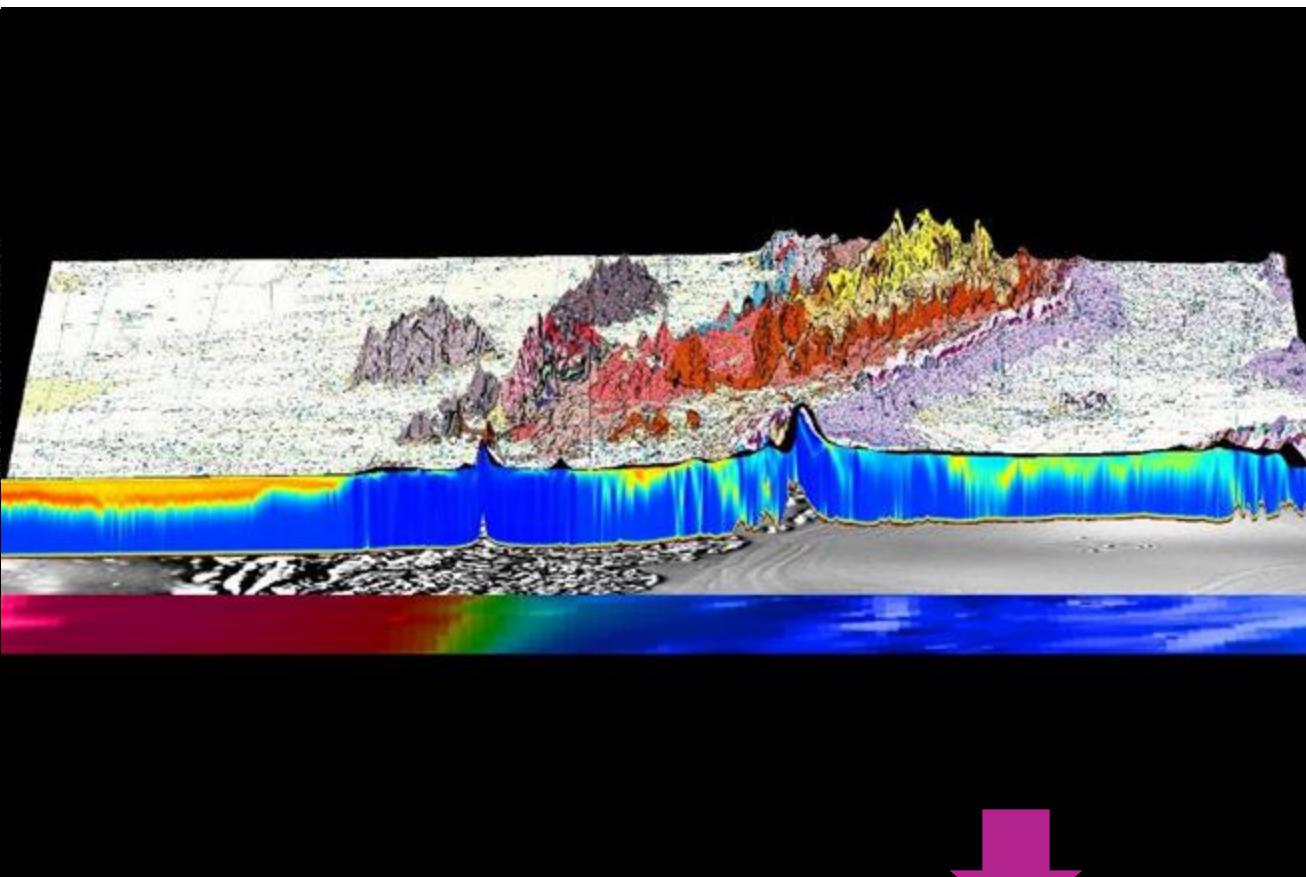


# Layered chronostratigraphic AEM interpretation

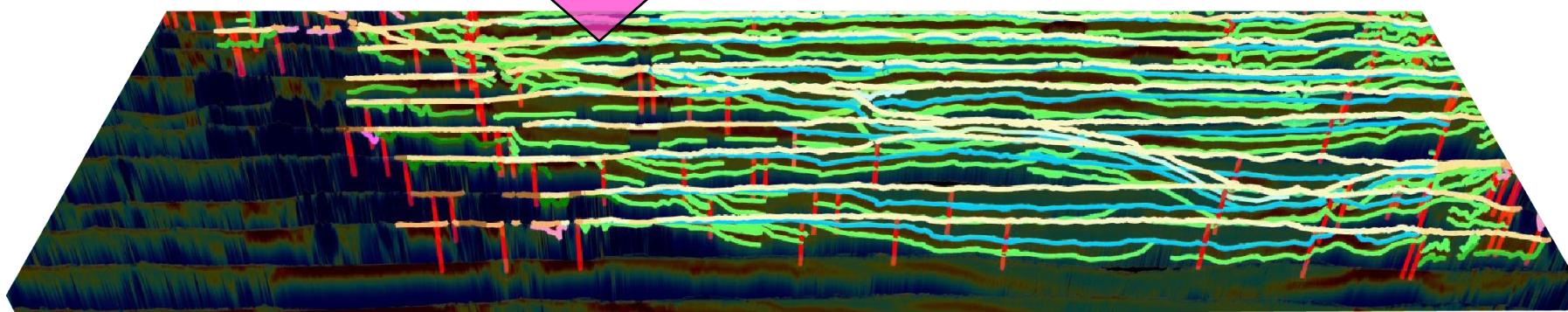
- Available in a range of formats
- Various 1D, 2D & 3D software
- eCat, EGGS and GA Portal 3D layers
- EFTF Extended Abstracts
- Workflow GA Record
- 480,000 points
- 24,000 line segments
- 110,000 line km
- 2,100,000 km<sup>2</sup>
- 27% national coverage



