California's Geological Framework & Consequent Fault-System Behavior

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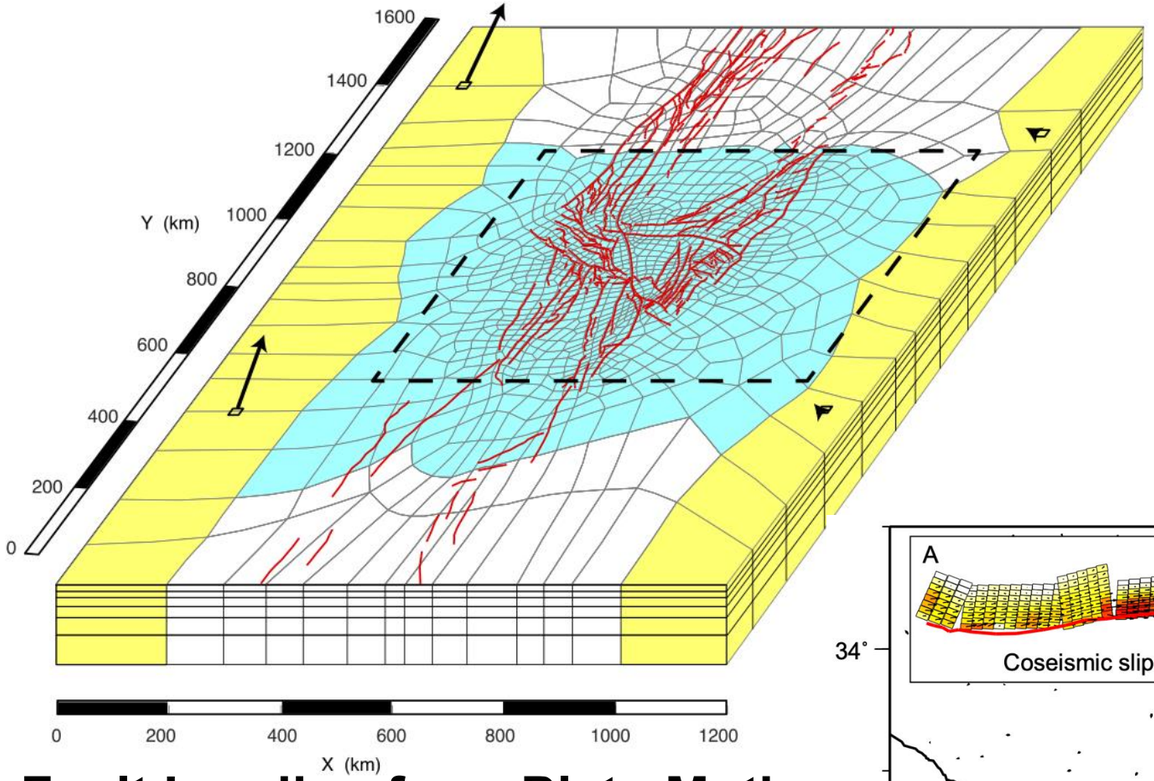
with contributions from:

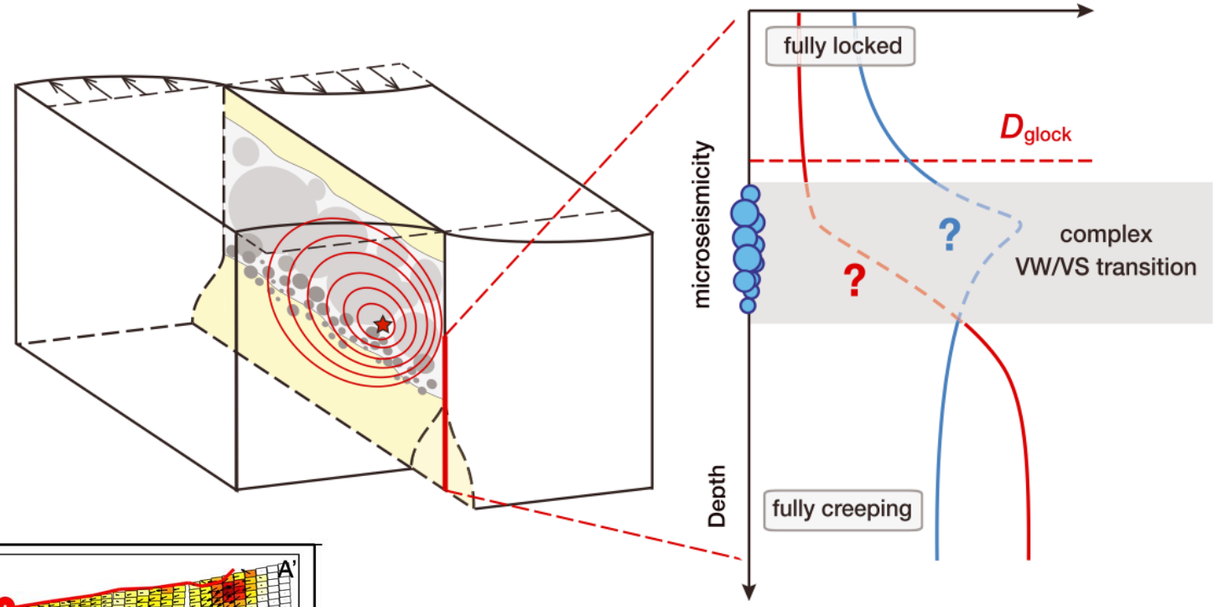
Sierra Rack, Ryan Lynch, Mark Legg, Laurent Montesi & Alex Morelan

Allosaurus (155-145 Myr)
Credit: Fred Wierum (CC)

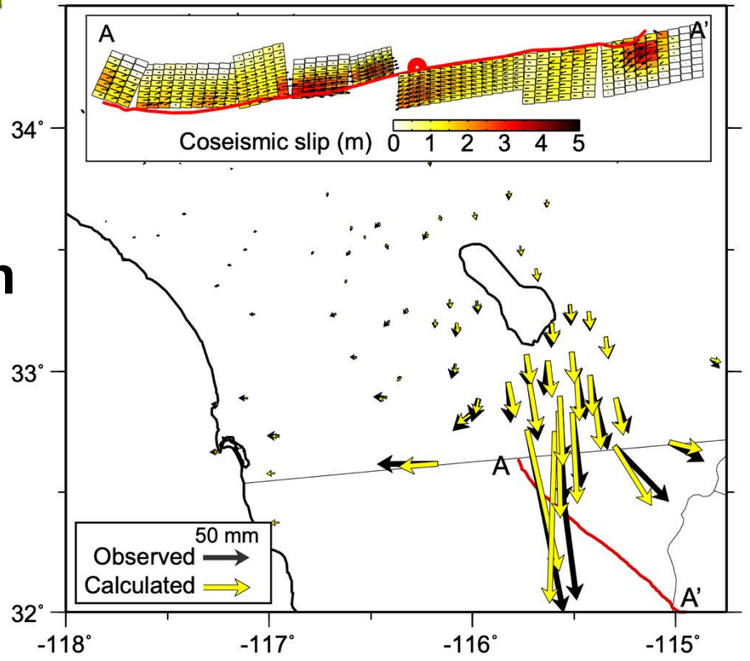
Realistic Rheology is Heterogeneous



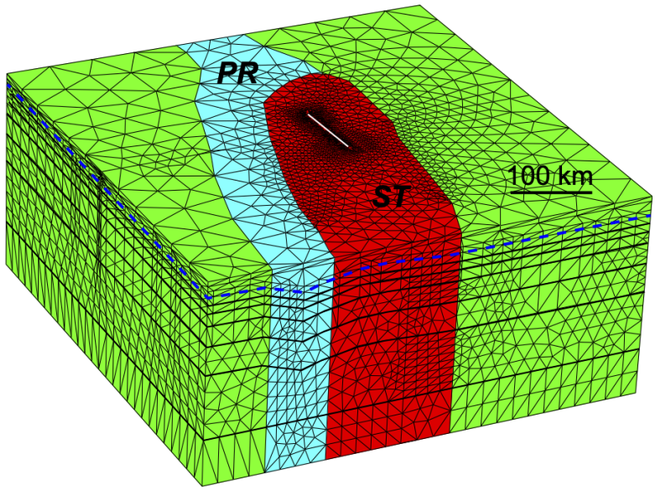
Fault Loading from Plate Motion
Hearn (2019)



Fault Friction Jiang & Fialko (2016)

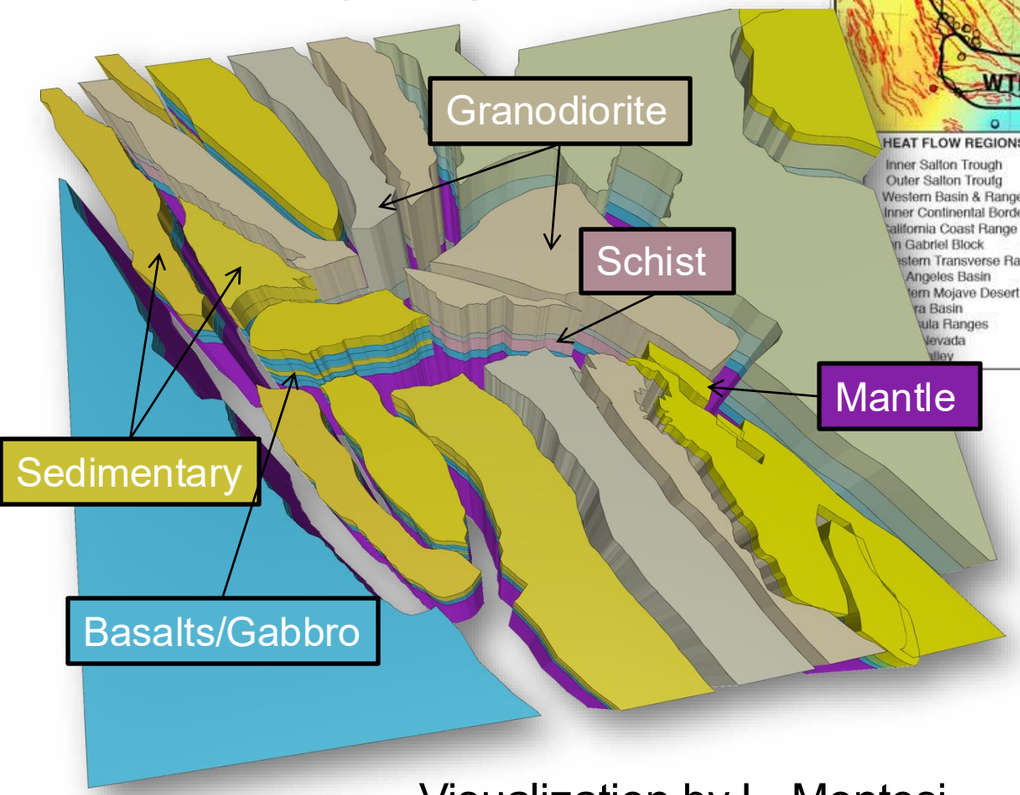


Post-Seismic Deformation
Dickinson-Lovell et al. (2018)

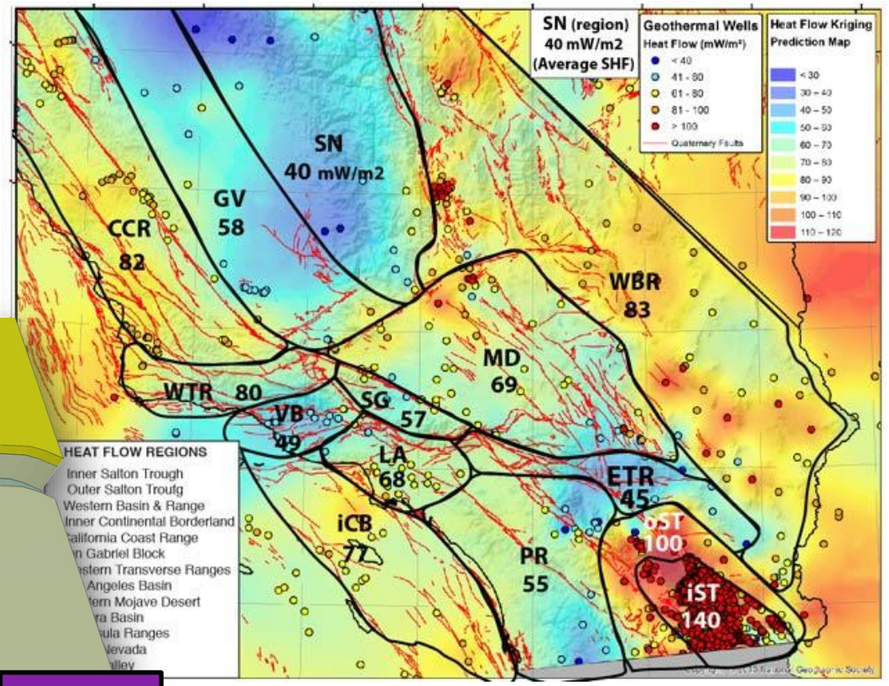


SCEC Community Rheology Model (CRM)

Geologic Framework Model (GFM)

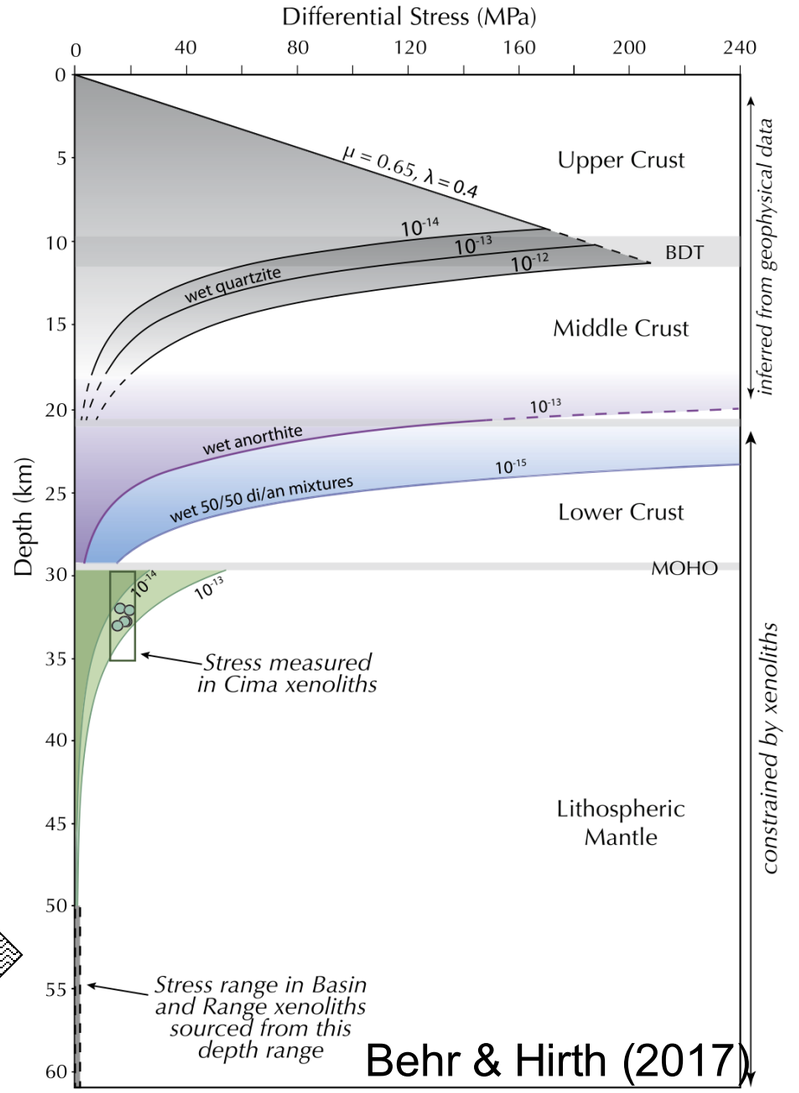


Visualization by L. Montesi



Community Thermal Model (CTM) Thatcher & Chapman

Shear Zone Model? (SZM?)



