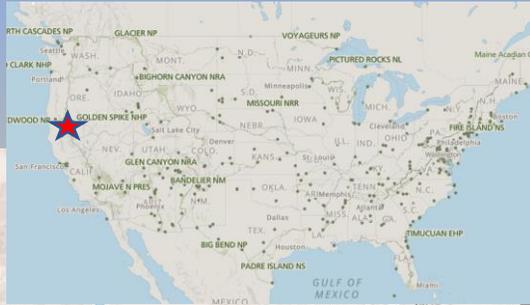


Geochronologic data reveal late Pleistocene to  
Holocene debris-flow history and wildfire  
association within Whiskeytown National  
Recreation Area, Klamath Mountains, northern  
California

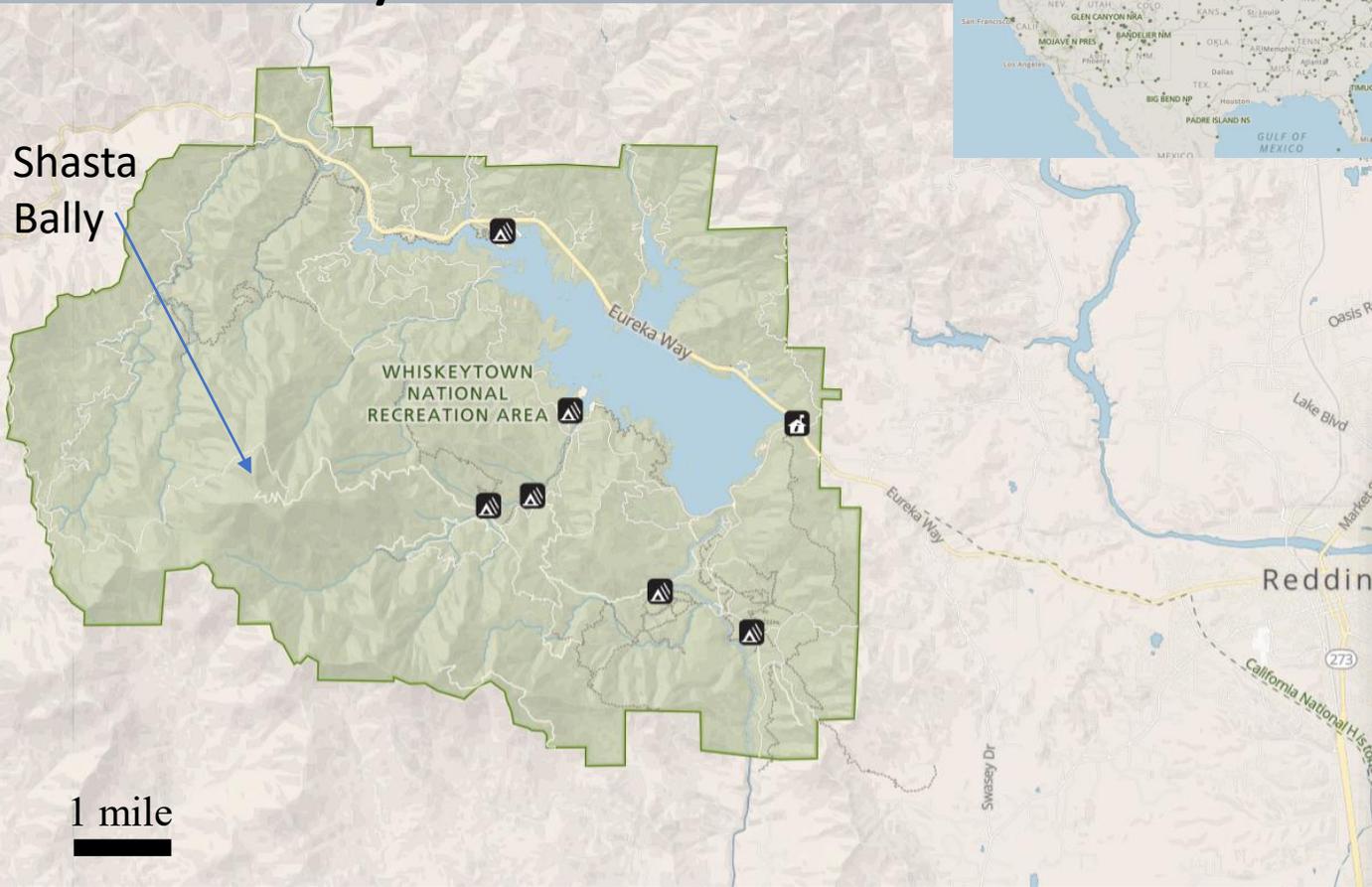
Shannon Mahan, Jack Wood, Eric L. Bilderback, Amy E. East, Brian A.  
Rasmussen, Emma T. Krolczyk, Karina S. Zyatitsky



