Toward a Sierran stream discharge forecast based on Tulare Lake-level reconstructions

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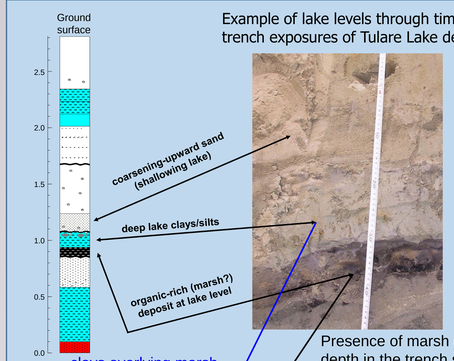
Abstract 1

The CSU Bakersfield Tulare Lake project team is studying outcrops, trench exposures and cores of lake sediments to build a high resolution record of lake-level change for Tulare Lake over the past 10,000 years. Because the level of Tulare Lake has been shown to be closely related to the collective discharge of its four major Sierran feeder rivers (Atwater et al., 1986), this record will also represent stream discharge into the southern San Joaquin Valley throughout the Holocene. Eventual comparison of this record with a growing database of Pacific sea-surface temperature (SST) records will establish a link between SSTs and Sierran river discharge, a link that will be exploited in forecasting Sierran discharge over the next few decades in response to expected changes in SSTs driven by global climate change. Initial lake-level results are based on trench exposures from near Kettleman City, on the NW edge of Tulare Lake (Negrini et al., 2006). Despite low temporal resolution, the overall lake level history has been confirmed by studies on lakes in southern California indicating that the observed climate events are regional (Kirby et al., 2011). Ongoing work is focused on increasing the temporal resolution to decadal in scale over the past millenium or two. This new work includes studies on lake sediment cores from the Kettleman City sites and outcrops exposed near the SE margin of Tulare Lake in a borrow pit on the Pixley National Wildlife Refuge. The core-based studies show that the relative lake levels inferred from geochemical (e.g., inorganic carbon %, C/N ratio) and geophysical (grain size) measurements on continuously deposited deep water sediments are consistent with results inferred from studies of exposed sediments in trenches (e.g., transition from laminated deep lake sediments to organic-rich sediments deposited in a nearshore marsh setting). Because the measurements on core samples are taken every cm or so down the core, they have the potential to provide data points representing every ~30 years.

West Side Sites: Trenches 3



Example of lake levels through time inferred from trench exposures of Tulare Lake deposits

clays overlying marsh deposits suggests deep lake after marsh

Presence of marsh deposits at this depth in the trench suggests that Tulare lake level was at 61 meters above sea level 6900 cal yr B.P.

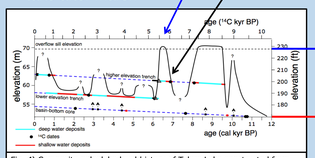


Fig. 4) Composite paleolake-level history of Tulare Lake constructed from two highstand trenches and a depocenter core (Negrini et al, 2006).

~10 km³/yr (8,000,000 acre ft/yr)

corresponding total stream discharge of 4 Sierran Rivers

< 2 km³/yr (< 1,600,000 acre ft/yr)

Consistent timing of deep lakes between Tulare Lake and southern California lakes over past 10,000 years

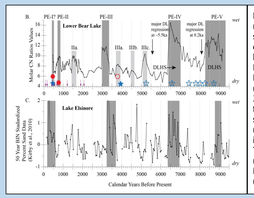
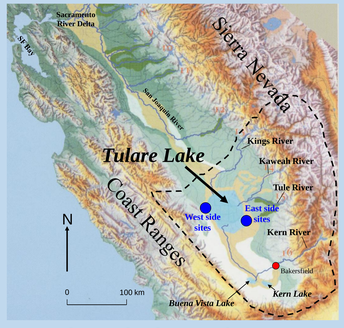


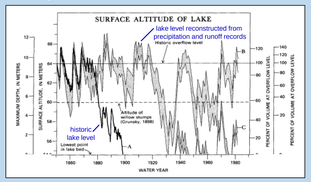
Fig. 5) C/N ratios and grain size data from other California lakes, Lower Bear Lake and Lake Elsinore (Kirby *et al.*, 2012). Signal from these lake supports regional implications of Tulare Lake record from Negrini *et al.* (2006).

Background 2

Tulare Lake is located in the San Joaquin Valley of California 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 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).

