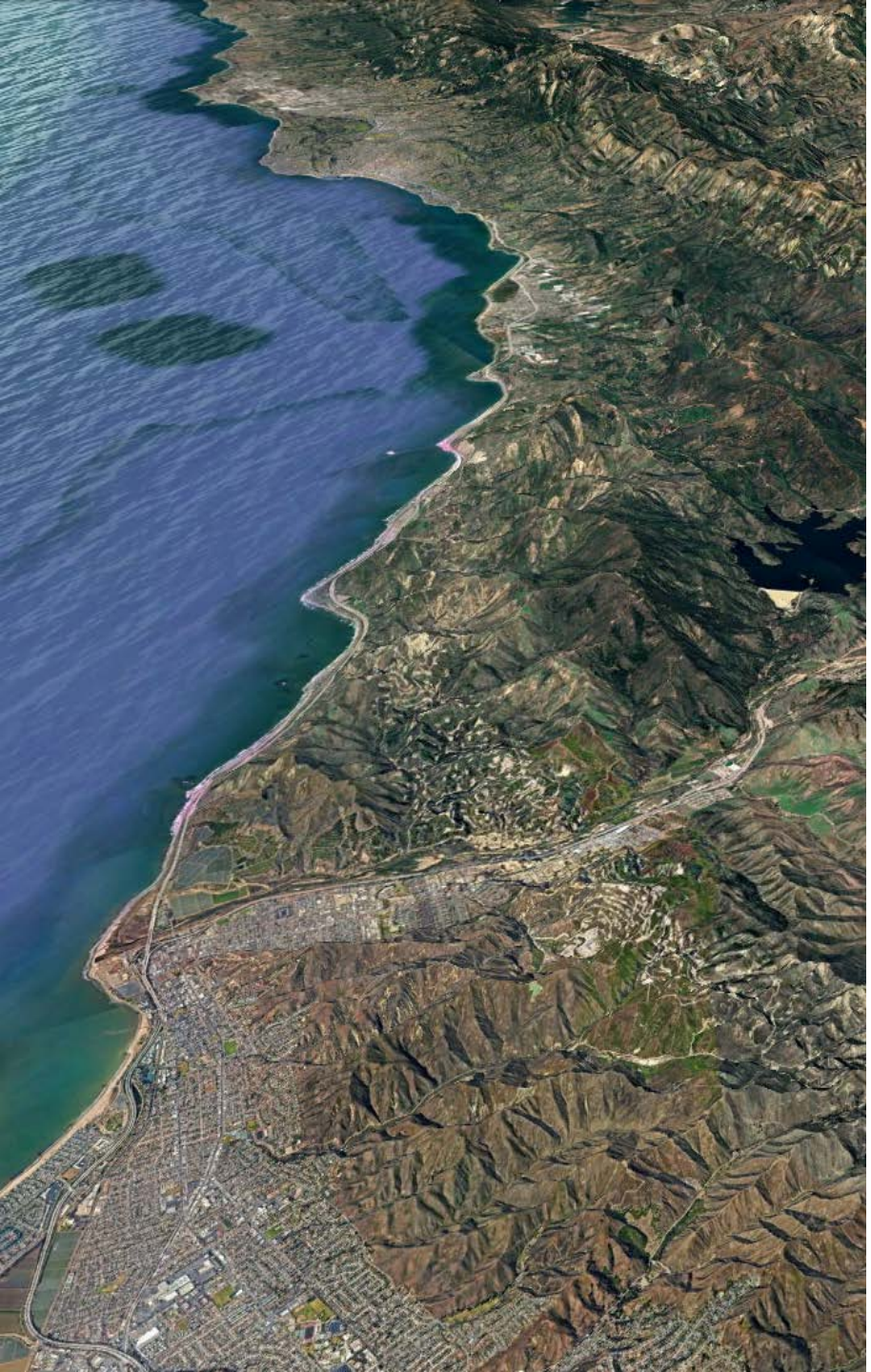


2025 SCEC Santa Barbara Earthquake Workshop, June 30

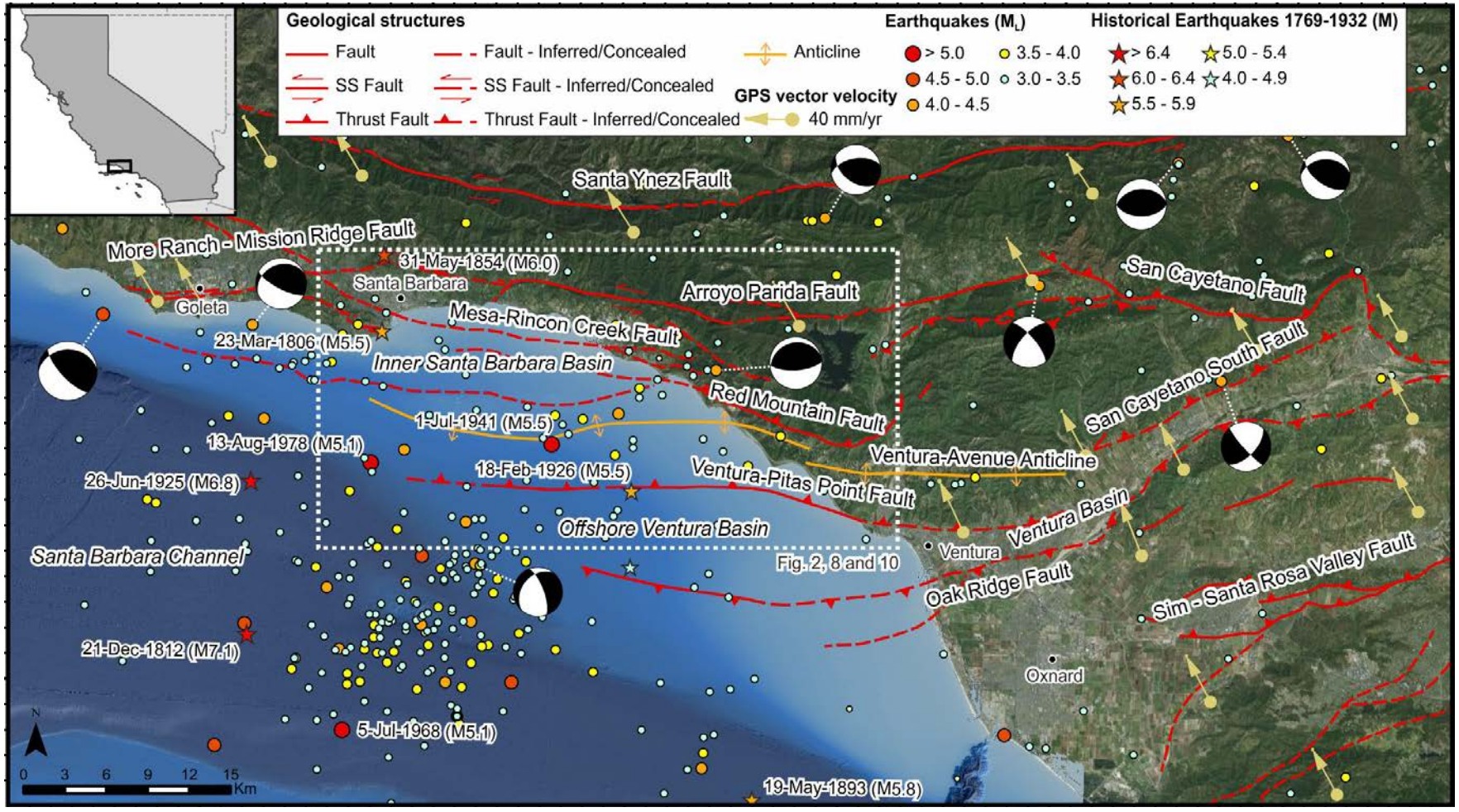
Faulting and Folding of the Transgressive Surface Offshore Ventura Records Deformational Events in the Holocene

