Holocene Salinity Variations in Great Salt Lake, Utah: Application & Calibration of the ACE Salinity Proxy

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November 23, 2022

Abstract

The Great Salt Lake (UT) is a hypersaline terminal lake in the US Great Basin, and the remnant of the late glacial-pluvial Lake Bonneville. During the Holocene, hydroclimate variations have been more subtle in the basin. These variations can be investigated by organic geochemical methods within the sediment core GLAD1-GSL00-1B, cored in 2000 and recently well-dated by radiocarbon for the Holocene section (Bowen et al., 2019) with 11 meters representing 8 ka to present. Sediment samples every 30 cm (˜200 years) were extracted and the total lipid extracts were analyzed by HPLC-MS to detect the full suite of microbial membrane lipids, including those responsive to temperature and salinity. Modern samples were also collected to provide local calibration for the archaeol-caldarchaeol ecometric (ACE) salinity proxy, where ACE = archaeol/(archaeol + caldarchaeol). ACE detects the increase in lipids of halophilic archaea, relative to generalists, as salinity increases. From currently analyzed data and calibrations, we find Holocene lake salinity estimates ranged from 239 to 283 psu, suggesting persistent hypersalinity with $<$ 50 psu variability across 8 kyr. For comparison, the modern salinity of the lake ranges from 100 to 160 psu in the southern half, and 240 to 270 psu in the north. From ˜7-6 ka, salinity estimates were relatively high at 270 to ˜280 psu. Following 6 ka, salinity decreases and reaches its lowest value of 239 psu at 4.8 ka. Afterwards, salinity increases and varies between ˜250 to ˜270 psu, remaining at 270 psu in the last 1 kyr. This new salinity record is compared to available shoreline reconstructions and regional climate records. The temperature proxy, MBT'$_{5Me}$, as calibrated by BayMBT, suggests mean annual air temperature estimates ranged from 12°C to 24°C (compared to modern mean temperature of 13°C). This indicates a substantial, variable complication from salinity in this consistently hypersaline lake, as recently reported for the MBT'$_{5Me}$ proxy.

Holocene salinity variations in Great Salt Lake, Utah

Application of the ACE salinity proxy and other GDGT indices

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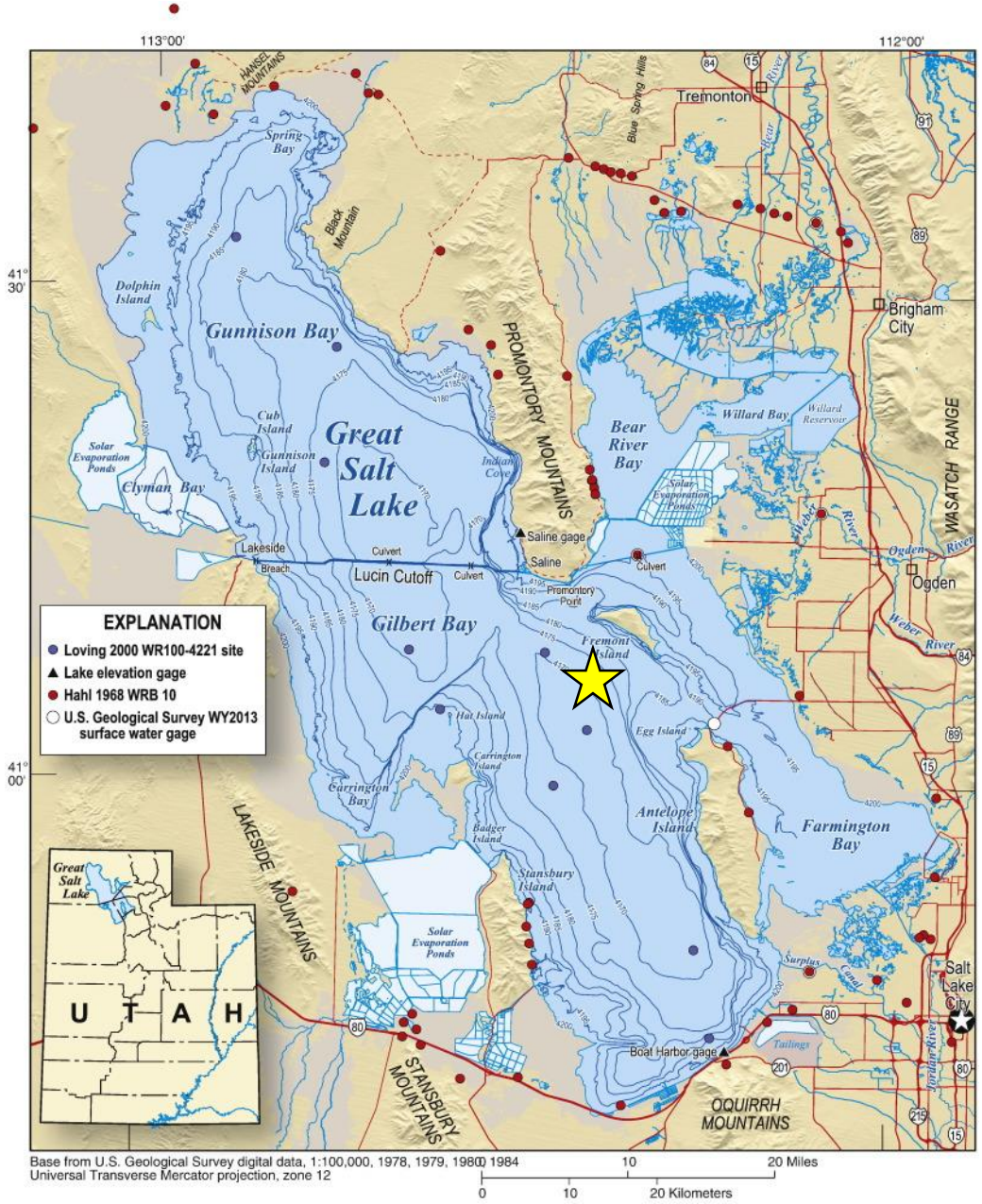
GSL Project details

