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Geomorphic evidence for recent deformation along the Southern San Cayetano fault

SCEC Ventura SFSA Workshop
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Motivation

Grey bars = geologic slip rate
White circles = geodetic slip rate
Red, blue, and green = geodetic slip rates using alternative block models

Problem:

Geologic rates on major faults are *highly uncertain*

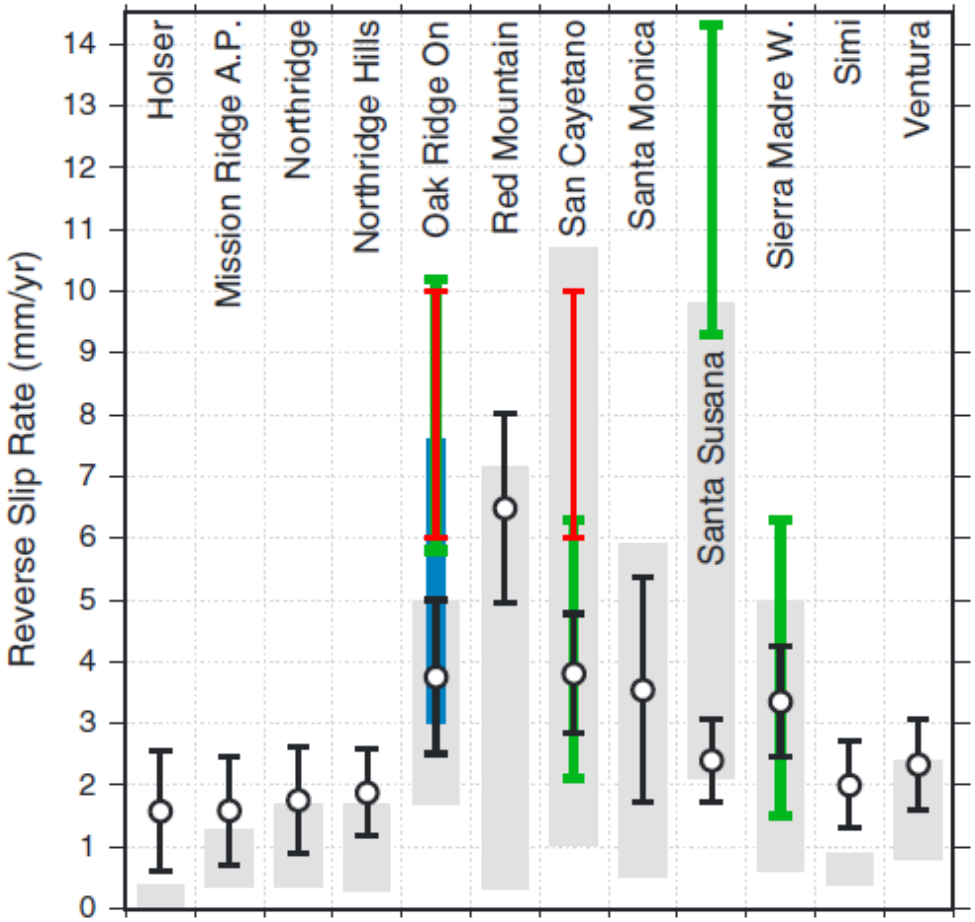
Needs:

-High resolution slip rates

-Location, geometry, and interactions of faults

Knowledge gap:

-Chronologic constraints on regional markers, e.g., ORF, VF



Source: Marshall et al. (2013)

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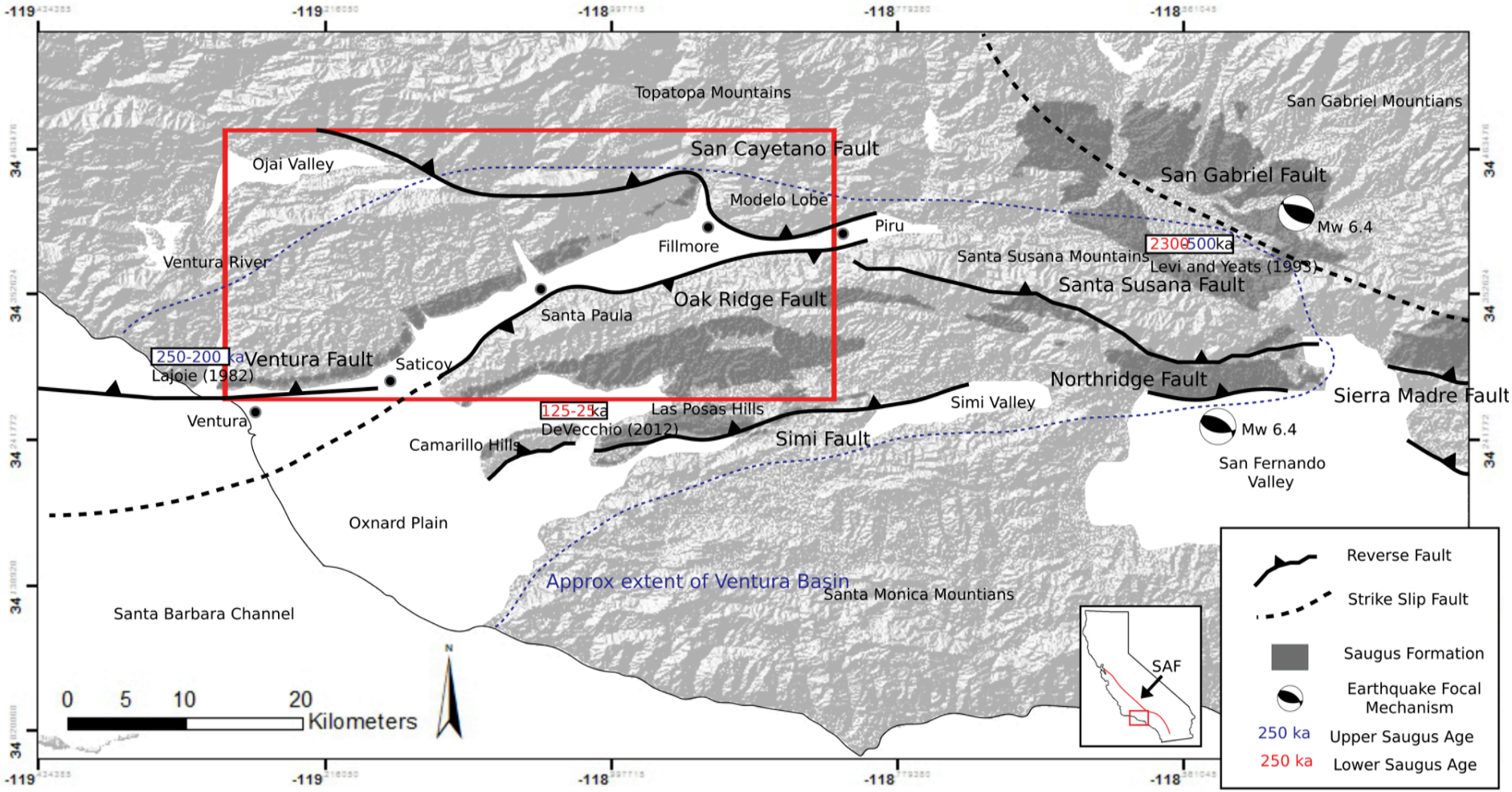
Western Transverse Ranges Faults and Plio-Pleistocene Saugus Formation



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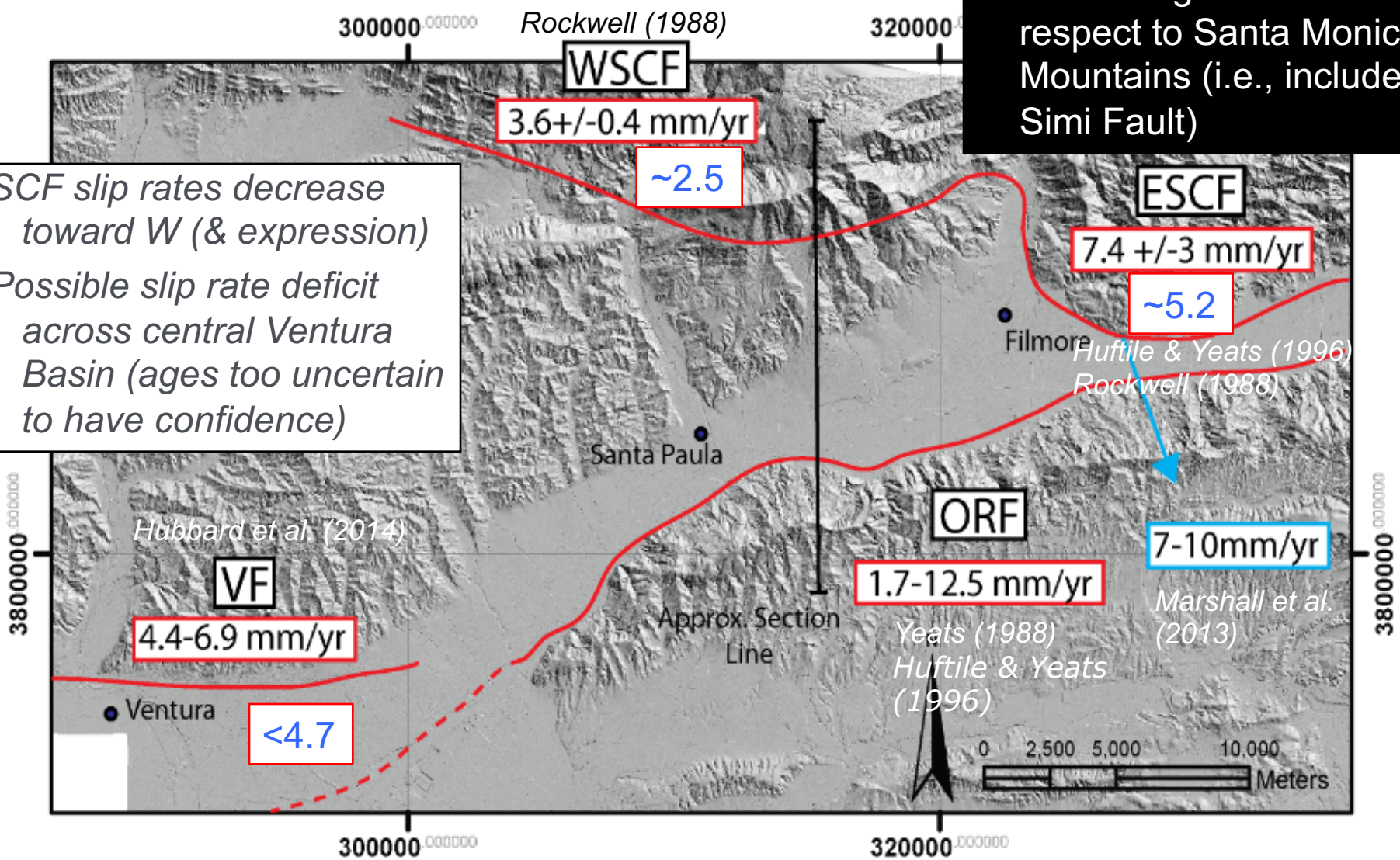
Without the Southern San Cayetano fault