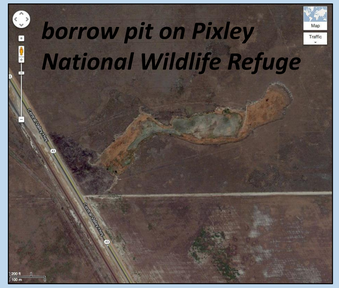


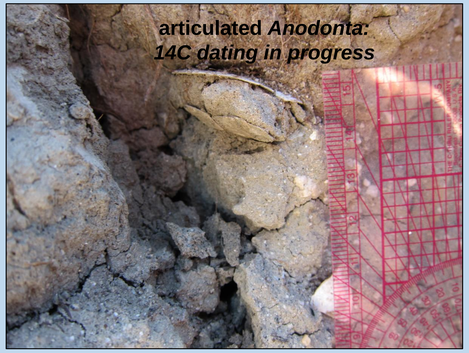
Tulare Lake drainage basin

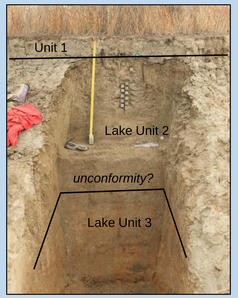


Tulare Lake levels before drainage diversions were closely related to Sierran stream discharge as per hydrologic balance model (Atwater et al., 1986). This results suggests that ***paleolake levels can be used to generate a prehistoric record of stream discharge.***

East Side Site: Pixley NWR 5

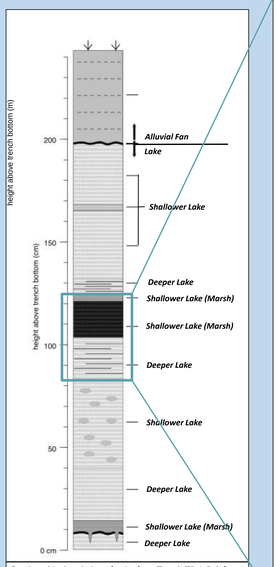




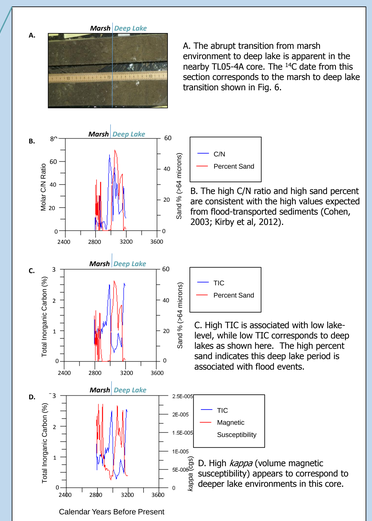


Initial excavations in PNWR borrow pit: Detailed record of most recent 1000 yrs?

West Side Sites: Improving trench records with detailed core studies. Toward multidecadal resolution? 4



Stratigraphic description of units form Trench TR A-D (after Negrini et al, 2006).



A. The abrupt transition from marsh environment to deep lake is apparent in the nearby TL05-4A core. The ¹⁴C date from this section corresponds to the marsh to deep lake transition shown in Fig. 6.

B. The high C/N ratio and high sand percent are consistent with the high values expected from flood-transported sediments (Cohen, 2003; Kirby et al, 2012).

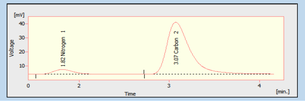
C. High TIC is associated with low lake-level, while low TIC corresponds to deep lakes as shown here. The high percent sand indicates this deep lake period is associated with flood events.

D. High *kappa* (volume magnetic susceptibility) appears to correspond to deeper lake environments in this core.

Geochemical and geophysical analyses of sediment cores sampled at 1 cm intervals are consistent with trench-based studies and show potential for multidecadal resolution

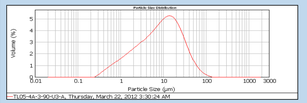
Carbon-Nitrogen Ratio

Samples were powdered and placed in a 105°C oven for at least 24 hours to remove any H_2O. 20-25 mg of each sample was measured and wrapped in tin foil cups then placed in the Costech 4010 Elemental Analyzer for analysis by flash combustion chromatographic separation, which yields nitrogen and total carbon weight percents. Total organic carbon is found by subtracting TIC values from TC values. High C/N ratio of may indicate flooding.



Grain Size Analysis

0.5 g of each sample was sieved to <1 mm. Samples were analyzed using four methods: 1) splitter, 2) vigorously stirred, 3) suspended grains, and 4) settled grains with a Malvern Mastersizer 2000. Abundant sand in otherwise silty sediment suggests flooding.



Magnetic Susceptibility

Samples were placed into a MS2 magnetic susceptibility meter to determine magnetic susceptibility (*k*), which indicates the variation in the amount of magnetite during deposition. Magnetite concentration often varies with lake condition but sense of change varies from lake system to lake system. Preliminary results for Tulare Lake suggests that *k* is high when lake level is high.

Total Inorganic Carbon

Each sample was ground and placed into a 105°C oven at least 24 hours. Approximately 100 mg sub-samples were analyzed for total inorganic carbon using a UIC acidifier module and coulometer CM135. High TIC often indicates low lake levels.

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Future Work

- ¹⁴C and paleomagnetic secular variation dating of west-side and east side sites.
- Geochemical and geophysical proxy measurments for east-side sediments
- Micropaleontology for all sites
- Location and excavation/coring of 4-5 more sites
- Compilation of composite multidecadal lake-level/stream discharge record and comparison with sea-surface temperature records to establish an SST/Sierran discharge transform function

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