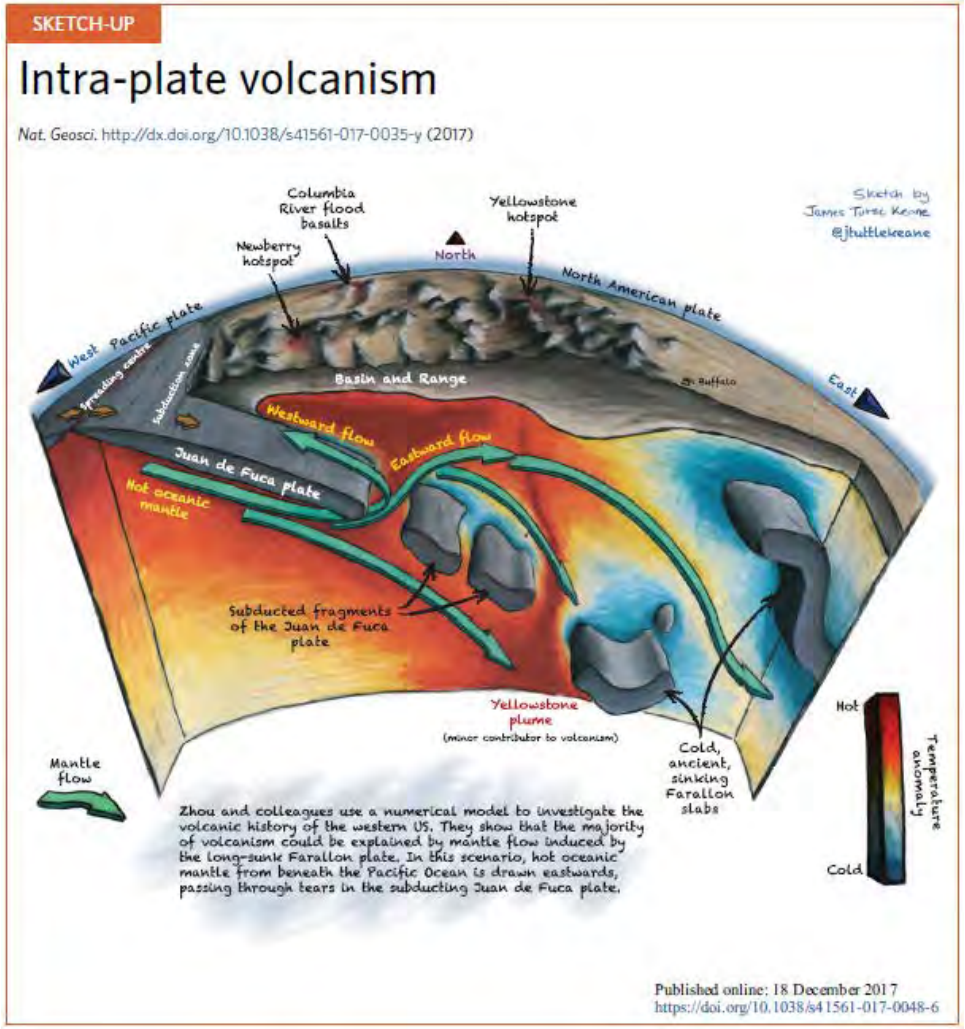
Western U.S. Volcanism due to Intruding Oceanic Mantle Driven by Ancient Farallon Slabs



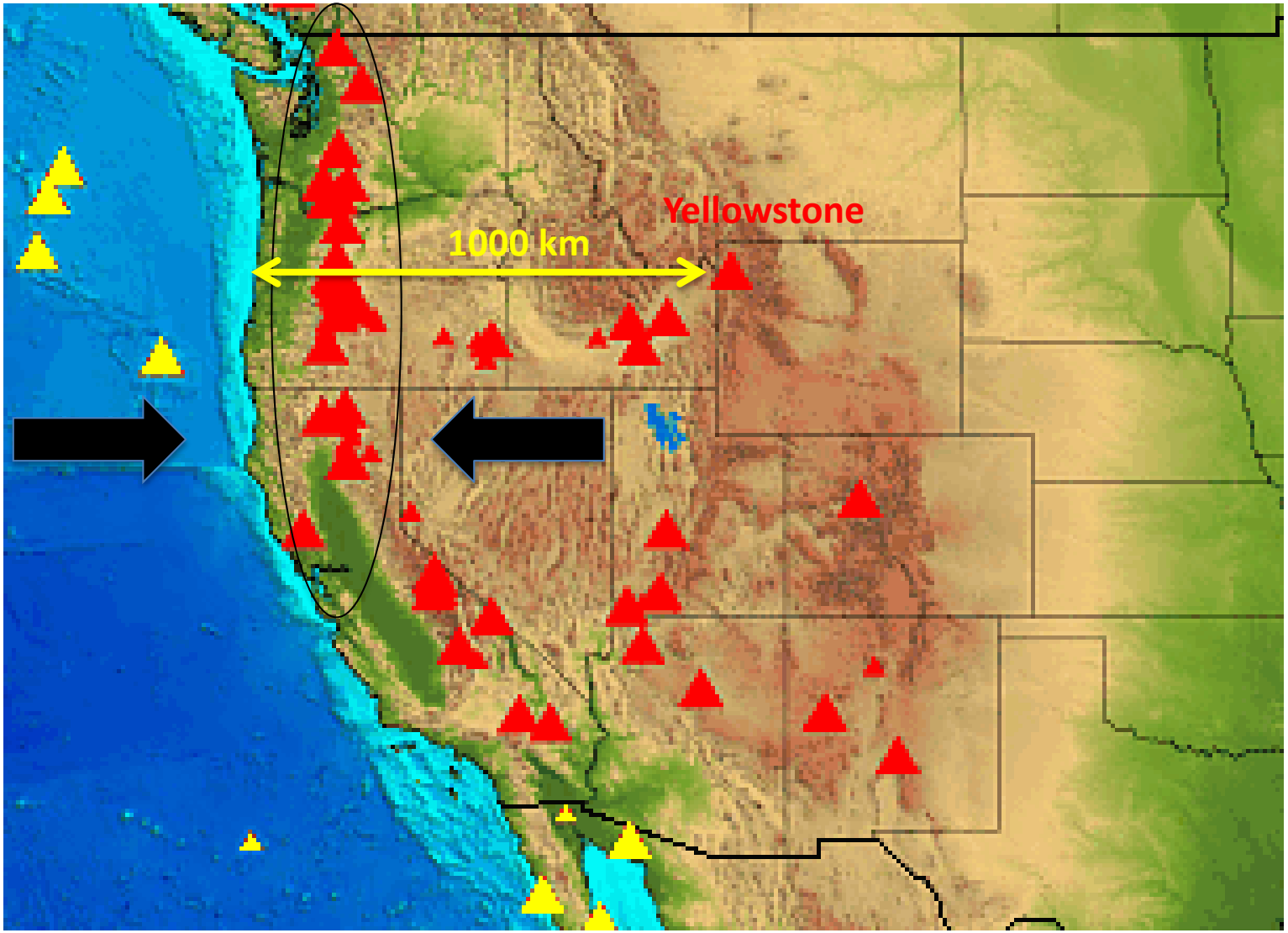
Project PI: Lijun Liu, Univ. of IL at Urbana-Champaign

