From Coalinga to the Tehachapi Mountains: Recent activity and earthquake potential of blind fault systems in the Southern San Joaquin Valley

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1 Abstract

Since August 2024, the Southern San Joaquin Valley has experienced a series of small to moderate magnitude earthquakes on faults within the CFM, as well as systems that are not yet represented in the model. In particular, blind faults in two regions have experienced this heightened seismicity: the Kettleman–Lost Hills fold-and-thrust belt and structures within the Maricopa sub-basin (north of the Tehachapi Mountains).

Along the Kettleman-Lost Hills fold-and-thrust belt, a series of earthquakes occurred on the lower segment of the ramp that generates Kettleman North Dome anticline in the vicinity of the 1983 M 6.1 earthquake on this system. In the Maricopa sub-basin, a recent M 5.2 earthquake ruptured a fault not yet modeled in the CFM or represented in the U.S.G.S. Qfaults database. This recent activity has motivated, in part, our efforts to examine the complete extent and 3D geometry of these faults in relation to other known seismic hazards (e.g.., the San Andreas and White Wolf faults). Using a diverse set of datasets (seismic reflection, CalGEM well, and relocated seismicity data), we define the fault geometry and kinematics of these two fault systems and explore their implications for regional seismic hazards.

In this work, we extend our previous findings in the Kettleman-Lost Hills by constraining the regional geometry of this fold-and-thrust belt to the SAF. We find that the active ramps link to lower detachments across the length of this fold and thrust belt, resulting in a large fault area that may have the potential to rupture in Mmax 8.1 earthquakes. In the Maricopa sub-basin, we find that there is a complex series of faults, previously unrecognized to be active in the Holocene, that generated the August 2024 M 5.2 earthquake. Of note, we find that both north- and south-dipping faults may have been activated during this event. These faults are a part of a larger regional fault network that could produce far larger earthquakes.

2 Seismicity in the Central Valley

Over the last year, two regions of the Central Valley have experienced a series of small to moderate earthquakes (M 3-3.4) and one moderate earthquake (M 5.2). We aim to address the following questions:

1) What is the maximum magnitude of the earthquake that the Kettleman-Lost Hills fold-and-thrust belt can generate?

2) What are the faults that produced the August 2024 M 5.2 earthquake?

