Lake-level changes in the Dead Sea during the Late Pleistocene recorded by fossil lake shorelines.

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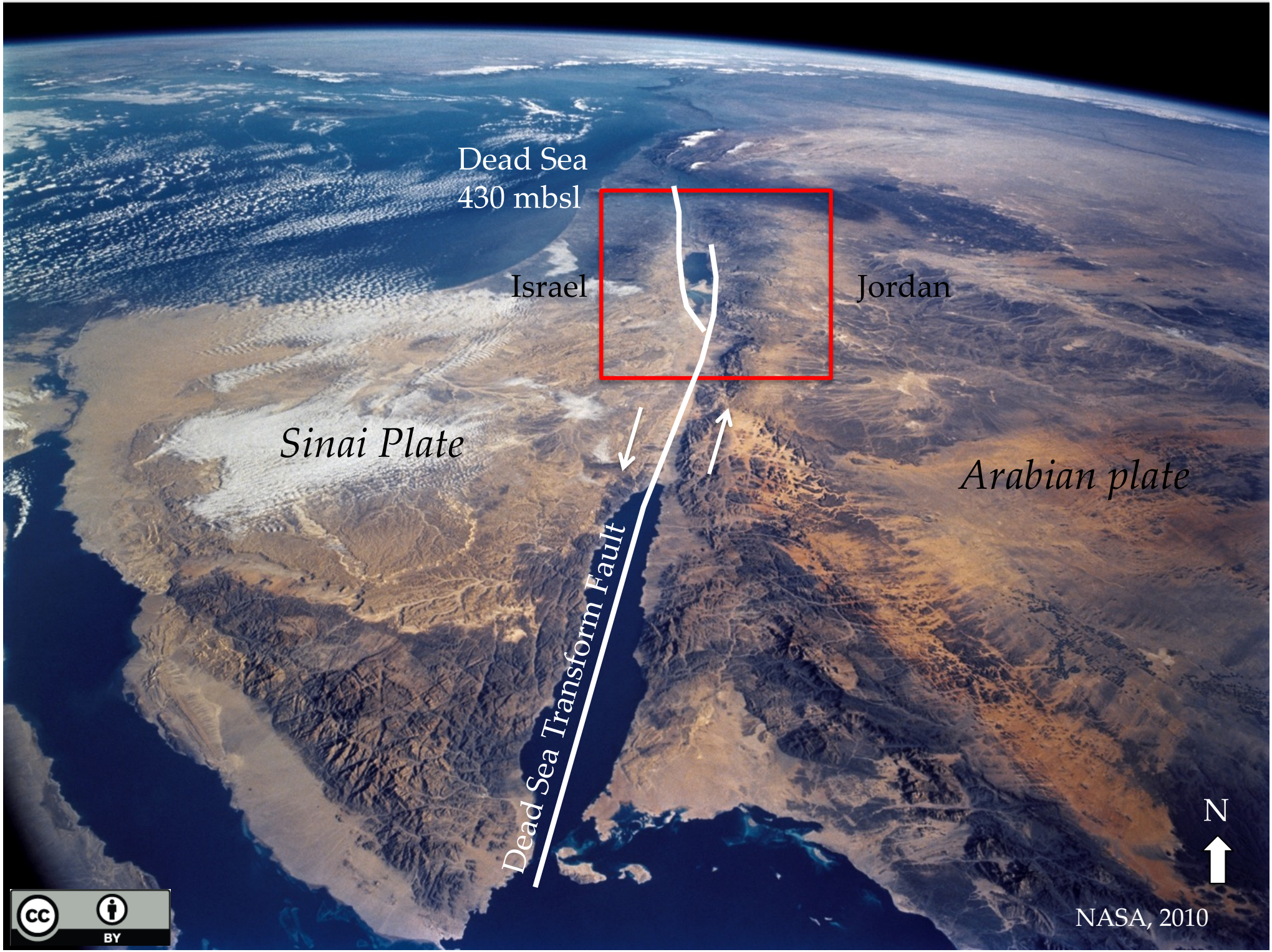
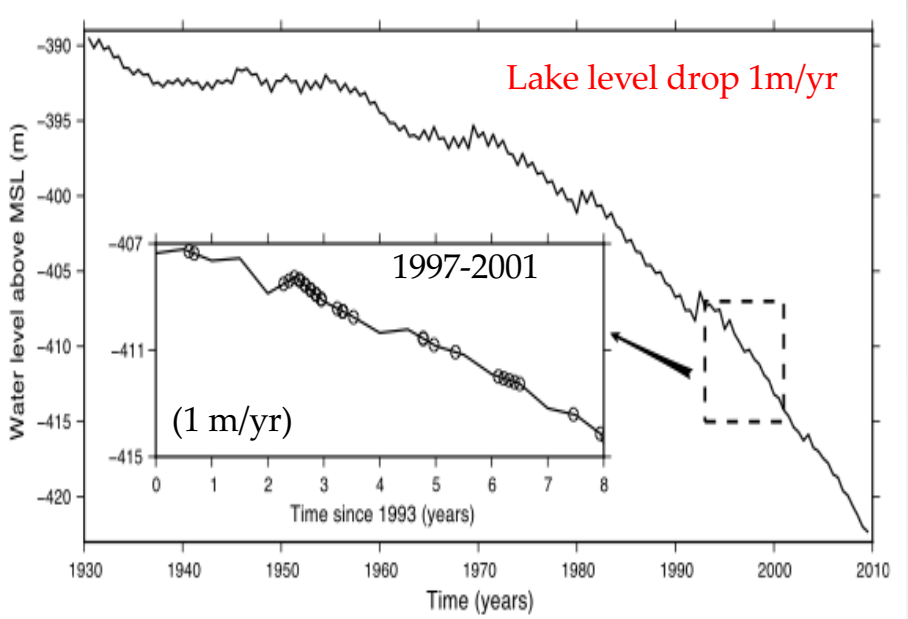
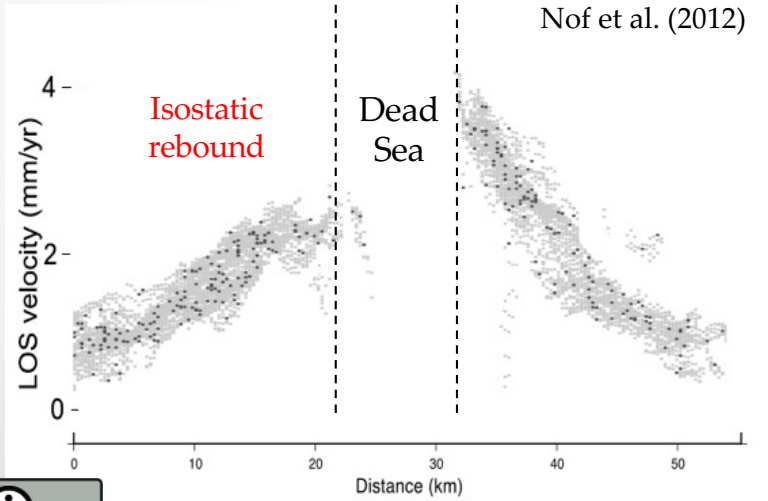

Dead Sea
430 mbsl
Israel
Jordan
Sinai Plate
Arabian plate
Dead Sea Transform Fault
N
NASA, 2010

Lake-level changes in the Dead Sea basin

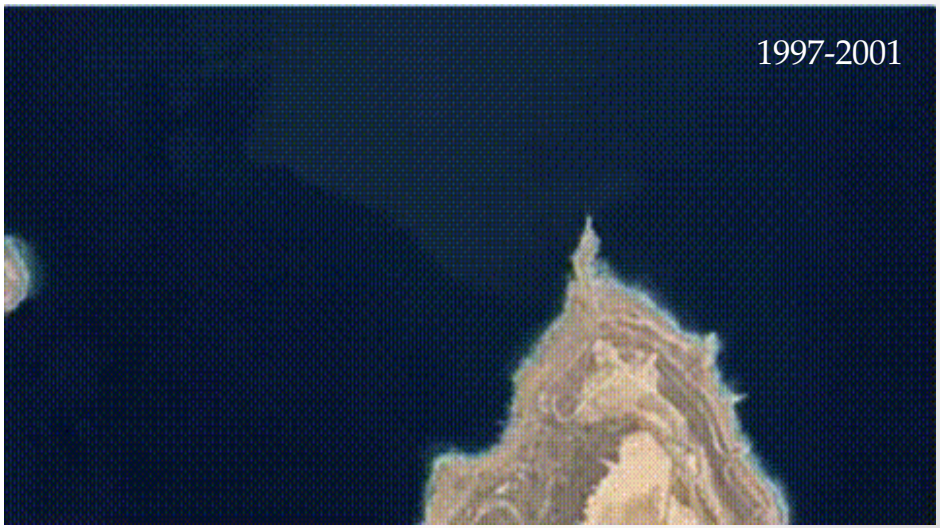
- Global warming and anthropic effects = dramatic lake level drop.
- Fast lake drop 1m/yr since 1970.
- Impact in the coastal morphology and the crust



Nof et al. (2012)



