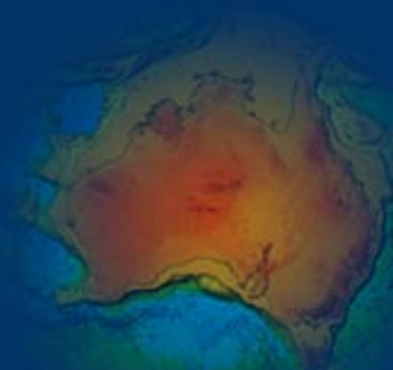
Australian Government

Geoscience Australia

Yilgarn crust and mantle lithosphere framework: geodynamic insights and interpretations

Minerals Exploration Seminar

Perth, 29 November 2004



Acknowledgements

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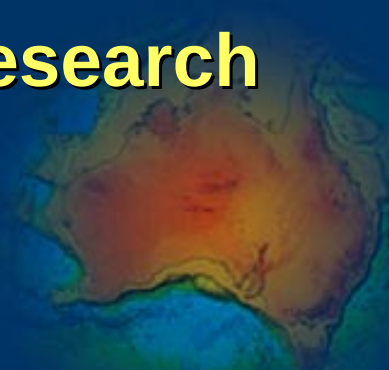
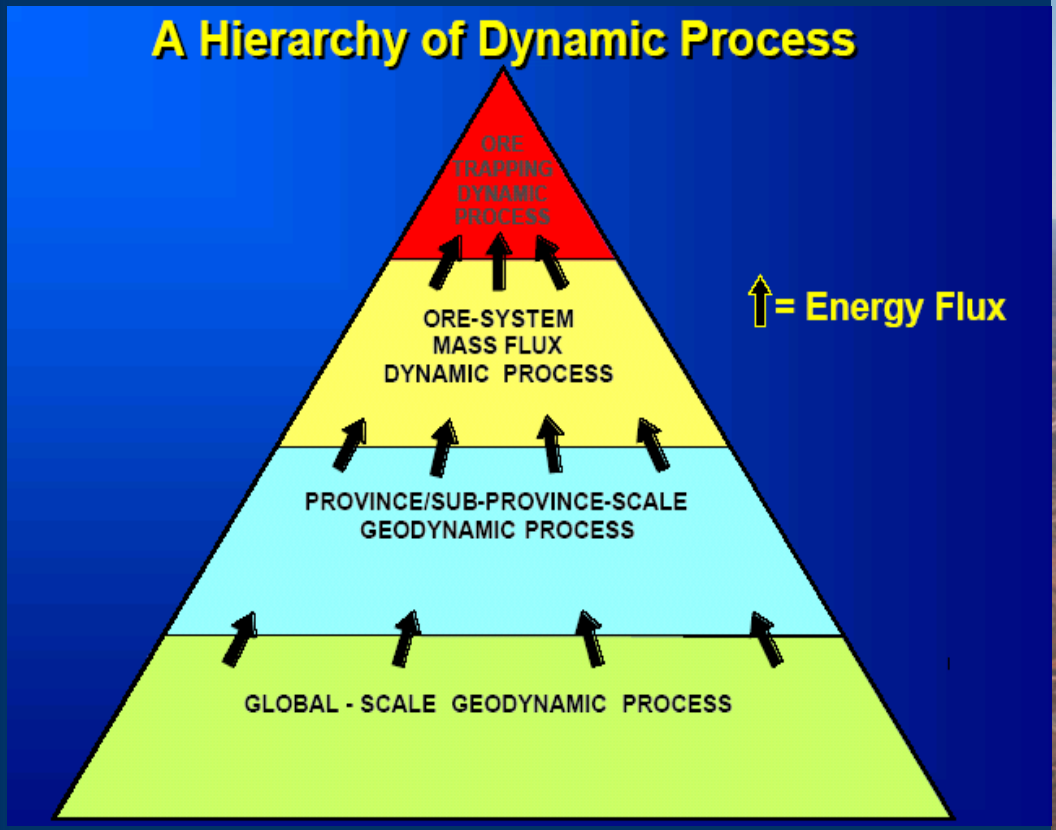
- ***pmd****CRC (Predictive Mineral Discovery)**
- **AMIRA P437/P437A, P482, P624**
- **Australian National Seismic Imaging Research (ANSIR) facility**
- **mineral exploration companies**



Mineral Systems

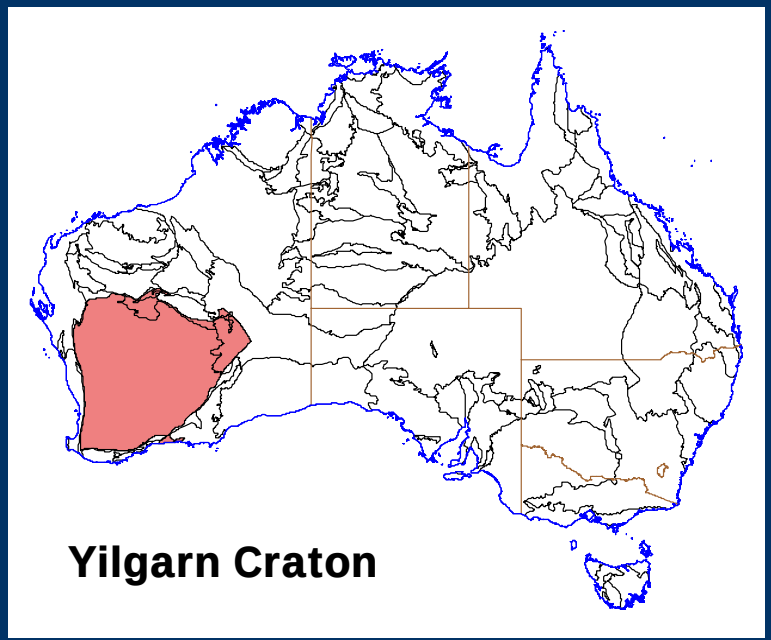


Jon Hronsky (Western Mining Corporation) presented at SEG 2004

- Ore deposits are focal points of large-scale energy and mass flux systems
- Generally, larger and more energetic systems equals bigger ore deposits
- The system may be recognised even though the precise genetic links with mineralisation are unclear

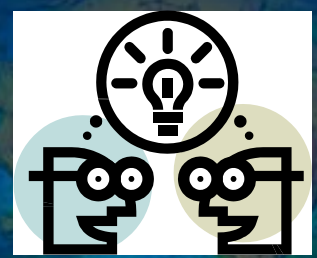
Talk Outline

What ‘signature’ has this energy and mass flux left on the Yilgarn’s crust and mantle lithosphere?

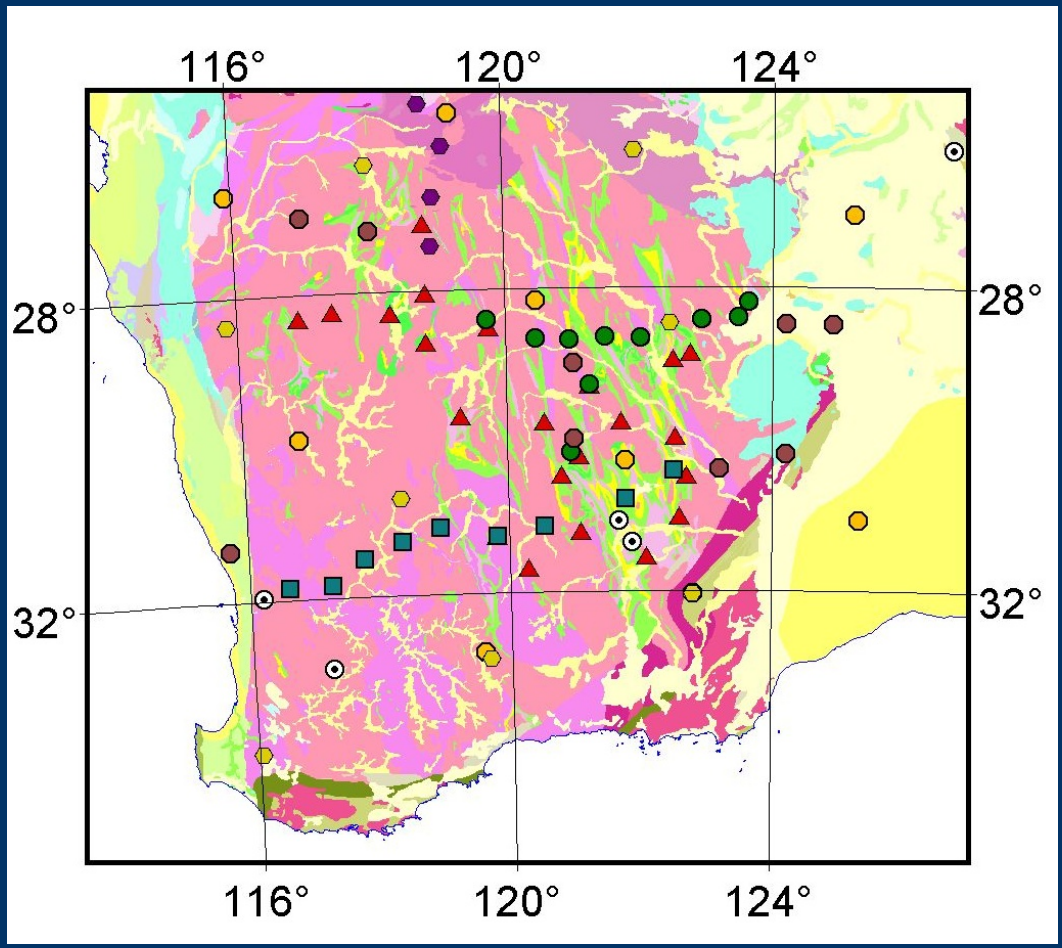


- Use seismic tools to examine the possible ‘signatures’
- Slabs, subduction, delamination?
- Plumes?
- Terranes?
- Conclusions

Examining hypotheses



Seismic tools: Broad Band

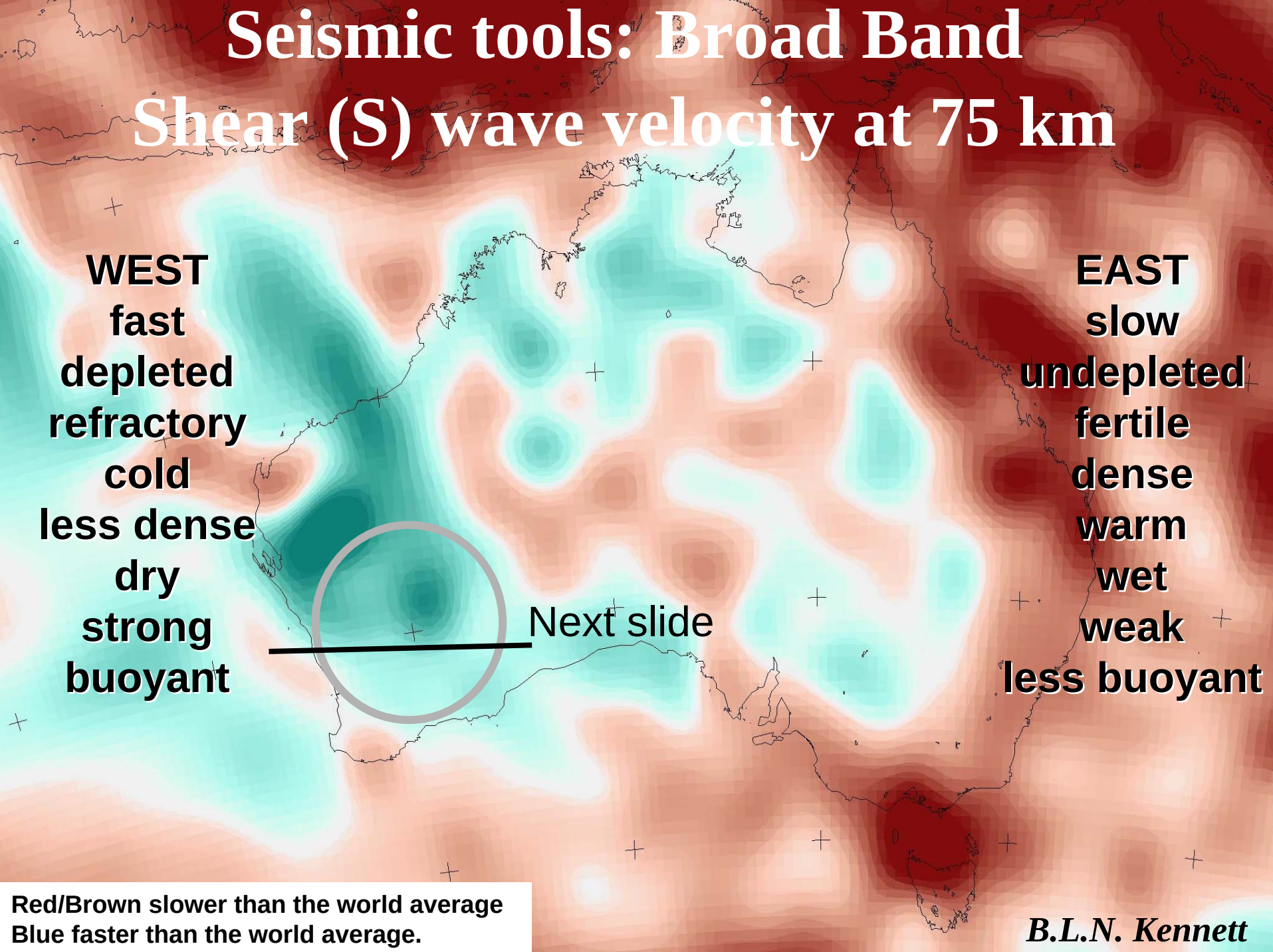


Location of Yilgarn recorders

- P-wave, S-wave and surface wave velocity from distant earthquakes
- Tomographic image of velocity structure of the Australian lithosphere (to 350 km)

