Coupled Warming and Megadroughts in New Mexico During the Mid-Pleistocene: The Valles Caldera Record

Peter Fawcett
University of New Mexico

Talk Outline

Brief Geologic History of the Valles Caldera and modern climate

Drilling lake sediments in the Valle Grande

Resulting Sediment Core VC-3

- Chronology
- Overview of the paleoclimatic record
- Interglacials and megadroughts (and fire too)
- Glacial periods and millennial-scale climate change

Collaborators

University of New Mexico

John Geissman
Fraser Goff
Linda Donohoo-Hurley
Catrina Johnson
Justin Dodd

Los Alamos National Lab

Jeff Heikoop
Fraser Goff
Giday WoldeGabriel
Julianna Fessenden-Rahn
Malu Cisneros-Dozal

Northern Arizona University

R. Scott Anderson
Susan Smith

U.S.G.S.

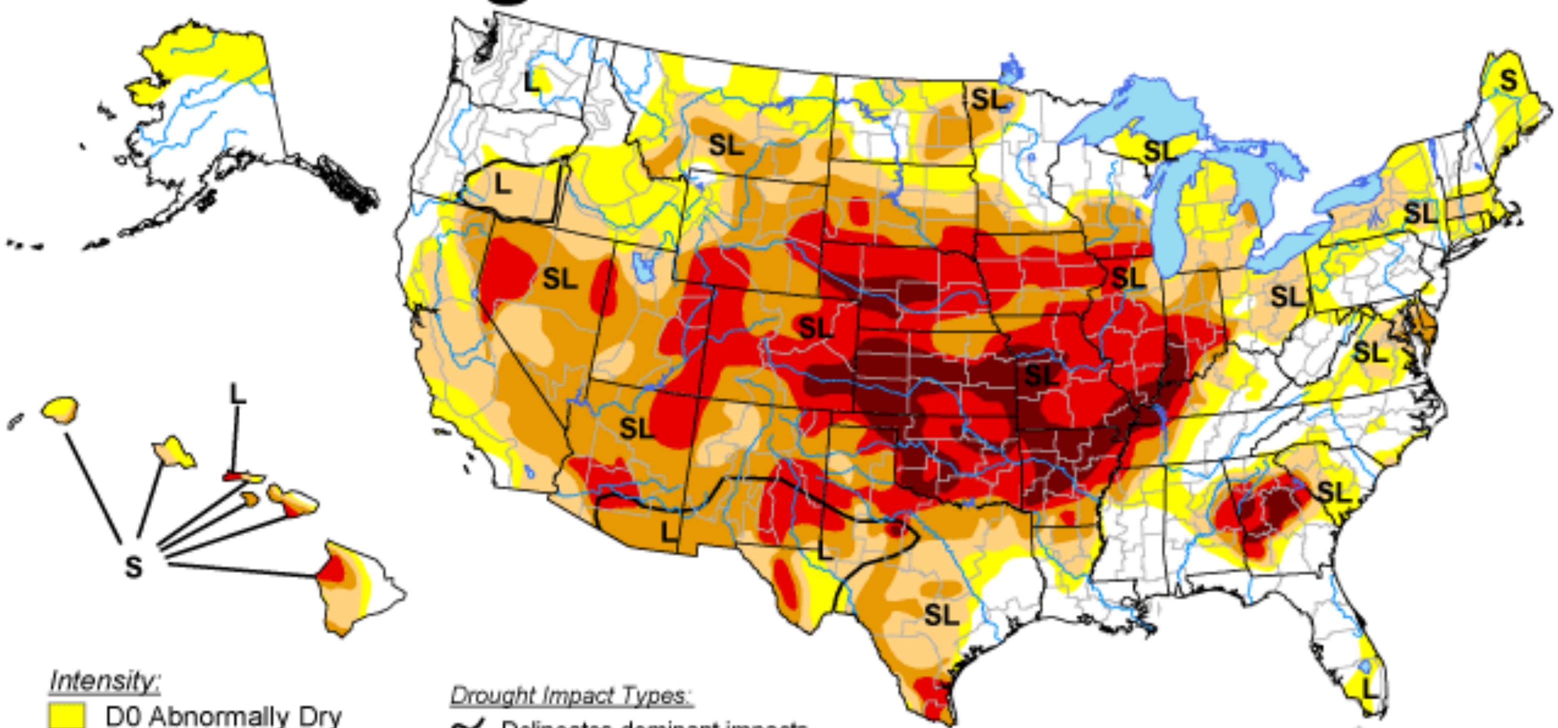
Craig Allen

U Minnesota Duluth

Erik Brown
Joe Werne
Sergio Contreras

U.S. Drought Monitor

August 14, 2012
Valid 7 a.m. EDT



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

~ Delineates dominant impacts

S = Short-Term, typically <6 months (e.g. agriculture, grasslands)

L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

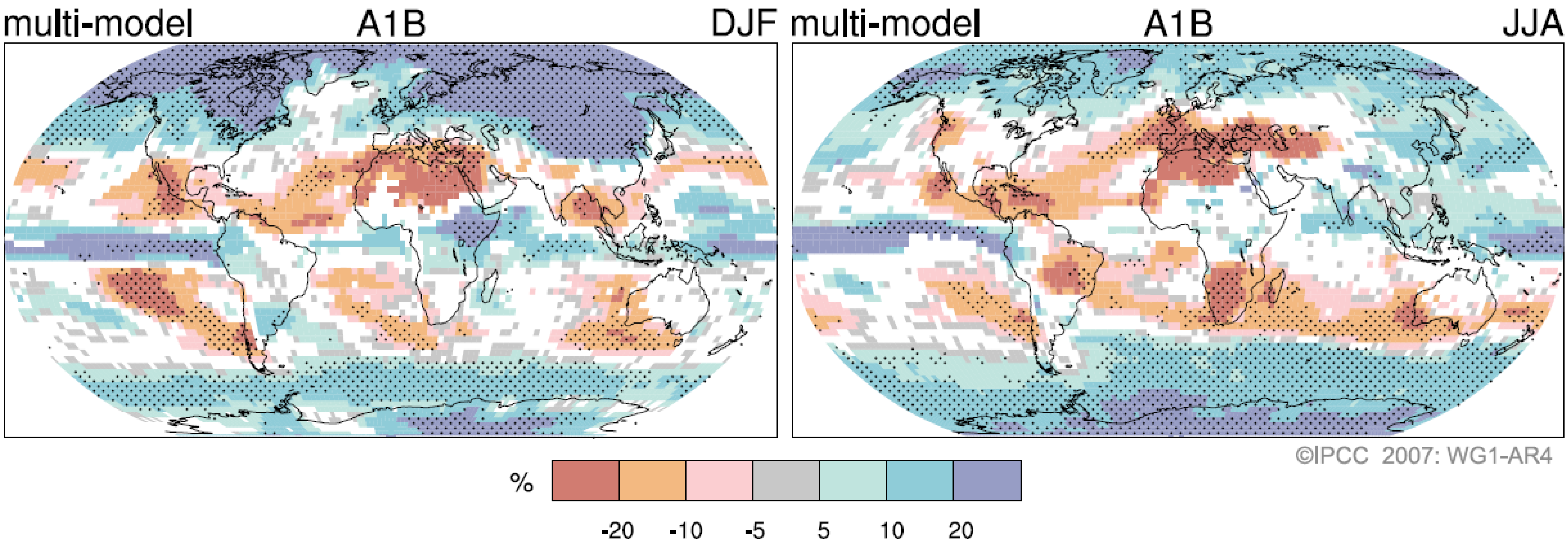
USDA National Drought Mitigation Center

http://droughtmonitor.unl.edu/

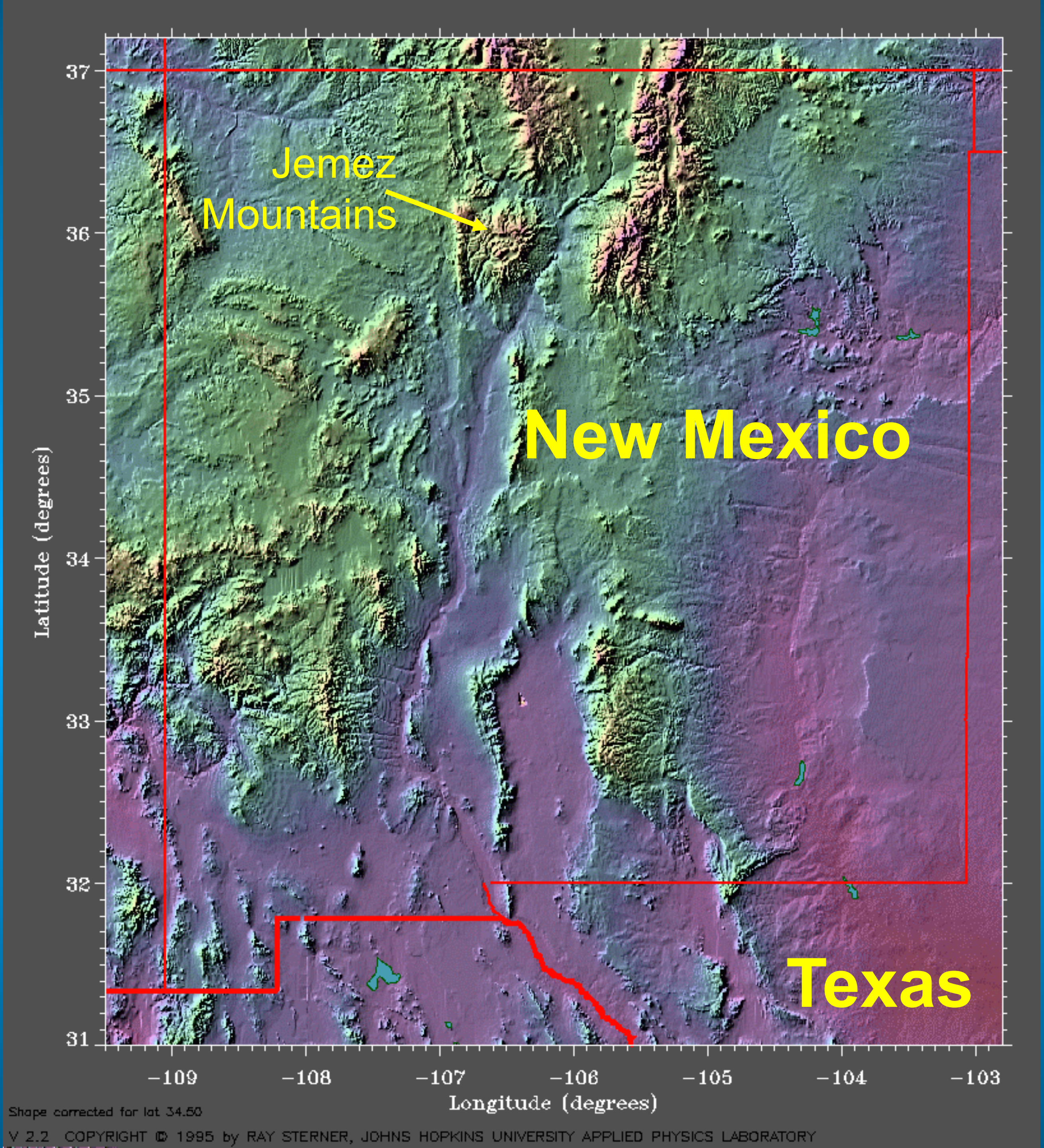
Released Thursday, August 16, 2012

Author: Michael Brewer/Liz Love-Brotak, NOAA/NESDIS/NCDC

PROJECTED PATTERNS OF PRECIPITATION CHANGES



All IPCC models predict more drought conditions for North American southwest in coming decades



