Fault and Deformation models in the

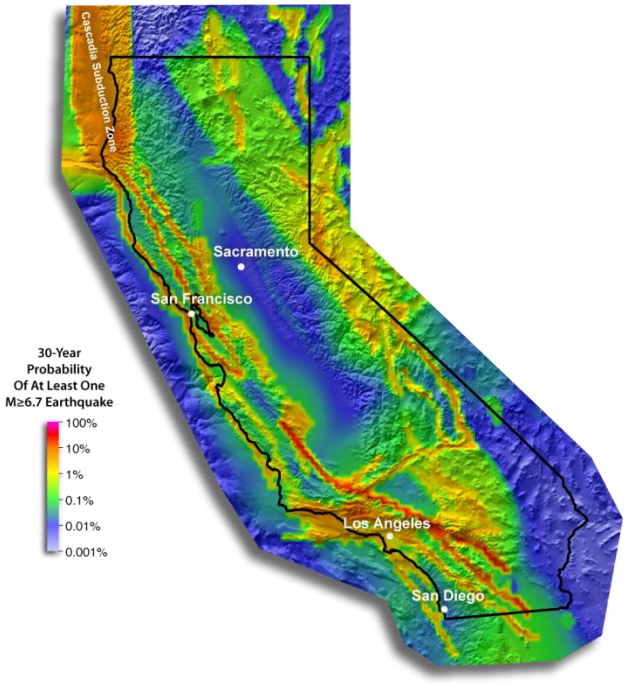
Uniform California Earthquake Rupture Forecast 2 (UCERF 2)

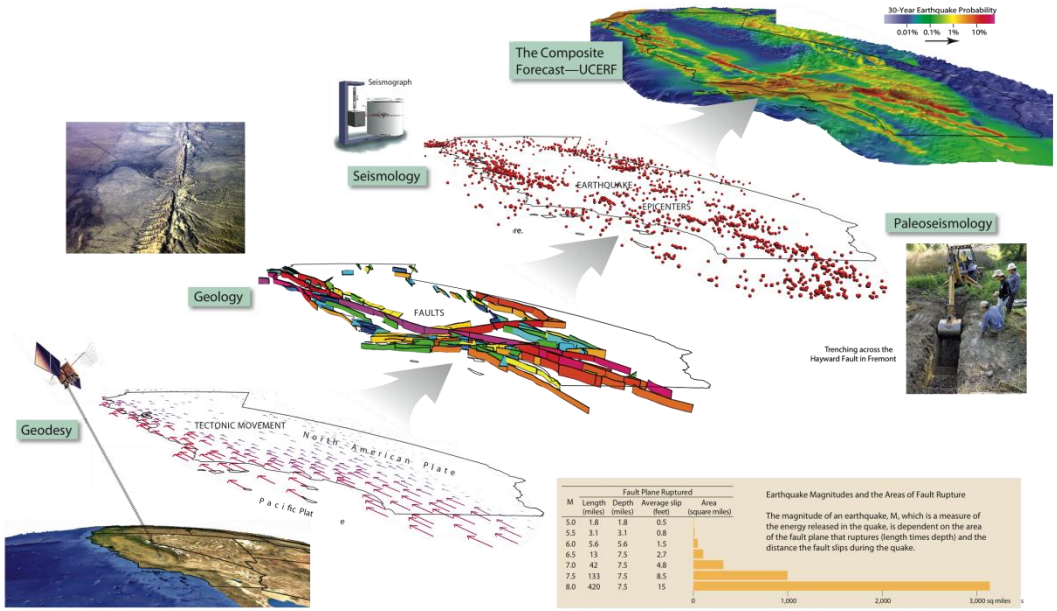
by the

Working Group on California Earthquake Probabilities (WGCEP)

&

Progress toward UCERF 3





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CGS CALIFORNIA GEOLOGICAL SURVEY

CEA CALIFORNIA EARTHQUAKE AUTHORITY

Components of the Uniform California Earthquake Rupture Forecast 2

Fault Models

Specifies the spatial geometry of larger, more active faults.

Deformation Models

Provides fault slip rates used to calculate seismic moment release.

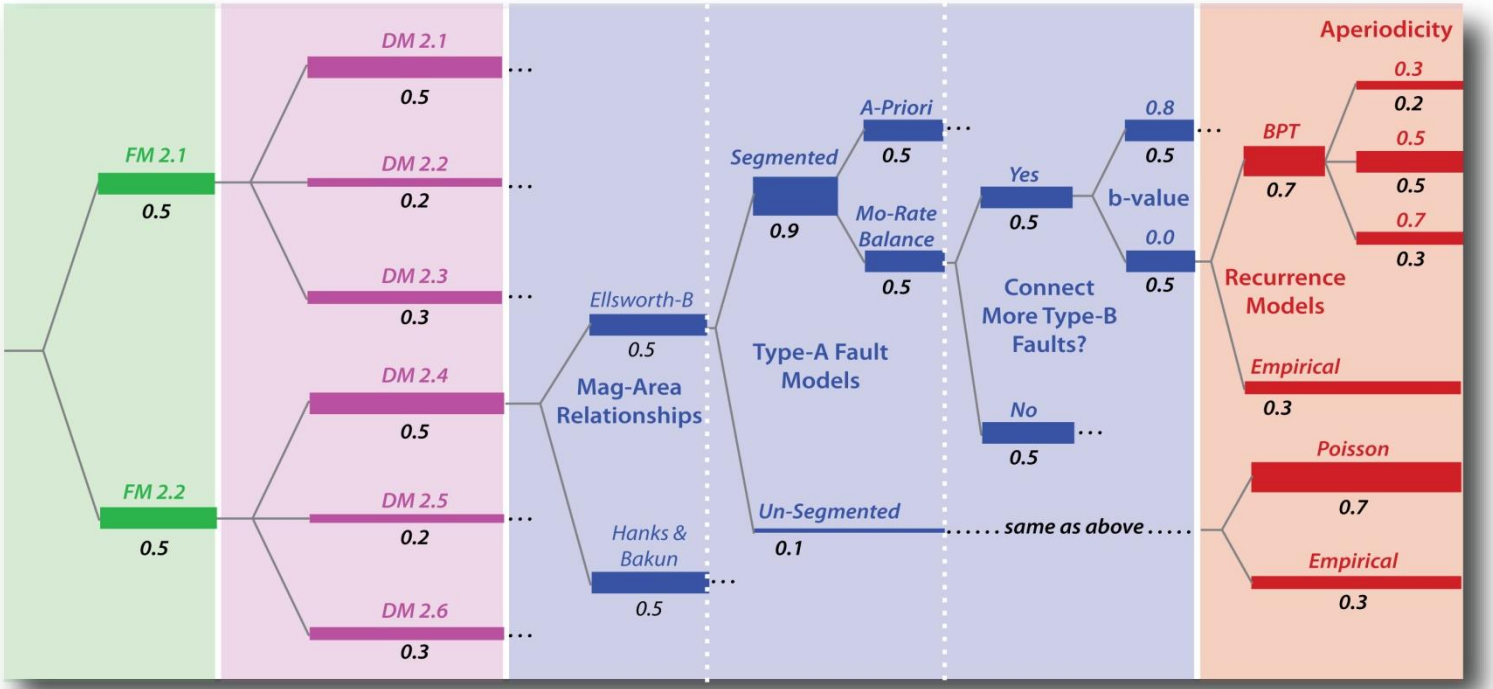
Earthquake-Rate Models

Gives the long-term rate of all possible damaging earthquakes throughout a region.

Probability Models

Gives the probability that each earthquake in the given Earthquake Rate Model will occur during a specified time span.

(abbreviated logic tree of 480 branches)



A. Fault Models

Specifies the spatial geometry of larger, more active faults.

B. Deformation Models

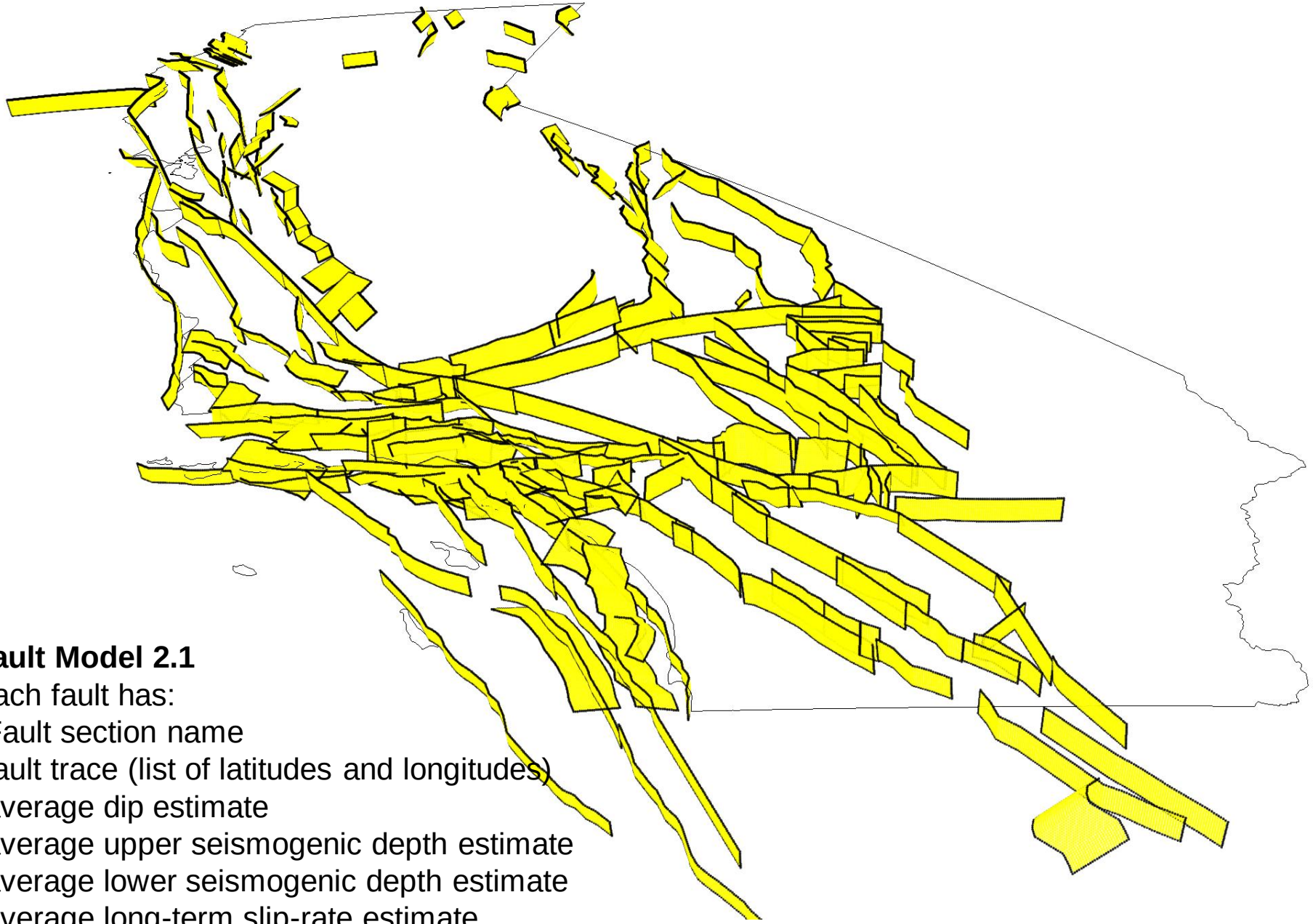
Provides fault slip rates used to calculate seismic moment release.

