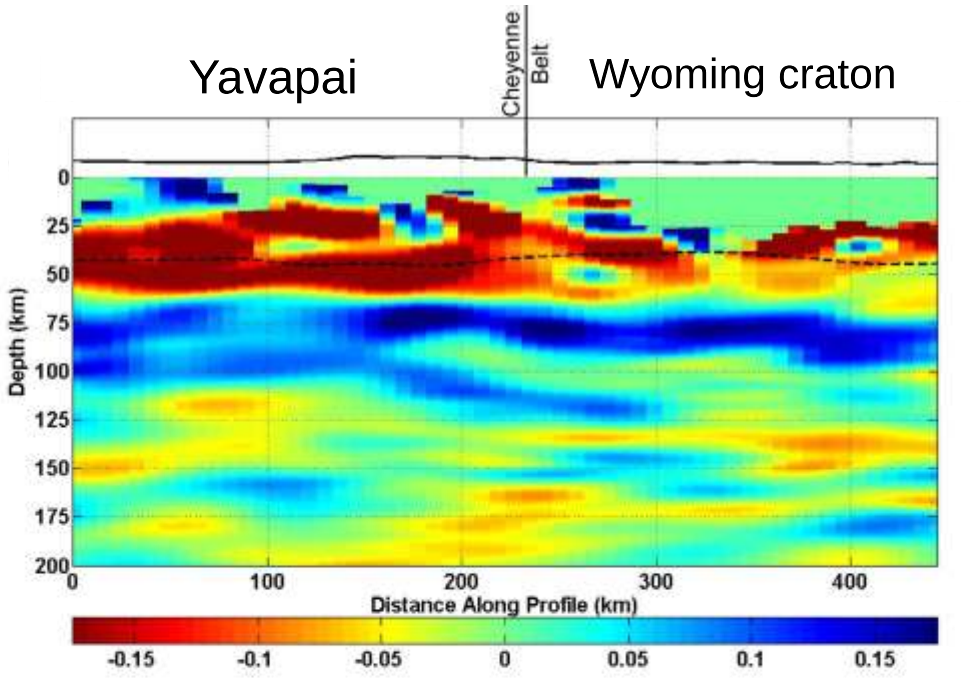
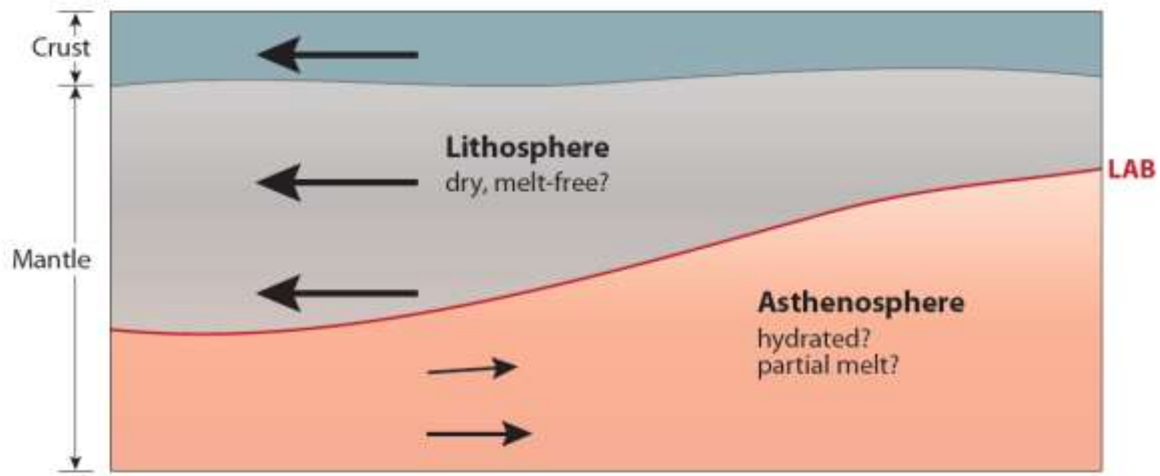
Cratons vs. Younger Continental Lithosphere: Internal and Lithosphere-Asthenosphere Boundary Structures

Karen M. Fischer[1], Emily Hopper[1], Ved Lekic[2], Heather Ford[3]

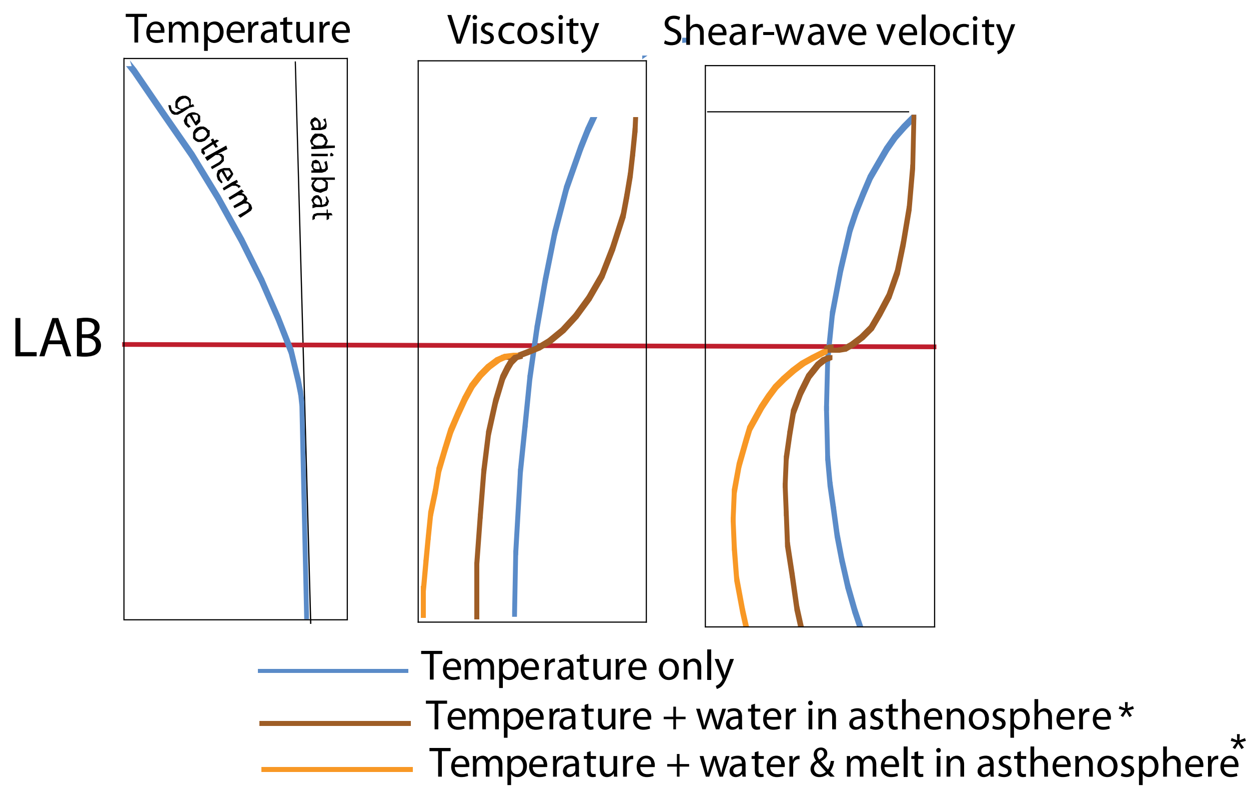
[1]Brown University, [2]University of Maryland, [3]Yale University



The seismological lithosphere-asthenosphere boundary



Does a fundamental LAB difference exist between cratons and younger continental regions?

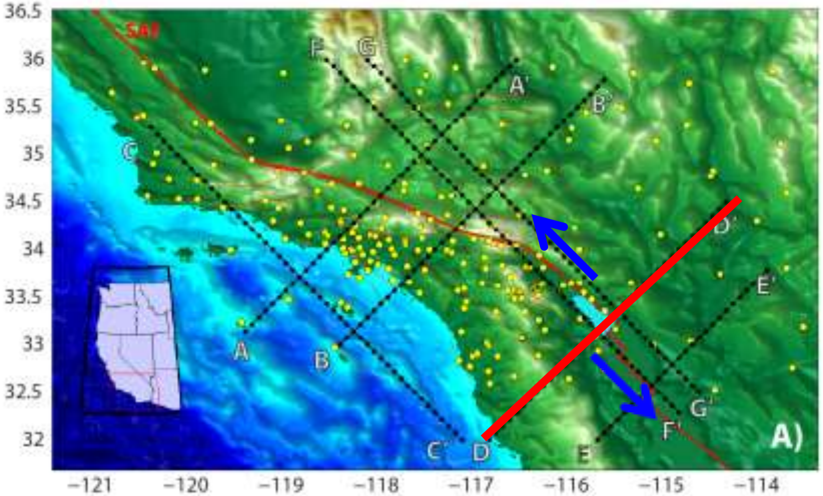


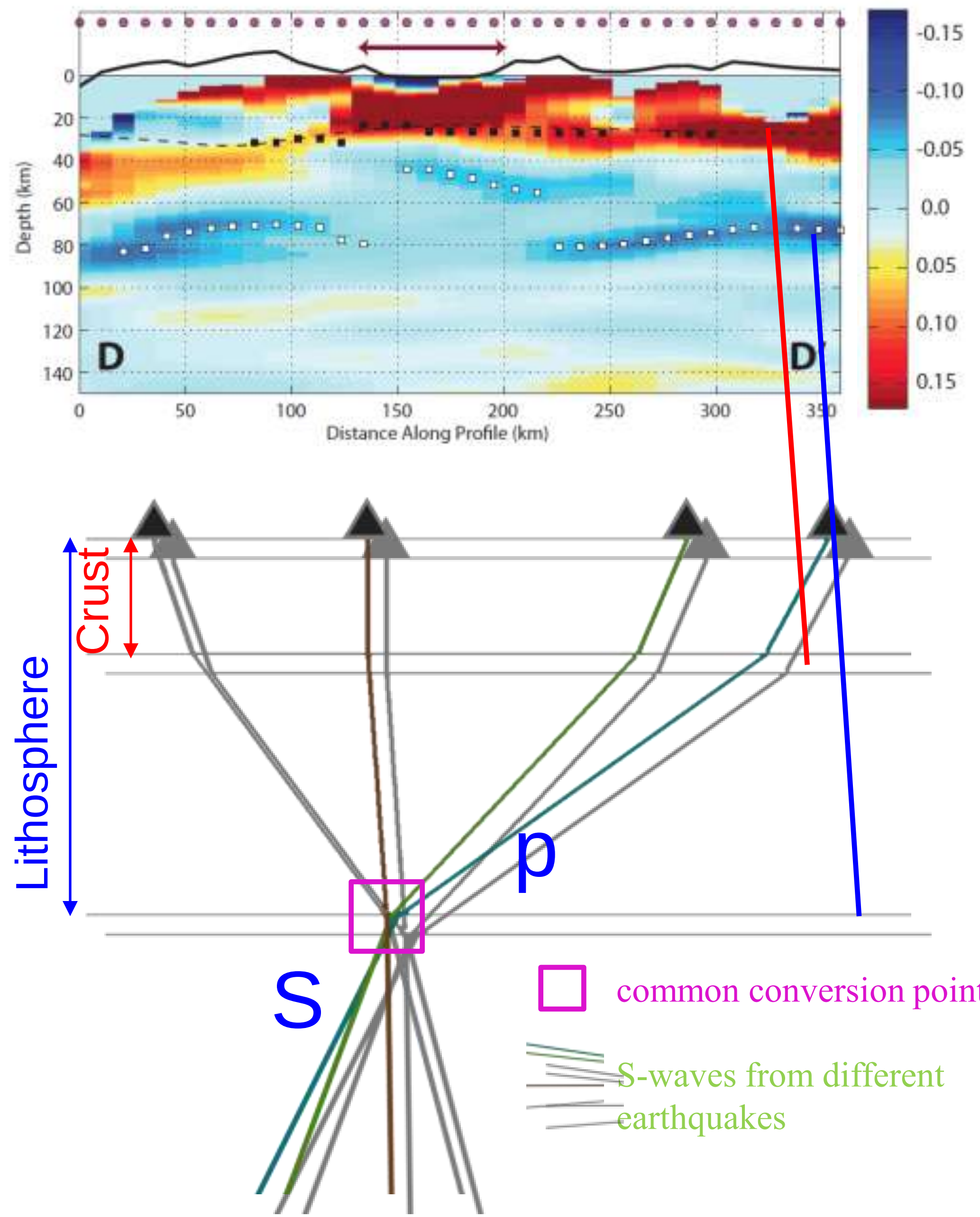
Fischer et al. (2010)

*Assumes dry, depleted lithosphere

Salton Trough

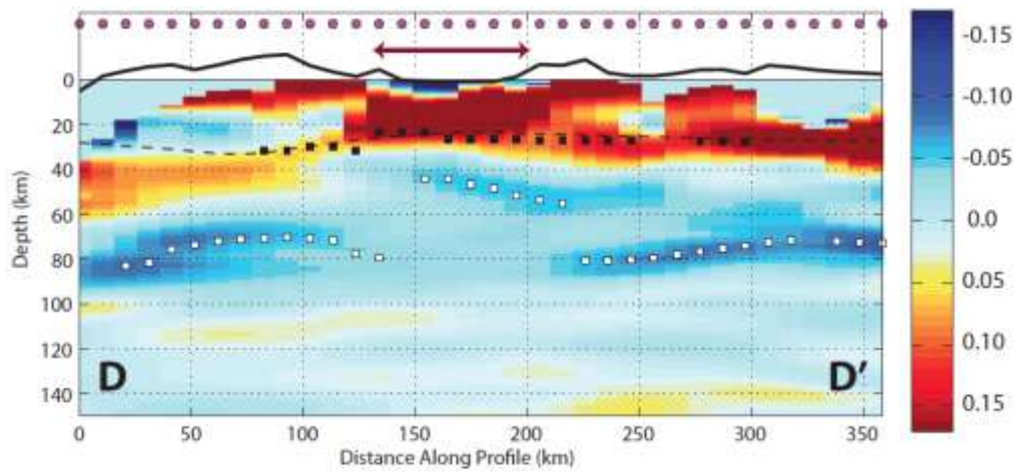
Sp CCP Stack
Lekic et al. (2011)

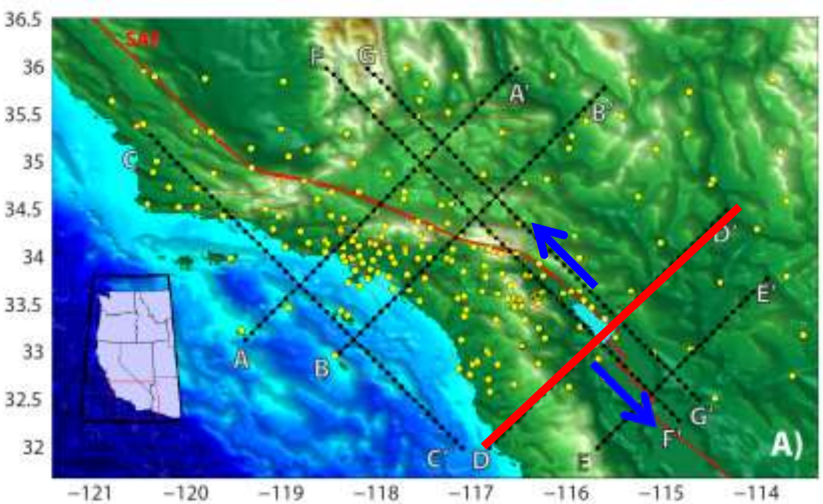




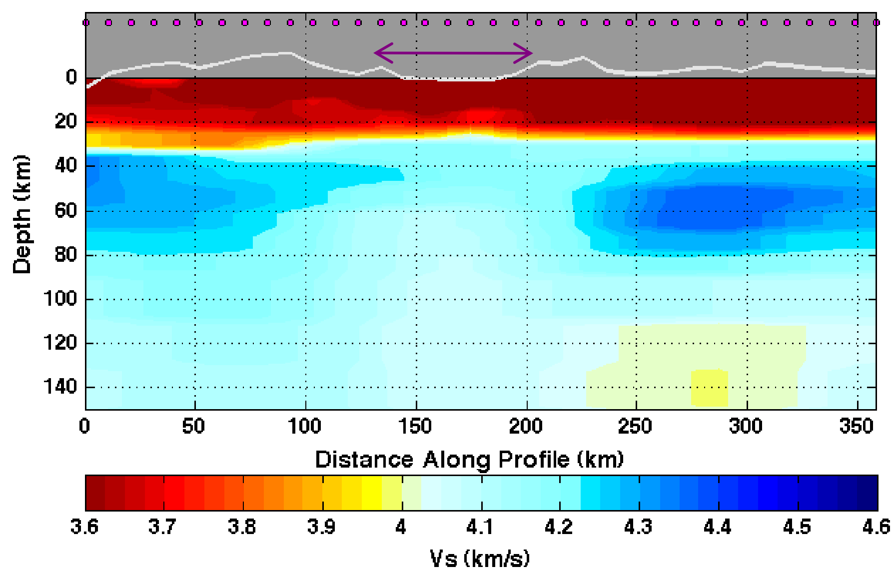
Salton Trough

Sp CCP Stack
Lekic et al. (2011)

