Latest Pleistocene Through Holocene Lake Levels From Tulare Lake, CA: Testing Results Using The Smear Slide Technique*

Kelsey Padilla[1], Lindsey Medina[1], Ashleigh Blunt[1], and Rob Negrini[1]

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Abstract

Lake sediments from deep lake settings are often associated with high deposition rates, offering a detailed repository of measurable quantities providing information on lake level, climate, and the terrestrial environment surrounding the lake. Prior to diversion of stream flow for the purpose of irrigation, Tulare Lake was the largest fresh water lake west of the Great Lakes (Preston, 1981). At that time, its lake level was predictably related to the discharge of four Sierran streams, the Kern, Tule, Kaweah, and Kings Rivers (Atwater et al., 1986). This relationship is the basis for temporal river discharge reconstruction by locating and dating the past surface elevations of Tulare Lake. This, in turn, will ultimately lead to improved forecasting for Sierran discharge over the next several decades after this record is compared to improving coeval records of sea-surface temperatures of the Pacific Ocean. The core-based record of Blunt (2013) has extended the trench-based record of Negrini et al. (2006) back to about 20,000 years ago. Furthermore, the former has a much-improved resolution corresponding to one sample every ~50 years, making it more useful towards decadal-scale forecasts of recharge.

This study uses the smear slide technique of Schnurrenberger et al. (2003) to test the findings of Blunt (2013). The smear slide technique allows for a detailed petrographic microscopic description of the core every 5cm, including the detection of features diagnostic of both deep, freshwater and shallow, brackish water paleoenvironments. In the time interval from 2,500 to 1,800 cal yr BP, Blunt (2013) suggests lake conditions as a shallow, fresh water marsh due to a low total inorganic carbon (TIC) value, which is not inconsistent with our initial observations of pristine sponge spicules and the pollen species Typha (i.e.,

cattail) in the smear slides from the corresponding depth interval. Using these initially observed relationships between smear slide content and previously collected geochemical and geophysical data, we may expect to have little to no organic matter present in the smear slides during the Tioga glaciation at ~18,000 cal yr BP, which is characterized by a high silt content, low carbon to nitrogen ratio (C/N), and low TIC predicting a cold climate.

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Outline

I. **Introduction**

II. Background

III. Previous Work

IV. Method

V. Discussion & Predicted Results

VI. Preliminary results

VII. Summary

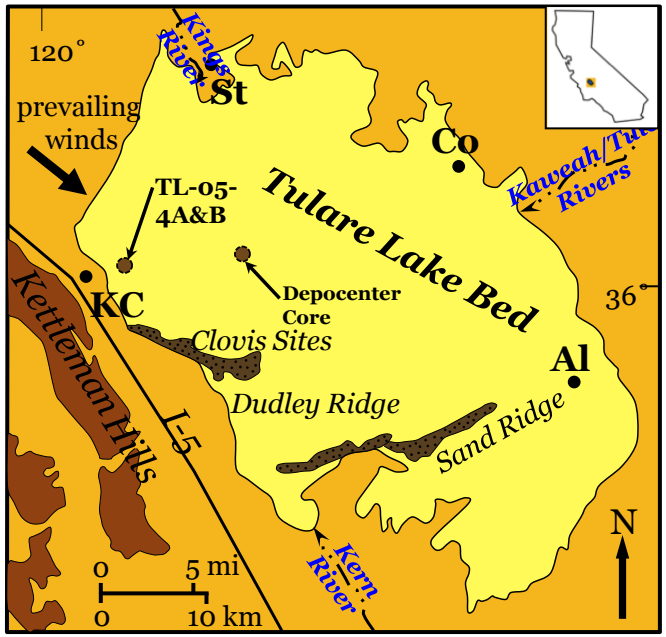
Introduction

•The core-based record of Blunt (2013) has extended the trench-based record of Negrini et al. (2006) back to ~20,000 years ago. Furthermore, the former has a much improved resolution corresponding to one sample every ~50 years, making it more useful towards decadal-scale forecasts of Sierran stream recharge.

•This study uses the smear slide technique of Schnurrenberger et al. (2003) to test the findings of Blunt (2013). The smear slide technique allows for a detailed petrographic description of the core every 5cm, including the detection of features diagnostic of both deep, freshwater and shallow, brackish water paleoenvironments.

Presentation Notes:
Prior to diversion of stream flow for the purpose of irrigation, Tulare Lake was the largest fresh water lake west of the Great Lakes (Preston, 1981). At that time, its lake level was predictably related to the discharge of four Sierran streams, the Kern, Tule, Kaweah, and Kings Rivers (Atwater et al., 1986). This relationship is the basis for temporal river discharge reconstruction by locating and dating the past surface elevations of Tulare Lake. This, in turn, will ultimately lead to improved forecasting for Sierran discharge over the next several decades after this record is compared to improving records of sea-surface temperatures of the Pacific Ocean. The core-based record of Blunt (2013) has extended the trench-based record of Negrini et al. (2006) back to ~20,000 years ago. The former has a much-improved resolution corresponding to one sample every ~50 years, making it more useful towards decadal-scale forecasts of Sierran stream recharge. This study uses the smear slide technique of Schnurrenberger et al. (2003) to test the findings of Blunt (2013). The smear slide technique allows for a detailed petrographic microscopic description of the core every 5cm, including the detection of features diagnostic of both deep, freshwater and shallow, brackish water paleoenvironments.