# Whiskeytown NRA



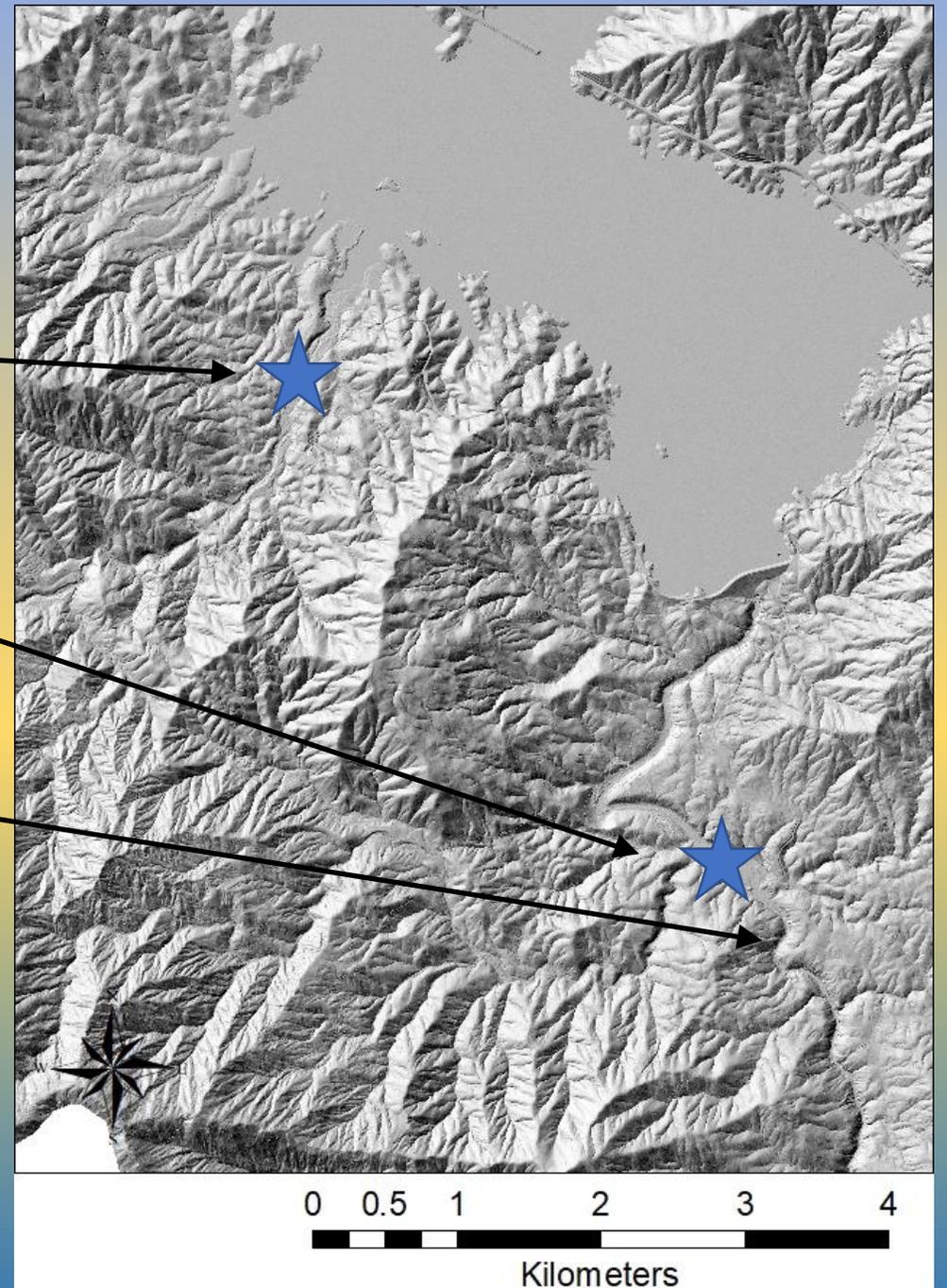
- Within the Trinity Range of northern California
- Steep slopes prone to mass wasting processes



- Geology dominated by igneous and metamorphic lithologies
  - Shasta Bally granodiorite and the chlorite and epidote rich Copley Greenstone

# Two areas of focus

- Brandy Creek watershed
- The National Environmental and Educational Development (NEED) camp and Paige-Boulder Creek watershed
  - Start of deep bedrock canyon
- Elevation in the area
  - 1889 asl (Shasta Bally)
  - 260 m along Clear Creek



# Debris flows

- Debris flows are **fast-moving landslides** that are particularly dangerous to life and property because they move quickly, destroy objects in their paths, and often strike without warning.
- They occur in a wide variety of environments throughout the world, including **all 50 states and U.S. Territories**.
- Debris flows generally occur during periods of **intense rainfall or rapid snowmelt** and usually start on hillsides or mountains.
- Debris flows can travel at **speeds up to and exceeding 35 mph** and can carry large items such as boulders, trees, and cars.
- If a debris flow enters a steep stream channel, **they can travel for several miles**, impacting areas unaware of the hazard.
- **Areas recently burned by a forest fire are especially susceptible to debris flows**, including the areas downslope and outside of the burned area.
- Debris flows **are a type of landslide** and are sometimes referred to as mudslides, mudflows, lahars, or debris avalanche.
- Precipitation intensity a key aspect per Binod et al., 2020
- [What is a debris flow? | U.S. Geological Survey](#)



Image source: <https://www.climatesignals.org/headlines/california-threats-jump-fires-floods-wet-season-hits>

# Debris flows at WHISKEYTOWN NRA

- The 2018 Carr fire
  - No large post fire debris flows
  - Ample rain, 50 cm in 9 days
- What is the history of events within the area?
  - Evidence of past large events along Brandy Creek
- ...and what's the story for the anomalously large terrace like feature at the environmental School?
  - Site of a debris flow in 1997