Constitutive Relationships

Assembling the SCEC geologic framework model

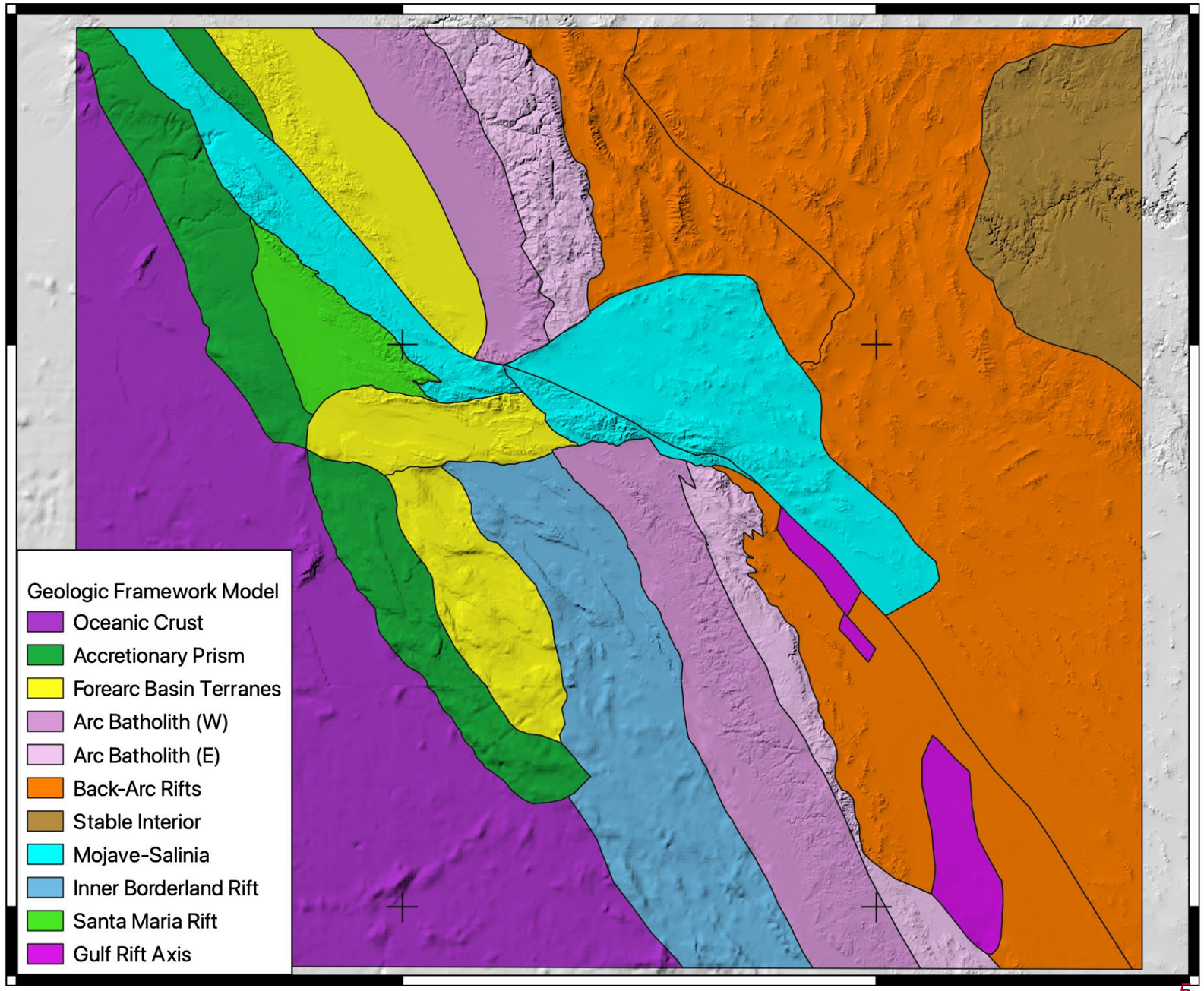
- **GOAL: Lithologic information sufficient to assign constitutive relationships to the lithosphere across California & adjacent areas**

- **Constructed through integration of diverse data sets:**
  - **Surface geology, well control, and cross-sections**
  - **Seismic imaging and potential fields**
- **Surface geology provides an incomplete picture of 3D lithology**
  - **Deep crust composition and structure seldom revealed.**
  - **Mantle information largely indirect except for xenoliths.**
- **Much must be inferred from tectonic history and map relationships**

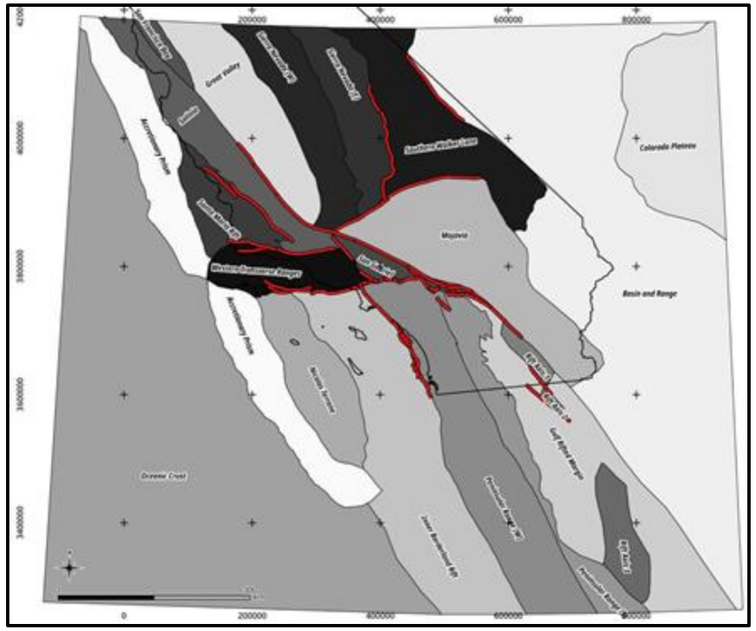
SCEC Geologic Framework Model (Southern California)

- **Lithotectonic blocks defined by lithology & tectonic history**
- **Vertical boundaries between blocks***
- **Uniform* layered lithology within each block**

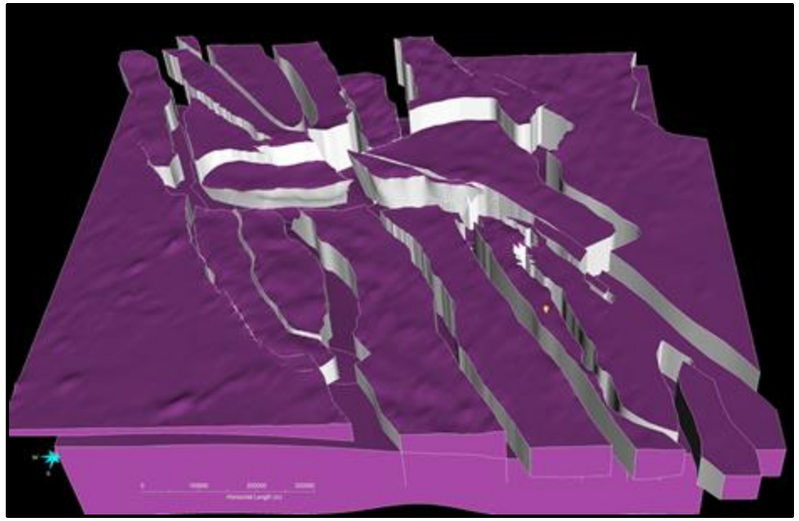
*** Improvements in progress**



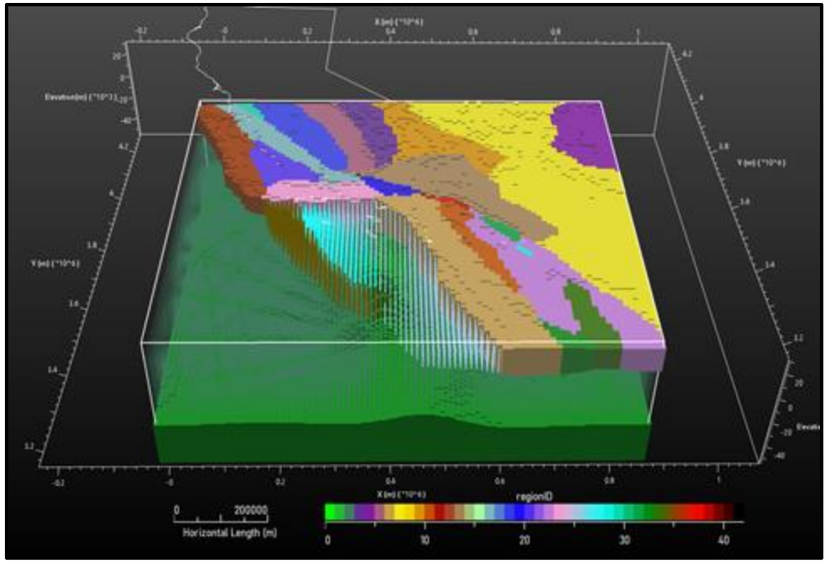
Model Improvement: Incorporating 3D Geologic information



GFM (Map)



GFM (Volumes)

