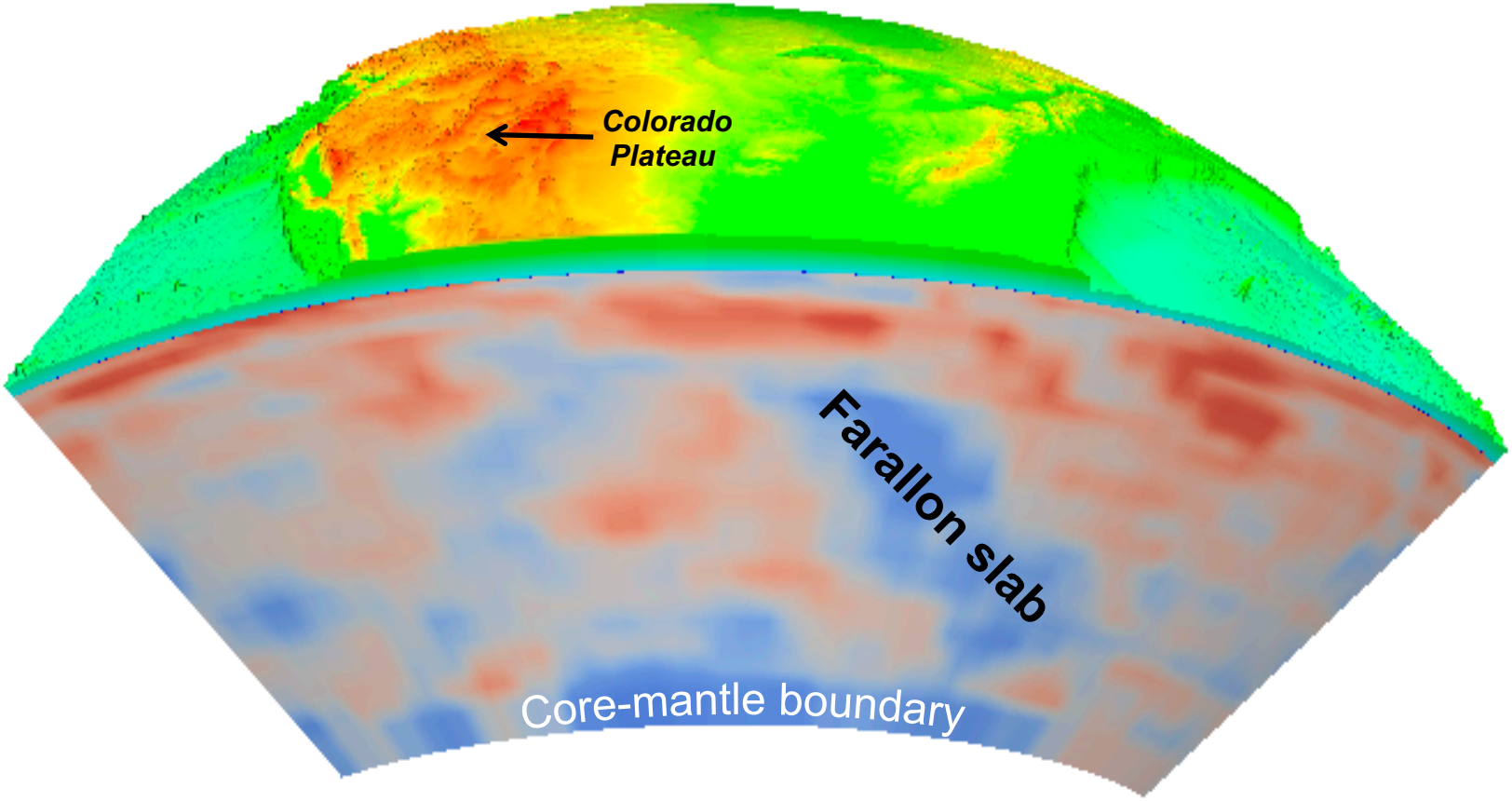
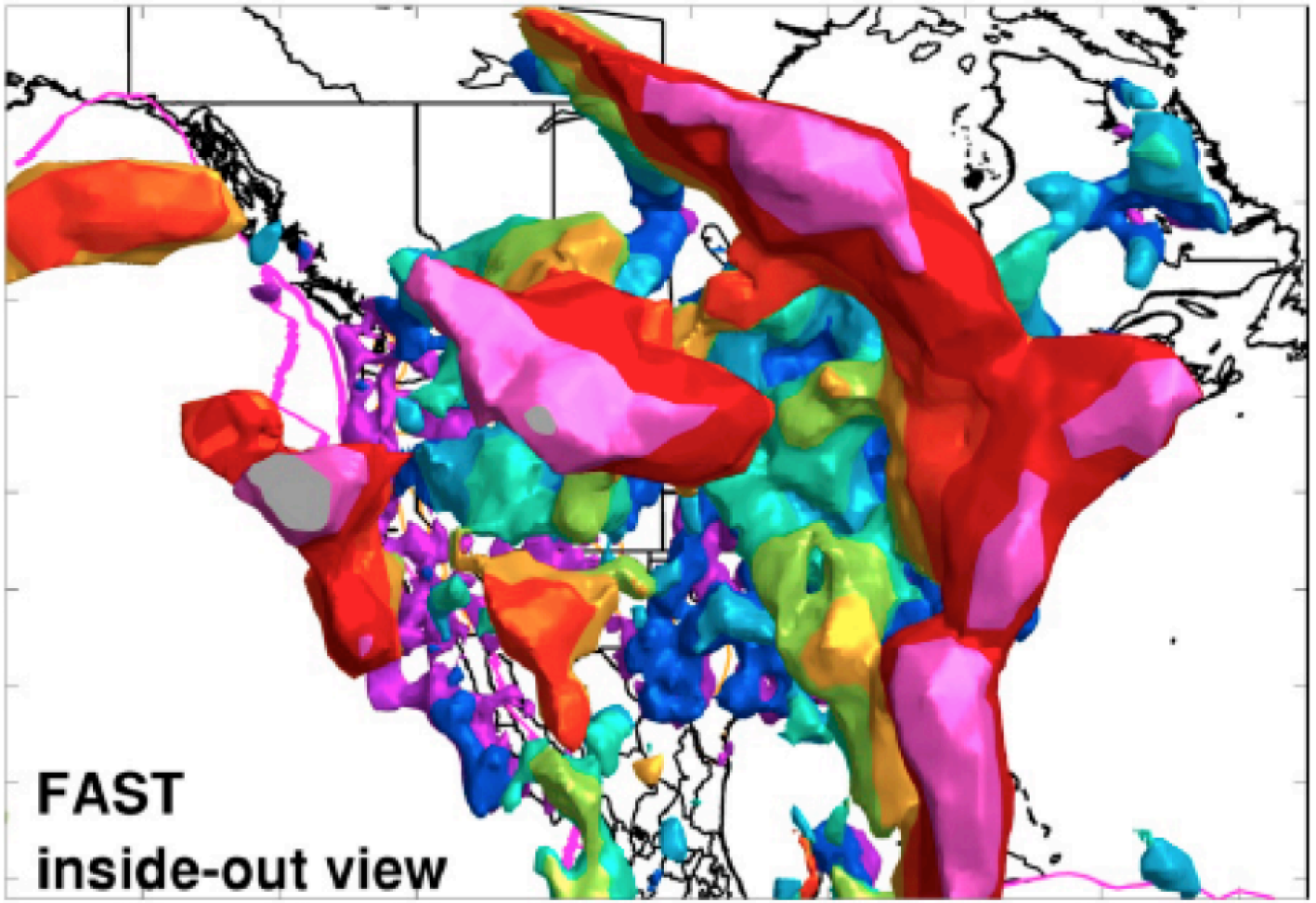
Impact of Farallon subduction on the evolution of the North American continent

Lijun Liu, Quan Zhou

University of Illinois

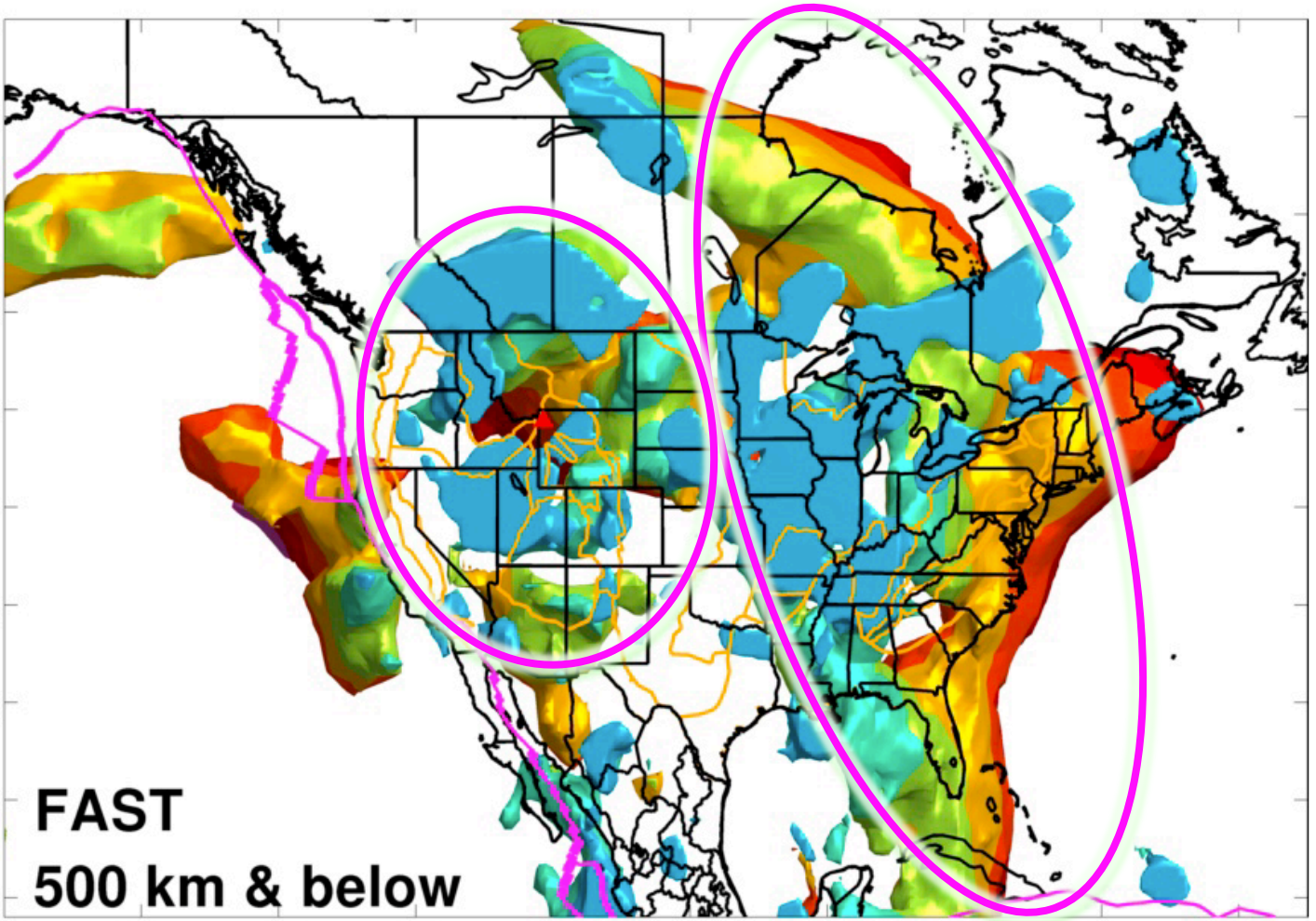


More recent seismic tomography



(Sigloch, *G^3*, 2011)

More recent seismic tomography



(Sigloch, *G^3*, 2011)

North American Tectonics

Elevation change:

>100 Ma: ***Above sea level***

100 - 65 Ma: ***Western Interior Seaway (WIS)***

< 80 Ma: ***Western U.S. uplift (no less than 2 km uplift)***

(http://jan.ucc.nau.edu/~rcb

North American Tectonics

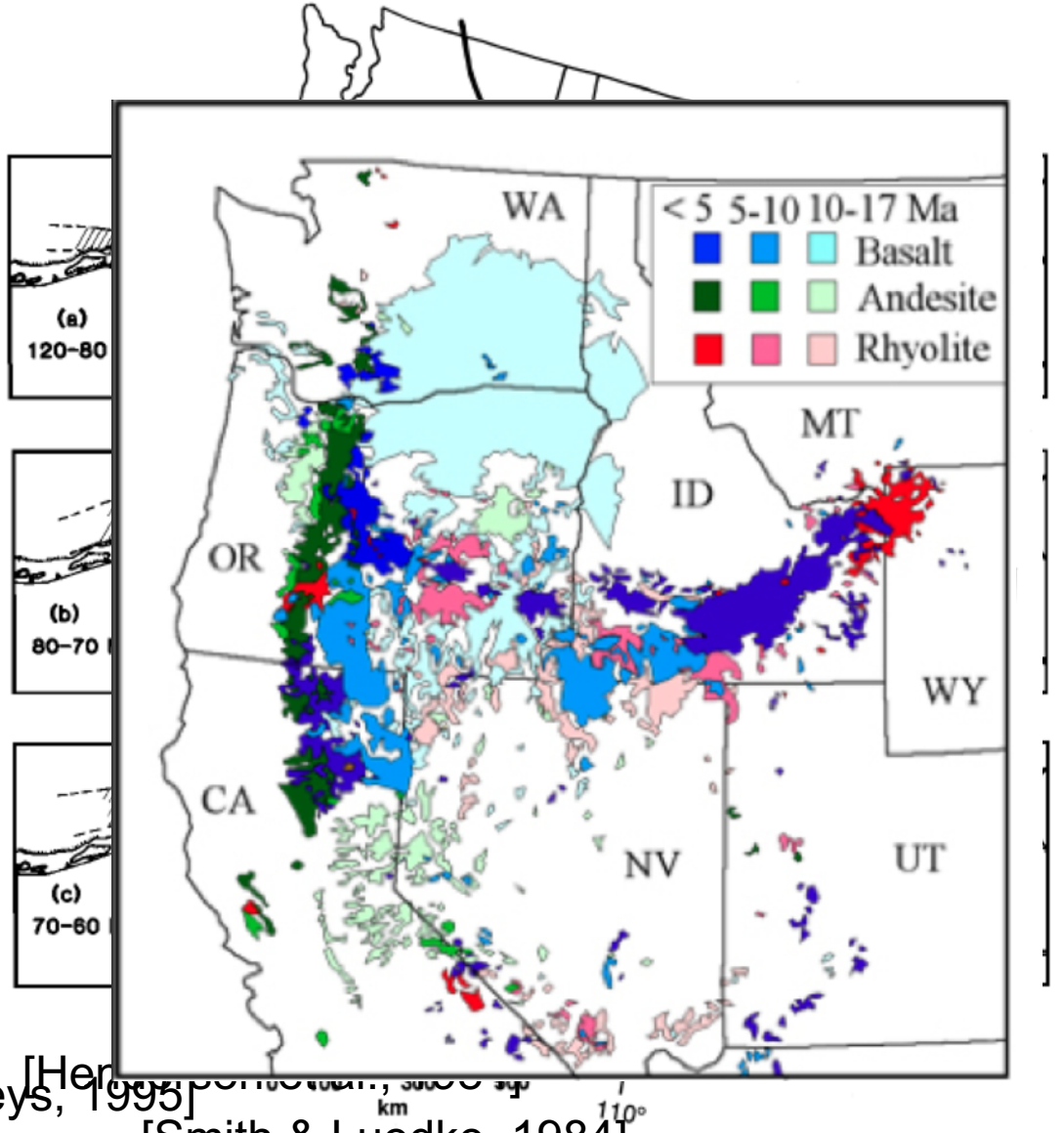
Volcanic history:

> 80 Ma: ***Normal volcanic arc***

80 - 50 Ma: ***Arc migration & magmatic lull***

50 - 20 Ma: ***Ignimbrite flare up***

< 17 Ma: ***CRB & YS-NB hotspot tracks***

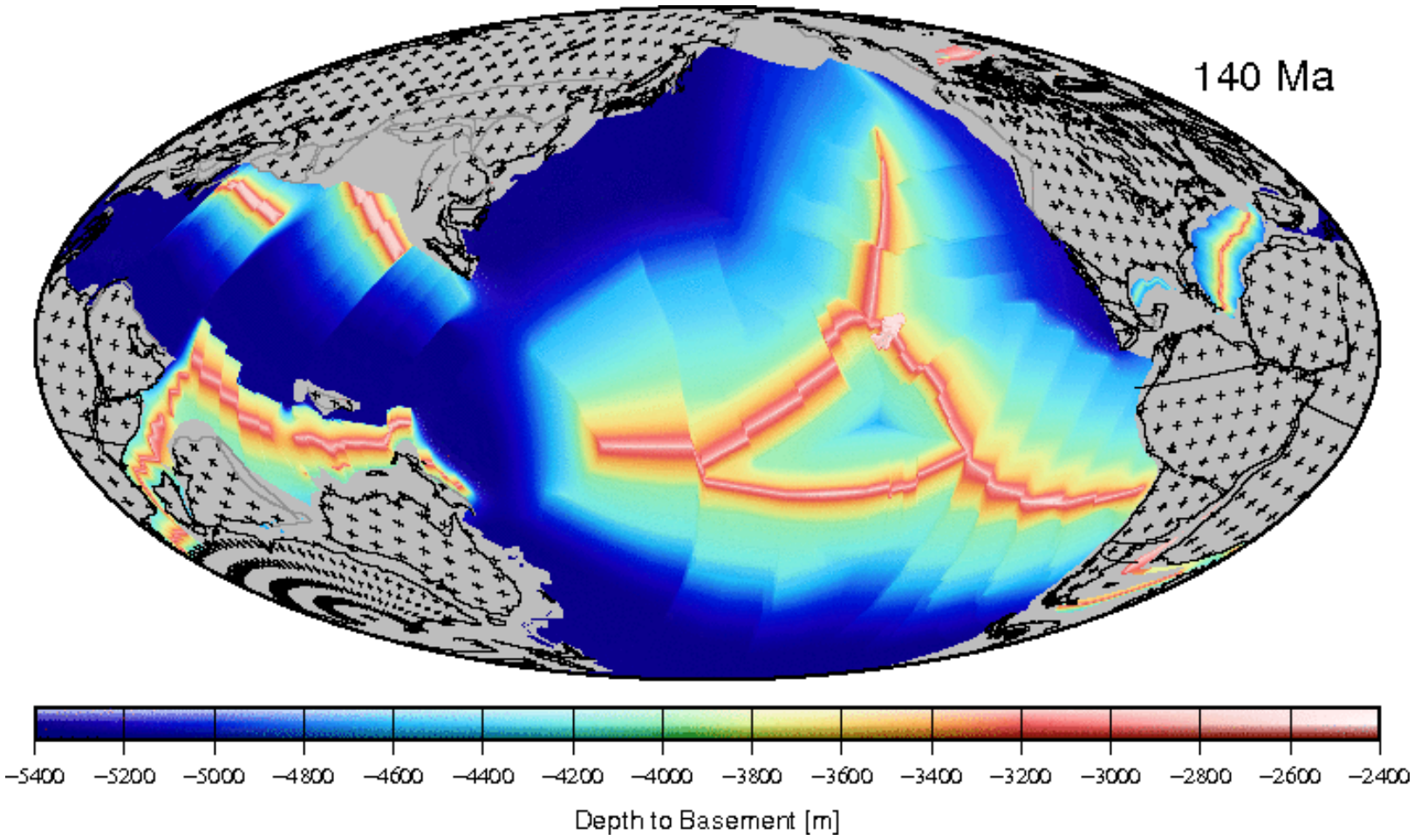


[Humphreys, 1995]

[Smith & Luedke, 1984]

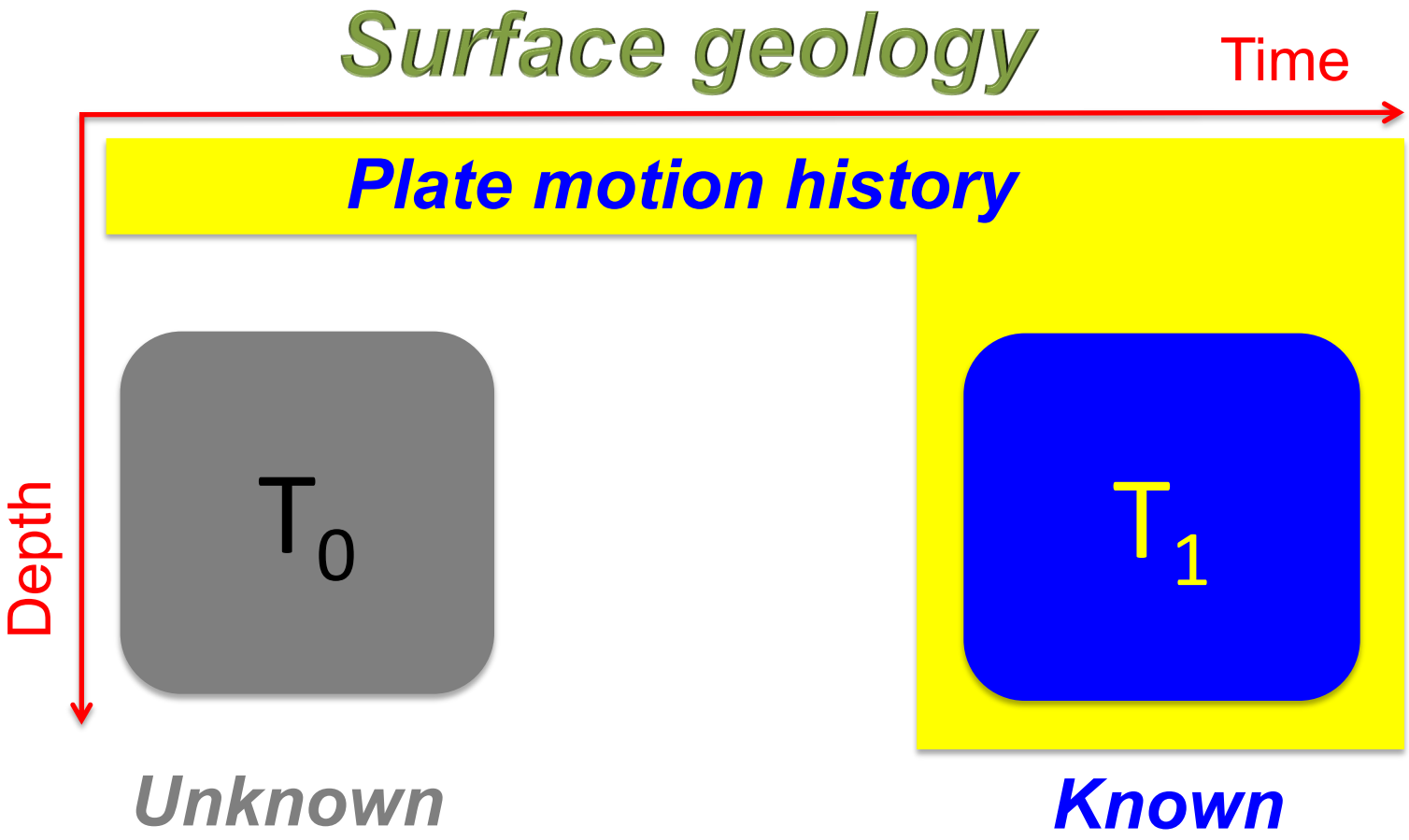
North American Tectonics

Subduction since the Cretaceous

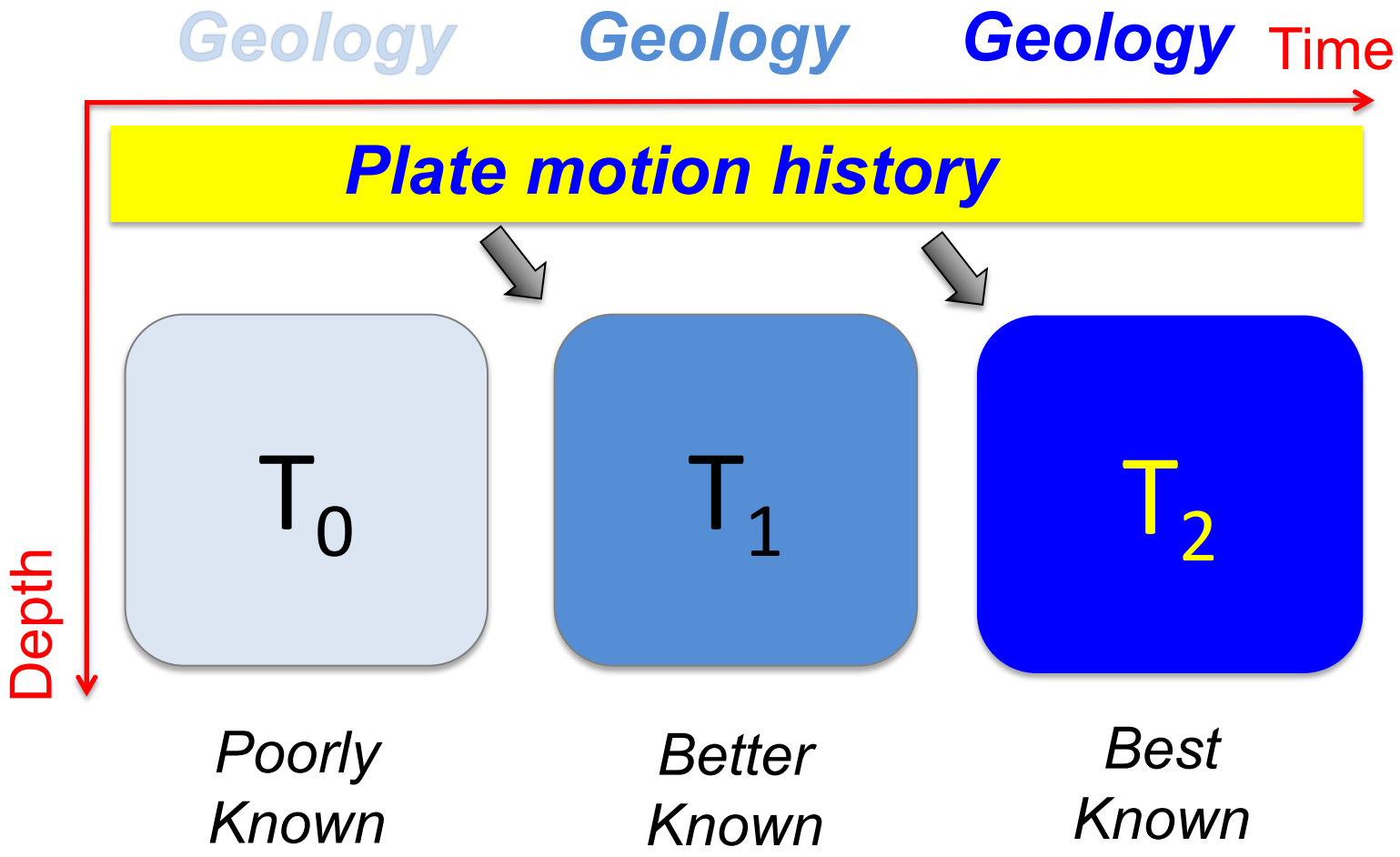


(Müller et al., *G^3*, 2008)

