Identifying active uplift across fault strands in the San Gorgonio Pass region: a TL thermochronology based approach.

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Abstract

The San Gorgonio Pass (SGP) in the southern San Andreas Fault Zone plays an important role in modulating earthquake ruptures. This region remains poorly understood largely due to its structural complexity and lack of datable materials in its mountainous terrain. In this study, we try to characterise SGP's crucial function in earthquake dynamics amid ongoing discussions on slip partitioning among its multiple fault strands. Our aim is to fill a knowledge gap concerning the fault activity spanning the last 100 – 10 thousand years. Previous studies in the region have utilised low temperature thermochronometers like Apatite U-Th/He (hereafter, AHe) cooling ages and cosmogenic ^{10}Be catchment wide erosion rates to inspect the activity of faults in the vicinity of SGP. Traditional thermochronometers like AHe can resolve uplift rates across a fault strand on million-year (Ma) time scale. On the other hand, cosmogenic ^{10}Be dating can successfully measure activity across fault segments on thousand years (ka) time scale, but the observations carry significant spatial and temporal biases. In this study, we use thermoluminescence (TL) thermochronology, a novel technique, to measure in-situ erosion rates from bedrock samples obtained from the Yucaipa Ridge Block (YRB) across the Galena Peak-Mill Creek Fault configuration in the SGP region. By juxtaposing erosion rate estimates across the Galena Peak-Mill Creek Fault configuration, our research aims to pinpoint which fault segments are active to improve the understanding of fault dynamics and seismic risk in the southern California.

How is slip routed through San Gorgonio Pass ?

Hypothesis: TL thermochronology can identify faults as active by resolving differential uplift across fault strands in the past 10 - 100 ka years.

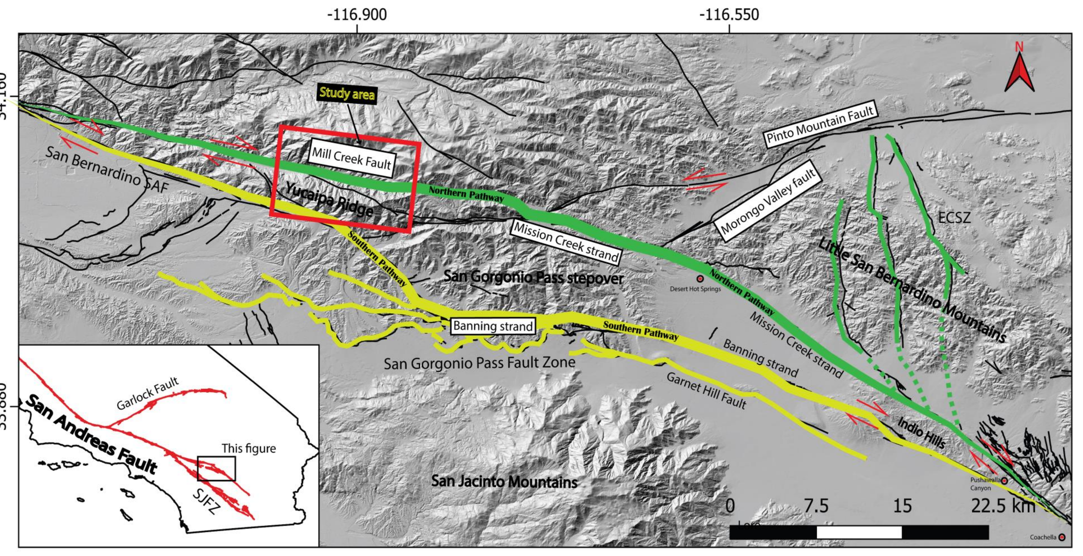

Figure 1: Hillshade map of the Southern San Andreas Fault indicating fault lines. Green marks the northern, and yellow the southern stress pathways, as defined by Gold et al. (2015). Both pathways are significant for stress transmission along the Southern San Andreas Fault. The study area is highlighted in red. Figure is adapted from Waco (2021).