# Layered chronostratigraphic AEM interpretation workflow



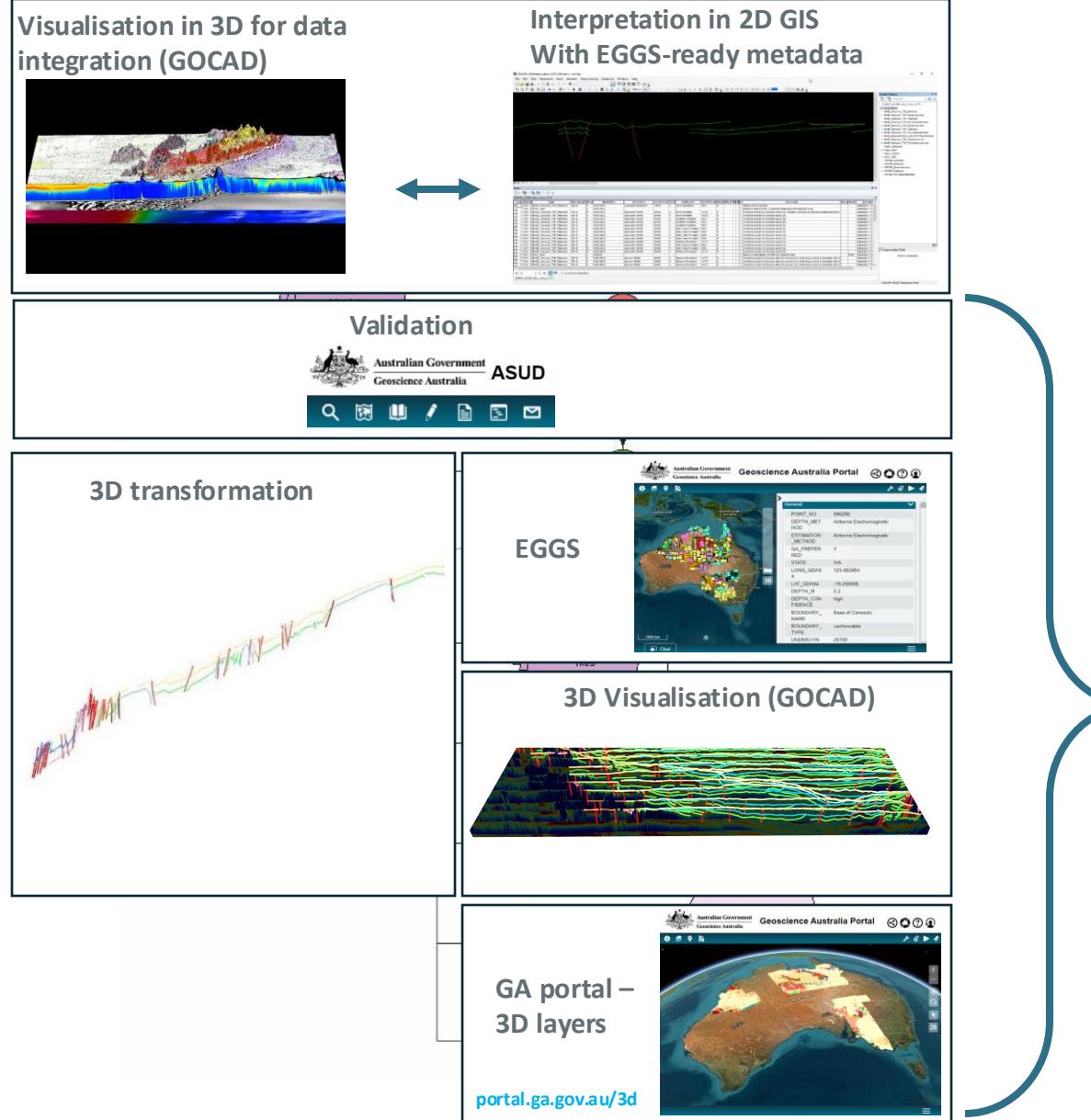
| Attribute examples                       | Input examples   |
|--|--|
| Geometry                                 | X,Y,Z coordinates  |
| Feature type                             | Base of Cenozoic / Top of Palaeoproterozoic  |
| Pick confidence                          | Moderate   |
| Contact type                             | Unconformity, faulted, intrusive   |
| Basis of interpretation                  | Interpretation of AEM, surface geology, magnetics and boreholes  |
| Overlying stratigraphic unit name        | sand plain   |
| Overlying stratigraphic unit number      | 38499  |
| Overlying stratigraphic unit confidence  | High   |
| Underlying stratigraphic unit name       | Gardiner Sandstone   |
| Underlying stratigraphic unit number     | 7009   |
| Underlying stratigraphic unit confidence | Moderate   |
| Hydrostratigraphic information           | Overlying is confined aquifer, underlying is aquitard  |
| Additional features                      | Discrete conductors, faults, base of weathering, etc.  |
| Comments                                 | Borehole BMR Tanami 15 has reddish-brown sand and lateritic ironstone from 0 to 6 m before intersecting the Gardiner Sandstone in this location. |



Wong et al., 2023 -  
[pid.geoscience.gov.au/dataset/ga/147251](https://pid.geoscience.gov.au/dataset/ga/147251)



# Workflow functionalities



## Interoperable

Operates on diverse software packages, including free and open source GIS/3D software



## Unrestricted

Outputs are not bound by proprietary limitation

### Graphical User Interface

AEM Workflow

Project definition files

- Geometry files
  - Extent files
  - Path files
- Conversion files
  - Boundary classes lookup table
  - Split type category lookup table
- Interpretation files
  - Multiple interpretation shapefiles
- Validation files
  - ASUD export

Select workflow implementation:  
 Python  
 Awk

Input project directory path  
C:\W10Dev\AEM\_Conversions\Northern\_Officer\_Basin\_021220