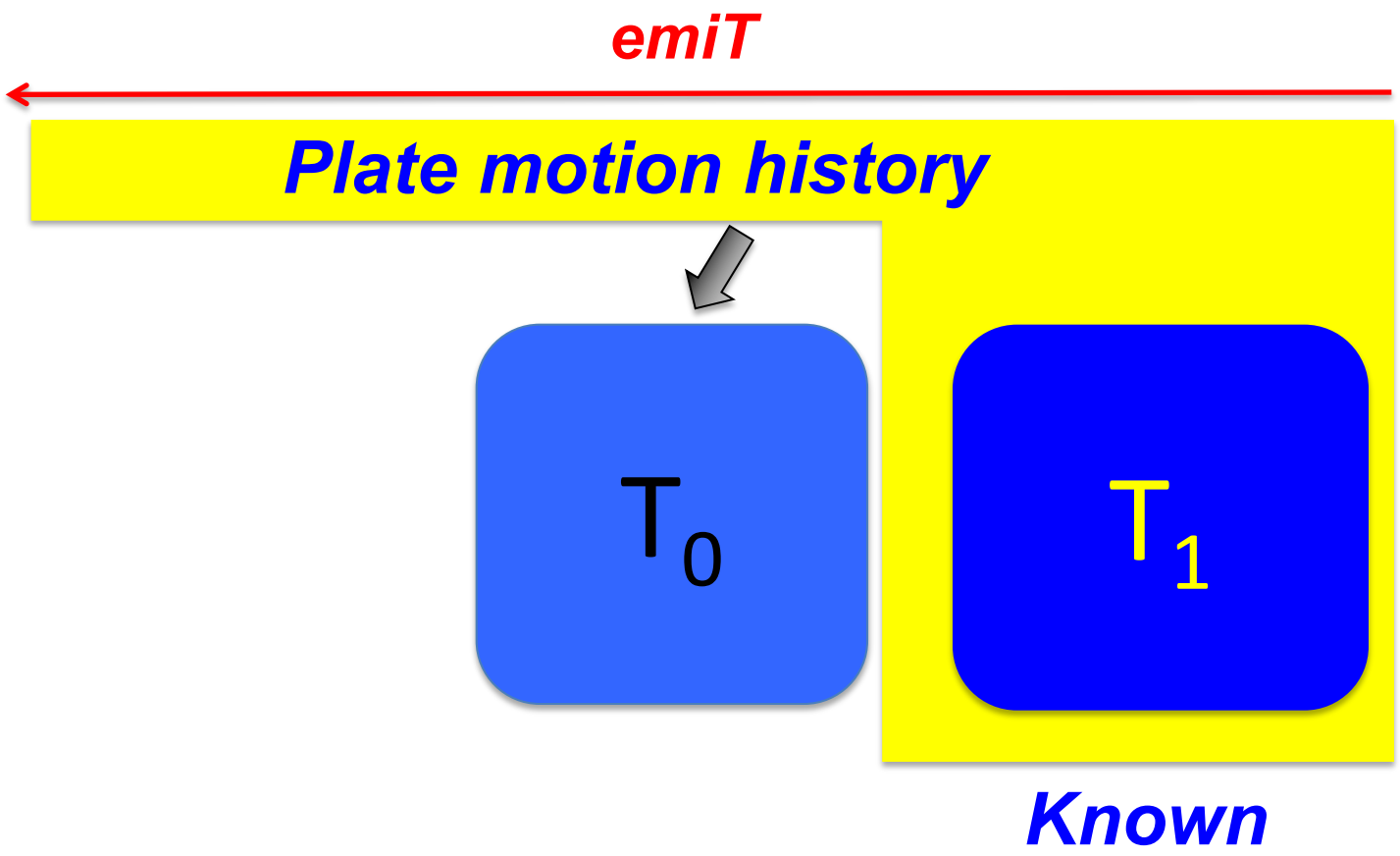
A Synthesis of Earth evolution



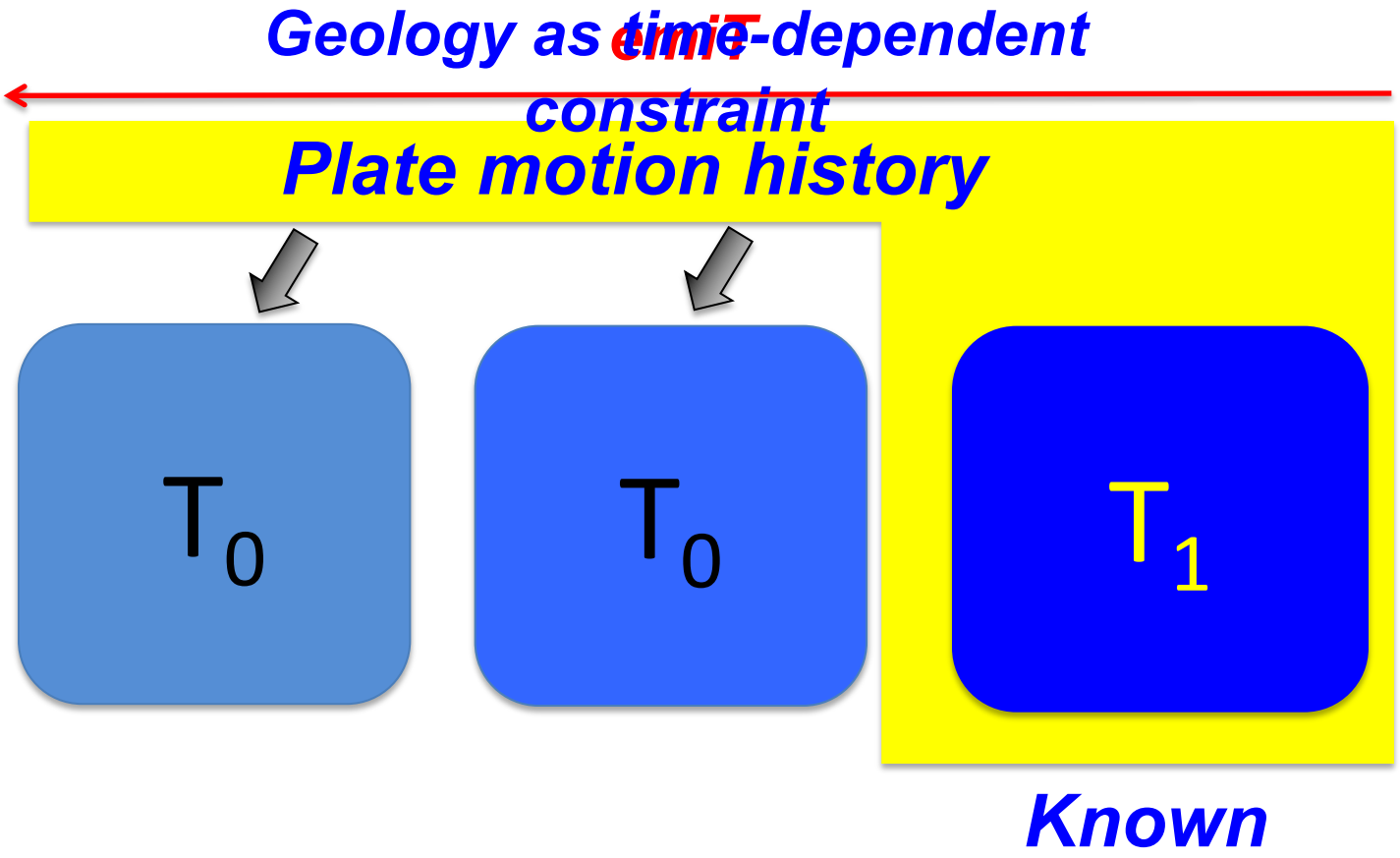
Forward simulation of Earth evolution



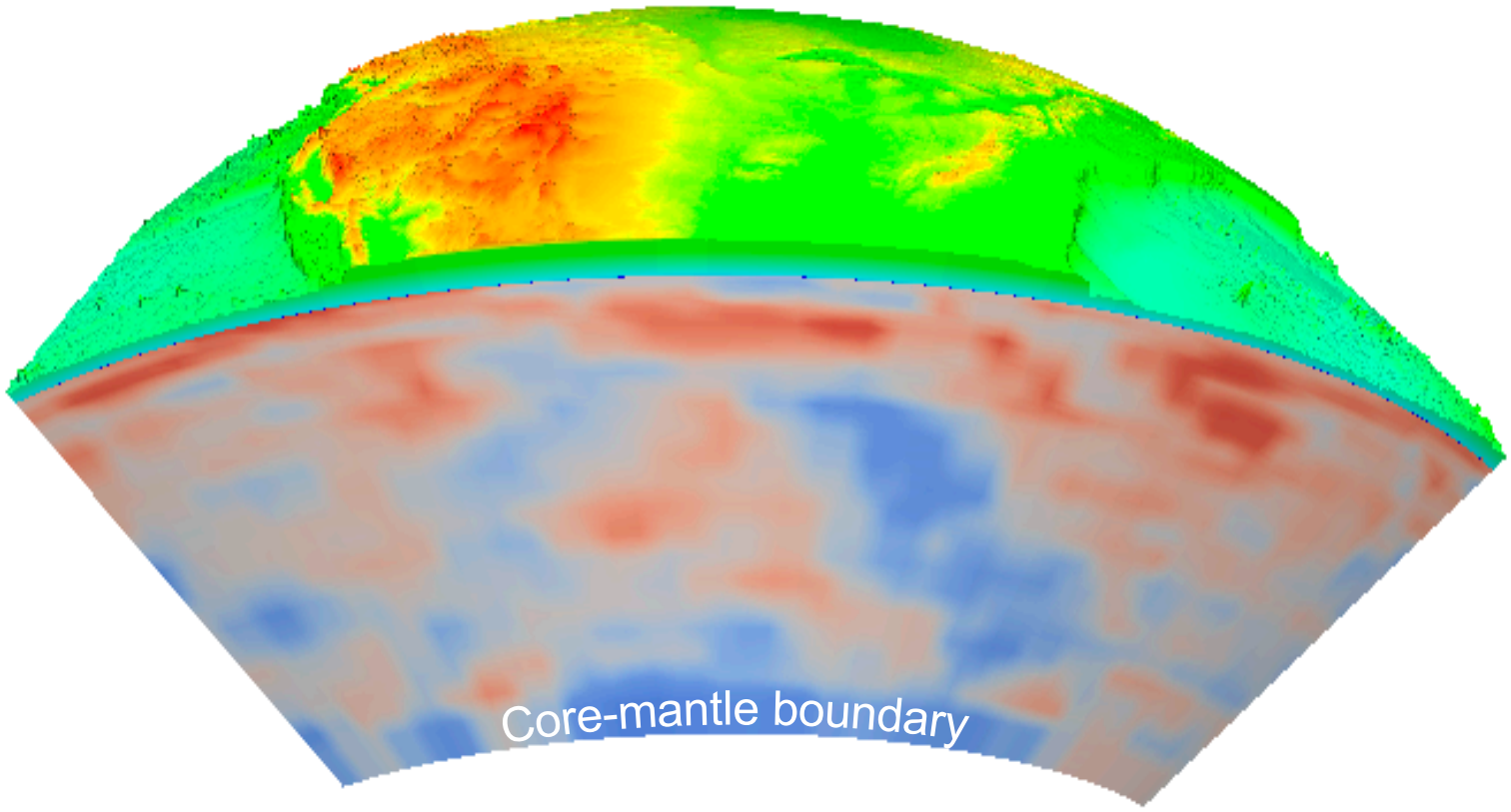
Inverse simulation of Earth evolution



Inverse simulation of Earth evolution



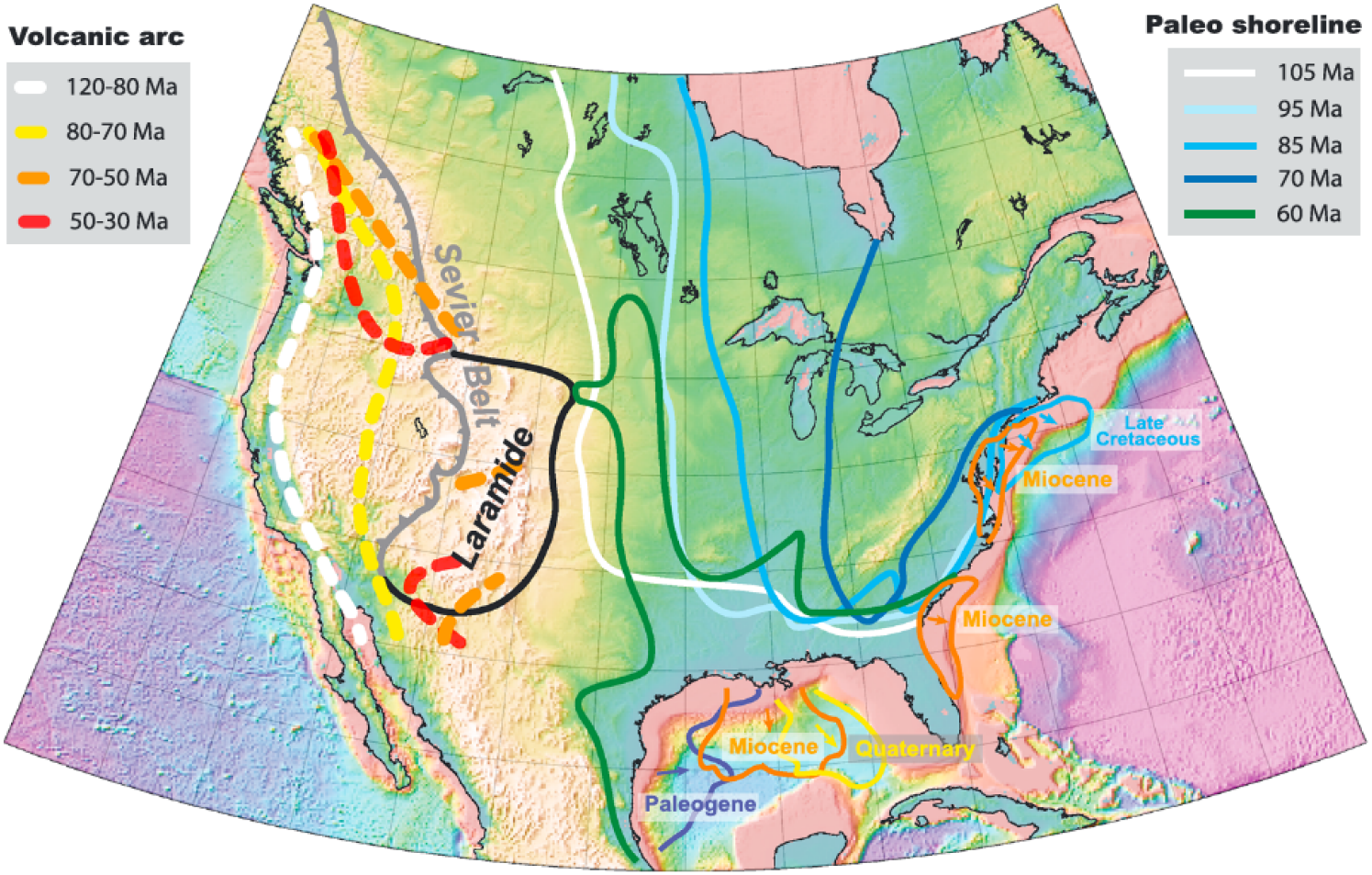
Invert Farallon subduction using *pre-EarthScope* tomography



(Liu, *Rev. Geophys.*, 2015)