- Holocene paleosalinity record
- Sediment from GLAD core 1B
  - 35 samples
  - 7206 to 291 cal yr BP
  - Bowen et al. (2019) age model
- Modern GSL conditions
  - Salinity range: 40-275 psu
  - pH: 8-9
  - Salt Lake City MAAT: 11.5°C
  - Salt Lake City MAF: 14.1°C

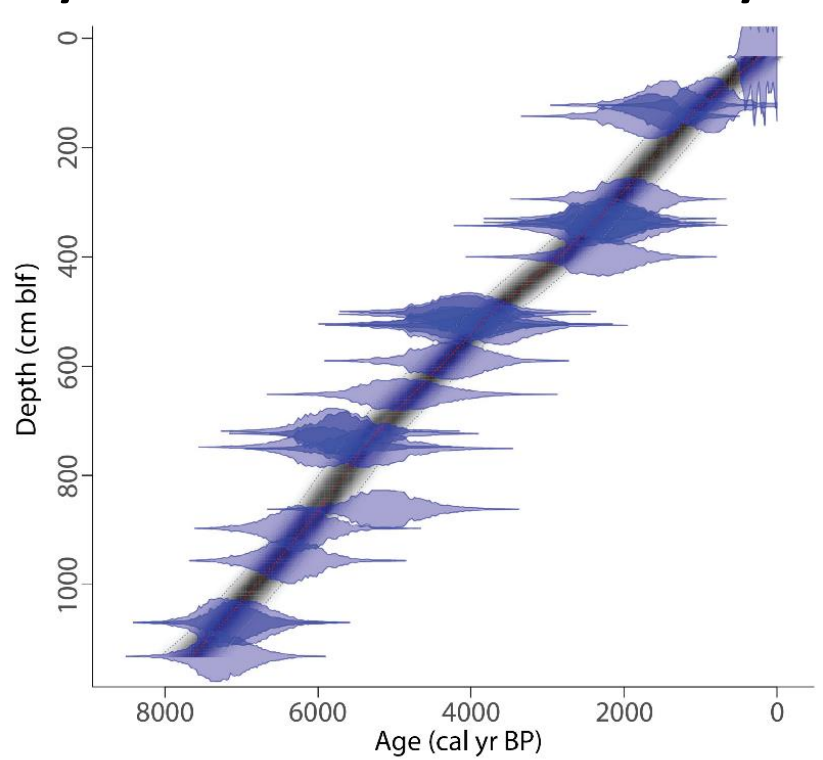


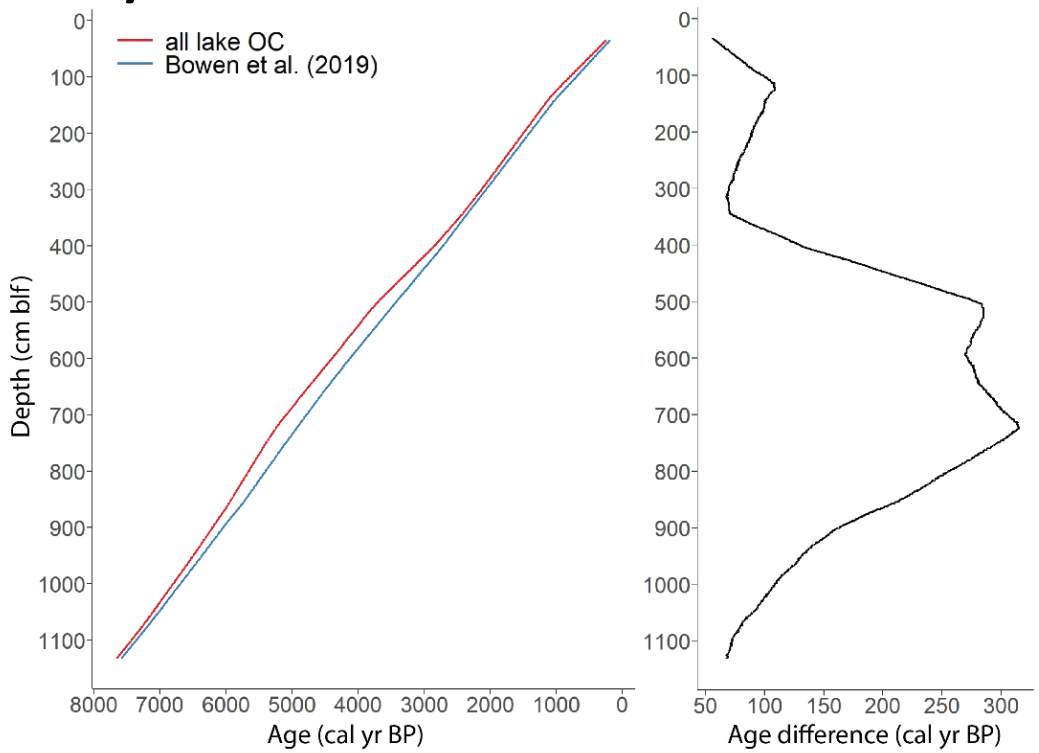
Shope and Angeroth (2015)

