Revisiting the Mission Creek Fault: Unravelling Holocene Activity and Slip Potential.

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Introduction

The San Andreas Fault (SAF) in southern California exhibits a multistranded configuration, with slip partitioned between northern and southern pathways, each consisting of a network of fault strands. Determining which pathway accommodates slip during large earthquakes is critical for seismic hazard assessment and requires constraints on the late Pleistocene to Holocene activity of individual faults. The Mission Creek Fault (MsCF), a key strand of the northern pathway, has been proposed as a major slip carrier, but its Holocene activity northwest of Pushawalla Canyon remains debated due to conflicting geomorphic evidence and a lack of geochronological constraints on its rupture history. This study presents new depositional ages from two sites near Mission Creek Stonehouse, northwest of Desert Hot Springs, to assess the Holocene activity of the MsCF. At Mission Creek Valley, single-grain post-infrared infrared-stimulated luminescence (pIR-IRSL) dating of alluvium overlying the fault trace yields a mean depositional age of 0.80 ± 0.04 ka, with a maximum depositional age of ~2.5 ka, contradicting previously inferred ages of >3–18 ka. A comparison of these luminescence ages with cosmogenic ^{10}Be abandonment ages from alluvial surfaces across the Mission Creek catchment reveals widespread sediment reworking, including a potential major reworking event at ~30 ka affecting surfaces Q1b and Q2b. The young alluvium ages and evidence for catchment-wide sediment recycling indicate that the valley is undergoing rapid resurfacing, which would erase rupture signatures unless they are a few hundred years old. To evaluate slip along the MsCF, we analysed two offset streams crossing the fault's southern splay atop the San Gorgonio Overlook fan. Alluvium was sampled upstream and downstream of the fault trace to estimate the timing of deposition before offset accumulation, while additional samples from the host surface were used to constrain the maximum possible age of offset initiation. However, steep downstream gradients and terrace degradation prevented the preservation of alluvium along the pre-earthquake streamflow direction, precluding a slip rate determination. While our findings do not provide definitive evidence of Holocene rupture along the MsCF, they also do not support its inactivity. The absence of rupture signatures may be attributed to rapid sediment reworking rather than a lack of fault movement. These results highlight the need for further geochronological and geomorphic investigations along regional fault strands to fully assess the role of the MsCF and the northern pathway in accommodating slip.