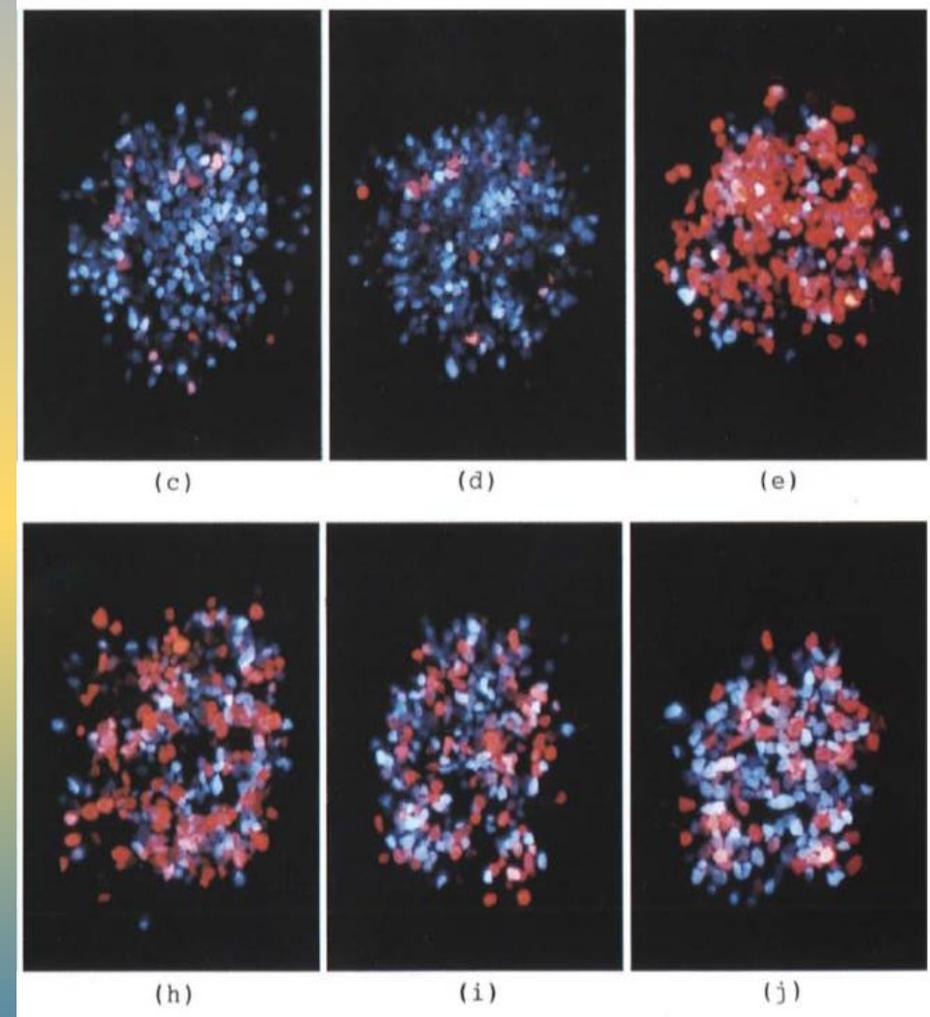


NPS image, authors

# What is luminescence/OSL dating?

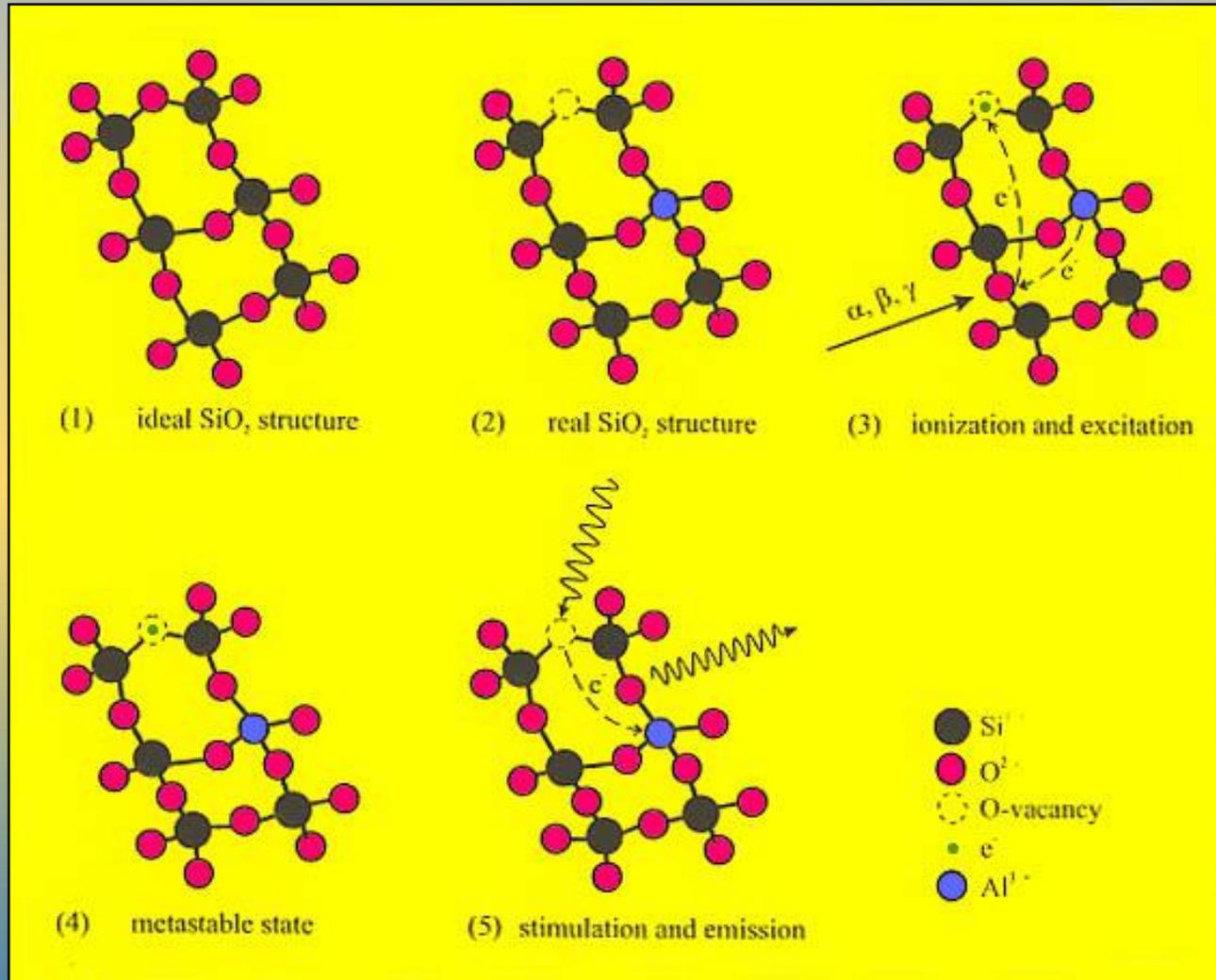
## Explanation #1

- All sediments and soils contain trace amounts of radioactive isotopes of elements K, U, Th, and Rb
- These slowly decay over time and the ionizing radiation produced is absorbed by quartz and K-feldspar
- The radiation causes charge to remain within the grains in structurally unstable electron traps
- The trapped charge accumulates over time at a rate determined by the amount of background radiation at the location of the buried sample
- Minerals used for dating are quartz and potassium feldspars (i.e. orthoclase, microcline)



# What is luminescence/OSL dating?

## Explanation #2



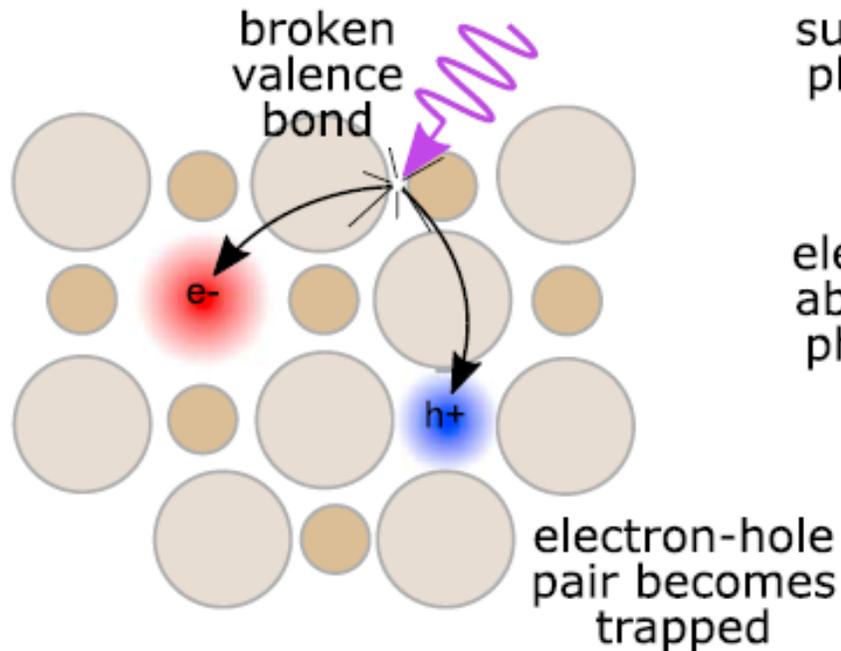
AGE =  
total energy accumulated  
during burial age / energy  
delivered each year from  
radioactive decay

