

# Holocene droughts, fires, floods and pluvials in southwestern California.

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- Dept. of Geological Science
- SCEC SoSAFE Workshop:  
Recent Successes and Future  
Challenges (Sept. 10, 2016)
- 13:30-14:00



# Acknowledgements

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## **STUDENTS.**

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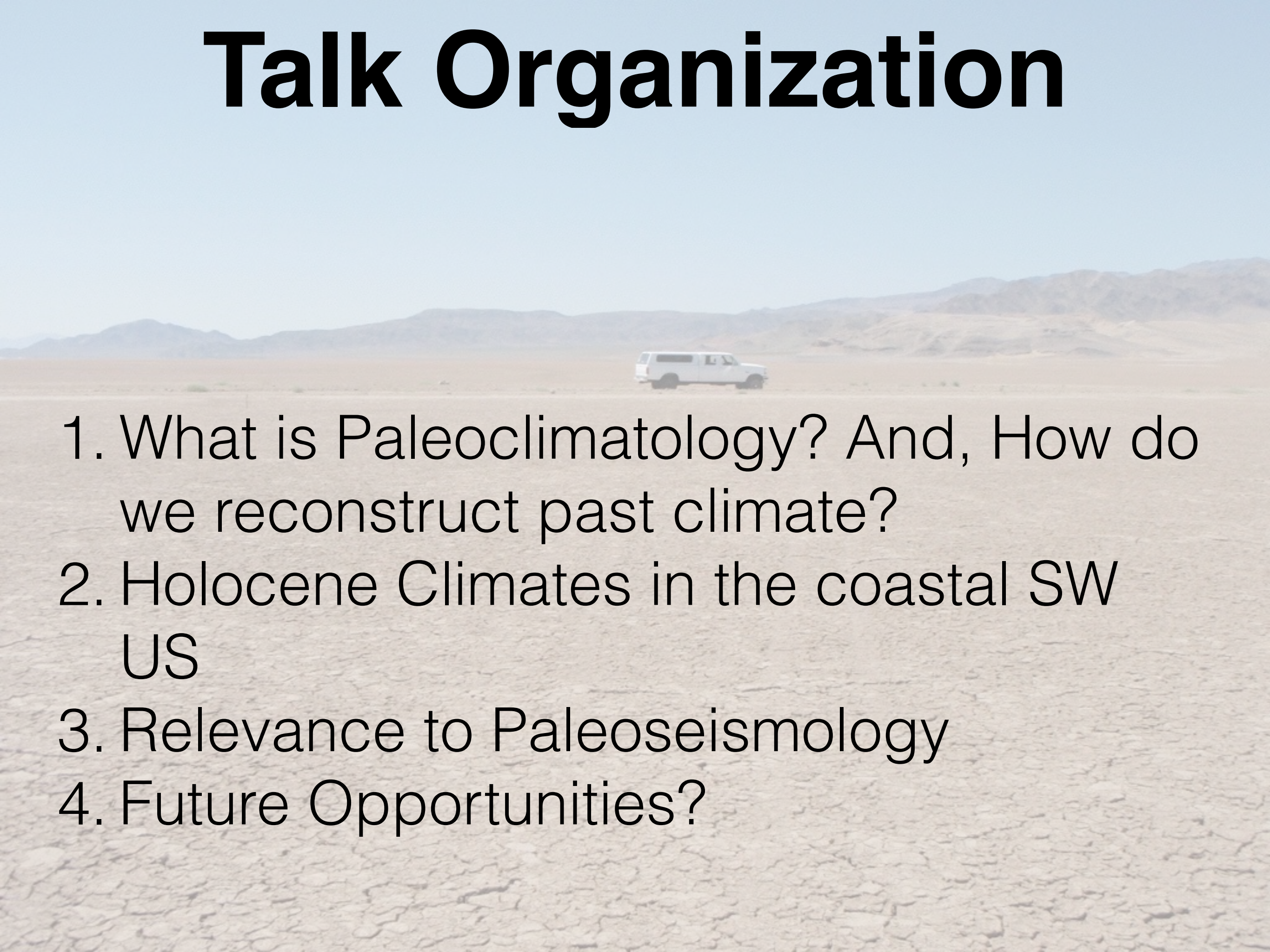
## **COLLABORATORS.**

### **Special Thanks to:**

Sarah Feakins, Bill Patterson, Steve Lund, Susan Zimmerman, Michael Anderson, Scott Starratt, Glen MacDonald, Chris Scholz



# Talk Organization

- 
1. What is Paleoclimatology? And, How do we reconstruct past climate?
  2. Holocene Climates in the coastal SW US
  3. Relevance to Paleoseismology
  4. Future Opportunities?



# What is paleoclimatology?

- paleoclimatology is the study of past climate



Zaca Lake mud



# How do we investigate past climate?

- we use proxies contained in geological archives to reconstruct past climate
  - geological archives include...
    - ice cores
    - marine sediments
    - **lake sediments**
    - tree rings
    - cave deposits
    - coral
  - a proxy is a substitute for a climate or climate related variable such as...
    - temperature
    - precipitation
    - atmospheric circulation patterns
    - ocean circulation patterns
    - flood events
    - fire activity
    - vegetation
    - geomorphic disturbance