C. Earthquake-Rate Models

Gives the long-term rate of all possible damaging earthquakes throughout a region.

D. Probability Models

Gives the probability that each earthquake in the given Earthquake Rate Model will occur during a specified time span.

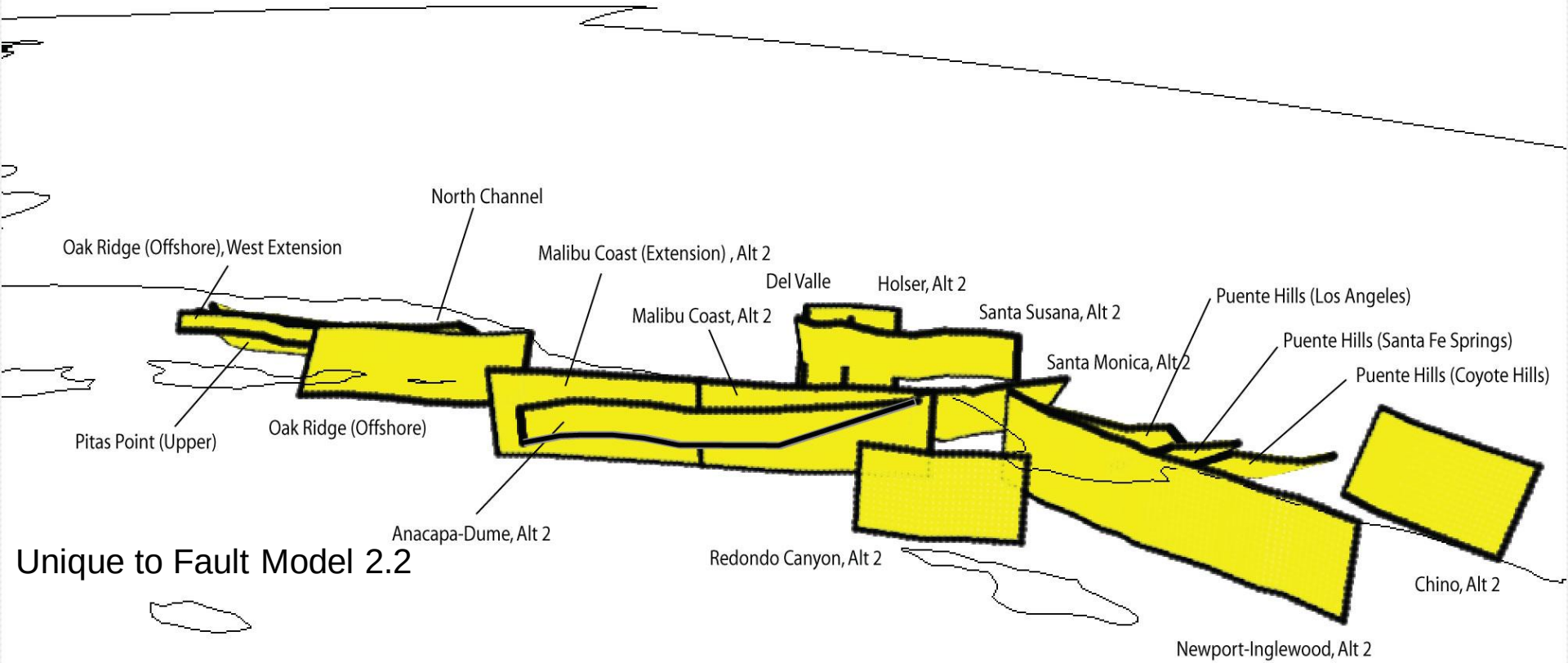


Fault Model 2.1

Each fault has:

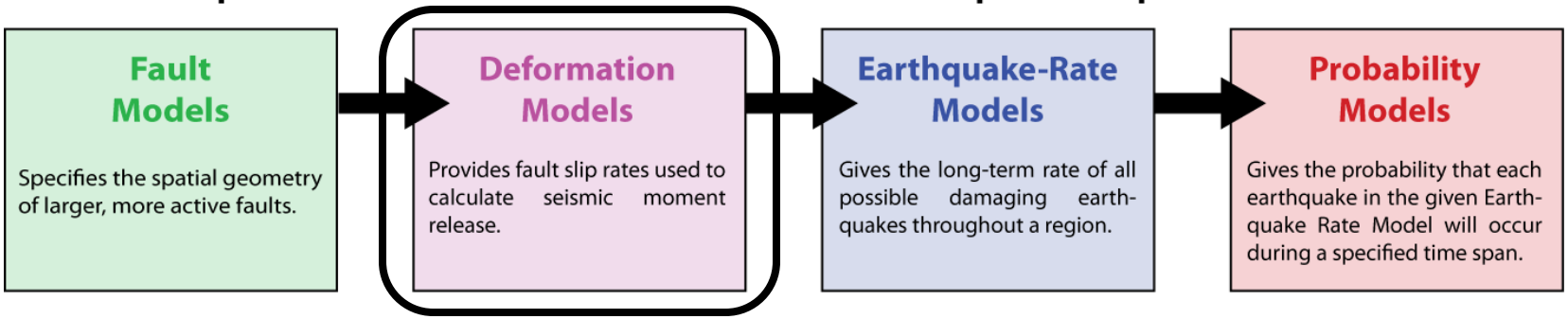
- Fault section name
- fault trace (list of latitudes and longitudes)
- average dip estimate
- average upper seismogenic depth estimate
- average lower seismogenic depth estimate
- average long-term slip-rate estimate
- average aseismic-slip-factor estimate
- average rake estimate

In some places there is evidence for active faulting, but there are alternative interpretations of the orientation of the faults, particularly at depth.
If there are mutually incompatible interpretations, alternative fault models can be included