- Minerals contain impurities and defects that “trap”
- Electron traps have a “thermal Lifetime”
- Naturally occurring minerals such as quartz and feldspars act as dosimeters, recording the amount of radiation to which they have been exposed.
- Determination of Equivalent Dose (i. e. the amount of luminescence already stored in a mineral)

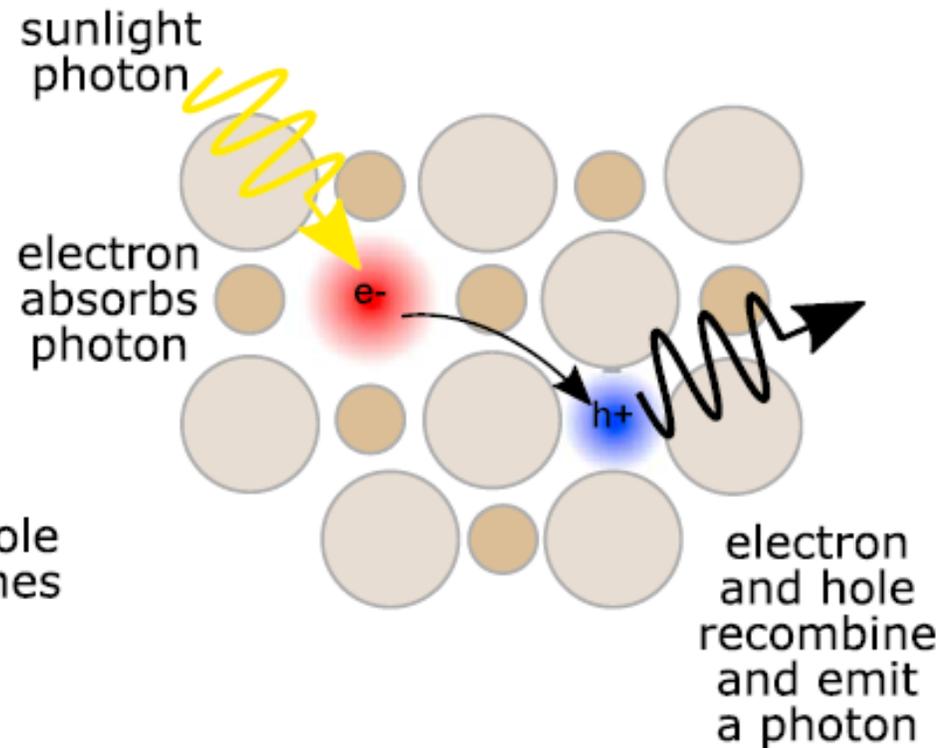
# What is luminescence/OSL dating?