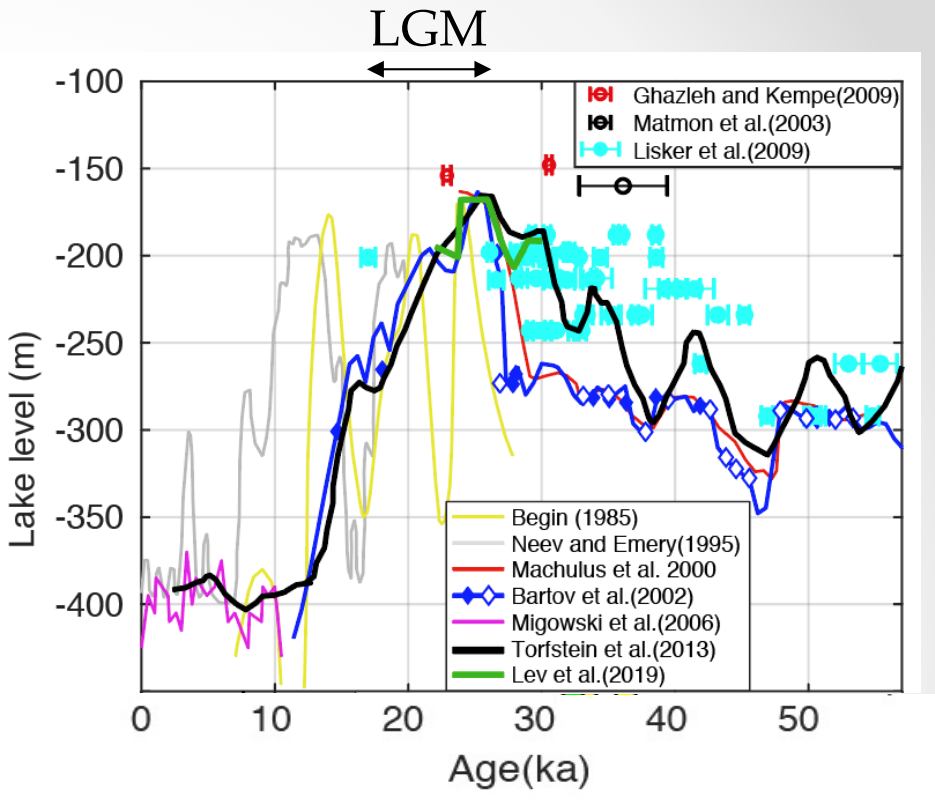
Nof et al. (2012)



Landsat time-lapse, Google-Engine

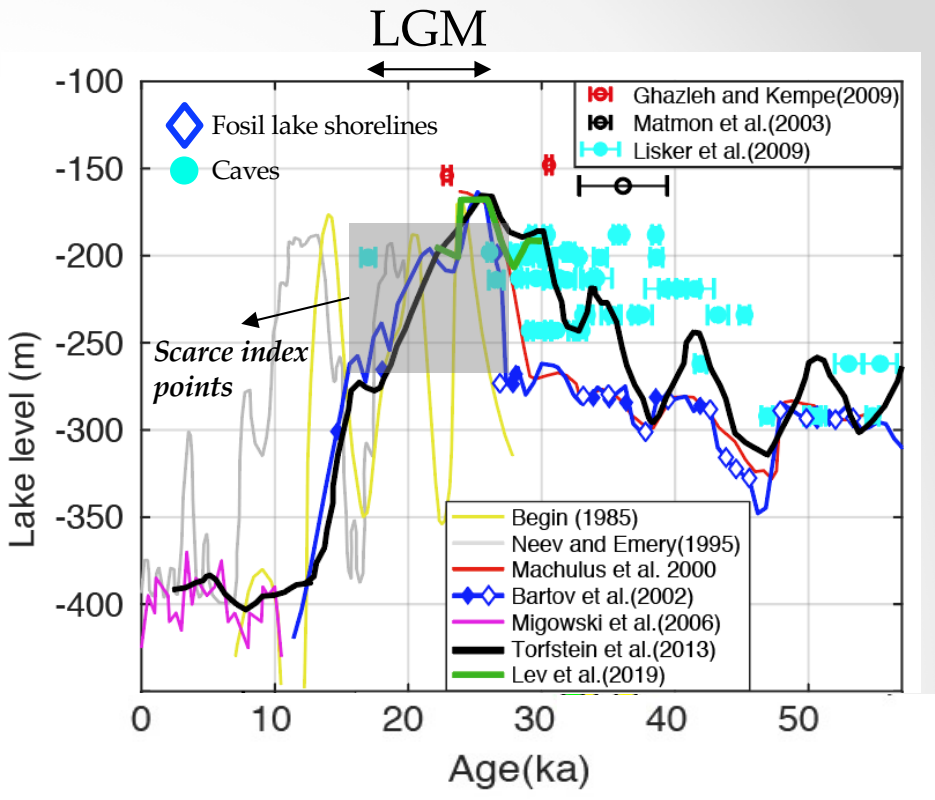
Lake-level changes in the Dead Sea basin

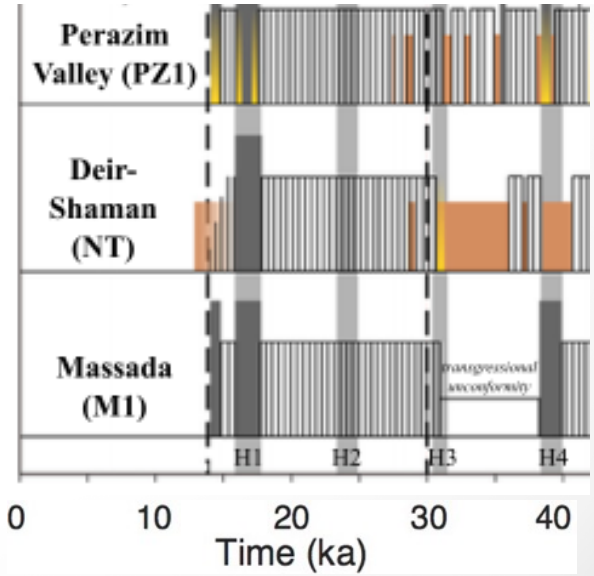
- Several lake level reconstruction during the Late Pleistocene and Holocene
- All of them suggest a highstand period during the LGM, known as Lake Lisan
- Followed by abrupt lake level drop after the LGM (Dead Sea)
- However, there are different points of view regarding the timing of lake level drop



Lake-level changes in the Dead Sea basin

- Latest reconstructions of lake level changes during LGM are based on lacustrine sediments Lisan Fm.
- High temporal resolution (U/Th and radiocarbon)
- Scarce index points (caves and fossil shorelines).
- Big spatial uncertainty regarding lake level positions





Torfstein et al., 2013

- In the other hand, the Dead Sea basin poses a unique sequence of dozens of lake shorelines exposed along the rims of the basin
- They represent fossil records of past lake level positions

Questions

- What can the fossil lake shorelines tell us about lake level changes in the Dead Sea basin?
- Are lake level reconstructions based on lake sediments analogous to lake-level changes registered by fossil lake shorelines?

Methods

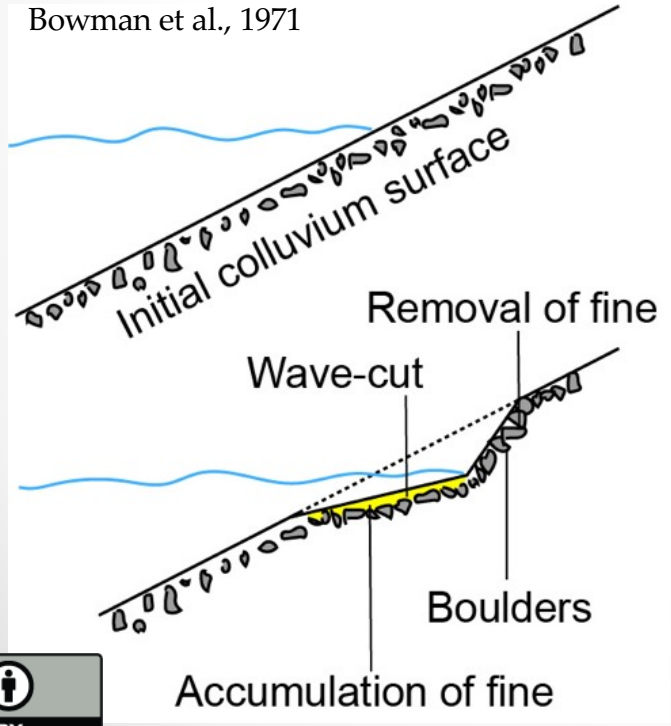
- High resolution drone topography of fossil lake shorelines at 8 sites in Israel and Jordan
- U-series and radiocarbon dating of stromatolites in each site
- Numerical modelling (Isostaic rebound)

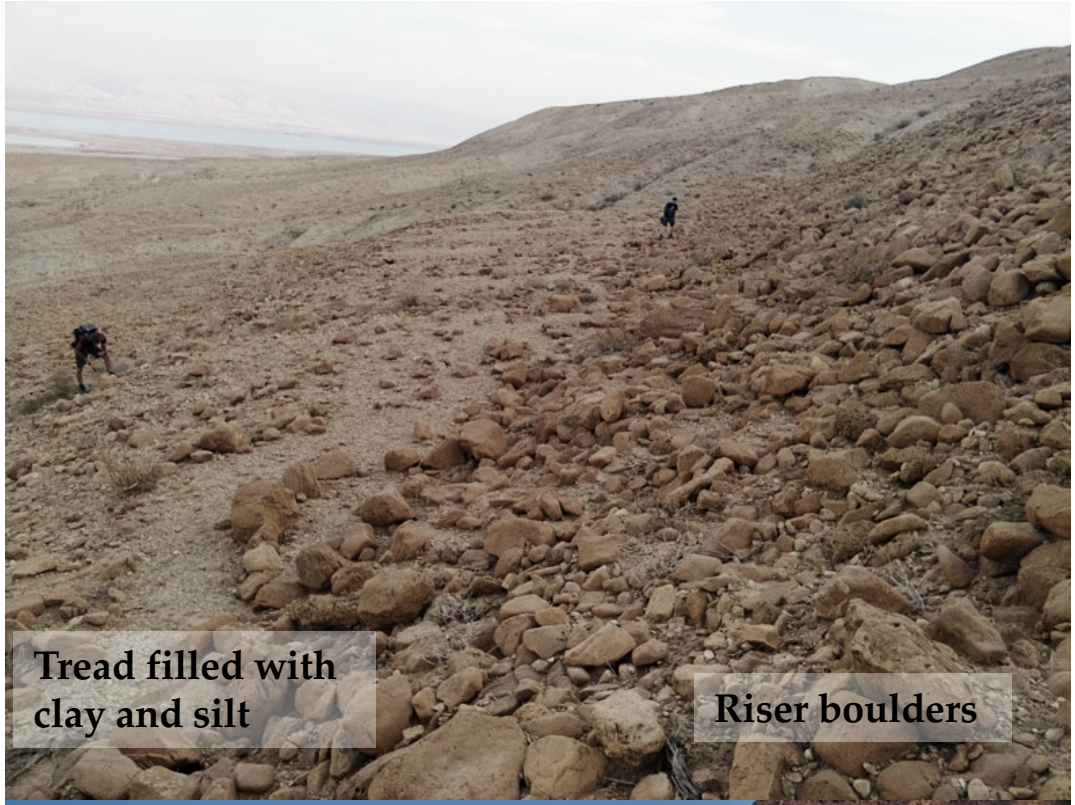
Examples of sampling and survey sites in Israel and Jordan

