MAPPING ONSHORE ACTIVE FAULTS, STYLE OF FAULTING, AND RATES OF UPLIFT SANTA BARBARA COASTAL PIEDMONT

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ABSTRACT

Active faults in the Santa Barbara fold belt (SBFB) form anticlinal and synclinal folds which are expressed as linear hills, ridges, and lowlands on the coastal piedmont. The 70 km long, oblique-slip Mission Ridge fault system (MRFS) is the principal onshore, seismic source in the SBFB. Segments of the active MRFS consist of, from west to east, the More Ranch, the Mission Ridge, and the Arroyo Parida-Santa Ana. The faults exhibit steeply, south-dipping geometry with oblique left-lateral strike-slip motion.

Marine terraces are bounded on the landward side by south-dipping, oblique faults and uplifted on the hanging wall block, and these terraces are also uplifted by oblique reverse, north-dipping faults located offshore. Chronology of first emergent marine terraces is established by uranium-series age dating of solitary corals sampled from UCSB-Isla Vista terrace deposits and the Santa Barbara City College terrace deposits, and are supplemented with OSL and radiocarbon age dates. Rates of uplift range from 0.5 mm/yr. to nearly 2 mm/yr. and decrease eastward.

Rates of vertical faulting are estimated by displaced and folded late Pleistocene marine terrace and alluvial fan deposits. Vertical rates of faulting of the MRFS range from ~0.5 mm/yr. to slightly more than 1 mm/yr. Based on kinematic indicators measured on fault surfaces on outcrops and in trench exposures, the oblique-slip component is 1.5 to more than 2 times greater and range from 1 to 2 mm/yr.

