How does pre-existing lithospheric structure control the architecture of rifted continental margins during and after breakup?

Jolante van Wijk
New Mexico Tech

Raton basin, Western Interior Seaway margin

Each rift is a different setting in terms of inheritance and forces involved in its formation

Jolante van Wijk
New Mexico Tech

Raton basin, Western Interior Seaway margin

East African Rift

Rift zones follow the outside of Tanzanian craton

Rift zones follow pre-existing orogenic fabric

Rift zones form above a plume

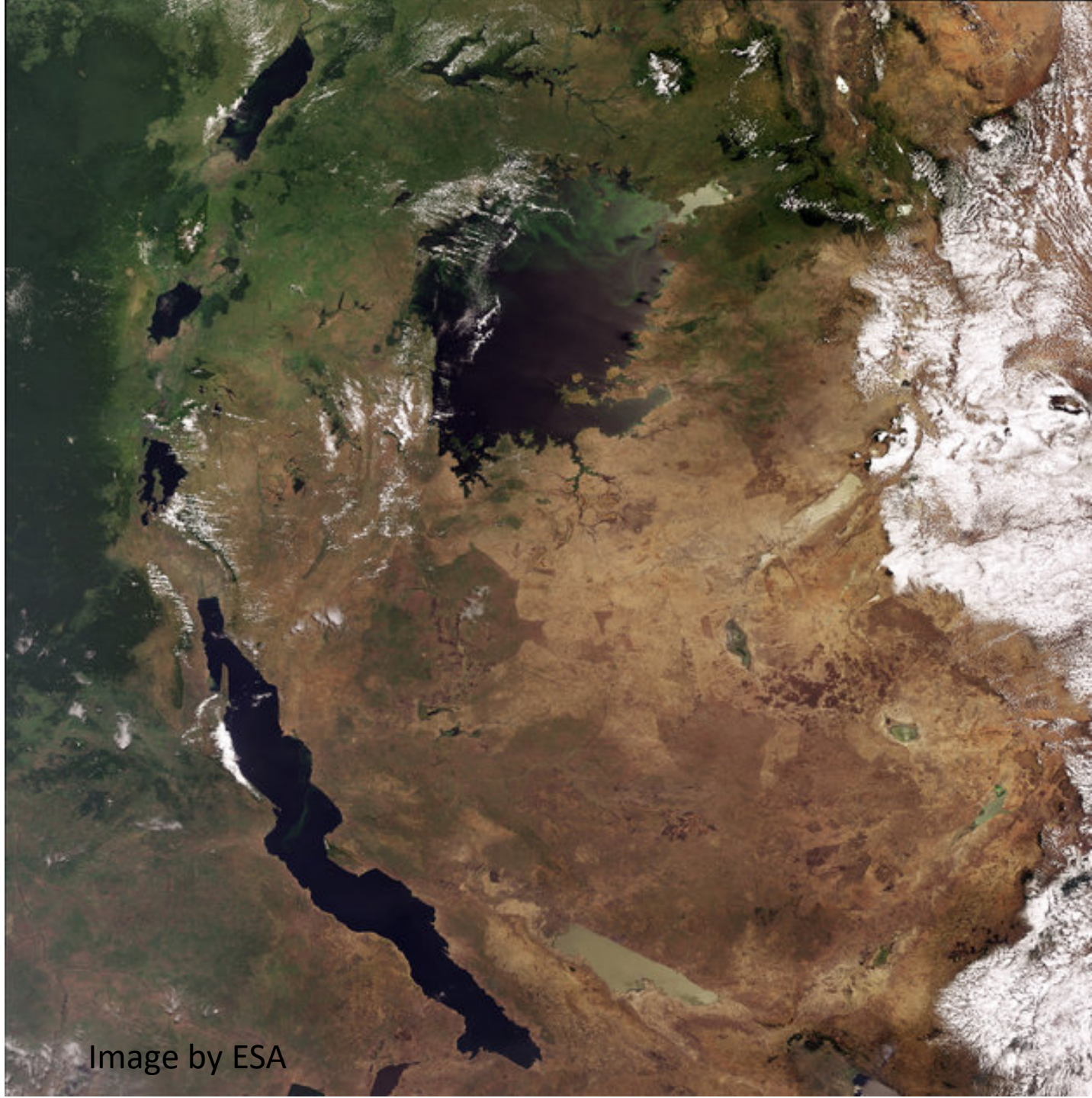

Image by ESA

East African Rift

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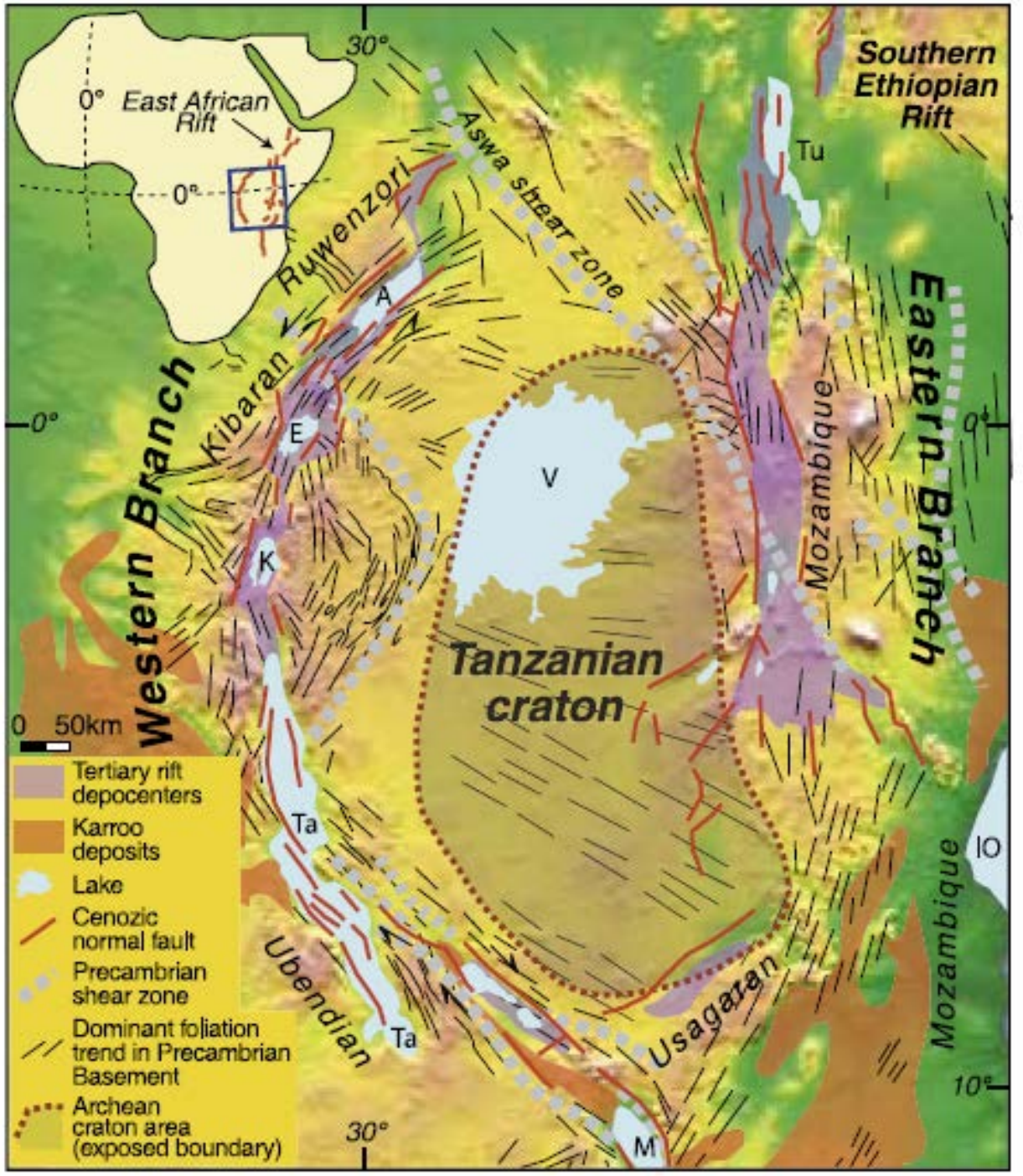
Why?