Radiocarbon Age Model

- Used more data points from Bowen et al. (2019) to constrain BACON age model
- Includes all lake-derived organic matter
- <300 yr difference from cyst-only model

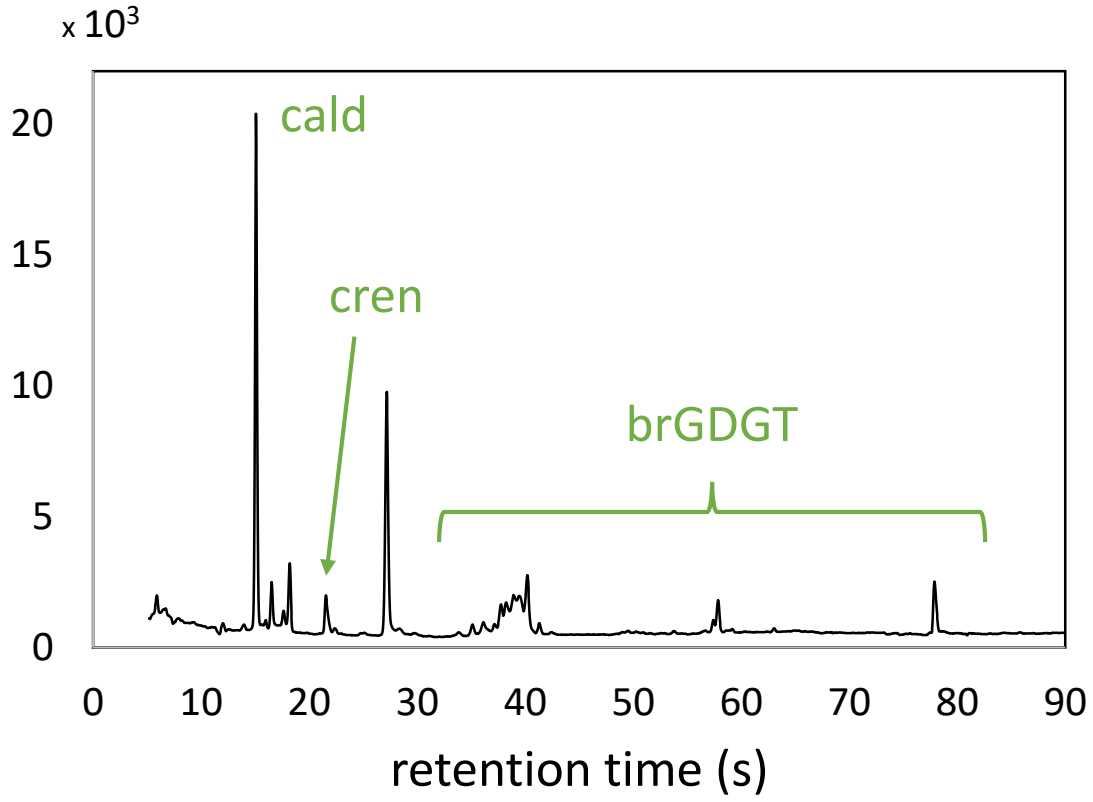
Bowen et al. (2019)