Presenter: Quan Zhou

NCSA team: Ryan Mokos, Bill Gropp, Darren Adams, Yifeng Cui

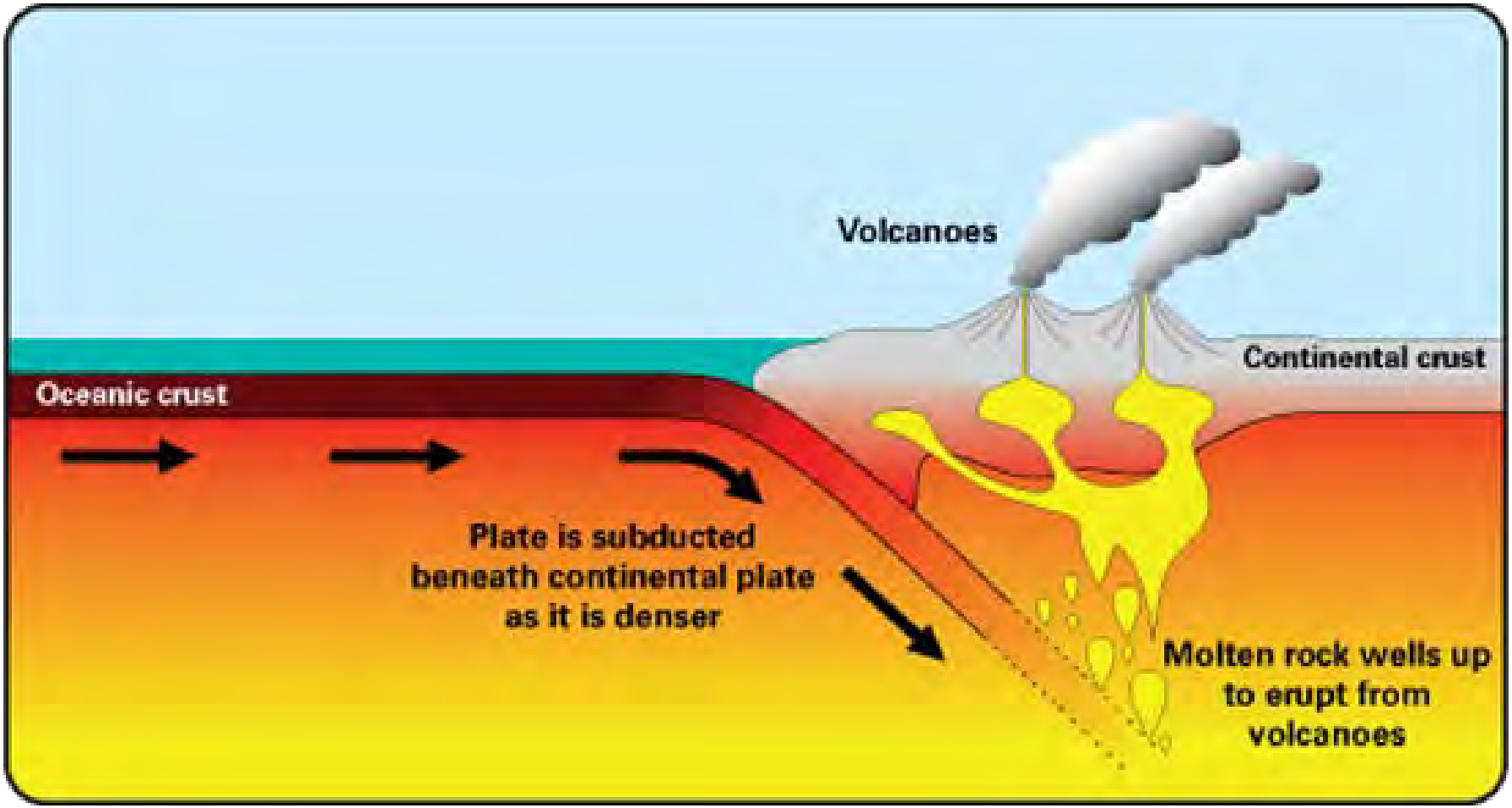
June 5

Blue Waters Symposium



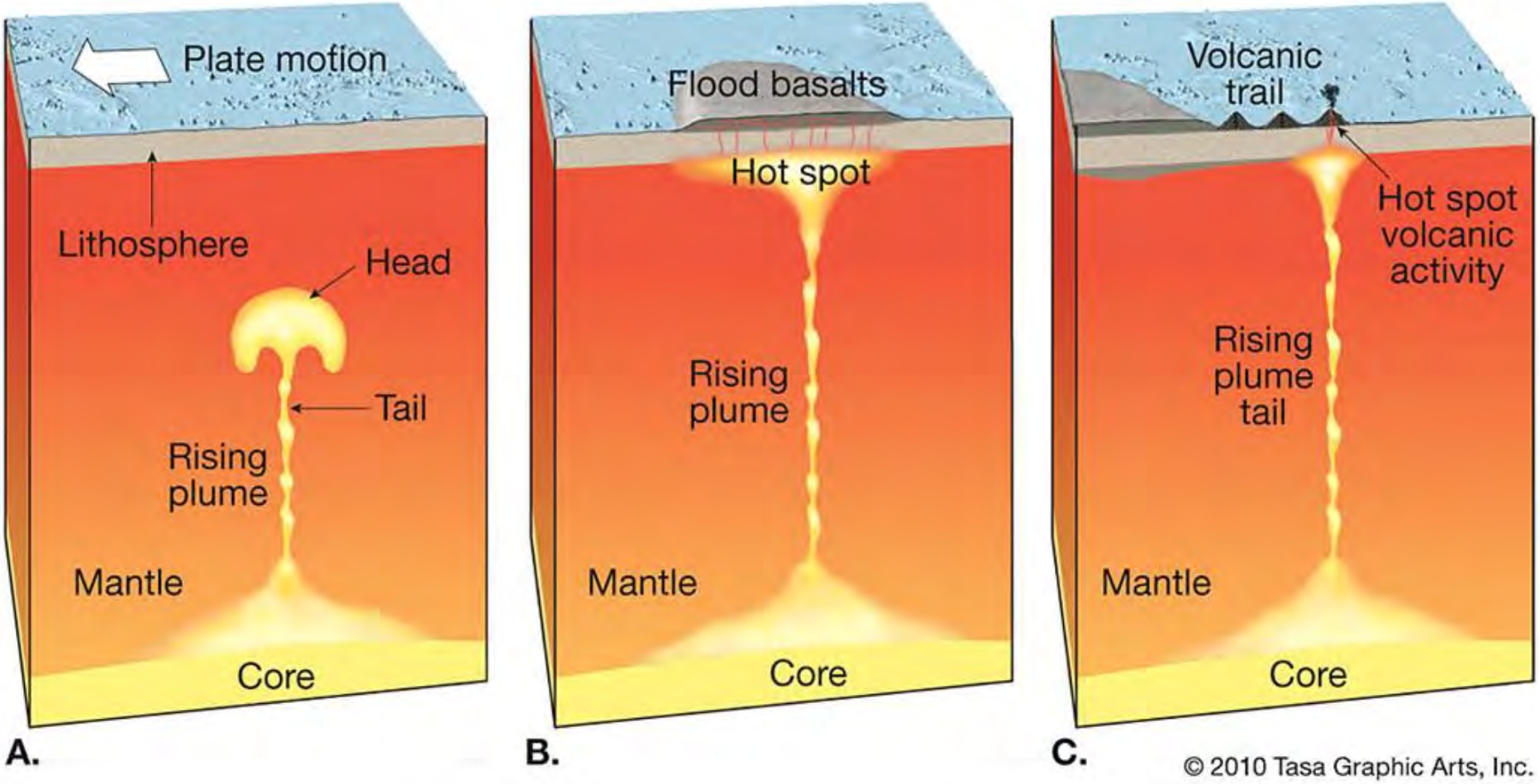
What are the processes forming these volcanoes?