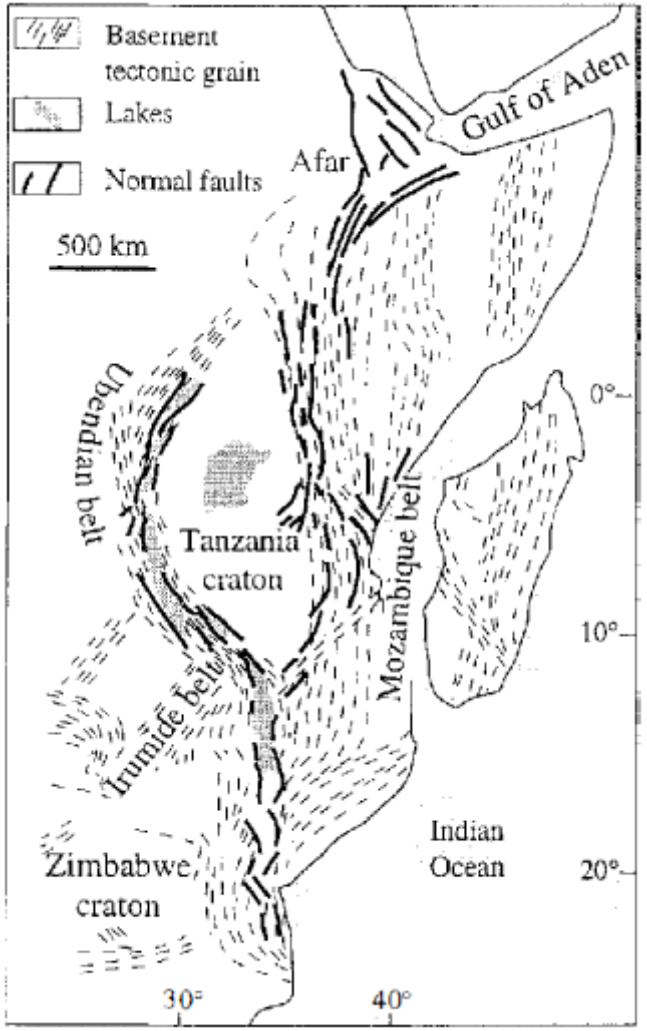


Corti et al. Tectonics 2007

Source of structural inheritance in fabric of lithospheric mantle

During continent assembly, deformation induces a lattice-preferred orientation of olivine in mantle rocks: a mechanical anisotropy in the lithospheric mantle

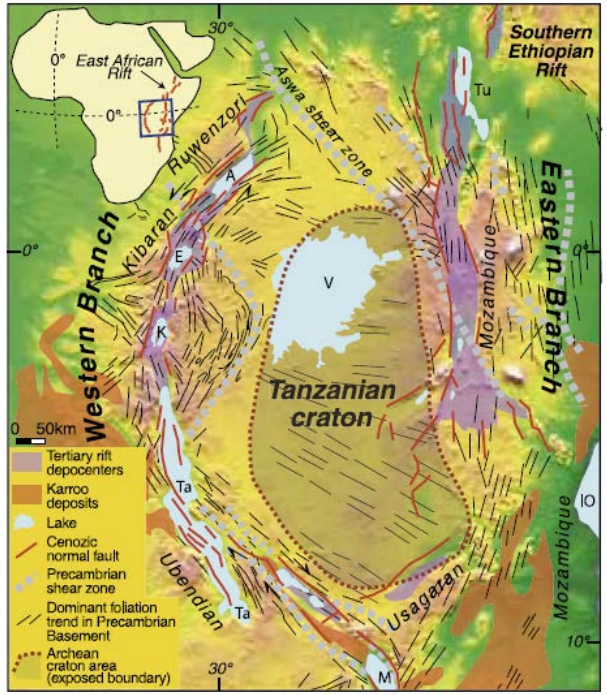
“Strength of anisotropic aggregates lower for extension normal to foliation plane system, and experiments show that reactivation of the initial fabric involves a strike-slip component”

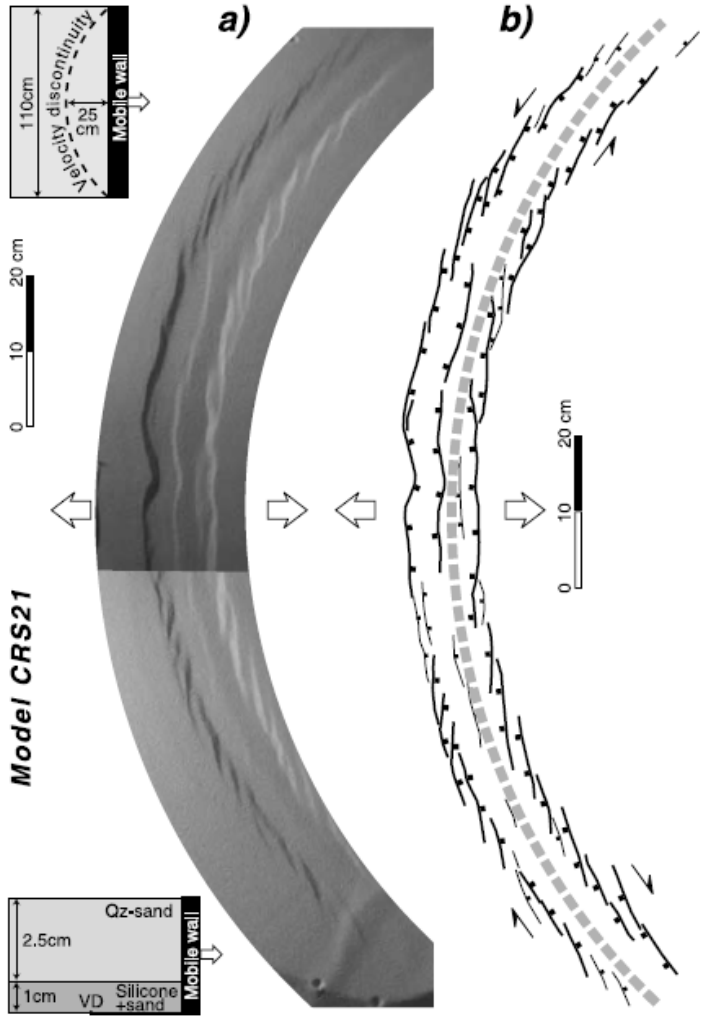


Vauchez et al. Terra Nova 1997

Lithospheric strength is less when crust is thick, and faults follow crustal fabric

Analogue model with homogeneous crust



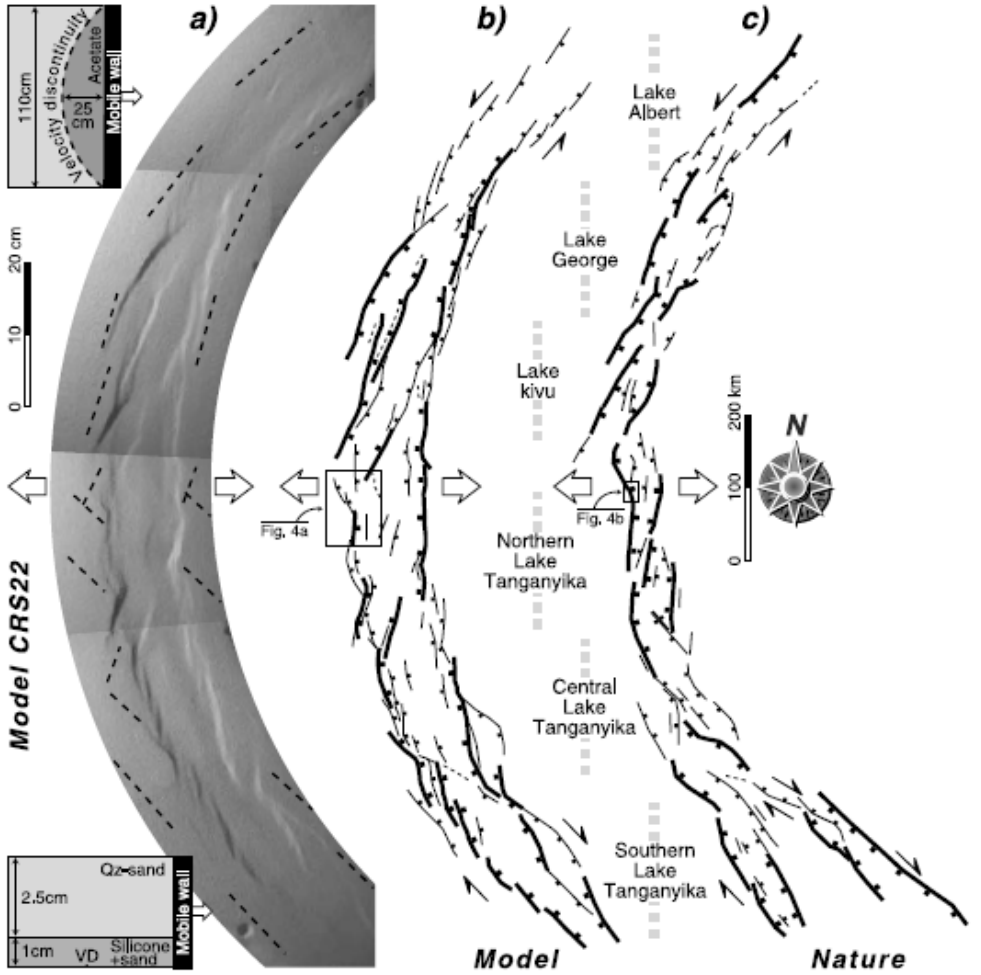


Corti et al. Tectonics 2007

Lithospheric strength is less when crust is thick, and faults follow crustal fabric

Analogue model with heterogeneous crust

Produces crustal deformation patterns similar to western branch

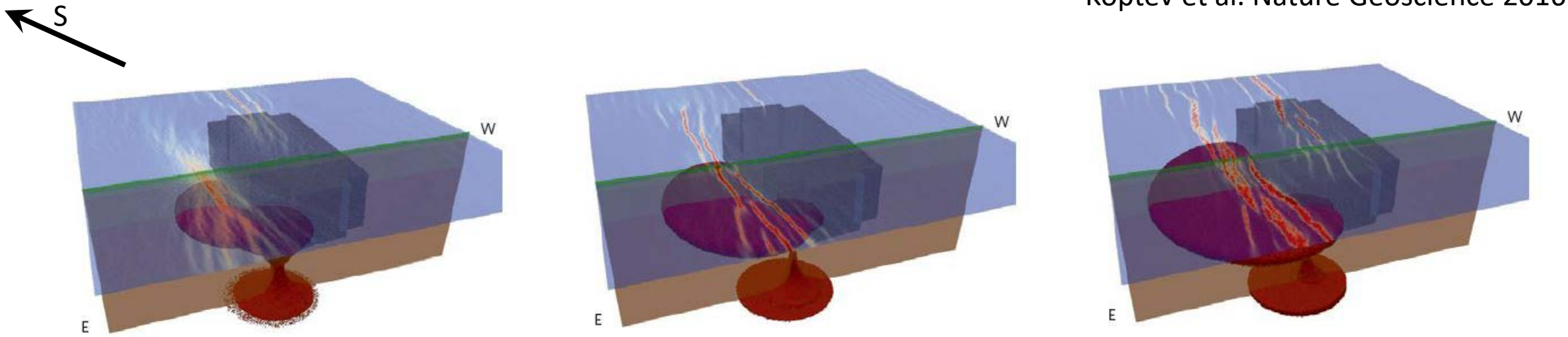


Corti et al. Tectonics 2007

Plume impact causes crustal extension and mantle lithosphere erosion outside of strong craton