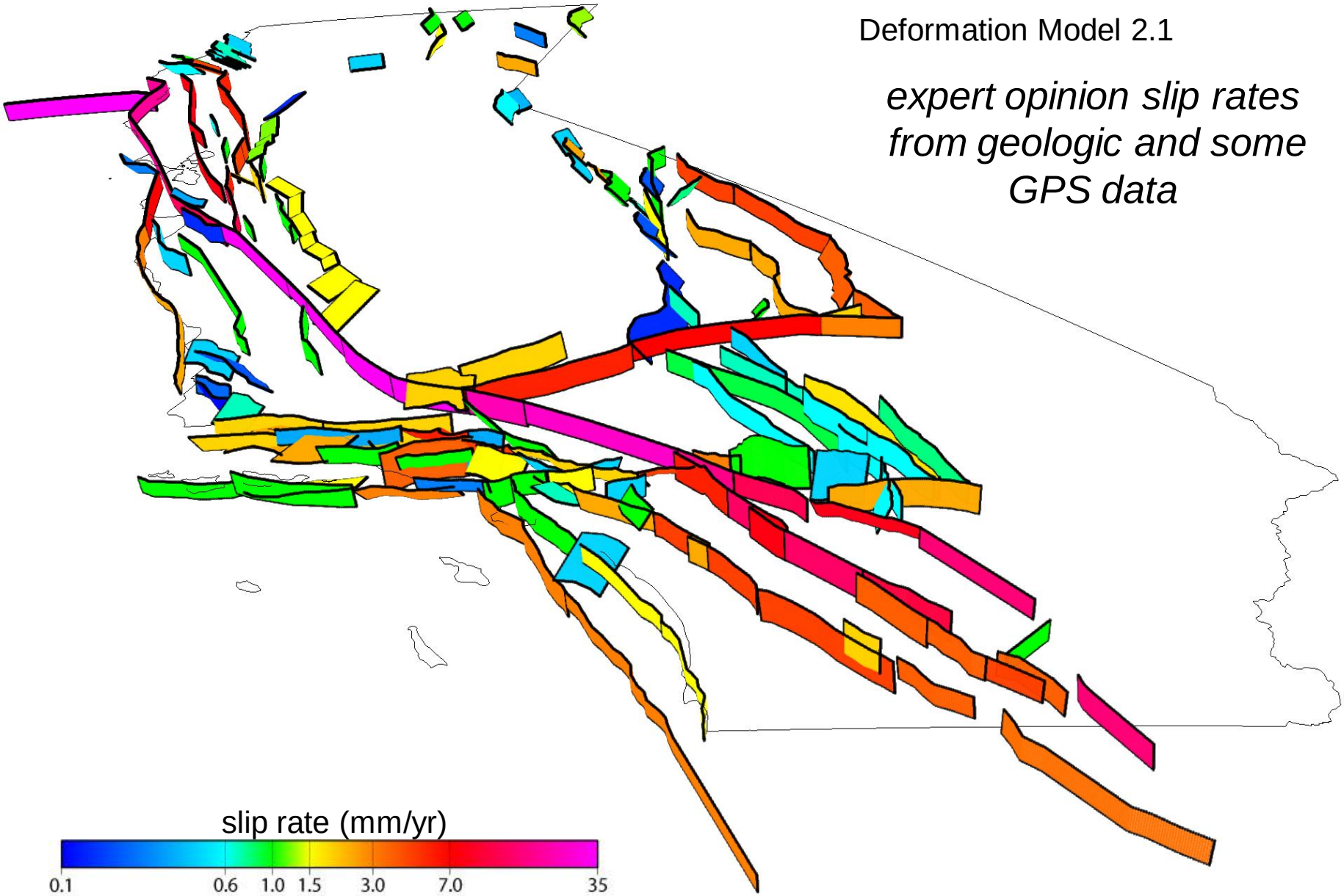
Unique to Fault Model 2.2

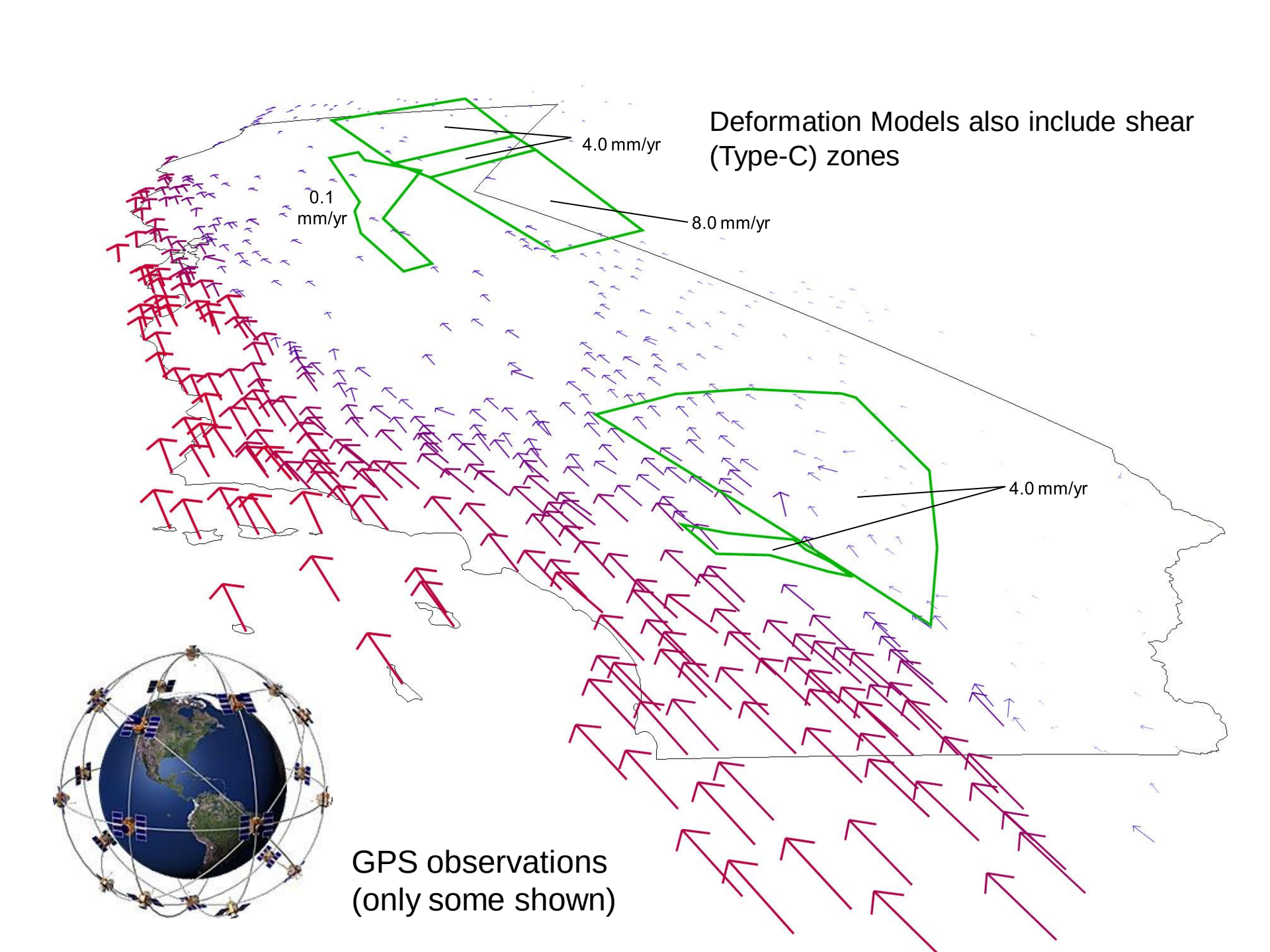
Components of the Uniform California Earthquake Rupture Forecast 2



Deformation Model 2.1

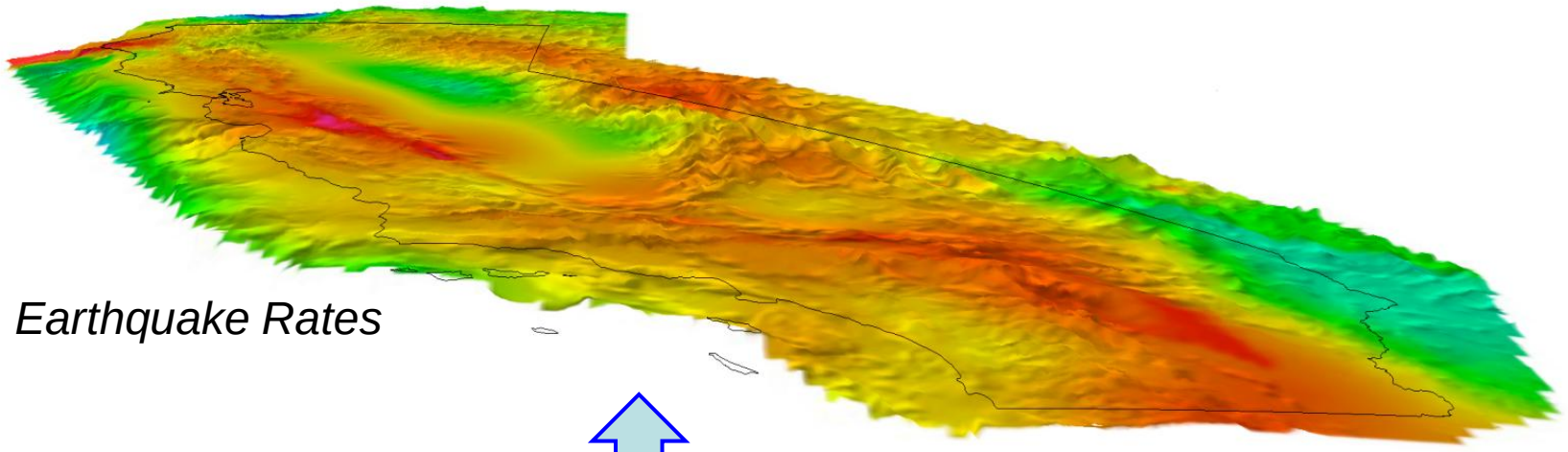
expert opinion slip rates from geologic and some GPS data




Deformation Models also include shear (Type-C) zones
4.0 mm/yr
0.1 mm/yr
8.0 mm/yr
4.0 mm/yr
GPS observations (only some shown)

