An open innovation platform for deep time spatio-temporal knowledge-discovery

Dietmar Müller, John Cannon, Thomas Landgrebe, Michael Chin,
and many others
The University of Sydney

THE UNIVERSITY OF SYDNEY

EarthBYTE
Linking observations to kinematic and dynamic models

AuScope
Simulation & Modelling

Paleogeographic Information Systems

- Geographic information systems form a core part of Earth Science
- Allow the growing repositories of digital geo-data to be integrated and visualised in a unified fashion.
- Systems cope with the wide variety of spatial data types, each with their own properties and metadata, allowing for a better understanding of how Earth processes operate.
- A unique requirement for the Earth Sciences is to take into account plate motion and crustal deformation processes acting through time, thus altering the various spatial relationships between datasets.
- The open-source GPlates (www.gplates.org) infrastructure has become the leading, standard tool for this type of analysis, providing the ability to reconstruct various datasets through time by attaching arbitrary multi-dimensional data to tectonic plates.

GPlates Open Innovation Platform

- Developed originally as a standlone software, GPlates has gradually grown into an open innovation platform (AuScope, ARC LF)
- **Open-standards-based information model**, implementing **extensive data import/export capabilities**, developing an emerging **python plugin framework** and by establishing **links to web services**.
- Extensible platform allows users to explore the evolution of the entire Earth system in accordance with past tectonic plate configurations by **combining GPlates with a variety of research tools, data and workflows**.
- **GPlates applications** include deep earth dynamics, tectonics and continental margin reconstruction, evolution of continental stress fields, evolution of river systems and carbonate reefs, long-term sea-level change, basin evolution, mountain building processes, continental paleogeography, and the evolution of climate and ocean circulation.

Solid Earth e-geoscience drivers

- Understanding the evolution of the Australian continent its internal boundaries, and its offshore territories, in a global and a deep Earth context

- Understanding the geodynamic context of mineral and energy systems in their original geological settings

- **Need to amalgamate an enormous diversity of data for joint analysis and modelling, towards construction of predictive models**

UNCOVER
AUSTRALIAN EXPLORATION GEOSCIENCE RESEARCH

SEARCHING THE DEEP EARTH

A VISION FOR EXPLORATION GEOSCIENCE IN AUSTRALIA

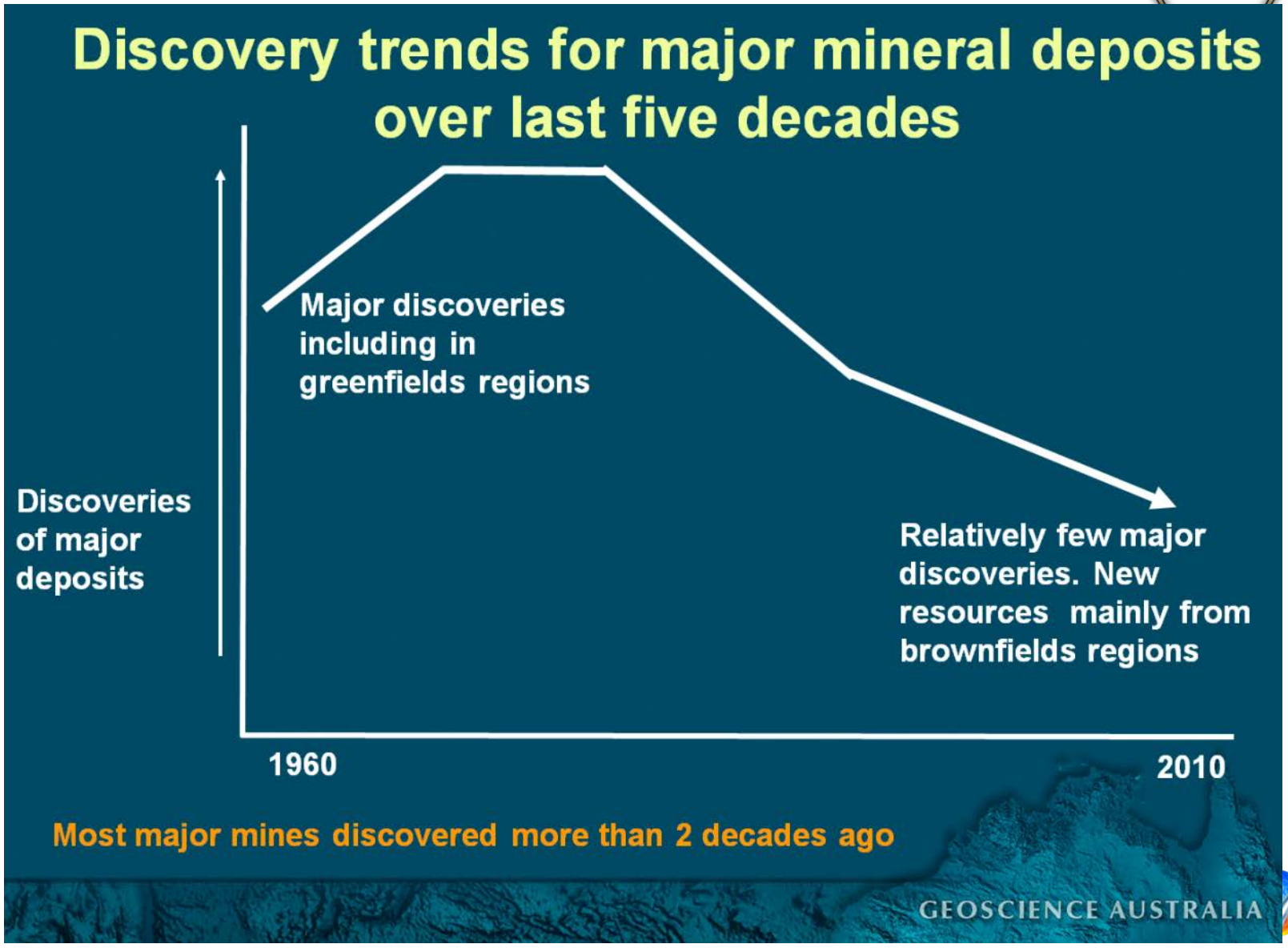
Prepared by UNCOVER under the aegis of the Australian Academy of Science

In 2010 the Academy hosted its annual High Flyers Think Tank on *Searching the Deep Earth: The Future of Australian Resource Discovery and Utilisation.*

A valuable opportunity for 60 of Australia's leading early and mid career researchers to identify and propose new directions for Australian minerals exploration research.

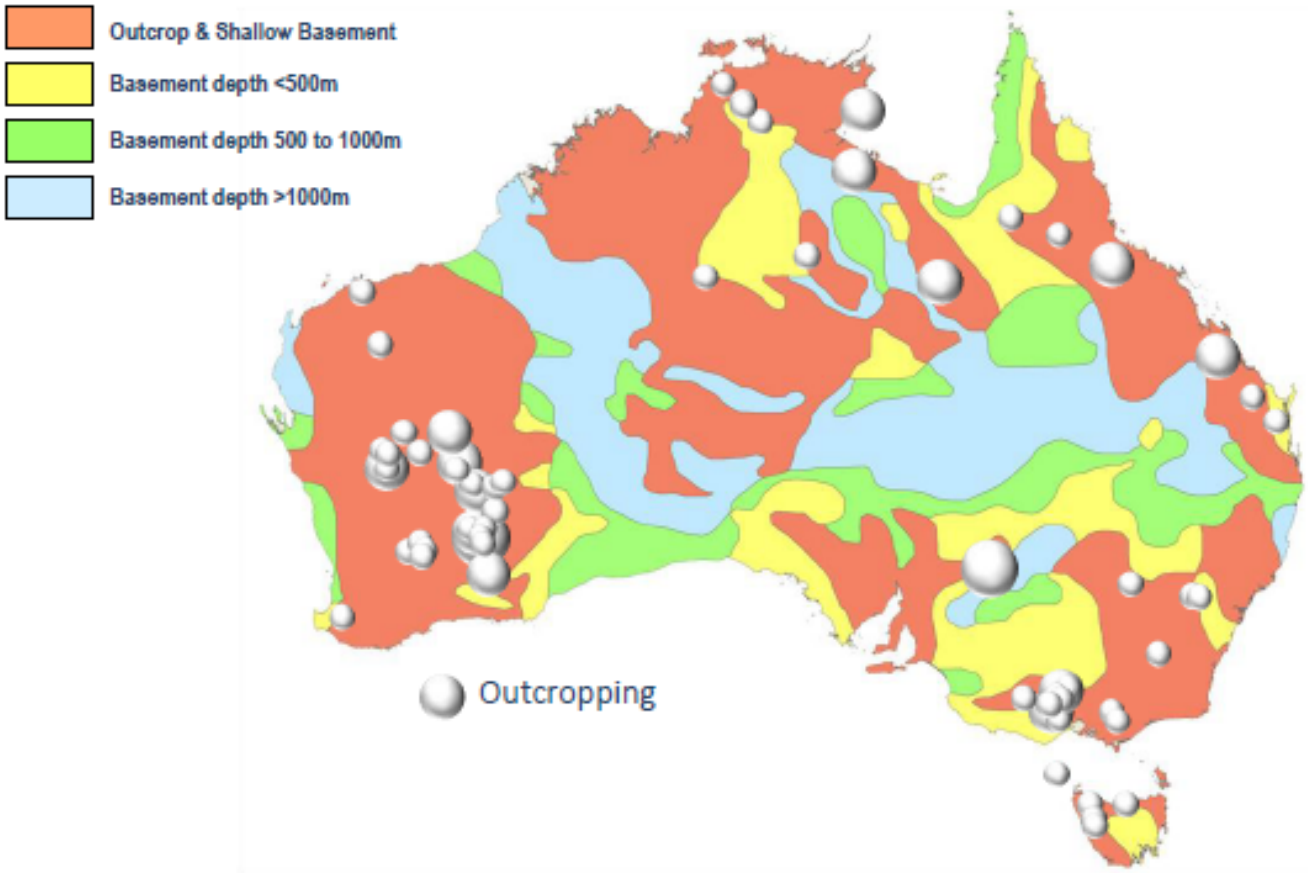
Participants identified new approaches, technologies, data management systems, and policy innovations to facilitate the science necessary to deliver a better understanding of the deep earth and ultimately help to maintain mining productivity into the future.

