Potentials and challenges with single-grain luminescence dating—re-evaluating our assumptions

Paleoseismic trench on the Banning strand, **North Palm Springs, California**

Funding Agencies:

USGS science for a changing world · NSF · SCEC an NSF+USGS center

Collaborators:

Katherine M. Scharer & **Devin McPhillips,** *USGS Pasadena*

Bryan A. Castillo, *Cal. State University, San Bernardino*

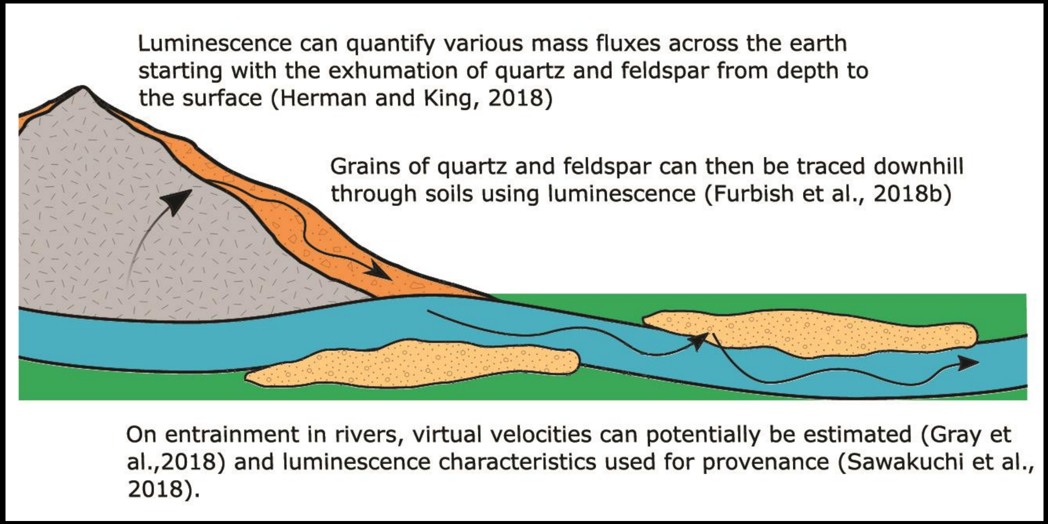
Doug Yule & James McNeil, *Cal. State University, Northridge*

UCLA Earth, Planetary, and Space Sciences

Sourav Saha, Seulgi Moon, Nathan D. Brown, Ed J. Rhodes, & Sally F. McGill

sahasv@mail.uc.edu

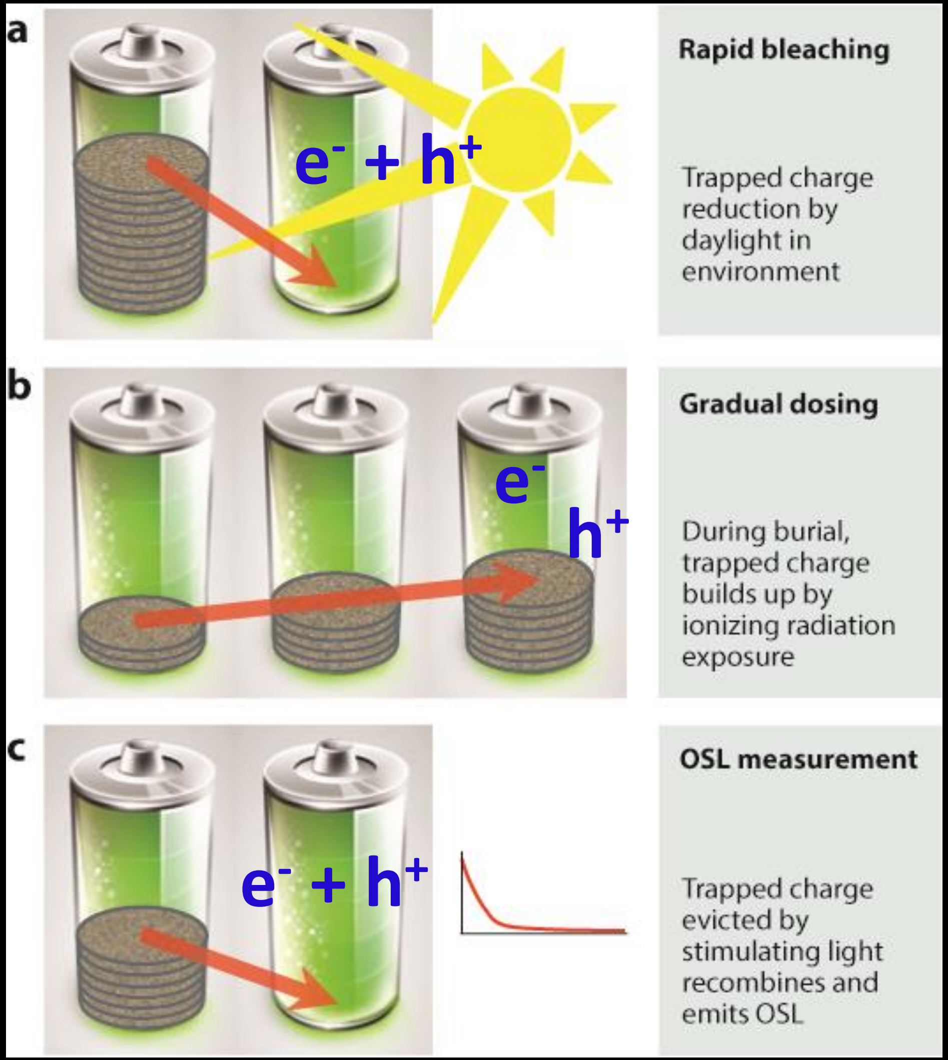
Luminescence (light) dating is burial dating technique



Gray et al. (2019)

