# Newly recognized active blind thrust faults in the northwest Los Angeles basin

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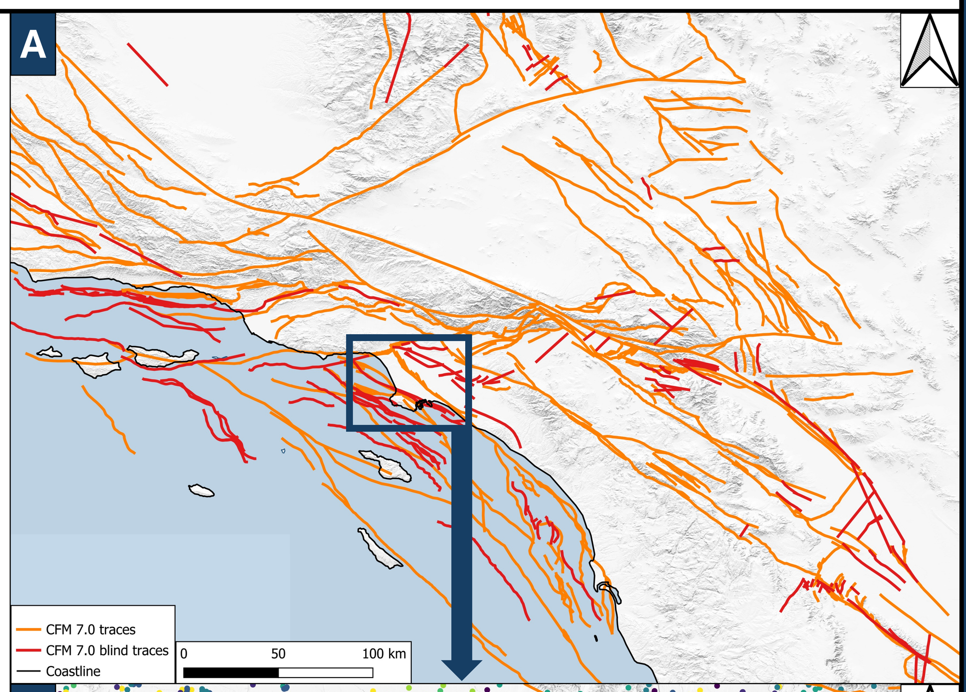
## Imbricate faulting and evidence of activity

Imbricate thrust faults pose some of the most significant earthquake hazards on the planet but are challenging to study due to their concealed nature, complex architecture, and rupture behaviors. The Los Angeles basin, a transpressional region influenced by the San Andreas fault restraining bend, offers an exceptional setting to study such systems. The basin contains a dense network of blind thrust and strike-slip faults that have sourced both historic earthquakes and those defined in the paleoseismic record.

This study investigates the areas extending from Larchmont to Westwood (from the Salt Lake to Sawtelle oil field) as well as Los Cerritos to Marina Del Rey (from the Dominguez to Playa Del Rey oil field) (results to come). In these regions, seismicity is well-documented but inadequately explained by structures in the SCEC CFM v7. In the northern belt, structures in the footwall of the SMF suggest the presence of an imbricated thrust system. The area's critical infrastructure, high population density, and documented deformation of Pleistocene stratigraphy merit a re-examination of deeper structures to improve seismic hazard assessments.