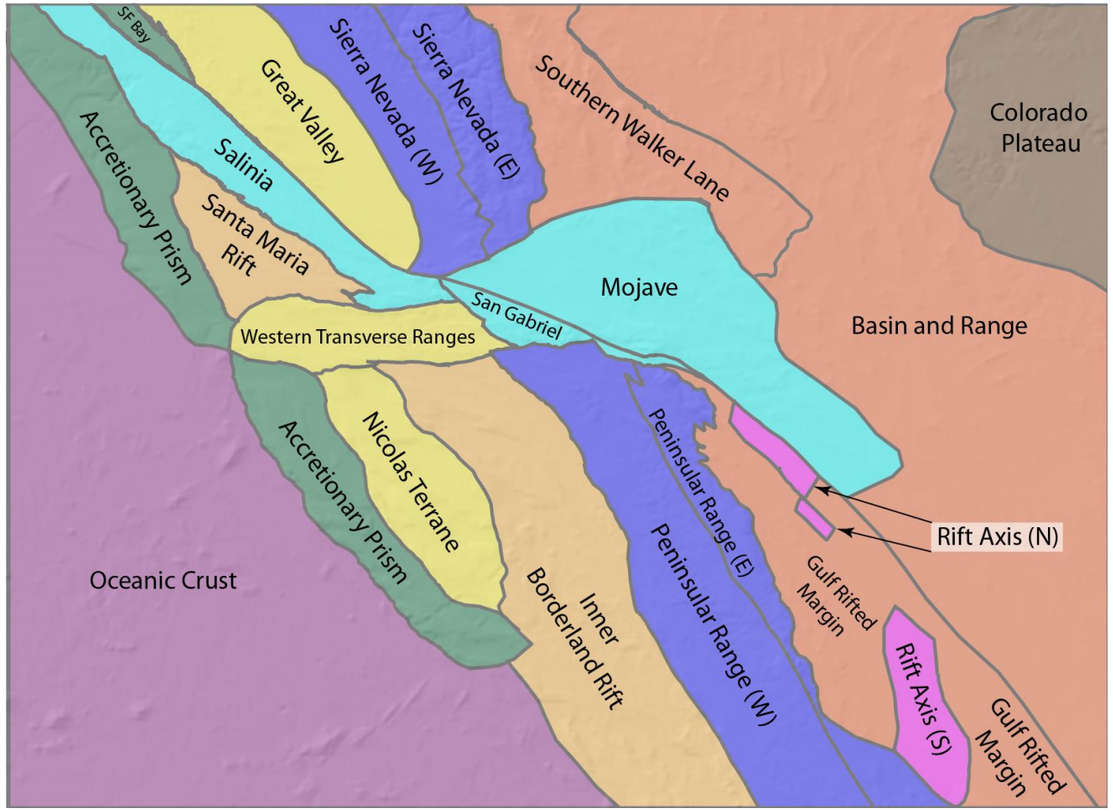


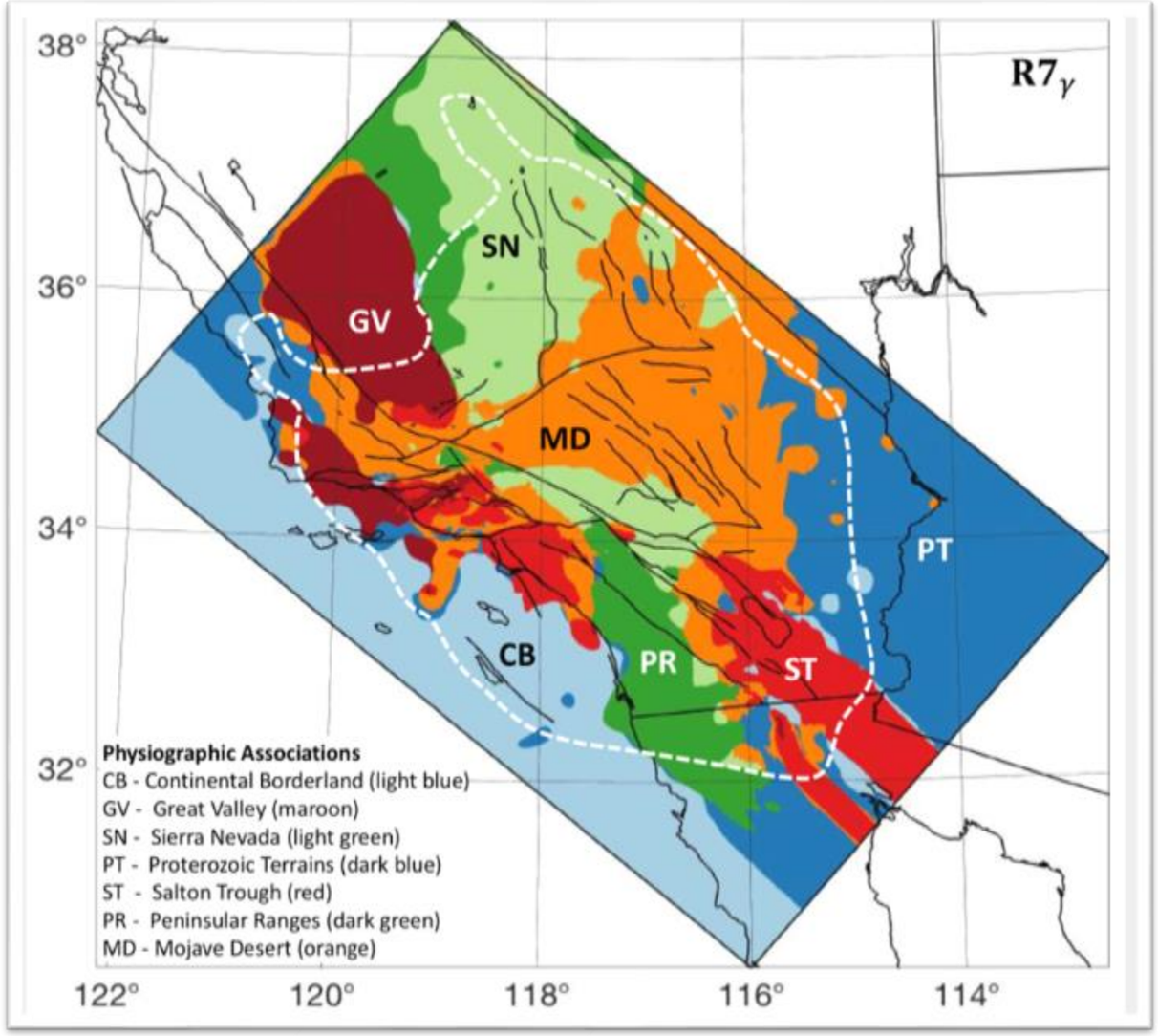
GFM v.1.0 grid

Plesch & Montesi (2025 GFM workshop)

& poster #339 by Montesi, Plesch & Shaw

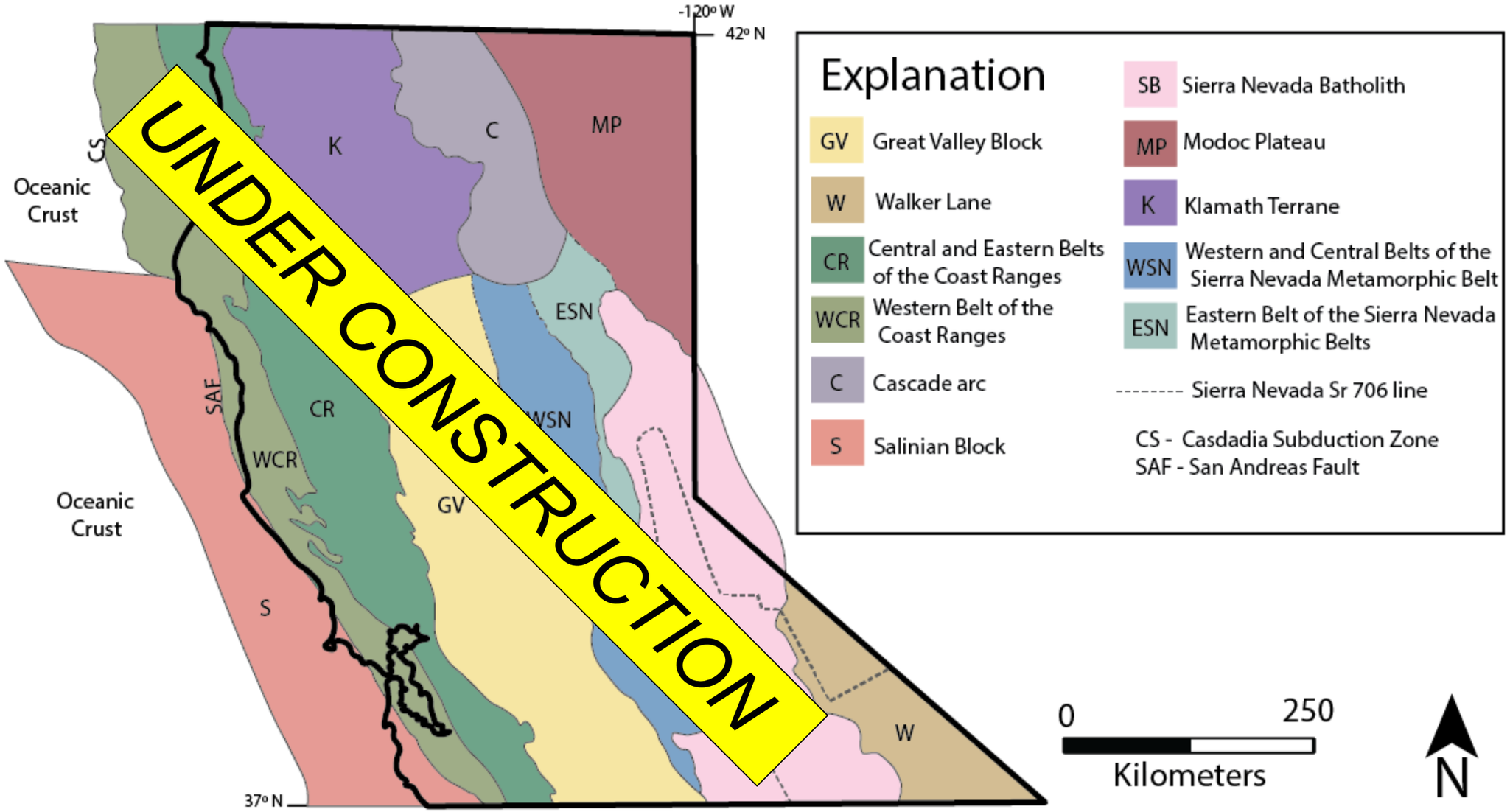
Model Validation: Comparison with Seismic Tomography





K-Means Regionalization, Eymold & Jordan (2018)

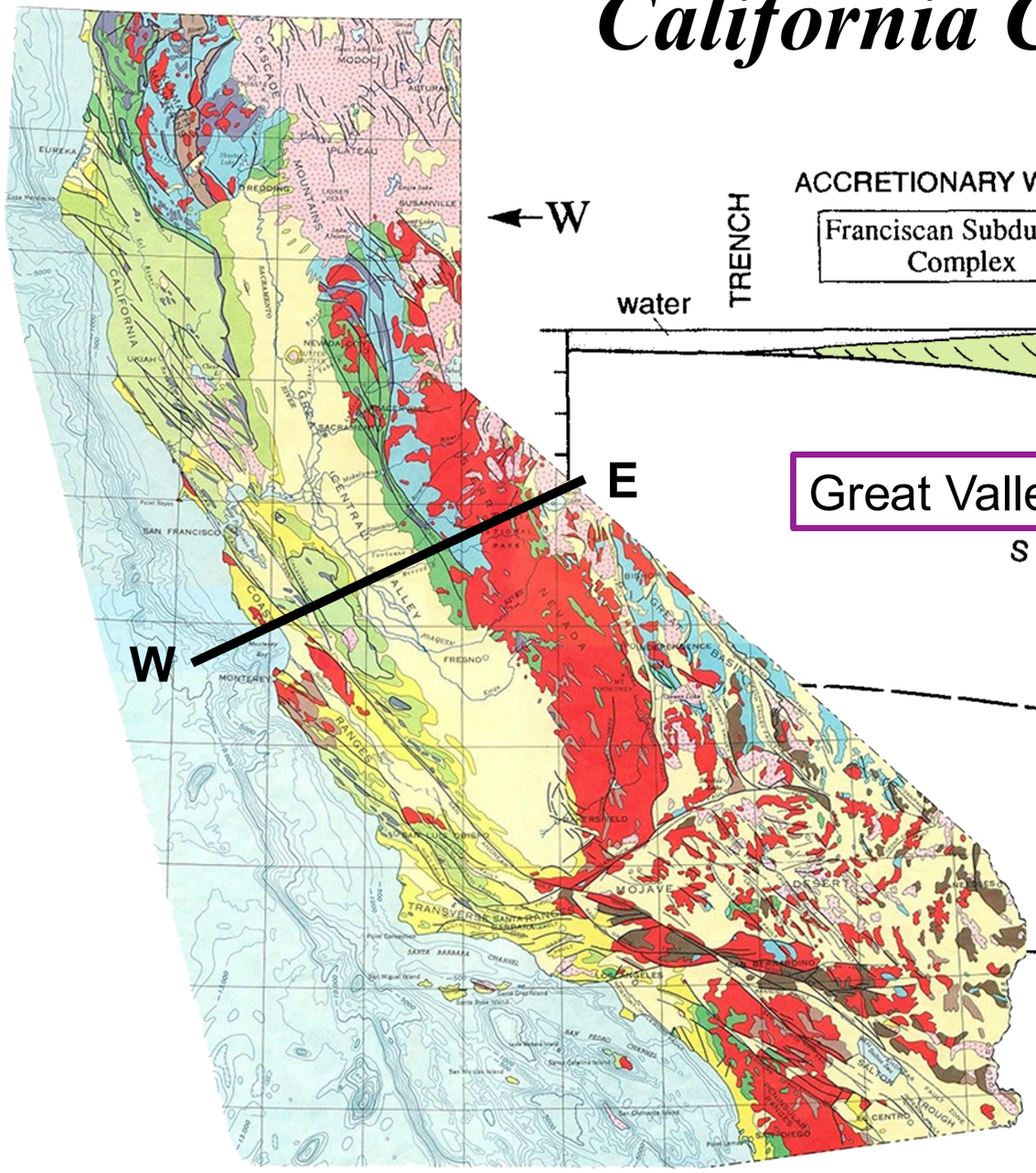
Model Expansion: Northern California

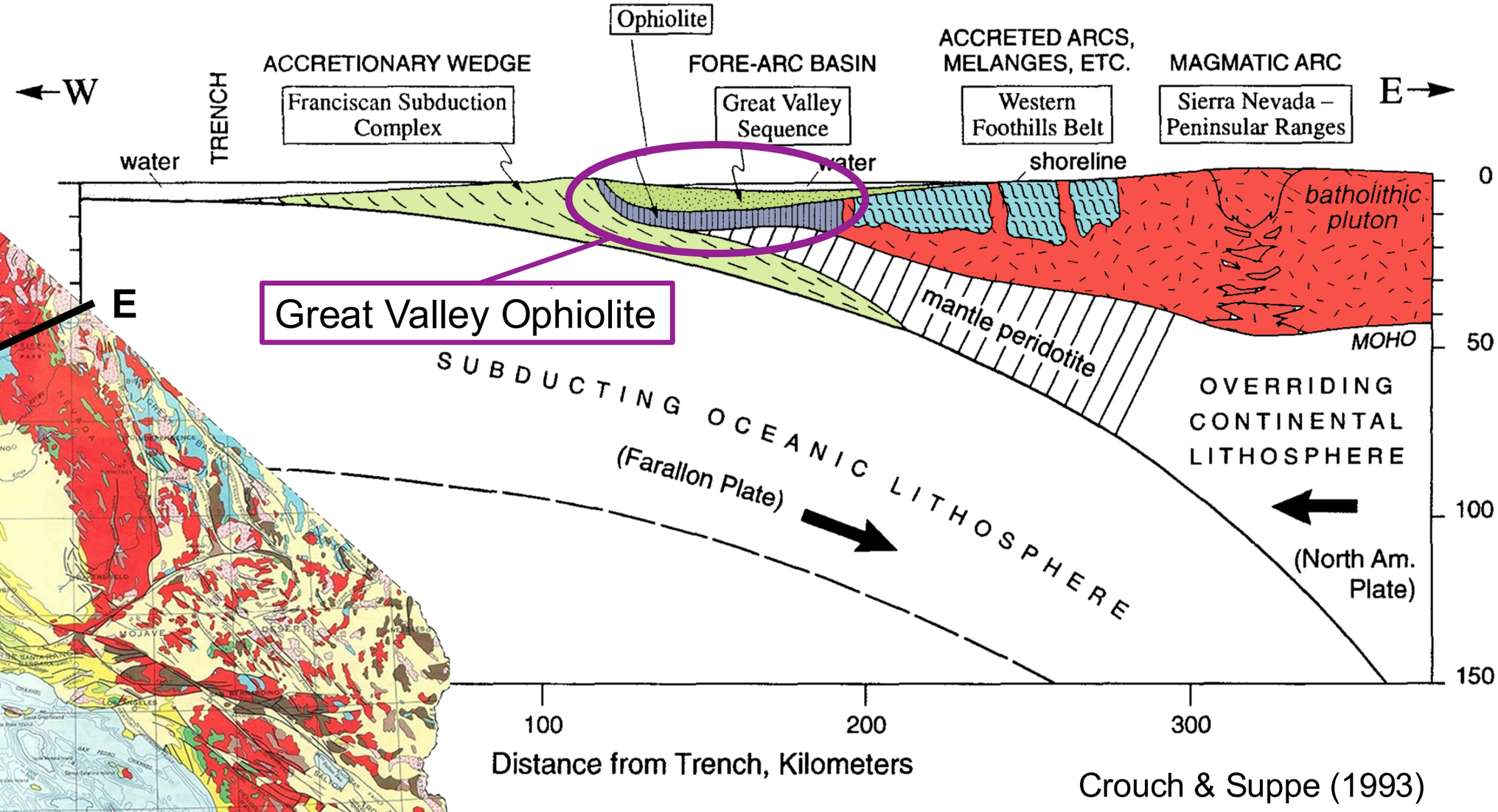


Outline & Conclusions

- **Conclusion #1: Four key events disrupted the California convergent margin and introduced heterogeneities that affect faulting today:**
  1. Formation of the Great Valley ophiolite (~165 Ma)
  2. Underplating & trenchward migration of Klamath terrane (~135 Ma)
  3. Underplating & trenchward migration of Mojave-Salinia terrane (~70 Ma)
  4. Formation of the Pioneer triple junction (~30 Ma)
- **Conclusion #2: Transform faulting localized primarily within three weak components of former convergent margin:**
  1. Accretionary wedge
  2. Ancestral Cascades arc & back-arc
  3. Inherited zones of underplating
- **Conclusion #3: Mafic crust is strong, but also promotes fault creep**
- **Conclusion #4: Geological heterogeneity = Nature's experiment**