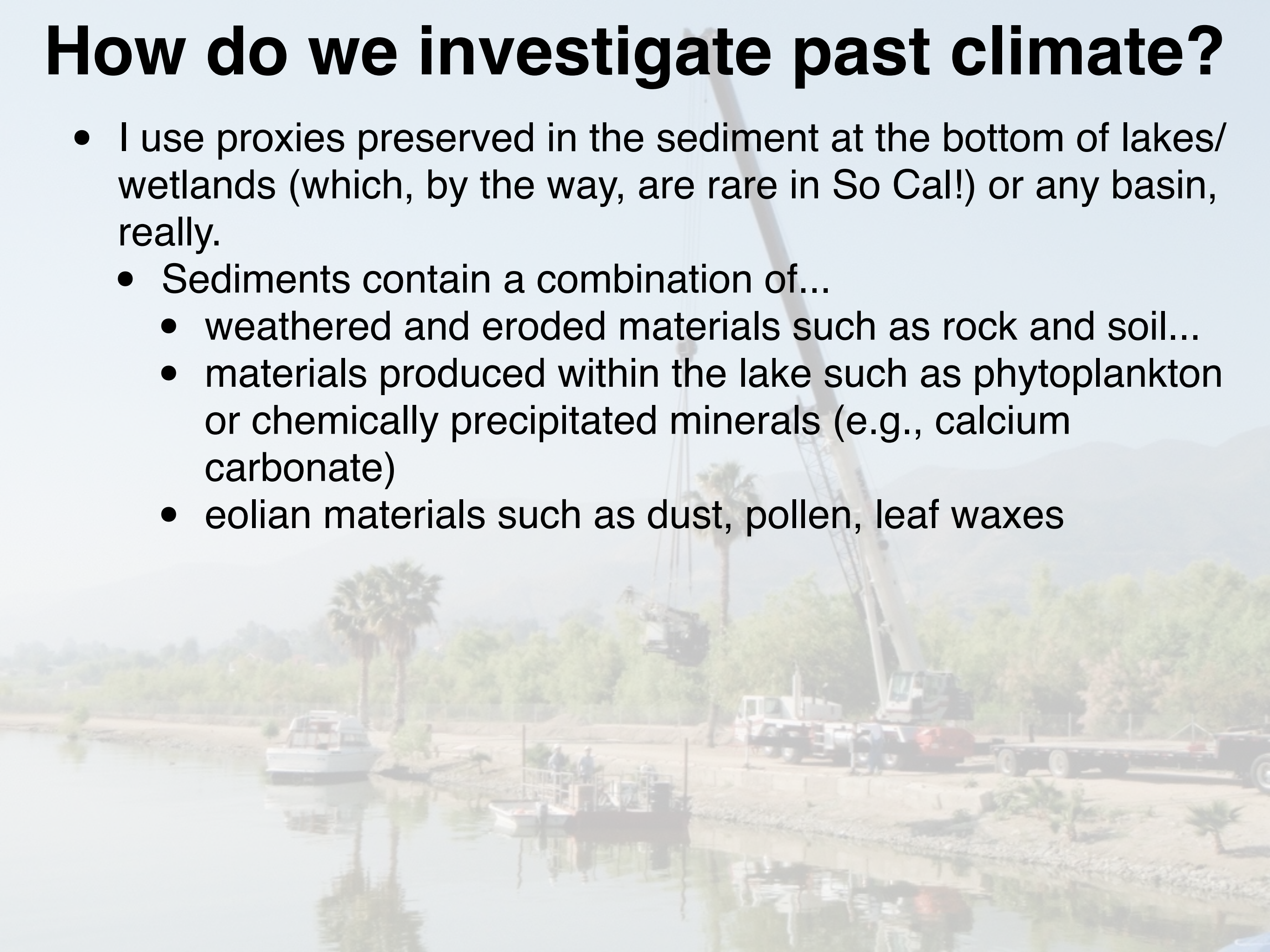


Zaca Lake, CA (July 2009)



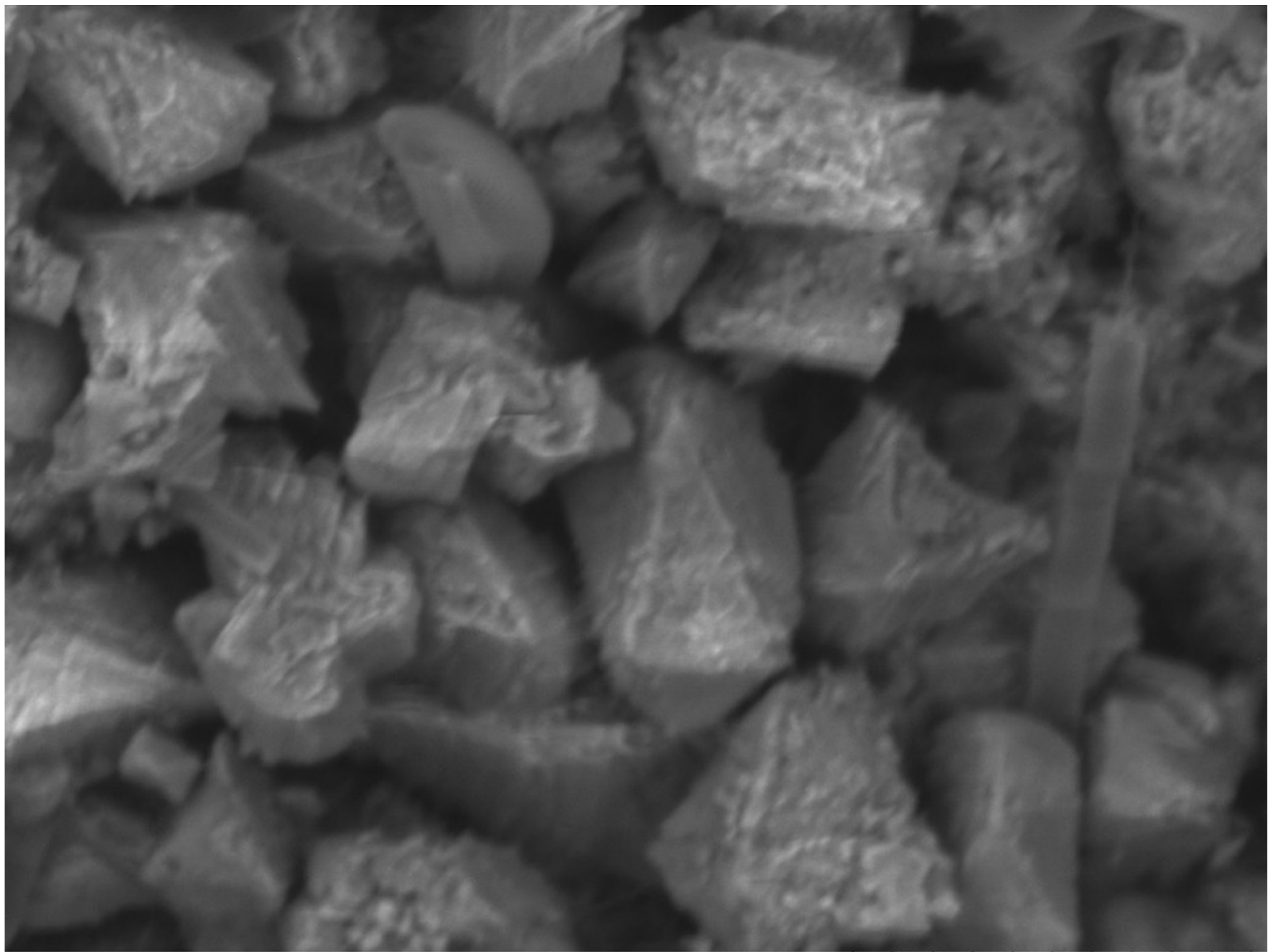
# How do we investigate past climate?