Background



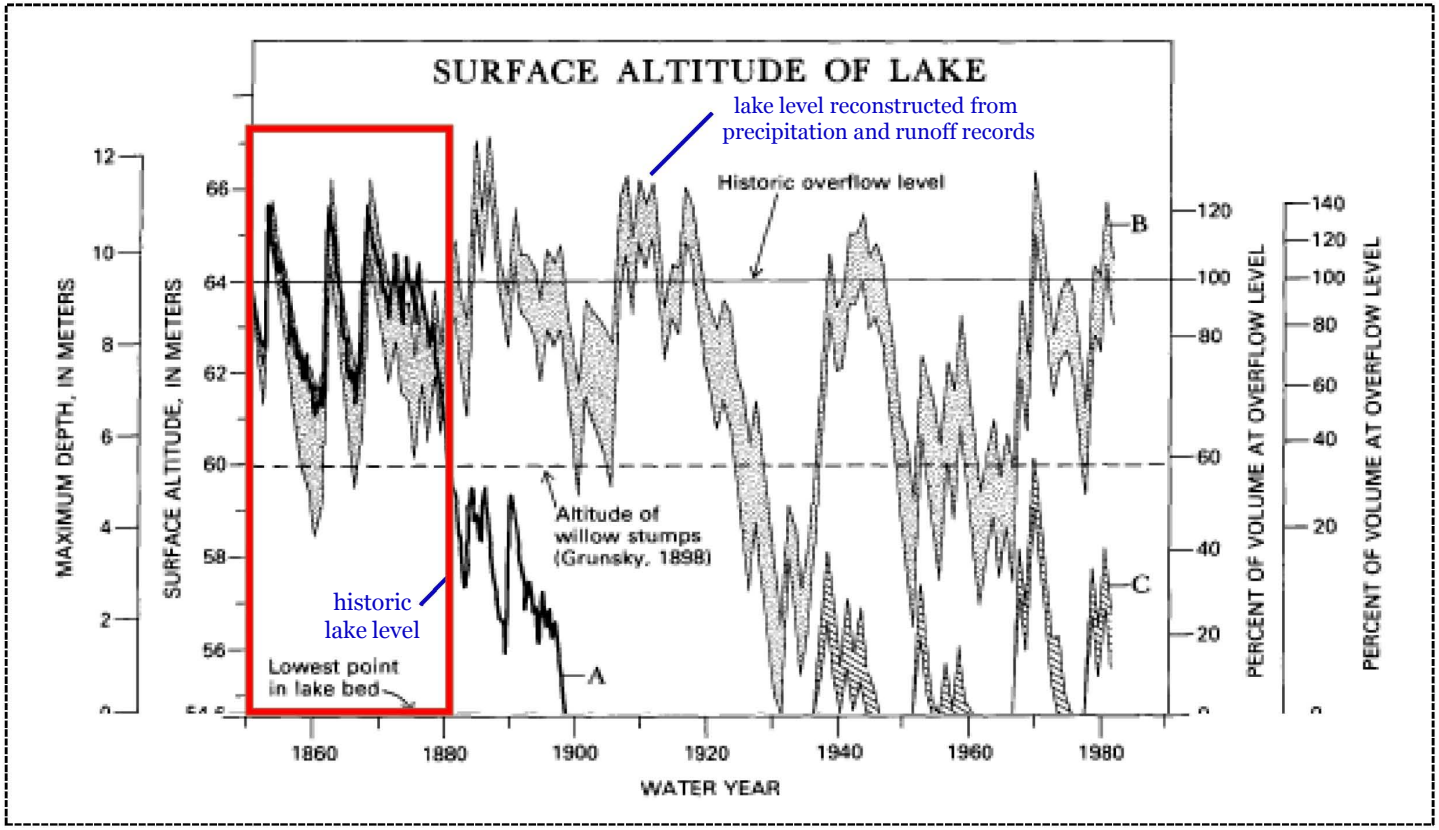
Simplified geologic map of Tulare Lake.

- Tulare Lake is located in the San Joaquin Valley of California between the Sierra Nevada and Coast Ranges.

- Historically, Tulare Lake occupied an area of up to 1600 km² with lake-level reaching as high as 12 m at which point water spilled northward over an alluvial fan formed sill into the San Joaquin Valley river system (Atwater, 1986). At its maximum, it contained 10% of the water currently used in CA each year.

Presentation Notes:
Tulare Lake is located in the San Joaquin Valley between the Sierra Nevada and Coast Ranges. Prior to agriculture diversion beginning in the late 1800s, Tulare Lake was the largest fresh water lake in the U.S. west of the Great Lakes. Approximately 95% of runoff into Tulare Lake occurs from the Sierra Nevadan Kings, Kaweah, Tule, and Kern Rivers. Small streams from the Kettleman Hills account for the remaining influx. Historically, Tulare Lake occupied an area of up to 1600 km^2 with lake-level reaching as high as 12 m at which point water spilled northward over an alluvial fan formed sill into the San Joaquin Valley river system (Atwater, 1986). At its maximum, it contained 10% of the water currently used in CA each year.