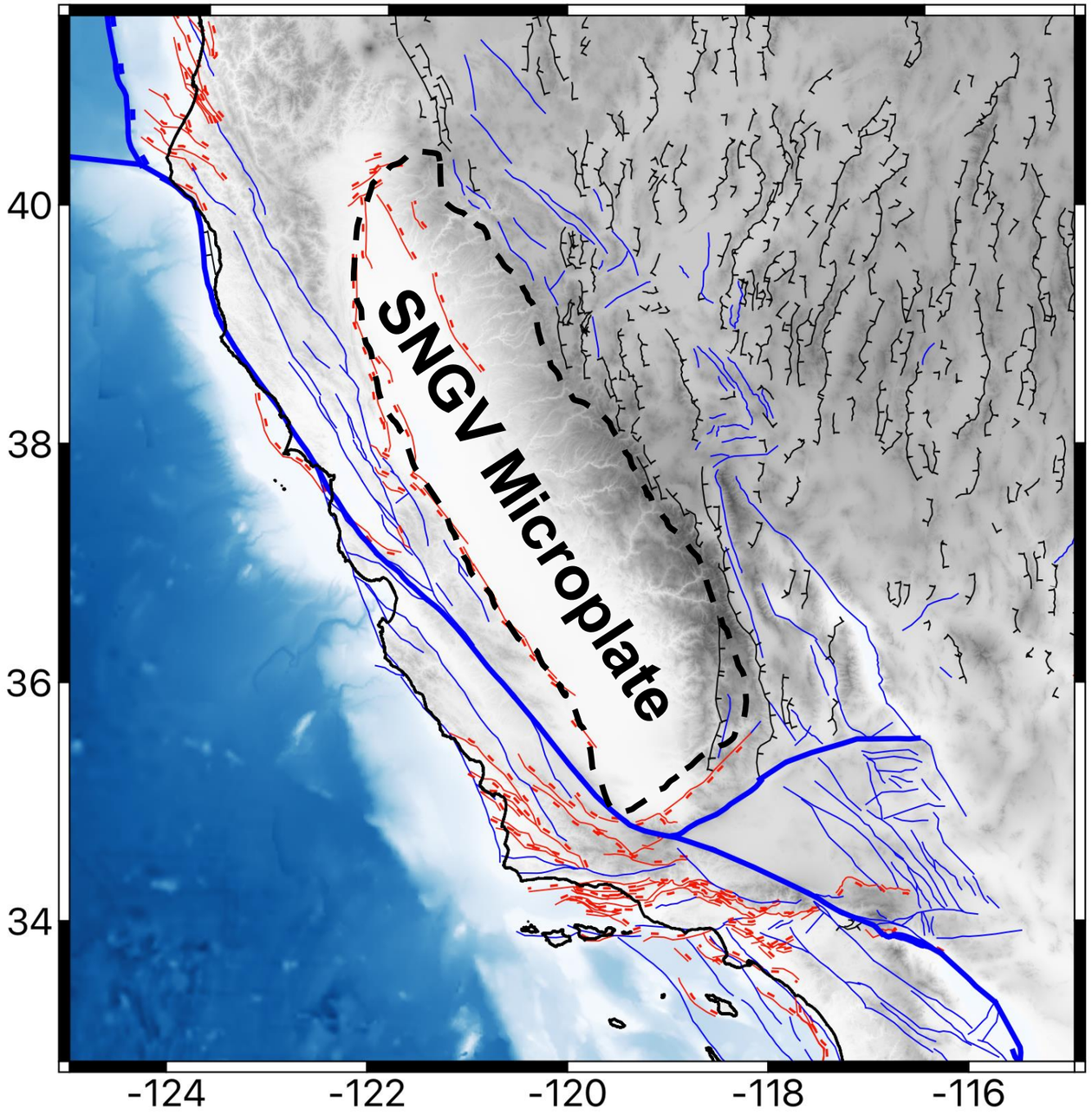
California Convergent Margin





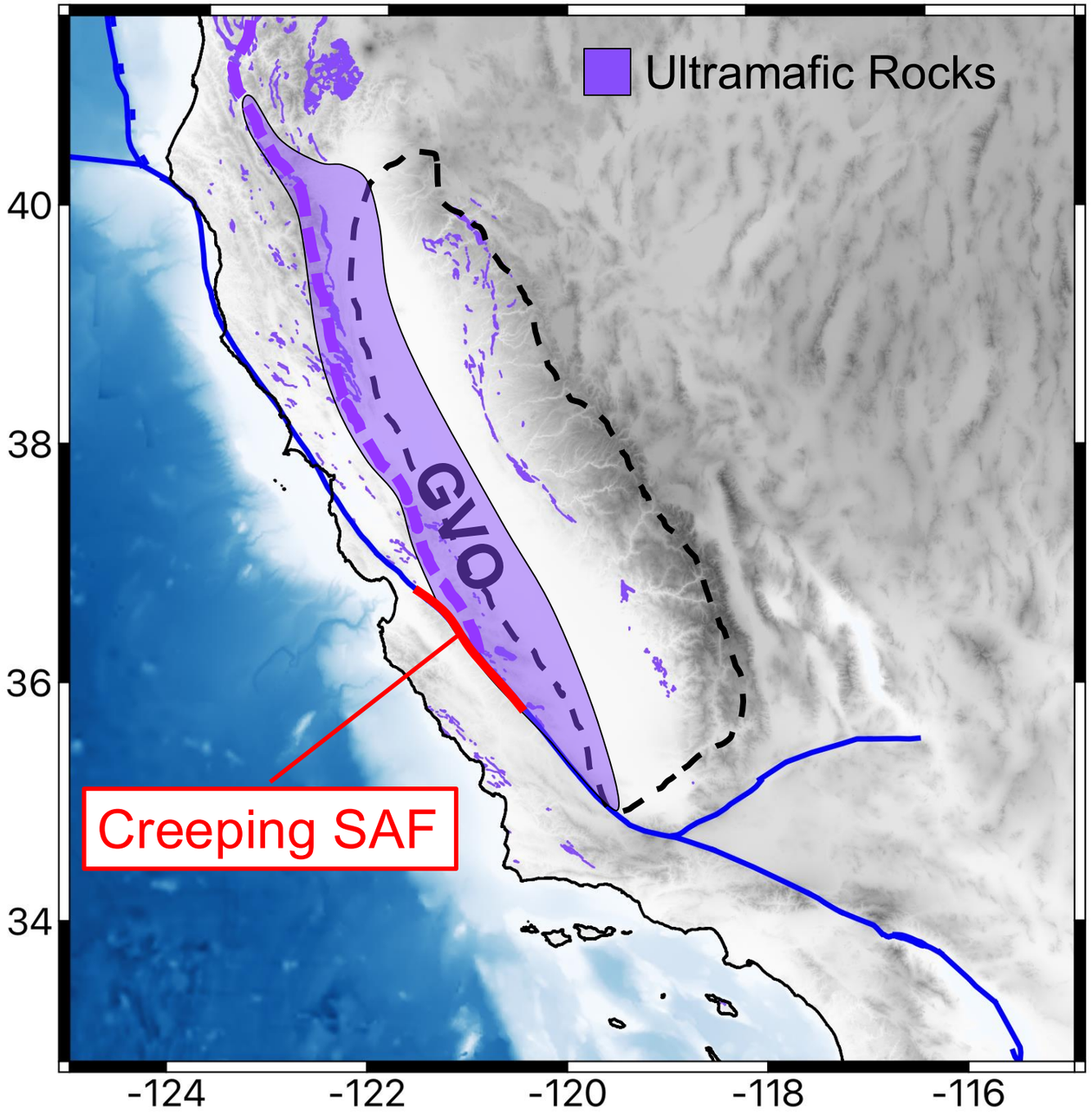
Crouch & Suppe (1993)

Sierra Nevada - Great Valley Microplate



- **SNGV block defines a microplate embedded within the transform plate boundary.**
- **SNGV separates Walker Lane Belt from San Andreas fault.**

Fault map from USGS NSHM (Hatem et al., 2023)



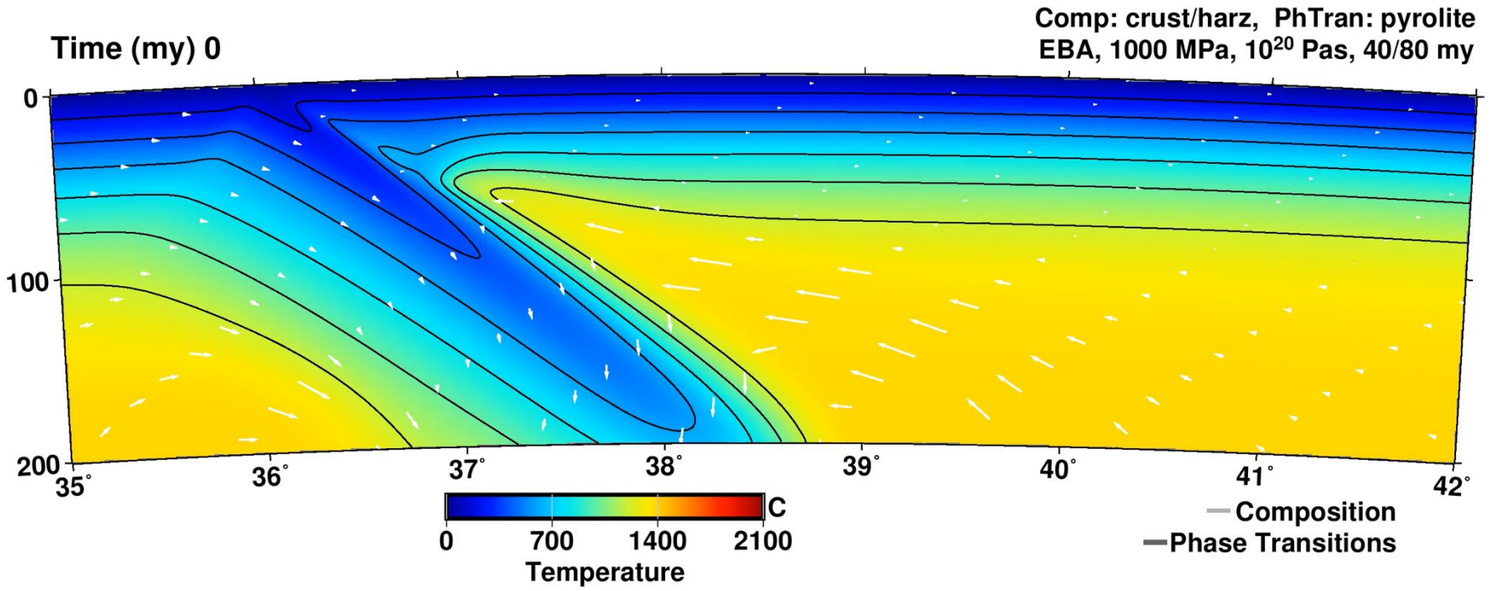
Ophiolitic Rocks in California

- **'Ophiolite' = Oceanic crust and/or upper mantle rocks**
- **Great Valley Ophiolite underlies western SNGV microplate (strong mafic lower crust…)**
- **Great Valley Ophiolite adjacent to Central & Creeping San Andreas (…but weak faults)**

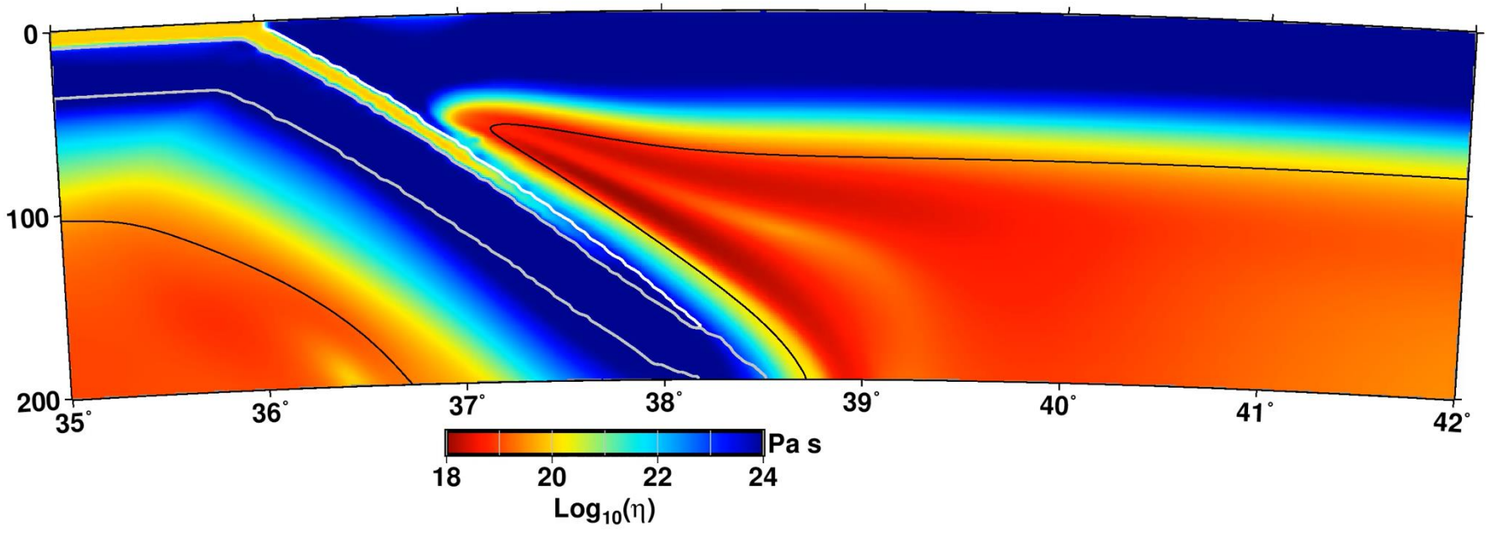
Geology from USGS Cooperative National Geologic Map (Colgan et al., 2025)