Coordinate Reference System (CRS)  
GDA94 / MGA zone 51 - EPSG:28351

Interpretation GIS software  
Esri ArcMap

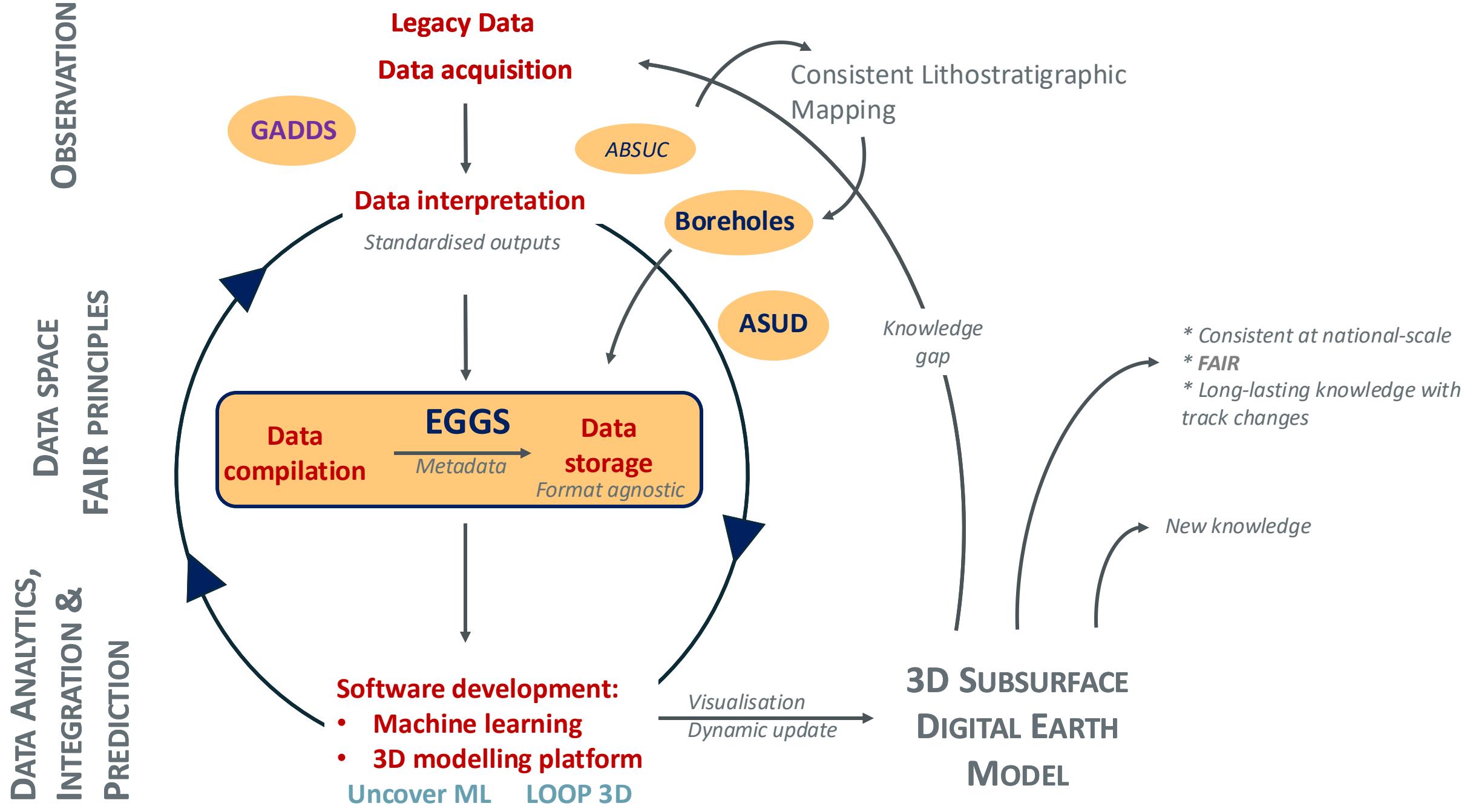
Confirm interpretation shapefiles

Input number of depth lines  
10

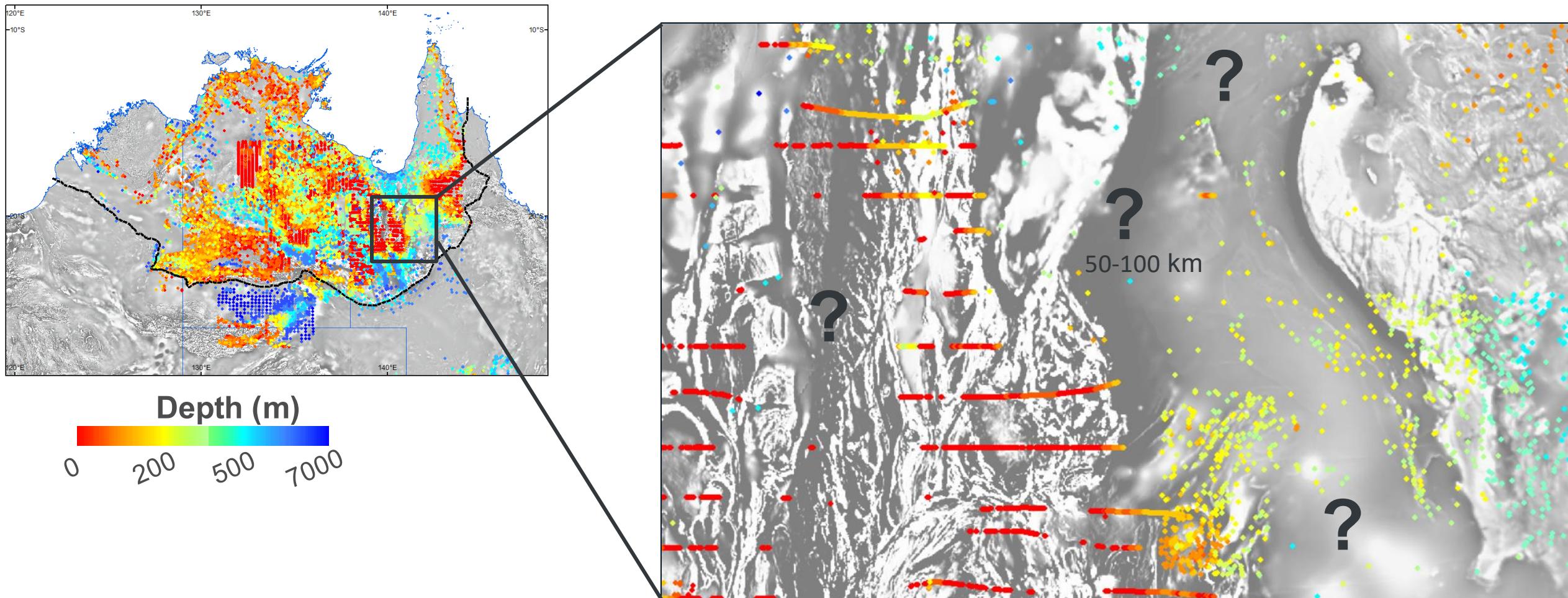
Input line increments in meters  
50

Pre-Interpretation





# The Modelling challenge : Data Distribution

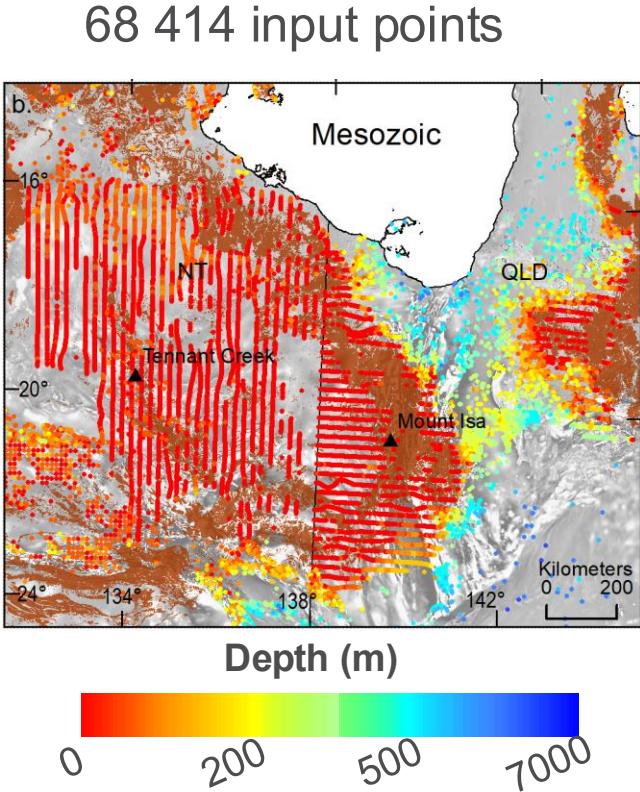