A

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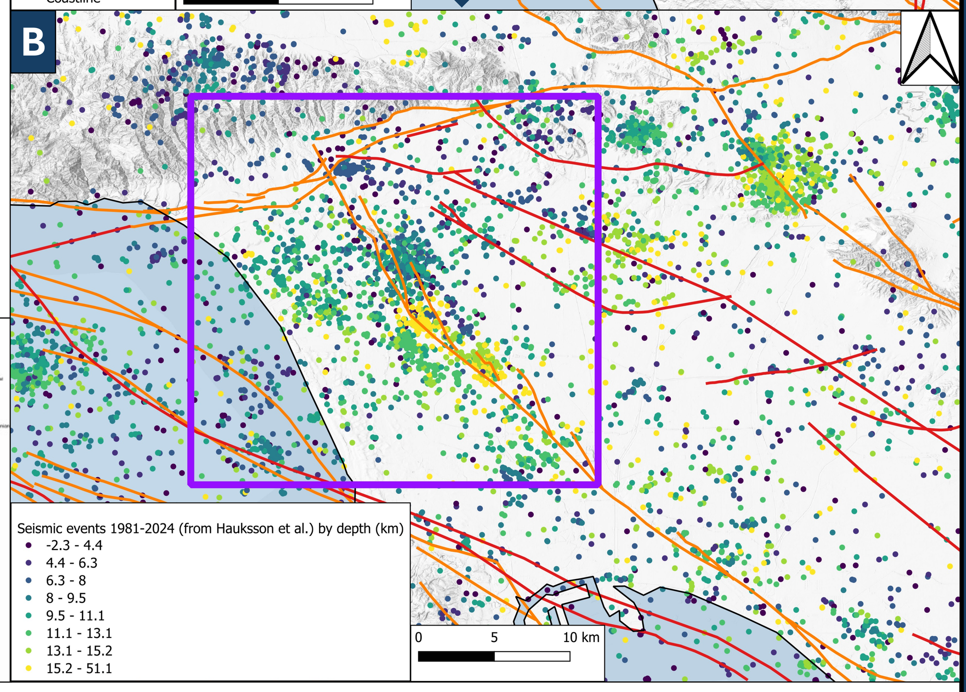


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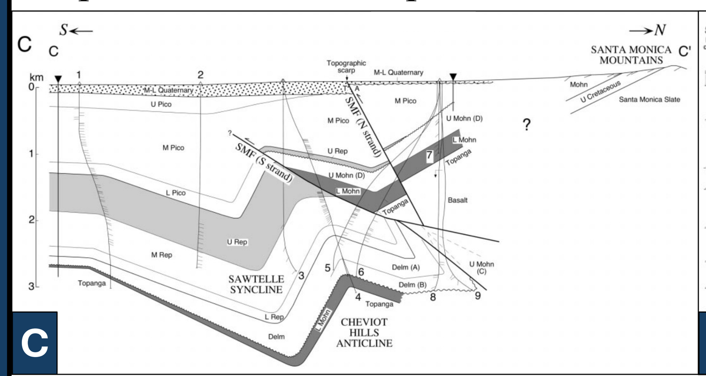


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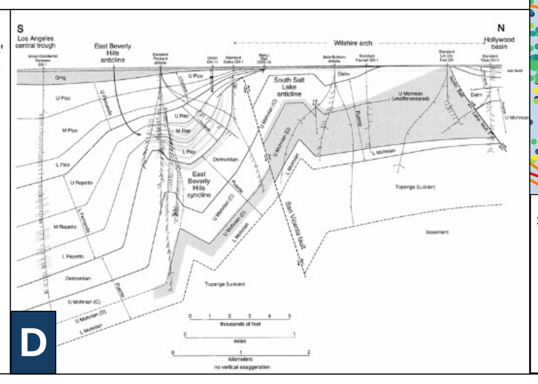


**A**: USGS shaded relief map of the Los Angeles basin with CFM fault traces.
**B**: Enlargement of region of interest, with study area displayed in purple box and focal mechanisms colored by depth.
**C**: Structural cross-section from Tsutsumi et al., 2001. Section trends approximately 25 degrees W of N through the Sawtelle oil field. Note folding S of the SMF unexplained by any underlying fault.
**D**: Structural cross-section from Schneider et al., 1996. Section trends approximately 20 degrees E of N through the East Beverly Hills, South Salt Lake, and Salt Lake oil fields. Note folding S of the SVF unexplained by any underlying fault.

## Data and methods

Using 3D structural modeling tools (Aspen SKUA and MOVE), we digitized and integrated:

- Contour maps and cross-sections from Tsutsumi et al., 2001
- Contour maps from the CA Department of Conservation Annual Report of the State Oil and Gas Supervisor, 1992
- Cross-sections from the AAPG Pacific Section, 1987 and 1990
- Oil well data from the CA Department of Conservation Geologic Energy Management Division database across a wide range of operators and years
- Regional stratigraphic data from Blake, 1989

