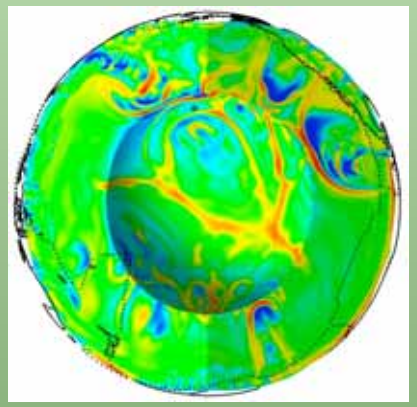
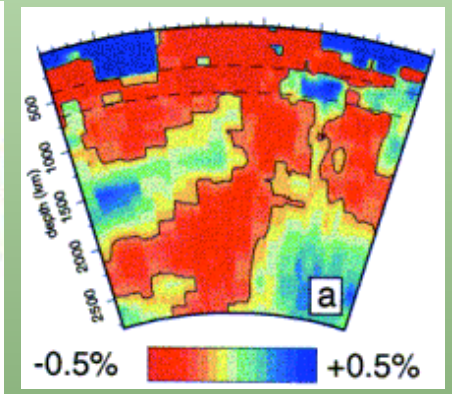
CRC AUSTRALIA

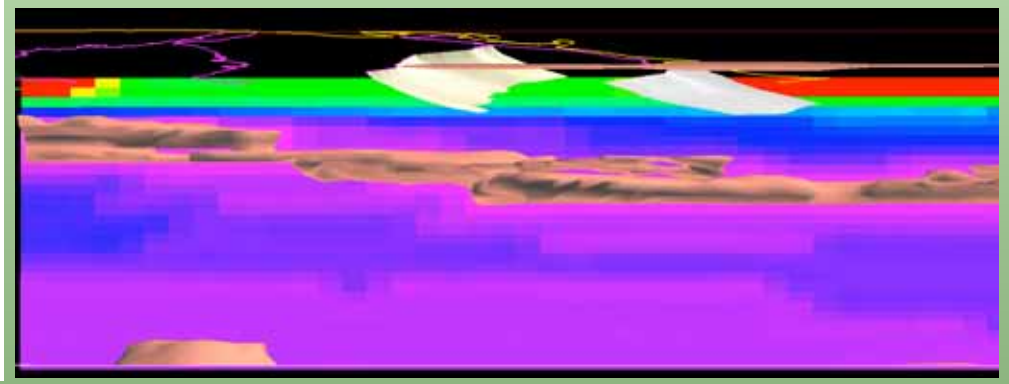
The Y2 project (2001-2004)

pmd*CRC

Lithospheric Geodynamics: a seismic view of the Yilgarn Craton







'Reduced Discovery Risk through Improved Targeting'

JCU James Cook University

The University of Western Australia

MONASH UNIVERSITY

The University of Melbourne

AMIRA INTERNATIONAL

CSIRO

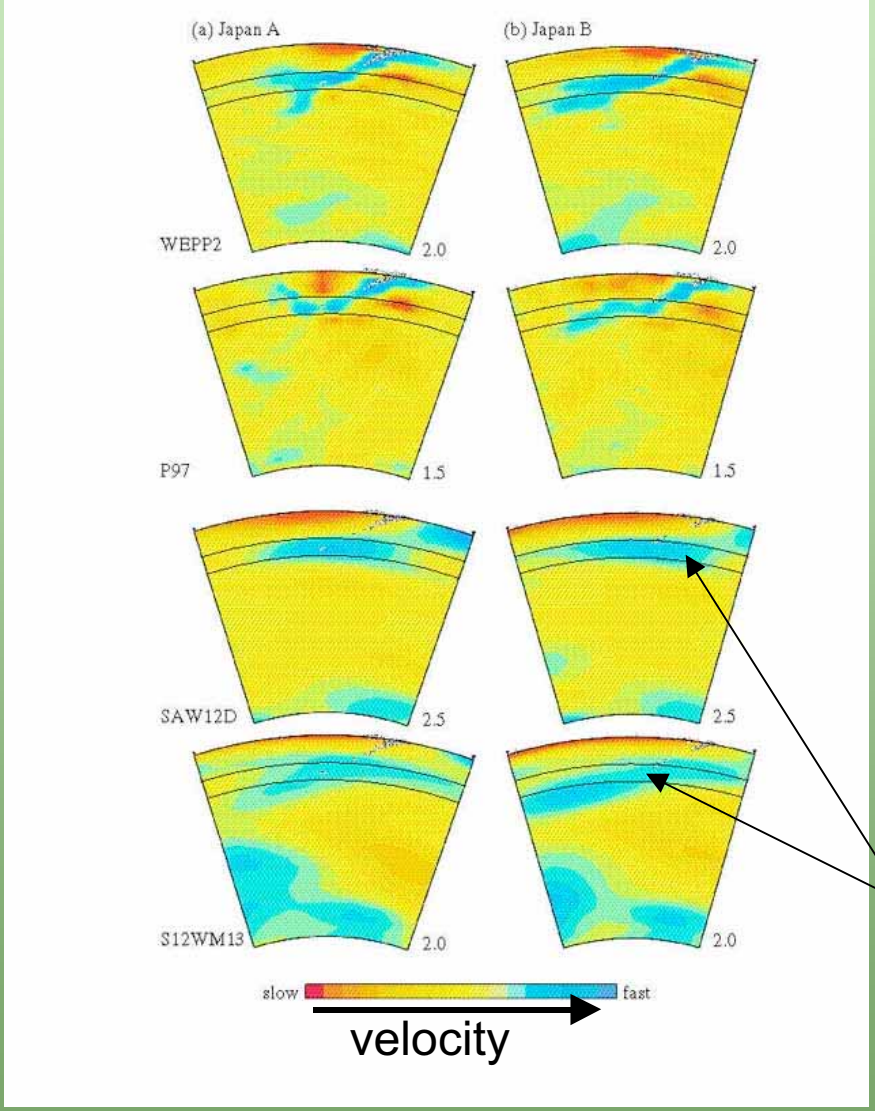
Australian Government
Geoscience Australia

Outline

Seismic (general sense) signature of:

- subduction and slabs
- mantle plumes
- delamination and possible generation of Low-Ca granites
- Provinciality/terranes
- Conclusions

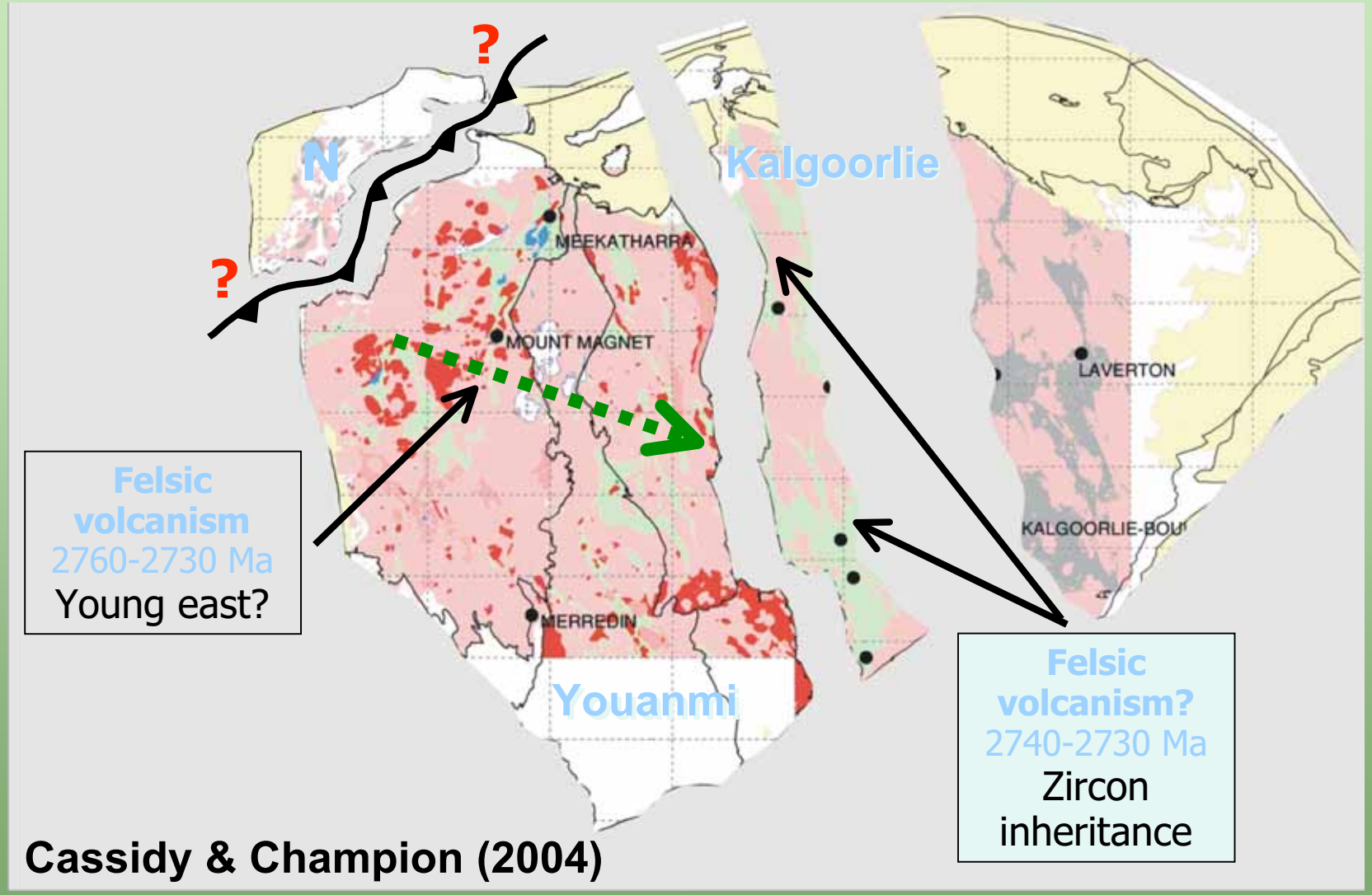
Subduction and tomography



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

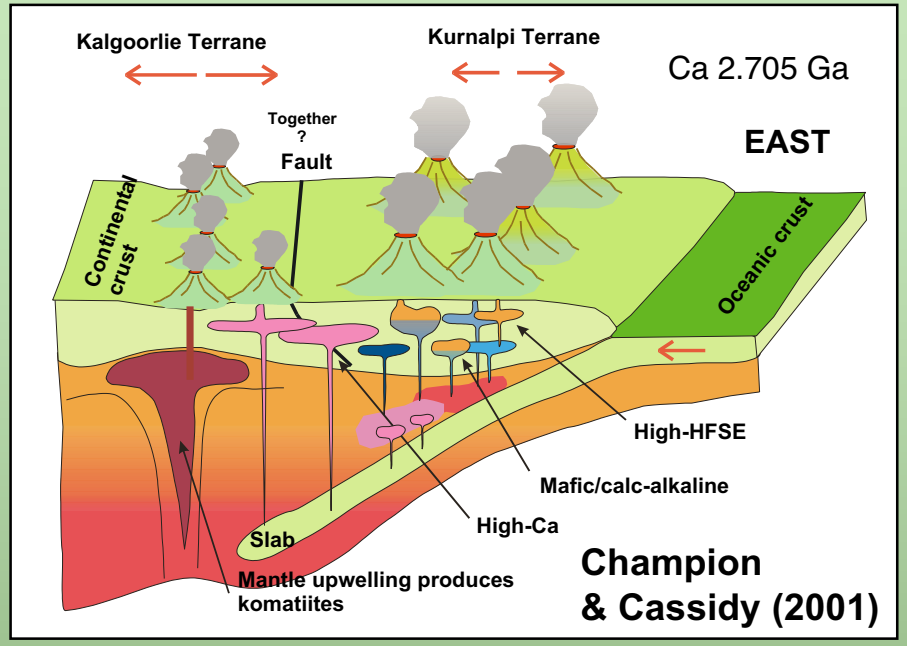
Tomography of slabs under Japan (Fukao et al. 2001)

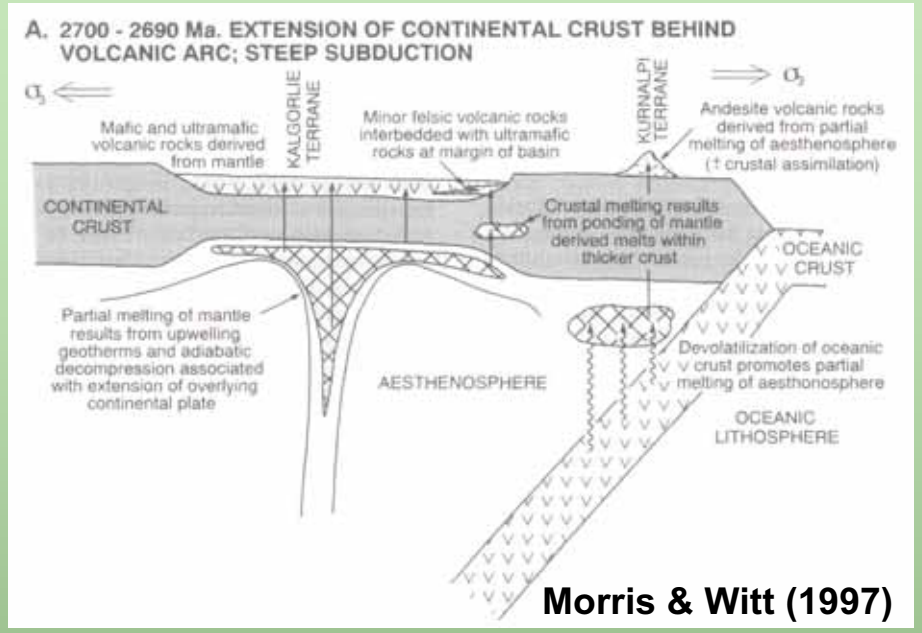
SE-dipping subduction zones?



Postulated SE-dipping slab ca 2.76-2.73 Ga

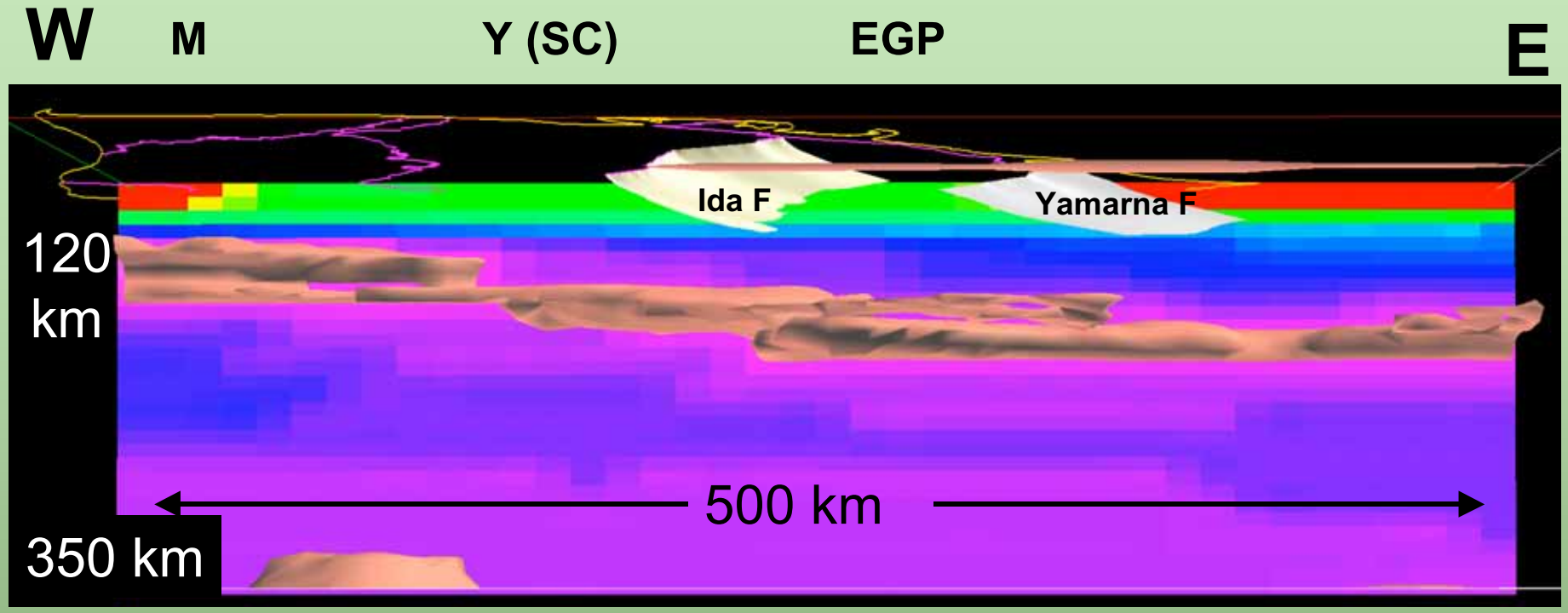
W-dipping subduction zones?