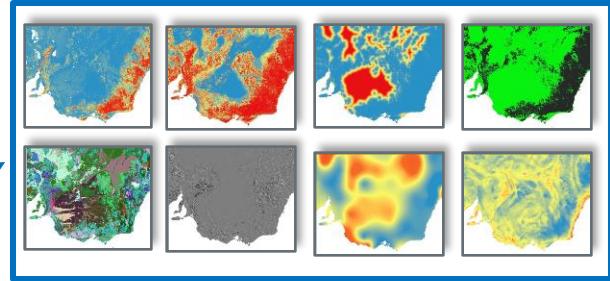
# Depth to cover modelling

Machine Learning  
Interpolation

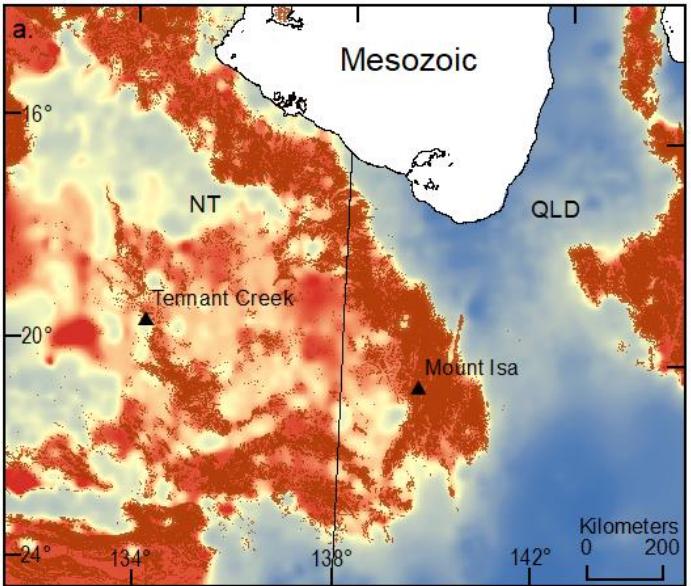
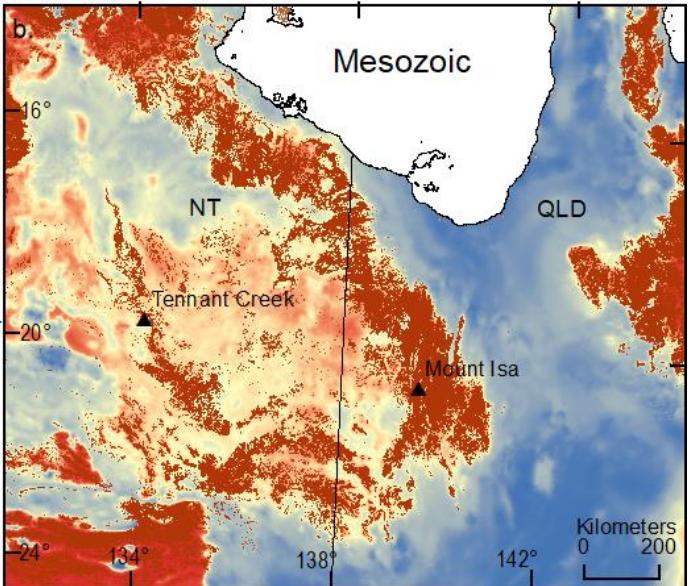
Observations



Predictive  
input datasets



2km cell size



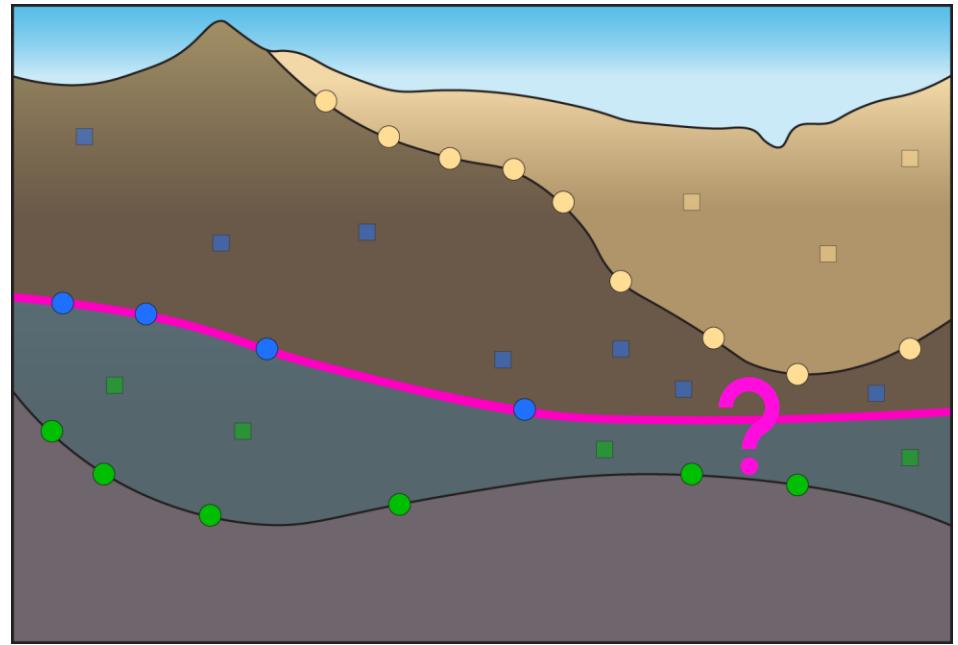
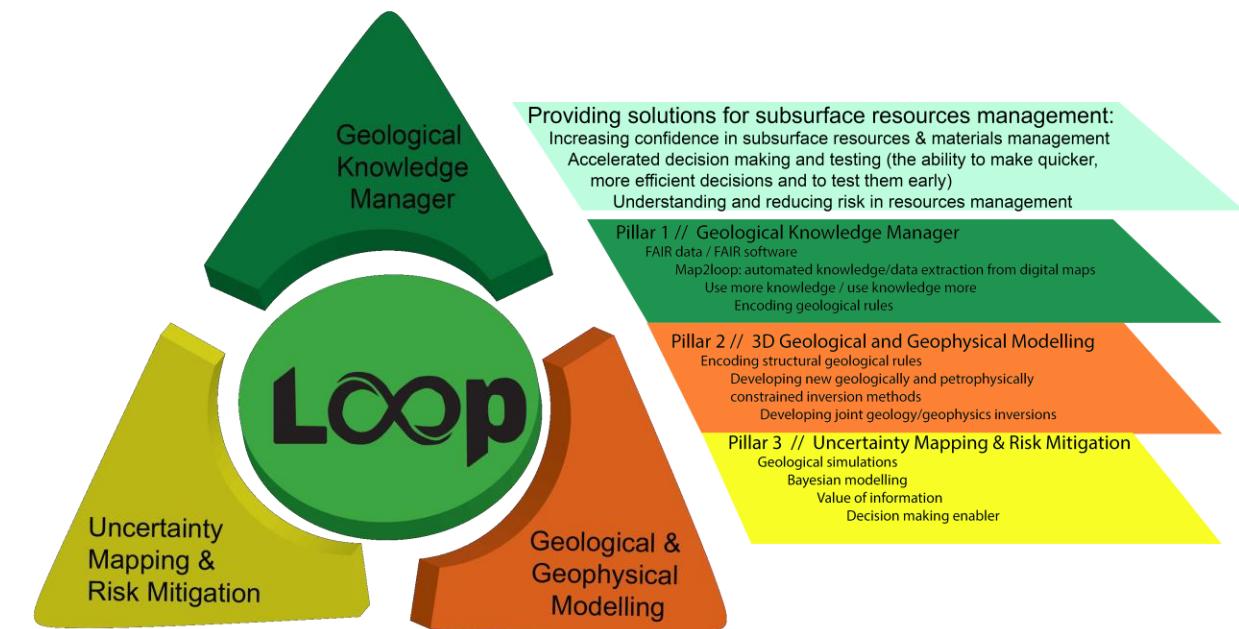
Wilford et al., 2020  
Bonnardot et al., 2020

