



Australian Government

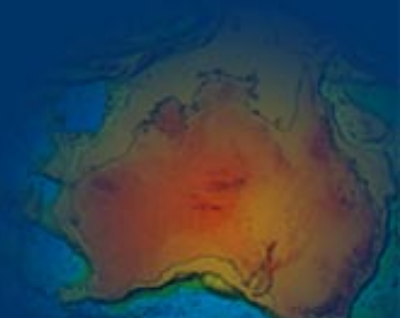
Geoscience Australia

Australian Diamond Exploration: Where to next?

**Lynton Jaques
Minerals Division
Geoscience Australia**

**World Diamond Conference,
Perth November 2004**

World Diamond Conference, Perth, 2004

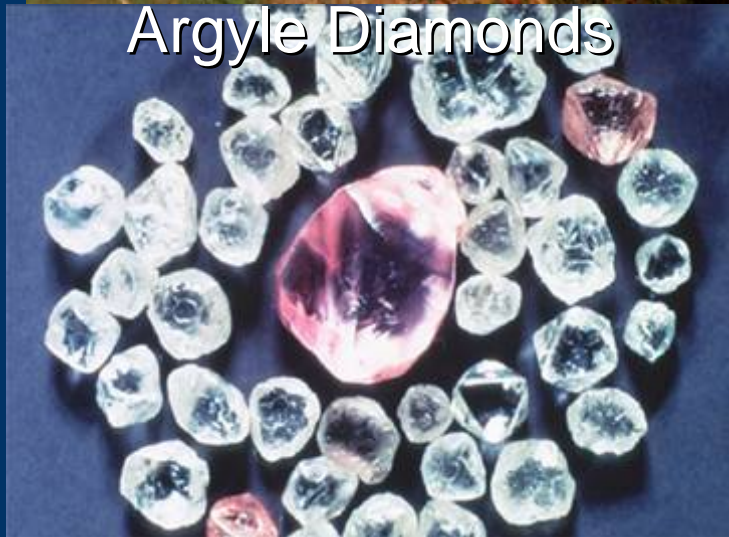


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Argyle



Argyle Diamonds



- Argyle mine is largest single producer in world
 - 31M carats in 2003
 - 22% of world production (wt)
- Produced >0.5B carats since 1985
- High grade pipe
- Underground 2008?
- Discovered in 1979

Ellendale



- Produced 57,000 cts in 2003
- Resource = 5 Mcts
- >US\$200/ct
- Discovered in 1976
- Ellendale Field ~ 80 lamproite bodies
- 3 new diamondiferous lamproites found in 2004

World Diamond Conference, Perth, 2004

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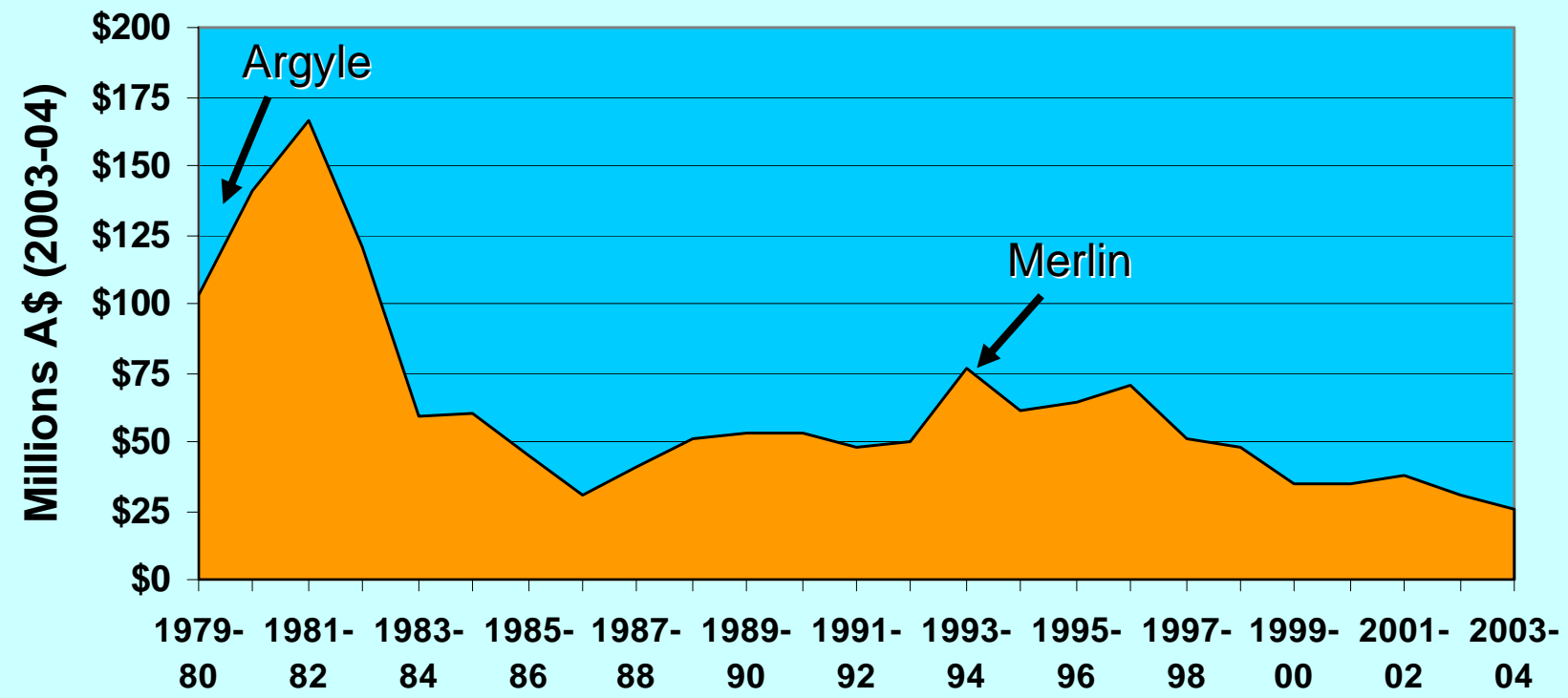
Merlin (1998-2003), Seppelt (?)



- Produced >0.5 M carats, incl. 104 ct 'Jungiila Bunajina'
- Average value US\$108/ct
- 14 pipes (< 5 ha), grades 14 - 56 ct/100t
- Remaining 1.8M carats (Striker Resources)
- Trial mining at Seppelt 2 in the North Kimberley

Australian Diamond Exploration Expenditure

Australian Diamond Exploration 1979-2004



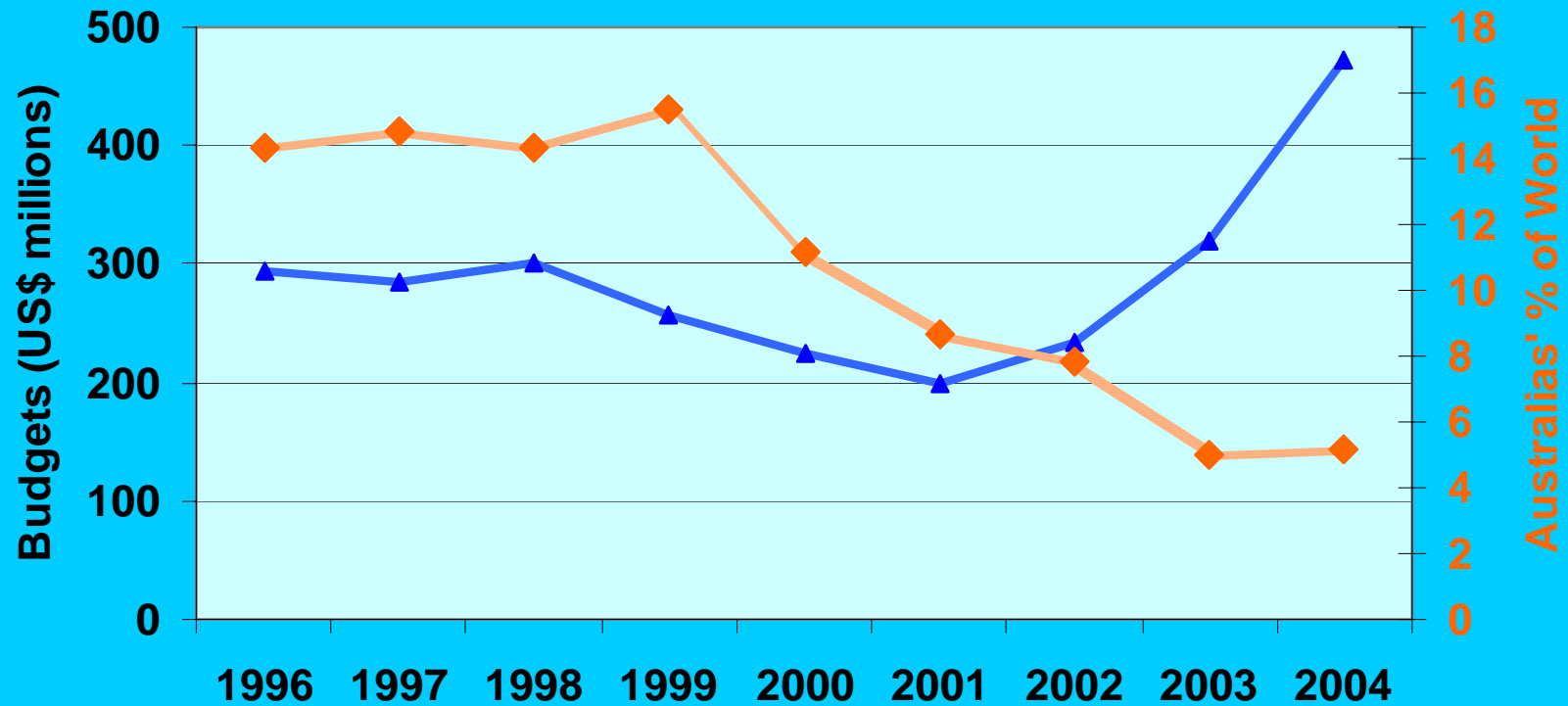
Source: ABS

World Diamond Conference, Perth, 2004

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- Where is it going?

World Diamond Exploration (Metals Economics Group)



Exploration Record

First generation surveys 1960s-1970s

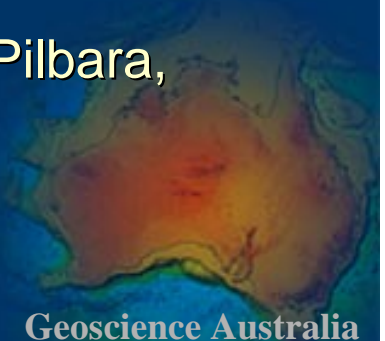
- Regional stream sediment surveys, airborne magnetics
- Discoveries:
 - Ellendale, Argyle lamproites
 - Kimberlites in North Kimberley, East Kimberley, Gawler, and alkaline ultramafic bodies at Carnarvon Basin and in SE Australia

Second generation surveys 1980s-1990s

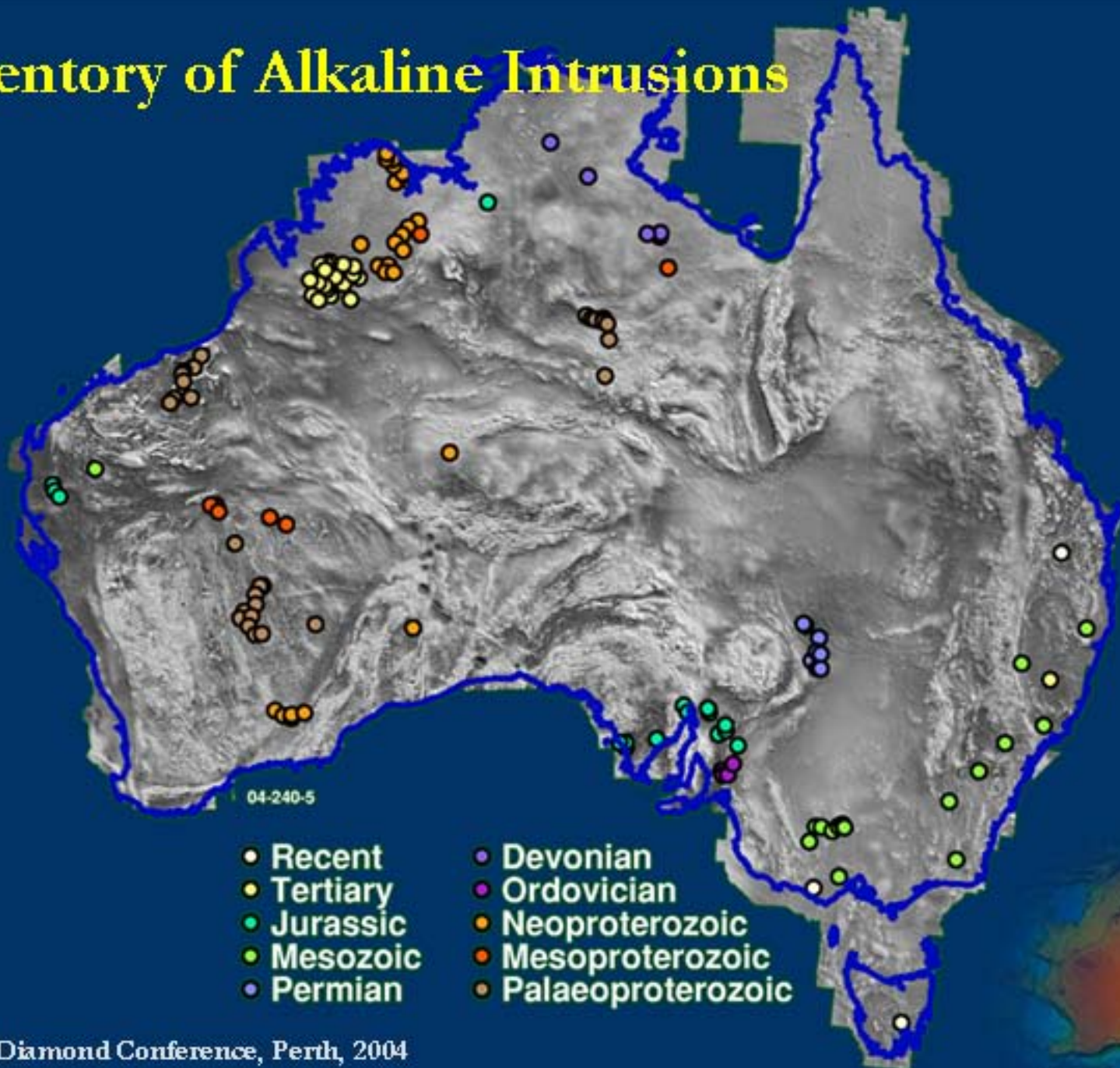
- Detailed and regional surveys, HR geophysical surveys, AEM
- Discovered Merlin pipes, Aries, Beta Creek-Ashmore, Forest River, Nabberu, Yilgarn

