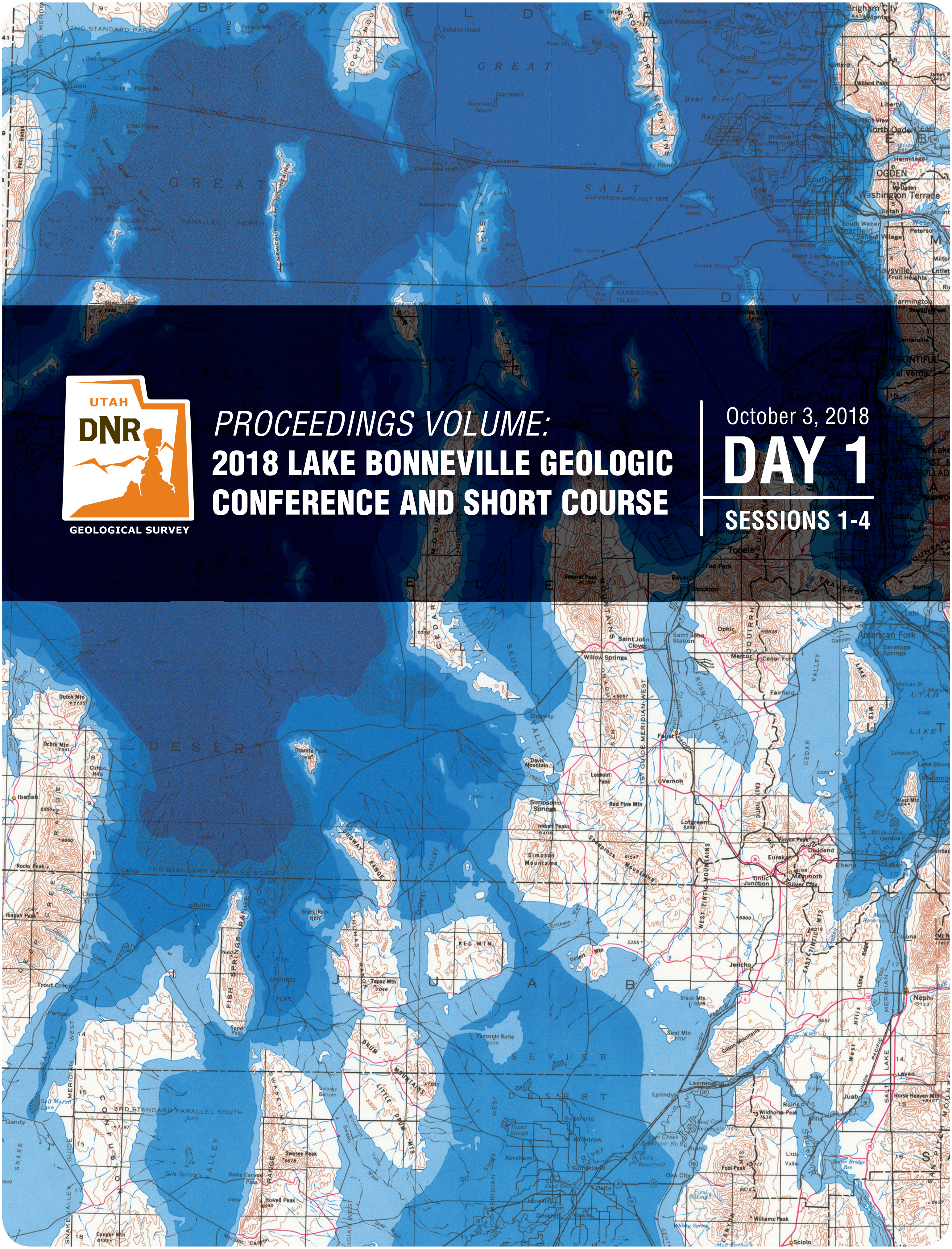

UTAH DNR

GEOLOGICAL SURVEY

PROCEEDINGS VOLUME:

2018 LAKE BONNEVILLE GEOLOGIC CONFERENCE AND SHORT COURSE

October 3, 2018

DAY 1

SESSIONS 1-4

2018 Lake Bonneville Geologic Conference and Short Course

October 3 – 6, 2018

Sponsored By

Partial funding for this educational opportunity has been provided by the
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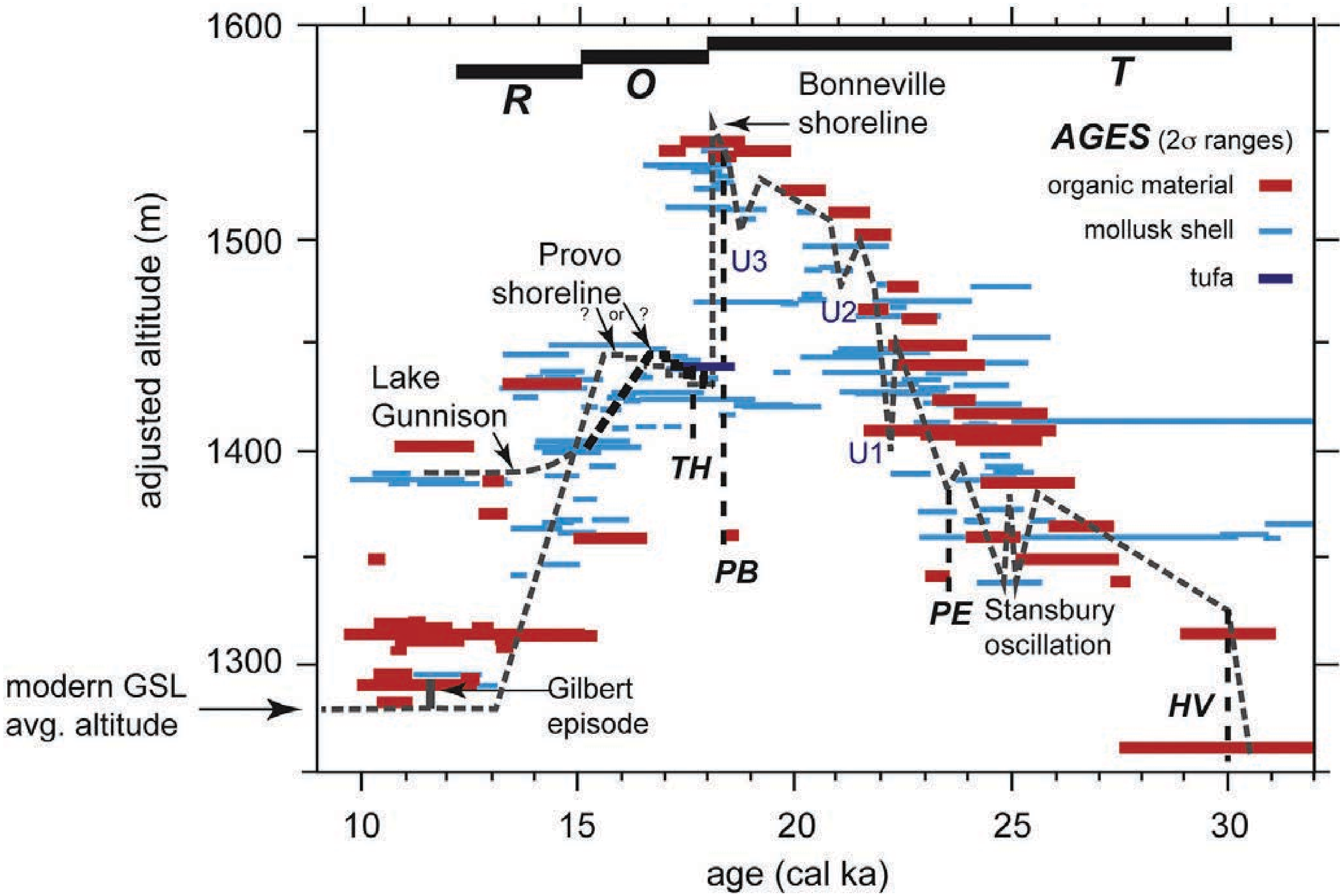
Introduction to Lake Bonneville

Jack (Charles G.) Oviatt

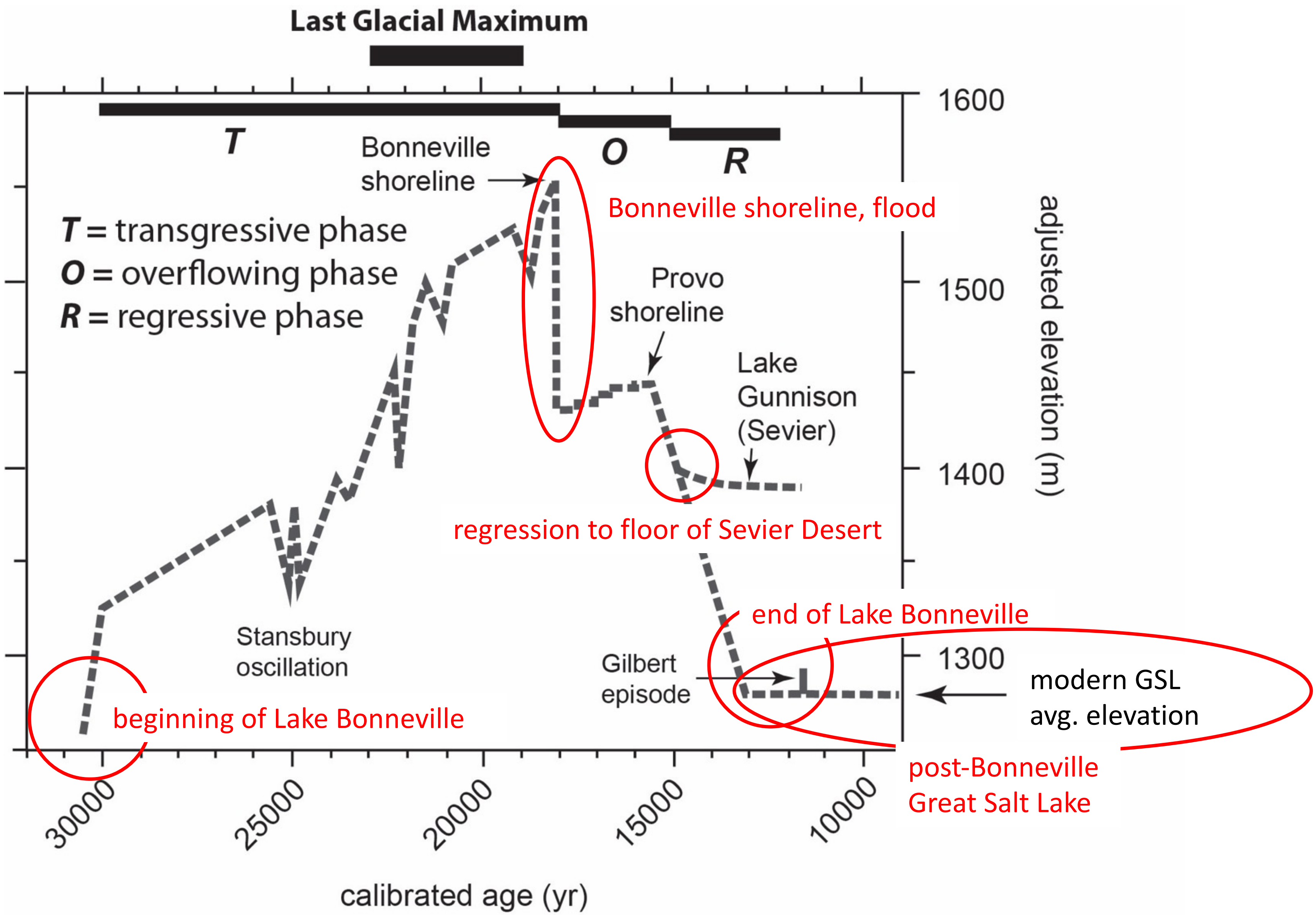
Socorro, NM

[emeritus professor at Kansas State University]



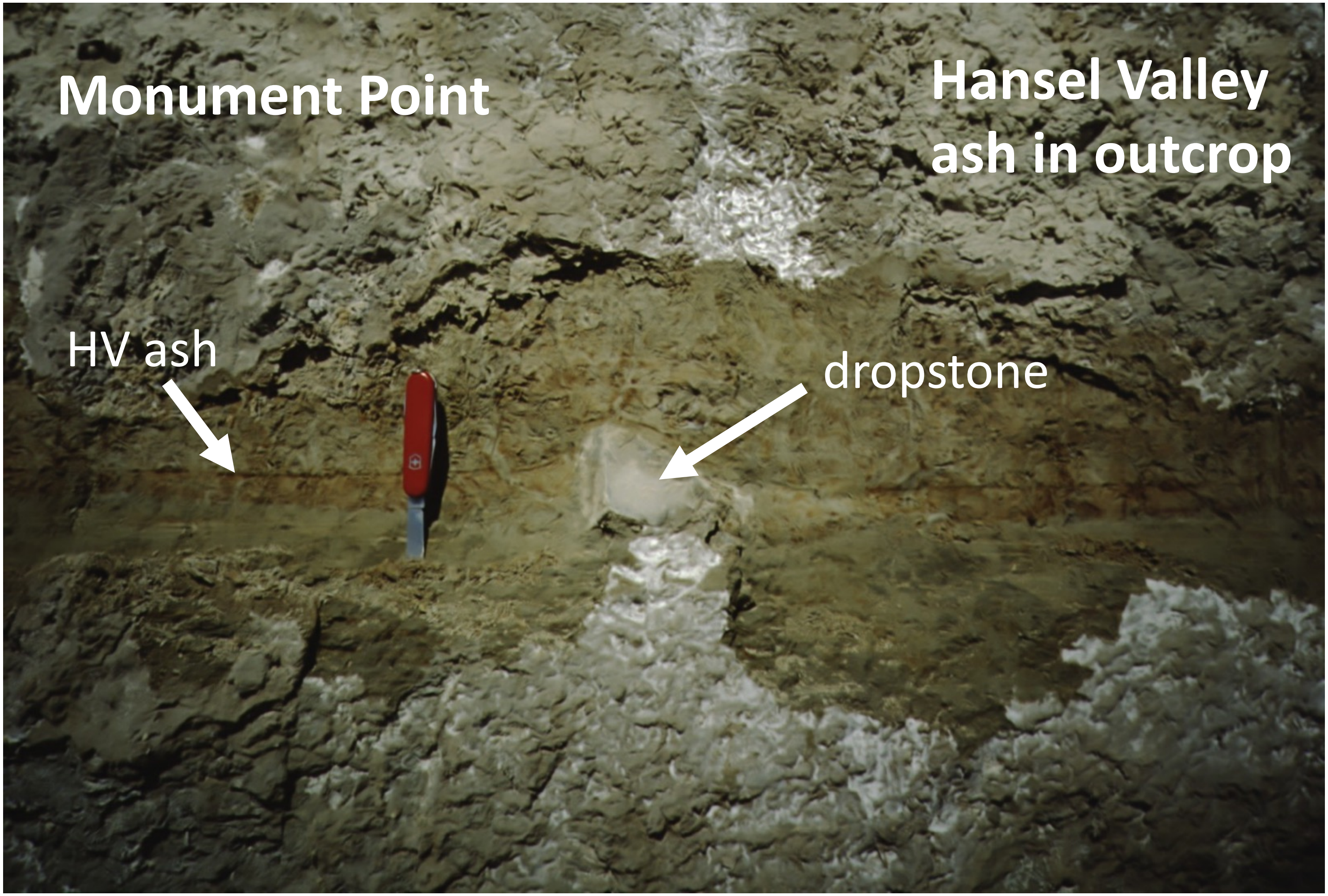
1600
1500
1400
1300
adjusted altitude (m)
R
O
T
Bonneville
shoreline
AGES (2σ ranges)
organic material
mollusk shell
tufa
Provo
shoreline
? or ?
U3
U2
U1
Lake
Gunnison
TH
PB
PE
Stansbury
oscillation
HV
modern GSL
avg. altitude
Gilbert
episode
10
15
20
25
30
age (cal ka)

Oviatt, 2015

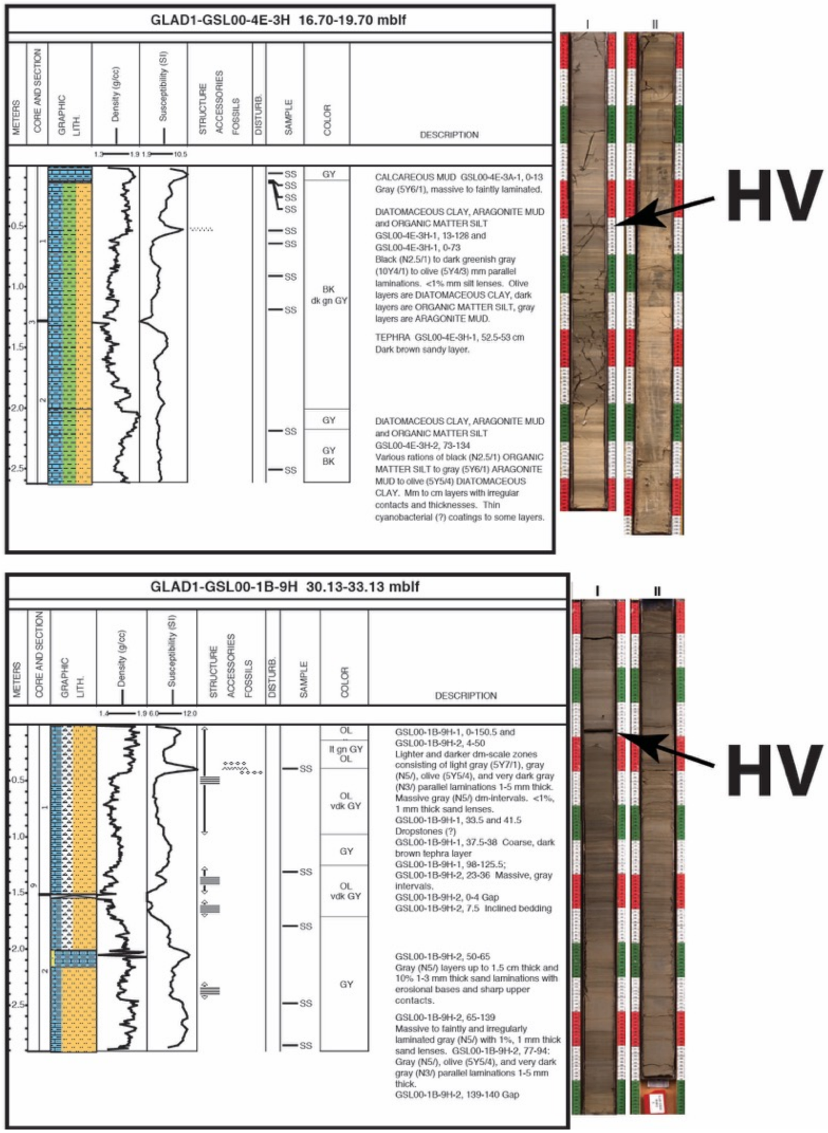


Last Glacial Maximum
T
O
R
Bonneville shoreline
T = transgressive phase
O = overflowing phase
R = regressive phase
Bonneville shoreline, flood
Provo shoreline
Lake Gunnison (Sevier)
regression to floor of Sevier Desert
end of Lake Bonneville
Stansbury oscillation
Gilbert episode
modern GSL avg. elevation
beginning of Lake Bonneville
post-Bonneville Great Salt Lake
1600
1500
1400
1300
adjusted elevation (m)
30000
25000
20000
15000
10000
calibrated age (yr)

beginning of Lake Bonneville

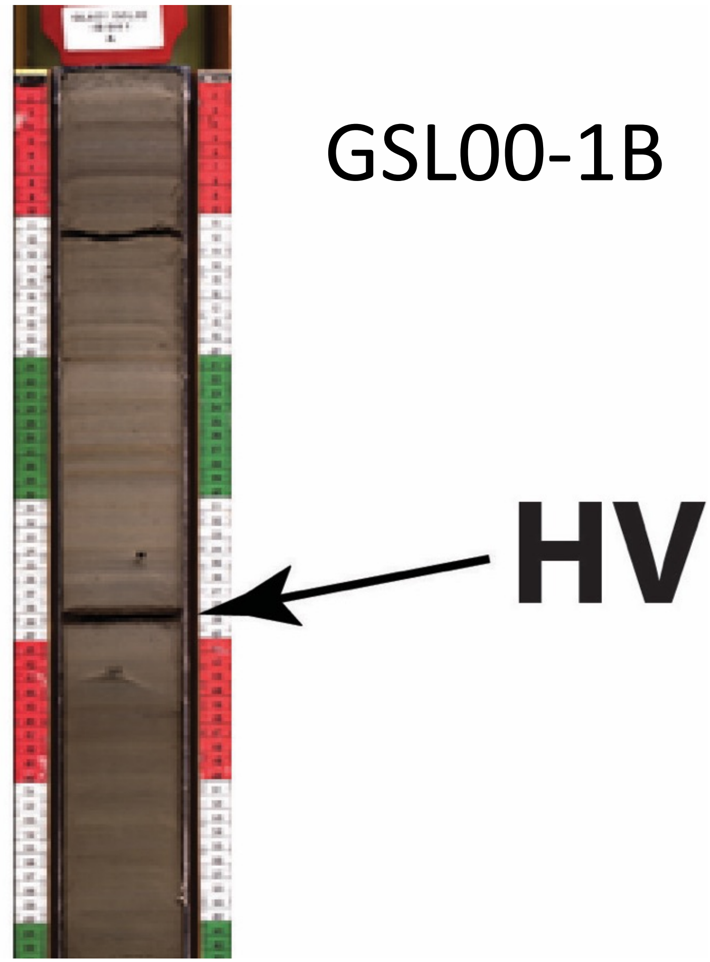

Monument Point
Hansel Valley
ash in outcrop
HV ash
dropstone

Hansel Valley ash in GSL cores



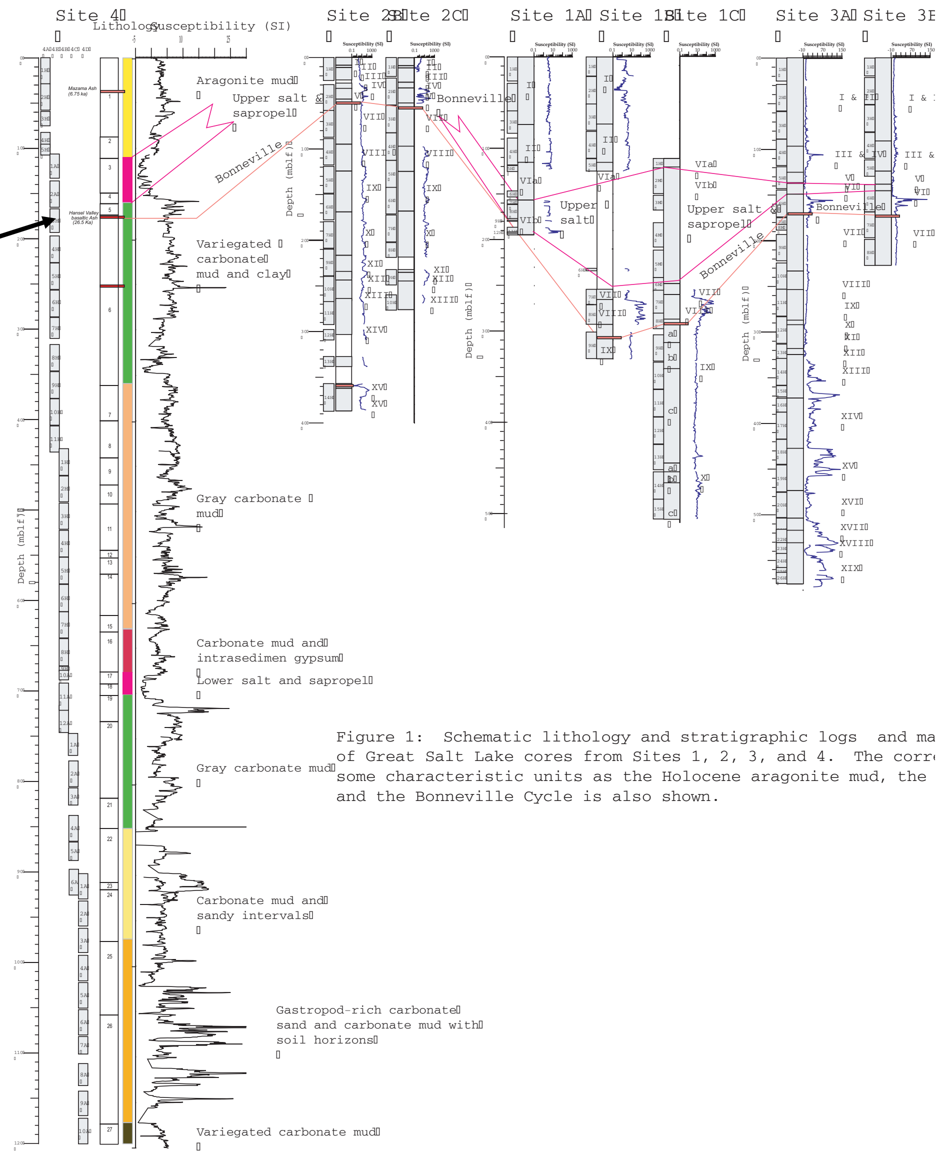
at, or near, the base of the Bonneville section in all cores where it's been found

GSL00-1B



Schnurrenberger and Haskell, 2001

Hansel Valley ash



correlation of GLAD cores from Great Salt Lake, 2000

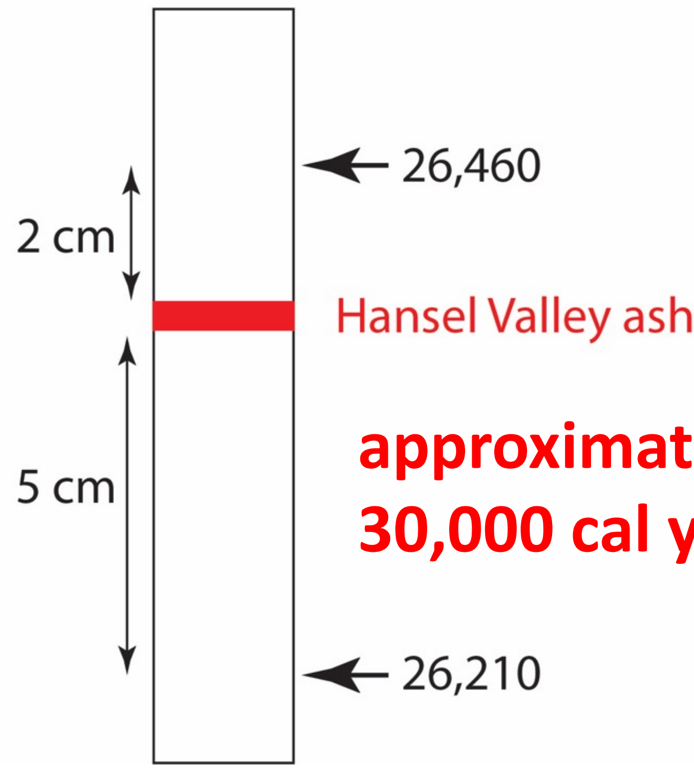
Laccore, unpublished

age of the Hansel Valley ash

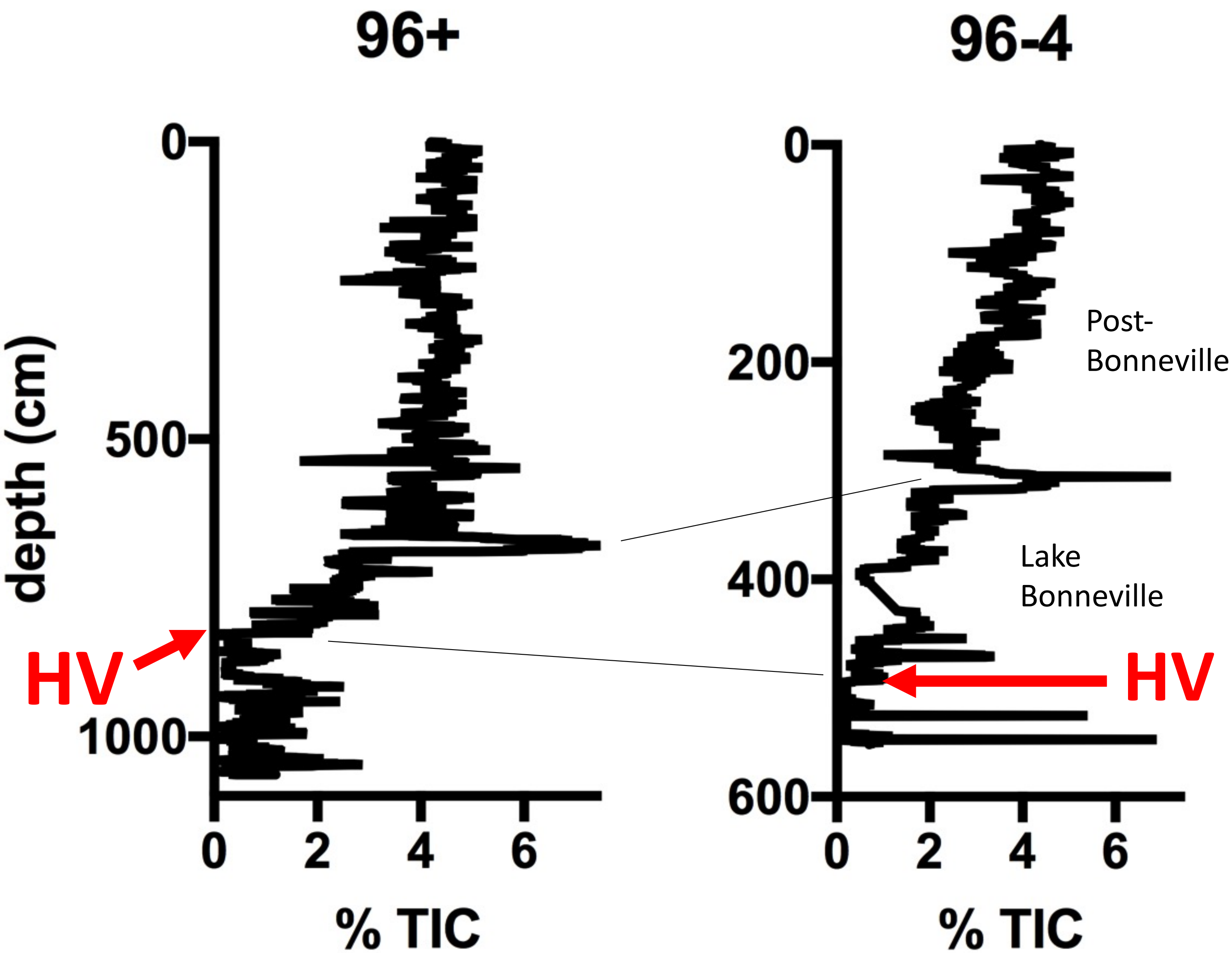
^{14}C age	+/-	calibrated median probability
26210	260	30465
26460	640	30503

^{14}C samples in two different cores

(If the original radiocarbon ages are adjusted by 1800 ^{14}C yr, as is applied higher in the core, the calibrated ages are closer to ~28,000 yr BP)



approximate age, rounded off: 30,000 cal yr BP



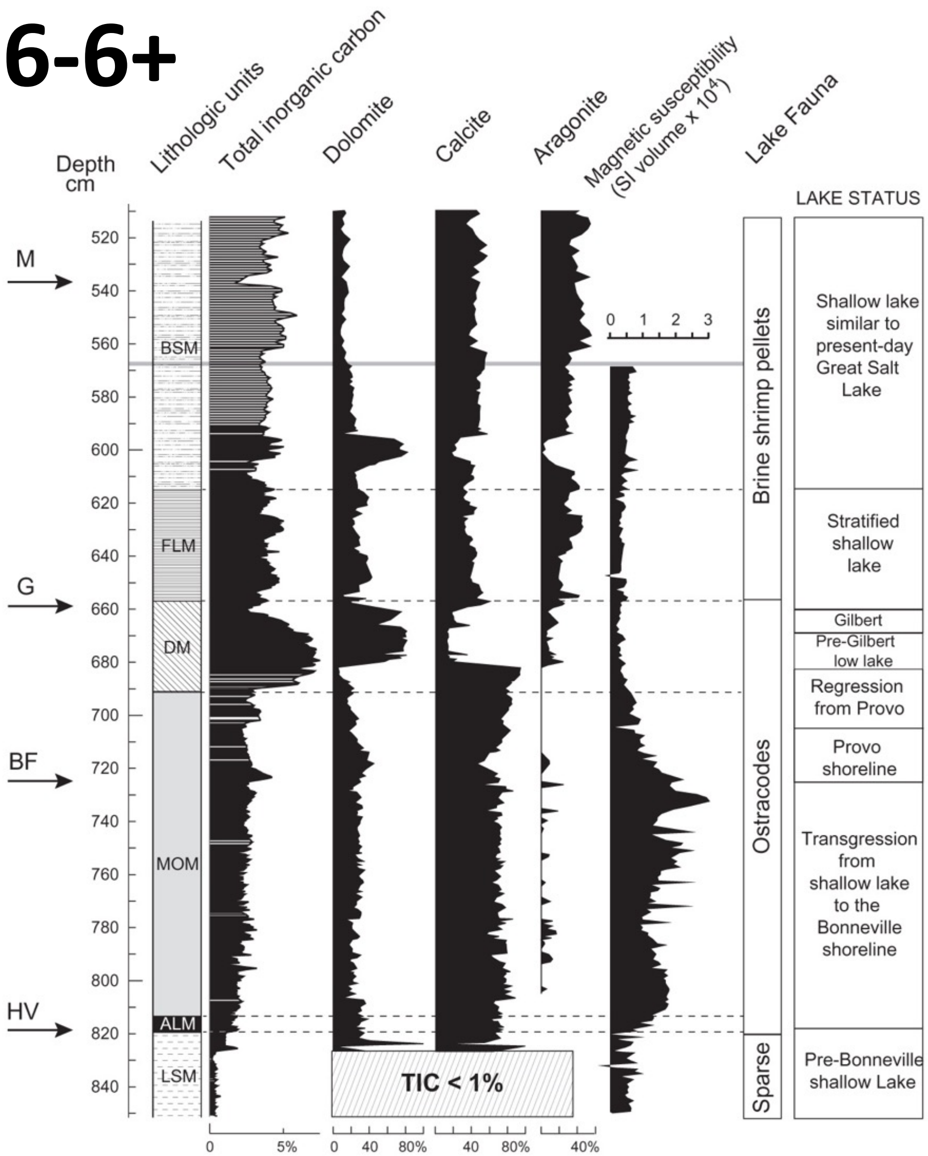
HV ash is found at the base of the Bonneville section ~80 m higher in outcrops than in cores, suggesting an abrupt lake rise at ~30,000 BP.

Things to note:

- **abrupt increase in TIC at beginning of Bonneville**
- **increasing trend in TIC, since ~30,000 BP**
- **increasing trend as Lake Bonneville rose**

Thompson and others (2016); Thompson and Oviatt, unpublished

GSL96-6+



Beginning of Lake Bonneville

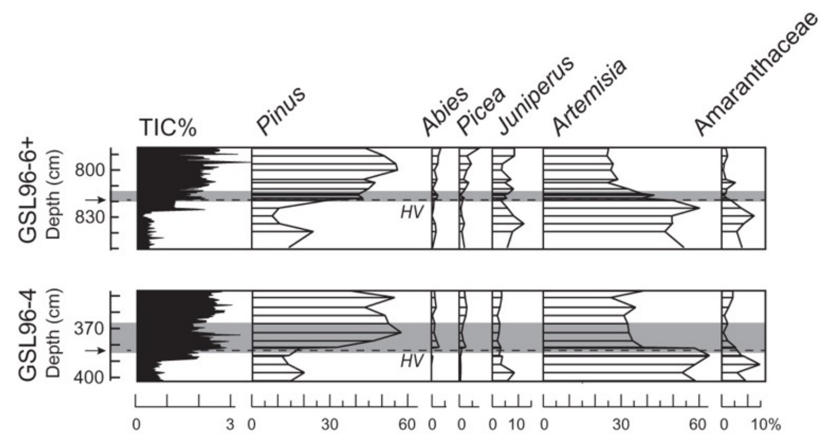
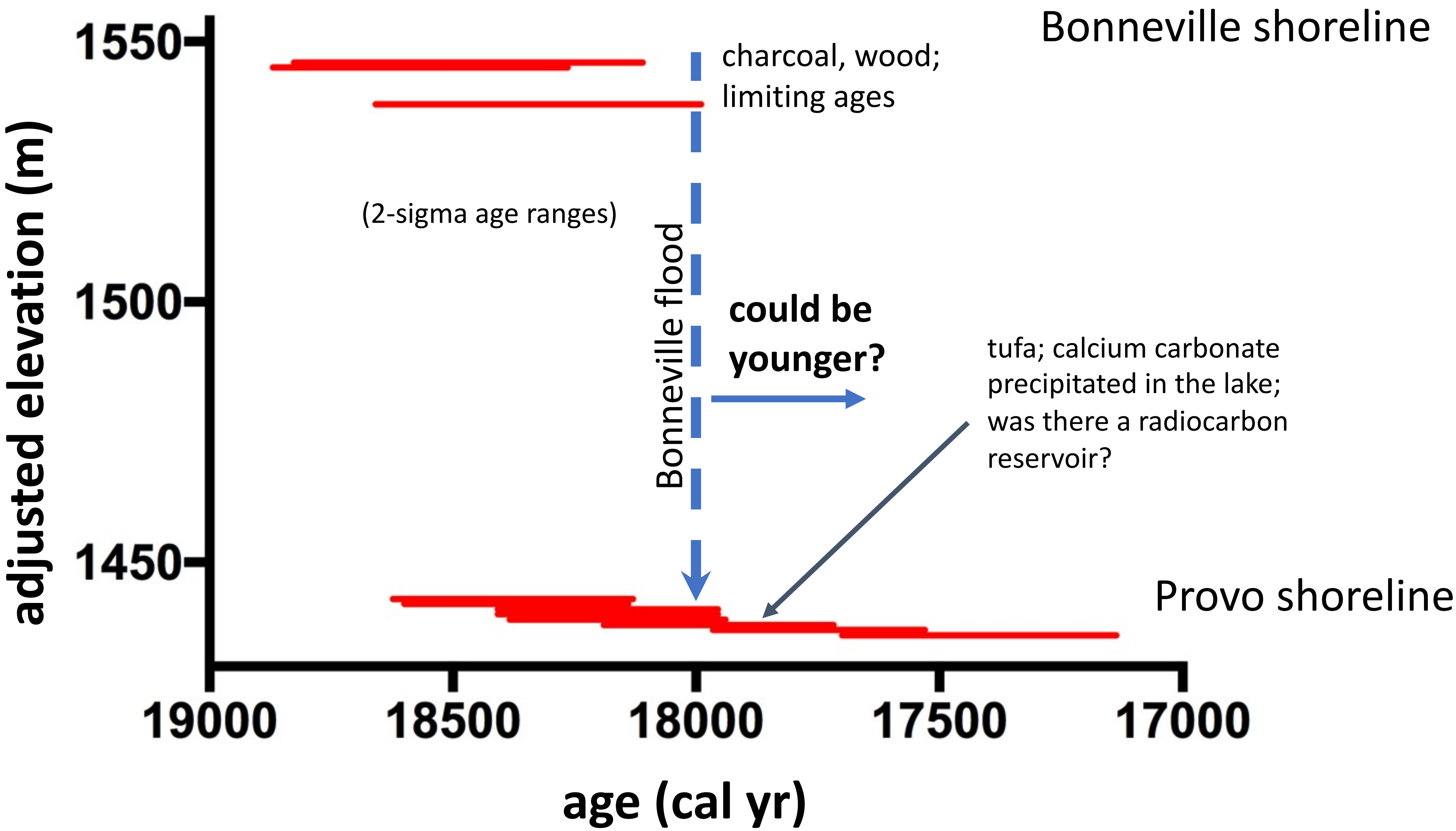
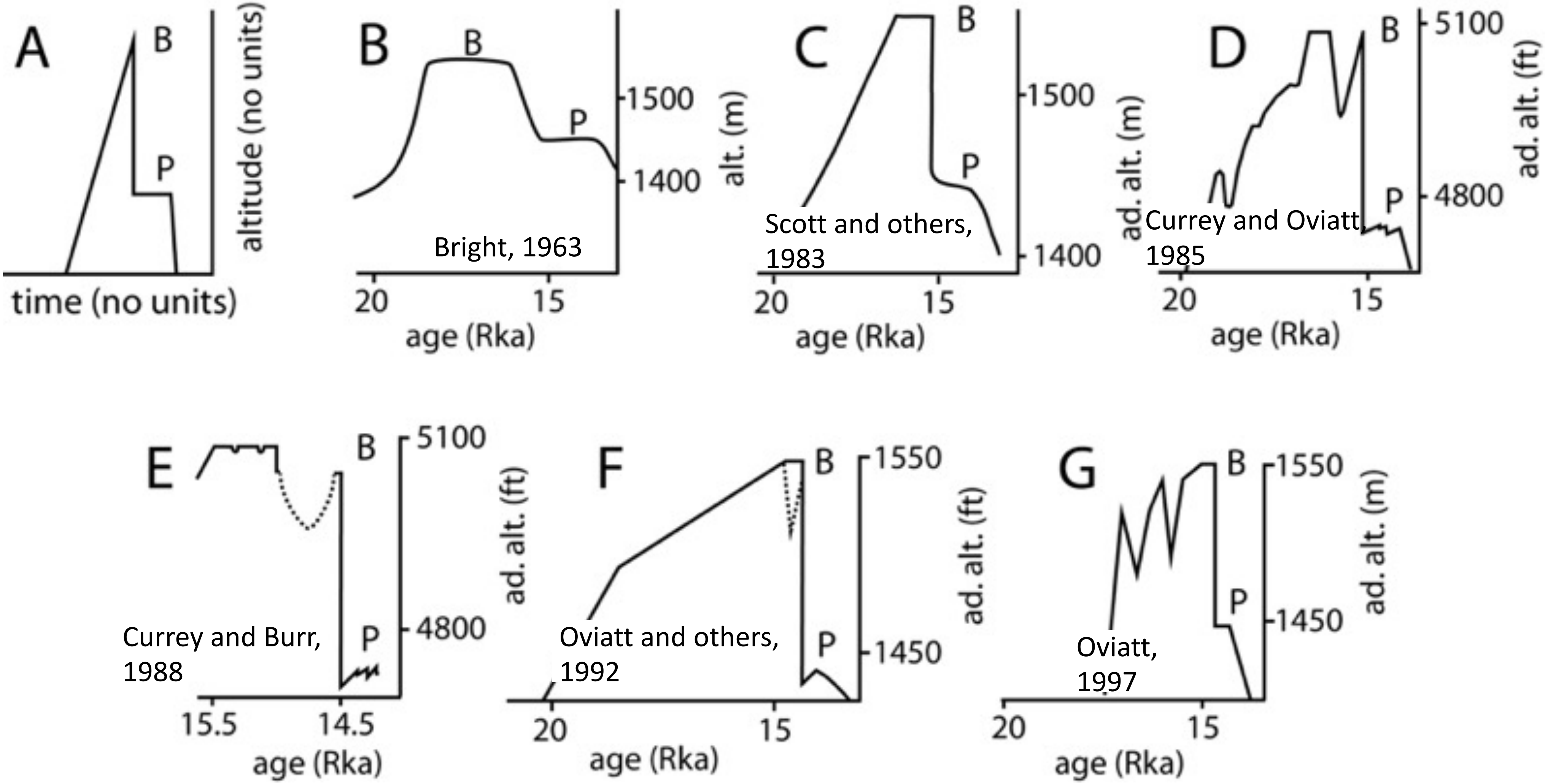


FIG. 11.10 The beginning of Lake Bonneville in sediment cores USGSL96-4 and USGSL96-6+. Depth vs the occurrence of ALM sediments (*gray band*), TIC%, Hansel Valley ash (HV; marked by the *arrow* and *dashed black line* in each core), and selected pollen types. This diagram shows that not much of the transition is missing from USGS96-6 at the core break between Drives 2 and 3.

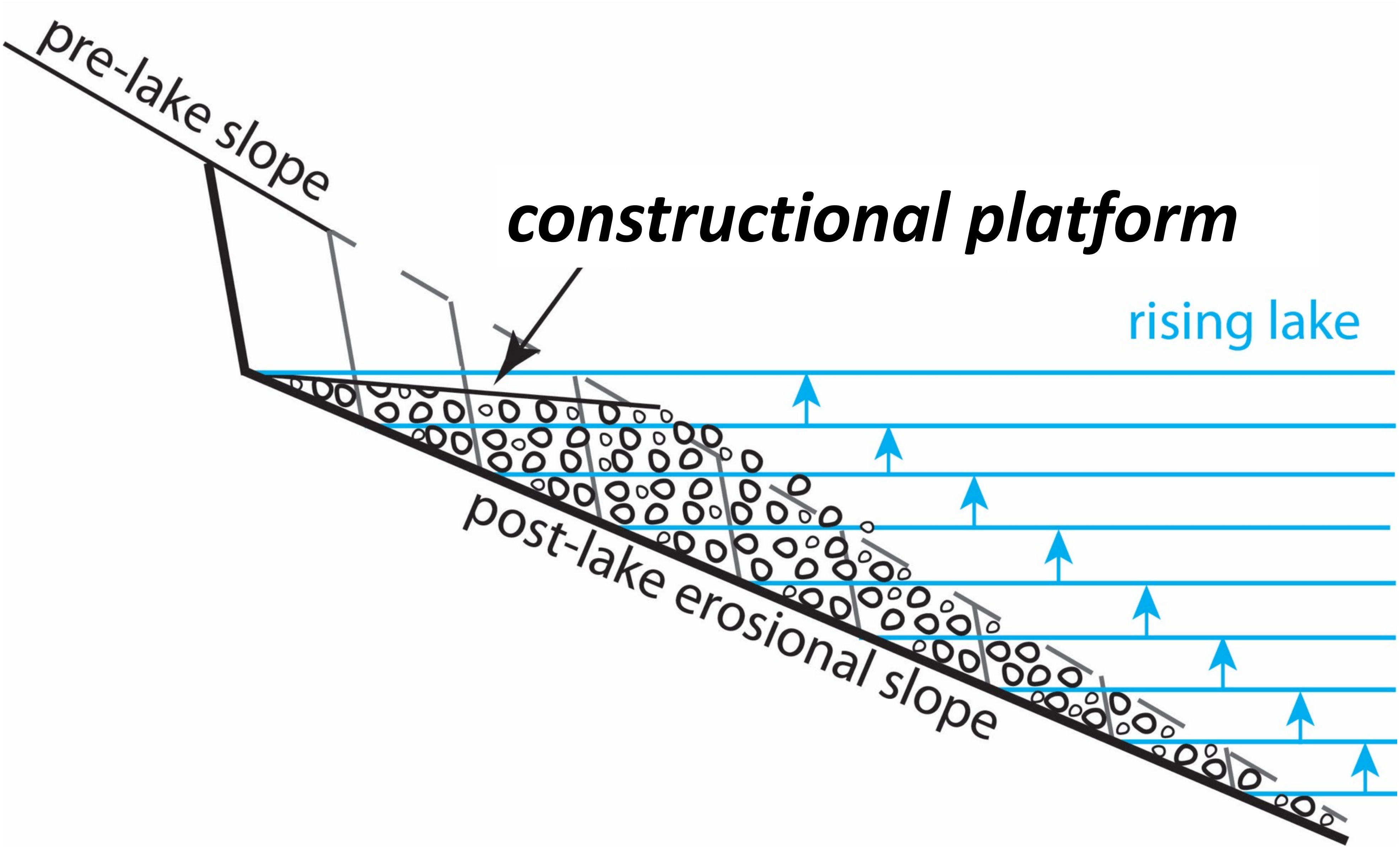
Thompson and others (2016)

age of the Bonneville shoreline and Bonneville flood

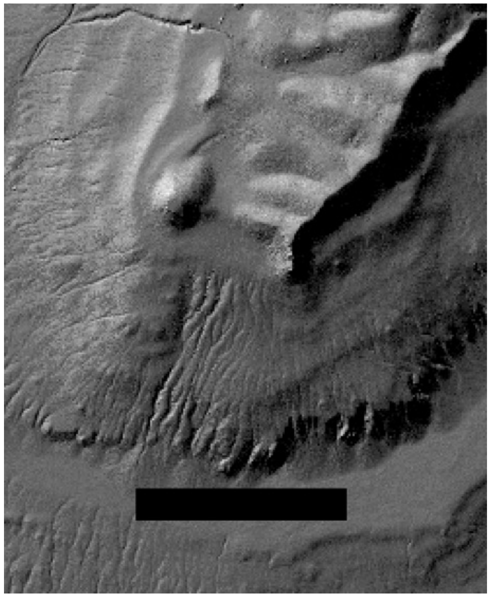

Bonneville shoreline
charcoal, wood;
limiting ages
(2-sigma age ranges)
Bonneville flood
could be
younger?
tufa; calcium carbonate
precipitated in the lake;
was there a radiocarbon
reservoir?
Provo shoreline
1550
1500
1450
adjusted elevation (m)
19000
18500
18000
17500
17000
age (cal yr)



Oviatt and Jewell, 2016


pre-lake slope
constructional platform
rising lake
post-lake erosional slope

Matlin Mountains



Monument Mountain

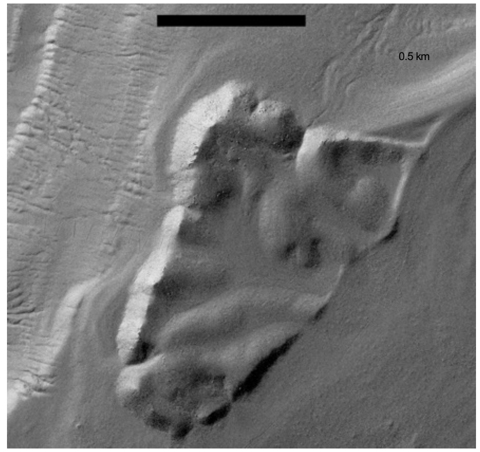
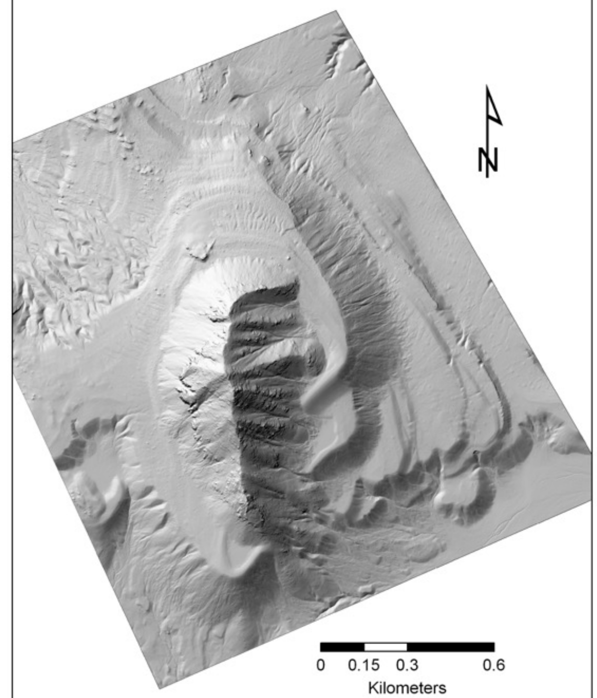
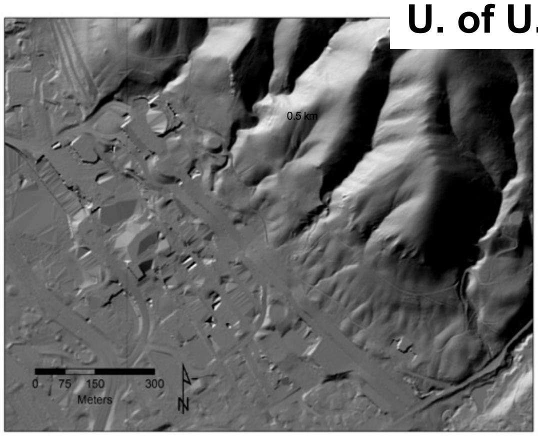


Table Mountain

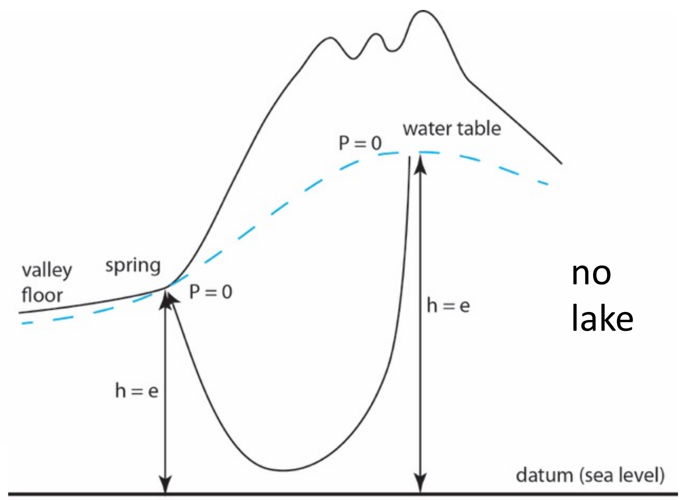


U. of U. hospital



lidar images from Paul Jewell

groundwater flow into Lake Bonneville

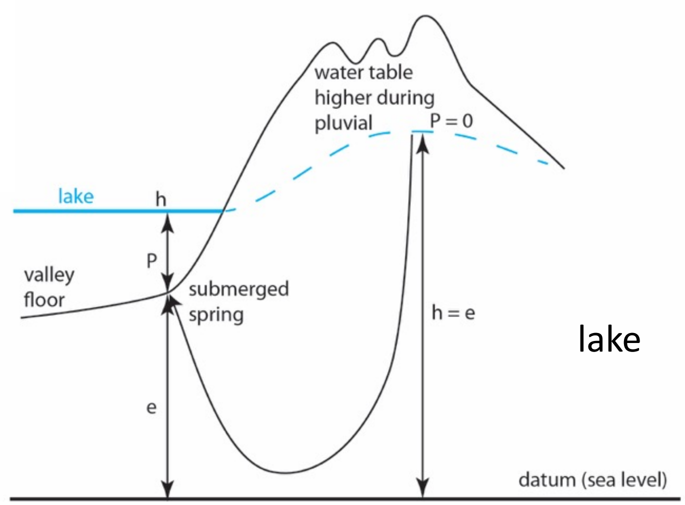


no
lake

h = hydraulic head
P = pressure head
e = elevation head

$h = e + P$

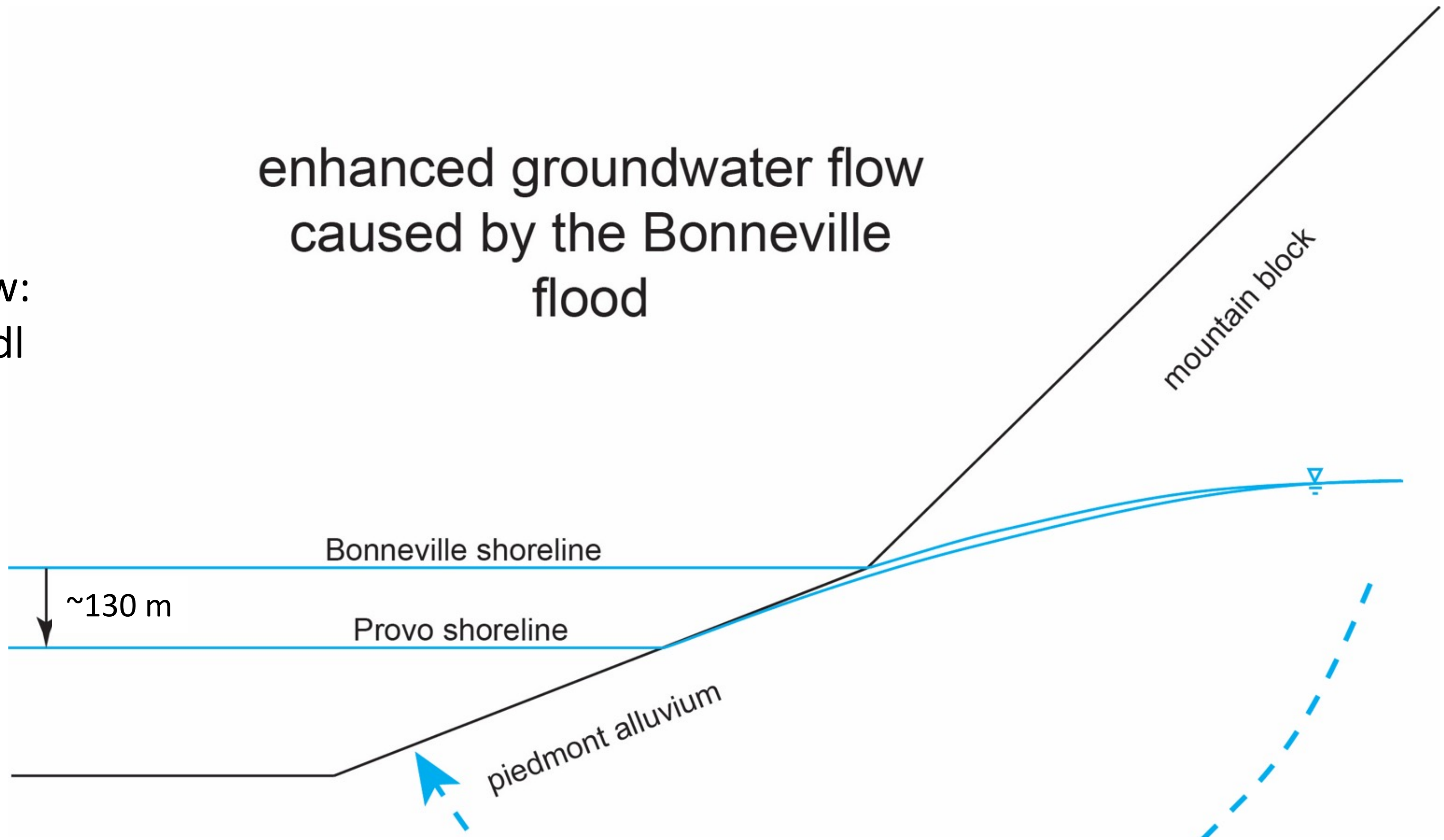
Darcy's law:
$q = K*dh/dl$



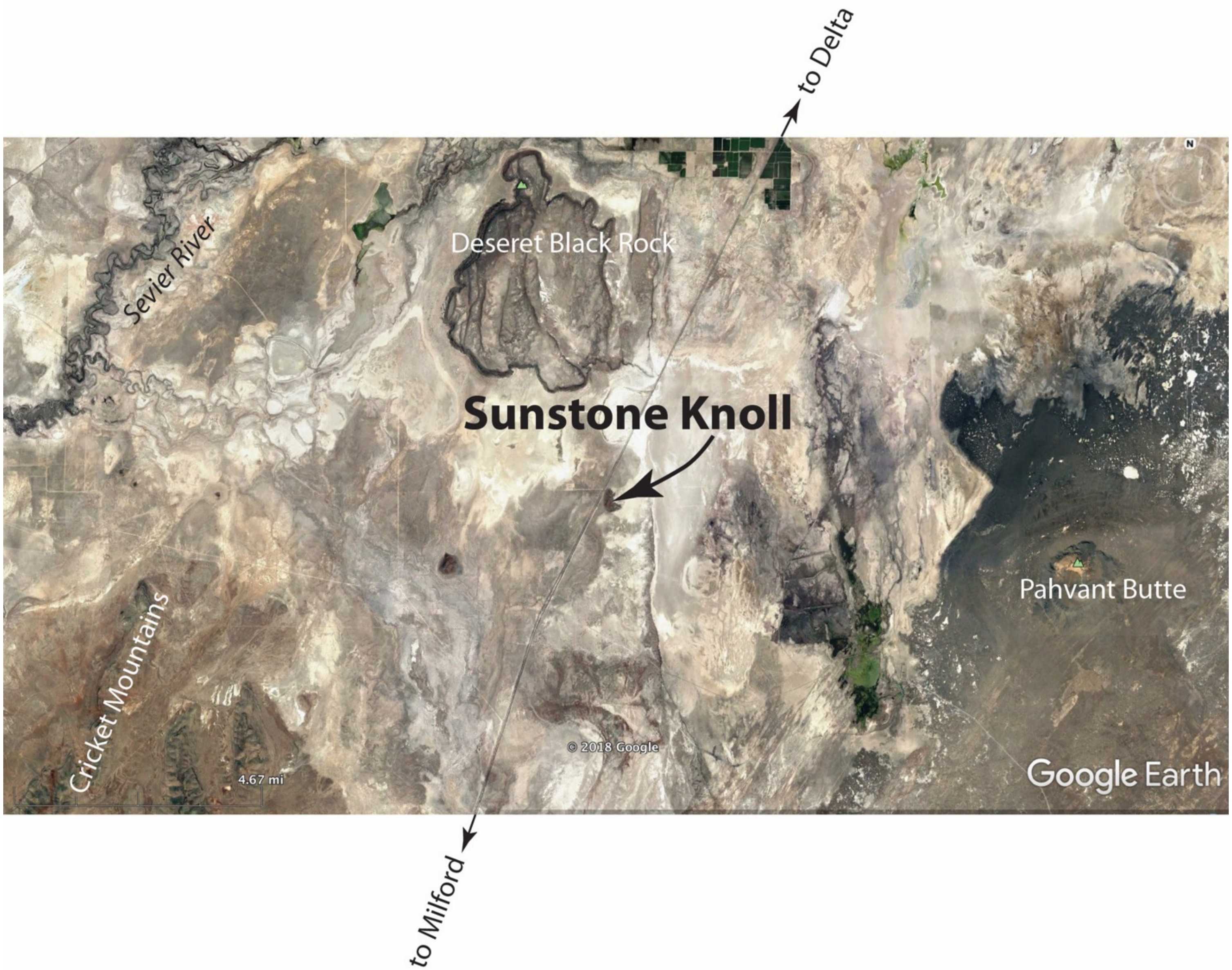
lake

Darcy's law:
q = K*dh/dl

enhanced groundwater flow caused by the Bonneville flood

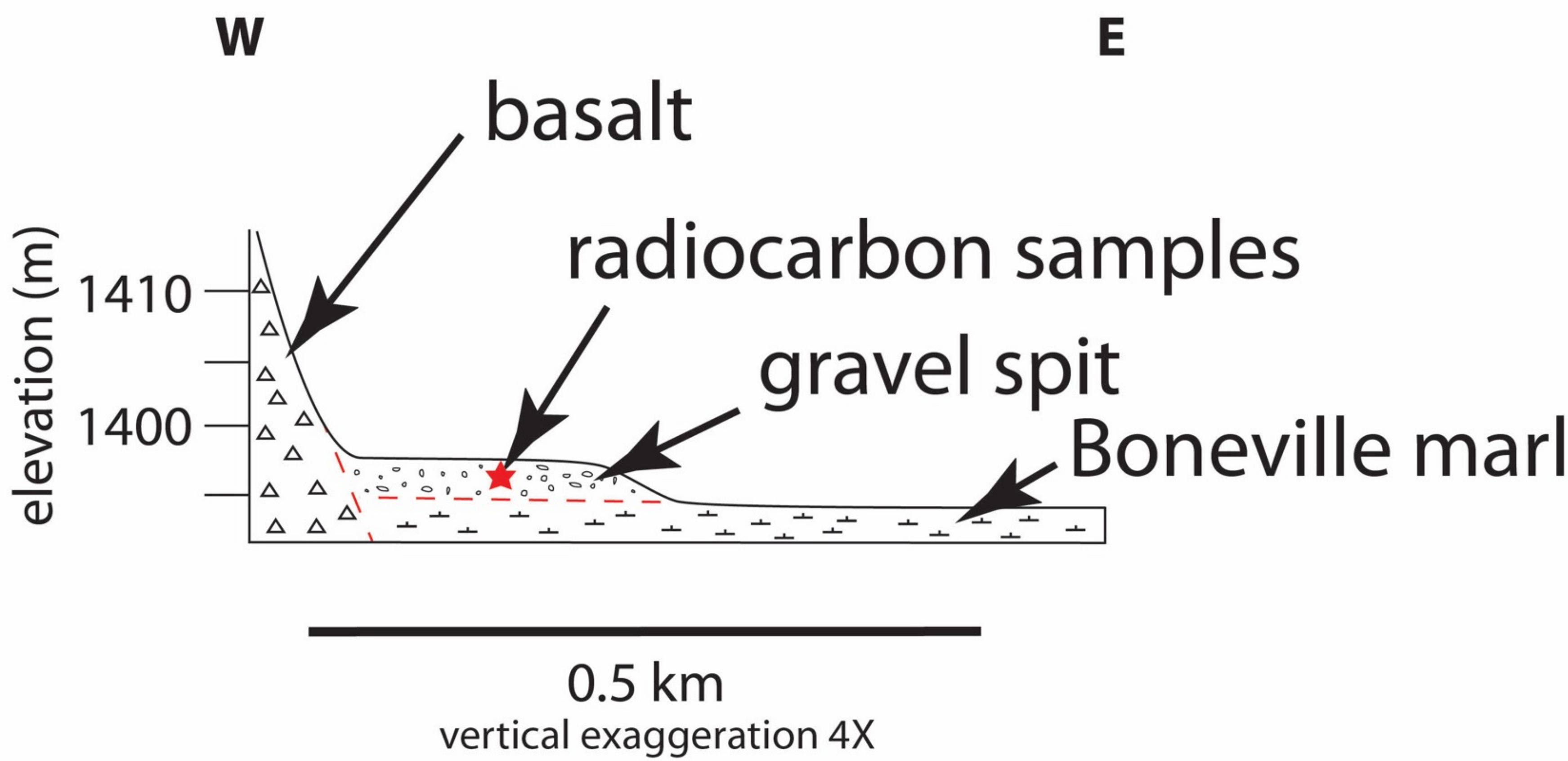


dh increased after the flood if recharge in the mountains remained high and the water table was not lowered age of the regression to the floor of the Sevier Desert (~1400 m; 4600 ft)

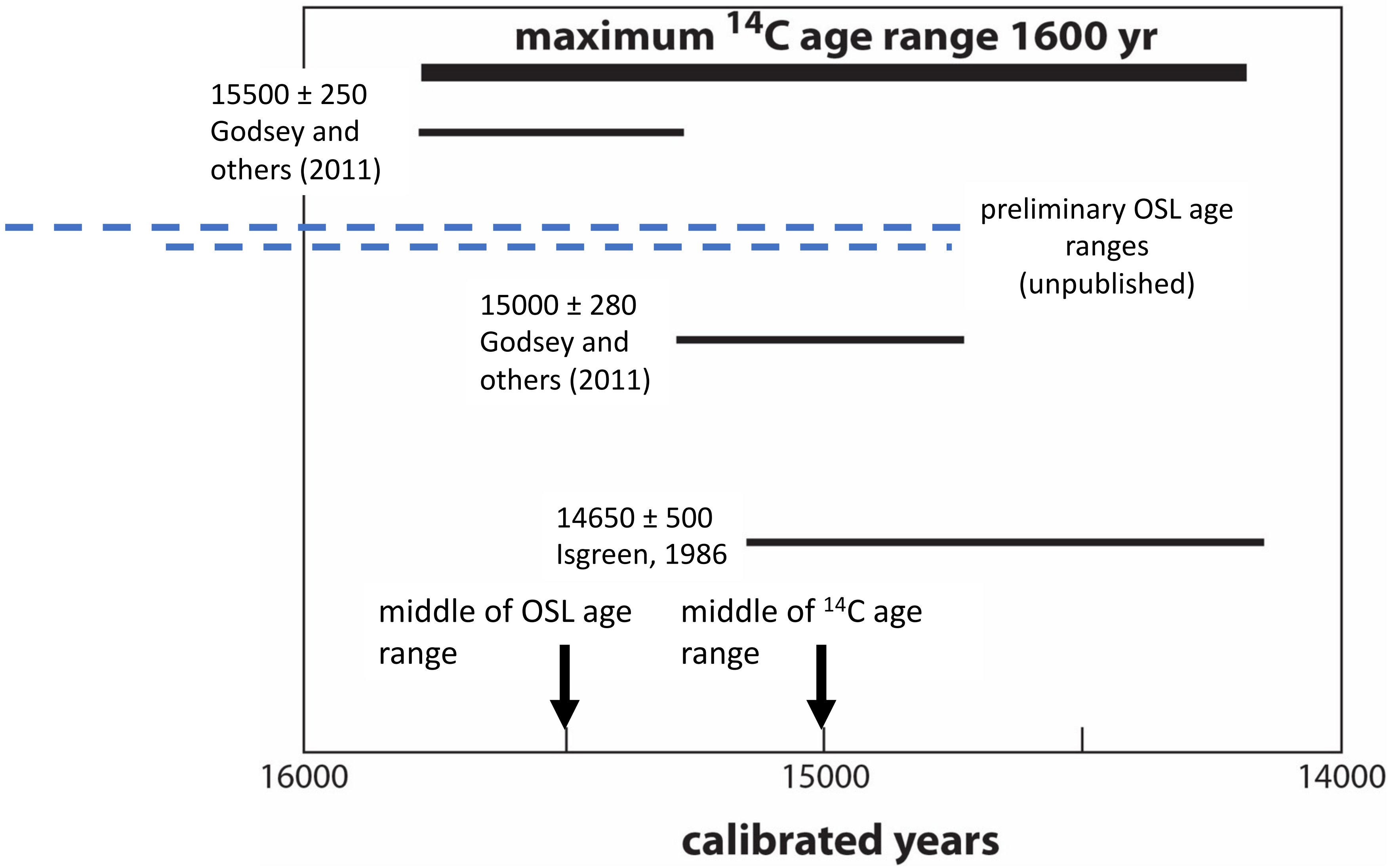


to Delta
Deseret Black Rock
Sevier River
Sunstone Knoll
Pahvant Butte
Cricket Mountains
4.67 mi
© 2018 Google
Google Earth
to Milford

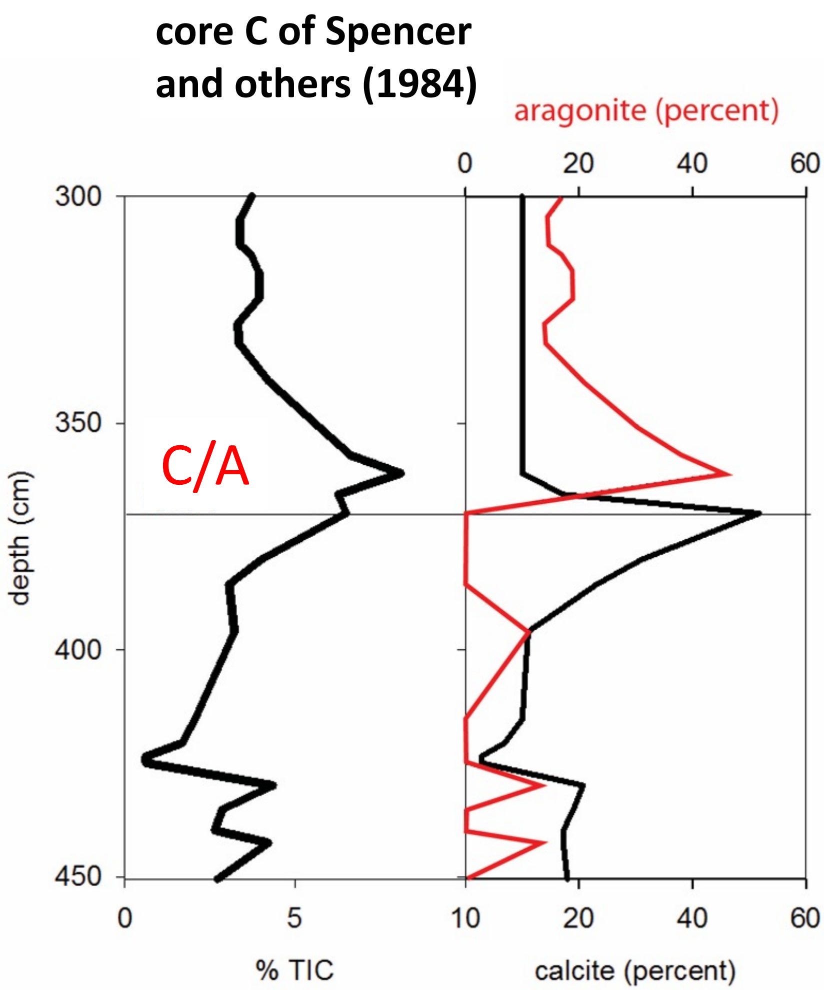
Sunstone Knoll



Sunstone Knoll ages



end of Lake Bonneville

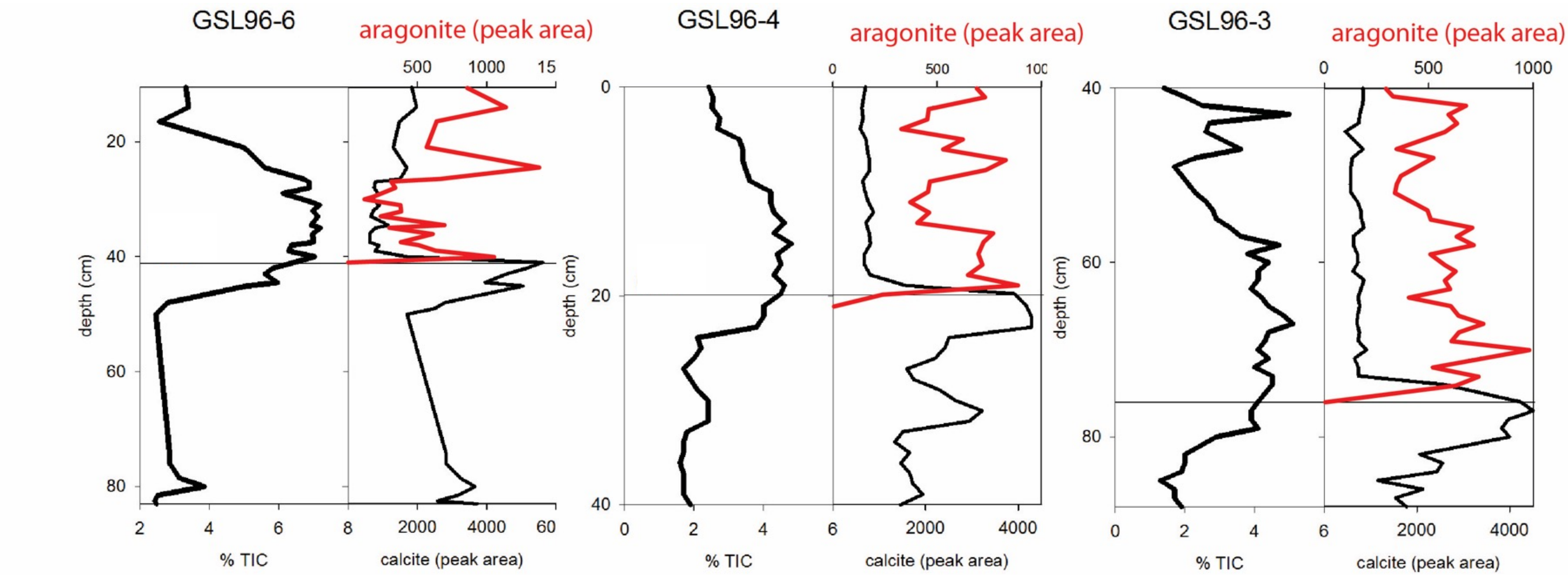


calcite-aragonite (C/A) shift

The dominant carbonate mineral changed abruptly as the lake neared the end of its regression and the ratio of Mg to Ca increased.

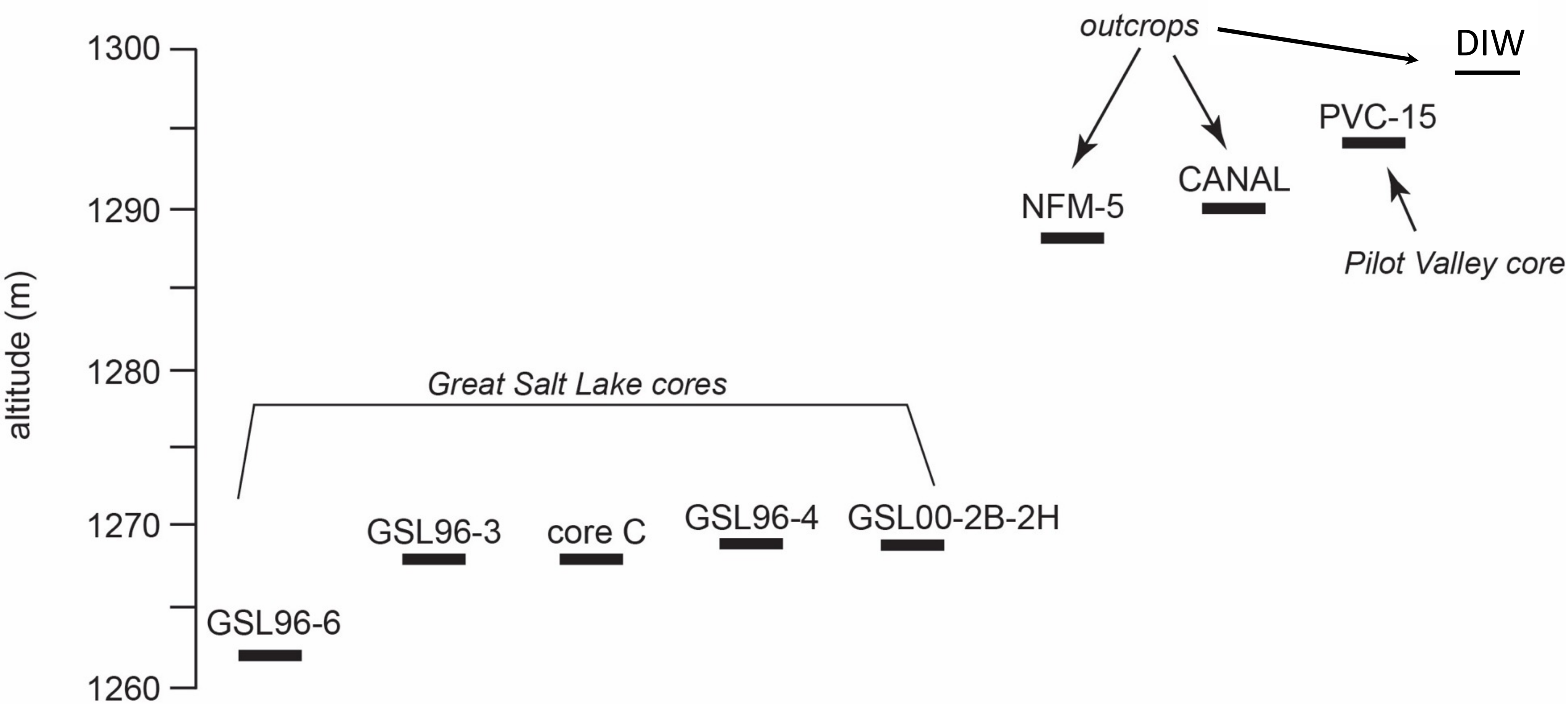
data from Spencer and others (1984); Thompson and others (1990); Jones and others (2009)

C/A shift in three USGS cores



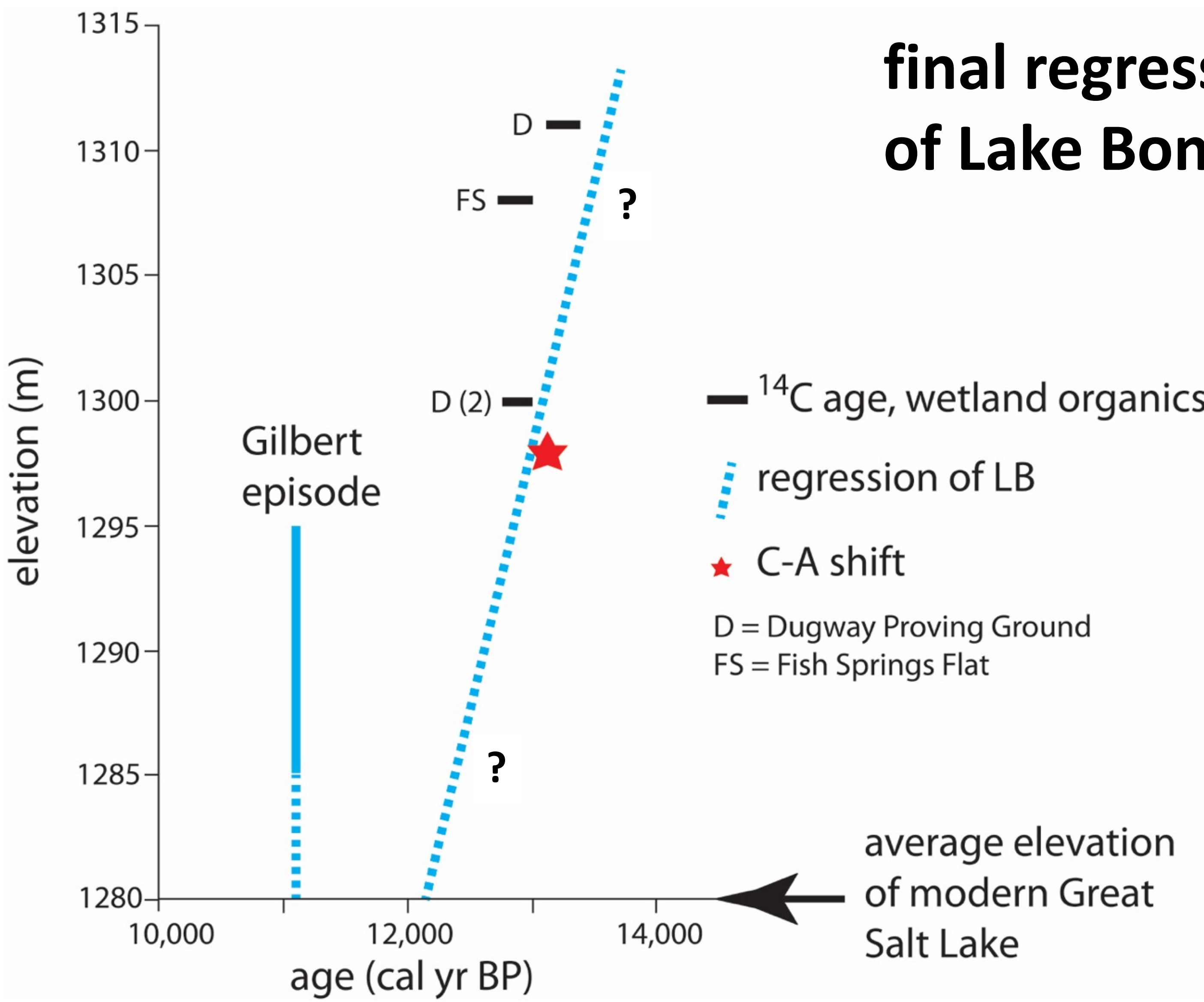
data from Thompson and Oviatt, unpublished;
Thompson and others (2016)

C/A elevations in cores and outcrops

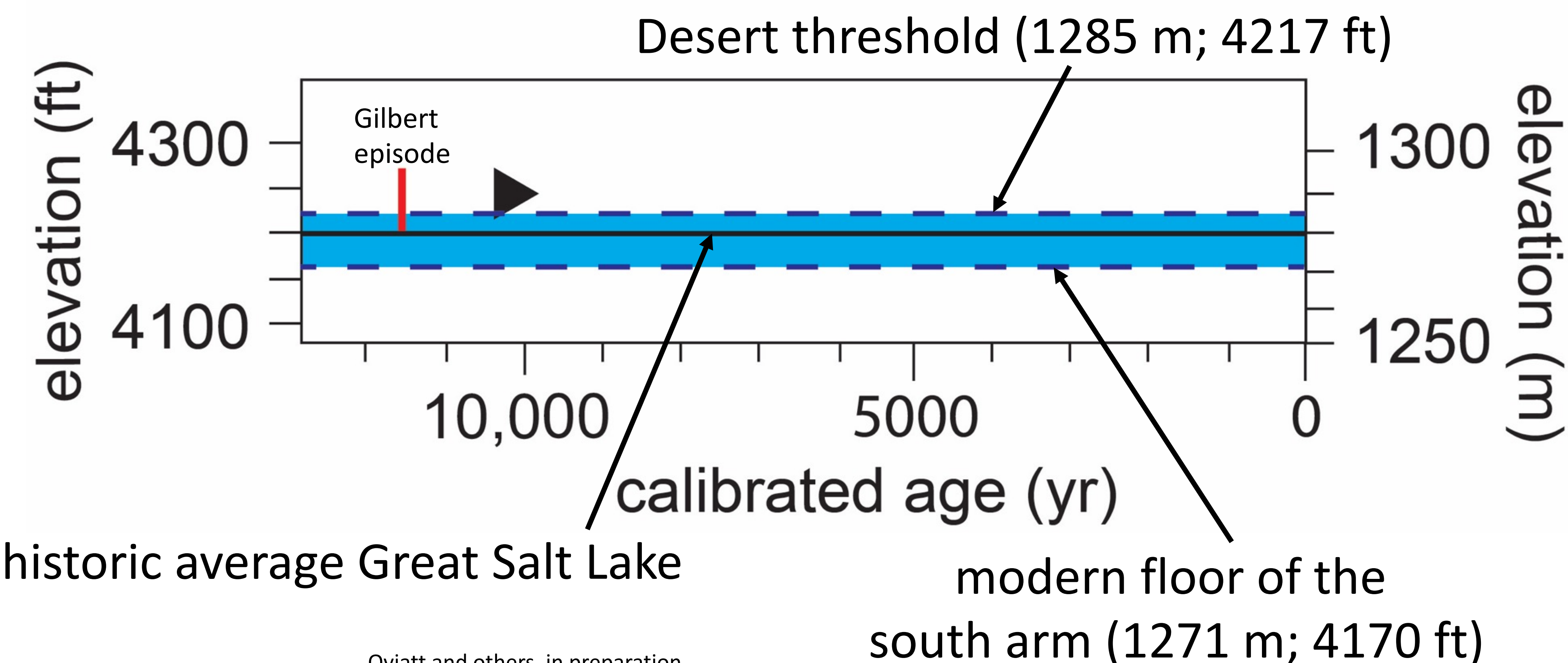


data from Oviatt and others, 1994; Oviatt, 1997; Oviatt and Miller, 1997; Oviatt, unpublished; Rey, 2012; Thompson and others, 2016; Thompson and Oviatt, unpublished

final regression of Lake Bonneville



Great Salt Lake



Oviatt and others, in preparation


Thanks!

GREAT SALT LAKE – LAKE BONNEVILLE: IT'S A SYSTEM, AND DON'T ASSUME SHORELINES ARE LEVEL

Genevieve Atwood

Earth Science Education, Salt Lake City, UT 84103

genevieveatwood@comcast.net

ABSTRACT

Great Salt Lake, Lake Bonneville, and their predecessors have fluctuated across low regions of the tectonically active eastern margin of the Great Basin. Great Salt Lake and Lake Bonneville are end members of a system, Lake Bonneville being the expression of global-glacial climate of Oxygen Isotope Stage 2 and Great Salt Lake being the expression of global-interglacial climate of Oxygen Isotope Stage 1. How can shoreline evidence of Great Salt Lake contribute to an understanding of Lake Bonneville? Both lakes' coastal processes contrast with those of marine margins. Specifically, Great Salt Lake is a closed-basin lake that is fetch-limited, shallow, ever-fluctuating, and that occupies multiple-basins. Those five characteristics, and others, have consequences for shorezone processes. Researchers of the Lake Bonneville–Great Salt Lake system should expect to find, and not be surprised to find shoreline evidence of a given "lake level" (meaning the still-surface-water elevation of the lake) across a range of values. This is the rule, not the exception. No wind. No waves. No (well… very little) geomorphic work. Shoreline superelevation (the difference in elevation between lake level and the shoreline evidence of that lake level) is a proxy for wave energy, but not necessarily for wind strength and direction. Should you be so fortunate to have a fetch-limited (less than 80 km diameter), circular lake, preferably with three equidistant islands, take confidence that its patterns of shoreline superelevation, shorezone slope, sedimentation, and vegetation give multiple lines of evidence of storm wind direction. Great Salt Lake is fetch-limited. Shorezone evidence of its 1986–1987 highstand appears to be consistent with storm wind direction and strength. As for Lake Bonneville, expect complexities and embrace them.

This content is a PDF version of the author's PowerPoint presentation.

Great Salt Lake

insights to Lake Bonneville?

Genevieve Atwood

2018 Lake Bonneville Geologic Conference and Short Course
October 3, 2018

#1 Review Atwood-Wambeam-Anderson's Chapter in Oviatt-Shroder, Lake Bonneville

#2 Review Atwood, Shoreline Superelevation…, UGS Misc Pub 06-9.

GSL = Accessible!!

GSL + LB =
End members of a system.

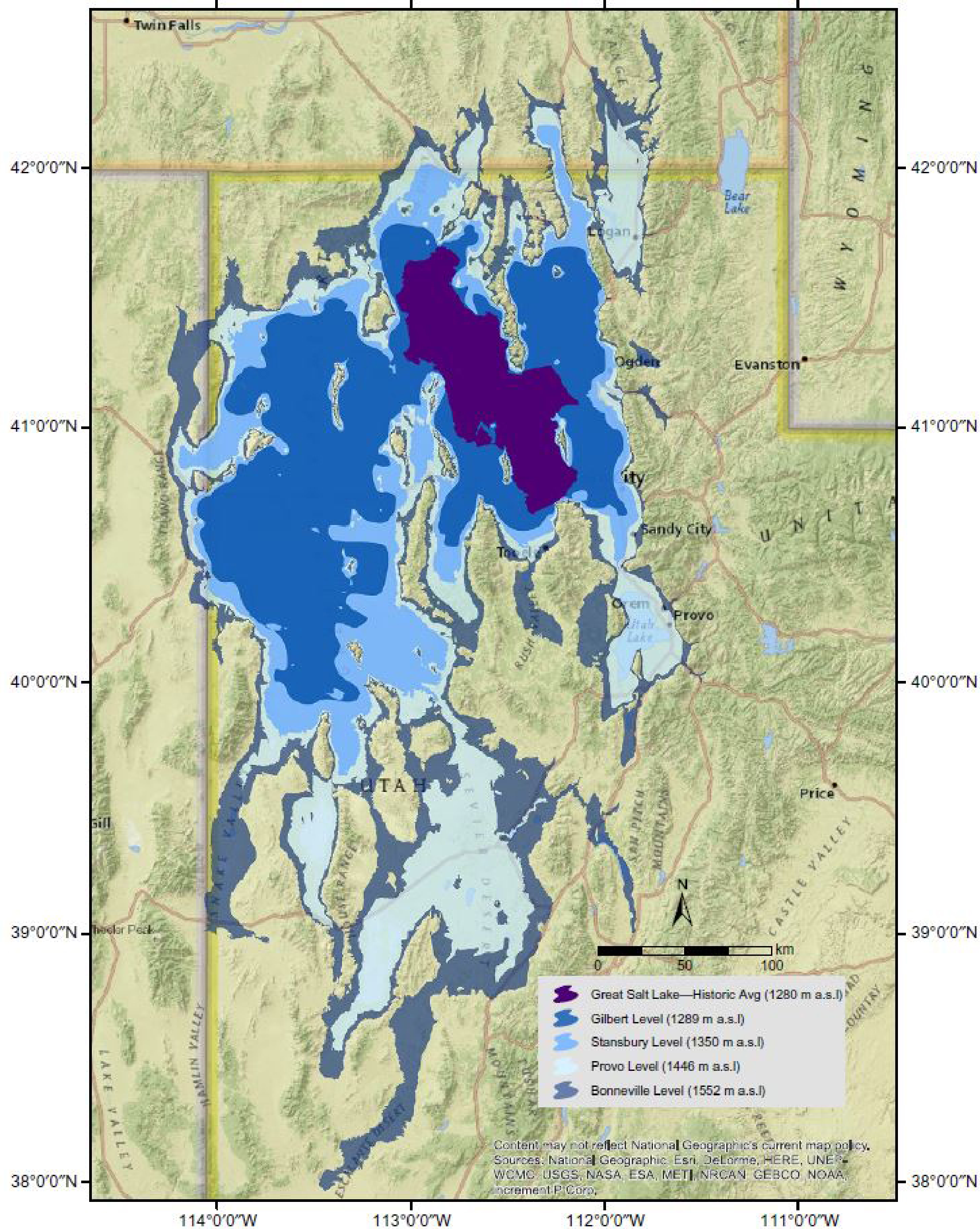
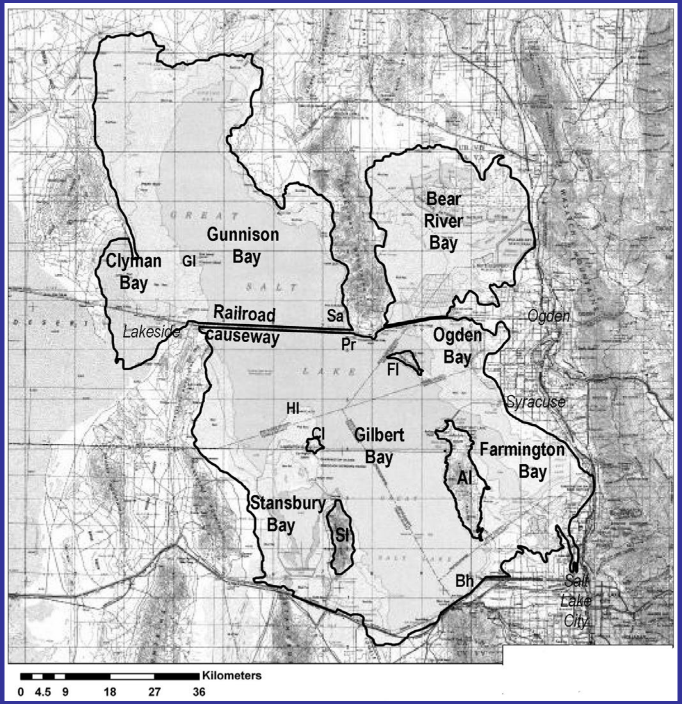


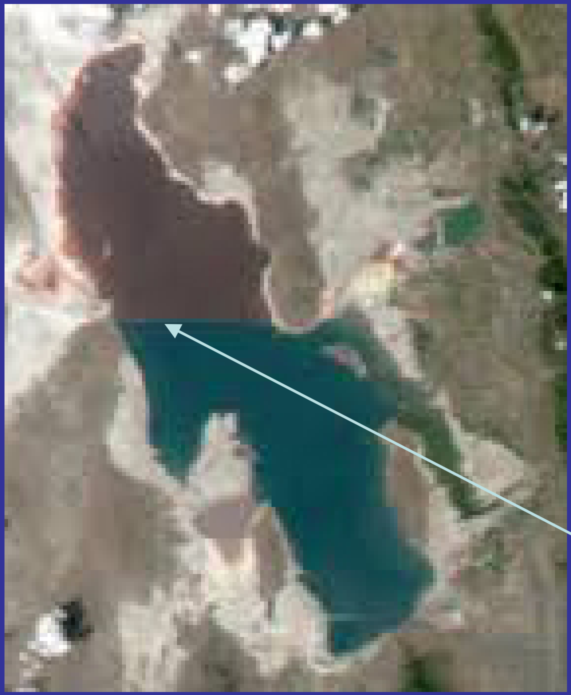
FIG. 1.2 Extent of major levels of Lake Bonneville and Great Salt Lake.



Effects of:
+Multiple basins,
+Thresholds between basins,
+Complex shapes
(hypsometry).

GSL as analog for LB.

Constrictions.
Basins aren't simply "open" or "closed."



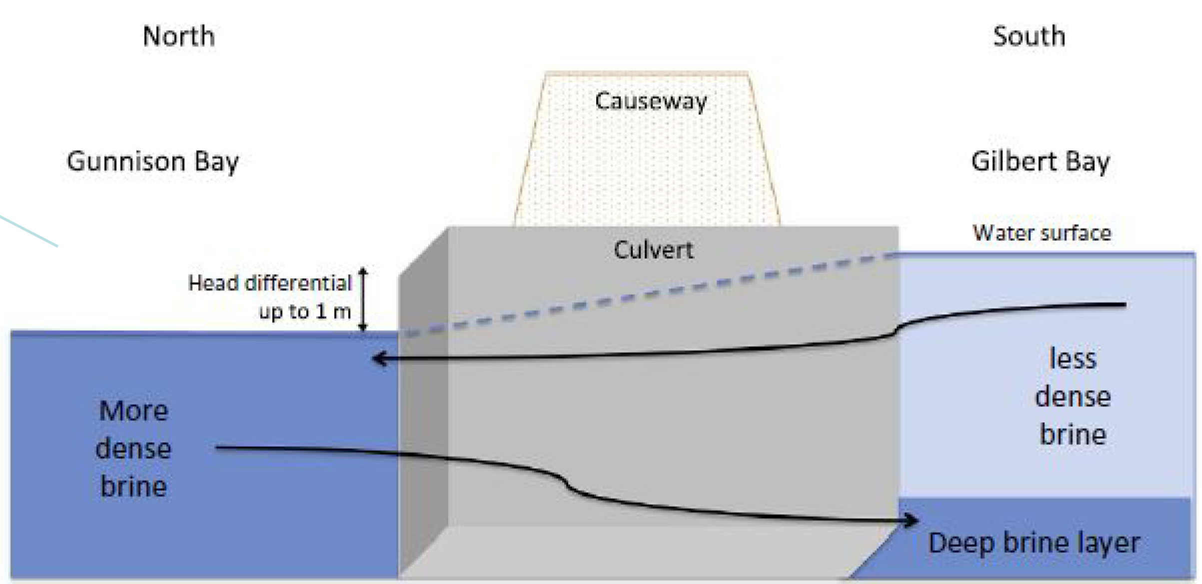
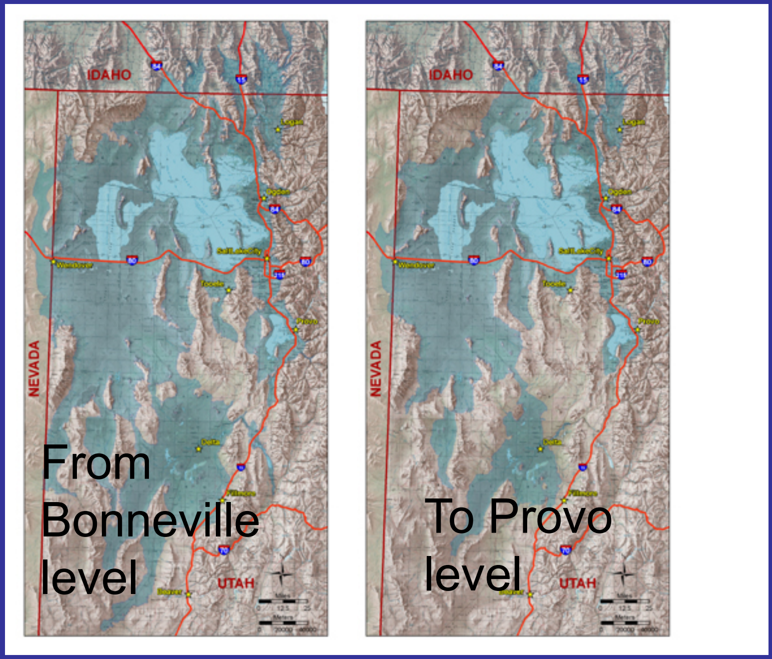


FIG. 1.11 Lake constrictions, Great Salt Lake. Constricted flow through culverts between Gilbert and Gunnison Bays alters lake chemistry of Great Salt Lake.

We say: "Great Salt Lake is a terminal lake." It's more complex than that.
Today, Gunnison Bay is the terminus of the Great Salt Lake watershed because of constrictions of the railroad causeway.



Constricted flow – LB

During Provo time, the main body of LB was somewhat analogous to Gunnison Bay of GSL.
The water balance and chemistry of the “main body” of Lake Bonneville changed from “open” to “constricted” when LB fell from the Bonneville level to the Provo level. Hence: marls and tufas of Provo level according to GK Gilbert.

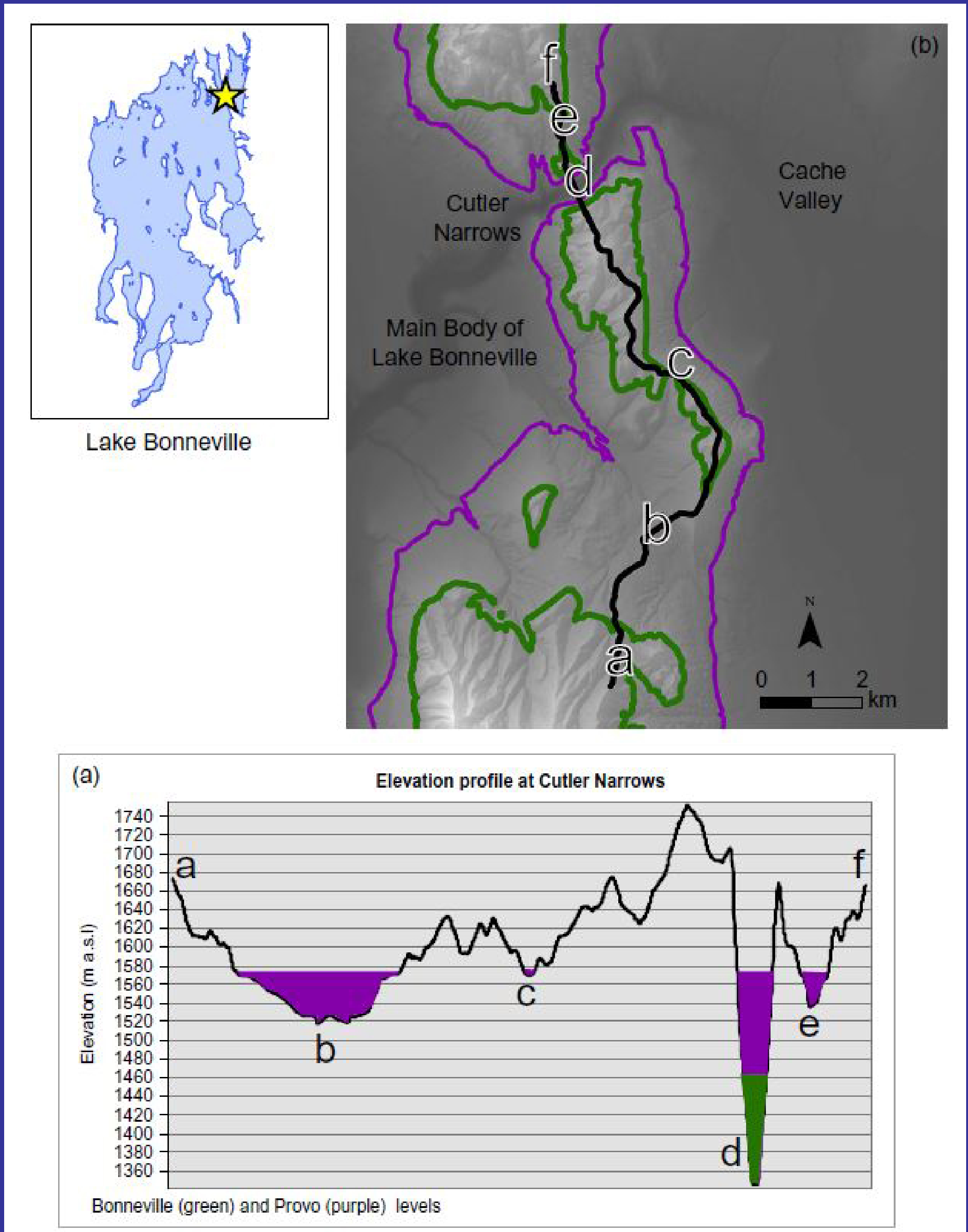


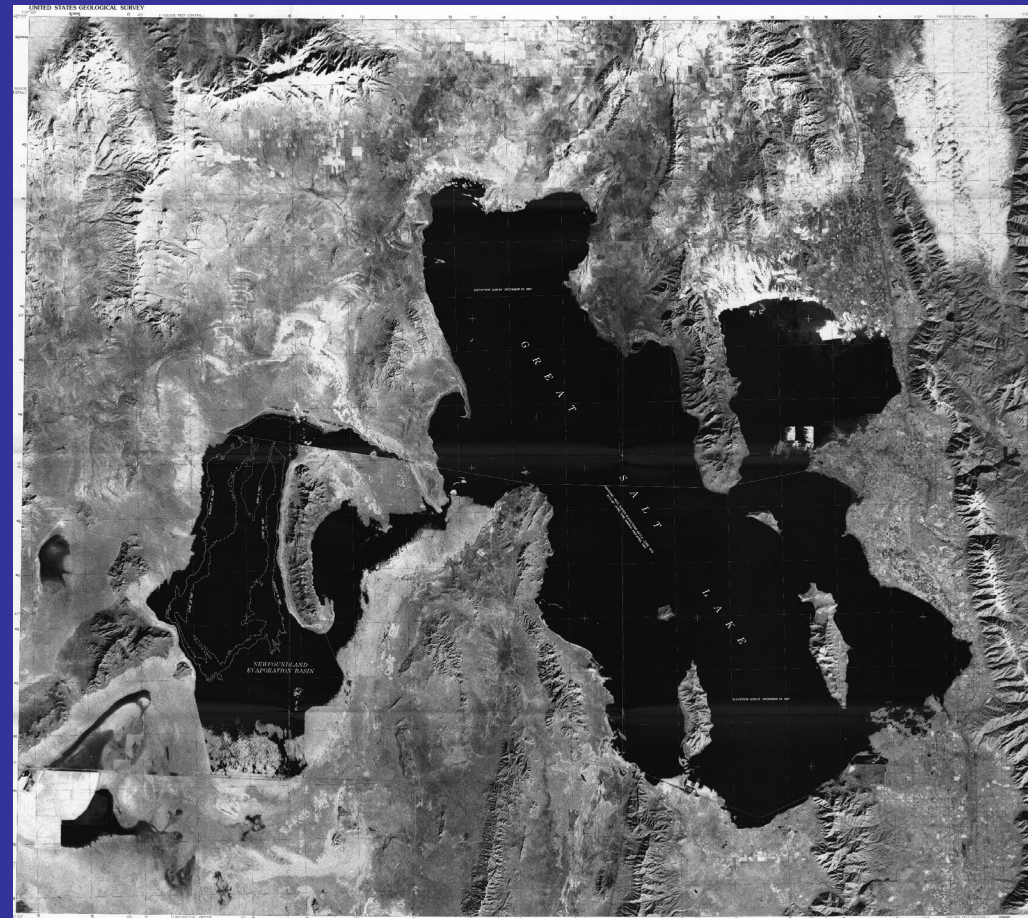
FIG. 1.12 Lake constrictions, Lake Bonneville. **Cutler Narrows - Bonneville vs Provo levels.**

#2. Present findings of Atwood, G., 2006, Shoreline Superelevation: evidence of coastal processes of Great Salt Lake, Utah, UGS, Misc Pub 06-9. Findings from UGS Misc Pub 06-9 were incorporated into Oviatt-Shroder Lake Bonneville.

Clarify what is meant by “shoreline.”
Coastal processes of GSL.
GSL = Fetch-limited, shallow lake.
GSL = Highly responsive

Correlating shorelines of closed-basin lakes is inherently difficult.

1960's low



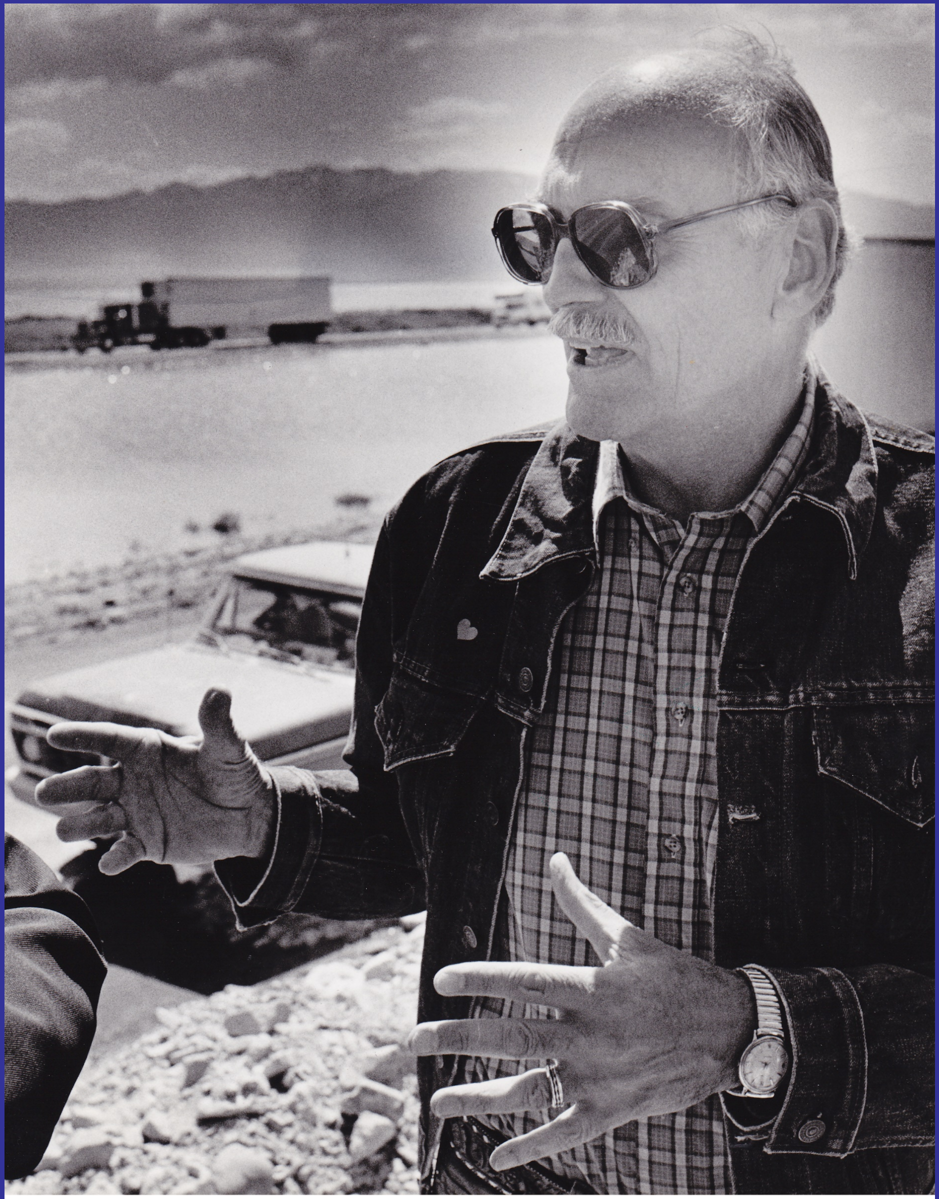
1980s high

Real time evidence of Great Salt Lake's surface elevations.

Great Salt Lake is highly responsive to decadal climate.
What can we learn from historic GSL about its shorelines and how to correlate them with lake fluctuations?

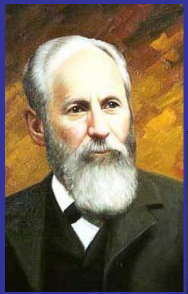
The 1980s wetcycle = 1982-1987
Lake level was monitored.
The lake's highstand level (4212 ft a.s.l. = 1283.7 m a.s.l.) was reached in 1986 and again in 1987.

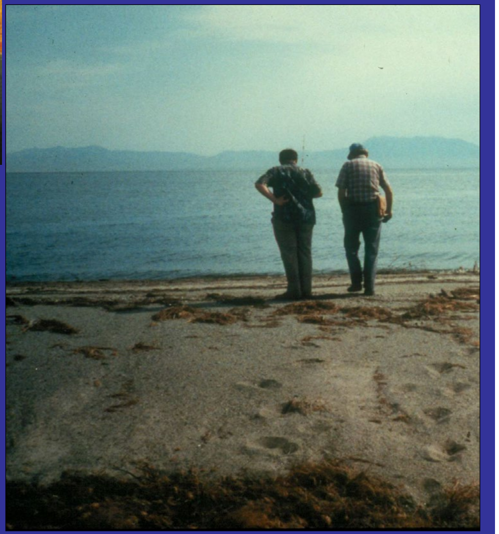
The Guv and others asked UGS:
How high will the lake rise?
How often has it happened?
What damages and how costly?

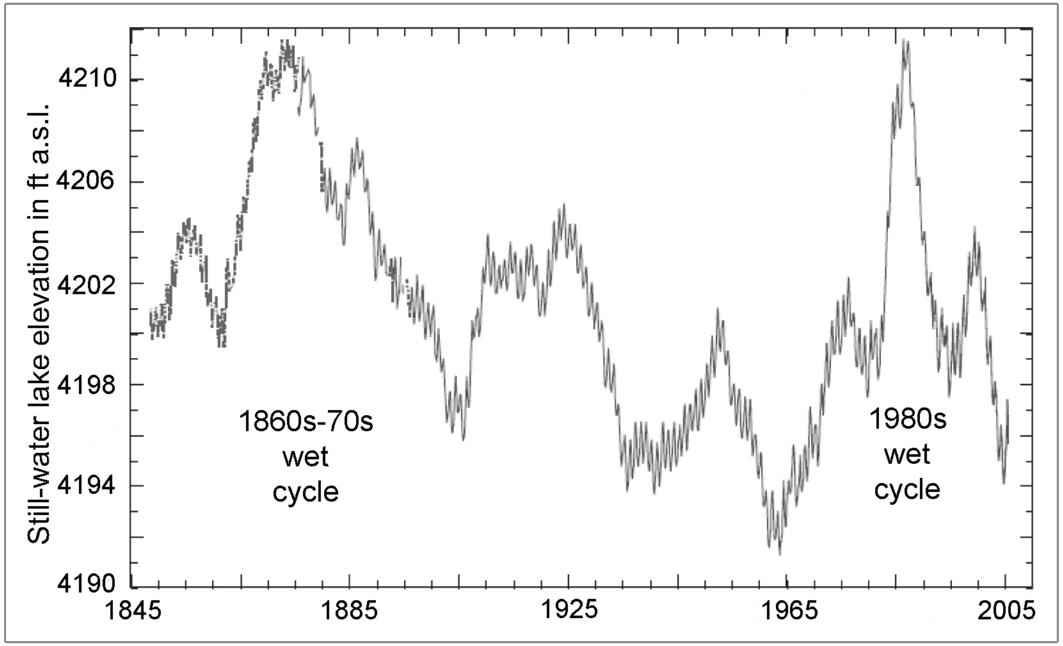


Deseret News photo, Don Grayston, June 10 1984 - used with permission.

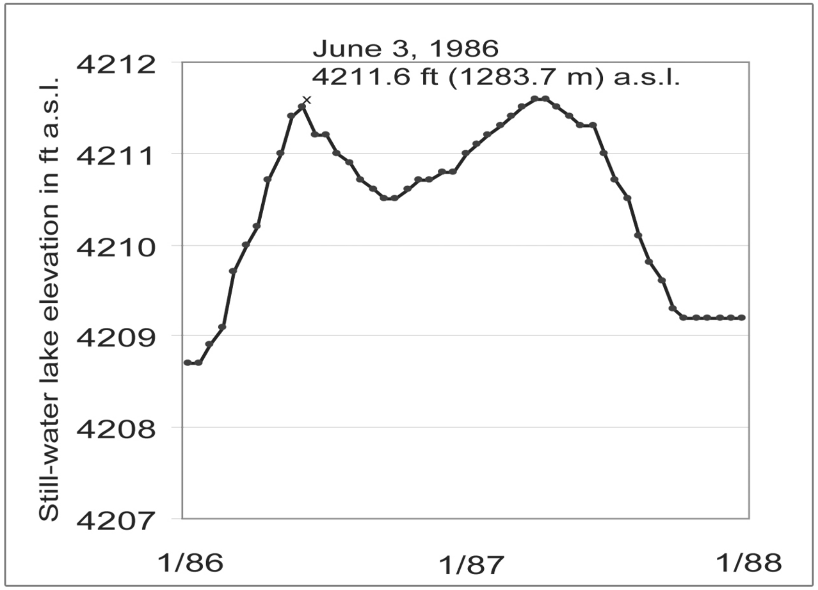
Governor Scott Matheson at Interstate-80.







I still ask myself those questions.

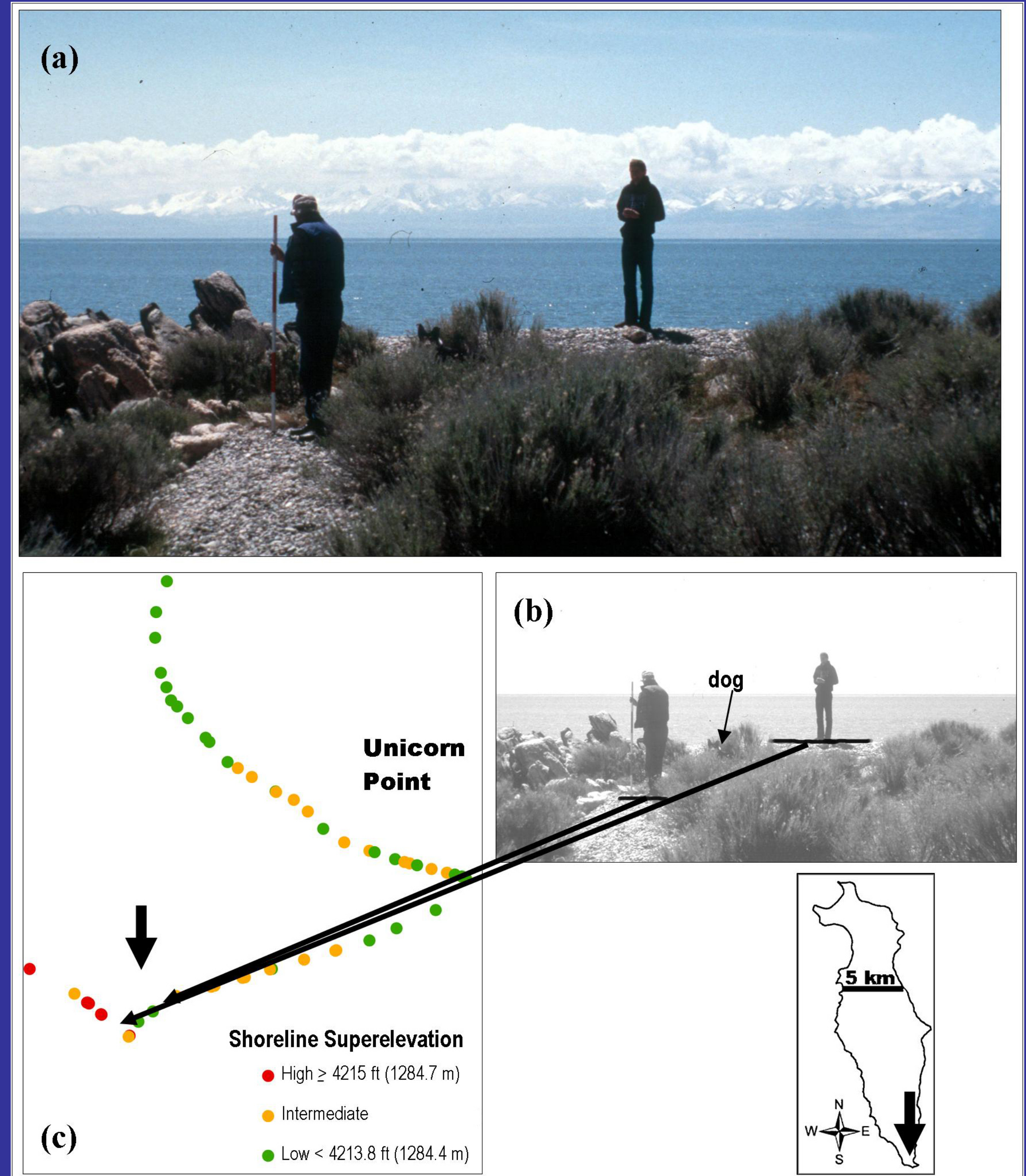


Does understanding GSL apply to LB? Of course. They are a system.

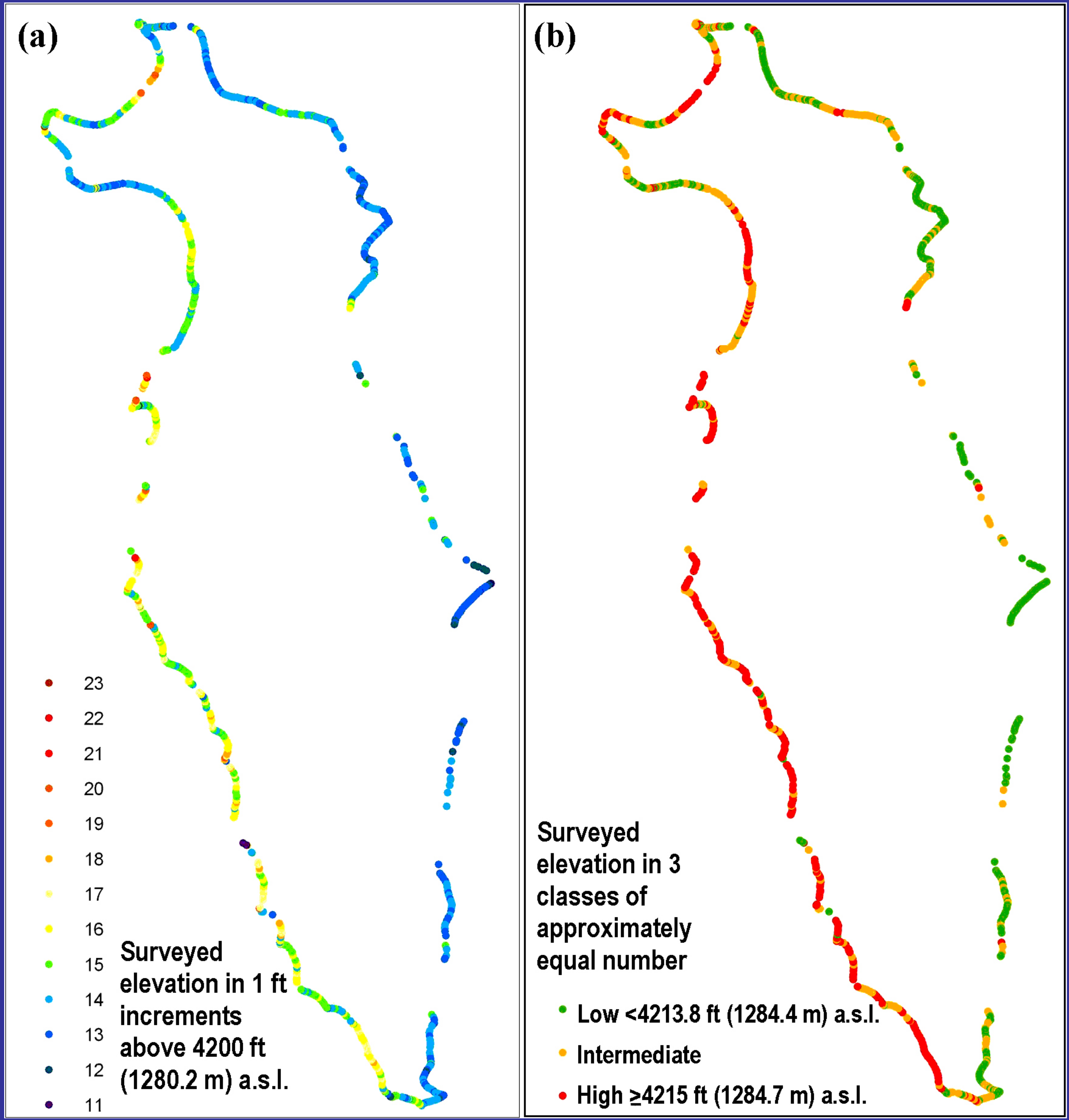
A shoreline is the hypothetical interface of water and land.
Still-water elevation implies a horizontal, quiet water interface.
No wind, No waves, No geomorphic work.
The lake does not leave recognizable evidence at its still-water level.

Waves create the “shorelines” of GSL. Elevation of shoreline evidence of the 1980s highstand varies… substantially.

Still-water level within a week of the 1986 highstand.



Both individuals stand on shoreline evidence of 1980s highstand.


(a)
23
22
21
20
19
18
17
16
15
14
13
12
11
Surveyed elevation in 1 ft increments above 4200 ft (1280.2 m) a.s.l.
(b)
Surveyed elevation in 3 classes of approximately equal number
Low <4213.8 ft (1284.4 m) a.s.l.
Intermediate
High ≥4215 ft (1284.7 m) a.s.l.

Why aren't shorelines of GSL at the still-water level?
And why do elevations vary?
THAT is the topic of UGS Misc Pub 06-09

POINT DATA
1228 locations surveyed for elevation of shoreline evidence.

THREE SETS of LINE DATA
667 shoreline stretches characterized for the 15 attributes.

305 shoreline stretches characterized for geomorphic attributes such as fetch and aspect from maps.

94 shoreline stretches characterized for their planform shape, such as convex or concave.

POLYGON DATA 208 shoreline stretches characterized with geologic attributes such as bedrock versus surficial materials.

Coastal processes of Great Salt Lake…

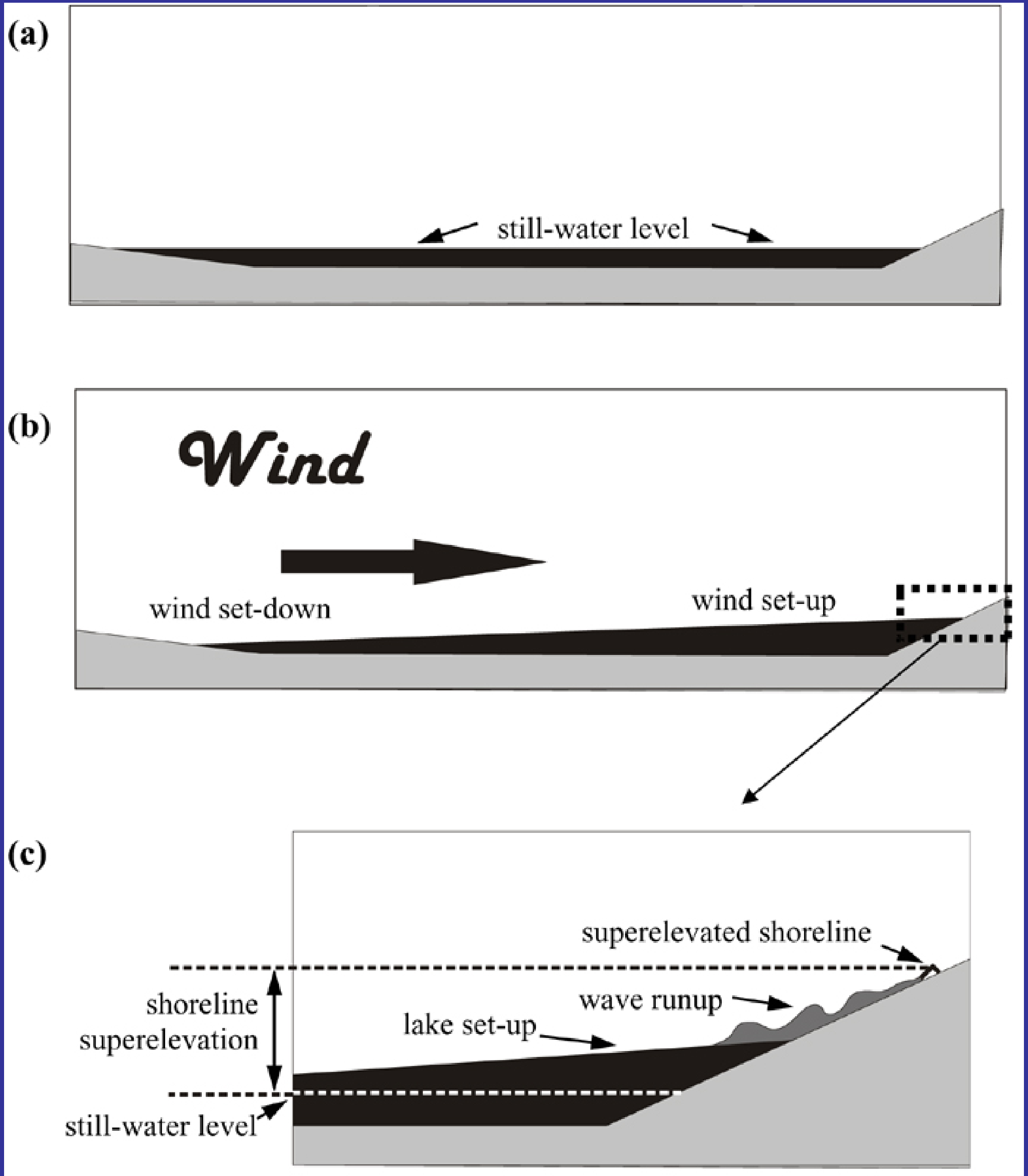
Still-water lake elevation (looking west across Farmington Bay to Antelope Island, 2005).

Big concept… Local storm winds create the waves of Great Salt Lake.