GitHub - [github.com/GeoscienceAustralia/uncover-ml](https://github.com/GeoscienceAustralia/uncover-ml)

# Depth to Cover Modelling

## Loop

- Loop 3D - an open-source 3D probabilistic geological and geophysical modelling platform
- Implicit interpolator built into the LoopStructural module
- Accounts for inequality constraints – adding bounds to the models



● Equality/base

■ Inequality/within

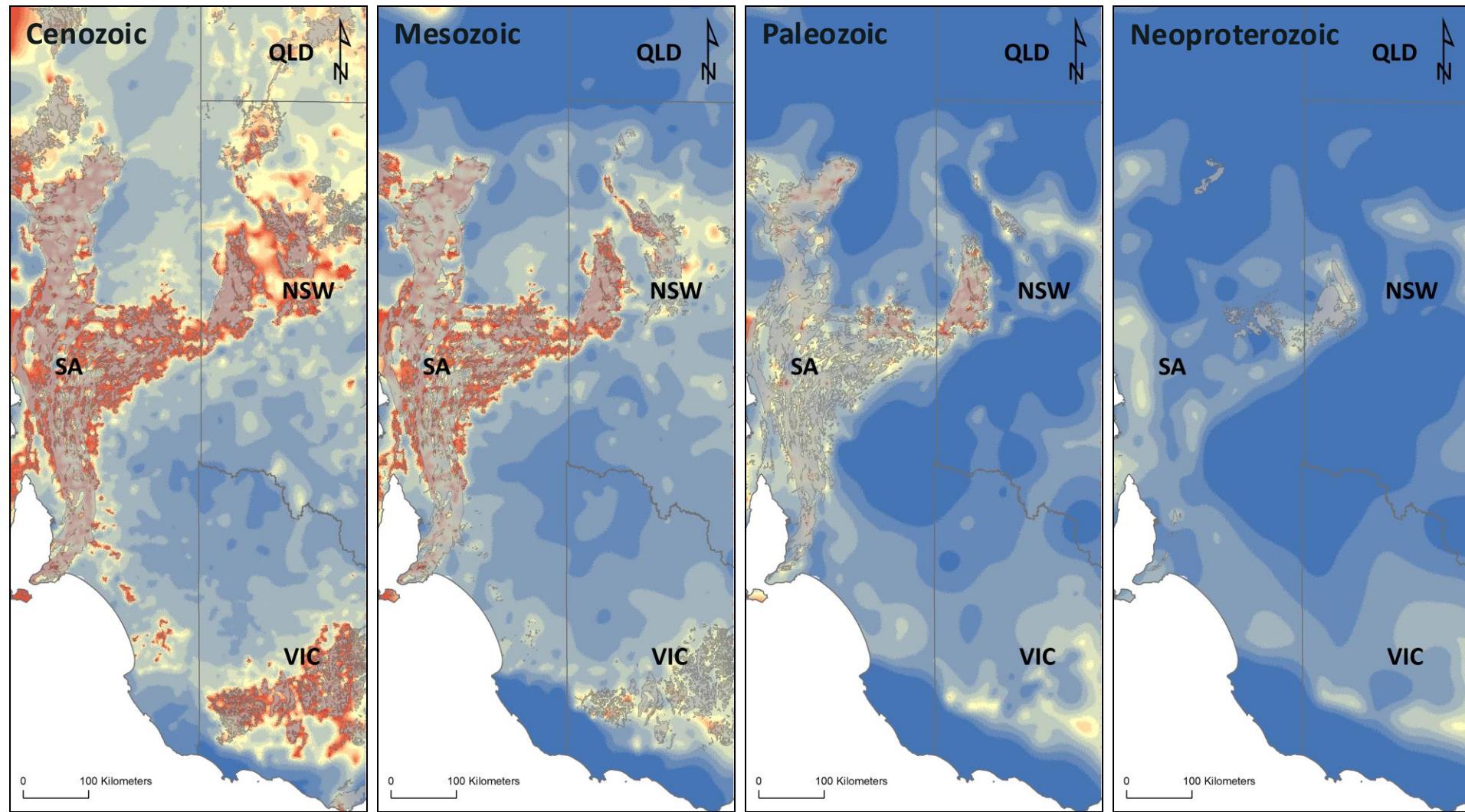
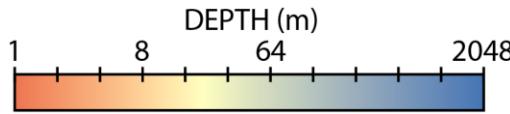
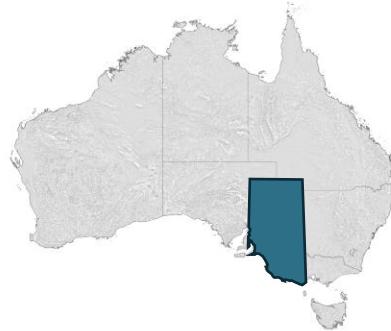
**GitHub** - [github.com/Loop3D/](https://github.com/Loop3D/)



# Darling-Curnamona-Delamerian (DCD) – Loop layered cover models

DCD depth estimate points  
and cover model grids

- Loop 3D software
- Multilayered cover models
- Base of geological eras
- Top-down modelling approach



