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A National Trajectory for Geoscience Research in Australia…. *and* some historical perspectives towards UNCOVER

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Acknowledgments to many colleagues, and collaborators on many projects (and many committees!)

Chair, National Committee for Earth Sciences (Aust. Academy of Science)
and
Director of the ARC Centre of Excellence for Core to Crust Fluid Systems (CCFS)

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THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence

Centre for EXPLORATION TARGETING

Curtin University

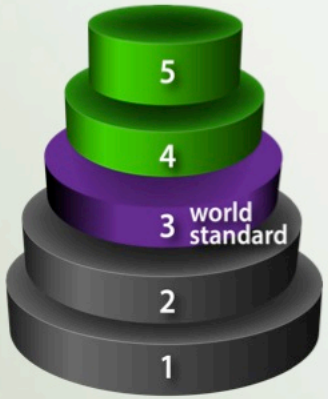
Geological Survey of Western Australia

Background Context

- University Geoscience University Research Position in Australia - high-level snapshot - ERA
- Role of the Academy of Sciences
  - Support for national lobbying
  - NCES (National Committee for Earth Sciences) – ***Decadal Plan***
  - Initiatives e.g. UNCOVER, training, EMCR support network
- Funded current National University Centres – roles and representation
  - CODES, DET CRC, CCFS (ARC Centre of Excellence (includes GEMOC)), CET
  - More about CCFS
- Eclectic examples of the role of fundamental research relevant to stakeholders – some history and future strategies
  - Technology developments
  - *Lithosphere framework – a new context*

Australian Geoscience *has been* world-leading

- The ERA exercise (Excellence of Research in Australia) 2012 *demonstrated* that most Earth Science disciplines across Australia are above world standard, and some (e.g. Geochemistry) *actually set benchmark levels internationally*.



- Challenges (highest level) are 3-fold:
  - Maintaining the edge
  - Translation to and alignment with stakeholders/end-users
  - Training for the future - sustainability (practitioners and Australian society)

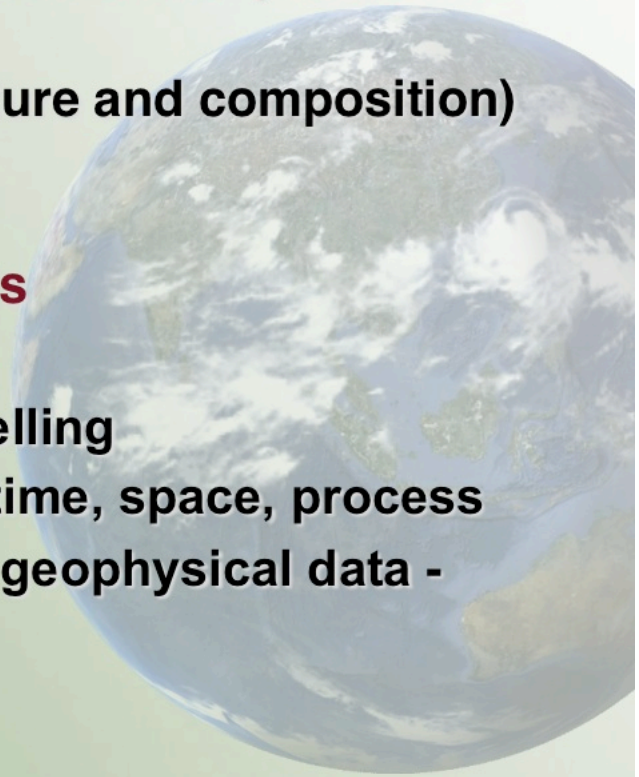
- UNCOVER provides opportunity
  - *To harness national resources (people,infrastructure, ideas, $) for maximum outcomes)*
  - Influence resource providers (including Government Departments, ARC, NCRIS (AuScope), CRC program)

Knowledge creation and translation

- **Blue-sky research?**
  - Imperative to articulate how basic research projects will inform large-scale first-order problems about the Earth
  - Ideally developed with end-user input – role for exploration industry and technology /instrument /IT companies
  - Parallel programs of basic research, problem-solving with end-user(s)
- **Impact of research?**
  - Can be a long-term process
  - Needs proof of concept (like medical research needs clinical trials)
  - Inspiration and scoping phase of blue-sky – time for visionary stakeholder input – one of UNCOVER's questions → mechanism

A New (21st Century) Perspective

- **Giant ore systems are the product of *lithosphere-scale* processes dependent on:**
  - the nature of the Earth's lithosphere (structure and composition)
  - fluid movement in the deep Earth
- **21st Century exploration --> predictive models**
  - Global 4-D tectonic analyses
  - Multi-dimensional datasets - effective modelling
  - Mantle-crust linkages - define fertility with time, space, process
  - Remote sensing of geochemical as well as geophysical data - knowledge framework for interpretation
- **21st Century tools:**
  - Global and regional geophysics --> seismic tomography, MT,
  - Geochemical advances (technology and methodology)
  - Tectonic, geodynamic and modelling power



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The deep Earth perspective

Mantle (convecting and lithospheric) - ultimate origin of the crust, atmosphere, oceans, ore-forming fluids and elements

Samples from magmas and massifs:

- the deep Lithosphere (20-250 km)
- Transition Zone (450-~700 km)
- Lower Mantle (~700-2900 km)