Hector Perea, Gülsen Ucarkus, Neal Driscoll, Graham Kent, Yuval Levy and Thomas Rockwell

Introduction and Motivation

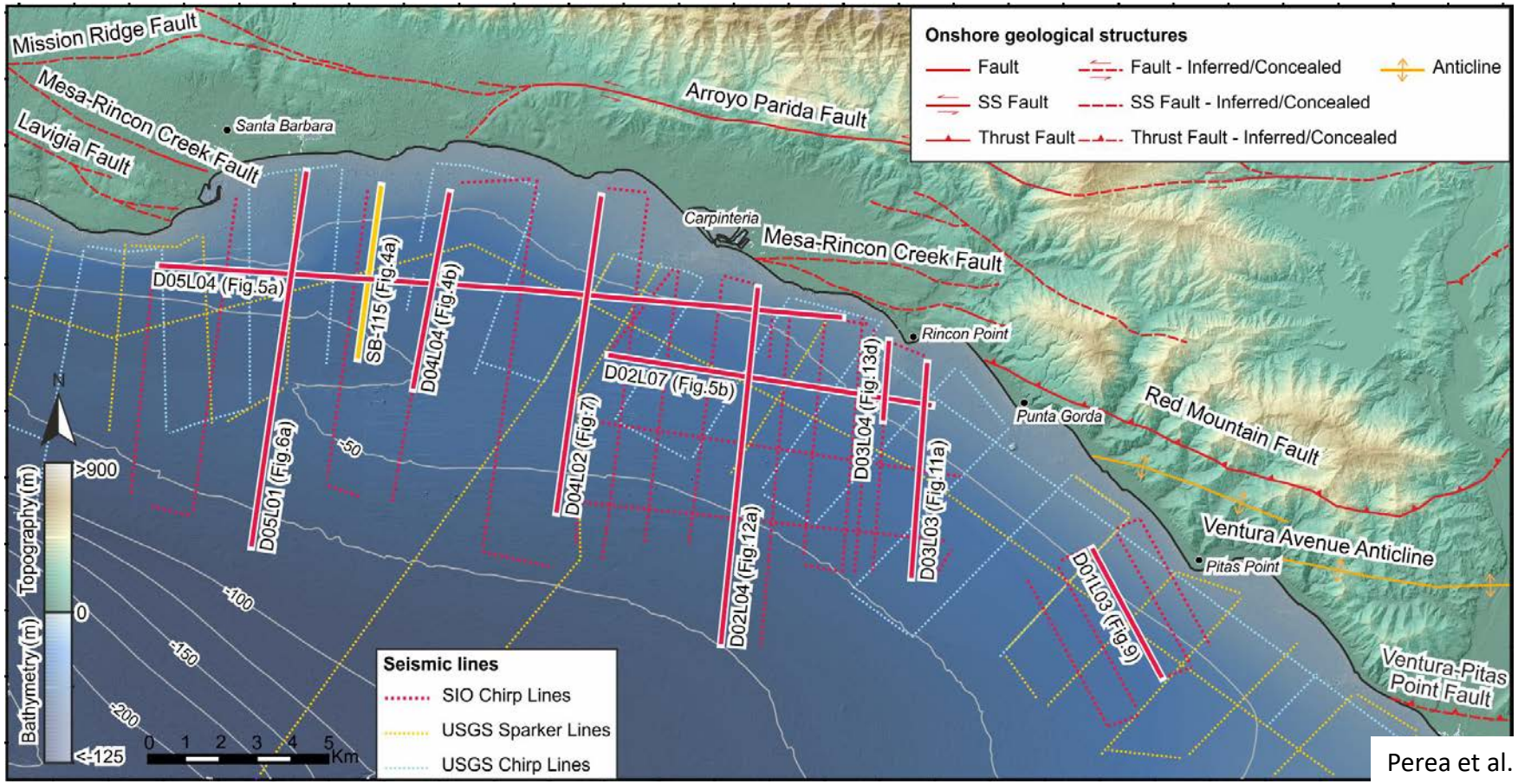
- The Western Transverse Ranges in Southern California are an E-W trending fold-and-thrust system accommodating significant N-S compression (7-10 mm/yr)
- Region has a history of large earthquakes (e.g., 1812 M7.1, 1925 M6.8)
- **Motivation:** Identifying the offshore thrust faults that could produce large earthquakes and seafloor uplift in the offshore Ventura → Critical for geohazard assessment