- Equality/base
- Inequality/within

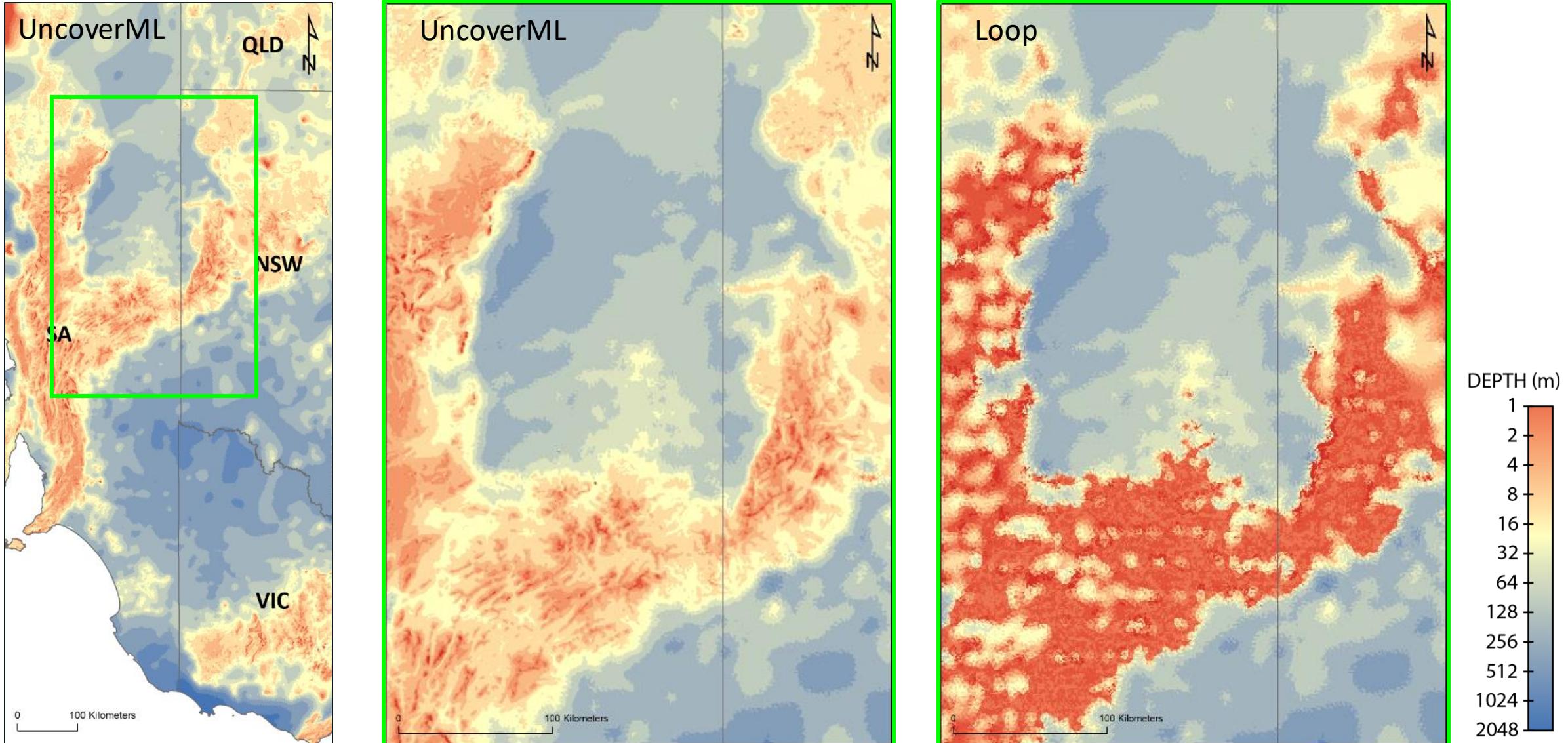


Outcrop older than modelled boundary

Bonnardot et al., 2024



# UncoverML Base of Cenozoic model – twin model approach



Extended Abstract: [doi.org/10.26186/149719](https://doi.org/10.26186/149719)

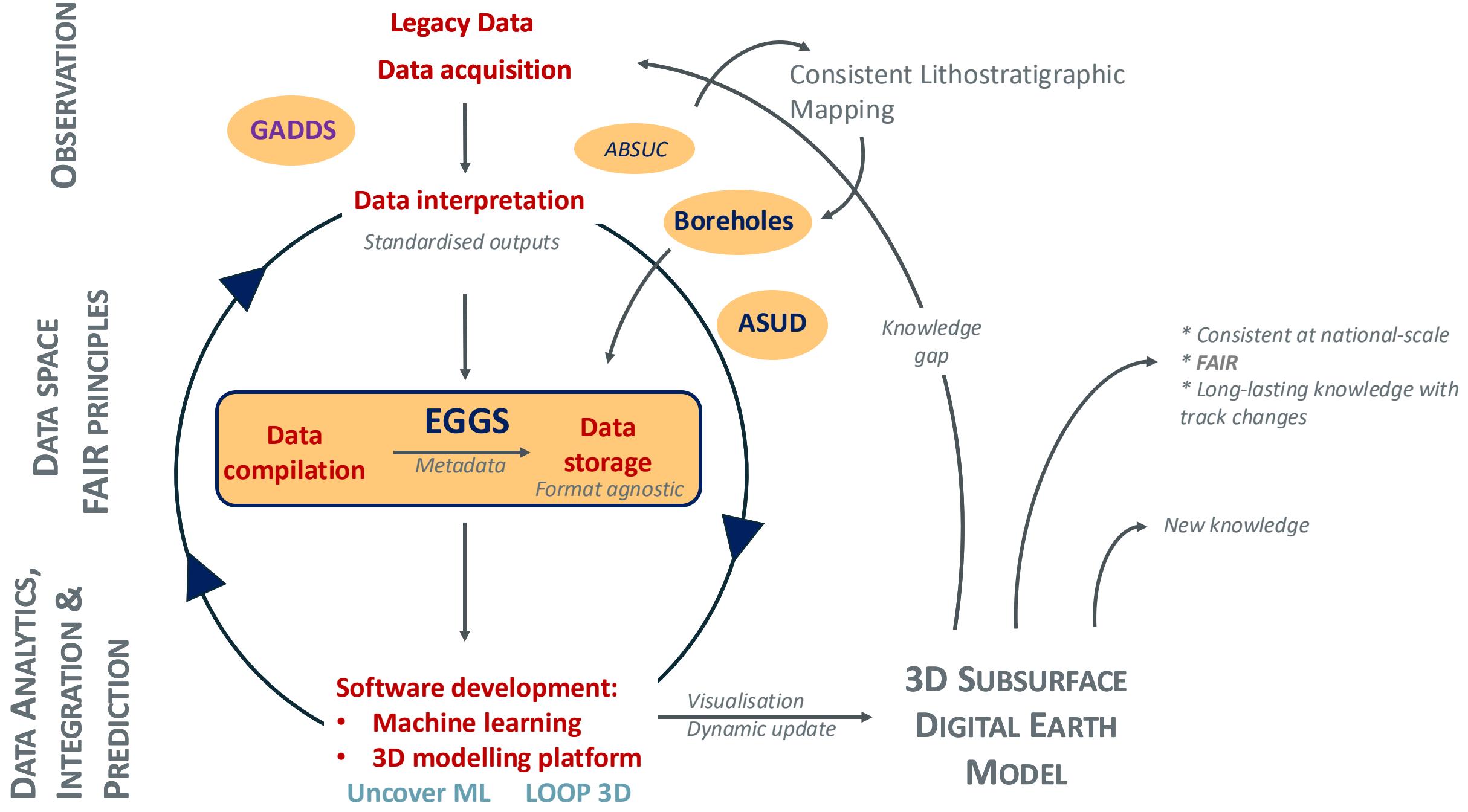
Bonnardot et al., 2024



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# Geoscience Australia's 3D data portal

The screenshot shows the Geoscience Australia 3D data portal interface. On the left, there is a sidebar with various controls and a search bar. The main area displays a 3D geological model of Australia and the surrounding oceans. A red arrow points to the 'Tools' button in the top right corner, which is circled in red.

**Australian Government  
Geoscience Australia**

**Geoscience Australia Portal**

[About](#) [Layers](#) [Location Search](#) [Data & Publications](#)

**Layers** [Map Layers](#) [3D Layers](#)

Ground Opacity: 50%

Show Stars:  On

Auto Rotate: Left  Off  Right

Vertical Exaggeration: Model  x29  Link Terrain  x29

Search 3D Layers  Search ...

