Big Geodynamic Questions about Rifting

What is the role of pre-existing crustal and lithospheric structure?

Are big hot mantle plumes needed to initiate continental breakup?

Big Geodynamic Questions about Rifting Eastern North America

What is the role of pre-existing crustal and lithospheric structure?

What was the role of the Appalachians in breakup of Pangea?

(The biggest pre-existing structure affecting continental breakup)

Are big hot mantle plumes needed to initiate continental breakup?

Why did the Central North Atlantic Magmatic Province formed just as rifting really got going?

(CAMP is one of the biggest 'Large Igneous Provinces')

Ideally

Data Inspires Model Development

↓

Models Guide Data Collection

↓

Data Disproves Some Models

Ideally

Data Inspires Model Development

↓

Models Guide Data Collection

↓

Data Disproves Some Models

But, it is always more complex

How did the Appalachians affect ENAM rifting?

How did they affect mantle melting and emplacement of magma?

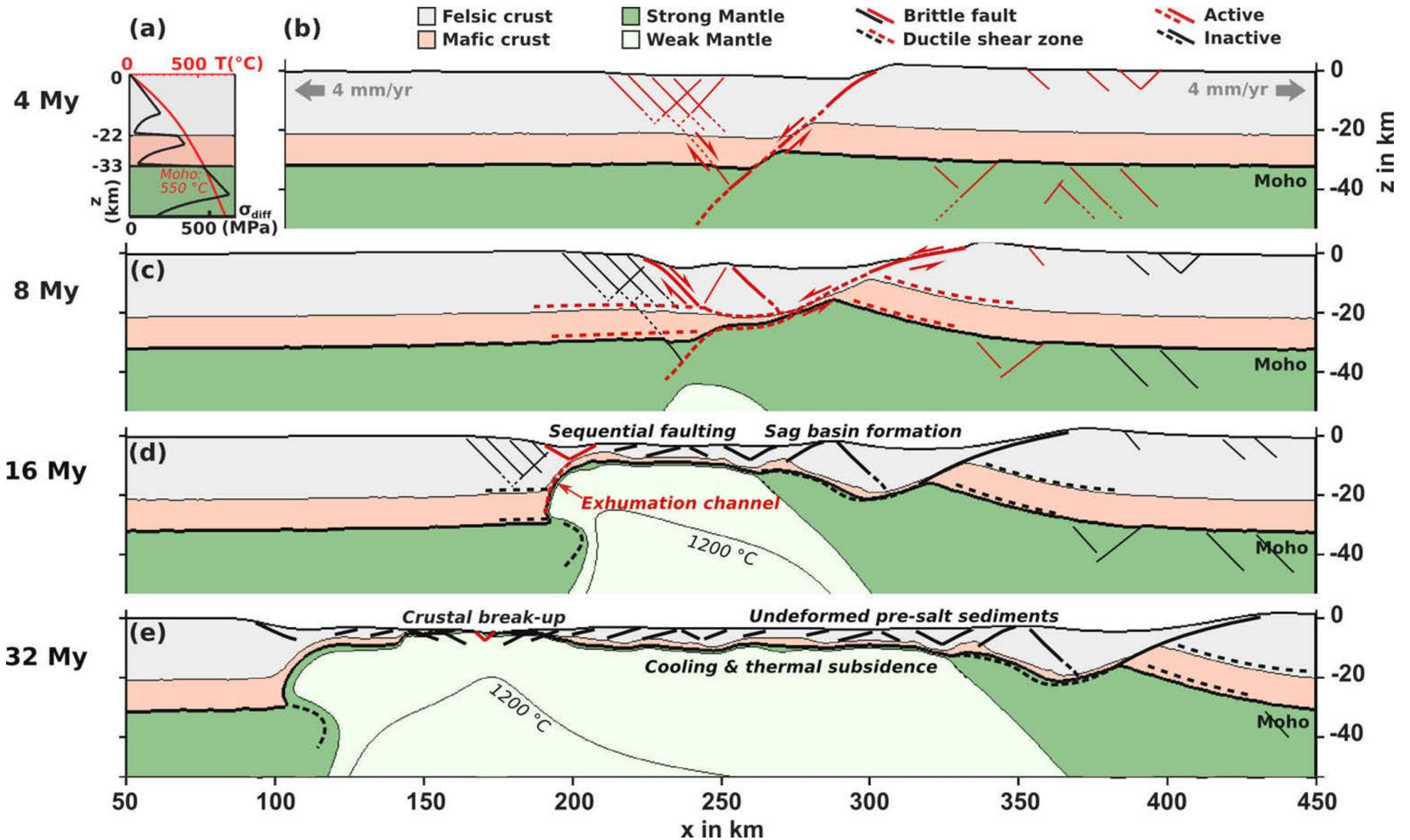
How did they affect when rifting started and how it evolved?

-One specific example: Were the Newark Series Basins formed during 30 Ma of slow rifting (i.e. plate separation) or via ‘orogenic collapse’?

CAMP Magmatism is partly along the collision zone

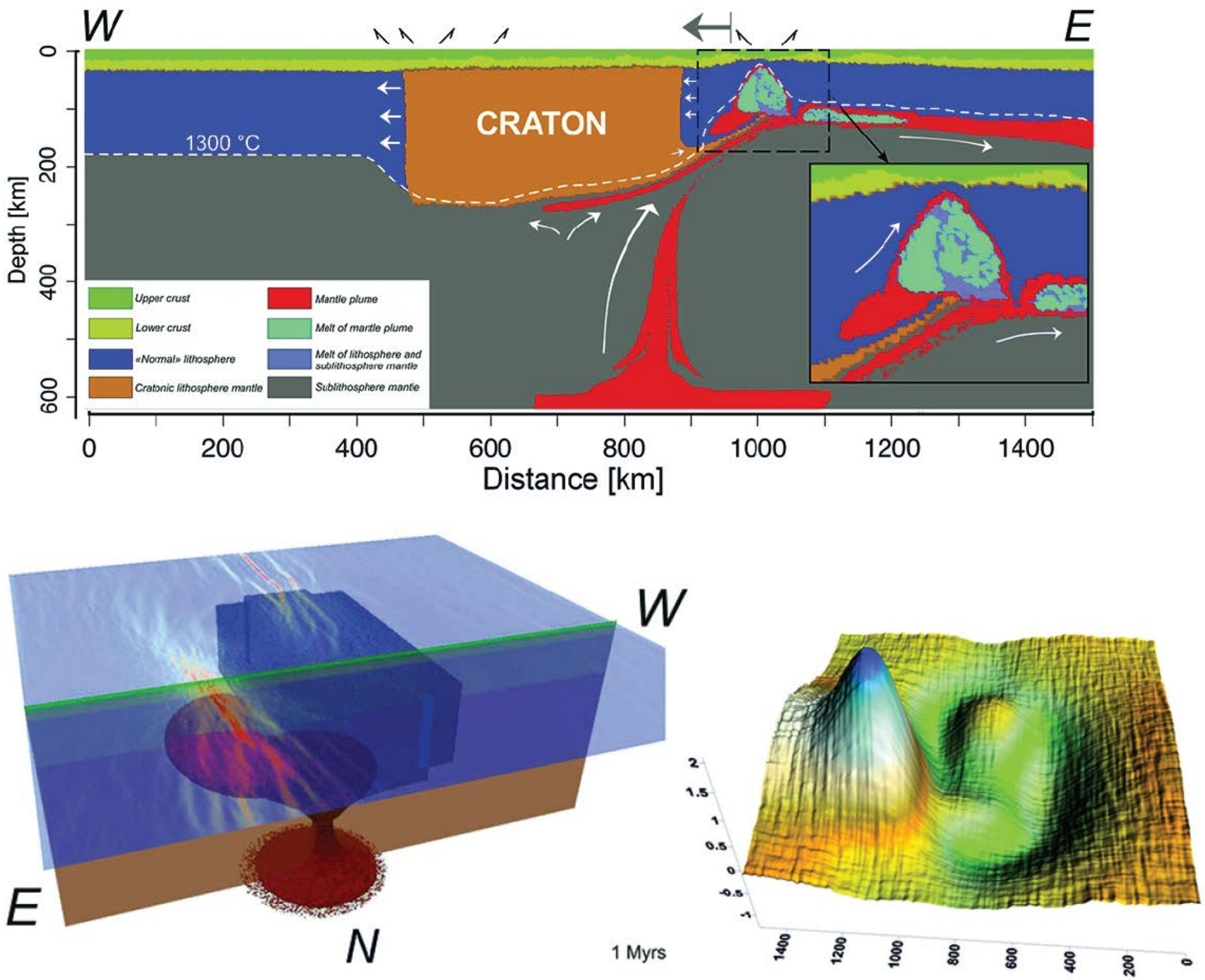
Pálfy& Kocsis (2014)

Numerical Models do a great job for lithosphric extension and faulting
But still often do not even try to deal with magmatism



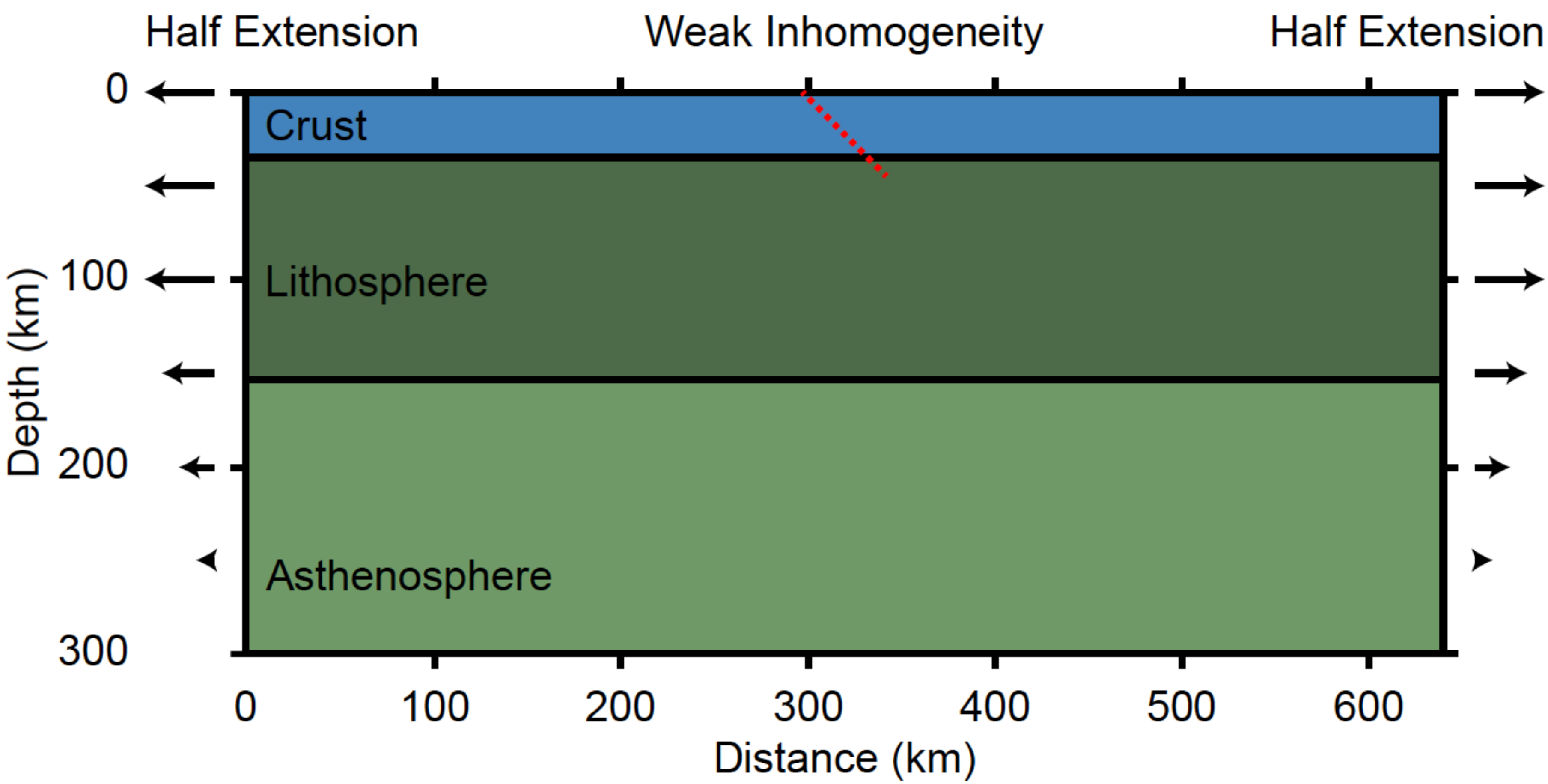
Brune et al. (2016)