Red boxes = geologic slip rates (blue values = shortening equivalent)

Blue box = geodetic shortening rate with respect to Santa Monica Mountains (i.e., includes Simi Fault)

- *SCF slip rates decrease toward W (& expression)*
- *Possible slip rate deficit across central Ventura Basin (ages too uncertain to have confidence)*



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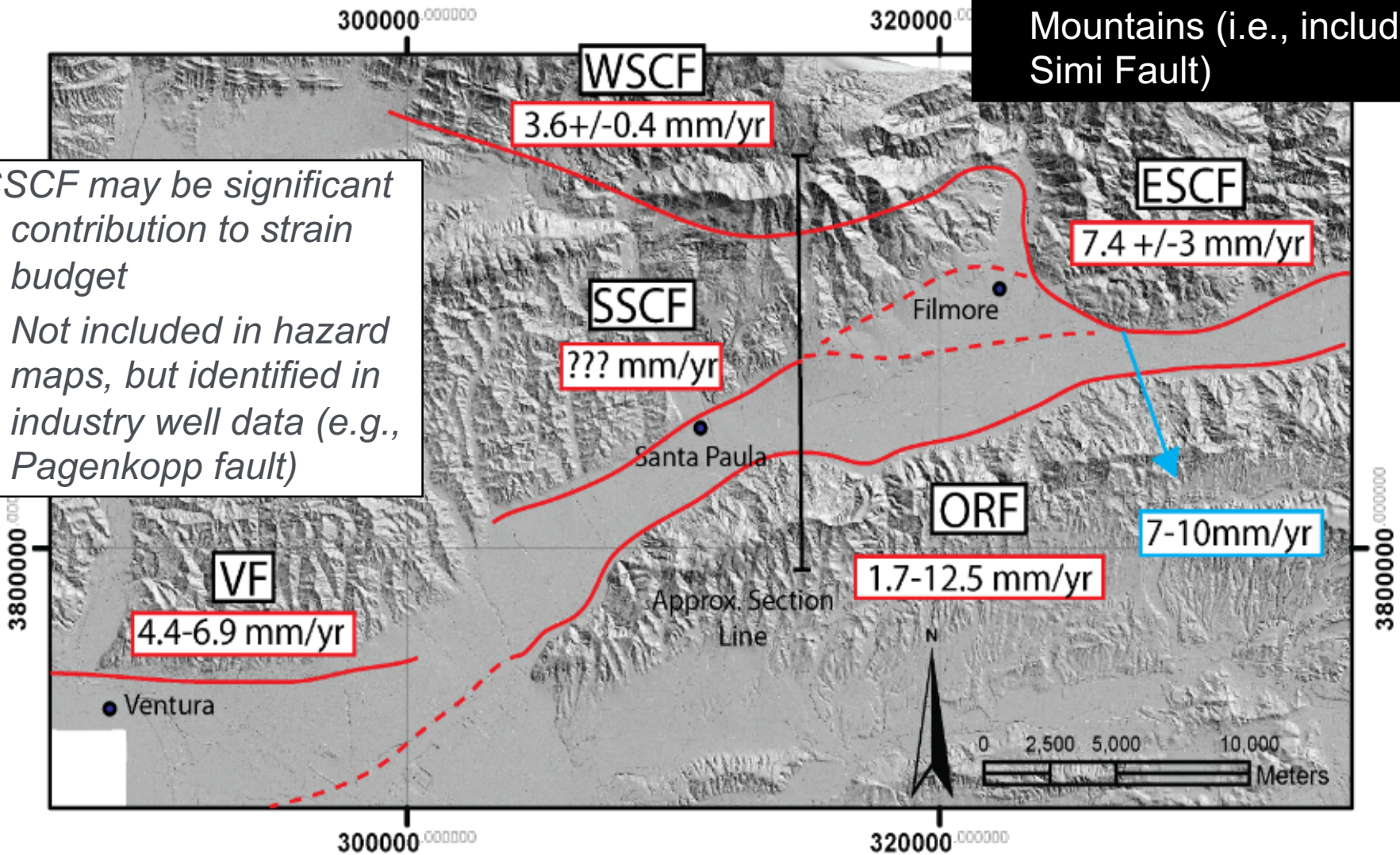
With the Southern San Cayetano fault (SSCF)

Red boxes = geologic slip rates

Blue box = geodetic shortening rate with respect to Santa Monica Mountains (i.e., includes Simi Fault)

- *SSCF may be significant contribution to strain budget*
- *Not included in hazard maps, but identified in industry well data (e.g., Pagenkopp fault)*



Hypotheses to be tested

- **H1: An unmapped blind(?) or emergent(?) N-dipping reverse fault, the Southern San Cayetano Fault (SSCF), exists beneath the range front between Santa Paula and Fillmore.**
  - T1: Conduct geomorphic mapping using lidar data to identify deformation
- **H2: Strain from the ESCF is being partitioned westward between the WSCF and the SSCF.**
  - T2: Compare slip rate on ESCF to WSCF and SSCF using lidar offsets and cosmogenic isotope exposure ages
- **H3: The SSCF transfers strain from the ESCF westward across the Ventura Basin to the onshore Ventura fault (VF) and offshore Pitas Point fault system.**
  - T3: Compare D-L plots and slip rates for ESCF, SSCF, and VF
- **H4: Strain is being transferred from the WSCF to the SSCF through time as deformation propagates southward into the basin**
  - T4: Assess whether slip rates on the SSCF increase through time, whereas slip rates for the WSCF decrease through time.

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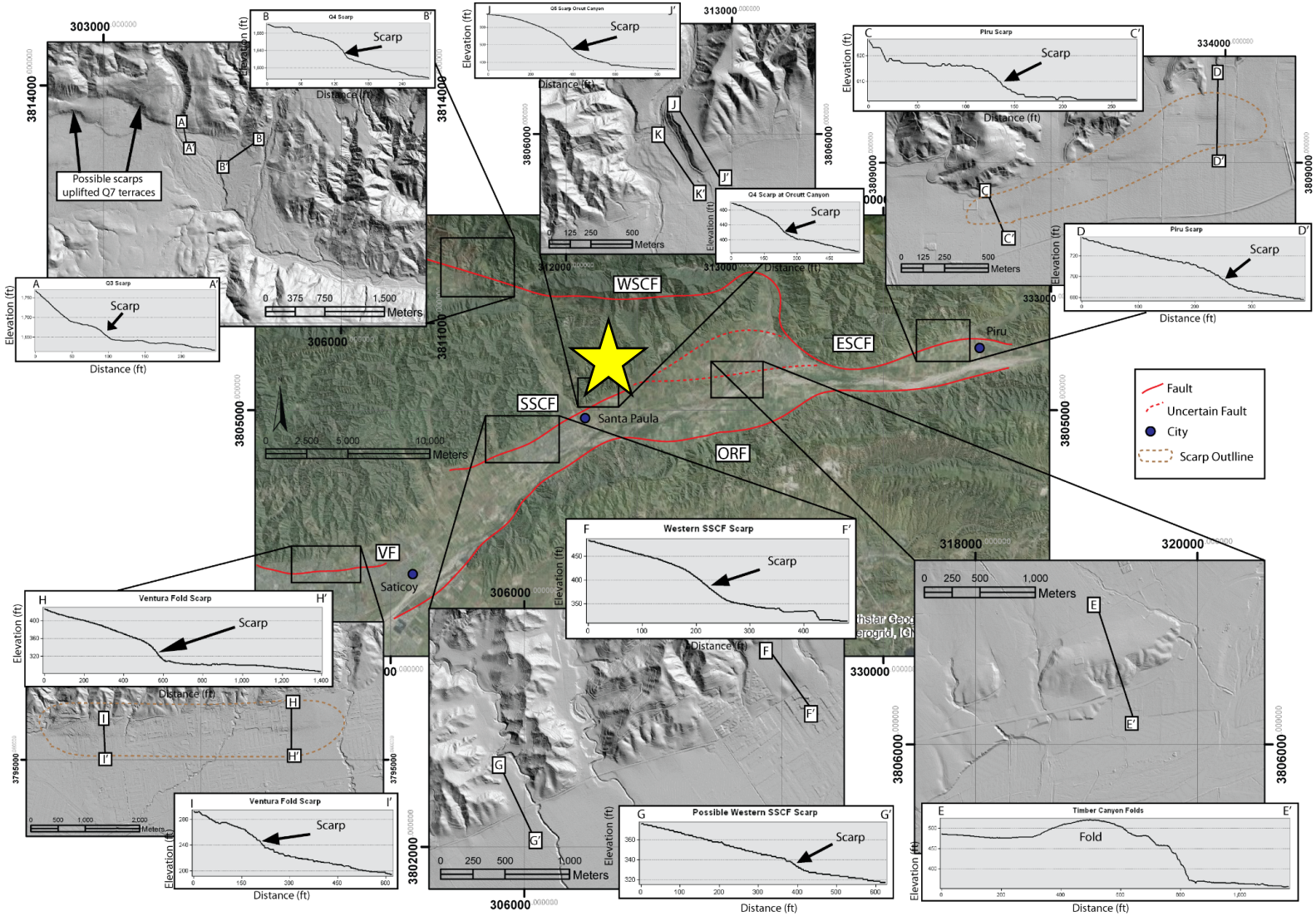
Evidence for active deformation in lidar data: SSCF