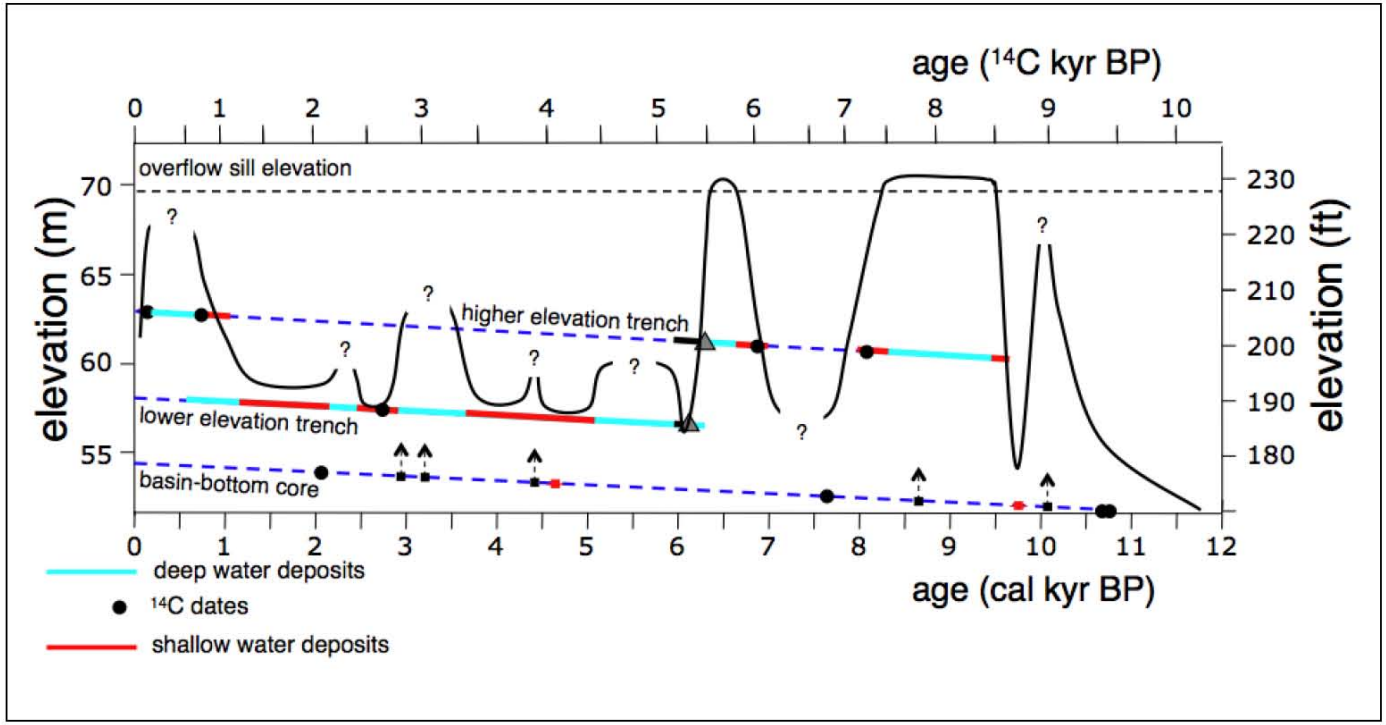
Background



Tulare Lake levels before drainage diversions were closely related to Sierran stream discharge as per hydrologic balance model (Atwater et al., 1986). These results suggest that ***paleolake levels can be used to generate a prehistoric record of stream discharge.***

Presentation Notes:
This graph shows the surface attitude of the lake prior to drainage diversions for agricultural purposes. The red box shows the lake before the diversion and the rest shows a lake level reconstruction based on precipitation and runoff records.

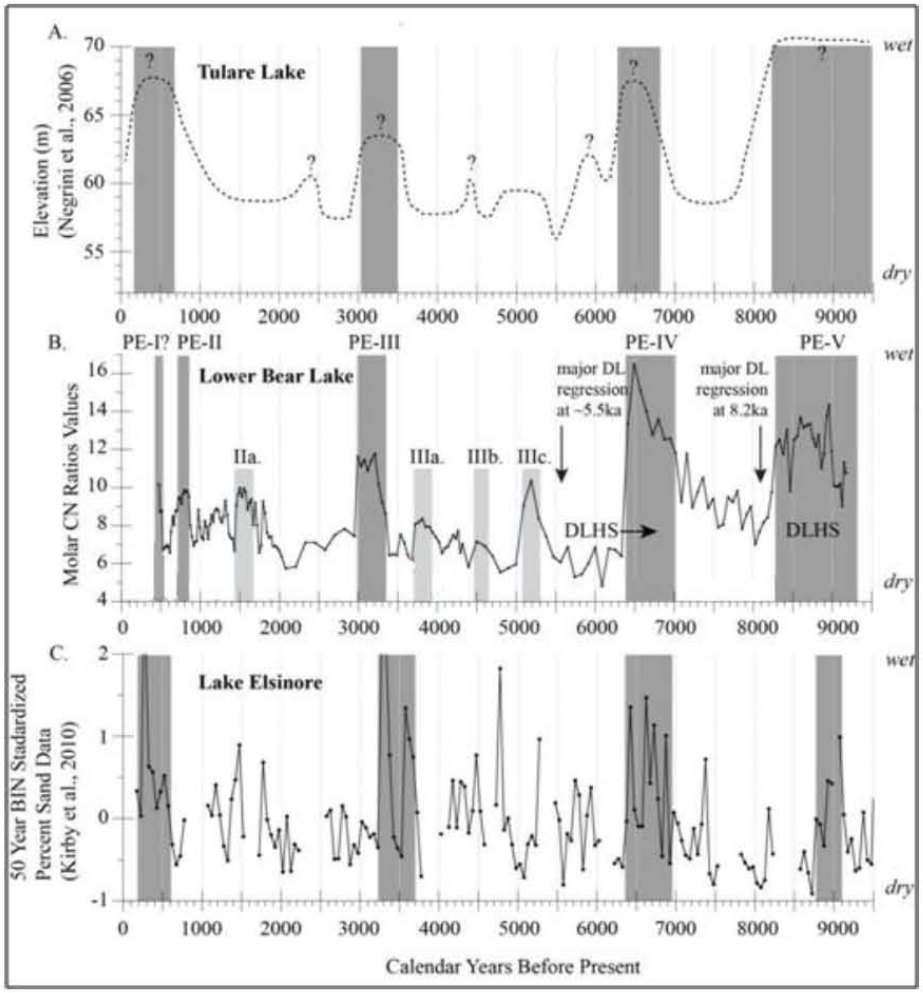
Previous Work



Paleolake-level history constructed from two highstand trenches and a depocenter core (Negrini *et al.*, 2006).

Presentation Notes:
Here is a paleolake level history constructed from two highstand trenches and a depocenter core. The axes show elevation of the lake compared to calibrated age. There are several highstands present within the record. The blue shows the deeper water deposits and the red shows the shallow water deposits. Previous research performed on Tulare Lake provides an overview of levels taken for approximately every 500 years.