K-feldspars

Quartz

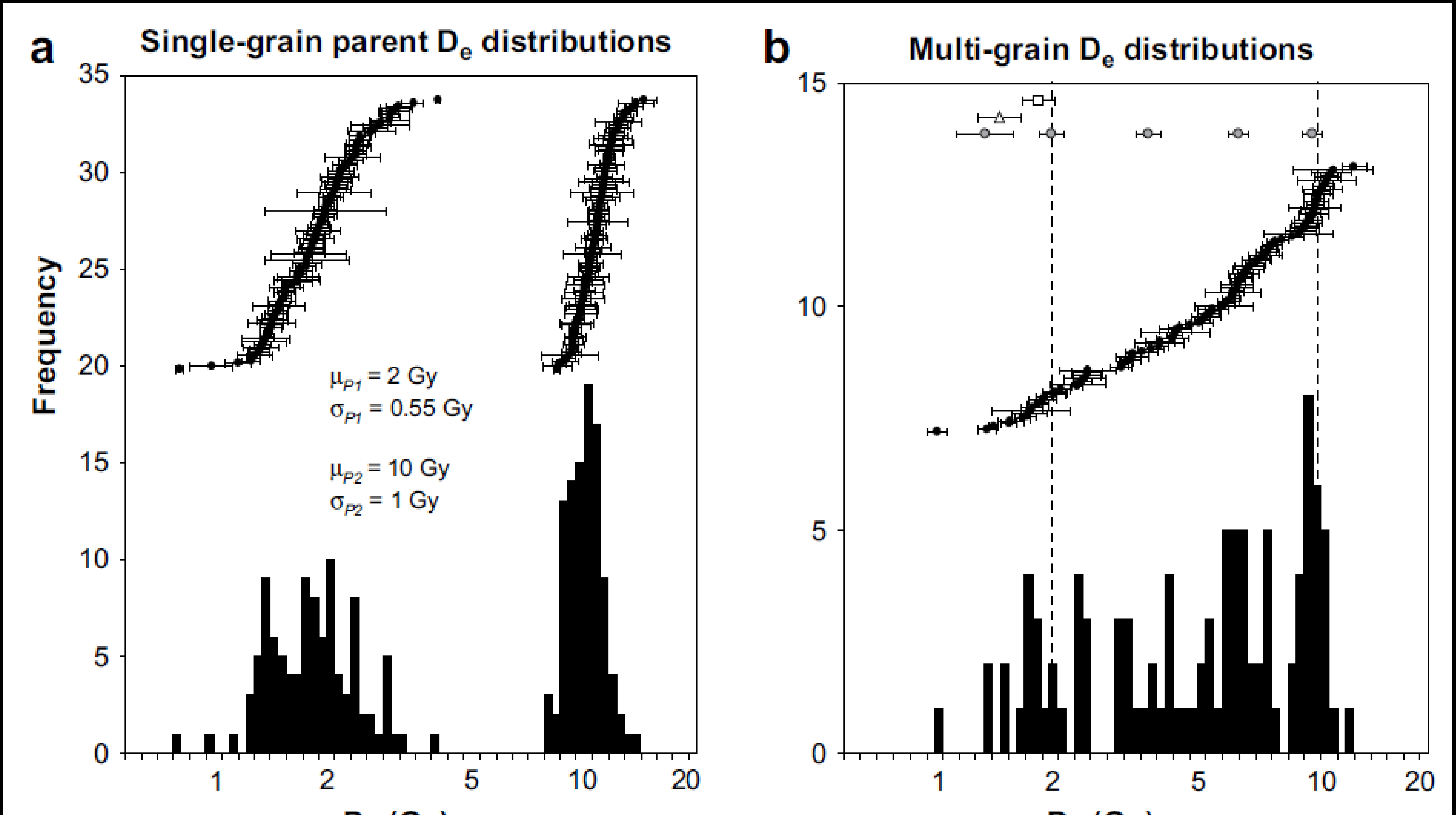


Rhodes (2011)

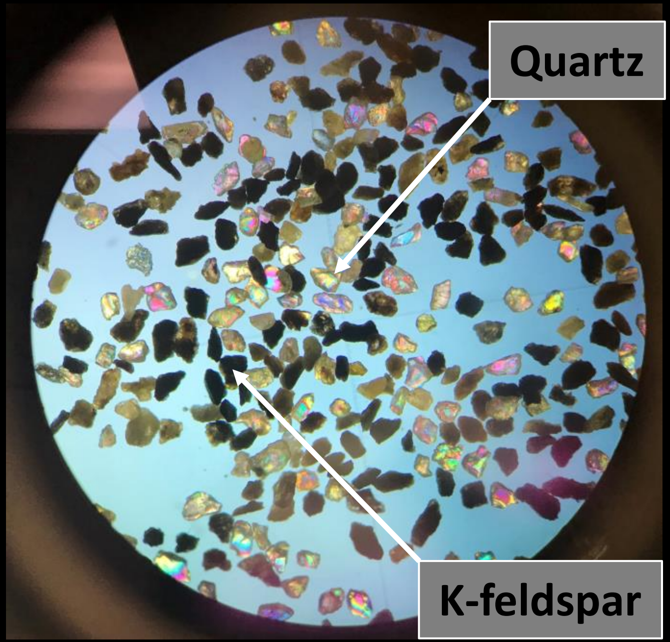
$$\text{Burial age} = \frac{\textbf{Equivalent dose}(De)}{\textbf{Dose rate}(D_R)}$$

Single-grain luminescence edges over the multigrain single-aliquot

- Post-depositional mixing as a dominant source of equivalent dose (De) scatter
- Statistical treatments are insufficient for multigrain single-aliquot
- 'Phantom' doses are an inevitable consequence of the 'averaging' effects of multi-grain De analysis



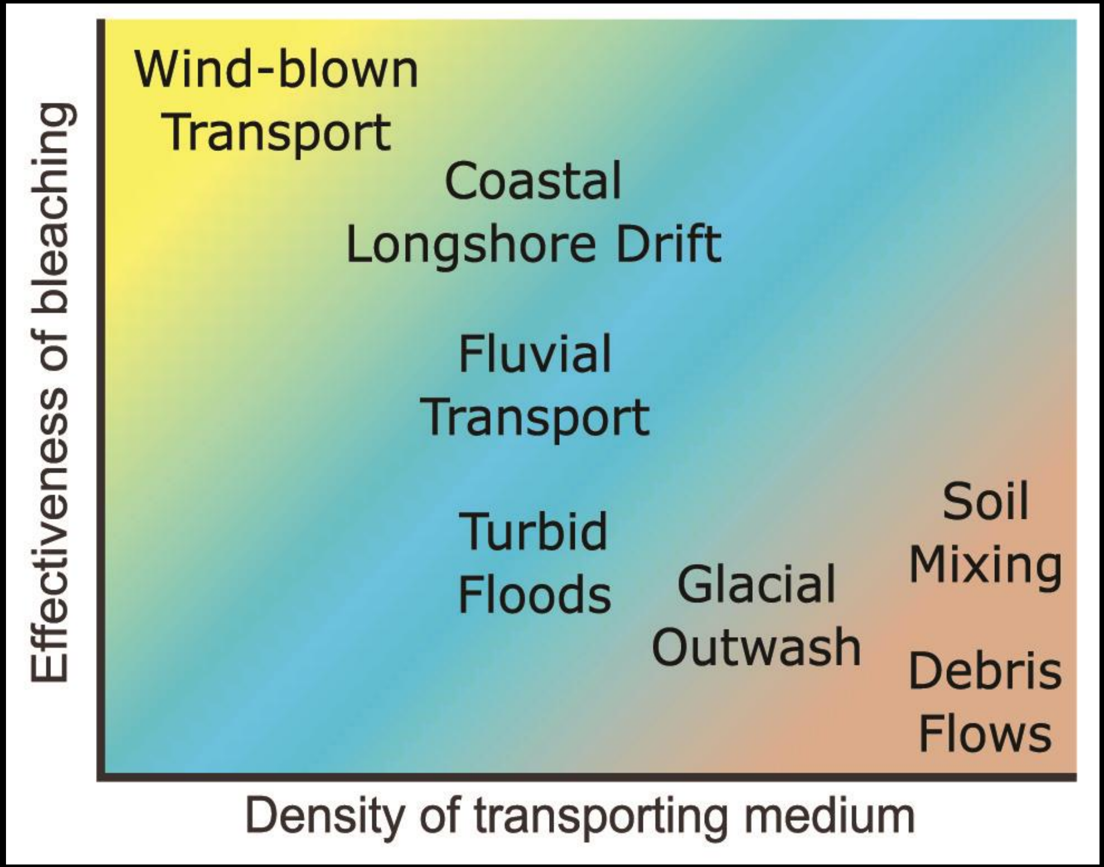
Arnold & Roberts, 2009



- Southern California quartz are dimmer
- K-feldspar are bright; suitable for dating

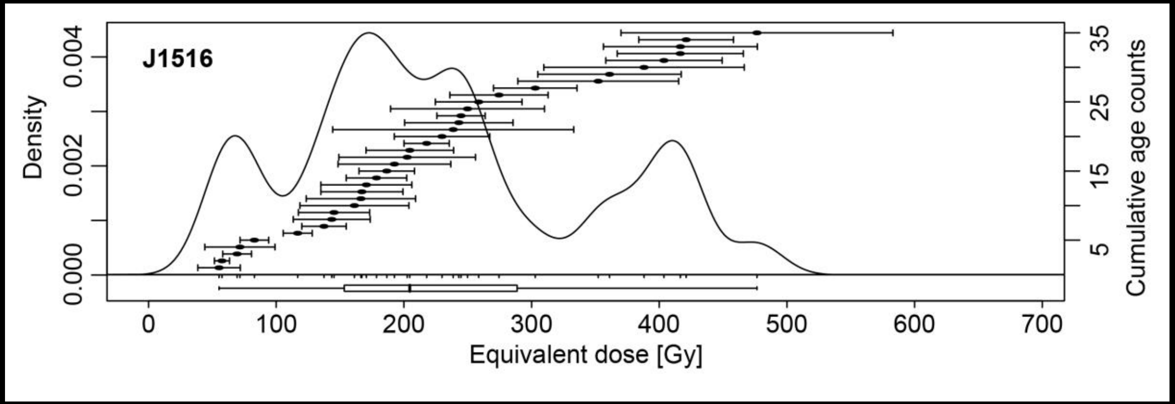
Feldspar single-grain's complicated bleaching (signal resetting) history:

Exposure duration, transport medium



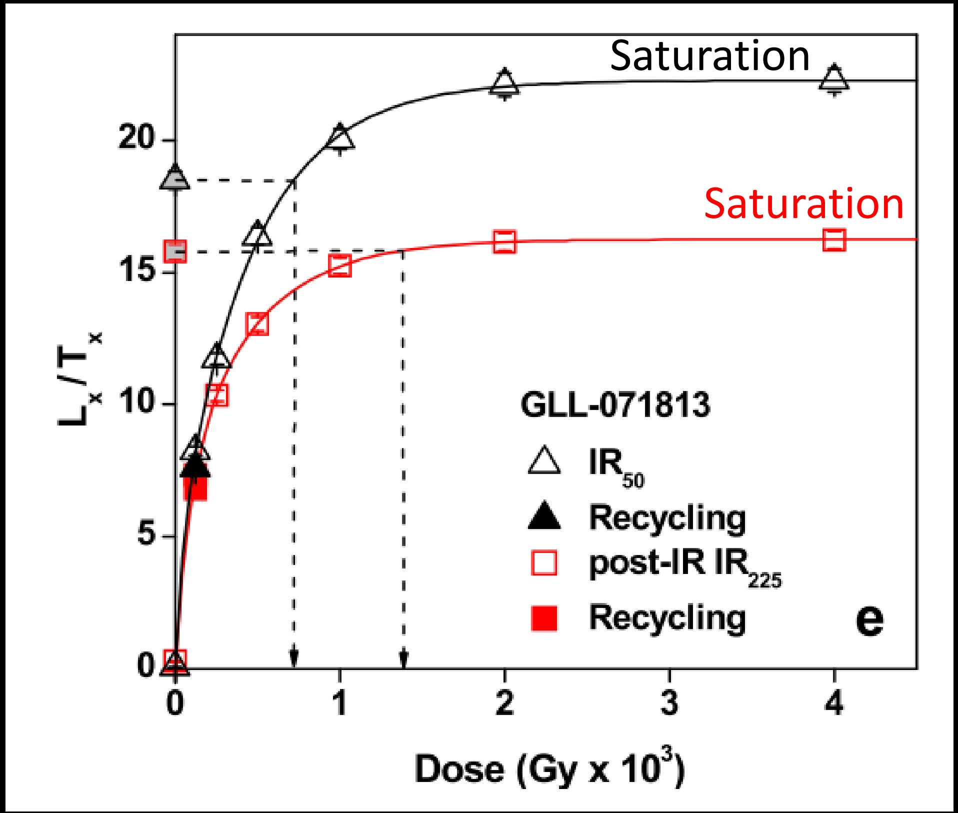
Gray et al. (2019)

- **Bleaching takes several minutes to hours (sec: Quartz)**
- **Concentrated flows dominate in the semi-arid southern California**
- **K-feldspar grain population in such transport medium often produces multiple single-grain subpopulations at a higher temperature**



Feldspar single-grain's complicated bleaching (signal resetting) history:

Bleachability of the targeted signal



Dose response curve
IR_{50} and post-IR IR_{225}

Romanian loess sample
Vasiliniuc et al. (2012)

Post-IR IRSL dating technique

- **IR_{50}: unstable, shallower traps, easy to bleach, but fade (signal loss) – less reliable**
- **IR_{225}: more stable, deeper trap, fade less to none, but often hard to bleach – reliable**

We can utilize these characteristics to date the

most recent and older depositional events

Potentials of K-feldspar SG

Introduction

- ❑ <u>**Effectiveness of SG luminescence: Lower Mission Creek**</u>

I. Prehistoric earthquakes on the Banning strand of the San Andreas fault, North Palm Springs, California

[Castillo, B., McGill1, S.F., Scharer, K.M., Yule, J.D., McPhillips, D., McNeil, J., **Saha, S.,** Brown, N.D., and Moon, S. 2021. Geosphere 17, 1–26. https://doi.org/10.1130/GES02237.1]

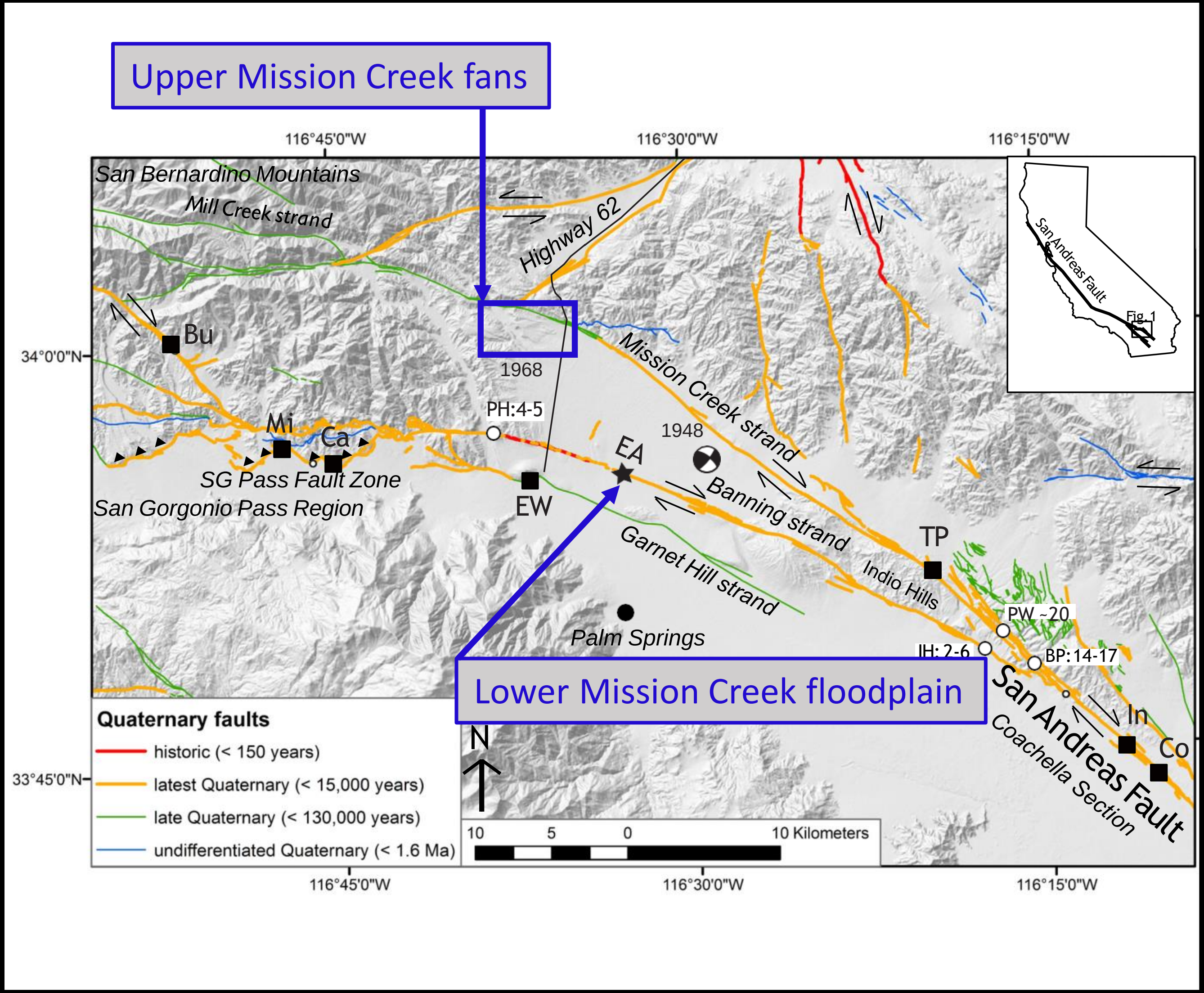
BONUS!