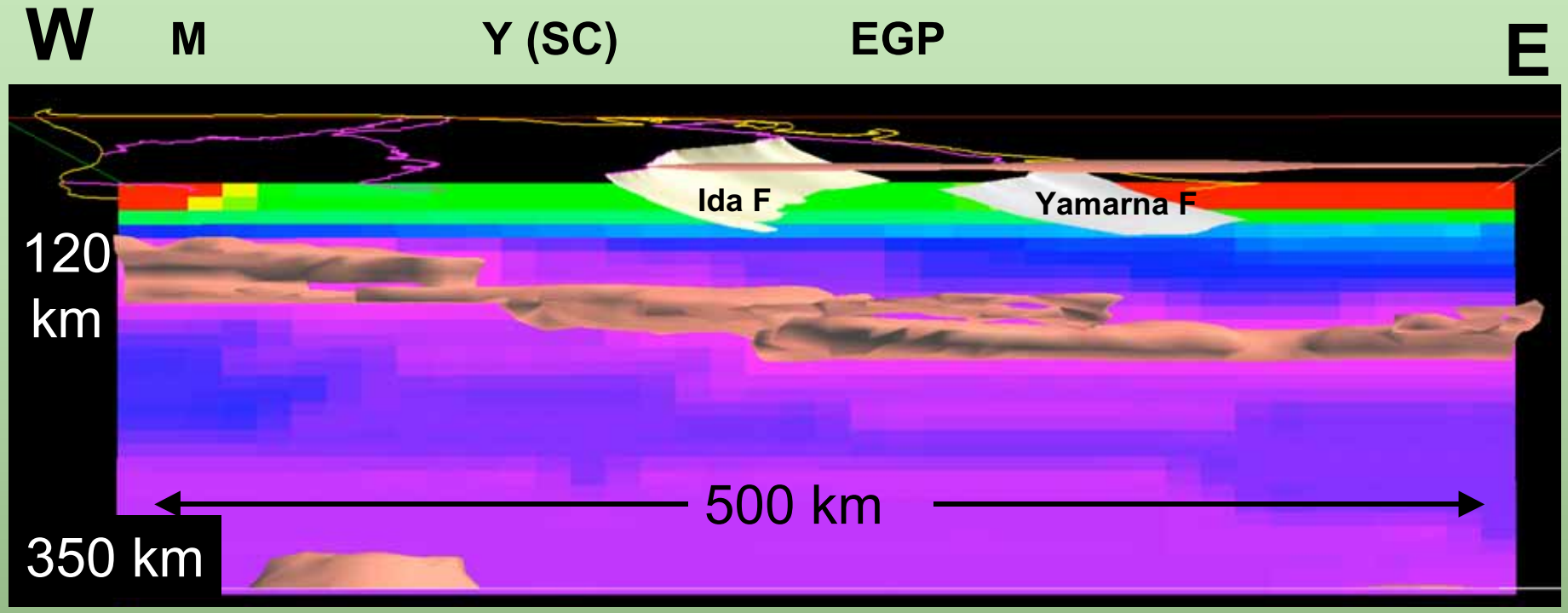


Models for West-dipping subduction at **~2.7** Ga

Stratified lithosphere as a slab?

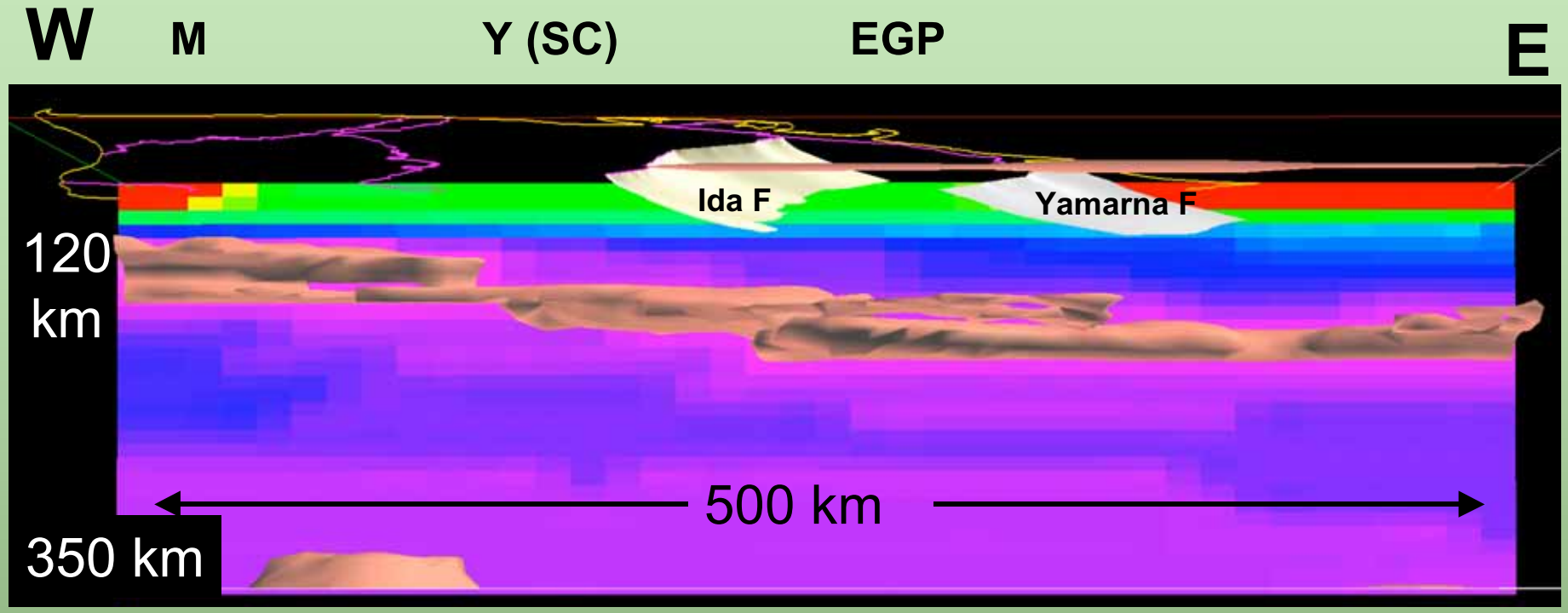


Stratified lithosphere as a slab?



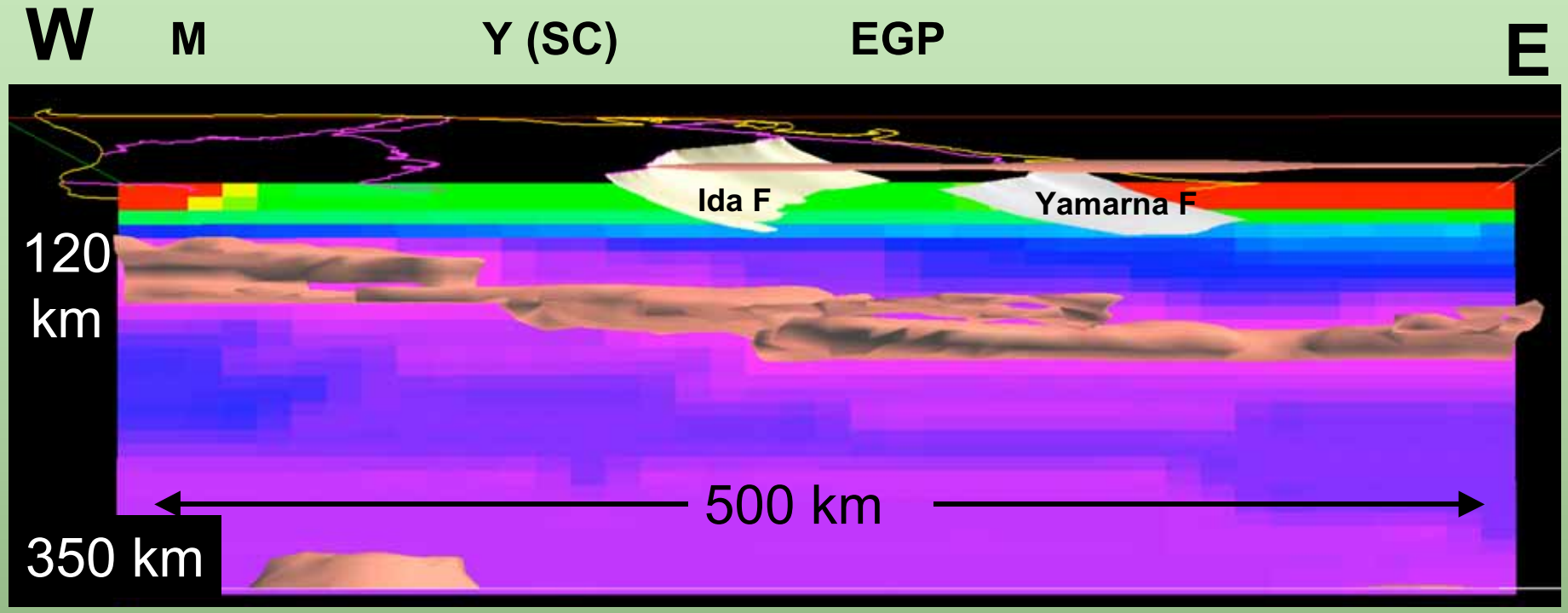
- **SE-dipping (low-angle) fast layer (4.8 km/s)**

Stratified lithosphere as a slab?



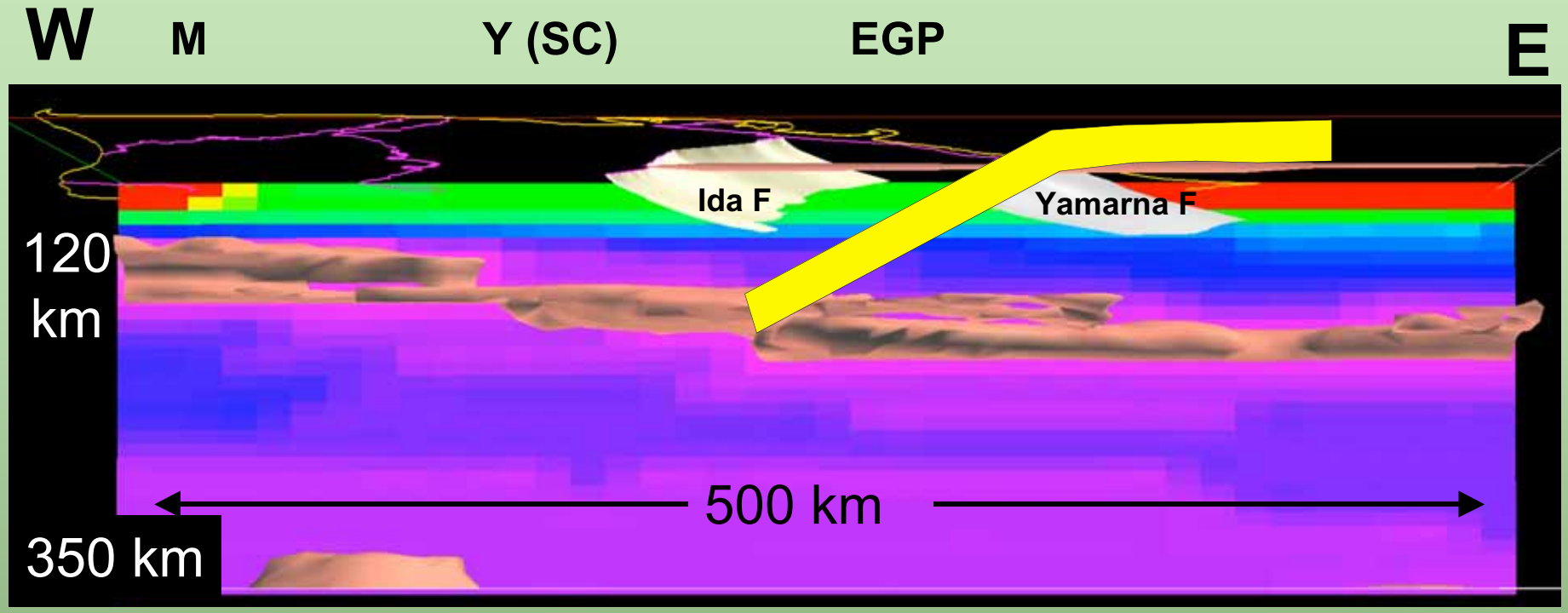
- SE-dipping (low-angle) fast layer (4.8 km/s)
- possibly a fossil slab (*cf*. Narryer at 2.75Ga)

Stratified lithosphere as a slab?