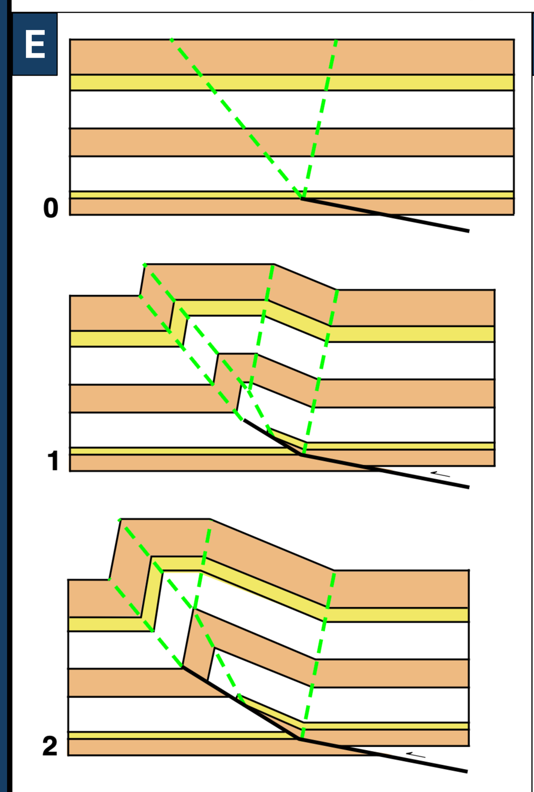
to investigate faulting in the region and build 3 approximate dip sections across the Sawtelle syncline, considering the reliability of and temporal relationships between our compiled data sources.

Fault-propagation folds form at the tips of faults and consume slip. Common to most of these structures are the following:

1. Folds are asymmetric, with forelimbs that are both steeper and narrower than corresponding back limbs
2. Synclines are pinned to the fault tip
3. Folds tighten with depth
4. Slip on the fault decreases upwards, terminating within the fold

After constructing cross-sections, we tested several kinematic theories for fault-propagation folding (Suppe and Medwedeff, 1990; Allmendinger, 1998) to derive fault geometries consistent with compiled structural and stratigraphic data. Here, we present models to explain the deformation in our sections consistent with constant thickness theory, which assumes angular fold hinges and conservation of bed length (AAPG, 2005). For sections 1 and 3, we interpolated back limb geometries, as lower strata was sheared by motion along the Santa Monica fault.