Jemez
Mountains
New Mexico
Texas
37
36
35
34
33
32
31
Latitude (degrees)
−109
−108
−107
−106
−105
−104
−103
Longitude (degrees)
Shape corrected for lat 34.50
V 2.2 COPYRIGHT © 1995 by RAY STERNER, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

The Valles Caldera, New Mexico

Ancient Lake with a mid-Pleistocene record (552 ka to 370 ka, MIS 14-10)

South Mountain Rhyolite Dome and the Valle Grande

Don Usner

Photo Credit: Peter Fawcett

Drilling Details:

Location:

Valle Grande, Jemez Mountains, NM

(35.87^{o}N, 106.46^{o}W, 2,594 m elevation)

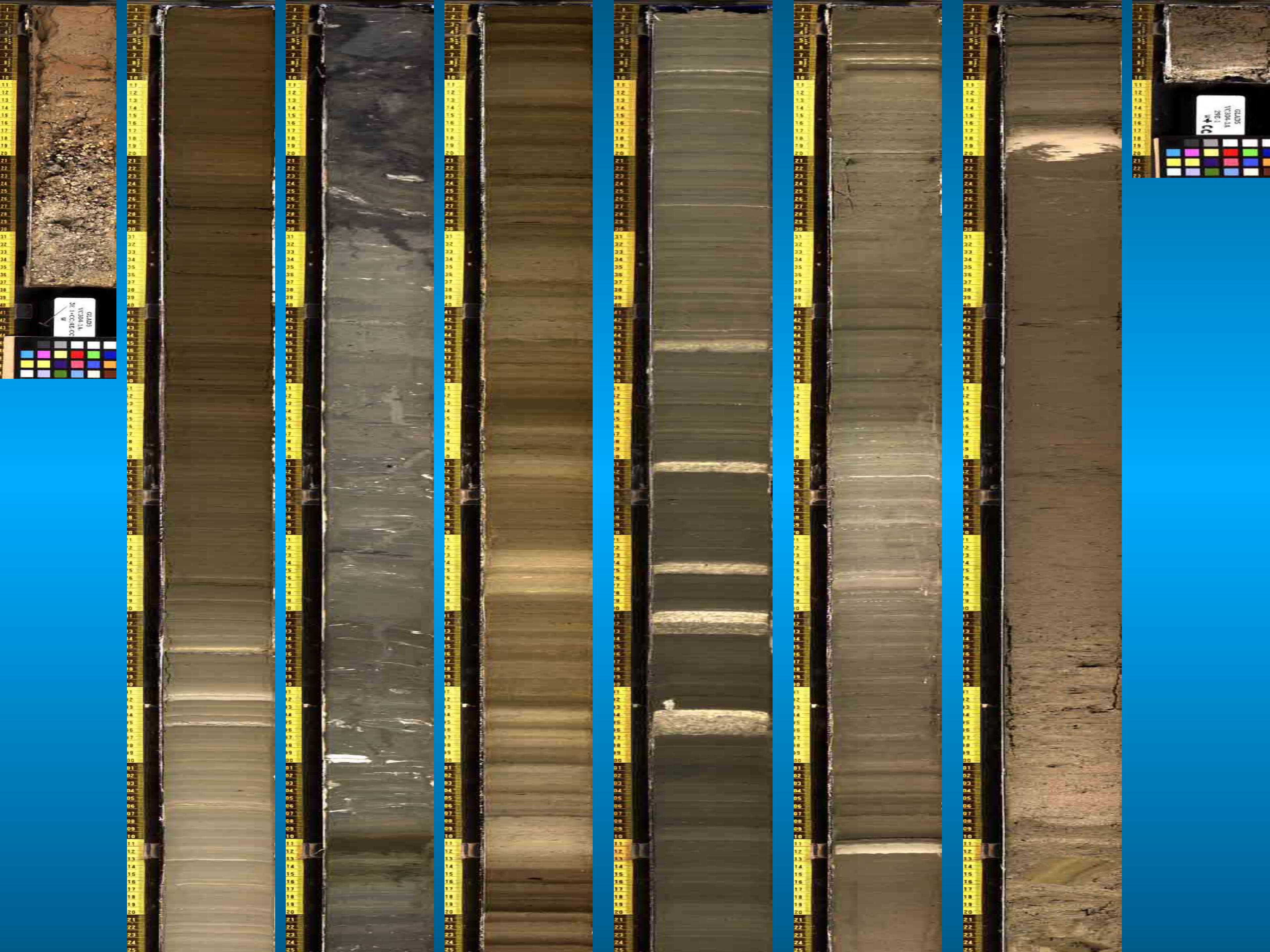
Driller: DOSECC using a CS500 Rig

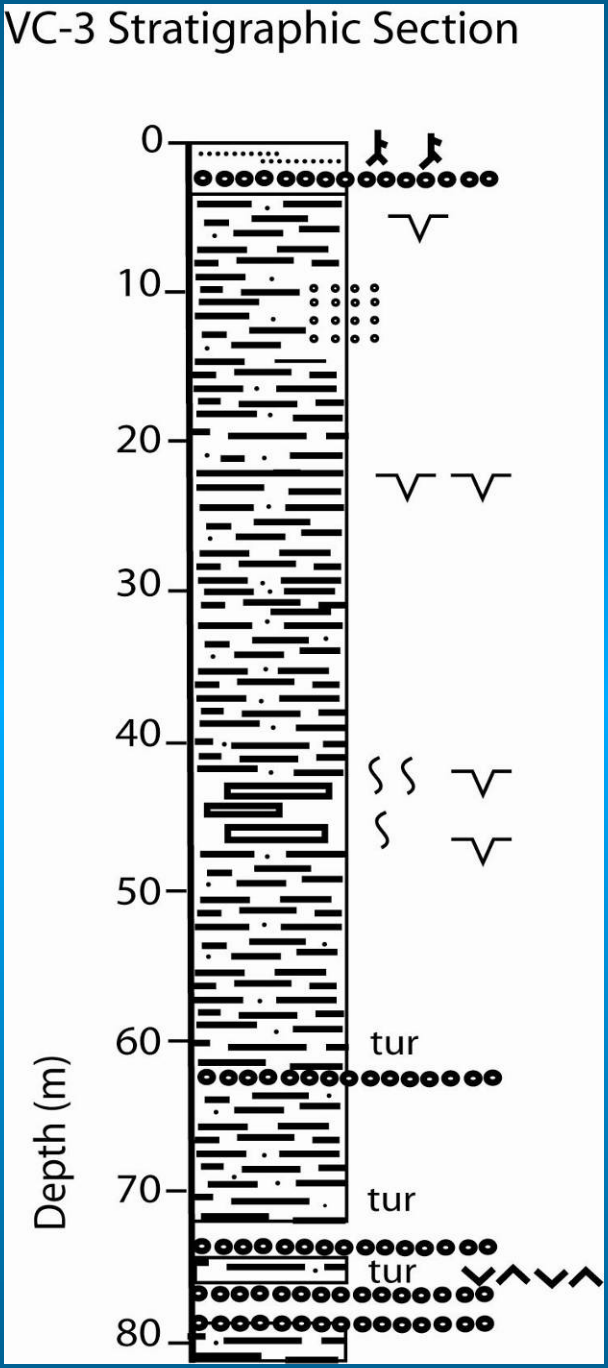
Total Depth Cored: 82.1m

Funded by: IGPP (LANL), USGS, NSF

Core archived at and assistance provided by LRC/LacCore, University of Minnesota


CS500


GLAD5
VC304-1A
GLAD5
VC304-1A
CC



Total Drilling Depth of 81 m

75 m lacustrine silty muds recovered

Overall core recovery better than 95%

Poor recovery in basal gravels and sands

Artesian aquifer at ~86 m!

Challenge: Establish a chronology for core VC-3

Talk Outline

Brief Geologic History of the Valles Caldera and modern climate

Drilling lake sediments in the Valle Grande

Resulting Sediment Core VC-3

- Chronology
- Overview of the paleoclimatic record
- Interglacials and megadroughts (and fire too)
- Glacial periods and millennial-scale climate change