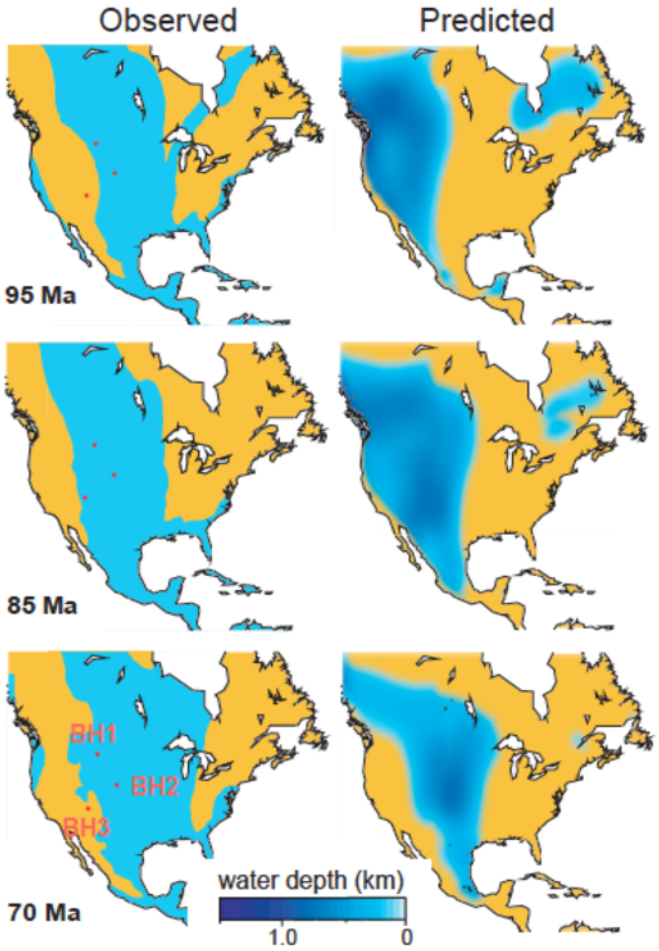
Invert Farallon subduction using *pre-EarthScope* tomography

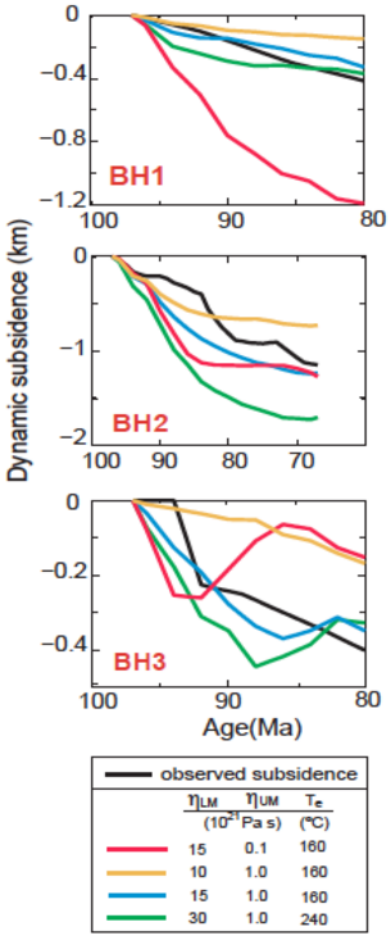
Time-dependent model requires **time-dependent** constraints

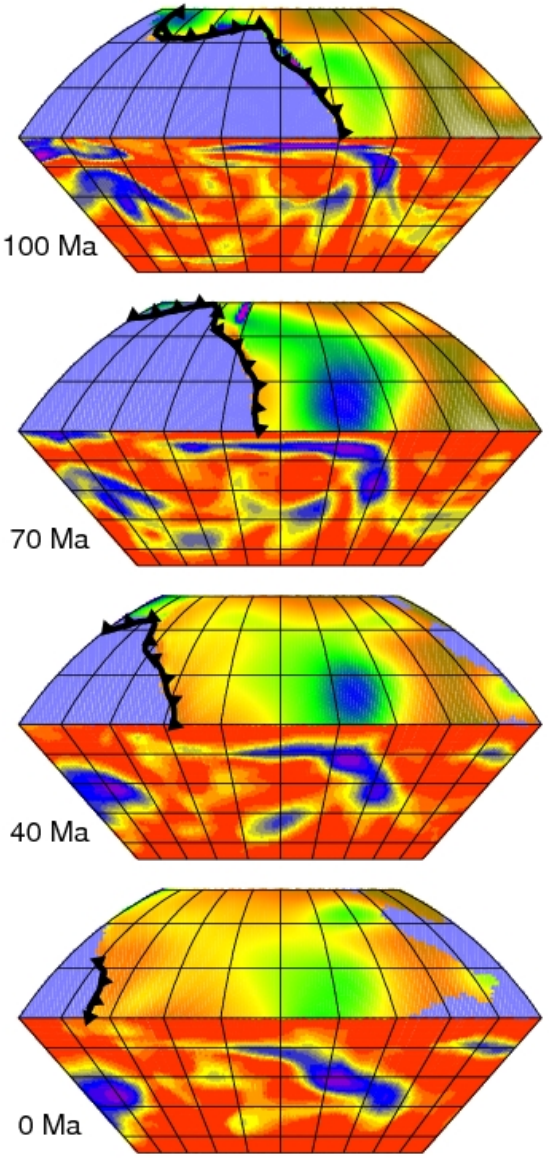


(Liu, *Rev. Geophys.*, 2015)

Dynamic subsidence due to flat-slab subduction forming the WIS



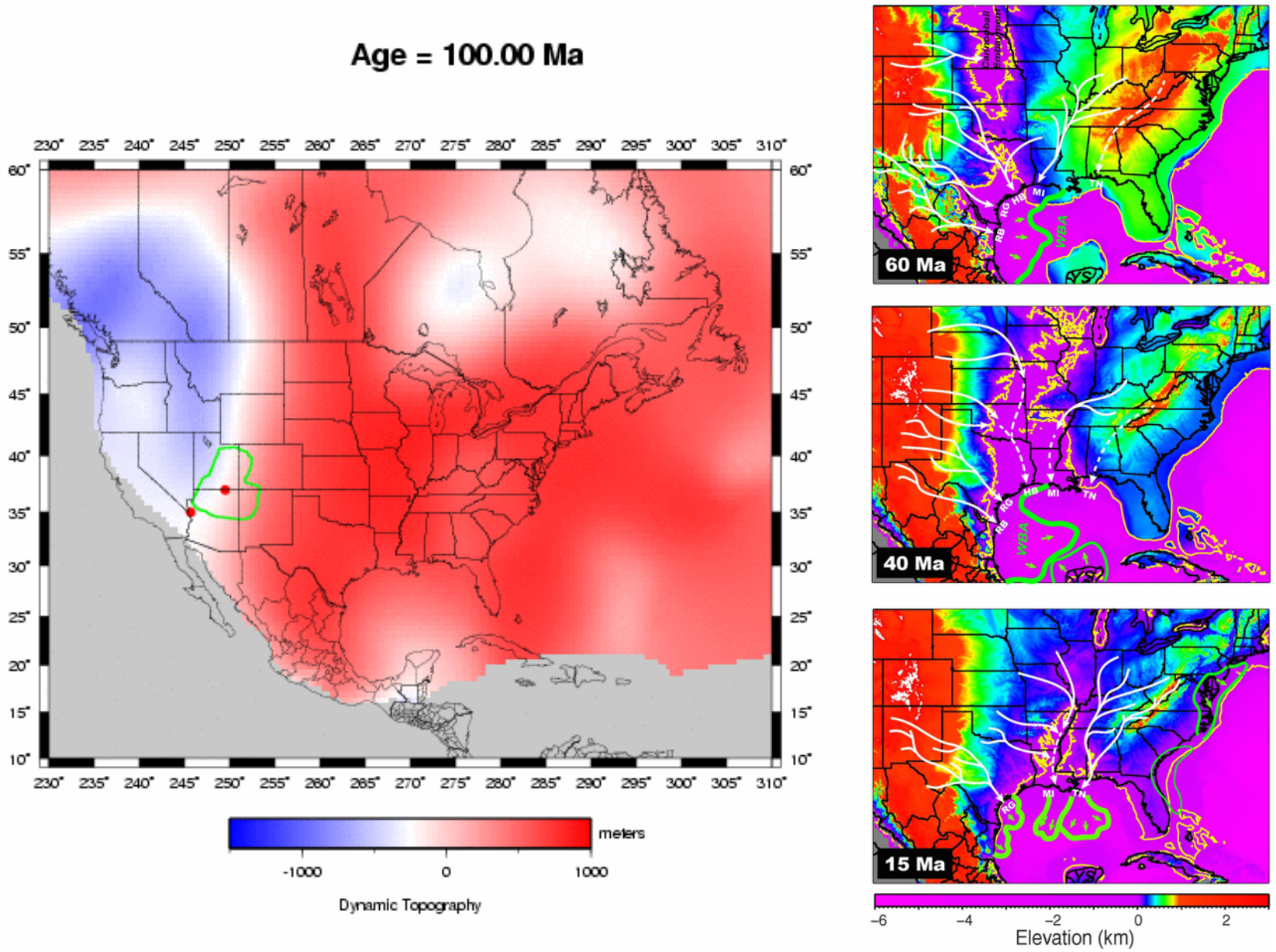




(Liu et al., *Science,* 2008)