Event #1: Formation of Great Valley Ophiolite ~165 Myr

Temperature



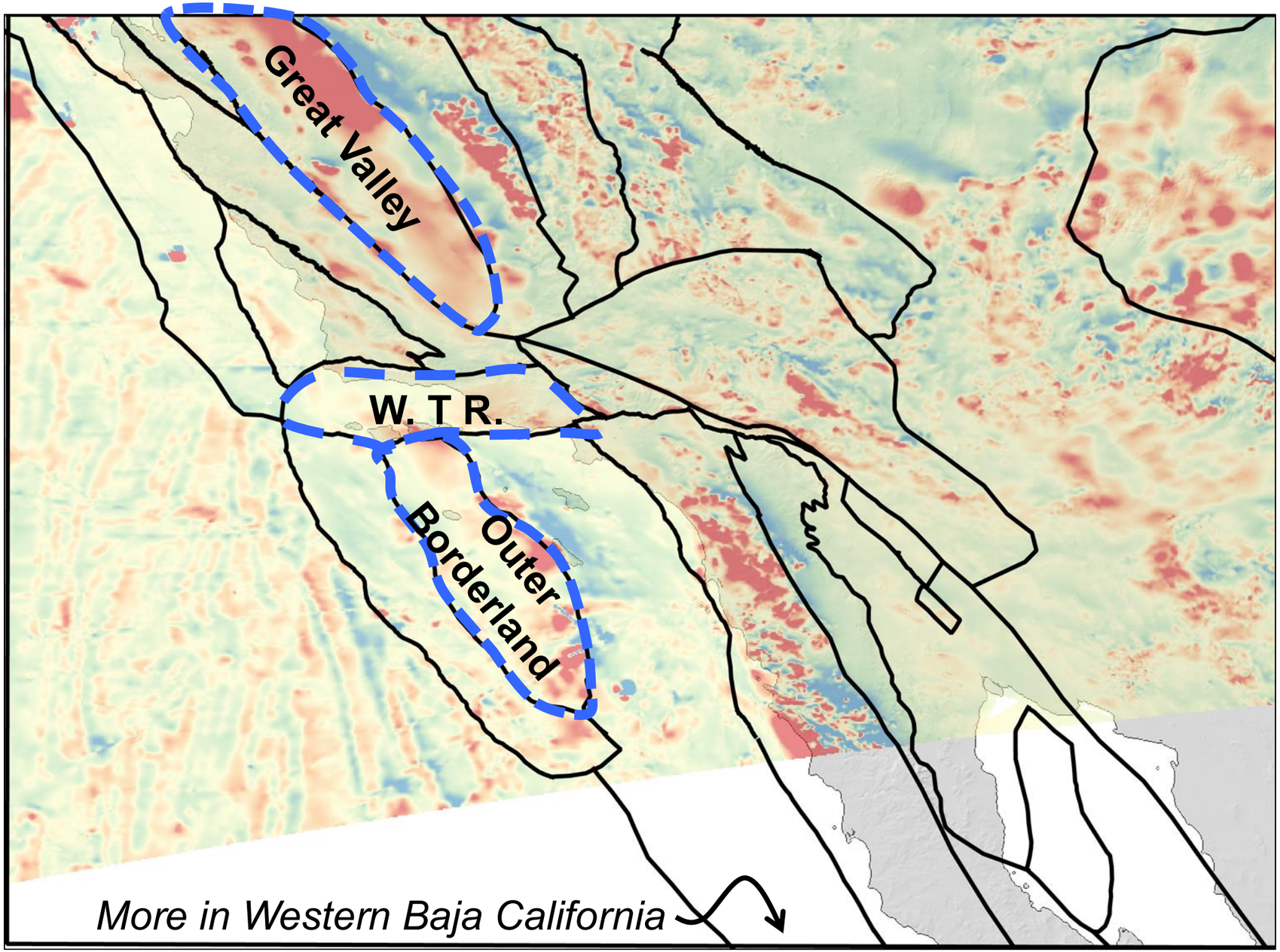
Viscosity

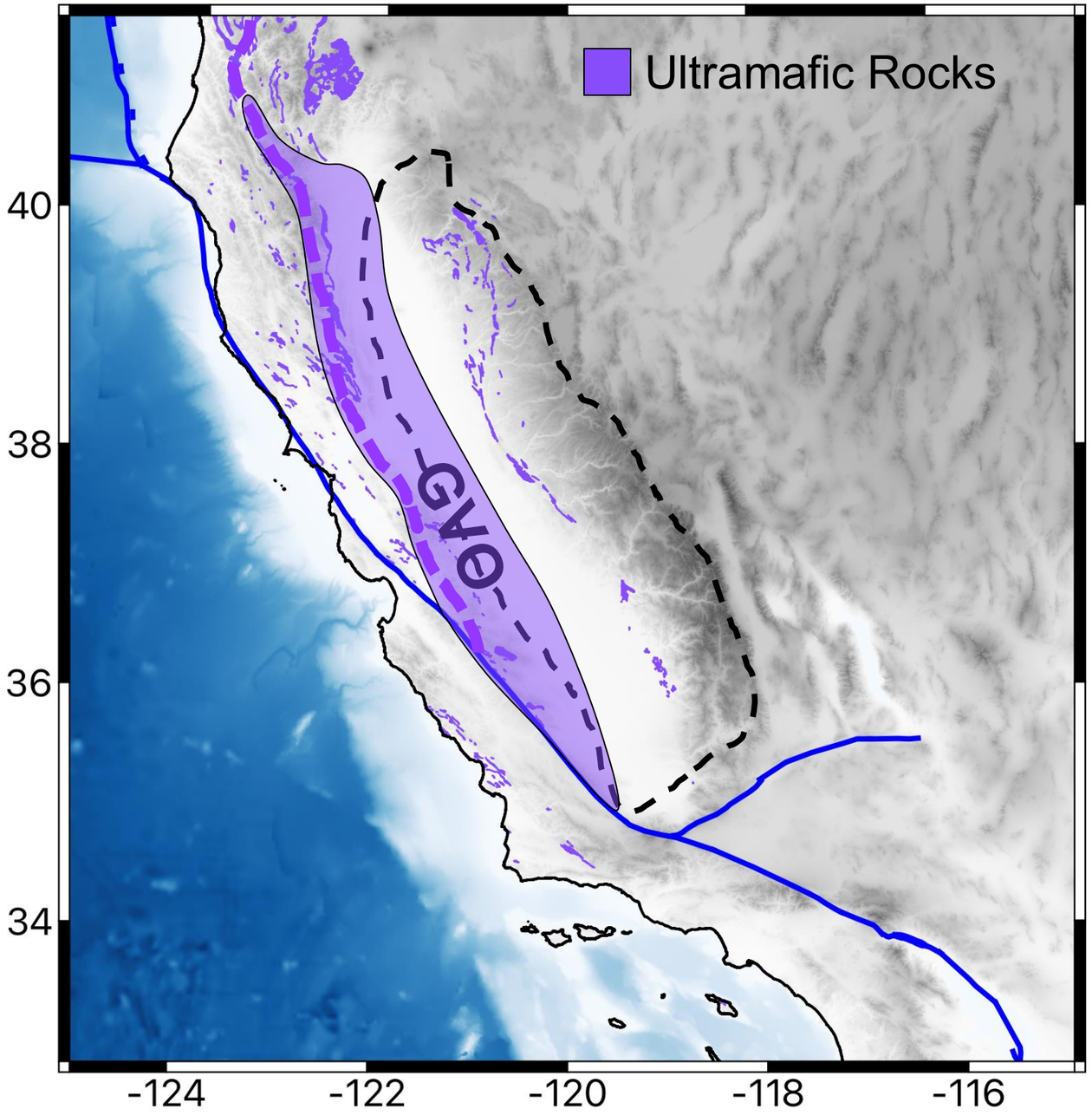


Arc rifting model from: Billen (2017)

Southward Continuation of Great Valley Ophiolite

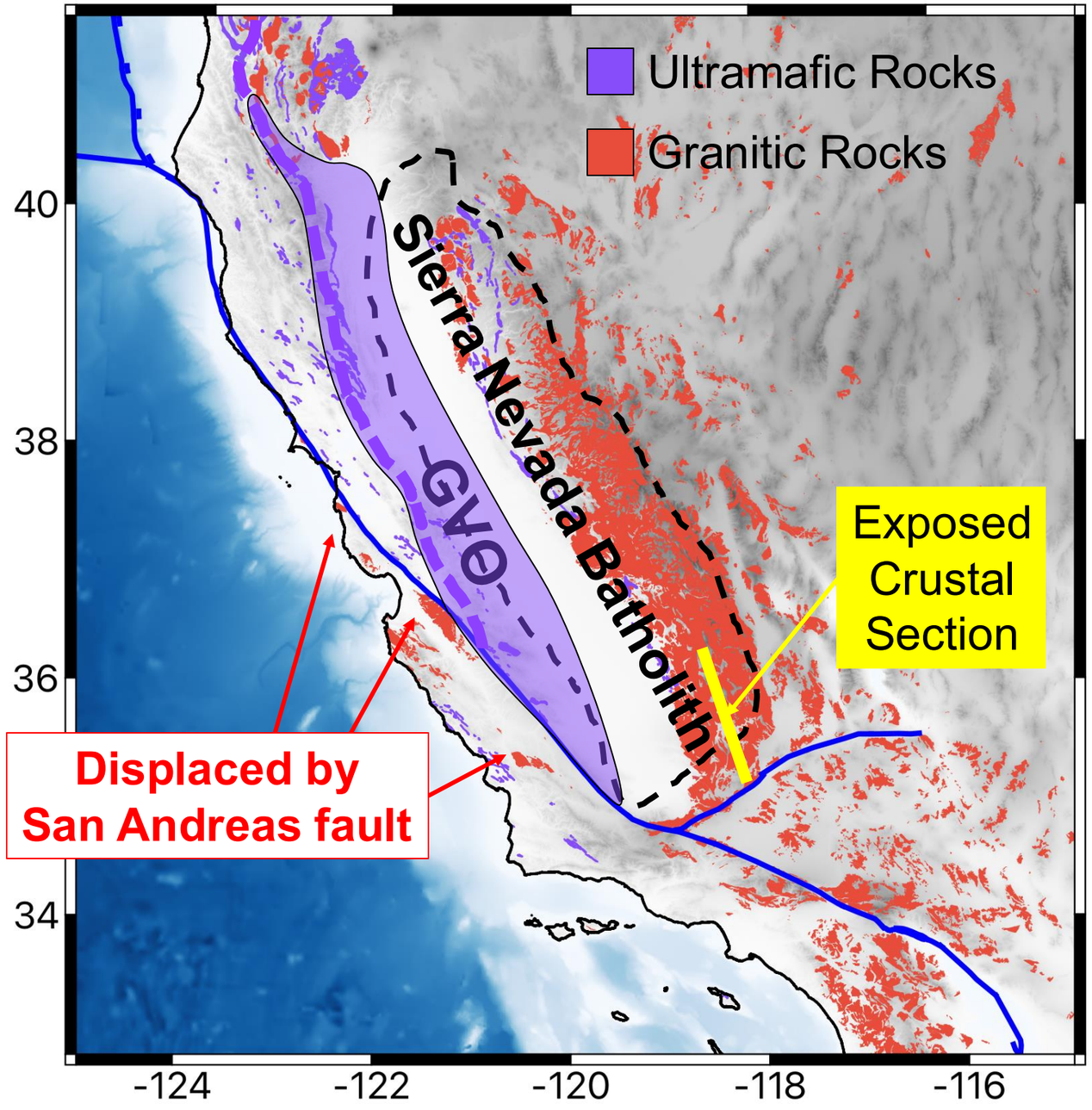
Aeromagnetic data confirms that mafic GVO basement also underlies forearc blocks in southern California





What underlies the rest of the SNGV Microplate?