Lambert, 2010



Major mineral deposits in Australia

Depth of cover

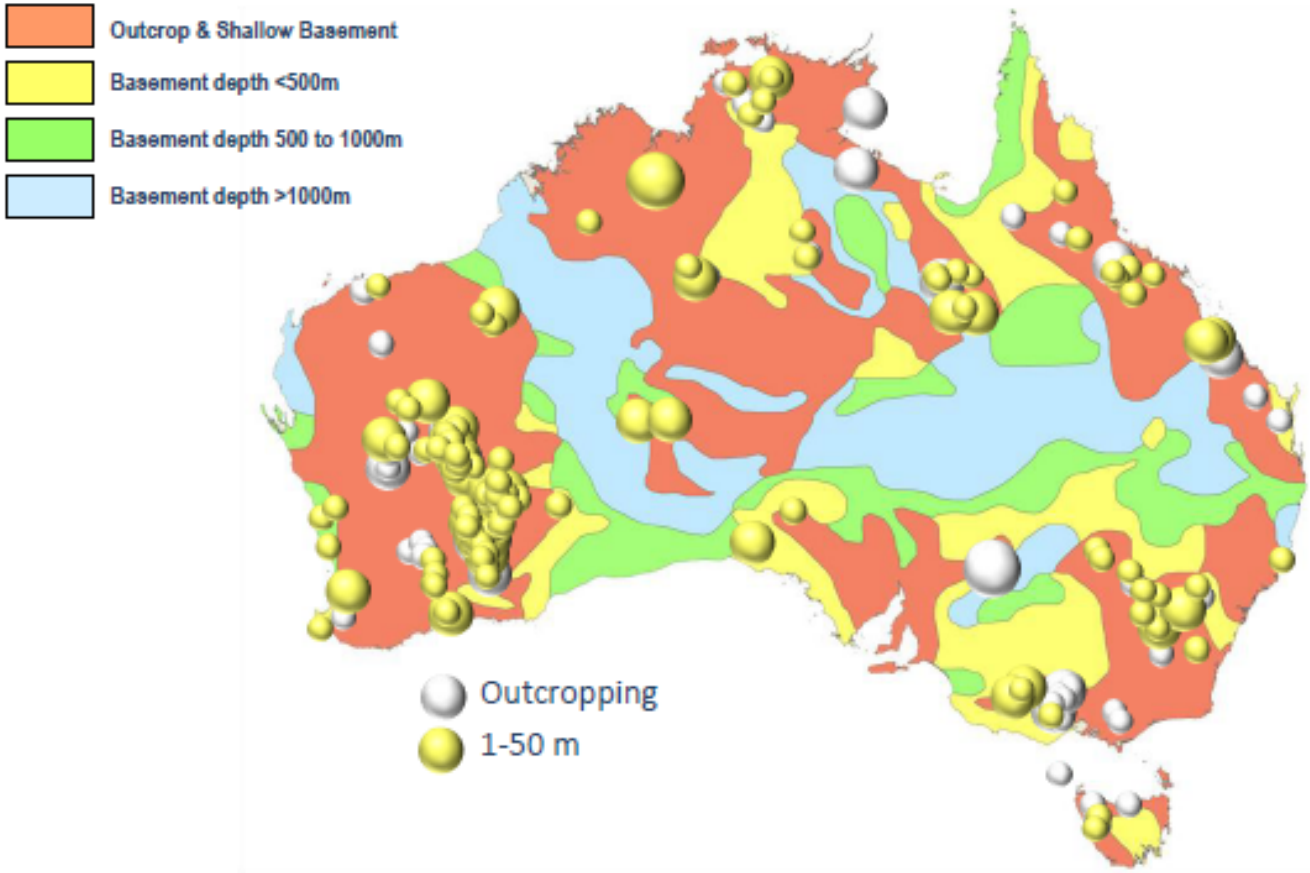


Note: Major defined as >1 moz Au, >1mt Cu, > 100kt Ni or equivalent
Excludes Bulk Minerals such as Coal, Bauxite and Iron Ore

Sources: MinEx Consulting August 2010
Geoscience Australia

Major mineral deposits in Australia

Depth of cover



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Major mineral deposits in Australia

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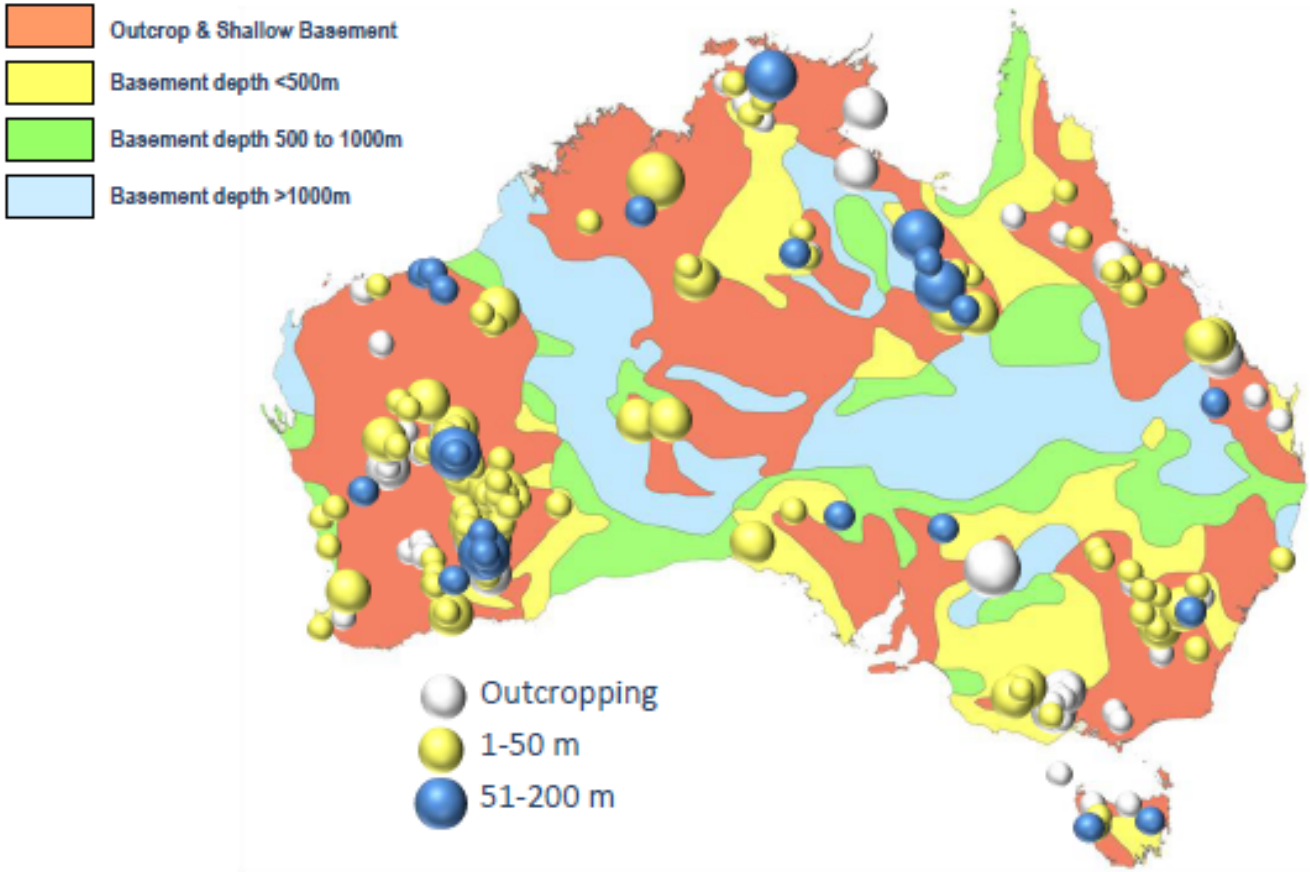

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Major mineral deposits in Australia