Distribution of slip across multistranded SAF

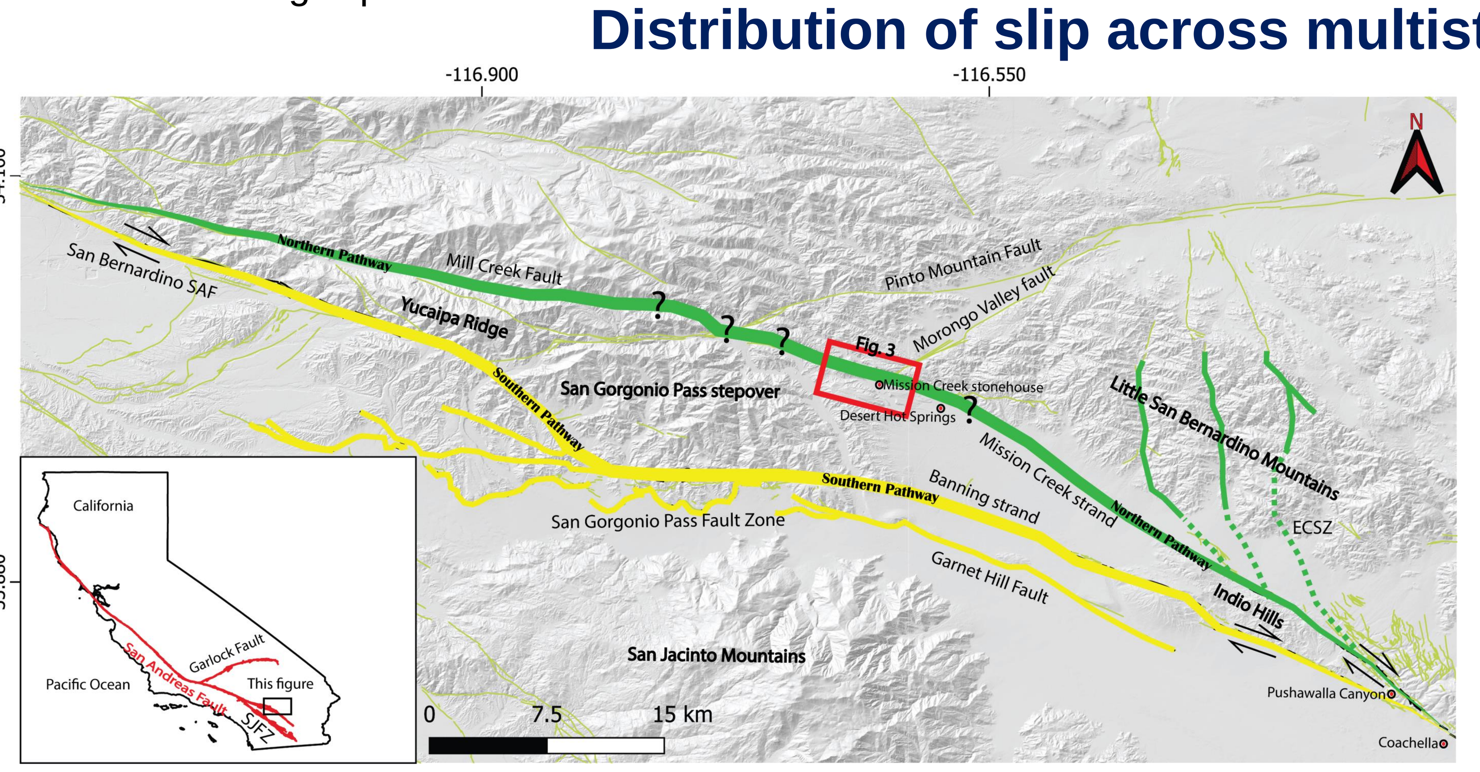


Figure 1: Hillshade map of the Southern San Andreas Fault depicting major fault strands in the region. The slip passing through this multistranded region is accommodated by faults along the northern pathway (labelled in green) and southern pathway (labelled in yellow) (Gold et al., 2015). Both pathways are significant for stress transmission along the Southern San Andreas Fault. The study area is near the Mission Creek stone house, northwest of the town of Desert Hot Springs, and is marked by a red box. The figure is modified from Waco (2021) and Blisniuk et al., (2021). Abbreviations used are: SJFZ (San Jacinto Fault Zone), ECSZ (Eastern California Shear Zone), and SAF (San Andreas Fault).

Which of these pathways would allow throughgoing rupture on the SAF?

