Seismic evidence for a fossil slab origin of the Isabella Anomaly in Central California

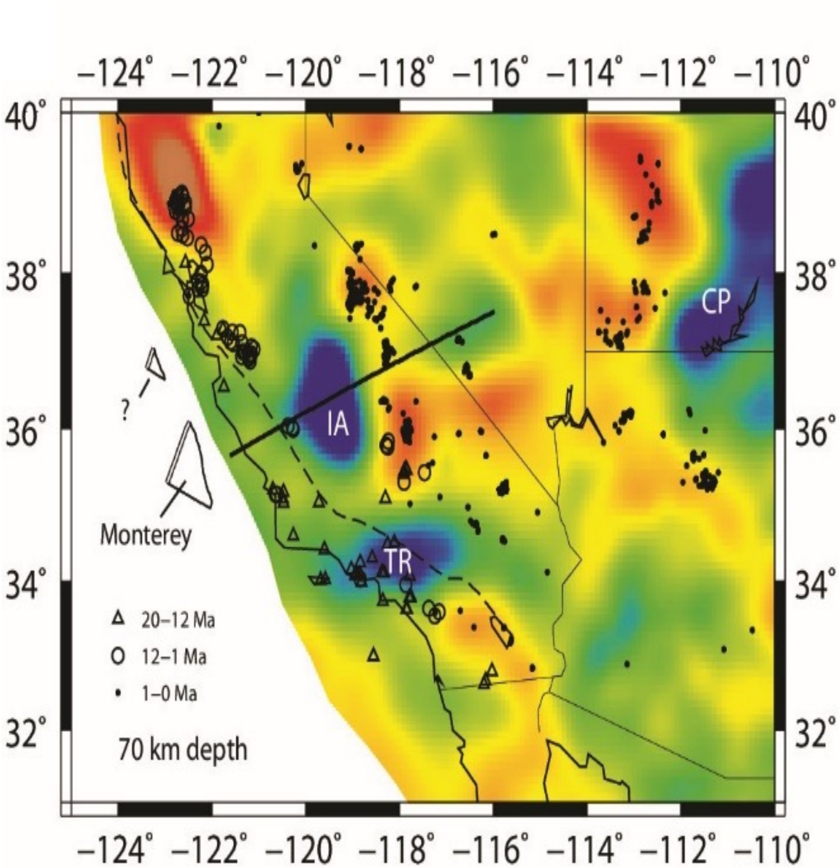
Chengxin Jiang, Brandon Schmandt, Steven M. Hansen (*UNM*)
Sara L. Dougherty (*USGS*)
Robert W. Clayton (*Caltech*)
Fan-Chi Lin, Jamie Farrell (U. Utah)

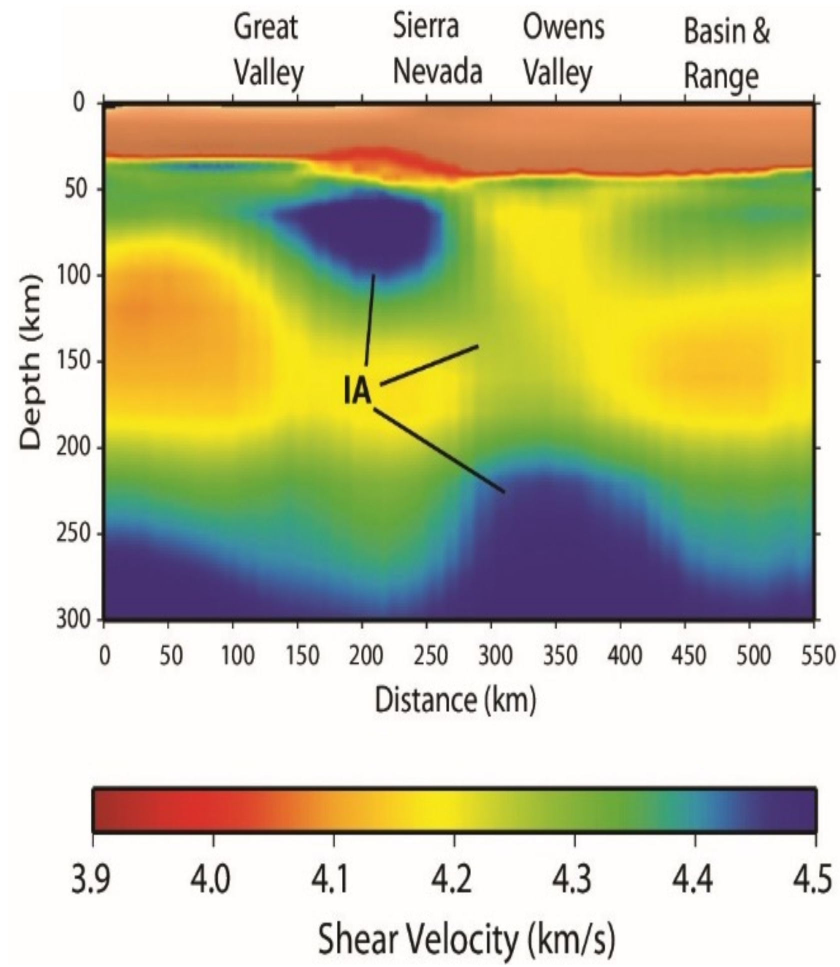
EAR 1315856

Outline

- Tectonic origins of Isabella Anomaly: fossil slab or foundering lithospheric root
- Central California Seismic Experiment
- Seismic imaging efforts:
  - Surface wave tomography
  - Scattered wave imaging
  - Body wave & surface wave joint inversion

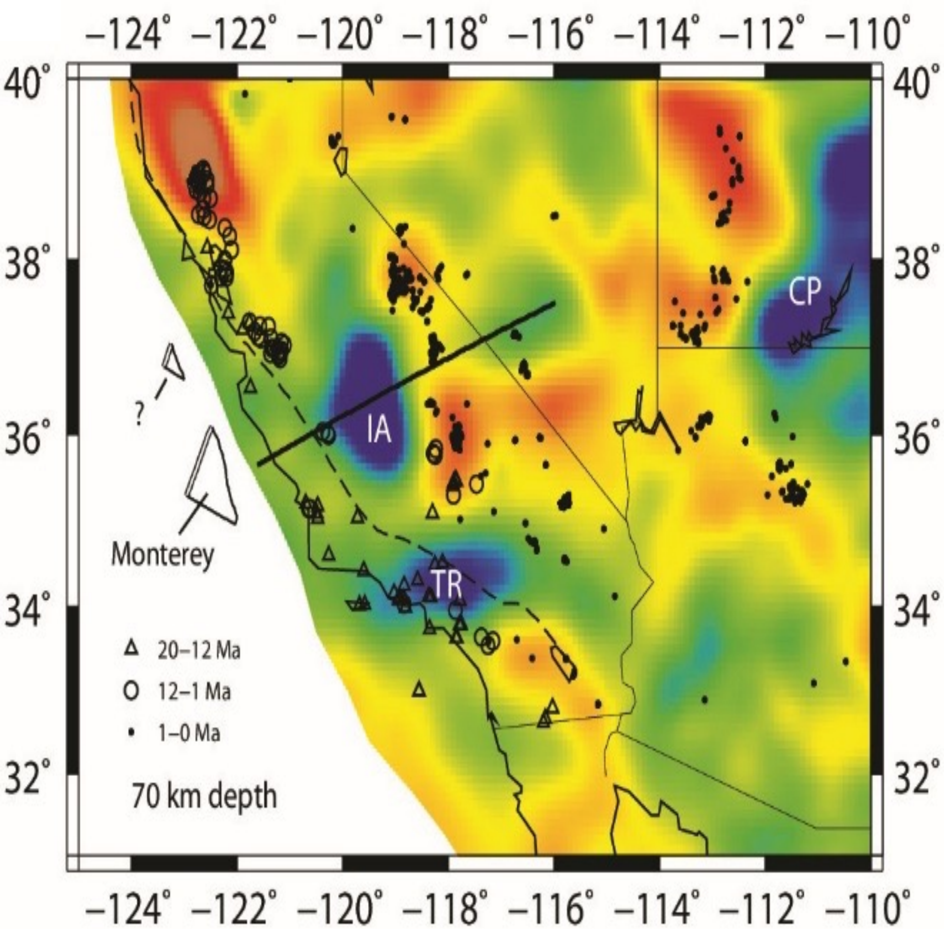
Isabella Anomaly



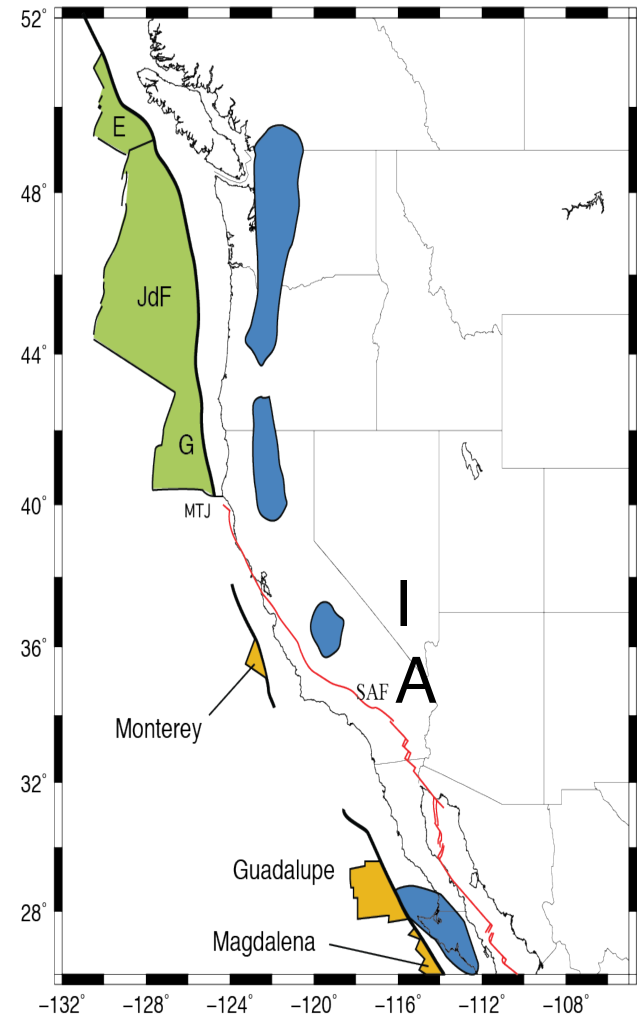


Wang et al. (2013)

Isabella Anomaly in a plate-



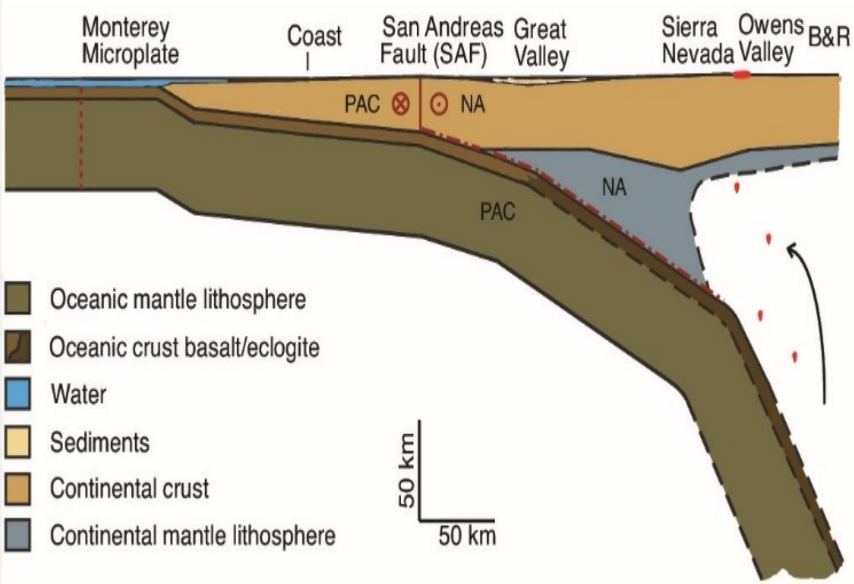
Wang et al. (2013)



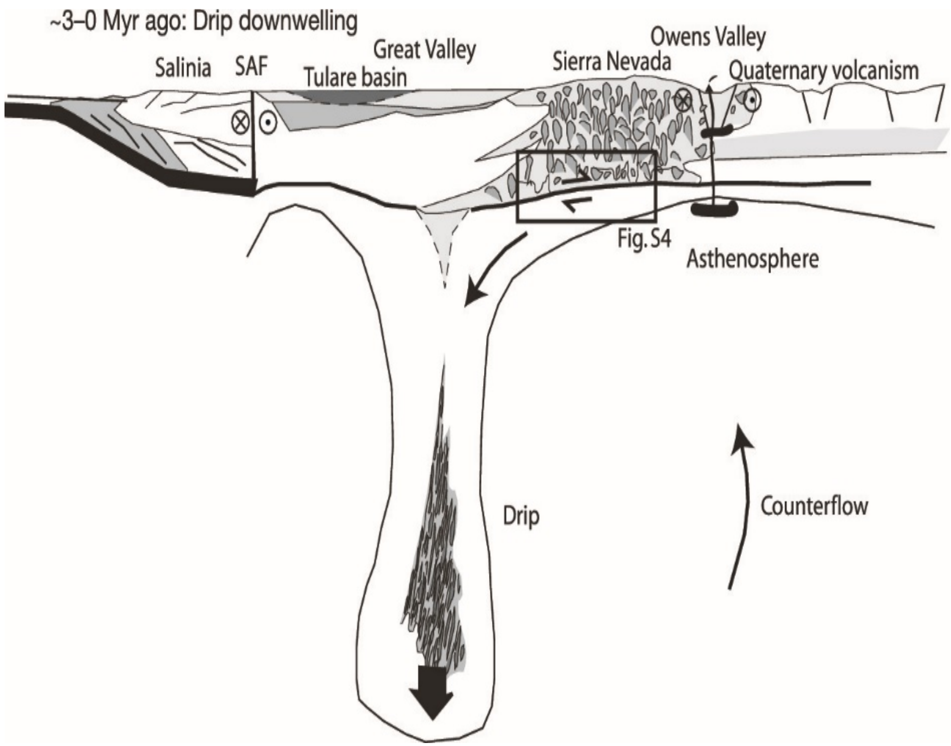
After Wang et al. (2013), Porritt et al. (2011)

Origin hypotheses

(A) Fossil Slab



(B) Foundering Lithospheric Root

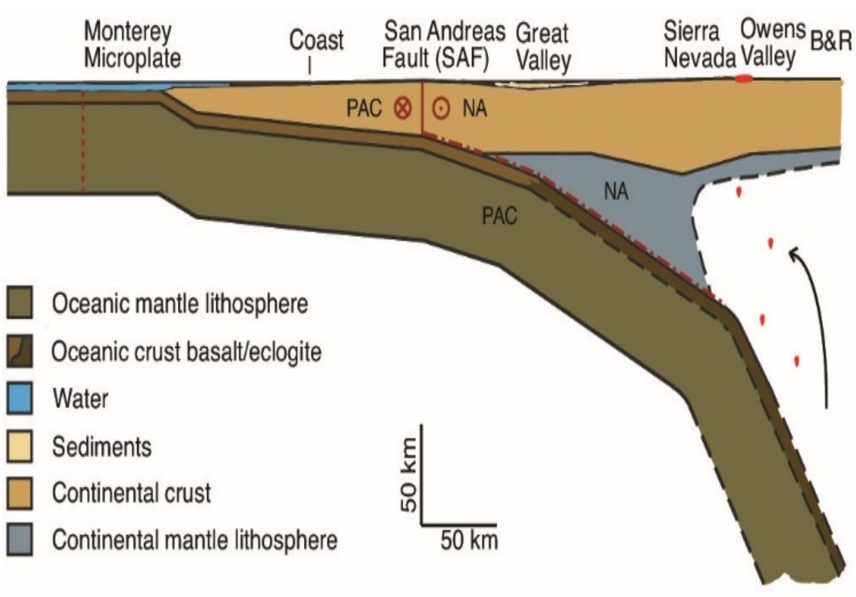


Wang et al. (2013)

Zandt et al. (2004)

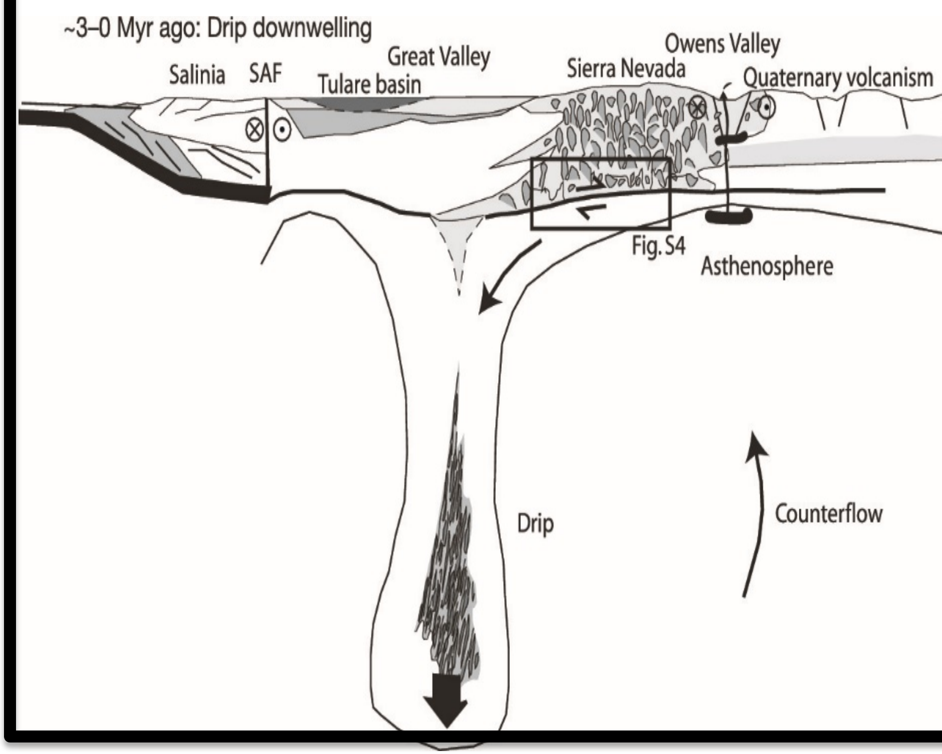
Origin hypotheses

(A) Fossil Slab



Wang et al. (2013)