Great Salt Lake
is not:

Hawaii

Coastal processes: wind set-up and wave runup

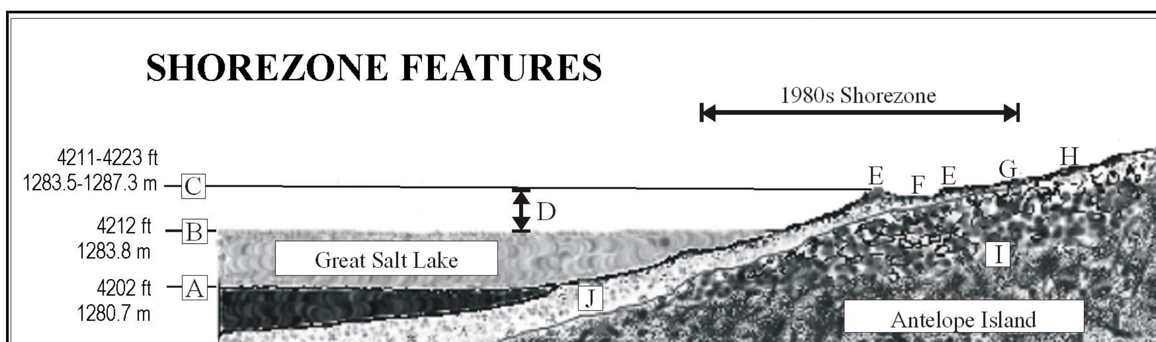


Shoreline superelevation =

elevation of shoreline debris above the stillwater lake level.

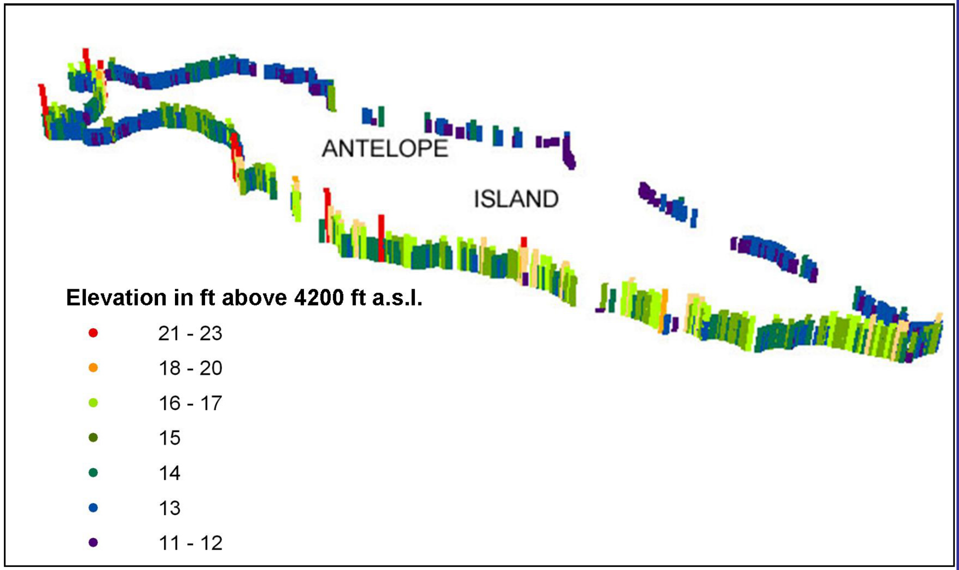
(a)

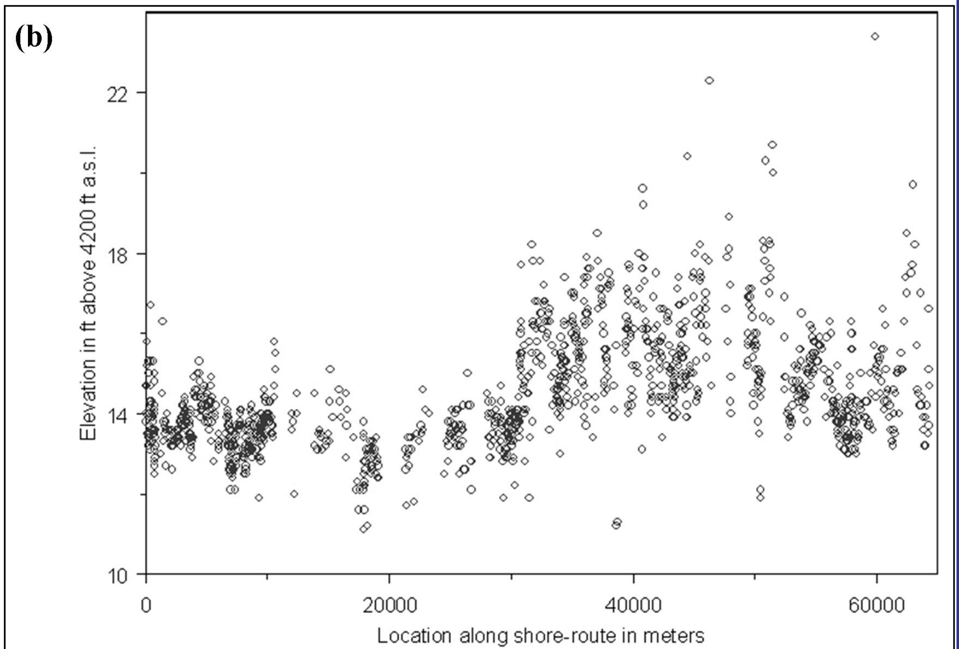
(b)

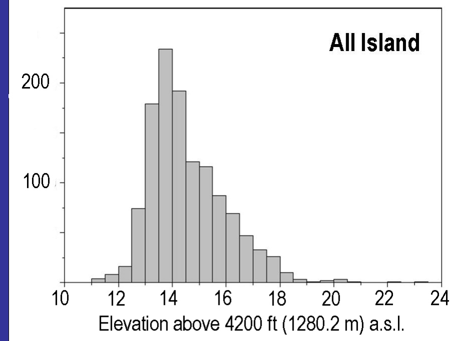


A	Historic average elevation of Great Salt Lake	F	1980s lagoon
B	Elevation of 1980s highstand stillwater lake surface	G	1980s killed vegetation
C	Elevation of Antelope Island's 1980s debris lines	H	Shorelines older than 1980s
D	Shoreline superelevation	I	Substrate
E	1980s debris lines	J	Lake deposits, 1980s and older

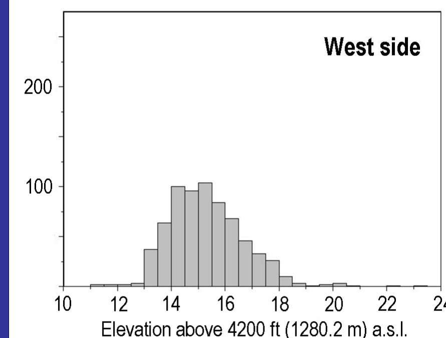
Elevation differences along the 1980s highstand shoreline of GSL.



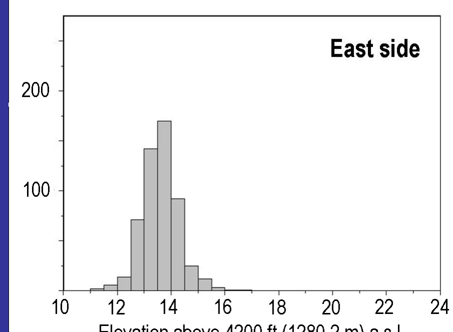




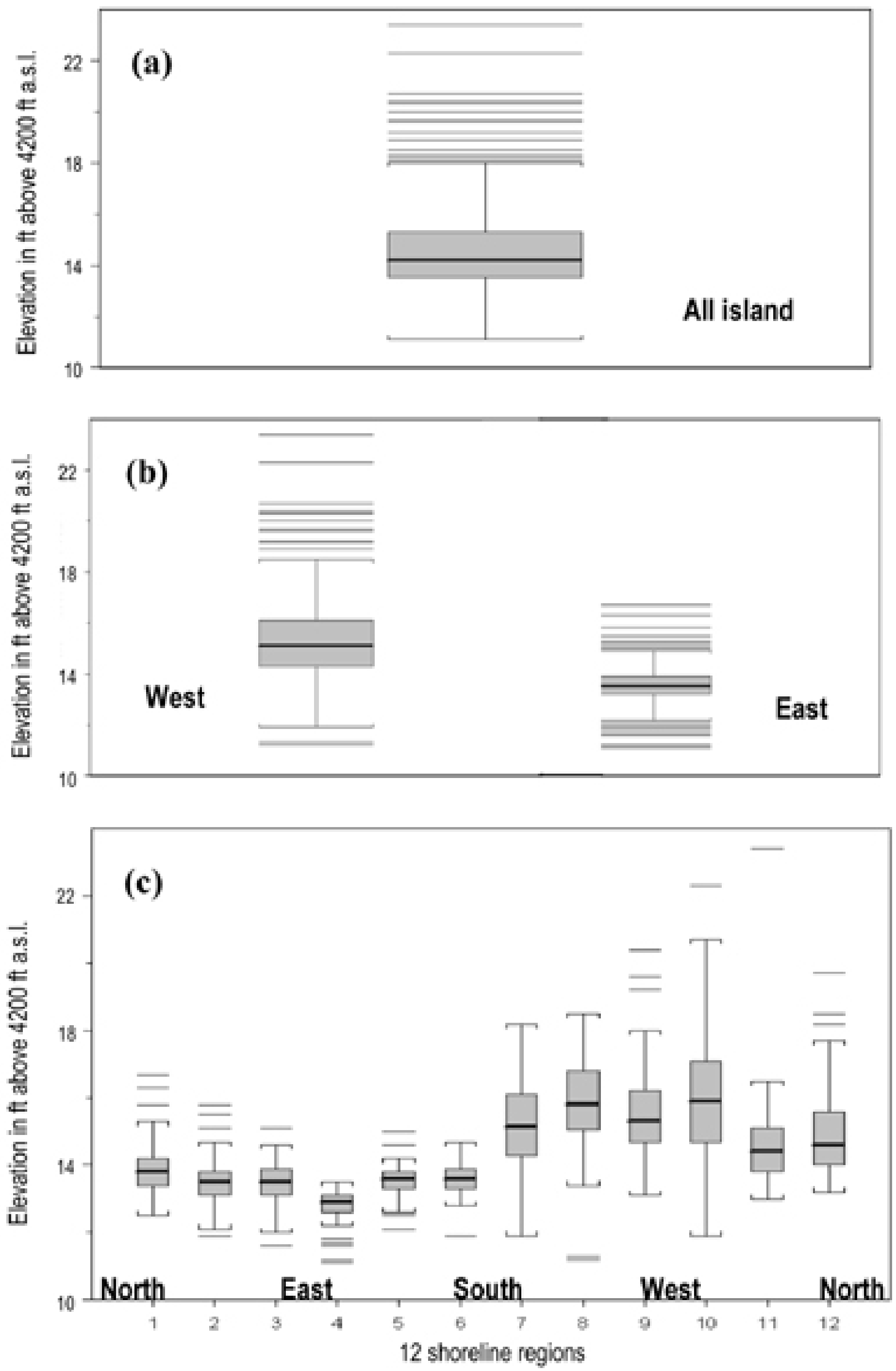
Summary	All Island
Minimum	11.1
1st Quartile	13.5
Mean	14.5
Median	14.2
3rd Quartile	15.3
Maximum	23.4
Surveyed locations	1228



Summary	West Side
Minimum	11.2
1st Quartile	14.3
Mean	15.3
Median	15.1
3rd Quartile	16.1
Maximum	23.4
Surveyed locations	689



Summary	East
Minimum	11.1
1st Quartile	13.2
Mean	13.6
Median	13.5
3rd Quartile	13.9
Maximum	16.7
Surveyed locations	539



Shoreline evidence vs Shoreline.

Shoreline superelevation of evidence of Great Salt Lake is…

NOT spatially random

NOT inconsequential

Far from expecting shoreline evidence to continue on a horizontal plane, one should expect variability due to coastal processes.

WIND energy into a water body
Waves gain energy but… then max out on growth.

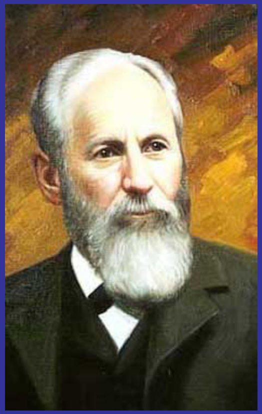
- Stronger wind… more energic waves.
- More distance across open water (fetch)… more energy into the lake, more energetic waves.
- Longer storm duration… more energy into the lake.

Disturbed seas begin with chaotic waves. With distance the waves sort out into wave trains.

Lakes are “fetch-dominated” or “fetch-limited.”

Fetch-dominated lakes are those with sufficiently long fetch that the contributions of energy from wind strength and storm duration are overwhelmed. In contrast, fetch-limited lakes’ energy grows with wind strength and storm duration.

Coastal processes of Lake Bonneville.



“At an early stage of the investigation, the writer … imagined that he had discovered therein the record of prevalent westerly winds ….

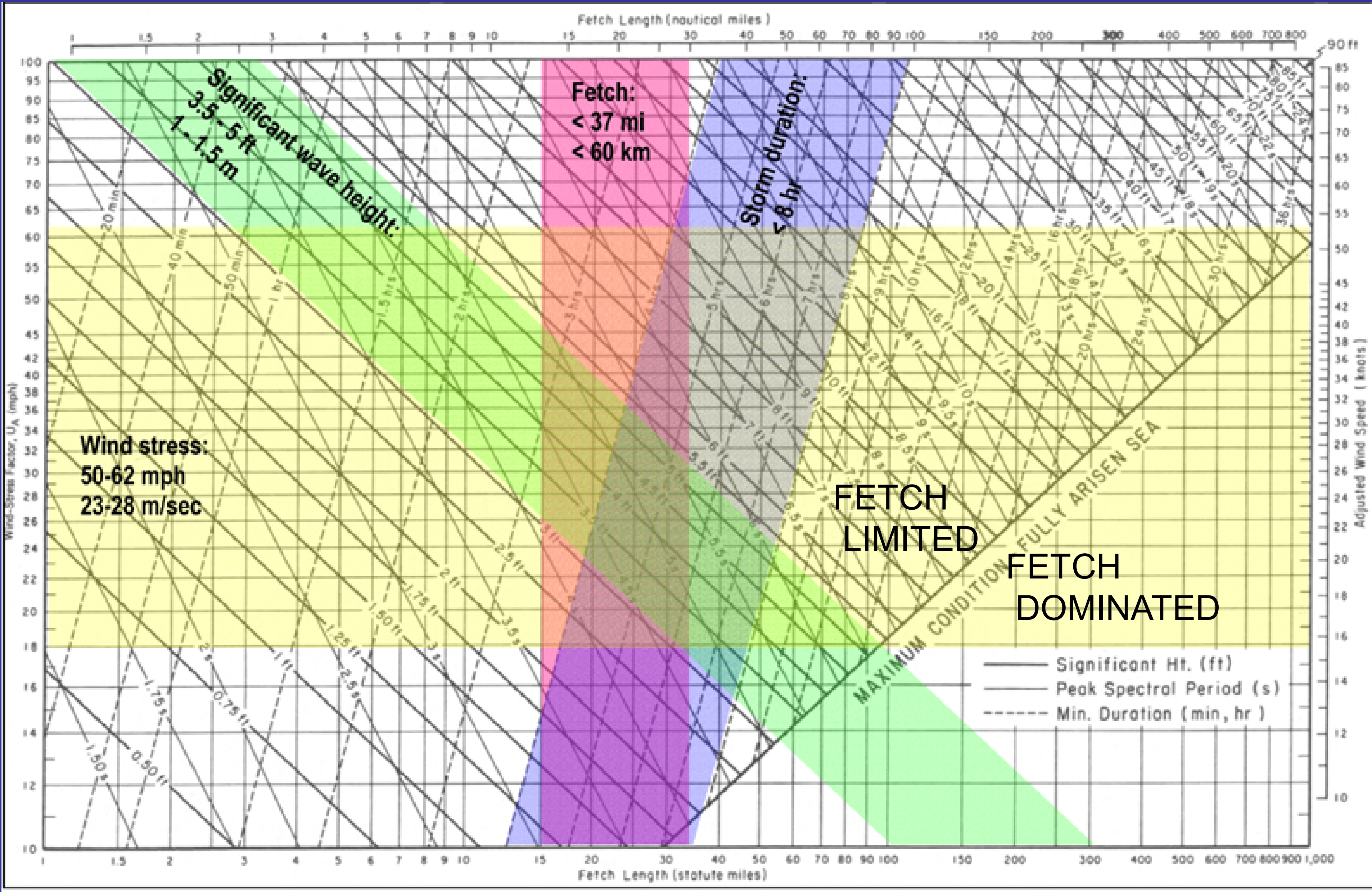
This belief was dissipated by further study; and he discovered, as students of modern shores long ago discovered, that there is a close sympathy between the magnitude of the shore features and the ‘fetch’ of the efficient waves….

The highest cliffs, the broadest terraces, and the largest embankments are those wrought by the unobstructed waves of the main body; and opposite coasts appear to have been equally affected.”

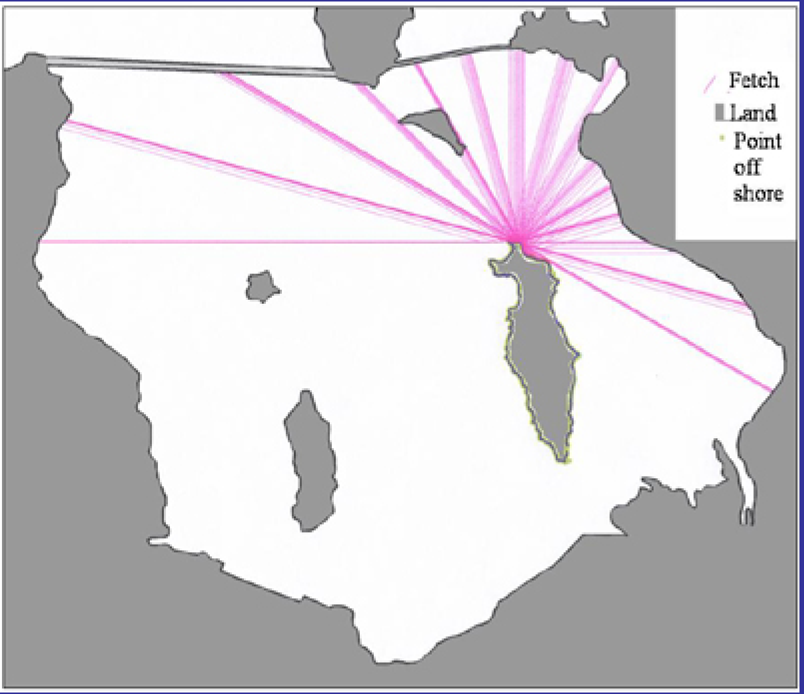
Gilbert, 1890, p. 107

Lake Bonneville has regions that are fetch-dominant.
Great Salt Lake is fetch-limited.

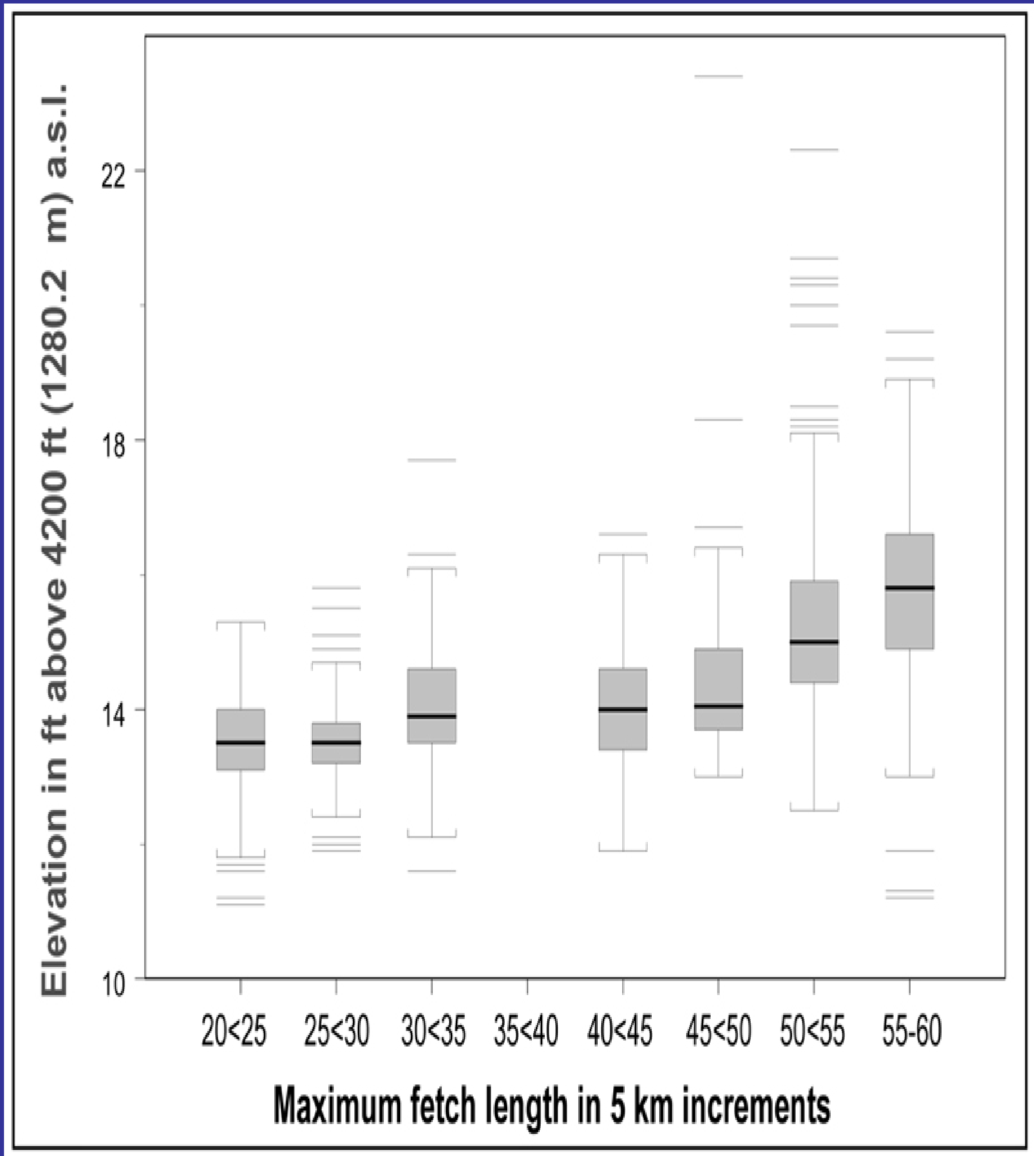
Nomograph for wave environments.
Great Salt Lake conditions indicate the lake is fetch limited.



Fetch = distance across open water to Antelope Island.



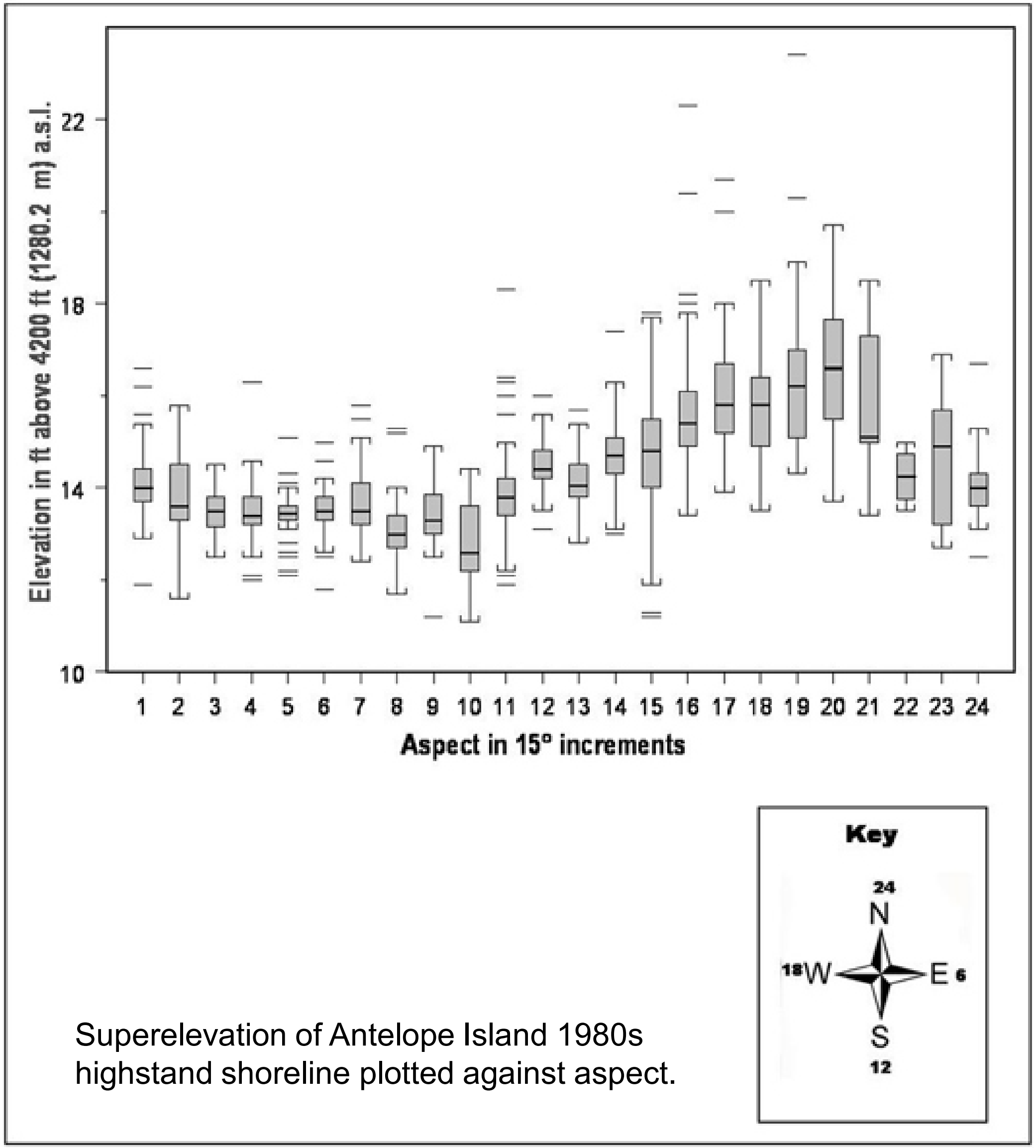
Above: Example of how fetch was calculated at 15 degree intervals for eight of 305 stretches of Antelope Island.



Right: Plot of 1228 surveyed shoreline elevations of the 1980s highstand shoreline on Antelope Island vs fetch length.

Wind strength

Aspect = the direction the shore faces… used as a proxy for direction of on-shore storm winds



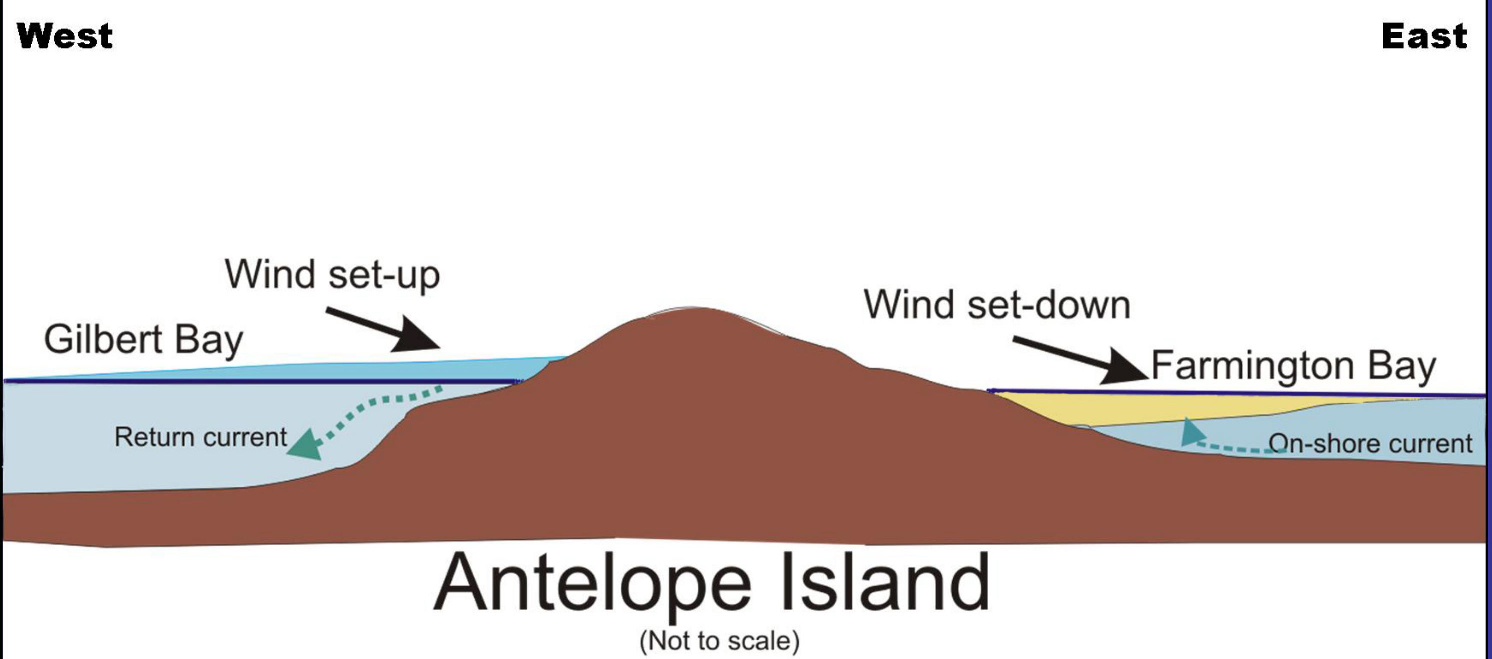
Superelevation of Antelope Island 1980s highstand shoreline plotted against aspect.

Winds across GSL were not monitored in 1986/87.

Assume: individual wind waves run generally in the direction of strong wind.

Shores that face directly into wind will have higher shoreline superelevation if the lake is fetch limited.

Coastal processes of Great Salt Lake – Shoreline superelevation documents wave energy.



<u>Windward - west side</u>
Wind set-up
On- shore wind drift
Offshore return current
High energy wave runup
Along-shore drift
Post-storm seiching

<u>Leeward - east side</u>
Wind set-down
Off-shore wind drift
On-shore return current
Low energy wave runup
Along-shore drift
Post-storm seiching

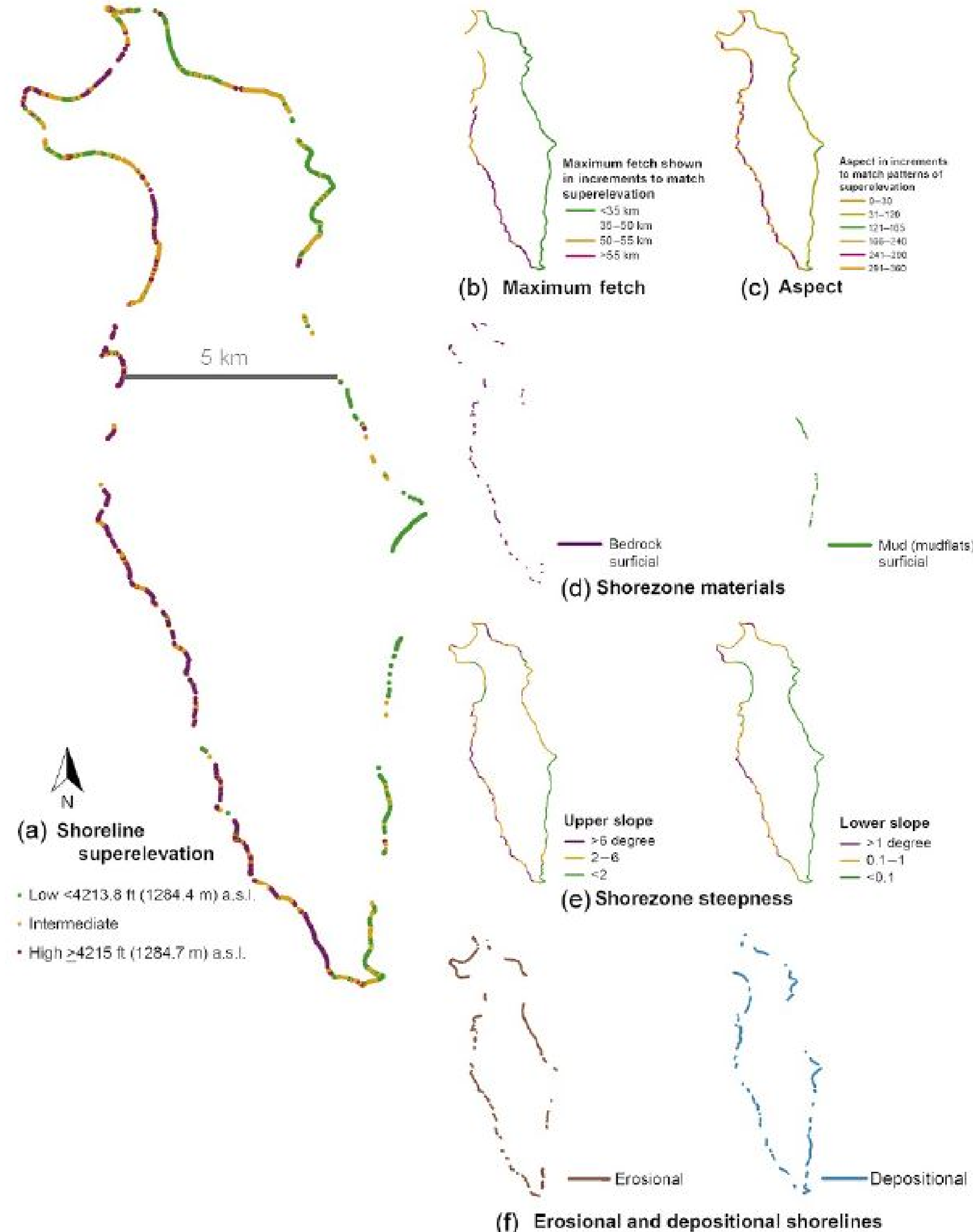
Higher Superelevation
 (greater wave energy)

Correlated with:

- Greater fetch
- Storm winds from NW and W
- Steeper slopes
- Shallower water off shore
- Erosional landforms versus depositional features.
- Bedrock vs mudflats.

Vegetation dampened wave energy.

Poor correlation of superelevation with material size.



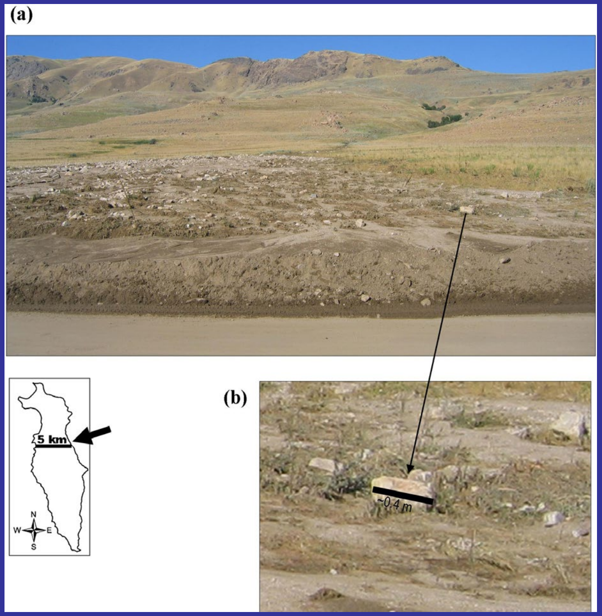
Beach materials and size

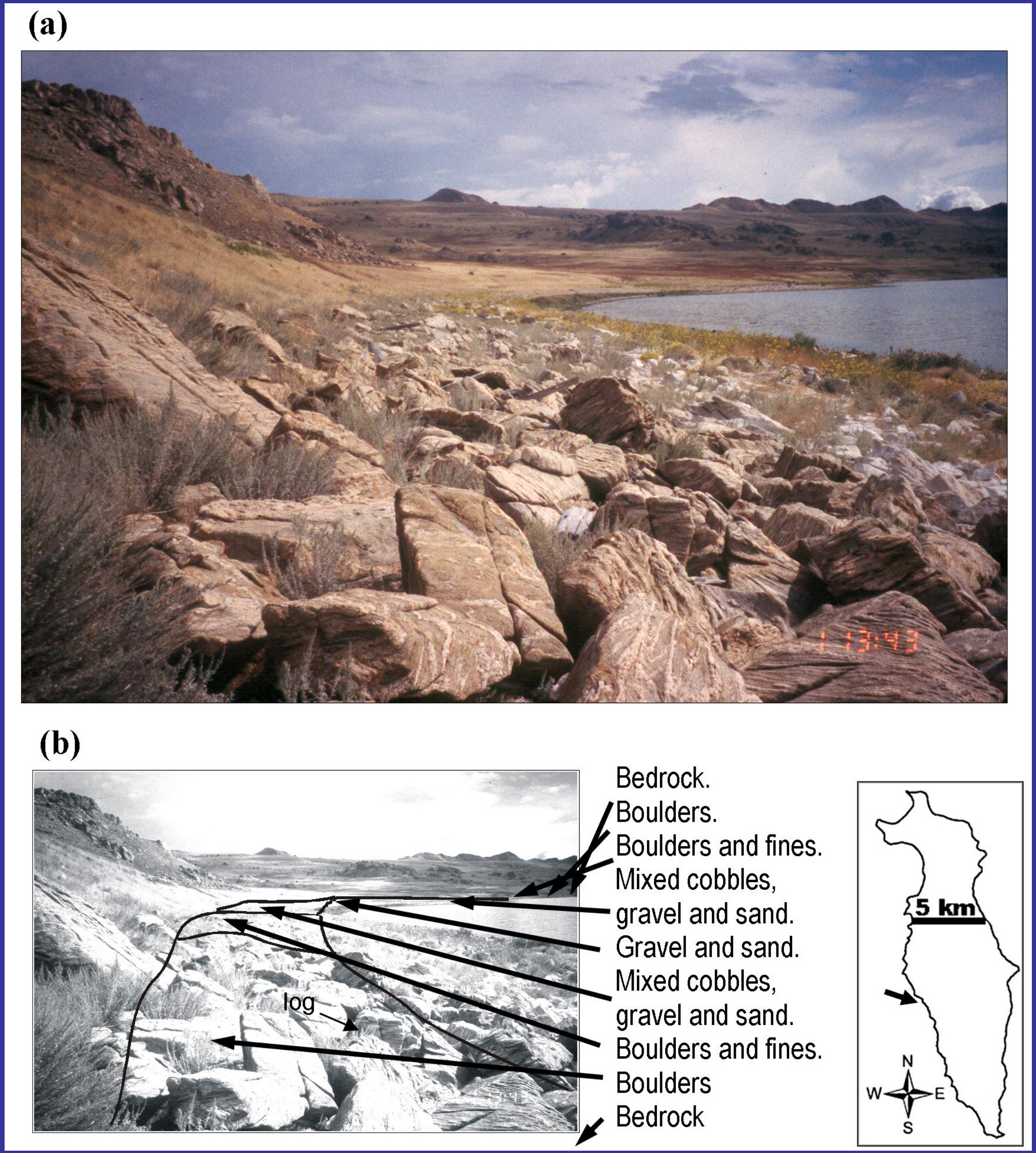
Beach material size and rounding a function of provenance…

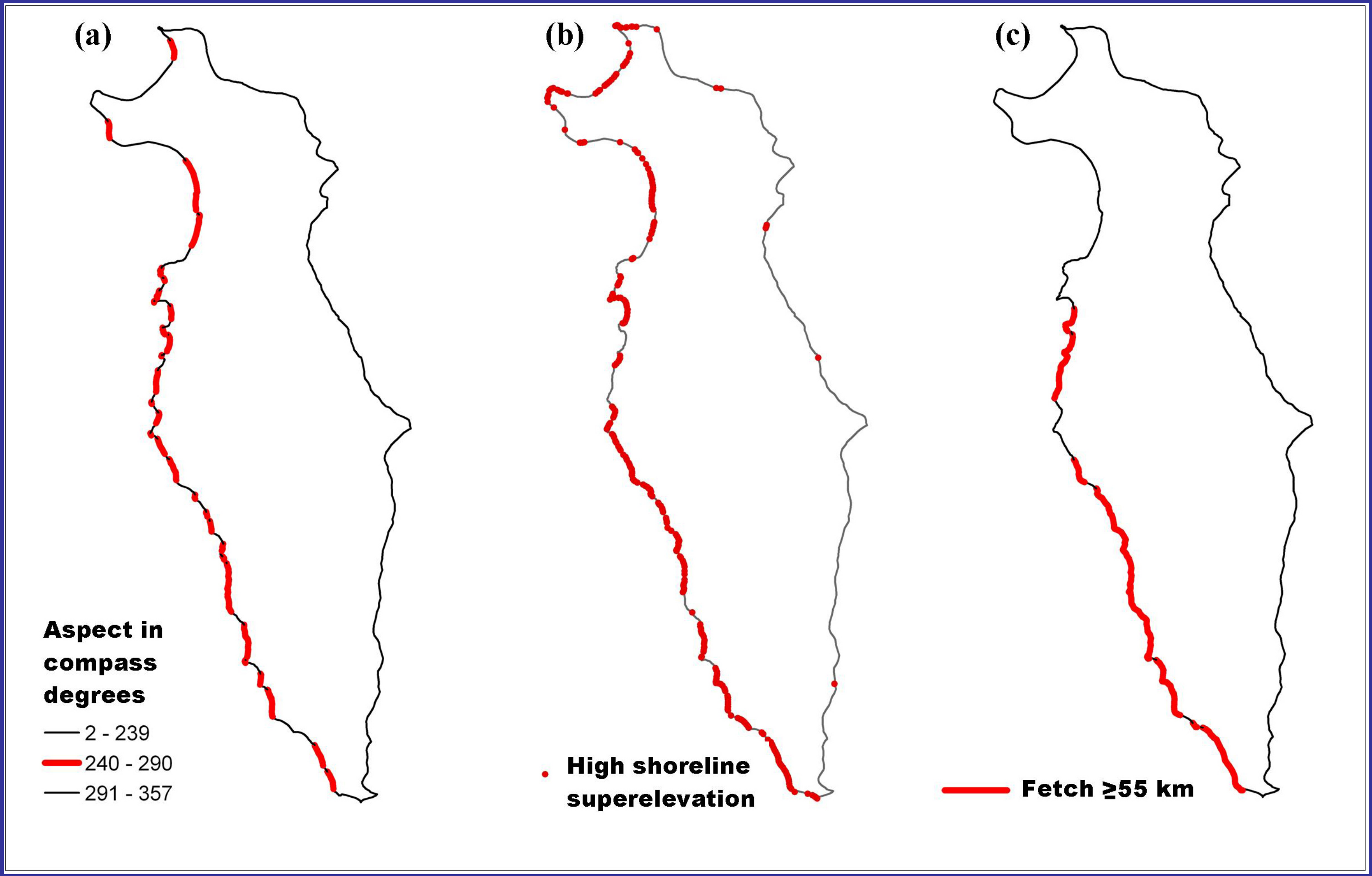
Distance from bedrock.

And nourishment by debris flows.

Why?







For Antelope Island –
Superelevation of the 1980s highstand shoreline correlated with both aspect (proxy for wind direction) and with fetch. Was it all fetch?

The research question of Antelope Island clarified by field work around the perimeter of GSL.

Survey of elevations of 1986/87 shoreline expressions around Great Salt Lake.

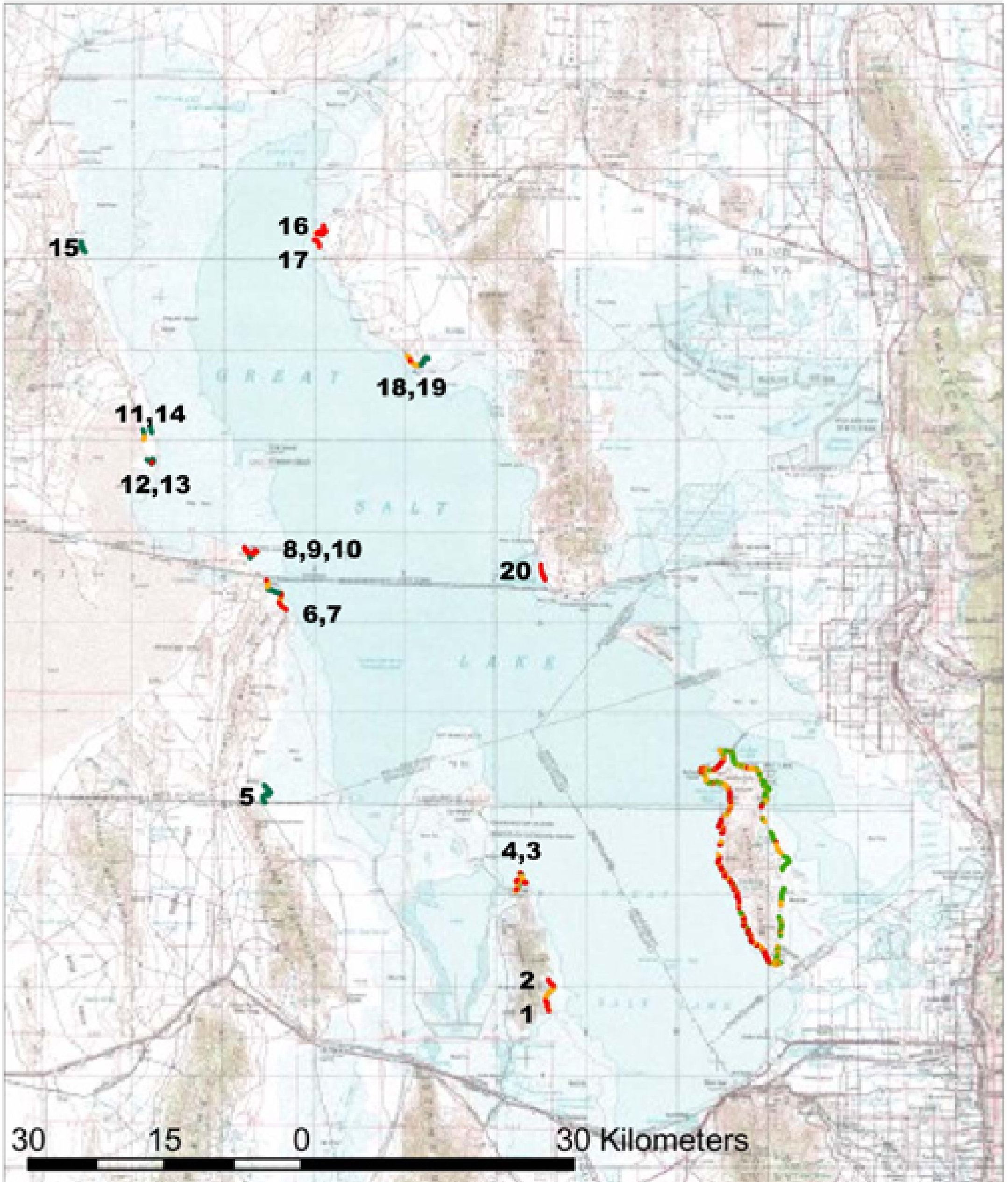
Places:

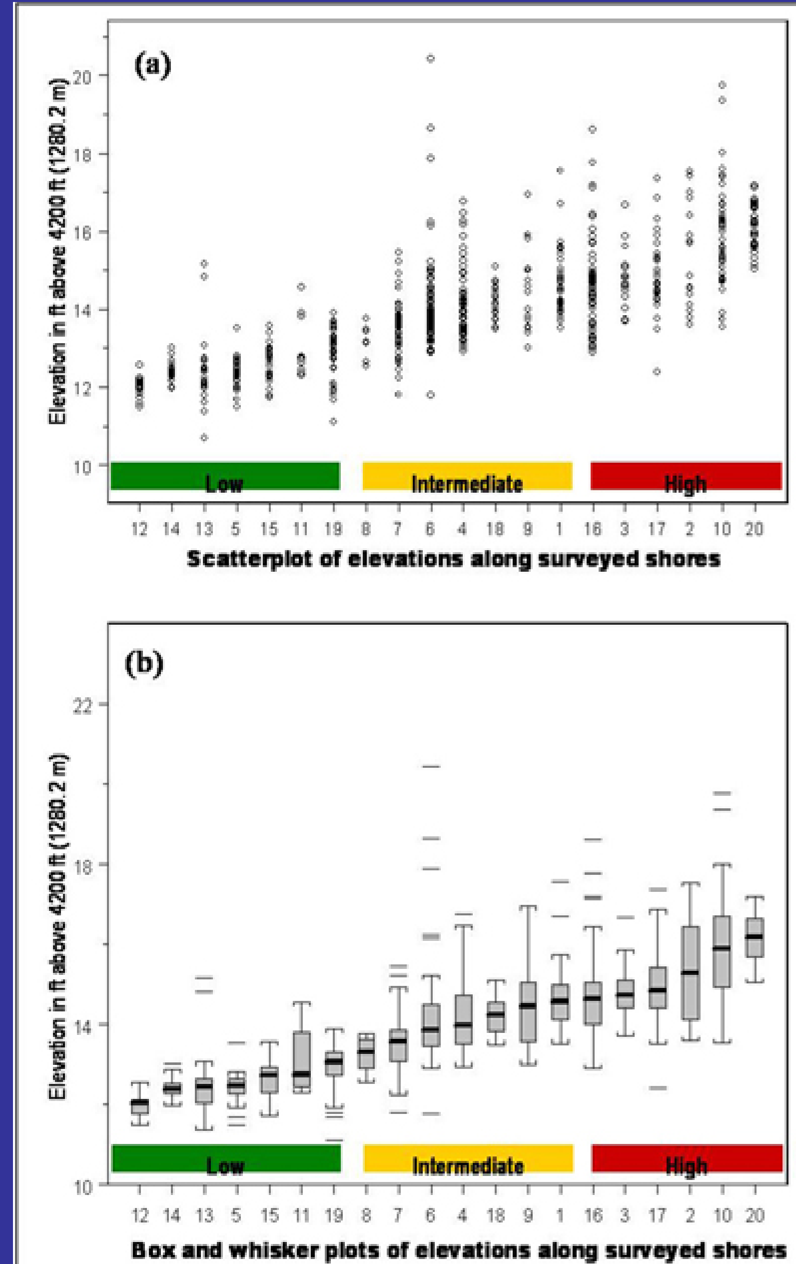
1. With vertical control
2. Distributed around the lake
3. With preserved evidence

Great Salt Lake data set tested
5 relationships of Antelope Island

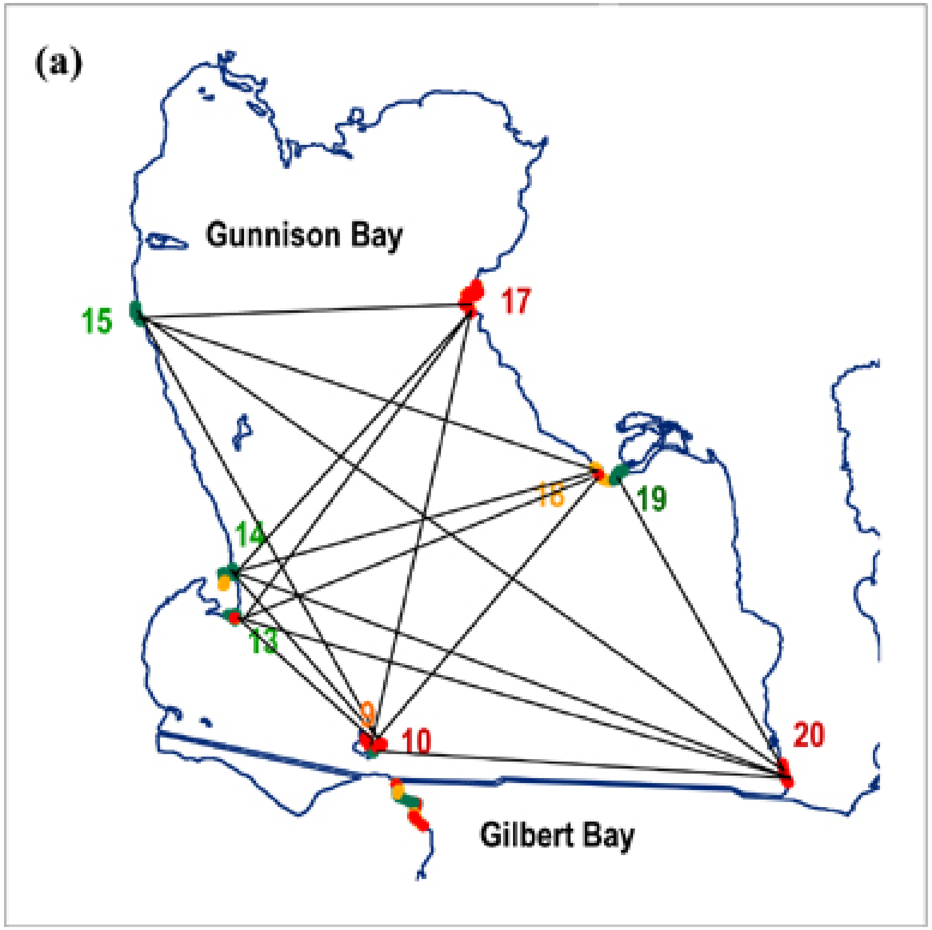
For 608 surveyed locations
At 10 shore regions
With 20 contrasting coastal conditions

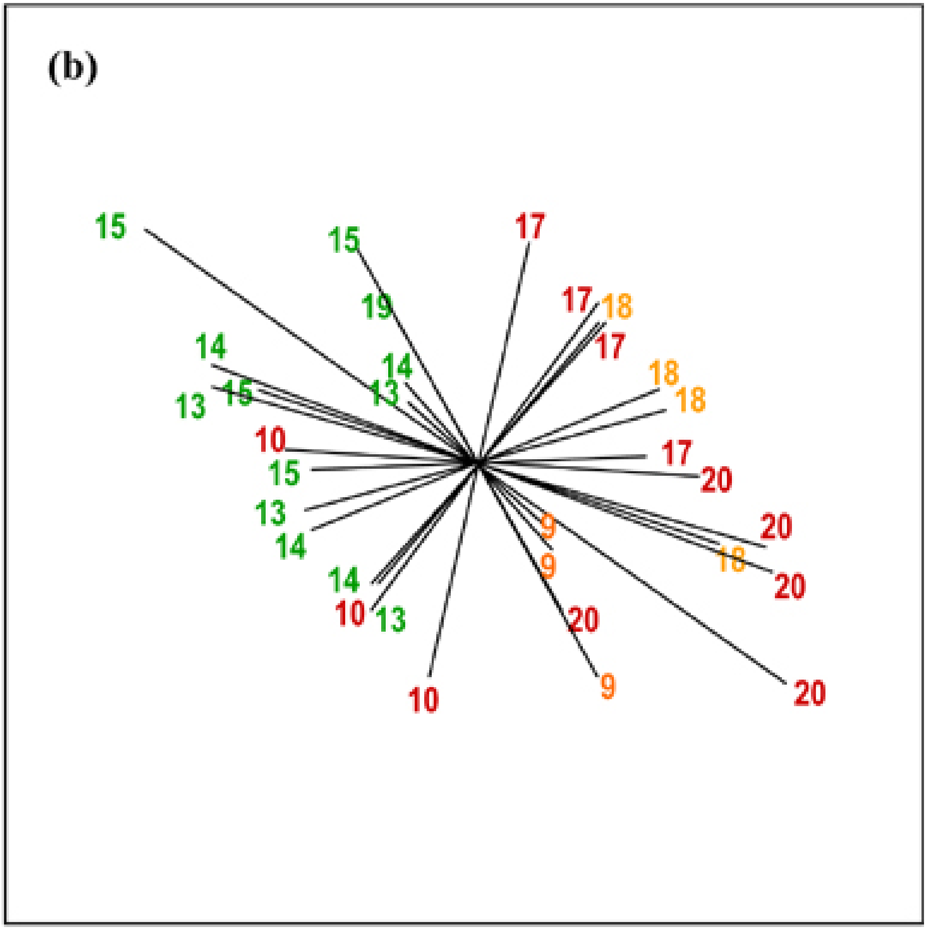
Great Salt Lake 1980s highstand shorelines surveyed.



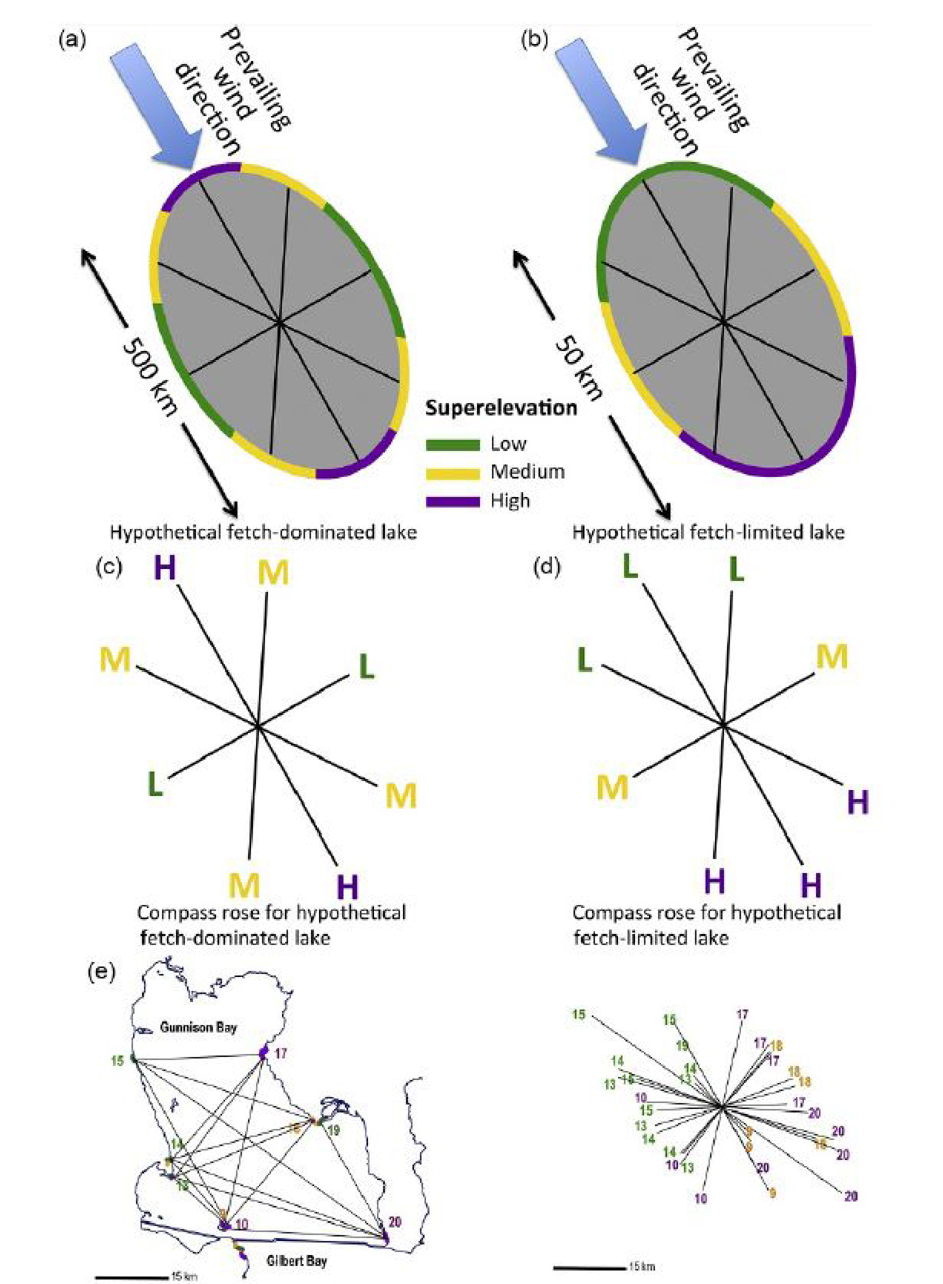


Fetch, aspect, and surperelevation of opposing shores of Gunnison Bay





If FETCH-DOMINANT, the pattern would be a bulls-eye with green in the center and red on the outside… Hmmmm not so!



Actual measurements of fetch-limited Gunnison Bay, Great Salt Lake, Utah.

FIG. 1.9 Fetch and wave energy.

Mental models: (from Atwood et al in Oviatt Shroder).

STEPS to understand the figure at left.

1. Connect surveyed places with vector (distance and direction).

2. Plot the vectors for distance and direction on an axis.

3. Note the patterns of figures.
(c) If fetch alone causes superelevation, the pattern will be a bulls-eye.
(d) If wind strength explains superelevation, the pattern will reflect prevailing storm-wind direction.

The pattern of superelevation of the highstand shoreline of GSL is not a bulls-eye. The pattern indicates direction of strongest storm winds, from the northwest and west. Fetch-limited lakes such as GSL can document wind direction by shoreline superelevation.

Summary

✓Expect shoreline evidence to NOT be at the elevation of still-water lake level. No wind, no waves, no work.

✓Contrasting elevations of shoreline evidence result from contrasting energy of waves due to fetch, wind strength, and geomorphic factors.

✓Fetch-dominated lakes are… fetch dominated! Such as Lake Michigan.
✓Great Salt Lake is fetch-limited. Fetch alone does not explain shoreline superelevation.
✓ Shoreline superelevation can be used to determine storm wind direction.
✓Expect regions of Lake Bonneville to have fetch-dominated and fetch-limited reaches.

✓Future work: To know paleo-wind direction (storm winds). Identify a fetch-limited lake (radius about 50 km (35 mi)), circular, preferably with three equi-distant islands. Study the superelevation of its shorelines and the windward-leeward patterns of sedimentation along the islands' shores.

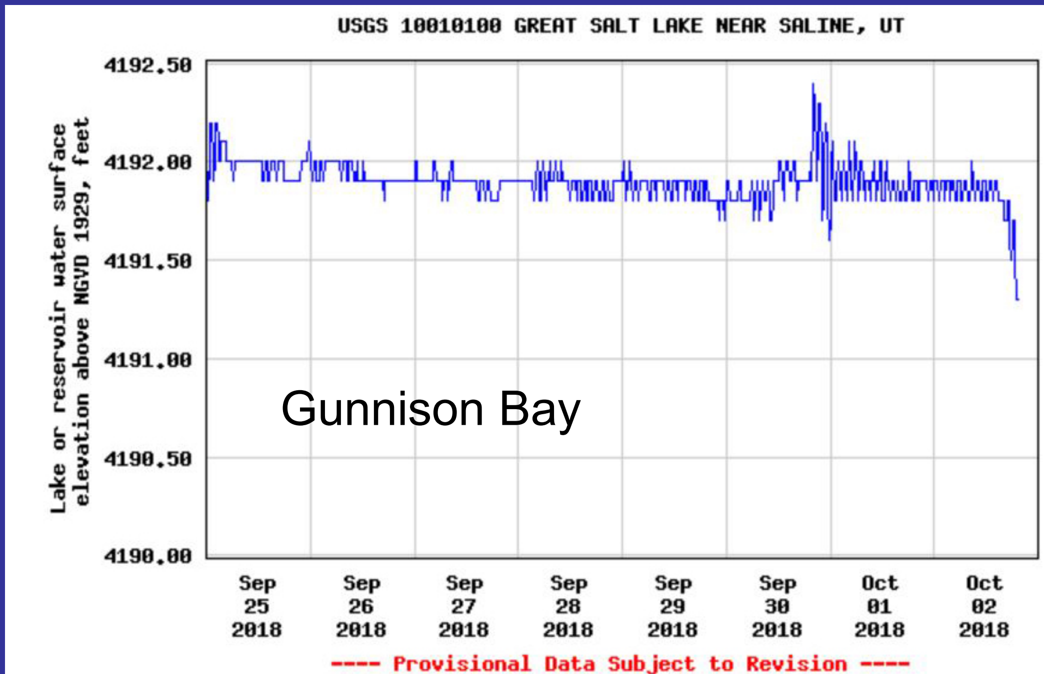
✓Advice: To estimate shoreline superelevation associated with closed-basin lakes, use the Army Corps of Engineers calculations for wave damage along lake shores.

✓Caution: Examine the provenance of shoreline materials of shallow closed-basin lakes before assuming their size and rounding indicate wave energy.

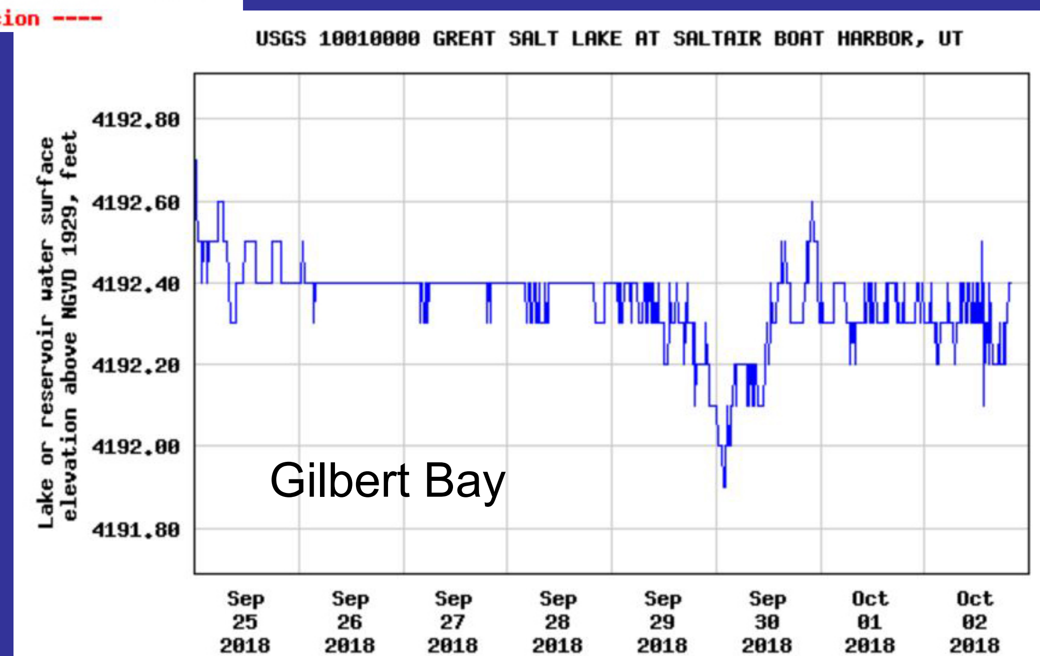
TIMELY EXAMPLE:

What is the “shoreline” of GSL this day of the converence and for the past couple days?

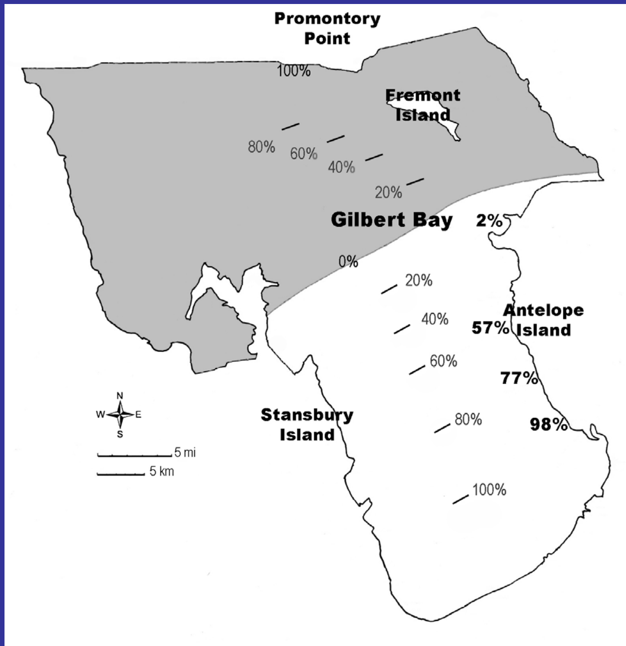
Effects of wind at the monitoring gages.



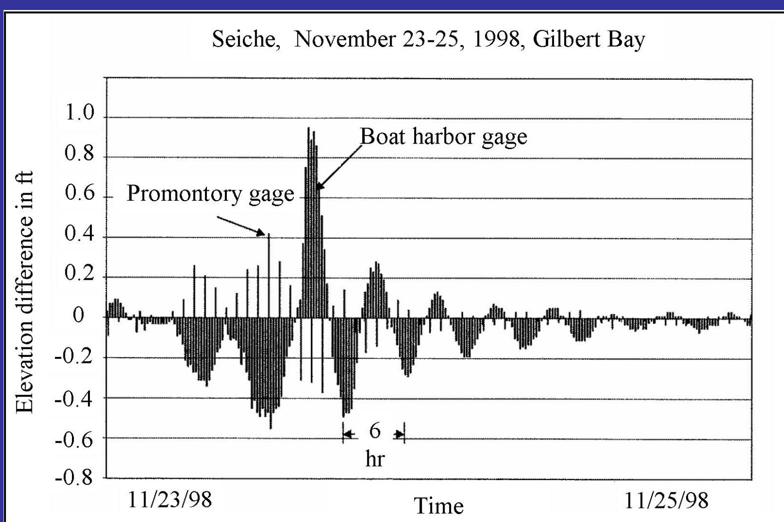
Note: Inconsistent scales…
Approx 1.5 ft fluctuation Gunnison Bay
Approx 0.7 ft fluctuation at Saltair.



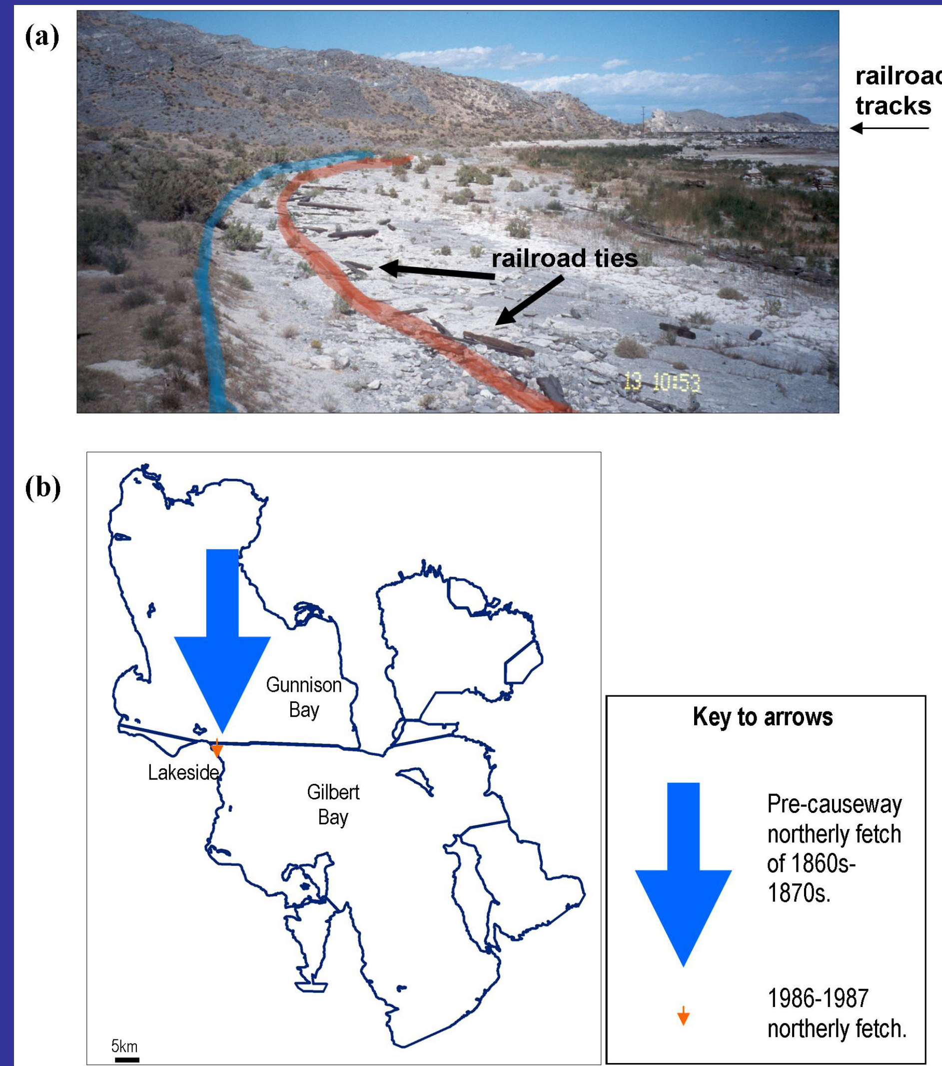
The surface of Great Salt Lake responds to storms… such as the week before the conference.



Promontory Point
100%
Fremont Island
80%
60%
40%
20%
Gilbert Bay
2%
0%
20%
40%
Antelope Island
57%
60%
77%
Stansbury Island
80%
98%
100%
N
W
E
S
5 mi
5 km



Seiche, November 23-25, 1998, Gilbert Bay
Boat harbor gage
Promontory gage
Elevation difference in ft
1.0
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
6 hr
11/23/98
Time
11/25/98



(a)
railroad tracks
railroad ties
13 10:53
(b)
Gunnison Bay
Lakeside
Gilbert Bay
5km
Key to arrows
Pre-causeway northerly fetch of 1860s-1870s.
1986-1987 northerly fetch.

THE NEW UTAH GEOCHRONOLOGY DATABASE

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ABSTRACT

The Utah Geological Survey (UGS) recently released the first version of the *Utah Geochronology Database*. The database contains age and related dating information for over 1700 soil and rock samples acquired in Utah. Age dates were obtained using argon ($^{40}Ar/^{39}Ar$), cosmogenic (^{10}Be and ^{36}Cl), fission track, fossil fusulinid, luminescence (thermoluminescence [TL], infrared-stimulated [IRSL], and optically stimulated [OSL]), radiocarbon (^{14}C), rubidium-strontium ($^{87}Rb/^{87}Sr$), tephrochronology, tritium (^{3}H), or uranium-thorium-lead (^{238}U-$^{235}U/^{206}Pb$-^{207}Pb) dating methods. The samples were analyzed for a variety of geologic-related projects by the UGS, U.S. Geological Survey (incorporates data from the legacy *National Geochronological Database*), and others.

These data have been used to determine the timing of past earthquakes, age of basalt flows, and the age of geologic units for mapping. Since geochronologic methods have significantly evolved and improved through time, older data are often not as reliable or usable as more recently dated materials. However, this new database ensures that all these high-cost and valuable geochronologic data are archived and made available to all. Users can access the database through a web mapping application (https://geology.utah.gov/apps/geochron/) or an ArcGIS geodatabase (https://gis.utah.gov/data/geoscience/geochronology/).

As the database is expanded in the future, we anticipate adding age results from other geochronologic methods. Our goal is to collect and permanently archive these invaluable data. Donations of Utah-based geochronology data to this database are appreciated. Contact the UGS or stevebowman@utah.gov for more details.

This content is a PDF version of the author's PowerPoint presentation.

The Utah Geochronology Database

Steve D. Bowman, Ph.D., P.E., P.G.
Geologic Hazards Program Manager

Current Status of the Utah Geochronology Database

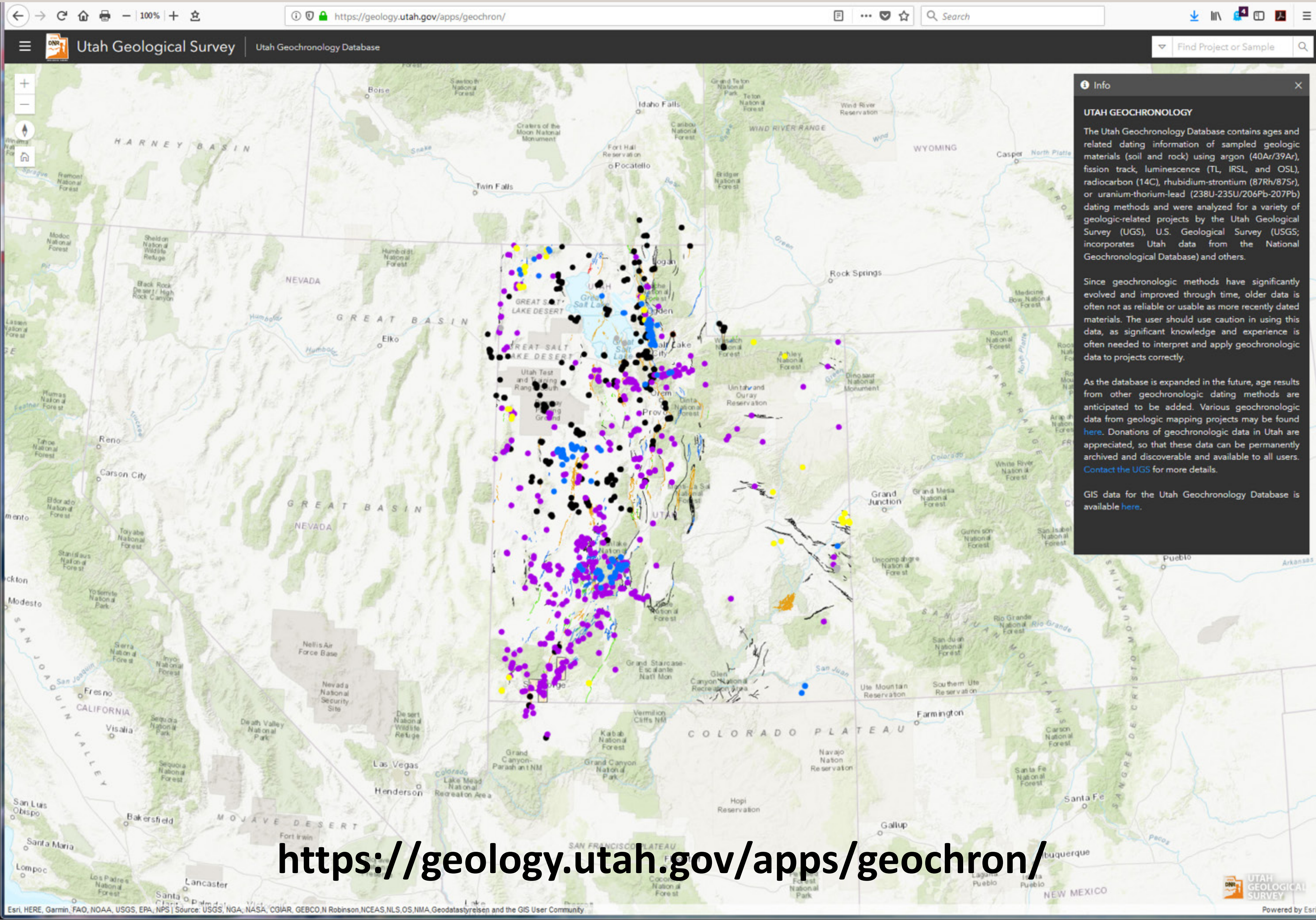
- Argon ($^{40}Ar/^{39}Ar$) – 548 samples
- Fission Track – 157 samples
- Luminescence (TL, IRSL, OSL) – 132 samples
- Radiocarbon (^{14}C) – 760 samples
- Rubidium/Strontium ($^{87}Rb/^{87}Sr$) – 92 samples
- Tephrochronology – 0 samples
- Uranium/Thorium/Lead (^{238}U-$^{235}U/^{206}Pb$-^{207}Pb) – 21 samples

Total Samples in Database = 1710

Contains:

- Most of the Utah Geological Survey (UGS), Geologic Hazards Program samples.
- UGS Geologic Mapping Program samples being added this year.
- Utah portion of the legacy U.S. Geological Survey *National Geochronological Database*.

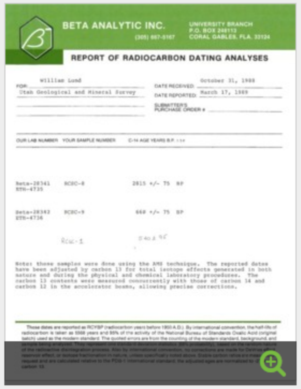
Utah Geochronology Database Web Mapping Application



https://geology.utah.gov/apps/geochron/

Report of Radiocarbon Dating Analyses, Rock Canyon Site, Wasatch Fault Zone, Utah

View all results



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UGS Program Hazards
Title Report of Radiocarbon Dating Analyses, Rock Canyon Site, Wasatch Fault Zone, Utah
Author Murry Tamers
Publisher Beta Analytic Incorporated
Date March 17 1989
Accession Number HB7972
USGS 7-1/2' Quadrangle Orem
County Utah
Keywords paleoseismology, chronologic dating, Quaternary geology
Source UGS Files
Original Filename HB7972_J.pdf
Published For/Client William R. Lund, Utah Geological and Mineral Survey
Document Type Report

Includes HB7972_A to HB7972_K.

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Any year
Any month
Clear
Search
Map Search
Advanced Search

Sample...
Report of...
Report of...
Report of...
Report of...
Report of...
Report of...
Report of...
Report of...
Western...
Final OSL...
Organic...

Future of the Utah Geochronology Database

Additions:

- Remainder of the UGS Geologic Hazards Program samples.
- Remainder of the UGS Geologic Mapping Program samples.
- Utah State University Luminescence Laboratory (Tammy Rittenour).
- Joel Pederson, Utah State University
- Data submitted by other organizations and researchers.

An Excel workbook is available to simplify the data transfer process.

- Also need the original laboratory reports, where available (UGS can scan if needed).

THE BEAR RIVER'S DIVERSION AND THE CUTTING OF ONEIDA NARROWS AT ~55-50 KA AND RELATIONS TO THE LAKE BONNEVILLE RECORD

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ABSTRACT

The Bear River's course has shifted over Quaternary time, and its late Pleistocene integration into the Bonneville basin long has been recognized as a possible explanation for why Lake Bonneville was apparently larger than the preceding lakes in its basin, and the only one to overflow its topographic threshold.

The middle-Pleistocene Bear River joined the Snake River to the north, likely via the Portneuf River drainage. Then an episode of volcanism in the Blackfoot-Gem Valley volcanic field ~100–50 ka diverted the Bear River southward into Gem Valley. Previous chronostratigraphic and isotopic work on the Main Canyon Formation in southern Gem Valley indicates internal-basin sedimentation during most of the Quaternary, with a possible brief incursion of the Bear River ~140 ka. New evidence confirms that the Bear River's final diversion at ~55 ka led to its integration into the Bonneville basin by spill-over at a paleo-divide above present-day Oneida Narrows dam. This drove rapid incision of 200 m of bedrock in the canyon and excavation of southern Gem Valley in the subsequent millennia, before the rise of Lake Bonneville back flooded the area, as constrained by new optically stimulated luminescence dates above, within, and below the canyon.

Bear River integration into the Bonneville basin early during marine isotope stage 3 seems to postdate the Cutler Dam lake cycle, although that penultimate pluvial lake is incompletely dated and understood. It is also possible the Bear River's hydrologic addition relates to the recently recognized but poorly constrained Pilot Valley shoreline that predates the main Bonneville lake cycle. Regardless, the Bear River certainly contributed to the rise of Lake Bonneville, culminating in the Bonneville flood.

This content is a PDF version of the author's PowerPoint presentation.

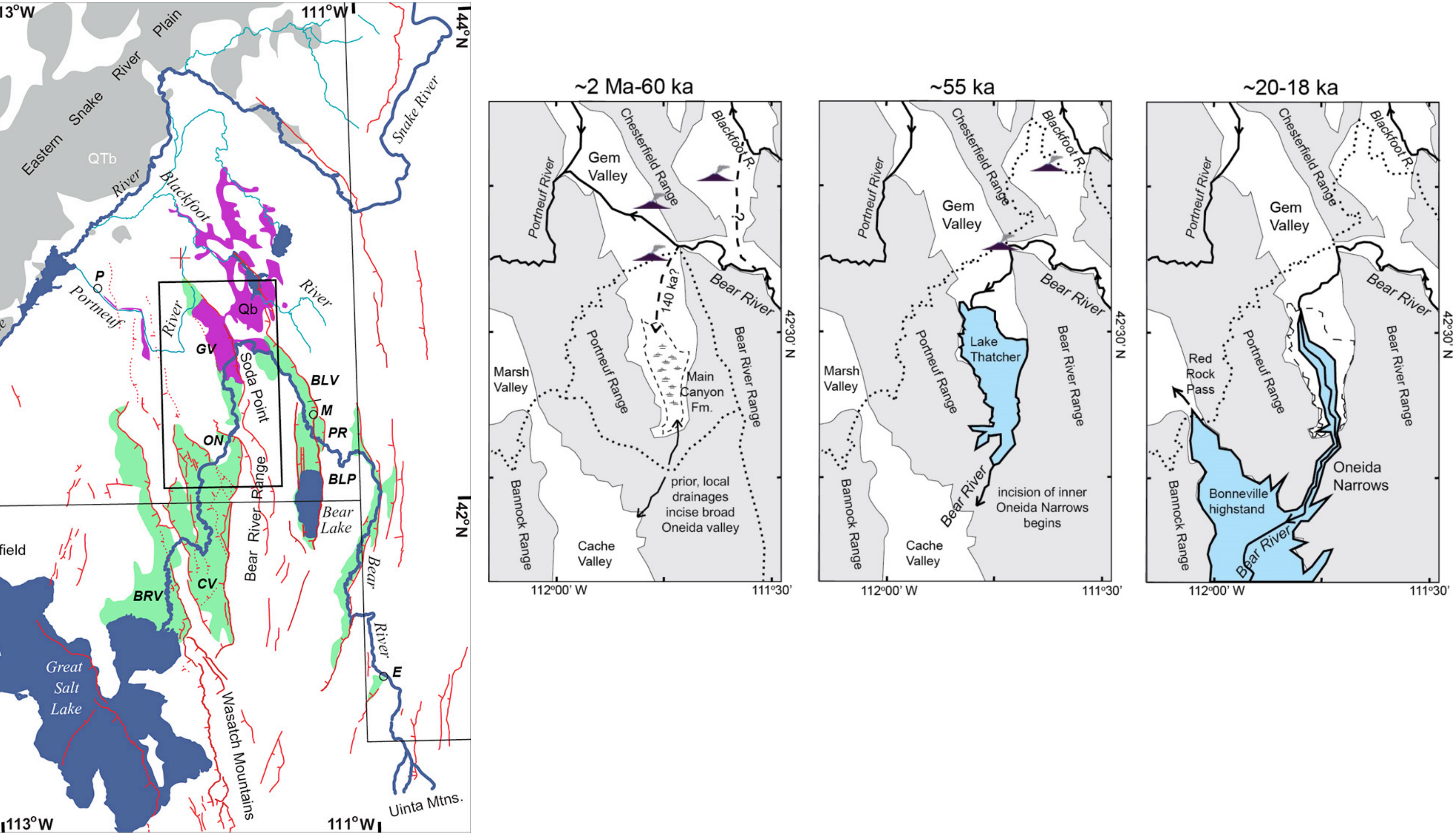
The Bear River's diversion, the cutting of Oneida Narrows at 55-50 ka, and relations to the Lake Bonneville record

Joel Pederson, Tammy Rittenour, Susanne Jänecke, and Robert Oaks, Jr.

UtahState University
DEPARTMENT OF GEOLOGY

1. Review of knowledge about Bear River's history and diversion
2. Evidence for river integration at ~55 ka
3. Rapid cutting of Oneida Narrows in subsequent millennia
4. Relations to the Lake Bonneville record

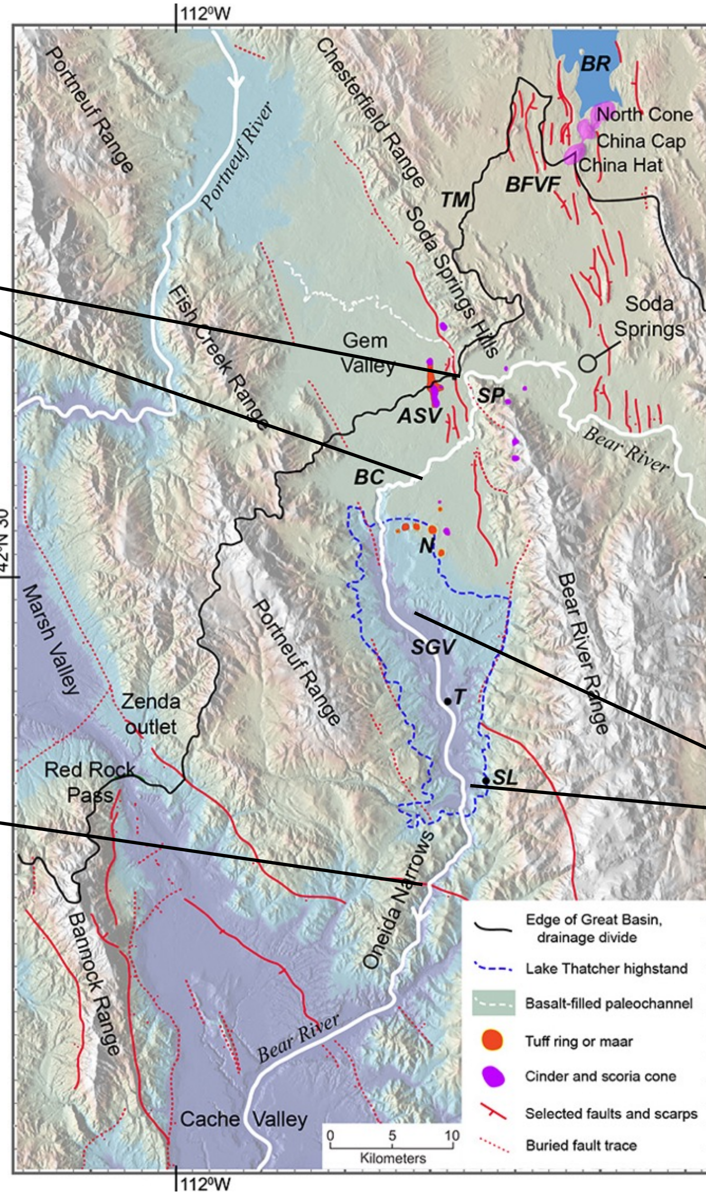
THIS TALK = virtual field trip



113°W
111°W
44°N
Eastern Snake River Plain
QTb
Snake River
Blackfoot River
River
Portneuf
P
River
Qb
GV
Soda Point
BLV
M
PR
ON
BLP
Bear Lake
Bear River Range
Bear River
42°N
field
BRV
CV
Great Salt Lake
Wasatch Mountains
E
Uinta Mtns.
113°W
111°W
~2 Ma-60 ka
Gem Valley
Chesterfield Range
Blackfoot R.
Portneuf River
Bear River
140 ka?
Marsh Valley
Portneuf Range
Main Canyon Fm.
Bear River Range
42°30' N
Bannock Range
prior, local drainages incise broad Oneida valley
Cache Valley
112°00' W
111°30'
~55 ka
Gem Valley
Chesterfield Range
Blackfoot R.
Portneuf River
Bear River
Lake Thatcher
Marsh Valley
Portneuf Range
Bear River Range
42°30' N
Bannock Range
Bear River
incision of inner Oneida Narrows begins
Cache Valley
112°00' W
111°30'
~20-18 ka
Gem Valley
Chesterfield Range
Blackfoot R.
Portneuf River
Bear River
Red Rock Pass
Portneuf Range
Bear River Range
42°30' N
Bannock Range
Oneida Narrows
Bonneville highstand
Bear River
112°00' W
111°30'

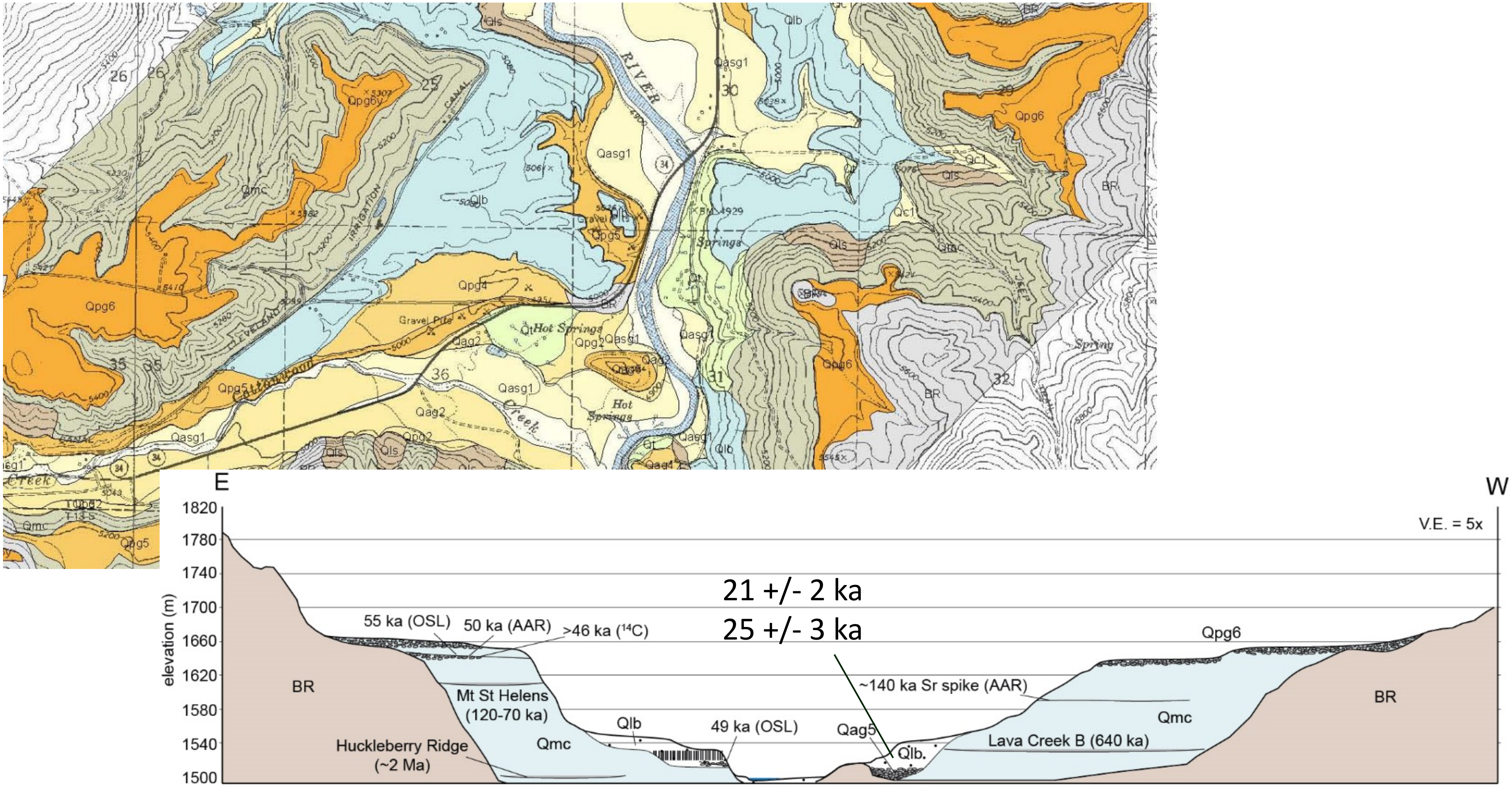
Soda Point
Black Canyon

Oneida dam
paleodivide



X-section Main Canyon Fm.
Smith locality
Sant Road outcrop

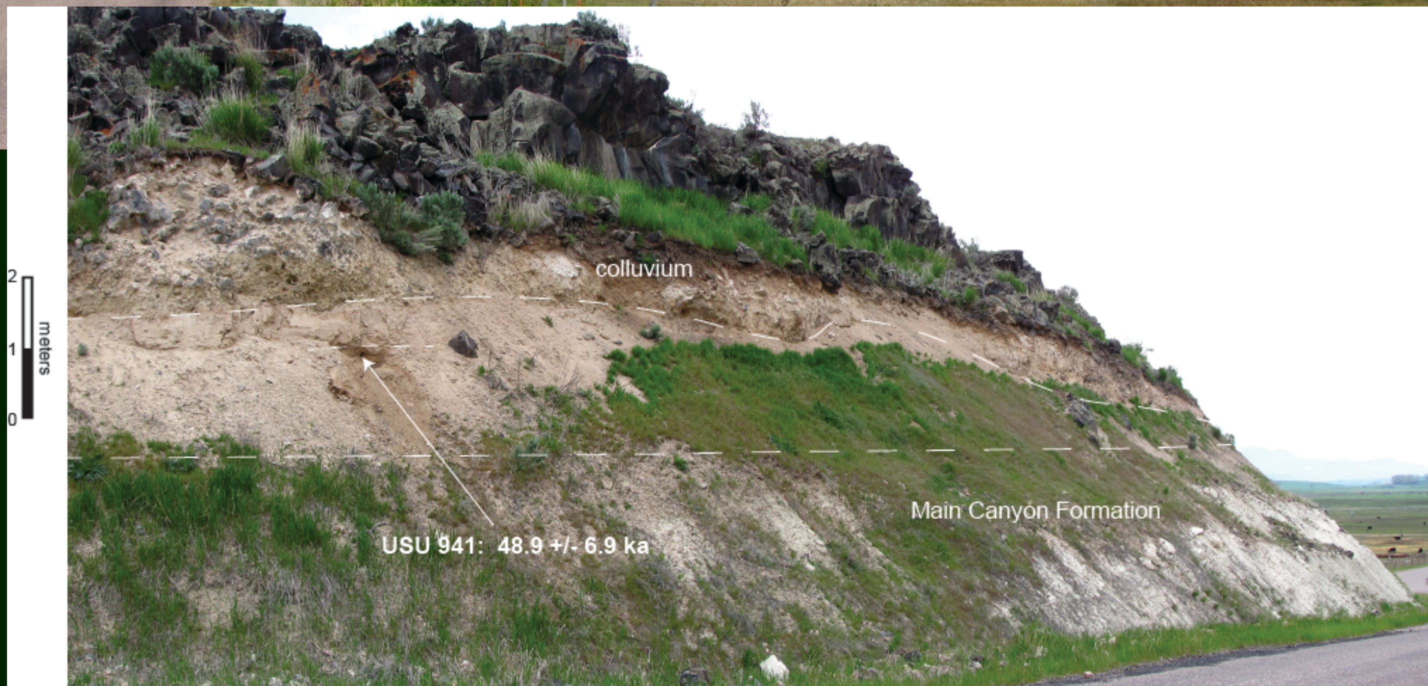
1. Review of knowledge about Bear River's history and diversion



1. Review of knowledge about Bear River's history and diversion

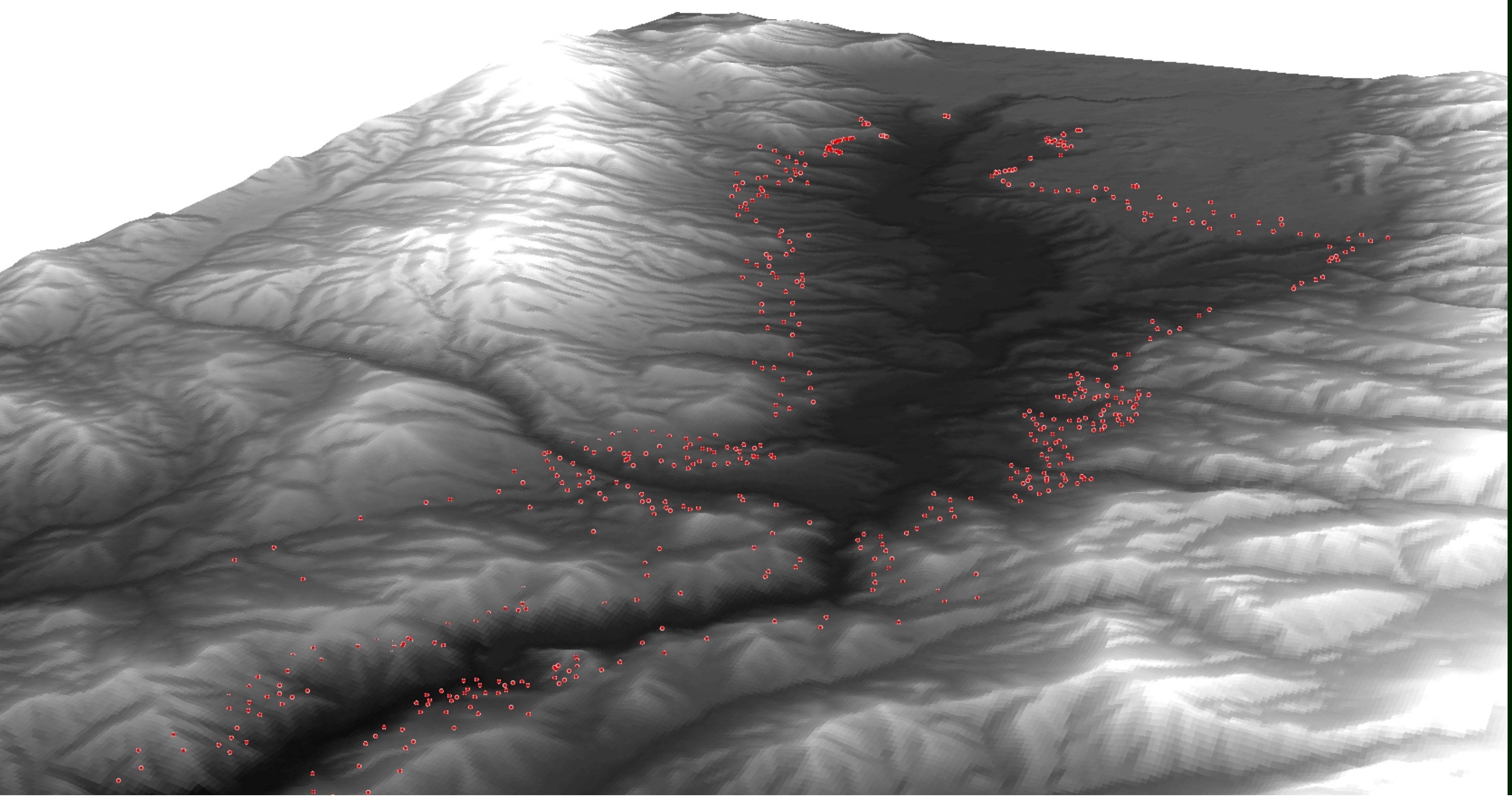
2. Evidence for river integration at ~55 ka

2. Evidence for river integration at ~55 ka

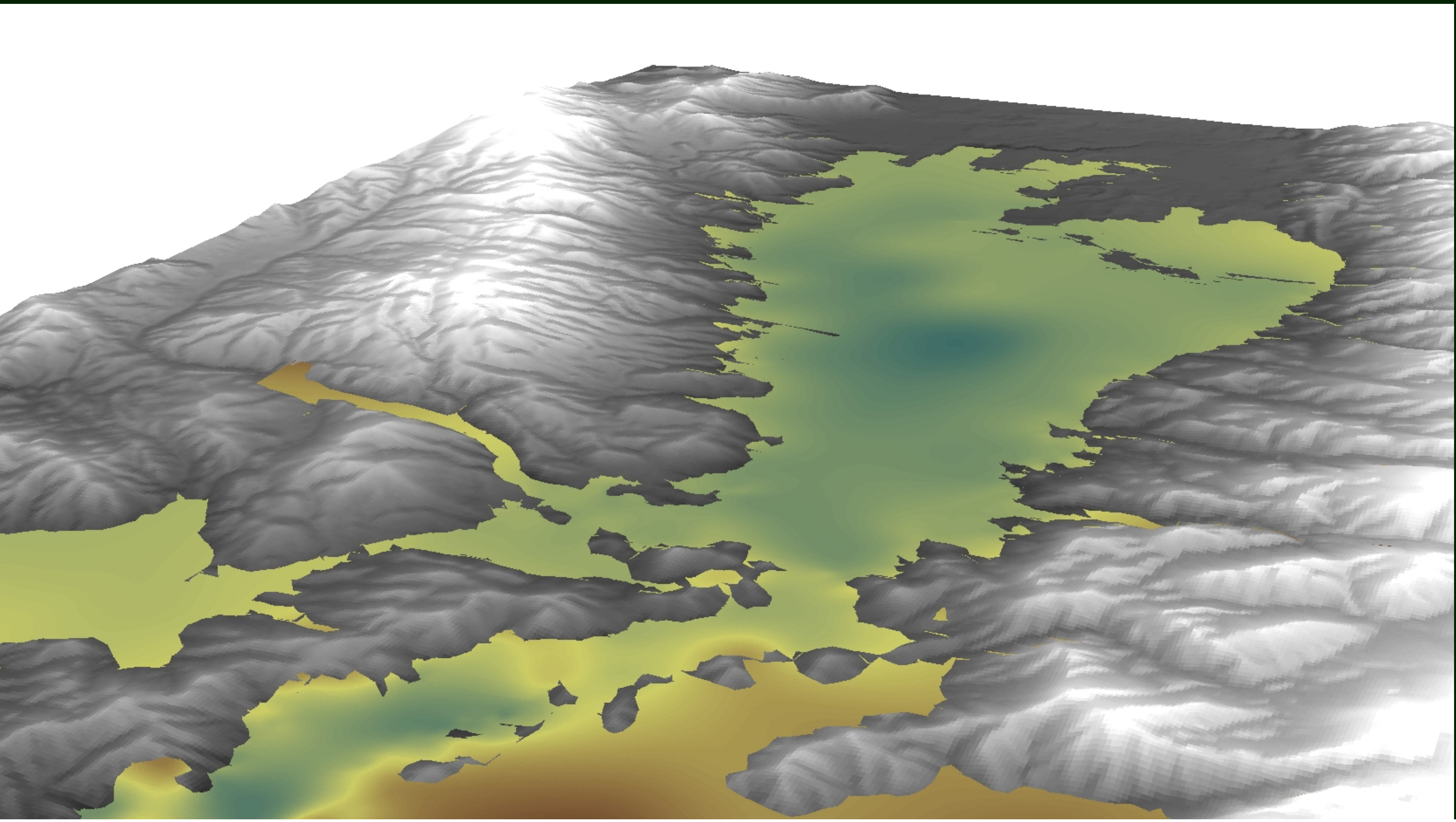


3. Rapid cutting of Oneida Narrows in subsequent millennia

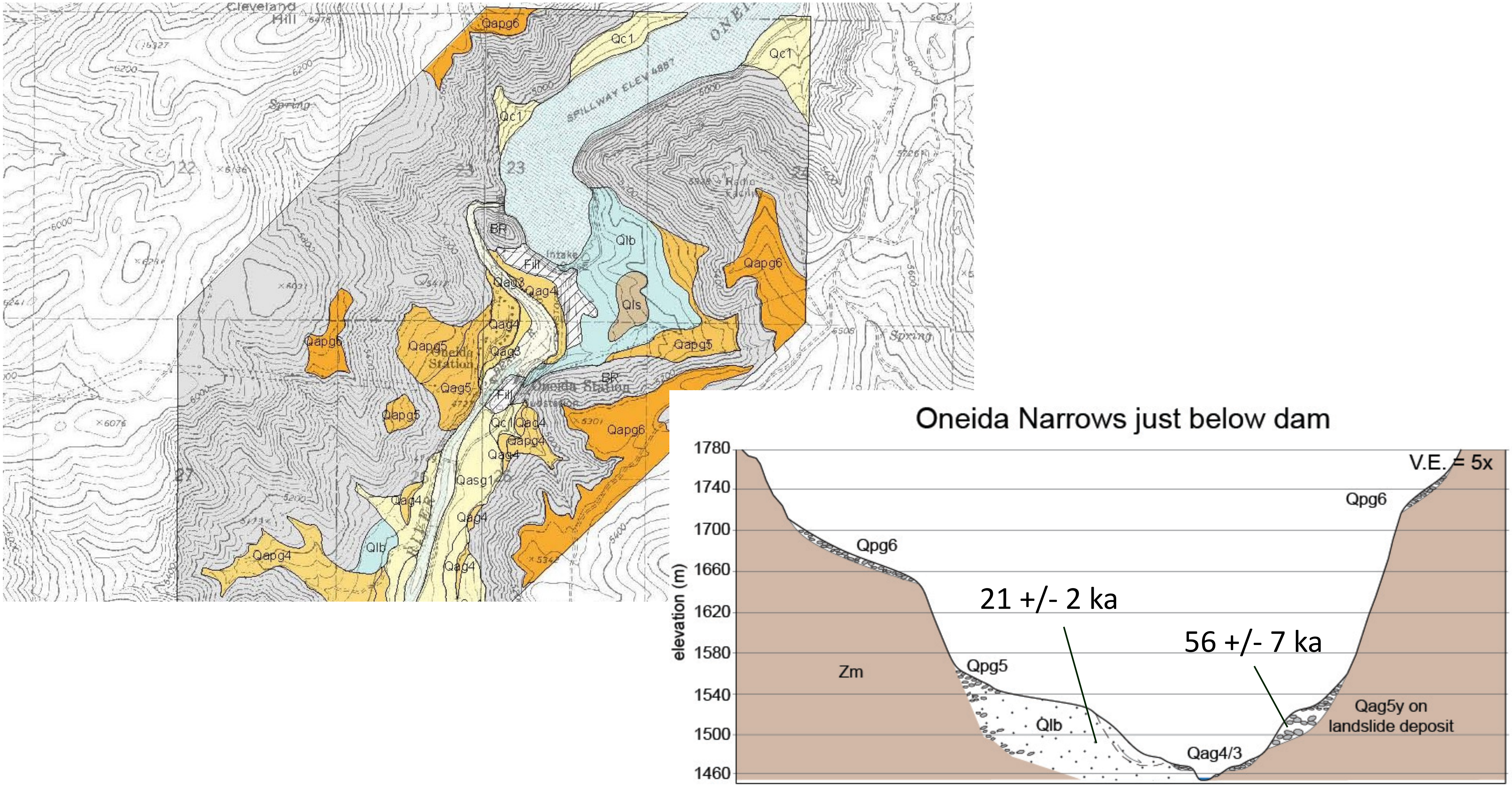
Reconstruction of basin topography prior to diversion



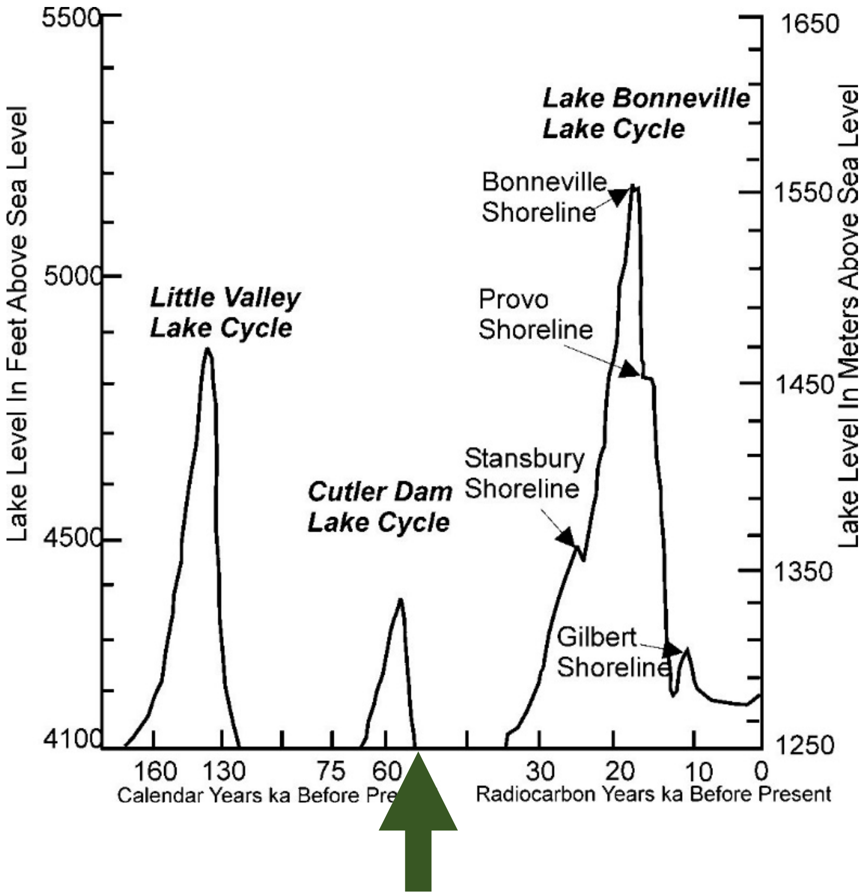
Reconstruction of basin topography prior to diversion



3. Rapid cutting of Oneida Narrows in subsequent millennia



3. Rapid cutting of Oneida Narrows in subsequent millennia



Bear River integration (MIS 3c)

Hart et al. (2004) *GSAB*

"…carbonates from the Little Valley and Cutler Dam lake cycles returned 87Sr/86Sr ratios of 0.71166 and 0.71207, respectively, and are too low to be produced by a lake without the upper Bear River input."

4. Relations to the Lake Bonneville record

Research needs

- Early Pleistocene path of upper Bear River

- Geology and geochronology of the (diverting) Gem Valley-Blackfoot volcanic field

- Main Canyon Fm. sedimentology

- Conflicting interpretation from Sr-isotope record – earlier incursion into Bonneville basin?

OSL-IRSL AGES OF TWO, PERHAPS THREE, PRE-BONNEVILLE DEEP-WATER PLUVIAL LAKES IN CACHE VALLEY, UTAH-IDAHO: IMPLICATIONS OF THEIR UNEXPECTED HIGH ALTITUDES FOR EXCAVATION OF CUTLER NARROWS FROM A LEVEL ABOVE 1494 M (4901 FT), DOWN TO THE PRESENT LEVEL OF 1314 M (4310 FT) MAINLY DURING THE BONNEVILLE LAKE CYCLE

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ABSTRACT

Pluvial-lake highstands in the Bonneville basin are known to be contemporaneous with periods of Quaternary glaciation. At least five lake cycles have been identified from prior studies of two deep cores (Eardley and Gvosdetsky, 1960; Eardley and others, 1973) and several isolated outcrops in the main part of the Bonneville basin and eastward in Cache Valley. These are the Lava Creek B (~620 ka, marine isotope stage MIS 16), Pokes Point (~420 ka, MIS12), Little Valley (~150 ka, MIS 6), Cutler Dam (~60 ka, MIS 4), and Bonneville (~18 ka, MIS 2) lake cycles (Oviatt and others, 1987, 1999; Lisiecki and Raymo, 2005). Cache Valley, straddling the Utah-Idaho border, held the northeastern arm of Lake Bonneville, and is the entry point of the Bear River, the largest river to supply water into the basin. This river did not fully enter the Bonneville basin until ~55 ka (Pederson and others, 2016).

Pre-Bonneville pluvial lakes in Cache Valley rose to near or somewhat above the Provo shoreline several times, and deposited stacked lacustrine gravel deposits exposed in an active Staker-Parson gravel pit on the southeast edge of Newton Hill (figures 1, 2). These deposits are separated either by multi-story, caliche- and clay-rich geosols, loess, erosional channels, or lag gravels. The multi-story geosols formed in the post-Cutler Dam interglacial. These geosols are dated to MIS 3, and reflect first a dry-condition Bk caliche soil, then deposition of loess and colluvium coincident with a period of more humid conditions. In eastern Cache Valley, in southeast Hyde Park, Utah, similar multi-storied geosols and loess deposits underlie Bonneville offshore silty sand with snails (west, lower) and post-Bonneville colluvial gravel (east, higher), respectively, where they overlie Little Valley gravels at ~1493 m (4898 ft) and undated alluvial-fan deposits at ~1512 m (4960 ft).

We document stratigraphic evidence and absolute ages from optically stimulated luminescence (OSL) of quartz sand and infrared stimulated luminescence (IRSL) of feldspar sand as evidence for at least two, perhaps three, pre-Bonneville lakes in Cache Valley during past pluvial epochs: (1) ~137-169 ka (Little Valley; n=4); (2) ~96 ka (Newton Hill beds; n=1); and (3) ~49-67 ka (Cutler Dam; n=3) (tables 1, 2). These reached highstands, respectively, of >1470 m (>4824 ft; perhaps 4901 ft), >1443 m (>4735 ft; perhaps 4768 ft), and ~1443 m (4733 ft). The Newton Hill beds might be the oldest lacustrine record of the Cutler Dam lake cycle, if that lake cycle had a long duration, or they may be coeval with problematic lacustrine deposits of similar ages, ~76 and 82 ka, in Hansel Valley (Robison and McCalpin, 1987) and ~90 ka in Gem Valley (Bouchard and others, 1998; Utley, 2017).

Subsurface data from thousands of water wells drilled across the valley bottom southeast of Newton Hill document four, perhaps five, successive deposits of deep-water muds with thin intervening gravels layers (Thomas and others, 2011; Oaks, unpublished). These muds aggregate a total thickness between 30 m and 37 m (100 ft and 120 ft). These are probably coeval with several of the nearshore gravel and sand deposits in the Newton Hill pit and with deposits of pluvial lakes in the main Bonneville basin.

Synthesis of our new stratigraphic and geochronologic data show that all of the pre-Bonneville, post-Pokes Point pluvial lakes rose to near or above the height of the Provo shoreline in the area of the Newton Hill gravel pit. Altitude control for older lakes has been determined at only about 11 sites in the main part of the Bonneville basin, with some corrected for rebound, others

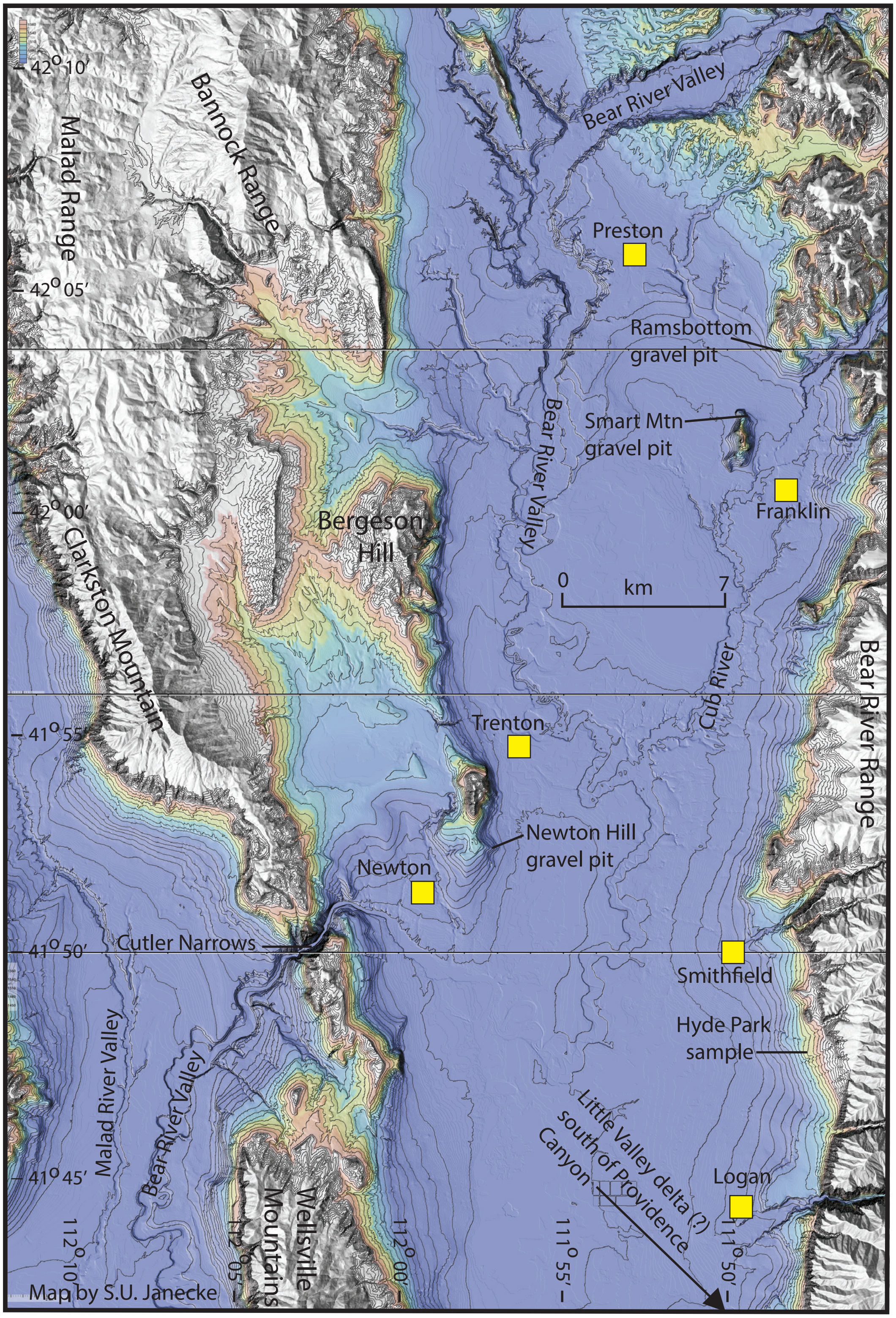

Figure 1. *Digital-elevation model (DEM) map of Cache Valley area showing 3 gravel pits and 2 other exposures with lake deposits older than Lake Bonneville. Type area of Cutler Dam unit is along the Bear River Valley just SW of Cutler Narrows. Bonneville highstand is ~lowest white; Provo highstand is ~top of blue.*

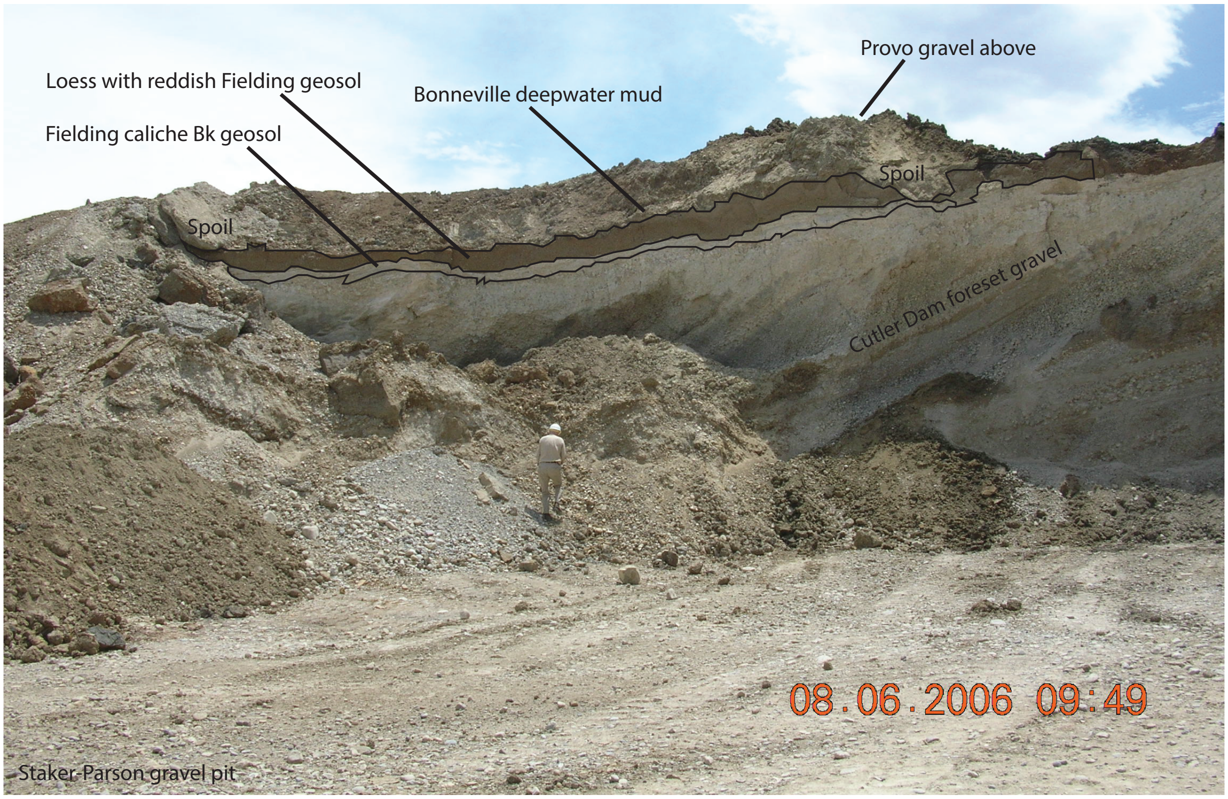

***Figure 2**. View SSE of Cutler Dam gravel dipping 25° to 35° east below Fielding multi-story geosol and overlying deepwaterBonneville mud. Figure is 6 feet tall. Photo By S.U. Jänecke.*

not. Our altitudes are uncorrected. Thus it is uncertain if there are significant differences or near correspondences of highstand levels among the post-Pokes Point, pre-Bonneville pluvial lake episodes. If notably different, then the older pluvial lakes in the Salt Lake Valley and in Cache Valley could have been synchronous adjacent lakes, rather than a single lake.

A Little Valley OSL sample of ~137 ka from Hyde Park, Utah, is near 1493 m (4898 ft). A well-developed shoreline near 1494 m (4901 ft) lies 24 m (80 ft) above our highest dated Little Valley gravels at the Newton Hill gravel pit, at 1469 m (4821 ft). This level of 1494 m (4901 ft) is 16m (53 ft) below the highest recorded uncorrected Little Valley deposits in the Bonneville basin (Scott and others, 1983; Scott, 1988), at Point of the Mountain, at 1510 m (4954 ft). Post-symposium work shows that there are two pre-Bonneville deltas built south from Providence Canyon to Millville, Utah, above the Provo-level delta and below the Bonneville highstand. The bases of their eastward shoreline scarps lie near 1522 m (4995') and 1550 m (5085') respectively. An OSL sample from the older, higher, well-dissected delta was collected in June 2019.

Our ~96 ka age determination and stratigraphic observations indicate a lake level of the Newton Hill beds at or above 1421 m (4663 ft). This is at least 80 m (263 ft) higher than the uncorrected altitude of 1341 m (4400 ft) proposed by Robison and McCalpin (1987) for problematic shallow-water deposits in Hansel Valley with luminescence ages of ~82 and ~76 ka. Our ~51 and ~67 ka age determinations and stratigraphic observations indicate that the known high stand of the Cutler Dam lake cycle in Cache Valley at ~1443 m (4733 ft) was at least 102 m (335 ft) higher than the uncorrected altitude of 1340 m (4396 ft) proposed by Oviatt (1986), Oviatt and McCoy (1988), and Kaufmann and others (2001) based on shallow-water Cutler Dam deposits in the main Bonneville basin just southwest of Cutler Narrows (figure 1).

Cache Valley is a complex graben east of a bedrock horst, the Cache Butte Divide, the latter upthrown between the Wasatch (west) and West Cache (east) fault zones. Cutler Narrows is the deep and narrow canyon of the Bear River across the Cache Butte Divide. It is cut in hard Paleozoic bedrock and is 392 m (1286 ft) deep on its south side. This canyon is presently deep enough to allow pre-Bonneville pluvial lakes with water levels between 1314 m (4310 ft) and 1517m (4978 ft) to connect exclusively through the horst there. At higher levels, water could connect across this horst at up to three additional high saddles between 1517 m (4978 ft) and 1577 m (5175 ft). The latter, 1577 m, coincides with the present rebounded altitude of the highest

Table 1. *OSL & IRSL sample information and age dates for Staker-Parson gravel pit, SE flank of Newton Hill, and SE Hyde Park City, Cache County, Utah.*

Sample Number USU-	Age in ka and Method	Hand-Level in Feet	EDM Altitude in Feet	Sample Altitude in Meters	Strati-graphic Unit	Location and Comments; ~65 m W correction from GPS data to 1927 North American datum for maps	Date and Collectors
859	15.20 ± 1.97 OSL	N.D. Map ~4790	4737 Depth ~53	1444	Late Qlbp	NW edge of pit; silt & sand beds dip E; below ~4780' Qlbp shore; ~ N 41°52.614' ~W 111°57.426'	9-15-2010 TR & MN
854	21.72 ± 3.75 OSL	~4748 Map ~4785	N.D. Depth ~37	~1447	Early Qlbb	S of road, SW corner of alcove; silty sand & clays above paleosol; N 41°52.4478' W 111°57.3978'	9-7-2010 TR & RO
1082	22.04 ± 5.93 OSL	~4665 Map ~4775	<4672 Depth~115	~1422	Early Qlbb	Center of pit; laminated silty sand over gravel; 10' above USU-1083; N 41°52.5244' W 111°57.3198'	12-2-2011 RO & TE
855	39.28 ± 4.99 OSL	~4739 Map ~4810	N.D. Depth ~71	~1444	Qf	SW alcove; red colluvium: sandy gravelly mud over loess paleosol; N 41°52.478' W 111°57.393'	9-7-2010 TR & RO
1084	48.99 ± 9.95 OSL	N.D. Map ~4875	4865 Depth ~10	1483	Qcd	W pit; white reworked ash in N-S channel, under E-dipping gravel & soil, over 4° W-dipping gravel; N 41°52.5045' W 111°57.5009'	12-5-2011 RO
858	50.50 ± 7.15 OSL	~4709 Map ~4790	N.D. Depth ~81	~1435	Qcd	W alcove; vf-med sand below gravel ~25 ft below paleosol base; N 41°52.473' W 111°57.382'	9-15-2010 TR & MN
856	67.10 ± 7.23 OSL	~4729 Map ~4810	N.D. Depth ~81	~1441	Qcd	W alcove; gravel 4.3' below red paleosol base; 9.8' below USU855; N 41°52.479' W 111°57.388'	9-7-2010 TR & RO
1083	96.2 ± 14.0 OSL	~4655 Map ~4780	<4673 Depth~125	~1419	Qnh	Center of pit; in gravel 8.4' below laminated silty sand of USU-1082; N 41°52.5243' W 111°57.3310'	12-2-2011 RO & TE
2895 SE Hyde Park City	136.7 ± 16.1 OSL	N.D. Map ~4865 Google [2108] ~4898	N.D. Depth 9.25	~1493	Qlv	Fresh N-S scarp; fine- to coarse sand within pale green marl below white caliche geosol below Qlbb fine- to very fine sand with snails; N 41°47.8341' W 111°47.8214'	7-27-2018 RO
2490	155.7 ± 21.4 IRSL	~4735 Map ~4840	N.D. Depth~105	~1443	Qlv	W center of pit in E-W cut; sand and gravel in cobble gravel, 22' lower than E margin of overlying channel; N 41°52.5203' W 111°57.4165'	9-26-2016 RO & TE
857	159.9 ± 25.0 OSL	N.D. Map ~4865 GPS 4824 TR	N.D./EDM 4821 at graded site Depth ~44	~1469	Qlv	W center of pit in WSW cut; sand & pebble groundmass in cobble gravel; N 41°52.492' W 111°57.477'	9-15-2010 TR & MN
2491	169.4 ±28.6 OSL	~4678 Map ~4805	N.D. Depth~127	~1426	Qlv	NW pit near south end of headwall; pebbly sand below sandy pebbly cobble gravel; N 41°52.5548' W 111°57.3882'	9-26-2016 RO & TE

OSL = optically stimulated luminescence on quartz sand; IRSL = infrared stimulated luminescence on feldspathic sand; ka = thousands of years ago; Google = Google Earth; EDM = total station, electronic distance measurements with laser; GPS = global-positioning-system measurement; HL = hand level used from EDM station 16; N.D. = no data; Map: original surface altitudes are interpolated from 1964 U.S. Geological Survey 7.5' Newton [C.I. = 5'] and Trenton [C.I. = 20'] topographic quadrangles; Qlbp = Provo lake stage; Qlbb = Bonneville highstand lake stage; Qf = Fielding emergent interval with 2 multistory geosols and higher N-S channel; Qcd = Cutler Dam lake stage; Qnh = Newton Hill lake stage; Qlv = Little Valley lake stage; MN = Michelle S. Nelson; RO = Robert Q. Oaks, Jr.; TE = Thad L. Erickson; TR = Tammy M. Rittenour. Note: Early Qlbb and all older lakes likely were separate from coeval lakes in the main Bonneville basin, and thus should be considered separate Cache Valley lakes.