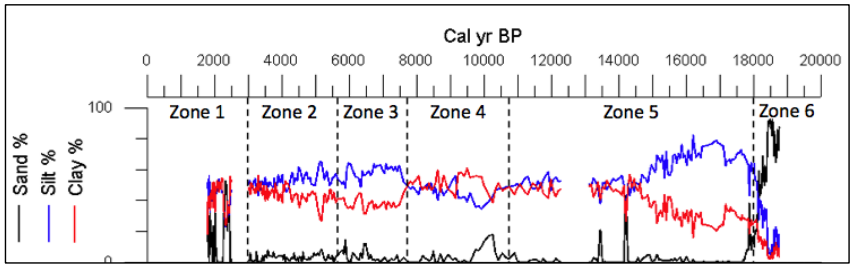
Previous Work



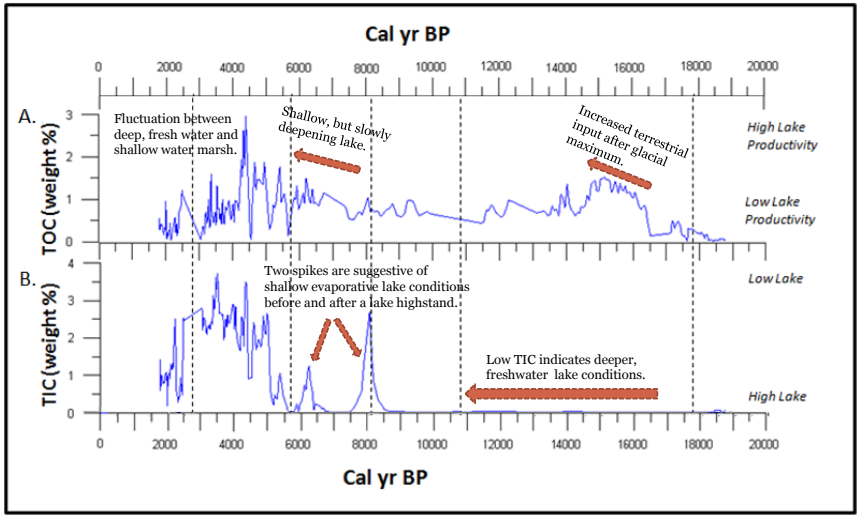
Pluvial events (PE) from different California lakes. C/N ratios and grain size data from other California lakes, Lower Bear Lake and Lake Elsinore (Kirby et al., 2012), indicate lake events with similar timing to each other and with the results of previous research on Tulare Lake.

Presentation Notes:
Here is a comparison of the previous Tulare Lake record to other southern California lakes. There are similar events within the three records that show that Tulare Lake levels are reflective of regional climate rather than local geomorphology.

Previous Work



Sand, silt, and clay percentages of the Tulare Lake TL05-4A and B cores. Zones are intervals of similar lake environments determined by (Blunt, 2013). Clay percent suggests deep calm lake environments from 14,500 to 8,000 cal yr B.P. and from 3,500 cal yr B.P. to the top of the record. This reaffirms the C/N data produced in this study.

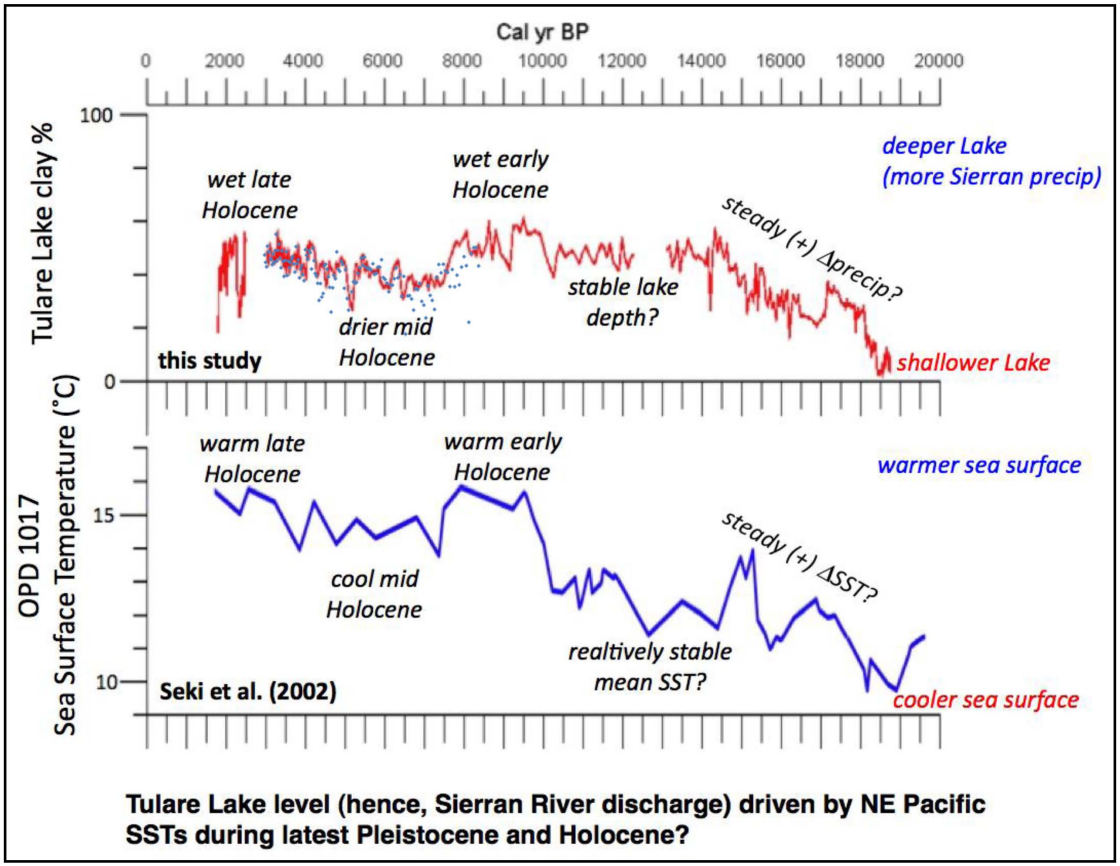


Geochemical data for TL05-4A/B. A) Total organic carbon (weight percent) and B) Total inorganic carbon (weight percent)

Presentation Notes:

The top graph shows the grain size results from the Blunt 2013 study and the zones are split into similar environments. Zone 6 shows a glacial outwash down to a glacial flour in zone 5. the clay percent from approximately 14,000 to 8000 years suggest a deep, calm lake. The lower graph shows the total organic and inorganic carbon weight percent. For TOC, there is an increased terrestrial input after the glacial maximum, a shallow, but slowly deepening lake, and the end of the record shows fluctuations between deep, fresh water and a shallow water marsh. For TIC, the low percent from the end of the record to about 8,500 yrs indicates a deeper, fresh water lake. The two spikes are suggestive of a shallow evaporative lake before and after a lake highstand, which corresponds to previous records. The rest of the record to the top of the core shows the fluctuations once again.