## Explanation #3

B) Ionizing Irradiation

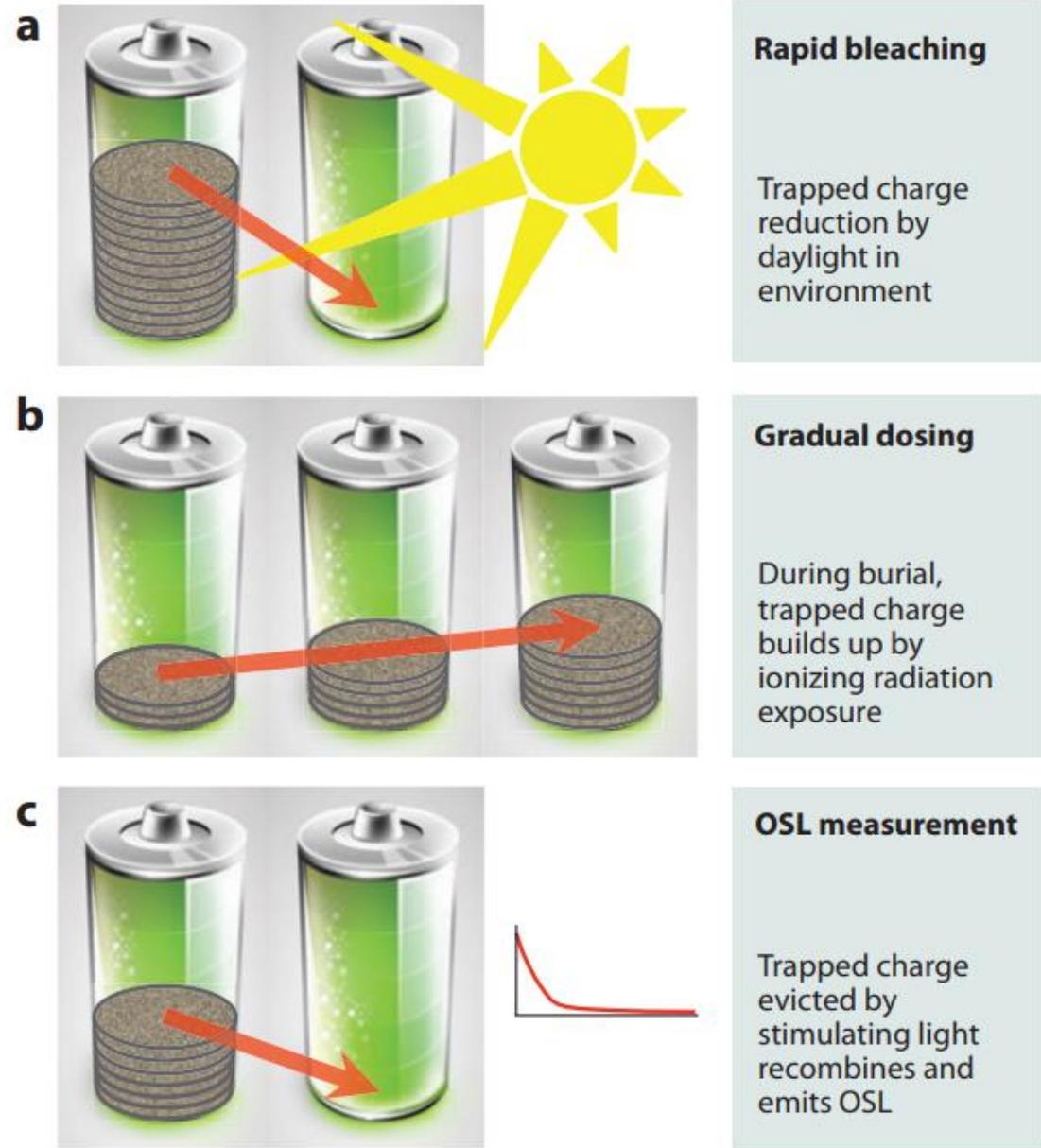


C) Sunlight Exposure



# A useful dating tool

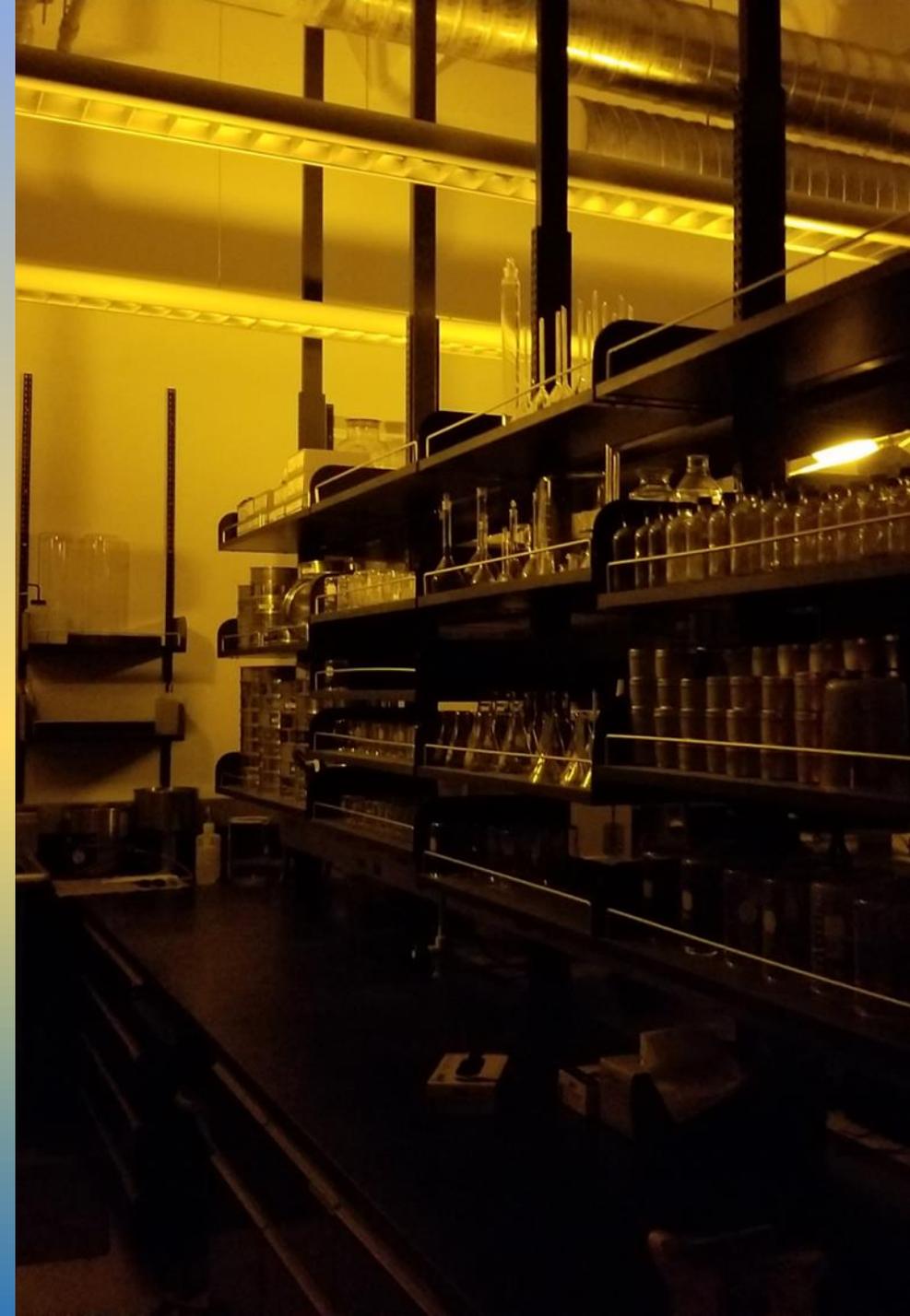
- Functionally, luminescence increases when a sand grain is buried, and decreases when exposed to sunlight
- For geological applications, the luminescence of quartz/feldspar sand (90-250  $\mu\text{m}$ ) can record the depositional time of the sediment
- Often used in conjunction with radiocarbon, cosmogenic dating, U-series dating, and historical records (or  $^{210}\text{Pb}/^{137}\text{Cs}$ )
- Time range is historic to  $\sim 350,000$  years



# The Luminescence Age Equation

- *Age* = time since last sunlight exposure (units=calendar yr) no before present
  - $D_E$  = 'equivalent dose'
  - How much luminescence is already in a sand grain (i.e. natural) (units=J/kg or Gray)
    - $D_R$  = 'dose rate'
  - How fast the luminescence grows when the grain is buried (units=J/kg/yr)

$$Age = D_E / D_R$$





## Charcoal Counting

To assess whether the prehistoric sediment source areas had included burned material

We counted the abundance of charcoal fragments in sediment samples from the matrix material of debris flows

Flakes are called pyrogenic carbon



## Luminescence on quartz grains

Deposits are a mixture of very large boulders (1.5 m by 1.5 m) and cobble to coarse sand