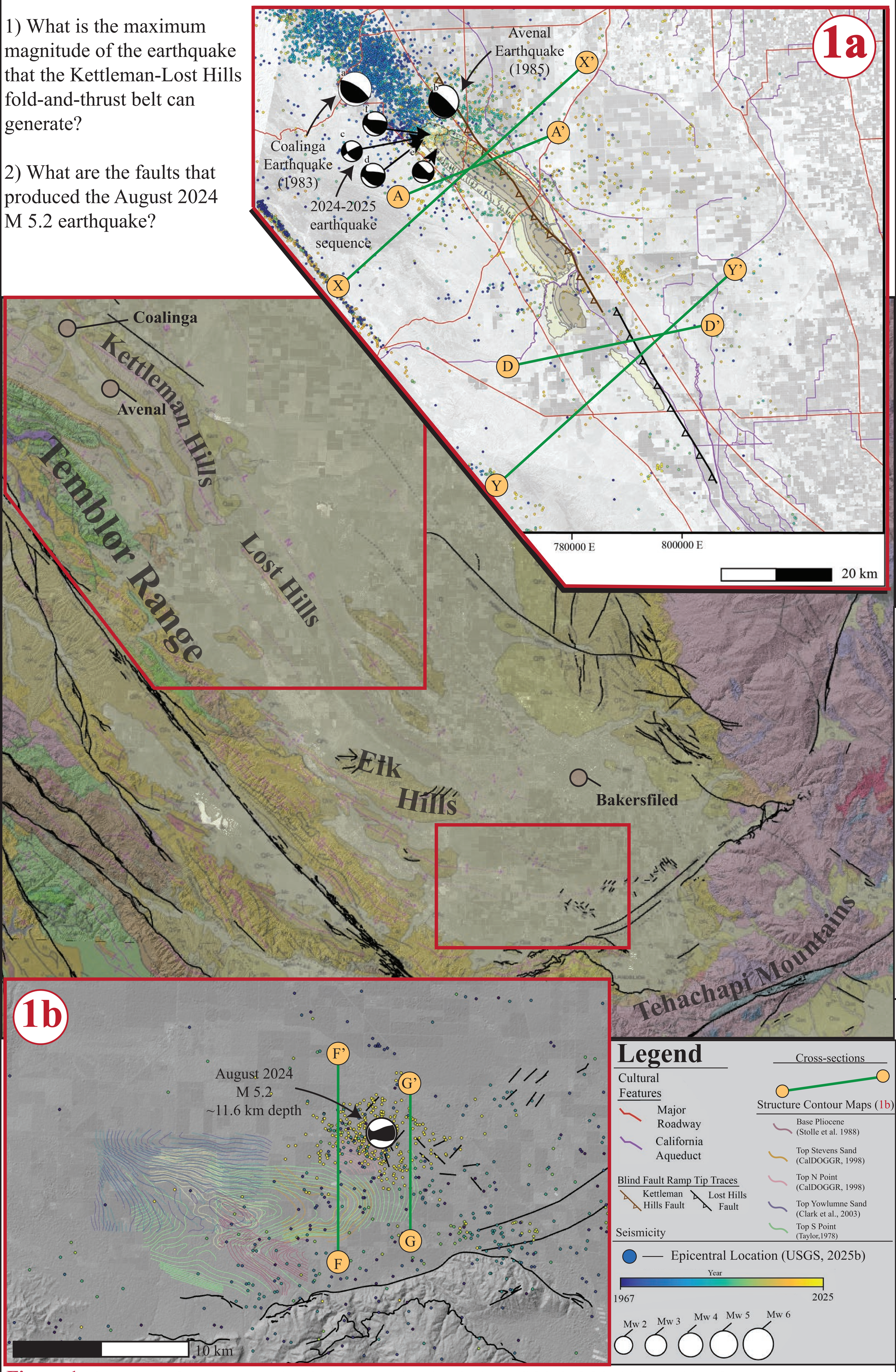


Figure 1: Overview of geology, previously interpreted active faults (USGS & CGS, 2025), with a focus on our two study areas and the datasets we compiled for each area. 1a: The Kettleman-Lost Hills Fold-and-Thrust belt detailing the location of the 1980s earthquake sequence and the 2024-2025 earthquake sequence. 1b: The San Emidio Nose Structural complex and the location of the August 2024 M 5.2 earthquake. Basemap from Jennings et al. (2010), digital elevation model from the USGS (2025a), and landsat imagery from Earth Explorer.

3 The Kettleman-Lost Hills Fold-and-Thrust Belt

The Kettleman-Lost Hills Fold-and-Thrust Belt is the source of the M 6.1 Avenal (North Dome) earthquake and the 2024-2025 M 3-3.6 earthquake sequence. Here, we address the potential of this fold-and-thrust belt to produce large earthquakes involving faults along strike and multiple segments (3a) and find that this system has the potential to generate earthquakes as large as M_{max} 8.1 (3b).