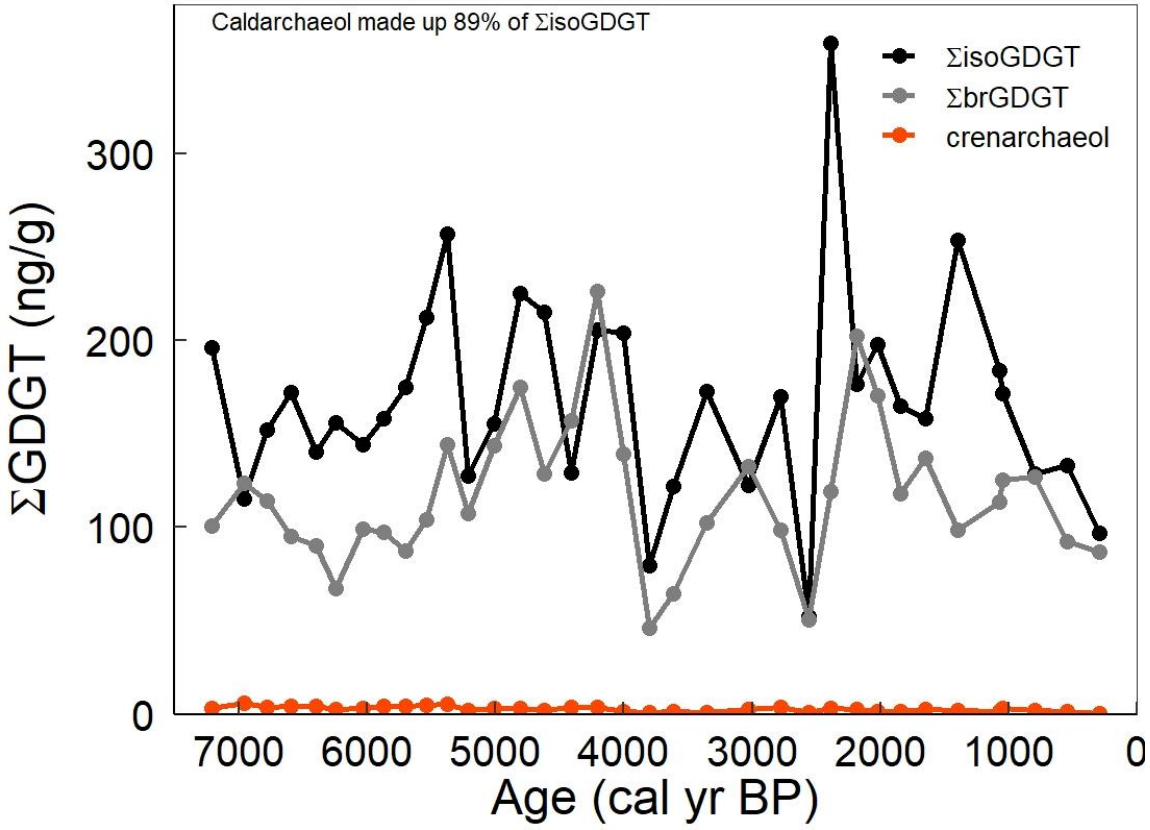




GSL microbial community lipids

- Caldarchaeol dominates isoGDGTs (89%), used for salinity proxy
- Crenarchaeol trivial, low lake production
- BrGDGTs used for temperature proxy





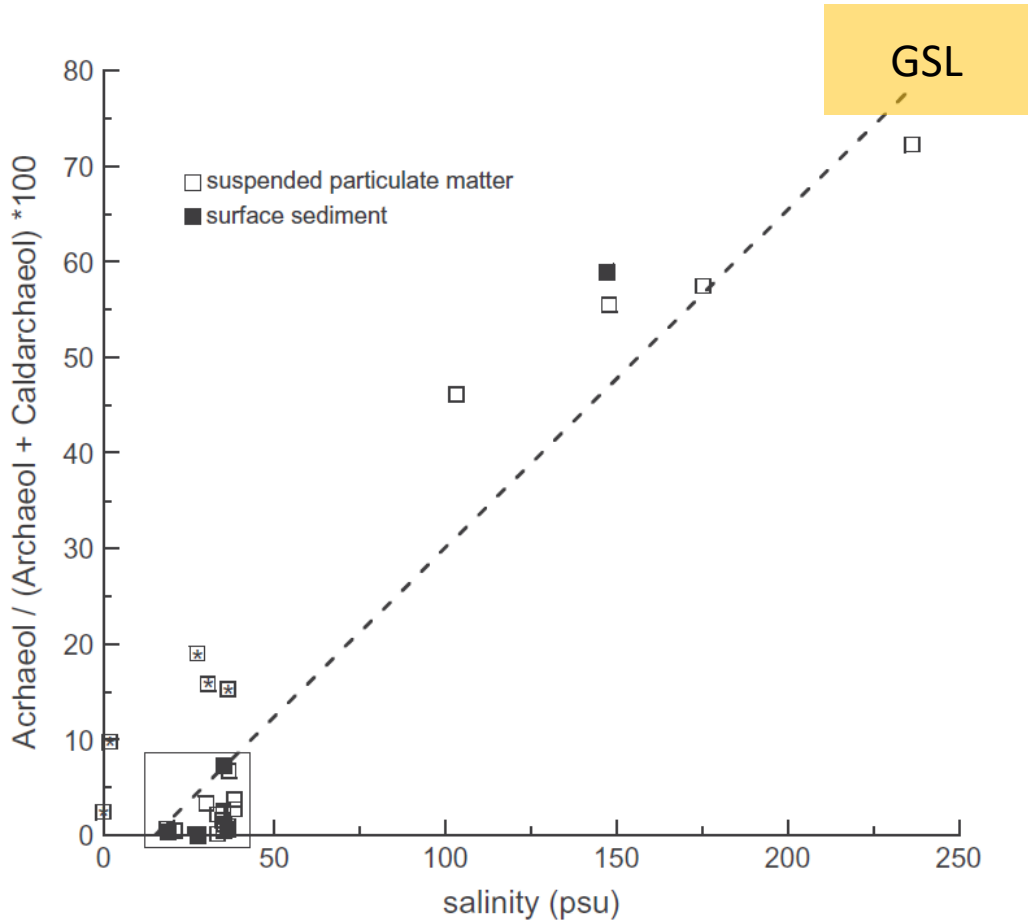
ACE Salinity Proxy

- Turich and Freeman (2011)