Lake shorelines

- Lake shoreline morphology, riser and tread.
- Tread formed by wave-cut platform or fine sediments.
- Risers formed by boulders

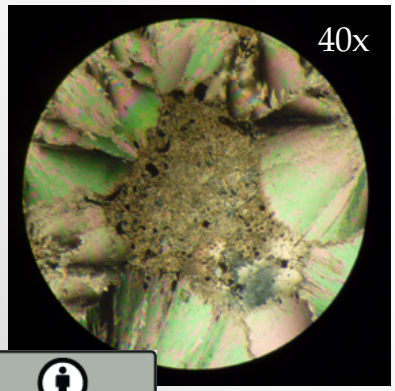
Bowman et al., 1971

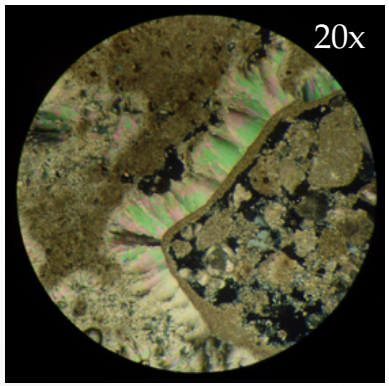




Fossil stromatolites

- Stromatolites associated to lake shorelines
- Sampling in situ specimens when possible
- Diverse texture and morphologies
- Formed by aragonite and detrital layers

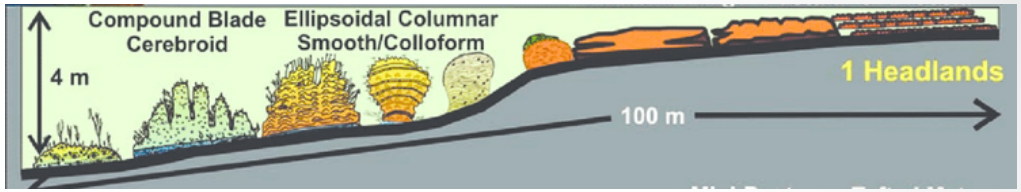




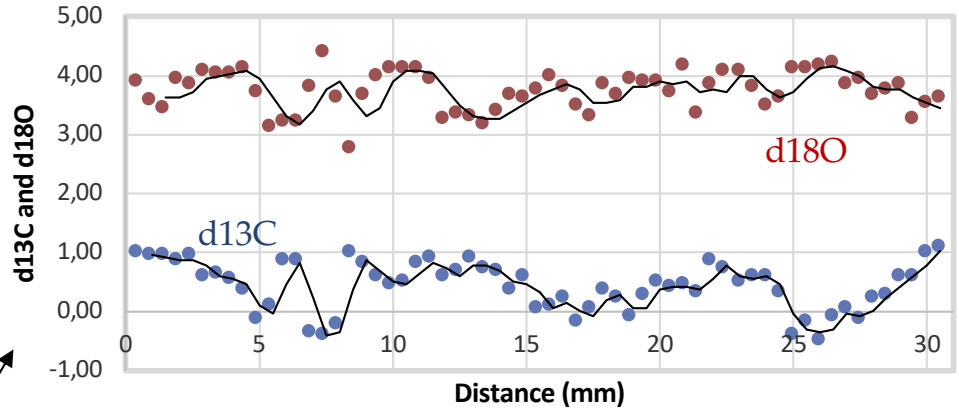
Can we use stromatolites to reconstruct lake level variations?

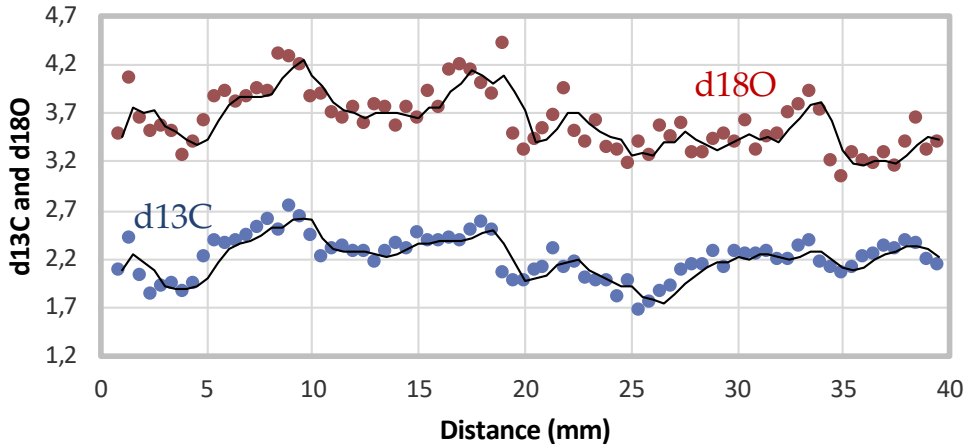
Arguments:

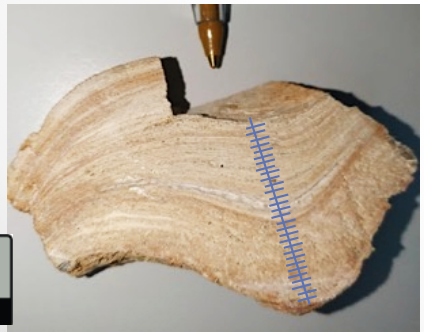
- Cyanobacteria live within the photic zone, but exceptions may occur (e.g. cave stromatolite, deep stromatolite)
- Isotope variability at millimeter scale resemble seasonal changes: *Occurring at shallow water depths.*
- Stromatolites were found in direct association to lake shorelines morphology



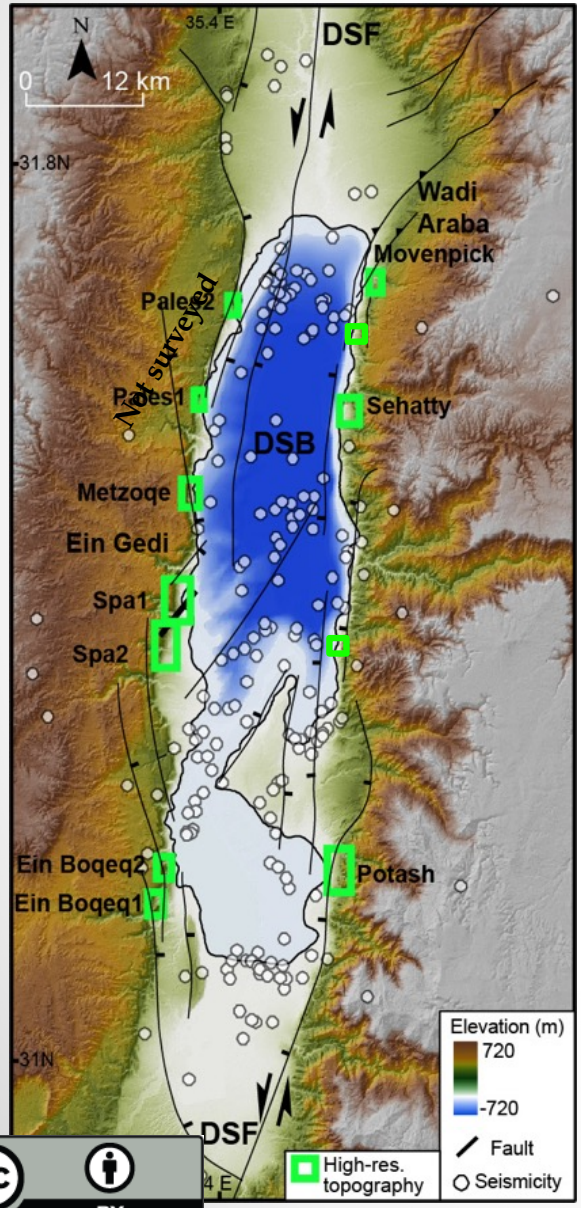
Jahnerta & Collins,2012, Marine Geology. Australia