Current

- Detailed follow-up surveys, HR geophysical surveys, AEM, airborne gravity gradiometry
- Focus: Ellendale, North Kimberley (Seppelt), Merlin, Pilbara, Flinders Ranges,

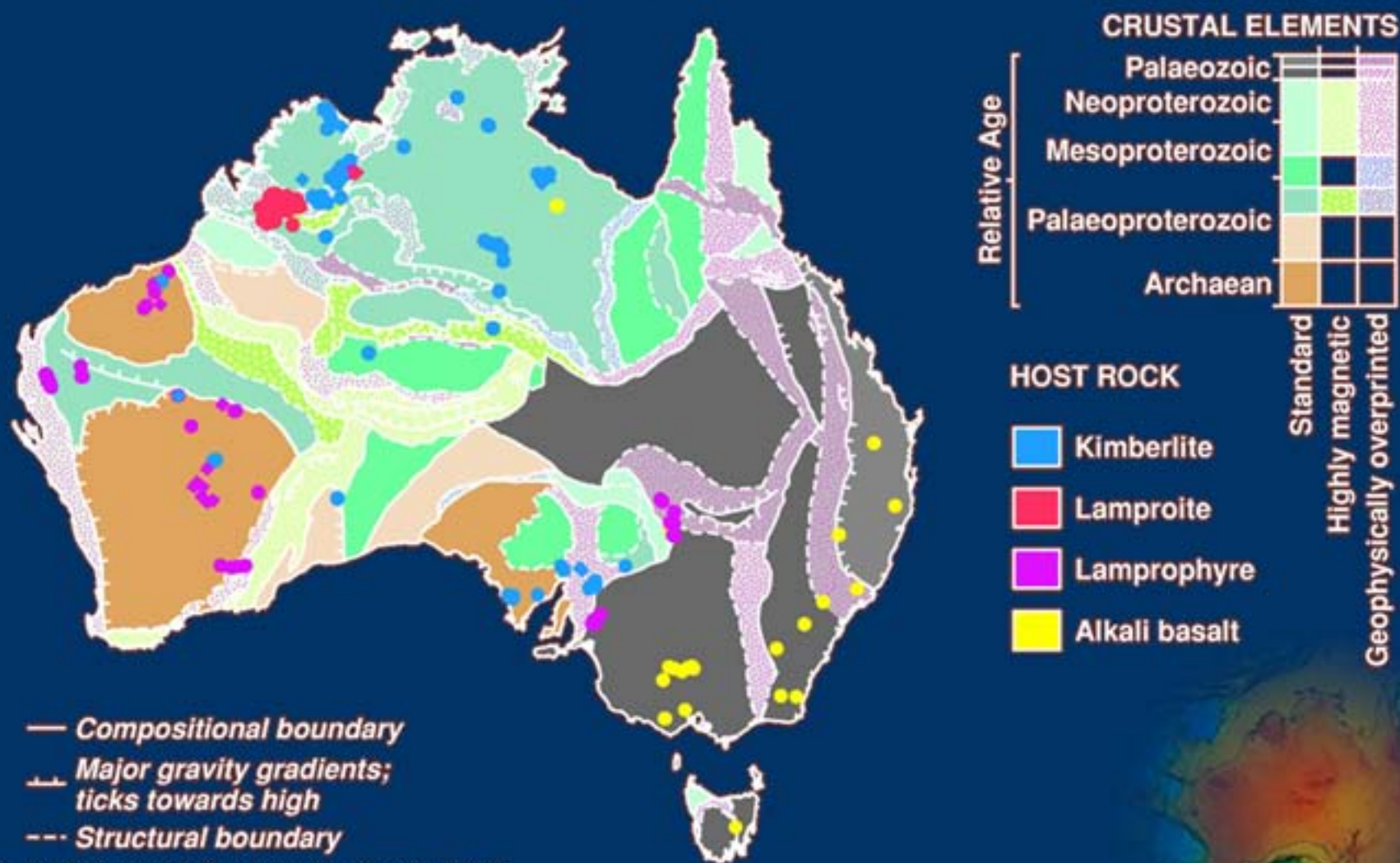


Inventory of Alkaline Intrusions



Inventory of alkaline intrusions

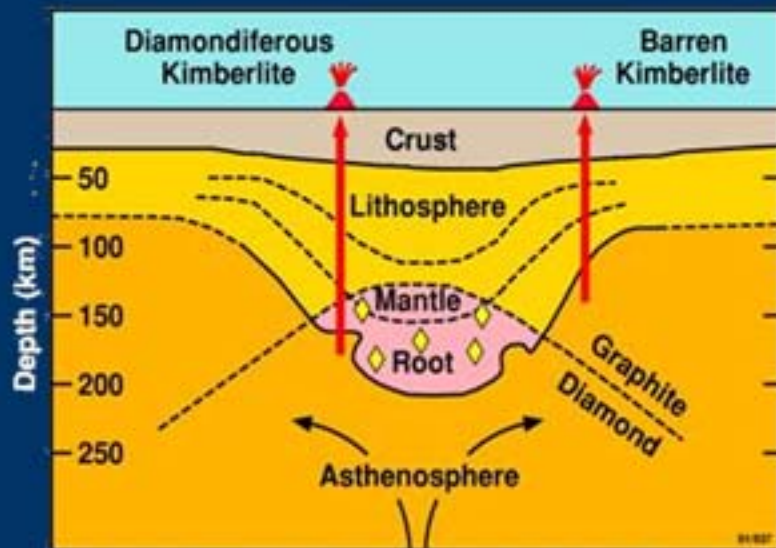
- range of rock types, different settings



World Diamond Conference, Perth, 2004

Diamond Exploration Models

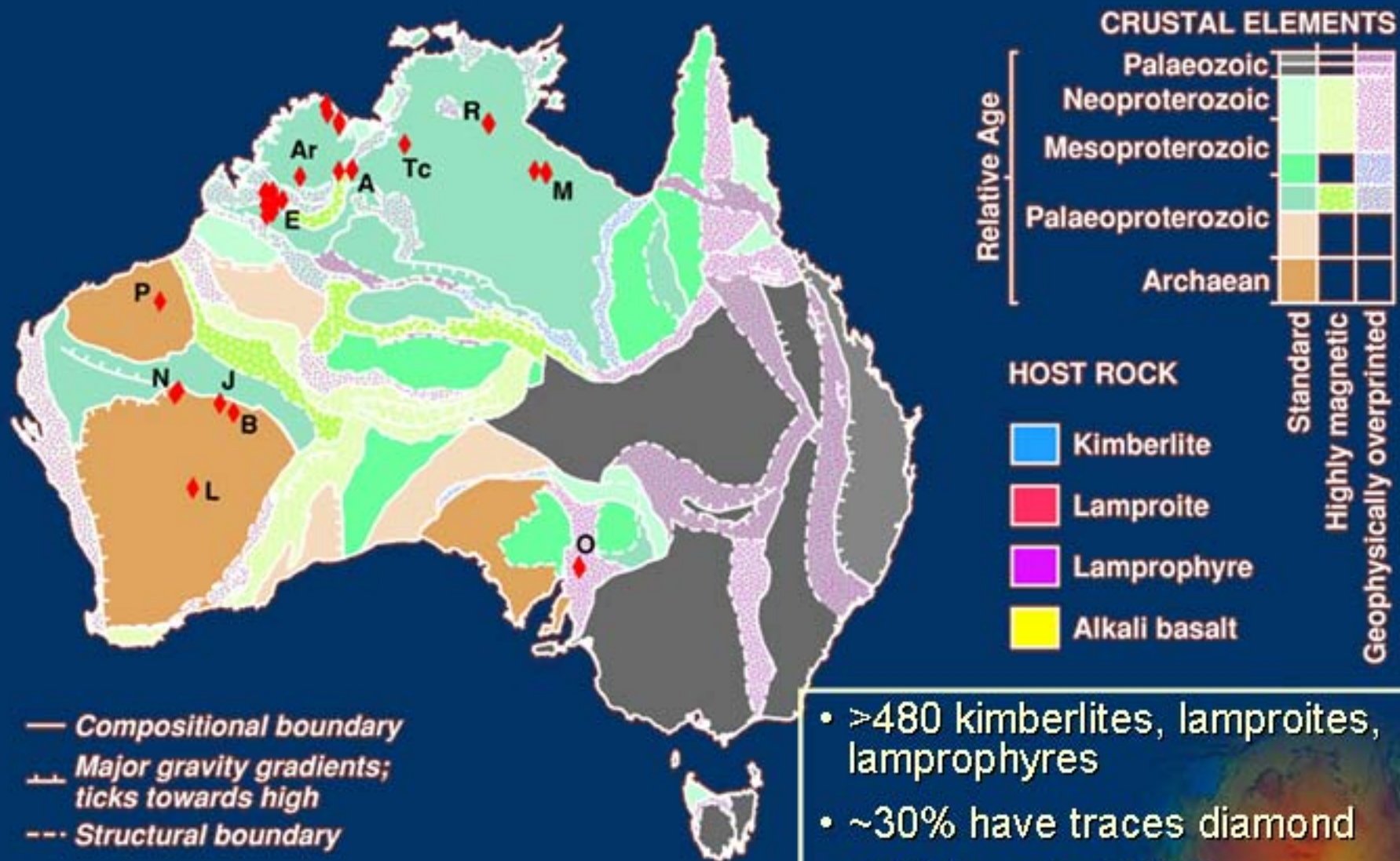
What can we learn from these discoveries?



(after Haggerty, 1986, Helmstaedt & Gurney, 1995)

- Diamond source regions
- Controls on distribution of diamond pipes (pathways)
- Preservation (erosion levels)
- Other exploration models?

