

Implications of paleoseismic data for complex, large-magnitude, multi-segment ruptures along the Ventura-Pitas Point-San Cayetano fault system

James Dolan, Jess Grenader, Lee McAuliffe, John Shaw, Ed Rhodes, Judith Hubbard, Tom Pratt

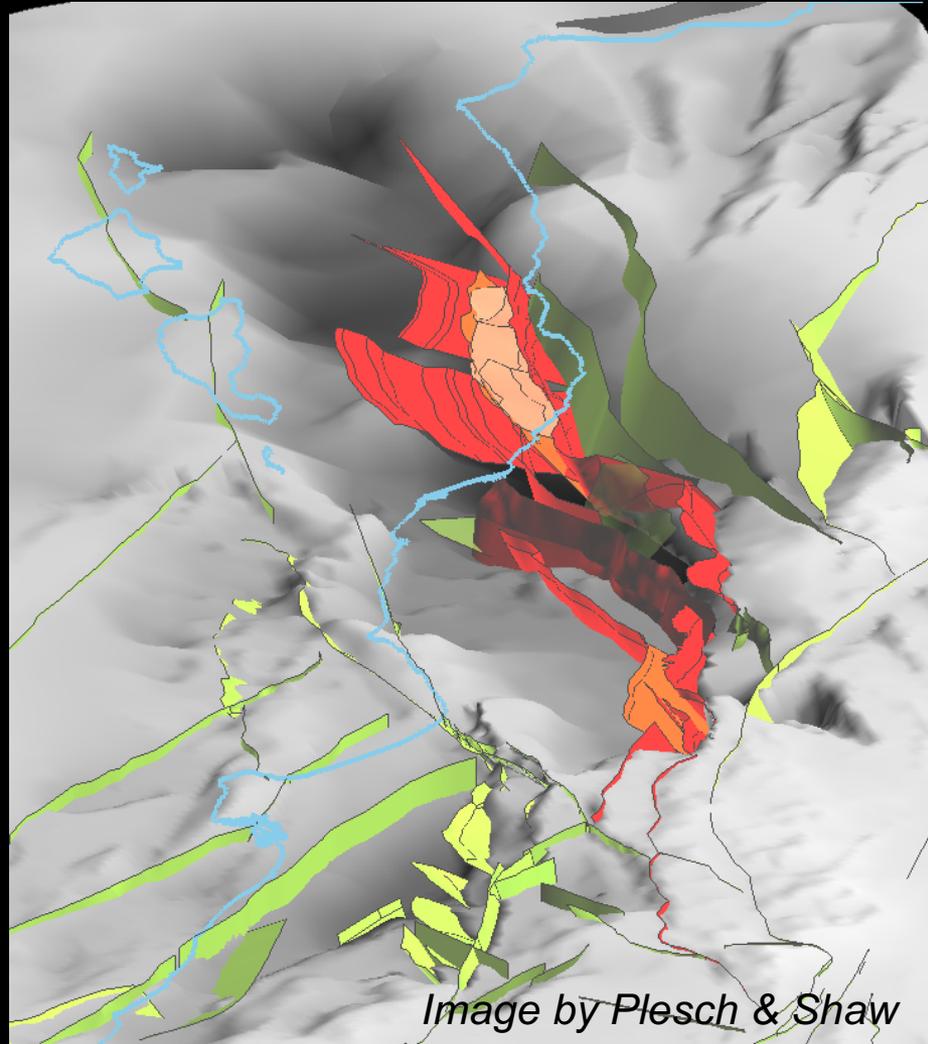
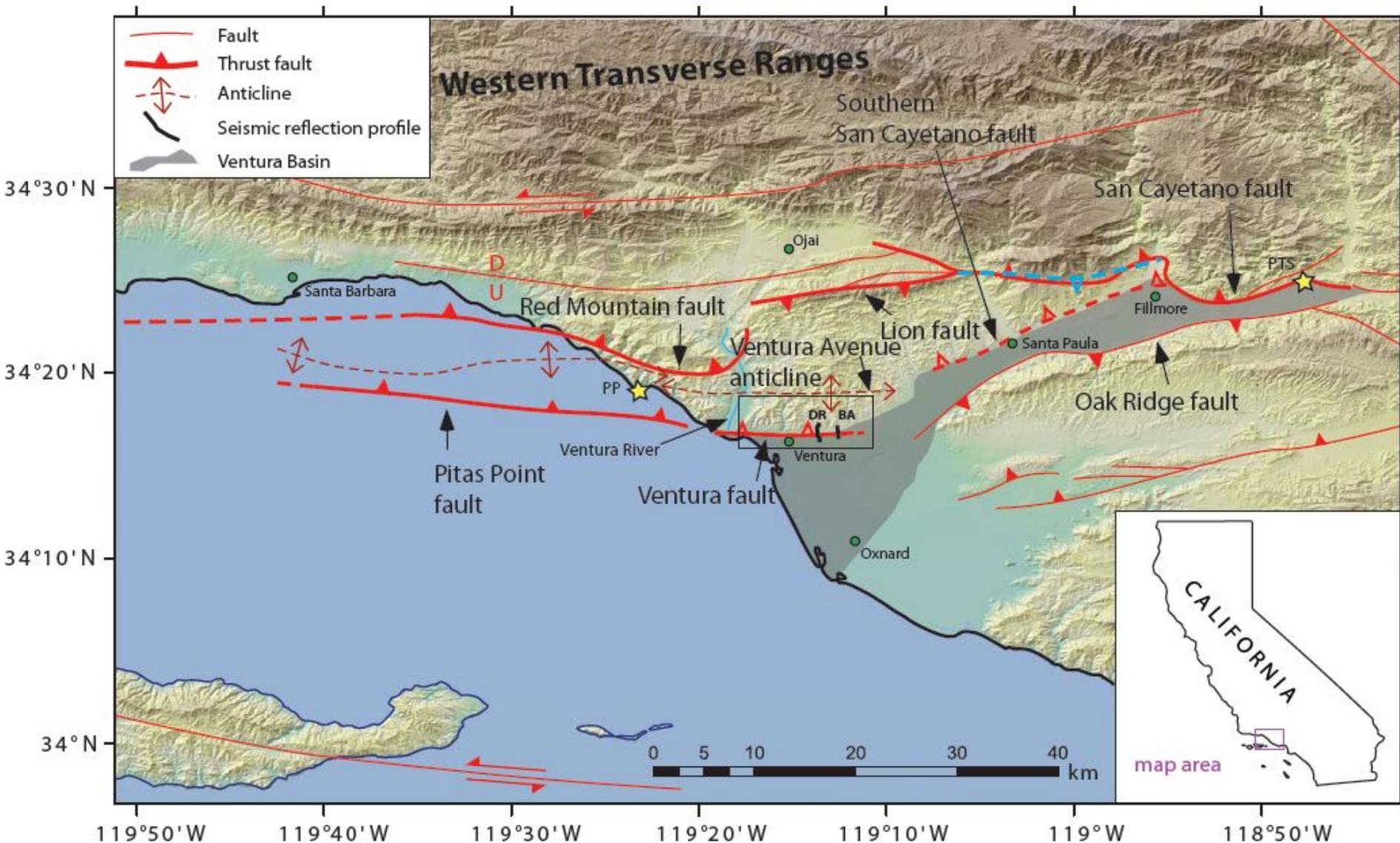


