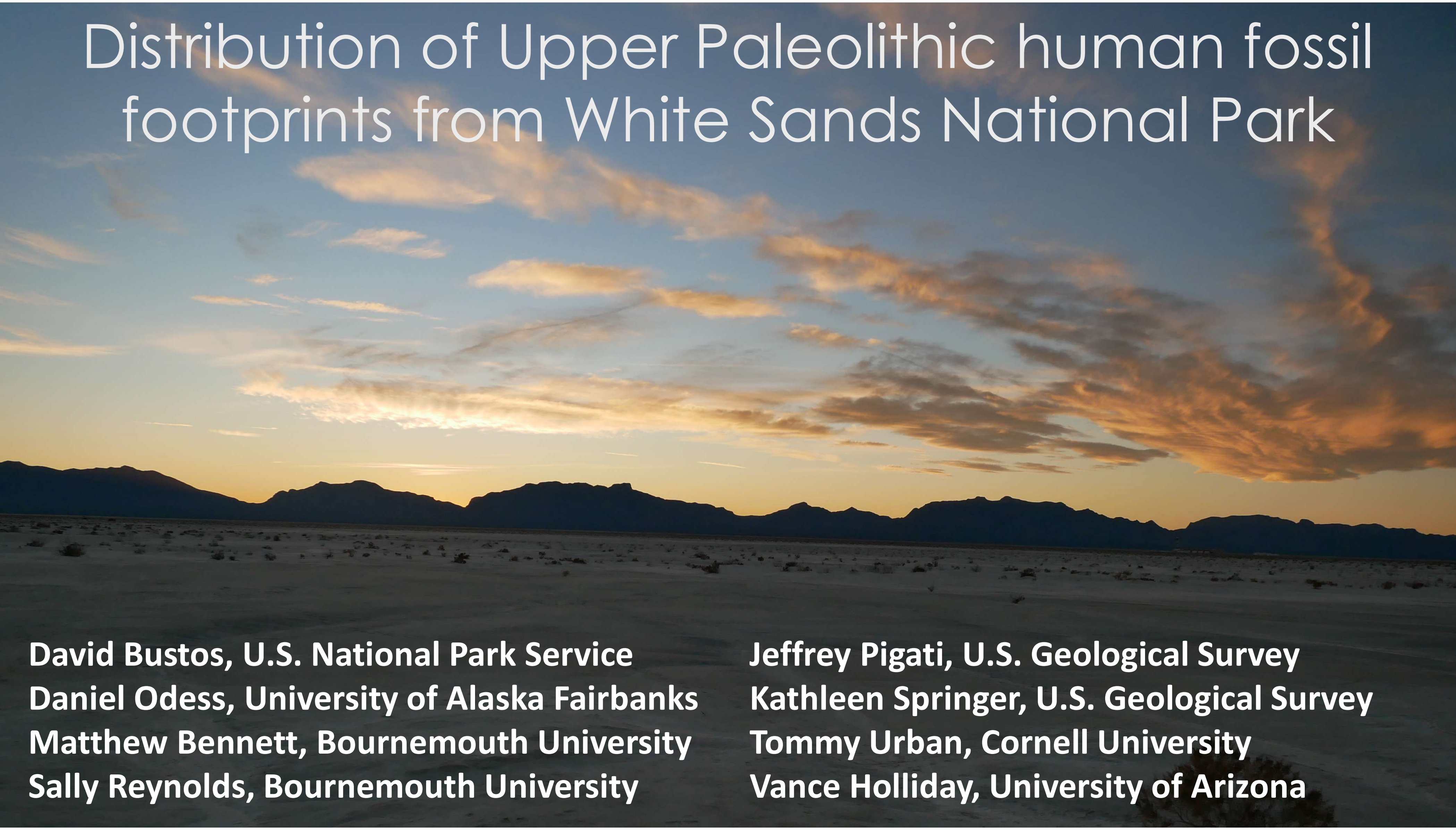
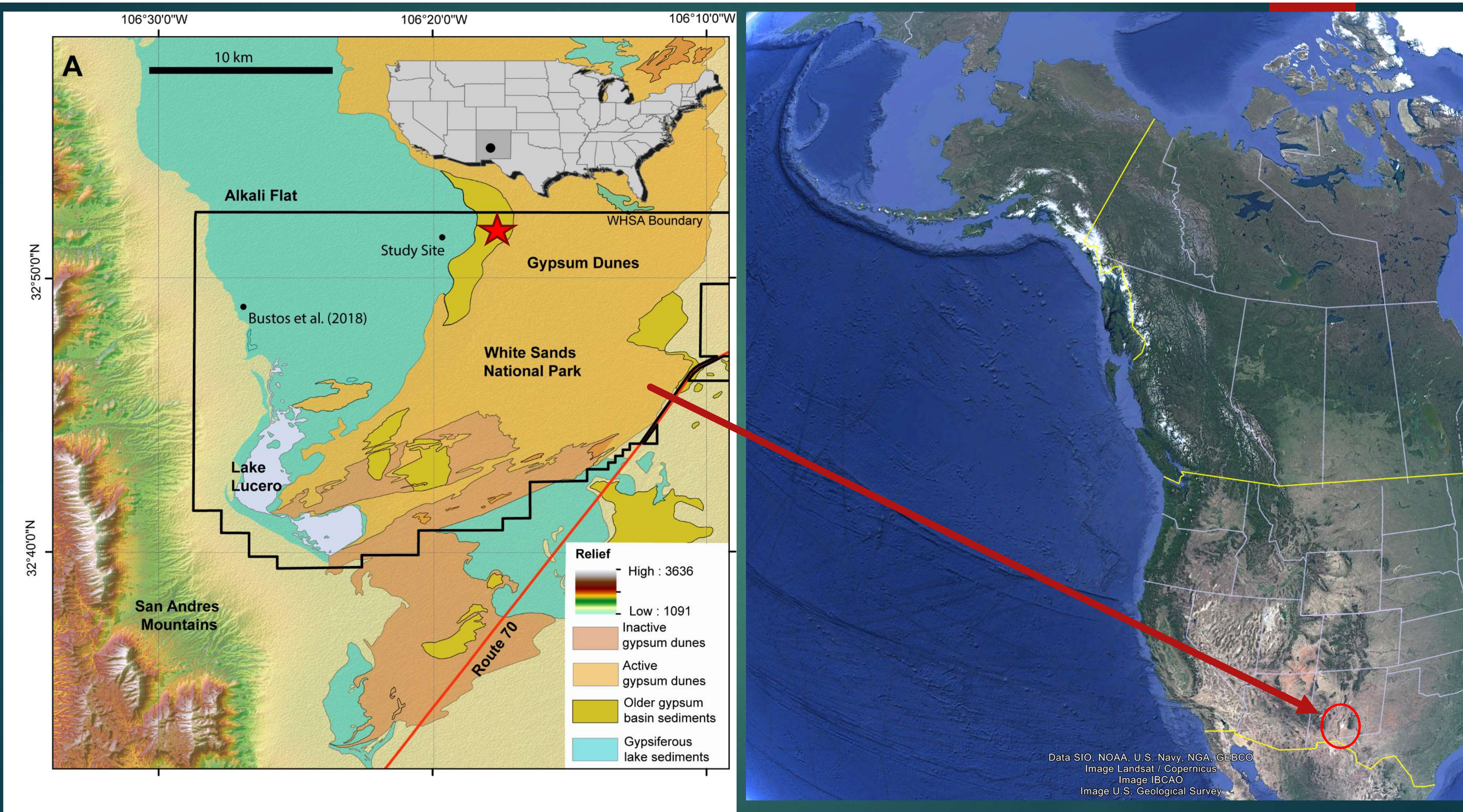


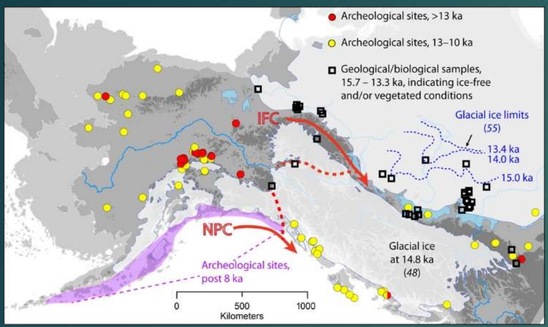
Distribution of Upper Paleolithic human fossil footprints from White Sands National Park

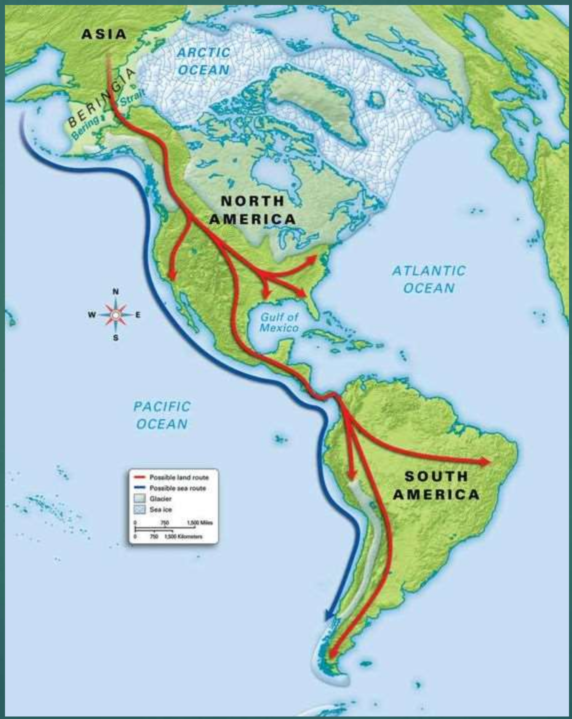
David Bustos, U.S. National Park Service
Daniel Odess, University of Alaska Fairbanks
Matthew Bennett, Bournemouth University
Sally Reynolds, Bournemouth University
Jeffrey Pigati, U.S. Geological Survey
Kathleen Springer, U.S. Geological Survey
Tommy Urban, Cornell University
Vance Holliday, University of Arizona

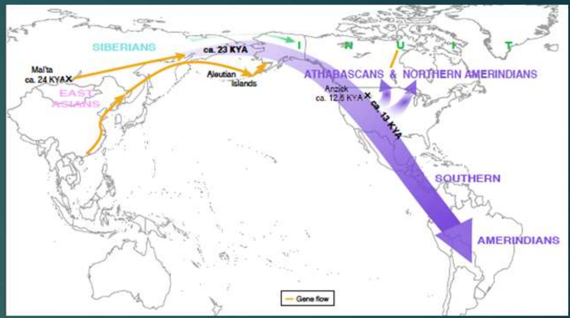


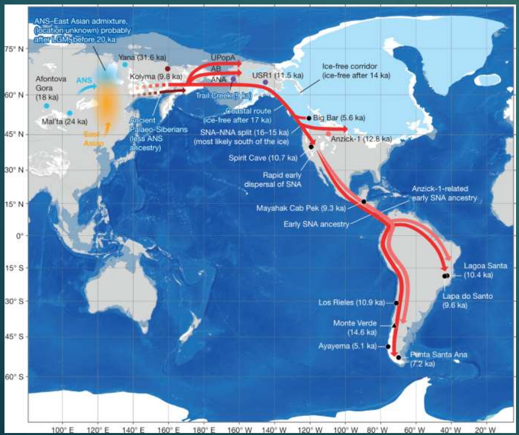
106°30'0"W
106°20'0"W
106°10'0"W
32°50'0"N
32°40'0"N
A
10 km
Alkali Flat
WHSA Boundary
Study Site
Gypsum Dunes
Bustos et al. (2018)
White Sands
National Park
Lake
Lucero
San Andres
Mountains
Route 70
Relief
High : 3636
Low : 1091
Inactive
gypsum dunes
Active
gypsum dunes
Older gypsum
basin sediments
Gypsiferous
lake sediments
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
Image IBCAO
Image U.S. Geological Survey