Plume initiates/accelerates/localizes rift opening

Koptev et al. Nature Geoscience 2016



1 my

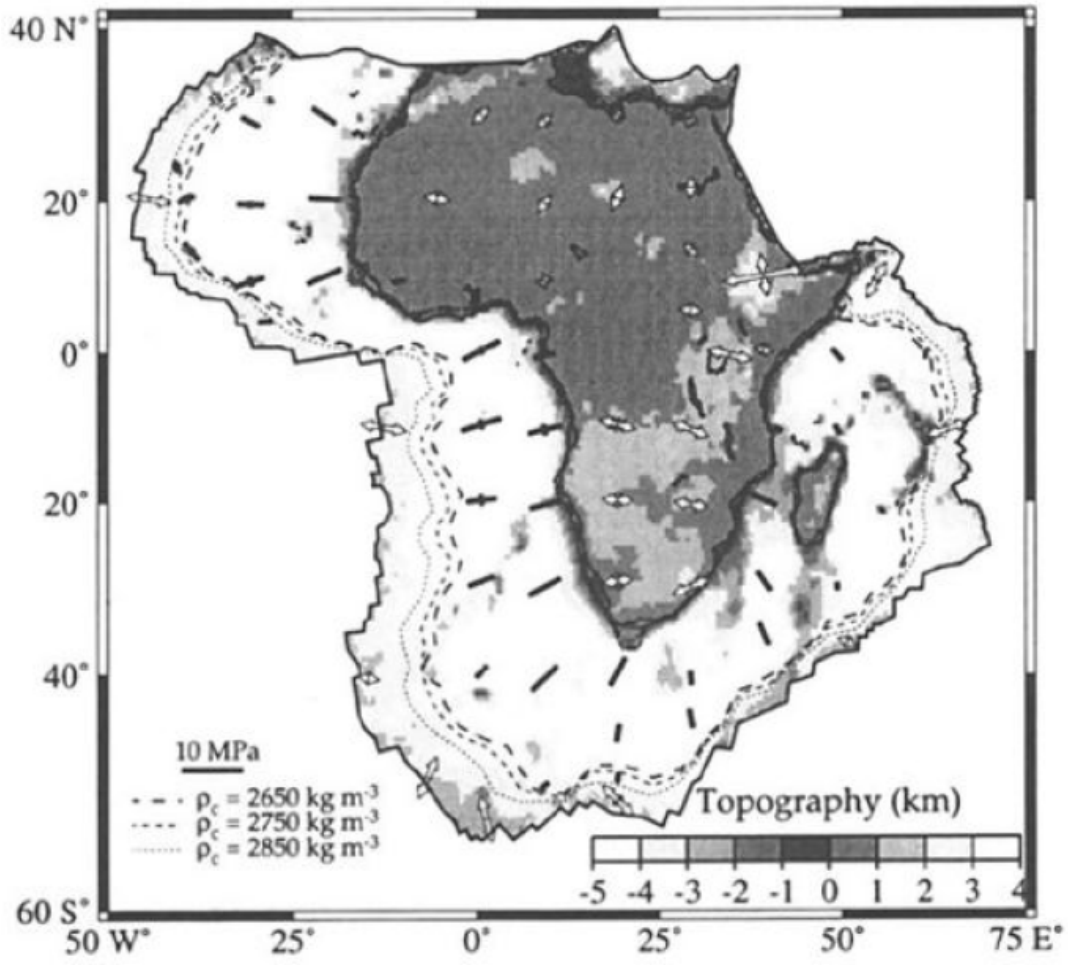
2.5 my

10 my

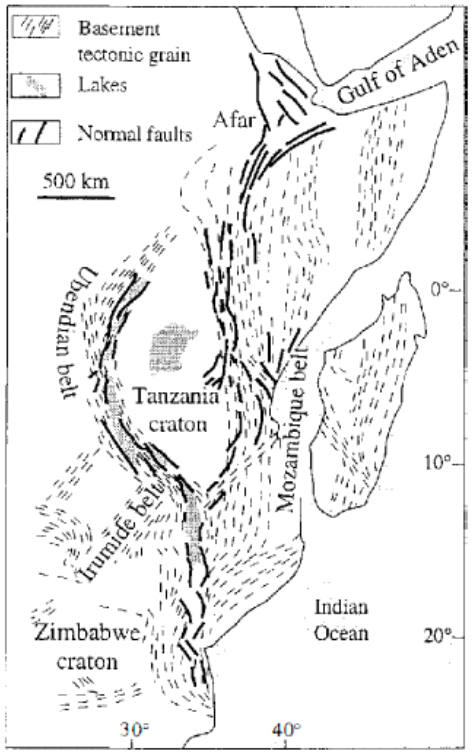
Tectonic stresses resulting from lateral variations in potential energy

Extensional stresses predicted in NE Africa

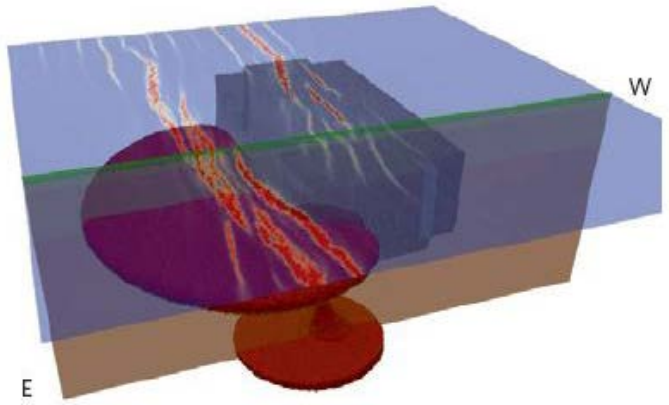
Magnitude of these stresses ~80% of force needed to deform crustal material