Ophiolitic chromite Tibet

Geophysical datasets

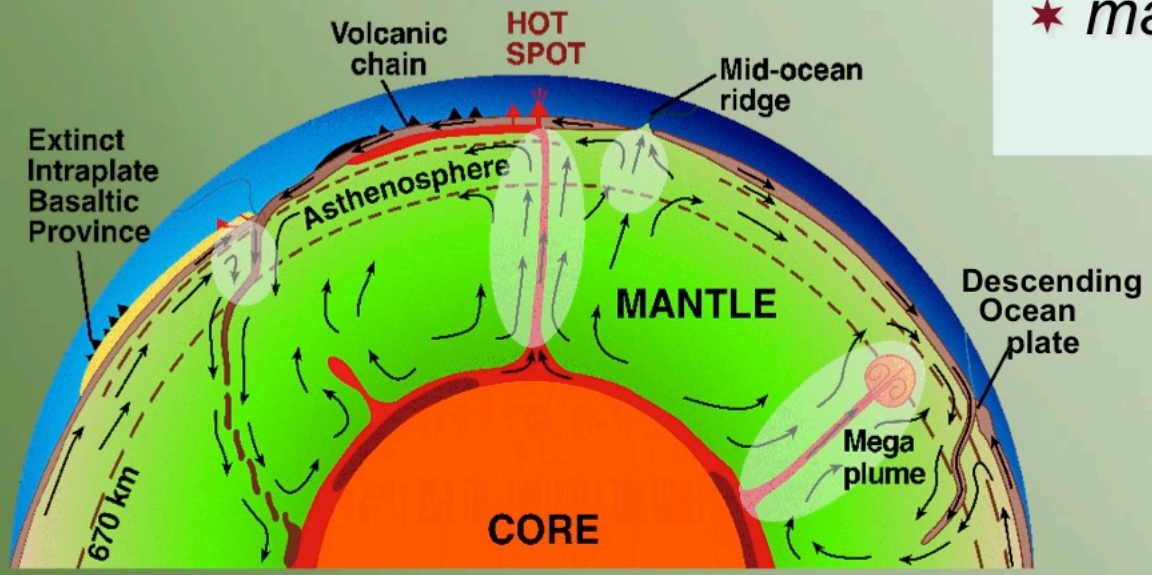
- seismic tomography
- deep magnetotellurics
- geodynamic modelling power

The lithospheric mantle is the reservoir and the archive for the ore-forming elements

- **How?**
- **When?**
- **Where?**

NEED knowledge of:

- *mantle architecture*
- *mantle geochemistry*
- *mantle fluid fluxes*
- *mantle evolution*



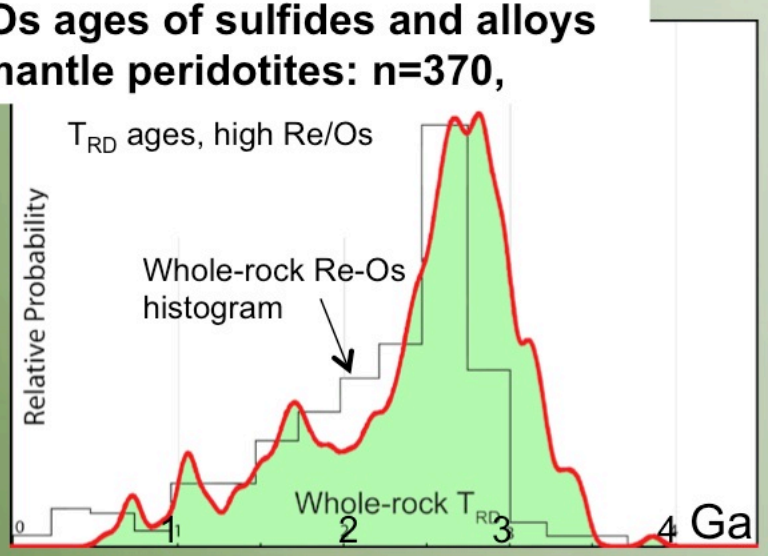
3 Major Advances since 2000: Tools to understand Earth's evolution

- In-situ analysis of Hf isotopes in zircon
  - Understand *origins* of magmas, not just ages
- In-situ analysis of Os isotopes in mantle sulfides
  - Ages of mantle depletion, fluid/melting events
- High-resolution seismic tomography
  - ***Geological interpretation*** from mantle petrology
  - Mapping extent of Archean lithosphere

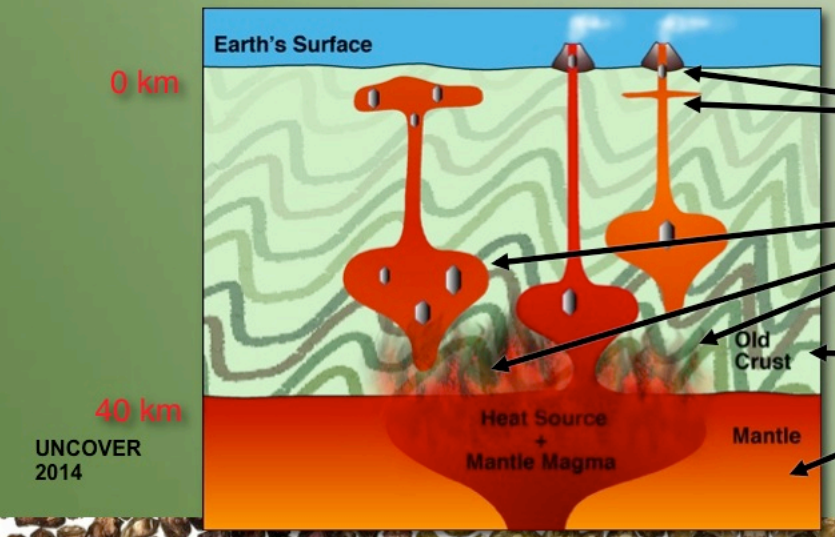
New understanding of *crust-mantle linkages*

Significance of role of ancient lithospheric mantle Global geodynamic consequences

Power of zircon: time and process barcoding



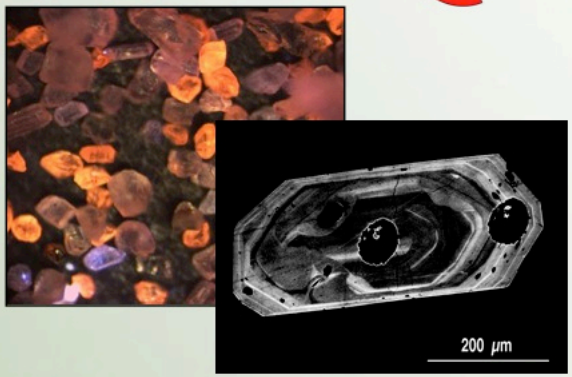
- ***Re-Os dating of mantle sulfides and rocks →***
  - ***Major peak 3.0 Ga - formation of most Archean SCLM?***
  - ***Timing of (multiple) fluid events in the lithosphere***