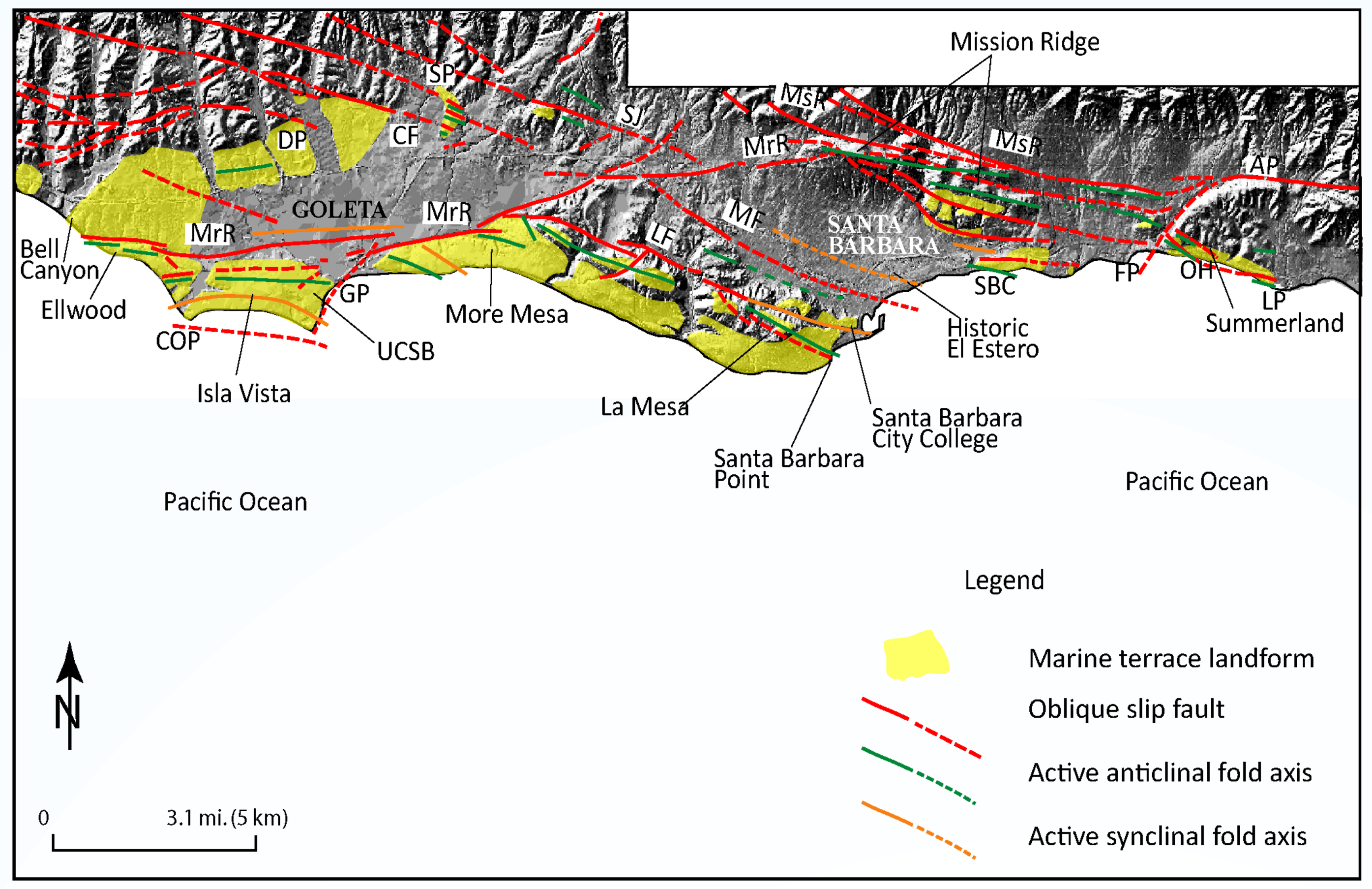


Figure 1. Seismic sources of the onshore Santa Barbara Fold Belt showing south-dipping, oblique faults with associated north-verging, hanging wall anticlines and footwall synclines. The Mission Ridge Fault System is subdivided into the More Ranch (MrR), the Mission Ridge (MsR), and the Arroyo Parida (AP) segments. Additional onshore reverse faults include the Dos Pueblos (DP), the Carneros (CF), the Goleta Point (GP), the Coal Oil Point, the San Jose (SJ), the San Pedro (SP), the Lavigia (LF), the Mesa (MF), the Santa Barbara Cemetery (SBC), the Fernald Point (FP), and the Ortega Hill (OH) - Loon Point (LP) fault system.

Table 1. Seismic sources of the onshore and offshore Santa Barbara Fold Belt with associated fault/fold dimensions, activity, and maximum expected earthquakes (M_W). Predicted magnitudes for earthquakes are determined using the methodology of Wells and Coppersmith (1994). Names of seismic source abbreviations for figure 2 are in parenthesis.

Fault	Folds(s)	Length (km)[a]	Slip	Vertical rate of faulting (mm/yr)	Activity[b]	Max. M_W
Mission Ridge Fault System[c]		69	Oblique: left lateral reverse to reverse left-lateral	0.8 – 1.1	(Apparently) active	7.2
More Ranch segment (MrR)	Ellwood, UCSB, More Mesa anticlines	18	Oblique: reverse left-lateral	0.3 – 0.4	(Apparently) active	6.5
Mission Ridge segment (MsR)	Mission Ridge, Montecito, Eucalyptus Hill, and Barker Pass anticlines	17	Oblique: left lateral reverse to reverse left-lateral	0.8 – 1.1	Apparently active	6.5
Arroyo Parida-Santa Ana segments (AP)		44	Oblique: reverse left lateral	0.4 (Ojai, CA)	Apparently active	7.0
Northwest-Striking Faults						
Mesa (MF)	Mesa anticline	12	Oblique	Unknown	(Apparently) active	6.5
Lavigia (LF)	Hope Ranch anticline Honda Valley folds	15	Oblique: reverse left-lateral	0.1	Potentially active	6.4
San Jose (SJ)	Goleta Valley anticline	7	Oblique	Unknown	Potentially active	6.1
San Pedro (SP)	unnamed anticlines	8	Oblique:	Unknown	Potentially active	6.1
Loon Point(LP)	Loon Point anticline	1	Oblique: reverse left-lateral	0.1	Active	5.1
Ortega Hill (OH)	Ortega Hill anticline	1	Oblique	Unknown	Potentially active	5.1
Santa Barbara Cemetery (SBC)	Santa Barbara Cemetery anticline	1	Oblique	0.4	Apparently active	5.1