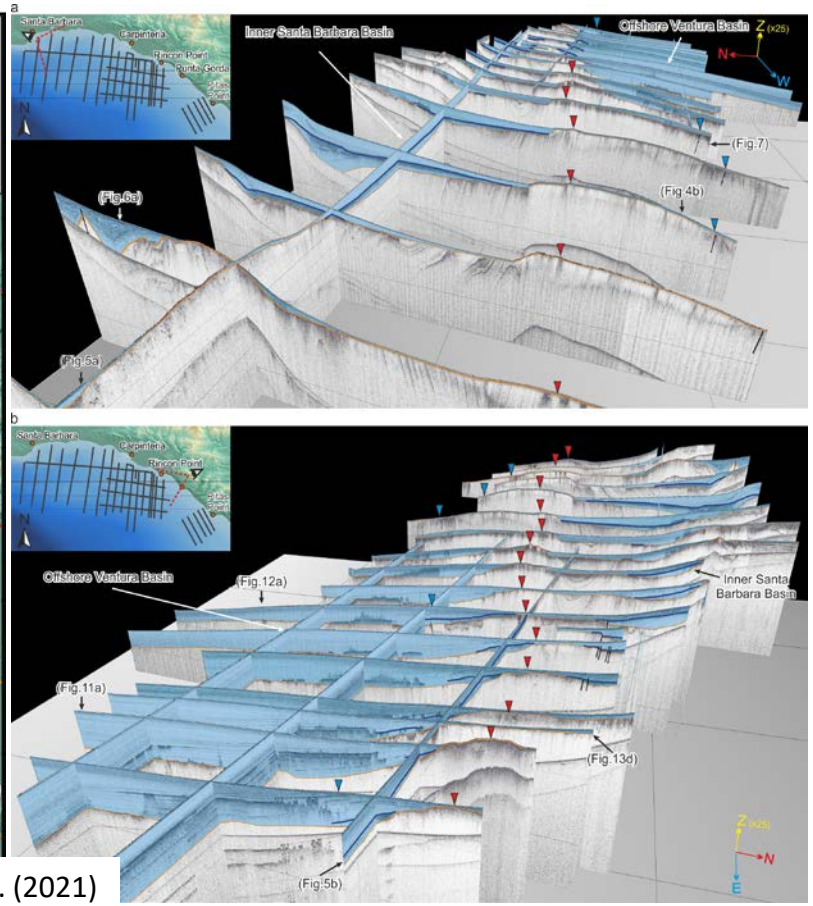
Perea et al. (2021)



Data and Methods – Unveiling Offshore Deformation

- **Data:** Interpretation of high-resolution CHIRP seismic data (2013) combined with reprocessed USGS mini-sparker and CHIRP profiles (2007-2008)
- **Key Marker:** Identification of the Last Glacial Transgressive Surface (LGTS) → An erosional unconformity formed after the Last Glacial Maximum (~10-12 ka BP) → Crucial stratigraphic horizon to track deformation



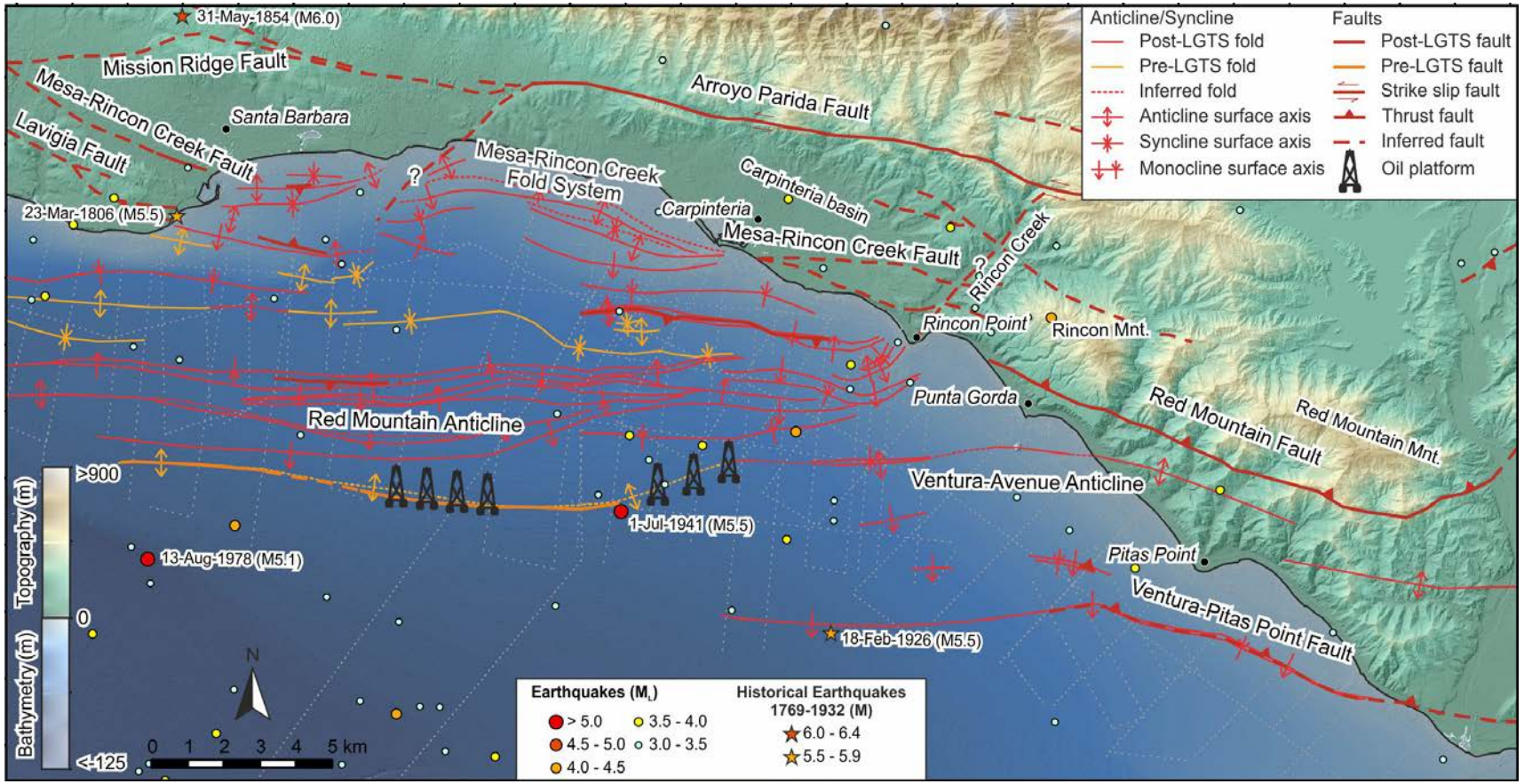


Perea et al. (2021)