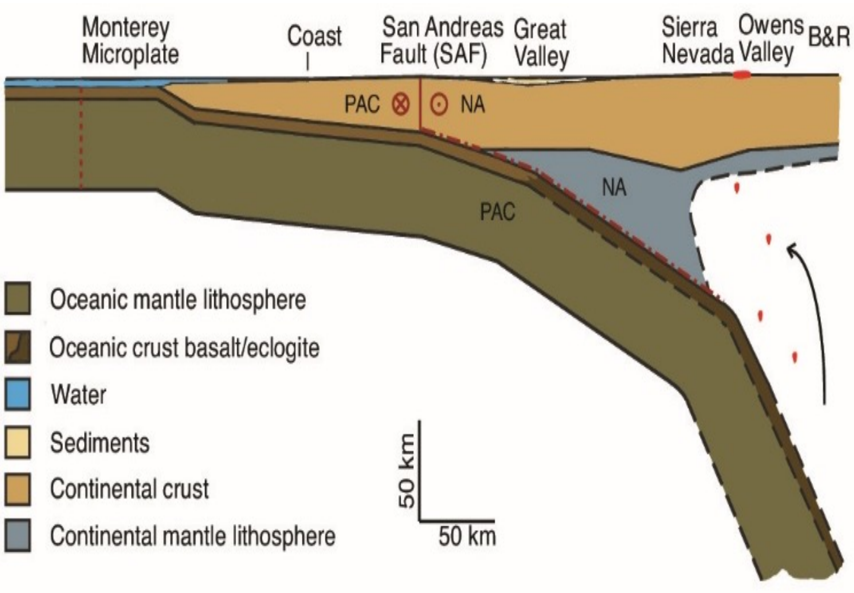
(B) Foundering Lithospheric Root



Zandt et al. (2004)

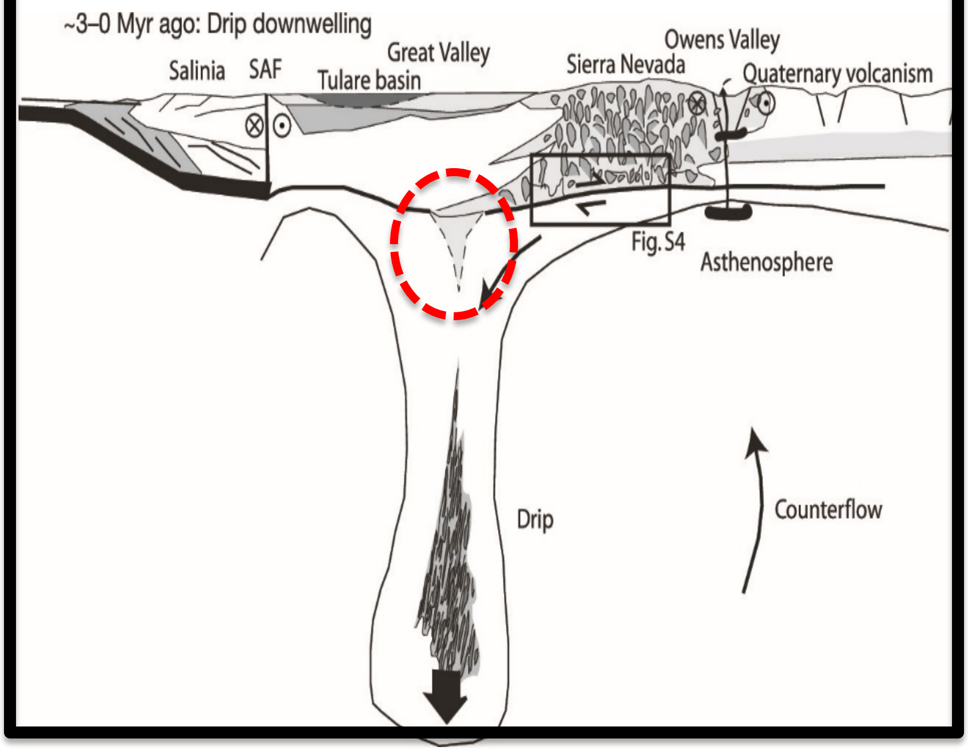
Origin hypotheses

(A) Fossil Slab



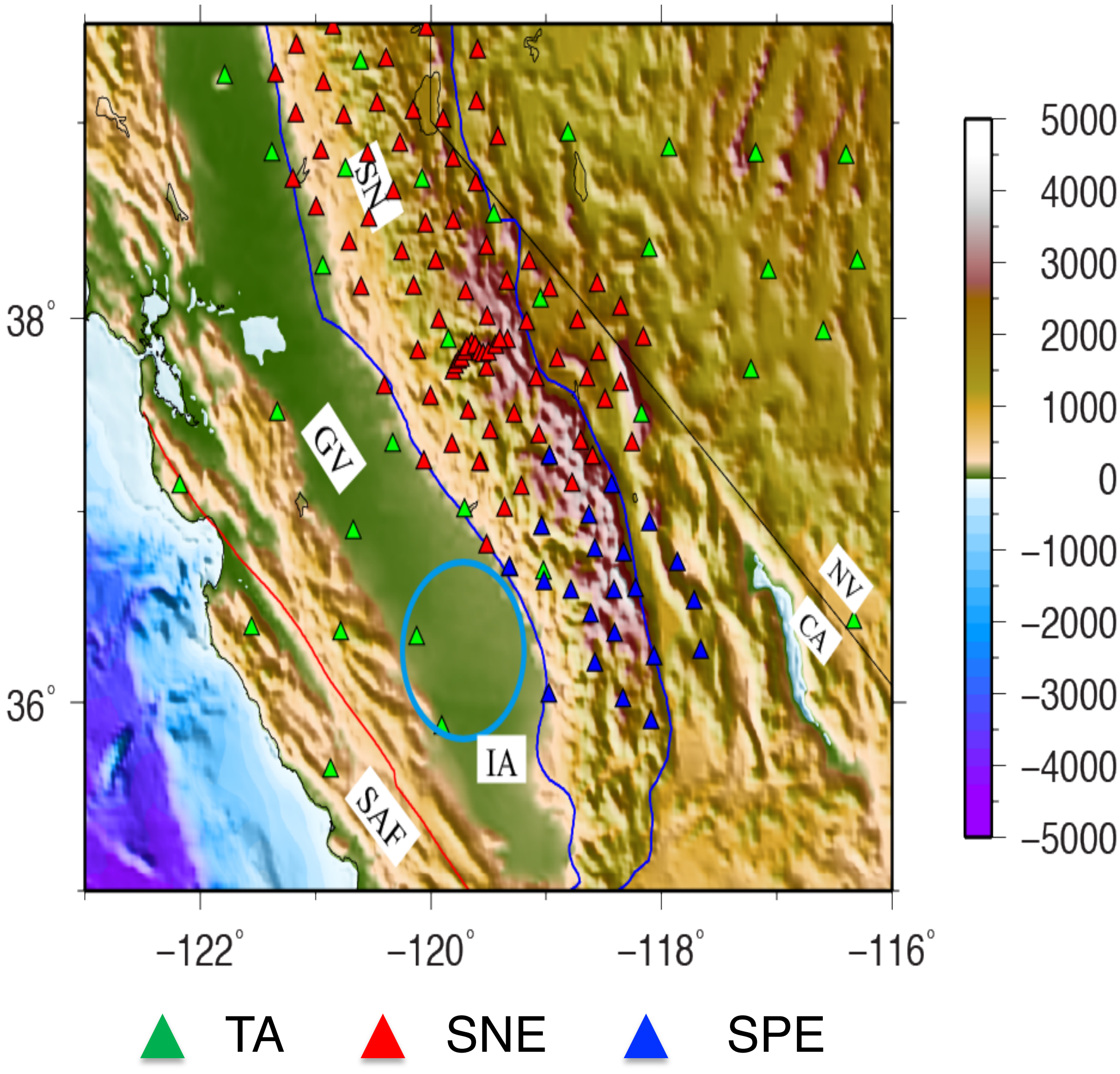
Wang et al. (2013)

(B) Foundering Lithospheric Root



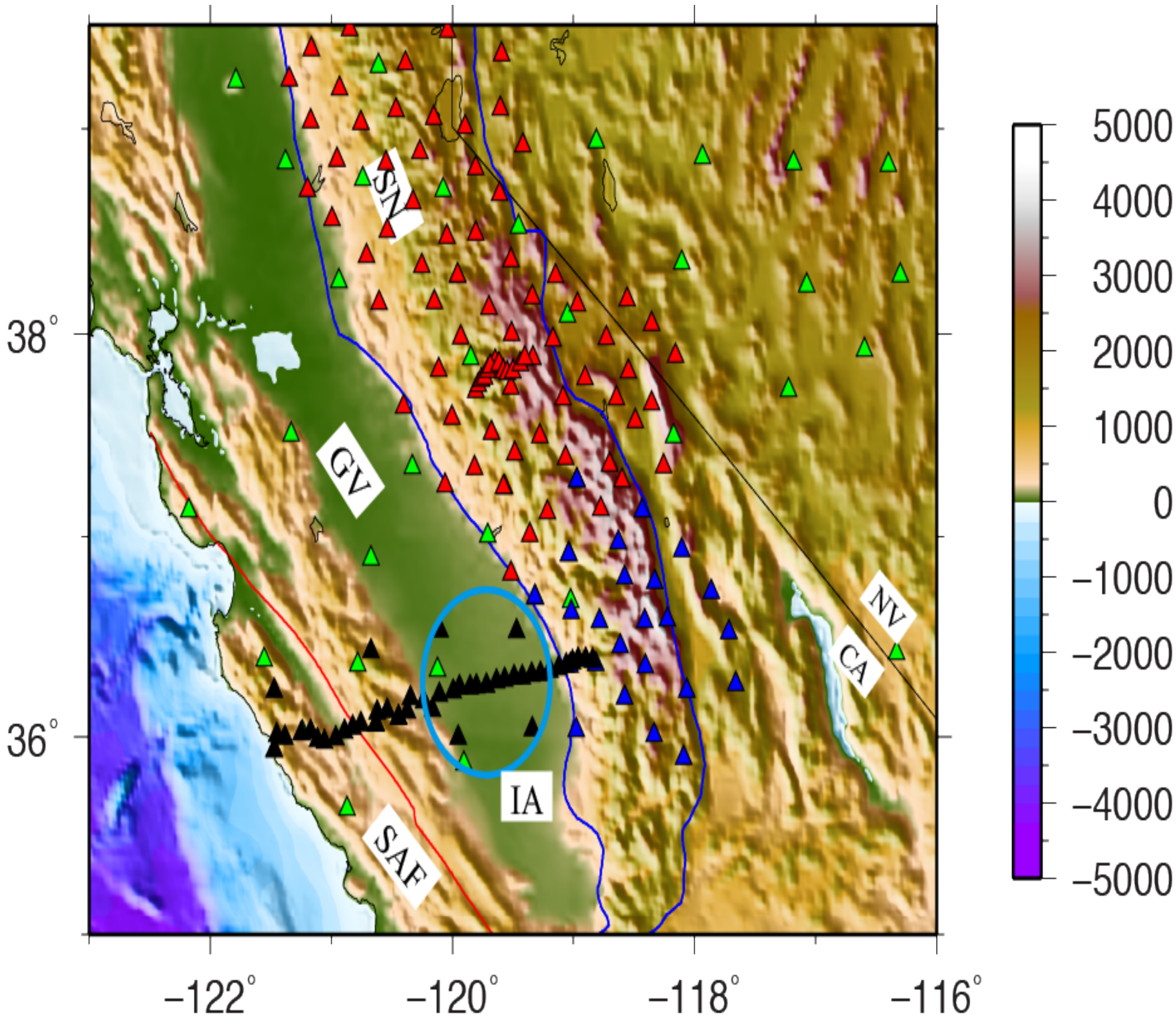
Zandt et al. (2004)

Central California Seismic



- Dec. 2013 – Oct. 2015
- Broadband seismic stations avoid the Isabella Anomaly

Central California Seismic Experiment (CCSE)

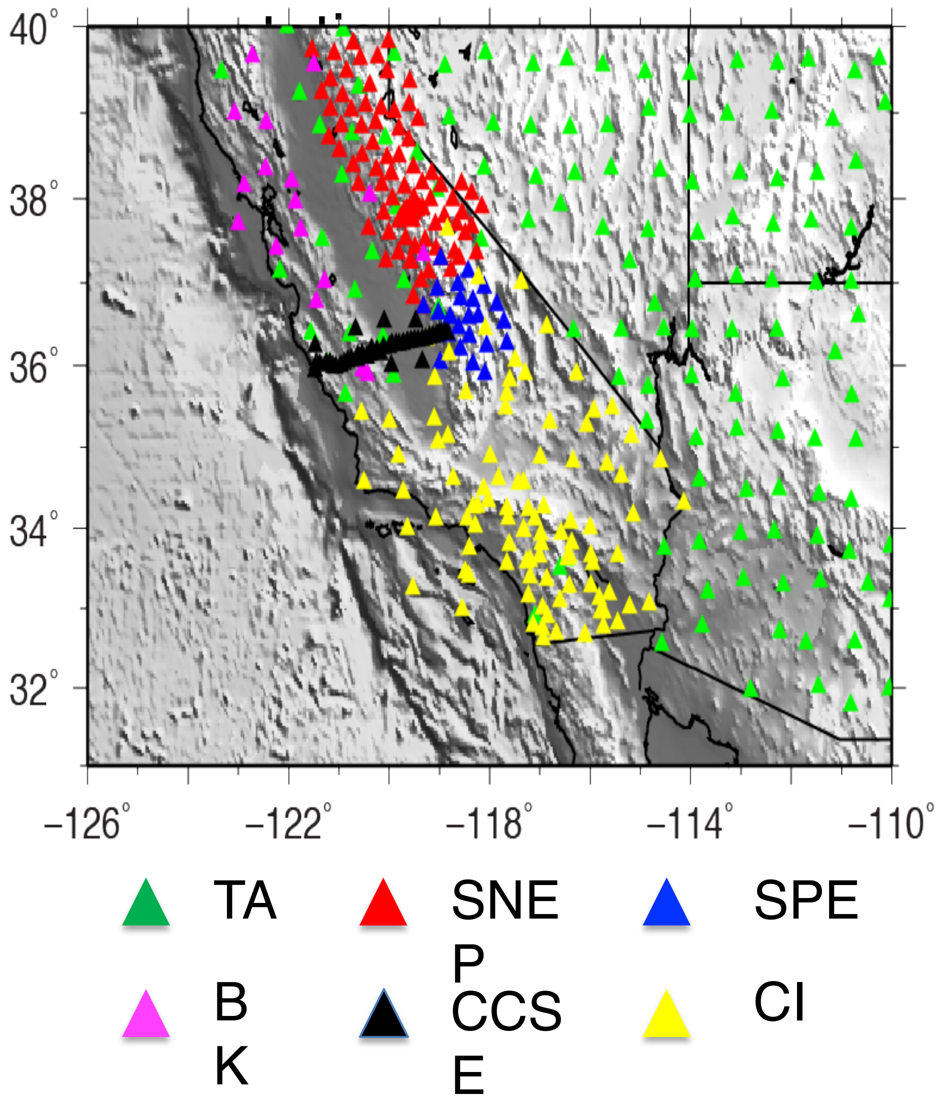


TA SNE SPE CCS

- 49 broadband
- 3 stations at foothills
- ~20 stations right above IA
- ~7 km spacing