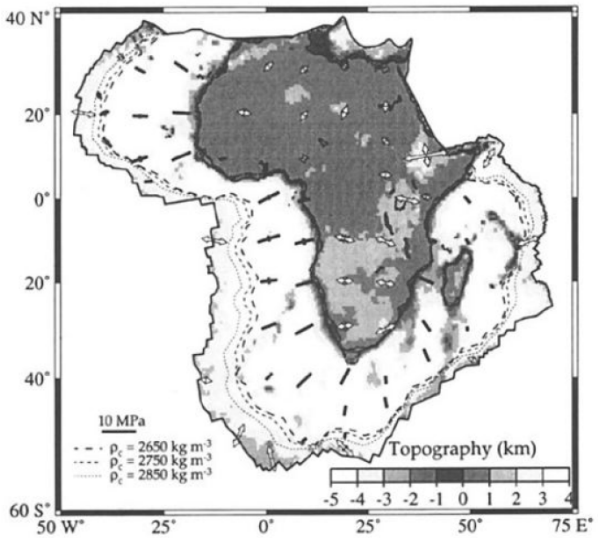
Coblentz and Sandiford Geology 1994



Mantle foliation

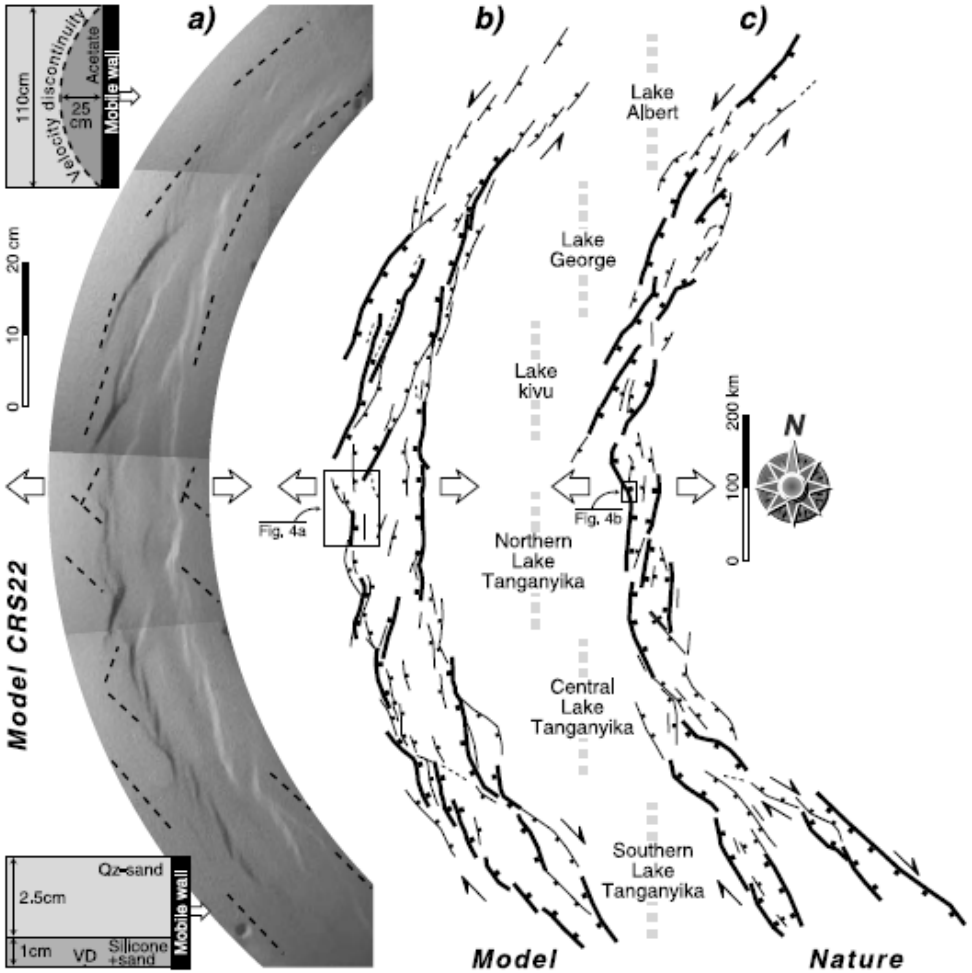


Plume



Gravitational potential energy

Crustal foliation



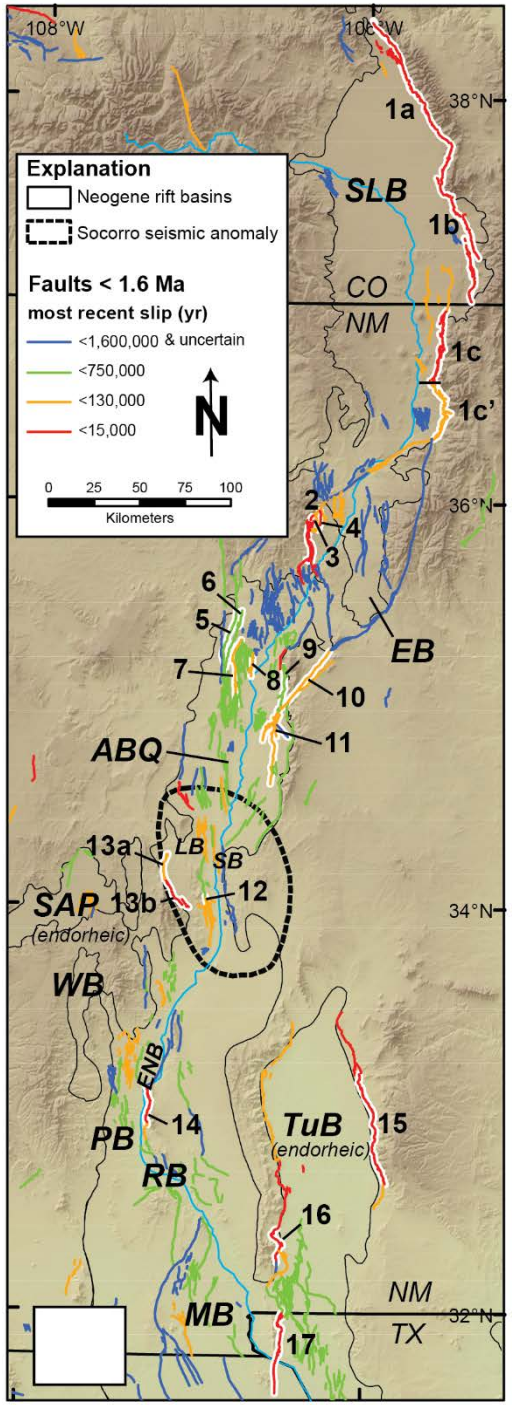
Rio Grande rift

Rift zone crosses Proterozoic boundaries

Rift zone follows hinge of flat Farallon slab

Rift zone follows step in lithosphere thickness

Rift zone not affected by weak plume



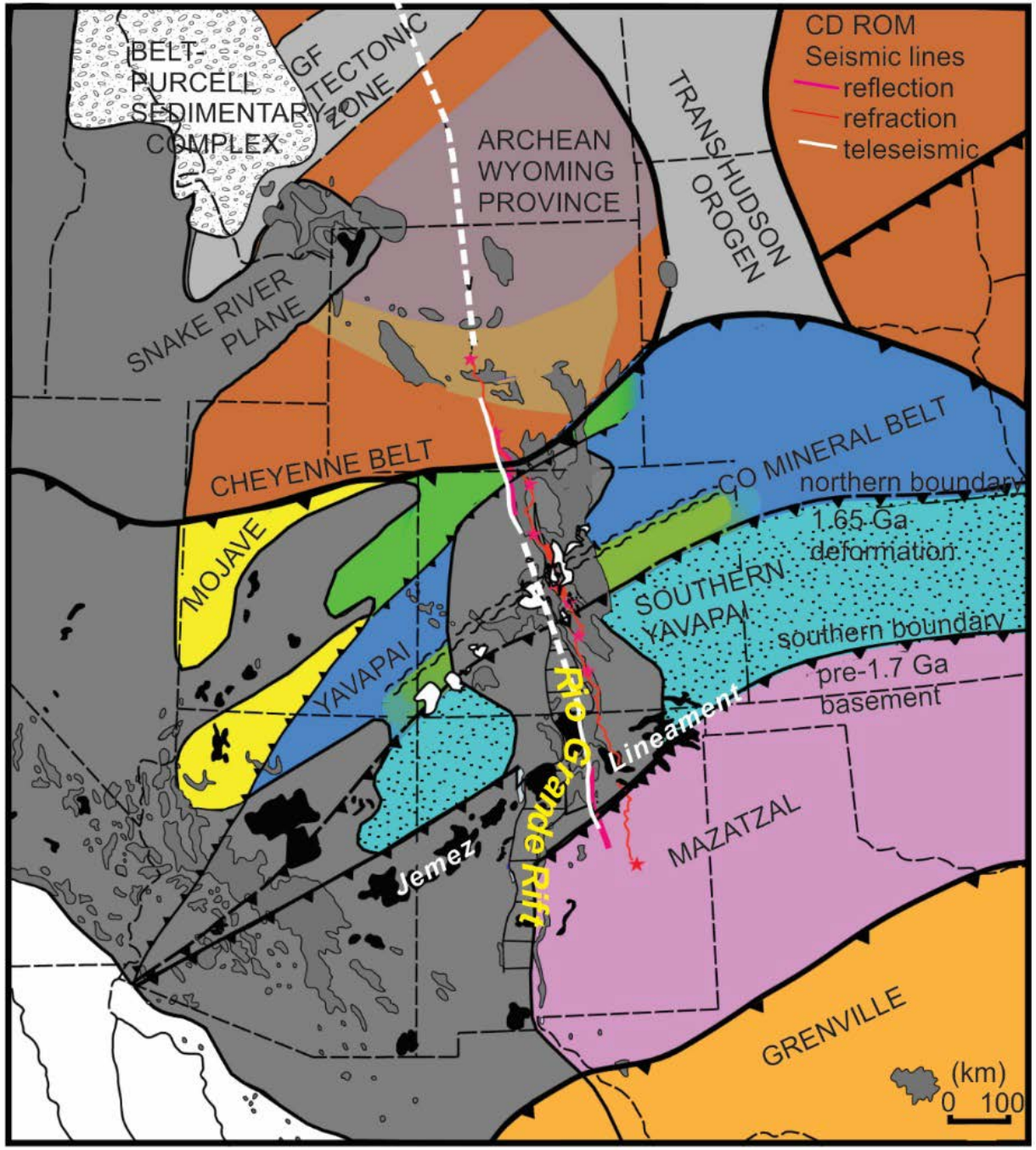
Rio Grande rift