Table 2. *Optically Stimulated Luminescence (OSL) and Infrared Stimulated Luminescence (IRSL) Age Information, Newton Pit and Hyde Park, Utah, Feb 2019.*

USU-number	Depth (m)	Number of aliquots[1]	Dose rate (Gy/ka)	D_{E2} ± 2σ (Gy)	Age ± 2σ (ka)	In-situ H_2O (%)[4]	Grain size (µm)	K (%)[5]	Rb (ppm)[5]	Th (ppm)[5]	U (ppm)[5]	Cosmic (Gy/ka)	OSL/ IRSL[6]
859	16.2	21 (57)	1.76 ± 0.07	26.73 ± 2.71	15.20 ± 1.97	5.9 (15%)	90-150	1.14 ±0.03	52.0 ±2.1	6.2 ±0.6	1.7 ±0.1	0.05 ±0.01	OSL
854	11.3	24 (37)	3.02 ± 0.12	64.72 ± 9.88 [4]	21.72 ± 3.75	14.4	90-150	1.91 ±0.05	97.2 ±3.9	12.3 ±1.1	2.4 ±0.2	0.08 ±0.01	OSL
1082	35.1	11 (42)	2.17 ± 0.09	47.80 ± 12.26 [4]	22.04 ± 5.93	7.4	150-250	1.48 ±0.04	66.5 ±2.7	8.8 ±0.8	1.9 ±0.1	0.02 ±0.00	OSL
855	21.6	24 (49)	3.90 ± 0.16	153.29 ± 15.01	39.28 ± 4.99	10.2	63-150	2.41 ±0.06	119.5 ±4.8	14.6 ±1.3	3.4 ±0.2	0.04 ±0.00	OSL
1084	3.1	13 (32)	2.74 ± 0.11	134.26 ± 25.04	48.99 ± 9.95	12.7	75-150	1.72 ±0.04	74.3 ±3.0	10.5 ±1.0	1.8 ±0.1	0.19 ±0.02	OSL
858	24.7	28 (57)	1.57 ± 0.06	79.39 ± 9.29	50.50 ± 7.15	3.2	150-250	1.27 ±0.03	34.7 ±1.4	4.4 ±0.4	1.1 ±0.1	0.03 ±0.00	OSL
856	24.7	21 (42)	1.77 ± 0.07	118.71 ± 8.36	67.10 ± 7.23	1.9	125-250	1.03 ±0.03	40.9 ±1.6	6.8 ±0.6	1.9 ±0.1	0.03 ±0.00	OSL
1083	38.1	14 (34)	1.20 ± 0.05	115.24 ± 13.88	96.22 ± 13.99	3.3	150-250	0.85 ±0.02	29.7 ±1.2	3.9 ±0.4	0.9 ±0.1	0.02 ±0.00	OSL
2895	2.8	16 (29)	1.27 ± 0.05	173.72 ± 14.76	136.66 ± 16.10	-	150-250	0.69 ±0.02	24.9 ±1.0	3.5 ±0.3	1.2 ±0.1	0.19 ±0.02	OSL
2490[6,7]	32.0	15 (17)	2.29 ± 0.10	234.56 ± 25.82	155.69 21.36	3.8	125-250	0.73 ±0.02 1.06 ±0.03	23.6 ±0.9 25.2 ±1.0	4.0 ±0.4 3.6 ±0.3	1.0 ±0.1 1.0 ±0.1	0.02 ±0.00	IRSL
857	13.4	31 (63)	0.94 ± 0.04	151.12 ± 20.12	159.93 ± 25.03	3.7	90-250	0.66 ±0.02	22.0 ±0.9	2.6 ±0.2	0.6 ±0.1	0.07 ±0.01	OSL
2491	48.2	23 (36)	1.13 ± 0.05	191.02 ± 28.12	169.42 ± 28.62	3.8	125-250	0.74 ±0.02	19.6 ±0.8	4.0 ±0.4	1.0 ±0.1	0.01 ±0.00	OSL

[1] Number of aliquots used in age calculation and number of aliquots analyzed in parentheses.
[2] Equivalent dose (D_E) calculated using the Central Age Model (CAM) of Galbraith and Roberts (2012), unless otherwise noted.
[3] OSL age analysis using the single-aliquot regenerative-dose procedure of Murray and Wintle (2000) on 1-2mm small-aliquots of quartz sand. IRSL age analysis using the two-temperature step (50°C, 225°C) pIR IRSL protocol of Buylaert and others (2009) on 1-2 mm small-aliquots of potassium-rich feldspar. IRSL age on each aliquot corrected for fading following the method by Auclair and others (2003) and correction model of Huntley and Lamothe (2001). Average g_{2days} fading rate for USU-2490 is 4.6±1.5 %/decade (50°C, 225°C combined.)
[4] Assumed 10±3% for moisture content over burial history for in-situ values <10%, excluding USU-859.
[5] Radioelemental concentrations determined by ALS Chemex using ICP-MS and ICP-AES techniques; dose rate is derived from concentrations by conversion factors from Guérin and others (2011).
[6] Grain-size based internal beta dose rate determined assuming 12.5% K and 400ppm Rb using Mejdahl (1979). Alpha contribution to IRSL dose rate determined using an efficiency factor, or 'a-value', of 0.09±0.01 after Rees-Jones (1995).
[7] Dose rate includes weighted average of radioelemental chemistry based on sand fraction (top value, 35%) and gravel fraction (bottom value, 65%).

wave-cut Bonneville shoreline there. Each of these three additional high saddles, in sharp contrast to the Cutler Narrows, is shallow, and overlies weak Neogene Salt Lake Formation with a thin Quaternary cover locally. Ongoing uplift probably has raised the highest bedrock at Cutler Narrows, now at 1706 m (5596 ft) on the south margin and 1670 m (5479 ft) on the north margin, above the subsequent highstand of Lake Bonneville, 1577 m (5174 ft). Thus, initial cutting at Cutler Narrows may be quite old, perhaps along an unmapped fault there.

Scott and others (1983) and Scott (1988) identified Little Valley deposits in Cache Valley at the Ramsbottom and Smart Mountain gravel pits (figure 1), based on amino-acid racemization of shells. We provide the first evidence of one or more pre-Bonneville, post-Little Valley deep-water lake deposits in Cache Valley, north-central Utah-Idaho, and reveal variable climates during the post-Cutler Dam interglacial. We also add the first four definite OSL and IRSL ages for Little Valley deposits in Cache Valley.

Initiation of cutting of Cutler Narrows may be geologically ancient. Part of its cutting could predate the oldest known pluvial deposits in the main part of the Bonneville basin, i.e., prior to the Lava Creek B lake cycle (~620 ka) or the Pokes Point lake cycle (~420 ka). However, the apparent lack of correspondence of highstands related to the Little Valley lake cycle, to the Newton Hill beds, and to the Cutler Dam lake cycle, plus ^{14}C and OSL evidence of an early rise of Lake Bonneville ~22 ka to above the Provo level at the Newton Hill gravel pit and to ~1510 to 1515 m (4954 ft to 4970 ft), corrected for rebound, at the mouth of Green Canyon (Jänecke and others, 2013; Jänecke and Oaks, this volume), ~22 ka (^{14}C), indicate higher levels in Cache Valley than recorded to date for the remainder of the Bonneville basin. This suggests that much of the excavation of Cutler Narrows postdates the Cutler Dam lake cycle. This would also be after the Bear River was diverted into Cache Valley from Gem Valley, in the northeast, where overflow culminated in the final incision of Oneida Narrows at ~55 ka (Pederson and others, 2016), coincident with the Cutler Dam lake cycle.

If the lake levels differed between Cache Valley and the main Bonneville basin until after the Cutler Dam lake cycle, an early rise of Lake Bonneville in Cache Valley above the threshold at Cutler Narrows would have initiated westward flow, perhaps with significant erosion, across that threshold into the main Bonneville basin. However, probably most of the excavation of Cutler Narrows was by subsequent eastward flow during the Bonneville flood, with perhaps some thereafter during outflow during the two Provo stages (Jänecke and Oaks, 2011a, 2011b). Minor post-Bonneville erosion has been by westward flow of the Bear River through Cutler Narrows.

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This content is a PDF version of the author's PowerPoint presentation.

OSL age dating of two, perhaps three, pre-Bonneville deep-water pluvial lakes in Cache Valley, Utah-Idaho: Implications of their unexpected high altitudes for excavation of Cutler Narrows from a level above 1494 m (4901'), down to the present 1314 m (4310') mainly during the Bonneville lake cycle

Robert Q. Oaks, Jr., Susanne U. Jänecke, Tammy M. Rittenour, Thad L. Erickson, and Michelle S. Nelson, Utah State University

Outline

- Geographic Setting: Cache Valley, N-central Utah & SE Idaho, NE arm of Lake Bonneville
- Database: Field Mapping, OSL Age Dates, and Drillers' Logs of Water Wells
- New Findings:

Compound geosol & 2 or 3 pre-Bonneville Gravels

First Definitive Evidence for 1 or 2 post-Little Valley, pre-Bonneville Lakes in Cache Valley

Lower >186 m of Cutler Narrows likely cut primarily post-Qlv, mostly < 30 ka, by both west and east flows

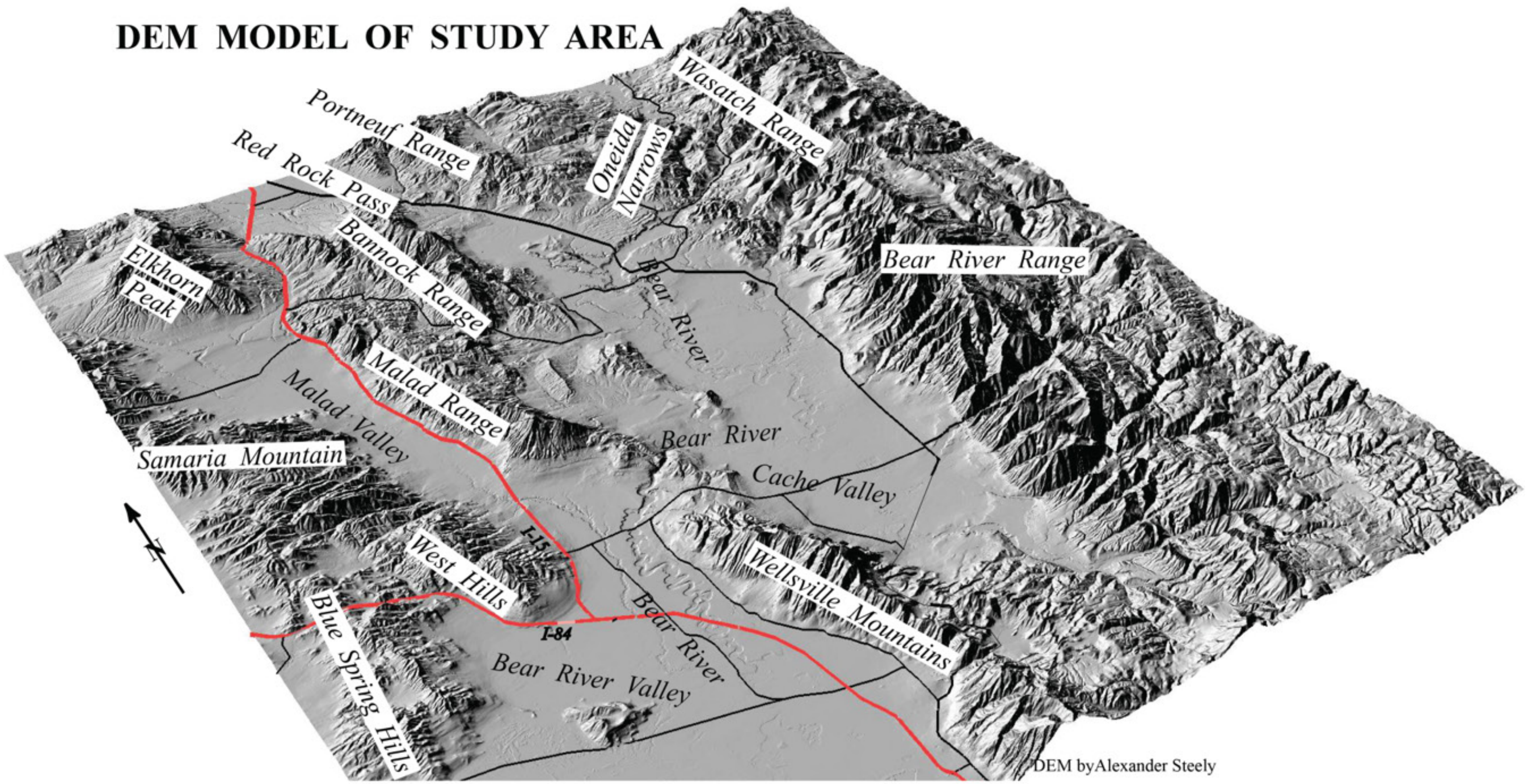

Figure 2. Digital-elevation model showing major topographic features and highways in the area of study (compiled by A. N. Steely)

Previous work in Cache Valley established that there are 4 or perhaps 5 successive lake cycles recorded in drillers' logs of water wells (Bjorklund and McGreevy, 1970; Robinson, 1999; Oaks, 2000; Thomas et al., 2011)

Bright (1963) found pre-Bonneville deposits at Ramsbottom pit, N of Smart Mountain >1477m

McCoy (1981) used amino-acid racemization to establish that deposits of the Little Valley lake cycle are present at Smart Mountain >1431 m

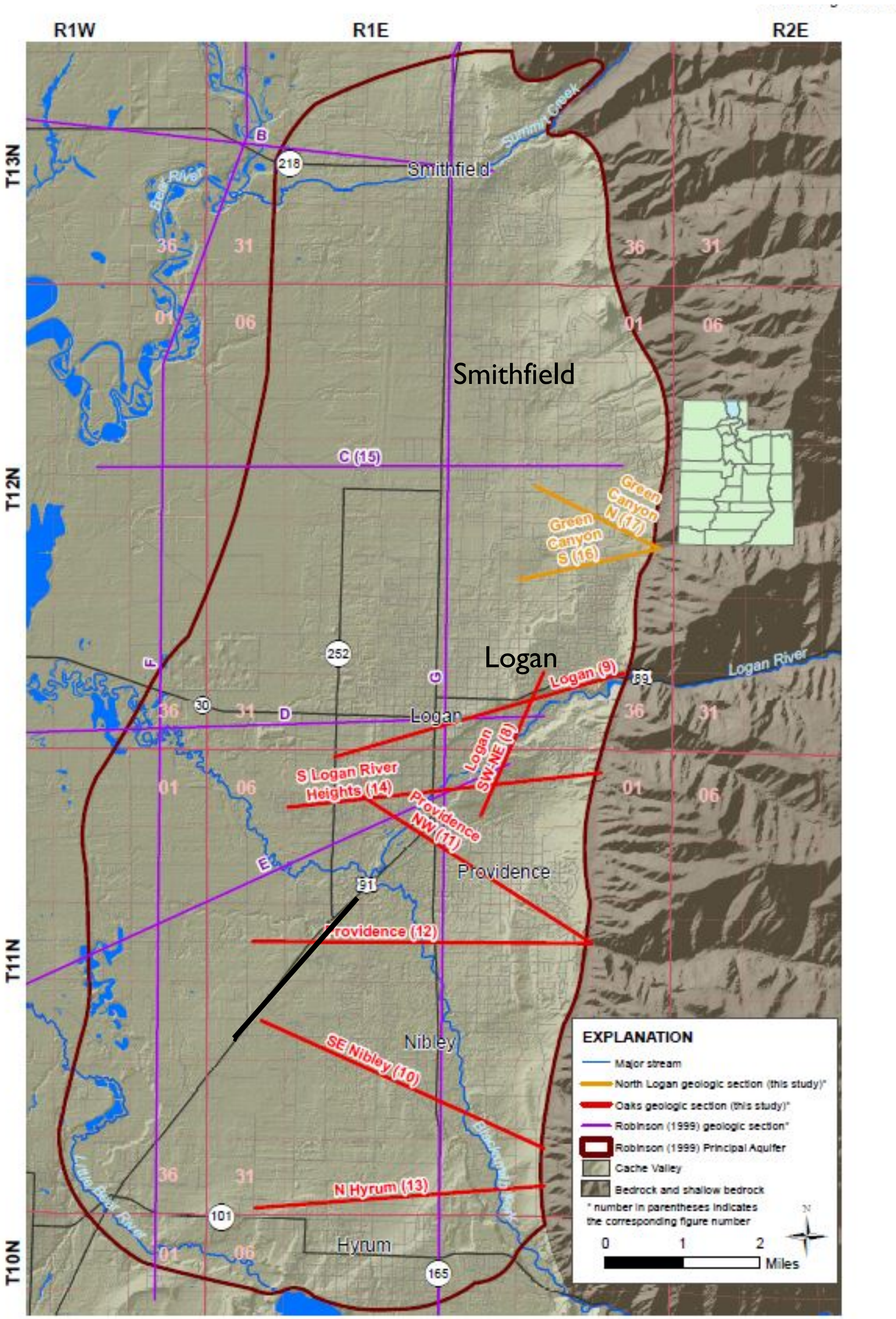

Figure 7. Location of geologic sections examined for this study. Robinson's (1999) geologic sections are purple and geologic sections made for this study are in red and orange.

From Thomas, Oaks, Inkenbrandt, Sabbah, & Lowe (2011); black line shows location of geologic section

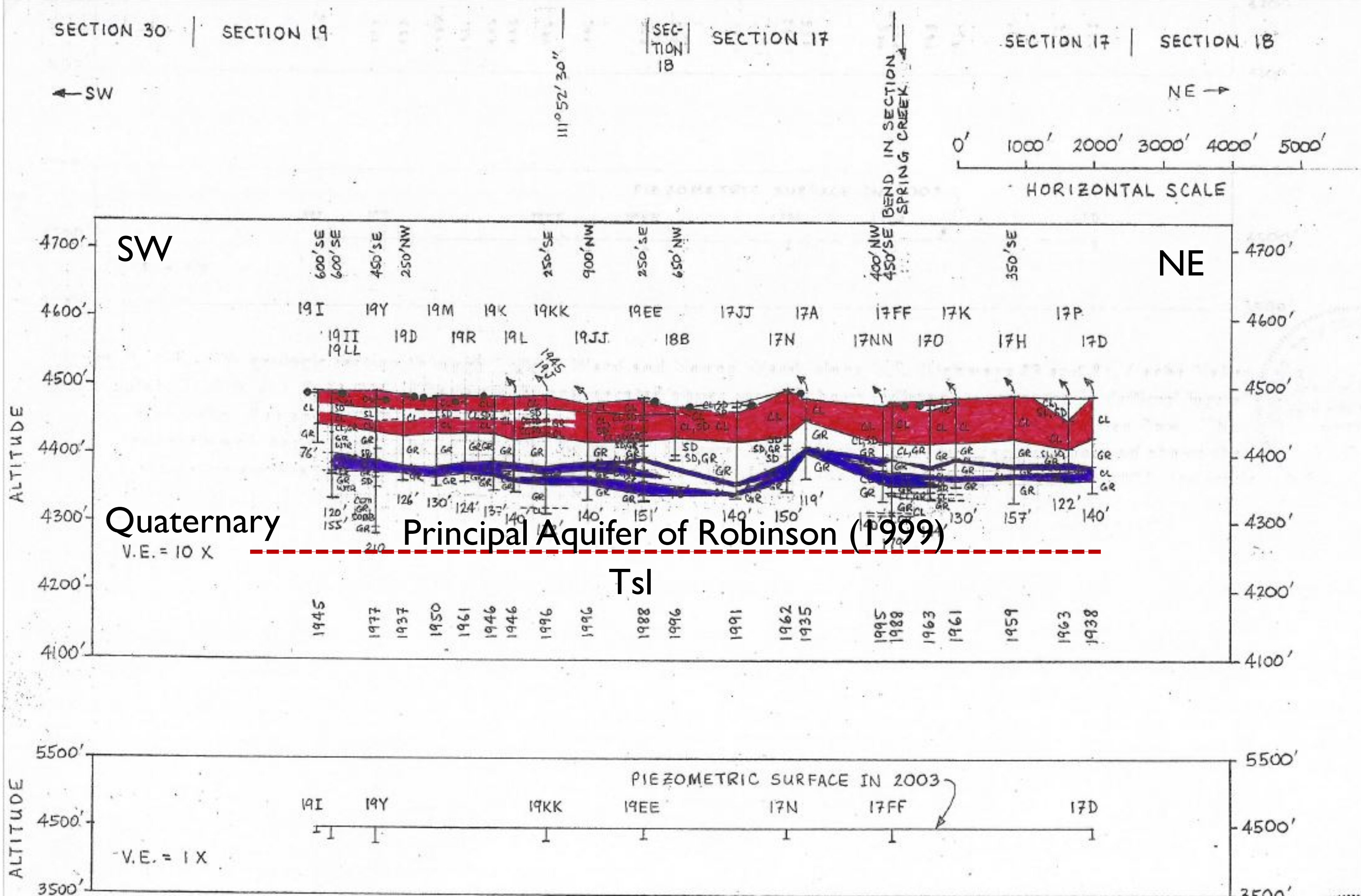

Figure 4. NE - SW geologic section through College Ward and Young Ward, along U.S. Highways 89 and 91, Cache Valley, Utah, T 11 N, R 1 E, SLBM. The vertically exaggerated upper section shows sediment types noted in drillers' logs of water wells. Bar and ball shows static water level when the well was completed; an arrow shows artesian flow. The year each well was drilled is shown along the bottom. The lower section has no vertical exaggeration, and shows the piezometric surface just above or very near the present surface from 1935 through 1995 (and through 2003: the static water level was -1.5 feet in well 19RR).

LICENSED PROFESSIONAL GEOLOGIST
DR. ROBERT Q. OAKS, JR.
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STATE OF UTAH

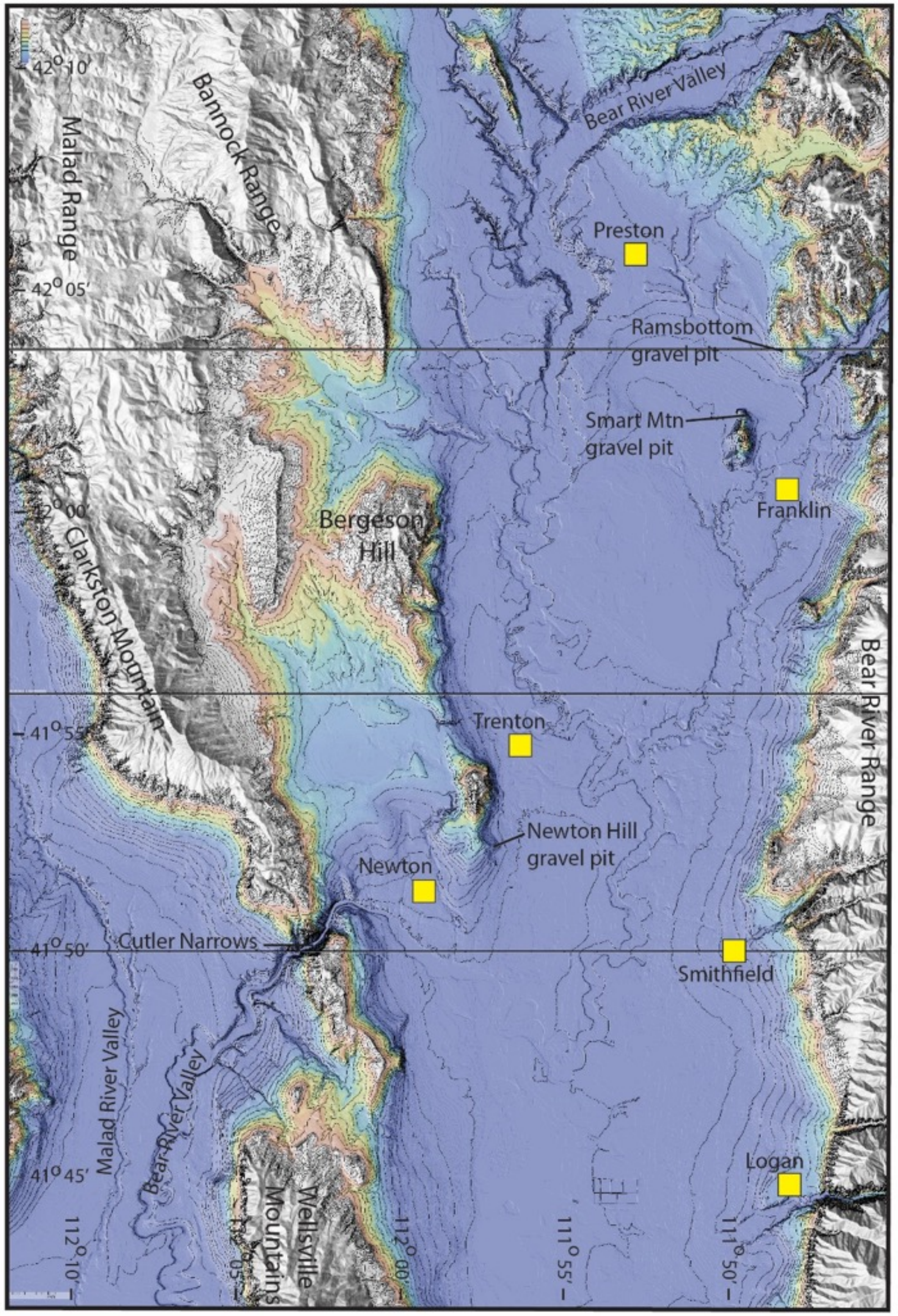
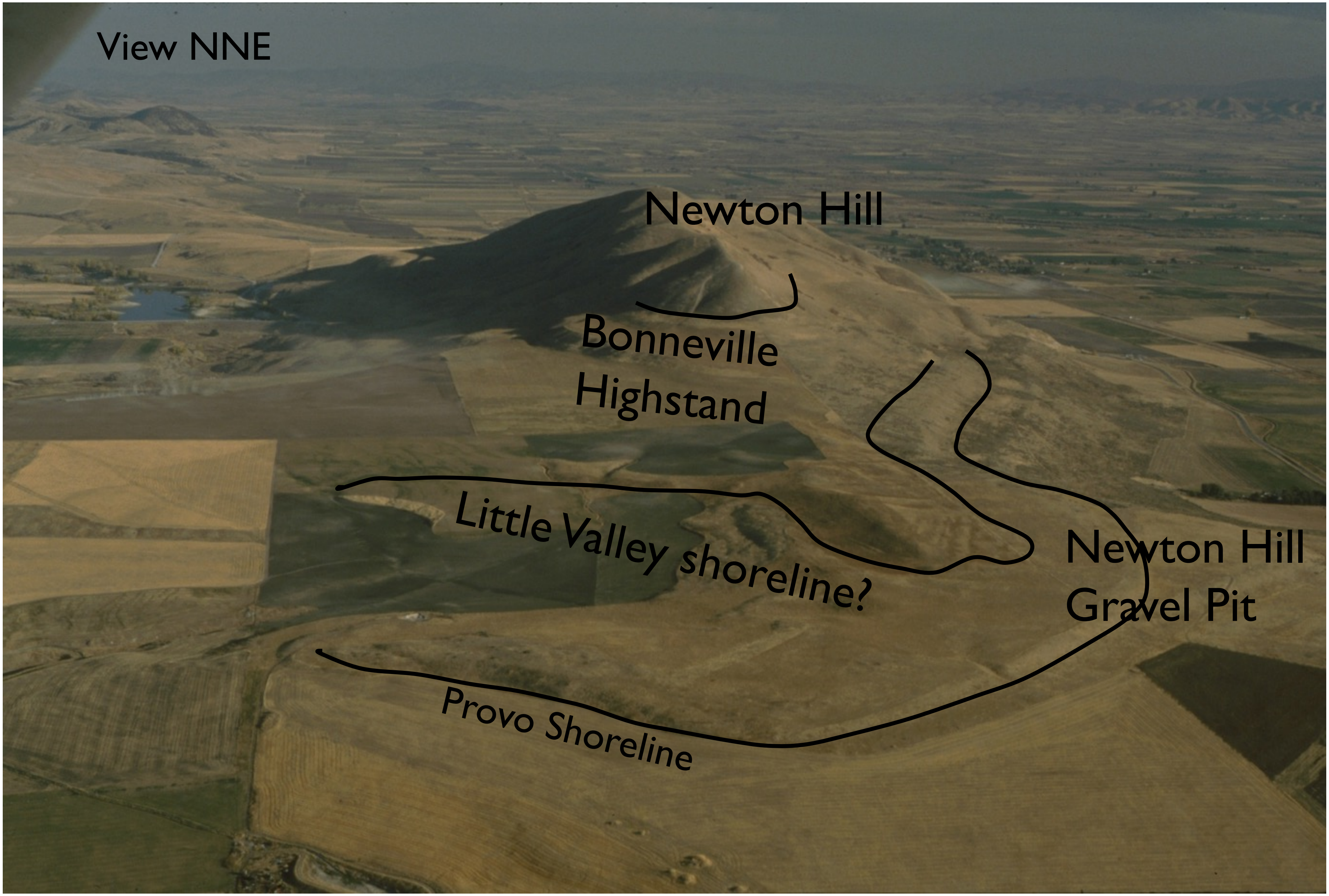
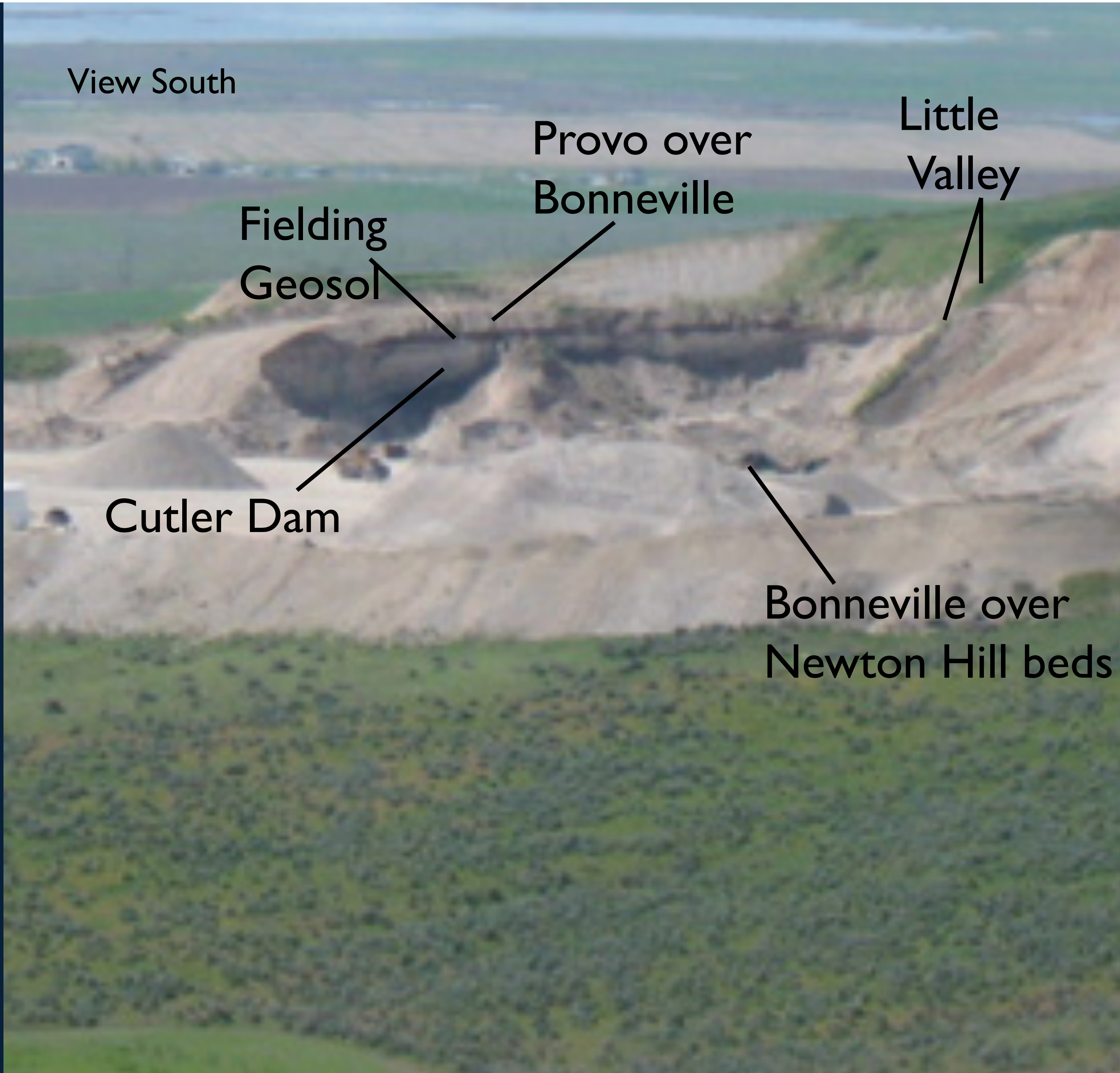
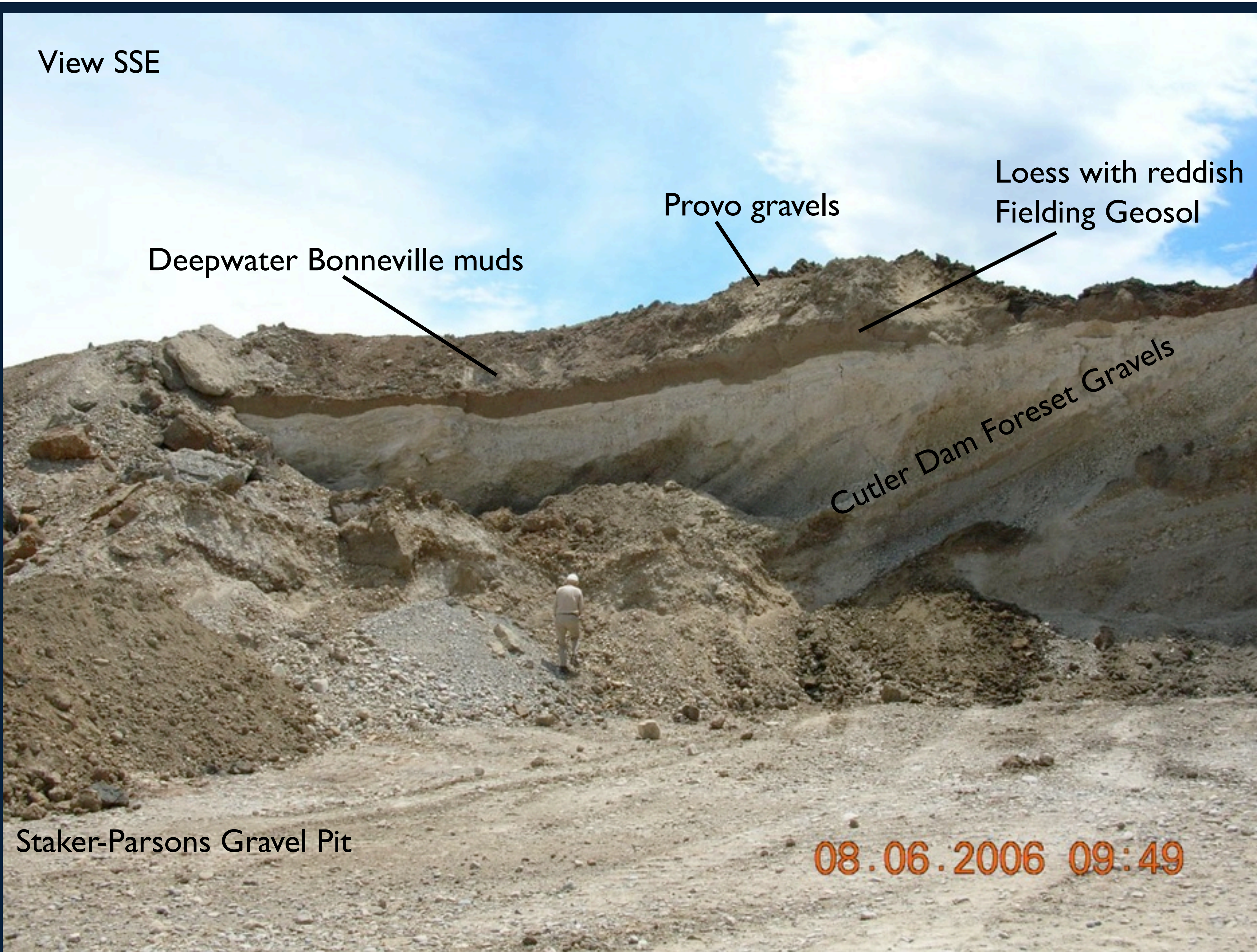


Figure 2. DEM map of Cache Valley area showing 3 gravel pits with lake deposits older than Lake Bonneville. Type area of Cutler Dam unit is along the Bear River Valley SW of Cutler Narrows. Bonneville highstand is near lowest white; Provo highstand is near top of blue.


View NNE
Newton Hill
Bonneville
Highstand
Little Valley shoreline?
Newton Hill
Gravel Pit
Provo Shoreline


Google Earth
File Edit View Tools Add Help
Search
Newton, Utah
Search
ex: Museums in New York, NY
Get Directions History
Newton, UT, USA
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Temporary Places
Layers
Earth Gallery
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
Sign in
Newton Hill
Bonneville Highstand
Provo Shoreline
172 ka
Little Valley Shoreline?
~151 ka
Staker-Parsons Gravel Pit
© 2013 Google
Google earth
1992
Imagery Date: 8/11/2011
41°52'45.74" N 111°57'21.77" W elev 4601 ft
eye alt 10980 ft


View South
Provo over Bonneville
Little Valley
Fielding Geosol
Cutler Dam
Bonneville over Newton Hill beds


View SSE
Loess with reddish
Fielding Geosol
Provo gravels
Deepwater Bonneville muds
Cutler Dam Foreset Gravels
Staker-Parsons Gravel Pit
08.06.2006 09:49

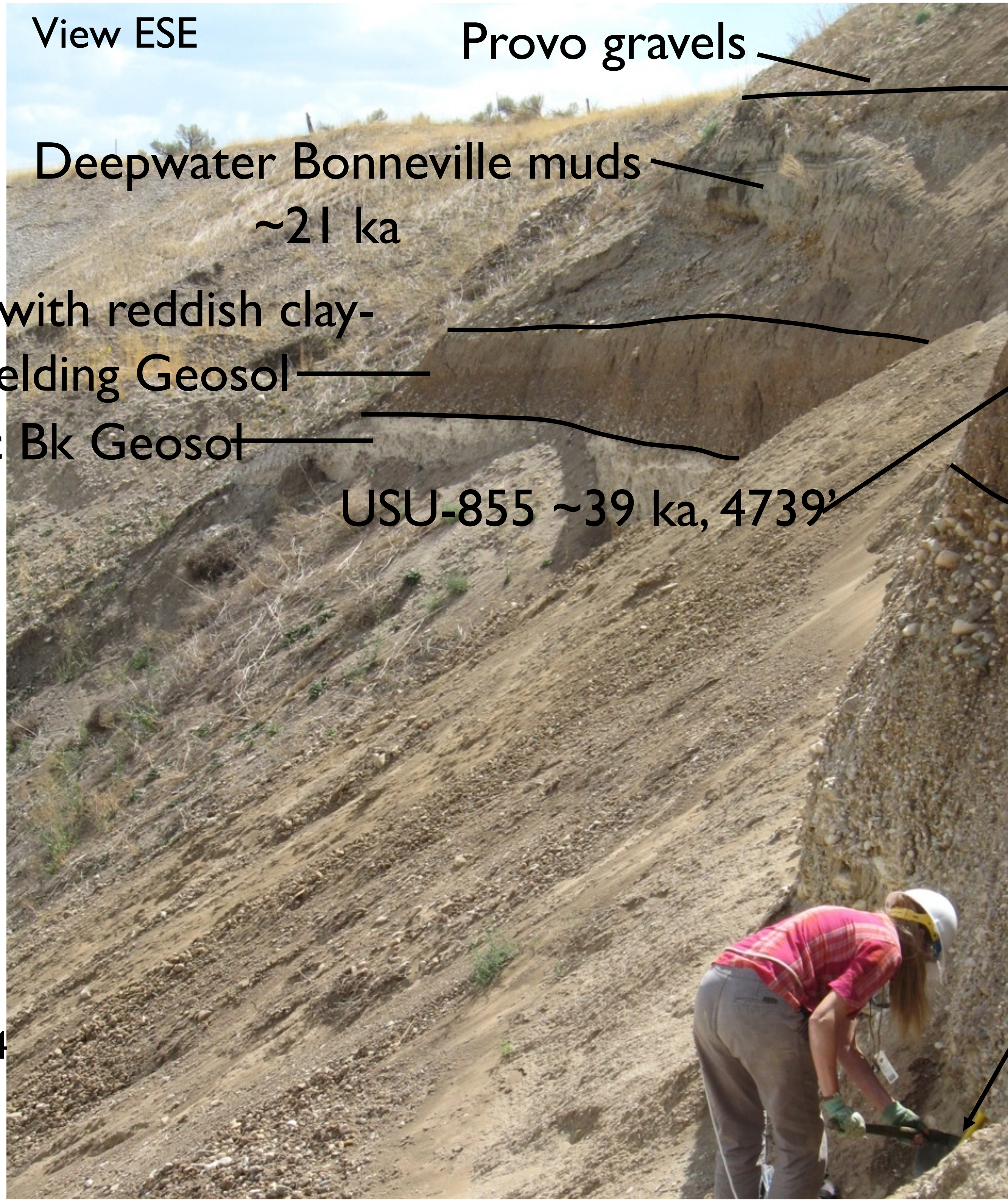
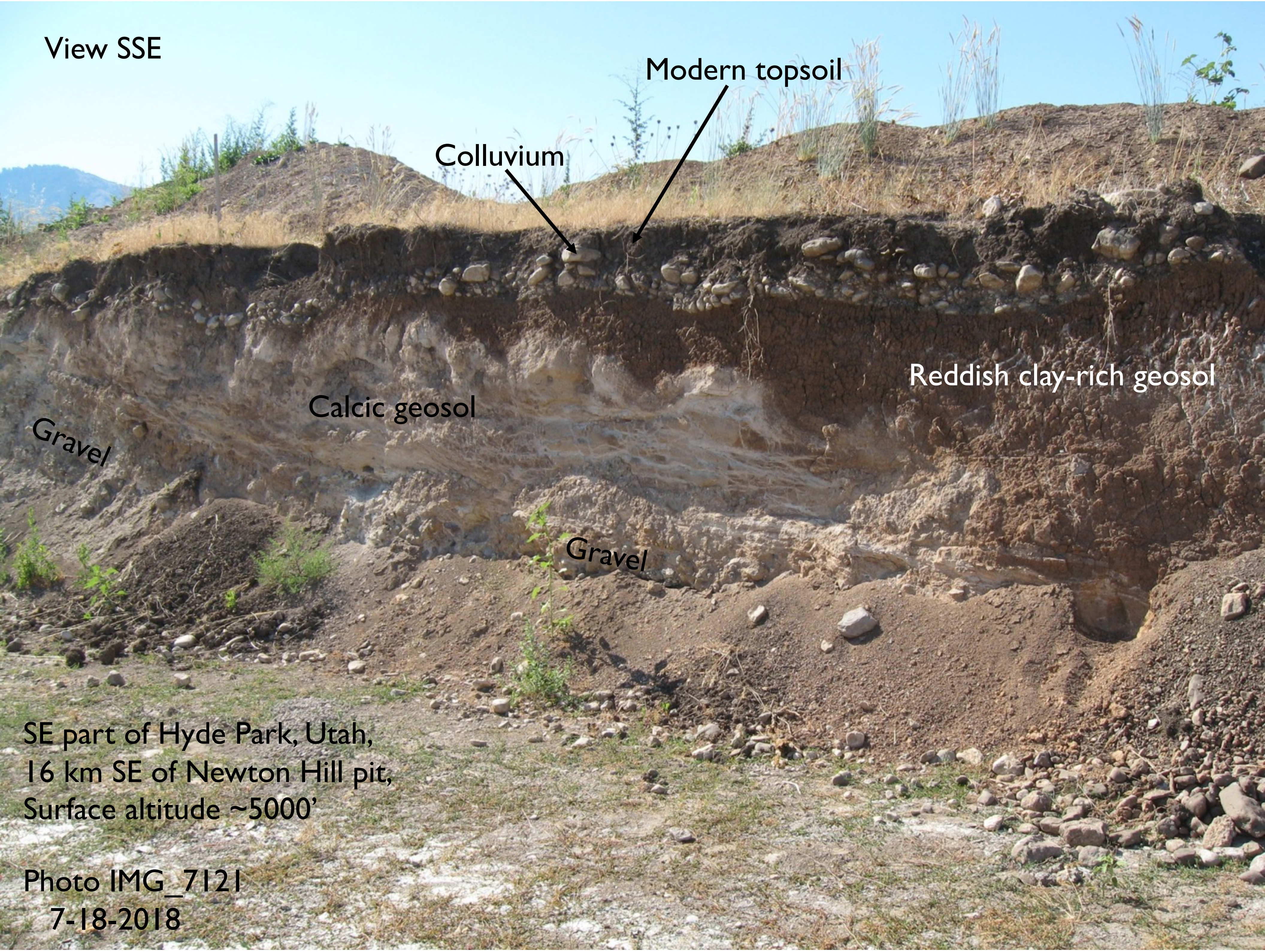


Photo IMG_2564
9-8-2010


View SSE
Modern topsoil
Colluvium
Reddish clay-rich geosol
Calcic geosol
Gravel
Gravel
SE part of Hyde Park, Utah,
16 km SE of Newton Hill pit,
Surface altitude ~5000'
Photo IMG_7121
7-18-2018

View East

50’ NNE

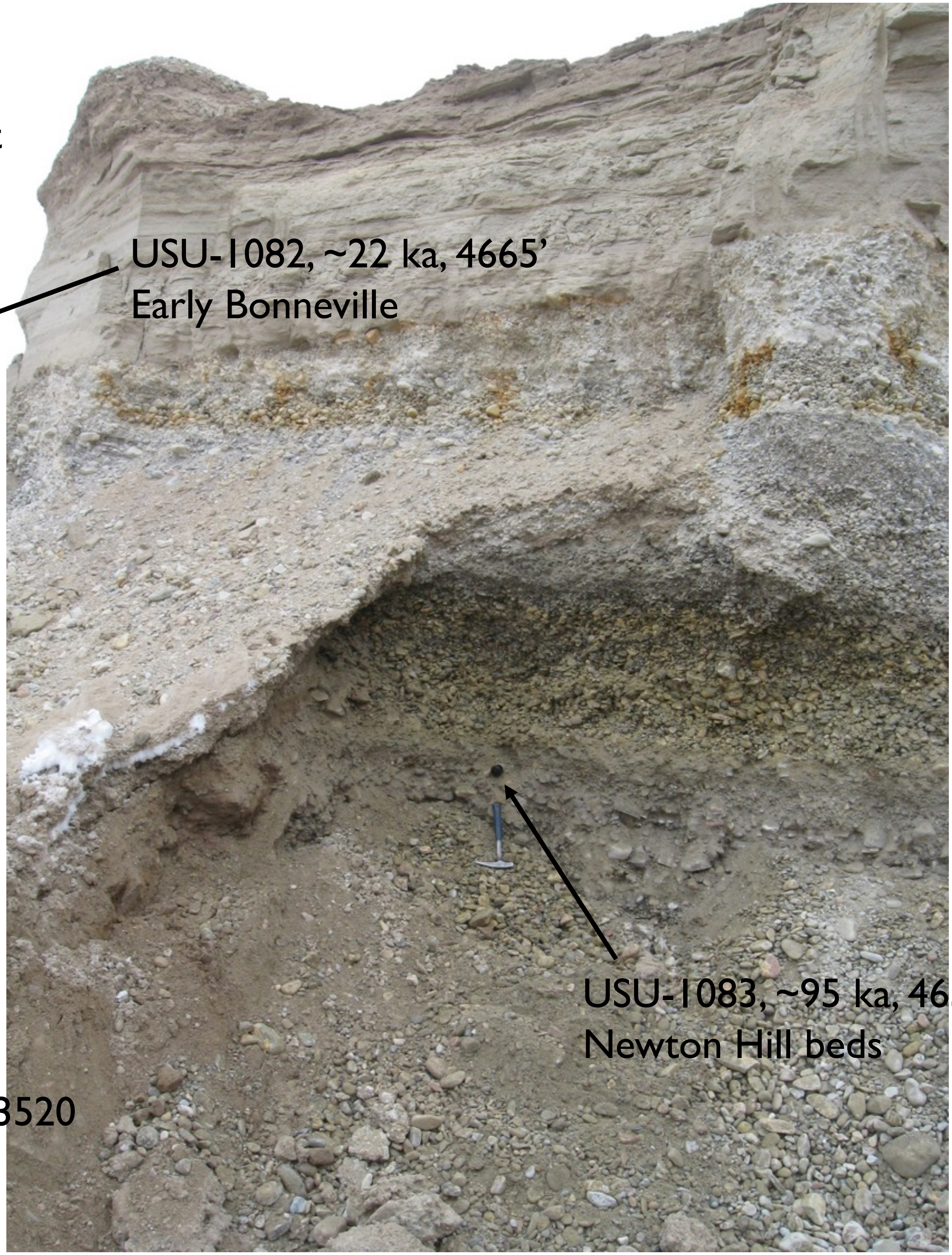
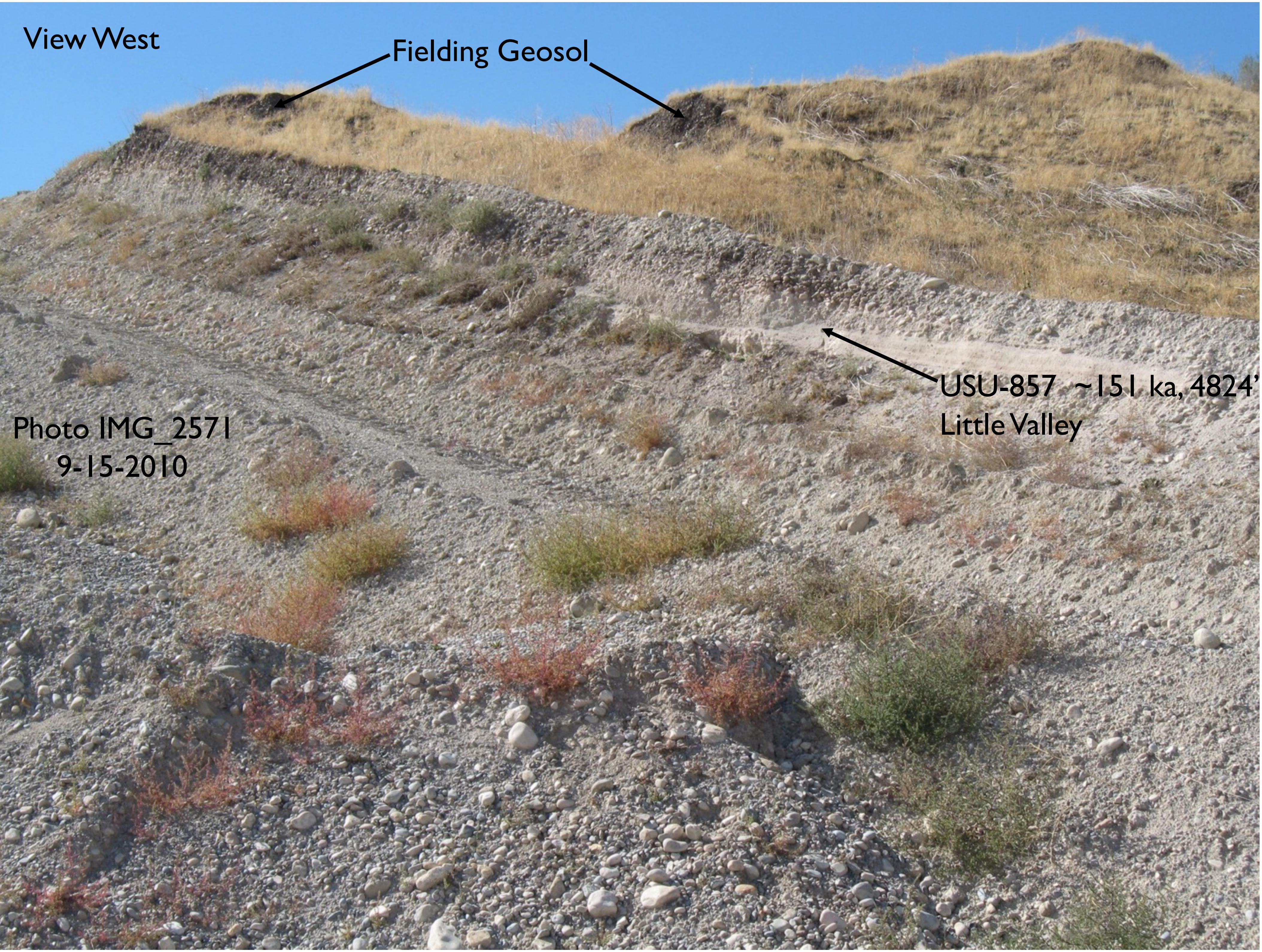
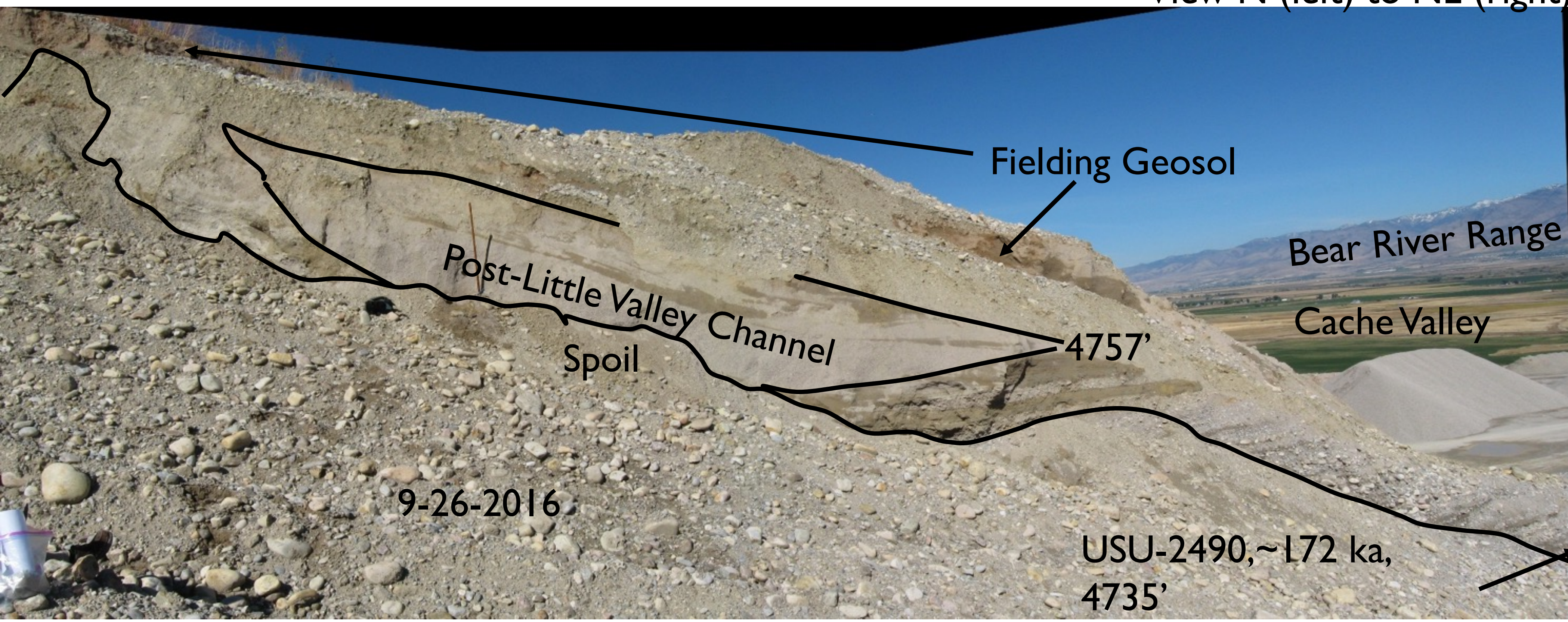


Photo IMG_3520
12-2-2011


View West
Fielding Geosol
USU-857 ~151 ka, 4824'
Little Valley
Photo IMG_2571
9-15-2010

View N (left) to NE (right)

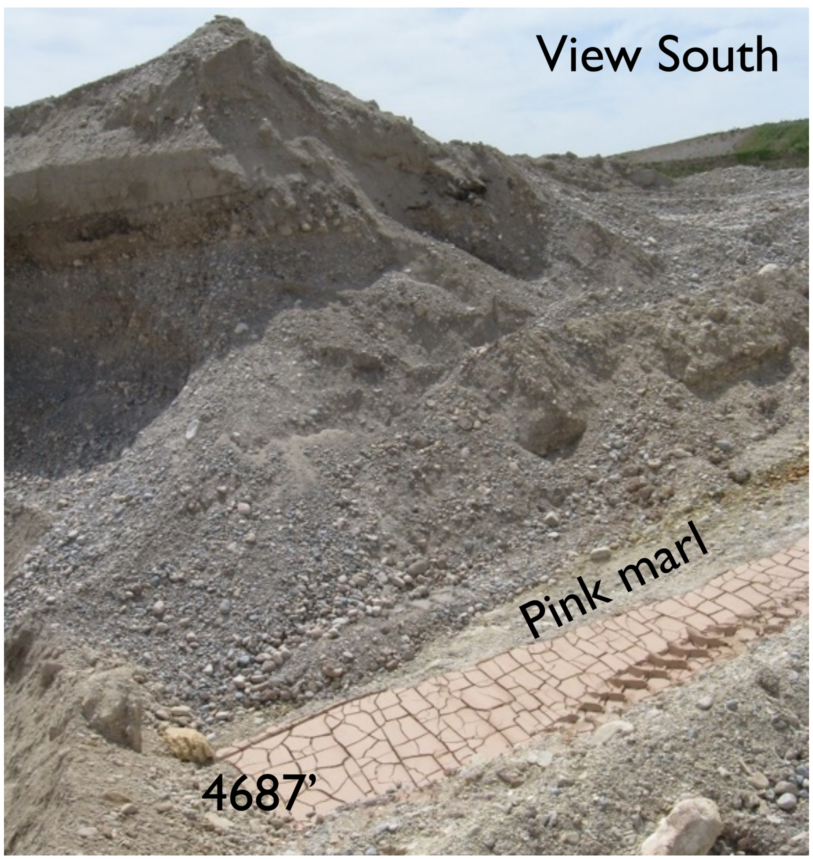


Little

–
Valley

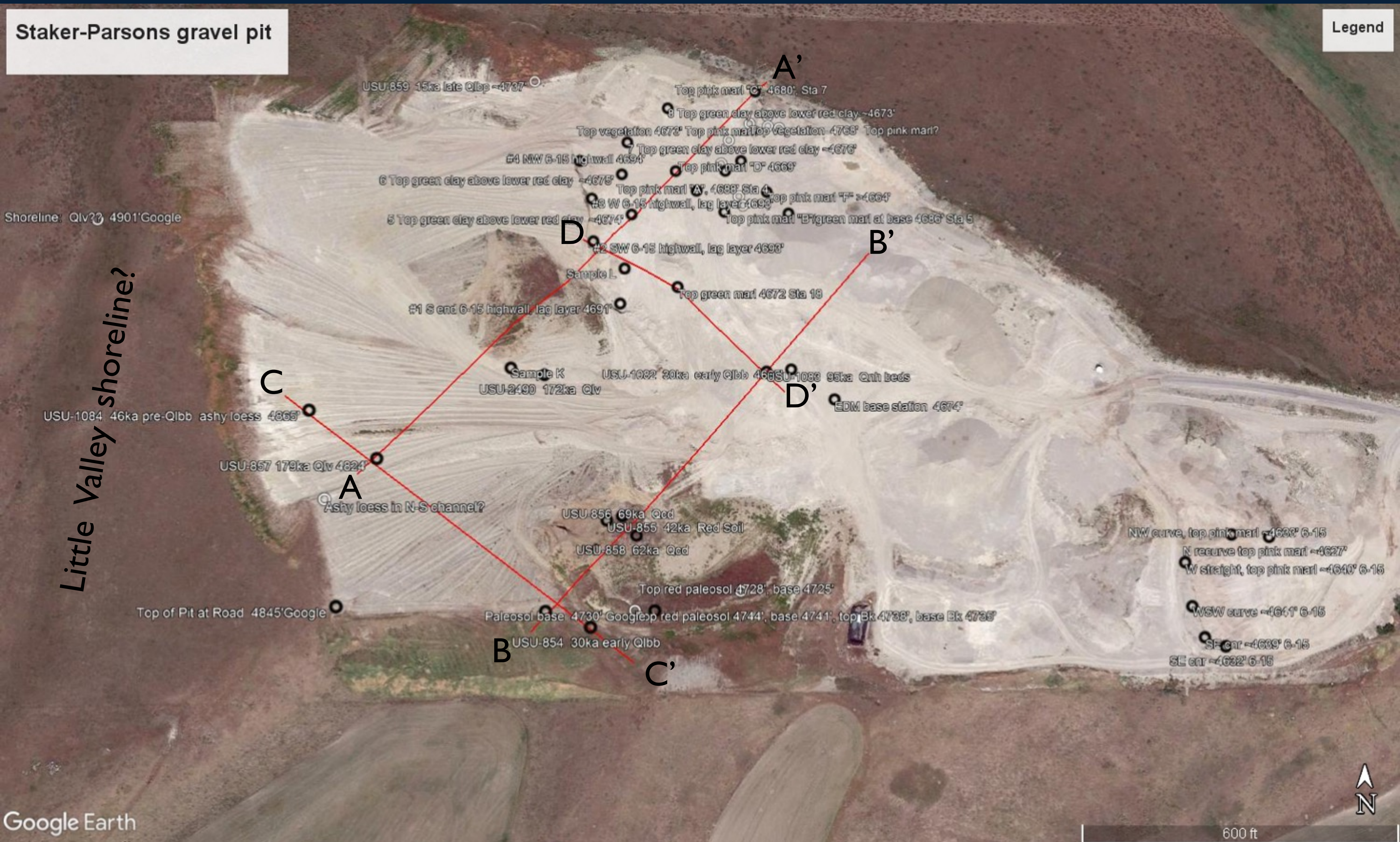
Photo IMG_5912 5914Stich; vertical staff 4.9’ (1.5 m) high; west of pit highwall

Pink marl



Side and top views of freshly exposed pink marl, which locally is white to pale green. It is 1’ to 3’ thick, widely distributed through the Newton Hill pit, and locally onlaps the red geosol westward. The white marl of Morrison (1966) at the Little Valley pit (not observed), overlies his Promontory geosol or the underlying Alpine Formation (Little Valley lake beds?).

Photo IMG_5478
5-5-2016



Google Earth image 6-18-2017 of Newton Hill pit shows stations and data tied to EDM survey and locations of geologic sections A-A', B-B', C-C', and D-D'

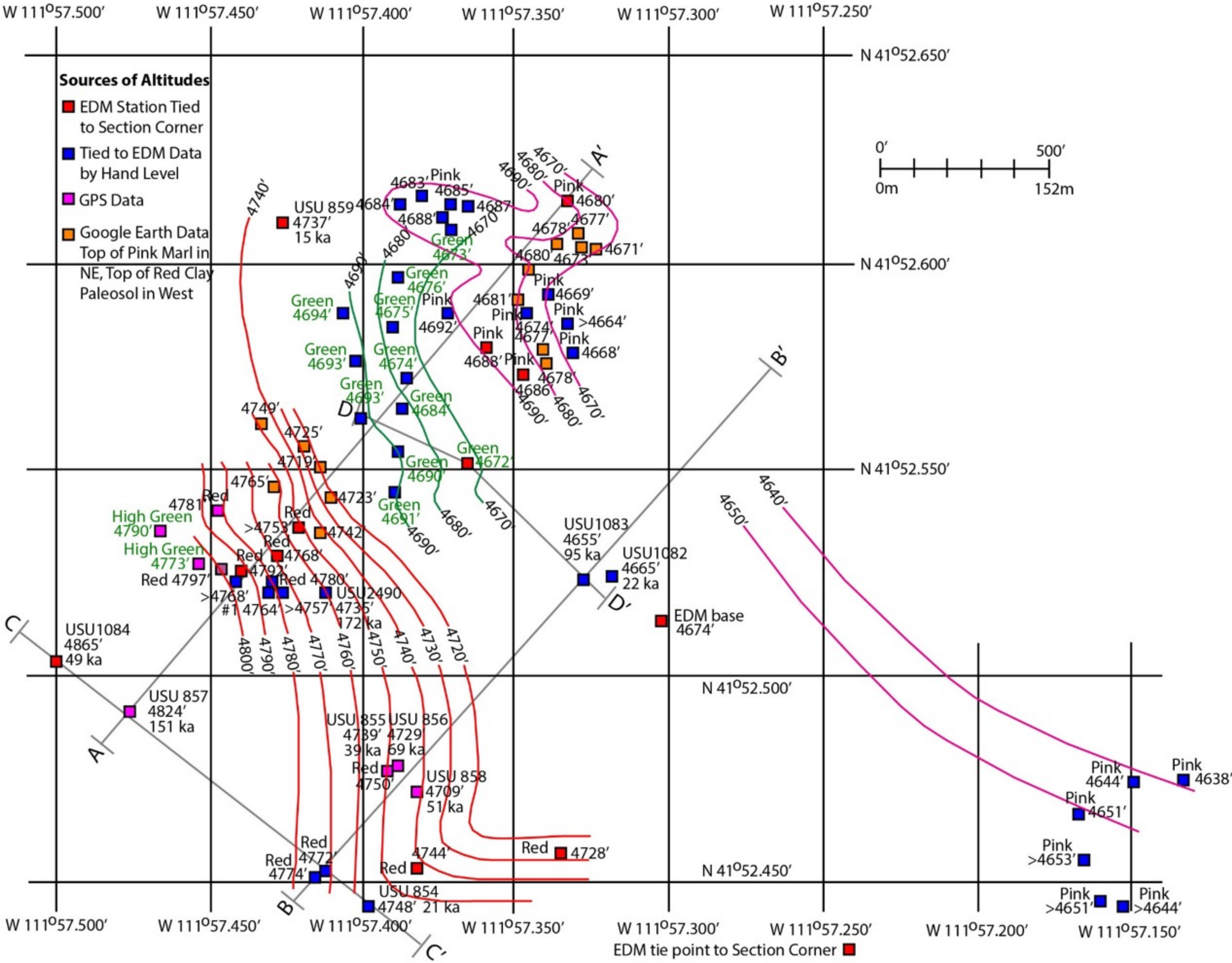


Figure 6. Map of Staker-Parsons gravel pit SE of Newton Hill shows control points with their sources of altitudes; locations of OSL age dates (Tables 2, 3); values and contours of the top of an extensive red sandy clay geosol in the south and west, pink/white/green marl in the northeast, and laminated green clay between them (contour interval = 10′); locations of four geologic sections (A - A′ to D - D′); latitudes and longitudes; and scale in feet and meters.

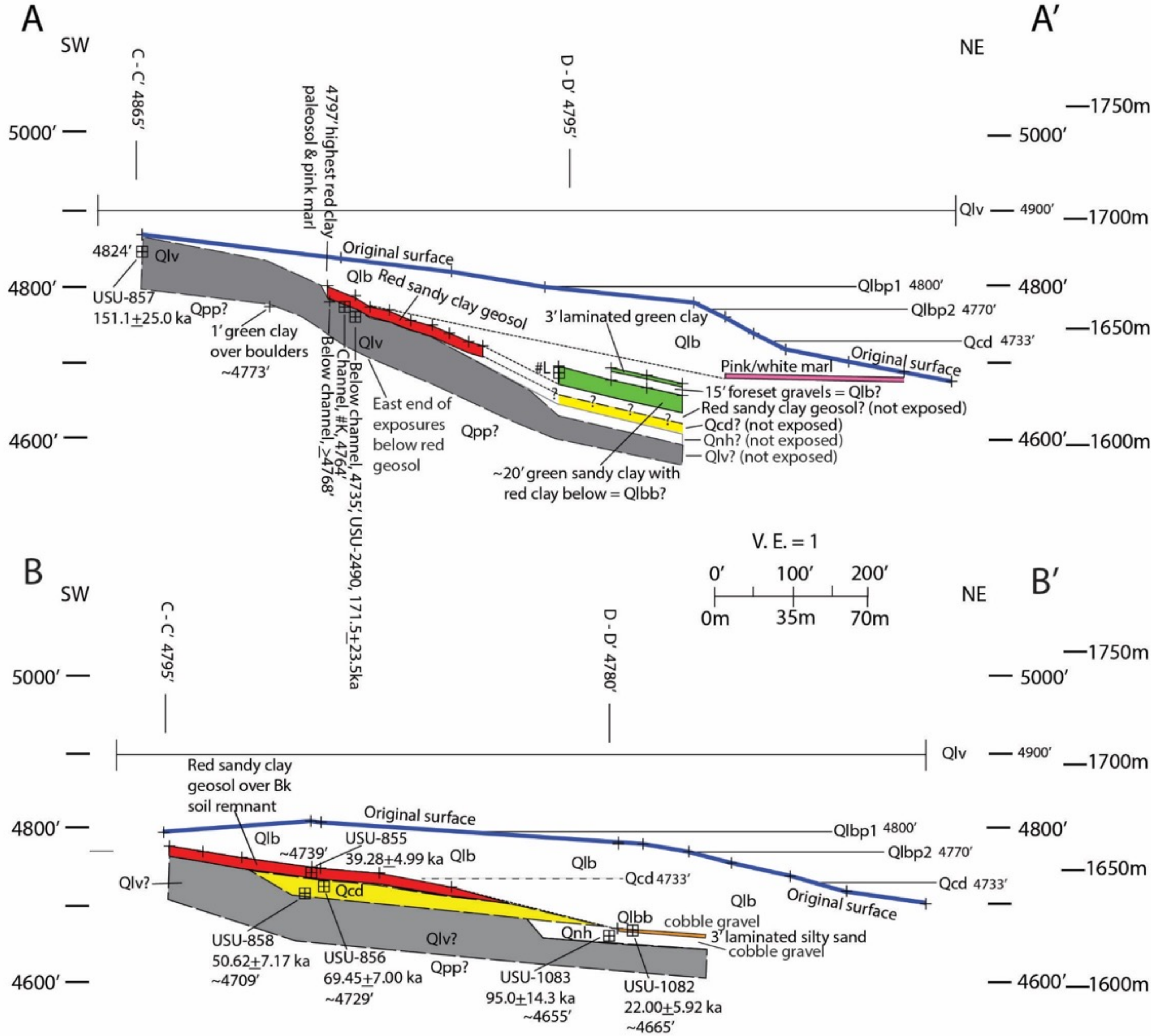


Figure 7. Geologic sections A - A′ and B - B′ showing extents of identified geologic units, original surface, OSL age dates (Tables 2, 3), highstand lake levels, and intersections with other geologic sections. Qlbp2 = younger Provo shoreline; Qlbp1 = older Provo shoreline; Qlbb = deposits related to the highest Bonneville shoreline (5160′); Qlb = undifferentiated Provo and Bonneville deposits; Qcd = Cutler Dam highest identified deposits and inferred shoreline (~4733′); Qnh = proposed Newton Hill unit based on stratigraphy and USU-1083 OSL age date; Qlv = Little Valley deposits; Qpp? = possible Pokes Point or older Quaternary deposits (not exposed). #K and #L in geologic section A - A′ are 2 additional samples collected for future OSL age dates.

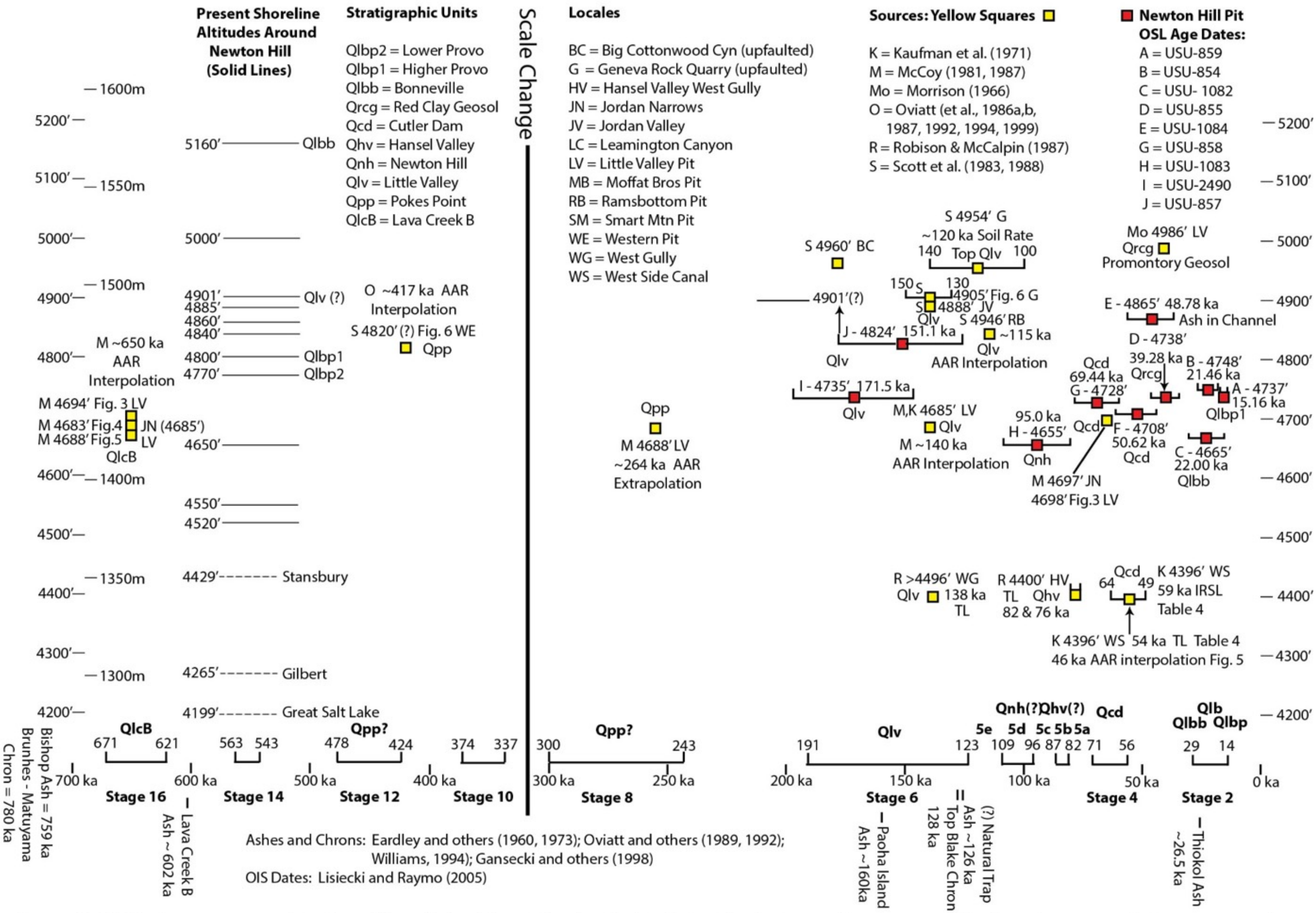


Figure 12. Highest occurrences of stratigraphic units in different locales, tied to determined or approximate ages, related marine oxygen-isotope ages, and shoreline altitudes near Newton Hill. See Table 3 for data from Newton Hill pit, shown in red here. AAR = amino-acid racemization; TL = thermoluminescence.

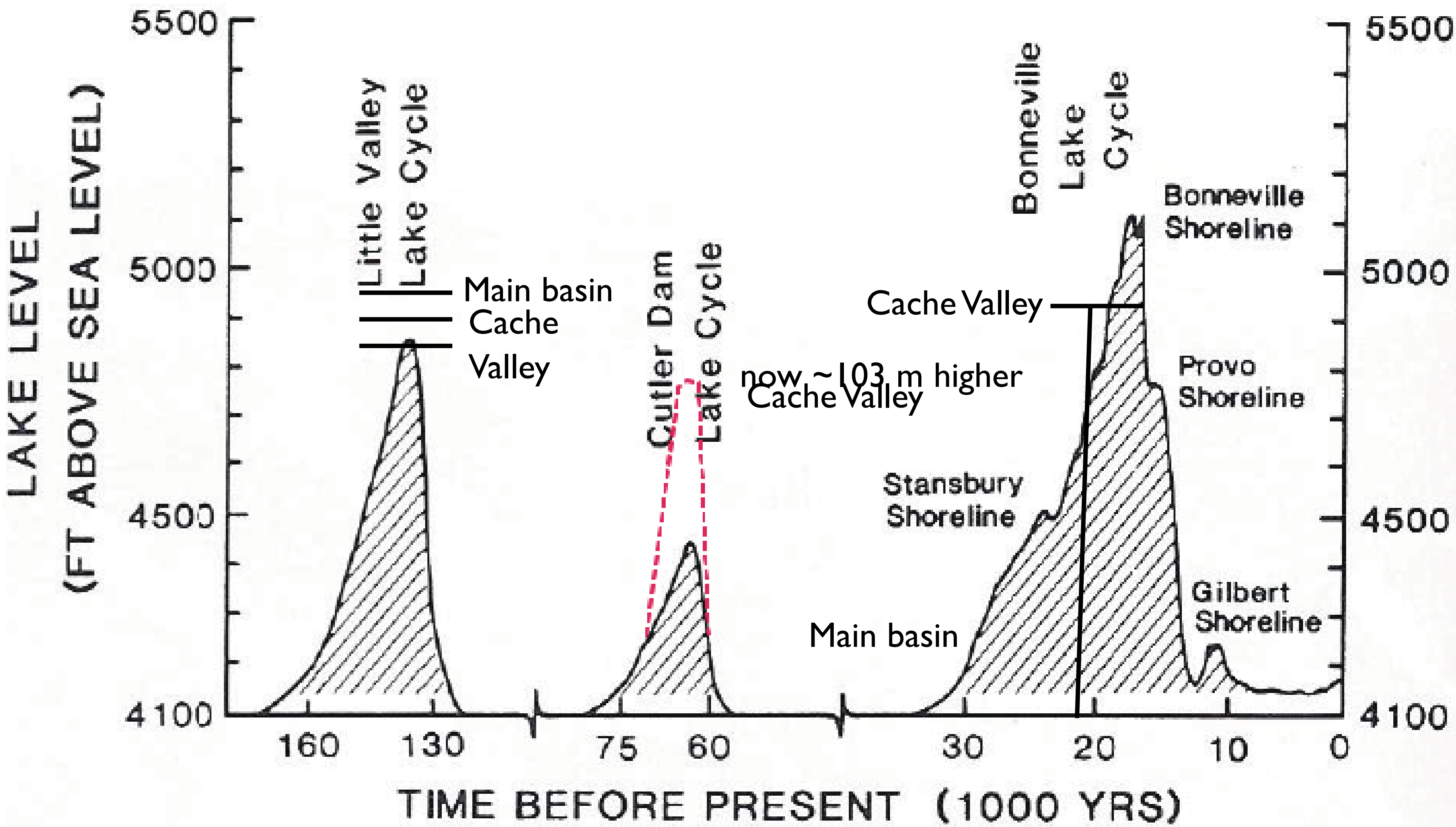
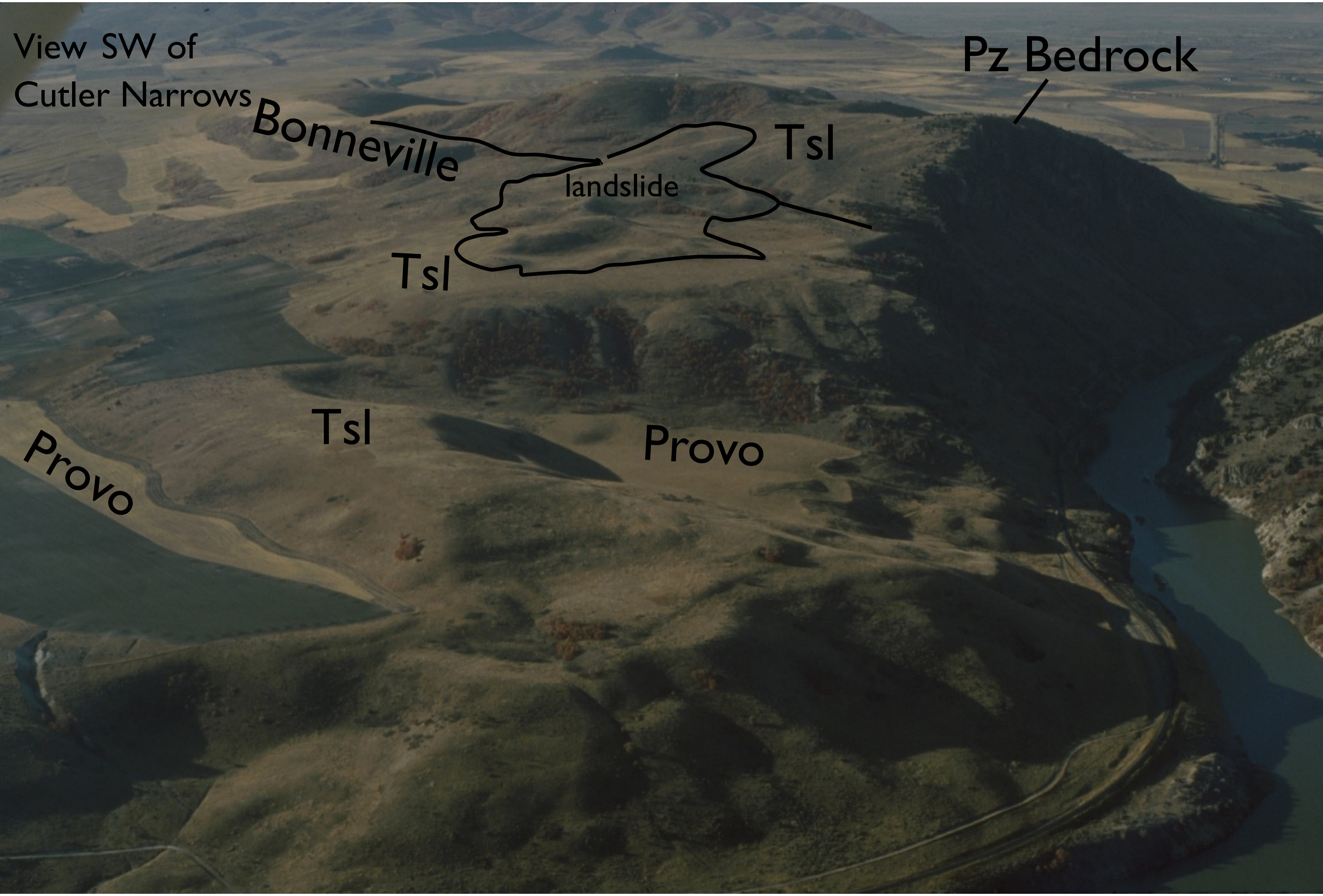
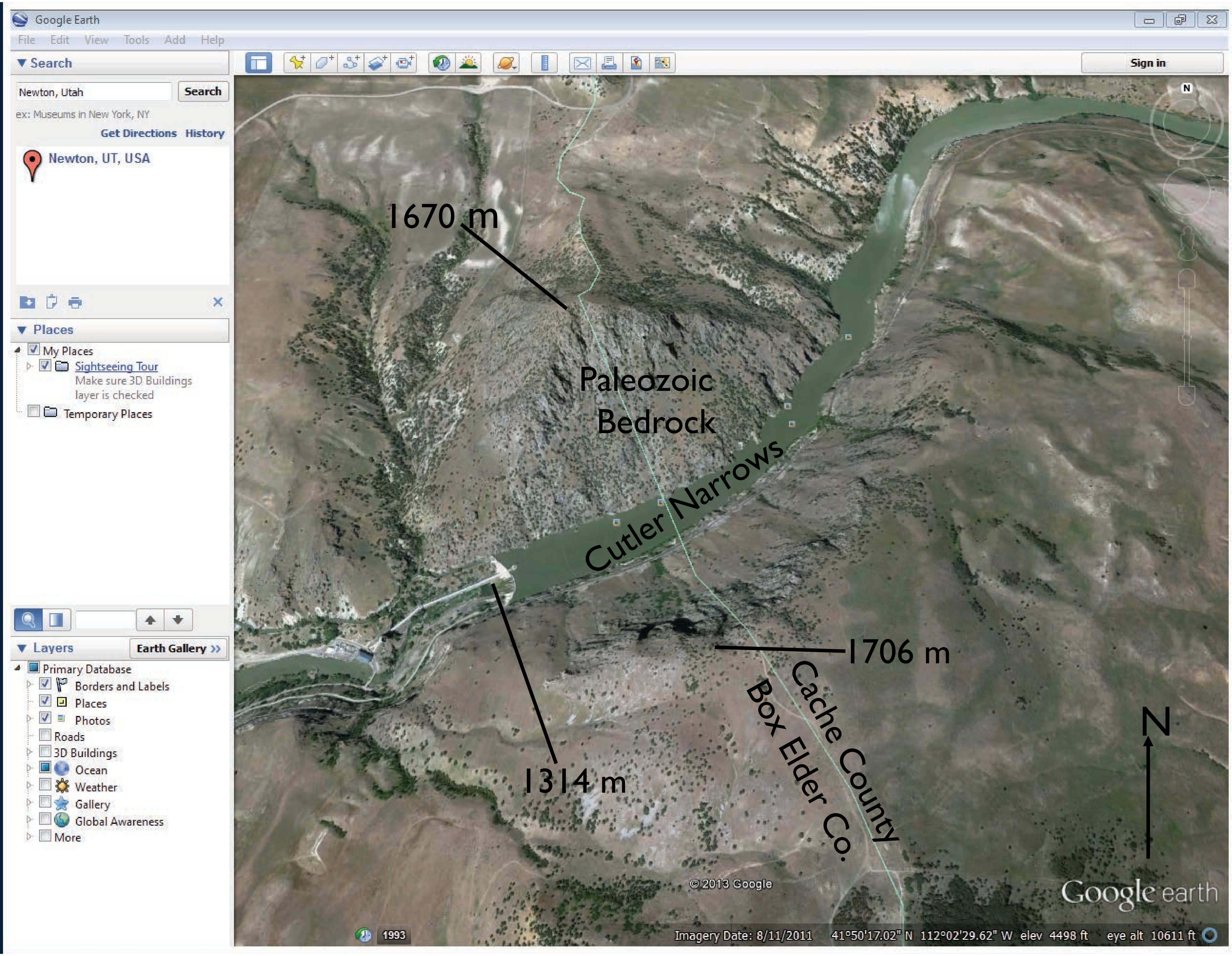


Figure 25. Shoreline levels of Lake Bonneville and the next two of four earlier lake cycles (Pokes Point and Lava Creek not shown) in the Bonneville Basin (from Machette and others, 1987), with modification based on OSL dates by Rittenour of sand and gravel from the Parson gravel pit SE of Newton Hill.

Shoreline Altitudes of Lake Cycles in Main Bonneville Basin Compared to Coeval Shorelines in Cache Valley, with Current Altitudes for Older Lakes and Altitudes Corrected for Rebound for Bonneville Shorelines.

	Main Bonneville Basin			Cache Valley Bay			
Lake Cycle	Location; Source	Age in ka	Shoreline Altitude	Location; Source	Age in ka	Shoreline Altitude	Altitude Difference in Cache Valley
Little Valley	Point of Mountain Scott et al., 1988	~120	~4954' ~1510 m	Newton Hill Pit	~151.1 ~171.5	>4824'; 4901'(?) >1470 m; 1494 m(?)	< -130'; -53'(?) < -40 m; -16 m(?)
Little Valley	Big Cottonwood Scott et al., 1983	~175	~4960' ~1512 m	Newton Hill Pit	Same	Same	< -136'; -59'(?) < -41 m; -18 m(?)
Hansel Valley; Newton Hill	West Gully; Robison & McCalpin, 1987	~82 ~76	~4400' ~1341 m	Newton Hill Pit	~95.0	~4662 ~1421 m	+ 262' + 80 m
Cutler Dam	Westside Canal; Kaufman et al., 1971	~59	~4396' ~1340 m	Newton Hill Pit	~69.4 ~50.6	~4733' ~1443 m	+ 337' + 103 m
Mid-Bonneville	Nelson, 2012 Curve	~22	~4413' ~1345 m	Green Canyon Pit	~22 ^{14}C	~4922' ~1500 m	+ 509' + 155 m
Mid-Bonneville	Oviatt, 2015 Curve	~22	~4856' ~1480 m	Green Canyon Pit	Same	Same	+ 66' + 20 m


View SW of
Cutler Narrows
Pz Bedrock
Bonneville
Tsl
landslide
Tsl
Tsl
Provo
Provo



Google Earth
File Edit View Tools Add Help
Search
Newton, Utah
Search
ex: Museums in New York, NY
Get Directions History
Newton, UT, USA
Places
My Places
Sightseeing Tour
Make sure 3D Buildings layer is checked
Temporary Places
Layers
Earth Gallery »
Primary Database
Borders and Labels
Places
Photos
Roads
3D Buildings
Ocean
Weather
Gallery
Global Awareness
More
Sign in
1670 m
Paleozoic Bedrock
Cutler Narrows
1706 m
1314 m
Cache County
Box Elder Co.
N
© 2013 Google
Google earth
1993
Imagery Date: 8/11/2011 41°50'17.02" N 112°02'29.62" W elev 4498 ft eye alt 10611 ft

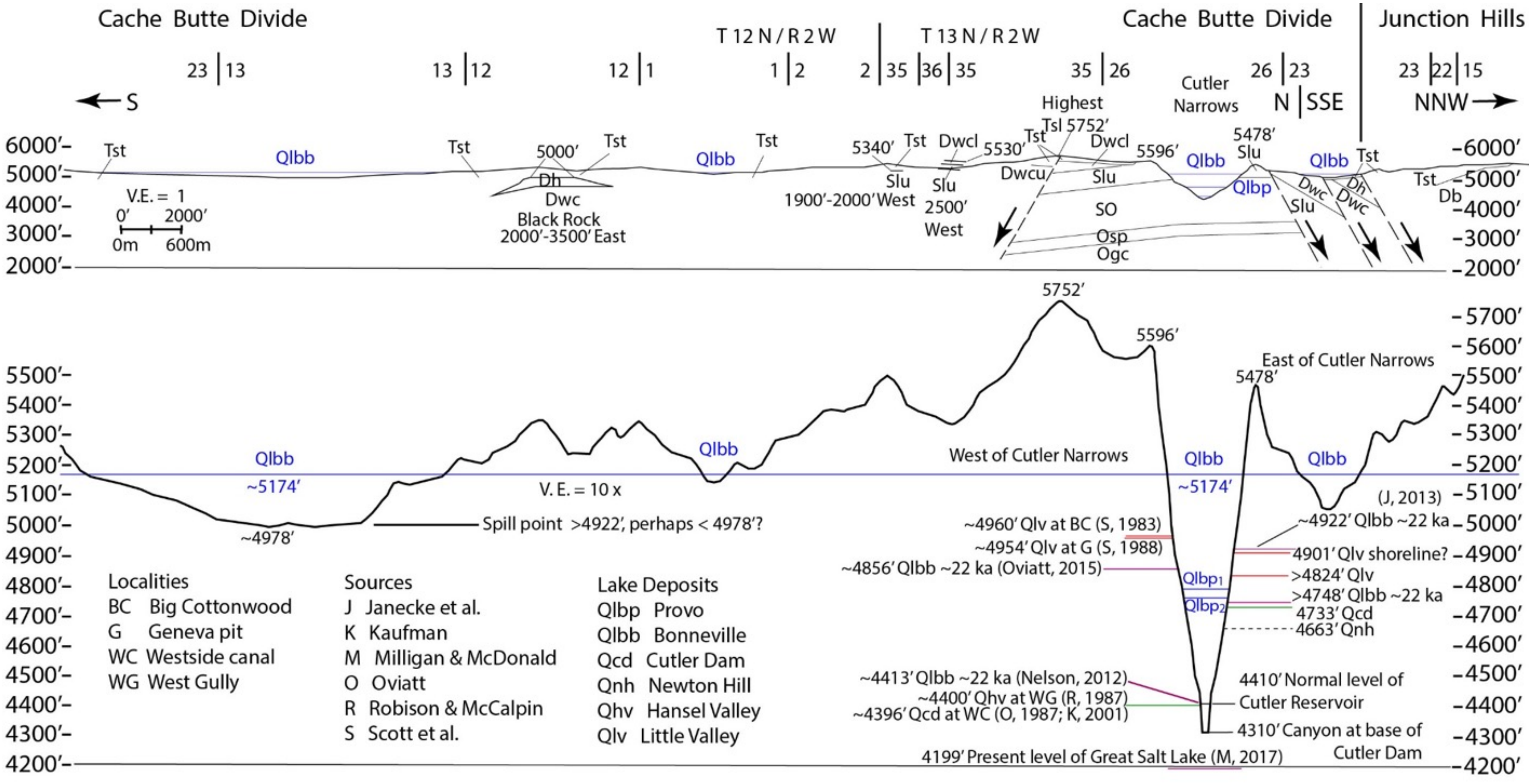
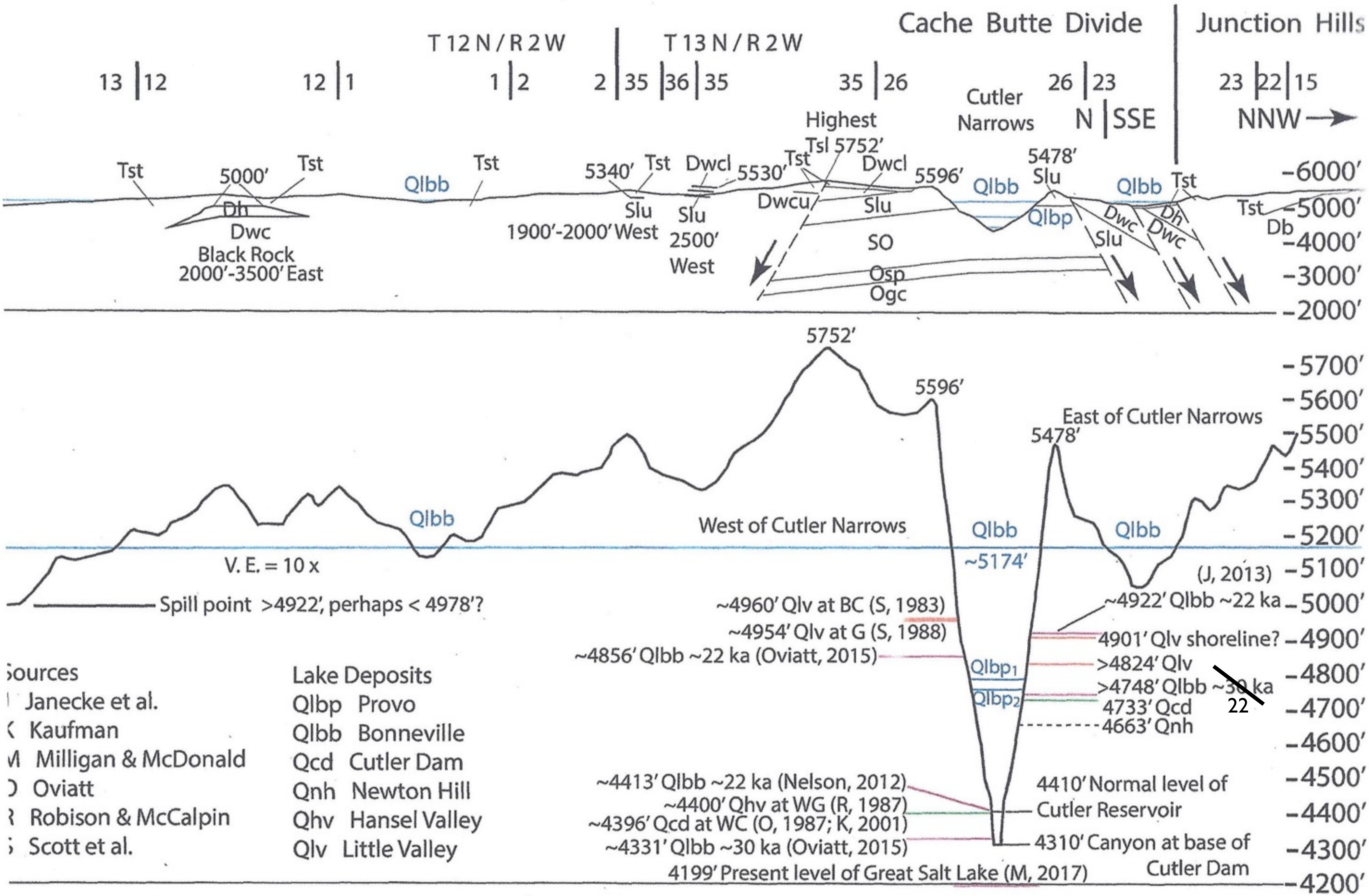


Figure 11. Topography along crest of the Cache Butte Divide between the Wellsville Mountains (south) and Junction Hills (north). Upper part, with no vertical exaggeration, shows highest bedrock (Oviatt, 1986b) along this profile or projected from east and west. Presence of the highest bedrock along the Cache Butte Divide at Cutler Narrows probably required superposition from a deep entrenched valley in erodable tuffaceous Tst member of the Salt Lake Formation (see Goessel, 1999; Oaks, 2000) after westward slip on the low-angle Beaver Dam fault (Figures 9, 10) after 4.4 Ma and subsequent uplift of the Cache Butte Divide along steep Basin-and- Range faults. Similar, yet differing altitudes of Little Valley (Qlv) highstands suggest Cutler Narrows was not yet eroded to ~4954′ during the Qlv highstand. Subsequent lake levels eastward, in Cache Valley, including the rising leg of Lake Bonneville, are significantly higher than their counterparts in the west. This suggests that the low point of Cutler Narrows stood higher than 4922′ at ~22 ka. Subsequently Cutler Narrows was excavated >612′ to its present depth of 4310′ by westward flow during the rise to the Bonneville highstand and then eastward flow during the Bonneville Flood. The post-Qlv higher relative levels in Cache Valley likely resulted from diversion of the entire flow of the Bear River into Cache Valley from Gem Valley via the Oneida Narrows ~55 ka (Bright, 1963; Bouchard and others, 1998; Pederson and others, 2016).



Cache Butte Divide
Junction Hills
T 12 N / R 2 W
T 13 N / R 2 W
13 | 12
12 | 1
1 | 2
2 | 35 | 36 | 35
35 | 26
26 | 23
23 | 22 | 15
Cutler Narrows
N | SSE
NNW →
Highest Tsl 5752'
Tst
5000'
Dh
Dwc
Black Rock
2000'-3500' East
Qlbb
5340'
Dwcl
5530'
Slu
1900'-2000' West
2500' West
Dwcu
SO
Osp
Ogc
5596'
5478'
Qlbp
Db
-6000'
-5000'
-4000'
-3000'
-2000'
5752'
5596'
East of Cutler Narrows
5478'
West of Cutler Narrows
Qlbb
~5174'
V. E. = 10 x
Spill point >4922', perhaps < 4978'?
(J, 2013)
~4922' Qlbb ~22 ka
~4960' Qlv at BC (S, 1983)
~4954' Qlv at G (S, 1988)
~4856' Qlbb ~22 ka (Oviatt, 2015)
4901' Qlv shoreline?
Qlbp1
>4824' Qlv
Qlbp2
>4748' Qlbb ~~~30~~ ka
22
4733' Qcd
4663' Qnh
Sources
J Janecke et al.
K Kaufman
M Milligan & McDonald
O Oviatt
R Robison & McCalpin
S Scott et al.
Lake Deposits
Qlbp Provo
Qlbb Bonneville
Qcd Cutler Dam
Qnh Newton Hill
Qhv Hansel Valley
Qlv Little Valley
~4413' Qlbb ~22 ka (Nelson, 2012)
~4400' Qhv at WG (R, 1987)
~4396' Qcd at WC (O, 1987; K, 2001)
~4331' Qlbb ~30 ka (Oviatt, 2015)
4410' Normal level of Cutler Reservoir
4310' Canyon at base of Cutler Dam
4199' Present level of Great Salt Lake (M, 2017)
-5700'
-5600'
-5500'
-5400'
-5300'
-5200'
-5100'
-5000'
-4900'
-4800'
-4700'
-4600'
-4500'
-4400'
-4300'
-4200'

Excavation of Cutler Narrows, Part 1:

1. Highest Paleozoic bedrock along the Cache Butte Divide is 1706 m (5596') asl; bedrock spanned Cutler Narrows

2. This is ~129 m (422') above present Bonneville highstand

3. Maximum canyon depth in bedrock is ~392 m (1286')

4. After lowering of the divide on a LANF <4.4 ma, a lake in Salt Lake Valley or Cache Valley overtopped the lowest point on this divide, cut a canyon through Tsl, and then was superimposed on Paleozoic bedrock near its highest point

5. Similar, yet differing altitudes of Little Valley highstands suggest Cutler Narrows was not yet eroded to ~1510 m (~4954') during the Little Valley highstand, ~190-125 ka.

Excavation of Cutler Narrows, Part 2:

6. Subsequent lake levels eastward, in Cache Valley, including the rising leg of Lake Bonneville, are significantly higher than their counterparts to the west. This suggests that the low point of Cutler Narrows stood higher than 1500 m (4922'), but lower than 1517 m (4978') at ~22 ka.

7. Most of Cutler Narrows was excavated >186 m (>612') to its present depth at 1314 m (4310') by westward flow during the rise to the Bonneville highstand and then by eastward flow during the Bonneville Flood. Most probably occurred during the latter.

8. The post-Little Valley higher relative levels in Cache Valley likely resulted from diversion of the entire flow of the Bear River from Gem Valley via the Oneida Narrows ~55 ka (Bright, 1963; Bouchard et al., 1998; Pederson et al., 2016).

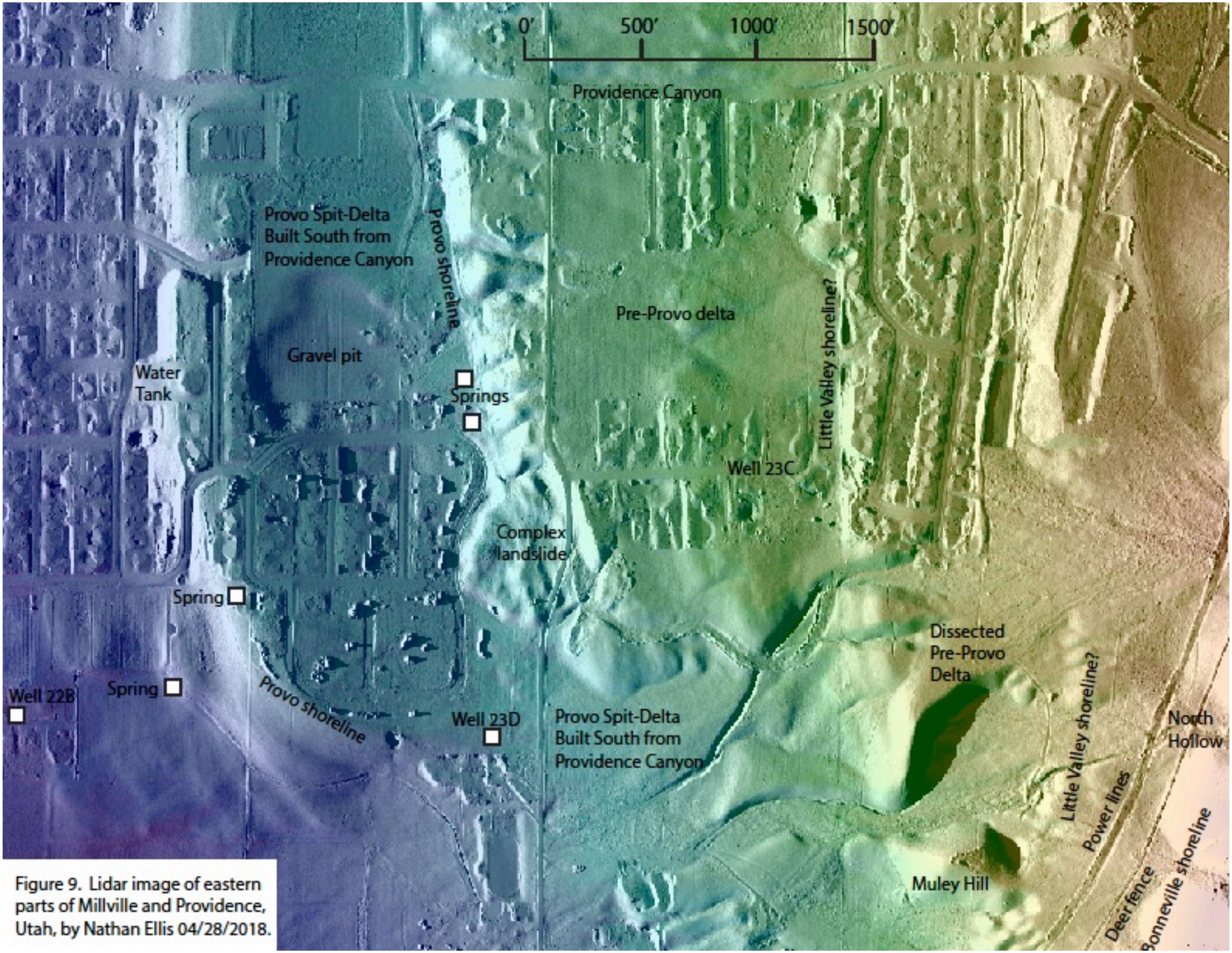


Figure 9. Lidar image of eastern parts of Millville and Providence, Utah, by Nathan Ellis 04/28/2018.

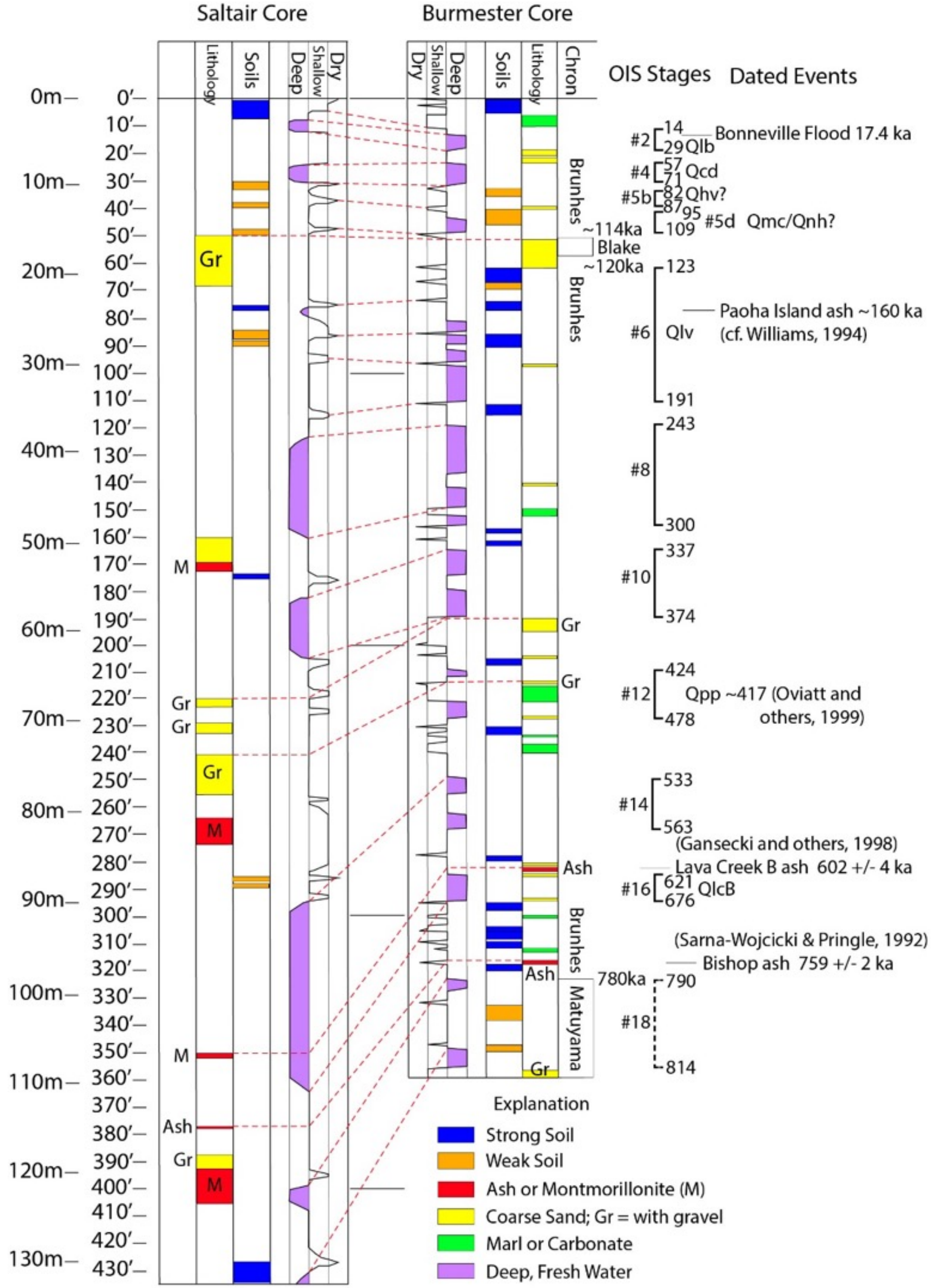
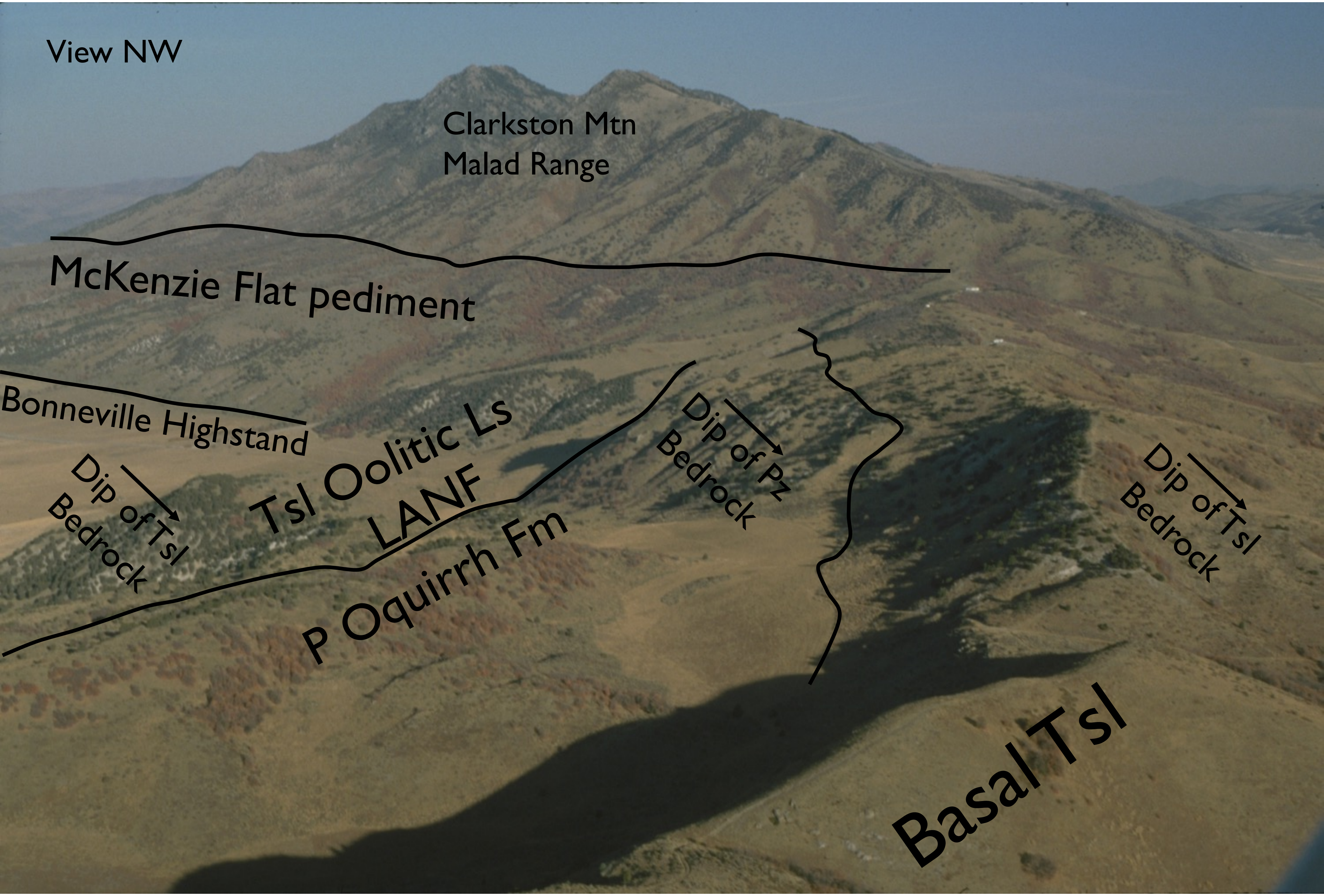


Figure 4. Proposed correlations of Saltair and Burmester cores. Water depths, soils, lithologies, and chrons from Eardley and Gvosdetsky (1960) and Eardley and others (1973). OIS stages from Lisiecki and Raymo (2005).

At least 5 pluvial lake cycles were identified in the main Bonneville Basin from two deep cores and isolated exposures in the main Bonneville Basin and eastward in Cache Valley: Lava Creek B (~620 ka); Pokes Point (~420 ka), Little Valley (~150 ka), Cutler Dam (~60 ka) and Bonneville (~18 ka).

Capture of the Bear River at Oneida Narrows ~55 ka and the Bonneville Flood both occurred at the north end of Cache Valley. Each had an important role in excavation of Cutler Narrows, between Cache Valley and the main Bonneville basin.


View NW
Clarkston Mtn
Malad Range
McKenzie Flat pediment
Bonneville Highstand
Dip of Tsl
Bedrock
Tsl Oolitic Ls
LANF
Dip of Pz
Bedrock
P Oquirrh Fm
Dip of Tsl
Bedrock
Basal Tsl

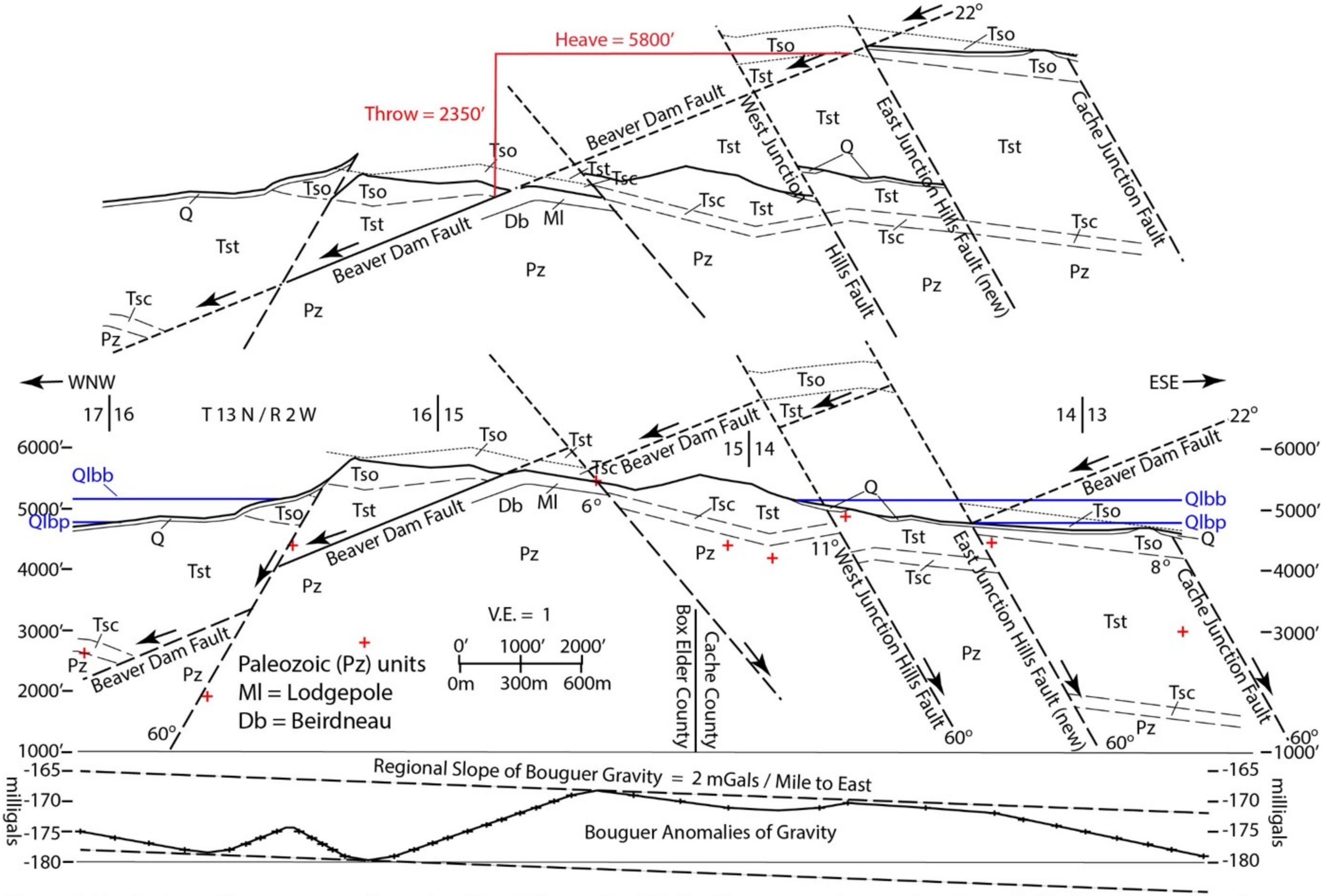


Figure 9. Geologic section across southern Junction Hills, north of Cutler Narrows, and reconstruction of offset on Beaver Dam low-angle normal fault (cf. Sprinkel, 1976; Goessel, 1999; Oaks, 2000) followed by deep erosion and offset by steeper normal faults. See Goessel (1999) and Oaks (2000) for descriptions, ages, and thicknesses of subunits of the Salt Lake Formation (Tsl).

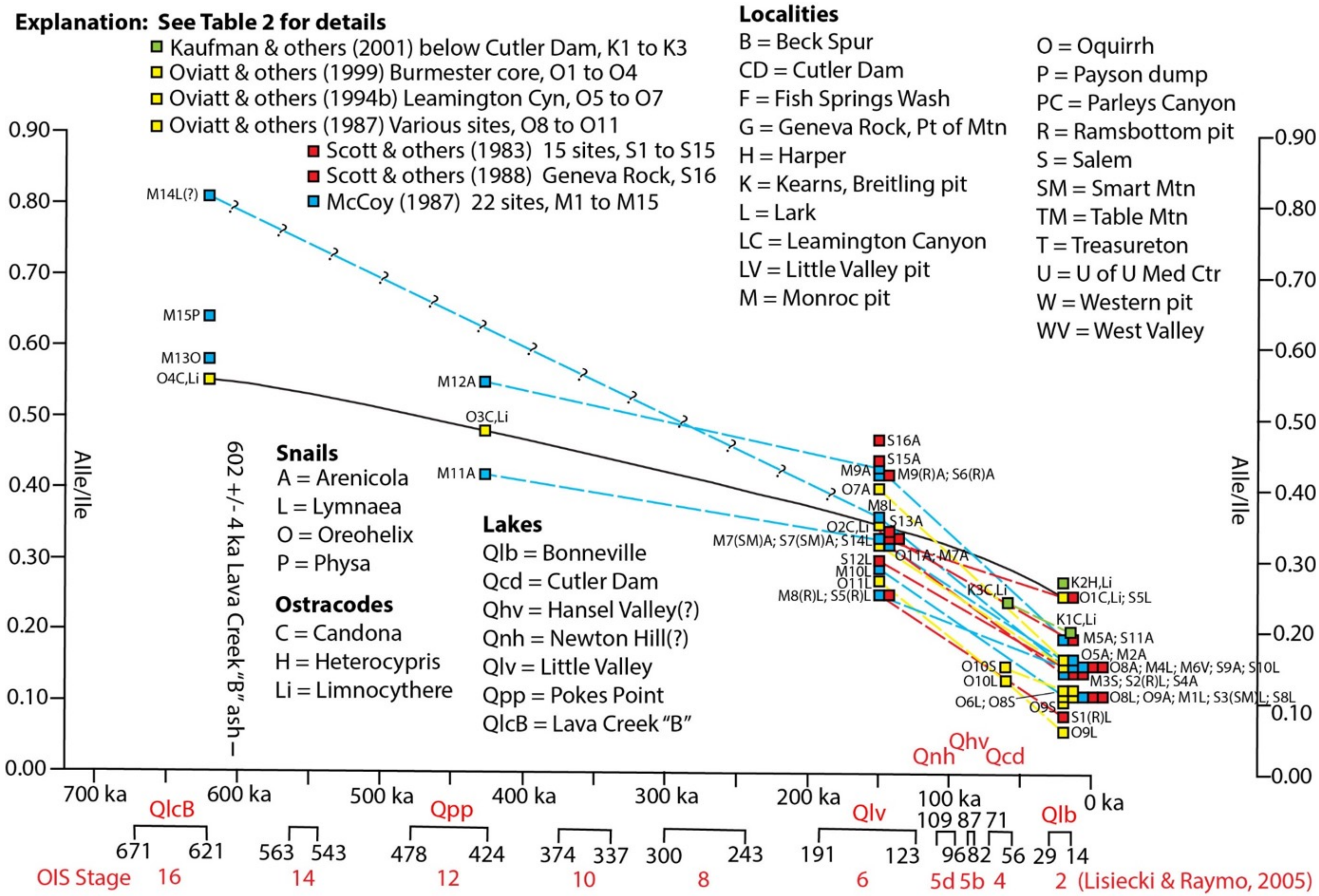


Figure 3. Amino-acid-racimization data correlated against approximate ages of Lake Bonneville and older lakes in the Bonneville Basin and Cache Bay. Correlation lines connect data from the same study for the same snail or ostracode genus.

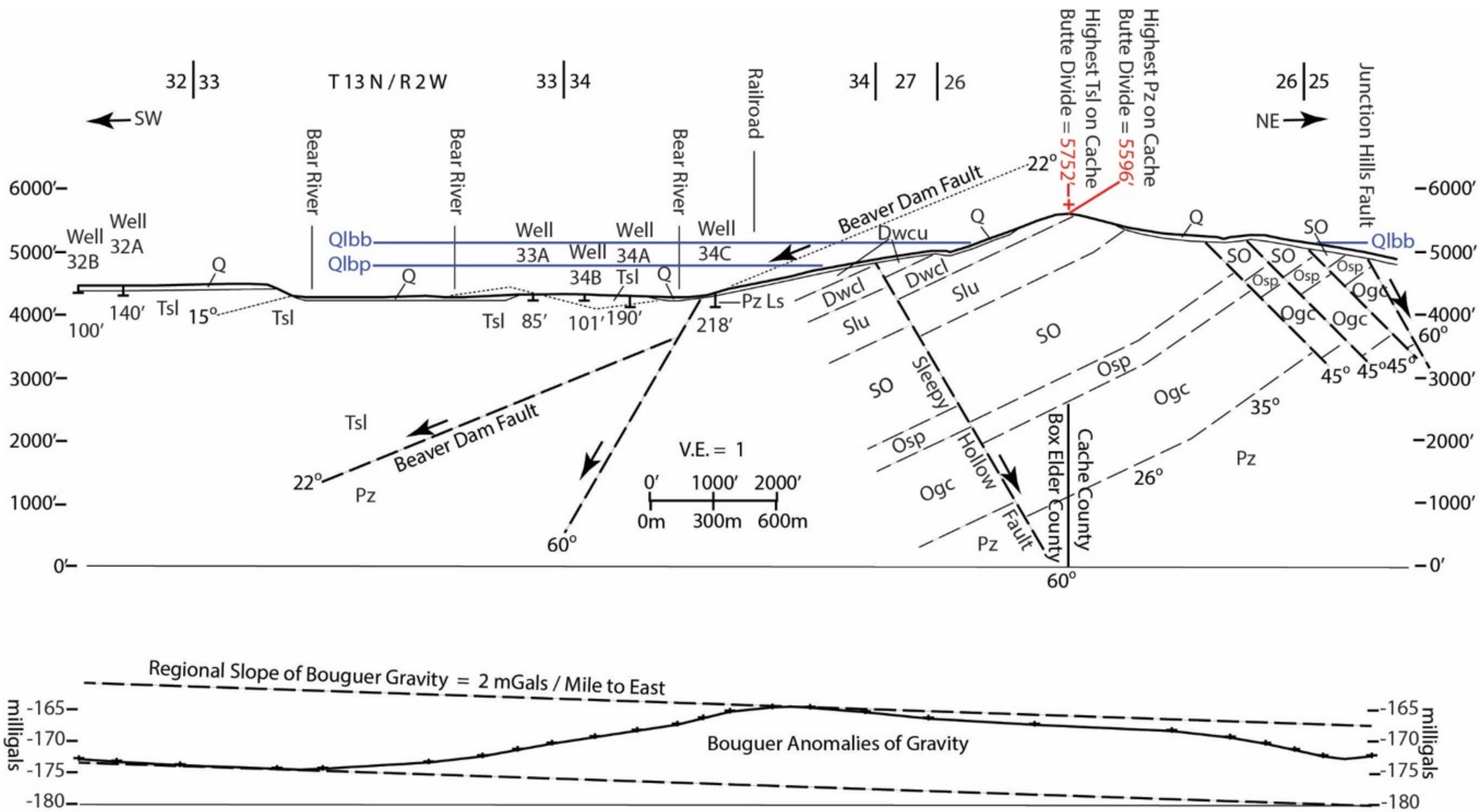


Figure 10. Geologic section immediately south of Cutler Narrows, though highest point of Paleozoic bedrock along Cache Butte Divide, based on mapping of outcrops and faults (Maw, 1968; Oviatt, 1986b; Goessel, 1999; Oaks, 2000), drillers' logs of water wells, and Bouguer anomalies of gravity. Qlbb and Qlbp are Bonneville and Provo highstands, respectively. Paleozoic (Pz) formations include Dwcu and Dwcl (upper and lower Water Canyon, respectively), Slu and SO (upper Laketown and Laketown-Fish Haven), Osp (Swan Peak), and Ogc (Garden City). The Beaver Dam fault lies above Pz at well 34C, but is shown offset by a younger normal fault along the west base of the Cache Butte Divide. The western part of this section crosses the type area of the Cutler Dam unit (Maw, 1968; Oviatt and others, 1987; Kaufmann and others, 2001) exposed along steep sides of the valley of the Bear River.

