Characterizing the Seismic Setting Offshore Southern California

Neal Driscoll (SIO) and Graham Kent (UNR)

Shannon Klotsko, Alistair Harding, James Holmes, Valerie Sahakian, Mackenzie Roberts, Leanne Hirsh, George Murray, Jillian Maloney (SIO)

Annie Kell, Steve Wesnousky, Jayne Bormann, Mounira Boudjema, John Louie (UNR)

Crews of the R/V Melville, R/V New Horizon, R/V Sproul, R/V Thompson

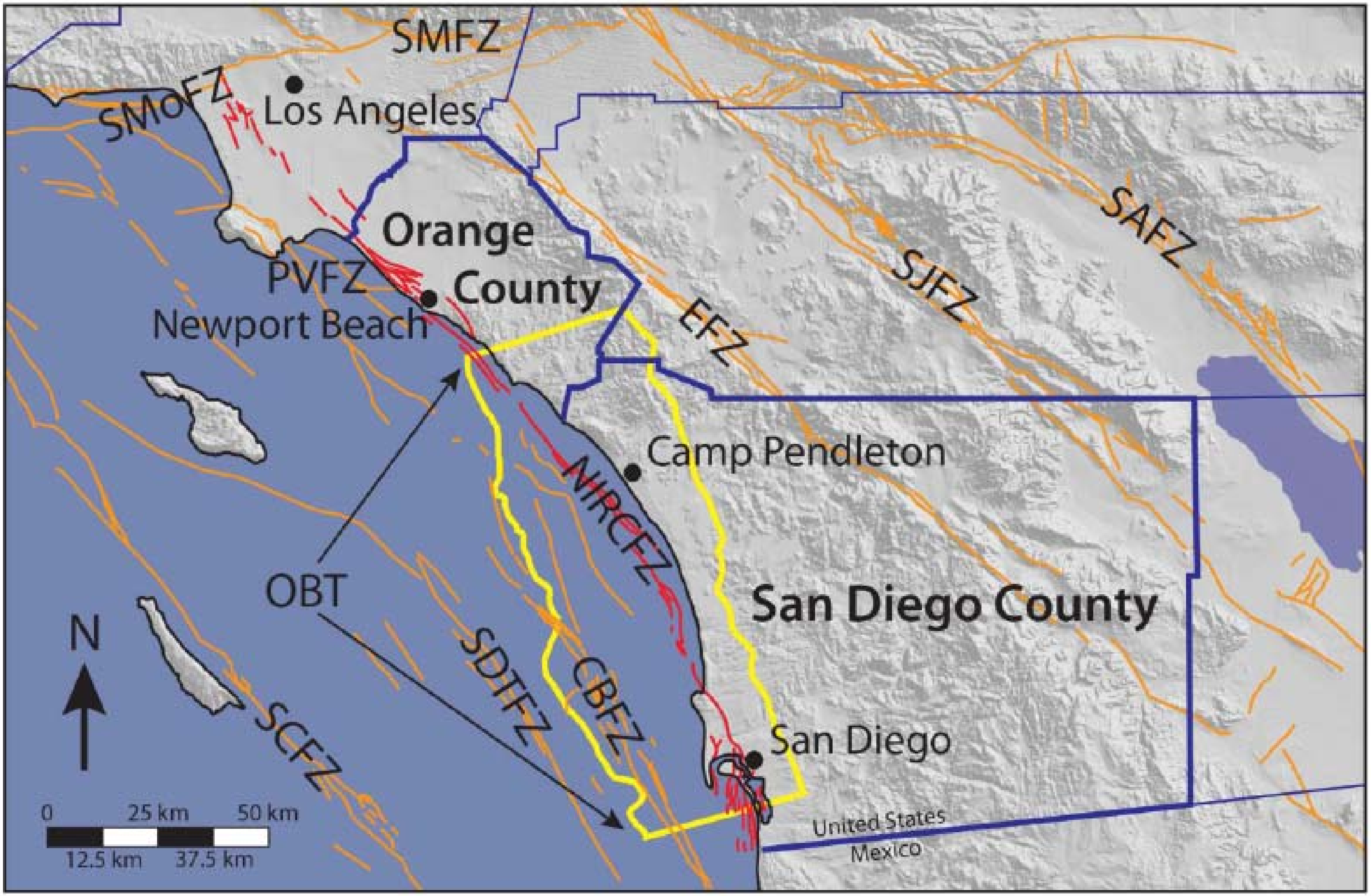
NEVADA Seismological Laboratory

SCRIPPS INSTITUTION OF OCEANOGRAPHY UC SAN DIEGO

Outline

- Assessing alternative models for recent offshore deformation and seismic hazard - Hypothesized Oceanside Blind thrust vs. segmented strike-slip faults
- Characterization of the Newport Inglewood/Rose Canyon Fault segmentation, rupture implications
- Near and far-field Tsunami Hazard for the Inner California Borderlands

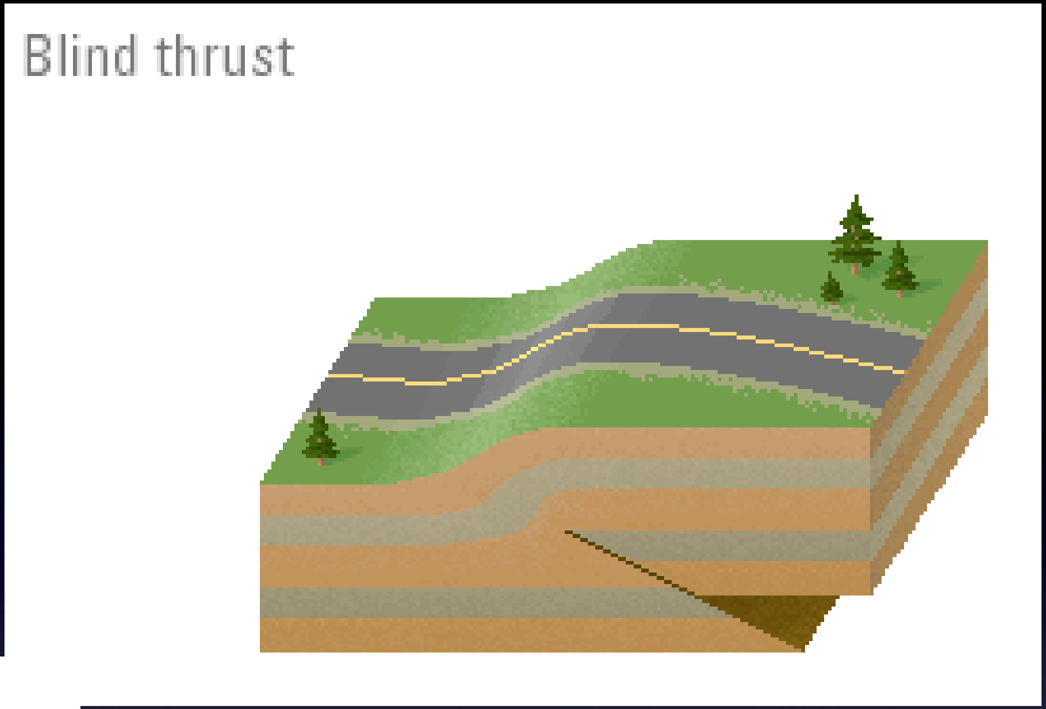
Seismic Sources for SONGS

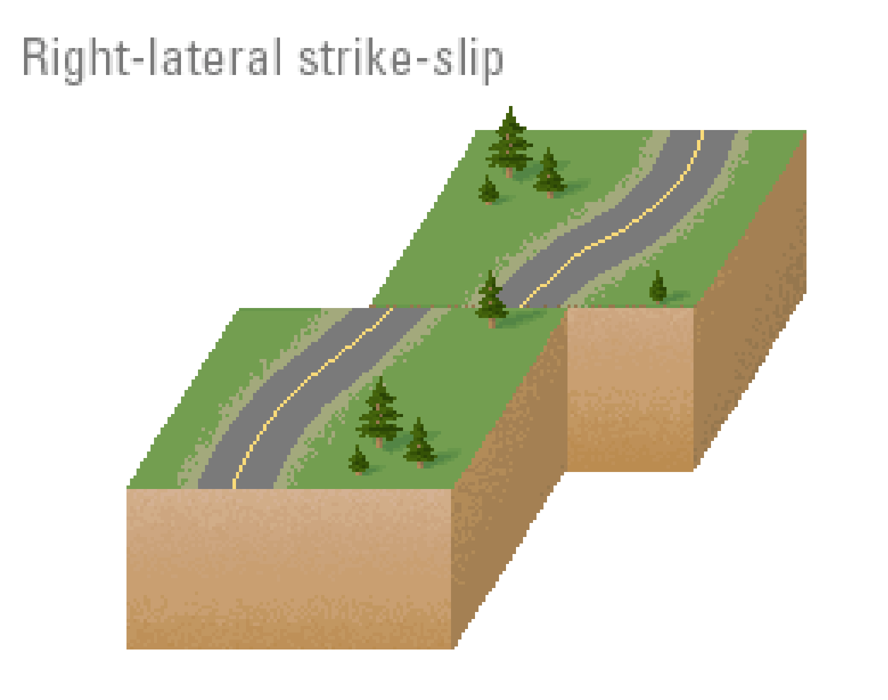


Regional Fault Distance from SONGS

San Andreas - 92 km, 57 miles
San Jacinto - 70 km, 43 miles
Elsinore - 38 km, 24 miles
Newport-Inglewood/Rose Canyon (NIRC) - 8 km, 5 miles
Hypothesized Oceanside Blind Thrust - 7 km, 4.3 miles
Palos Verdes/Coronado Bank - 32 km, 20 miles
San Diego Trough - 46 km, 29 miles
San Clemente - 94 km, 58 miles