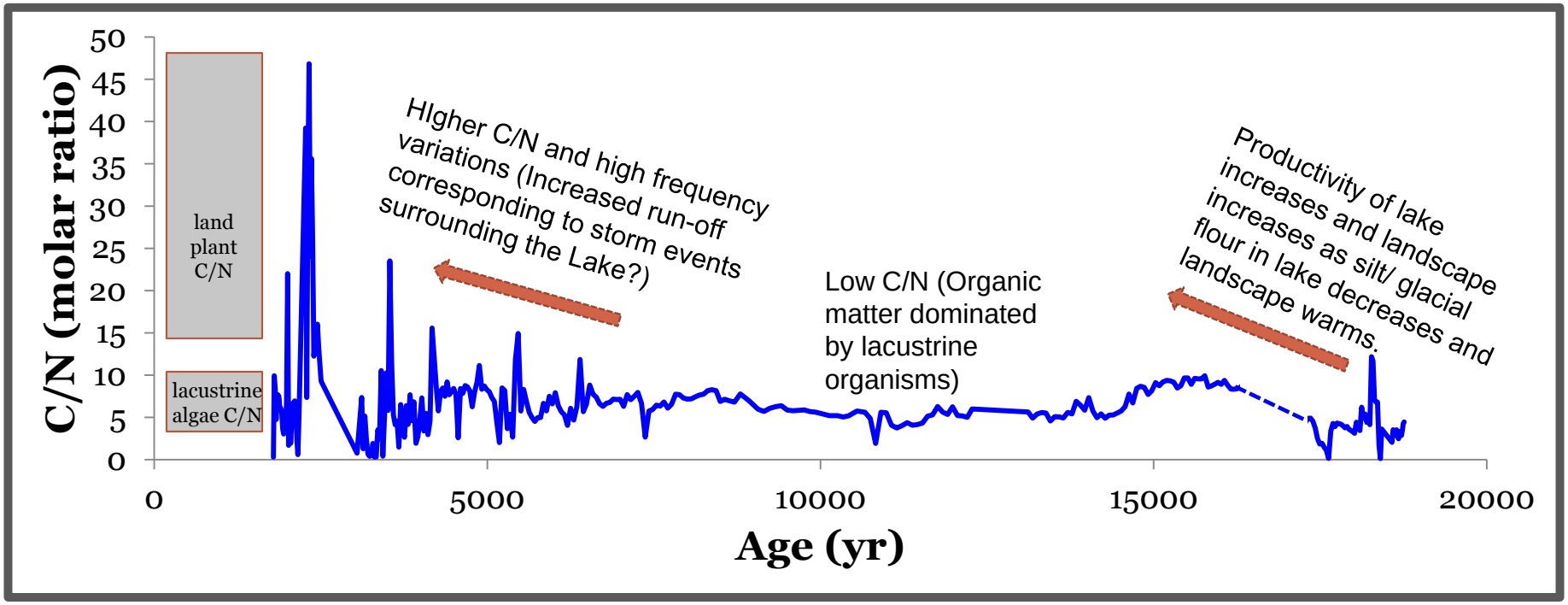
Previous Work



Tulare Lake clay content compared to sea-surface temperatures through the last 20,000 cal yr BP. The blue dots in the Tulare Lake clay percentage graph illustrates reproduced results from clay percentages from the second drive of core B.

Presentation Notes:
This record reiterates that the stream discharge is driven by sea surface temperatures.

Previous Work



Carbon to nitrogen ratios for the TL05-4 A1-3 and B2 cores. C/N ratio of lake indicates that organic matter is usually dominated by lacustrine algae (Meyers and Lallier-Vergés, 1999)