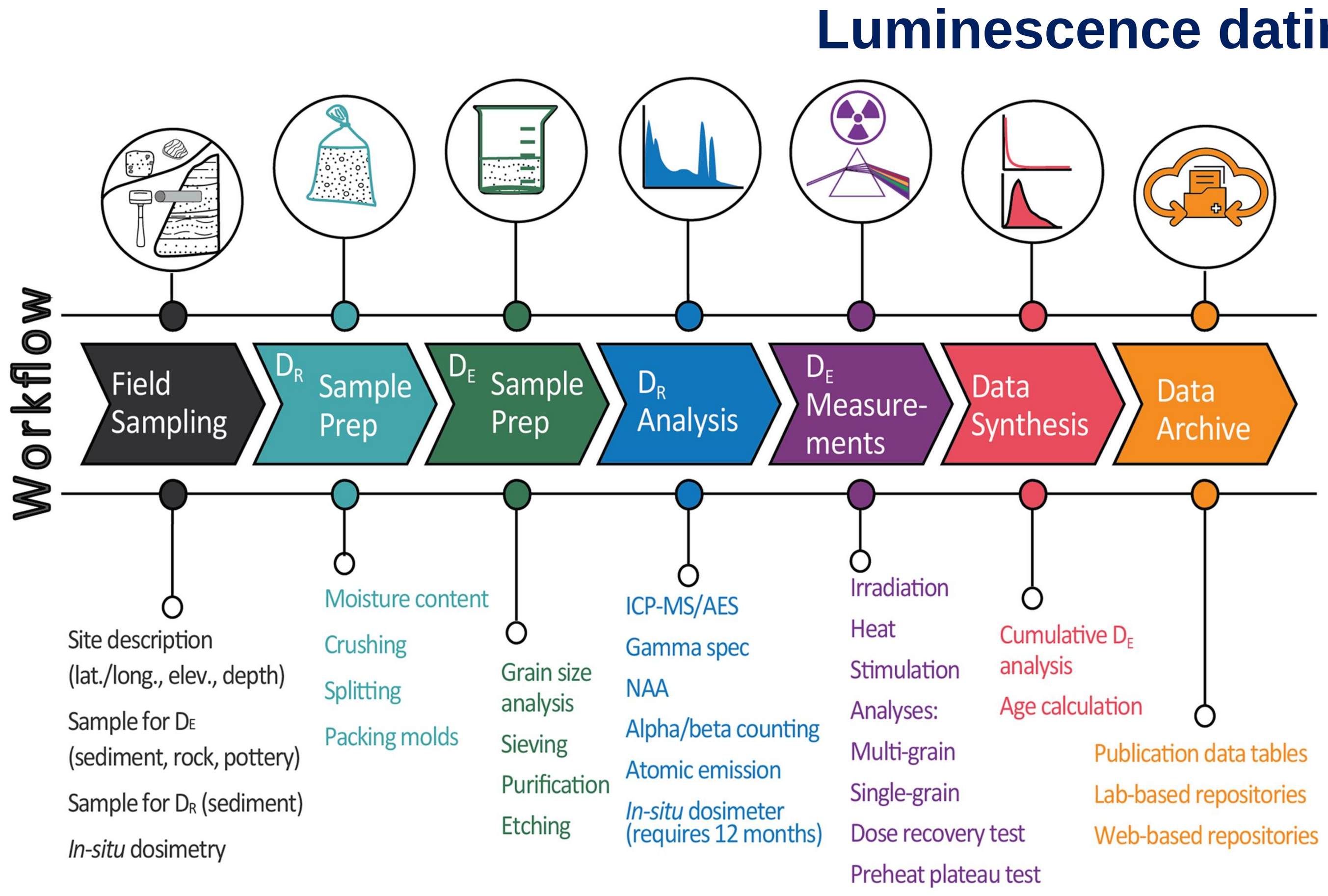
Northern Pathway: absence of slip signatures northwest of Desert Hot Springs.

Southern Pathway: cumulative slip estimated across faults is significantly less than the total expected slip along intact SAF

Goals:

1. When was the Mission Creek alluvium last ruptured at the Mission Creek Stonehouse site?
2. What is the slip rate along the Mission Creek Fault?