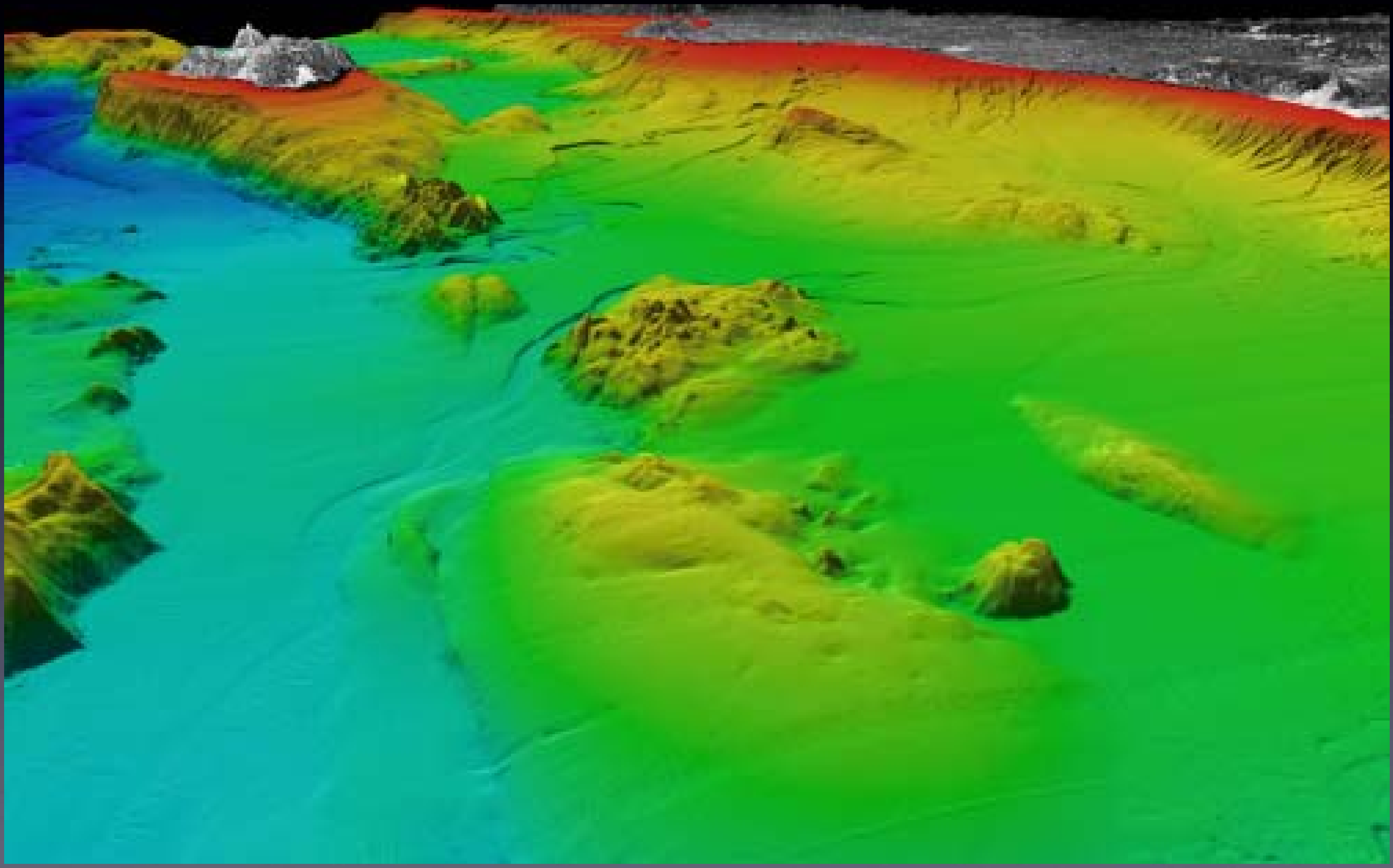
Compression due to horizontal shortening