Image by Plesch & Shaw

Major Active Faults of the Ventura Region



Many potential fault interconnections

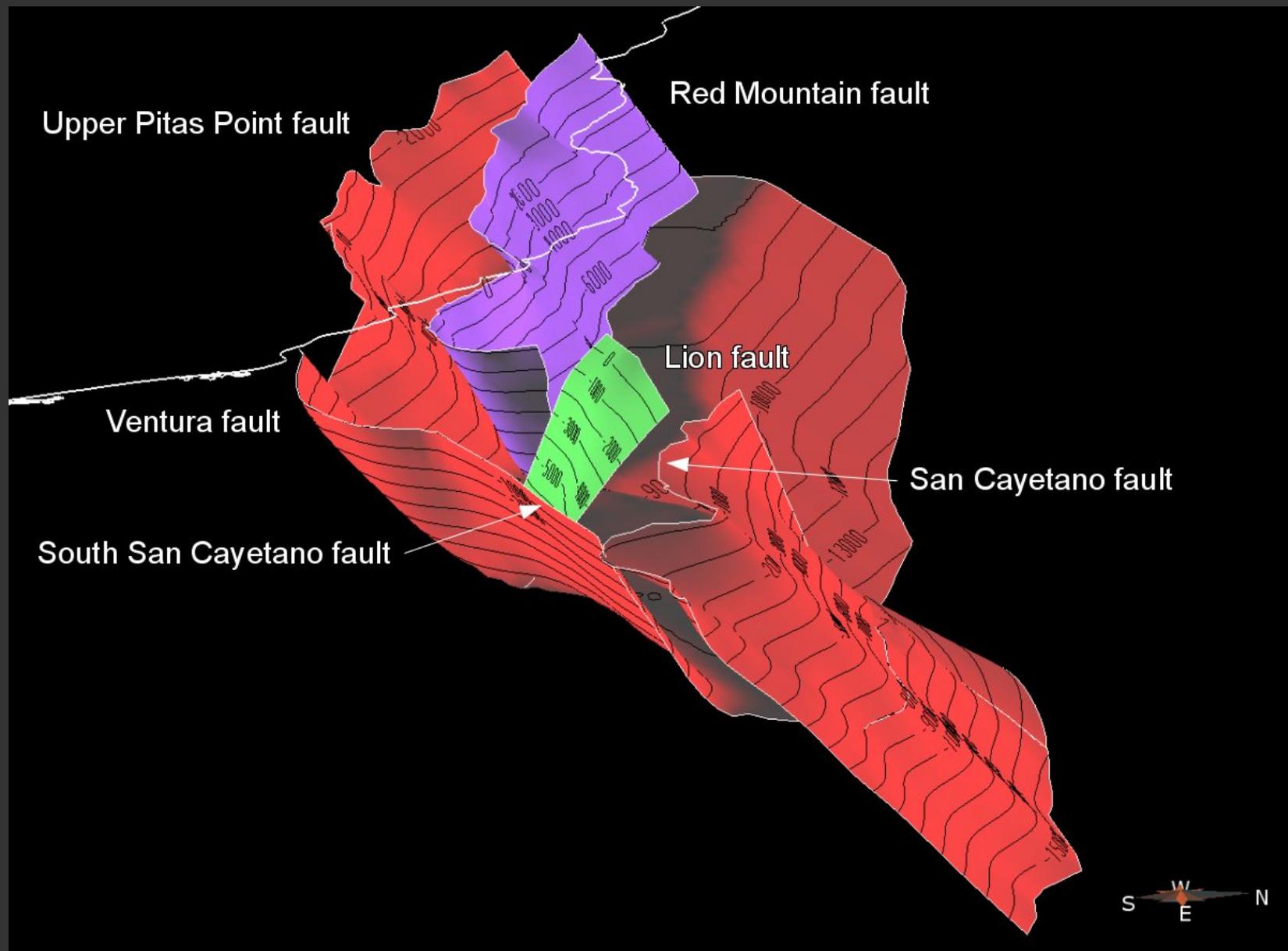
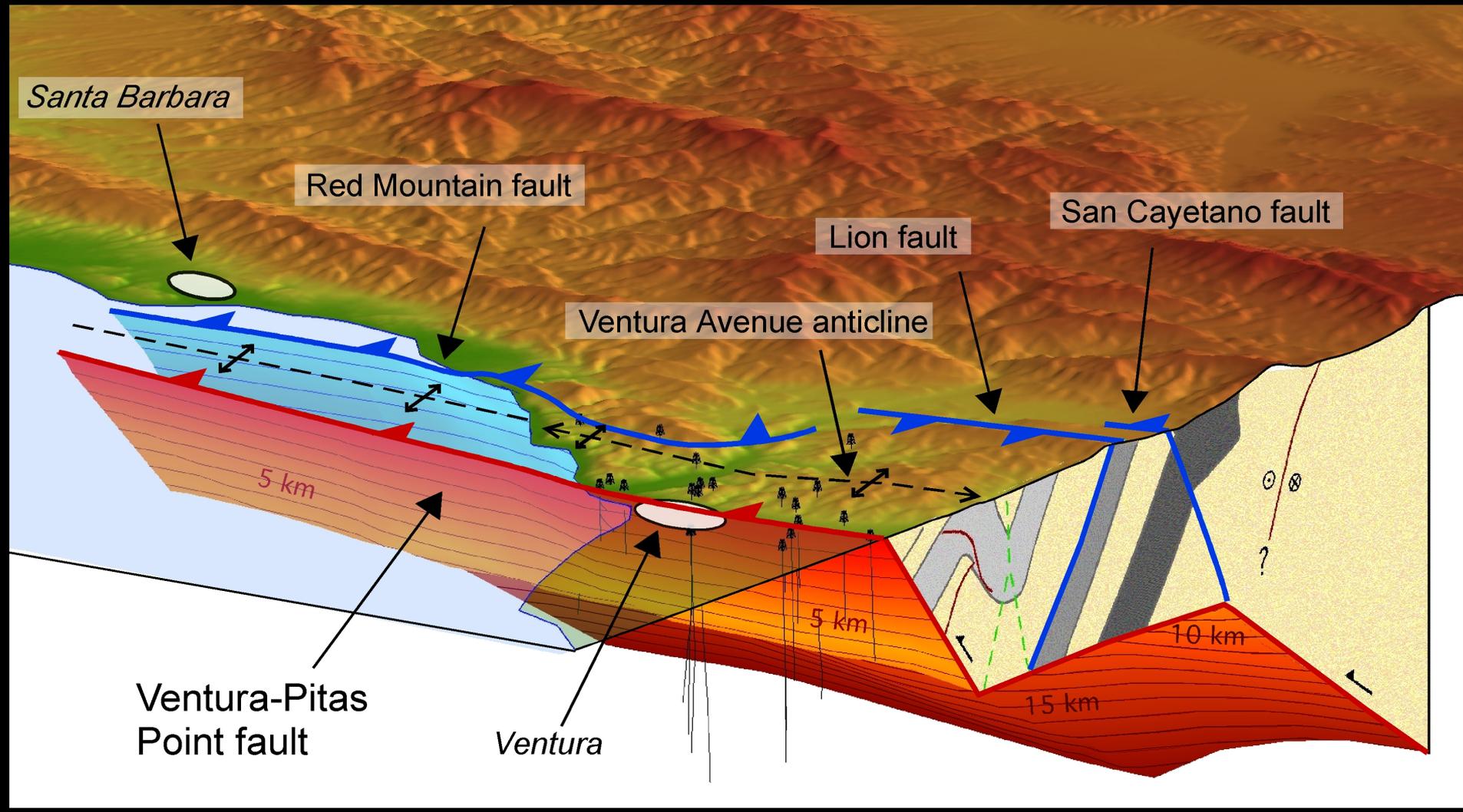
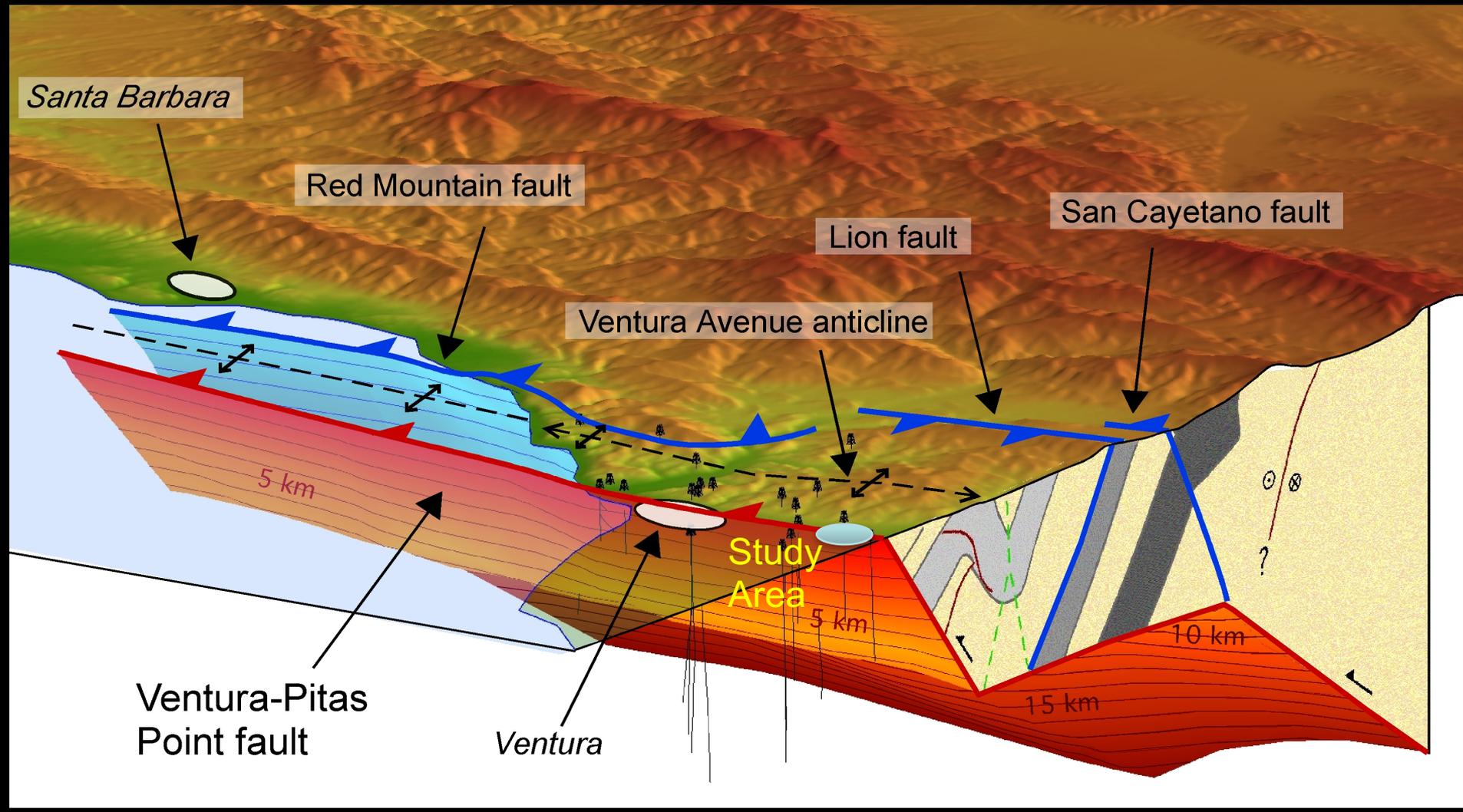