Plume Lithosphere interactions are beginning to be modeled



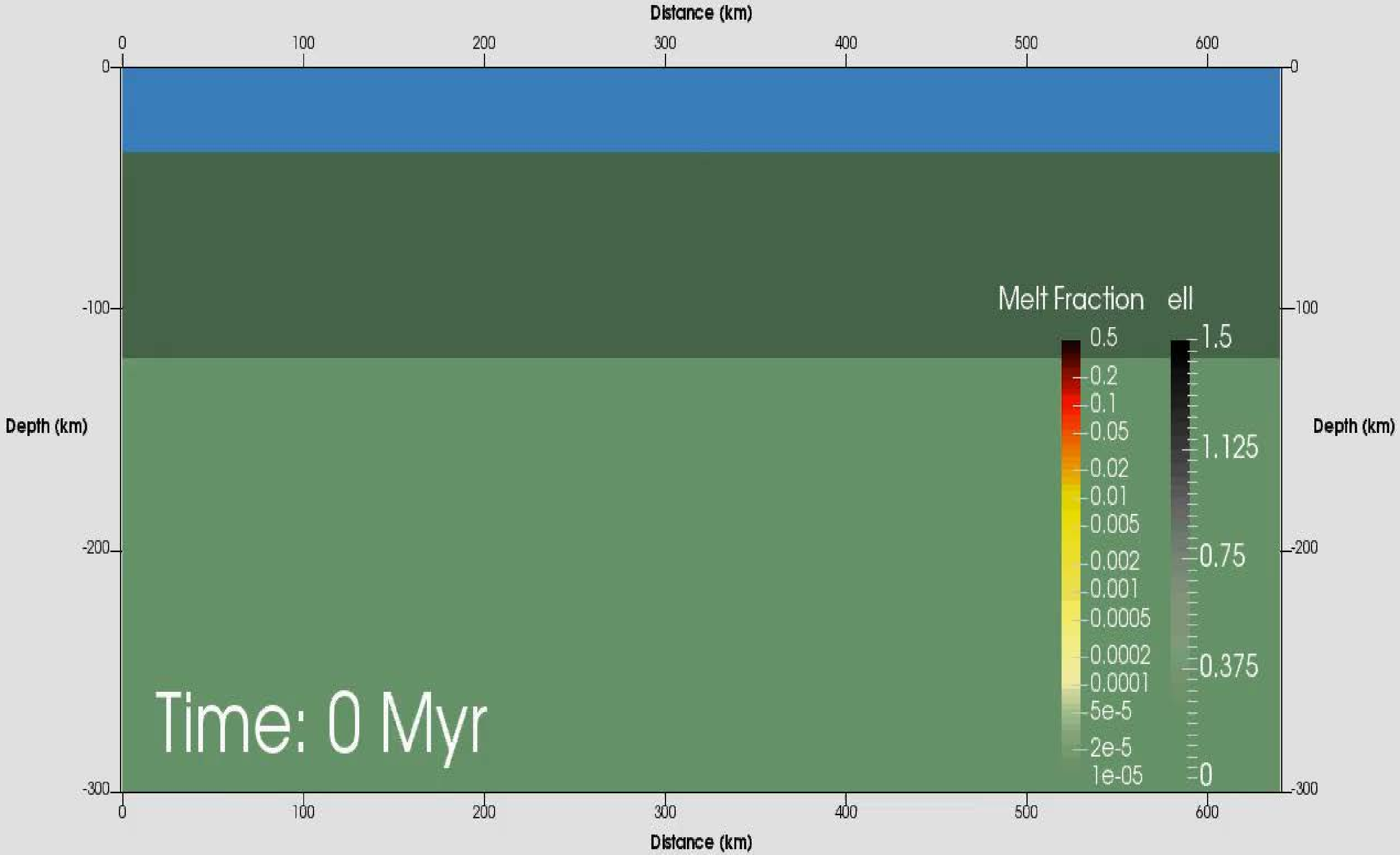
Koptev at al. (2016)

Models with reasonable thermal structures & rheologies are starting to include mantle melting

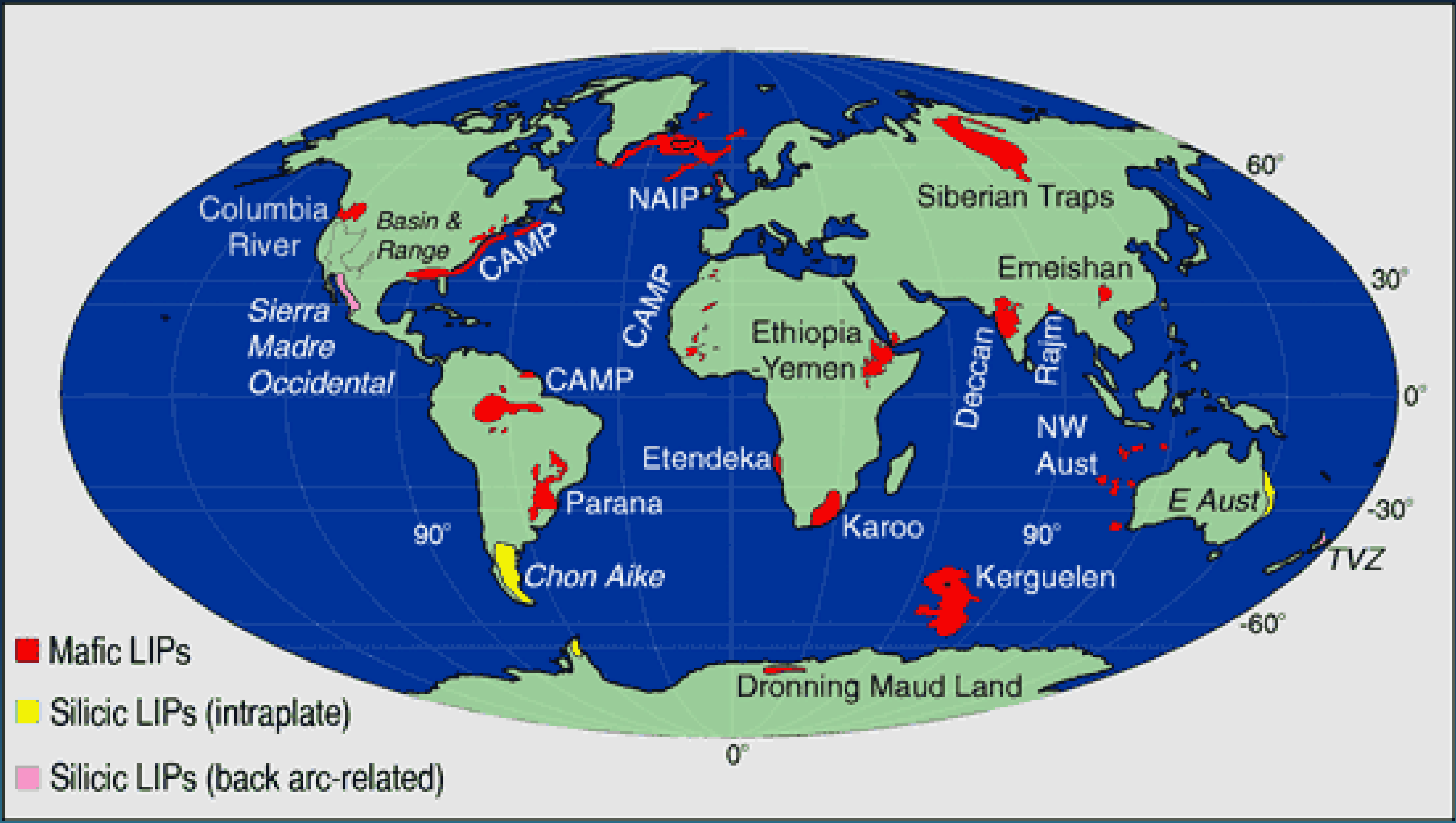


Davis et al., 2017

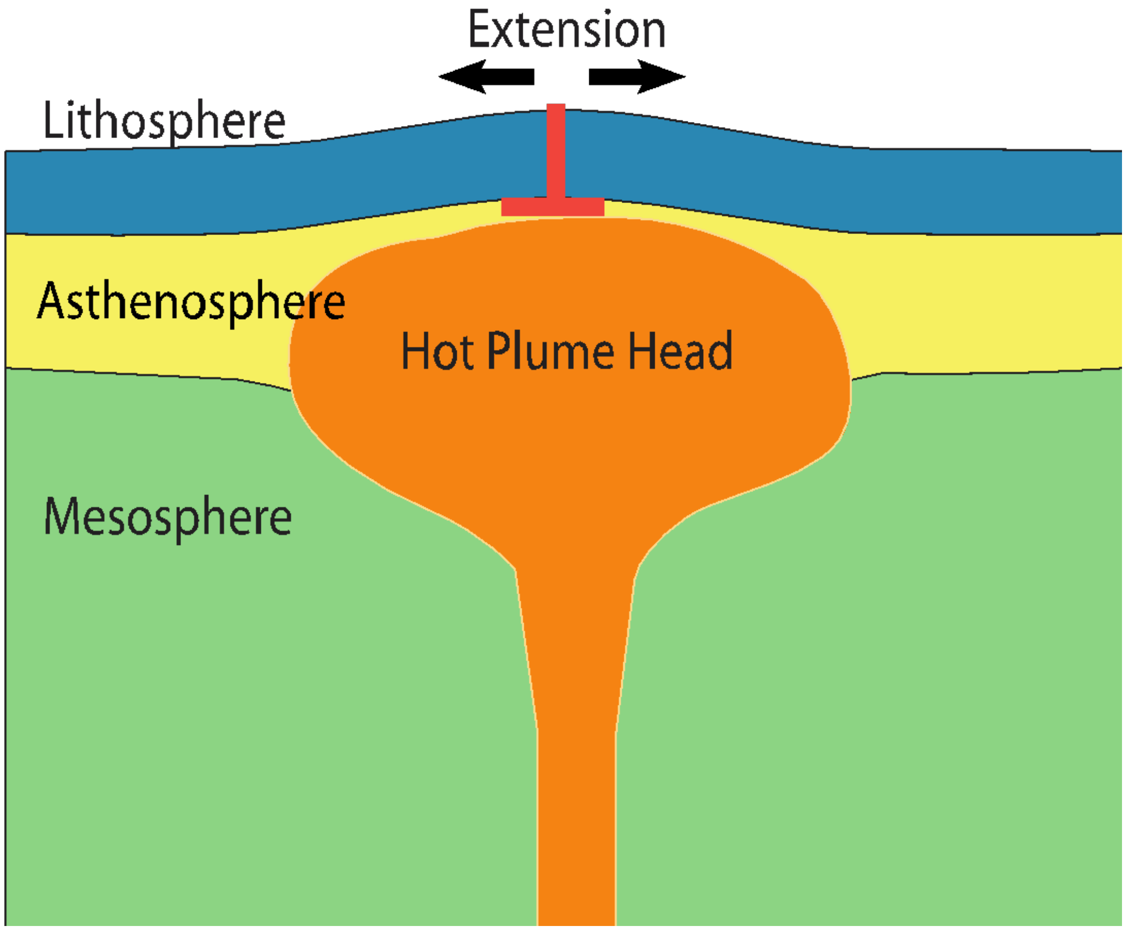
Davis et al., 2017



Dating of Large Igneous Provinces (LIPs) shows that they form just before most major rifting events