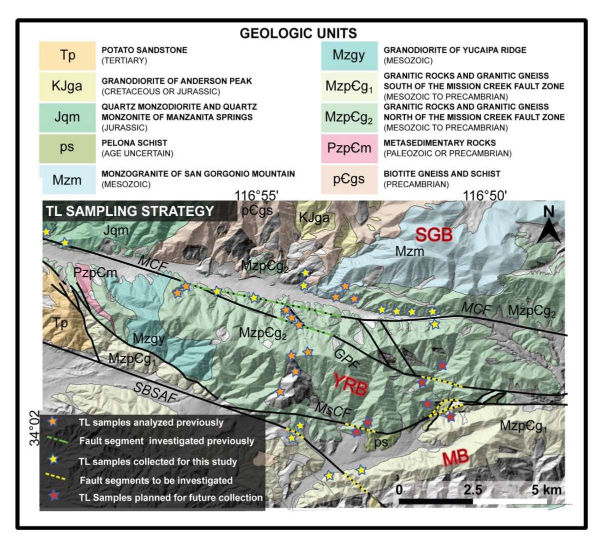

Figure 2: Hillshade map of the study area depicting the regional geologic units, sampling sites and the fault strands investigated in this study. This figure was modified from a NEHRP proposal figure by Brown that adopts geologic unit mapping from Matti et al. (1983) and fault mapping from Alex Morelan's Ph.D. thesis work (unpublished).

Research questions

1. How does slip partitioning among various fault strands in the San Gorgonio Pass (SGP) region occur, and which of these faults are potential producers of large earthquakes?
2. Can systematic differences in bedrock erosion rates across active fault strands in the SGP region provide insights into spatial variability in tectonic uplift, and hence, fault activity?

TL Thermochronology

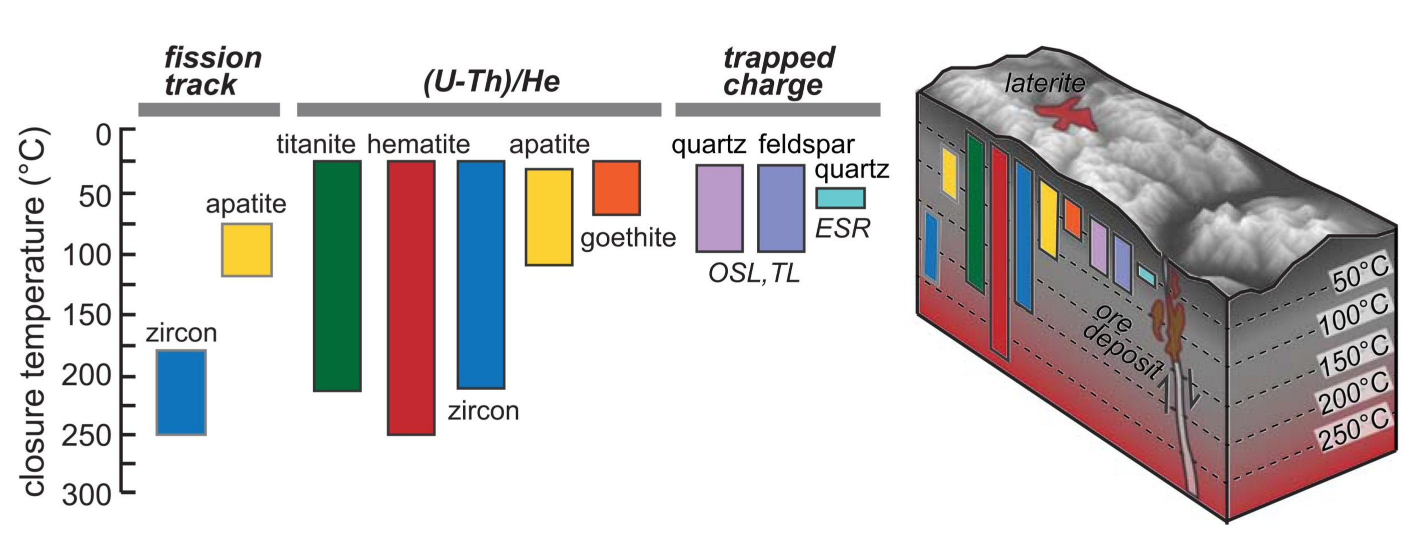

Figure 3: The diagram presents closure temperatures for various thermochronometers within mineral systems, including Fission Track, (U-Th)/He, and trapped charge methods. Accompanying the data is a three-dimensional crustal block illustration displaying isotherms and respective thermochronometer closure temperatures. The thermochronometers are indicated with abbreviations: OSL (optically stimulated luminescence), TL (thermoluminescence), and ESR (electron spin resonance). Figure is taken from Ault et al., (2019).