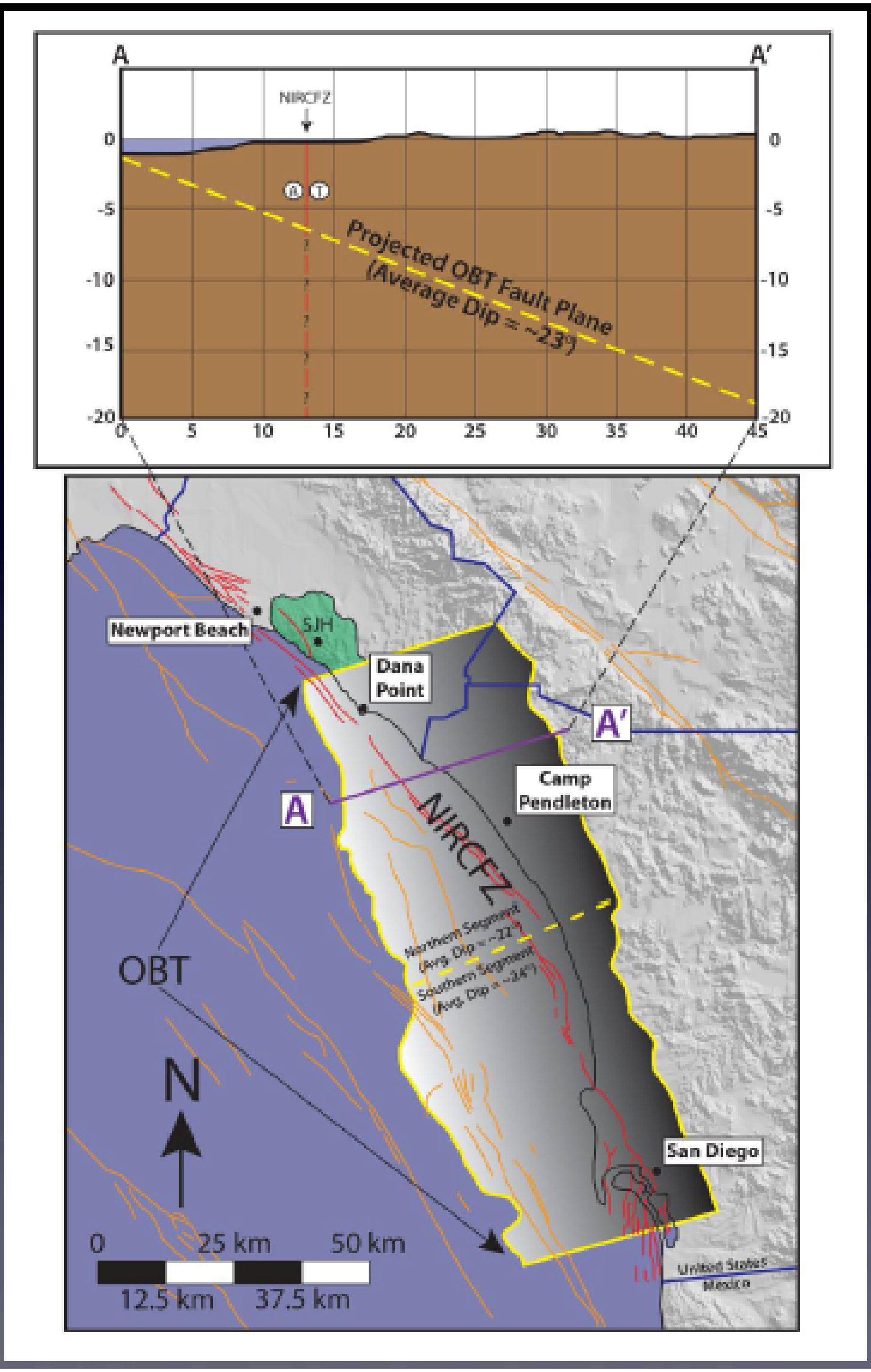




Horizontal motion with little vertical deformation

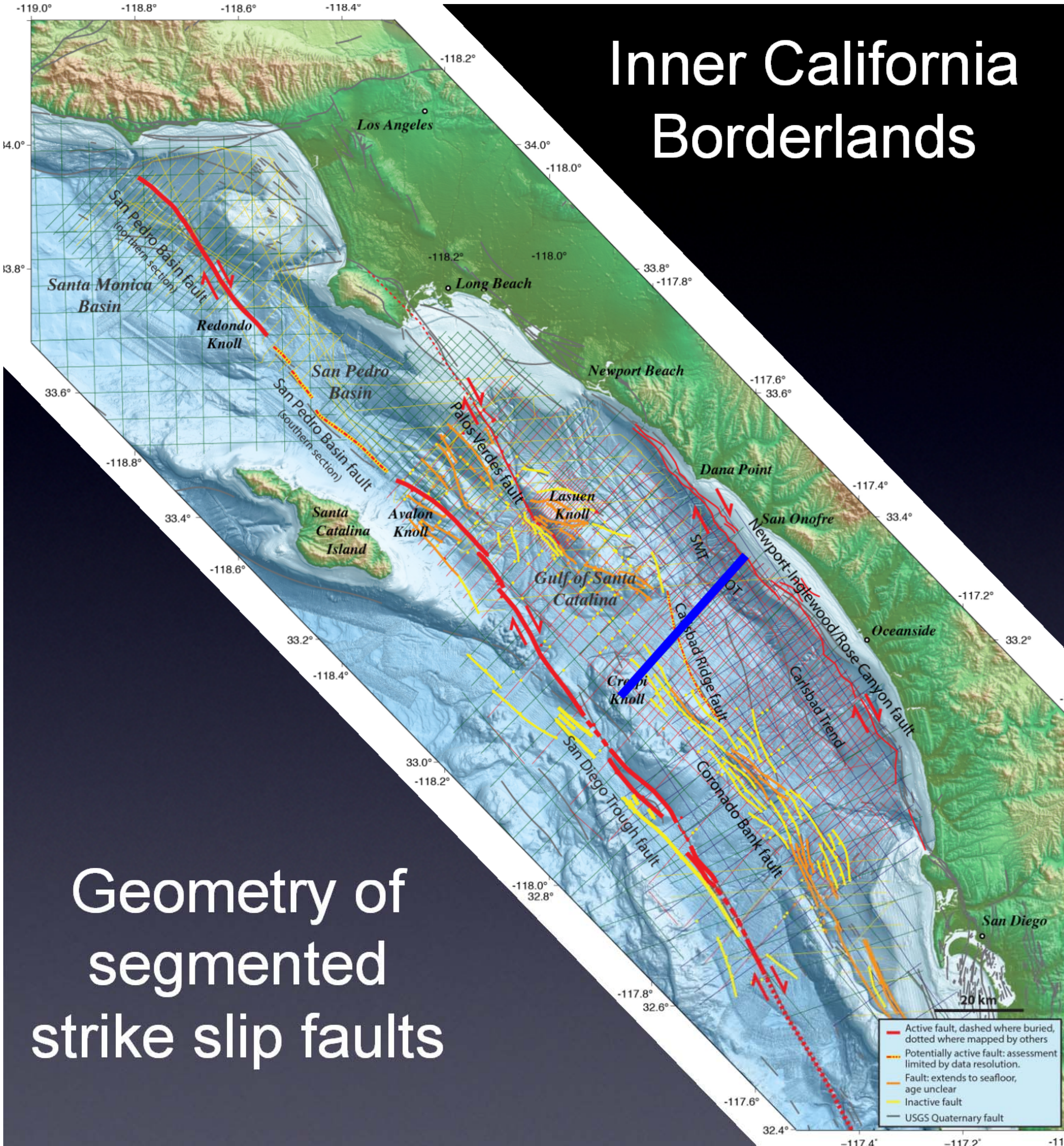
The recent deformation observed offshore has been explained by (1) a hypothesized blind thrust - Oceanside Blind Thrust (OBT) or (2) releasing and constraining bends along segmented strike-slip fault systems

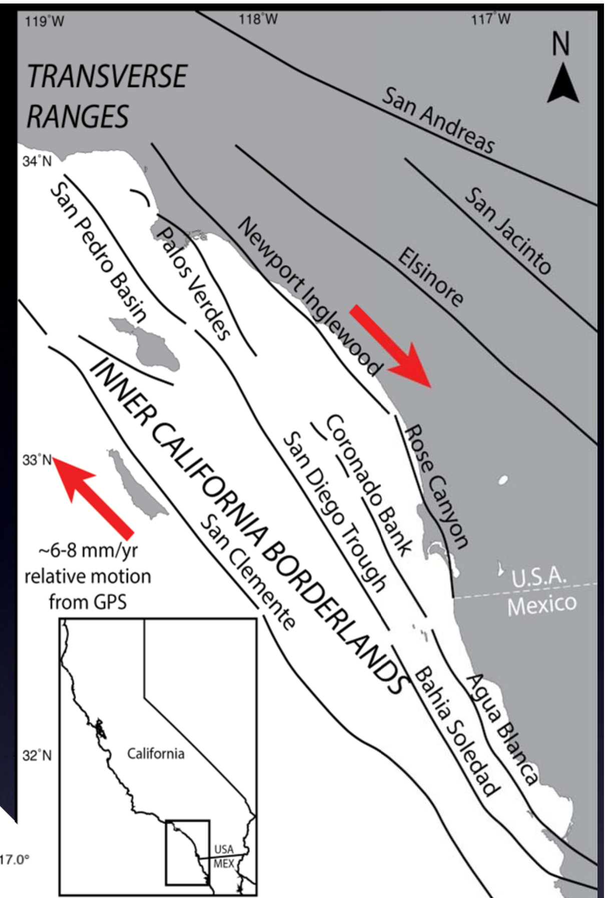




Geometry and extent of the hypothesized Oceanside Blind Thrust

Inner California Borderlands



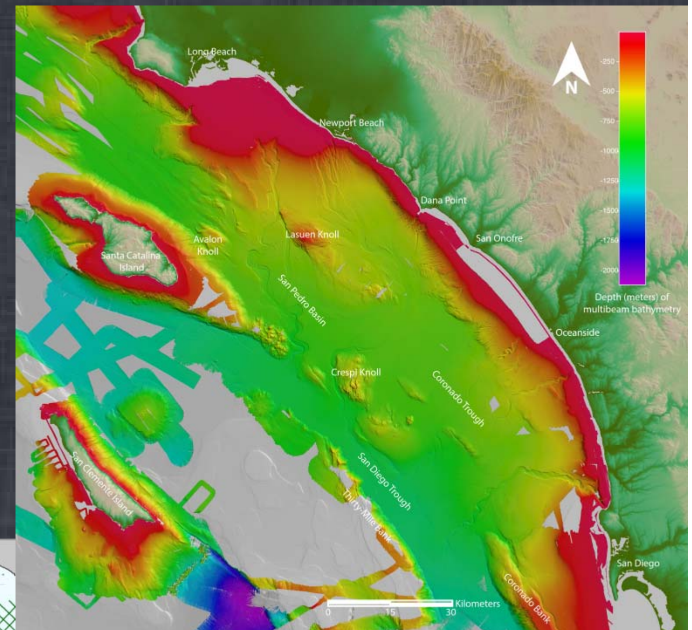


Offshore faults are segmented

Geometry of segmented strike slip faults

Approach to test between the two hypothesis

100 days of geophysical data collection

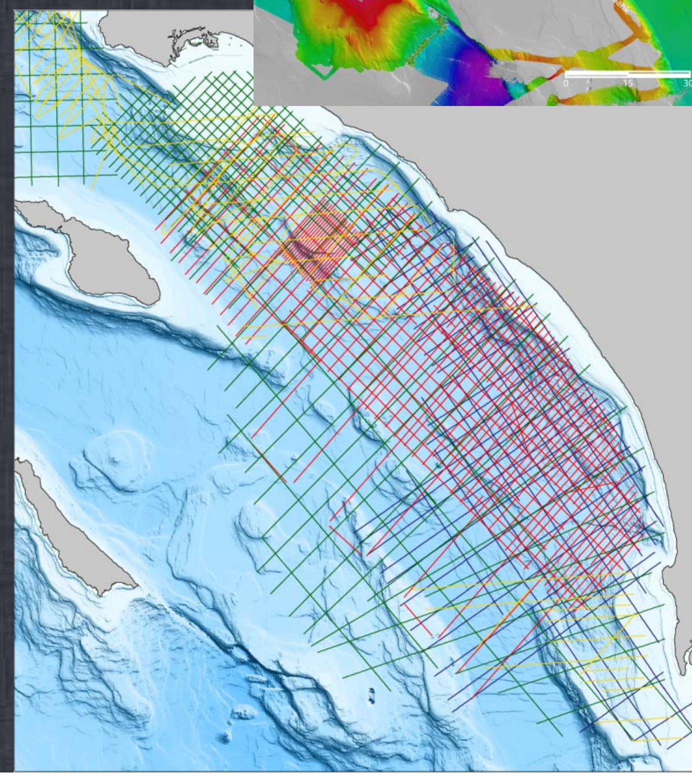


New data includes:

- Multibeam Bathymetry collected with the USGS

Dartnell, Driscoll et al., 2015, Colored shaded-relief bathymetry, acoustic backscatter, and selected perspective views of the inner continental borderland, Southern California, U.S. Geological Survey Scientific Investigations Map 3324, 3 sheets, http://dx.doi.org/10.3133/sim3324.

- 4500 line-km regional grid of 2D high-resolution sparker MCS reflection data
- 100 sq. km of high-resolution 3D data



Additional data includes:

- 2000 line km of reprocessed chevron data

- high-resolution and legacy industry datasets from USGS archives

Nested depth resolution and density of these datasets allow us to image faults in the ICB at an unprecedented scale.