Data sets for surface wave

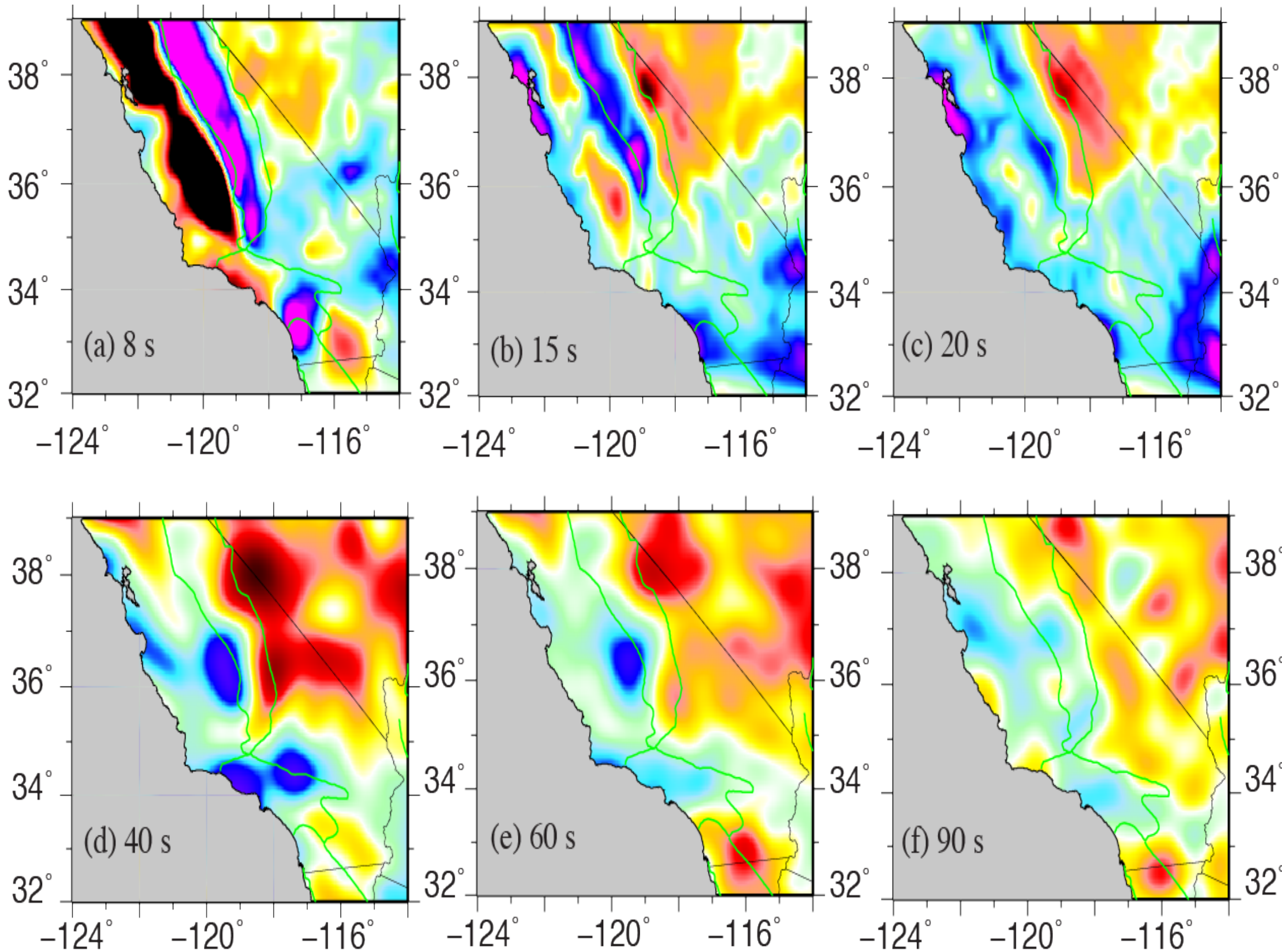
413 broadband



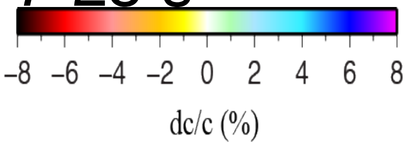
Surface wave signals from:

- Ambient noise interferometry (7-25 s) Lin et al., 2008, 2009
- Earthquake events (25-100 s) using two-plane wave tomography Forsyth & Li 2005 Yang & Forsyth 2006

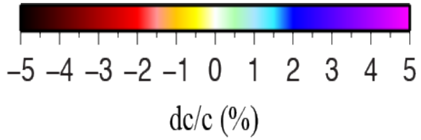
Phase velocity maps



Ambient noise: 7-25 s

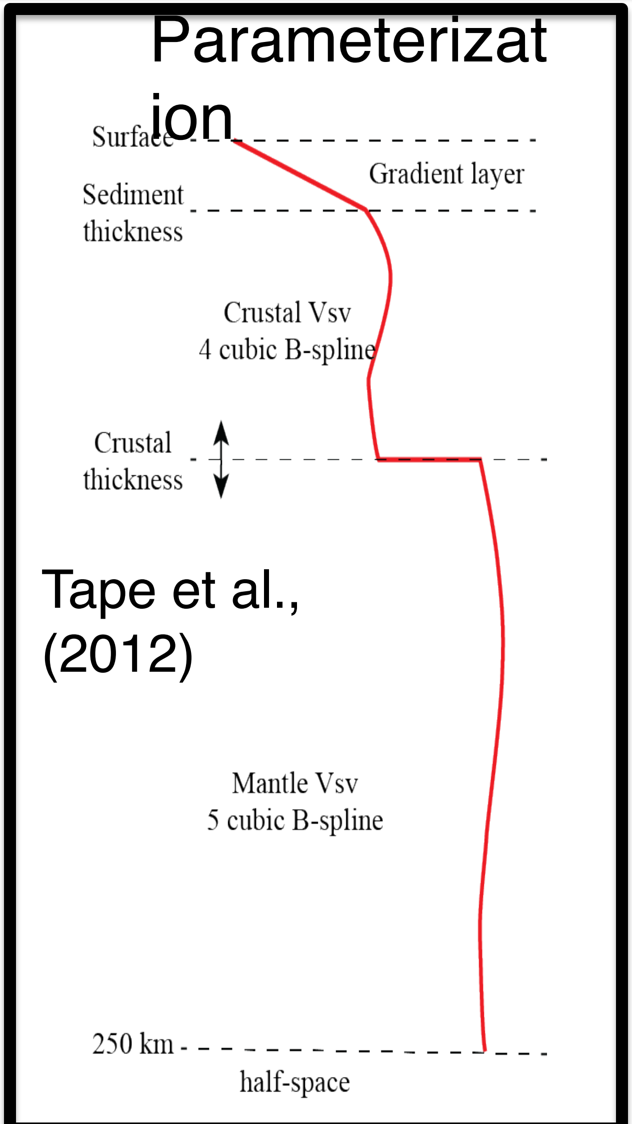


Earthquakes: 25-100 s



MC inversion for 1D Vs profile

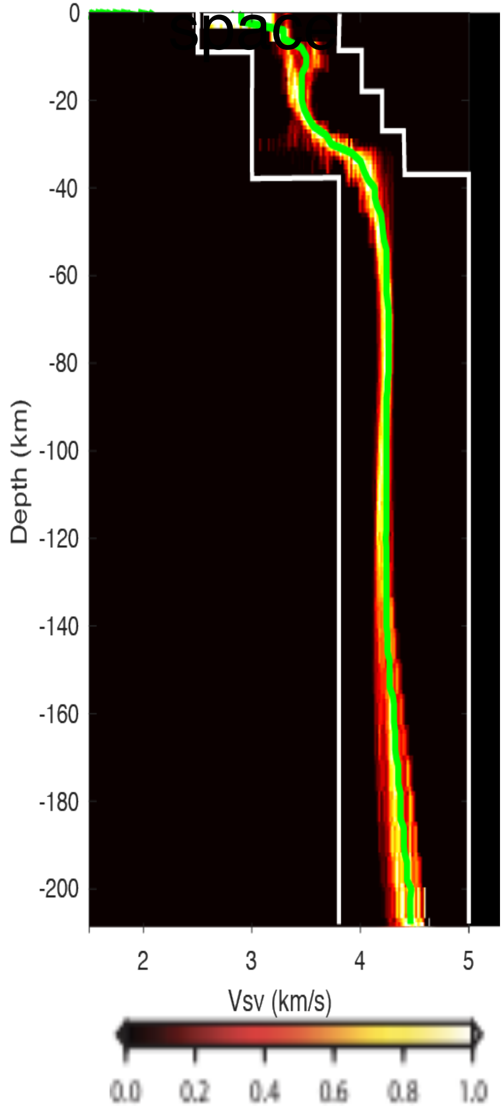
Parameterization



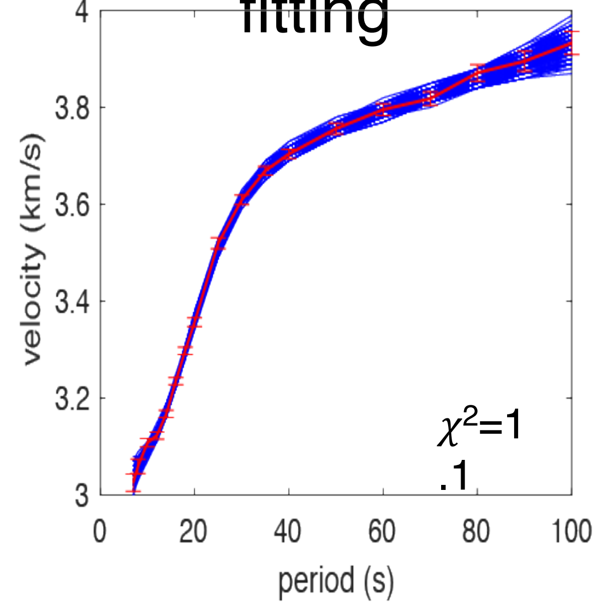
Tape et al., (2012)

After Shen et al., (2013)

Model space



Data fitting



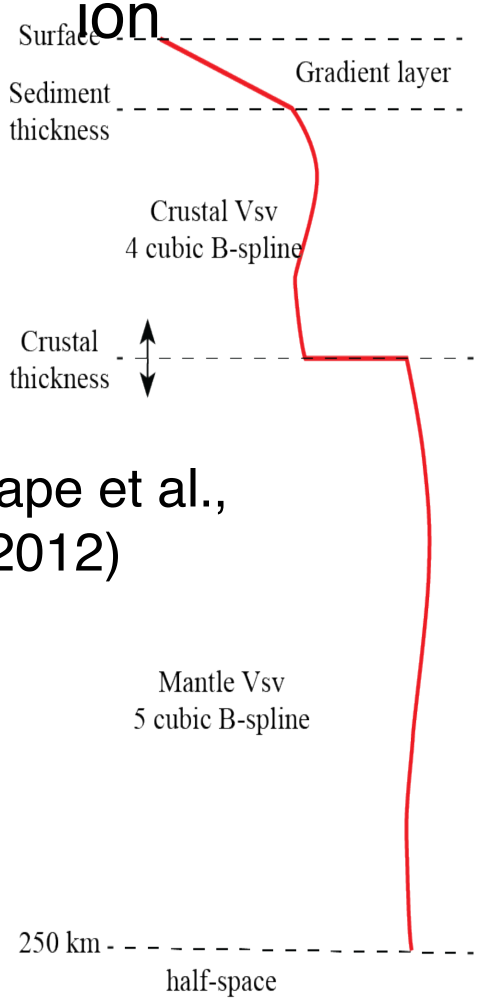
χ^2=1.1

Prior information

1. Vs free to vary in crust
2. Positive Vs gradient in the uppermost mantle

MC inversion for 1D Vs profile

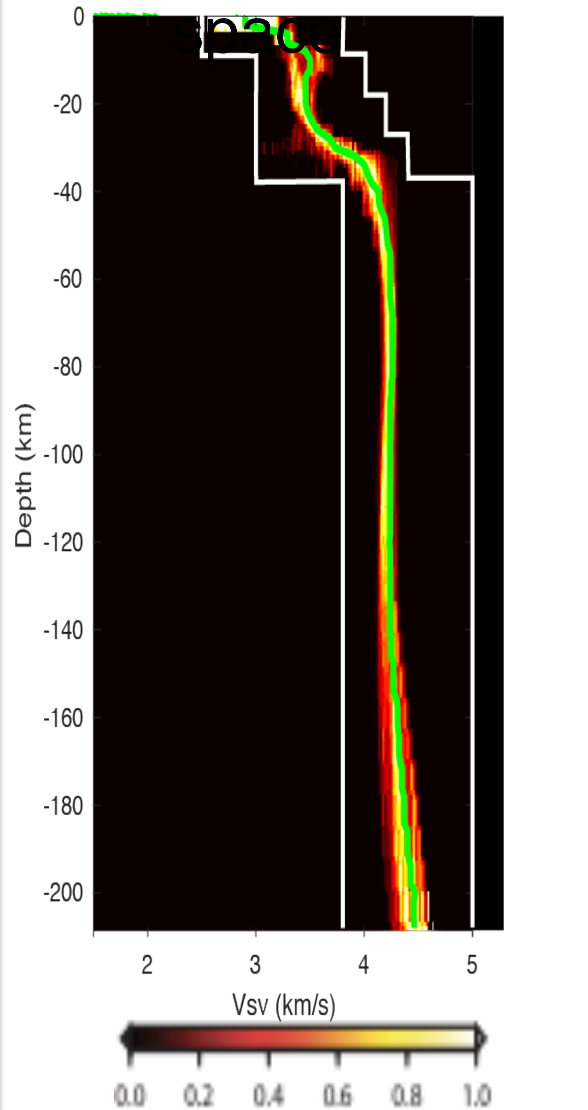
Parameterization



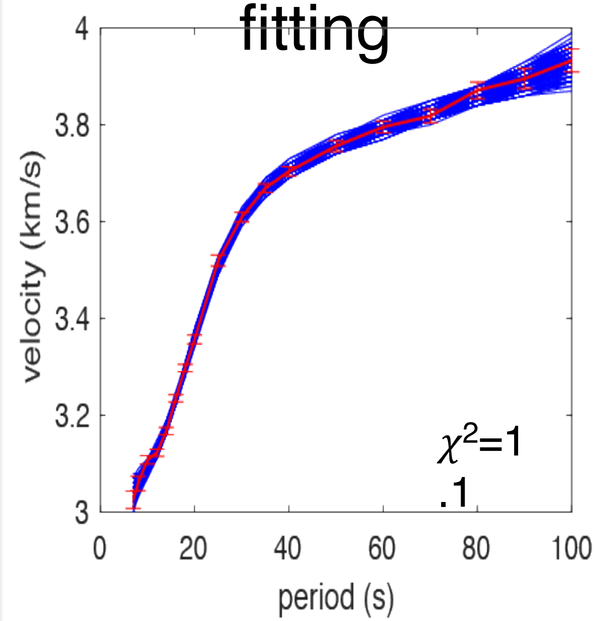
Tape et al., (2012)

After Shen et al.,

Model space



Data fitting

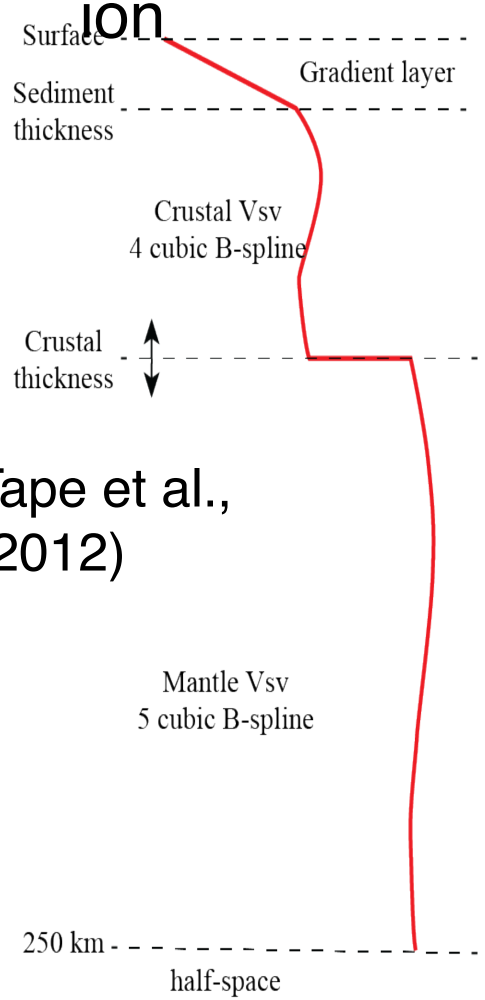


Prior information

1. Vs free to vary in crust
2. Positive Vs gradient in the uppermost mantle

MC inversion for 1D Vs profile

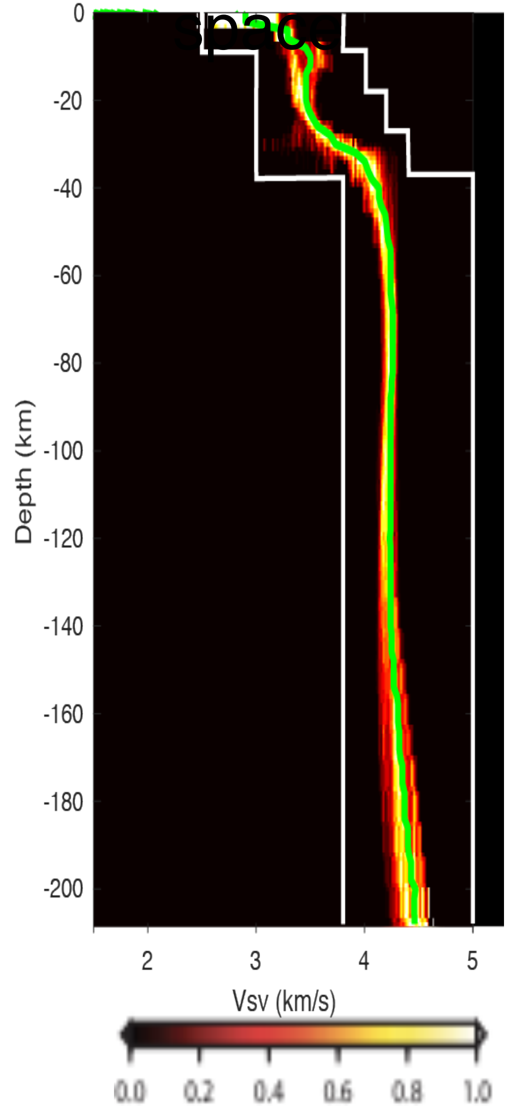
Parameterization



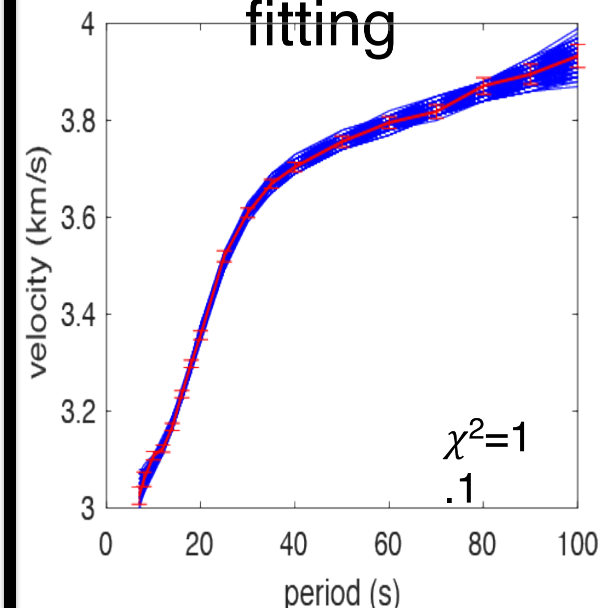
Tape et al., (2012)