Outline

I. Introduction

II. Background

III. Previous Work

IV. Method

V. Discussion & Predicted Results

VI. Preliminary results

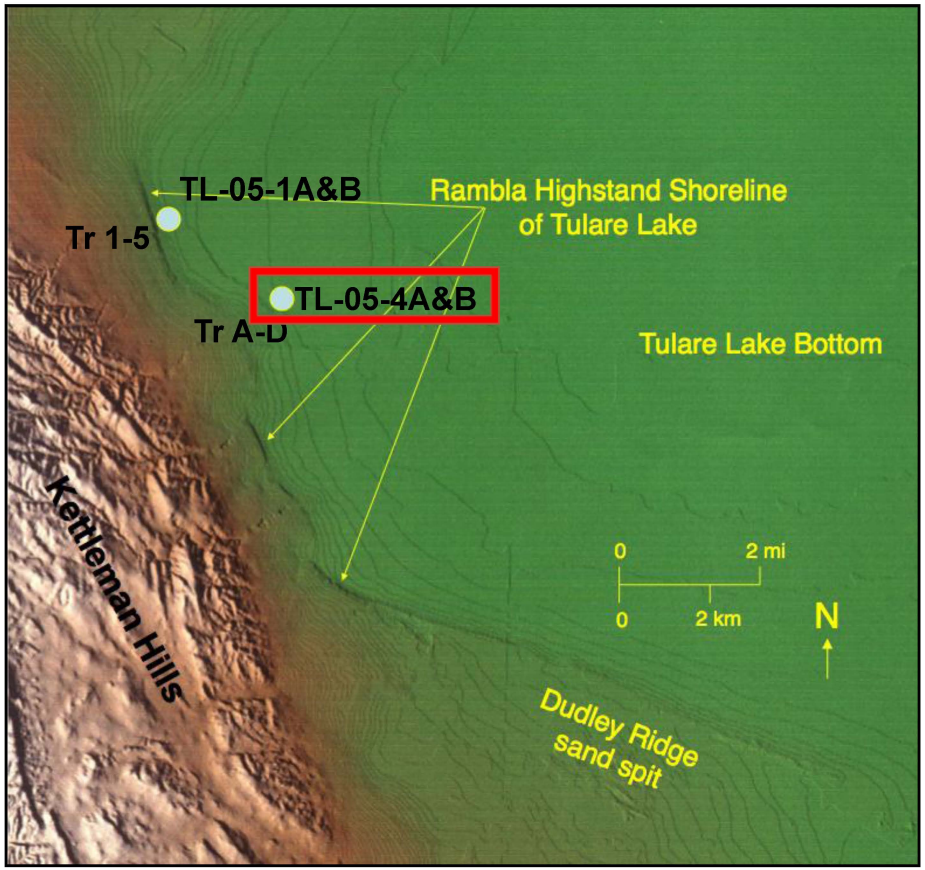
VII. Summary

Method

Schnurrenberger (2003) smear slide technique

• Two adjacent, multidrive lake plain cores, TL05-4A and TL05-4B were extracted from the western margin of the Tulare Lake bed. (Blunt, 2013)

•Samples at 5cm intervals were collected from a core depth ranging from 39cm to 442cm below ground surface level, which spans from approximately 2,800-18,500 cal yr BP.

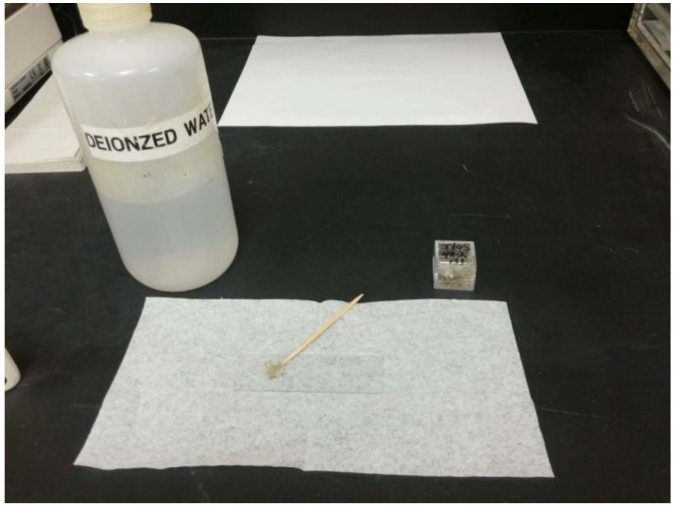


Location of trenches in Negrini *et al.,* (2006) and cores TL-05-4A&B and TL-05-1A&B used for this project and future work.

Method

Schnurrenberger (2003) smear slide technique

•A small amount of each sample was then smeared onto an individual, labeled slide using a few drops of deionized water.

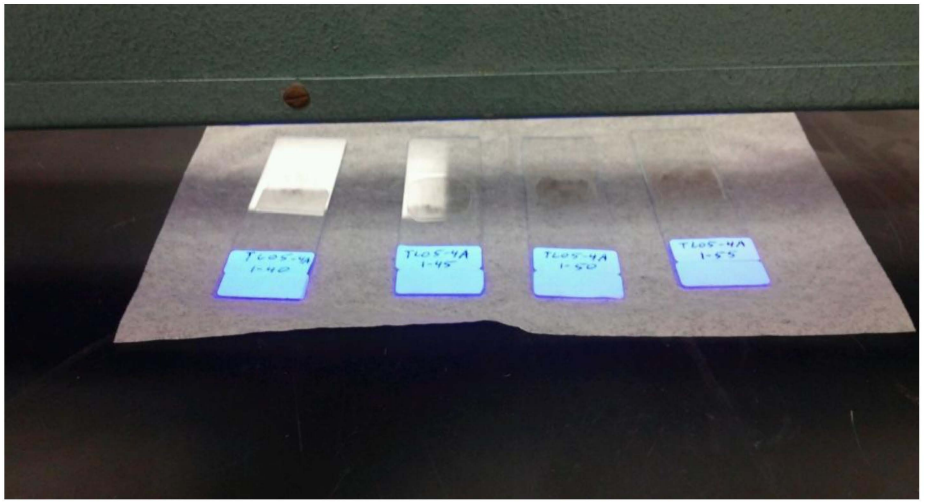


•The slide was dried on a hot plate and, once cooled, cemented using Norland optical cement as a medium.

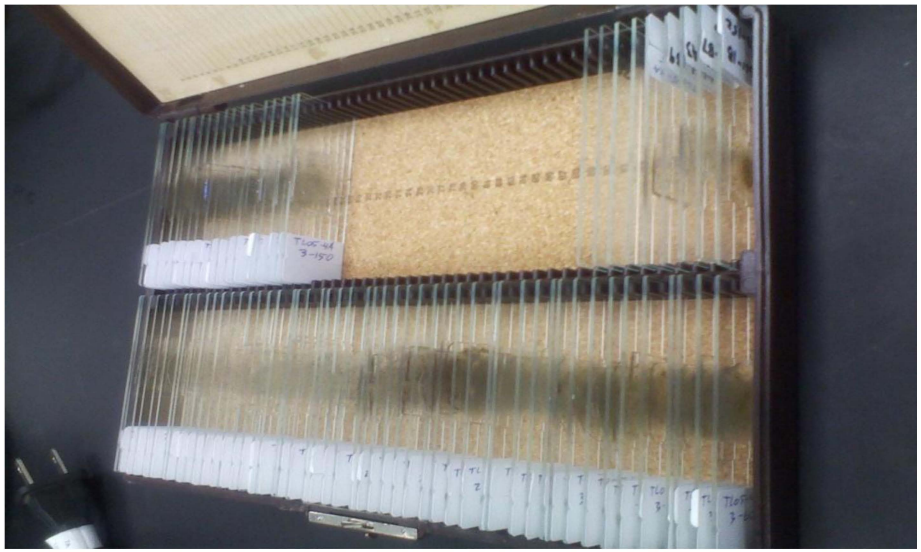
Method

Schnurrenberger (2003) smear slide technique

•A cover slip was then placed on top of the sample and cured under an ultraviolet light.