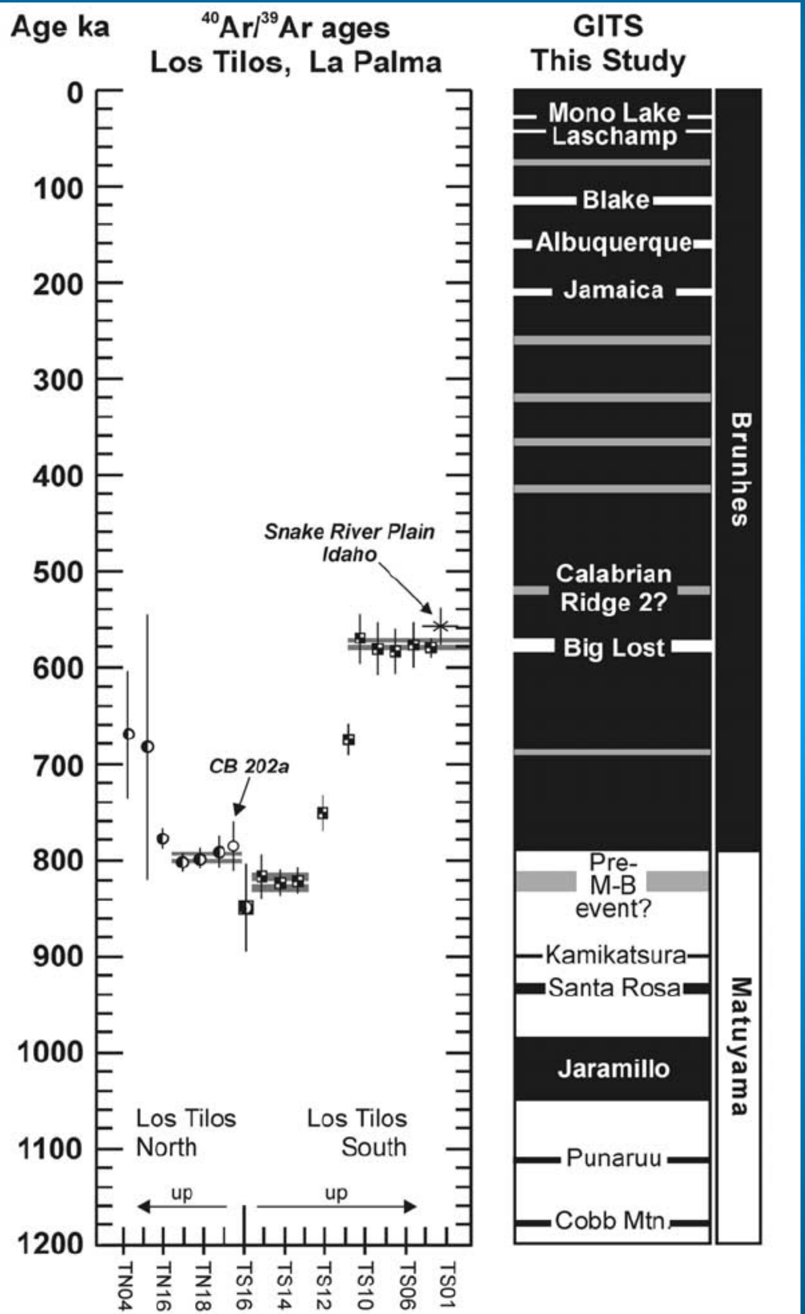
75.72 to 75.81 m

Tephra:
Ar-Ar Date
552 ± 3 ka

76.0 to 76.1 m

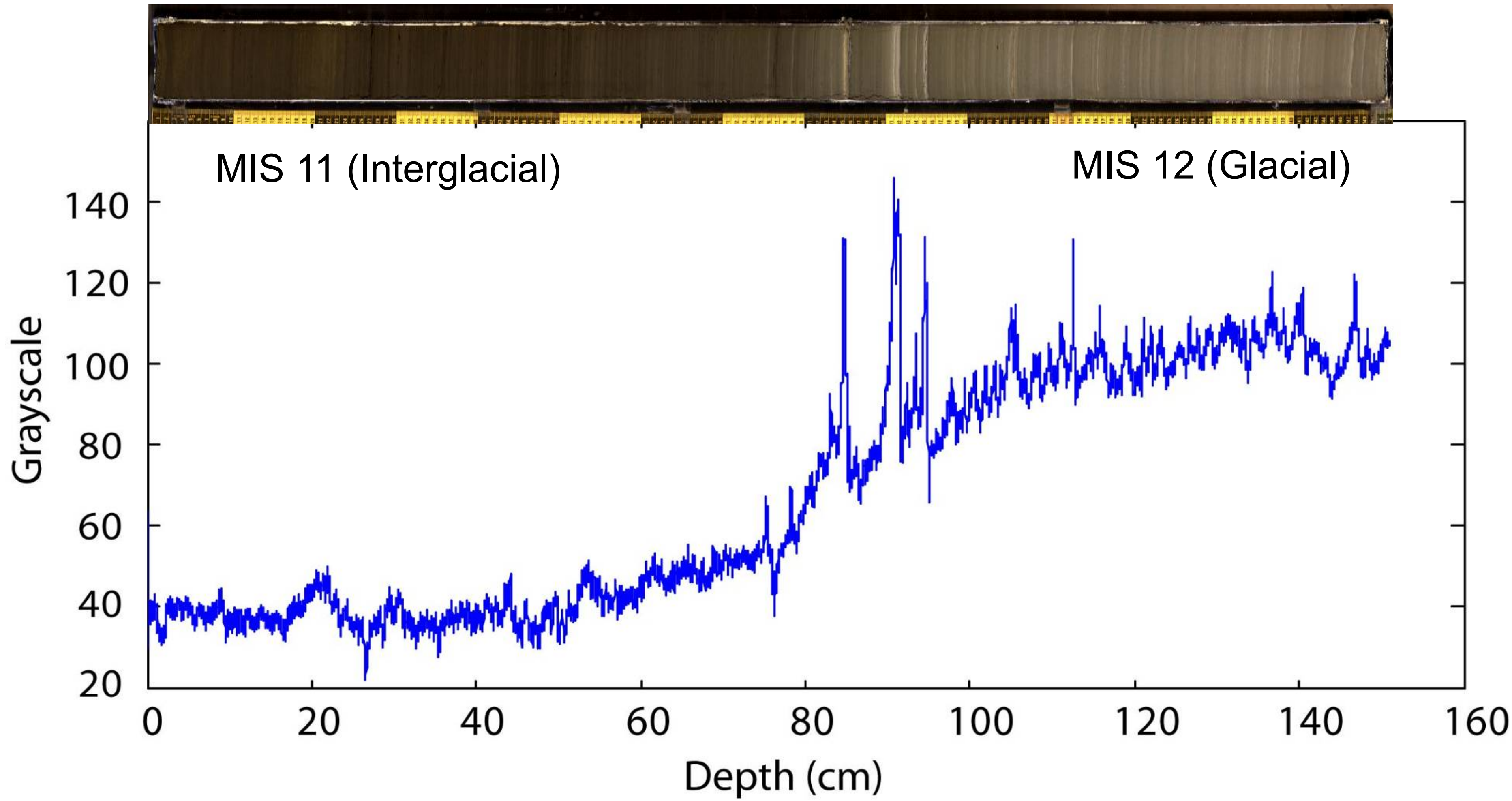
Pumiceous Sandy Gravel
Ar-Ar Date
552 ± 3 ka

Summary of Brunhes-aged magnetic field excursions



Singer et al., 2002

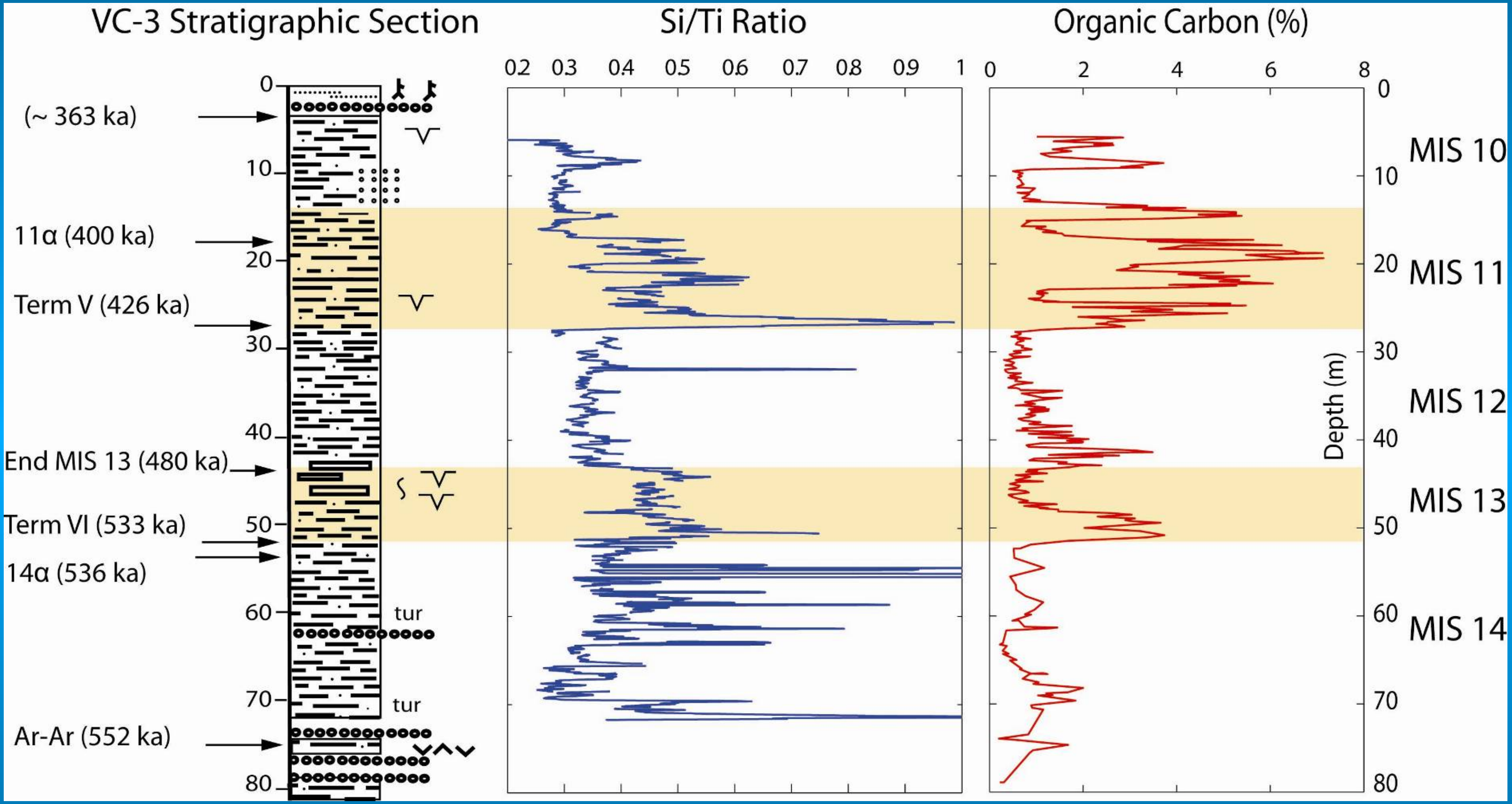
Run 13H-1: 26.7 m to 28.2 m depth



Glacial Termination V (426 ka)

(Sediment color darker with more organic carbon)

VC-3 Chronology



Glacial terminations V and VI correlated with Lisiecki and Raymo, 2005

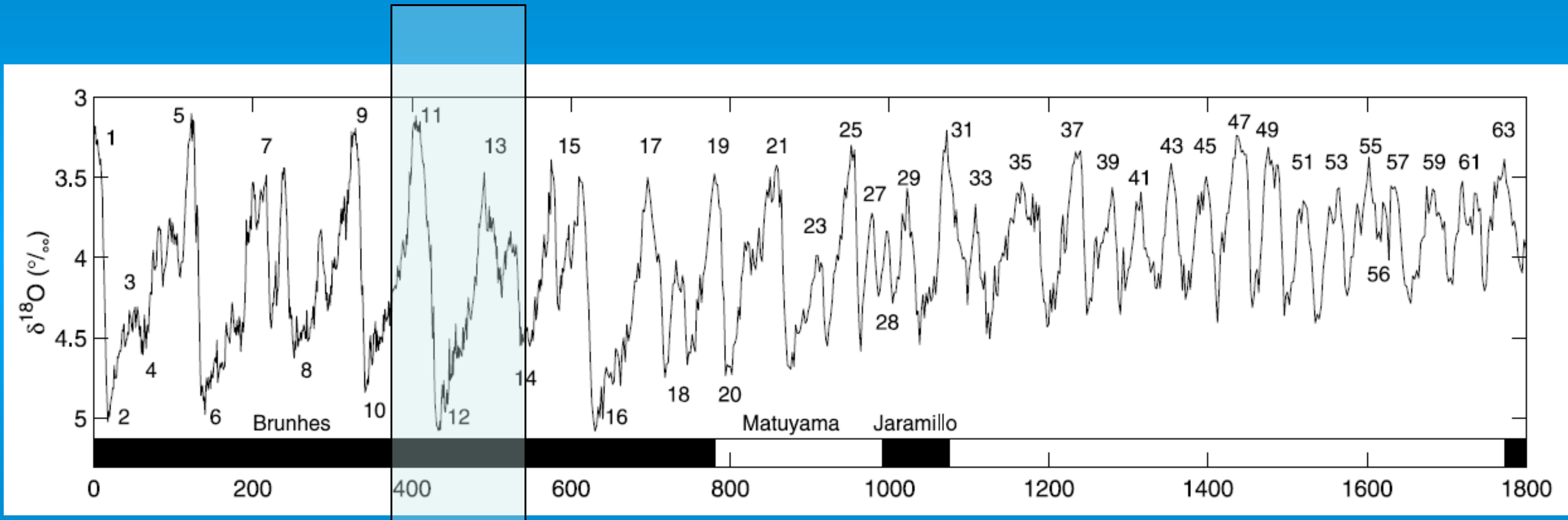
Geomagnetic field events 14α and 11α (Lund et al., 2006)

Marine Oxygen Isotopes Define Glacial and Interglacial Periods

(isotopic profiles reflect both continental ice volume and SSTs)

Interglacial

Glacial



Timespan covered by core VC-3

552 ka to ~370 ka

Lisiecki and Raymo, 2005

MBT/CBT Temperature Proxy

Branched Tetraether Membrane Lipids from Soil Bacteria

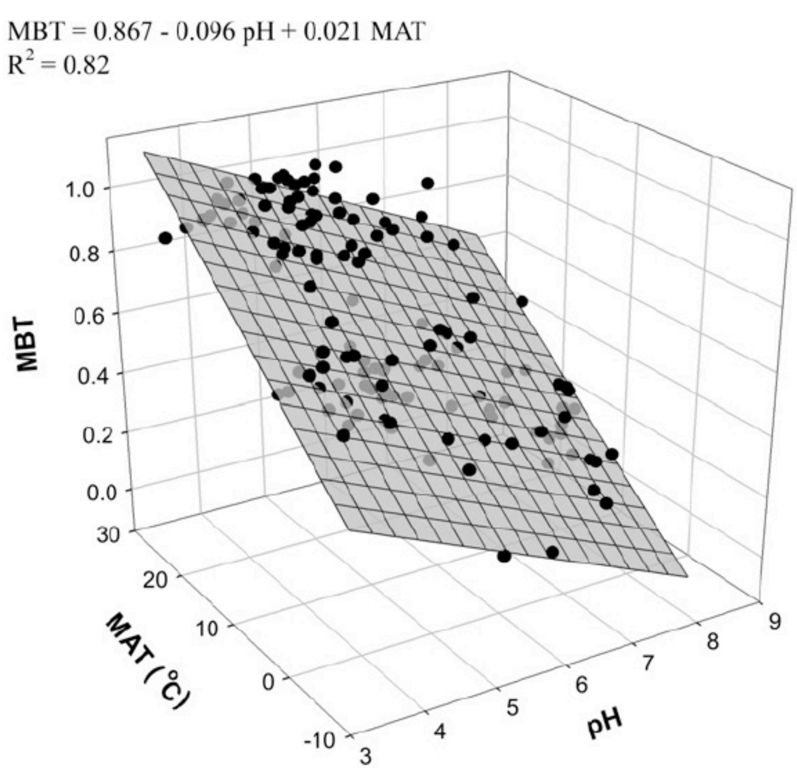


Fig. 7. 3-D calibration plot of the methylation index of branched tetraethers (MBT) in soils vs. soil pH and annual mean air temperature (MAT).