Luminescence dating



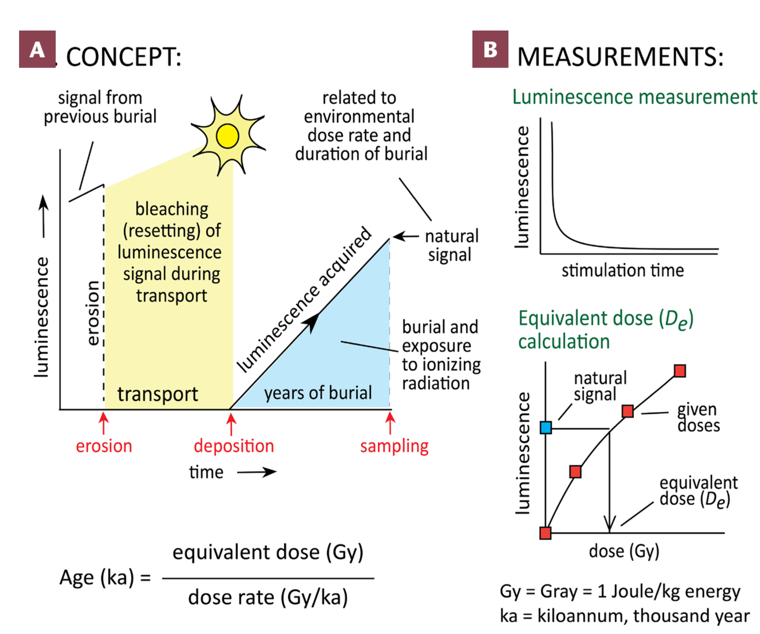


Figure 2: Schematic representation of the complete workflow for luminescence dating, detailing each stage from sample collection and pre-treatment to final measurement for depositional age estimation (Mahan et al., 2023; Rittenour, 2018)

Mission Creek Alluvium

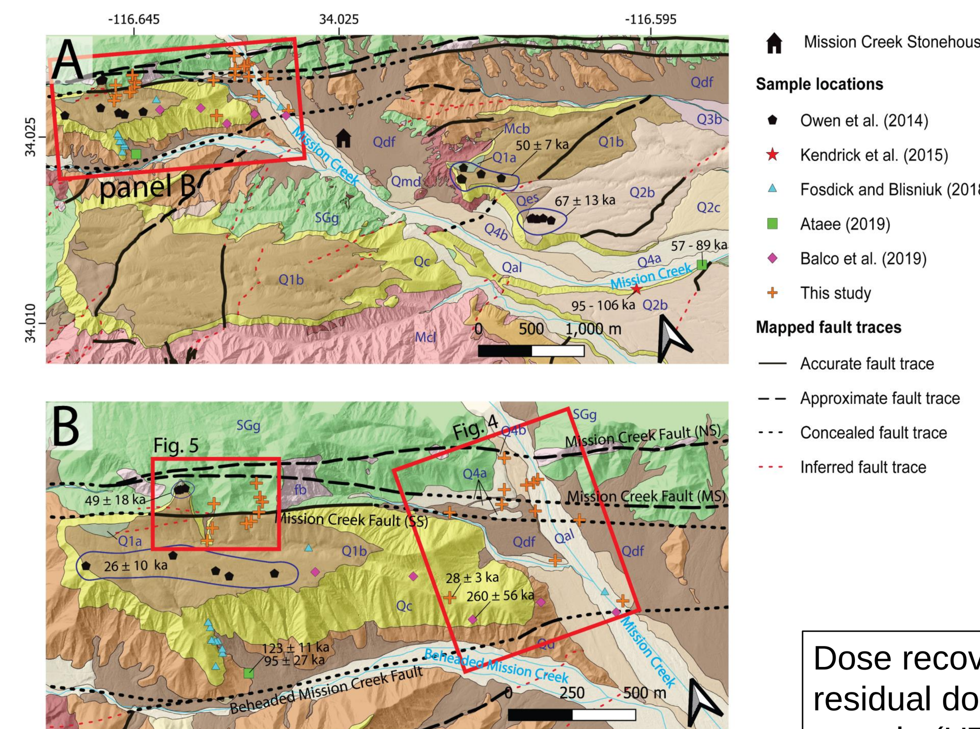


Figure 3: **(A)** Geological units within the Mission Creek drainage, delineated based on the geological mapping of Waco (2021). **(B)** Close-up view of samples collected in this study, alongside those from previous investigations near the Mission Creek Stone House. Two red rectangular boxes delineate the primary sampling locations, which include: (i) alluvium sampled within the Mission Creek valley adjacent to the active channel (Fig. 4), (ii) perched alluvial deposits (Fig. 4), and (iii) alluvium from the offset channel site atop the San Gorgonio Overlook fan (Fig. 5).