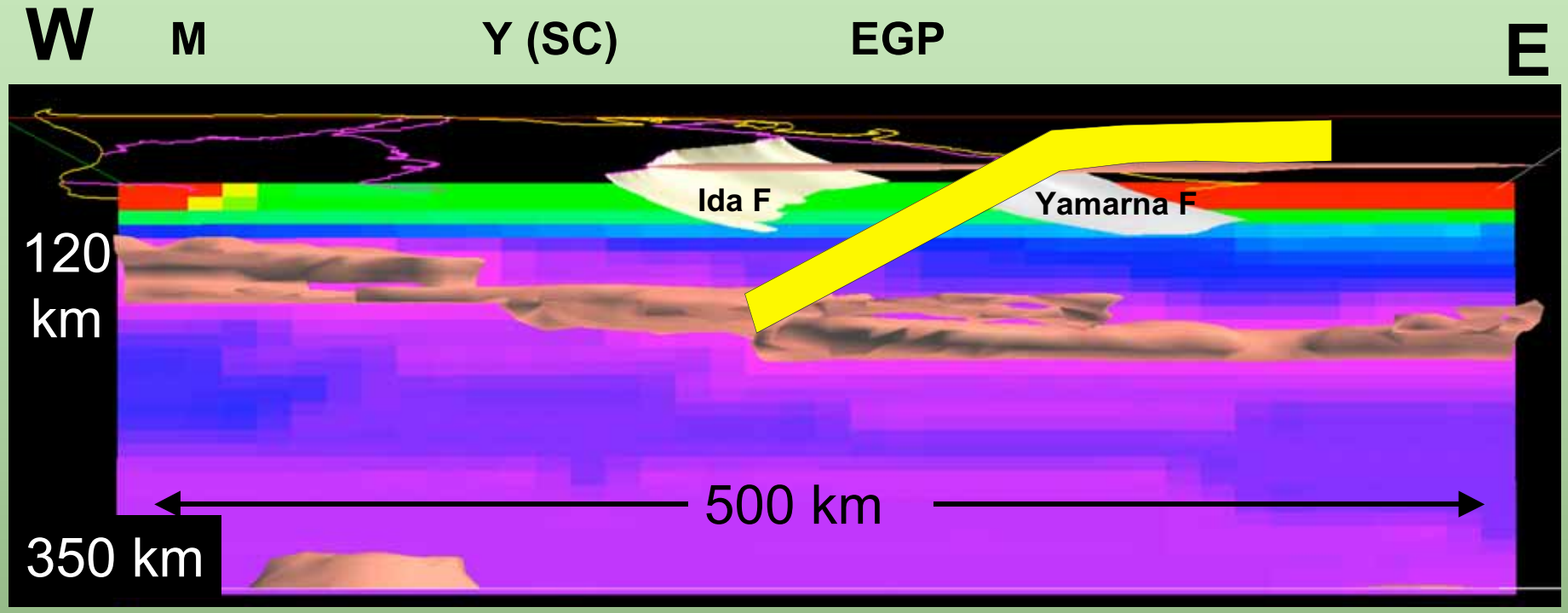
- SE-dipping (low-angle) fast layer (4.8 km/s)
- possibly a fossil slab (*cf*. Narryer at 2.75Ga)

Stratified lithosphere as a slab?



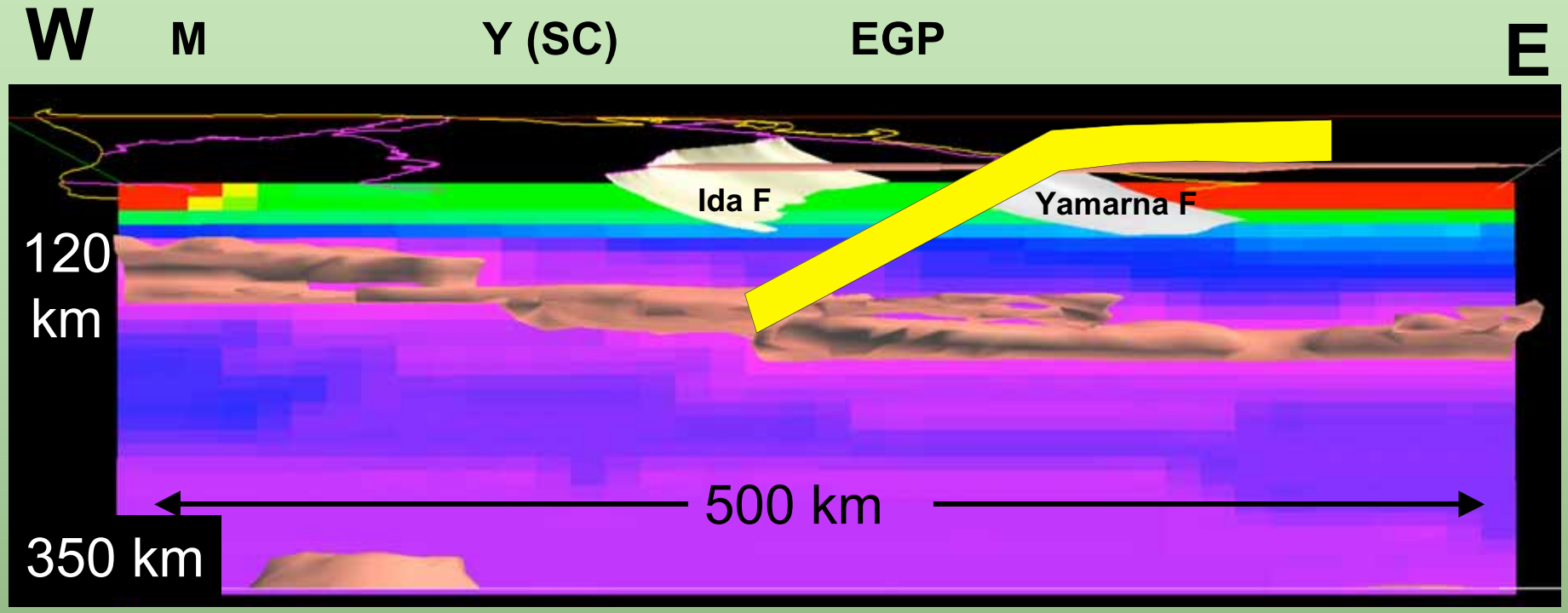
- SE-dipping (low-angle) fast layer (4.8 km/s)
- possibly a fossil slab (*cf.* Narryer at 2.75Ga)
- no evidence for the W-dipping 2.7 Ga slab?

Stratified lithosphere as a slab?



- SE-dipping (low-angle) fast layer (4.8 km/s)
- 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

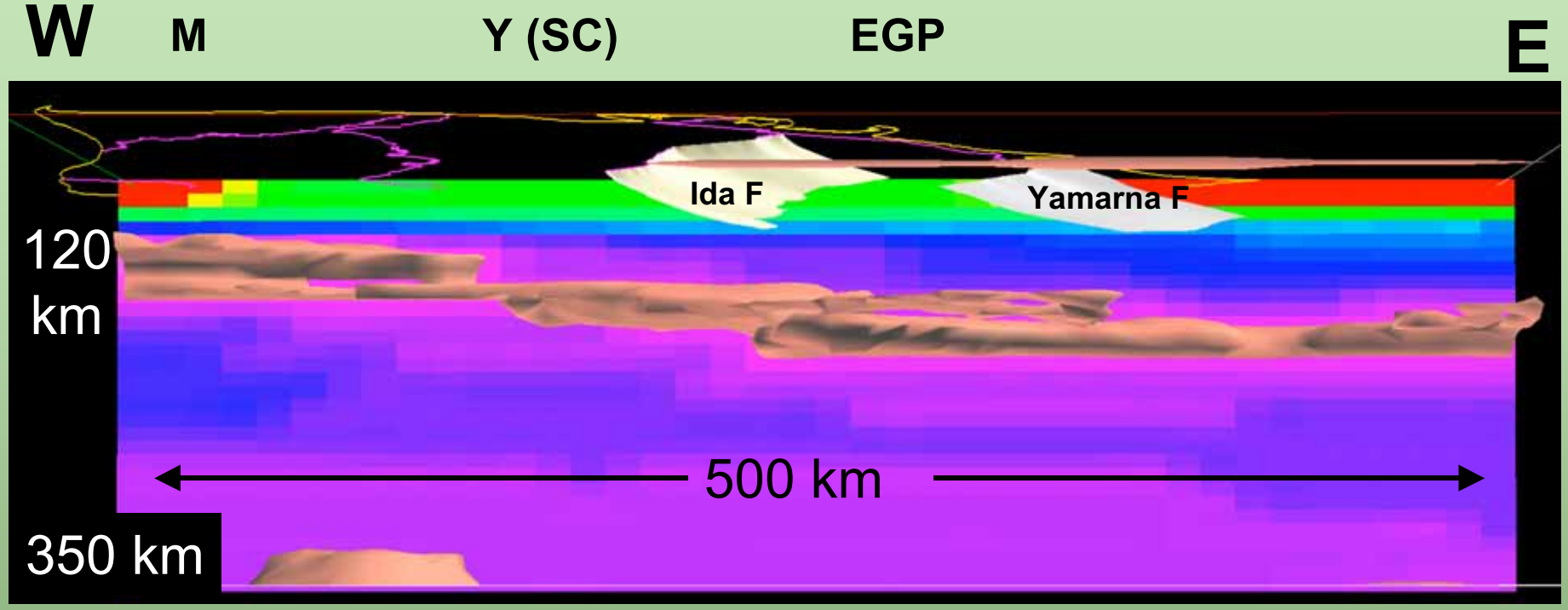
Stratified lithosphere as a slab?



- SE-dipping (low-angle) fast layer (4.8 km/s)
- 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

We can not rule slabs in or out on this evidence

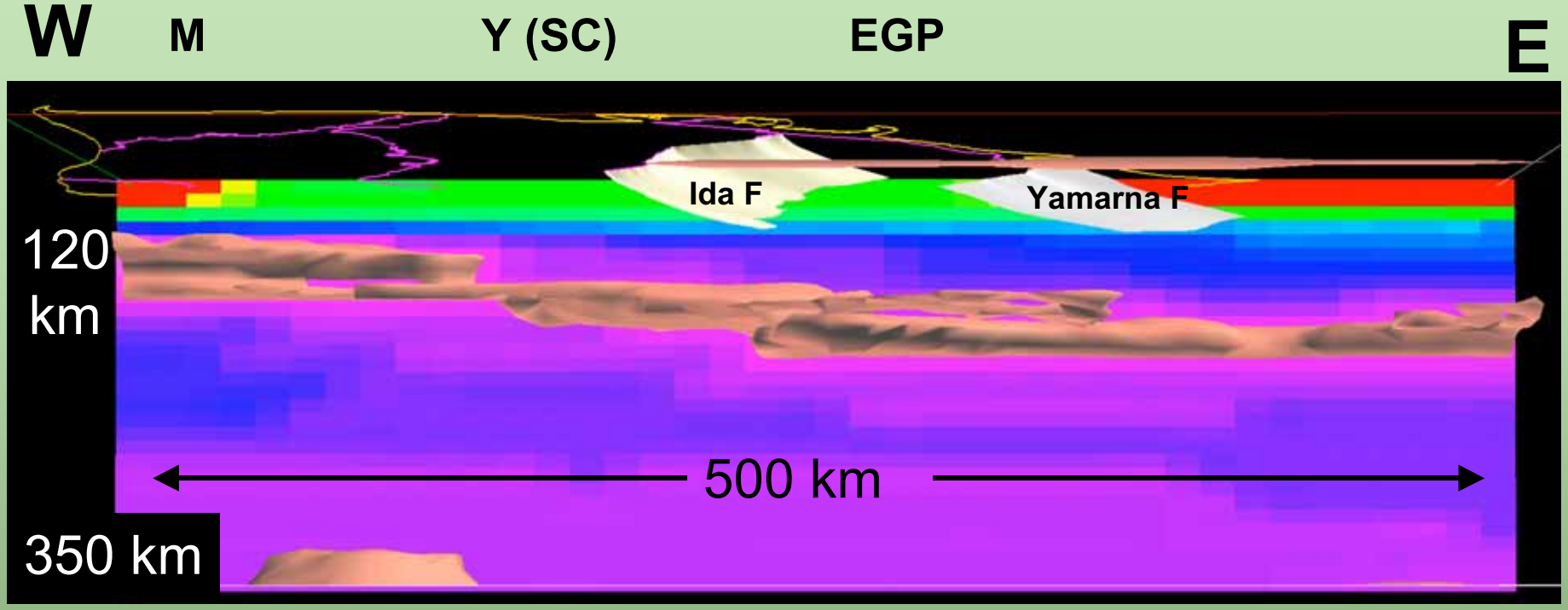
Chilean analogue for flat subduction

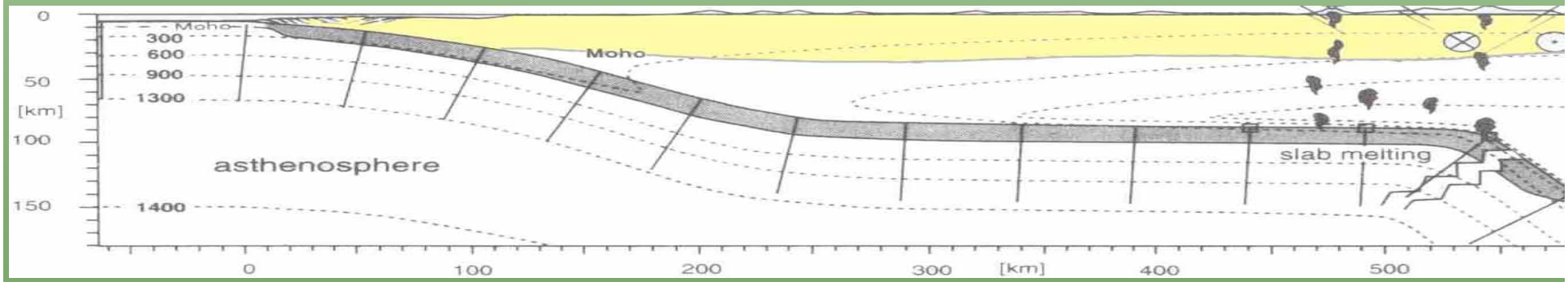


Gutscher et al. (2000)

500 km

Chilean analogue for flat subduction

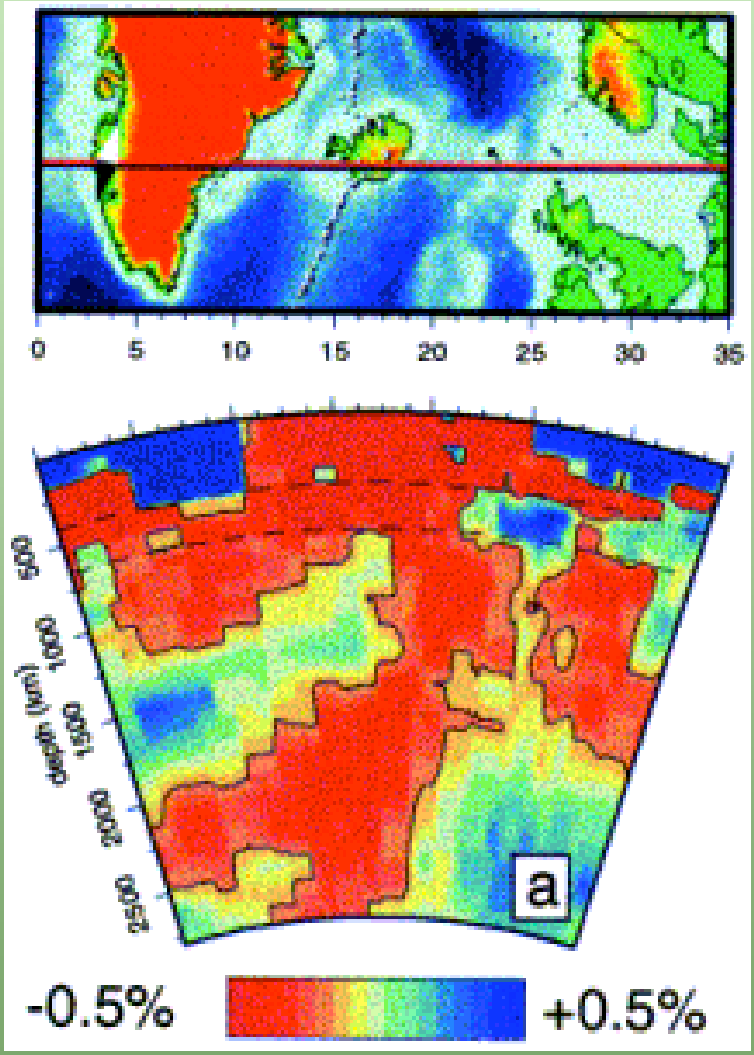




Gutscher et al. (2000)