Process I: Subduction

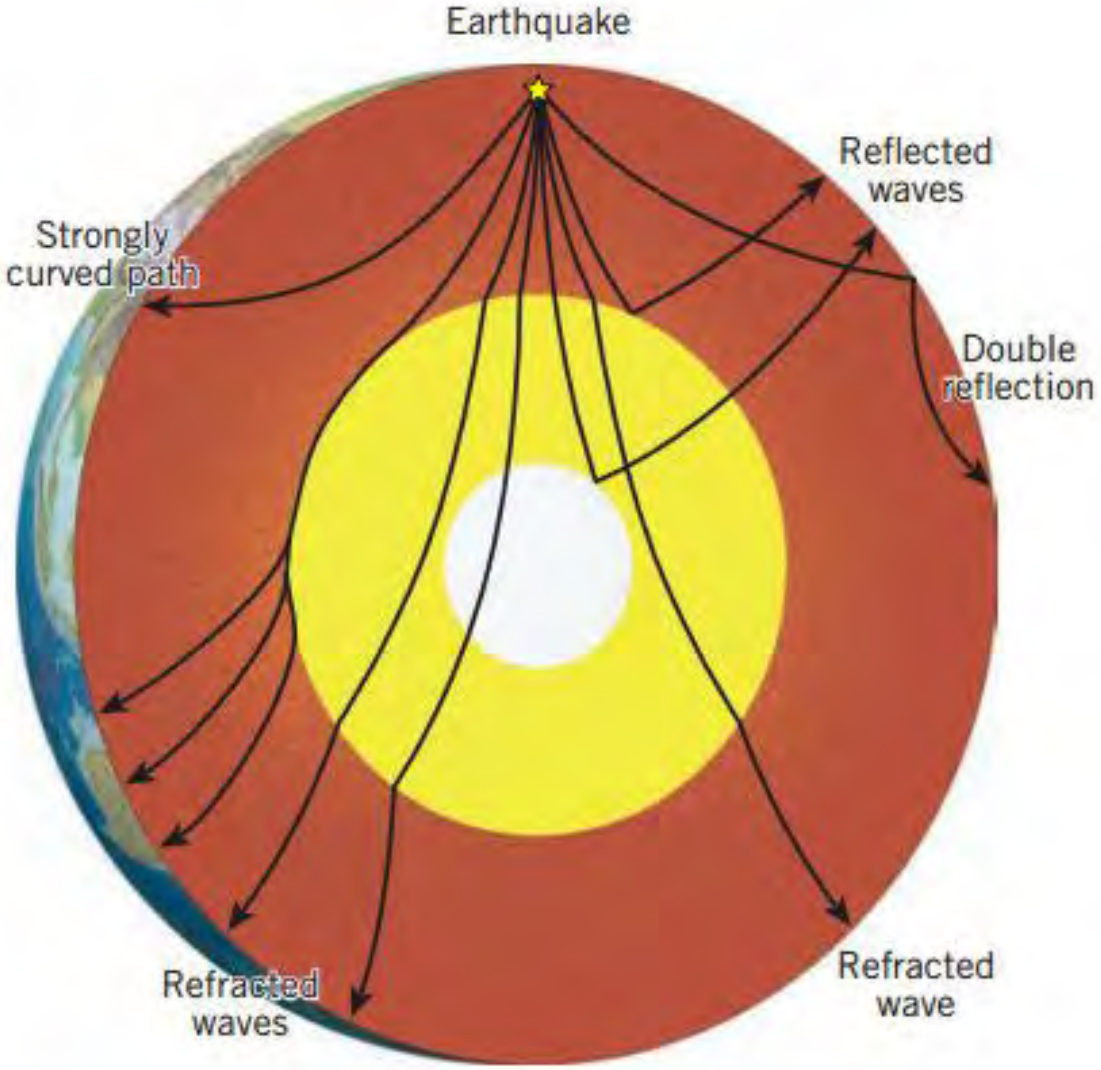


http://www.bgs.ac.uk/discoveringgeology/hazards/volcanoes

Process II: Mantle plume



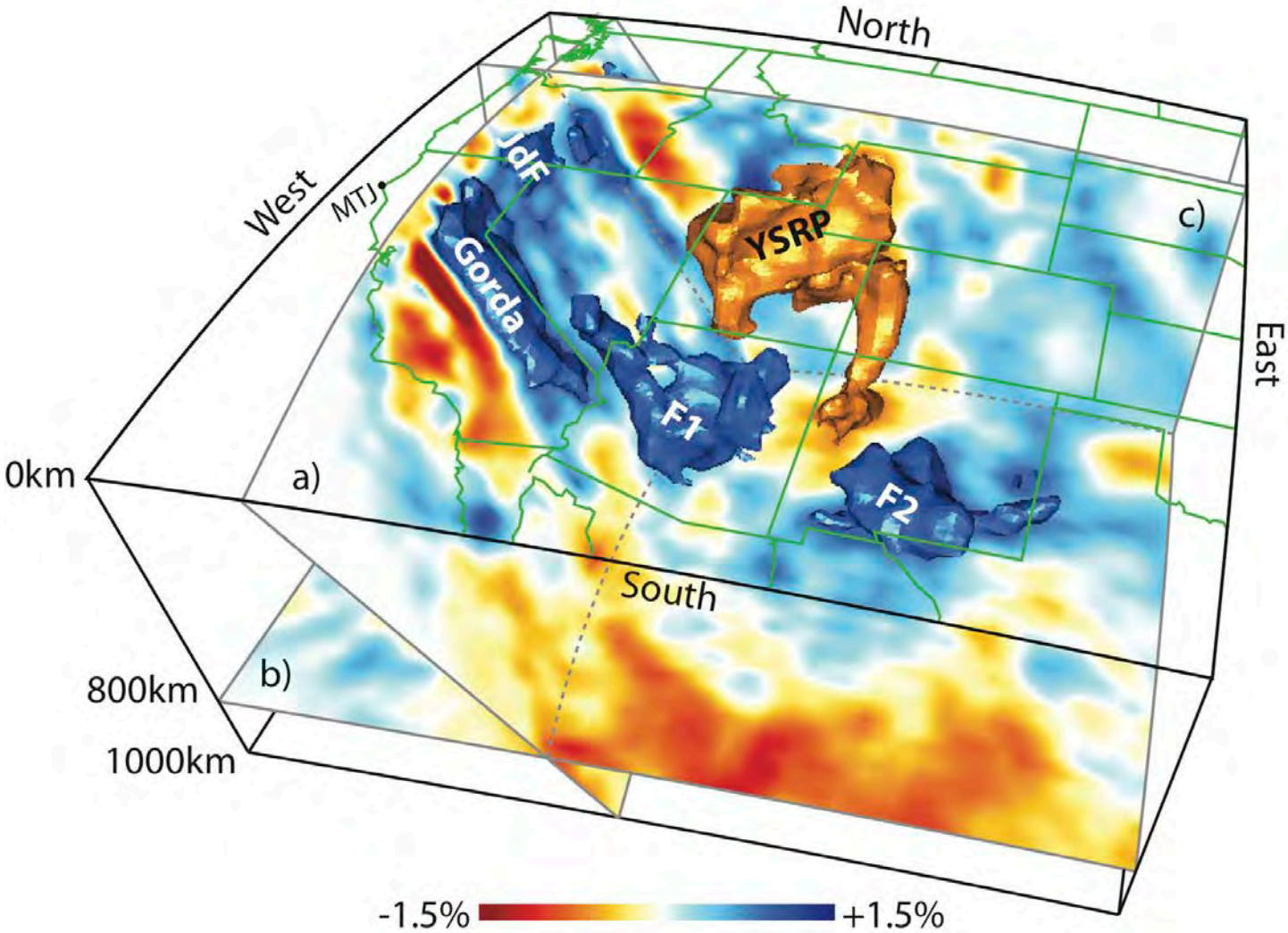
Earth Tomography



https://geology45.blogspot.com/2016/12/describe-how-seismic-waves-are-used-to.html

Observations in mantle

Seismic Tomography



(Obresbki et al. 2010)

Earth mantle simulation

Governing Equations

$$\nabla \cdot \vec{u} = 0 \tag{1}$$

$$-\nabla P + \nabla \cdot [\eta(\nabla \vec{u} + \nabla^T \vec{u})] + (\alpha Ra T + Ra_b C)\vec{e}_r = 0 \tag{2}$$

$$\frac{\partial T}{\partial t} + \vec{u} \cdot \nabla T = \kappa \nabla^2 T \tag{3}$$

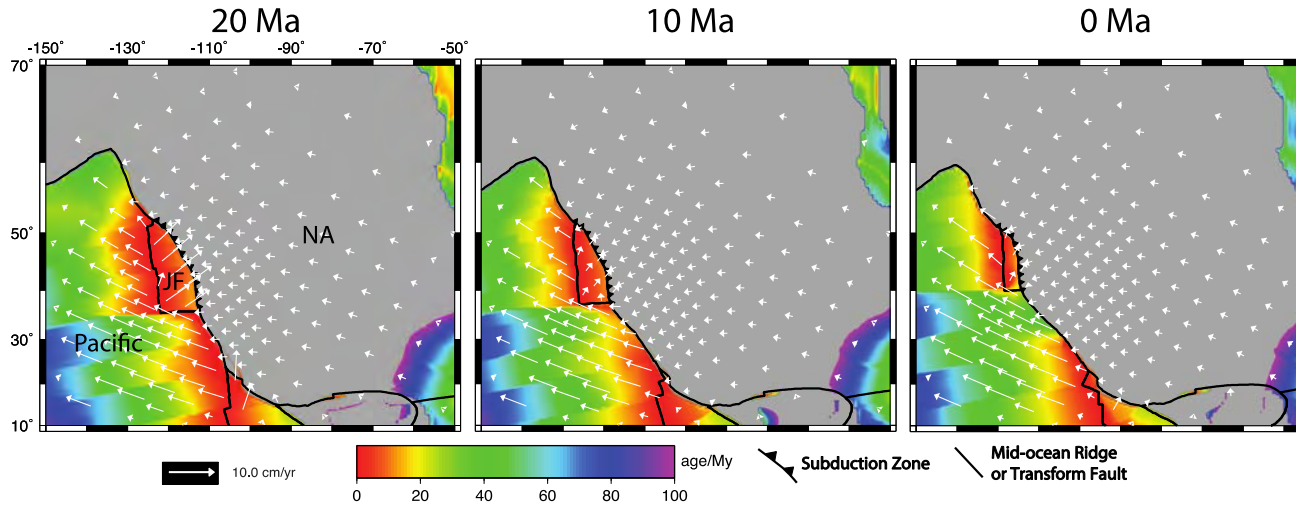
Assume the mantle is an **incompressible** fluid, which satisfies the **Boussinesq** approximation

