Oceanic plateau subduction beneath North America and its geological and geophysical implications

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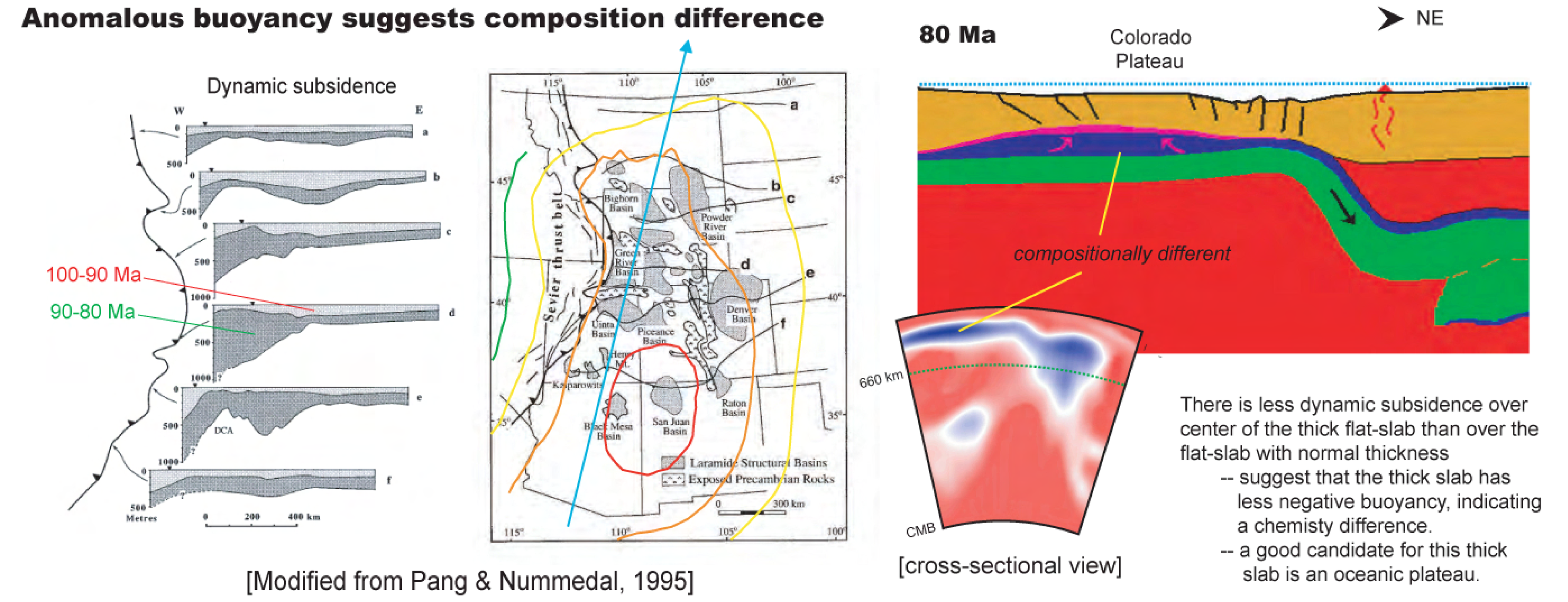
Abstract:

We use two independent approaches, inverse models of mantle convection and plate reconstructions, to predict the temporal and spatial association of the Laramide events to subduction of oceanic plateaus. Inverse convection models recover two prominent anomalies on the Farallon plate during Late Cretaceous that coincide with paleogeographically restored configurations of the Shatsky and Hess conjugate plateaus when they collided with North America. The distributed deformation of the Laramide orogeny closely tracked the passage of the Shatsky conjugate massif, suggesting that subduction of this plateau dominated the distinctive geology of the western United States. Subduction of the Hess conjugate corresponds to termination of a Latest Cretaceous arc magmatism and intense crustal shortening in Early Paleogene along the Mexican foreland thrust belt. At present, conjugates of the Shatsky and Hess plateaus are located beneath the east coast of N. America, and the predicted +4% seismic anomalies in both P and S wave velocities associated with the remnant plateau crusts should make predicted sharp boundaries detectable by the USArray seismic experiment.