New Offshore Structural Correlations

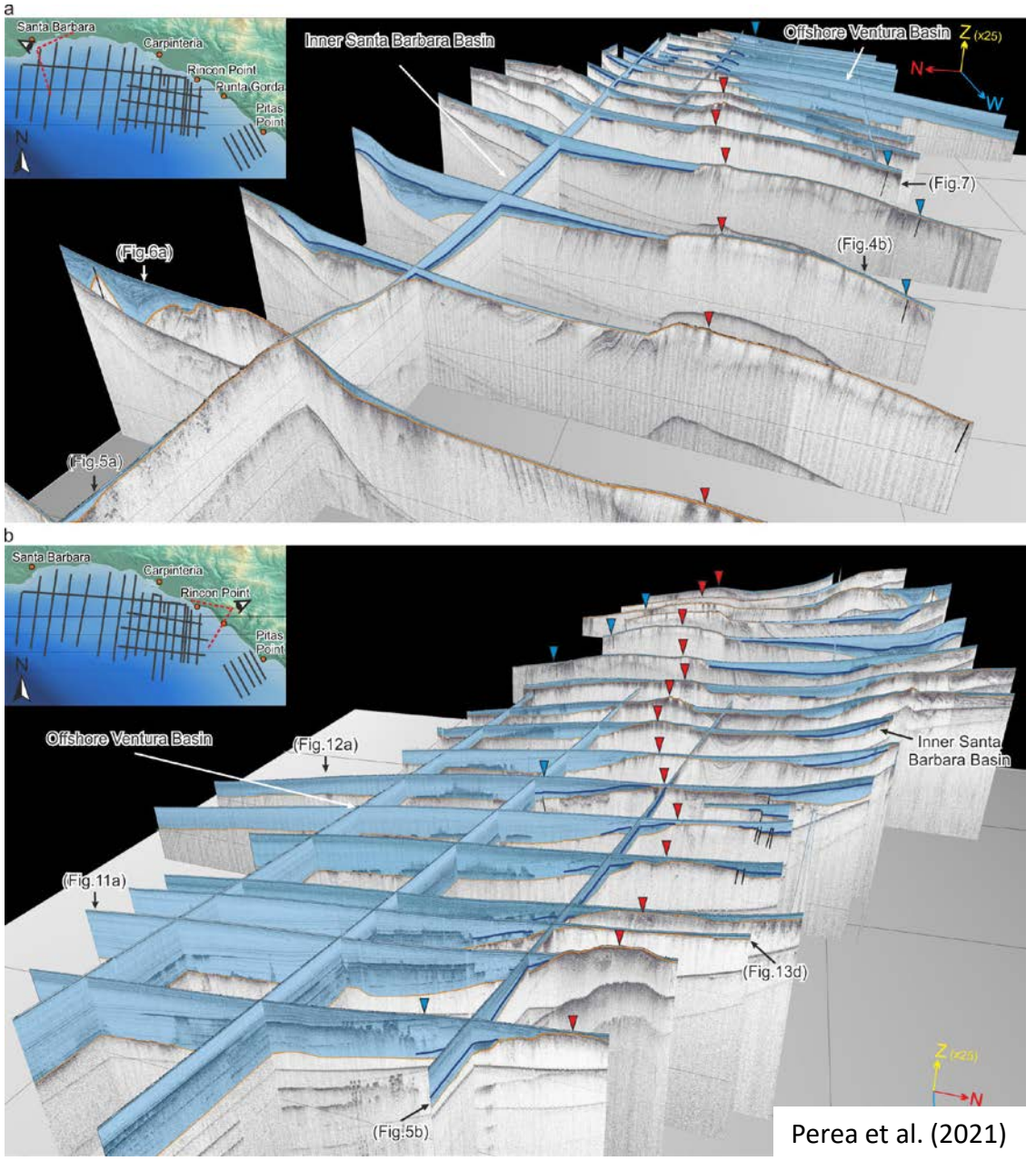
- **Onshore-Offshore Continuity:** The Ventura-Pitas Point fault (mapped offshore for 19 km) and the Ventura-Avenue anticline trend (mapped offshore for 27.5 km) continue offshore
- **Mesa-Rincon Creek fold system** also extends offshore, forming a wide deformation zone with multiple anticlines and synclines
- **Significant Revision:** Unlike previous interpretations, our analysis suggests no direct connection between the onshore Red Mountain fault and the offshore Red Mountain anticline
  - Proposed a tear-fault or lateral ramp aligned with Rincon Creek acts as a structural boundary separating these features

Perea et al. (2021)