**000\_STAGING**

- Boreholes, Drill Holes and Wells
- Elevation and Depth
- Geology
- Geophysics
- Hazards, Scenarios and Risks
- Mines, Mineral Occurrences, Mineral Deposits, Mineral Resources and Mineral Potential
- Water

**Contact us** [Provide Feedback](#) [Questionnaire](#)

**Welcome back, Simon** ([Logout](#))

**Tools** [Clip](#)

**2D**

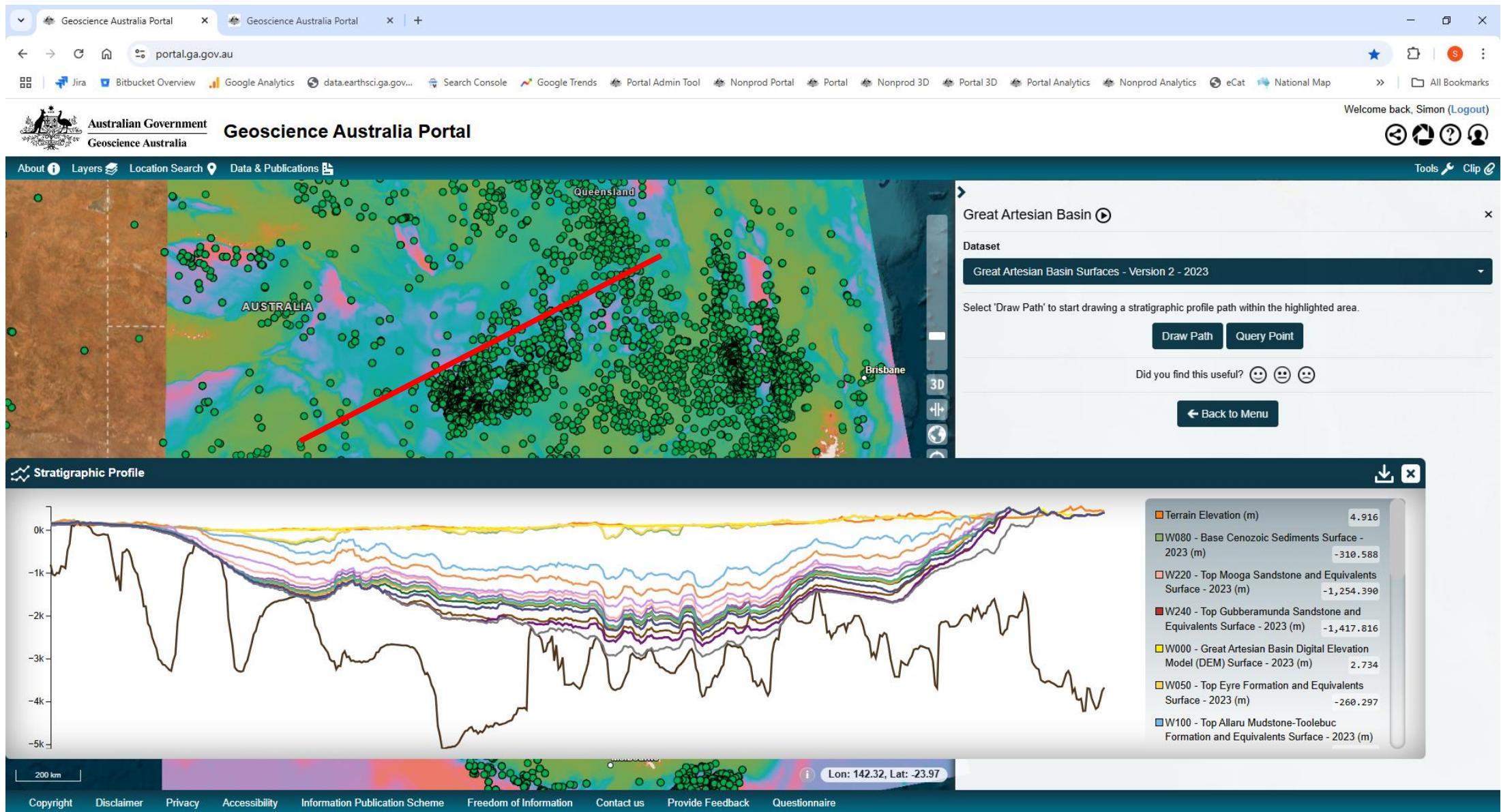


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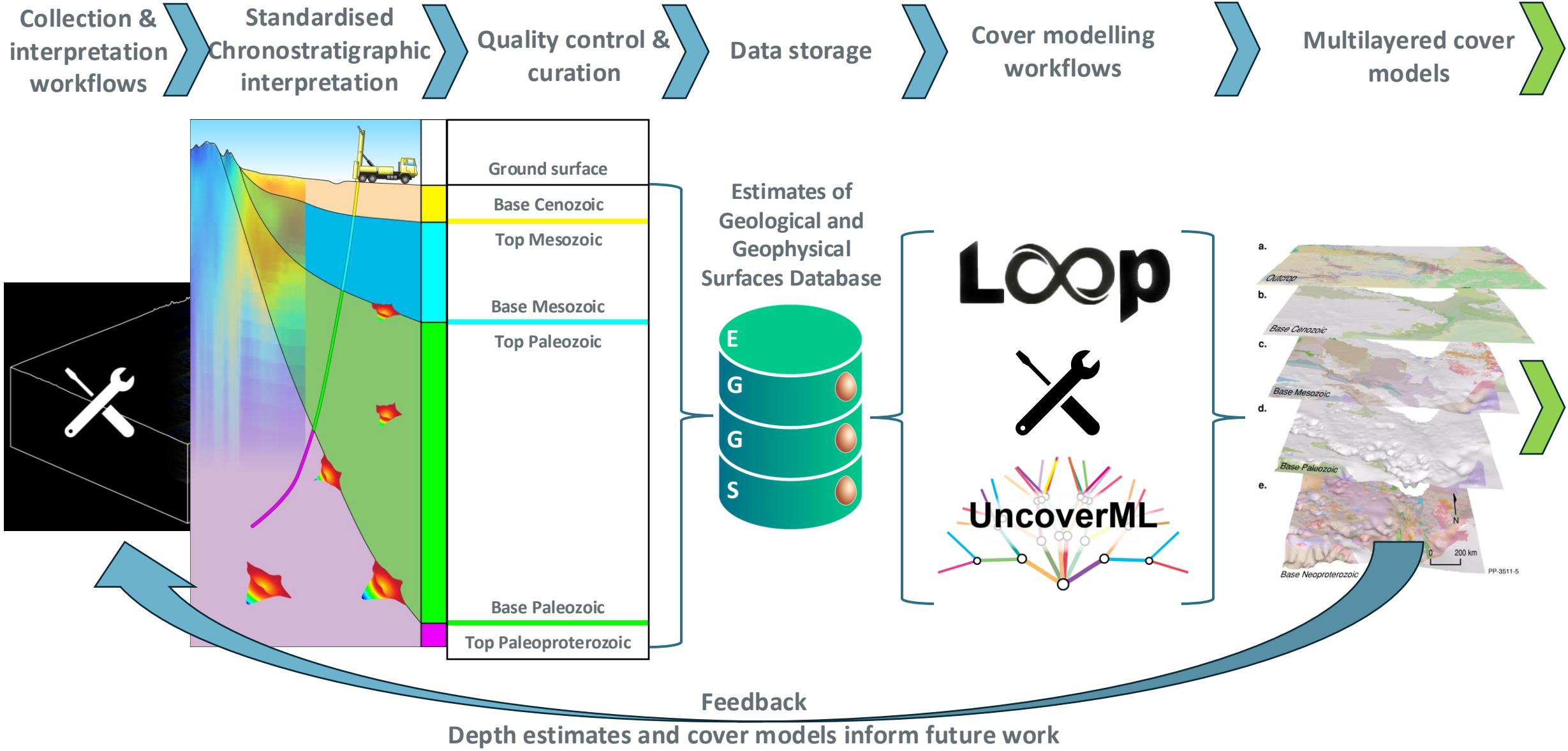
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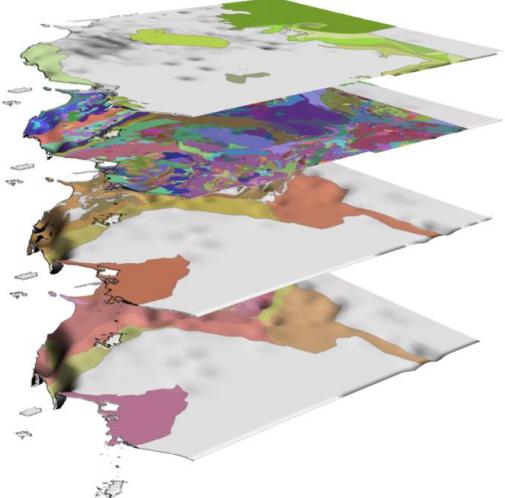
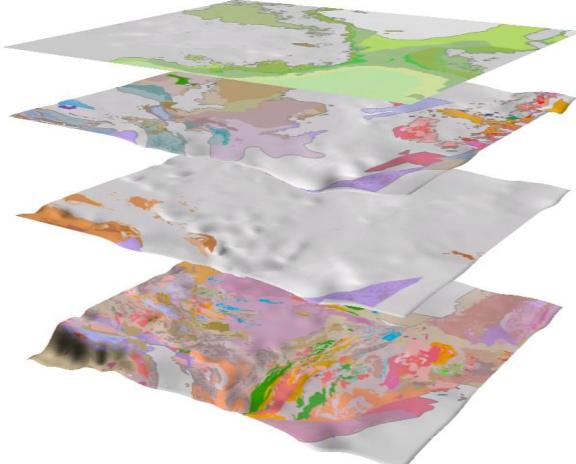
# Geoscience Australia's 3D data portal – Cross-section function