Flat subduction of the Shatsky conjugate caused subsidence/ uplift and tilt of the Colorado Plateau (CP). With the arrival of the flat slab, dynamic subsidence starts at the southwestern CP and reaches a maximum at ~86 Ma. Two stages of uplift follow the removal of the Farallon slab: one in Latest Cretaceous and the other in Eocene with a cumulative uplift of ~1.2 km. The SW plateau reaches a high dynamic topography in the Eocene which is sustained to the present. Both the descent of the slab and buoyant mantle upwelling may have contributed to late Cenozoic plateau uplift. The plateau tilts downward to the NE before Oligocene, caused by NE trending subduction of the Farallon slab. The NE tilt diminishes and switches to a SW tilt during the Miocene when buoyant mantle upwellings occur.

Anomalous buoyancy suggests composition difference



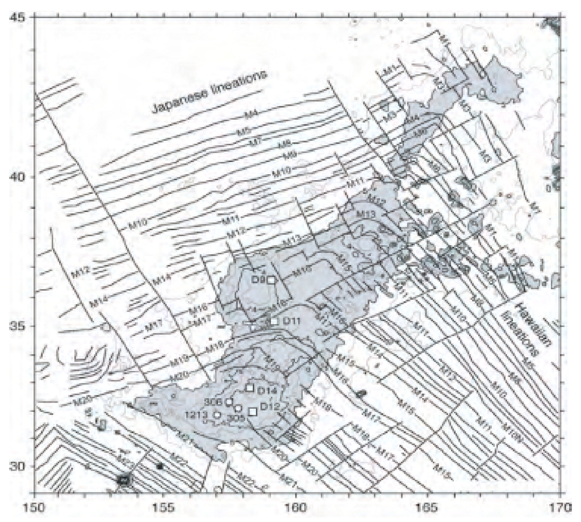
[Modified from Pang & Nummedal, 1995]

[cross-sectional view]

Assumptions

1. Shatsky Rise formed at PA-FA-IZ TJ.

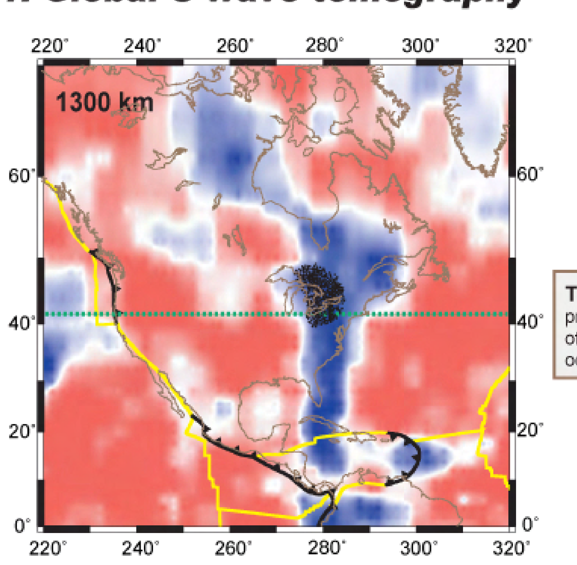
2. Symm. spreading



Work flow

1. Starting point and prediction target: seismic tomography
2. Forward-adjoint iterations to retieve past mantle structure
3. Use stratigraphy as proxy of dynamic topo. to constrain the model.

1. Global S wave tomography



[Grand, 2002]

2.