500 km

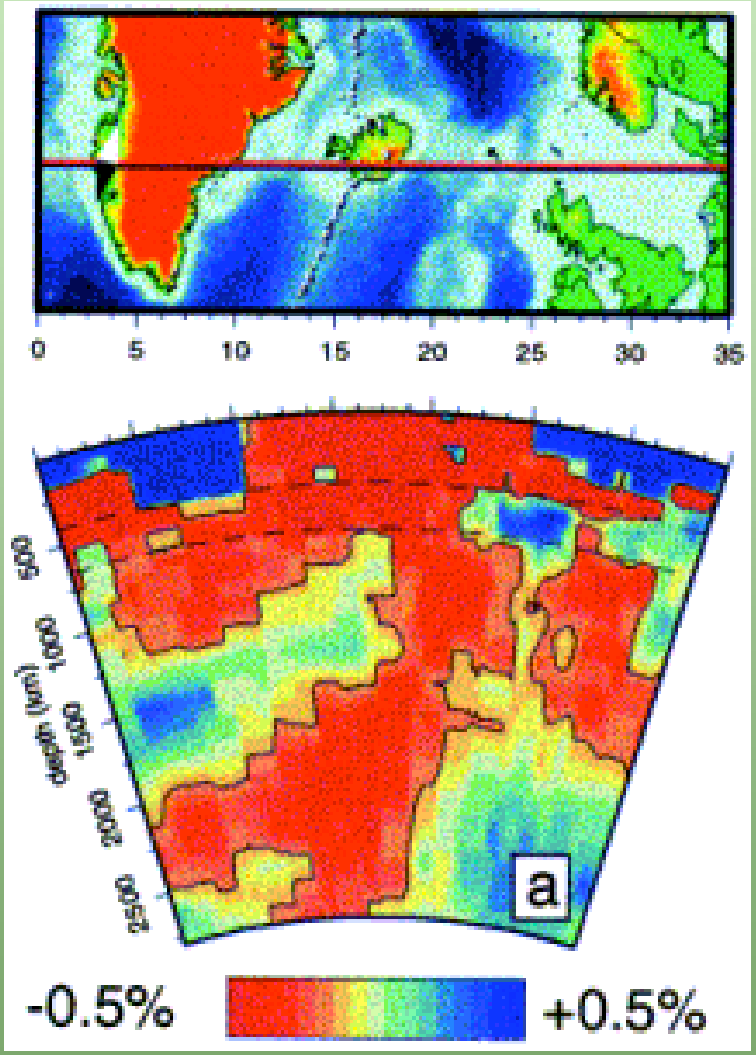
Mantle plumes and tomography



Modern mantle plumes are:

Bijwaard et al. (2004) Iceland plume tomography

Mantle plumes and tomography

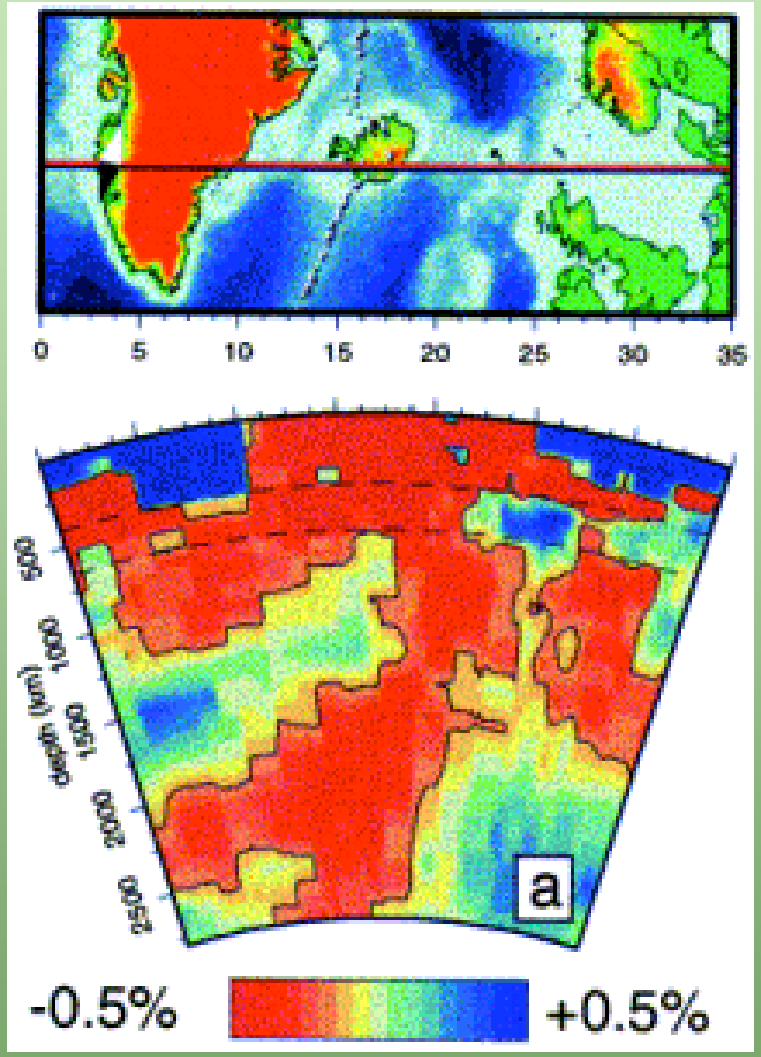


Modern mantle plumes are:

- **large (several 100's to 1000's kms in diameter)**

Bijwaard et al. (2004) Iceland plume tomography

Mantle plumes and tomography

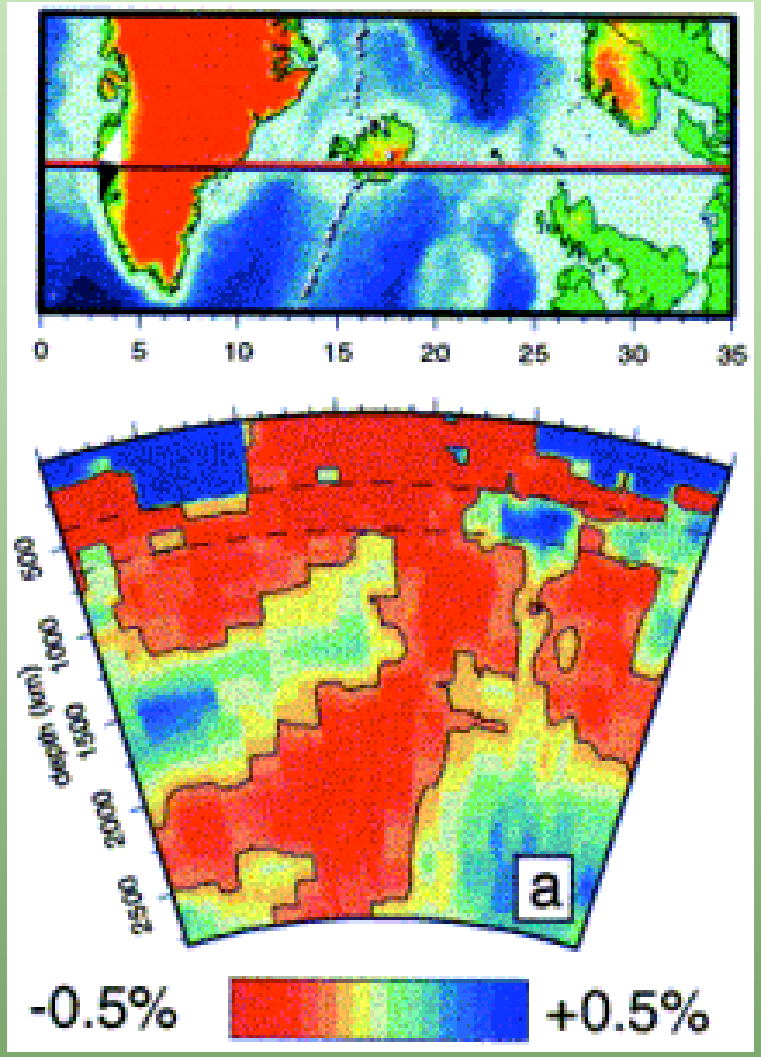


Modern mantle plumes are:

- **large (several 100's to 1000's kms in diameter)**
- **Originate from the very deep earth**

Bijwaard et al. (2004) Iceland plume tomography

Mantle plumes and tomography



Modern mantle plumes are:

- **large (several 100's to 1000's kms in diameter)**
- **Originate from the very deep earth**
- **Have low P- and S-wave velocities**

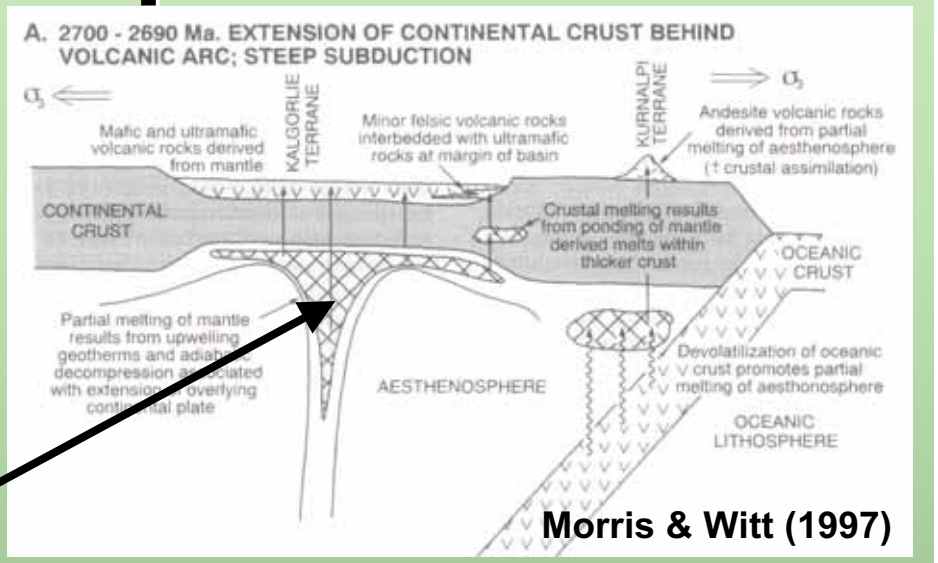
Bijwaard et al. (2004) Iceland plume tomography

Yilgarn mantle plumes?

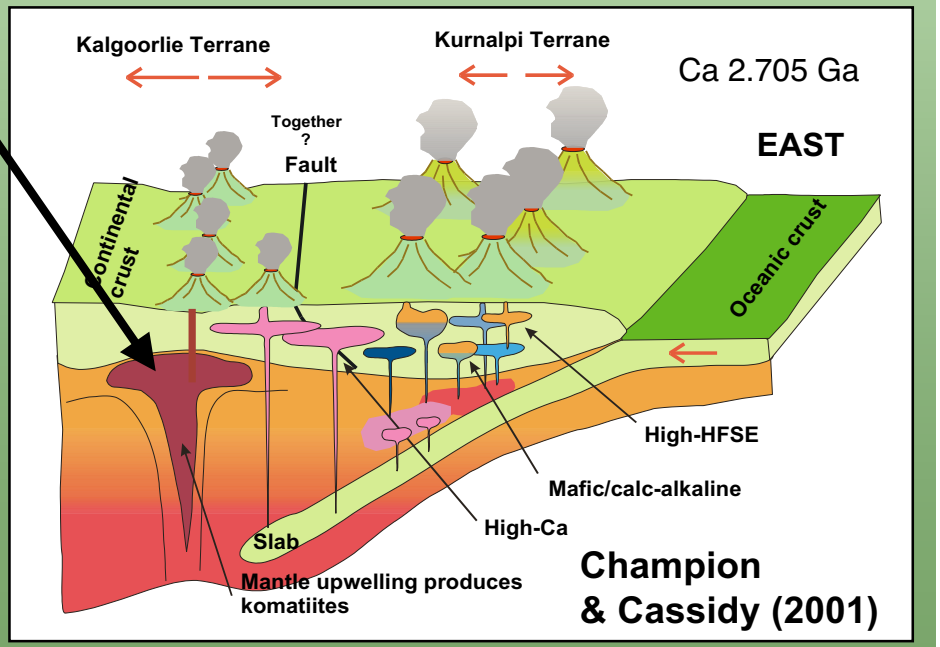
Plumes have been hypothesised for komatiites (eg Morris & Witt, 1997; Champion etc),

and many granites (eg Campbell & Hill, 1988 and later papers)

Plume

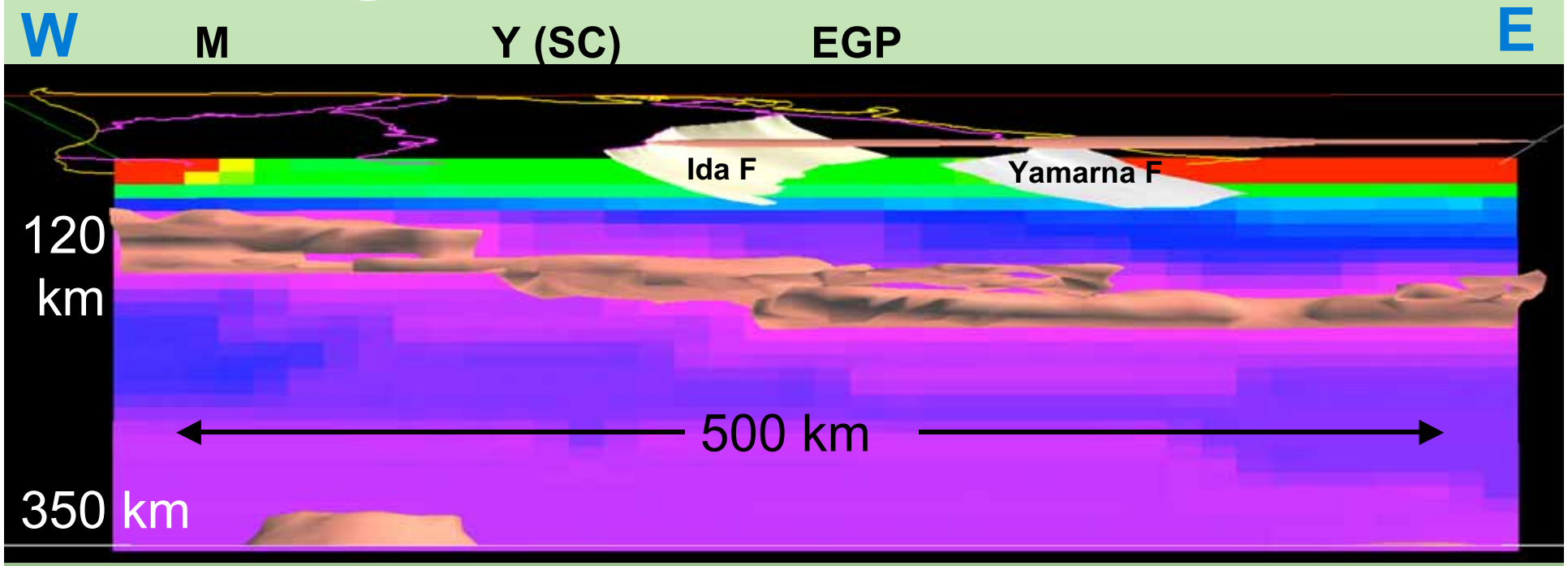


Morris & Witt (1997)

