Tectonic Rom-Coms

Tearing Plates Apart and Bringing Them Back Together

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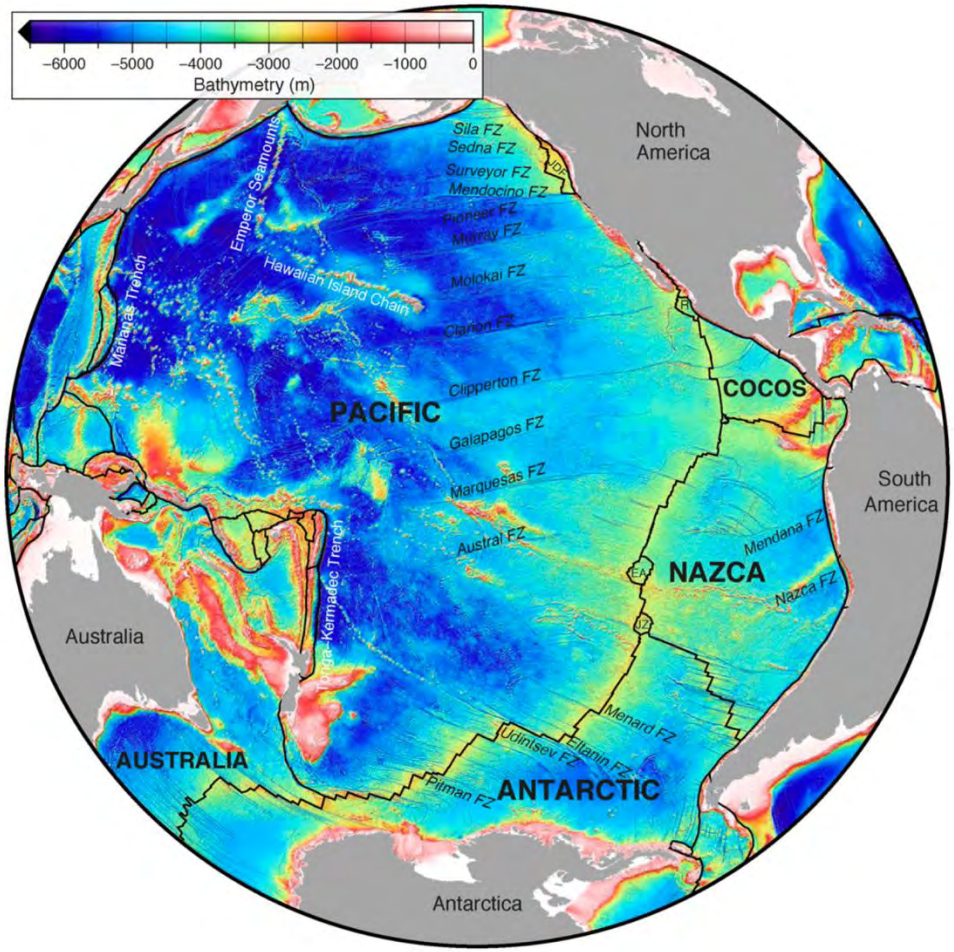
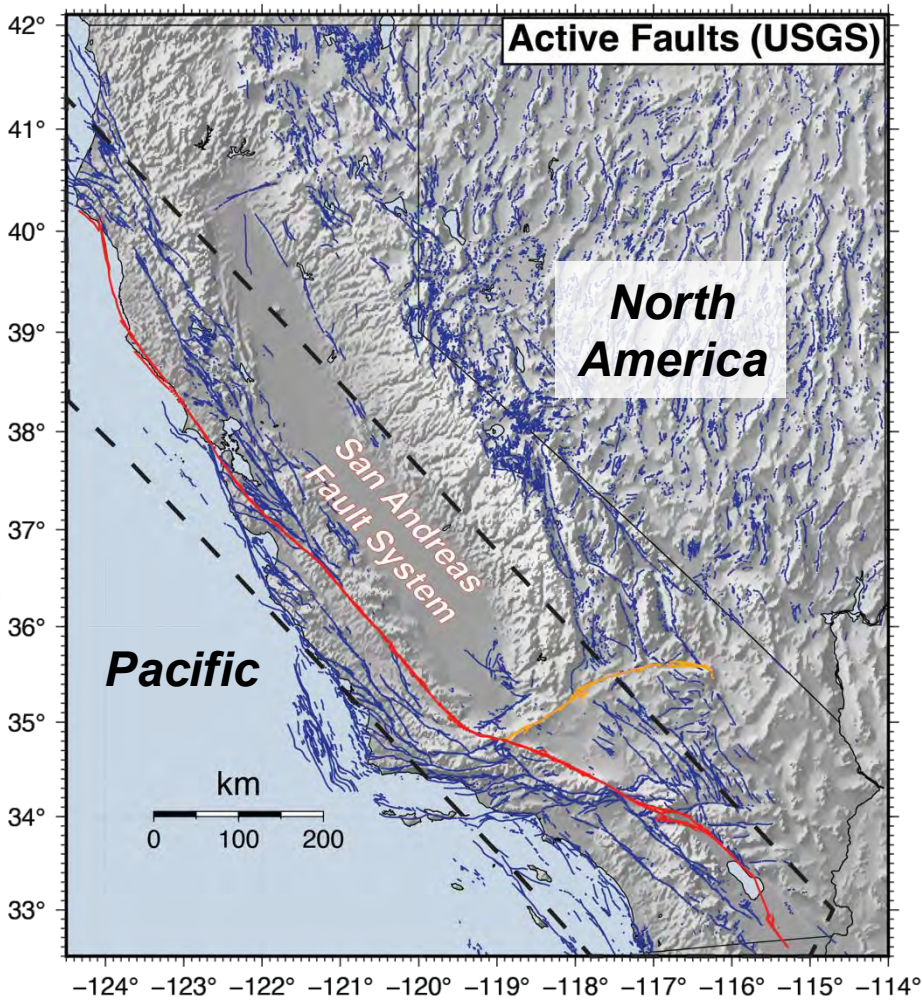
CSU Bakersfield

Meet Cute

When Pacific Met North America

The iconic San Andreas fault is the boundary between the Pacific and North American plates through California

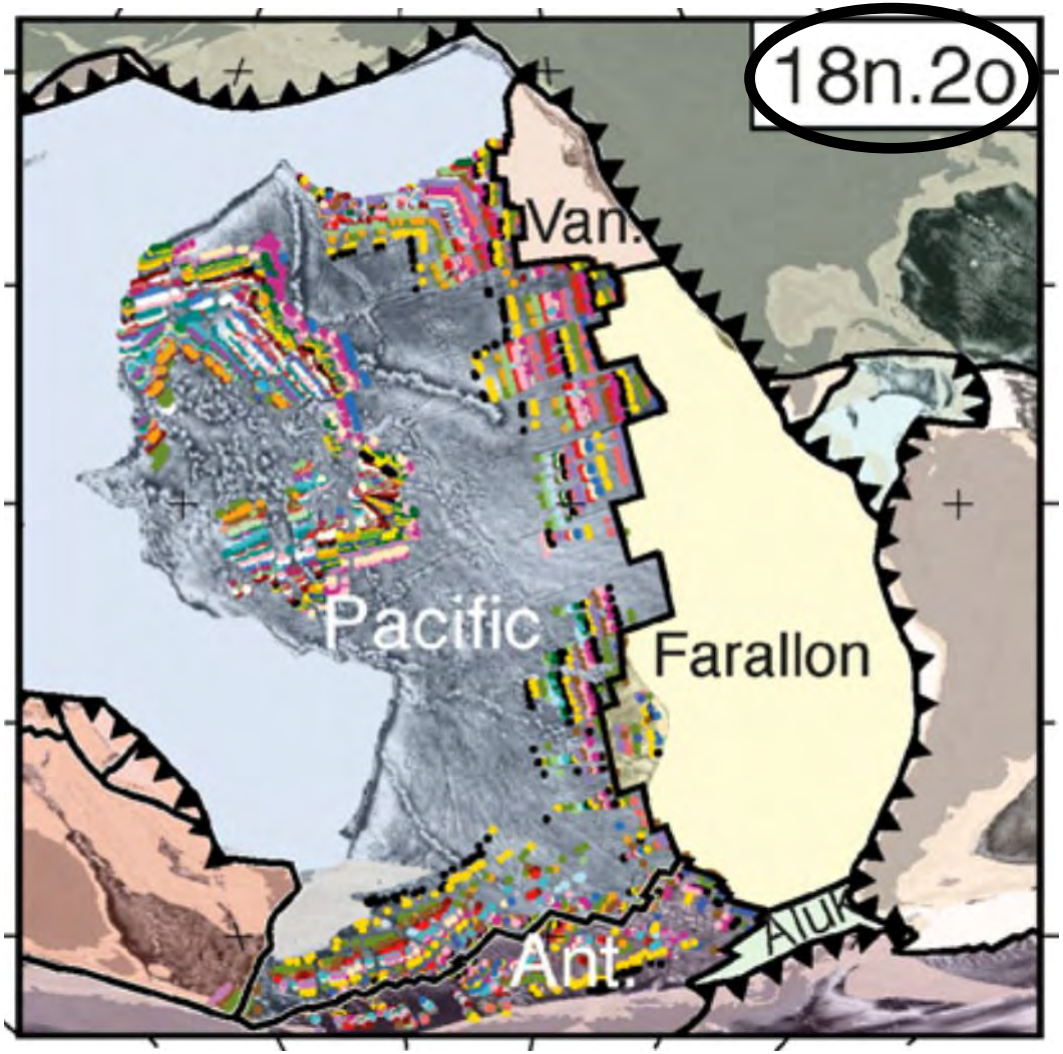




But they were not always together!

Wright et al. (2016)

When Pacific Met North America



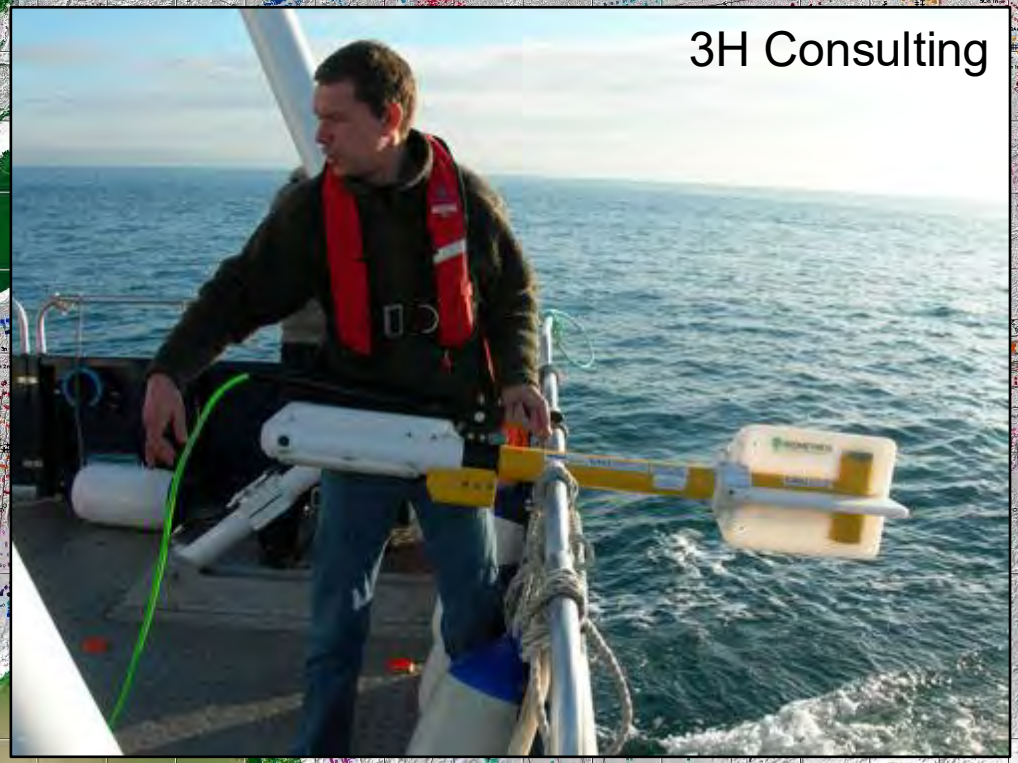
A plate tectonics way of saying "40 million years ago"