Kinetic parameters and cooling age: Thermal experiments are used to constrain kinetic parameters that regulate charge growth and decay within Feldspar.

TL thermochronology: Ultra-low temperature dating technique that can replicate bedrock exhumation history, using Feldspar's luminescence signals to probe thermal history over 10^4 to 10^5 years.

Role of geothermal heat: Geothermal heat affects the accumulation of the luminescence signal in Feldspar. With the TL signal, we can record the bedrock's thermal history during the latter stages of its exhumation, spanning tens to hundreds of meters, which is crucial for understanding topographical changes due to tectonic and erosional processes.

Cooling Ages

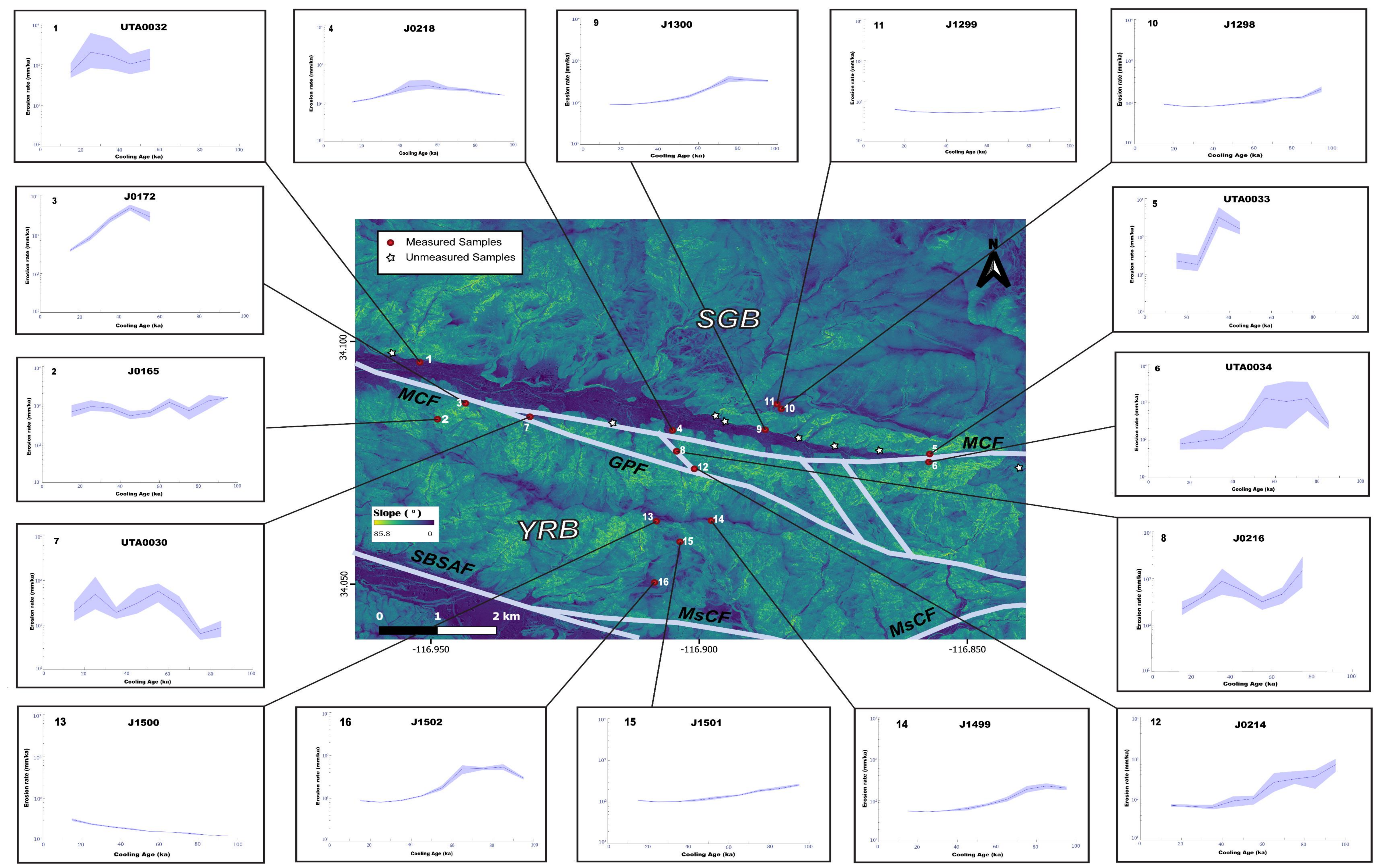

Figure 4: The figure displays erosion rate versus cooling age data for samples from the Mill Creek and Galena Peak fault areas. Central to the image is a slope map of the study area, showing key faults and sample sites. Red dots represent samples analyzed in this study, while white stars denote samples that have been prepared but not analysed yet. Key geological features are labeled: YRB (Yucaipa Ridge block), SGB (San Gorgonio block), MCF (Mill Creek fault), GPF (Galena Peak fault), MsCF (Mission Creek fault), and SBSAF (San Bernardino San Andreas fault).