Luminescence used the 212-180 micron size and charcoal counting >212

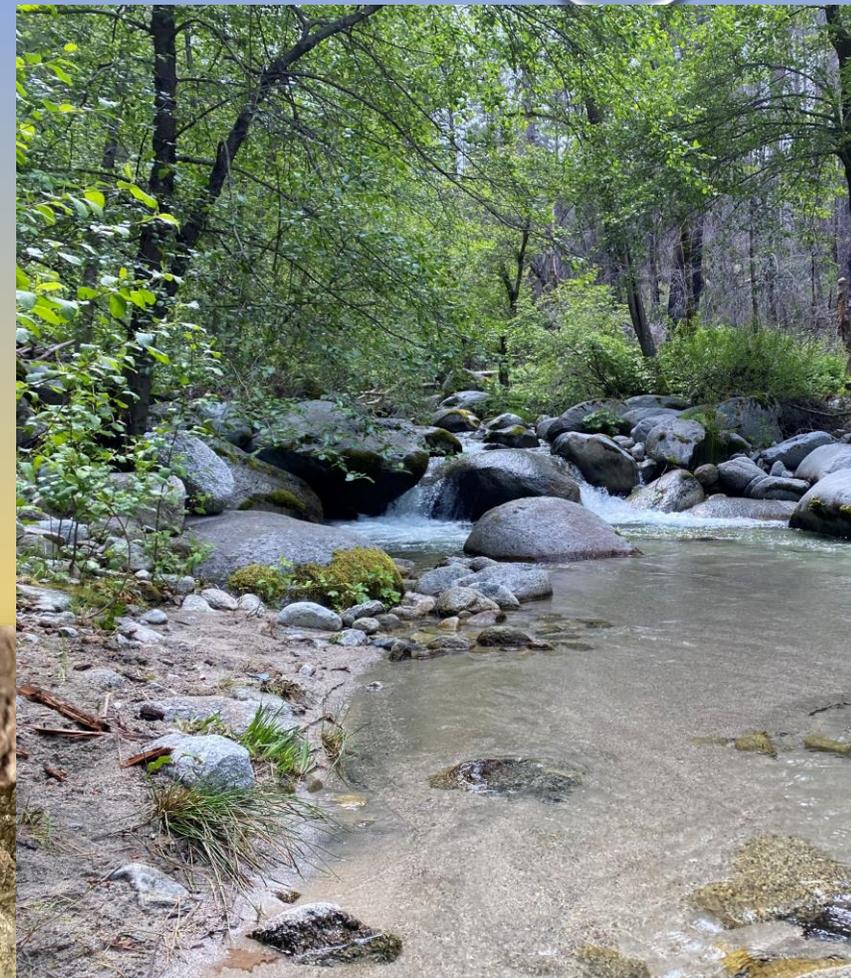
Both quartz and feldspar measured

Quartz and Feldspar had very bright signals due to Long Transport Path or Wildfire Heating



1<sup>st</sup> investigate  
older flows

13,400 ± 800 years  
quartz OSL



Older Debris flow  
at the top of  
Brandy/Boulder  
Creek Watershed



USGS-3379  
2,030 ± 150 yr  
Not modern

# 2<sup>nd</sup> investigate Boulders along Brandy Creek

- Brandy 3
  - One of 5 boulders
  - USGS 3382 -  $600 \pm 50$  yr

- Investigation OSL

- Quartz  $600 \pm 50$
- Radiocarbon ages
  - Brandy 4  $\sim 355$  yr bp (OSL  $710 \pm 80$  yr)
  - Brandy 5  $\sim 865$  yr bp (OSL  $880 \pm 70$  yr)



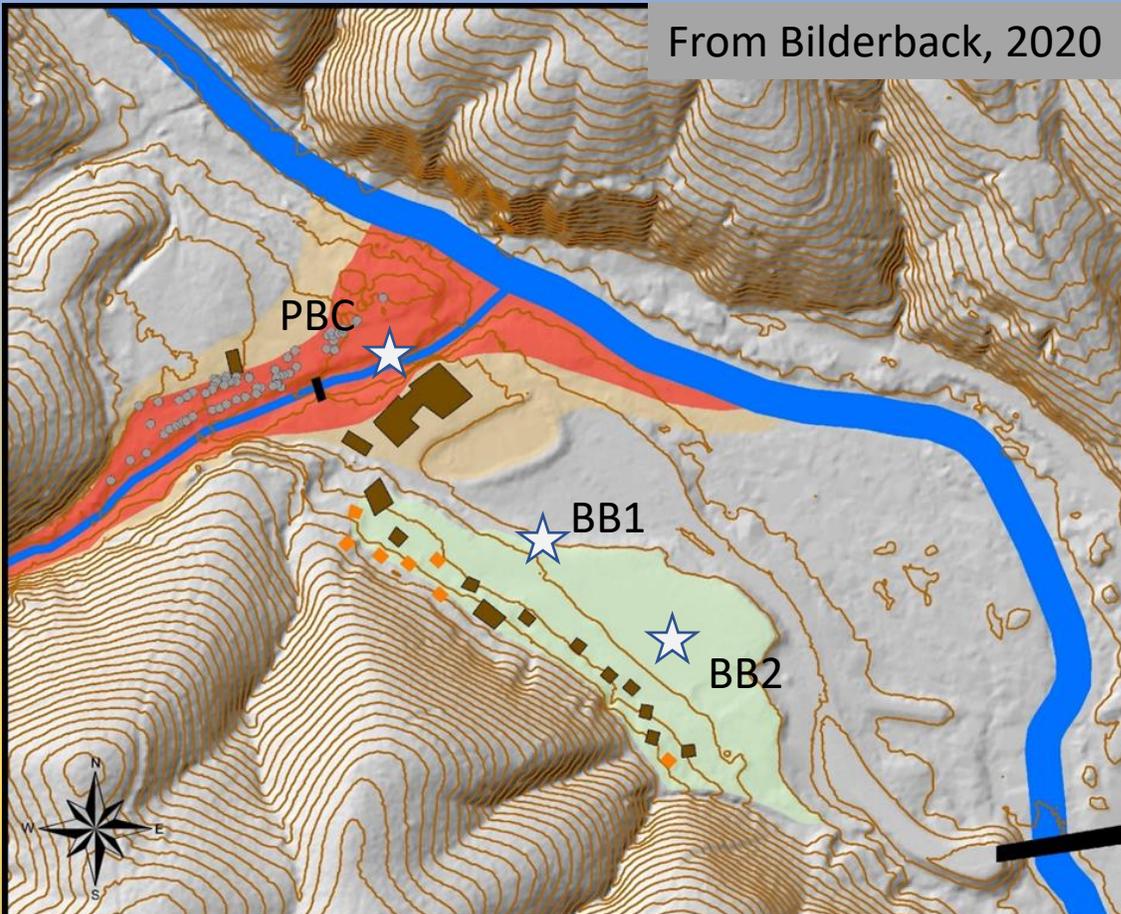
# What have we got?

## - Debris flows large enough to move boulders

- 355-410 yr (1610-1670 AD)
- 600 yr (1420 AD)
- 740-710 (1280-1310 AD)
- and 880-865 (1140-1160 AD) years ago
- (roughly a 125-150 year cycle)
- Notably, all of the sub-boulder sediment ages are extremely young (less than 1,000 years), nothing even approaching the older debris flow age at Sheep Camp of 13,380 years.