Rift zone crosses Proterozoic boundaries

Rift zone follows hinge of flat Farallon slab

Rift zone follows step in lithosphere thickness

Rift zone not affected by zone of focused mantle upwelling



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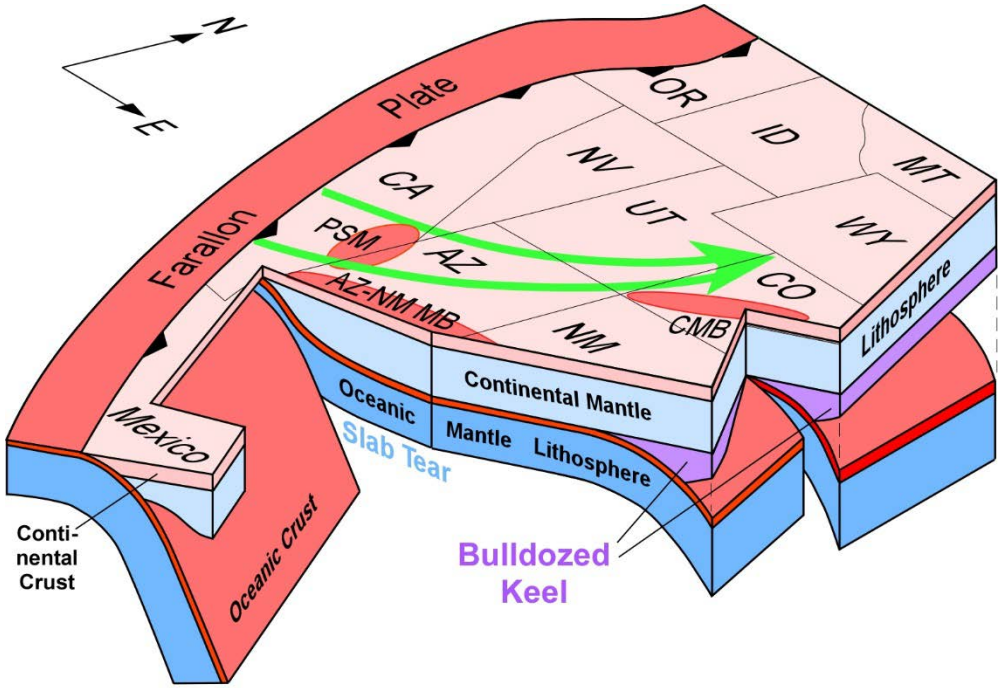
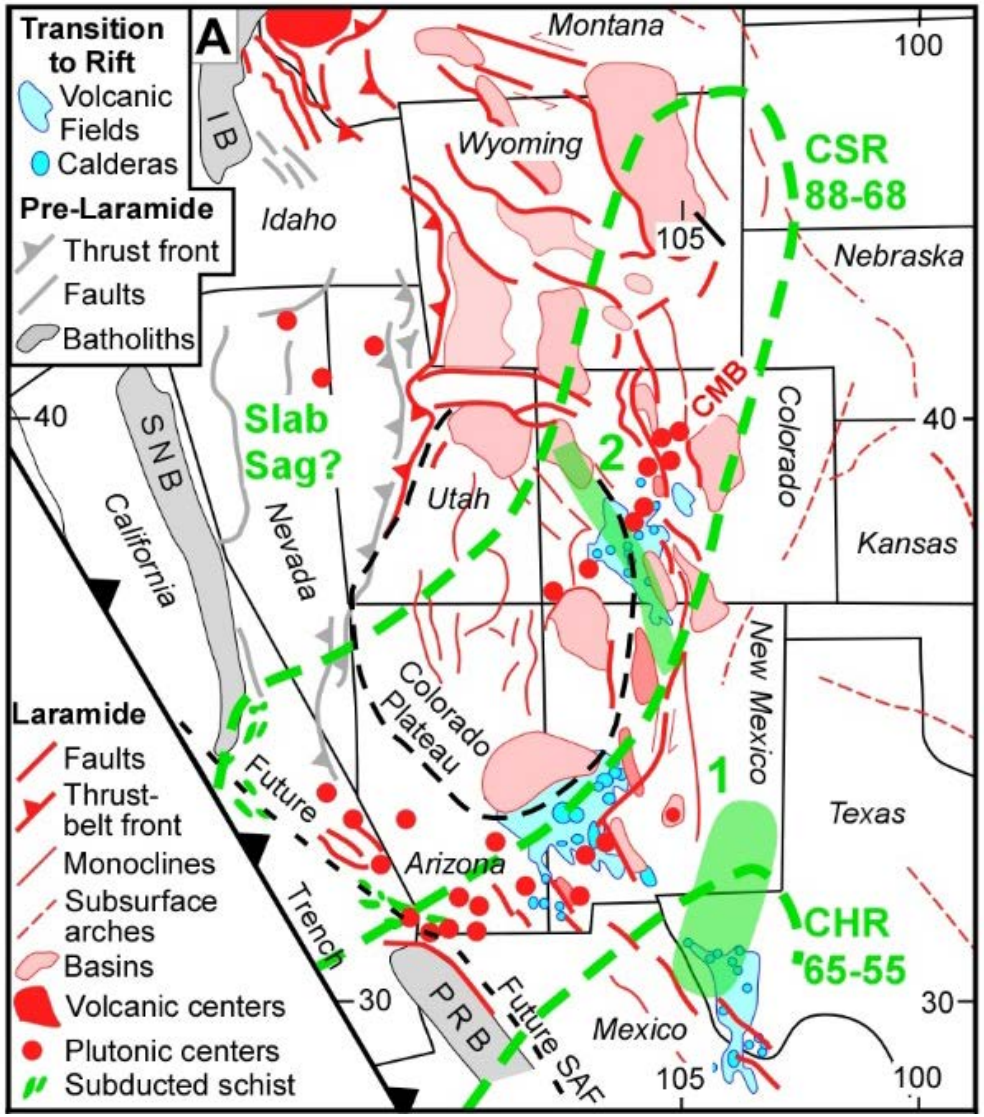


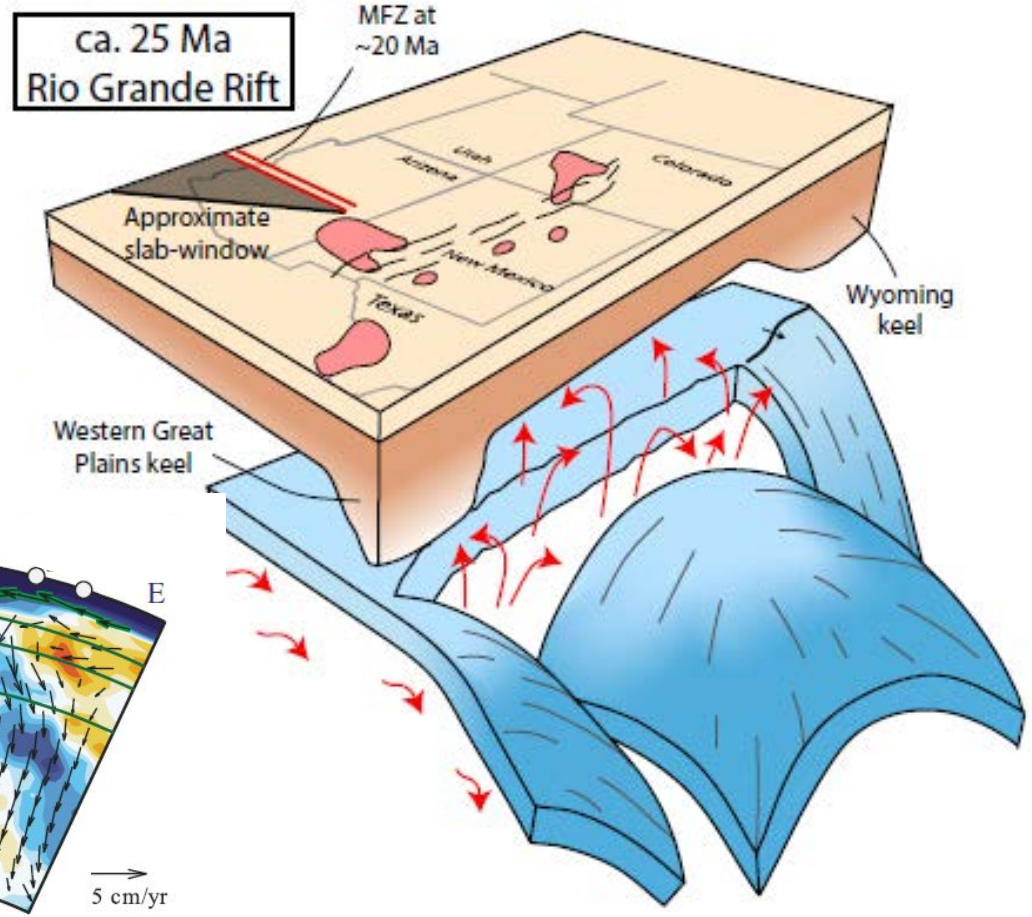


Axen et al. Nature Geoscience 2018

Rio Grande rift

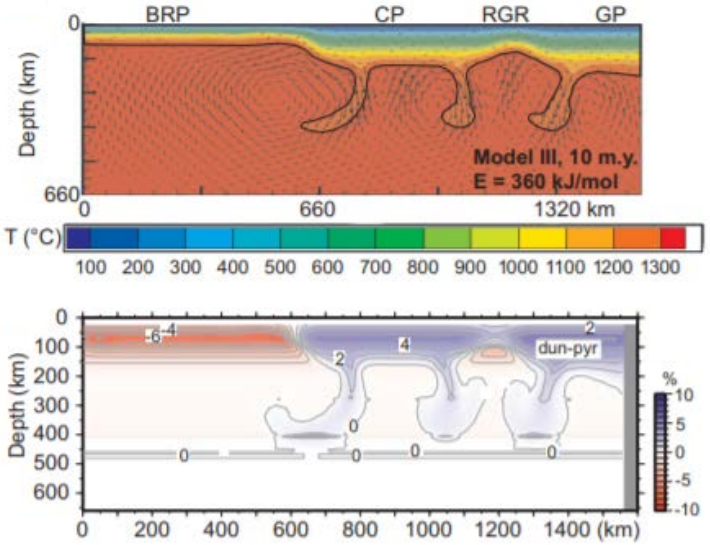
Rio Grande rift formed above opening gap in slab