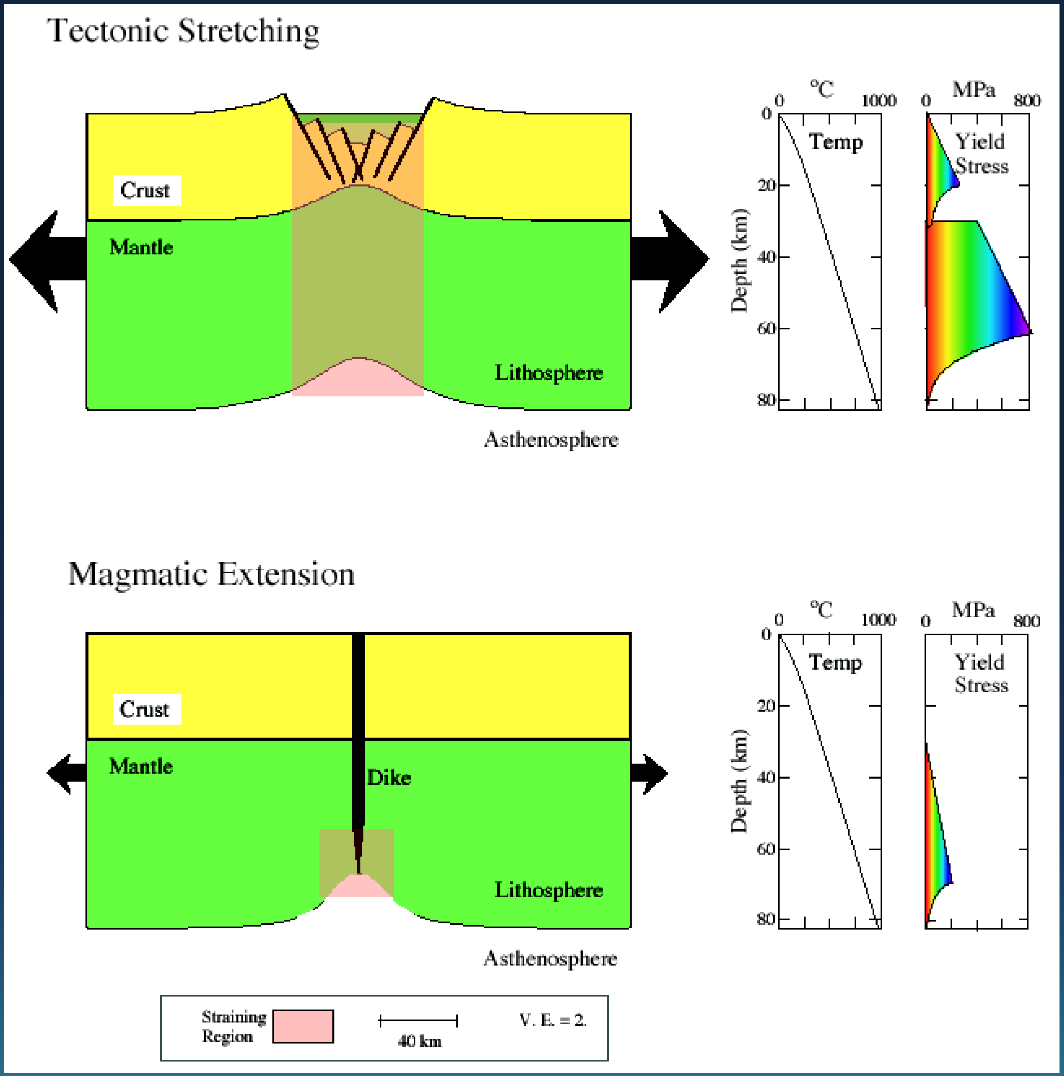


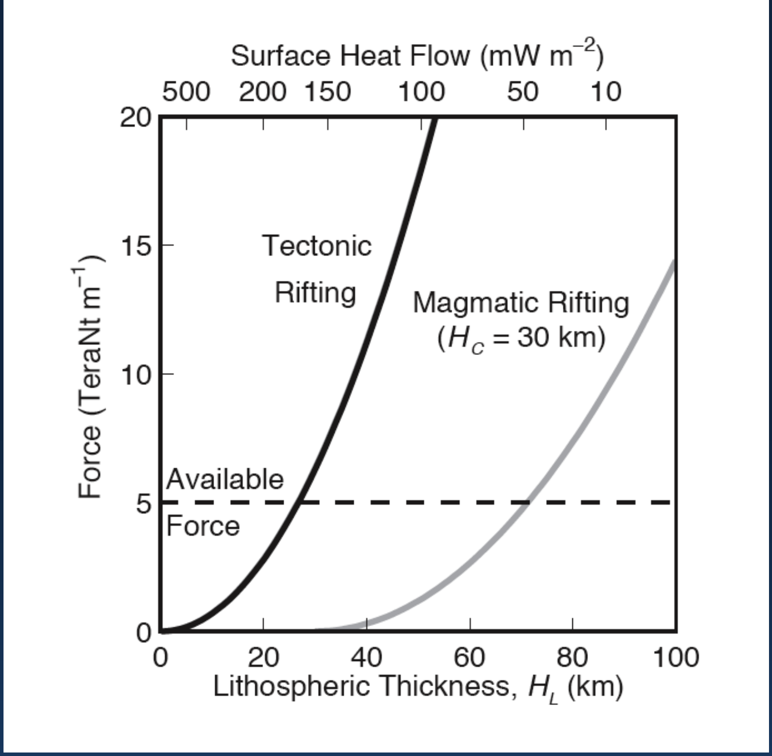
After White and McKenzie (1989); Courtillot et al., 1999



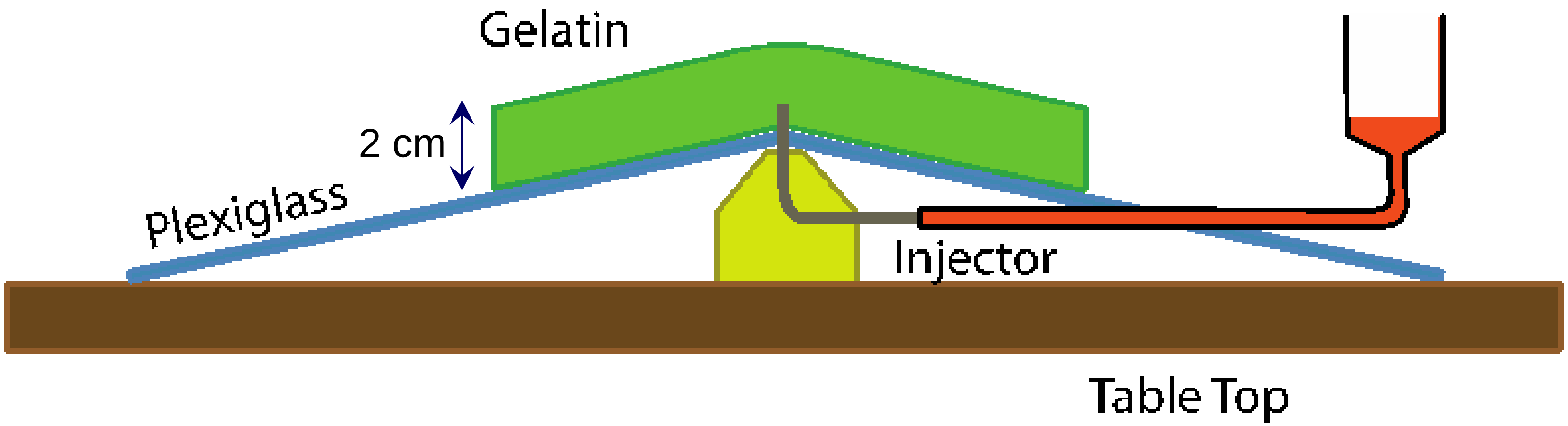
Plume/Plume Head Uplift leads to extensional force <~5 TNt/m and massive magma flux

For “normal“ lithosphere the force to magmatically rift is ~ 10 time less than to tectonically rift