- ***Zircon U-Pb + Hf isotopes + TE:***
  - ***Age and type of magma***
  - ***Age of source region + location (deep crust or mantle or mixing)***
  - ***Identifies fertility of host magma and deep source (eg Au, Cu)***

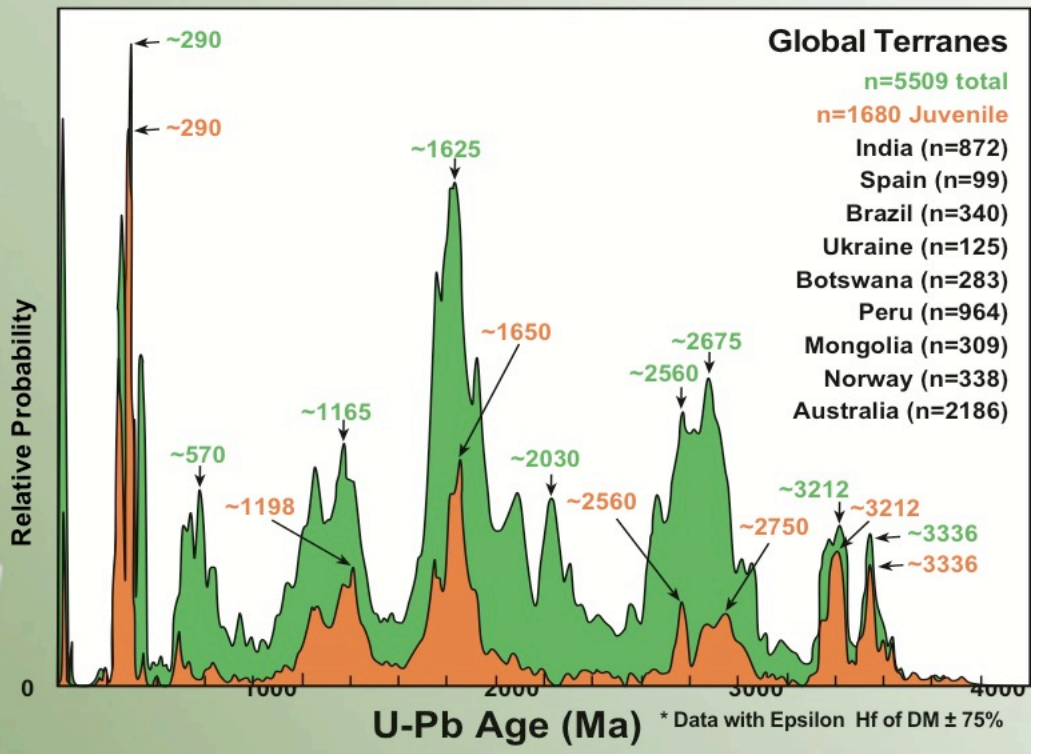
Zircon data for crustal evolution i

- ***Hf isotopic data from lower crustal and upper crustal inherited zircons***
  - reveal extensive domains of previously unknown Archean lower crust
  - these domains overlie Archean *mantle lithosphere* (the *life-raft)*



- ***Zircon Hf isotopes :***
  - identify ages of deep crust that may not be exposed in surface geology

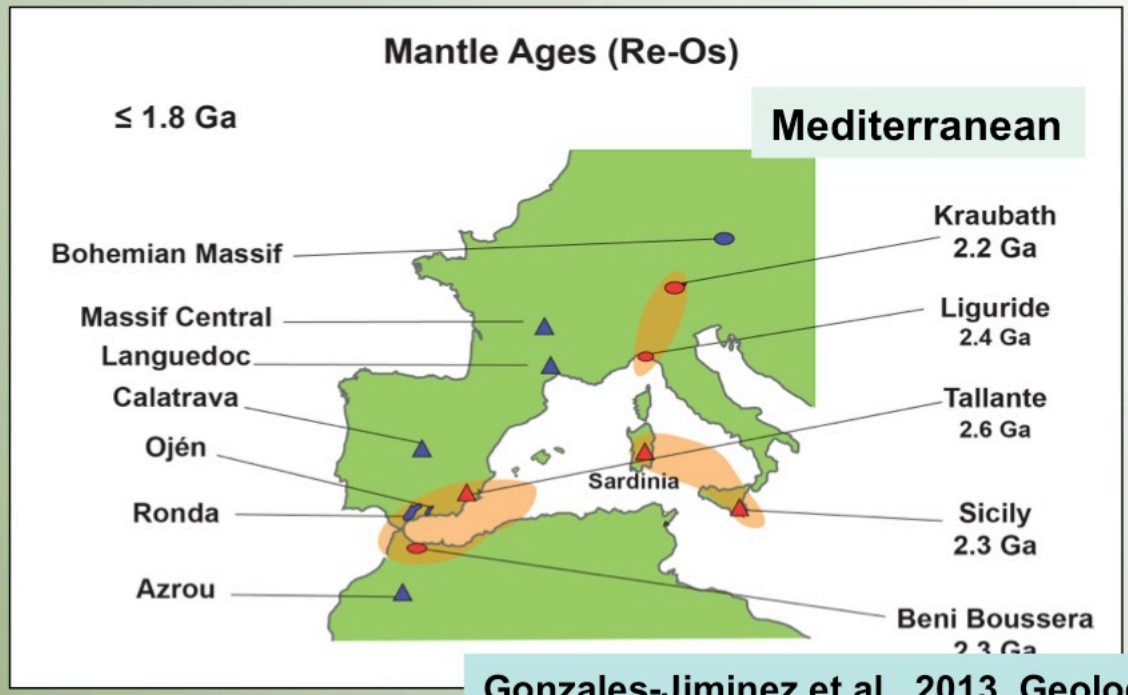
- ***Zircon U/Pb ages +Hf isotopes track tectonic events globally in time***



Widespread Archean lower crust

- *Archean lower crust now identified in many "new" regions with younger upper crust eg:*
  - Southeastern China
  - Yangtse Craton
  - Spitsbergen
  - North China Craton
  - NE Australia