Method

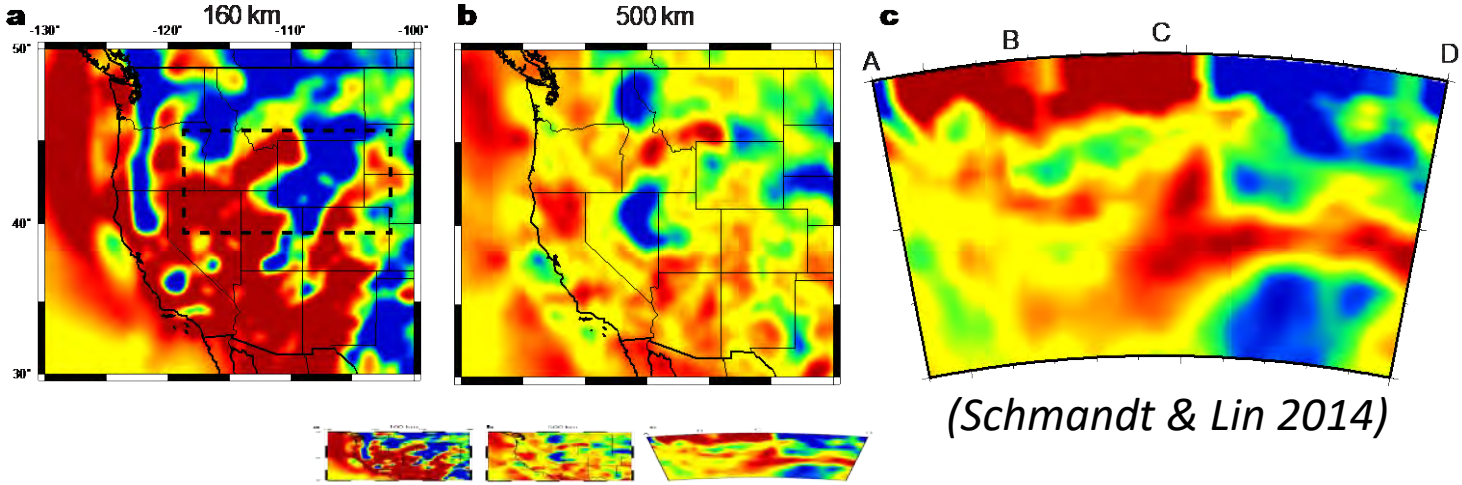
Data assimilation mantle convection simulation

Data can be assimilated:

Plate motion and sea-floor age

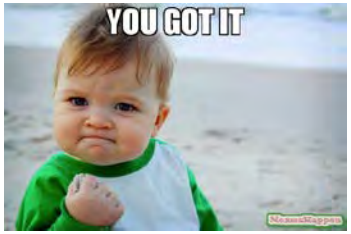


Tomography

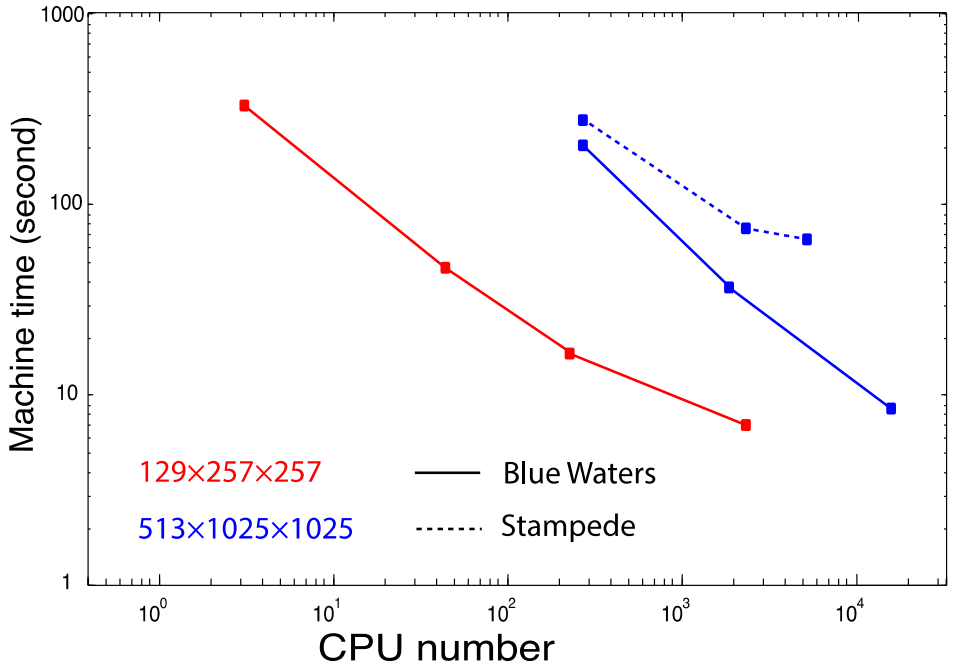


(Schmandt & Lin 2014)

Different data assimilation methods

Method	Summary	Data assimilated
Forward /Sequential	Solving the governing equations forward in time, updating the model when observational constraints are available (imposing plate motion, and updating oceanic lithosphere temperature based on sea-floor age)	Plate Motion Sea-floor age
Simple Backward Inverse(SBI)	Solving the governing equations backward in time, either neglecting thermal diffusion or using normal diffusion.	Plate motion Tomography
Adjoint /Variational	Starting with a first guess of the initial condition, normally generated from the SBI. And then a forward integration predicts the present-day mantle structure, whose difference from the observed structure is integrated back to the initial time using the adjoint solver, correcting the initial condition.	Plate motion Tomography
Hybrid (foward+adjoint) 	First, obtaining a rough estimate of the initial condition through SBI. Second, applying the sequential method to forward predict the present-day mantle structure. Third, introducing the adjoint method to further refine the initial condition and subsequent mantle evolution.	Plate motion Sea-floor age Tomography

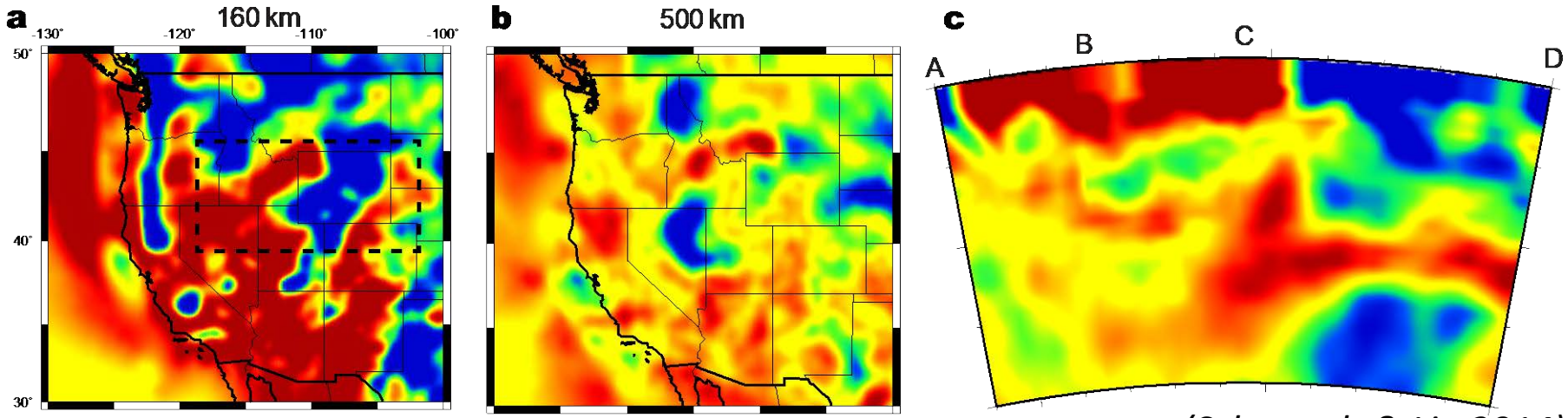
Why Blue Waters



- CitcomS has a very good scalability, up to ~10,000 CPUs on Blue Waters.
- Blue Waters is compatible with the softwares we use, including CitcomS, DrexS and FSTRACK
- Larger capacity leads to larger allocation and shorter waiting time.

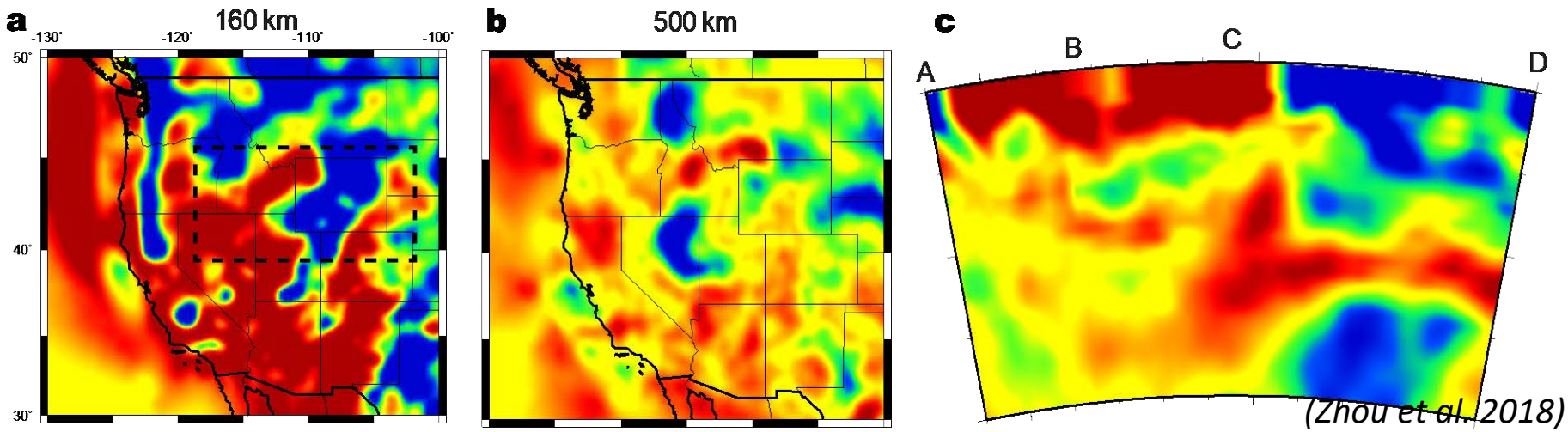
Modeled vs. observed present mantle structure based on the hybrid convection model