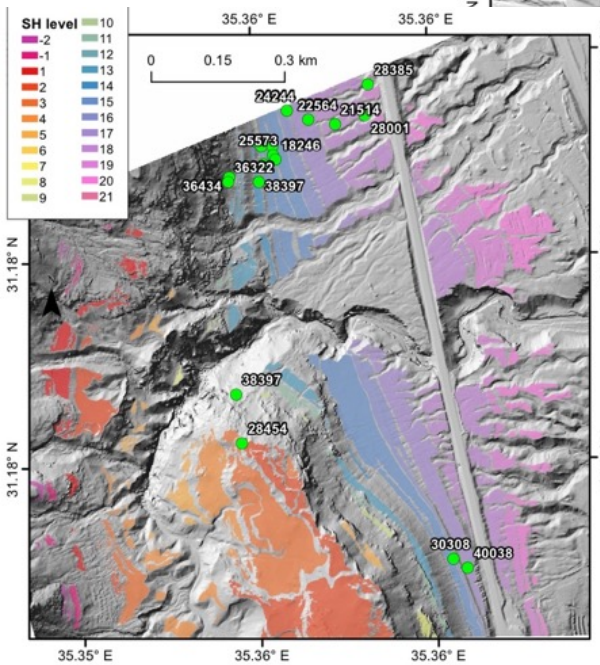


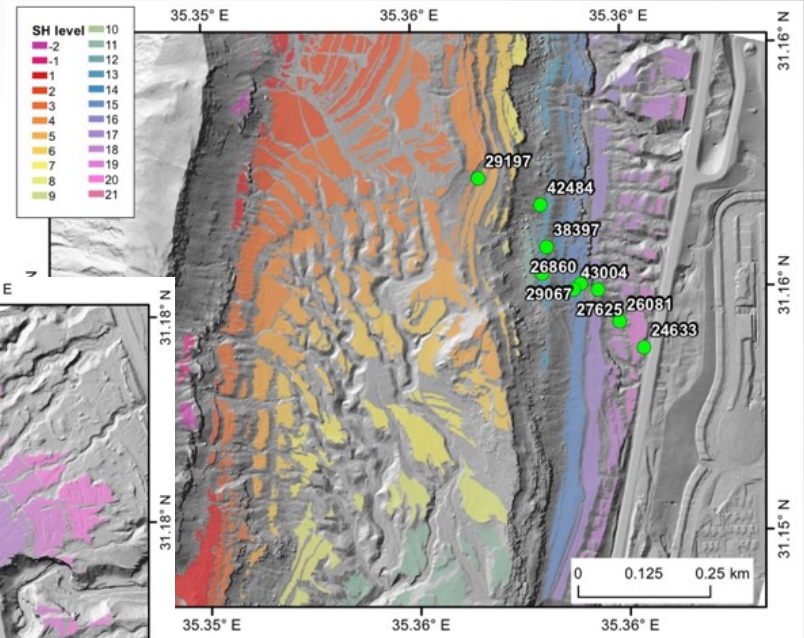


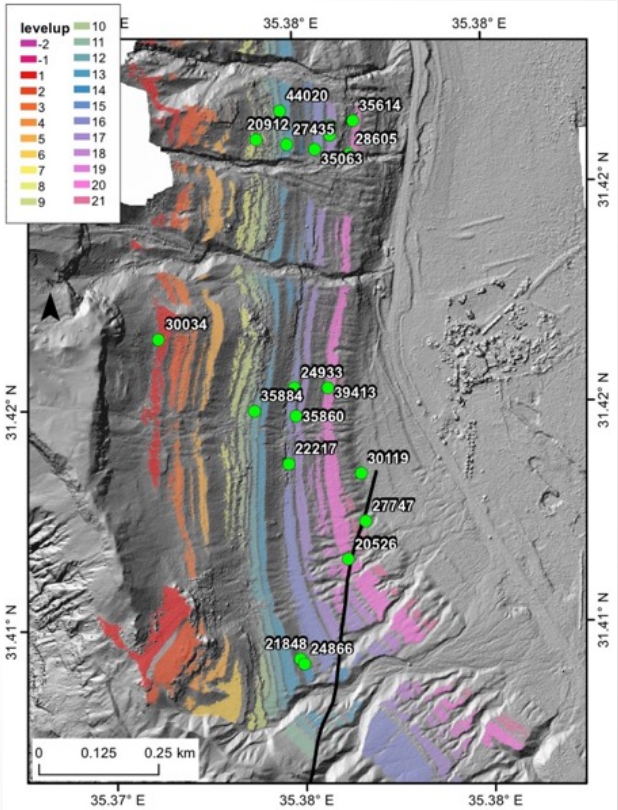


Sampling and mapping lake-shorelines





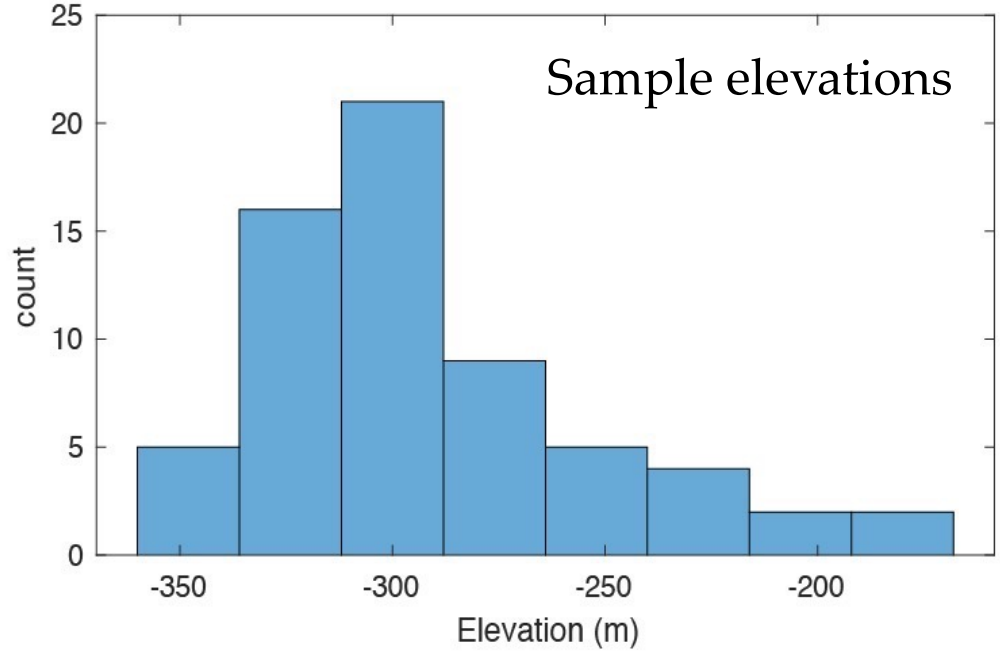


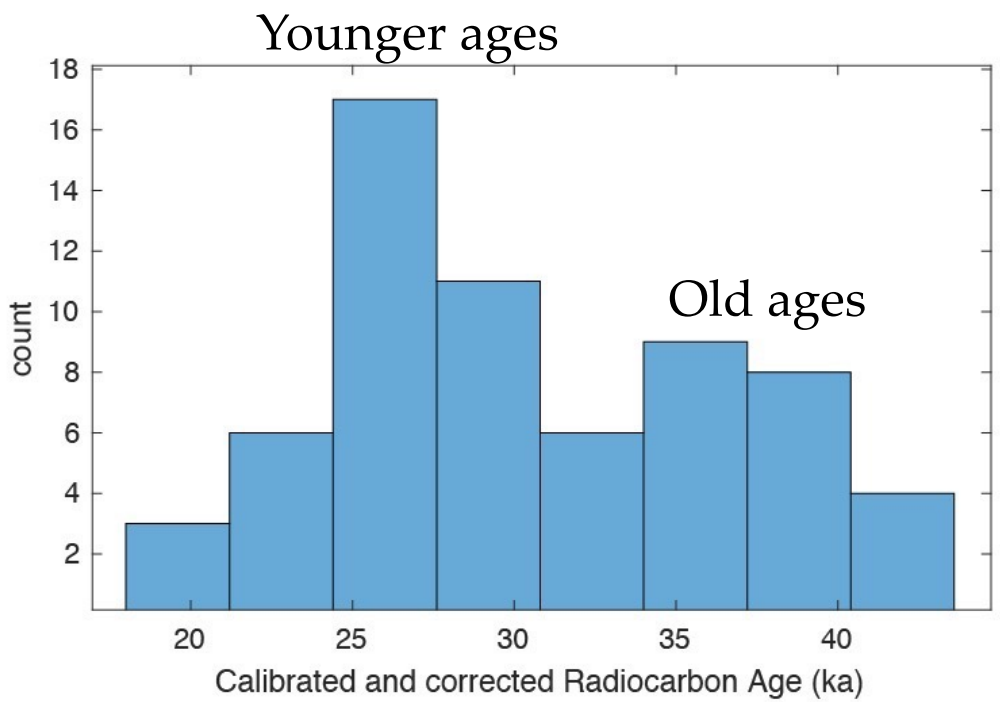


- Example of lake shoreline drone surveys and mapping using high resolution topography (10 cm/px)