a. We assume fault length is the surface rupture length and may be slightly different than map lengths shown on Figure 2.
b. Active = demonstrated Holocene (last 10,000 yr.) activity;
Apparently Active = very young (probably Holocene) topographic expression of activity;
Potentially Active = active in Pleistocene (last 1.65 million years)
c. We account for the onshore length and do not include the offshore segment.

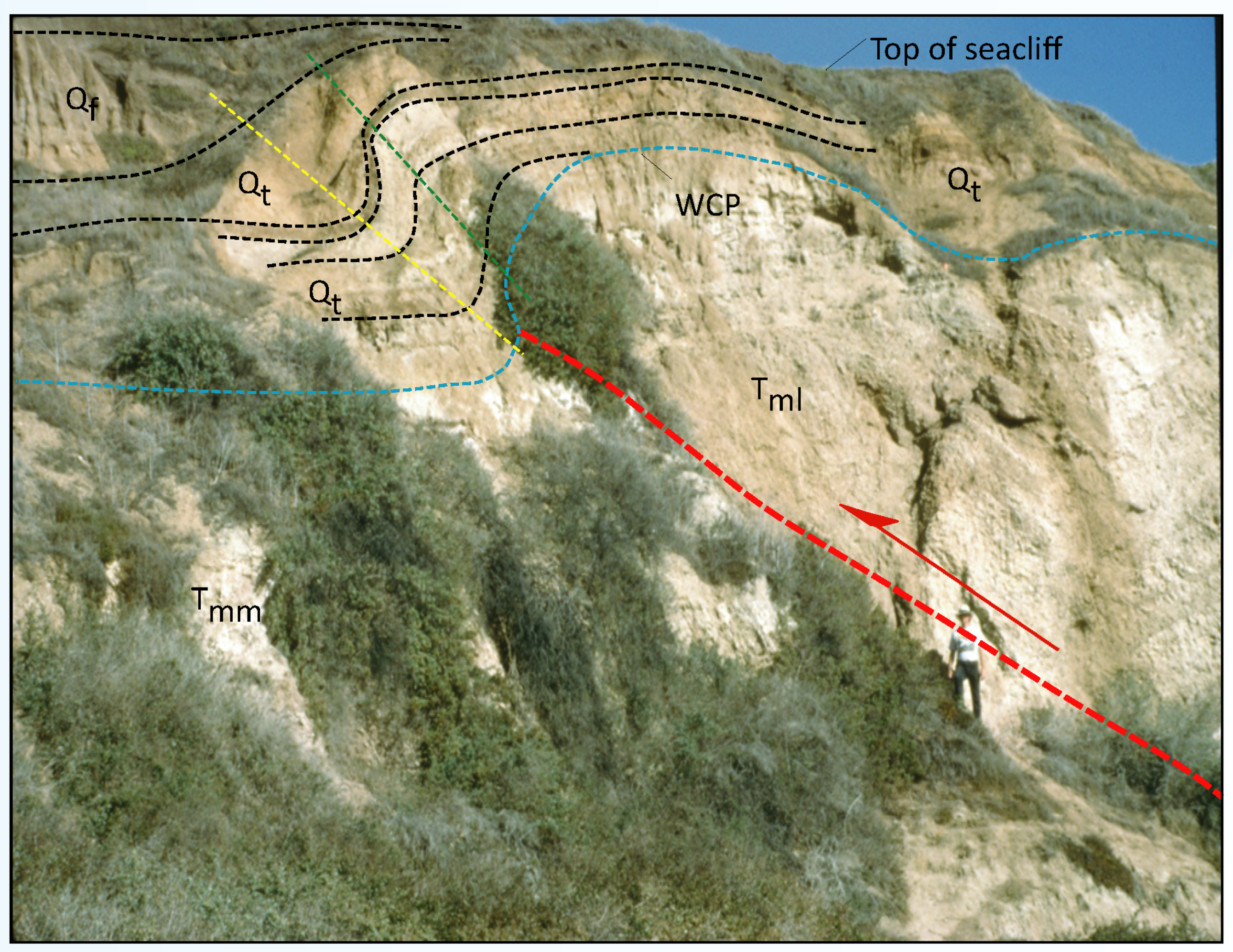


Figure 2. Photograph of the sea cliff exposure of the north Branch of the More Ranch fault (red dashed line) at Ellwood Beach, Santa Barbrara County, California. The oblique slip fault juxtaposes lower Monterey Formation against middle Monterey Formation. Detailed mapping of the sea cliff face reveals that the wave-cut platform (WCP) is warped and a monoclinal fold is formed in the marine (Qt) and fluvial (Qf) terrace units. Note the person standing near the fault for scale.