E

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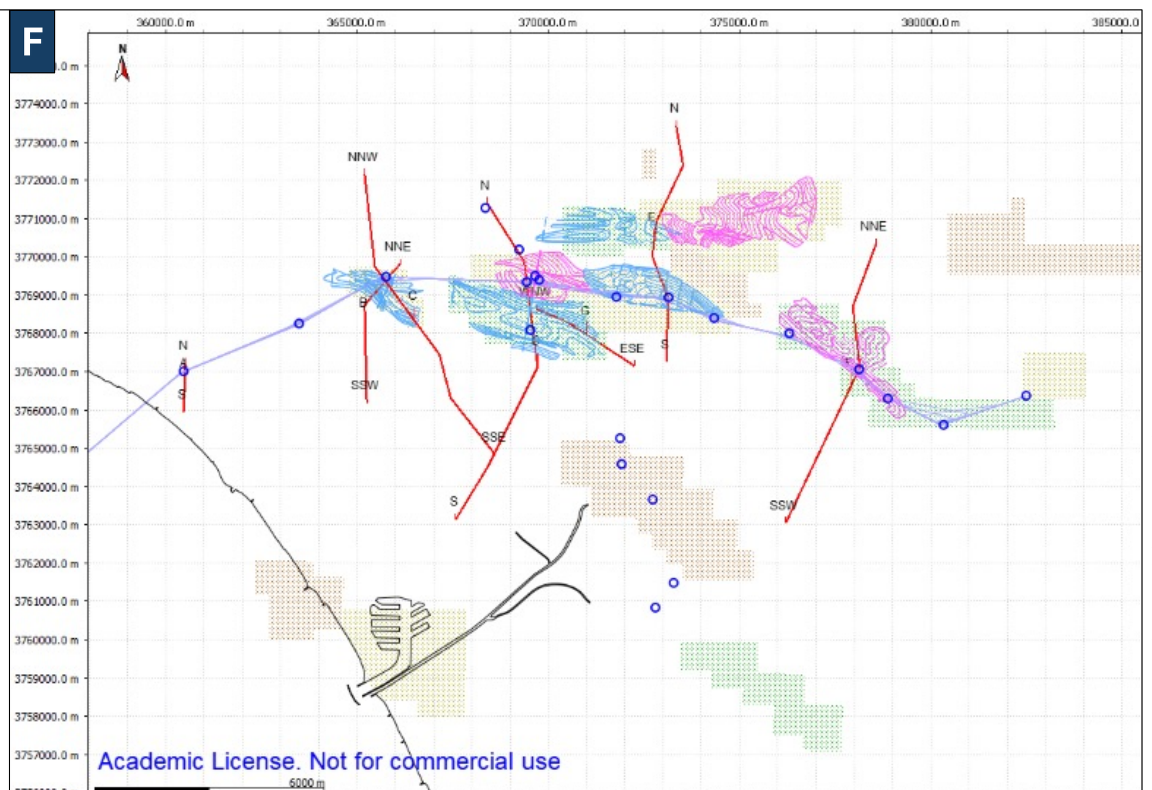
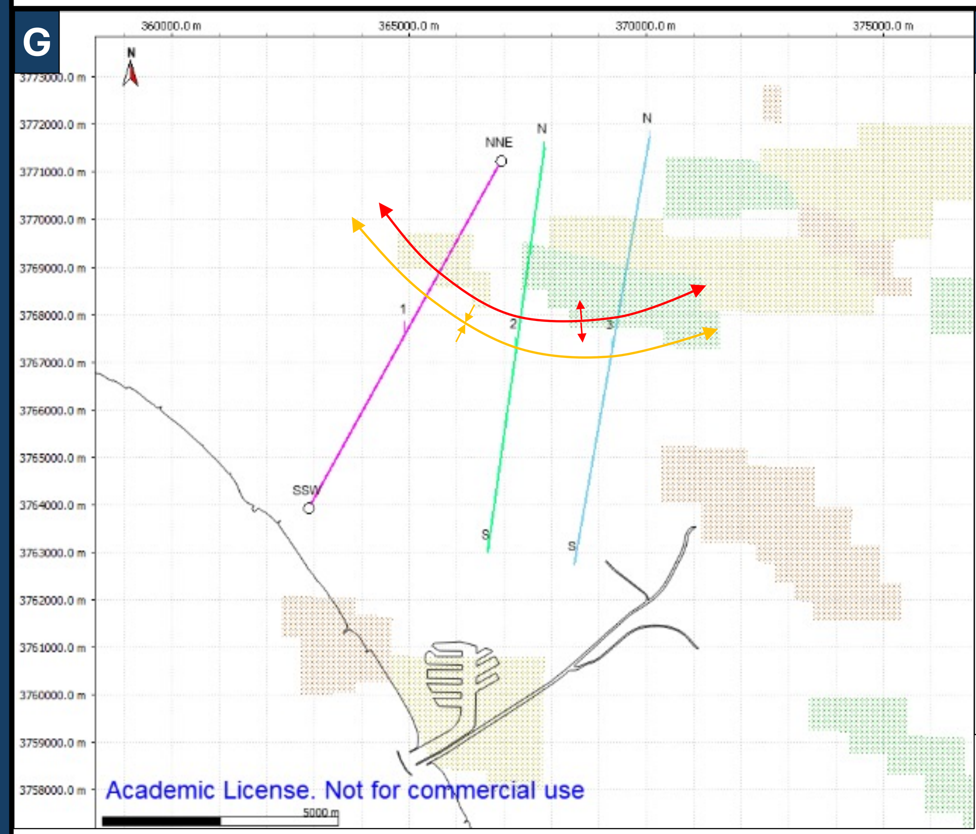



**E**: Kinematic representation of a constant thickness fault-propagation fold from AAPG, 2005.
**F**: Data availability map from MOVE, with coastline in black as well as oil and gas fields in green, tan, and brown for reference. Tsutsumi sections are in red, AAPG sections are in lavender, wells are in dark blue, and 1992 contoured surfaces are in blue and pink.