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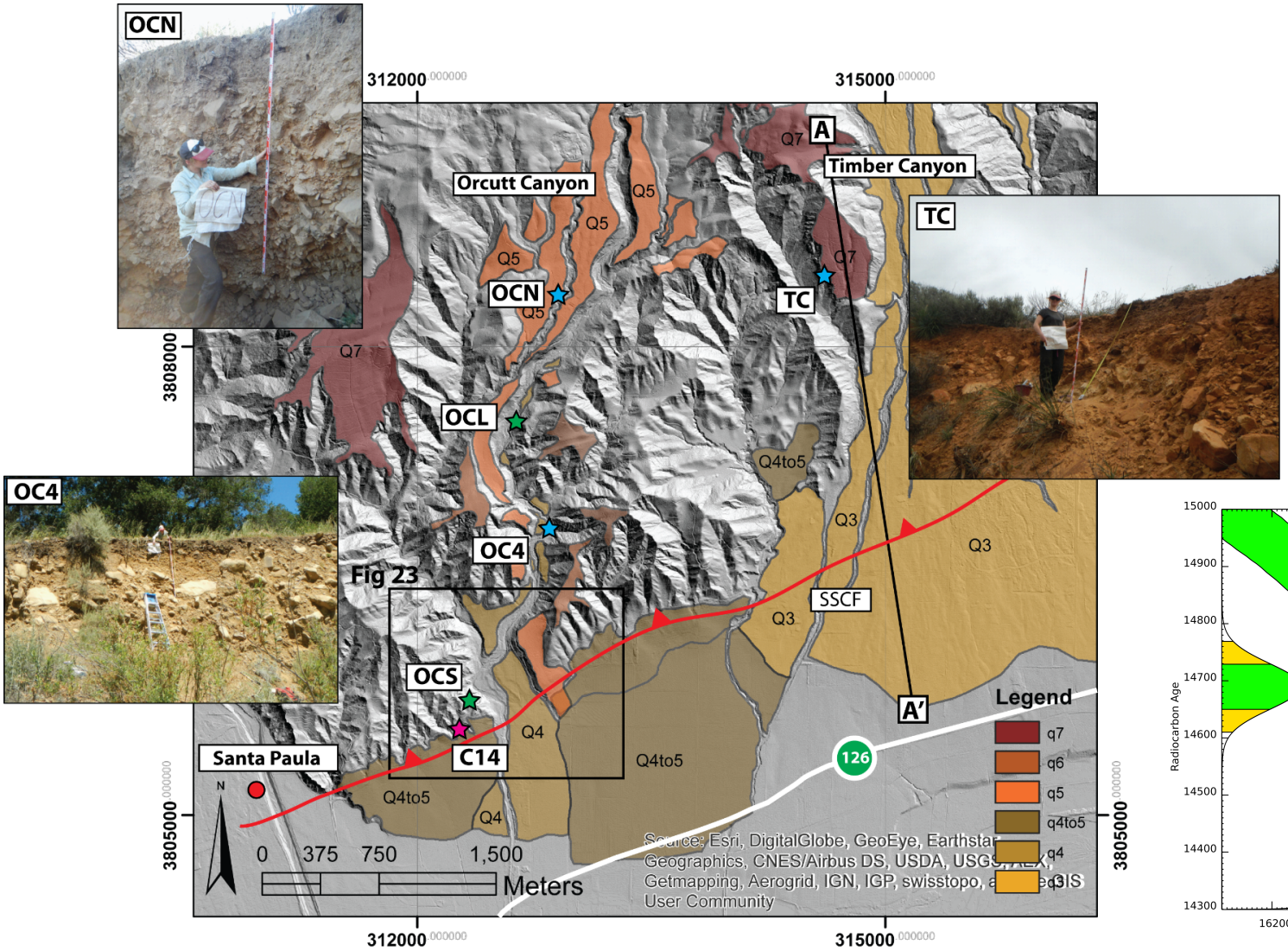
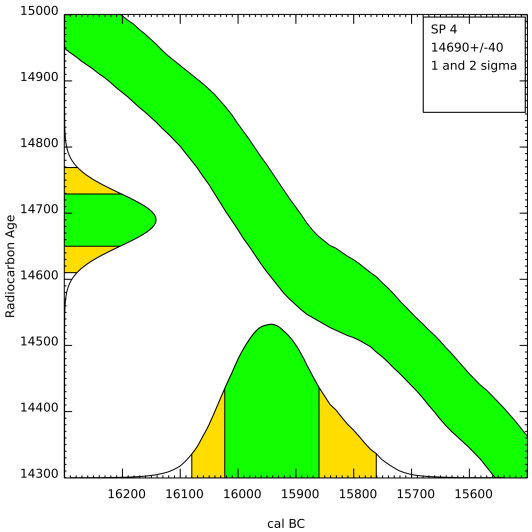
Orcutt Canyon: Geomorphology and cosmogenic isotope dating samples



Unpublished ^{14}C age (Earth Consultants International, 2006)

16022-15860 cal BC (1σ)



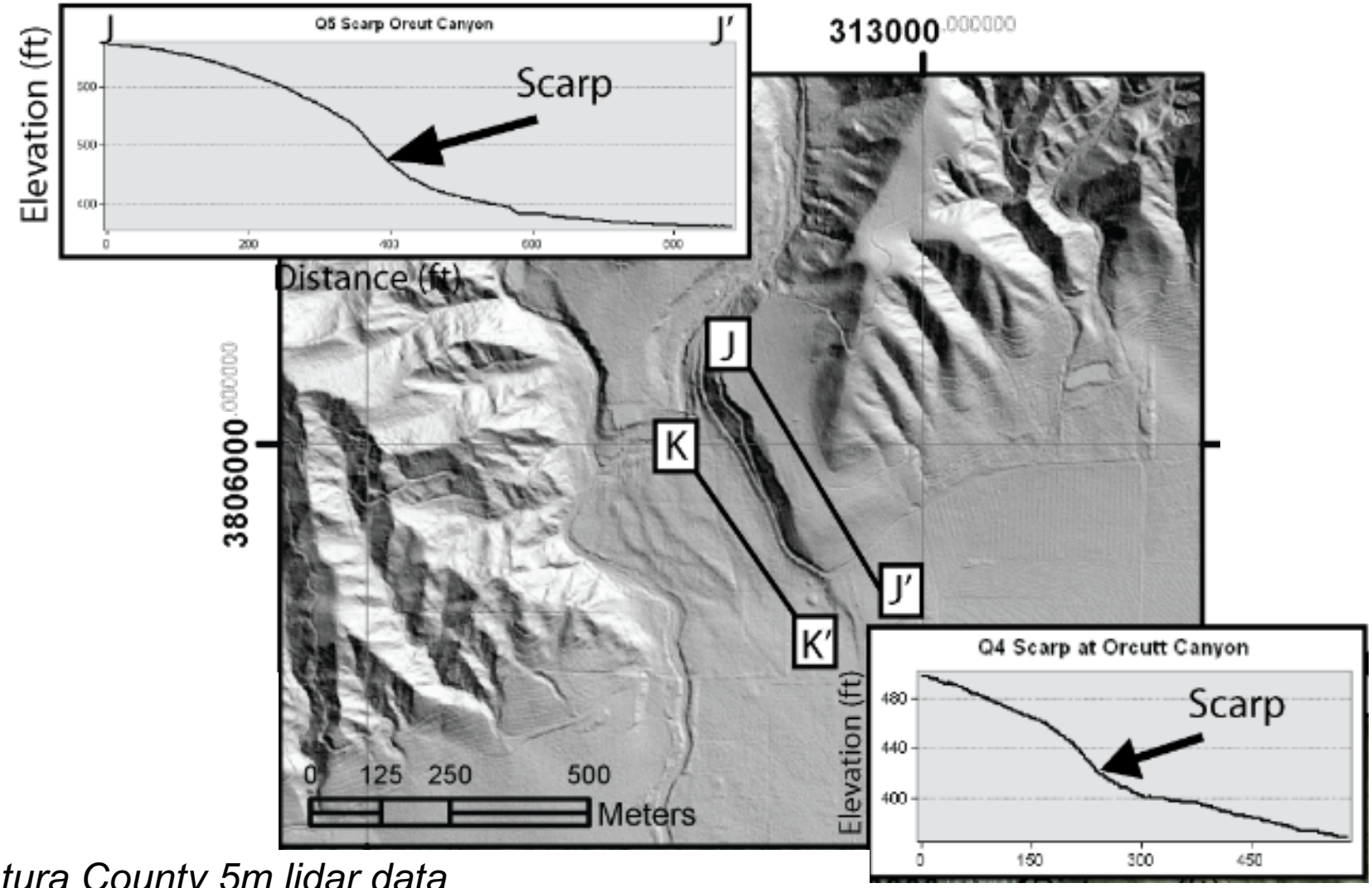
Soil ages of terraces from Rockwell (1988)

Terrace	Radiocarbon Age (years)	Method
Q1	10-20	Soil Profile
Q2	<250	Soil Profile
Q3	500-5,000	^{14}C dates, dendrochronology, soil profile
Q4	8,000-12,000	^{14}C dates, relative fault displacement
Q5	15,000-30,000	^{14}C dates, relative fault displacement
Q6	38,000-92,000	^{14}C dates, relative fault displacement
Q7	160,000-200,000	relative fault displacement