Seismic tools: Broad Band

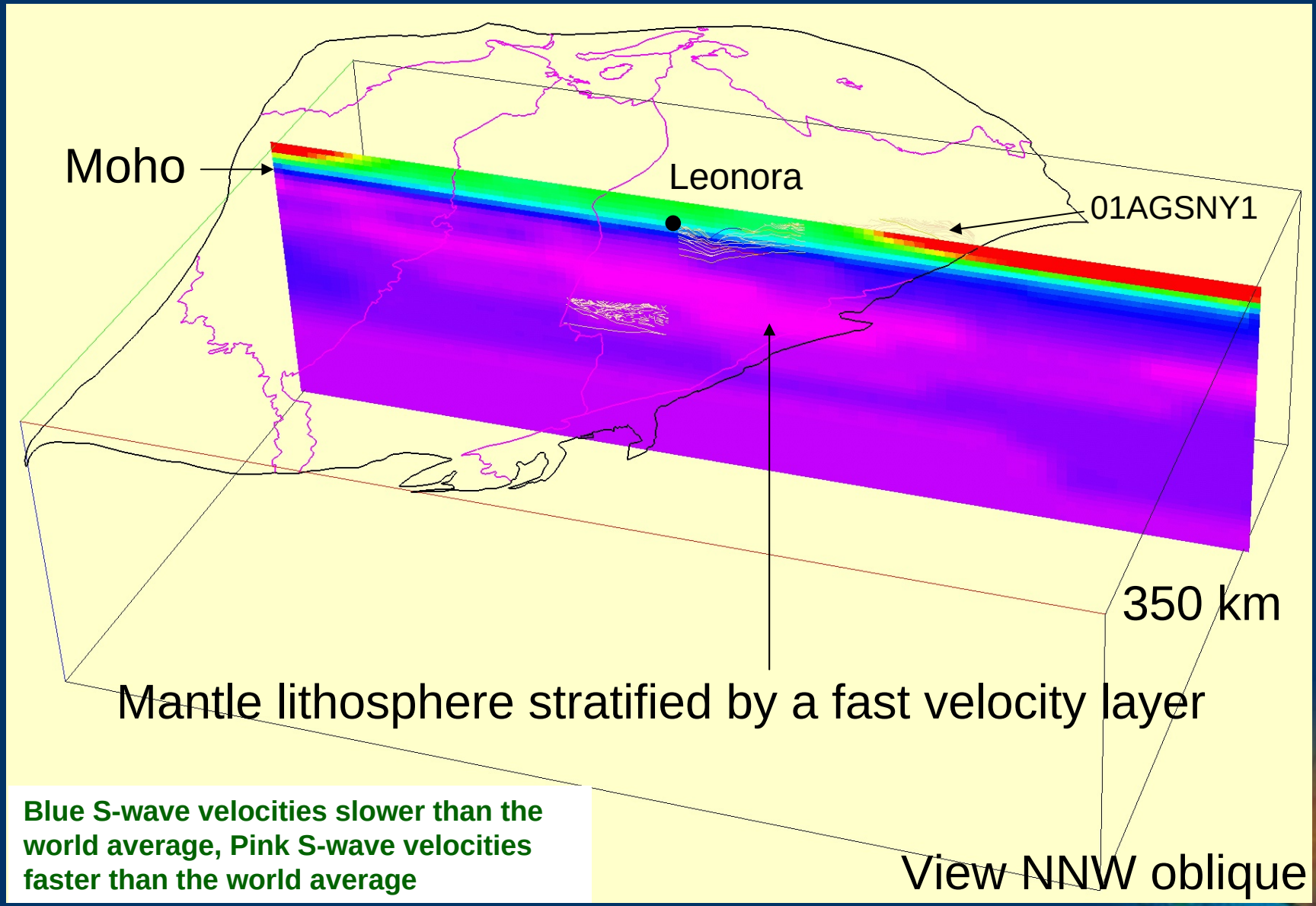
Shear (S) wave velocity at 75 km



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

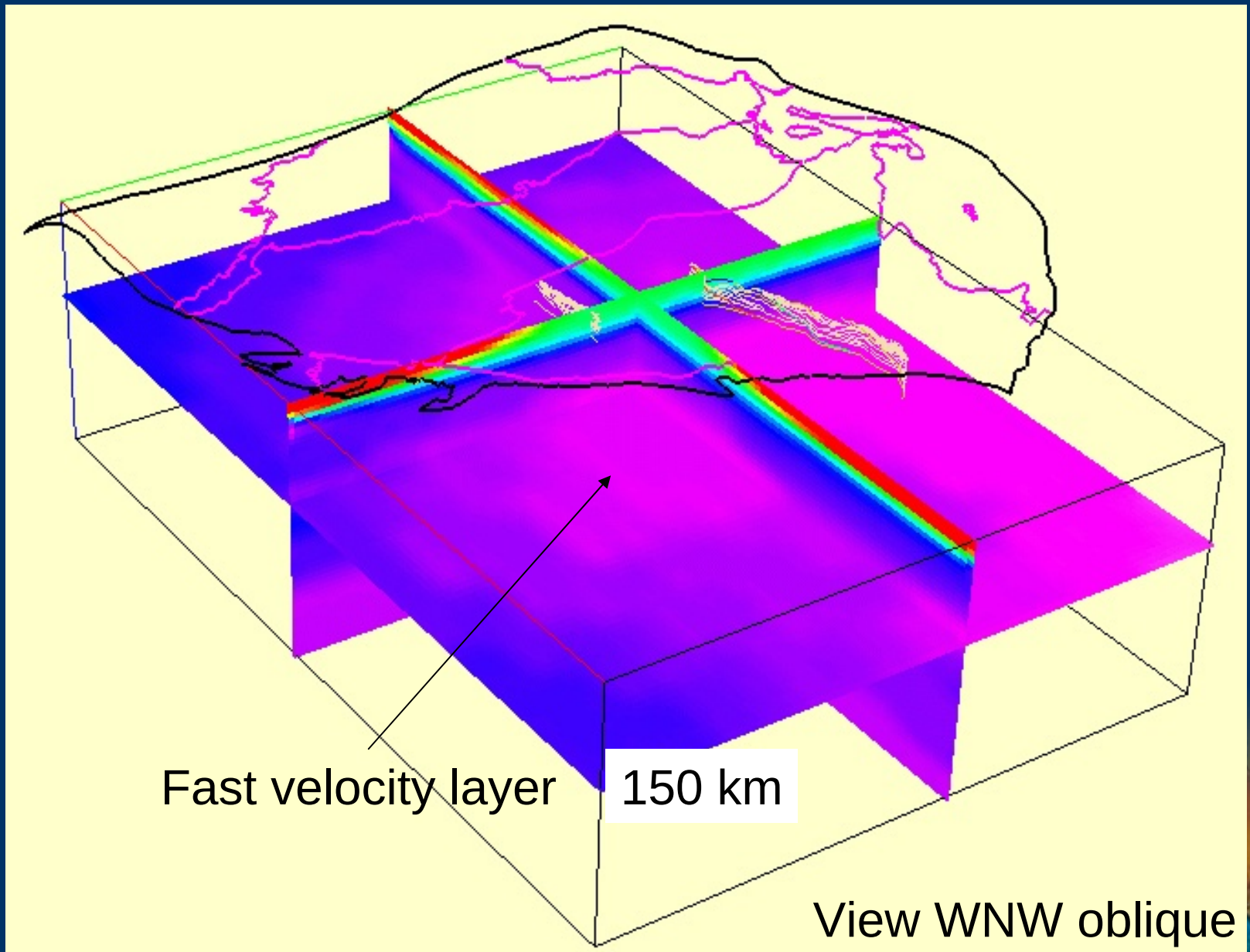
B.L.N. Kennett

S-wave velocity model (transect)

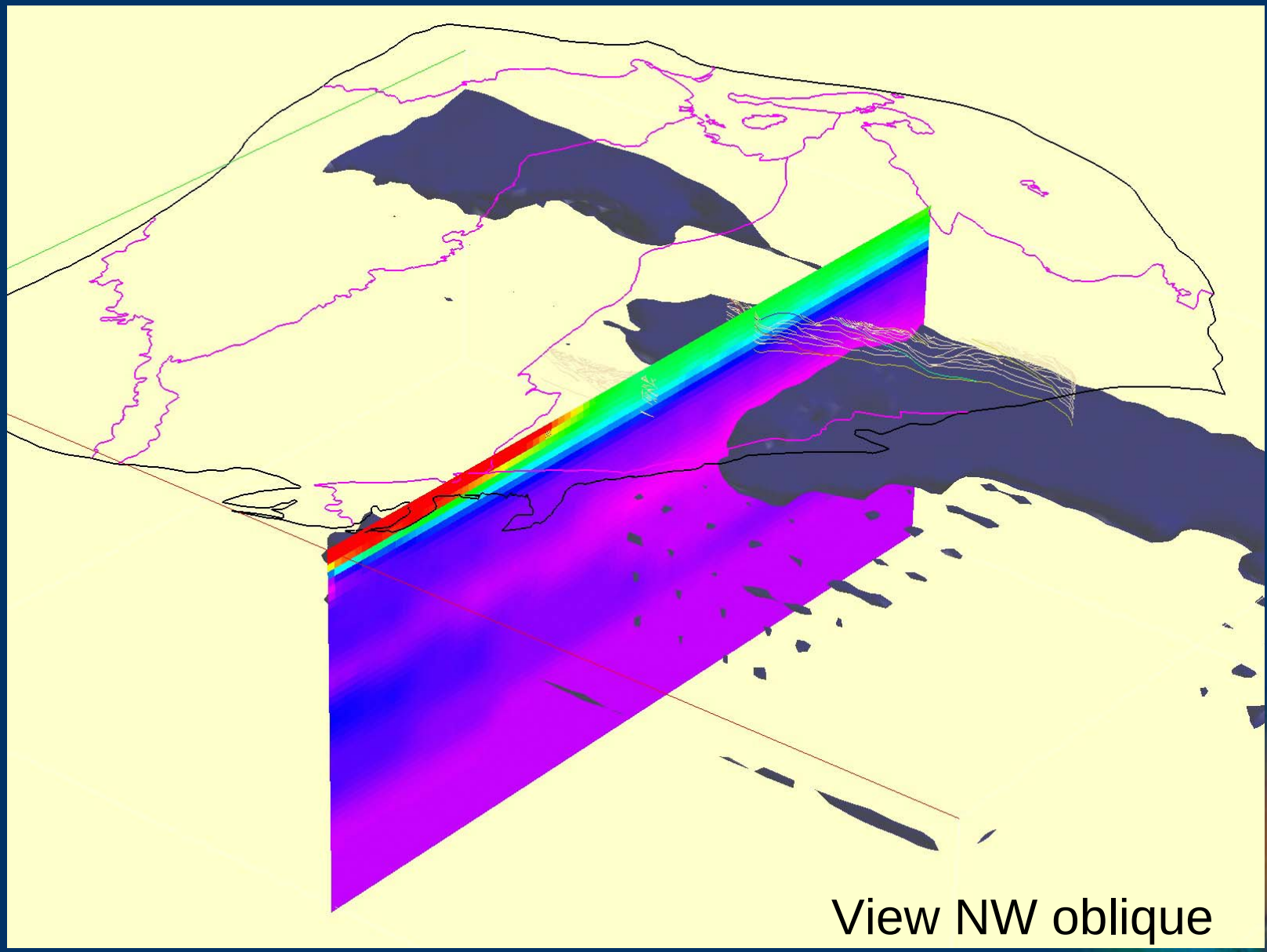


Blue S-wave velocities slower than the world average, Pink S-wave velocities faster than the world average

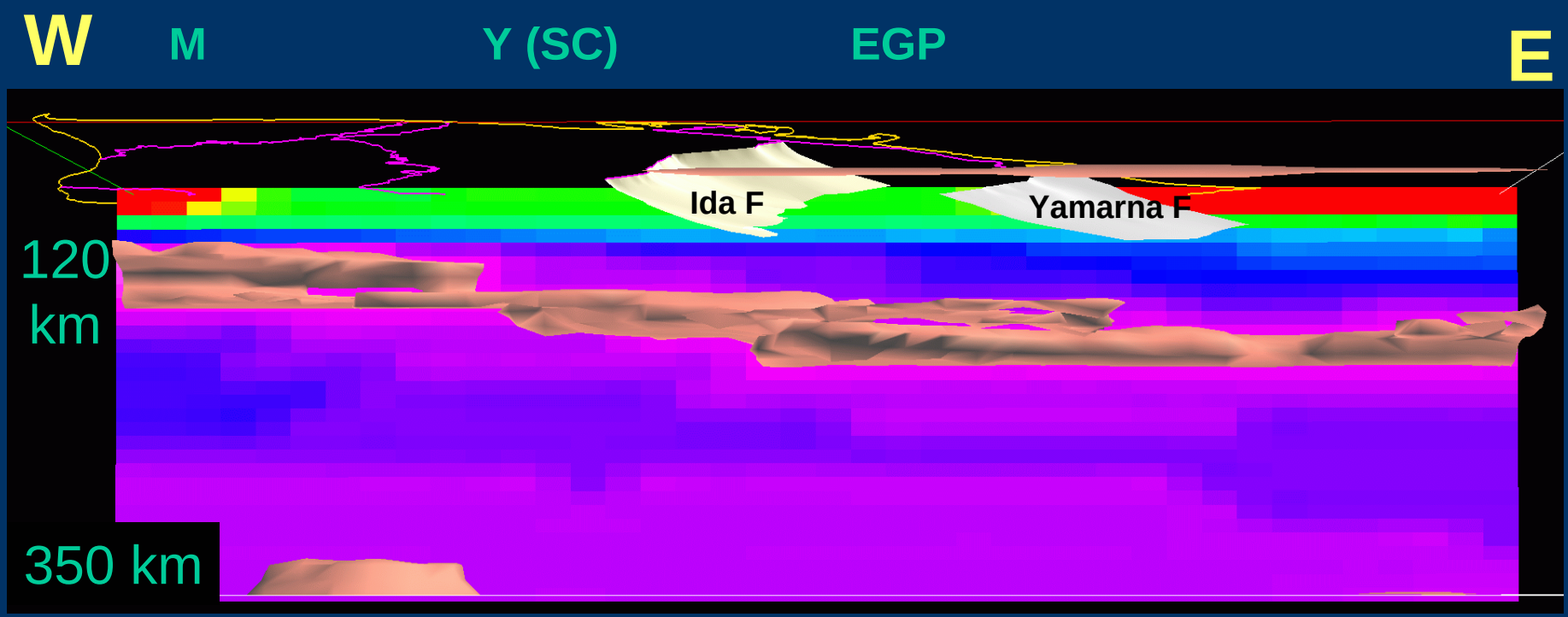
S-wave velocity model (3D slices)



S-wave velocity model (4.8 km/s)



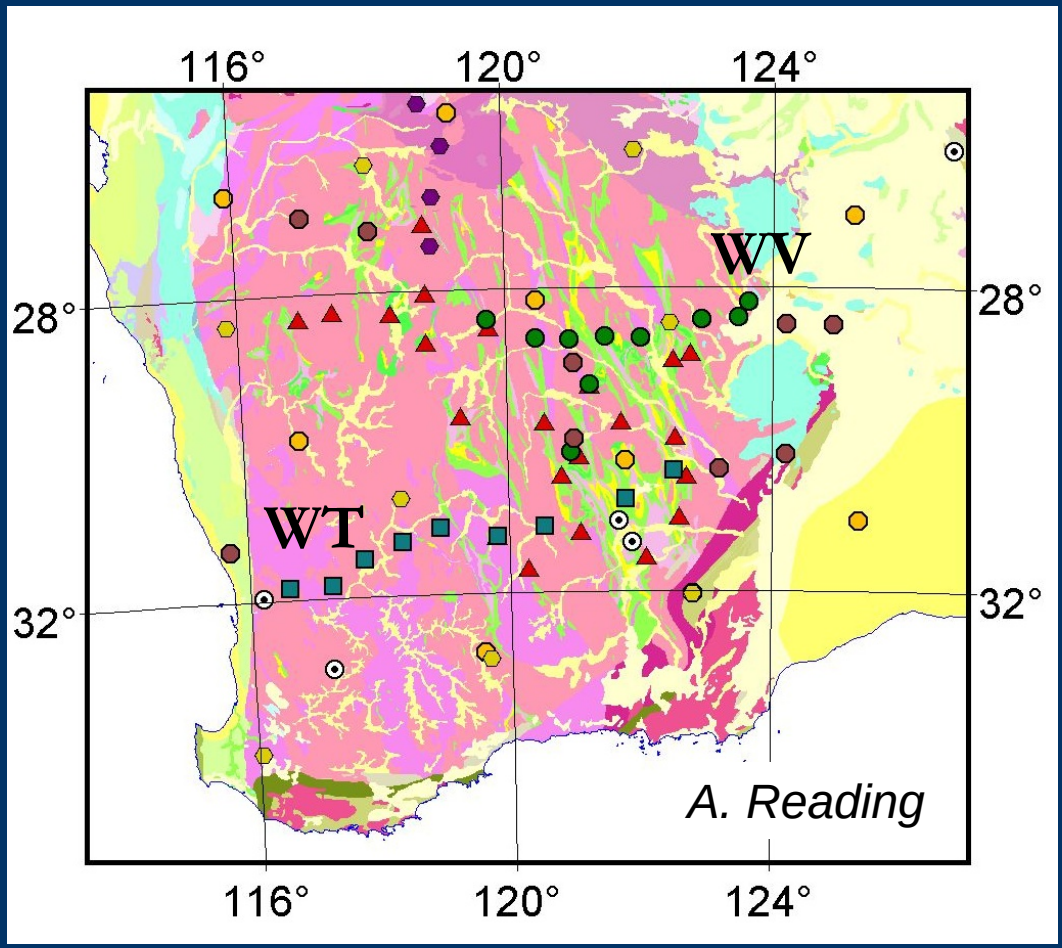
S-wave velocity model (3D slice)



View to north looking up from ~100 km depth

Intriguing SE-dipping fast-velocity body, what is it?