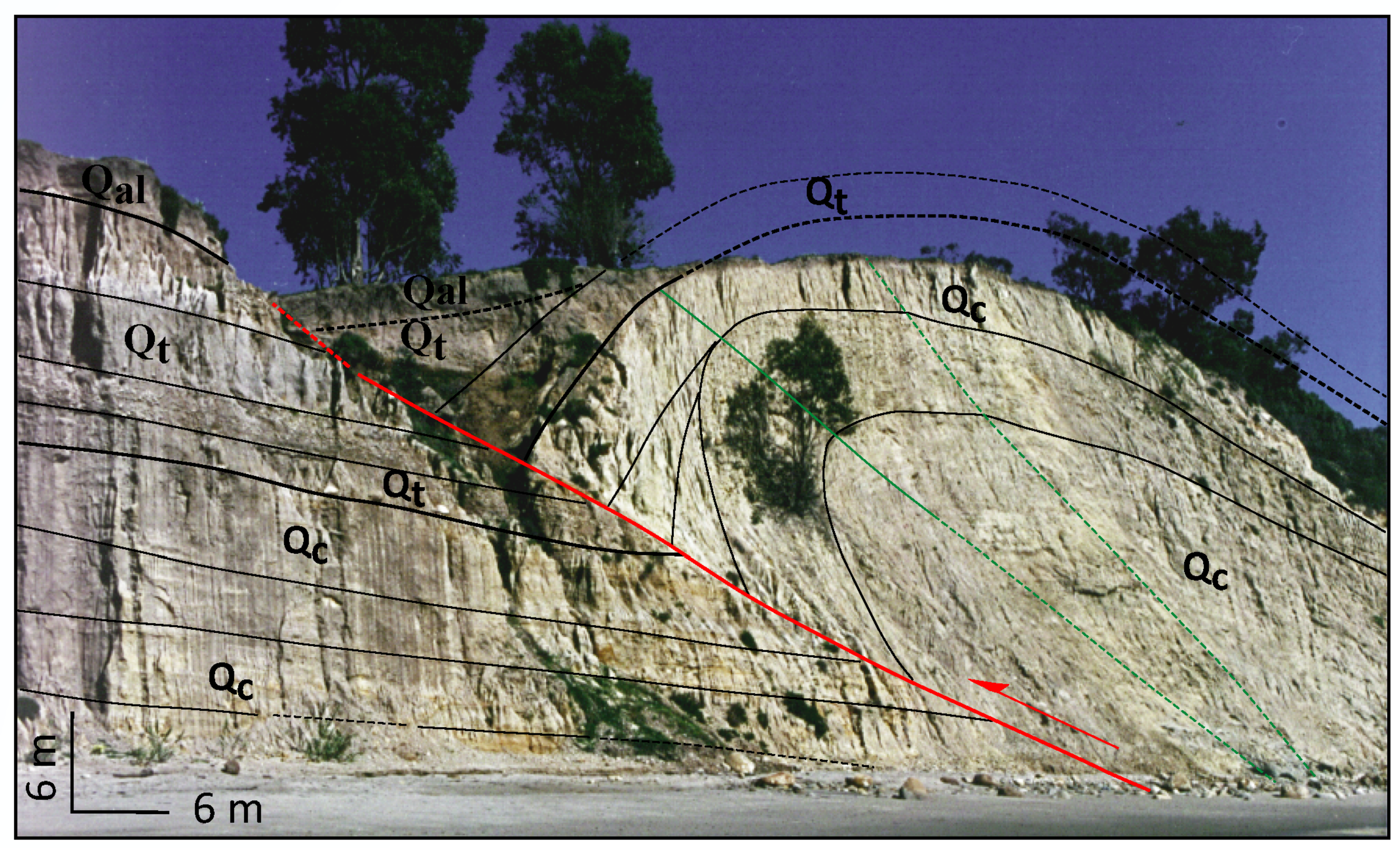


Figure 3. Photograph with the view along strike of the Loon Point fault-propagation fold. The fault (shown in red) forms a hanging-wall anticline that forms two axial surfaces (shown in green). The fold deforms Quaternary Casitas Formation (Q_C) and late Pleistocene marine terrace deposits (Q_t). The formation contacts are indicated as thick black lines. The marine platform is vertically offset approximately 7 m and the projection of the eroded, marine platform across the fold crest is shown. Slip on the fault is transferred to a north-dipping backthrust splay that is located to the east (right of the image). A trench excavated along the fault trace revealed displaced Holocene-age alluvium (Qal).