After Shen et al.,

Model space



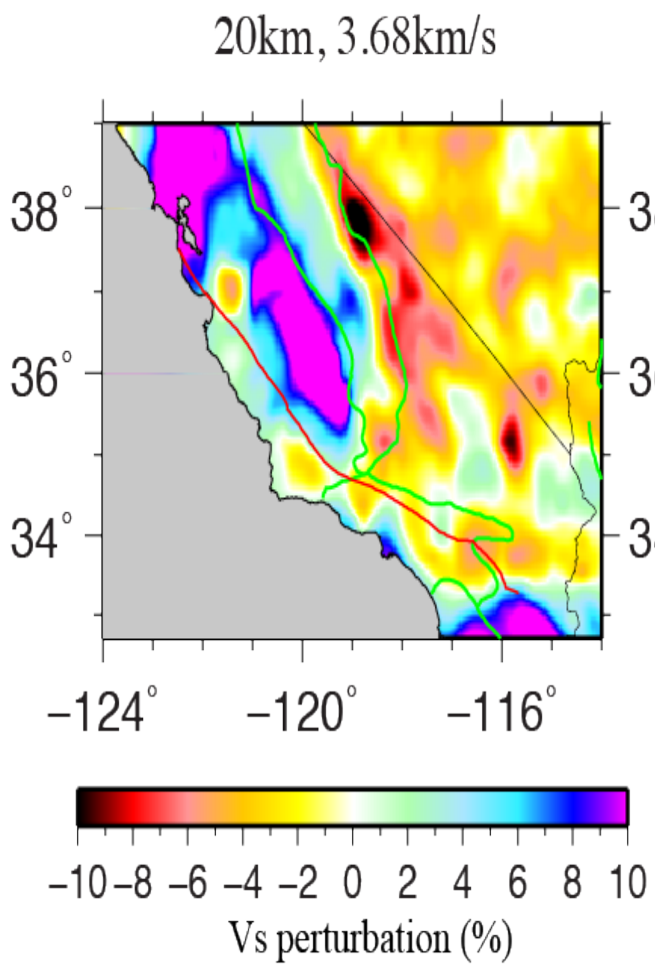
Data fitting



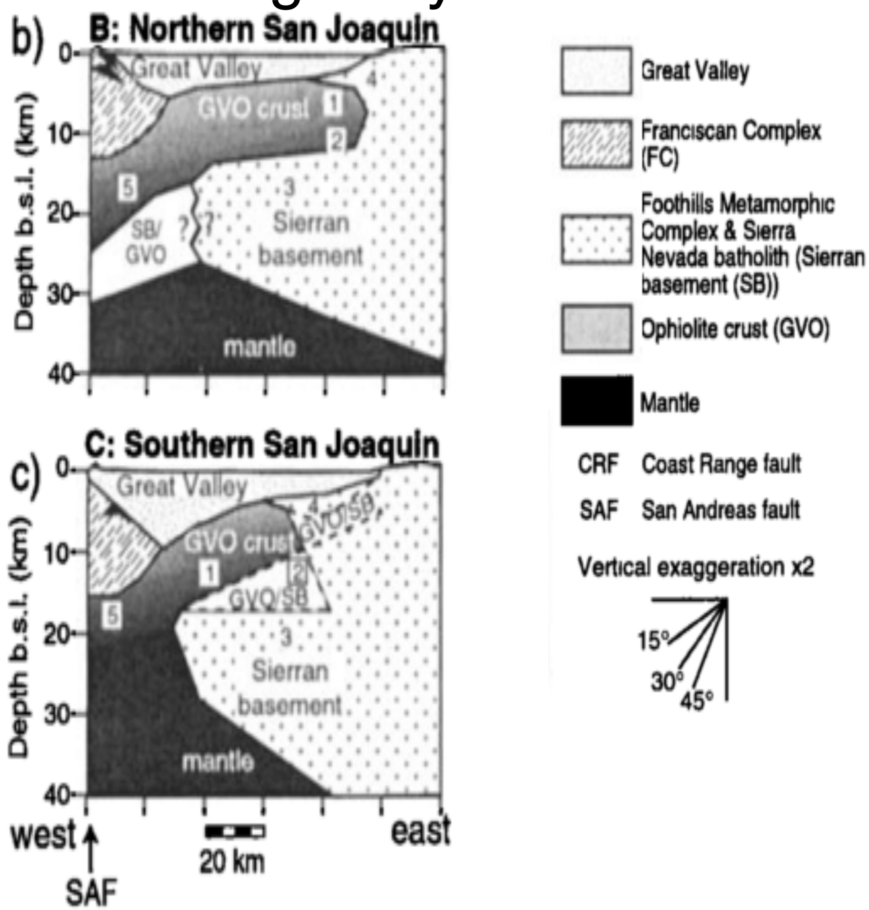
Prior information

1. Vs free to vary in crust
2. Positive Vs gradient in the uppermost mantle

Ophiolitic materials beneath Great Valley



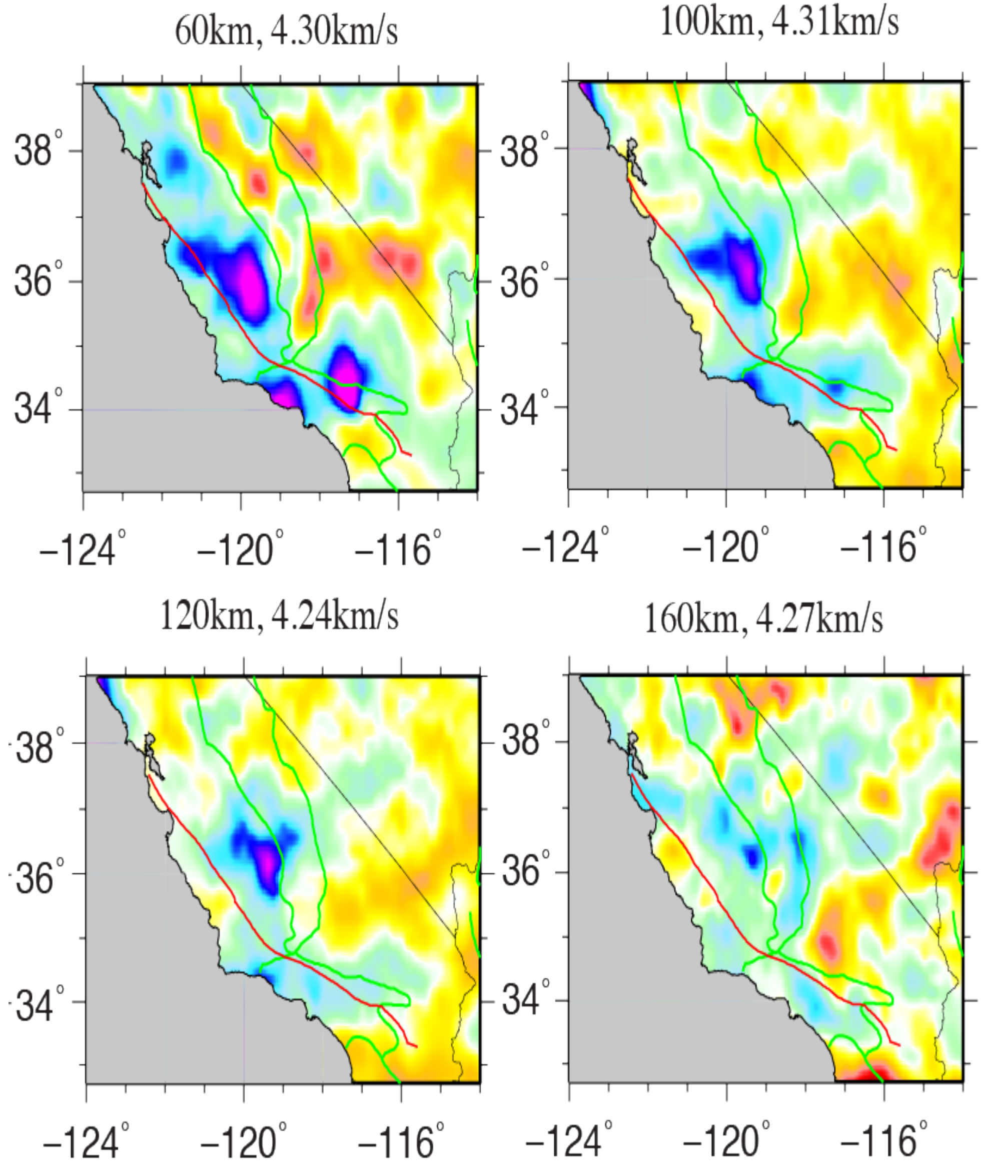
Active source seismic and gravity



- High velocity in the mid crust of the Great Valley

Godfrey & Klemperer, (1998)

Uppermost mantle velocity structures



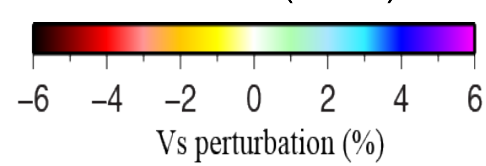
Isabella Anomaly

- circular-shape
- > 4.45 km/s
- diminish at 160 km depth

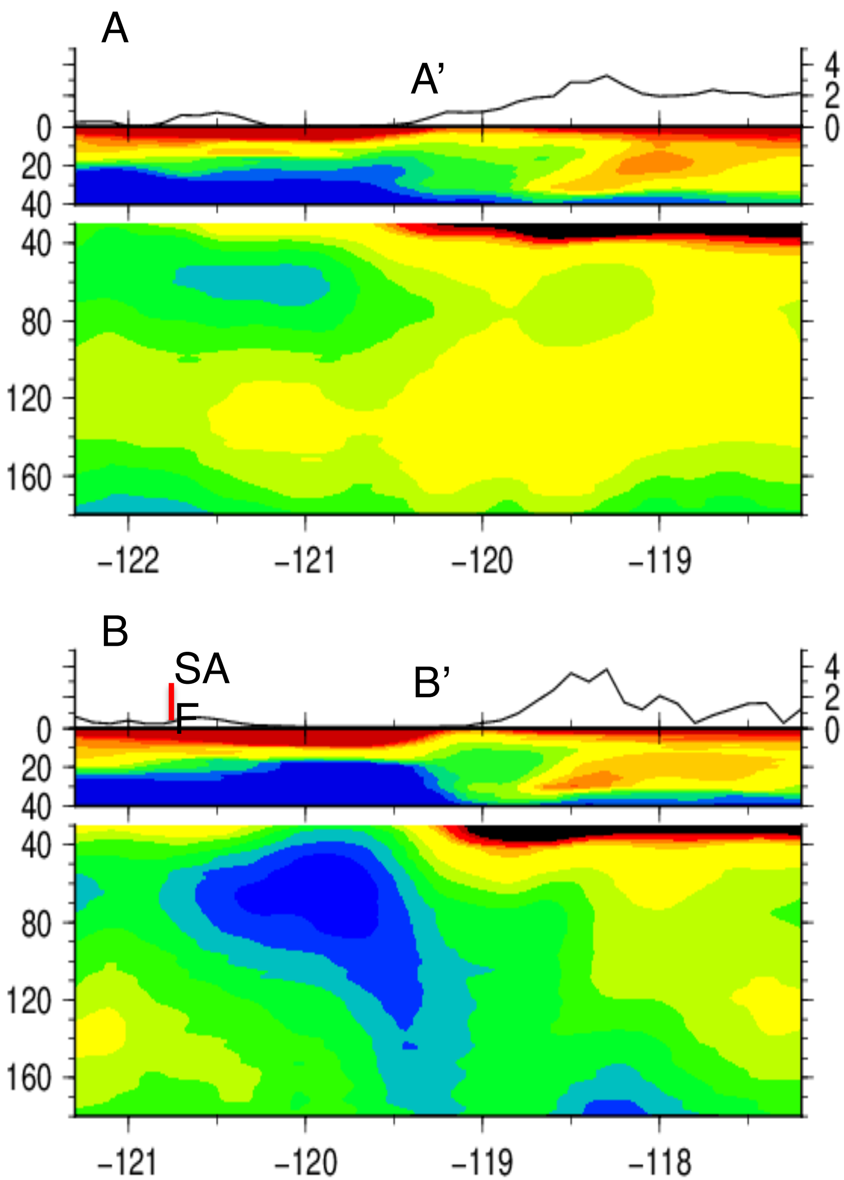
Low velocity from Moho to ~80 km

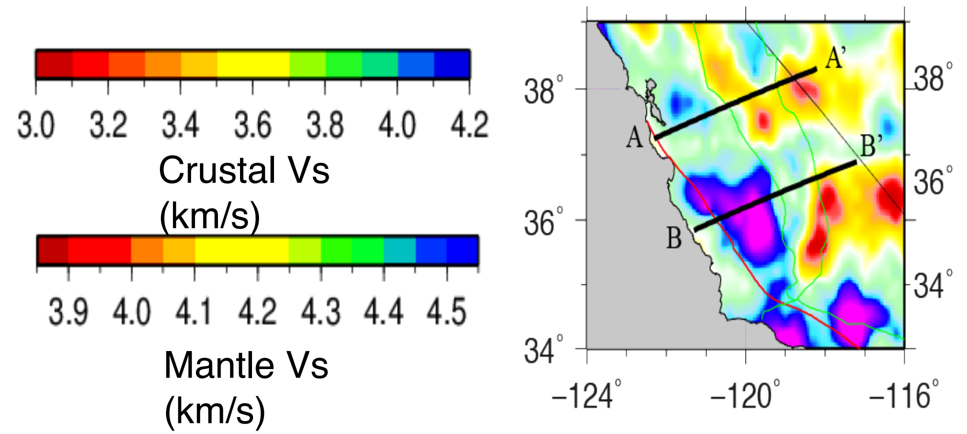
- Correlated with < 1Ma volcanos
- 4.1-4.2 km/s suggests existence of melts

Rau & Forsyth (2011)



Vertical cross sections





Distinct lithospheric structures beneath Great Valley

In the North:

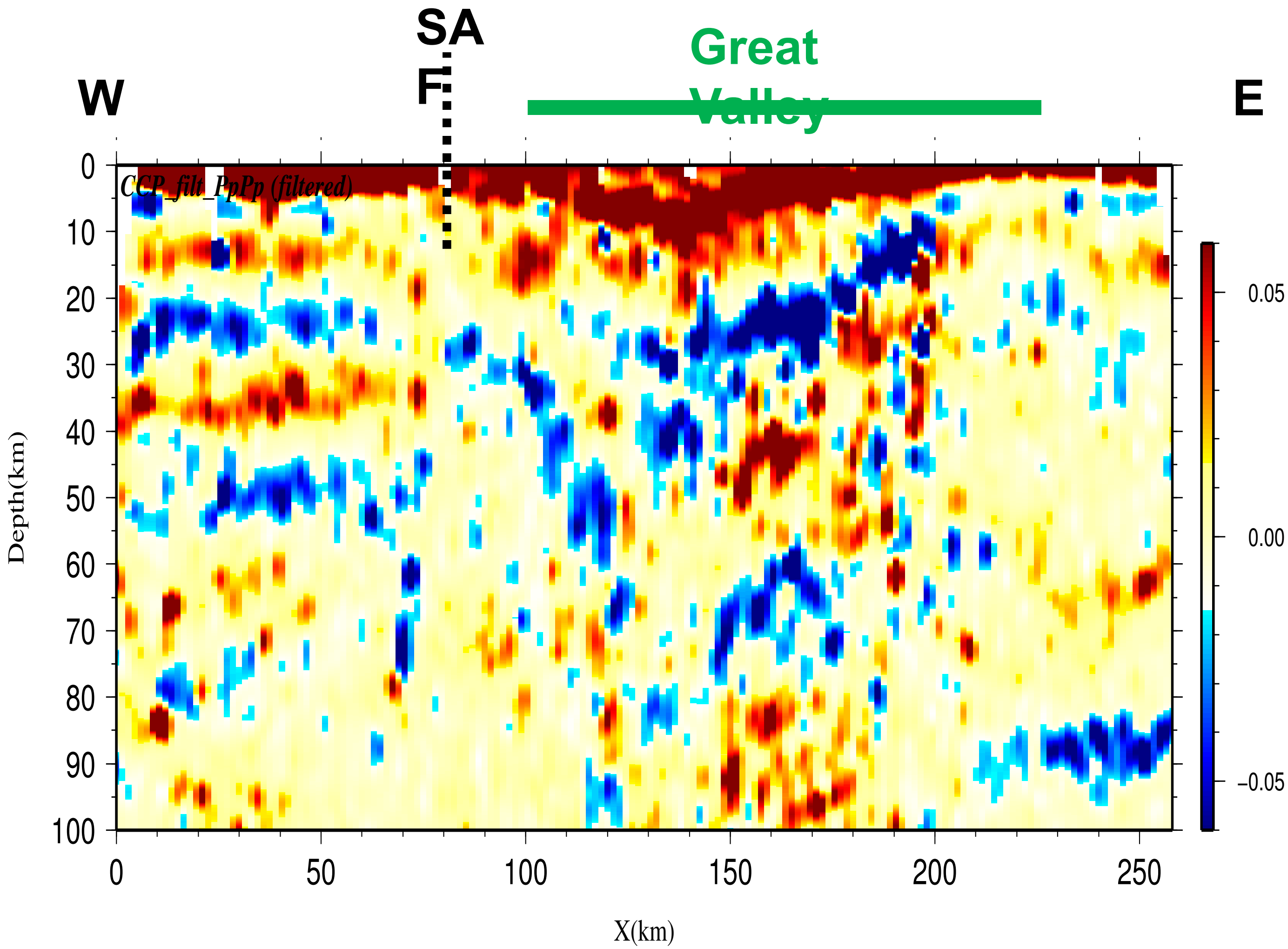
- Low velocity
- Horizontal

In the South:

- High velocity (>4.45 km/s)
- East dipping
- >100 km away from east

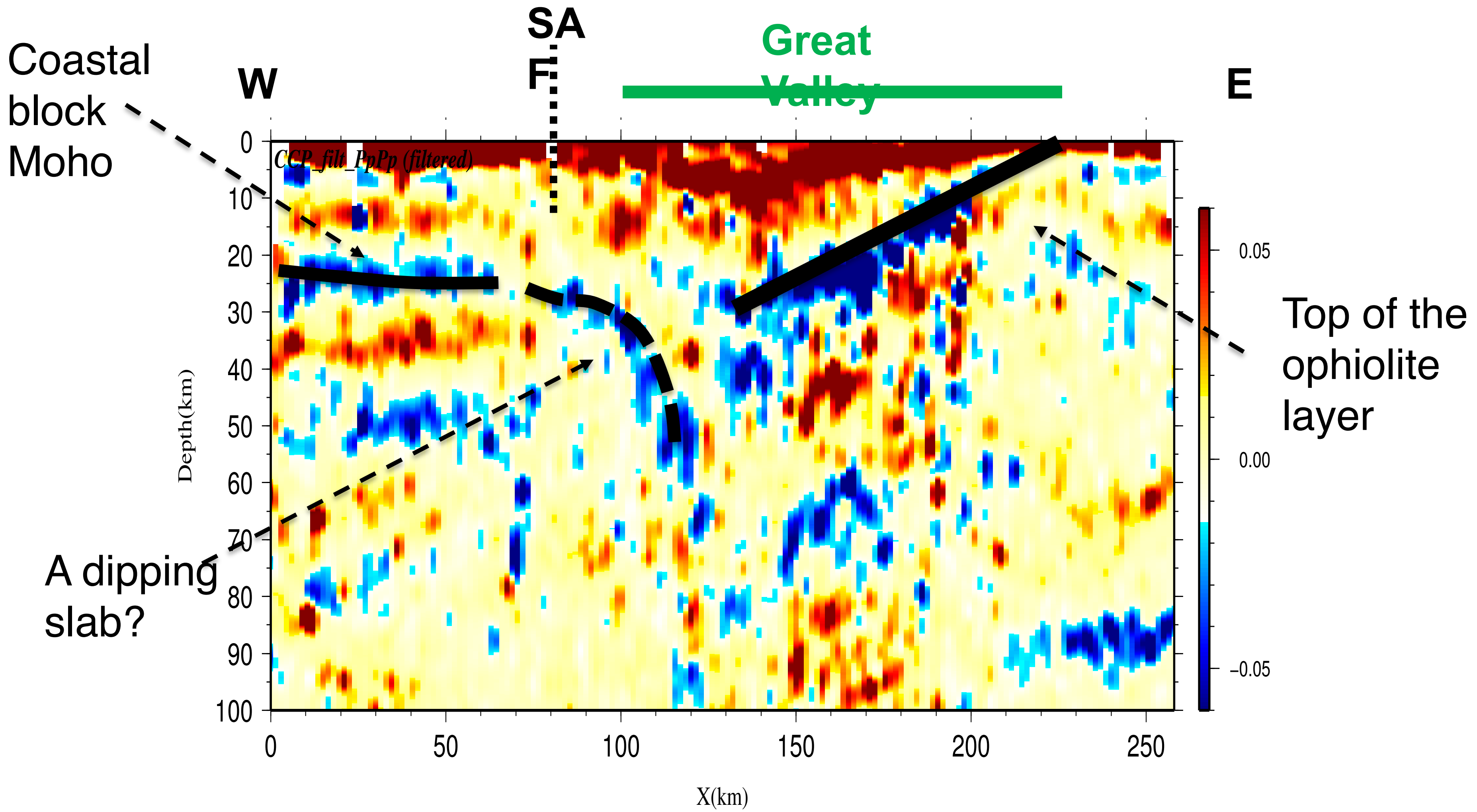
CCP Stacking of PpPp phases

Filtered at 7-20 s



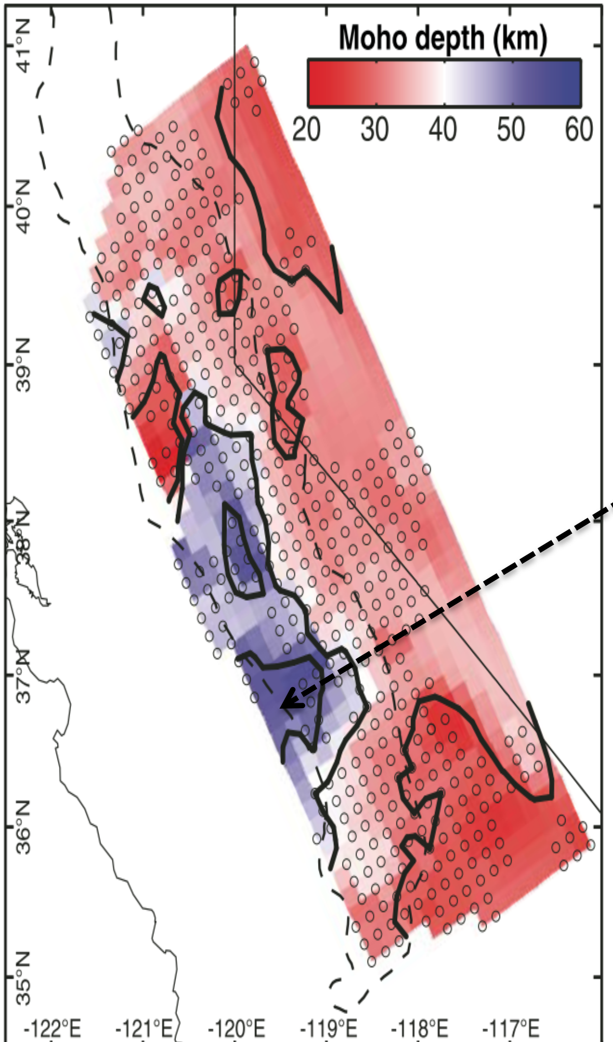
Sara Dougherty (*USGS*)

CCP Stacking of PpPp phases



Sara Dougherty (*USGS*)

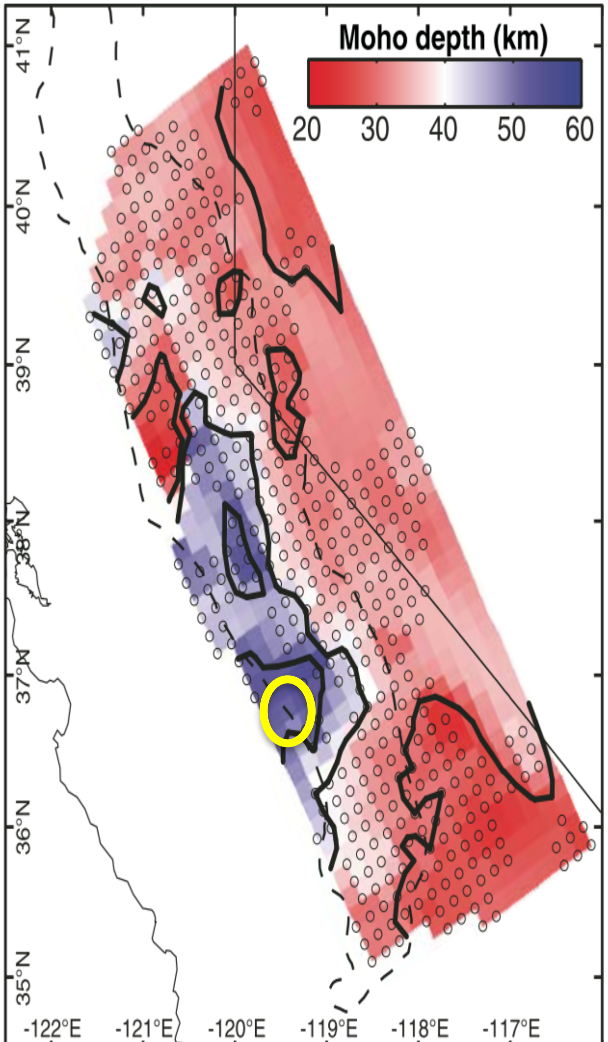
Lack of crustal thickening beneath foothills



Sierra Paradox Experiment
in 1997
~6-month seismic
recordings

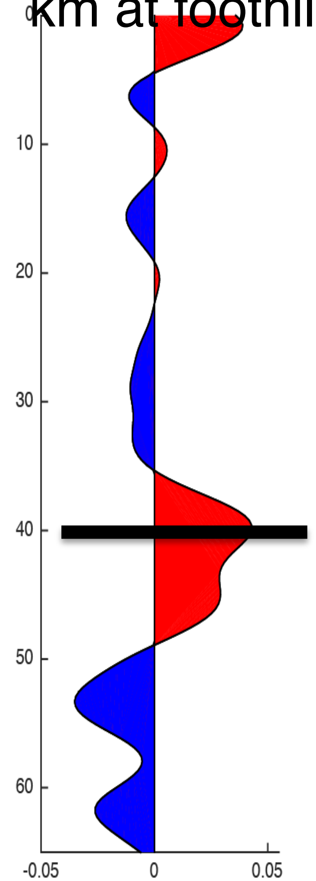
Frassetto et al., 2011

Lack of crustal thickening beneath foothills

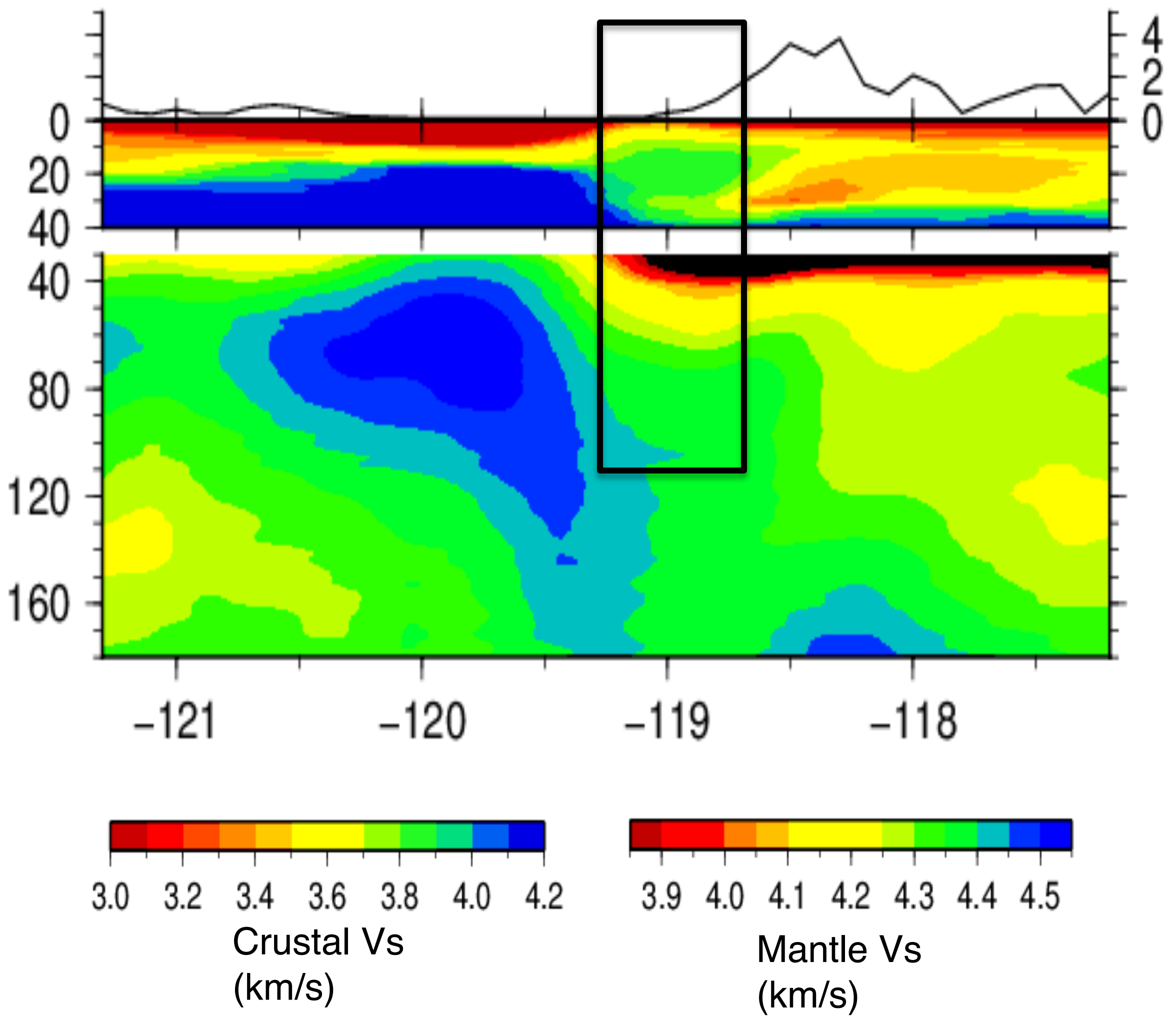


Frassetto et al., 2011

Stacked receiver functions within 15 km at foothills



Lack of crustal thickening beneath foothills



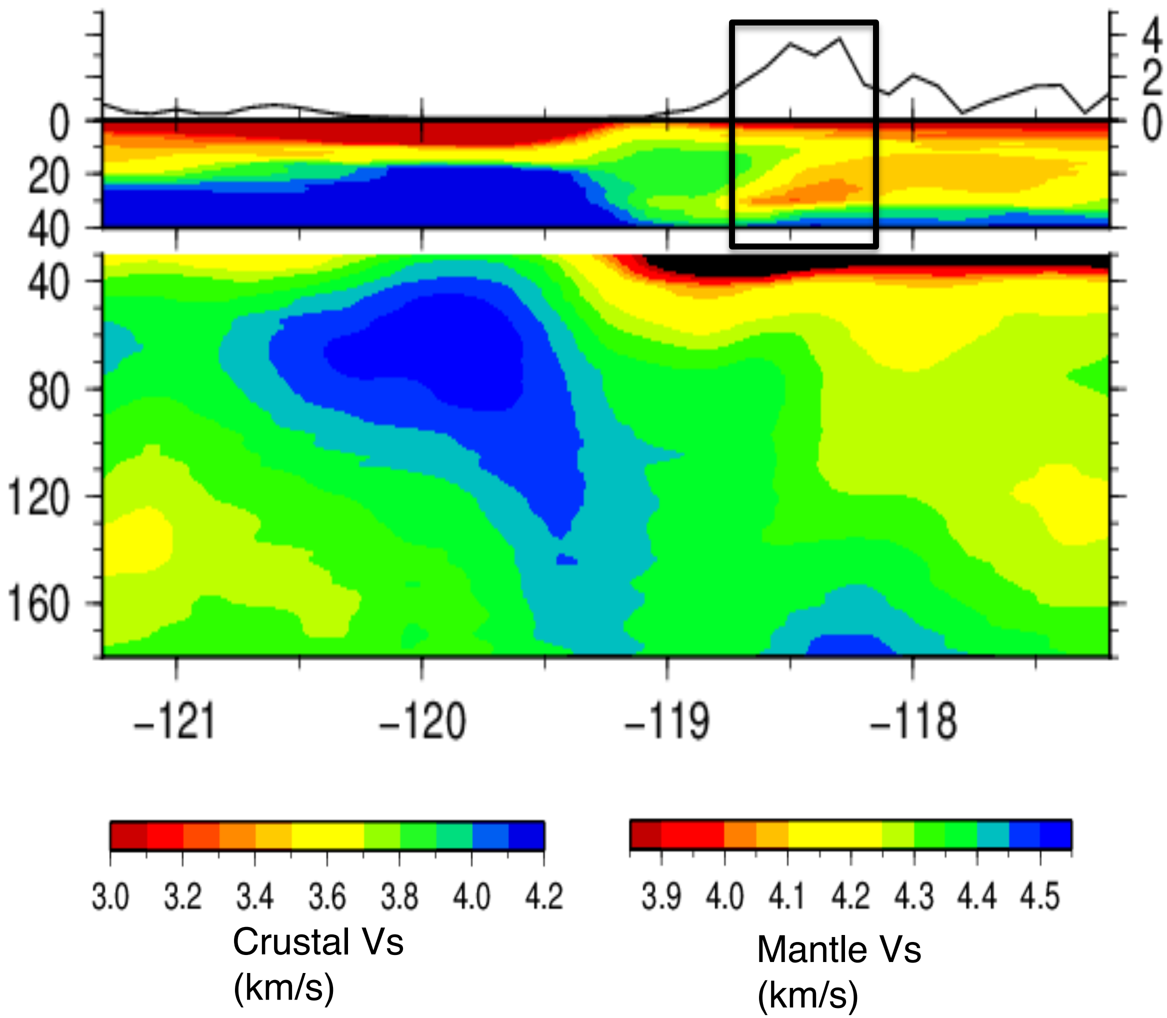
Foothills

- Crustal thickness of ~40 km
- ~4.2 km/s in the uppermost mantle

Eastern Sierra Nevada

- Concentrated low velocities ~3.3 km/s
- Highest topography
- Velocity reversal in the crust helps fit the dispersion
- Compacted delamination