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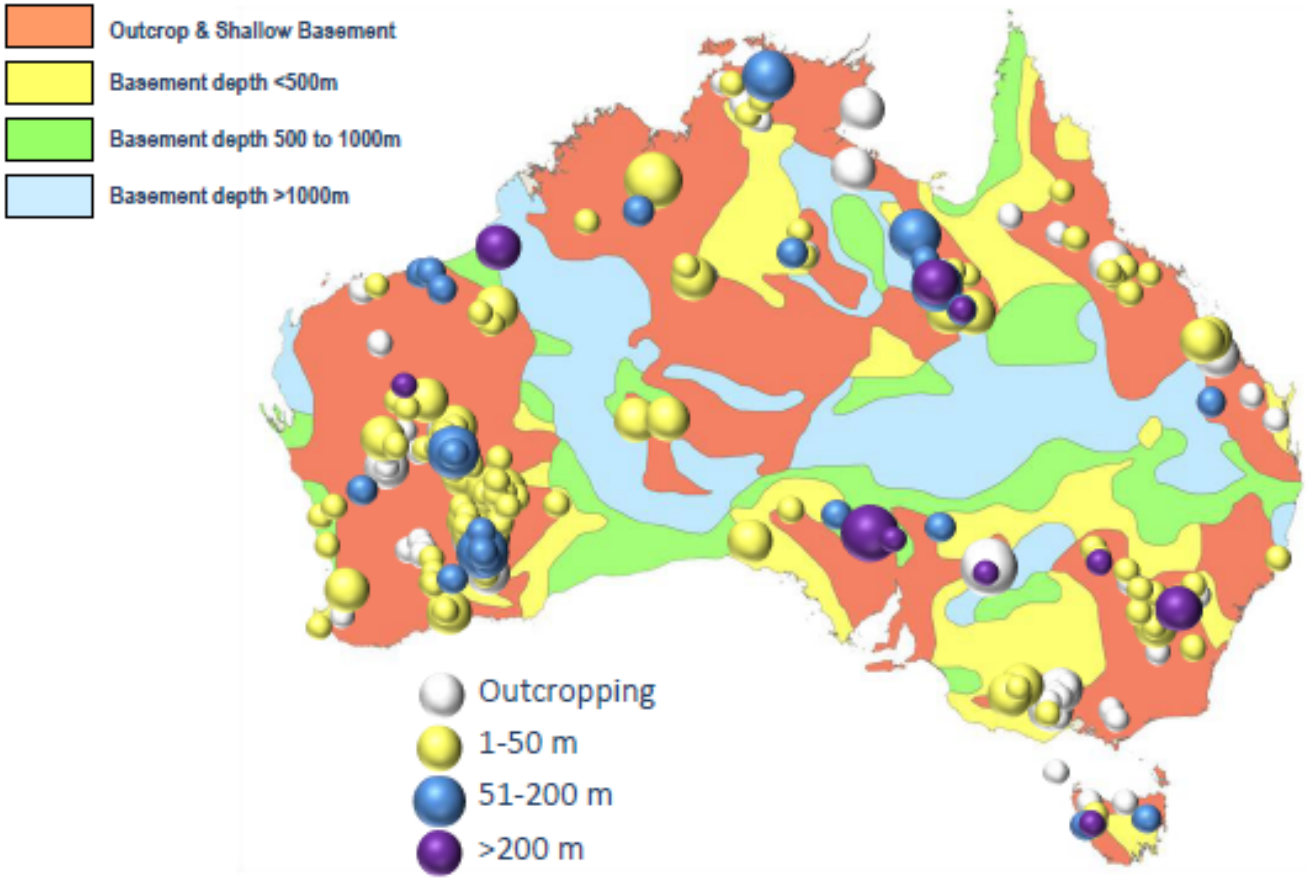
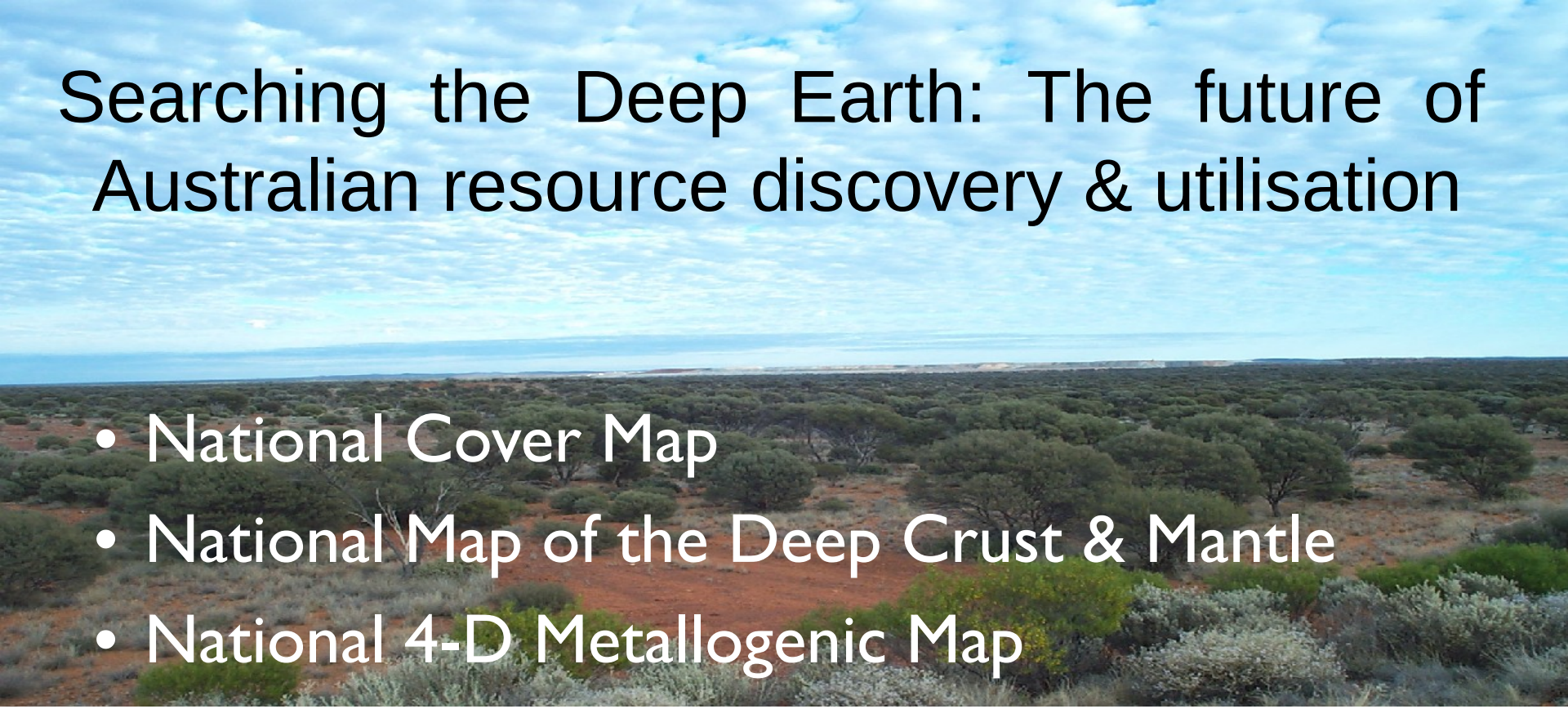


Note: Major defined as >1 moz Au, >1mt Cu, > 100kt Ni or equivalent
Excludes Bulk Minerals such as Coal, Bauxite and Iron Ore

Sources: MinEx Consulting August 2010
Geoscience Australia

Searching the Deep Earth: The future of Australian resource discovery & utilisation



- National Cover Map
- National Map of the Deep Crust & Mantle
- National 4-D Metallogenic Map
- National Distal Footprints Map
- National Researcher Network
- National Education Outreach & Transfer Program

GPlates history and specs

- 10+ years of development, starting in 2003
- Collaborative development includes Caltech, NGU and TUM
- Open-source and platform-independent
- Information model and file format based on Geographic Markup Language (GML, ISO standard)
- Interoperability with ArcGIS and QGIS (shapefile I/O)
- Interoperability with netcdf grids (raster data standard)
- Interoperability with open source data-mining software (Orange) underway
- Linking to web feature services (WFS) underway
- GPlates service on NCI's MASSIVE system

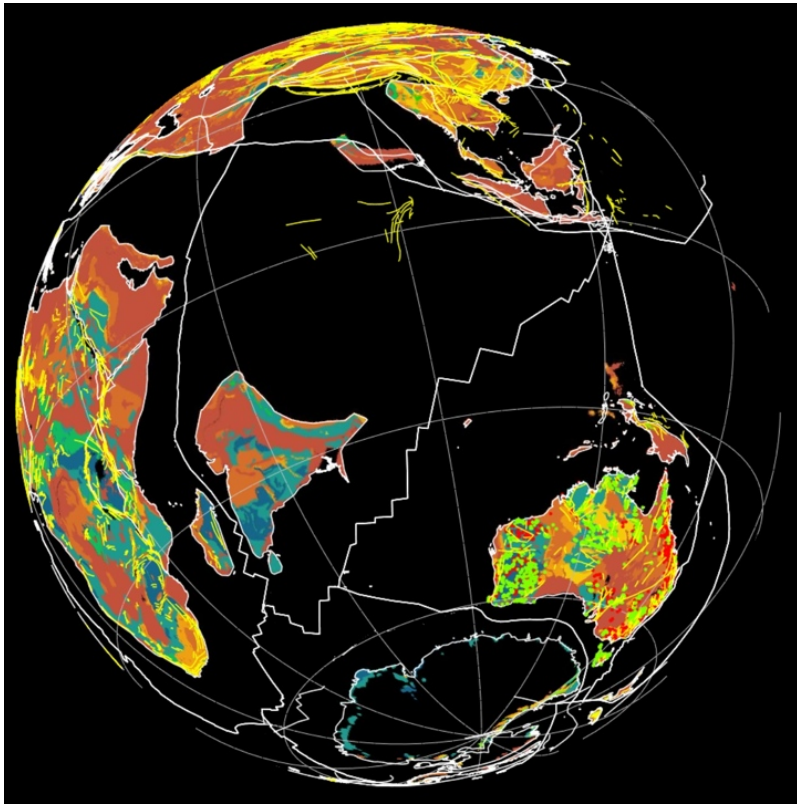
GPlates workflows and extensions

- Workflows for linking tectonic models via GPlates to **HPC codes**: **CitcomS, Terra, Boundary Element Code (BEM), Slim3D, Rhea**
- **Additional links to many other codes** established or underway (Underworld, Tellus, Madagascar, GoCAD, ArcGIS, Quantum GIS, Generic Mapping Tools, Orange data mining)
- **Links to various web feature services and online databases underway** (e.g. paleobiology, paleomag, GA data); future: VGL data
- **Python plugin infrastructure** under development will enable easy interoperability with other codes such as escript and data sources, EarthScope interoperability
- Users can **build regional or global models**, import their own data and digitise features in a "Paleo-GIS" environment