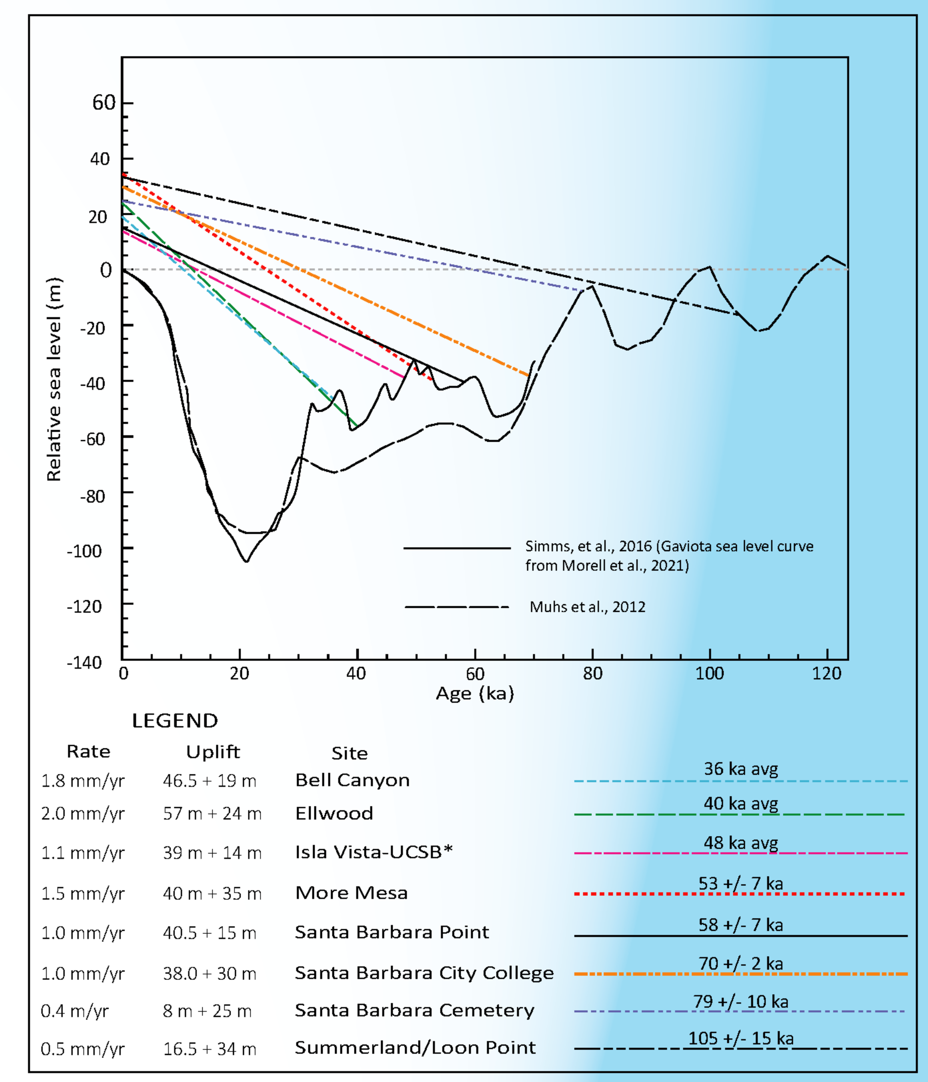