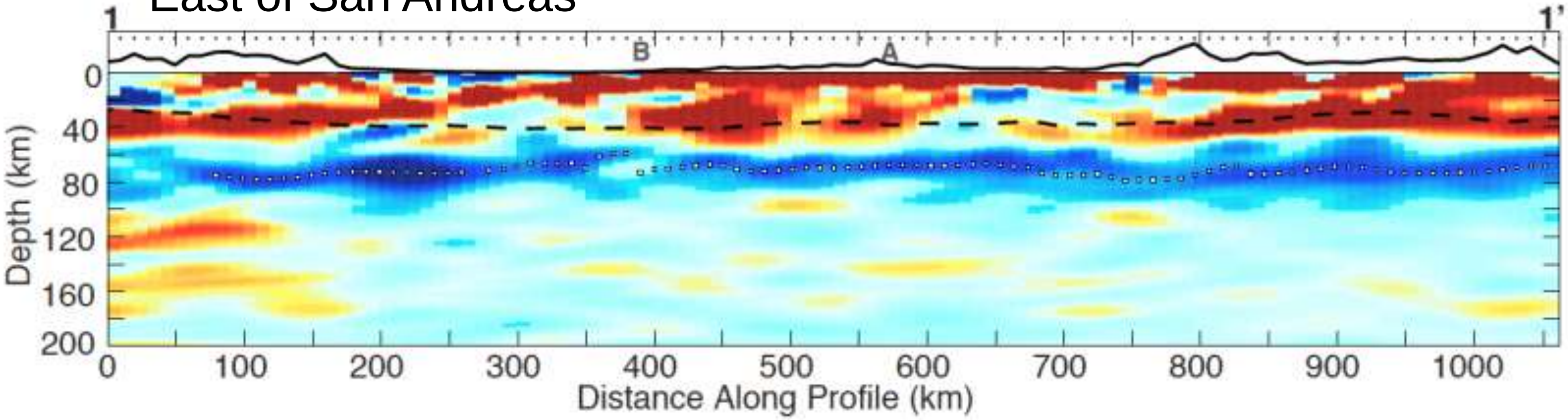




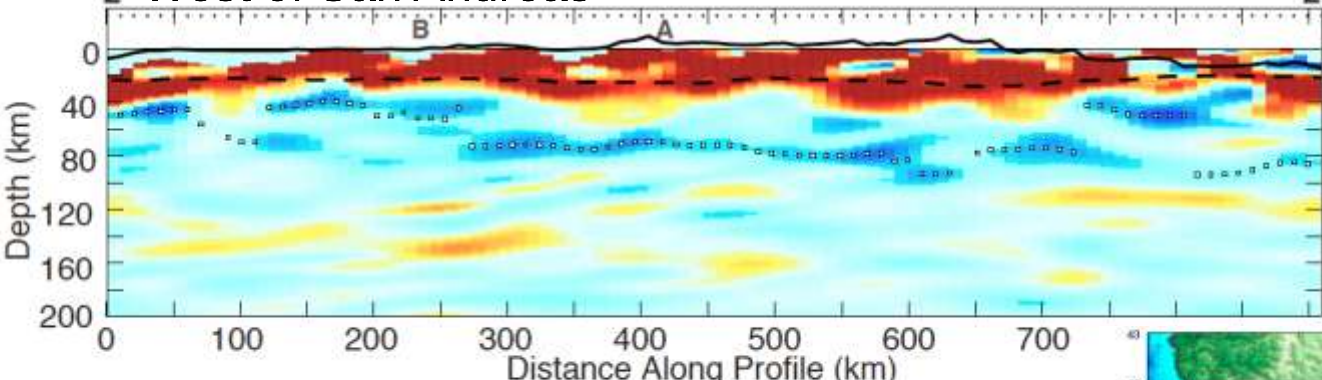
Shear wave velocity from
Rayleigh wave tomography
Rau and Forsyth (2011)



East of San Andreas



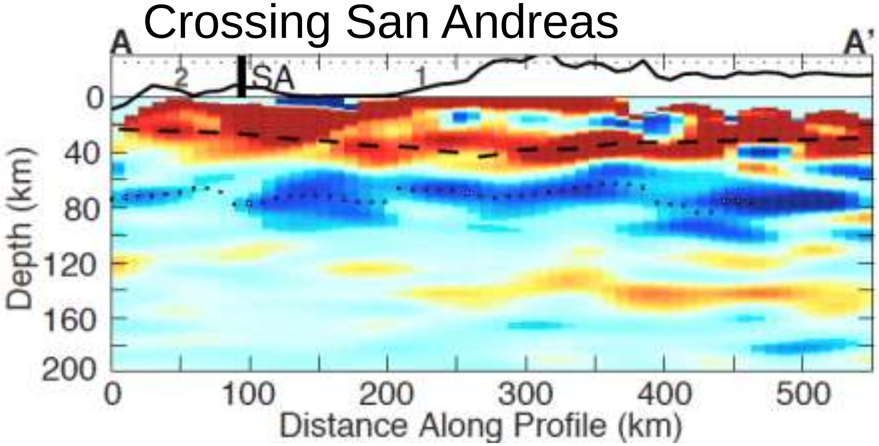
West of San Andreas

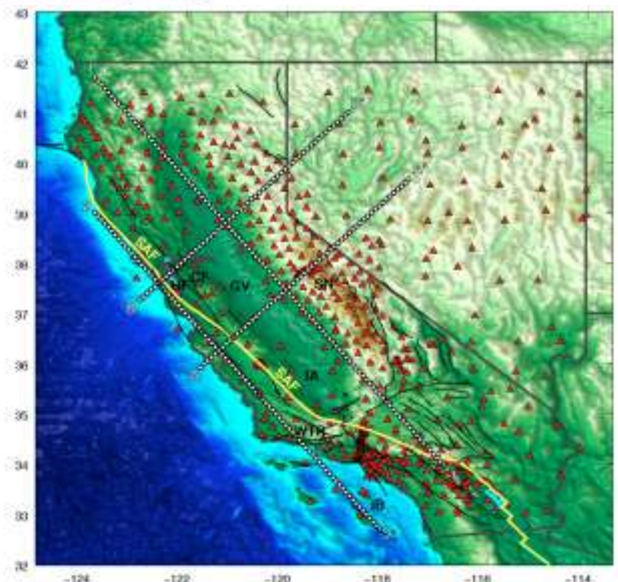


Sp CCP Stack

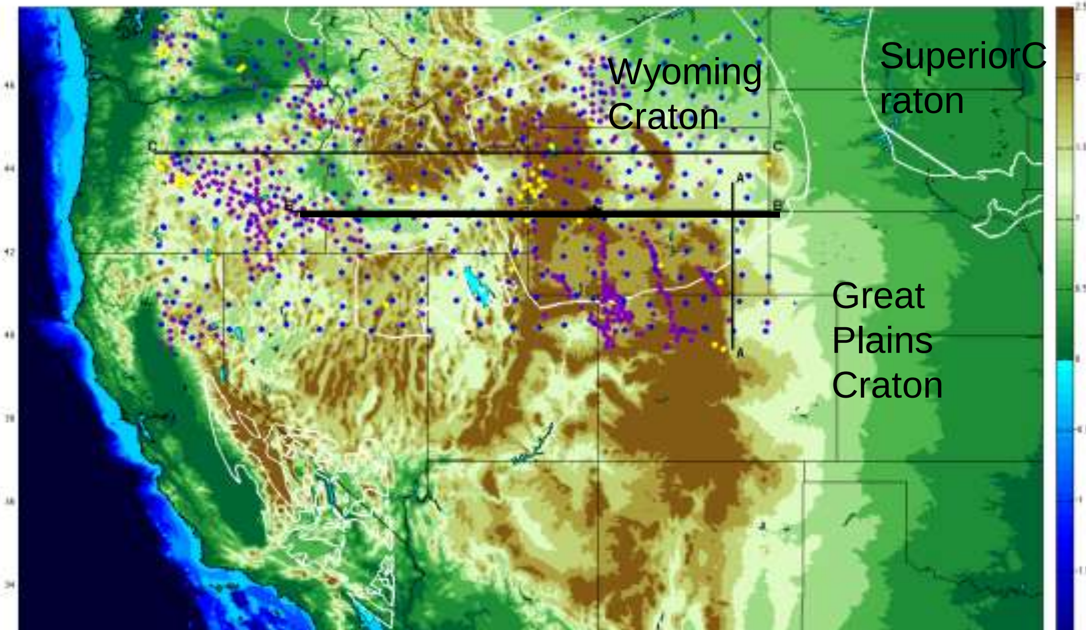
Ford et al. (2013)

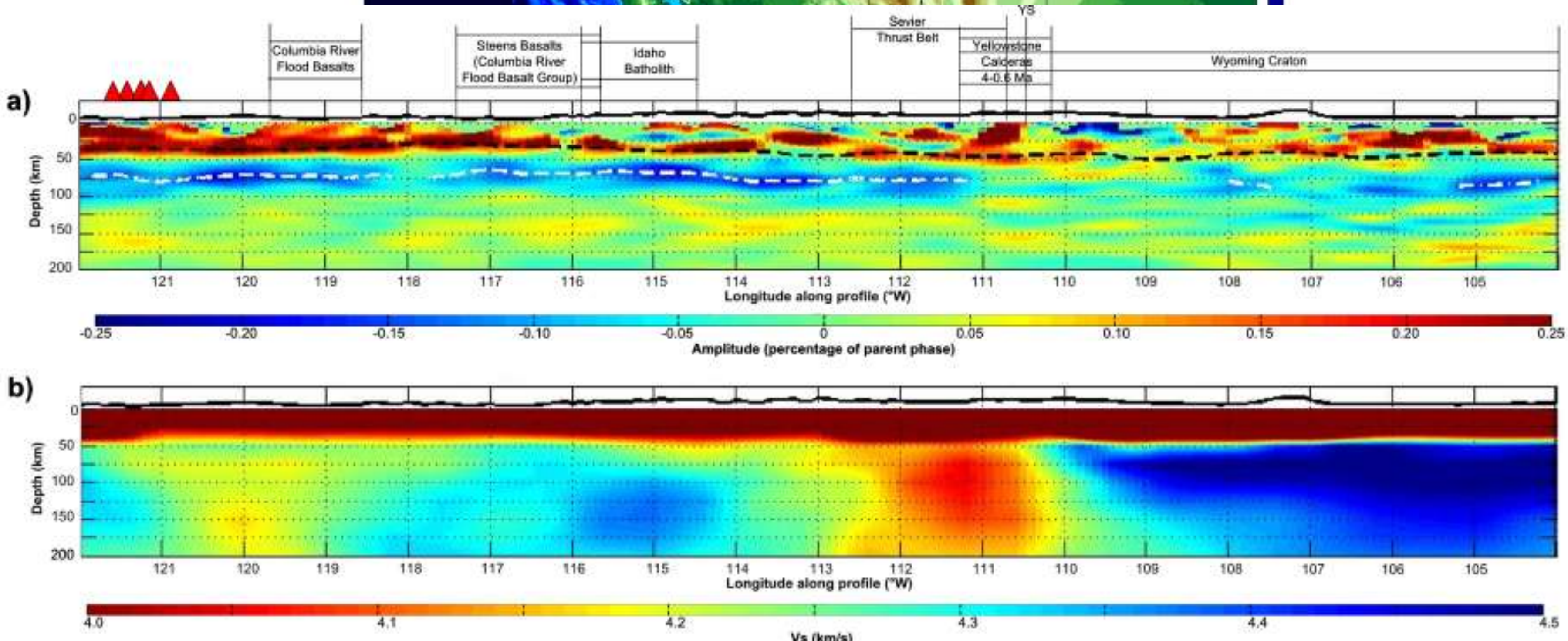
Crossing San Andreas





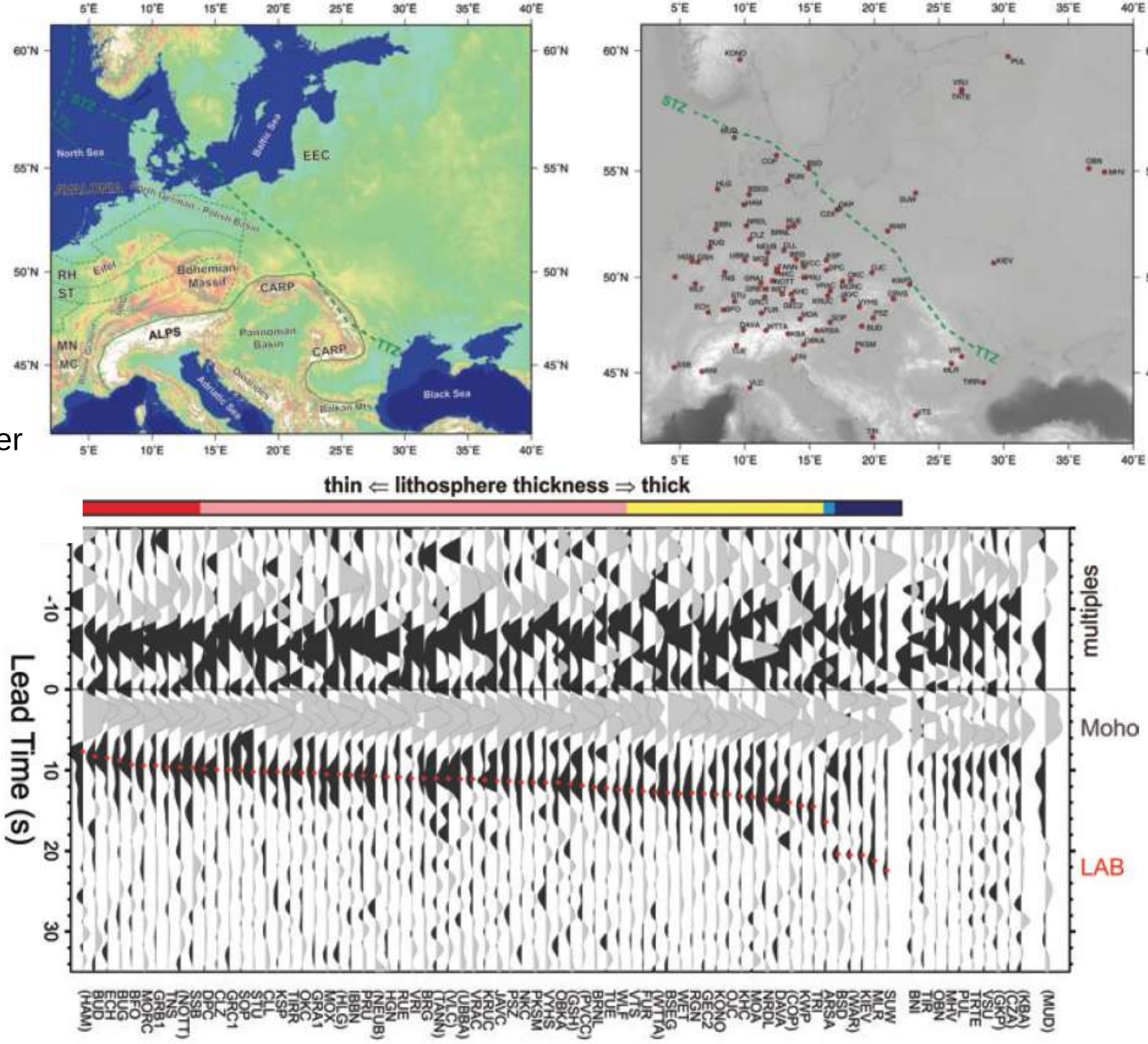
Hopper et al. (2013)