Distribution of diamondiferous intrusions

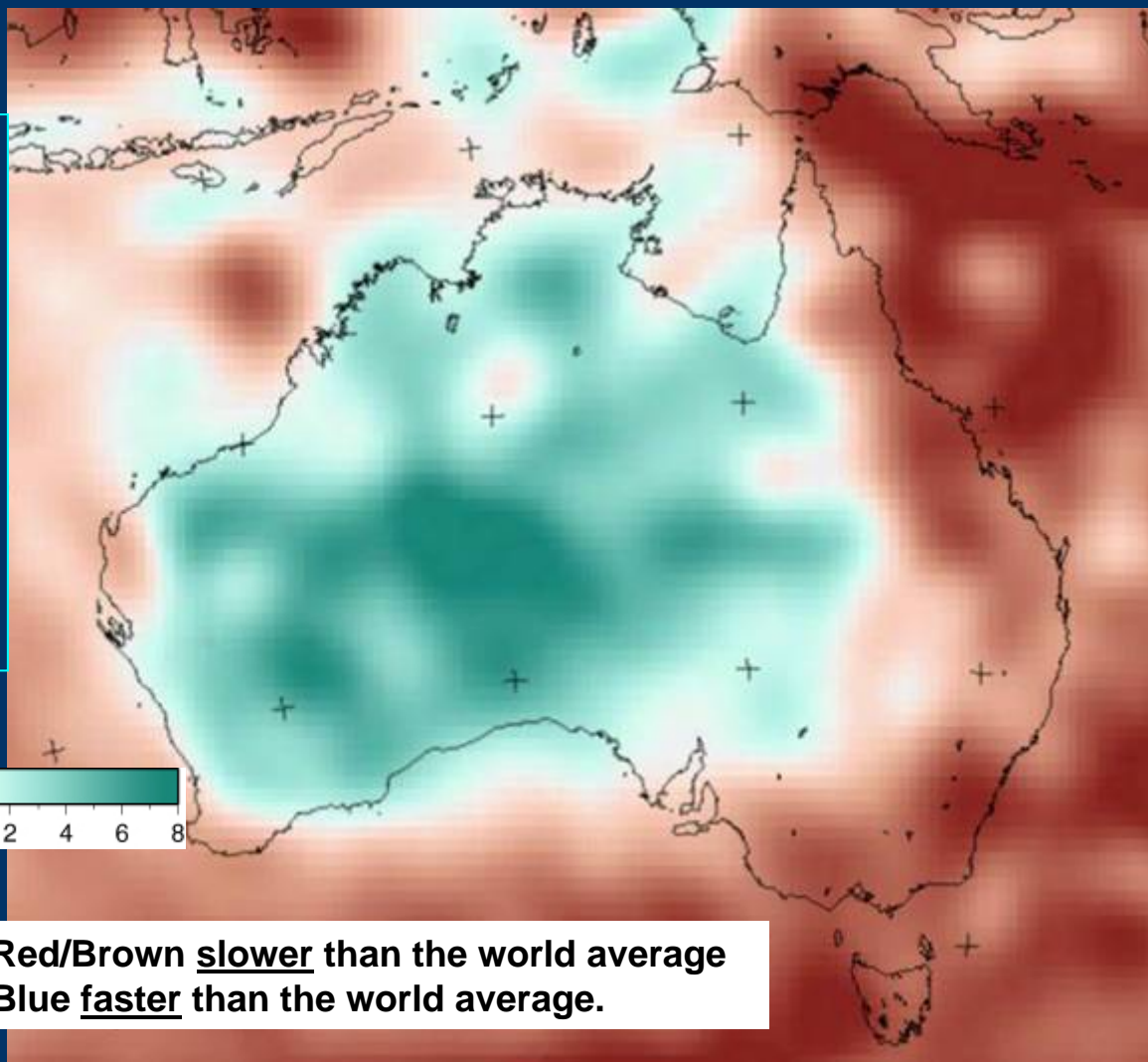


Structure of the Australian Lithosphere

Broad Band Seismic Shear (S) wave velocity at 125 km

West

- fast
- cold
- refractory
- less dense (buoyant)
- dry
- strong



East

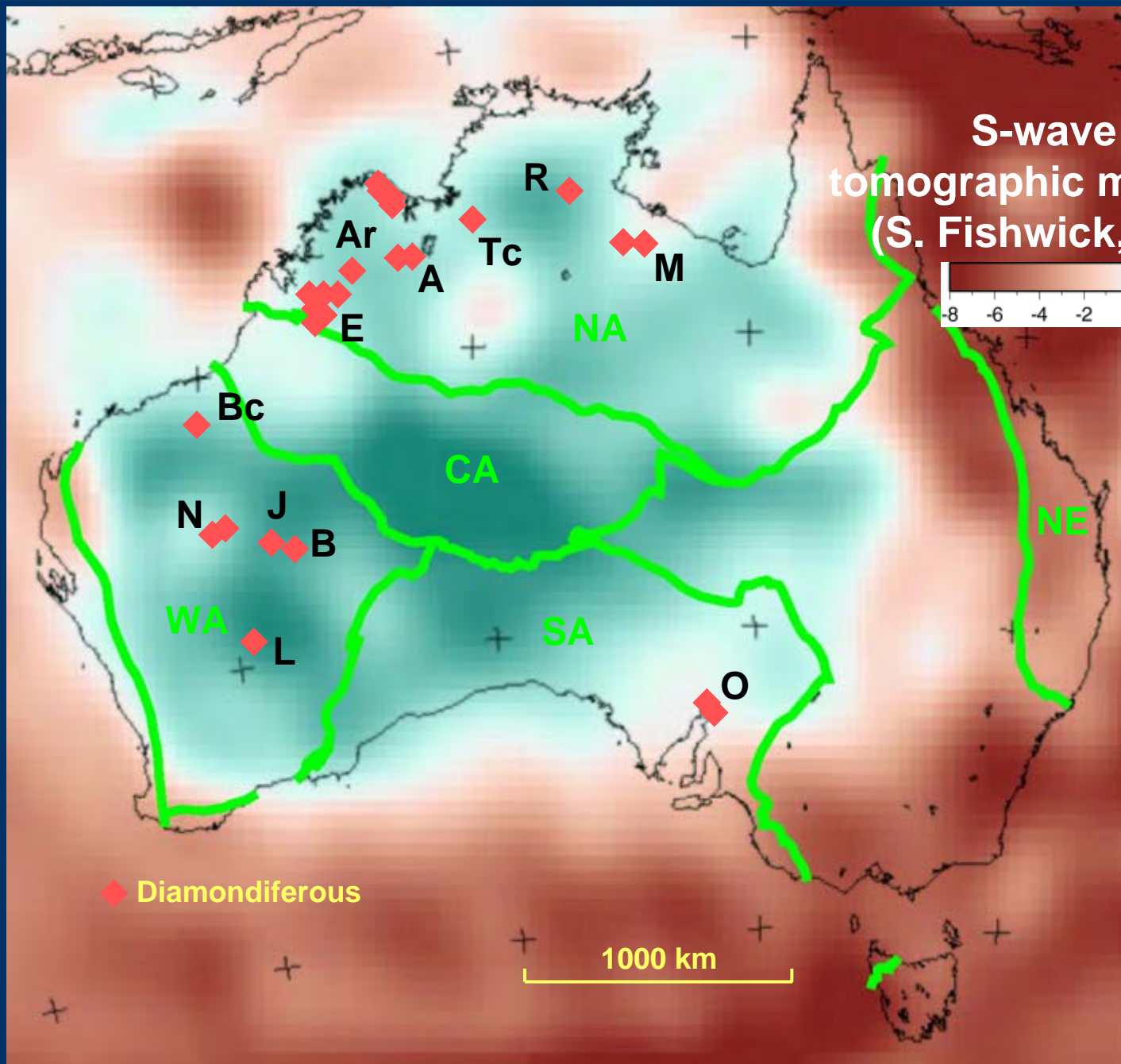
- slow
- warm
- fertile
- dense (less buoyant)
- wet
- weak

S. Fishwick & B. Kennett, RSES, ANU, 2004

Red/Brown slower than the world average
Blue faster than the world average.

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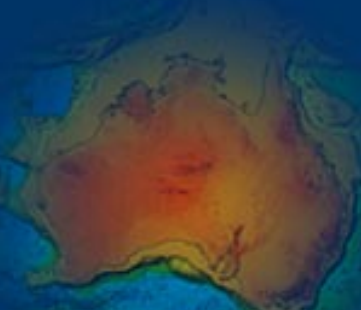


S-wave seismic tomographic model at 125 km (S. Fishwick, RSES, ANU)

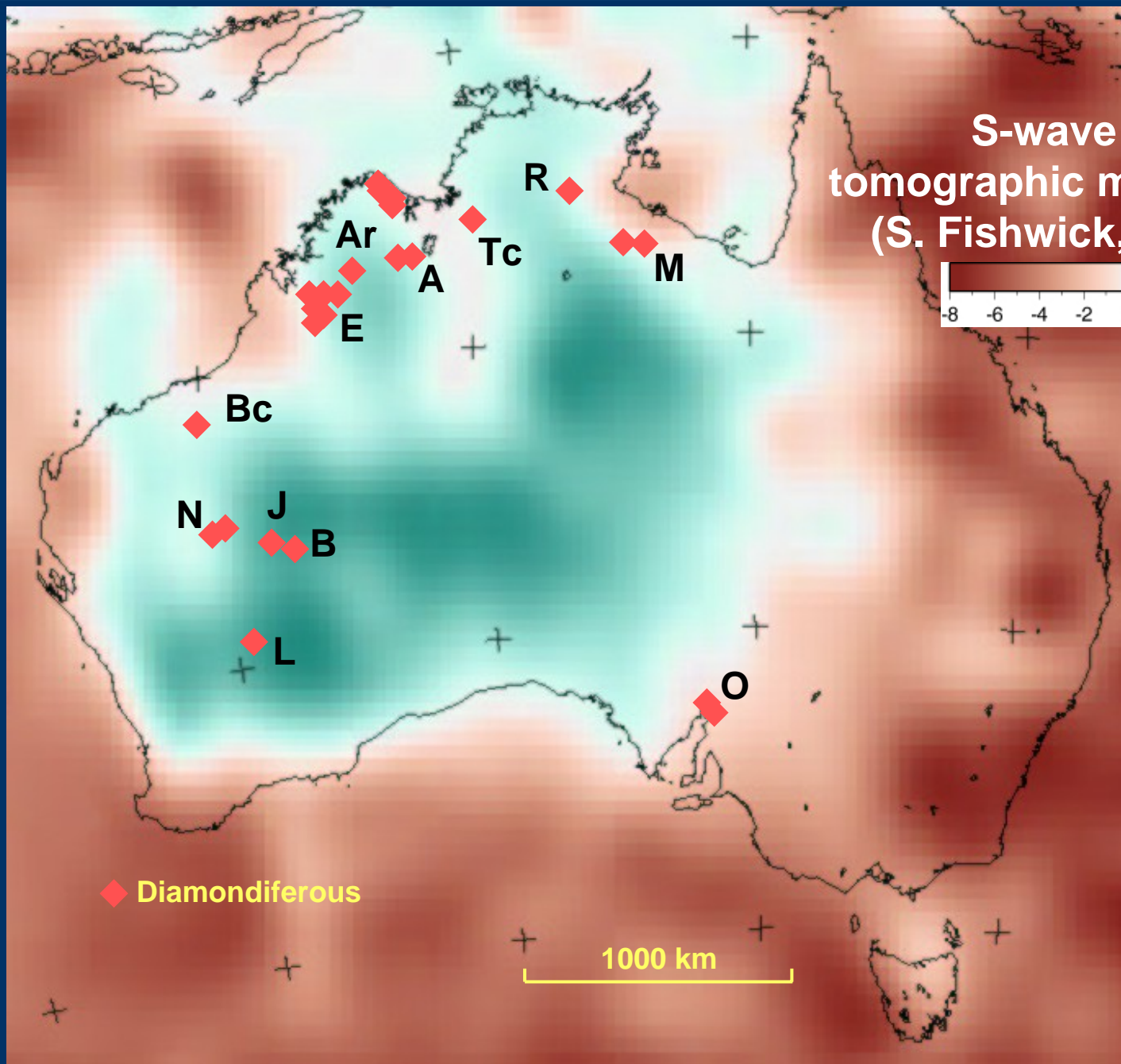
◆ Diamondiferous

1000 km

World Diamond Conference, Perth, 2004



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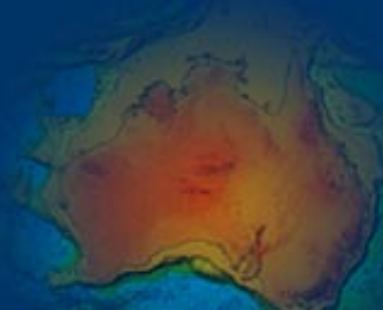


S-wave seismic tomographic model at 175 km (S. Fishwick, RSES, ANU)

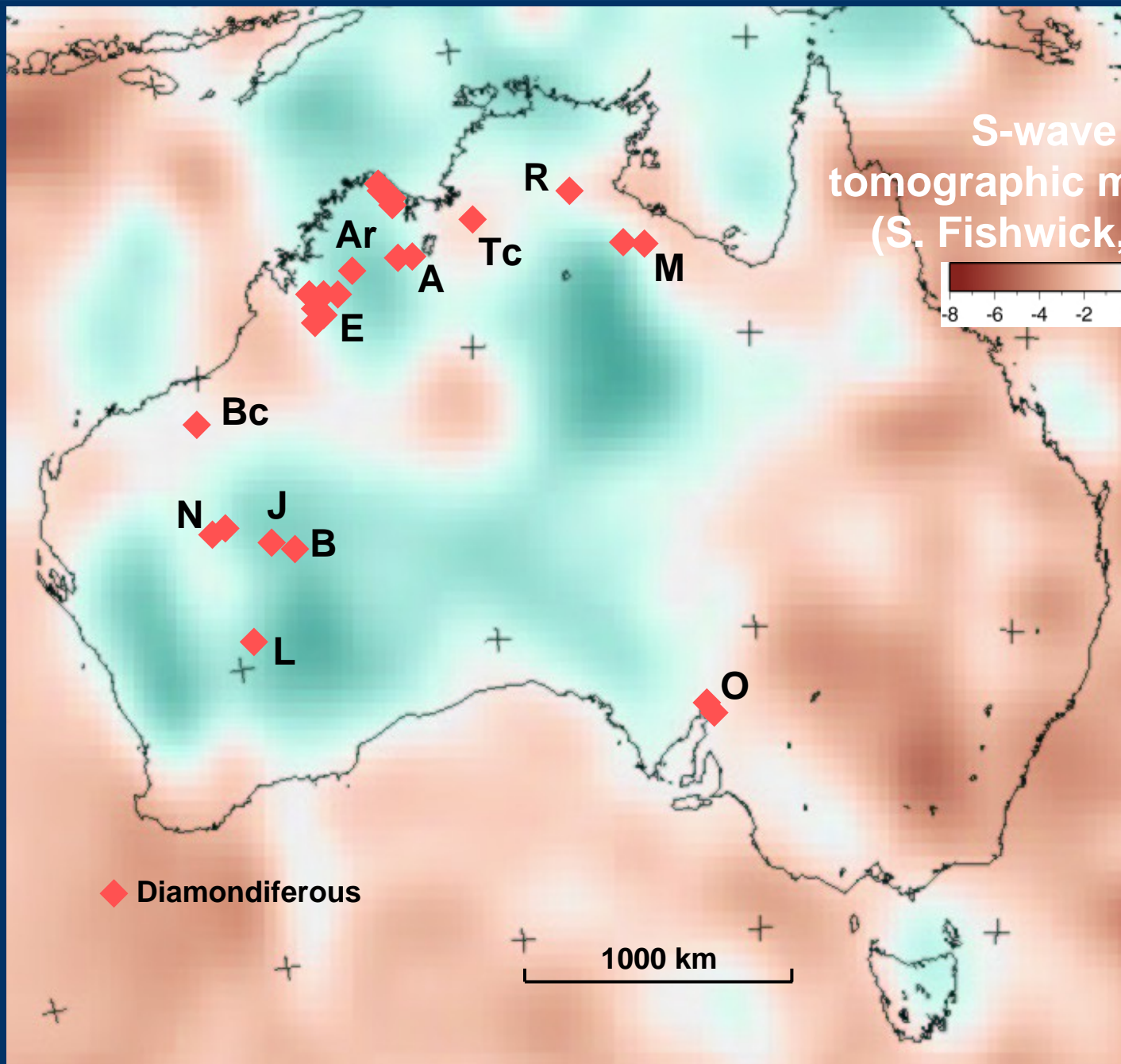
◆ Diamondiferous

1000 km

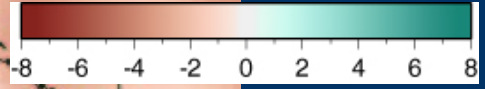
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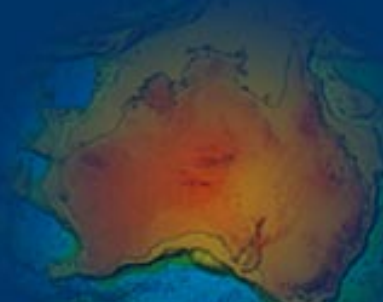
S-wave seismic tomographic model at 225 km (S. Fishwick, RSES, ANU)