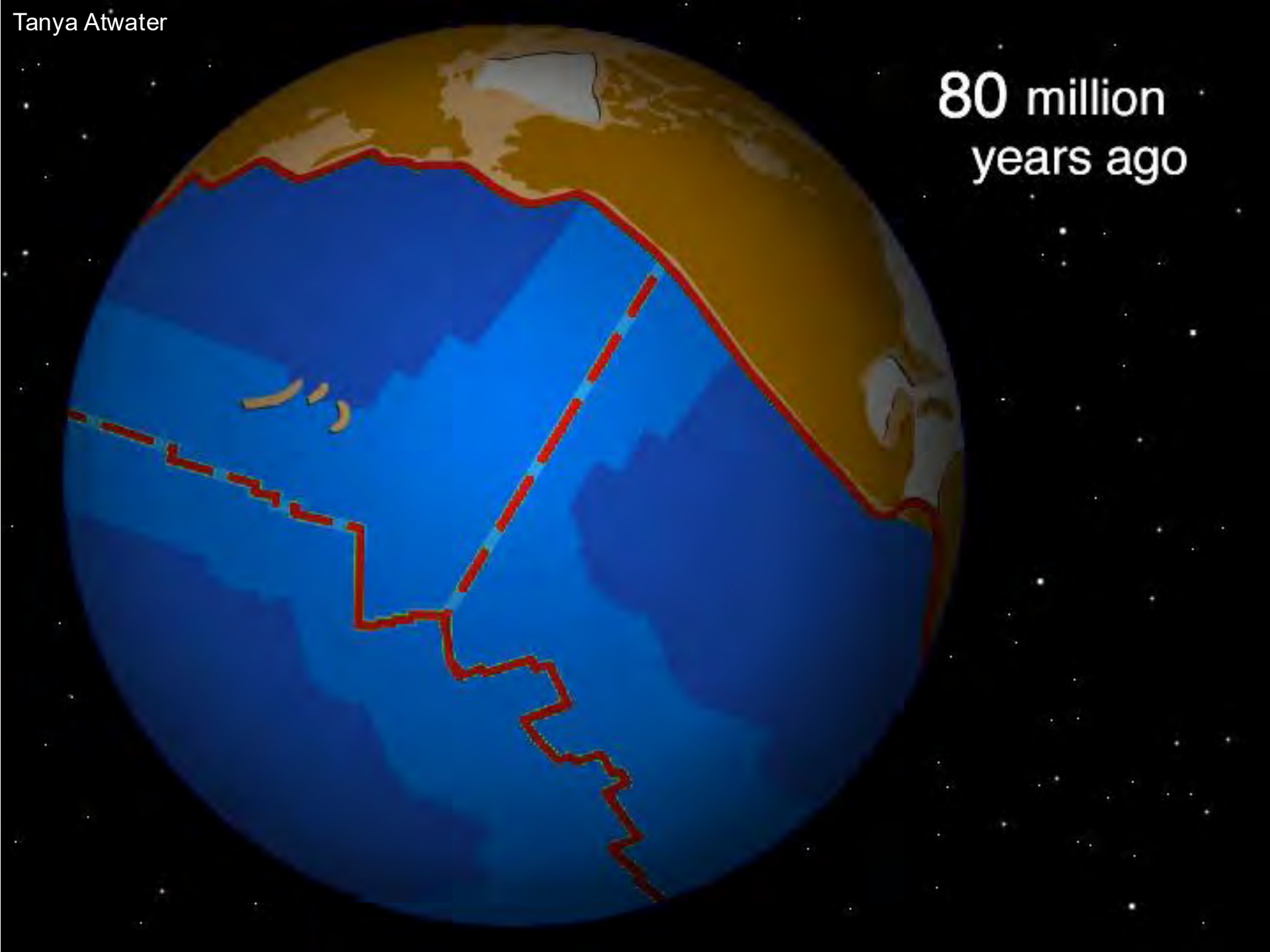
At this point in Earth's history, the Pacific plate did not touch North America in California

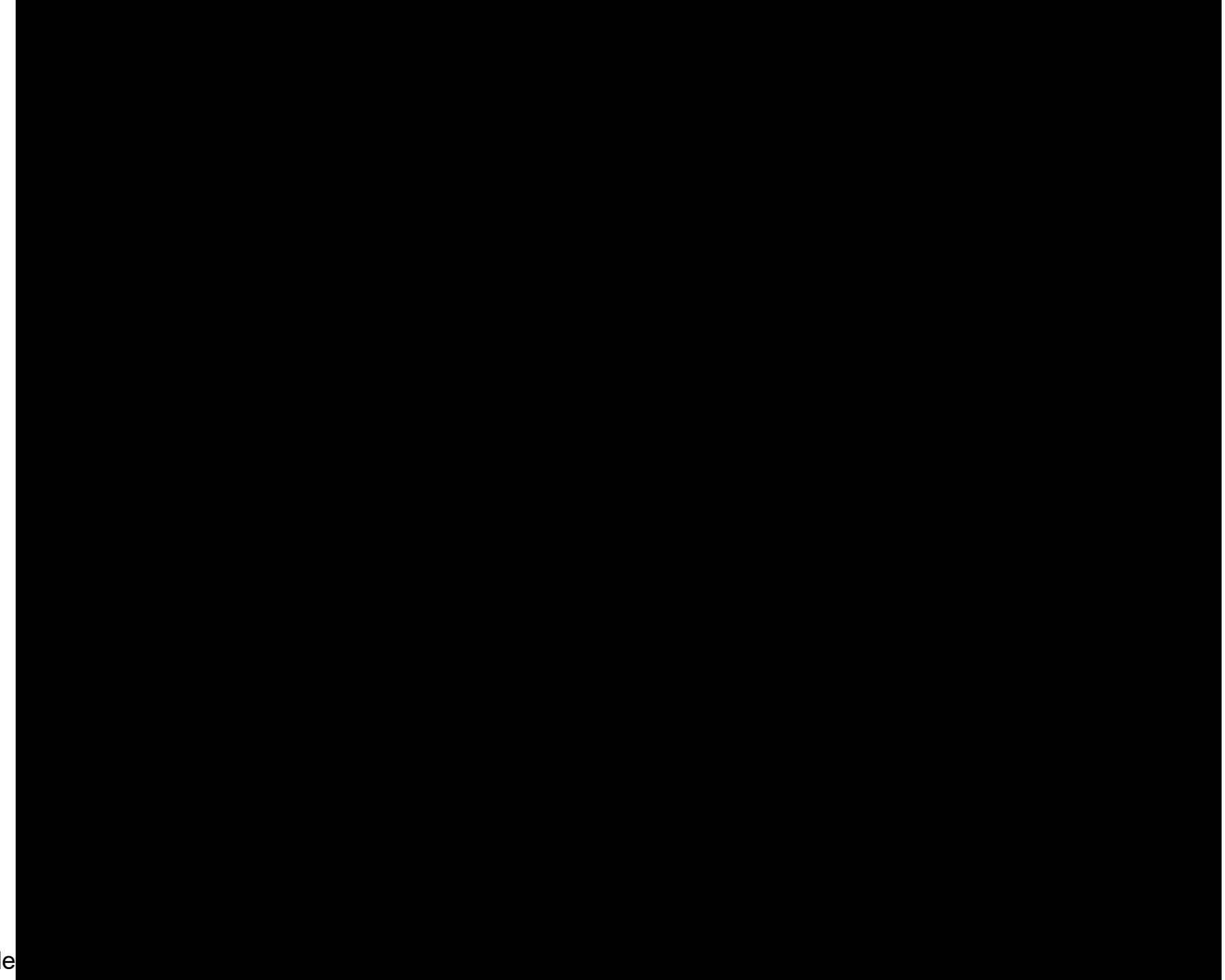
*The **Farallon plate** was in the way!*

Wright et al. (2016)

How do we know which plates were where? The magnetism of Earth's oceans recorded during their formation let's us reconstruct plates back in time!




Tanya Atwater
80 million
years ago

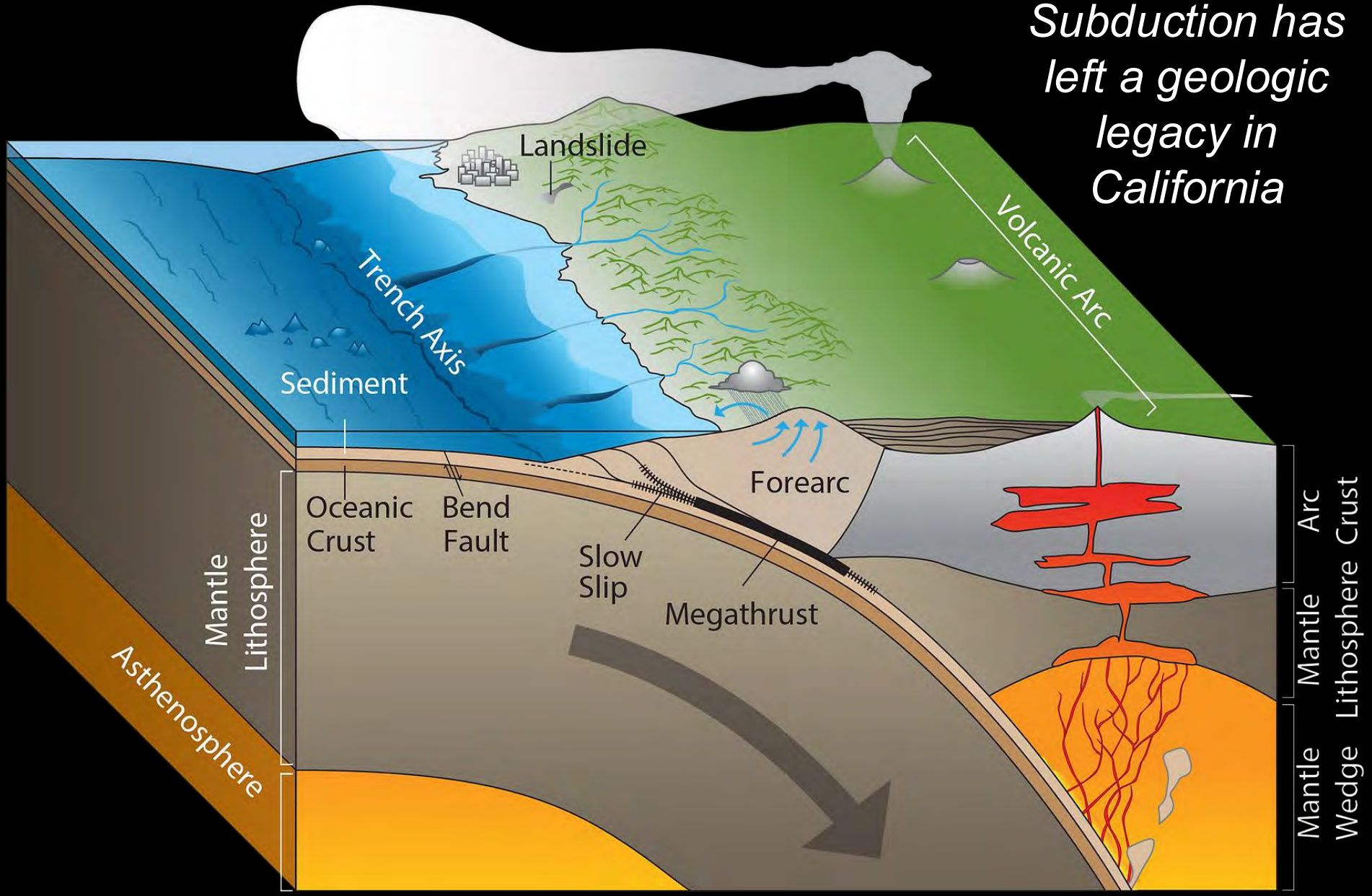


How does a tectonic plate just disappear???

SZ4D

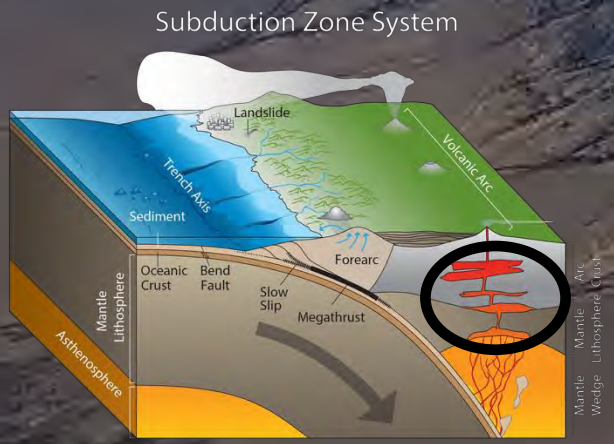
Subduction Zone System

Subduction has left a geologic legacy in California

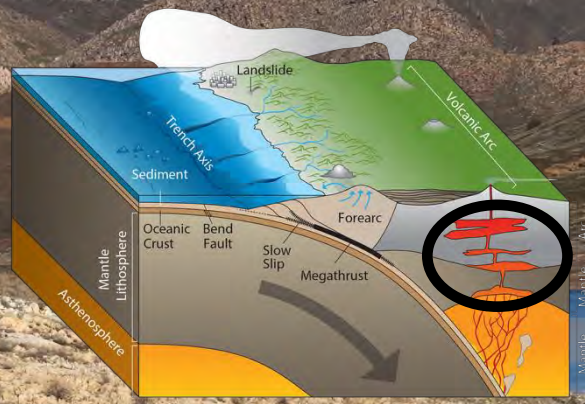


Dicklyon/Wikimedia Commons

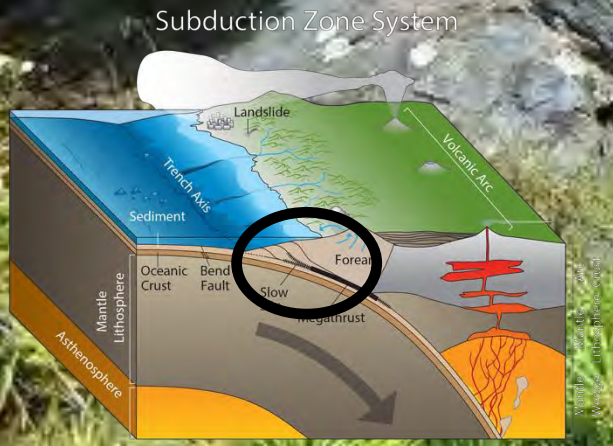
Sierra Nevada



Sierra Nevada



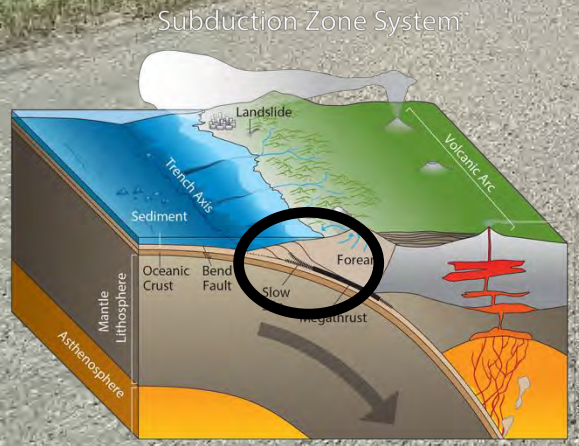
Franciscan Blueschist (former ocean buried in a subduction zone) in Oakland