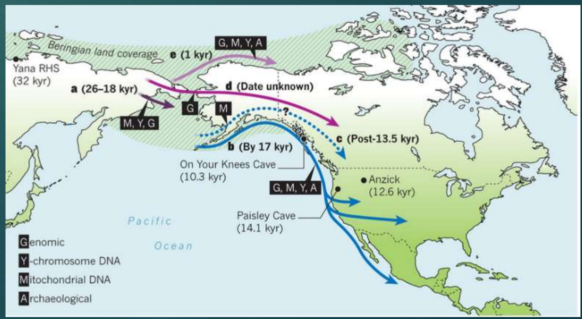
Connections through Space and Time





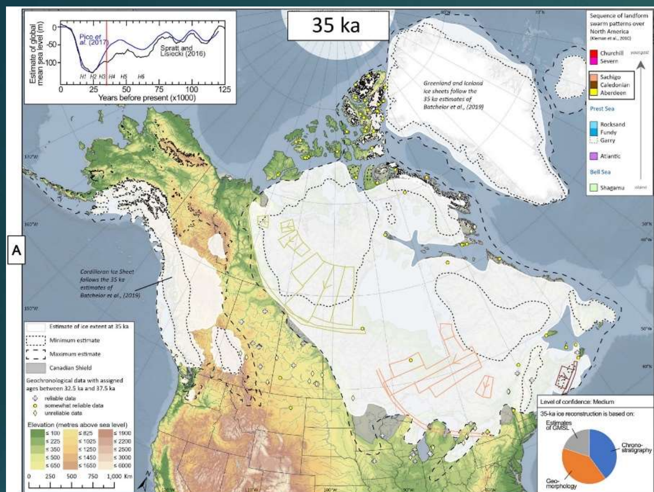


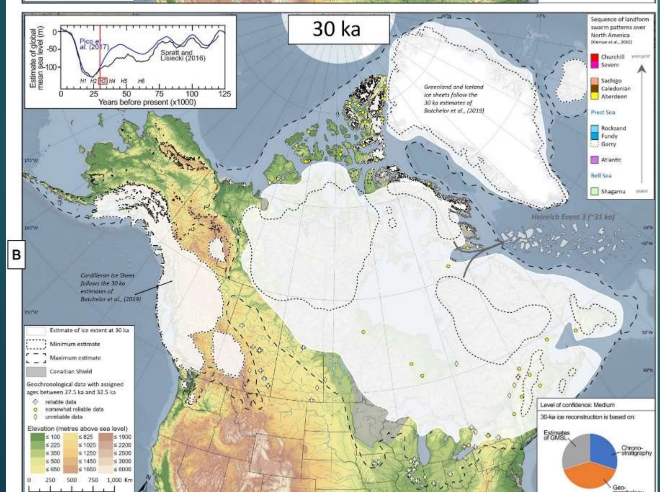


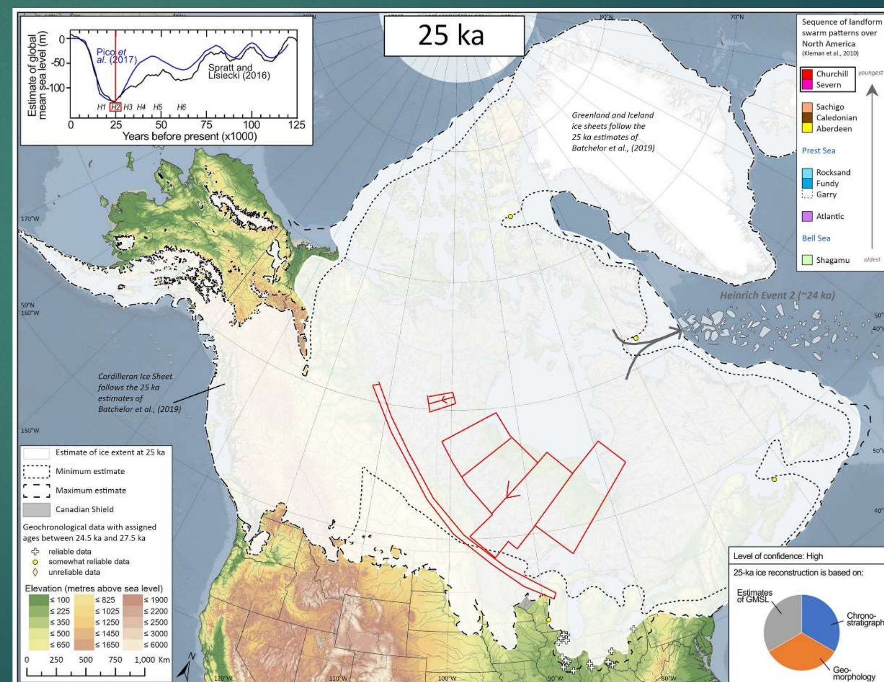


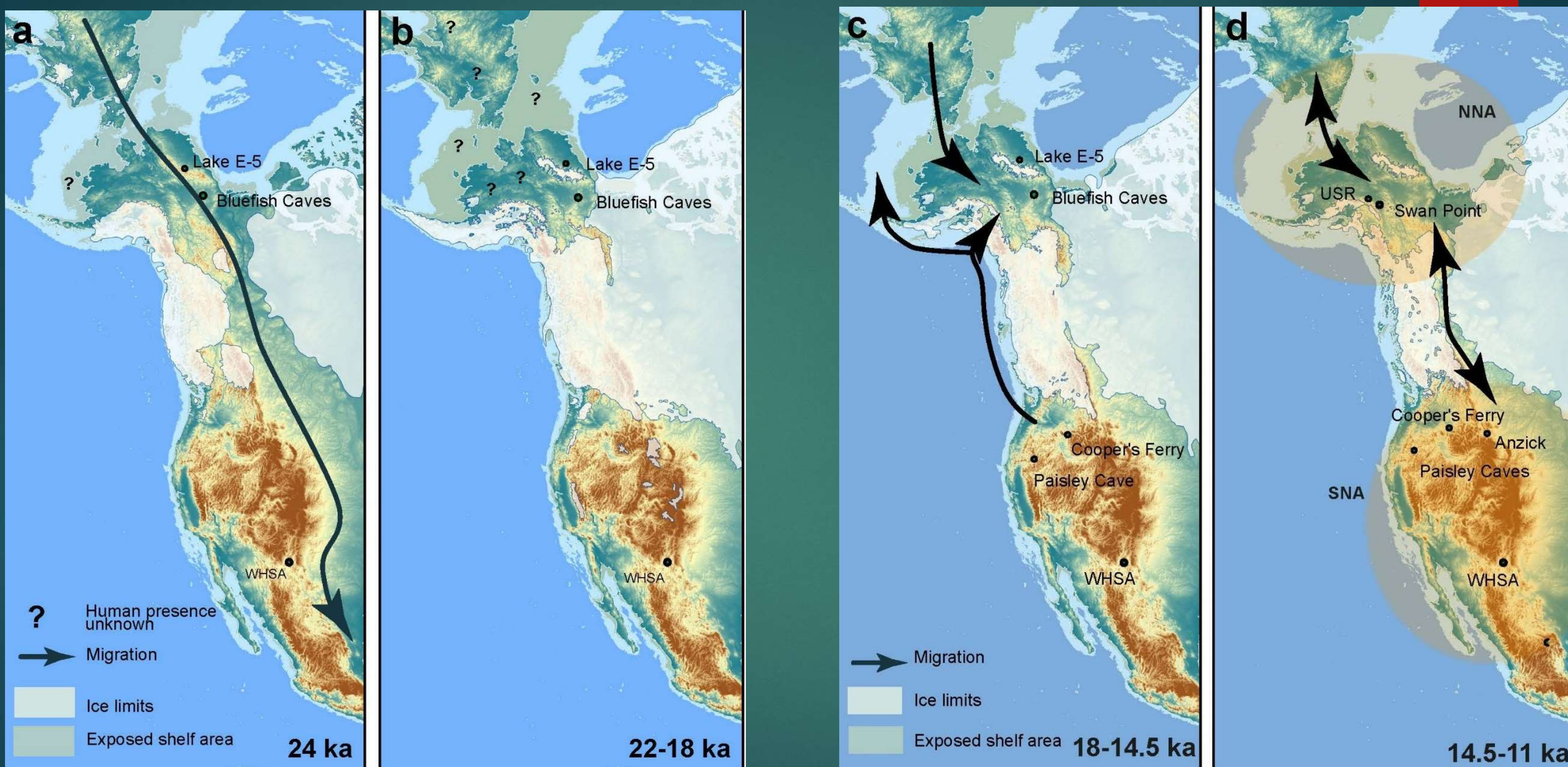
The Position of Ice Before the Last Glacial Maximum

(Dalton et al. 2022 ESR)

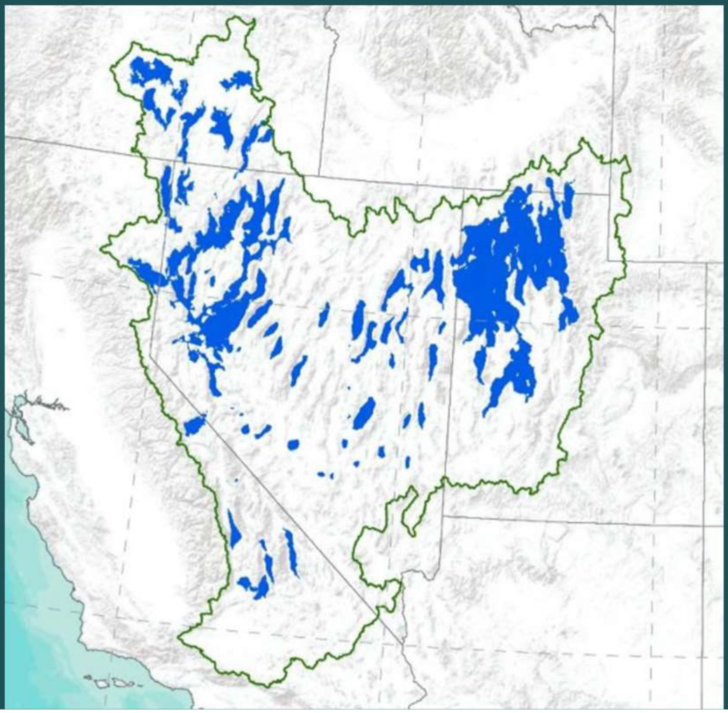


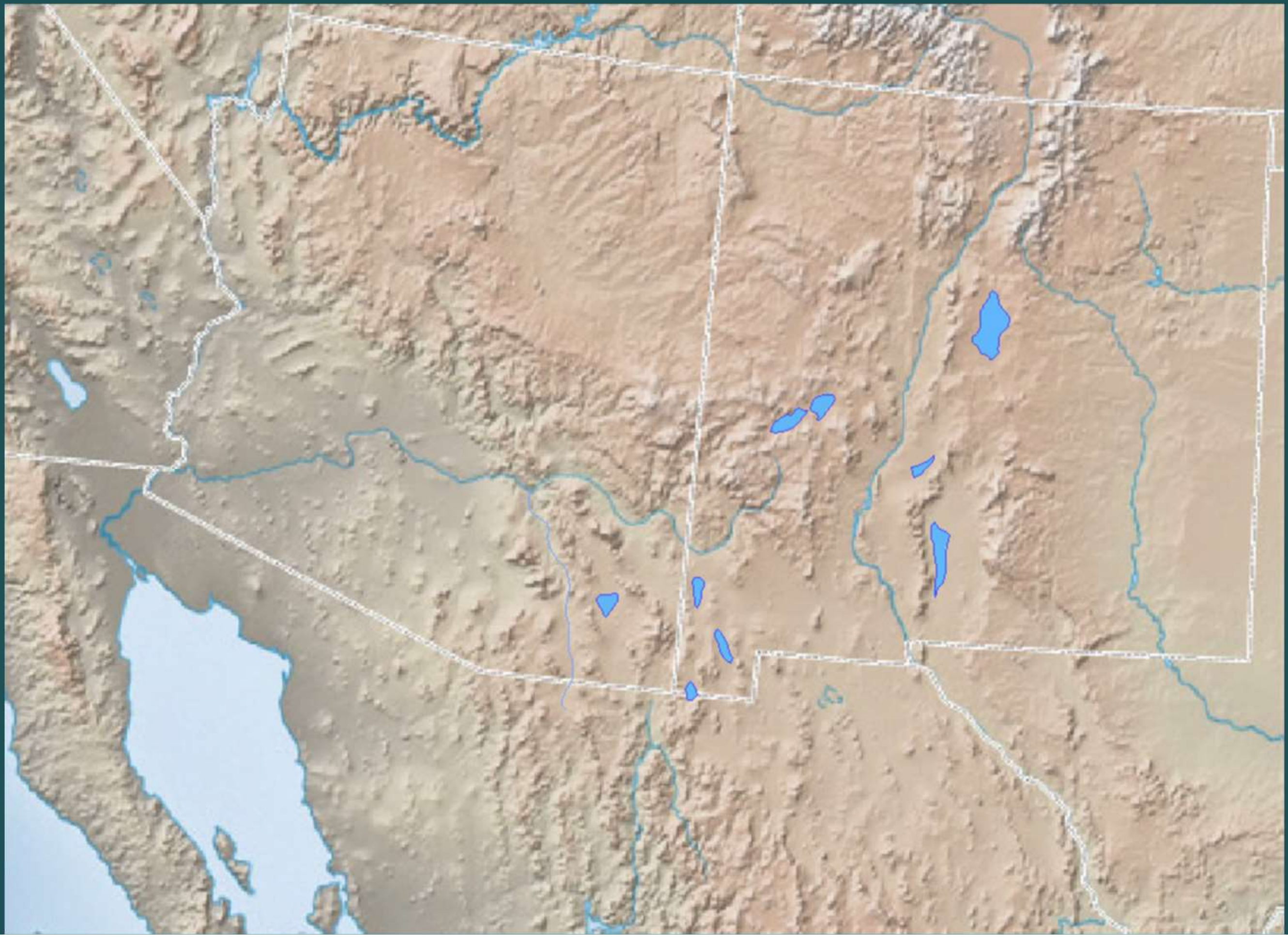


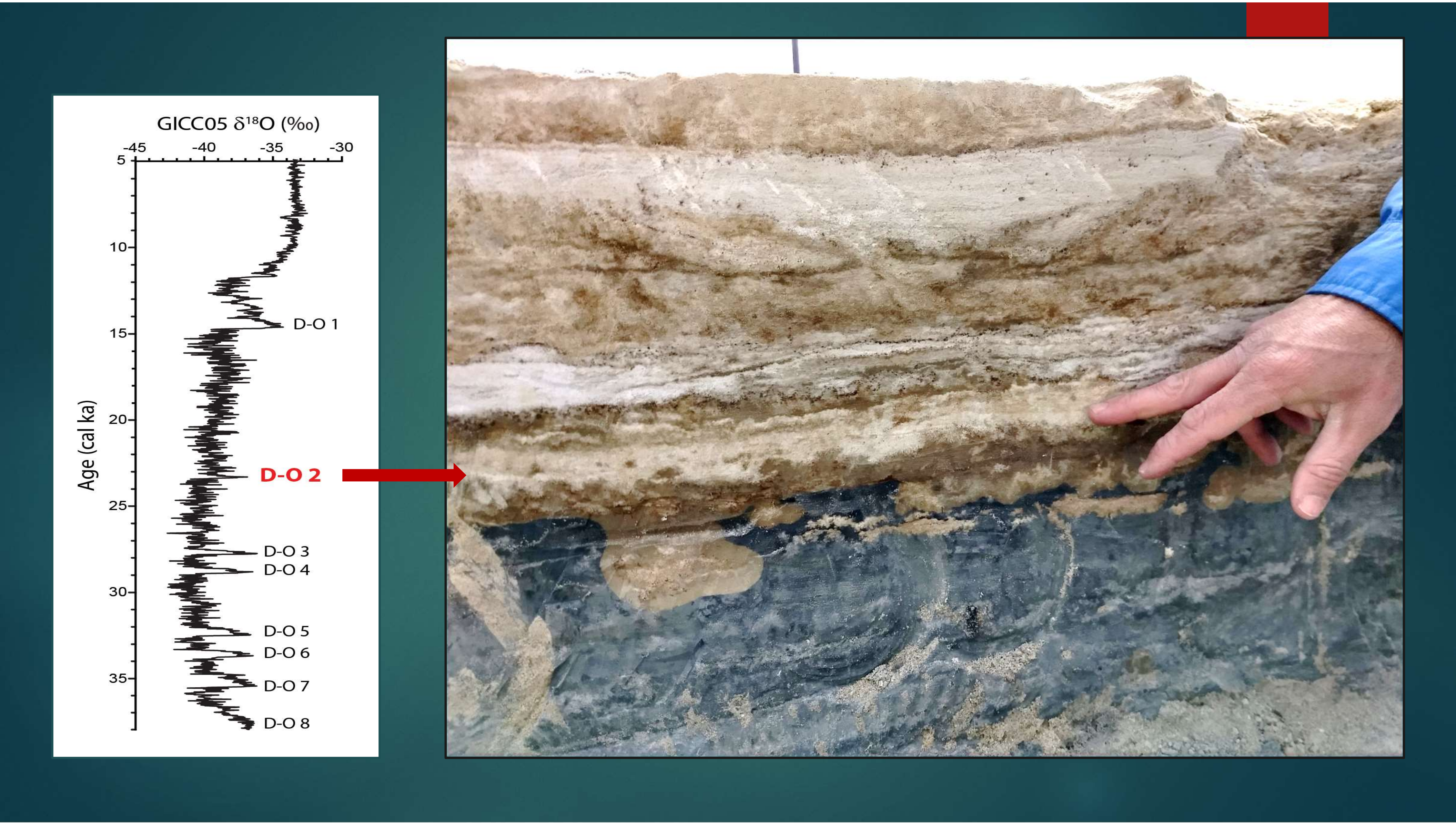



a
?
Lake E-5
Bluefish Caves
WHSA
?
Human presence unknown
Migration
Ice limits
Exposed shelf area
24 ka
b
?
Lake E-5
Bluefish Caves
WHSA
22-18 ka
c
Lake E-5
Bluefish Caves
Cooper's Ferry
Paisley Cave
WHSA
Migration
Ice limits
Exposed shelf area
18-14.5 ka
d
NNA
USR
Swan Point
Cooper's Ferry
Anzick
Paisley Caves
SNA
WHSA
14.5-11 ka

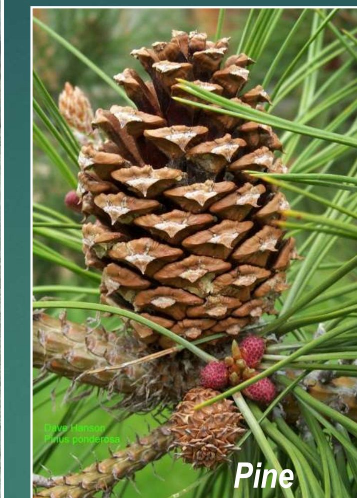
Rich Pluvial Lake Systems and Modern Dry Wastelands