- I use proxies preserved in the sediment at the bottom of lakes/wetlands (which, by the way, are rare in So Cal!) or any basin, really.
- Sediments contain a combination of...
  - weathered and eroded materials such as rock and soil...
  - materials produced within the lake such as phytoplankton or chemically precipitated minerals (e.g., calcium carbonate)
  - eolian materials such as dust, pollen, leaf waxes









Berelson

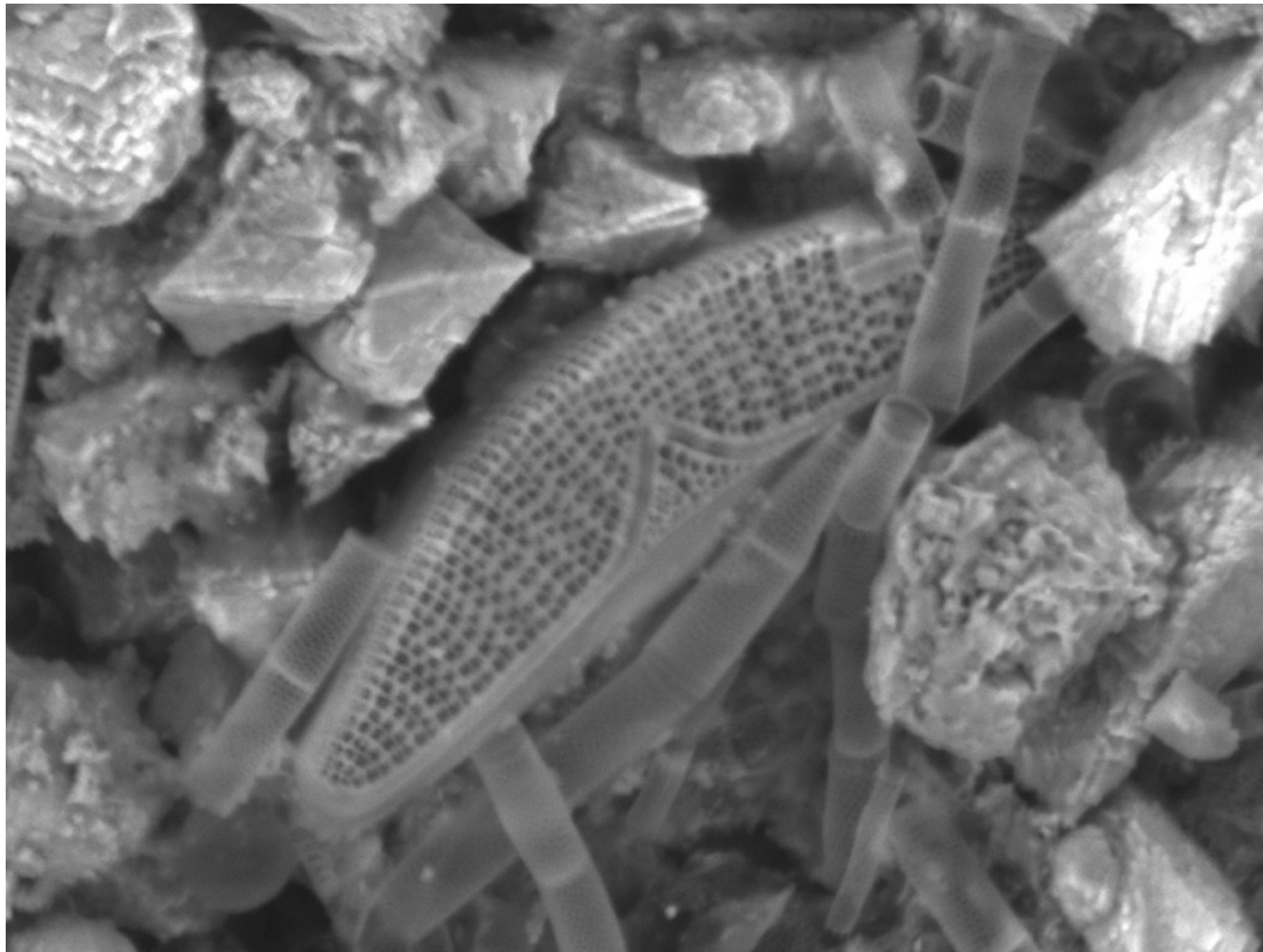
2009/02/19 11:47

D4.3

x2.0k

30 um





Berelson

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30 um



Berelson

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D4.8

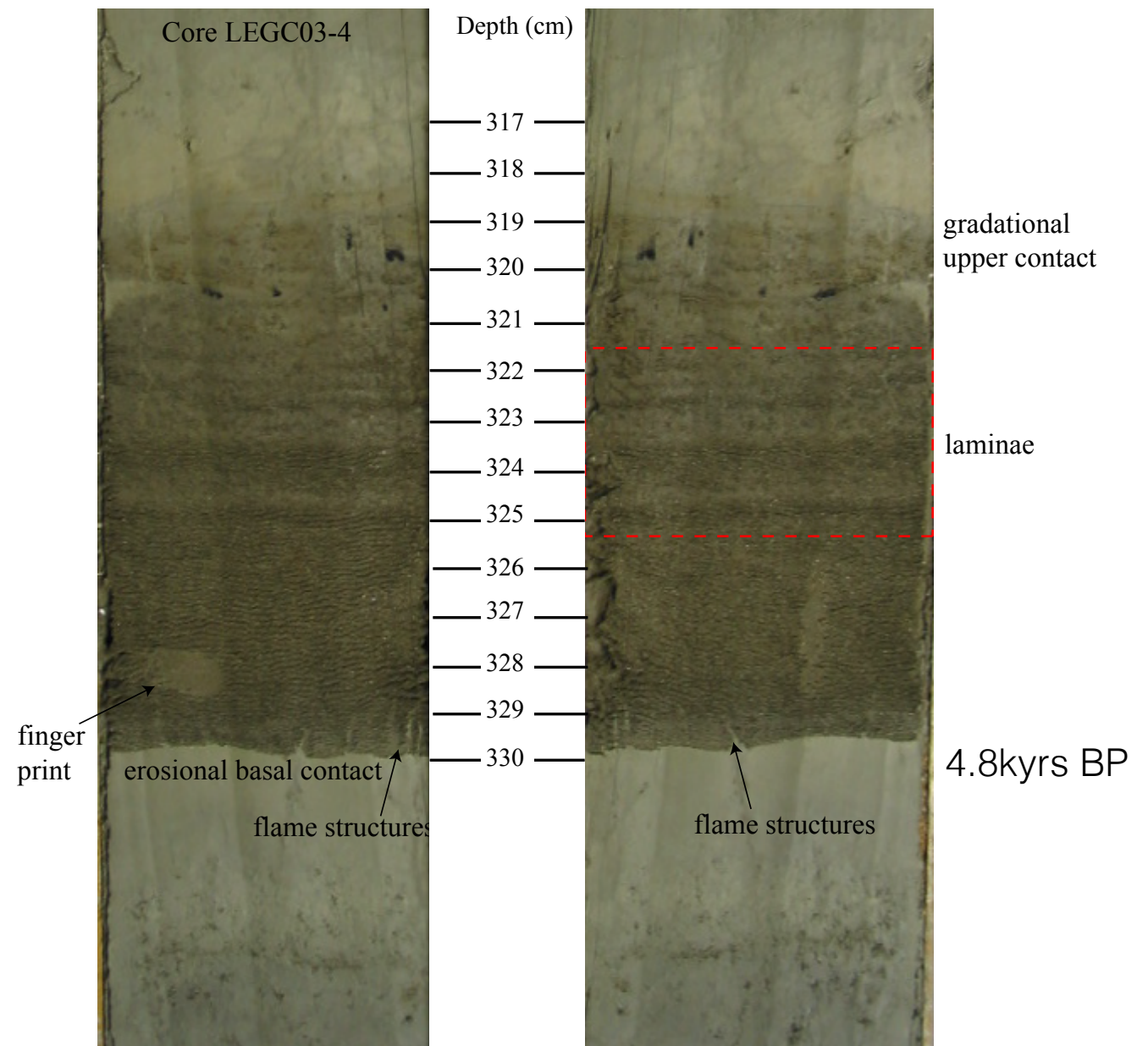
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50 um



# Holocene Climates in the coastal SW US

- Remarkably, our knowledge of past climate in the coastal southwest US was extremely limited, until recently...
  - limited to some tree ring records (<1000 yrs), low resolution sediment records, and packrat middens (*Lynch 1931; Wells and Berger 1967; Ore and Warren 1971; Heusser 1978; Meko et al. 1980; Cole and Webb 1985; Enzel et al. 1989, 1992; Spaulding 1990; Rosen 1991; Brown and Rosen 1995; Cole and Wahl 2000; Biondi et al. 2001; D'Arrigo et al. 2001; Byrne et al. 2003*)
    - note: I am not including the SBB records in this talk
- Relevant to this workshop are...
  - Sediments that accumulate in basins - lakes, wetlands, sag ponds(?), etc...
    - often continuous
    - can capture annual to millennial scale information
    - record geomorphic processes
    - are not limited to past 1000-2000 yrs, as are tree rings
      - tree rings are extremely important archives BUT they cannot tell us about
        - past floods,
        - geomorphic responses to climate such as drought,
        - fire activity,
        - vegetation changes,
        - and many other things that are stored in basin sediments...
      - And, they are also poorly represented in arid environments like the coastal SW US
- so, we need other sources of paleoclimatic information!



Kirby et al. in review Lake Elsinore  
mega flood event



# Holocene Climates in the coastal SW US

- Developed paleoclimate sites
  - as relevant to this workshop and their value to the paleoseismic record







Lots of unknowns!

no tree rings  
no packrat middens





Still lots of unknowns!

with tree rings  
no packrat middens



# Holocene Climates in the coastal SW US

- So, let's take a virtual tour through time...