3a Evidence for multi-segment earthquakes

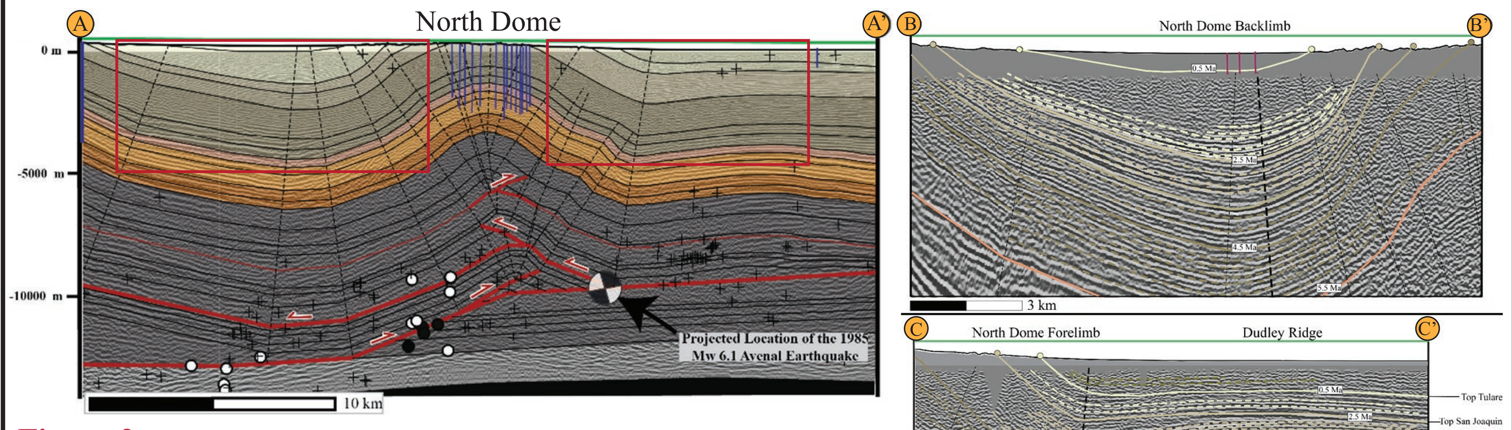


Figure 2: North Dome cross-section. Cross-section A-A' (1:1 vertical exaggeration) details our North Dome interpretation with a focus on the fault geometry and regional structure. Note the detachment and ramp transition here. Cross-section B-B' and C-C' (4:1 vertical exaggeration) details the geometry of the younger stratigraphy on the backlimb and forelimb of the structure.

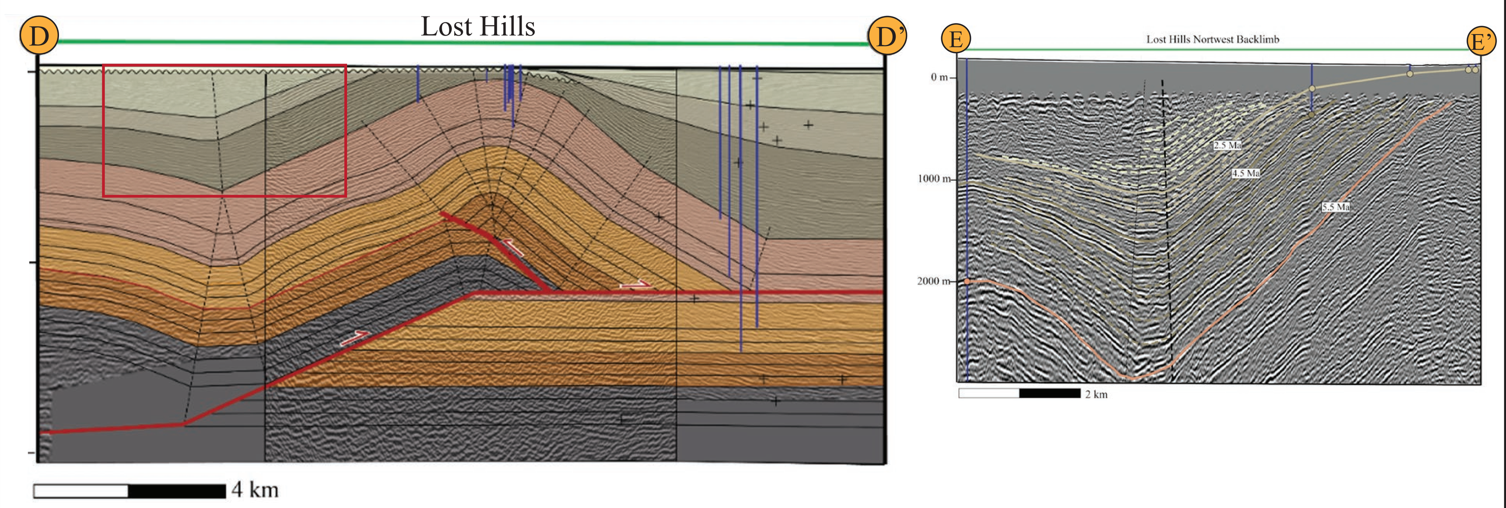


Figure 3: Lost Hills Northwest cross-section. Cross-section D-D' (no vertical exaggeration) shows our Lost Hills Northwest interpretation with a focus on the fault geometry and regional structure. Note the detachment and ramp transition here. Cross-section E-E' (4:1 vertical exaggeration) shows our Lost Hills Northwest interpretation with a focus on the geometry of the younger stratigraphy. Note here the folding of the sediments through the axial surface related to the ramp-detachment transition.