Observations based on Offshore Seismic Surveys

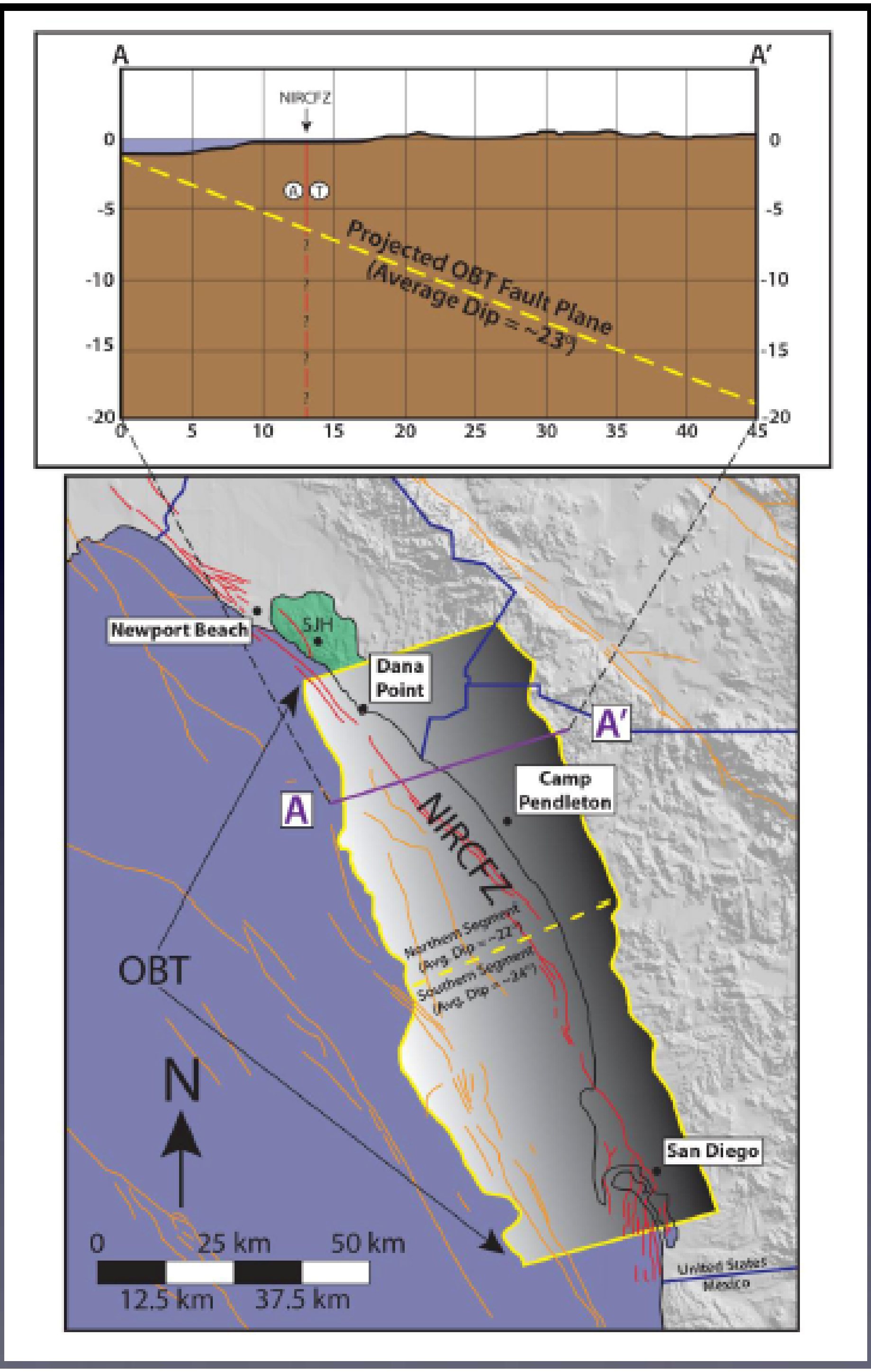
(1) Onlapping sequences reveal that the deformation becomes younger toward the east

(2) Transport of 'Monterey' blocks is toward the south/ southwest

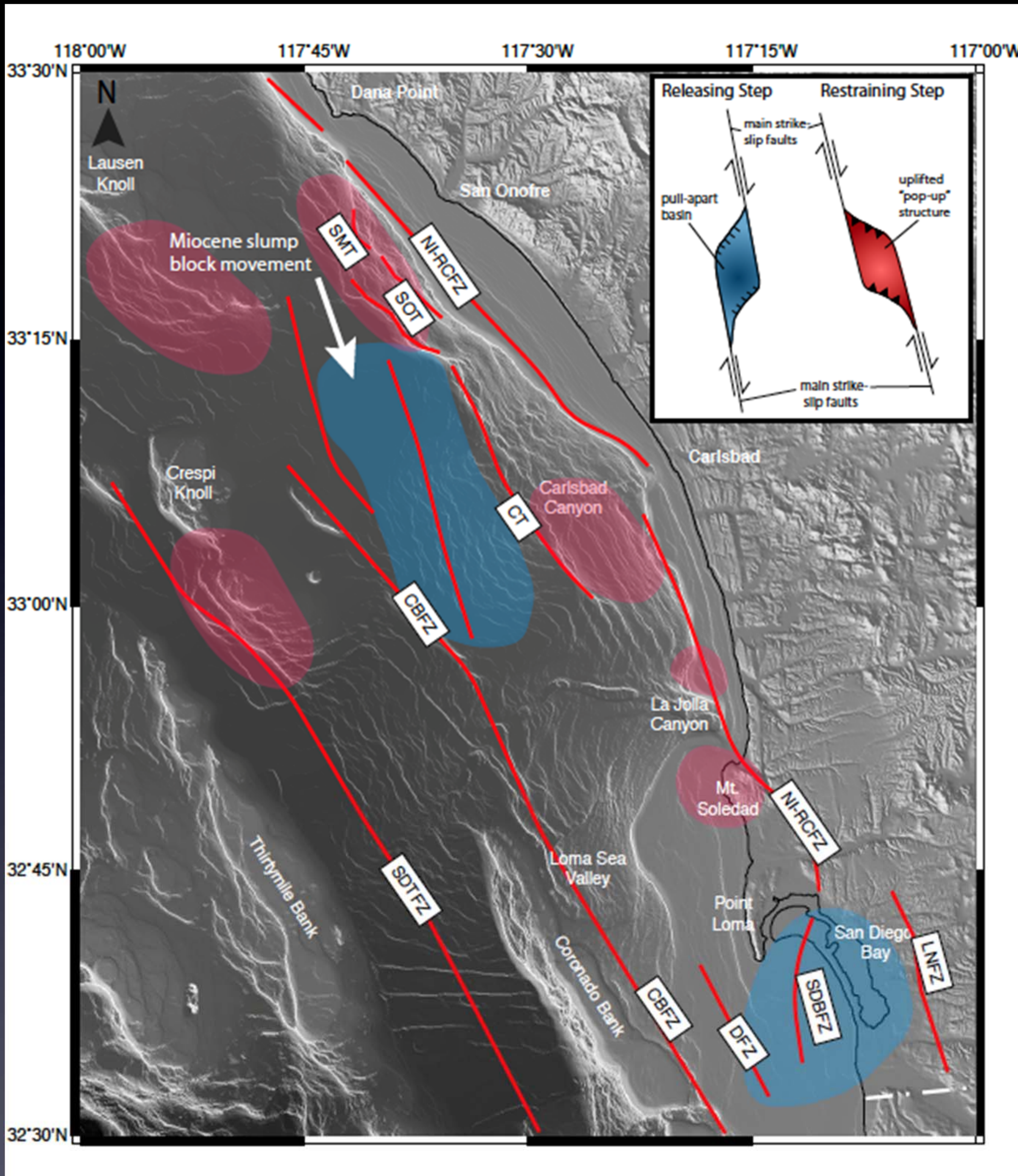
(3) Localized regions of compression and extension

(4) Basin depth increases above Catalina basement markedly toward the south

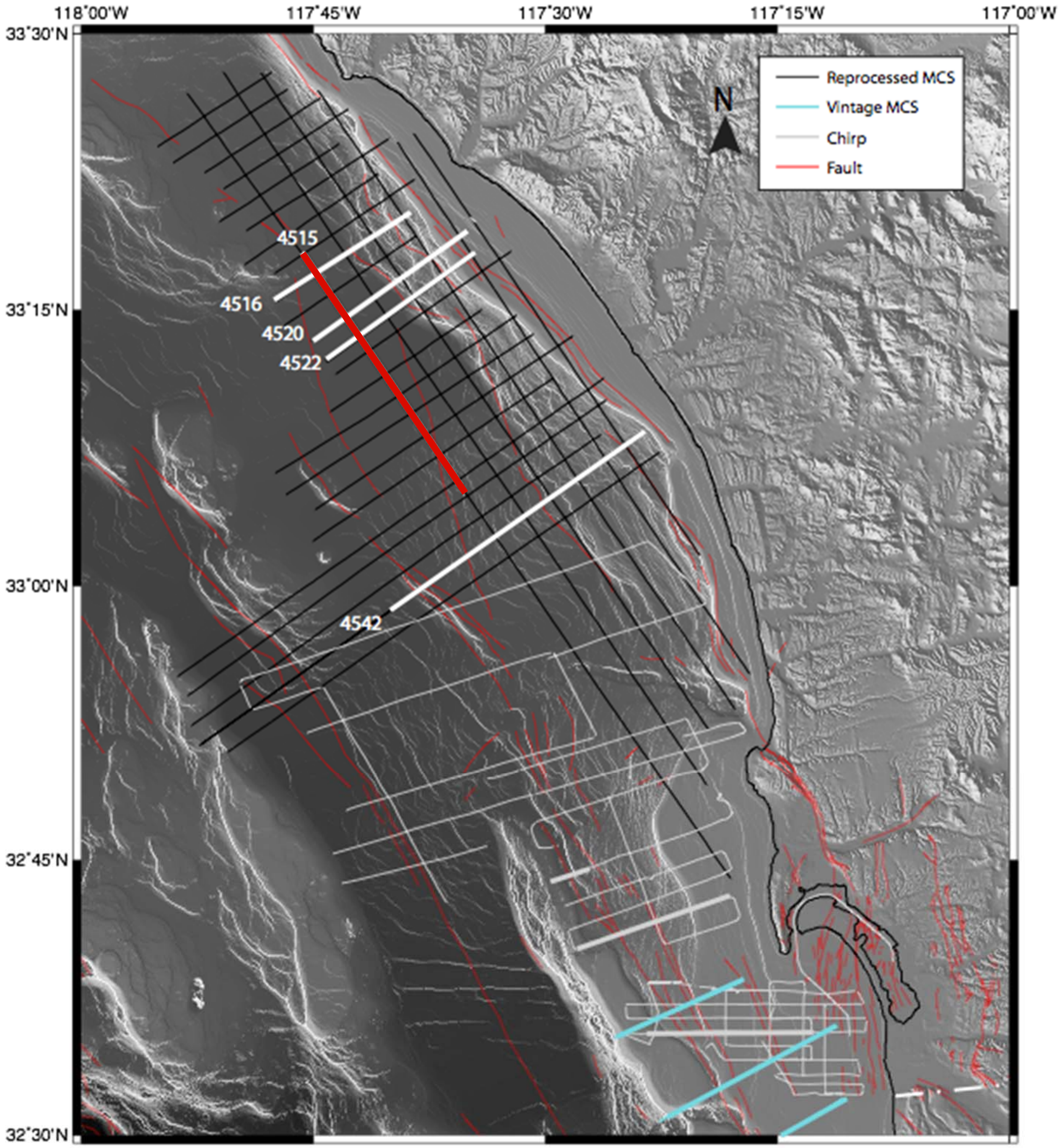
Maloney, J.M., Driscoll, N.W., Kent, G.M., Duke, S., Freeman, T., and Bormann, J.M., 2016, Segmentation and step-overs along strike-slip fault systems in the Inner California Borderlands: implications for fault architecture and basin formation, *in* Anderson, R., and Ferriz, H., eds., Applied Geology in California: Association of Environmental and Engineering Geologists, Special Publication Number 26: 655- 677.