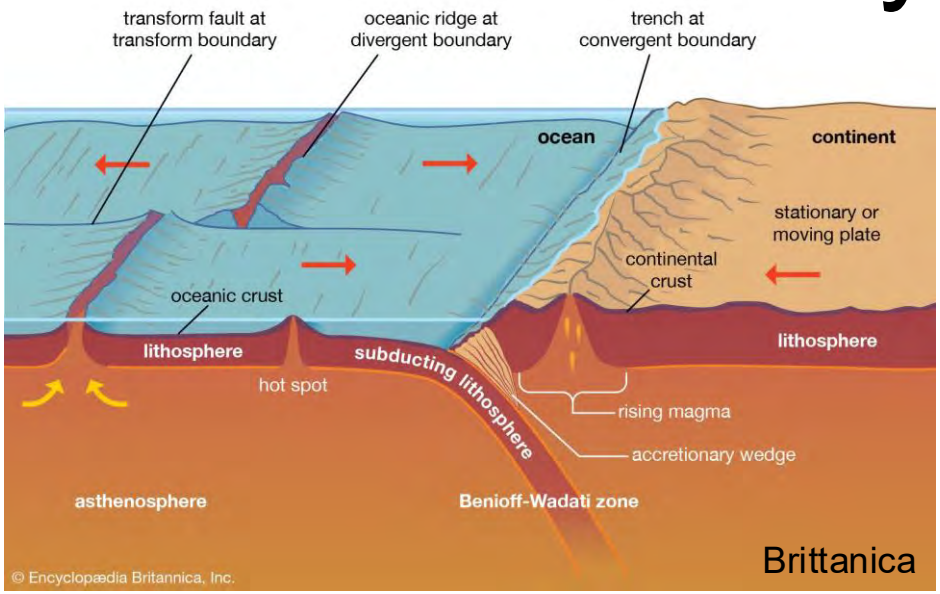
Franciscan Eclogite (former ocean buried in a subduction zone)

Catalina Schist (former ocean buried in a subduction zone) on Catalina Island

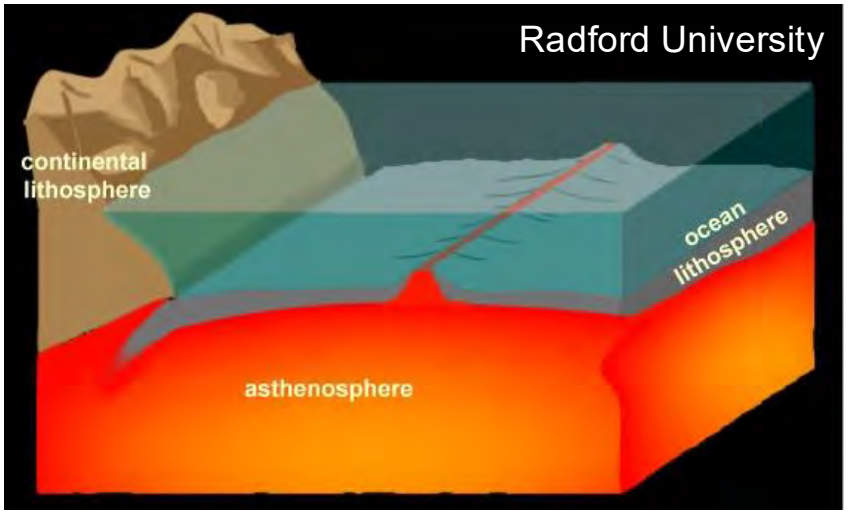
Franciscan Serpentinite (former ocean buried in a subduction zone) in W. Kern Co.
SJGS Field Trip!

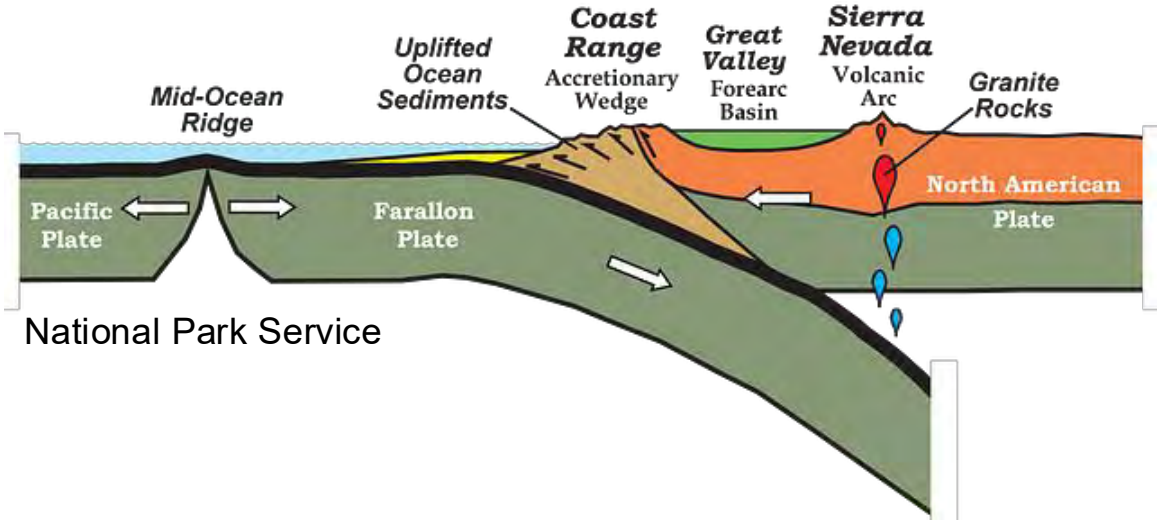


“Textbook” Subduction: Conveyor Belt

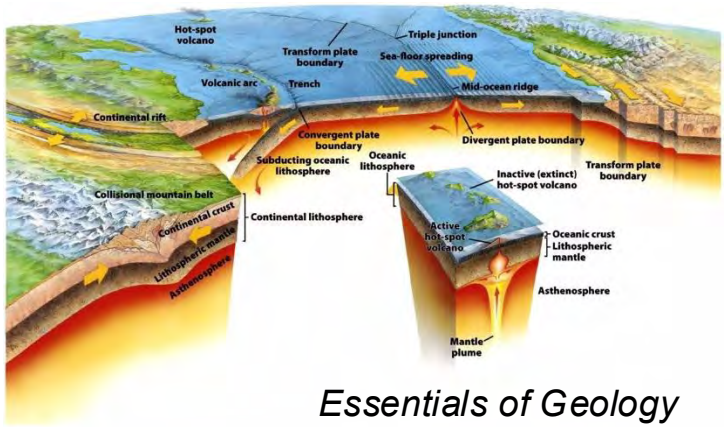


Brittanica





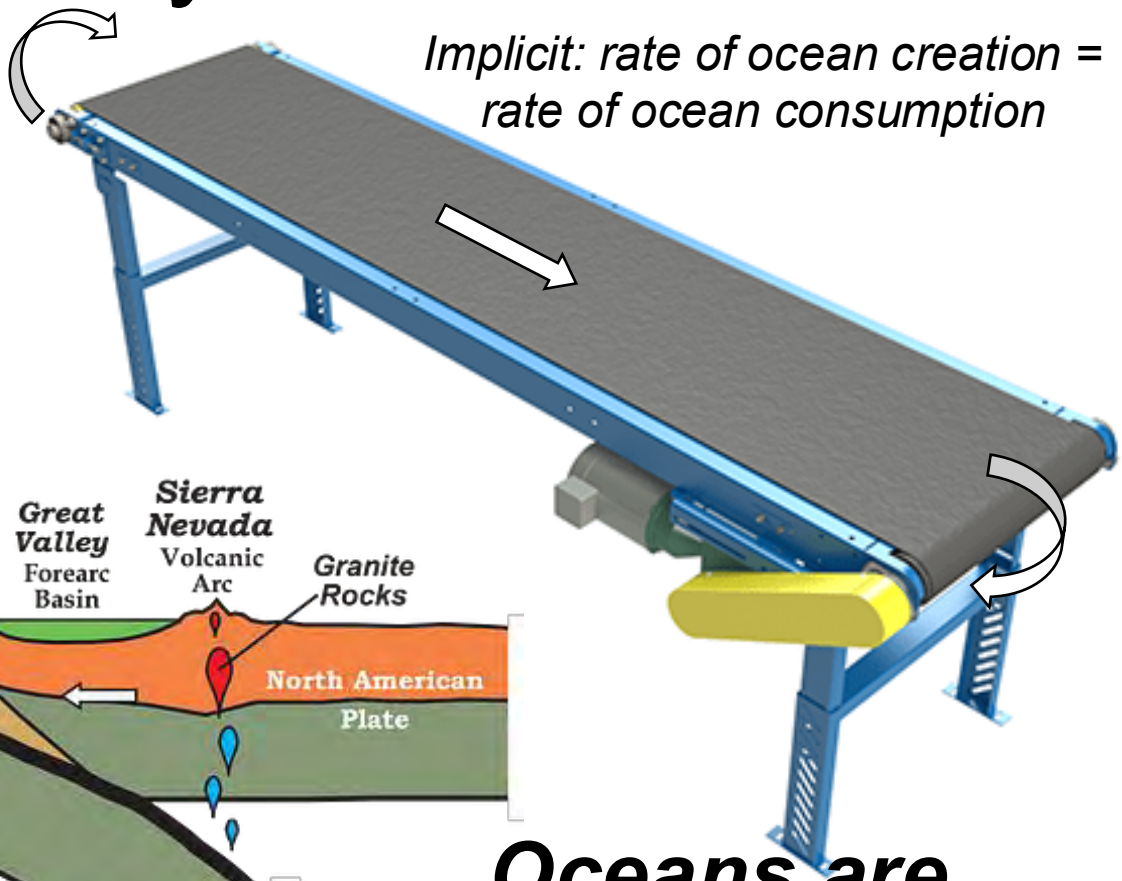
National Park Service



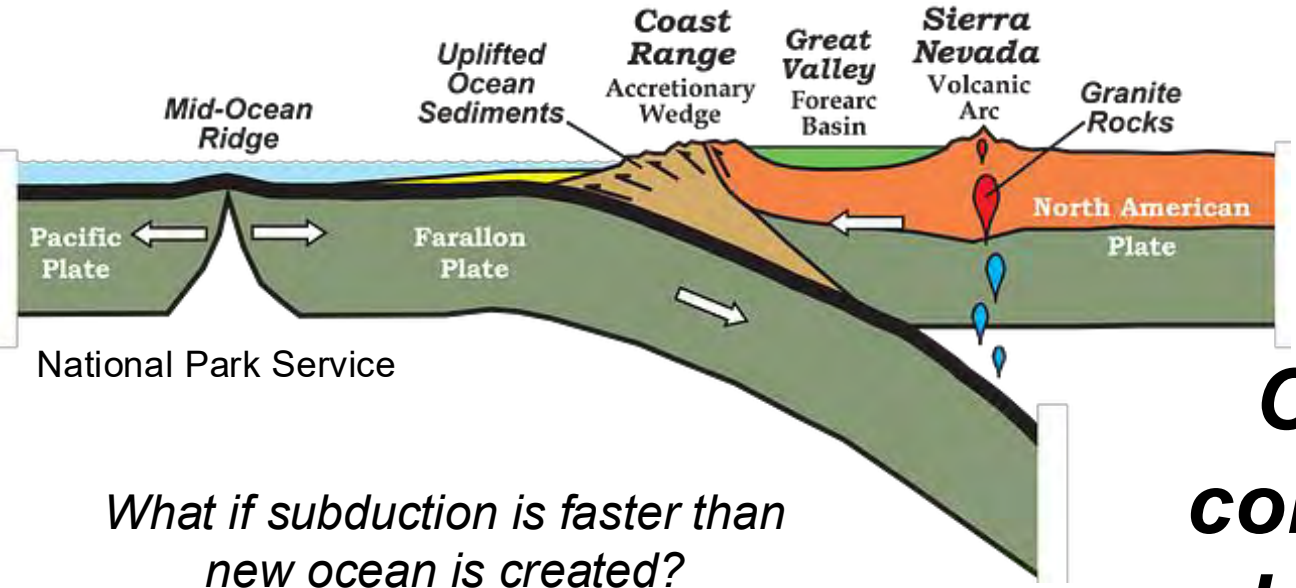
Essentials of Geology

“Textbook” Subduction: Conveyor Belt

New ocean is made at a mid-ocean ridge



Implicit: rate of ocean creation = rate of ocean consumption

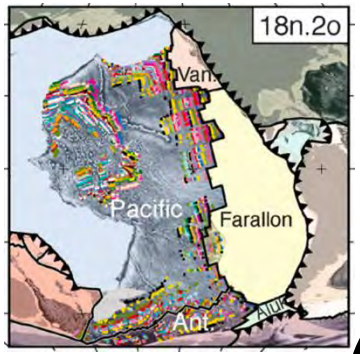


National Park Service

What if subduction is faster than new ocean is created?