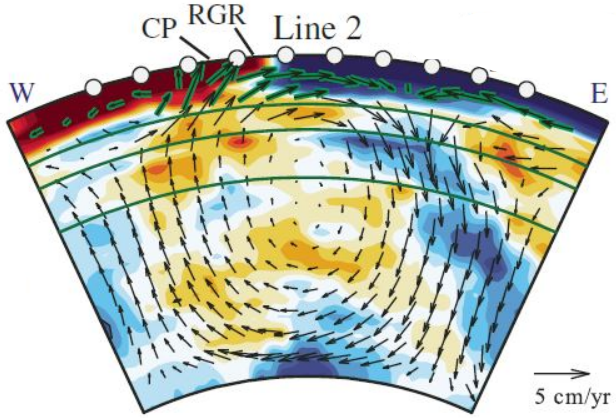
Or by mantle convection

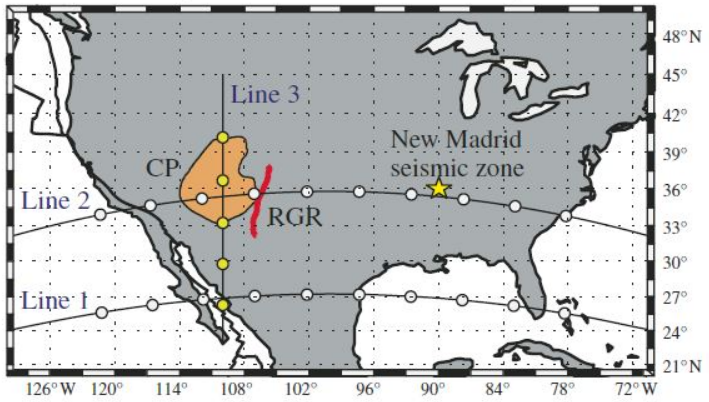


Ricketts et al. Geosphere 2016

Edge-driven (van Wijk et al. Geology 2008, 2010)



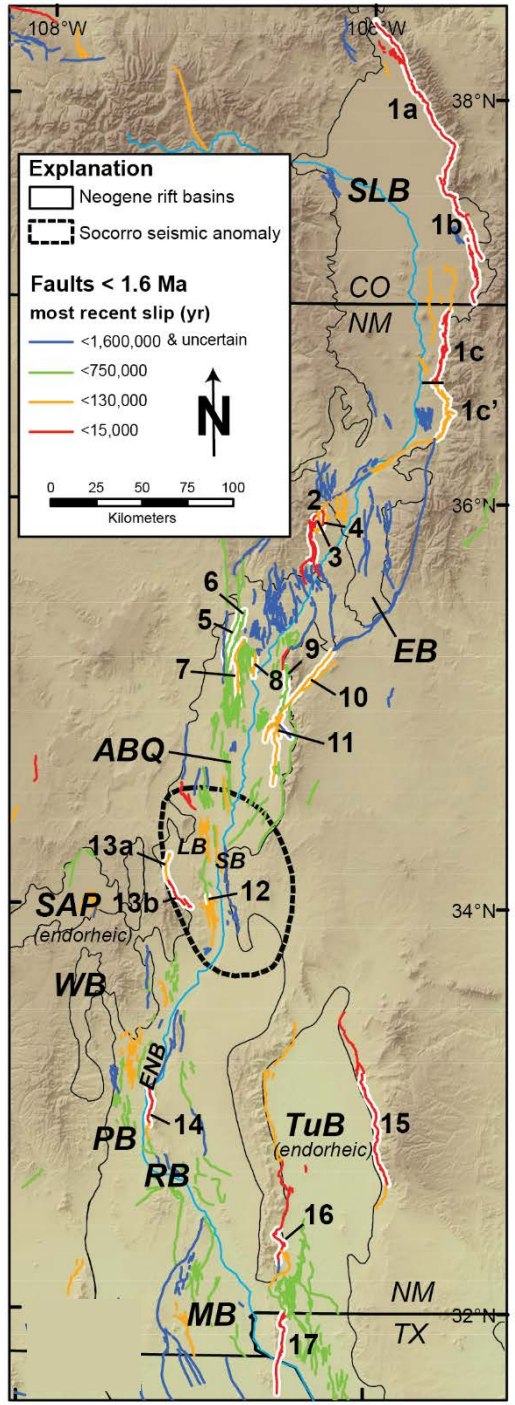




Shear (Moucha et al. Geology 2008)