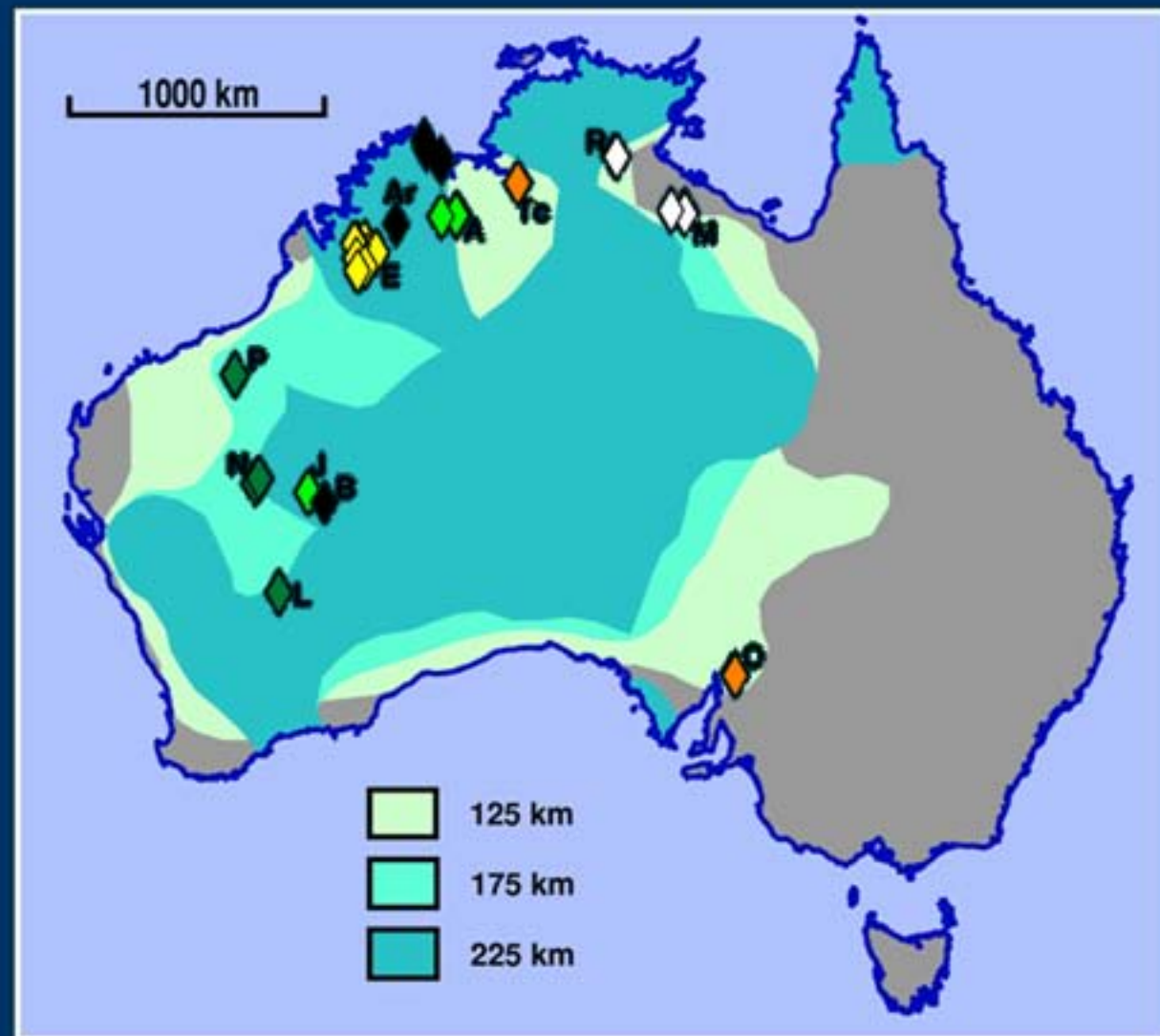
◆ Diamondiferous

1000 km

World Diamond Conference, Perth, 2004



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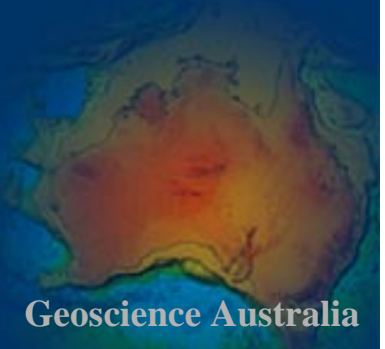
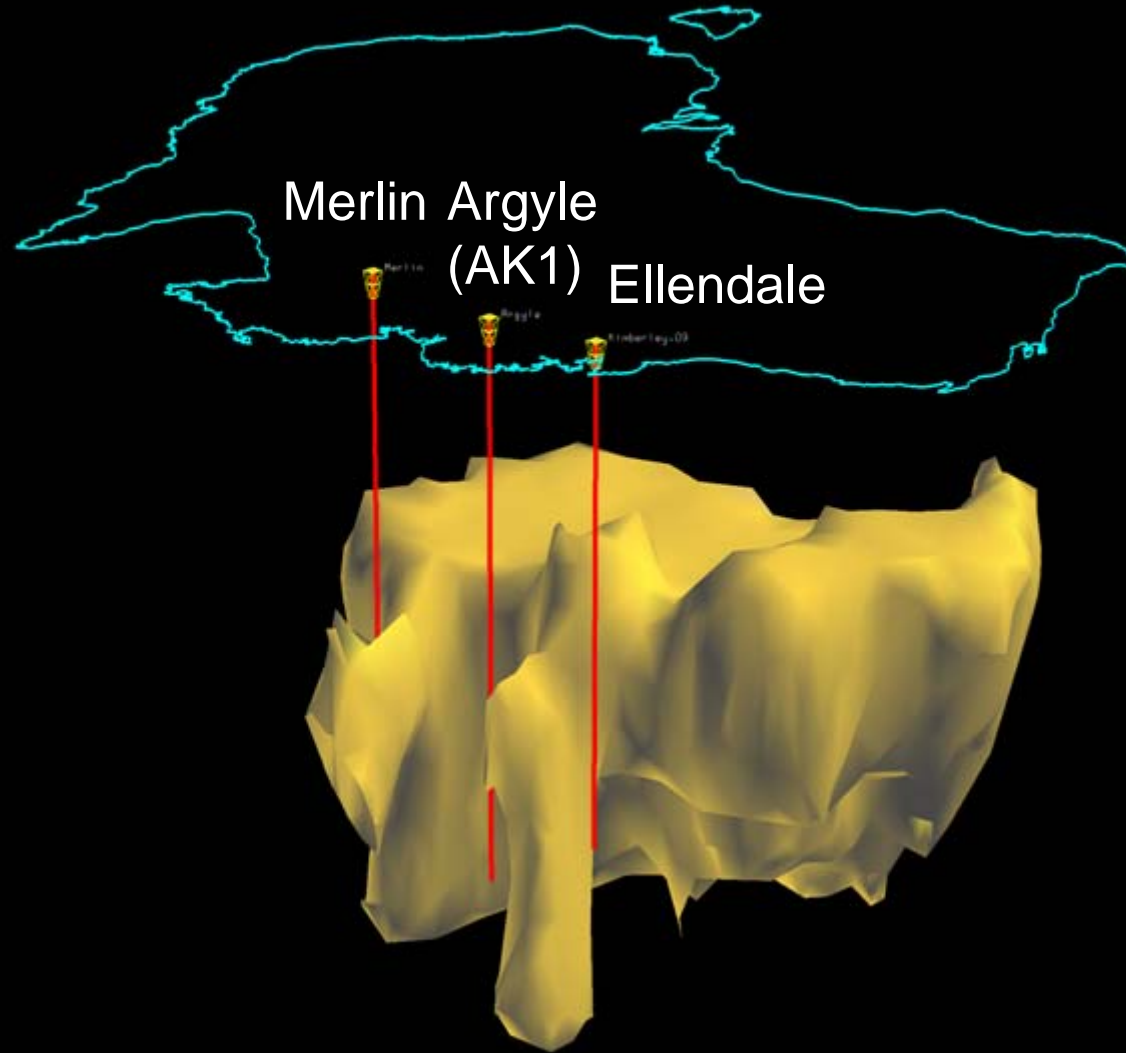
Seismic S-wave tomographic model

Coloured areas have 3D S-waves faster than average mantle at depth slices of 125, 175 and 225 km. Data clipped to coastline.

(S. Fishwick, RSES).

- ◆ Miocene (20 Ma)
- ◆ Jurassic (180-160 Ma)
- ◆ Devonian (380 Ma)
- ◆ Neoproterozoic (850 Ma)
- ◆ Mesoproterozoic (1300-1200 Ma)
- ◆ Palaeoproterozoic (2020-1900 Ma)

Mantle Roots

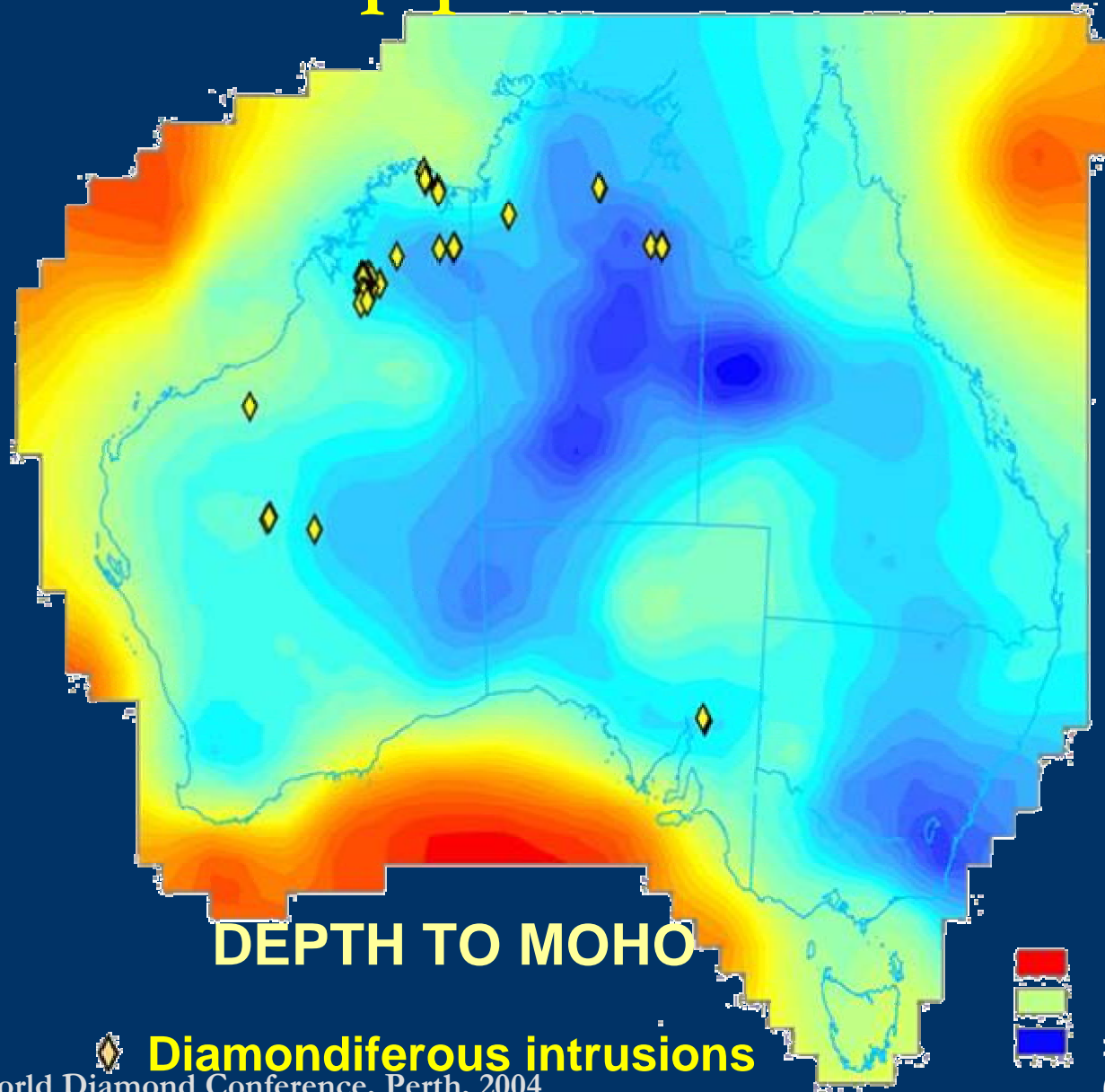


Continental Scale Controls

- Diamondiferous bodies lie within/at margin of old (>1.6 Ga, basement >2 Ga?), cold lithosphere.
- Crustal thickness = 35-55 km.
- Mostly cratonic palaeogeotherms (limited data).
- Peridotitic indicators indicate moderately refractory mantle source (G9 Iherzolite dominant).
- Multiple diamond events
 - Some associated with major extension events e.g. Rodinia (~800 Ma), Gondwanaland (~160-180 Ma)

.... but what about province-scale controls?

Diamond pipes and crustal thickness



DEPTH TO MOHO

 **Diamondiferous intrusions**

DEPTH



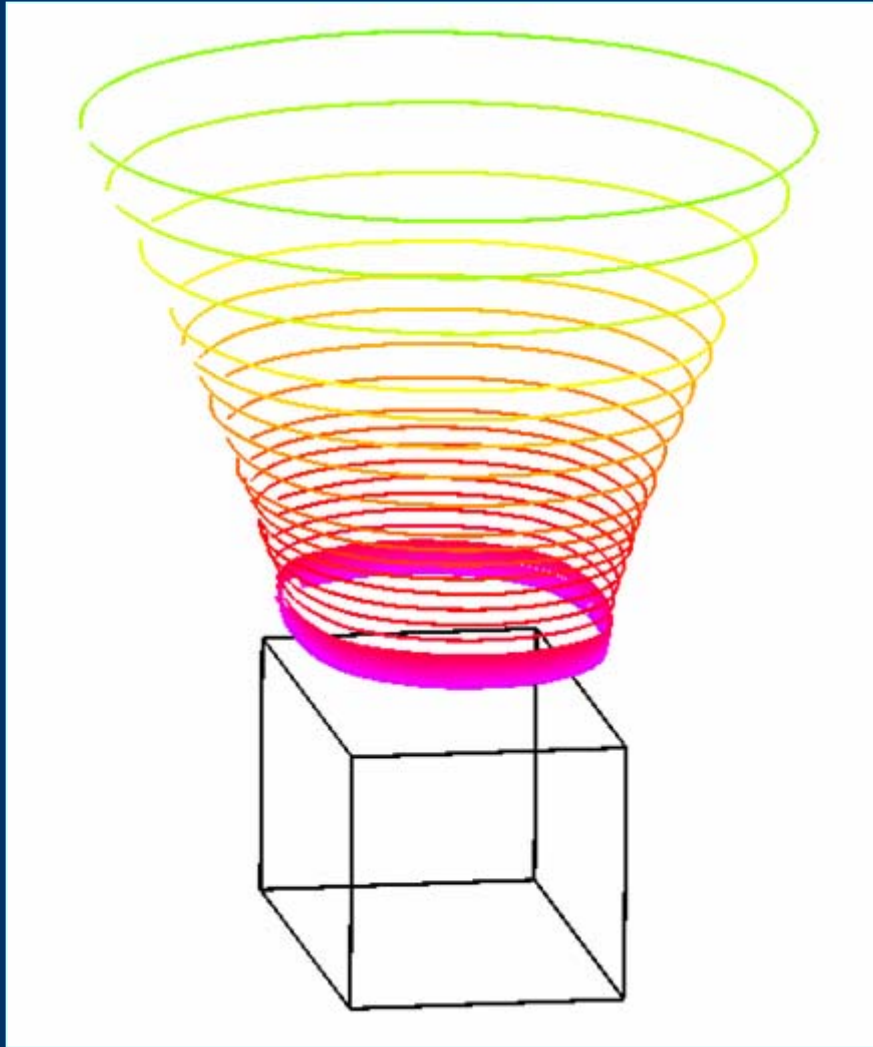
5 km
30 km
> 50 km

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(Collins et al, 2002)