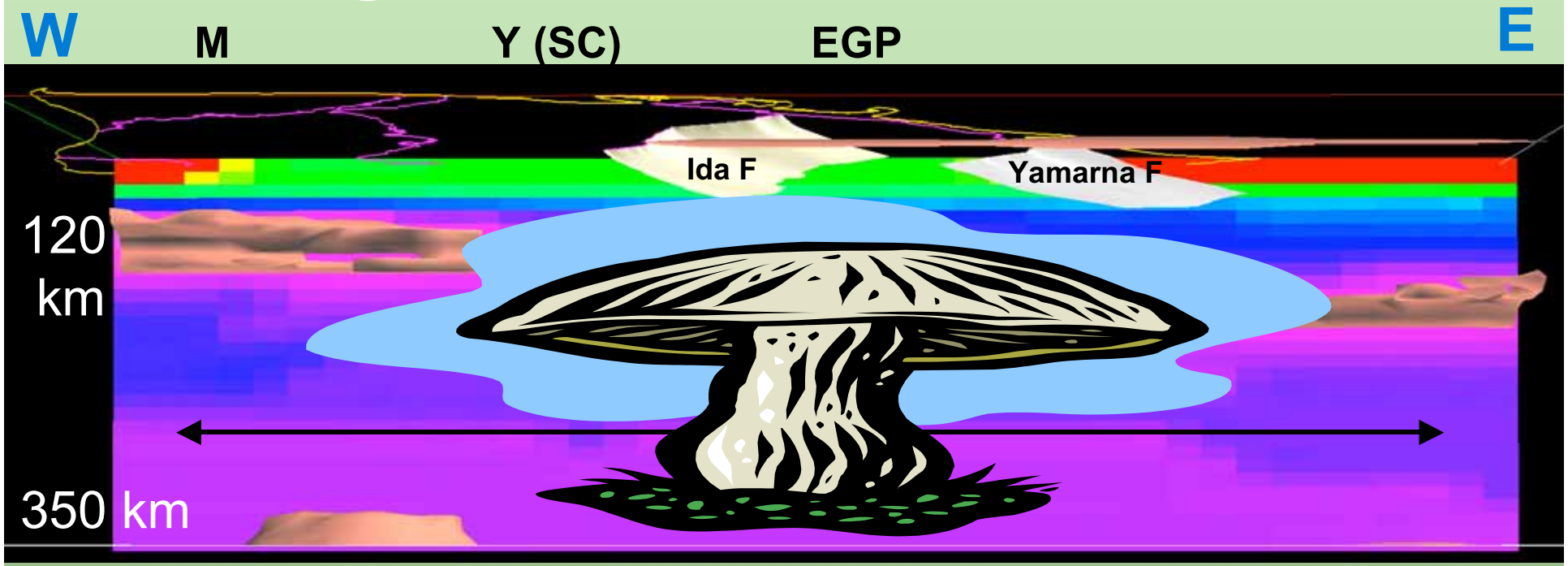


Champion & Cassidy (2001)

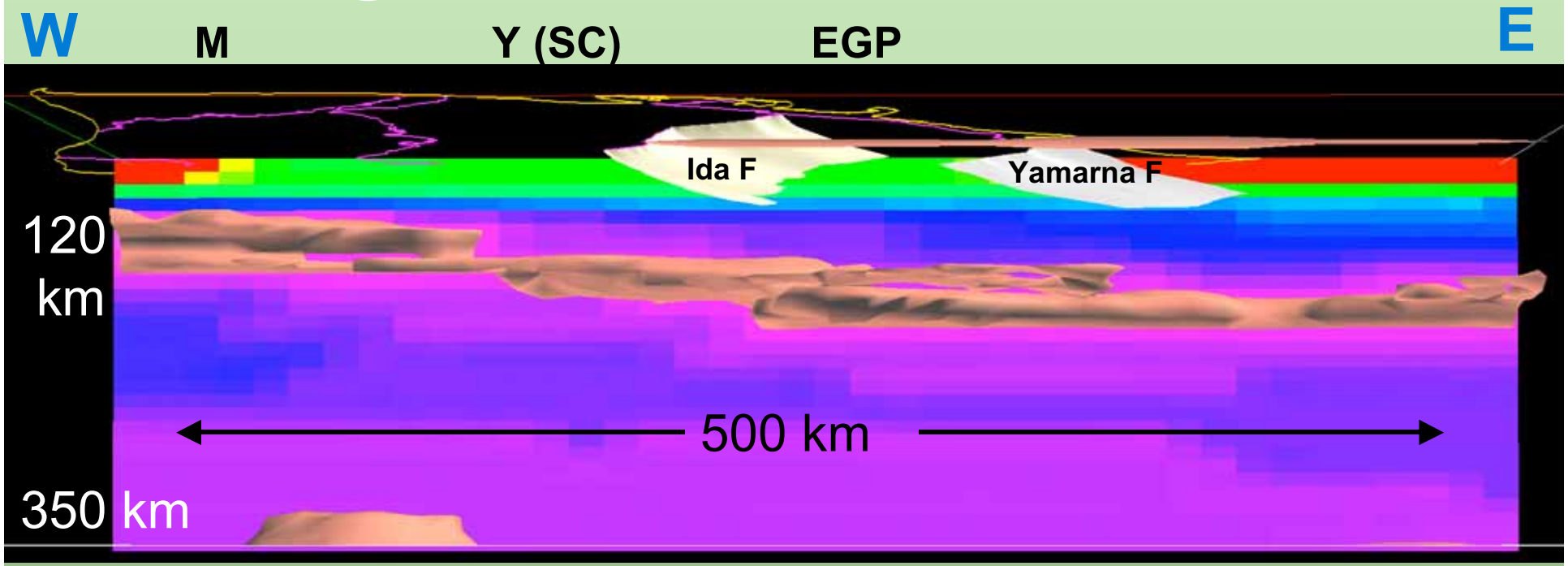
Impingement of a mantle plume?



Impingement of a mantle plume?

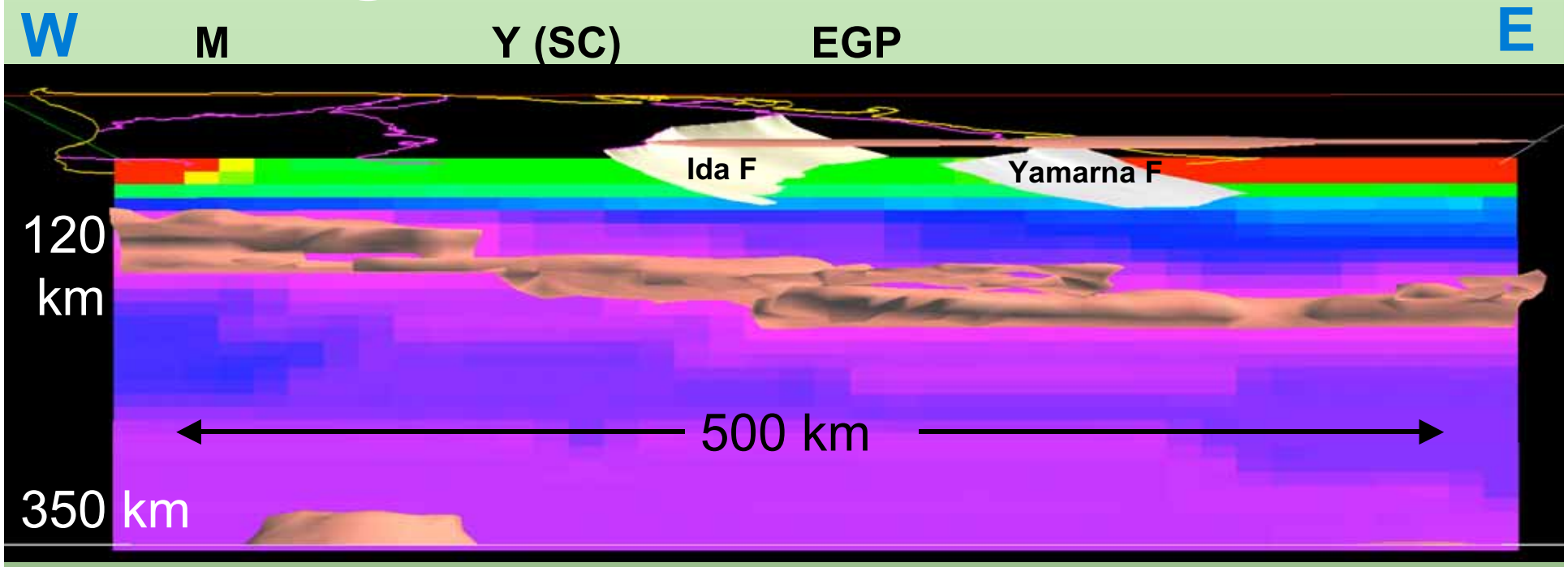


Impingement of a mantle plume?



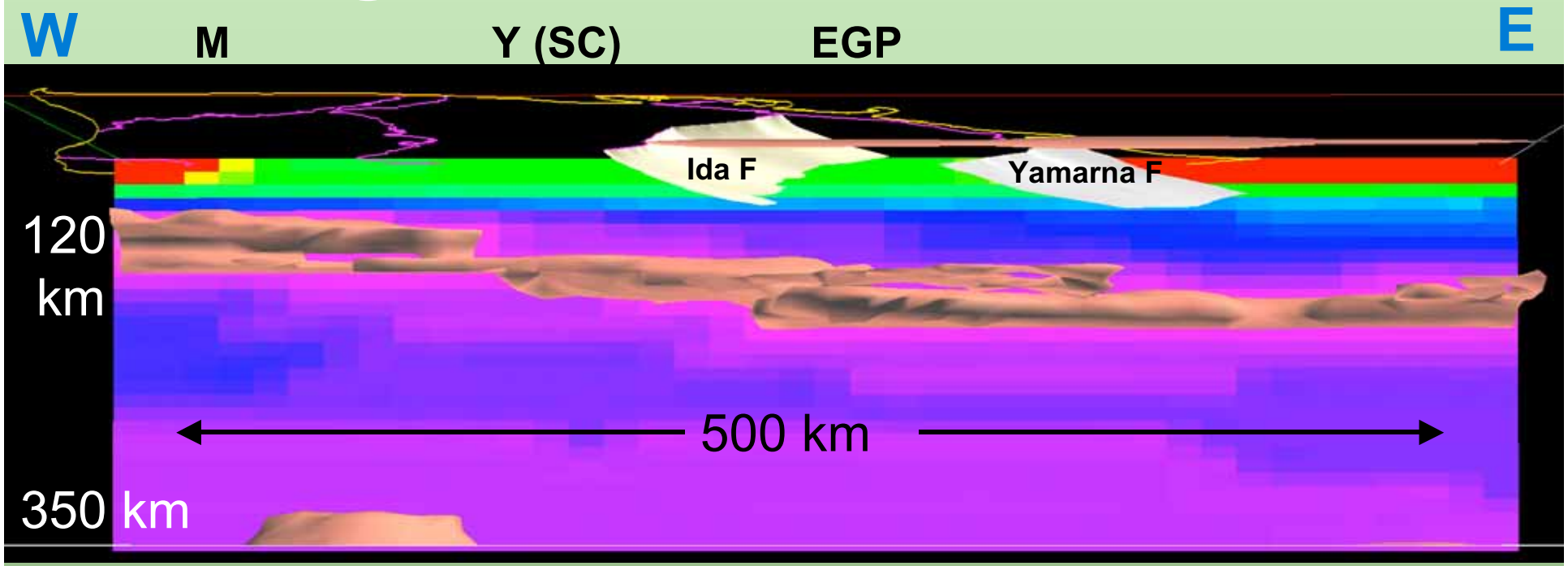
- If a high-level plume: it would disrupt this stratification (assuming stratification is old)

Impingement of a mantle plume?



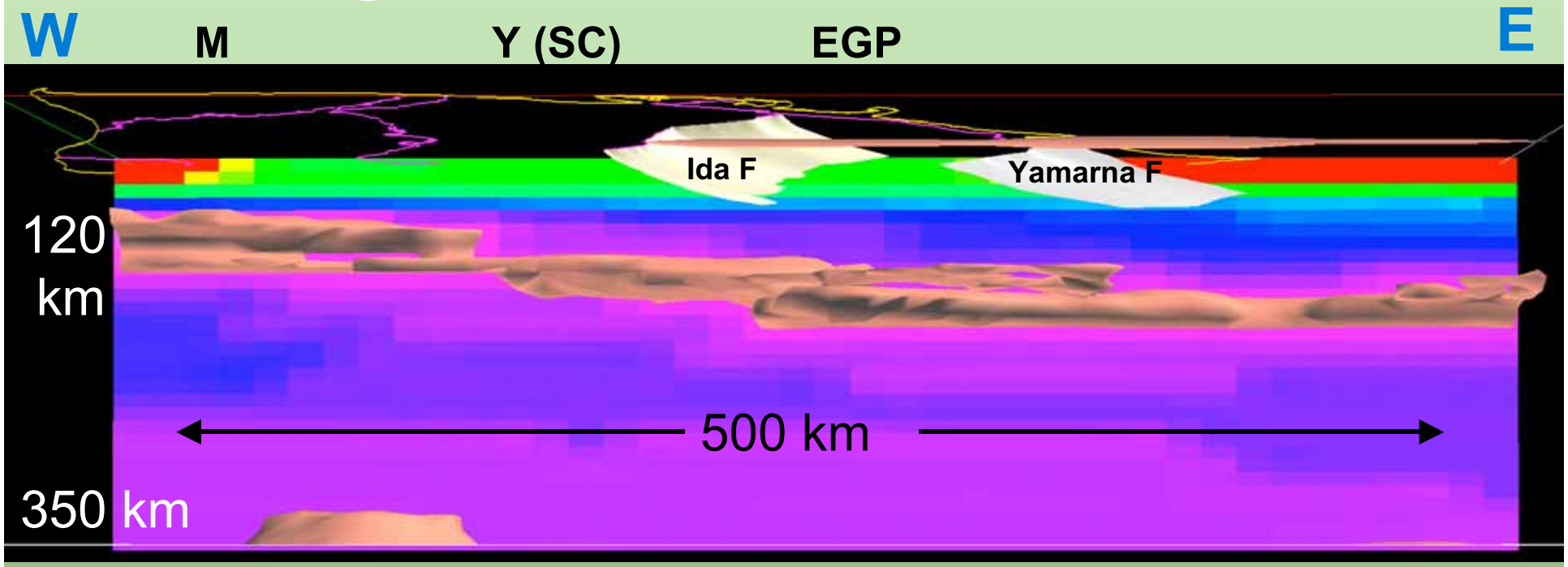
- If a high-level plume: it would disrupt this stratification (assuming stratification is old)
- Or, horizontal reworking was dominant after the plume

Impingement of a mantle plume?