Takeaways: Folding of Pliocene to upper Pleistocene sediments indicates late Pleistocene along-strike activity, and evidence of multi-segment (ramps & detachments) ruptures.

3b Regional fault geometry and M_{max} calculation

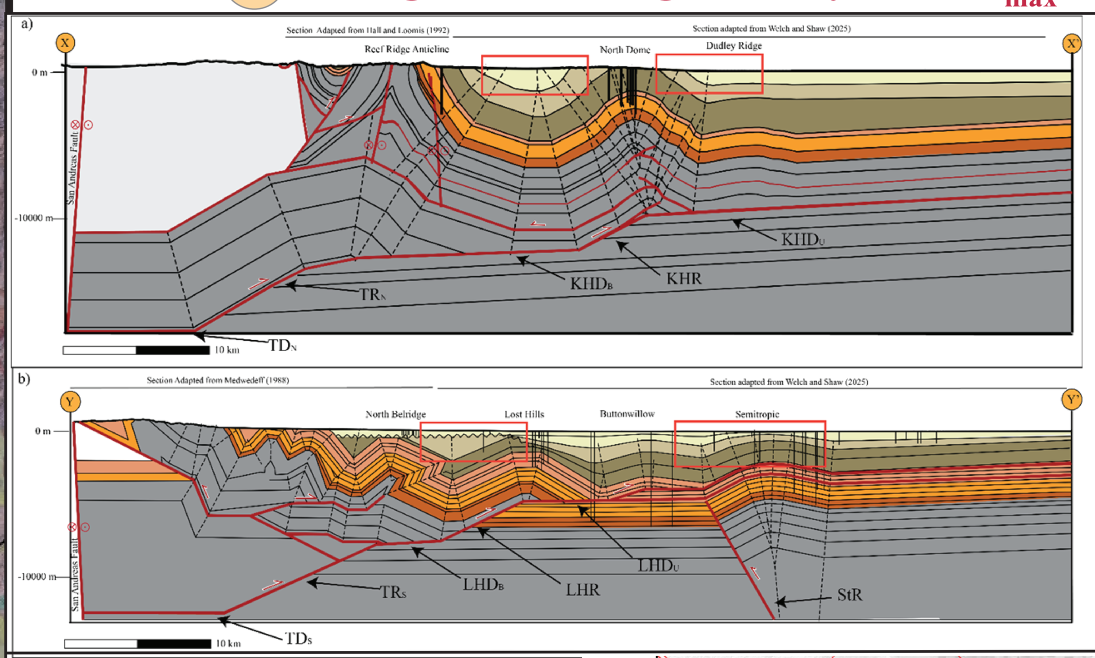


Figure 4 (left): Regional cross-sections illustrating the connection of the Kettleman-Coalinga fold-and-thrust belt to the structures in the Temblor Range and the San Andreas Fault.

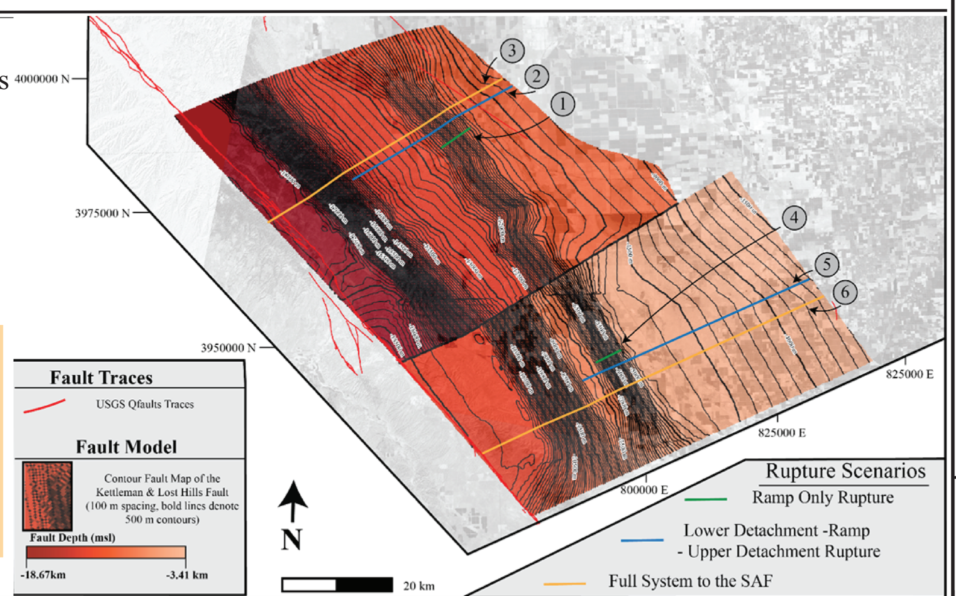
Abbreviations are as follows: TDN – Northern Temblor Detachment; TRN – Northern Temblor Ramp; KHDB – Kettleman Hills Basal Detachment; KHR – Kettleman Hills Ramp; KHDU – Kettleman Hills Upper Detachment; TDS – Southern Temblor Detachment; TRS – Southern Temblor Ramp; LHDB – Lost Hills Basal Detachment; LHR – Lost Hills Ramp; LHDU – Lost Hills Upper Detachment; StR – Semitropic Thrust