Dating fossil stromatolites

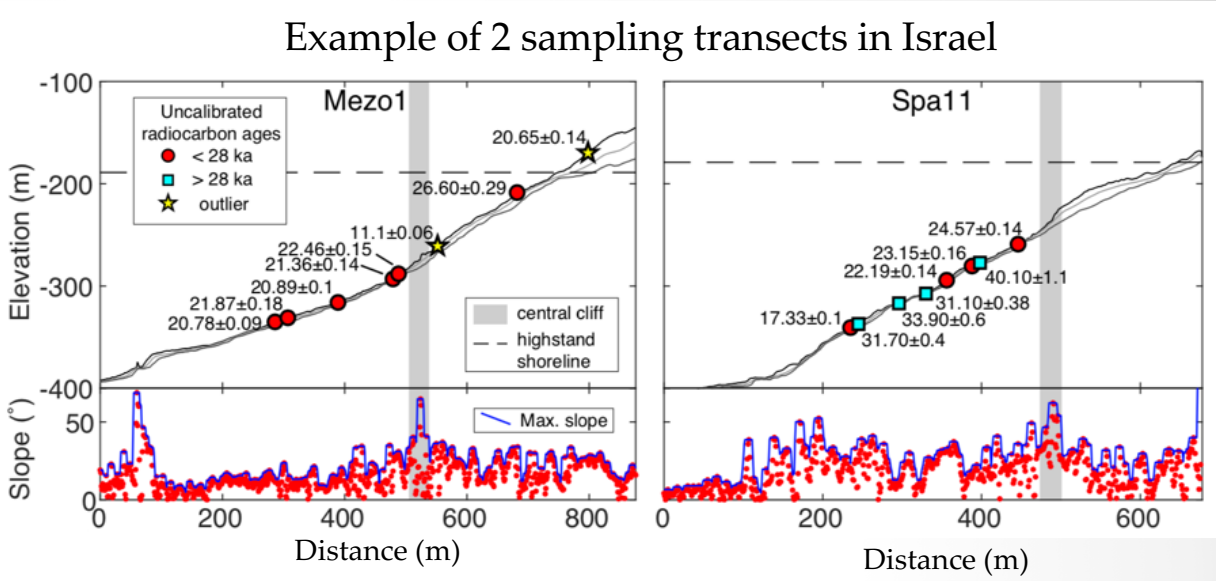
- 100 new ages of fossil stromatolites. *To date the most complete record from lake shorelines.*
- 70 radiocarbon ages
- 30 U/Th ages, (6 samples multiple dating)
- Uncal. ages range between ~10 and ~45 ka
- Bimodal population

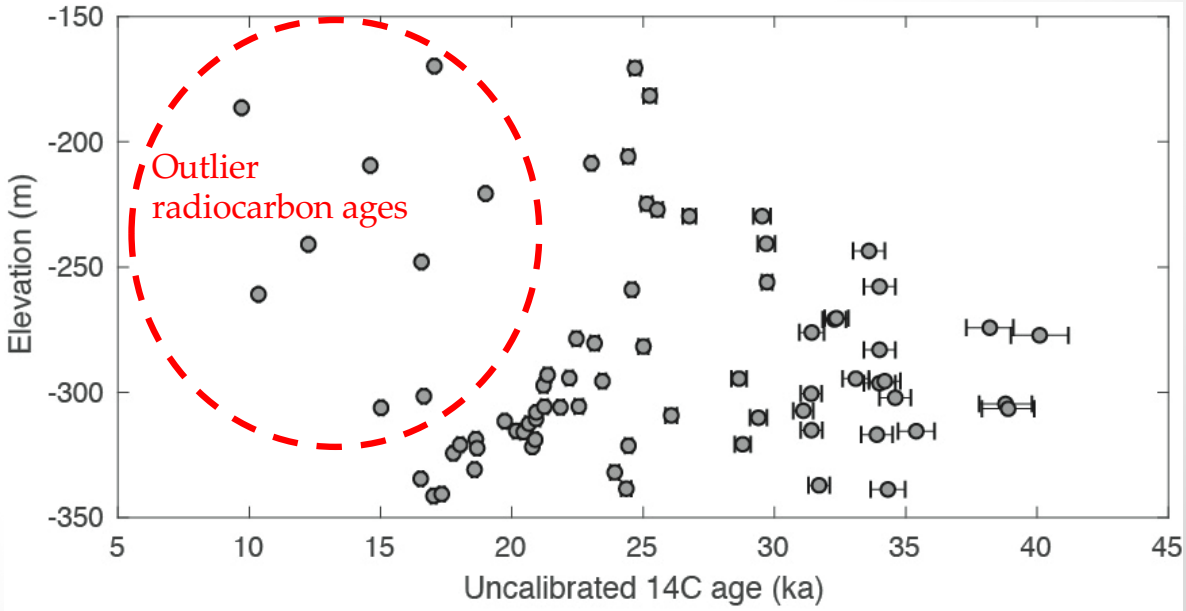




Radiocarbon ages

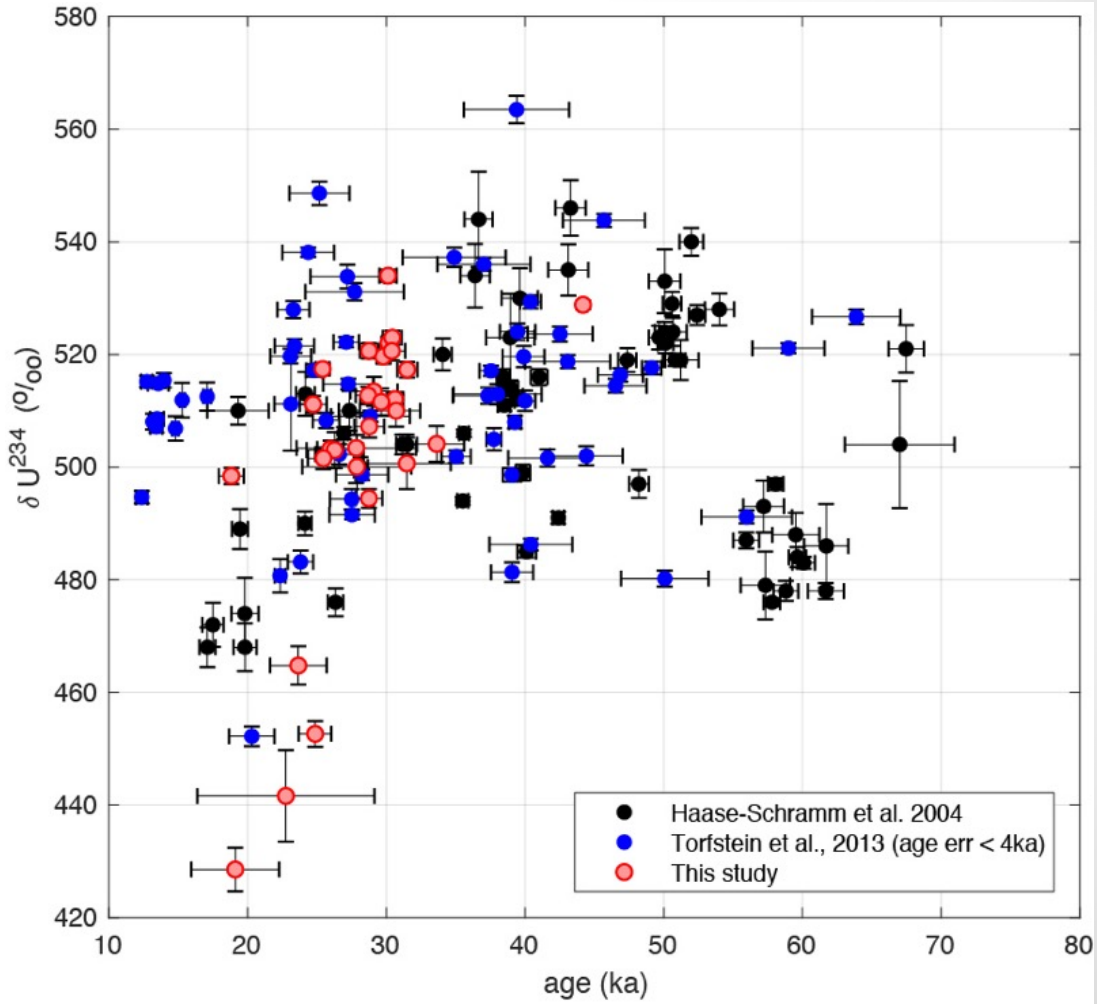
- Consistent age/elevation trend of younger ages (<28 uncal. ka) and scattered older ages (>28 uncal. ka).
- Outliers, extremely young ages, inconsistent age/elev.
- Precipitated CaCO3 may produce younger ages.
- Associated to highly porous stromatolites