  New ancient mantle finds
  - Tibet (ophiolites)
  - Mediterranean



Gonzales-Jiminez et al., 2013, Geology

- *Implications:*
  - Significant crustal "resurfacing"
  - Archean lower crust and lithospheric mantle formed and commonly (but not always) persisted together
  - *Need to rethink the more traditional models of crustal growth rates*

Geochemical Remote Sensing with zircon: TerraneChron®

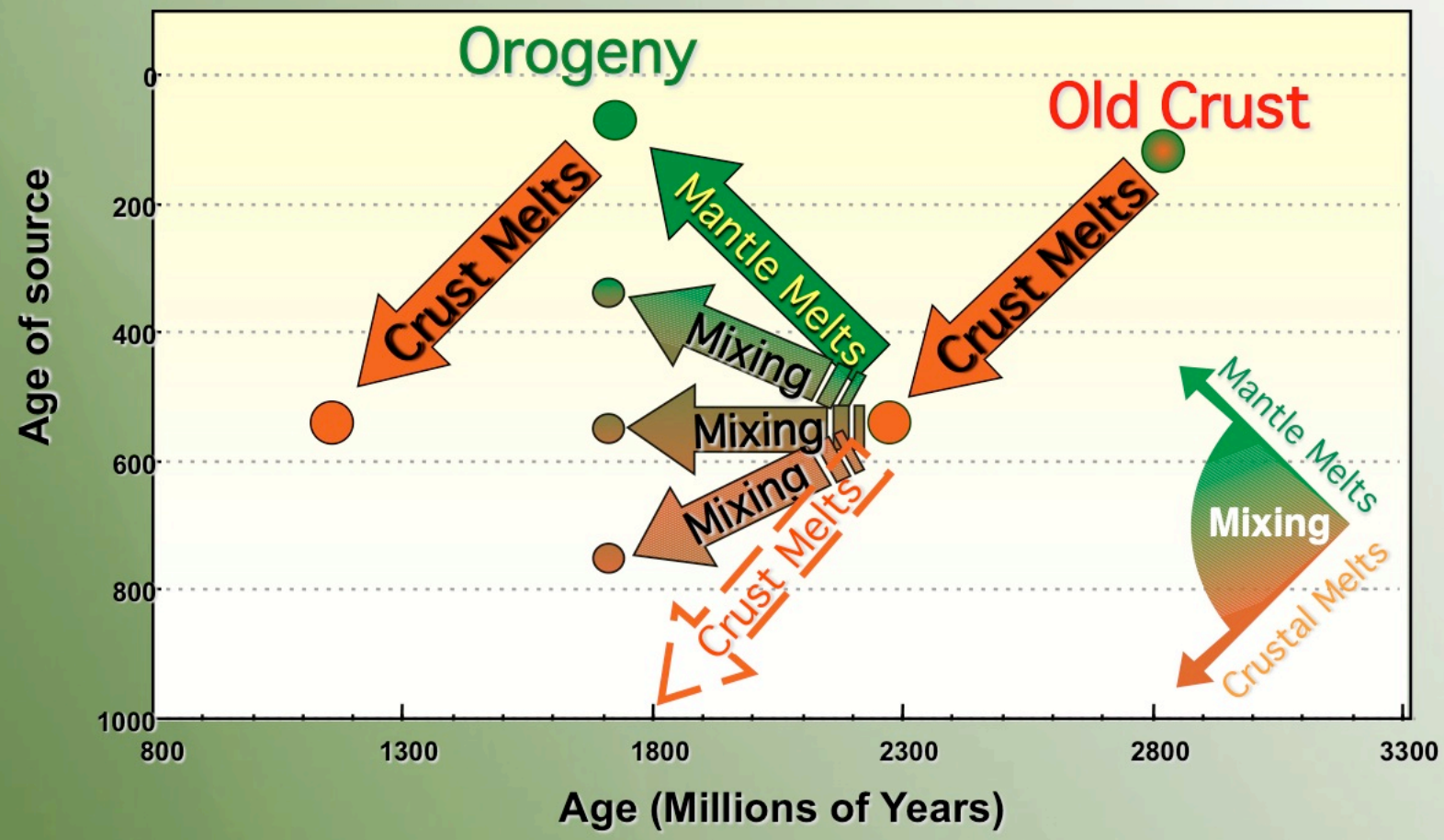
- Uses drainage sands, then:
  - zircon concentration
  - U-Pb +Hf isotopes +trace elements
  - Fingerprints host rock and original source type
- Identifies regional tectonic events and crust evolution
- Fingerprints crust and mantle input + fertility
- ***Probes inaccessible regions remotely***