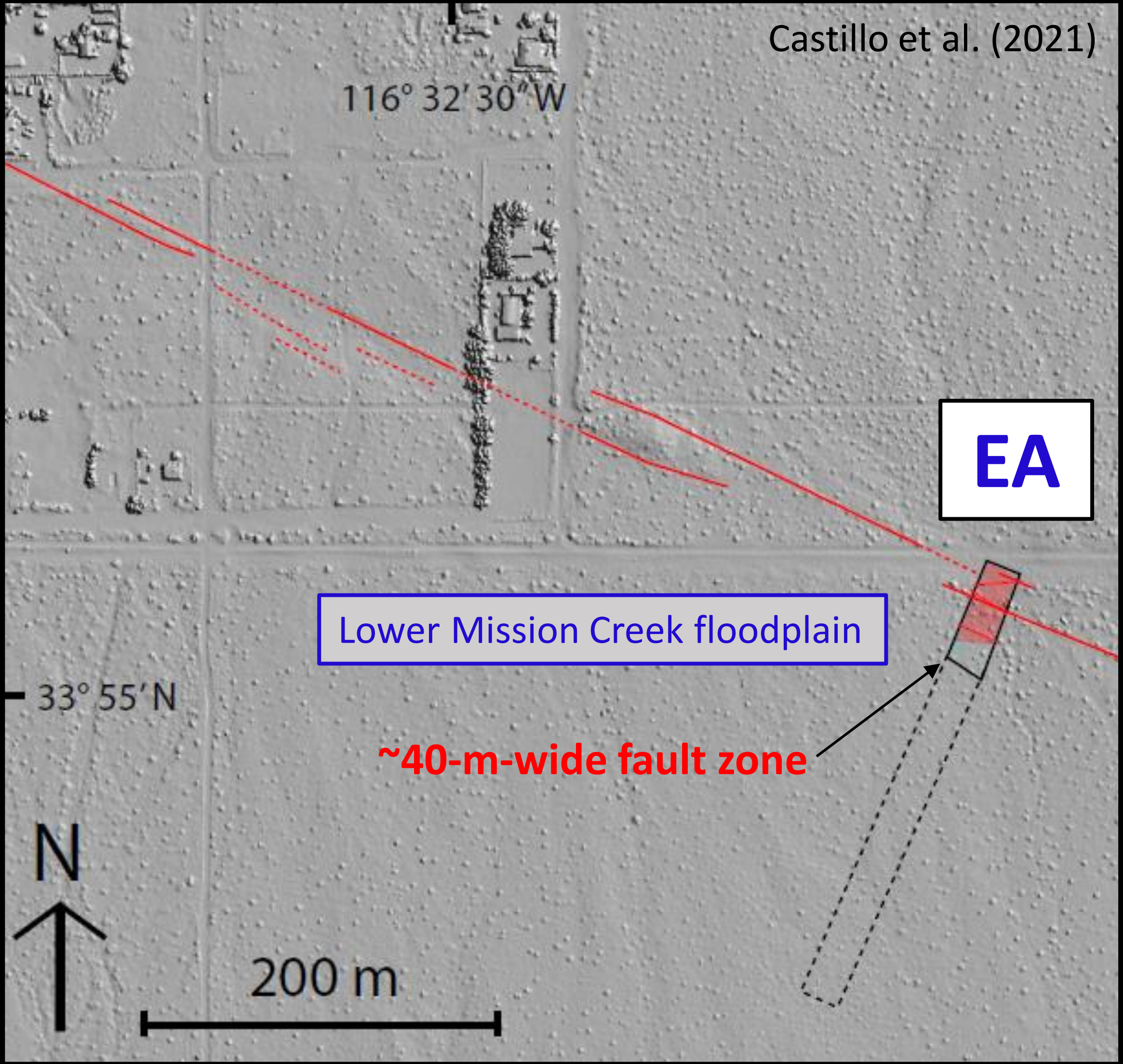
- ❑ <u>**Additional info. between events from the same sample: Lower & upper Mission Creek**</u>

II. Holocene depositional history inferred from single-grain luminescence ages in southern California, North America.

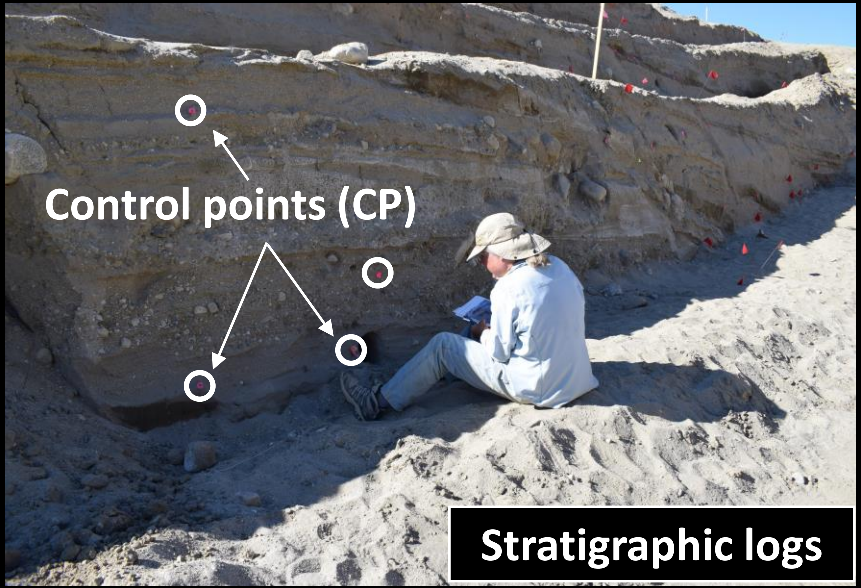
[Saha, S., Moon, S., Brown, N.D., Rhodes, Scharer, K.M., McPhillips, D., McGill, S. F., and Castillo, B. A. 2021. Geophysical Research Letter 48, e2021GL092774. https://doi.org/10.1029/2021GL092774]

Quaternary fault map of the Mission Creek: 18th Avenue paleoseismic site (EA) on the Banning strand of the SSAF





Stratigraphic logging, photomosaic, & 17 luminescence samples are collected from distinct strat units of both walls