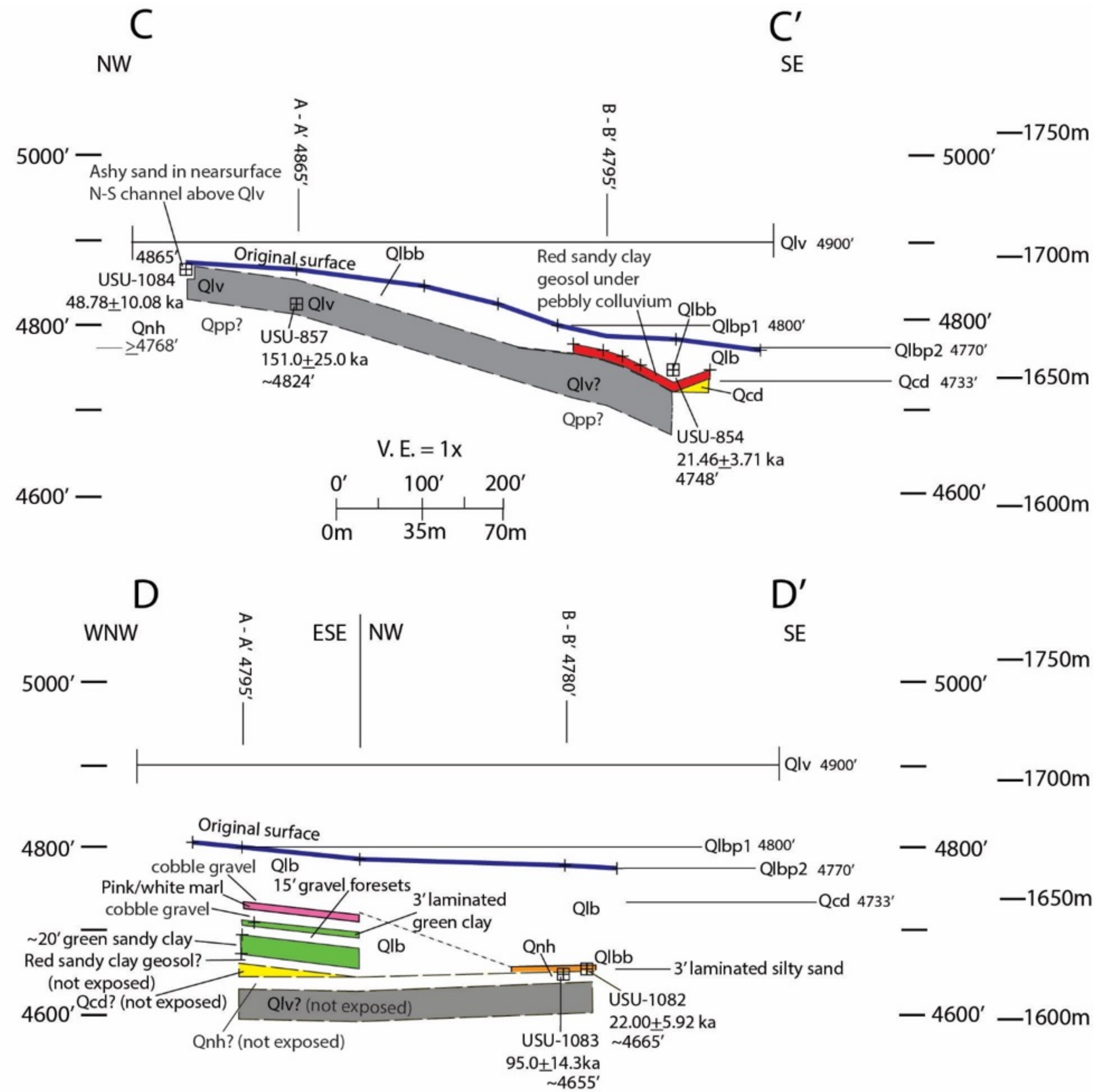


Figure 8. Geologic sections C - C′ and D- D′ showing extents of identified geologic units, original surface, OSL age dates (Tables 2, 3), highstand lake levels, and intersections with other geologic sections. Qlbp2 = younger Provo shoreline; Qlbp1 = older Provo shoreline; Qlbb = deposits related to the highest Bonneville shoreline (~5160′); Qlb = undifferentiated Provo and Bonneville deposits; Qcd = Cutler Dam highest identified deposits and inferred shoreline (~4733′); Qnh = proposed Newton Hill unit based on stratigraphy and on USU-1083 OSL age date; Qlv = Little Valley deposits; Qpp? = possible Pokes Point or older Quaternary deposits (not exposed).

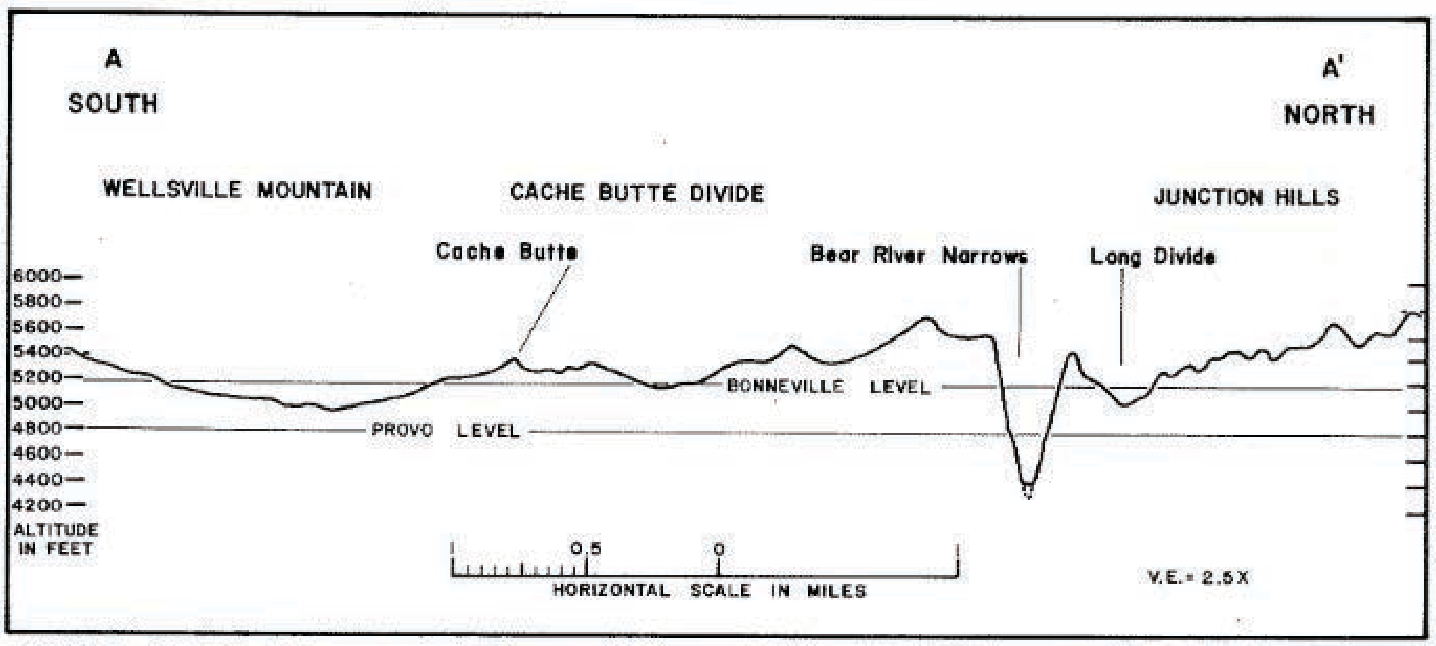


FIGURE 3. TOPOGRAPHIC PROFILE ALONG CACHE BUTTE DIVIDE BETWEEN WELLSVILLE MOUNTAIN AND JUNCTION HILLS, CUTLER DAM 7.5-MINUTE QUADRANGLE, NORTHERN UTAH. DIVIDE SEPARATES SALT LAKE VALLEY AND CACHE VALLEY.

14

Figure 3 from Glade G. Maw's USU M.S. thesis, 1968

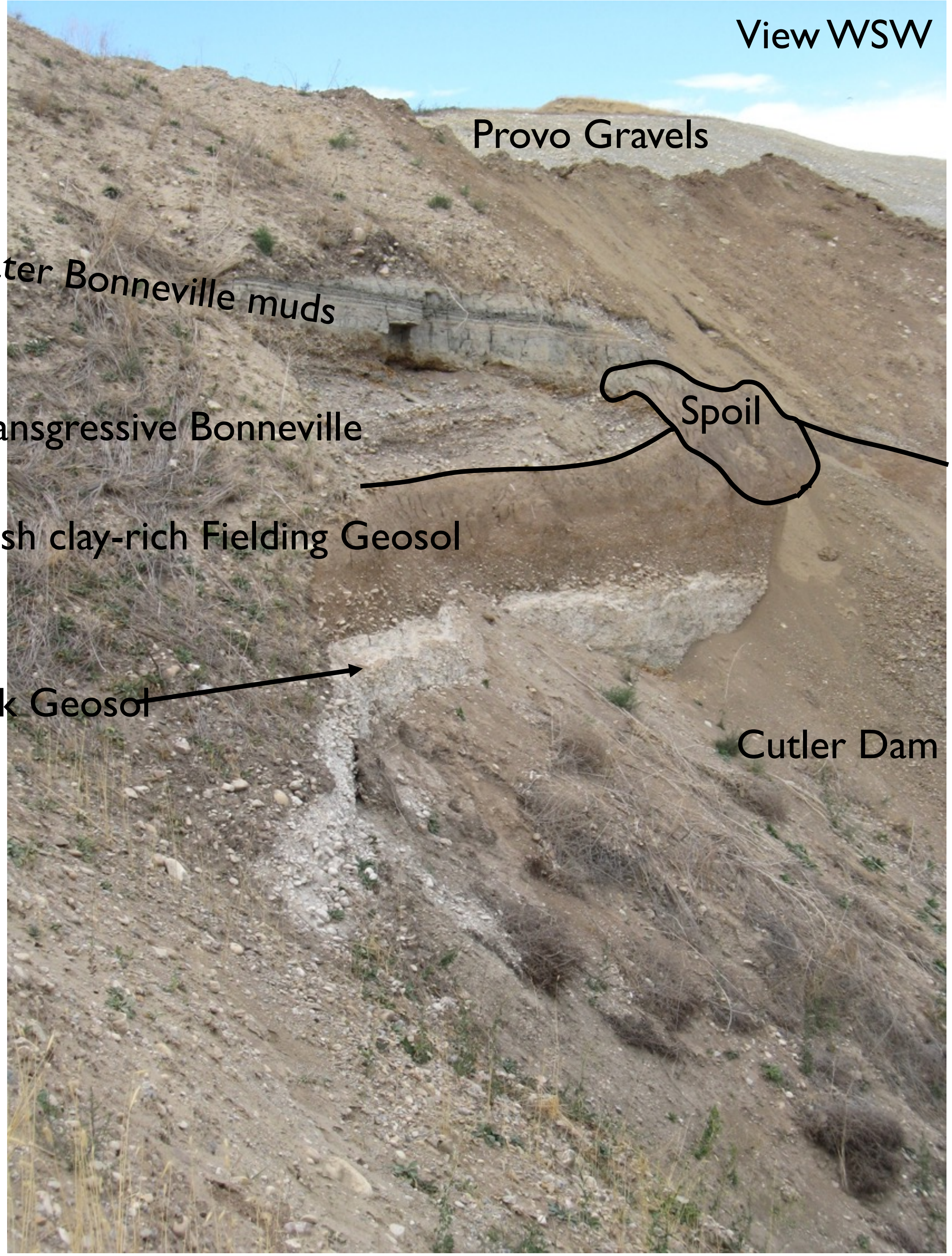


Photo IMG_2554
9-8-2010

Some Background

Thad Erickson's first job after graduation in 1960 from Utah State's geology program was field assistant for Roger Morrison in the Little Valley pit. In 2006 he discovered a compound geosol in the Staker-Parsons pit, then assisted in collecting 3 OSL samples, and used the USU EDM total station with Bob Oaks to establish precise altitudes of numerous points in that pit. His recognition of a distinctive pink/white/green marl in the pit as identical to one in older deposits of Lake Bonneville in the Little Valley pit helped sort out the stratigraphy before all of our OSL age dates were completed.

Glade Maw (1968), Bob Oaks' first graduate student at USU, identified the Fielding Geosol along canal exposures west of Cutler Dam, and recognized that the underlying Cutler Dam beds were older than Lake Bonneville. Jack Oviatt (1986) later named these units.

OSL sample information and age dates for Staker-Parsons gravel pit, SE flank of Newton Hill, Cache County, north-central Utah.

Sample Number USU-	OSL Age in ka	GPS Altitude in Feet	Google Altitude in Feet [Year]	Hand-Level in Feet	EDM Altitude in Feet	Sample Altitude in Meters	Strati-graphic Unit	Location and Comments; ~65 m W correction from GPS data to 1927 N. American datum for maps	Date and Collectors
859	15.44 ± 2.05	N.D.	4732 [2011] Map ~4790	N.D.	4737 Depth ~53'	1444	Late Qlbp	NW corner of pit; silt & sand beds dip E; below ~4780' Qlbp shore ~ N 41°52.614' ~W 111°57.426'	9-15-2010 TR & MN
854	30.05 ± 4.22	4766 TR	4773 [2009] Map ~4785	~4748	N.D. Depth ~37'	1447	Early Qlbb	S of road, SW corner of alcove; silty sand & clays above paleosol; N 41°52.4478' W 111°57.3978'	9-7-2010 TR & RO
1082	30.27 ± 7.19	4674 RO	4669 [2011] Map ~4775	~4665	<4672 Depth~115	~1422	Early Qlbb	Center of pit; laminated silty sand over gravel; 10' above USU-1083 N 41°52.5244' W 111°57.3198'	12-2-2011 RO & TE
855	41.87 ± 5.48	4745 TR	4715 [2009] Map ~4810	~4739	N.D. Depth ~71'	~1444	Qf	SW alcove; red colluvium: sandy gravelly mud over loess paleosol; N 41°52.478' W 111°57.393'	9-7-2010 TR & RO
1084	45.60 ± 9.59	4818 RO	4863 [2011] Map ~4875	N.D.	4865 Depth ~10'	1483	Qf	W pit; white reworked ash in N-S channel, under E-dipping gravel & soil, over 4° W-dipping gravel; N 41°52.5045' W 111°57.5009'	12-5-2011 RO
858	61.63 ± 8.39	4656 TR	4705 [2009] Map ~4790	~4709	N.D. Depth ~81'	~1435	Qcd	W alcove; vf-med sand below gravel ~25 ft below paleosol base; N 41°52.473' W 111°57.382'	9-15-2010 TR & MN
856	69.44 ± 9.44	4735 TR	4703 [2009] Map ~4810	~4729	N.D. Depth ~81'	~1441	Qcd	W alcove; gravel 4.3' below red paleosol base; 9.8' below USU855; N 41°52.479' W 111°57.388'	9-7-2010 TR & RO

Sample Number USU-	OSL Age in ka	GPS Altitude in Feet	Google Altitude in Feet [Year]	Hand-Level in Feet	EDM Altitude in Feet	Sample Altitude in Meters	Strati-graphic Unit	Location and Comments	Date and Collectors
1083	95.0 ± 14.3	4654 RO	4669 [2011] Map ~4780	~4655	<4673 Depth~125	~1419	Qnh	Center of pit; in gravel 8.4' below laminated silty sand of USU-1082; N 41°52.5243' W 111°57.3310'	12-2-2011 RO & TE
2490	171.5 ± 23.5	4704 RO	4747 [2014] Map ~4840	~4735	N.D. Depth ~ 105'	~1443	Qlv	W center of pit in E-W cut; sand and gravel in cobble gravel, 22' lower than E margin of overlying channel; N 41°52.5203' W 111°57.4165'	9-26-2016 RO & TE
857	179.0 ± 25.7	4824 TR	4821 [2011] Map ~4865	N.D.	N.D. EDM 4821 at graded site Depth~44'	~1470	Qlv	W center of pit in WSW cut; sand & pebble groundmass in cobble gravel; N 41°52.492' W 111°57.477'	9-15-2010 TR & MN

OSL = optically stimulated luminescence; ka = thousands of years ago; Google = Google Earth; EDM = total station, electronic distance measurements with laser; HL = hand level used from EDM station 16; N.D. = no data; Map: original surface altitudes are interpolated from USGS 7.5' Newton [C.I. = 5'] and Trenton [C.I. = 20'] topographic quadrangles [1964]; Qlbp = Provo lake stage; Qlbb = Bonneville highstand lake stage; Qf = Fielding emergent interval with 2 paleosols and channel; Qcd = Cutler Dam lake stage; Qnh = Newton Hill lake stage; Qlv = Little Valley lake stage; MN = Michelle S. Nelson; RO = Robert Q. Oaks, Jr.; TE = Thad L. Erickson; TR = Tammy M. Rittenour

Conclusions:

1. New OSL age dates establish presence of pre-Bonneville Cutler Dam (~60 ka) and perhaps Newton Hill (~95 ka) lake cycles and reconfirms presence of the Little Valley (~190-125 ka) lake cycle in Cache Valley

2. Cutler Dam lake level is ~103 m higher than west of Cutler Narrows

3. Newton Hill beds are ~80 m higher than Hansel Valley shallow-water beds at West Gully

4. Cutler Narrows was excavated after 165 ma, probably after Oneida Narrows was fully cut ~55 ka

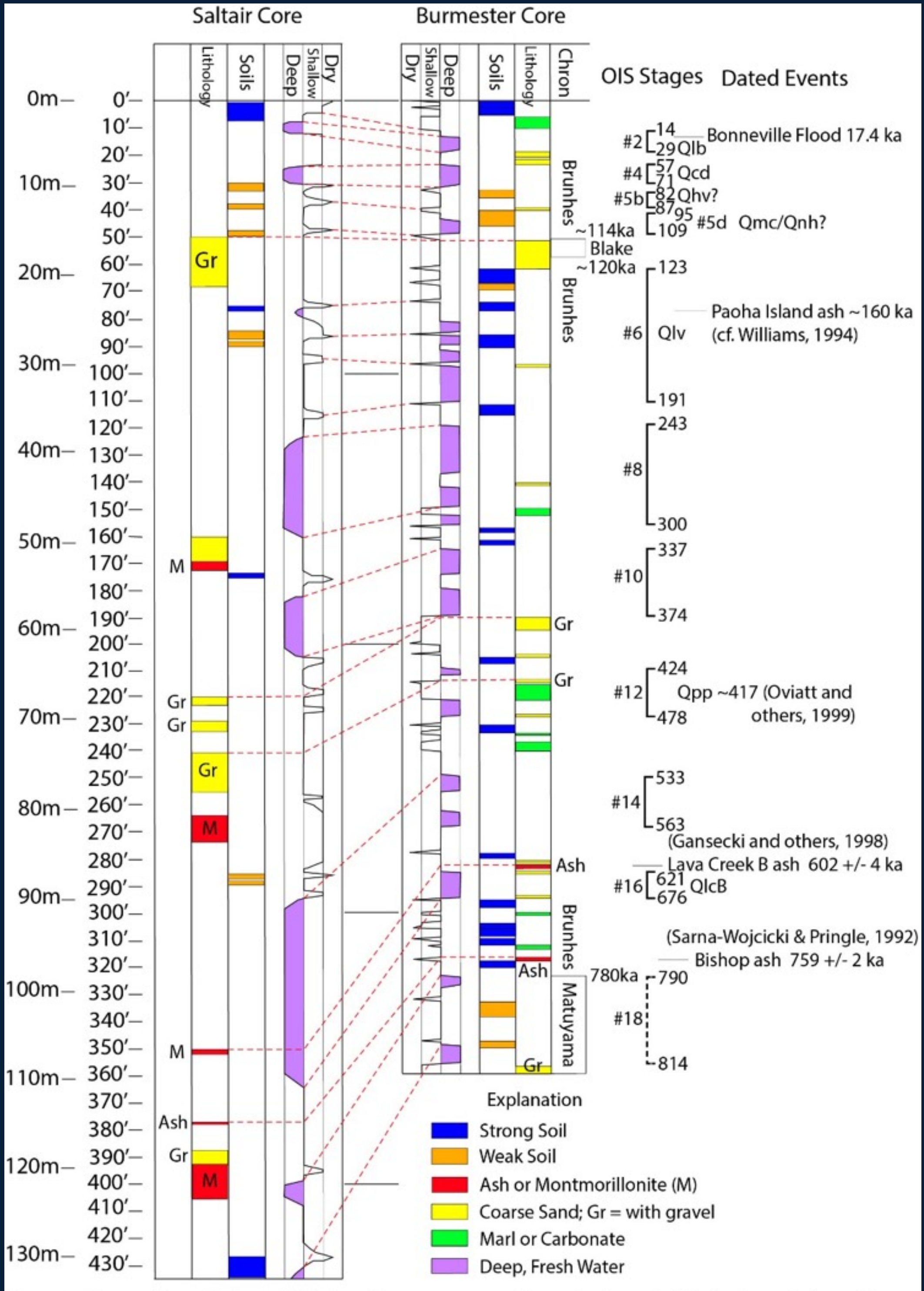
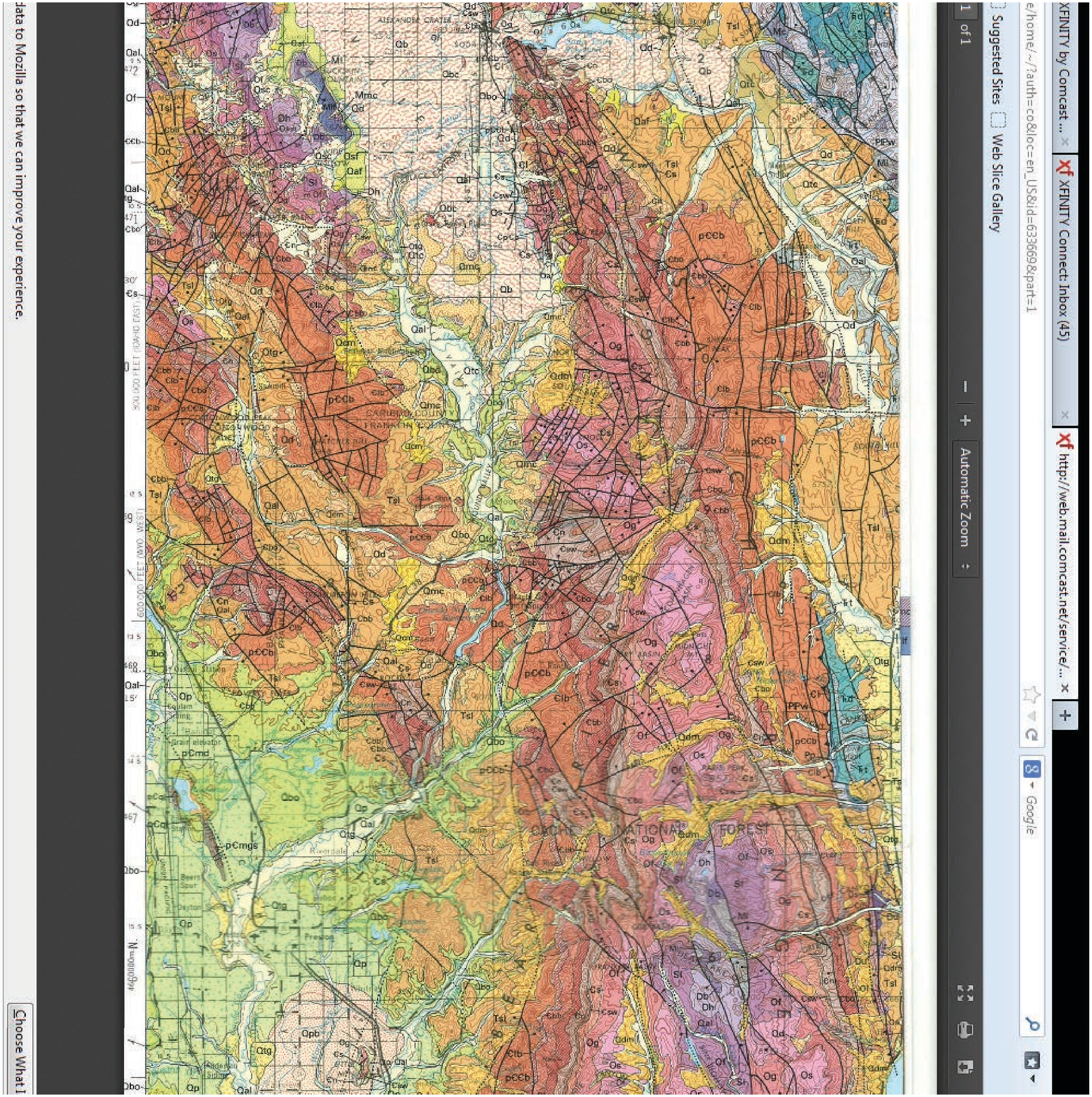
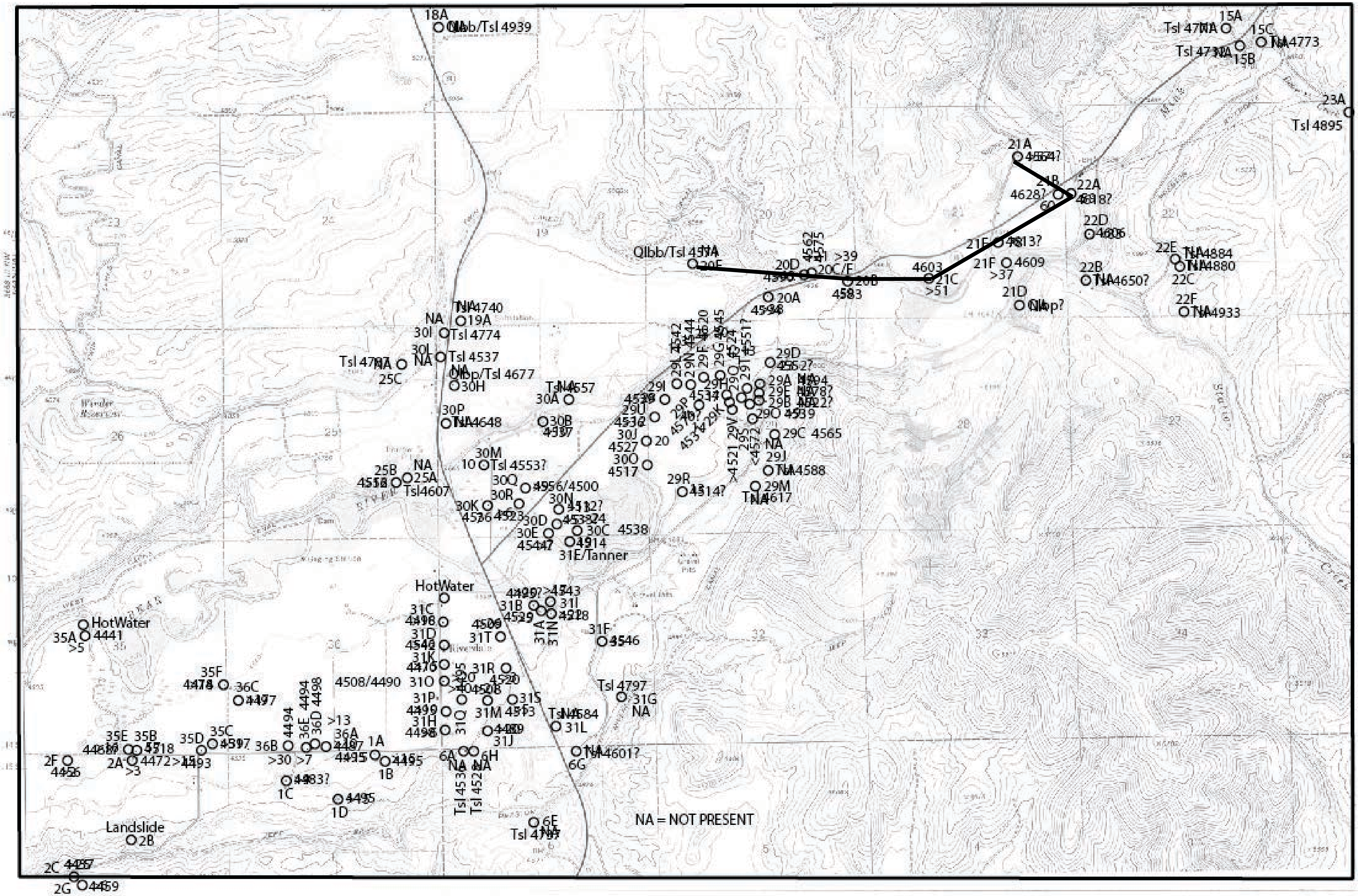
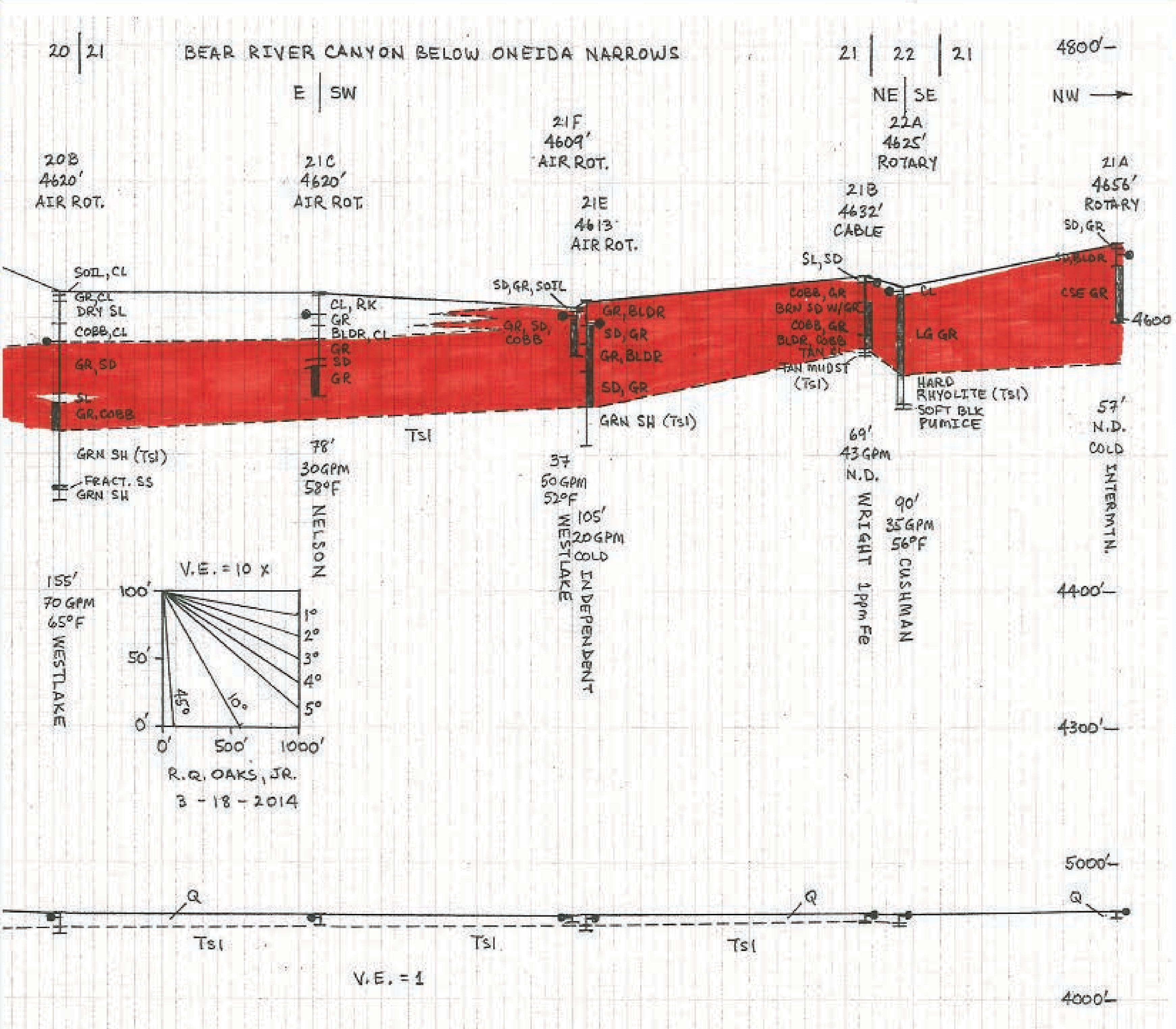


Figure 4. Proposed correlations of Saltair and Burmester cores. Water depths, soils, lithologies, and chrons from Eardley and Gvosdetsky (1960) and Eardley and others (1973). OIS stages from Lisiecki and Raymo (2005).


XFINITY by Comcast ...
XFINITY Connect: Inbox (45)
http://web.mail.comcast.net/service/...
Suggested Sites
Web Slice Gallery
1 of 1
Automatic Zoom
CACHE NATIONAL FOREST
data to Mozilla so that we can improve your experience.
Choose What I

TopoMapRiverdaleOneidaMinkCreekArea.0315 [Converted].ai @ 150% (CMYK/Preview)




BEAR RIVER CANYON BELOW ONEIDA NARROWS
20 | 21
E | SW
21 | 22 | 21
NE | SE
NW →
4800'
4600
4400'
4300'
5000'
4000'
20B 4620' AIR ROT.
21C 4620' AIR ROT.
21F 4609' AIR ROT.
21E 4613' AIR ROT.
21B 4632' CABLE
22A 4625' ROTARY
21A 4656' ROTARY
SOIL, CL
GR, CL
DRY SL
COBB, CL
GR, SD
SL
GR, COBB
GRN SH (Tsl)
FRACT. SS
GRN SH
CL, RK
GR
BLDR, CL
GR
SD
GR
SD, GR, SOIL
GR, SD, COBB
GR, BLDR
SD, GR
GR, BLDR
SD, GR
GRN SH (Tsl)
SL, SD
COBB, GR
BRN SD W/GR
COBB, GR
BLDR, COBB
TAN SL
TAN MUDST (Tsl)
CL
LG GR
HARD RHYOLITE (Tsl)
SOFT BLK PUMICE
SD, GR
SD, BLDR
CSE GR
Tsl
155' 70 GPM 65°F WESTLAKE
78' 30GPM 58°F NELSON
37 50GPM 52°F WESTLAKE
105' 20GPM COLD INDEPENDENT
69' 43GPM N.D. WRIGHT 1ppm Fe
90' 35GPM 56°F CUSHMAN
57' N.D. COLD INTERMTN.
V.E. = 10 x
100'
50'
0'
0'
500'
1000'
1°
2°
3°
4°
5°
45°
10°
R.Q. OAKS, JR.
3 - 18 - 2014
Q
Q
Q
Tsl
Tsl
Tsl
V.E. = 1

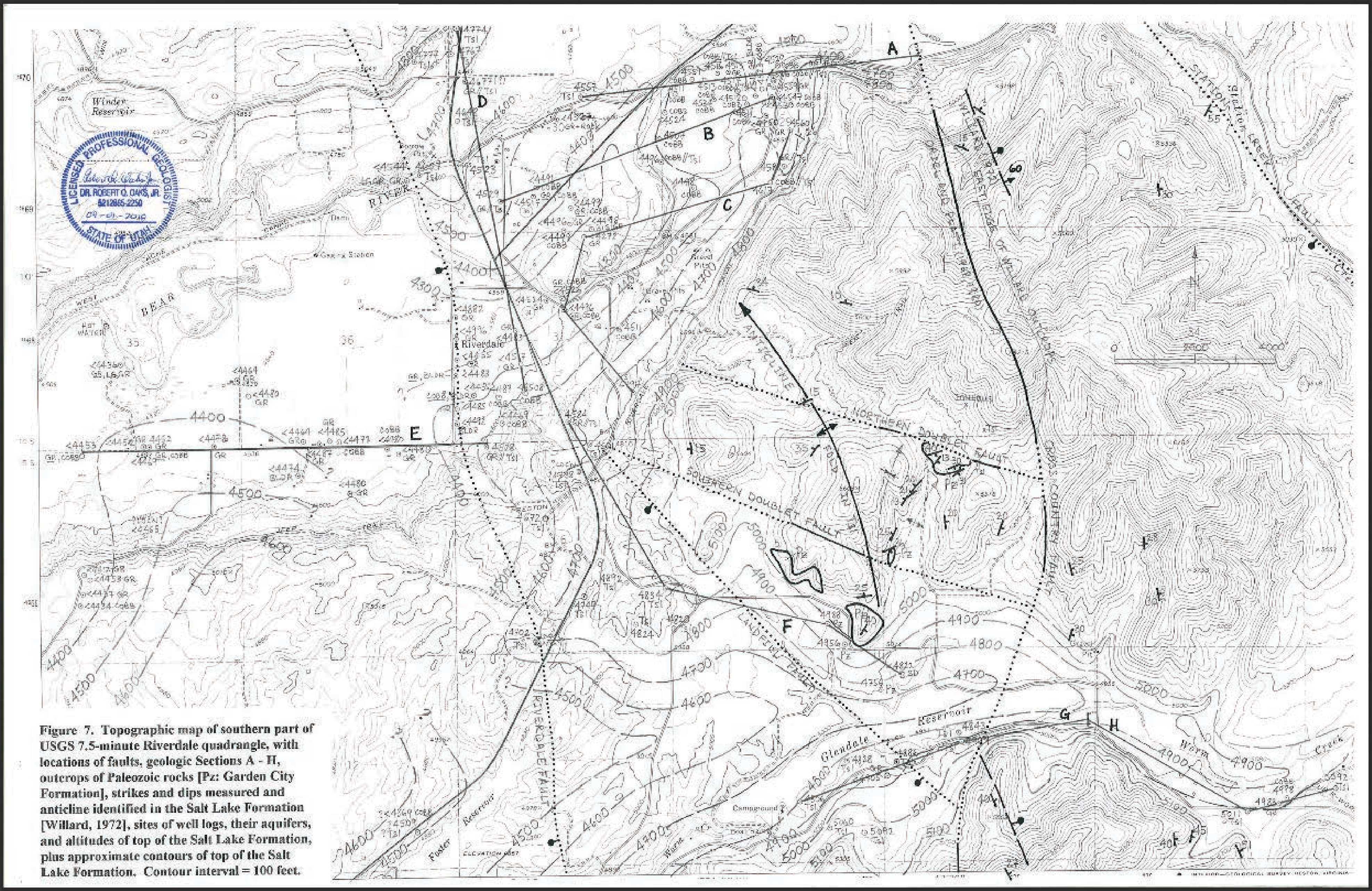
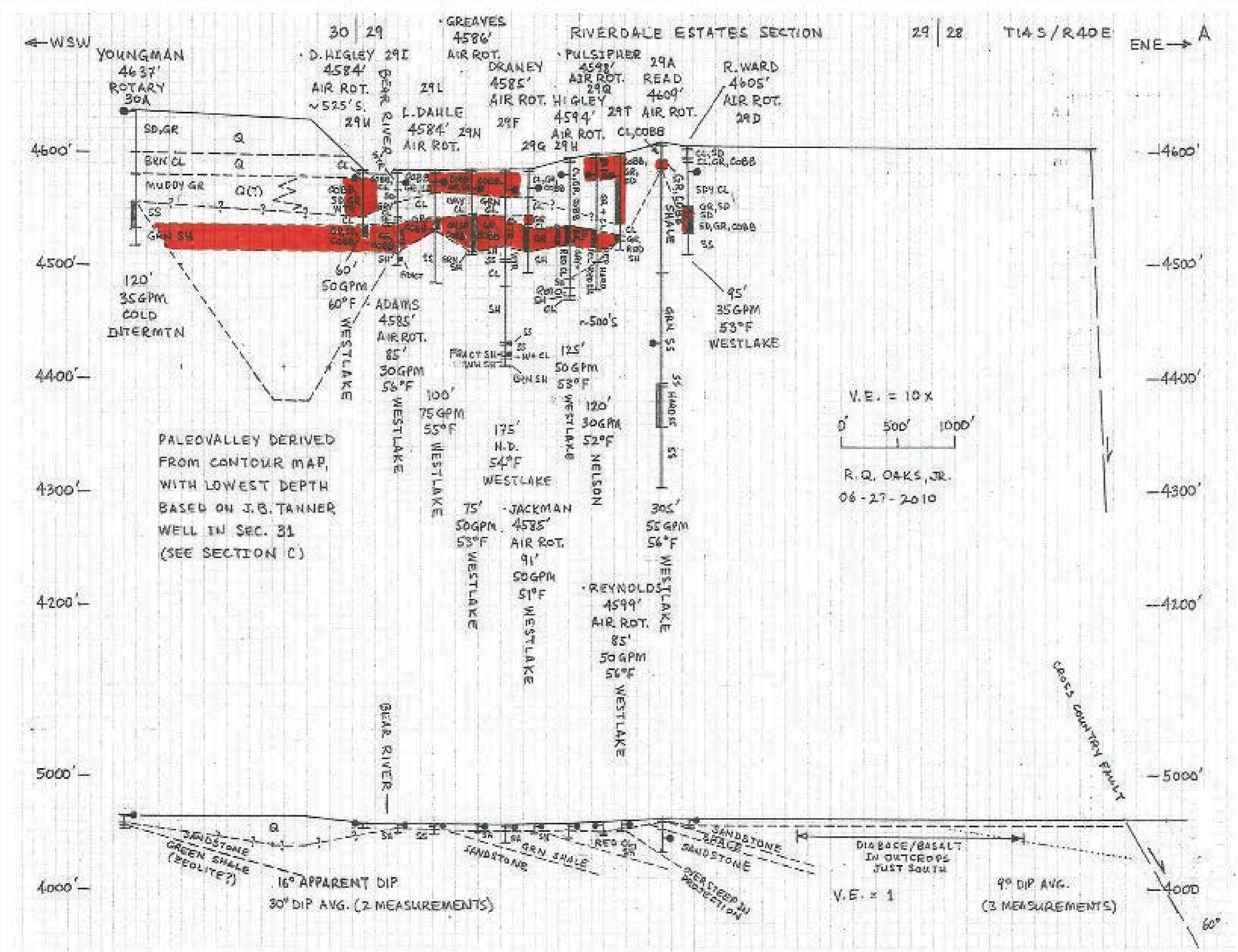
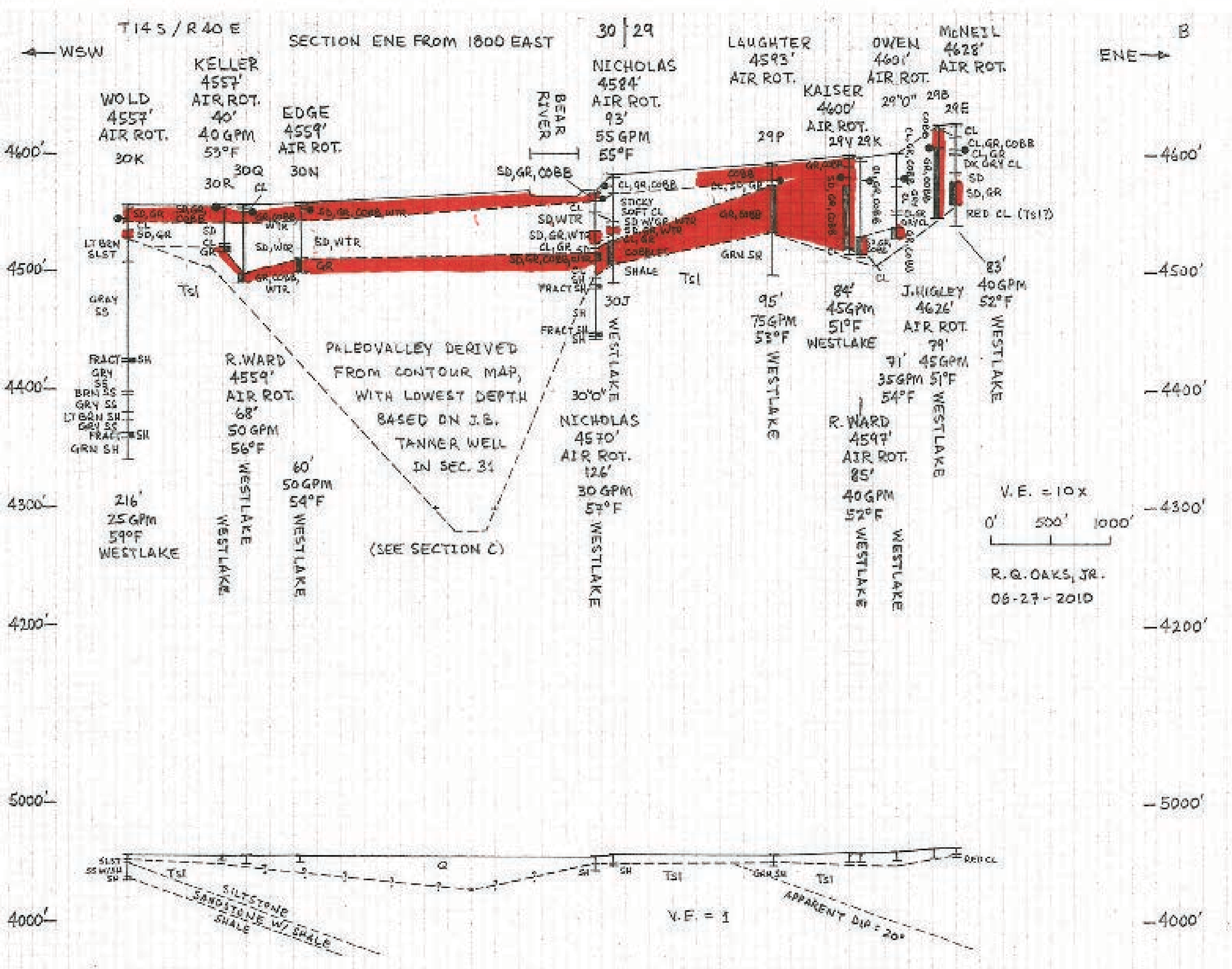
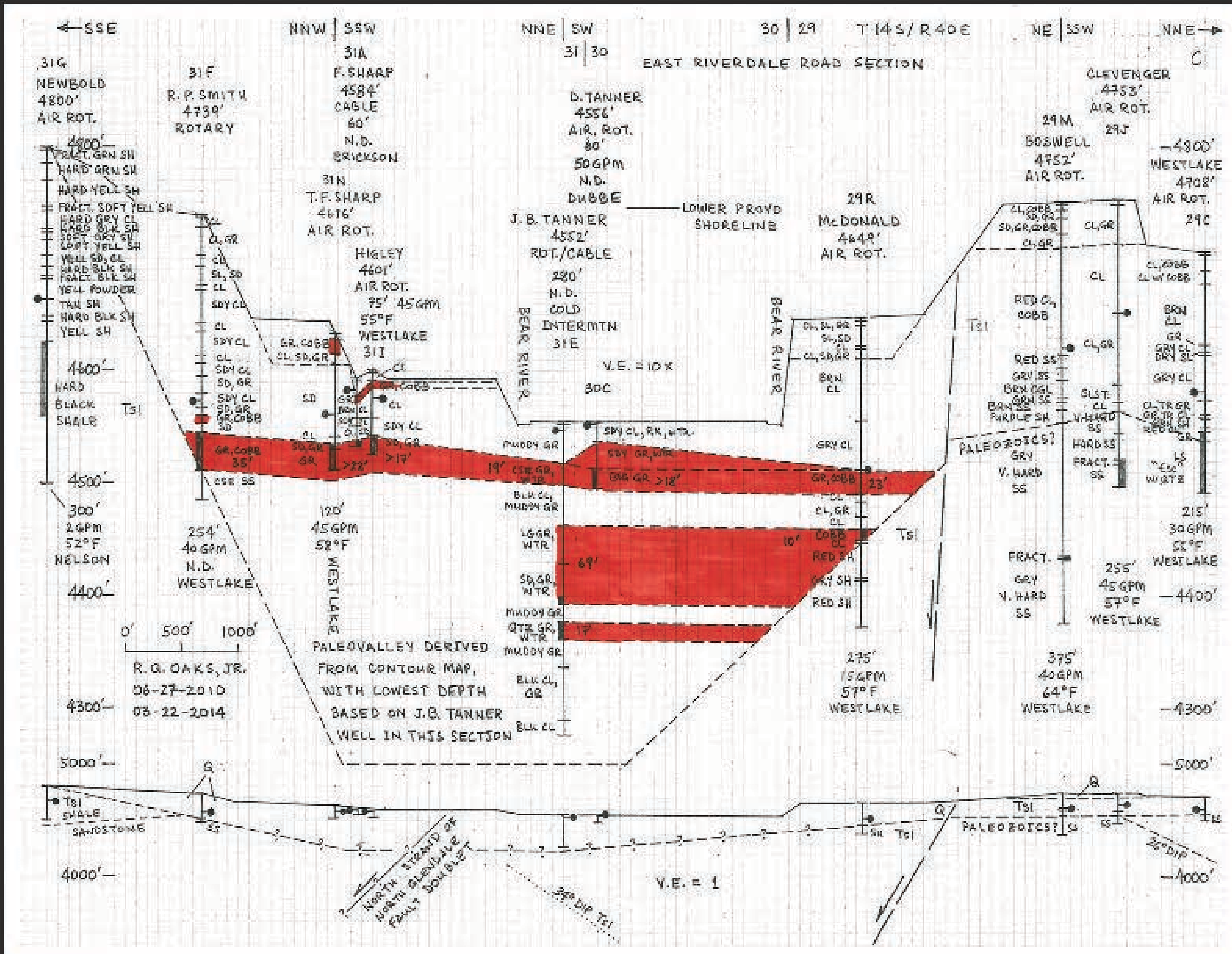


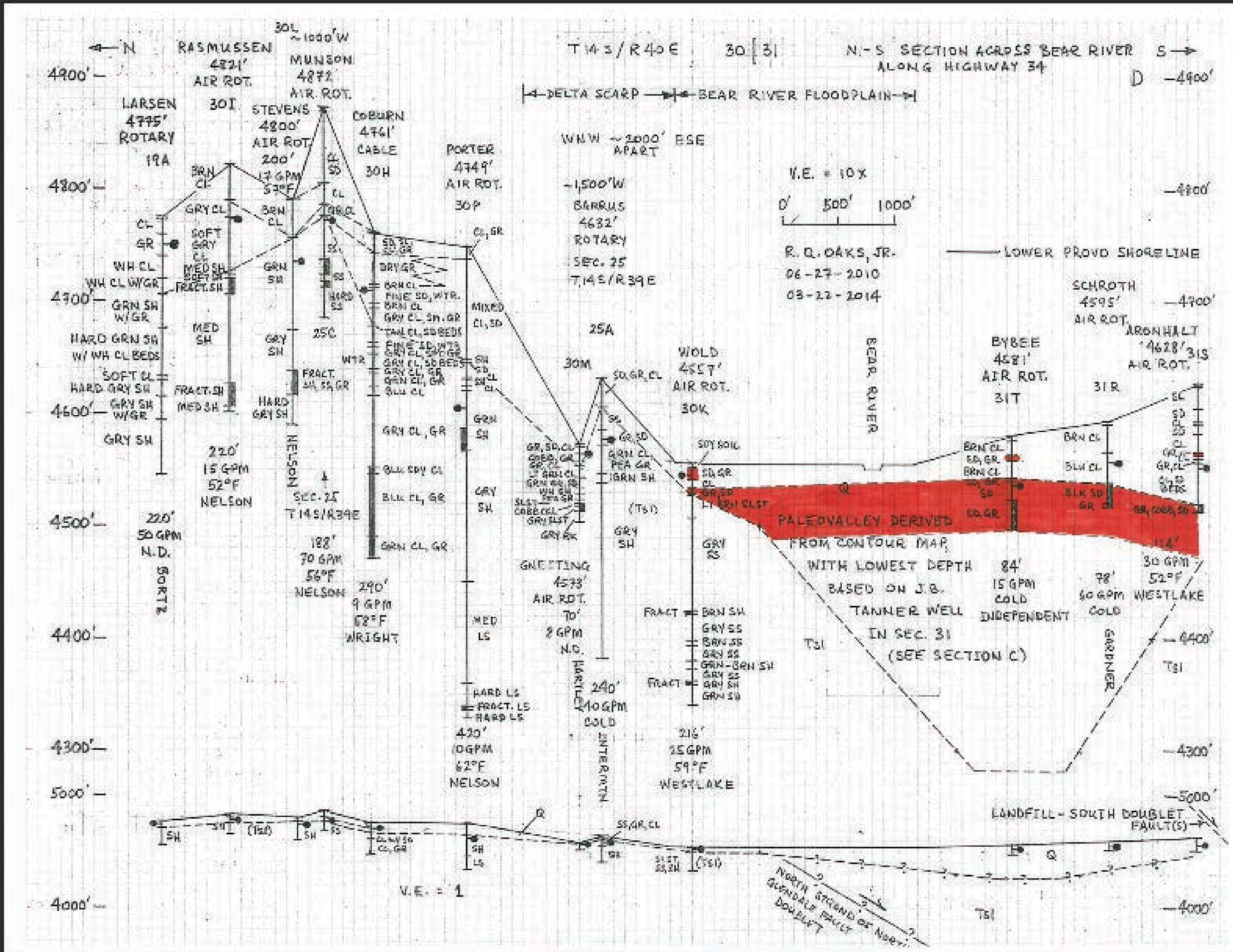
Figure 7. Topographic map of southern part of USGS 7.5-minute Riverdale quadrangle, with locations of faults, geologic Sections A - H, outcrops of Paleozoic rocks [Pz: Garden City Formation], strikes and dips measured and anticline identified in the Salt Lake Formation [Willard, 1972], sites of well logs, their aquifers, and altitudes of top of the Salt Lake Formation, plus approximate contours of top of the Salt Lake Formation. Contour interval = 100 feet.


RIVERDALE ESTATES SECTION
T14S/R40E
WSW
ENE
A
YOUNGMAN 4637' ROTARY 30A
D. HIGLEY 29I 4584' AIR ROT. ~525'S.
GREAVES 4586' AIR ROT.
DRANEY 4585' AIR ROT.
PULSIPHER 4598' AIR ROT. 29Q
HIGLEY 4594' AIR ROT.
READ 4609' AIR ROT.
R. WARD 4605' AIR ROT. 29D
L. DAHLE 4584' AIR ROT.
BEAR RIVER
4600'
4500'
4400'
4300'
4200'
5000'
4000'
120' 35GPM COLD INTERMTN
60' 50GPM 60°F WESTLAKE
ADAMS 4585' AIR ROT. 85' 30GPM 56°F WESTLAKE
100' 75GPM 55°F WESTLAKE
175' N.D. 54°F WESTLAKE
125' 50GPM 53°F WESTLAKE
120' 30GPM 52°F NELSON
95' 35GPM 53°F WESTLAKE
75' 50GPM 53°F WESTLAKE
JACKMAN 4585' AIR ROT. 91' 50GPM 51°F WESTLAKE
REYNOLDS 4599' AIR ROT. 85' 50GPM 56°F WESTLAKE
305' 55GPM 56°F WESTLAKE
PALEOVALLEY DERIVED FROM CONTOUR MAP, WITH LOWEST DEPTH BASED ON J.B. TANNER WELL IN SEC. 31 (SEE SECTION C)
V.E. = 10X
0' 500' 1000'
R.Q. OAKS, JR. 06-27-2010
CROSS COUNTRY FAULT
SANDSTONE
GREEN SHALE (OOLITE?)
16° APPARENT DIP
30° DIP AVG. (2 MEASUREMENTS)
GRN SHALE
RED SH
OVERSTEEP IN PROJECTION
DIABASE/BASALT IN OUTCROPS JUST SOUTH
V.E. = 1
9° DIP AVG. (3 MEASUREMENTS)
60°


T14S/R40E
SECTION ENE FROM 1800 EAST
B
WSW
ENE
WOLD 4557' AIR ROT. 30K
KELLER 4557' AIR ROT. 40' 40 GPM 53°F
EDGE 4559' AIR ROT. 30N
BEAR RIVER
NICHOLAS 4584' AIR ROT. 93' 55 GPM 55°F
LAUGHTER 4593' AIR ROT.
KAISER 4600' AIR ROT.
OWEN 4601' AIR ROT.
McNEIL 4628' AIR ROT.
PALEOVALLEY DERIVED FROM CONTOUR MAP, WITH LOWEST DEPTH BASED ON J.B. TANNER WELL IN SEC. 31
(SEE SECTION C)
R. WARD 4559' AIR ROT. 68' 50 GPM 56°F
216' 25 GPM 59°F WESTLAKE
60' 50 GPM 54°F
NICHOLAS 4570' AIR ROT. 126' 30 GPM 57°F
95' 75 GPM 53°F
84' 45 GPM 51°F WESTLAKE
J. HIGLEY 4626' AIR ROT. 79' 45 GPM 51°F
71' 35 GPM 54°F
83' 40 GPM 52°F
R. WARD 4597' AIR ROT. 85' 40 GPM 52°F
WESTLAKE
V.E. = 10x
0' 500' 1000'
R. Q. OAKS, JR.
08-27-2010
4600' 4500' 4400' 4300' 4200' 5000' 4000'
V.E. = 1
SILTSTONE SANDSTONE W/ SHALE SHALE
APPARENT DIP ≈ 20°
Tsl
Q

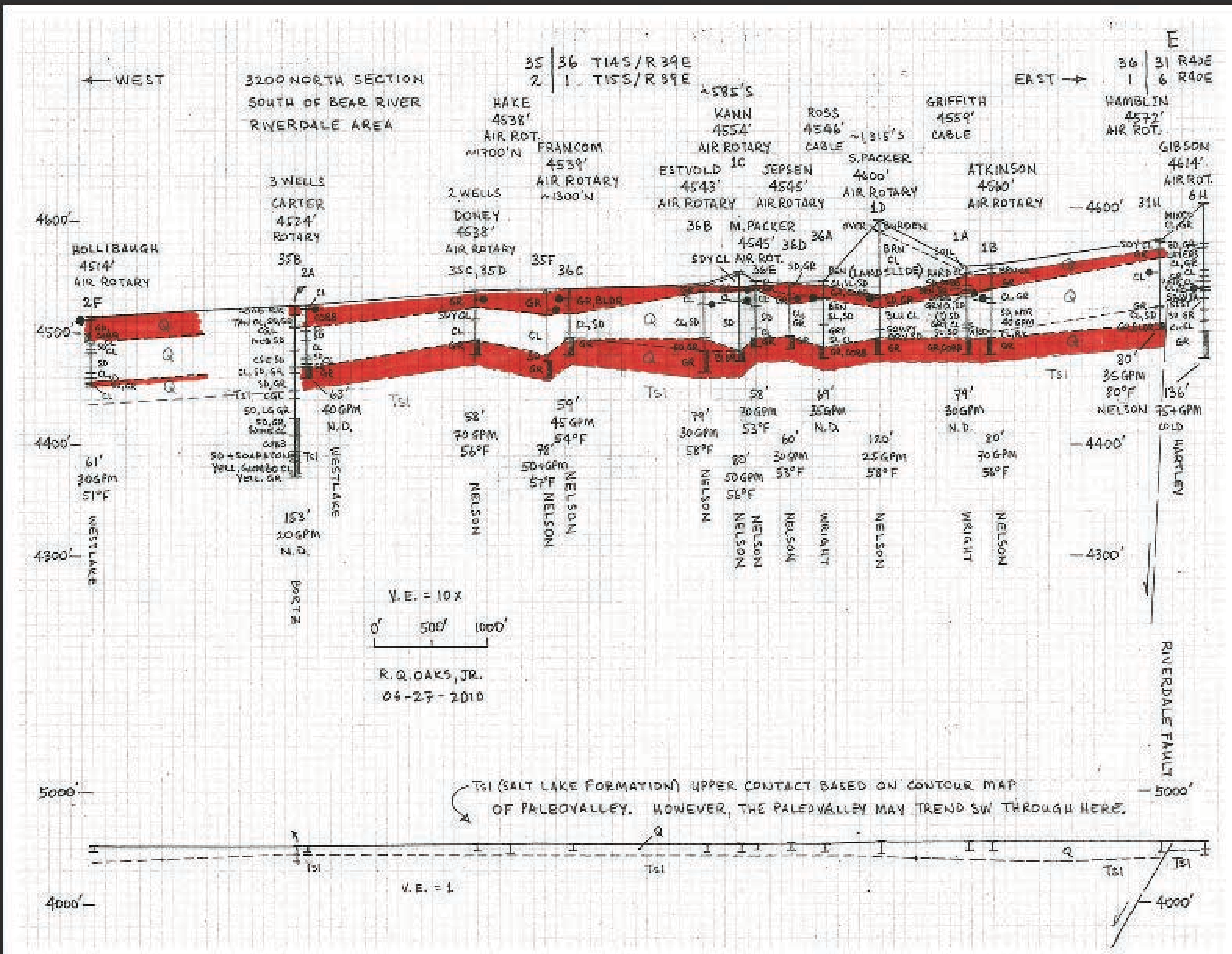


EAST RIVERDALE ROAD SECTION
T 14S/R 40E
←SSE
NNW | SSW
NNE | SW
31 | 30
30 | 29
NE | SSW
NNE→
31G NEWBOLD 4800' AIR ROT.
31F R.P. SMITH 4739' ROTARY
31A F. SHARP 4584' CABLE 60' N.D. ERICKSON
31N T.F. SHARP 4616' AIR ROT.
HIGLEY 4601' AIR ROT. 75' 45GPM 55°F WESTLAKE 31I
D. TANNER 4556' AIR. ROT. 80' 50GPM N.D. DUBBE
J.B. TANNER 4552' ROT./CABLE 280' N.D. COLD INTERMTN 31E
LOWER PROVO SHORELINE
29R McDONALD 4649' AIR ROT.
29M BOSWELL 4752' AIR ROT.
CLEVENGER 4753' AIR ROT. 29J
WESTLAKE 4708' AIR ROT. 29C
BEAR RIVER
V.E. = 10X
30C
Tsl
PALEOZOICS?
HARD BLACK SHALE
300' 2GPM 52°F NELSON
254' 40GPM N.D. WESTLAKE
120' 45GPM 58°F WESTLAKE
275' 15GPM 57°F WESTLAKE
375' 40GPM 64°F WESTLAKE
255' 45GPM 57°F WESTLAKE
215' 30GPM 55°F WESTLAKE
35'
>22'
>17'
19'
>18'
23'
10'
69'
17'
0' 500' 1000'
R.G. OAKS, JR.
06-27-2010
03-22-2014
PALEOVALLEY DERIVED FROM CONTOUR MAP, WITH LOWEST DEPTH BASED ON J.B. TANNER WELL IN THIS SECTION
4800'
4600'
4500'
4400'
4300'
5000'
4000'
V.E. = 1
SHALE
SANDSTONE
Q
NORTH STRAND OF NORTH GLENDALE FAULT DOUBLET
25° DIP Tsl
35° DIP

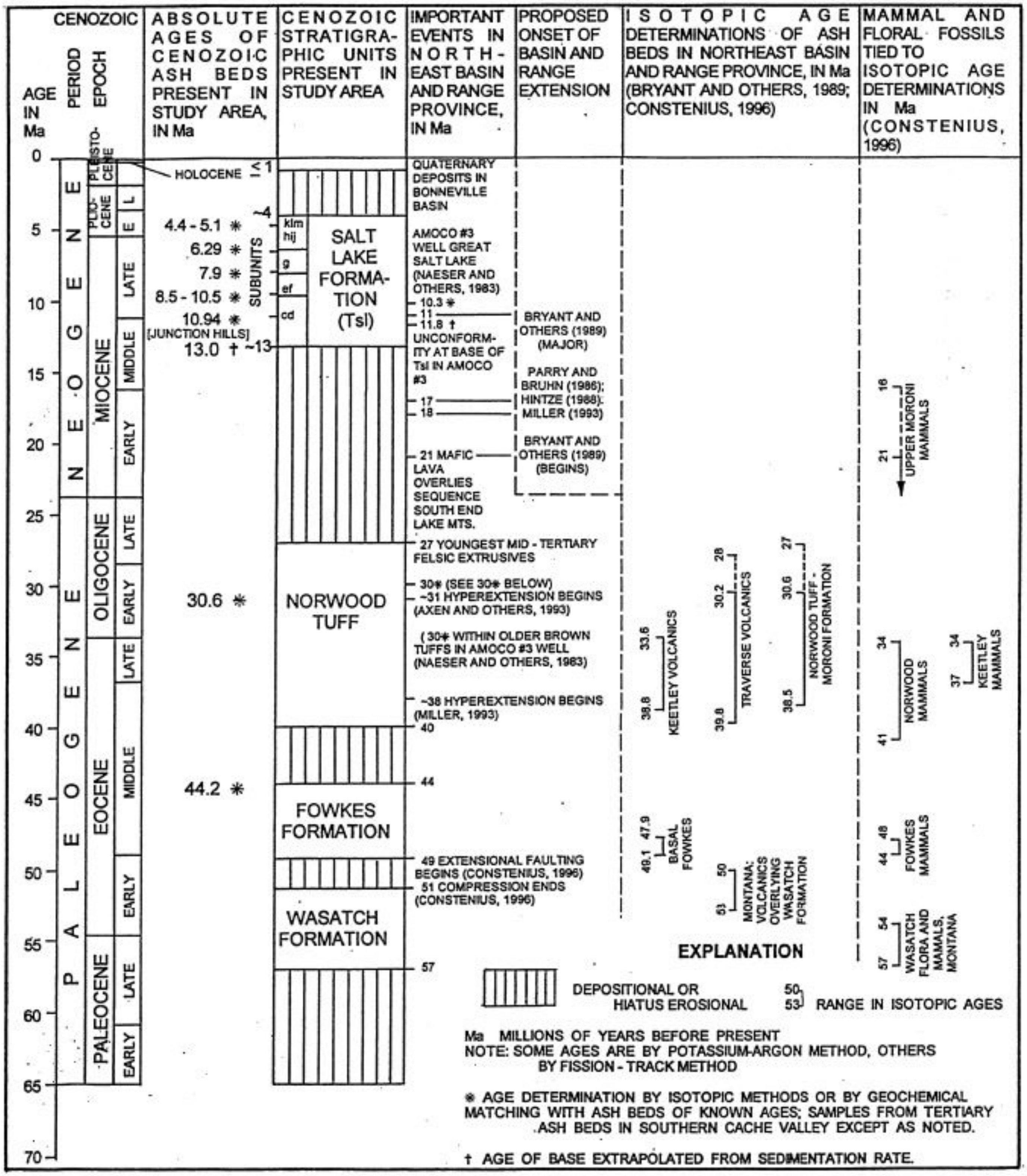


Web Slice Gallery

75%



← WEST
3200 NORTH SECTION
SOUTH OF BEAR RIVER
RIVERDALE AREA
35 | 36 T14S/R39E
2 | 1 T15S/R39E
EAST →
E
36 | 31 R40E
1 | 6 R40E
HOLLIBAUGH 4514' AIR ROTARY
3 WELLS CARTER 4524' ROTARY
HAKE 4538' AIR ROT. ~1700'N
2 WELLS DONEY 4538' AIR ROTARY
FRANCOM 4539' AIR ROTARY ~1300'N
ESTVOLD 4543' AIR ROTARY
KANN 4554' AIR ROTARY
JEPSEN 4545' AIR ROTARY
M.PACKER 4545' AIR ROT.
ROSS 4546' CABLE
S.PACKER 4600' AIR ROTARY
GRIFFITH 4559' CABLE
ATKINSON 4560' AIR ROTARY
HAMBLIN 4572' AIR ROT.
GIBSON 4614' AIR ROT.
4600'
4500'
4400'
4300'
Q
Tsl
WESTLAKE
NELSON
WRIGHT
HARTLEY
BORTZ
V.E. = 10 X
0' 500' 1000'
R.Q.OAKS, JR.
06-27-2010
RIVERDALE FAULT
Tsl (SALT LAKE FORMATION) UPPER CONTACT BASED ON CONTOUR MAP OF PALEOVALLEY. HOWEVER, THE PALEOVALLEY MAY TREND SW THROUGH HERE.
5000'
4000'
V.E. = 1


AGE IN Ma
PERIOD
EPOCH
CENOZOIC
ABSOLUTE AGES OF CENOZOIC ASH BEDS PRESENT IN STUDY AREA, IN Ma
CENOZOIC STRATIGRAPHIC UNITS PRESENT IN STUDY AREA
IMPORTANT EVENTS IN NORTHEAST BASIN AND RANGE PROVINCE, IN Ma
PROPOSED ONSET OF BASIN AND RANGE EXTENSION
ISOTOPIC AGE DETERMINATIONS OF ASH BEDS IN NORTHEAST BASIN AND RANGE PROVINCE, IN Ma (BRYANT AND OTHERS, 1989; CONSTENIUS, 1996)
MAMMAL AND FLORAL FOSSILS TIED TO ISOTOPIC AGE DETERMINATIONS IN Ma (CONSTENIUS, 1996)
NEOGENE
PALEOGENE
PLEISTOCENE
PLIOCENE
MIOCENE
OLIGOCENE
EOCENE
PALEOCENE
HOLOCENE ≤1
4.4 - 5.1 ✱
6.29 ✱
7.9 ✱
8.5 - 10.5 ✱
10.94 ✱
[JUNCTION HILLS]
13.0 † ~13
30.6 ✱
44.2 ✱
SUBUNITS
klm hij g ef cd
SALT LAKE FORMATION (Tsl)
NORWOOD TUFF
FOWKES FORMATION
WASATCH FORMATION
QUATERNARY DEPOSITS IN BONNEVILLE BASIN
AMOCO #3 WELL GREAT SALT LAKE (NAESER AND OTHERS, 1983)
10.3 ✱
11
11.8 †
UNCONFORMITY AT BASE OF Tsl IN AMOCO #3
17
18
21 MAFIC LAVA OVERLIES SEQUENCE SOUTH END LAKE MTS.
27 YOUNGEST MID - TERTIARY FELSIC EXTRUSIVES
30✱ (SEE 30✱ BELOW)
~31 HYPEREXTENSION BEGINS (AXEN AND OTHERS, 1993)
(30✱ WITHIN OLDER BROWN TUFFS IN AMOCO #3 WELL (NAESER AND OTHERS, 1983)
~38 HYPEREXTENSION BEGINS (MILLER, 1993)
40
44
49 EXTENSIONAL FAULTING BEGINS (CONSTENIUS, 1996)
51 COMPRESSION ENDS (CONSTENIUS, 1996)
57
BRYANT AND OTHERS (1989) (MAJOR)
PARRY AND BRUHN (1986); HINTZE (1988); MILLER (1993)
BRYANT AND OTHERS (1989) (BEGINS)
KEETLEY VOLCANICS 33.6 38.8
TRAVERSE VOLCANICS 28 30.2 39.8
NORWOOD TUFF - MORONI FORMATION 27 30.6 38.5
BASAL FOWKES 47.9 49.1
MONTANA: VOLCANICS OVERLYING WASATCH FORMATION 50 53
UPPER MORONI MAMMALS 16 21
NORWOOD MAMMALS 34 41
KEETLEY MAMMALS 34 37
FOWKES MAMMALS 44 48
WASATCH FLORA AND MAMALS, MONTANA 54 57
EXPLANATION
DEPOSITIONAL OR HIATUS EROSIONAL
50 53 RANGE IN ISOTOPIC AGES
Ma MILLIONS OF YEARS BEFORE PRESENT
NOTE: SOME AGES ARE BY POTASSIUM-ARGON METHOD, OTHERS BY FISSION - TRACK METHOD
✱ AGE DETERMINATION BY ISOTOPIC METHODS OR BY GEOCHEMICAL MATCHING WITH ASH BEDS OF KNOWN AGES; SAMPLES FROM TERTIARY ASH BEDS IN SOUTHERN CACHE VALLEY EXCEPT AS NOTED.
† AGE OF BASE EXTRAPOLATED FROM SEDIMENTATION RATE.

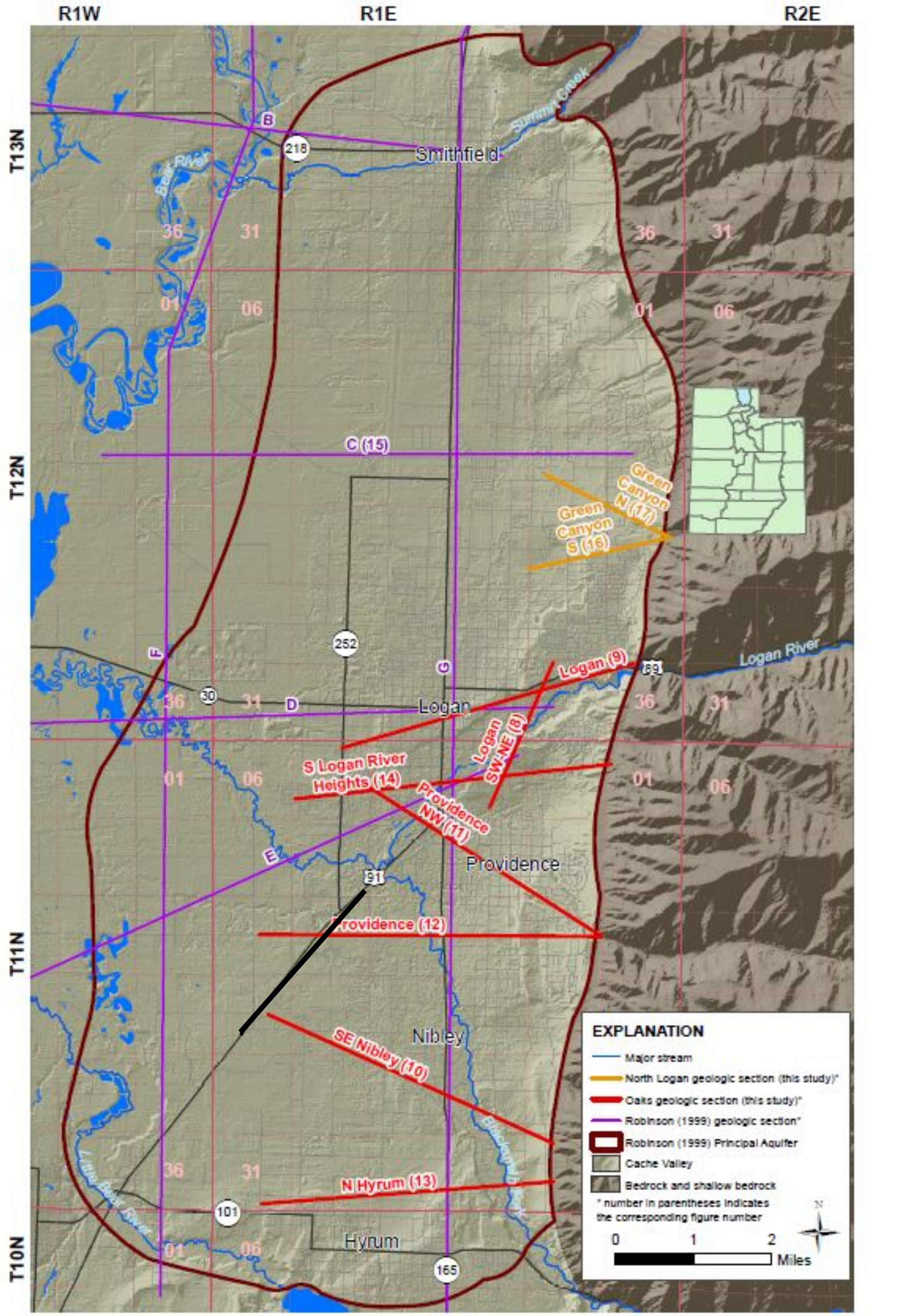


Figure 7. Location of geologic sections examined for this study. Robinson's (1999) geologic sections are purple and geologic sections made for this study are in red and orange.

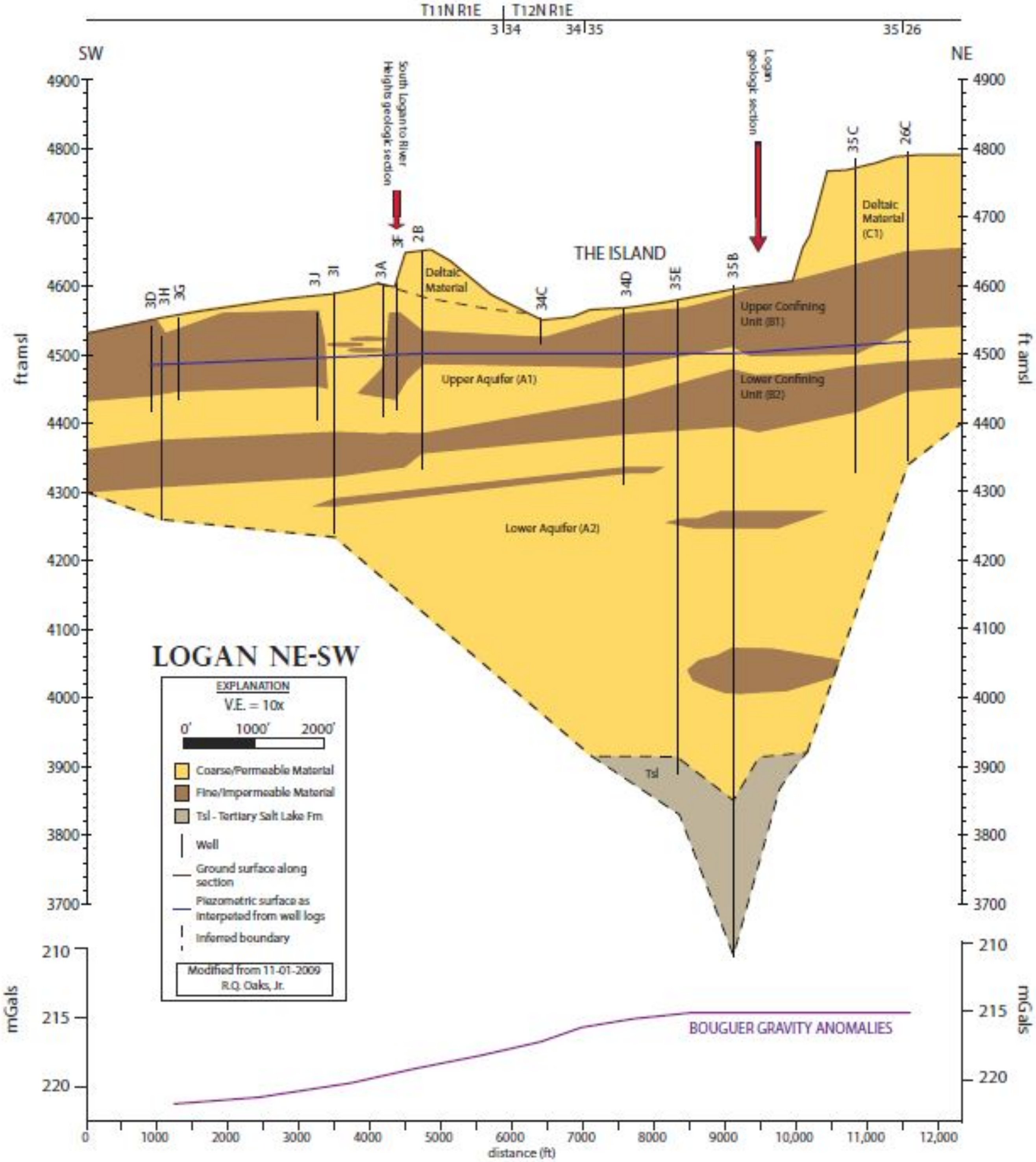


Figure 8. Northeast to southwest geologic section of Logan area basin fill. See figure 7 for location of section.

LATE PLEISTOCENE LAKE SHAMBIP, CENTRAL UTAH

Daren T. Nelson[1] and Paul W. Jewell[2]

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ABSTRACT

The Lake Shambip shoreline was first recognized and described in the early 1980s on the basis of subtle geomorphic features south of the Stockton bar, a prominent feature of late Pleistocene Lake Bonneville. The lake developed in Rush Valley south of the Stockton bar at approximately the same time as the lower and more widely recognized Provo shoreline in Tooele Valley north of the Stockton bar. However, Lake Shambip shoreline elevations are significantly higher than typical Provo shorelines. The shoreline is best expressed as a feature that cross-cuts earlier (> ~18,000 yr) transgressive barrier bars at ~1540 m above sea level. Radiocarbon ages for Lake Shambip shorelines range from 13,300–14,100 yr B.P. (16,720–17,560 cal yr B.P.). Sr-isotopes of mollusks collected in the shoreline and modern streams draining into Rush Valley suggest variable water sources for Lake Shambip. The volume of water necessary to maintain a lake such as this during the late Pleistocene however is problematic.

This content is a PDF version of the author's PowerPoint presentation.

Late Pleistocene Lake Shambip, Central Utah

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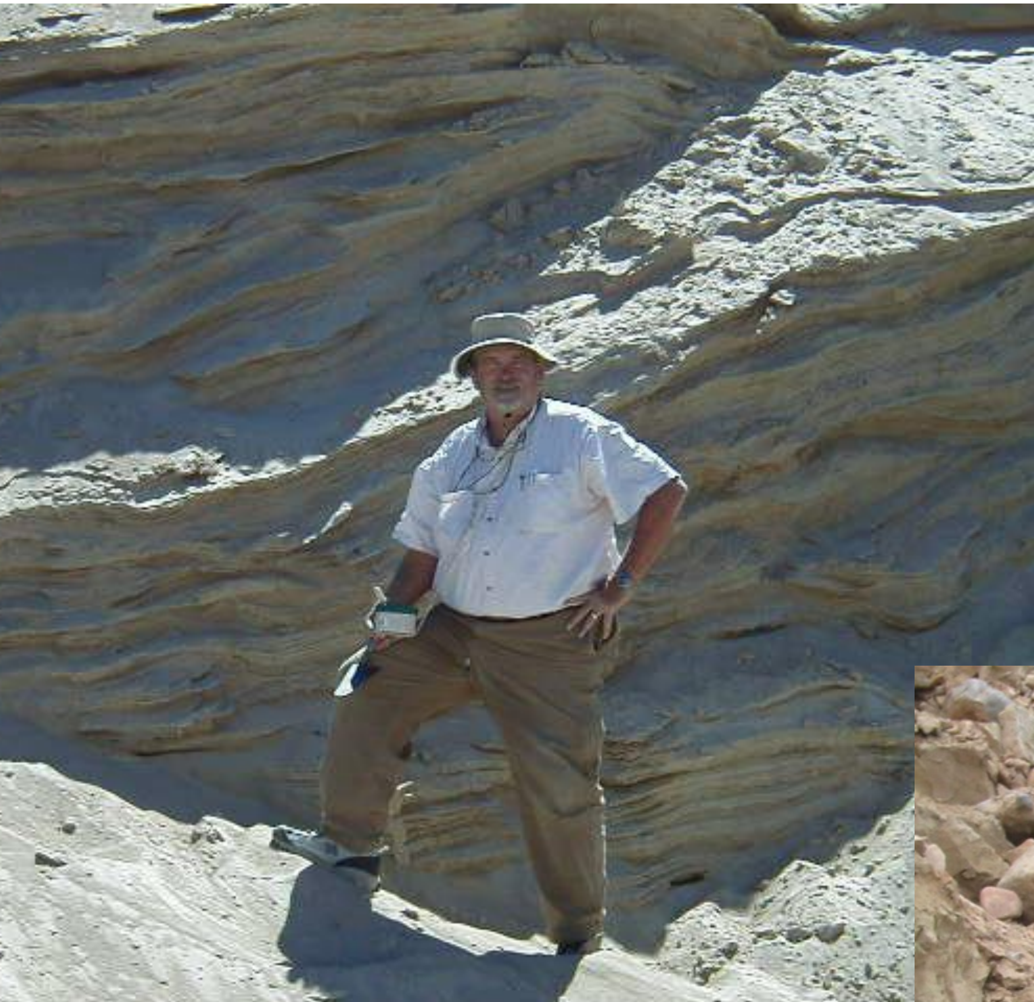
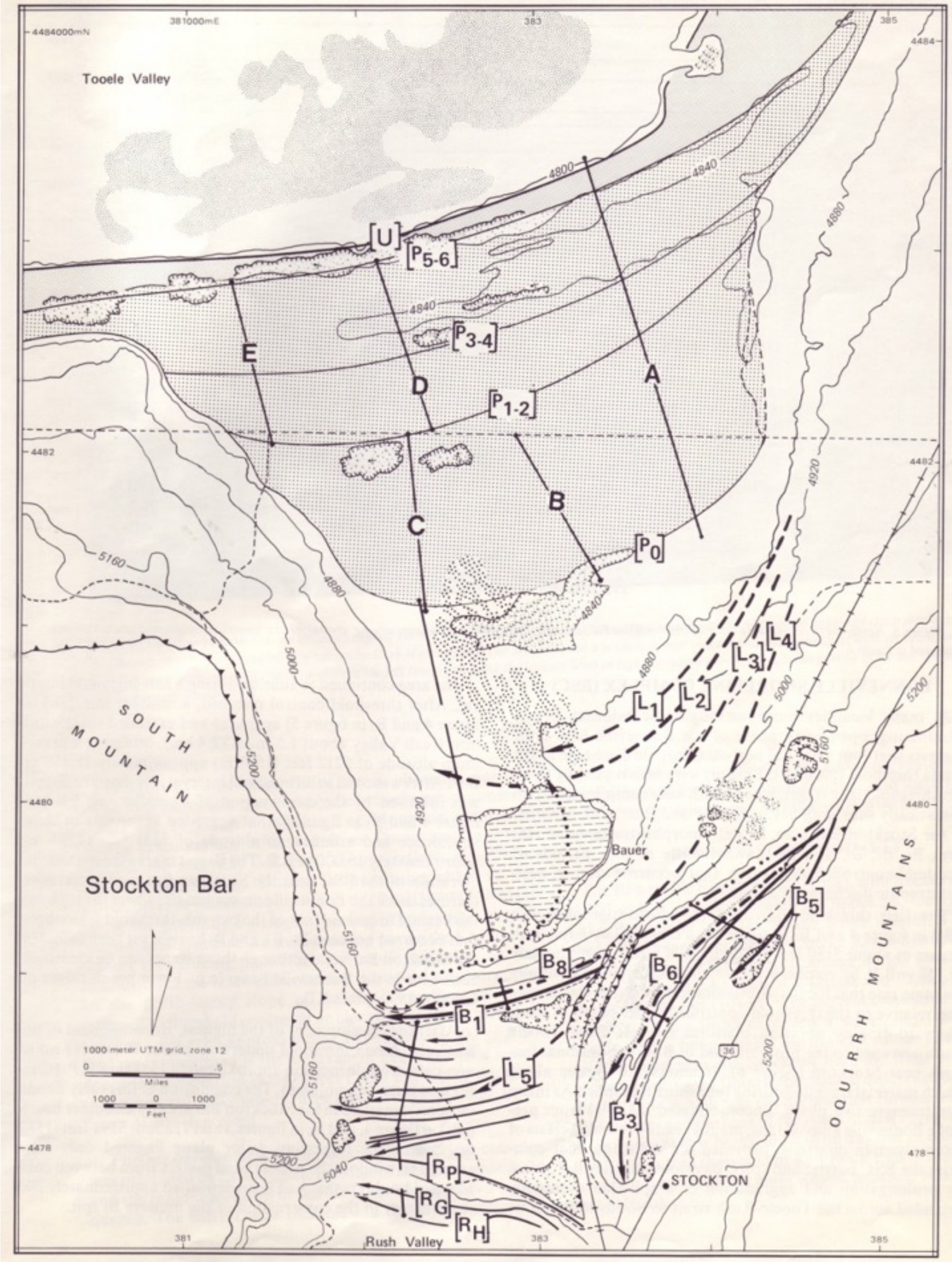
Lake Bonneville Conference
October 3, 2018

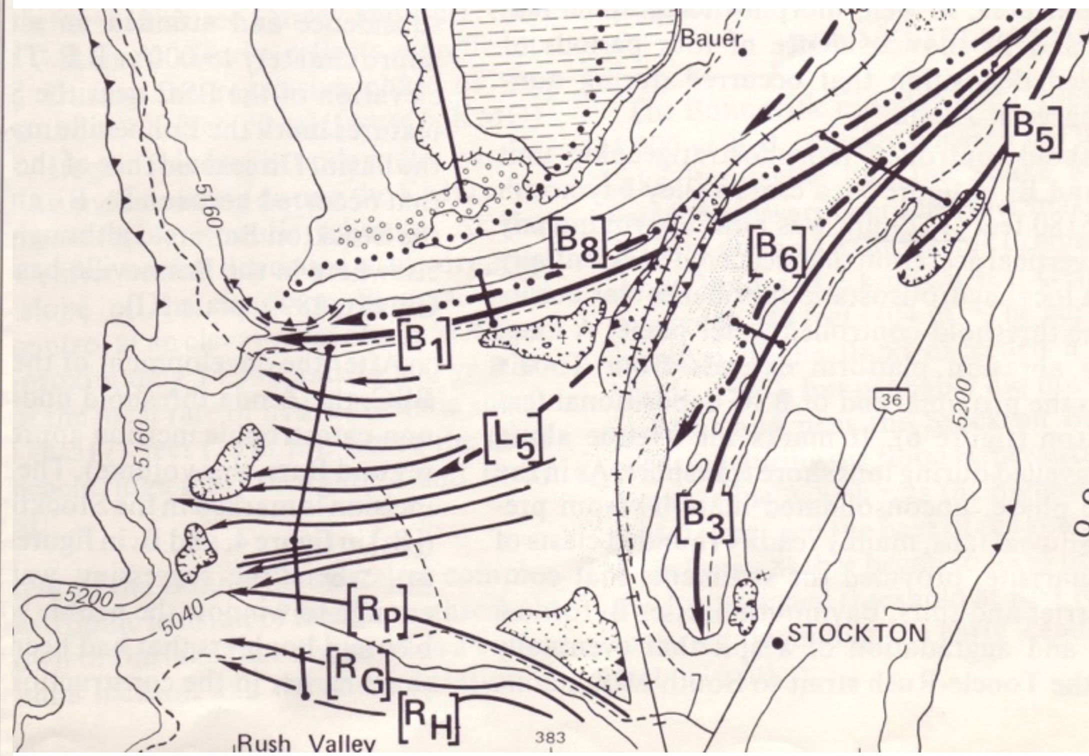
Acknowledgements

- Jack Oviatt, other Lake Bonneville researchers
- National Science Foundation grant 1053129
- College of Mines and Earth Sciences Dean's Office

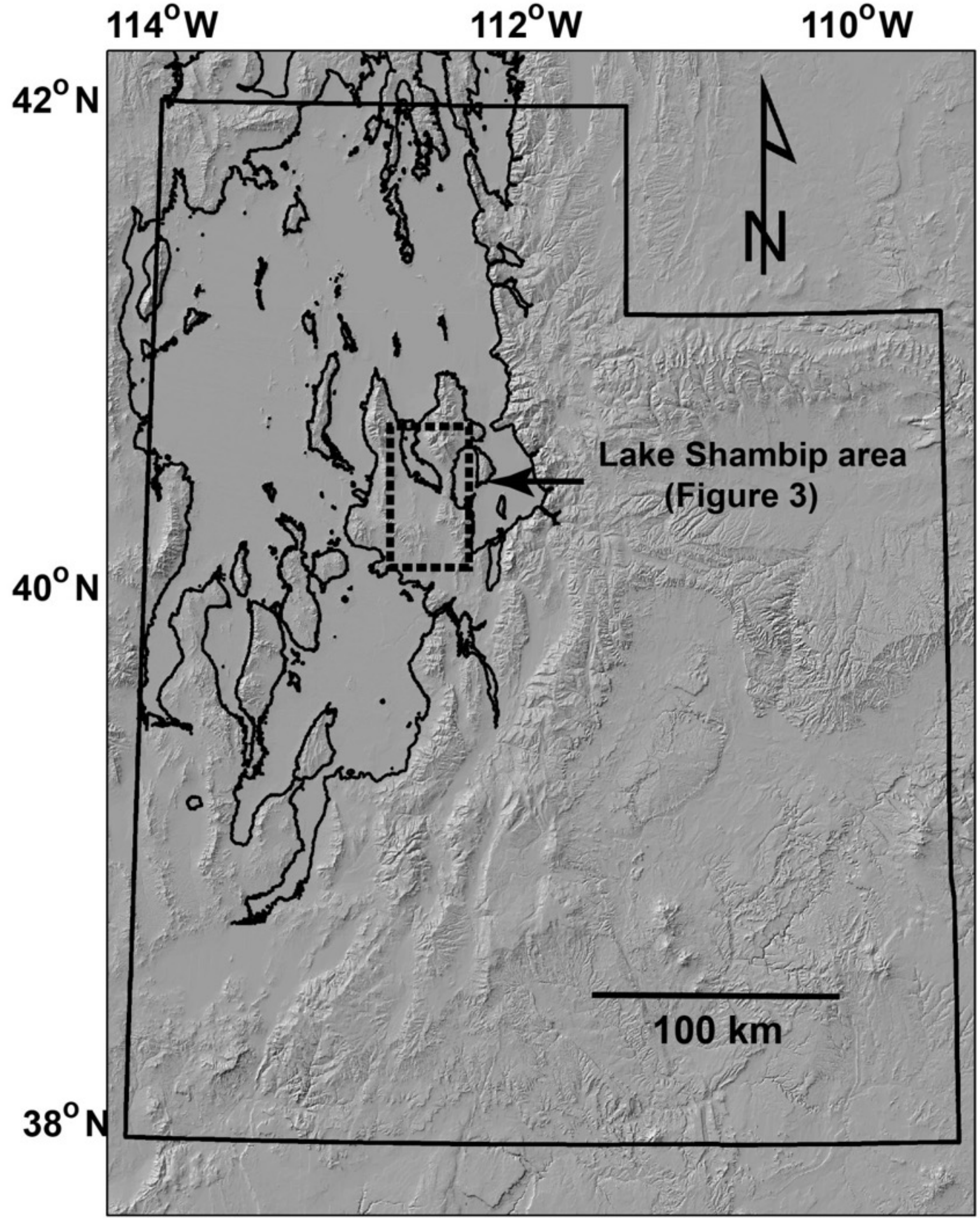


Burr and Currey, 1988

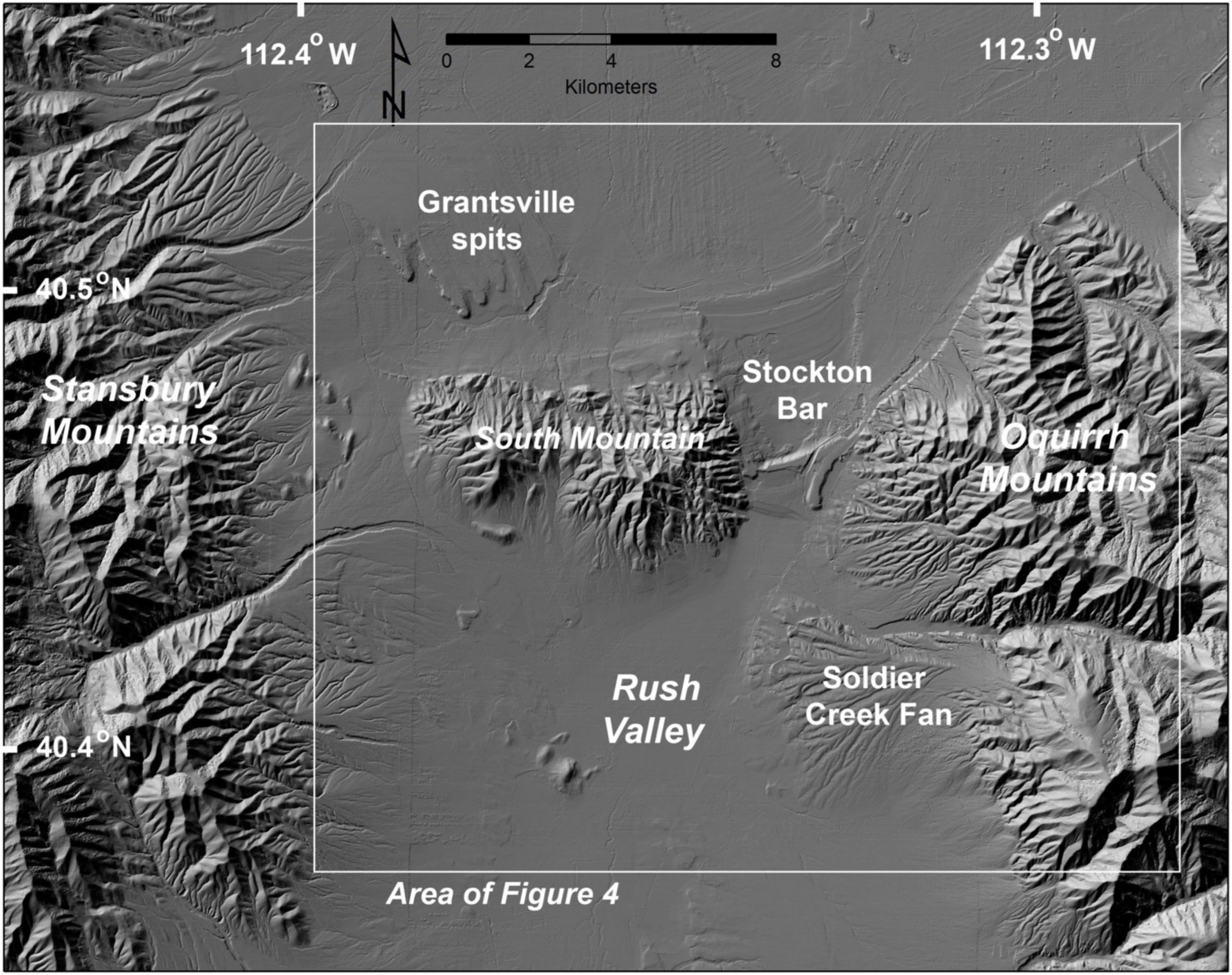


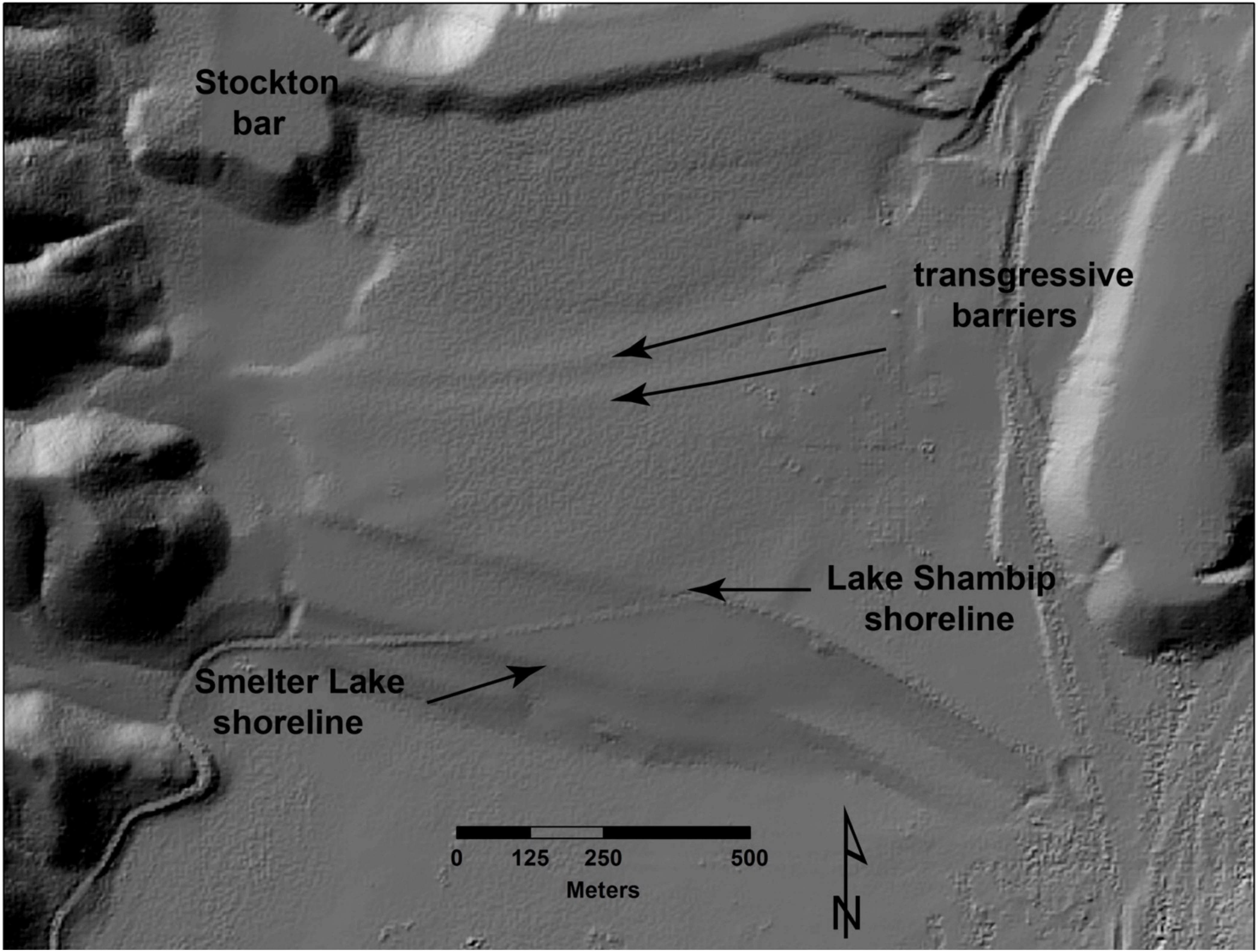


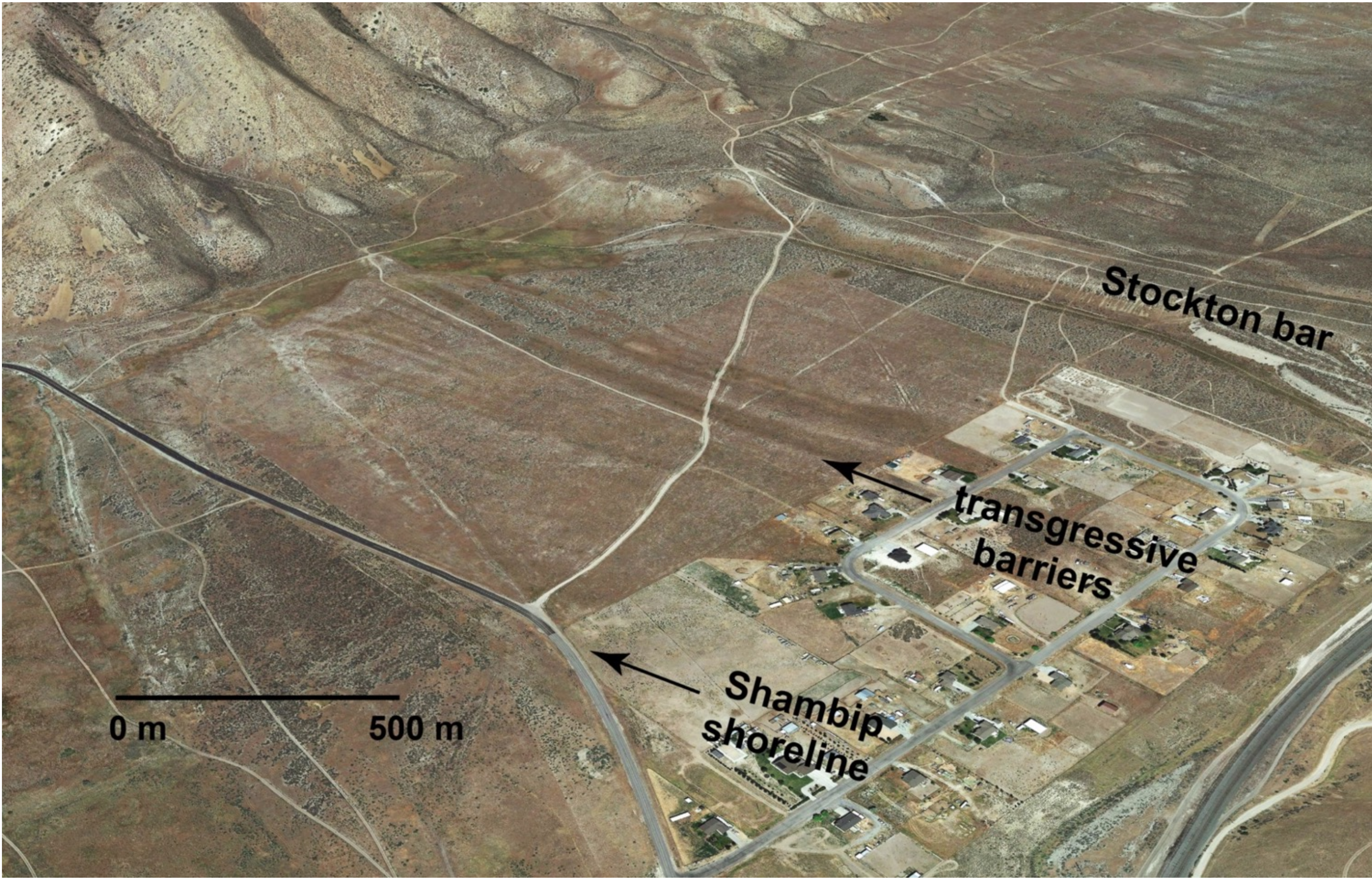
Rp = Lake Shambip shoreline (~1540 m a.s.l.)
Rg = Smelter Lake shoreline
P1 = highest Provo shoreline (~1480 m a.s.l.)



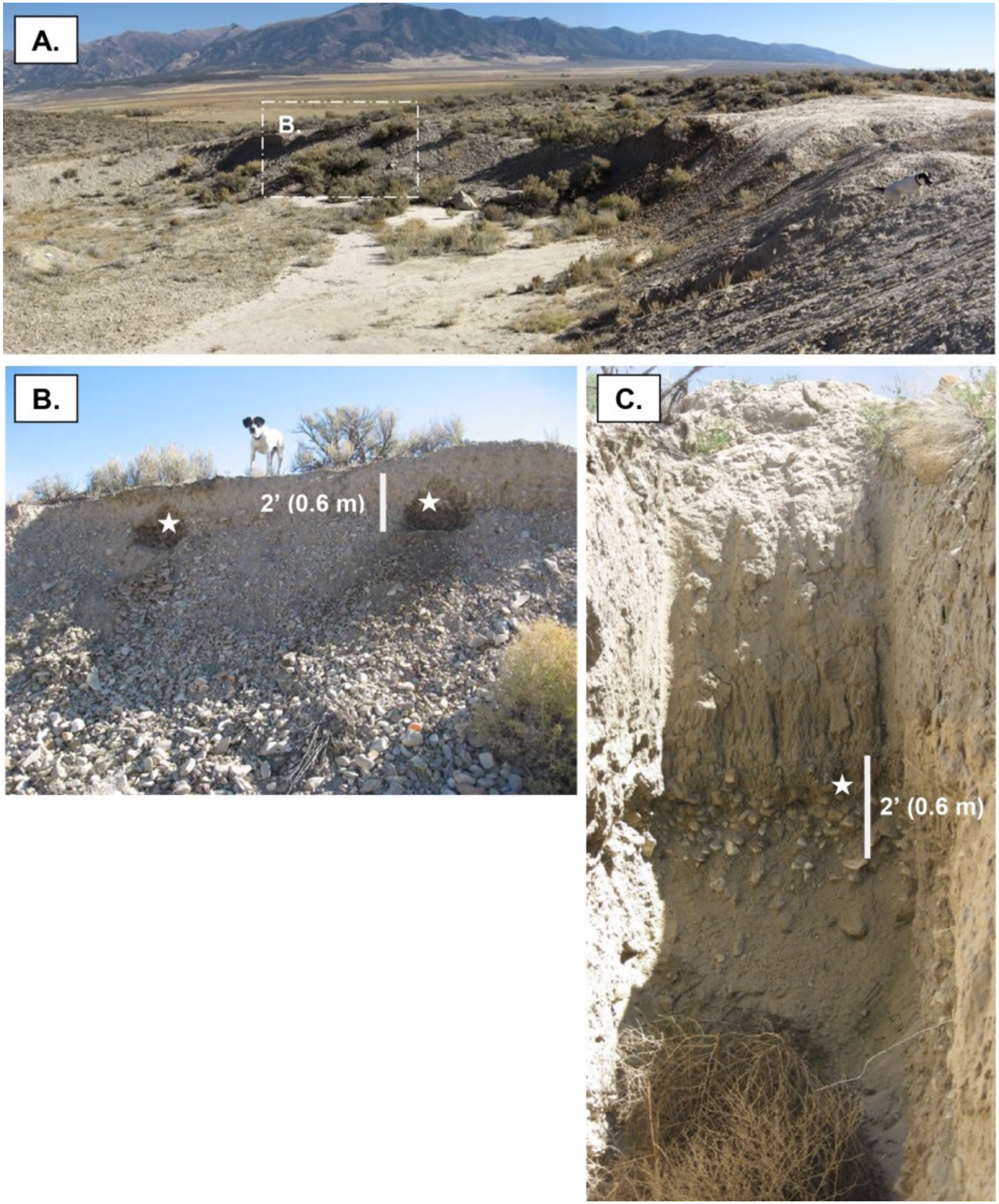
114°W
112°W
110°W
42° N
40° N
38° N
N
Lake Shambip area
(Figure 3)
100 km


112.4° W
112.3° W
0
2
4
8
Kilometers
N
40.5°N
40.4°N
Grantsville spits
Stansbury Mountains
South Mountain
Stockton Bar
Oquirrh Mountains
Rush Valley
Soldier Creek Fan
Area of Figure 4

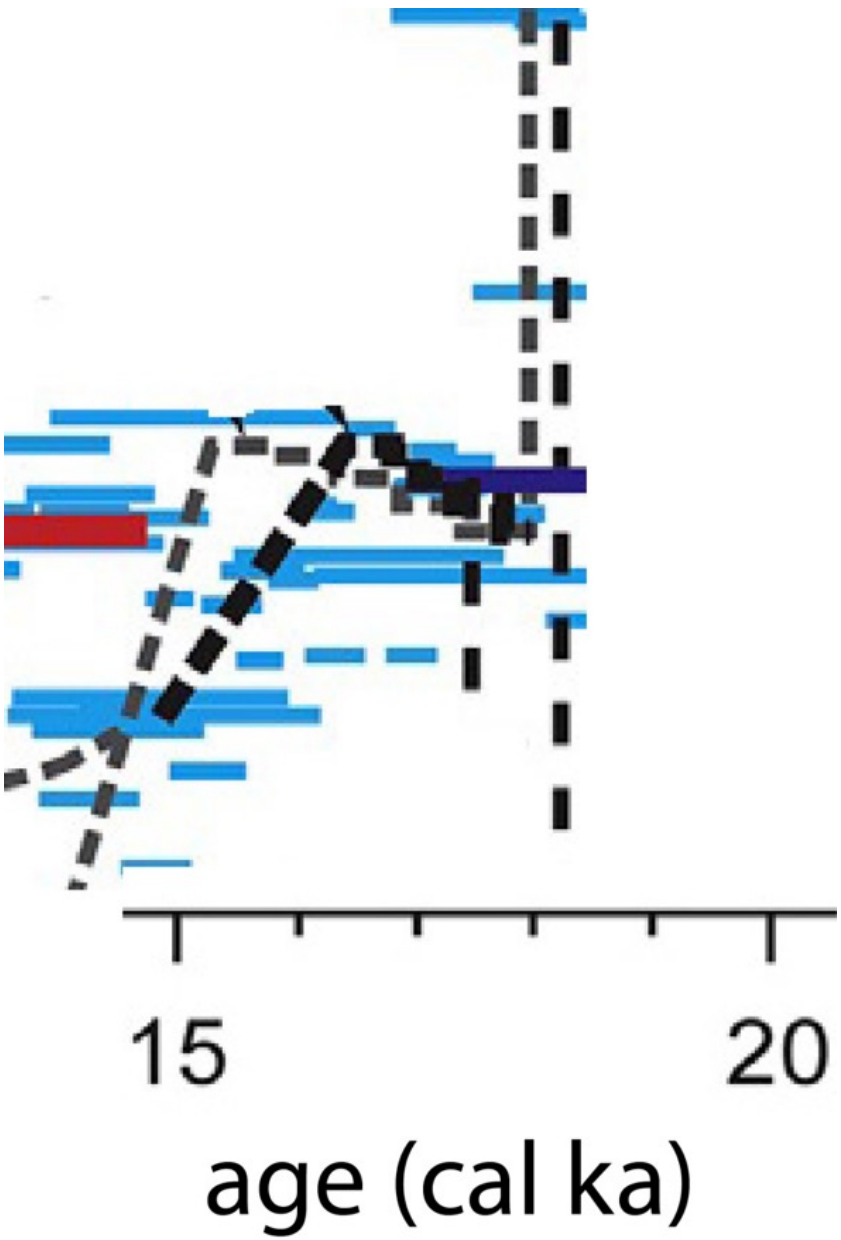

Stockton bar
transgressive barriers
Lake Shambip shoreline
Smelter Lake shoreline
0
125
250
500
Meters
N



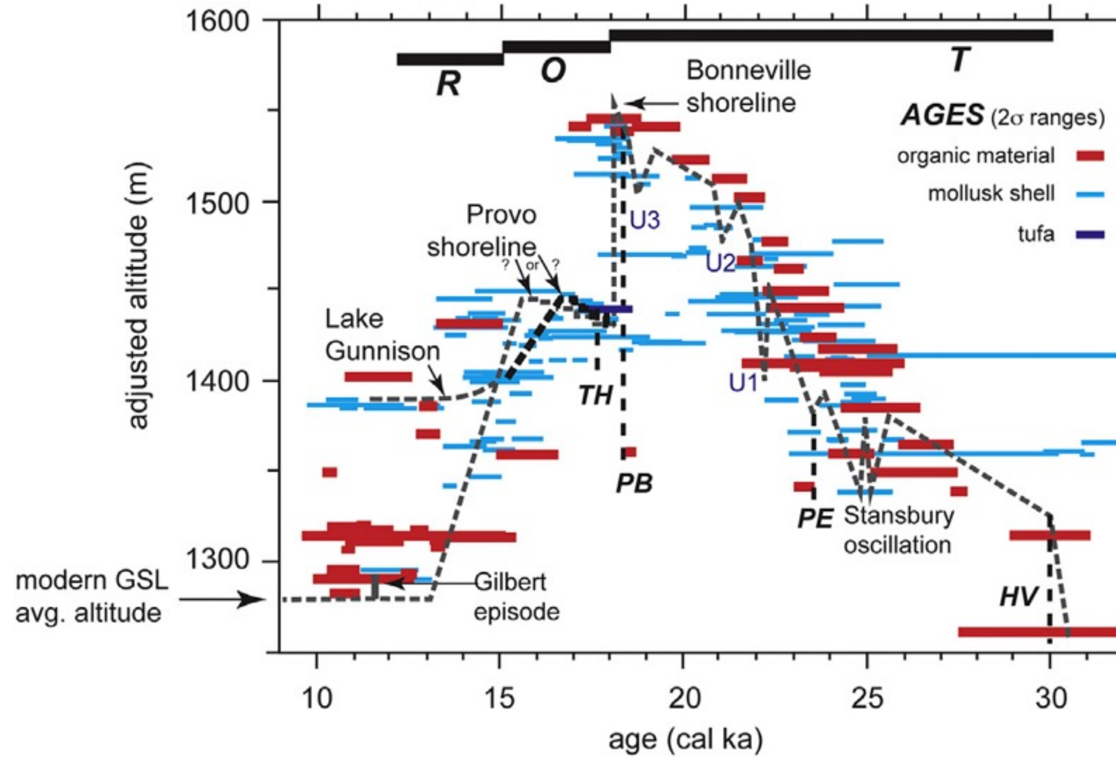
Stockton bar
transgressive barriers
Shambip shoreline
0 m
500 m


A.
B.
B.
2’ (0.6 m)
C.
2’ (0.6 m)

Sample	Method	Material	Location (UTM Zone 12)	Age (^{14}C yr B.P.)	Calibrated age (yr B.P.)
Belta-307253	AMS	Shells	378750 E 4472300 N	13,360 $\pm$ 50	16,750 -16,850
Belta-307252	AMS	Shells	378750 E 4472300 N	13,300 $\pm$ 50	16,720 -16,830
Belta-307254	AMS	Shells	380000 E 4476000 N	13990 $\pm$ 50	17,190 -17,550
Beta-457941	AMS	Shells	380000 E 4476000 N	14,100$\pm$50	17,445-17,665

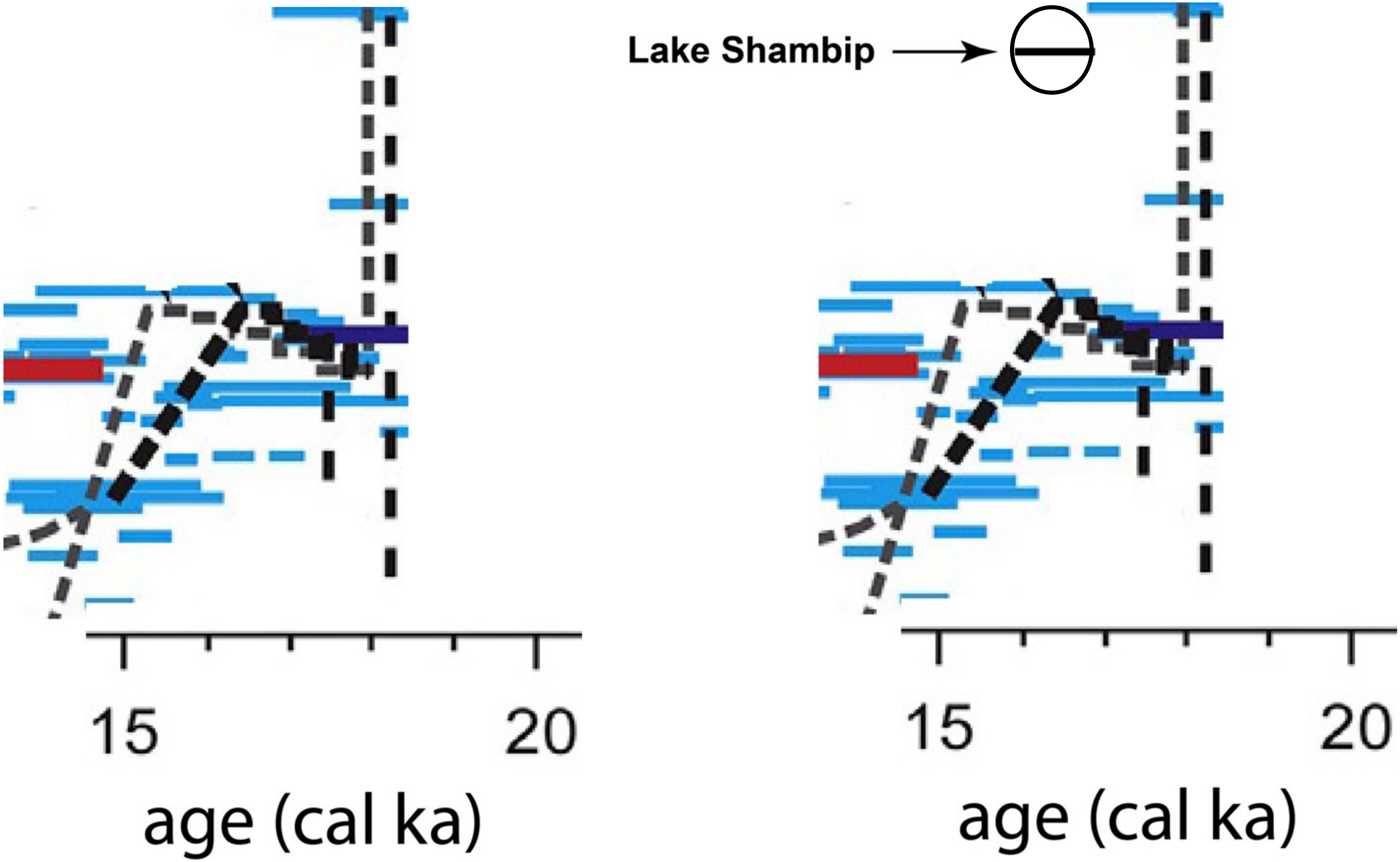


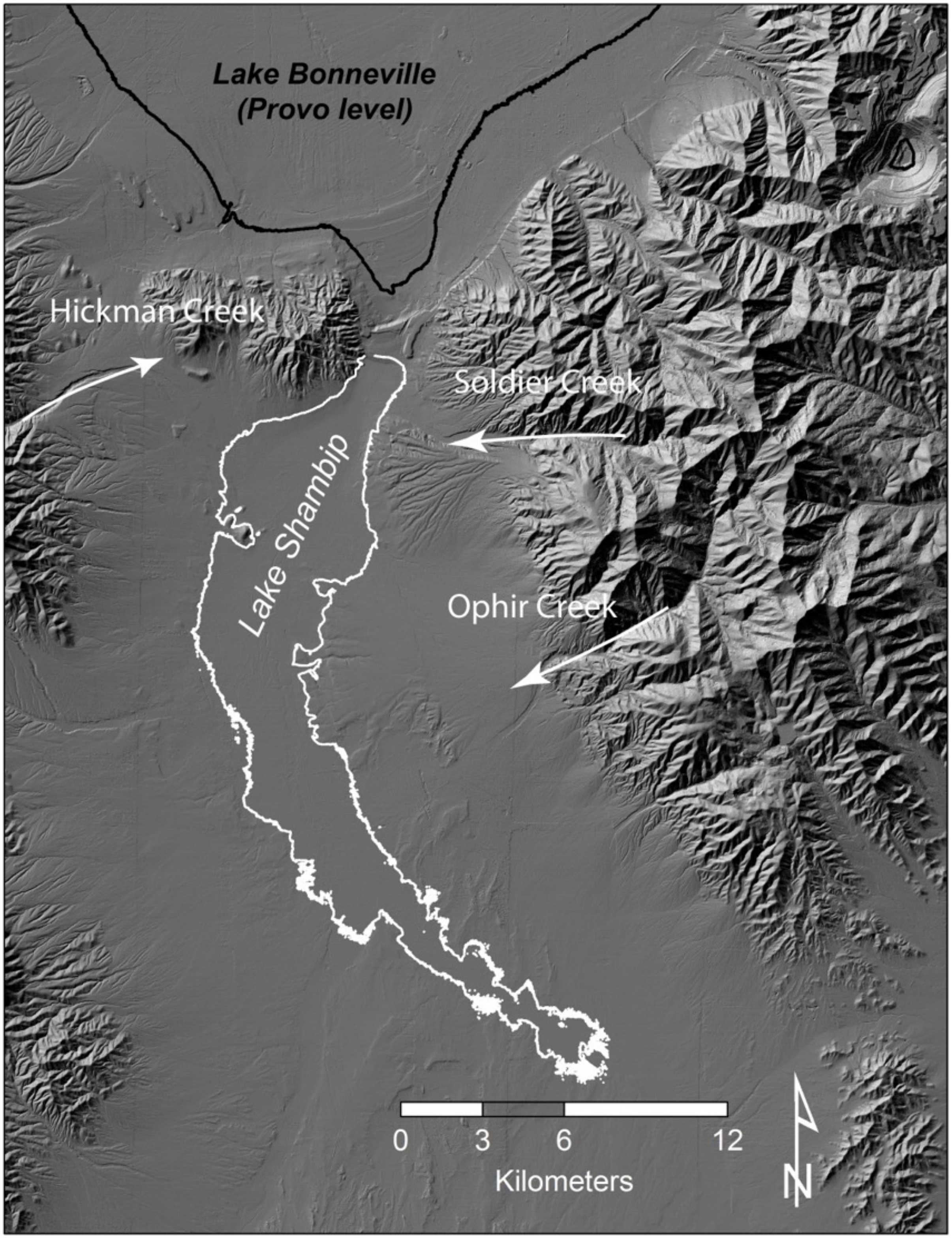
15
20
age (cal ka)



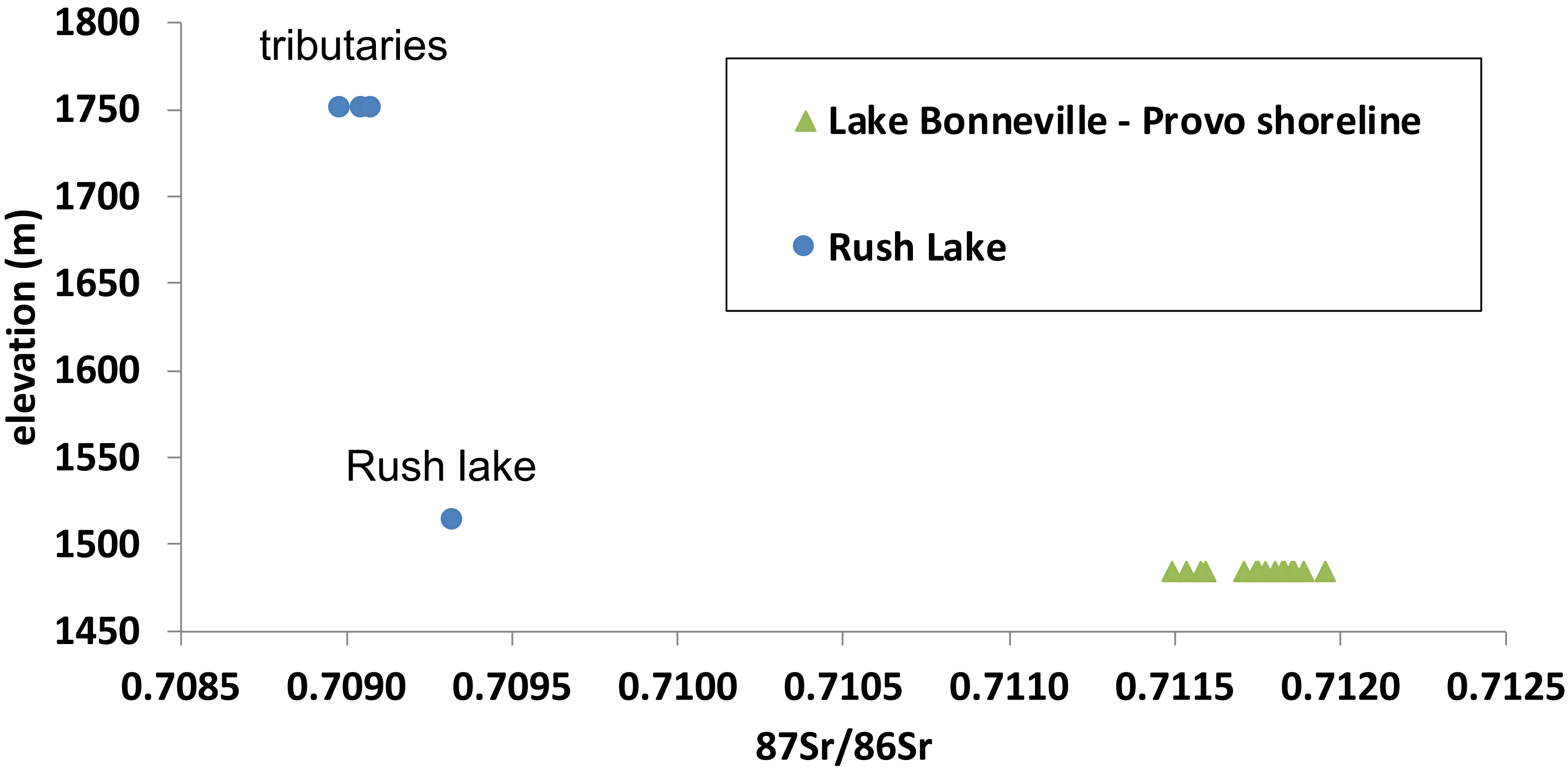
1600
1500
1400
1300
adjusted altitude (m)
R
O
T
Bonneville shoreline
AGES (2σ ranges)
organic material
mollusk shell
tufa
U3
U2
U1
Provo shoreline
Lake Gunnison
TH
PB
PE
Stansbury oscillation
HV
modern GSL avg. altitude
Gilbert episode
10
15
20
25
30
age (cal ka)

Oviatt, 2015

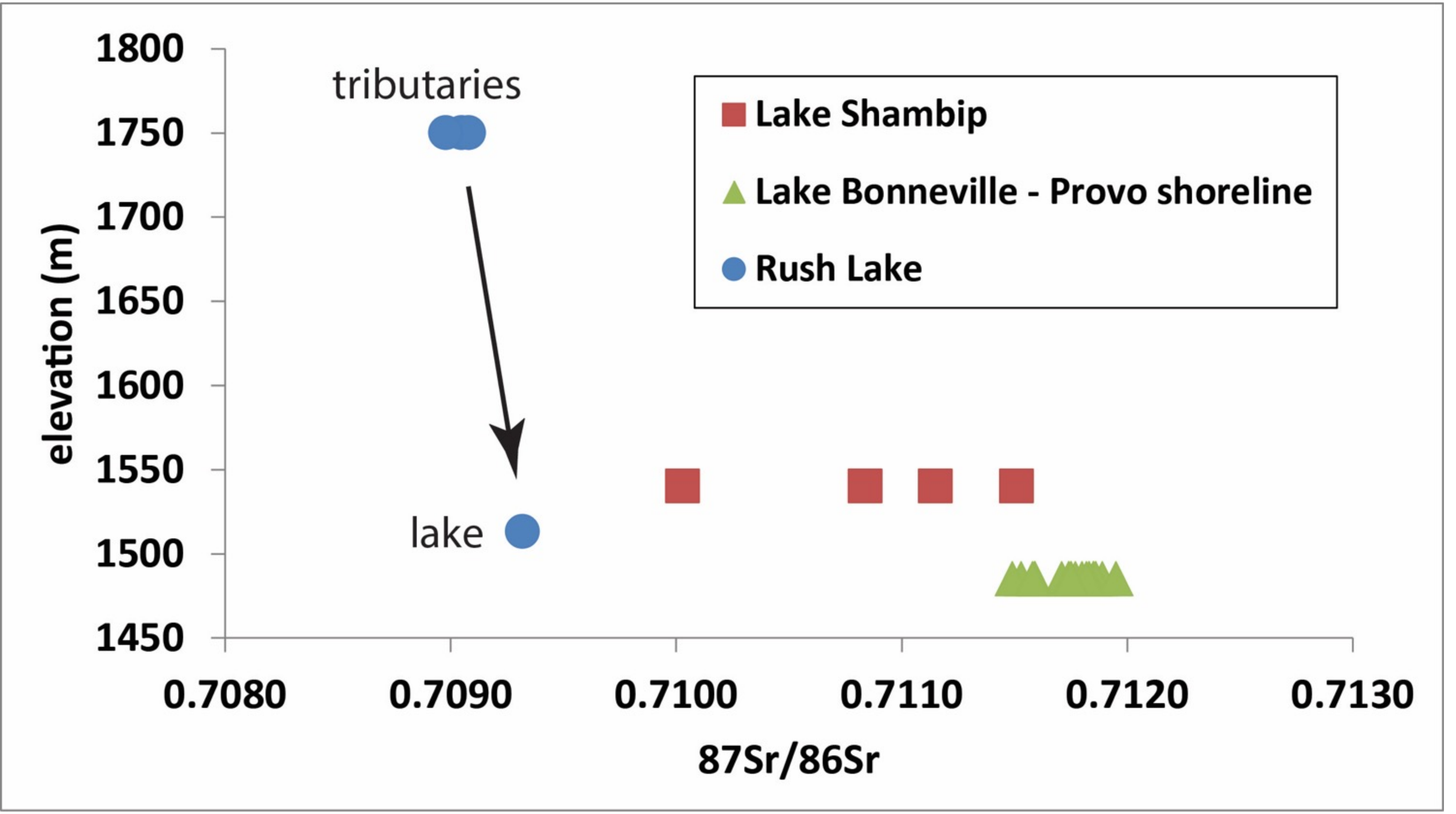

15
20
age (cal ka)
Lake Shambip
15
20
age (cal ka)