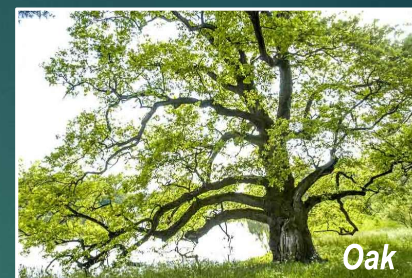




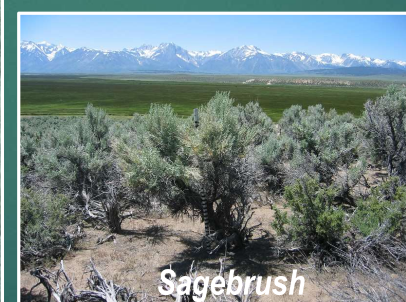


GICC05 δ18O (‰)
-45
-40
-35
-30
5
10
15
20
25
30
35
Age (cal ka)
D-O 1
D-O 2
D-O 3
D-O 4
D-O 5
D-O 6
D-O 7
D-O 8


Pine


Oak


Grasses and weeds


Sagebrush

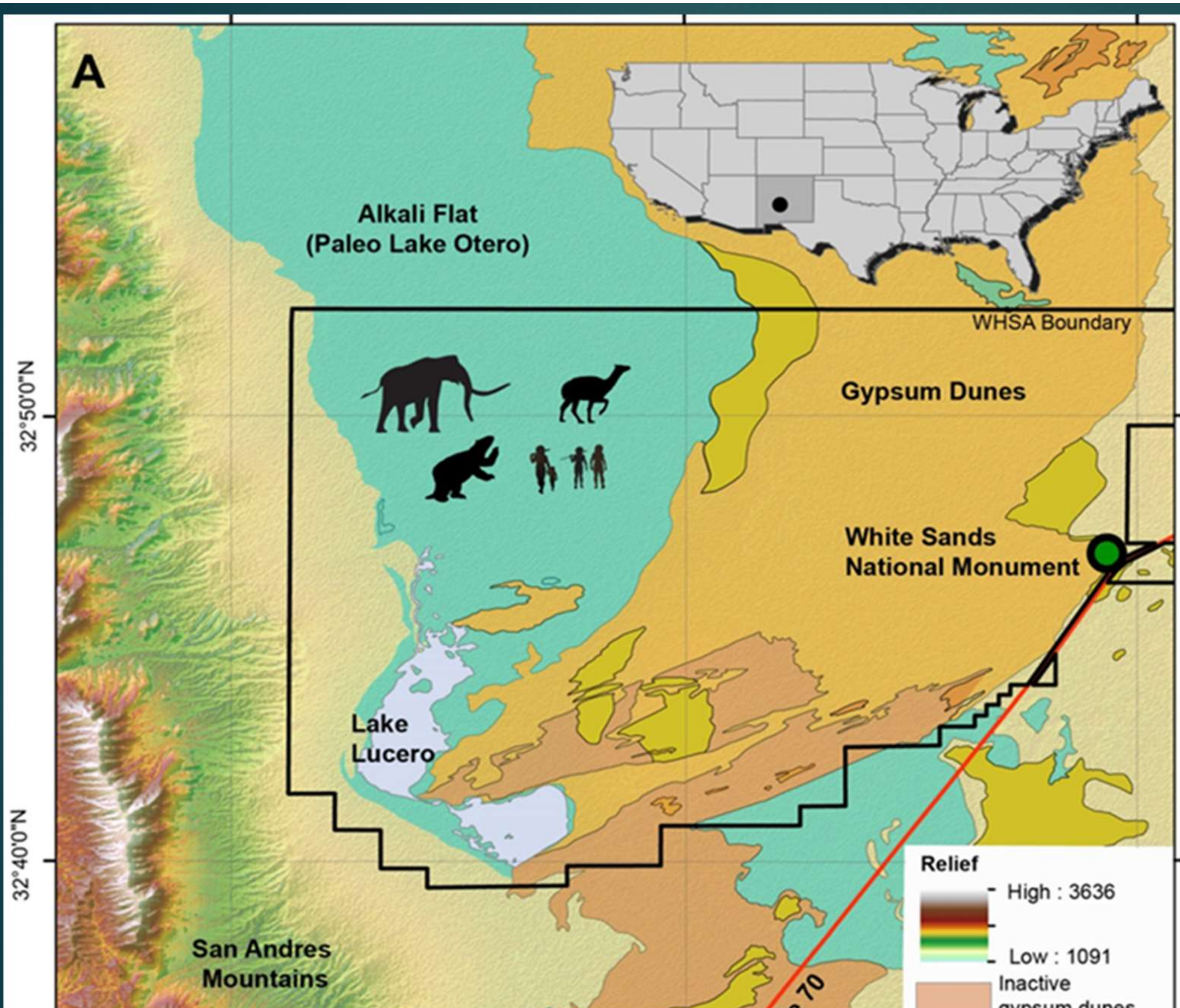

Fir


Spruce

Help of our tribal partners

- Involving Tribal Youth in resource management
- Working with Tribes on new interpretation.
- Assistance with research and monitoring

Glimpses of the Past


A
Alkali Flat
(Paleo Lake Otero)
WHSA Boundary
Gypsum Dunes
White Sands
National Monument
Lake
Lucero
San Andres
Mountains
32°50'0"N
32°40'0"N
Relief
High : 3636
Low : 1091
Inactive

Ice Age Fossil Prints from White Sands

Bear

Dog/wolf

Large Cat

Sloth

Camelid

Mammoth

Human

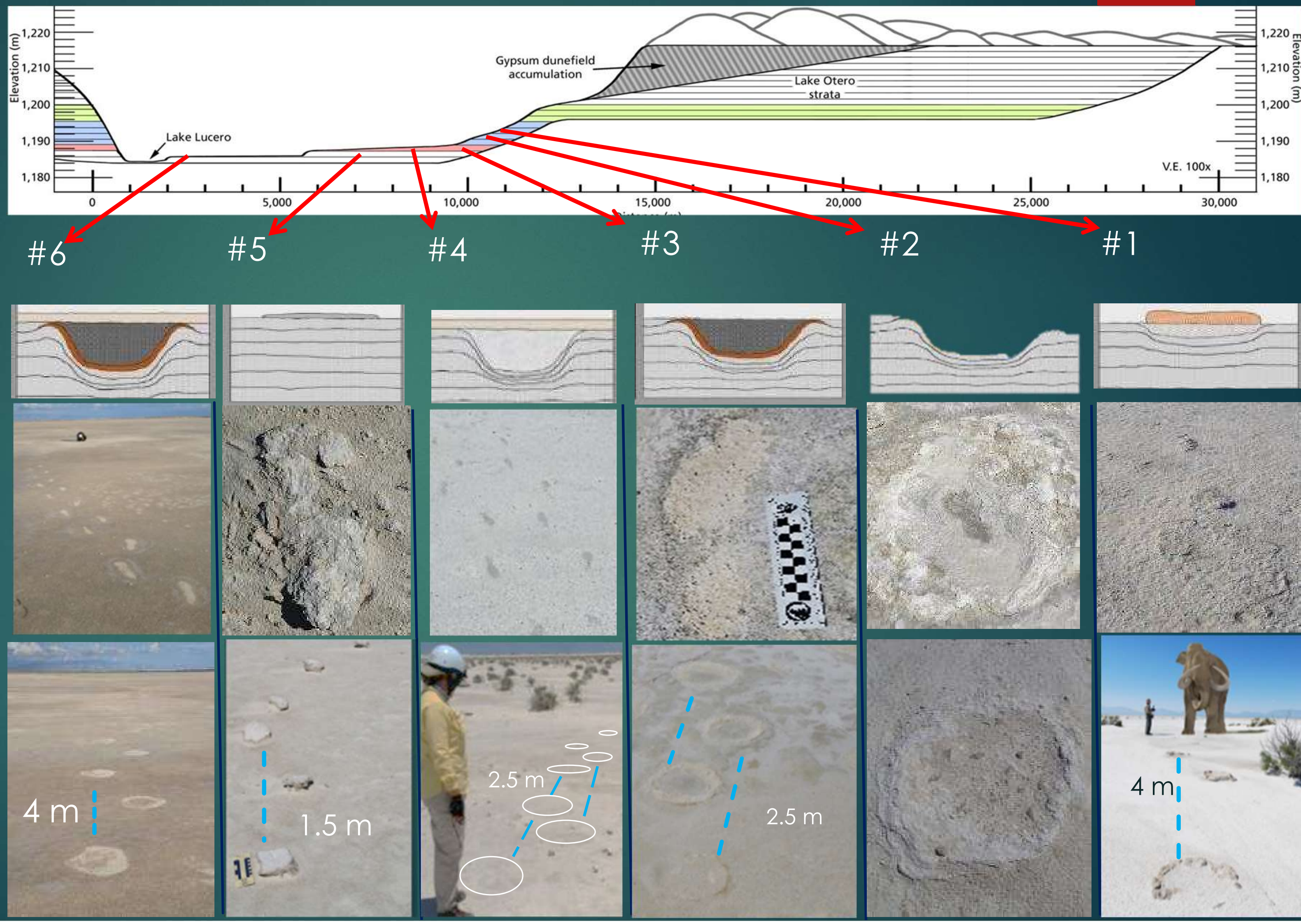
Child and Adult prints from the last ice age

Six Print Types:

1. Clay, positive relief
2. Exposed, negative relief
3. Fine gray sand, no cap
4. Pale Fine Sand with cap
5. Dolomite, positive relief
6. Gary Coarse Sand with cap

Human Prints

Megafauna Prints

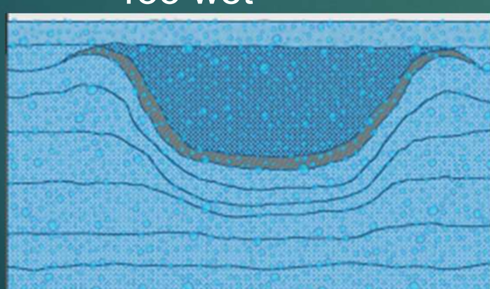


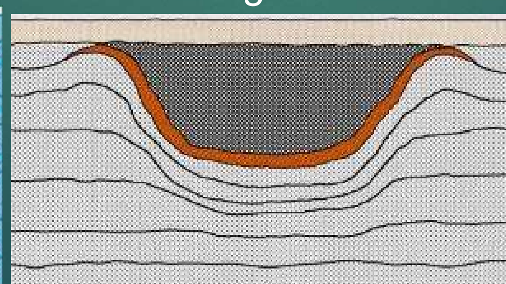
"Soil Moisture Visibly Dependent Prints"
Always Present, but not always seen