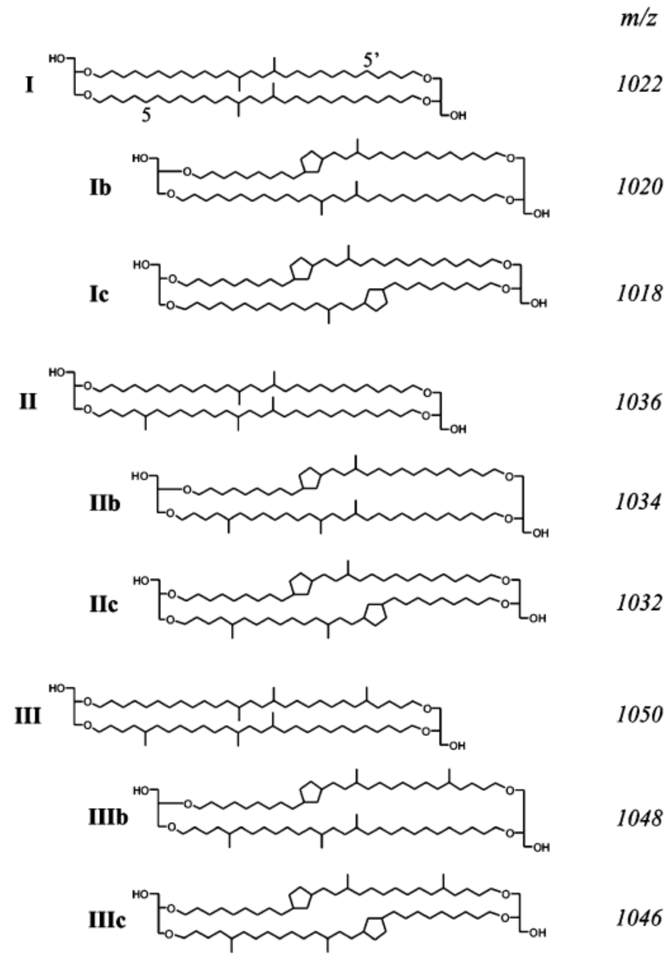
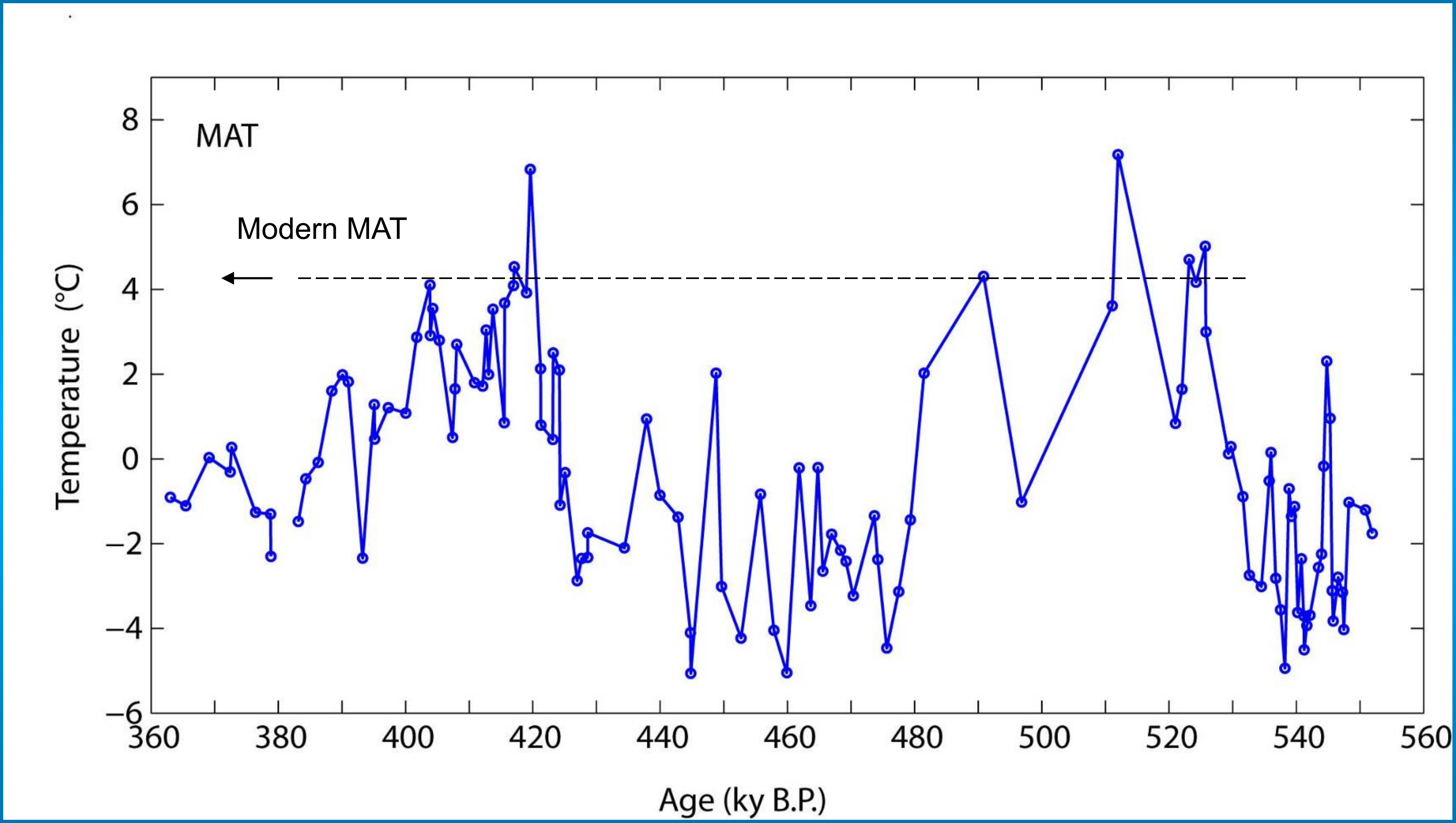


Fig. A1. Chemical structures of the branched glycerol dialkyl glycerol tetraether (GDGT) membrane lipids discussed in the text.

$$\mathrm{MBT} = \frac{[\mathbf{I + Ib + Ic}]}{[\mathbf{I + Ib + Ic}] + [\mathbf{II + IIb + IIc}] + [\mathbf{III + IIIb + IIIc}]}$$