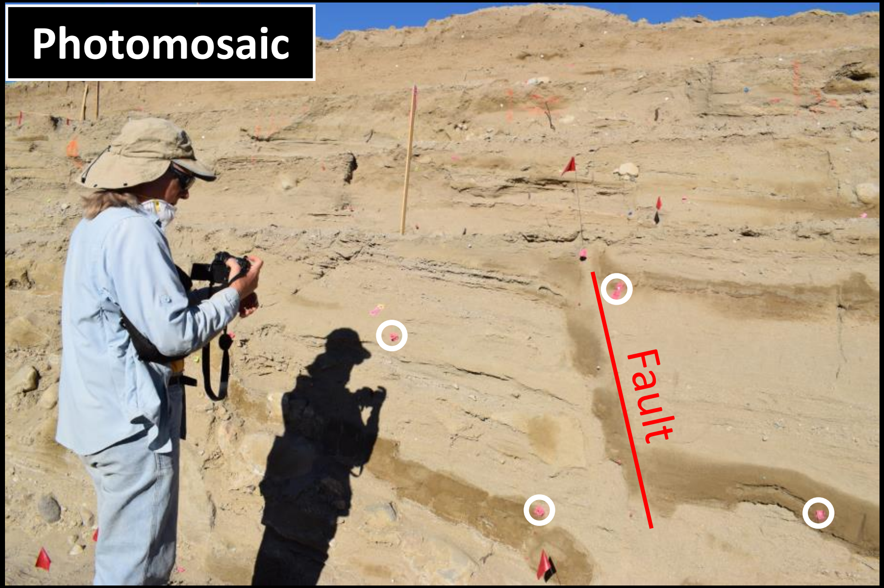
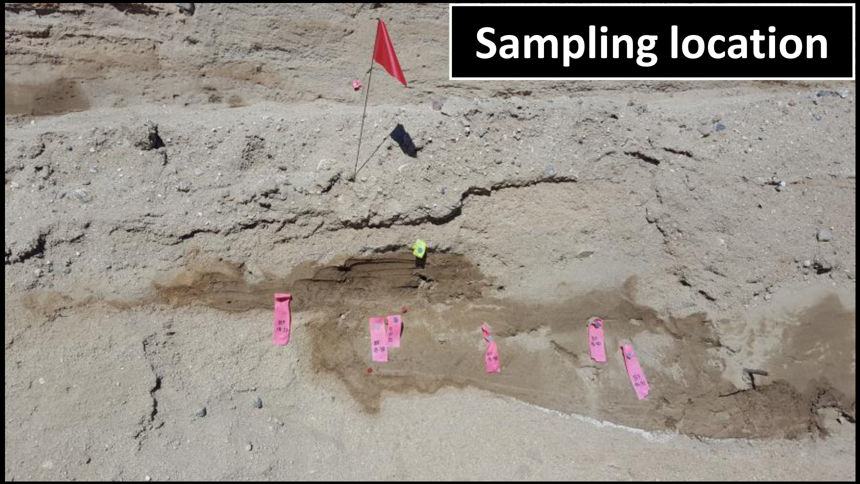
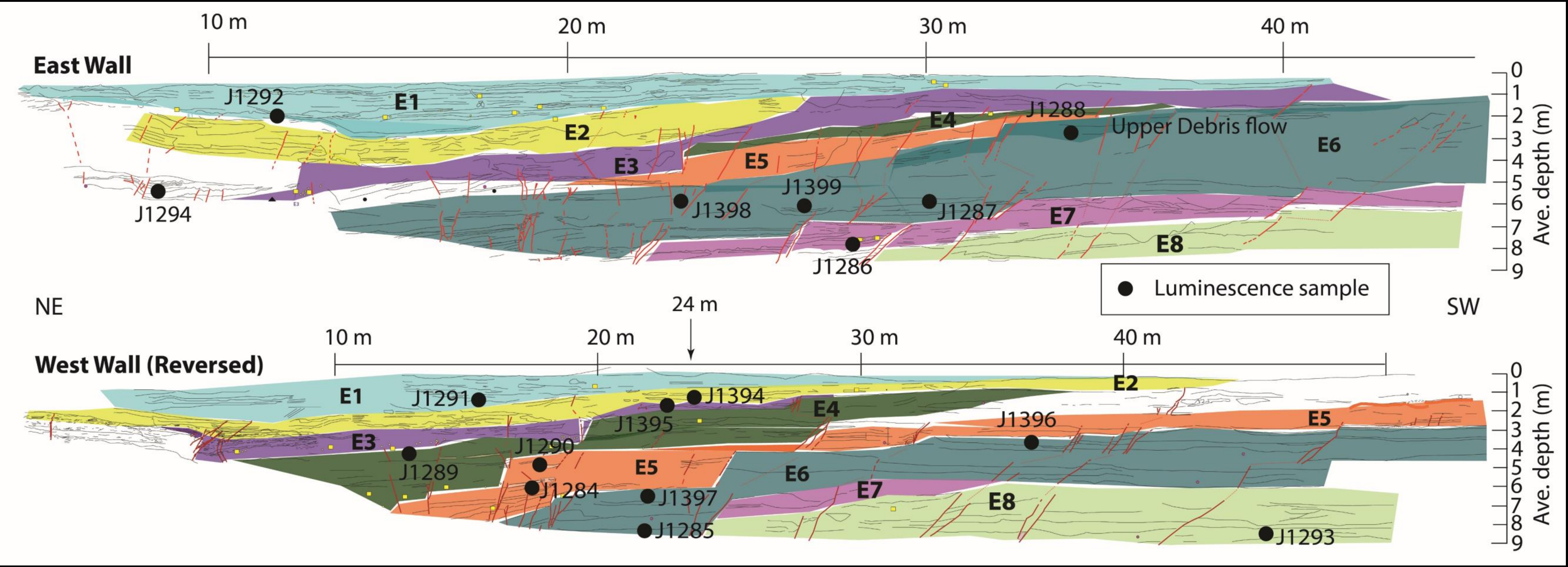


Photo credit: S. Moon & Sally McGill



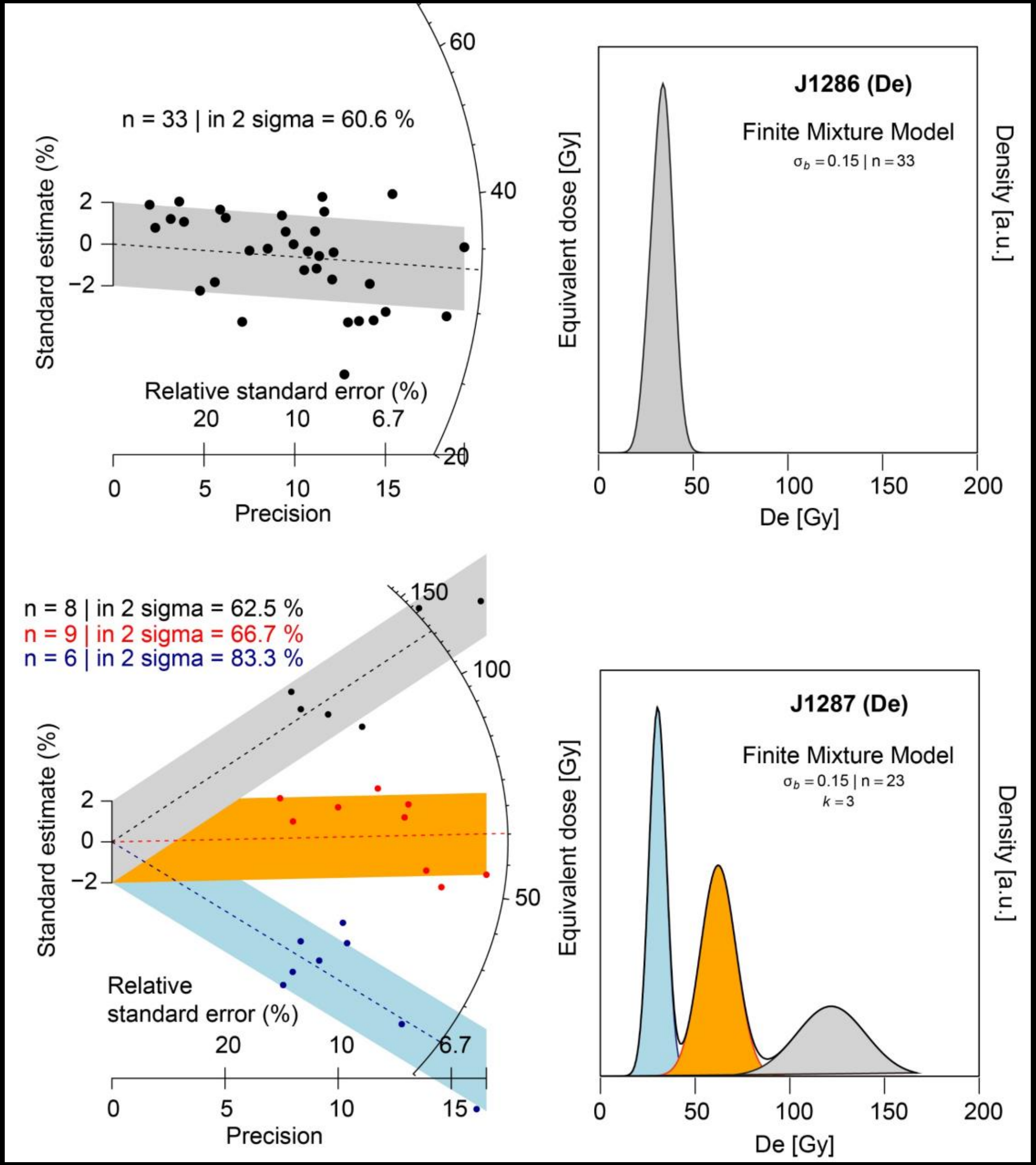
8 event horizons were dated using 17 luminescence (754 K-feldspar single-grains) & 33 radiocarbon samples (charcoals)