★ Paleogeophysics

★ Paleotectonics

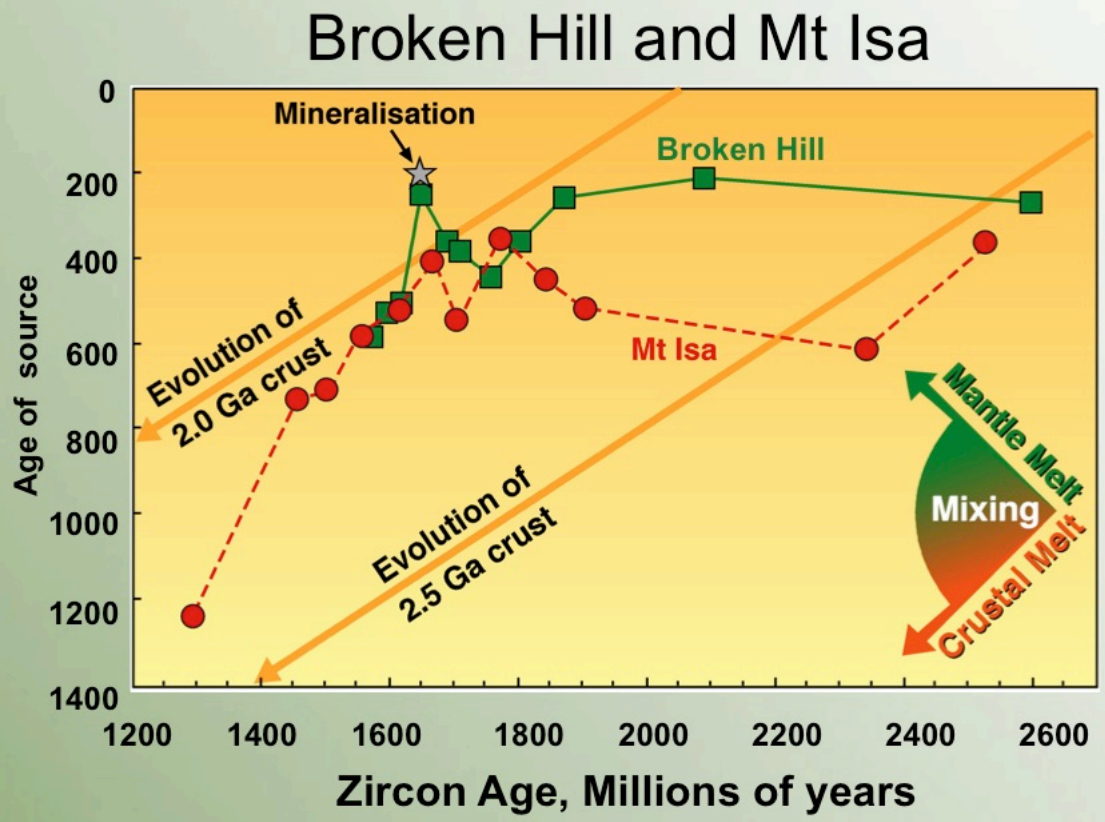
Quickfire session Tuesday

Event Signatures – an easy visual presention

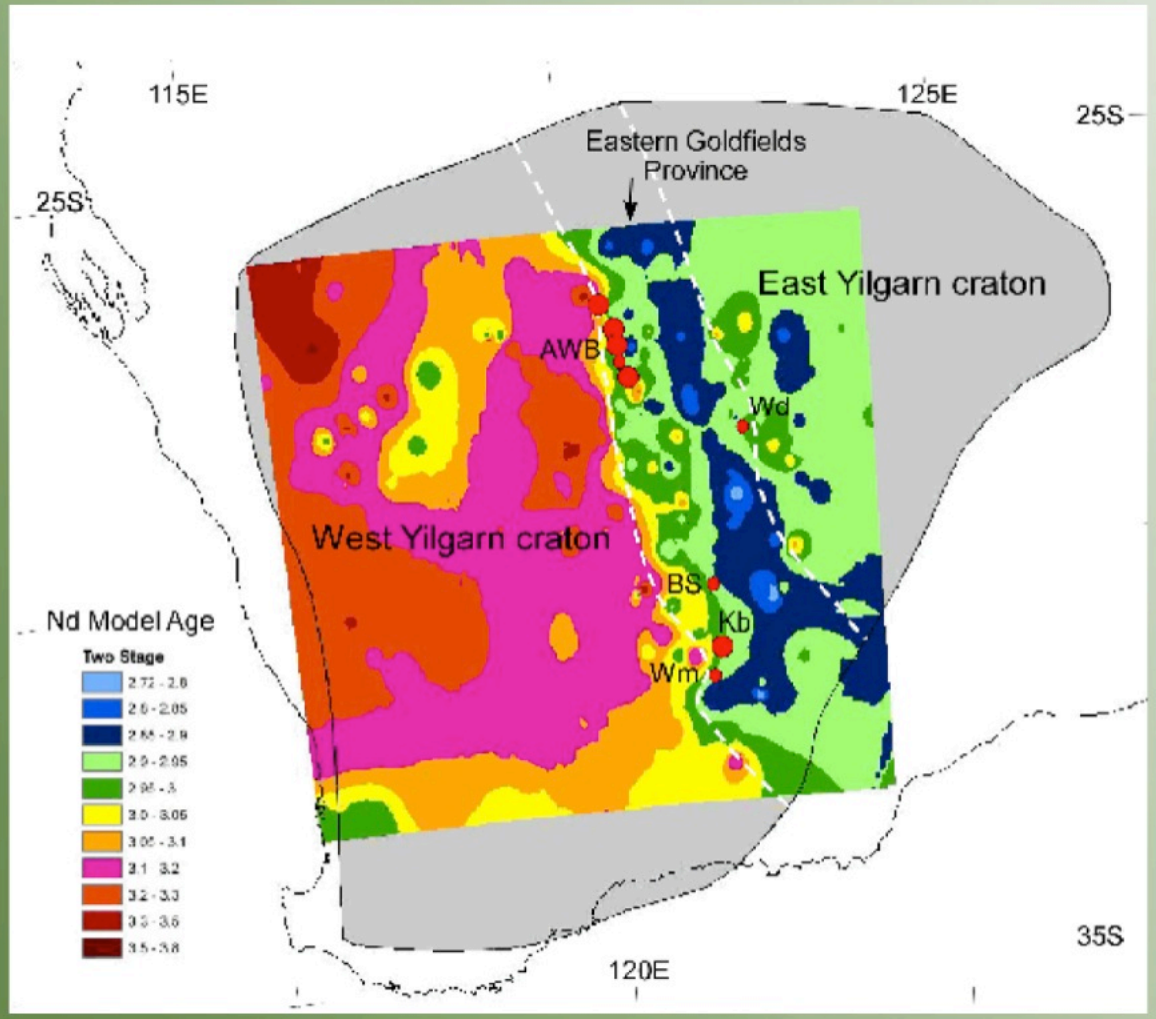


Pinpointing time of mineralisation with TerraneChron® *Event Signatures*

- Analogues to polar-wander curves
- Show when terranes may have separated or docked?
- Broken Hill and Mt Isa mineralisation at ~1.65 Ga - ***after patterns coincide***



Yilgarn – Isotopic Mapping
Neoarchean NiS



Nd map (Cassidy et al.)