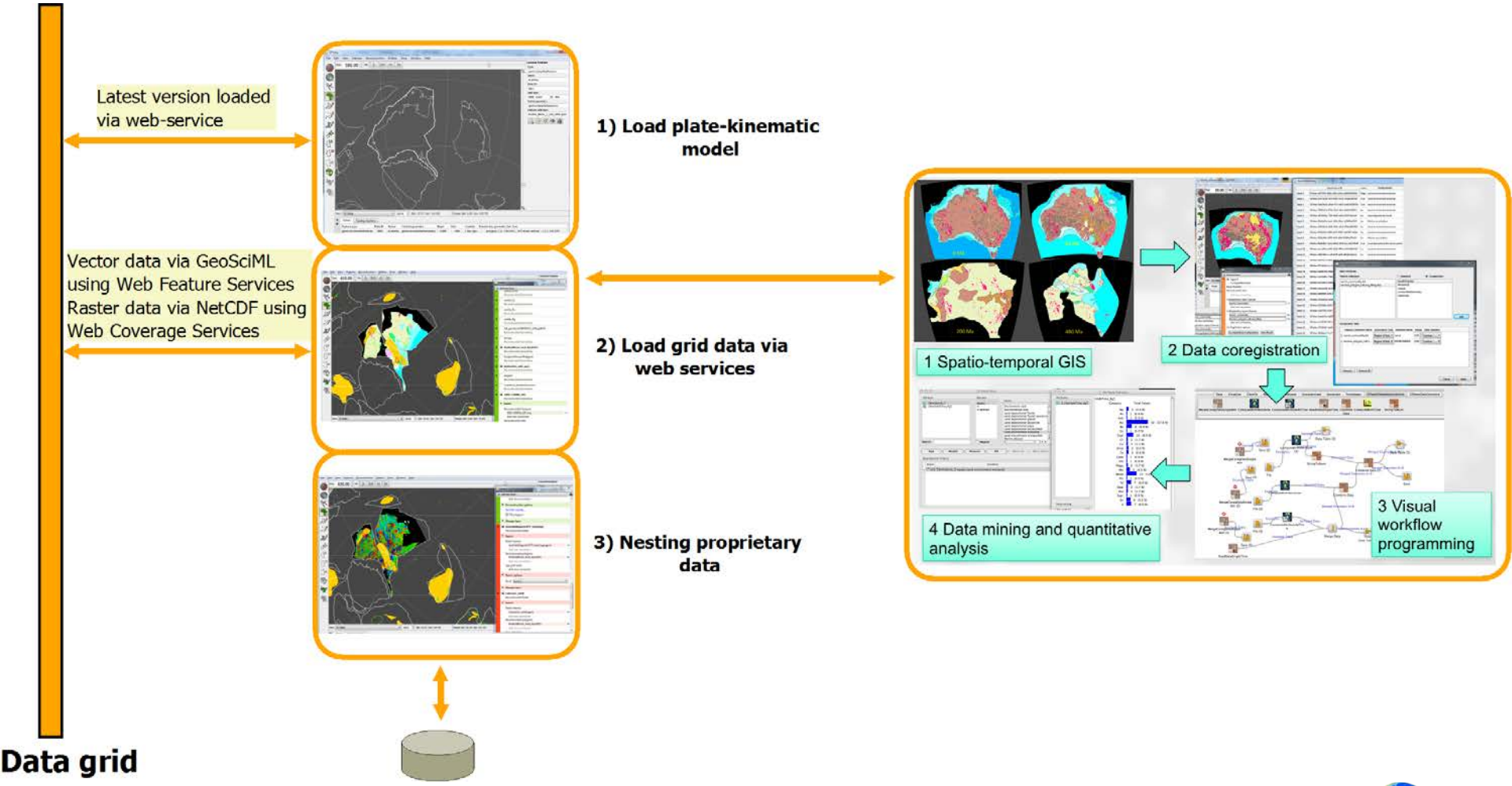
Who uses GPlates ?

- > 30,000 downloads
- Users in 137 countries

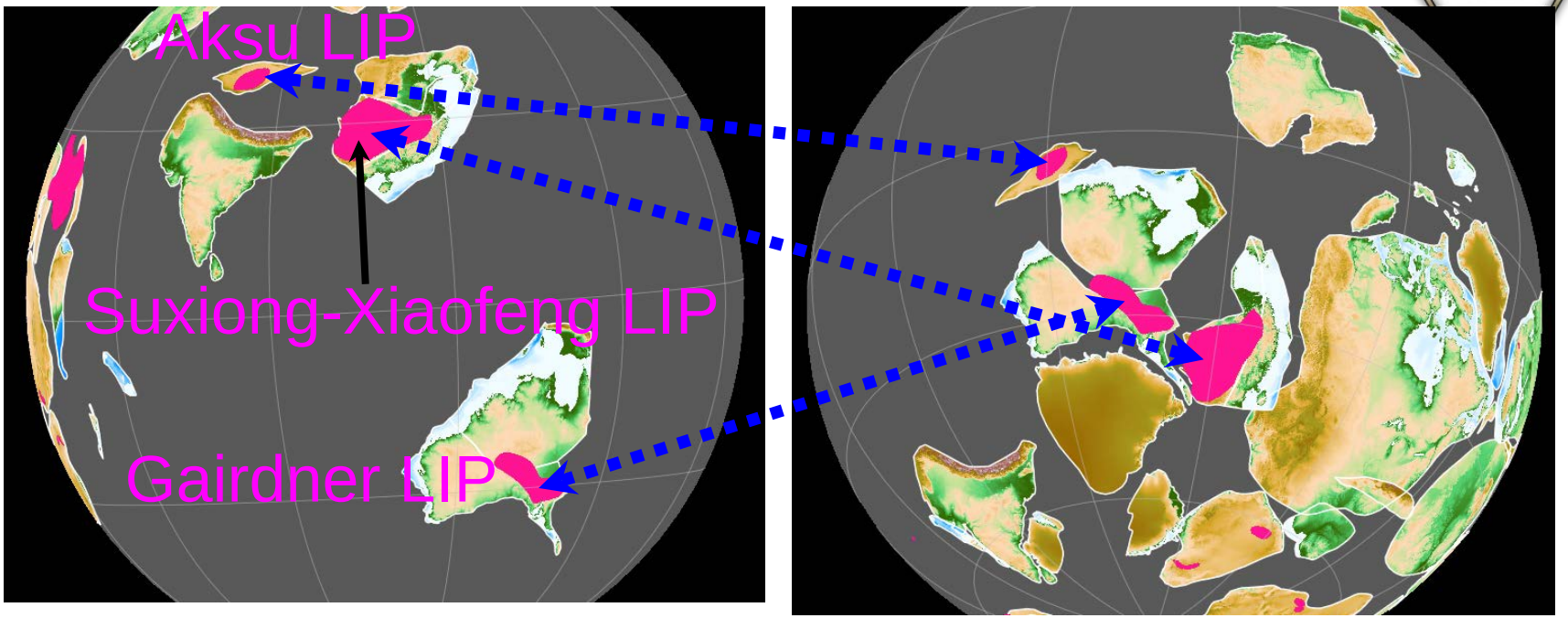
- Anyone who studies the Earth back through time
- Geologists and Geophysicists, Plate modellers, Geodynamicists, Resource Exploration
- Paleogeographers, Paleoceanographers, Paleobotanists
- Educational Tool



GPlates Interoperability



Spatio-temporal data-mining



Large igneous provinces at 820Ma (no reconstruction)

Large igneous provinces at 820Ma (Rodinia reconstruction)

- Data mining is about finding **patterns in complex data**
- In exploration we need to consider Earth's plate tectonic history to reveal them – in this case the plate alignment at 820 Ma reveals a single, giant magmatic event

Data-mining – SMH, 12 May 2012: "Data miner is the hottest new job you've never heard of"

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Digging for data the new mining boom

Catherine Armitage, Nicky Phillips
May 12, 2012

Read later

"Big data is the new business black" ... enterprises will invest more than $US120 billion by 2015 in data capture and analysis across hardware, software and services.
Photo: istock

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There's another mining boom you may have missed. It too involves paying young people six-figure salaries in their first jobs, and exploring deeper for resources which may have been previously overlooked. But it's not about driving trucks or digging holes. It's about building algorithms and crunching facts and numbers. It's mining for data.

"The whole place is big data mad. Industries like banking, insurance, and increasingly pharmaceuticals are competing on the back of predictive models that get built by mining data."

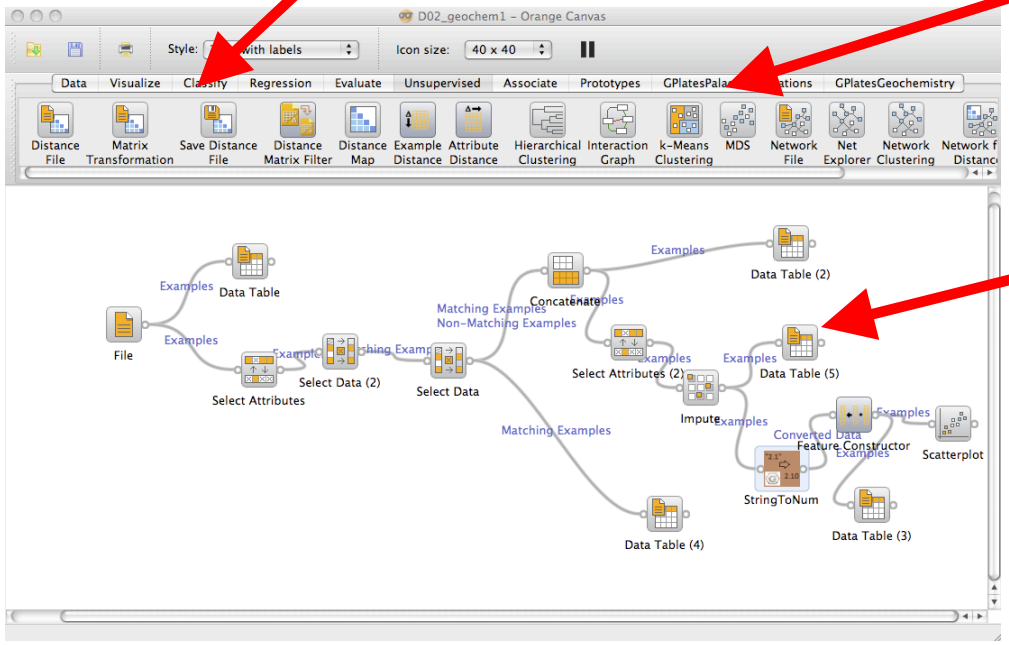
Data-mining library options

Library	Functionality	Flexibilty/ Extensibility	Compatibility	Usability	Licensing/platforms
PRTools	Excellent	Excellent	No - Matlab	Experts only	Library open but Matlab commercial
AiLab Orange	Good	Excellent – has plugin infrastructure, plotting tools, scipy, numpy	Yes - python	Visual programming environment to abstract complexity	Open source, cross-platform
Weka	Very good	Excellent – has plugin infrastructure	No - Java	Visual programming environment	Open source, Java i.e. cross platform
RapidMiner	Excellent	Excellent – but biased towards statistics, not signal processing	No - Java	Visual programming environment	Open source and commercial options
MDP	Limited	Good	Yes - python	Experts only	Open source, cross platform
Waffles	Limited	Limited	Yes – C++	Experts only	Open source, cross platform

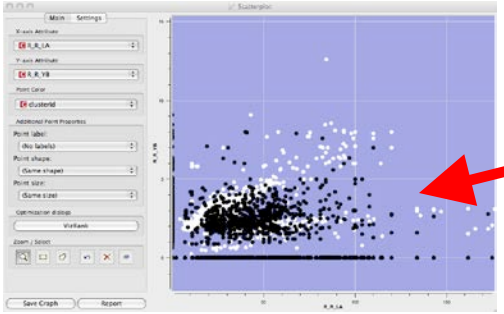
AILab Orange

Several data-mining plugins including data manipulation, supervised/unsupervised classification, plotting tools etc