Revised Chronology: Holocene depositional ages challenge earlier estimates of >3–18 ka (Yule et al., 2021).

Tectonic Overprinting: Absence of offset signatures in sampled units likely reflects rapid catchment resurfacing.

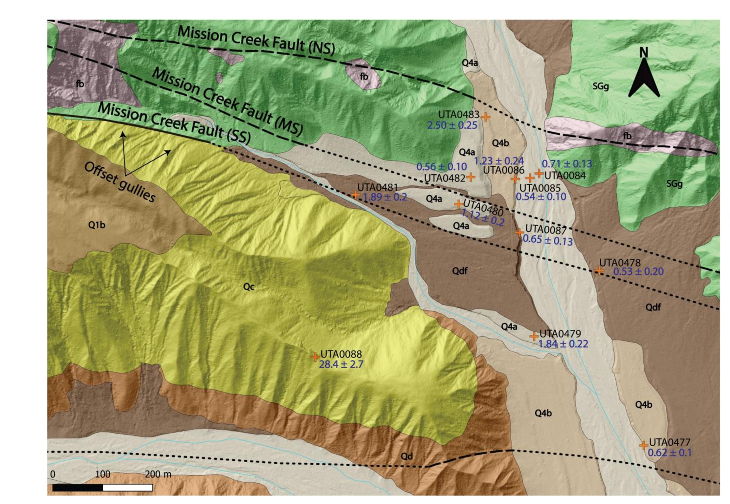
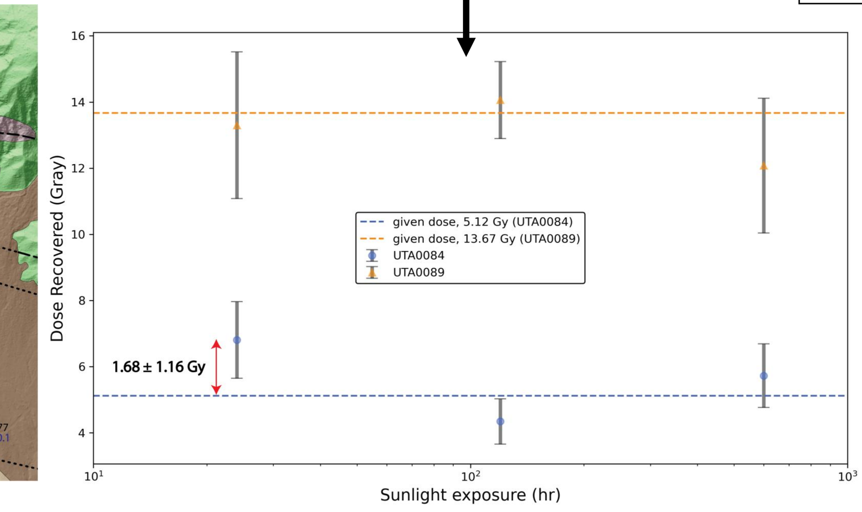
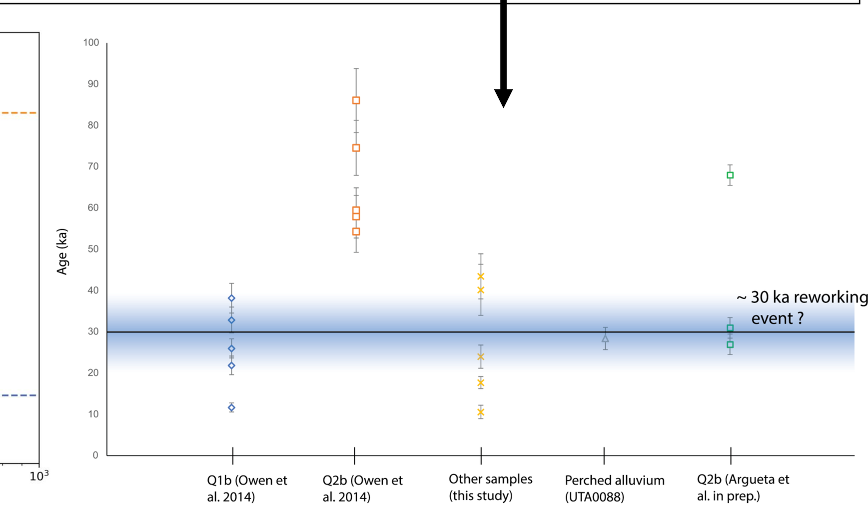