From Bilderback, 2020



2 meter  
contour interval

0 25 50 100 150 200

Meters

### Legend

- |   |  |
|---|--|
|  Bridges                             |  Granite boulders deposited by debris flows                 |
|  Structures                          |  Older terrace associated with Clear Creek or other process |
|  Burnt Structures                    |  2 m contour  |
|  Destructive debris flow hazard zone |  Clear Creek  |
|  High discharge flood hazard zone    |  Paige Boulder Creek  |

## 3<sup>rd</sup> investigate terraces near debris flows

- NEED School site along Clear Creek
  - Paige-Boulder Creek Bluebird 1 and 2



## NEED SCHOOL TERRACE

- Historic destructive events
  - 1997 Whiskeytown NRA
  - Likely initiated from poorly abandoned logging roads
  - Another less known event in 1954



NPS Image

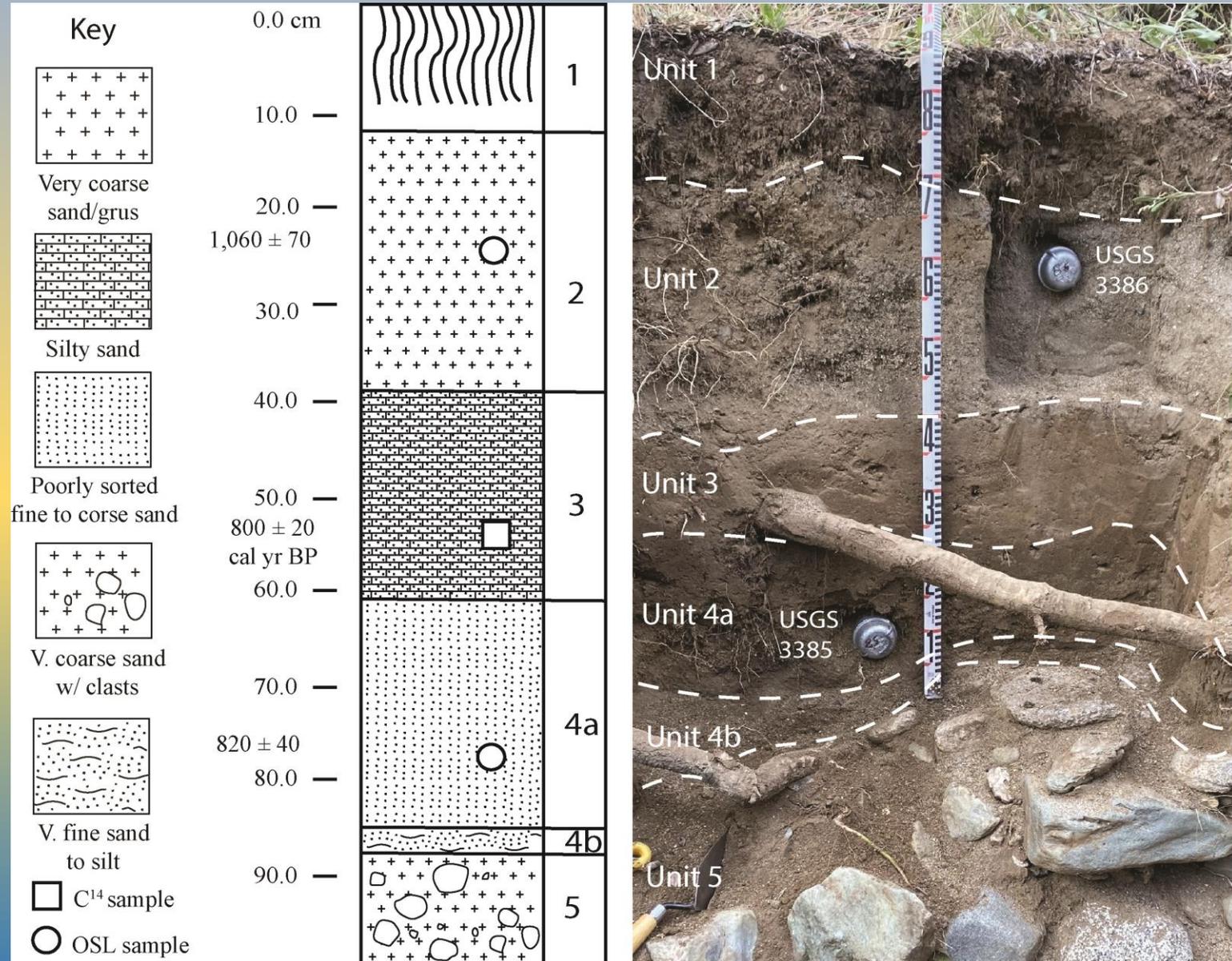
# Deposits at NEED Camp



- 1997 debris flow emplaced sediment and boulders
- Ample woody debris

# Terrace investigation

- Section location near area with boulder levee
- Main question though is what has the school been built on?
- Two ways to investigate
  - Stream cut in the terrace
  - Excavations into tread and edge



# Terrace investigation

100 cm depth

- Bluebird 1

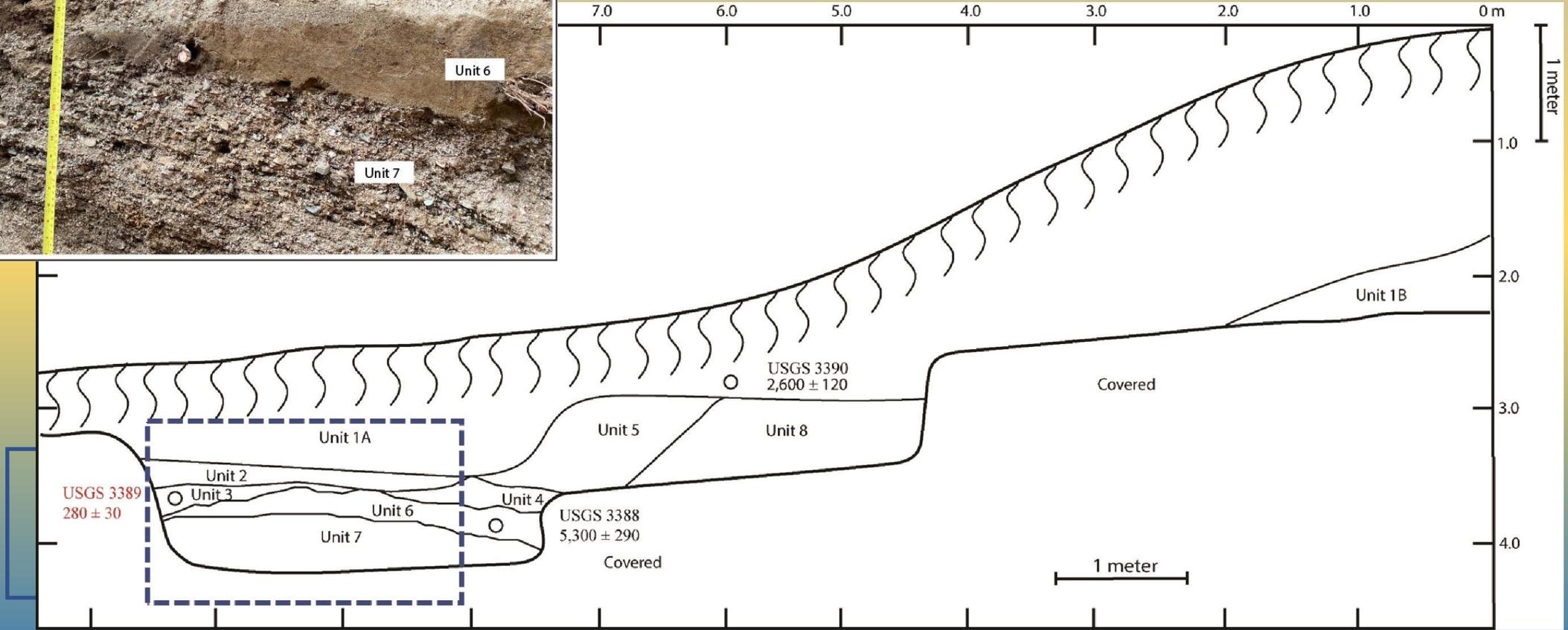


# Terrace investigation

- Bluebird 2



# Trench: Bluebird 2



SAMPLES FROM WHISKEYTOWN NATIONAL REC.