Buck (2004)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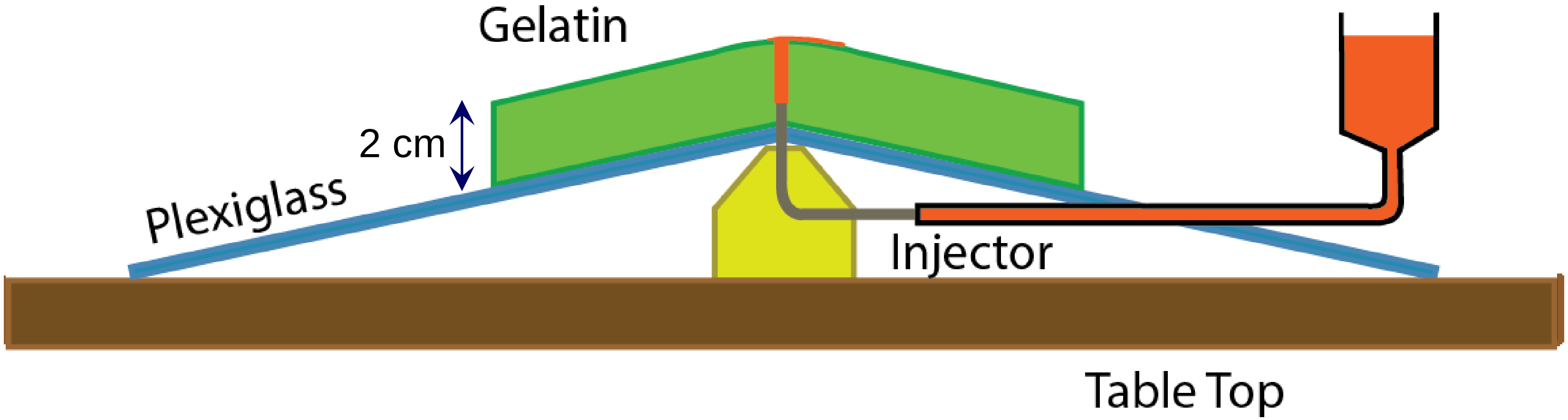
2 cm
Plexiglass
Injector
Table Top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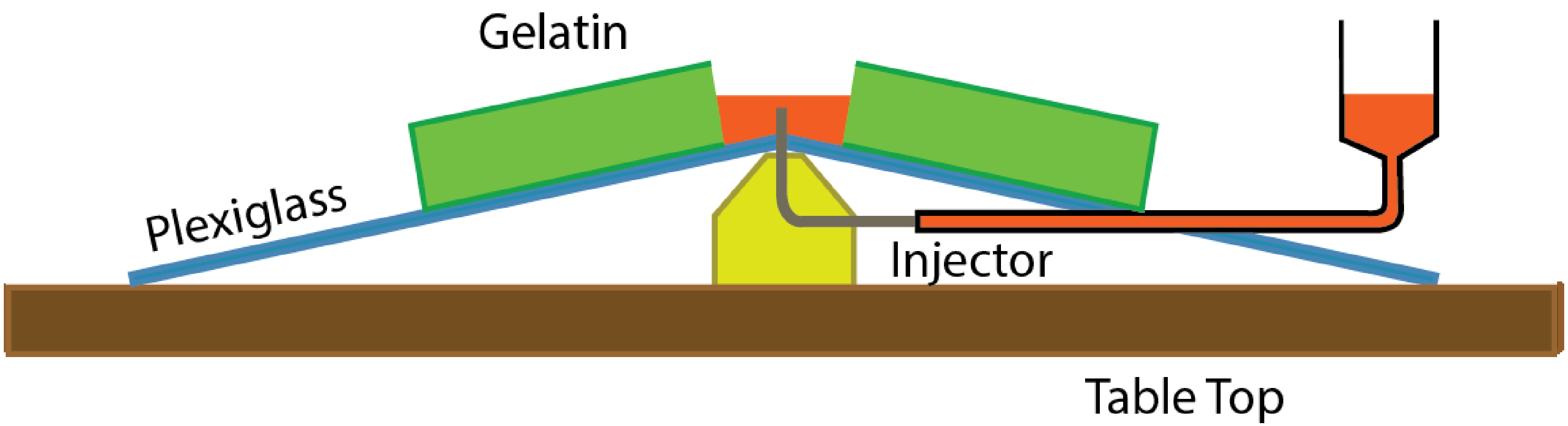
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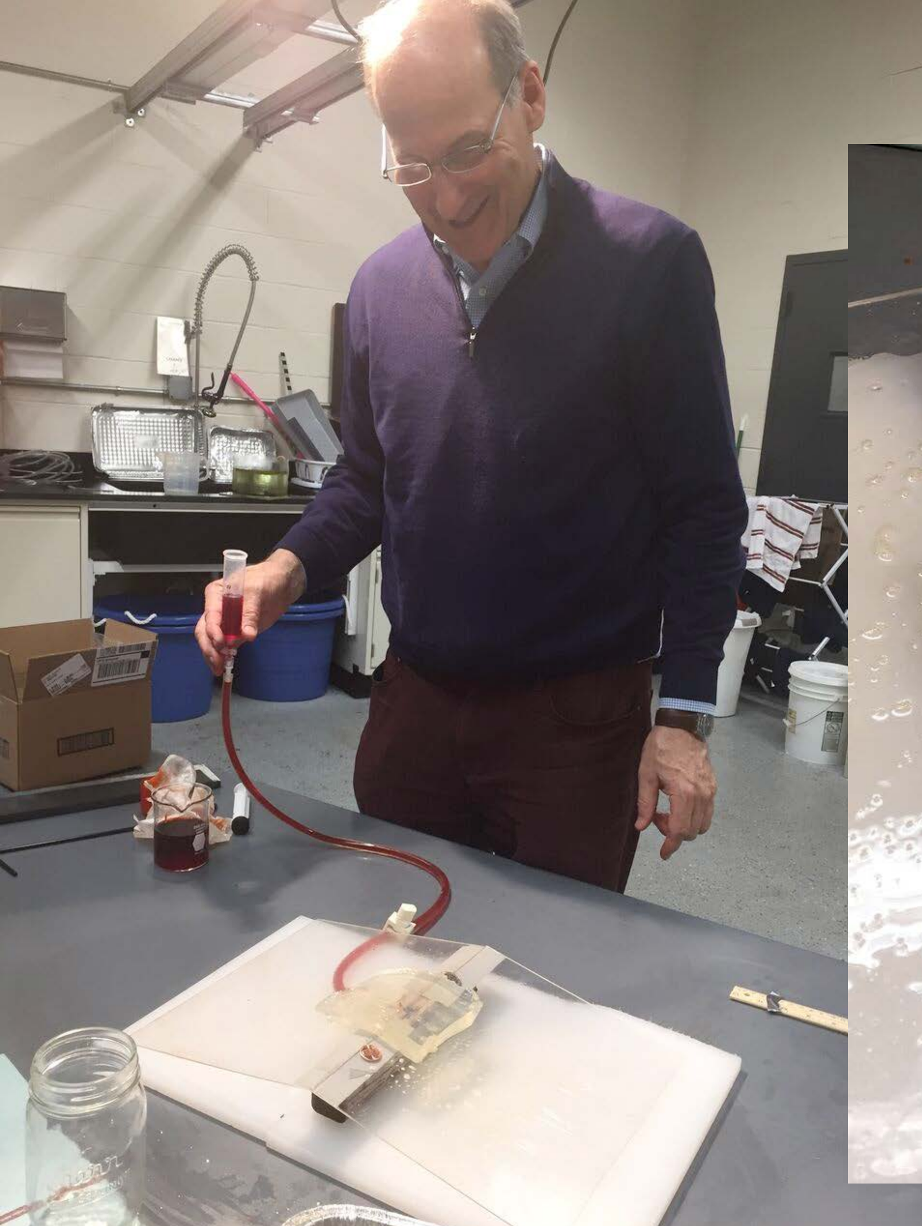
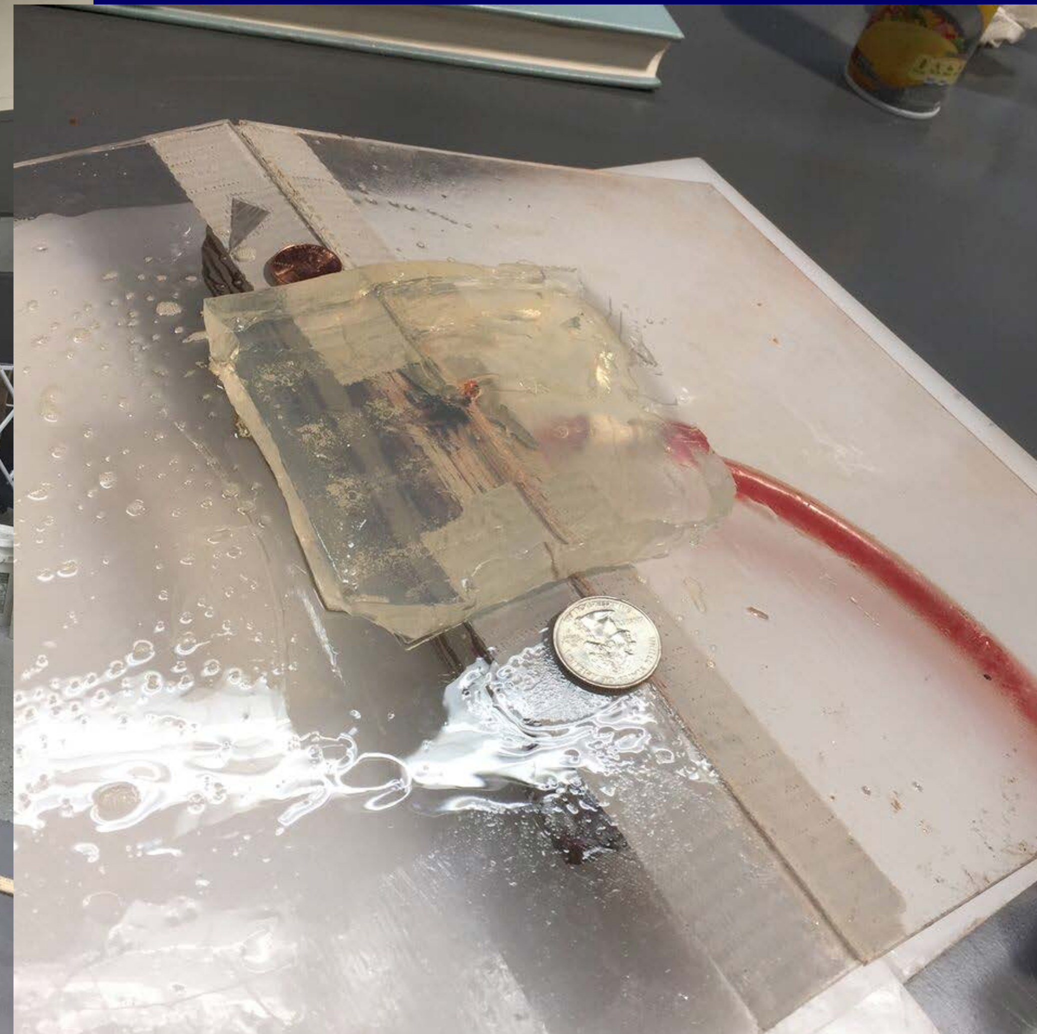
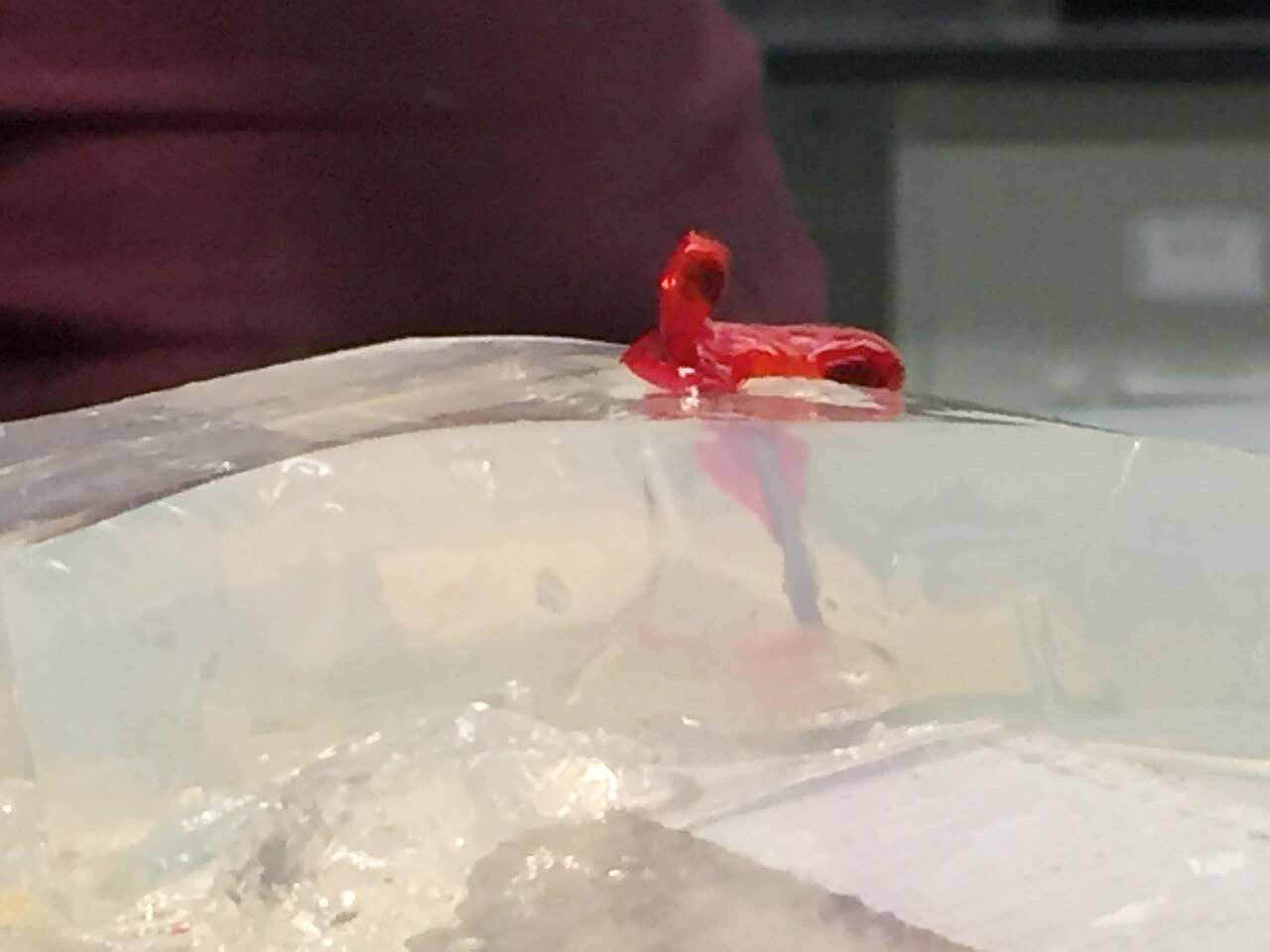
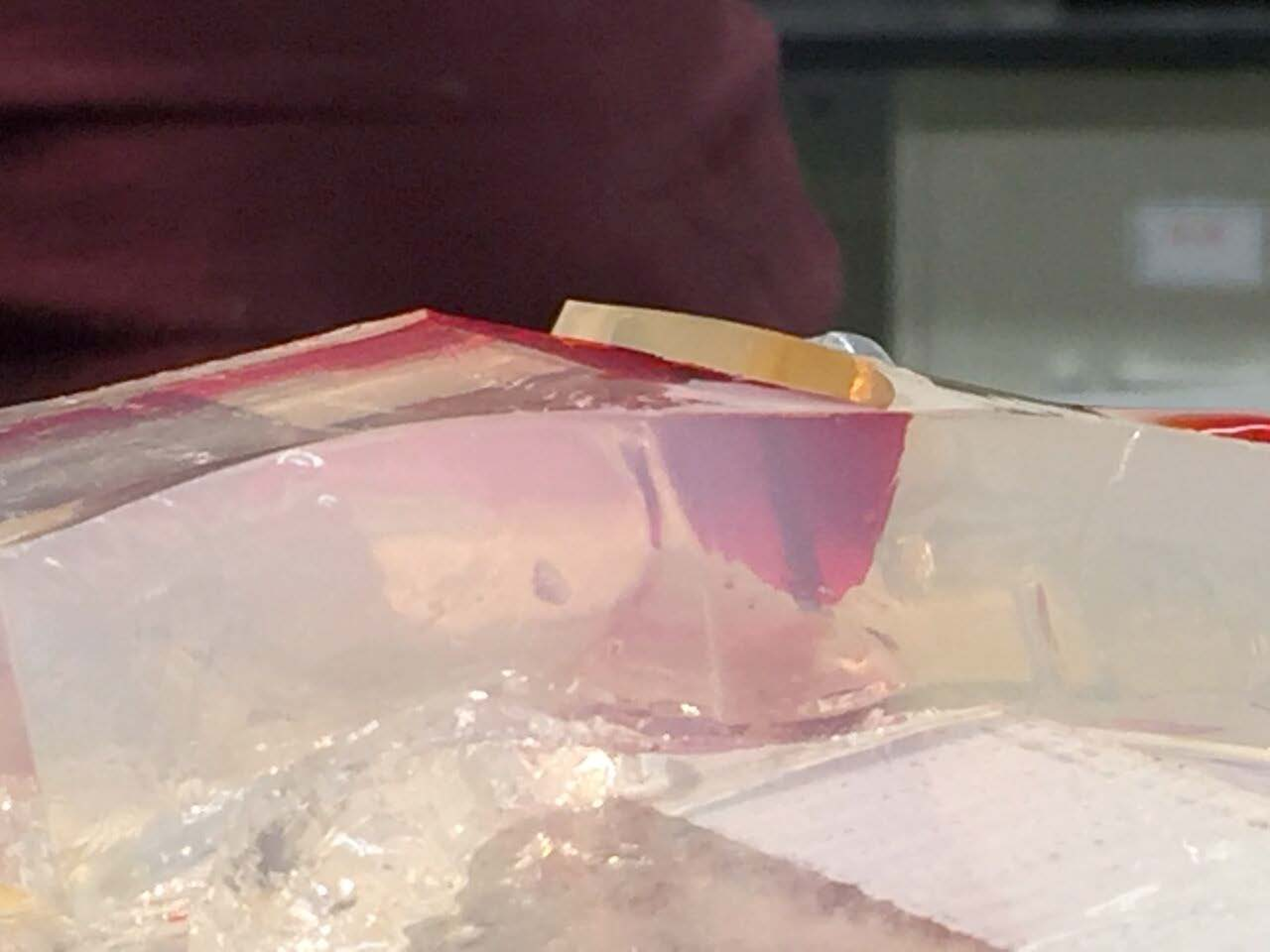
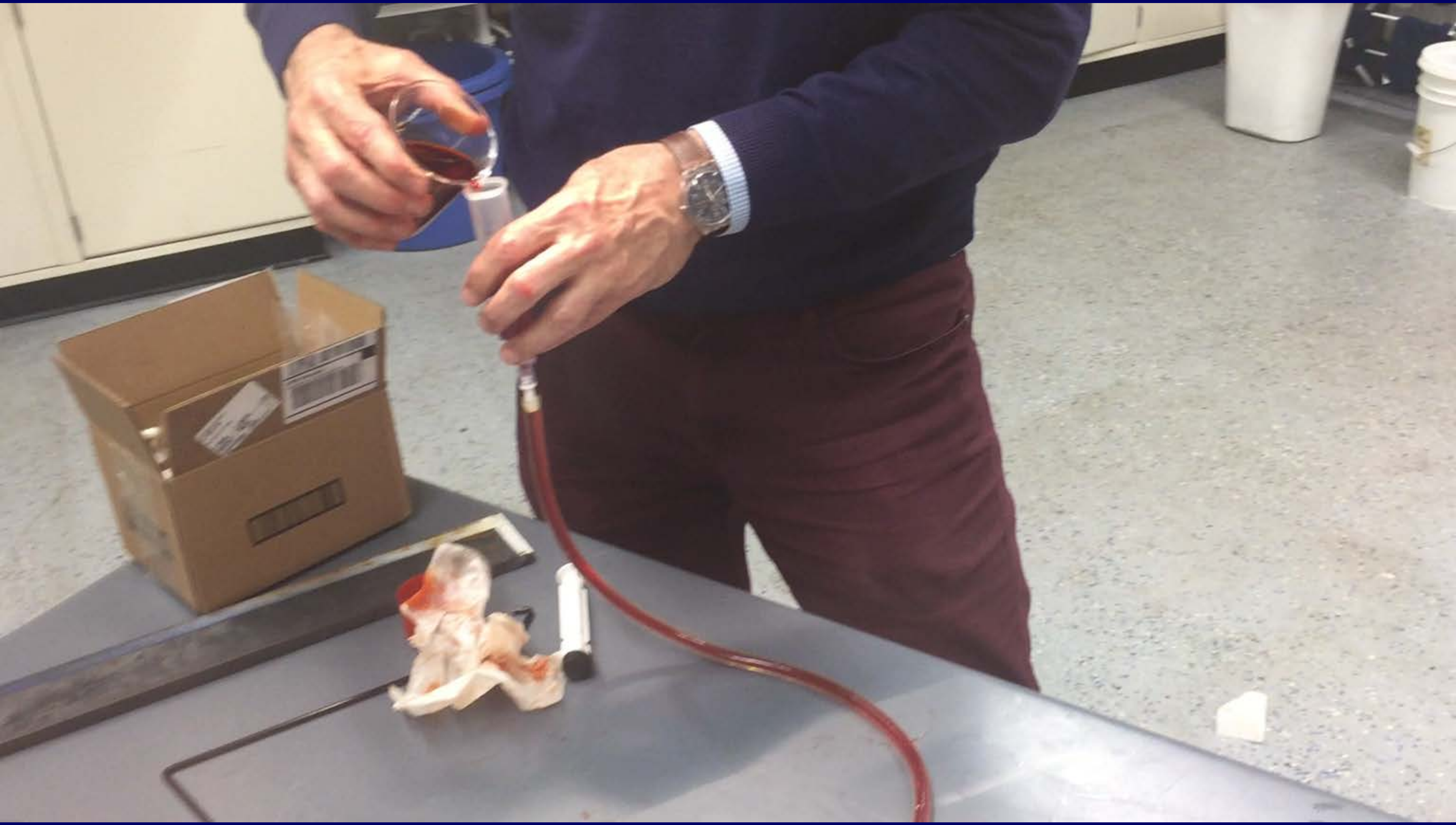