Oceans are consumed at a subduction zone

50 Ma



Pacific
Farallon
North America

Pacific
Farallon
North America

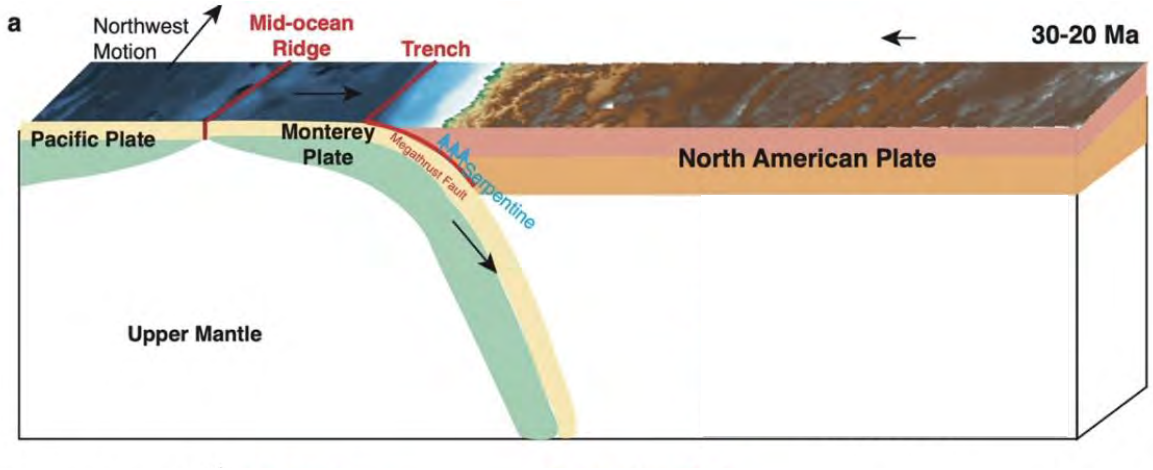
Pacific
Farallon
North America

What happens as the ridge approaches the trench?

~30 Ma

Pacific
Farallon
North America

After Atwater (1970)



*Subduction happens because an **old, cold, dense** slab wants to sink into the mantle*

*As the ridge nears the trench, the subducting ocean is **young, hot, buoyant***

The subduction zone clogs up!

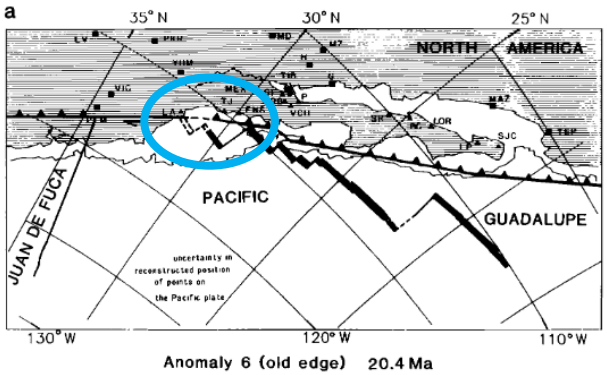
*The rest of the slab is still pulling downward, so the slab **breaks off ("detaches")***

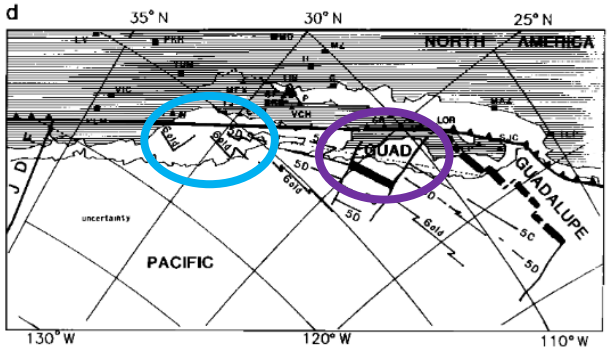
The force for spreading is gone and the ridge shuts down => the Pacific "captures" the slab fragment

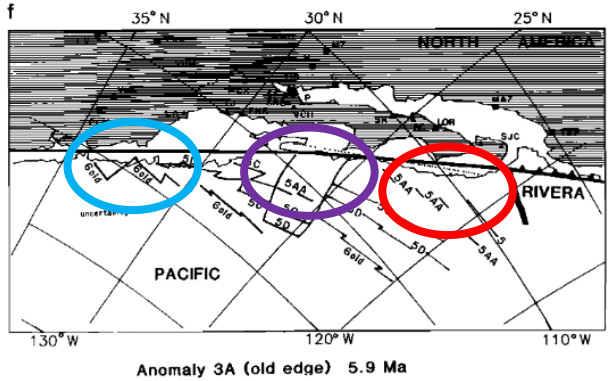
*Pacific-North American motion drives the formation of the new **"San Andreas Fault"***

Mao and Gurnis (2023)

When Pacific Met North America





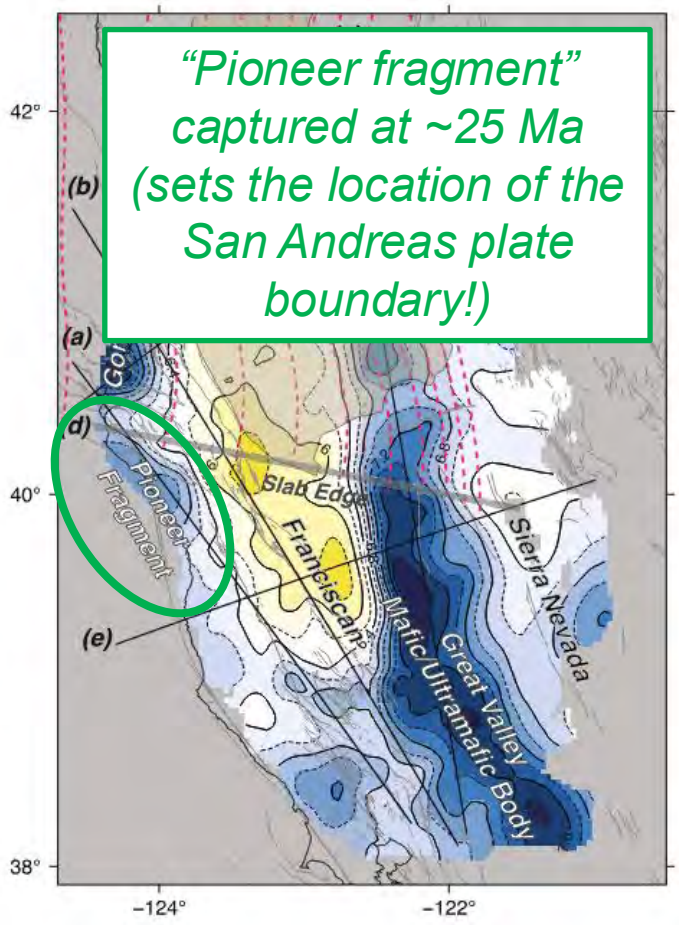


Can this microplate capture really happen?
Yes! Multiple times! We see evidence in plate motions and geophysical images.

"Monterey fragment" captured at ~20 Ma

"Guadalupe fragment" captured at ~15 Ma

"Magdalena fragment" captured at ~12 Ma



"Pioneer fragment" captured at ~25 Ma (sets the location of the San Andreas plate boundary!)

Stock and Hodges (1989)

Furlong et al. (2024)

Enemies to Lovers/ Second Act Breakup

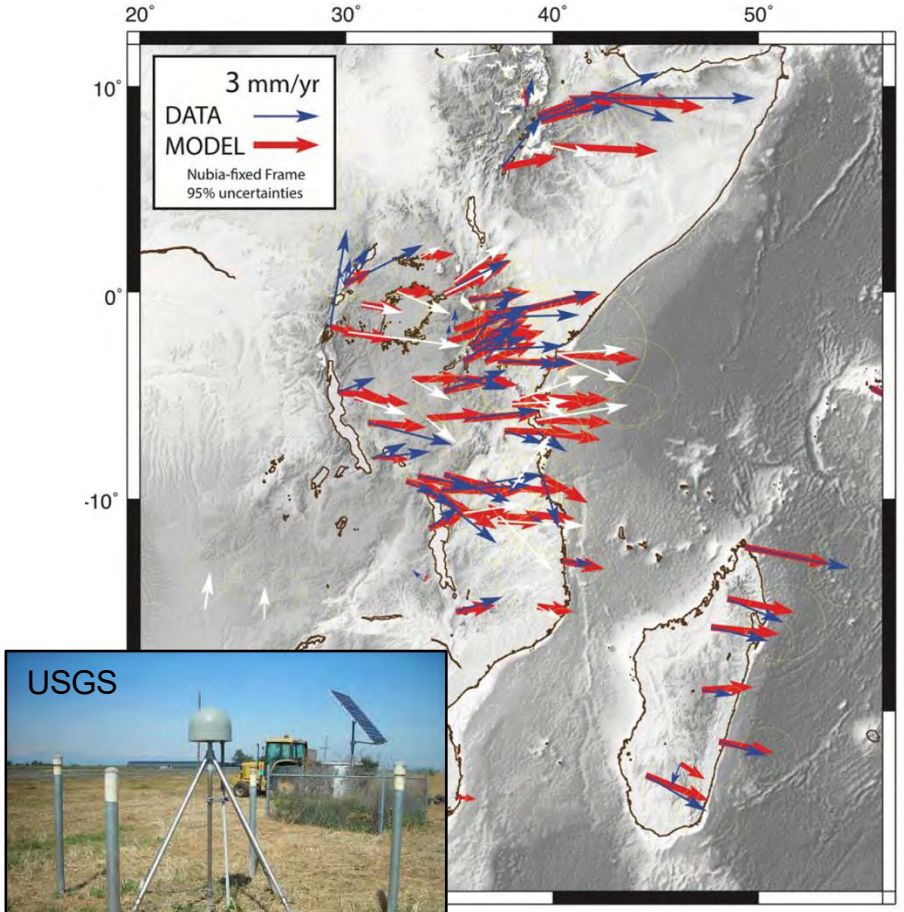
Continental Breakup

Continental Breakup

What does a breakup look like?
(Geologically speaking...)

Slow motion
(≤ 6 mm/yr)

Wide region (1000+ km wide)



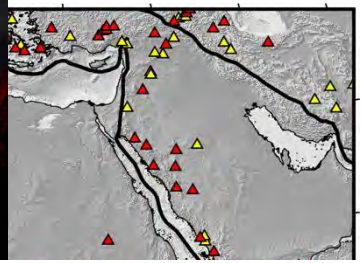
Stamps et al. (2018)

Mt. Nyarigongo, DR Congo
(Martin Rietze)

o

e?

Lots of volcanoes!



Wide region (1000+ km

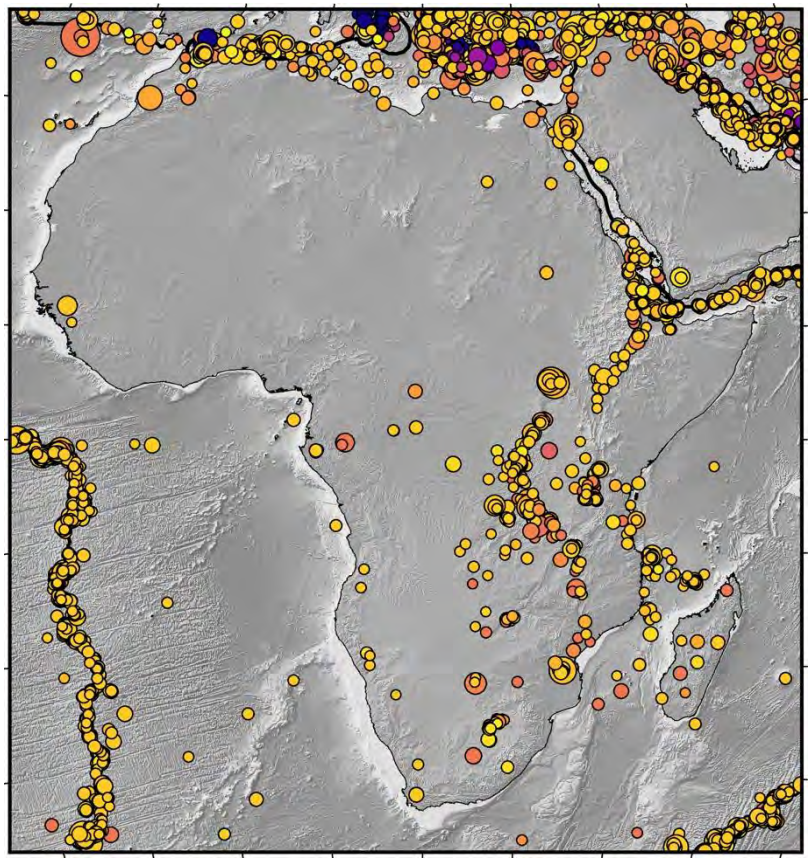
Hayli Gubbi Volcano, Ethiopia
(Afar Communication Bureau)

Continental Breakup

What does a breakup look like?
(Geologically speaking...)

Lots of earthquakes, too!