Image by Andreas Plesch &
John Shaw

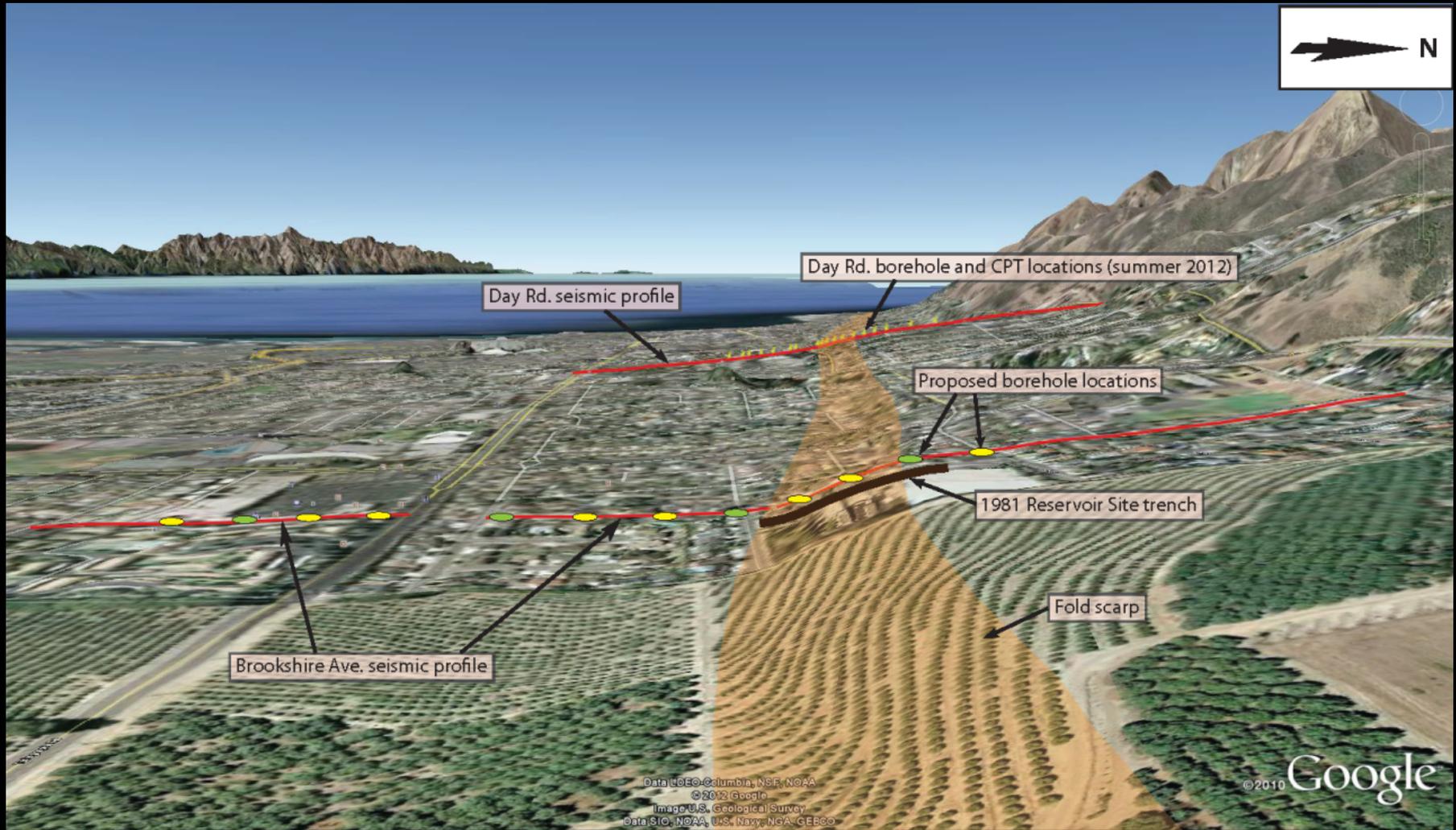
The Ventura-Pitas Point fault system



The Ventura-Pitas Point fault system



Motivation – Prominent fault & fold scarps in Ventura

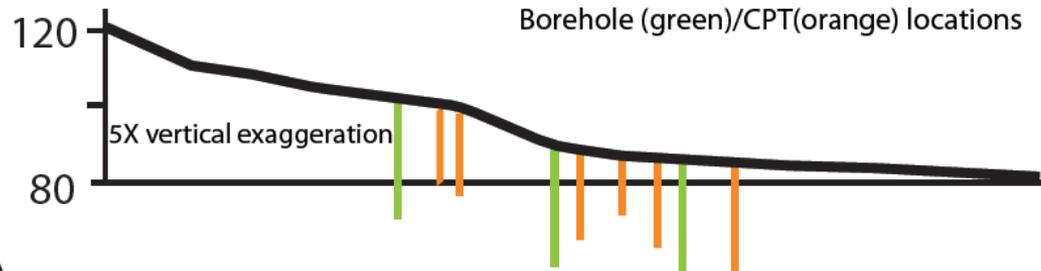


Surface manifestation of the Ventura fault forms a prominent scarp running through the city of Ventura – target for paleoseismic investigations focused on discrete tipline folding.

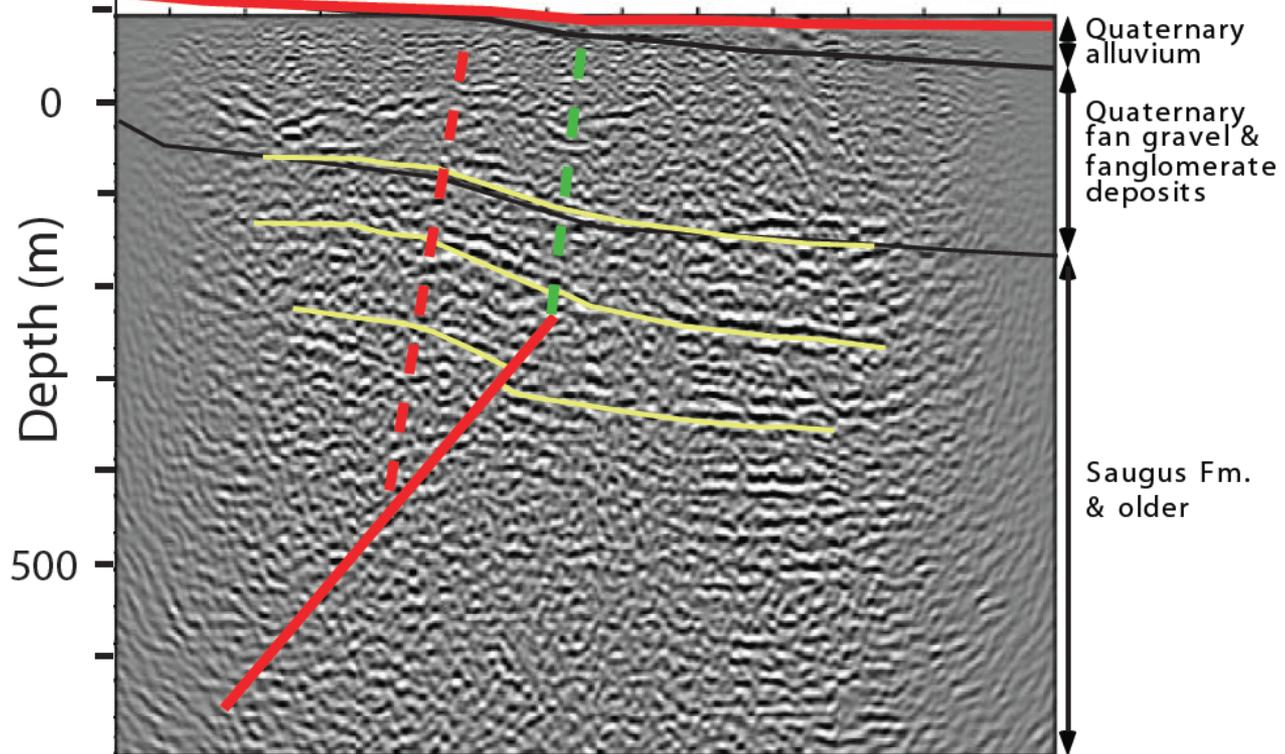
McAuliffe et al., 2015

Brookshire Avenue High-Resolution Seismic reflection profile

(A)

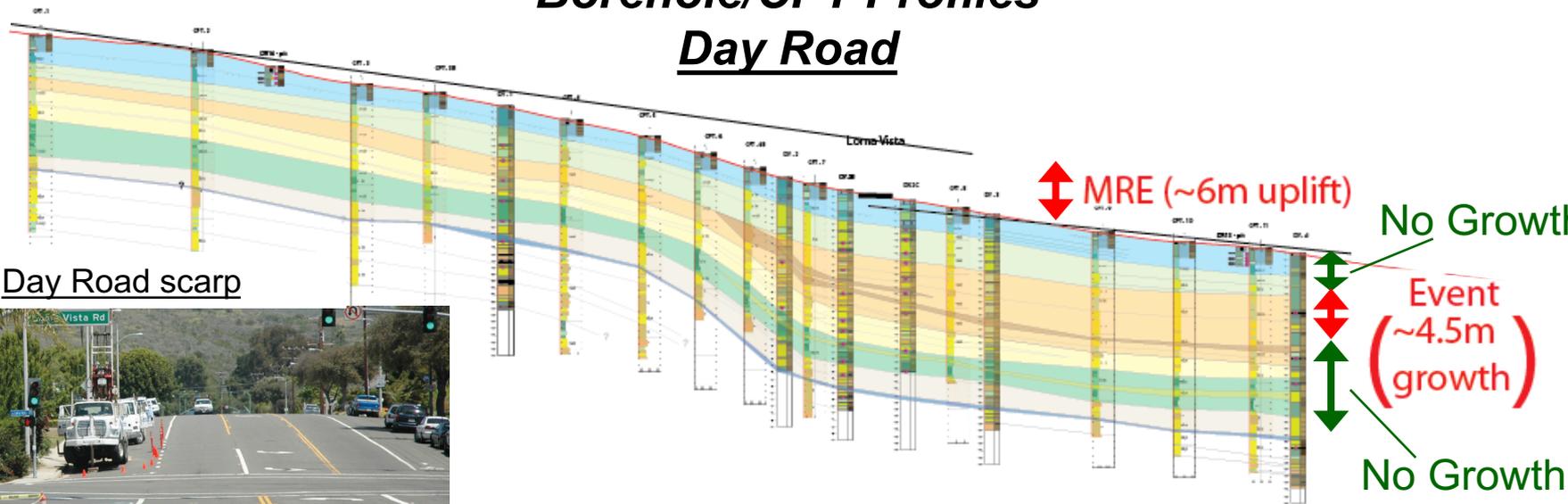


(B)



N

Borehole/CPT Profiles Day Road

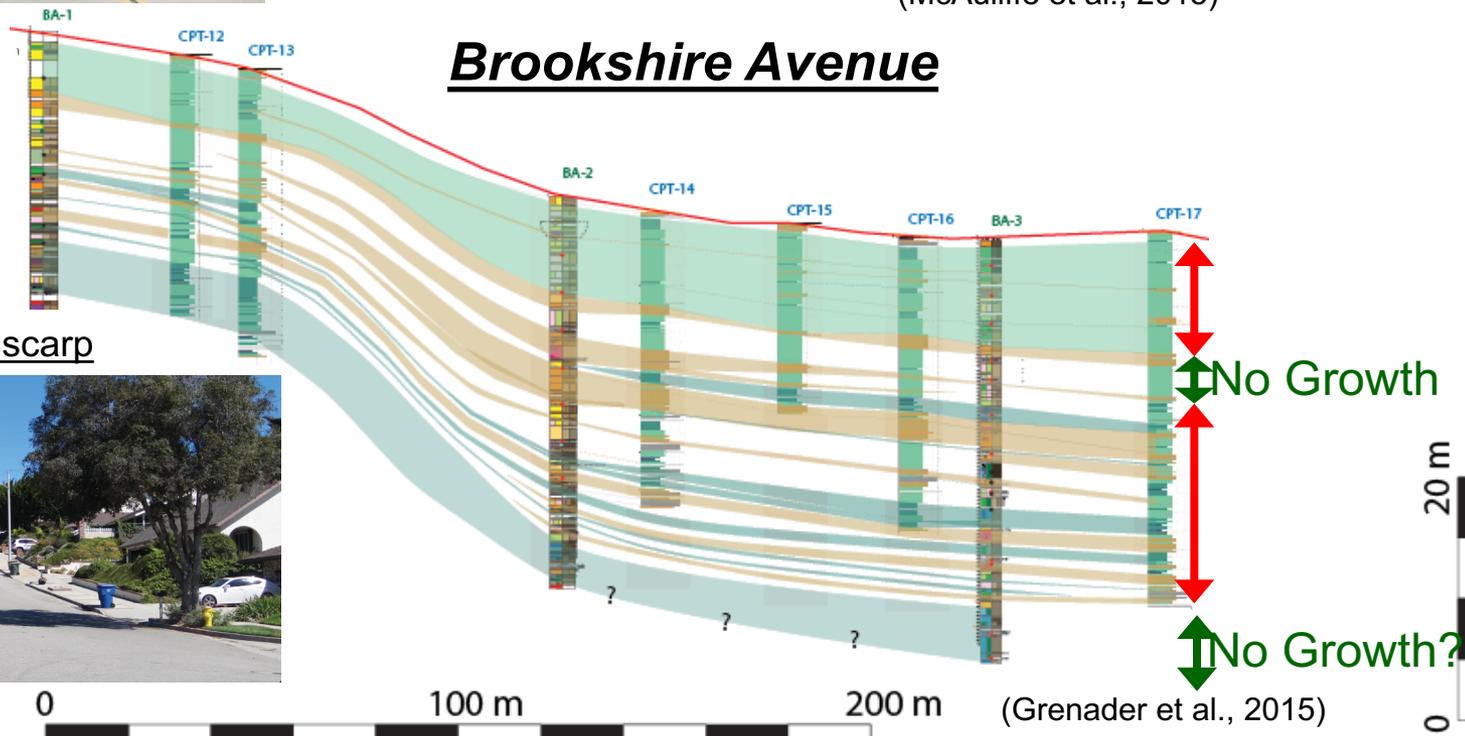


Day Road scarp



(McAuliffe et al., 2015)