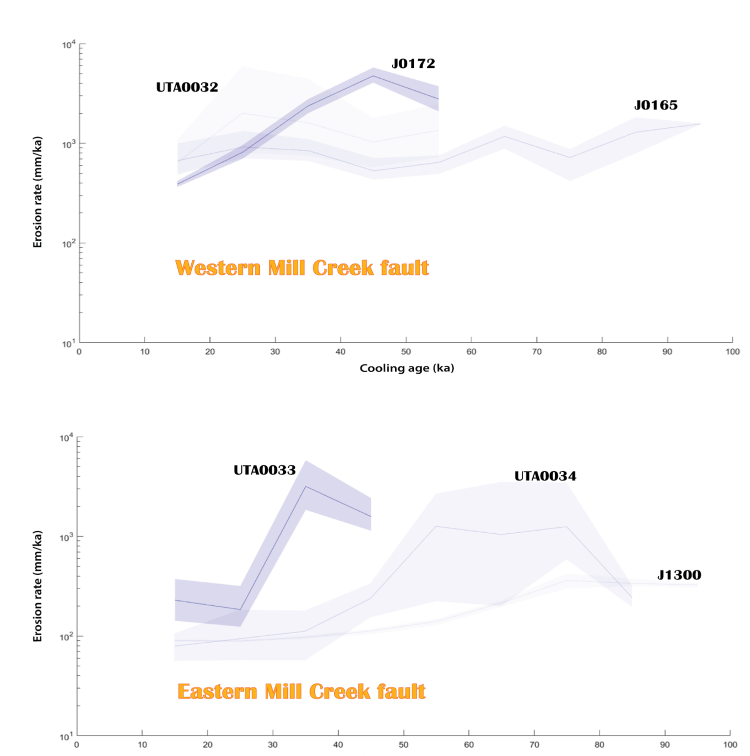

Figure 5: Erosion rate comparison from samples collected from the eastern and western segments of the Mill Creek fault.

Observations

Western Mill Creek fault:
- Erosion rates inferred from samples UTA0032 and J0165 suggest stability over the period of 60 - 10 ka, with rates remaining consistent and high in comparison to the rest of the region.
- Conversely, sample J0172 exhibits a pronounced decrease in erosion rate from 50 to 10 ka, yet it maintains an elevated level, aligning with the overarching regional erosion pattern.

Eastern Mill Creek fault:
- Samples UTA0033, UTA0034, and J1300, all demonstrate a trend of decreasing erosion rate from 70 - 10 ka.
- This consistent decrease with time suggests a period of diminishing erosional activity across the fault.

Big takeaways :
- Samples near the eastern Mill Creek fault segment undergo erosion at a slower pace than samples near the western end.
- The slower erosion rates exhibited by samples UTA0033 and UTA0034, situated near the steep valley head of the catchment, suggest the upward migration of a knickpoint through the catchment in response to a base level shift.

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