Rio Grande rift

Not formed by plume, cuts across Proterozoic boundaries

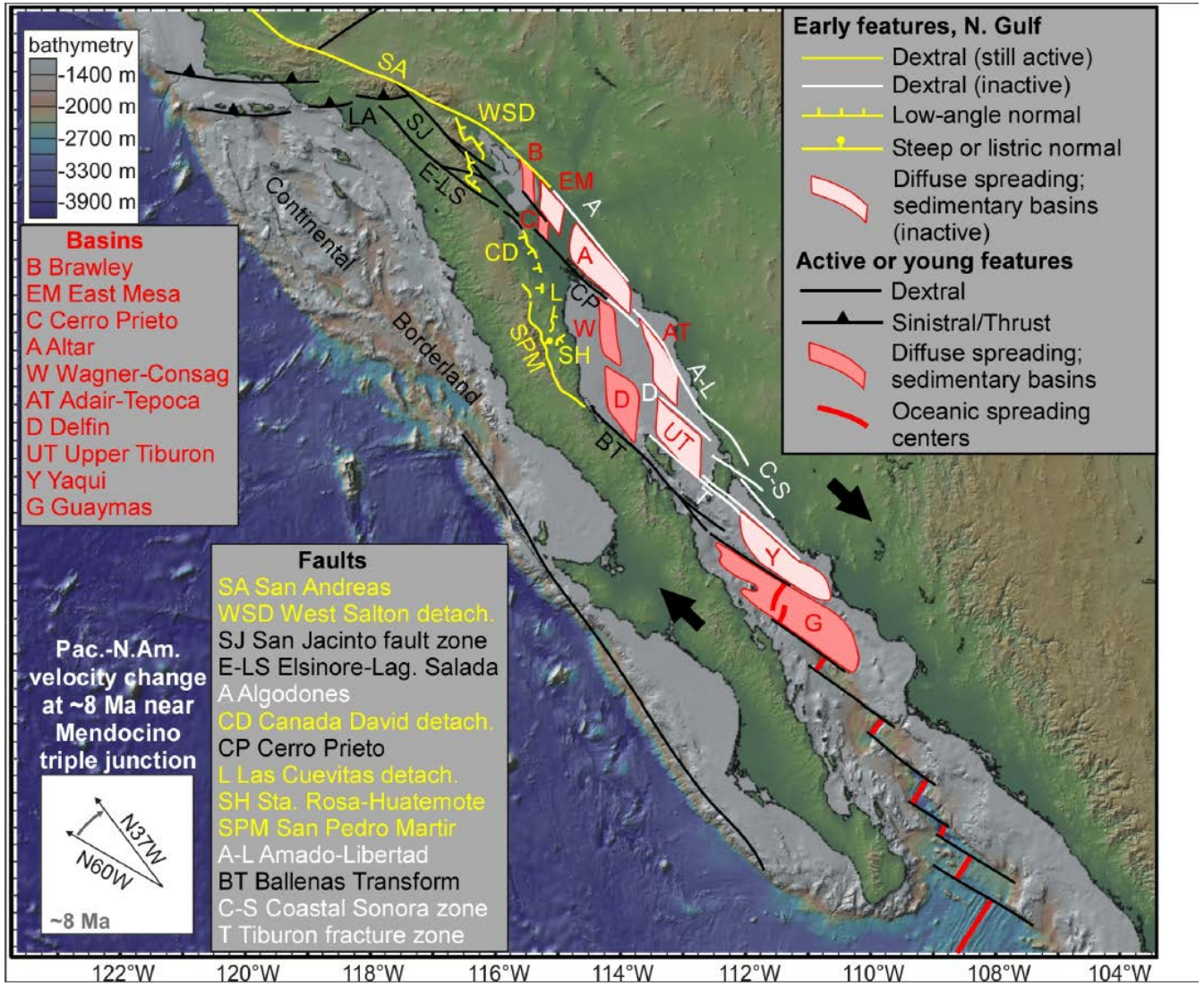


van Wijk et al. Geosphere 2018

Gulf of California

Extensional province follows arc

Breakup in southern Gulf



van Wijk et al. Geosphere 2019

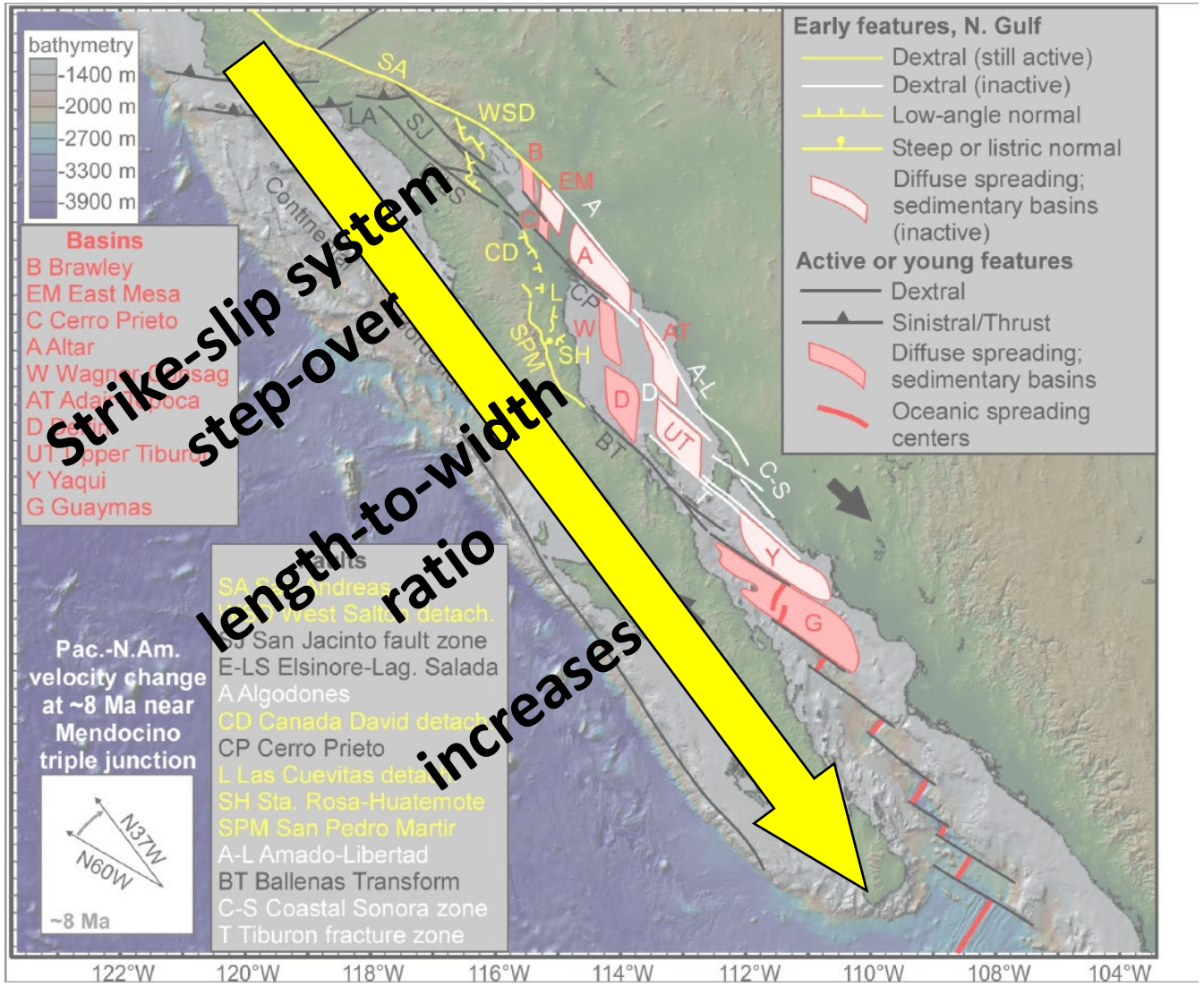
Tectonophysics 2018

Gulf of California

Difference in development between northern and southern Gulf

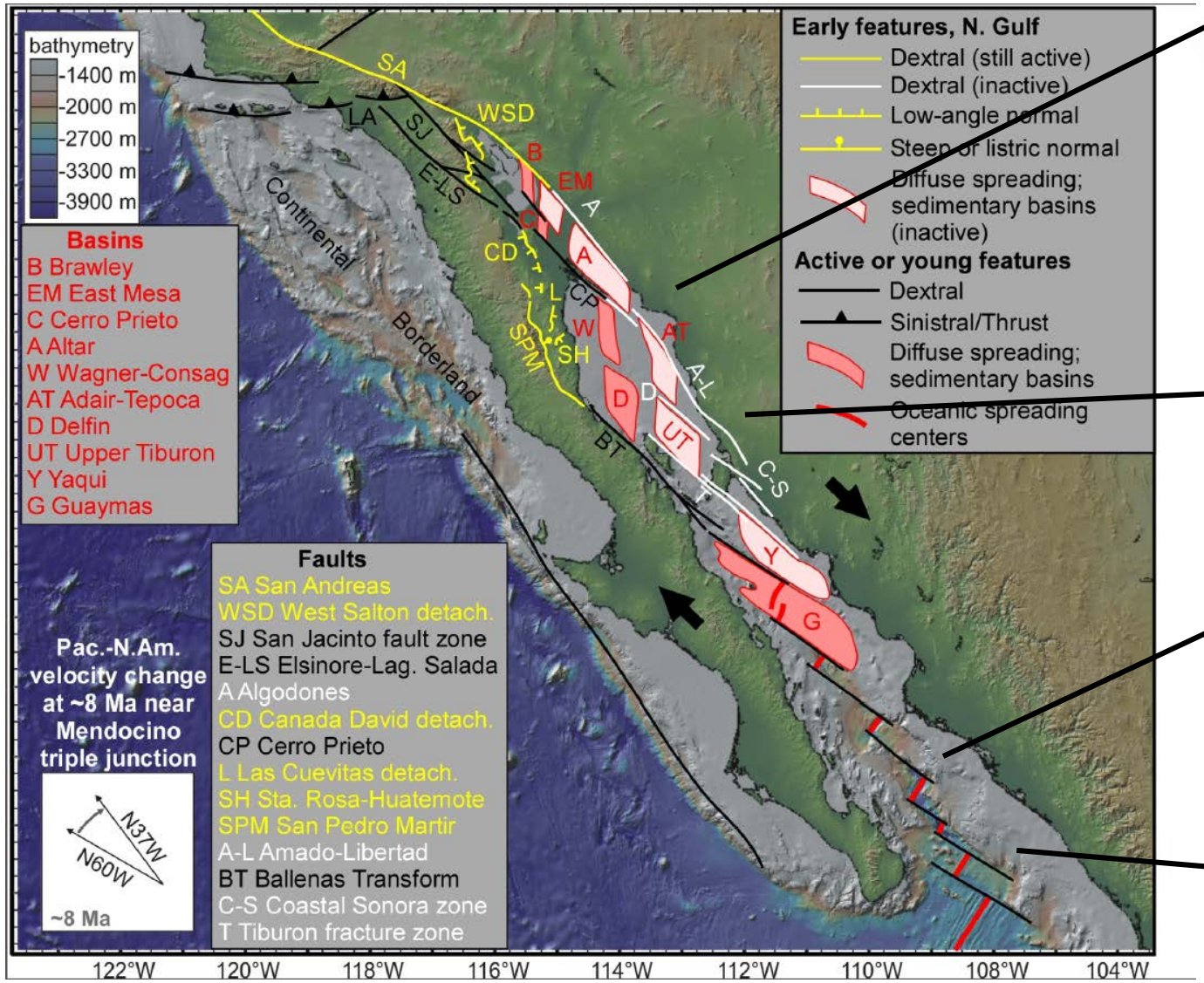
Northern Gulf covered by thick layer of sediments

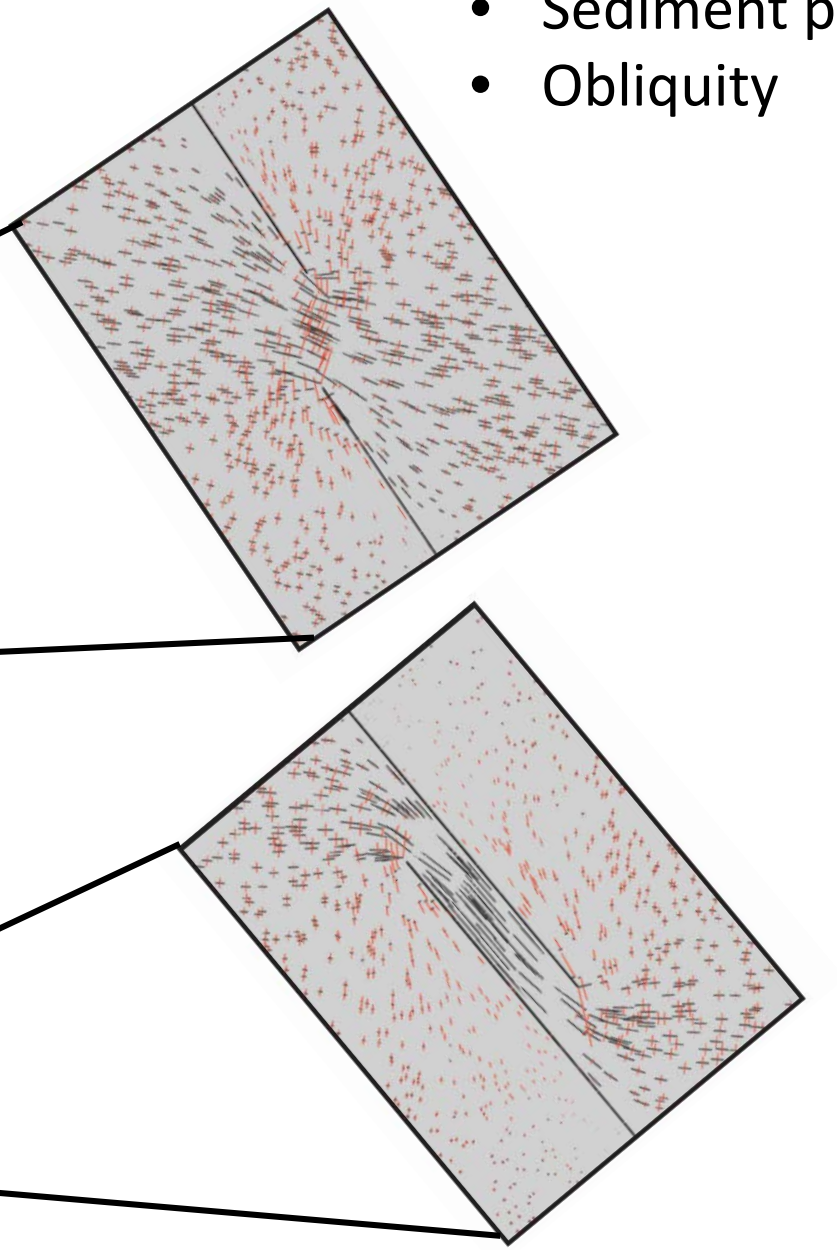
Difference in obliquity between south and north