## New fault models

G

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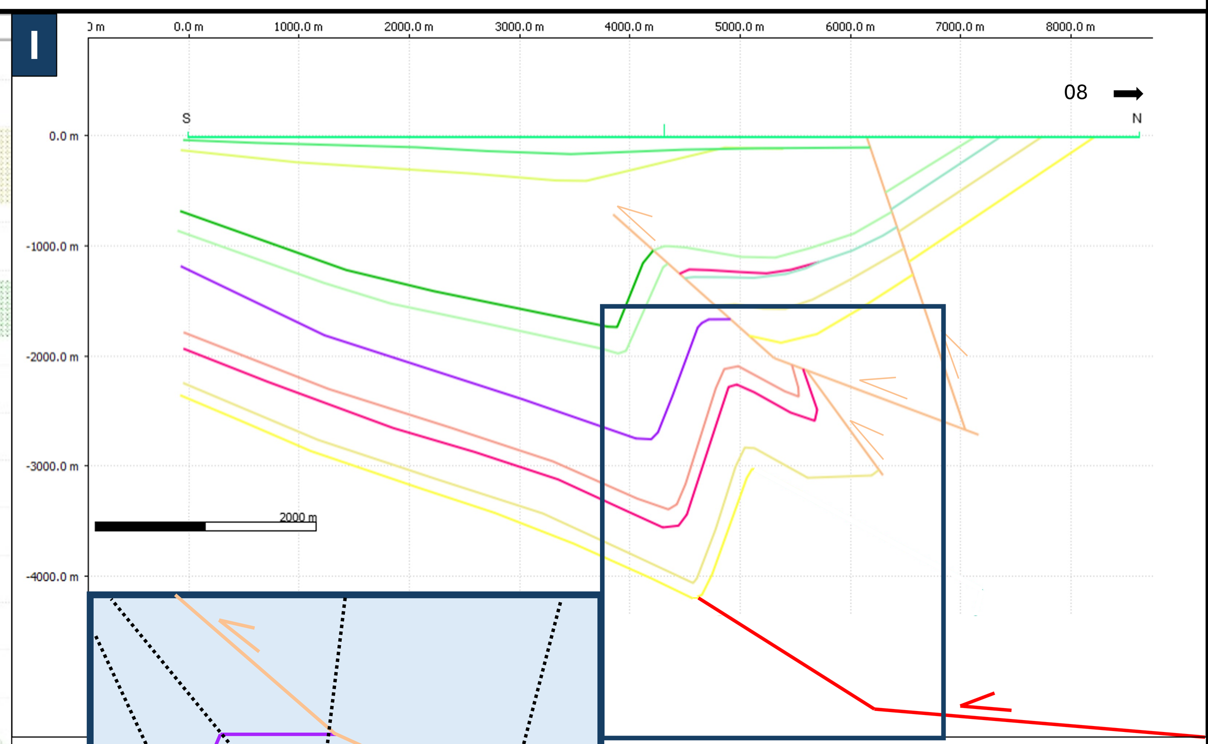

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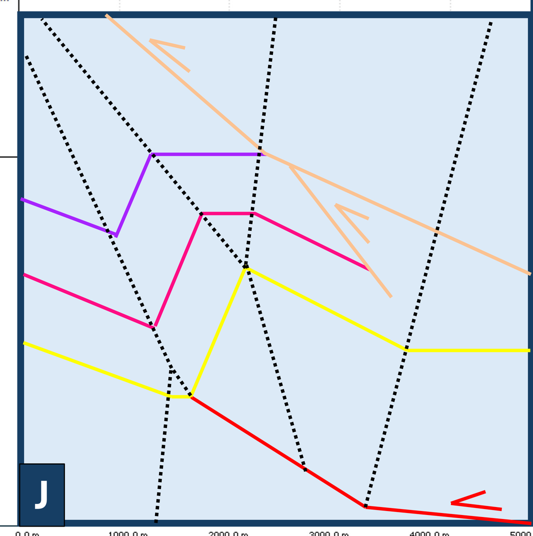