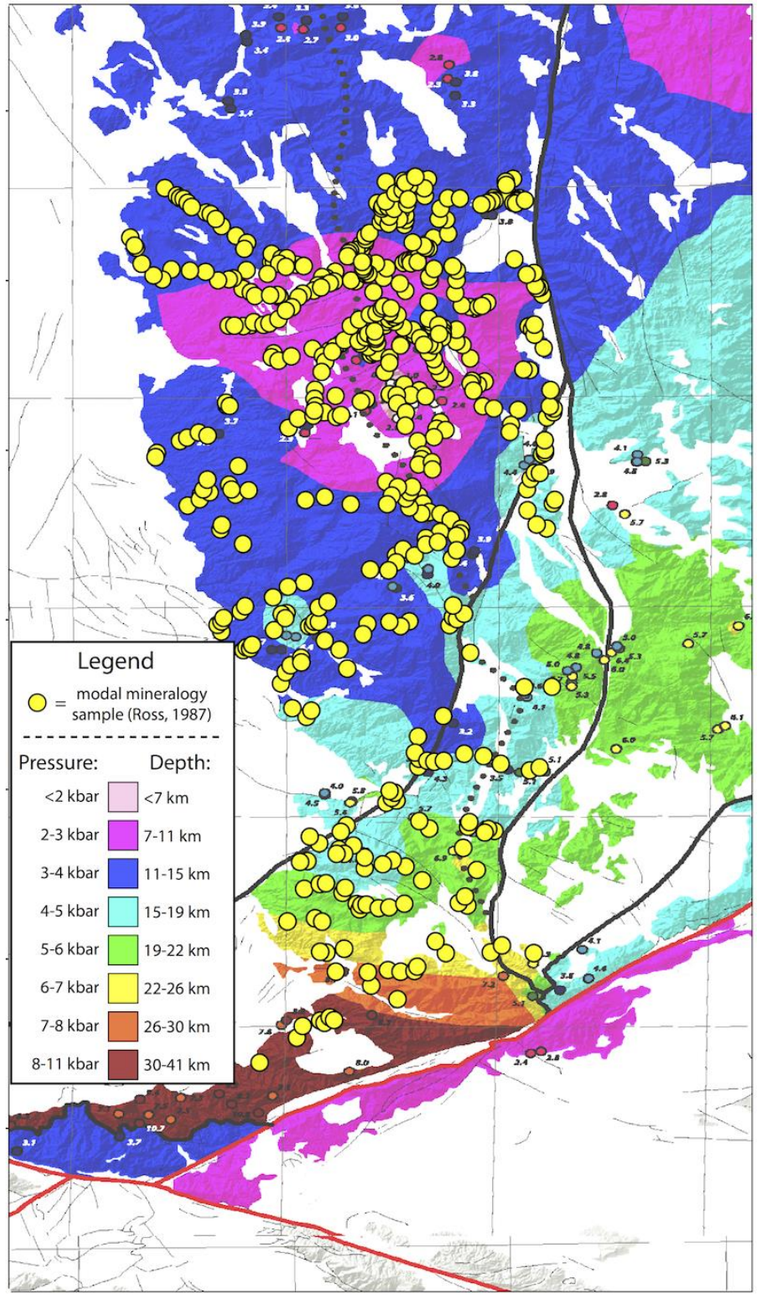
Geology from USGS Cooperative National Geologic Map (Colgan et al., 2025)

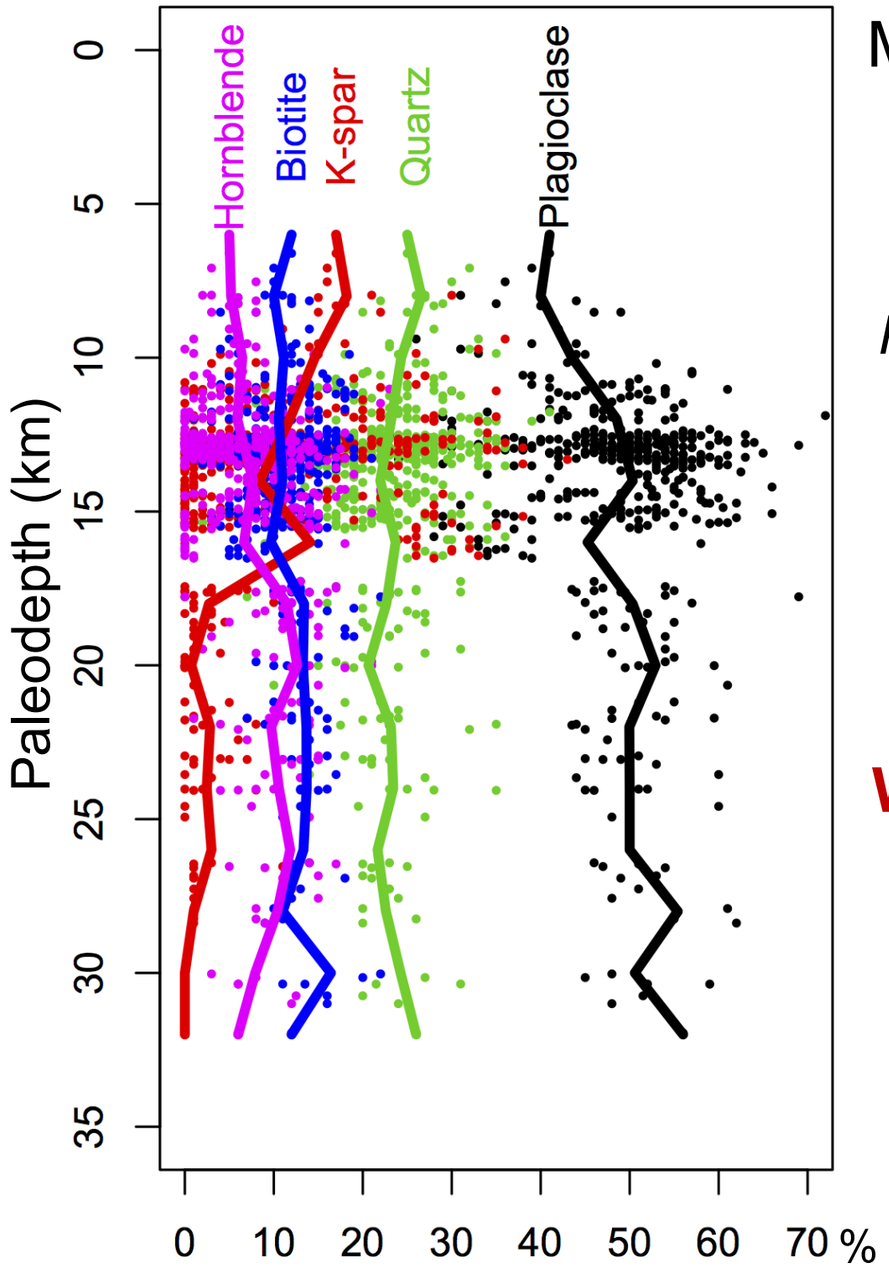


Mesozoic Granitic Rocks

- **'Batholith' = amalgamated granitic intrusions**
- **Sierra Nevada batholith underlies central & west SNGV microplate**
  - **Strong annealed crust or…**
  - **Low heat flow / thermally strong**
- **Note granitic rocks displaced to northwest by San Andreas fault**
- **Southern Sierra Nevada exposes cross-section of batholith crust.**

Geology from USGS Cooperative National Geologic Map (Colgan et al., 2025)





Modal Mineralogy of Southern Sierra Nevada Exhumed Crustal Section

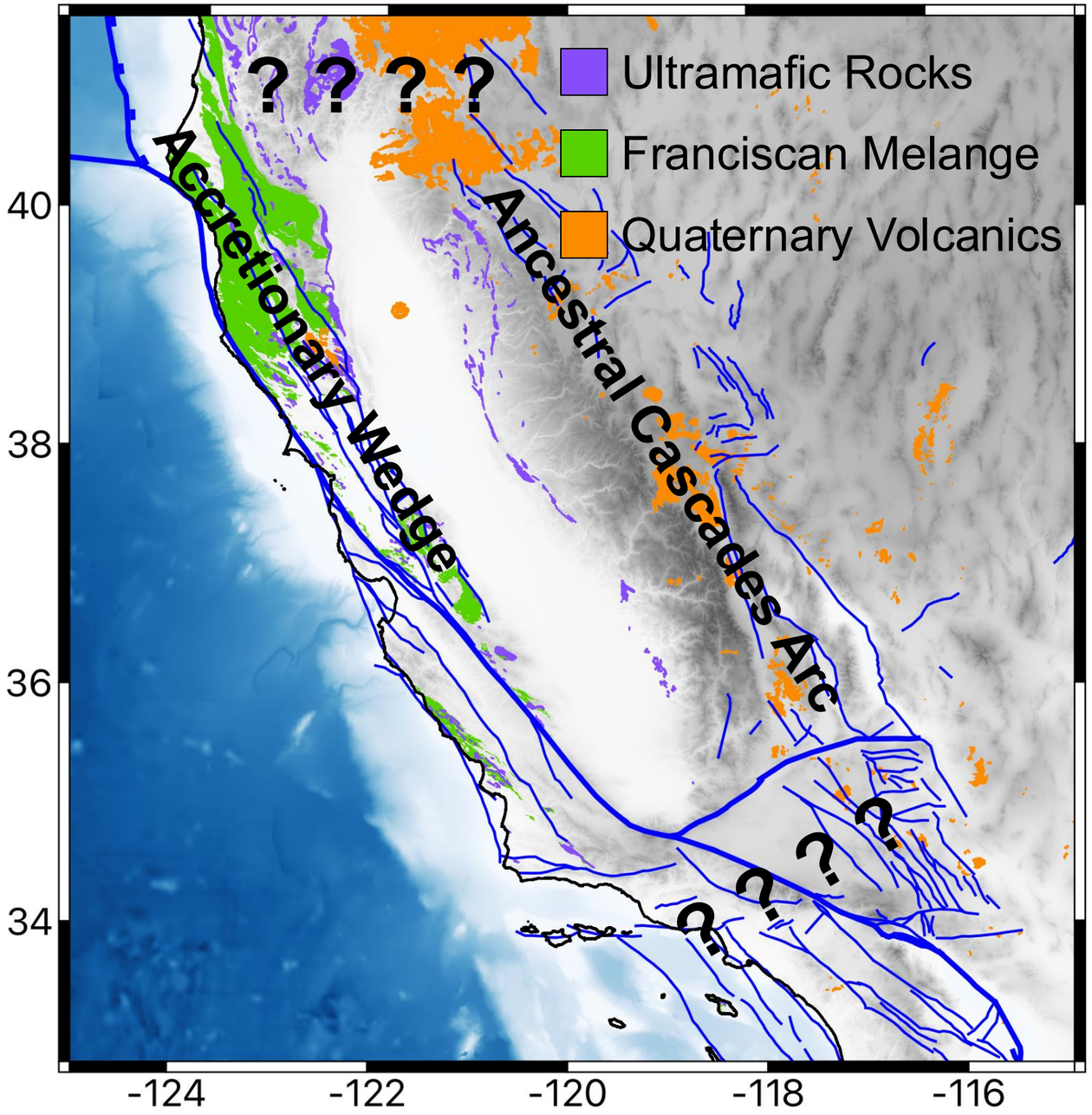
Mineralogy: Ross (1983, 1987)
Paleodepth: Chapman et al. (2012)

Compiled by A. Morelan

Framework: Plagioclase

Weak Phases: Quartz, Biotite

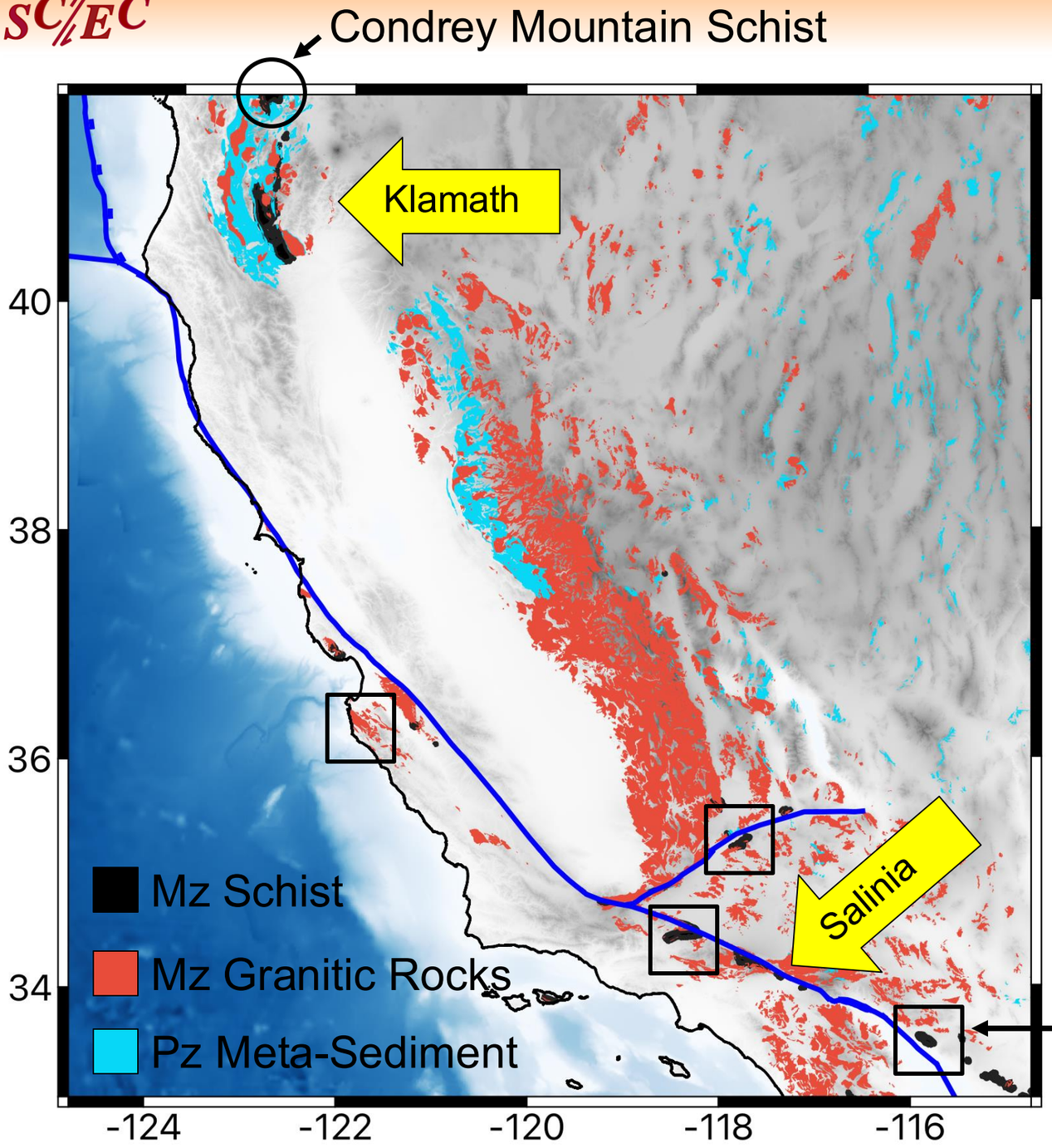
No depth variation except feldspar type



Localization of Transform Faulting

- **Former accretionary wedge hosts ~80% of dextral plate motion along San Andreas & nearby faults**
- **Former Cascades arc hosts remaining ~20% of dextral plate motion along Walker Lane. *This area remains volcanically active***
- **What happened where this pattern changes?**

Strike-slip faults from USGS NSHM (Hatem et al., 2023)