- Soil chronostratigraphy based on Ventura River terraces

- Cosmogenic isotope surface exposure dating will <u>refine this chronology</u>

Southern San Cayetano fault: Orcutt Canyon terraces



Ventura County 5m lidar data

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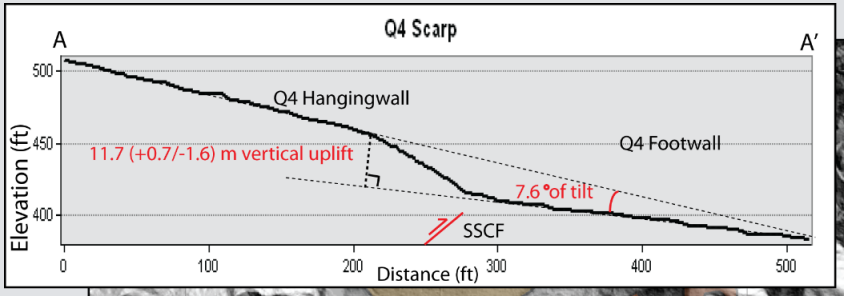
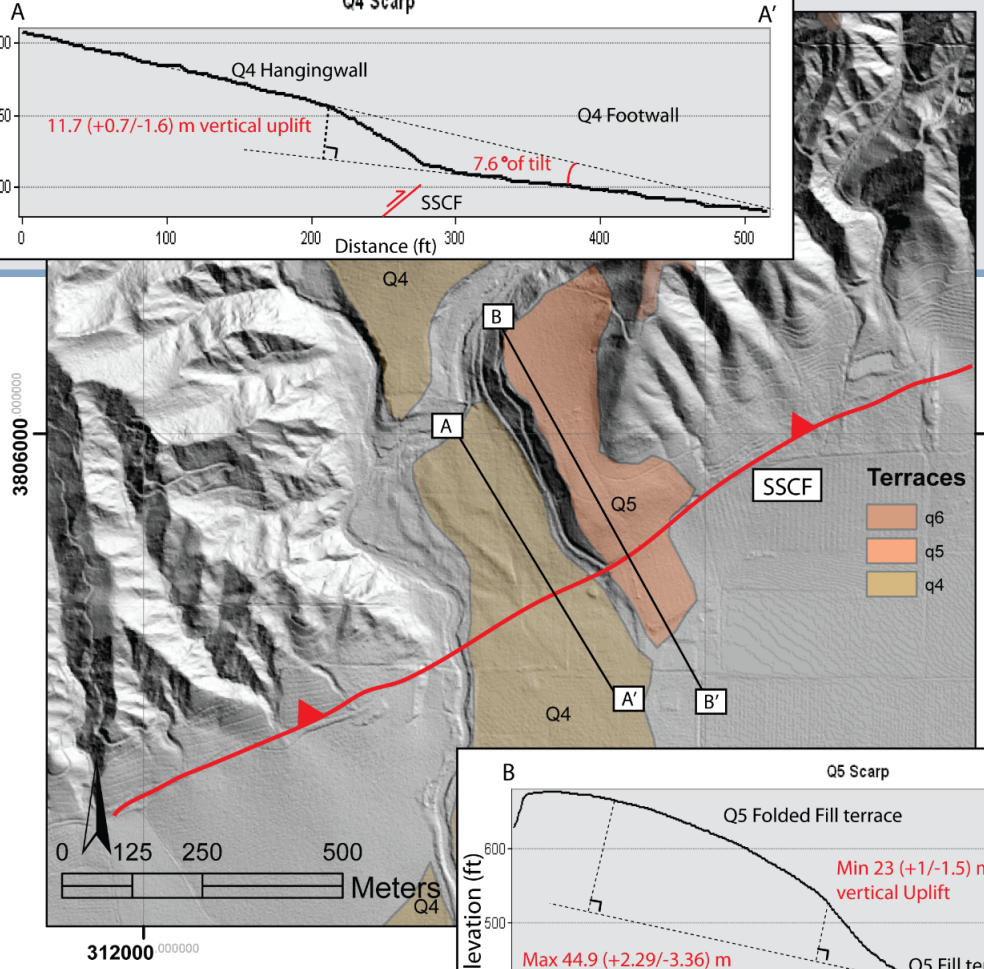
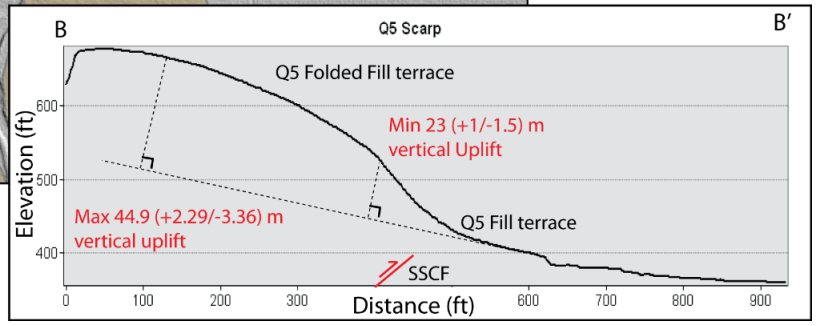
SSCF: Orcutt Canyon







Terrace	Age (ka)	Offset (m)	Throw rate (mm yr^{-1})	Slip rate (mm yr^{-1})
Q4	8-12	11.7 (+0.7/-1.6)	1.46 (+0.09/-0.2)	2.07 (+0.12/-0.29)*
Q4	16.081	11.7 (+0.7/-1.6)	0.73 (+0.04/-0.1)	1.02 (+0.05/-0.13)**
Q5	15-30	23 (+1.02/-1.54)	1.53 (+0.07/-0.1)	2.17(+0.09/-0.15)

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Scarp in Q4 terrace at Orcutt Canyon

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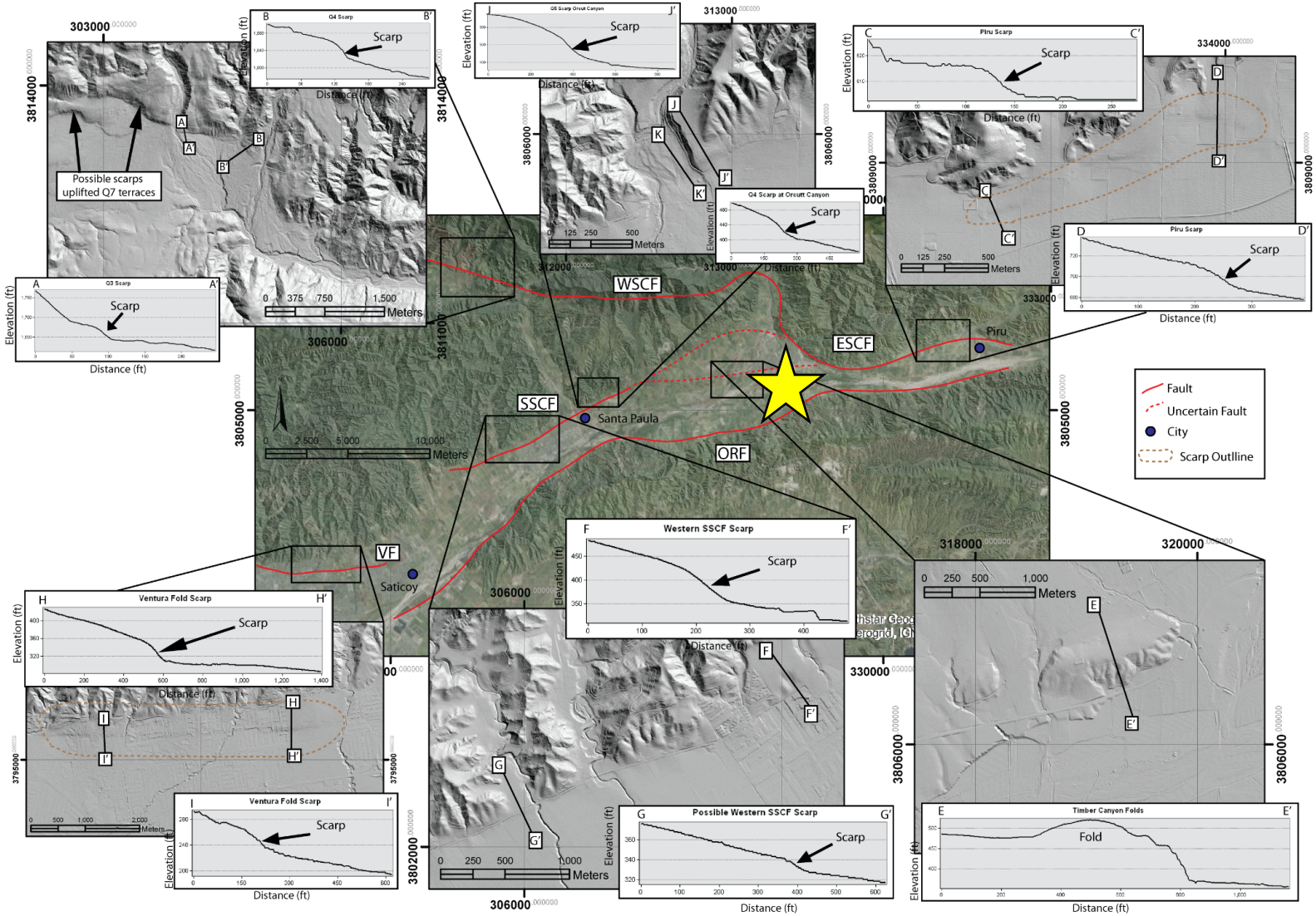
Evidence for active deformation in lidar data



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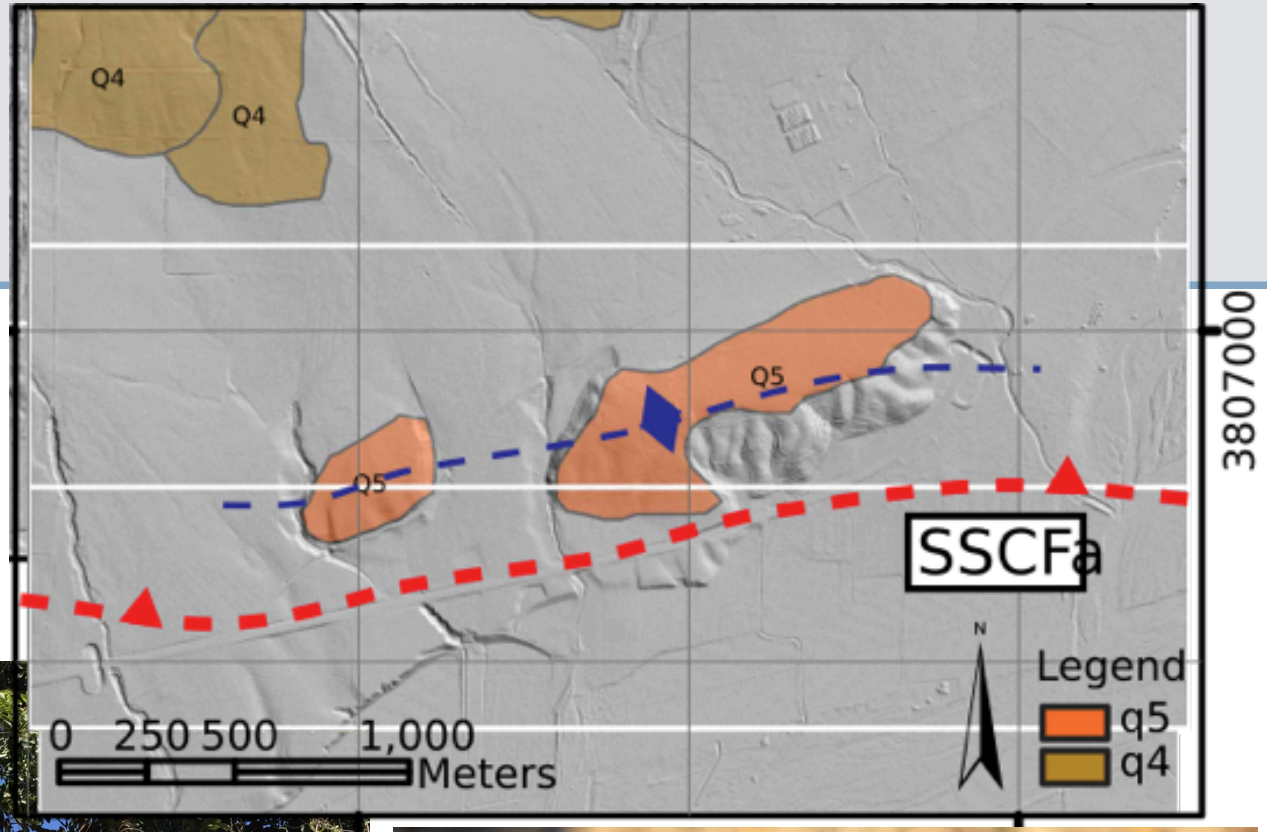
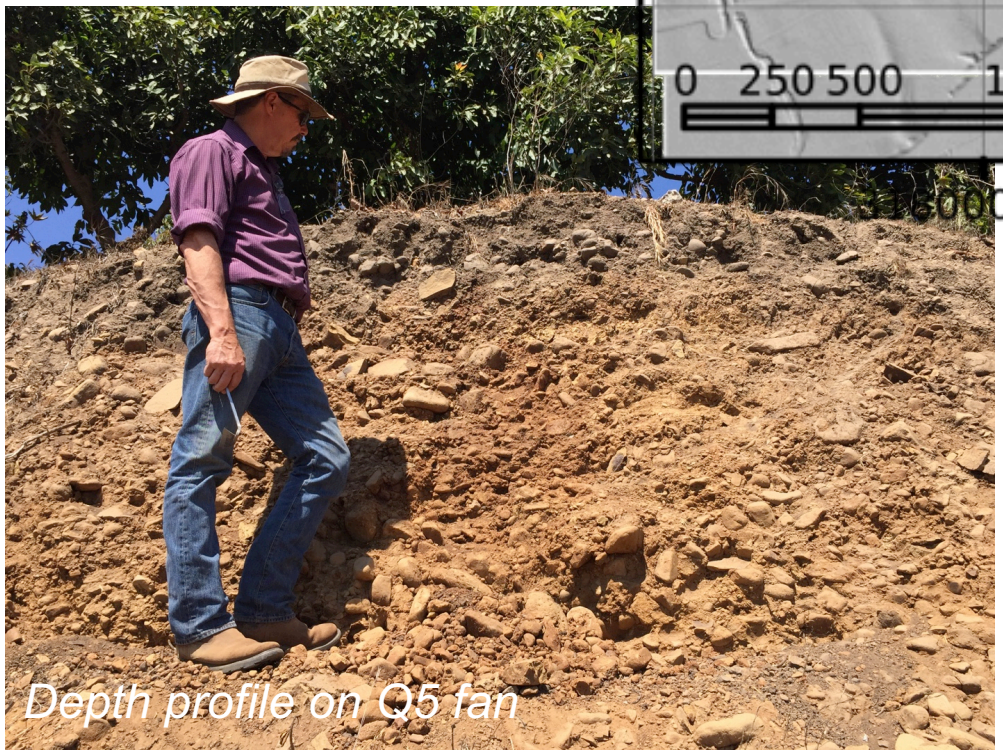
SSCF: Fold near Fillmore