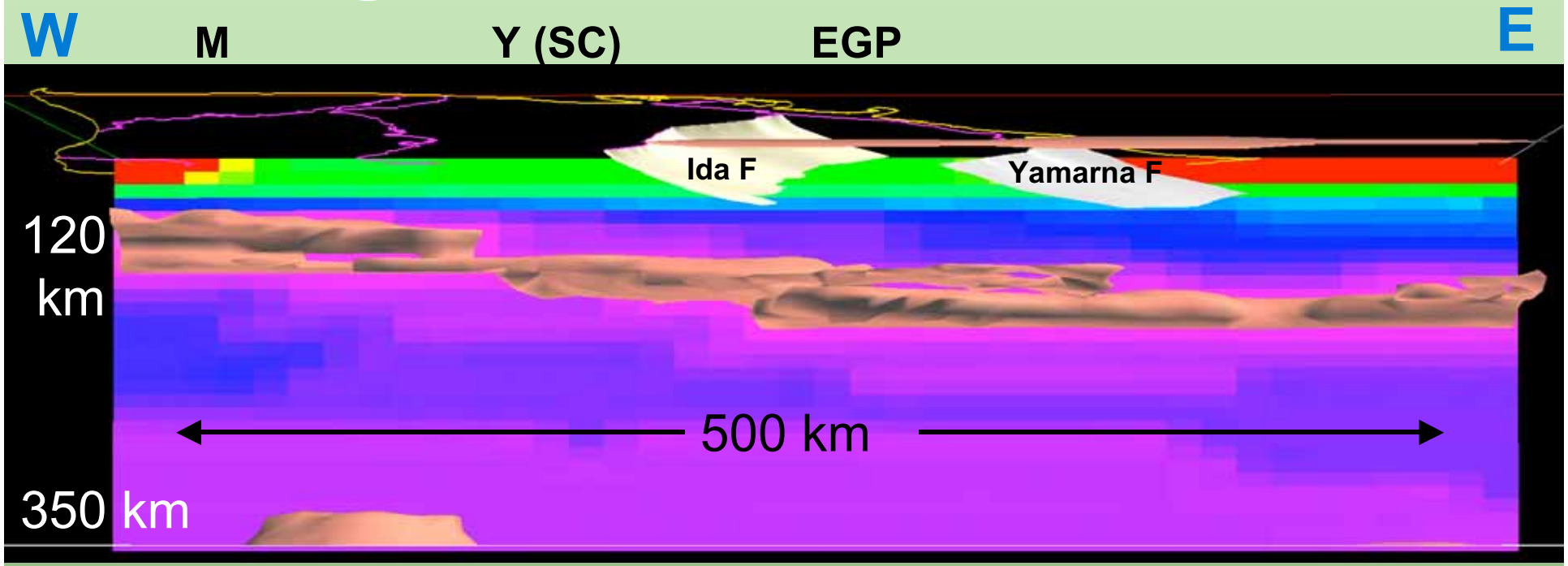
- If a high-level plume: it would disrupt this stratification (assuming stratification is old)
- Or, horizontal reworking was dominant after the plume
- Or, disruption is out of this plane

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

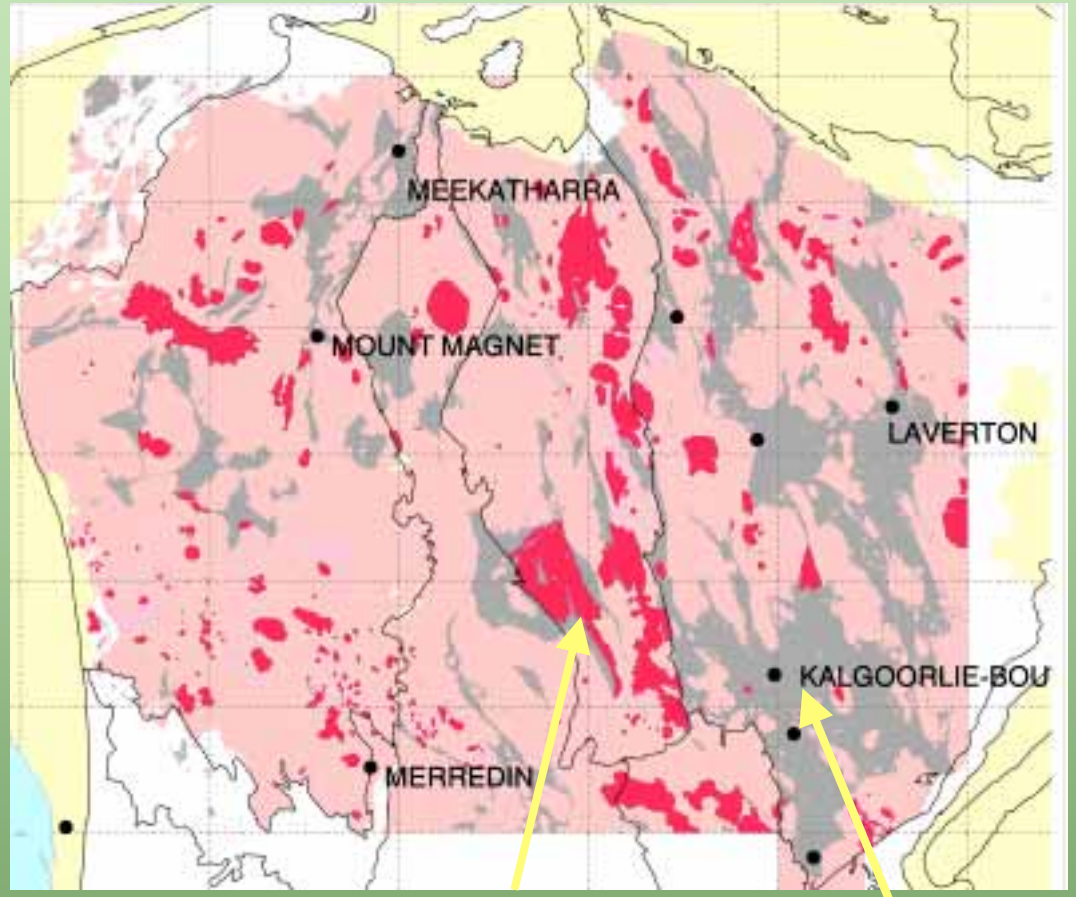
Impingement of a mantle plume?



- 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

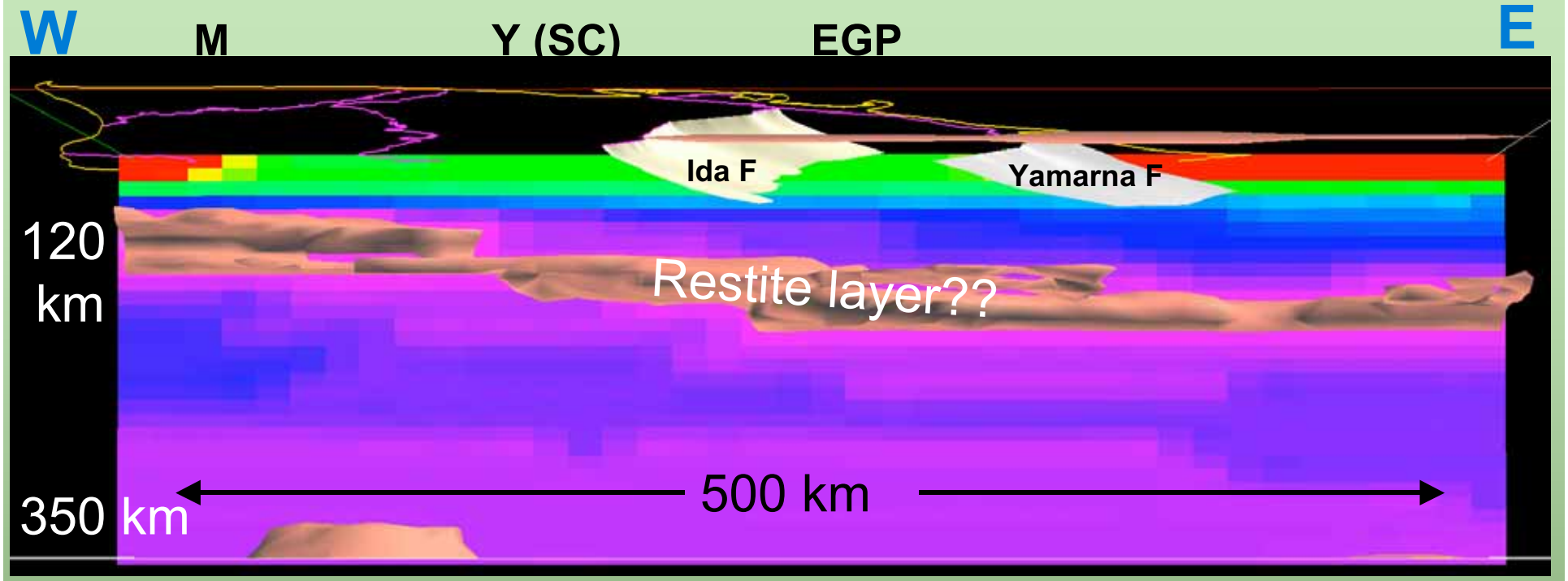
Yilgarn delamination?



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

Champion & Sheraton (1997)

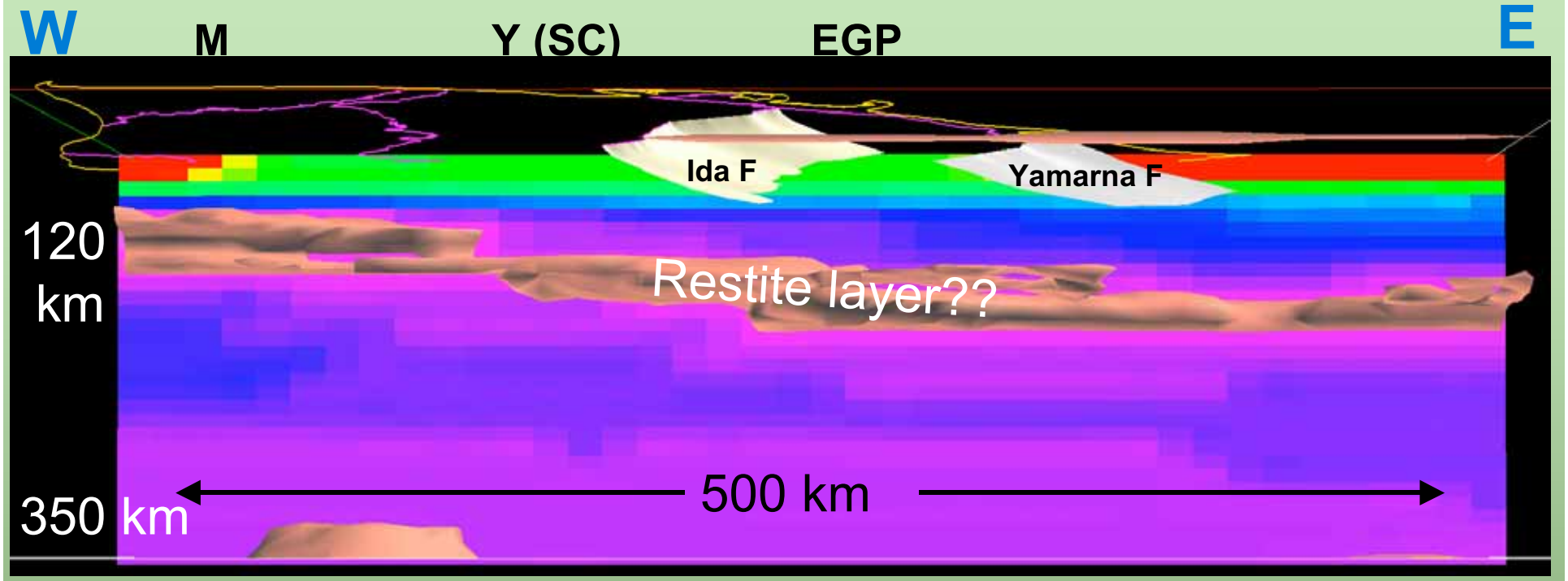
Fast layer as delaminated ‘restite’?



Delamination:

AMIRA P624; Blewett et al., 2004

Fast layer as delaminated ‘restite’?

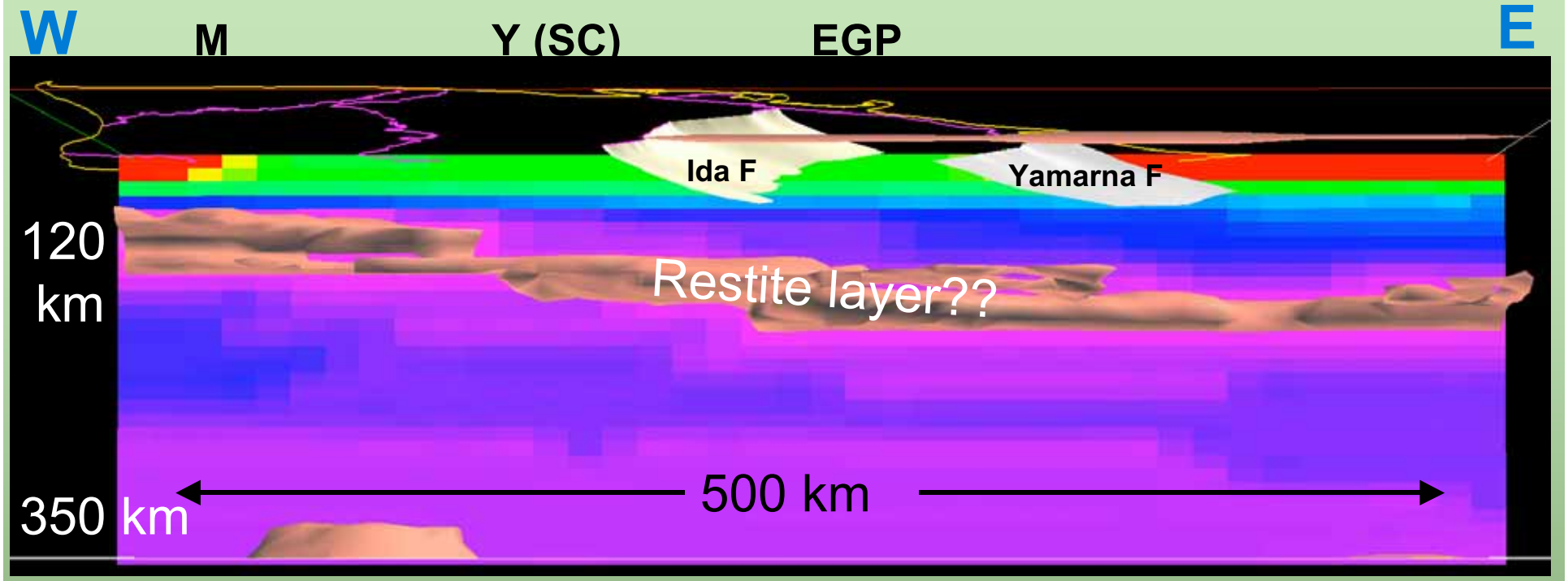


Delamination:

- **delivers heat across entire Yilgarn (Low-Ca are craton-wide)**

AMIRA P624; Blewett et al., 2004

Fast layer as delaminated ‘restite’?