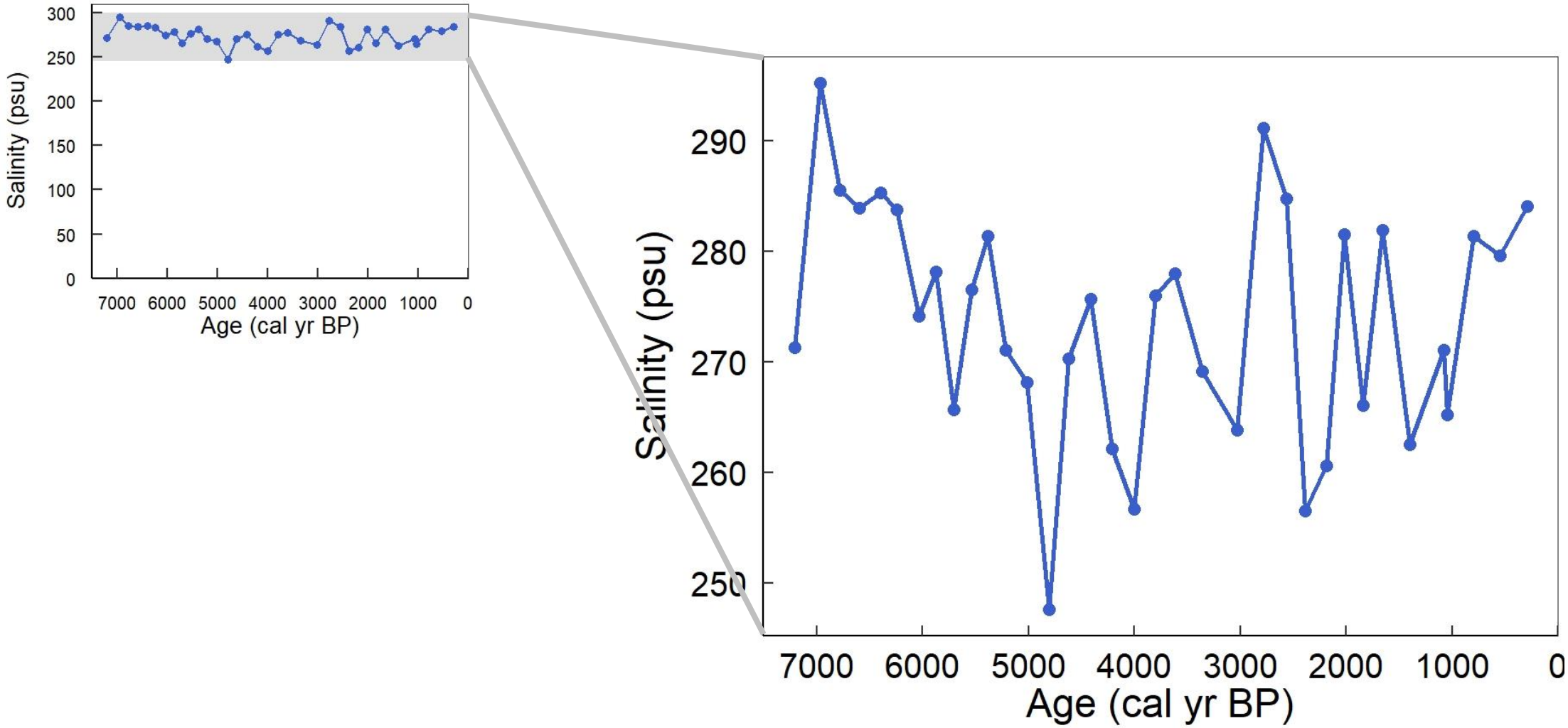
$$ACE = \frac{archaeol}{archaeol + caldarchaeol} \times 100$$