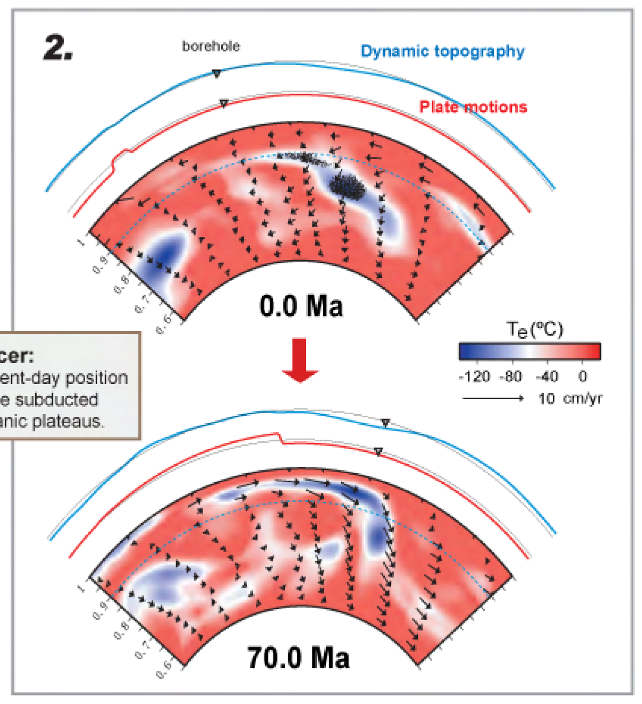
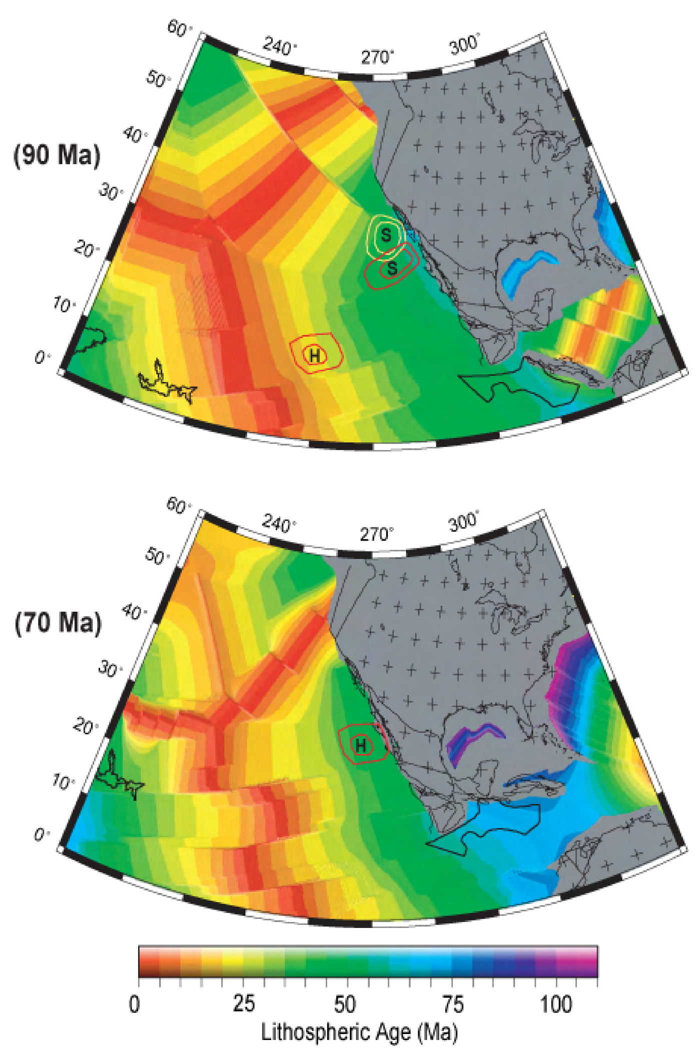
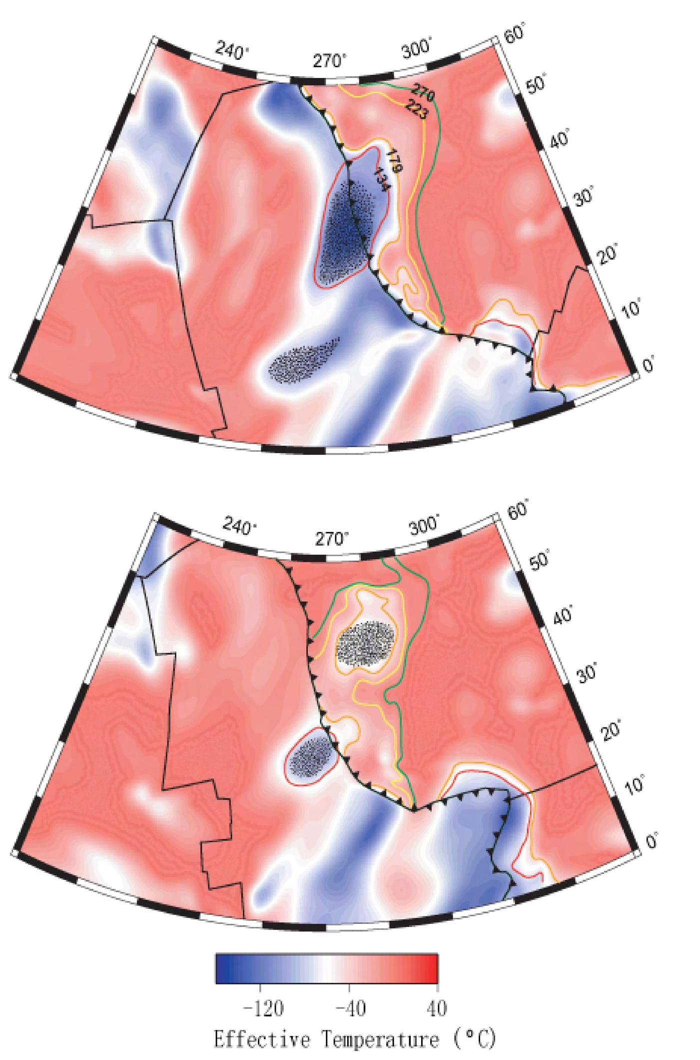