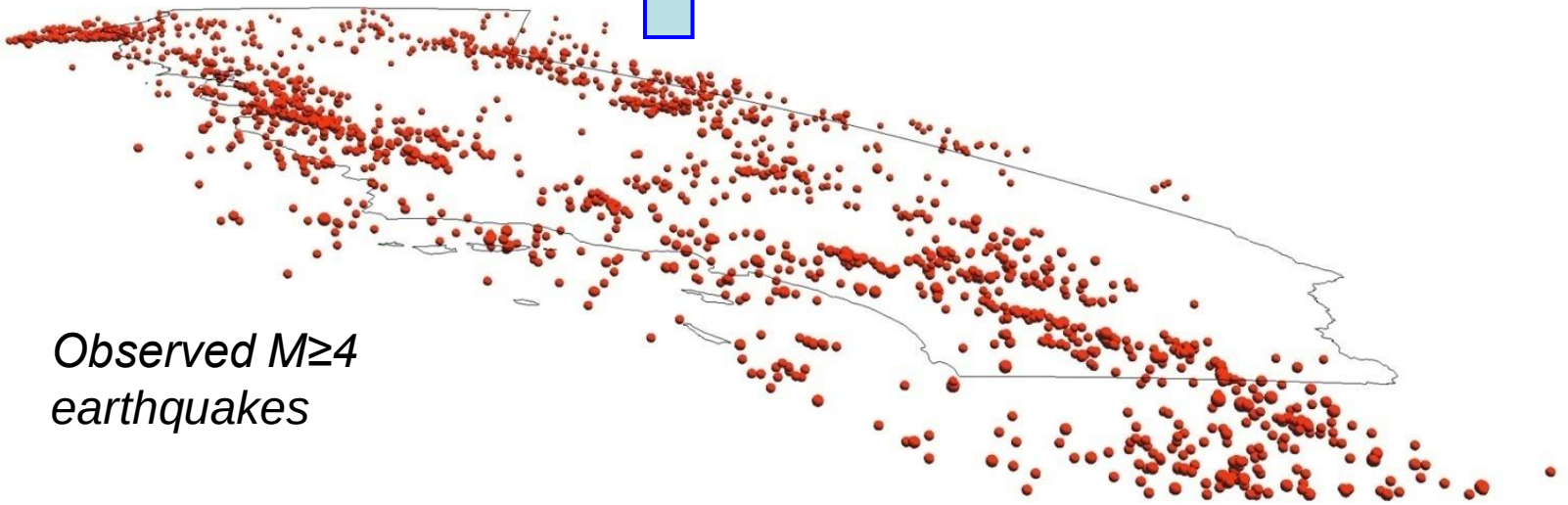
Earthquake Rate Model

Background Seismicity



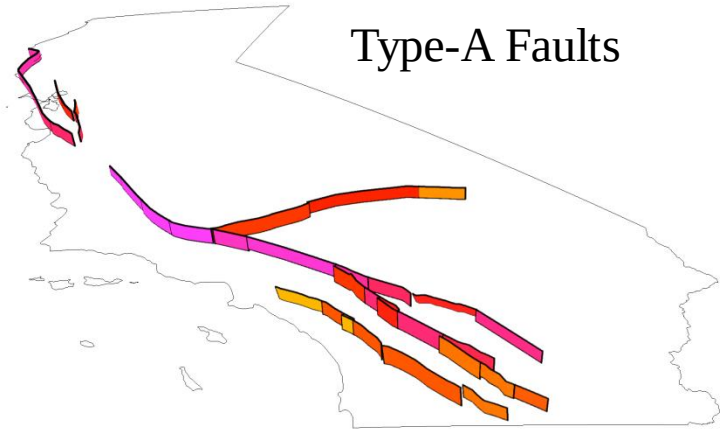
Earthquake Rates

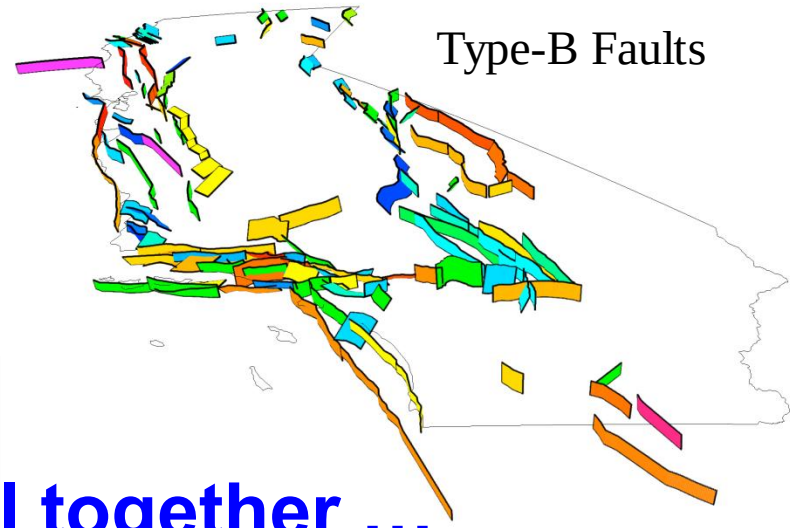
spatial smoothing



Observed M≥4 earthquakes

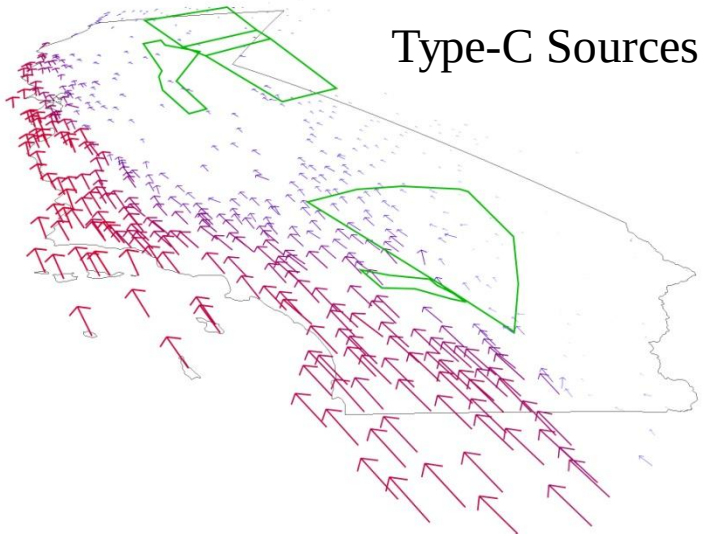
Earthquake Rate Model

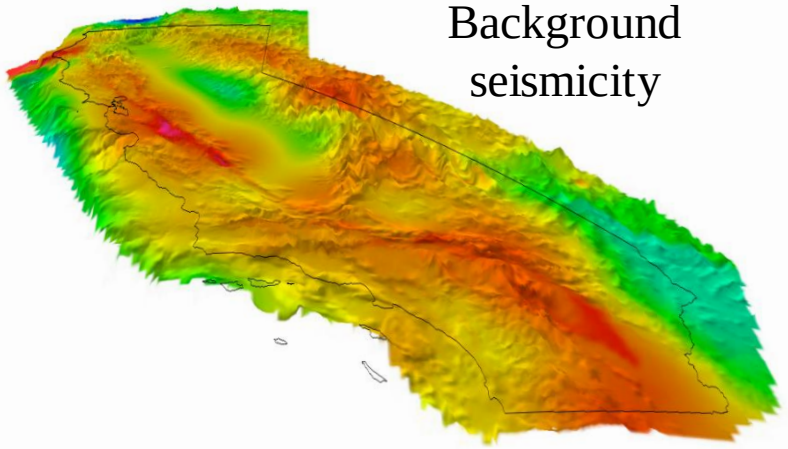




Quake rates on known faults

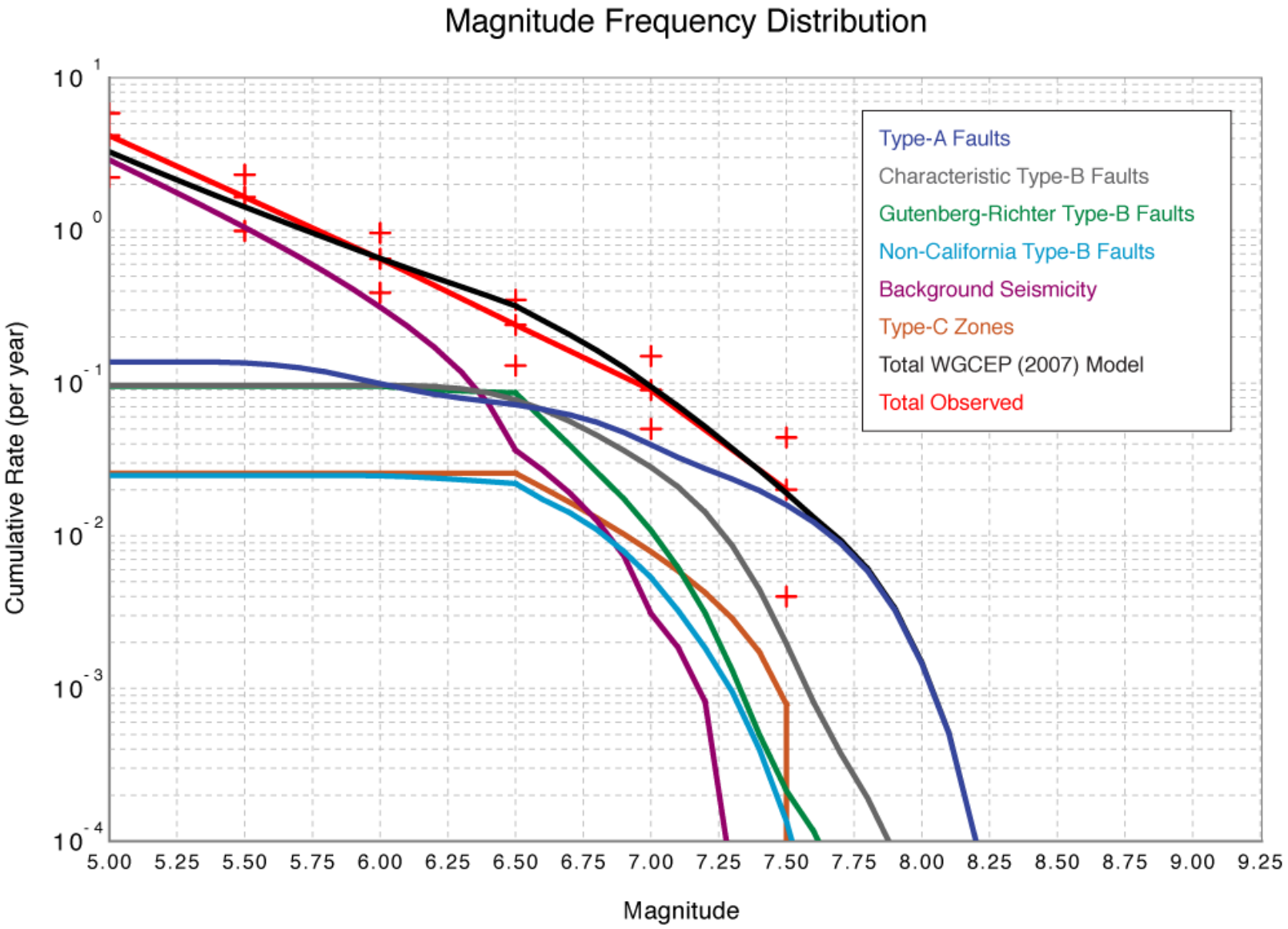
Putting it all together …





Quake rates elsewhere

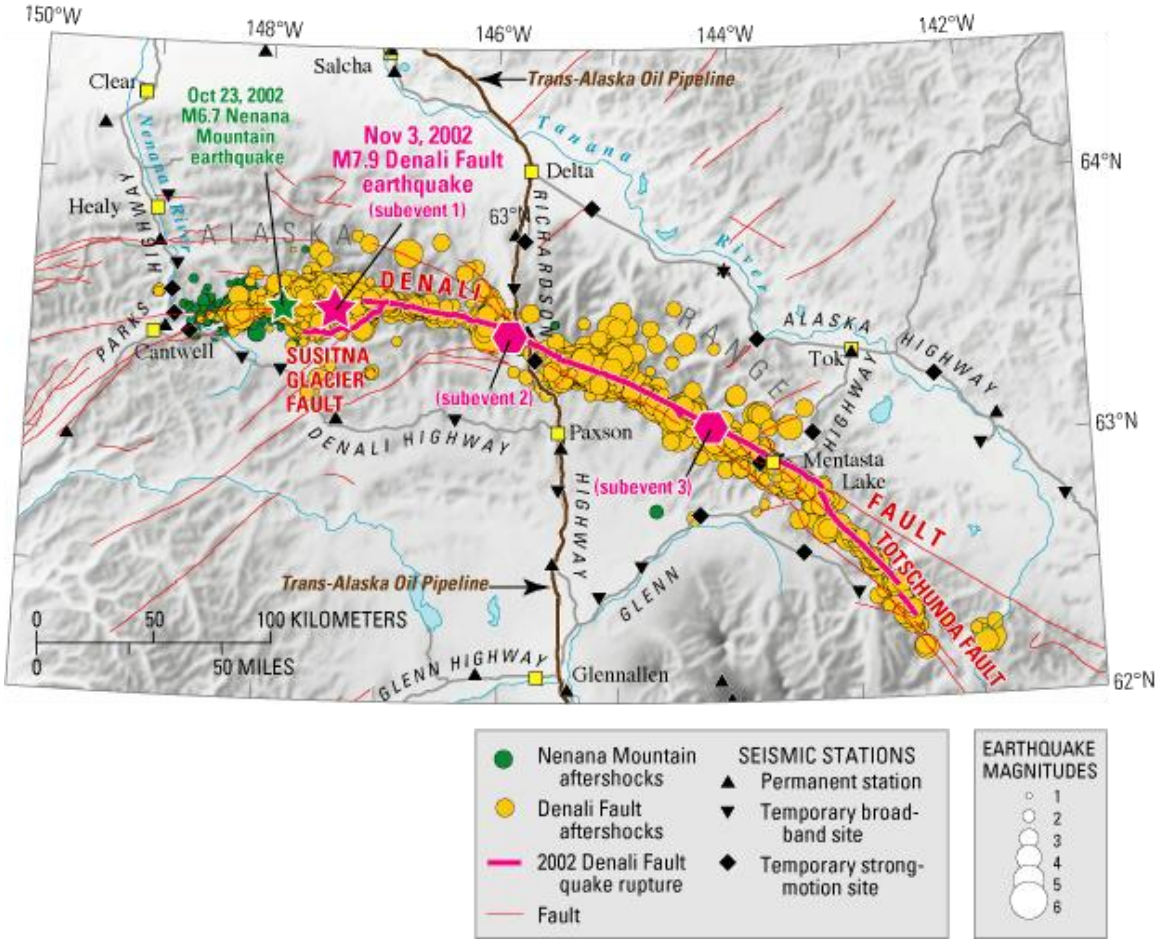
Earthquake Rate Model



UCERF2 Limitations:

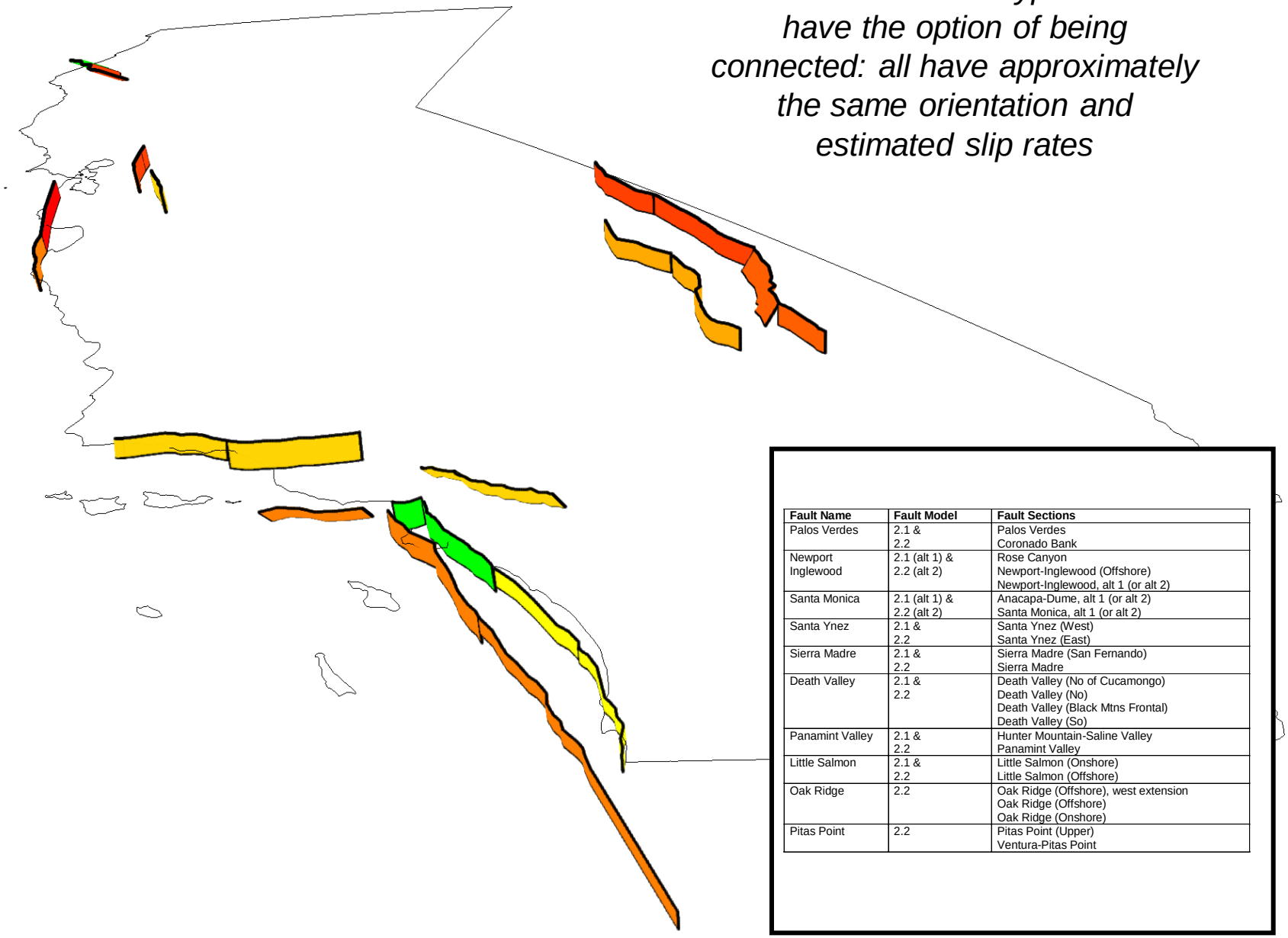
Excludes multi fault ruptures

(may over-predict M 6.5-7.0 & under-predict M >7 events)



Earthquake Rate Model allows for limited connections between faults

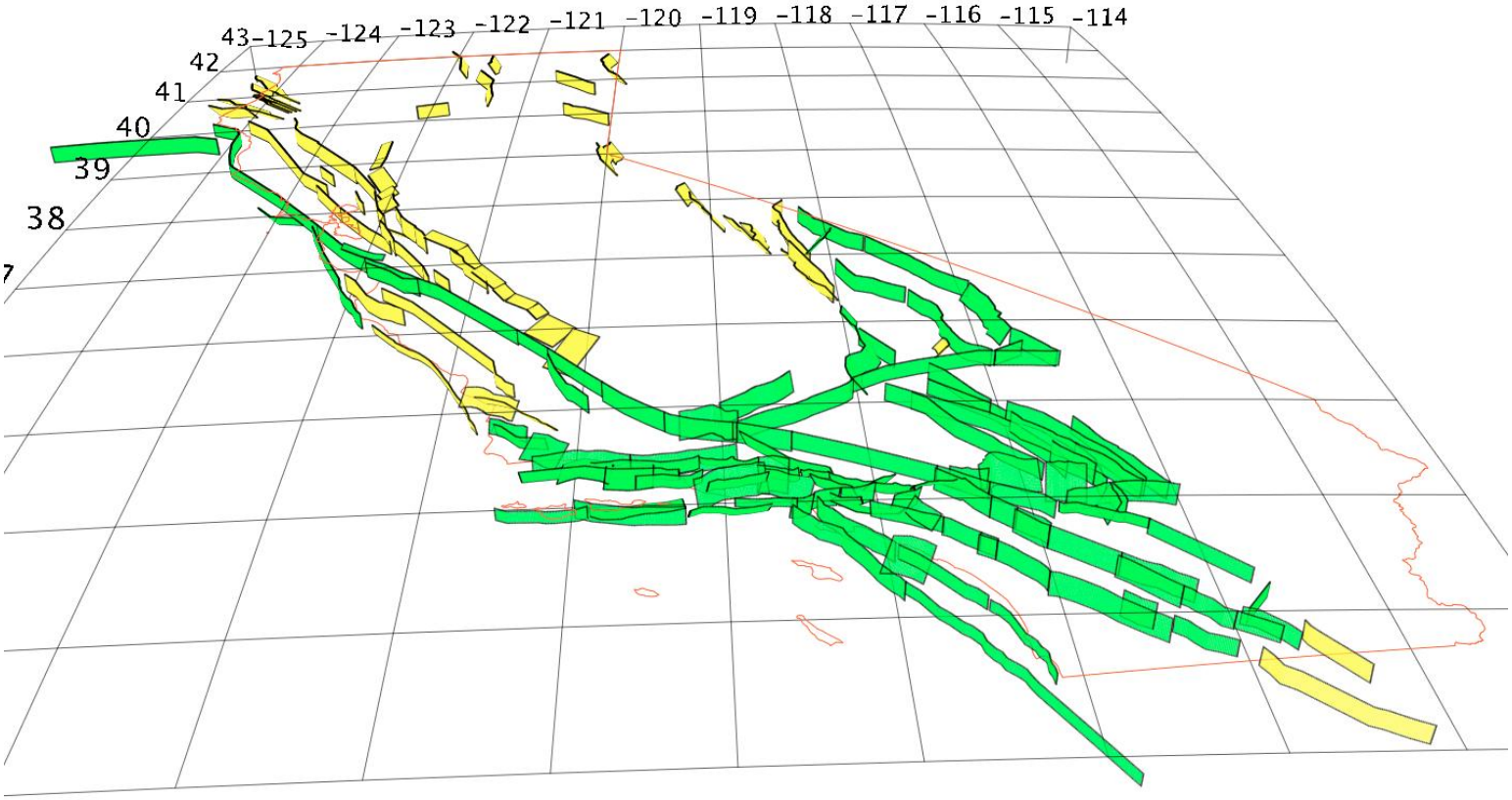
In UCERF-2 these Type-B faults have the option of being connected: all have approximately the same orientation and estimated slip rates

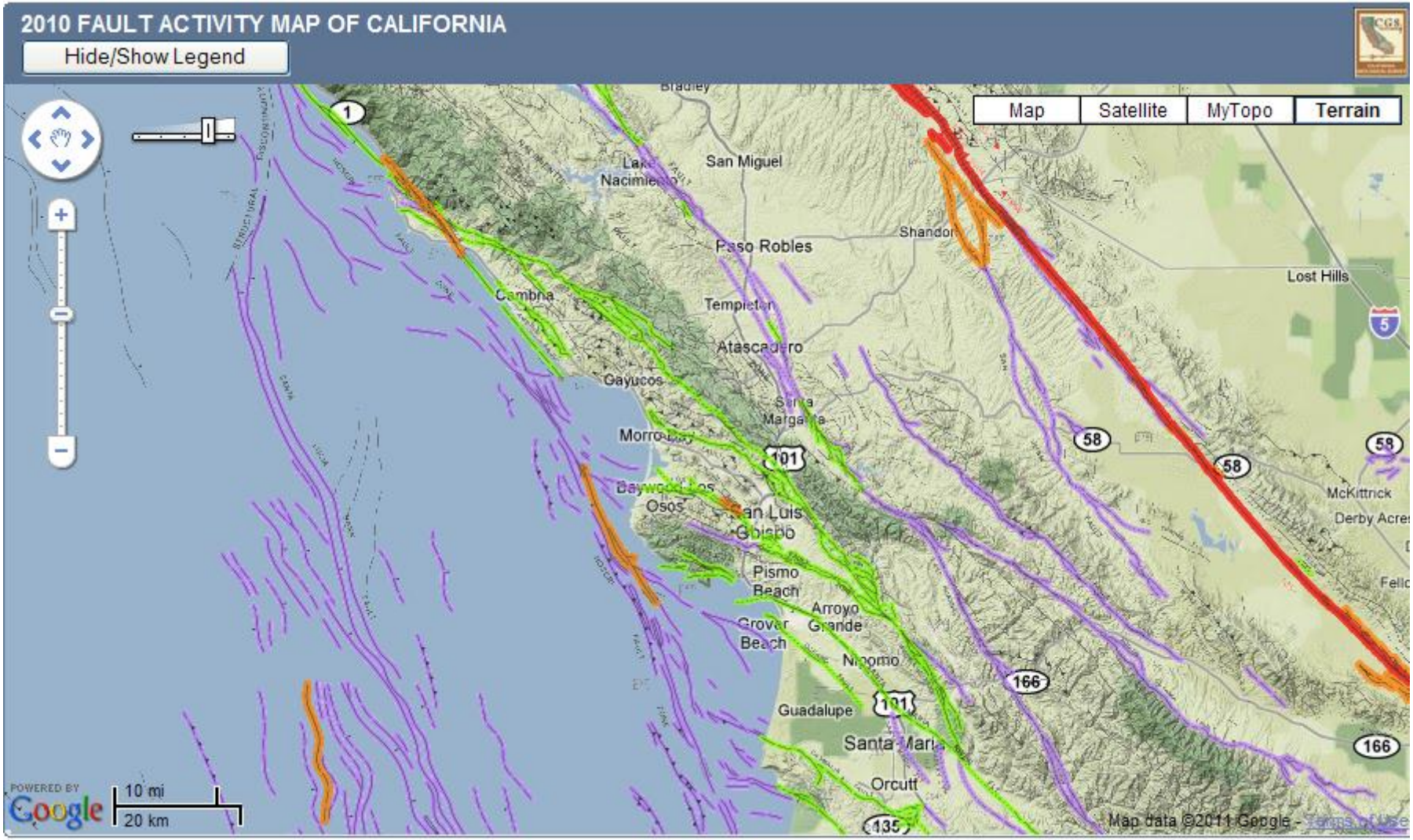


Fault Name	Fault Model	Fault Sections
Palos Verdes	2.1 & 2.2	Palos Verdes Coronado Bank
Newport Inglewood	2.1 (alt 1) & 2.2 (alt 2)	Rose Canyon Newport-Inglewood (Offshore) Newport-Inglewood, alt 1 (or alt 2)
Santa Monica	2.1 (alt 1) & 2.2 (alt 2)	Anacapa-Dume, alt 1 (or alt 2) Santa Monica, alt 1 (or alt 2)
Santa Ynez	2.1 & 2.2	Santa Ynez (West) Santa Ynez (East)
Sierra Madre	2.1 & 2.2	Sierra Madre (San Fernando) Sierra Madre
Death Valley	2.1 & 2.2	Death Valley (No of Cucamongo) Death Valley (No) Death Valley (Black Mtns Frontal) Death Valley (So)
Panamint Valley	2.1 & 2.2	Hunter Mountain-Saline Valley Panamint Valley
Little Salmon	2.1 & 2.2	Little Salmon (Onshore) Little Salmon (Offshore)
Oak Ridge	2.2	Oak Ridge (Offshore), west extension Oak Ridge (Offshore) Oak Ridge (Onshore)
Pitas Point	2.2	Pitas Point (Upper) Ventura-Pitas Point