$$ACE = 0.35 \times salinity - 5.4$$

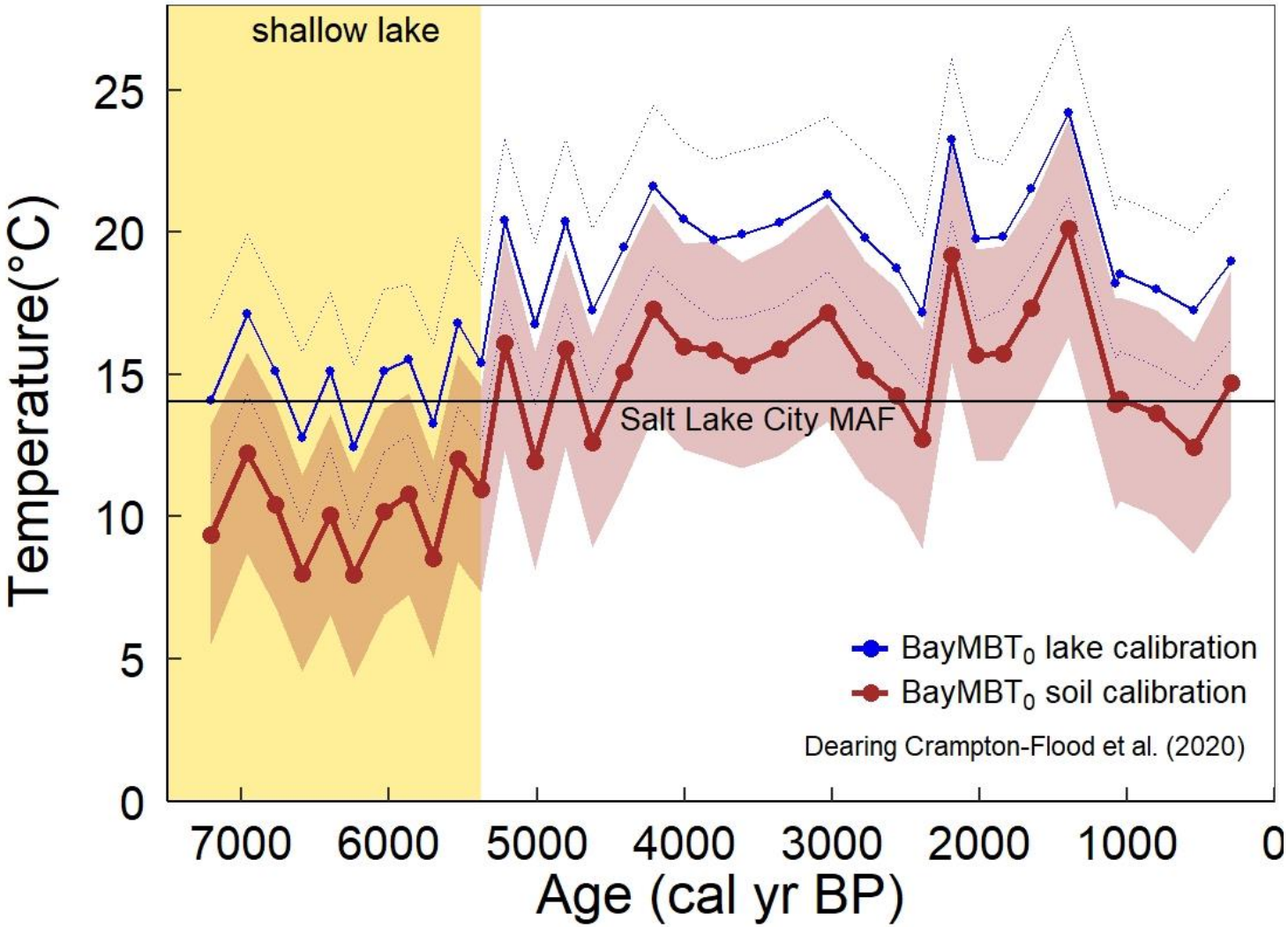
- Low proxy sensitivity at upper end of ACE index (0.8-1)



ACE detects hypersalinity and <50 psu variability in Holocene GSL Record



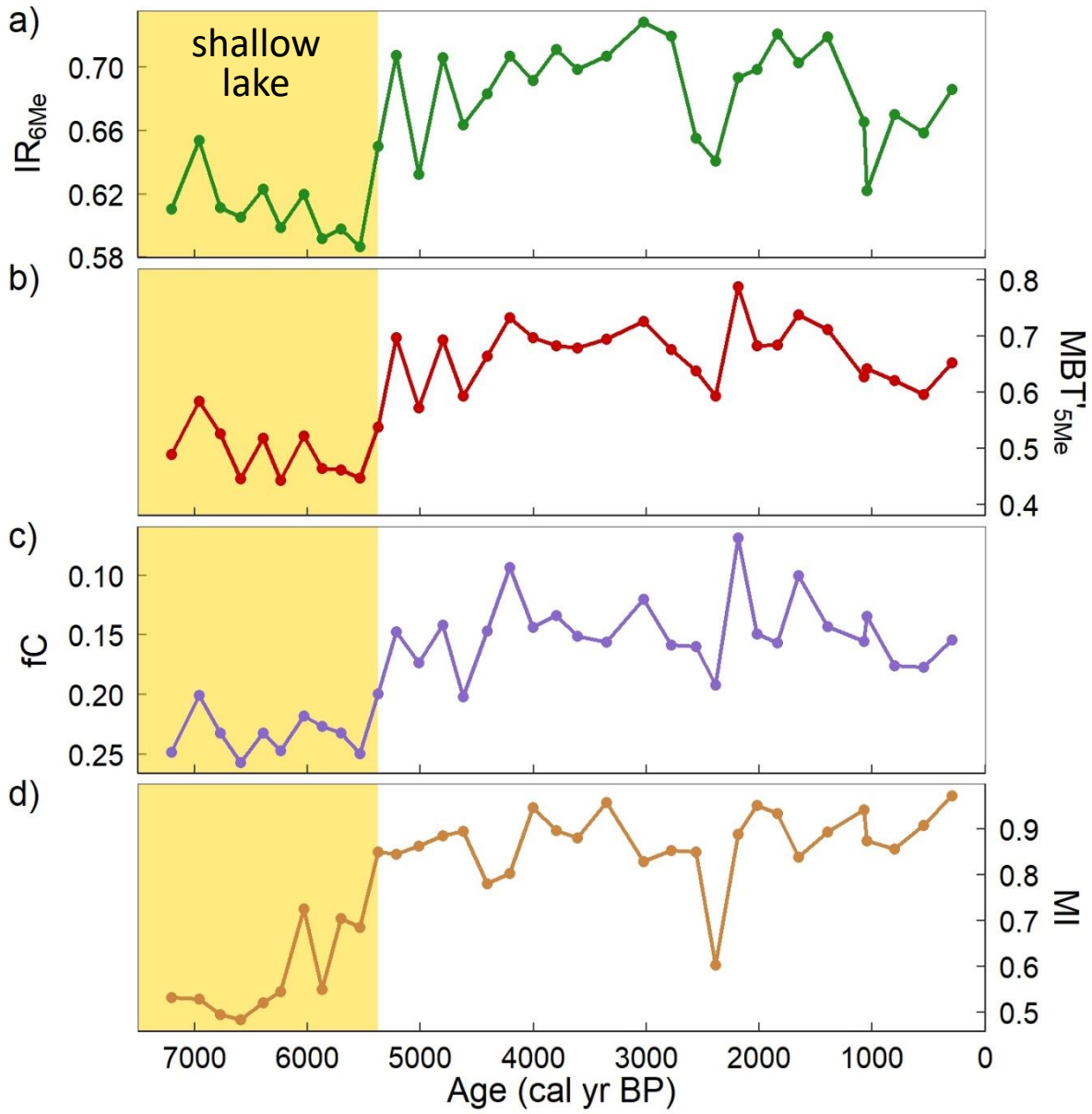
MBT'_{5Me}: Soils calibration suggested for hypersaline lakes