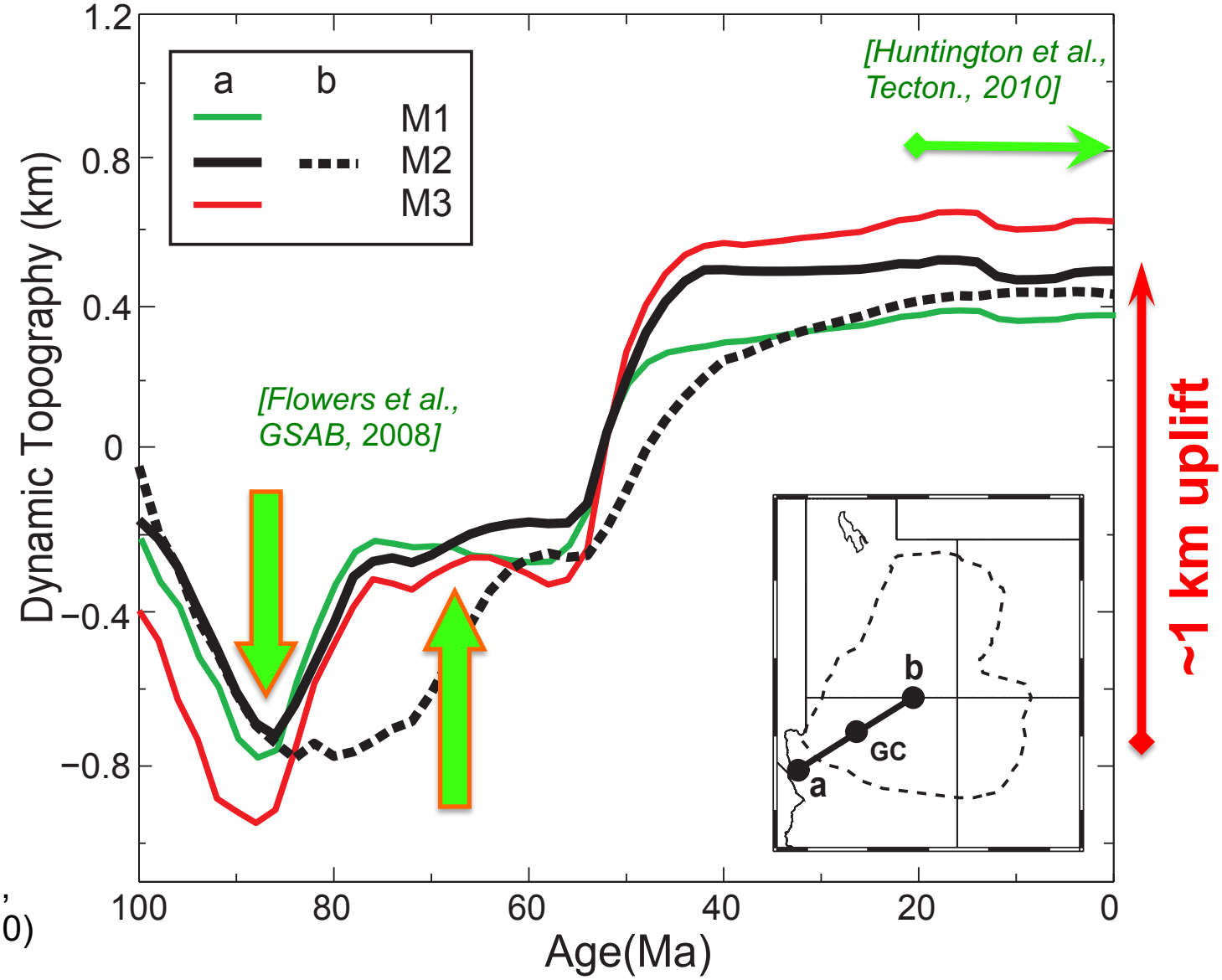
(Replotted based on Liu et al., *Science*, 2008)

Eastward propagating subsidence across N. America



(Liu, *Nature Geosci.*, 2014)

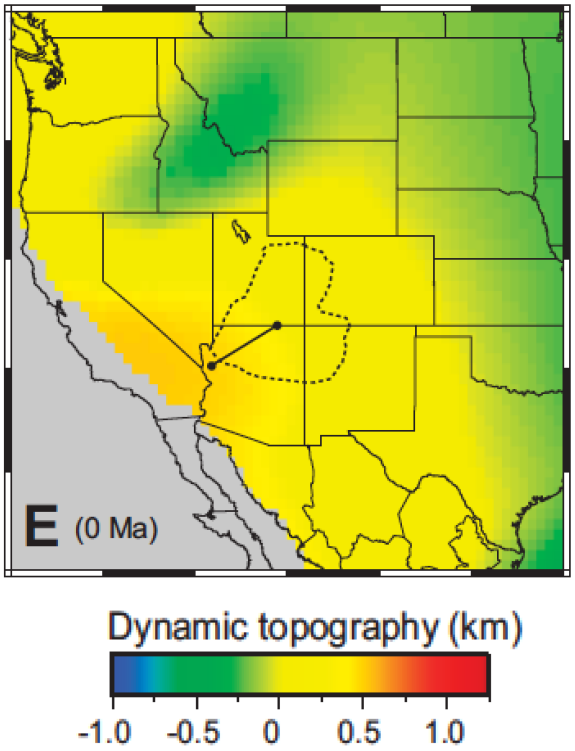
Subsidence & uplift of Colorado Plateau (CP)



(Liu & Gurnis, *Geology,* 2010)

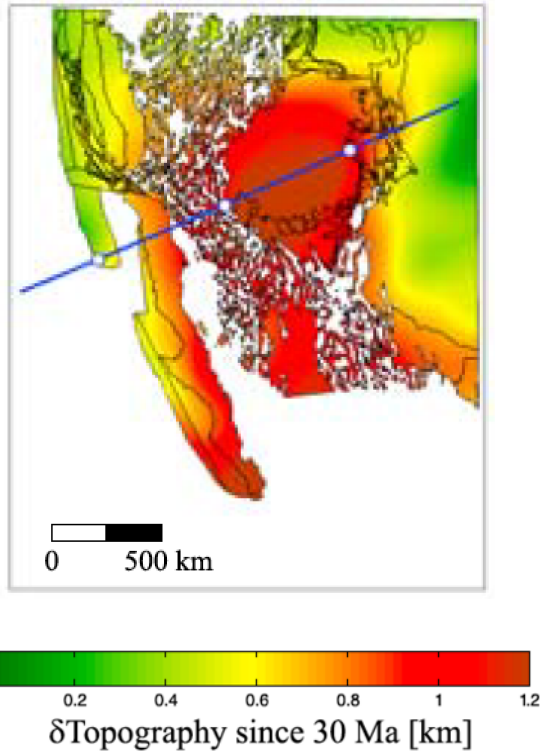
Debated Colorado Plateau uplift history

Pre-USArray tomography
No hot mantle below west US
Time-dependent constraints



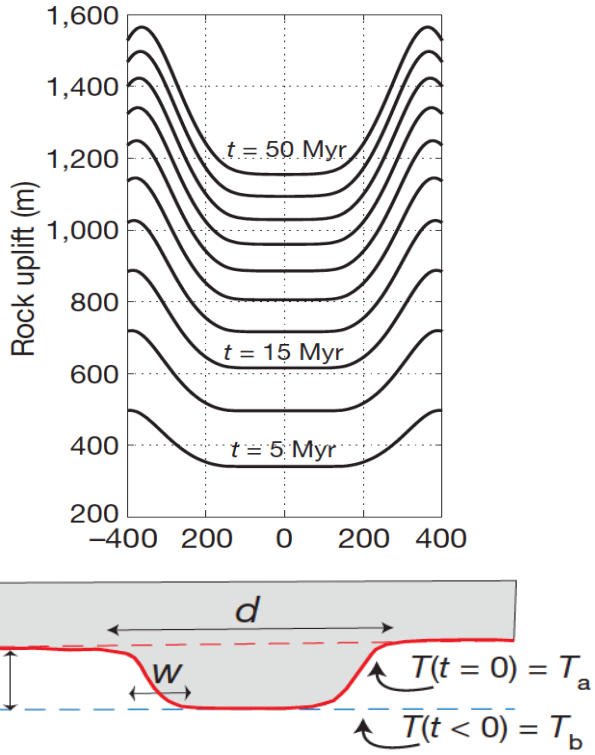
(Liu & Gurnis, *Geology*, 2010)

Pre-USArray tomography
Hot western US mantle
Constrained by 0-Ma data



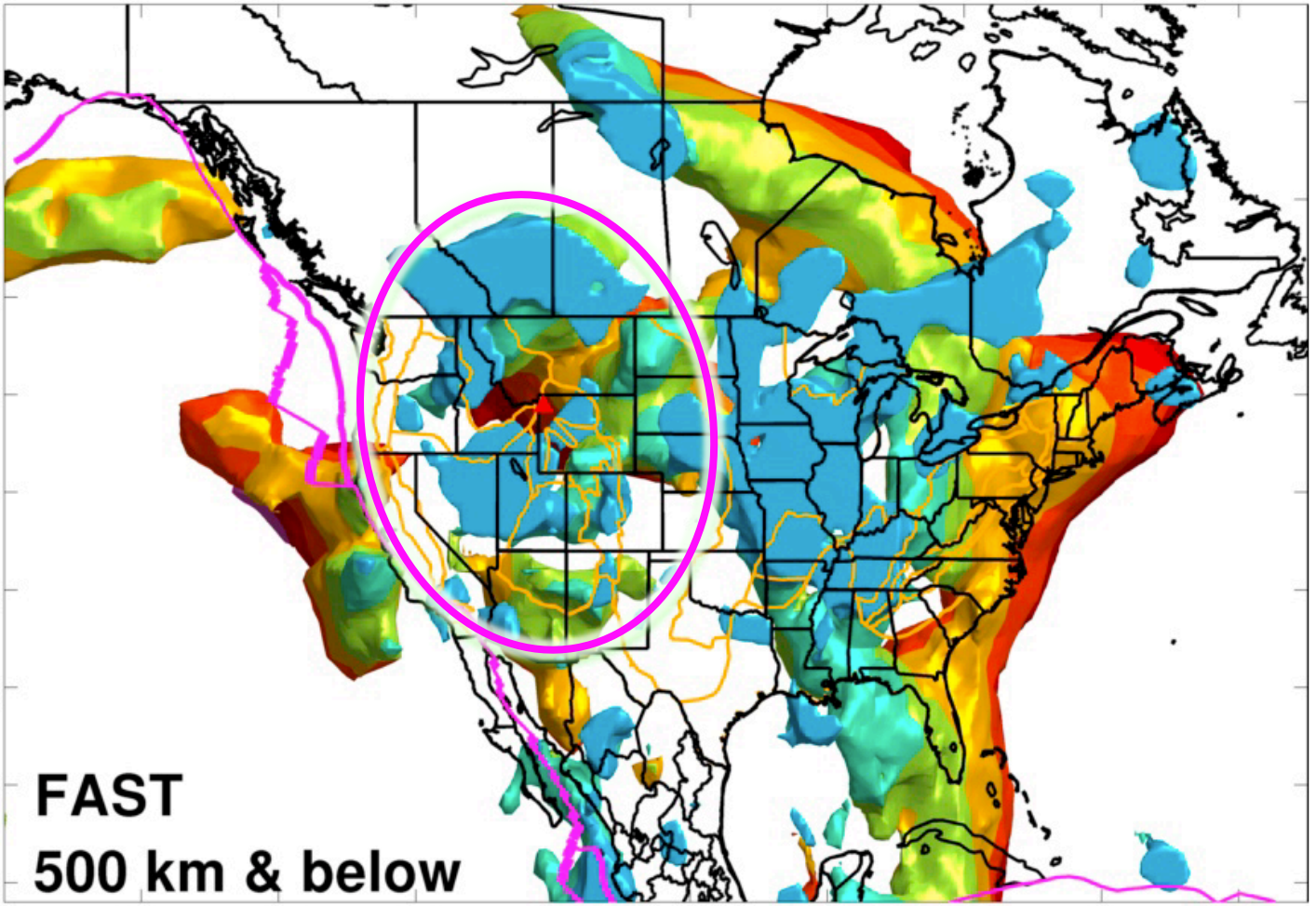
(Moucha et al., *GRL*, 2009)

Cenozoic Colorado
Plateau uplift due to
lithosphere warming



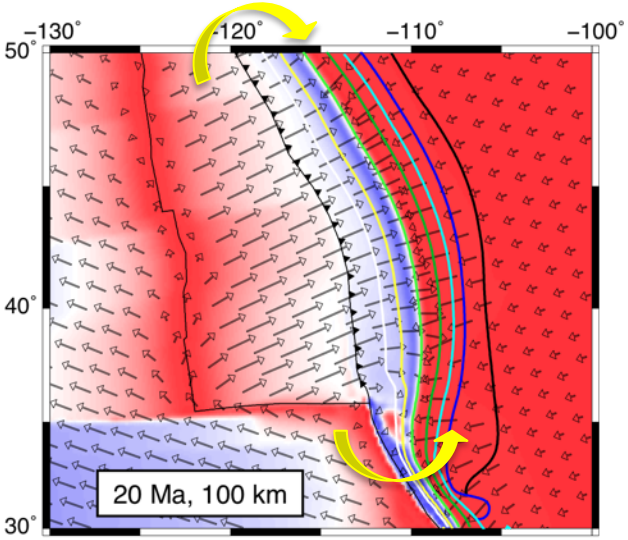
(Roy et al., *Nature*, 2009)