Castillo et al., (2021)

- **Luminescence samples at the UCLA luminescence lab**
- **^{14}C samples at the Center for Accelerator Mass Spectrometry at Lawrence Livermore National Laboratory**

CAM, MAM, FMM – Finding the suitable subpopulation(s)



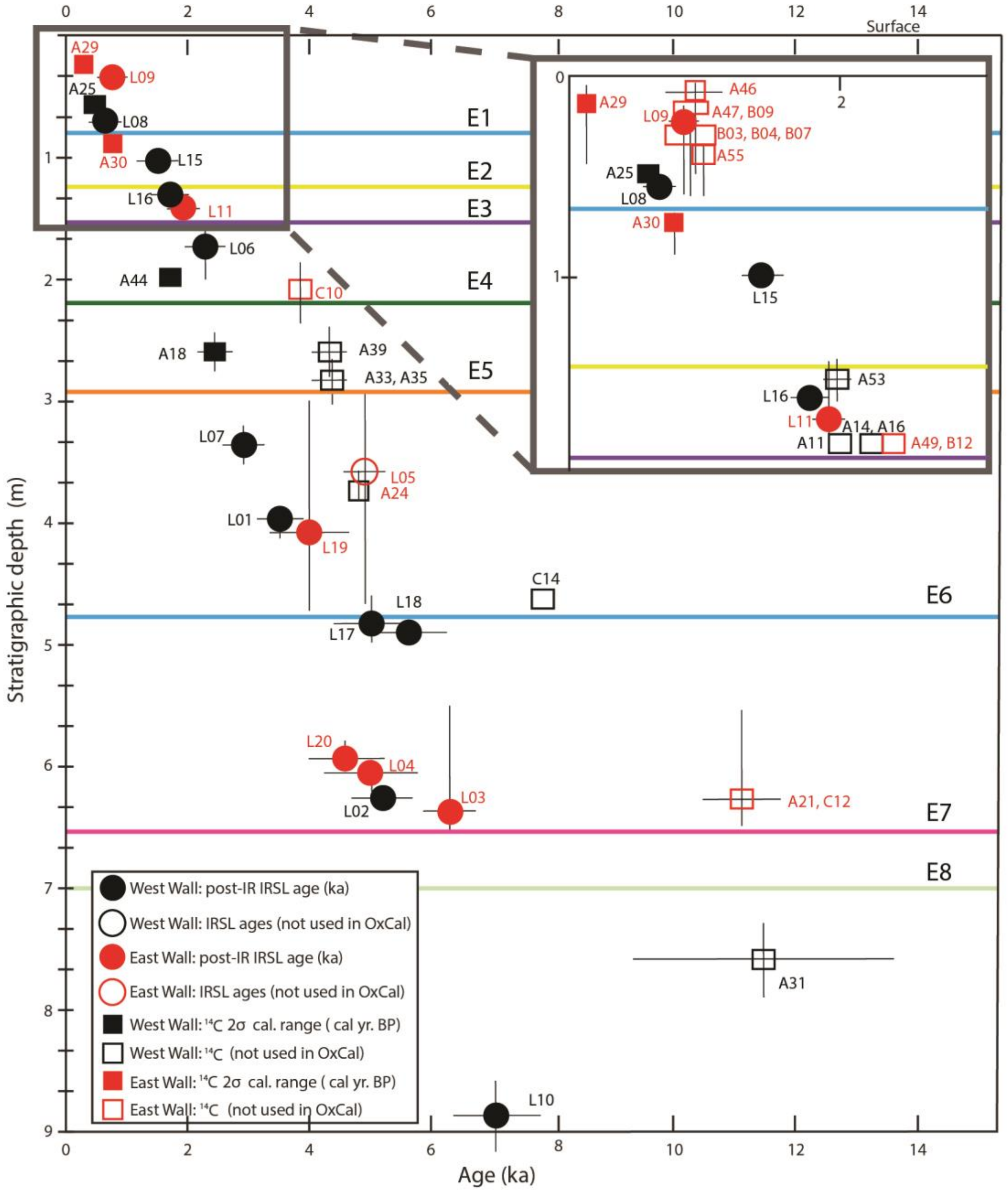
Castillo et al. (2021); Saha et al. (2021)

- **OD <15% → CAM** (Rhodes, 2015)
- **OD >15% → MAM**
  Youngest subpopulation
  (Galbraith and Green, 1990)
- **OD >15% → FMM**
  multiple subpopulations
  (Galbraith and Green, 1990; Galbraith and Laslett, 1993; Galbraith, 2005)

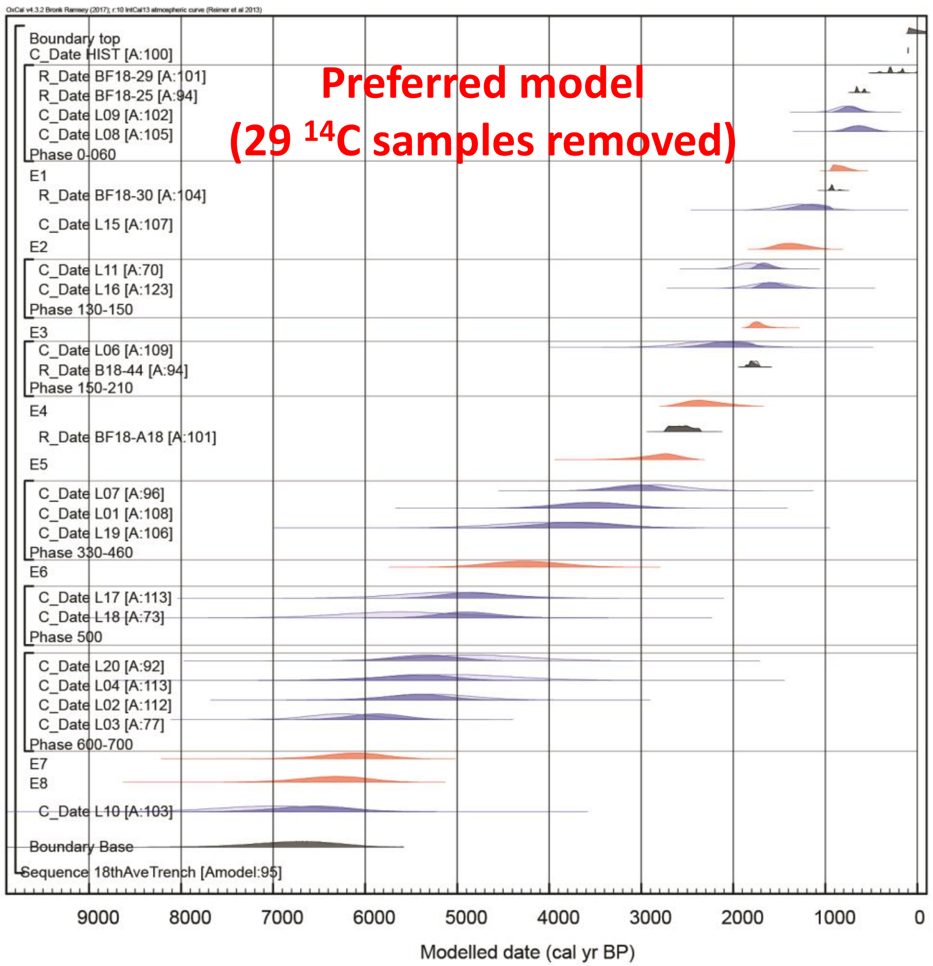
- **Most recent event = CAM or MAM**
- **Older depositional history = FMM**

i.e., distinguish **two or more component mixture** (k age components)

Paleoseismic dating results: Average RI of 380–640 yr (1–5 EQ)