Migration of Active Deformation and Sea Level Influence

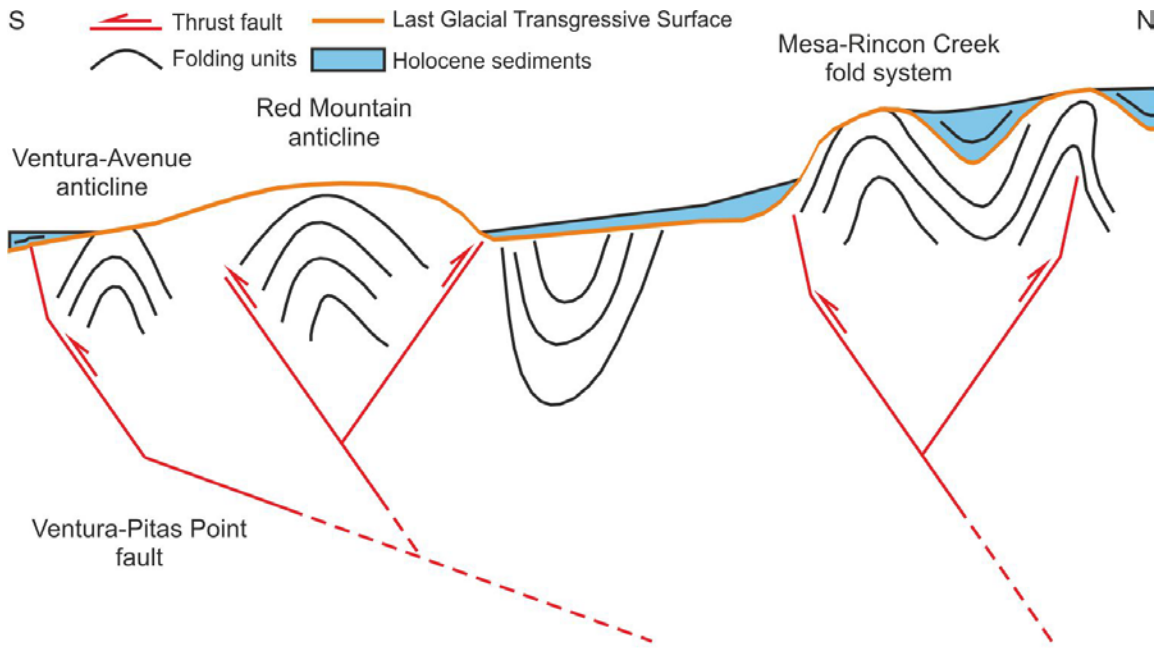
- **Observed Pattern:** A systematic decrease in offshore deformation affecting the LGTS from east to west
- **Out-of-Sequence Propagation:** The decrease in deformation on one structure (e.g., Ventura-Avenue anticline) coincides with an increase in deformation on an adjacent northern structure (e.g., Red Mountain anticline)
- **Proposed Mechanism:** "Right-stepping" pattern → Deformation migrates northward towards the hinterland → Could be linked to sea level rise after the Last Glacial Maximum? → Higher sea levels could have increased normal stress on frontal offshore structures → Shifting activity to inland structures
- **Discussion:** Could environmental changes influence regional tectonic activity?



Perea et al. (2021)

Inferring Deep Structure from Surface Deformation

- **Insight:** Surface deformation patterns (folding of the LGTS and Holocene units) provide crucial constraints on the geometry of deeper blind thrust faults → Often not directly imaged by shallow seismic data
- **Conceptual Model:** The main thrust faults are interpreted to dip towards the north with decreasing dip at depth → Frontal thrusts could eventually link to a common detachment at depth
- **Discussion:** The shared detachment could explain the observed migration of strain towards the hinterland structures during the Holocene



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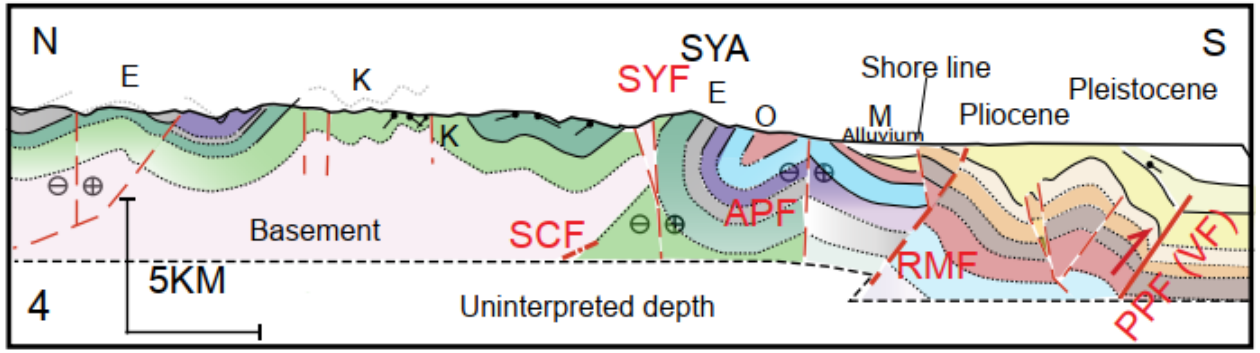
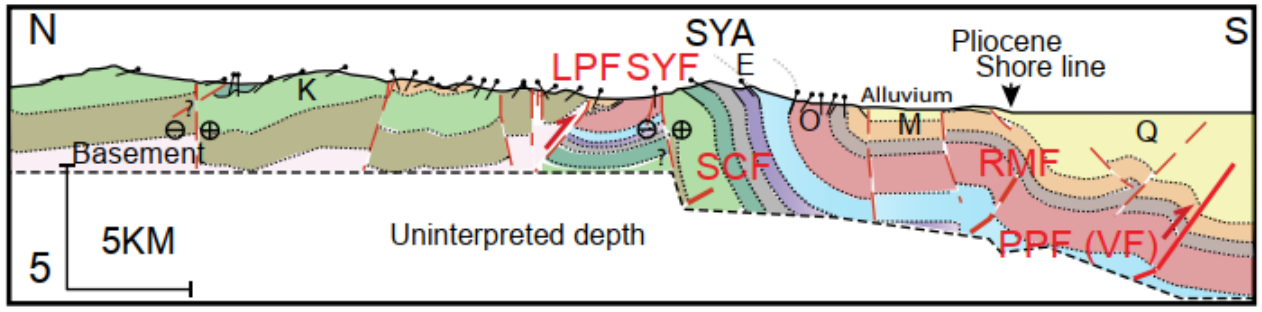
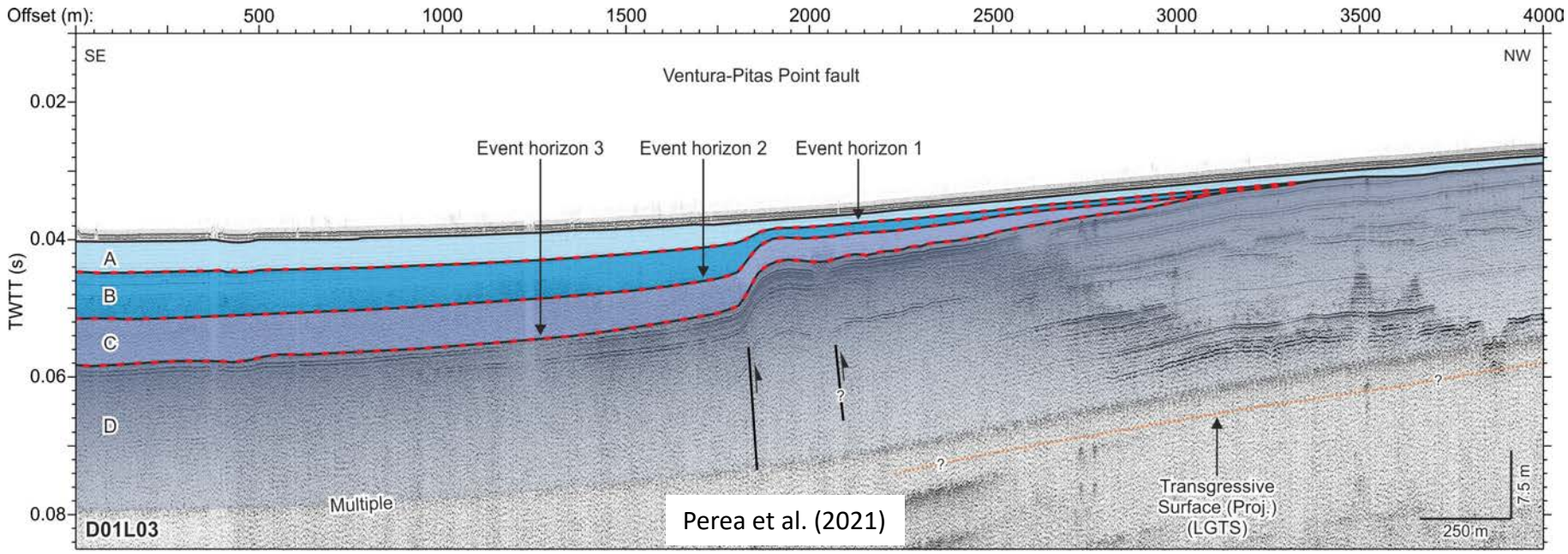