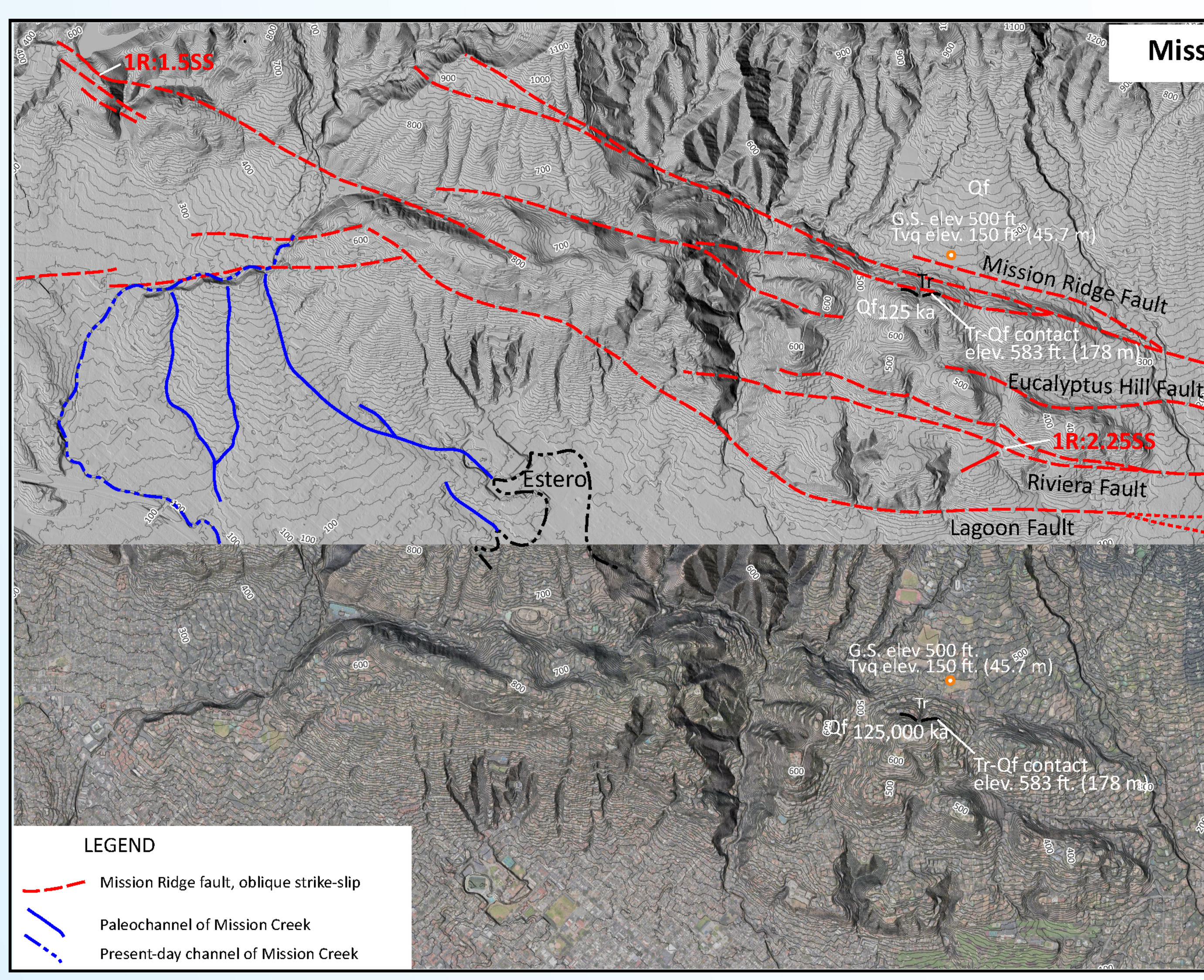