**WARNING!!**

\*lots of wiggles ahead

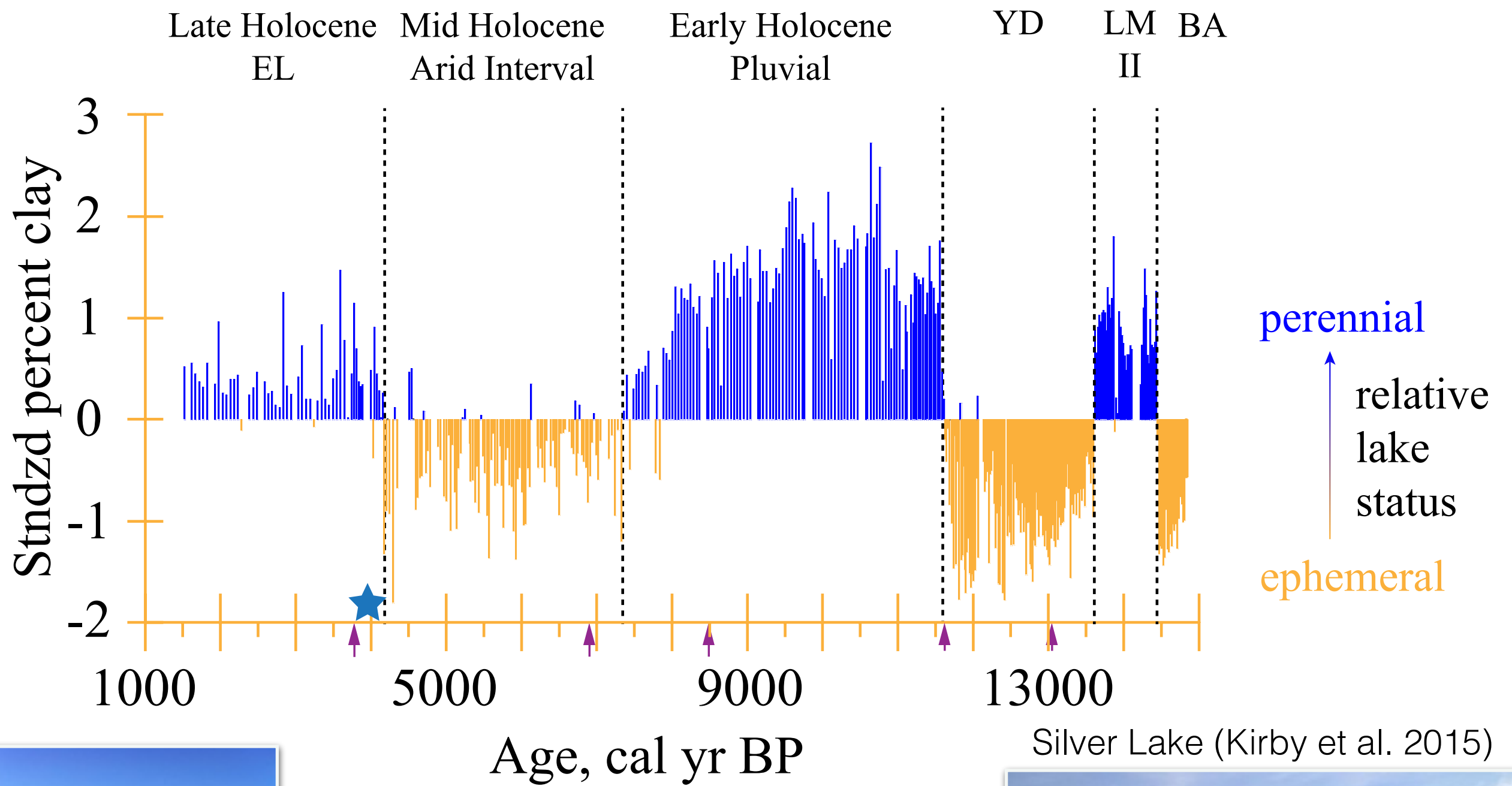
\*lots of quick explanations

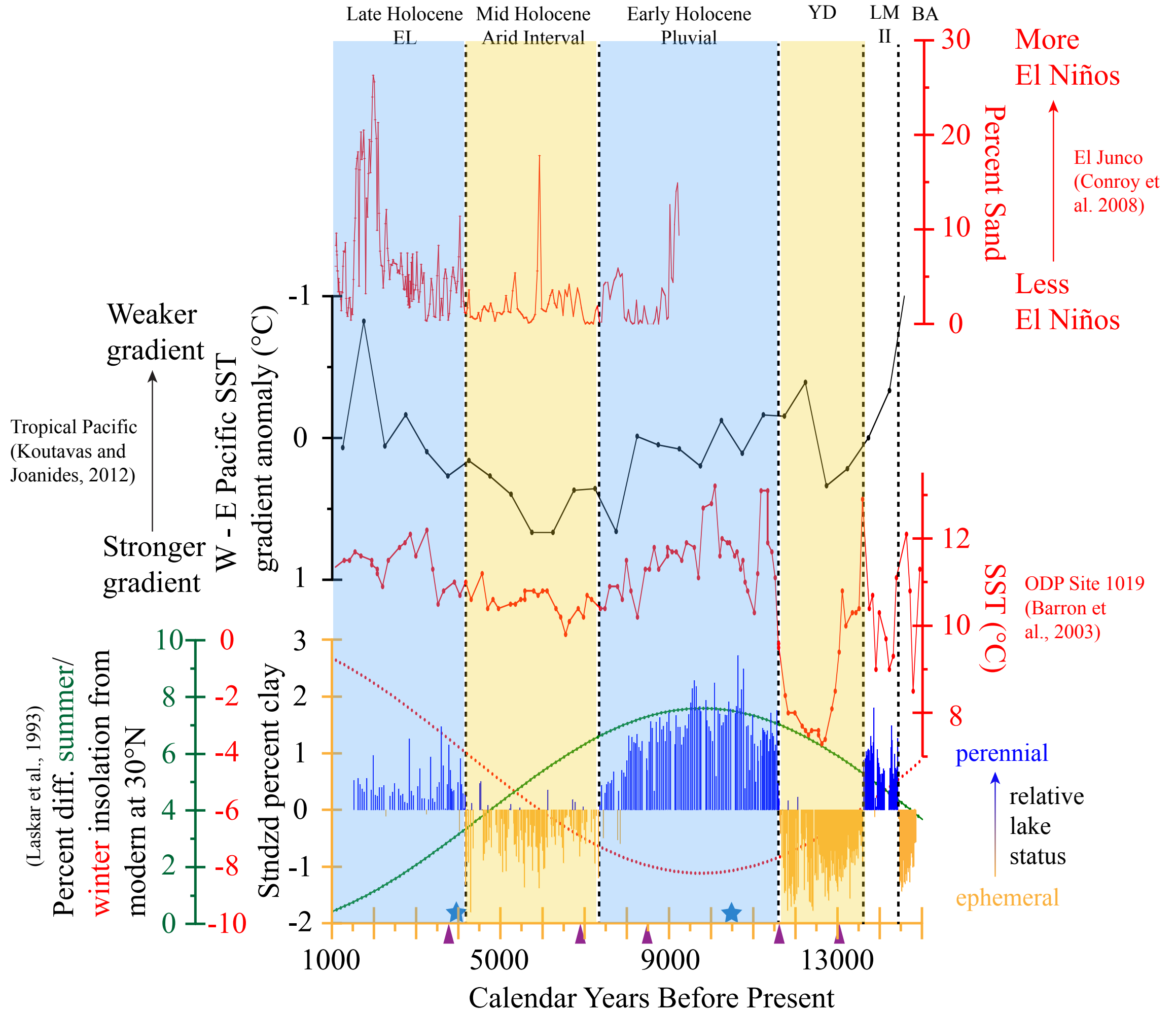


# Holocene Climates in the coastal SW US

- Holocene perspective
  - **Millennial scale**
    - Milankovitch (insolation) and large-scale Pacific ocean-atmosphere dynamics drive the signal
    - Examples
      - Lake Elsinore (Kirby et al. 2004, 2005, 2007, 2010, 2013; Heusser et al. 2015)
      - Dry Lake (Bird and Kirby, 2006; Bird et al., 2010)
      - **Silver Lake (Kirby et al., 2015)**