World Diamond Conference, Perth, 2004

Potential Field Edge Detection & Trend Analysis

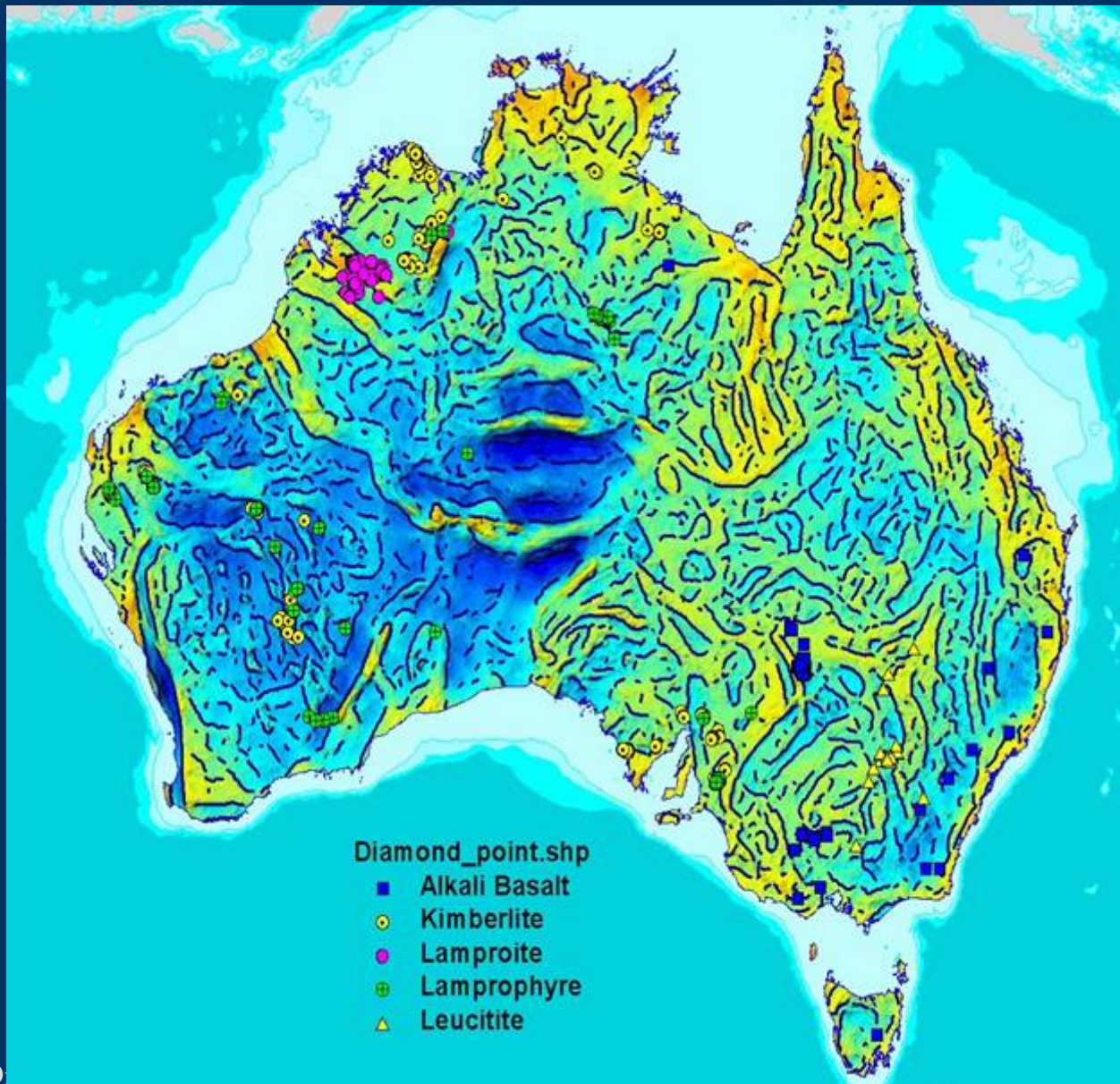


Prism model with “strings” or polylines joining points computed at the maxima of many levels of upward continuation of the gravity response, and plotted at the appropriate upward continuation level.

Coloured by the strength of the horizontal gradient at each point (magenta high, green low).

P. Milligan, Geoscience Australia

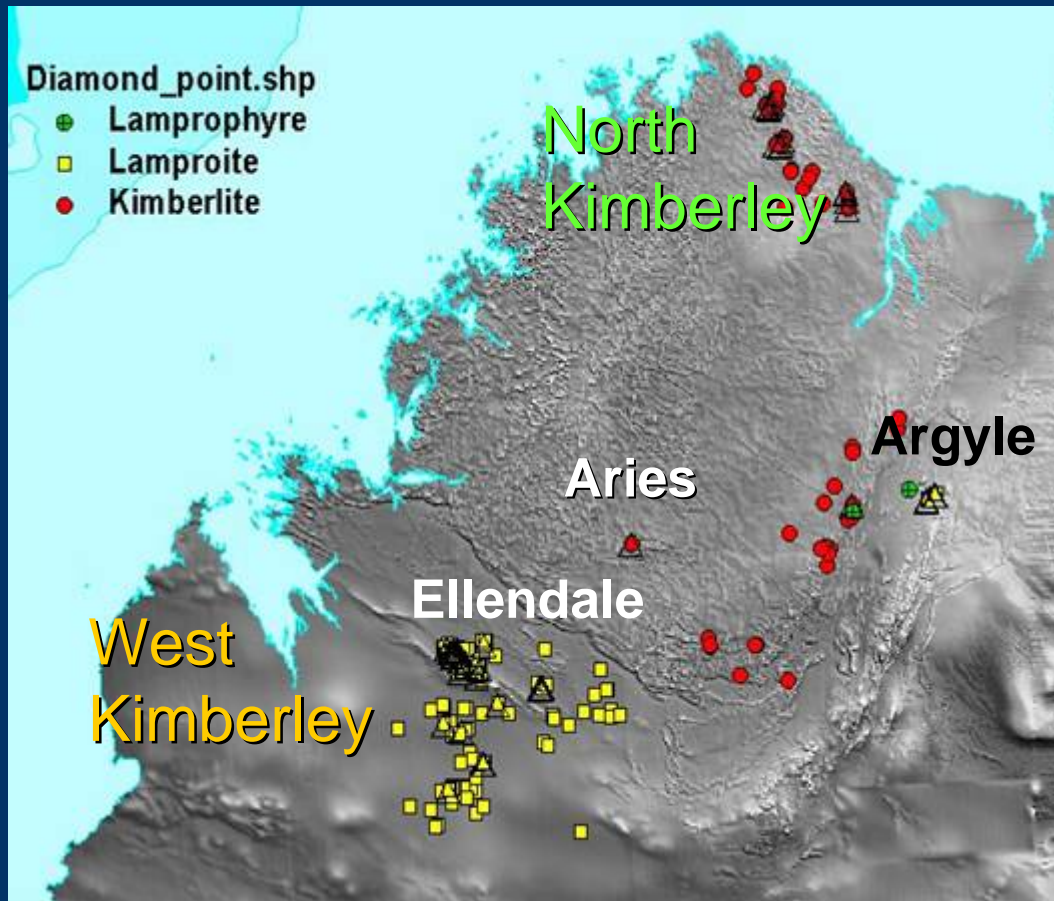
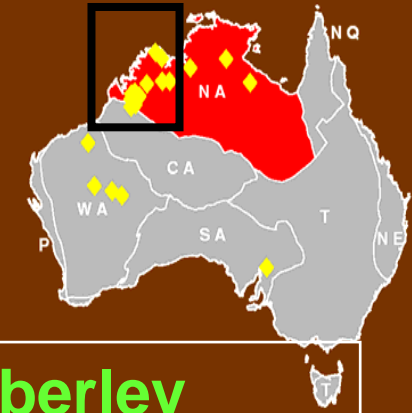
Intrusions on total horizontal gravity gradient



20 km upward
continuation

Jaques &
Milligan, 8IKC,
2004

Kimberley Craton



Greyscale of Total Magnetic Intensity

North Kimberley

- >40 kimberlites (800 Ma)
- >50% diamondiferous

East Kimberley

- >20 kimberlites (800 Ma)
- 1200 Ma Argyle lamproite

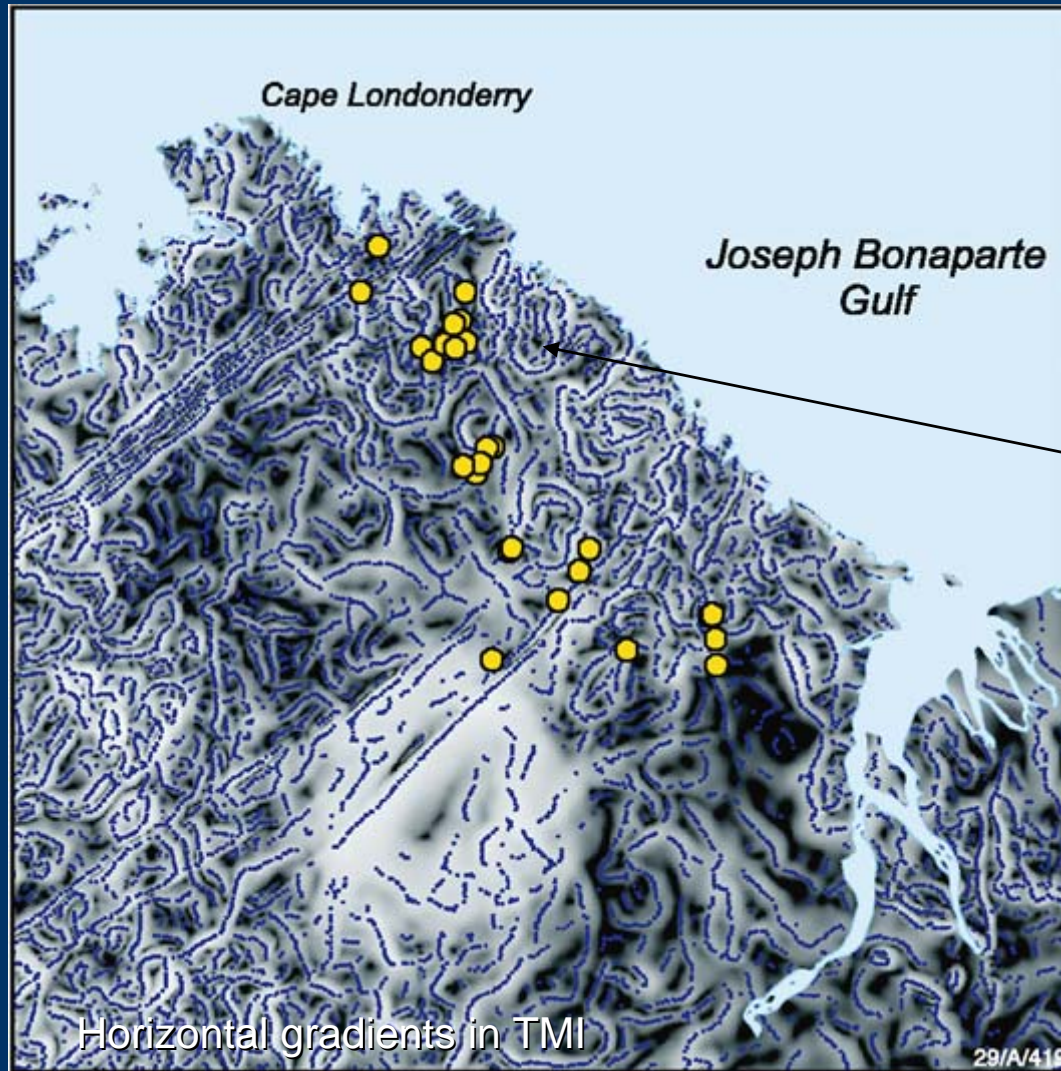
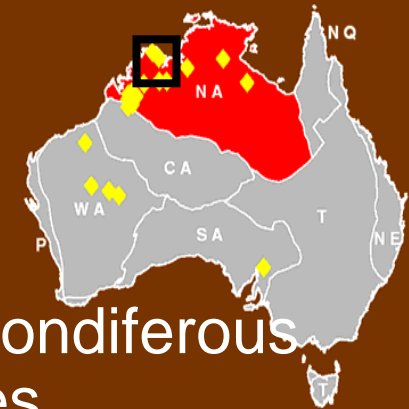
Central Kimberley

- Aries + satellite pipes

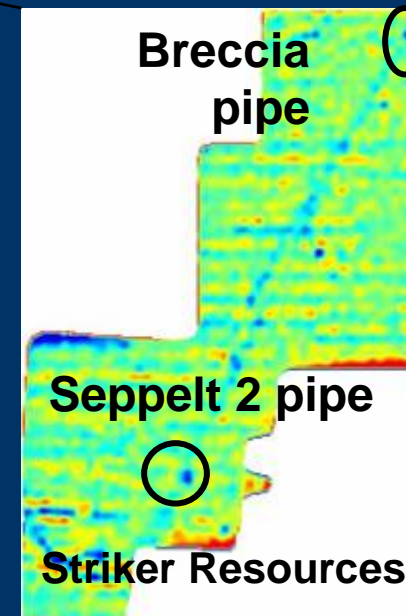
West Kimberley

- >150 lamproites (20 Ma)
- ~2/3 Ellendale pipes diamondiferous (low grade)

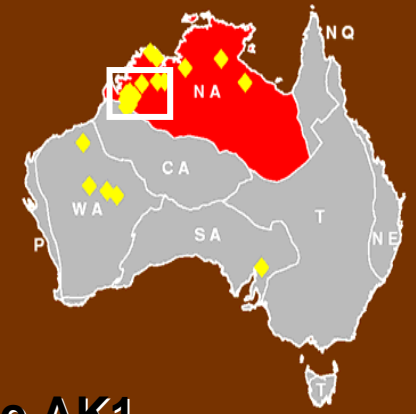
North Kimberley Province



- >20 diamondiferous kimberlites,
- 800 Ma
- NE control on NW gravity high (corridor)