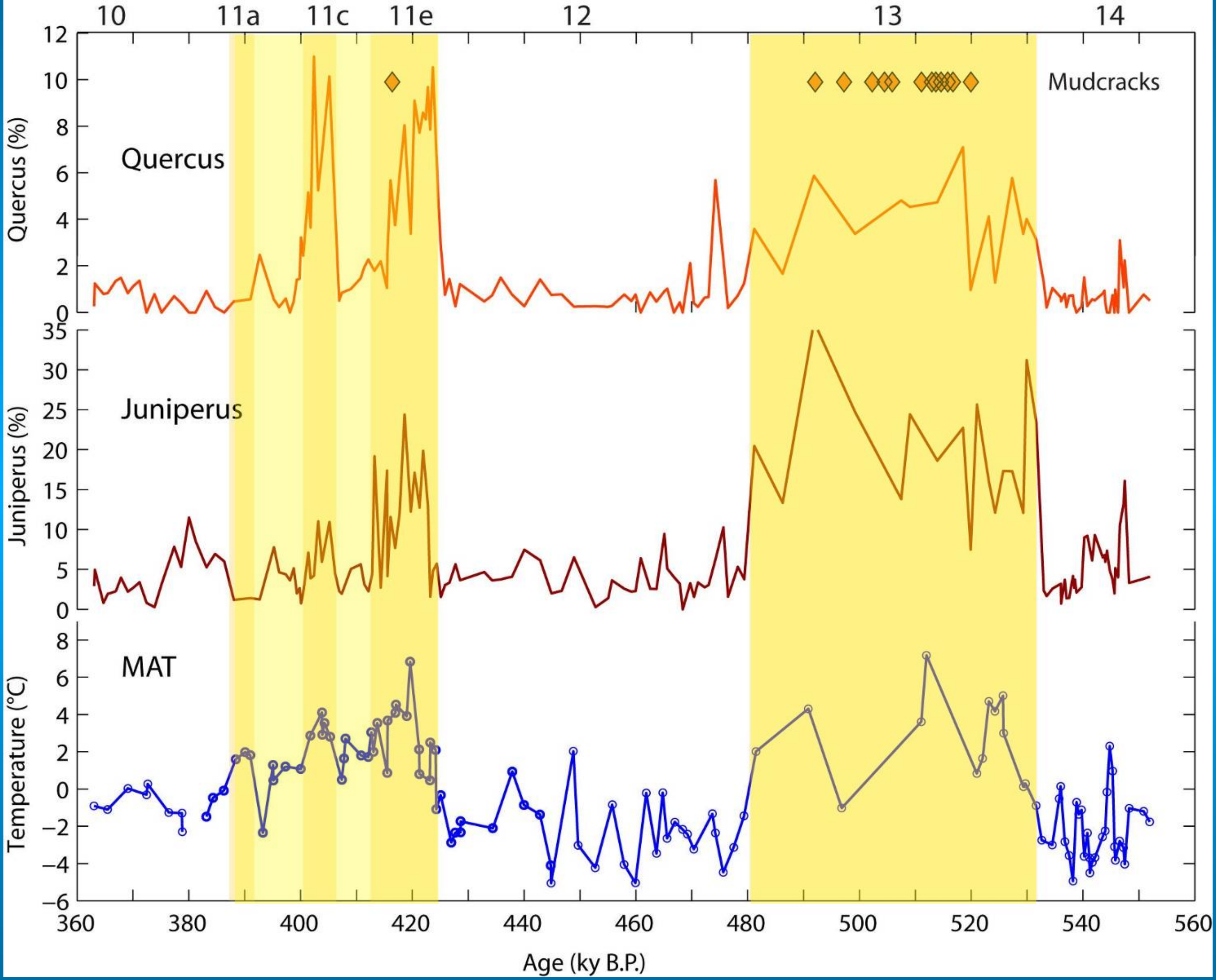
Weijers et al., 2007

Valles Caldera Mean Annual Temperature Estimates from MBT/CBT



Modern MAT in Valle Grande = 4.6°C

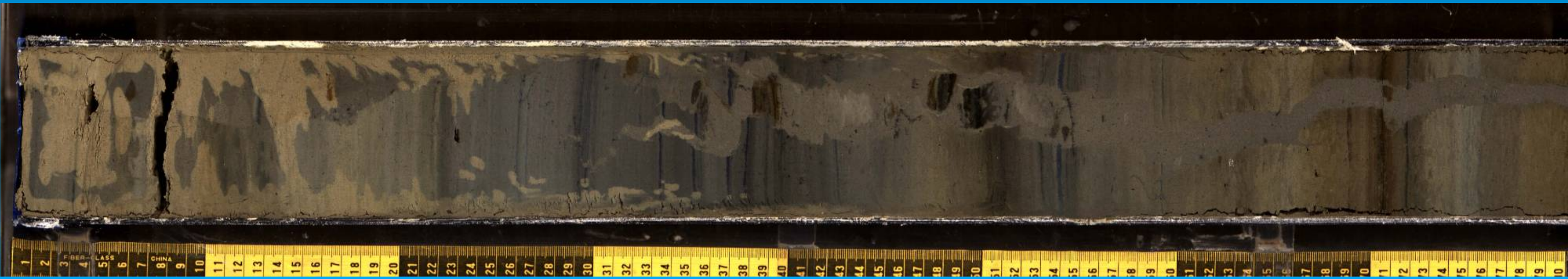
MAT and Warm Pollen Taxa (Oak and Juniper)



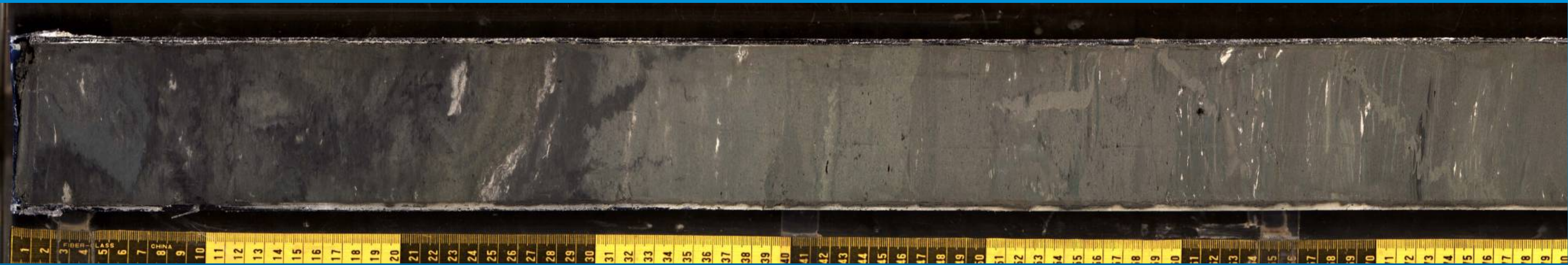
Mudcracks indicating severe drought form during warmest periods in the record

Mudcracks representing megadroughts

23.68 m to 25.18 m depth Interglacial MIS 11

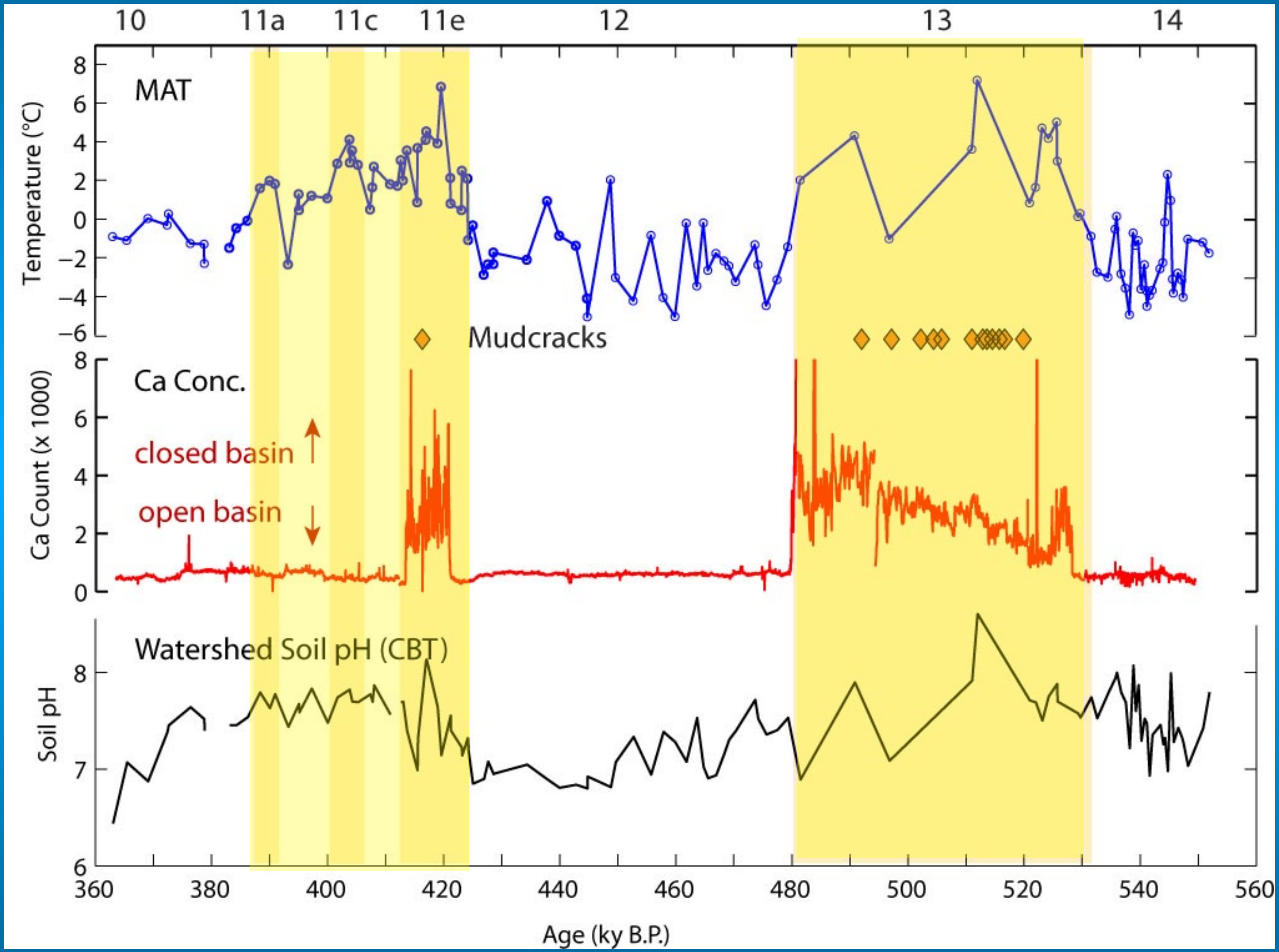


← This way up!



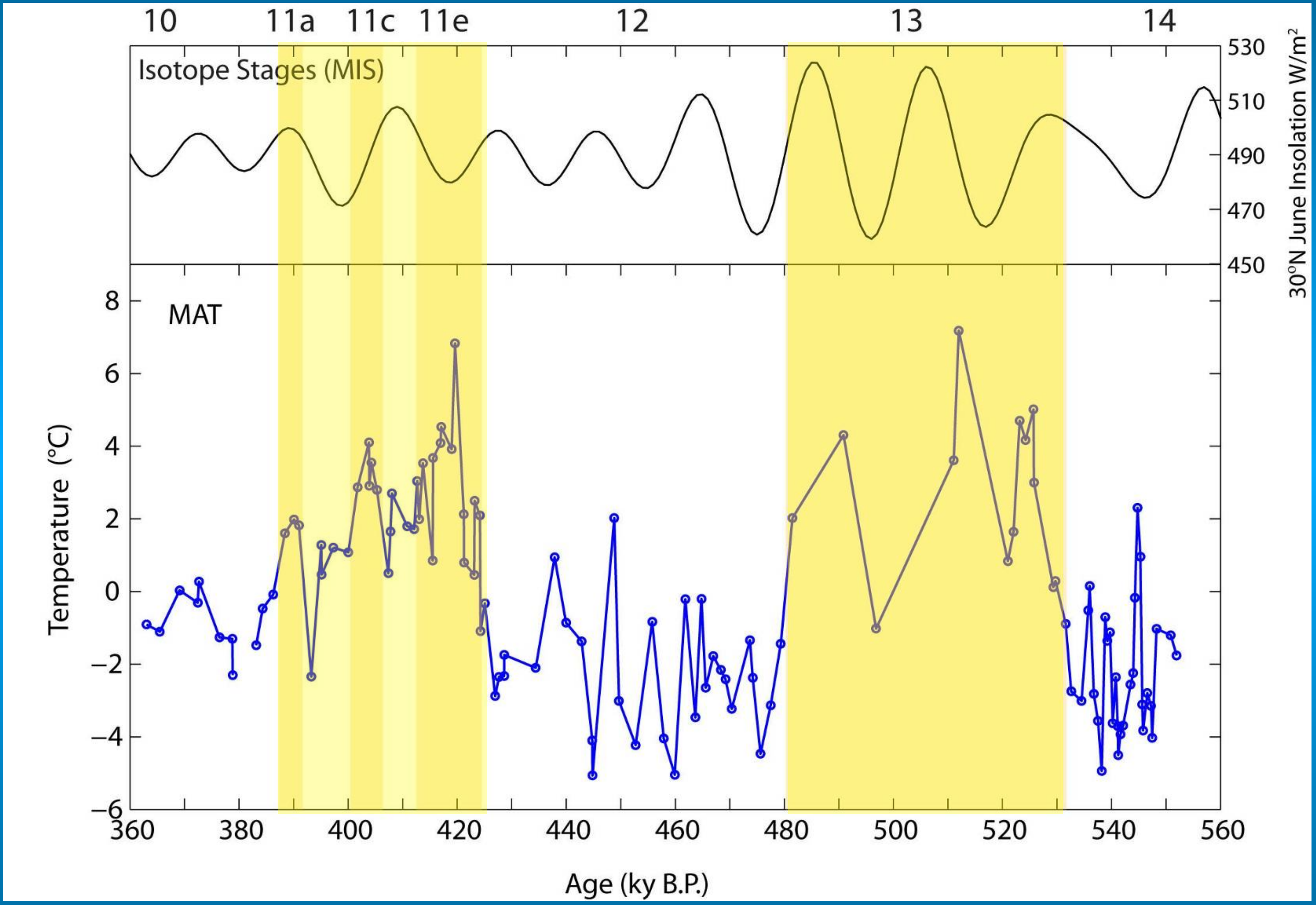
46.18 m to 47.63 m depth Interglacial MIS 13

MAT, Ca (Calcite) and Watershed Soil pH (from CBT)