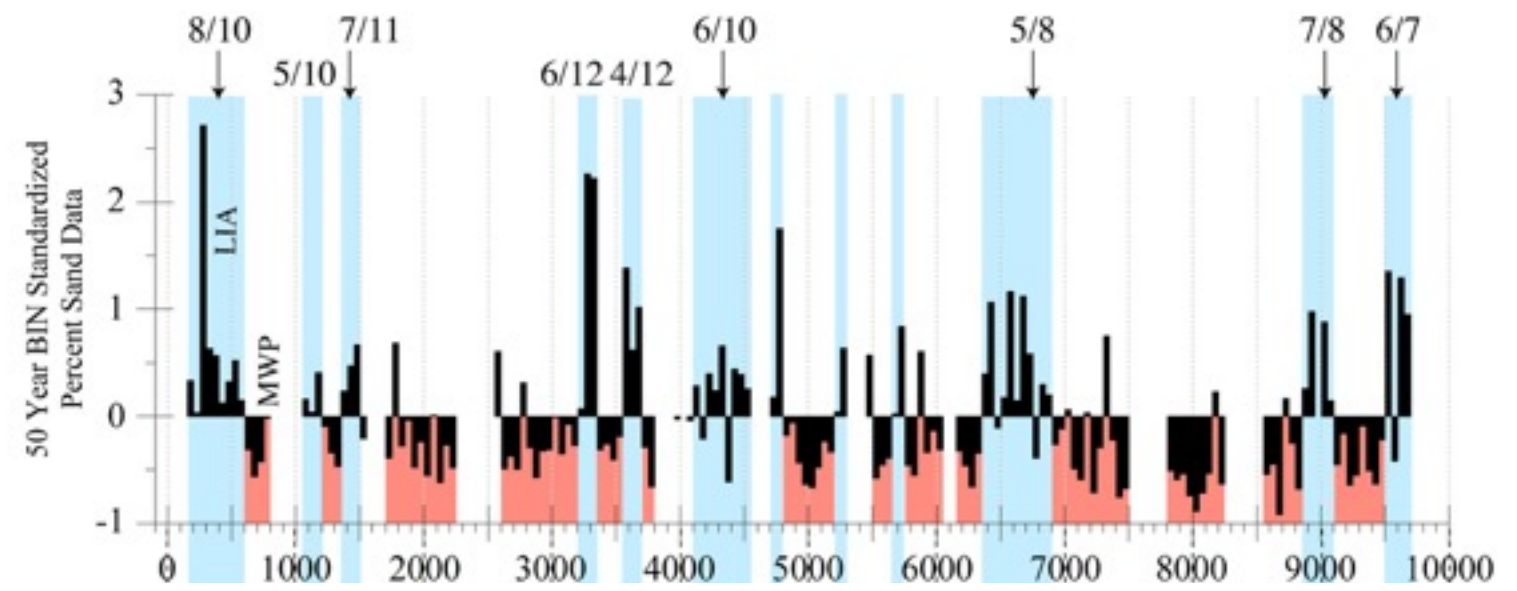






# Holocene Climates in the coastal SW US

- Holocene perspective
  - **Sub millennial to centennial scale**
    - Pacific sourced ocean-atmosphere forcing (ENSO, PDO)
      - evidence for climate state changes?
  - Holocene pluvials
    - Examples
      - **Lake Elsinore**
        - PDO forcing
      - **Lower Bear Lake**
        - Holocene pluvials
          - linked to changes in atmospheric river frequency?



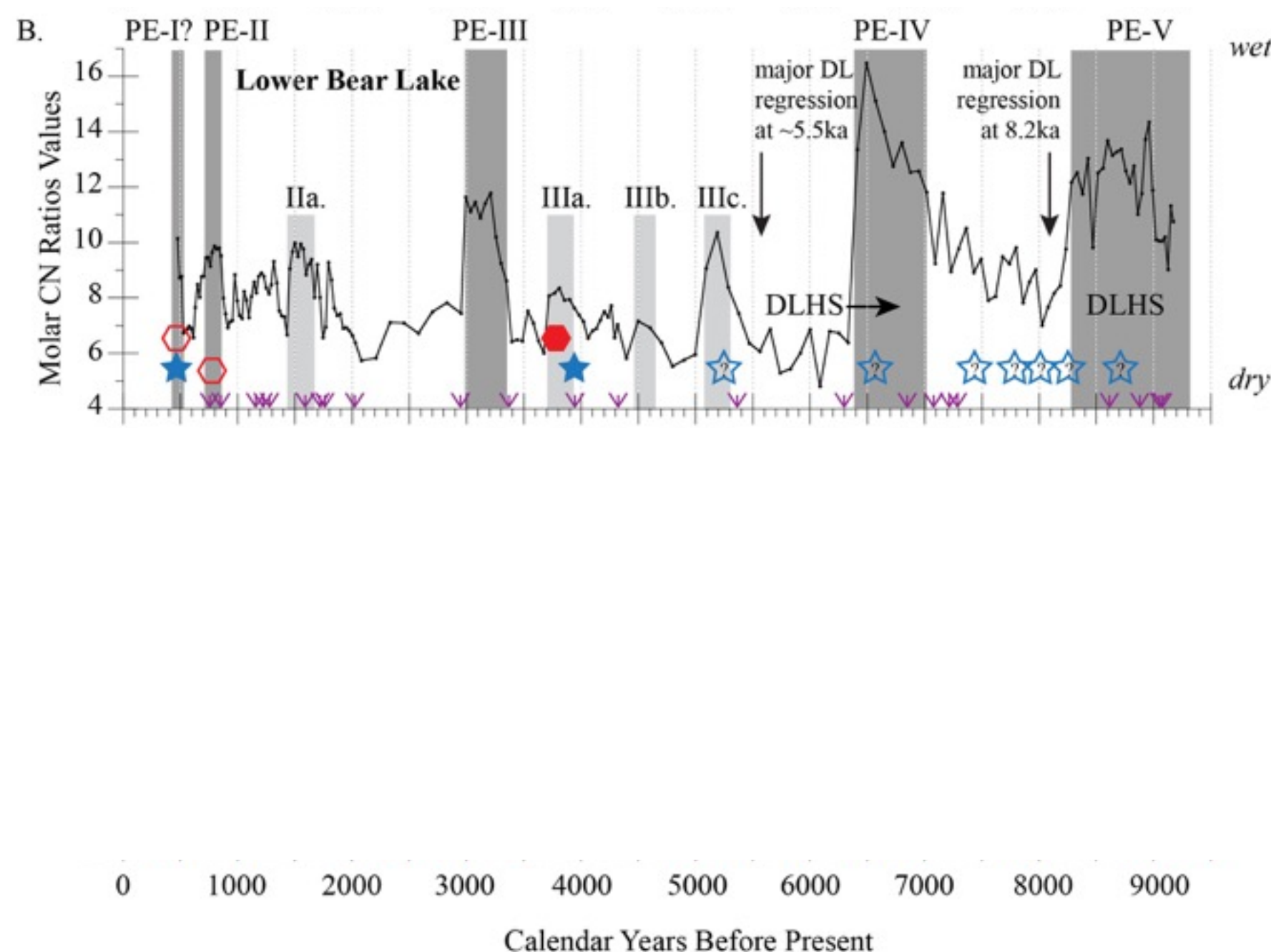
Lake Elsinore (Kirby et al. 2010)