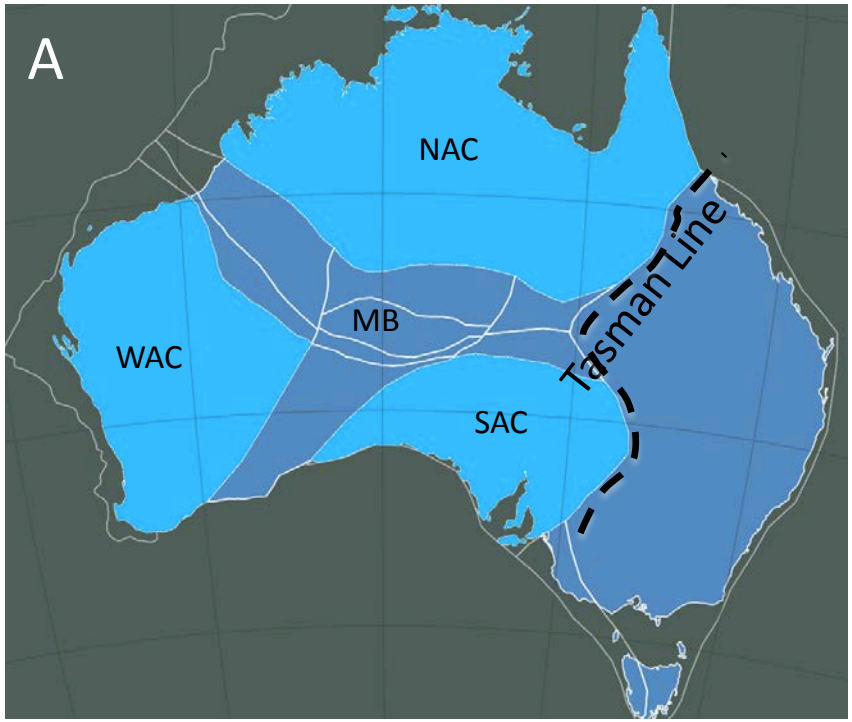
Make your own “widgets” by writing Python scripts e.g. GPlatesPalaeoAssociation plugin has widgets to analyse a timeseries



Visual programming canvas – can abstract complexity.



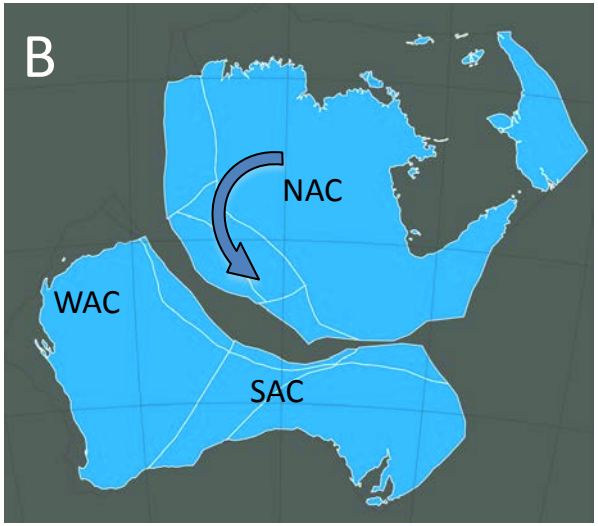
Python Matplotlib is used to create useful plots e.g. scatterplots

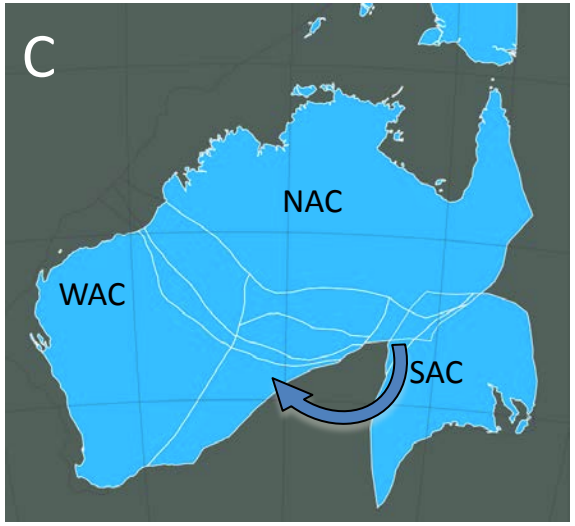


Cratonic Blocks of Australia, simplified after Myers et al (1996). Brighter blue areas are cratonic blocks the North, South and West Australian Cratons (NAC, SAC and WAC respectively). Darker blue areas comprise Proterozoic and younger units, subdivided to allow these units to be attached to different cratons in the alternative reconstruction models. MB = Musgrave Block.

Crust to the east of the Tasman Line formed by Phanerozoic accretion. (b-d) different plate reconstruction scenarios proposed for Australia since the early Mesoproterozoic (~1600 Ma).

(b) after Li and Evans (2011), a 40° rotation of NAC;
(c) Giles et al (2004), 52° rotation of SAC;
(d) after Henson et al (2011), translation of NAC relative to WAC and SAC.

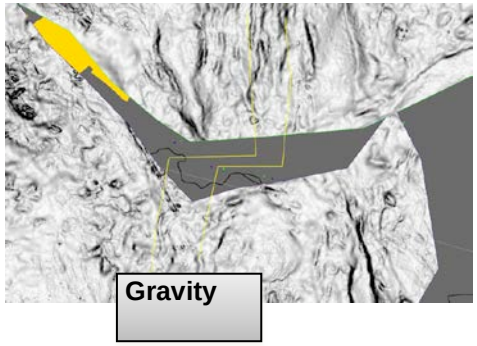


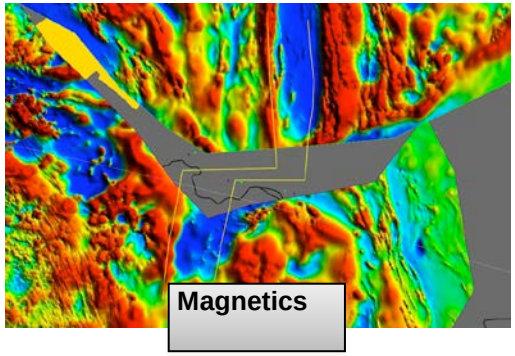


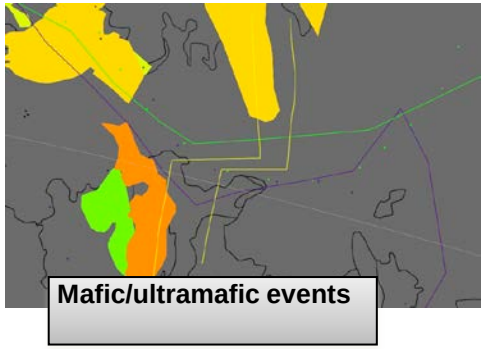
Spatio-temporal data miner

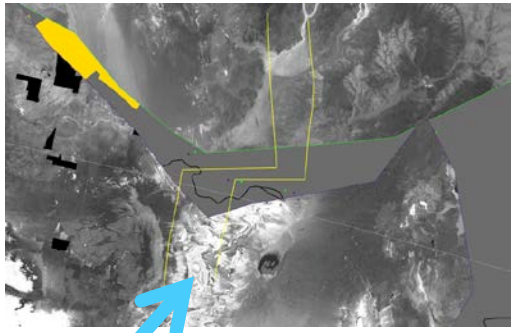
- Can help to derive a candidate plate motion model