Brookshire Avenue

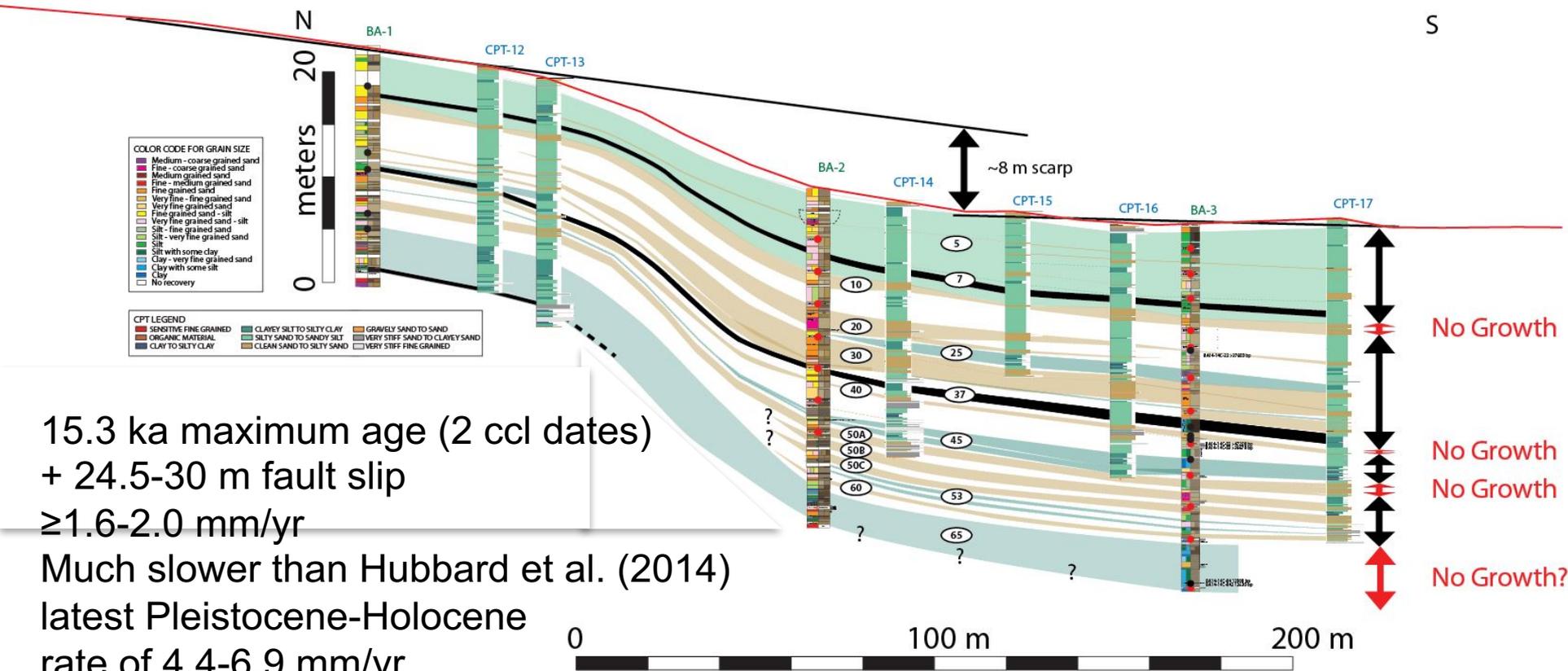


Brookshire Avenue scarp



(Grenader et al., 2015)

Brookshire Avenue Borehole/CPT Transect



Grenader et al., in prep. 2016

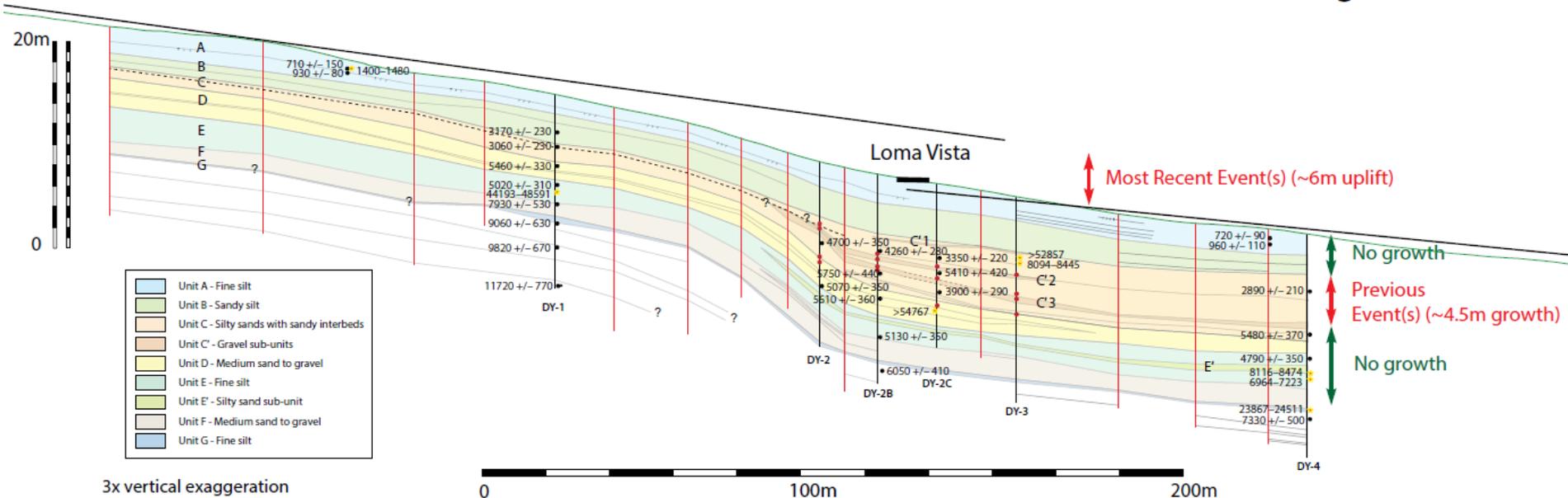
Day Road Borehole/CPT Transect

Active alluvial fan deposition at site
 More continuous record than at Brookshire Avenue site
 Evidence for two stratigraphically discrete, very large (4.5-6.5 m) uplift events
 MRE post-800 yBP? IRSL dating vs. ^{14}C ?
 Event 2 occurred 4.1-4.7 ka



— Brookshire Avenue high-resolution seismic reflection profile — Brookshire Avenue borehole/CPT area
— Day Road high-resolution seismic reflection profile — Day Road borehole/CPT area — Ventura Fault scarp

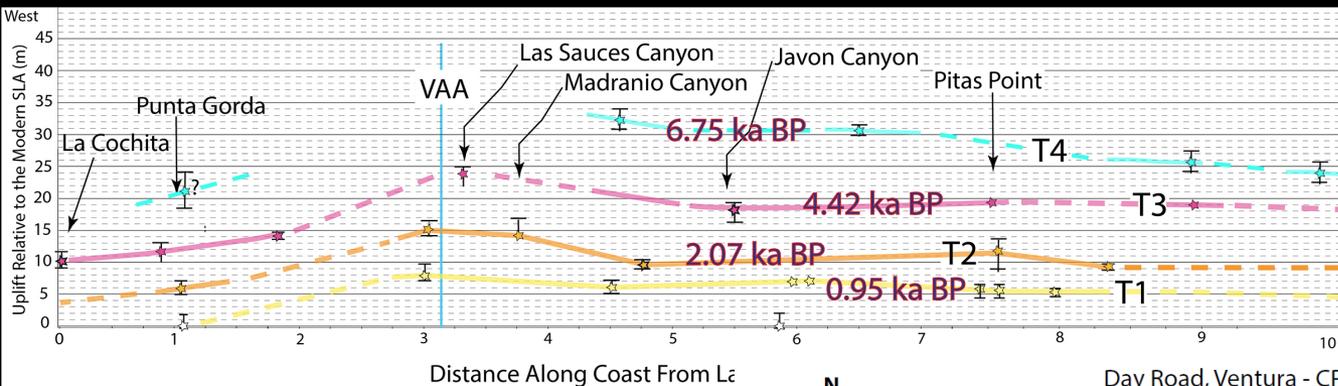
N Day Road, Ventura - CPT/Borehole S



3x vertical exaggeration

0 100m 200m

Comparison of record of discrete tipline folding at Day Road with record of coastal uplift events related to growth of VAA