Figure 5 (right): 3D fault model of the region. In 3a, we find evidence that earthquakes have not been limited to the ramp segment of the North Dome Thrust but extend along strike and dip. Here, we propose six (labeled 1-6) different rupture scenarios based on those observations in 3a. The seventh scenario is the entire fault area rupturing.

Total fault area: ~ 6190 km^2

M_{max}: 8.1*

***(Calculated using the approach by Biasi and Weldon, 2006.)**



Takeaways: Our 3D fault model, in conjunction with our observations of along-strike and dip activity, indicates that this system has the potential to generate earthquakes of M_{max} 8.1

4 The San Emidio Structural Complex

The San Emidio structural complex is home to three major oil fields and other minor fields, including the Yowlumne, San Emidio, and Rio Viejo fields. On August 6, 2024, this region experienced a M 5.2 earthquake (USGS, 2025b). This earthquake occurred on a previously unrecognized active fault in the Holocene. In this section, we detail our preliminary fault and structural models.

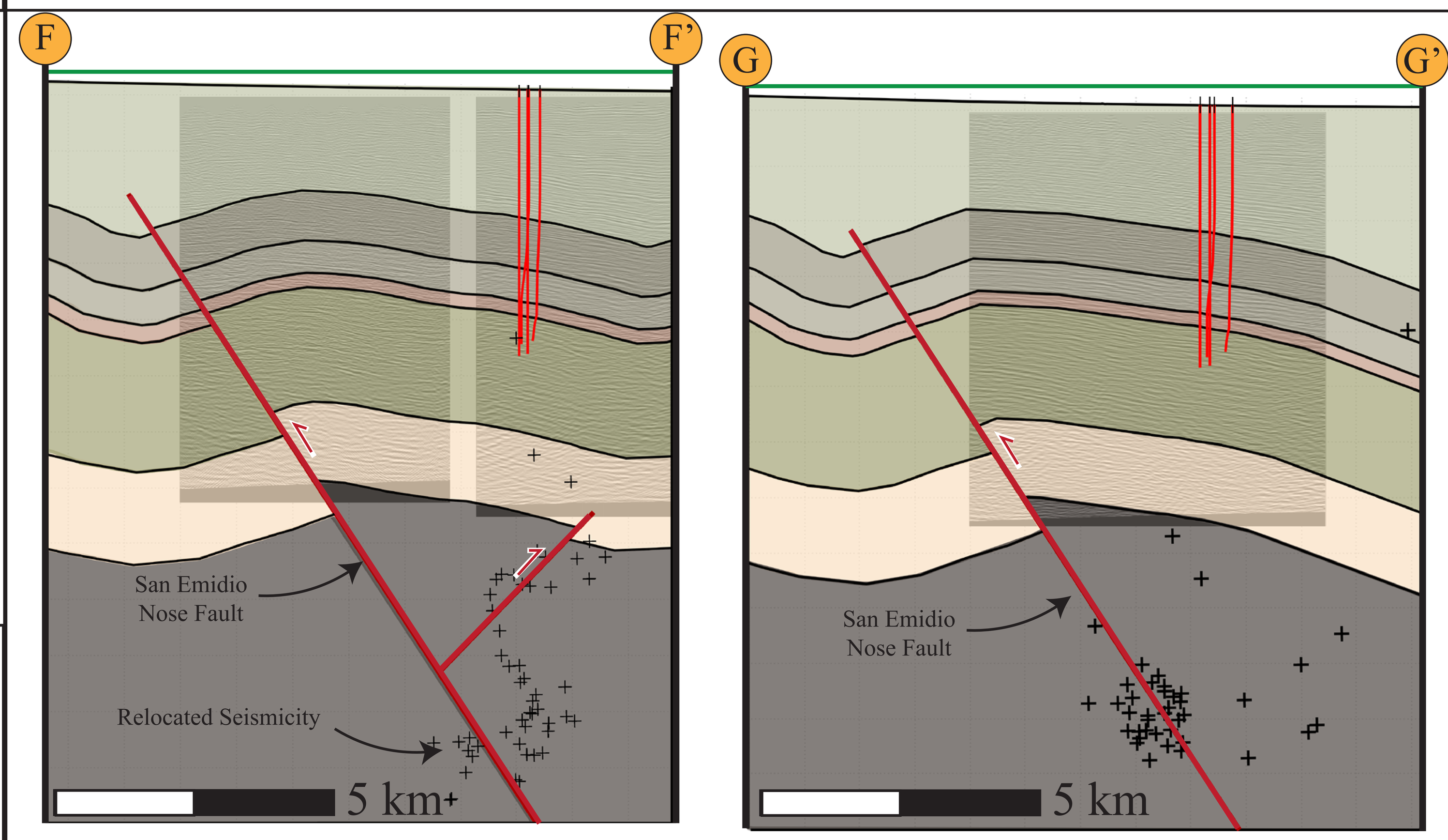


Figure 6: Cross-sections of the San Emidio Structural Complex in the vicinity of the faults in the area of the August 2024 M 5.2 earthquake. 6a: Cross-section F-F' highlighting the San Emidio field and the high-angle reverse faults. 6b: Cross-section G-G' highlighting the Rio Viejo field and the high-angle reverse fault that generates the structure. Relocated seismicity provided by E. Hauksson (personal communication). These sections are constrained by additional wells and field contour maps. No vertical exaggeration. Well data from CalGEM(2025).