- Lake calib. has warm bias in saline lakes
- Soil calib. has realistic estimates after ~5.5 ka
- Proxy indicates stable T after ~5.5 ka

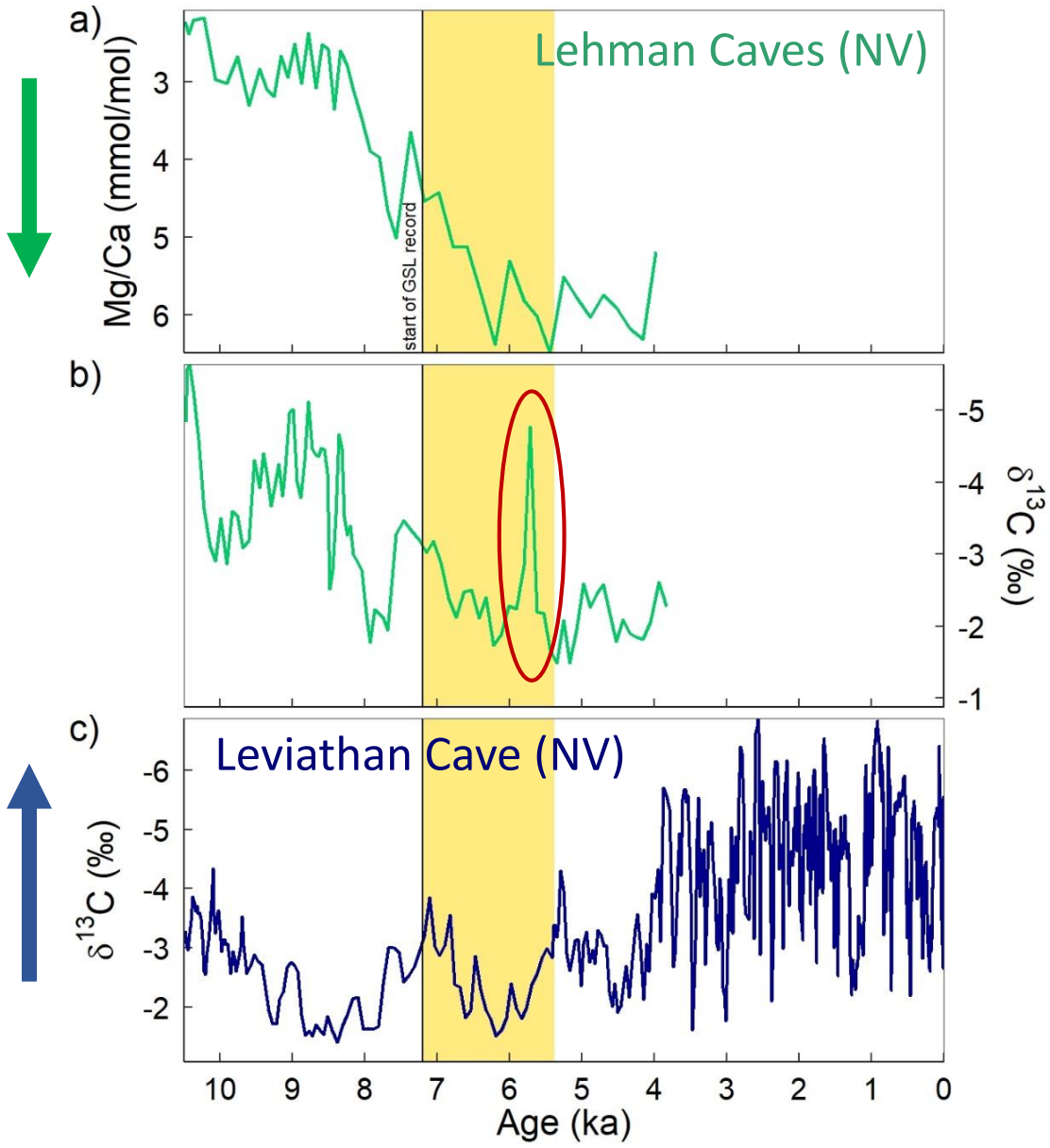
~5.5 ka step change in IR_{6Me}, MBT'_{5Me}, fC, MI