Observation



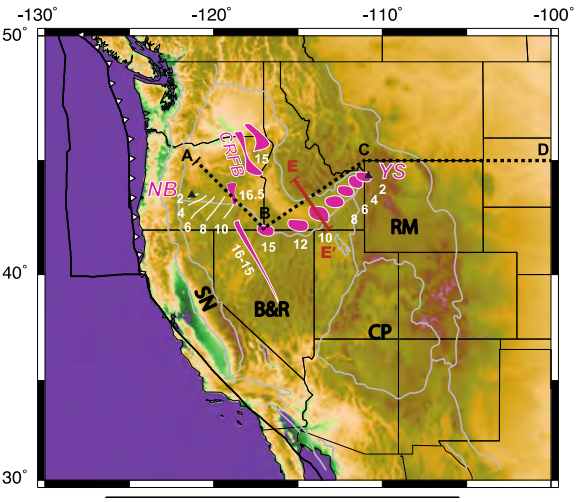
(Schmandt & Lin 2014)

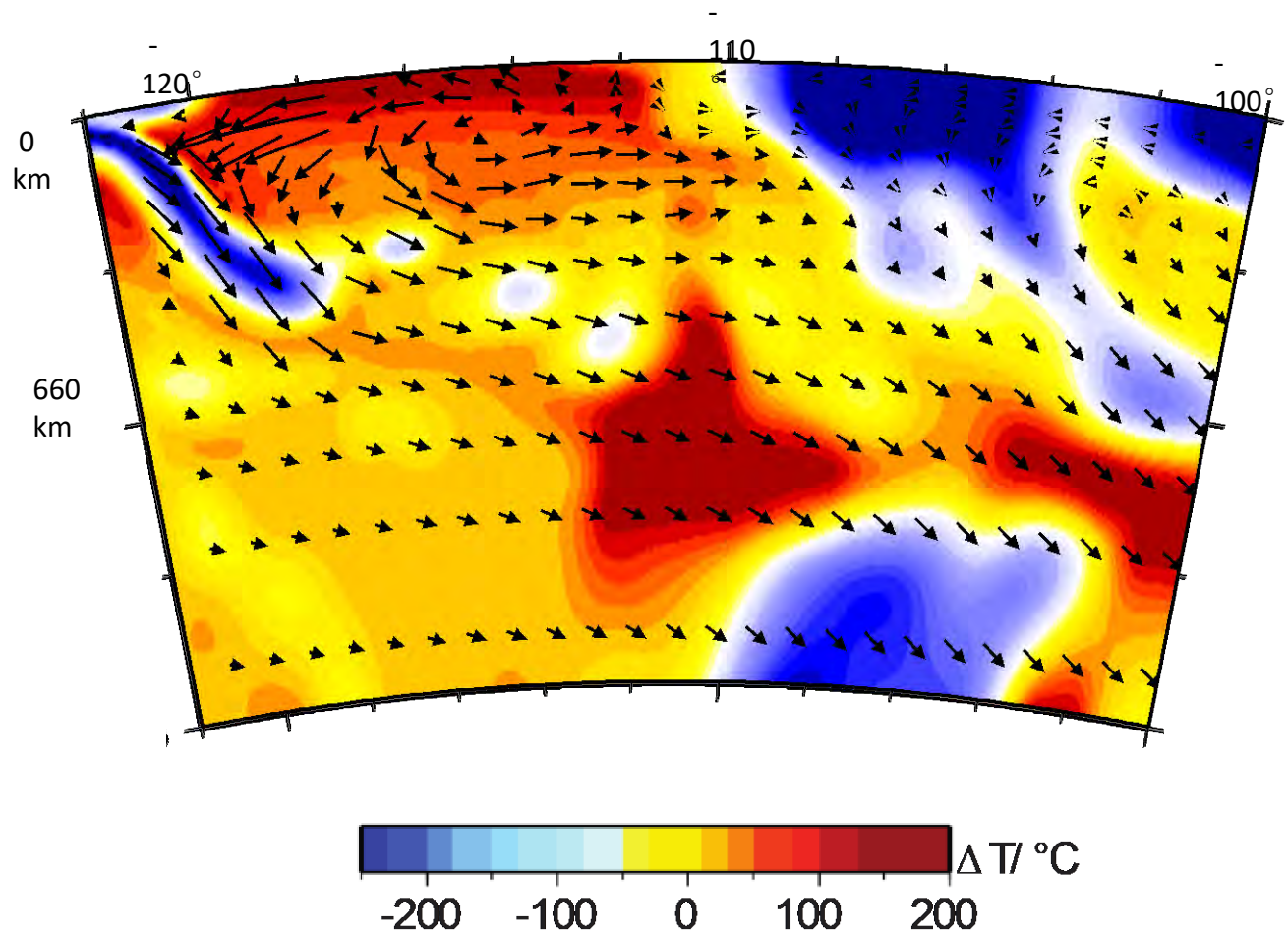
Modeling



(Zhou et al. 2018)