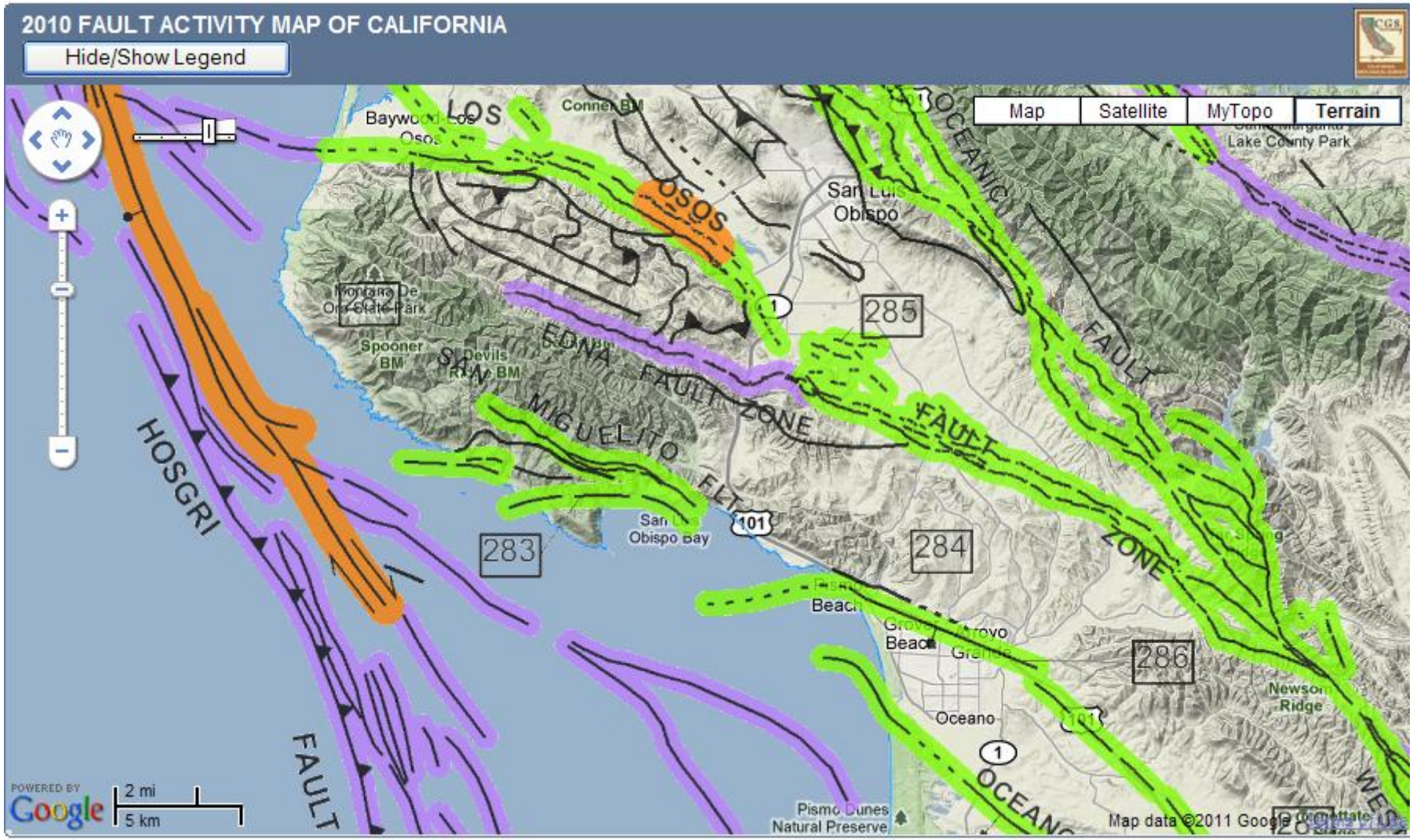
UCERF-3 may consider the possibility that faults can rupture together if there is less than a 5 km gap between their end-points

You can move from any point on the green fault cluster to any other point without jumping more than 5 km (includes 66% of the fault sections). This includes faults of different types and directions of movement, some of which are very unlikely to rupture together. The details of implementation of this concept still need to be worked out.





Fault Activity Map of California by C.W. Jennings and W.A. Bryant, 2010, California Geological Survey Geologic Data Map 7. Available on-line at http://www.conservation.ca.gov/cgs/cgs_history/Pages/2010_faultmap.aspx



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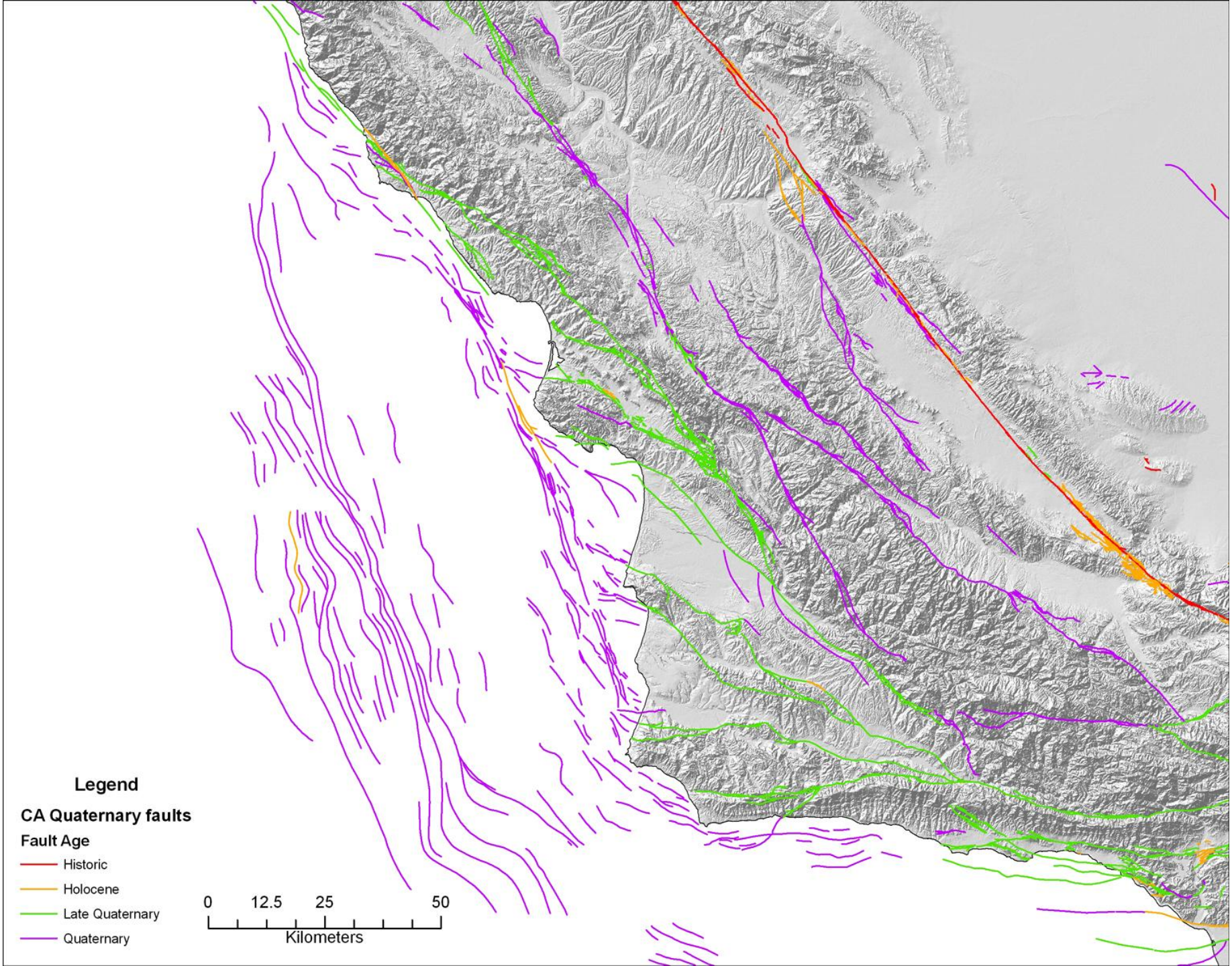
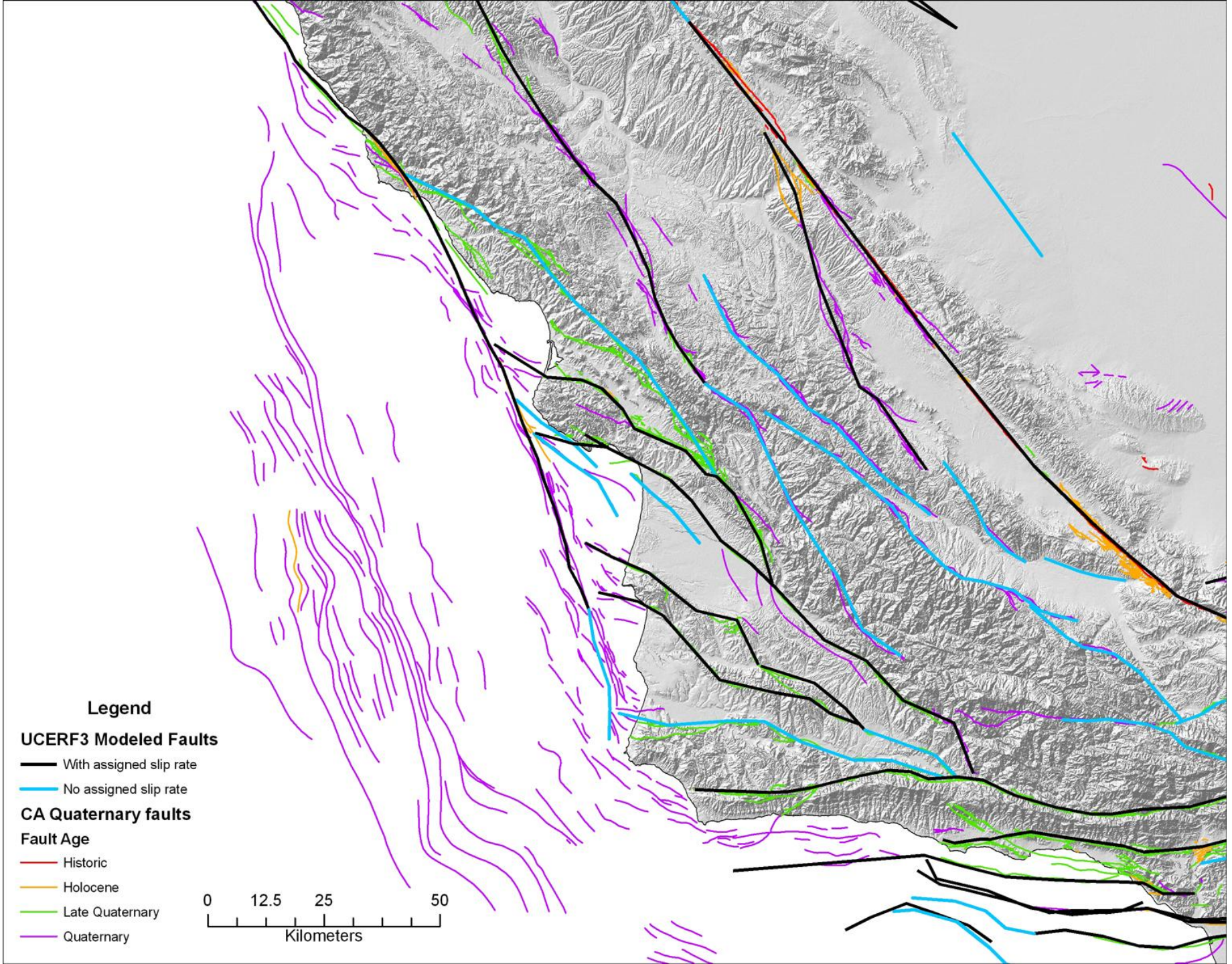
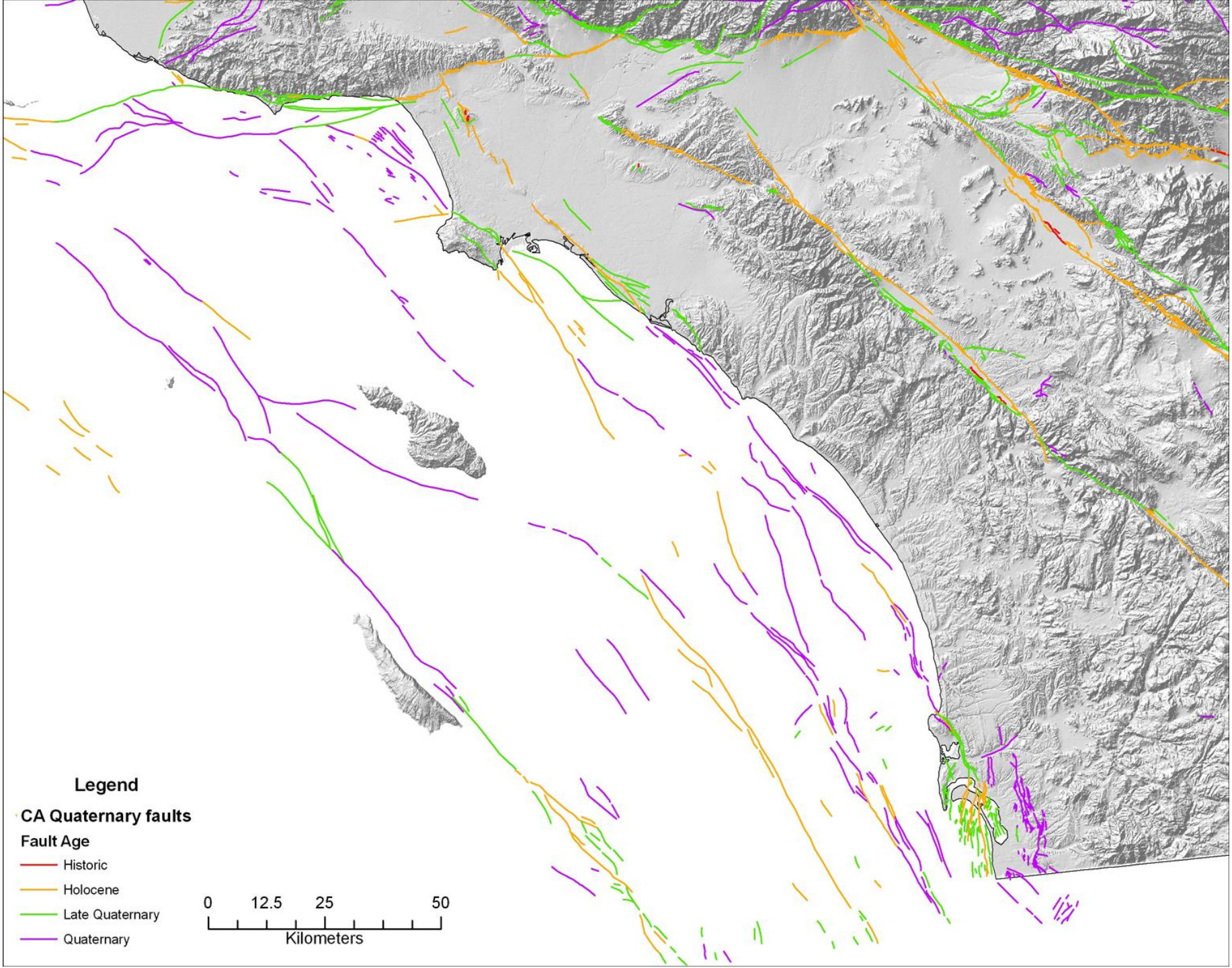