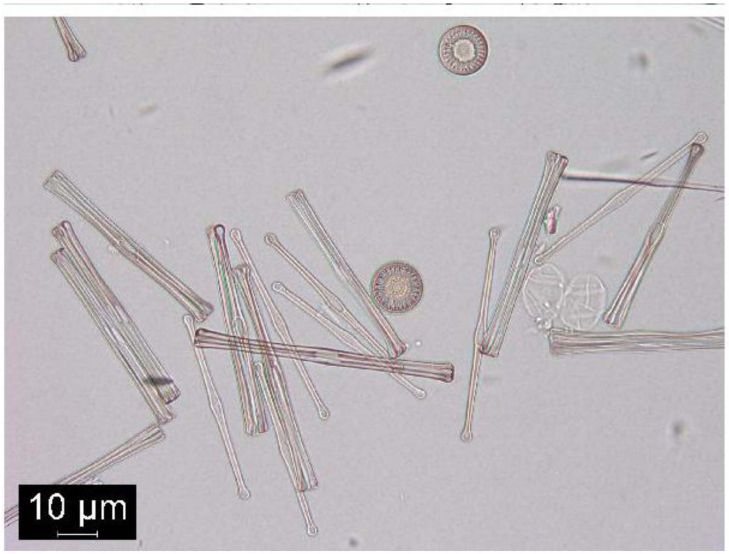
•The analysis was conducted using a petrographic microscope for both organic and inorganic material.

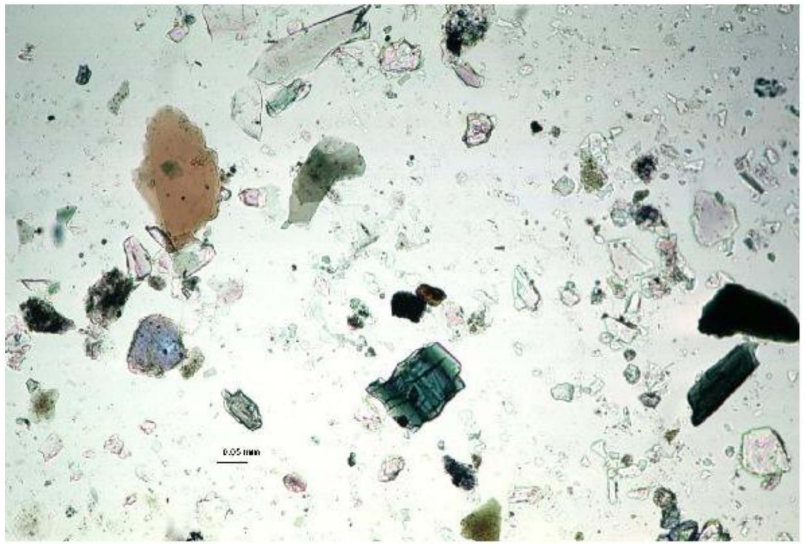


Previous Work using Method

•Previous work using the smear slide technique include Cohen's Paleolimnology textbook (2003) and the Benson et al. study on the Pyramid and Winnemucca lake basins (2012).

•There is also an online database through the University of Minnesota dedicated to the analysis of smear slides. This is the LacCore: National Lacustrine Core Facility.





Outline

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II. Background

III. Previous Work

IV. Method

V. Discussion & Predicted Results

VI. Preliminary results

VII. Summary

Discussion & Comparison with Predicted Results

	Time Interval	Predicted Lake Environment (Blunt, 2013)	Predicted Smear Slide Results	Preliminary Smear Slide Results
Zone 6	~19,000 – 18,000 yrs BP	Infilling of the lake as the temperature rose during the last glacial maximum (glacial outwash)	Little to no organic matter. Higher sand content.	Detrital minerals only (no precipitate minerals or organic matter)
Zone 5	~18,000 – 11,000 yrs BP	Filling of the lake due to flooding events (higher C/N ratio)	Increased terrigenous organics and higher silt content.	
Zone 4	~11,000 – 8,000 yrs BP	Fresh, deep lake conditions	Higher clay content, lack of precipitates	
Zone 3	~8,000 – 5,600 yrs BP	Shallower lake.	Precipitate minerals, coarser detritus	
Zone 2	~5,600 – 2,500 yrs BP	Shallow, but slowly deepening lake due to high runoff. High fluctuations.	High silt to clay content and terrestrial organic matter.	
Zone 1	~2,500 – 1,800 yrs BP	Shallow fresh water marsh.	High frequency and amplitude fluctuations in lake conditions including freshwater marsh organics.	Presence of pristine sponge spicules and freshwater pollen species *Typha* (i.e. cattail)

Presentation Notes:
In the time interval from 2,500 to 1,800 cal yr BP, Blunt (2013) suggests lake conditions as a shallow, fresh water marsh due to a low total inorganic carbon (TIC) value, which is not inconsistent with our initial observations of pristine sponge spicules and the pollen species *Typha* (i.e. cattail) in the smear slides from the corresponding depth interval. Cattails appear when there is renewed influx of fresher water into the Tulare Lake Basin. (Wigand, 2013) Using these initially observed relationships between smear slide content and previously collected geochemical and geophysical data, we may expect to have little to no organic matter present in the smear slides during the Tioga glaciation at ~18000 cal yr BP, which is characterized by a high silt content, low carbon to nitrogen ratio (C/N), and low TIC predicting a cold climate.