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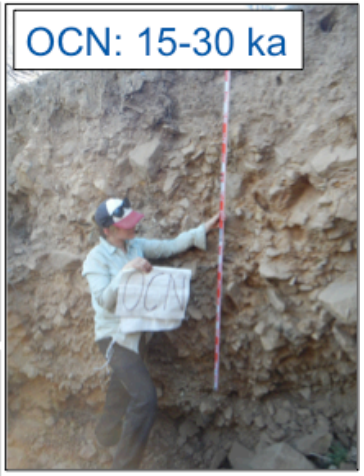
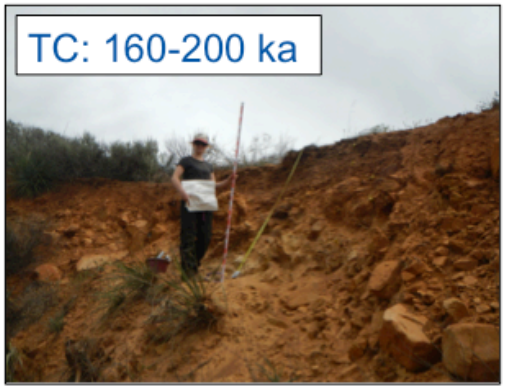
Cosmogenic isotope surface exposure dating samples

WSCF: Bear Canyon Q4



SSCF: Orcutt Canyon Q5

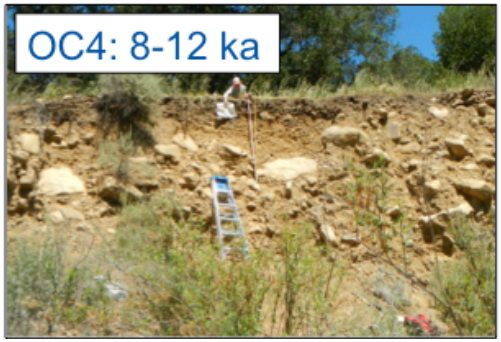
SSCF: Timber Canyon Q7



Boulder Sample:
BCB15
80-100+/-ka

WSCF: Bear Canyon Q6

WSCF: Orcutt Canyon Q4



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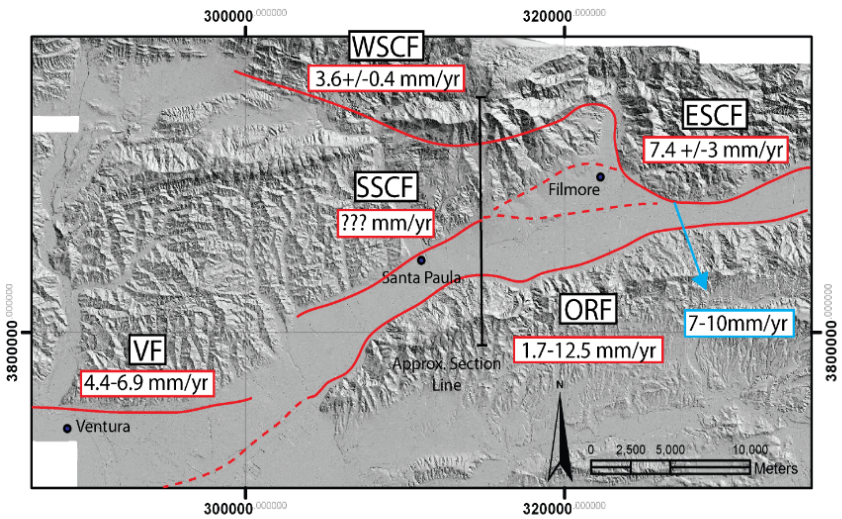
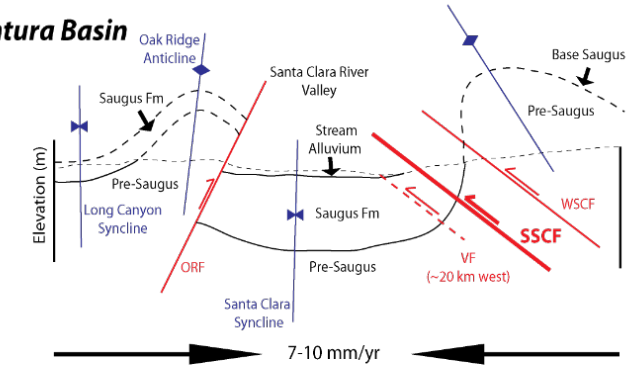
Proposed conceptual model including SSCF

INCLUDING THE SSCF:

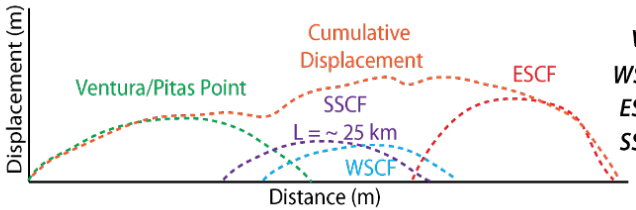


Central Ventura Basin



SR-ORF cos(∢ ORF)
+
SR-WSCF cos(∢ WSCF)
+
SR-SSCF cos(∢ SSCF)
+
Fold Strain
=
7-10 mm/yr
(including Simi Fault)

D-L Plots



VF: L = ~40 km > Mw ~6.9
WSCF: L = ~20 km > Mw ~6.6
ESCF: L = ~20 km> Mw ~6.6
SSCF: L = ~25 km > Mw ~6.7

CUMULATIVE: L = ~85 km > Mw~7.5

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Preliminary slip rate summary: SSCF vs. WSCF

Terrace	Age (ka)	Offset (m)	Throw rate (mm yr^{-1})	Slip rate (mm yr^{-1})
Southern San Cayetano				
Q4	8-12	11.7 (+0.7/-1.6)	1.46 (+0.09/-0.2)	2.07 (+0.12/-0.29)*
Q4	16.081	11.7 (+0.7/-1.6)	0.73 (+0.04/-0.1)	1.02 (+0.05/-0.13)**
Q5	15-30	23 (+1.02/-1.54)	1.53 (+0.07/-0.1)	2.17(+0.09/-0.15)
Q7	160-200	294 (+17/-5.4)	1.84 (+0.1/-0.04)	2.60 (+0.15/-0.05)*
Western San Cayetano				
Q4	8-12	8.13+/-1	1.02 (+/-0.12)	1.44 (+/-0.18)
Q6	92+/-13	156+/-7.9	1.95 (+/-0.1)	2.75 (+/-0.14)

Note: **Slip rates for the SSCF are based on a hypothetical 45° dip for the SSCF that is assumed the same dip as the WSCF.*

***This is a C-14 age (sample C-14) from an unpublished geotechnical investigation (Earth Consultants International (2006)). The sample was taken at 2.7 m below the surface. This age is therefore, older than the true surface age and the corresponding uplift and slip rates are minimum rates.*

Preliminary Conclusions

- Geomorphological evidence suggests an unmapped blind(?) or emergent(?) N-dipping reverse fault, the SSCF, beneath the range front between Santa Paula and Fillmore (*consistent with H1*).
- Strain in the central Ventura Basin may be partitioned between the SSCF and the WSCF (*possibly consistent with H2*).
- The SSCF could link the ESCF to the VF (*possibly consistent with H3*) creating a ~85 km long rupture; such a multi-fault rupture could therefore produce a ~M_w 7.5 (or greater) earthquake.
- Slip rates for the WSCF may have decreased by 50%, from 2.8 mm yr^{-1} since 80 ka to 1.4 mm yr^{-1} since 8 ka (*possibly consistent with H4*).
- Max. preliminary slip rates for the SSCF are 2.6 mm yr^{-1} since 160 ka, 4.2 mm yr^{-1} (using larger offset) since 15 ka, and 2.1 mm yr^{-1} since 8 ka (*unclear relationship to H4 – future geochronology will refine slip rates*).
- The SSCF is an active structure, which should be included in future seismic hazard maps, hazard assessments, and SCEC community fault model.
- However, **more high-resolution chronologic data and trenching are necessary**