Offshore observations are not consistent with predictions of the hypothesized Oceanside Blind Thrust

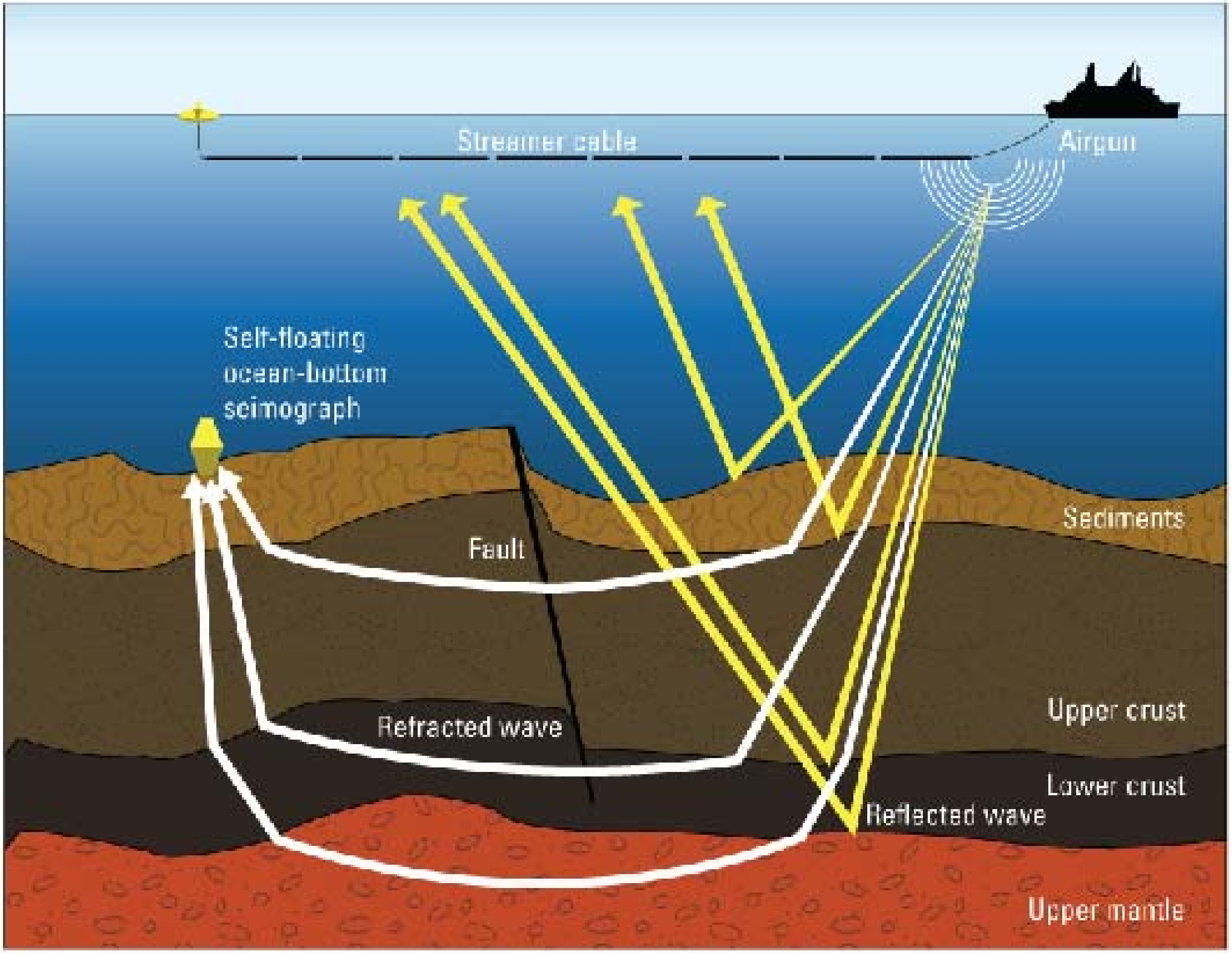


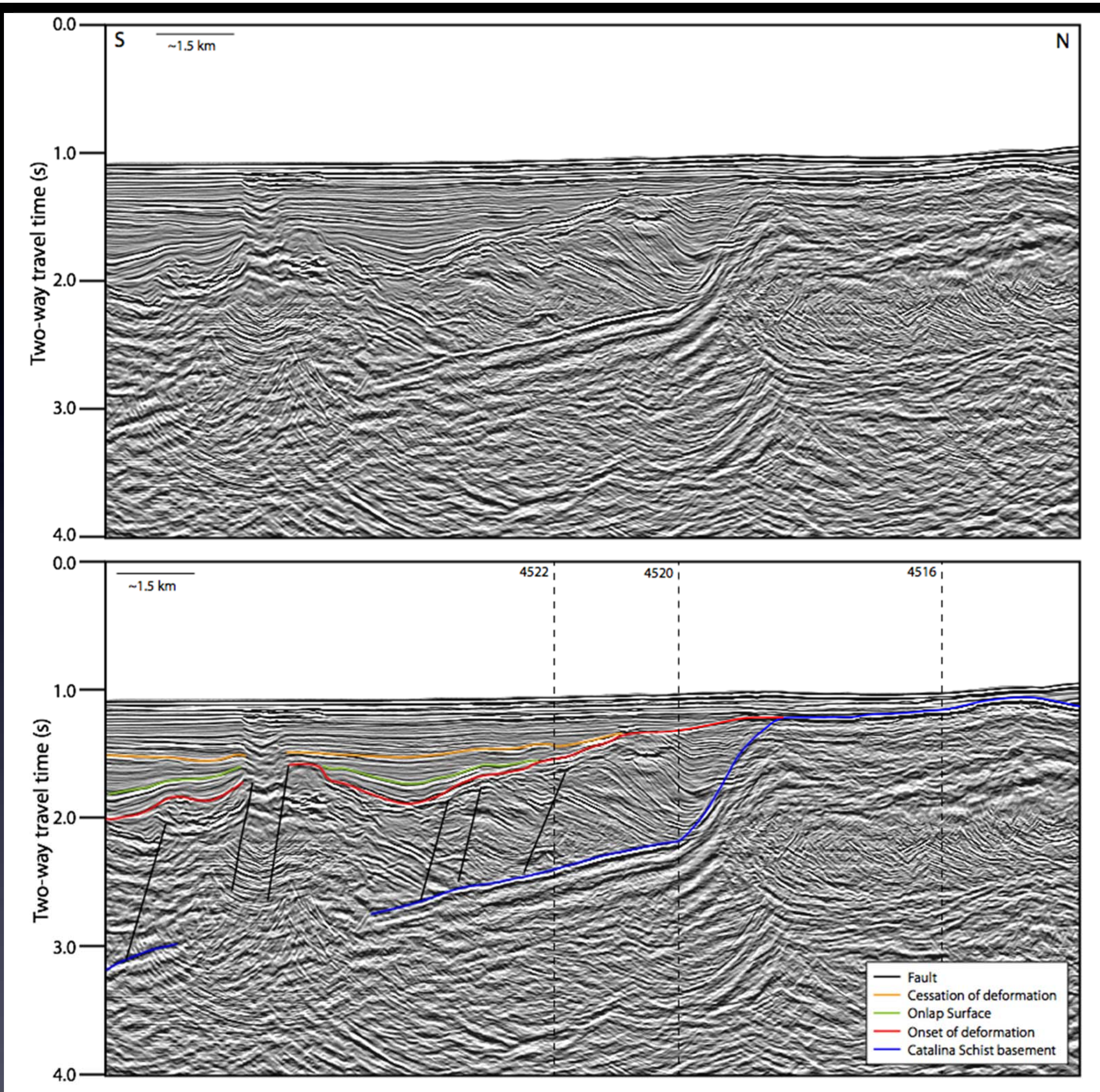
Offshore observations are consistent with the predictions of a segmented strike-slip model



One example of offshore observations:

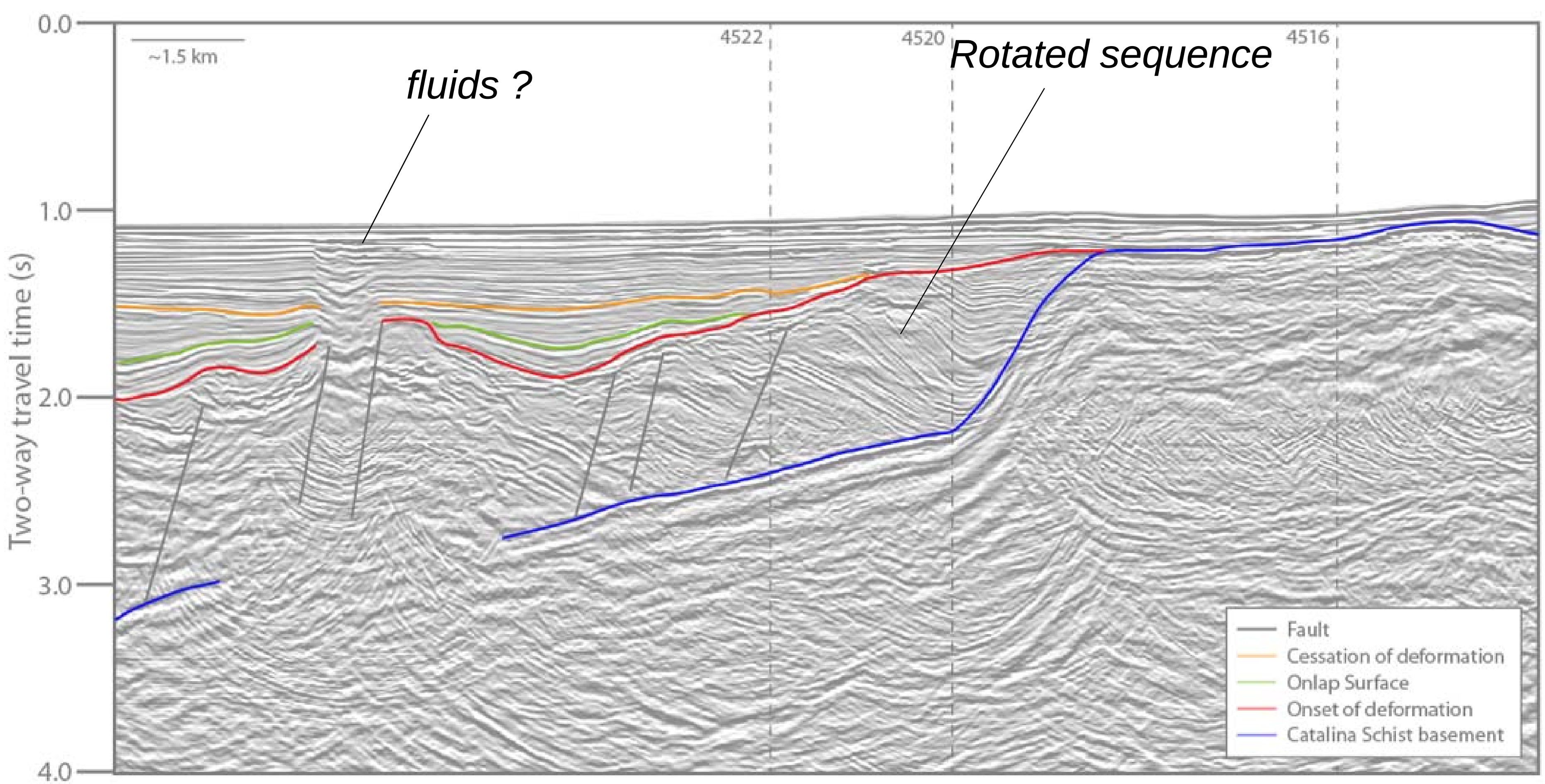
Line 4515 shows that block movement is toward the south not to the west as predicted by the hypothesized Oceanside Blind Thrust


Streamer cable
Airgun
Self-floating
ocean-bottom
scimograph
Fault
Sediments
Refracted wave
Upper crust
Lower crust
Reflected wave
Upper mantle



S
N
~1.5 km
Two-way travel time (s)
0.0
1.0
2.0
3.0
4.0
4522
4520
4516
Fault
Cessation of deformation
Onlap Surface
Onset of deformation
Catalina Schist basement

South North



0.0
1.0
2.0
3.0
4.0
Two-way travel time (s)
~1.5 km
4522
4520
4516
fluids ?
Rotated sequence
Fault
Cessation of deformation
Onlap Surface
Onset of deformation
Catalina Schist basement

Summary - Seismic Sources

- Observations based on the offshore seismic surveys are not consistent with the predictions of the hypothesized Oceanside Blind Thrust (OBT) model

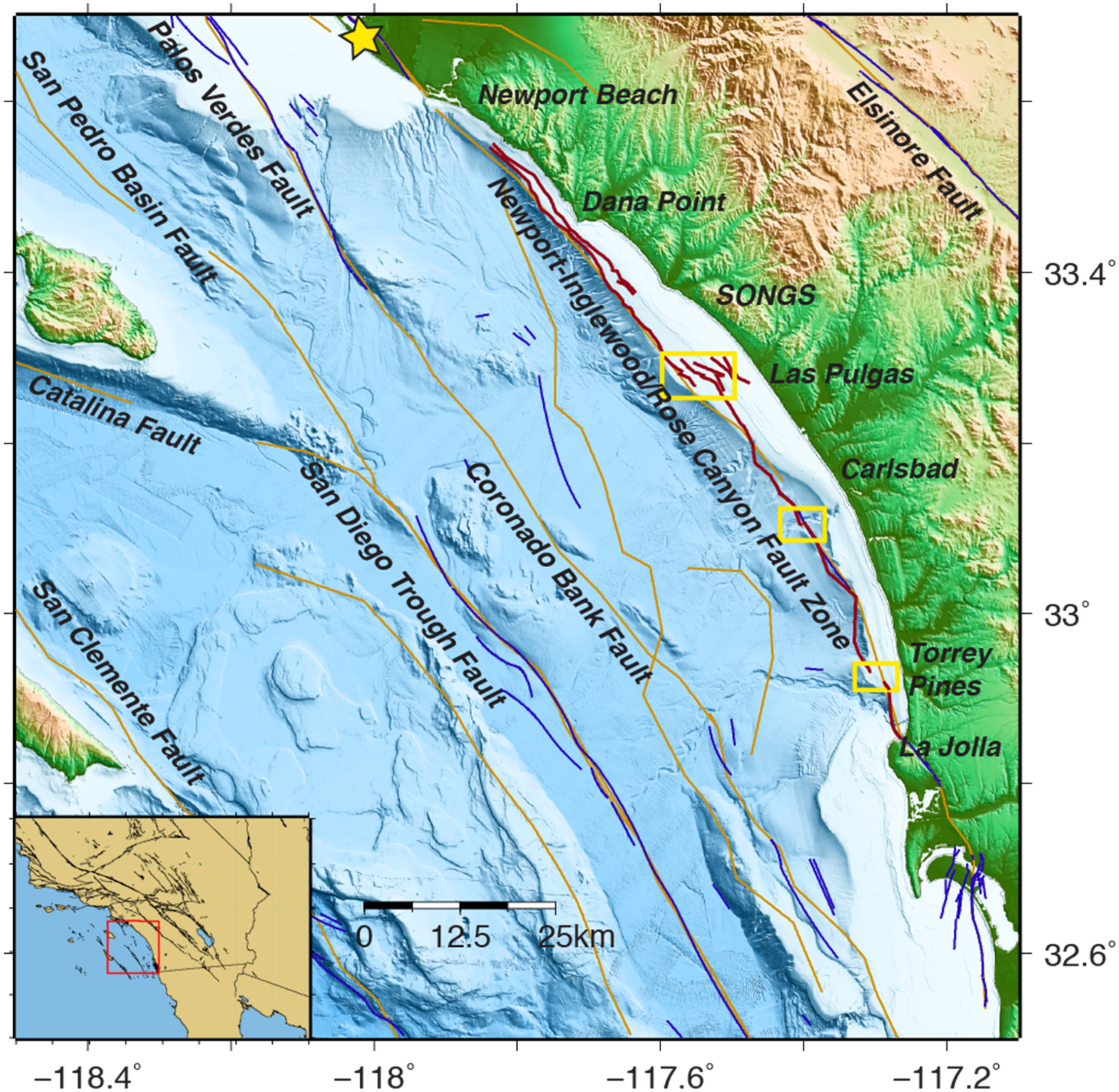
- Observations are consistent with the segmented strike-slip fault model

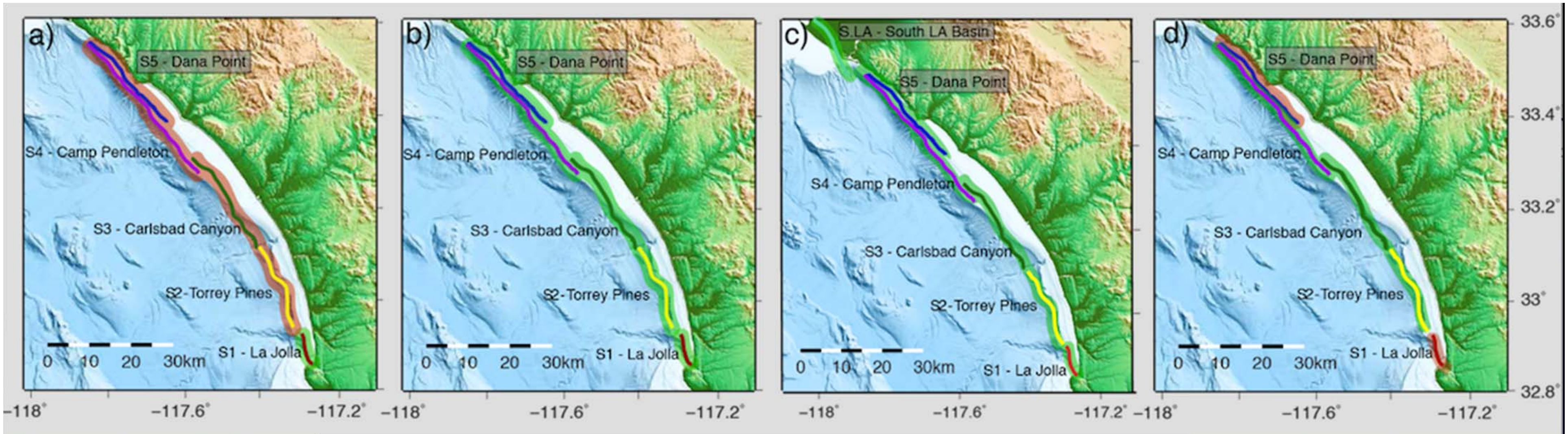
- These results suggest the hazard for coastal regions in southern California is reduced because the slip (0.62 mm/yr) on the purported OBT does not exist

- In addition, there will be no potential hangingwall effects on ground motion or tsunamigenic hazards associated with the OBT

Architecture of the NI/RC Fault

- ✴ Mw 6.4 1933 Long Beach
- ✴ Rose Canyon: 1650 AD +/- 120 years
- ✴ 0.5 - 2 mm/yr
- ✴ stepovers are 2 kilometers or less in width.