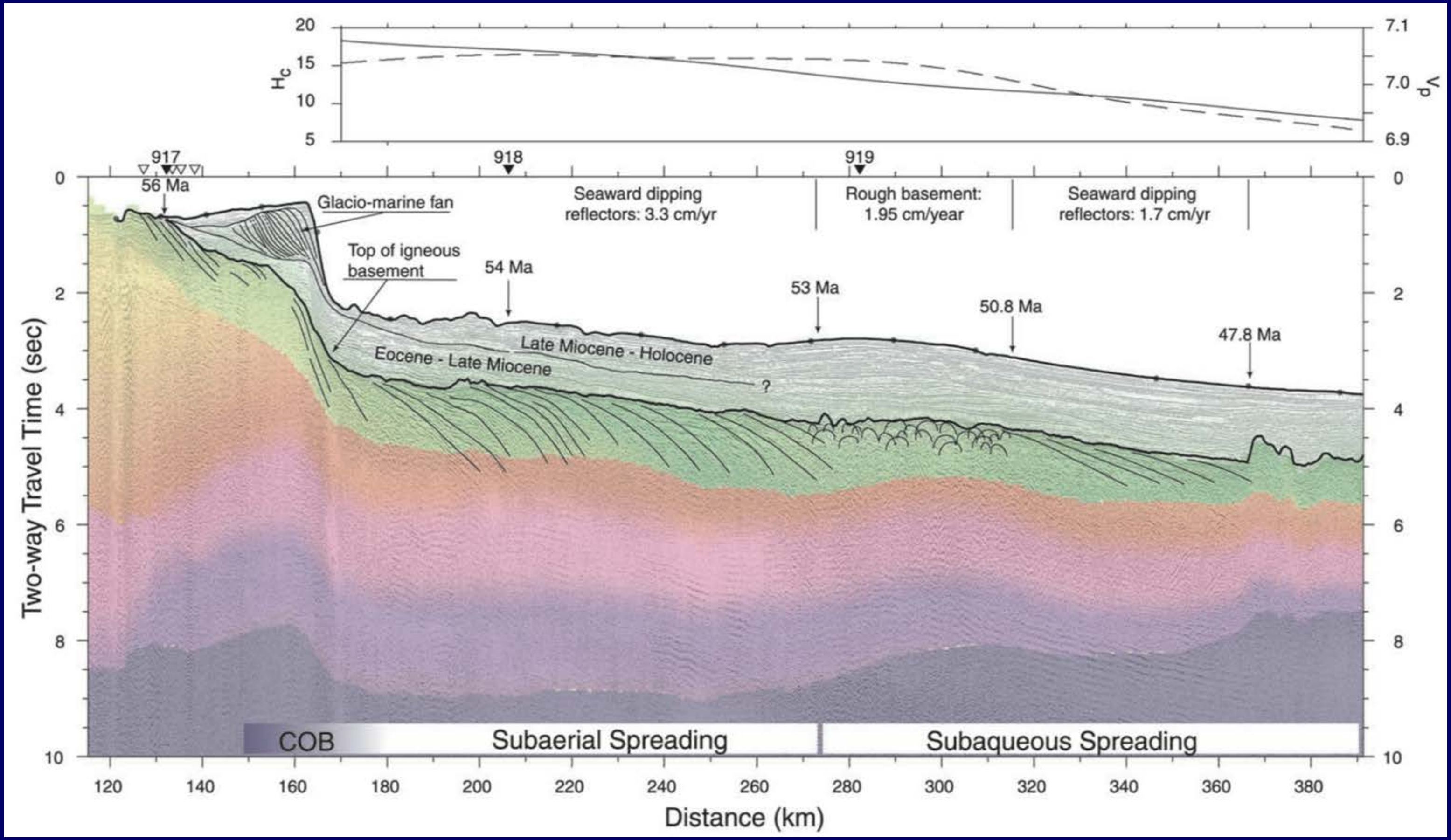








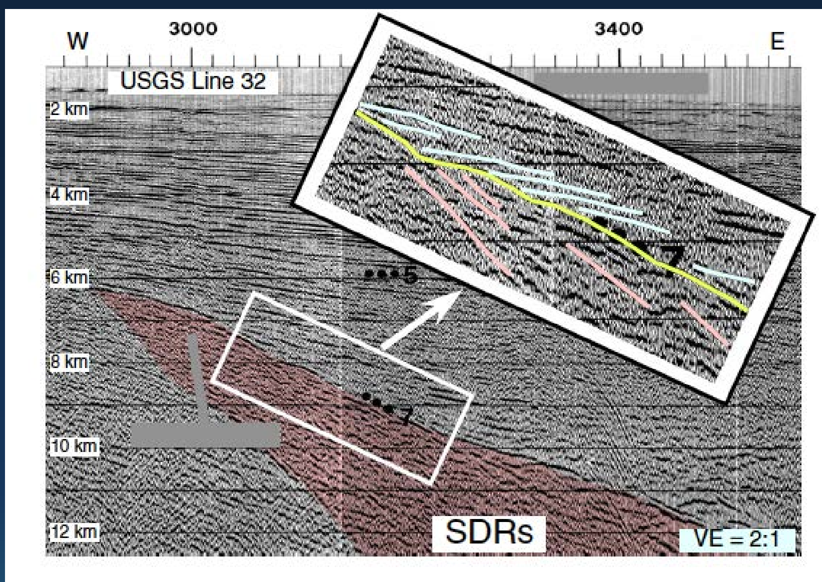
Example of Seismic Data East of Greenland Showing Seaward Dipping Reflectors Thought to be Volcanic Flows



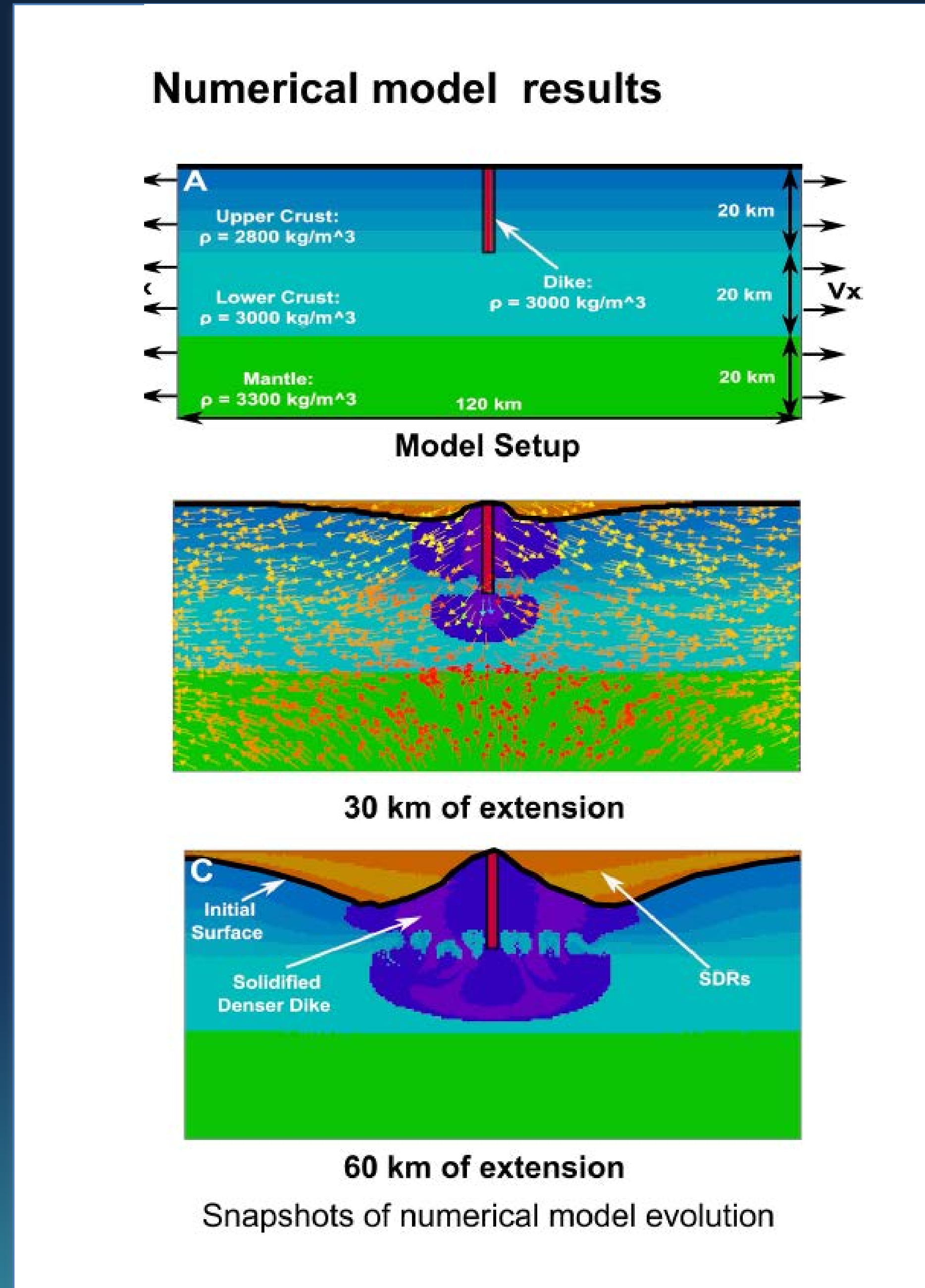
Hopper et al., 2003

Numerical Work on Seaward Dipping Reflectors:

Consider ways to get outer margin collapse

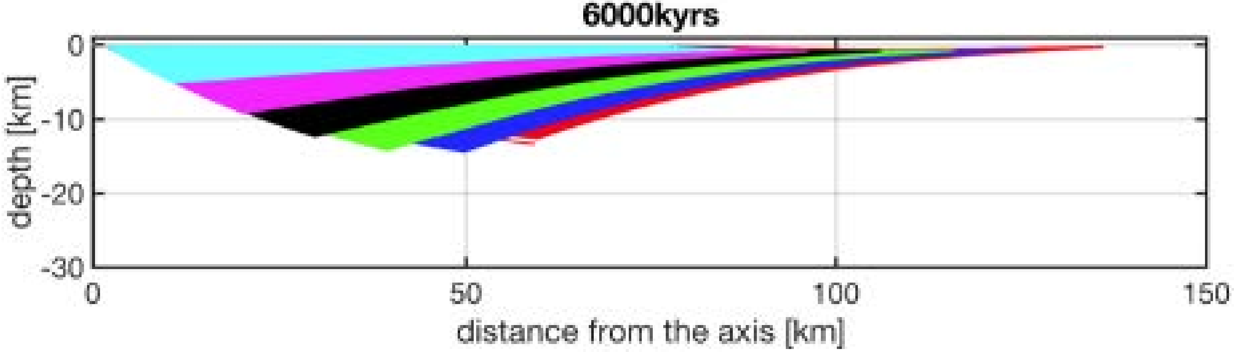


Pindell et al. (2014) argue that onlap At top of some SDRs indicated rapid collapse