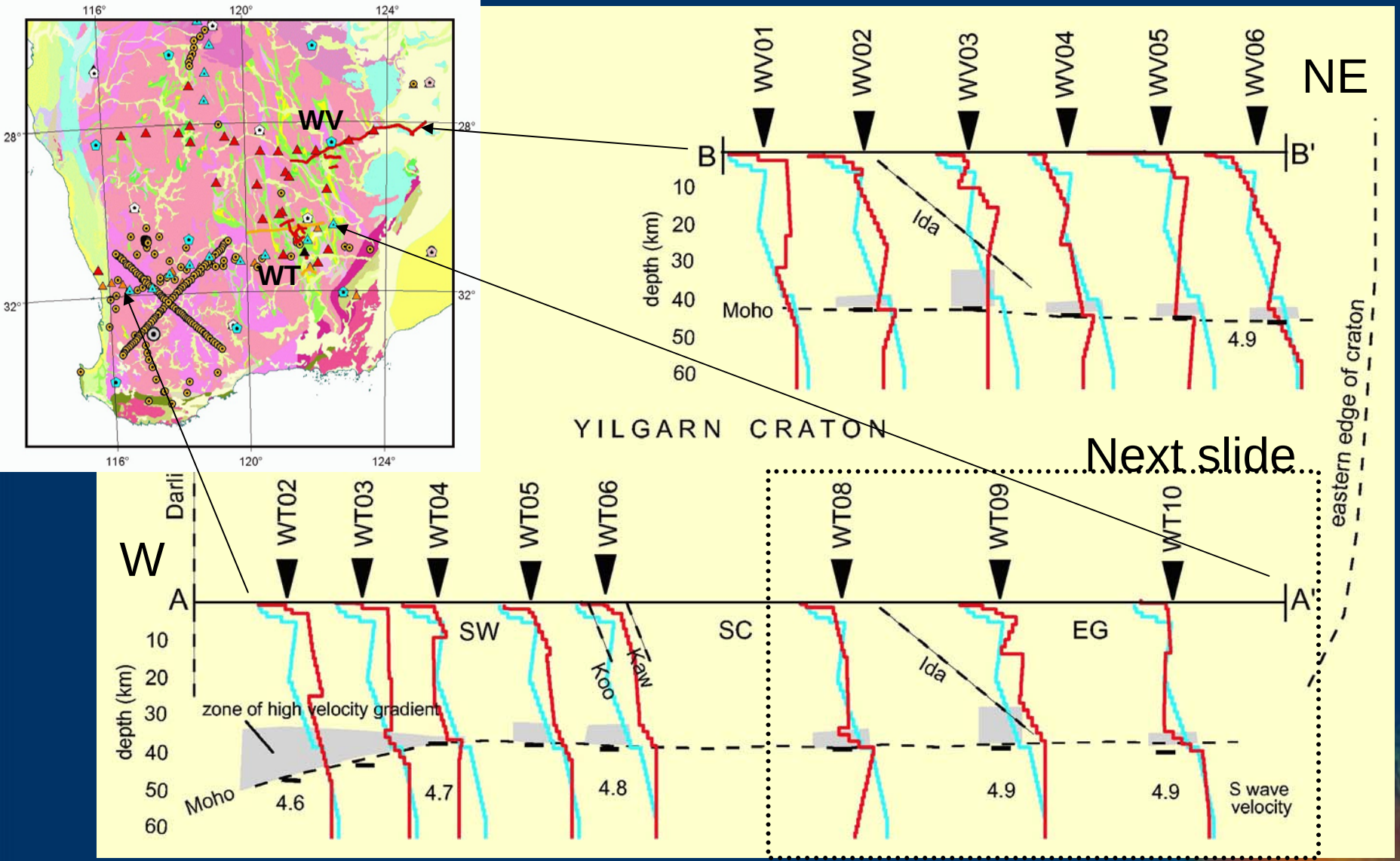
Seismic tools: Receiver Functions



Location of Yilgarn recorders

- Yilgarn transect (WT and WV)
- Non-linear inversion for crustal velocity
- Map Moho
- Characterising provinciality

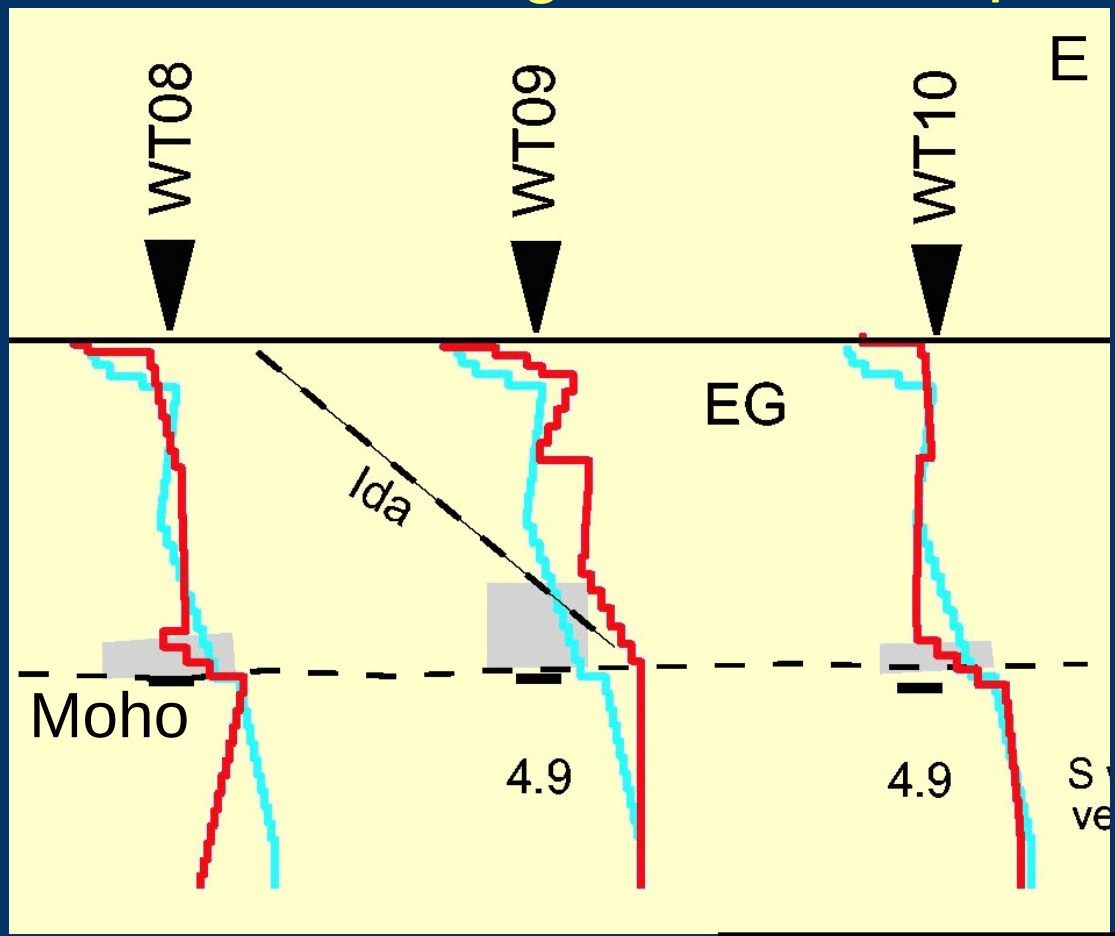
Seismic tools: Receiver Functions



Reading et al. (2003)

Seismic tools: Receiver Functions

Youanmi Kalgoorlie Kurnalpi



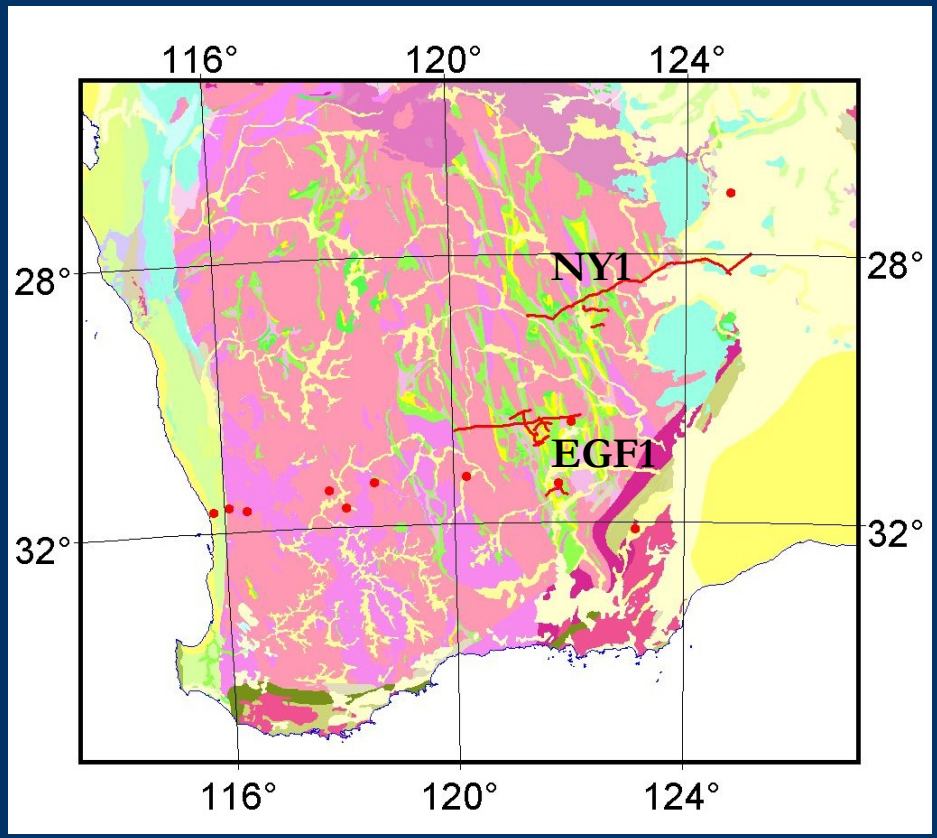
- Velocity generally increases with depth (~ density)
- Characteristic patterns in some terranes (eg Kalgoorlie)

S-wave velocity increase

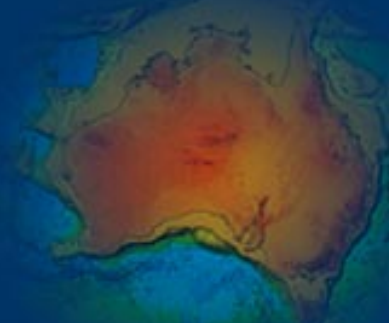
Australian average velocity profile

Calculated crustal velocity profile

Seismic tools: Reflection seismology



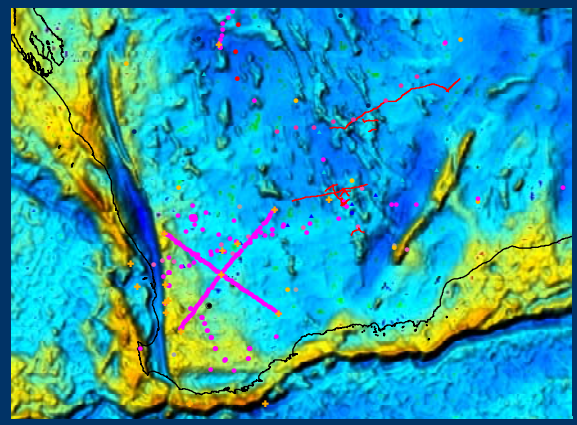
- Deep seismic reflection explosives & vibs (1991-2001)
- Information on crustal architecture
- Some velocity and lithological information
- Quantum leap in 3D understanding and geodynamics