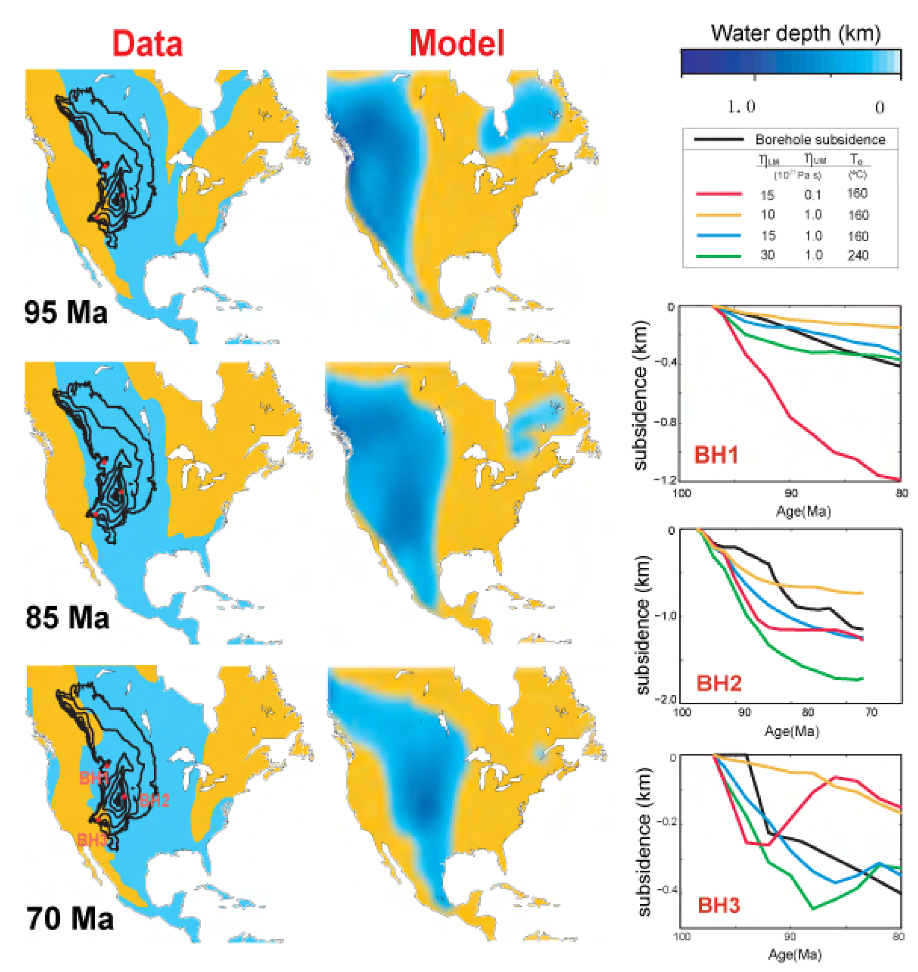
Plate reconstruction



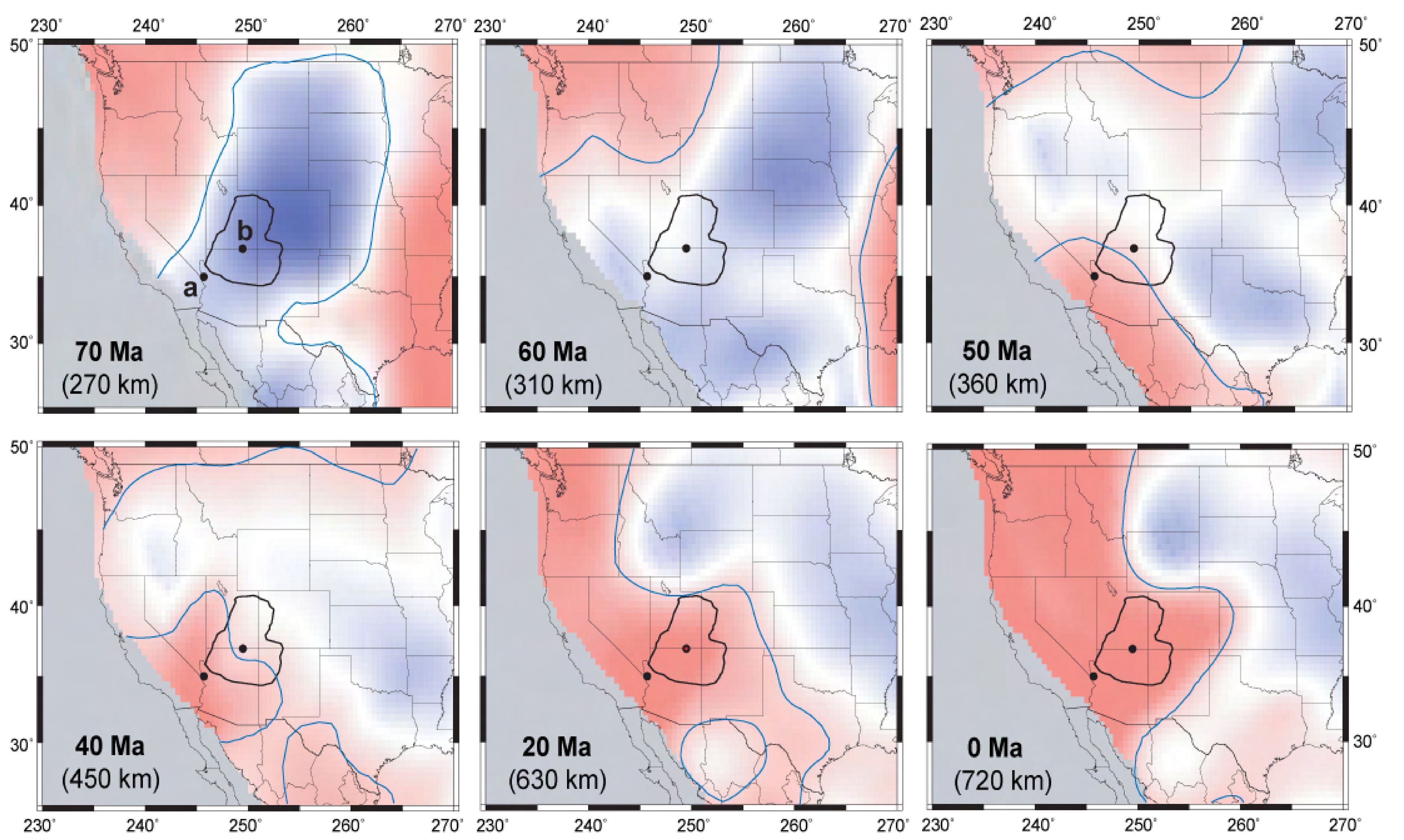
Adjoint convection model