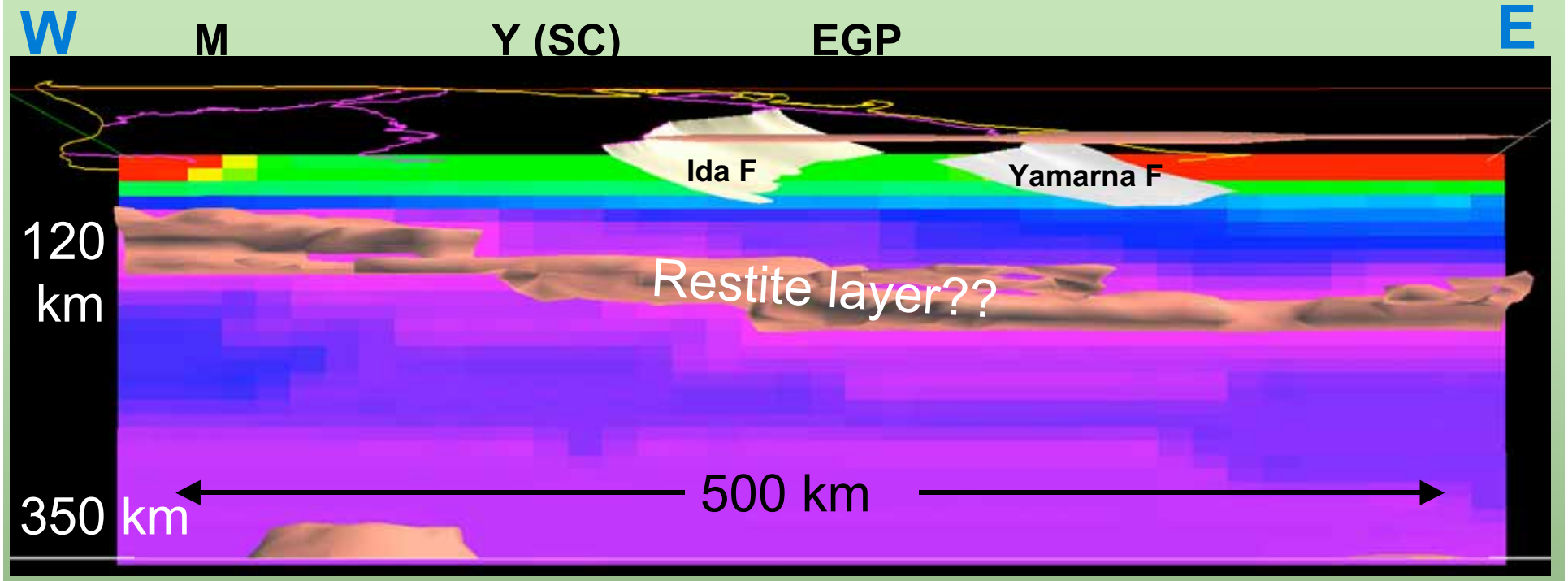


Delamination:

- **delivers heat across entire Yilgarn (Low-Ca are craton-wide)**
- **Initiated at ~2670 Ma (first D2a event in east)**

AMIRA P624; Blewett et al., 2004

Fast layer as delaminated ‘restite’?

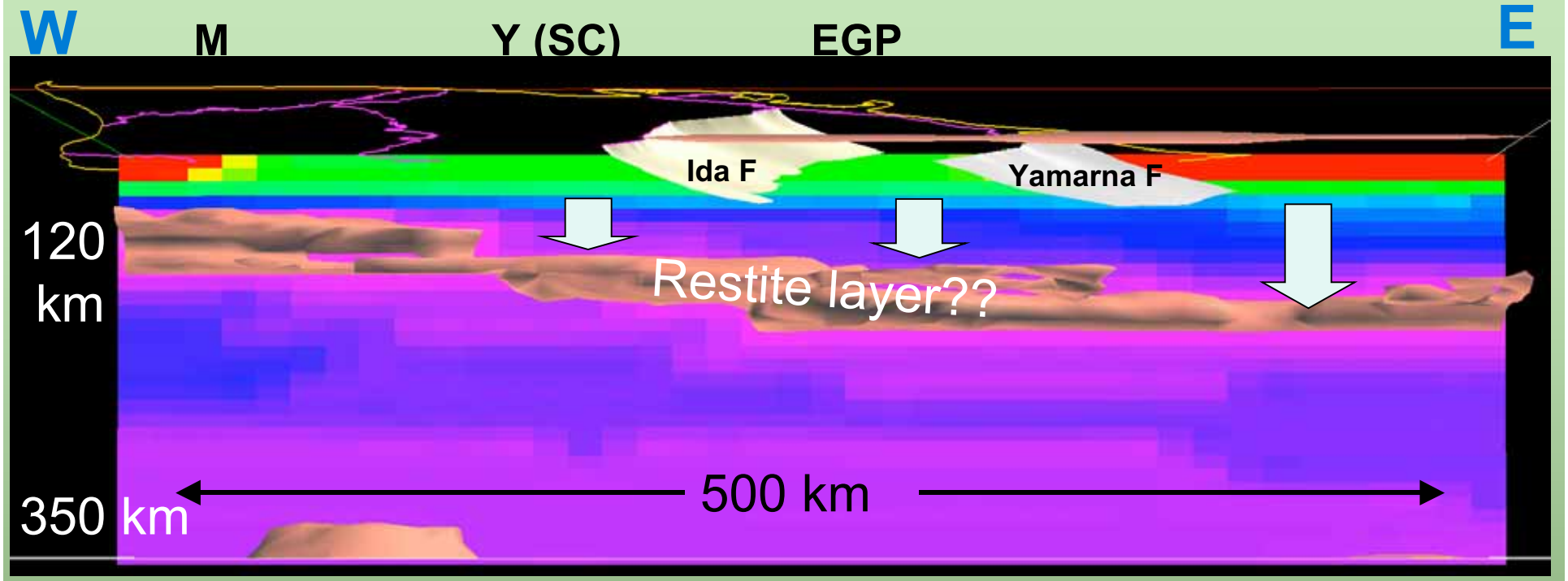


Delamination:

- **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)**

AMIRA P624; Blewett et al., 2004

Fast layer as delaminated ‘restite’?

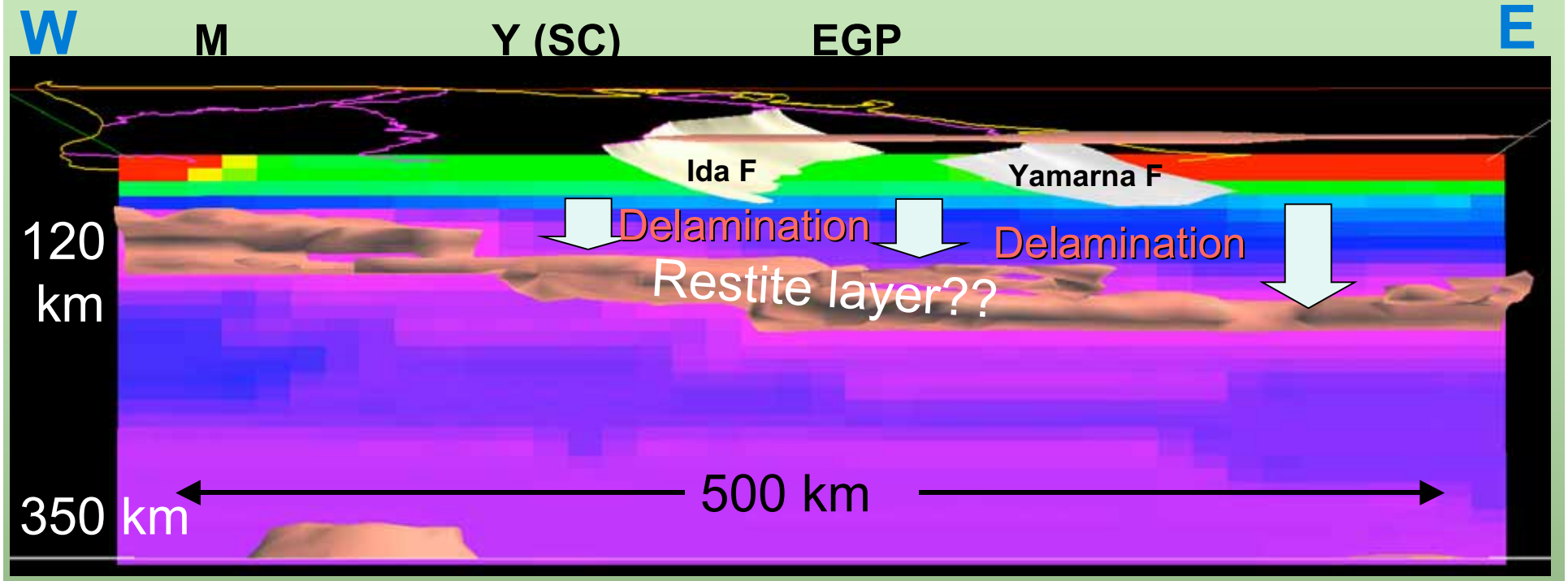


Delamination:

- **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

Fast layer as delaminated ‘restite’?

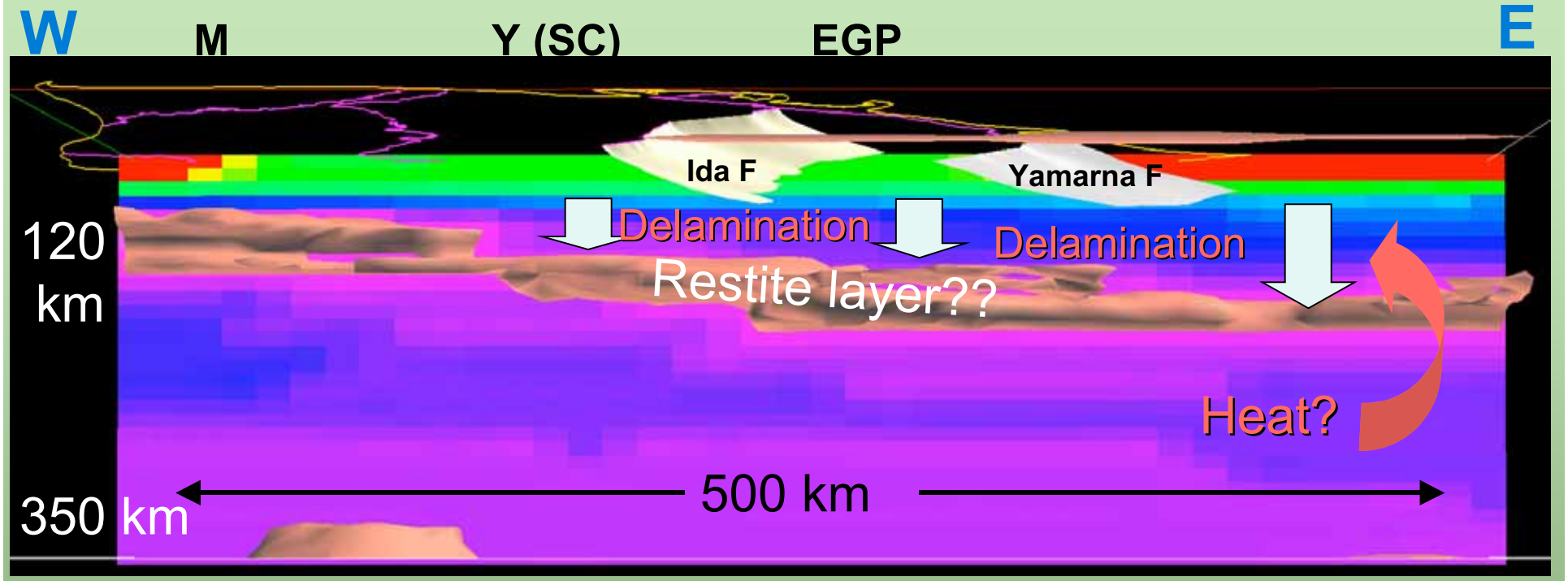


Delamination:

- 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

Fast layer as delaminated ‘restite’?

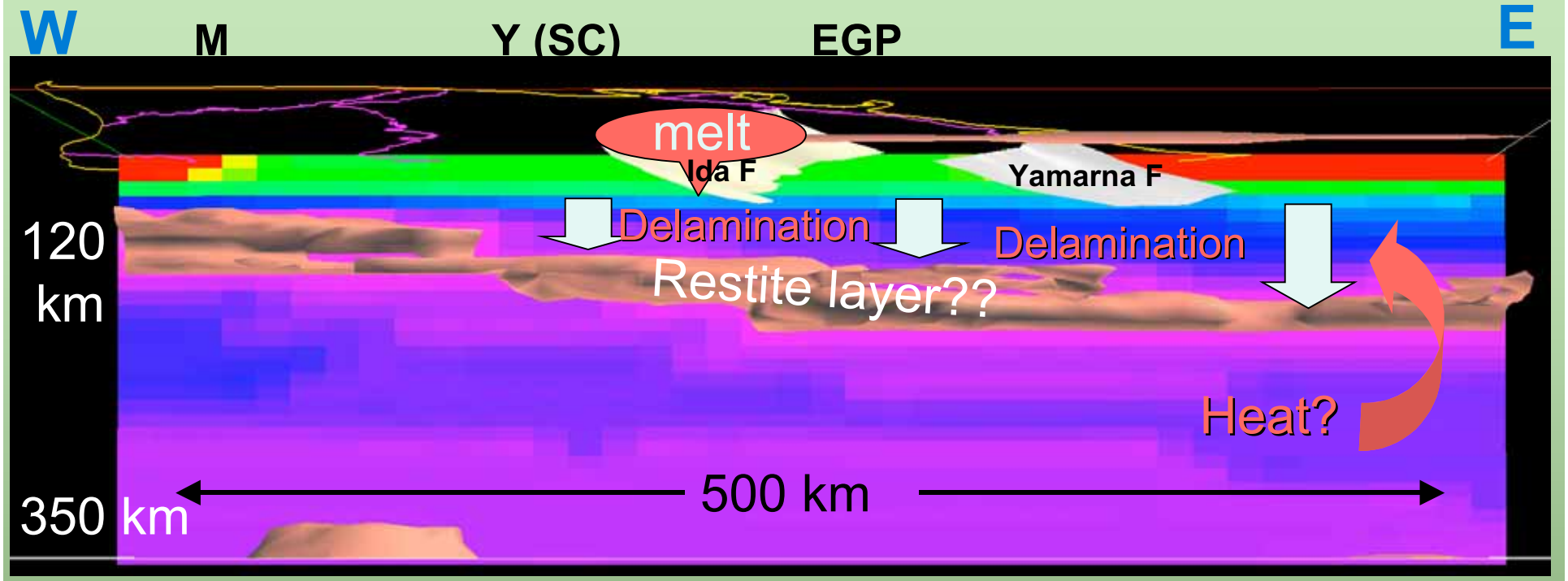


Delamination:

- **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

Fast layer as delaminated 'restite'?