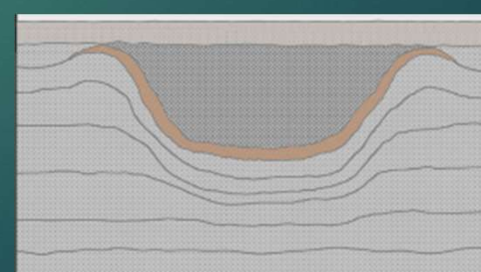
Too wet

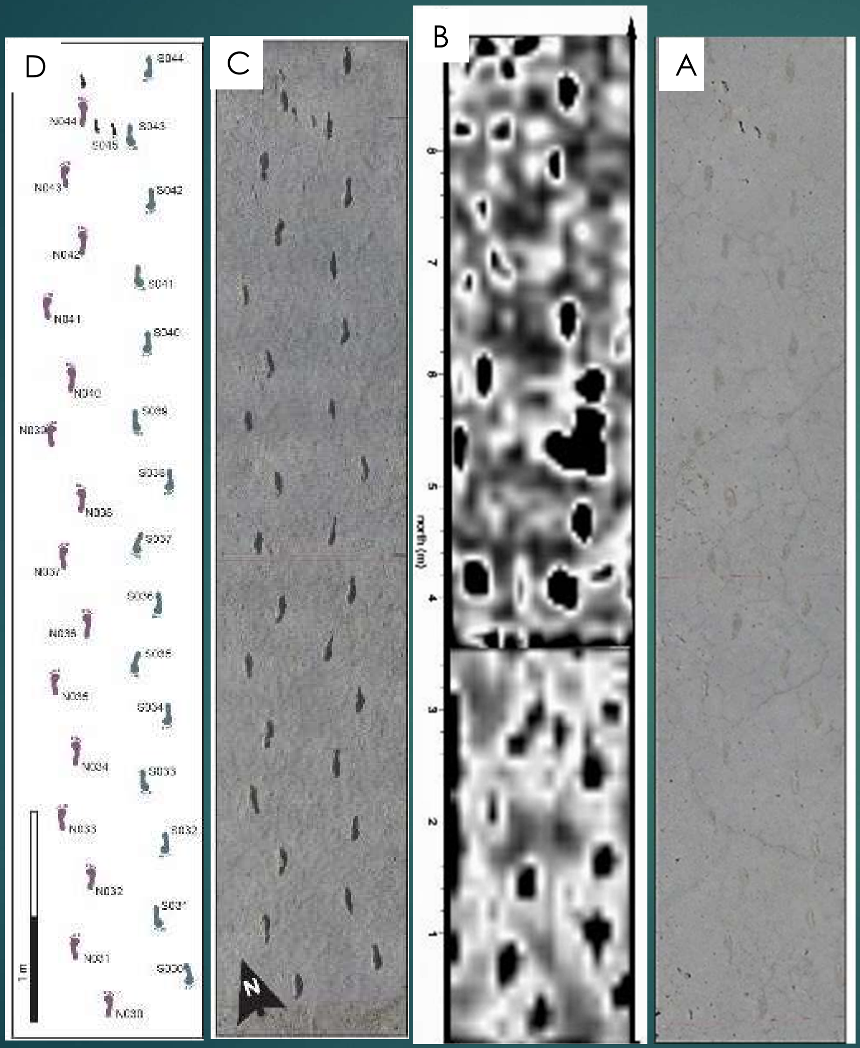
Just right

Too dry



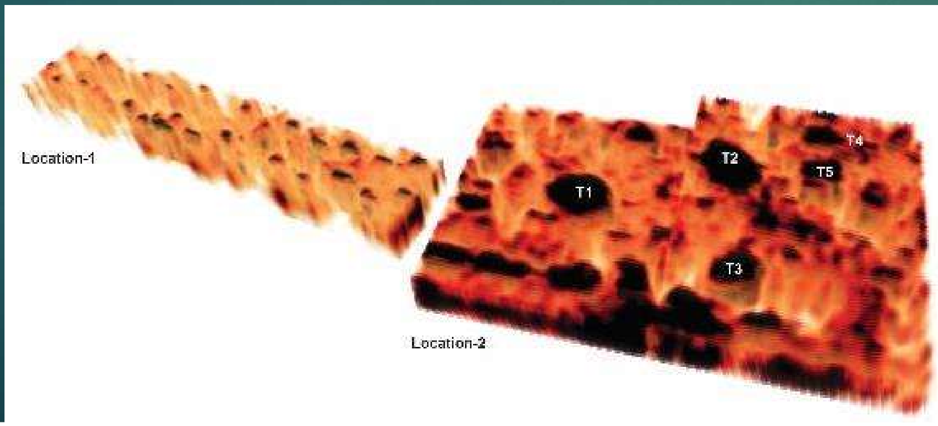


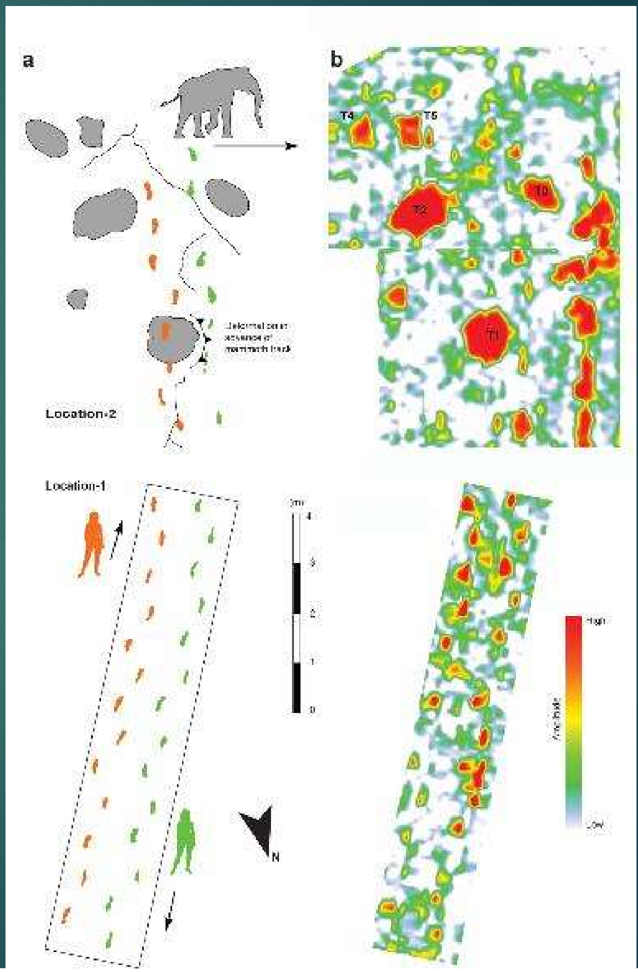




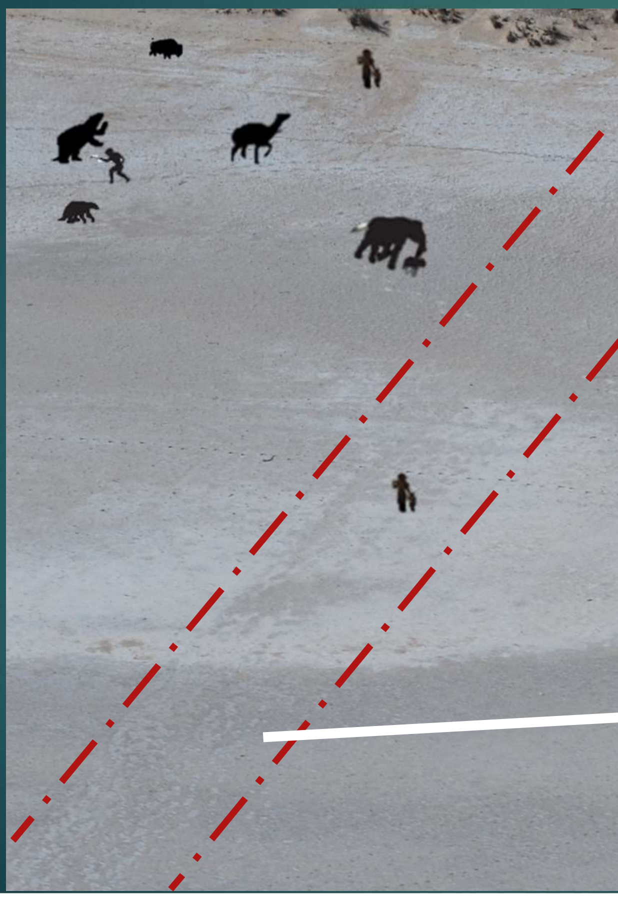
Urban, Thomas M., et al. "3-D radar imaging unlocks the untapped behavioral and biomechanical archive of Pleistocene ghost tracks." *Scientific reports* 9.1 (2019): 1-10.

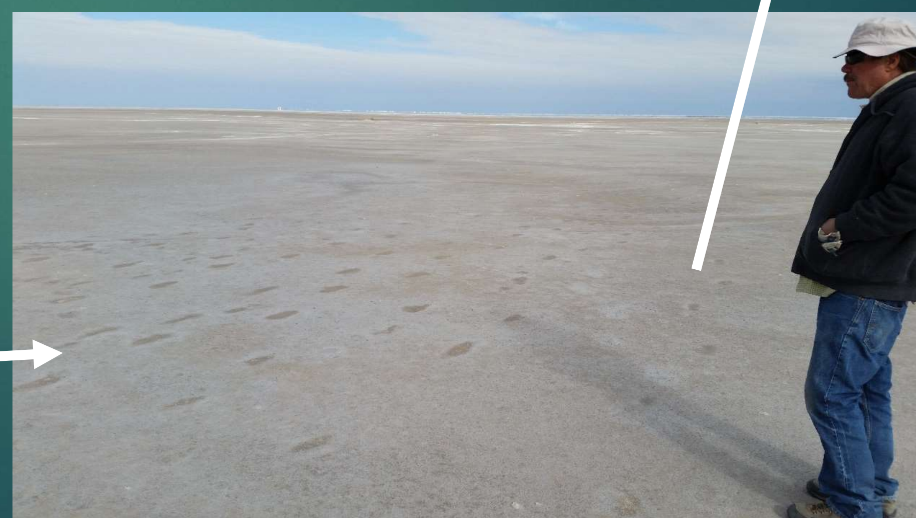
Documenting and Locating with GPR





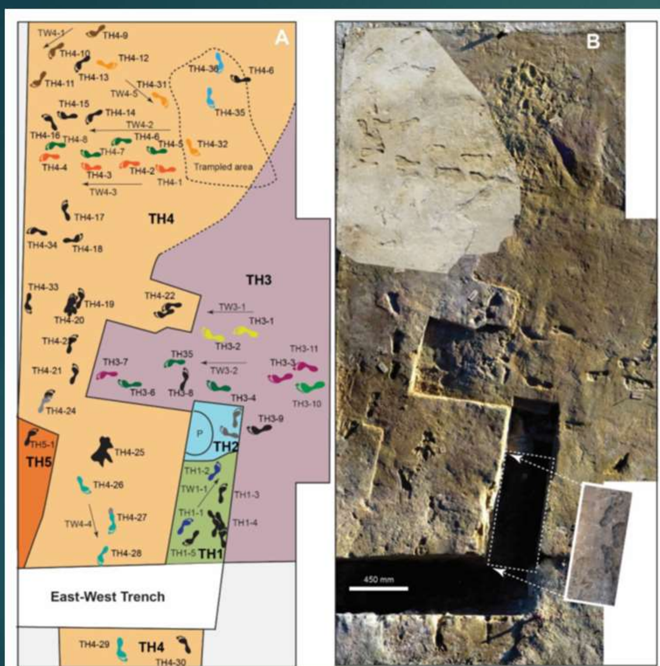
Great assemblage of human footprints (in area and number): New class of behavior data for archaeological sites

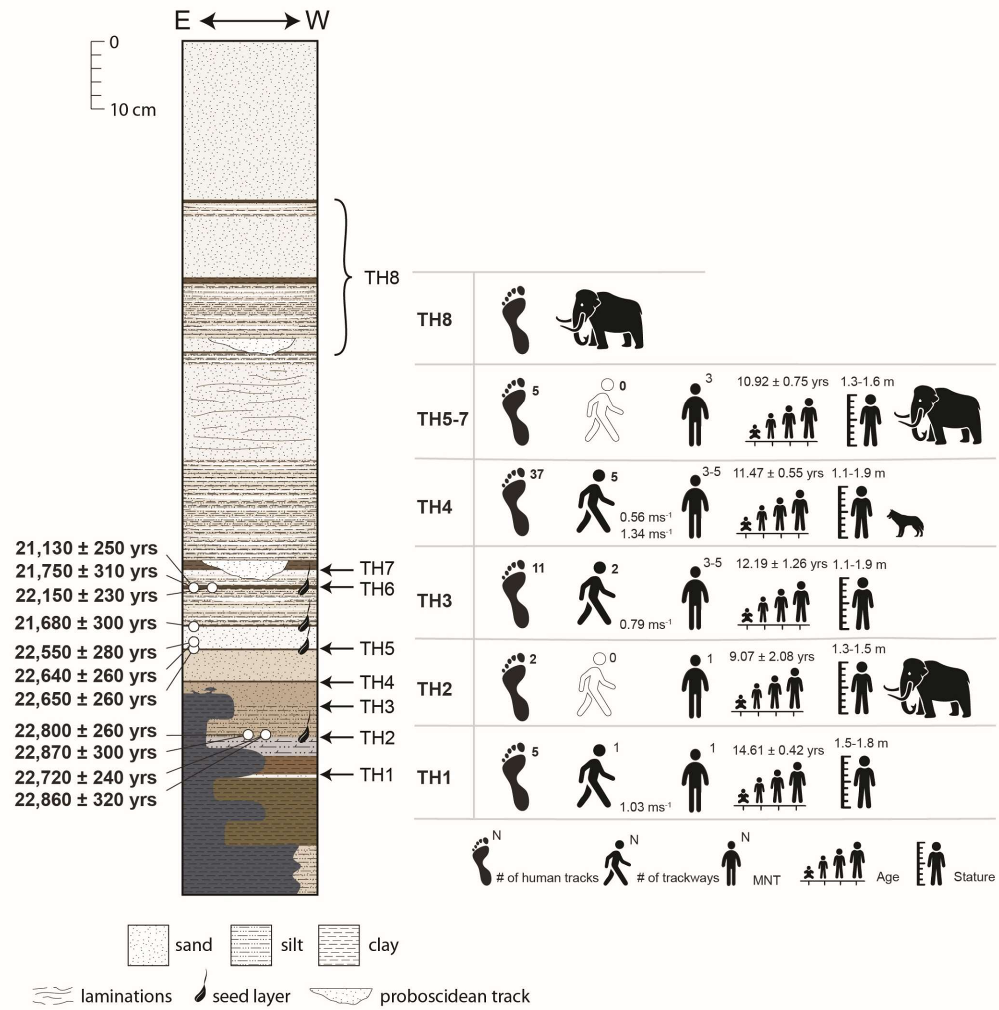




Tracks extend over great distances

Layers Range From 21,000 to 23,000 BP

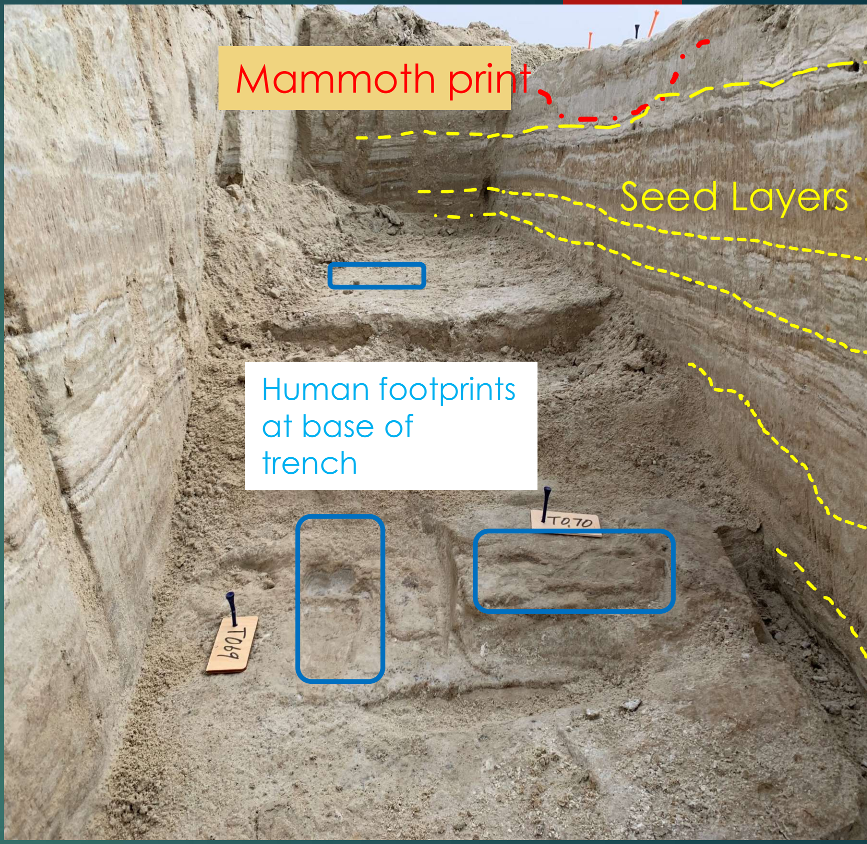




Bennett, M. R., Bustos, D., Pigati, J. S., Springer, K. B., Urban, T. M., Holliday, V. T., ... & Odess, D. (2021). Evidence of humans in North America during the last glacial maximum. *Science*, *373*(6562), 1528-1531.

Over 11 stratified layers of organics and fossil prints

(6. shown below)



Defining the age of the prints

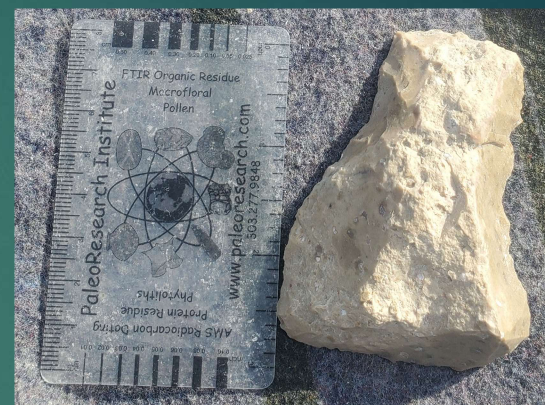
[Fossilized Footprints Video - B roll - White Sands National Park (U.S. National Park Service) (nps.gov)]

Nice prints, but where are the lithics ???