Wide region (1000+ km wide)



USGS Seismicity M5+ 1970-Present

Continental Breakup

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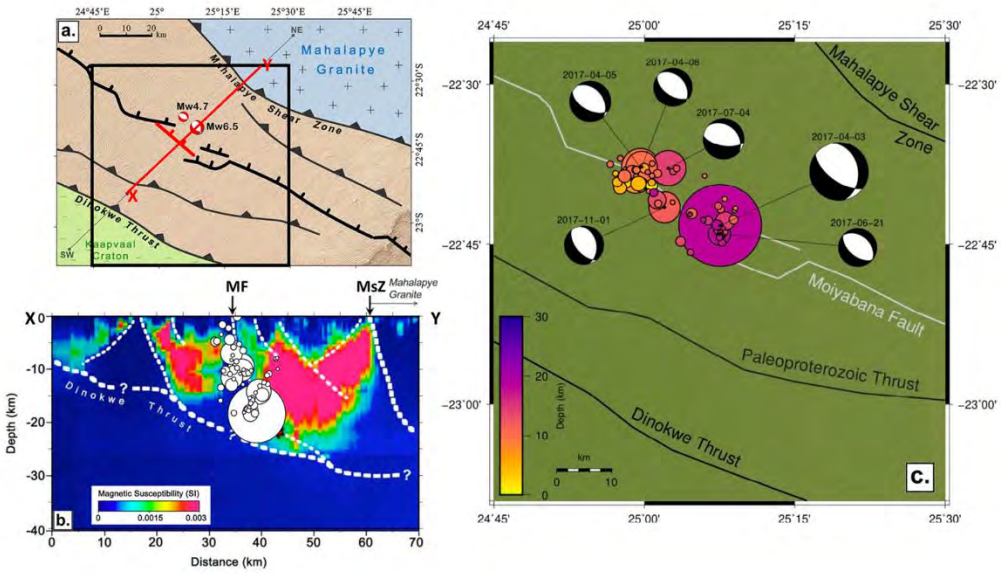
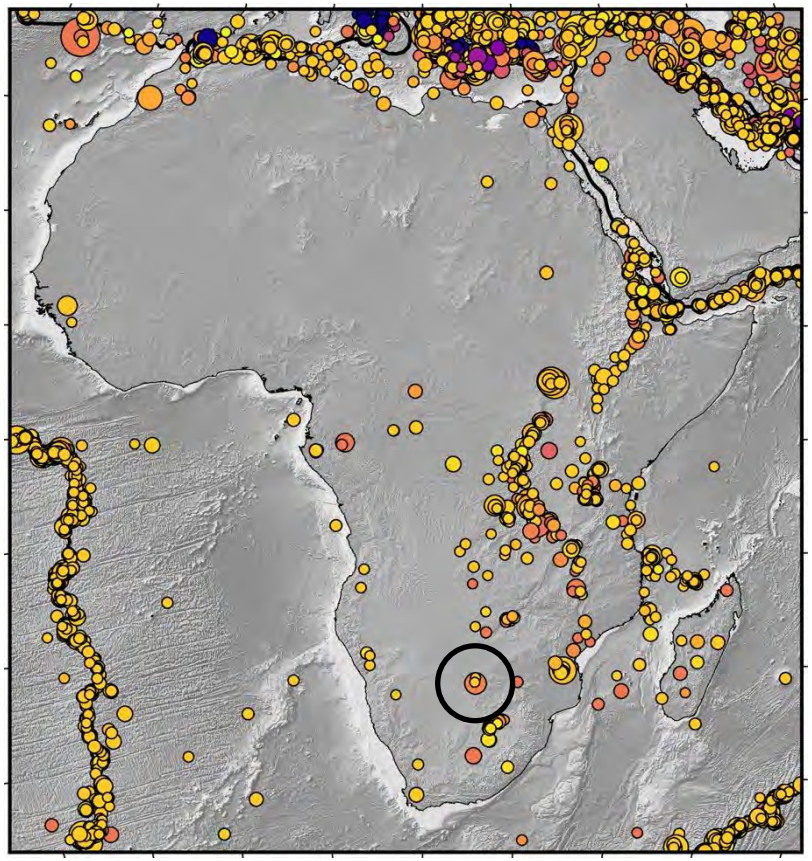


Paulssen et al. (2022)

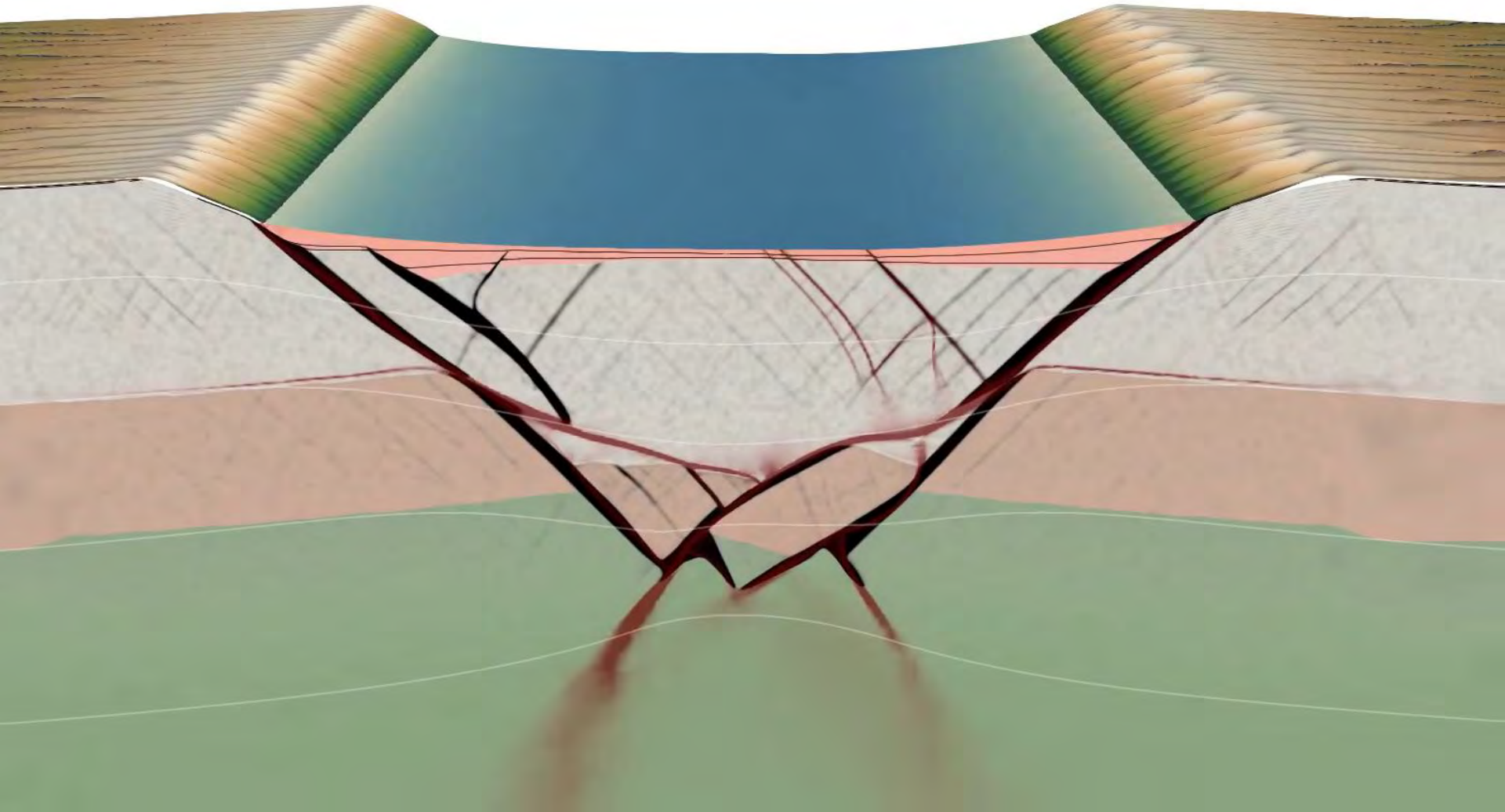


USGS Seismicity M5+ 1970-Present

Although the extension (and volcanoes) are most evident further north, earthquakes in Botswana suggest rifting might one day propagate further south!

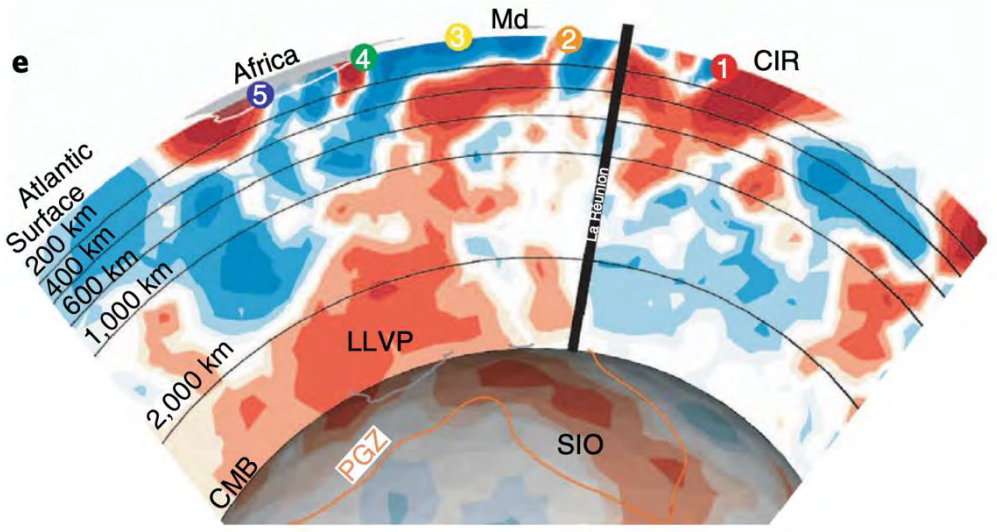
Geodynamic model by Neuharth et al. (2022)

Continental Breakup



Continental Breakup

What causes the breakup?



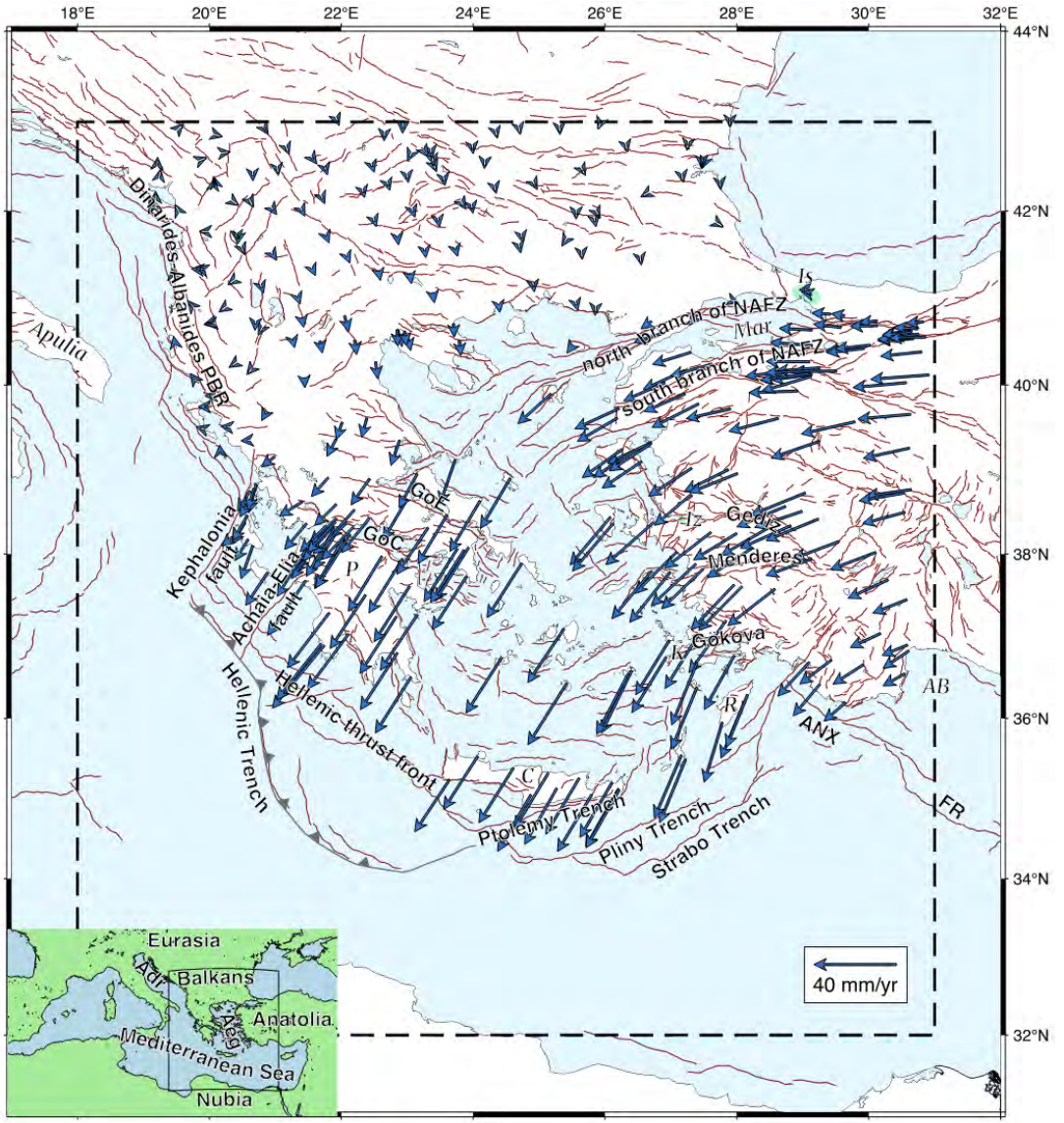
You might not be able to diagnose human relationships with CT scans, but we can use similar techniques with seismic waves to see a large mantle plume under East Africa

This is still an open scientific question!

Tsekhmistrenko et al. (2021)

Continental Breakup, version 2

Aegean Sea

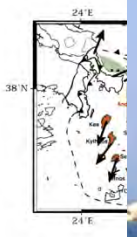


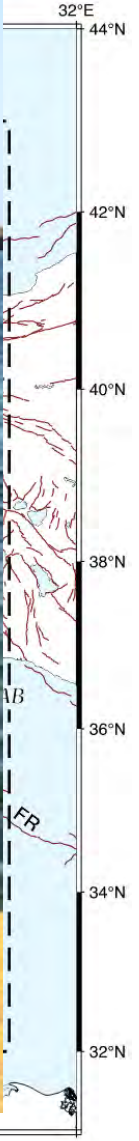
Govers et al. (2025)

Naxos, 2019
(My Honeymoon!)