OxCal Model used to estimate EQ ages



- SG luminescence
- ^{14}C
- EQ event horizon

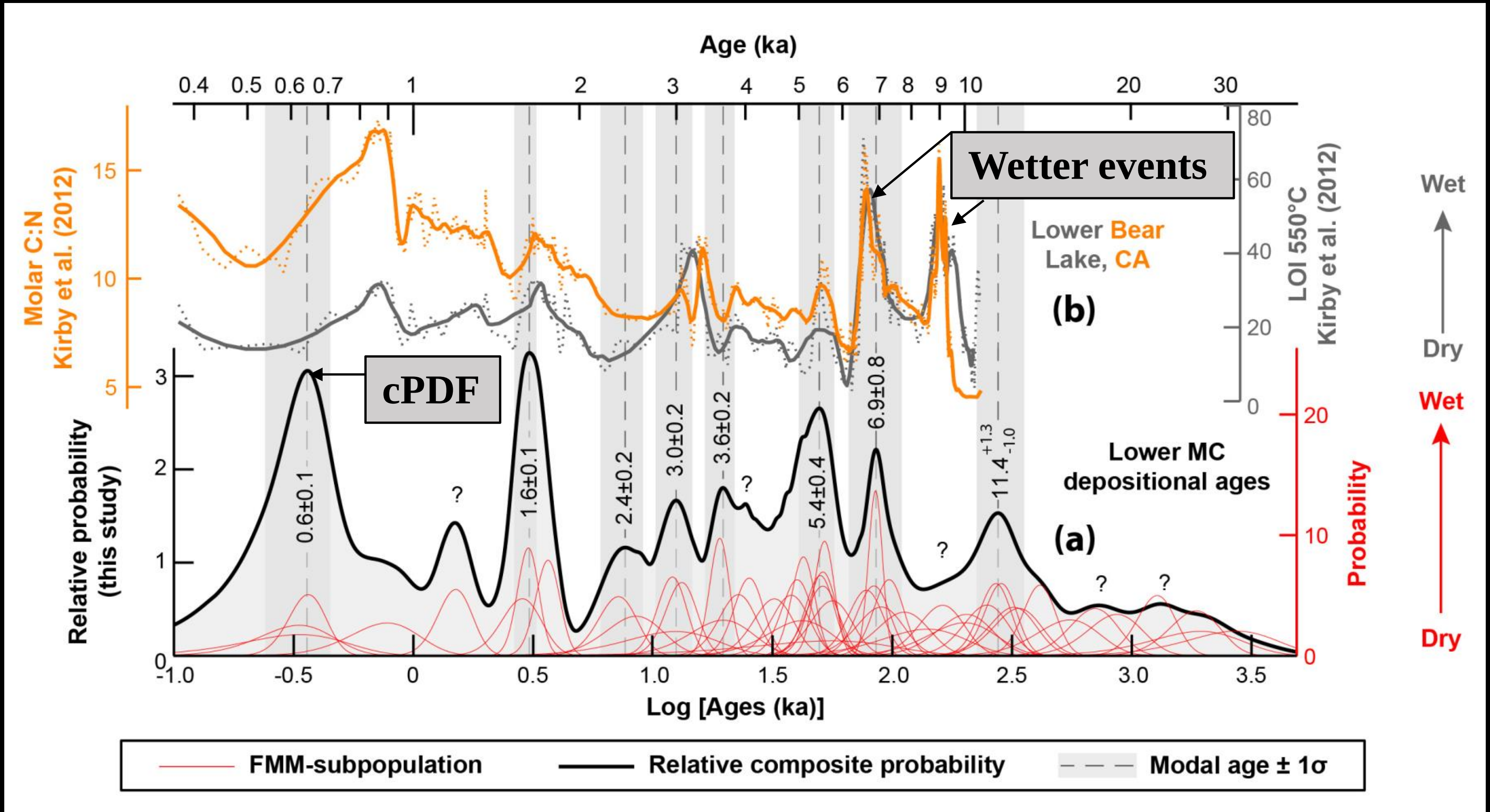
Castillo et al. (2021)
Bronk Ramsey, 2009)

- MAM/CAM ages corresponds well with younger detrital ^{14}C charcoal ages at ±1 σ (<3 ka deposits)
- Most recent events are dated successfully
- ~5 surface-rupturing earthquakes since ~3 ka and
- Or ~8 earthquakes since ~7.1 ka

What more information can we extract from the site?

Understanding the depositional history between the EQ events

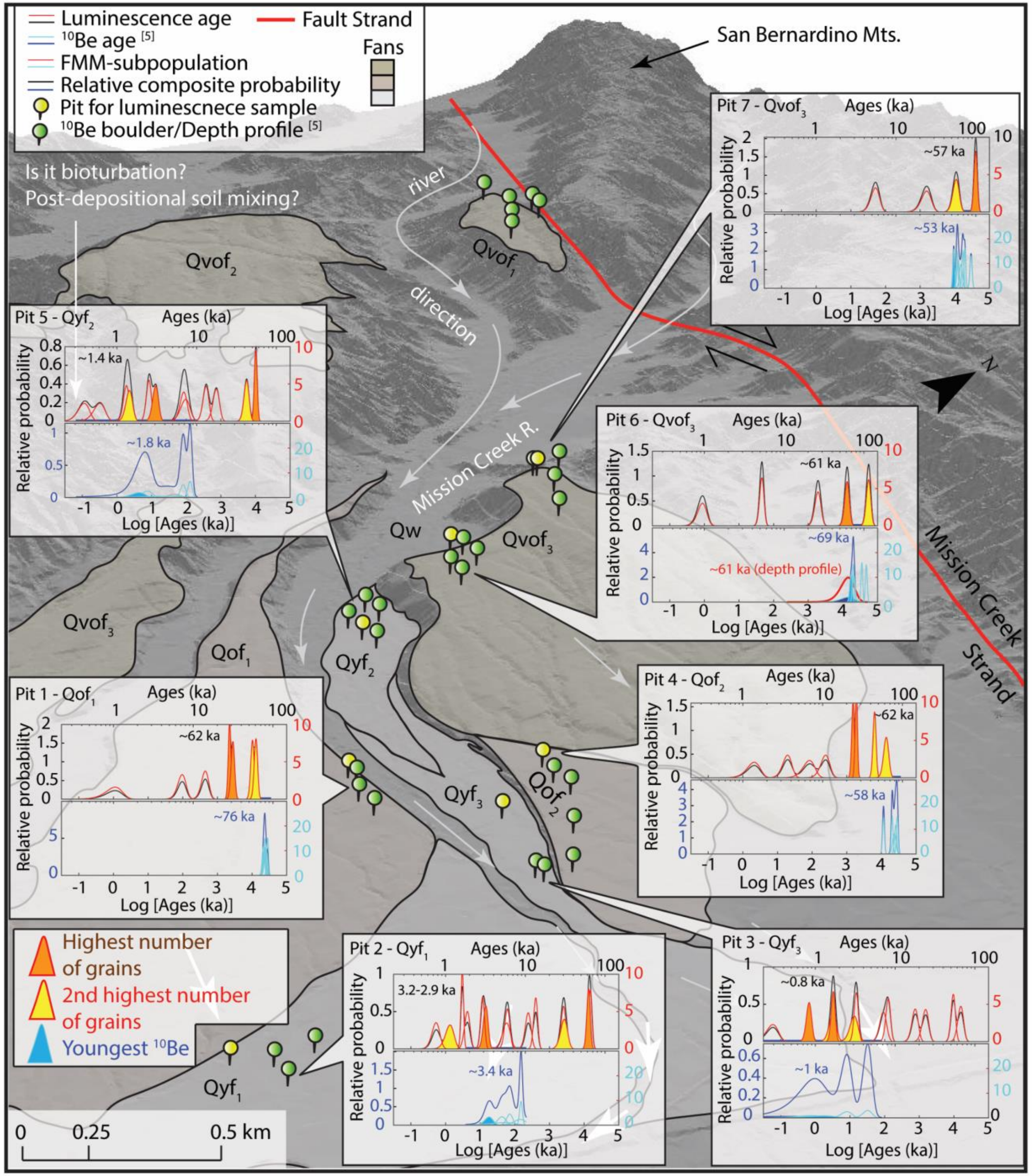
- ❖ **Using 51 single-grain FMM subpopulations from all 17 samples**
- ❖ **8 age clusters likely indicate significant depositional periods in the past ~12 ka**
- ❖ **Show good correspondence with the wetter than average Holocene climate intervals**