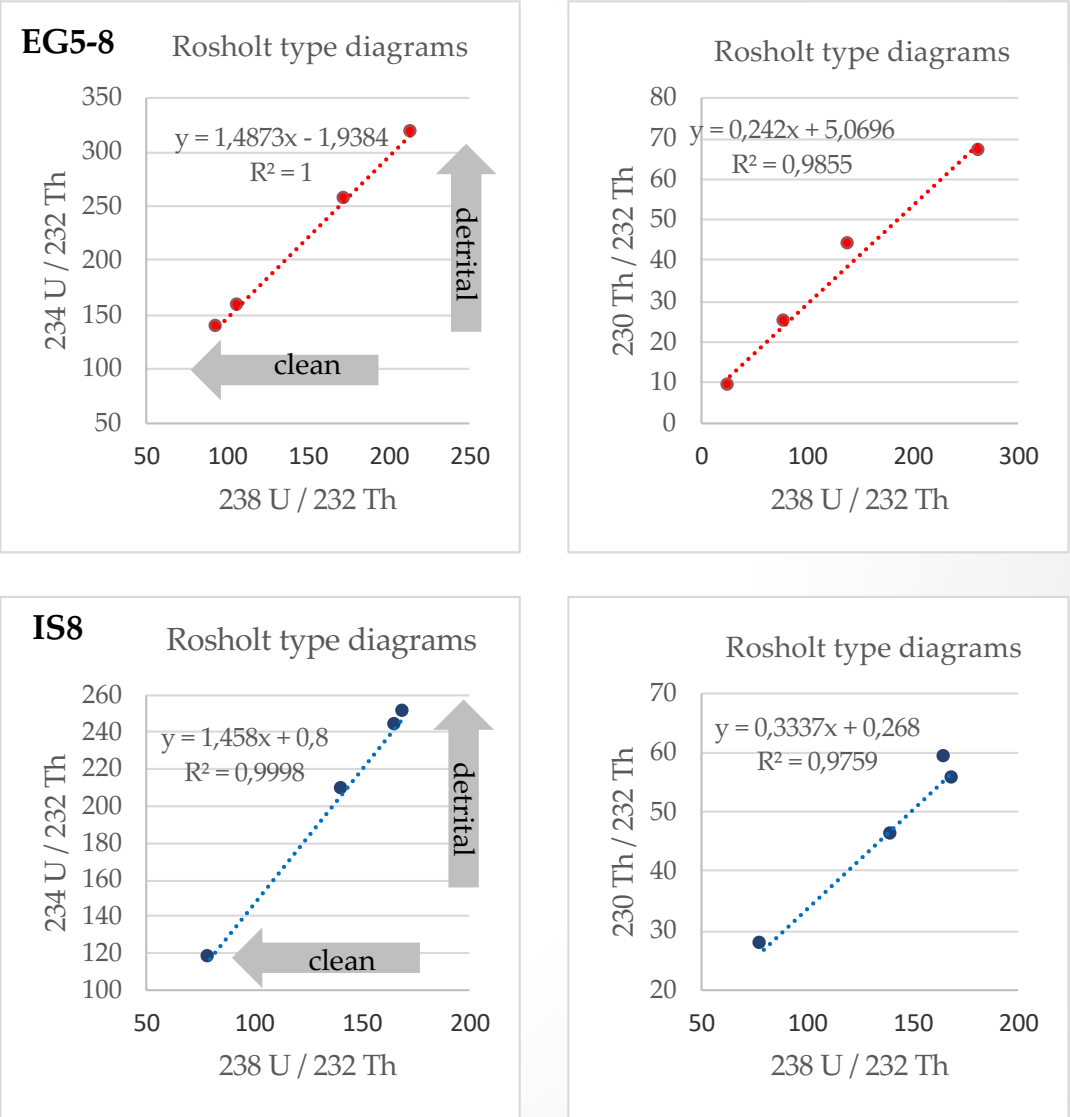
U-series dating of fossil stromatolites

- 30 U-series ages between 18 and 44 ka
- Delta U234 are similar than previous ages from the Lisan Fm. (430-540 o/oo)
- Except for two young samples of low U



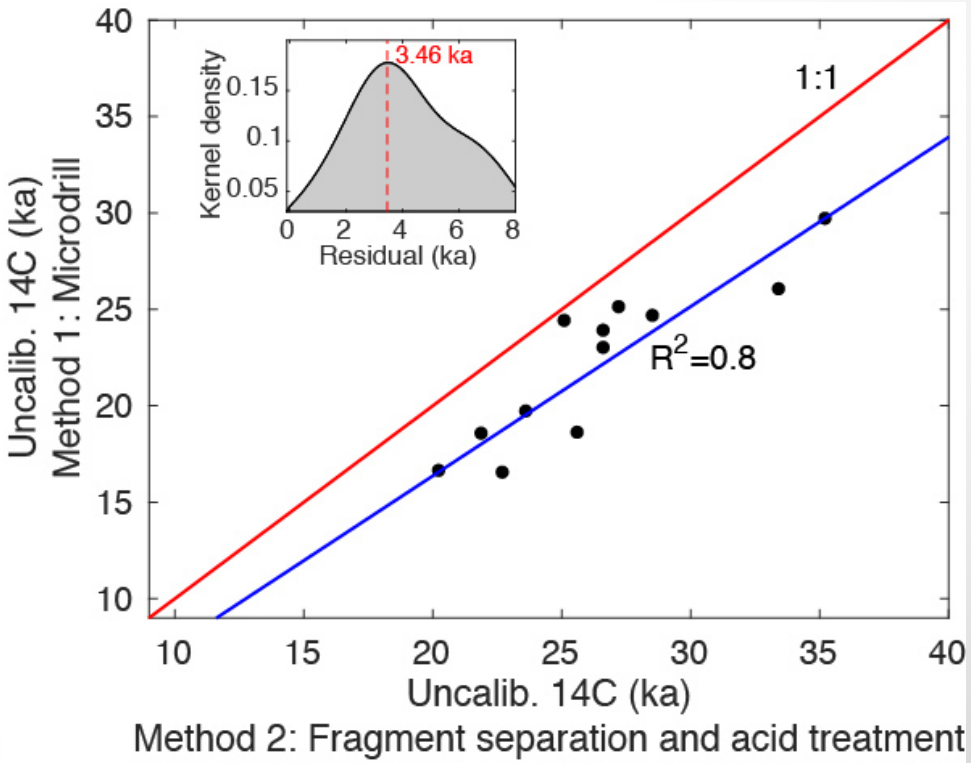
U-series dating: Isochrone correction

- 26 paired radiocarbon – U/Th for reservoir estimate
- 20 U-series ages were used for the isochrone calibration method
- 4 ages are combined to get a sample isochrone
- Variability depict different amounts of detrital contamination
- 4 unpaired ages used to complement radiocarbon dating



Temporal corrections: Radiocarbon contamination

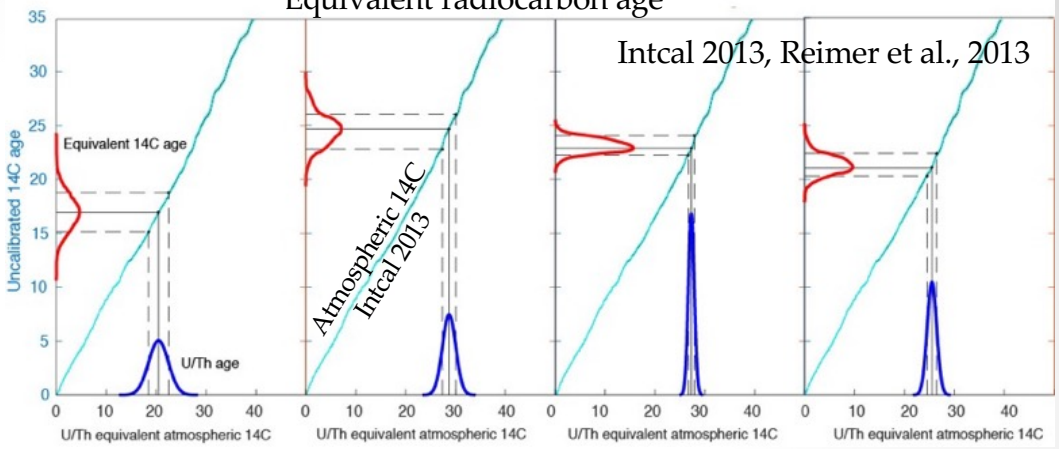
- Different sampling method produced slightly different ages. We compare 12 ages.
- Method 1: Microdrill sampling from aragonite layers.
- Method 2: Fragment separation and acid treatment (2%HCl).
- Difference ~3.5 ka. Effect of young radiocarbon contamination?
- Added to age uncertainty when soaking of fragments was not possible.



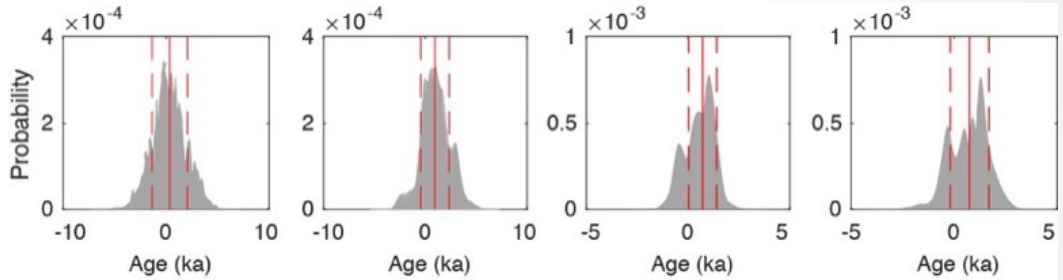
Temporal corrections: Radiocarbon reservoir

- Carbon reservoir estimated from paired ages
- Probabilistic approach
- Reservoir age between ~400 and ~2000 yrs
- Errors ~ 200 to ~ 1500 yrs

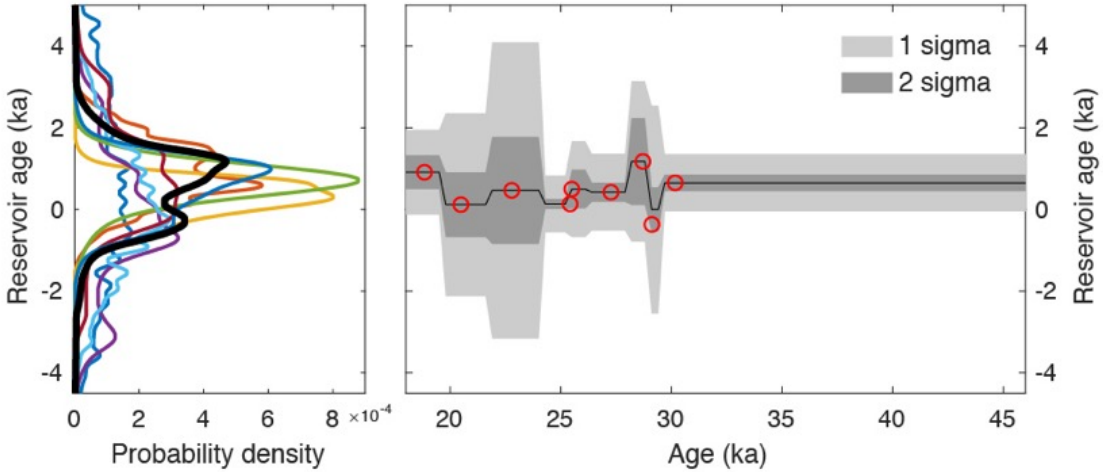
Equivalent radiocarbon age



Age difference (14C uncalib. – U/Th atm equiv.)