Extra slides

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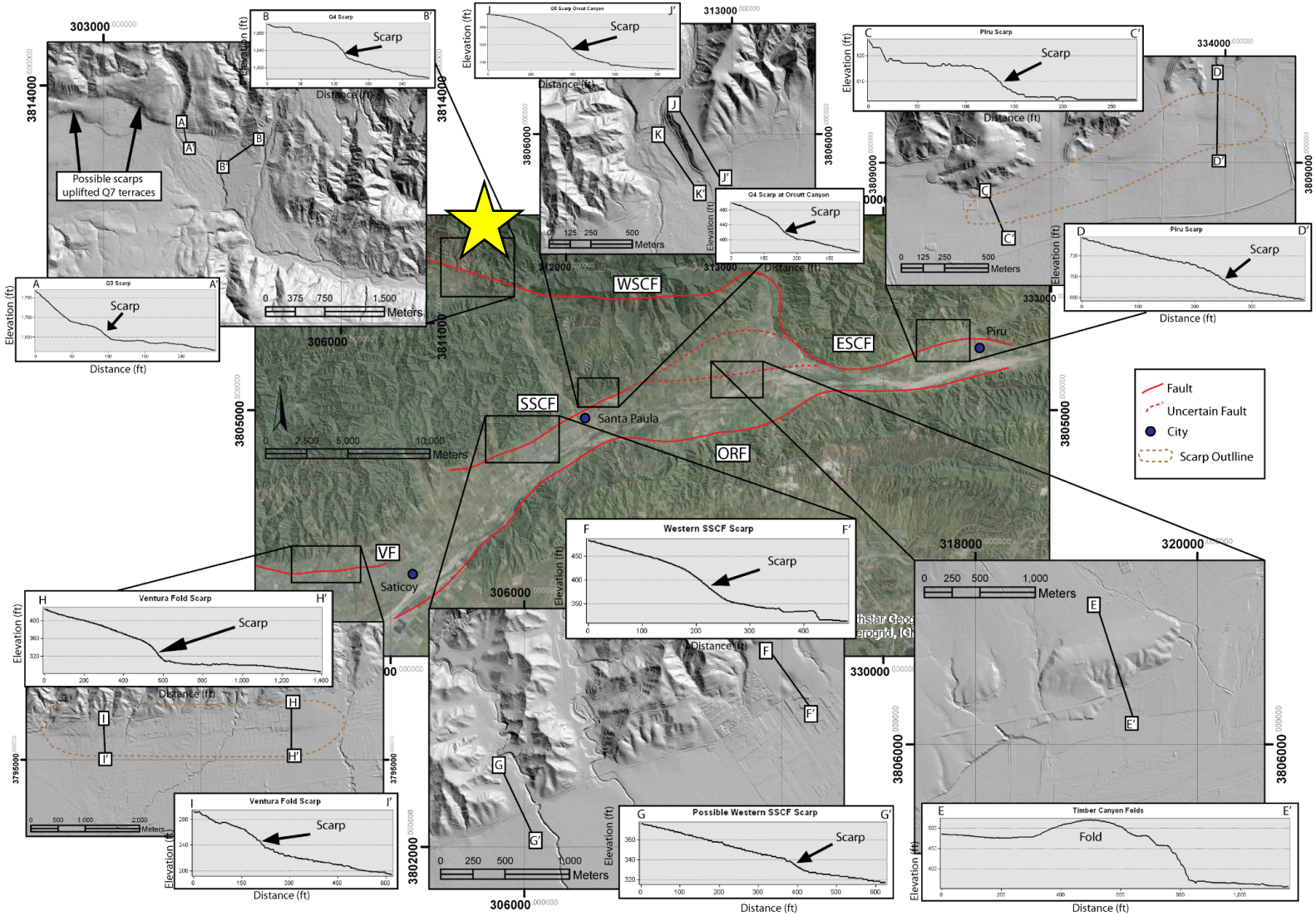
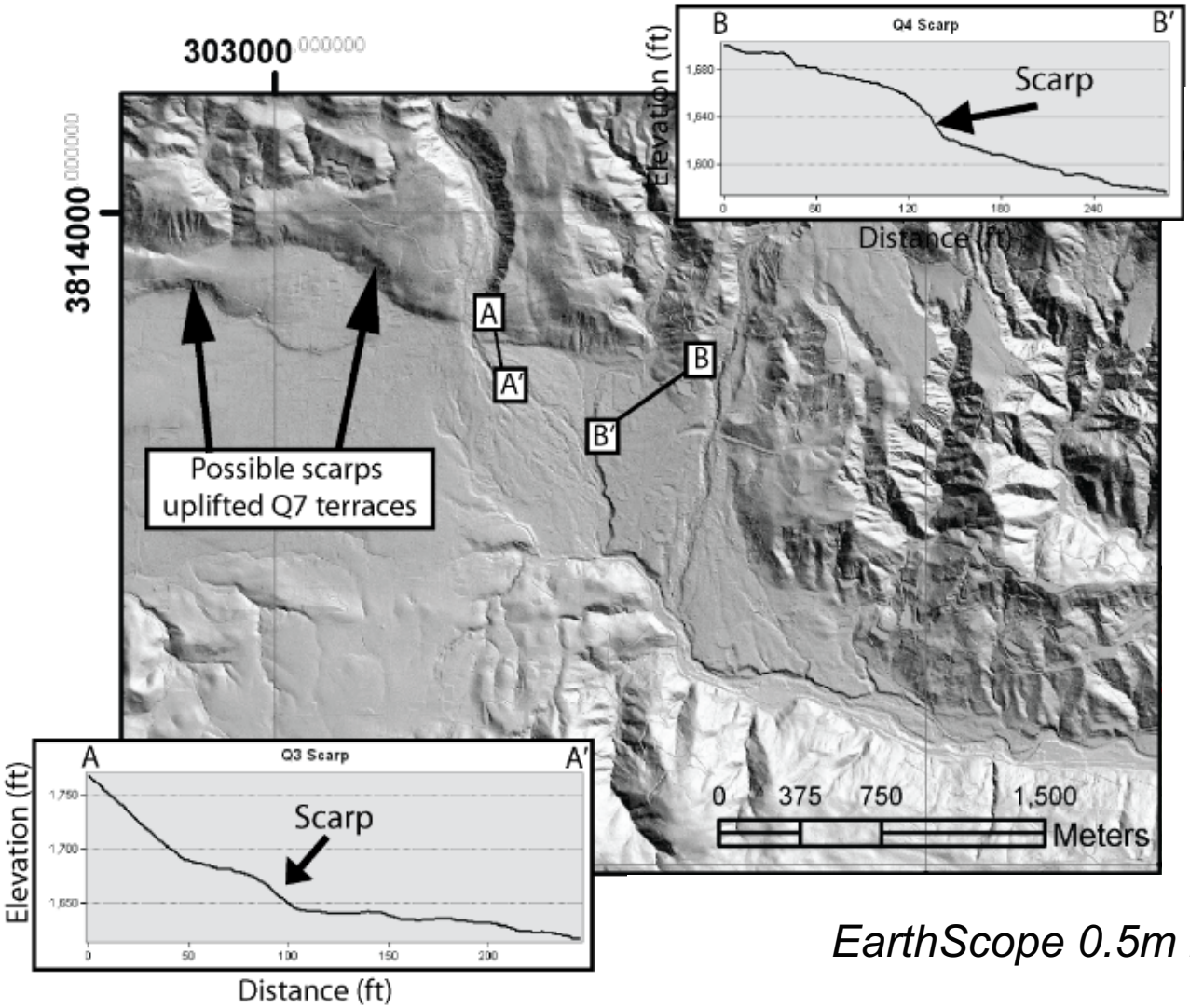
Evidence for active deformation in lidar data: WSCF



Western San Cayetano Fault (WSCF)



EarthScope 0.5m lidar data

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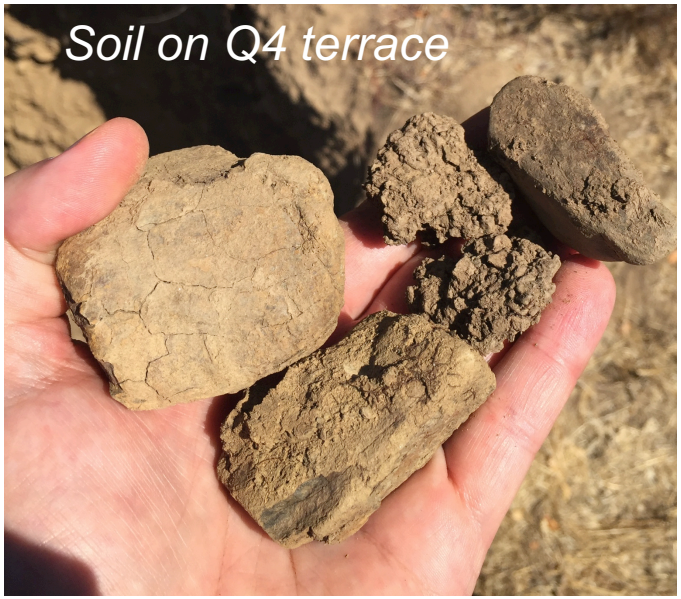
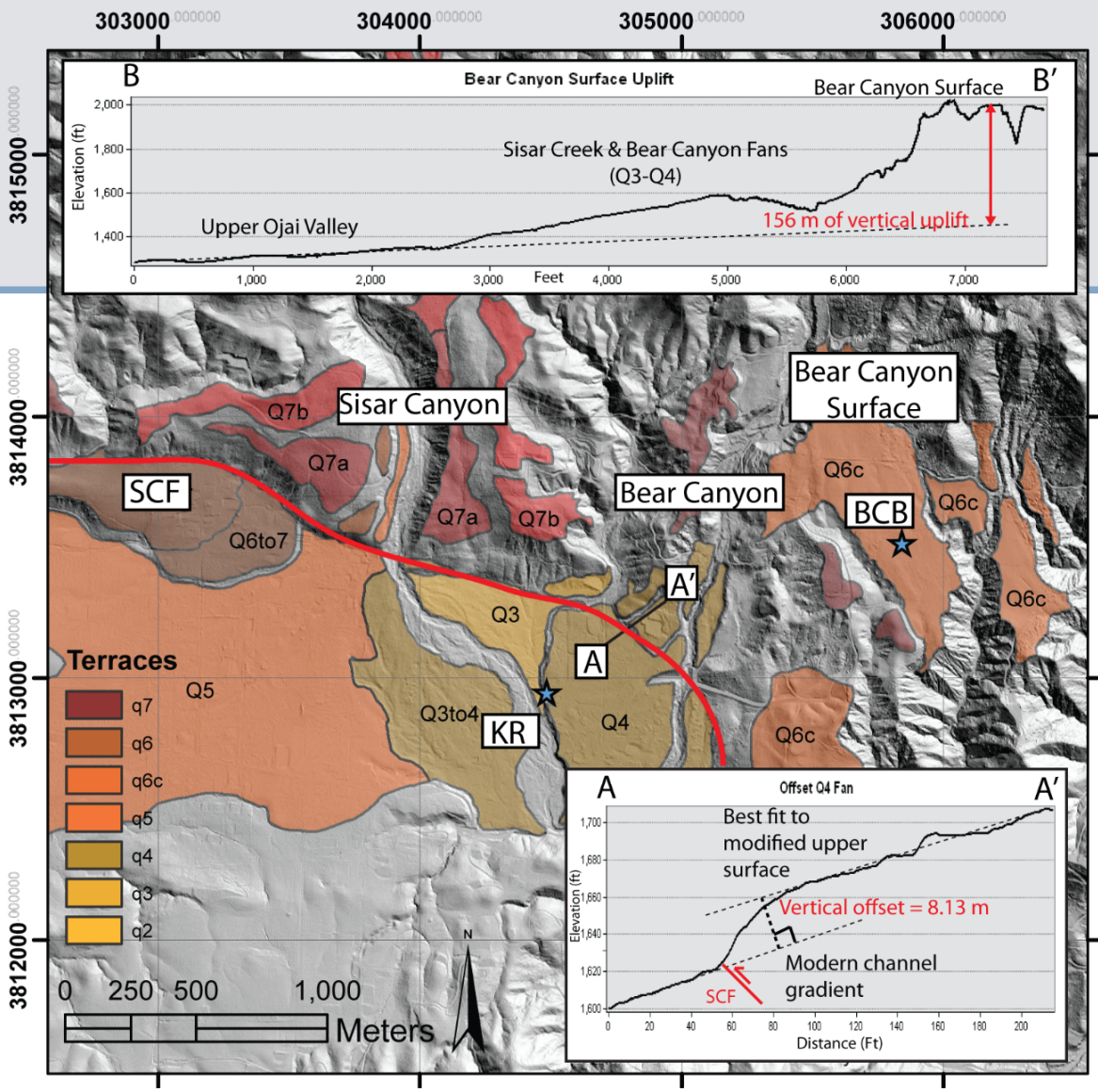
Western San Cayetano Fault (WSCF)