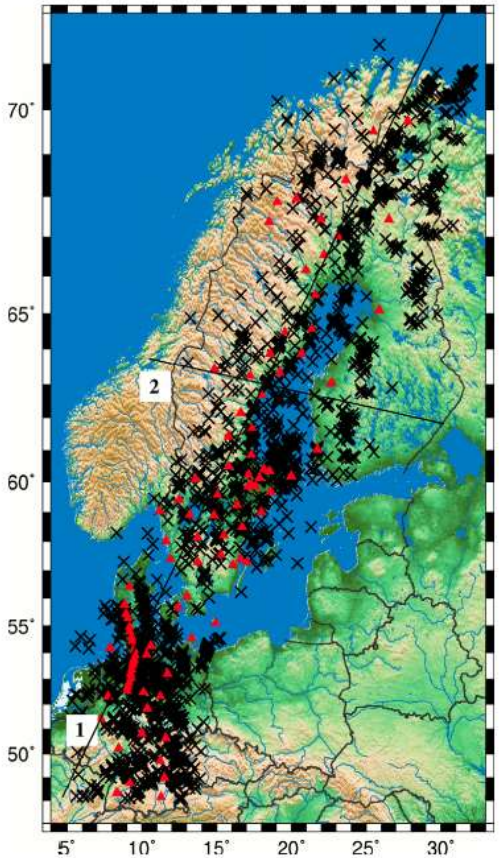


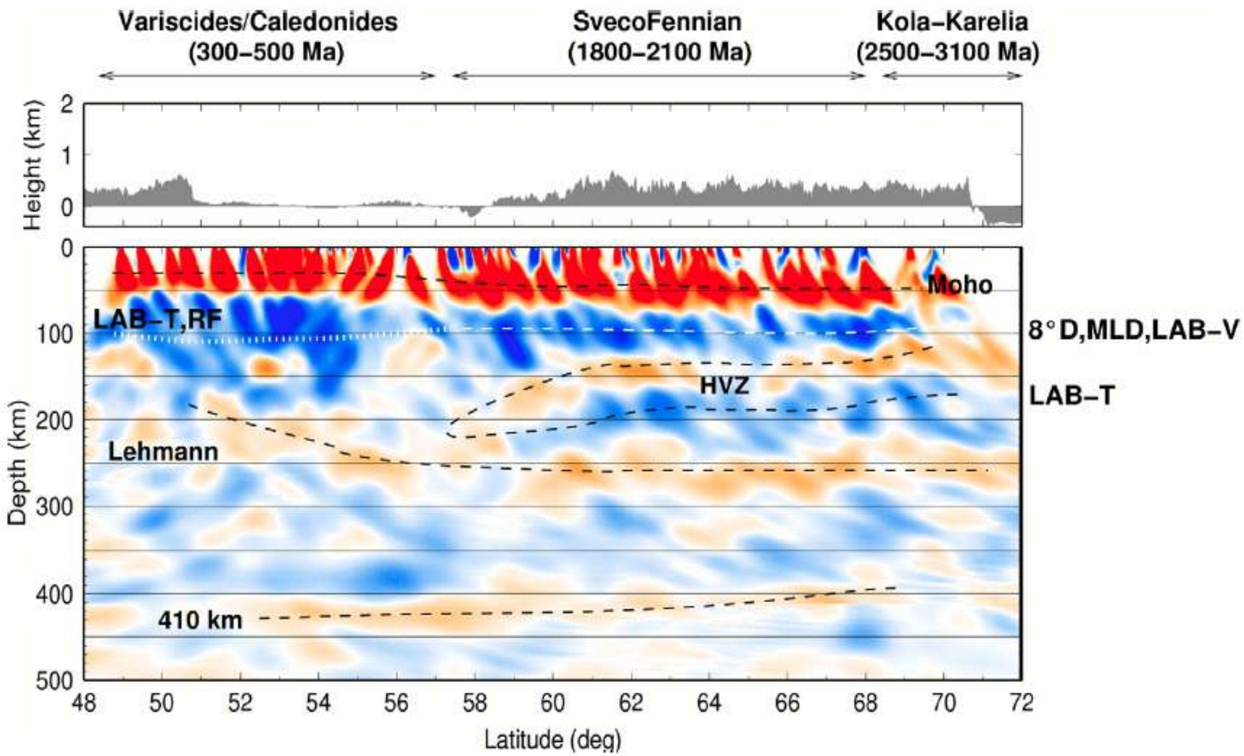


Obrebski et al. (2011)

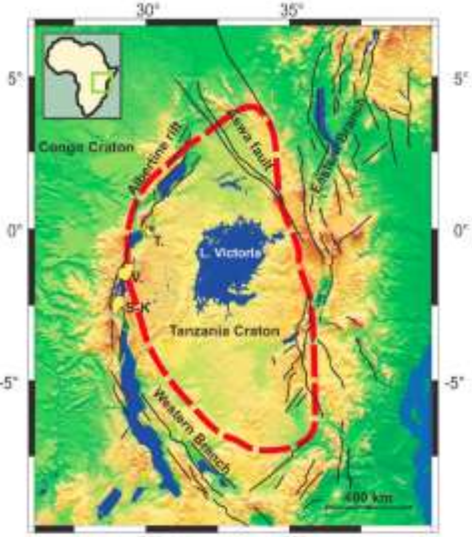
Geissler et al. (2010)



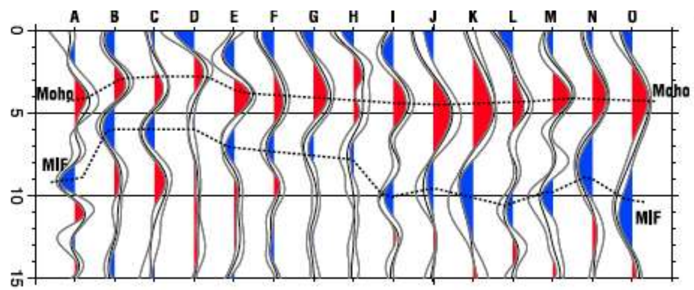


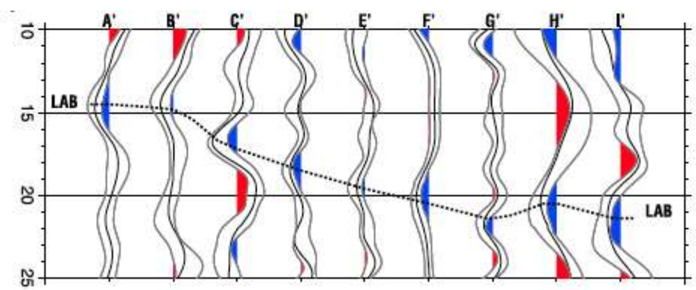


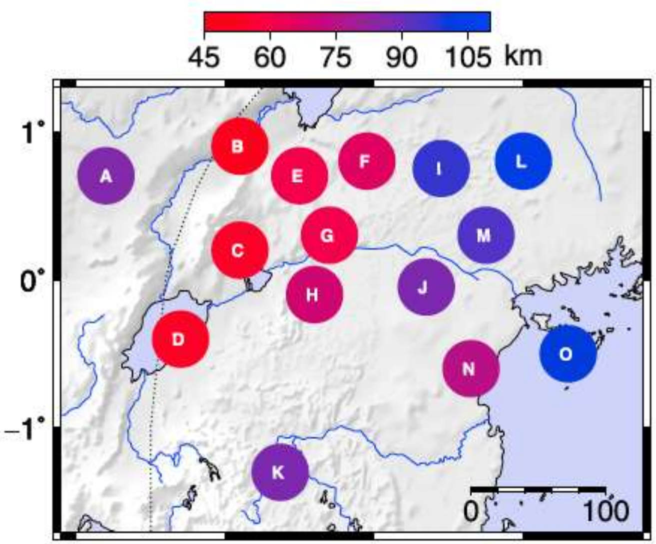
Kind et al. (2013)



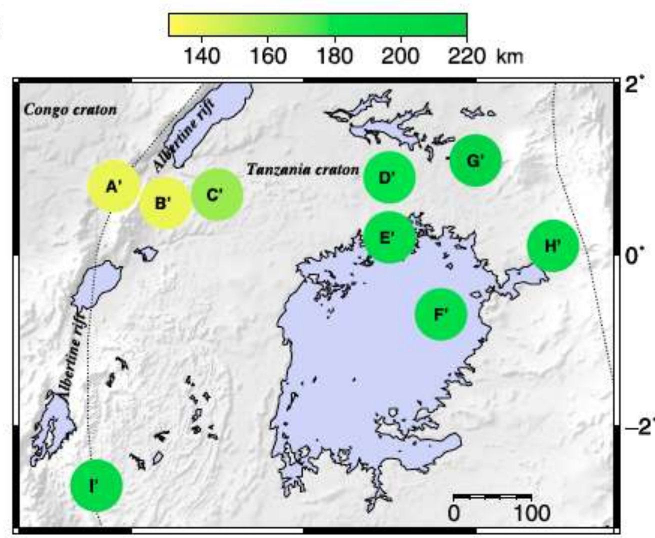
Wolbern et al. (2012)



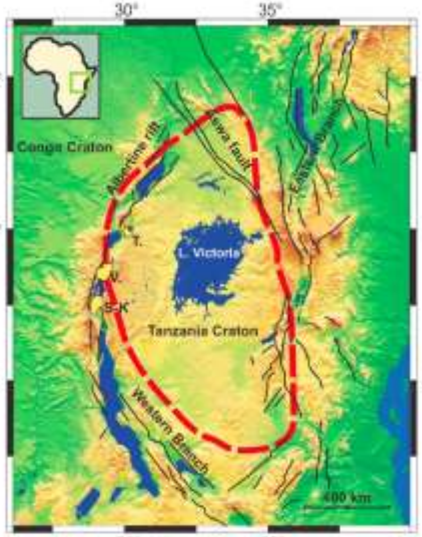




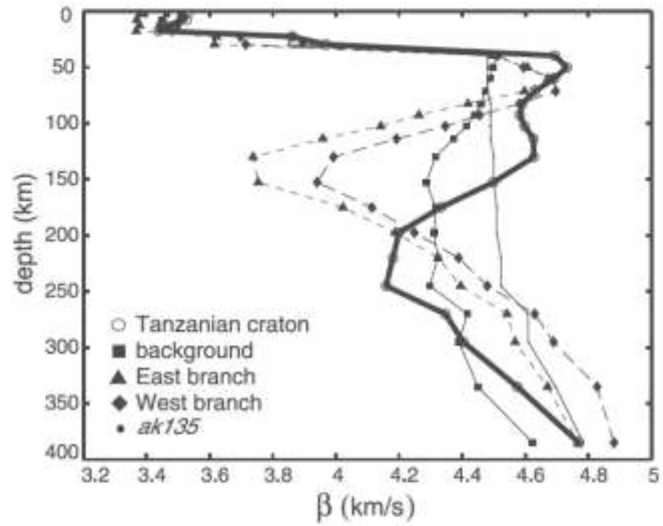
(f)

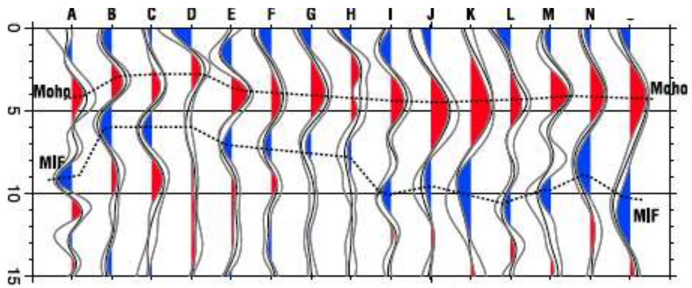


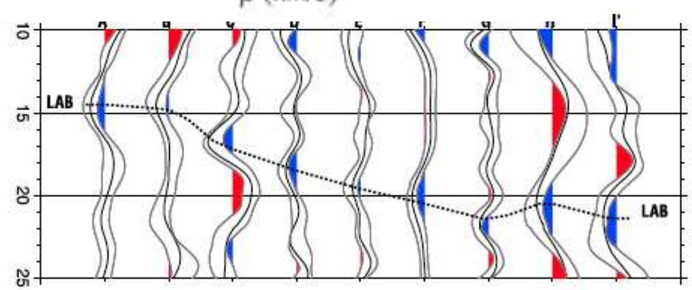
Wolbern et al. (2012)

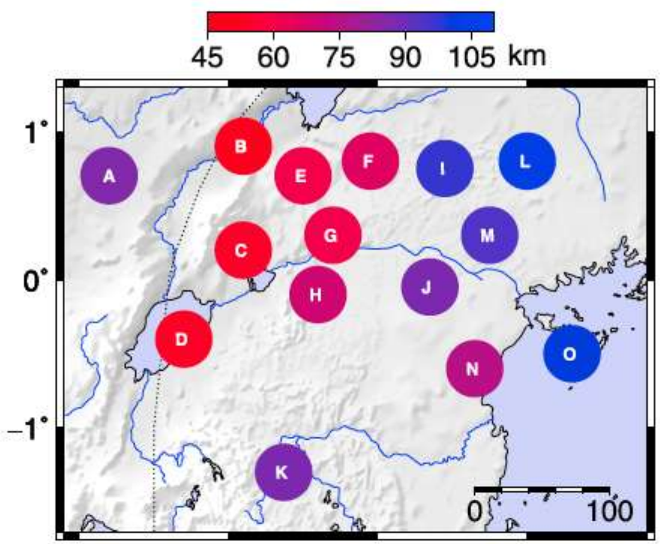


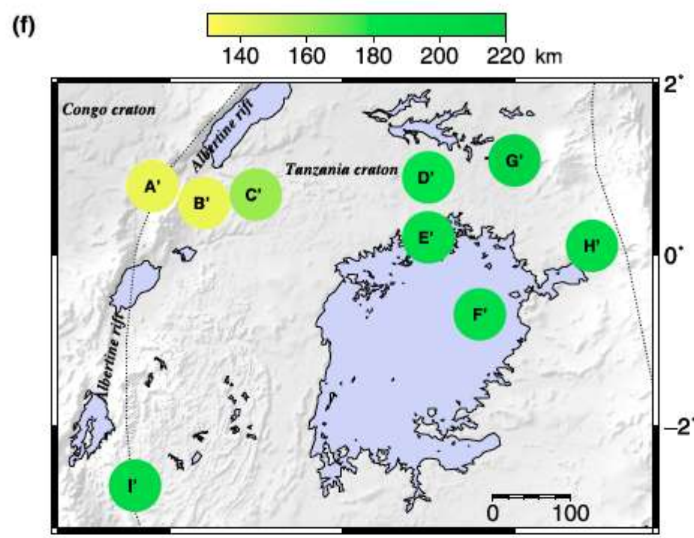
Weeraratne et al. (2003)











Young continent LAB: ~6% velocity drop in < ~30 km (N. America and Australia)

> 5°C/km temperature gradient (Faul and Jackson, 2005)

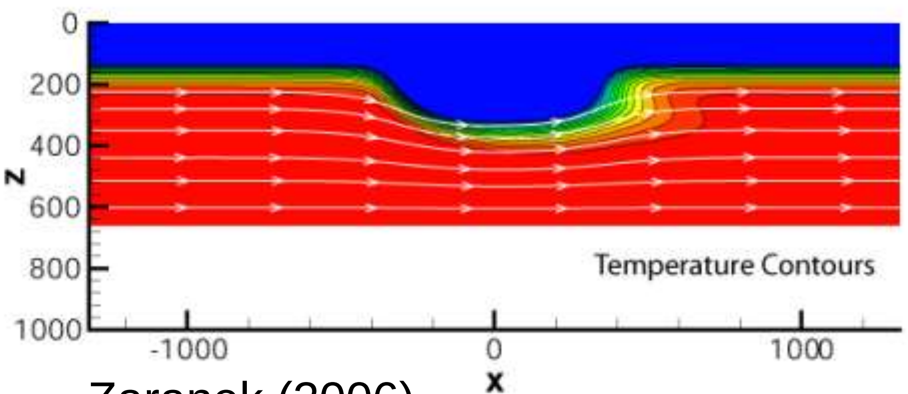
Velocity gradient too localized in depth to be defined by temperature alone; indicates contrasts in volatiles or melt at LAB

Sub-cratonic LAB:

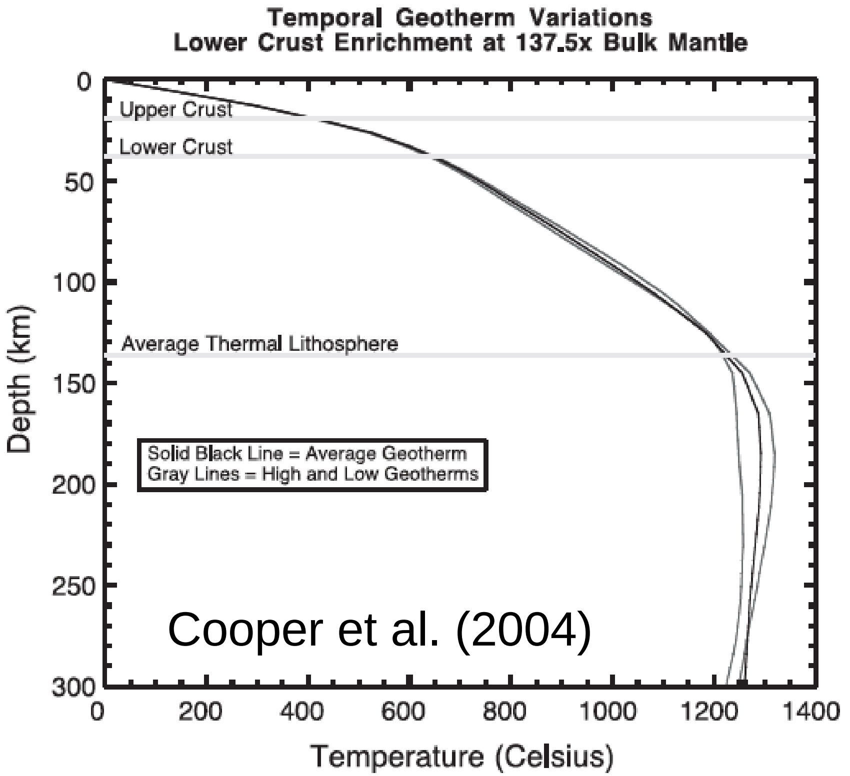
Some regions ~4% velocity drop in > ~60 km

Others more localized vertical gradients

Temperature alone sufficient in places, volatiles or melt in asthenosphere needed to localize LAB in others



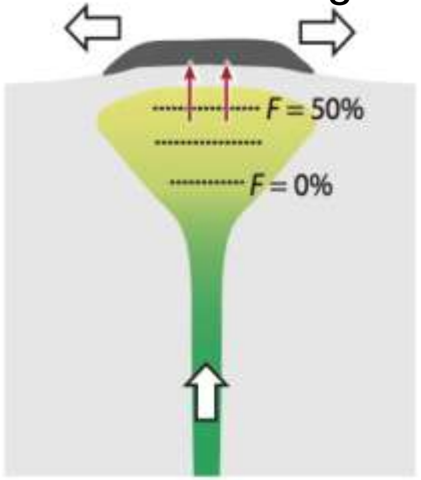
Zaranek (2006)



Cooper et al. (2004)

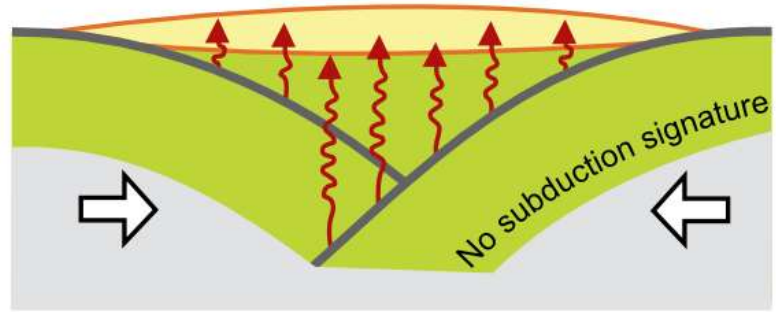
Cratonic mantle formation models

Plume melting

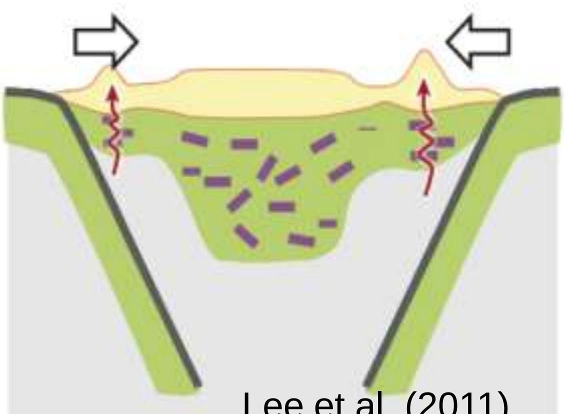


Lee et al. (2011)

Imbrication of oceanic lithosphere



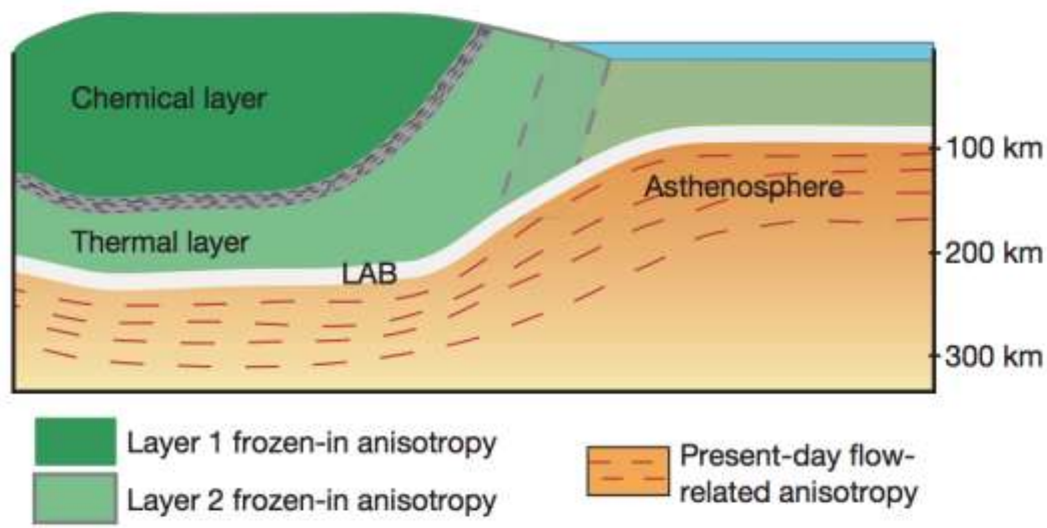
Accretion of sub-arc mantle

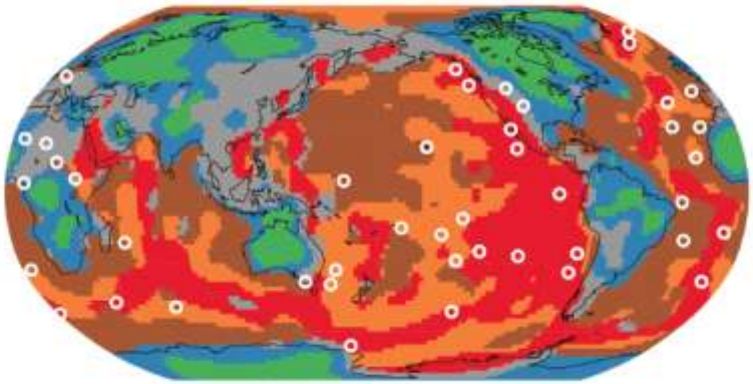


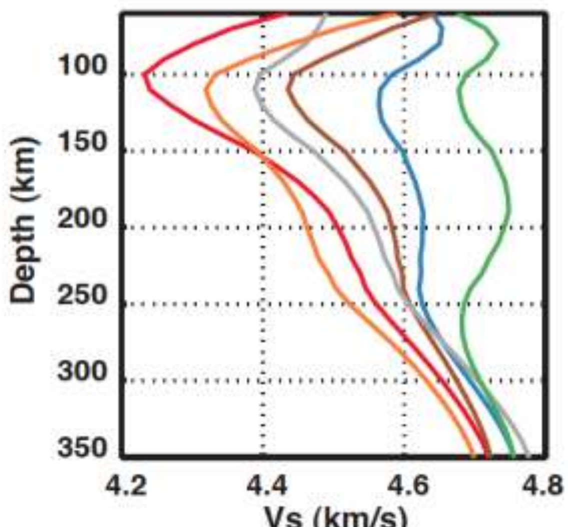
Lee et al. (2011)

Chemically depleted layer over thermal boundary layer

Yuan & Romanowicz (2010)

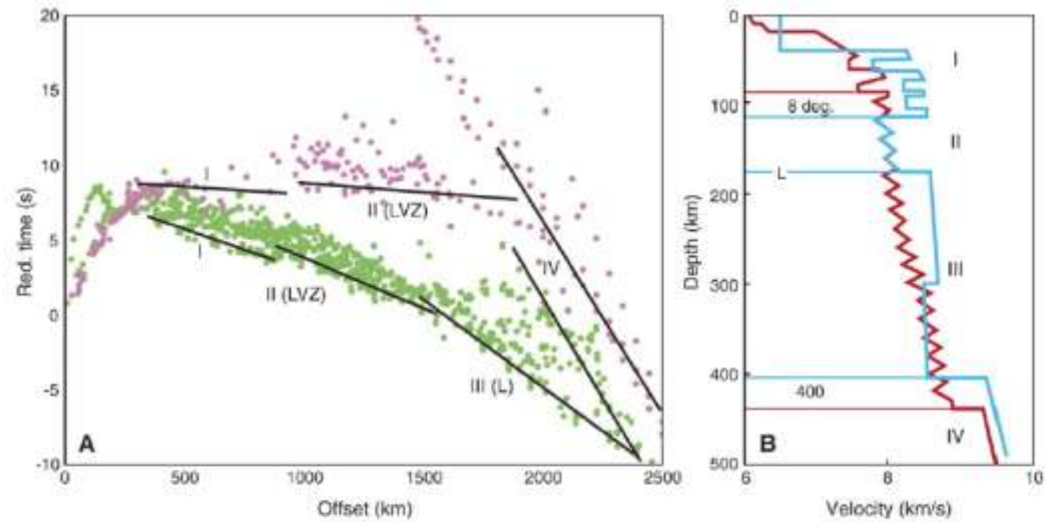






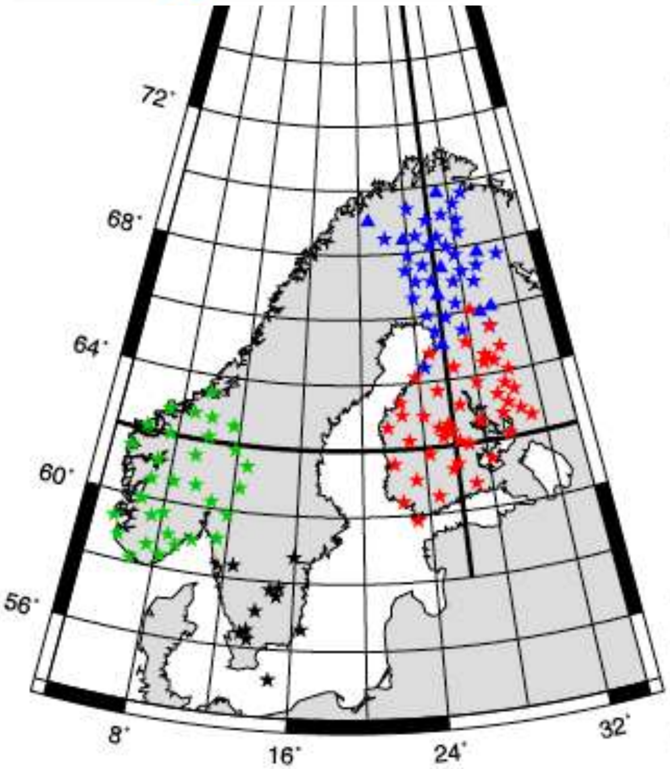
Lekic & Romanowicz (2011)

8˚ Discontinuity

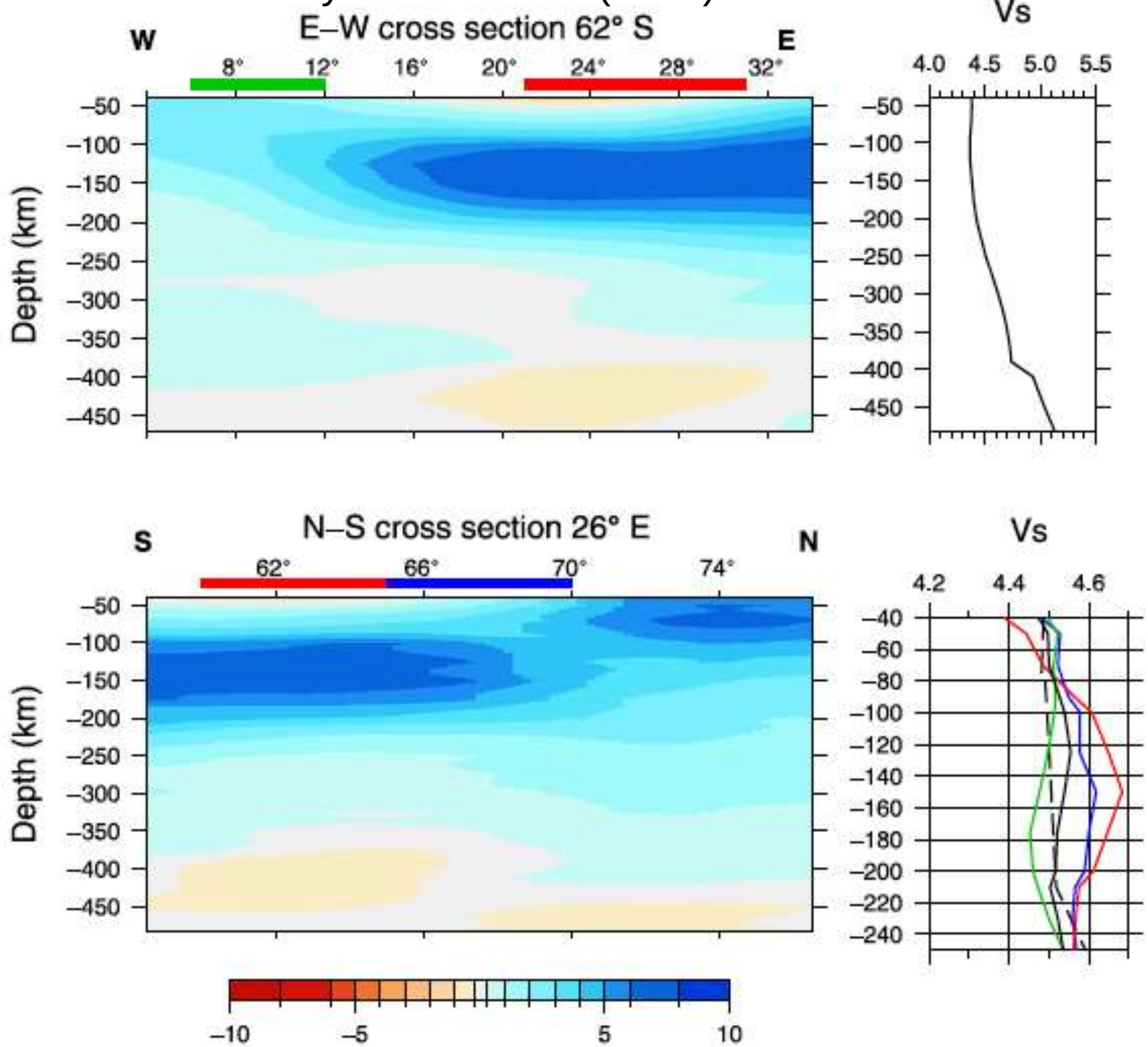


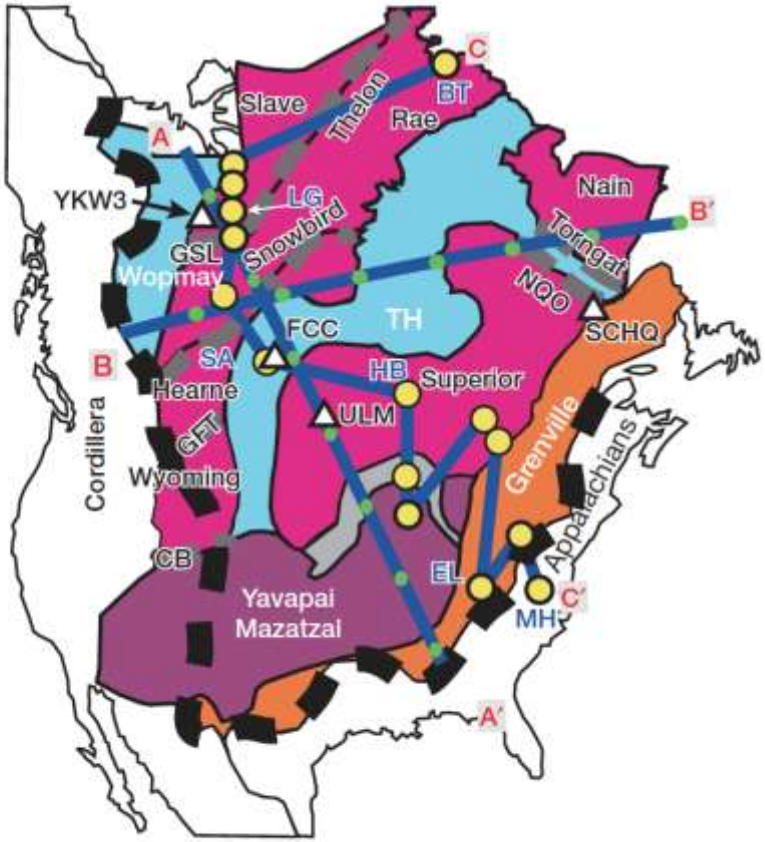
Thybo (2006)