Lack of crustal thickening beneath



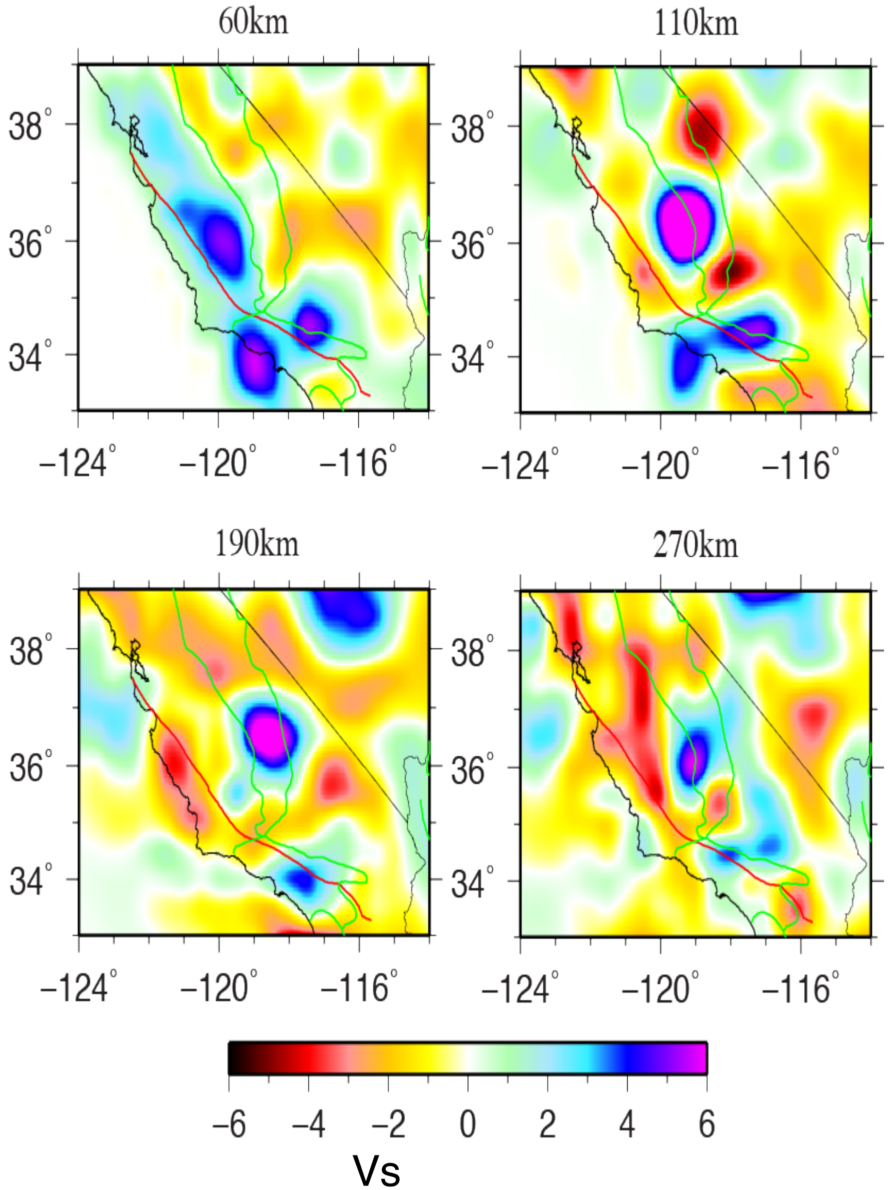
Foothills

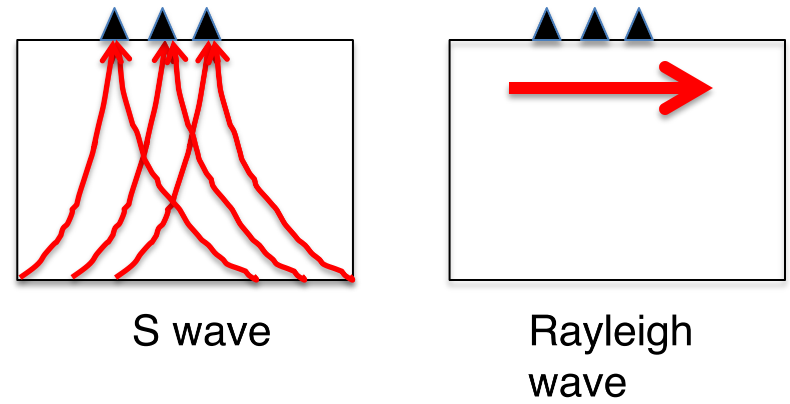
- Crustal thickness of ~40 km
- ~4.2 km/s in the uppermost mantle

Eastern Sierra Nevada

- Concentrated low velocities in the lower crust
- ~3.3 km/s
- Highest topography
- Velocity reversal in the crust required to fit the data
- Compacted delamination

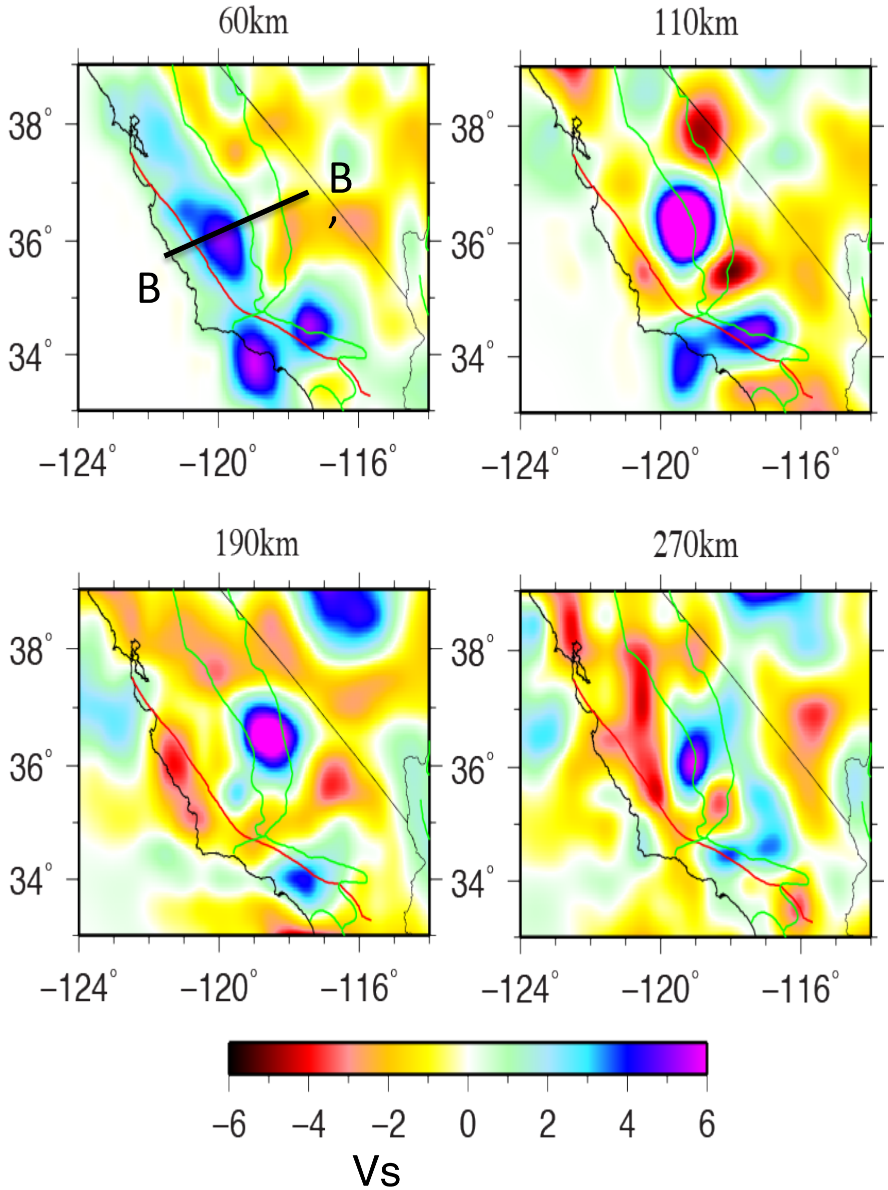
S wave and surface wave joint inversion

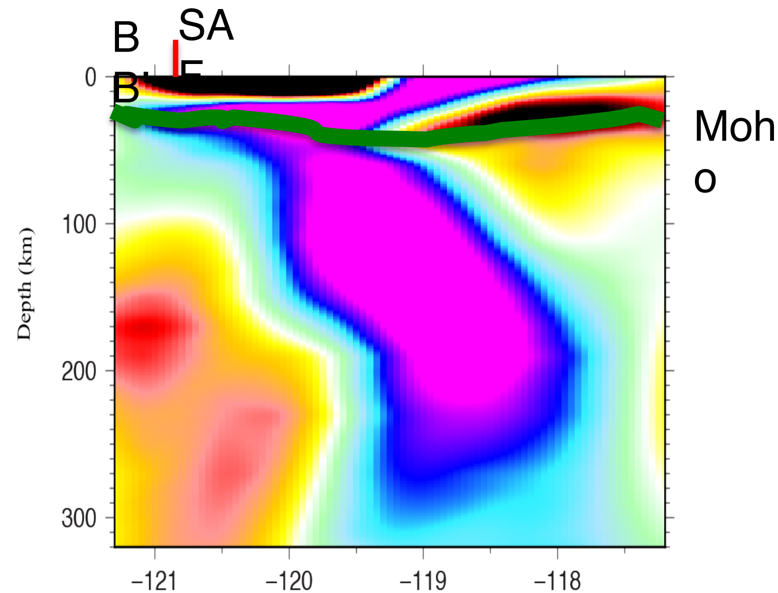




- Starting model from surface wave inversion from 0-160 km
- 3D ray tracing using Fast Marching method

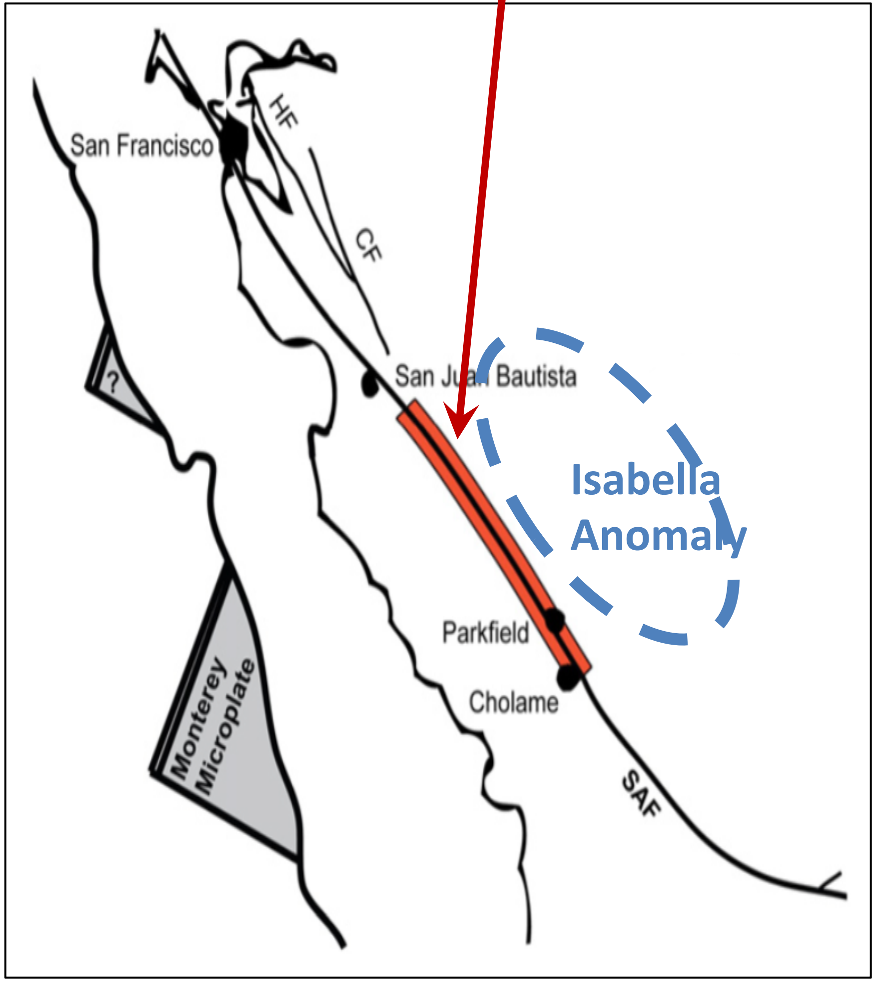
S body wave and surface wave





- Isabella Anomaly extends to ~270 km depth with a dipping angle of ~40°

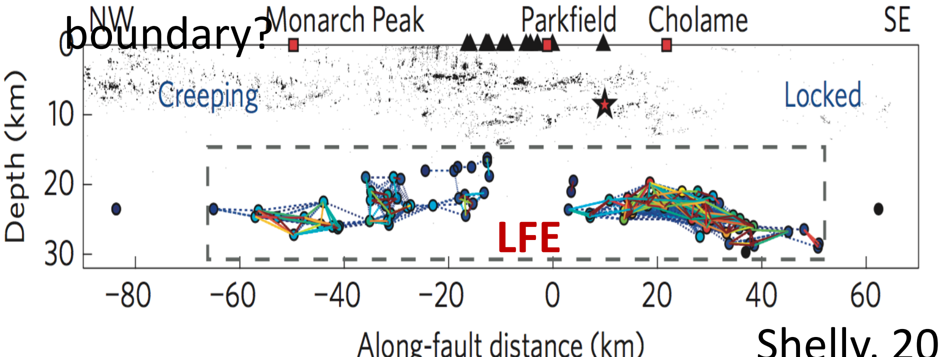
Creeping section of San Andreas fault



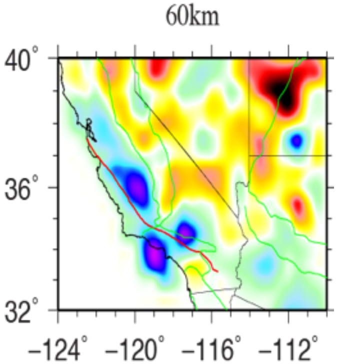
Modified from Pikser et al. 2012

Low frequency earthquakes **(LFE)** deep on the creeping section of the San Andreas fault.

Does a fossil slab influence along strike variations in the present day transform boundary?