Gulf of California

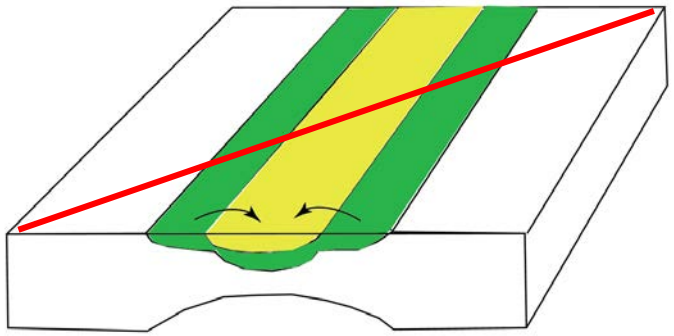
- Sediment package
- Obliquity



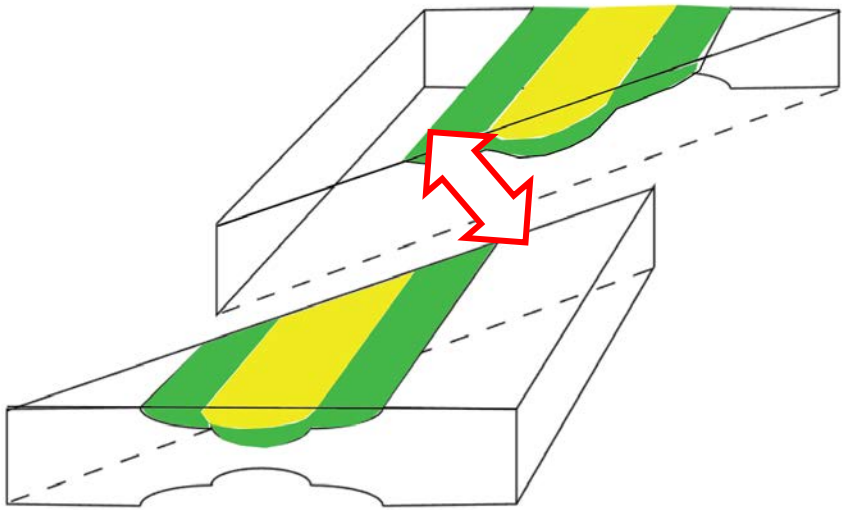


van Wijk et al. Tectonophysics 2018

North Atlantic breakup



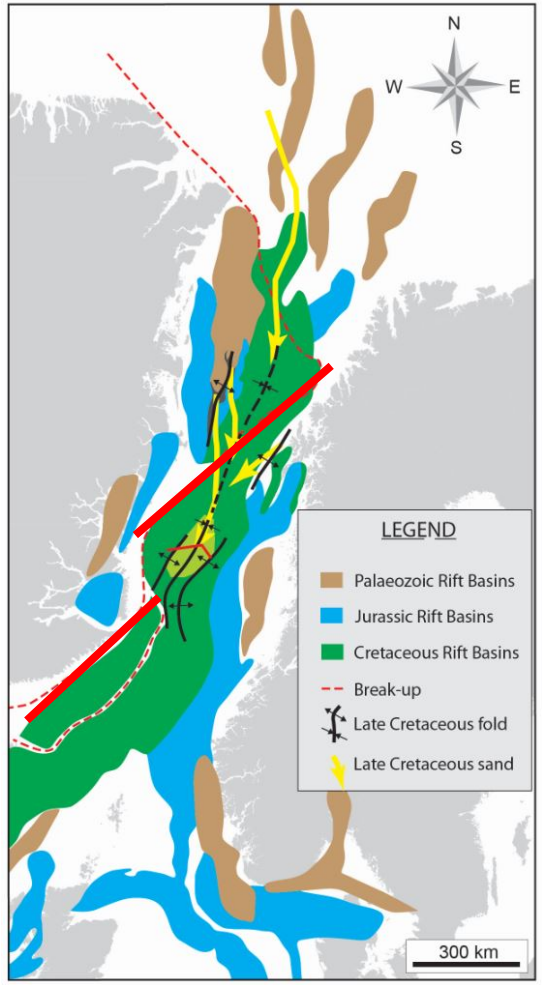
NE Greenland



Mid-Norway

1) Episodic crustal thinning

2) Breakup line slices across basin axes

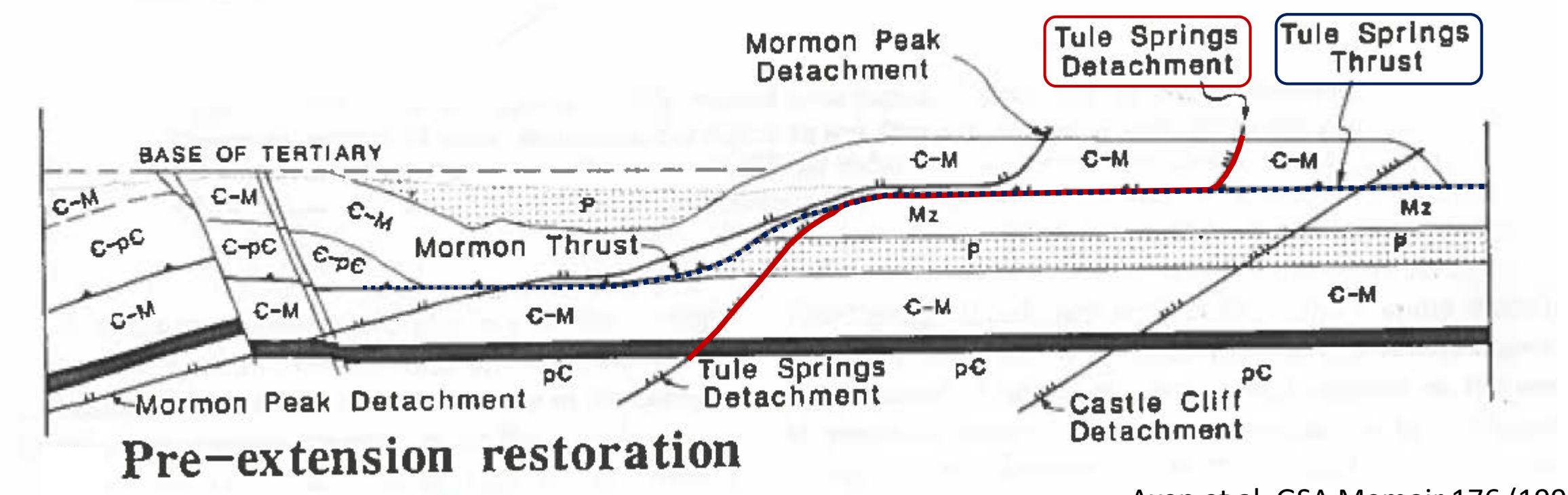


Lundin and Dore GS London 2018

Field-scale observations

Tule Springs thrust and Tule Springs detachment, southern Nevada

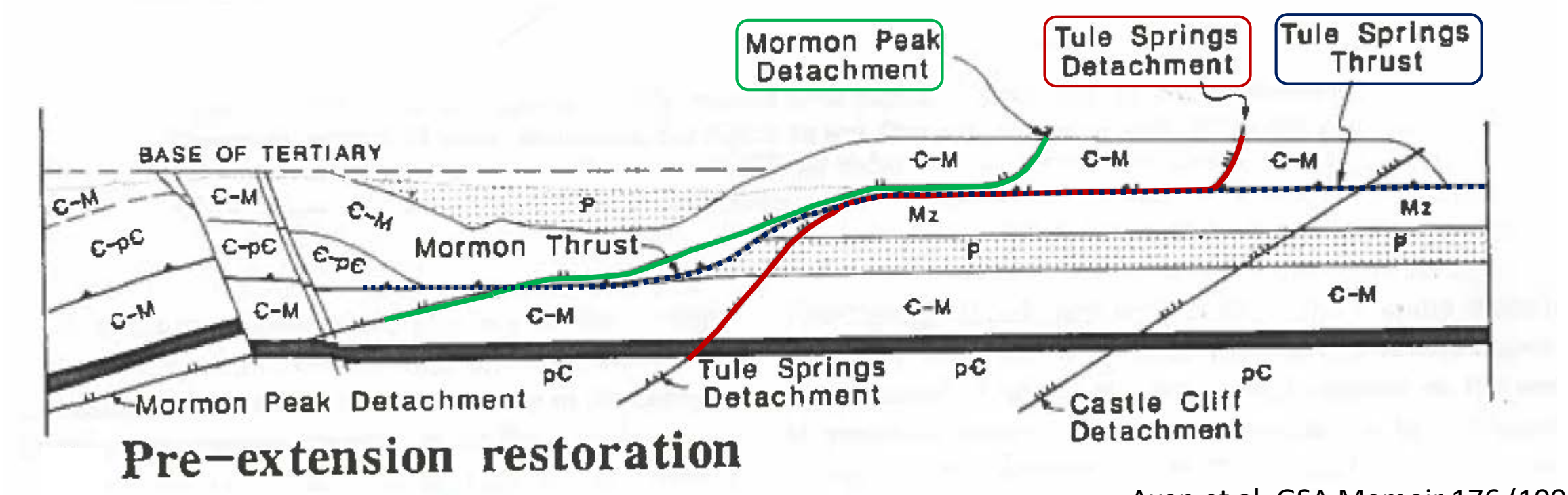
Footwall is cut by Tule Springs detachment



Axen et al. GSA Memoir 176 (1990)

Field-scale observations

Commonly assumed that listric normal faults follow thrust ramps and flatten into thrust flat



Axen et al. GSA Memoir 176 (1990)

Thank you!

Raton basin, Western Interior Seaway margin