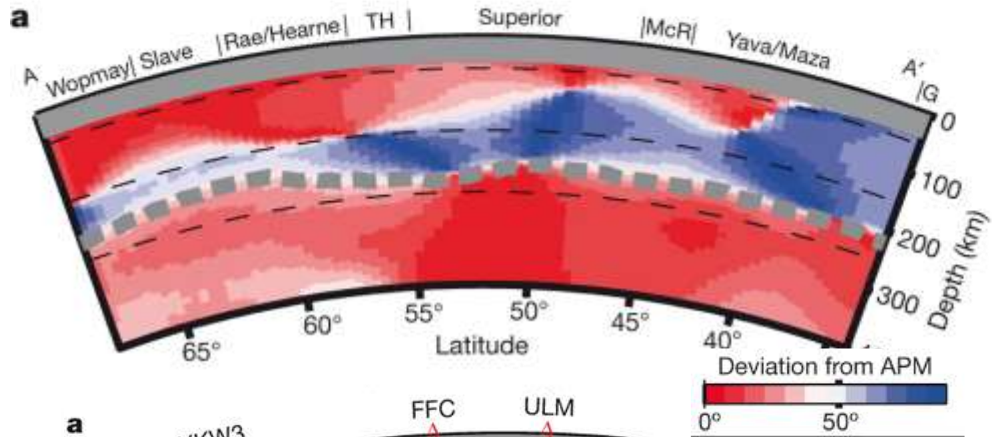
Pedersen et al. (2013)

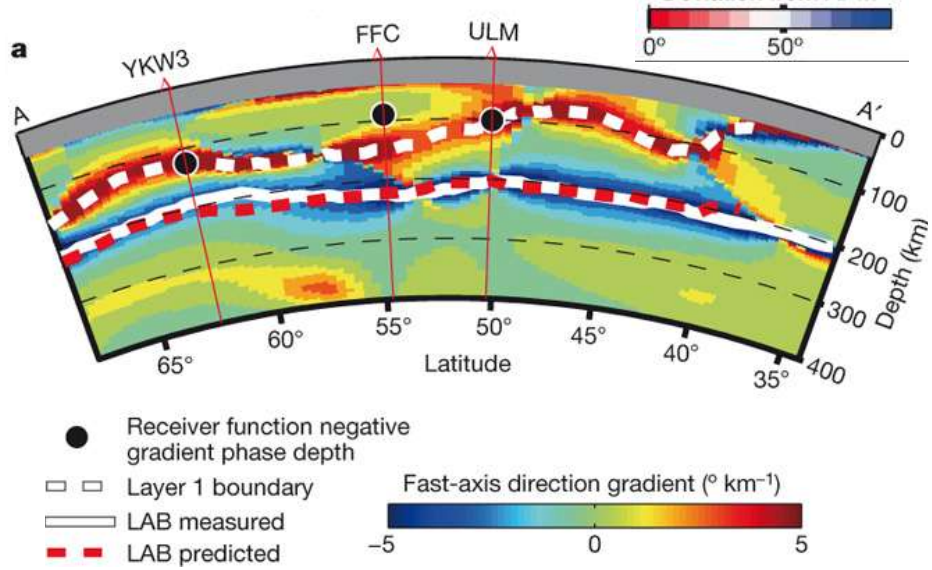


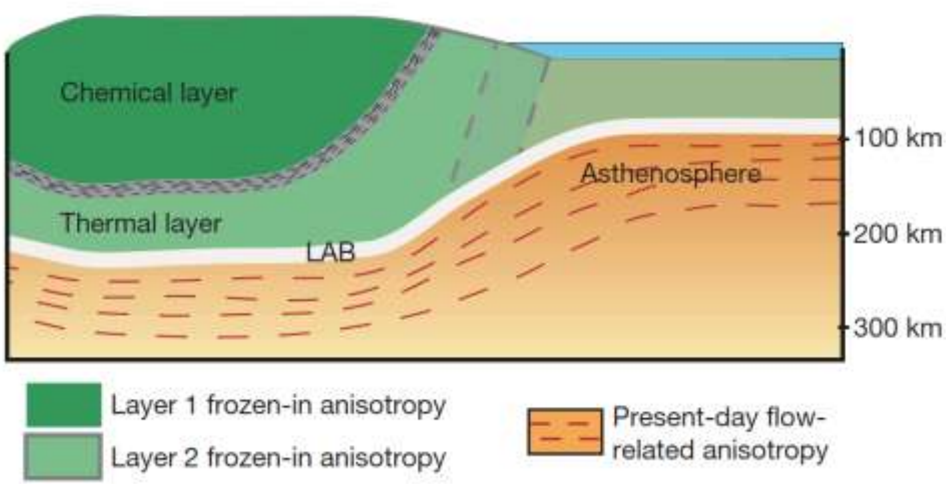
Debayle and Ricard (2012)





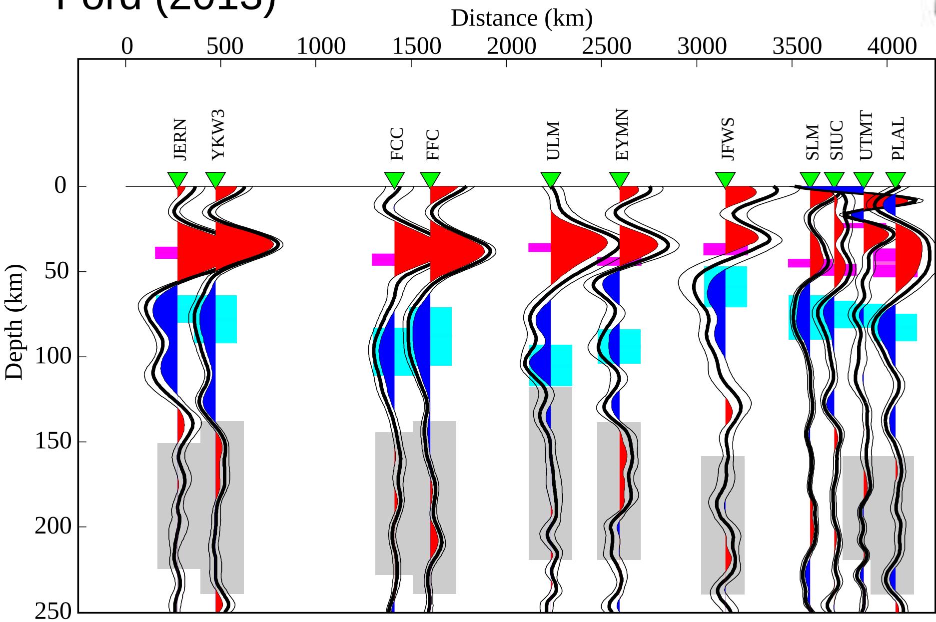


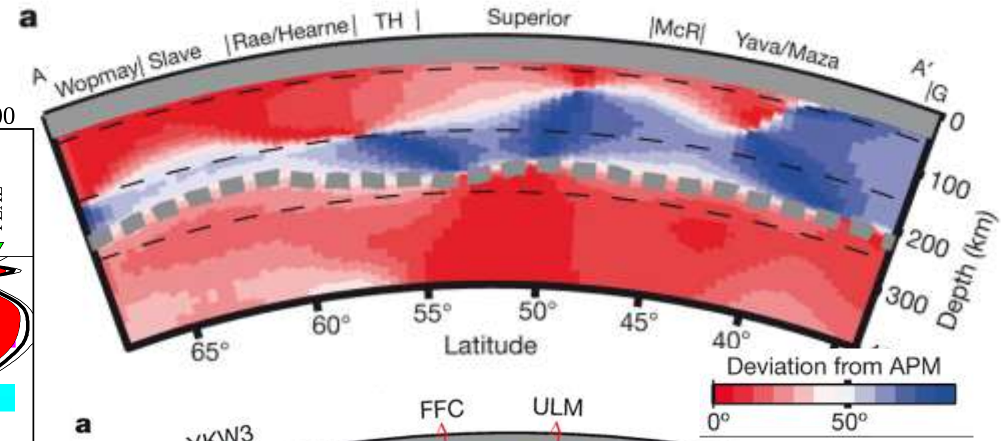


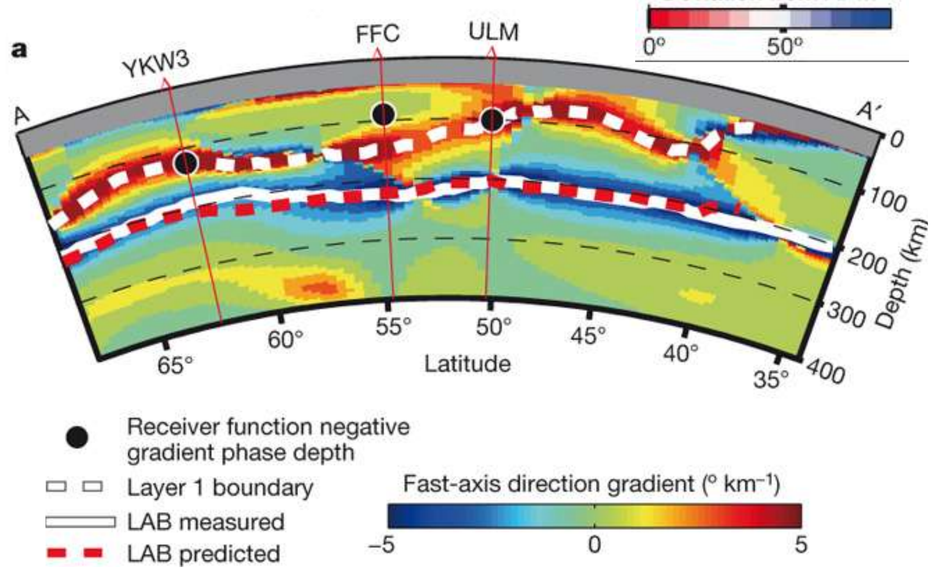


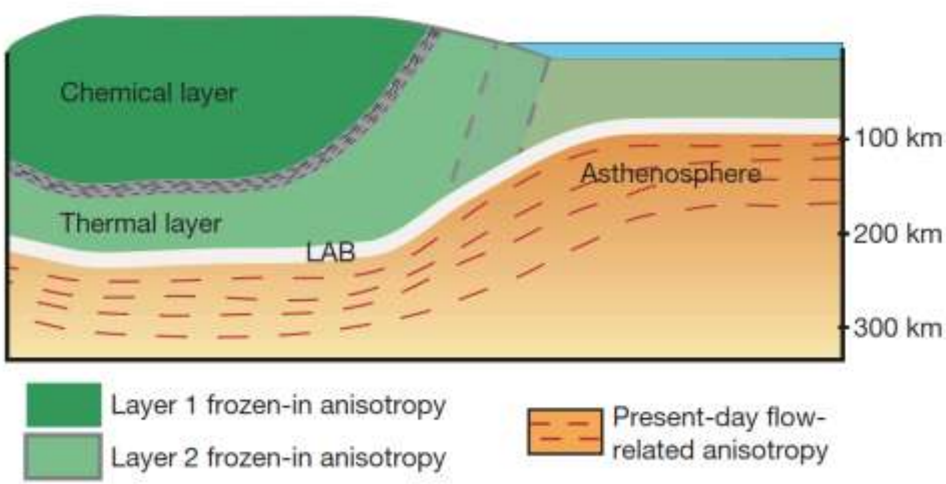
Yuan & Romanowicz (2010)

Ford (2013)