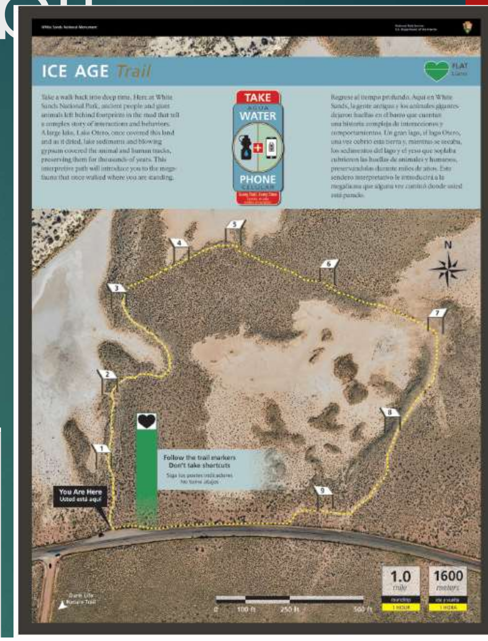
- Lithics found on same surface as prints
- Age unknown, could be the same age or younger
- Many large lithics, retouched edges, do not fit known typologies well
- No local stones present on salt flats
- Increased number of sites with lithics found on surface with trackways across 324 km (80,000 acres)

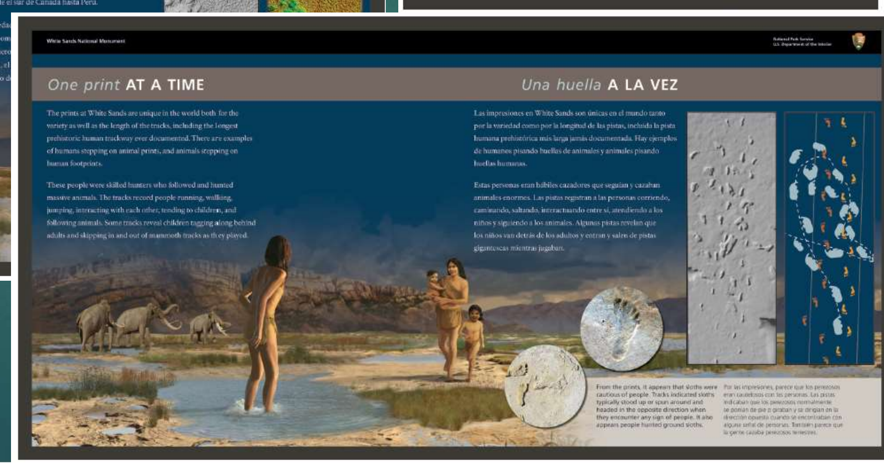
Large Tools Found Near Fossil Prints

Very large bifacial, uniface, and blades with retouched edges



New Ice Age Trail Exhibit





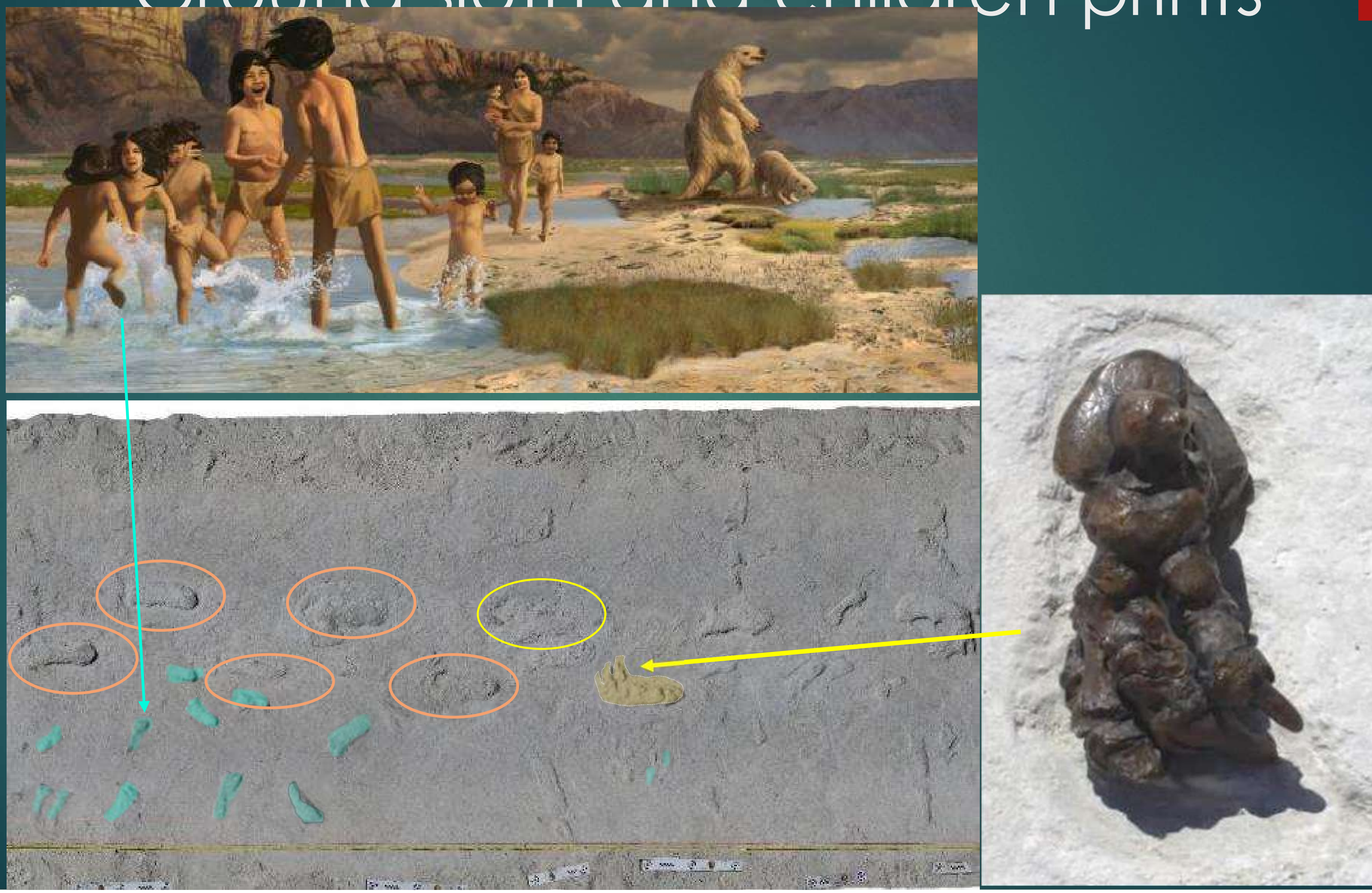
EXPERIENCE YOUR AMERICA

Human print in mammoth print

Tracks show interactions occurred

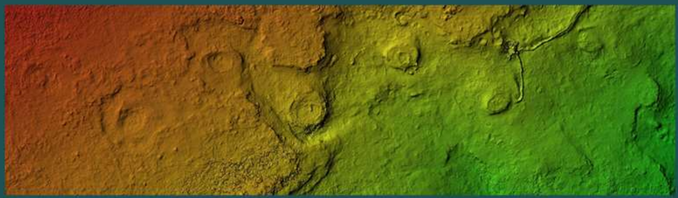
Footprints preserve terminal Pleistocene hunt? Human-sloth interactions in North America.
Bustos, D., Jakeway, J., Urban, T. M., Holliday, V. T., Fenerty, B., Raichlen, D. A., ... & Santucci, V. L. (2018).
Science advances, *4*(4), eaar7621.

Ground sloth and children prints



Erosion Exposes Tracks

Loss of Mammoth Trackway
2018



2020

Racing to capture the stories





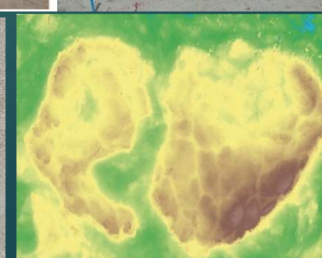






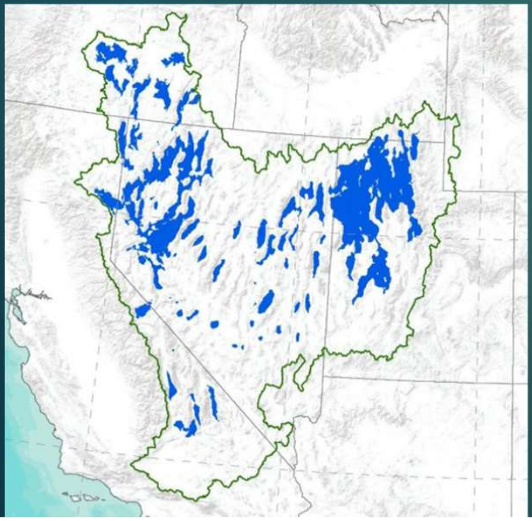


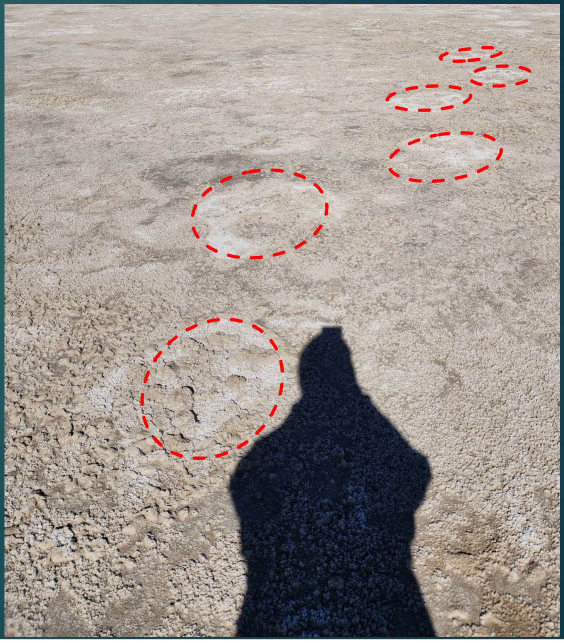


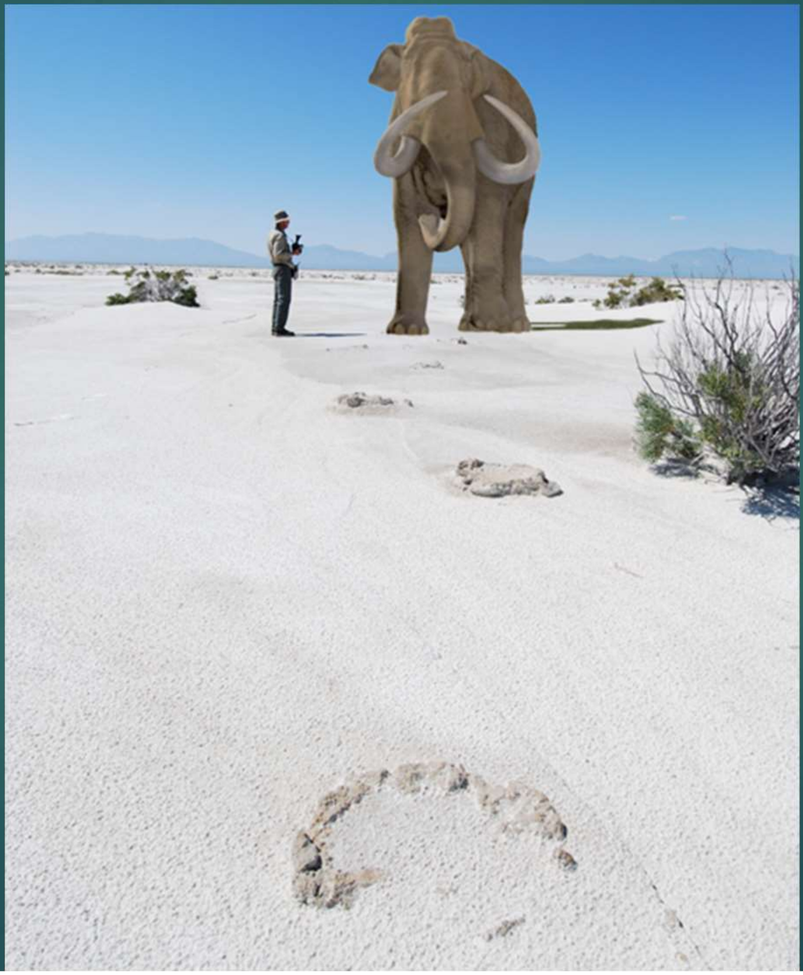

One of many

- Large pluvial lakes common throughout the Americas
- Support for large migrations
- Rapid erosion is a common theme
- White Sands can server as an analog for other playas where late Pleistocene trace fossil are present and being lost

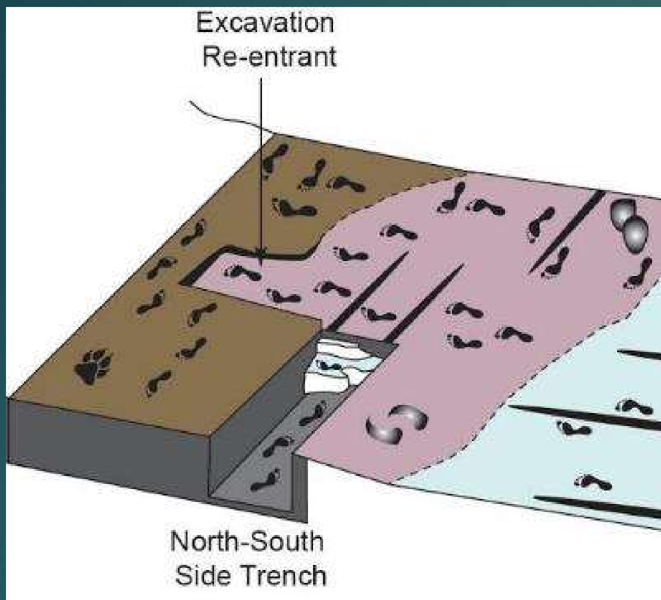


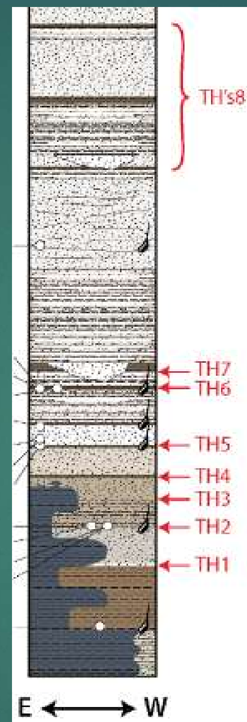


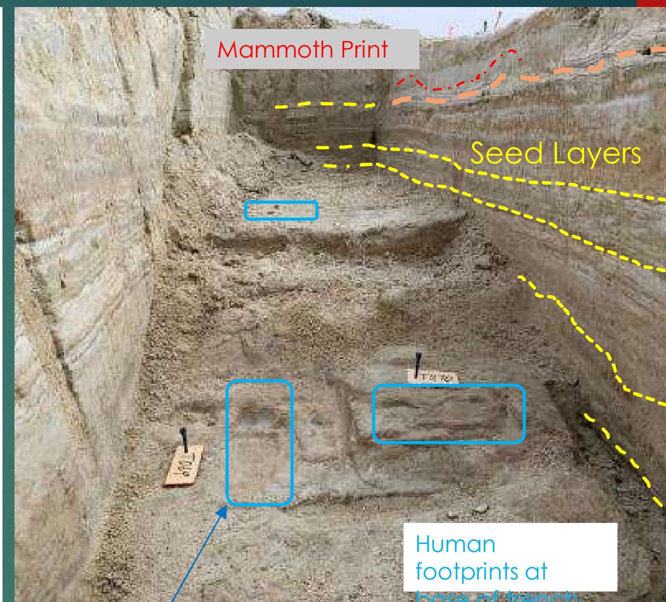
Thank you!

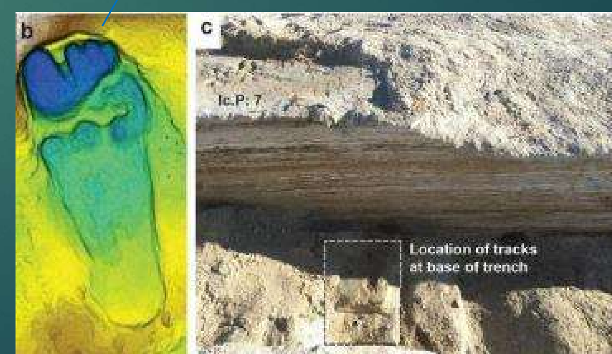


Defining the age of the prints









New Trackways found on Westside

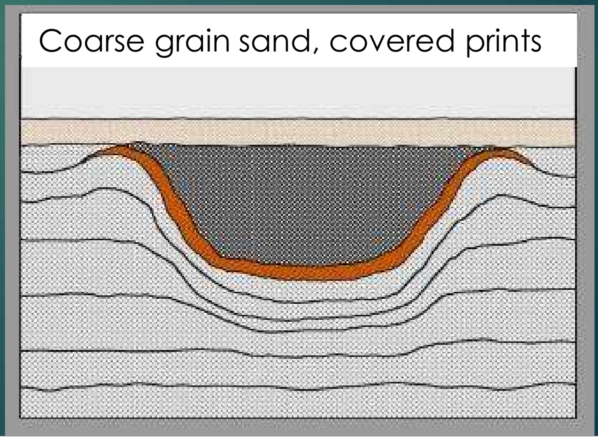
EXPERIENCE YOUR AMERICA

Soft- sediment deformation

Bennett, M. R., Bustos, D., Belvedere, M., Martinez, P., Reynolds, S. C., & Urban, T. (2019). Soft-sediment deformation below mammoth tracks at White Sands National Monument (New Mexico) with implications for biomechanical inferences from tracks. *Palaeogeography, Palaeoclimatology, Palaeoecology*, *527*, 25-38.