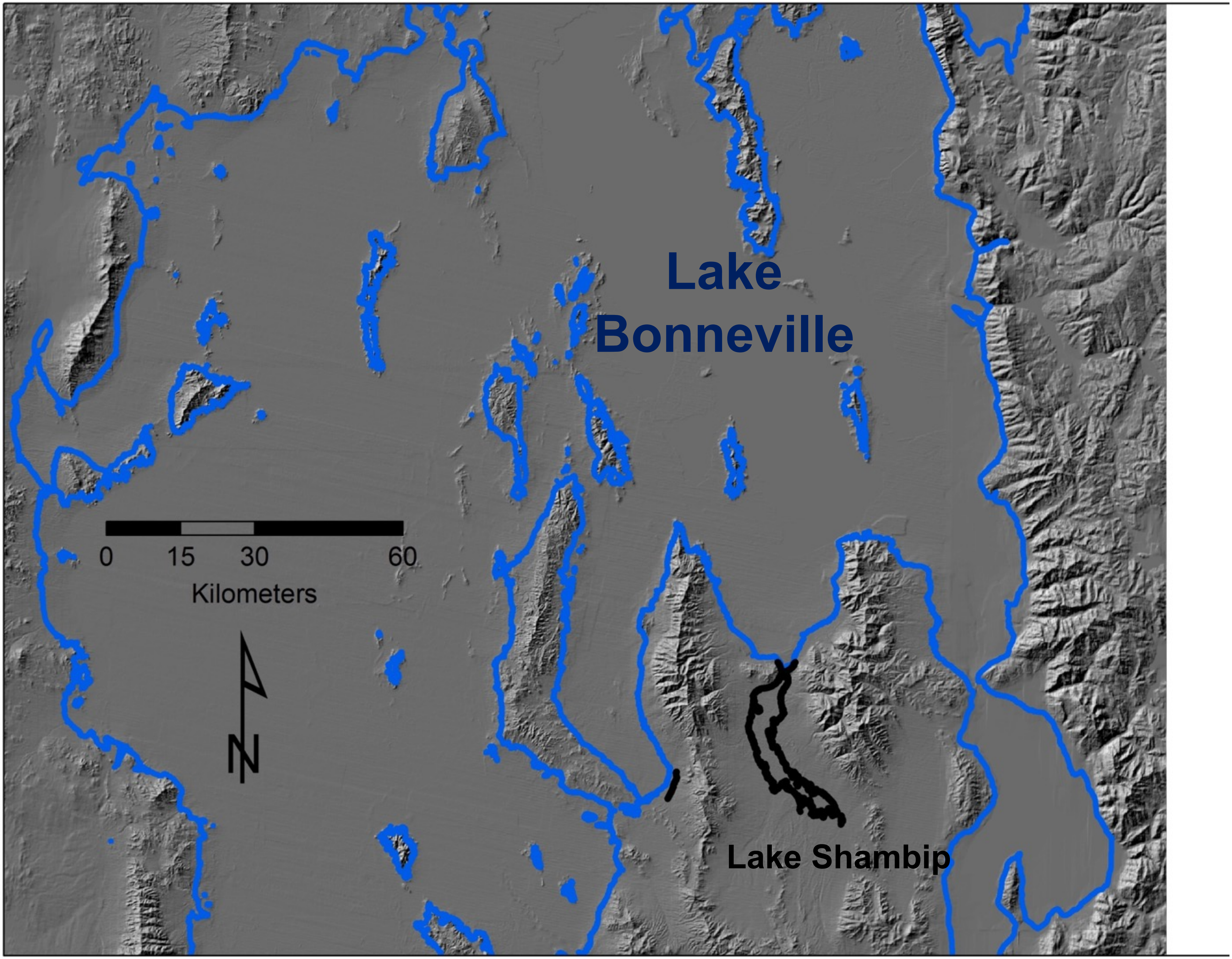
Lake Bonneville
(Provo level)
Hickman Creek
Soldier Creek
Lake Shambip
Ophir Creek
0
3
6
12
Kilometers
N

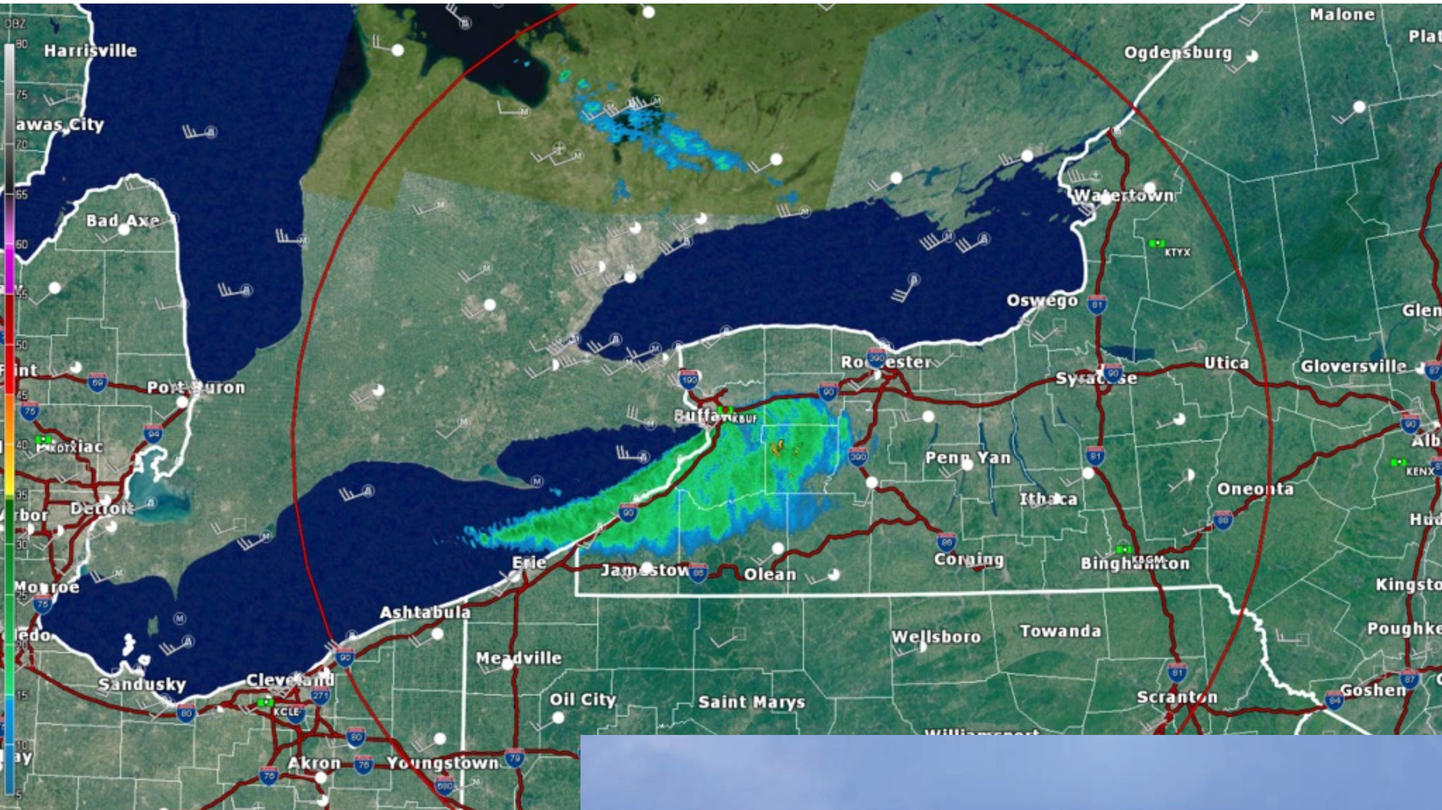


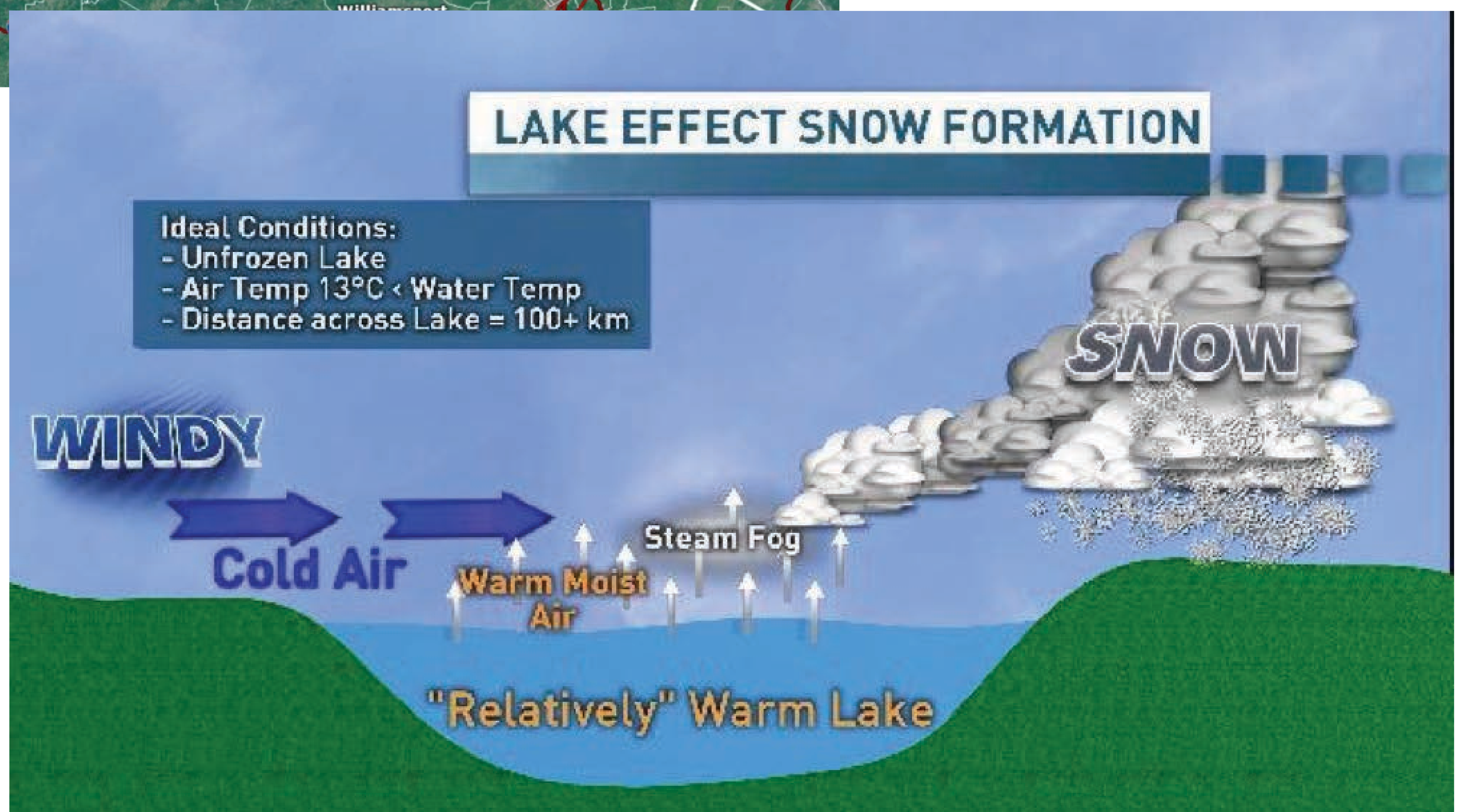
1800
1750
1700
1650
1600
1550
1500
1450
elevation (m)
tributaries
Rush lake
Lake Bonneville - Provo shoreline
Rush Lake
0.7085
0.7090
0.7095
0.7100
0.7105
0.7110
0.7115
0.7120
0.7125
87Sr/86Sr

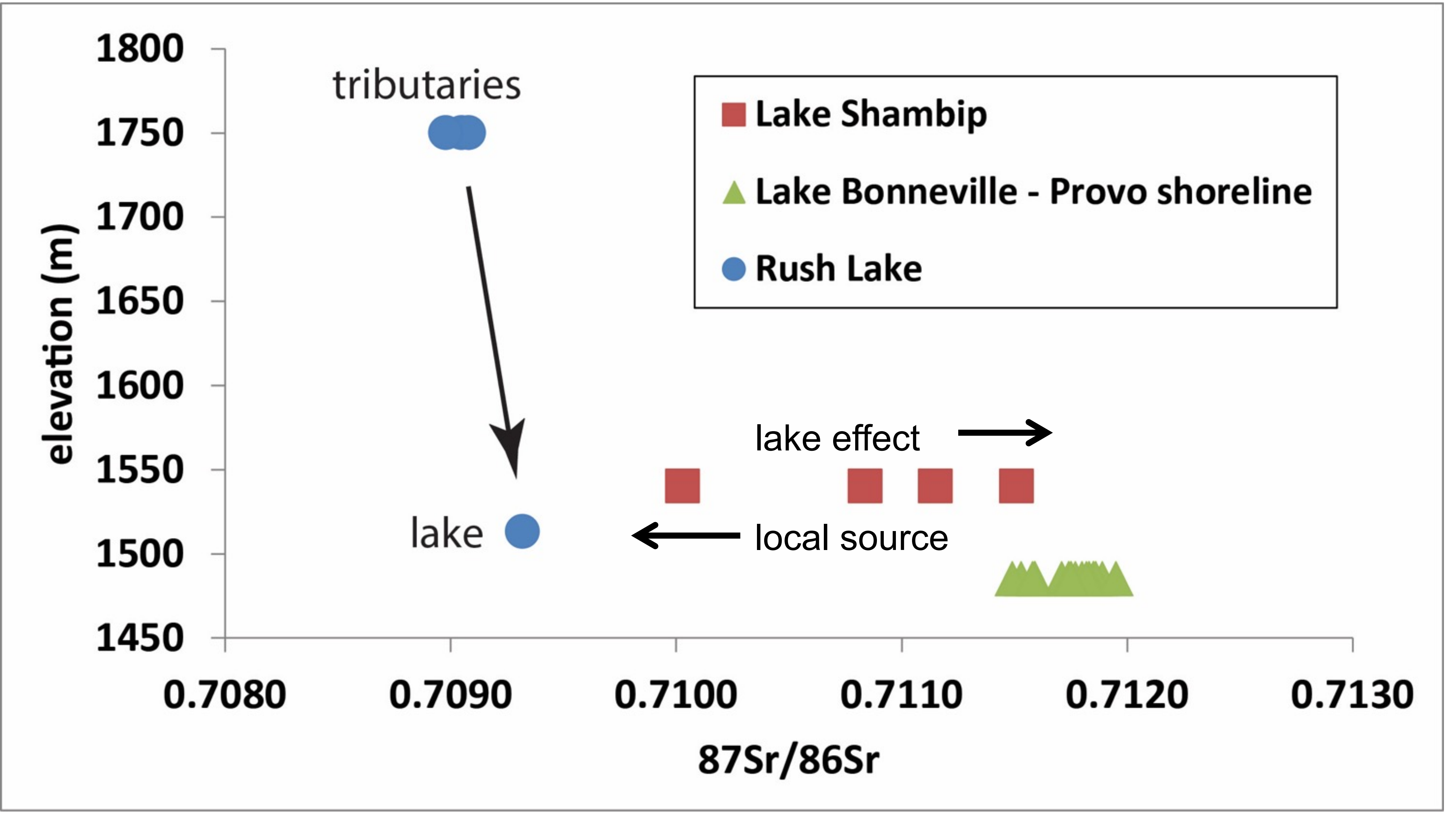


1800
1750
1700
1650
1600
1550
1500
1450
elevation (m)
tributaries
lake
Lake Shambip
Lake Bonneville - Provo shoreline
Rush Lake
0.7080
0.7090
0.7100
0.7110
0.7120
0.7130
87Sr/86Sr

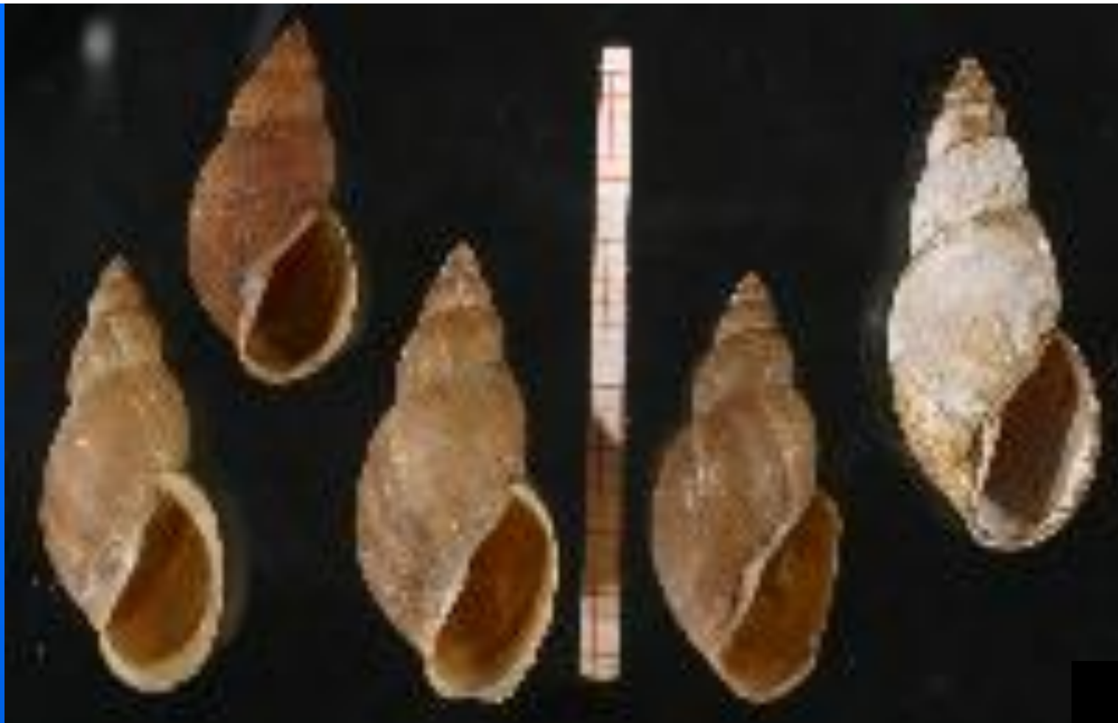

Lake
Bonneville
0
15
30
60
Kilometers
N
Lake Shambip


Harrisville
Bad Axe
Port Huron
Detroit
Monroe
Sandusky
Cleveland
Akron
Youngstown
Ashtabula
Erie
Meadville
Oil City
Saint Marys
Jamestown
Olean
Buffalo
Rochester
Oswego
Syracuse
Utica
Watertown
Ogdensburg
Malone
Gloversville
Penn Yan
Ithaca
Oneonta
Corning
Binghamton
Wellsboro
Towanda
Scranton
Kingston
Goshen


LAKE EFFECT SNOW FORMATION
Ideal Conditions:
- Unfrozen Lake
- Air Temp 13°C < Water Temp
- Distance across Lake = 100+ km
WINDY
Cold Air
Warm Moist Air
Steam Fog
SNOW
"Relatively" Warm Lake



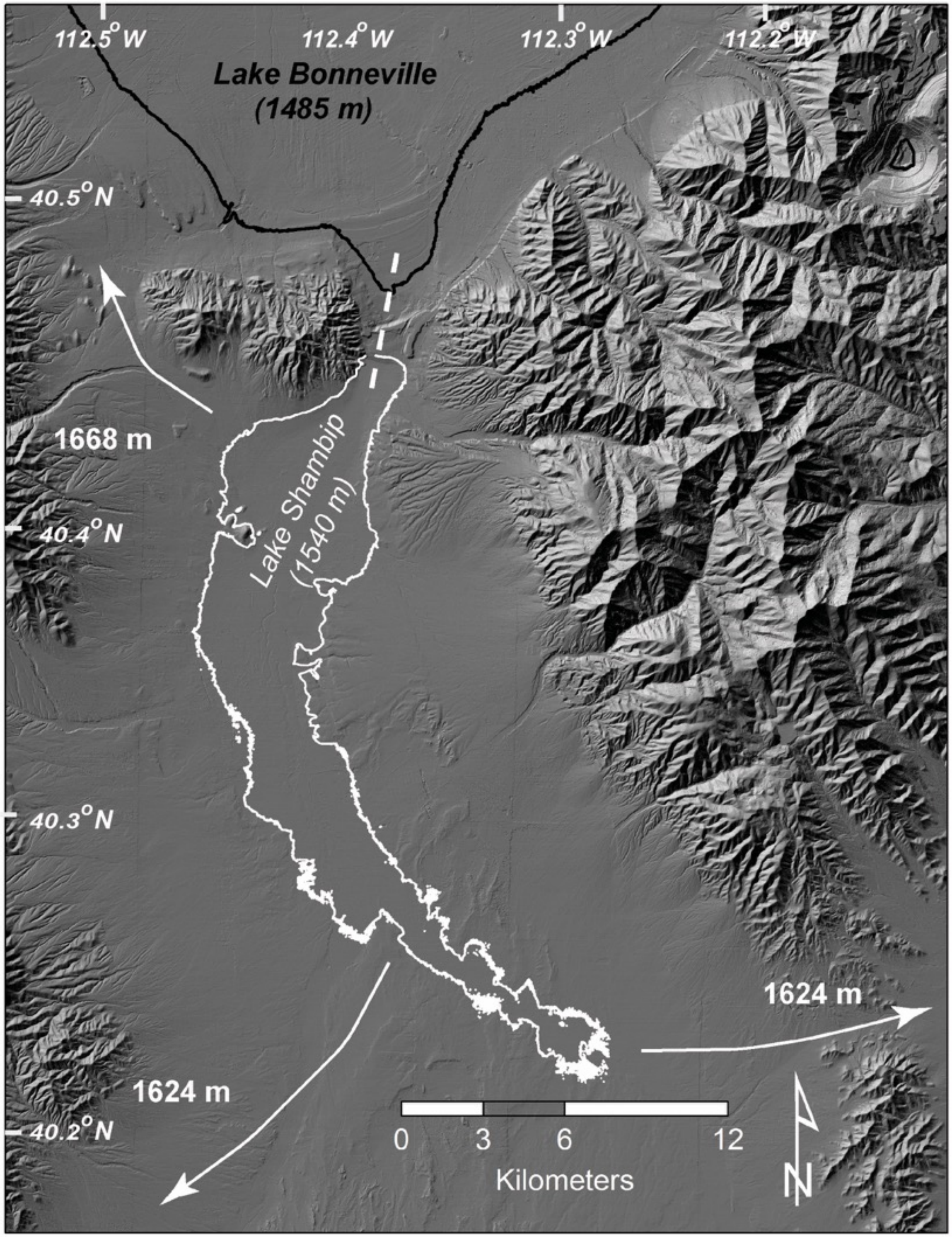
tributaries
lake
lake effect
local source
Lake Shambip
Lake Bonneville - Provo shoreline
Rush Lake
elevation (m)
1800
1750
1700
1650
1600
1550
1500
1450
0.7080
0.7090
0.7100
0.7110
0.7120
0.7130
87Sr/86Sr

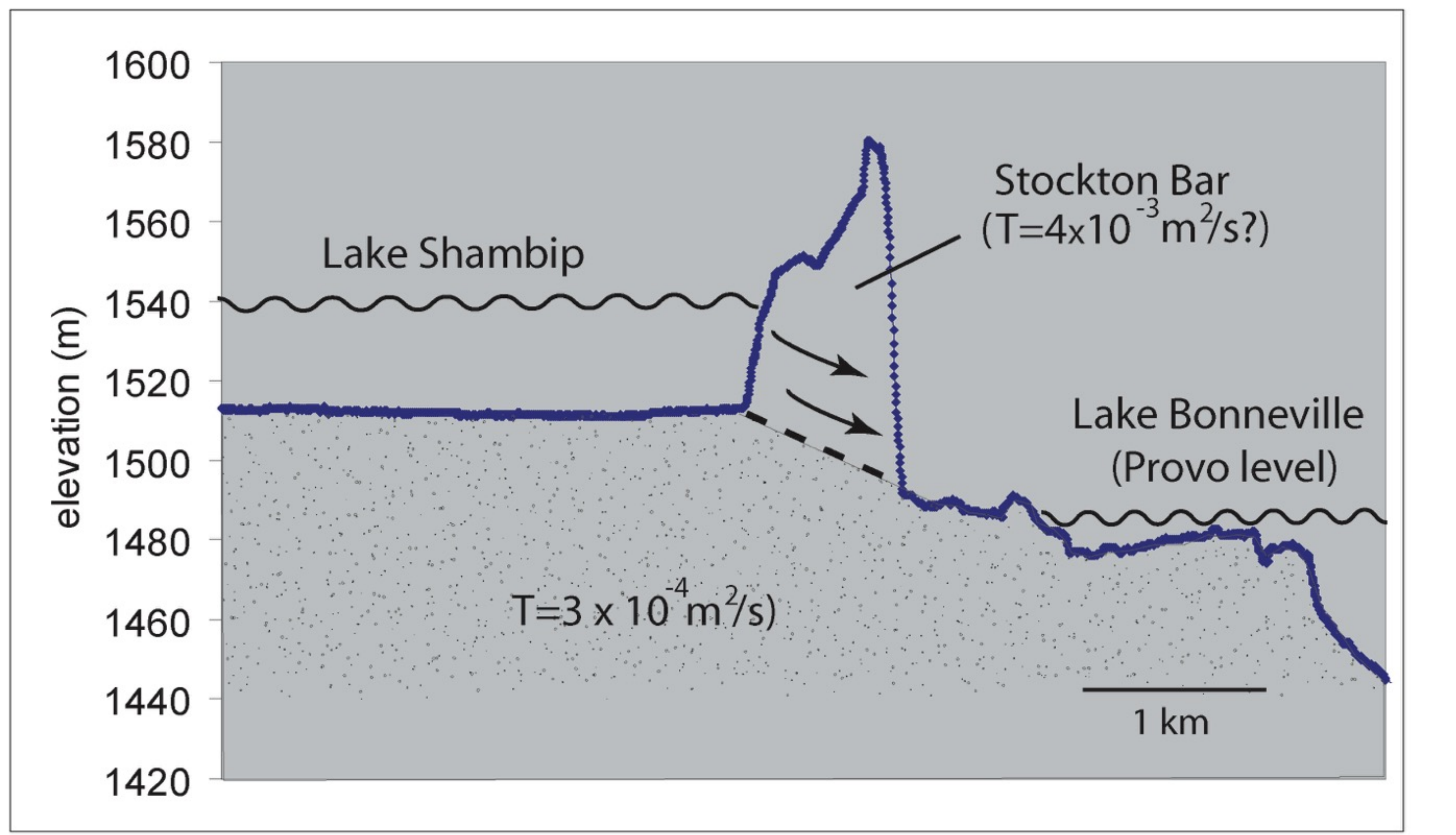


Radiocarbon dating of shallow water organisms

Water balances

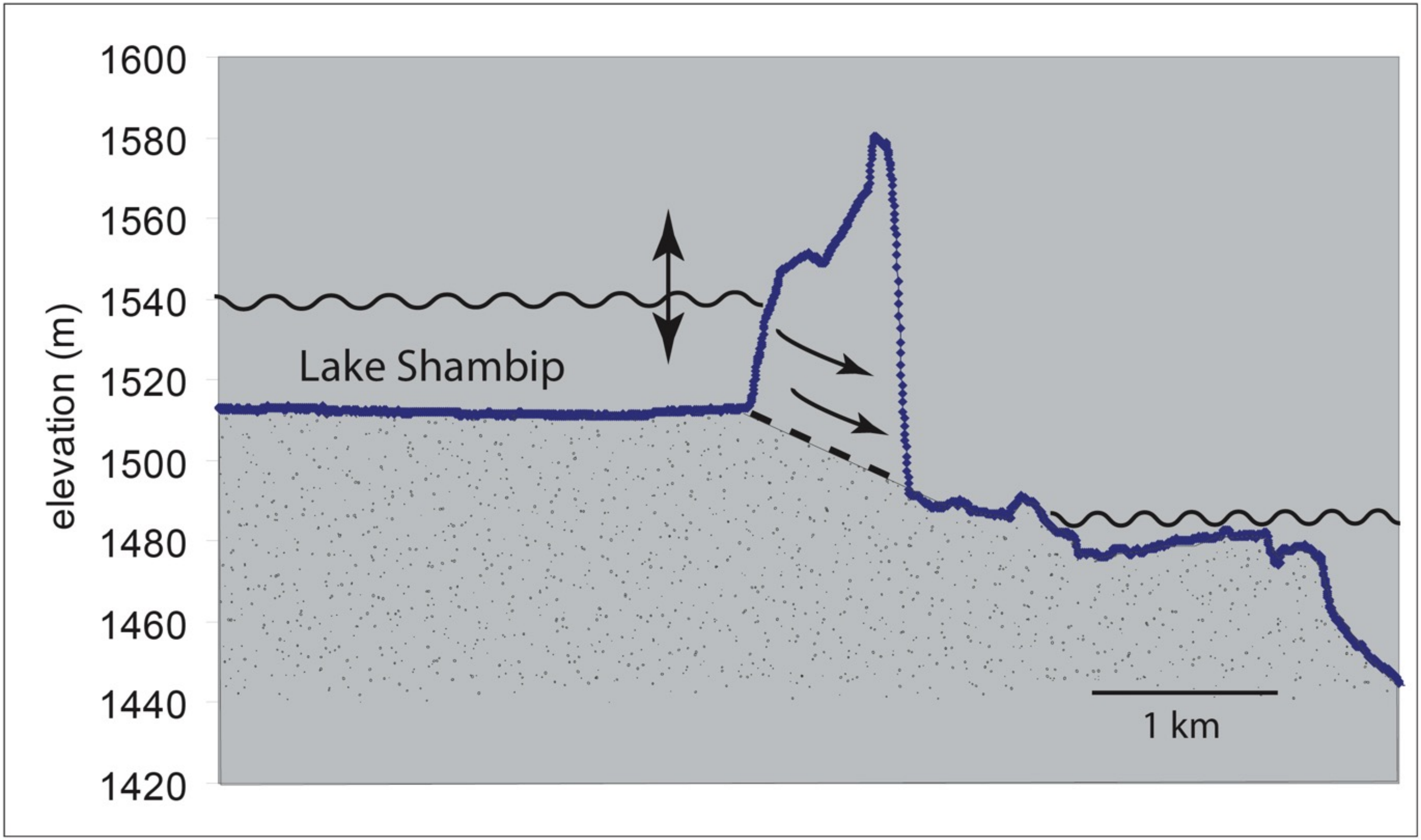
- Inputs: streams, groundwater, precipitation
- Outputs: evaporation, groundwater


112.5° W
112.4° W
112.3° W
112.2° W
Lake Bonneville
(1485 m)
40.5° N
40.4° N
40.3° N
40.2° N
1668 m
Lake Shambip
(1540 m)
1624 m
1624 m
0
3
6
12
Kilometers
N



Gardner and Kirby (2011): **4.8 x 10^7 m^3/yr**

Maximum outflow through the Stockton bar**: 1.2 x 10^6 m^3/yr**



1600
1580
1560
1540
1520
1500
1480
1460
1440
1420
elevation (m)
Lake Shambip
1 km

Conclusions

- Lake Shambip was hydrologically isolated from the main body of Lake Bonneville but appears to be contemporaneous with the long-lived Provo shoreline of Lake Bonneville to the north.

- Multiple water sources (surface inflows, groundwater, and lake effect precipitation) surrounded Lake Shampbip but there are no obvious significant outflows.

- A stable Lake Shambip thus implies a strong evaporative climate of this area during the time of the lake's existence.

CEDAR VALLEY LAKE—AN ISOLATED LAKE IN CEDAR VALLEY, UTAH COUNTY, UTAH, DURING THE BONNEVILLE LAKE CYCLE

Adam P. McKean and Jim M. Davis

Utah Geological Survey, Salt Lake City, UT 84116

Corresponding author (McKean): adammckean@utah.gov

ABSTRACT

Recent geologic mapping of Cedar Valley (Utah County, Utah) identified evidence for a lake that occupied the valley following the Lake Bonneville highstand. After the Bonneville flood 18,000 years ago, Lake Bonneville dropped to the Provo shoreline lake level and below the northern and southern thresholds of Cedar Valley. During the flood, waters flowing out of Cedar Valley appear to have scoured surficial deposits and Tertiary bedrock at the southern threshold, just south of Goshen Pass. Isolated from Lake Bonneville, the Cedar Valley drainage basin reverted to its own closed basin. Cedar Valley Lake stabilized at an elevation of about 4900 feet (1494 m) or 45 feet (14 m) below the southern threshold. Evidence for a stabilized lake level in Cedar Valley includes shorelines, gravel bars, beach deposits, and oversized alluvial channels. Since the lake level was well below the southern threshold, other factors within its catchment contributed to a stabilized lake elevation, potentially including precipitation, temperature, evaporation, stream flow, springs, seepage through bedrock, and groundwater. The lake likely persisted beyond the overflowing phase and perhaps into the regressive phase of Lake Bonneville.

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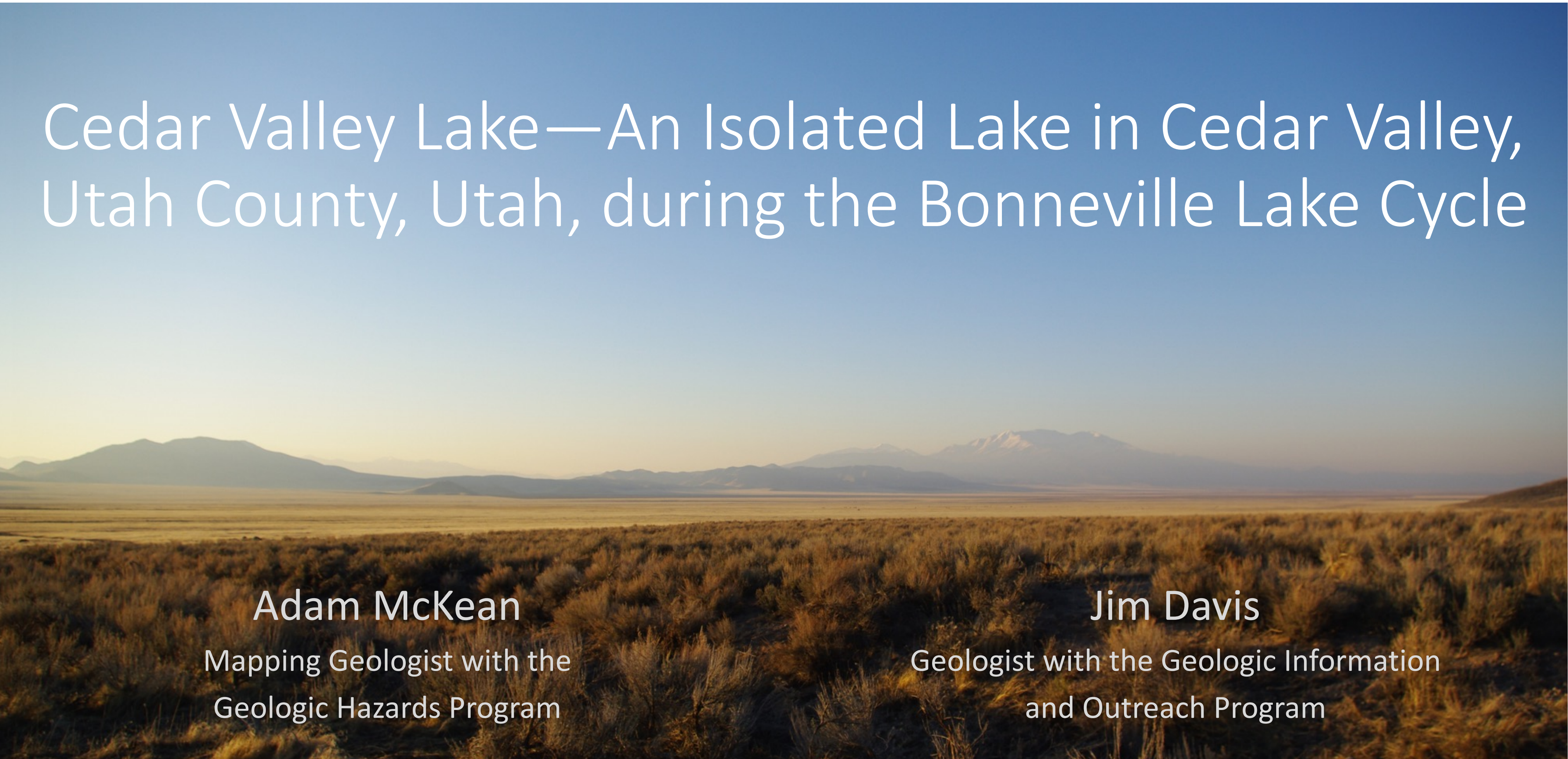


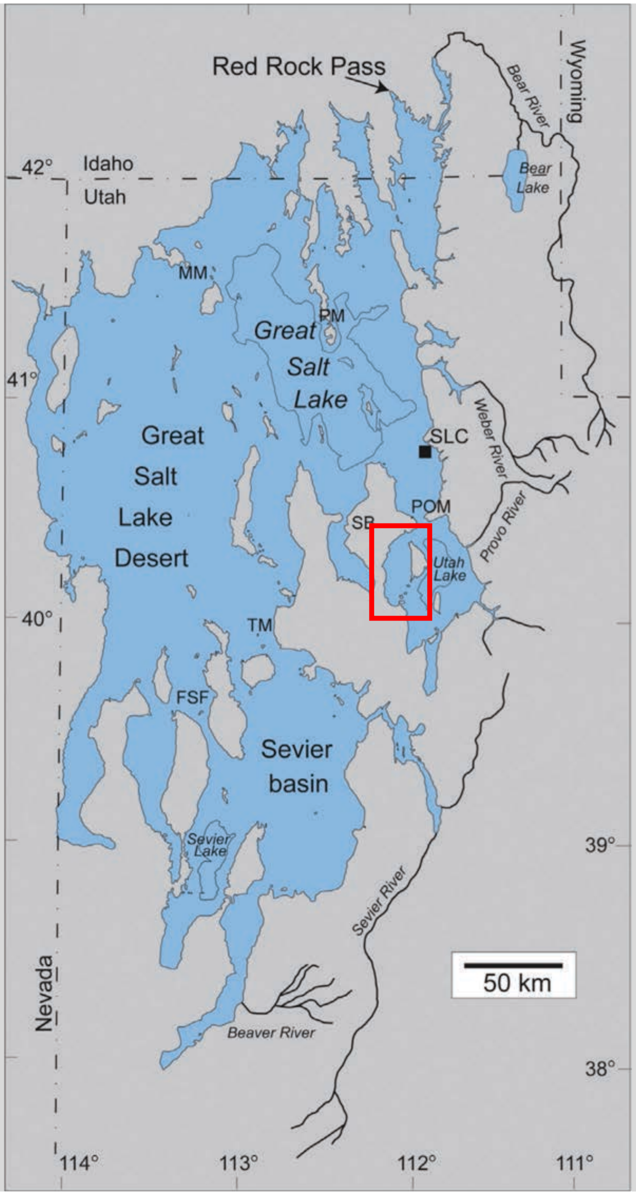
Cedar Valley Lake—An Isolated Lake in Cedar Valley, Utah County, Utah, during the Bonneville Lake Cycle

Adam McKean

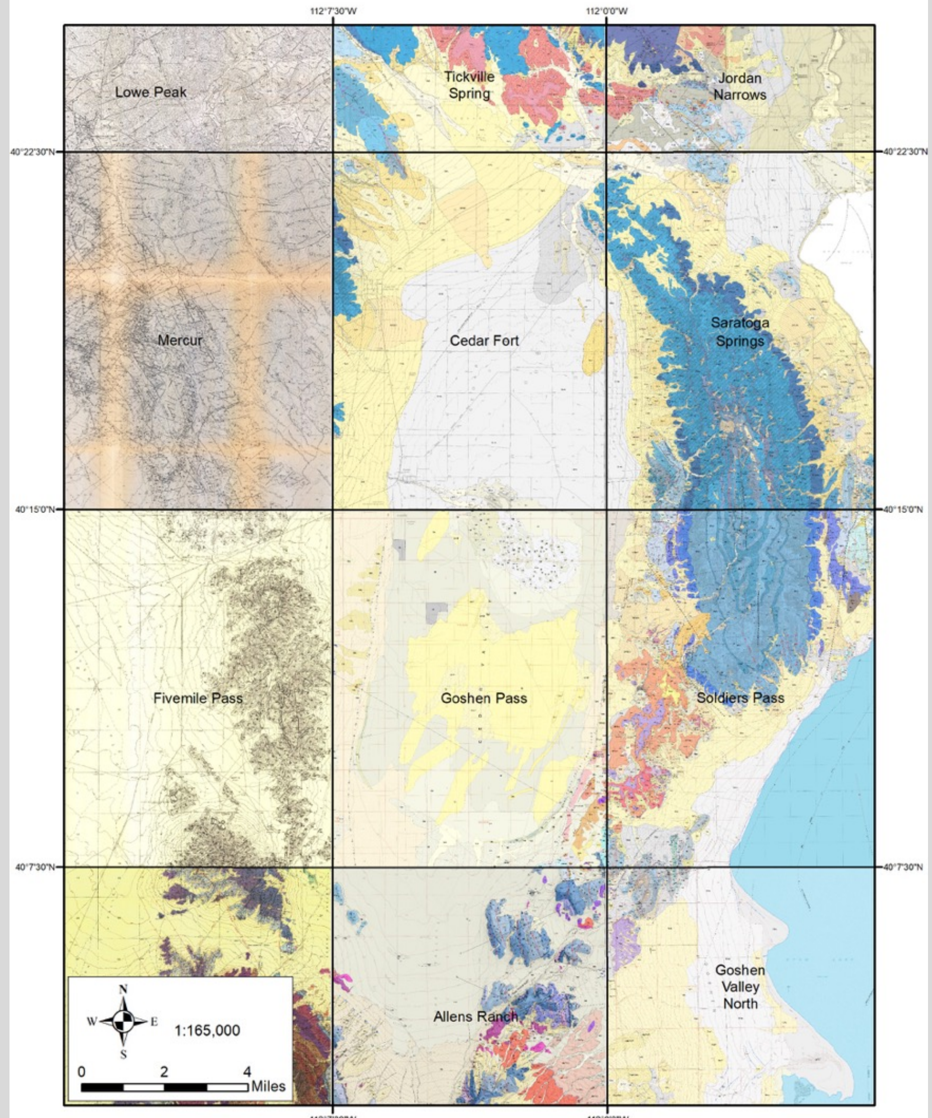
Mapping Geologist with the Geologic Hazards Program

Jim Davis

Geologist with the Geologic Information and Outreach Program



Oviatt and Jewell, 2016



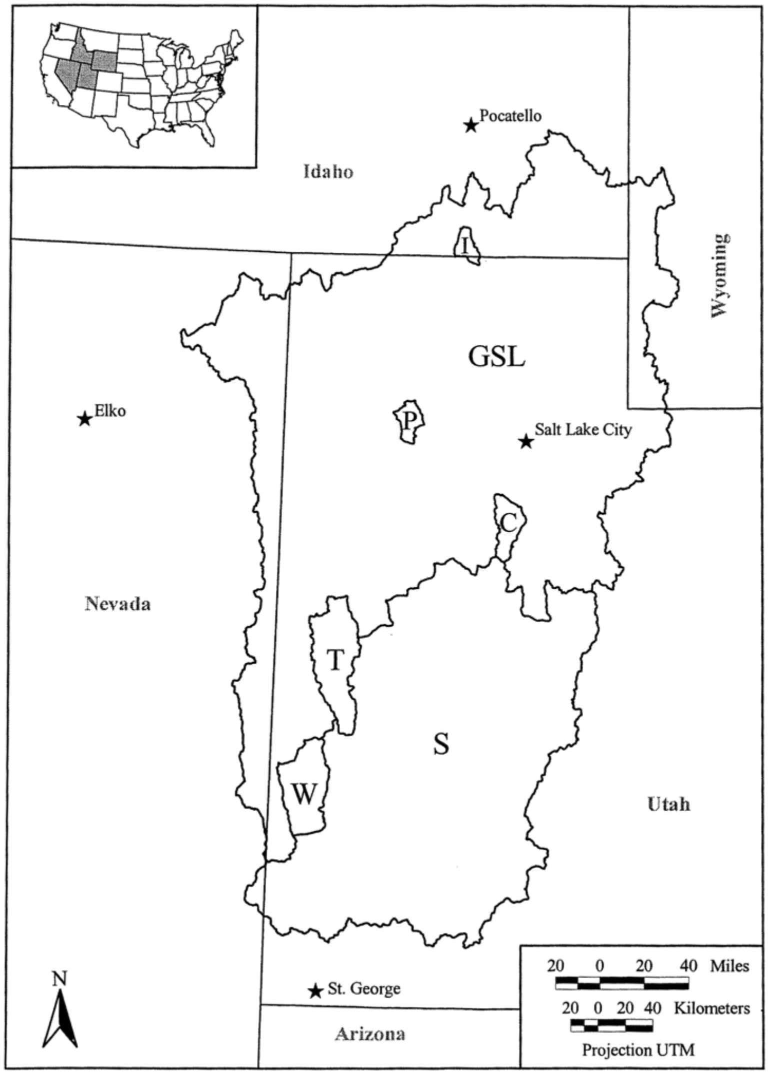


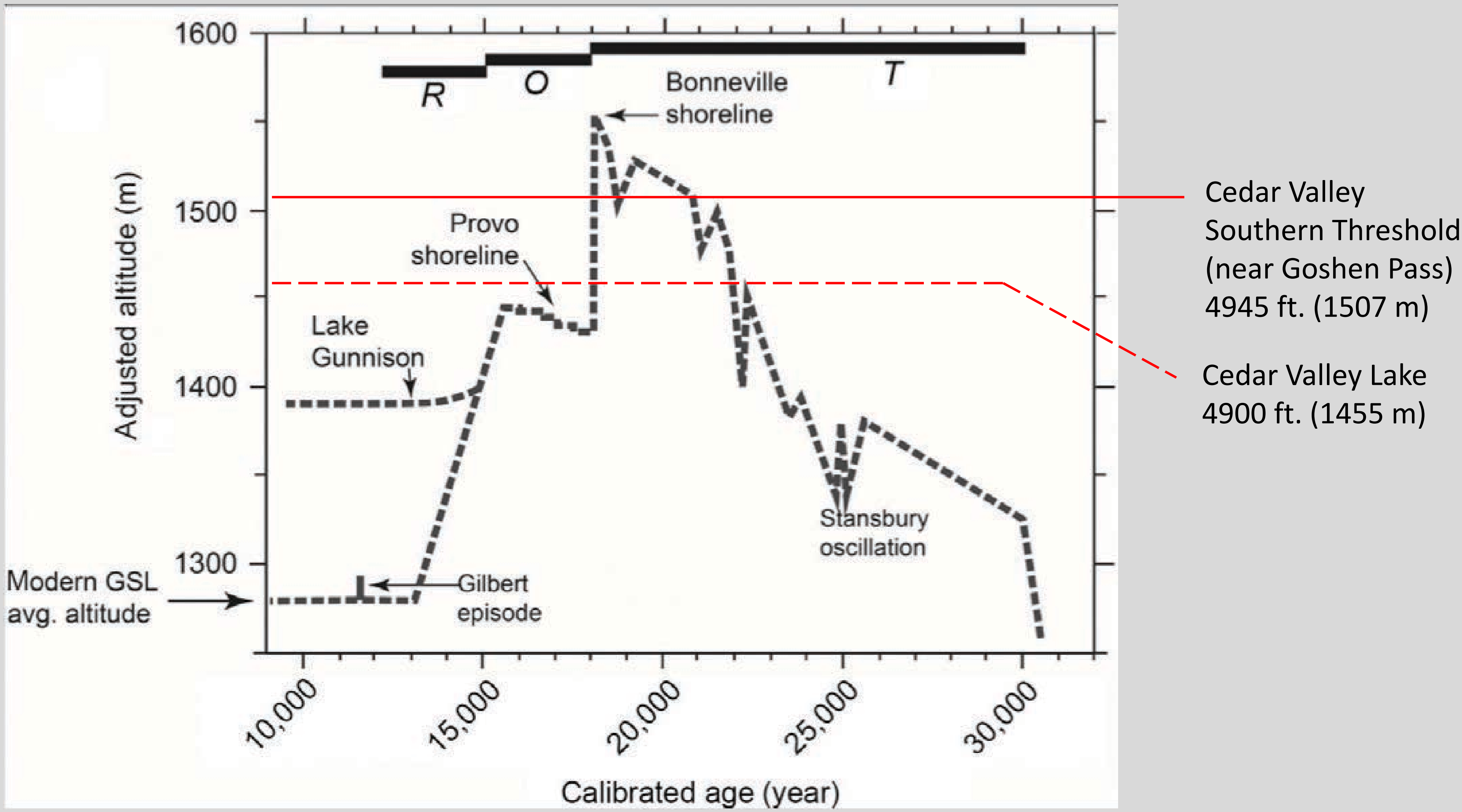
Fig. 6. Drainage basins for the different levels of Lake Bonneville:
C= Cedar Valley, GSL = Great Salt Lake basin, I = Pocatello Valley,
P = Puddle Valley, S= Sevier basin, T = Tule Valley, and W = Pine Valley.

Tamara J. Wambeam 2001, Modeling Lake Bonneville basin morphology using digital elevation models

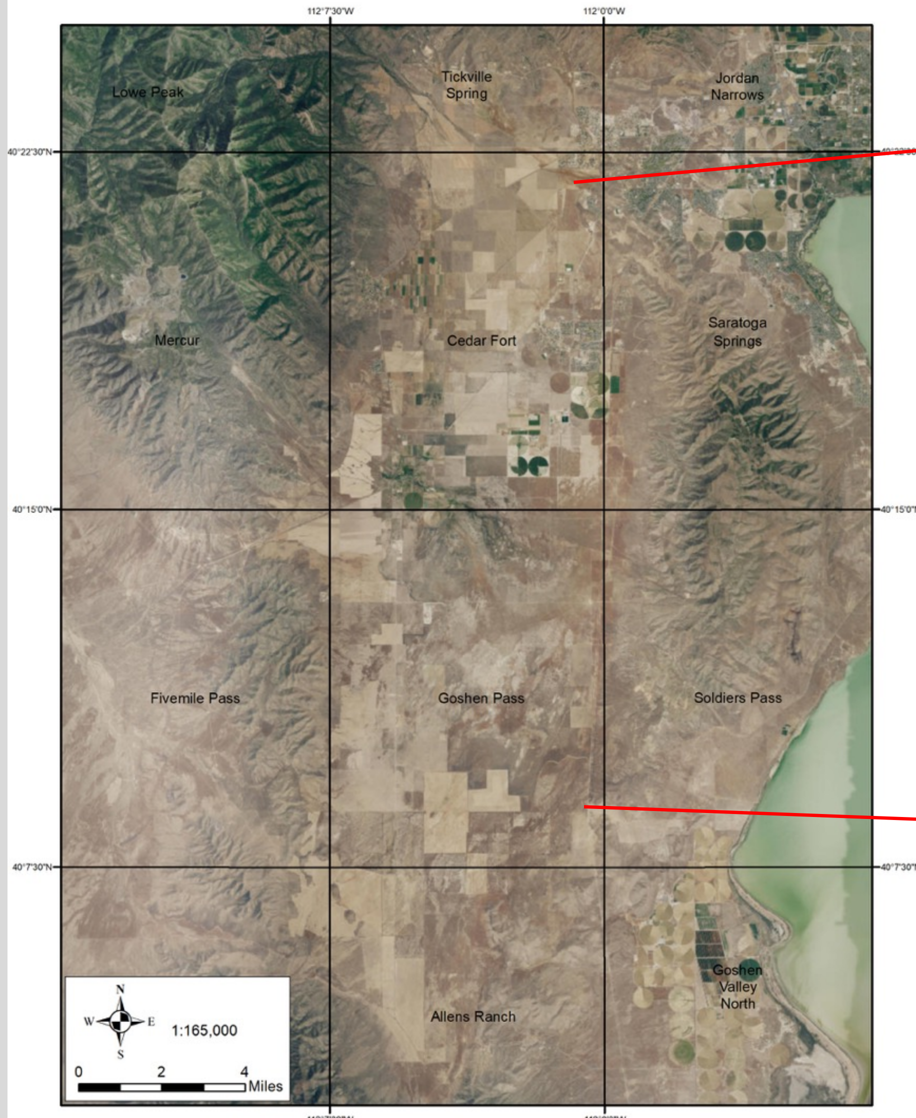
University of Utah, M.S. Thesis

Table 2. DRAINAGE BASIN AREAS

Drainage Basin	Area (km^2)
Bonneville basin (minus all other basins)	88,364
Cedar Valley, UT	699
Pine Valley, UT	1,903
Pocatello Valley, ID & UT	305
PuddleValley, UT	395
Sevier, UT	42,707
Tule Valley, UT	2,441
Total Bonneville drainage area	134,606

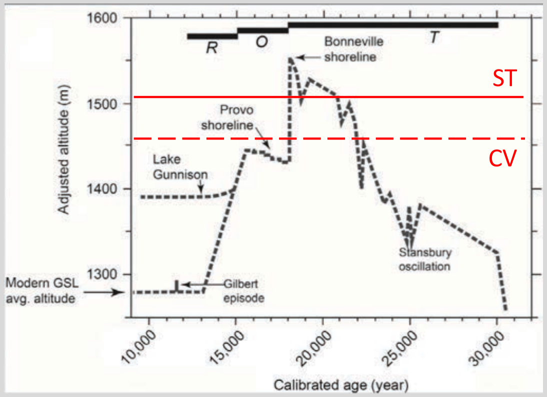


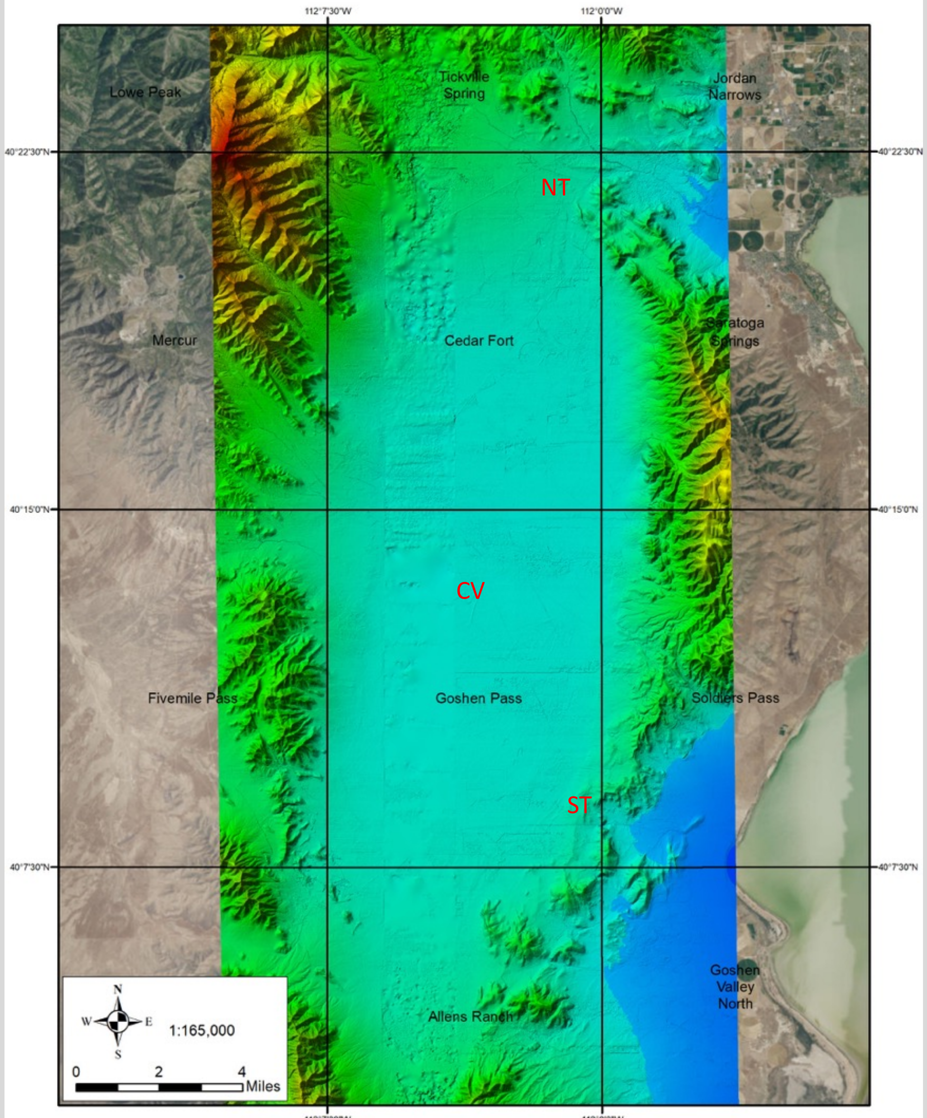
Oviatt and Jewell, 2016



Cedar Valley North Threshold (Cedar Pass)

Cedar Valley Southern Threshold (near Goshen Pass)





5140 ft. (1567 m) Lake Bonneville Highstand

Bonneville Flood

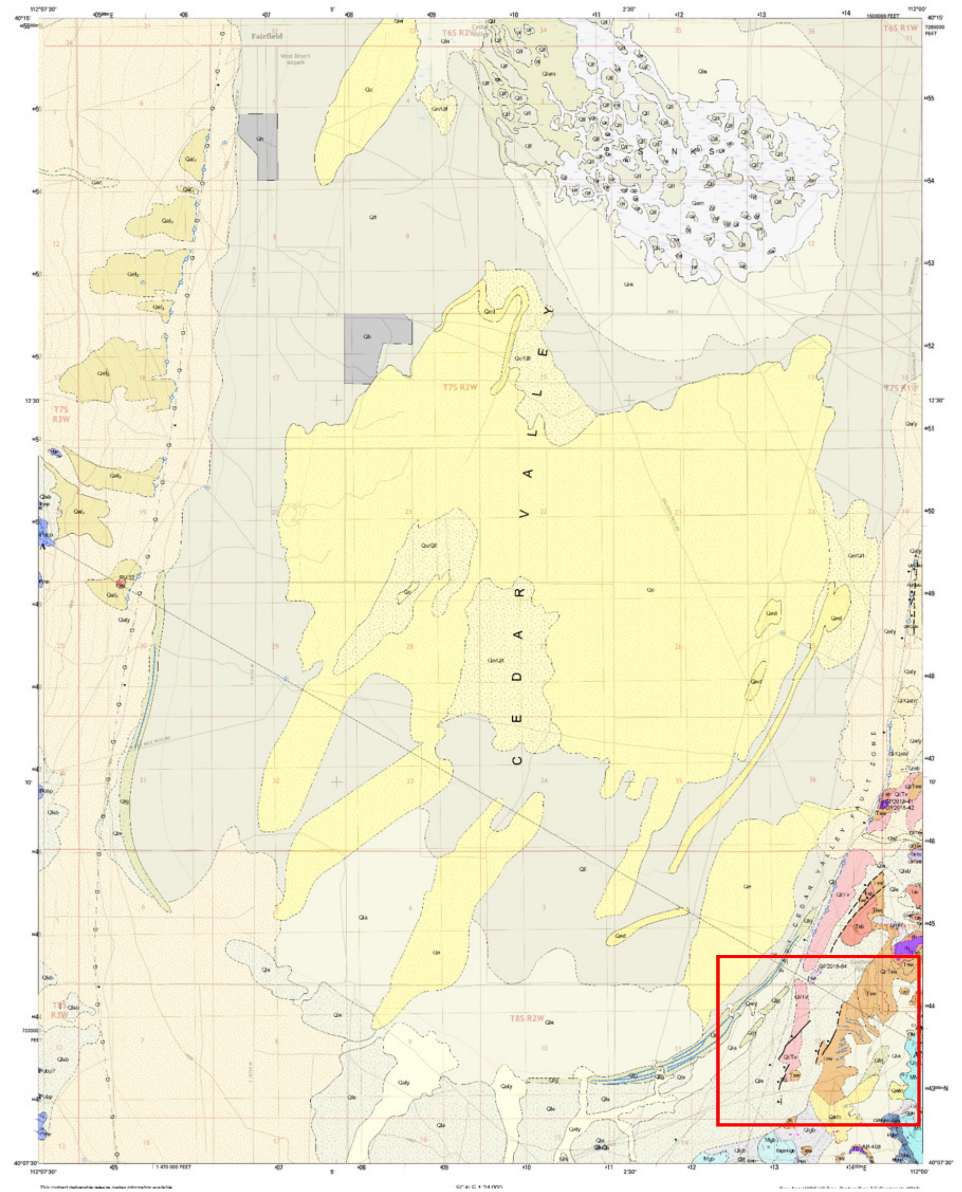
- 4985 ft. (1519 m) Cedar Valley North Threshold (NT) (Cedar Pass)
- 4950 ft. (1509 m) Cedar Valley South Threshold (ST) (near Goshen Pass)
- 4940 ft. (1506 m) Cedar Valley South Threshold (ST) (near Goshen Pass)

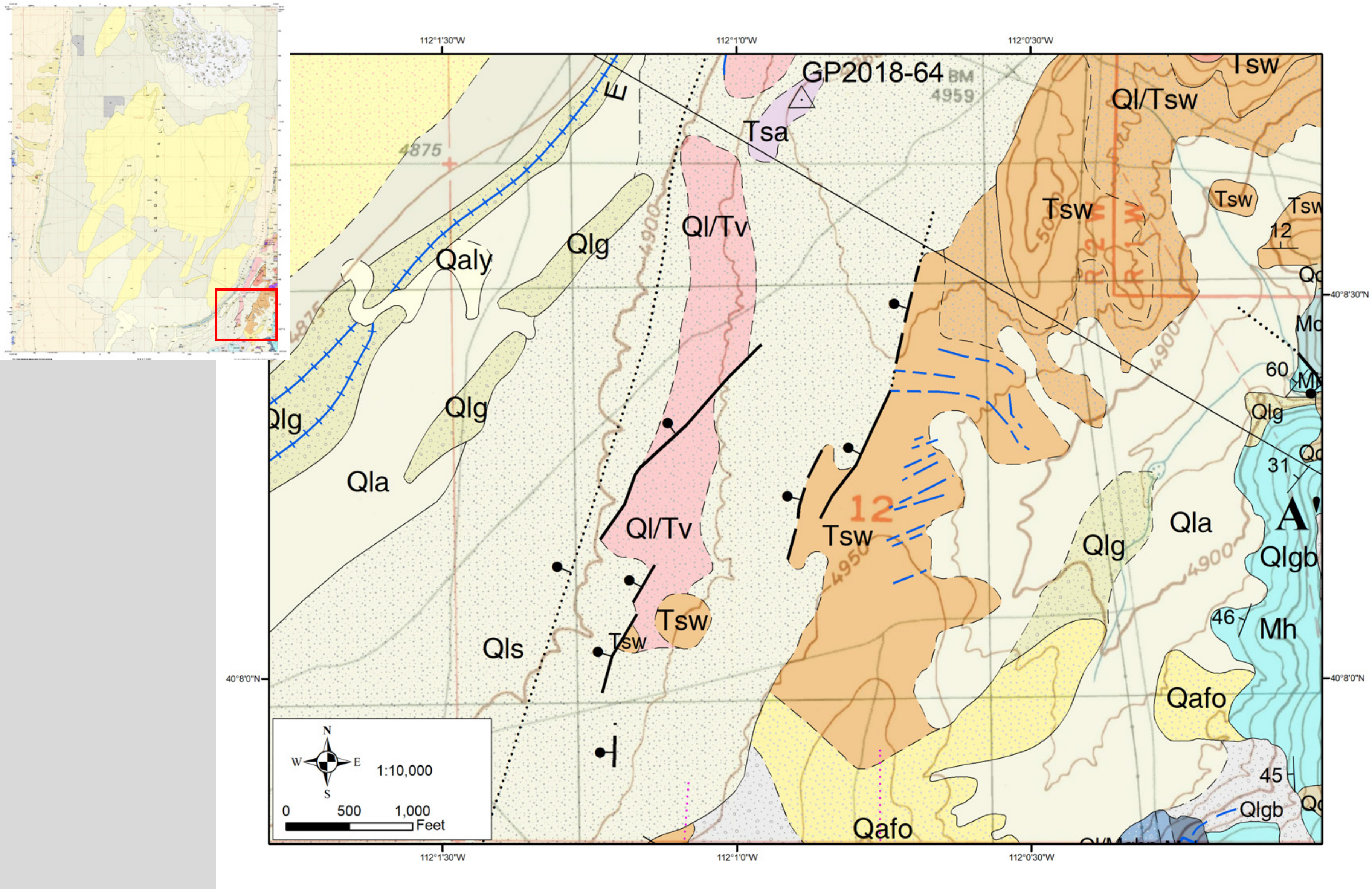
4900 ft. (1494 m) Cedar Valley Lake (CV)

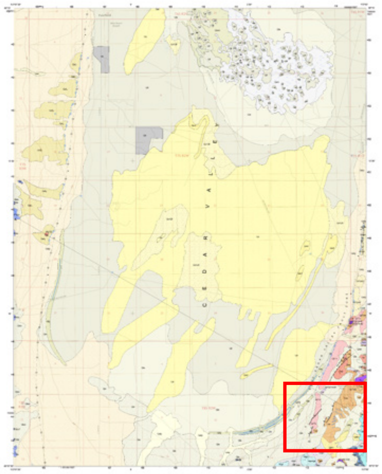
4775 ft. (1455 m) Provo Shoreline

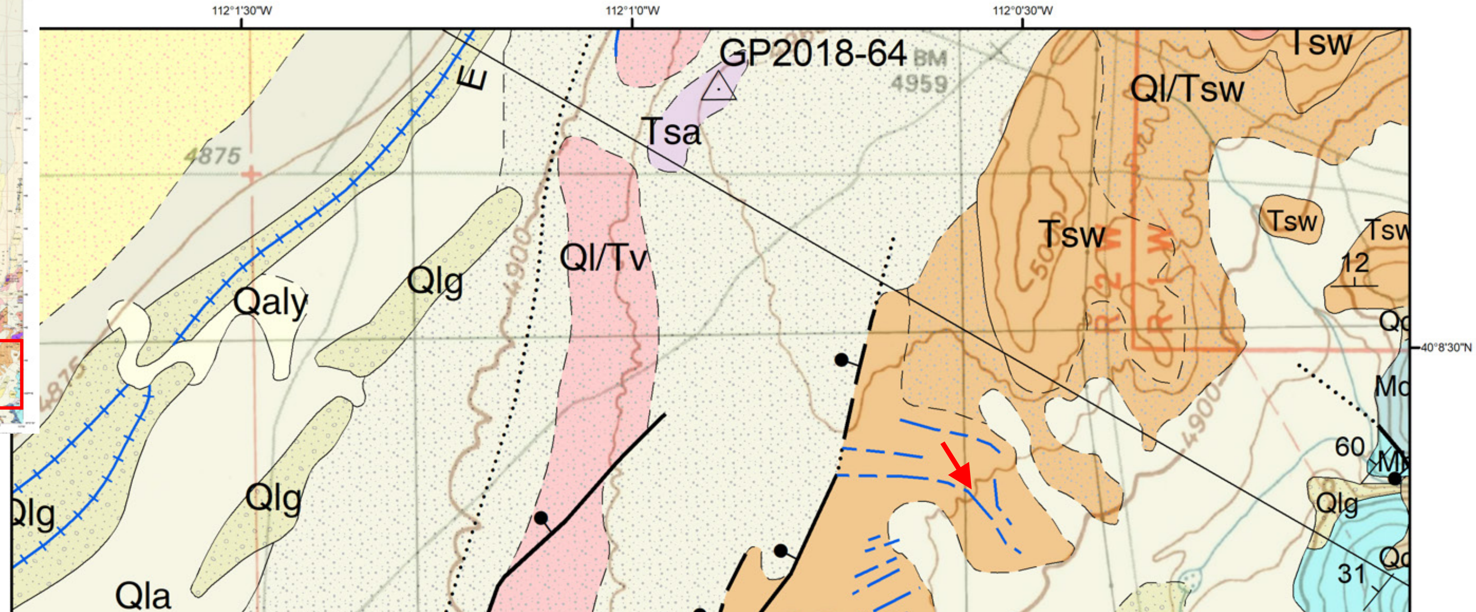
Evidence of the Bonneville Flood waters leaving Cedar Valley at the Southern Threshold:

- Scoured surficial deposits
- Scoured Tertiary bedrock




112°1'30"W
112°1'0"W
112°0'30"W
40°8'30"N
40°8'0"N
GP2018-64
BM
4959
4875
4900
4950
Tsa
Tsw
Ql/Tsw
Ql/Tv
Qaly
Qlg
Qla
Qls
Qafo
Qlgb
Mh
A'
12
60
31
46
45
N
S
W
E
1:10,000
0
500
1,000
Feet





112°1'30"W
112°1'0"W
112°0'30"W
40°8'30"N
GP2018-64
BM
4959
Tsw
Ql/Tsw
Tsa
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4900
Ql/Tv
Qlg
Qaly
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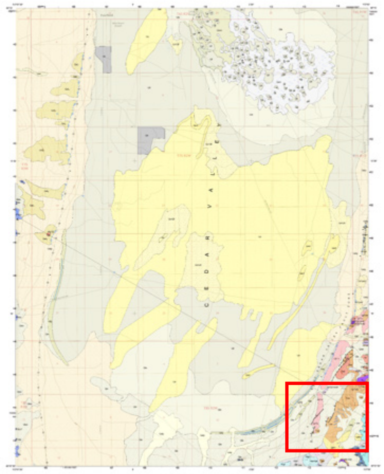
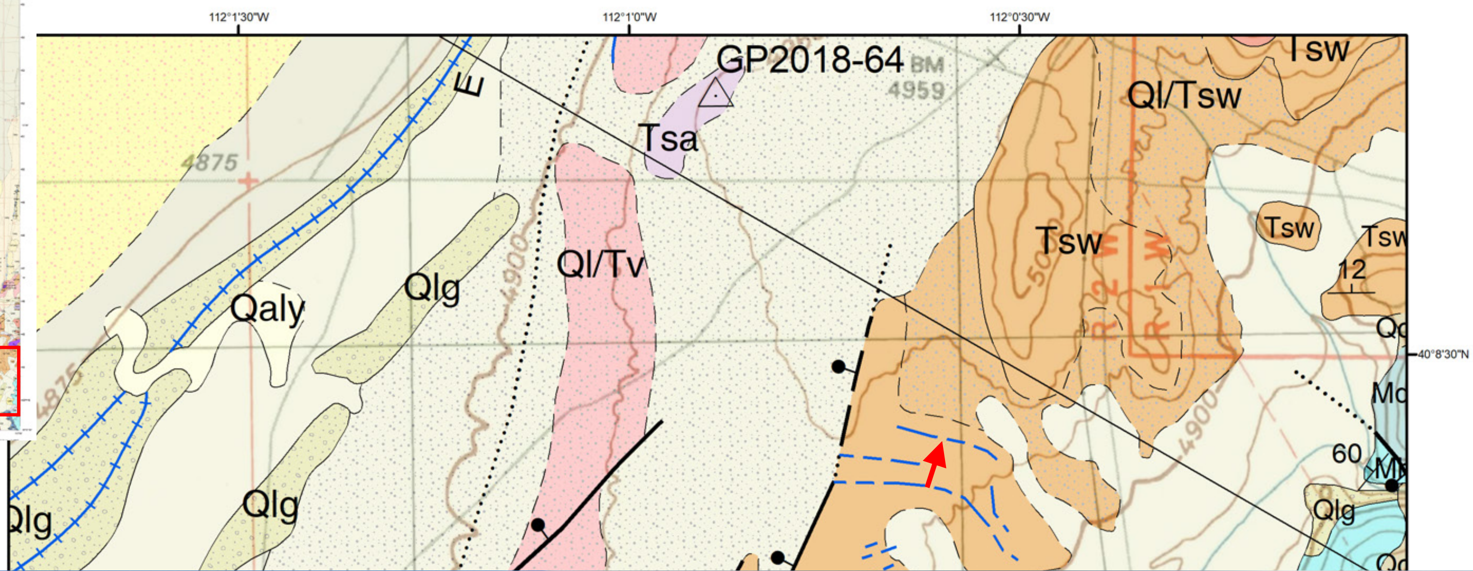
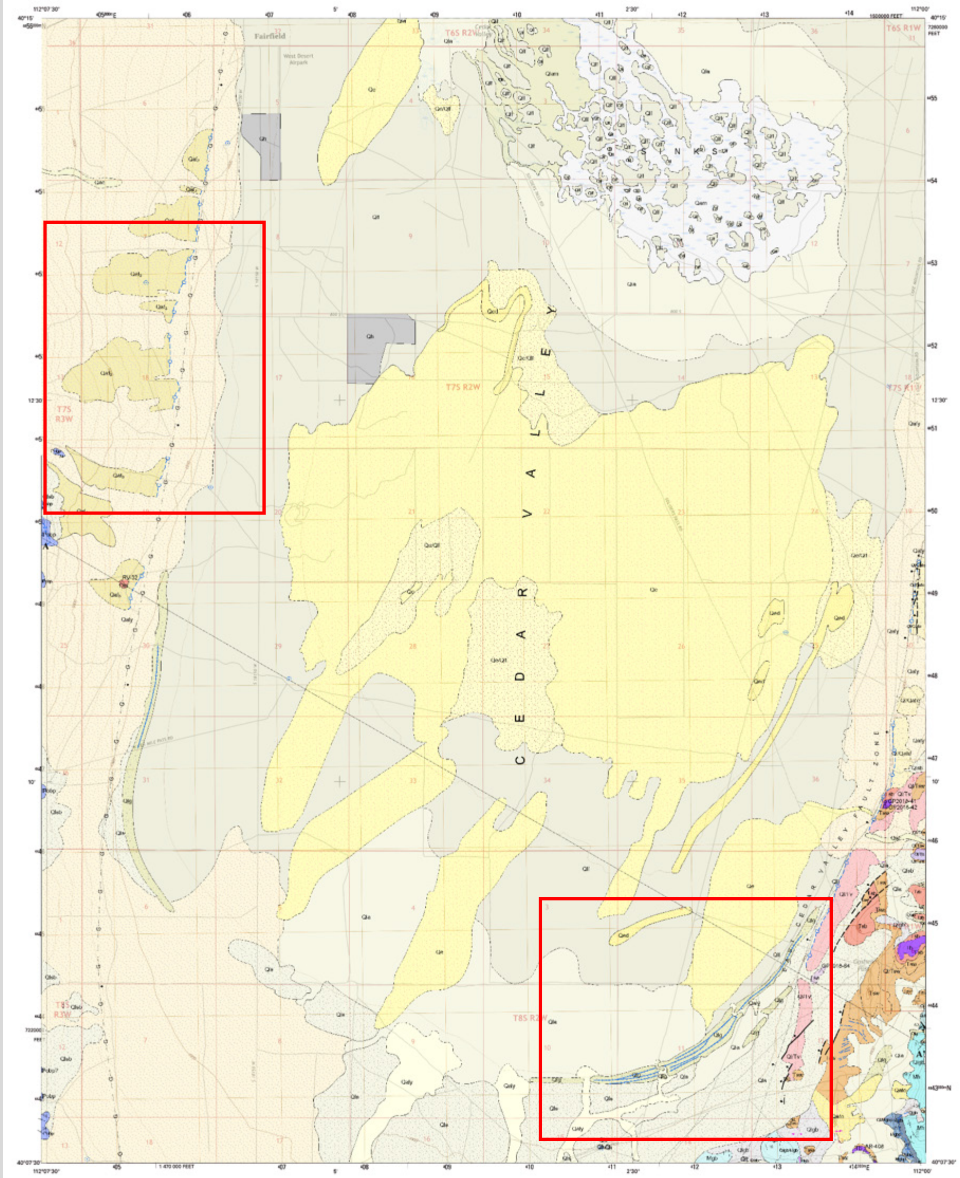
Tsw
12
60
31
Qlg
Qla

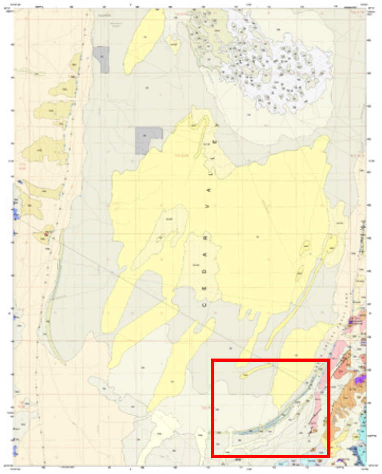


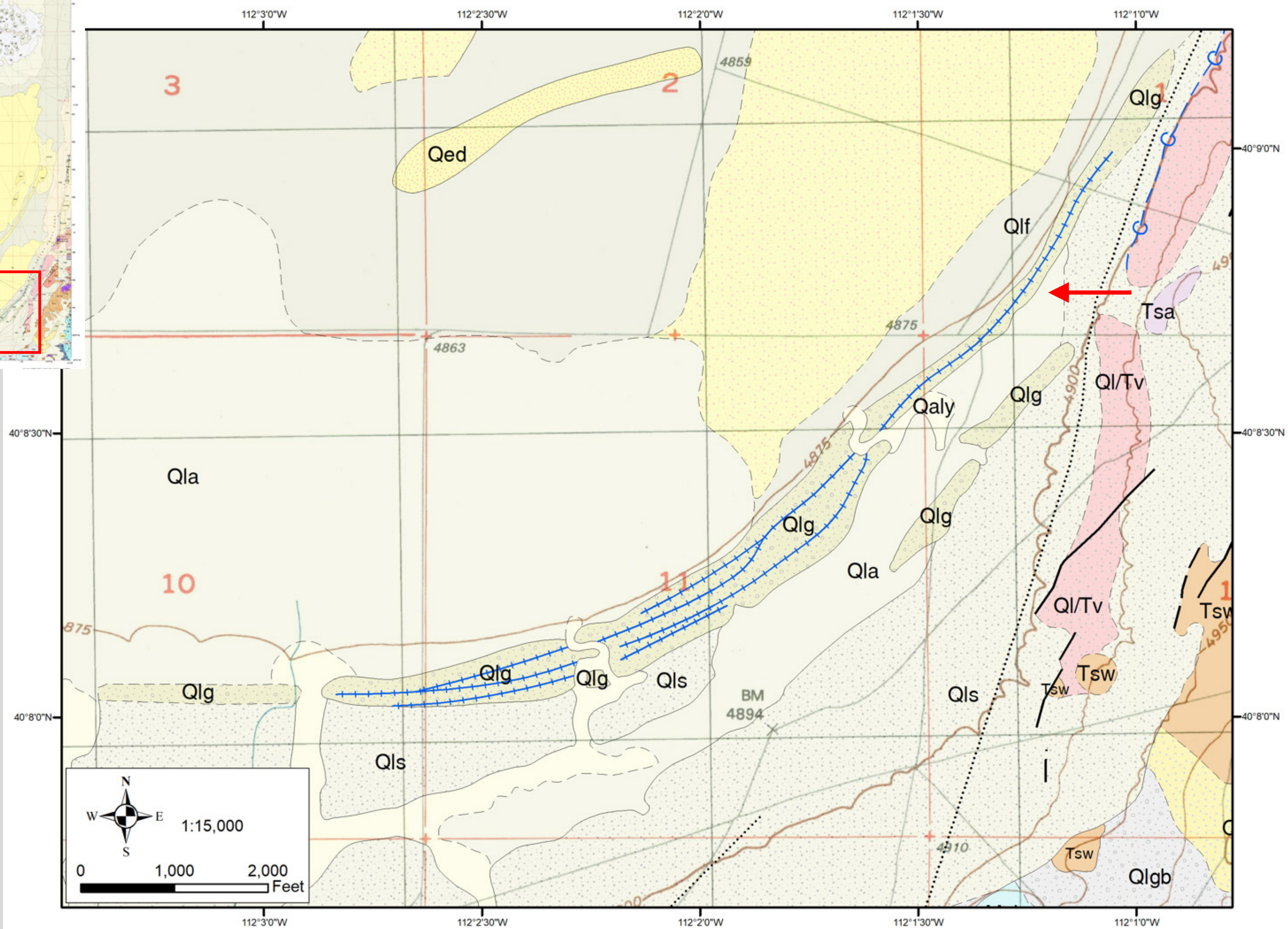

112°1'30"W
112°1'0"W
112°0'30"W
GP2018-64
BM
4959
Tsw
Ql/Tsw
Tsa
4875
Ql/Tv
Qlg
Qaly
Qlg
Qlg
Tsw
Tsw
Tsw
12
40°8'30"N
60
Qlg
4900

Evidence for a stabilized lake level in Cedar Valley includes:

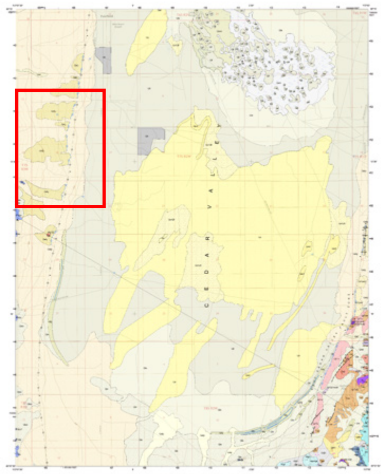
- Shorelines
- Gravel bars
- Beach deposits
- Oversized alluvial channels

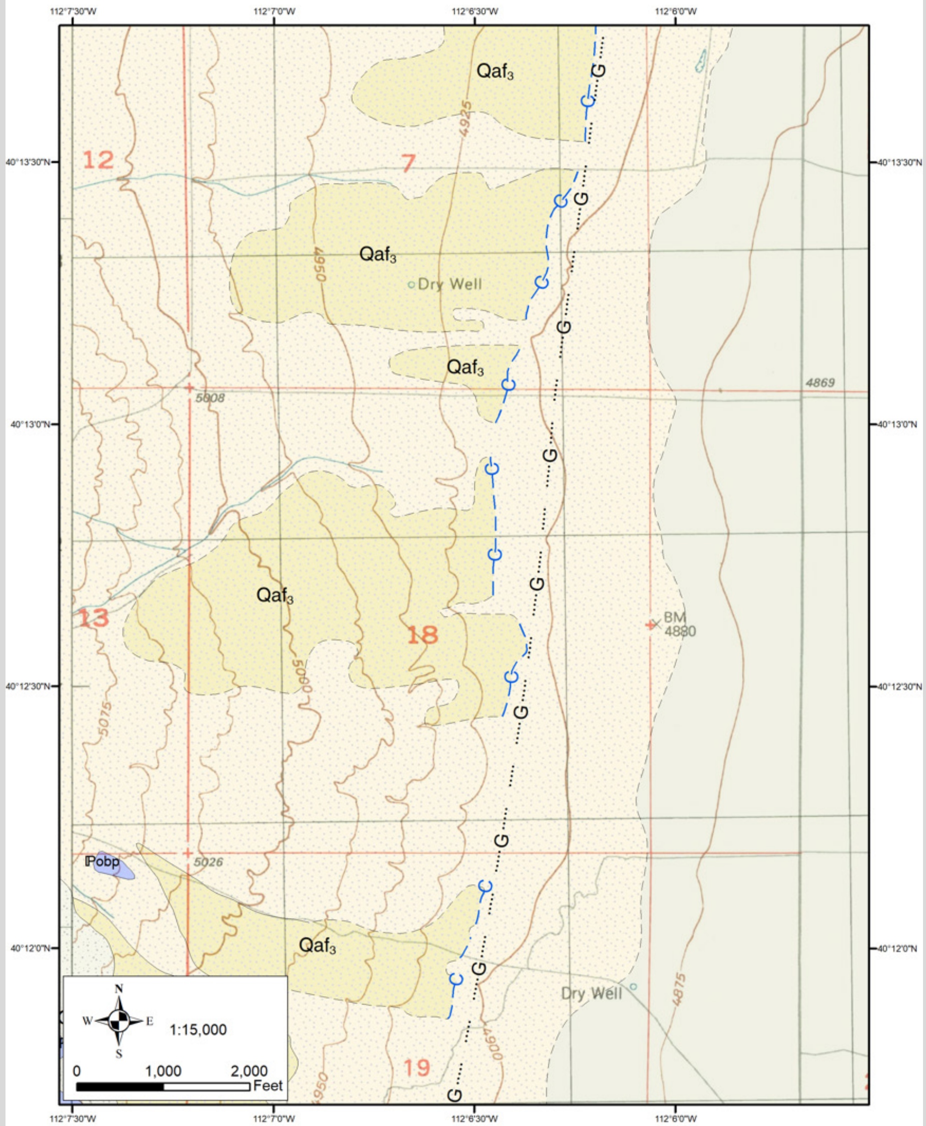






112°3'0"W
112°2'30"W
112°2'0"W
112°1'30"W
112°1'0"W
40°9'0"N
40°8'30"N
40°8'0"N
3
2
10
11
4859
4863
4875
4900
4910
Qed
Qla
Qlf
Qlg
Qaly
Qls
Qlgb
Tsa
Tsw
Ql/Tv
BM
4894
N
W
E
S
1:15,000
0
1,000
2,000
Feet




112°7'30"W
112°7'0"W
112°6'30"W
112°6'0"W
40°13'30"N
40°13'0"N
40°12'30"N
40°12'0"N
Qaf$_3$
Qaf$_3$
Qaf$_3$
Qaf$_3$
Qaf$_3$
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7
13
18
19
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Dry Well
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4950
5008
4869
5075
5000
5026
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N
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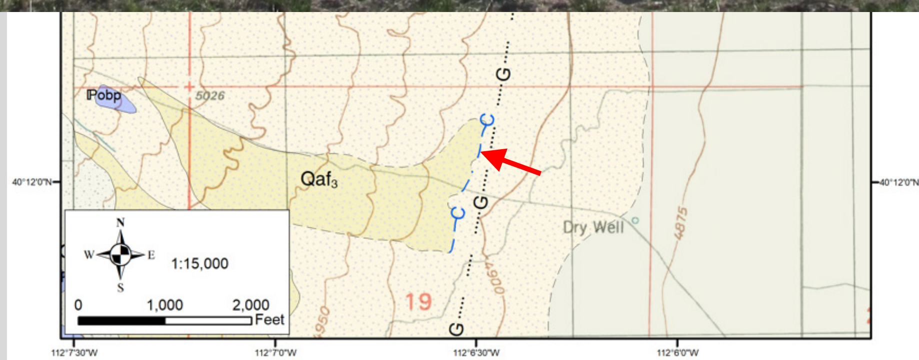
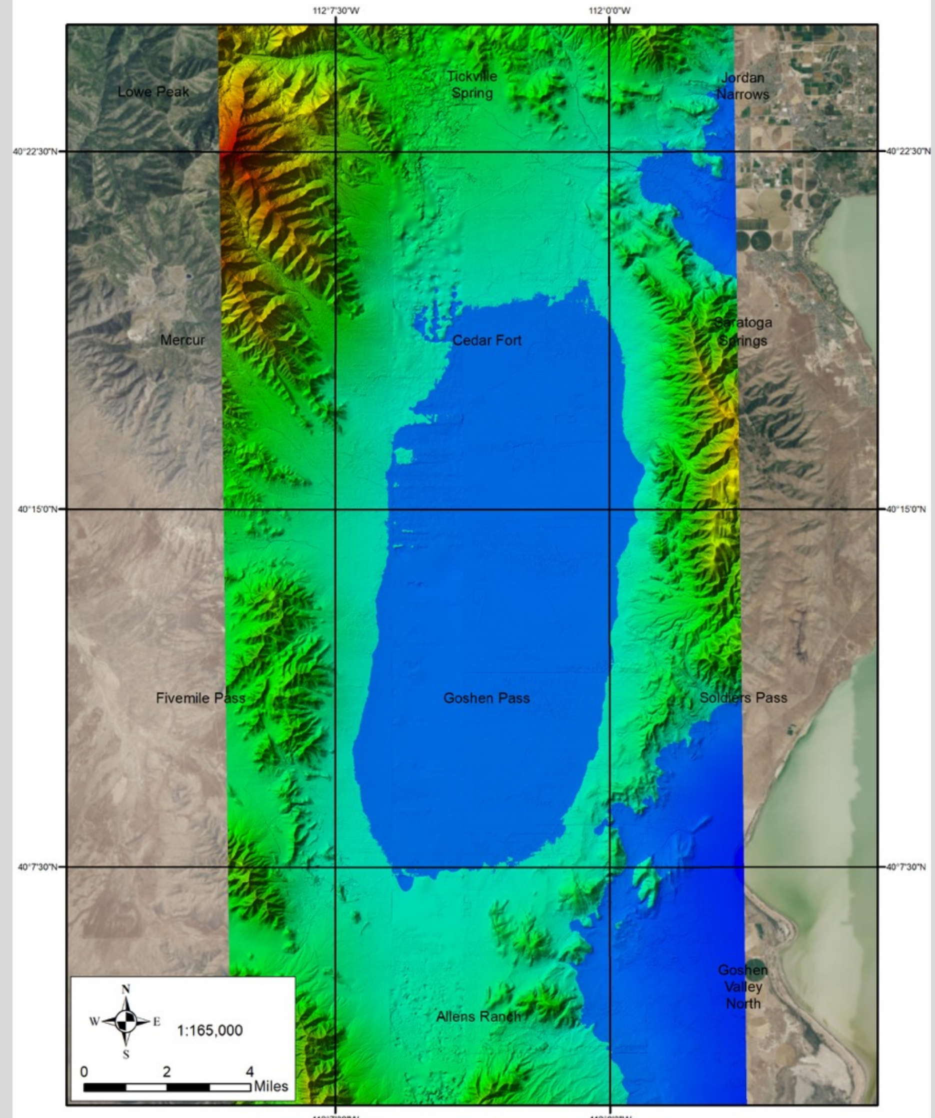
E
S
1:15,000
0
1,000
2,000
Feet



Pobp
5026
Qaf3
G
C
Dry Well
4875
4900
4950
19
N
S
E
W
1:15,000
0
1,000
2,000
Feet
40°12'0"N
112°7'30"W
112°7'0"W
112°6'30"W
112°6'0"W

Since the lake level was well below the southern threshold, other factors within its catchment contributed to a stabilized elevation, potentially including:

- Precipitation
- Temperature
- Evaporation
- Stream flow
- Springs
- Interbasin groundwater flow



Thank you

REVISITING THE DEFORMED HIGH SHORELINE AND ISOSTATIC REBOUND OF LAKE BONNEVILLE

Christine Y. Chen[1], Jacky Austermann[2], Konstantin Latychev[2,3], Harriet C.P. Lau[3], Adam Maloof[4]

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[2]Lamont-Doherty Earth Observatory, Columbia University, NY 10964;
[3]Harvard University, Cambridge, MA 02138;
[4]Princeton University, Princeton, NJ 08544

Corresponding author (Chen): ccy@mit.edu

ABSTRACT

Late Pleistocene Lake Bonneville is one of the classic locales for study of the solid earth response to surface loading. Due in large part to the semi-arid Holocene climate, Lake Bonneville's shorelines are outstandingly well preserved, recording a complex history of lake level variations induced by deglacial climate change. The spatial pattern of the elevations of these shoreline features are famously deformed such that features from the center of the lake are uplifted by ~75 m relative to features along the periphery (Currey, 1982; Chen and Maloof, 2017).

Our presentation has two parts: We present (1) a dataset of 176 unique shoreline feature elevations of the highest Bonneville shoreline, which were measured using high-precision differential GPS (dGPS) (Chen & Maloof, 2017); and (2) computations of lake and Laurentide ice sheet loading and rebound, which we use to infer constraints on upper mantle viscosity and show the possible far-field effect of the Laurentide ice sheet on the pattern of Lake Bonneville shoreline deformation (Austermann and others, in preparation).

For (1), we build upon work by Currey (1982) and investigate the relationship between different shoreline feature elevations and the still water level (SWL). From this analysis, we estimate the uncertainty of the elevation of the SWL relative to each shoreline feature elevation measurement in the compilations by Chen and Maloof (2017) and Currey (1982). Combining these two datasets, we use these constraints on the SWL to reconstruct our best estimate of the lake volumes of the Bonneville and Provo lake stages.

For (2), using the revised lake level chronology of Oviatt (2015), and the aforementioned lake volume constraints, we compute gravitationally self-consistent calculations of lake and Laurentide ice sheet loading that utilize 1-D (depth-dependent only) and 3-D viscosity structures (Kendall and others, 2005; Latychev and others, 2005) based on improved mapping of the lithosphere and subsurface (Watts, 2006; Obrebski and others, 2011). We also investigate to what degree lateral variations in viscosity are required to fit both the lake rebound and tilt from the peripheral bulge of the coincident Laurentide ice sheet.

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ADAPTATION, MITIGATION, AND BIOPHYSICAL FEEDBACKS IN THE CHANGING BONNEVILLE SALT FLATS

Brenda Bowen[1], Ciaran Harman[2], Matthew Brownlee[3], Kevin Deluca[4],
William Brazelton[5], and John Horel[6]

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[2]Environmental Health and Engineering, Johns Hopkins University, Baltimore, MD 21218;
[3]Parks and Conservation Area Management, Clemson University, Clemson, SC 29634;
[4]Department of Communication, University of Utah, Salt Lake City, UT 84112;
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ABSTRACT

Bonneville Salt Flats (BSF) in northwest Utah is one of the final depositional remnants of the Lake Bonneville system, and contains important evaporite sedimentological records of lake desiccation, but is also impacted by complex modern environmental and human-related processes. The system is highly dynamic, responding to variations in rain, wind, evaporation, and groundwater flux, and also to a century of land-speed racing, potash mining, and recreation which creates an intertwined social and hydrologic system. North of I-80, a century of racing has created a culture that loves the salt. South of I-80, a century of mining divides salty basins into different classes of brine evolution to produce potash, a key ingredient in the agricultural fertilizer used to feed an expanding global population. The system is now changing in ways that are limiting historical uses, and managers are responding with mitigation efforts to try to maintain multiple uses.

The character of BSF changes on daily, weekly, monthly, annual, and geologic time scales in response to fluctuations in water balance, solute flux, and groundwater flow which is impacted by both local meteorology and water management associated with mining. In addition, the texture of the salt surface is changed by land use including racing activities, which impacts water fluxes through the crust. Land managers and stakeholders are actively making decisions about what to do to try to preserve this environment, primarily for the legacy of land speed racing, while still maintaining opportunities for natural resource extraction and ecosystem function. However, without a clear and quantified understanding of the processes governing the biophysical system and the complex connections between the social fabric and biophysical processes, mitigation efforts may not have the desired outcomes.

Our research aims to transform our understanding of both the social and natural systems that are intertwined at BSF to enable data-driven decision-making and effective relationships among those interconnected by this unique place. The environmental, hydrological, and microbiological conditions at BSF impact the salt crust over a range of spatial and temporal scales. Five years of field observations and sampling, analyses of satellite imagery dating back the 1980s, and geochemical analysis of surface brines have shown that spatiotemporal changes in surface water and fluctuations in the surface salt footprint are linked to both climate and land use. A new weather station installed in the Fall of 2016 in the middle of BSF allows for unprecedented analyses of halite surface dynamics. An understanding of the processes that change the surface composition and texture through time inform interpretation of subsurface saline deposits at BSF. In addition, human activities, decisions, mitigation efforts, and adaptation to changing conditions impact the biophysical system. Ongoing research seeks to quantify the rates and characteristics of biophysical and hydrological change and evaluate the feedbacks between the biophysical changes and the stakeholder communities. BSF provides a unique platform for providing broadly transferable insights into the complex dynamics and feedbacks between coupled social-ecological systems in an actively changing and highly valued environment.

This content is a PDF version of the author's PowerPoint presentation.

Adaptation, Mitigation, and Biophysical Feedbacks in the Changing Bonneville Salt Flats

Brenda Bowen, Ciaran Harman, Matthew Brownlee, Kevin Deluca, William Brazelton, and John Horel

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https://youtu.be/6OfULicrhJg

Adaptation, Mitigation, and Biophysical Feedbacks in the Changing Bonneville Salt Flats

Oct.3, 2018

Brenda Bowen, Geology & Geophysics, University of Utah
Ciaran Harman, Environmental Health & Engineering, Johns Hopkins University
Matthew Brownlee, Parks & Conservation Area Management, Clemson University
Kevin DeLuca, Communication, University of Utah
William Brazelton, Biological Sciences, University of Utah
John Horel, Atmospheric Sciences, University of Utah

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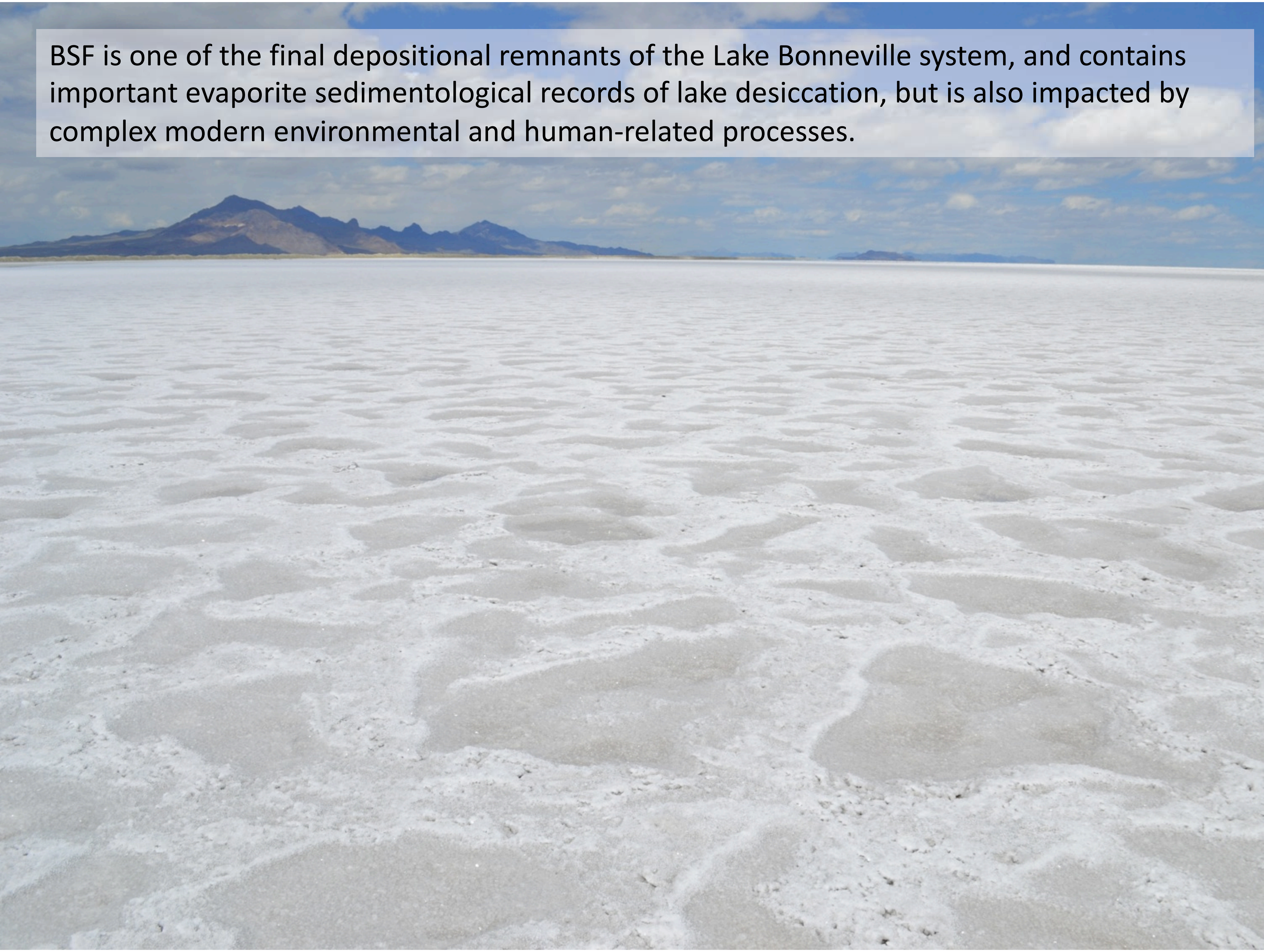
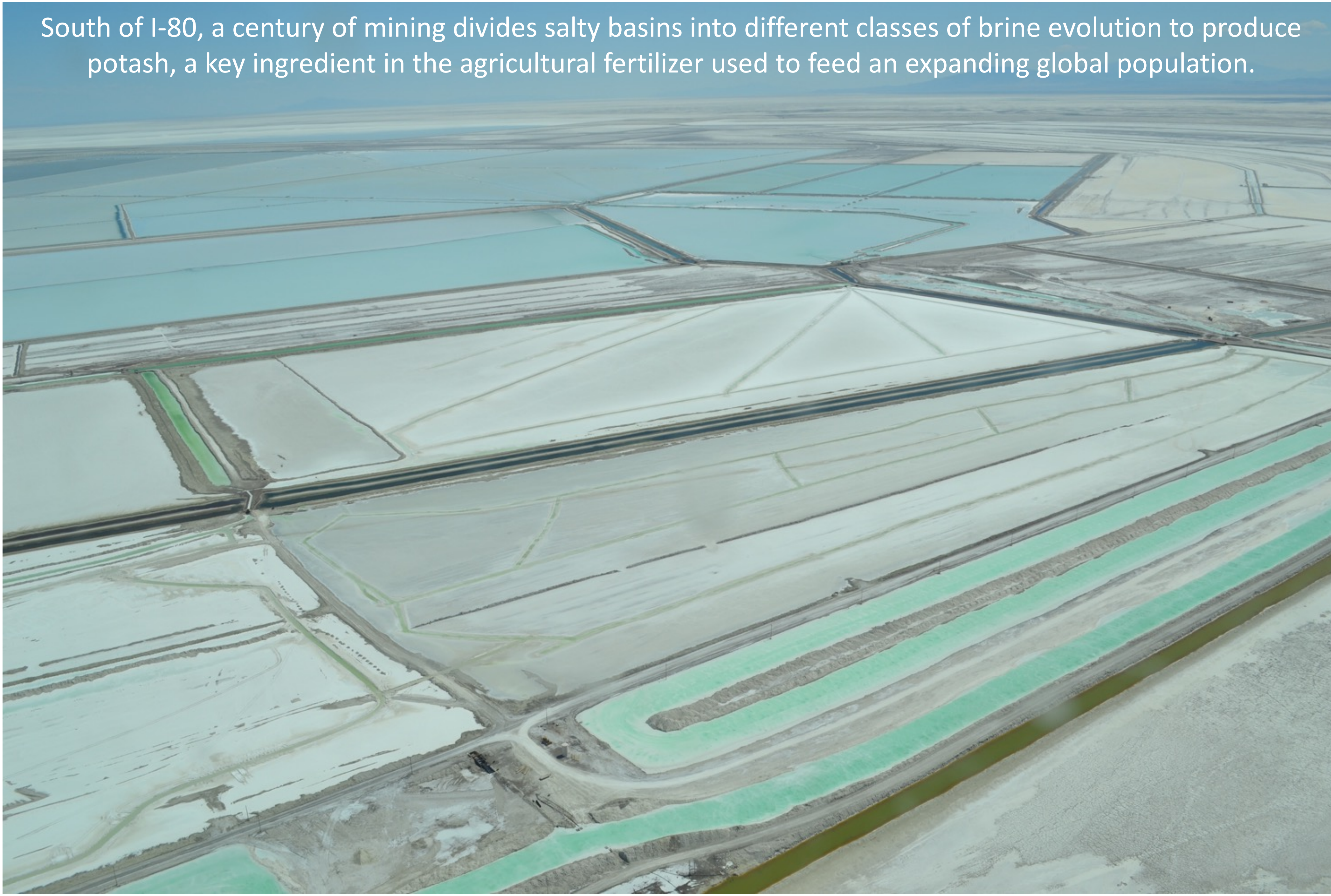


Pirates of the Caribbean, 2007

The system is highly dynamic, responding to variations in rain, wind, evaporation, and groundwater flux, and also to a century of land-speed racing, potash mining, and recreation which creates an intertwined social and hydrologic system.

North of I-80, a century of racing has created a culture that loves the salt.


South of I-80, a century of mining divides salty basins into different classes of brine evolution to produce potash, a key ingredient in the agricultural fertilizer used to feed an expanding global population.

THE SALT LAKE TRIBUNE, SUNDAY MORNING, SEPTEMBER 12, 1915.

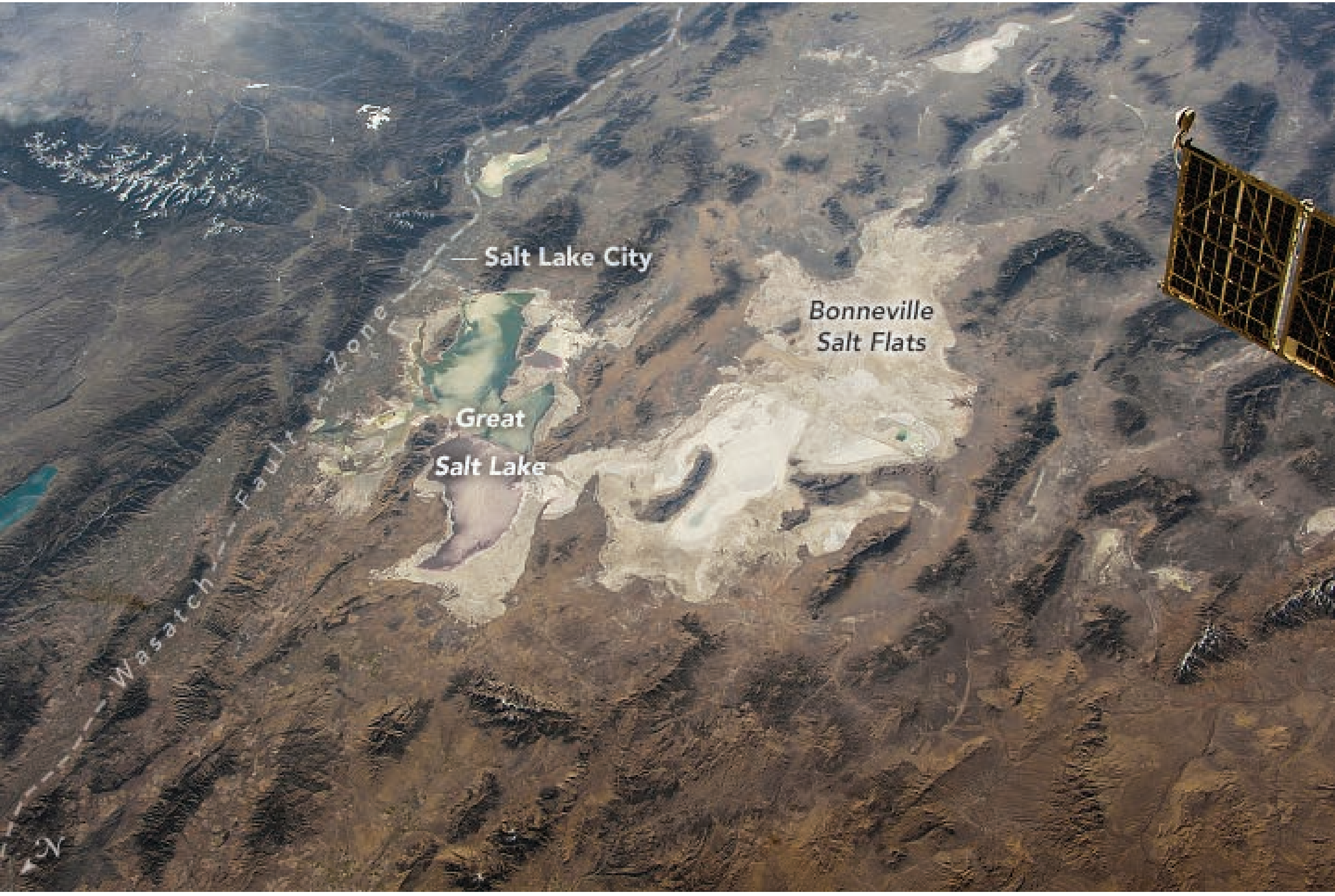
MIGHTY BED OF SALT BEING SCOOPED UP FOR USE OF MANKIND

MOTOR TRUCK AND PLOW USED TO GARNER RICH SALINE HARVEST

SNAPSHOTS OF UTAH'S NEWEST SALT REFINERY AT SALDURO. No. 1—Loosening the salt by means of a motor truck attached to a plow. No. 2—The new refinery. No. 3—Interior of the refinery, showing the big revolving drum in which the moisture is removed from the crude salt.

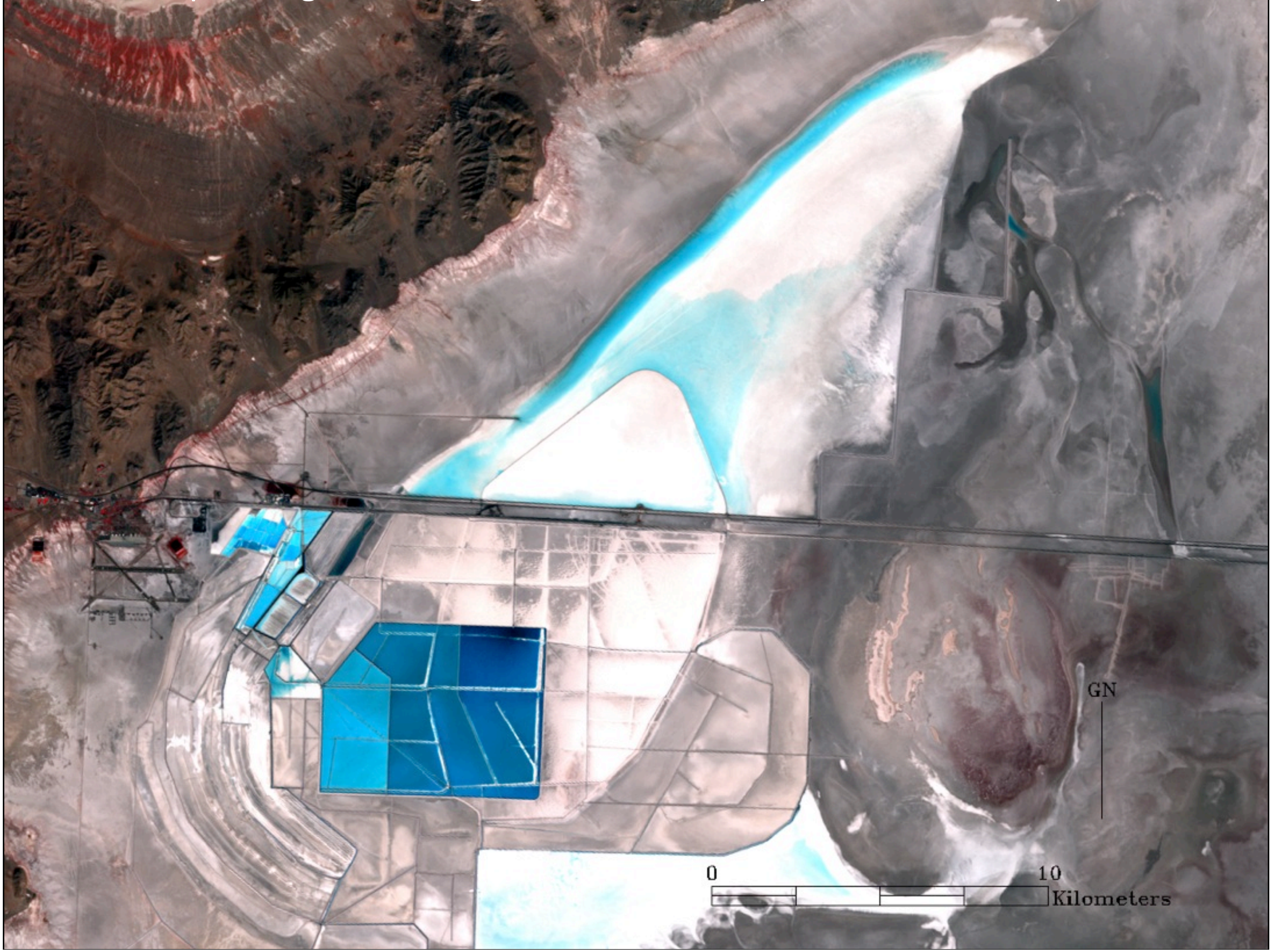
Image by: Leia Larsen

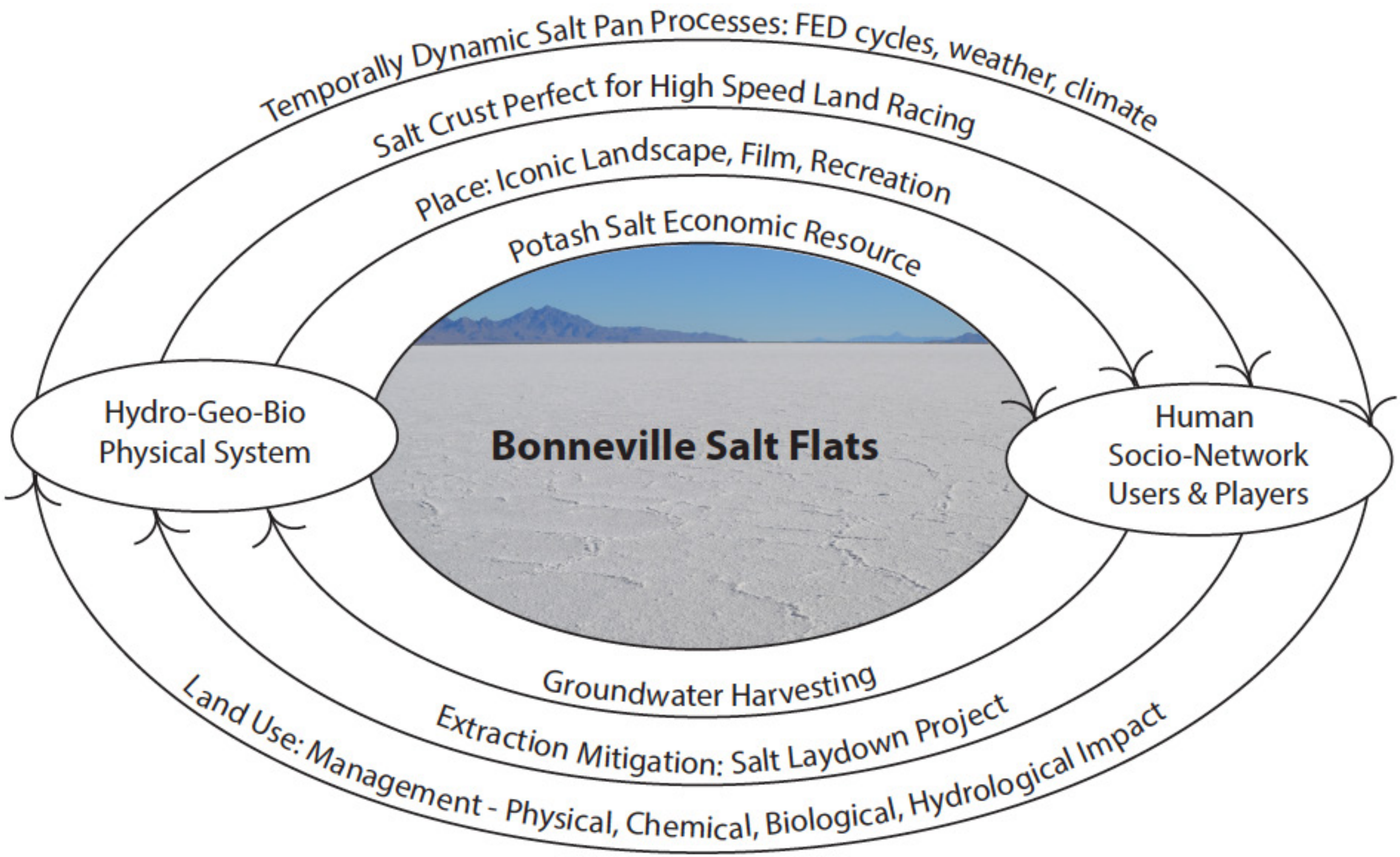
http://www.standard.net/Environment/2016/05/01/Great-Salt-Lake-provides-significant-portion-of-national-global-commodities



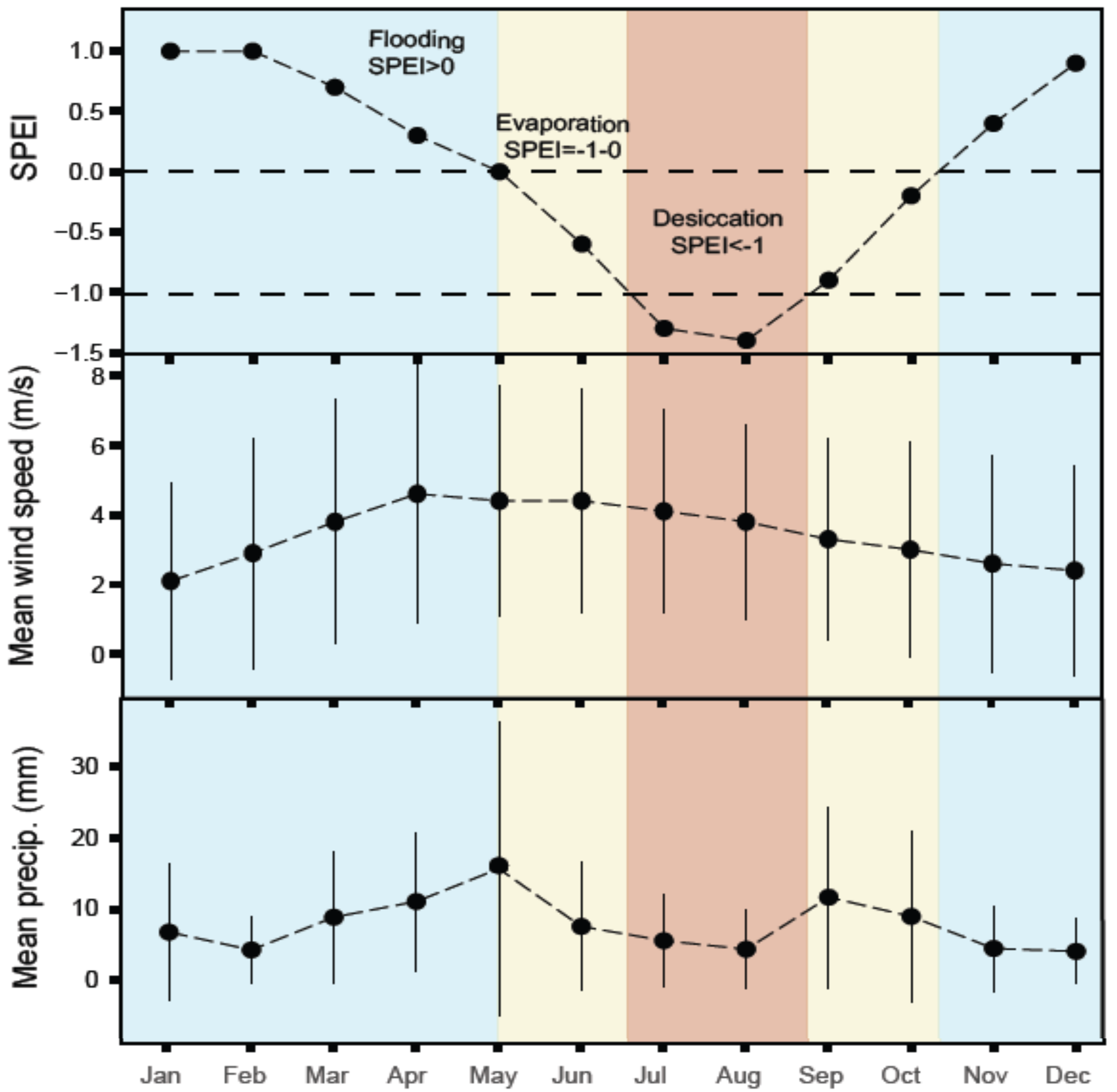
Salt Lake City
Bonneville
Salt Flats
Great
Salt Lake
Wasatch Fault Zone
N

The system is changing in ways that are limiting historic uses, and managers are responding with mitigation efforts to try to maintain multiple uses.