Legend
CA Quaternary faults
Fault Age
Historic
Holocene
Late Quaternary
Quaternary
0
12.5
25
50
Kilometers


Legend
UCERF3 Modeled Faults
With assigned slip rate
No assigned slip rate
CA Quaternary faults
Fault Age
Historic
Holocene
Late Quaternary
Quaternary
0
12.5
25
50
Kilometers


Legend
CA Quaternary faults
Fault Age
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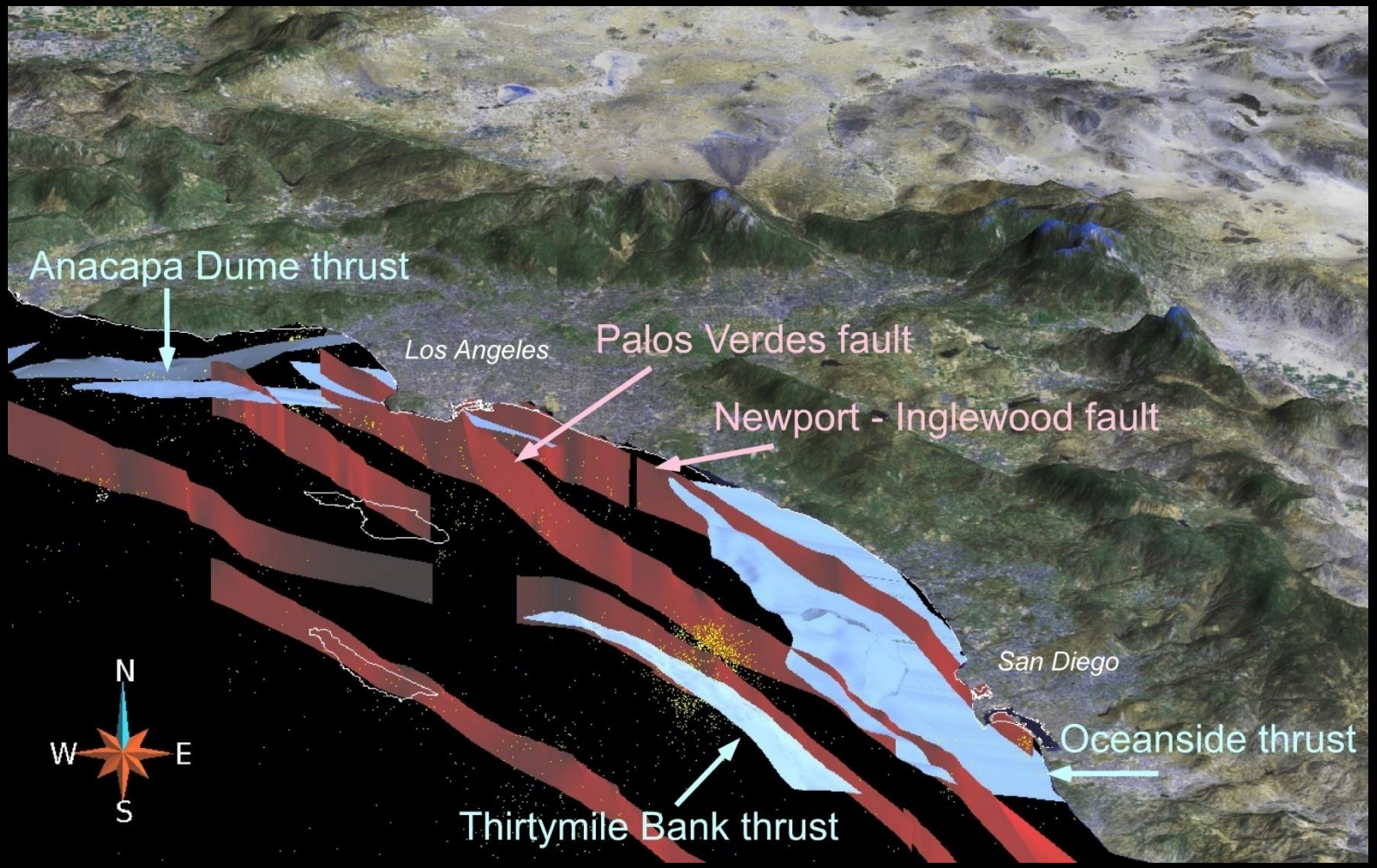
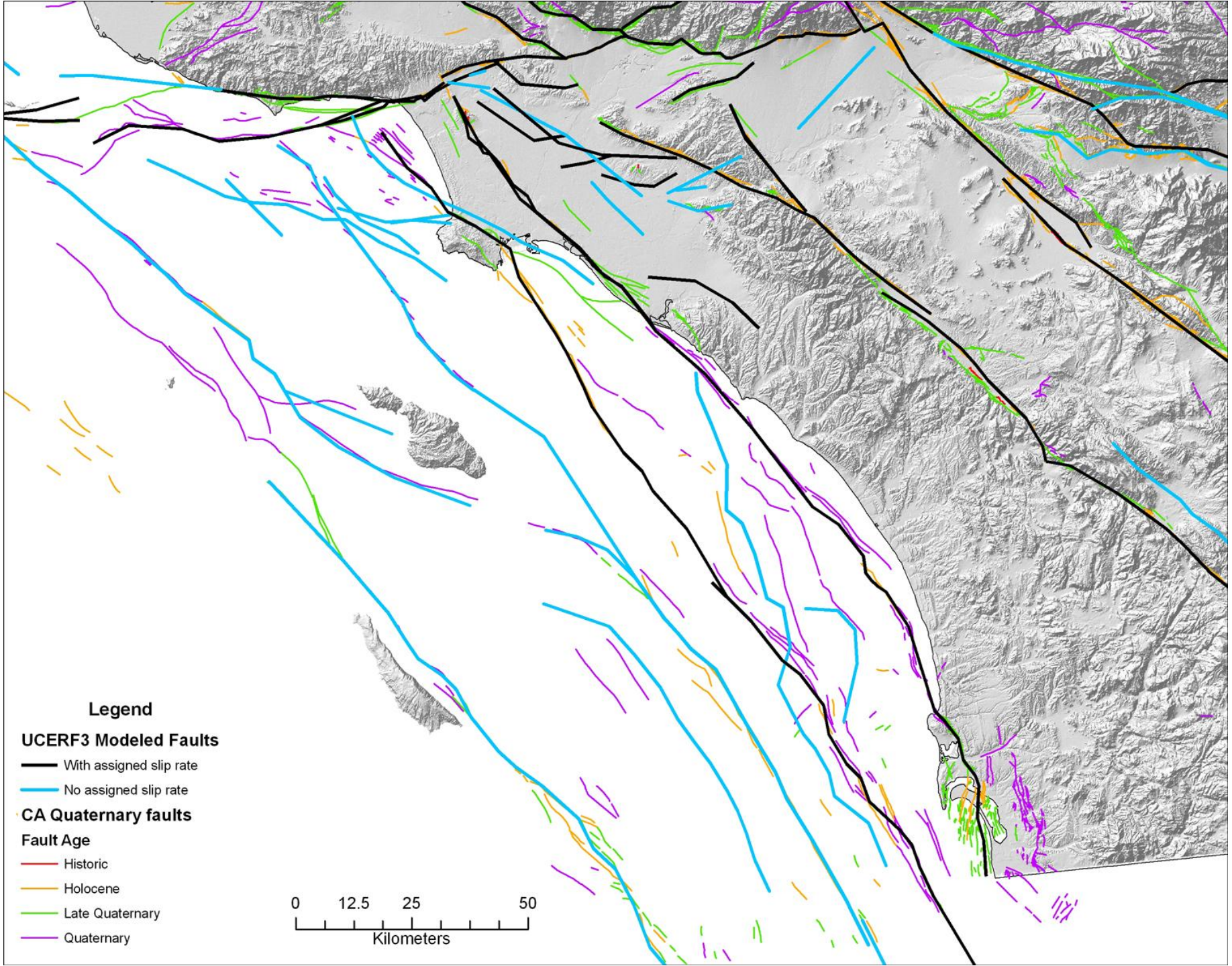
Quaternary
0
12.5
25
50
Kilometers