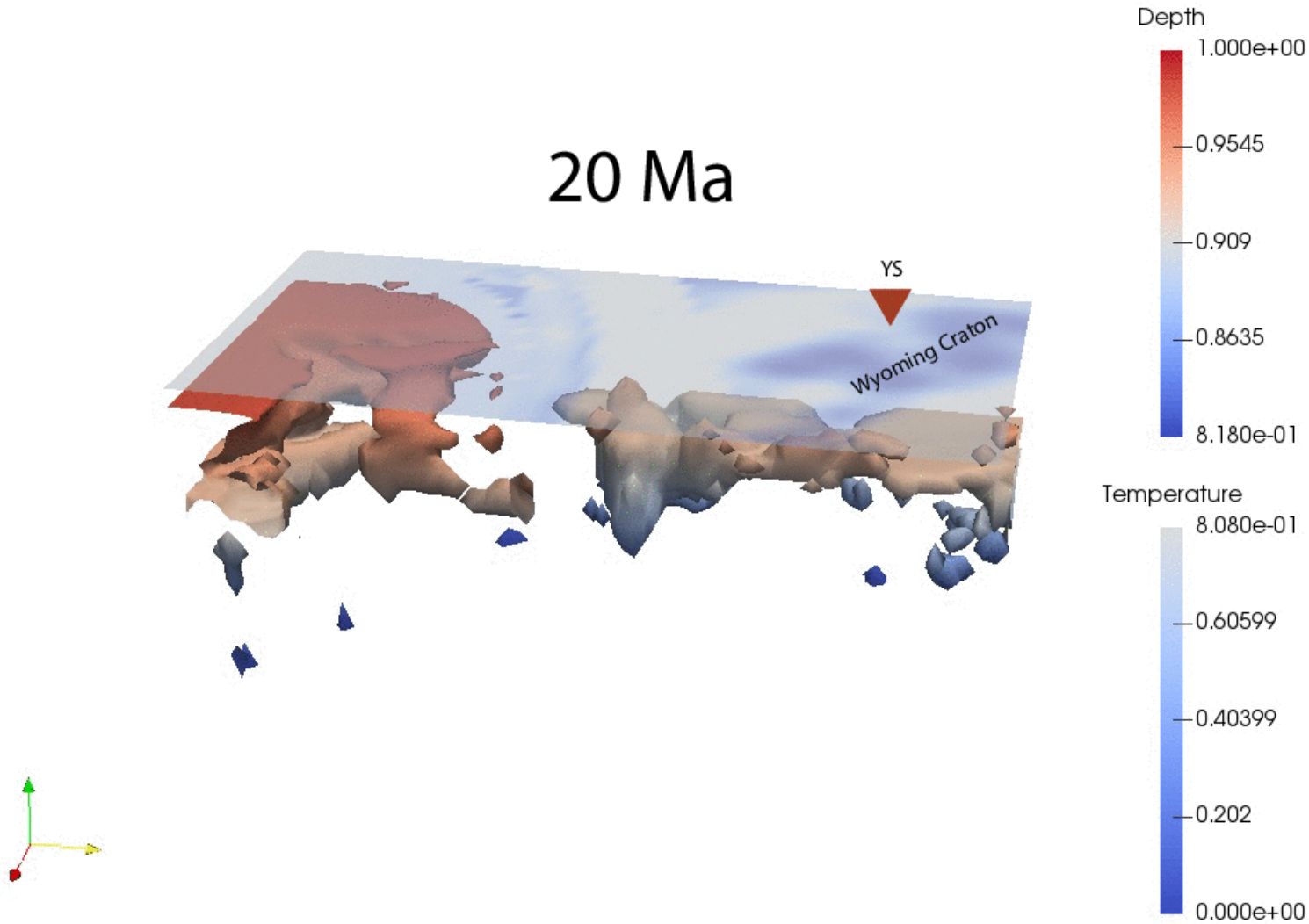
Subduction and Mantle Flow





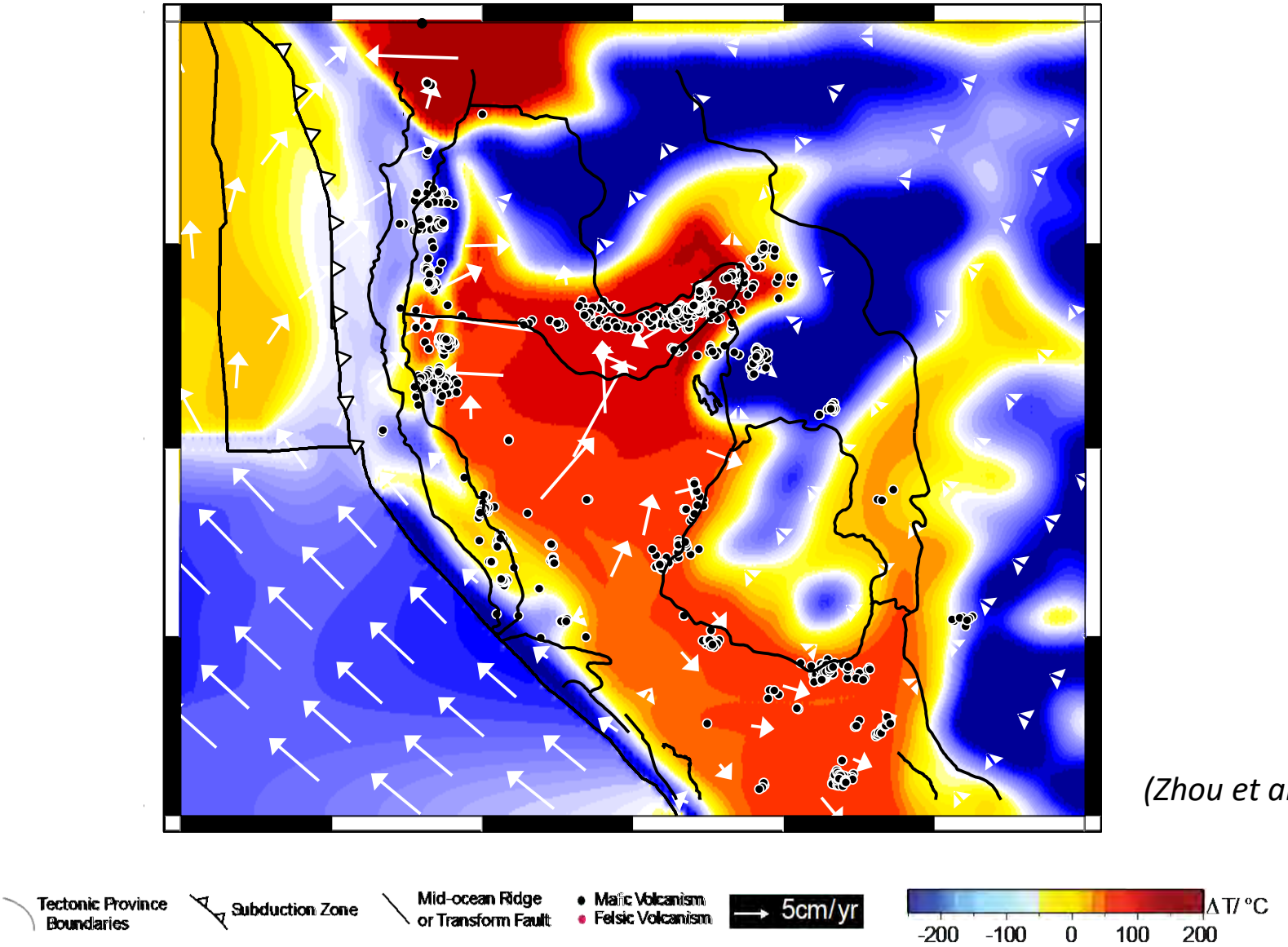
(Zhou et al. 2018)