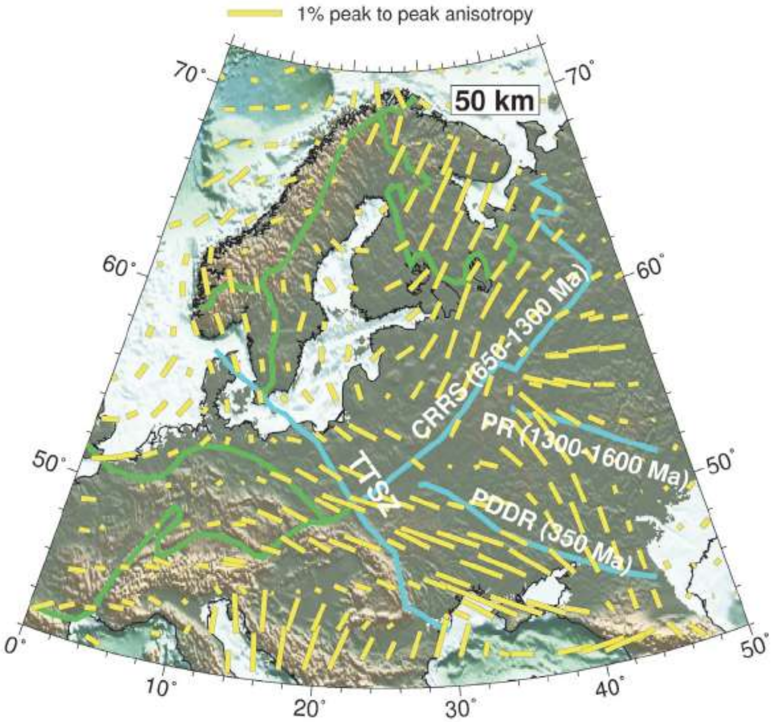


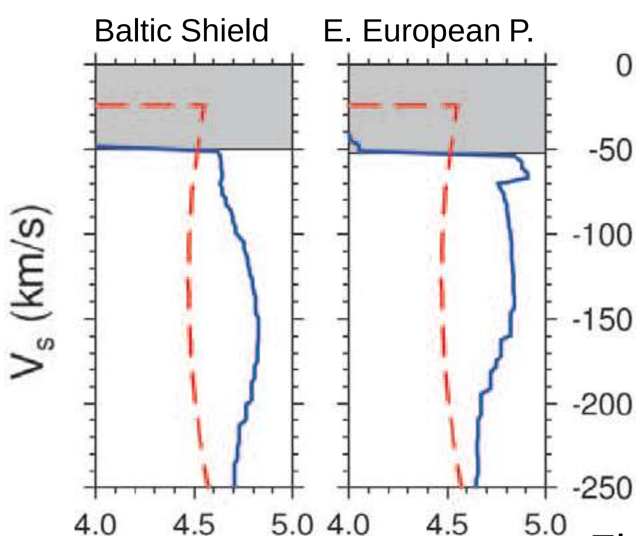


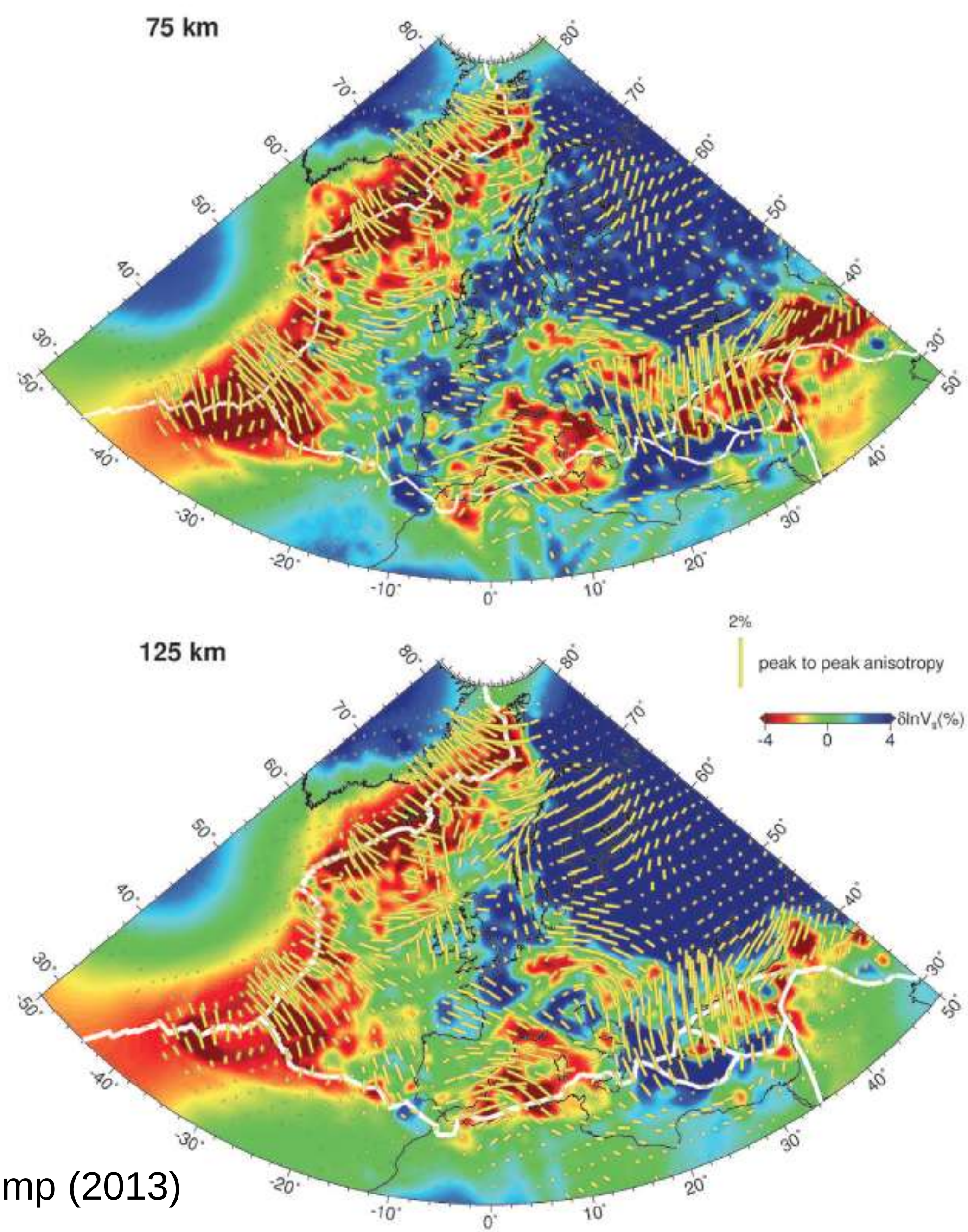




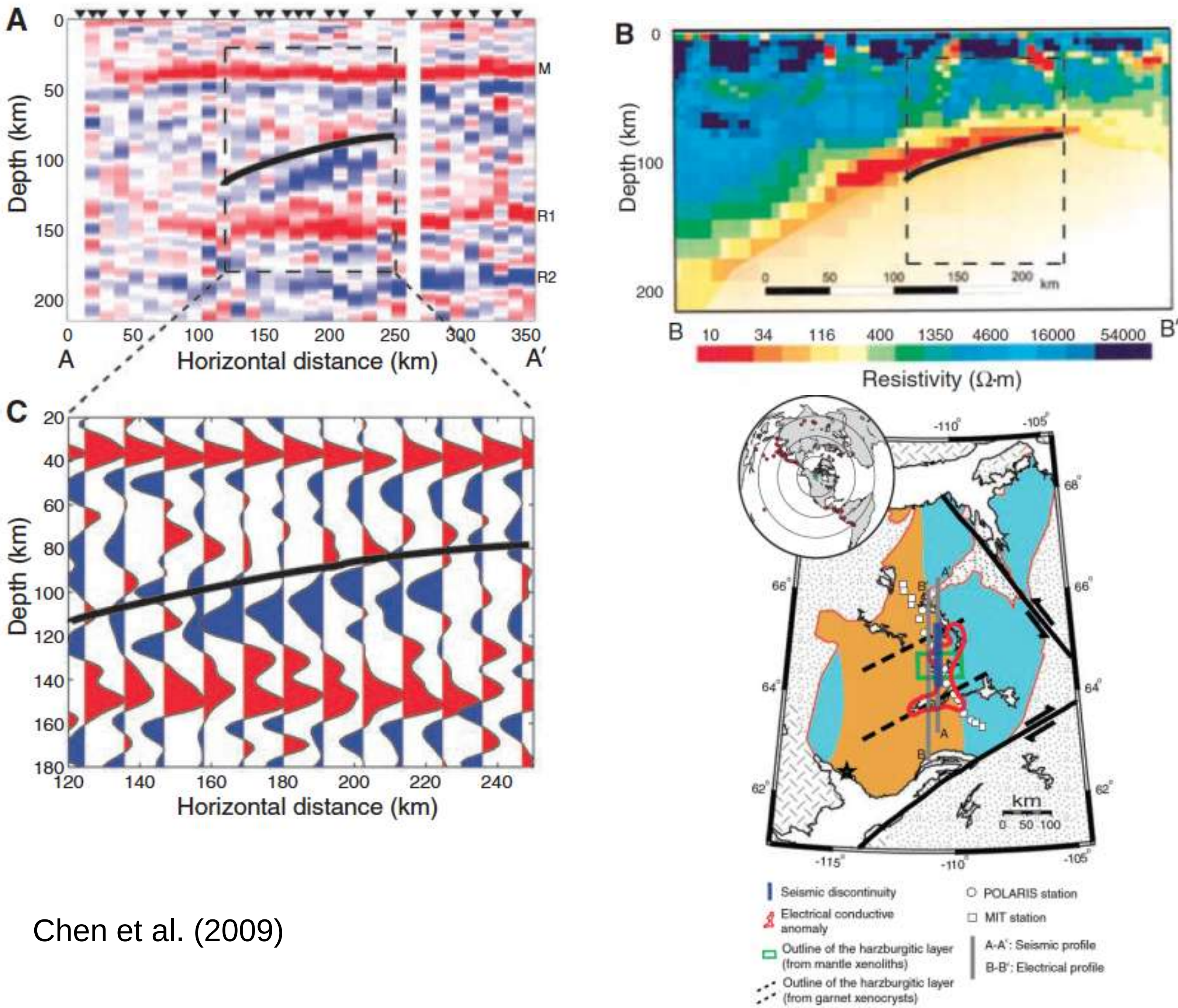
Yuan & Romanowicz (2010)



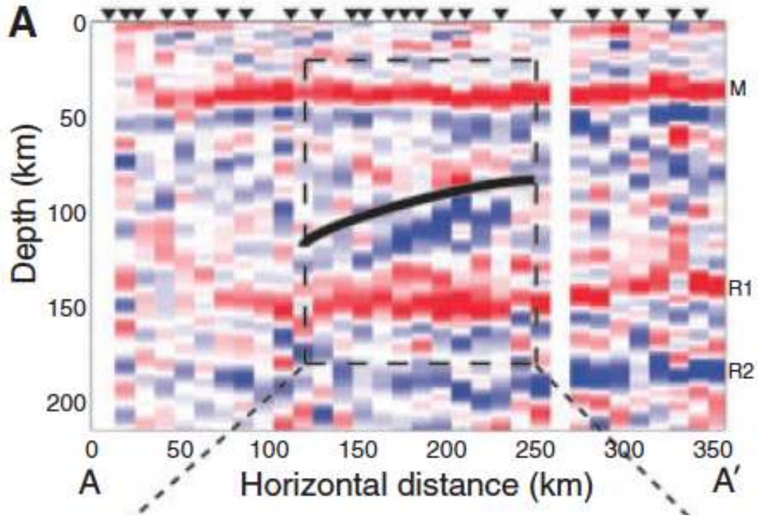


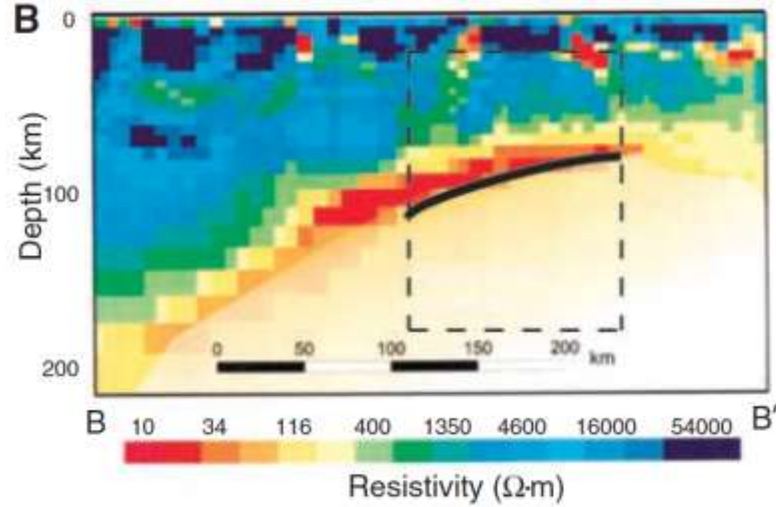


Zhu & Tromp (2013)

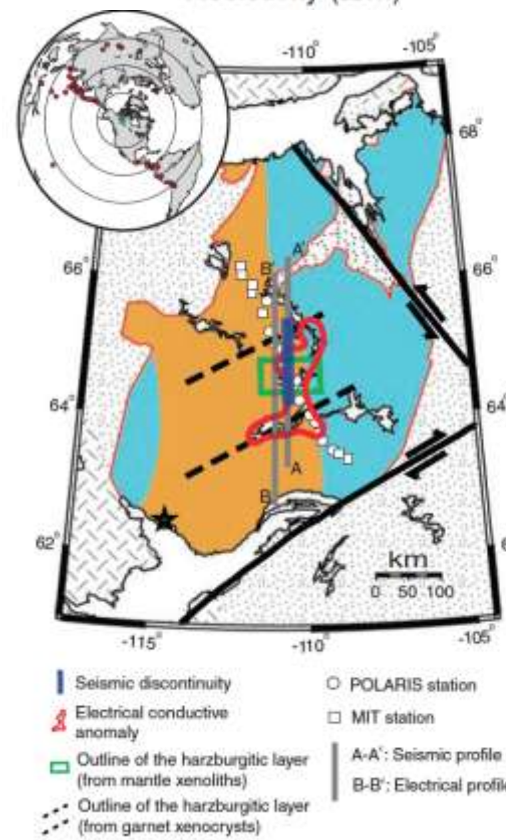


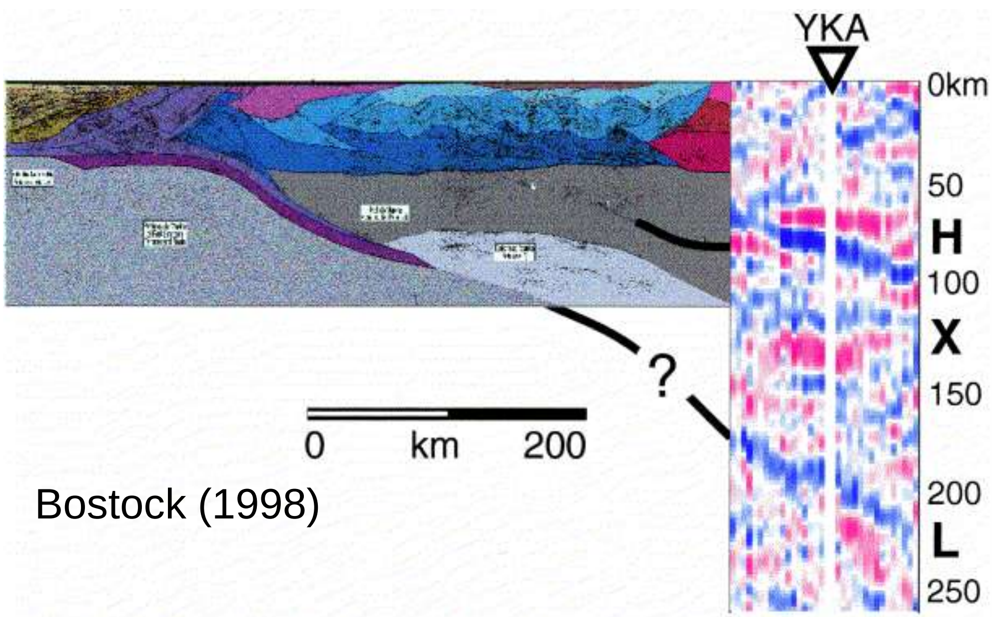
Chen et al. (2009)





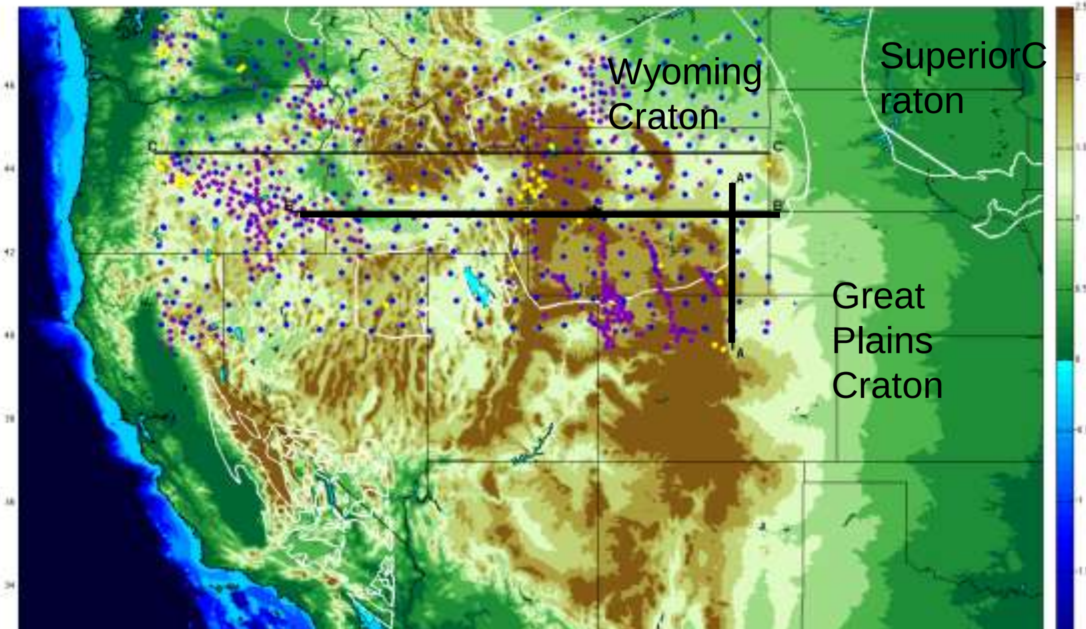
Chen et al. (2009)

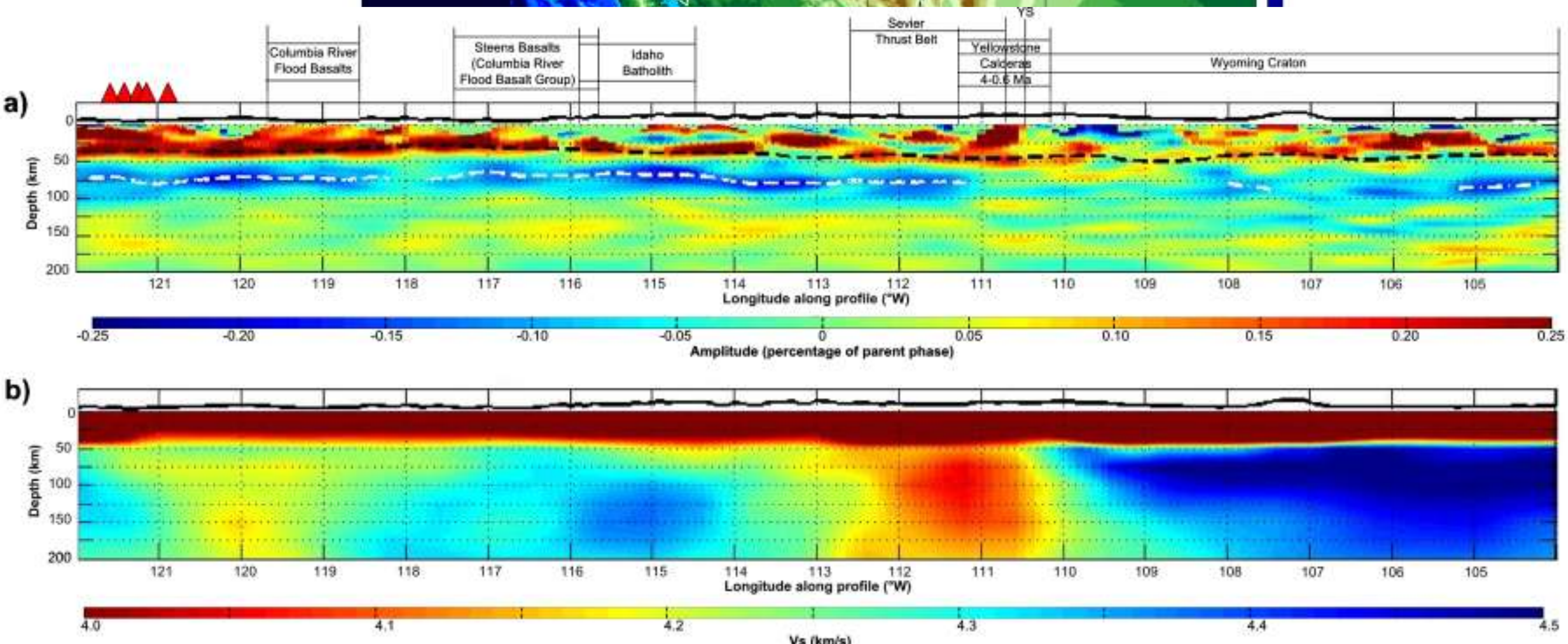




Bostock (1998)