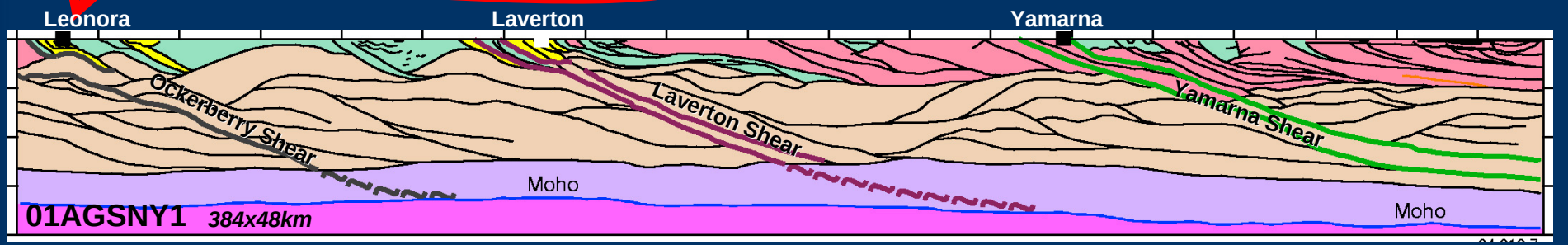


Seismic tools: Reflection seismology

Kalgoorlie

91EGF1 *213x45km*

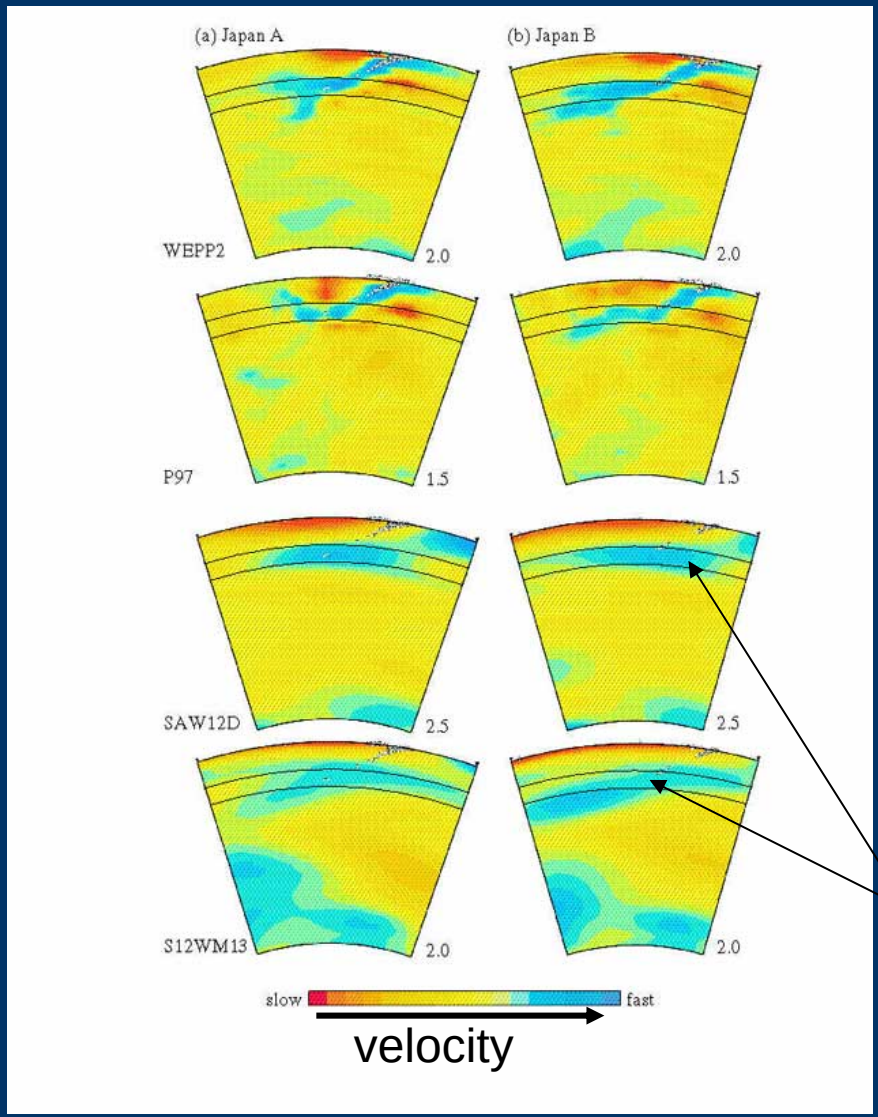




Leonora to Lake Yeo

- Moho deepens to east
- three broad crustal layers
- prominent low-angle east dip (foreland fold-thrust belt)
- 4 crustal-penetrating??? shear zones

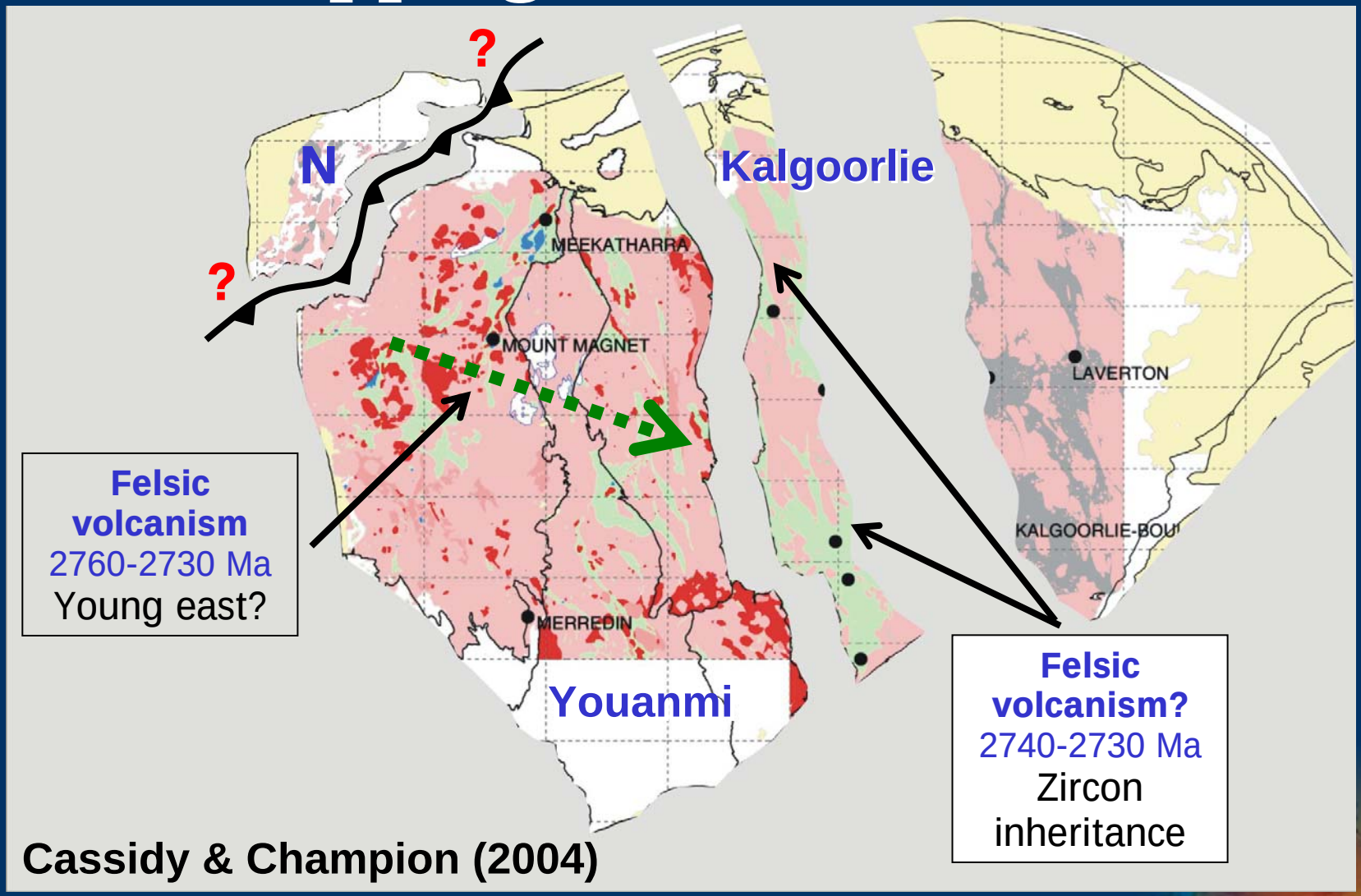
Subduction, slabs, delamination etc?



- **Yilgarn subduction at various times (geochemistry)**
- **Both east- and west-dipping slabs**
- **Can we see the 'signature' of subduction?**
- **Slabs characterised by <u>fast</u> S-wave velocities**

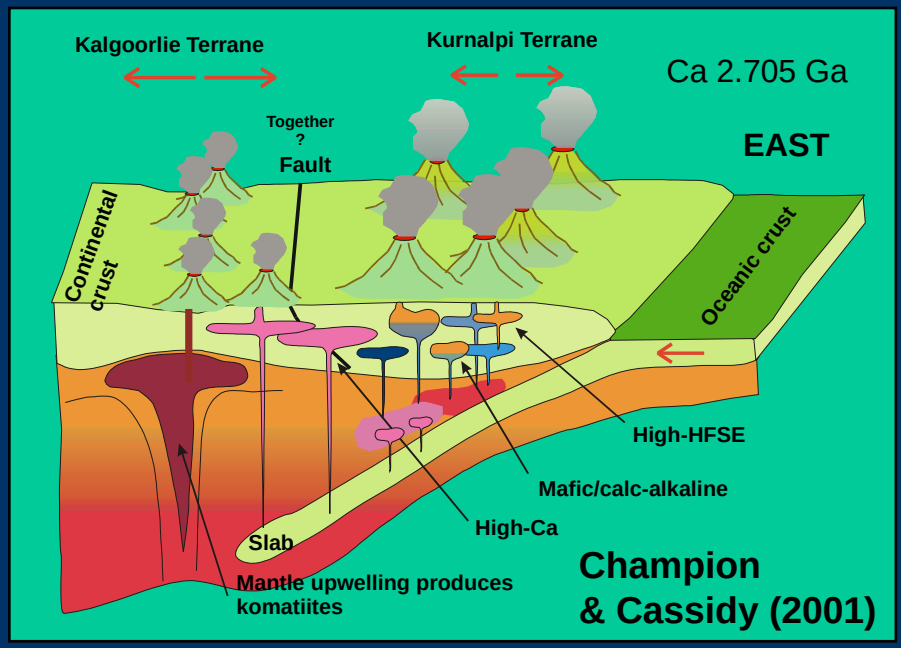
Tomography of slabs under Japan (Fukao et al. 2001)

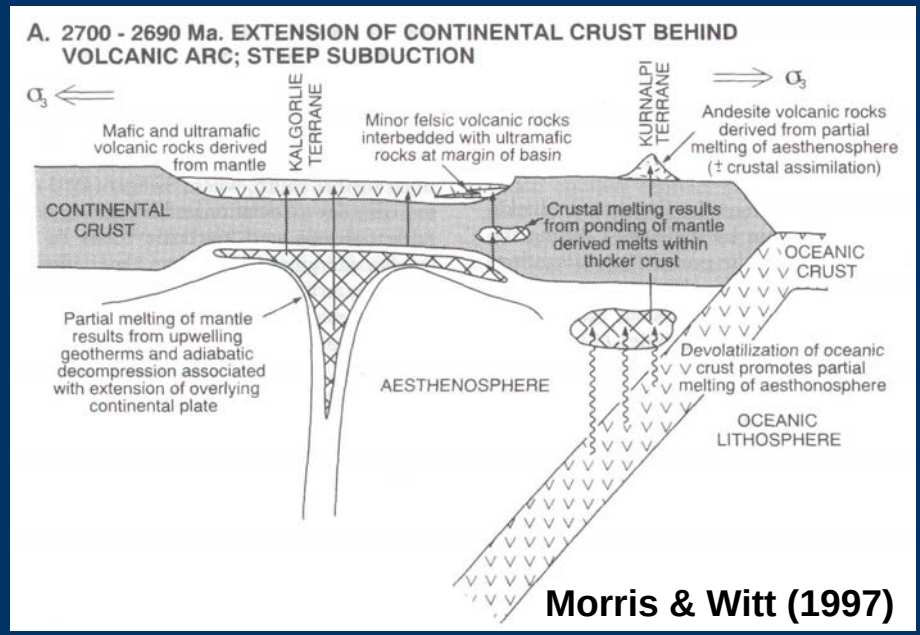
SE-dipping subduction zones?



Postulated SE-dipping slab ca 2.76-2.73 Ga

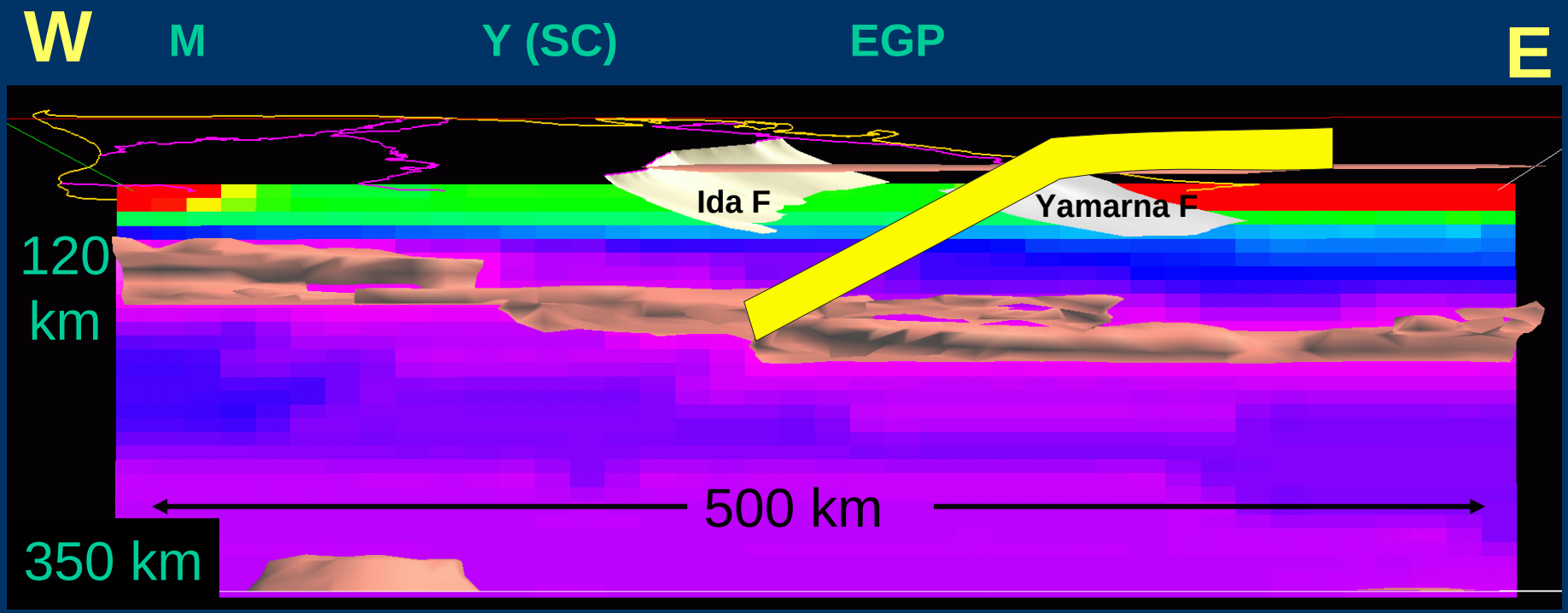
W-dipping subduction zones?