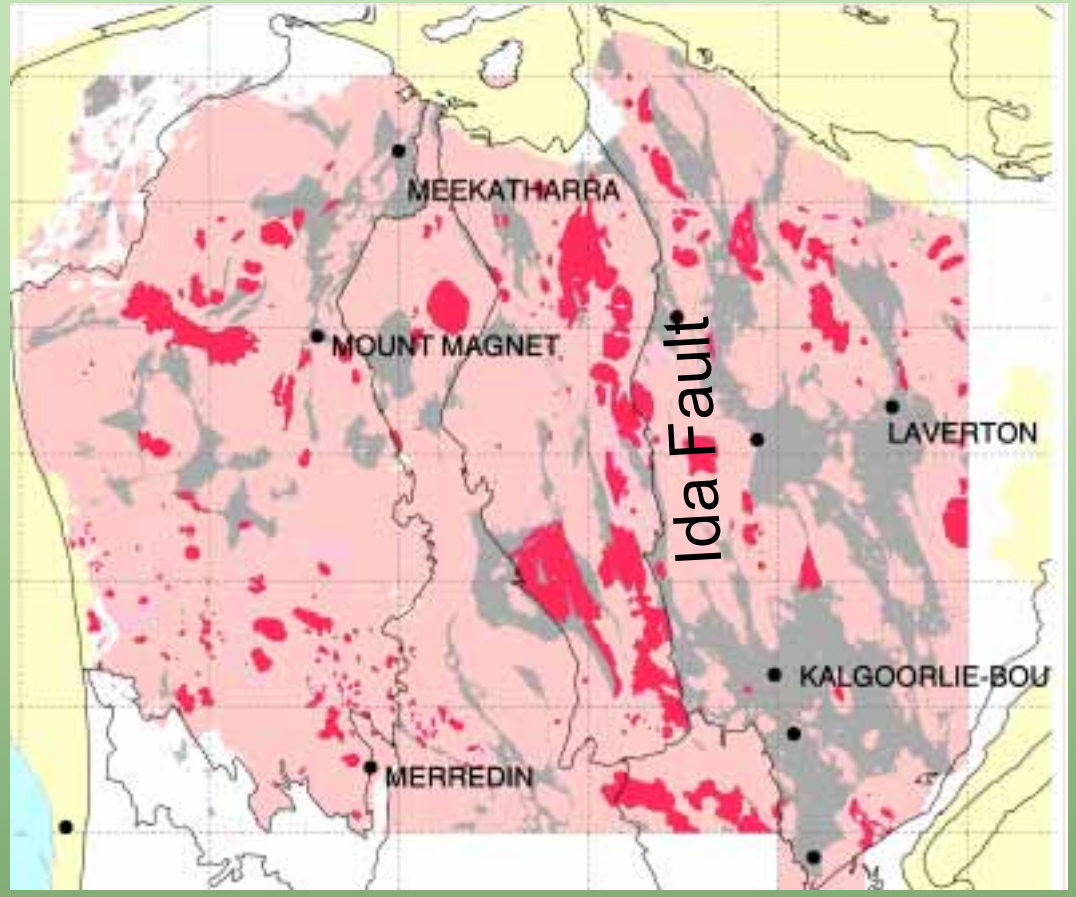


Delamination:

- **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

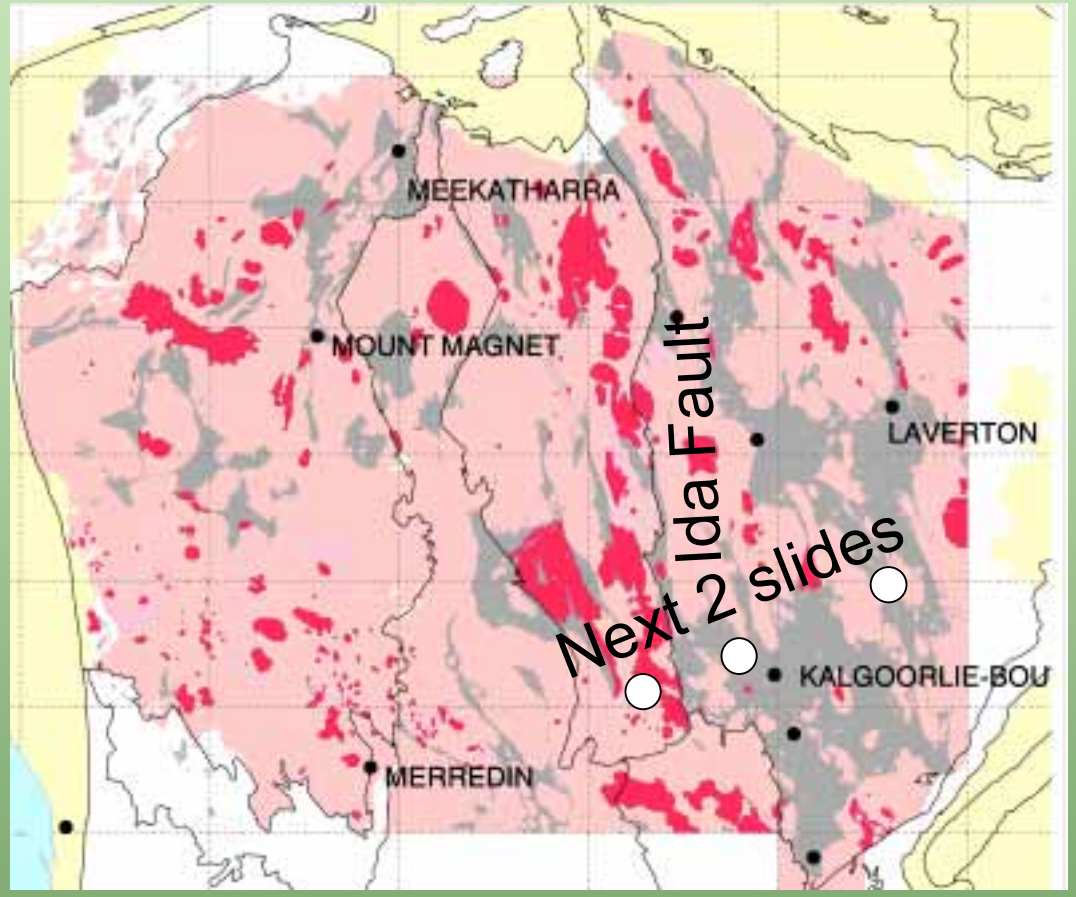
Terranes of the Yilgarn Craton: the Low-Ca granites



Low-Ca granite greenstone

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

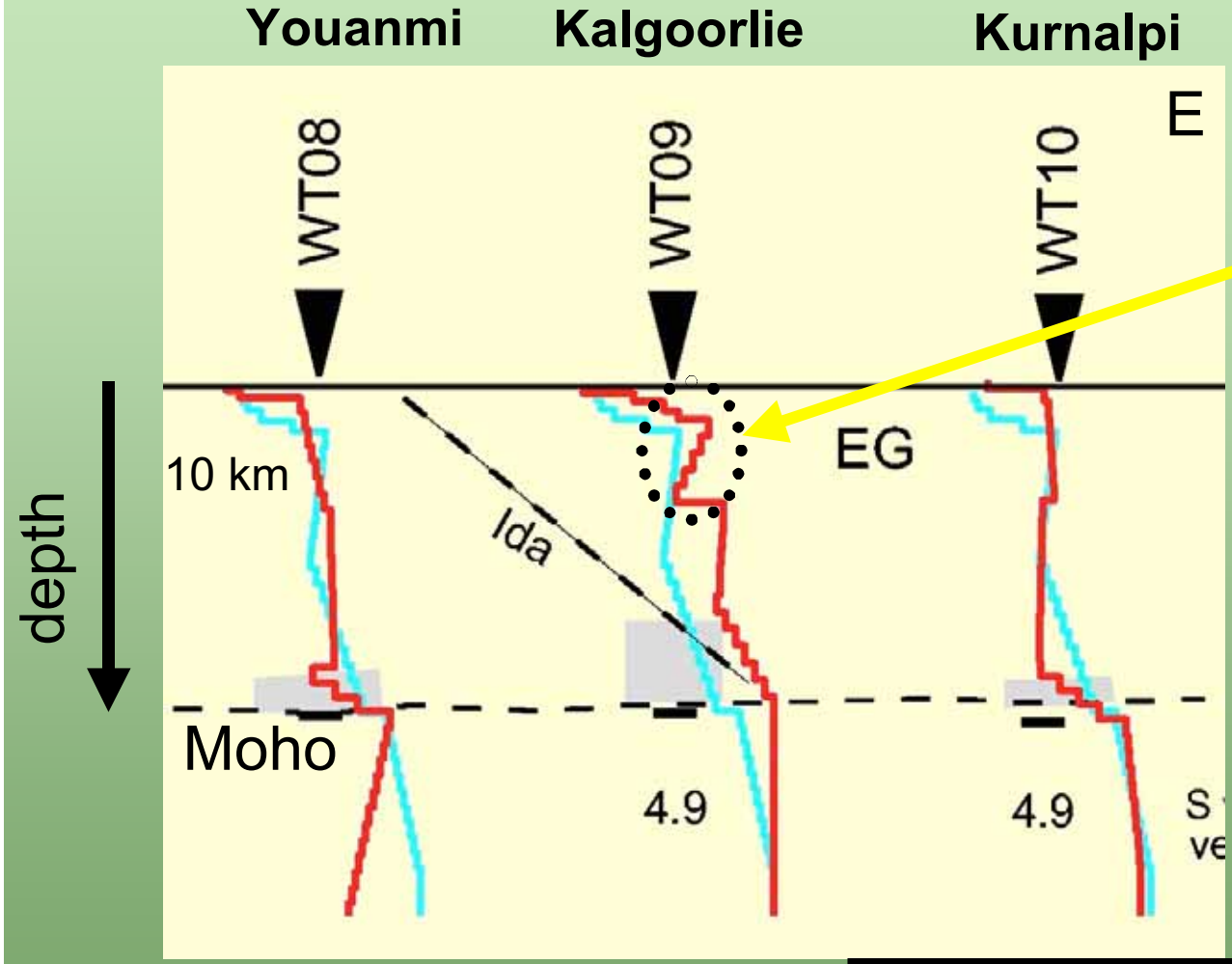
Terranes of the Yilgarn Craton: the Low-Ca granites



Low-Ca granite greenstone

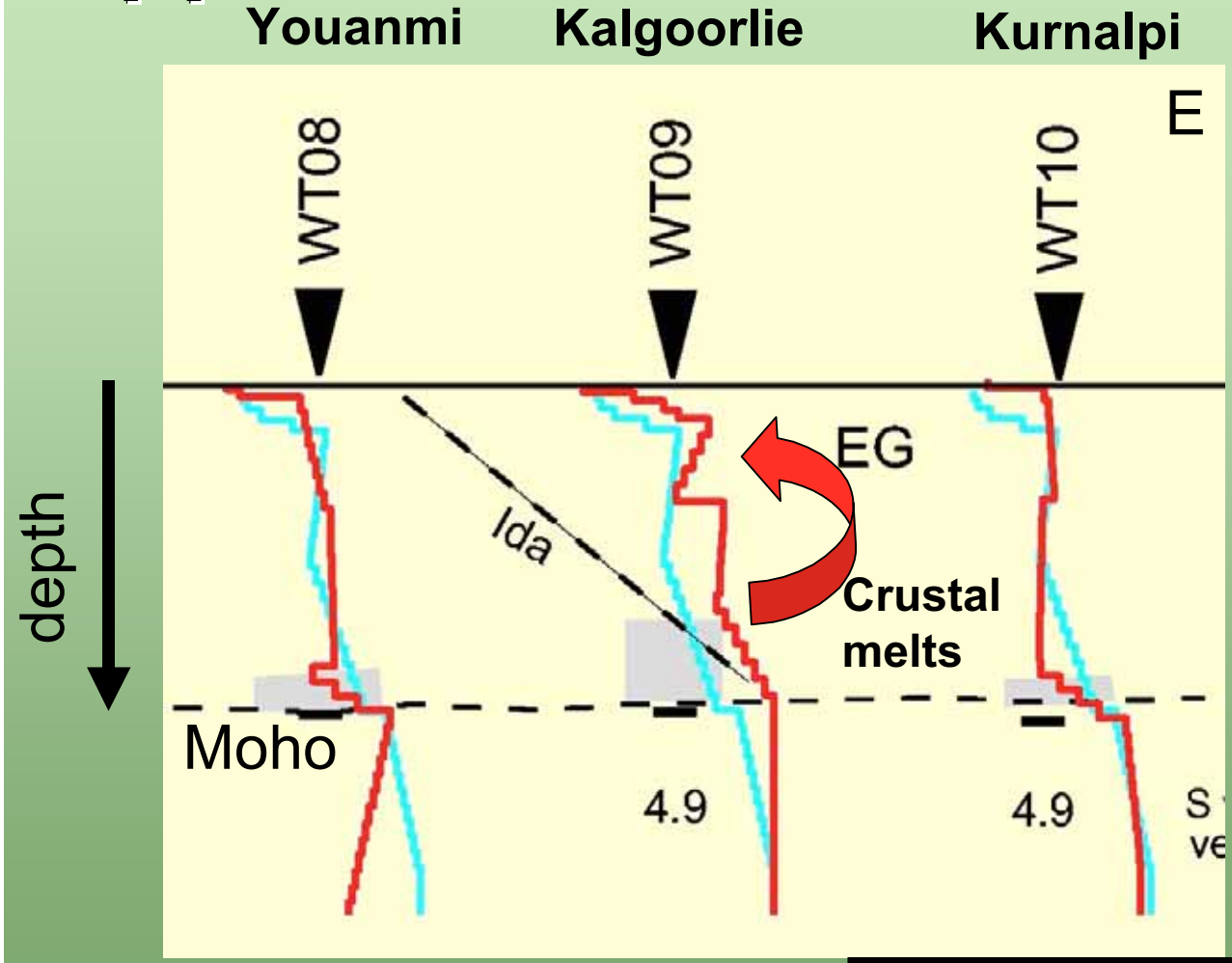
- **Intrude external granites (base of greenstone)**
- **Relatively low density, relatively slow (seismically)**

Terranes of the Yilgarn Craton: upper crust from receiver functions



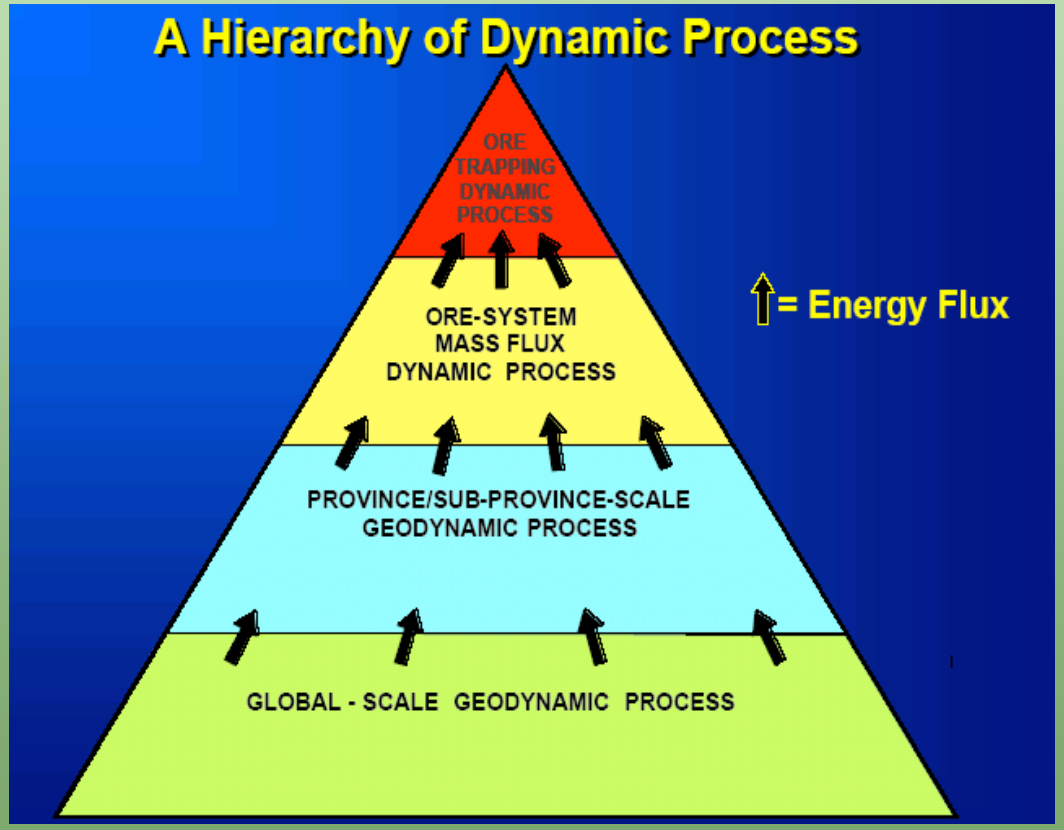
- **Kalgoorlie has low-velocity layer at ~10 km = less density**
- **Not simply reflecting overlying greenstones**

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?



Jon Hronsky (WMC)

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

Conclusions

- 'Signatures' of the mass and energy flux at the largest scale are visible in various seismic methods (tomography, receiver functions)
- 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

Predictive Mineral Discovery

- Yilgarn is data-rich 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),**

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
(*pmdCRC Y-New project)**


Thanks for listening
pmd*CRC
Australian Government
Geoscience Australia