Isotopic mapping reveals important fundamental terranes

Most NiS deposits formed on edge of West Yilgarn craton

Easy and cost-effective to map large areas with TerraneChron® - GSWA + DMITRE + GSNSW + CCFS

Global Lithosphere Architecture Mapping (GLAM): Africa Vs Tomography 100-175 km

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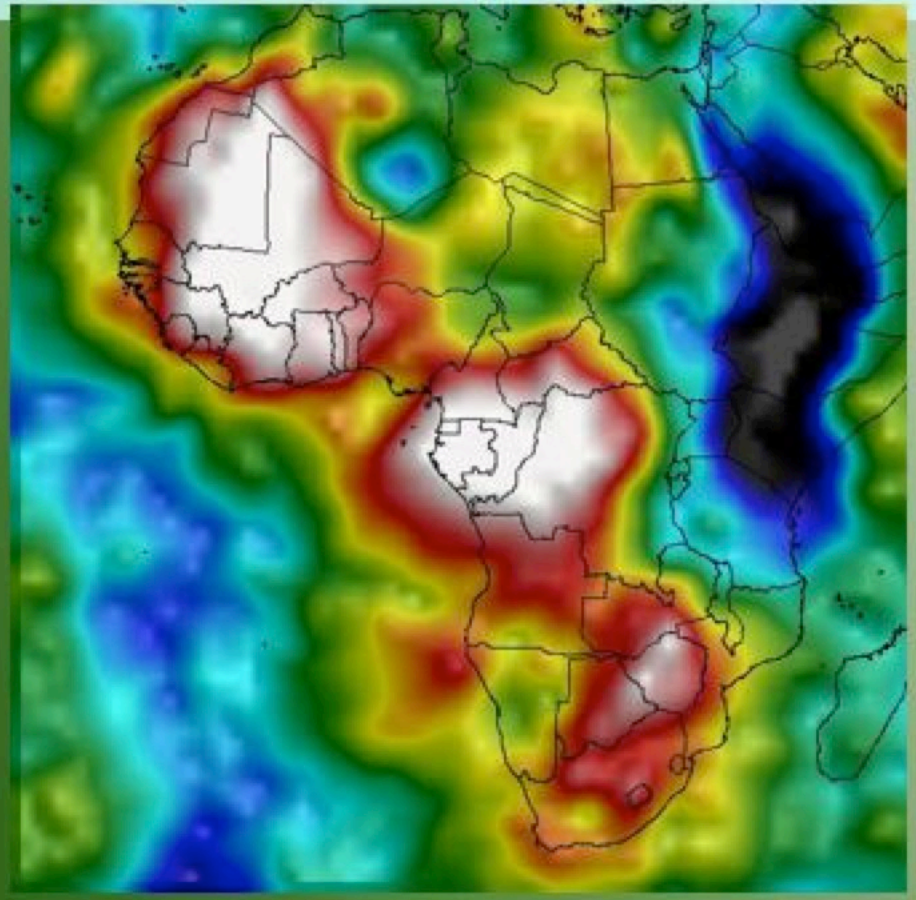
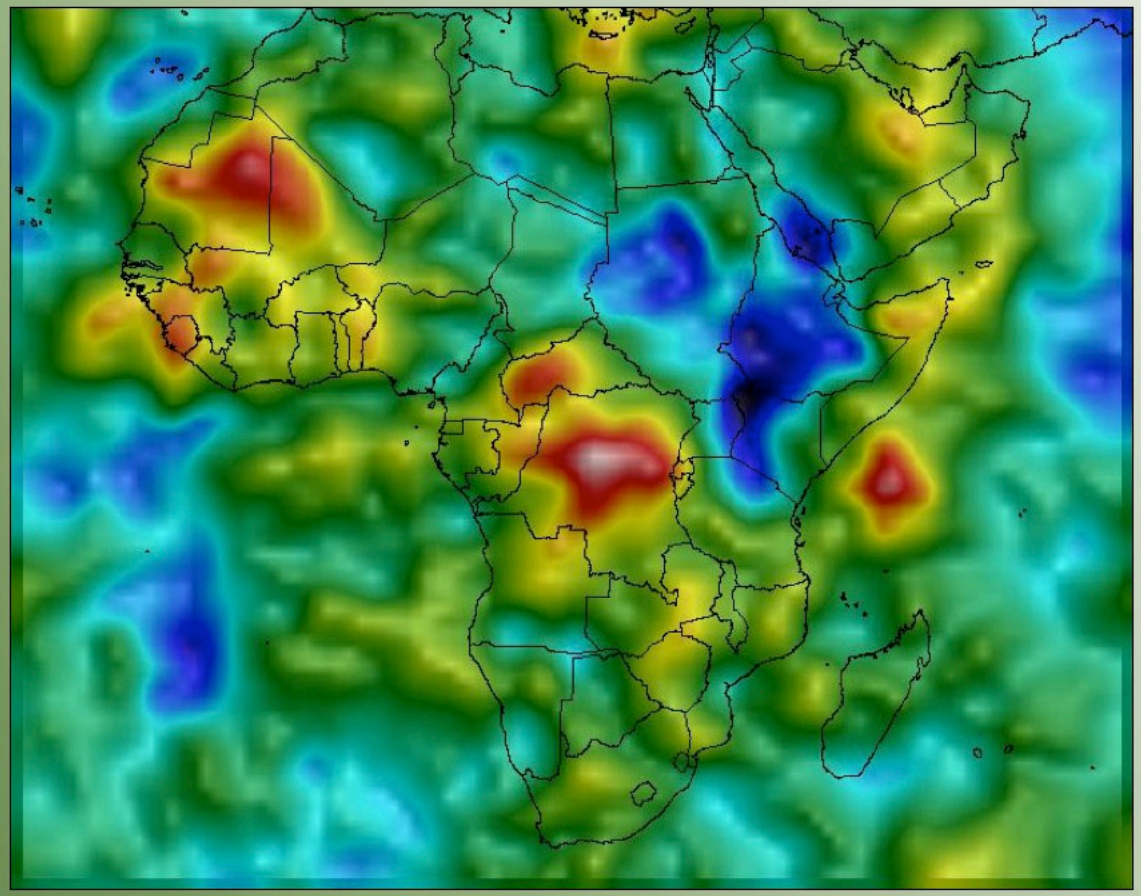
(Model from Steve Grand, refined by WMC, BHP Billiton - under continual refinement)



- Integrates global seismic tomography with deep xenolith petrology, geochemistry, geochronology, tectonic history and regional geophysical datasets
- Window to subcontinental lithospheric mantle (SCLM) and lower crust domain distribution
- → *identification of tomographic signature for Archean SCLM compositions*