Lamproites in Orogenic Belts



Kimberley Craton

**Late Archaean-
Palaeoproterozoic**

**Argyle AK1
lamproite pipe
1180 Ma**

**Ellendale Field
lamproites
~20 Ma, >50
diamondiferous
lamproites**

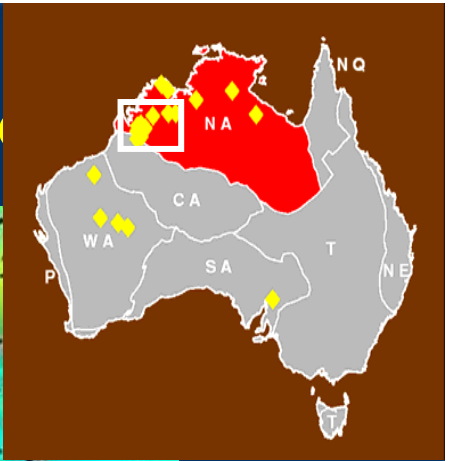
King Leopold Orogen

Halls Creek Orogen

Faults on Bouguer anomaly

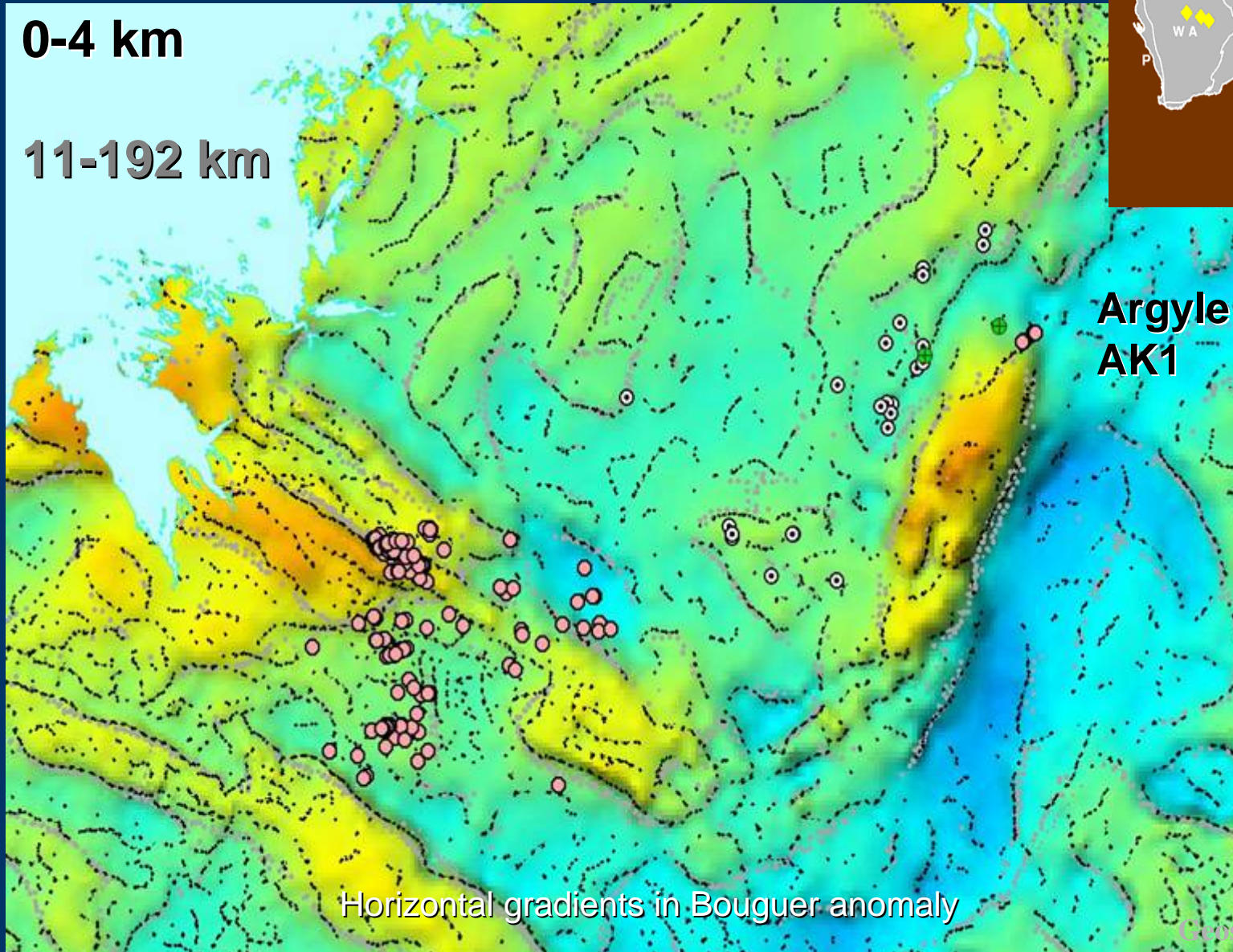
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Controls on Lamproite Distribution



0-4 km

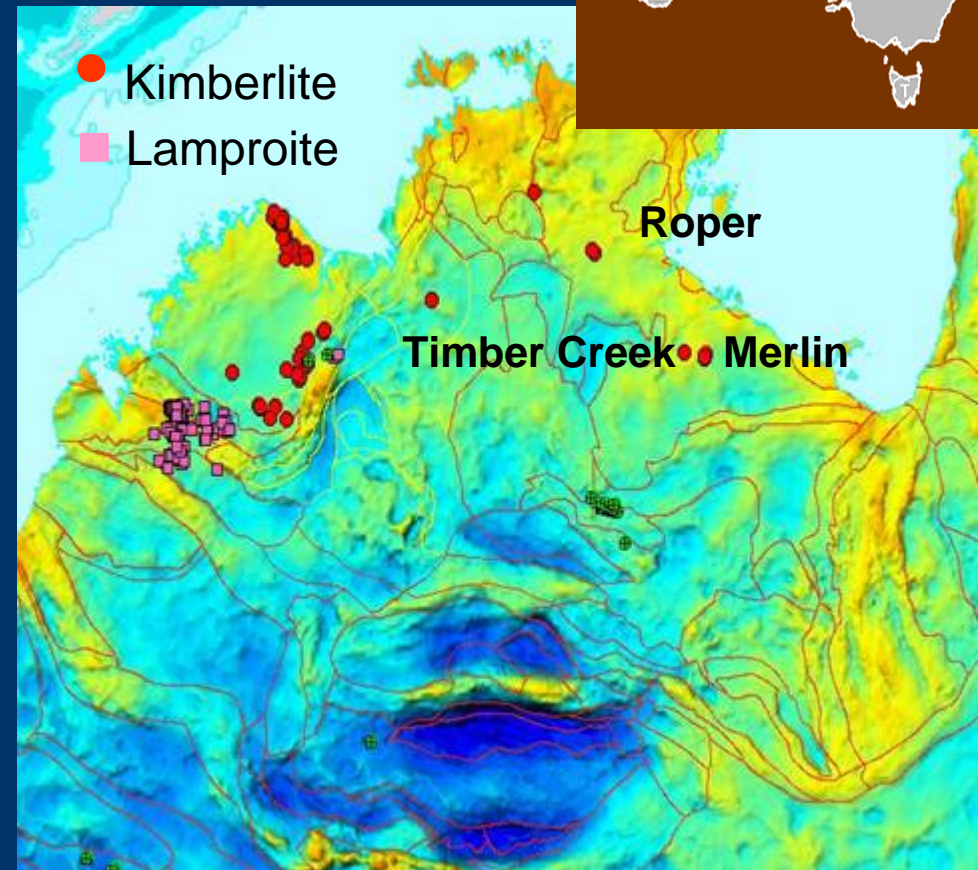
11-192 km



Horizontal gradients in Bouguer anomaly

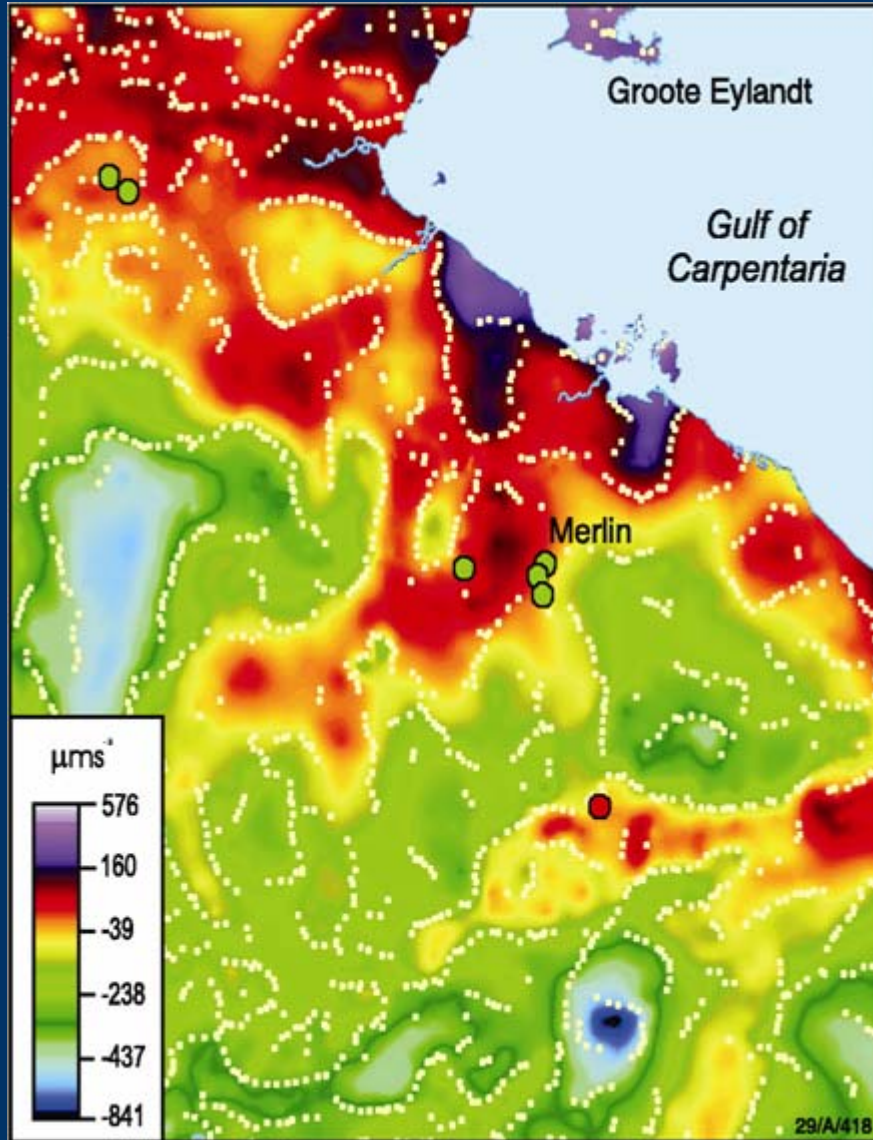
North Australia Craton

- Diamondiferous kimberlites
 - Merlin 380 Ma, Roper
 - Timber Creek 180 Ma
- Proterozoic ('Barramundi') basement but inherited Archaean zircons common
 - Archaean nuclei ?
- Mesozoic and regolith cover