Figure 4: Depositional ages of different geologic units sampled within the Mission Creek Valley (Waco, 2021).

Dose recovery test shows significant residual dose in the modern valley sample (UTA0084)



A synthesis of luminescence and cosmogenic ^{10}Be ages from alluvial deposits across the Mission Creek catchment, derived from multiple studies, reveals a significant reworking event occurring around ~30 ka.



Offset Channels

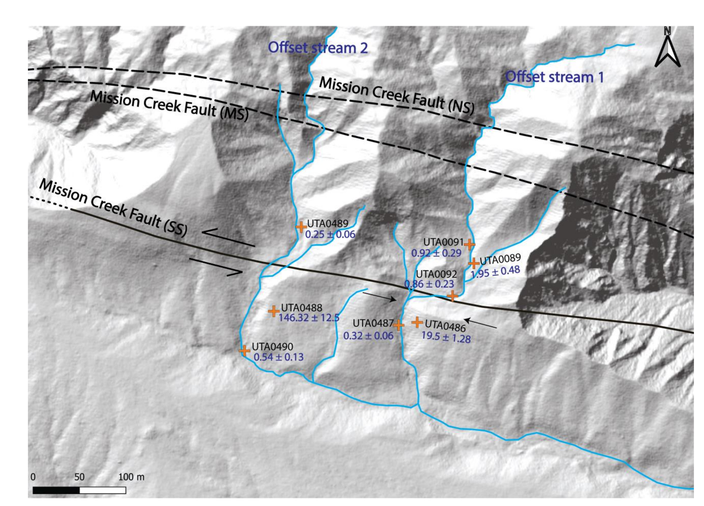
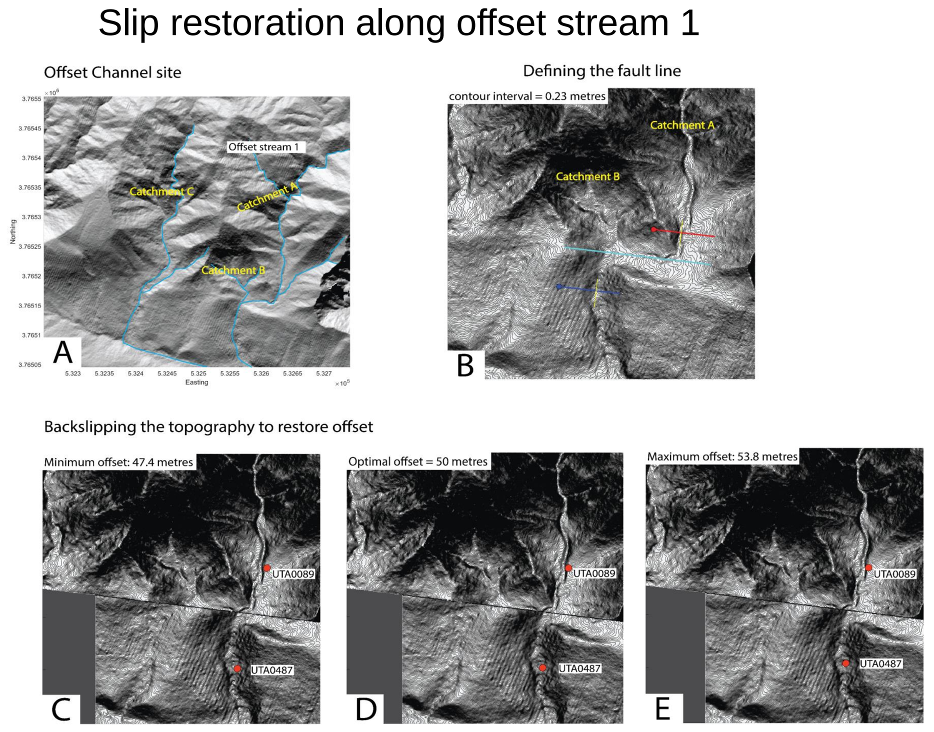
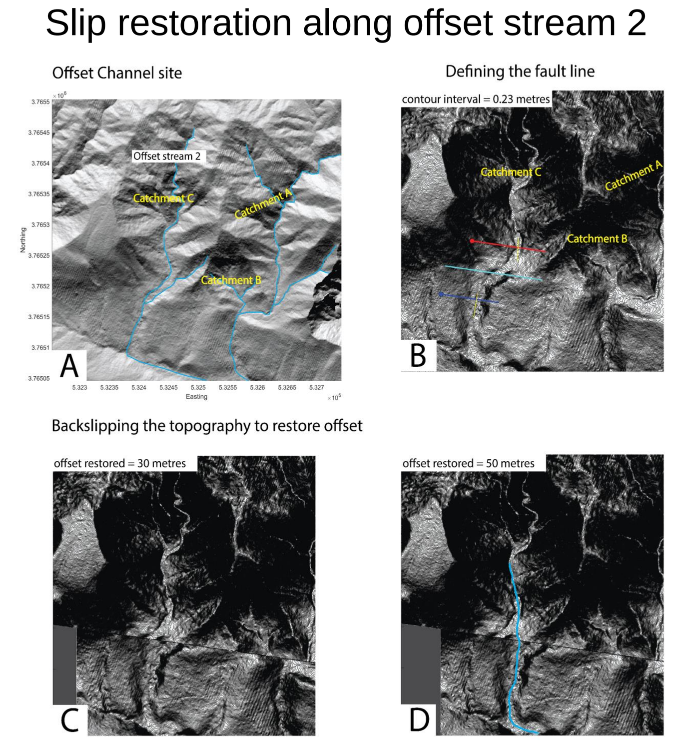