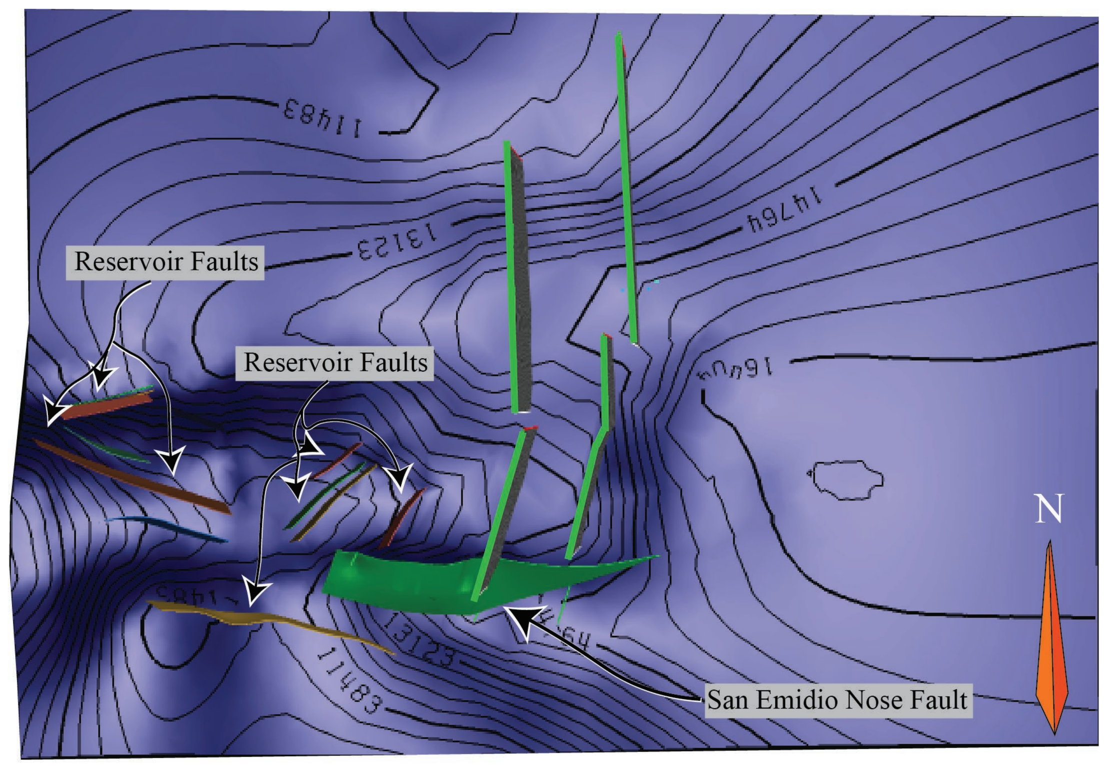


Figure 7: Top down view of our 3D structural model of the region illustrating the architecture of the San Emidio structural complex. The top surface shown is that of the top Miocene. Note the location of the San Emidio Nose Fault as named by Stolle et al. (1988). Note that the contours are in feet below sea level.

Takeaways: Using 2D seismic reflection, well, and previously published structure contour maps, we develop a regional structural model indicating the possible fault geometry of the fault that generated the M 5.2 event.

5 Conclusions & Next Steps

Conclusions:

- We find evidence that the Kettleman-Lost Hills fold-and-thrust belt has generated multi-segment ruptures and has the potential to generate earthquakes as large as M_{max} 8.1.
- The fault that generated the August 2025 M 5.2 earthquake is a high-angle reverse fault that was previously unrecognized as active in the Holocene.

Next Steps:

- **Kettleman-Lost Hills:** Identify the potential of multi-segment earthquakes in the Holocene.
- **San Emidio:** Refining our fault model and explaining the shallow aftershock sequence in the M 5.2 earthquake.
- Develop a reservoir model to assess injector impacts on the faults.

6 References Cited

Biasi, G.P., Weldon, R.J., 2006, Estimating Surface Rupture Length and Magnitude of Paleoearthquakes from Point Measurment of Rupture Displacement,

CalGEM, 2025, California Department of Conservation Well Finder: California Department of Conservation, https://www.conservation.ca.gov/calgem/Pages/wellfinder.aspx (July, 2025)