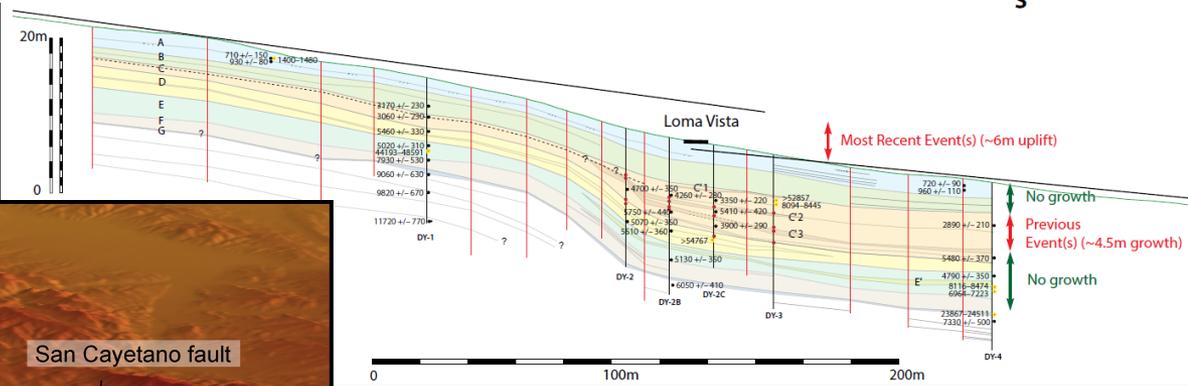


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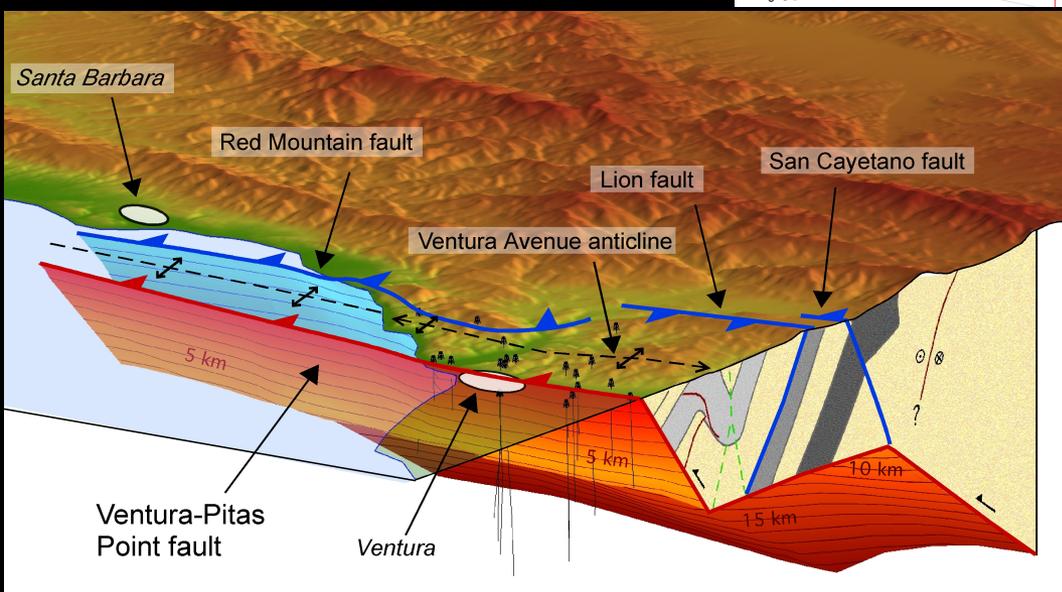
Day Road, Ventura - CPT/Borehole

S

Rockwell et al. 2016



McAuliffe et al. 2015



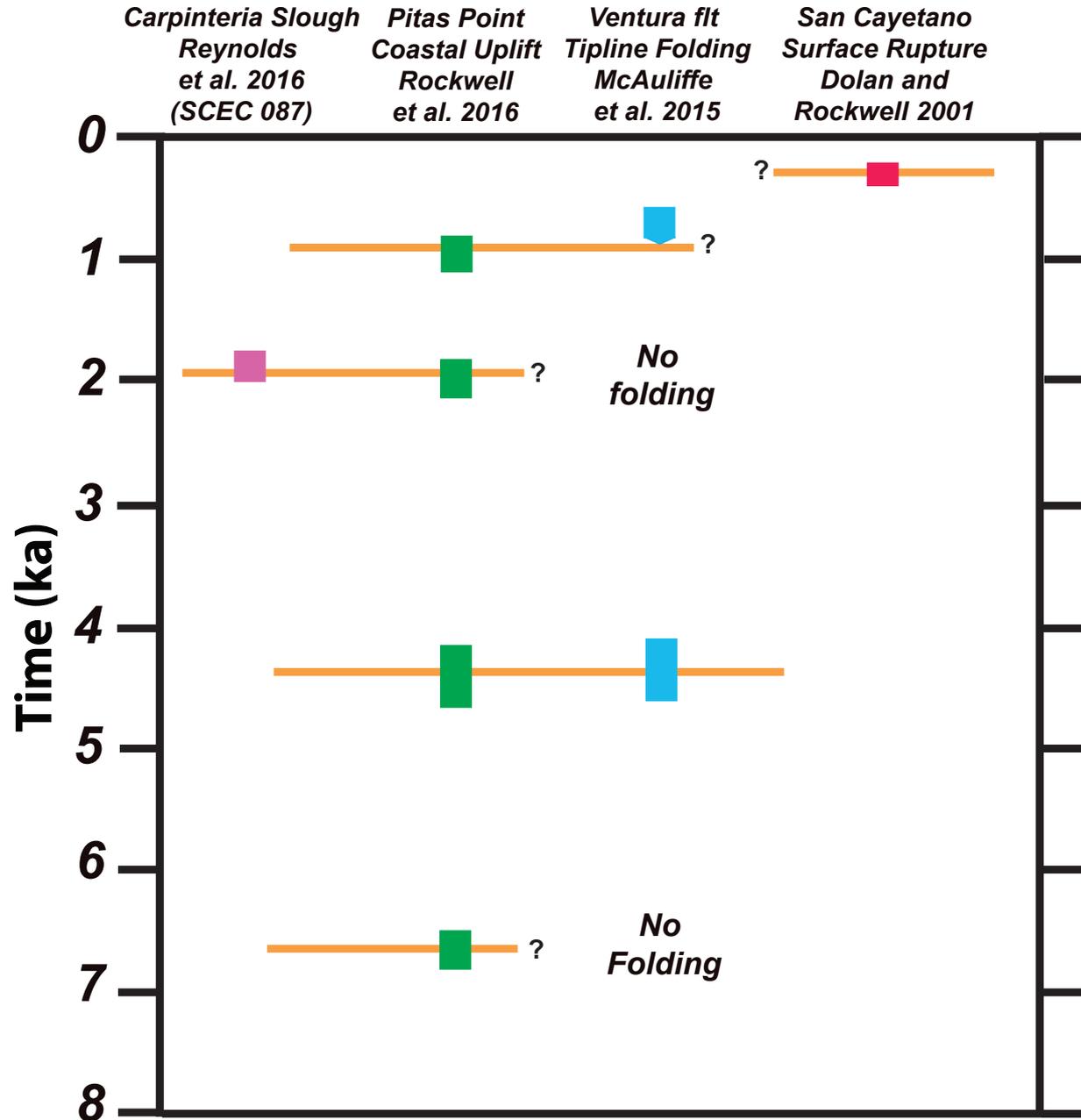
Hubbard et al. 2014

Paleo-earthquake data from the Ventura-Pitas Point Fault System

Basic Observations:

- (1) Four mid- to late Holocene uplift events observed at Pitas Point (0.95 ka, 2.07 ka, 4.42 ka, and 6.75 ka; Rockwell et al., 2016)**
- (2) Only two of these events (MRE and ca. 4.37 ± 0.3 ka earthquake) are observed as discrete fault tipline folding along the eastern part of the Ventura-Pitas Point system (McAuliffe et al., 2015). The other two PP events (2.07 ka & 6.75 ka) demonstrably did not cause discrete tipline folding in Ventura.**
- (3) At both sites, these events generated very large uplifts (4.5-6 m in Ventura, up to 8 m across VAA fold crest west of PP), consistent with very large co-seismic displacements (5.5 – 11 m).**

Ventura-Pitas Point-San Cayetano fault system paleo-earthquake ages



Grenader et al.
in prep. 2016

Paleo-earthquake data from the Ventura-Pitas Point Fault System

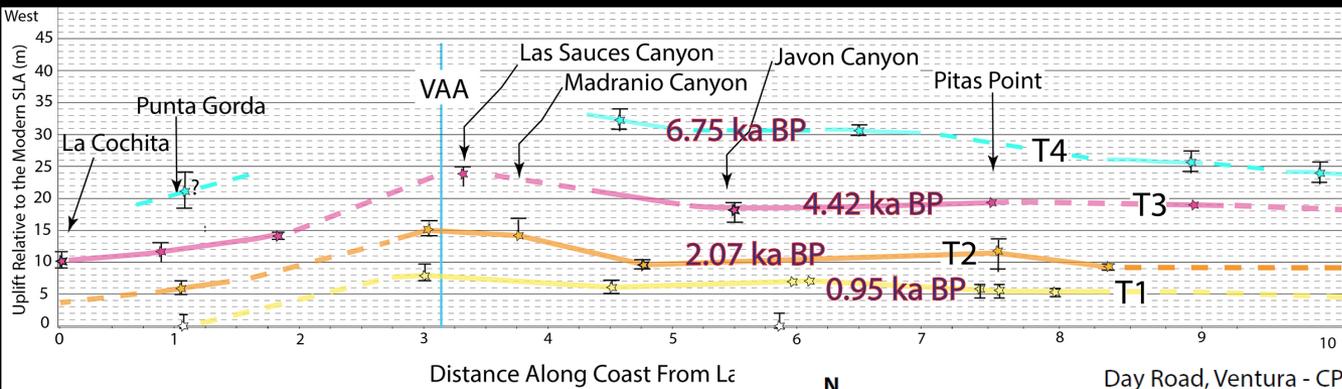
Possible Explanations:

(1) Events observed at Pitas Point sometimes do not extend as far East as Ventura. Arguing against this is the presumed relative structural continuity of the Ventura-Pitas Point system. This seems an unlikely explanation.

(2) Slip in some system-wide events extending through the soft Ventura–Southern San Cayetano fault segment boundary bypasses the Ventura fault sites of McAullife et al. (2015) & Grenader et al. (in prep.). Possible, but if 50% of the ruptures extend north of the geomorphically prominent Ventura fault scarp, where is the surface manifestation of this slip?

Neither of these scenarios provides a very compelling potential explanation of the observations. So what is going on?