Plume Evolution 3D View

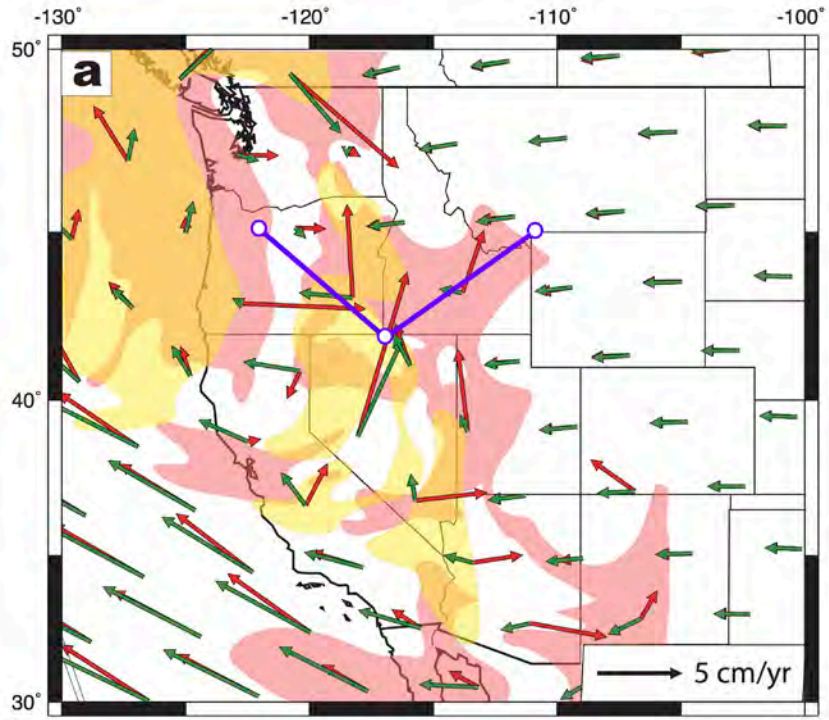


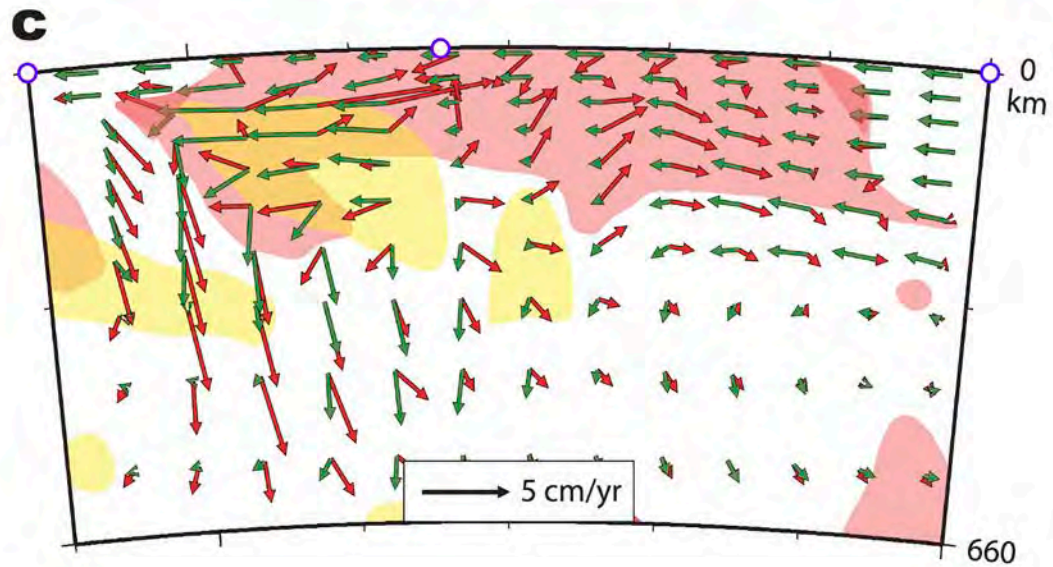
Implication on Intra-plate volcanism

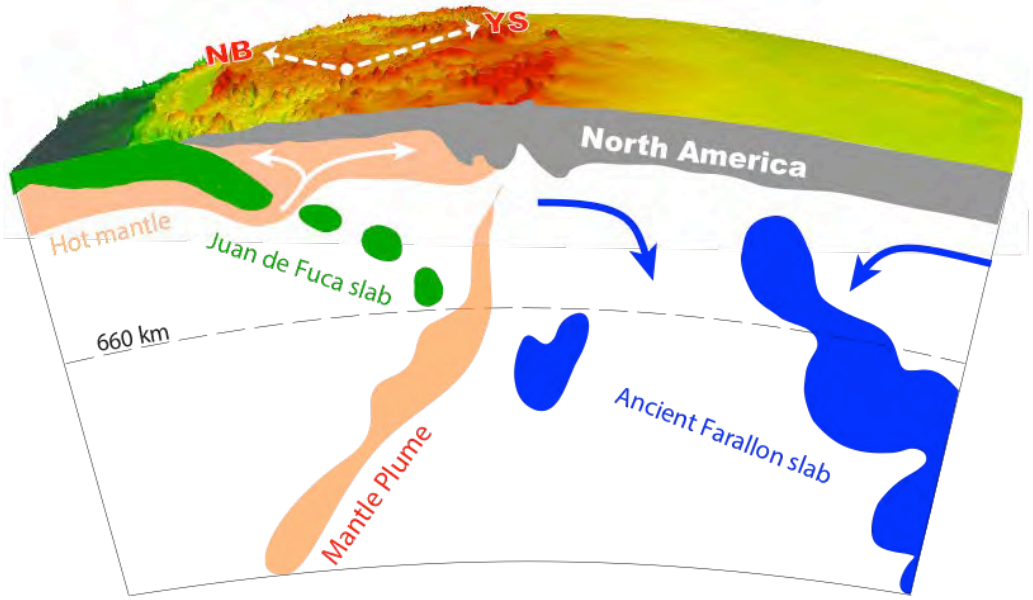
0 Ma



(Zhou et al. 2018)





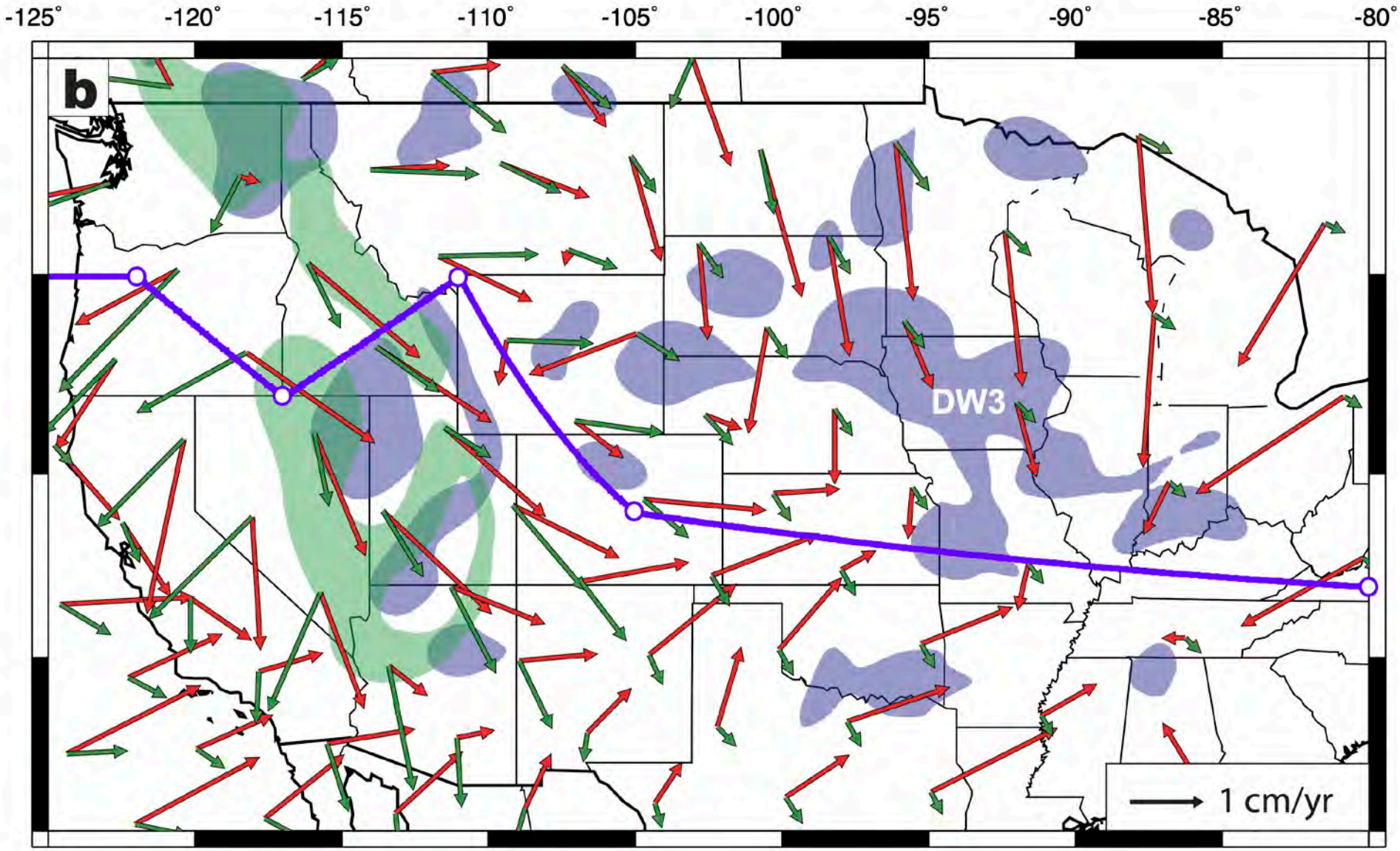


(Zhou et al. 2018)

Conclusions

- ✓ The sinking ancient Farallon slab drives the hot anomalies below the oceanic lithosphere to intrude into the western U.S.
- ✓ The propagation of oceanic hot anomalies below the western U.S. induces the intra-plate volcanisms

Driving force: Ancient Farallon Slab



(Zhou et al. 2018)

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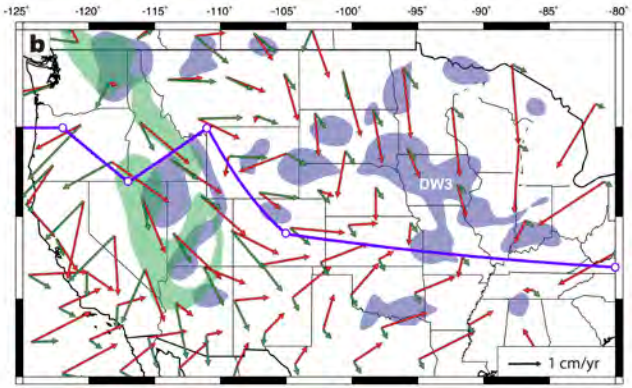