Aridity indicators: mudcracks, high [Ca] (closed basin) and high soil pH values

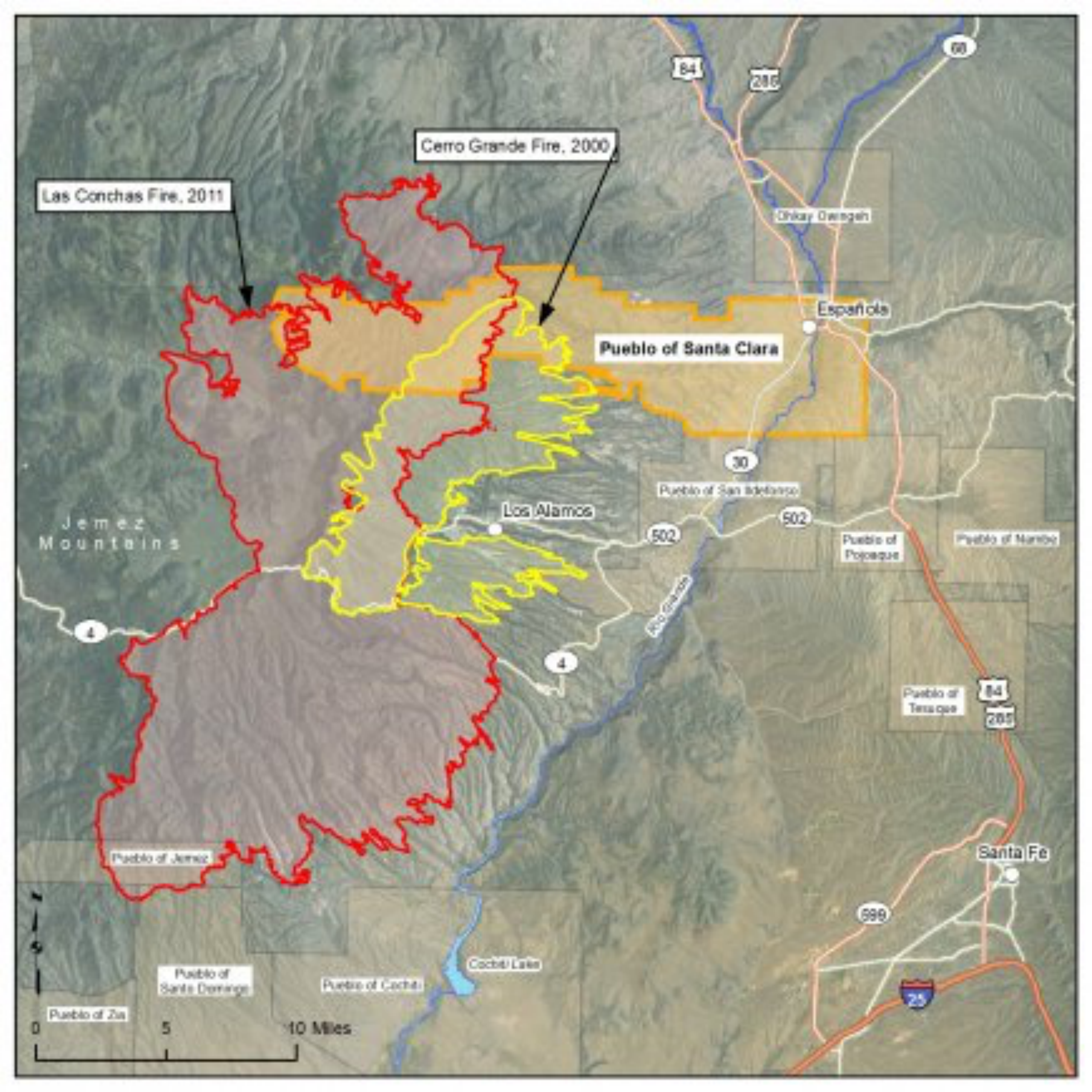
MAT Estimates from MBT and 30°N June Insolation



Three orbital (precession) cycles (warmer, cooler) during MIS 11 interglacial
Suggests that current interglacial should be cooling naturally(10 kyr since deglaciation)

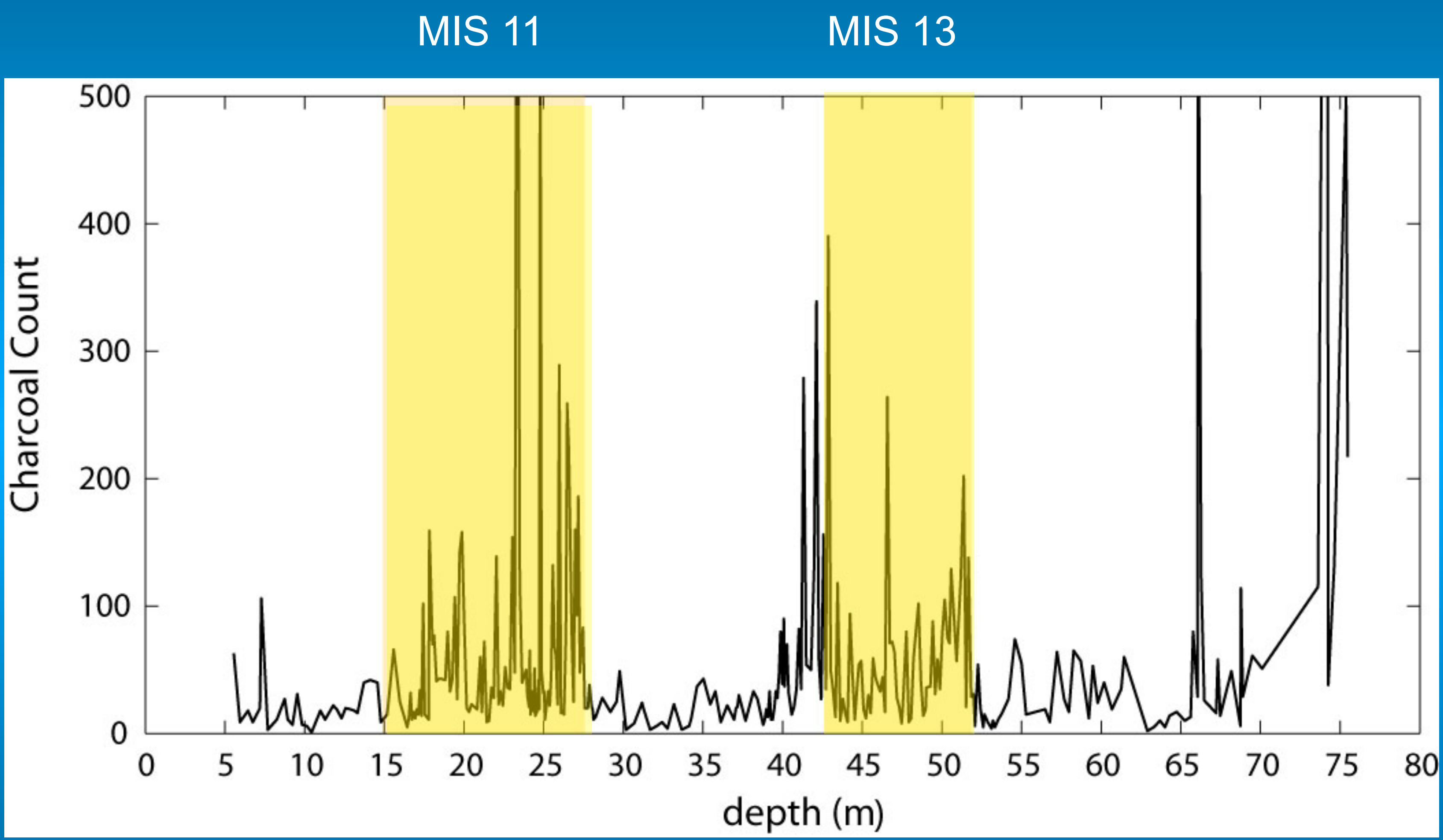
Las Conchas Fire, Summer 2011

Source: REUTERS / Eric Draper



Over 63,000 hectares burned

Core VC-3 Charcoal Count vs. Depth



Much greater natural wildfire activity during the interglacials and onset of glacial MIS 12

S. Anderson and S. Smith unpublished data

Talk Outline

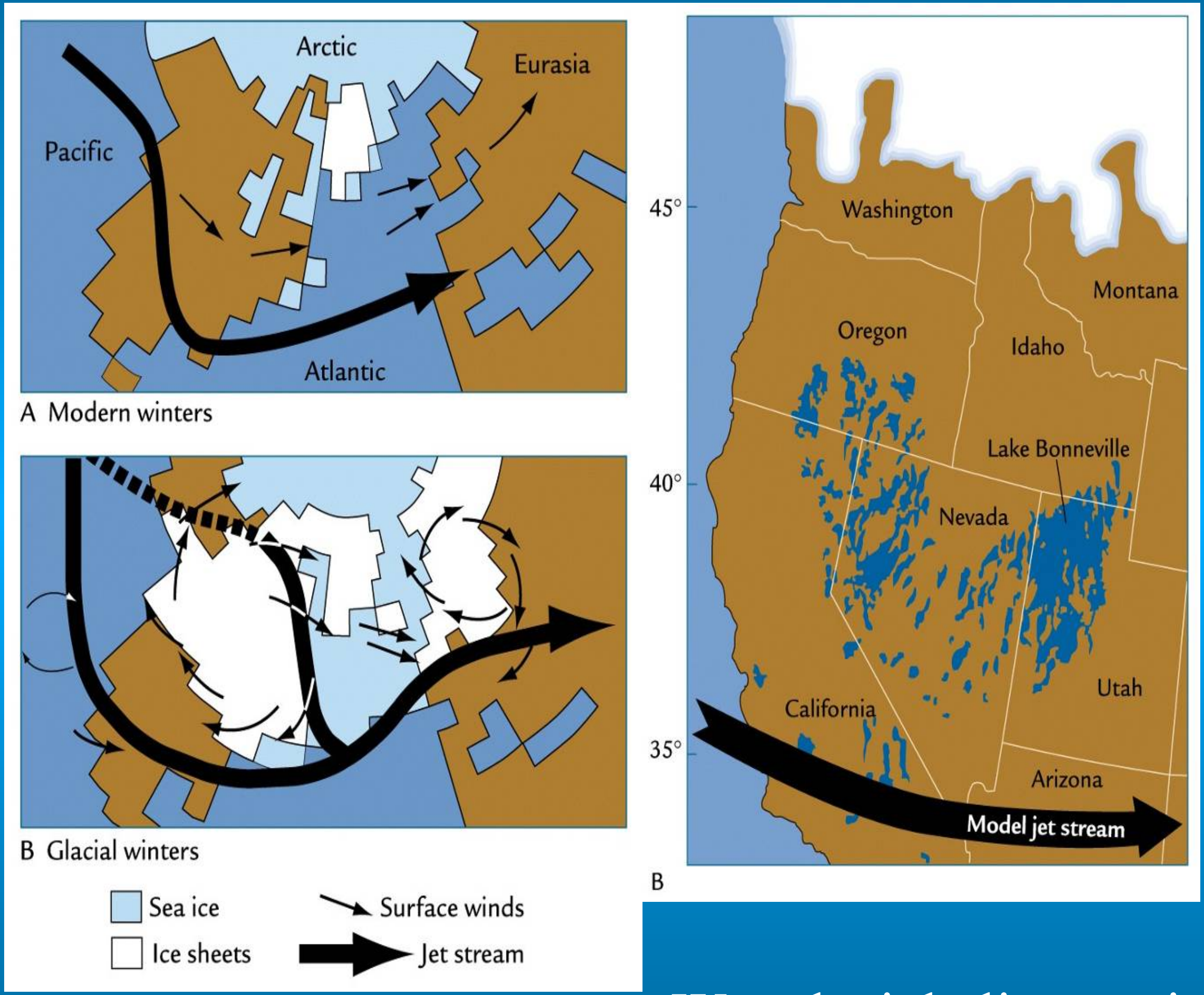
Brief Geologic History of the Valles Caldera and modern climate