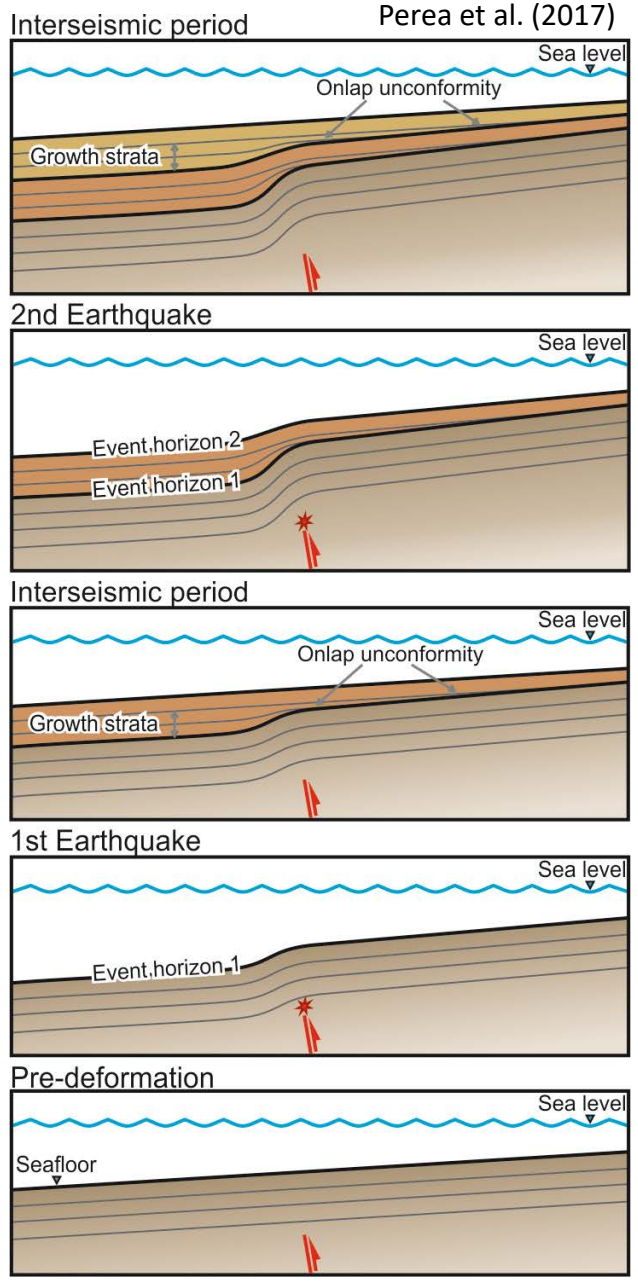
Levy et al. (2019)

Holocene Deformation Events

- **Evidence Types:** Events are recorded by fold scarps, growth strata sequences, onlap unconformities, and erosion surfaces in the Holocene sediment layers
- **Interpretation:** These uplift events are interpreted as evidence of coseismic deformation → Essentially indicating the occurrence of past earthquakes
- **Result:** Identified three to four discrete deformational Holocene events across the major offshore structures → Ventura-Pitas Point fault, Ventura-Avenue anticline, Red Mountain anticline and Mesa-Rincon Creek fold system