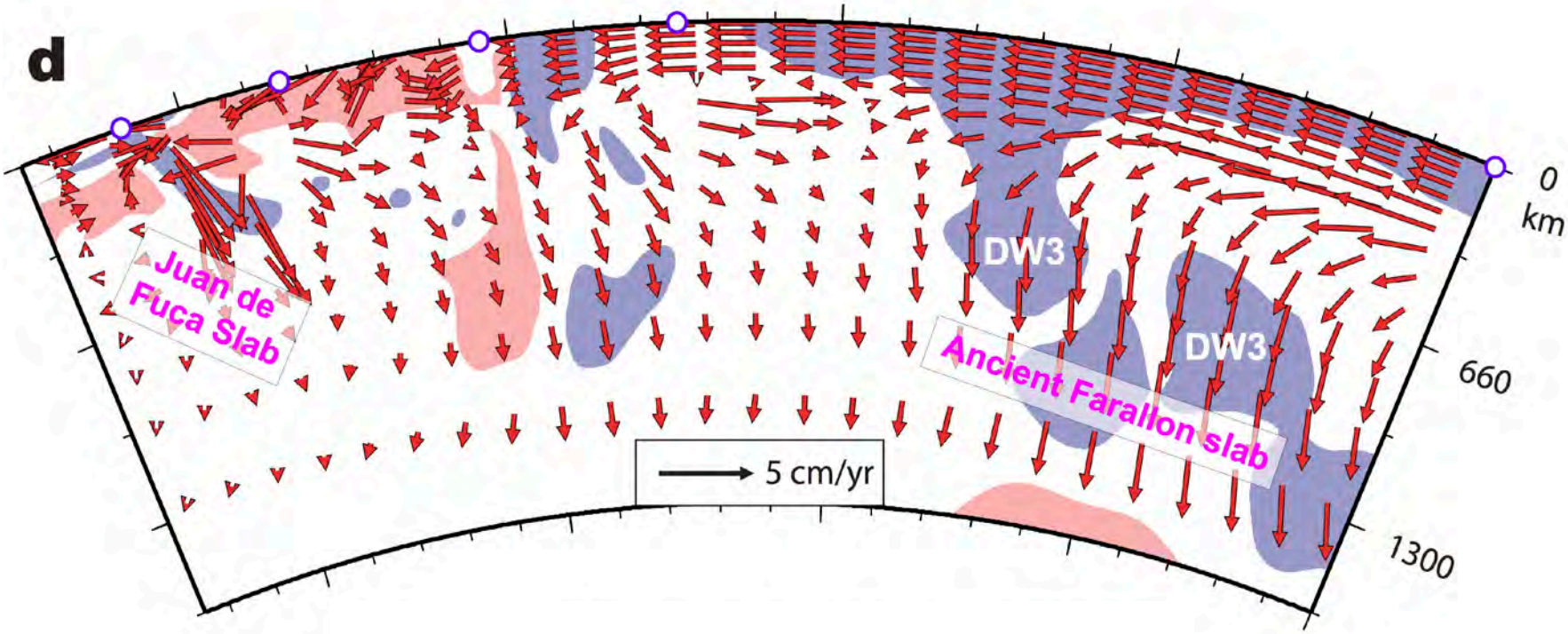

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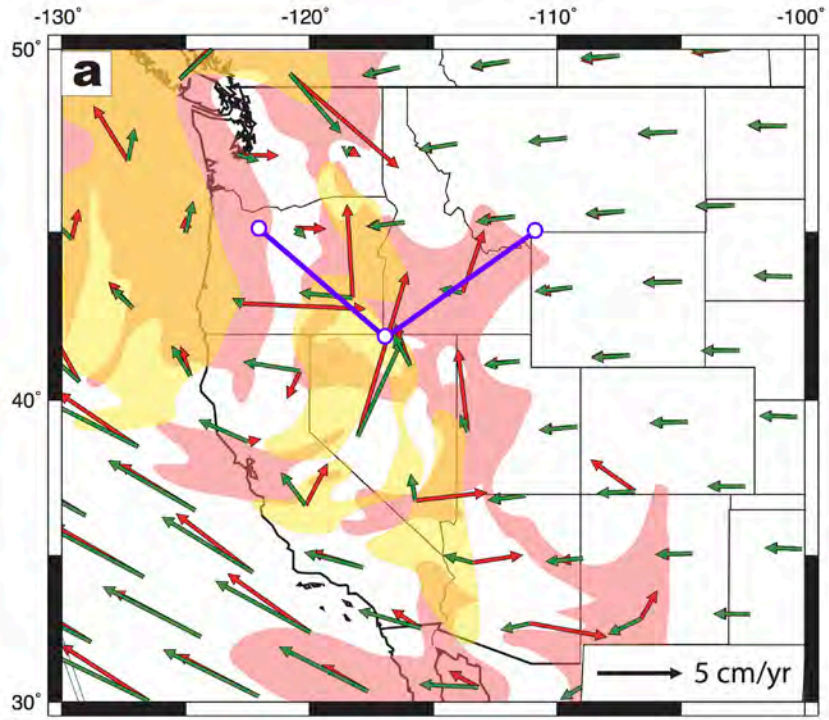

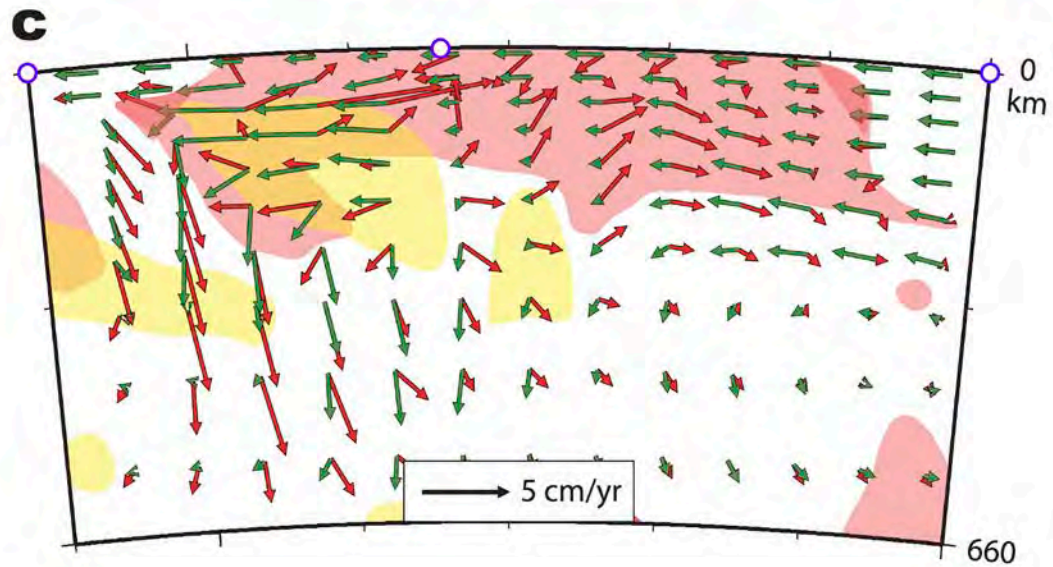

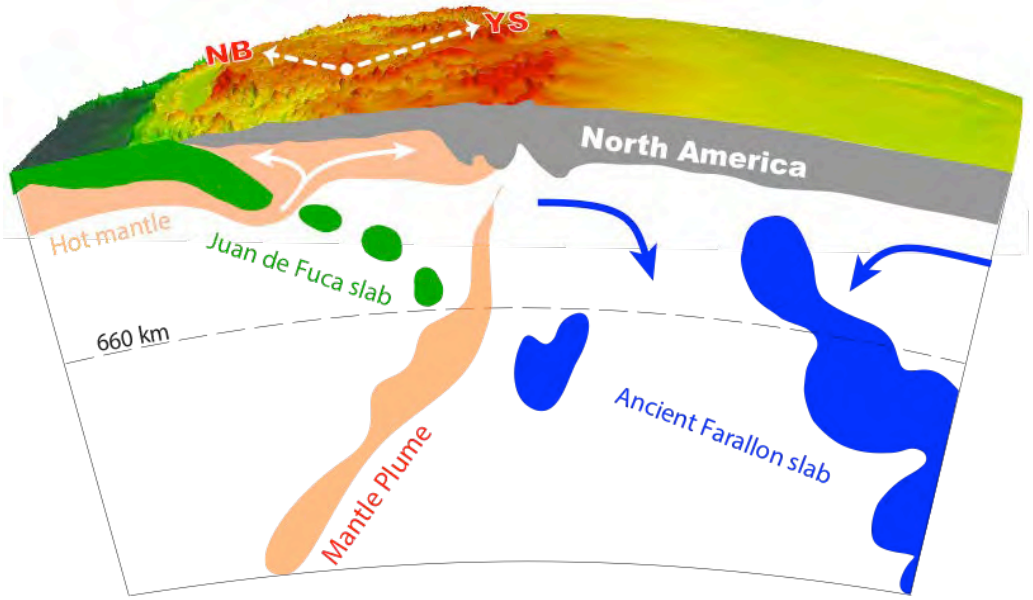

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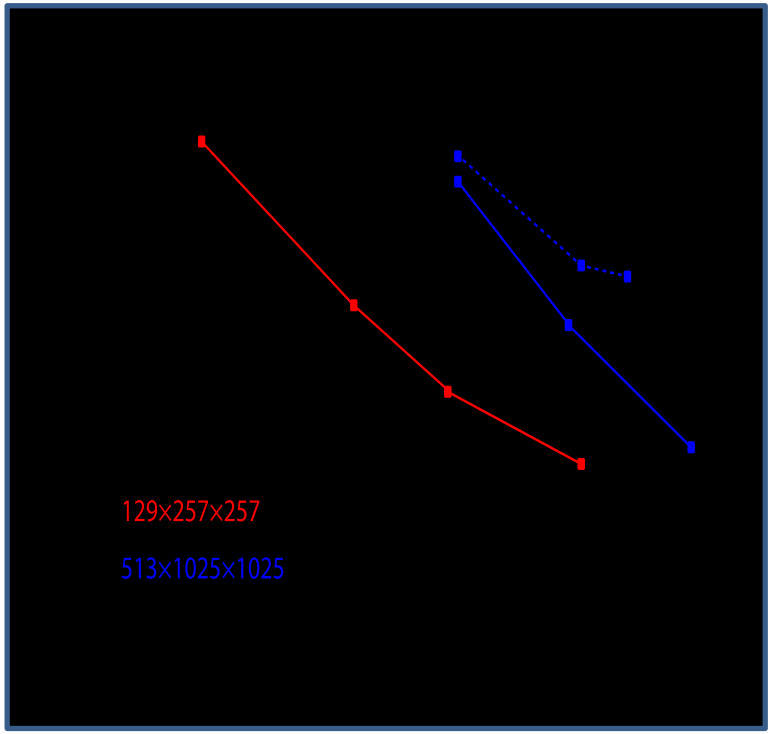

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