Models for West-dipping subduction at **~2.7** Ga

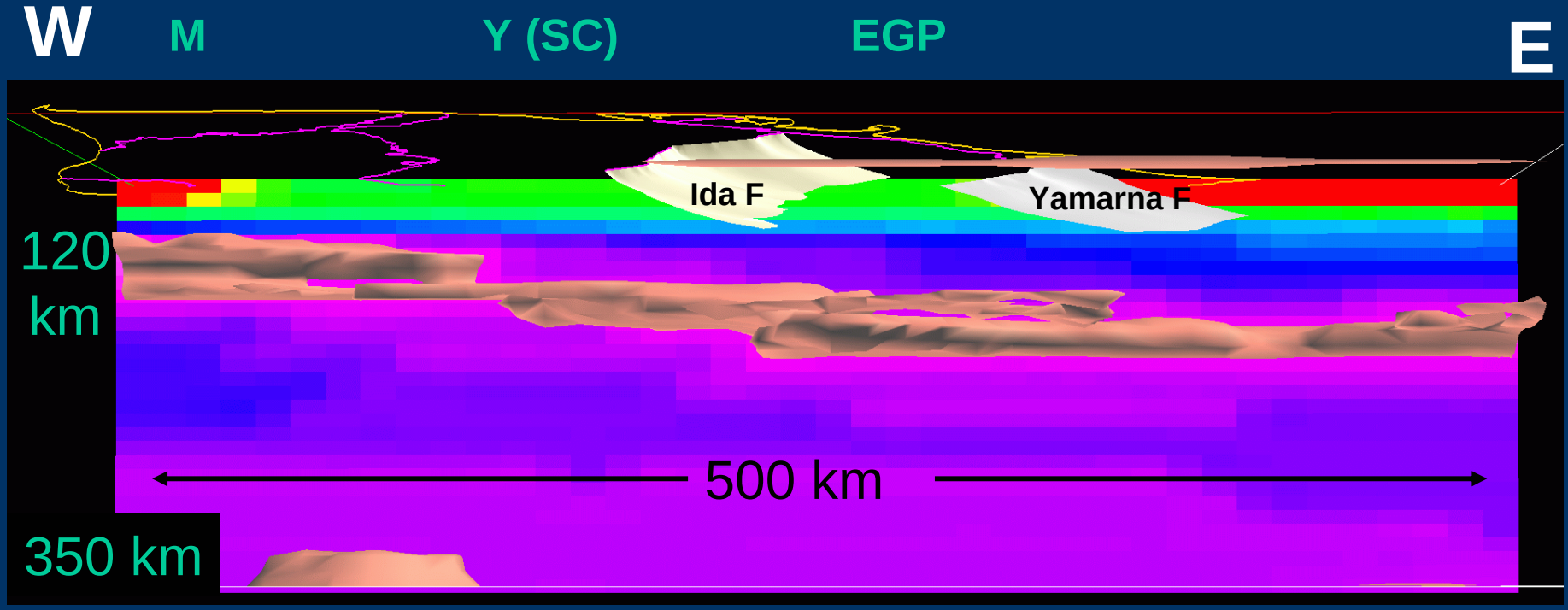
Stratified lithosphere as a slab?

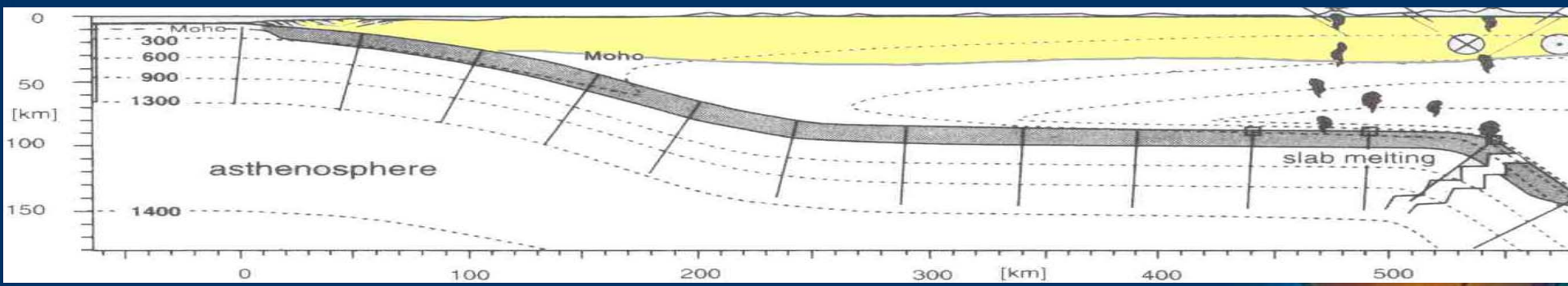


- SE-dipping (low-angle) fast layer @ 100-120 km depth
- possibly a fossil slab (*cf*. Narryer at 2.75Ga)
- no evidence for the W-dipping 2.7 Ga slab?

The age of the high-velocity layer is unknown

Flat subduction in Chile as analogue?

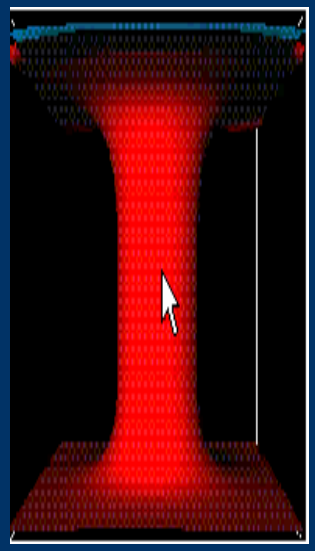




Gutscher et al. (2000)

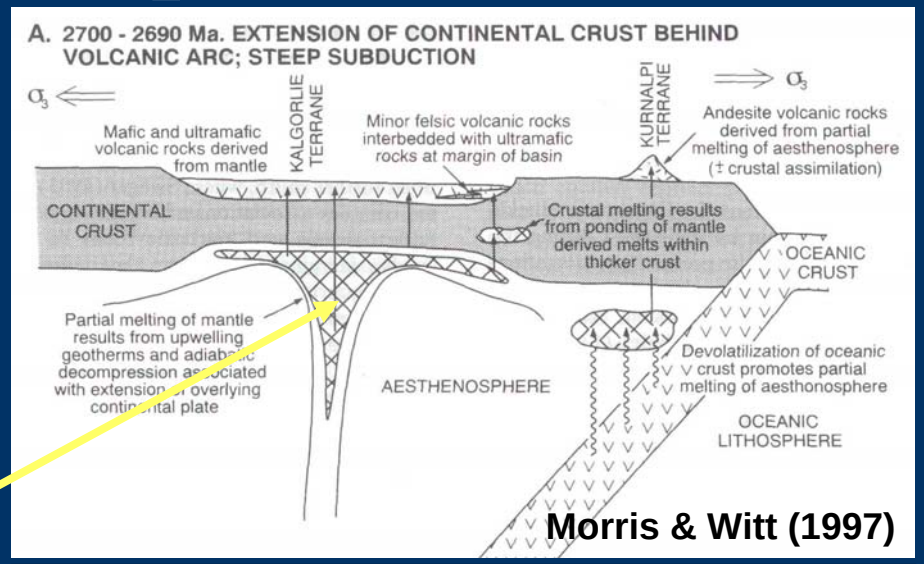
500 km

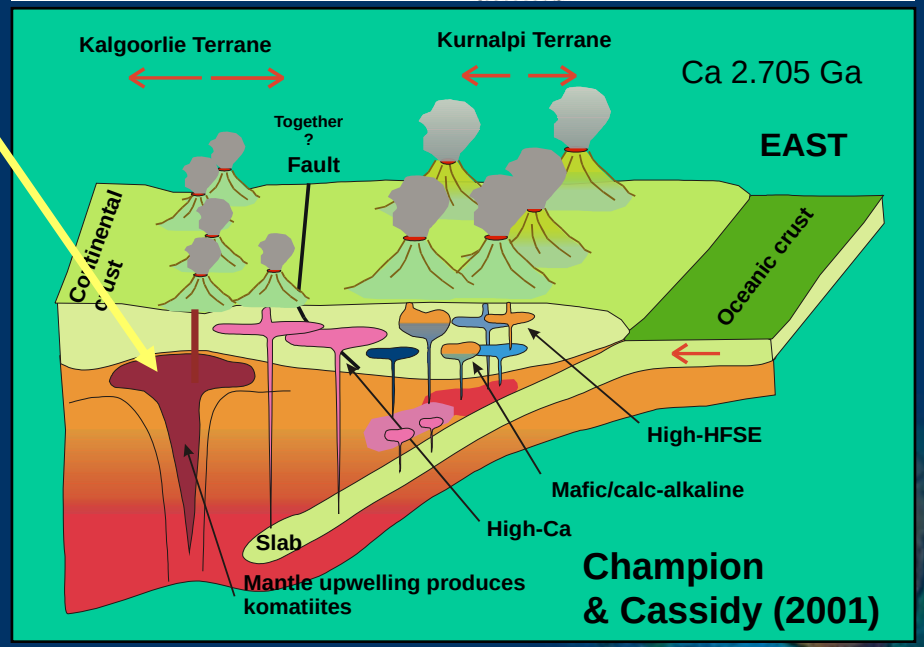
Yilgarn mantle plumes?



Plume movie

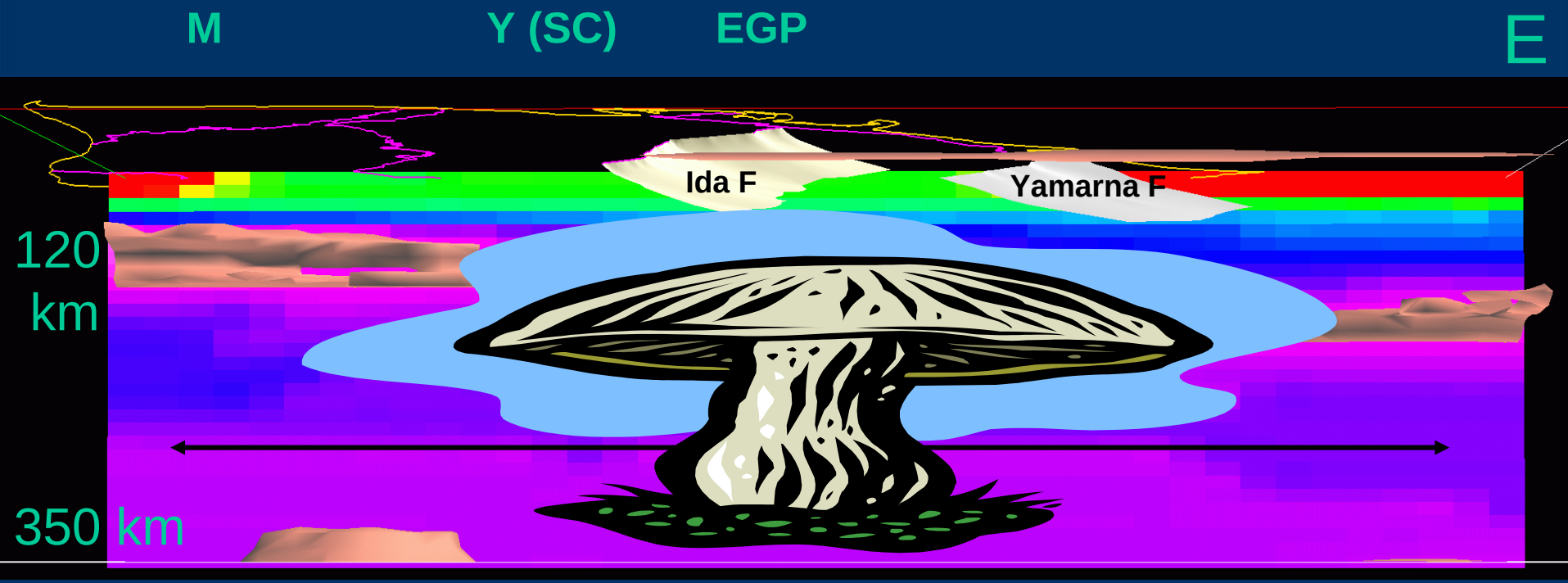
Plume





Plumes have been hypothesised for komatiites (eg Morris & Witt, 1997; Champion etc), and many granites (eg Campbell & Hill, 1988 and later papers)

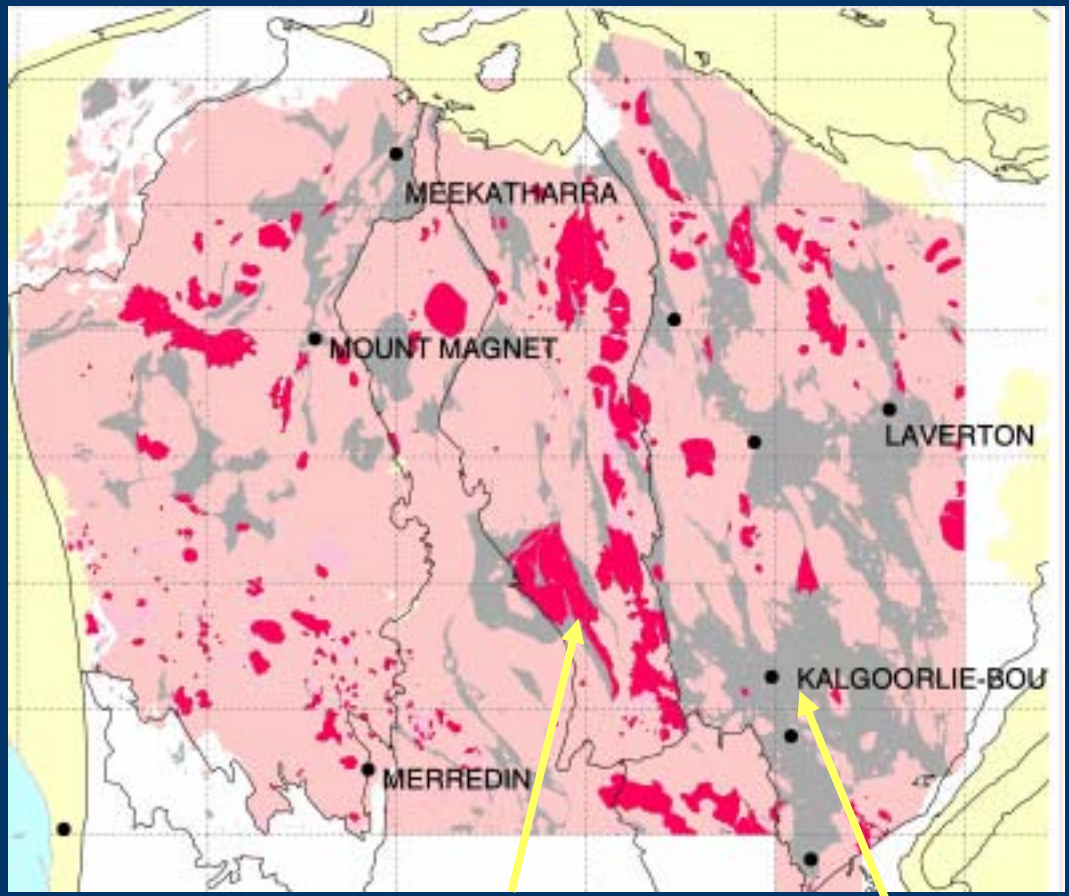
Impingement of a mantle plume?