- Note colour reversal :
- red = fast (high Vs) blue = slow (low Vs)

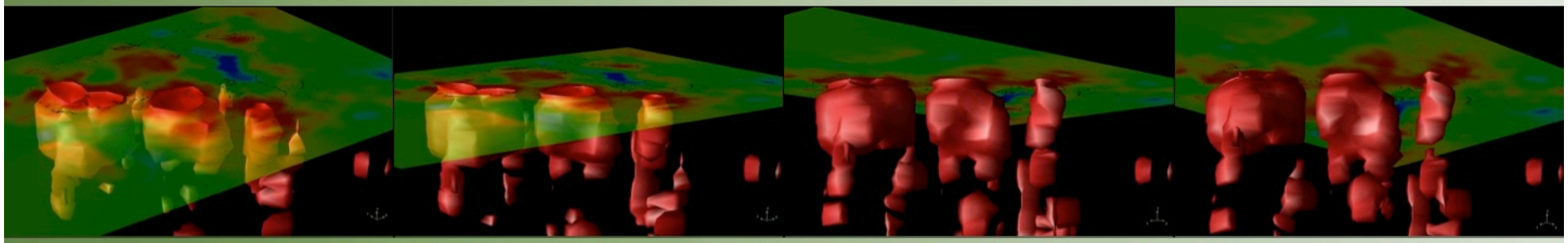
Africa Vs Tomography 325-400 km



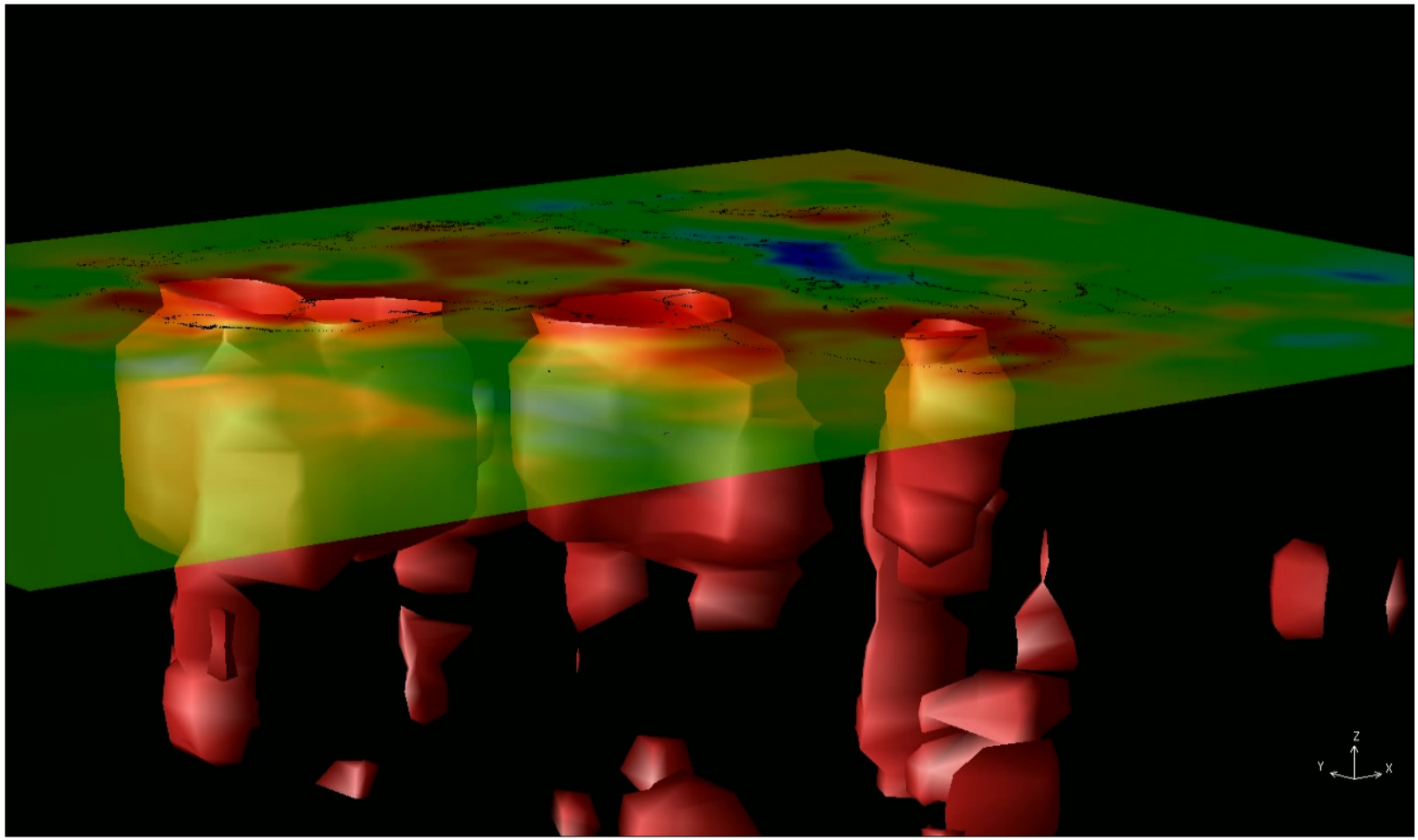
Cratons still visible to 400 km as regions with contrasting Vs

- **Craton Vs higher than Earth model**
- **Upwellings (rift, Hoggar) follow old pathways - reveal deep fluid pathways**