AREA:

Amy East, Landscape Response to Disturbance, Task 3: Post-fire sediment mobilization

Volume of each vial is 1/4 tsp

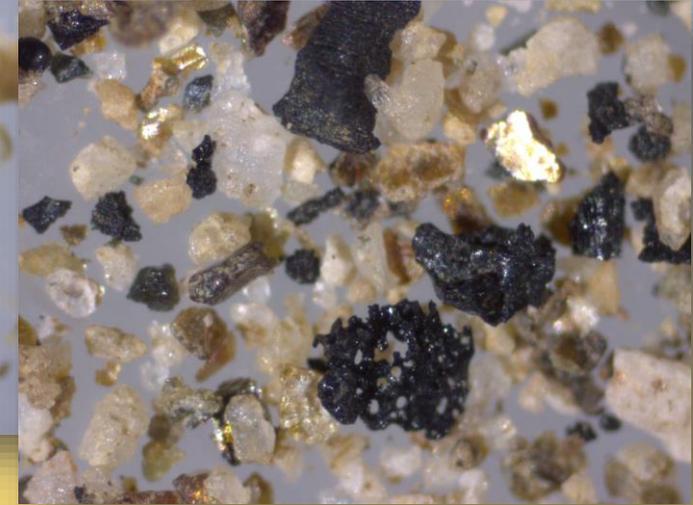
Date	Name on sample vial	Latitude	Longitude	(Bleached)	Charcoal	Charcoal count	Notes
				Lab analysis date	Count Date		
5/10/2022	Sheep Camp	40.598799	-122.594217	6/26/2022	7/16/2022	2	Old, moldy debris flow. OSL USGS 3378
5/11/2022	Brandy 1	40.61078	-122.57647	6/26/2022	7/16/2022	22	Under 1st boulder. OSL USGS 3380
5/11/2022	Brandy 2	40.61078	-122.57647	6/26/2022	7/16/2022	31	5 m away from Brandy 1. OSL USGS 3381
5/11/2022	Brandy 3	40.61078	-122.57647	6/26/2022	7/16/2022	33	OSL USGS 3382
5/11/2022	Brandy 4	40.61613	-122.57336	6/26/2022	7/16/2022	101	OSL USGS 3383
5/11/2022	Brandy 5	40.61613	-122.57336	6/26/2022	7/17/2022	65	Near Brandy 4. OSL USGS 3384
5/11/2022	Paige Boulder 1	40.58188	-122.54237	6/26/2022	7/17/2022	33	Sampled 70 cm below surface; OSL USGS 3385, 3386
5/12/2022	Bluebird 1 100 cm	40.58086	-122.54121	6/26/2022	7/17/2022	36	100 cm below surface
5/12/2022	Bluebird 1 125 cm	40.58086	-122.54121	6/26/2022	7/17/2022	2	125 cm below surface
5/12/2022	Bluebird 1 175 cm	40.58086	-122.54121	6/26/2022	7/17/2022	0	175 cm below surface

## Radiocarbon analysis

Receipt #	Date Reported	Submitter Identification	Type	Process	Accession #	F Modern	Fm Err	Uncalibrated Age (yrs)	Age Err	$\delta^{13}C$ Source	$\Delta^{14}C$	Calibrated Age (calendar yrs)	Age Err	Probability
180290	10/3/2022	Bluebird #1a	Charcoal	(OC) Organic Carbon	OS-168884	0.8981	0.0020	865	20	Not Measured	-109.67	800	20	95%
180291	10/3/2022	Bluebird #1b	Charcoal	(OC) Organic Carbon	OS-168885	0.5657	0.0015	4,580	20	Not Measured	-439.24	5,340	40	76%
180292	10/3/2022	Brandy 4	Charcoal	(OC) Organic Carbon	OS-168886	0.9703	0.0019	240	15	Not Measured	-38.12	355	30	70%
												230	30	25%
180293	10/3/2022	Brandy 5	Charcoal	(OC) Organic Carbon	OS-168887	0.8890	0.0020	945	20	Not Measured	-118.74	865	20	95%

# Pyrogenic carbon

- Isolating the  $>125$   $\mu\text{m}$  fraction for counting
- Counts from Brandy 4 (101) and 5 (65) are on par with recent fire-caused debris flows in California
- In Bluebird 1 – residence times for PyC suggest that upper section enriched
  - Agricultural history
  - bioturbation



# Overview of Results

- Ample evidence of pre-historic debris flows
  - Likely fire associated debris flows from charcoal content
- Large boulders seemingly preserve sediments below
- Series of debris carrying events ca 600-800 yr BP
  - Another hypothesis: The 880-865-year-old debris flow brought the boulders in and subsequent debris flows moved them around while depositing only finer grained material.
  - The layers above the cobbles near Paige Boulder Creek at 820 years are very similar to ages of the boulder-rich debris-flow forms on Brandy Creek.
- Either way... flow events seem concordant with period punctuated by regionally increased occurrence of drought (Walker Lake, NV - Yuan et al., 2006 and SF Bay, CA – Malamud-Roam et al., 2006 and Abbott Lake, CA – Hiner et al., 2016)
- Terrace at the school is apparently stable since mid-Holocene
  - Back-water deposition behind a debris dam?

A close-up photograph of a field of blue lupine flowers. The flowers are in various stages of bloom, with some showing white centers. They are surrounded by green grass and brown, dried seed pods. The background is a dense field of similar flowers, creating a textured, layered effect.

Gratitude to:

Scott McCoy, Univ. Nevada, Reno

Don Lindsay, California Dept of Conservation

Staff of WHIS (especially the excavator operator)

Andrew Billy, Redding Rancheria Tribe

and all of the Wintu, Yana and Pit River people, past and present

Thank you!