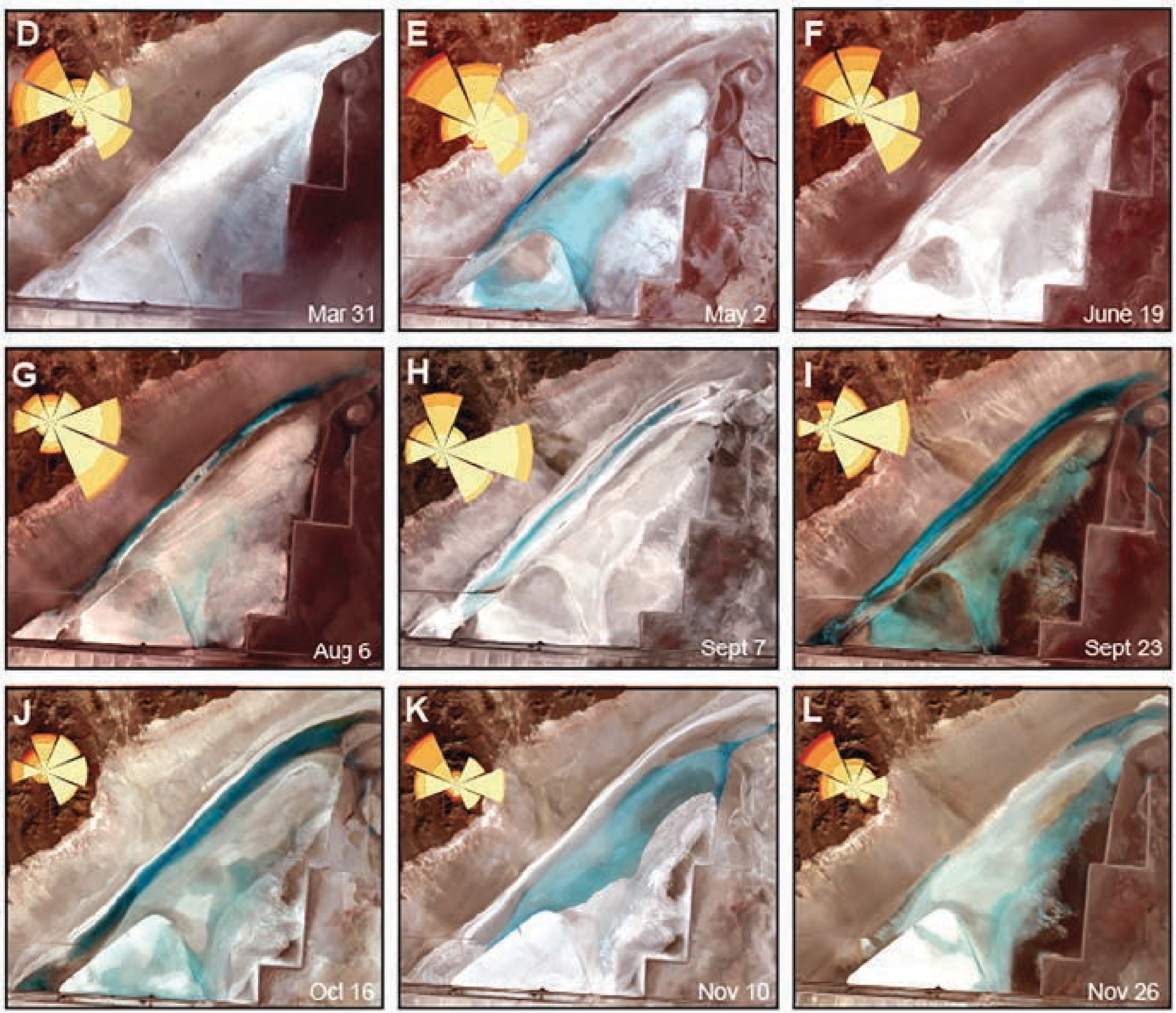



Temporally Dynamic Salt Pan Processes: FED cycles, weather, climate
Salt Crust Perfect for High Speed Land Racing
Place: Iconic Landscape, Film, Recreation
Potash Salt Economic Resource
Hydro-Geo-Bio Physical System
Bonneville Salt Flats
Human Socio-Network Users & Players
Groundwater Harvesting
Extraction Mitigation: Salt Laydown Project
Land Use: Management - Physical, Chemical, Biological, Hydrological Impact

Seasonal Flooding, Evaporation, Desiccation (FED) Cycles

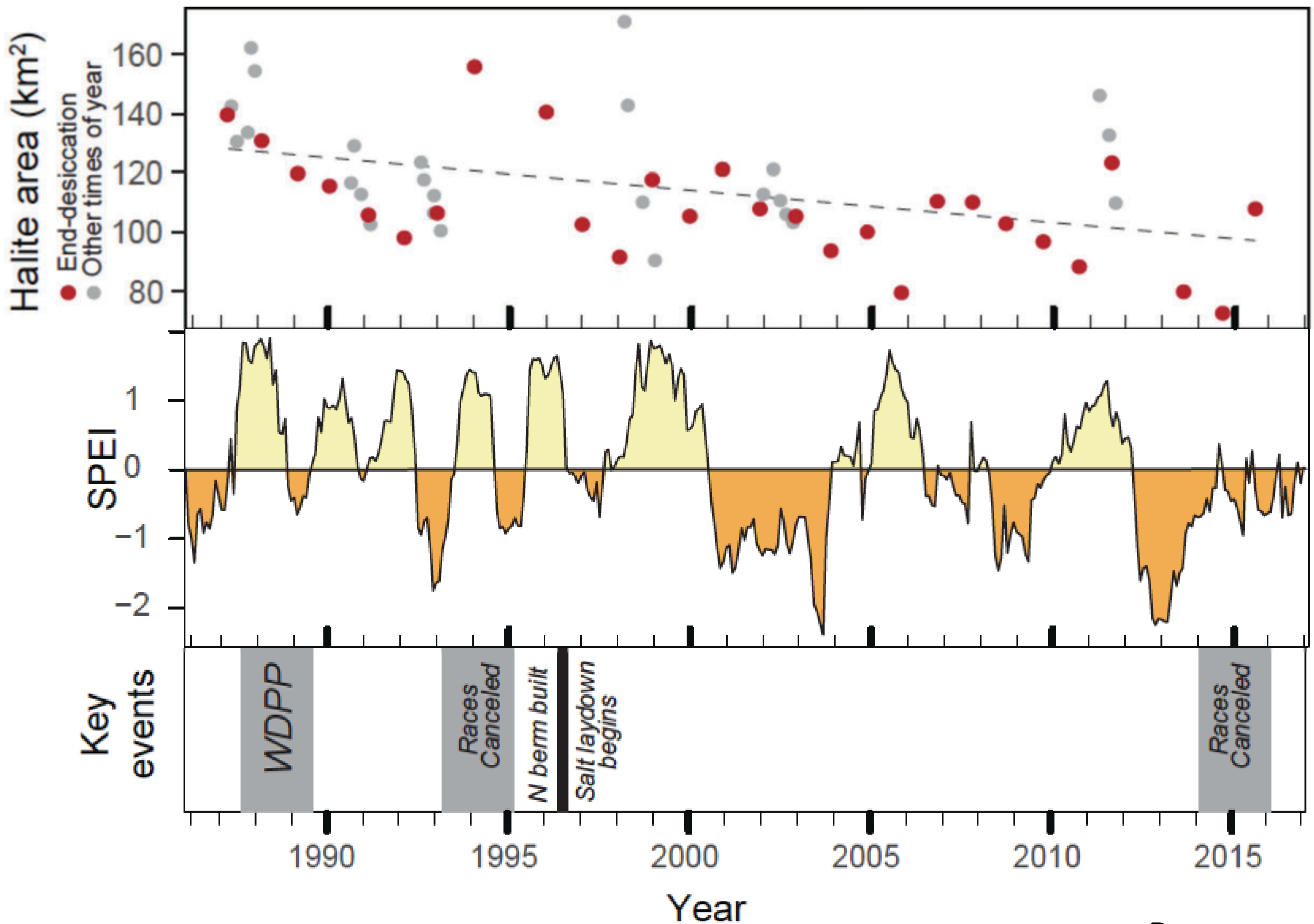


Bowen et al., 2017



Bowen et al., 2017

Halite area through time

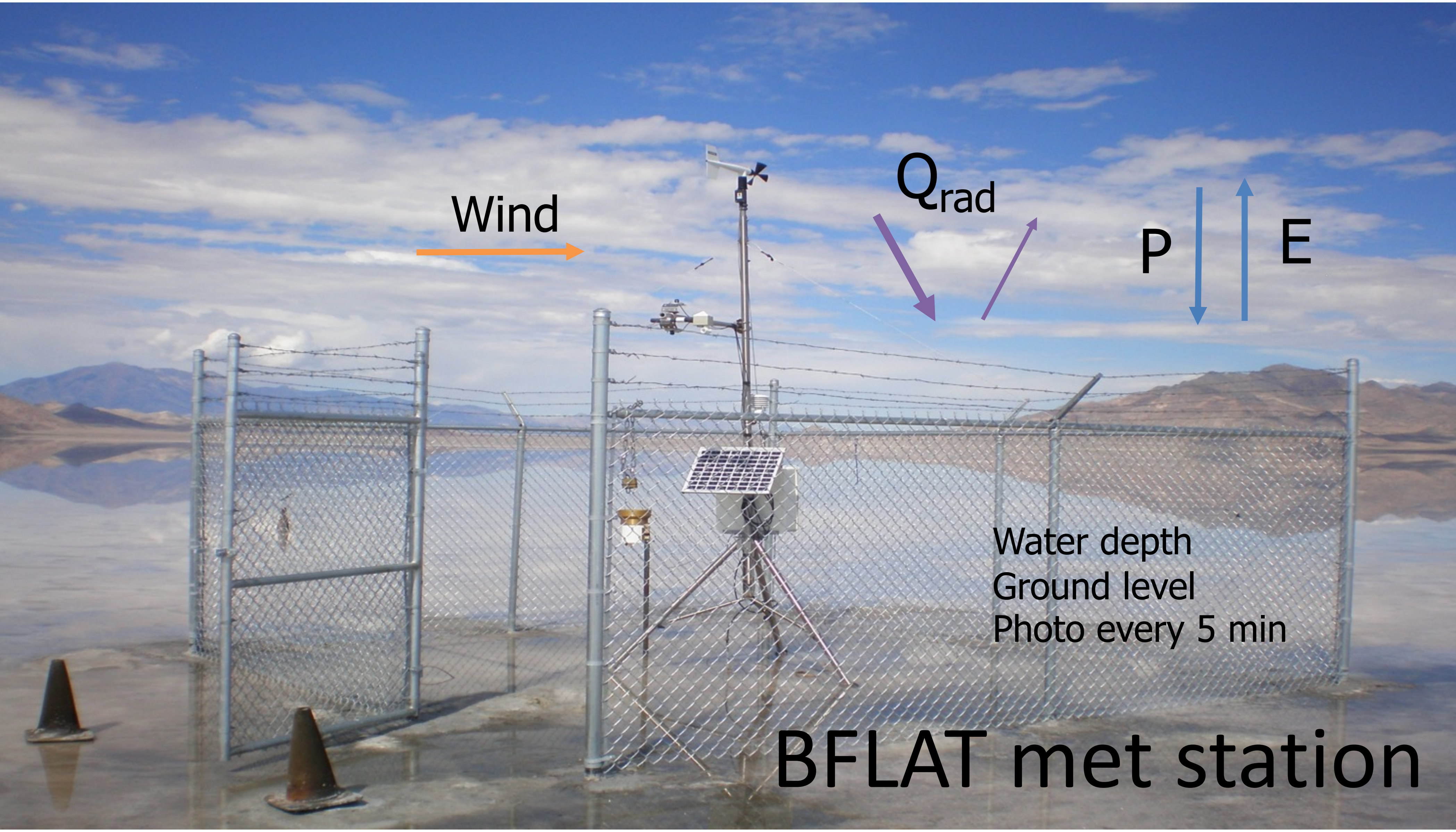


Bowen et al., 2017

MesoWest

1997-2017 Celebrating 20 years

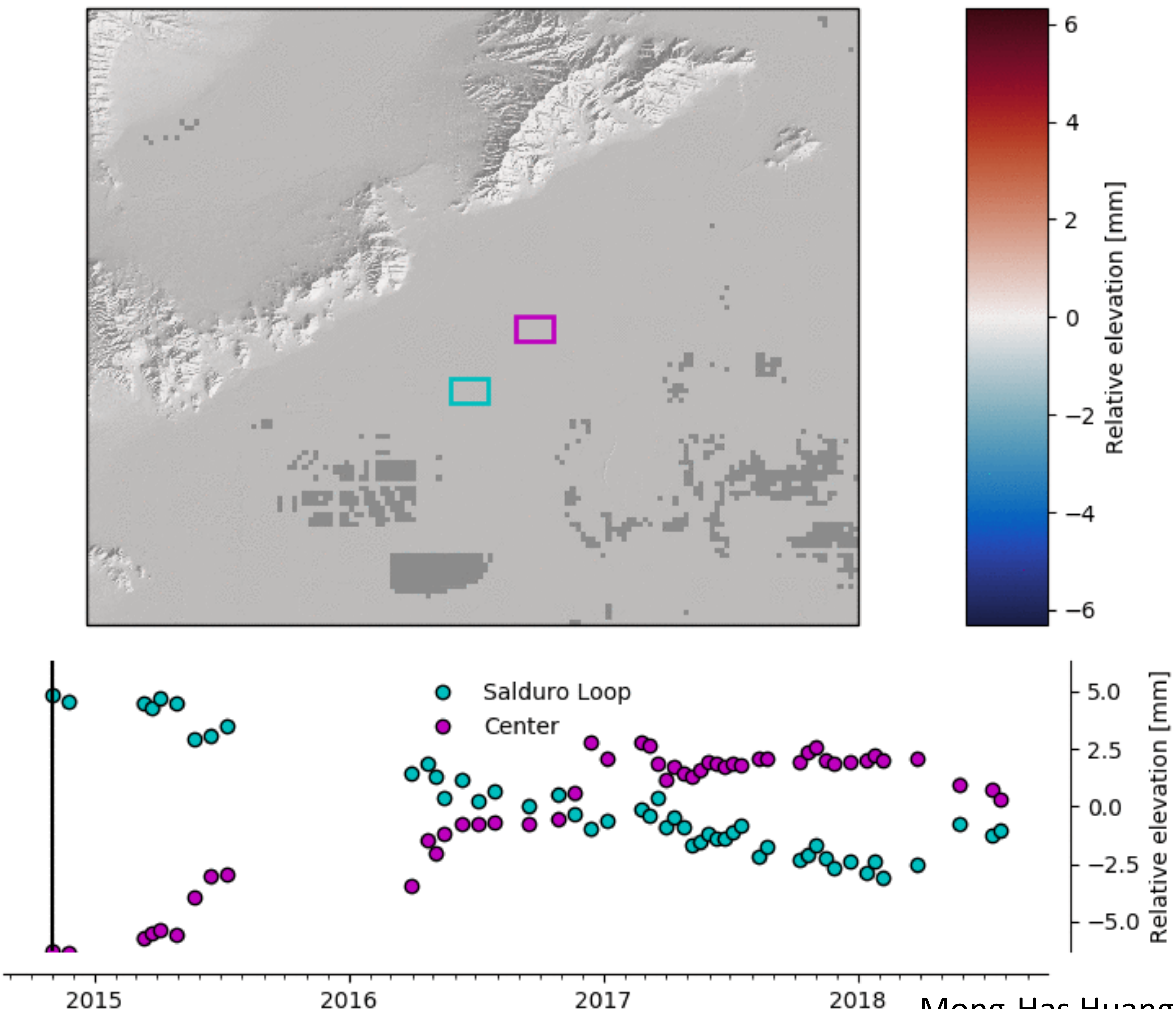
The University of Utah



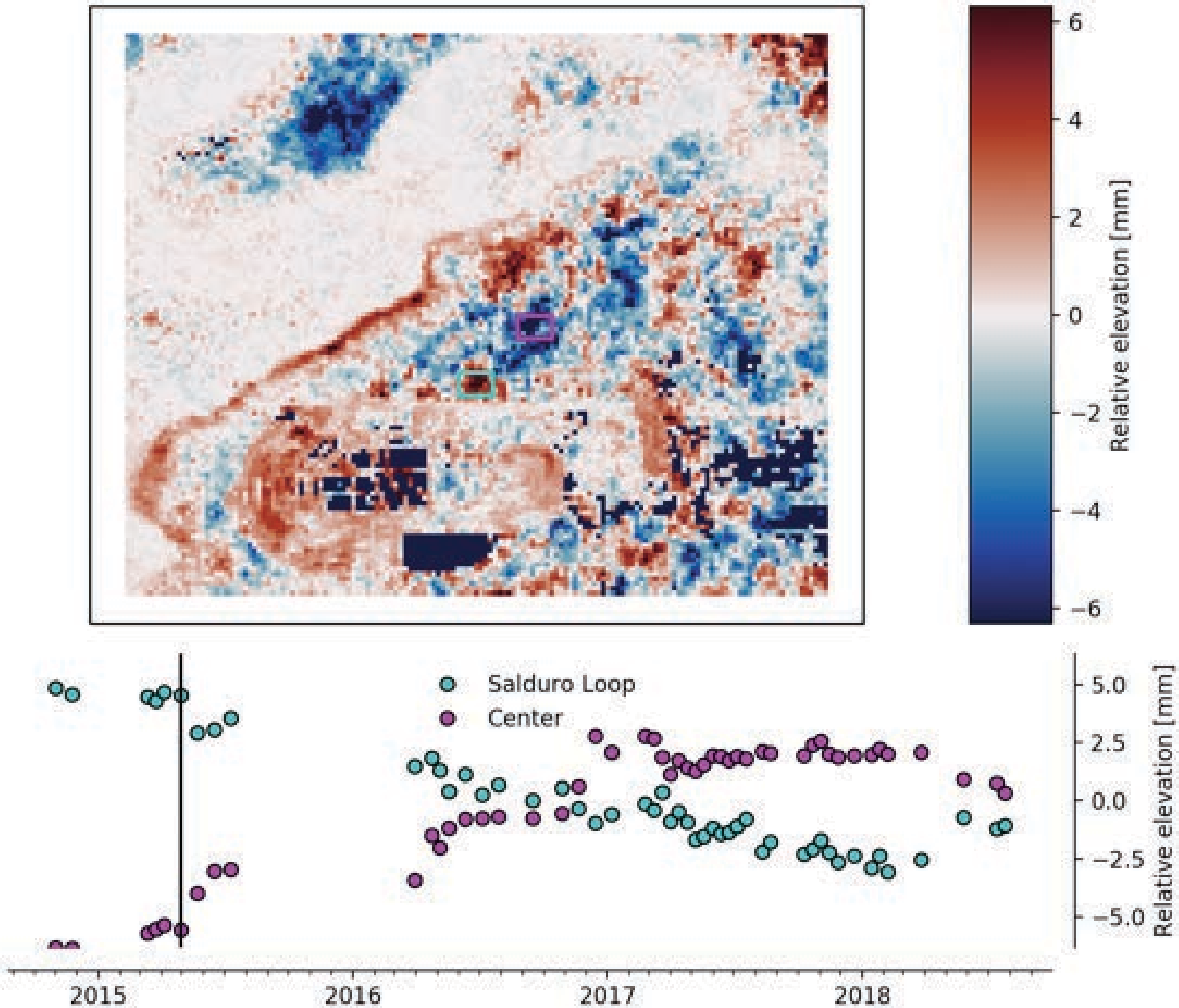
The character of BSF changes on daily, weekly, monthly, annual, and geologic time scales in response to fluctuations in water balance, solute flux, and groundwater flow which is impacted by both local meteorology and water management associated with mining.


1997-2017
MesoWest
Bonneville Salt Flats 2017-09-22 09:05:02


1997-2017
MesoWest
Bonneville Salt Flats 2017-10-08 13:25:08



Mong-Has Huang, U of Maryland



6
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−2
−4
−6
Relative elevation [mm]
Salduro Loop
Center
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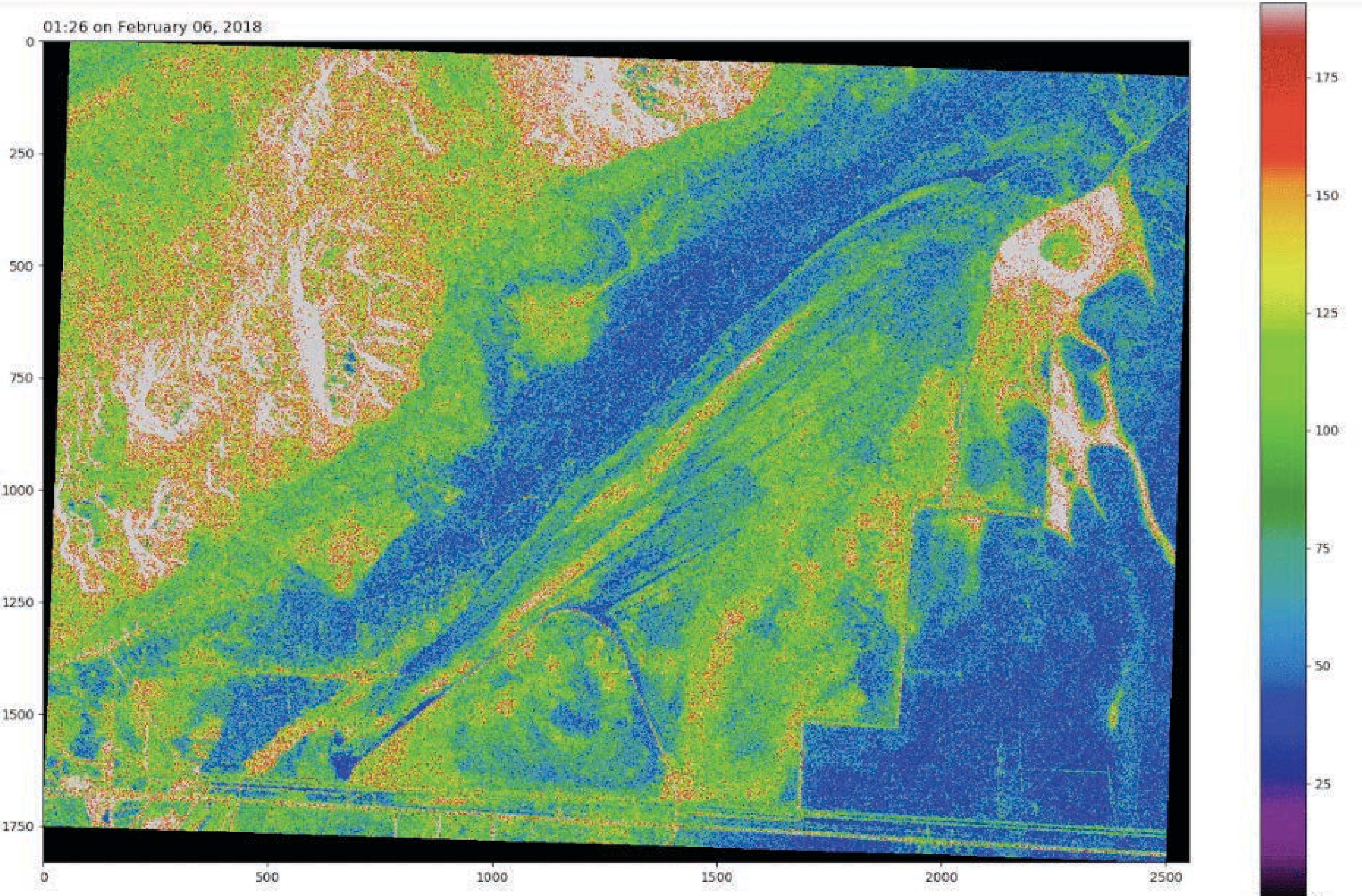
2.5
0.0
−2.5
−5.0
Relative elevation [mm]
2015
2016
2017
2018

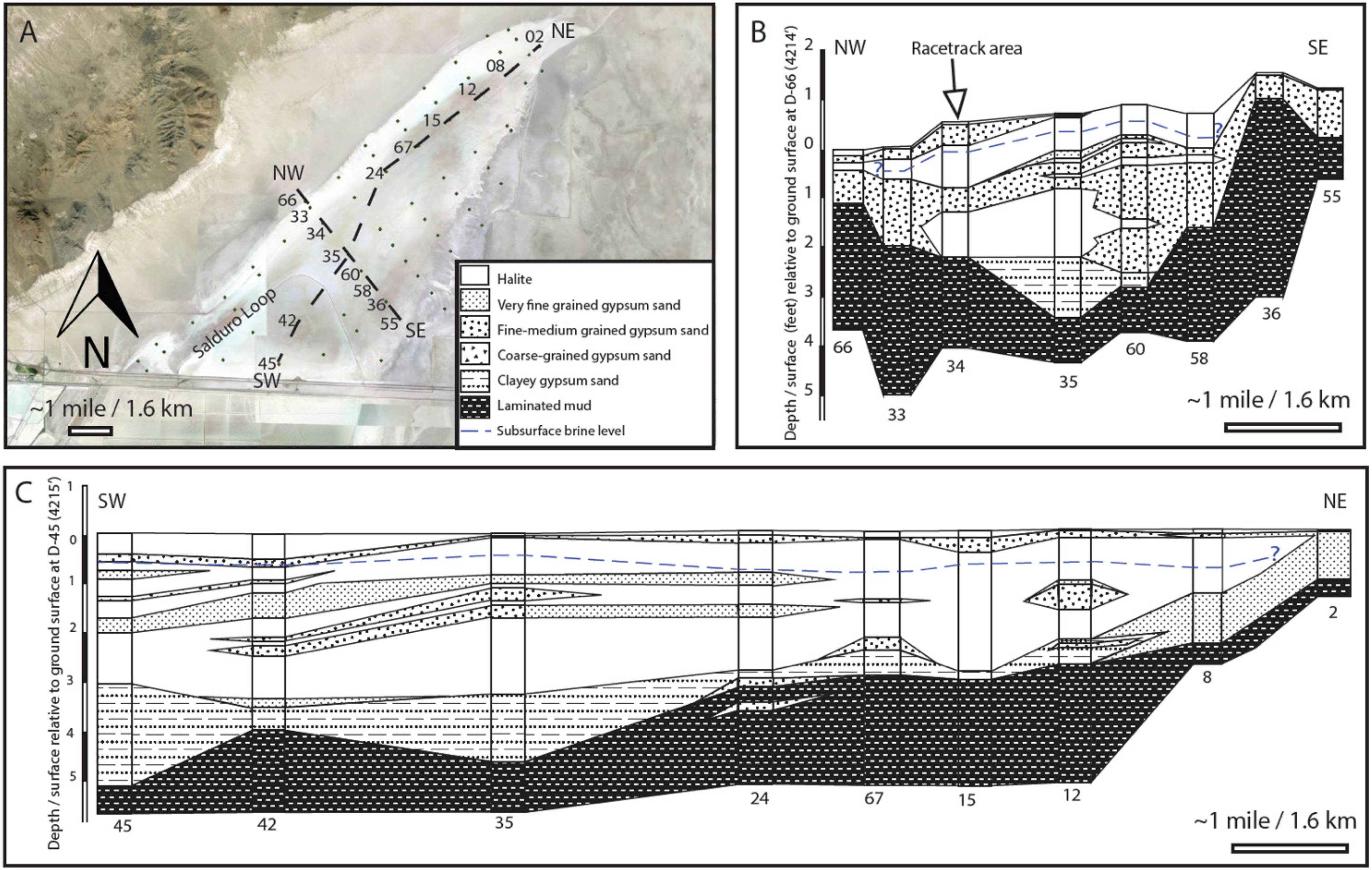
Texture of the salt surface is changed by land use including racing activities, which impacts water fluxes through the crust.



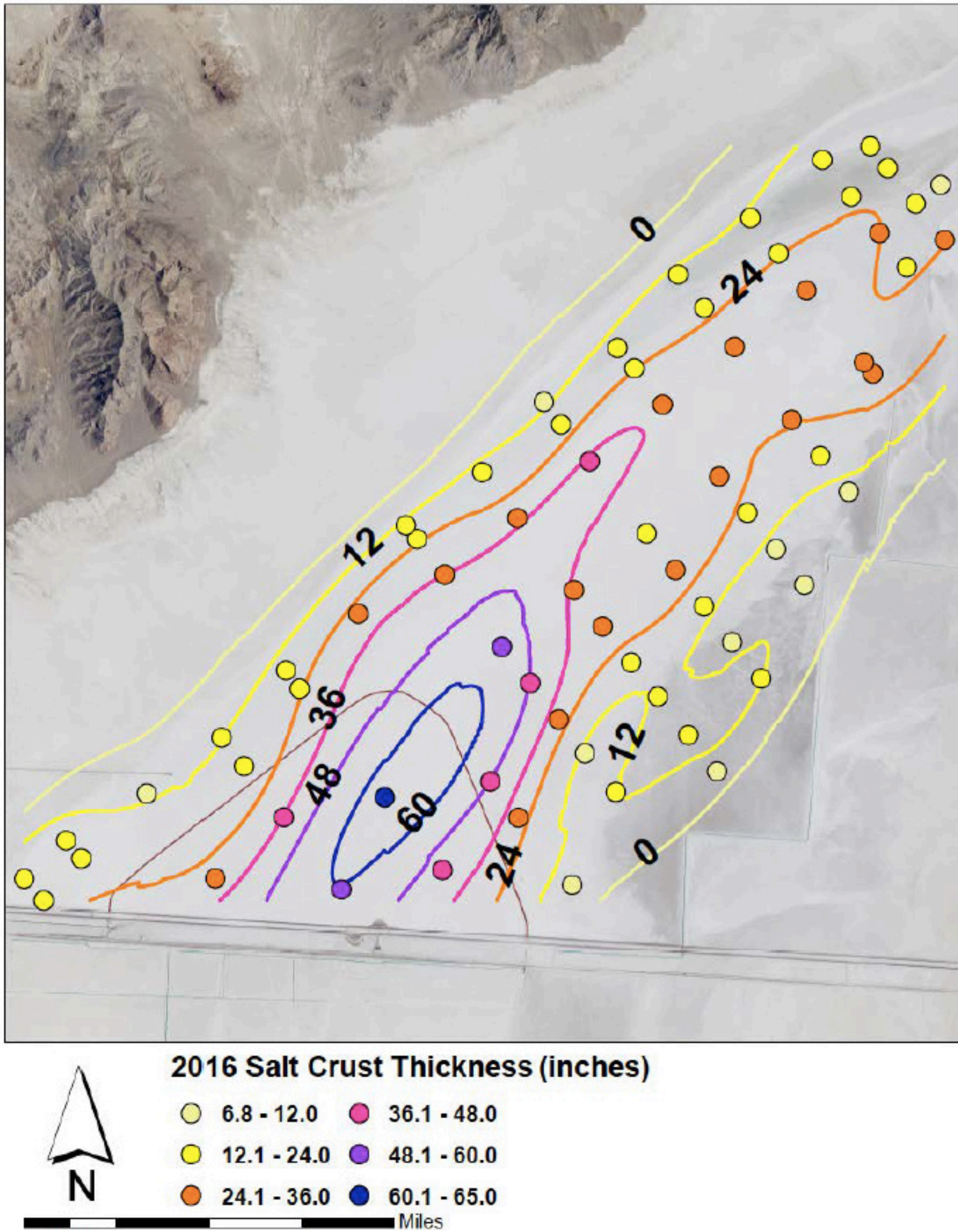

Evaporation
Desiccation
Use
Flooding

Land managers and stakeholders are actively making decision about what to do to try to preserve this environment, primarily for the legacy of land speed racing, while still maintaining opportunities for natural resource extraction and ecosystem function.

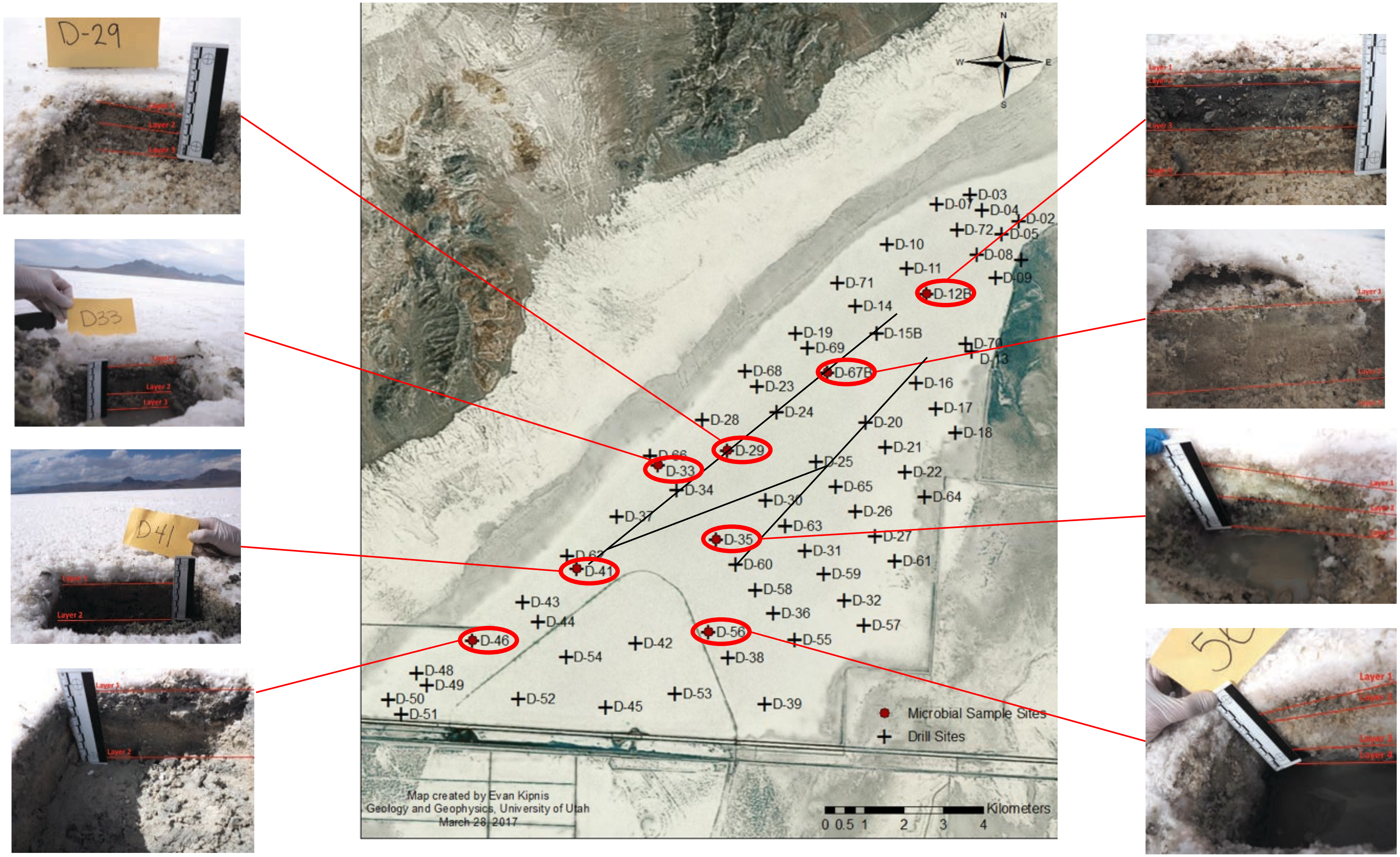
July 2015, Mile 3 of long track



Bowen et al., 2018



Bowen et al, 2018



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Layer 3
Layer 4
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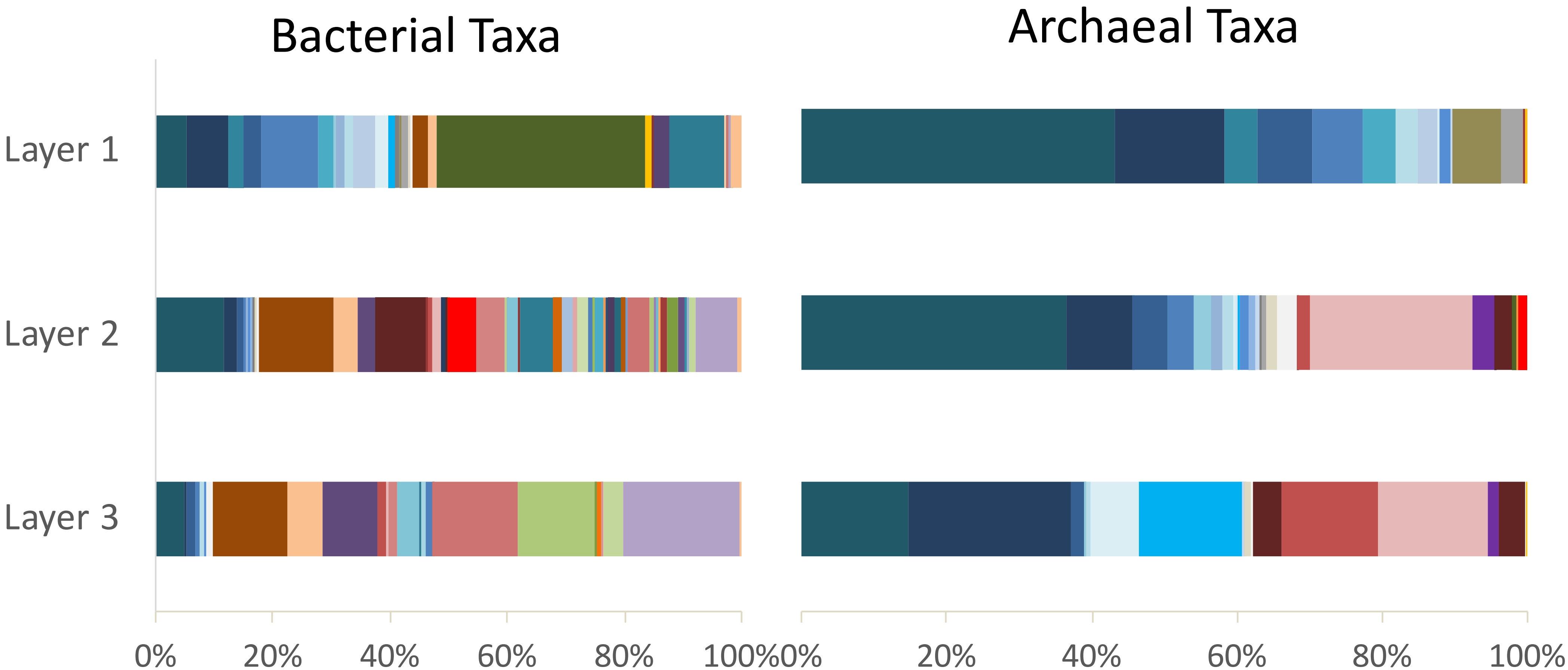
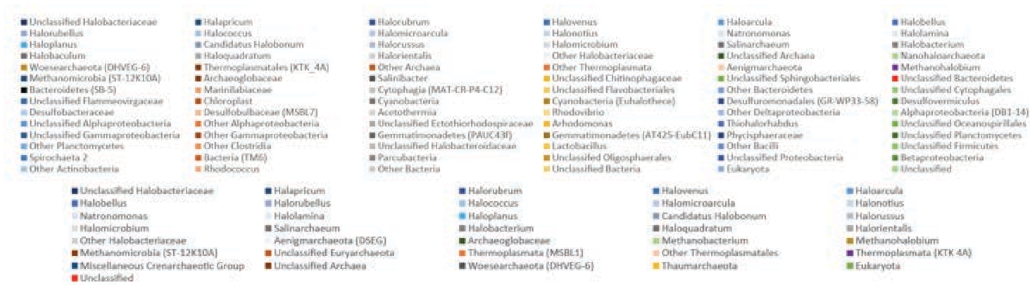
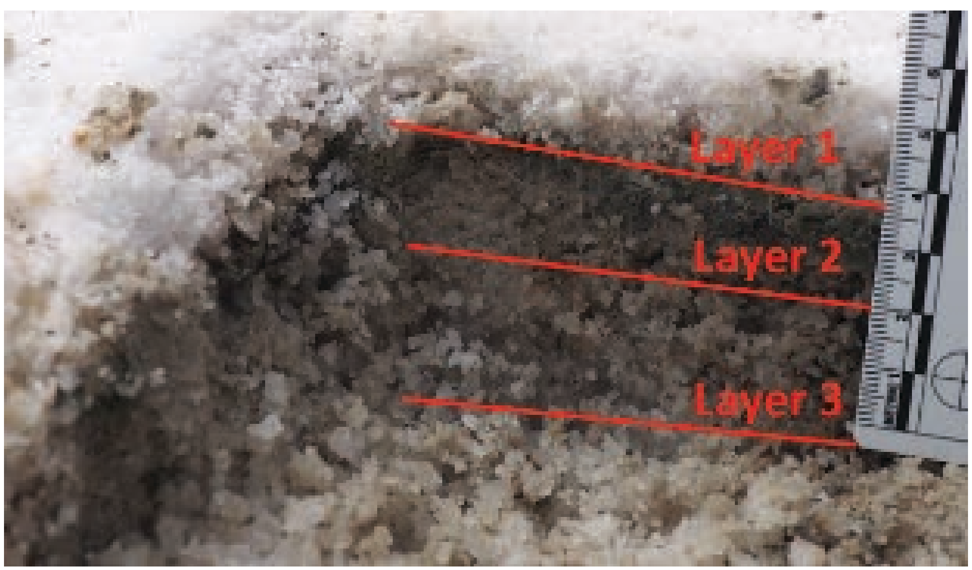
Microbial Sample Sites
Drill Sites
Map created by Evan Kipnis
Geology and Geophysics, University of Utah
March 28, 2017
Kilometers
0 0.5 1 2 3 4

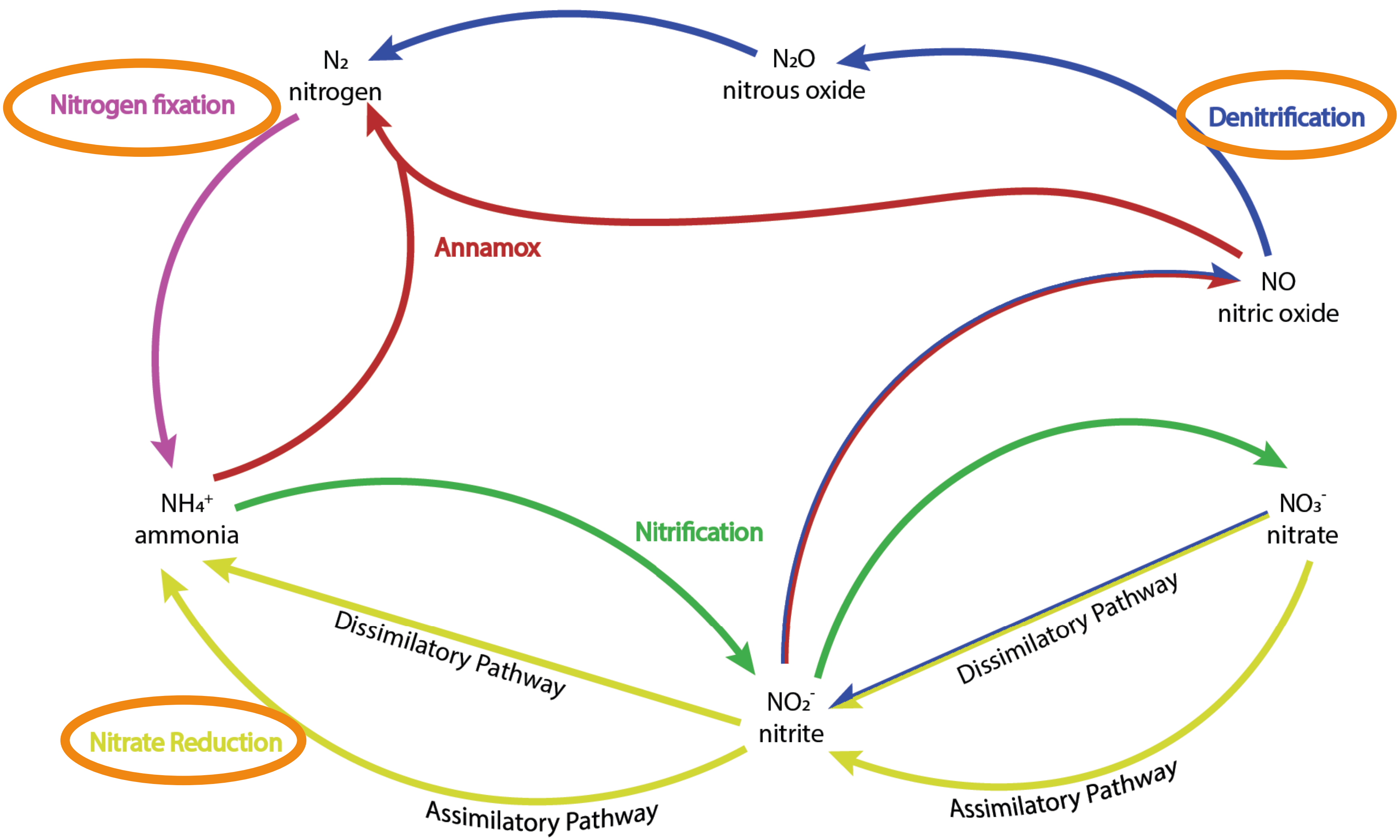




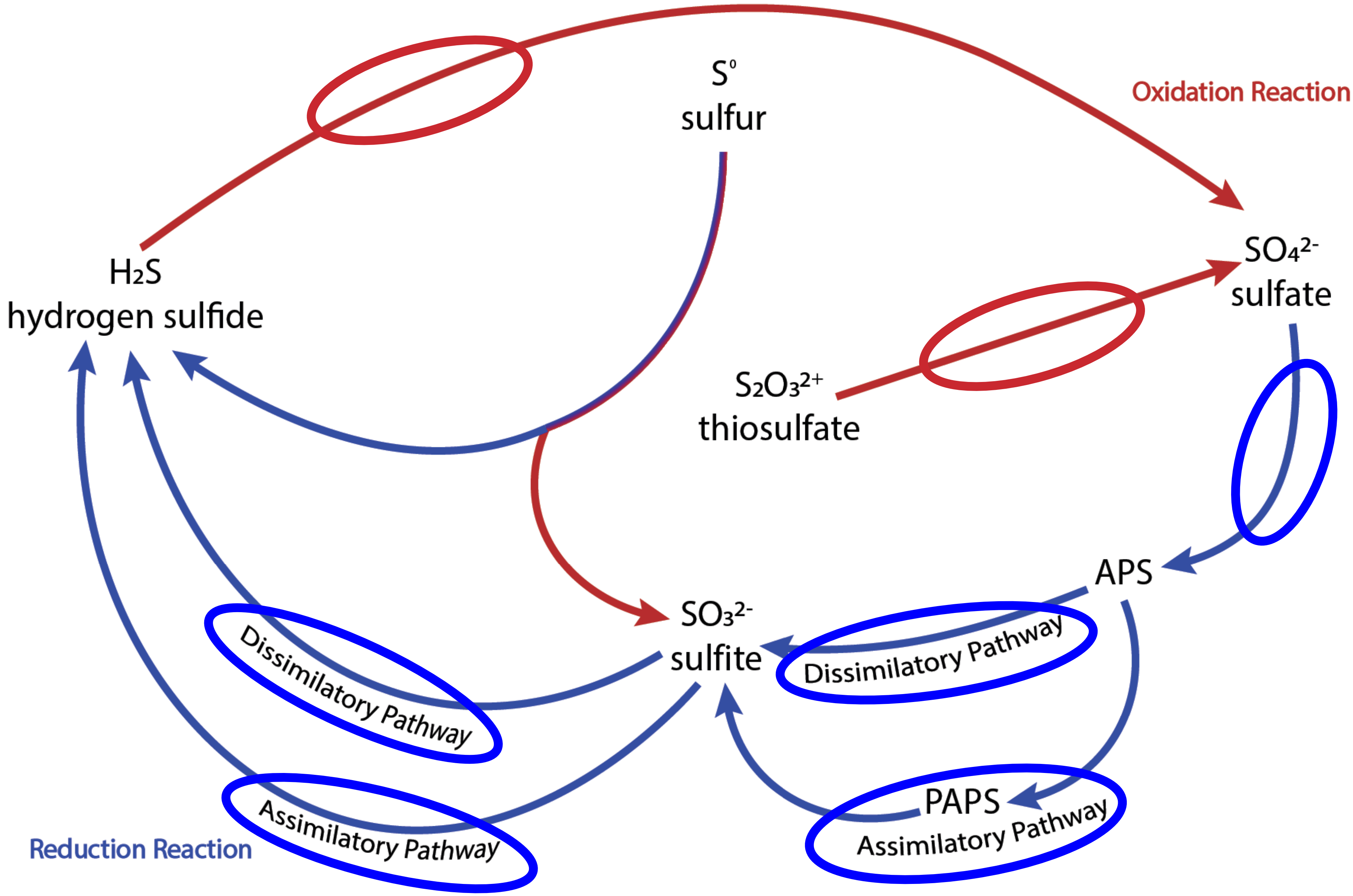


Salt crust strata have distinct microbial communities with greater diversity in lower layers.

N cycle from metagenomes



S cycle in metagenomes



The salt crust microbial community has the potential to be highly active in the carbon, nitrogen, and sulfur cycles.

BSF provides a unique platform for providing broadly transferable insights into the complex dynamics and feedbacks between coupled social-ecological systems in an actively changing and highly valued environment.


Depositional and diagenetic clues from the sedimentary record at BSF

Solute and water sourcing: geochemical clues from groundwater feeding into the western Bonneville basin


The role of humans in environmental change at BSF:
Clues from the water, solute, salt budget

Without a clear and quantified understanding of the processes governing the biophysical syste
the complex connections between the social fabric and biophysical processes, mitigation effor
not have the desired outcomes.

THE TRANSITION OF LAKE BONNEVILLE TO THE BONNEVILLE SALT FLATS

Jeremiah Bernau[1] and Brenda Bowen[1,2]

[1] Department of Geology and Geophysics, University of Utah, Salt Lake City, UT 84112;
[2] Global Change and Sustainability Center, University of Utah, Salt Lake City, UT 84112

Corresponding author (Bernau): jeremiahbernau@gmail.com

ABSTRACT

The Bonneville Salt Flats (BSF) in the Utah West Desert is a remnant of Lake Bonneville. However, the timing of the transition in depositional environment from lacustrine to saline pan setting is not well documented. This research aims to describe the timing and processes that governed how Lake Bonneville transitioned to the present day BSF. The BSF is an ephemeral saline pan that consists of up to ~2 m of interbedded halite and gypsum. Lower gypsum layers are coarser grained and contain ooids. The gypsum layers on the periphery of the BSF also contain oolitic grains. The origin of BSF layers is likely a mix of detrital gypsum grains and ooids eroded from exposed areas in the West Desert and in-situ chemical precipitates. There is evidence for halite and gypsum crystallization at the surface and displacive growth in the subsurface. The evaporites of the BSF are underlain by laminated lacustrine sediment with geochemical (XRF), sedimentological, and micropaleontological (ostracods, brine shrimp fecal pellets/ooids) indicators of environmental change. Current research indicates that this portion of the West Desert may have undergone erosion or significant deposition prior to the deposition of the BSF, as the laminated aragonite sediment at the base of a four-meter core did not include Lake Bonneville sediments. Ongoing research aims to utilize optically stimulated luminescence to determine the age of this sediment and test the hypothesis that this area sustained significant erosion or deposition during the Holocene. This research extends our understanding of the evolution of this region of the western desert. Furthermore, it reveals the heterogeneity of deposition/erosion in the post-Lake Bonneville system.

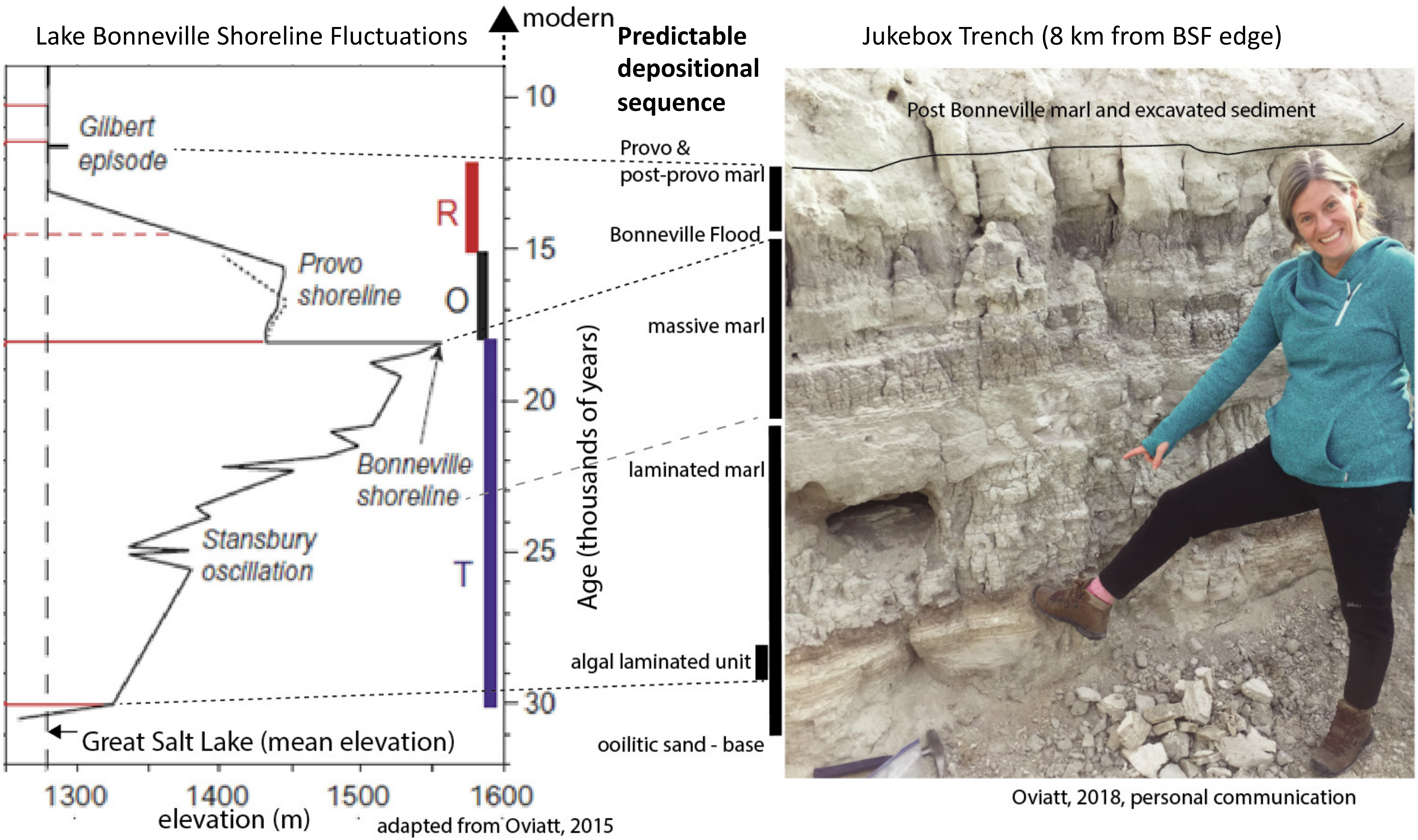
This content is a PDF version of the author's PowerPoint presentation.

Transition of Lake Bonneville to the Bonneville Salt Flats

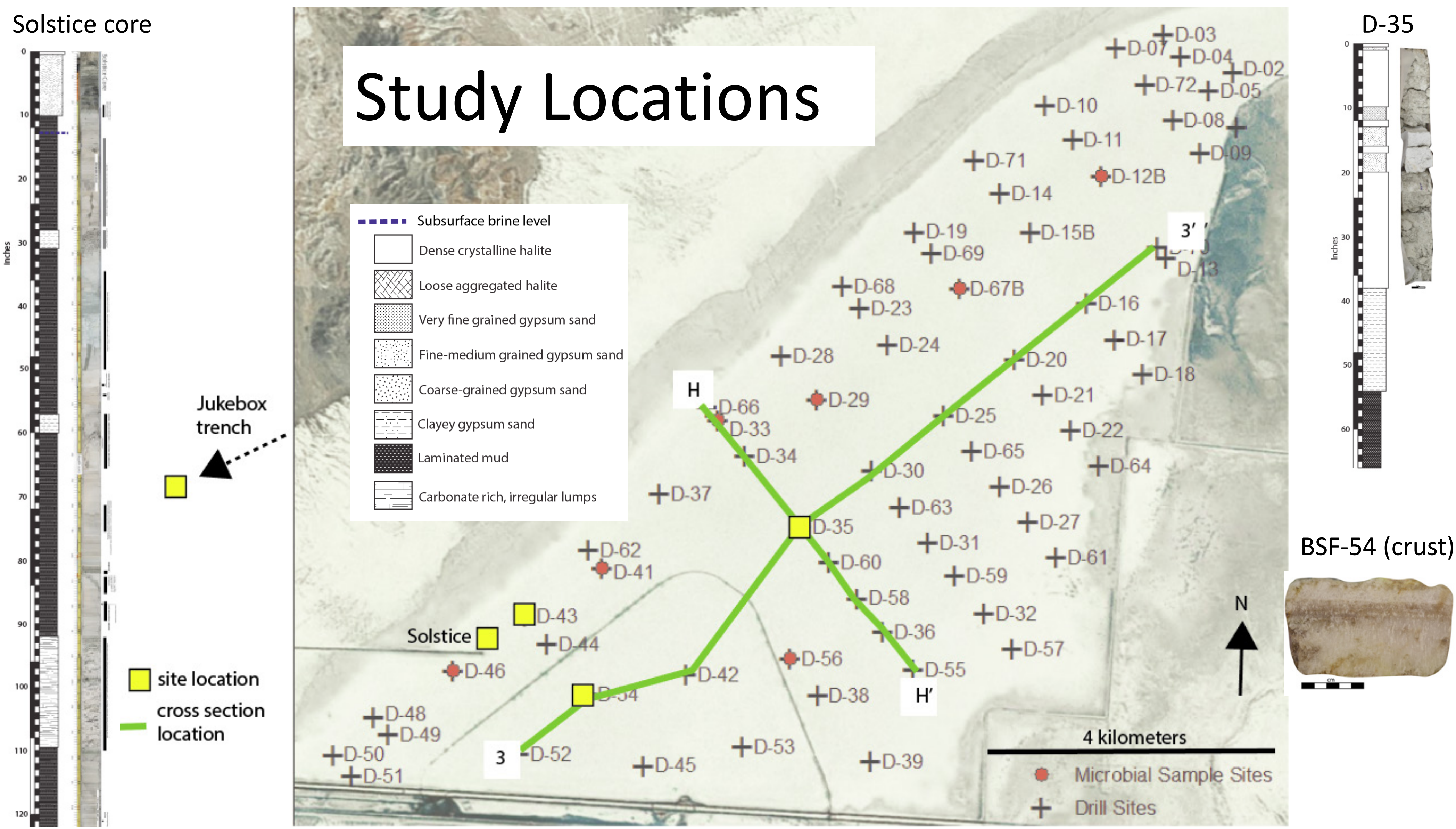
THE UNIVERSITY OF UTAH

Jeremiah A. Bernau,
Brenda B. Bowen

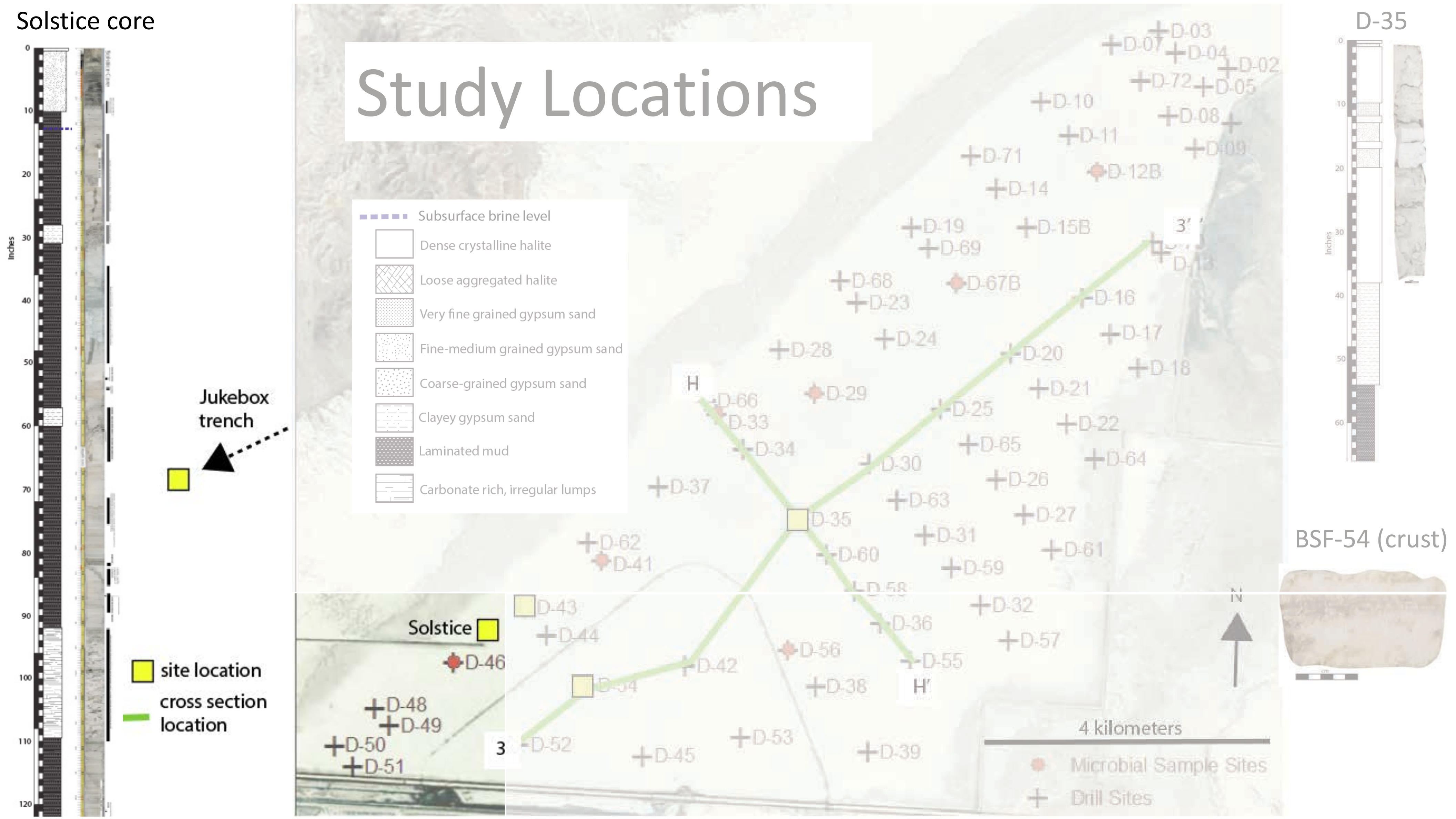
Geology and Geophysics,
University of Utah



Lake Bonneville Shoreline Fluctuations
modern
Gilbert episode
R
Provo shoreline
O
Bonneville shoreline
Stansbury oscillation
T
Great Salt Lake (mean elevation)
10
15
20
25
30
Age (thousands of years)
1300
1400
1500
1600
elevation (m)
adapted from Oviatt, 2015
Predictable depositional sequence
Provo & post-provo marl
Bonneville Flood
massive marl
laminated marl
algal laminated unit
ooilitic sand - base
Jukebox Trench (8 km from BSF edge)
Post Bonneville marl and excavated sediment
Oviatt, 2018, personal communication



Study Locations
Solstice core
Inches
Jukebox trench
site location
cross section location
Subsurface brine level
Dense crystalline halite
Loose aggregated halite
Very fine grained gypsum sand
Fine-medium grained gypsum sand
Coarse-grained gypsum sand
Clayey gypsum sand
Laminated mud
Carbonate rich, irregular lumps
D-03
D-07
D-04
D-02
D-72
D-05
D-10
D-08
D-11
D-09
D-71
D-12B
D-14
D-19
D-15B
D-69
3′
D-13
D-68
D-67B
D-23
D-16
D-28
D-24
D-17
D-20
D-18
H
D-66
D-29
D-21
D-33
D-25
D-22
D-34
D-65
D-64
D-30
D-37
D-26
D-63
D-27
D-35
D-31
D-62
D-61
D-60
D-41
D-59
D-58
D-43
D-32
Solstice
D-36
D-44
D-57
D-56
D-46
D-55
D-42
D-38
H′
D-48
D-49
D-52
3
D-50
D-45
D-53
D-39
D-51
4 kilometers
Microbial Sample Sites
Drill Sites
N
D-35
BSF-54 (crust)



Study Locations
Solstice core
Inches
Jukebox trench
site location
cross section location
Subsurface brine level
Dense crystalline halite
Loose aggregated halite
Very fine grained gypsum sand
Fine-medium grained gypsum sand
Coarse-grained gypsum sand
Clayey gypsum sand
Laminated mud
Carbonate rich, irregular lumps
Solstice
D-35
BSF-54 (crust)
H
H'
3
3'
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Microbial Sample Sites
Drill Sites
D-03
D-07
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D-10
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D-12B
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D-49
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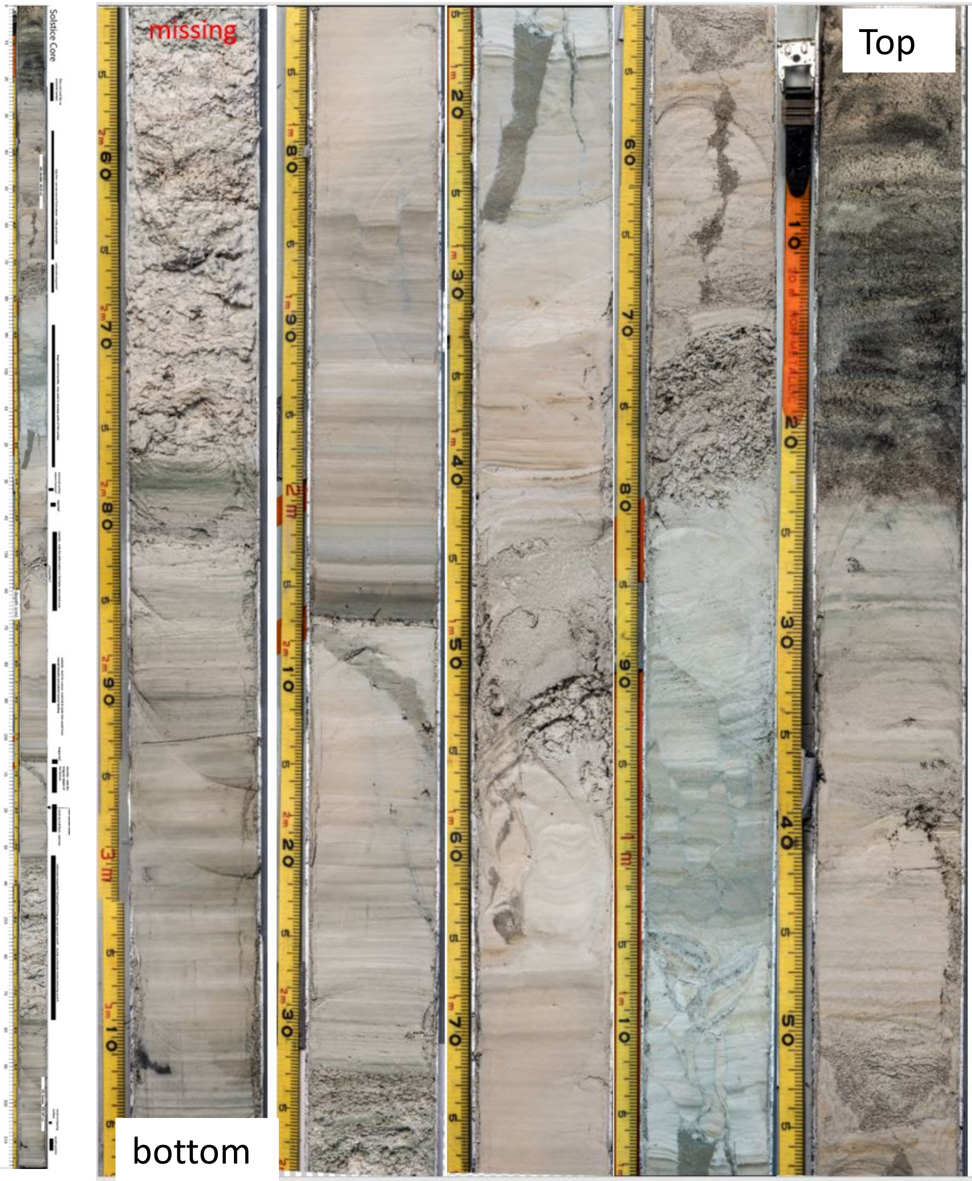
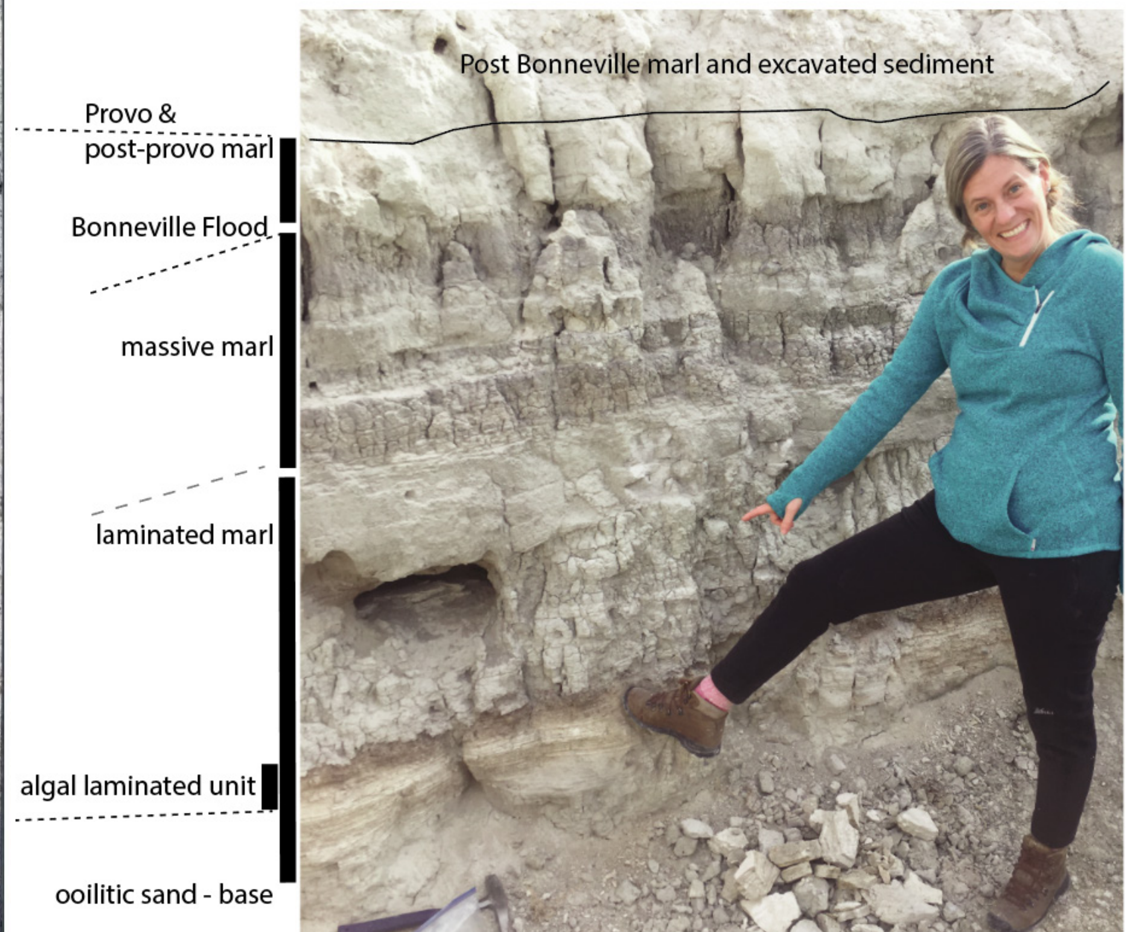
D-53
D-45
D-39
D-51

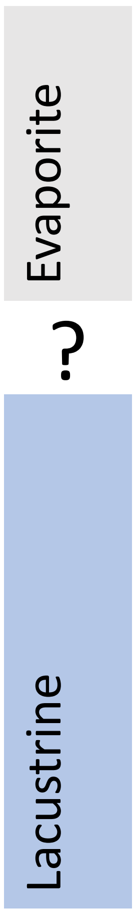
Beneath BSF sediment is not Bonneville Sediments





Oviatt, 2018, personal communication

Hypotheses



Lake to Flats

1. Lake Bonneville -> Bonneville Salt Flats
2. Lake Bonneville -> erosional period -> Bonneville Salt Flats
3. Lake Bonneville -> shallow lake -> Bonneville Salt Flats
4. Lake Bonneville -> other process -> Bonneville Salt Flats

Hypotheses

Evaporite

?

Lacustrine

Evaporite Deposition

5. Gypsum deposited under varying conditions
    - a) during dry periods as detrital input
    - b) during wet periods as precursor precipitate to halite
6. Preserved halite deposited under wet (non-desiccated) conditions
7. All halite below ~1 ft depth is recrystallized
8. >100 year old surface layers

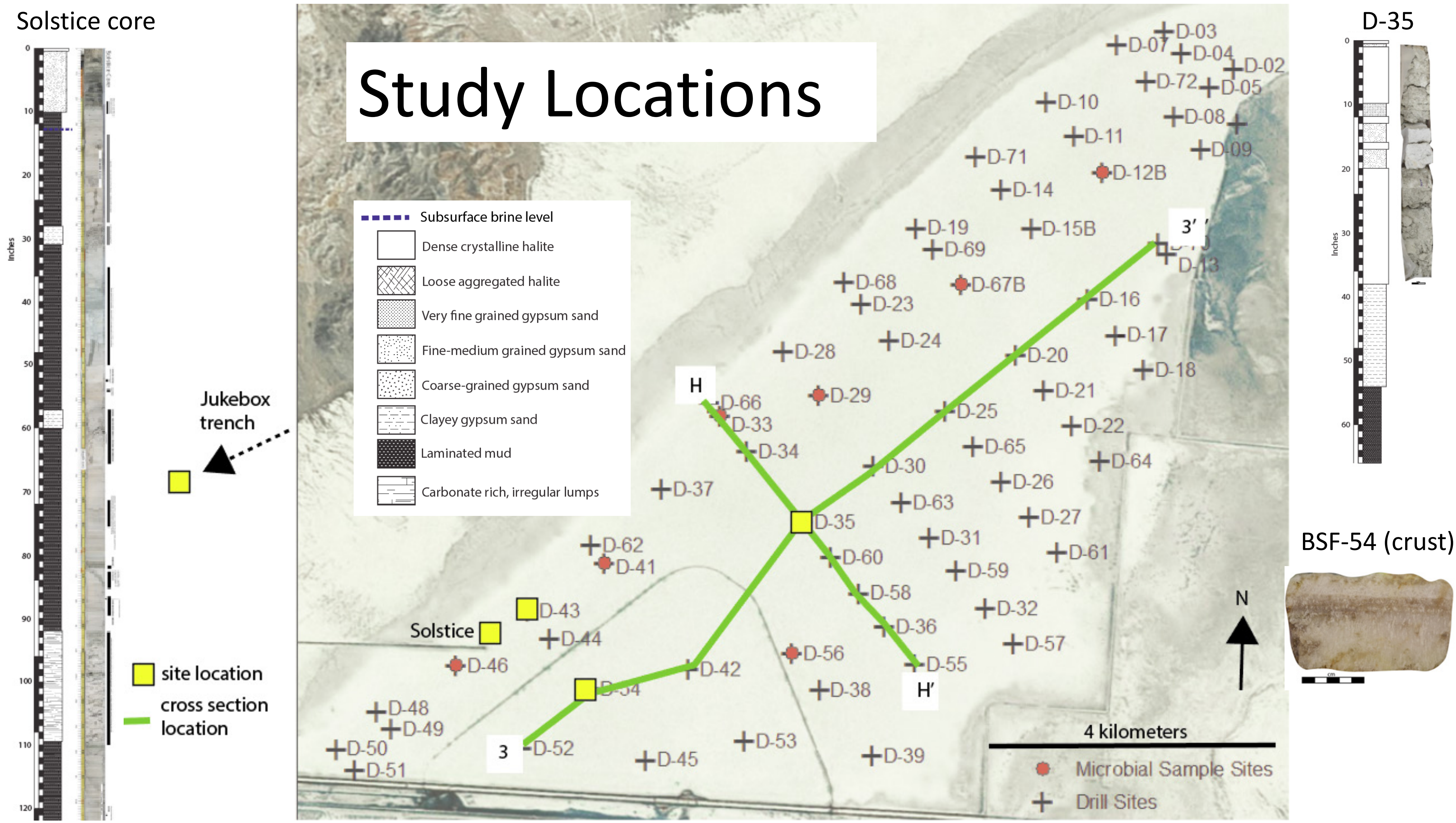
Lake to Flats

1. Lake Bonneville -> Bonneville Salt Flats
2. Lake Bonneville -> erosional period -> Bonneville Salt Flats
3. Lake Bonneville -> shallow lake -> Bonneville Salt Flats
4. Lake Bonneville -> other process -> Bonneville Salt Flats

Proxies/Tools

Tool	Lacustrine	Evaporite	Stage of research
XRF - water chemistry and sediment chemistry	X	X	In process
Ostracods –water chemistry/salinity	X		In process
Ooids –salinity	X		In process
Grain Size – sediment sourcing	X	X	Performed
Depositional/diagenetic textures			performed

Geochronology – awaiting preliminary results


Study Locations
Solstice core
Inches
0
10
20
30
40
50
60
70
80
90
100
110
120
Jukebox trench
site location
cross section location
Subsurface brine level
Dense crystalline halite
Loose aggregated halite
Very fine grained gypsum sand
Fine-medium grained gypsum sand
Coarse-grained gypsum sand
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D-57
D-46
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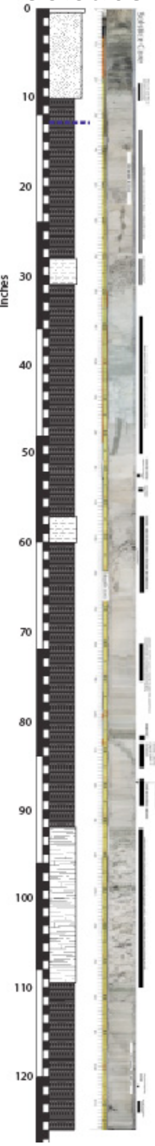
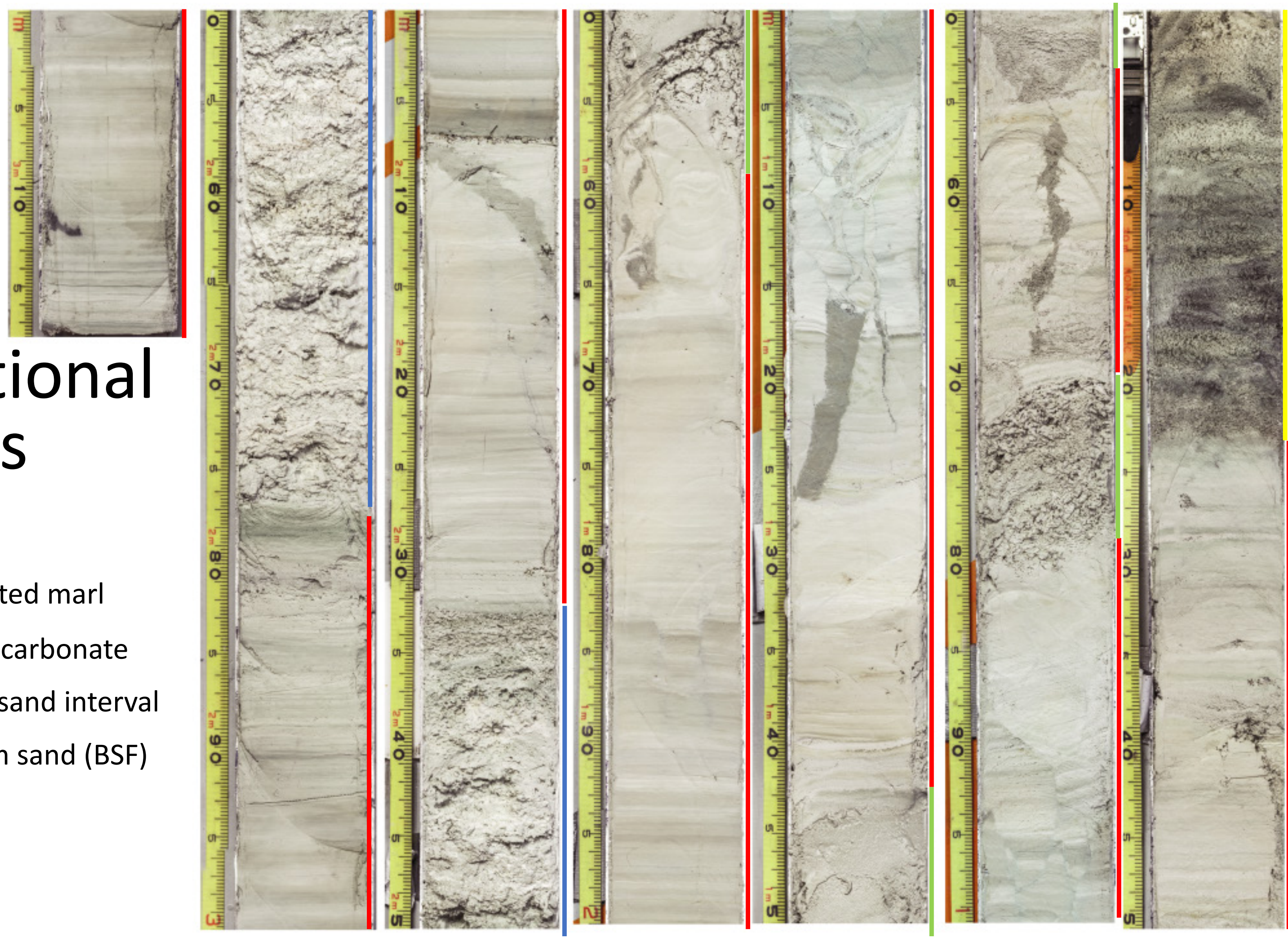
D-42
D-38
H′
D-48
D-49
4 kilometers
D-50
3
D-52
D-53
D-45
D-39
D-51
Microbial Sample Sites
Drill Sites
D-35
0
10
20
30
40
50
60
BSF-54 (crust)

Solstice core



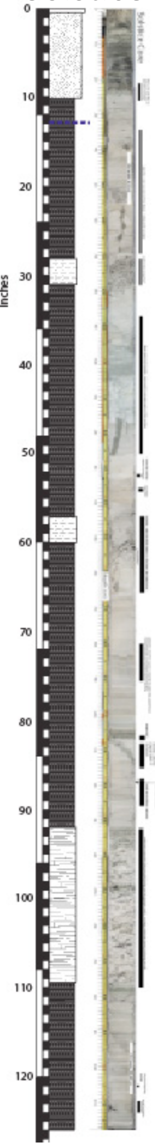
Depositional Textures

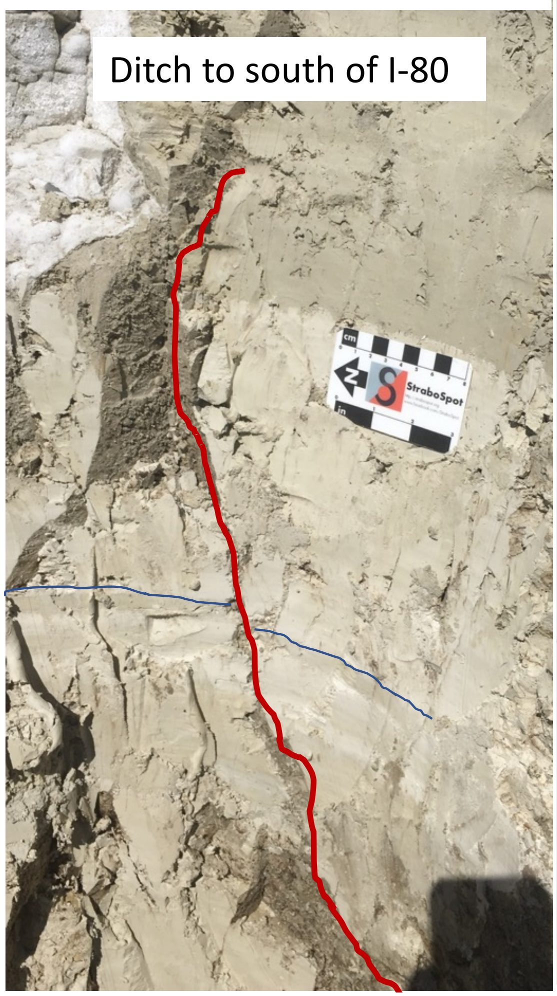
- Laminated marl
- Lumpy carbonate
- Oolitic sand interval
- Gypsum sand (BSF)



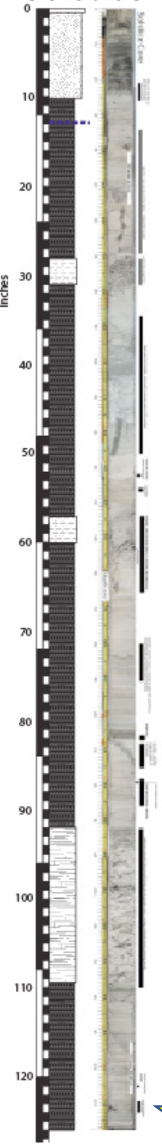
Seismites

Solstice core





Solstice core

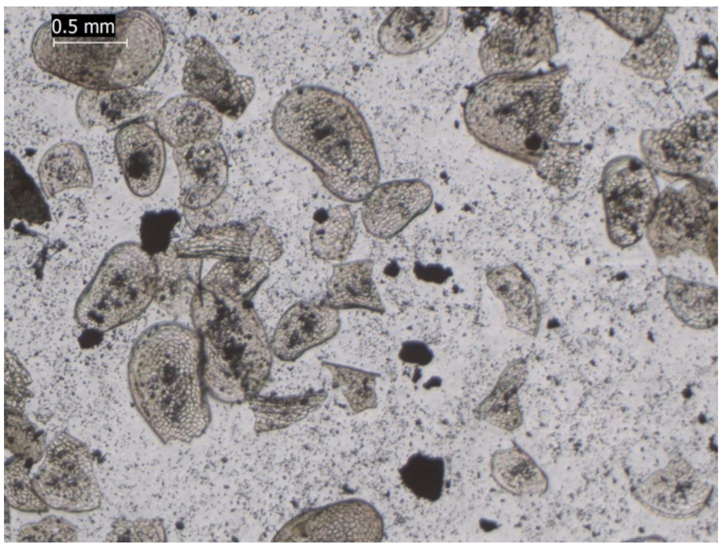


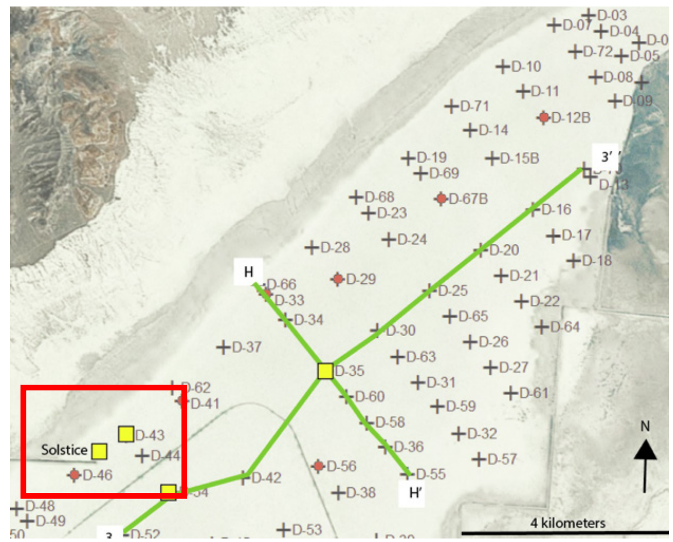
Samples under analysis

L. staplini

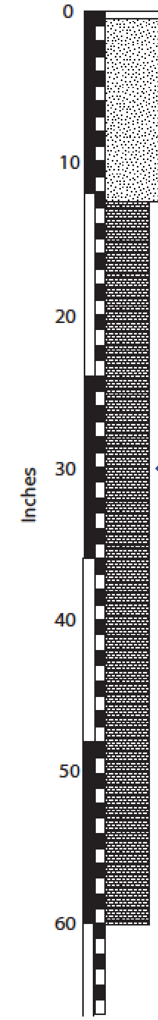
Ostracodes (preliminary data)

- L. staplini – brackish, <u>low-alkalinity</u> water
  first ostracode to show up in Lake Bonneville as it started to rise, and for a while it was the only ostracode able to live in the rising lake
- L. sappaensis – brackish tolerant, <u>high-alkalinity</u> water





Core #: 43
Total Core Depth: 5′

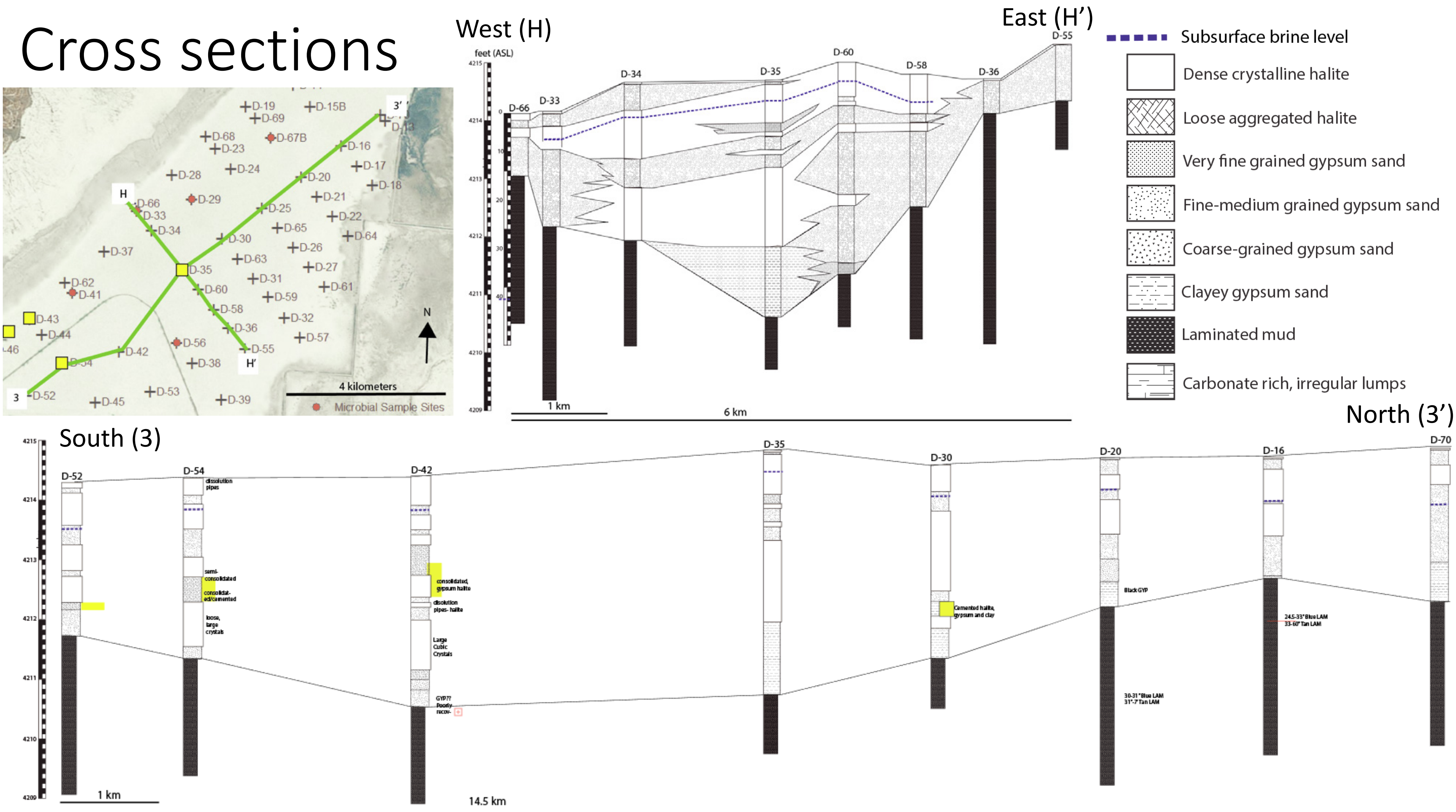


L. sappaensis

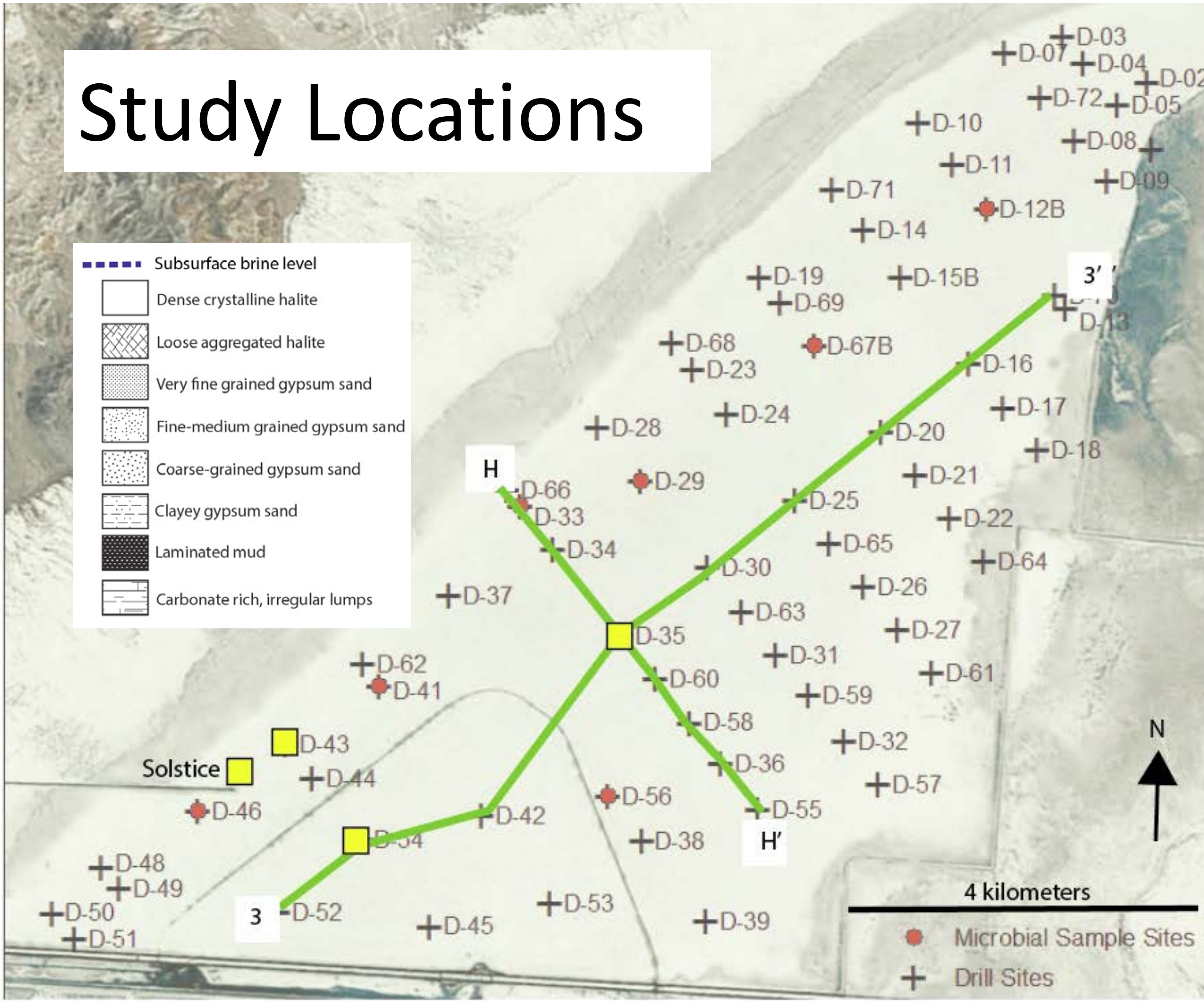
L. staplini

Personal communication with J. Oviatt, 2018

Cross sections



Solstice core
Jukebox trench
site location
cross section location


Study Locations
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D-69
3′
D-13
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D-67B
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D-16
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Solstice
D-36
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D-42
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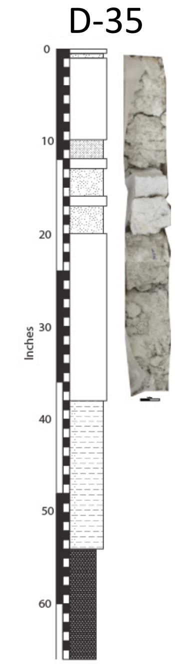
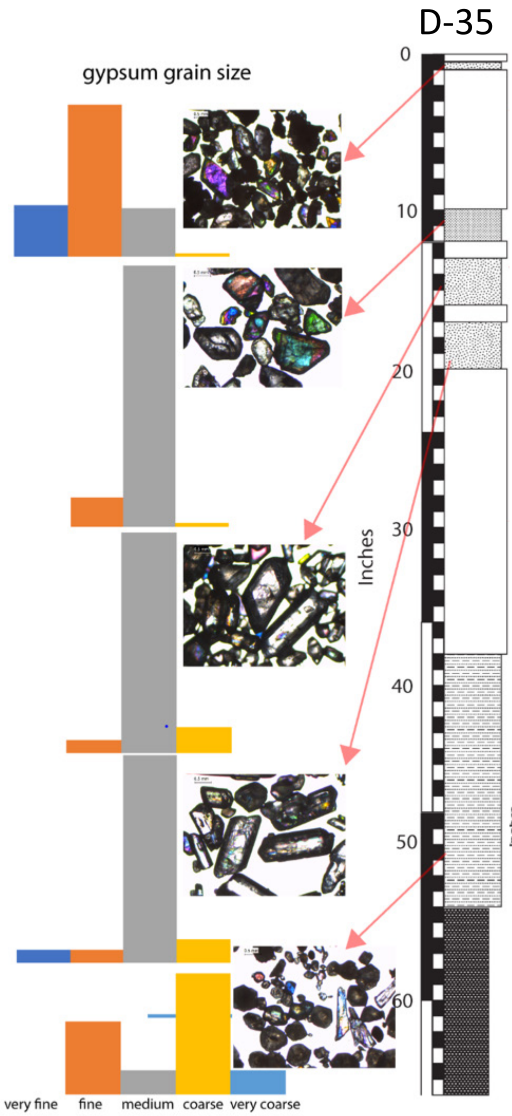
D-38
H′
D-48
D-49
3
D-52
D-53
D-50
D-45
D-39
D-51
N
4 kilometers
Microbial Sample Sites
Drill Sites

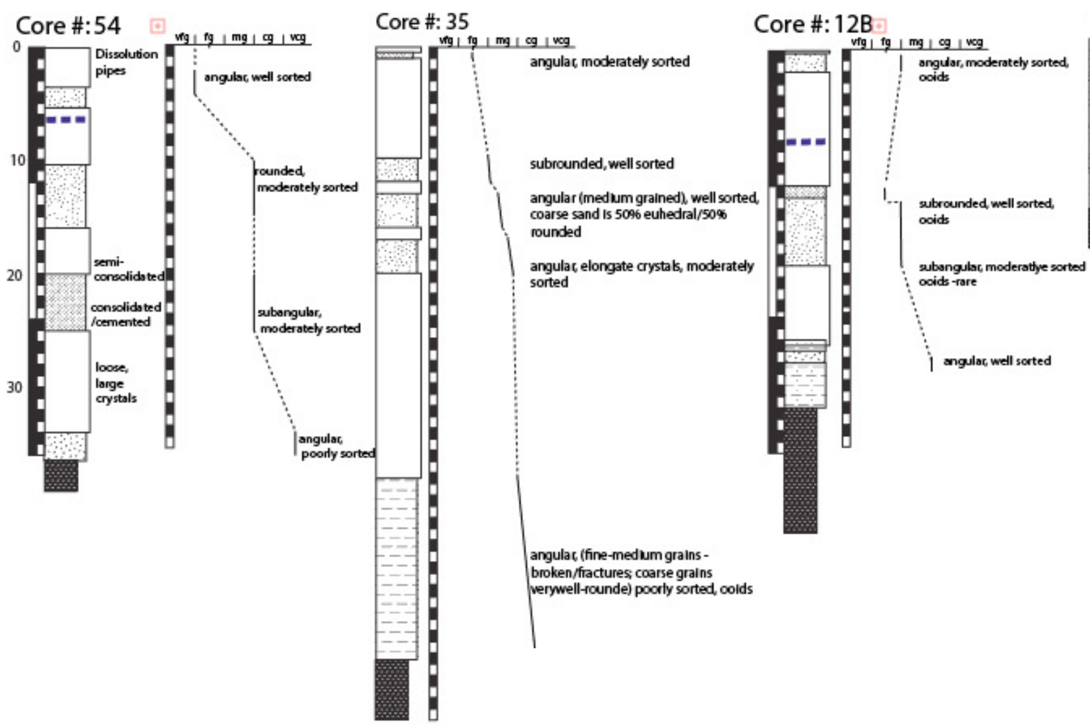

D-35
0
10
20
30
40
50
60
Inches

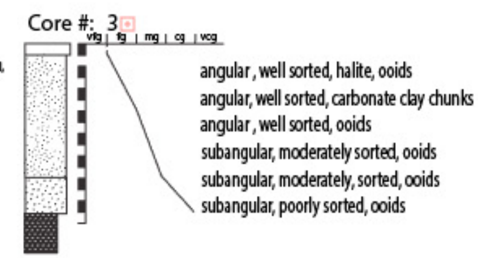

BSF-54 (crust)

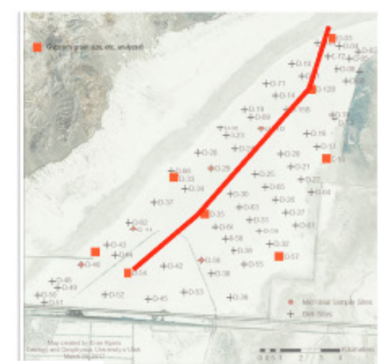


Sand Analysis

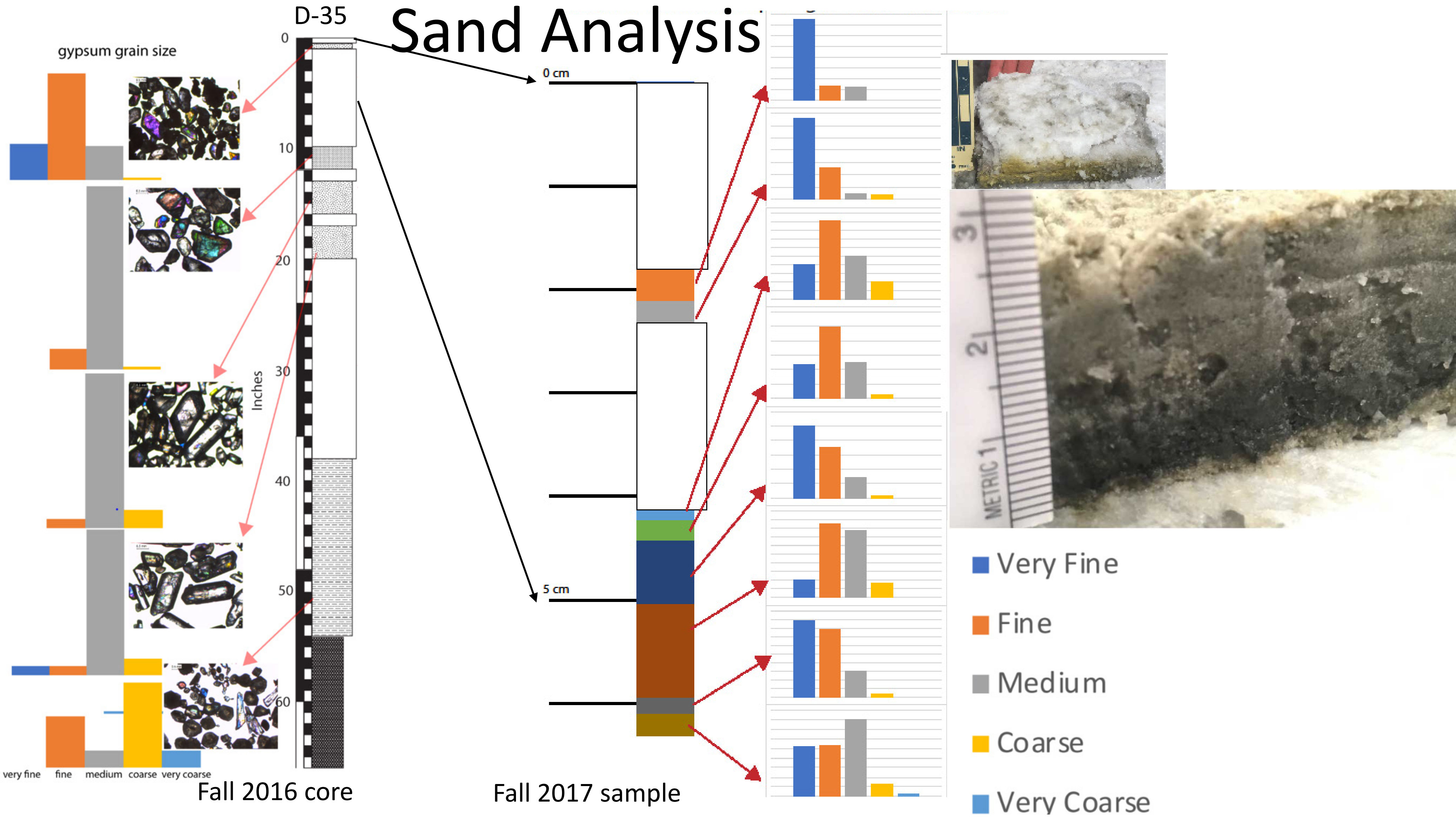
- Size, shape/angularity
- Sorting
- Composition



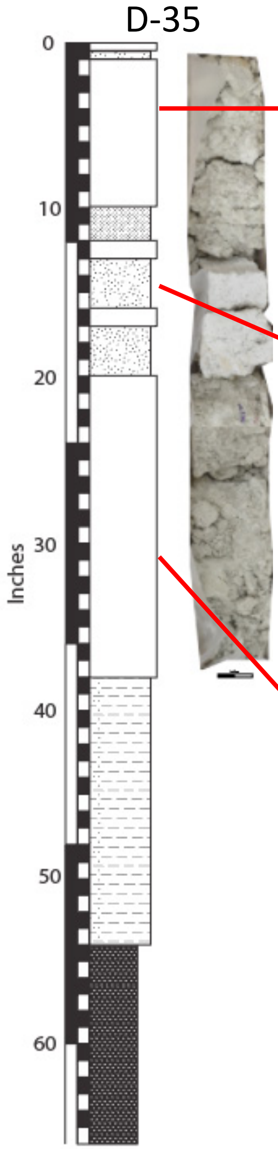


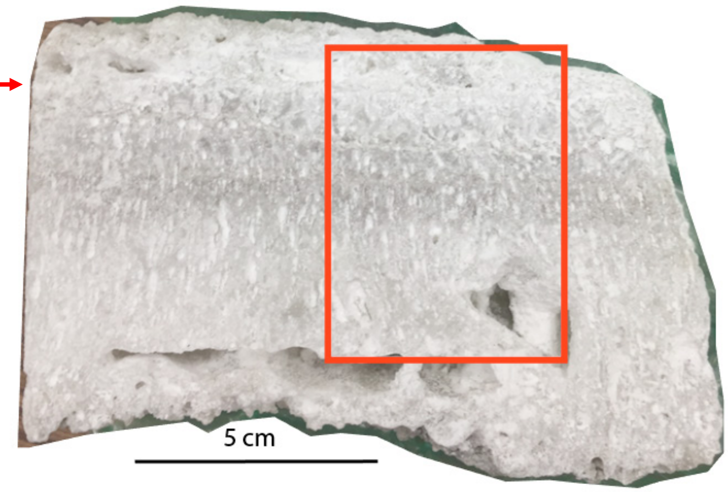


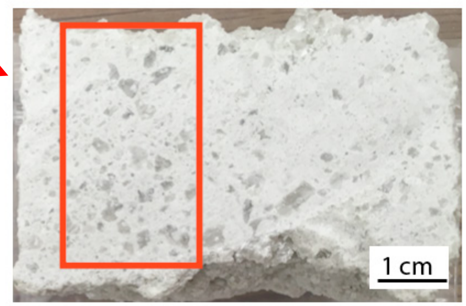
Sand Analysis



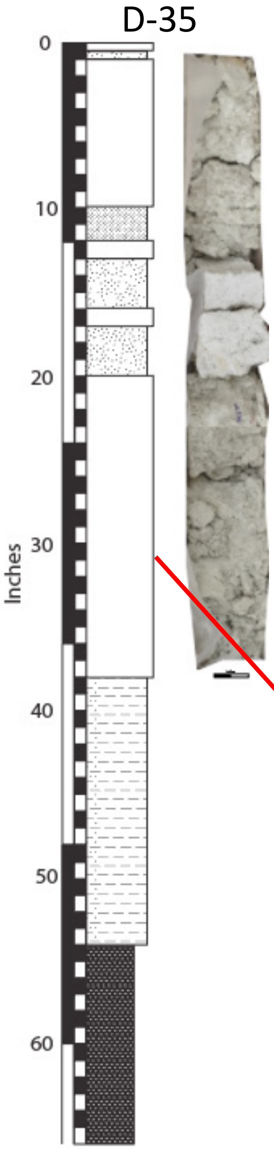
Evaporite Depositional Textures

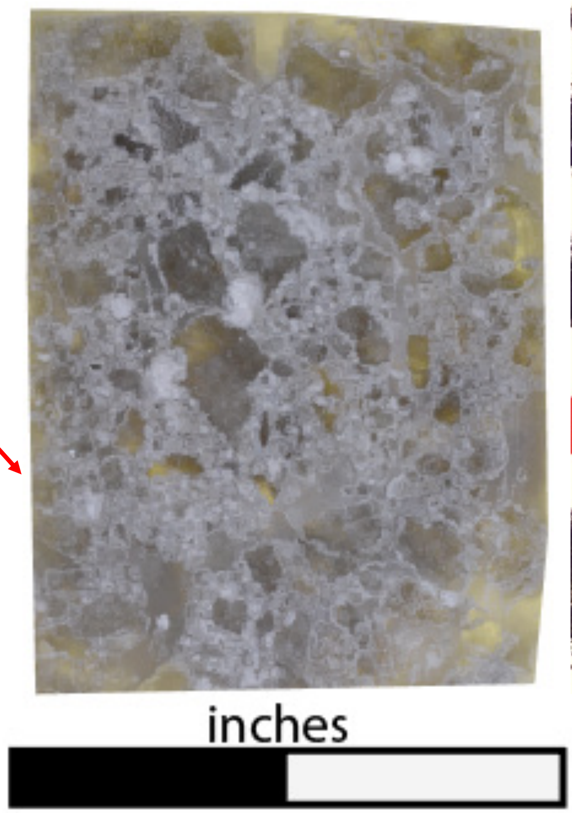


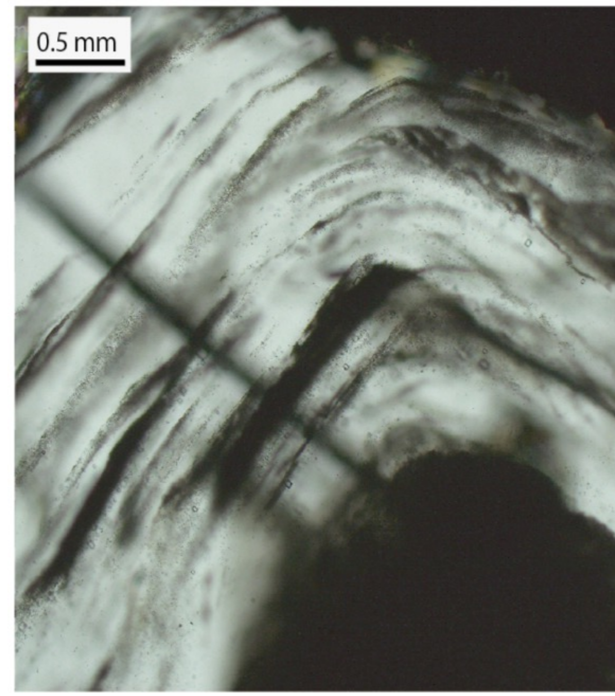




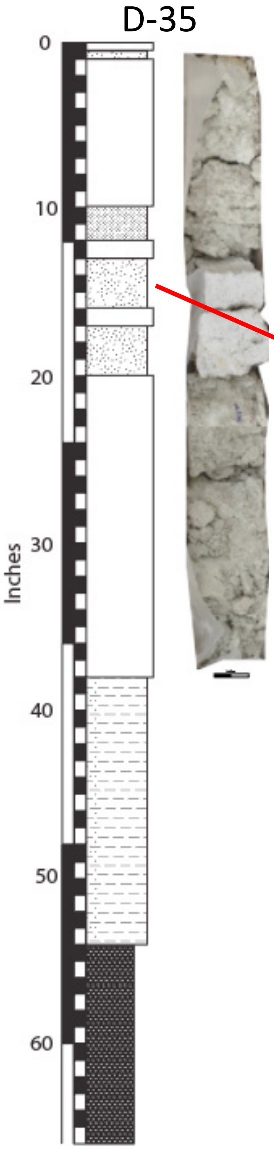
Evaporite Depositional Textures

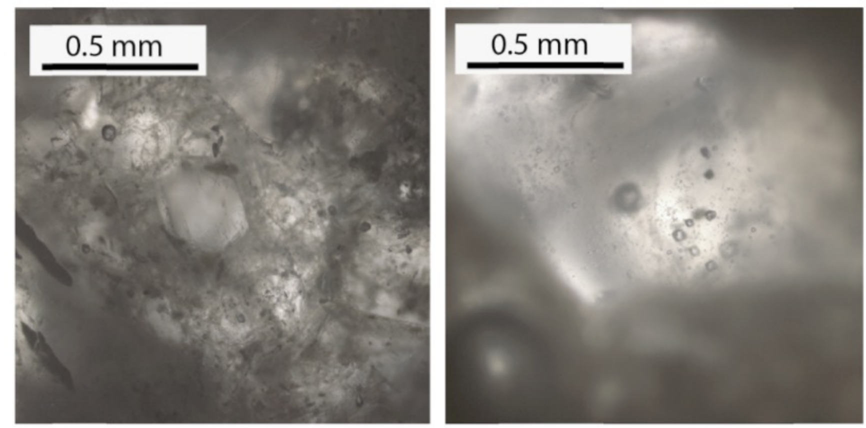


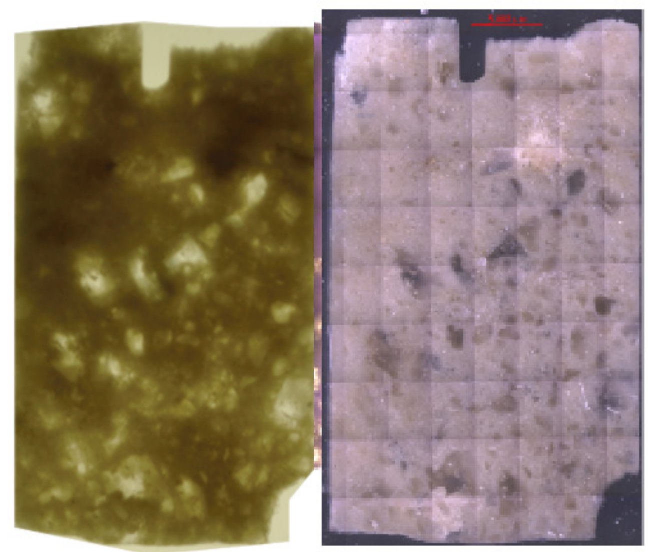




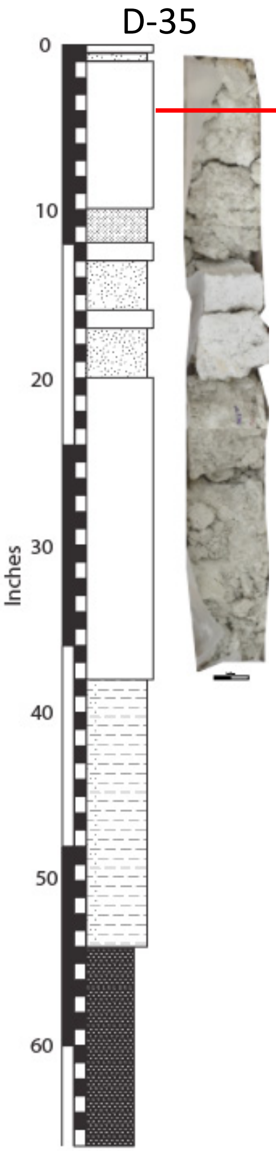
Evaporite Depositional Textures

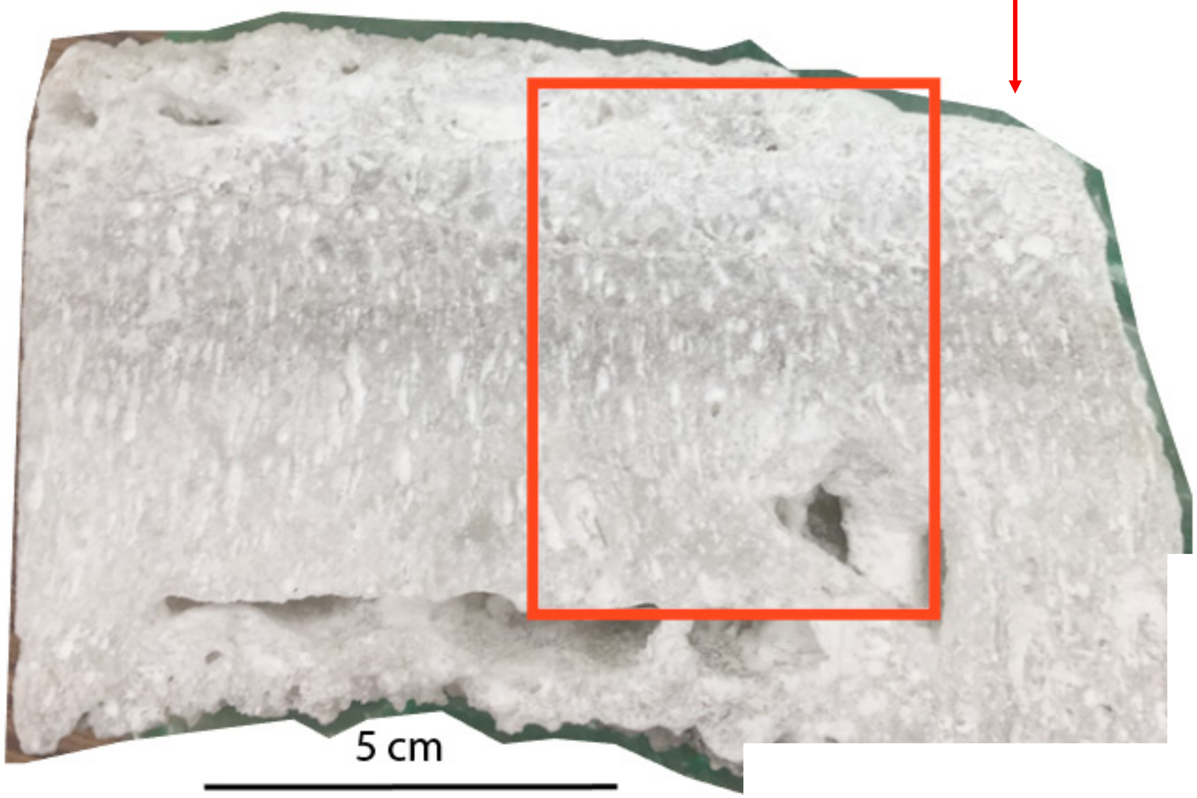


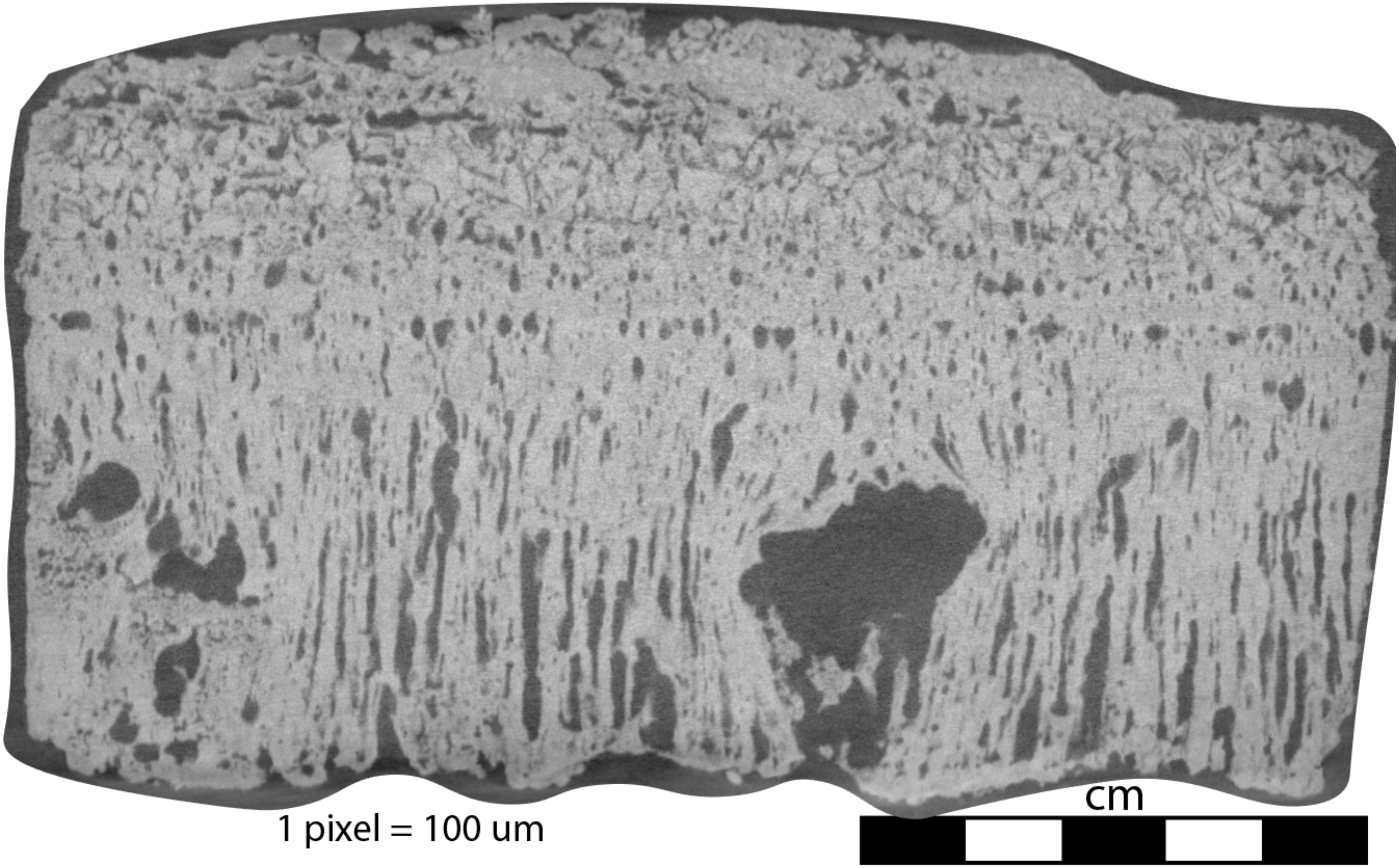


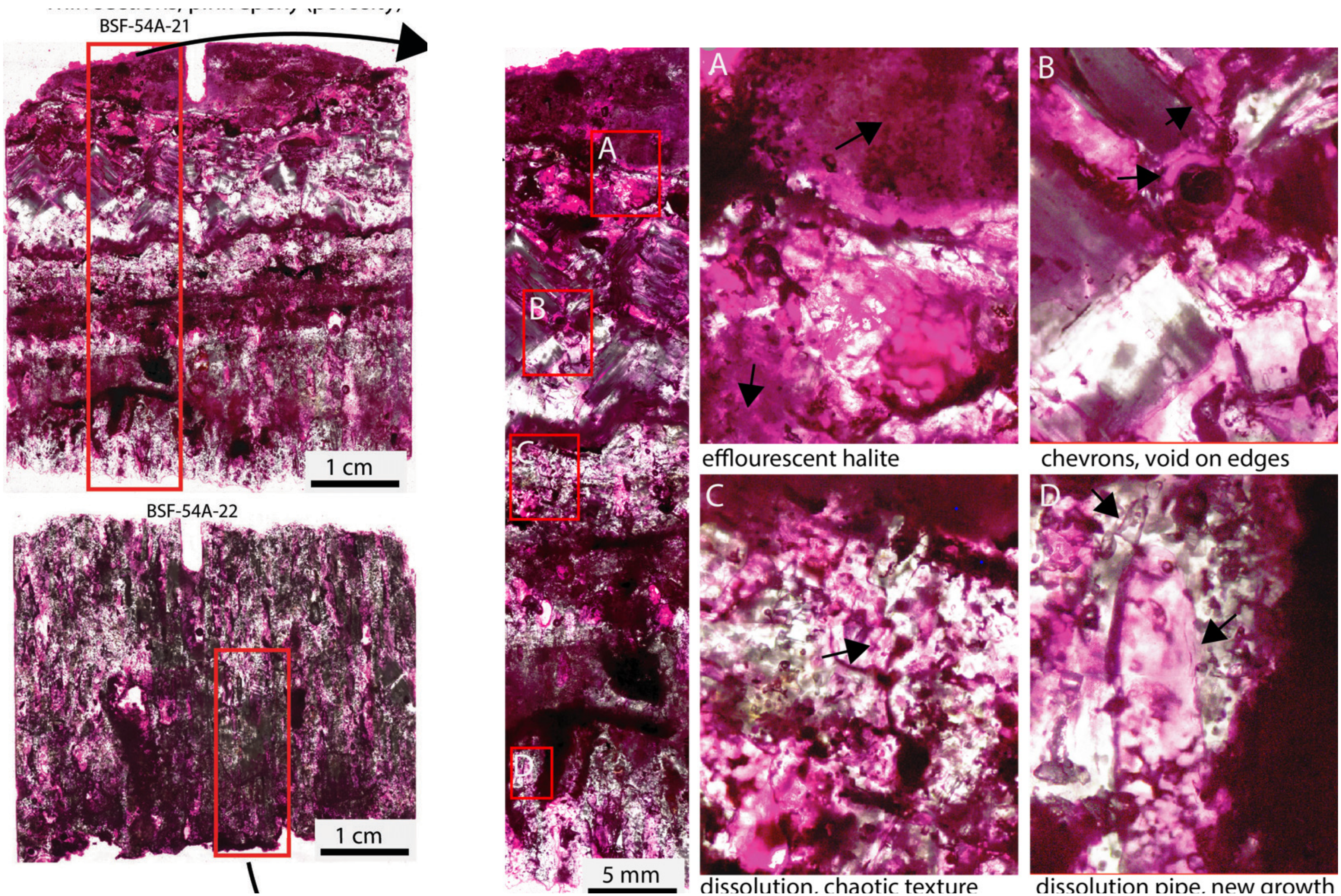


Evaporite Depositional Textures

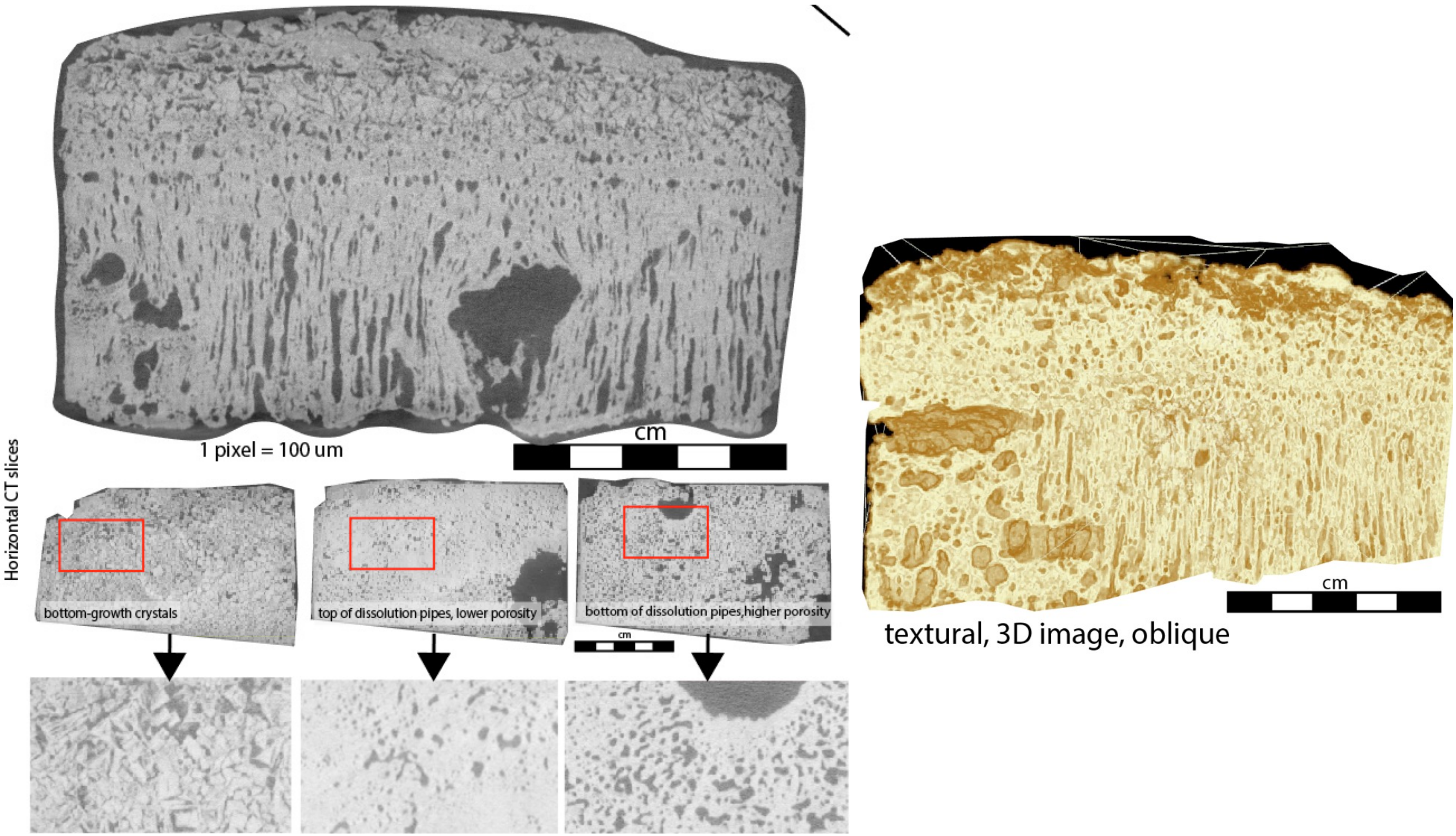




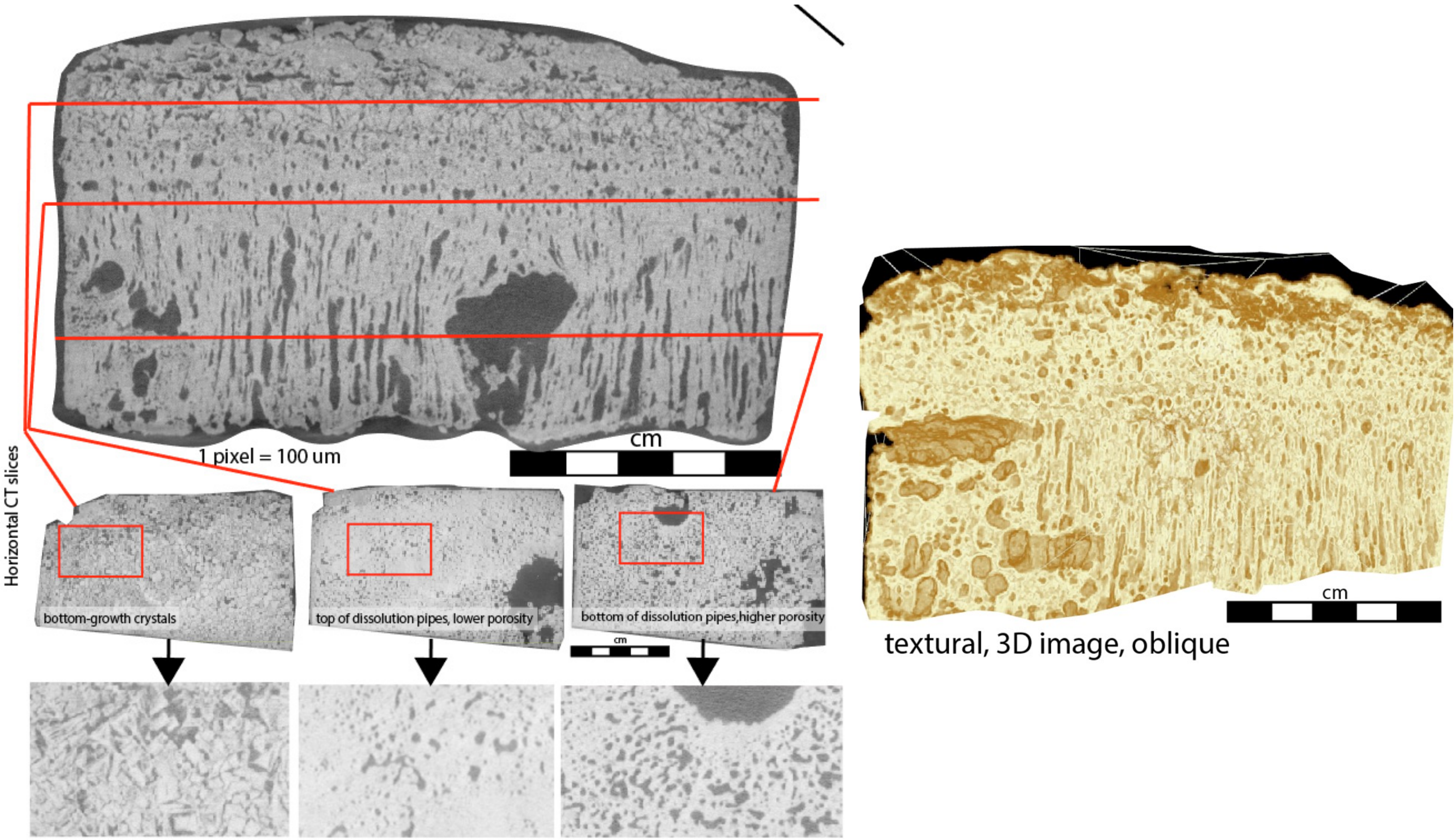

cm
1 pixel = 100 um



BSF-54A-21
1 cm
BSF-54A-22
1 cm
A
B
C
D
5 mm
A
B
efflourescent halite
chevrons, void on edges
C
D
dissolution, chaotic texture
dissolution pipe, new growth



1 pixel = 100 um
cm
Horizontal CT slices
bottom-growth crystals
top of dissolution pipes, lower porosity
bottom of dissolution pipes,higher porosity
cm
cm
textural, 3D image, oblique


Horizontal CT slices
1 pixel = 100 um
cm
bottom-growth crystals
top of dissolution pipes, lower porosity
bottom of dissolution pipes,higher porosity
cm
cm
textural, 3D image, oblique

Tying depositional record to modern observations

Testing Geochronology – Future Work

Geochronology

Tool – use	Lacustrine	Evaporite
OSL – fine grain fraction	X	?
Lead-Cesium		X
Carbon dating - Pollen	X	?
Uranium Series	X	?

Questions?

Special thanks to Jack Oviatt, Dave Dinter, Andrea Brunelle, Pete Lippert, Kaylee Barket Jones,

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@bsfscience

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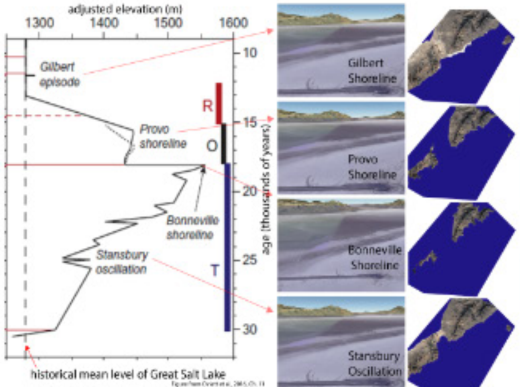
BSF Science

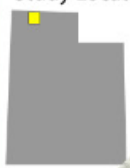
Research Questions: How, and when, did the Bonneville Salt Flats form? How are they changing now?

Background

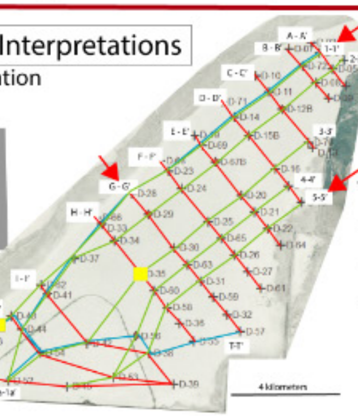


Interpretations

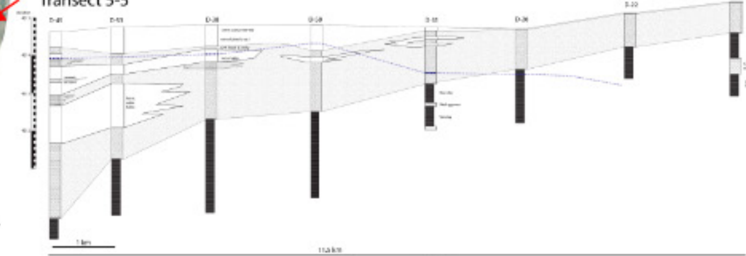
Study Location



Cores: Cross Section Transects



Transect 5-5'



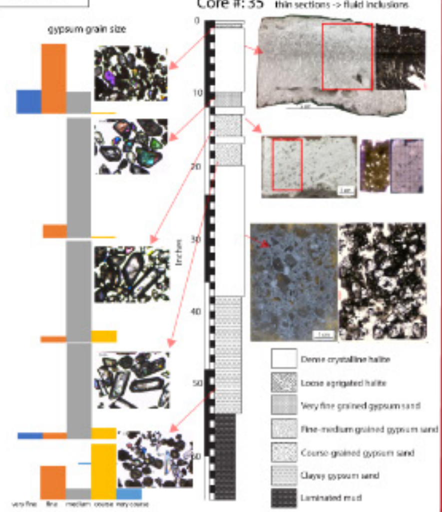
Conclusions

- Multiple processes: eolian, flooding, halite precipitation, etc. built the Bonneville Salt Flats
- Many environmental proxies can yield valuable insights
- More research necessary for better correlations and age determinations

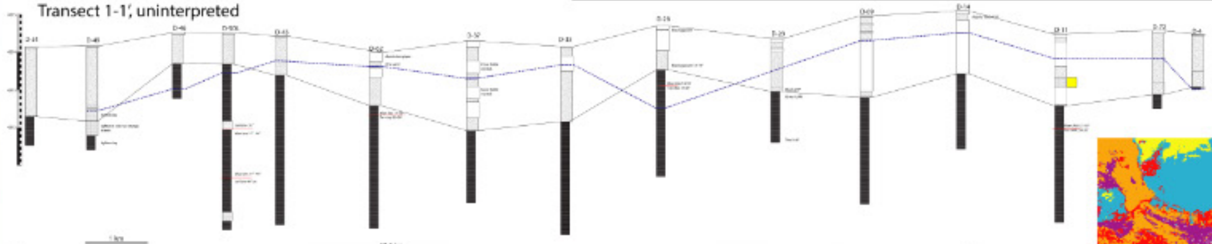
Acknowledgments: this research was funded by a NSF-CNH grant and would not have been possible without the input of Brenda Bowen, Evan Kipnis, and Lily Wetterlin.