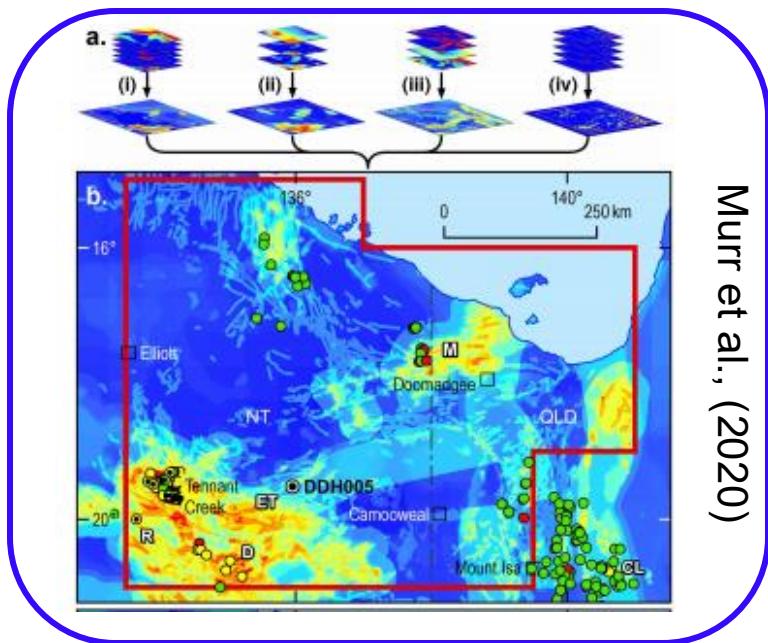
# Summary



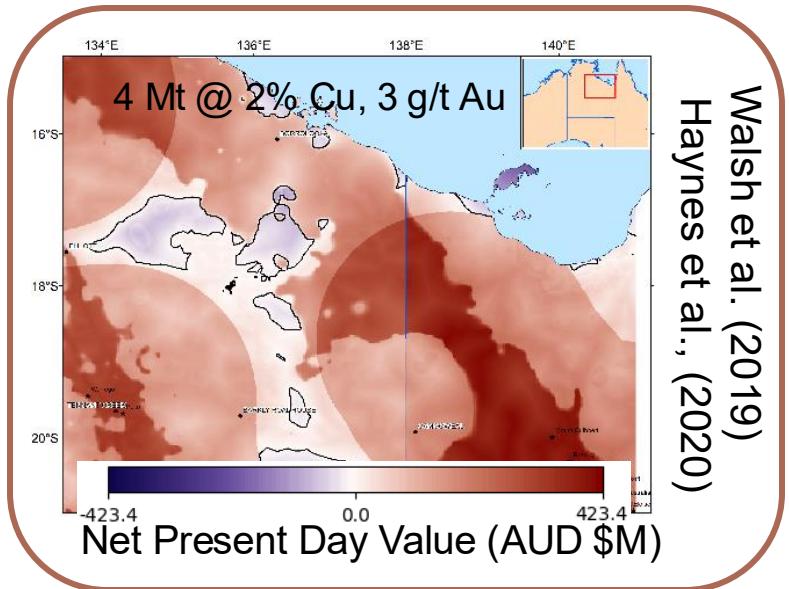
# Example application of 3D geology



Mineral potential  
mapping  
Layered geology



Economic Fairways  
*Cover model*



<https://portal.ga.gov.au/>

<https://www.eftf.ga.gov.au/economic-fairways>



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# Conclusions



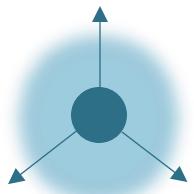
Quality over quantity



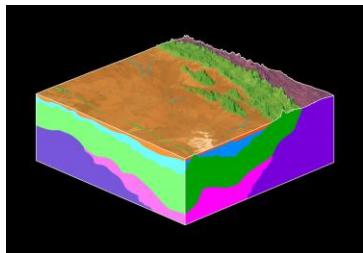
Establish common standards to improve data quality

Coordination of data compilation at national scale

Maintenance - Provide feedback to maintain currency



Uncertainties mapping, e.g. interpretation



Volumetric modelling, e.g. test new dataset

# Acknowledgements



Geological Survey of  
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MONASH University

Loop



GEOLOGICAL  
SURVEY OF  
South Australia



THE UNIVERSITY  
OF QUEENSLAND  
AUSTRALIA



MinEx CRC





Australian Government  
Geoscience Australia

Exploring for  
the Future

# Thank you!

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