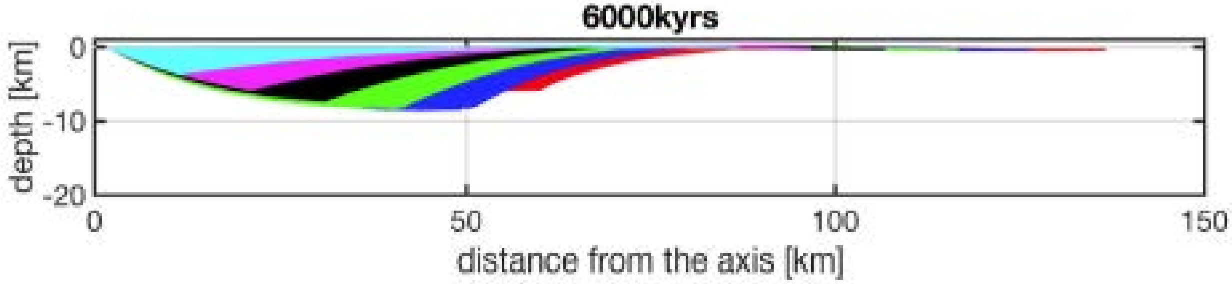


Constant thermal structure with Plasticity

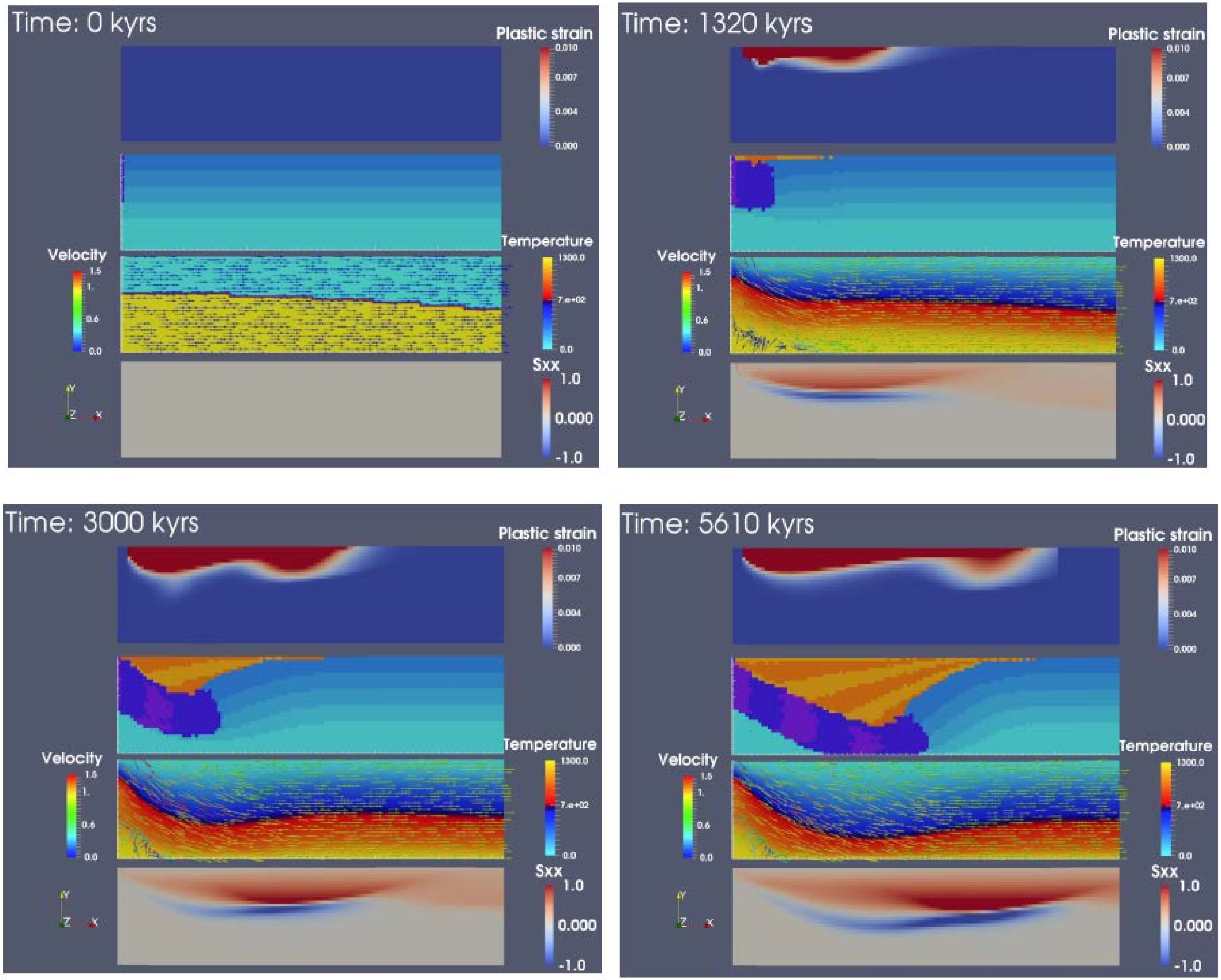
H = 20 km



H = 8 km

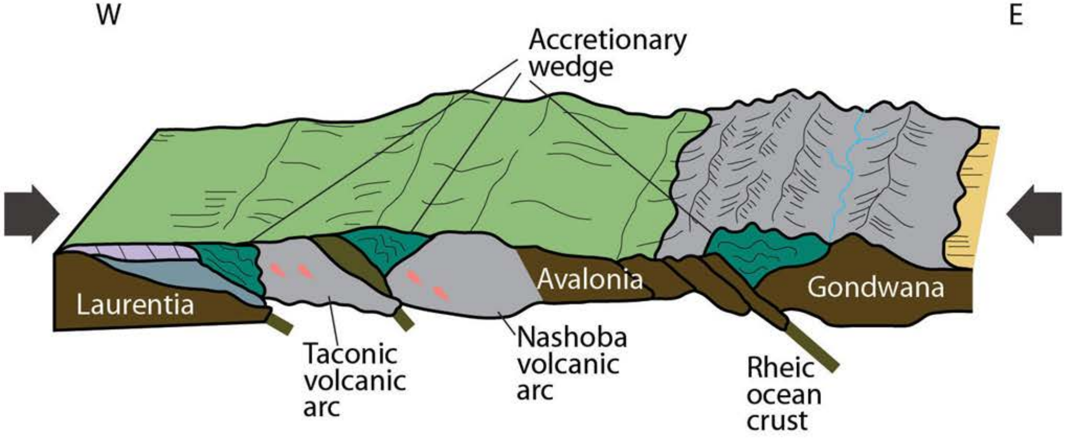


Models with thermal evolution

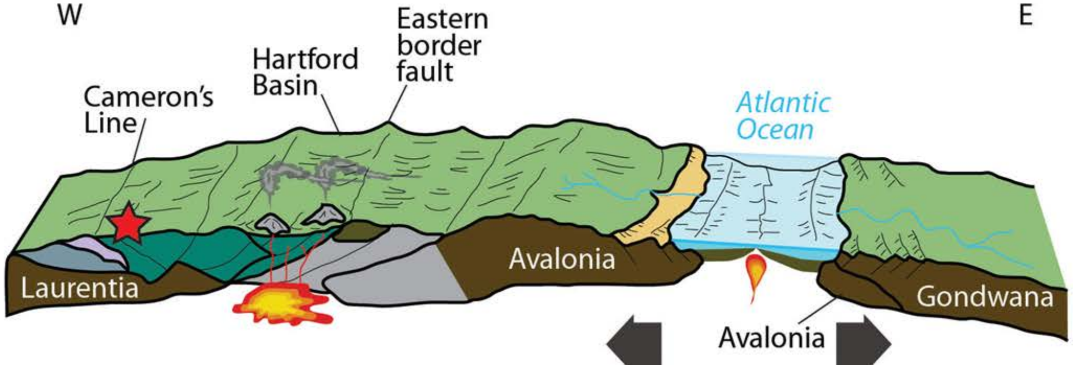


See talk by Xiachuan Tian, Thursday

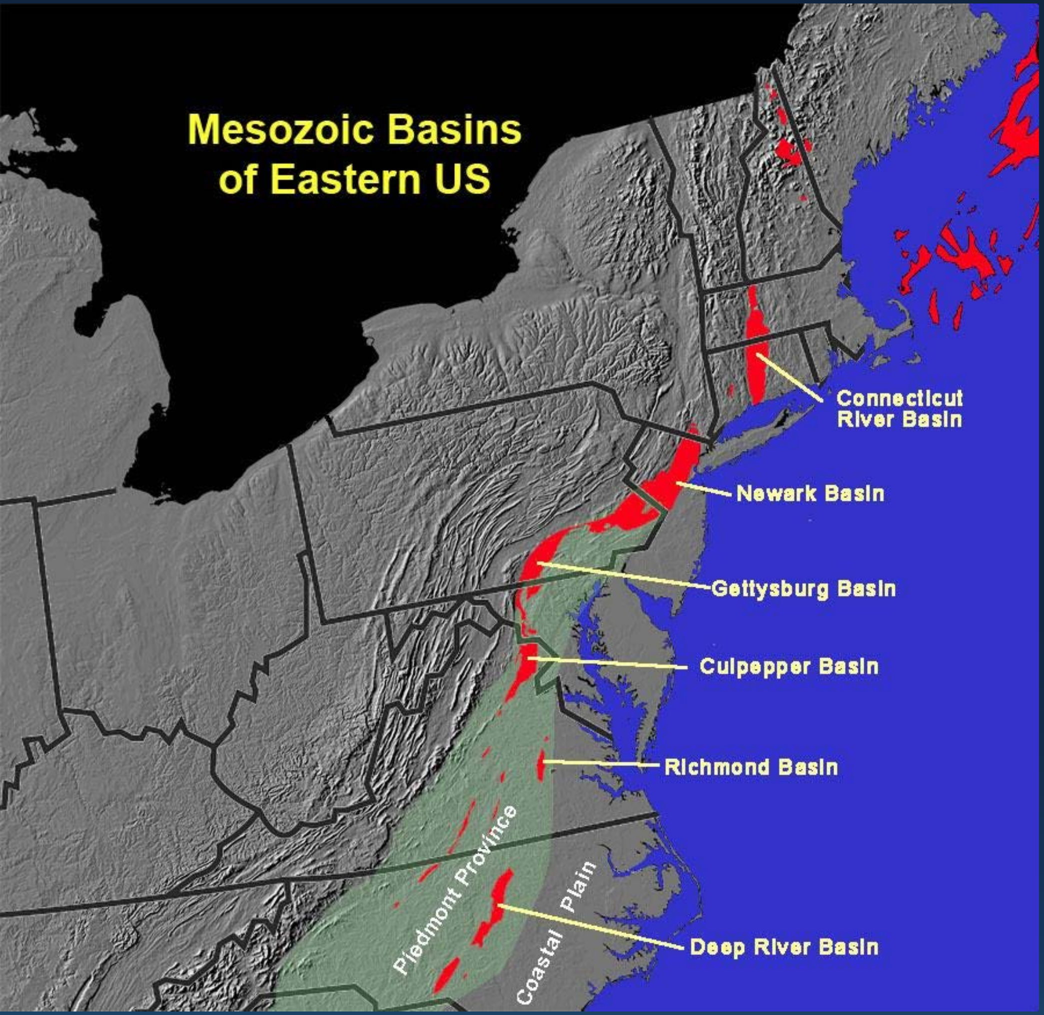
Extension is Seen in Eastern North America for ~30 Ma before CAMP Magmatism

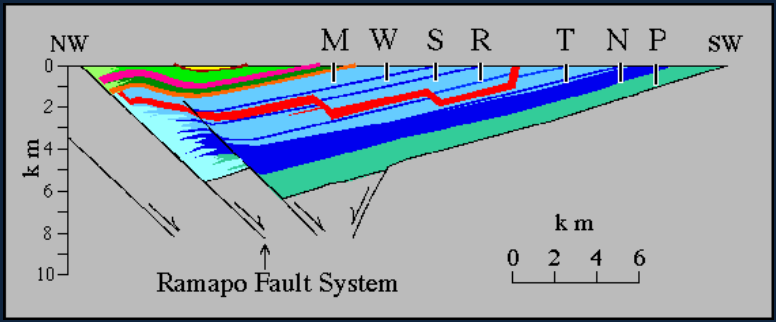


310 million years ago
The Rheic Ocean closed and the supercontinent Pangaea formed during the Alleghanian Orogeny when Gondwana collided with the eastern margin of North America that now includes Laurentian, Taconic, Nashoba, and Avalonian bedrock.

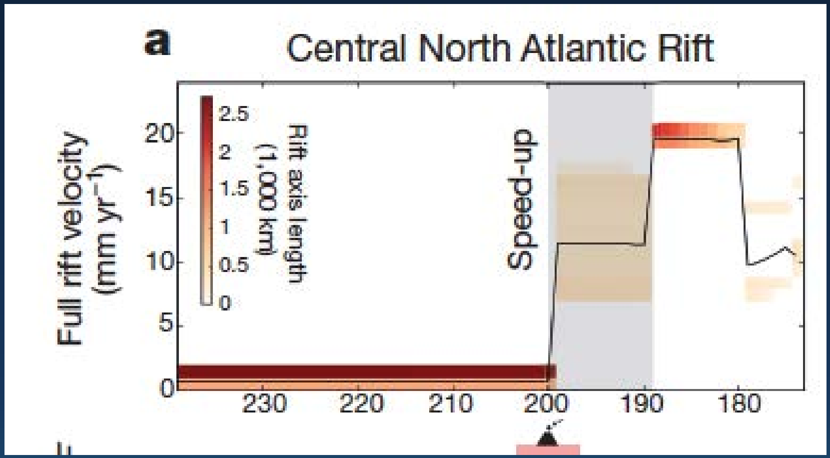


200 million years ago
During the Early Jurassic, Pangaea rifted apart, forming the Atlantic Ocean between the African and North American continents. In Connecticut, normal faulting and volcanism accompanied the formation of the Hartford rift basin.





Data show acceleration as CAMP starts



Brune et al. (2016)

Syn- and Post-Orogenic Extension is Seen in Virtually all Mountain Belts

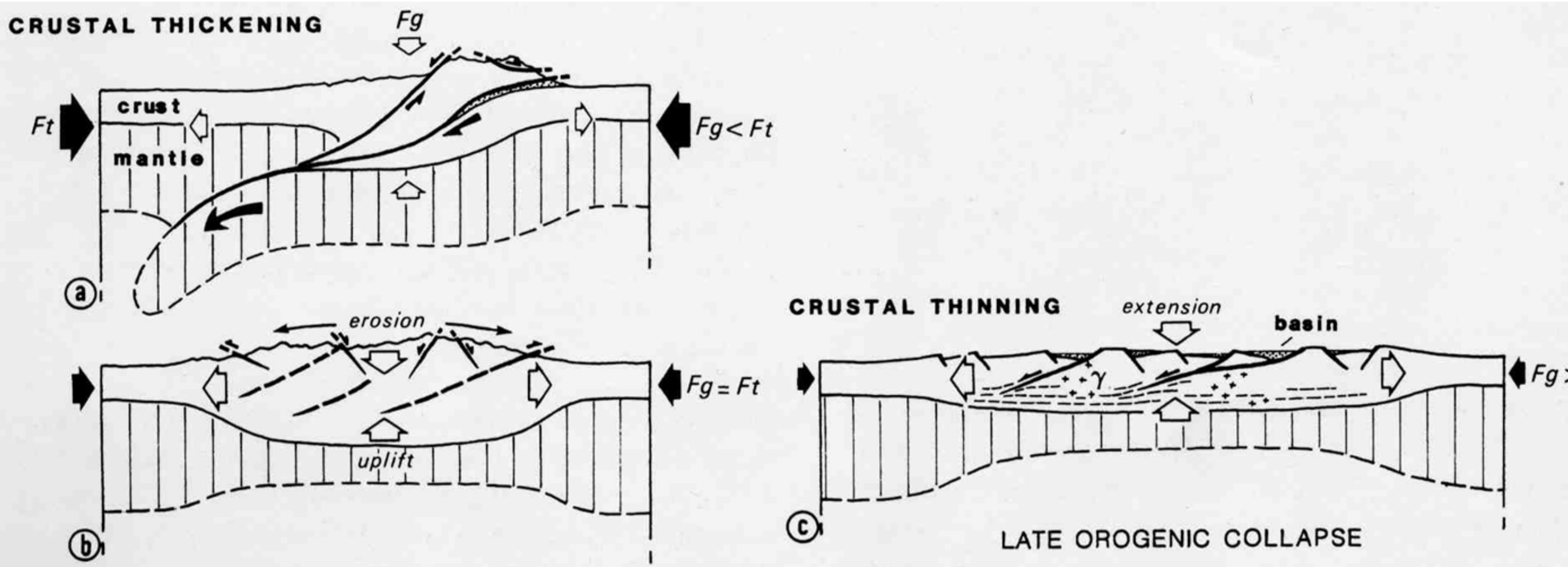
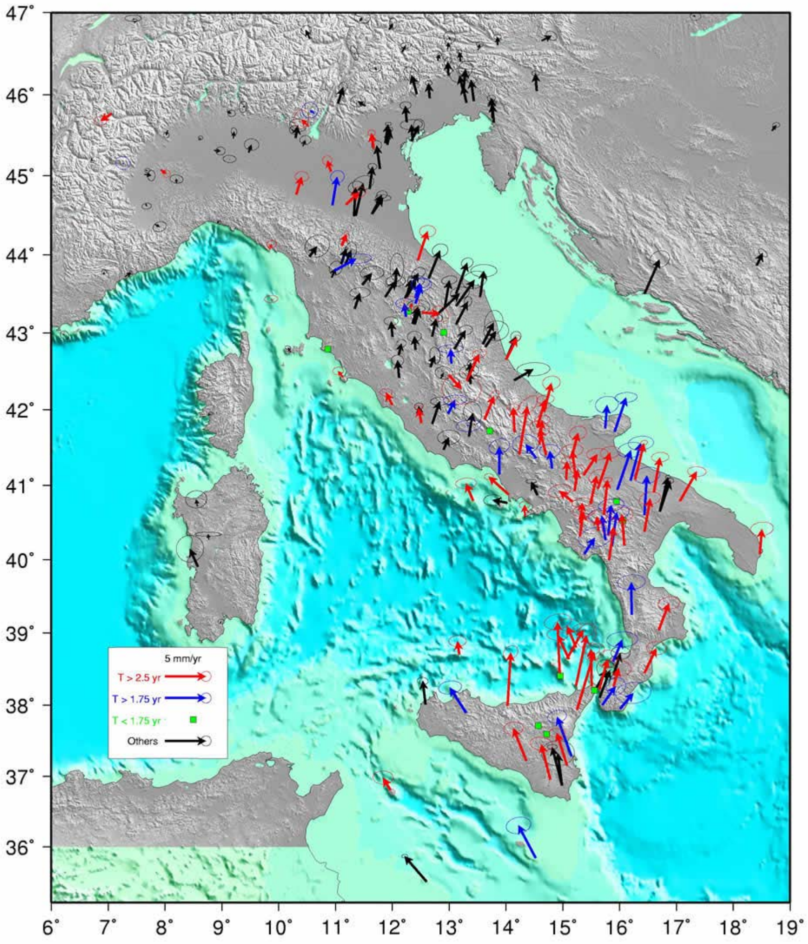


Fig. 1. Extension in mountain belts for tectonic settings (a and b) crustal shortening and (c) late orogenic extension. Fg is gravitational forces, and Ft is tectonic forces.

Malavielle (1993)