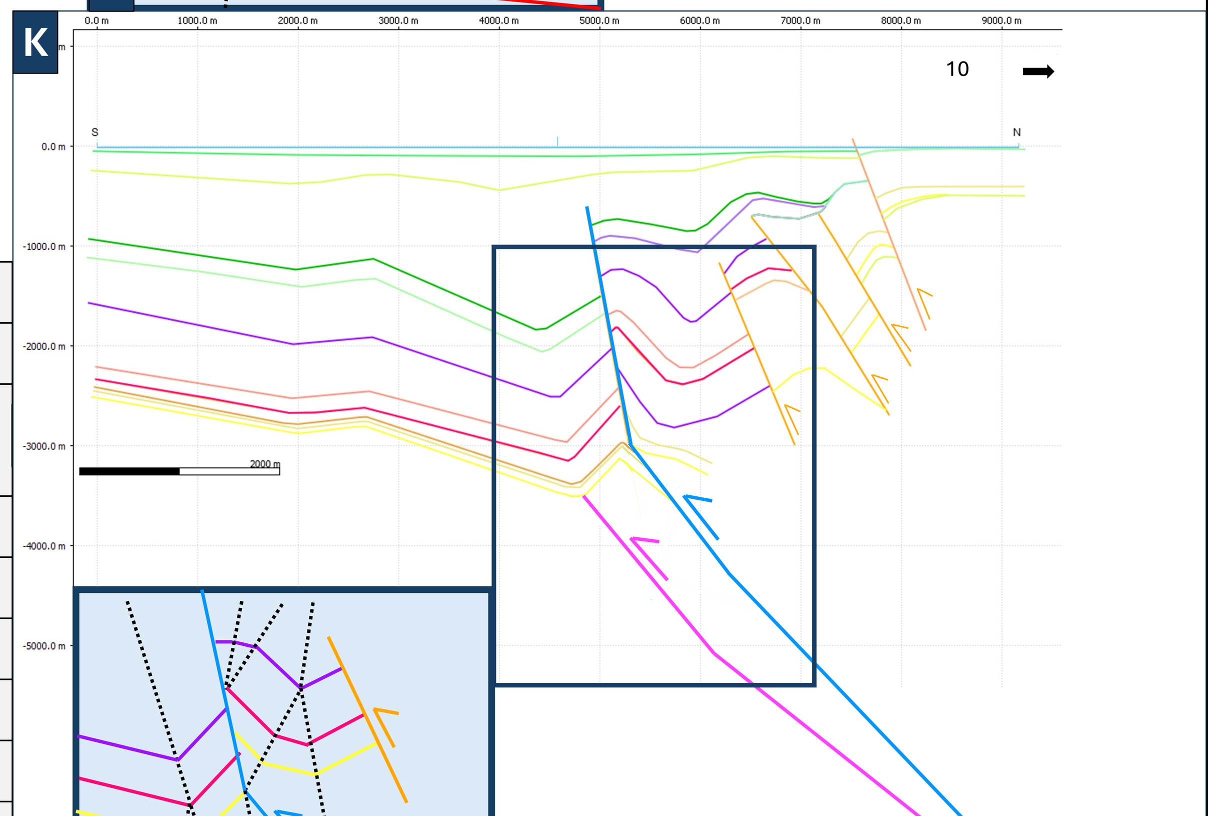
**J**: Geometric simplification of stratigraphy used in the model solution shown in I. The dip and positions of interpreted faults are based on measured bed dip and constructed axial surfaces.

**G**: Map view of 3 constructed dip sections from MOVE, with oil fields and the CA coastline for reference. Plunging synclinal and anticlinal axial traces are represented in orange and red, respectively. The full along-strike extent of these structures is unknown.
**H**: Regional stratigraphic column from Blake, 1989.
**I**: Dip section 2 with low-angle fault solution represented in red. SMF strands represented in orange.
**K**: Dip section 3 with high-angle solution represented in pink (Sawtelle fault) and blue (Rancho fault).

H

| Unit Name | Color | Geologic Age |
|---|---|---|
| Upper Pico | | Early to Late Pleistocene |
| Middle Pico | | Late Pliocene to Early Pleistocene |
| Lower Pico | | Late Pliocene |
| Upper Repetto | | Early Miocene |
| Middle Repetto | | Early Pliocene |
| Lower Repetto | | Early Pliocene |
| Delmontian A | | Late Miocene |
| Delmontian B | | Late Miocene |
| Upper Mohnian | | Late Miocene |
| Lower Mohnian | | Middle Miocene |
| Topanga | | Early to Middle Miocene |