My lovely wife, Kate, graciously allowed me to talk about Greek geology once per day. Until I corrected the leader of our wine tour on Santorini. Then I was muzzled.

Jolivet





Kotowski et al. (2022)

A "blueschist" is a former ocean rock that has gone down into a subduction zone

Blueschists from Syros, Greece

Lawsonite pseudomorphs (other metamorphic rocks) in Syros

Geology Field Trip 2007
(20 years ago!)

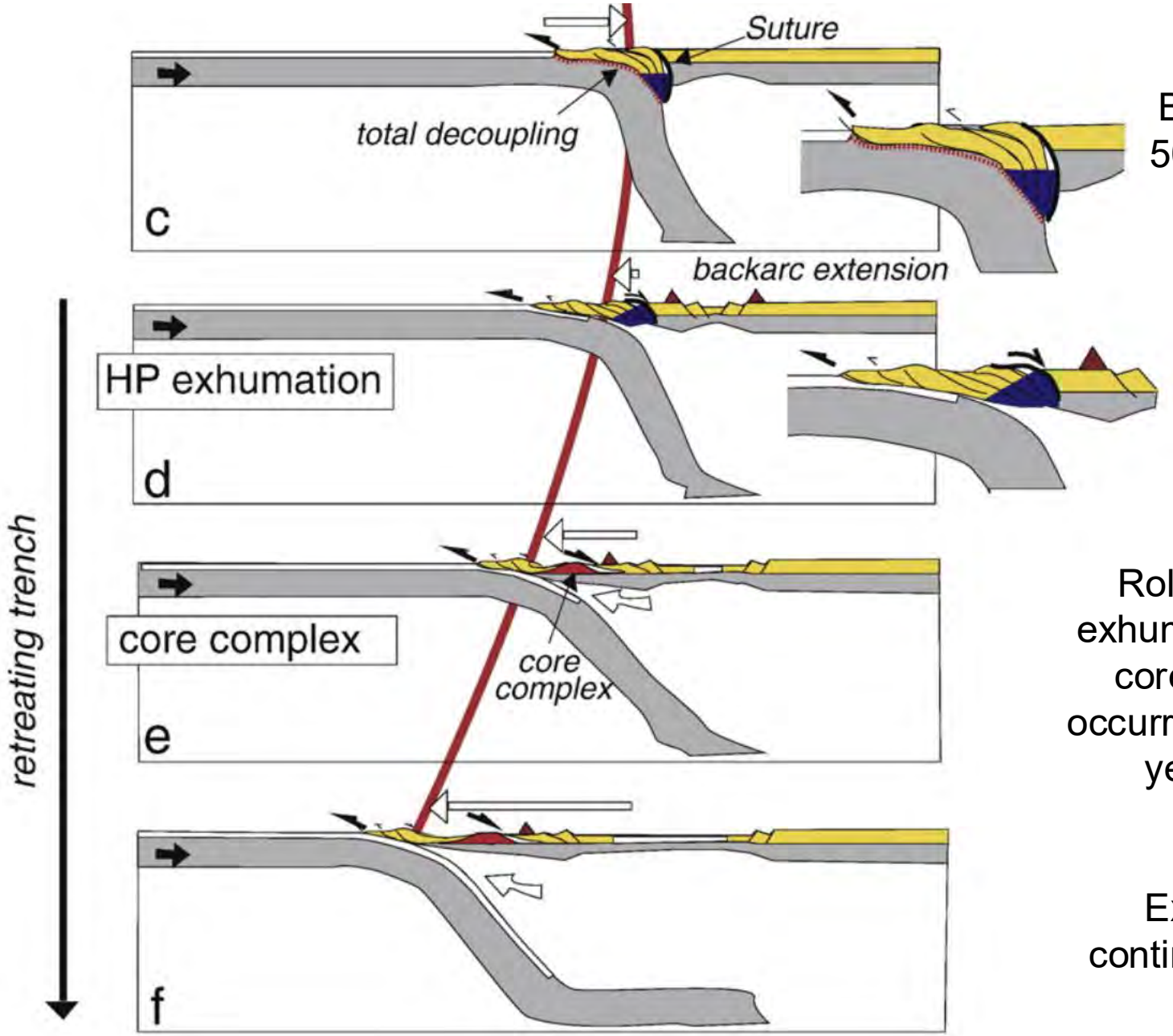
A "blueschist" is a former ocean rock that has gone down into a subduction zone

Blueschists from Syros, Greece

Continental Breakup, version 2

What causes the breakup?

Chen et al. (2015)



Blueschists formed 50 million years ago during active subduction

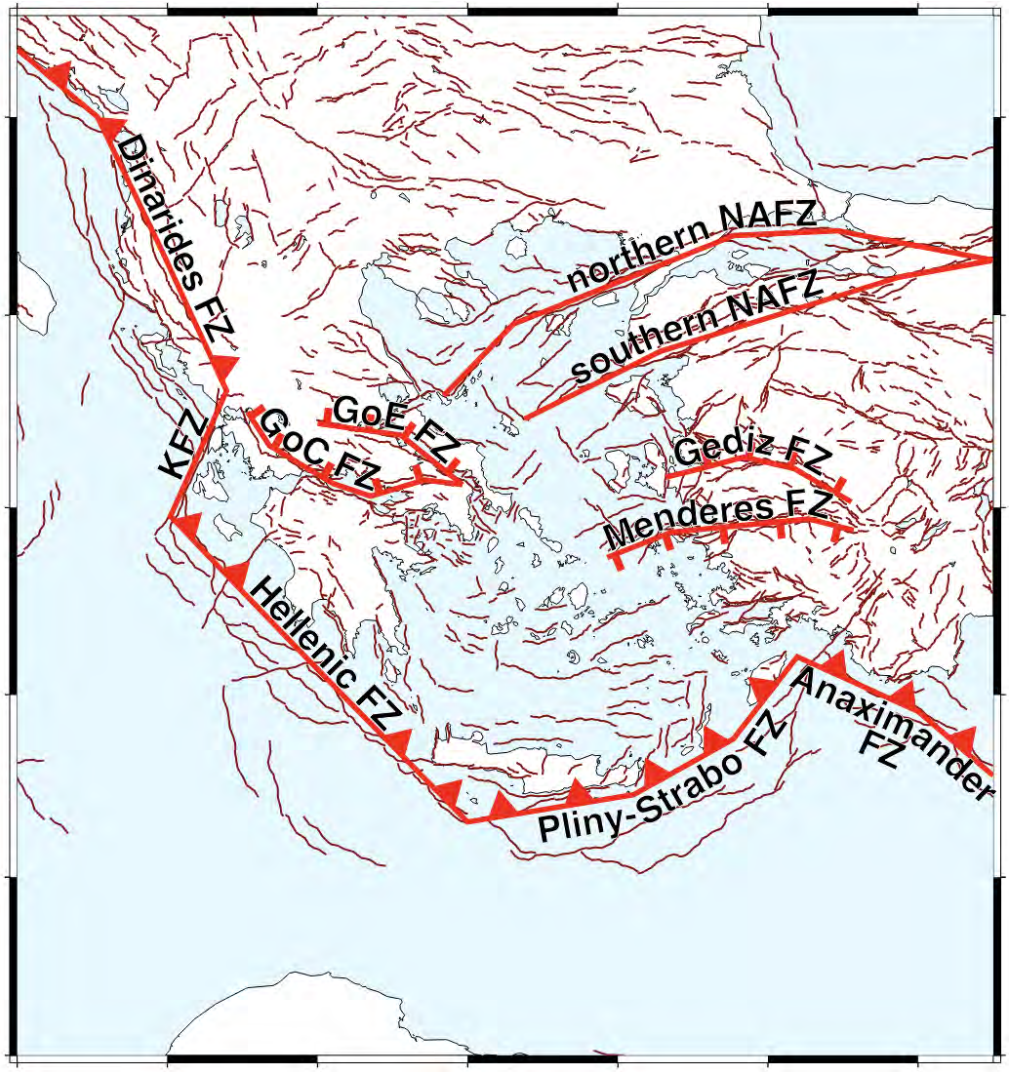
Rollback and exhumation in the core complex occurred 20 million years ago

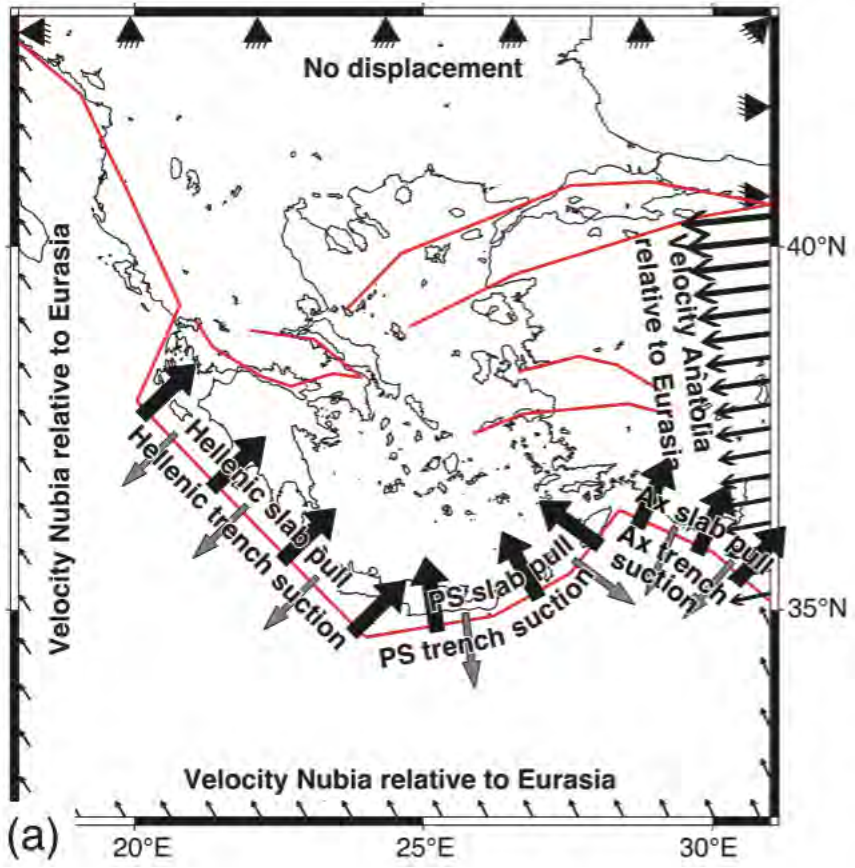
Extension continues today!

Brun and Faccenna (2008)

Continental Breakup, version 2

What causes the breakup?