Active Extension in the Apennines With Normal Faulting Earthquakes



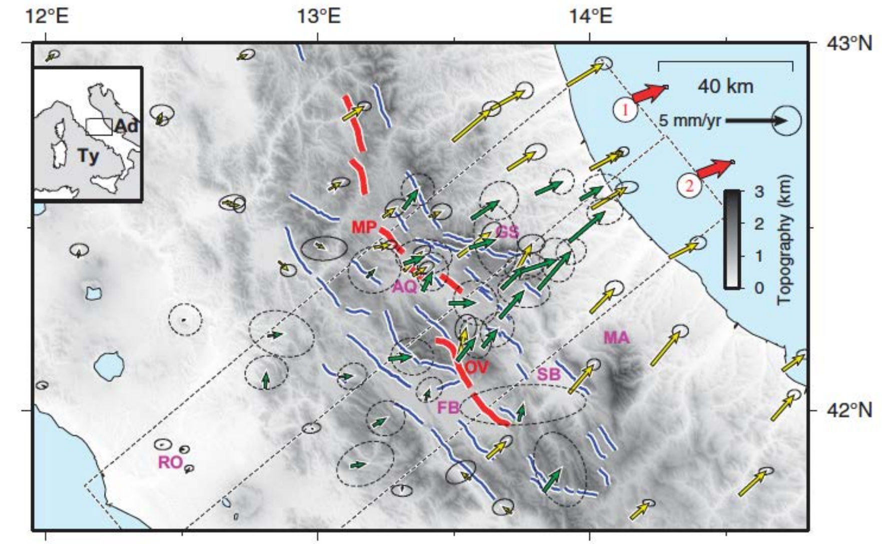
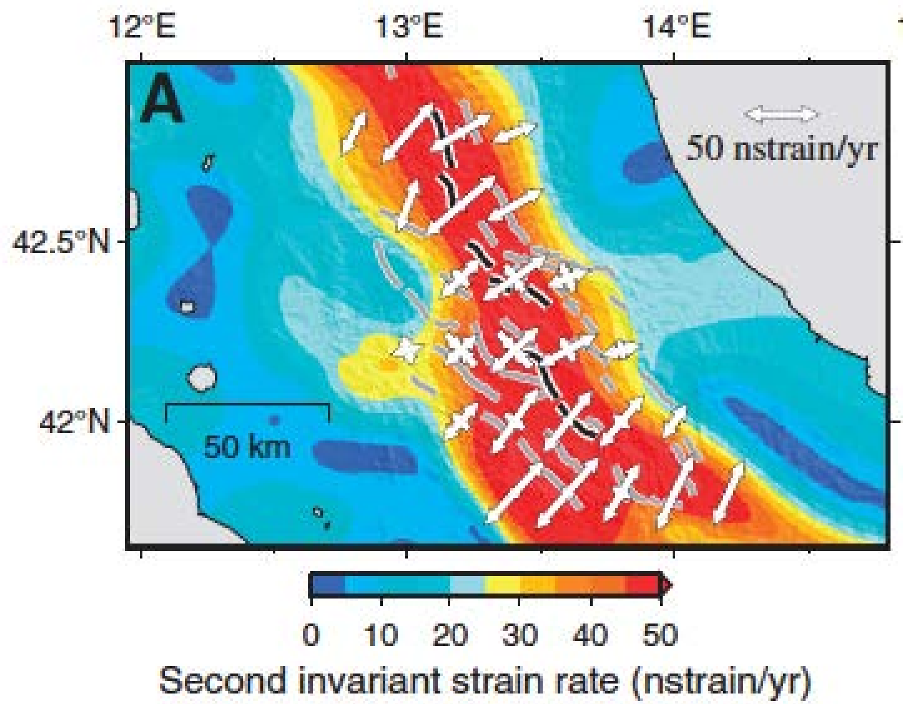
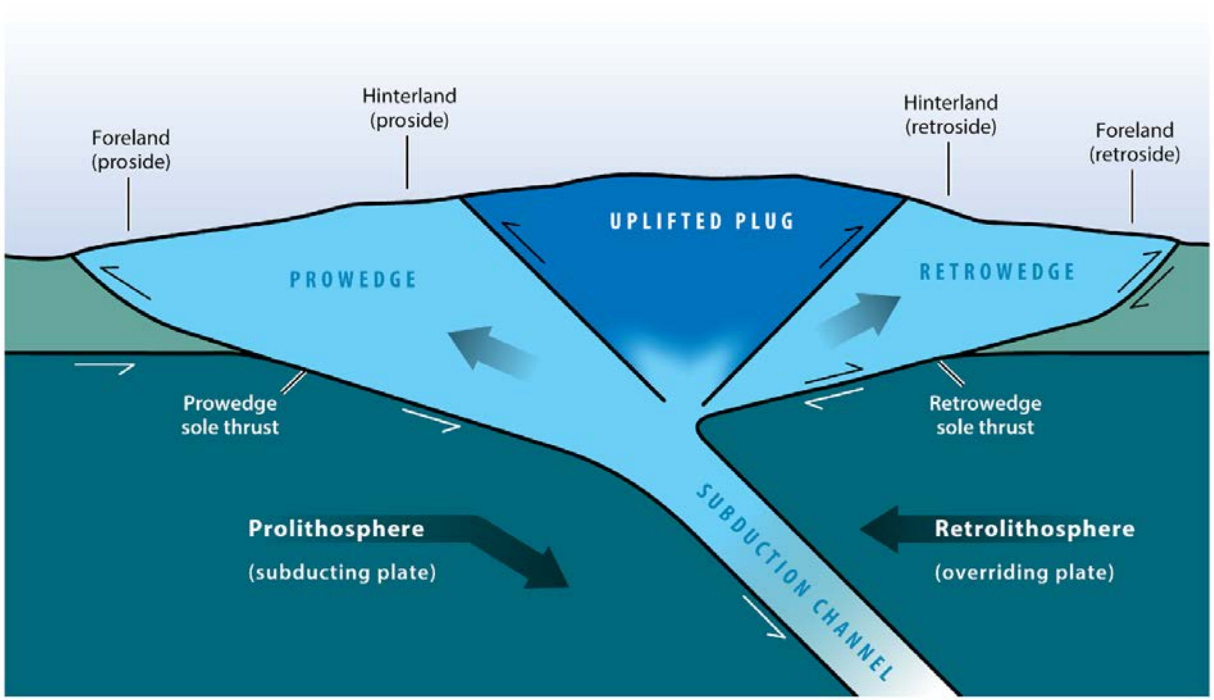


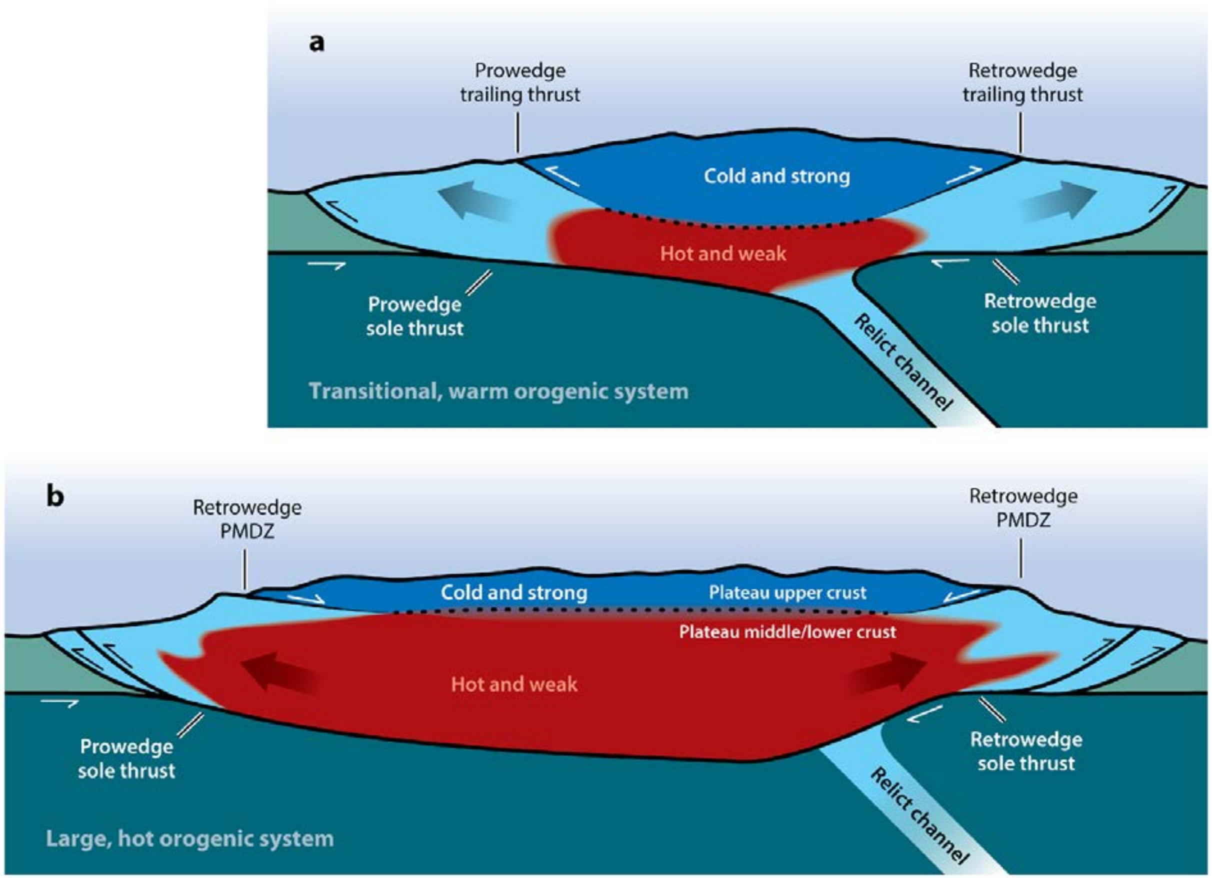
Figure 1. Global positioning system (GPS) velocities (95% confidence interval error ellipses) in



D'agostino et al. (2011)



Hodges KV. 2016.
Annu. Rev. Earth Planet. Sci. 44:685–708



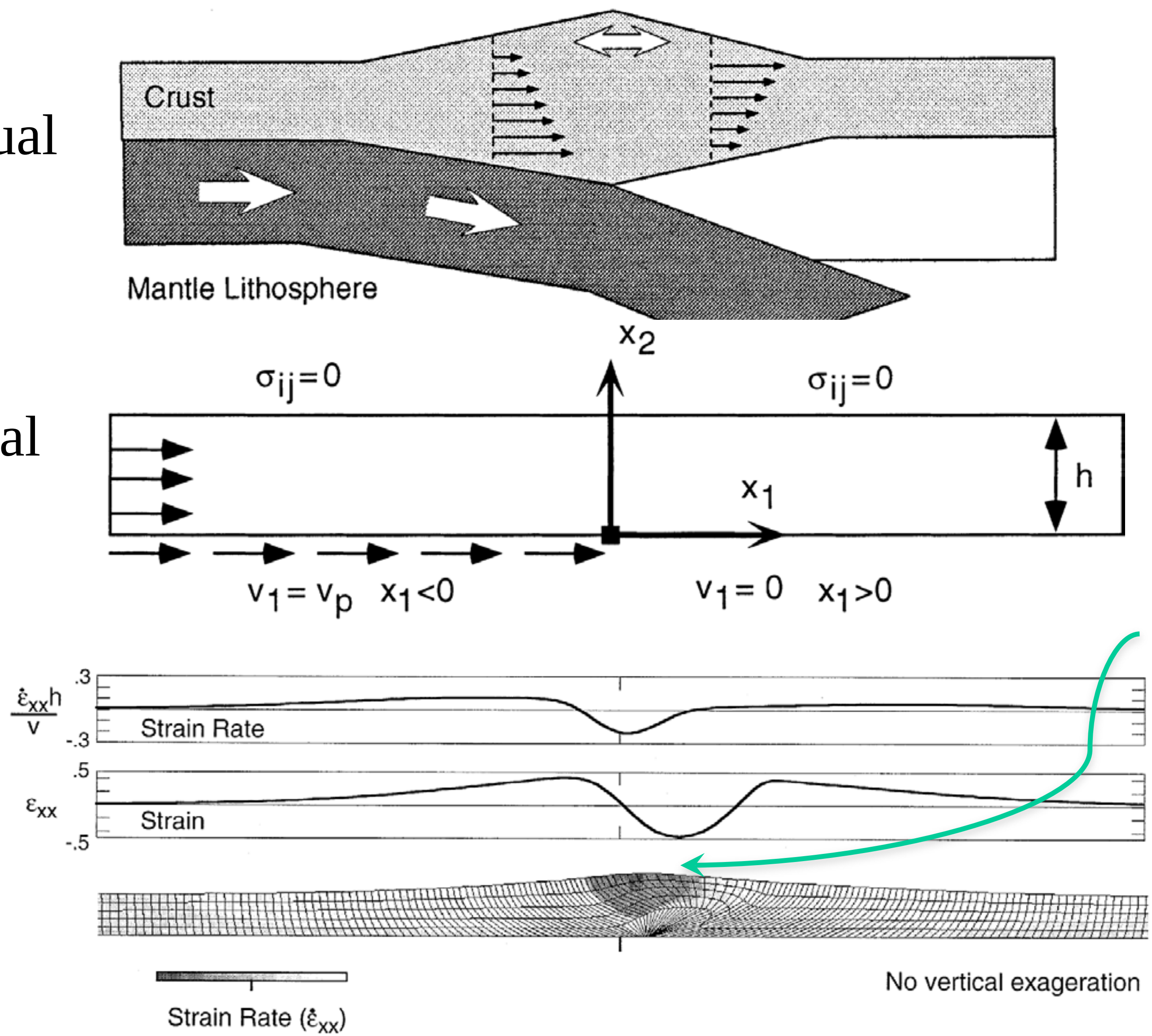
Hodges KV. 2016.
Annu. Rev. Earth Planet. Sci. 44:685–708

Modeling of Syn-Extension is quite limited

Conceptual Setup

Numerical Setup

Resuts For Viscous "Crust"



Zone Of Extension

Willett (1999)

Great Modeling Challenges Related to ENAM

The impact of plumes on rifting

-Uplift and driving forces
-Active early mantle melting and later passive melting
-Magma interaction with the lithosphere

The impact of orogeny on rifting

-Interaction of a plume and a mountain belt
-Basic controls on extension