Lower Bear Lake (Kirby et al. 2012)

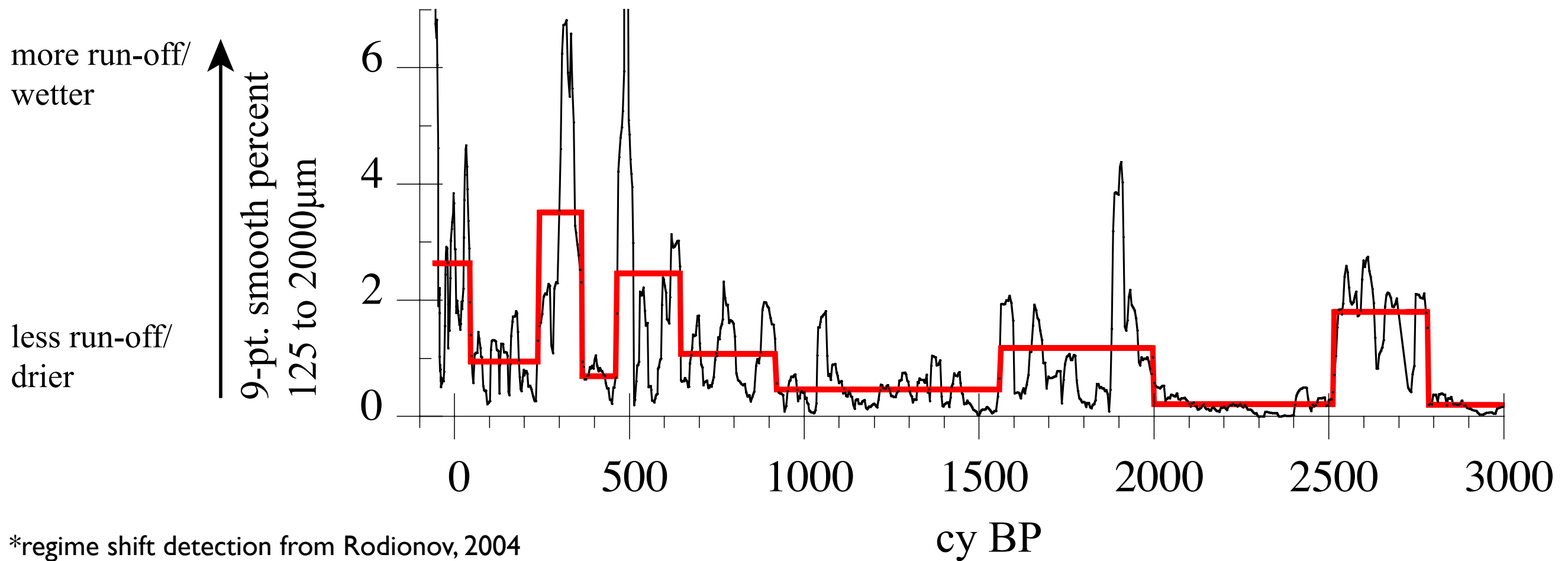
A  
 Silver Lake pluvial = ☆ (based on age model); Silver Lake pluvial = ★ (bulk organic  $^{14}\text{C}$ )  
 Cronese Lake pluvial = ◻ (discrete organic  $^{14}\text{C}$ ); Cronese Lake pluvial = ● (bulk organic  $^{14}\text{C}$ )



# Holocene Climates in the coastal SW US

- Holocene perspective
  - **Sub Centennial to decadal scale**
    - Pacific sourced ocean-atmosphere forcing (ENSO, PDO)
      - data indicate real spatiotemporal variability
      - requires improved and quantitative wiggle matching
      - working with 2 CSUF statistics professors (Drs. Kevin Nichols and Reza Ramezan) to quantify the patterns of climate change across different records with varying age control
    - extending this comparison to aggregate tree ring records for the region
      - Examples
        - **Zaca Lake**
          - tropical Pacific forcing
        - Abbott Lake (Kirby et al. in press)
          - tropical and N Pacific forcing
        - Crystal Lake
          - a storm story linked to tropical and N Pacific forcing





Zaca Lake (Kirby et al. 2014;  
Feakins et al. 2014; Dingemans  
et al. 2014)







# Holocene Climates in the coastal SW US

- Holocene perspective
  - **Annual scale**
    - generally a Pacific sourced ocean-atmosphere forcing... other things too (e.g. volcanism)
    - Examples
      - **Cook et al. (2004, 2009) PDSI reconstructions**
        - how do these records relate to sediment based reconstructions? Zaca vs. Tree Rings

Zaca >125  $\mu$ m sand  
(9pt. smooth)

US PDSI<sub>CSW</sub>

1  
0  
-1  
-2  
8  
6  
4  
2  
0

0

500

Calendar Years Before Present

1000

1500

2000

2500

3000

IPCC  
LIA

IPCC  
MCA

data from Cook et al. (2004)

data from Cook et al. (2004)

Cook et al. (2004)  
Epic Droughts

way more epic

20

40

60

Drought Area western US

0

500

1000

1500

2000

2500

3000



# Relevance to Paleoseismology

- “While several studies have compared paleoseismic event histories at neighboring sites to appraise earthquake synchronicity (e.g., Onderdonk et al. 2013; Scharer et al. 2014), *there have yet to be comprehensive studies that focus on the climatically-controlled geomorphic changes throughout the earthquake record.* For instance, *are there simultaneous depositional or erosional events across regions of southern California that we can tie to an historical mega-flood or decade-long wet period?* If yes, as proposed by Grant-Ludwig et al. (2010) and Scharer et al. (2014), **we can use sedimentary and pedogenic records of these geomorphic events as benchmarks to refine the paleoseismic record.**” *quoted directly from proposal by Salisbury and Arrowsmith (SCEC prop 2015)*

# Relevance to Paleoseismology

- Clearly, paleoseismic sites contain a wealth of paleoclimatic data...but, only if approached with the correct methodologies/protocols
  - sampling
  - dating
  - recovery time for climate signal to establish post-disturbance
  - coring will not work (see next slide)