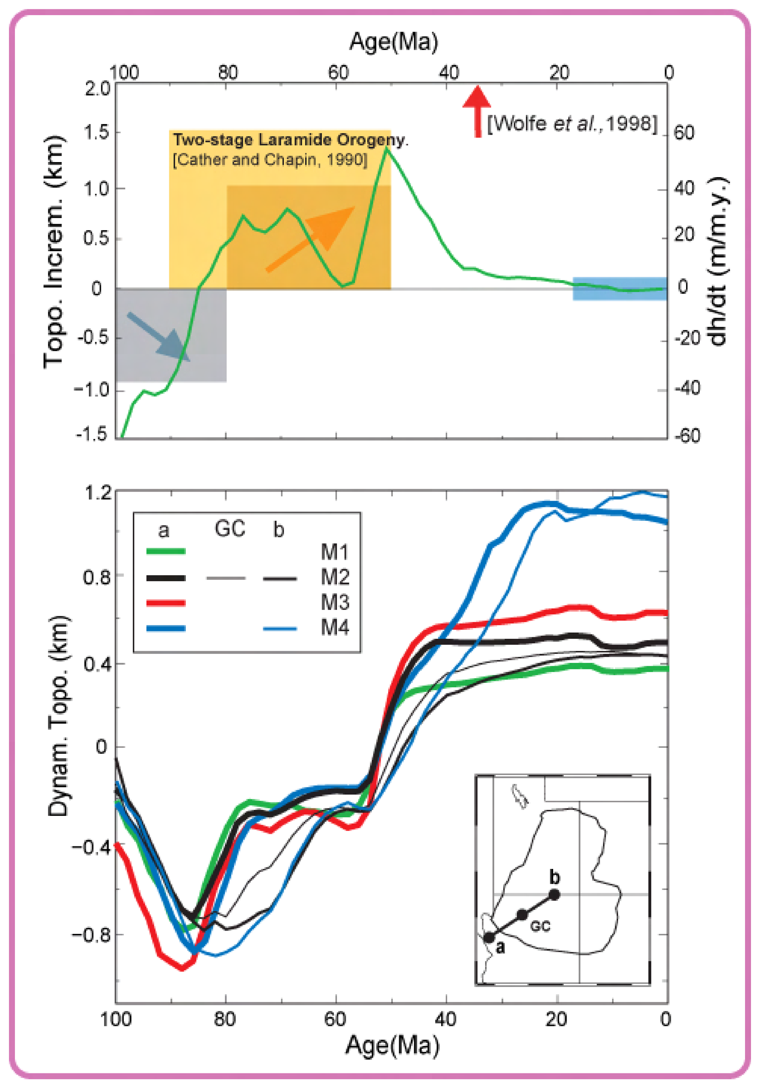


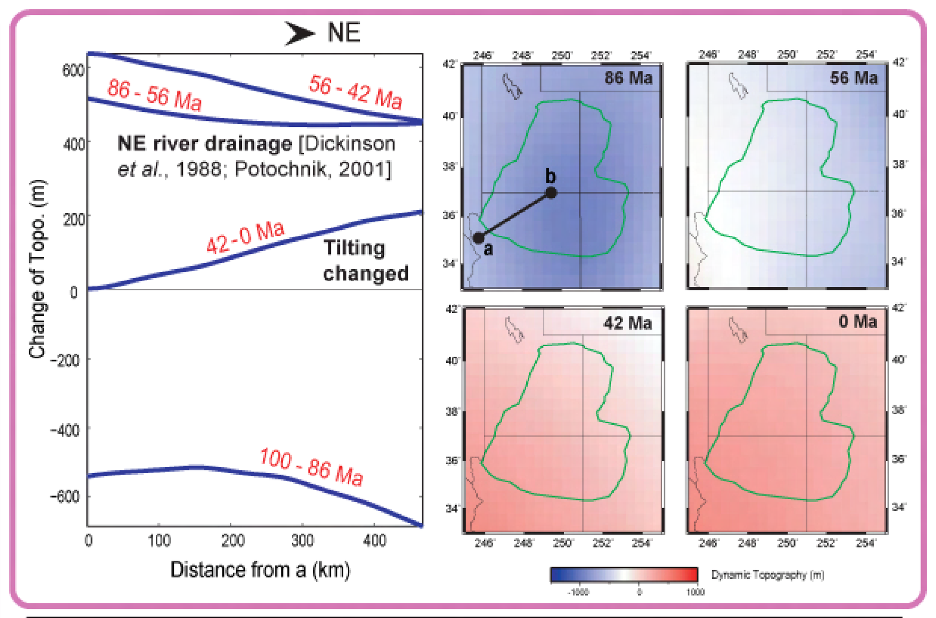
3. Model calibration: Paleoshorelines and borehole subsidence rates constrain the best fit model to be: $\eta_{LM}=1.5\times10^{22}$ Pas, $\eta_{UM}=10^{21}$ Pas and $T_e=160$°C.