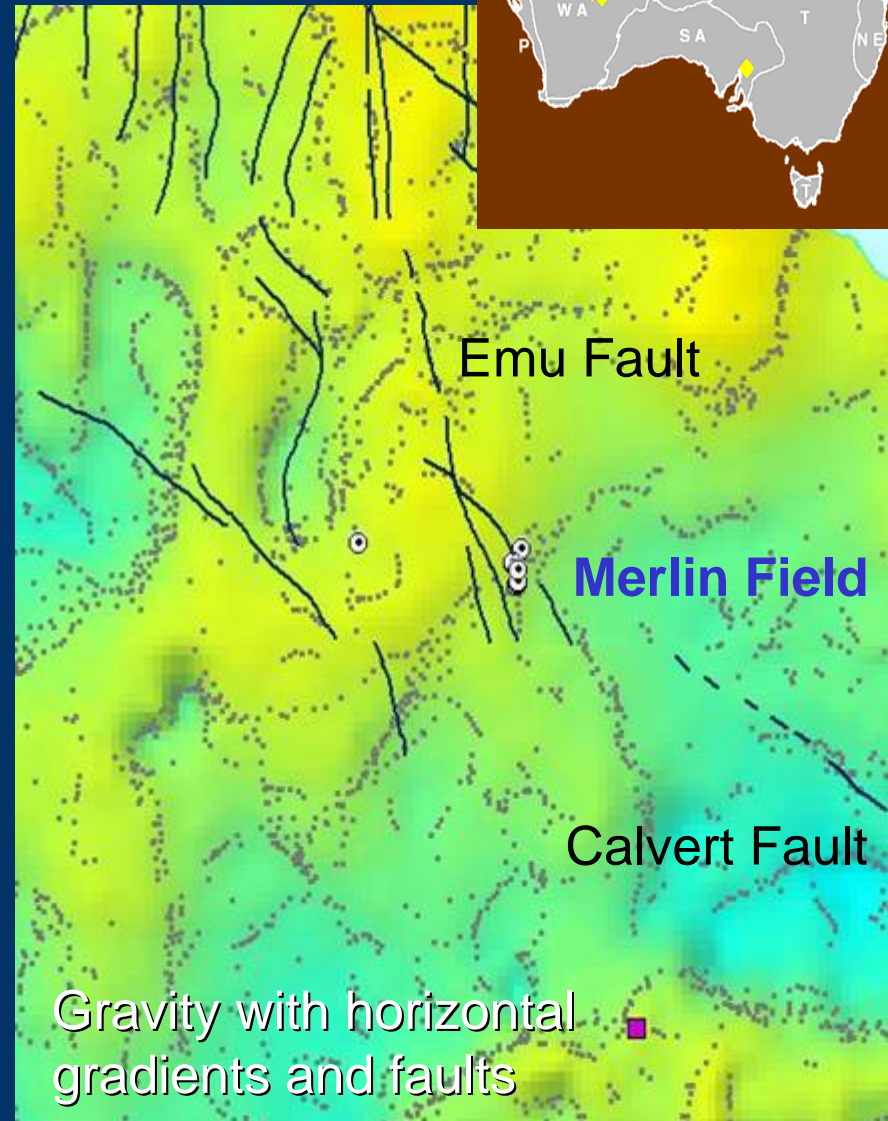


Bouguer anomaly map

Structural control on Merlin kimberlites

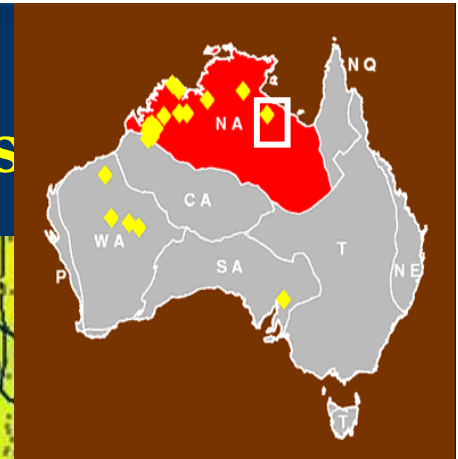


World Diamond Conference, Perth, 2004



Gravity with horizontal gradients and faults

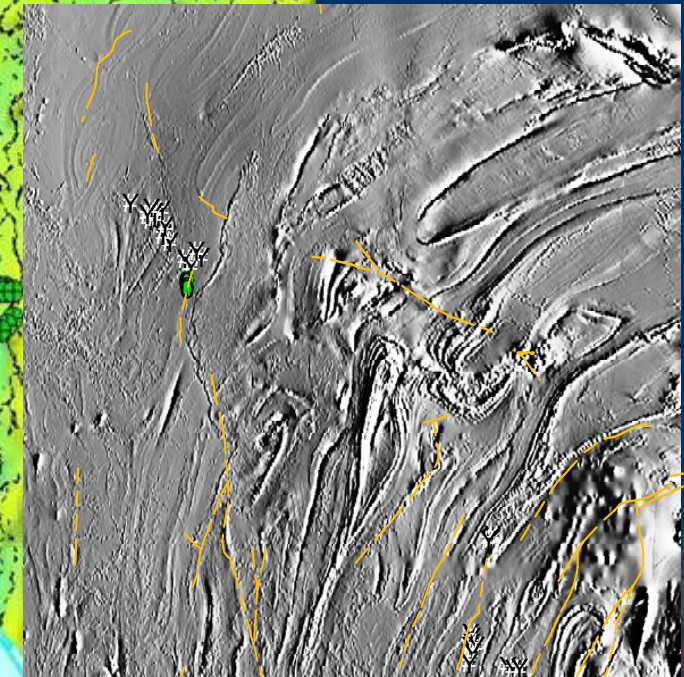
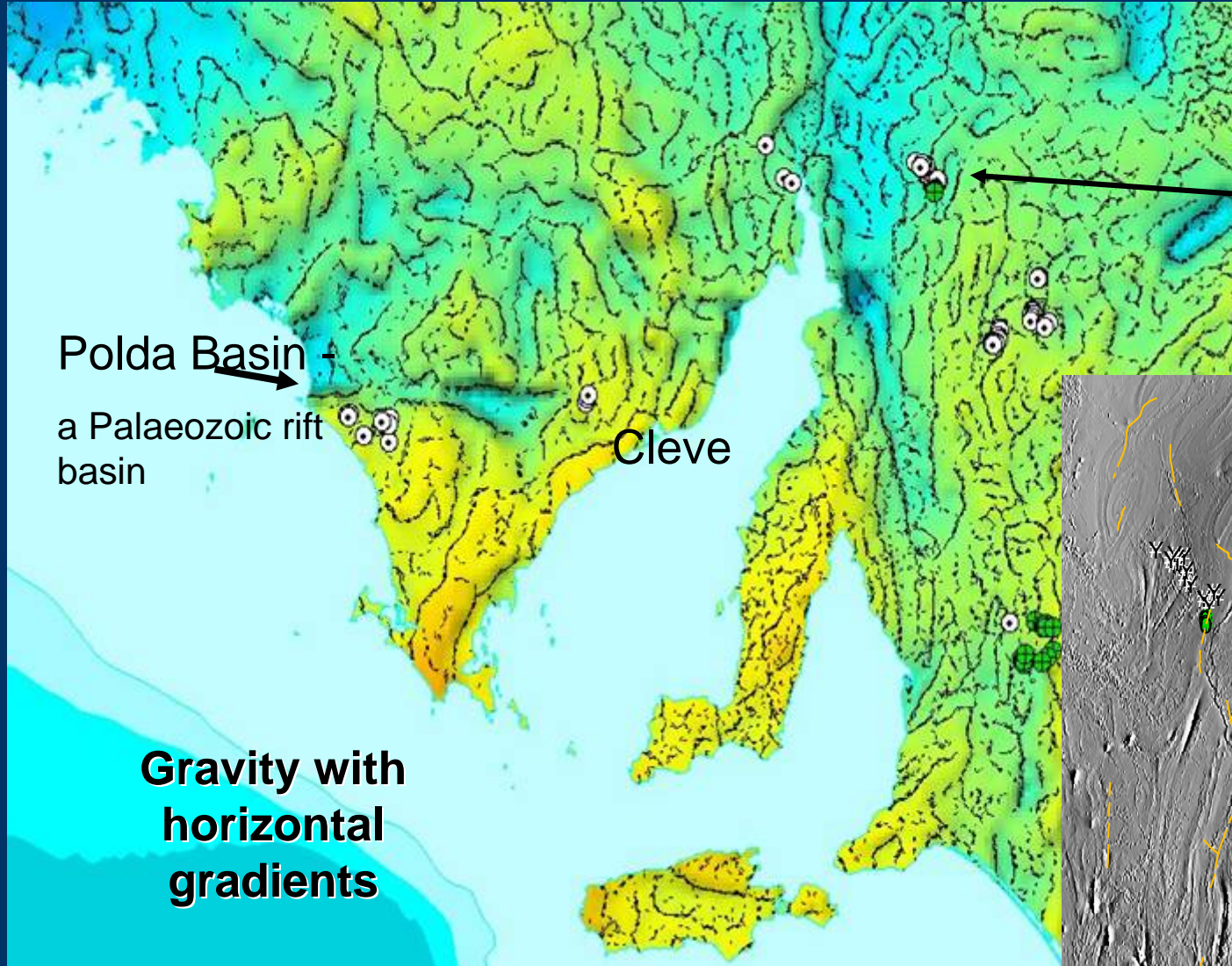
Geoscience Australia



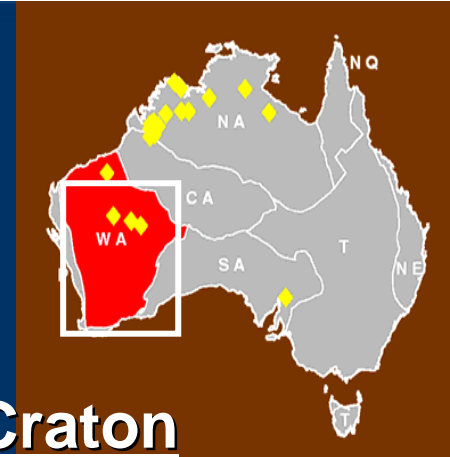
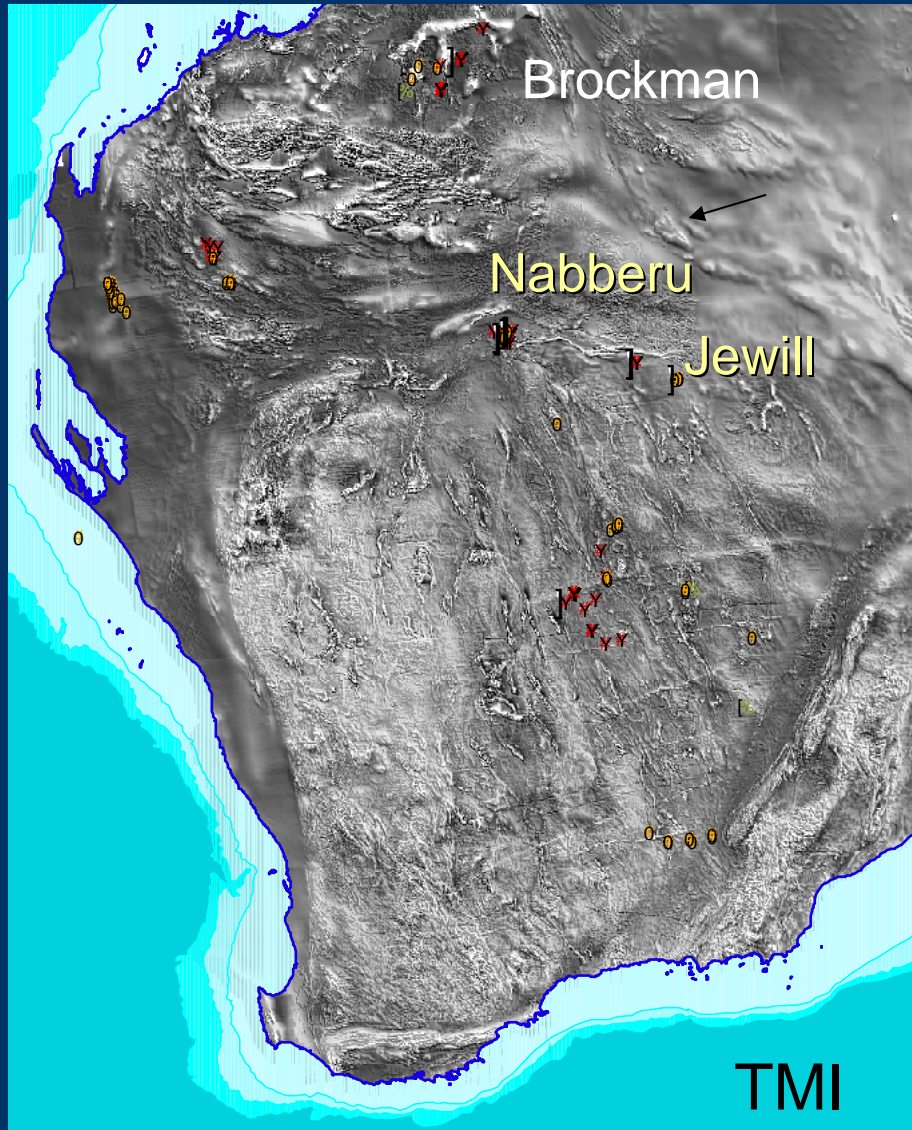
Gawler Craton



Orroroo
kimberlites



Yilgarn - Pilbara Craton



Pilbara Craton

1900 Ma kimberlite

Yilgarn Craton

Multiple ages of kimberlite and ultramafic lamprophyre

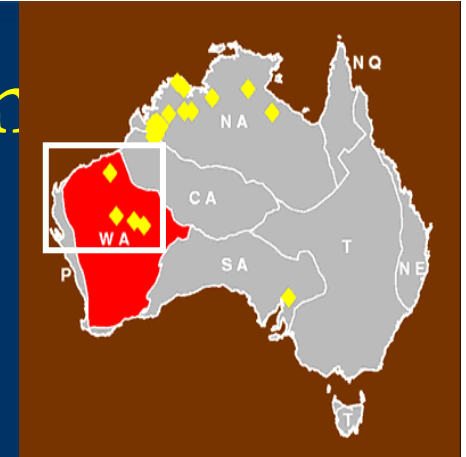
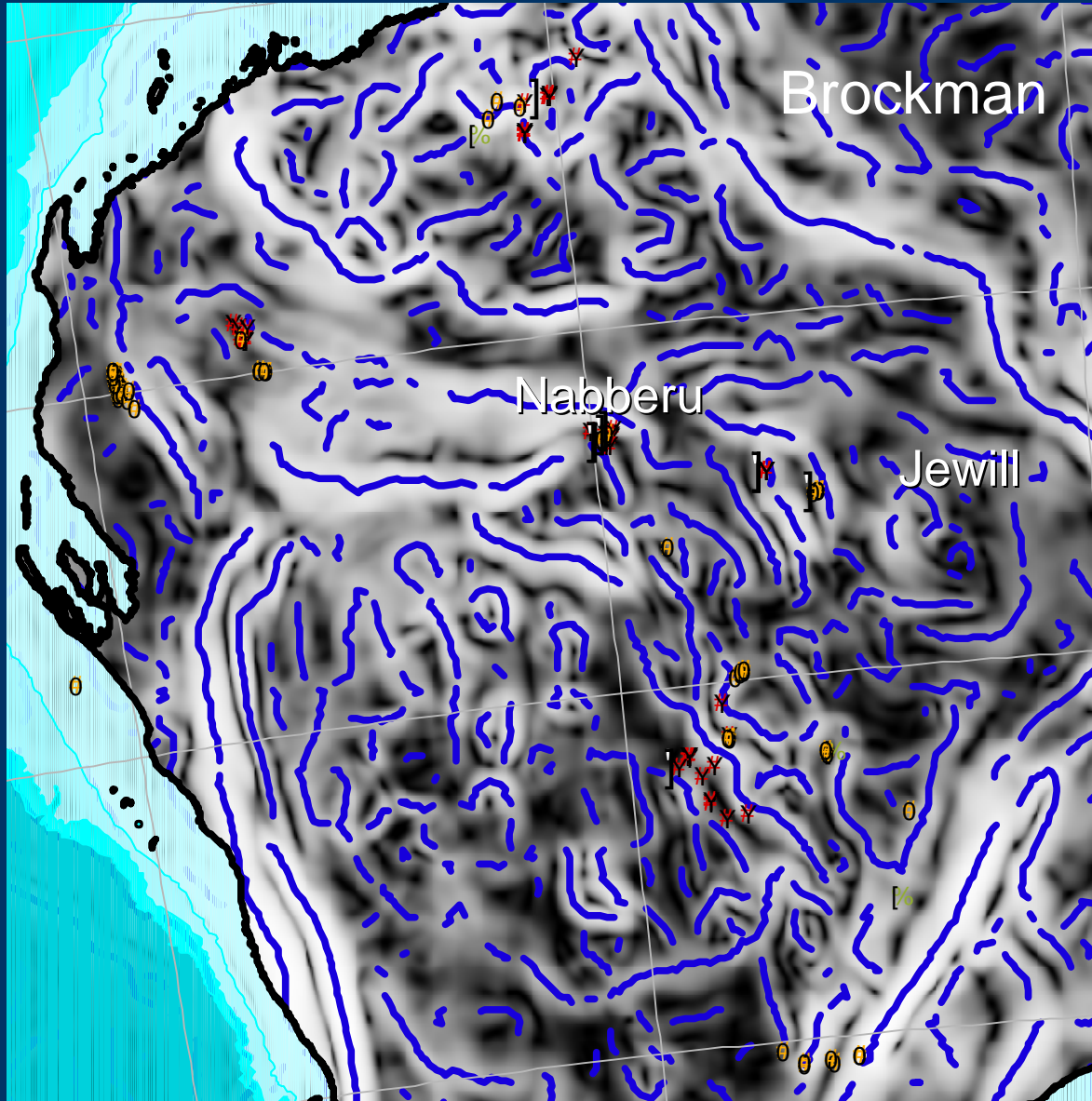
850 Ma - lamprophyre