Thrust faulting in the Inner California Borderlands: *the Oceanside and Thirtymile Bank blind thrusts*



- Our view is that both strike-slip and thrust faults accommodate crustal deformation in the Inner California Borderlands.
- Challenges are to define the recent activity, slip rates, and seismogenic potential of these faults, including the blind thrust systems.


Legend
UCERF3 Modeled Faults
With assigned slip rate
No assigned slip rate
CA Quaternary faults
Fault Age
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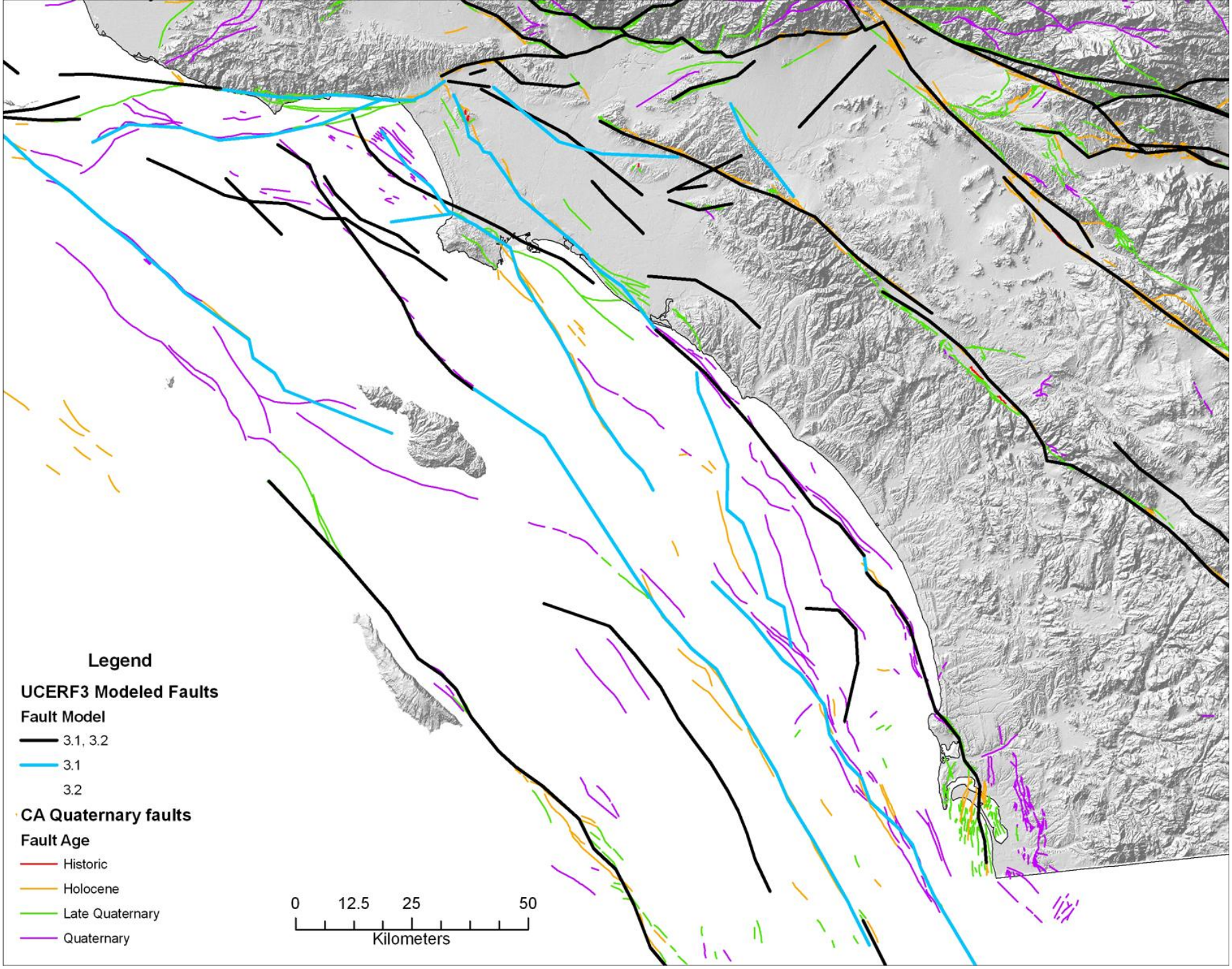
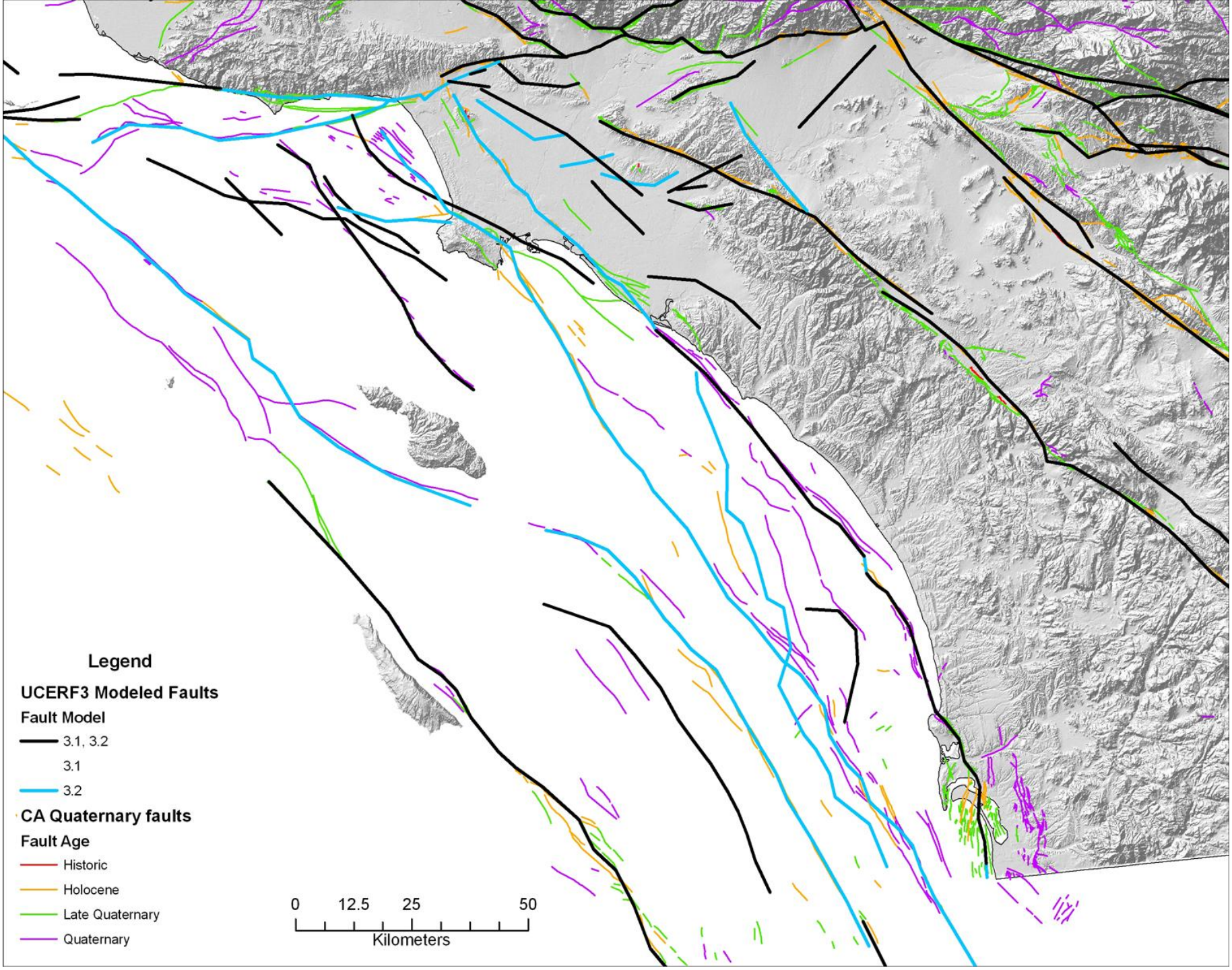
Holocene
Late Quaternary
Quaternary
0
12.5
25
50
Kilometers


Legend
UCERF3 Modeled Faults
Fault Model
3.1, 3.2
3.1
3.2
CA Quaternary faults
Fault Age
Historic
Holocene
Late Quaternary
Quaternary
0
12.5
25
50
Kilometers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25
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Research Needs for Improved Understanding of Seismic Hazard Affecting the California Coast

Identification of Active Faults

- High-resolution bathymetry (marine) and LiDAR (land)
- Aeromagnetic survey
- Marine and land gravity surveys
- New and reprocessed seismic reflection surveys
- Augment existing land-based seismic stations
- New ocean bottom seismic stations

Recency of Faulting

- Detailed geologic investigations to date fault offsets
- High-resolution seismic surveys
- Sampling of marine deposits (ROV & piston core)

Seismic Potential

- Detailed geologic investigations to establish slip rates
- Augment existing land and island GPS stations
- New ocean floor GPS