Drilling lake sediments in the Valle Grande

Resulting Sediment Core VC-3

- Chronology
- Overview of the paleoclimatic record
- Interglacials and megadroughts (and fire too)
- Glacial periods and millennial-scale climate change

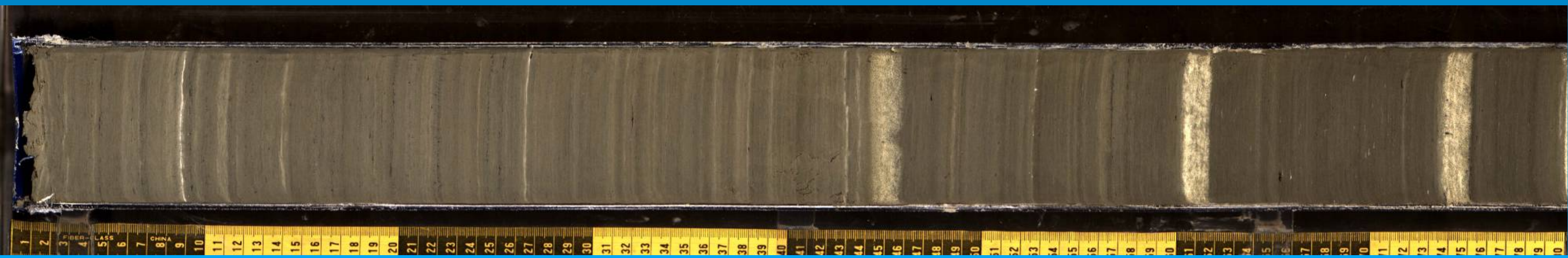
Climate Model Simulations of Winter Jet Streams

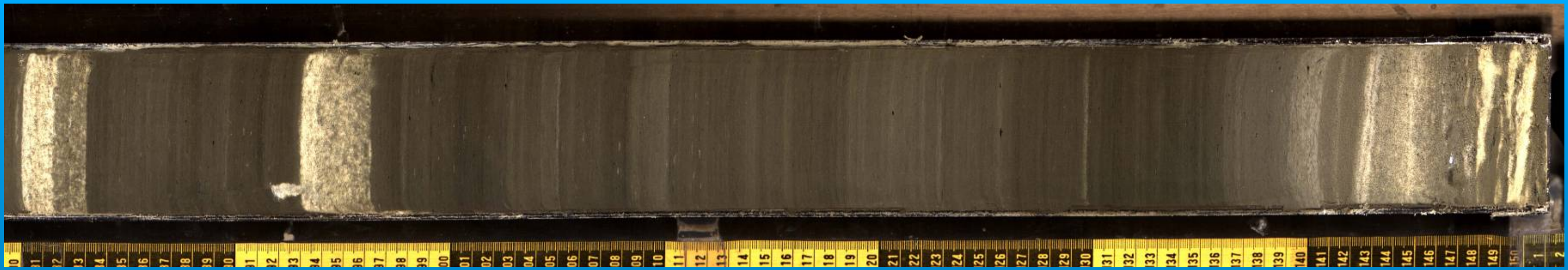


from Ruddiman, 2001

Wet glacial climates in the southwest
(big pluvial lakes)

Run 22H-1: 53.68 m to 55.18 m depth Glacial MIS 14

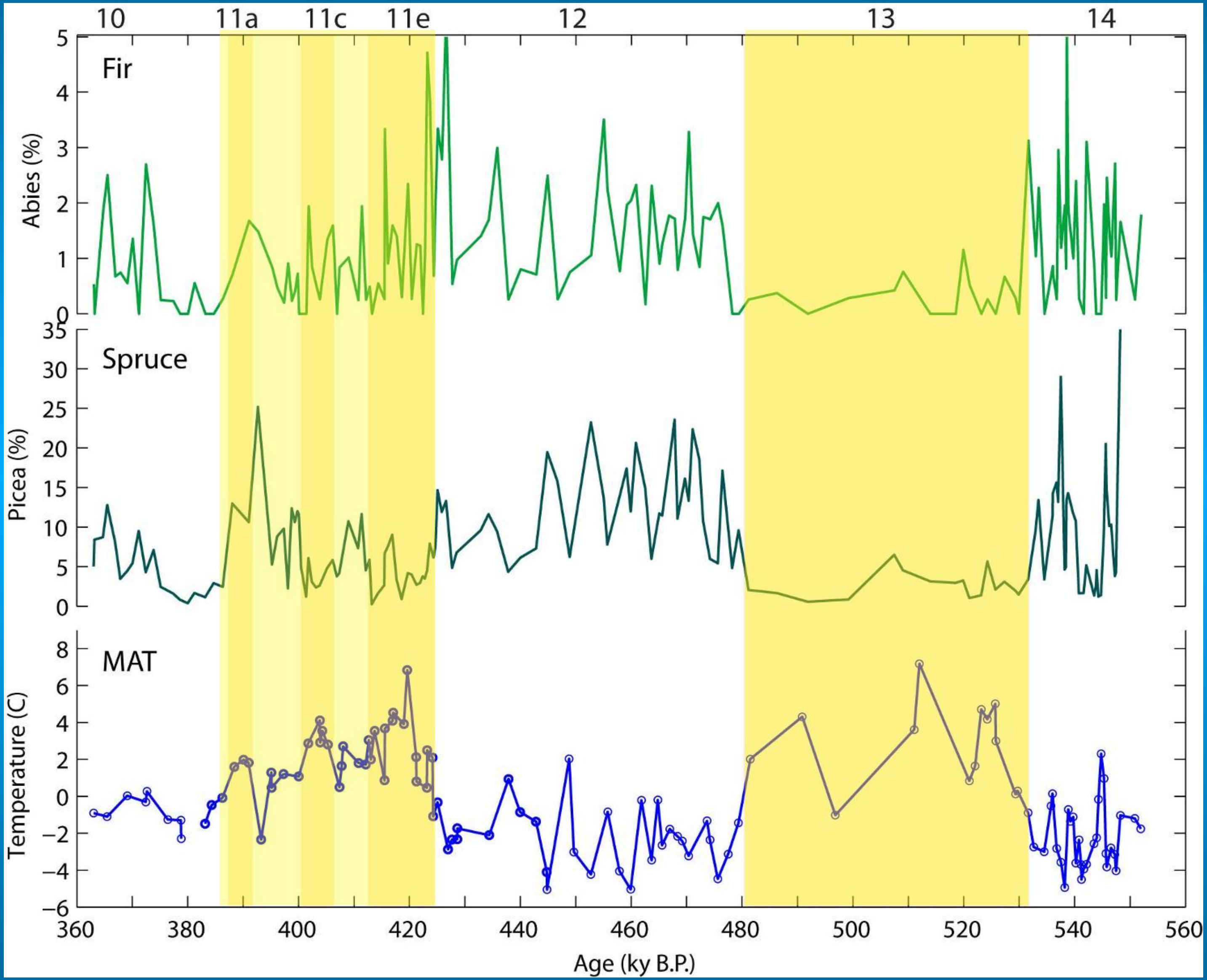




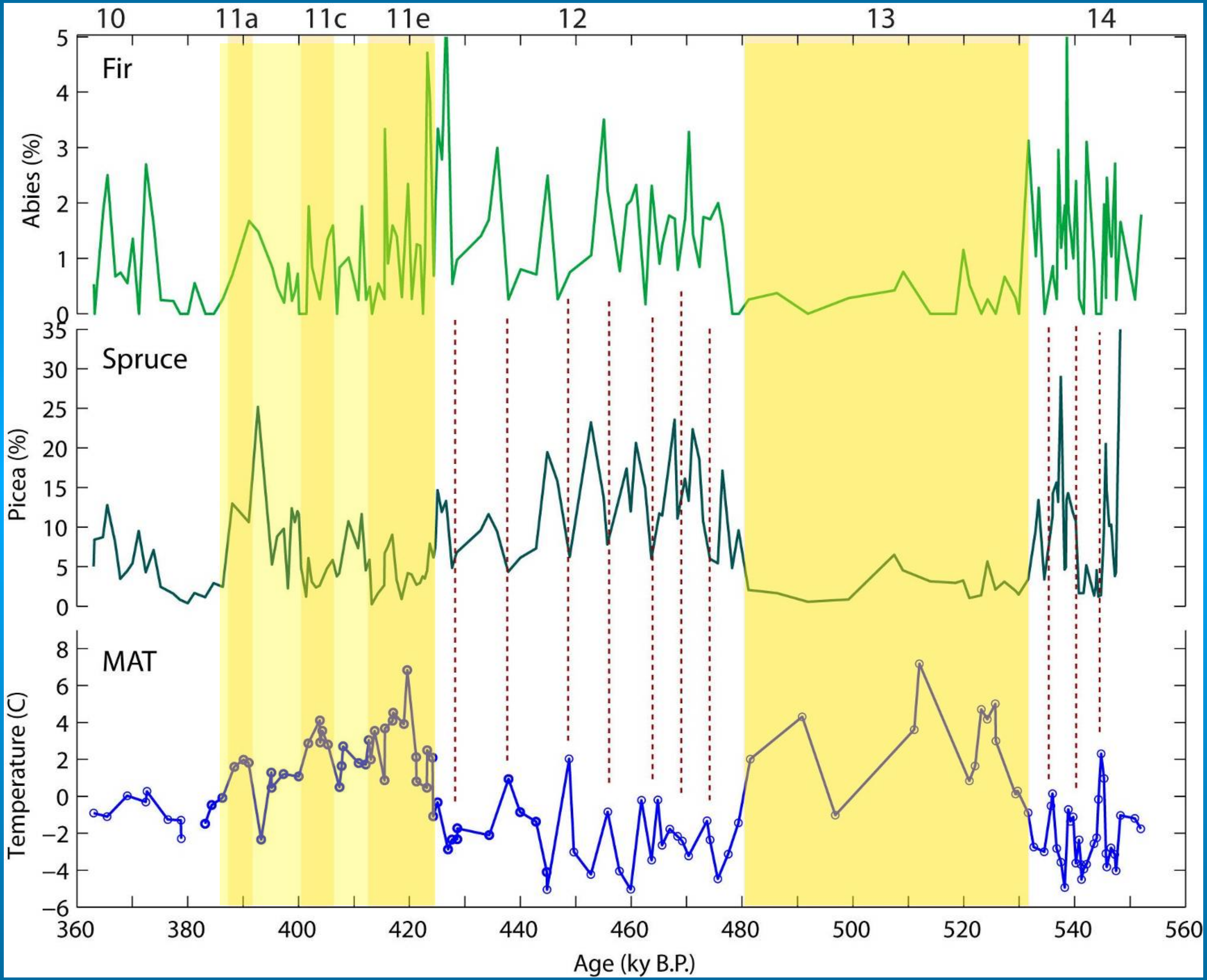
Thinly laminated silty diatomaceous clay with thick diatomites

Relatively deep lake

MAT and Boreal Pollen Taxa (Spruce and Fir)