Data

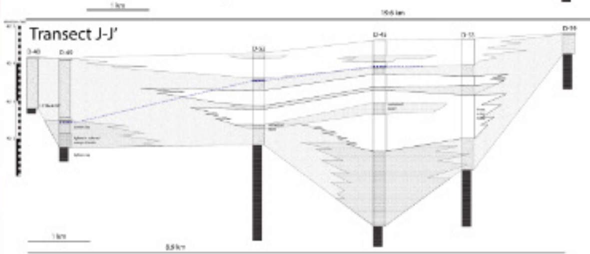
Core #: 35 thin sections -> fluid inclusions



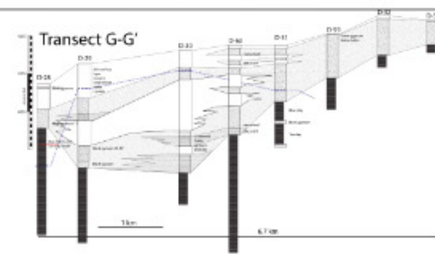
Transect 1-1', uninterpreted



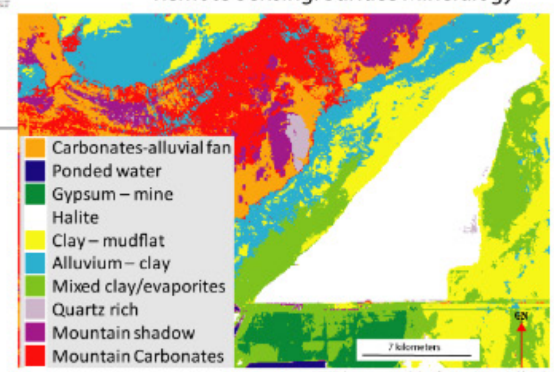
Transect J-J'



Transect G-G'

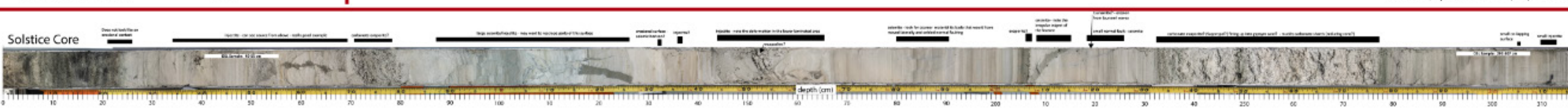


Remote Sensing: Surface Mineralogy



ASTER data, supervised classification, 14 spectral bands

Solstice Core



Jeremiah A. Bernau
jeremiahbernau@gmail.com
Brenda B. Bowen

Deposition and Diagenesis of the Bonneville Salt Flats

THE UNIVERSITY OF UTAH

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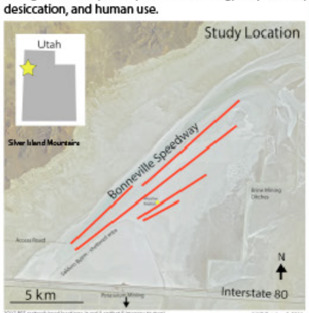
BSF Science

Introduction

BSF is an ephemeral saline pan consisting of a lens-shaped surface layer of up to ~2m of interbedded halite and gypsum overlying fine grained carbonate-rich laminated mud that is generally interpreted as a remnant of the desiccation of Lake Bonneville. The surface landscape and surface evaporite sediments change seasonally in response to flooding, evaporation, desiccation, and human use.



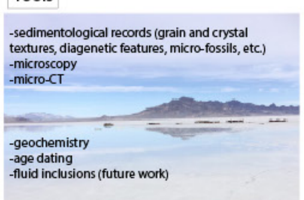
Research Questions

How, and when, did the Bonneville Salt Flats form?

-What are modern and paleo-timescales of deposition and erosion?

-What processes are driving chemical sediment precipitation, accumulation, dissolution? (Unique opportunity to study modern surface processes as well as recent depositional record)

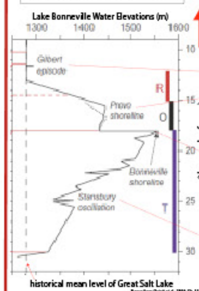
Tools



-sedimentological records (grain and crystal textures, diagenetic features, micro-fossils, etc.)
-microscopy
-micro-CT

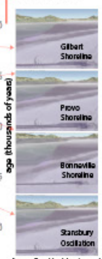
-geochemistry
-age dating
-fluid inclusions (future work)

Geological Context



historical mean level of Great Salt Lake

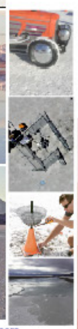
study time period - past 10,000 years



Access Road looking toward Silver Island Mountains

Current Processes

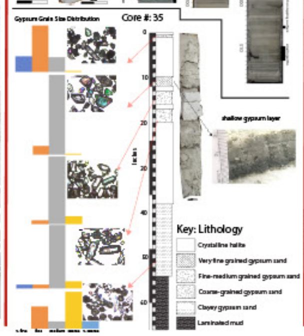
Other Processes: erosion, runoff, eolian input, racing, mining, brine management



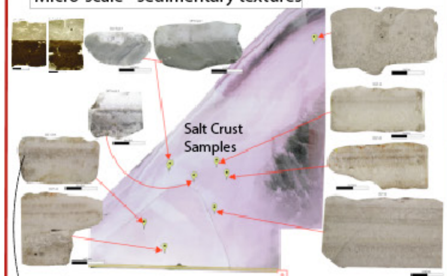
See current crust conditions: bit.ly/bsfcamera

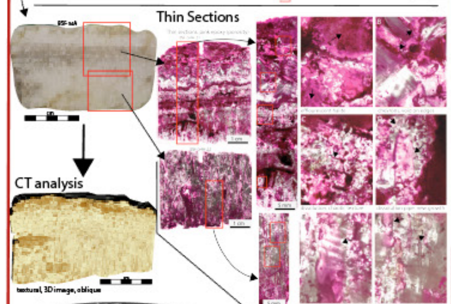
Core Data

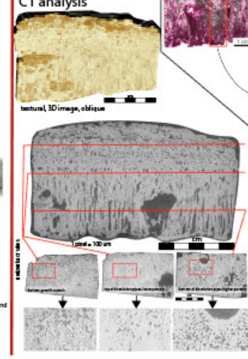
69 shallow non cased cores (up to 6 ft), one 10-foot vibracore

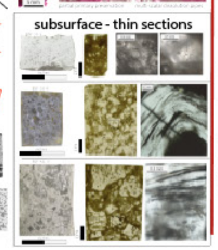


Micro-scale - sedimentary textures

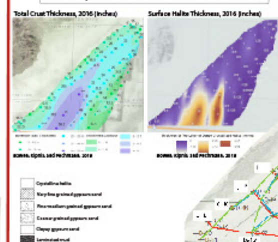


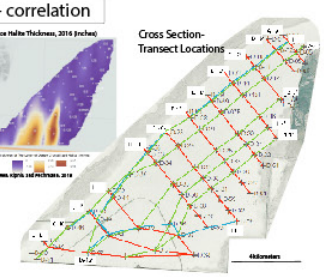


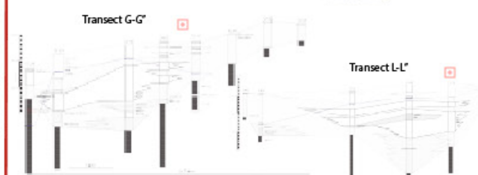


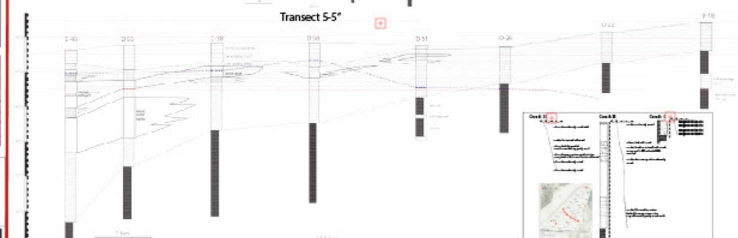


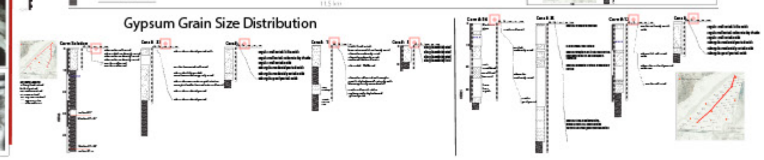
Interpretation - correlation











Interpretations

Halite:

- primarily deposited and preserved as bottom growth chevrons
- isolated accumulation from wind concentrating rafts
- organic material preserved within halite
-primary fluid inclusions indicate surface halite growth associated with dissolution pipes

Gypsum:
- mixed gypsum sand sources
- eolian reworking of some gypsum
- fining upward trend

Diagenesis:
-halite porosity increases with depth
-chevron crystals cemented as porosity increases along dissolution pipes
-halite preservation decreases with depth

Acknowledgments: this research was funded by a NSF-CNH grant and would not have been possible without the input of Evan Kipnis and Lily Wetterlin.

IS WATER FROM LAKE BONNEVILLE STILL WITH US? A GEOCHEMICAL EVALUATION OF GROUNDWATER IN THE WESTERN BONNEVILLE BASIN

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Corresponding author (Lerback): jory.lerback@gmail.com

ABSTRACT

Groundwater flowing into the Bonneville basin (BB) is used by phreatophytic vegetation, agriculture and domestic use, the U.S. Army (Dugway Proving Ground), mining, and is a critical component controlling the landscape of the Bonneville Salt Flats (BSF). Saline groundwater in BB is pumped from north and south of BSF onto the surface of BSF in an attempt to mitigate salt removal by mining. Blue Lake (BL), just south of BSF, is one of the largest springs in Utah's West Desert, and likely hydrologically connected to BSF through the relatively homogenous BB basin-fill lake sediment. This research aims to address 1) how connected and homogenous the groundwater beneath the western BB is, and 2) whether the groundwater has moved along regional flow paths toward BB, or is a direct remnant of infiltration from Lake Bonneville (LB).

Radiocarbon (^{14}C) dating of the water at BL and groundwater wells at BSF suggest these flow systems recharged 8000-16,000 years ago. A deep well (350 ft) northwest of BSF has a 2.7 percent modern carbon (pmC), compared to the 8.5 pmC at BL. These waters may have recharged at a time when LB still covered the basin, and possibly directly from the lake. Sr isotopic composition of the BL and wells at BSF ($^{87}Sr/^{86}Sr$ = 0.7135 and 0.7126, respectively) indicate that BL discharge might have similar water-rock interactions as BSF groundwater, meaning all may have been LB water. The major ion compositions (Na^+, Ca^{2+}, Mg^{2+}, Cl^-, $HCO3^-$, $SO4^{2-}$) and noble gas composition (^{20}Ne, ^{40}Ar, ^{84}Kr) of BL is more similar to that of BSF groundwater than that of the groundwaters sampled from outside the BB.

However, particle tracking simulations in the Great Basin Carbonate and Alluvial Aquifer System Numerical Model (Brooks and others, 2014) show that water in BB may be a mixture of water from the nearby mountain ranges and inter-basin flow from the surrounding nested valleys. Additional ^{14}C dates were obtained to address whether the water of BL and BSF wells are from different interbasinal flow systems as the hydrologic model suggests. Wells in the adjacent valleys (Deep Creek and Antelope Valleys) have corrected radiocarbon transit times of 2000–9500 years (corrected from 16–63 pmC). These results are ambiguous as younger ages in potential recharge areas may be interpreted that these samples are higher up on a similar flow path, moving ultimately to BB where older ages are to be expected. Deuterium and $\delta^{18}O$ isotopes also indicate that all waters sampled have a similar origin, as they trend along a common path of isotopic evolution toward the end member of the highly evaporated BSF waters.

Understanding the composition, chemical evolution, and overall availability of this deep groundwater in the western BB will inform how groundwater affects the landscape at BSF, and how it can be used to further human activities there.

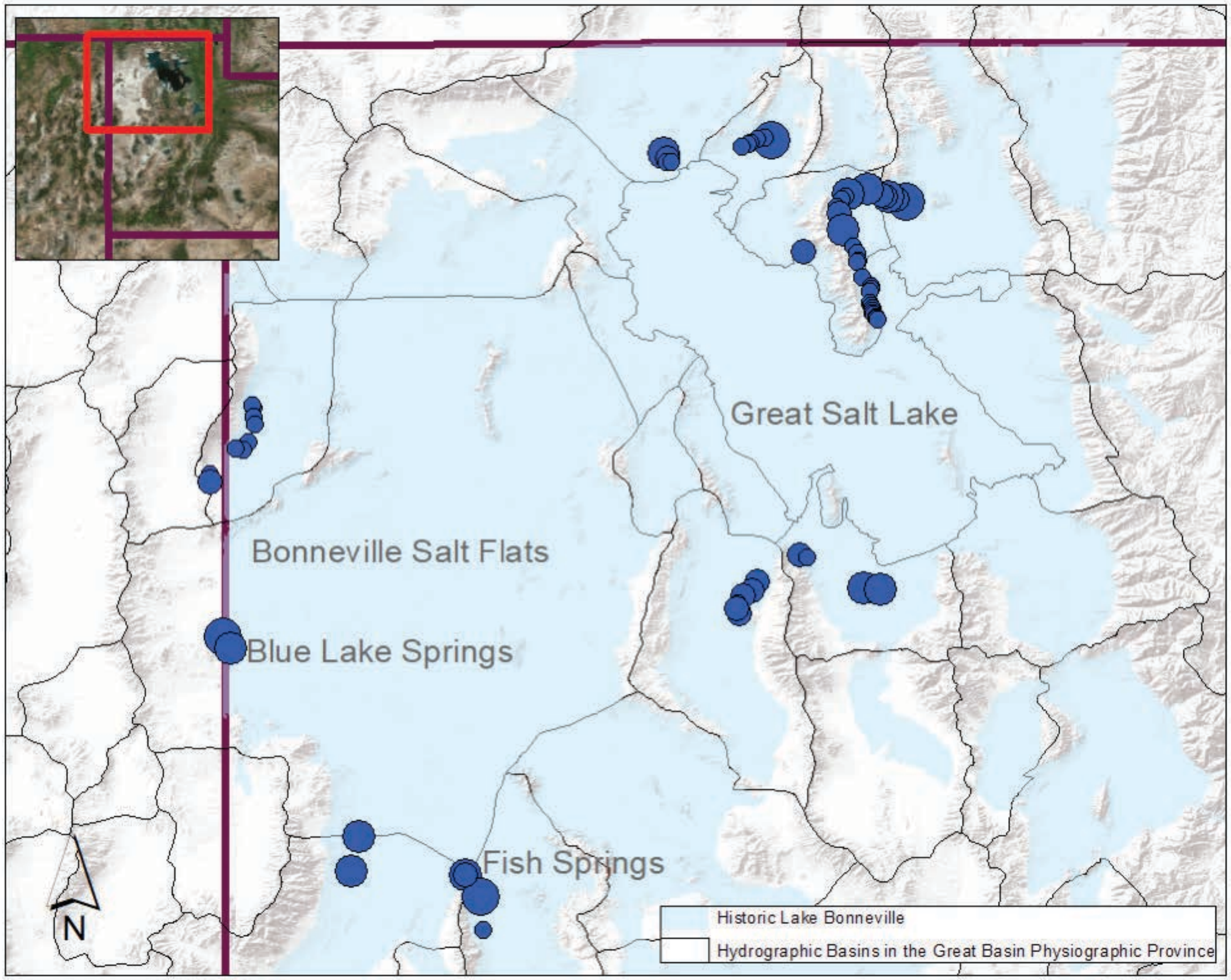
REFERENCE

Brooks, L. E., Masburch, M.D., Sweetkind, D.S., and Buto, S.G., 2014, Steady-state numerical groundwater flow model of the Great Basin carbonate and alluvial aquifer system: US Geological Survey Scientific Investigation Report 124-5213, 124 p.

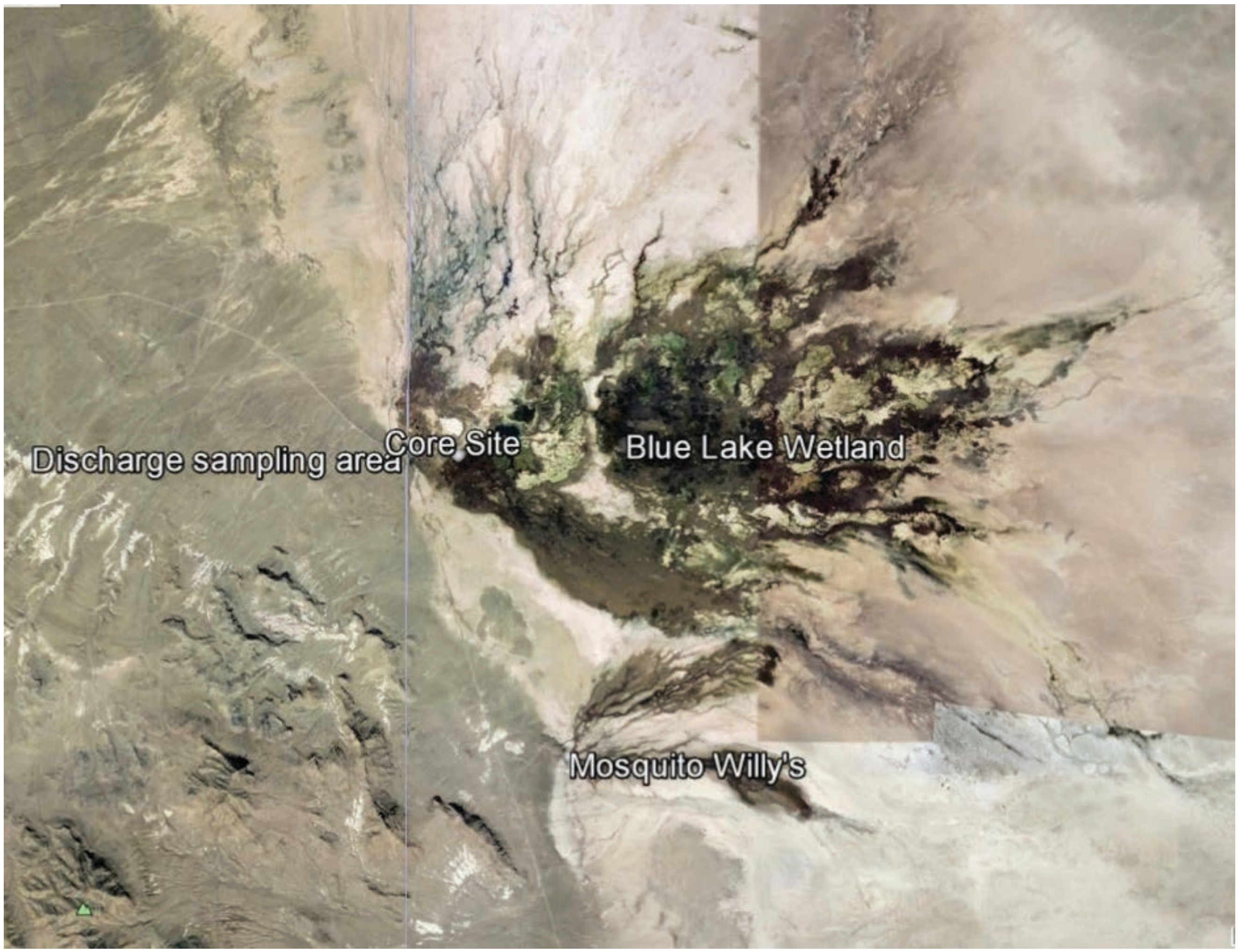
This content is a PDF version of the author's PowerPoint presentation.

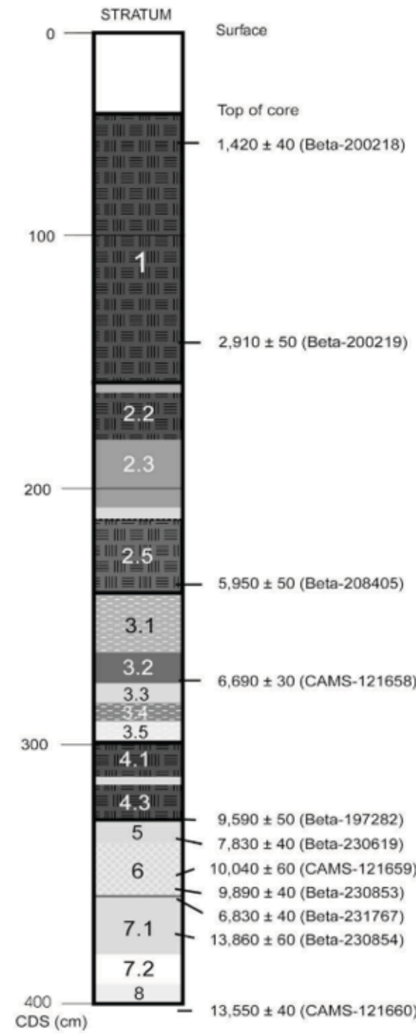
A geochemical evaluation of groundwater in the western Bonneville basin

Jory Lerback[1], Brenda Bowen[1], Scott Hynek[1,2], Chris Bradbury[1]
[1]Department of Geology and Geophysics, University of Utah
[2]U.S. Geological Survey, Utah Water Science Center


Great Salt Lake
Bonneville Salt Flats
Blue Lake Springs
Fish Springs
N
Historic Lake Bonneville
Hydrographic Basins in the Great Basin Physiographic Province

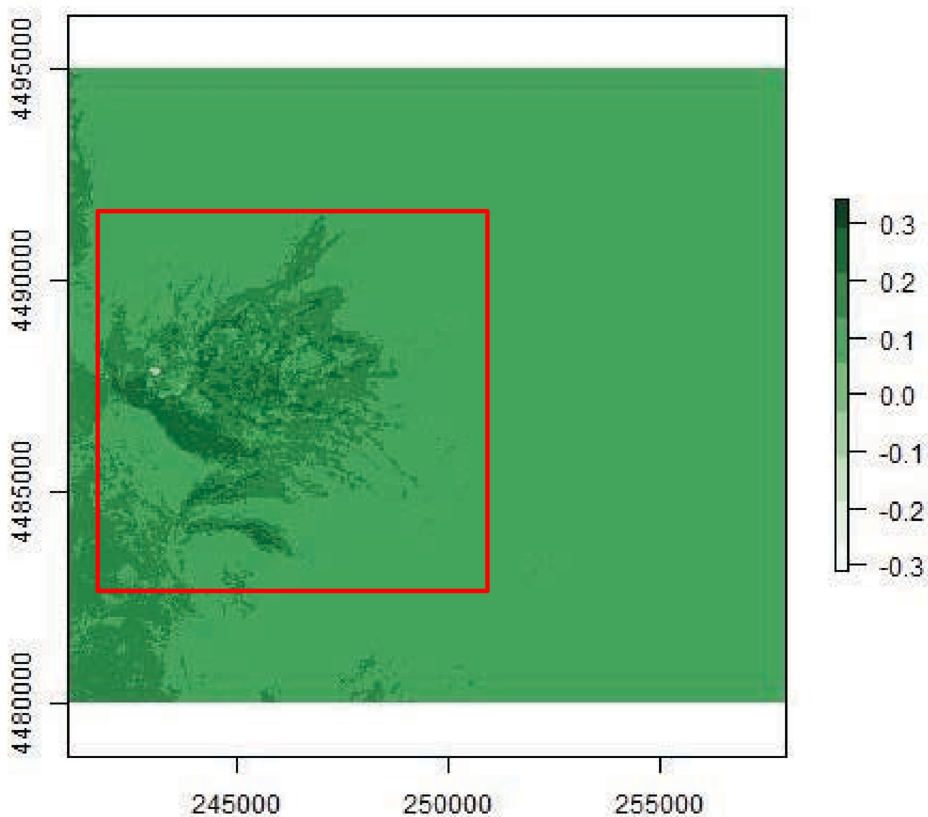
Blue Lake
Redden Springs
Fish Springs
Google Earth
Image Landsat / Copernicus
N
60 km





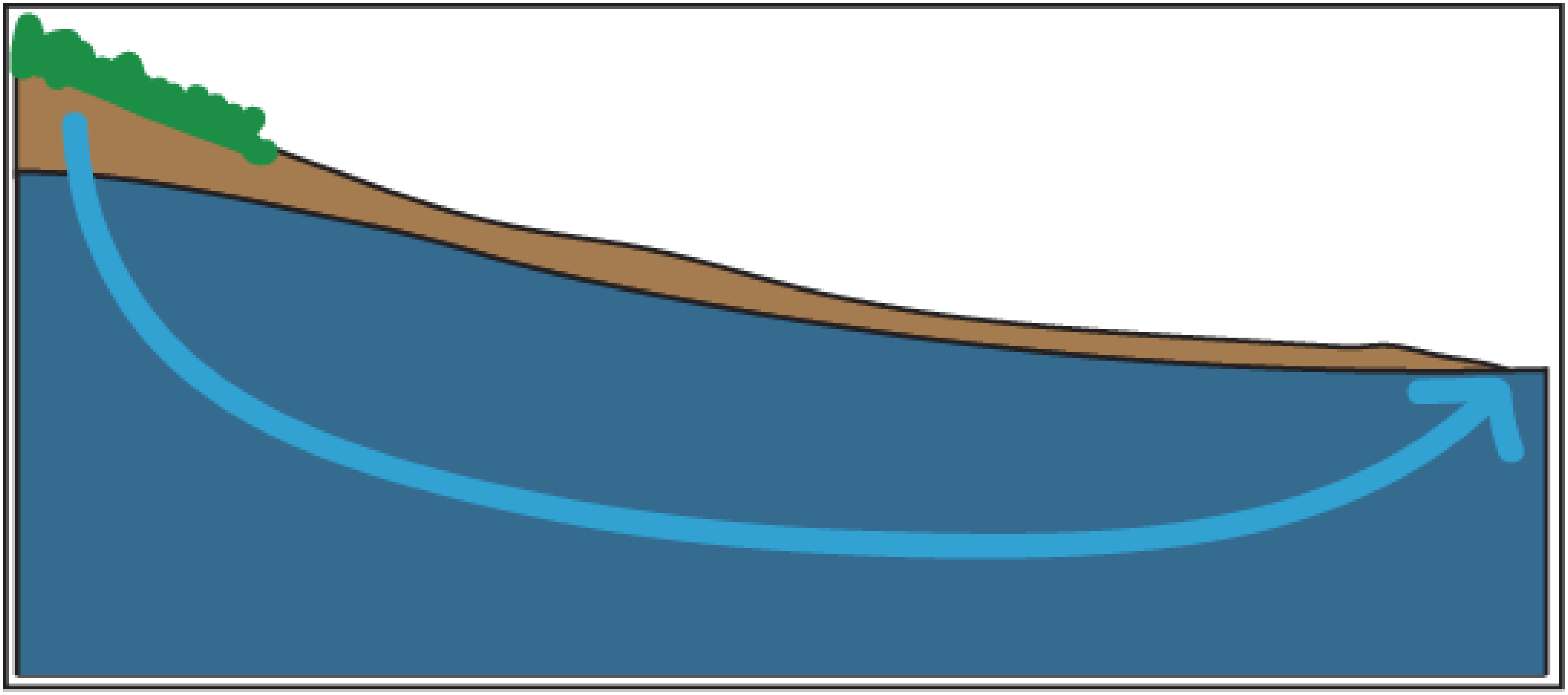
Louderback and Rhode, 2009

Water balance at Blue Lake (BL)

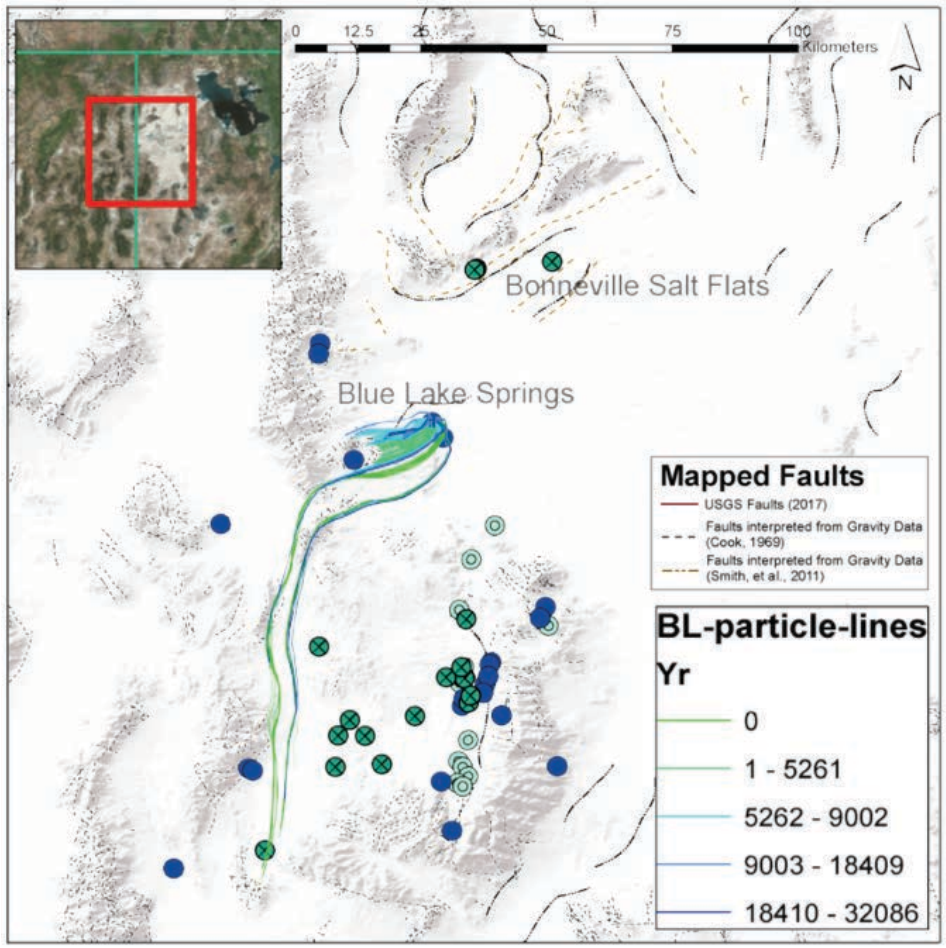


Gardner & Masbruch, 2015; Flint & Flint, 2007

Hypothesis 1: Mountain Front Recharge



Hypothesis 2: Interbasinal Groundwater Flow



Hypothesis 3: Pluvial Infiltration

- Storage in alluvial and limestone aquifers would change
- Discharge rates variable through time

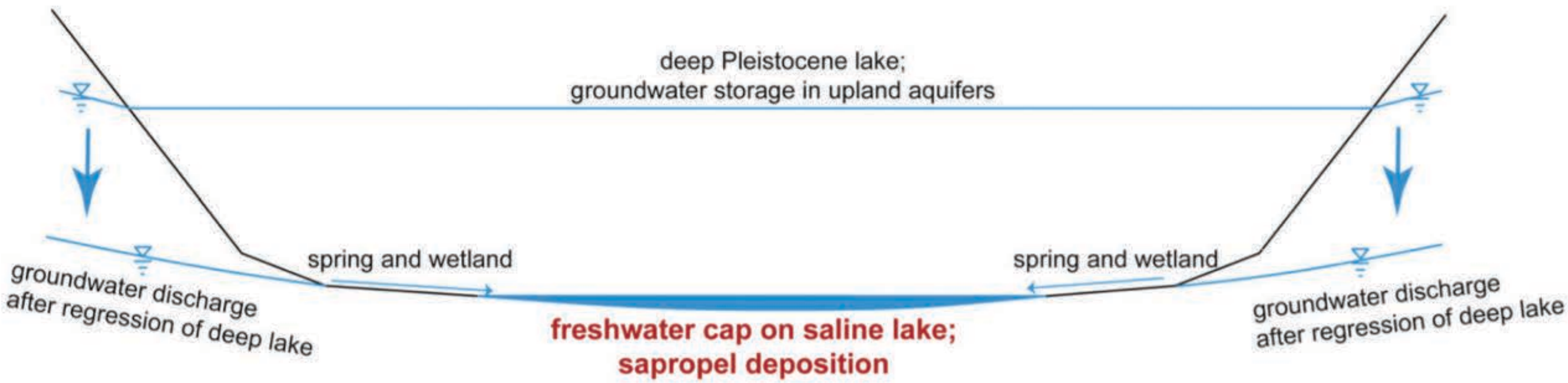
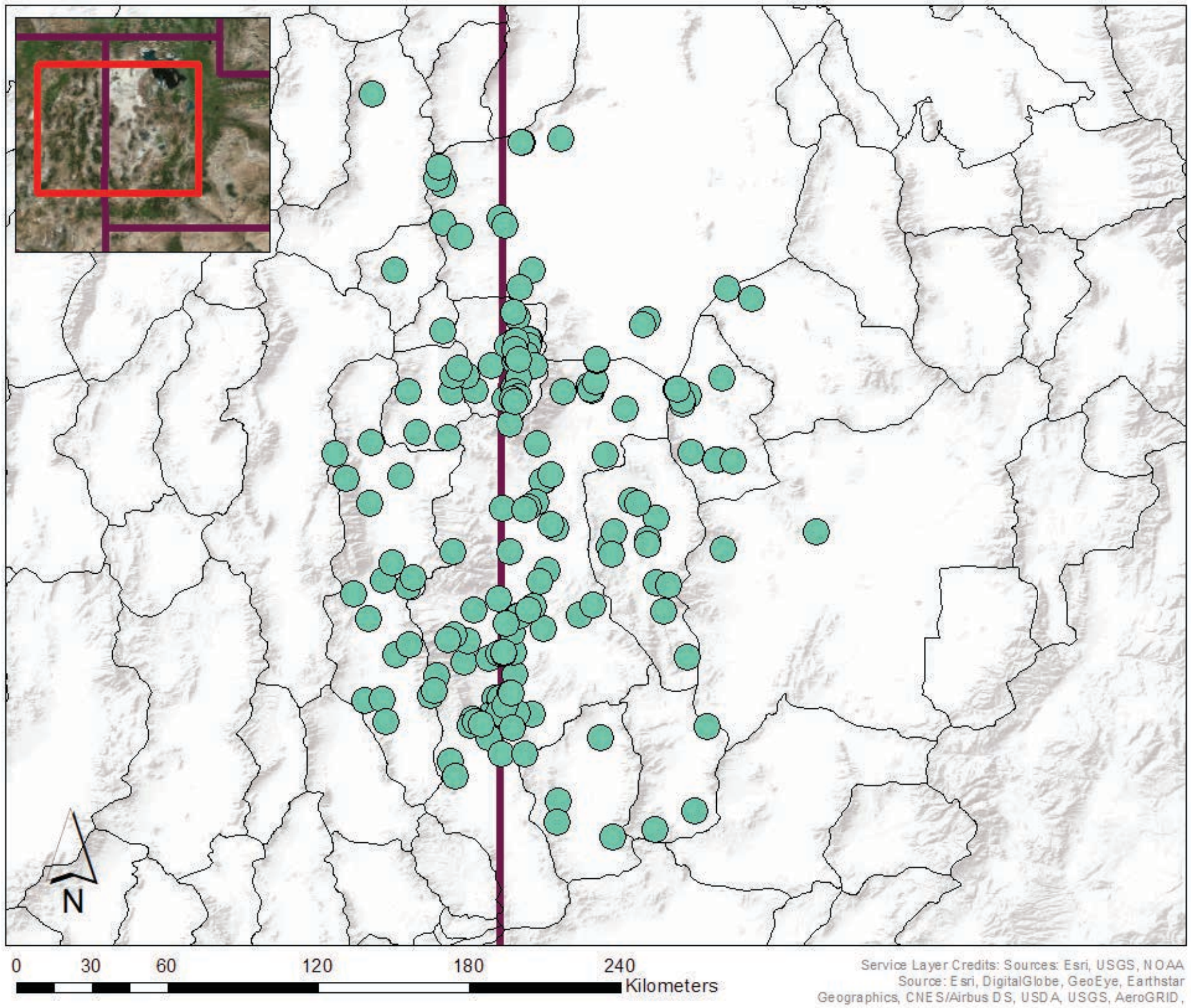
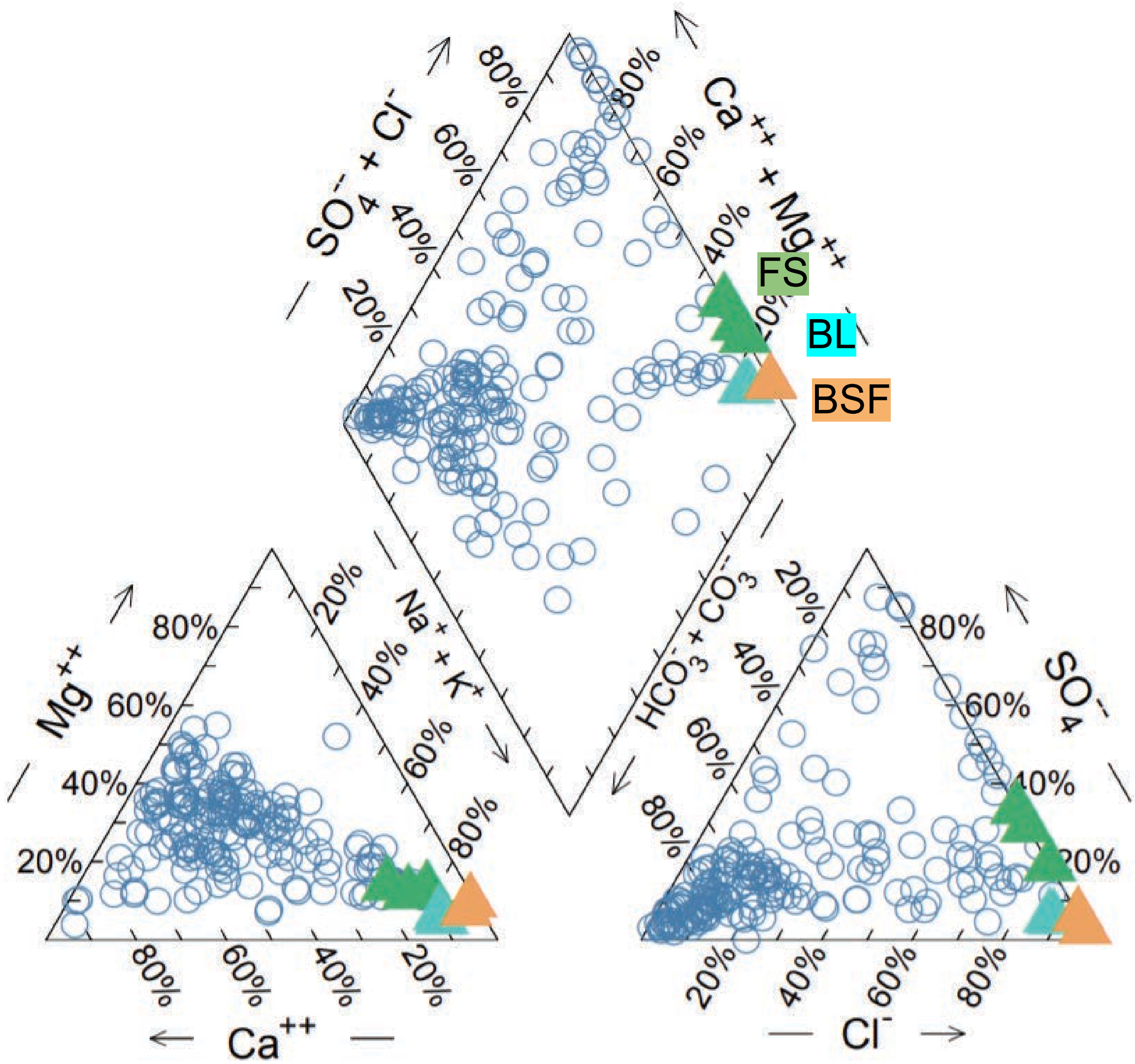


Figure 11. Conceptual model for the deposition of organic-rich laminated mud on the floor of shallow GSL during the early Holocene.

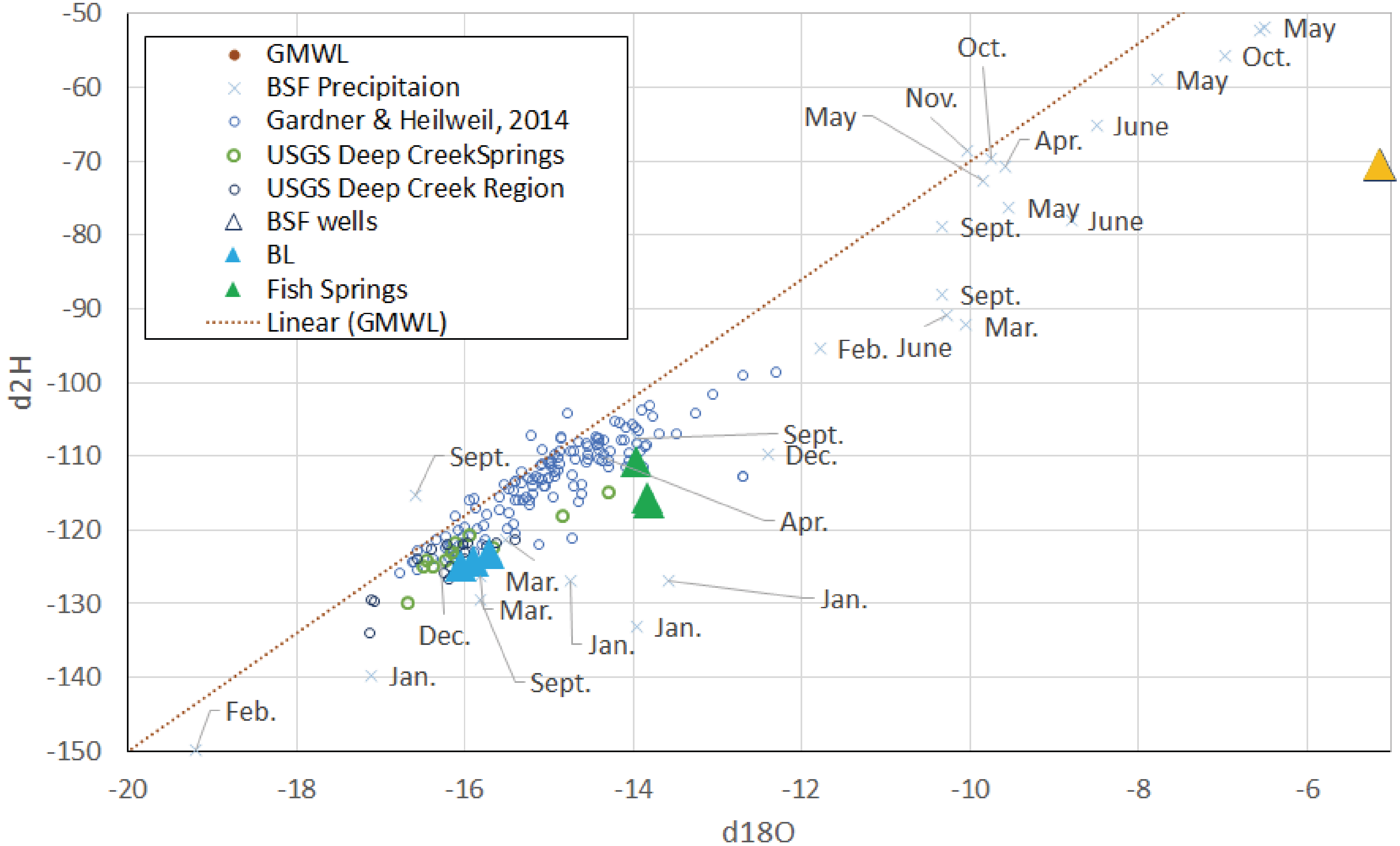
Oviatt et al., 2015



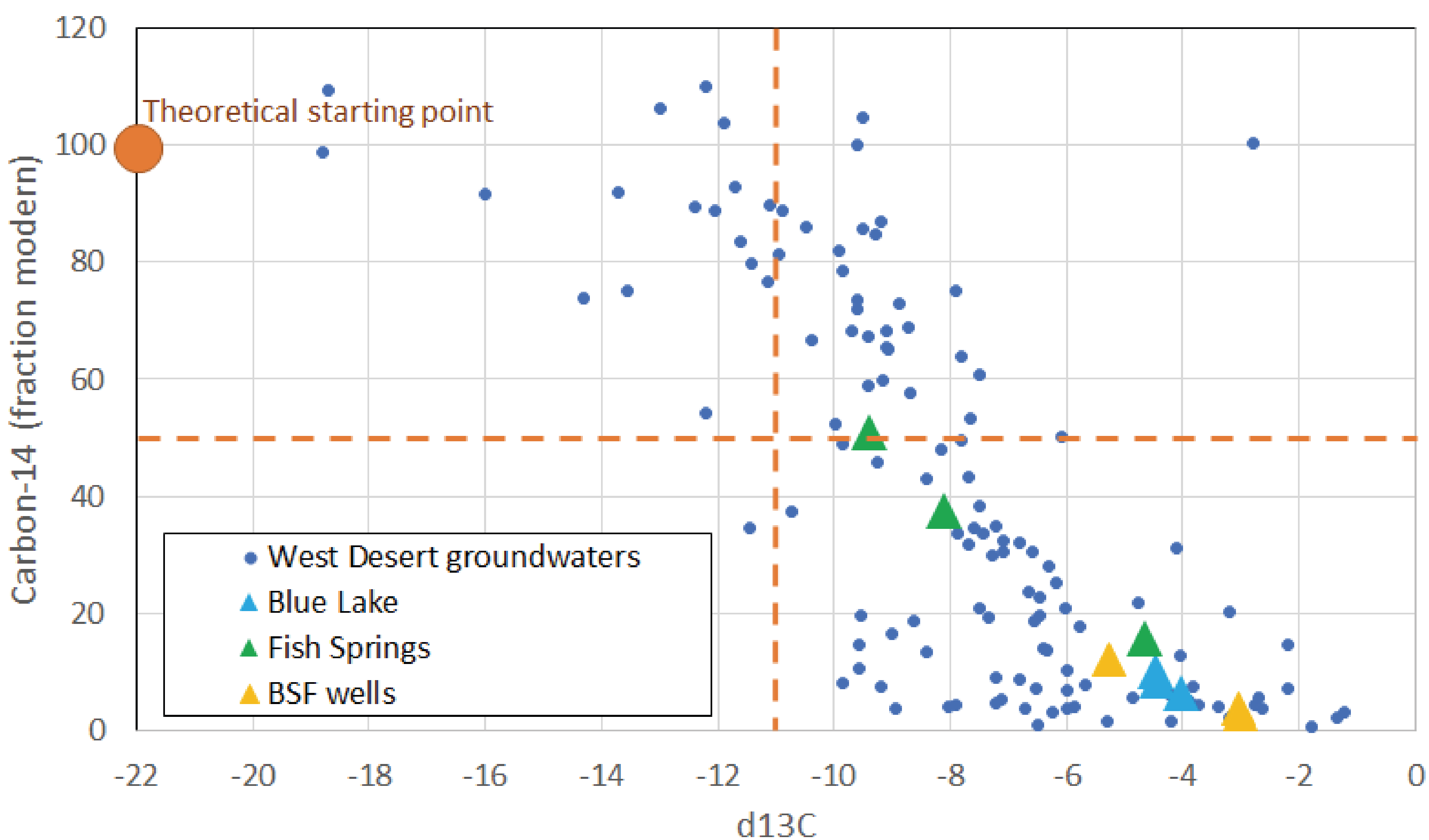
West Desert groundwaters after Gardner & Heilweil, 2014, Gardner and Masbruch, 2015, USGS, and Current study



West Desert groundwaters after Gardner & Heilweil, 2014, Gardner and Masbruch, 2015, USGS, and Current study



West Desert groundwaters after Gardner & Heilweil, 2014, Gardner and Masbruch, 2015, USGS, and Current study

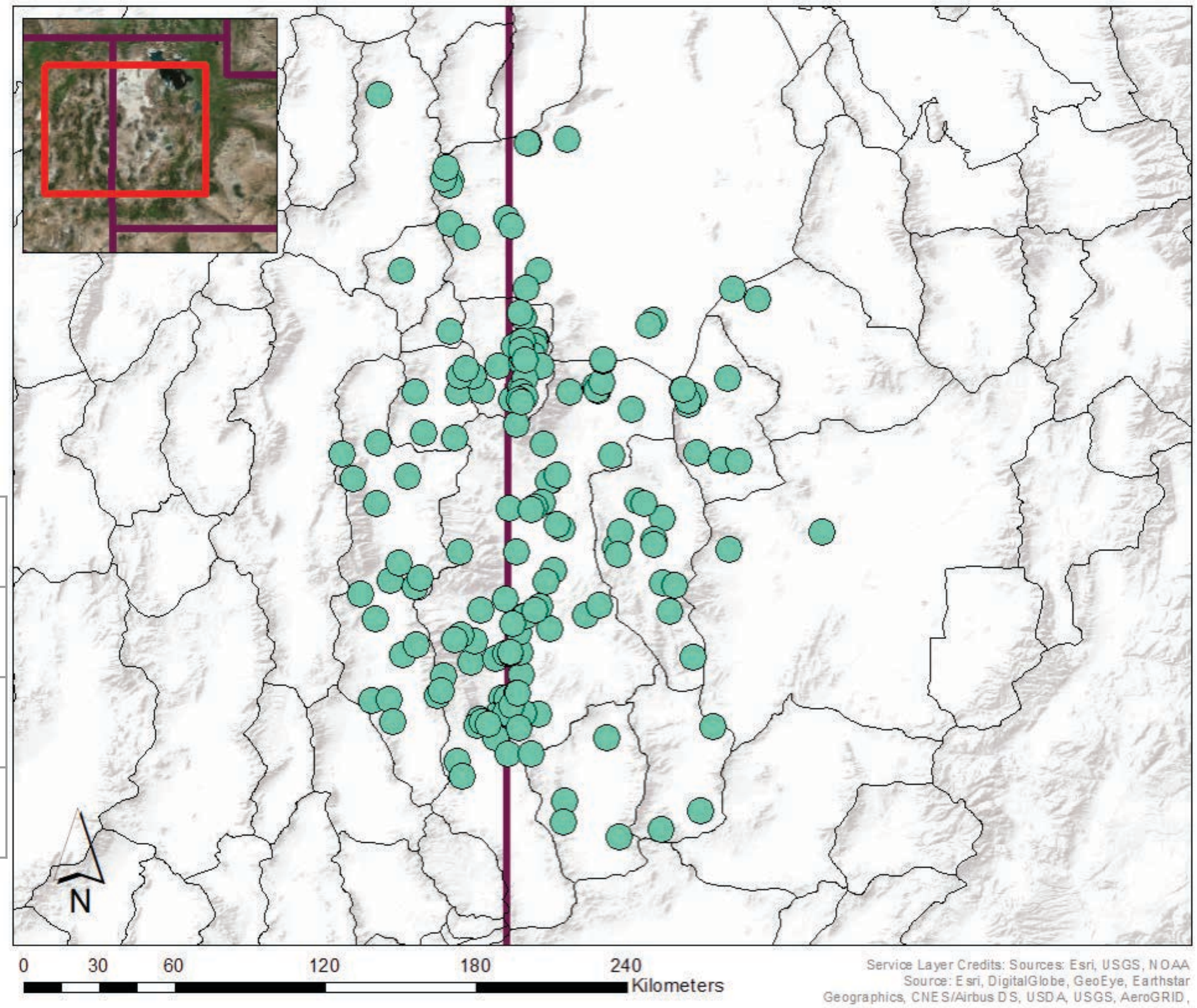


West Desert groundwaters after Gardner & Heilweil, 2014, Gardner and Masbruch, 2015, USGS, and Current study

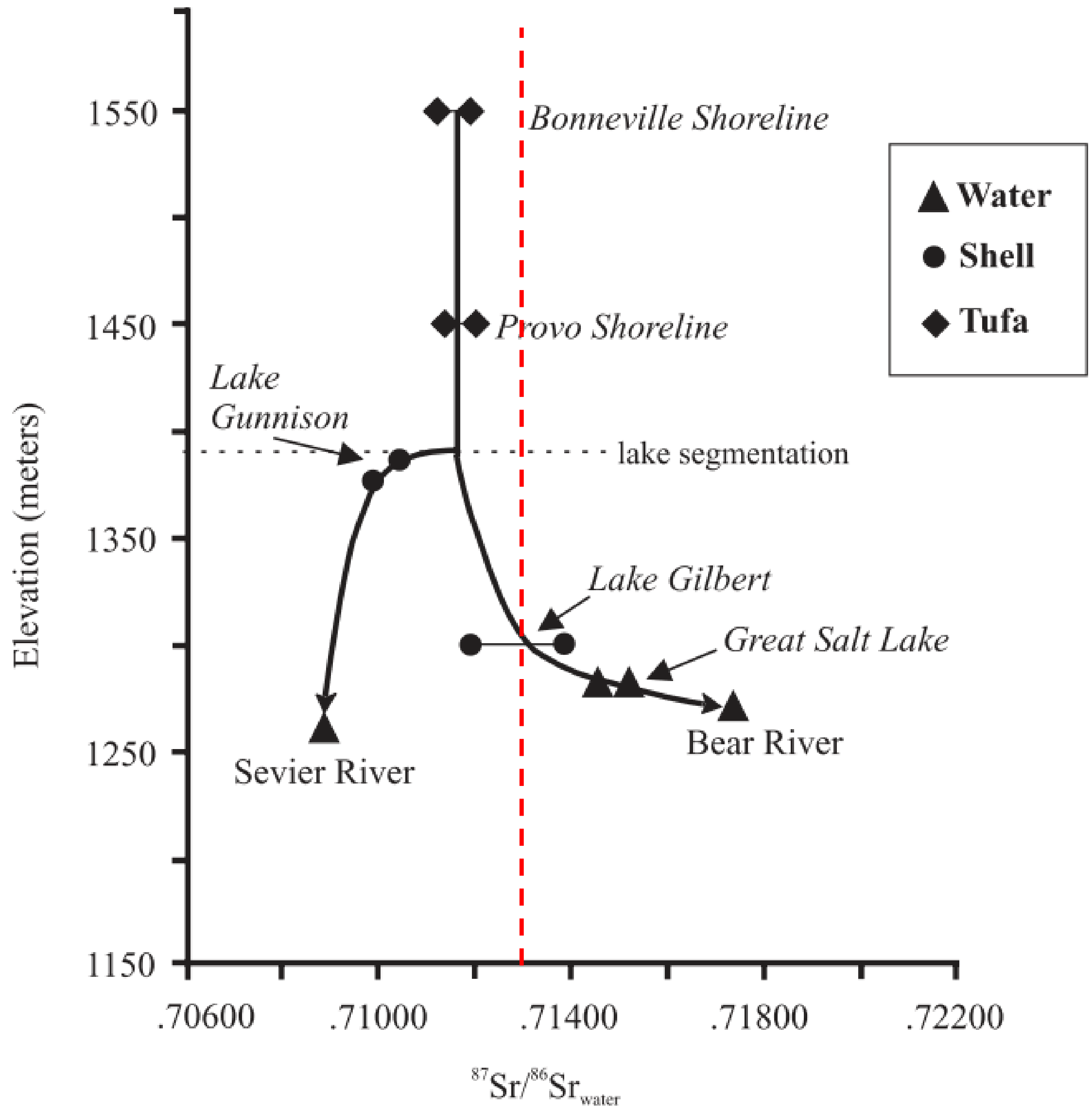
Radiocarbon dates

Using the Han and Plummer, 2013 groundwater correction model and the Gonfiantini, 1972 IAEA model

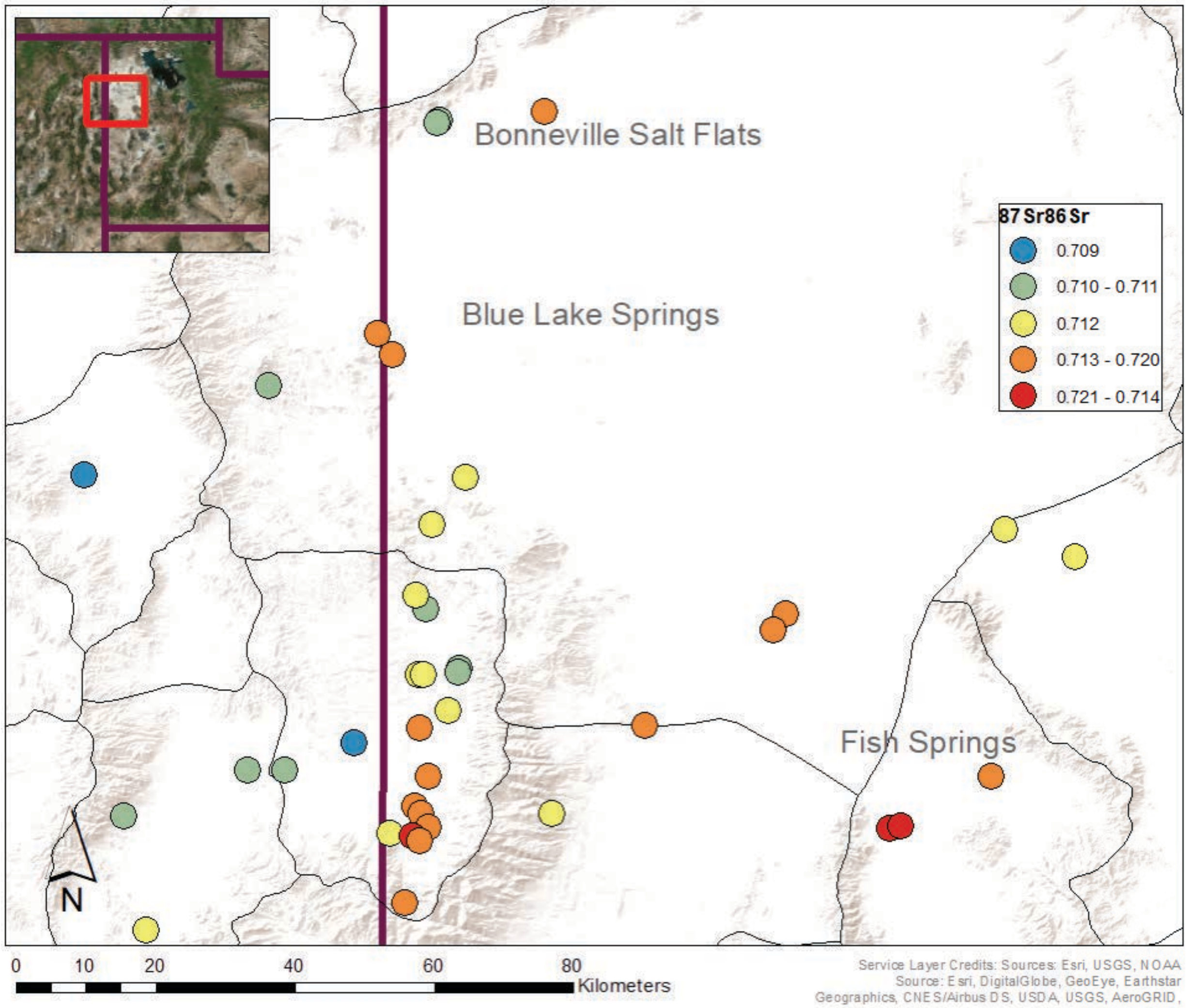
Site	Mean Transit Time Range
BL	5-12ka
FS	800 yr - 6ka
BSF deep well	10-16ka

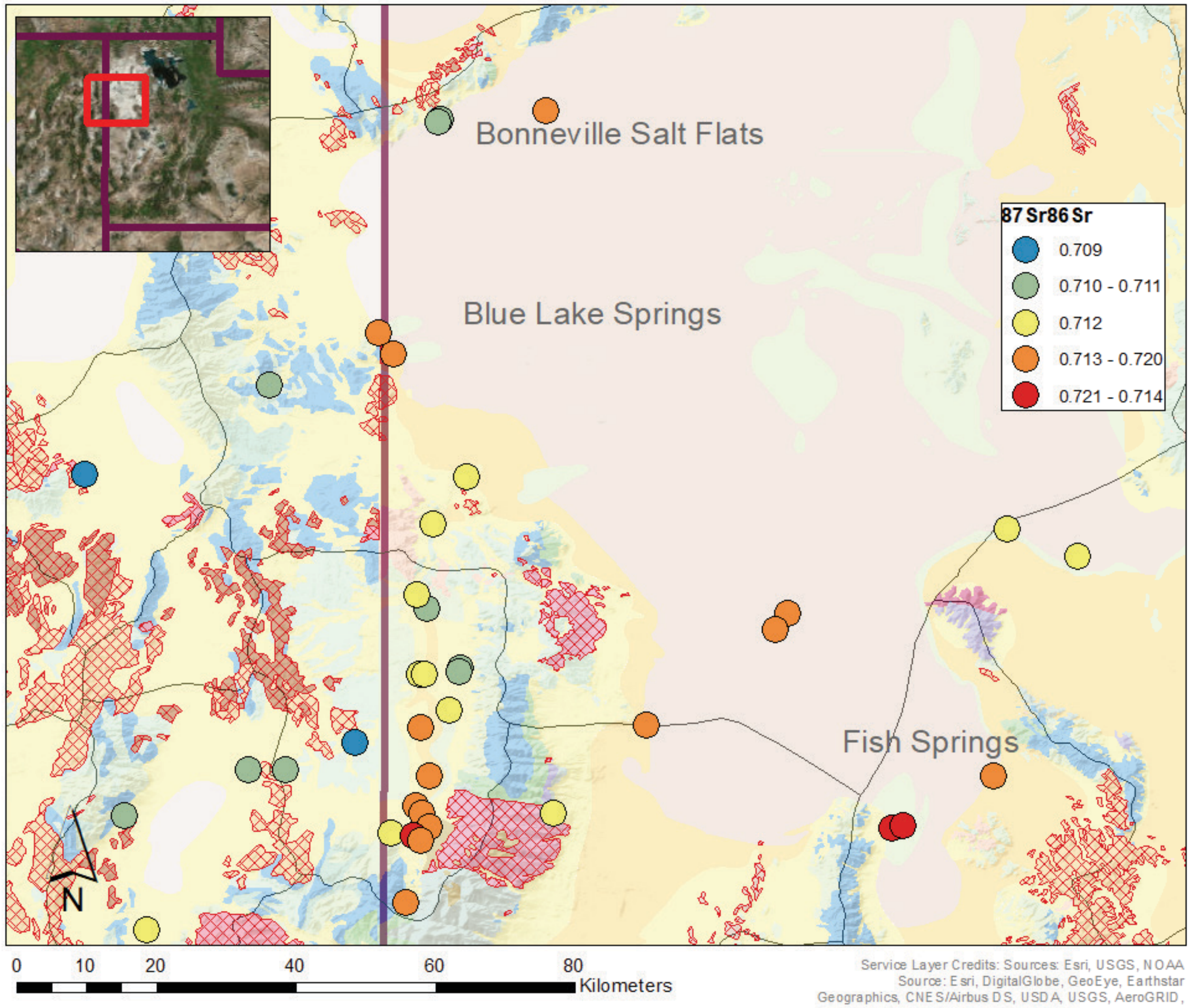


West Desert groundwaters after Gardner & Heilweil, 2014, Gardner and Masbruch, 2015, USGS, and Current study



Hart et al., 2004


Bonneville Salt Flats
Blue Lake Springs
Fish Springs
87 Sr86 Sr
0.709
0.710 - 0.711
0.712
0.713 - 0.720
0.721 - 0.714
N
0
10
20
40
60
80
Kilometers
Service Layer Credits: Sources: Esri, USGS, NOAA
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,


Bonneville Salt Flats
Blue Lake Springs
Fish Springs
87 Sr86 Sr
0.709
0.710 - 0.711
0.712
0.713 - 0.720
0.721 - 0.714
N
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40
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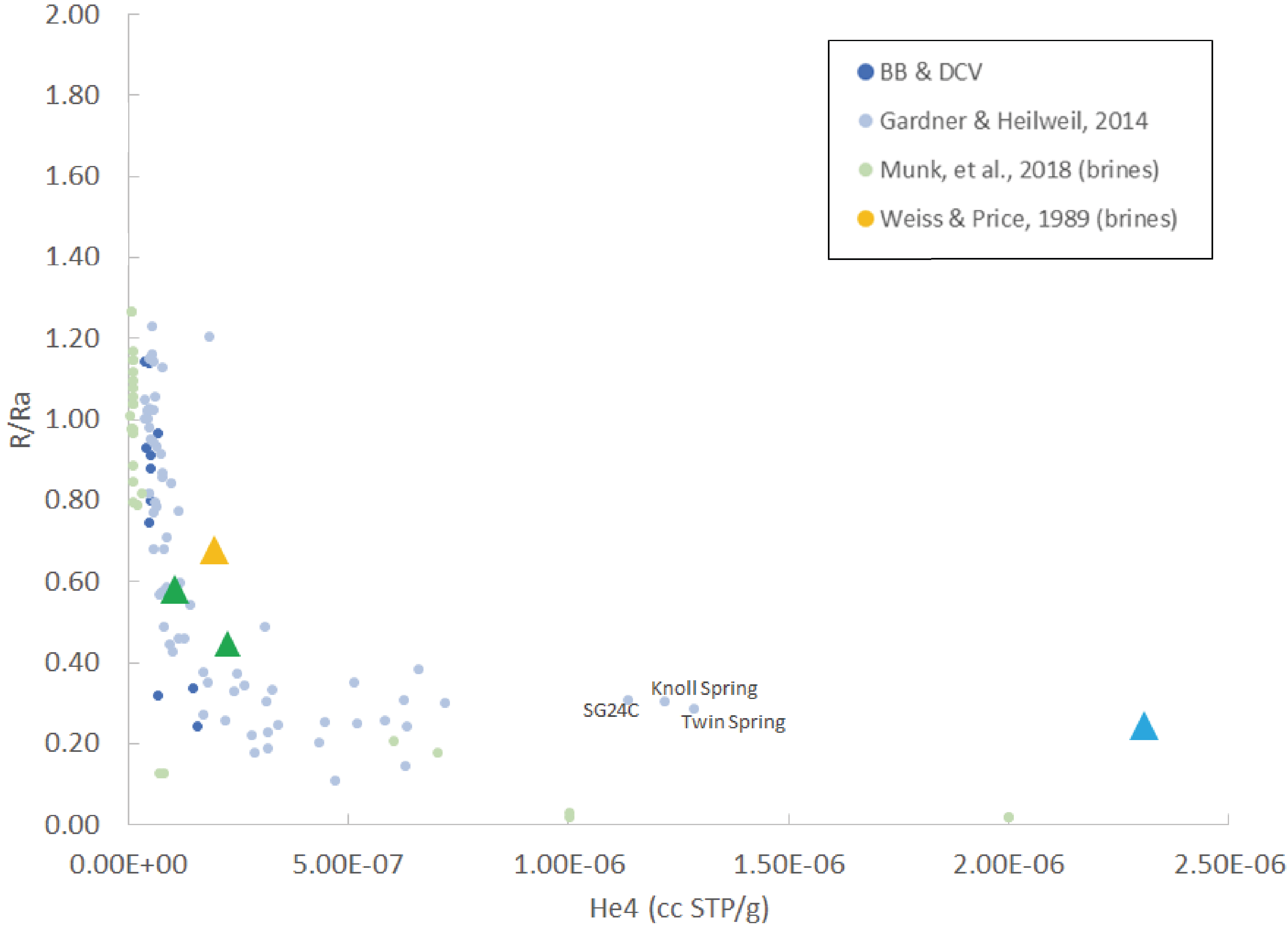
Kilometers
Service Layer Credits: Sources: Esri, USGS, NOAA
Source: Esri, DigitalGlobe, GeoEye, Earthstar
Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID,


BB & DCV
Gardner & Heilweil, 2014
Munk, et al., 2018 (brines)
Weiss & Price, 1989 (brines)
R/Ra
He4 (cc STP/g)
Knoll Spring
SG24C
Twin Spring
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.00E+00
5.00E-07
1.00E-06
1.50E-06
2.00E-06
2.50E-06

Implications

- Groundwater provenance
- Groundwater budgets
- Solute Flux
- Archaeology

Acknowledgements:

USGS science for a changing world

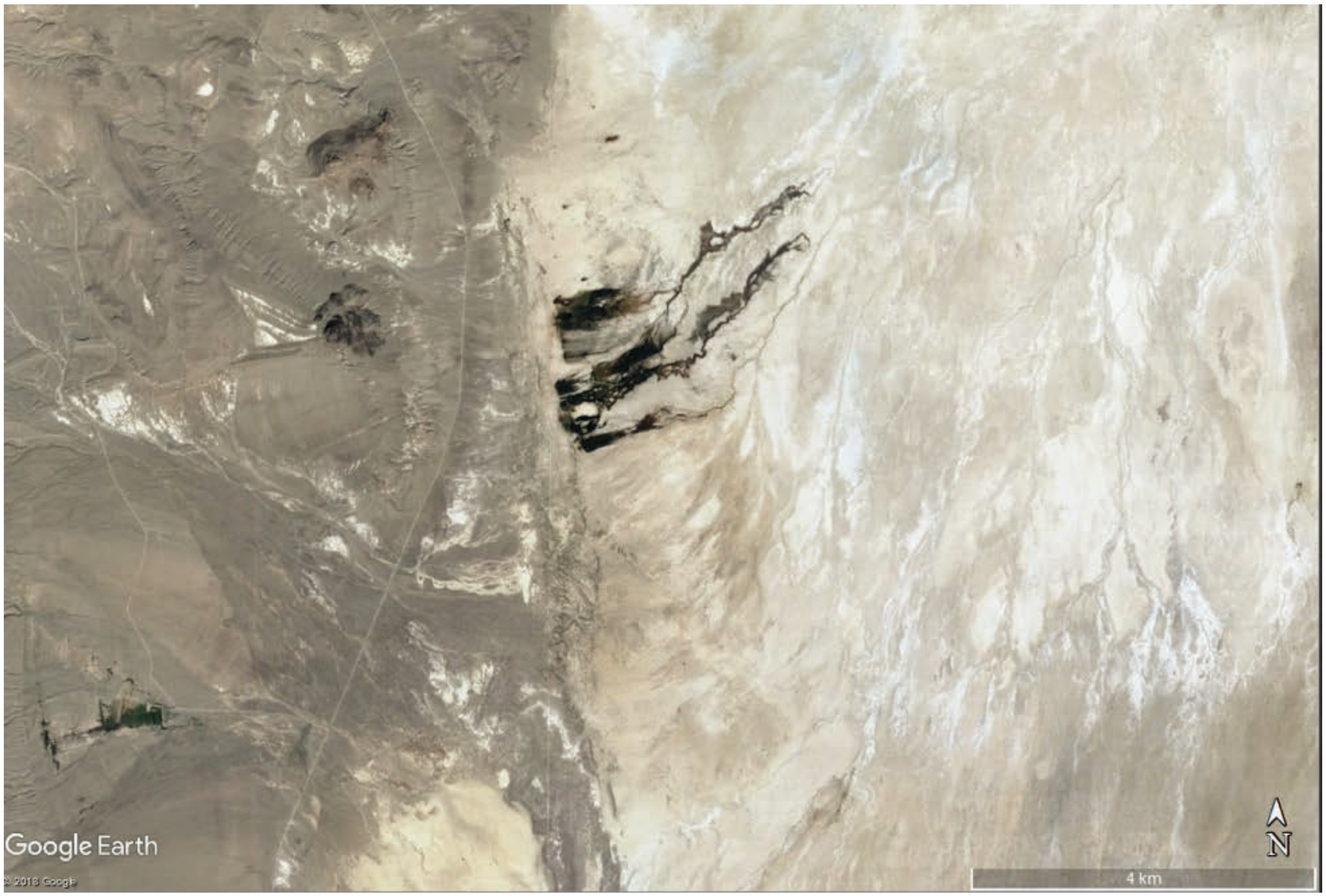
THE UNIVERSITY OF UTAH
GLOBAL CHANGE & SUSTAINABILITY CENTER

THE GEOLOGICAL SOCIETY OF AMERICA

NOBLE GAS LAB
College of Mines and Earth Sciences

ICP MS Metals Lab

Redden Springs



Fish Springs

MODERN GREAT SALT LAKE SALINITY GRADIENTS INFLUENCE THE BIOLOGY OF MICROBIALITES

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The information for this presentation is included in the publication below:

Lindsay, M.R., Anderson, C., Fox, N., Scofield, G., Allen, J., Anderson, E., Bueter, L., Poudel, S., Sutherland, K., Munson-McGee, J.H., Van Nostrand, J.D., Zhou, J., Spear, J.R., Baxter, B.K., Lageson, D.R., Boyd, E.S., 2016, Microbialite response to an anthropogenic salinity gradient in Great Salt Lake, Utah: Geobiology, https://onlinelibrary.wiley.com/doi/abs/10.1111/gbi.12201

STABLE ISOTOPE VARIABILITY IN MODERN GREAT SALT LAKE SEDIMENTS: HOW DO LOCAL MICROBIAL PROCESSES TRANSLATE TO THE SEDIMENTARY RECORD?

Miquela Ingalls[1,2], Lizzy Trower[1], Carie Frantz[3], and Kathryn Snell[1]

[1]Department of Geological Sciences, University of Colorado, Boulder, CO 80309;
[2]Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125;
[3]Department of Geosciences, Weber State University, Ogden, UT 84408

Corresponding author (Ingalls): miquela.ingalls@colorado.edu

ABSTRACT

The abundance and distribution of carbon and oxygen stable isotopes within carbonate lake sediments are commonly used to reconstruct physicochemical conditions in ancient terrestrial environments (e.g., temperature, aridity, elevation, and vegetation). However, we hypothesize that microbe-sediment interactions in the subsurface alter the primary isotopic composition of carbonate either directly, e.g., by metabolic pathways such as sulphate reduction, or indirectly by altering the porewater dissolved inorganic carbon (DIC) pool from which authigenic carbonate precipitates. How does early, localized isotopic alteration manifest itself in the sedimentary record? In this study, we measure carbon and oxygen isotopic composition of carbonate sediments (carb), organic matter (OM), and porewater DIC from sediment cores in Great Salt Lake (GSL). When microbial metabolic processes (e.g., sulfate reduction, respiration, methanogenesis) impact carbon cycling within the porewater-carbonate system, we expect an anti-correlated trend in $\delta^{13}C$ values of OM and carbonate due to mixing of DIC and DOC pools and reduced correlation between $\delta^{13}C$ and $\delta^{18}O$. In addition, carbonates associated with OM respiration typically have lower $\delta^{18}O$ values, and thus we test the fidelity of $\delta^{18}O$ as a secondary indicator of microbial influence on carbonate stable isotopes. We find significant $\delta^{18}O$ and $\delta^{13}C$ variability within and between five core sites (GSL State Park, Spiral Jetty, and three sites at Antelope Island). The measured carbonate sediments and microbialites formed within geologically contemporaneous macro-environments, and thus isotopic variability likely reflects perturbations to local carbonate chemistry via biological processes in the sub-surface rather than changes in climate or environment.

A single sedimentary bed should record a snapshot in an environment's depositional history. Our data suggest that sampling across theoretically contemporaneous modern GSL sediments would yield ranges in $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ of at least 5‰ and 3‰VPDB, respectively. In the rock record, this variability would likely be interpreted as post-burial, late-stage diagenesis rather than biologically driven eogenesis in the sub-surface environment. Thus, we demonstrate the importance of lateral sampling of coeval geological sediments across intrinsically complex lake systems to fully characterize and use the geochemical and isotopic variability driven by localized biological processes to fingerprint true primary environmental signatures.

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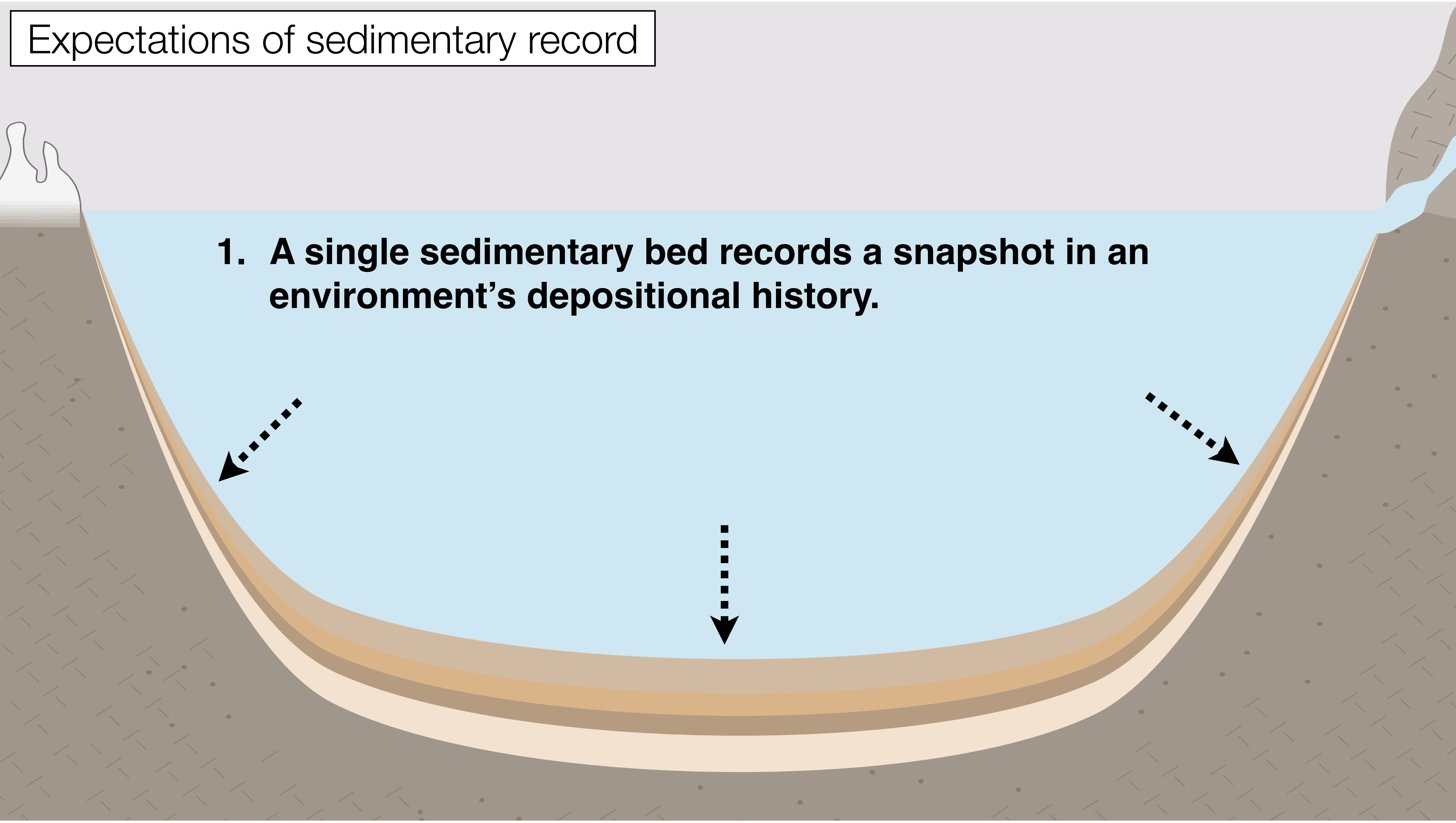
Spatial stable isotope variability in modern lacustrine carbonate: How do local processes translate to the sedimentary record?

Miquela Ingalls[1,2], Lizzy Trower[1], Carie Frantz[3] & Katie Snell[1]

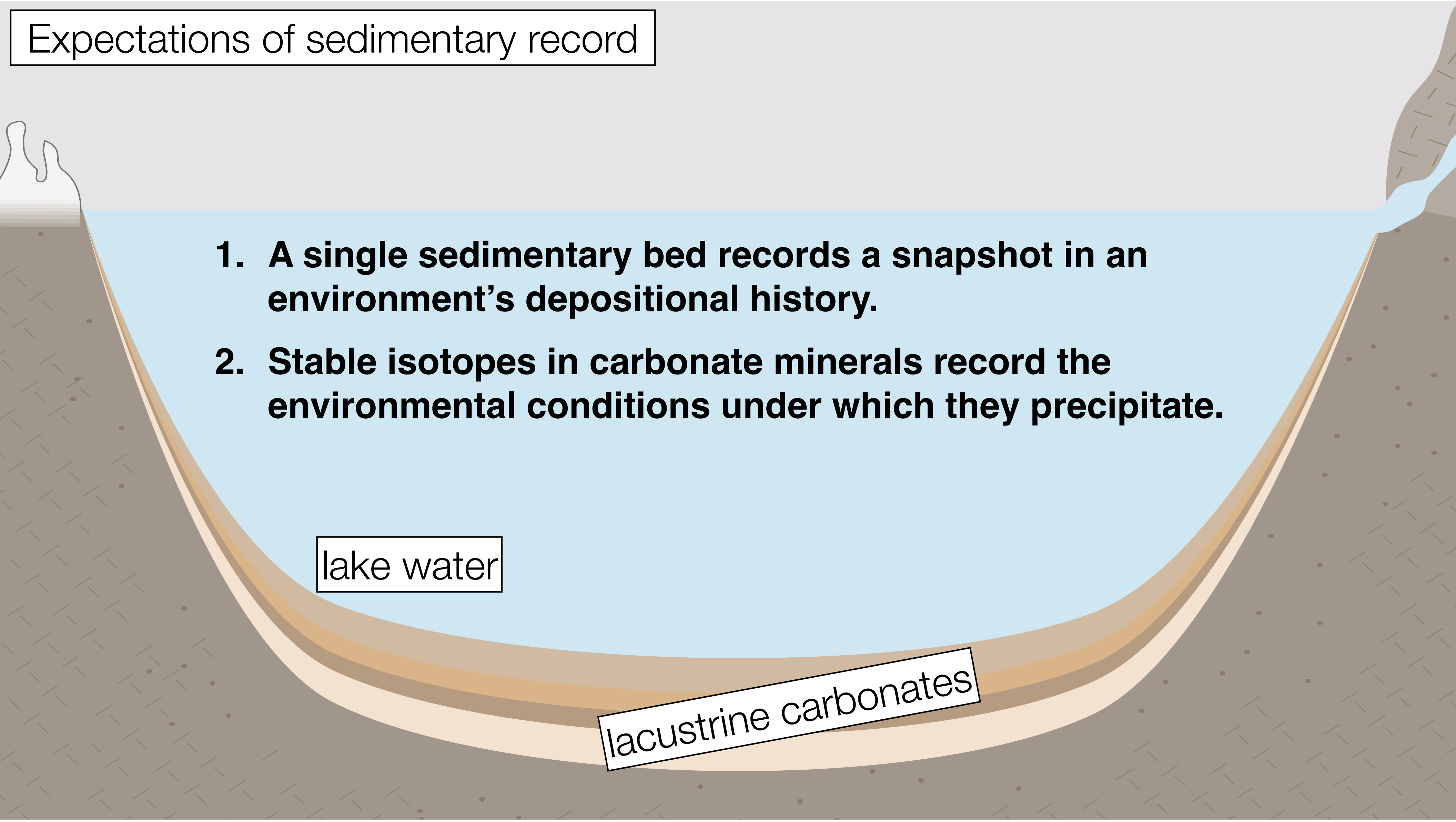
1 University of Colorado **Boulder** 2 Caltech 3 Weber State University

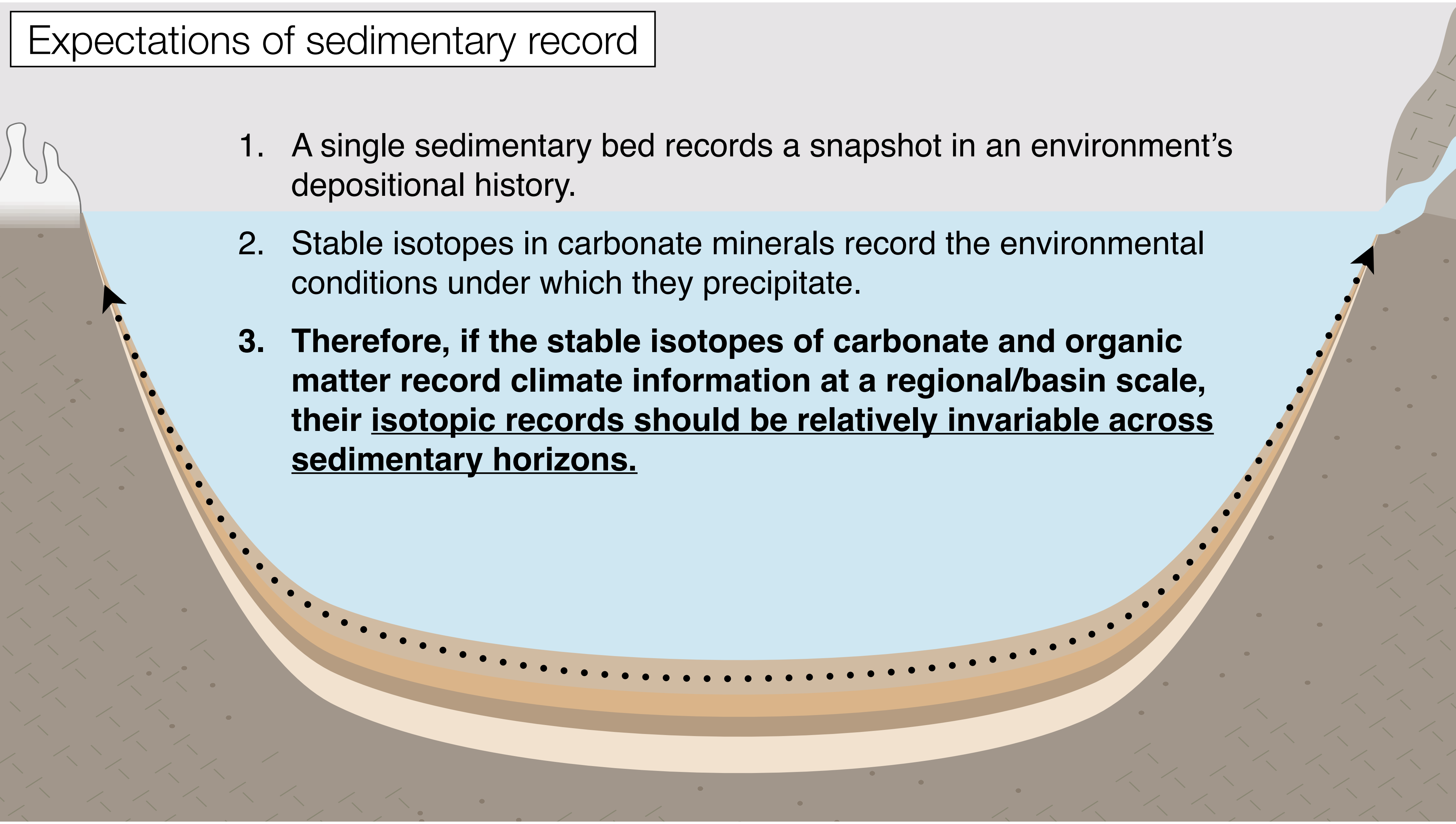
mingalls@caltech.edu | October 3, 2018

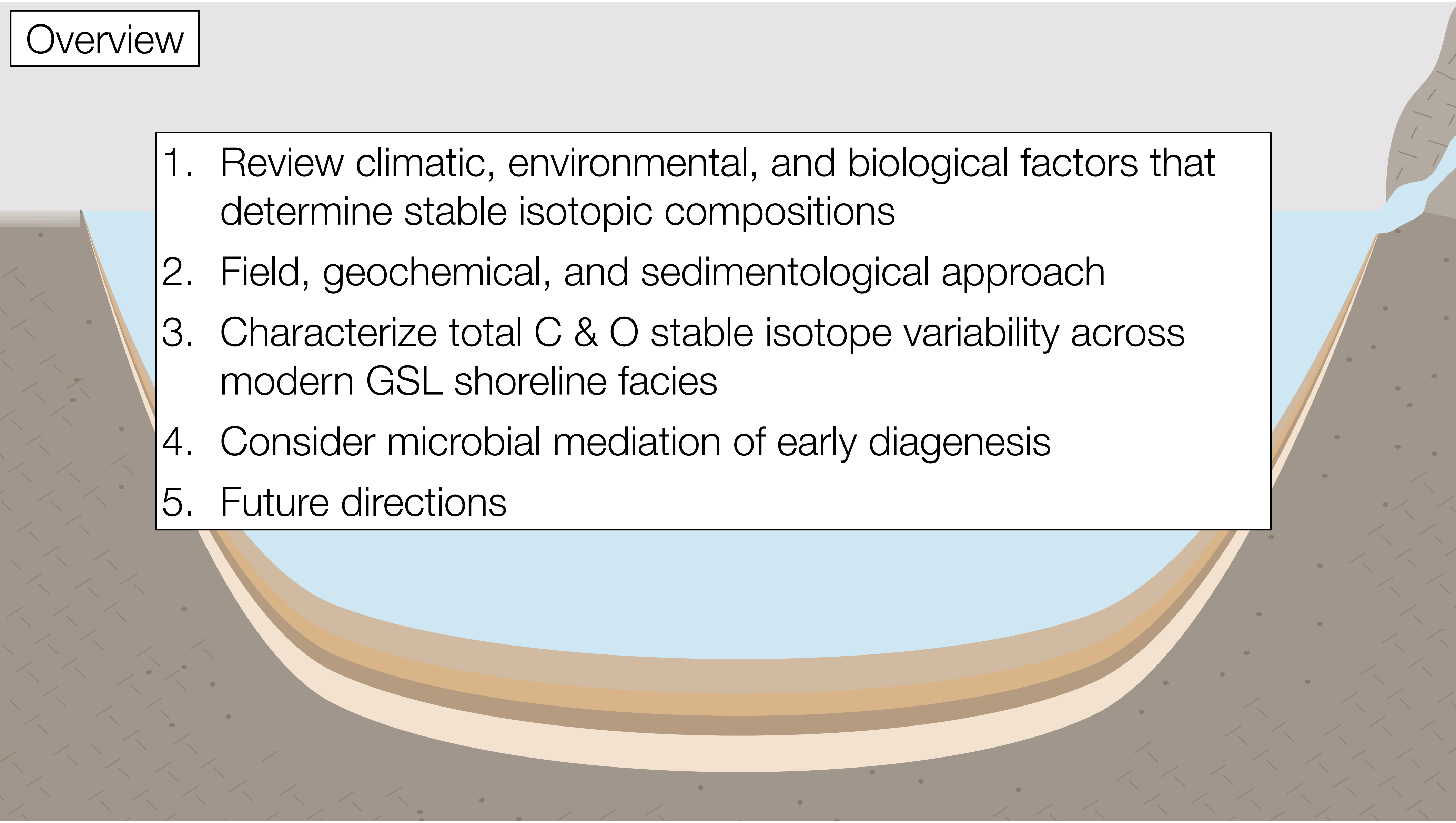

Expectations of sedimentary record
1. A single sedimentary bed records a snapshot in an environment's depositional history.

Expectations of sedimentary record

1. **A single sedimentary bed records a snapshot in an environment's depositional history.**
2. **Stable isotopes in carbonate minerals record the environmental conditions under which they precipitate.**

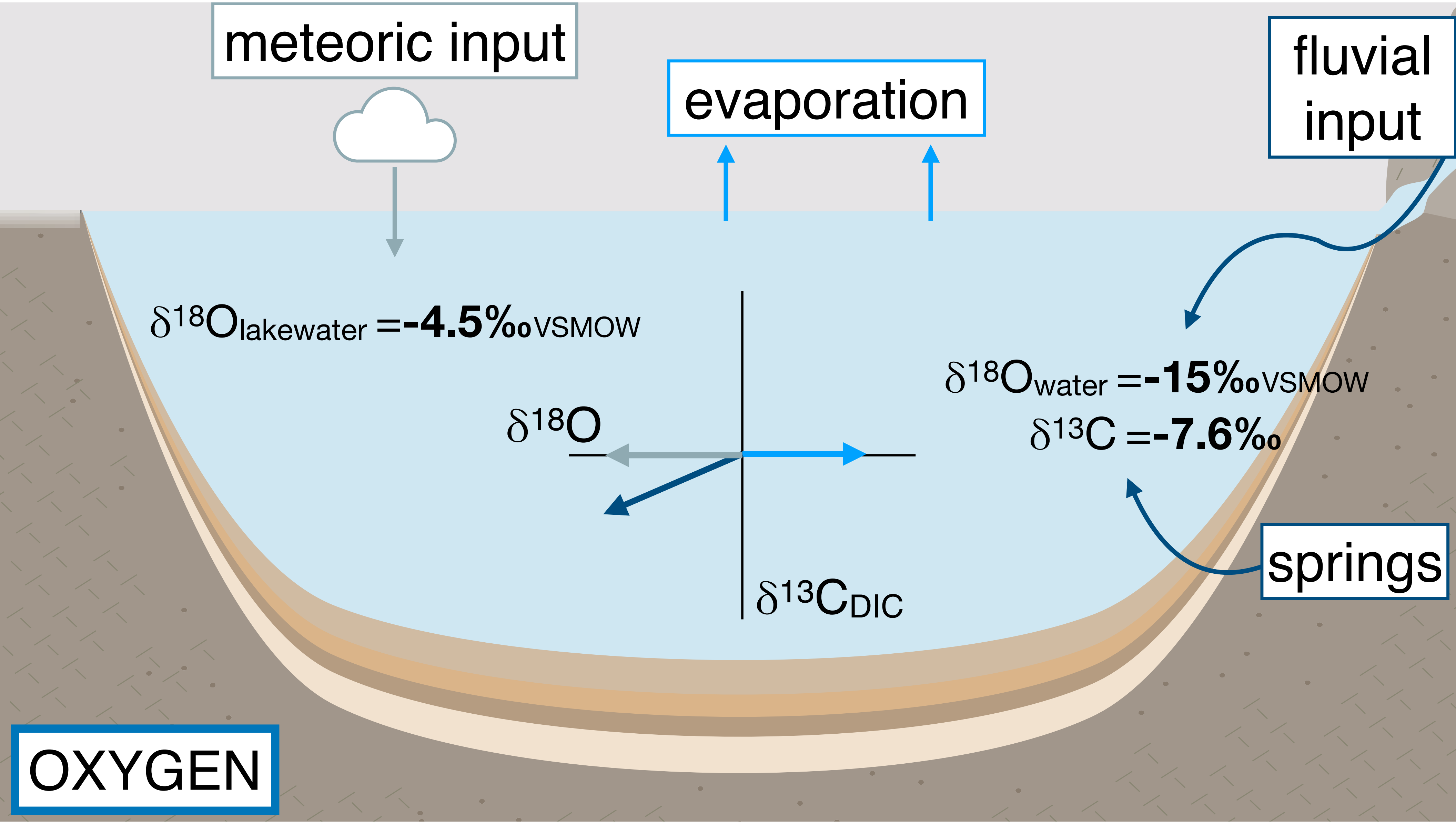



Expectations of sedimentary record
1. A single sedimentary bed records a snapshot in an environment's depositional history.
2. Stable isotopes in carbonate minerals record the environmental conditions under which they precipitate.
3. Therefore, if the stable isotopes of carbonate and organic matter record climate information at a regional/basin scale, their isotopic records should be relatively invariable across sedimentary horizons.

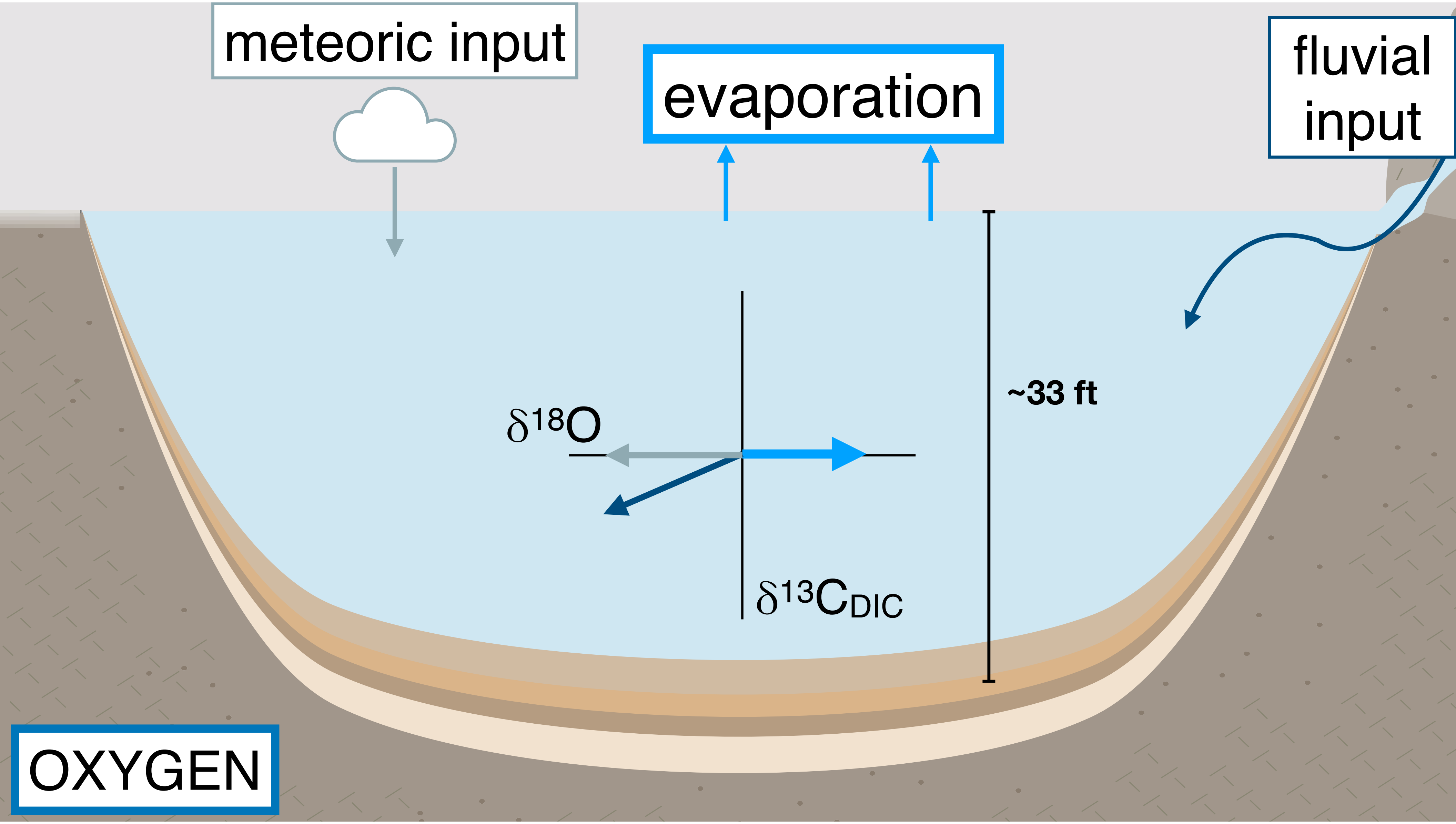


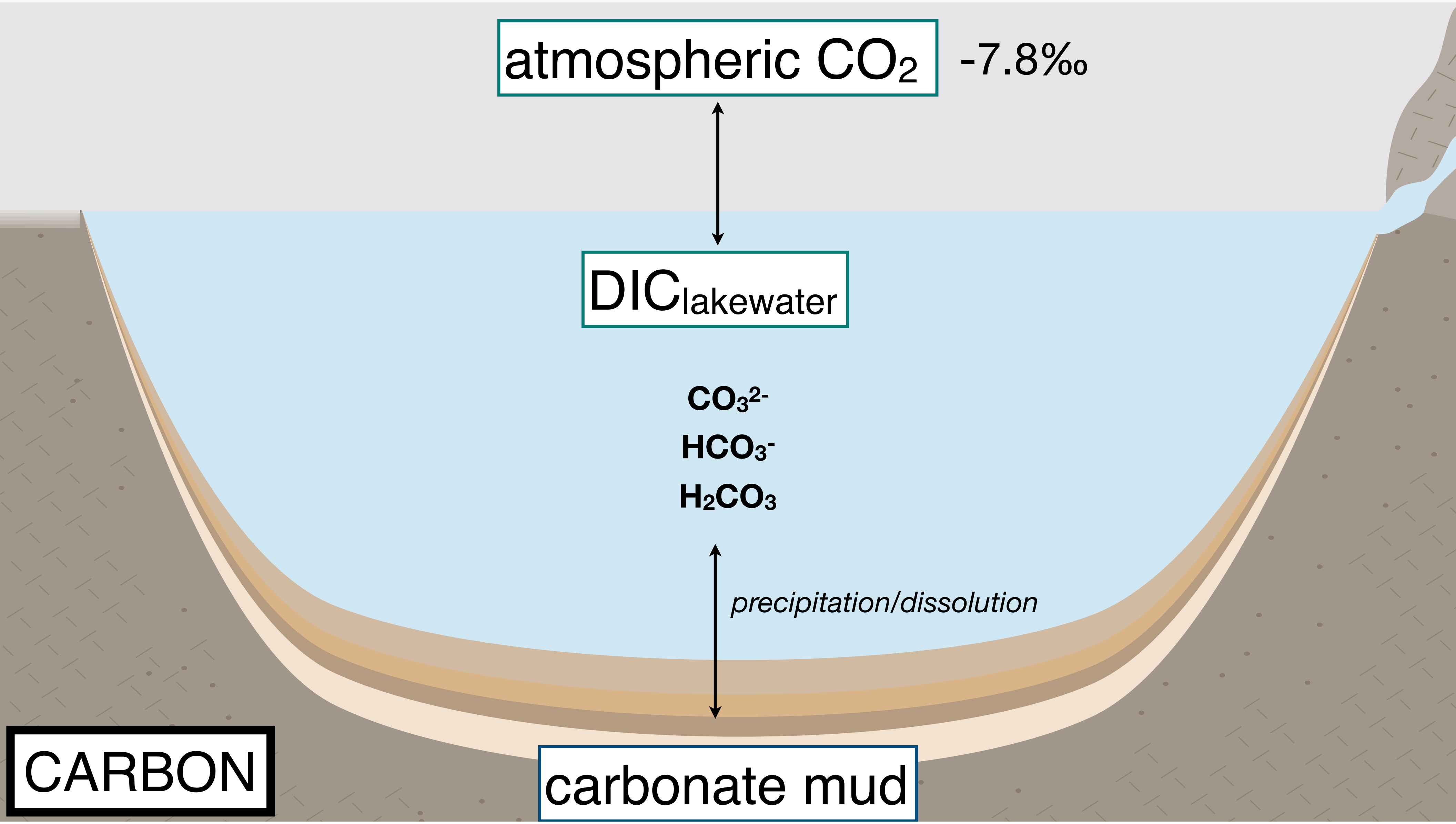
Overview

1. Review climatic, environmental, and biological factors that determine stable isotopic compositions
2. Field, geochemical, and sedimentological approach
3. Characterize total C & O stable isotope variability across modern GSL shoreline facies
4. Consider microbial mediation of early diagenesis
5. Future directions

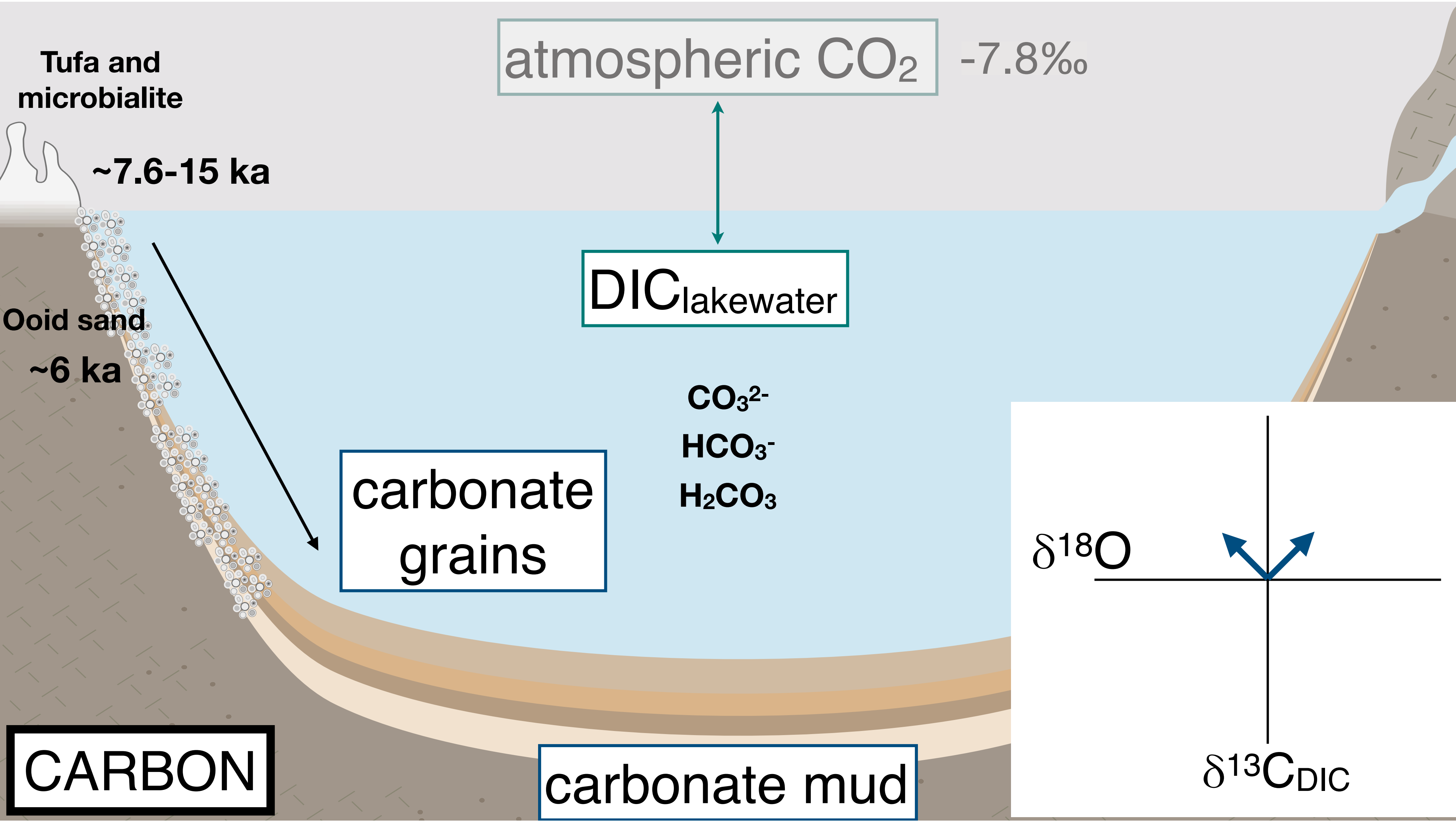


meteoric input
evaporation
fluvial input
$\delta^{18}O_{lakewater}$ =**-4.5‰**VSMOW
$\delta^{18}O_{water}$ =**-15‰**VSMOW
$\delta^{13}C$ =**-7.6‰**
$\delta^{18}O$
$\delta^{13}C_{DIC}$
springs
OXYGEN

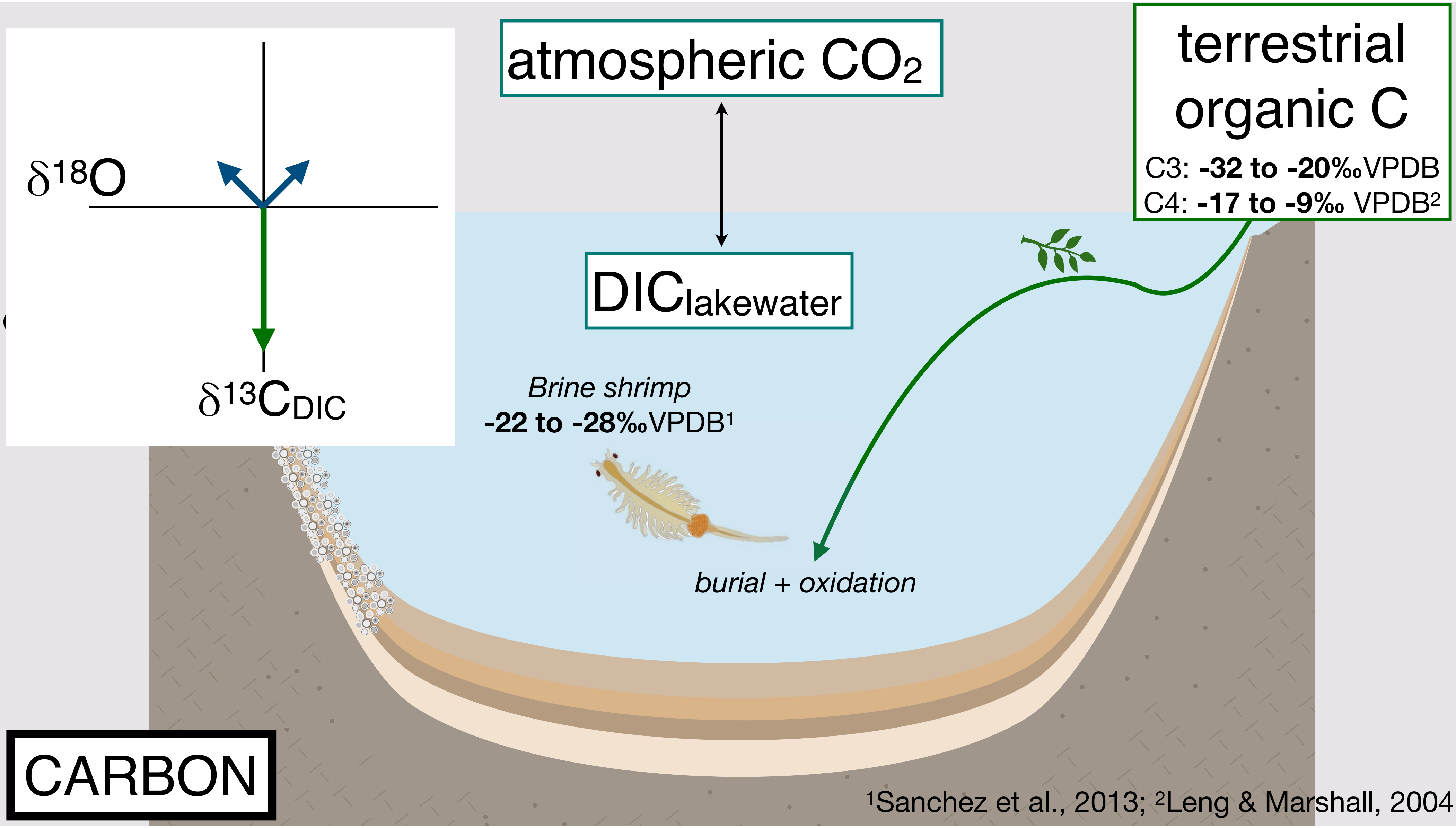

meteoric input
evaporation
fluvial input
$\delta^{18}O$
$\delta^{13}C_{DIC}$
~33 ft
OXYGEN



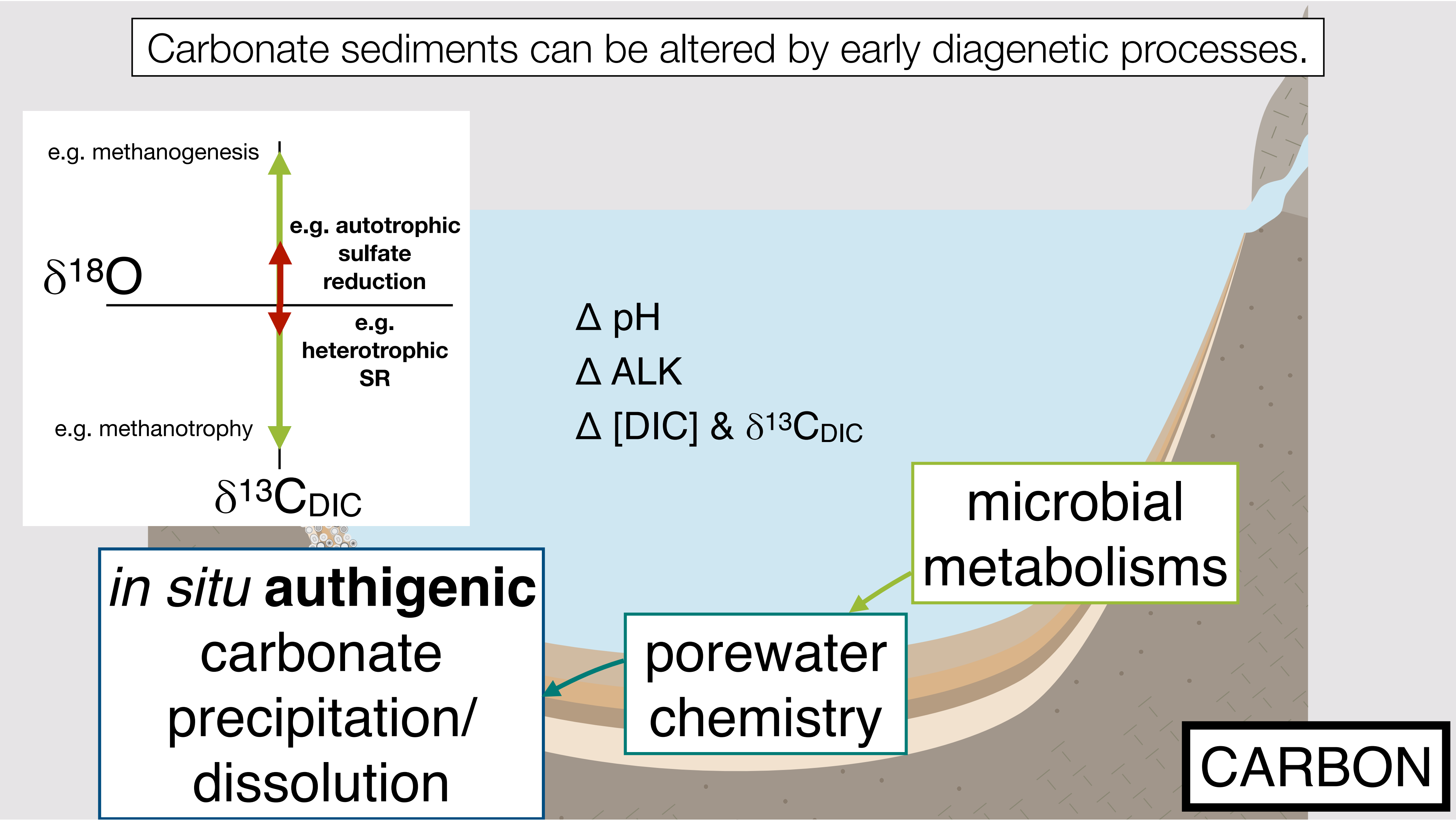
atmospheric CO_2
-7.8‰
DIC$_{lakewater}$
CO_3^{2-}
HCO_3^-
H_2CO_3
precipitation/dissolution
CARBON
carbonate mud



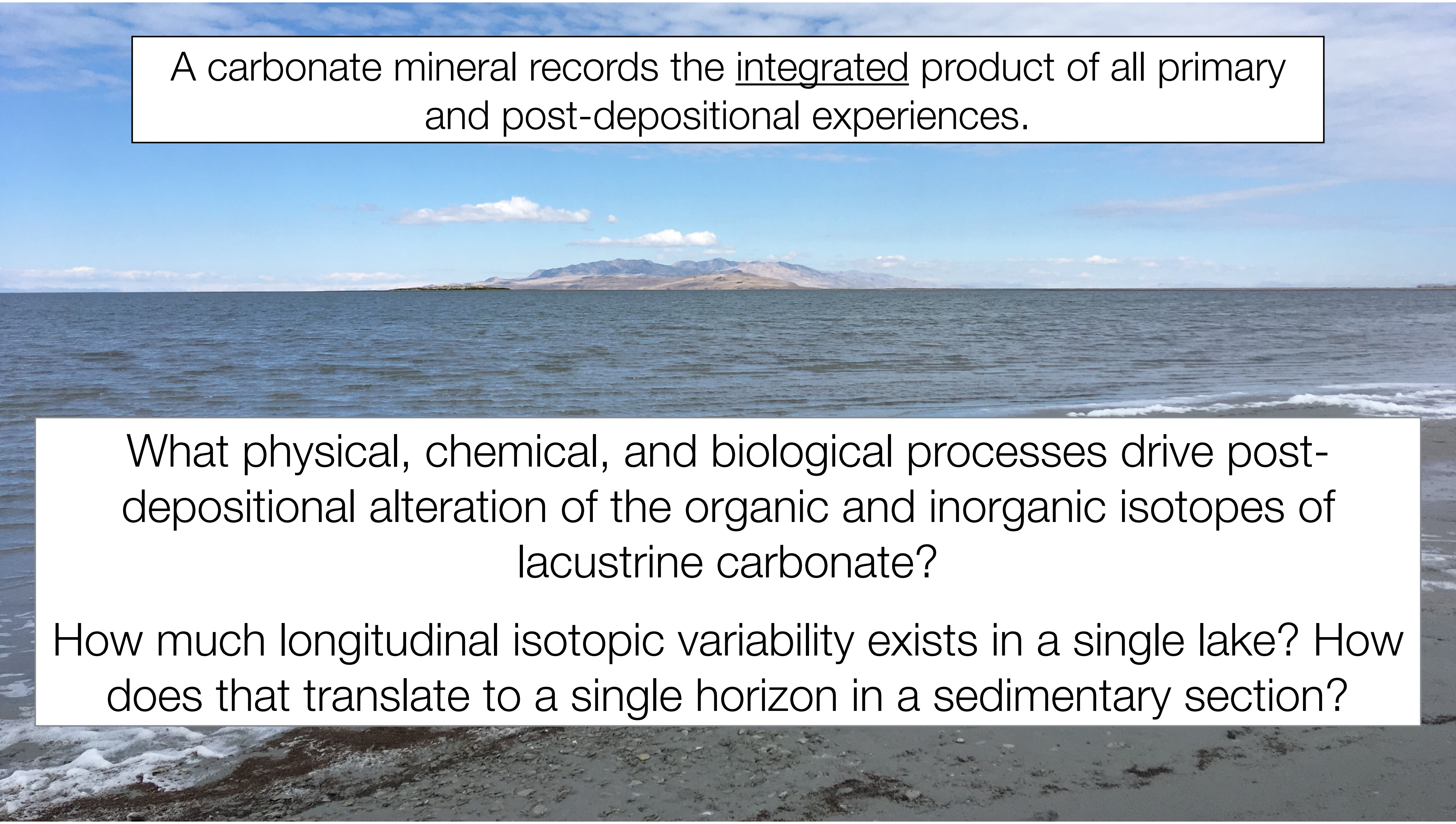
Tufa and microbialite
~7.6-15 ka
Ooid sand
~6 ka
atmospheric CO_2
-7.8‰
$DIC_{lakewater}$
CO_3^{2-}
HCO_3^-
H_2CO_3
carbonate grains
carbonate mud
CARBON
$\delta^{18}O$
$\delta^{13}C_{DIC}$

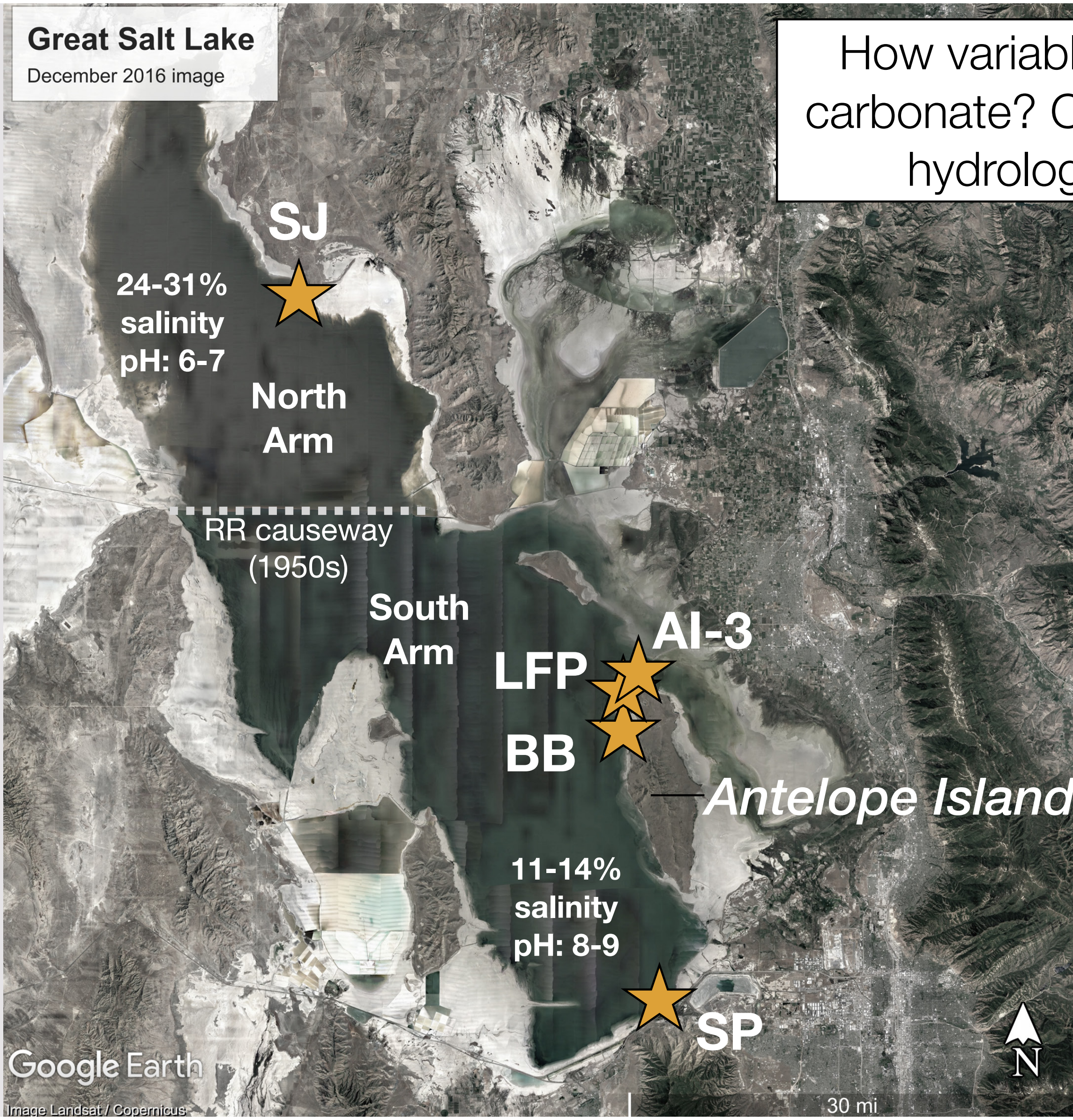


[1]Sanchez et al., 2013; [2]Leng & Marshall, 2004



Carbonate sediments can be altered by early diagenetic processes.
e.g. methanogenesis
e.g. autotrophic sulfate reduction
$\delta^{18}O$
e.g. heterotrophic SR
e.g. methanotrophy
$\delta^{13}C_{DIC}$
Δ pH
Δ ALK
Δ [DIC] & $\delta^{13}C_{DIC}$
microbial metabolisms
porewater chemistry
in situ **authigenic** carbonate precipitation/ dissolution
CARBON


A carbonate mineral records the <u>integrated</u> product of all primary and post-depositional experiences.
What physical, chemical, and biological processes drive post-depositional alteration of the organic and inorganic isotopes of lacustrine carbonate?
How much longitudinal isotopic variability exists in a single lake? How does that translate to a single horizon in a sedimentary section?



How variable are $\delta^{13}C$ and $\delta^{18}O$ records of lacustrine carbonate? Can we tie $\delta^{13}C$ and $\delta^{18}O$ to highly localized hydrological effects and biological processes?