K



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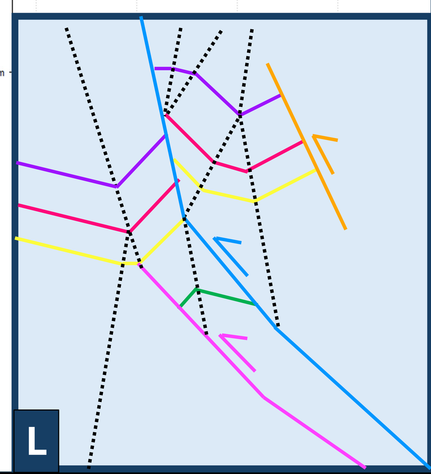


**L**: Geometric simplification of stratigraphy used in the model solution shown in K.

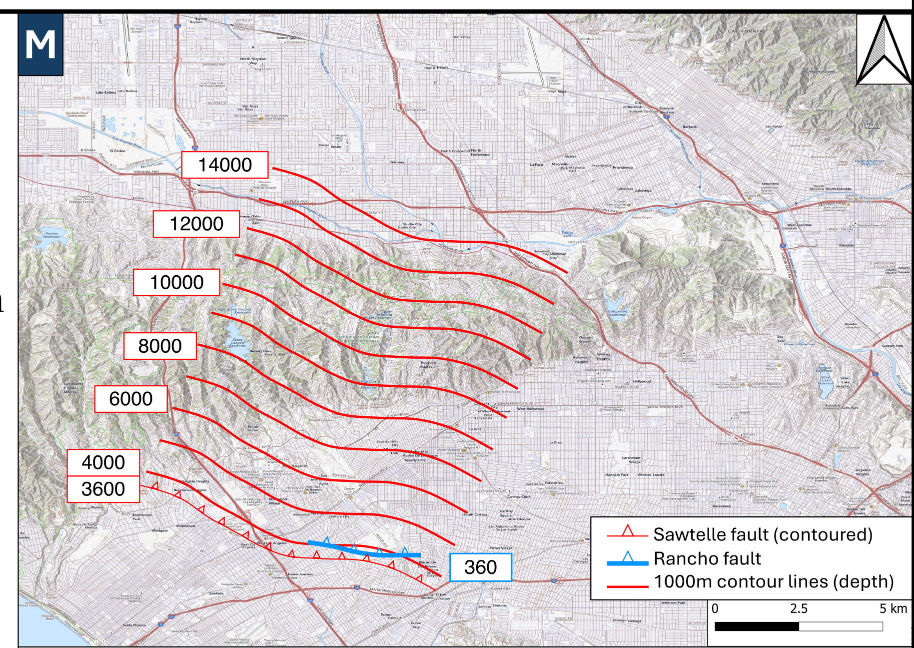
## Conclusions and acknowledgements

1. We document existence of the Sawtelle fault and present both low-angle (32° and 5°) and high-angle (49° and 39°) fault dip solutions.
2. We refine the geometry of the Rancho fault, a multi-bend thrust interpreted as a hanging wall splay of the Sawtelle fault, with dips ranging from 46° to 79°. Its lateral extent remains unconstrained.
3. Preliminary evidence of Pleistocene deformation suggests this system may be seismogenic. Accordingly, we map its extent to the BPT base.

Future work is devoted to:

1. Investigating late Pleistocene and Holocene activity within this fault system using water-well data
2. Refining current models for potential incorporation into the CFM
3. Extending this workflow (1) east of the NIF, where we hypothesize the presence of a laterally offset, active corresponding fault system, and (2) southward into the thrust belt described in the introduction
4. Characterizing associated seismic hazards through deterministic and probabilistic analyses

M




**M**: Map view of Sawtelle and Rancho faults, with cultural map of LA for reference. Assuming local seismogenic crust thickness of ~15 km, the Sawtelle fault extends ~14km ~20° E of N in map view. Rancho fault extent in depth not contoured.

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**References**: AAPG (2005). Seismic Interpretation of Contractional Fault-Related Folds; Allmendinger, R.W. (1998). Tectonics **17**, 640–656; Blake, G. H. (1991). Active Margin Basins **52**, 135–184; Schneider, C. L., Hummon, C., Yeats, R. S. & Huftile, G. L. (1996). Tectonics **15**, 341–355; Suppe, J. & Medwedeff, D. (1990). Eclogae Geol. Helv. **83**, 409–454; Tsutsumi, H., Yeats, R. S. & Huftile, G. J. (2001). Geol. Soc. Am. Bull. **113**, 454–468.