Proboscidean Prints (Mammuthus columbi)

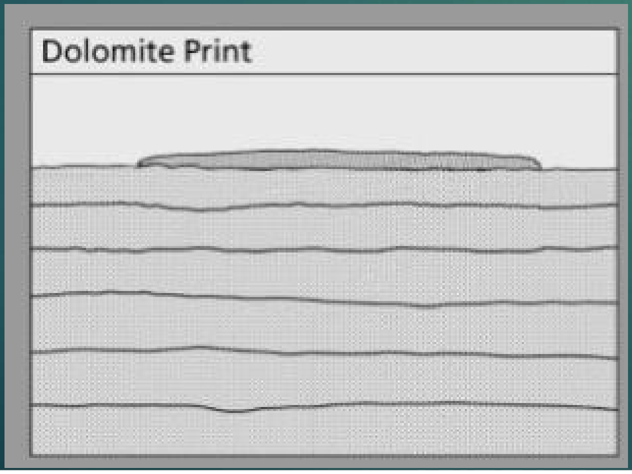
Cross section of mammoth print



Camelops conidens

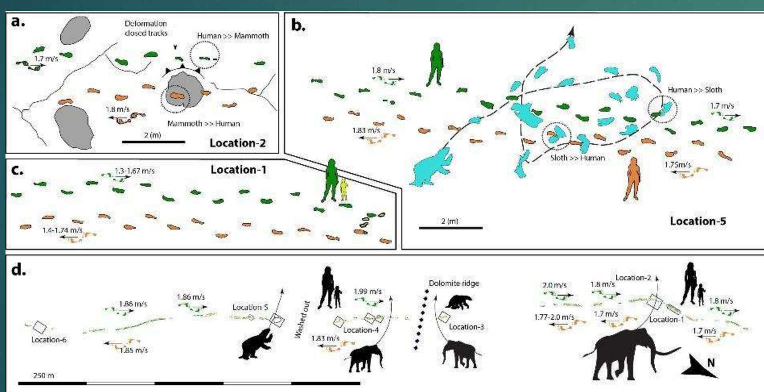
Lucas, S. G., Allen, B. D., Morgan, G. S., Myers, R. G., Love, D. W., & Bustos, D., (2007). Mammoth footprints from the upper Pleistocene of the Tularosa Basin, Doña Ana County, New Mexico. *Cenozoic Vertebrate Tracks and Traces*, *42*, 149-154.

Two mile dolomite camel trackway



Longest known record human fossil trackway, over 1.5 kilometers

Bennett, Matthew R., et al. "Walking in mud: Remarkable Pleistocene human trackways from White Sands National Park (New Mexico)." *Quaternary Science Reviews* 249 (2020): 106610.



EXPERIENCE YOUR AMERICA

Tracks suggest interactions occurred

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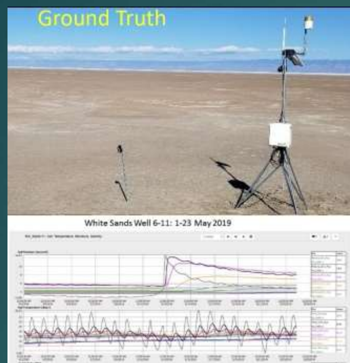
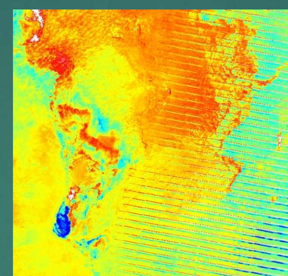
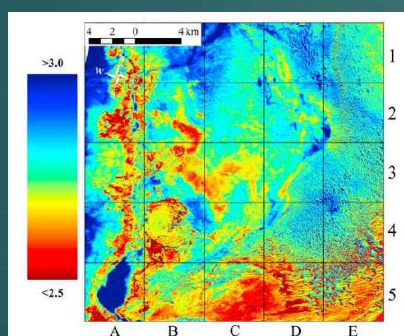
Science advances, *4*(4), eaar7621.



Reflection band math

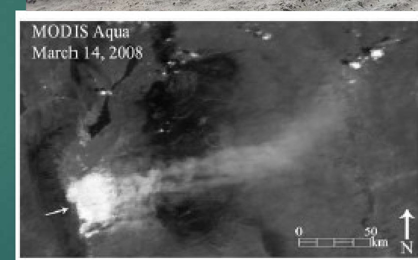


Thermal model

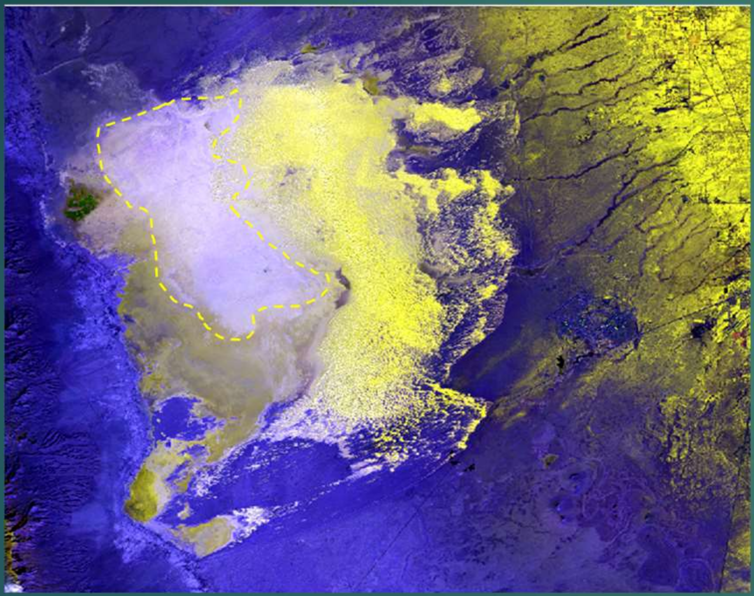


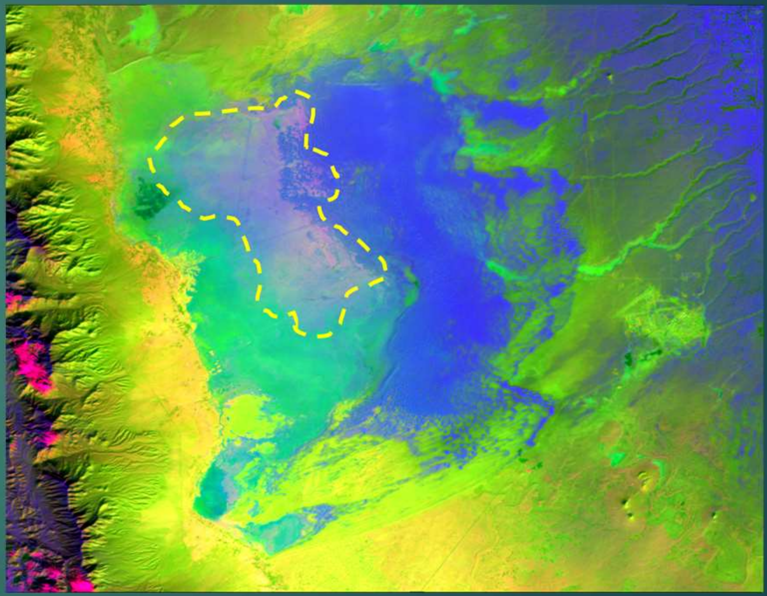
Trend Analysis and Predictive Model

Testable hypothesis are generated, parameters can be based on future climate models, and management is informed by science



Use of Satellite Imagery to Monitor Landscape Soil Moisture and Temperature Changes



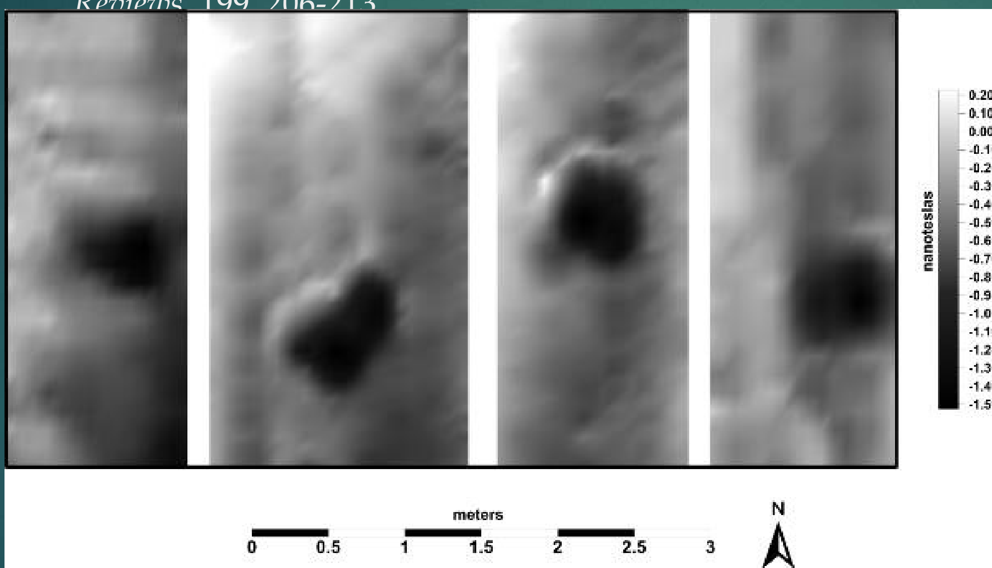



San Andres
Mountains
Sacramento Mountains

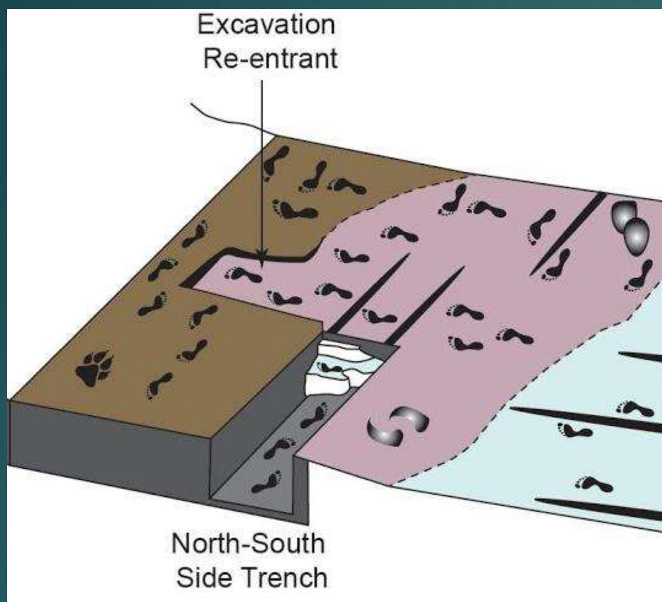
Inventory & Monitoring

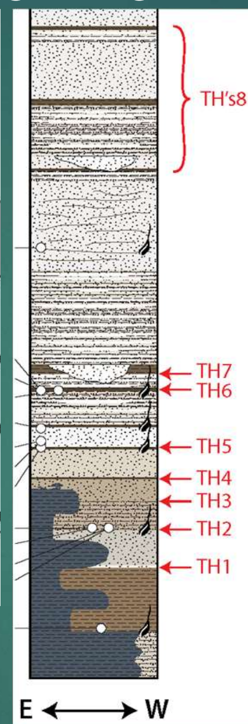
Use of magnetometry for detecting and documenting multi-species Pleistocene megafauna tracks.

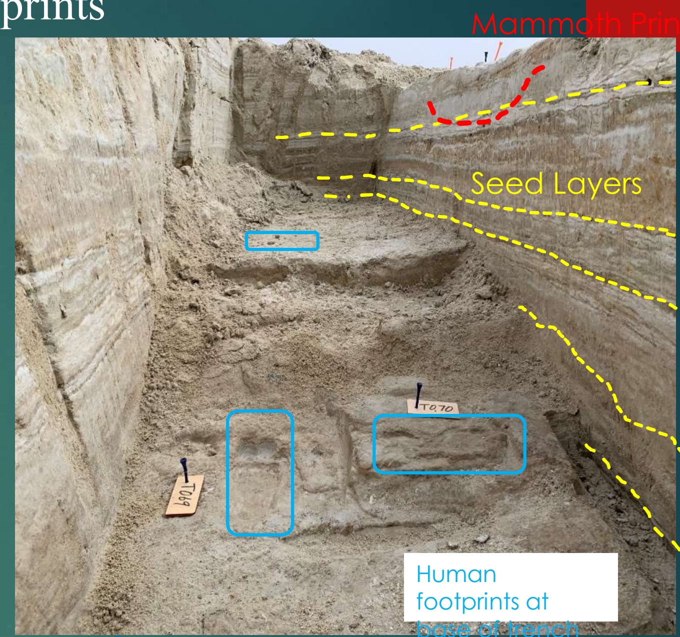
Urban, T.M., Bustos, D., Jakeway, J., Manning, S.W. & Bennett M.R. 2018. *Quaternary Science Reviews*, 199, 206-213