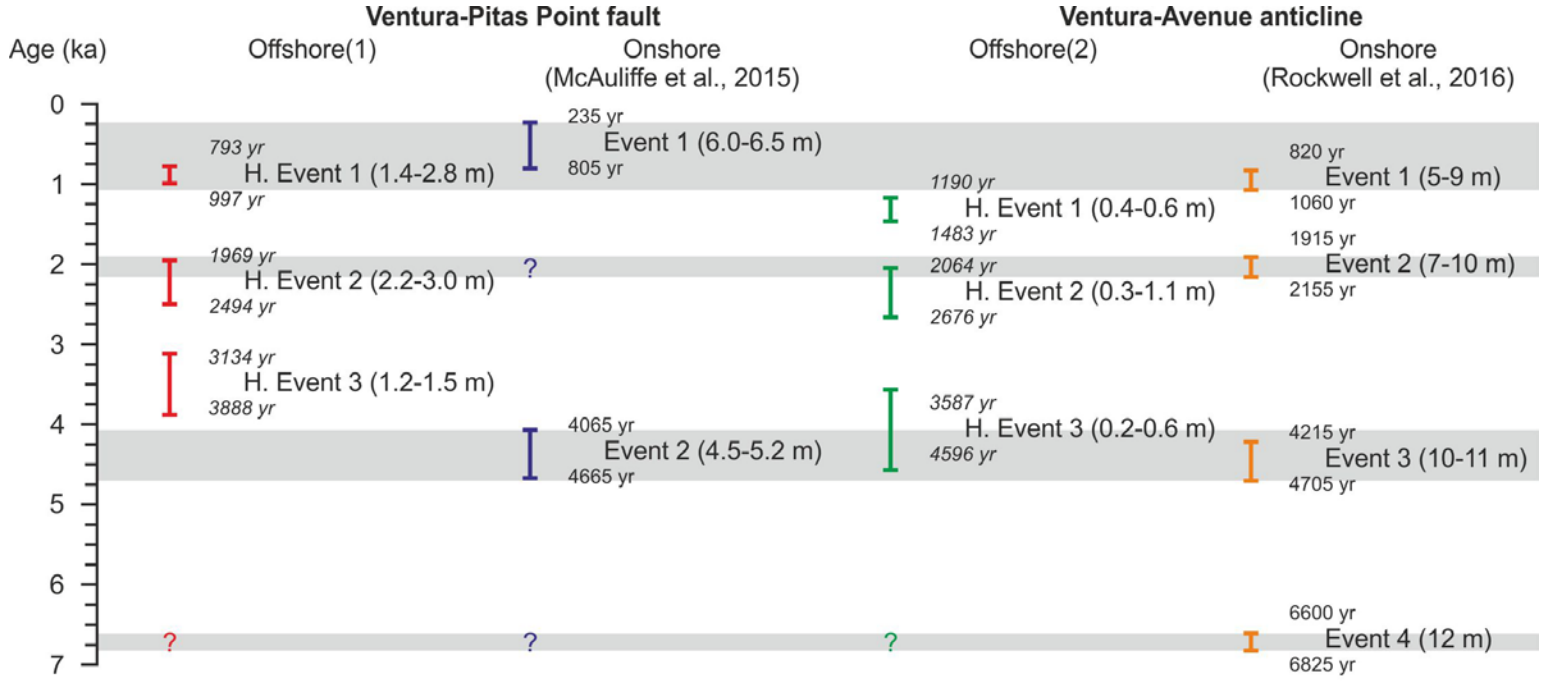


Perea et al. (2021)



Correlation with Onshore Paleoseismological Studies

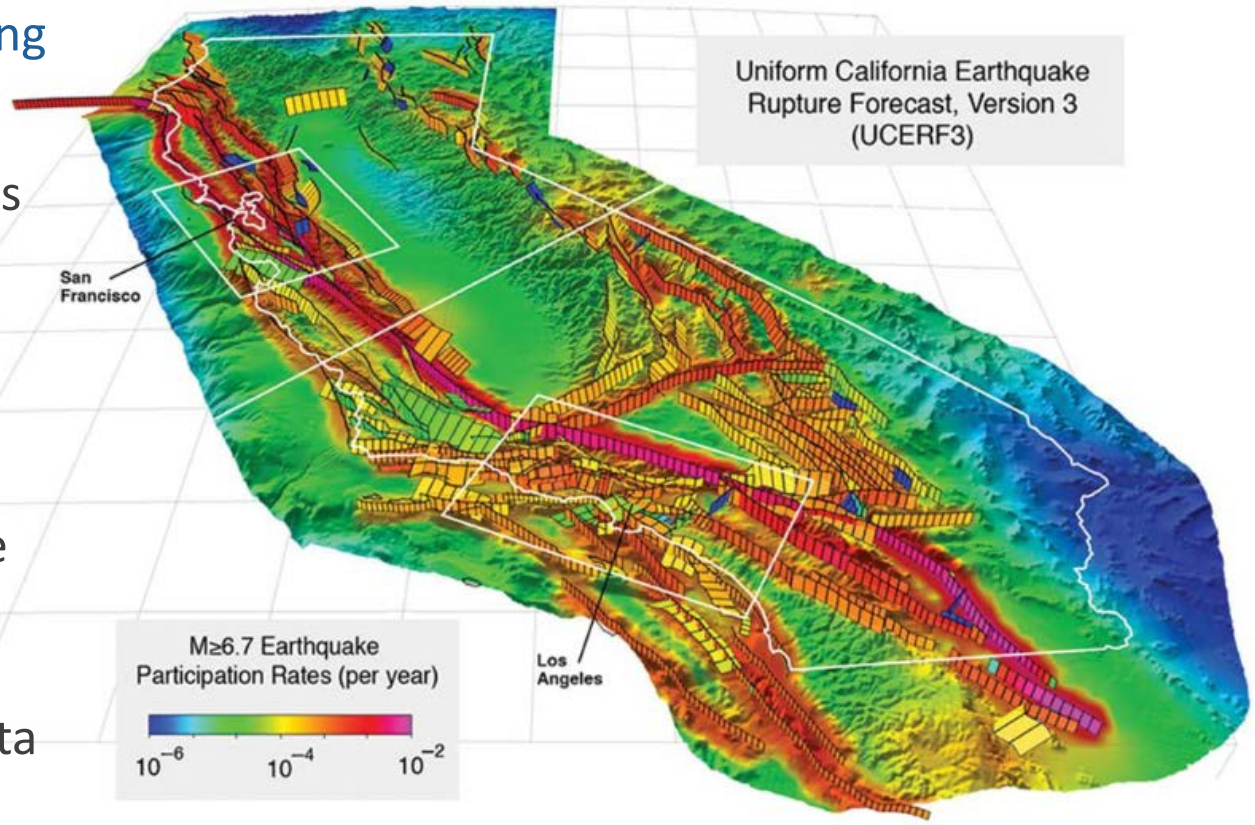
- **Consistency:** Age estimates for offshore deformation events (based on calculated sedimentation rates) show a rough correlation with previously documented onshore paleoseismological events for the Ventura-Pitas Point fault and the Ventura-Avenue anticline
  - **Example:** The youngest offshore event for the Ventura-Pitas Point fault has an estimated age range (793-997 yr) that overlaps with the most recent onshore event (235-805 yr)
- **Implication:** The general correlation and similar number of events across structures suggest a potential for large earthquakes to rupture both the Ventura-Pitas Point fault and Ventura-Avenue anticline simultaneously