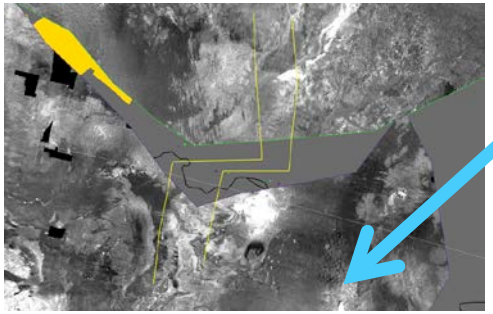
Develop candidate plate configurations



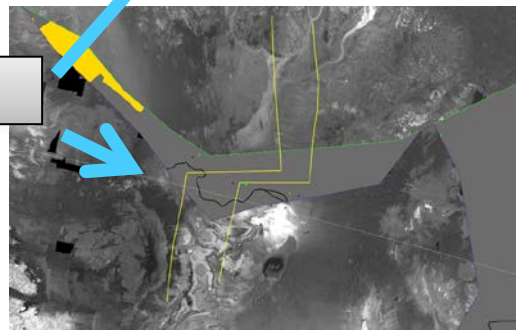


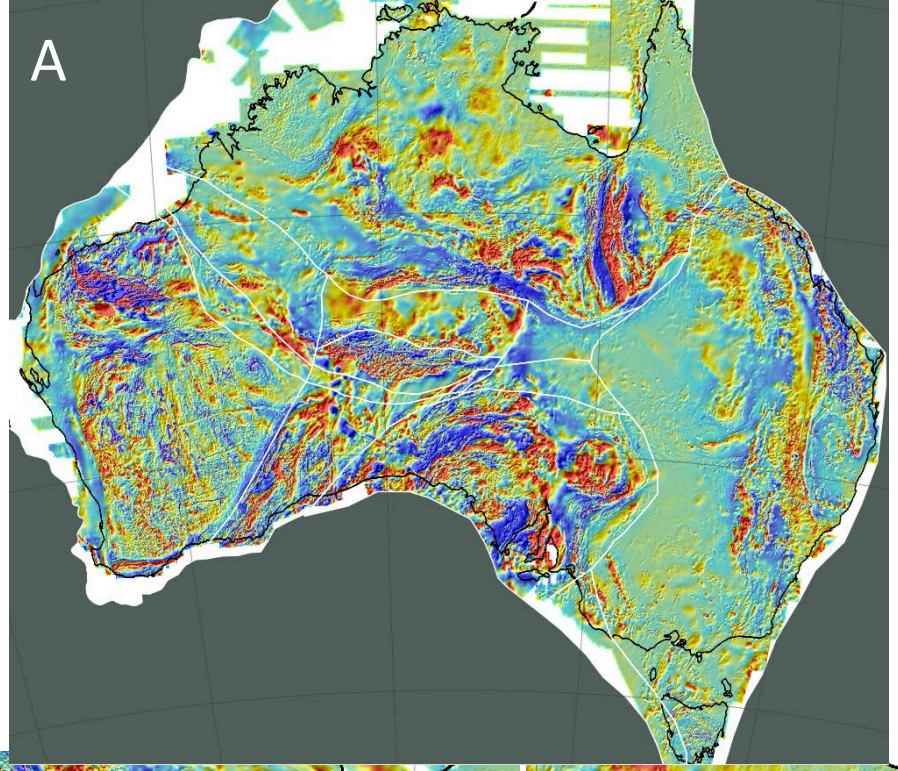




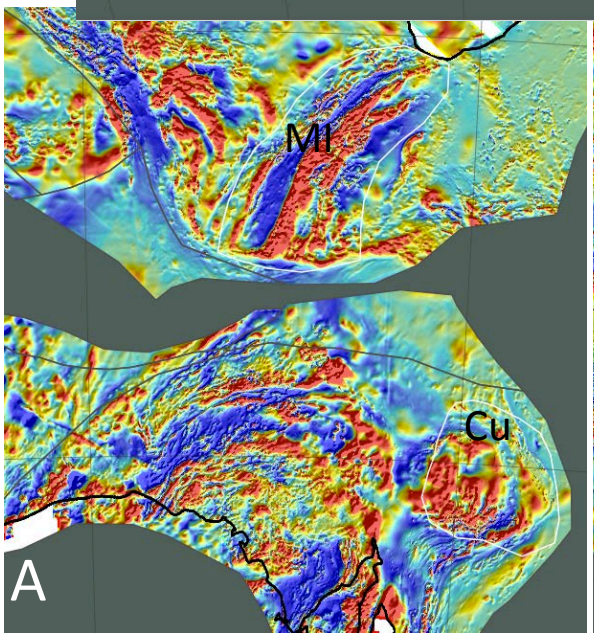


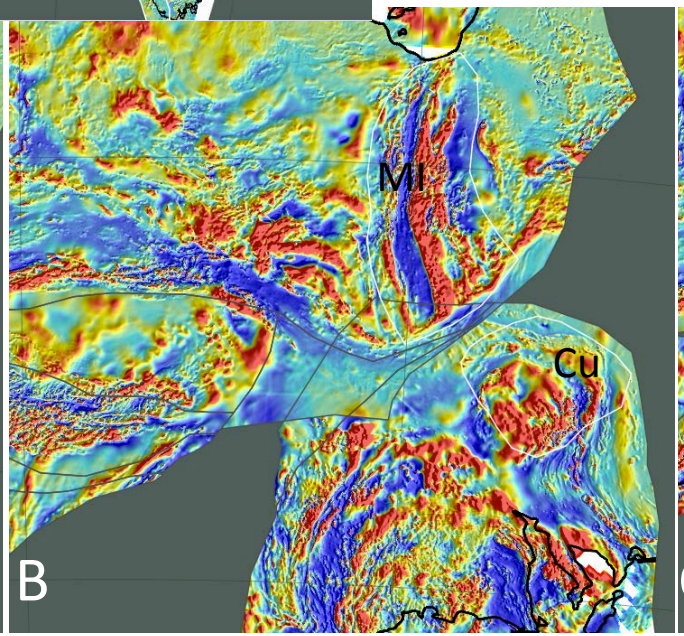
Radiometrics

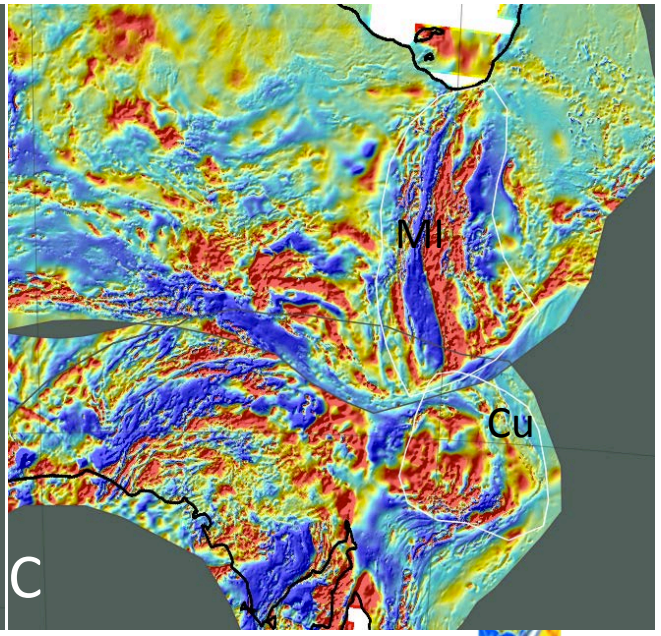




(a) Reduced-to-pole magnetic anomalies for Australia. Data are taken from the Australia magnetic compilation and a variable inclination reduction-to-the-pole applied to remove inclination-dependence of the shape of induced anomalies (Milligan 2011, pers comm.)
(b-d) Magnetic data from (A) reconstructed using 3 candidate plate configurations shown in figure 4;
(a) after Li and Evans (2011);
(b) Giles et al (2003);
(c) after Henson et al (2011). White outlines show the Curnamona Province (labelled Cu) and Mount Isa Block (labelled MI).







Testing of alternative supercontinent reconstruction hypotheses: Rodinia

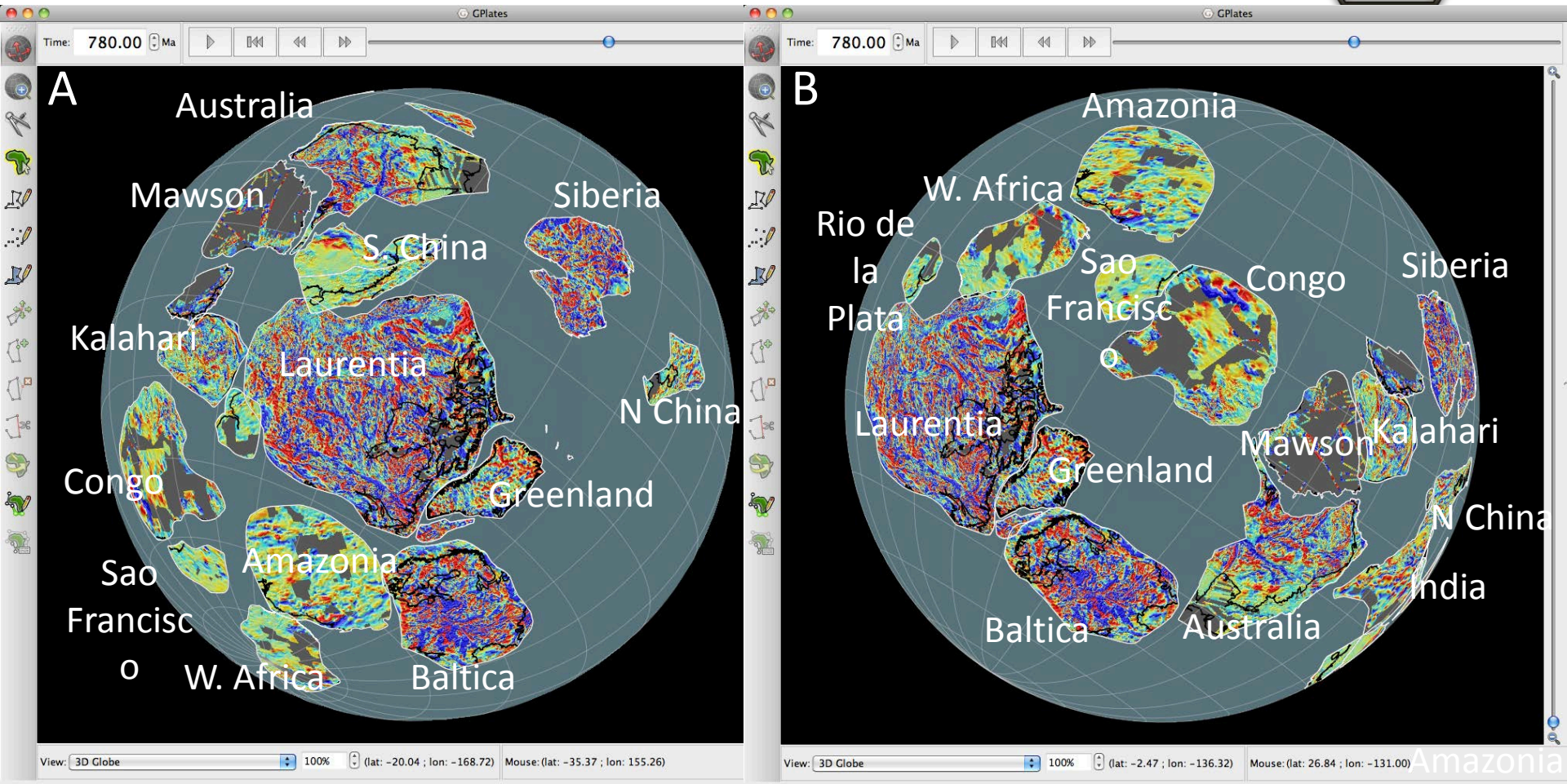
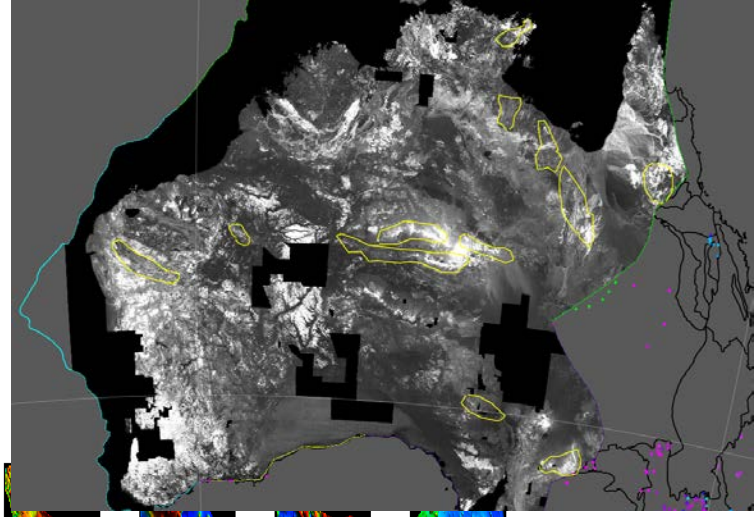
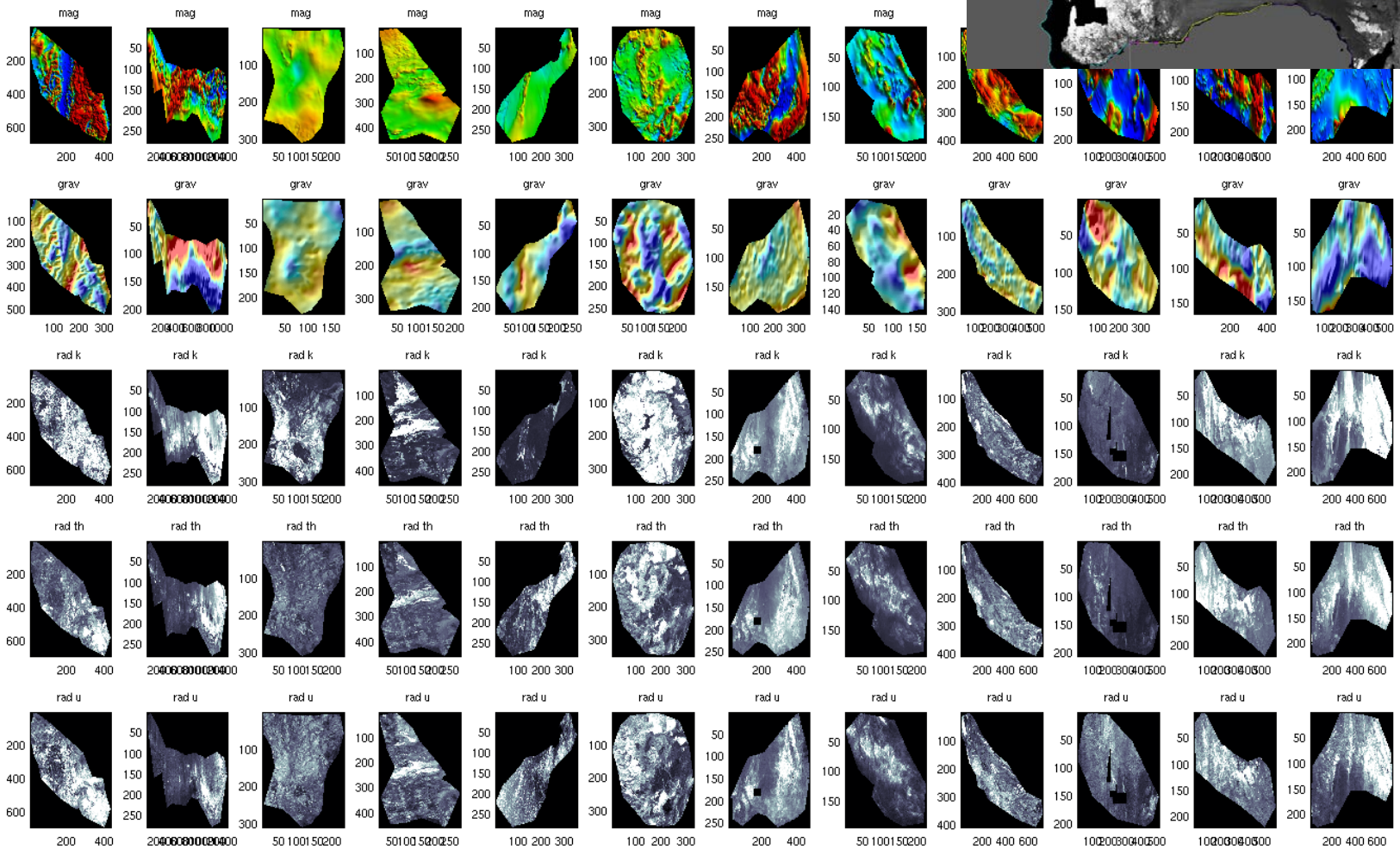