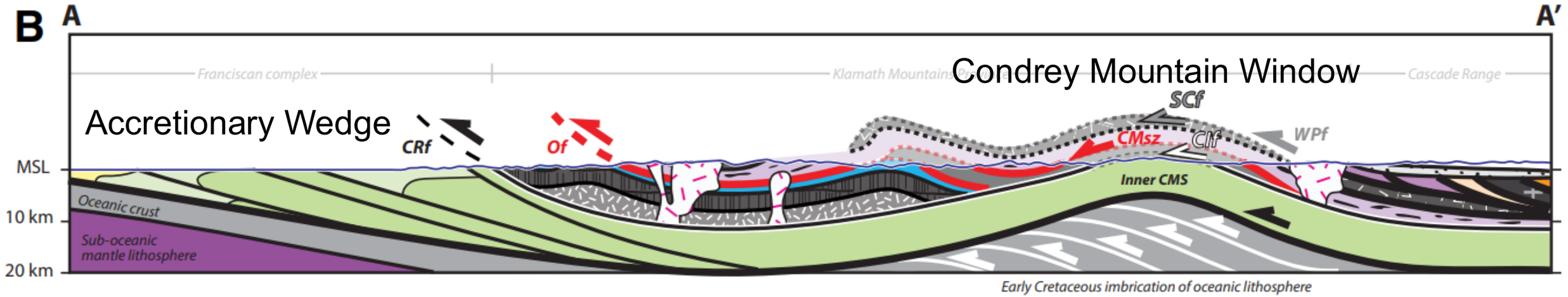


Events #2 & #3: Schist Underplating

- **Low-angle subduction and underplating of accretionary wedge sediments beneath arc**
- **Segments of arc crust extended and moved toward trench**
- **This happened *twice* during the Mesozoic:**
  - ***~135 Myr: Klamath Terrane***
  - ***~70 Myr: Mojave – Salinia Terrane***

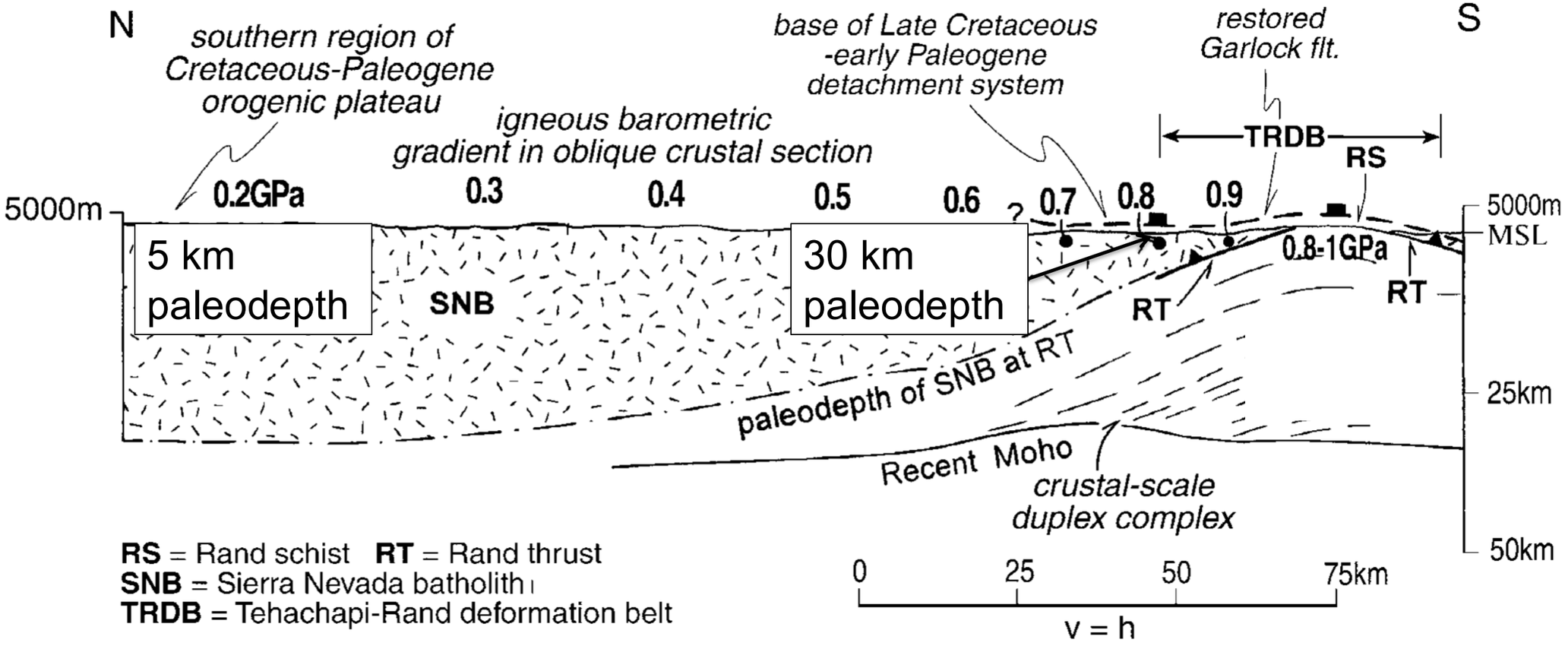
PORS Schist
(PORS = Pelona, Orocopia, Rand, Salinas)

Event #2: Underplating of Klamath Mountains Terrane

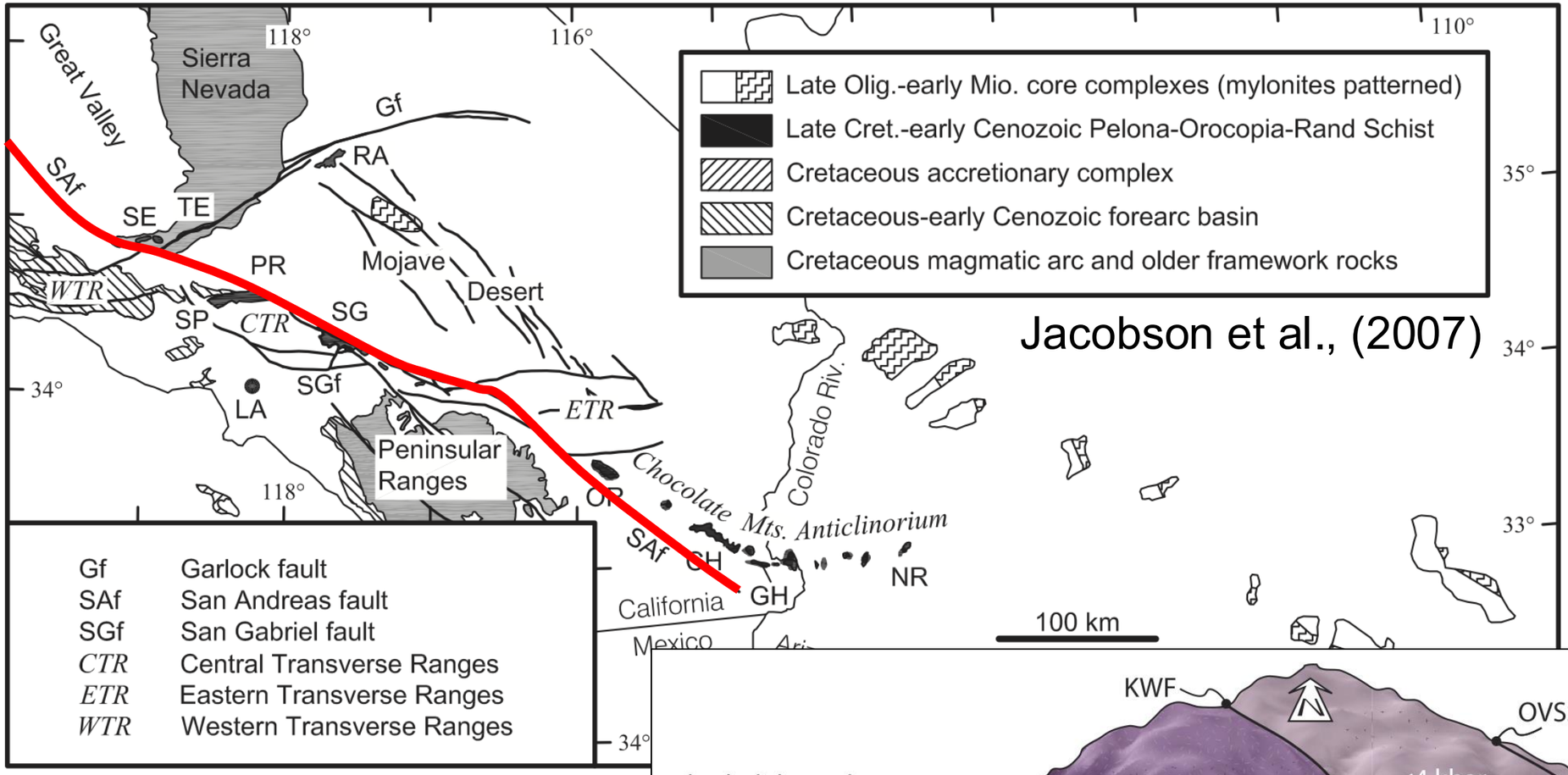


Cross-Section from Chapman et al. (2024)

Event #3: Underplating of Mojave-Salinia Terrane

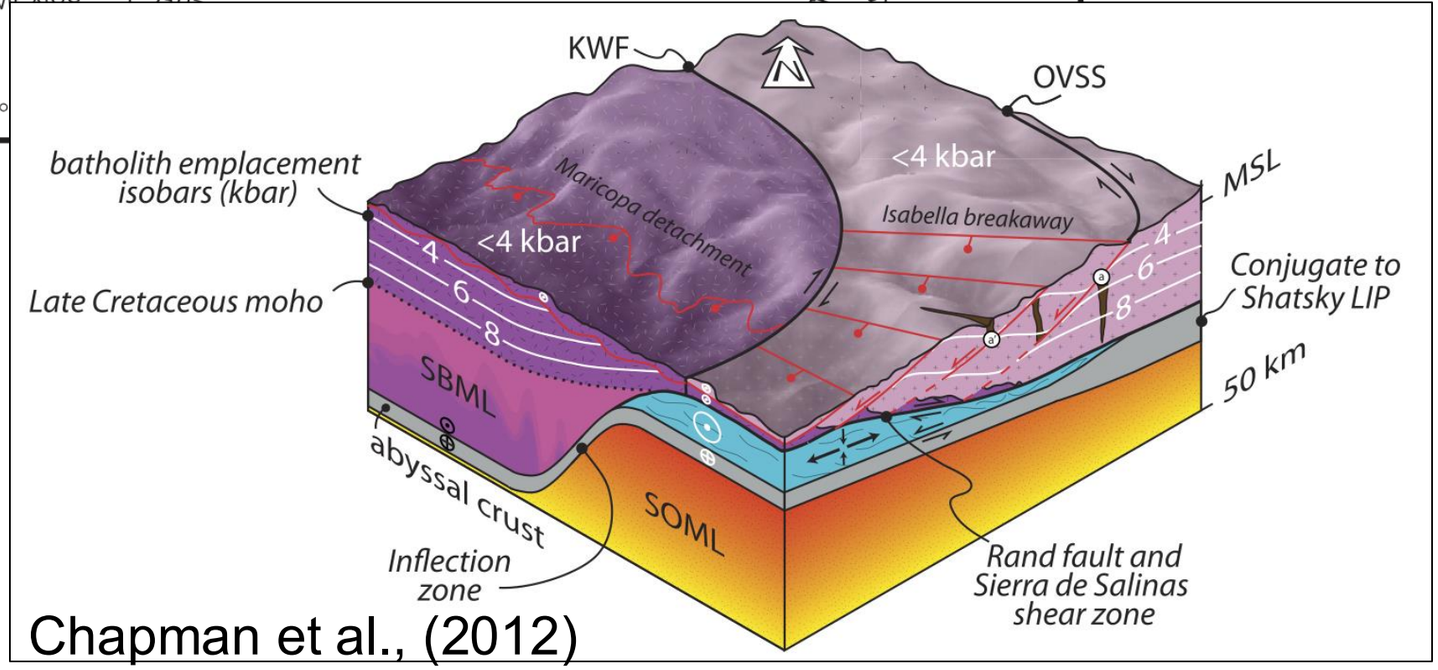


Saleeby (2003)



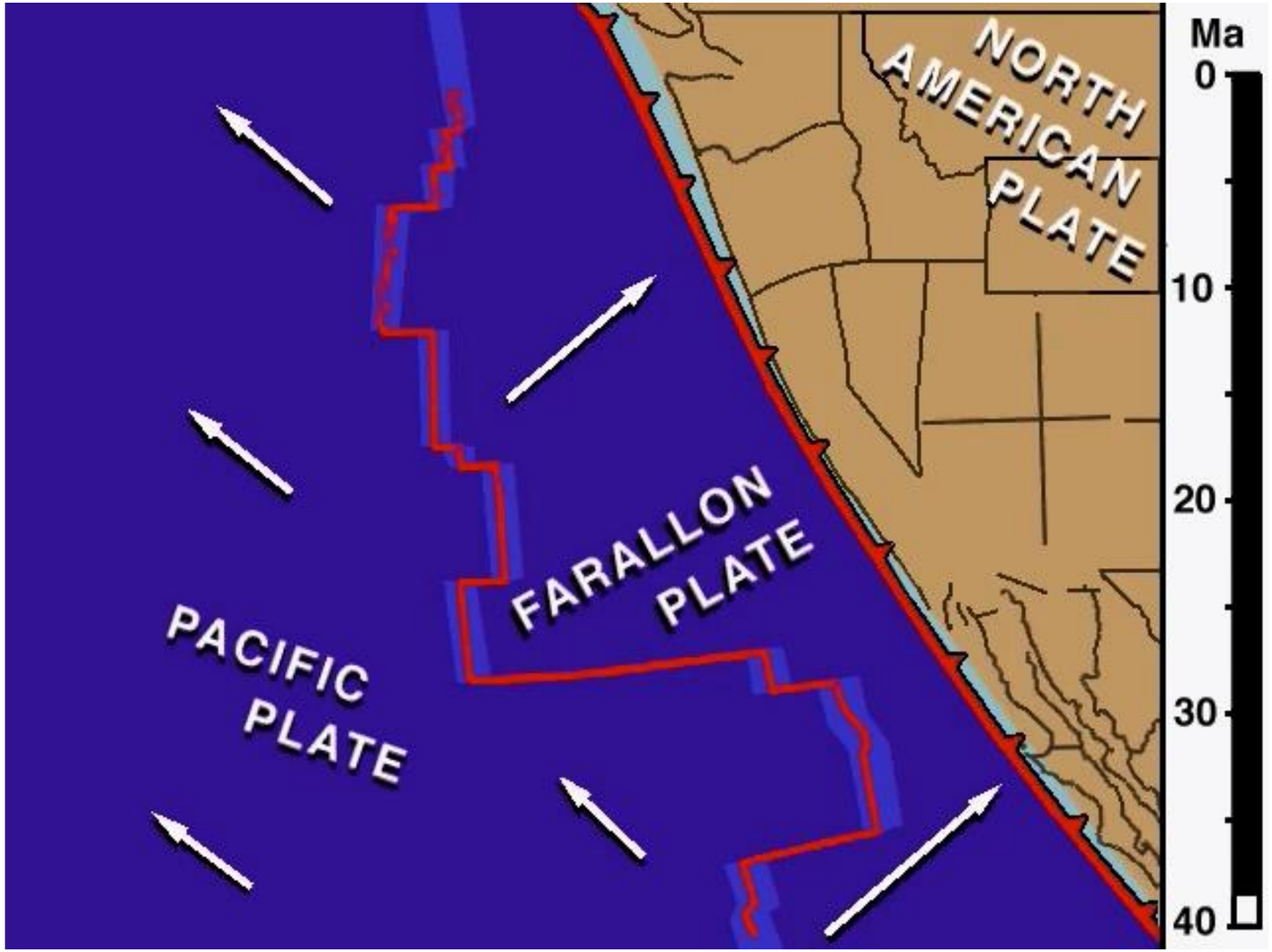
Jacobson et al., (2007)