★ 5 shallow water coring sites (Antelope Island cored in Sept + May)

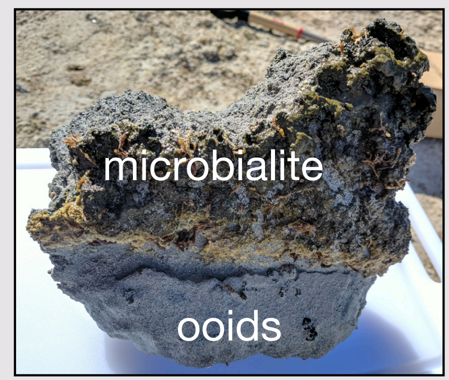
Measurements:

$\delta^{18}O_{carbonate}$

$\delta^{13}C_{DIC}$

$\delta^{13}C_{carbonate}$

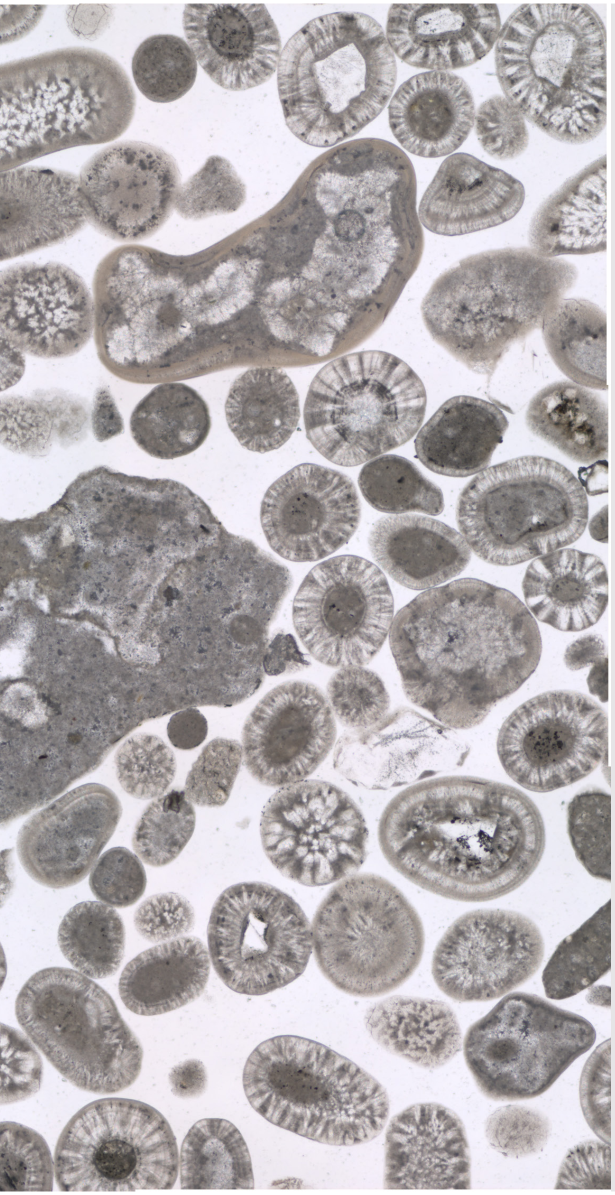
$\delta^{13}C_{organic}$

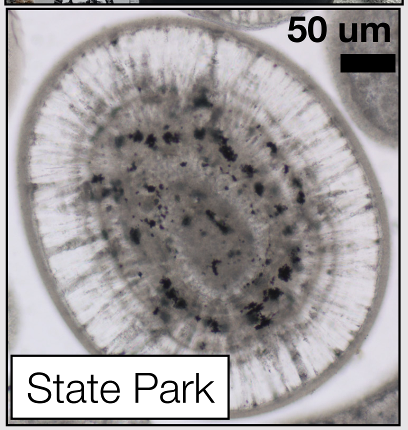


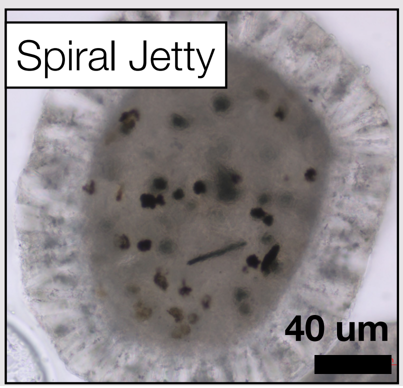
Two main facies in GSL shoreline sediments:
Carbonaceous **MUD** vs. **OOLITIC**

★ 5 shallow water coring sites (Antelope Island cored in Sept + May)

DETRITAL GRAINS + MUD
vs
OOILITIC





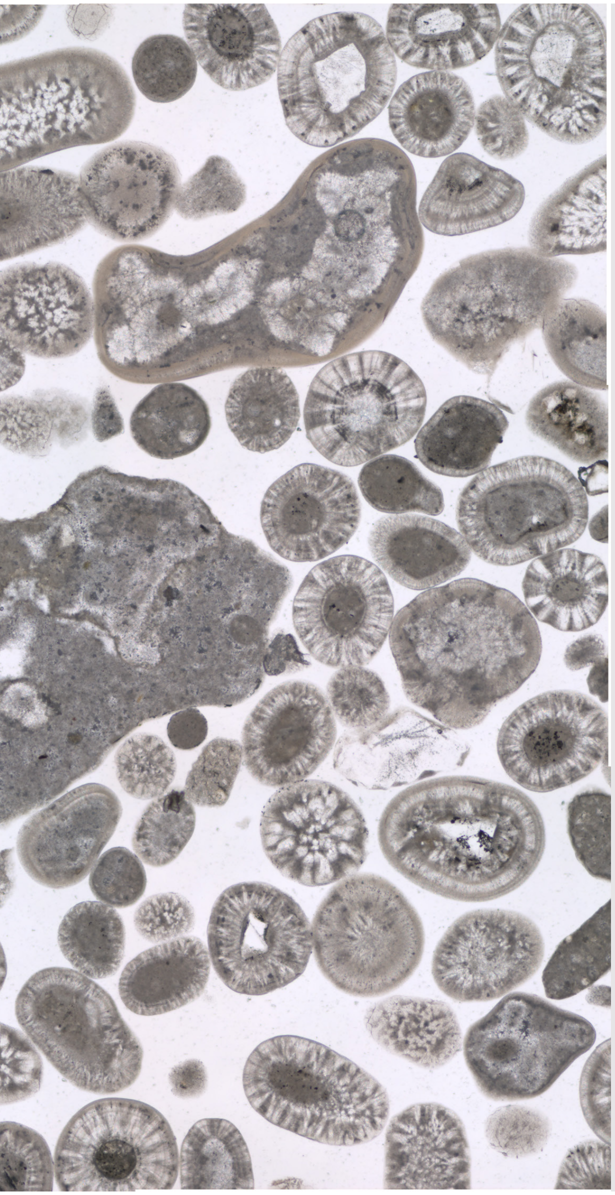


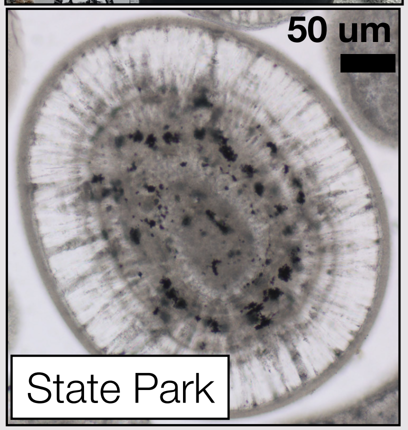
OOLITIC facies: SJ, SP, BB

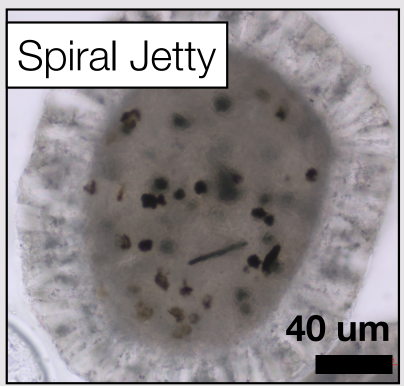
Bridger Bay: medium sand-size ooids with broken ooid fragments and detrital quartz grains

State Park: fine to medium-size ooids; micritic Artemia fecal pellets; carbonate-coated intraclasts

Spiral Jetty: poorly sorted fine sand-size ooids; elongated peloids; detrital pyrite-bearing lithic fragments







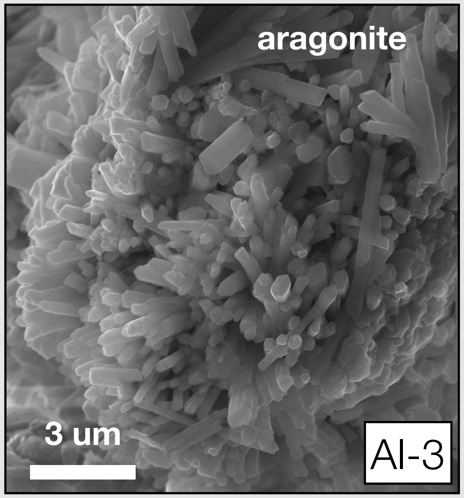
OOLITIC facies: SJ, SP, BB

^{14}C ages of inorganic and organic C from Antelope Island ooid nuclei ~6600 yr BP, with **6000 subsequent years of growth** (Paradis et al., GSA 2017)

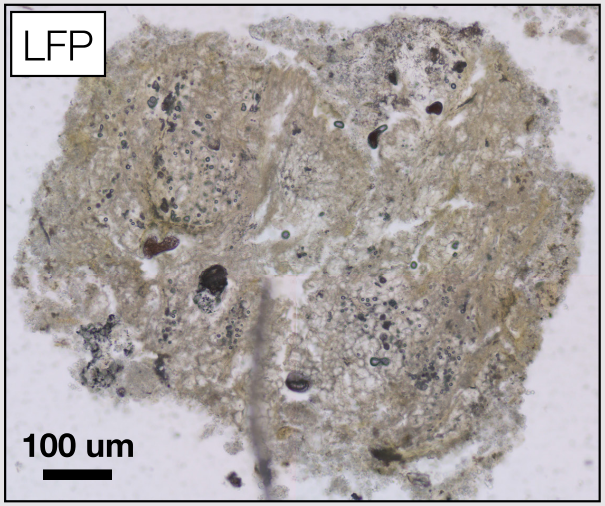
Time-averaged isotopic signal

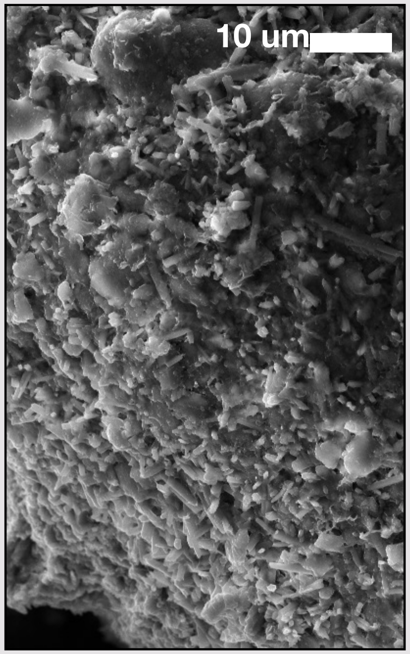
Carbonaceous mud + detrital facies:
LFP, AI-3

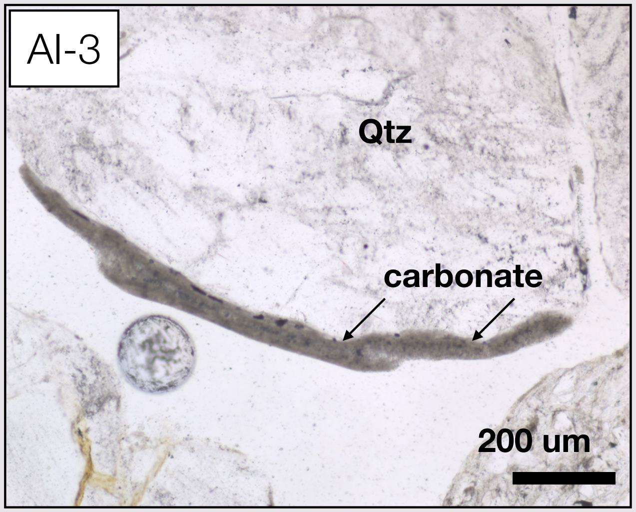
Mud and fine-grained authigenic carbonate likely record a *shorter time interval* of carbonate precipitation than oolitic facies



Mud-size micritic carbonate



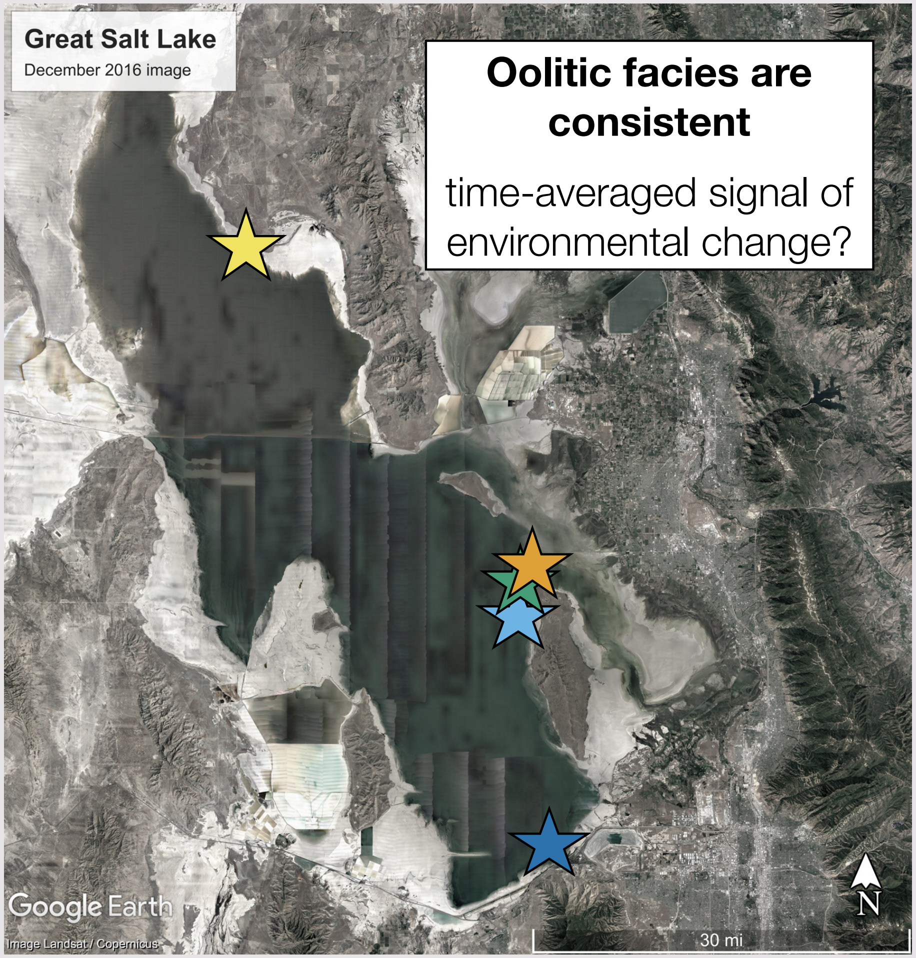




Microbialite intraclasts
(peloidal to clotted thrombolite)

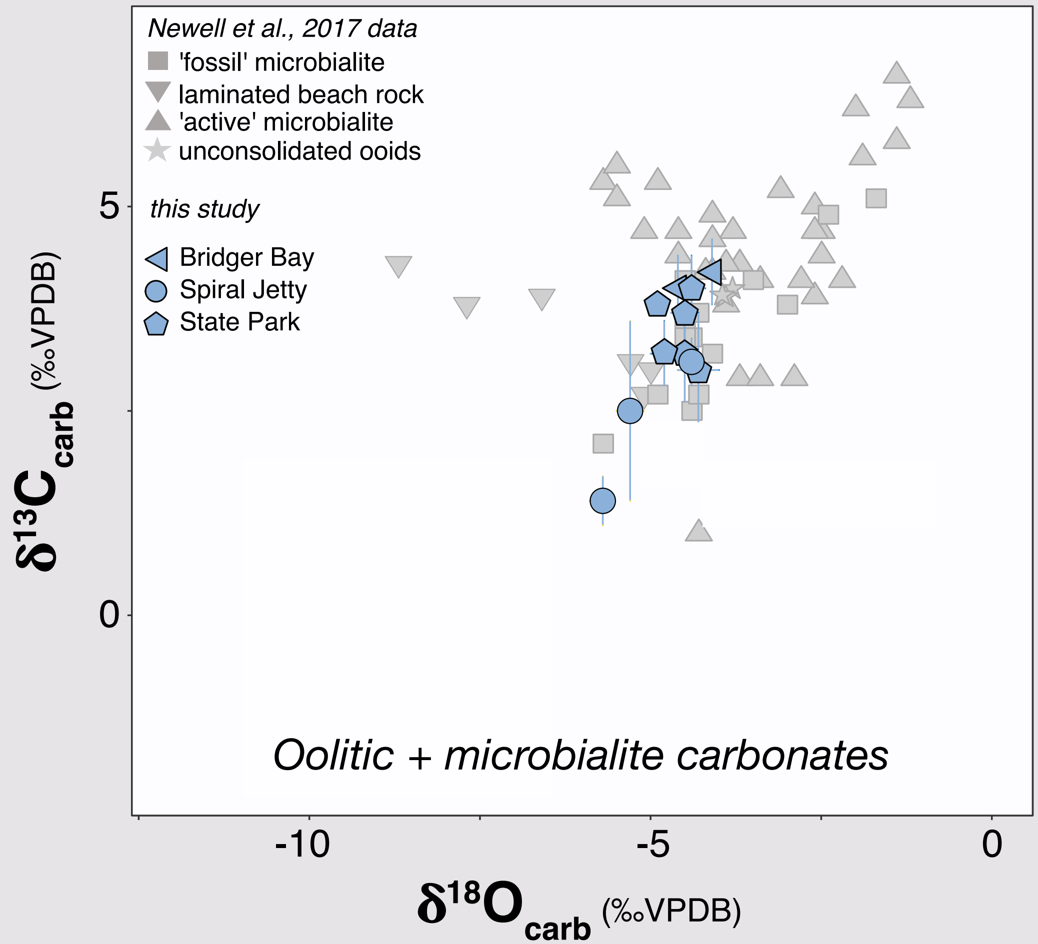
Detrital quartz grains with thin (<50um) carbonate coatings

$\delta^{13}C$ and $\delta^{18}O$ variability dependent on lacustrine carbonate facies

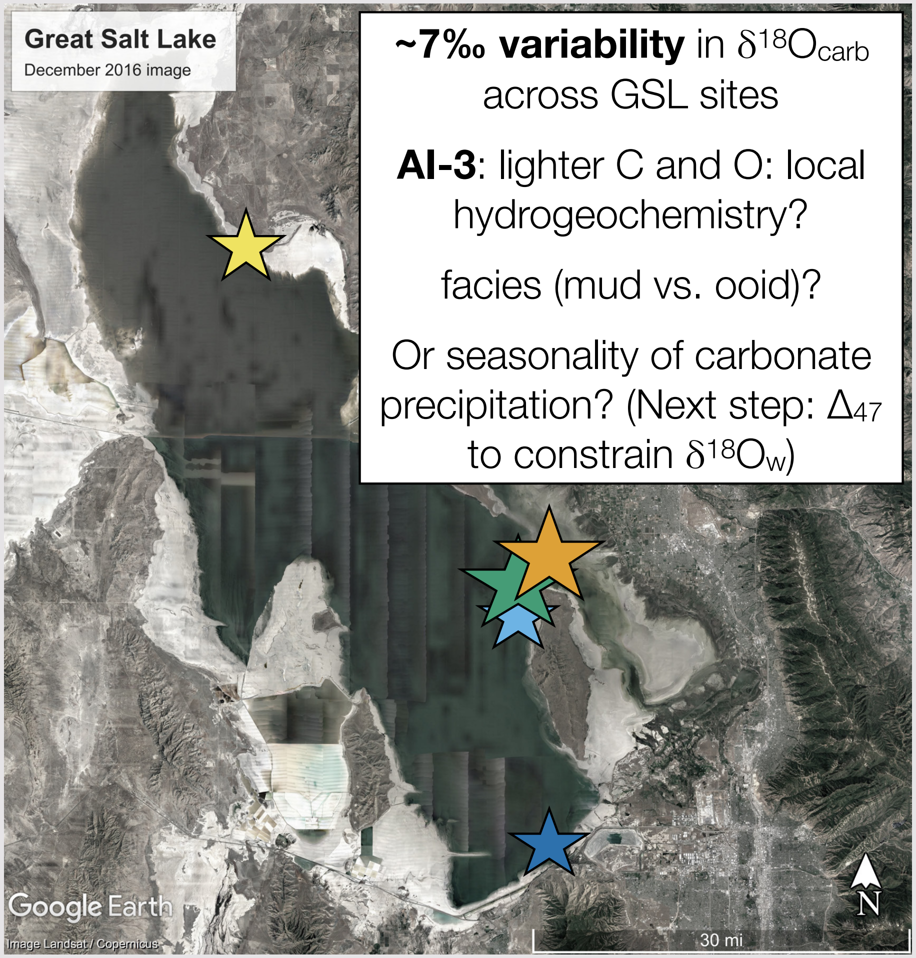


Oolitic facies are consistent

time-averaged signal of environmental change?



How **variable** are $\delta^{13}C$ and $\delta^{18}O$ records of lacustrine carbonate due to highly localized **hydrological effects**, biological processes, and/or **seasonality** of carbonate precipitation?

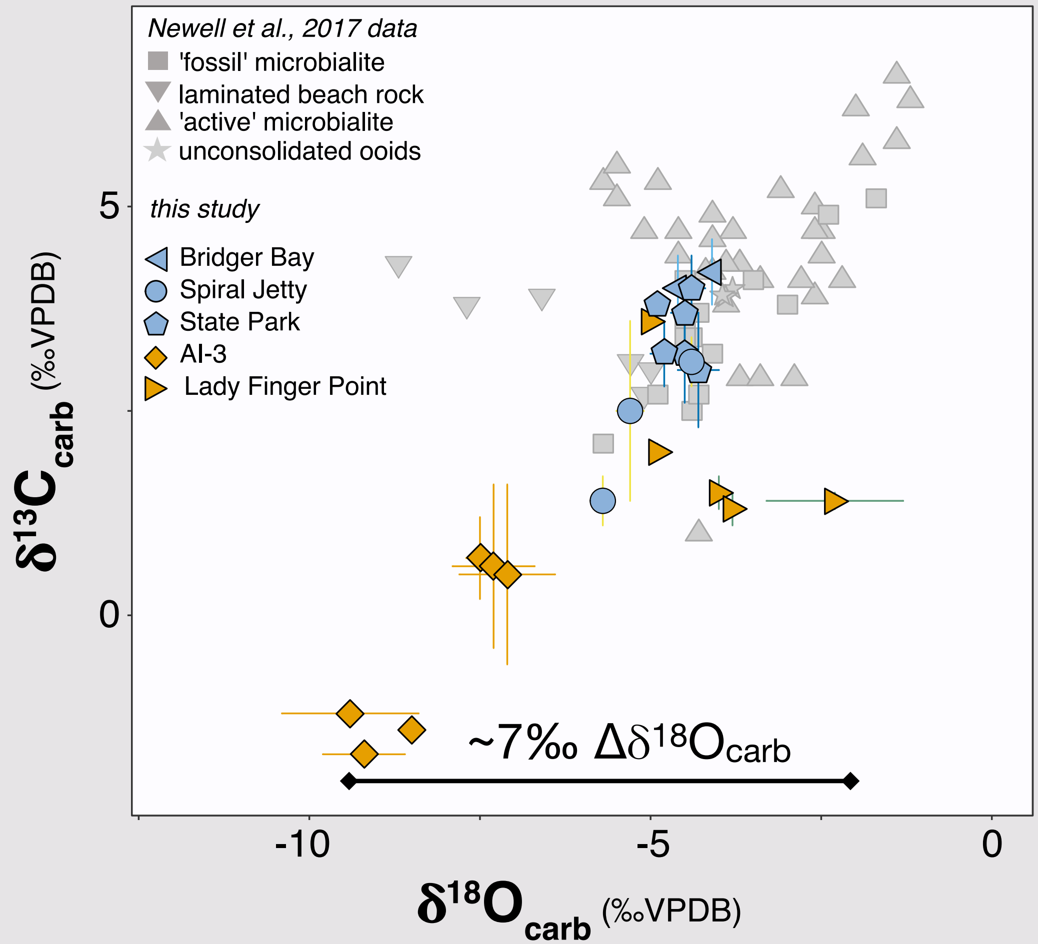


~7‰ variability in $\delta^{18}O_{carb}$ across GSL sites

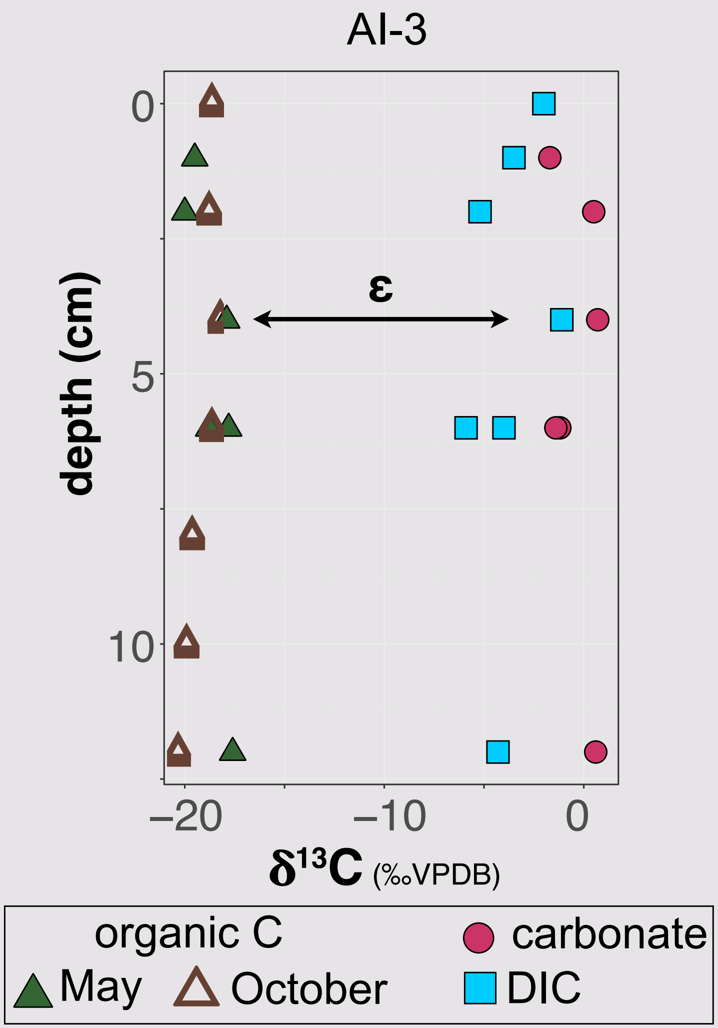
AI-3: lighter C and O: local hydrogeochemistry?

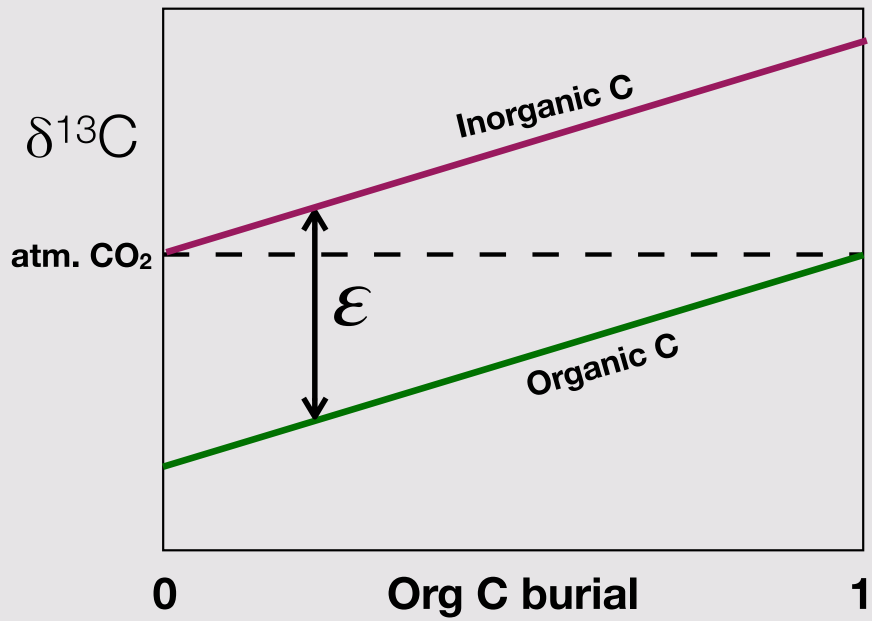
facies (mud vs. ooid)?

Or seasonality of carbonate precipitation? (Next step: Δ_{47} to constrain $\delta^{18}O_w$)



Down-core variability and trends: muddy facies off Antelope Island

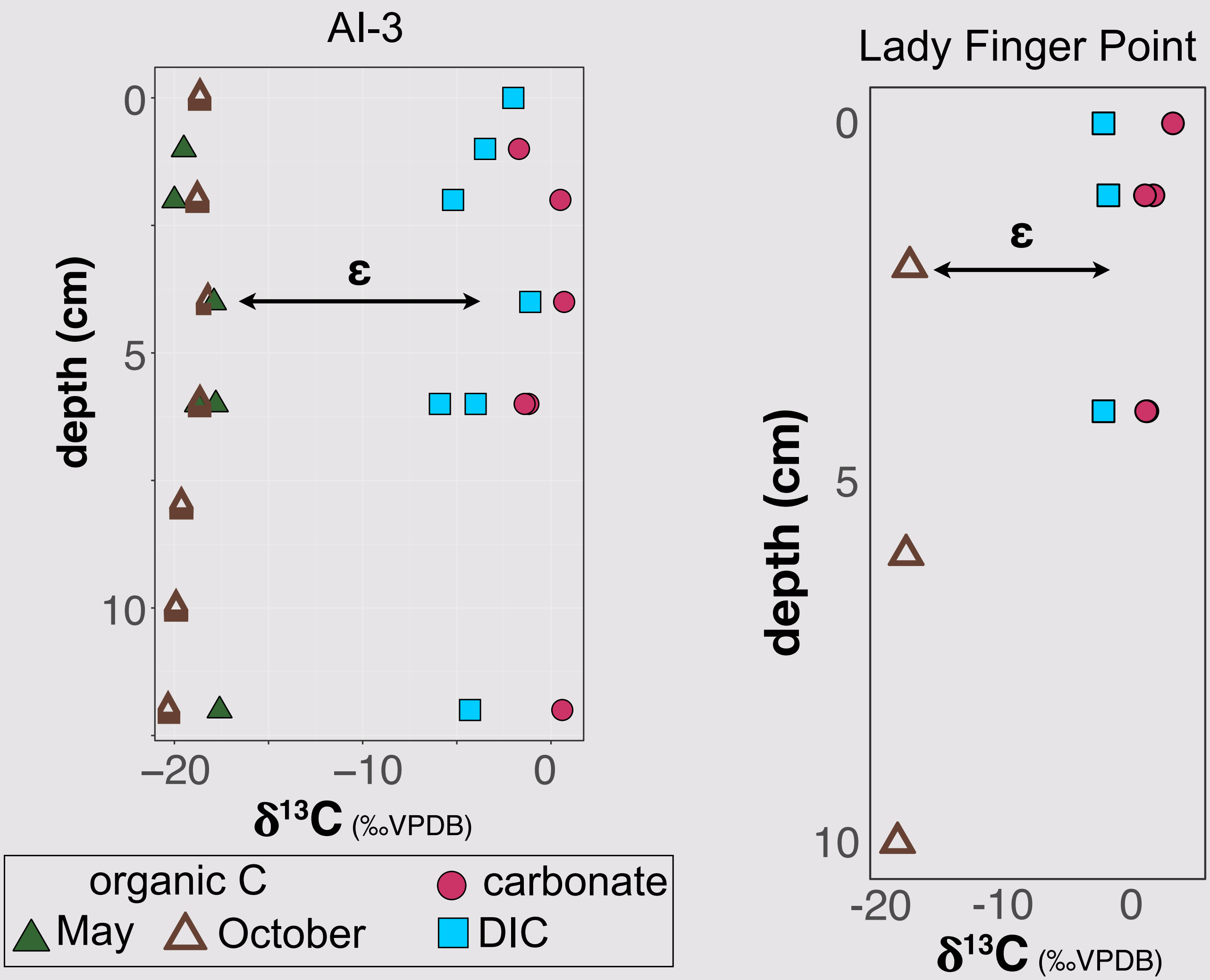




AI-3: $\delta^{13}C_{org}$ 10-20‰ lighter than carbonate and DIC consistently across seasons; Typical for most carbon fixation pathways

$$\varepsilon = \delta^{13}C_{inorganic} - \delta^{13}C_{organic}$$

Down-core variability and trends: muddy facies off Antelope Island

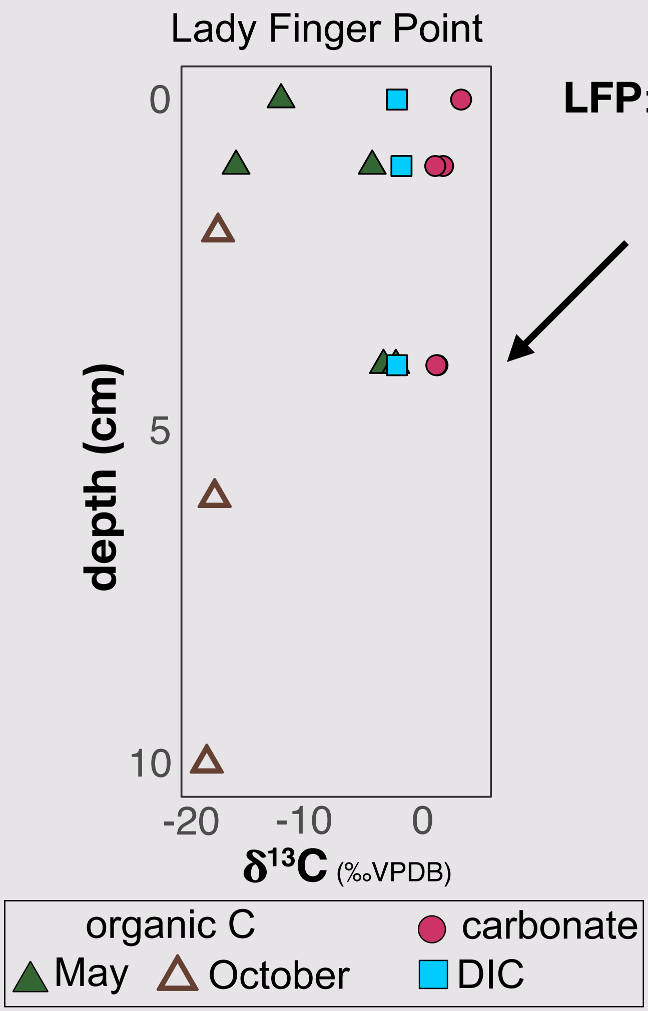


Similar offset between organic C and inorganic C in LFP October and AI-3

ε typical of most carbon fixation pathways

$$\varepsilon = \delta^{13}C_{carb} - \delta^{13}C_{org}$$

Down-core variability and trends: muddy facies off Antelope Island



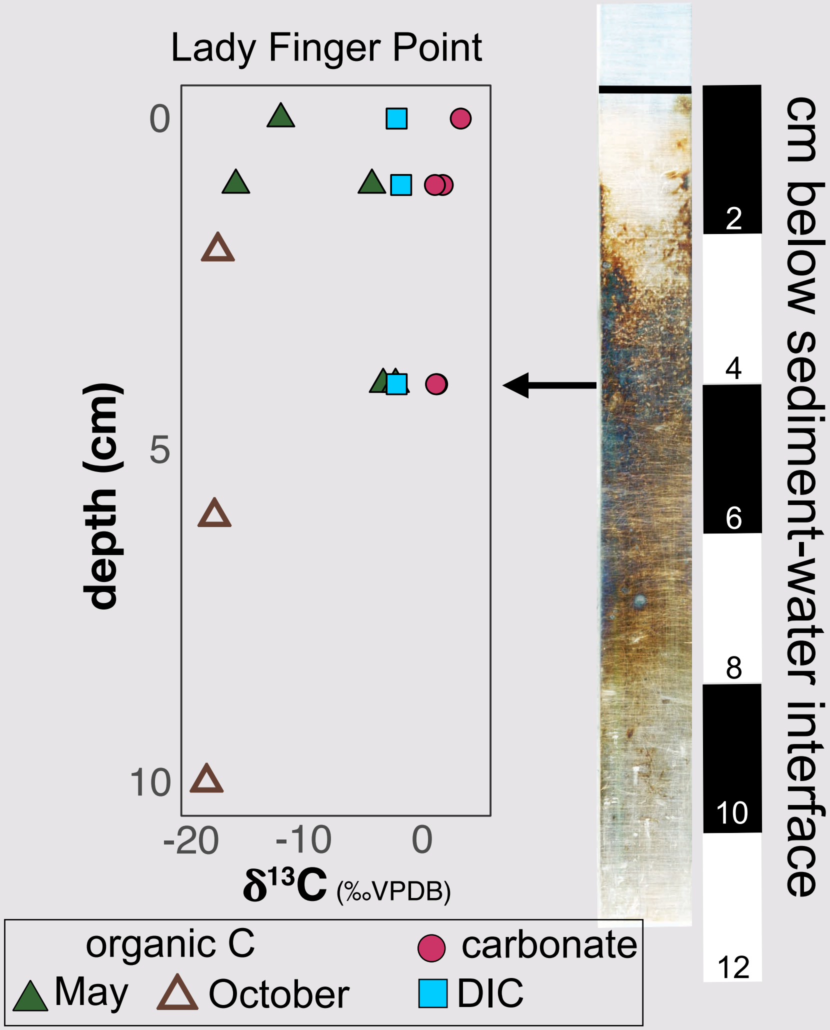
LFP: $\delta^{13}C_{org}$, $\delta^{13}C_{c}$, and $\delta^{13}C_{DIC}$ values **converge at 4cm**

In May, could not push-core below 4cm because of a thick carbonate hard ground

Examples of carbonate hardgrounds at the surface at LFP

brine fly casings for scale

Has **closed system sulfate reduction** caused fractionation of $\delta^{13}C_{org}$ to heavier values?



Sulfide precipitation as evidence of sulfate reduction

$$2[CH_2O] + SO_4^{2-} + OH^- \rightarrow 2HCO_3^- + HS^- + H_2O$$

$$HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H^+$$

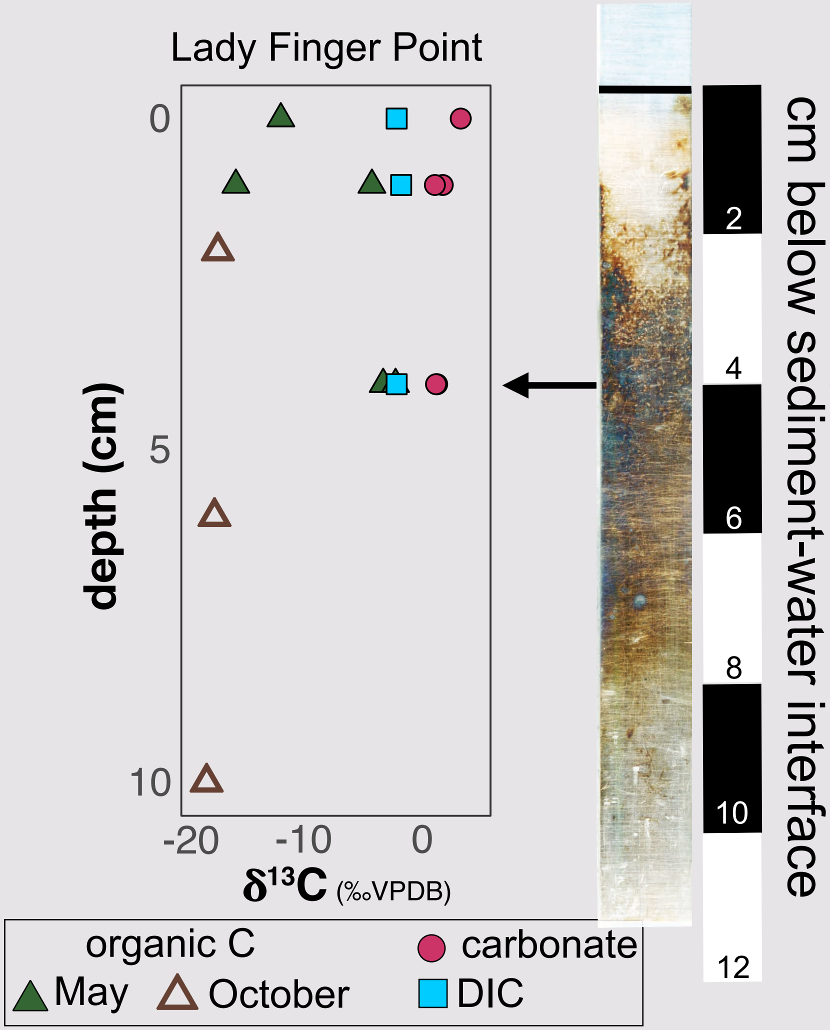
$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$

$$\left.\begin{array}{r} 2[CH_2O] + SO_4^{2-} \\ + OH^- + Ca^{2+} \end{array}\right\} \rightarrow \left\{\begin{array}{l} \boxed{CaCO_3} + CO_2 + 2H_2O \\ \quad + \boxed{HS^-} \end{array}\right.$$

$$(\text{net: } +1\ CaCO_3)$$

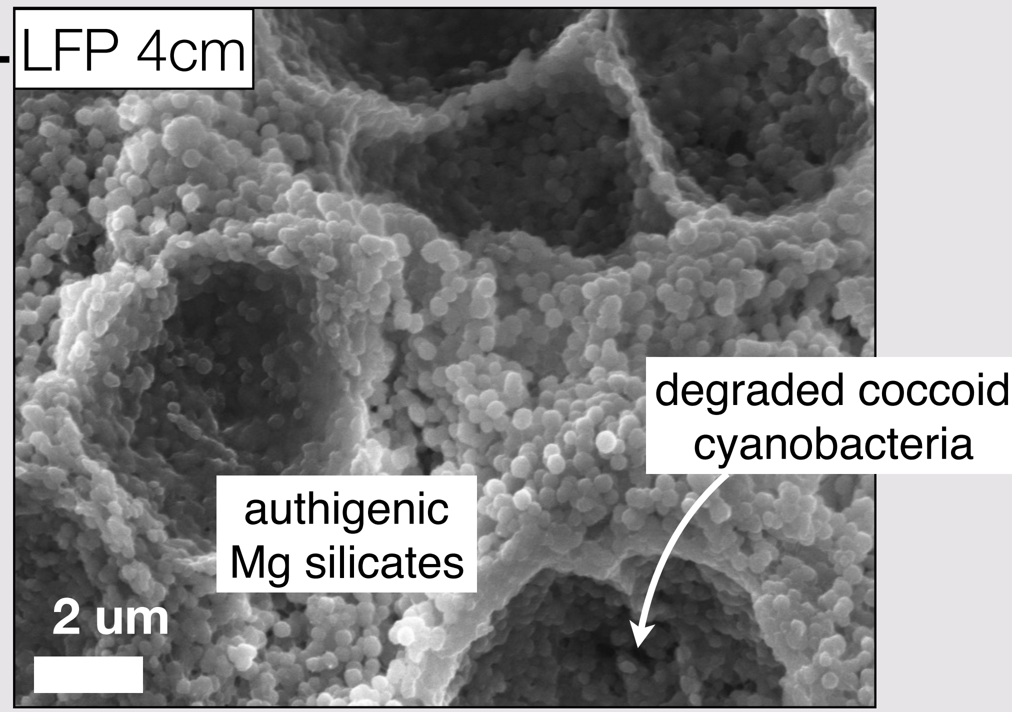
SRBs locally increased carbonate saturation state, allowing for precipitation + lithification of carbonate hardground

Has **closed system sulfate reduction** caused fractionation of $\delta^{13}C_{org}$ to heavier values?



Interpretation of hardground lithification:

1) Sediment burial below photic zone; cyanobacteria degrade
2) Cyano casts coated by authigenic Mg-Si phase **associated with sulfate reduction** (Pace et al., 2016)
3) Aragonite precipitates mimicking EPS structure, lithifying hardground

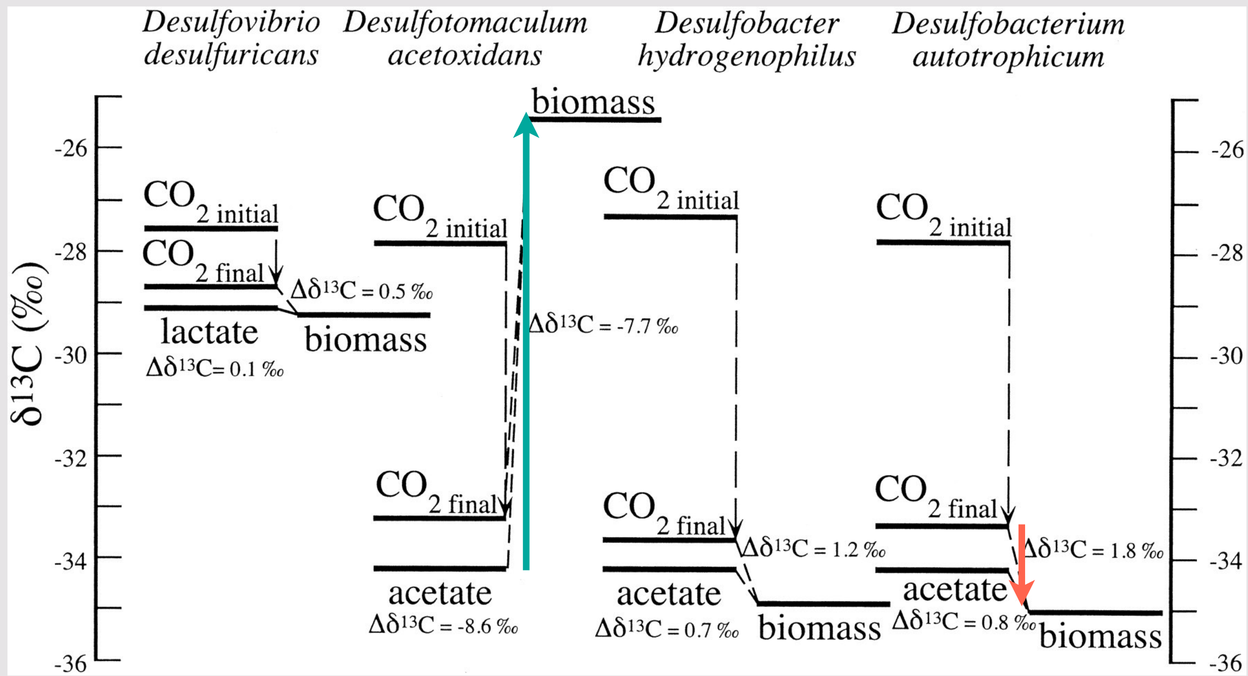


Has **closed system sulfate reduction** caused fractionation of $\delta^{13}C_{org}$ to heavier values?

1. Alter local alkalinity via microbial respiration of org C

$$2[CH_2O] + SO_4^{2-} + OH^- \rightarrow 2HCO_3^- + HS^- + H_2O$$
$$HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H^+$$
$$HCO_3^- + H^+ \rightarrow CO_2 + H_2O$$
$$\left.\begin{array}{c} 2[CH_2O] + SO_4^{2-} \\ + OH^- + Ca^{2+} \end{array}\right\} \rightarrow \left\{\begin{array}{c} CaCO_3 + CO_2 + 2H_2O \\ + HS^- \end{array}\right.$$
$$\text{(net: } \boxed{+1\ CaCO_3}\text{)}$$

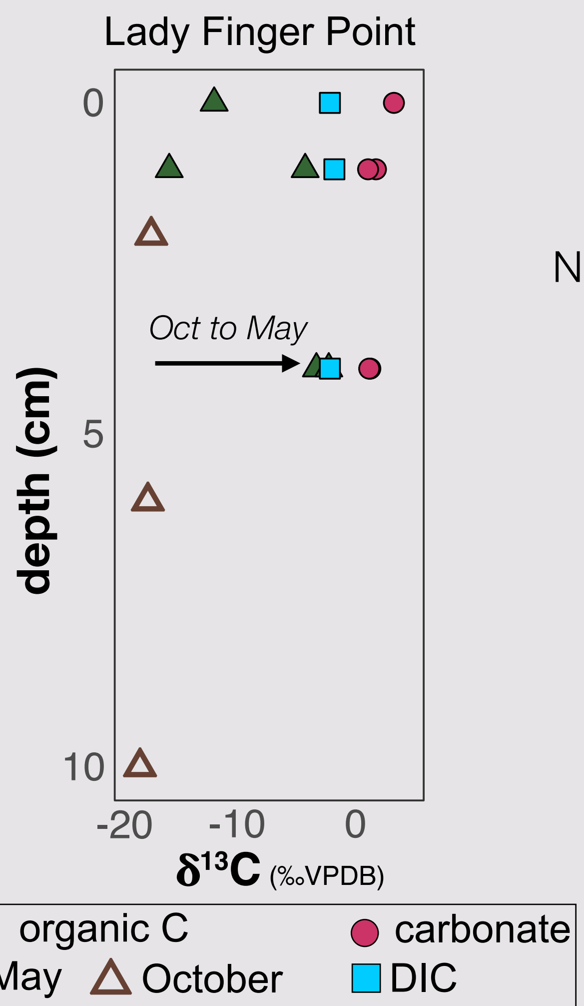
2. Magnitude and direction of fractionation between organic and inorganic carbon pools during SR determined by <u>who does it</u> and with <u>what electron donor</u> (here: acetate).



Next step: 16S rRNA amplicon sequencing to ID SRB and pathways

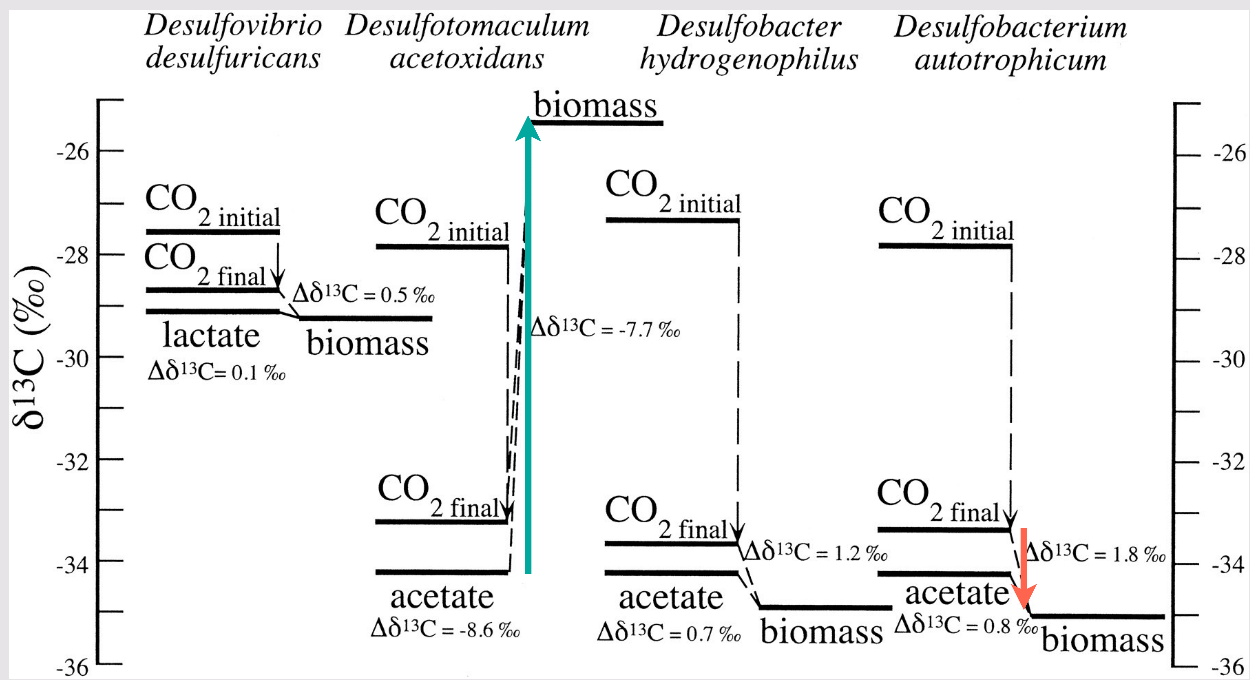
Londry & Des Marais, *Applied and Environmental Microbiology*, 2003

Has **closed system sulfate reduction** caused fractionation of $\delta^{13}C_{org}$ to heavier values?



Hypothesis: Local increase in $\delta^{13}C_{org}$ due to community change: cyanos to SRB?

Next step: 16S rRNA amplicon sequencing to ID SRB and pathways



Londry & Des Marais, *Applied and Environmental Microbiology*, 2003

Sediment-water interface as an approximation of a single stratum

Significant for paleoclimate!

Sediment-water interface as an approximation of a single stratum

Recent GSL $\delta^{18}O_{water}$ = -4.5‰

$\delta^{18}O_{carb} = f(\mathbf{T}, \delta^{18}O_{water})$

12 to 37°C

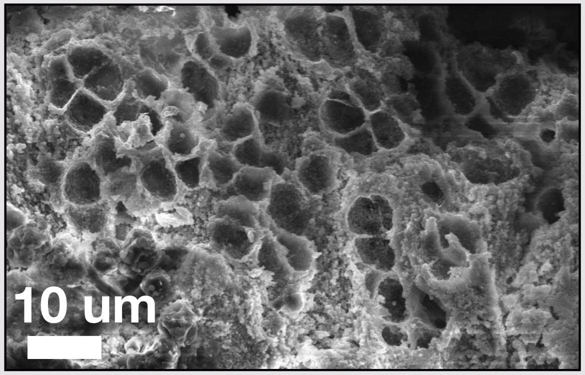
Significant for paleoclimate!

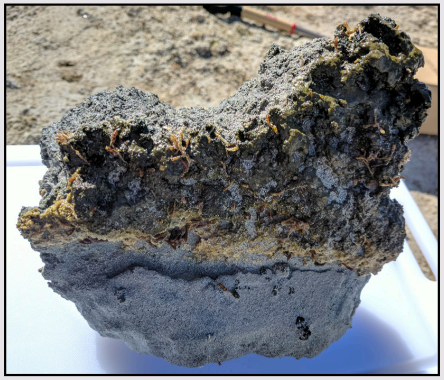
Conclusions

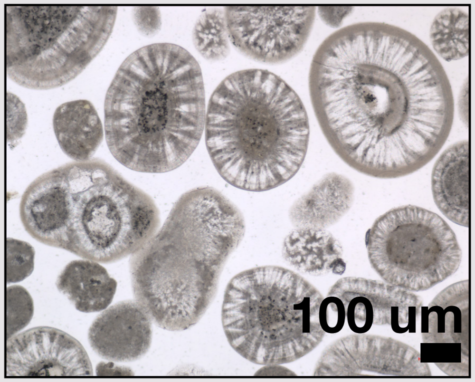
Stable isotopic variability across a single depositional horizon in Great Salt Lake basin could lead to discrepant interpretations of ancient environments

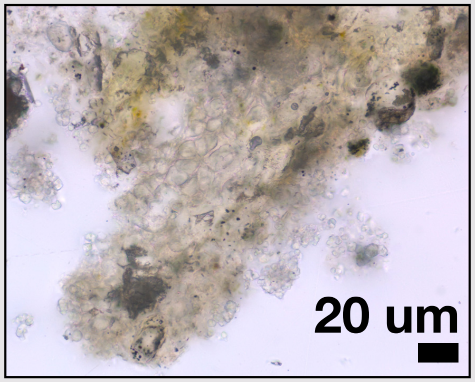
Interannual shifts in microbial community composition drive significant alteration of $\delta^{13}C$
Future work: 16S rRNA

Organic-inorganic C recycling in ooid nuclei results in unusually heavy $\delta^{13}C_{org}$? TBD
…facies matter in sampling the rock record for environmental and climatic reconstructions









Editor's note:
Subsequent to the conference an error was discovered in some of the data presented, a few presentation slides with erroneous data have been removed.

GREAT SALT LAKE MICROBIALITE CHRONOLOGY AND ISOTOPE GEOCHEMISTRY: IMPLICATIONS FOR PALEOLAKE BIOGEOCHEMICAL EVOLUTION

Dennis L. Newell[1], Michael D. Vanden Berg[2], Carie M. Frantz[3], and Jordan L. Jensen[1,4]

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[2]Utah Geological Survey, Salt Lake City, UT 84116;
[3]Department of Geosciences, Weber State University, Ogden, UT 84408;
[4]Department of Geosciences, University of Arizona, Tucson, AZ 85721

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ABSTRACT

Extensive lacustrine microbialite deposits exposed along the shores of Great Salt Lake (GSL), Utah, preserve a rich continental paleoenvironmental record. We report microbialite carbon and oxygen stable isotope ratios in carbonate, and radiocarbon dates from both carbonate and trapped organic matter. These data inform paleolake hydrological and biogeochemical changes from the late Pleistocene through the Holocene. Uncalibrated ^{14}C dates range from 14,747 +/- 50 to 3362 +/- 26 yr B.P. Calibrated dates range from 17,945 to 3606 cal yr B.P., assuming that the radiocarbon was in equilibrium with the atmosphere when incorporated into the microbialites. The presence and impact of some long-residence time, older carbon on these dates (known as the reservoir effect) is unknown, and could yield dates that are too old by a few hundred to few thousand years. Positive correlations between carbonate $\delta^{18}O$ and $\delta^{13}C$ in some microbialites are consistent with a holomictic (mixes at least once per year), hydrologically closed-basin lake with fluctuations in volume, chemistry, and associated changes in lake primary production. However, inverse $\delta^{18}O$ and $\delta^{13}C$ correlations present in a number of microbialites are enigmatic, but may imply periods of higher salinity and stable lake stratification (meromixis) similar to modern GSL conditions. The preliminary geochronology and isotope geochemistry in this study may indicate two prior periods of meromixis between ~13 and 9.5 ka, and 6 and 3.6 ka, separated by periods dominated by holomictic conditions in GSL.

This content is a PDF version of the author's PowerPoint presentation.

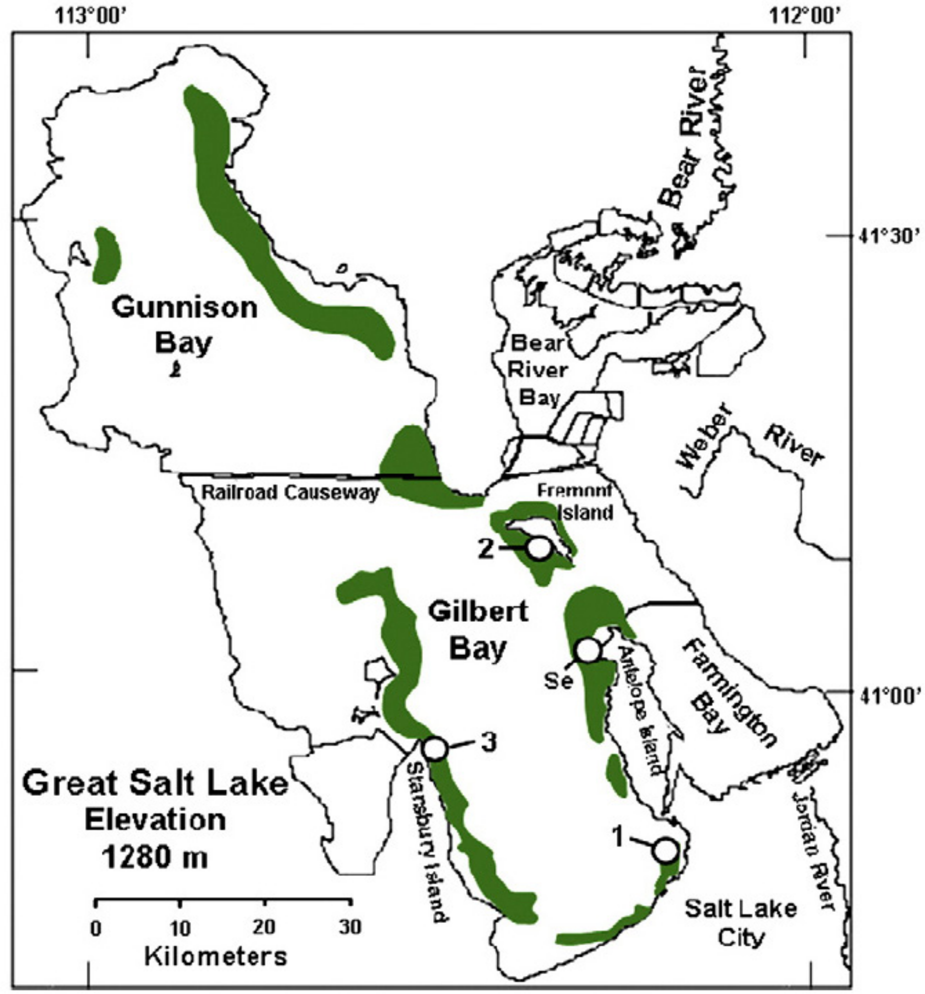
Great Salt Lake (Utah) microbialite chronology and isotope geochemistry: implications for paleolake biogeochemical evolution

Dennis L. Newell[1], Michael D. Vanden Berg[2], Carie M. Frantz[3], and Jordan L. Jensen[1,4]
[1]Dept. of Geology, Utah State University
[2]Utah Geological Survey
[3]Dept. of Geosciences, Weber State University
[4]Exxon Mobil

ACKNOWLEDGEMENTS

- Antelope Island State Park, Utah Department of Natural Resources
- Dr. Susanne Janecke, USU - sample donation
- Funding from the USU Office of Research and Graduate Studies and College of Science
- Fen-Ann Shen - USU Microscopy Core Facility

Great Salt Lake Microbialites



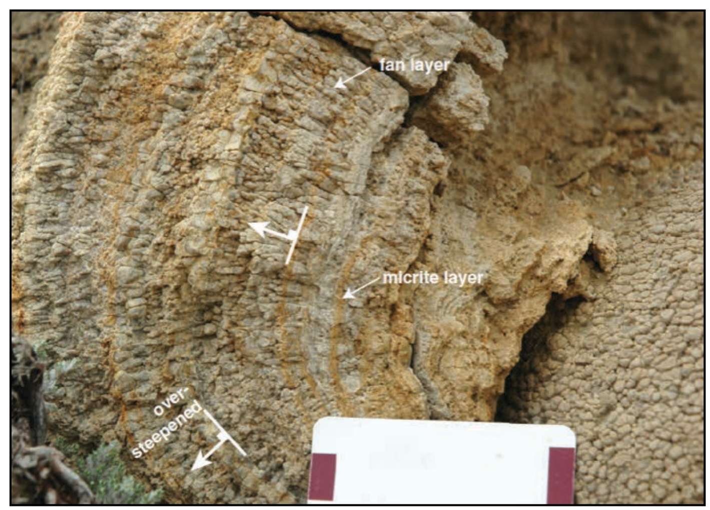
(Wurtsbaugh et al., 2011)

Research Questions

- Does microbialite geochemistry preserve a record of lake composition and biogeochemical cycling?
- How old are GSL microbialites?
- Are they "growing" today?
- How and when do they grow?

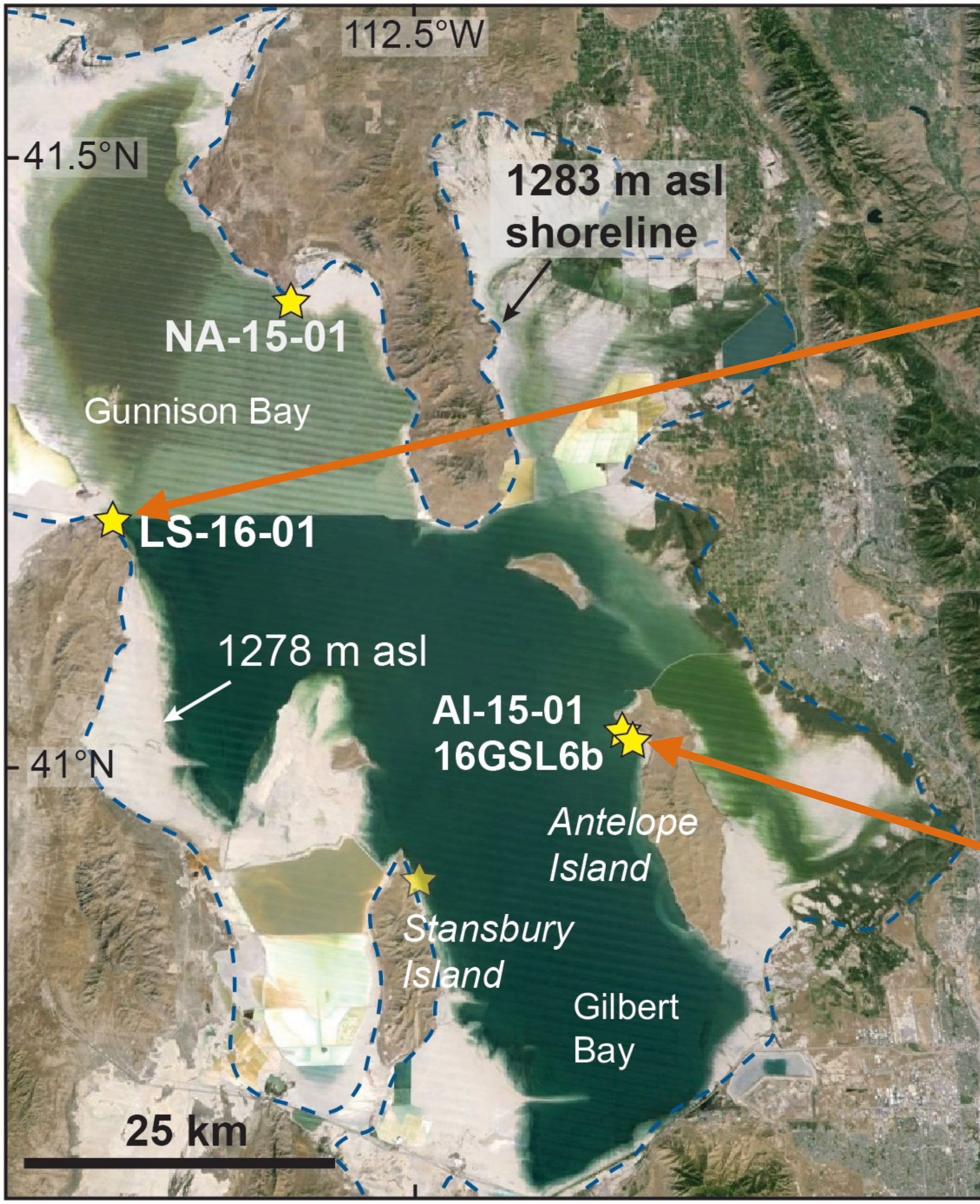
Great Salt Lake

Eocene Green River Fm



(Frantz et al., 2014)

GSL Study Locations



MICROBIALITE TEXTURES

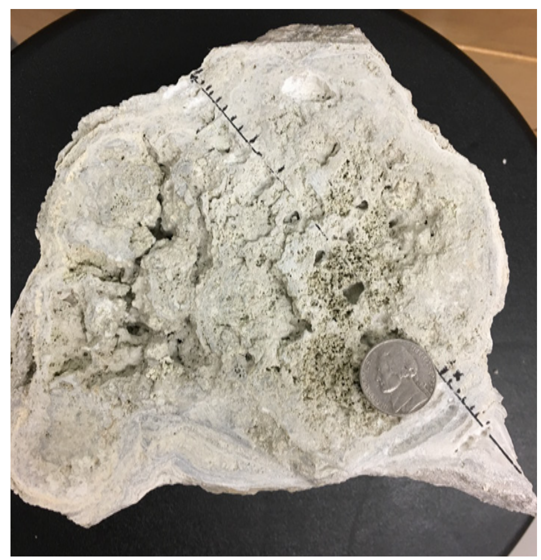
AI-15-01

Buffalo Pt,
Antelope Island

16GSL6b

Lakeside
LS-16-01

(sample credit - M. Vanden Berg, Utah Geological Survey)



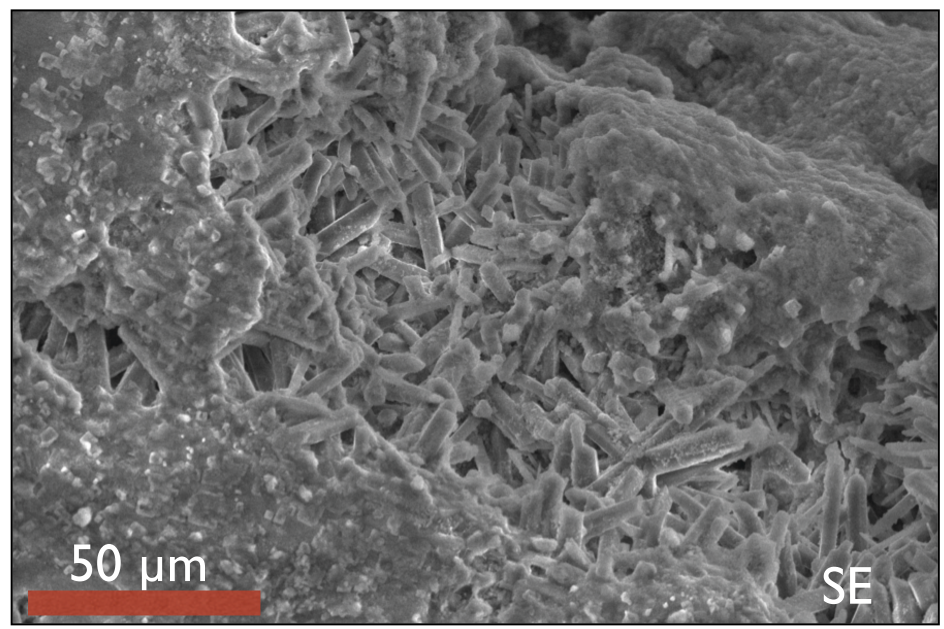
(sample credit - S. Janecke, USU Geology)

North Arm
NA-15-01

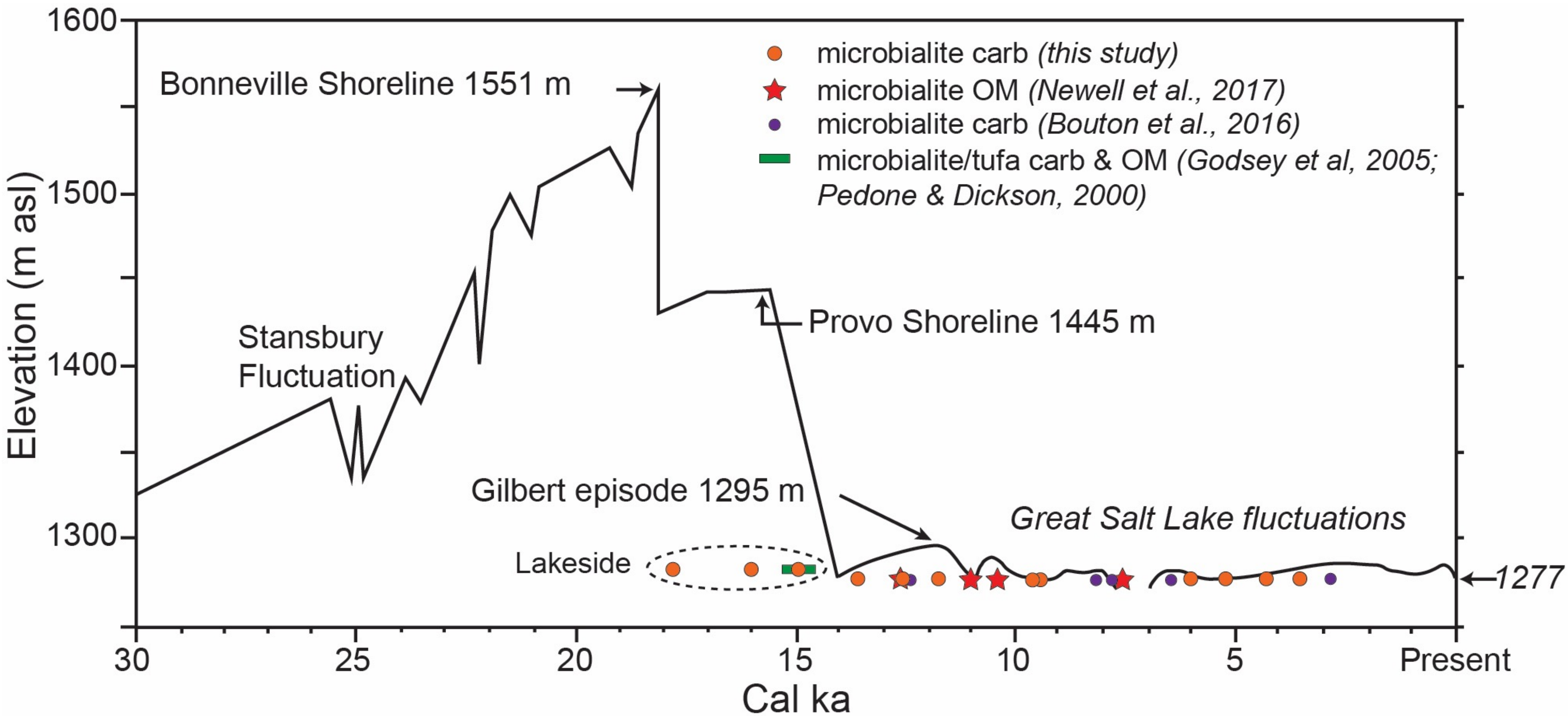
MICROBIALITE TEXTURES

(Newell et al., 2017)

AI-15-01 from Buffalo Point, GSL

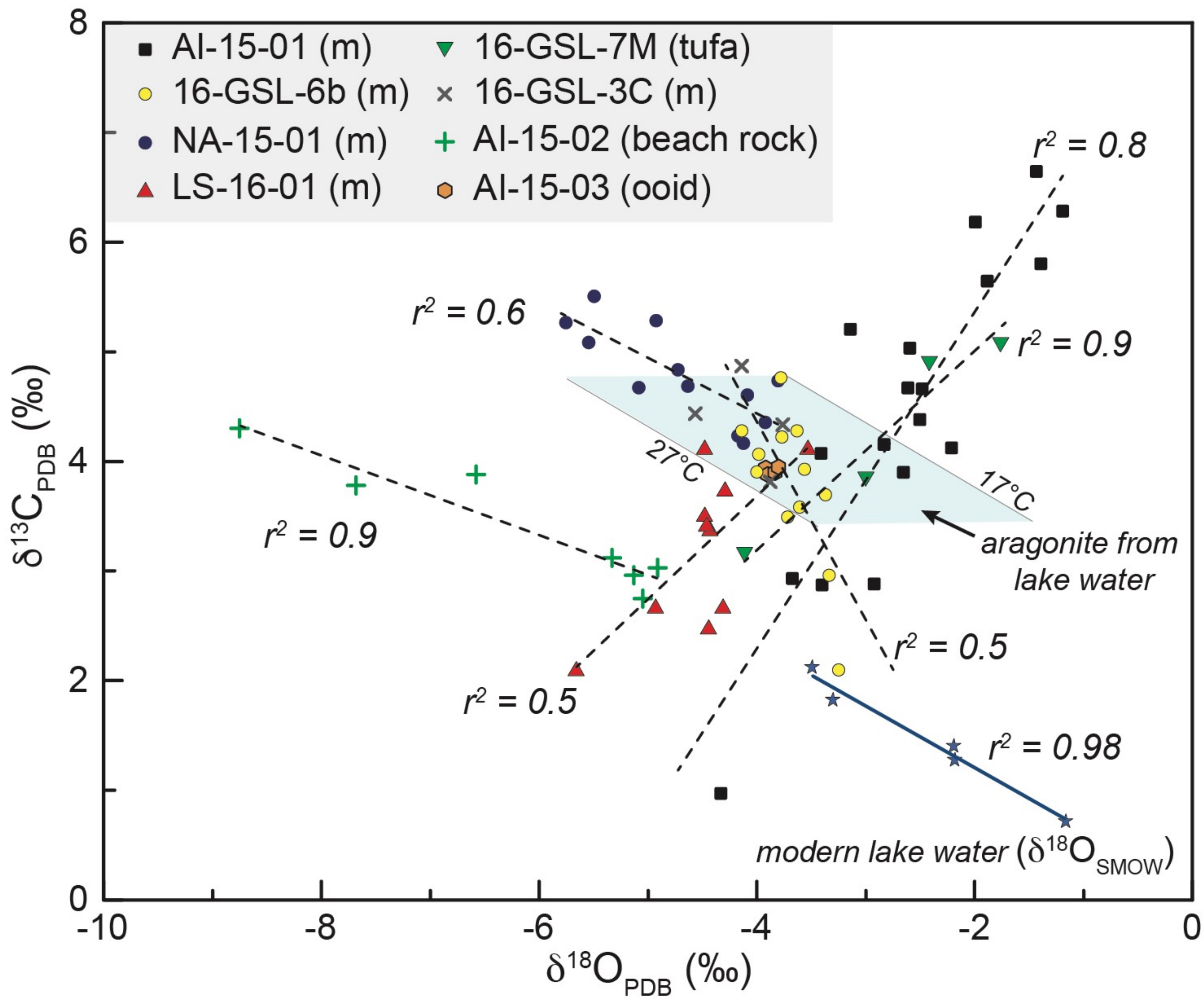


Microbialite Radiocarbon Dates



Understanding impact of reservoir effect & diagenesis critical for interpreting radiocarbon dates

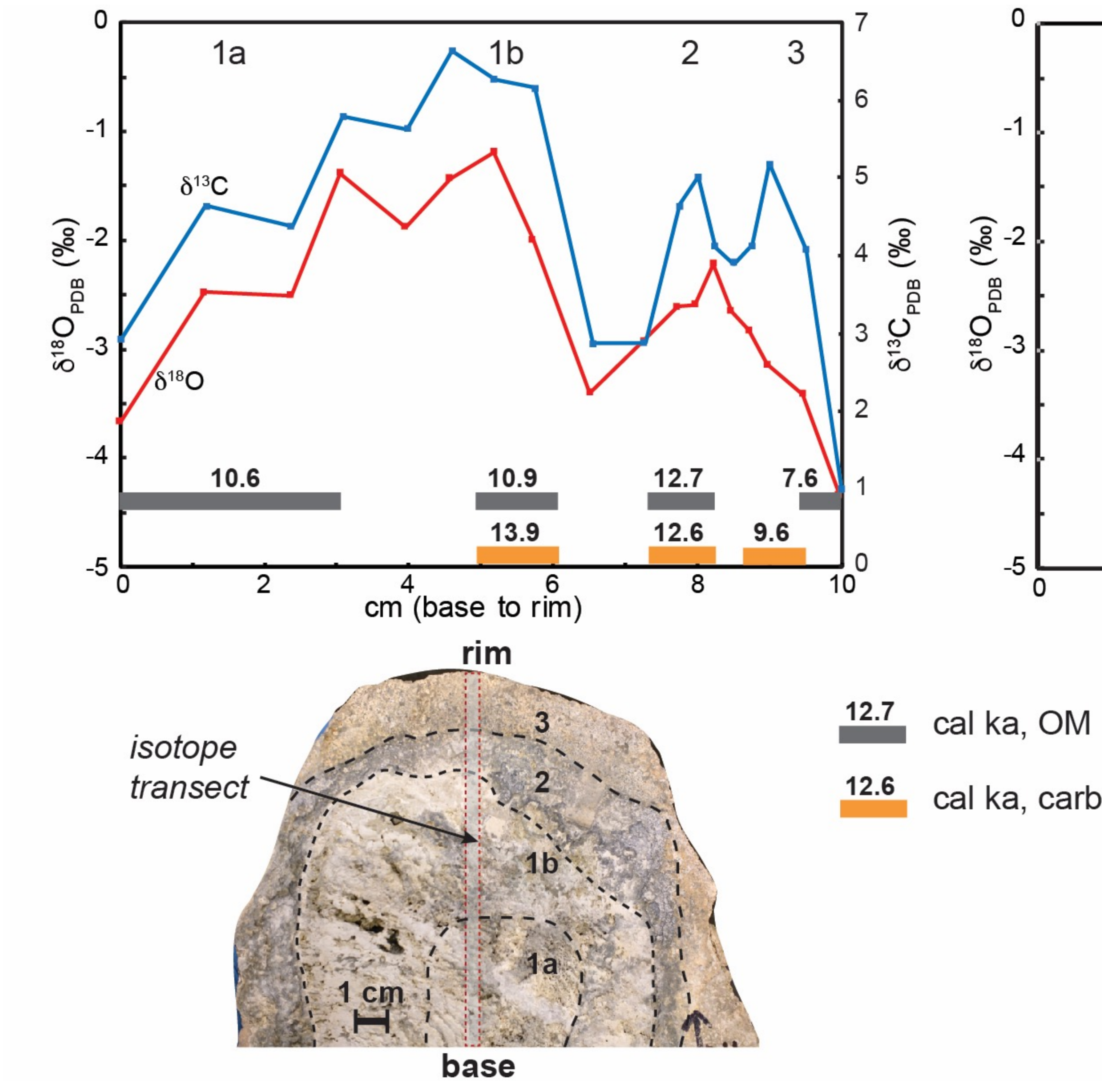
Stable Isotope Geochemistry



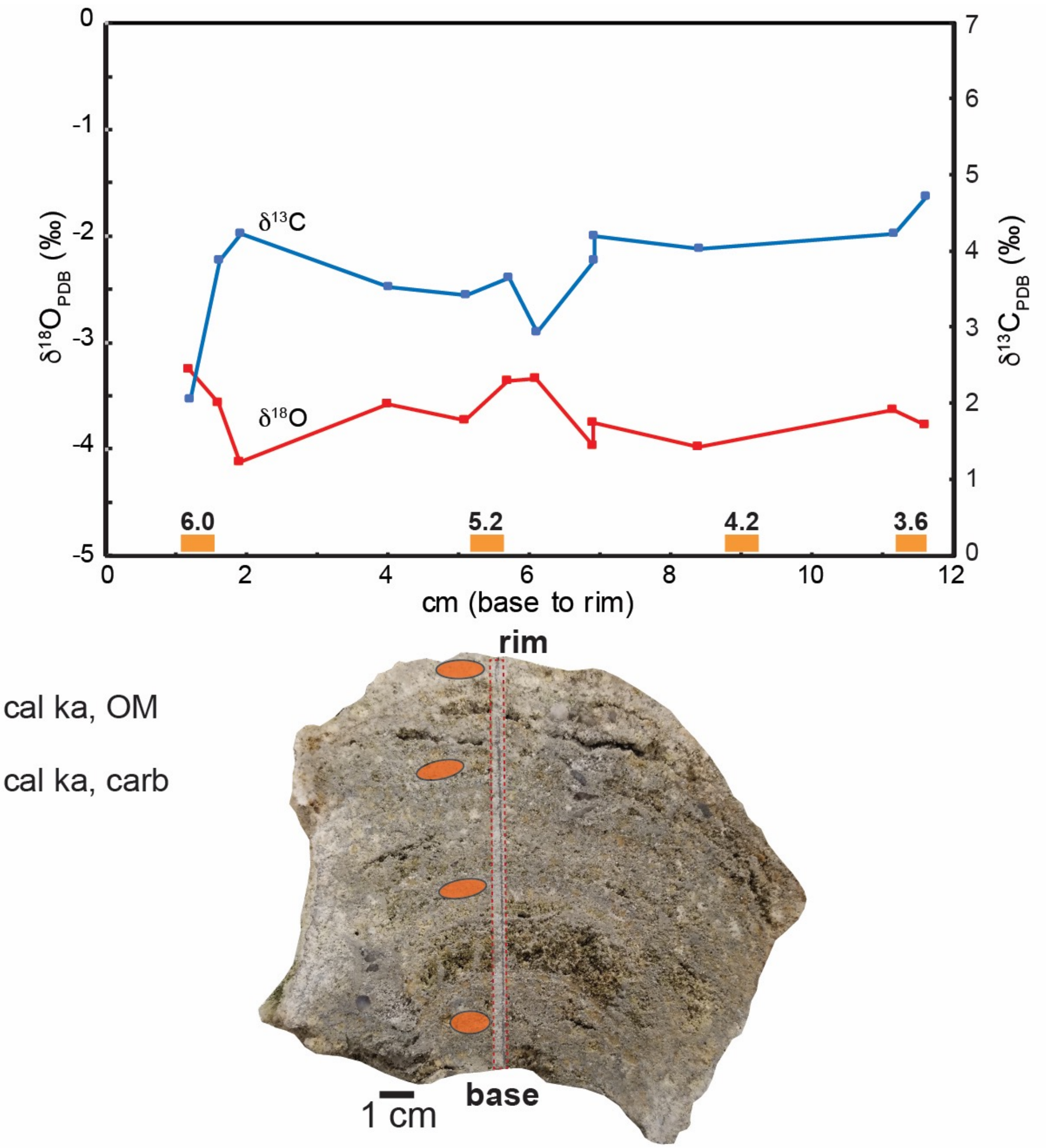
(modified from Newell et al., 2017)

Stable Isotopes + Geochronology

Positive correlation

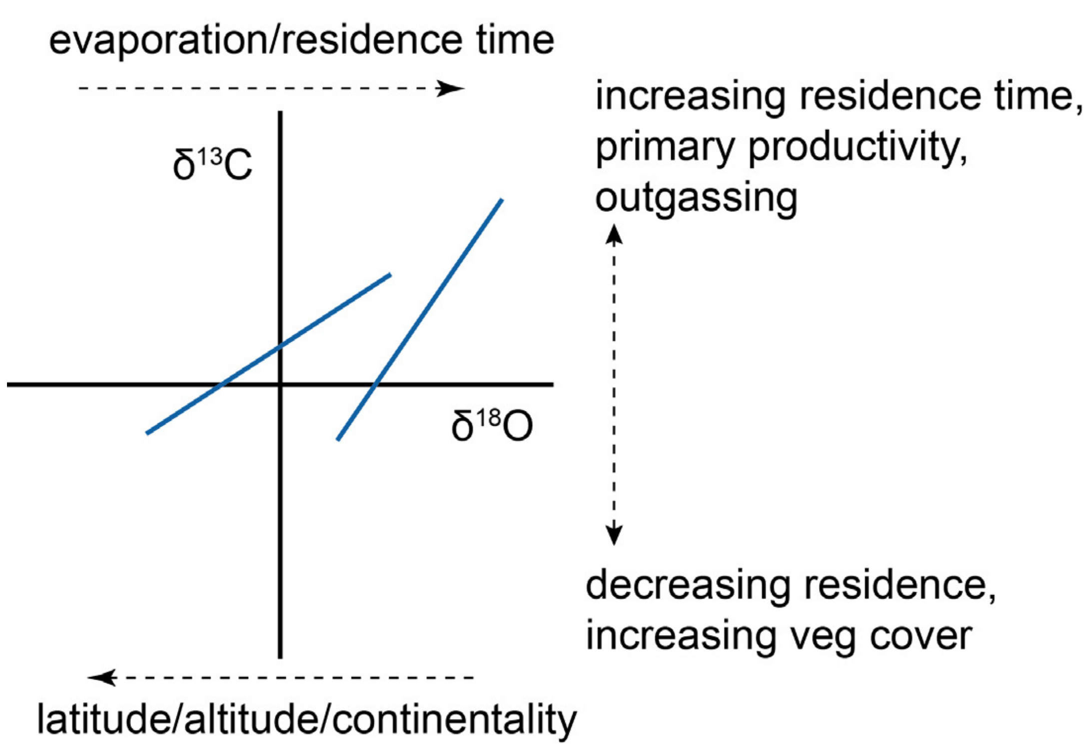


Inverse correlation

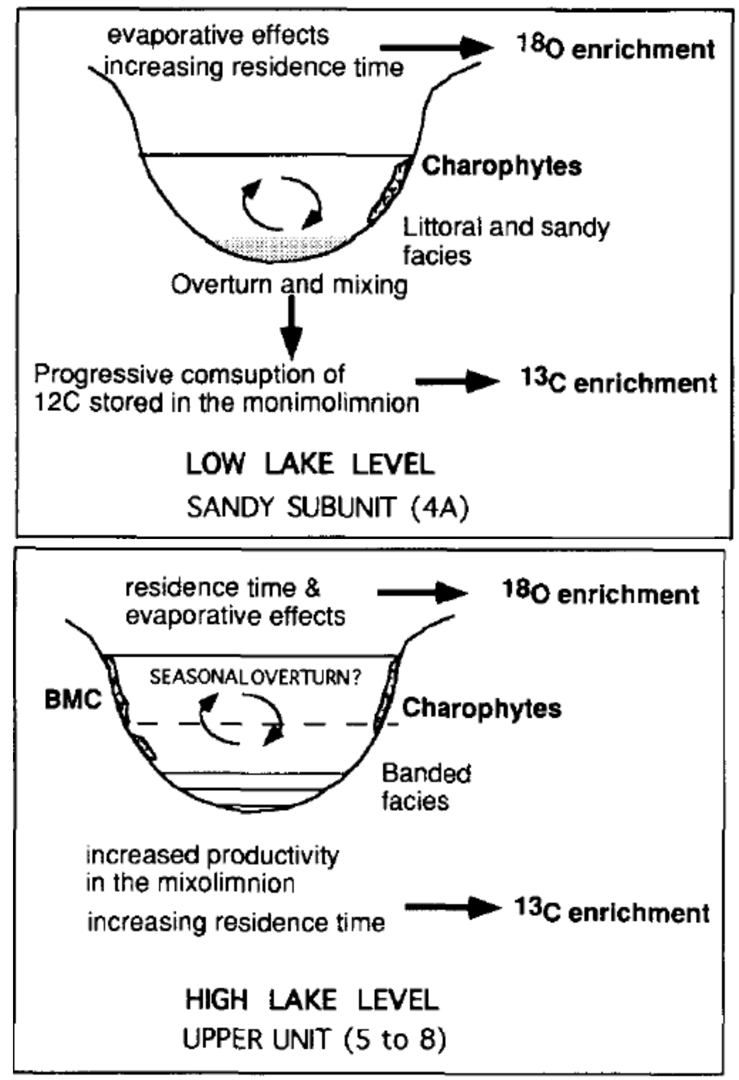


Stable Isotope Geochemistry

Positive Correlations



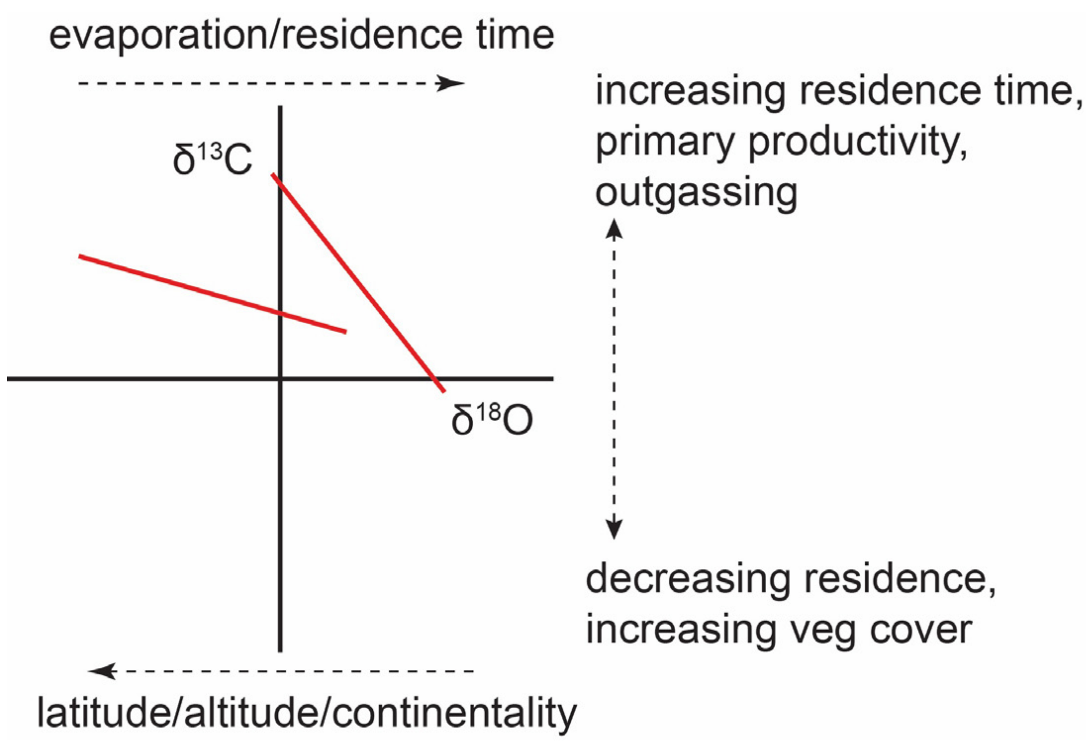
(modified from Talbot, 1990)



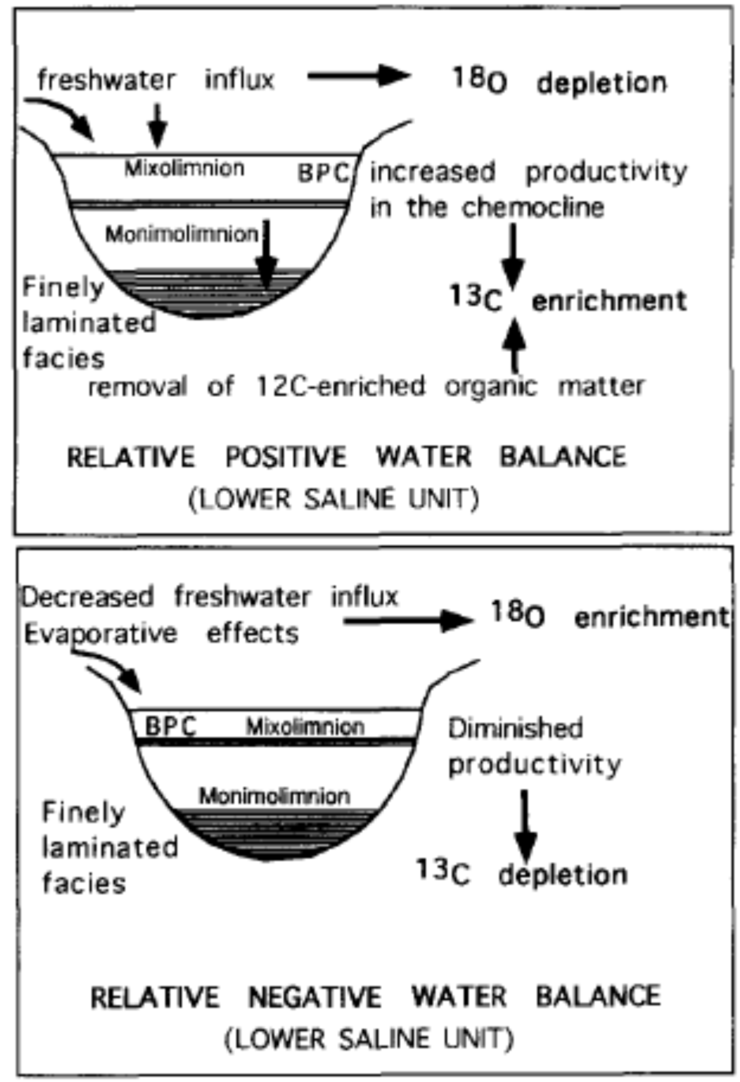
(from Garcés et al., 1995)

STABLE ISOTOPE GEOCHEMISTRY

Inverse Correlations?

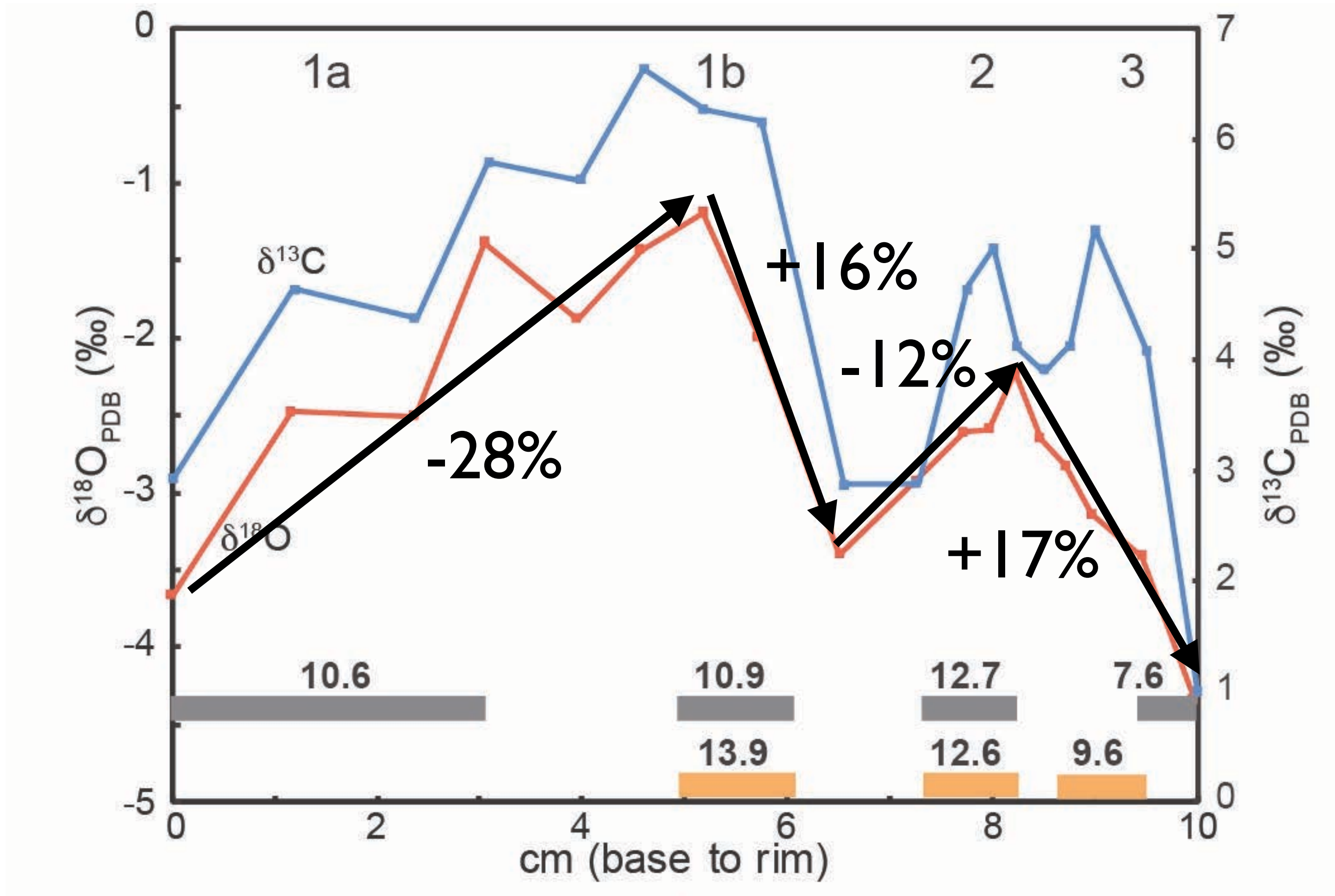


(modified from Talbot, 1990)



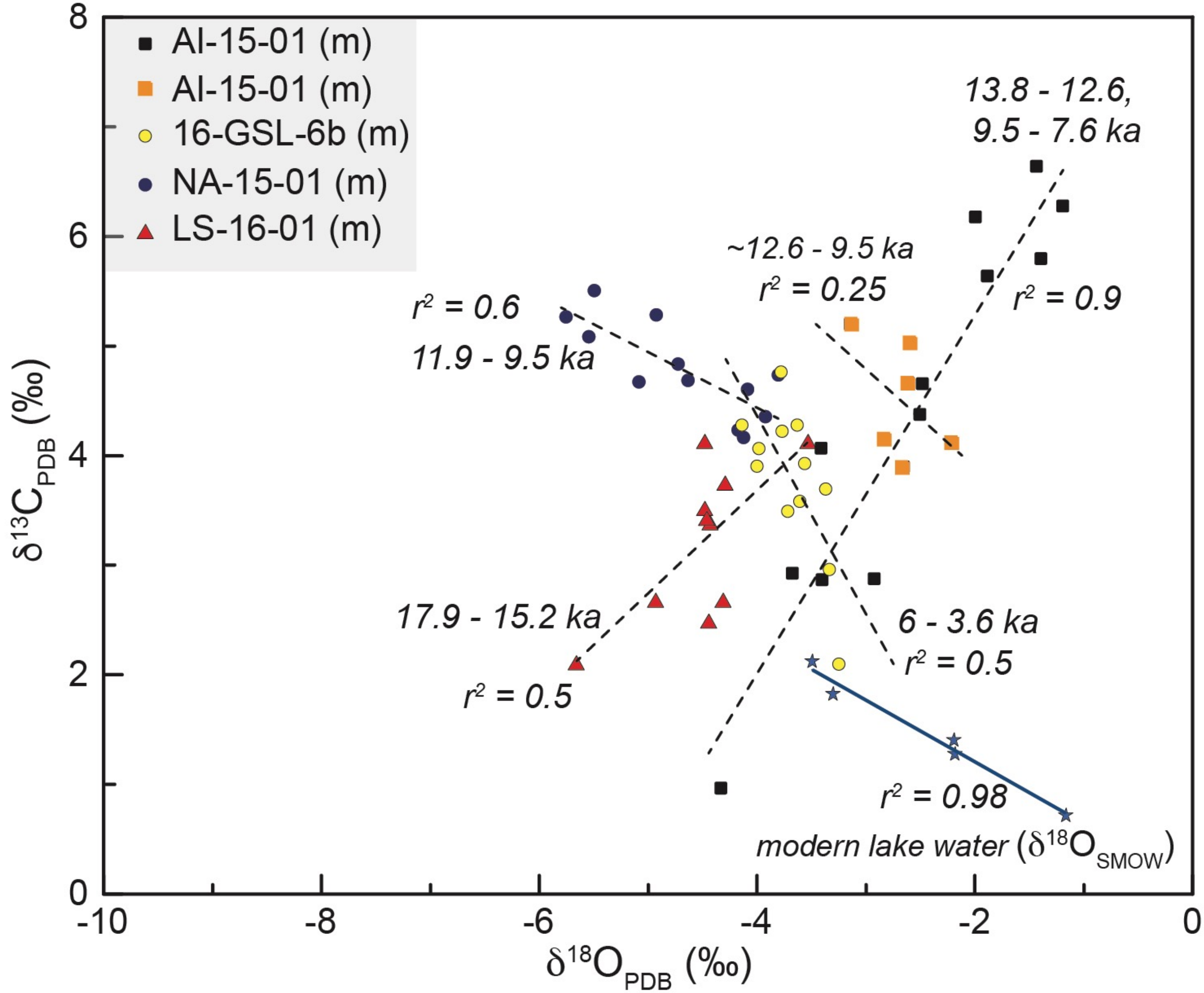
(from Garcés et al., 1995)

Record of Volume Change?

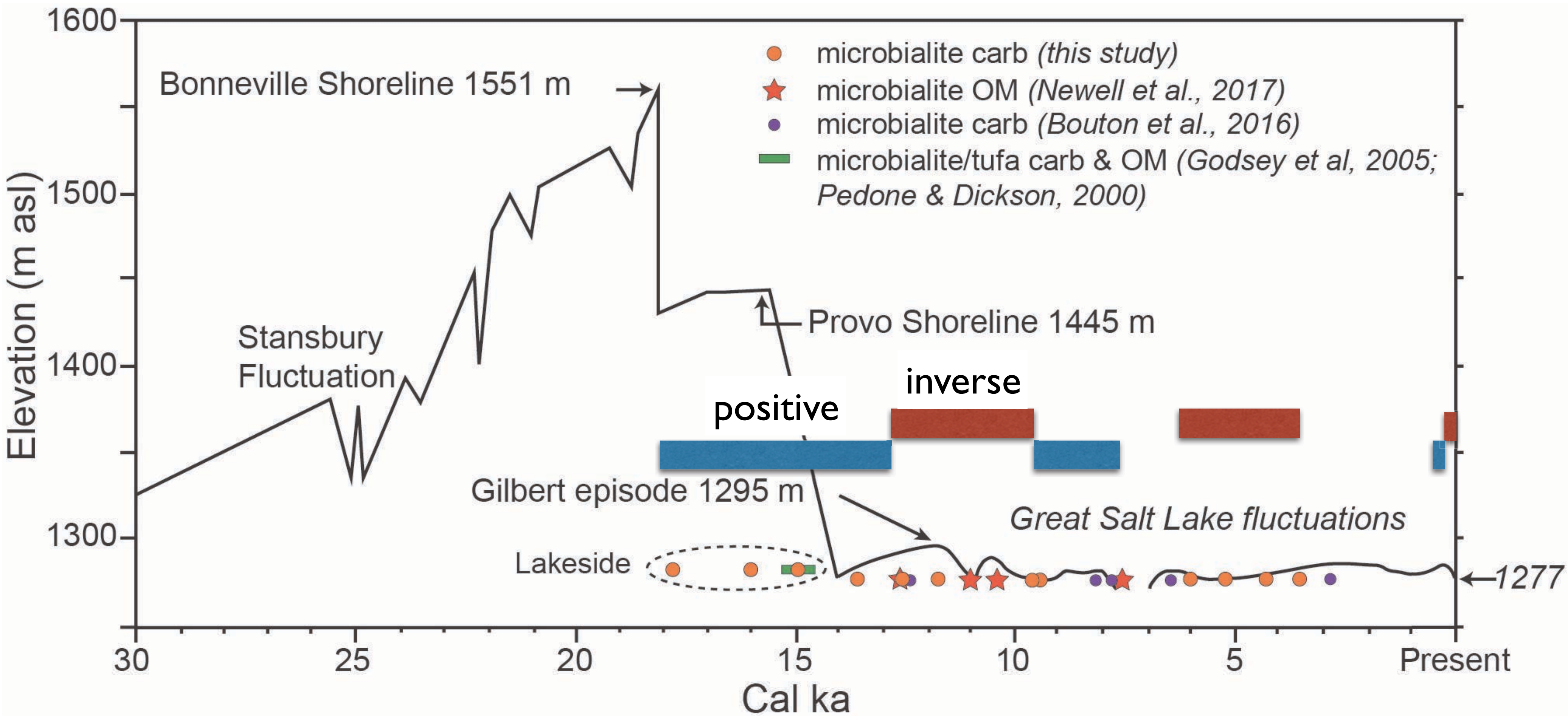


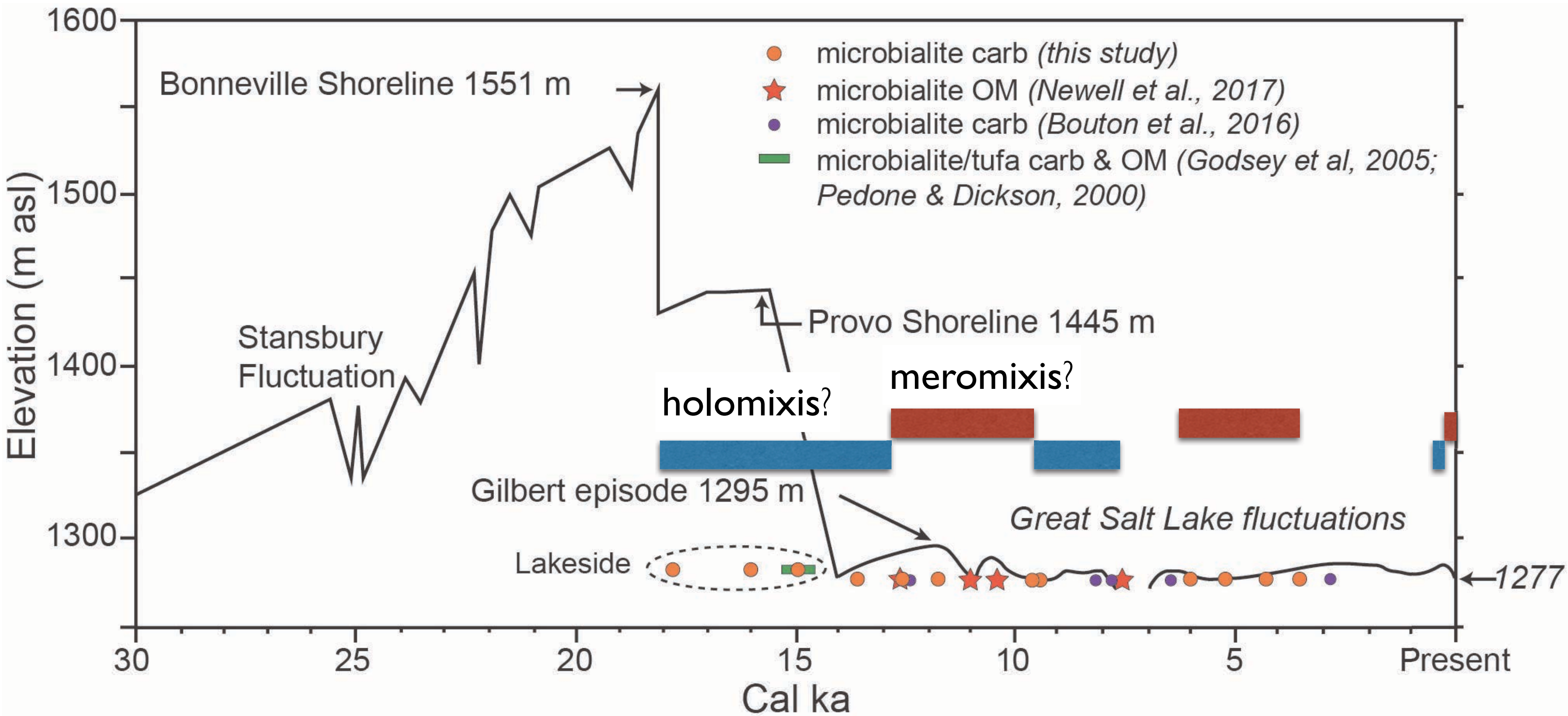
simplified model based assuming just transient volume change - changing residence time and steady-state volume possible

Stable Isotopes + Geochronology



ISOTOPE CORRELATIONS





1600
1500
1400
1300
Elevation (m asl)
30
25
20
15
10
5
Present
Cal ka
microbialite carb (this study)
microbialite OM (Newell et al., 2017)
microbialite carb (Bouton et al., 2016)
microbialite/tufa carb & OM (Godsey et al, 2005; Pedone & Dickson, 2000)
Bonneville Shoreline 1551 m
Provo Shoreline 1445 m
Stansbury Fluctuation
holomixis?
meromixis?
Gilbert episode 1295 m
Great Salt Lake fluctuations
Lakeside
1277

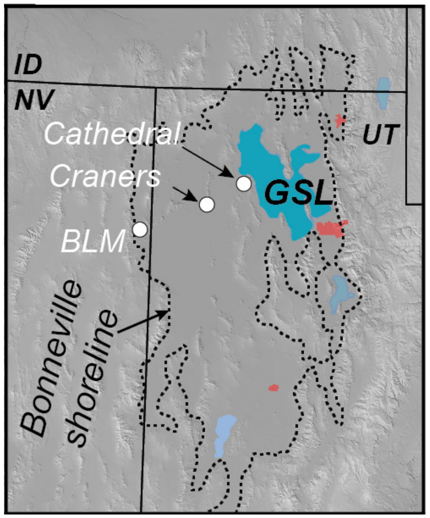
Summary

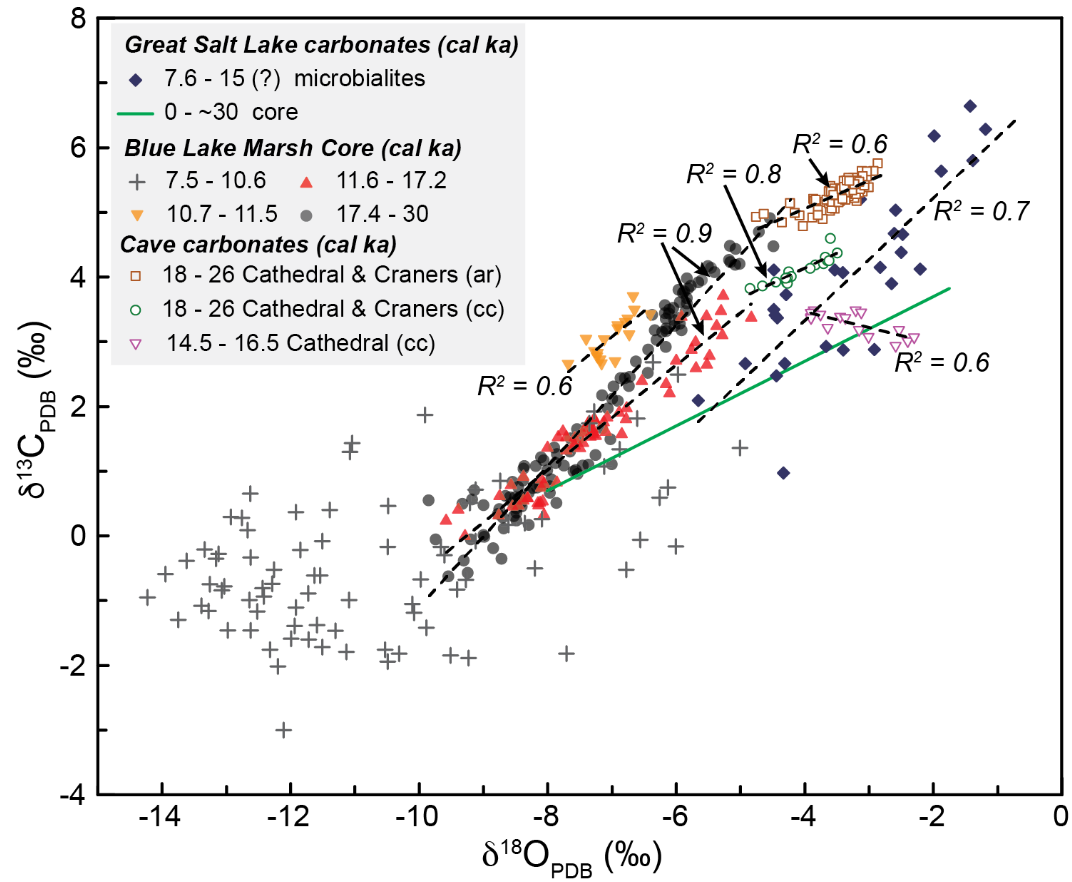
Periodic microbialite growth since the Pleistocene provides a proxy record for Great Salt Lake hydro- and bio-geochemical conditions

C and O stable isotopes likely track lake geochemistry and may indicate past well-mixed periods versus more stable stratification (like today)

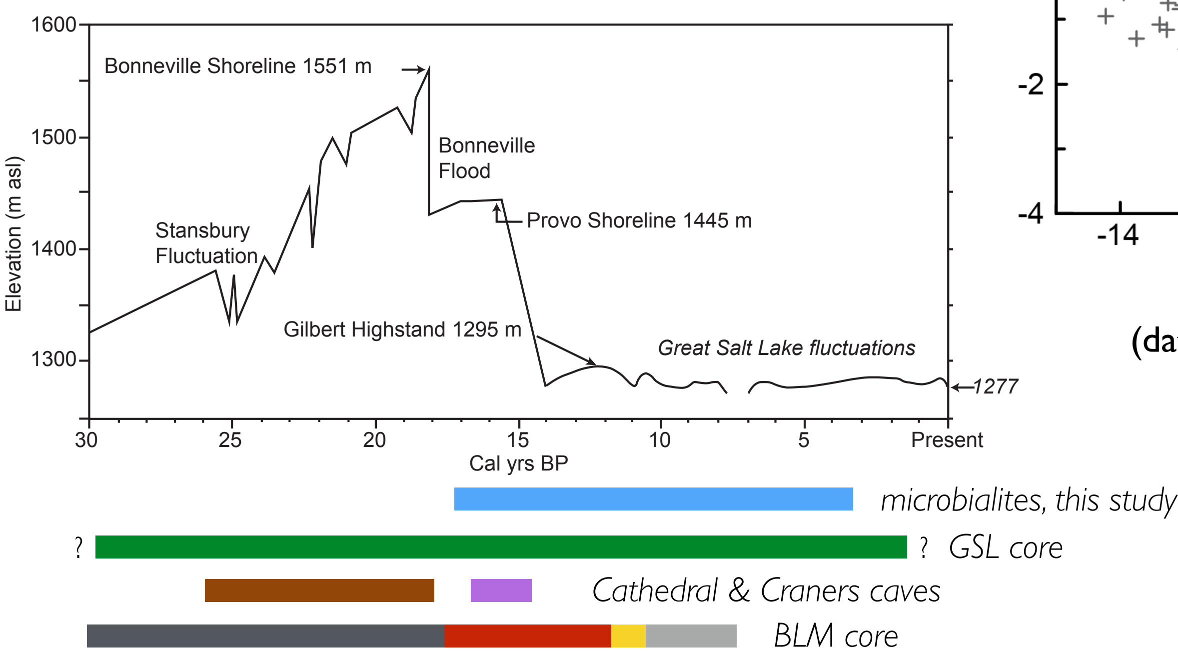
Isotopic variations within and between microbialites may track changes in basin hydrology, lake biogeochemistry, and lake extent

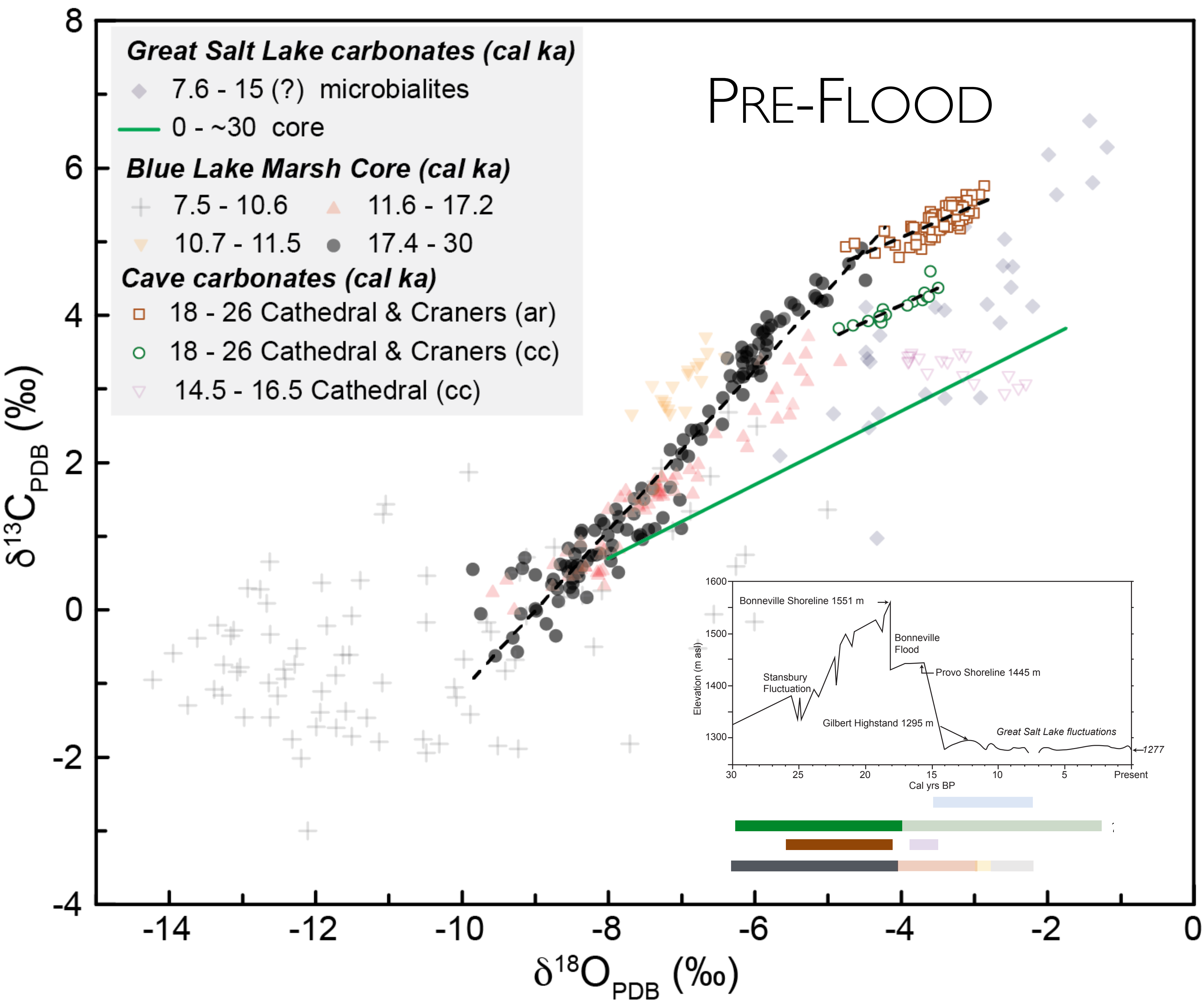
Comparison to other carbonate records



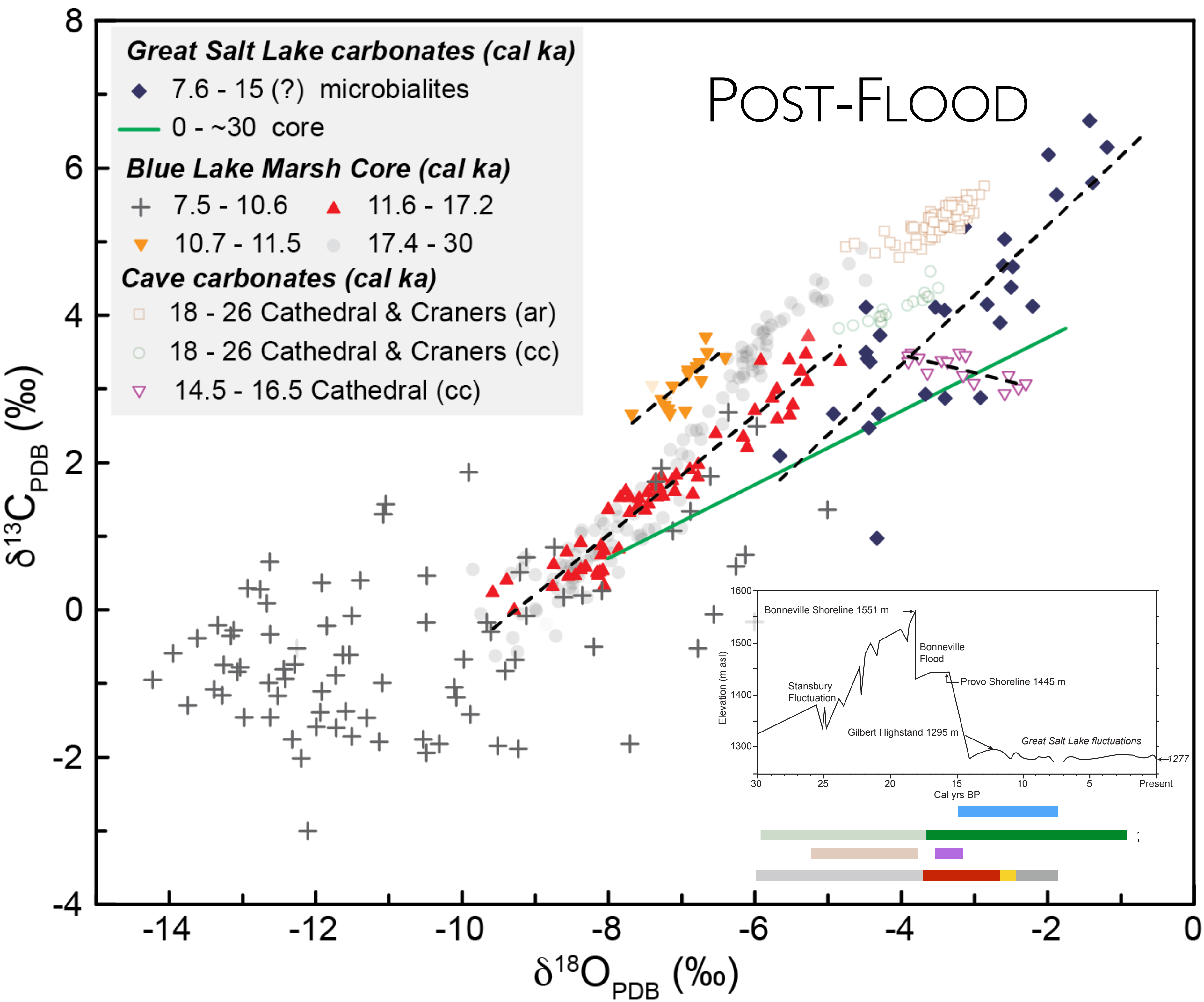


(data from Spencer et al., 1984; McKenzie & Eberli, 1987; Benson et al., 2011; McGee et al., 2012)





PRE-FLOOD
Great Salt Lake carbonates (cal ka)
7.6 - 15 (?) microbialites
0 - ~30 core
Blue Lake Marsh Core (cal ka)
7.5 - 10.6
11.6 - 17.2
10.7 - 11.5
17.4 - 30
Cave carbonates (cal ka)
18 - 26 Cathedral & Craners (ar)
18 - 26 Cathedral & Craners (cc)
14.5 - 16.5 Cathedral (cc)
$\delta^{13}C_{PDB}$ (‰)
$\delta^{18}O_{PDB}$ (‰)
Bonneville Shoreline 1551 m
Bonneville Flood
Provo Shoreline 1445 m
Stansbury Fluctuation
Gilbert Highstand 1295 m
Great Salt Lake fluctuations
1277
Elevation (m asl)
Cal yrs BP
Present



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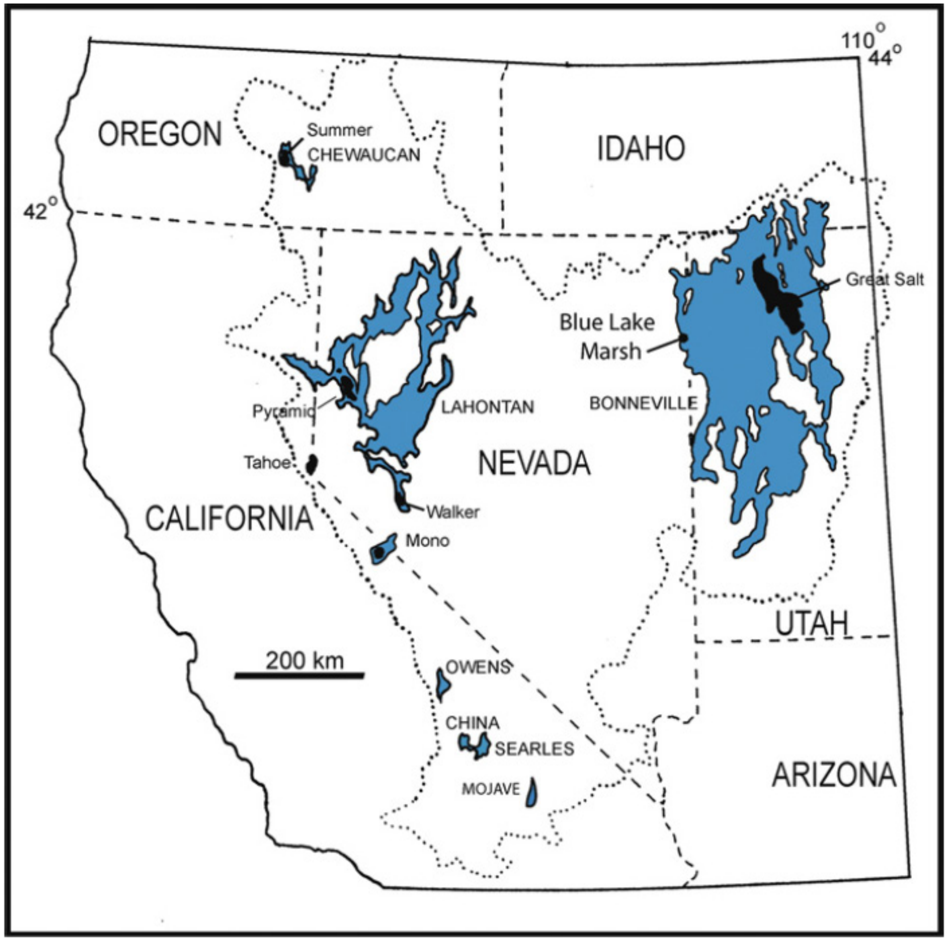
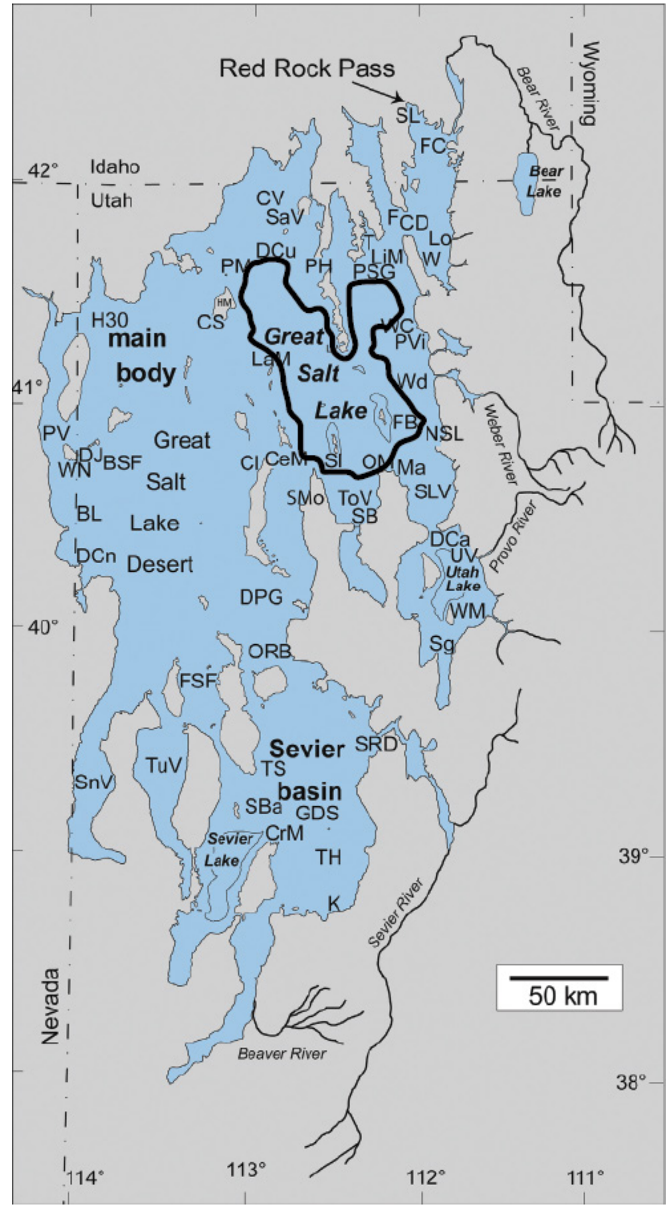
1277
Elevation (m asl)
Cal yrs BP
Present

Lake Bonneville and Great Salt Lake



Great Basin lakes (Benson, et al., 2011)



(Oviatt 2015)

INTO HOT WATER OR OUT OF OUR DEPTH? TUFA, TRAVERTINE, AND MICROBIALITES AT LAKESIDE UTAH

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ABSTRACT

The continental carbonates along the modern shoreline at Lakeside, Utah, combine microbialites, travertine, and tufa in a connected depositional system. Continental carbonates are well exposed at Atwoods Point, Death Point, and Dos Equis Point close to Lakeside. Facies analysis and mapping in the field was supported by thin section petrography, as well as XRD, SEM-EDS, and isotope analyses. Mississippian Great Blue Limestone bedrock is cut by fractures and an earlier karst system, providing pathways for hyperalkaline groundwater. Other groundwater conduits, lined by carbonate, have been preserved in lake margin cliff faces, exposed by collapse under shoreline processes. Onshore lake margin springs deposited drapes, cascades, rimmed pools, and mounds of aragonitic carbonate. Shoreline lacustrine microbialites were physically linked to the onshore travertine. Slightly deeper lacustrine microbialite benches completed the carbonate depositional system.

Carbonate mounds measuring meters to tens of meters across are cut by crevices that acted as vents for carbonate rich groundwater. Alkaline groundwater flowed from bedrock outlets down and into the lake. Pavements and benches of microbialites developed as nearshore and longshore reefs, possibly with the influence of longshore currents. Permanent flooding of lacustrine carbonates, and recurrent flooding and exposure of the shoreline carbonates, led to precipitation of "dolomites" comprising very high Mg-calcite, non-stoichiometric dolomite, and stoichiometric dolomite. Deeper lacustrine microbialites have been pervasively dolomitized, while shoreline microbialites were dolomitized to a lesser extent. Shoreline microbialites and groundwater spring carbonates were modified by pedogenesis with vadose and phreatic dolomitic cements. "Dolomites" gradually diminish in the carbonates above the paleoshoreline, to disappear before reaching 10 m above historical lake levels suggesting that lake water was the Mg source for the Mg-Ca carbonates.

Aragonite composition, as opposed to calcite, provides circumstantial evidence for mesothermal temperatures of resurgent groundwater (>40°C). Skeletal aragonite and dendritic calcite fabrics indicate precipitation from hyperalkaline fluids. Isotope geochemistry supports the interpretations of evaporitic conditions in groundwater-fed ponds, as well as of the meteoric groundwater origin of late calcitic drapes.

Swash zone beach deposits are interbedded with shoreline lacustrine microbialites. This shows that the lake elevation at the time of these Lakeside carbonates was between 1282 m and 1285 m, similar to historical Great Salt Lake. The system at Lakeside was likely triggered by fall of the lake's elevation to Great Salt Lake level. Further analytical work on the ages of the geomorphic features and on the paleotemperatures of the different carbonates is underway in order to test this proposal.