Perea et al. (2021)

Potential Seismic and Tsunami Hazards

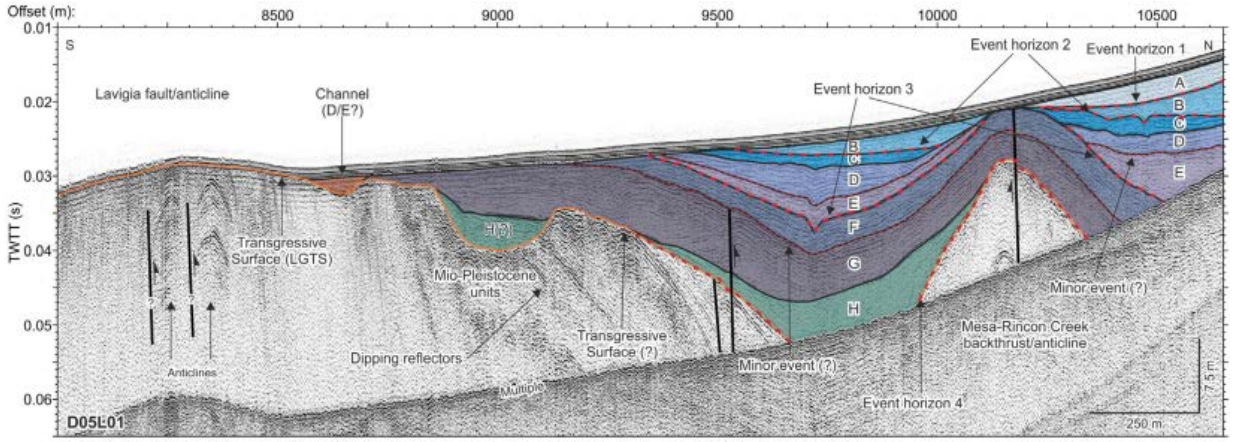
- **Multifault Rupture Scenario:** The similar number of deformation events across different fault systems suggests possible fault interaction → Through triggering or simultaneous rupture during large events
- **Earthquake Magnitude:** If a multifault rupture involves all faults from Ventura to Point Conception (~125 km length) → Generate a large magnitude earthquake (>Mw 7.4–7.9)
- **Tsunamigenic Threat:** The maximum single-event vertical uplift observed offshore is 10-11 meters in the Mesa-Rincon Creek fold system → Such rapid and significant seafloor uplift could generate a tsunami impacting the coastal areas between Ventura and Santa Barbara
- **Discussion:** These findings highlight significant seismic and tsunami hazard to the coastal communities between Ventura and Santa Barbara

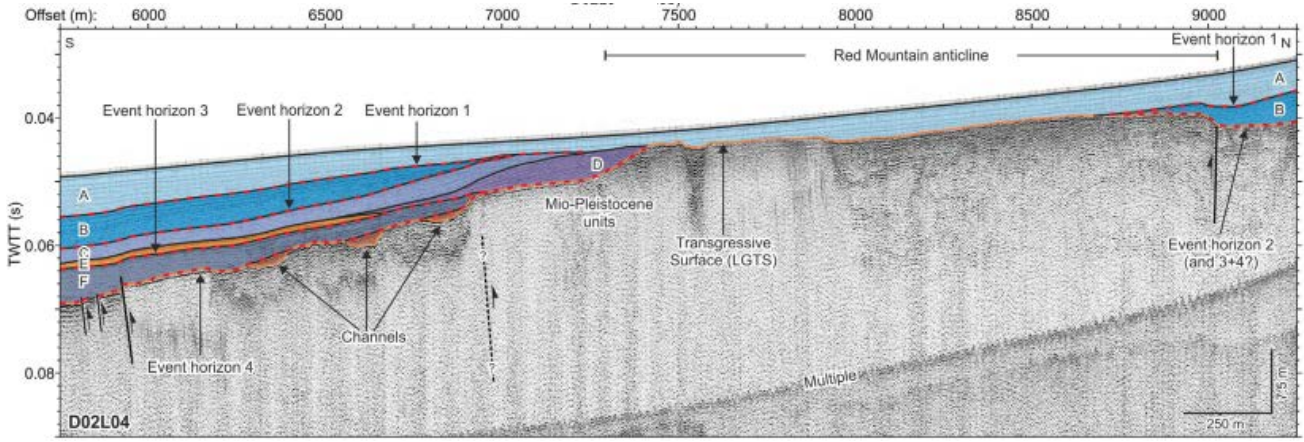


Fields et al. (2014)

Conclusions and Future Work

- **Key Contributions:**
  - Provided critical information on active offshore structures, their connection to onshore events, and the recency of deformation in the Western Transverse Ranges
  - Hypothesized sea level rise influencing strain migration to northern structures
  - Identified multiple Holocene paleoearthquakes offshore
  - Proposed the potential for large, tsunamigenic multifault earthquakes (>Mw 7.4-7.9)
- **Future Directions:** Further research, particularly coring expeditions → Needed to improve the chronostratigraphic framework and refine the ages of offshore events → Crucial for more precise hazard assessment





Perea et al. (2021)

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