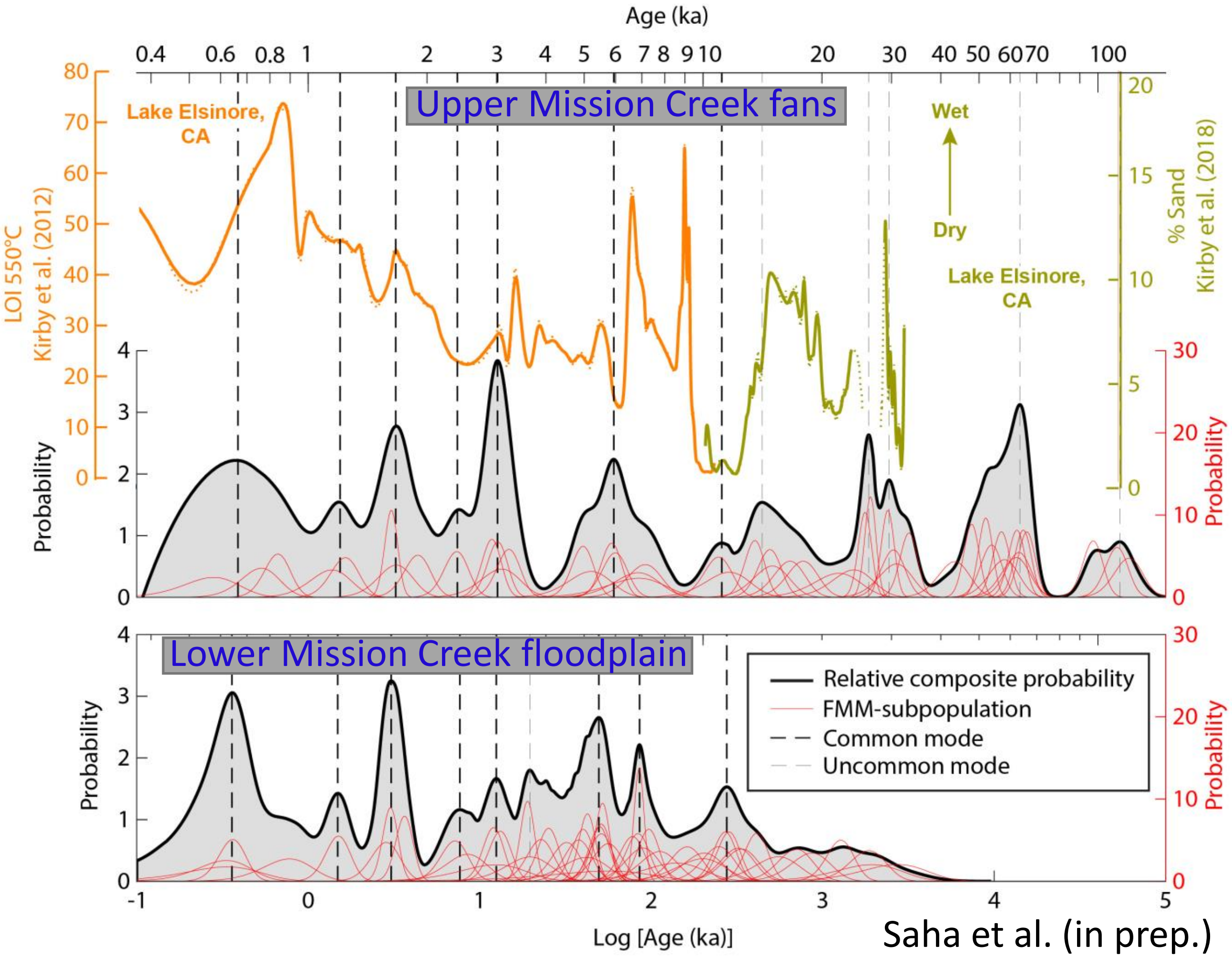


e.g., Akciz & Arrowsmith, 2013

Saha et al. (2021)

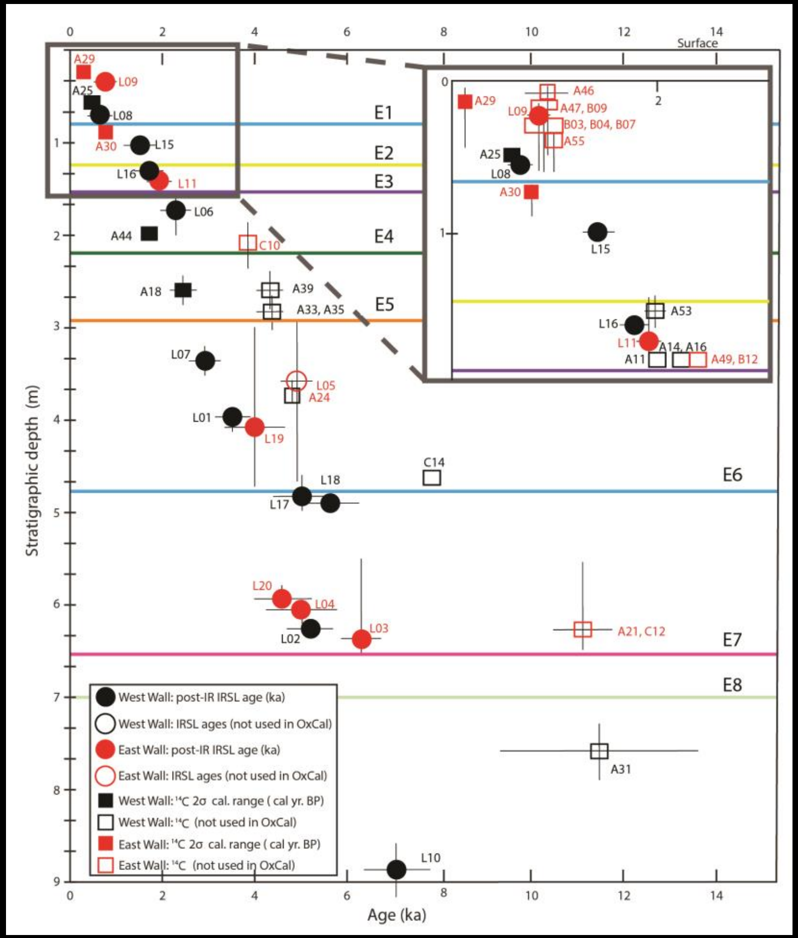
At least six major corresponding depositional periods may be identified in both the upstream & downstream deposits in the past 12 ka at MC





Saha et al. (in prep.)

Take-home message



I. **K-feldspar SG luminescence compliment ^{14}C dating** where reworking of charcoals are problematic, or suitable organic matters are absent

II. It has the potentiality to **date both the most recent** and **older depositional history**

III. That means, we can extract additional details about **climate-controlled sediment flux and depositional history**—the information in between EQ events

IV. **Wetter than average Holocene climate** has the 1^{st} order control on sediment deposition in southern California

V. This has important implications for tectonic or paleoclimatic studies that rely on **stratigraphic completeness**, especially in terrestrial settings (e.g., Washburn et al., 2003; Le Béon et al., 2018)

Poster #088, San Andreas Fault System (SAFS)

Marina Argueta, S. Saha, S. Moon, N.D. Brown, T.K. Rockwell, K.M. Scharer, Z. Morgan, & J. Leidelmeijer.

Constraining long-term sediment depositional history at ancient Lake Cahuilla, Coachella, California

Future work

- **Finding better ways to develop more collaborations with Paleoseismologists, Paleoclimatologists, and other Geochronologists to extract additional information between earthquake events utilizing SG techniques**