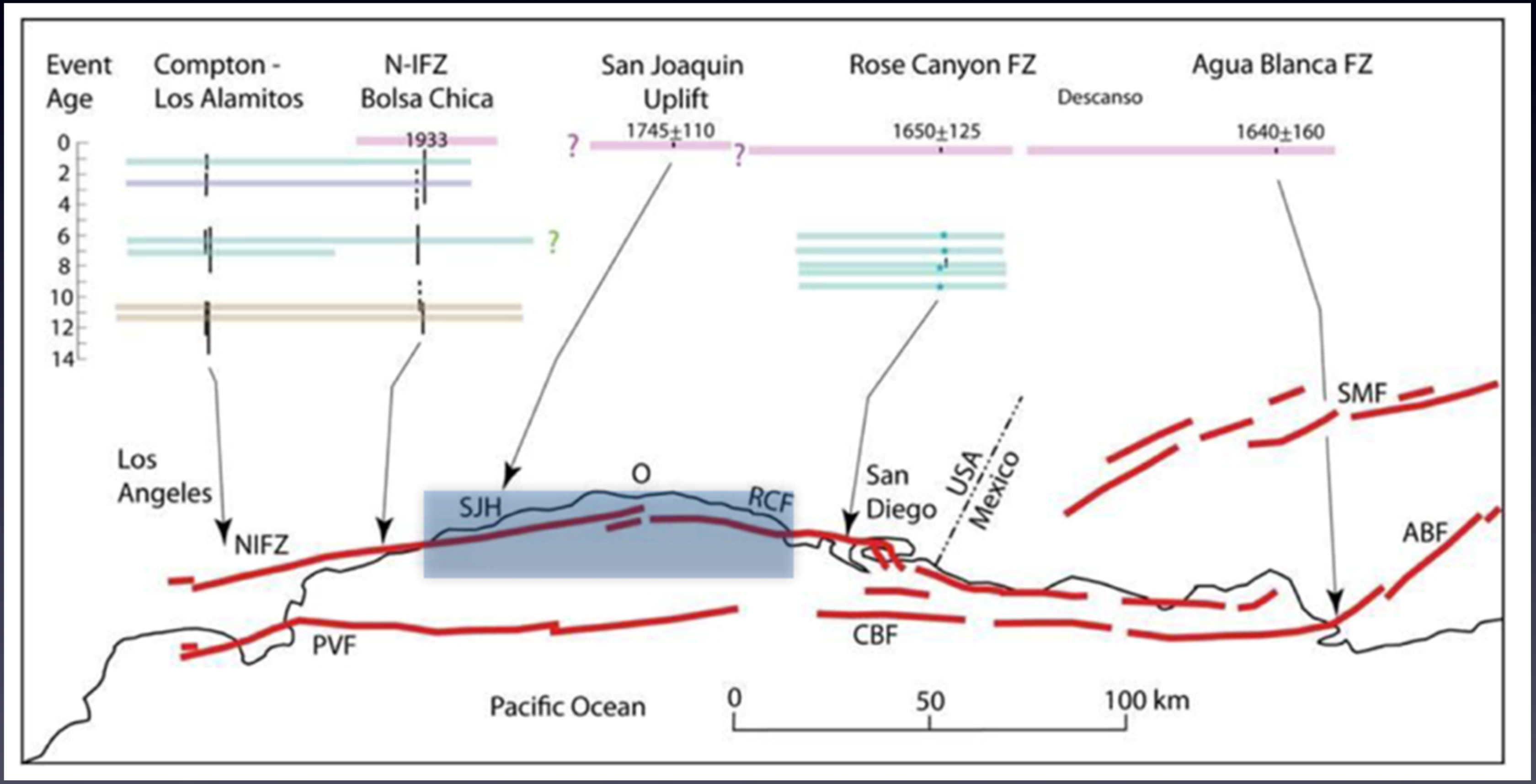




Rupture Scenario	Strands	Total Rupture Length	Wells-Coppersmith	Slip: 0.5 m μ: 20 GPa	Slip: 0.5 m μ: 45 GPa	Slip: 2 m μ: 20 GPa	Slip: 2 m μ: 45 GPa
Scenario I (La Jolla strand – Fig 11)	S1	8 km	M 5.7 ± 0.11	M 6.0	M 6.2	M 6.4	M 6.6
Scenario II (All strands – Fig 12)	S1, S2, S3, S4, S5 (1/2 slip on S4 and S5)	125 km	M 7.3 ± 0.16	M 6.7	M 6.9	M 7.1	M 7.3
Scenario II b (4 strands + Northern onshore segment)	S1, S2, S3, S4, S5, S. LA (1/2 slip on S4 and S5)	158 km	M 7.3 ± 0.16	M 6.7	M 7.0	M 7.1	M 7.4
Scenario III (4 strands – Fig 13)	S2, S3, S4	89 km	M 7.2 ± 0.16	M 6.6	M 6.9	M 7.0	M 7.3

Based on water depth, radiocarbon dating, and sediment rates, the segment of the NI/RC fault offshore SONGS has not ruptured since ~10, 500 - 13, 600 BP

Onshore and offshore data suggest that all segments of the NI/RC have not ruptured together in the past



Klotsko, S, Driscoll, N., Kent, G., Brothers, D. 2015. Continental shelf morphology and stratigraphy offshore San Onofre, California: The interplay between rates of eustatic change and sediment supply. Marine Geology,369:116-126.