Distinct Mantle Seismic Domains



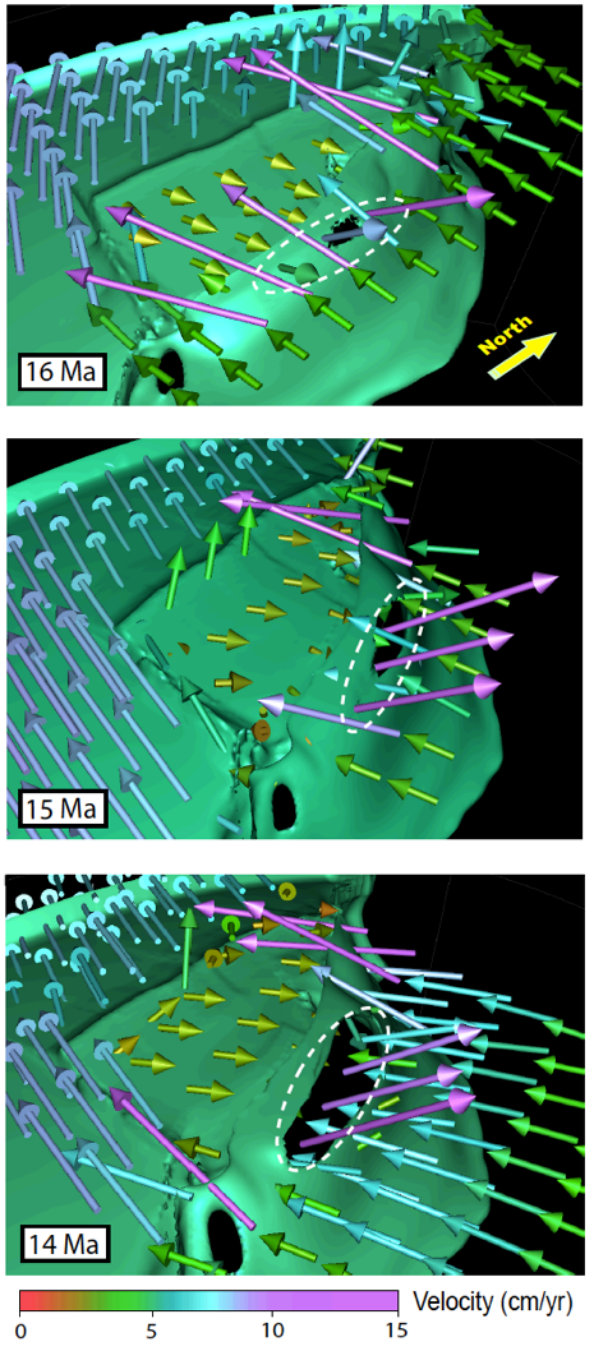
(Sigloch, *G^3*, 2011)

Forward simulation of Farallon subduction



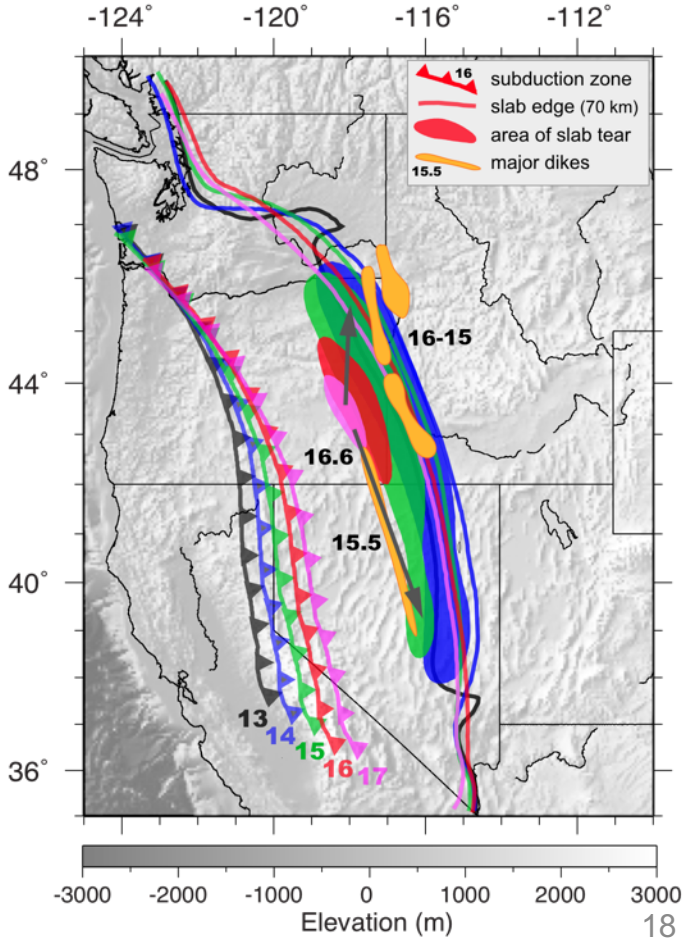
(Liu & Stegman, *EPSL,* 2011)

Miocene slab segmentation attributed to Columbia River flood basalt

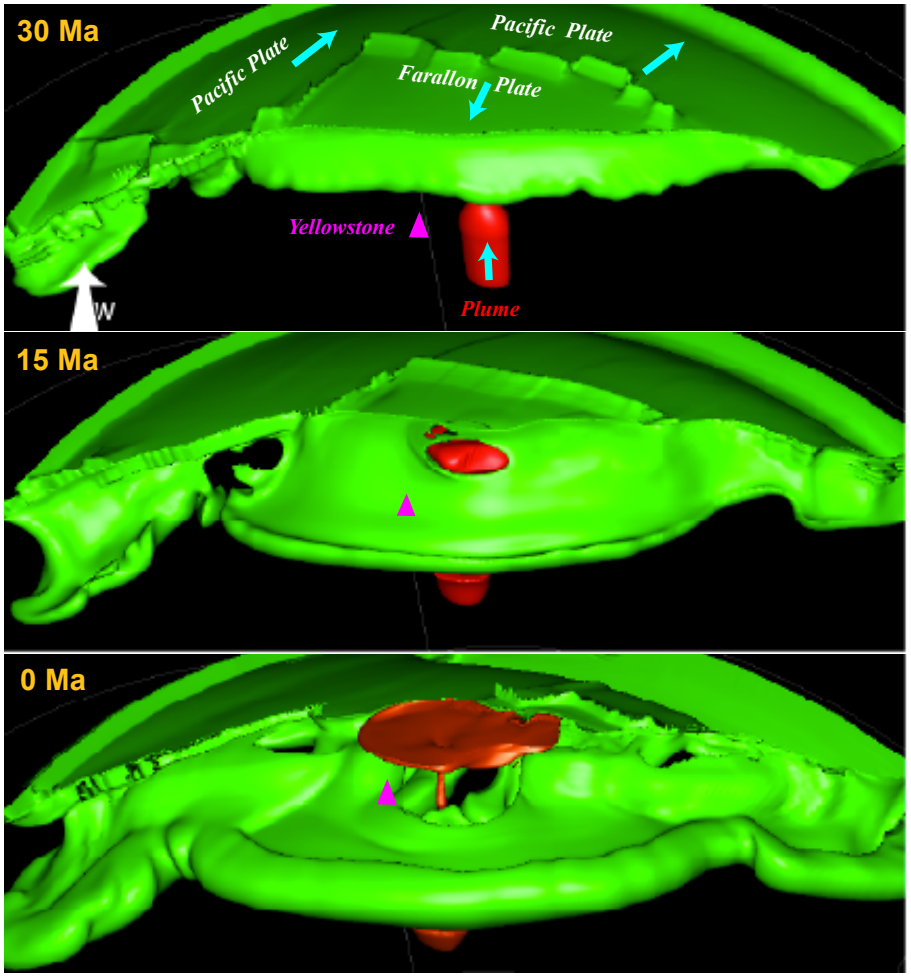


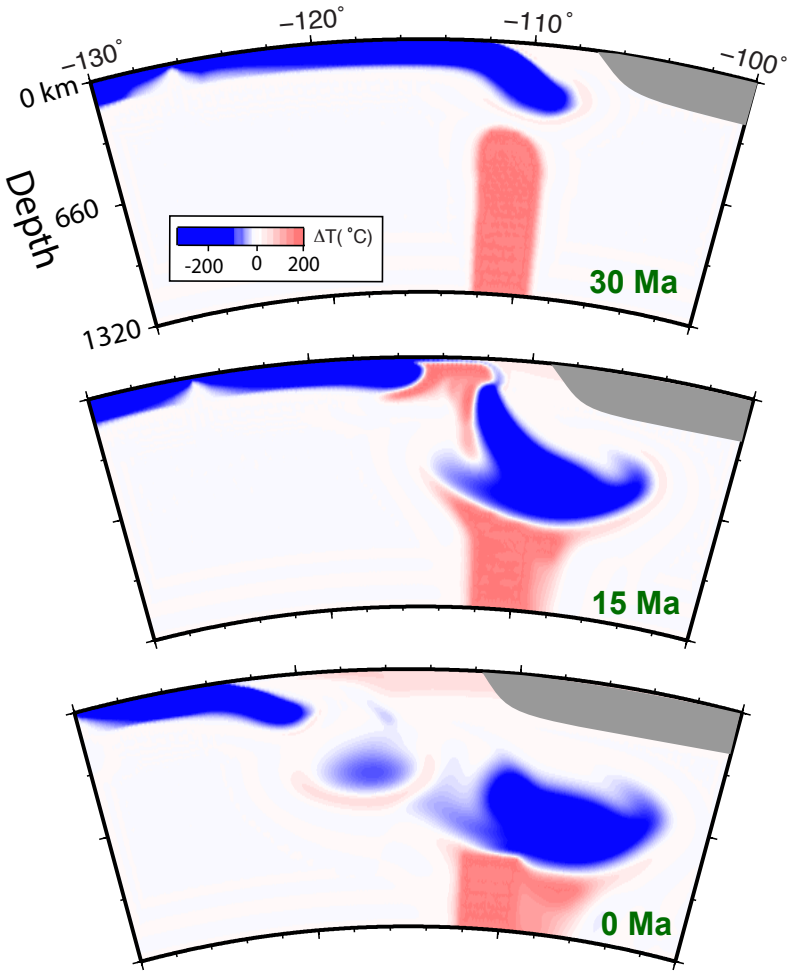
(Liu & Stegman, *Nature,* 2012)

LIP formation due to slab tearing



Forward simulation of slab-plume interaction





(Leonard & Liu, *GRL*, 2016)

Hybrid data assimilation: Forward + Adjoint

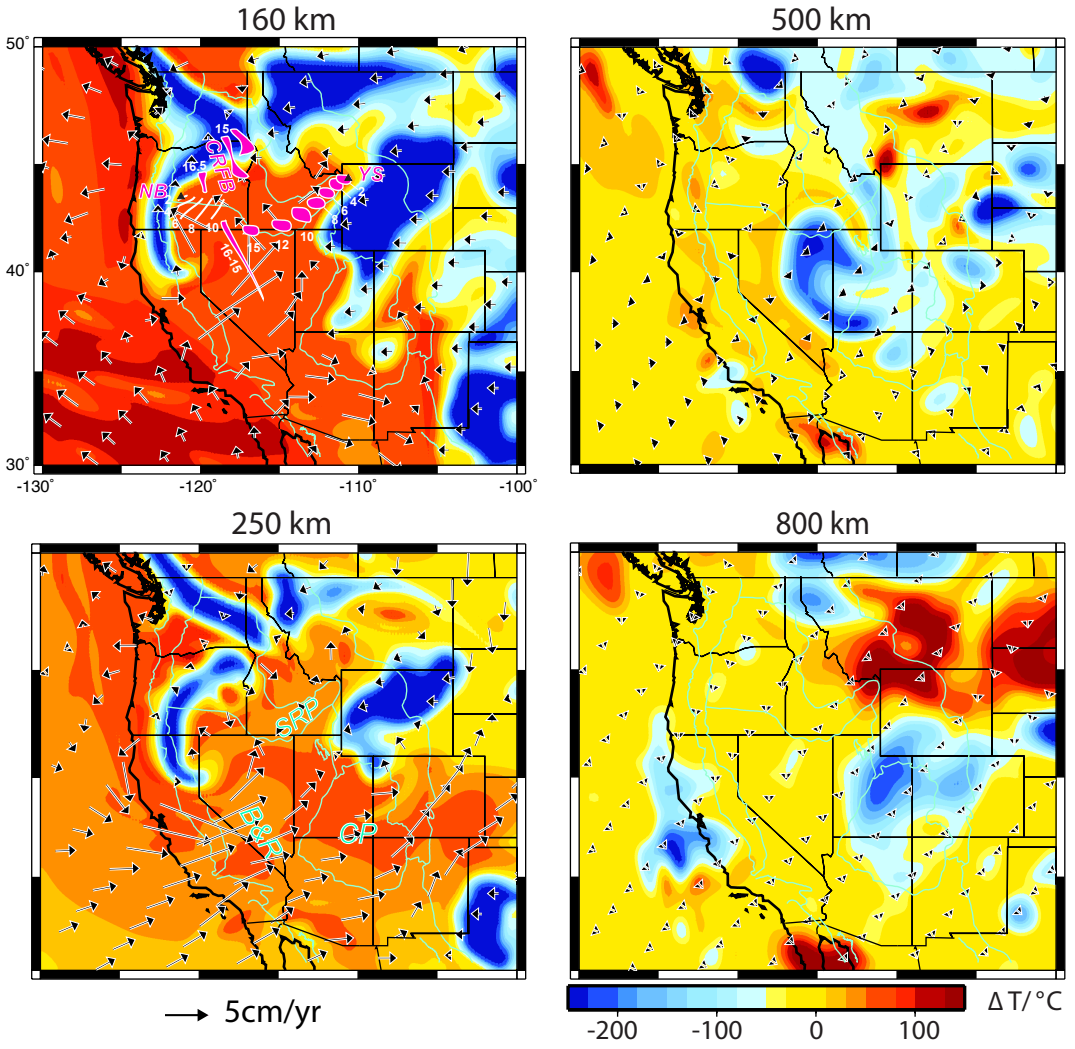
Data constraints:

- Seismic tomography
- Gravity
- Past plate motions
- Seafloor age history
- B&R kinematics

Simultaneously solves:

- Heat source of YS hotspot
- WUS seismic anisotropy
- Topography history

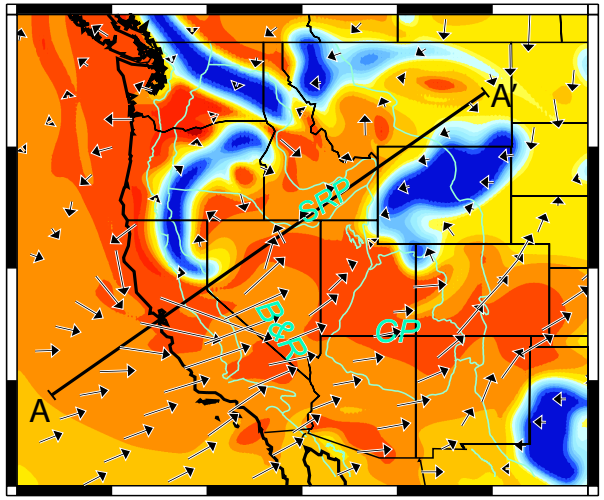
[See poster **# 12**]



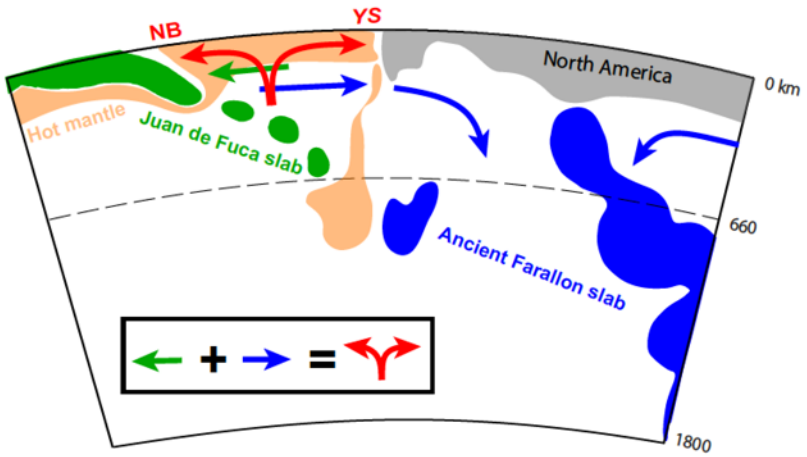
(Zhou et al., in revision)

[Used tomography: Schmandt & Lin, 2014]

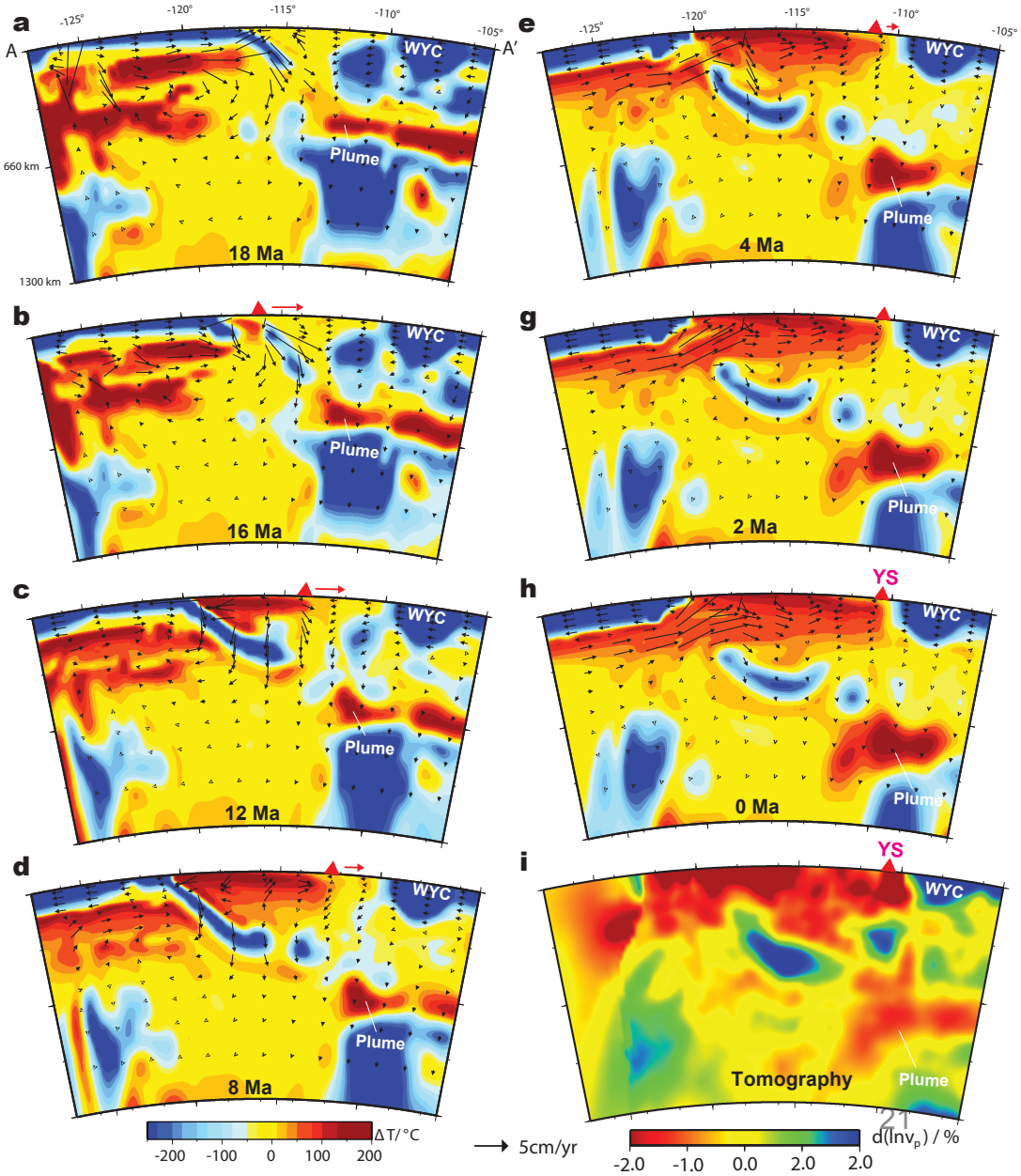
Hybrid data assimilation



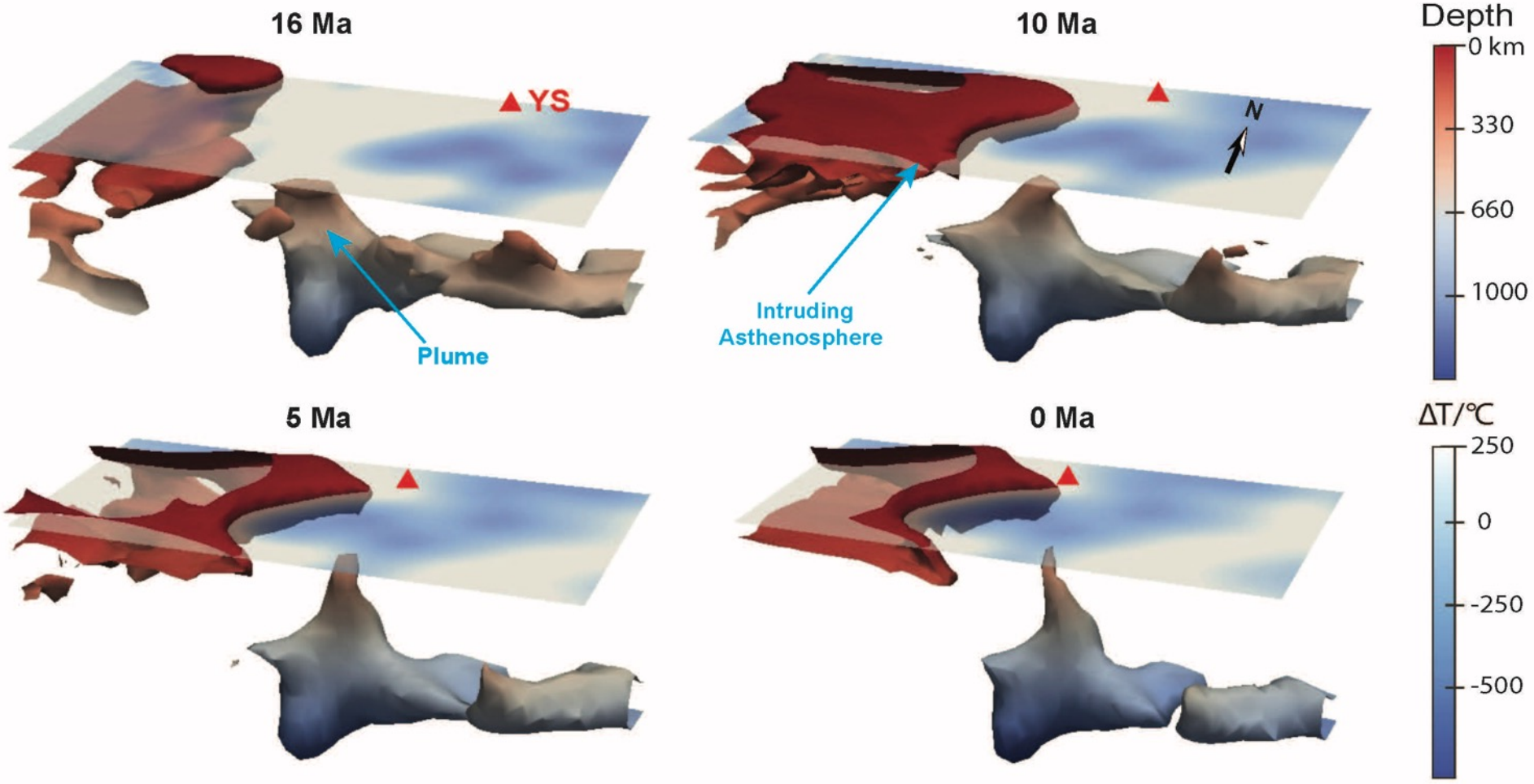
[250 km @ 0 Ma]