# Relevance to Paleoseismology

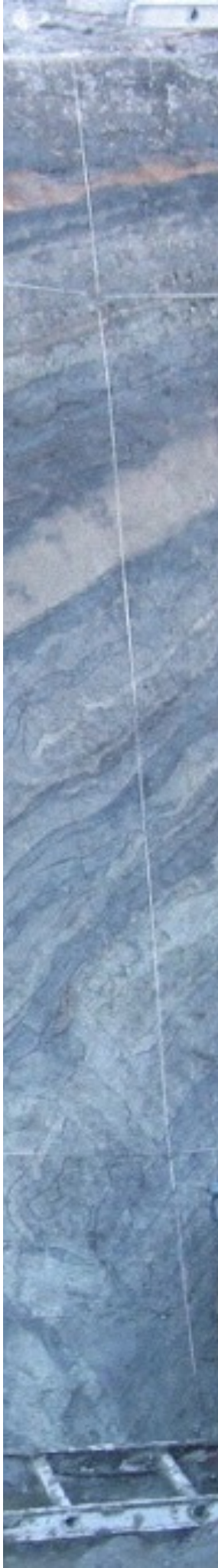
- Example of issues...

Wow, what a  
beautiful  
section!  
-core #1

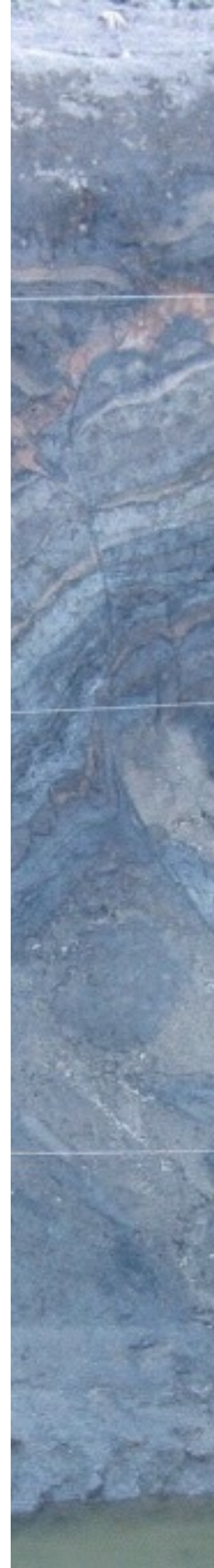




Hmmm, what  
an ok section.  
-core #2



D'oh! what a  
crappy  
section!  
-core #3





\*oh no! cores at this site  
would equal  
paleoclimatic failure!!

\*what's the solution for  
working in seismically  
disturbed basins (e.g.  
sag ponds...)

-paleoclimatologist  
and paleoseismologist  
must work together in  
the open trench to  
deconvolve the  
climatic and seismic  
history!

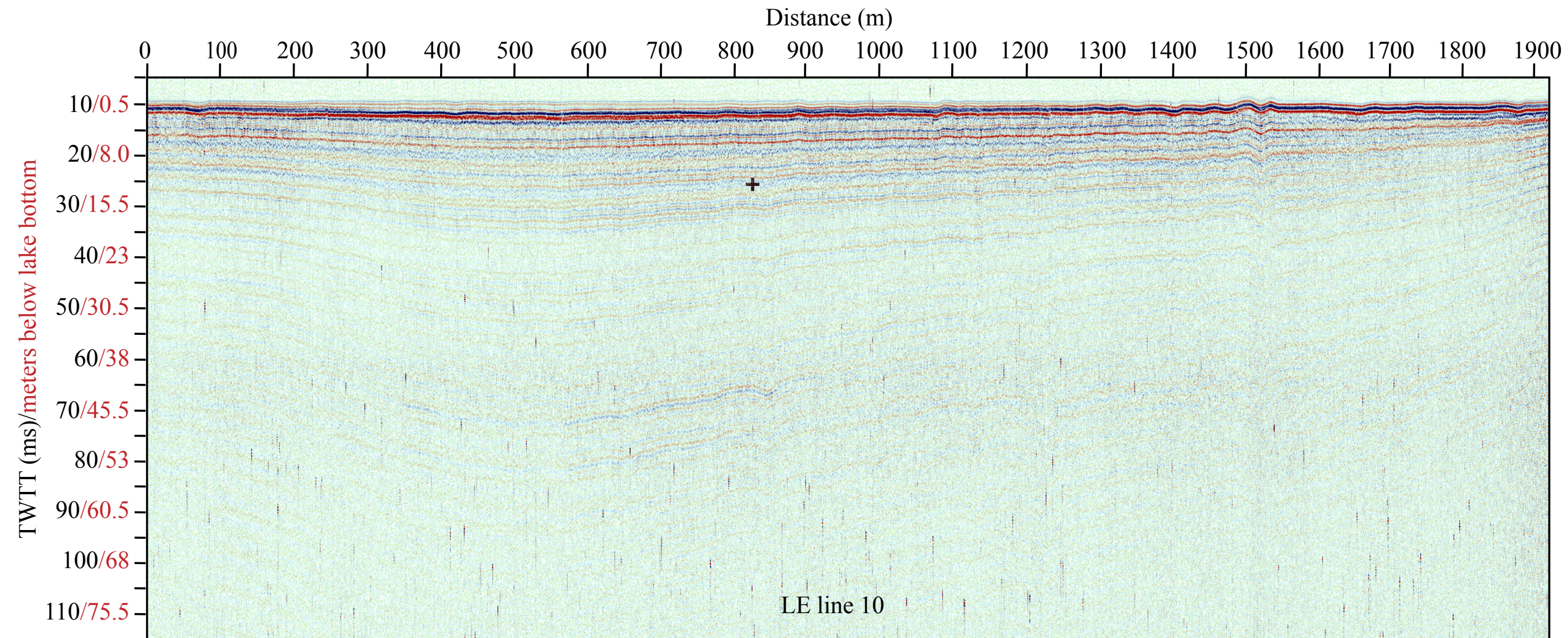


# Future Opportunities?

- Remember the slide with the tree and sediment sites?
  - mostly empty
    - BUT, a lot of that emptiness can be filled using paleoseismic sites where permanent lakes and trees are rare
    - climate is spatially and temporally complex...
      - we MUST fill in the spatial and temporal gaps IF climate records are to be used as “benchmarks to refine the paleoseismic record”
  - but, sediment-based paleoclimate work requires \$\$
    - So, where do these future collaborations find their funding?



# Thank You!



seismic reflection line down the long axis of Lake Elsinore, CA (Kirby et al. in prep)