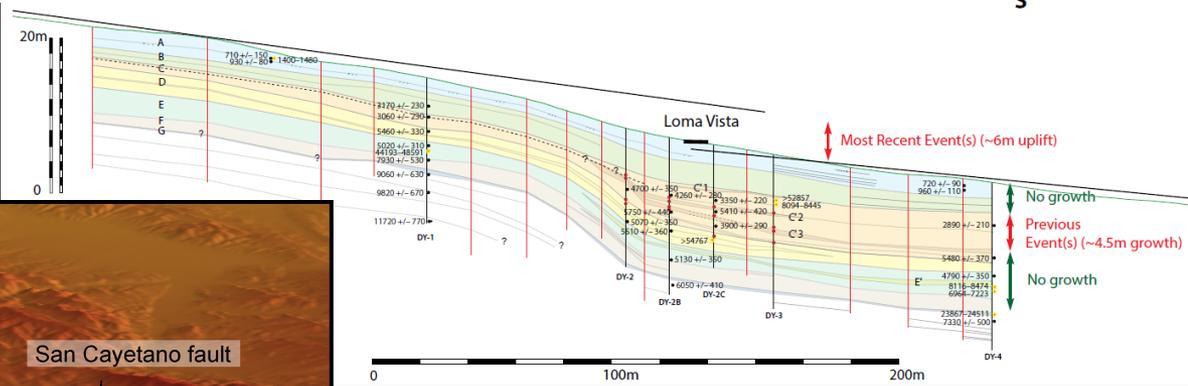
Comparison of record of discrete tipline folding at Day Road with record of coastal uplift events related to growth of VAA



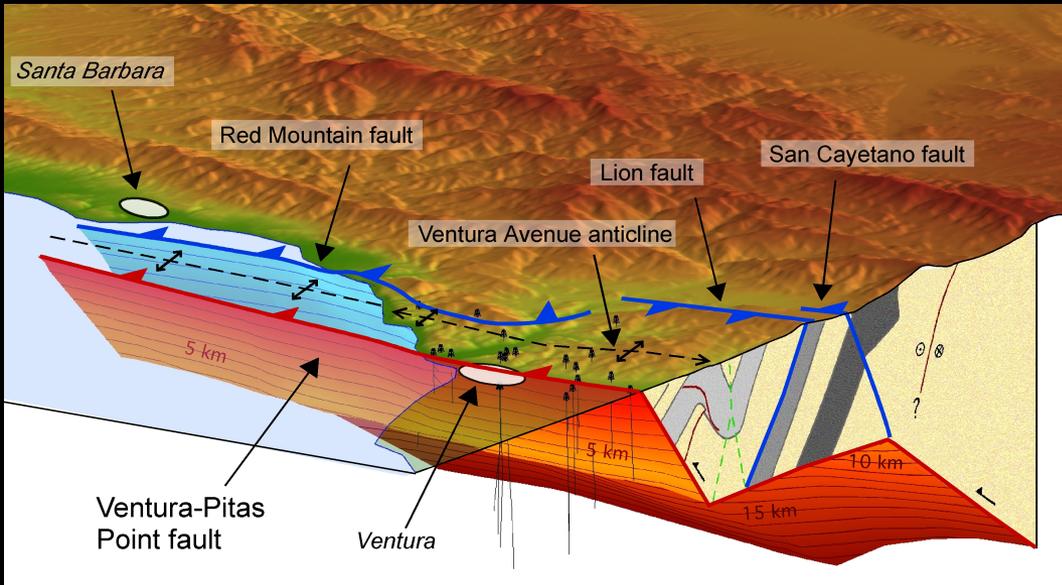
Records Uplift of VAA (not fault-specific)

Records Discrete tipline folding (fault-specific)

Rockwell et al. 2016



McAuliffe et al. 2015



Hubbard et al. 2014

Paleo-earthquake data from the Ventura-Pitas Point Fault System

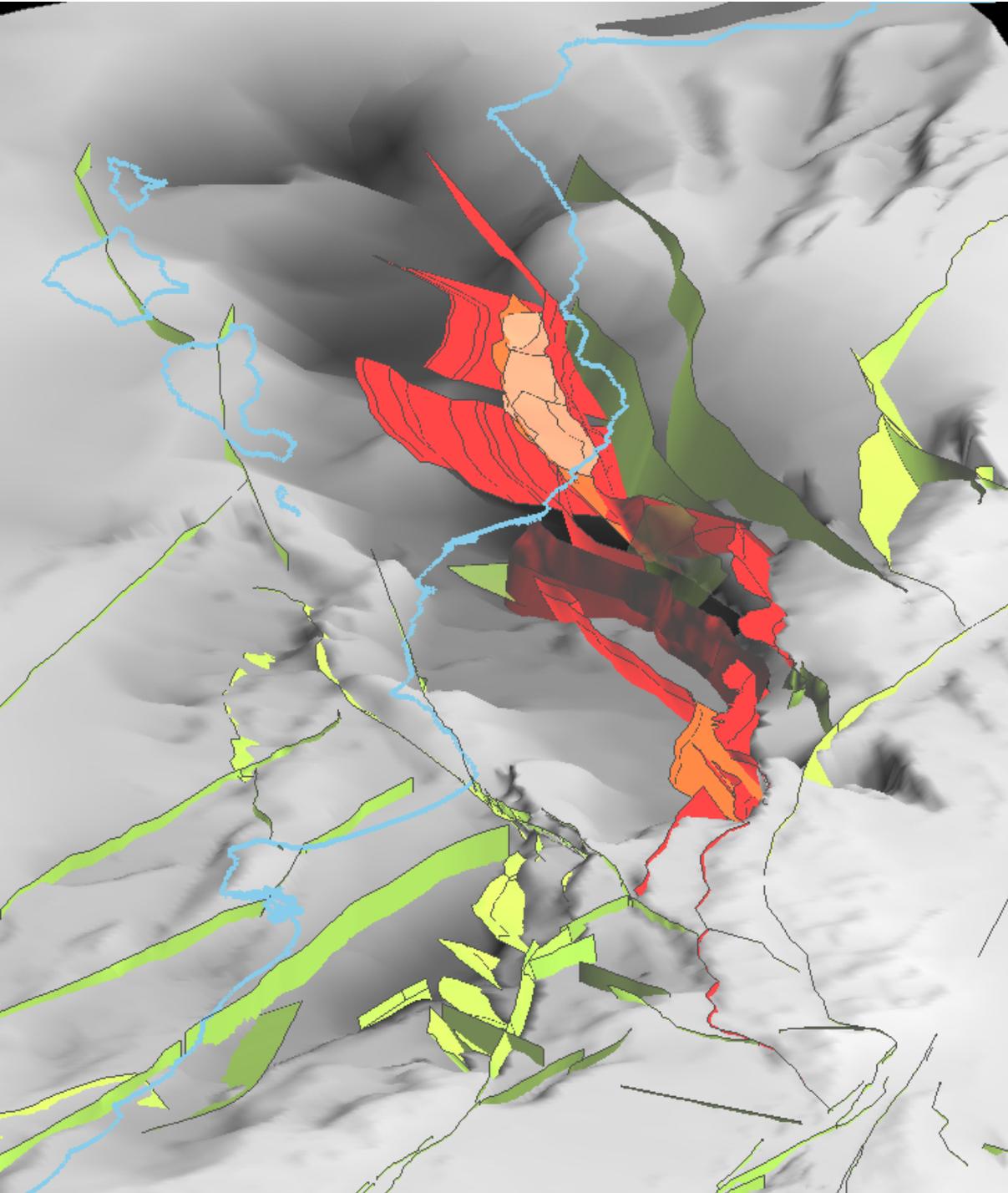
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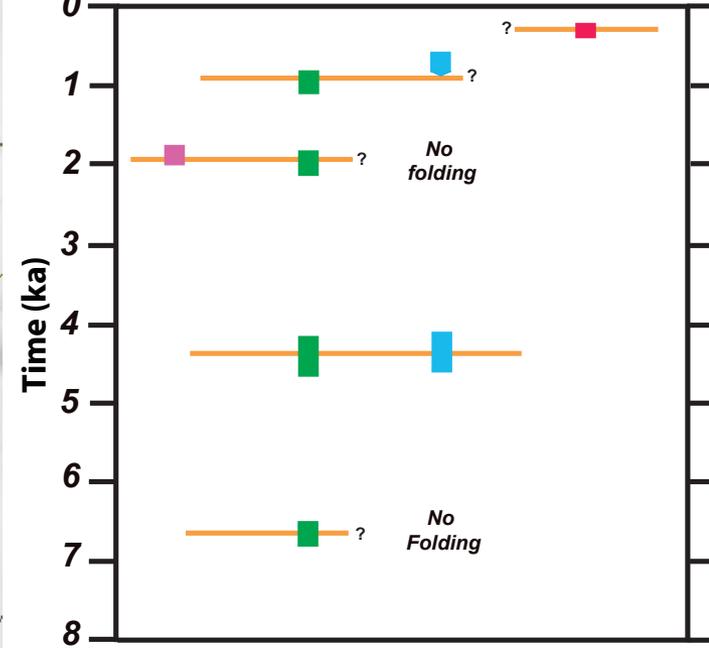
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(3) Slip in some PP events extends to the surface not at the tipline of the Ventura-Pitas Point thrust ramp, but rather along backthrusts.

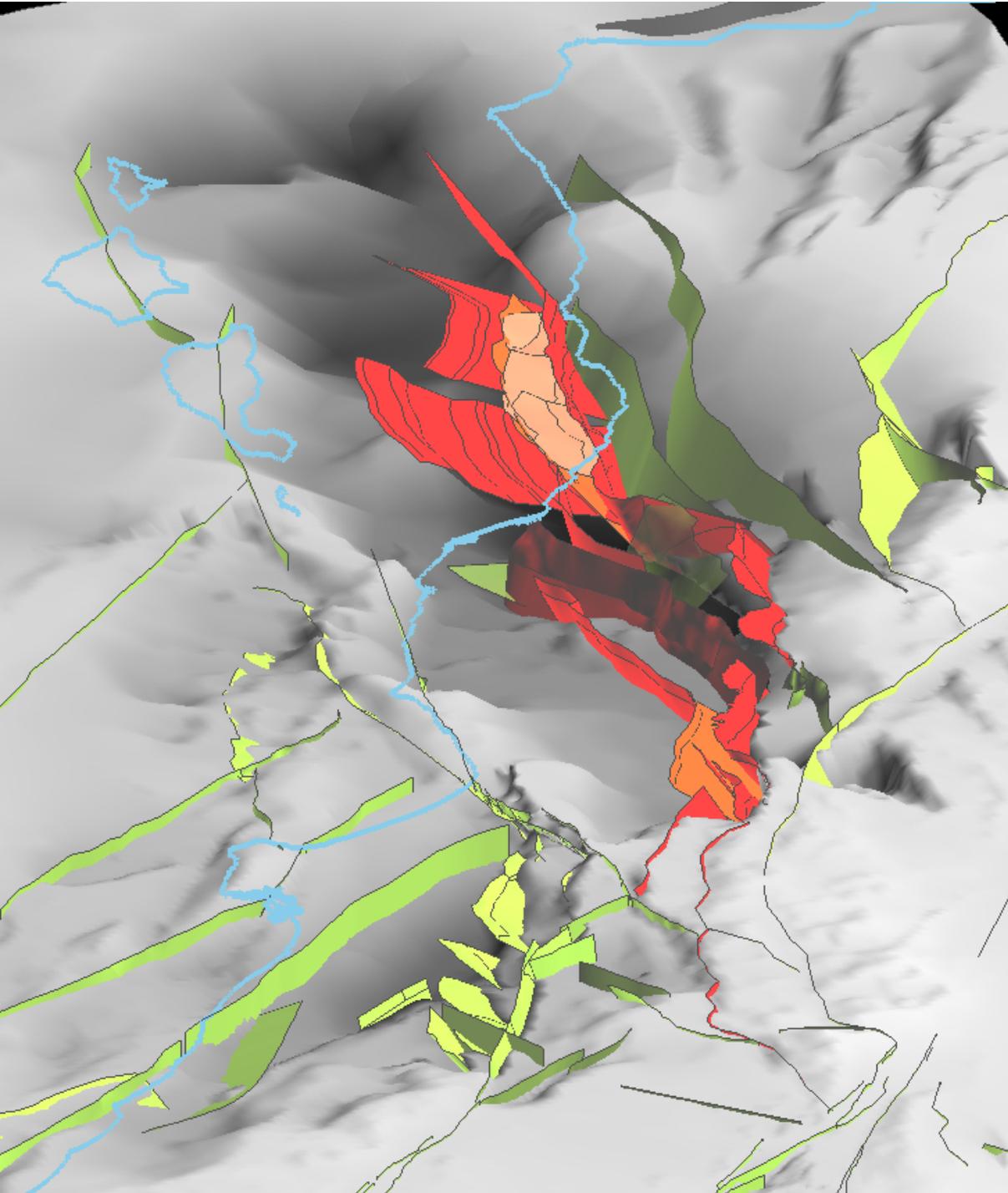
Large backthrusts in Ventura region thrust system