- If a high-level plume: it would disrupt this stratification (assuming stratification is old)
- Or, horizontal reworking was dominant after the plume
- Or, disruption is out of this plane
- If a deep plume we wouldn't see it in this section

We can not rule plumes in or out on this evidence

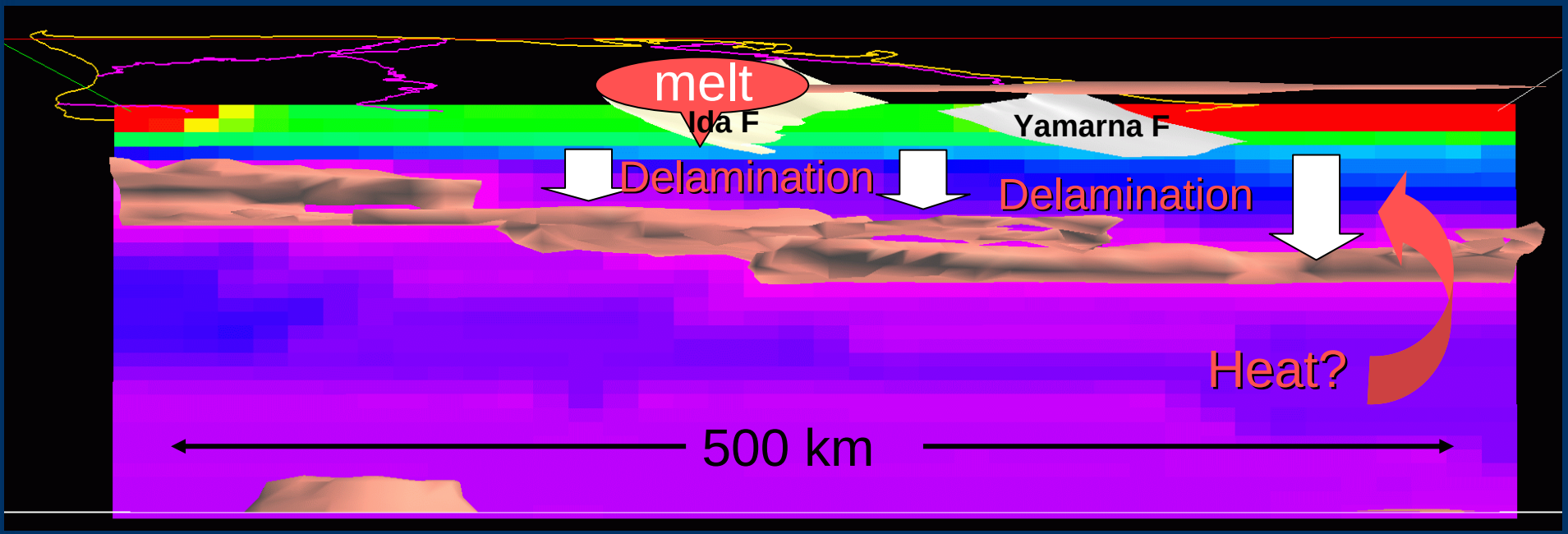
Yilgarn delamination?



- Major types (High-Ca, **<u>Low-Ca</u>**)
- Crustal melts
- Intrude external granites (at base of greenstone)
- Late <2655 Ma

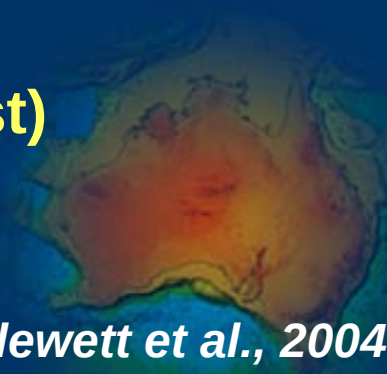
Champion & Sheraton, 1997

Fast layer as delaminated ‘restite’?



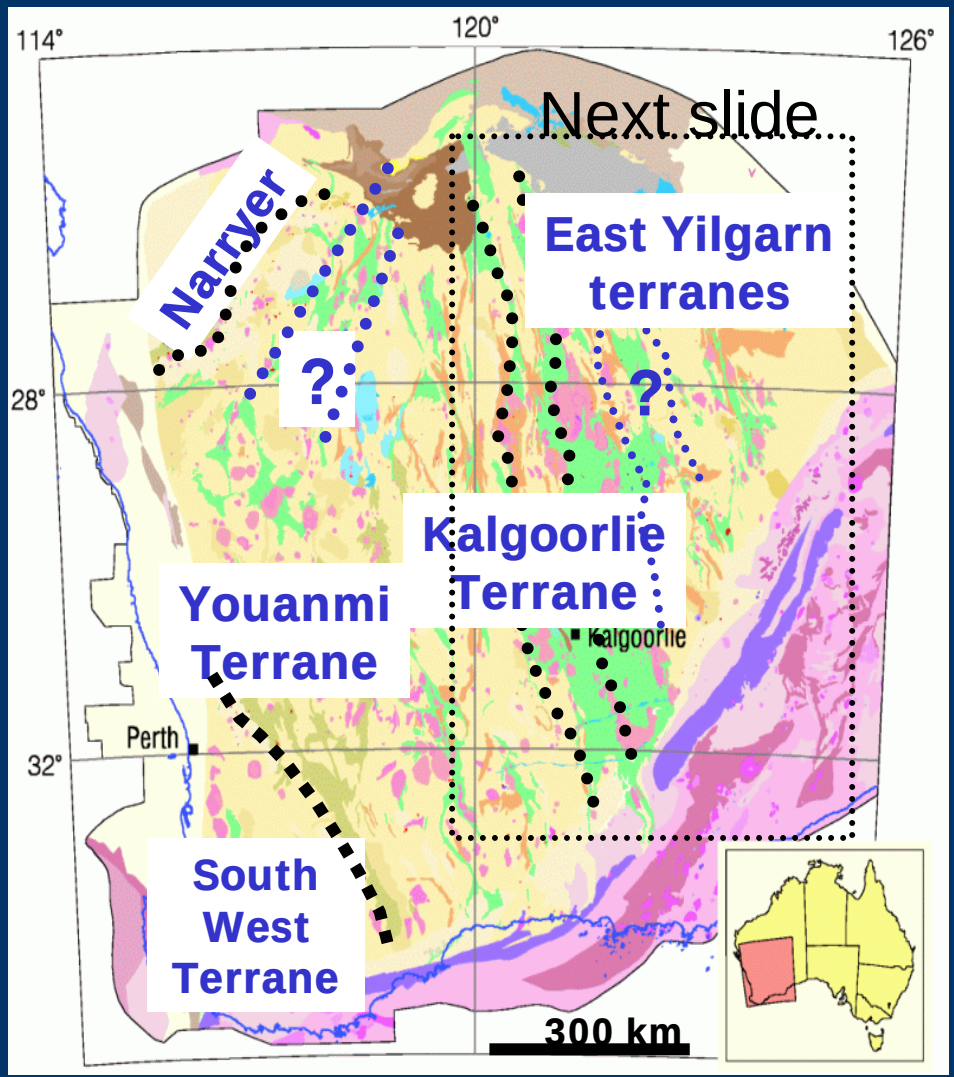
Delamination:

- **delivers heat across entire Yilgarn (Low-Ca are craton-wide)**
- **Initiated at ~2670 Ma (first D2a event in east)**
- **Low-Ca granites ~2655 Ma (E) to 2640 (W)**
- **Synchronous with Au ages?**



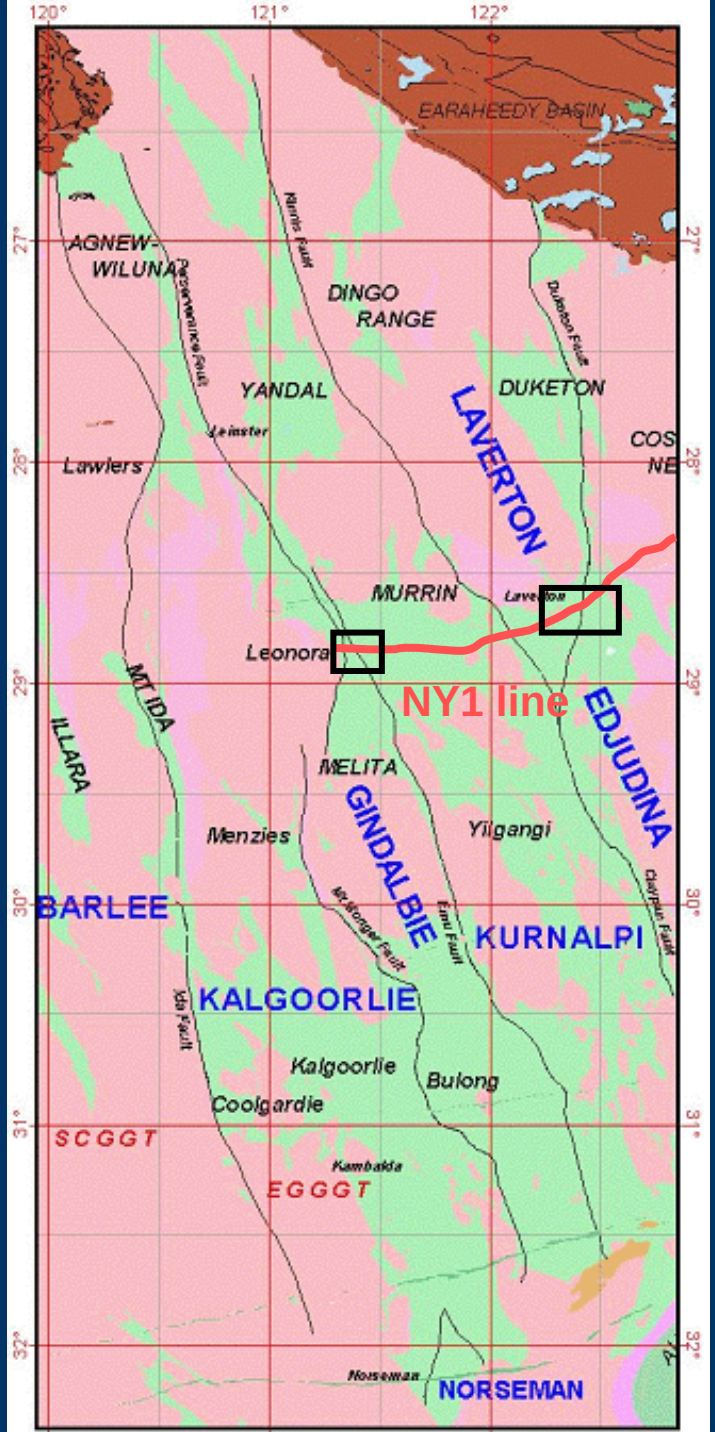
AMIRA P624; Blewett et al., 2004

Terranes of the Yilgarn Craton



- Various subdivisions of Yilgarn
- Based on geology, geochemistry, isotopes, magnetics/gravity, structure
- Various amalgamation models:
  - autochthonous
  - allochthonous
  - strike-slip

What are the seismic 'signatures' of the terranes and their boundaries?

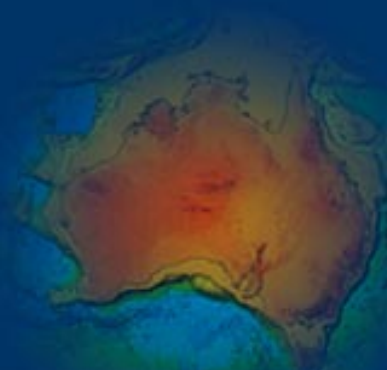


Terranes of the Yilgarn Craton

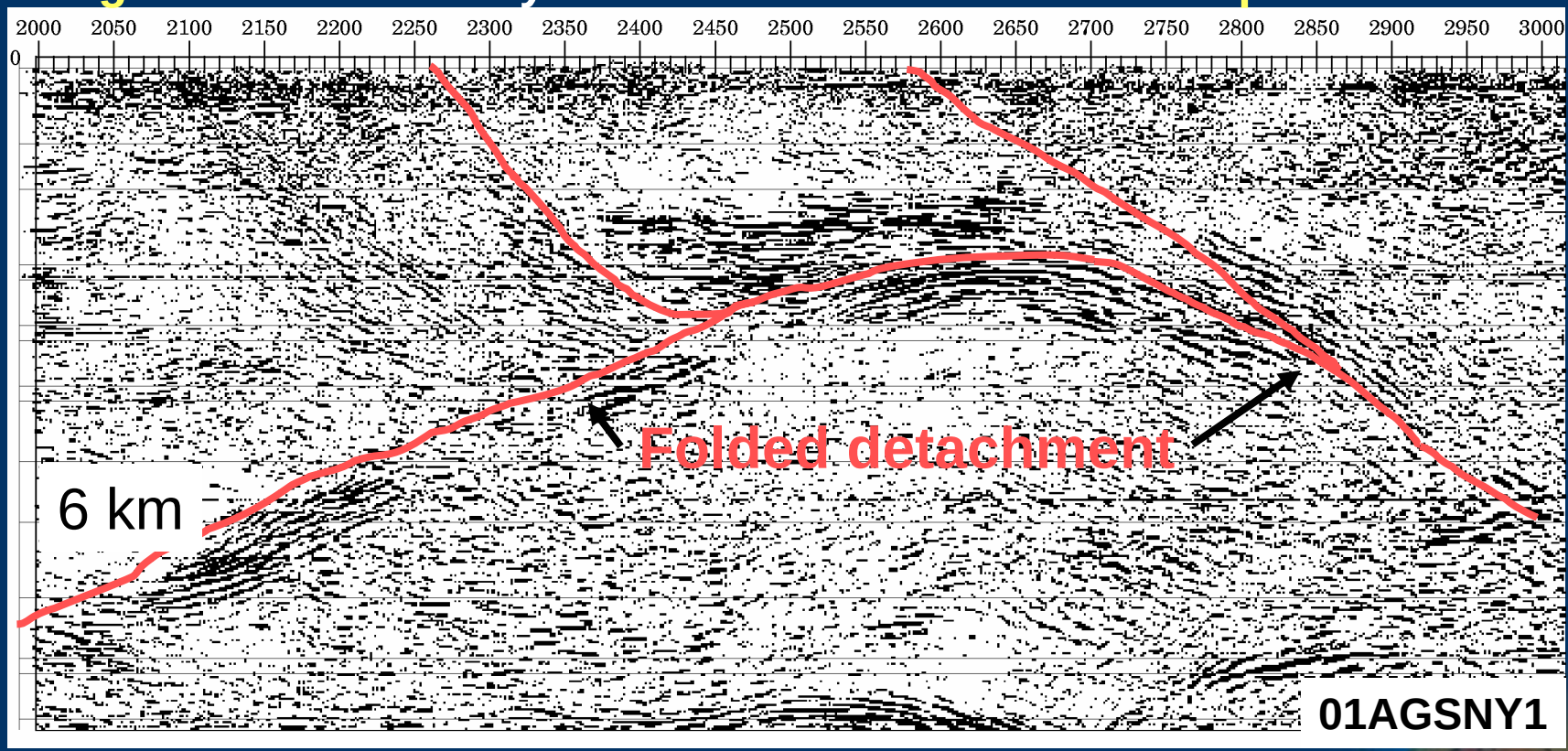
6 tectono-stratigraphic terranes

- **Norseman**
- **Kalgoorlie**
- **Gindalbie**
- **Kurnalpi**
- **Laverton**
- **Edjudina**

after Myers (1997)