Big-Bend of San Andreas Fault follows PORS schist 'windows'

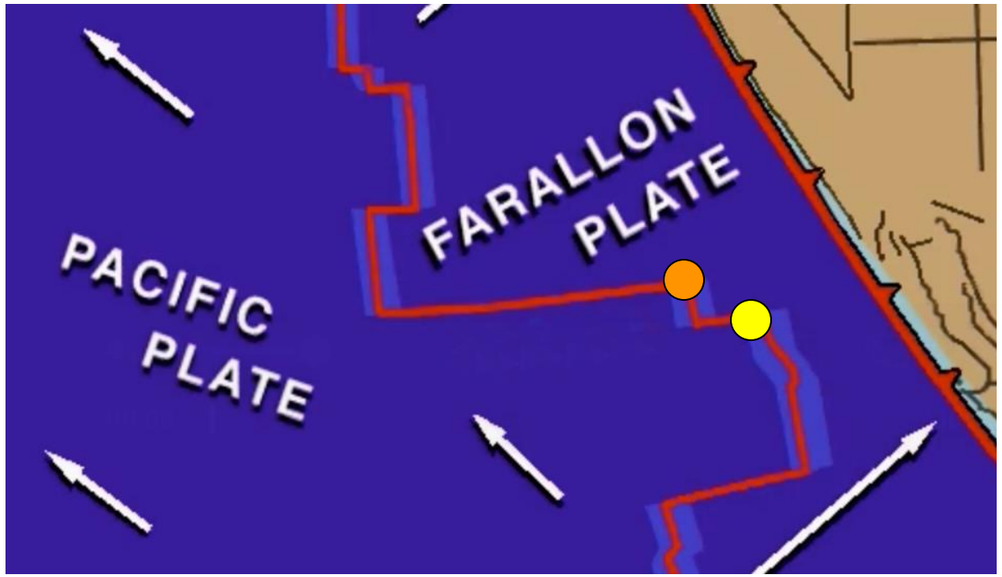


Chapman et al., (2012)

Event #4: Formation of Pioneer Triple Junction

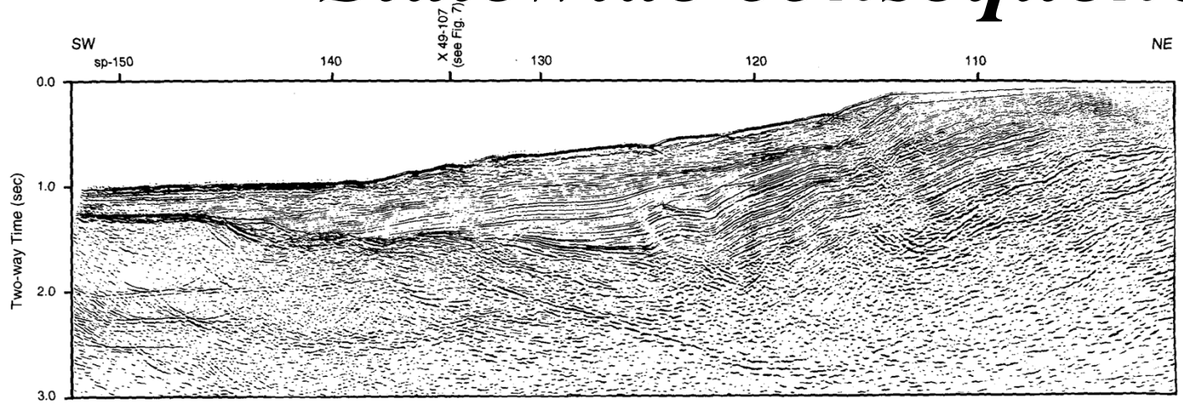


- **Pioneer Triple Junction (PTJ) formed first at ~32 Myr**
- **Mendocino Triple Junction (MTJ) took over ~27 Myr**

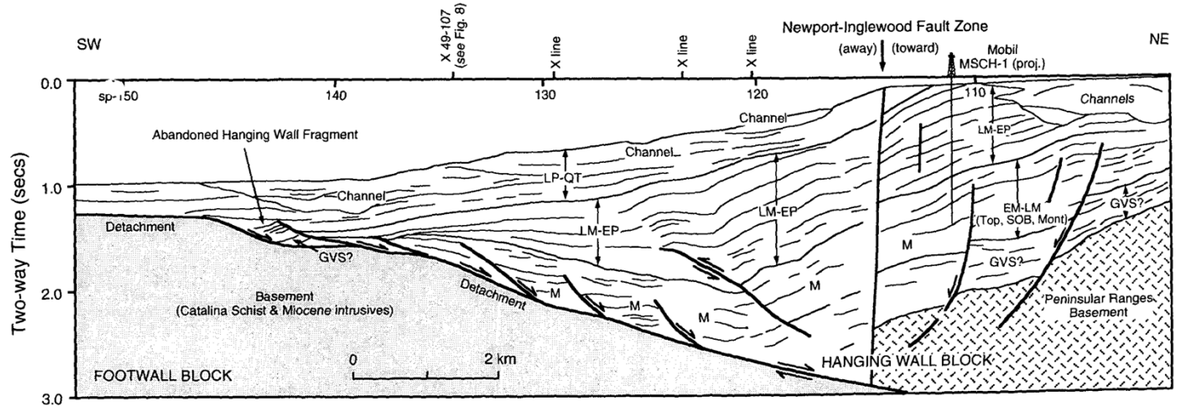


Animation by Tanya Atwater

Statewide consequences of PTJ formation

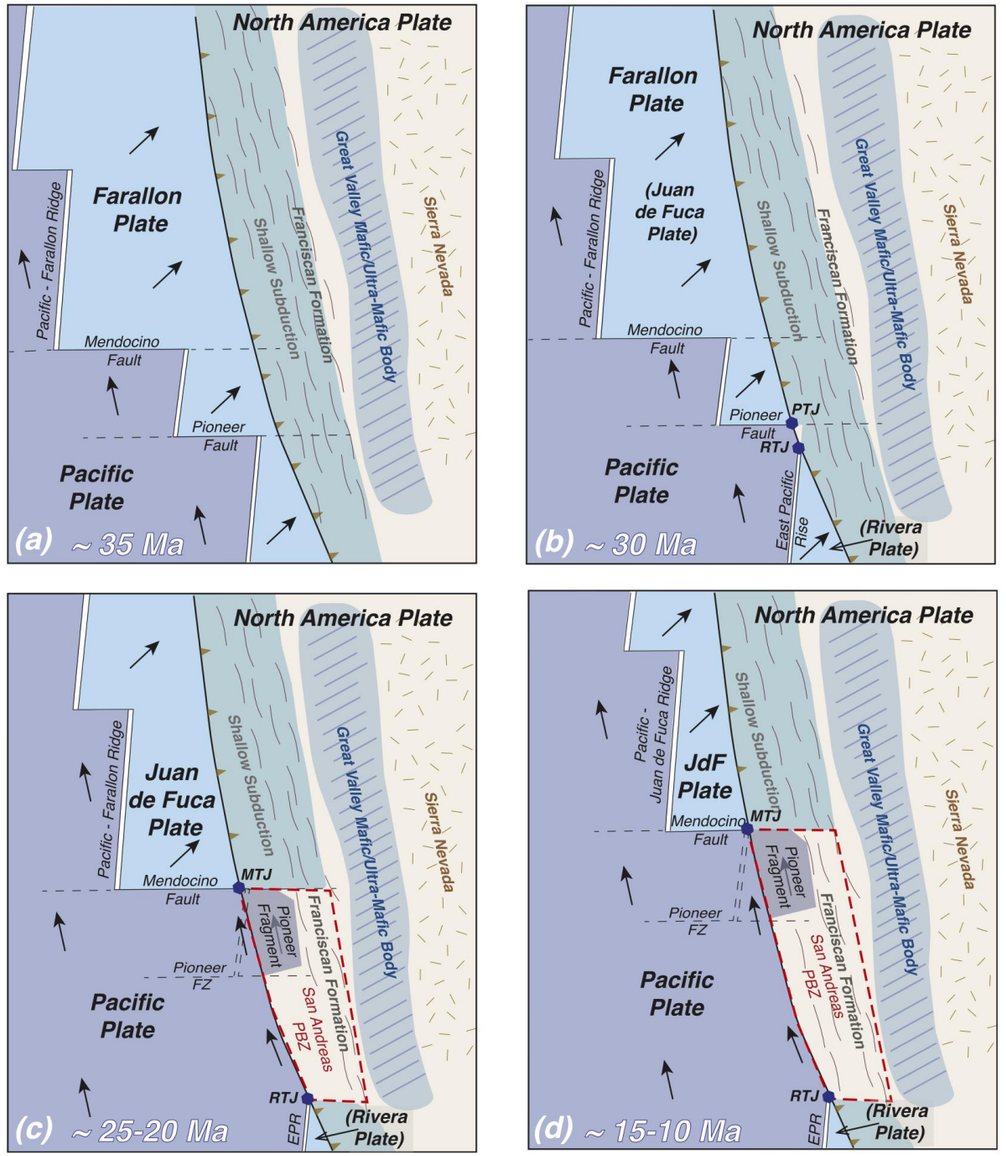


Crouch & Suppe (1993) LINE 49-100



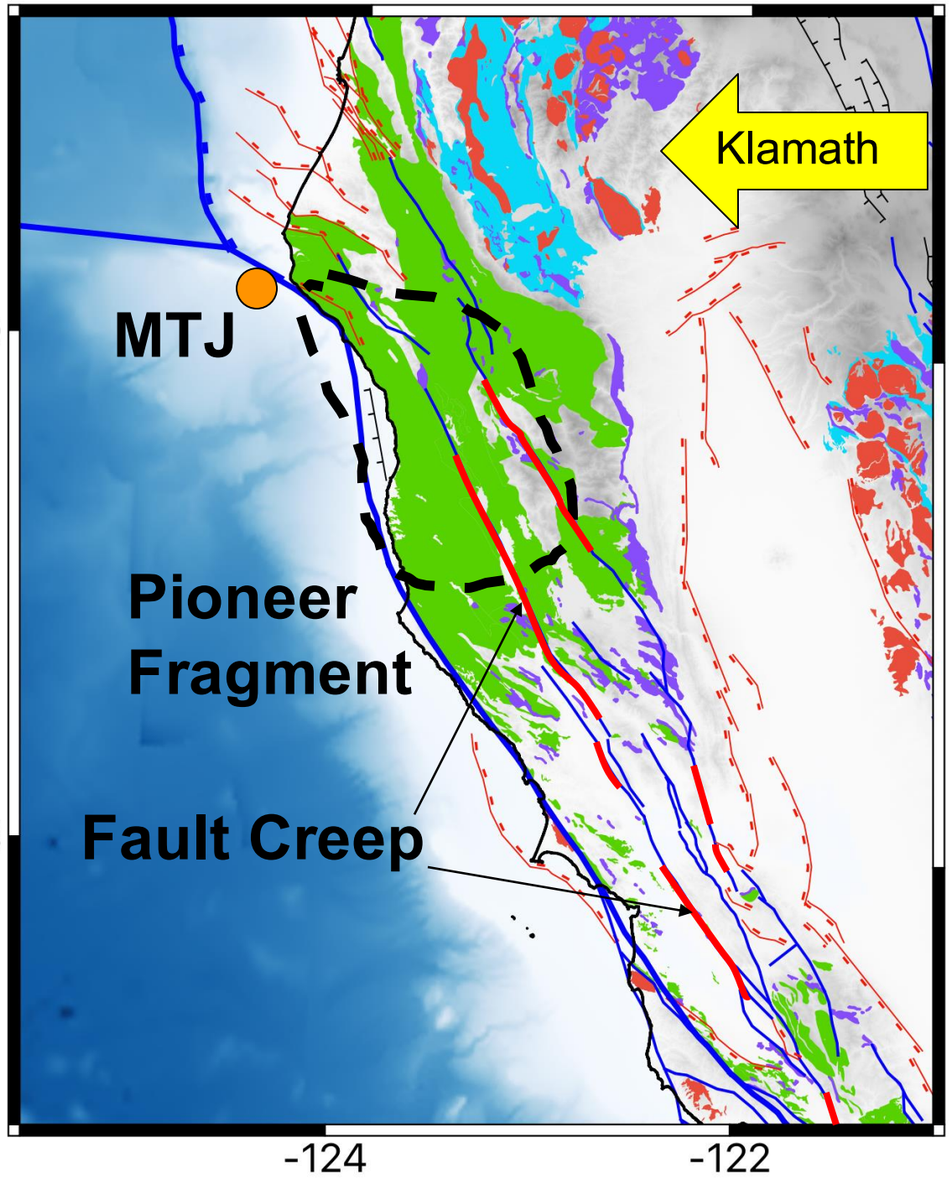
Southern California: Inner Borderland Rifting & Rotation of Western Transverse Ranges

Northern California: Pioneer plate fragment drives distributed shear zone formation



Furlong et al. (2024)

Rheologic Heterogeneity of MTJ Region



- Rapidly evolving transition from Cascadia subduction to San Andreas transform system
- Adjacent to underplated Klamath terrane
  - See poster #102 by Lynch & Oskin for newly discovered faults here
- Pioneer fragment, coupled to Pacific plate, underlies nascent northern California transform faults
  - See poster #84 by Herman & Furlong for model of transform fault development
- Creeping faults & ophiolitic rocks
  - See next presentation by Ault

Outline & Conclusions

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