Carpinteria Slough Reynolds et al. 2016 (SCEC 087)	Pitas Point Coastal Uplift Rockwell et al. 2016	Ventura fjt Tipline Folding McAuliffe et al. 2015	San Cayetano Surface Rupture Dolan and Rockwell 2001
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Grenader et al.
in prep. 2016



Large backthrusts in Ventura region thrust system

*e.g., Lion fault (and its
possible eastward extension
Southern San Cayetano
fault), as well as smaller
examples such as Rincon
Creek fault (Carpinteria
Slough subsidence 1.9 ka)
and Javon Canyon fault*

*Image by Andreas Plesch
& John Shaw*

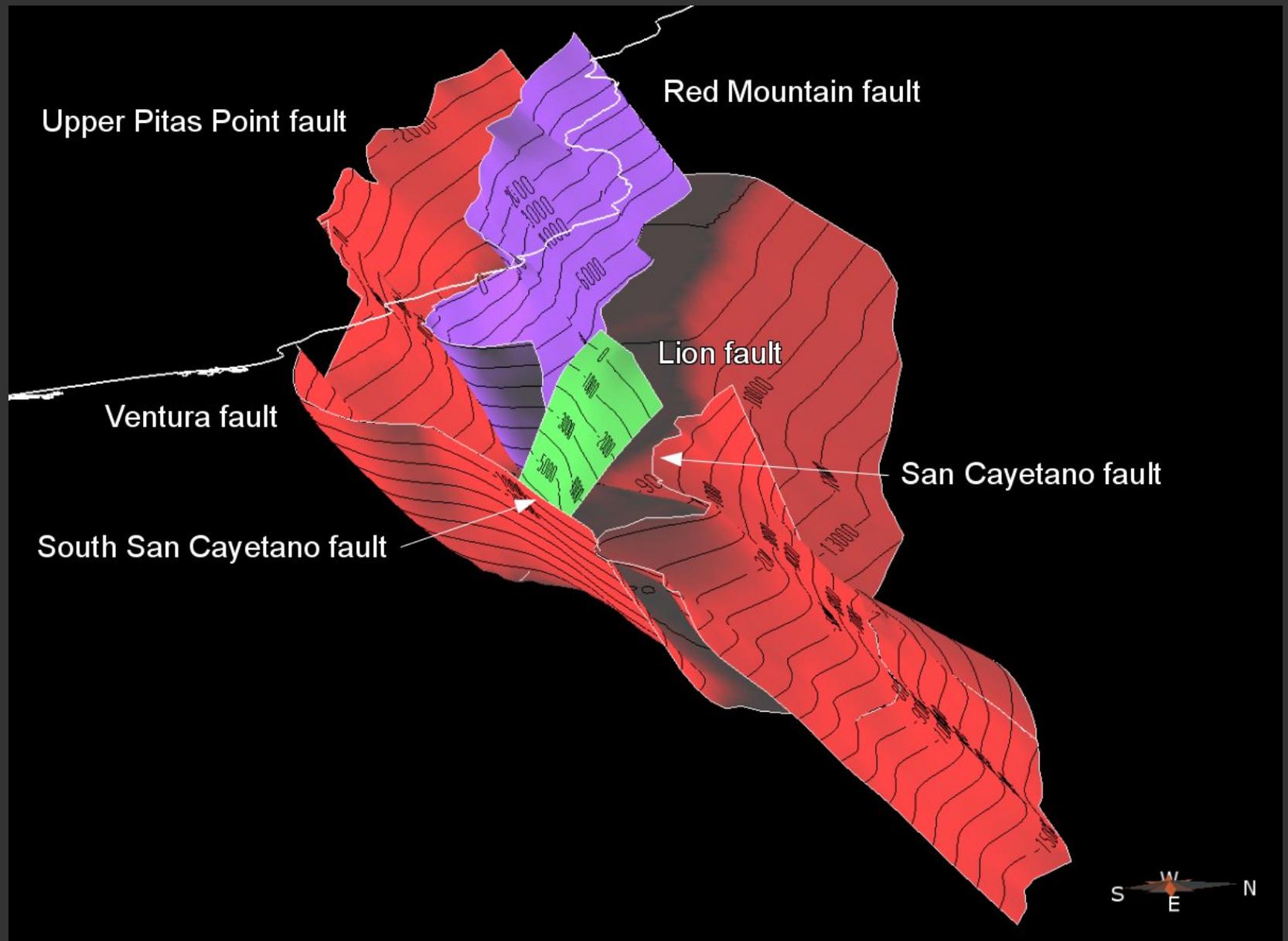
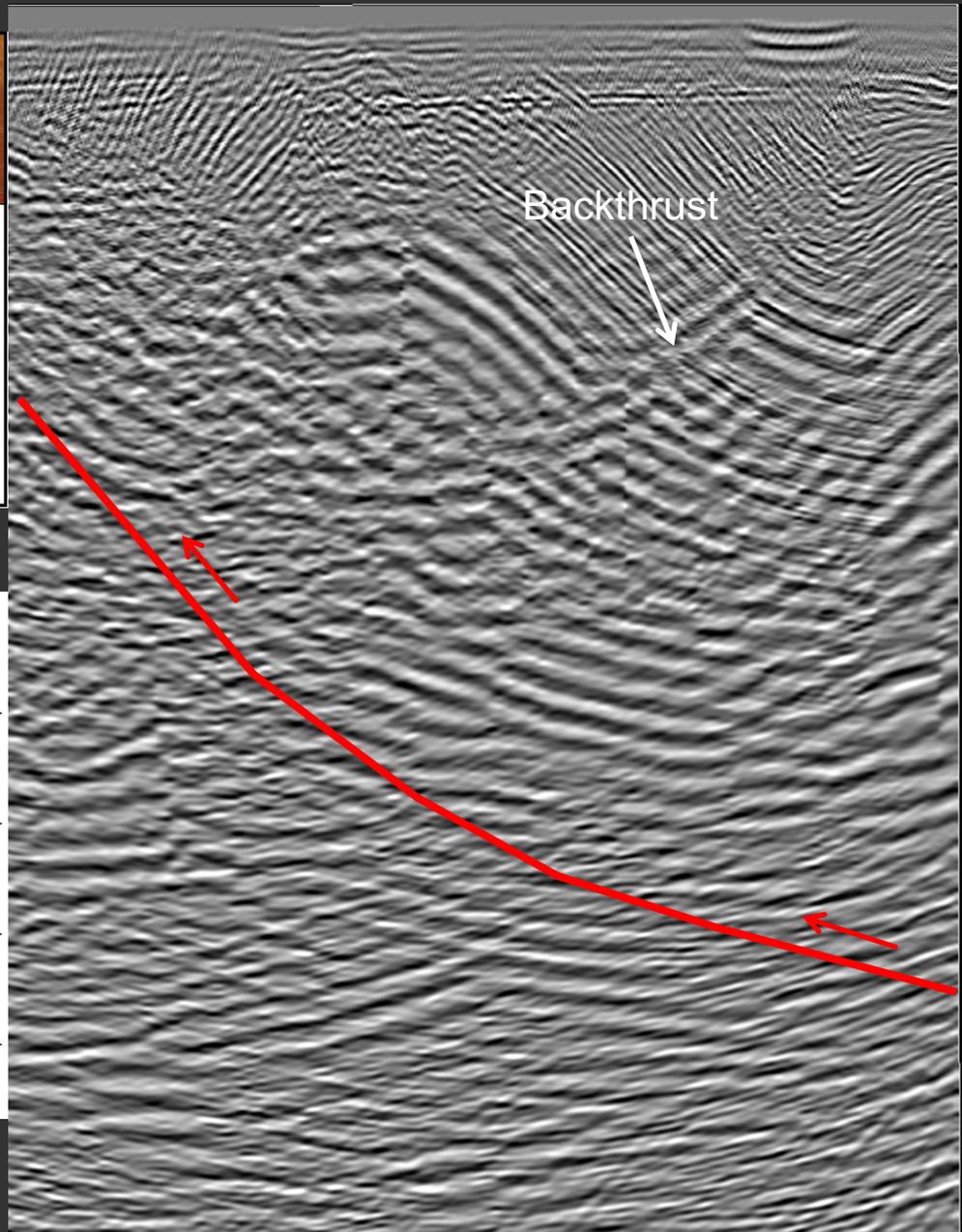
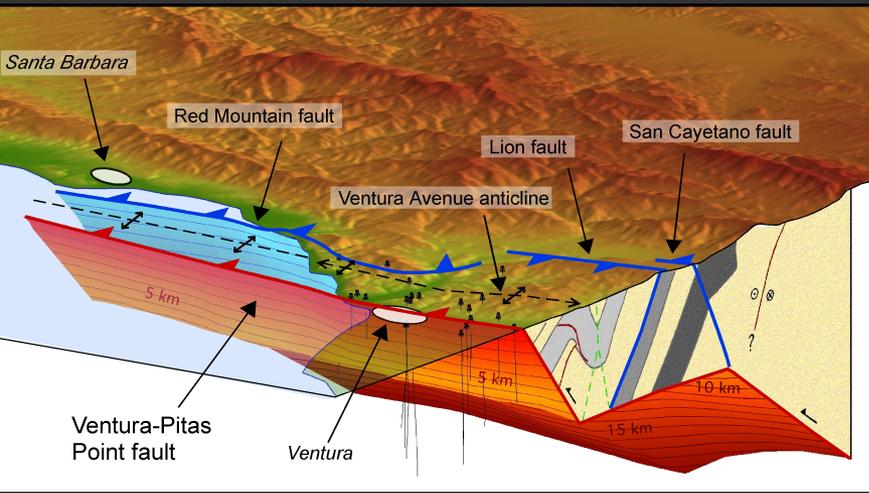