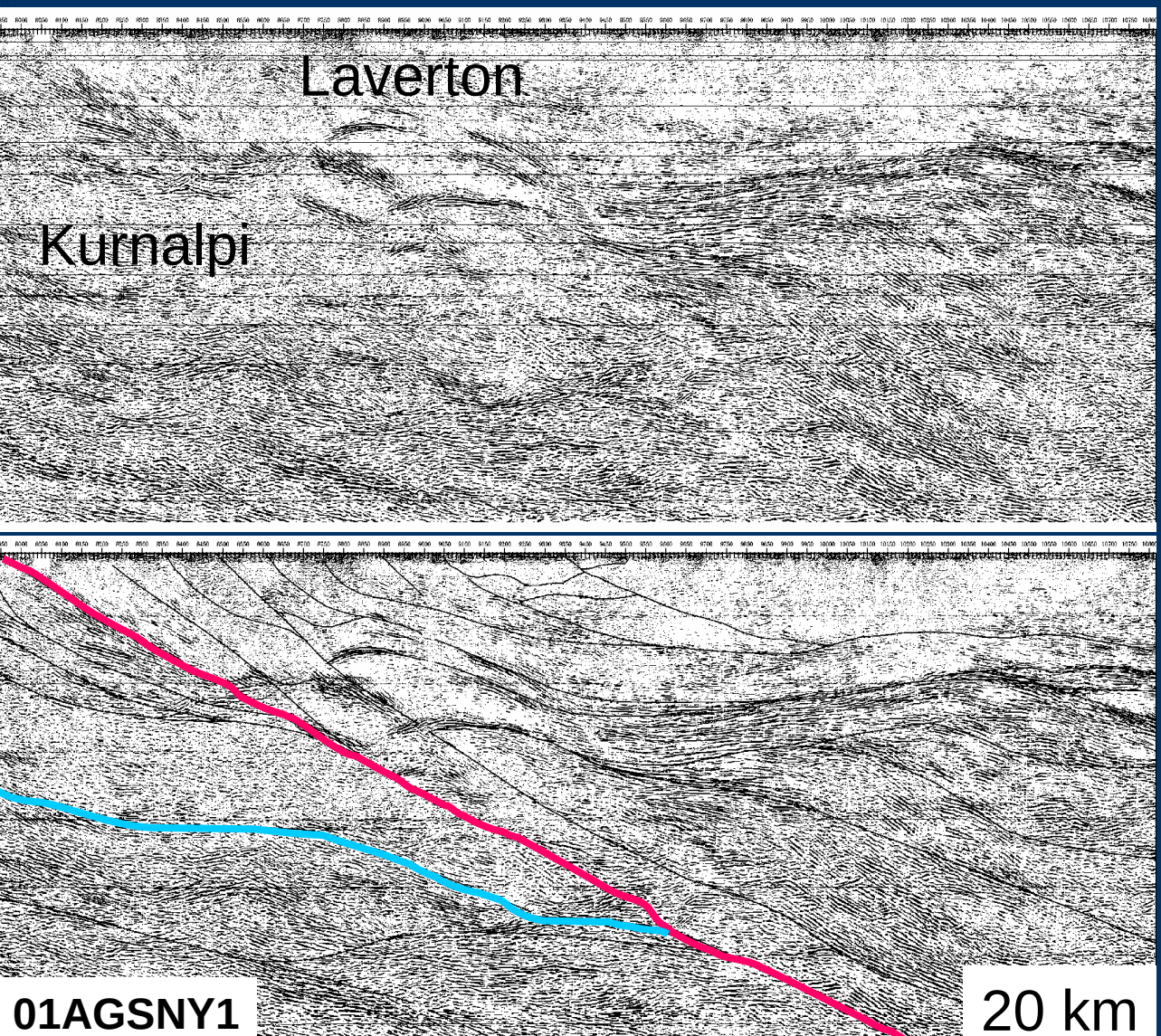


Terranes of the Yilgarn Craton: upper crust from seismic



Terrane boundaries appear thin-skinned and sole out on to the folded detachment

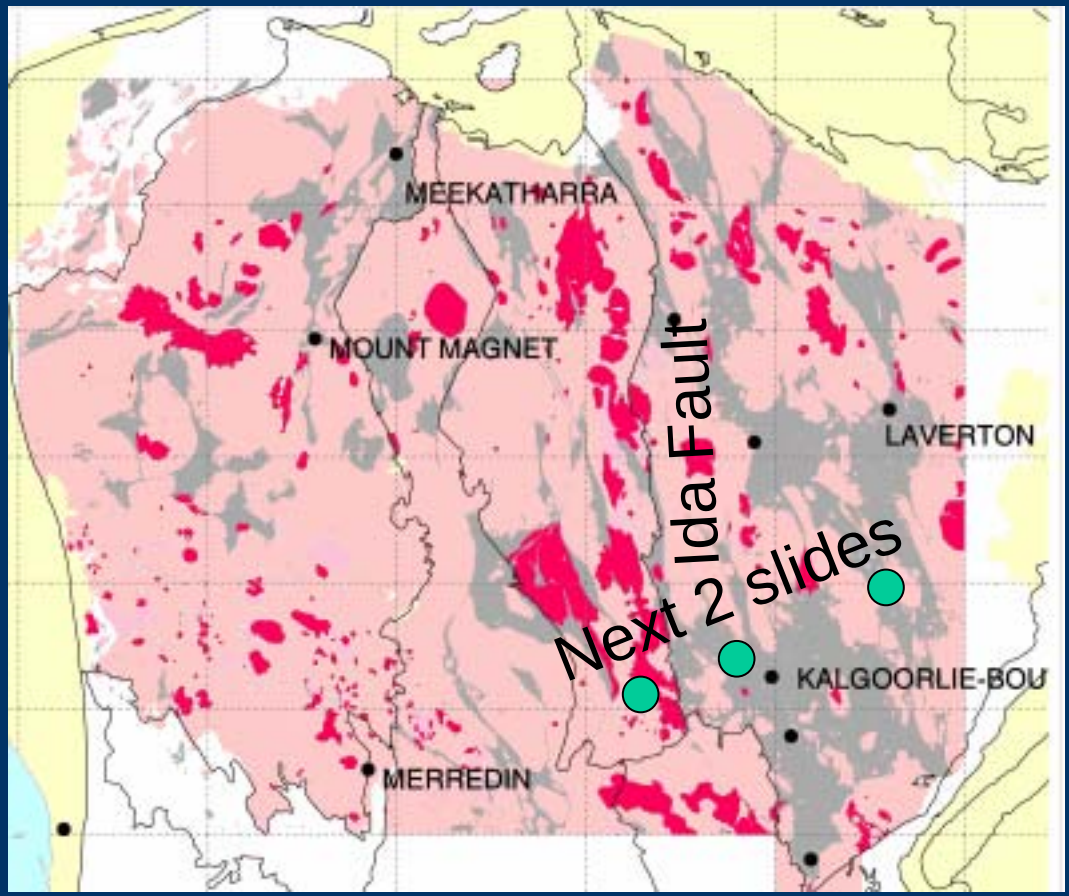
Terranes of the Yilgarn Craton: upper crust from seismic



Laverton-Kurnalpi boundary may be a major crustal fault

Prominent moderate east-dips suggest thrust amalgamation (cf. strike-slip)

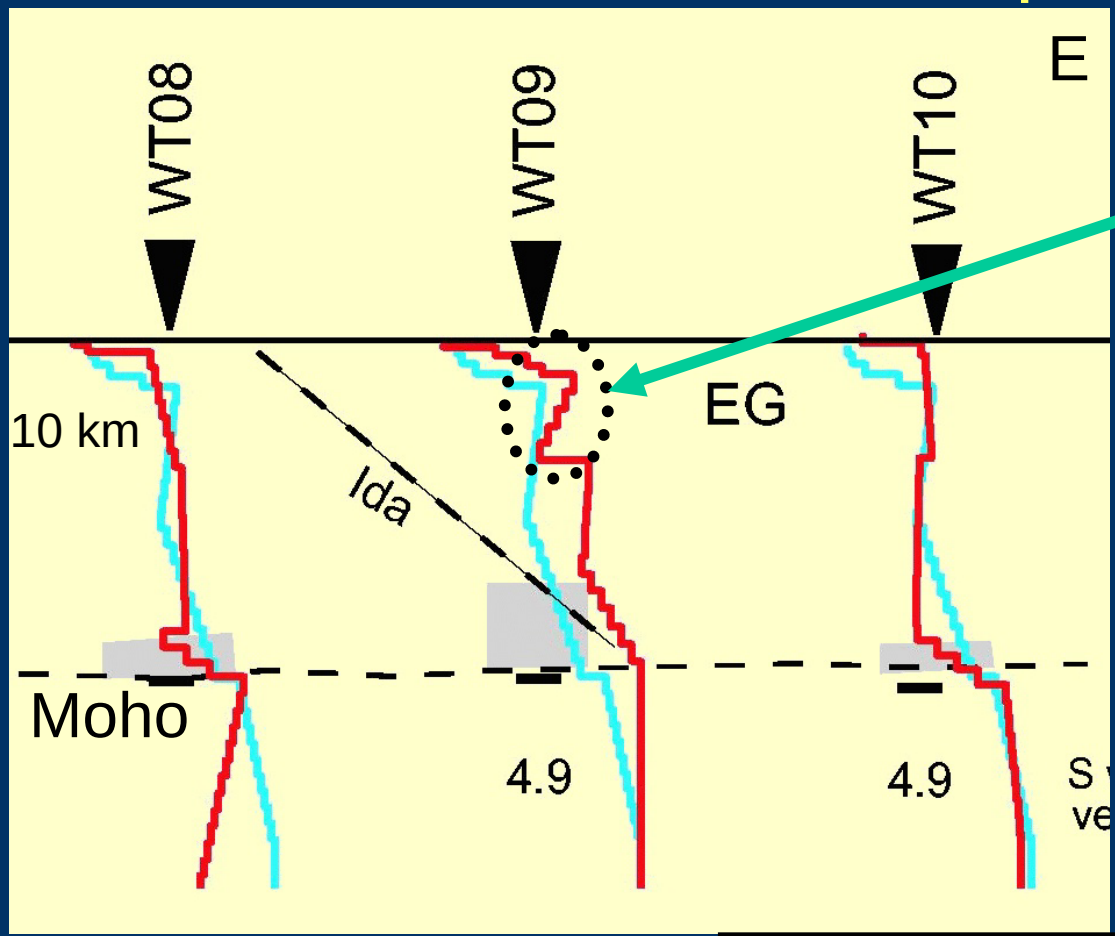
Terranes of the Yilgarn Craton: the Low-Ca granites



Low-Ca granite greenstone

- Intrude external granites (base of greenstone)
- Relatively low density, relatively slow (seismically)

Terranes of the Yilgarn Craton: upper crust from receiver functions

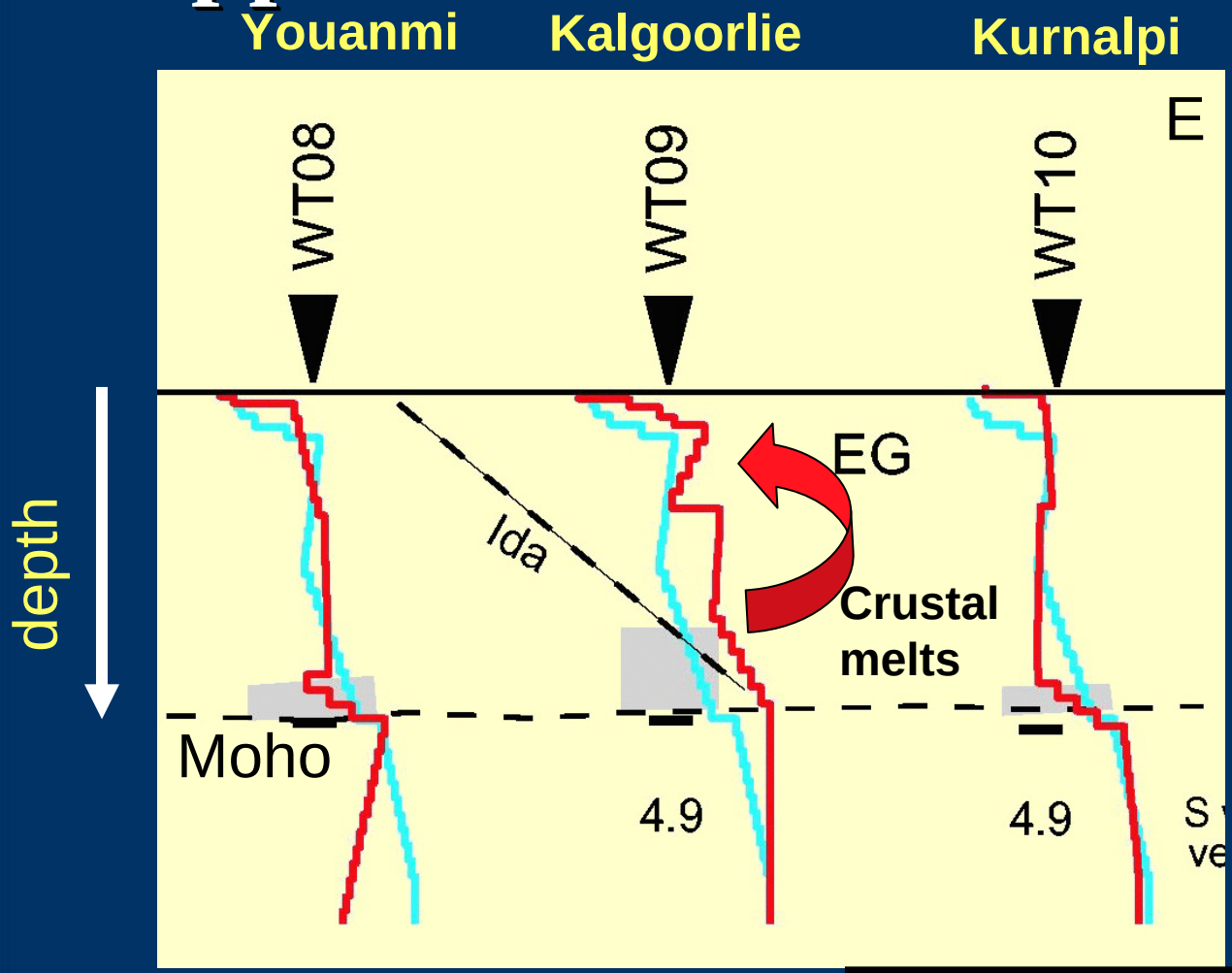


- **Kalgoorlie has low-velocity layer at ~10 km = less density**
- **Not simply reflecting overlying greenstones**