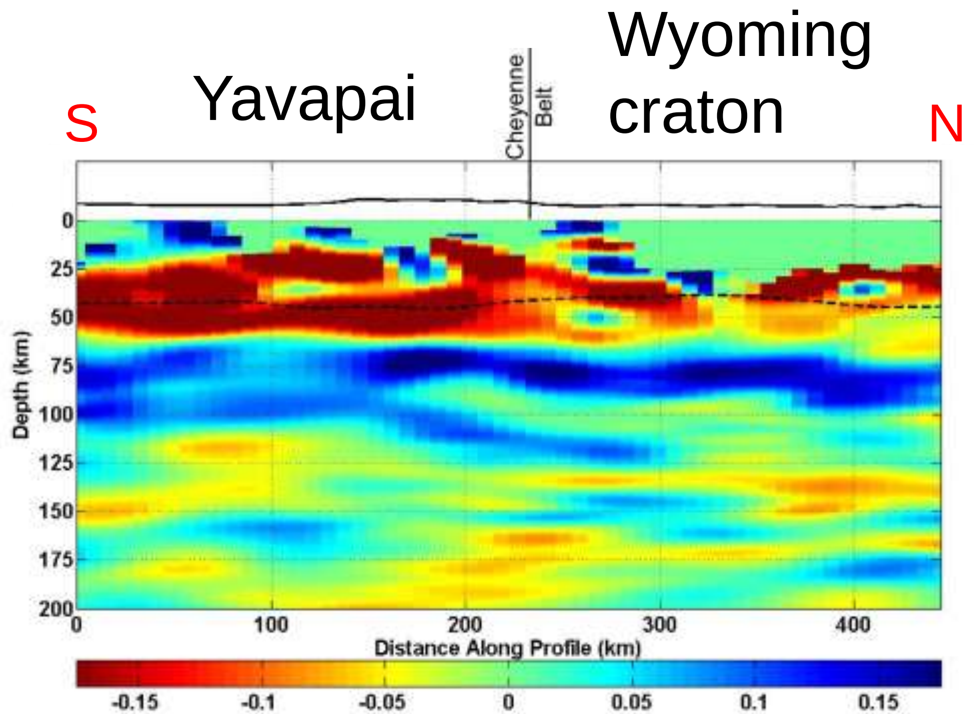
Hopper et al. (2013)



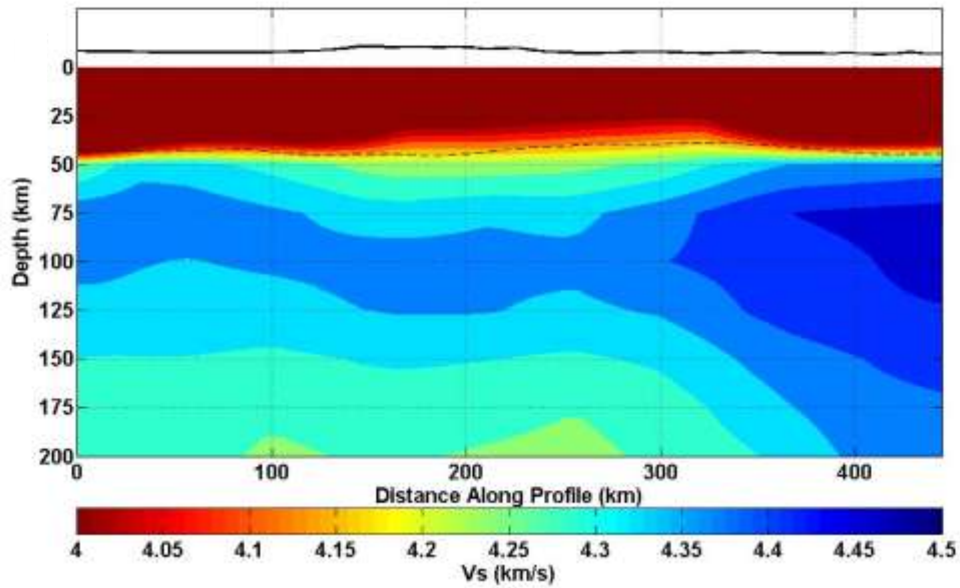


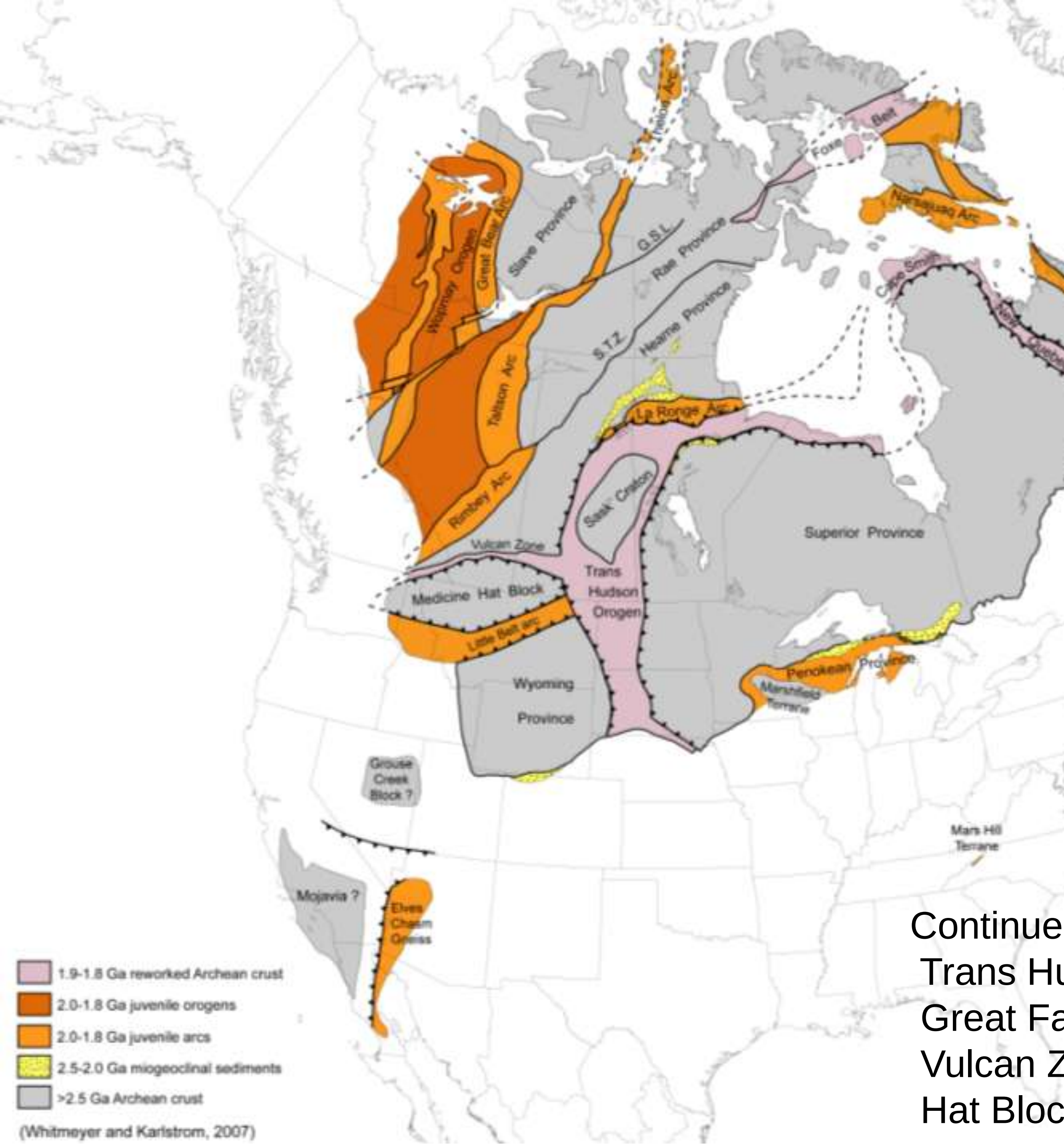
Obrebski et al. (2011)

Sp CCP stack
(Hopper et al., 2013)



Shear wave velocity tomography
(Obrebski et al., 2011)

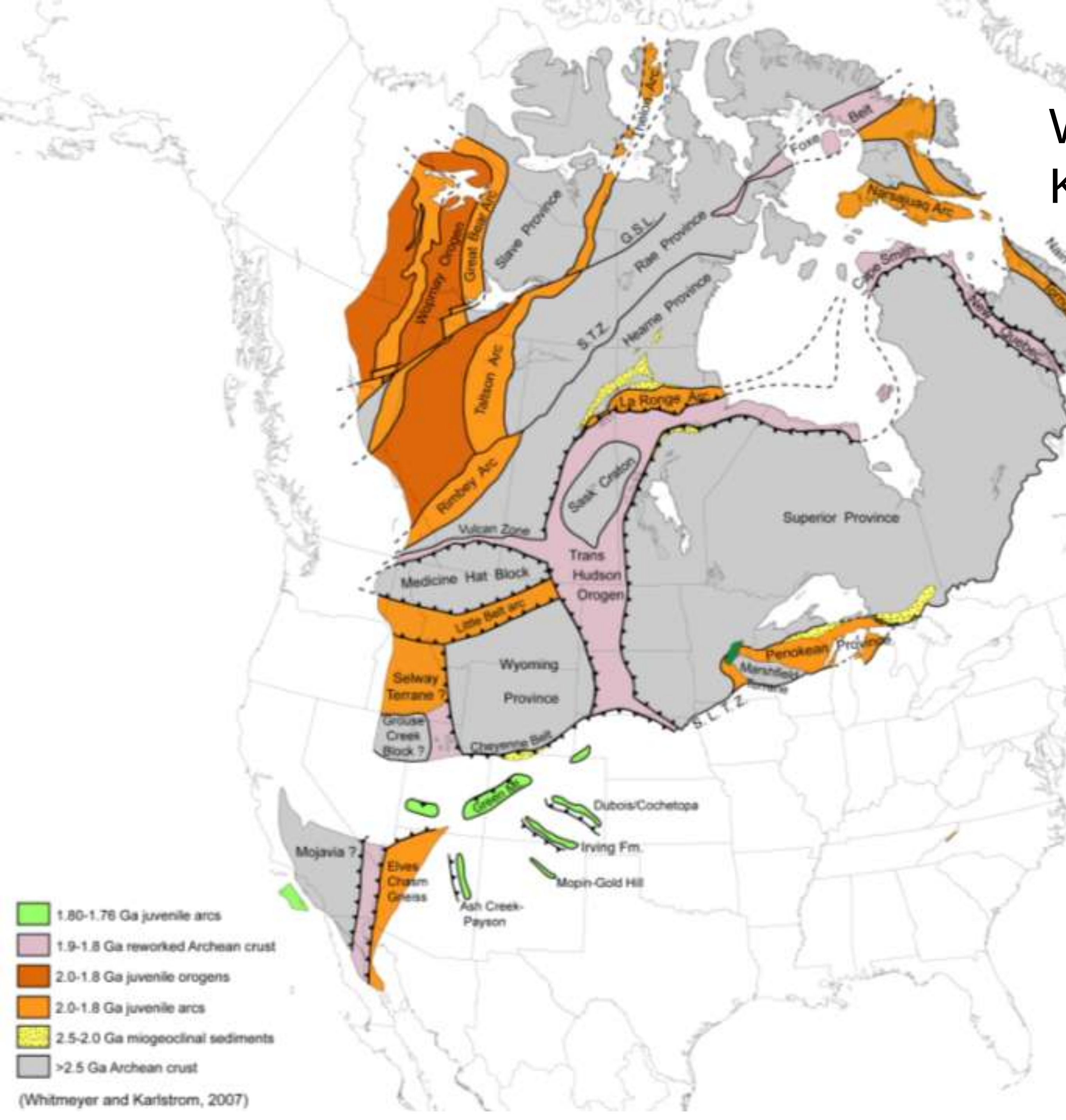




Whitmeyer & Karlstrom (2007)

1.82-1.80 Ga

Continued shortening across Trans Hudson orogen; closure of Great Falls Tectonic Zone and Vulcan Zone; accretion of Medicine Hat Block, and Wyoming Province

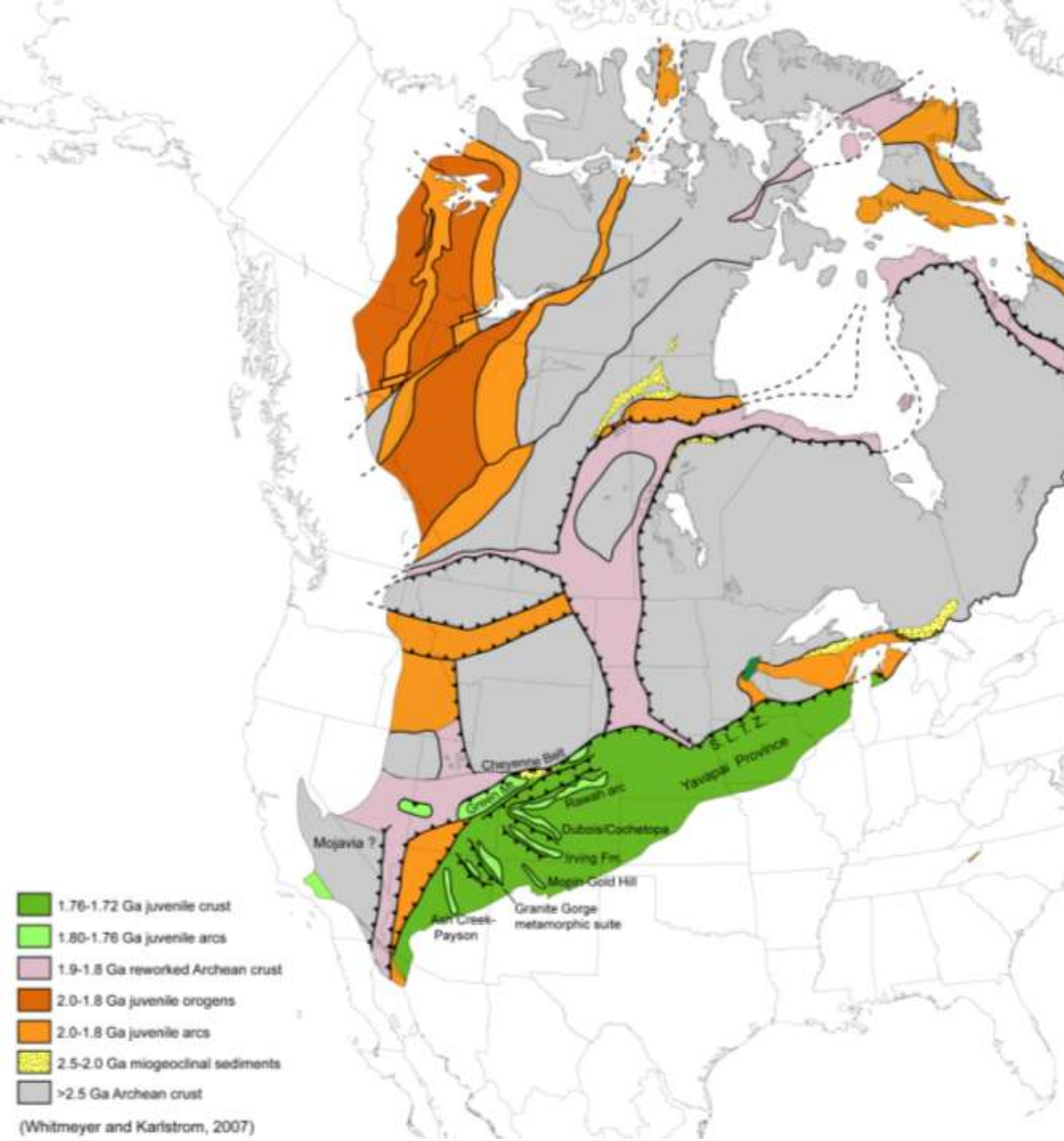


Whitmeyer & Karlstrom (2007)

1.80-1.76 Ga

Accretion of Archean(?) Grouse Creek Block and Selway Terrane; Mojave Province and Yavapai arcs outboard