Radiocarbon reservoir



Spatial corrections: Isostatic rebound

- We account for the effect of hydro isostatic rebound

- **Elastic thin plate model:**

-Variable elastic thickness: Perez-Gussinyé et al., 2009
-Young modulus: 100e9 pas
-Poisson's ratio: 0.25
-mantle density: 3300 kg/m3
-SRTM1 30 m/px topography

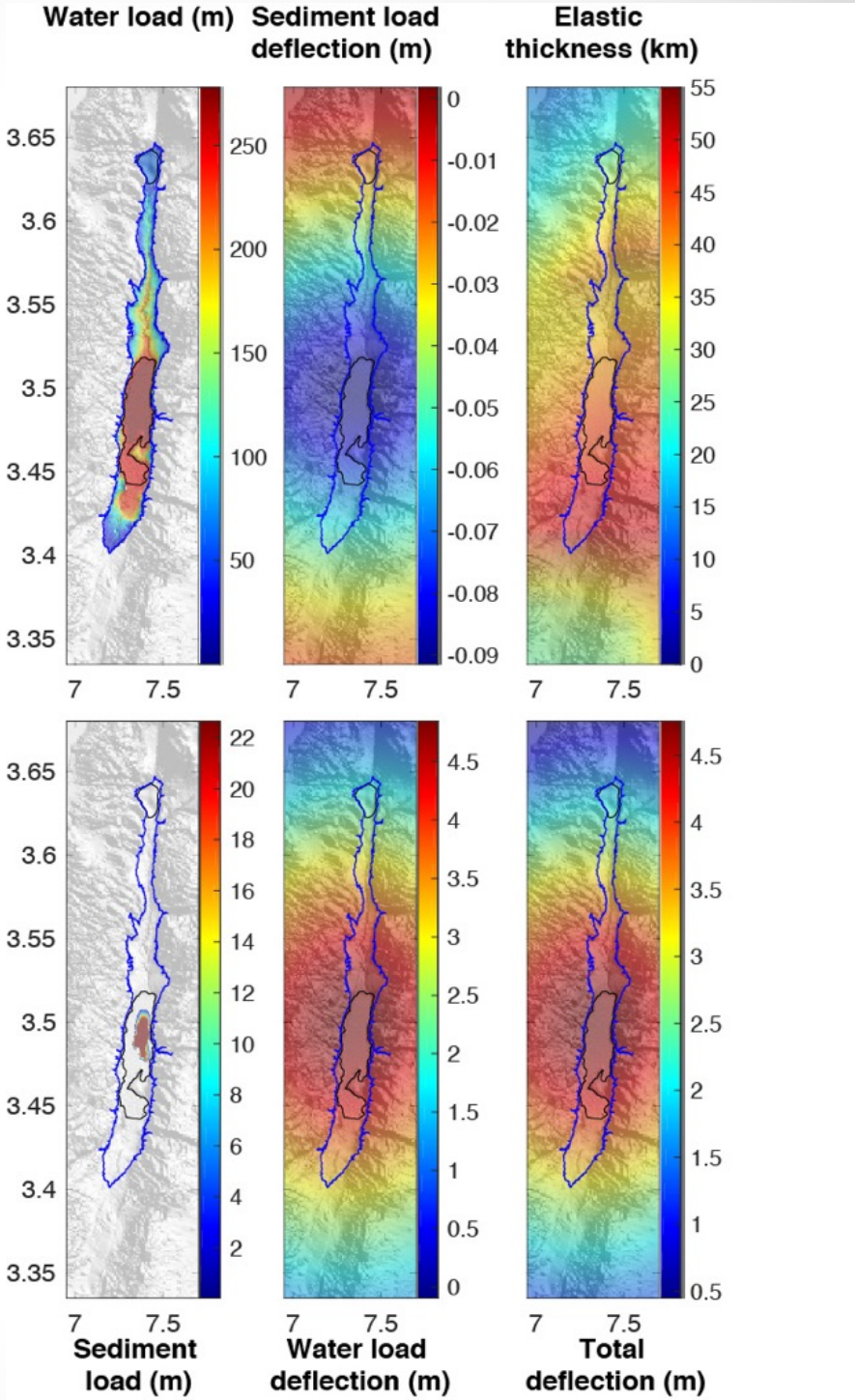
- **Uplift driven by lake volume drop:**

-270 m lake drop until the present
-water density 1000 kg/m3

- **Subsidence driven by sedimentation:**

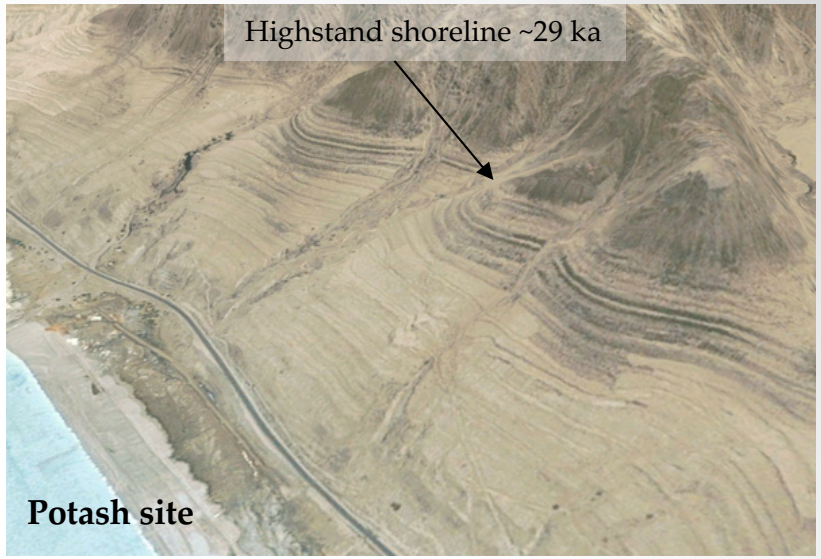
- Sedimentation rate: 0.8 m/ka (Schramm et al., 2004; Bartov et al., 2002)
-Density of sediment: 2250 kg/m3 (Wetzler et al., 2015, Choi et al., 2011)
-Duration: 29 ka

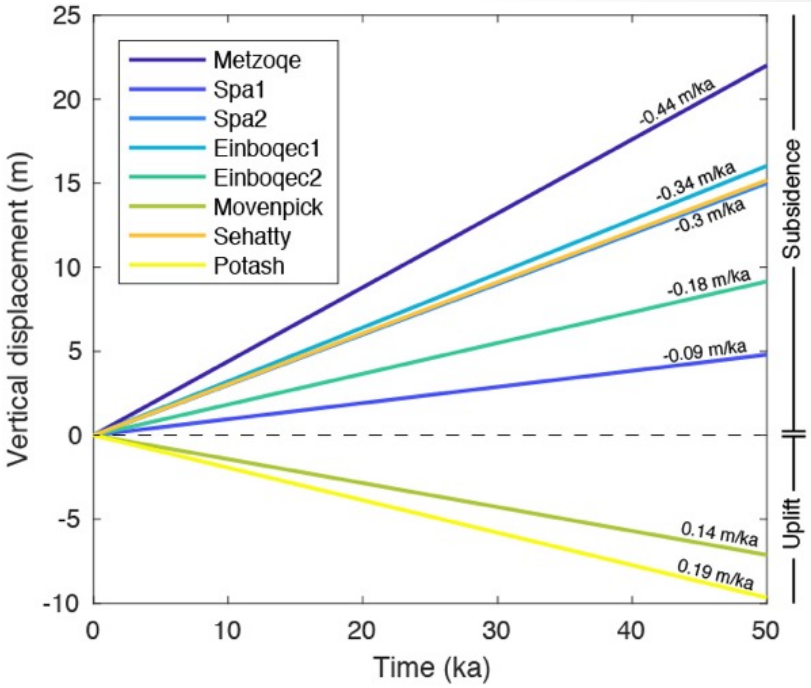
- Rebound values range between 4.1 and 4.7 m and were subtracted from ple elevations