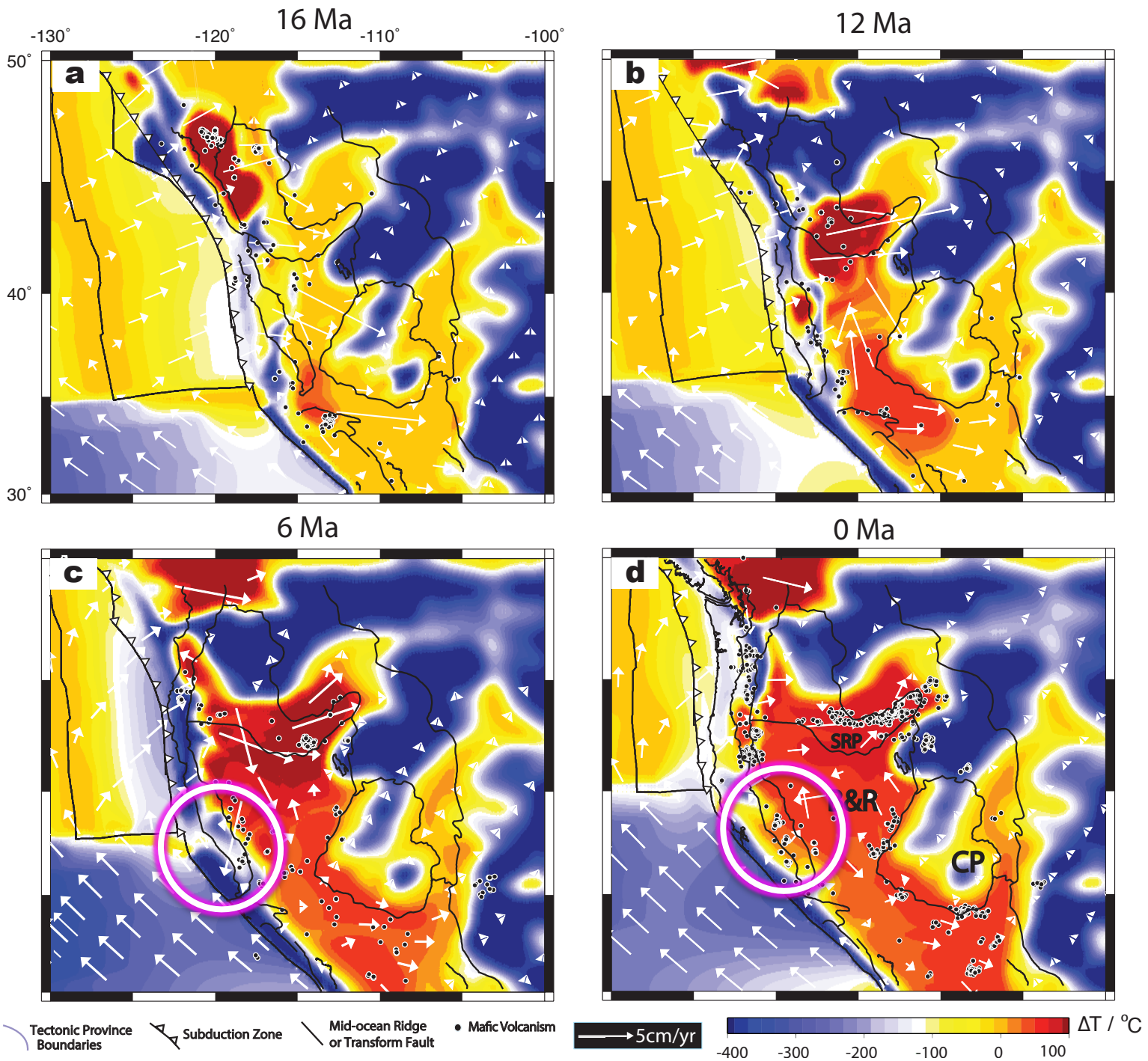
(Zhou et al., in revision)



Hybrid data assimilation

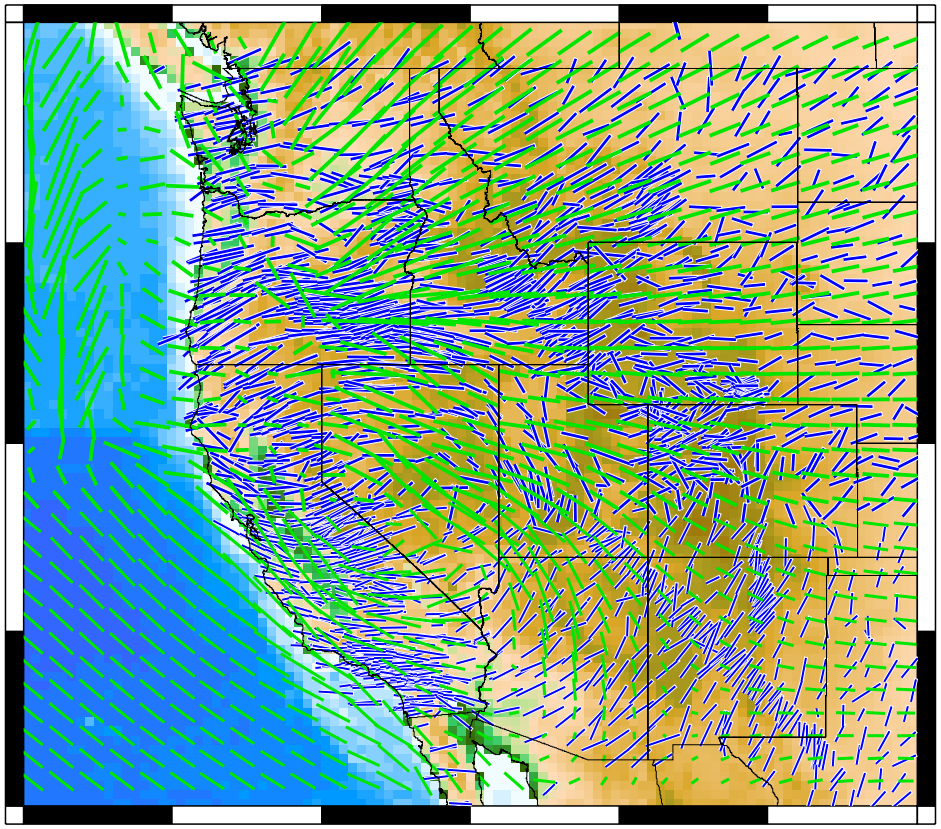


(Zhou et al., in revision)


16 Ma
12 Ma
6 Ma
0 Ma
-130˚
-120˚
-110˚
-100˚
50˚
40˚
30˚
a
b
c
d
SRP
&R
CP
Tectonic Province Boundaries
Subduction Zone
Mid-ocean Ridge or Transform Fault
Mafic Volcanism
5cm/yr
ΔT / ºC
-400
-300
-200
-100
0
100

Caused the peculiar western U.S. seismic anisotropy

Predicted vs. **observed** SKS from the slab model *(Liu & Stegman, 2011)*.

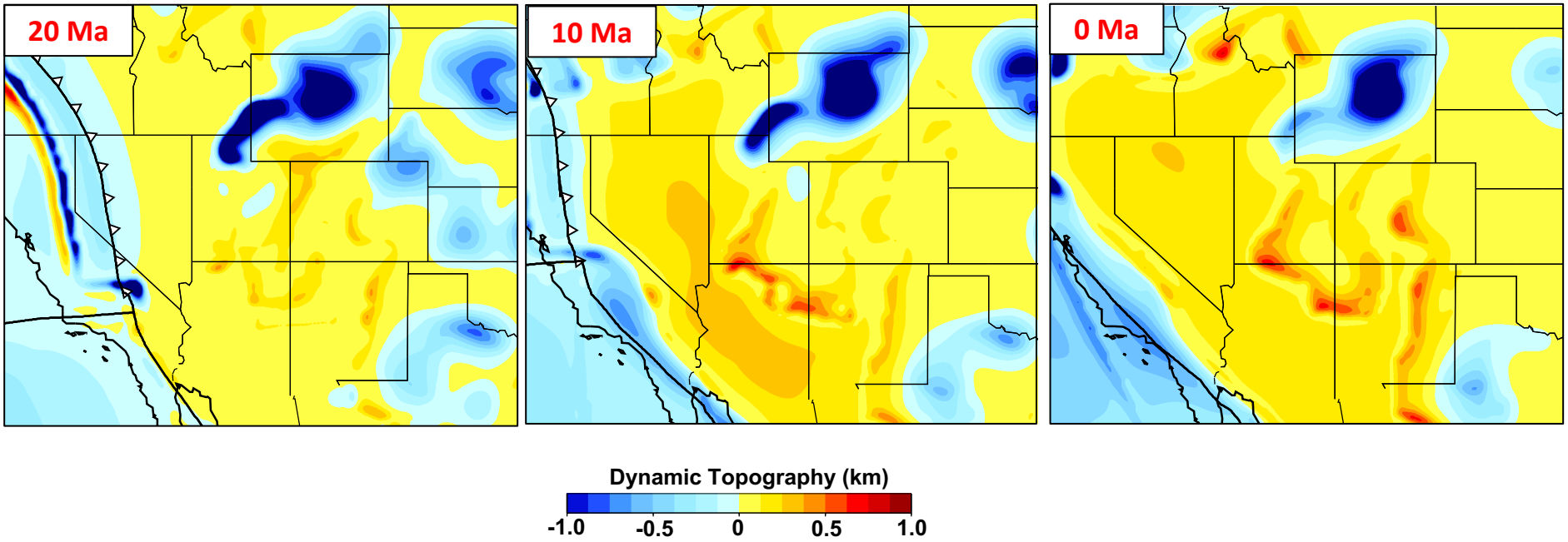


(Zhou et al., in prep)

WUS topography since 20 Ma

(Including both dynamic & isostatic topography)

- Hot mantle spreads laterally, resulting in small upward stress (uplift)
- <200 meters of uplift within western U.S. since 20 Ma
- Large-amplitude uplift along Plateau edges since 20 Ma



(Zhou & Liu, in prep)

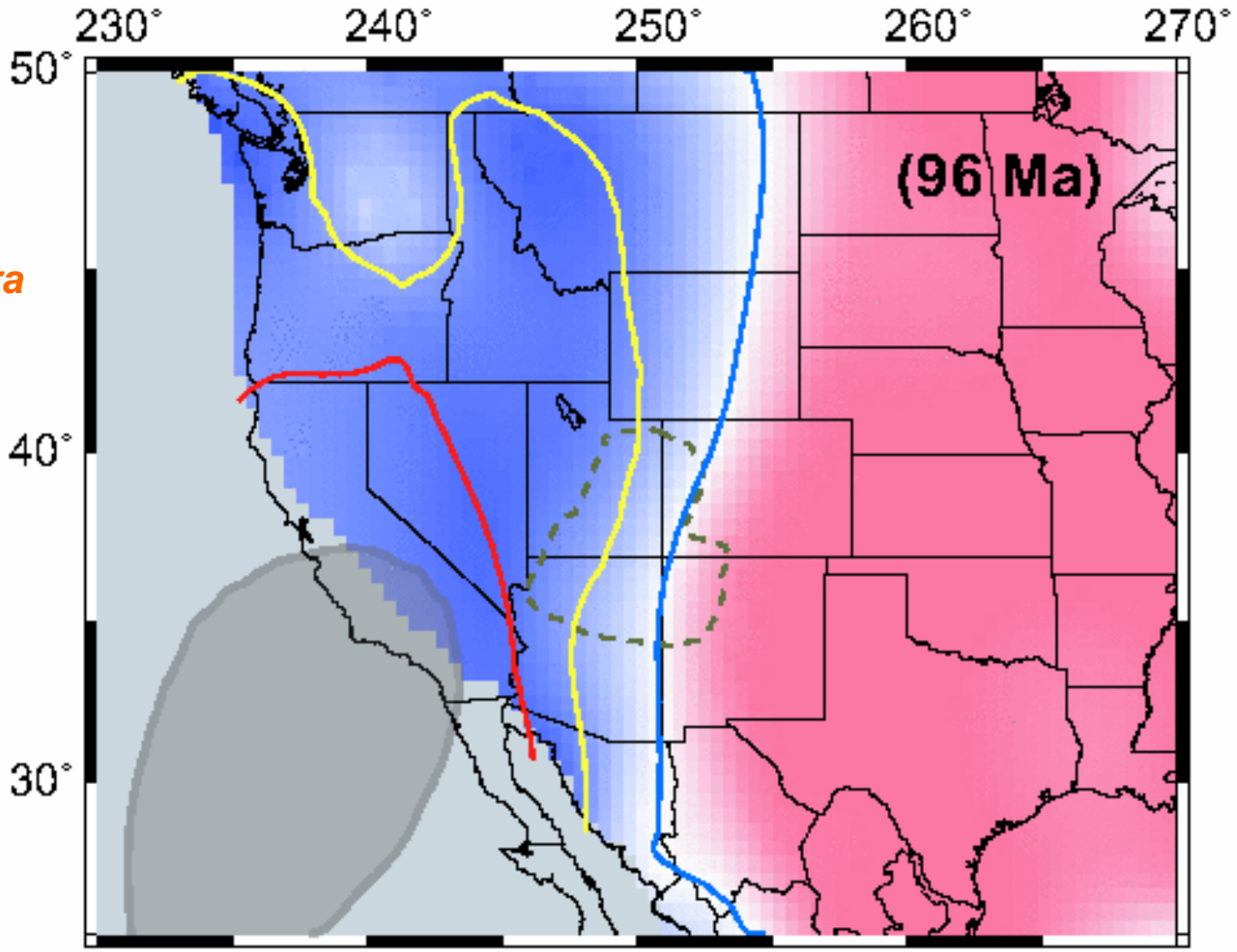
Implications on North American evolution

- The Colorado Plateau experienced up to ~1.2 km **dynamic** uplift (due to subduction & hot mantle) since 80 Ma, significantly less than the observed >2 km uplift.
- Other processes, such as lithosphere warming/alteration/foundering, should have **isostatically** increased WUS topography by up to 1 km.
  - Such lithosphere changes could have occurred during/after the Farallon flat-slab subduction.

Predicted flat-slab (Shatsky conjugate) subduction

Implication:

Lithospheric deformation/alteration since Late Cretaceous



(Liu et al., *Nature Geosci.,* 2010)