Figure 5: Depositional ages of alluvium sampled at the offset channel site. The two streams are offset right laterally as they cross the trace of Mission Creek Fault (Blisniuk et al., 2021)

Slip restoration along offset stream 1



Slip restoration along offset stream 2



Offset stream 1: UTA0089 (protected alluvium upstream of the fault) and UTA0489 (downstream) were deposited by the same stream before displacement occurred.

Slip rate: Assuming the age of protected alluvium represents the pre-earthquake orientation of the stream, we can estimate slip rate as:

$$\frac{\textit{Total accumulated slip}}{\textit{Age}}$$

The average slip along Mission Creek Fault equals 25.8 ± 3.7 mm/yr which is close to previous estimates at this site: 16 ± 3 mm/yr since 260 ka (Balco et al., 2019), 20-30 mm/yr since 100 – 500 ka (Fosdick and Blisniuk, 2018), and 21.6 ± 2 mm/yr since 95 ka (Blisniuk et al., 2021).

Offset stream 2: The complex morphology of Offset Stream 2 prevents precise restoration of displacement.

Post-Slip Degradation: Anomalously wide downstream channel indicates significant geomorphic degradation of terrace risers following offset initiation.

- Rapid resurfacing within the Mission Creek valley likely obscures the geomorphic evidence for a recent rupture on the MsCF
- With no major earthquake on the SAF in the past ~168 years, despite an estimated ~100-year recurrence interval (Grant and Sieh, 1994), a major event may be overdue and could potentially involve the MsCF

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