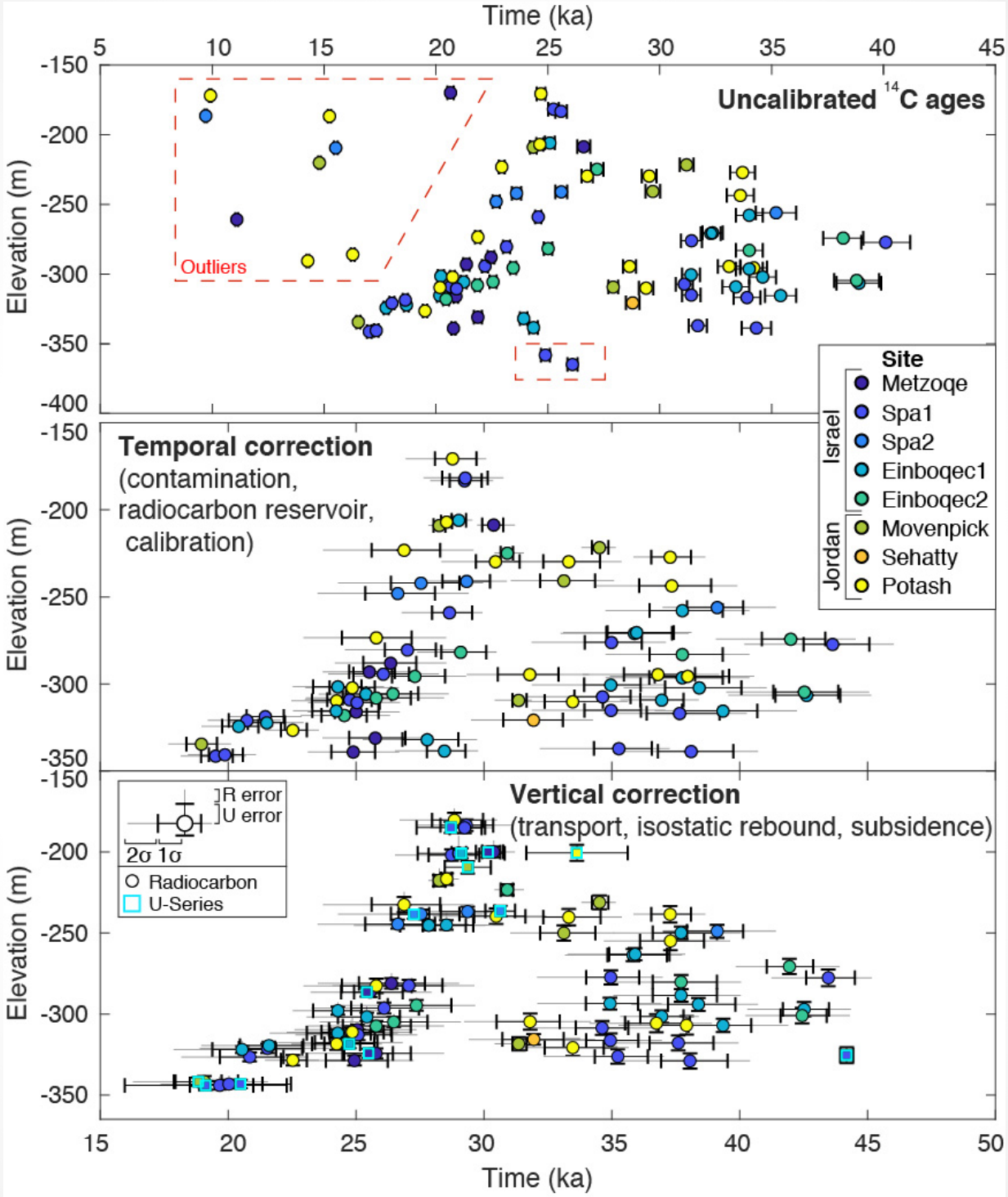


Spatial corrections: Tectonic uplift

- After isostatic correction we account for tectonic uplift
- The highstand shoreline, is the most notorious feature observed in all sites at ~150 to ~180 mbsl.
- We estimate differences in elevation of highstand shorelines in each with respect to SPA2 site
- Using the 29 ka age of the higstand we estimate relative uplift rate (-0.1 to 0.5 m/ka).
- Nearby SPA2 (Masada plain) Bartov et al., (2006) estimated an subsidence rate of 0.3 m/ka
- The we added this estimate to our relative uplift rates to obtain absolute vertical deformation rates. (0.14 to -0.44 m/ka)
- Vertical displacements derived from absolute uplift/subsidence rate and sample ages were added to sample elevation. (-7 to 13 m)

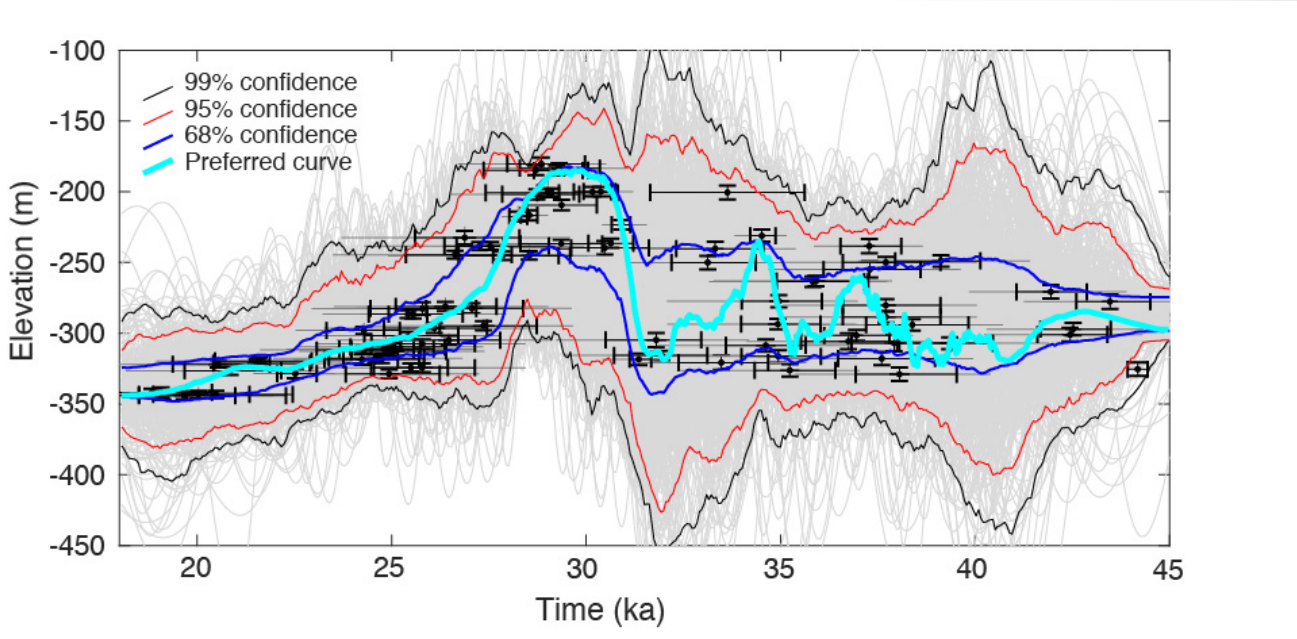





Time (ka)
Uncalibrated ^{14}C ages
Outliers
Elevation (m)
Temporal correction
(contamination,
radiocarbon reservoir,
calibration)
Site
Israel
Metzoqe
Spa1
Spa2
Einboqec1
Einboqec2
Jordan
Movenpick
Sehatty
Potash
R error
U error
2σ 1σ
Radiocarbon
U-Series
Vertical correction
(transport, isostatic rebound, subsidence)

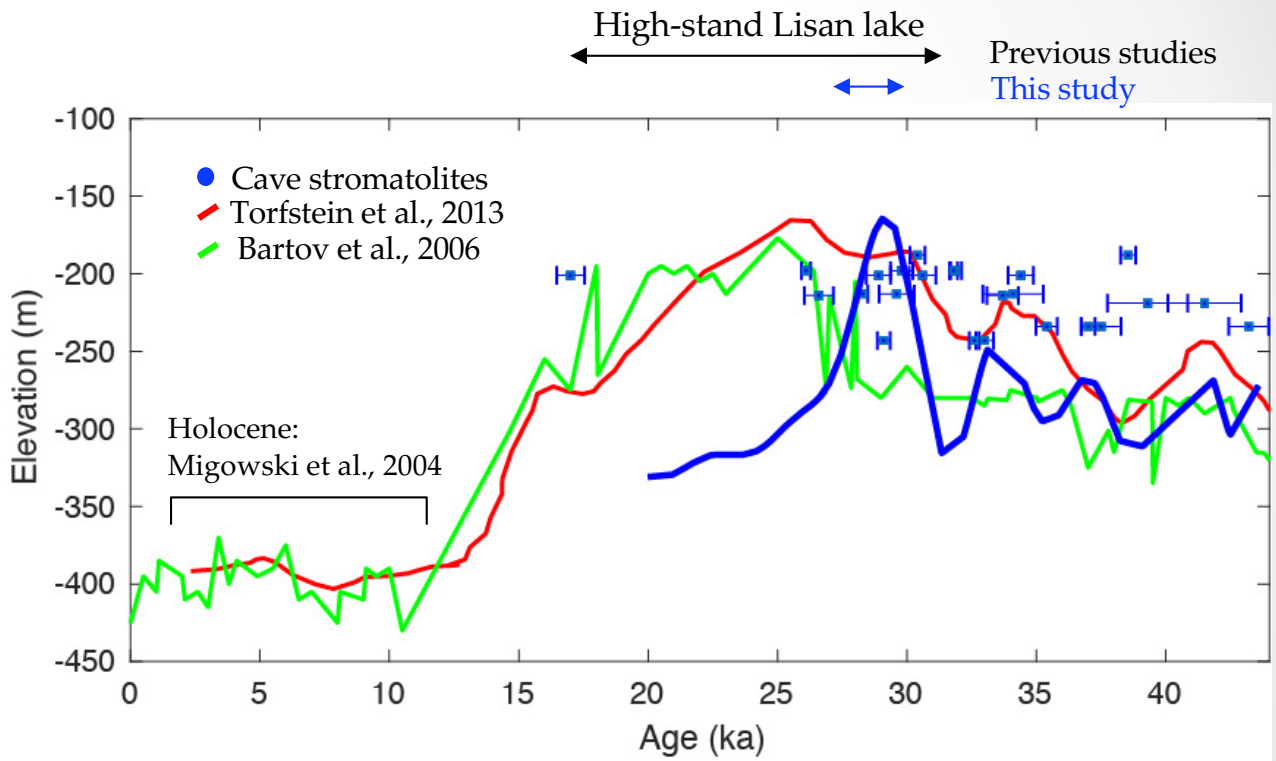
Lake level fluctuations

- Lake level curve using Montecarlo approach
- High variability before 30 ka
- Abrupt drop 29 -27 ka of ~80 m
- Slow drop after 27 ka of ~50 m



Discussion: Comparing lake level reconstructions

- Previous studies show a long lasting Lisan lake (~15 ka)
- We show a short lived Lisan, and rapid drop at ~28ka
- Drop is 15 ka earlier than previous studies
- What this means?



Thank you