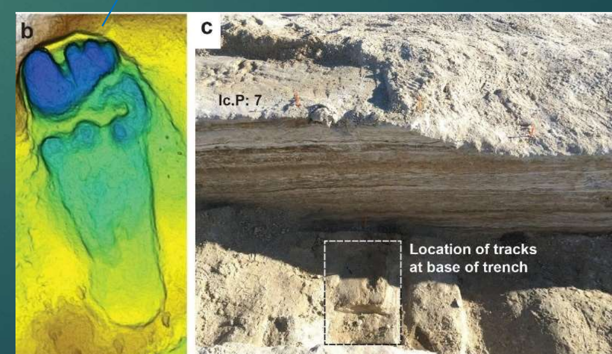


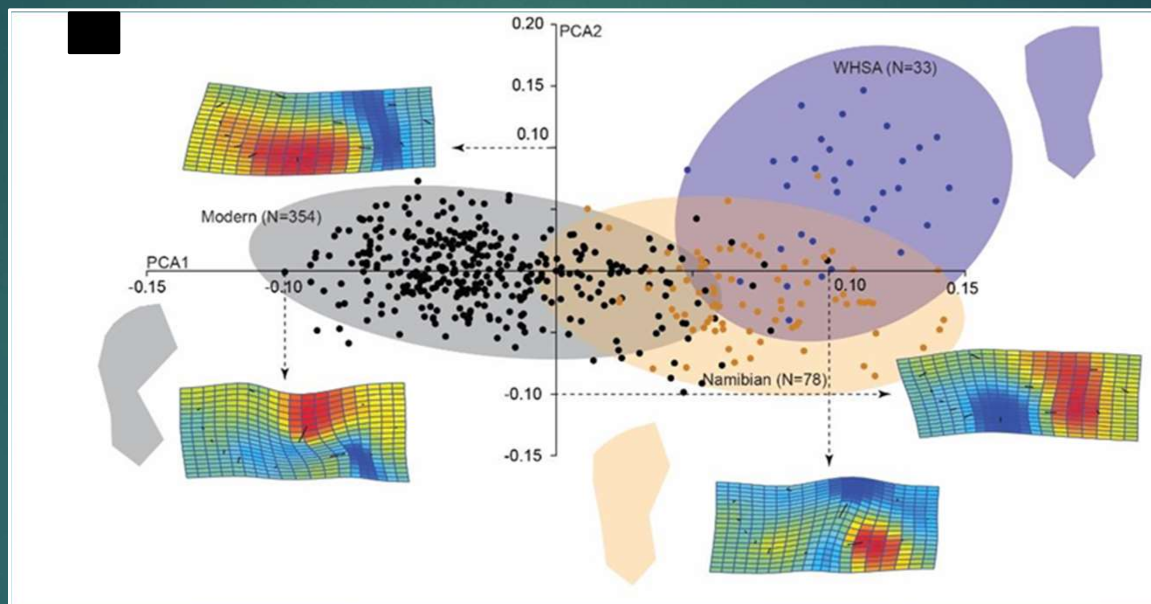
Defining the age of the prints



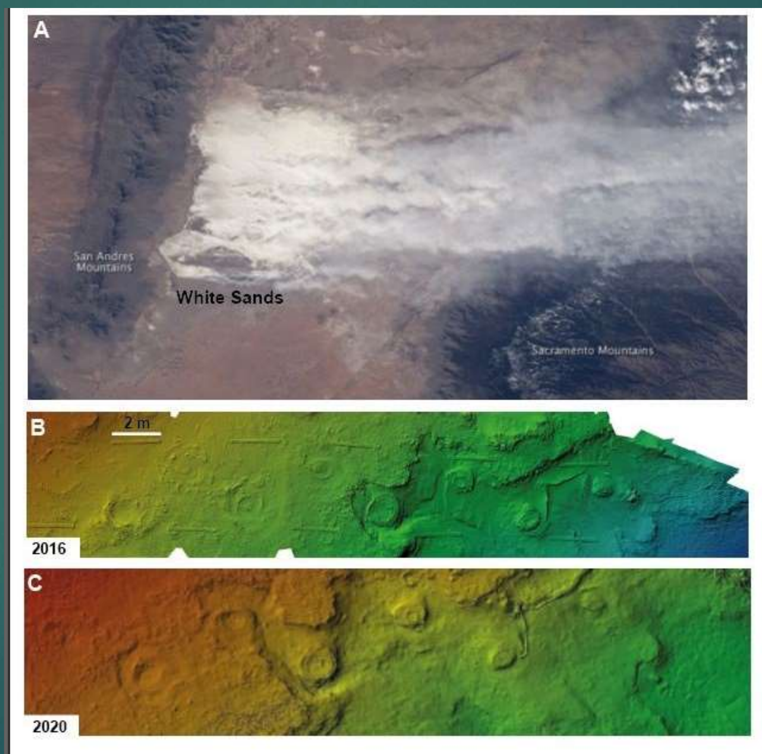


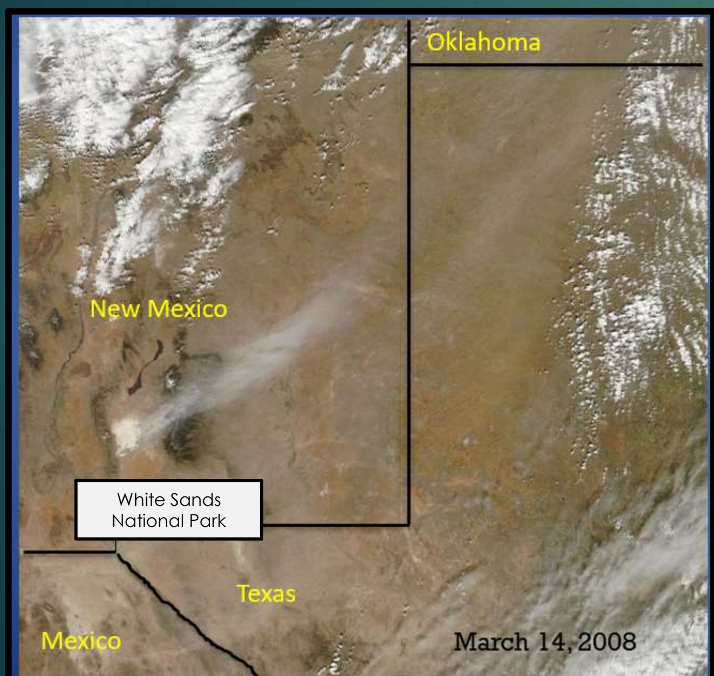






Bennett et al., 2022, *Science*

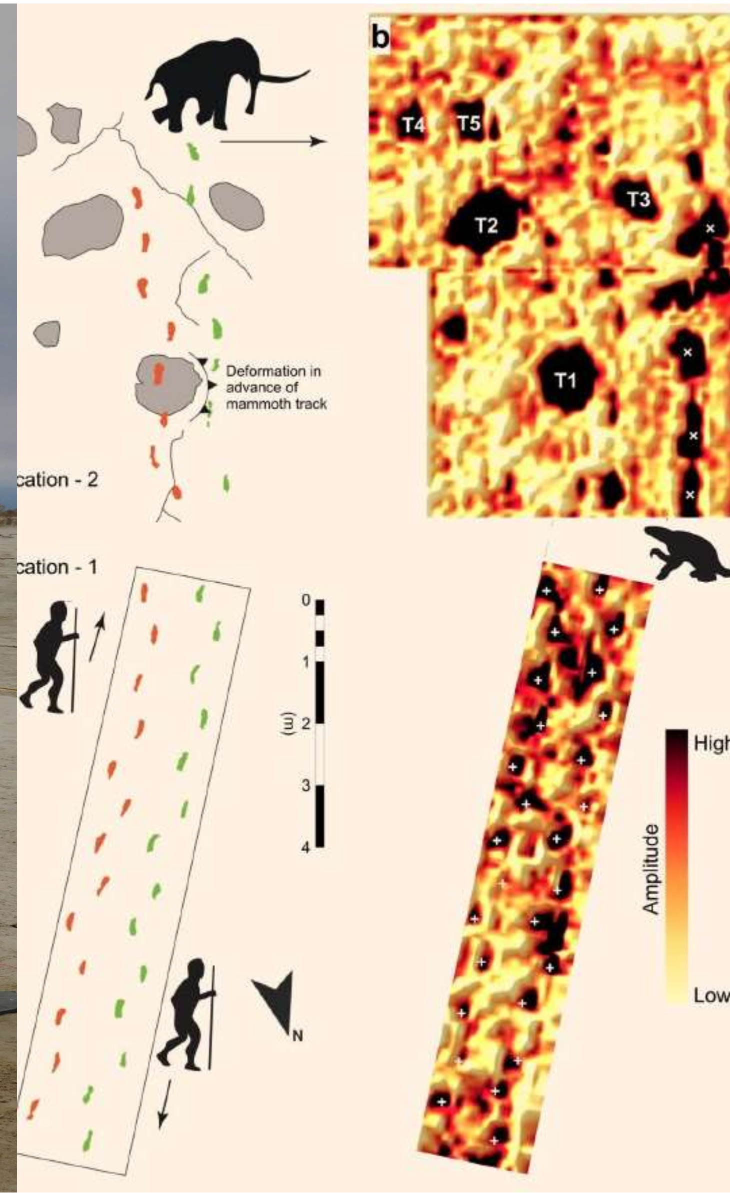

A
San Andres Mountains
White Sands
Sacramento Mountains
B
2 m
2016
C
2020



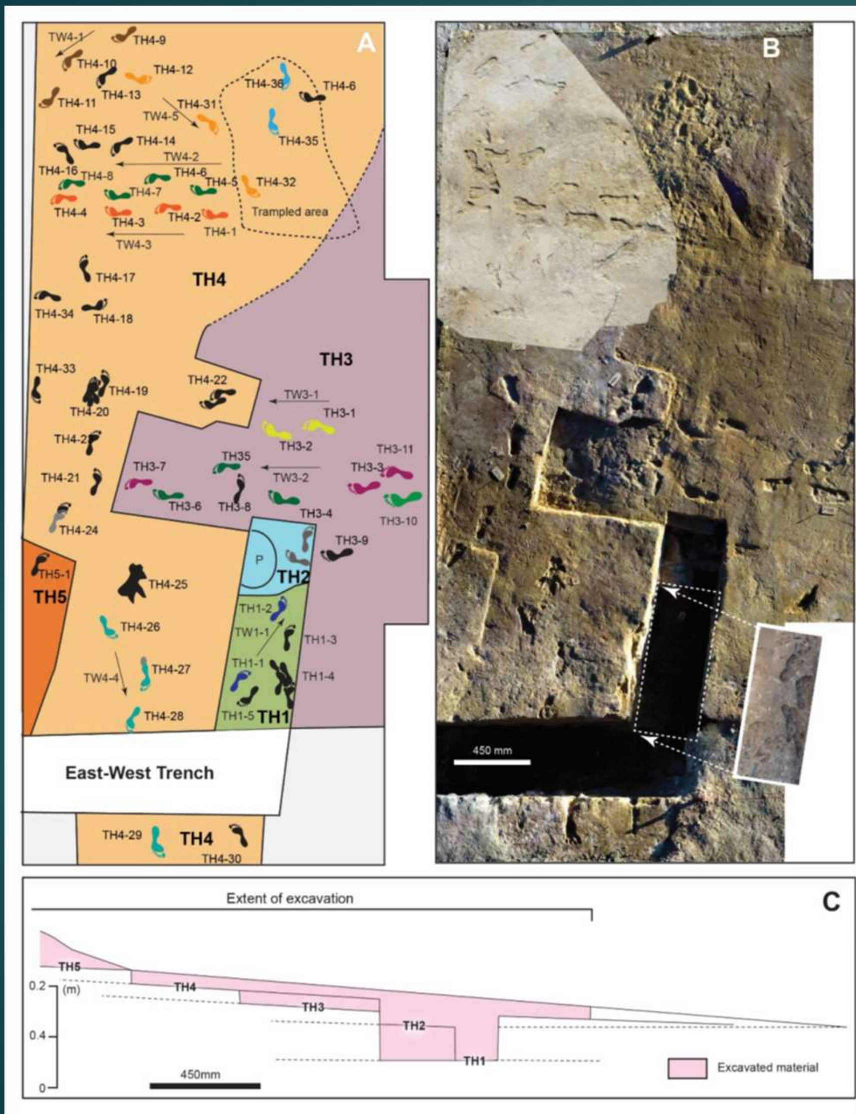
WATER PROVIDES GYPSYM DUNE STABILITY

02/26/2009 03/16/2010 05/26/2011

Mammoth Trackway

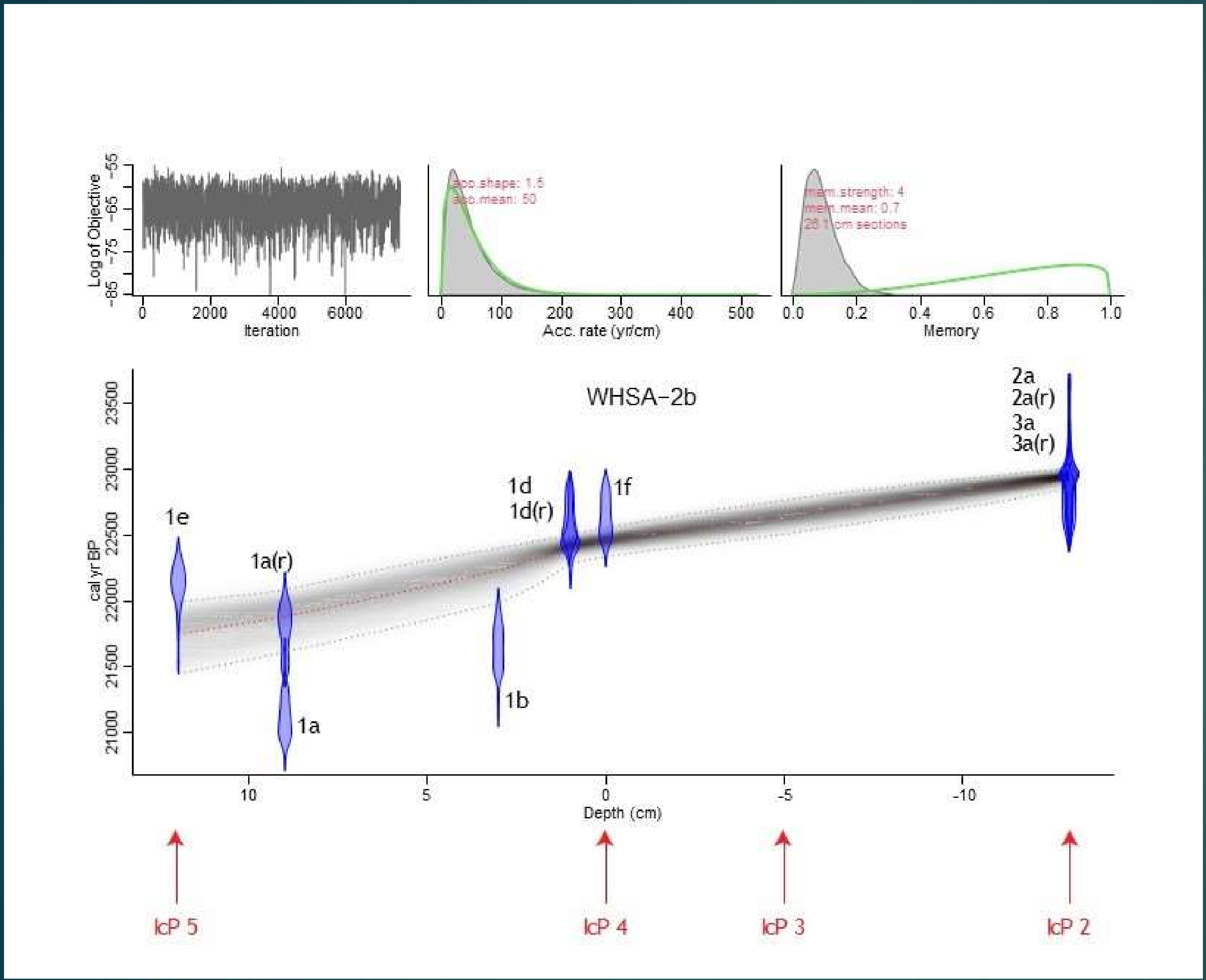

b
T4
T5
T3
T2
T1
Deformation in
advance of
mammoth track
cation - 2
cation - 1
0
1
2
3
4
(m)
N
High
Amplitude
Low

Ruppia cirrhosa



Overview of Work at Locality 2 Done in 2020

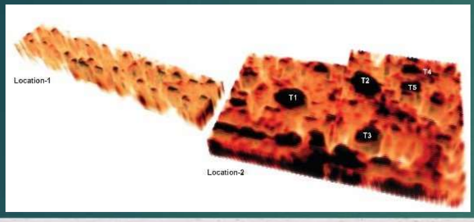

NCPTT

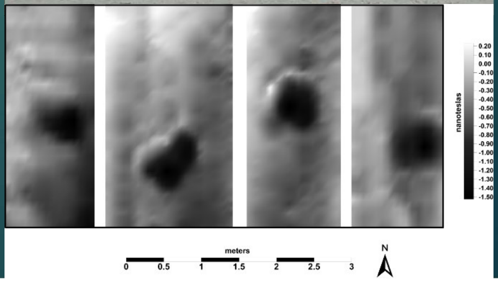


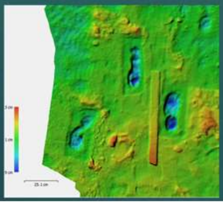
AMS Dates Constrain Ages of Track Horizons 2 to 5.