California Department of Conservation Division of Oil, Gas, and Geothermal Resources, 1998, California Oil and Gas Fields Volume 1 - Central California (CD-1) contour maps, cross-sections and data sheets for California's oil and gas fields: California Department of Conservation Division of Oil, Gas, and Geothermal Resources, TR11, p. 499

Clark, M.S., Prather, R.K., Melvin, J.D., 2003, Characterization and exploitation of the distal margin of a fan-shaped turbidite reservoir; the ARCO-DOE 91X-3 horizontal well project, Yowlumn Field, San Joaquin Basin, California, American Association of Petroleum Geologists, V. 14, p. 11-26.

Jennings, C.W., with modifications by Gutierrez, C., Bryant, W., Saucedo, G., and Wills, C., 2010, Geologic map of California: California Geological Survey, Geologic Data Map No. 2, scale 1:750,000.

Stolle, J.M., Nadolny, K.A., Collins, B.P., Greenfield, D.S., March, K.A., 1988, Landslide Oil Field, Kern County, California - A Success Story An Exploration/Development Case History, Selected Papers - San Joaquin Geological Society, V. 7, P. 1-13.

Taylor, D.S., 1978, California's Yowlumne Field; from basics to barrels, The Oil and Gas journal, v. 76, p. 192-200.

U.S. Geological Survey, 2025a, 3D elevation Program 1 Meter Resolution Digital Elevation Model (published 20200606), accessed July 26, 2025 at URL https://www.usgs.gov/the-national-map-data-delivery

U.S. Geological Survey, 2025b, Earthquake catalog (1967-2025), accessed August 30, 2025 at URL https://earthquake.usgs.gov/earthquakes/search/

U.S. Geological Survey, California Geological Survey, 2025, Quaternary fault and fold database for the United States, accessed August 26, 2025, at: https://www.usgs.gov/natural-hazard/earthquake-hazards/faults.

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