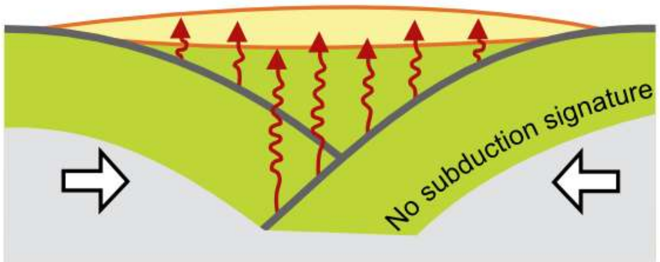
Whitmeyer & Karlstrom (2007)

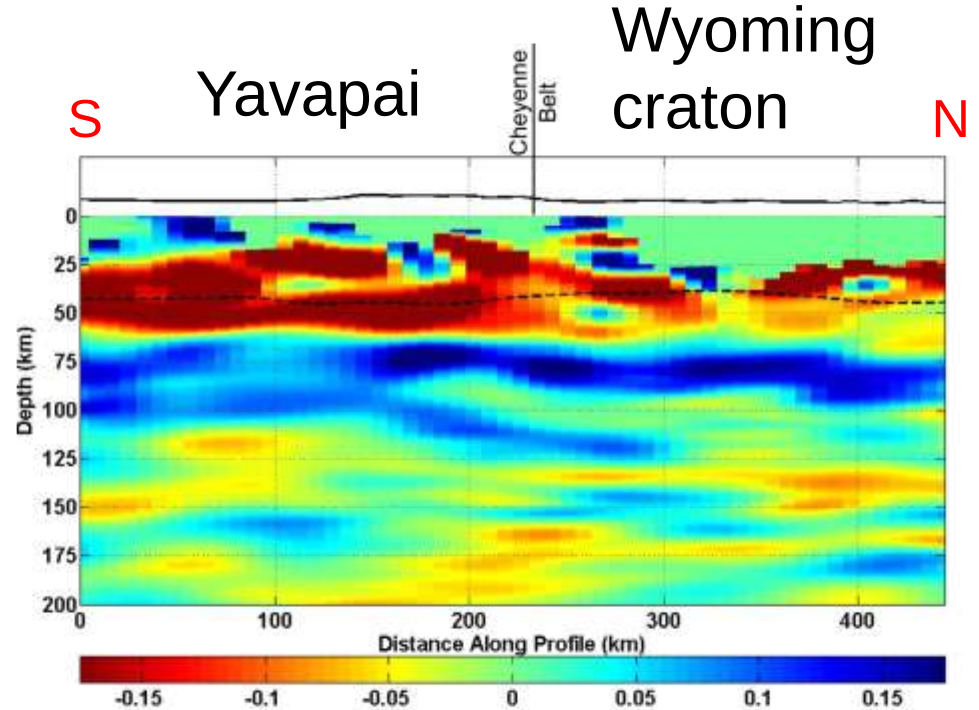


1.76-1.72 Ga

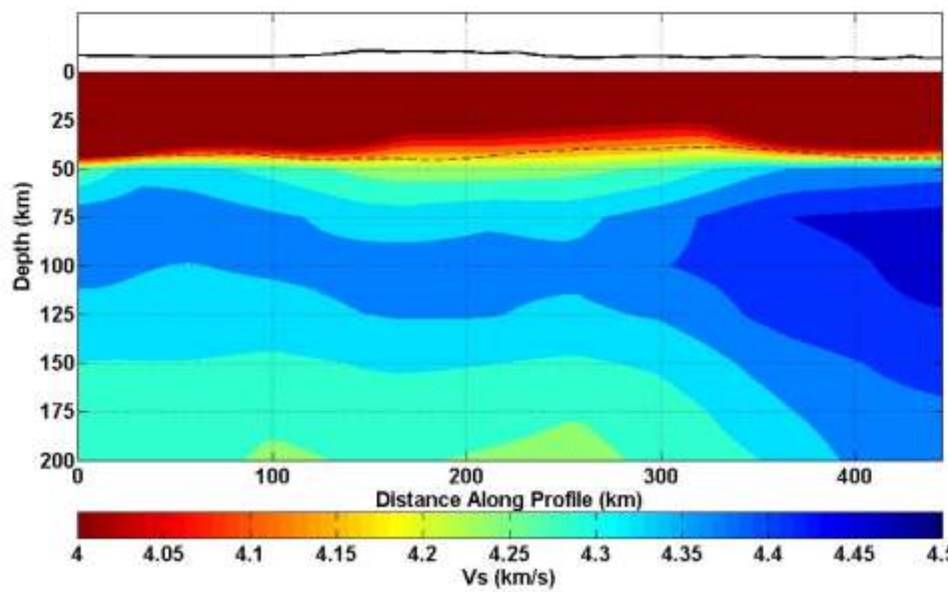
Accretion of Mojavia(?) and Yavapai Province, as a Banda Sea style assembly of arcs

Sp CCP stack
(Hopper et al., 2013)





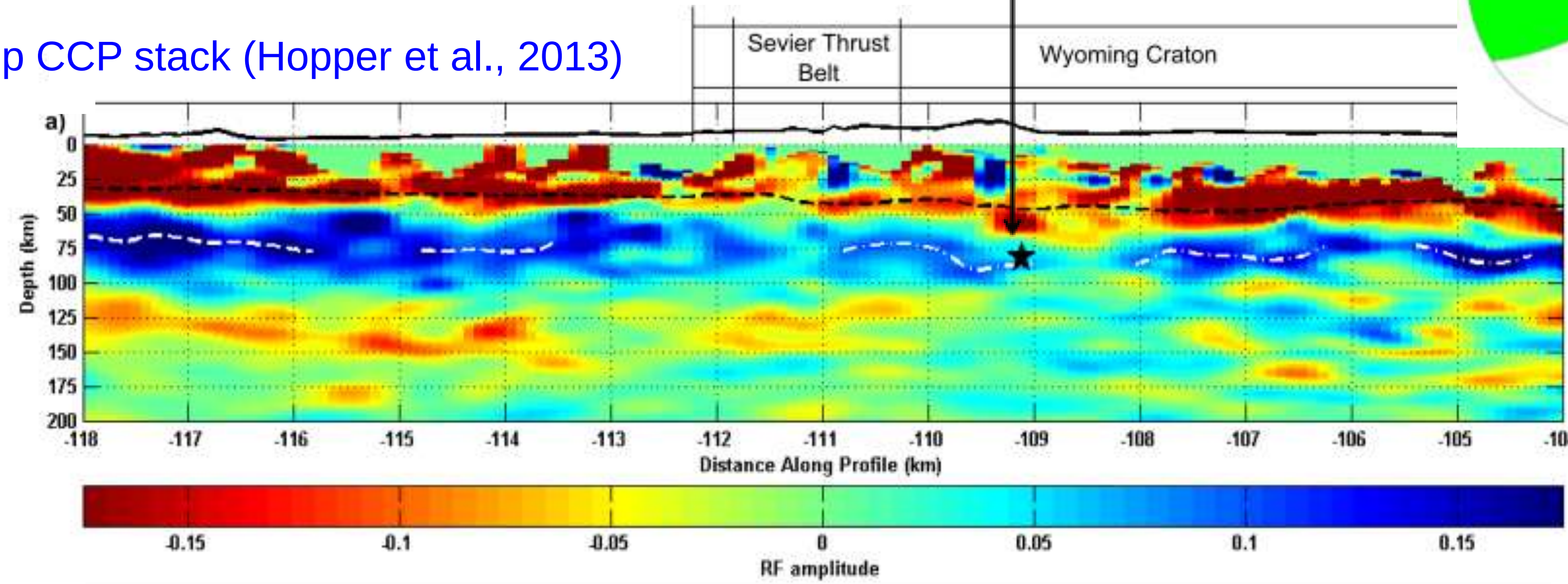
Shear wave velocity
tomography
(Obrebski et al., 2011)

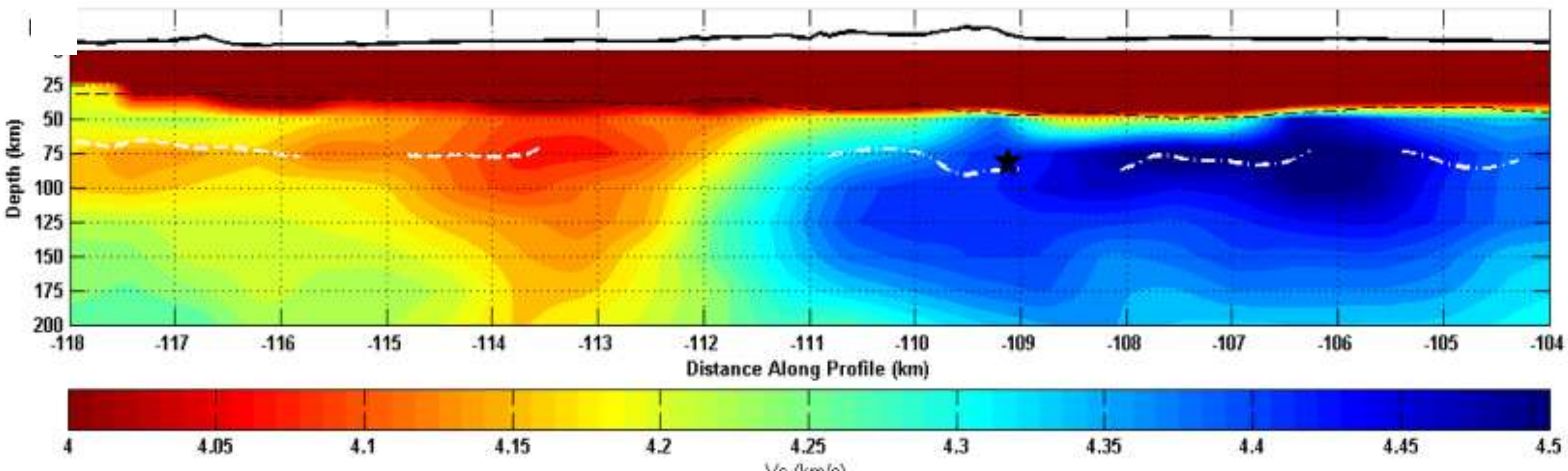


Earthquake at 80 km depth (Mw=4.8)
Wyoming, Sept. 2013

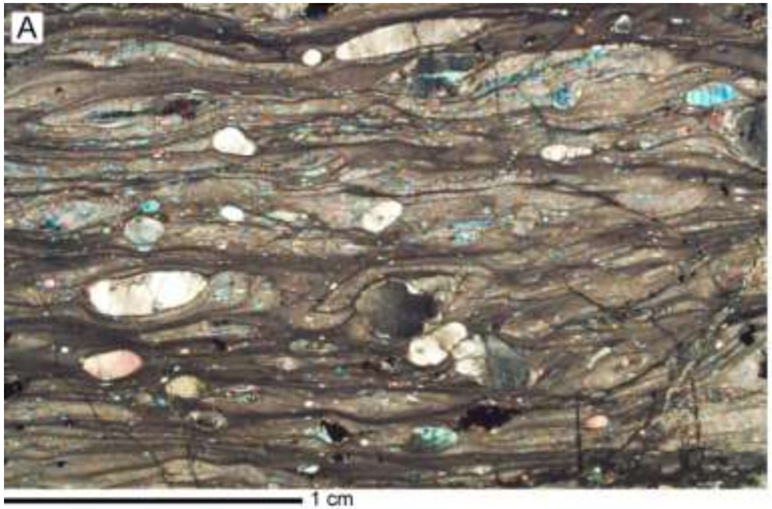
Global CMT

Sp CCP stack (Hopper et al., 2013)

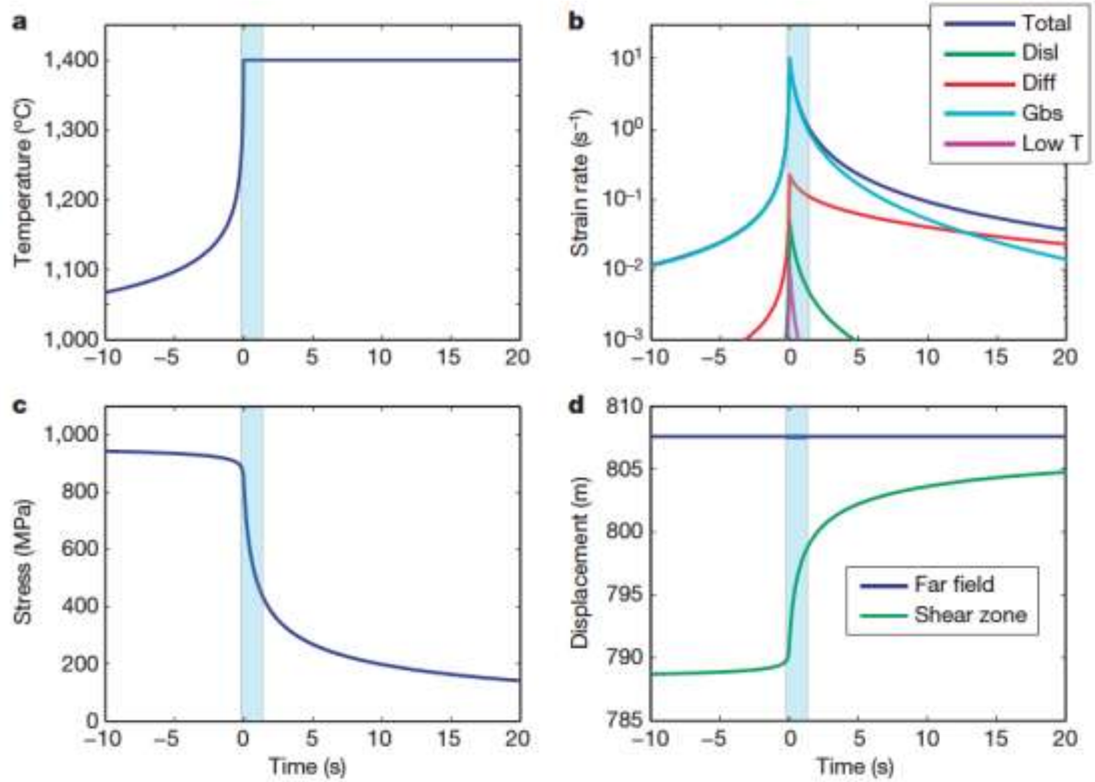


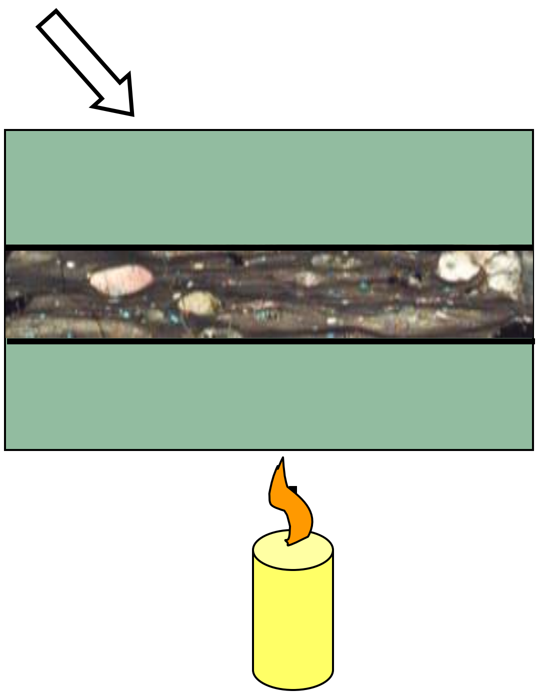


Shear wave velocity tomography (Obrebski et al., 2011)



Kelemen and Hirth (2007)





- Mantle with pre-existing fine-grained shear zone
- Viscous deformation leads to shear heating instability & rapid displacement
- Preferred conditions for instability: 600˚- 800˚C

- Consistent with xenocryst geotherms for Wyoming craton mantle at ~80 km (Griffin et al., 2004)

Conclusions

Cratonic lithosphere-asthenosphere boundary

- Velocity gradient typically more gradual (>60 km) than beneath younger continental regions (<30 km); consistent with purely thermal gradients
- In some regions velocity gradients are more vertically localized; suggest zones with higher volatiles or melt in asthenosphere

Layering within cratonic mantle

- Many forms: isotropic velocities, azimuthal anisotropy, 8°discontinuity, scattered/reflected wave discontinuities
- Layering in azimuthal anisotropy suggests multi-stage formation
- Widespread mid-lithospheric discontinuity at ~70-100 km
- Dipping discontinuities suggest accretion of paleo-slabs
- 2013 Wyoming earthquake at 80 km depth = runaway shear instability in fined-grained mantle at 600°- 800°C?