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Q4	8-12	8.13+/-1	1.02 (+/-0.12)	1.44 (+/-0.18)
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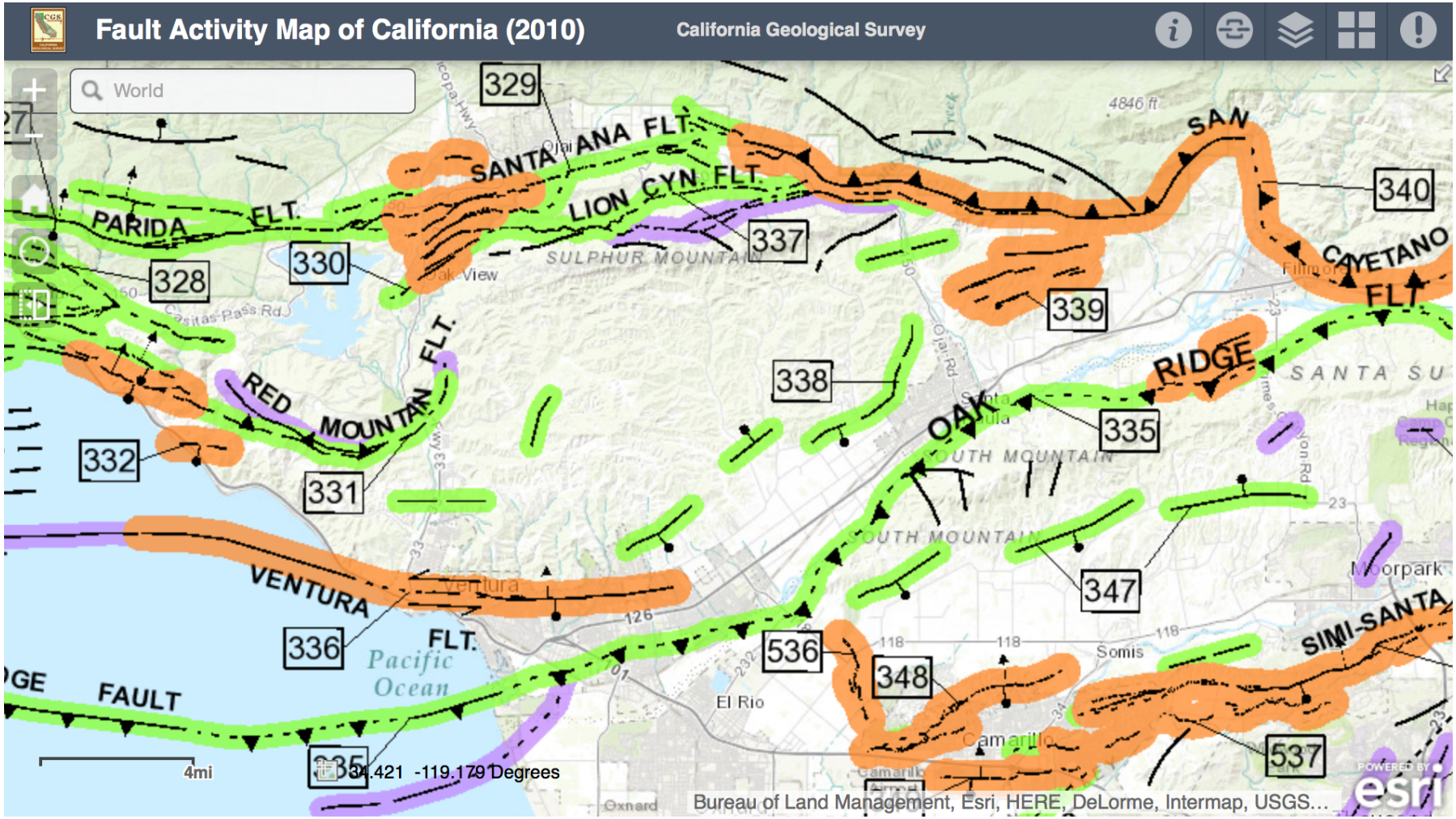
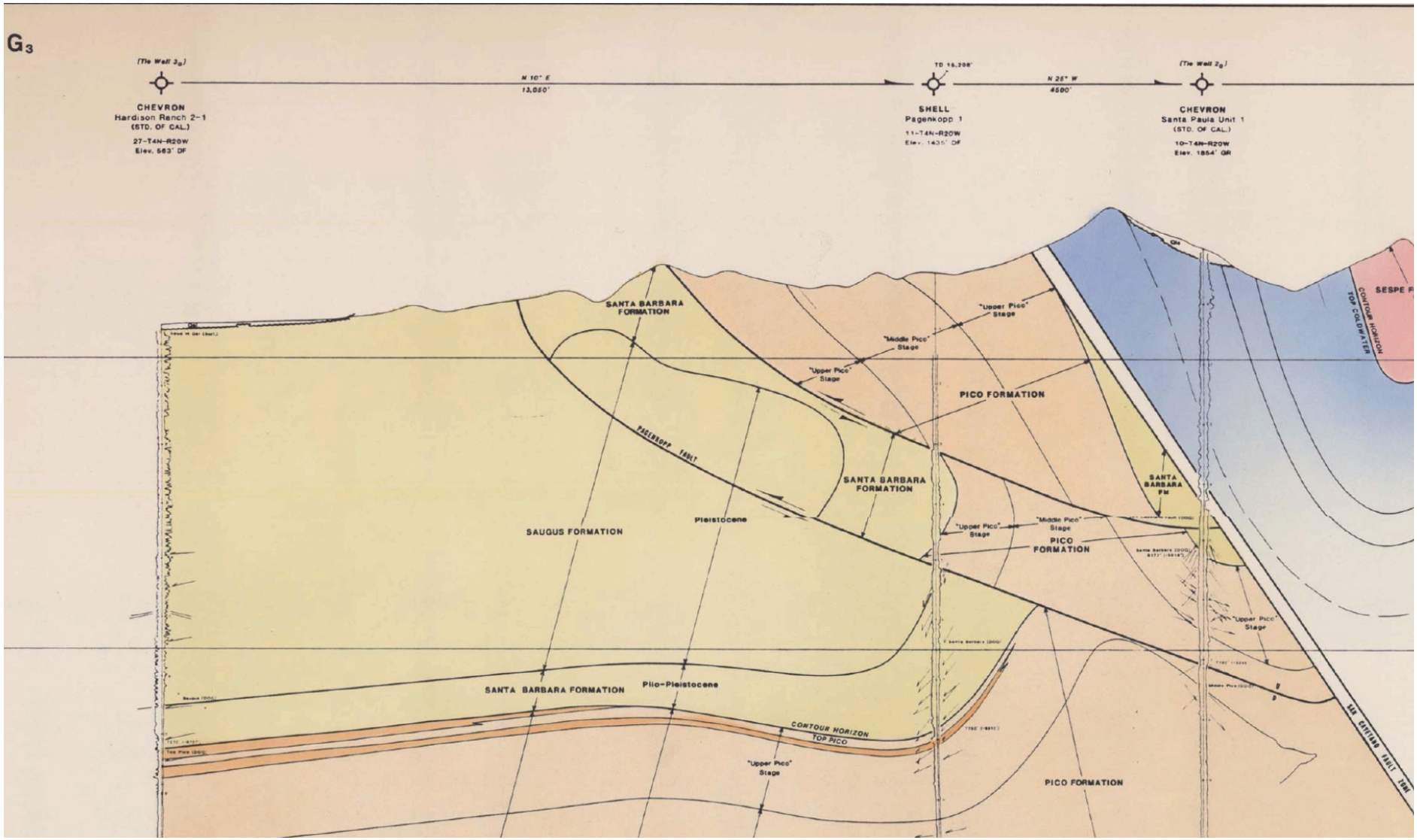
CGS Fault Activity Map of California