Australian average velocity profile

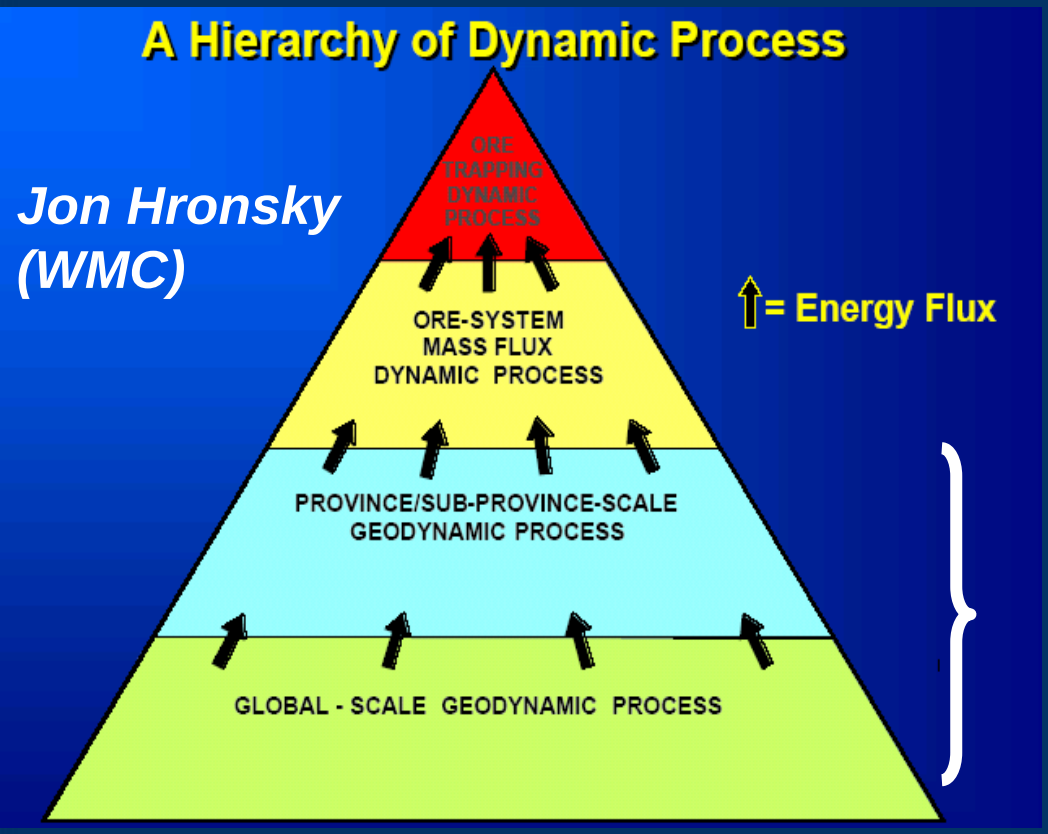
Calculated crustal velocity profile

Terranes of the Yilgarn Craton: upper crust from receiver functions

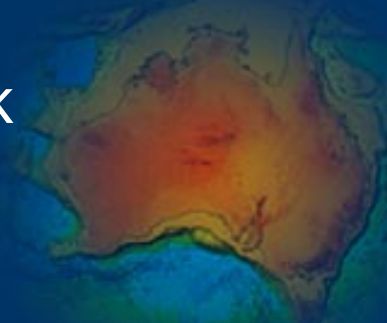


- Thick Low-Ca granite 'underplate' under Kal from crustal anatexis (link to Au)
- Thick Low-Ca signature of Kal endowment??

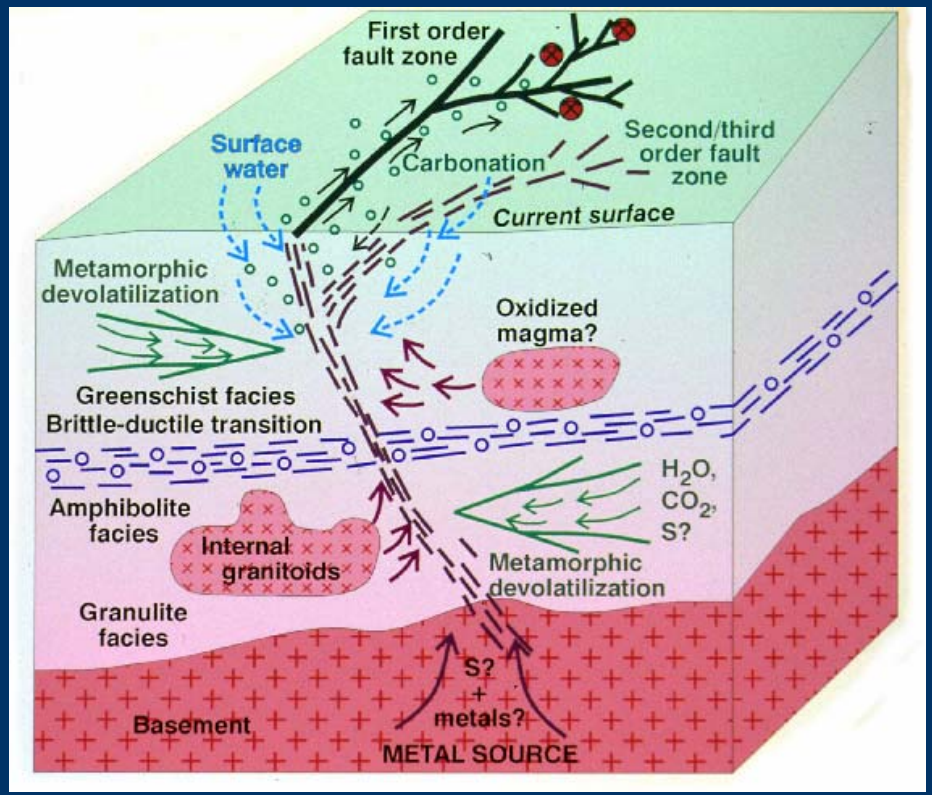
Lots of arm waving is interesting, but how does it help us?



Focus of this talk



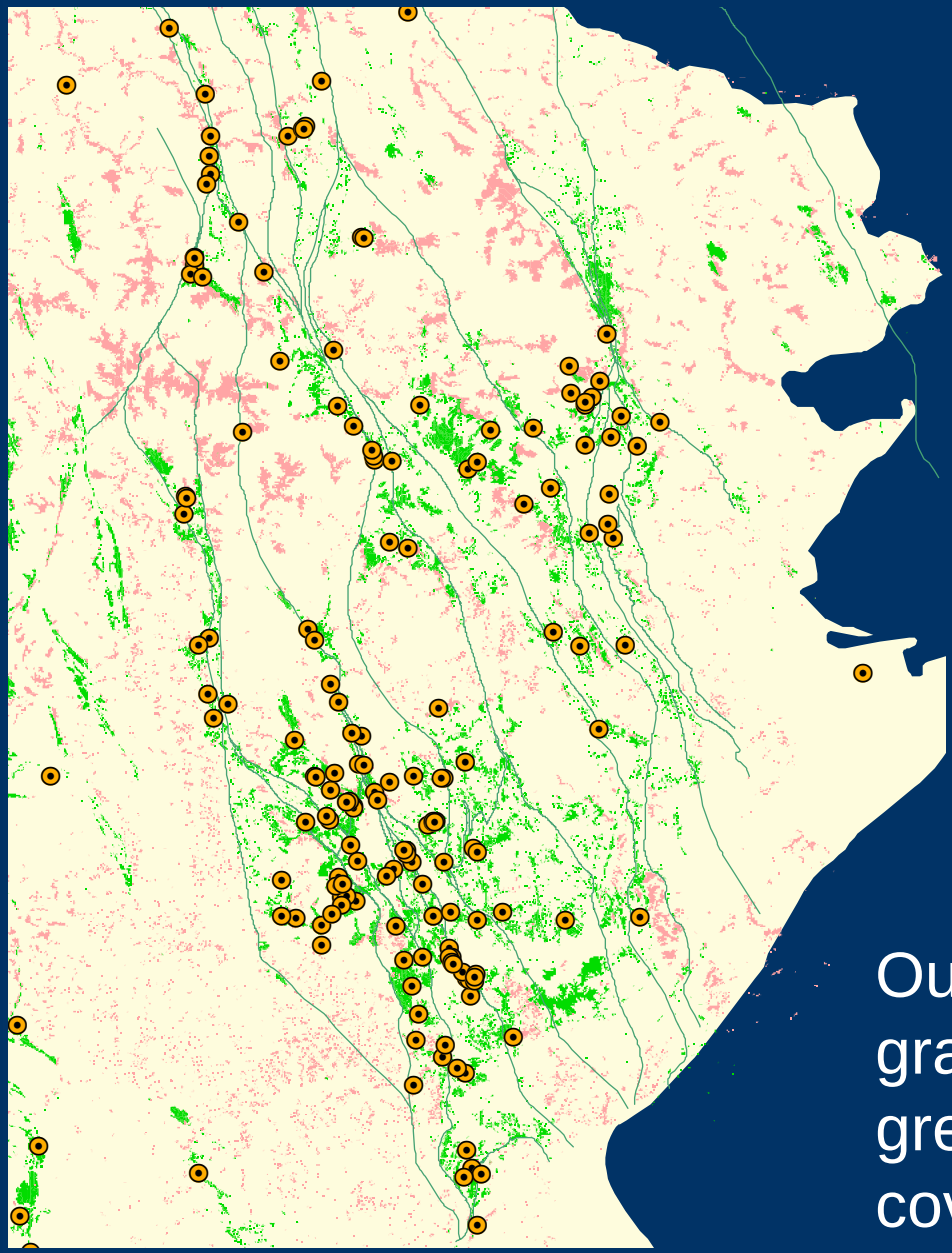
Help through….



Better understanding of the minerals system process – geodynamics is an integral component and driver of the mass and energy flux

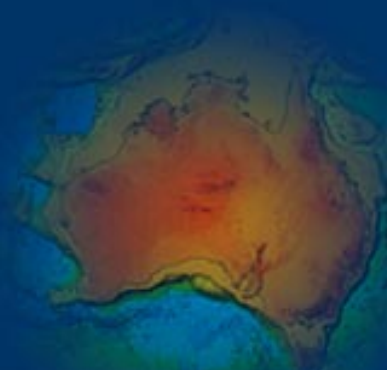
Cassidy & Hagemann (2003)

Help through….



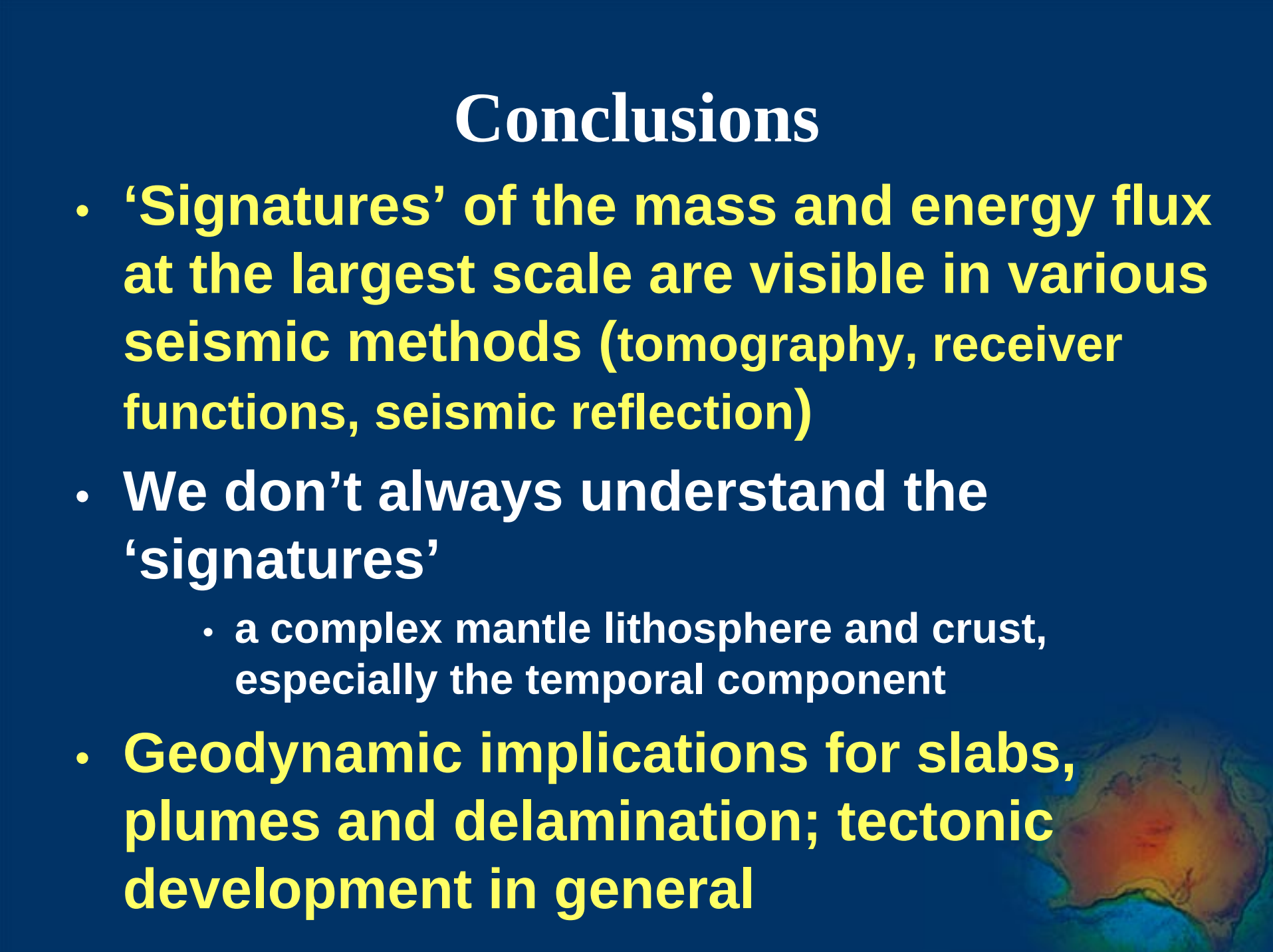
- **being predictive in space and time**
- **taking this understanding under cover**

Outcrop map (Pink - granite, Green – greenstones, yellow - cover



Conclusions

- **'Signatures' of the mass and energy flux at the largest scale are visible in various seismic methods (tomography, receiver functions, seismic reflection)**
- **We don't always understand the 'signatures'**
  - **a complex mantle lithosphere and crust, especially the temporal component**
- **Geodynamic implications for slabs, plumes and delamination; tectonic development in general**



Conclusions

- **The Yilgarn is a data-rich region and we need a better methodology (paradigm?) to understand the 'signatures'**
- **The way forward is clearly a holistic systems approach across all lithospheric scales and dimensions**
- **Need to integrate in 3D with time**
- **Erect multiple hypotheses and apply suitable tests**

Challenge for us all

- **Challenge is being predictive with this new understanding and knowledge**
- **The system may be recognised even though the precise genetic links with mineralisation are unclear (Hronsky, 2004),**

but we are working hard on it
(pmd*CRC)


Thanks for listening