- Regional climate dry in Mid-Holocene
- Change in lake ecology after ~5.5 ka
- MI increases after ~5.5 ka
- Increased methanotrophs and deep (>10 m), stratified lake



Great Basin Speleothems

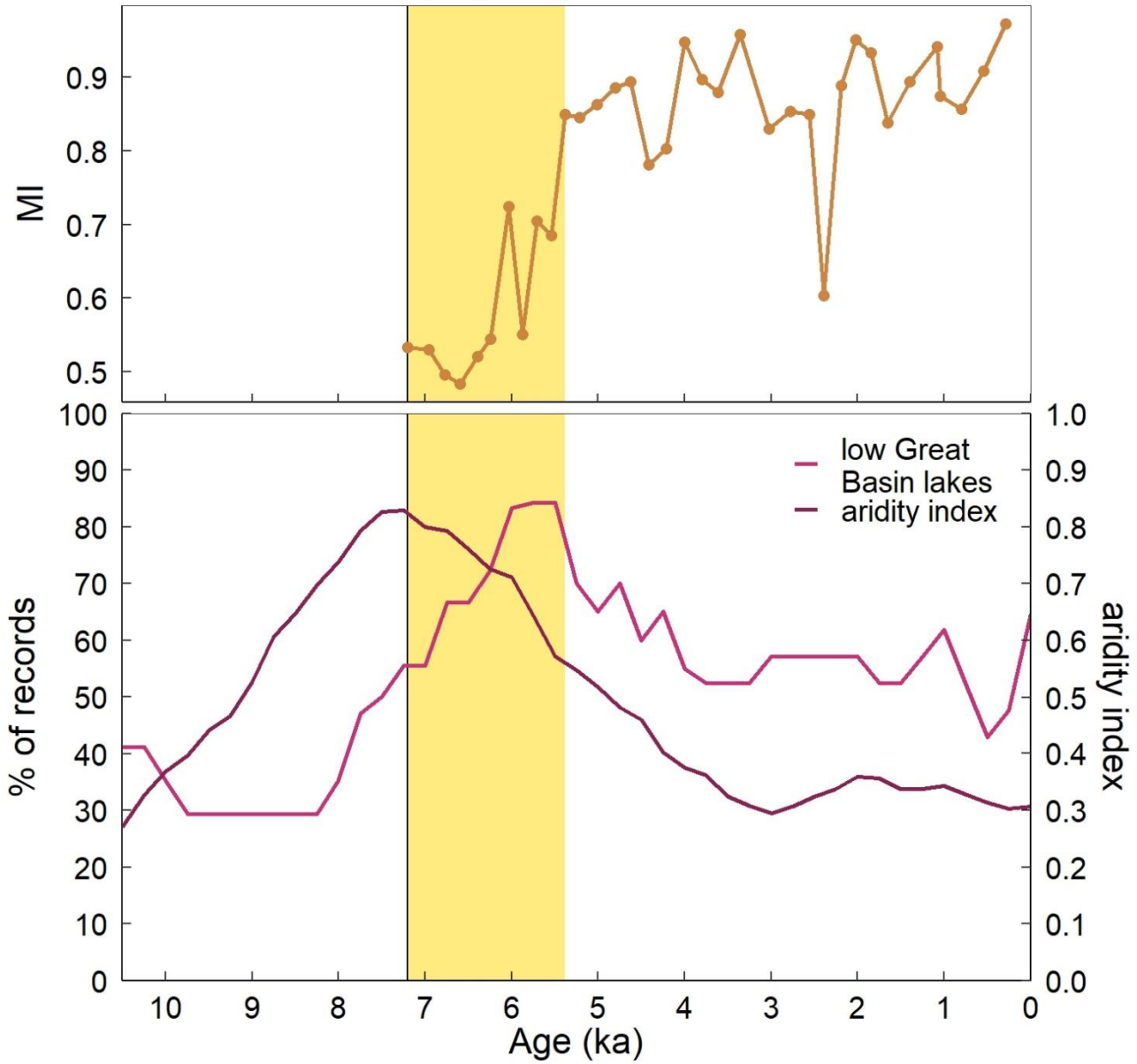
- 8 ka onset of aridity
- Spike in water infiltration before step change
- Increased effective moisture after 4 ka



Steponaitis et al. (2015)
Lachniet et al. (2020)

GSL and Regional Climate

- Peak aridity in SW US at ~7.5 ka.
- Large number of low lakes in Great Basin ~6 ka.
- Coincide with GSL GDGT step change



Steponaitis et al. (2015)
Lachniet et al. (2020)

Holocene GSL conclusions

- Hypersaline throughout record, <50 psu of salinity variability, near upper limit of ACE index
- MI detects threshold in lake depth (~10 m)
- BayMBT$_0$ soil calibration better for Late Holocene GSL
- Evidence for Mid-Holocene drought
- Varying hypersaline lake chemistry, lake ecology, and stratification affect proxy functionality
- Future work is to expand regional ACE calibrations

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