1300 Ma - kimberlite, lamprophyre

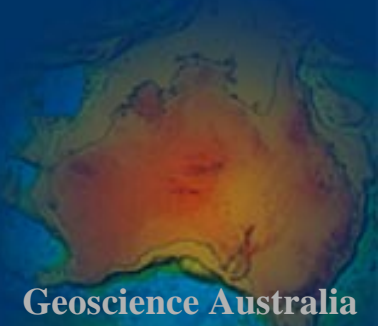
1900 Ma - kimberlite

2050 Ma - kimberlite

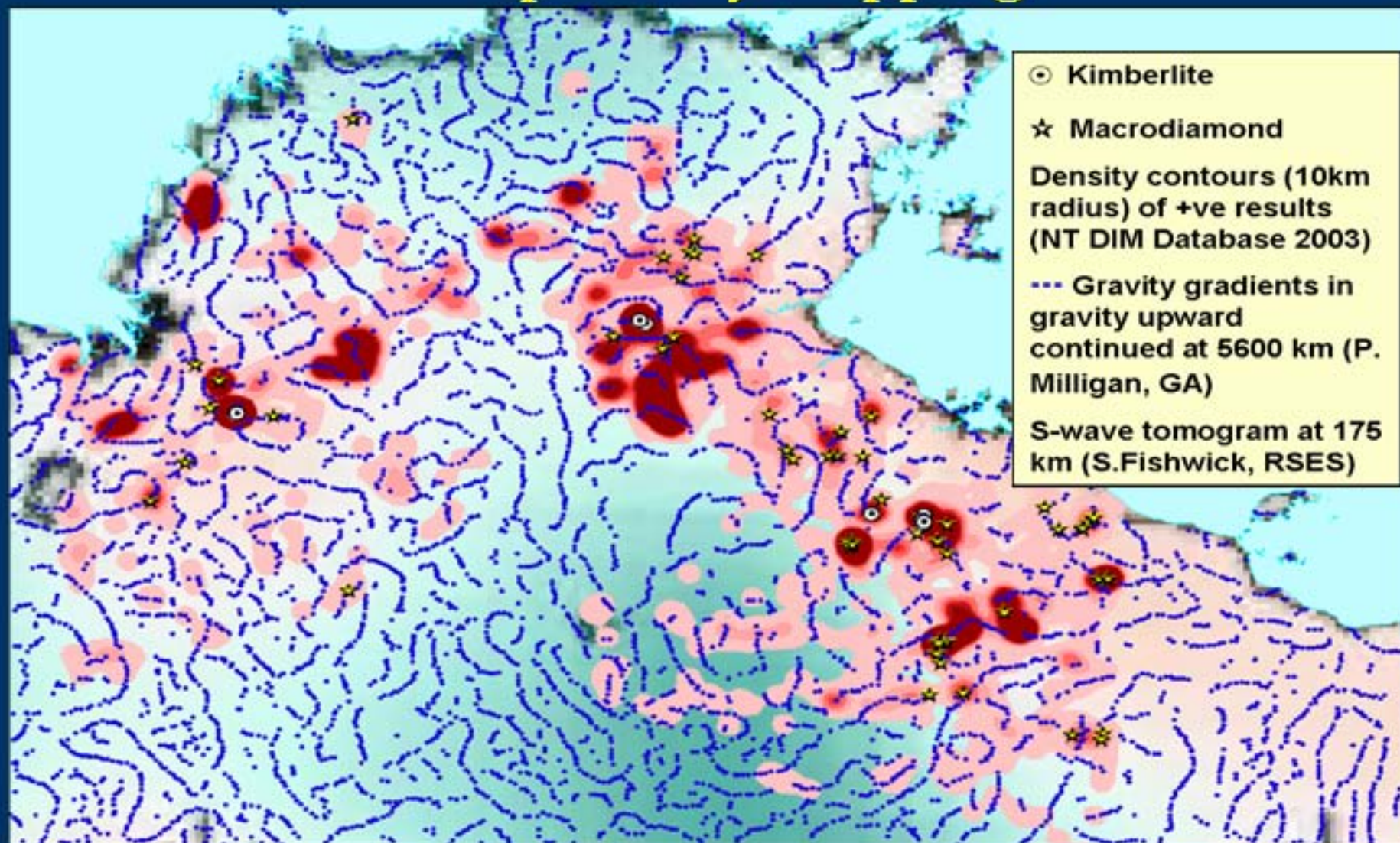
Yilgarn - Pilbara Craton



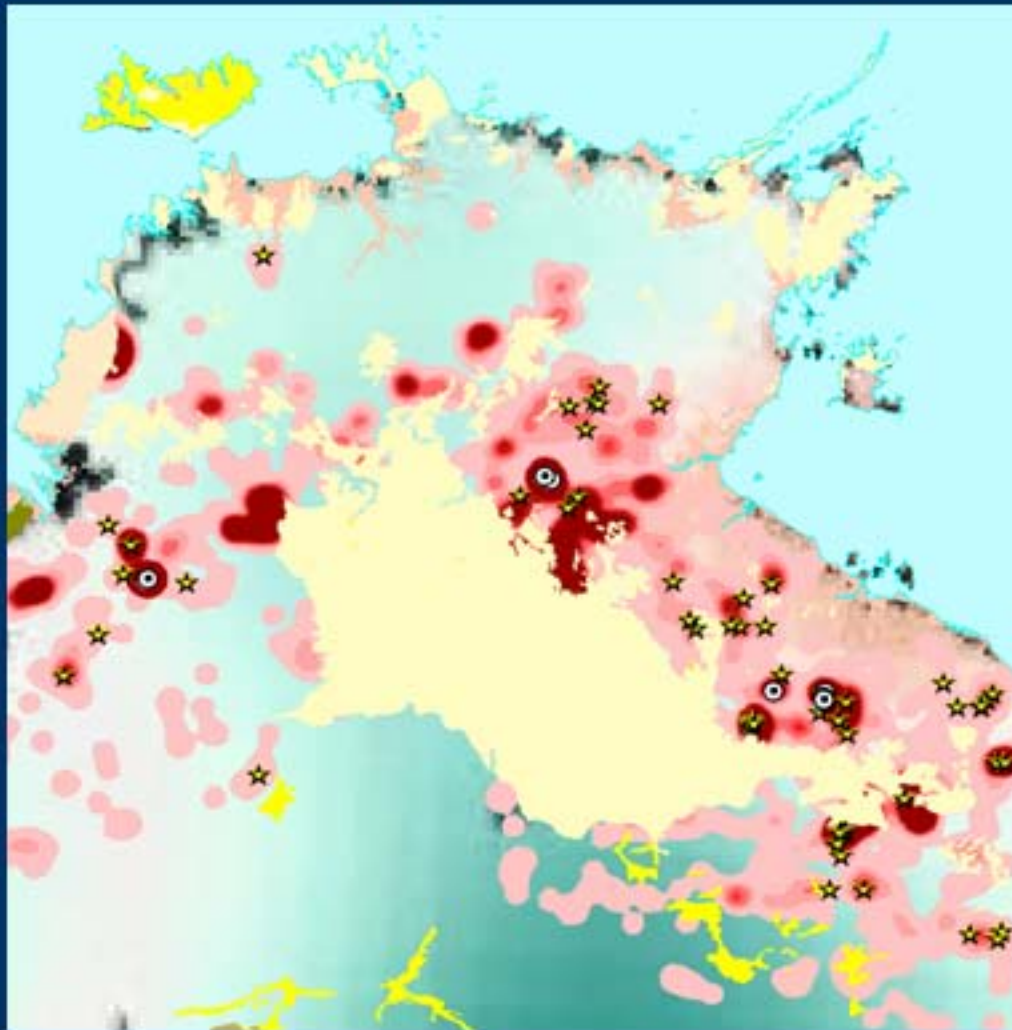
**Gravity
horizontal
gradients
to 2 km**



Prospectivity Mapping



Limitations to empirical prospectivity mapping



Cretaceous and younger cover

⊙ Kimberlite

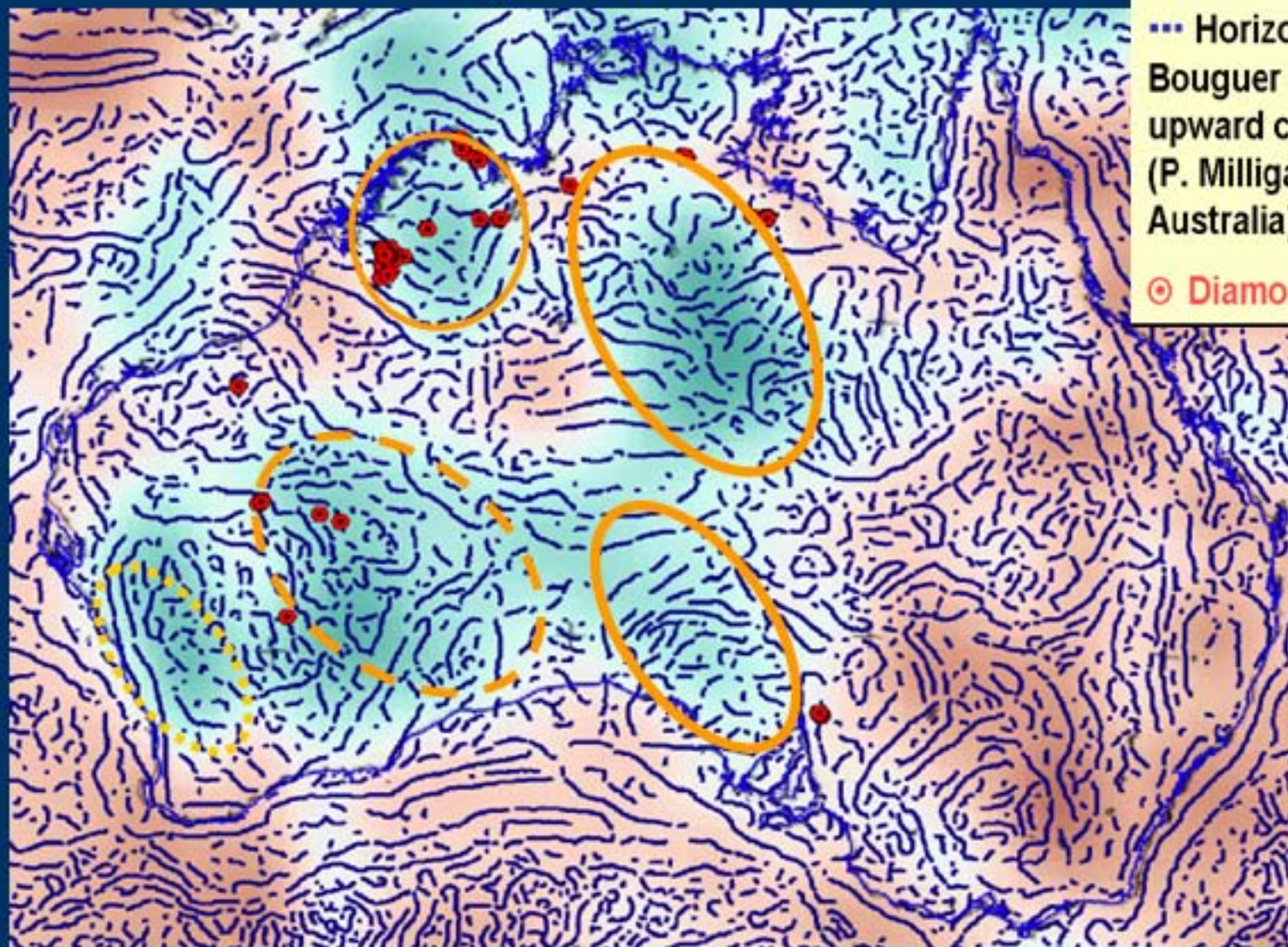
☆ Macrodiamond

Density contours (10km radius) of +ve results (NT DIM Database 2003)

--- Gravity gradients in gravity upward continued at 5600 km (P. Milligan, GA)

S-wave tomogram at 175 km (S.Fishwick, RSES)

Where to next? Prospective Craton Roots?



--- Horizontal gradients in Bouguer gravity anomaly upward continued to 20km (P. Milligan, Geoscience Australia)

⊙ Diamondiferous pipes

S-wave seismic tomographic model at 175 km (S. Fishwick, RSES, ANU)

Conclusions

- **Significant number of kimberlites, lamproites and ultramafic lamprophyres found**
 - **new diamondiferous discoveries**
- **Australian diamond exploration needs a significant new discovery to keep us on the diamond radar screen**
- **Much of the Australian Shield is prospective but how can we to narrow the search area?**
- **Exploration difficult because of regolith/cover**
 - improved targeting required
 - potential under cover
 - poor survival of indicators, and erratic distribution

Conclusions 2

- **Role for continental-scale geophysics to define fertile source regions (mantle roots) and identify favourable tectonic zones/corridors**
- **Many intrusions show structural control**
- **Structures commonly evident in potential field data (horizontal gradients of upward continued gravity and magnetic data)**
 - - Multi-scale approach needed (fine & coarse scale structures)
 - - Diamond pipes located at boundaries/breaks in lithosphere and crustal domains?
- **Increasing use of geophysics - VHR magnetics, AEM, airborne gravity gradiometry**



P. Milligan, M. Nicholas,
M. Ratajkoski, GA
Stewart Fishwick, Brian
Kennett, RSES, ANU



- De Beers Ltd
- Kimberley Diamond Co
- Rio Tinto Ltd
- Striker Resources NL

Australian Diamond Deposits, Kimberlites and Related Rocks 1:5M map 2004