Imaging the architecture of deep fluid conduits



3-D seismic tomography

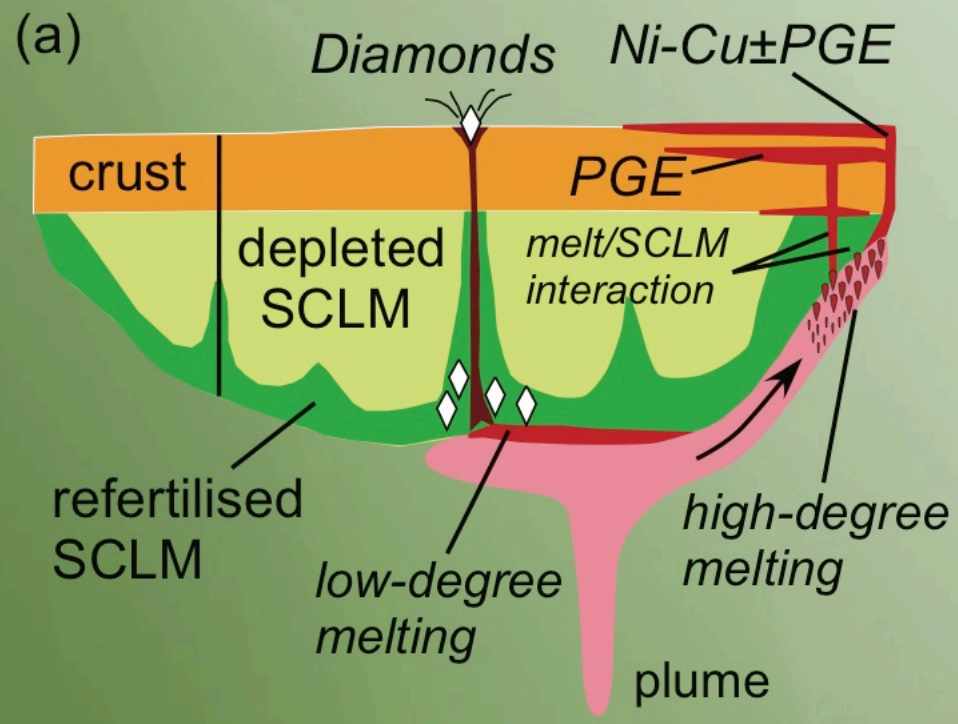


Begg et al., Geosphere, 2009 5, 23-50 doi:10.1130/GES00179.1

The mantle – the Fount of all Ores?

What lies *beneath cover* in Australia?

- **How?**
- **When?**
- **Where?**



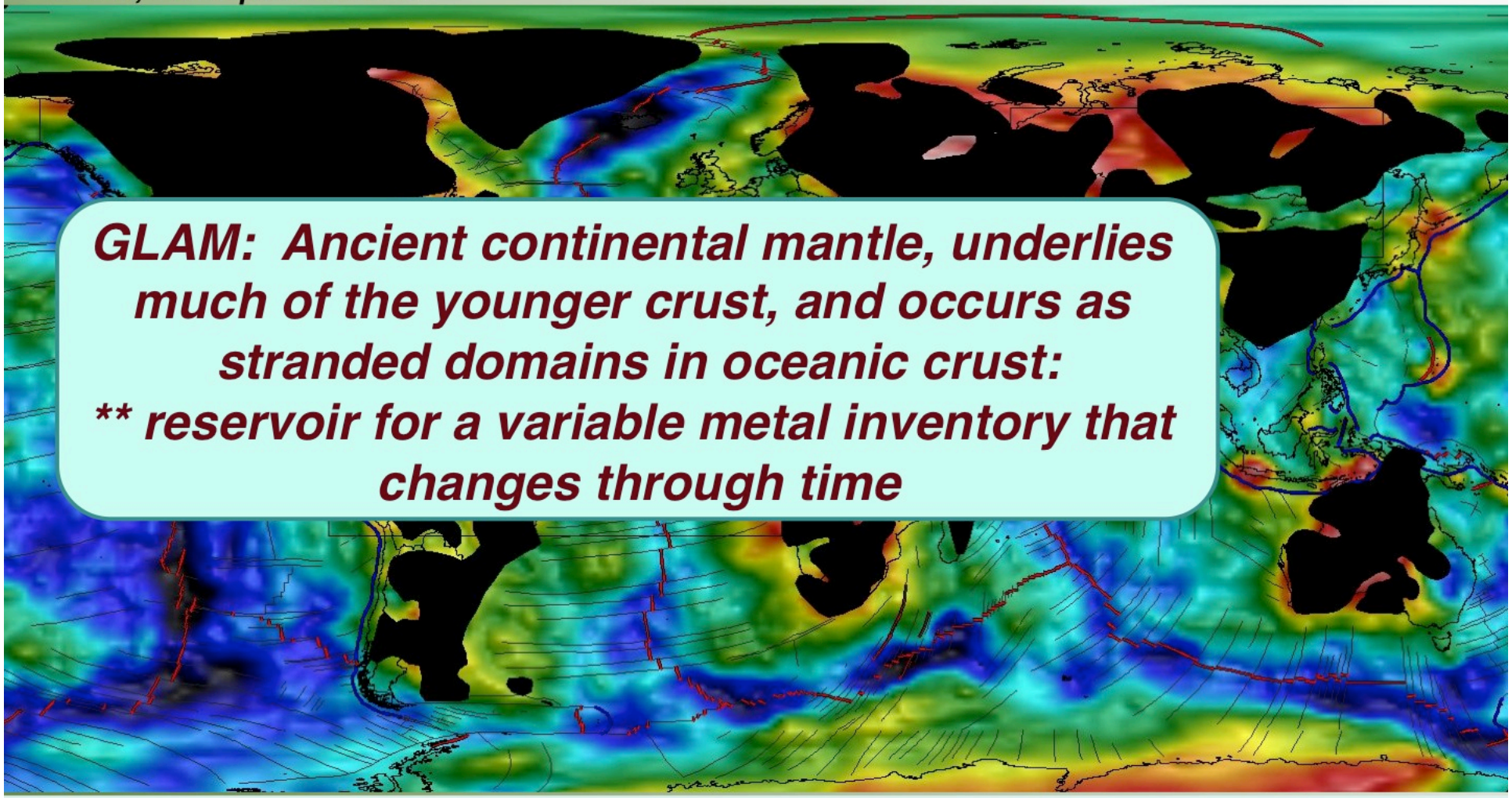
NEED knowledge of:

- *mantle architecture*
- *mantle geochemistry*
- *mantle fluid fluxes*
- *mantle evolution*

Griffin et al., Nature Geosc. 2013

SCLM with Archean Heritage

Griffin, Lithosphere Session



>70% of ALL SCLM mapped so far ***by integrating geochemical, tectonic and seismic tomography datasets,*** **is identified as Archean!**