Plate Tectonic reconstruction in GPlates at 780 Ma, (a) is based on the block definitions and poles of rotation of Li et al (2008); (b) uses the same block definitions but the poles of rotation of Evans (2009). The data are the world magnetic anomaly map (EMAG2, Maus et al 2009).

Spatio-temporal data miner

- Analyse data from many crustal fragments, eg those formed between 1.7 and 1.5 Ga (share event chronology segments)





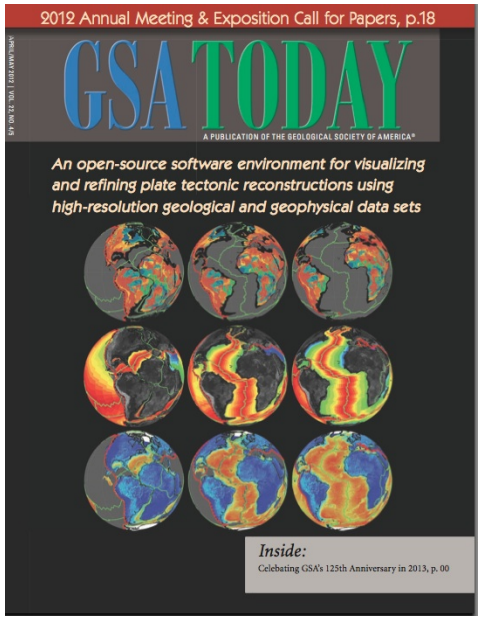
Magnetics

Gravity

Radiometrics, Potassium

Radiometrics, Thorium

Radiometrics, Uranium



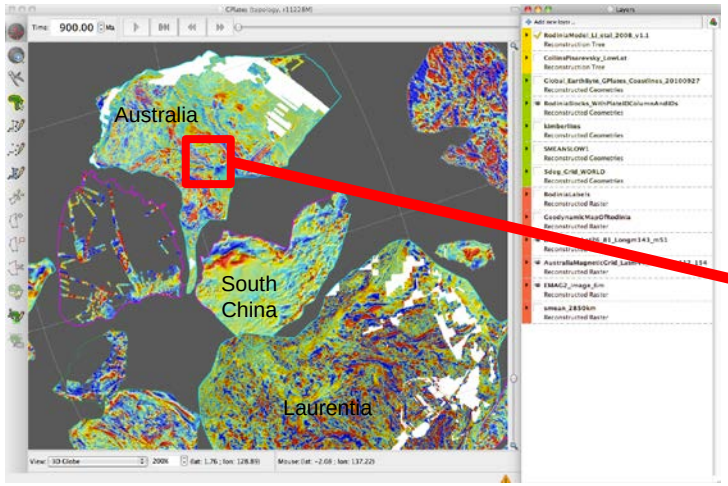
4-D Metallogenic Maps

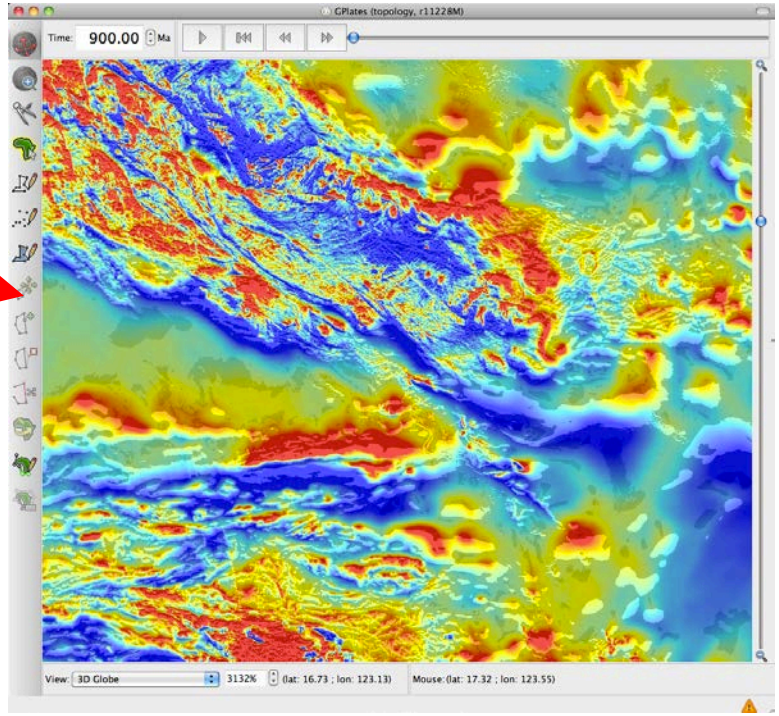
Constrain reconstructions
beyond the Phanerozoic