Table 2. Ages of the first emergent marine terraces plotted on a glacio-isostatic adjusted paleo-sea level curve for the latitude of Gaviota (from Morell et al., 2021) which best applies to the SBFB. The sea level curve was generated by Simms et al. (2016). The rate of uplift is shown in the left column and rates in parenthesis are based on Muhs et al. (2021) sea level curve. The total amount of uplift is determined by the paleo-sea level elevation that formed the terrace and is cumulative with the elevation of the shoreline angle for the first emergent terrace. If the shoreline angle is eroded and removed or faulted and deeply buried, then the maximum elevation is used for correlation.

Mission Ridge Fault System Map



Scale in Feet 0 1,000 2,000
Scale in Meters 0 300 600

Figure 4. A water well encountered the base of late Pleistocene alluvium (Vaqueros Fm) at an elevation of 150 ft. (45.7 m). The position of the base of alluvium uplifted on Mission Ridge at an elevation of 583 ft. (178 m), the fault displaces the base of the 125 ka alluvial fan ~433 ft. (132 m).
The min. vertical rate of faulting is ~1.1 mm/yr. Based on kinematic indicators, the min. rate of oblique slip of faulting is 1.5 mm/yr., possibly as high as 2 mm/yr. given the motion on the Riviera fault.

Upper map: 2018 LiDAR hillshade map. Lower map: 2018 LiDAR hillshade map with Google Earth overlay.

CONCLUSIONS

1) The (MRFS) is a steeply, south-dipping fault system and the the principal onshore, seismic source in the SBFB.

2) Active faults in the (SBFB) typically form anticlinal-synclinal fold pairs that deflect and in some cases, uplift and defeat south-flowing creek channels.

3) Chronology of marine terraces established the formation of first emergent marine terraces during paleo-sea levels MIS 3 and MIS 5. Rates of uplift decrease eastward along the coastal plain from Ellwood to LoonPoint from 1.6 mm/yr. to 0.5 mm/yr.

4) Strain is partitioned across the onshore and offshore SBFB and produces a system of steely-dipping, oblique strike-slip of onshore faults as compared to the system of moderately-dipping, oblique reverse offshore faults.

5) Segments of the MRFS exhibit kinematic indicators the demonstrate oblique left-lateral strike-slip motion that generally ranges from 1.5:1 to 3:1 ratio of strike-slip to reverse motion, and locally varies to 1:1 ratio.

6) Rates of vertical faulting are determined by displaced, late Pleistocene marine terraces and alluvial fan deposits. Rates of vertical faulting generally range from 0.5 mm/yr. to 1 mm/yr. Kinematic indicators establish that rates of oblique slip range from 1.5 mm/yr. to more than 2 mm/yr.

7) If a single segment of the MRFS ruptures in the Santa Barbara area, a Mw of 6.5 is estimated. If the entire Arroyo Parida ruptures or the entire MRFS ruptures in a single event, then a Mw of 7.0 to 7.2 is esimated.

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