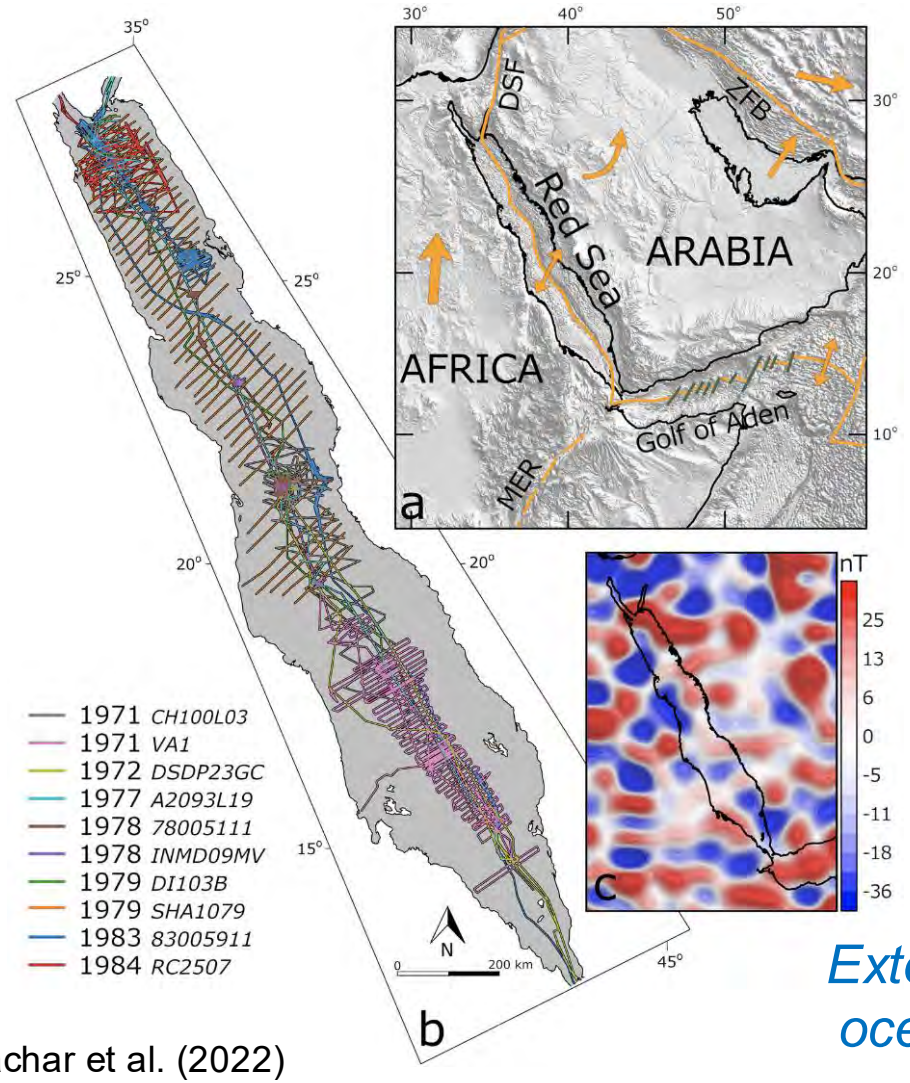


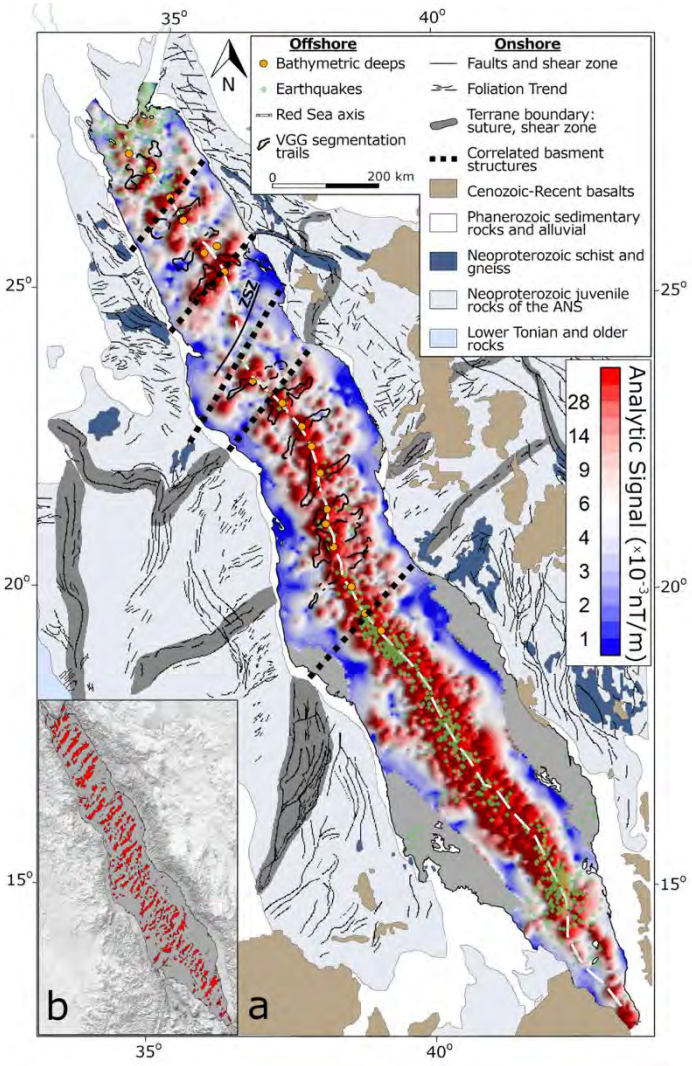
Models require slab rollback to be a major force!

Govers et al. (2025)

Continental Breakup, The End

The formation of new ocean marks the end of continental breakup



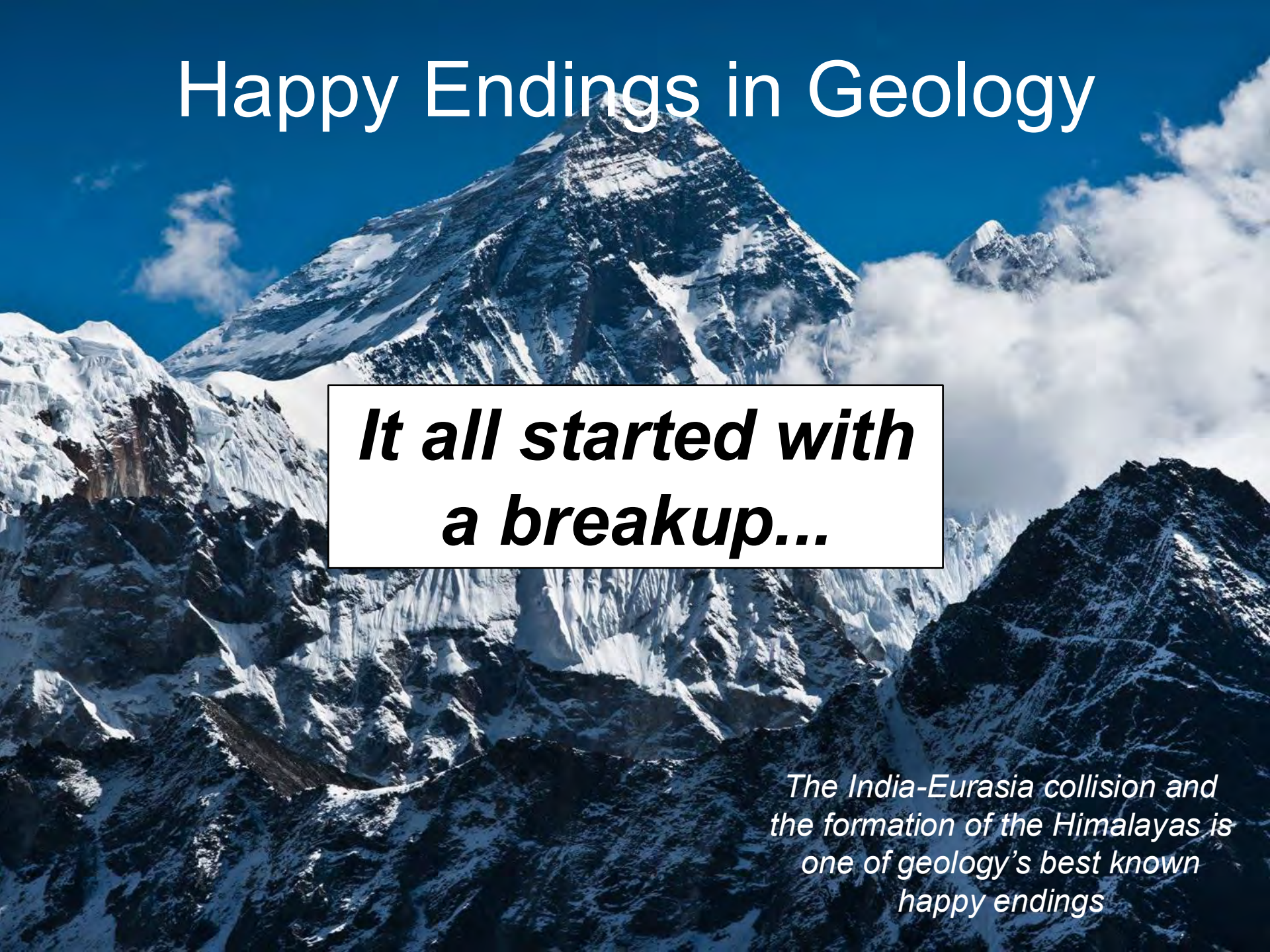


Extension collapses onto the weak mid-ocean ridge and the plates drift apart...

Issachar et al. (2022)

Happy Ending

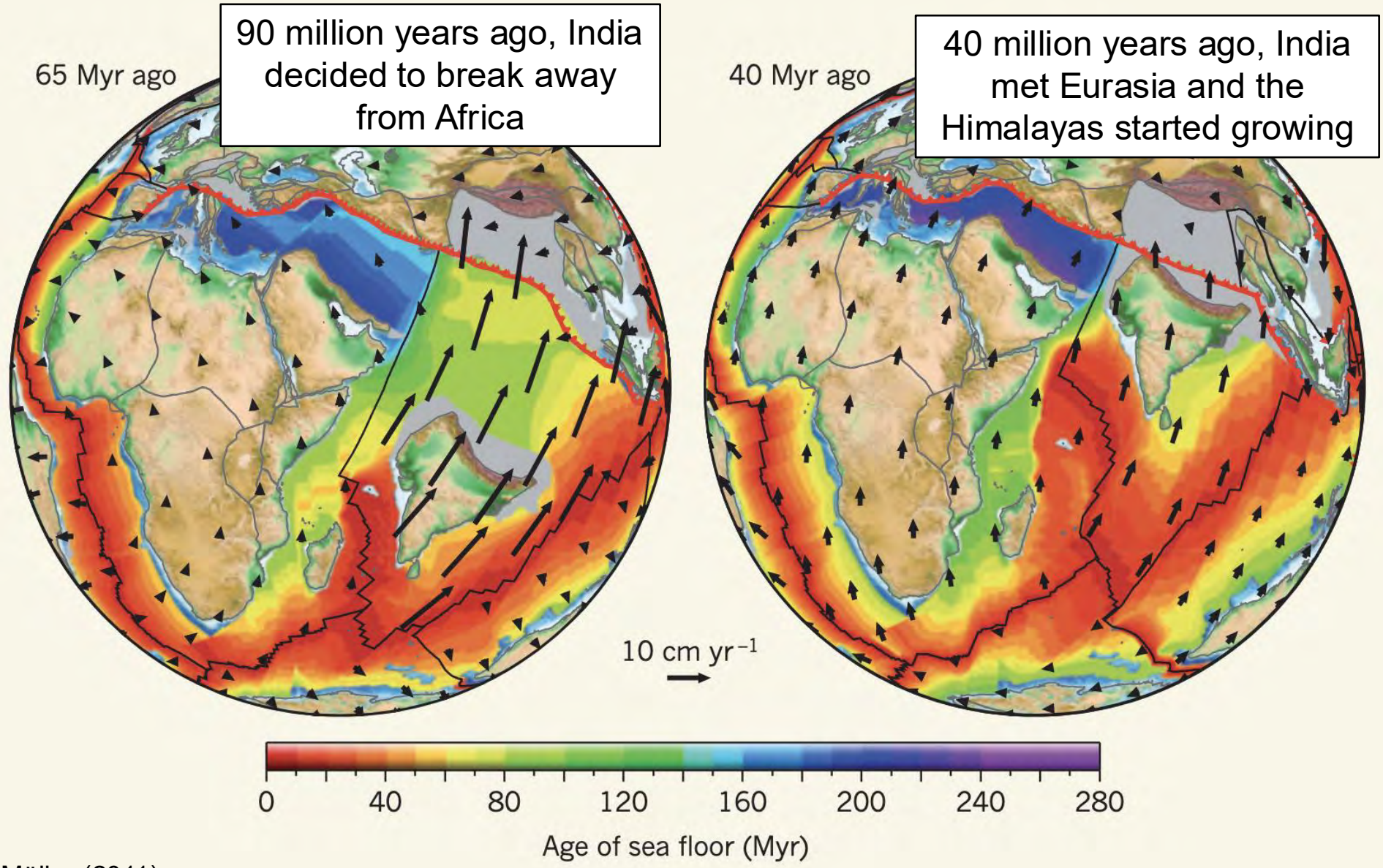
Happy Endings in Geology



It all started with a breakup...

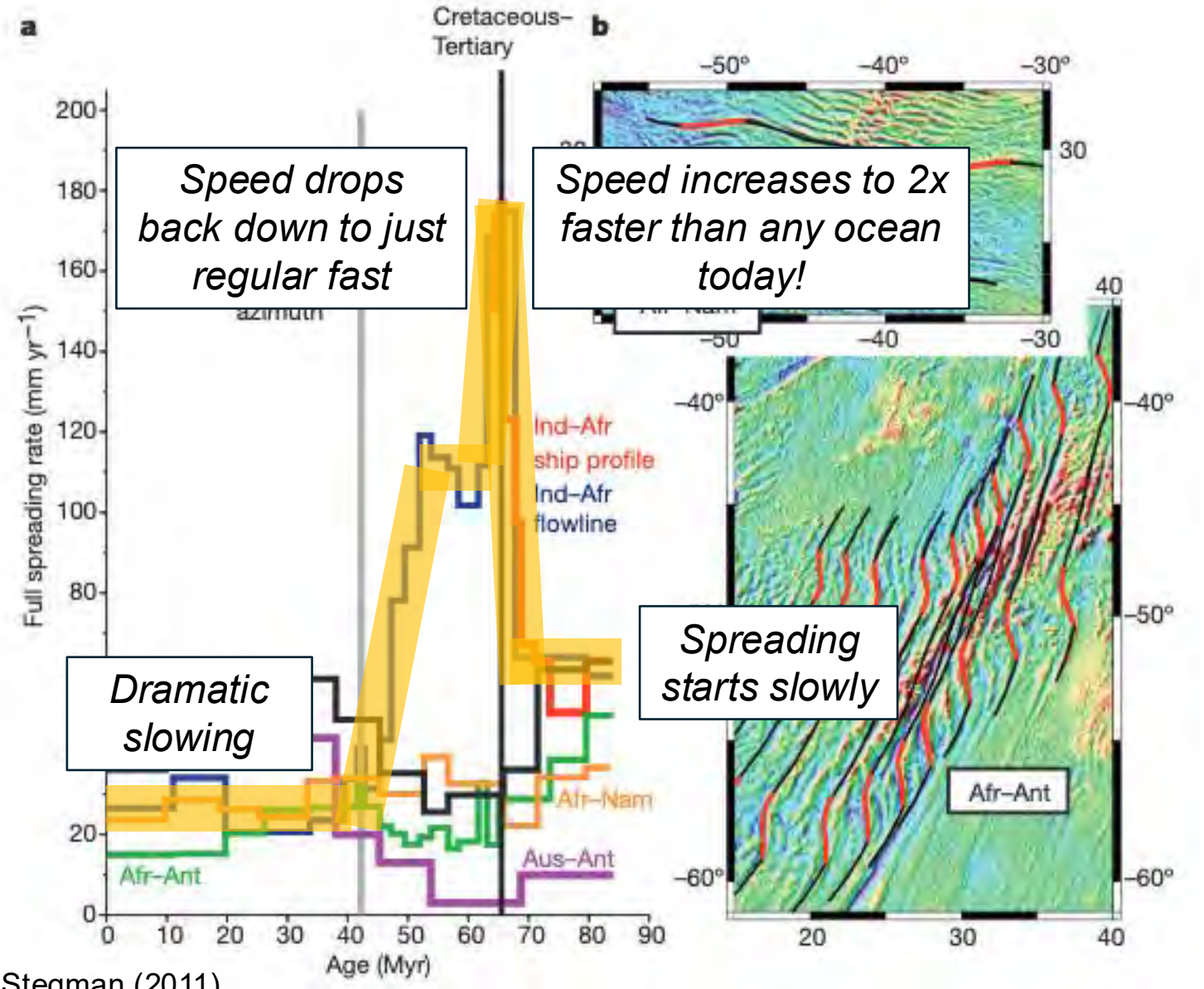
The India-Eurasia collision and the formation of the Himalayas is one of geology's best known happy endings