Palaeo-alignments

Age-tag mineral systems

Prediction

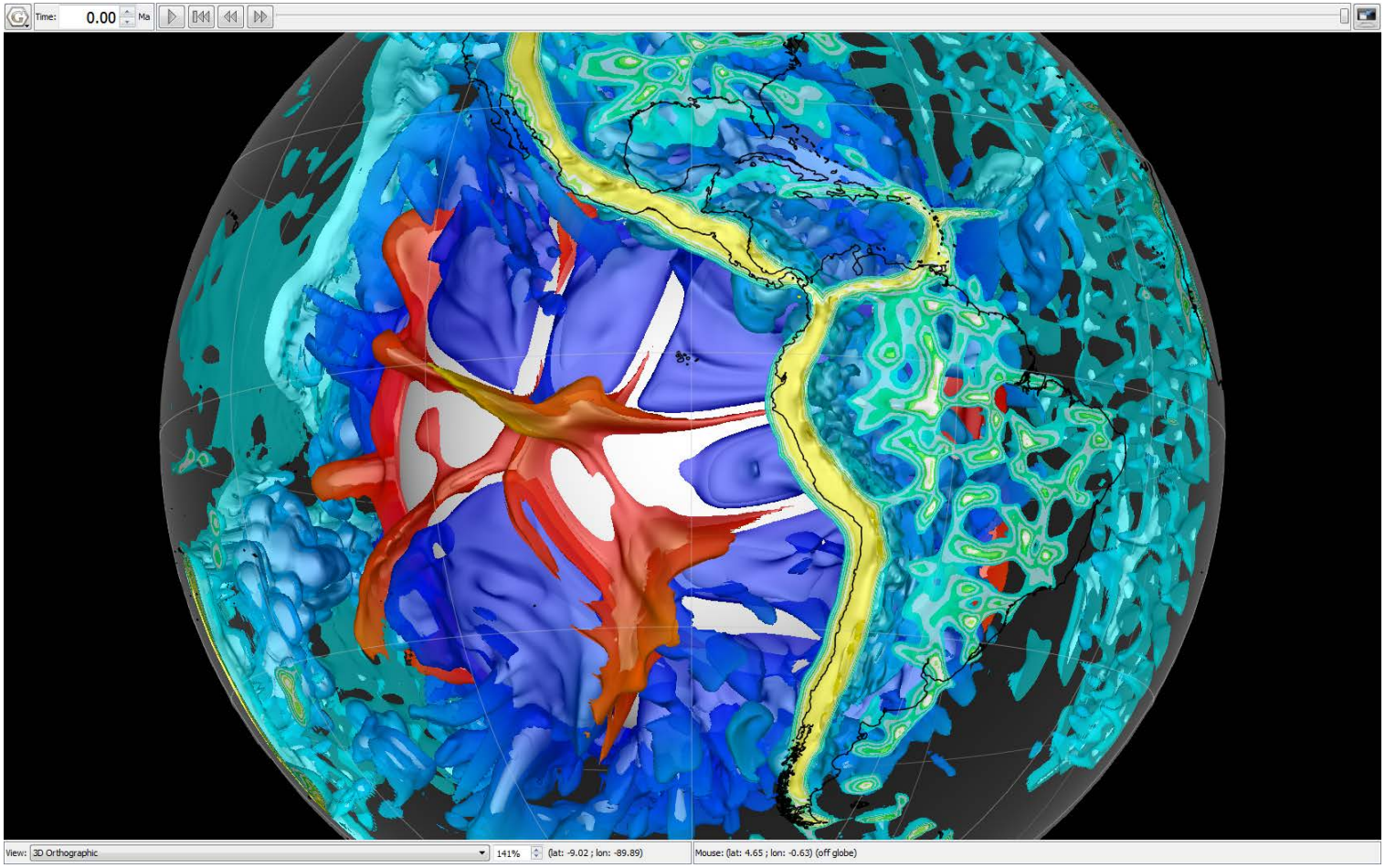




Reconstructed images comprise
- global 2 minute grid
- higher resolution public domain grids for North America and Australia

Greater level of detail for Australia is revealed when we zoom in

GPLates1.3 (release in December 2012): Volume visualisation

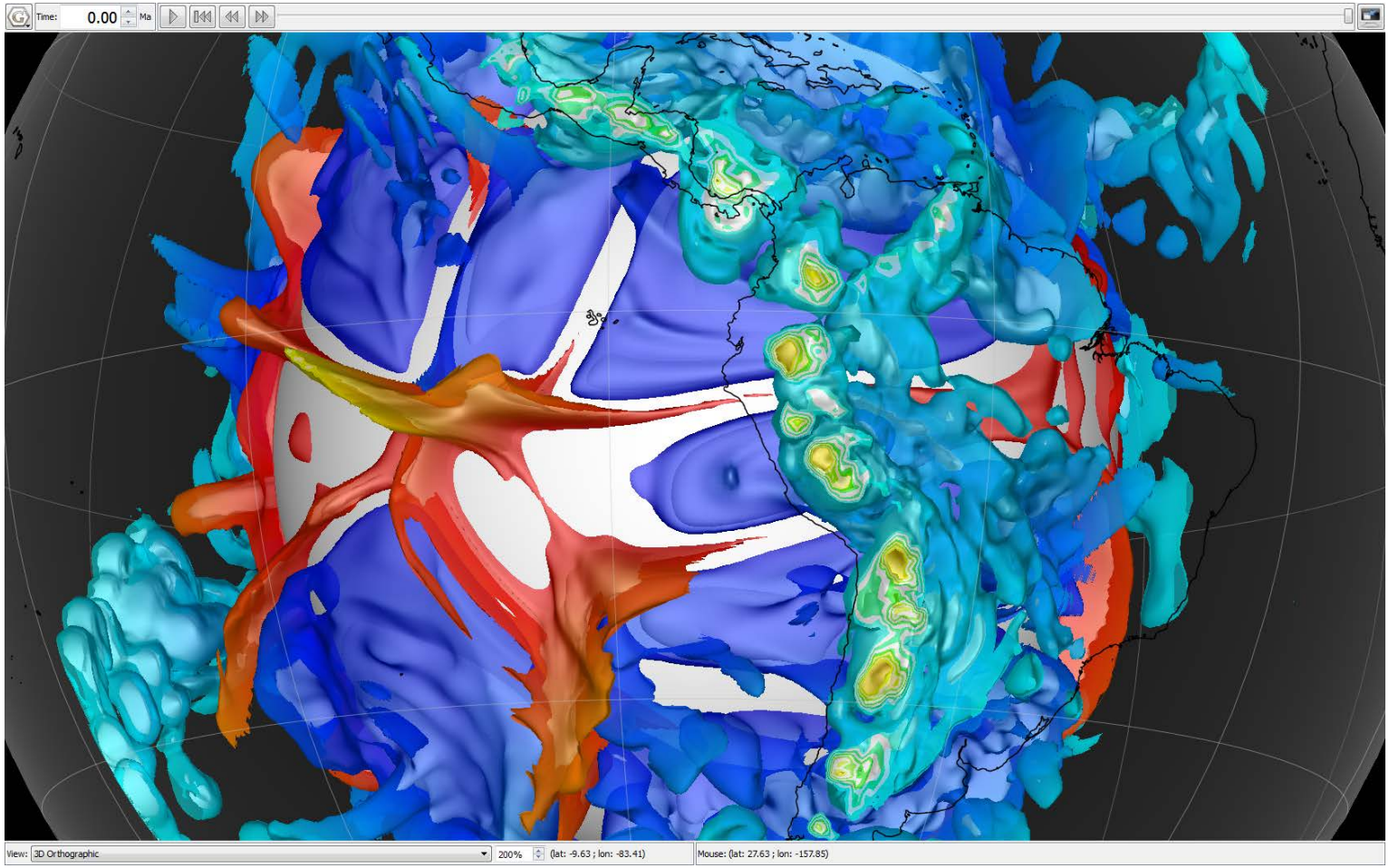


Mantle Temperature

Shepard et al., 2012 EPSL

Two central isosurfaces with isovalues *isovalue1* and *isovalue2*.
Each with its own deviation window (symmetric or asymmetric).

GPLates1.3 (release in December 2012): Volume visualisation



Mantle Temperature

Shepard et al., 2012 EPSL

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Each with its own deviation window (symmetric or asymmetric).

GPlates Online Resources

Step-by-Step Tutorials, Reference Manual

GPlates Tutorials

https://sites.google.com/site/gplatestutorials/

Google Scholar | HRonline | Google | SMH | EbyteCentral | EGU2012 | Other Bookmarks

GPlates

Tutorials

Tutorial 1: Loading/Saving Data and Changing Colours
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Tutorial 3: Plate Reconstructions
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Tutorial 5: Creating Features
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Tutorial 6: Changing Rotations
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Tutorial 7: Working with Paleomagnetic Data
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Tutorial 8: Shapefiles
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Tutorial 9: Preparing Data in ArcGIS for GPlates
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Tutorial 10: Time-Dependent Rasters and Age-based Masking of Raster Images
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Tutorial 12: Southeast Asia Use Case
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Tutorial 13: Constructing a Plate Model from Scratch
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Tutorial 14: Topological Closed Plate Polygons
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Tutorial 15: Data mining I
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Tutorial 16: Data mining II
View in browser | Download PDF | Download Sample Data

Tutorial 17: Flowlines and Motion Paths
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GPlates: User Documentation

www.gplates.org/docs.html

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GPlates

User Documentation

The GPlates User Manual

The official GPlates user-manual is written by GPlates users in the EarthByte Project, in close collaboration with the GPlates software development team.

Read the user manual to learn about GPlates' many functions. The manual describes all of the canvas tools, menus, and dialogs that are present in GPlates and how they can be used.

As well as the on-line HTML version of the manual, there is a downloadable PDF version available.

Tutorials introducing GPlates workflows

There are many Introductory Tutorials viewable online via Google Docs or downloadable as PDF. Each one describes how to accomplish a specific task in GPlates. Read these for a more in-depth guide that explains how various GPlates functions can be used within the context of an example workflow.

A video showcasing some of the most recently added functionality of GPlates can be found on the Features page.

The GPlates Data Manual

Read the Data Manual if you wish to understand how the GPlates model works and how GPlates stores data in its native file format (GPML). This manual may be of particular use to people who want to know how to structure their data so that it can be imported into GPlates easily.

Key GPlates papers

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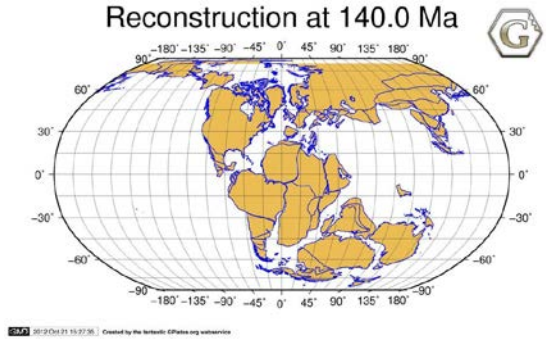
NeCTAR/ANDS #nadojo competition winner 2012



- Michael Chin from the Earthbyte group won this year's NeCTAR/ANDS e-research 2012 #nadojo competition
- Demonstration of a new web-enabled GPlates prototype on the NECTAR/ANDS eResearch computing infrastructure
- Porting some of the new tectonic plate reconstruction capabilities to the internet
- The web-enabled GPlates infrastructure won on the basis of its novelty and future potential
- A judge was quoted as saying: "...being able to look at tectonic plates and how they move over 140Ma years ago brought me back to that child-like awe of wonder and amazement, like the first time you look up at the stars and realise how many (light?) years away they are..."

200 Ma (Zahirovic et al. 2012, G-Cubed)