Older and Younger Horizons remain undated.

Preserving Trackv





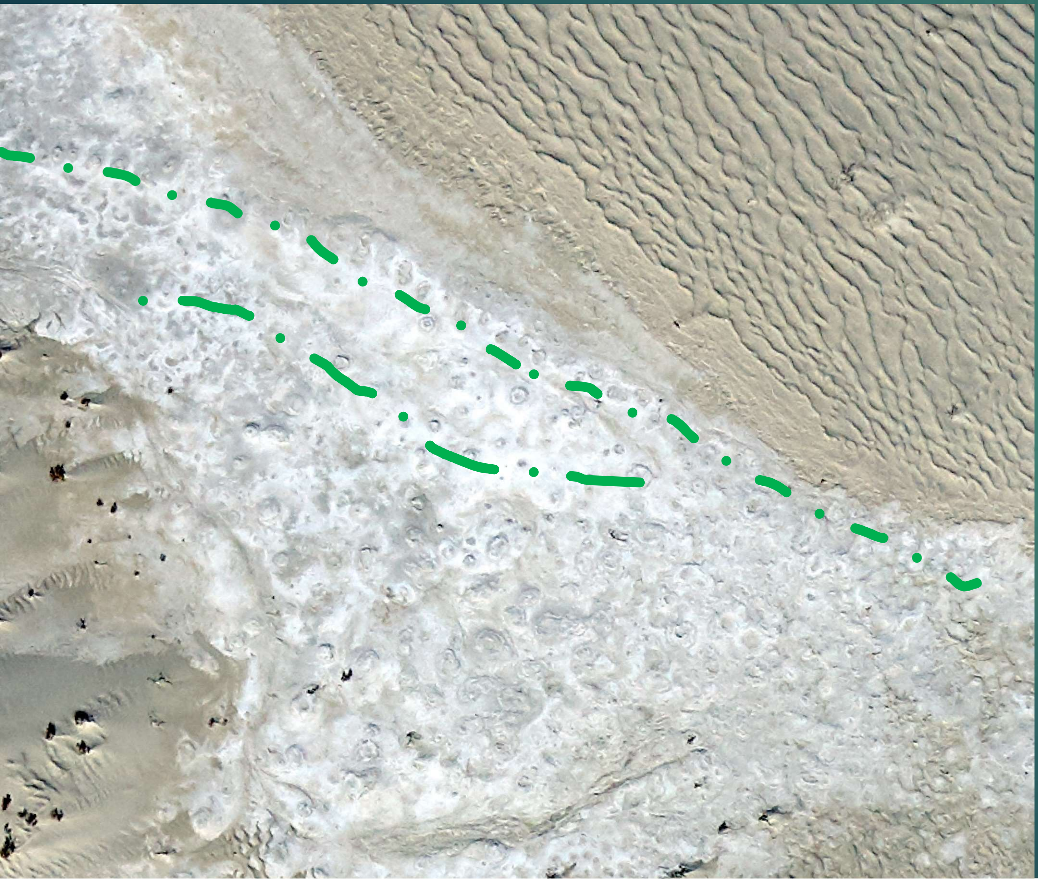


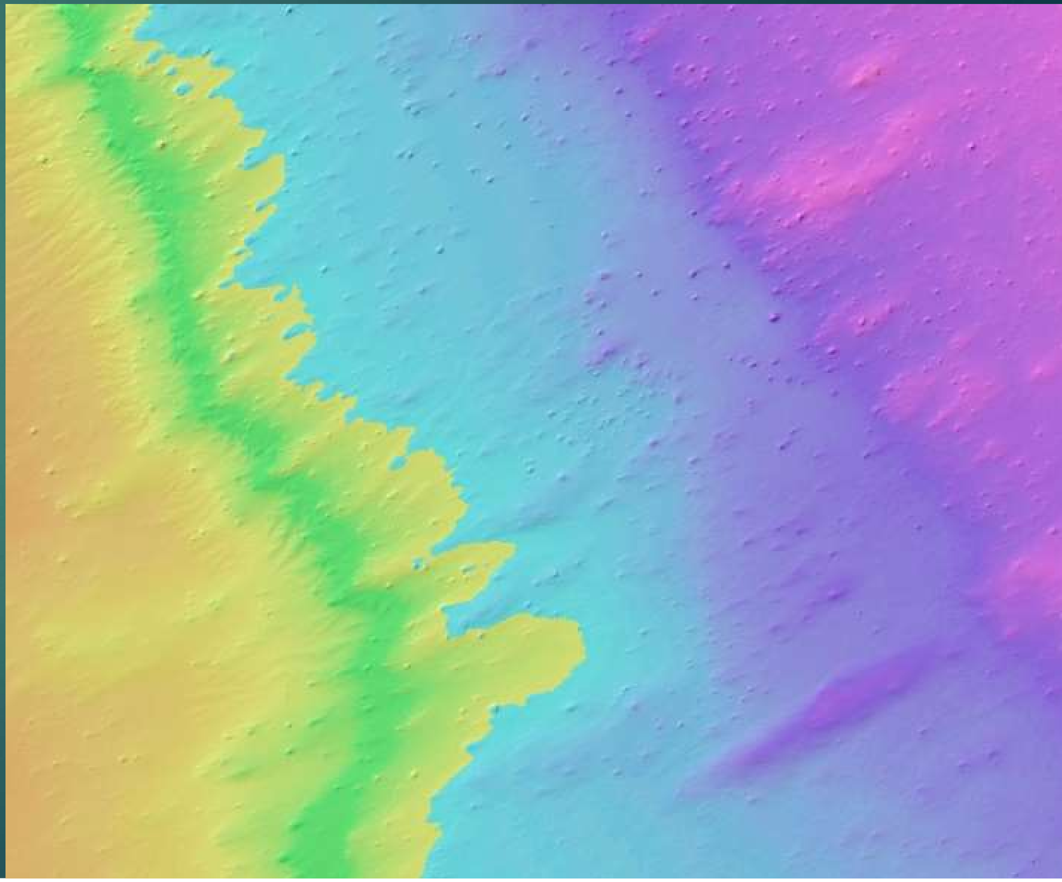
WHSA CLIMATE PROJECTIONS (1950-1999 vs 2040)

	Warm/Rain-No ∆	Hot Wet	Hot Dry
Warming	**Common Across Scenarios** • Warming in all seasons • Significant drop in days <32 °F		
	Degree of warming • ~ 1.5 °F • 26 days >100 °F (+6 days)	Degree of warming • ~ 4.1 °F • 36 days >100 °F (+16 days)	Degree of warming • ~ 4.1 °F • 42 days >100°F (+22 days)
Precipitation	**Variable**		
	• No change	• 2" annual increase concentrated in Jul/Aug (↑~66%)	• 1.5" annual decrease evenly distributed across June-Dec
Water Balance	**Common Across Scenarios** • Increases in soil moisture deficit		
	• Annual soil moisture deficit increases 7%	• Annual soil moisture deficit increases 12%	• Annual soil moisture deficit increases 27%

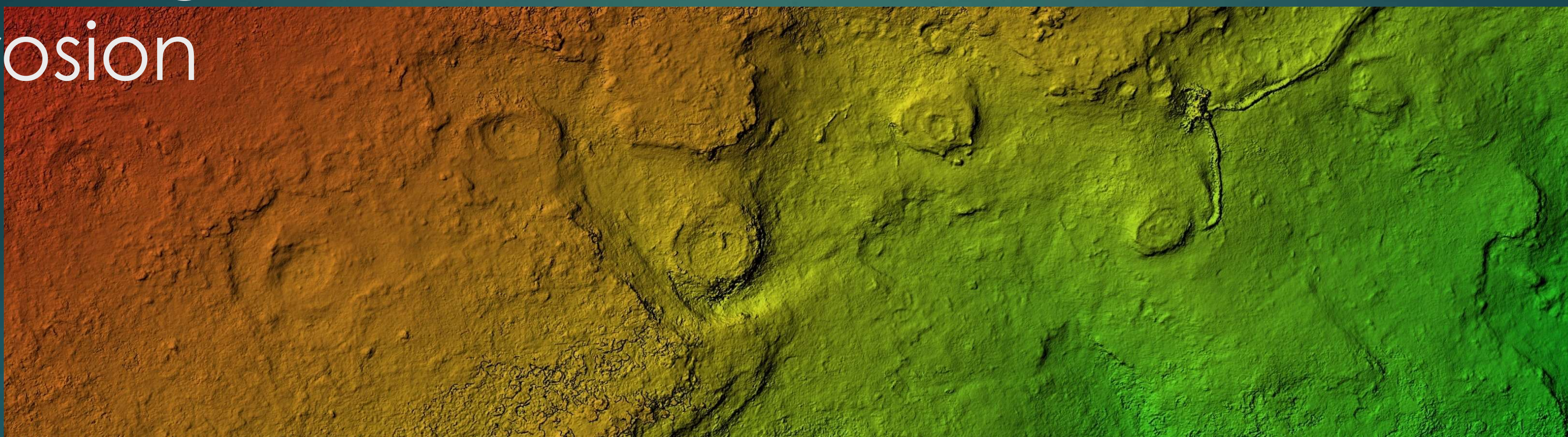
Gregor Schuurman, NPS CCRP (2017)

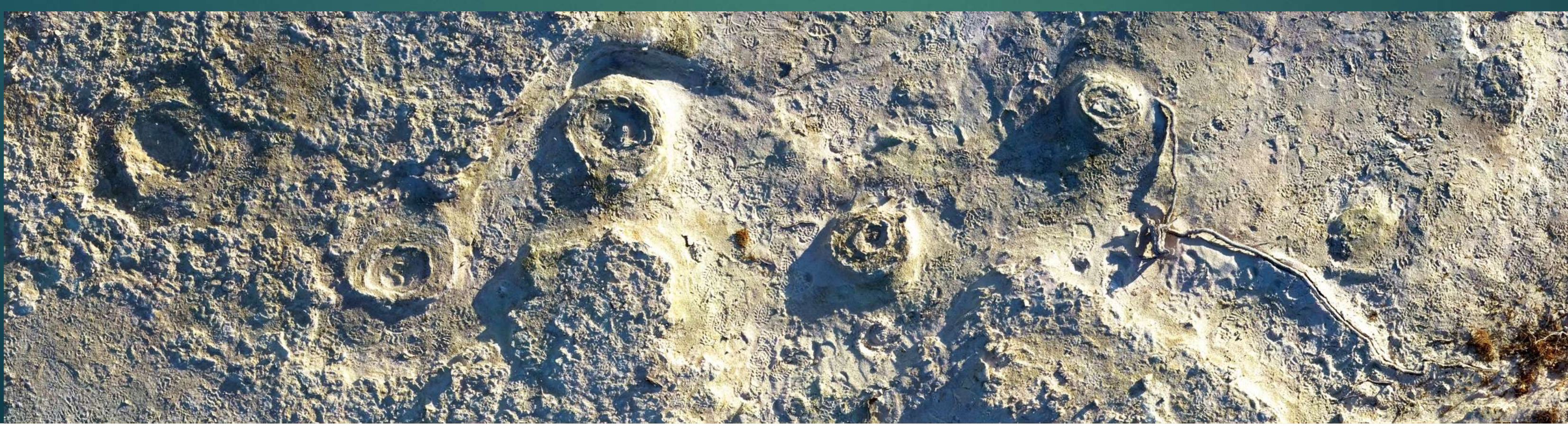
Use of Lidar, Aerial, Imagery, and photogrammetry to detect prints and monitor erosion



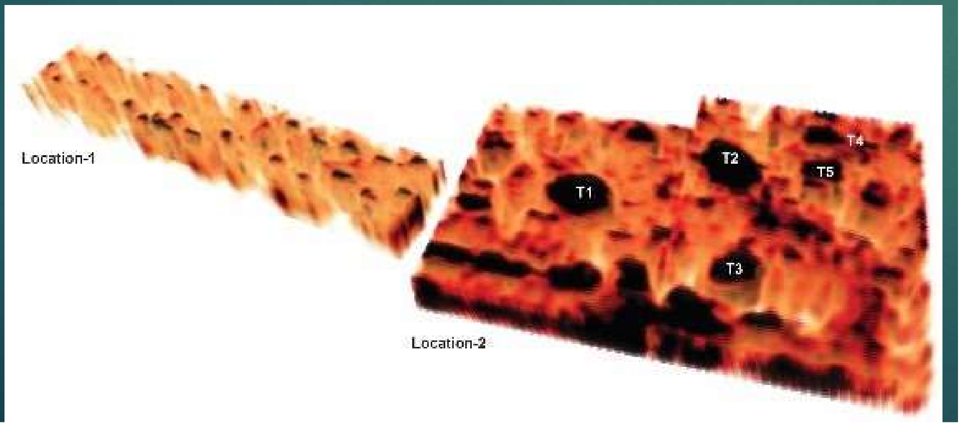


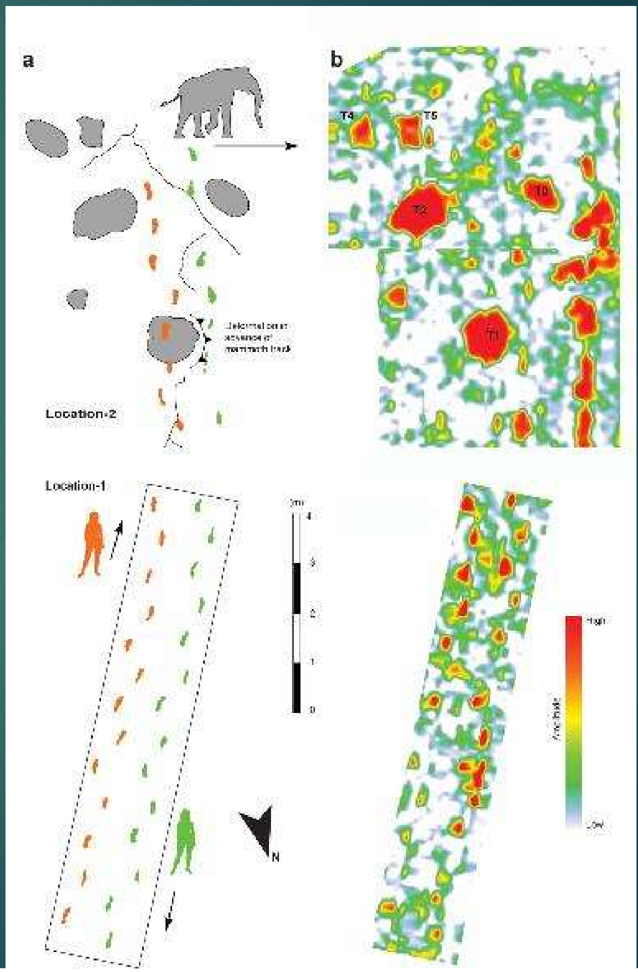
Use of Lidar, Aerial, Imagery, and photogrammetry to detect prints and monitor erosion





Documenting and Locating with GPR





02/26/2009

03/10/2010

05/26/2011

Eroding Tracks

Modern Day and Pleistocene

Modern Day and Pleistocene Proboscidean

WHSA Fossil Print

Modern Day Elephant