Industry well data: Pagenkopp fault



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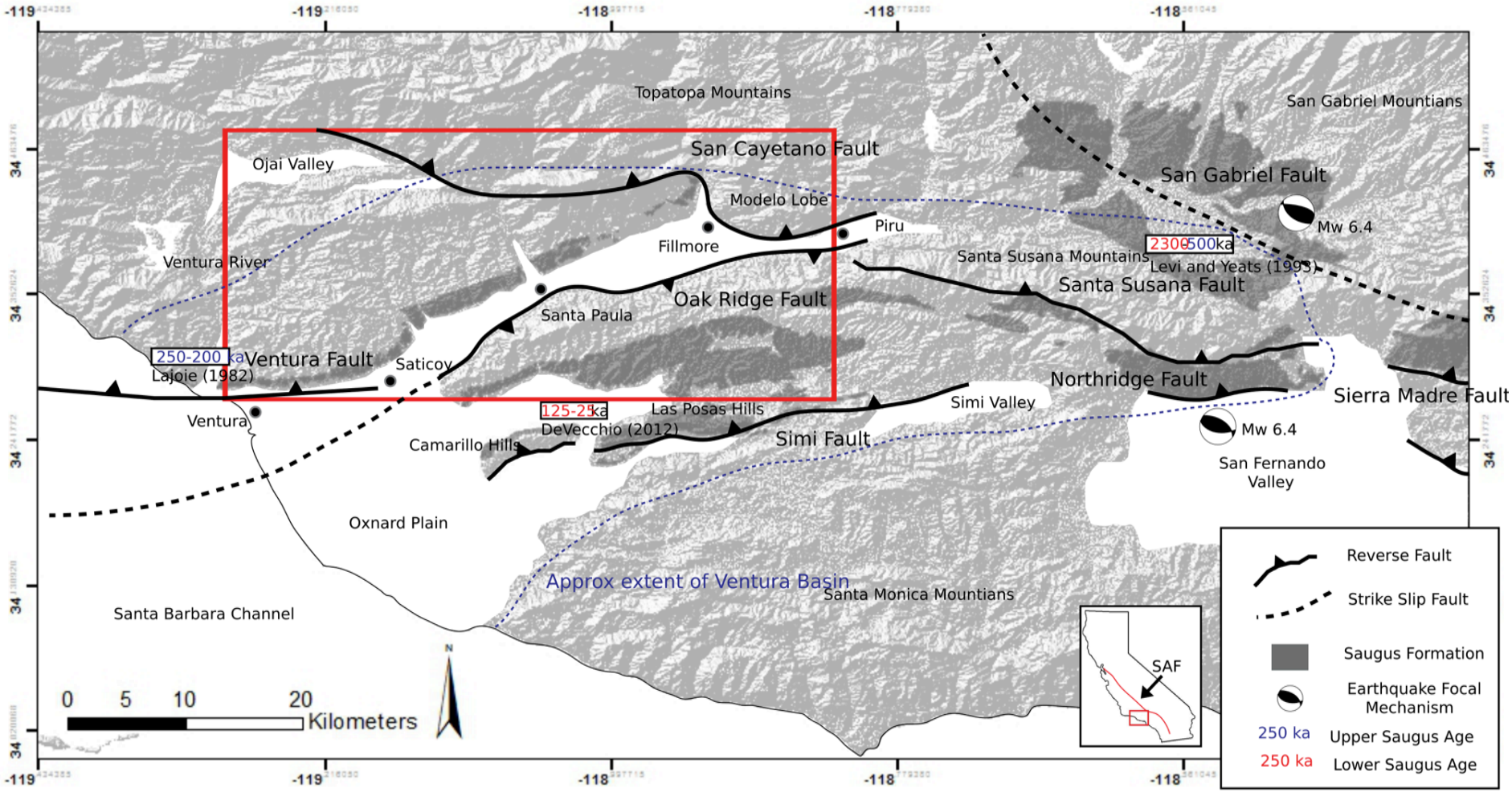
Western Transverse Ranges Faults and Plio-Pleistocene Saugus Formation



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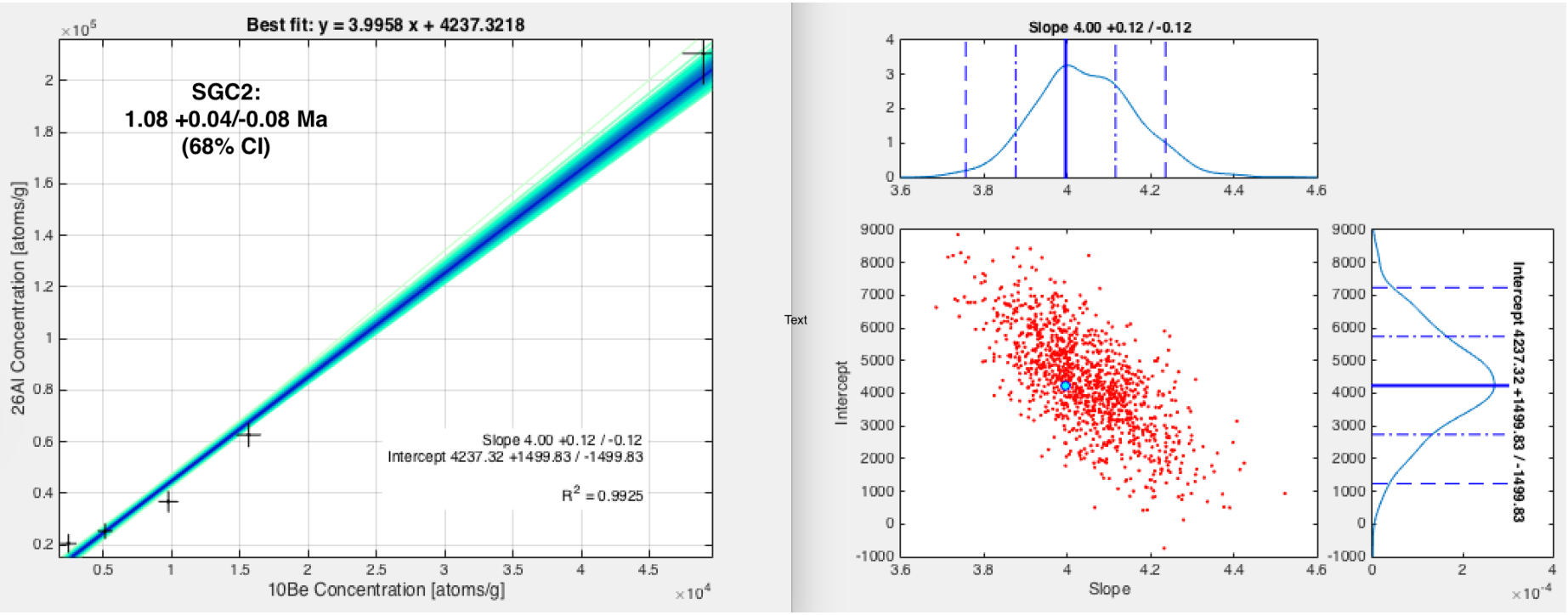
Base of Saugus Formation (Oak Ridge fault hangingwall)



^{26}Al-^{10}Be isochron burial dating results

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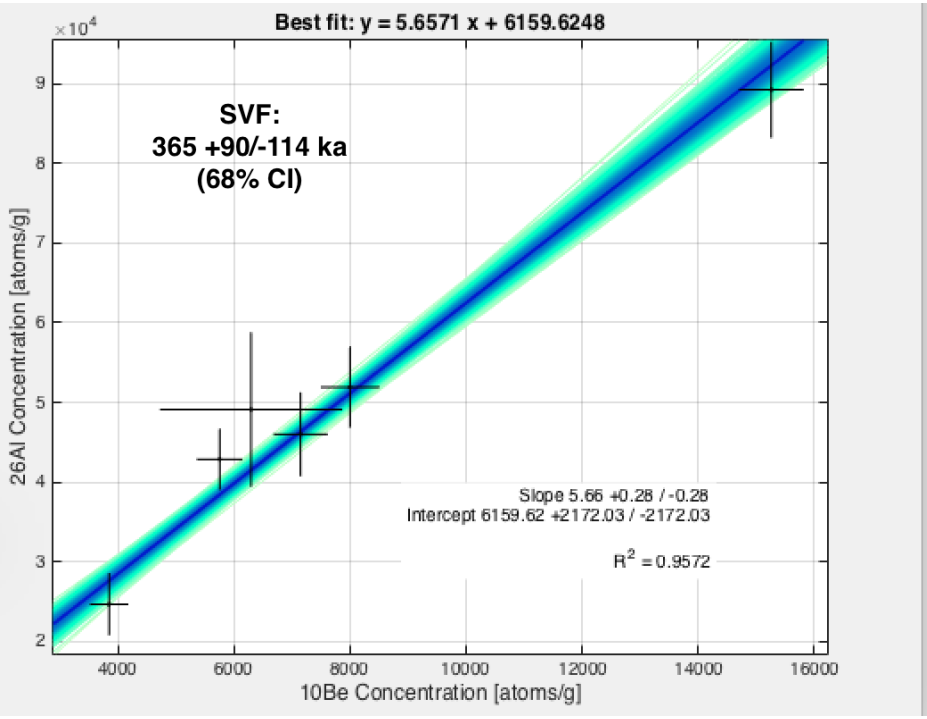
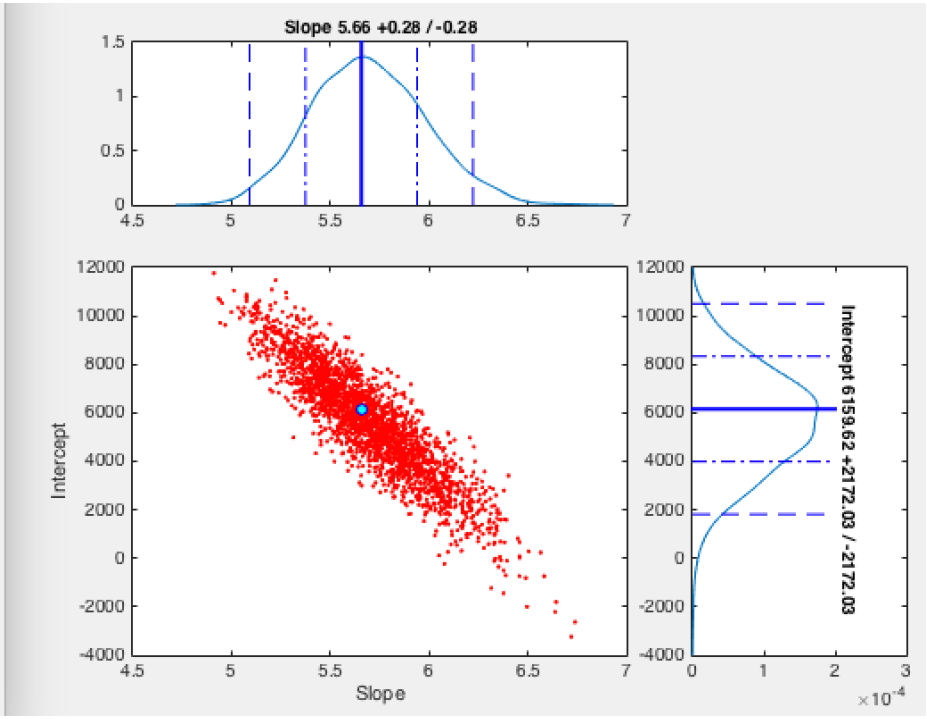
Top of Saugus Formation (Ventura fault hangingwall)





^{26}Al-^{10}Be isochron burial dating results