Outline

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II. Background

III. Previous Work

IV. Method

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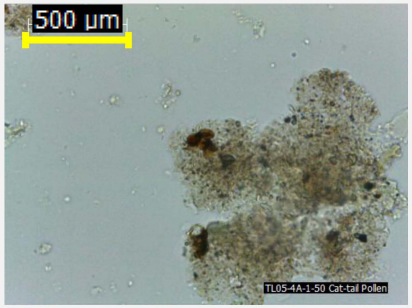
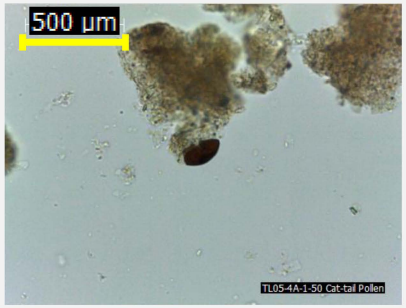
VI. Preliminary results

VII. Summary

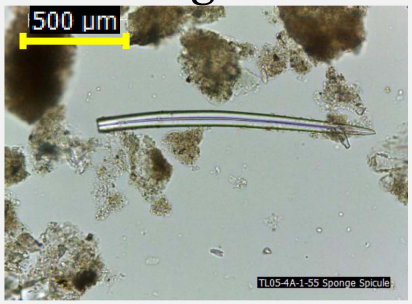
Preliminary Results: Uppermost zone-freshwater marsh

Typha (i.e. cattail) at 630 magnification under plane polarized light and attached to clay covered grains.





Fresh water sponge spicules at 400 magnification under plane polarized light. Spicules surrounded by mixed grain assemblages.



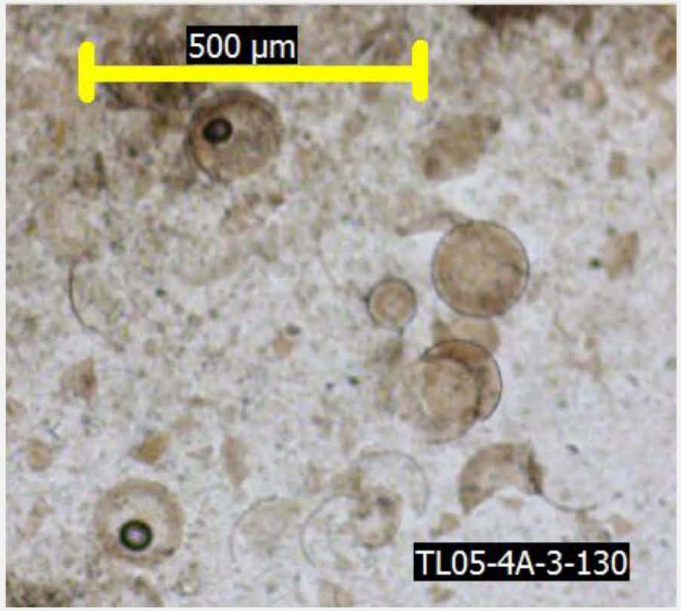
Juniperus communis (i.e. juniper) at 630 magnification under plane polarized light. Broken diatom to the left of the uppermost spores surrounded by clay.

Asteraceae (i.e. ambrosia) at 630 magnification under plane polarized light.

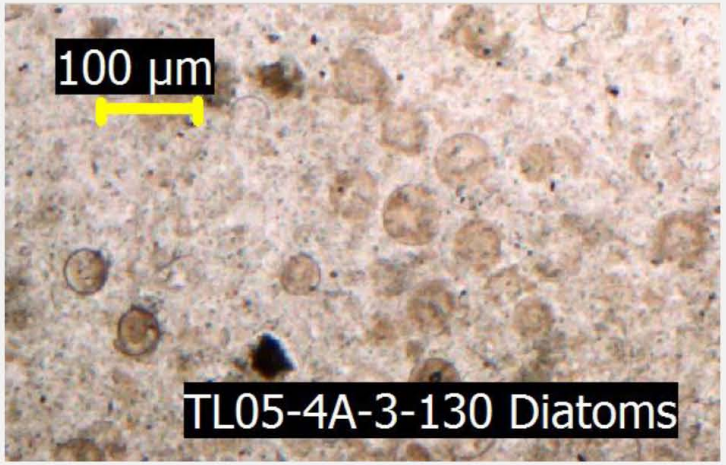
Preliminary Results: Lowest zone-glacial outwash

Detrital minerals at 40 magnification. There is an absence of both organic material and precipitate minerals as the glacier was washing into the basin.

Preliminary Results: End of glacial outwash



Diatom assemblage at 100 magnification under plane polarized light.



Diatom assemblage at 40 magnification under plane polarized light.

Presentation Notes:
The end of the glacial outwash is indicated by increased terrigenous organics and higher silt content. The diatom assemblage indicates fresh to slightly brackish oligotrophic to eutrophic waters from 18,000-17,650 cal yr BP. Coupled with the low CN during that time, likely fresh and oligotrophic.

Summary

- In the time interval from 2,500 to 1,800 cal yr BP, Blunt (2013) suggests lake conditions as a shallow, fresh water marsh due to a low total inorganic carbon (TIC) value, which is not inconsistent with our initial observations of pristine sponge spicules and the pollen species *Typha* (i.e. cattail) in the smear slides from the corresponding depth interval.

- The Tioga glaciation at ~18000 cal yr BP is characterized by a high silt content, low carbon to nitrogen ratio (C/N), and low TIC predicting a cold climate, which is seen in the smear slides as having no organic or precipitate minerals present.

- Using these initially observed relationships between smear slide content and previously collected geochemical and geophysical data, we predict to continue seeing consistent results throughout the remainder of the core.

Presentation Notes:
Cattails appear when there is renewed influx of fresher water into the Tulare Lake Basin. (Wigand, 2013)

Acknowledgements

- This project was supported by Agriculture and Food Research Initiative Competitive Grant no. 2011-38422-31204 from the USDA National Institute of Food and Agriculture.

- Funding for the purchase of the UIC Coulometer CM135, Costech 4010 Elemental Analyzer, and Malvern Mastersizer 2000 laser particle analyzer was provided by the US Department of Education Award #P031C080013-09.

- The NSF DHR CREST Award #1137774 also provided infrastructural support and salary support for other team members not supported by USDA funds.

Questions?

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