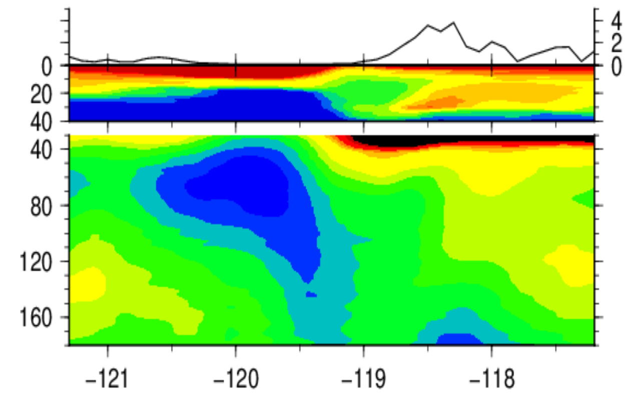
Shelly, 2015



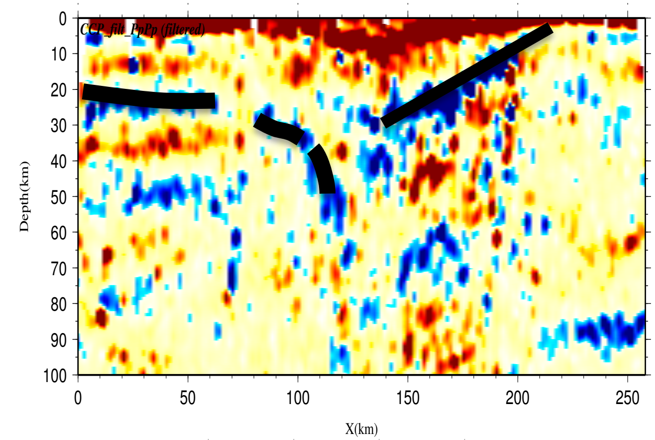
Joint S + Rayleigh tomography

Conclusions & Questions

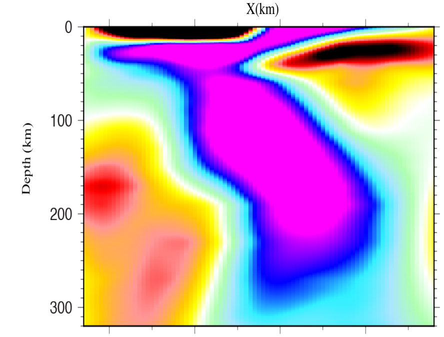
- Surface wave tomography highlights E-dipping IA anomaly in upper mantle and high velocity materials in the mid/lower crust of the Great Valley



- Seismic scattered imaging delineate E-dipping interface and prominent W-dipping interface

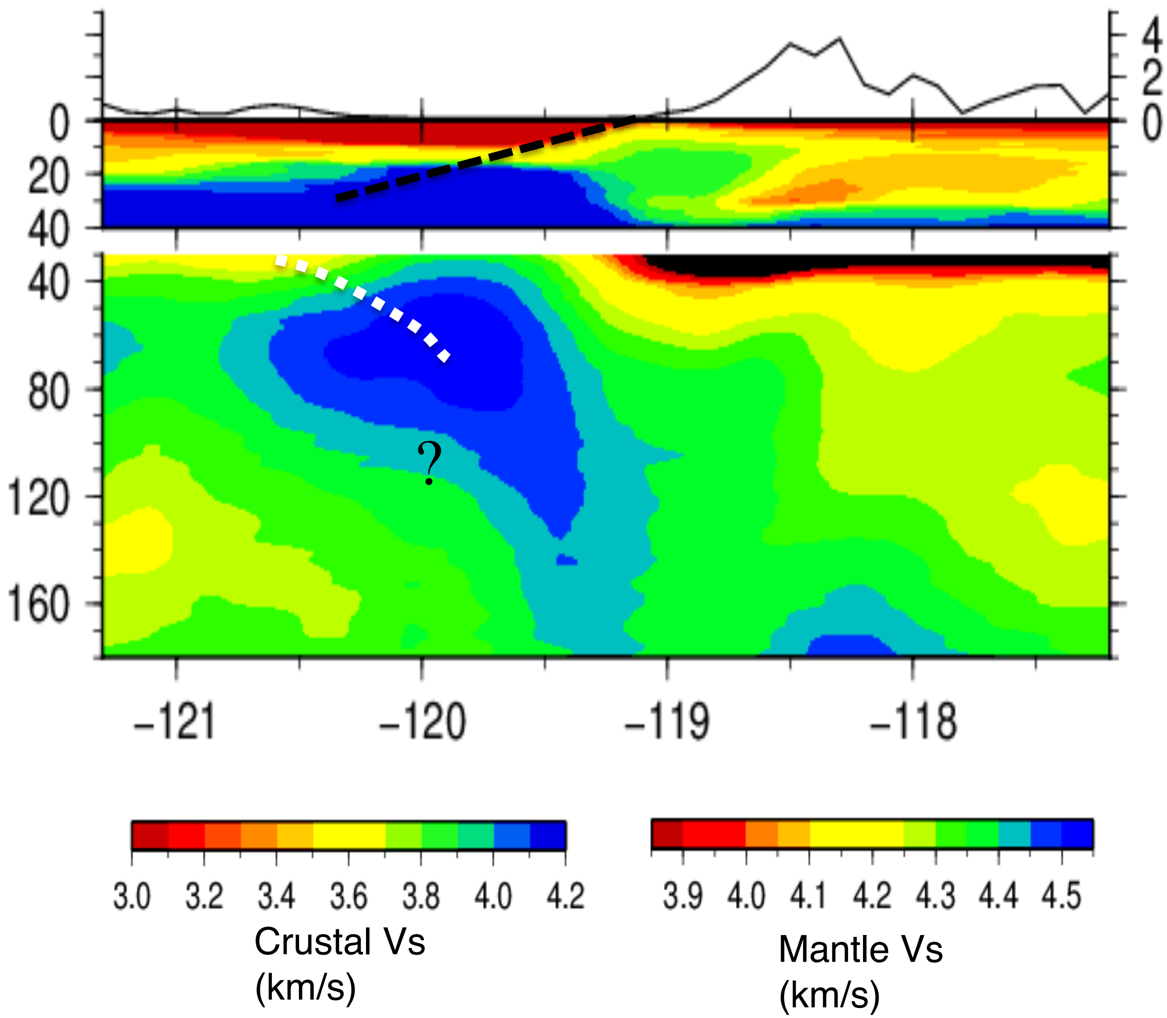


- Body wave and surface wave joint inversion images IA extend to ~270 km with an angle of 40 °



- Suggest fossil slab origin for Isabella anomaly

Conclusions & Questions



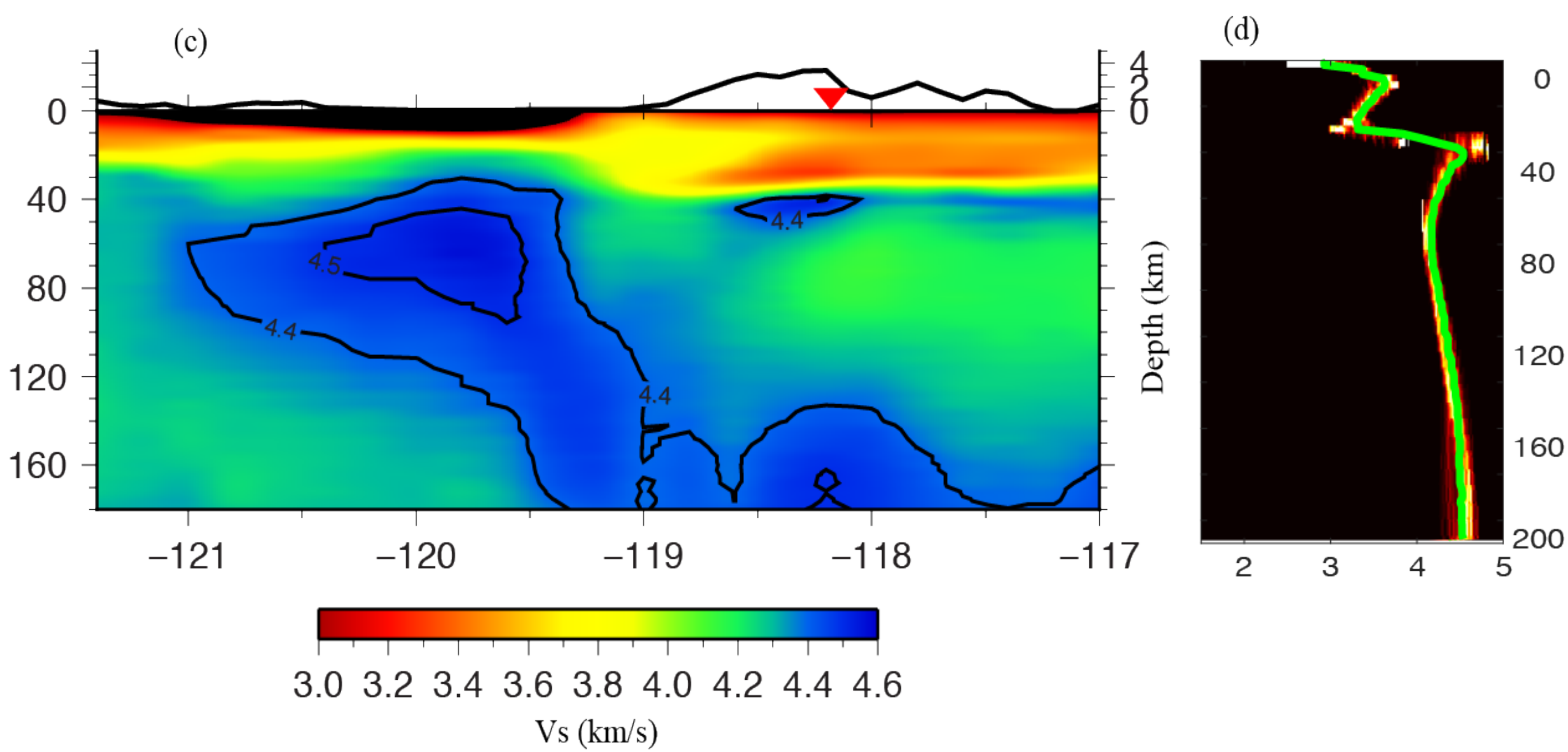
- Resolution test of seismic scattering & surface wave tomography in progress

Thank you for your attention!

Questions?

Effects of prior constraints on

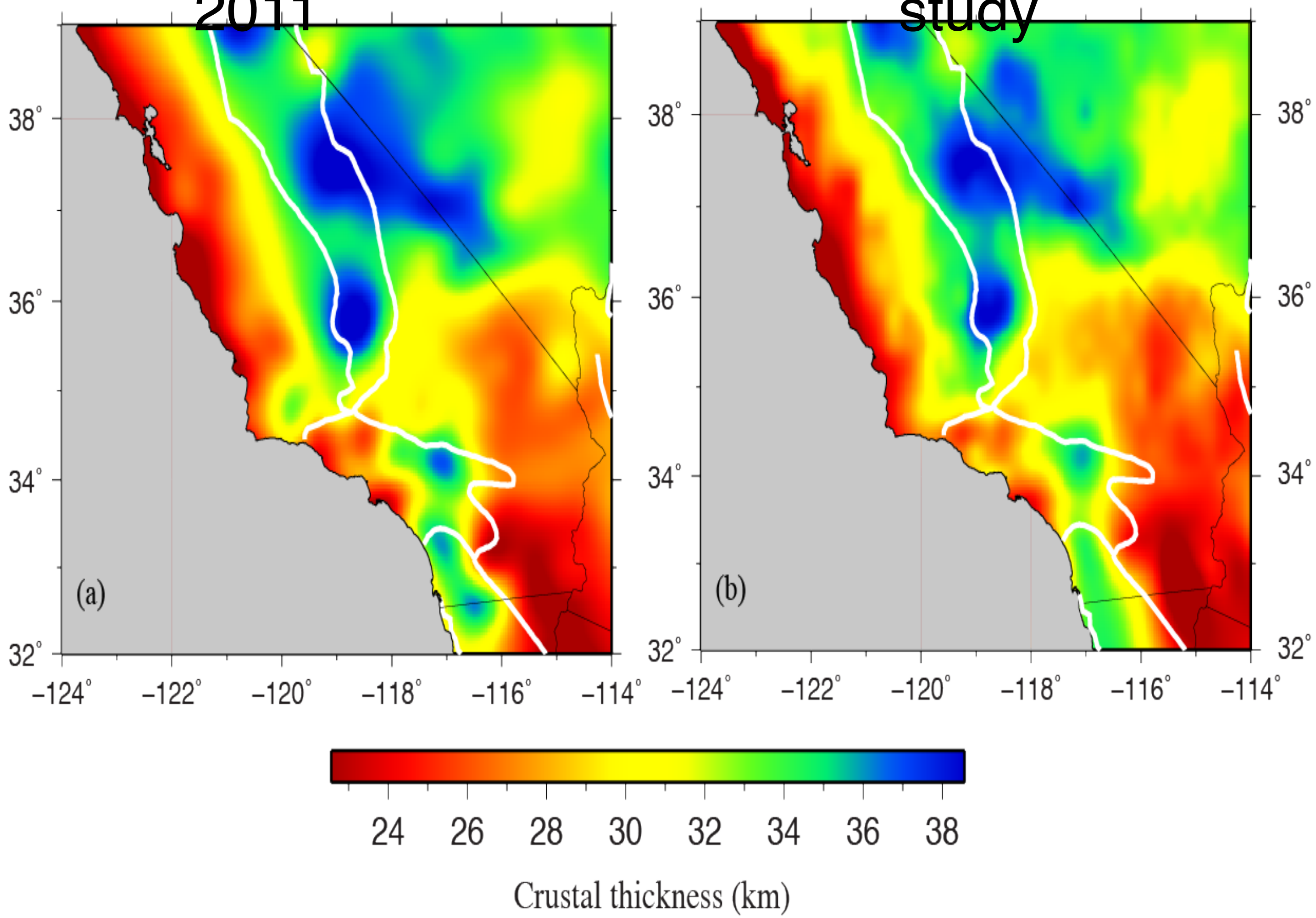
- Positive Vs gradient in the uppermost mantle layer