Image by Andreas Plesch & John Shaw

3D seismic showing south-dipping backthrust offshore



Hubbard et al., 2014

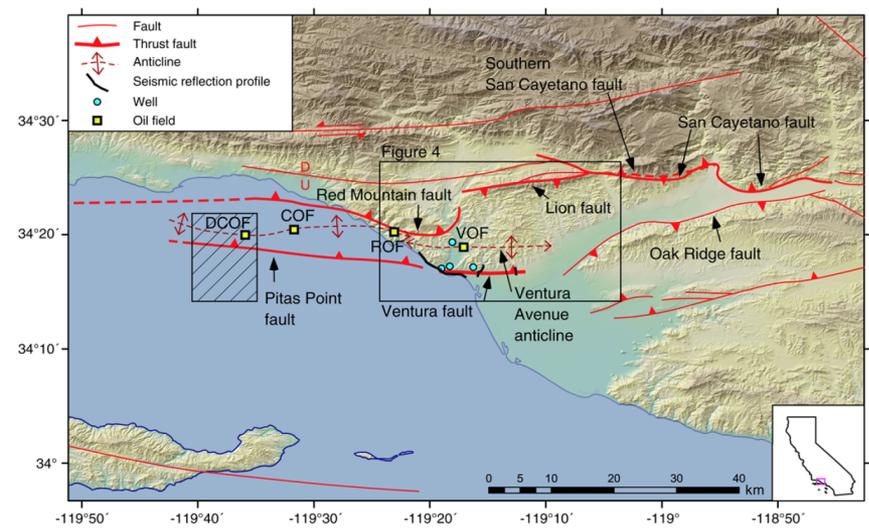


Image from John Shaw

Conclusions

Very large uplifts require very large displacement events that indicate large-magnitude earthquakes

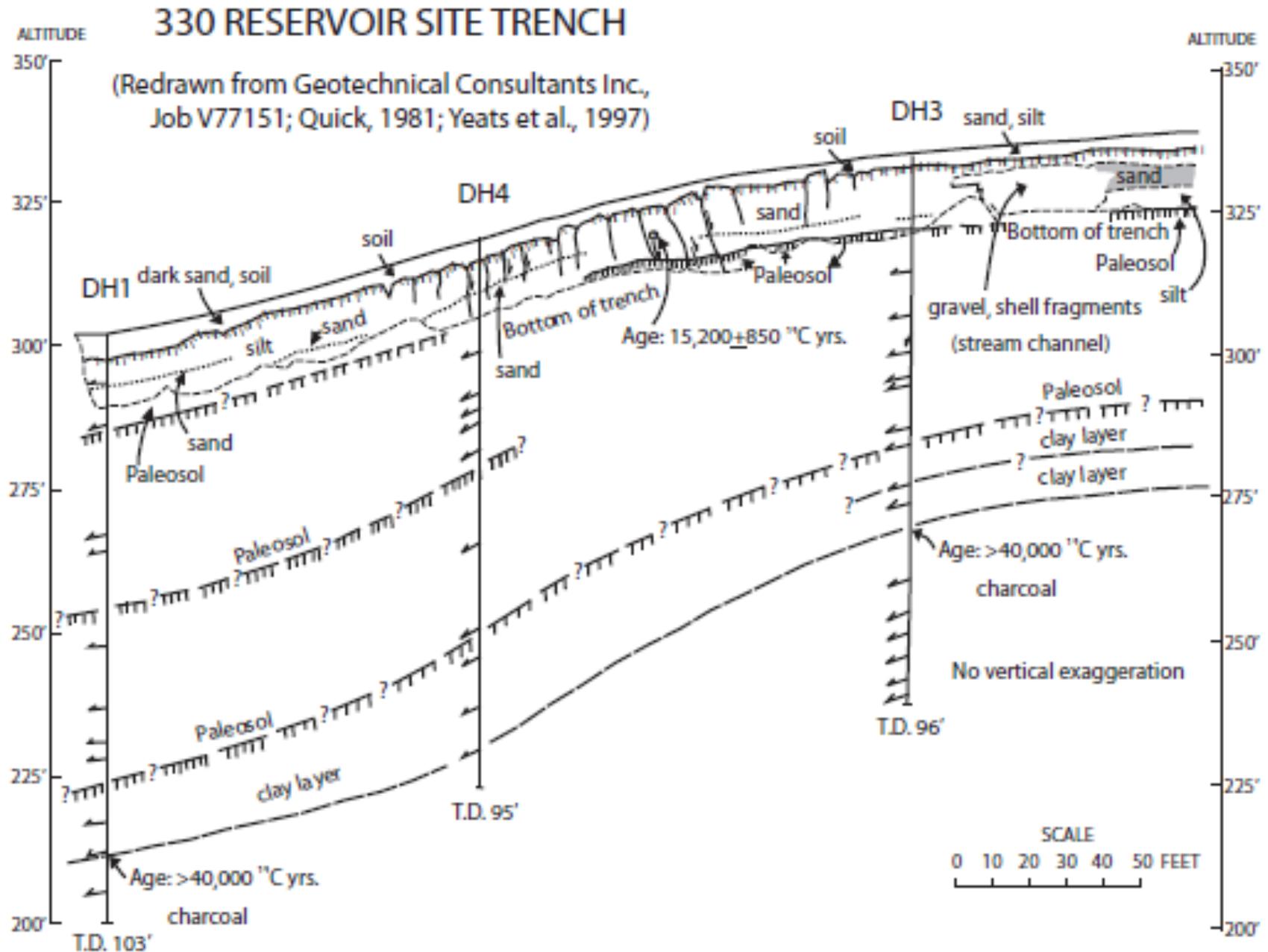
Most of this uplift is related to slip on the Ventura-Pitas Point ramp, resulting in growth of the VAA

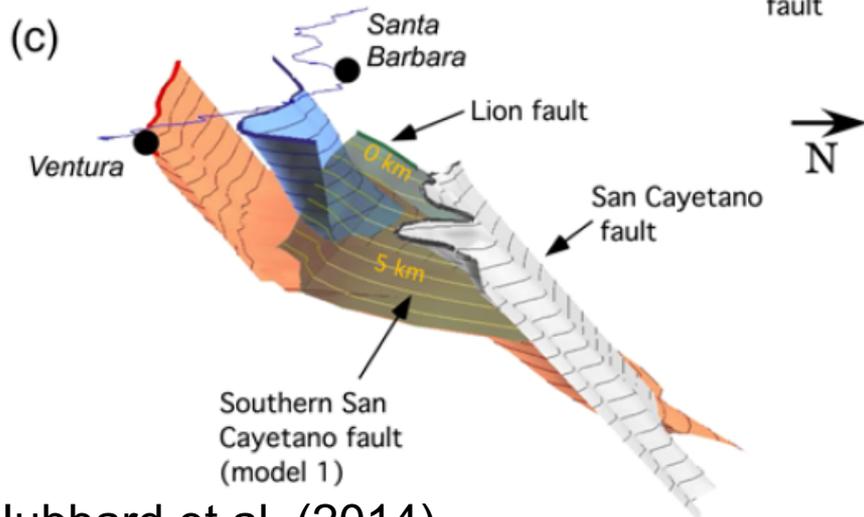
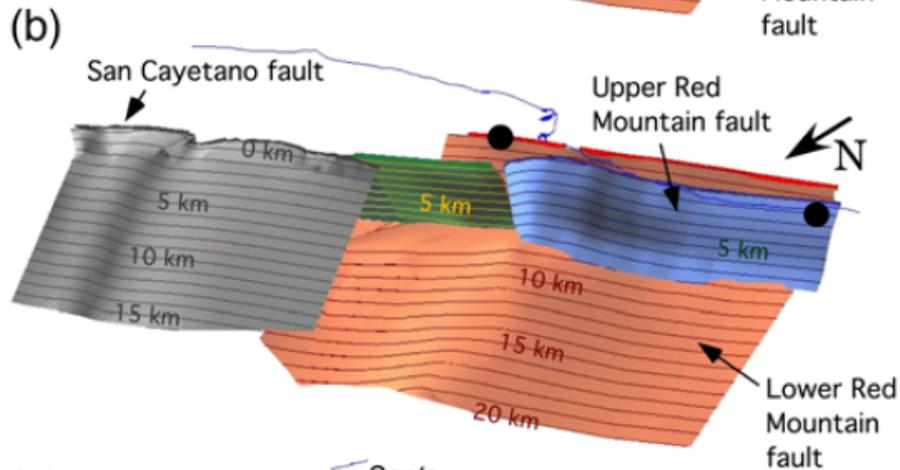
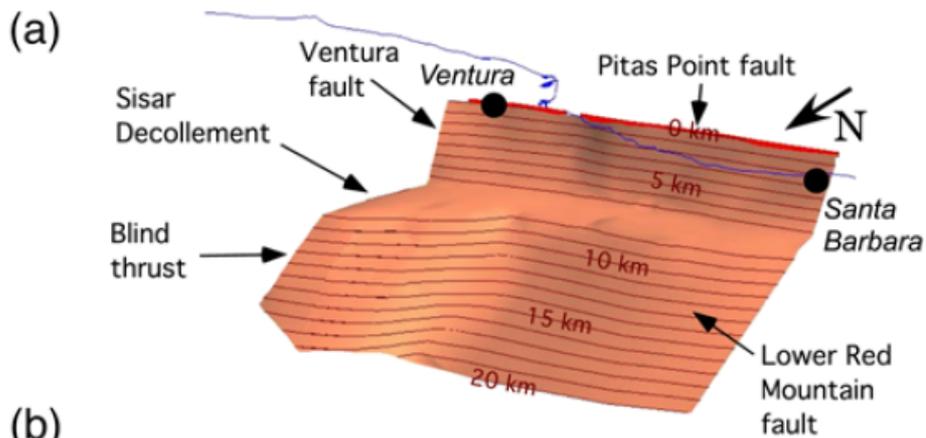
Some events propagate all the way to the (near) surface along the main north-dipping ramp (e.g., 0.9 ka and 4.5 ka events), whereas others likely extend into the near-surface along backthrusts (e.g., 2 ka and 6.7 ka events observed at PP as coastal uplift, but not as discrete tipline folding in Ventura; Grenader et al., in prep.)

Slip is transferred eastward from the V-PP system onto the blind Southern San Cayetano fault and ultimately the SCF. Limited data suggest that MRE on the SCF was likely somewhat younger (500 yr-ish?) than MRE on V-PP

Check out Berelson et al. poster #311!

Previous Work





- Ventura fault continues offshore as Pitas Point fault
- Ventura fault is structurally linked by shared decollement below 7.5 km to other reverse faults (Hubbard et al., 2014)
- Recent modeling of geodetic data which suggests longer faults or series of connected fault surfaces do a better job of fitting current GPS rates (Marshall et al., 2013)
- **This linkage heightens the threat of large, multi-segment earthquakes**