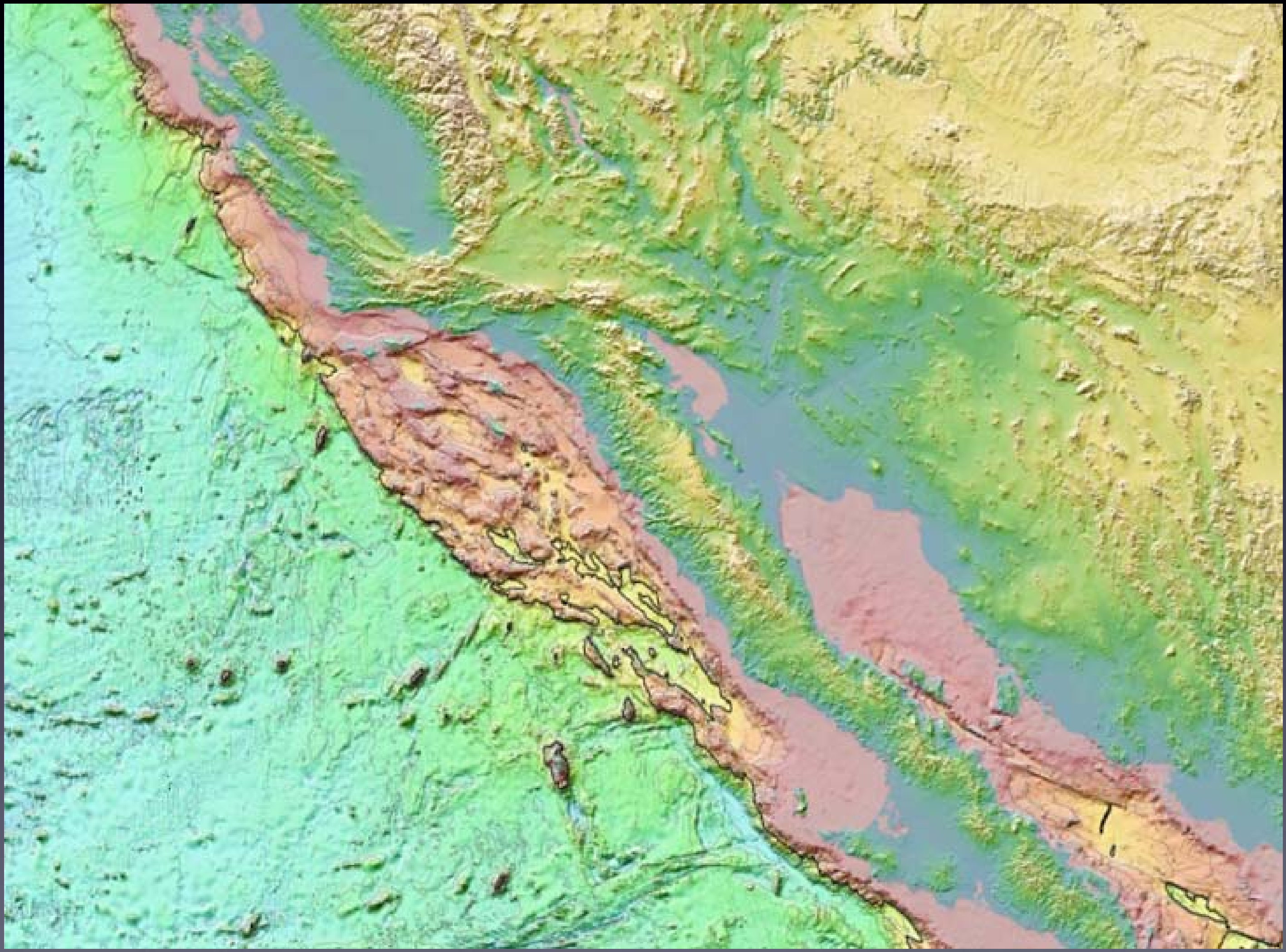
Summary - NI/RC Fault

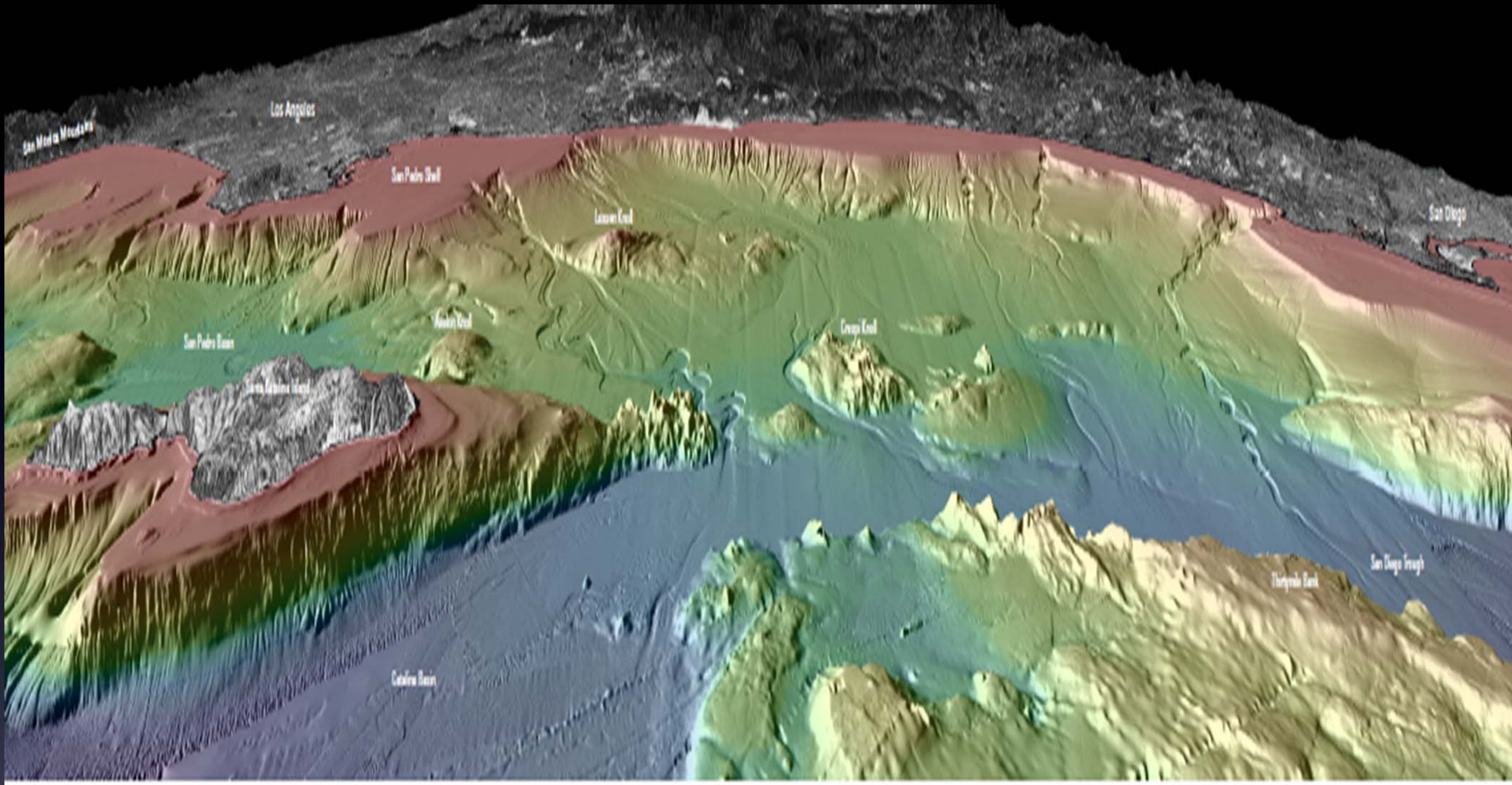
- Four main fault strands of the NI/RC fault are identified, separated by three main stepovers along strike, all of which are 2 kilometers or less in width.

- Based on the new mappings and segment offsets, the offshore portion of the NIRC fault zone could, depending on rupture characteristics, produce an earthquake of up to magnitude Mw 7.3, or Mw 7.4 if a northern onshore segment is included.

- Onshore and offshore data indicate that all segments of the NI/RC have not ruptured together in the past

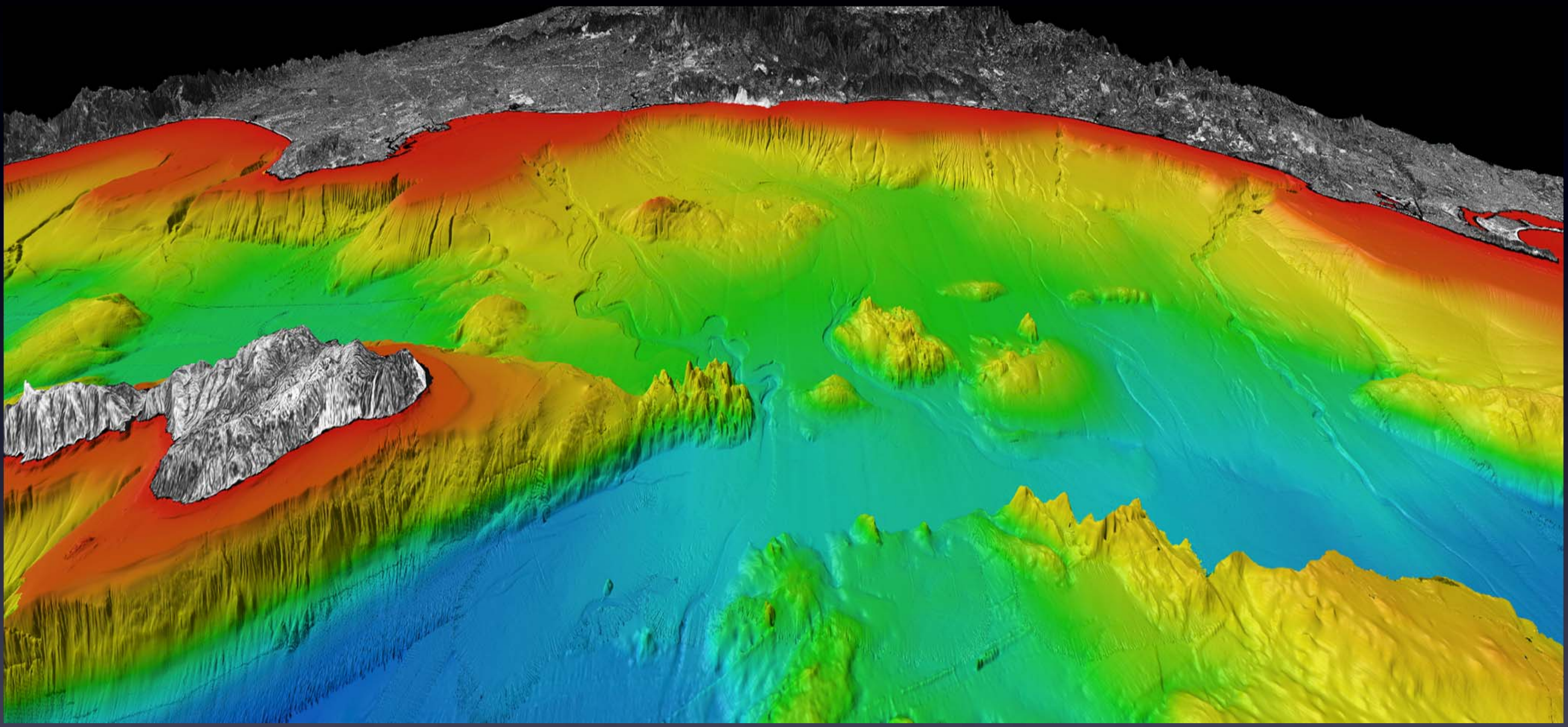
Tsunami Hazard along the Inner California Borderlands: near vs far field sources





Offshore bathymetry in the CA Borderlands consists of numerous shallows and deeps, which interferes with incoming tsunami waves. The offshore bathymetry acts as a natural baffle to tsunami waves.

Evidence for near-field tsunamigenic slope failures



New high resolution seismic and bathymetry data show no signs of past large slope failures that could be tsunamigenic.

Summary - Tsunami Hazard

- The irregular bathymetry of the Inner California Borderlands acts as a natural baffle to far-field tsunamis.

- Potential near-field tsunamis sources are engendered by earthquakes on local fault systems or by slope failure
- The largest historical tsunami wave height in California was 4.5 m, reported in October 1868 in the San Francisco Bay region.