Dynamic subsidence and uplift of the Colorado Plateau



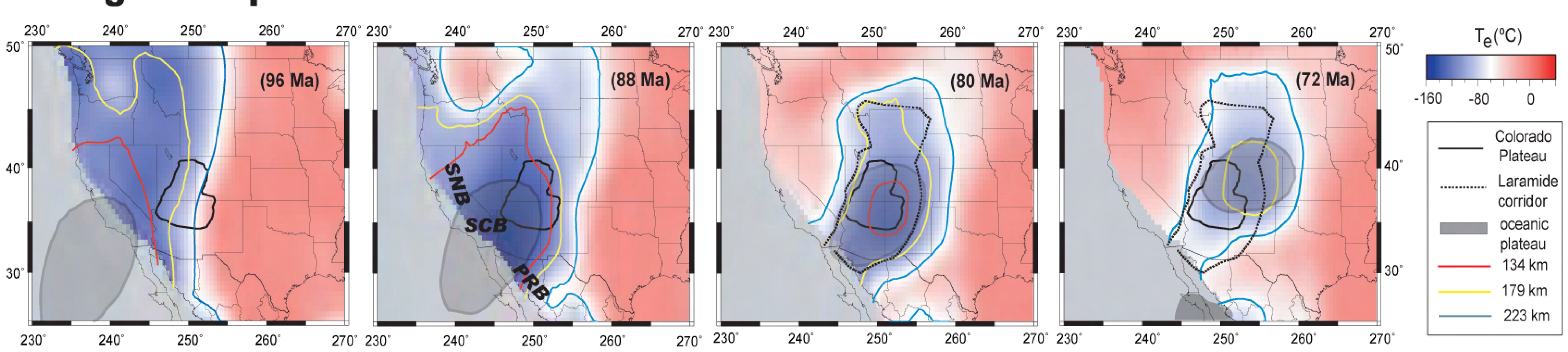




- Clumped carbon isotopes on carbonates. [Huntington, Wernicke, Eiler, 2009]
- Burial and unroofing of sediment rocks from (U-Th)/He low temperature thermochronolgoy. [Flowers, Wernicke, Farley, 2008]

Model name	η_{UM} (10^{21} Pa s)	η_{LM} (10^{21} Pa s)	T_e (°C)	Active upwelling included?
M1	30	1.0	160	No
M2	15	1.0	160	No
M3	30	1.0	240	No
M4	15	1.0	160	Yes

Geological implications



1. Subduction of the Shatsky conjugate may have cuased:
   - -- Fast destruction of the fore arc and rapid exhumation of southernmost SNB between 96 and 86 Ma [Saleeby *et al.*, 2007].
   - -- Waning arc magmatism at SNB between 90-85 Ma [Nadin & Saleeby, 2008] and an abrupt eastward migration of magmatism in PRB [Silver *et al.*, 1979].
   - -- The Laramide deformation corridor along S. California to the Colorado Plateau and Central Rockies [Saleeby, 2003].
2. Subduction of the Hess conjugate caused the Latest Cretaceous PRB magmatism termination, followed by intense crustal shortening [Campa, 1985].
3. Passage of these oceanic plateaus beneath western US seems responsable for the Late Cretaceous flat-slab subduction and the subsequent uplift.

Implications:

1) The CP underwent rapid subsidence as the Shatsky conjugate subduct beneath it before 80 Ma.
2) Removal of the Shatsky conjugate from under CP caused the surface to rebound btw 80 - 60 Ma.
3) NE removal of the whole Farallon slab led to fast SW to NE dynamic uplift of the CP after 55 Ma.
4) The CP experienced an uplfit of > 1.2 km before 40 Ma; possible mantle upwelling beneath the CP caused an extra uplift of ~600 m; this is consistent with paleobotanical study [Wolfe *et al.*, 1998].
5) CP tilted to NE before Miocene due to the NE subduction of the Farallon slab, and changed to a SW tilting direction during around 10 Ma due to an active upwelling.

References:

Liu, L., S. Spasojevic and M. Gurnis, 2008, Reconstructing Farallon Plate Subduction Beneath North America Back to the Late Cretaceous, Science, 322, 934-938.

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