Input and Output Moho model

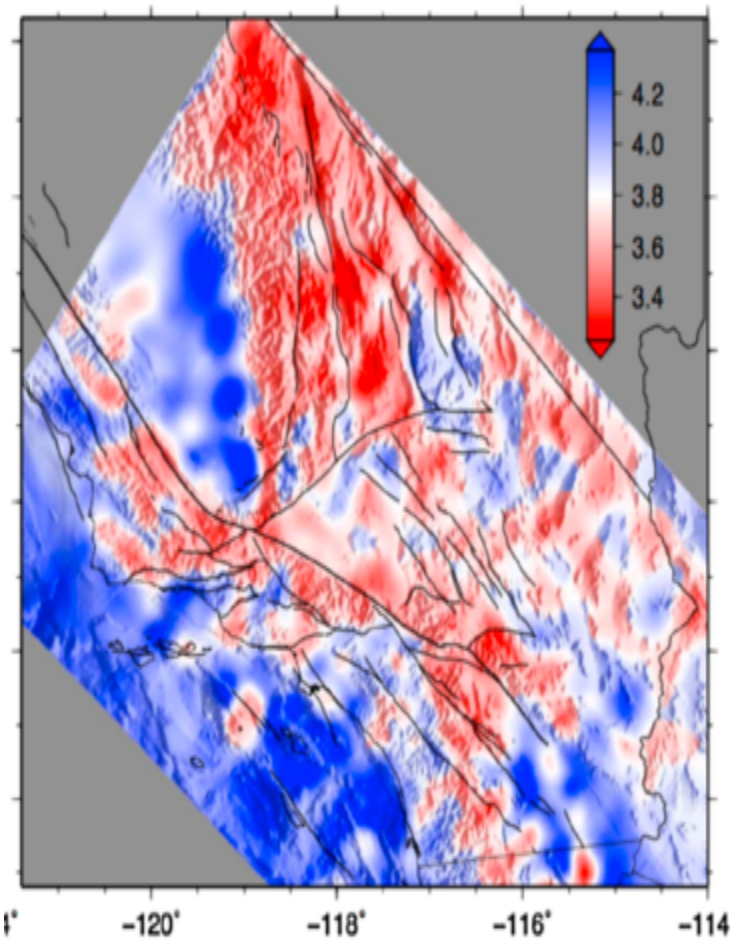
Tape et al., 2011

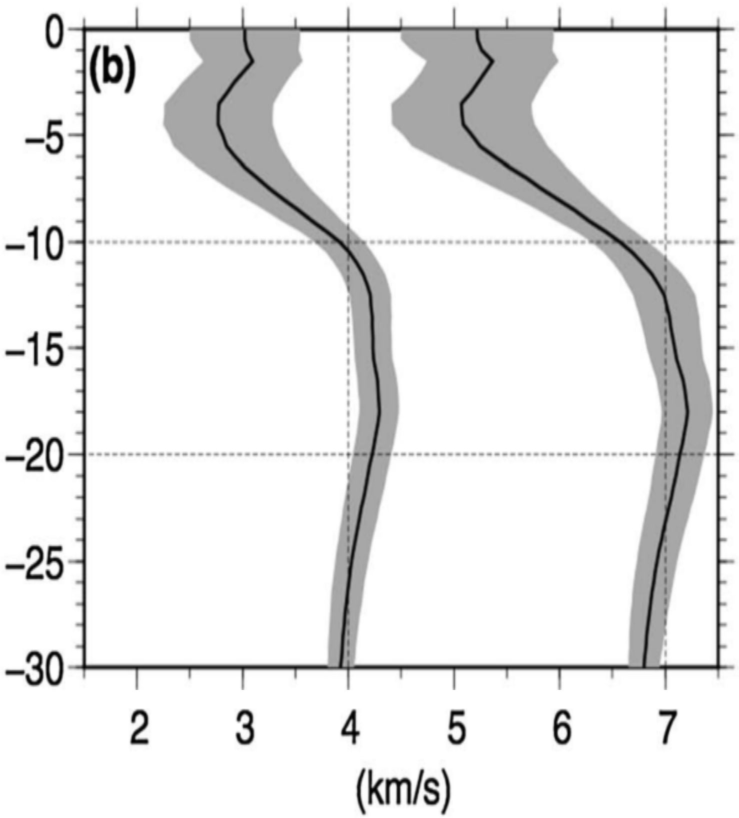
This study



Full-waveform tomography in S. California

CVM–S4.26 Vs @ 20 km

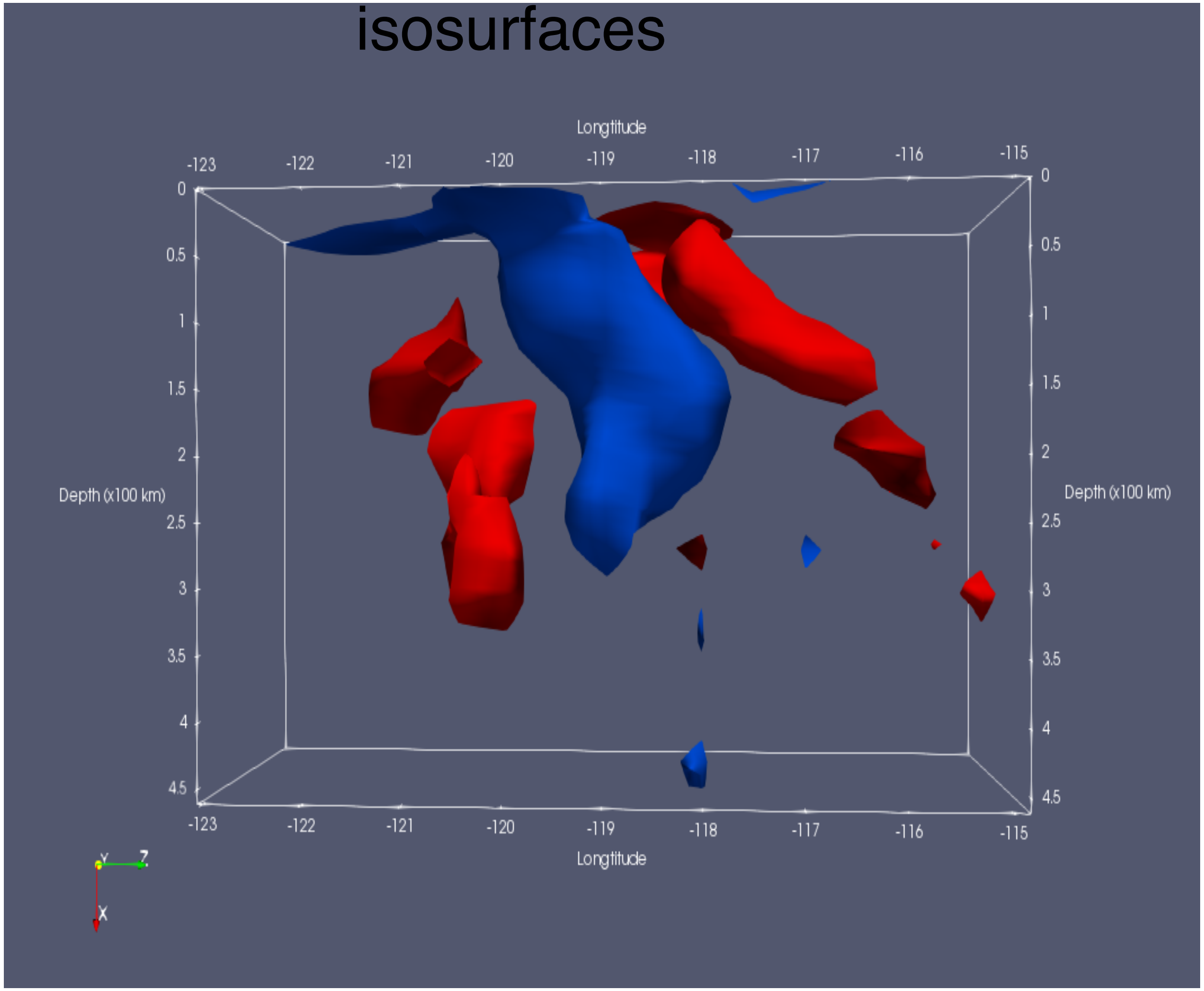




Lee et al., 2014

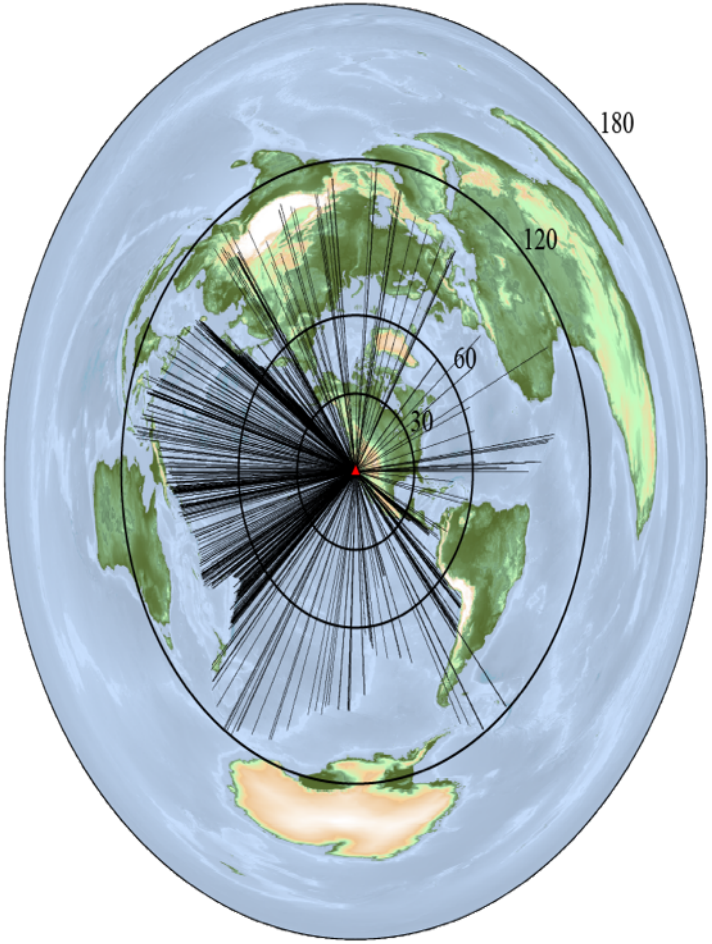
Isabella anomaly in 3D

3% and -3% isosurfaces

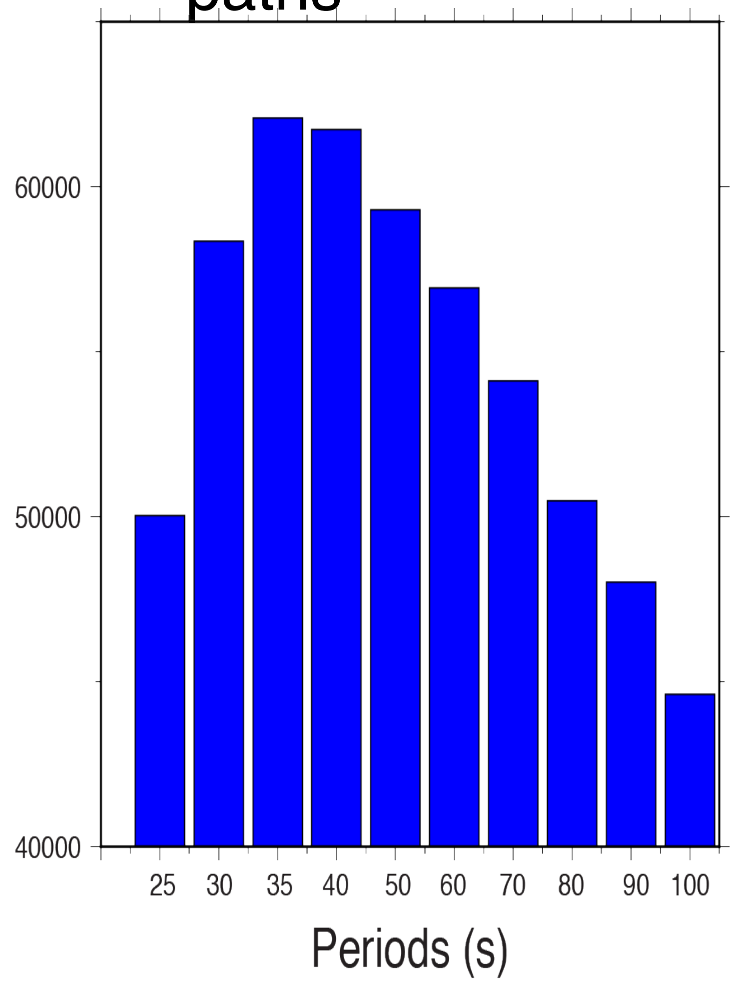


Teleseismic data

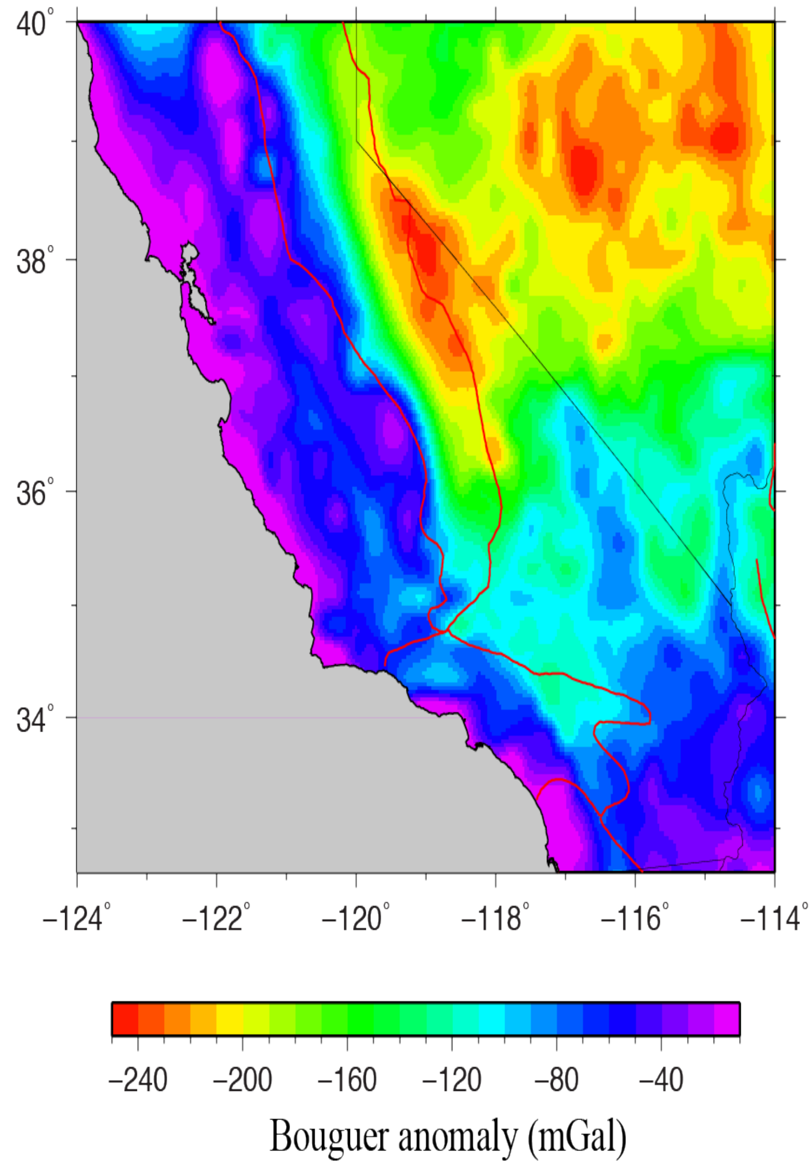
Event distribution



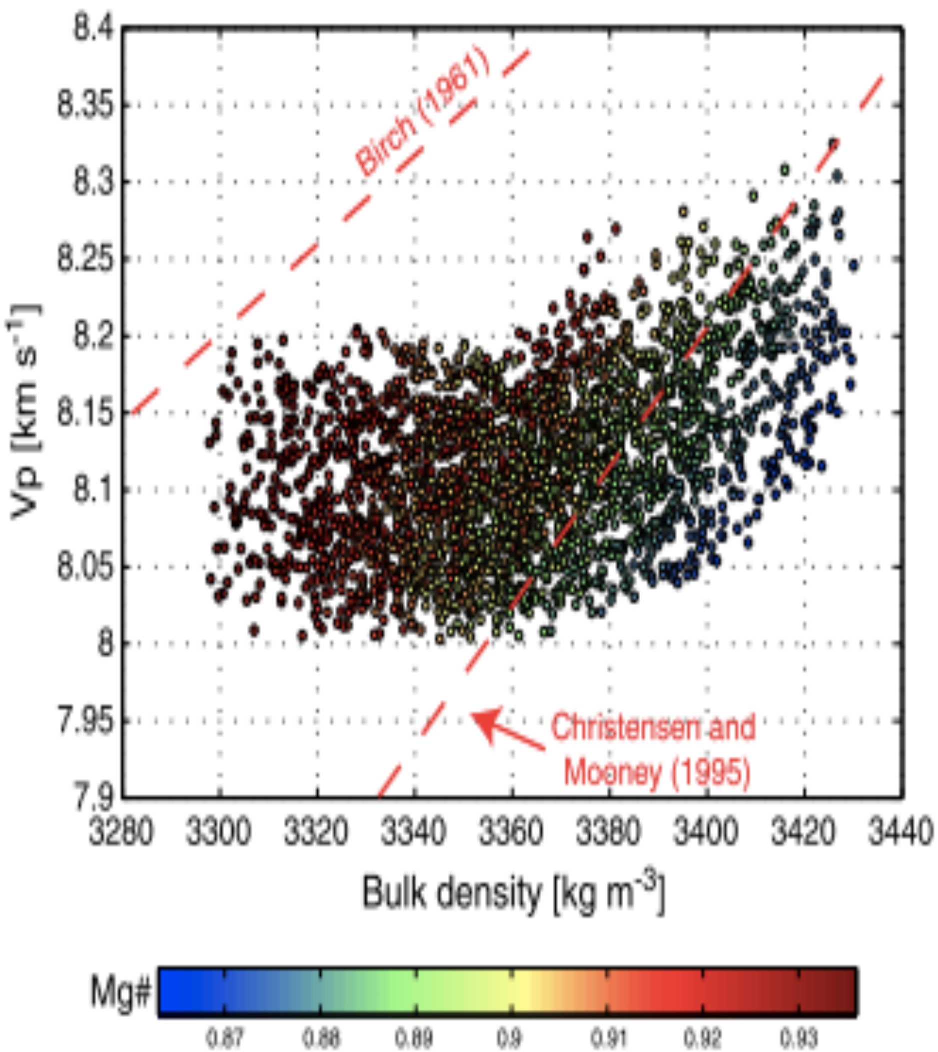
Number of Ray paths



Bouguer gravity anomaly



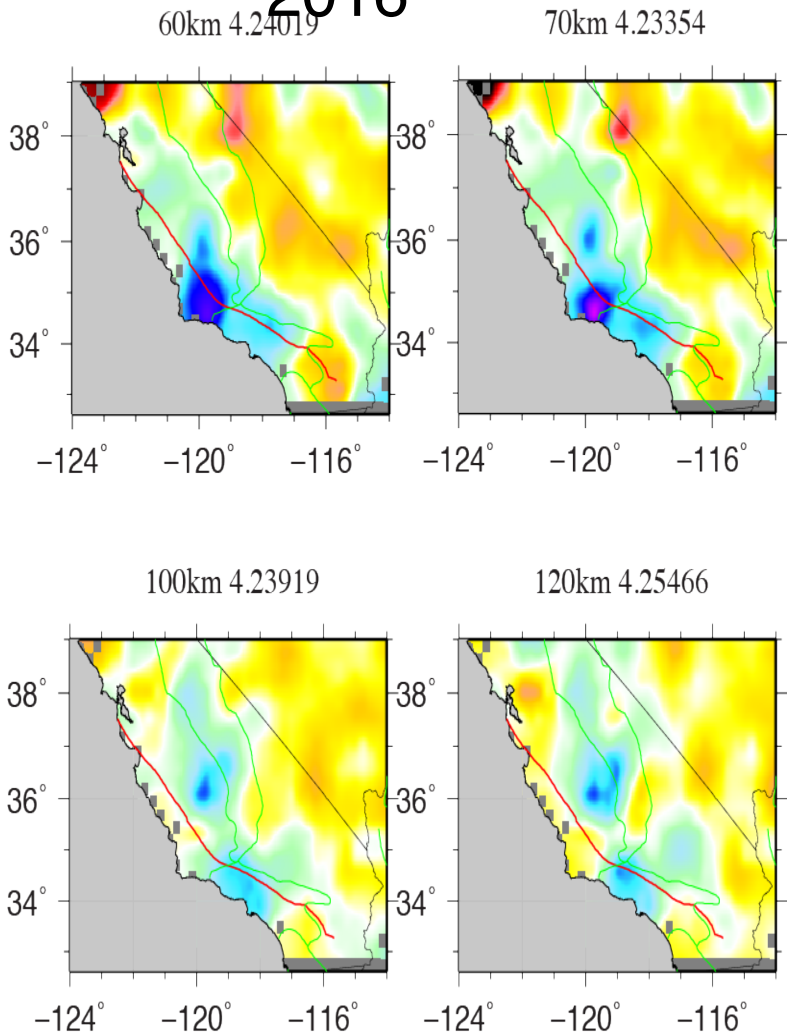
Density vs. Mg#



Afonso et al., 2013

Model comparison

Shen et al., 2016



This study