Happy Endings in Geology



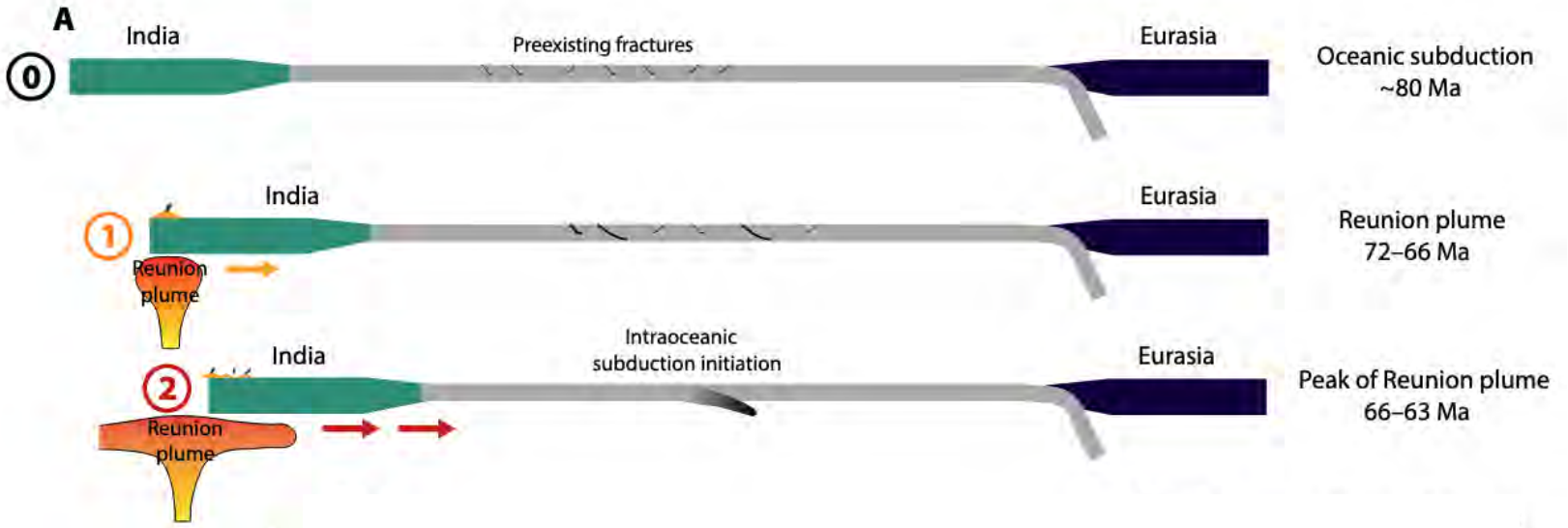
Müller (2011)

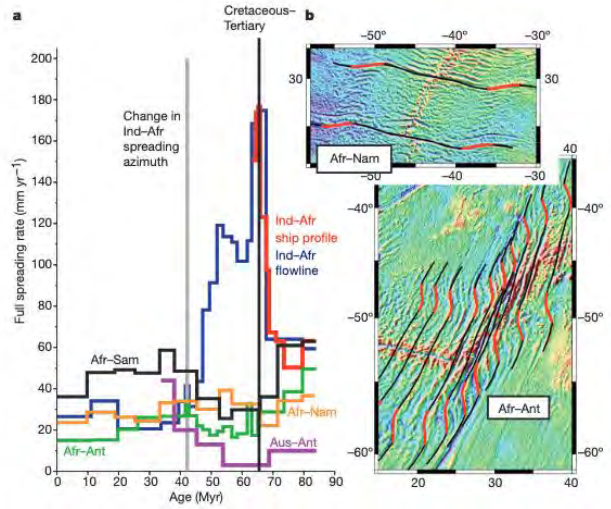
Happy Endings in Geology



Cande and Stegman (2011)

Happy Endings in Geology





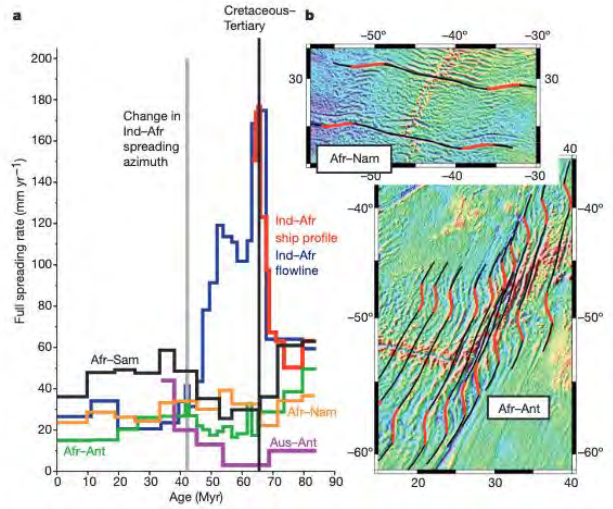
India received a "kick in the pants" from the Reunion plume, causing it to move away from Africa at almost 200 mm/yr!

Cande and Stegman (2011)

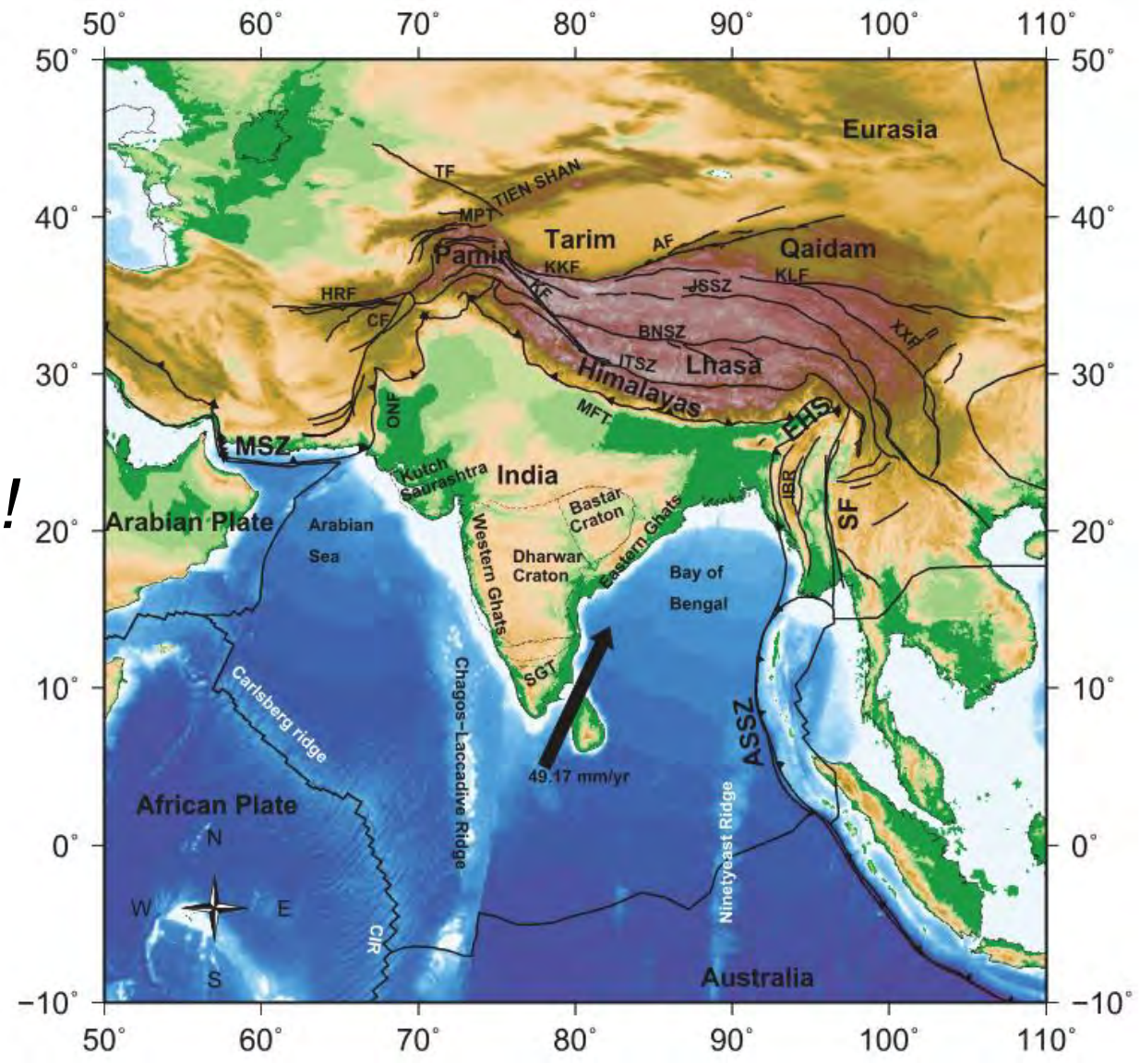
Pusok and Stegman (2020)

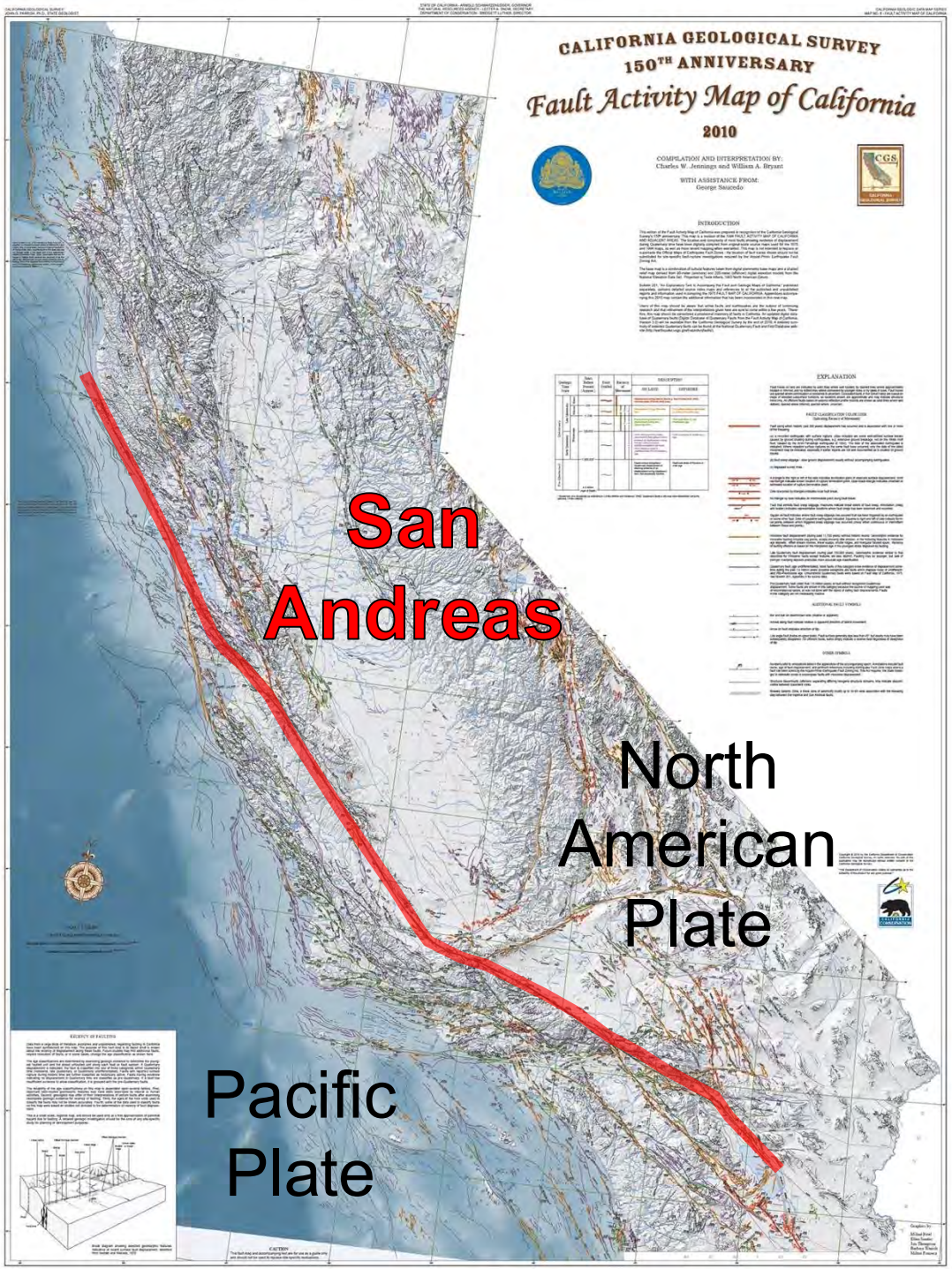
Happy Endings in Geology

India "met" Eurasia 40 million years ago, rearranging plates around the world and building the Tibetan Plateau!



Cande and Stegman (2011)





Happy Endings in California

All of California's resources, climate, and landscapes owe themselves to these tectonic processes

Happy ≠ Safe! We have lots of natural hazards!

The story does not end here! The Pacific still moves at 50 mm/yr northwest past North America. In 10 million years, Los Angeles and San Francisco can celebrate their new supercity! (In Bakersfield, we will wave at Los Angeles as it passes by.)