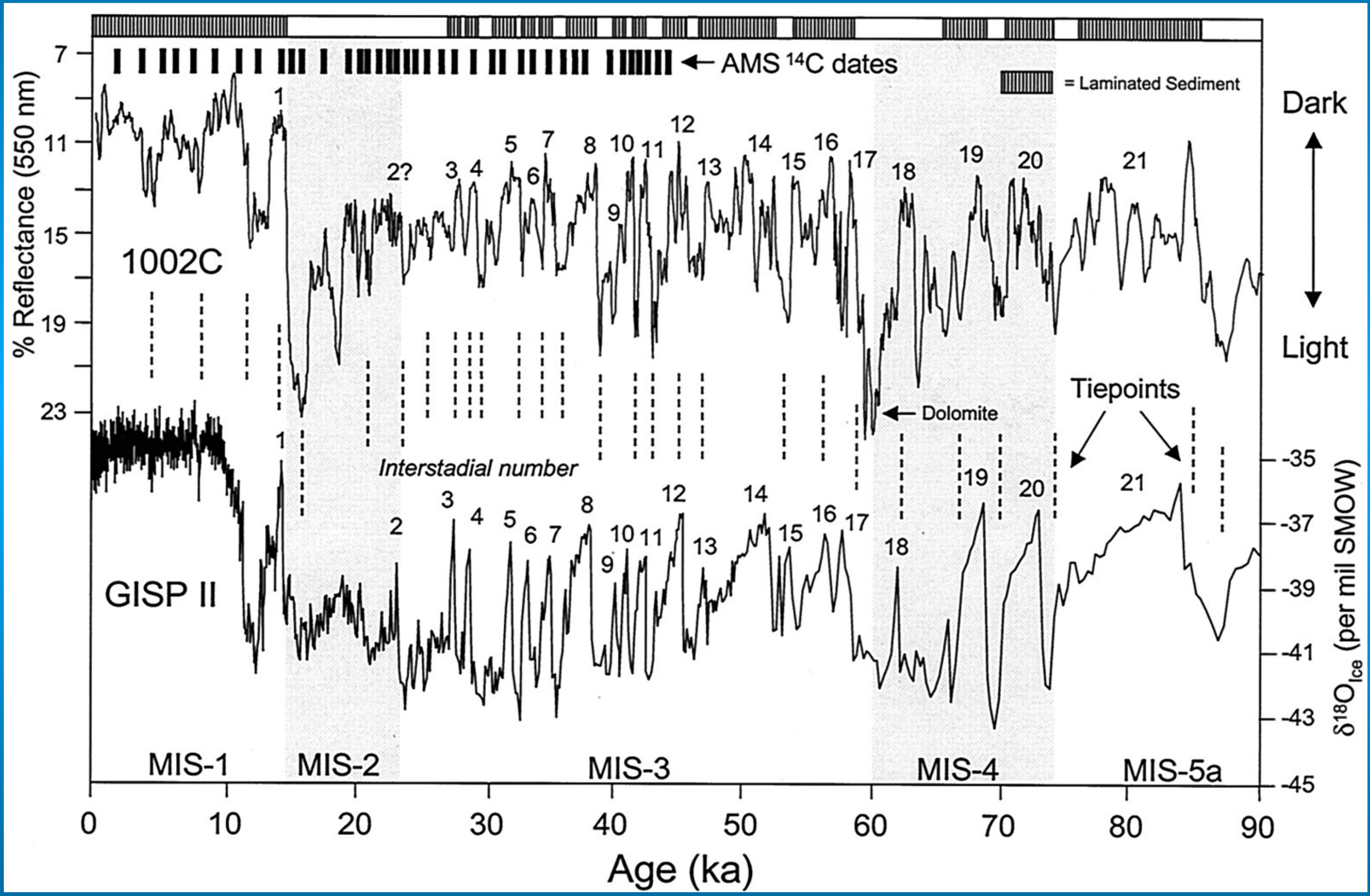


MAT and Boreal Pollen Taxa (Spruce and Fir)



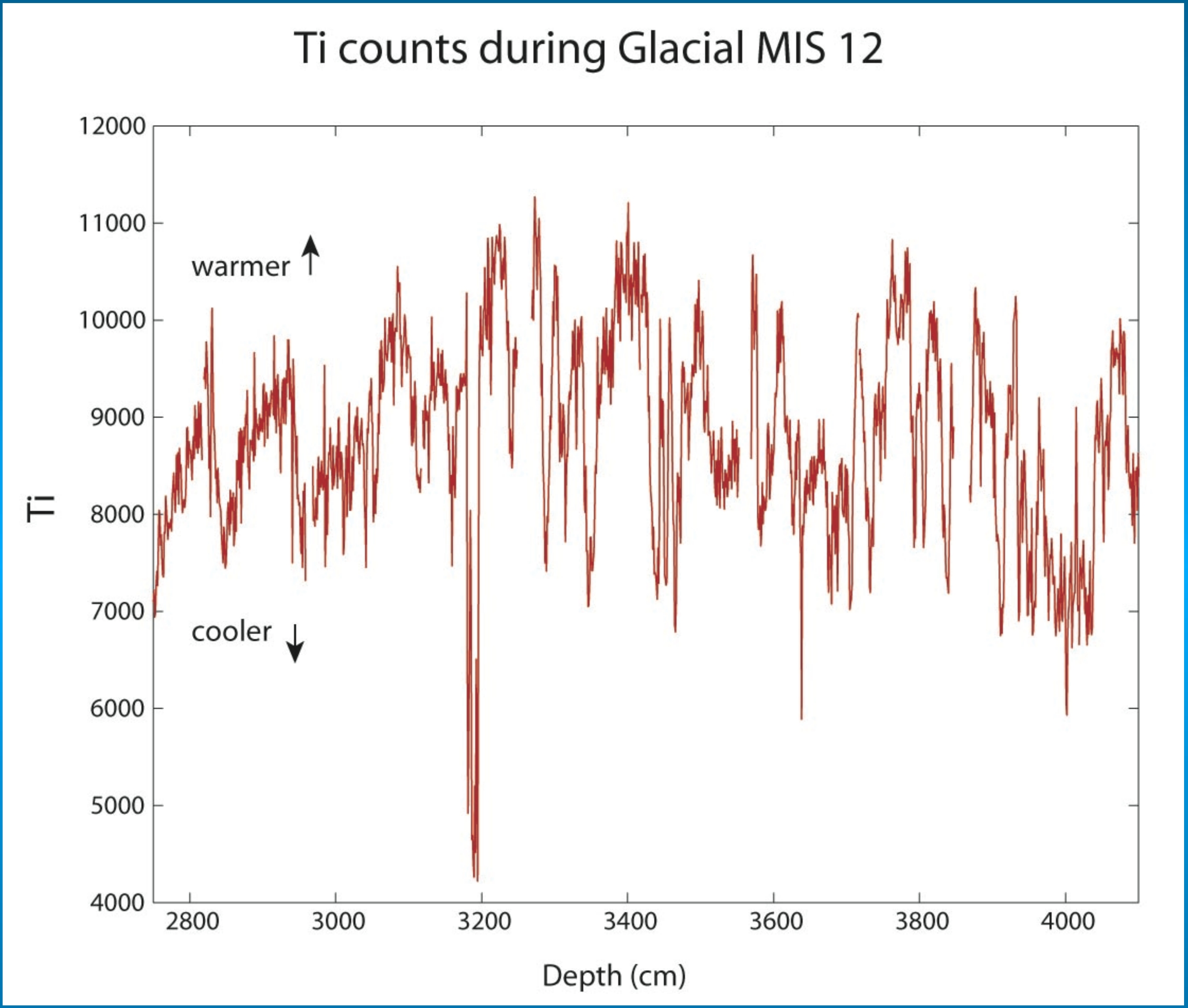
Millennial-scale climate change evident during glacial stages

Millennial Scale Climate Change During the Last Ice Age from Greenland and Venezuela



Gradual coolings followed by abrupt warmings

Peterson et al. 2000

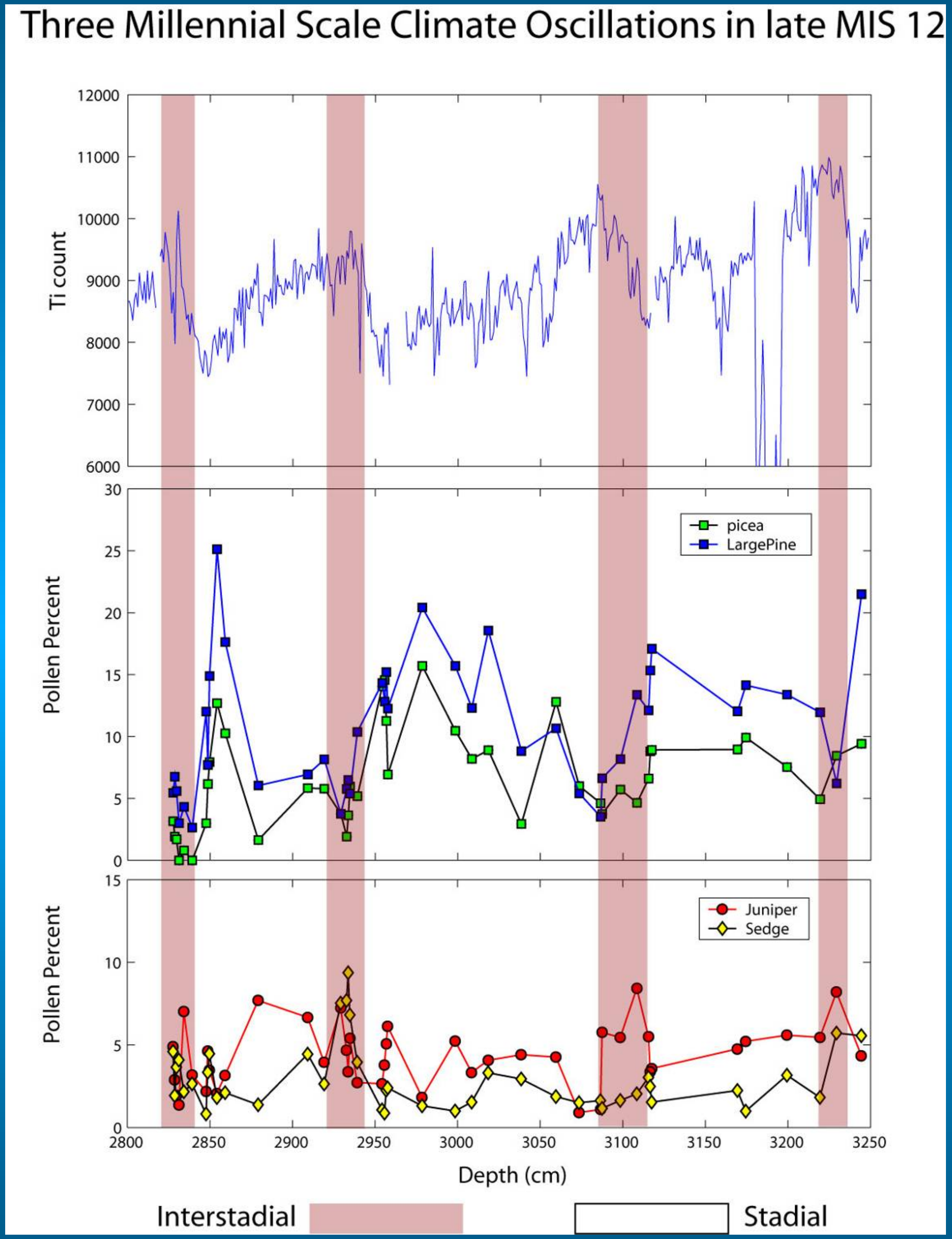


~ 21 millennial-scale Dansgaard-Oeschger – like events
(gradual coolings followed by abrupt warmings)

warmer

cooler

warmer



During Interstadials

Higher Ti:

Dust input increases?

Less ice cover and enhanced runoff?

Sharp decreases in Pine and Spruce

Increases in Juniper and Sedge

Summary

- Core VC-3 spans ~ 200 kyr over the middle Pleistocene (MIS 14 - MIS10) from ~550,000 years ago to ~360,000 years ago.

- New paleotemperature technique based on soil bacteria lipid structure (MBT/CBT) appears to work well in this setting – matches vegetation

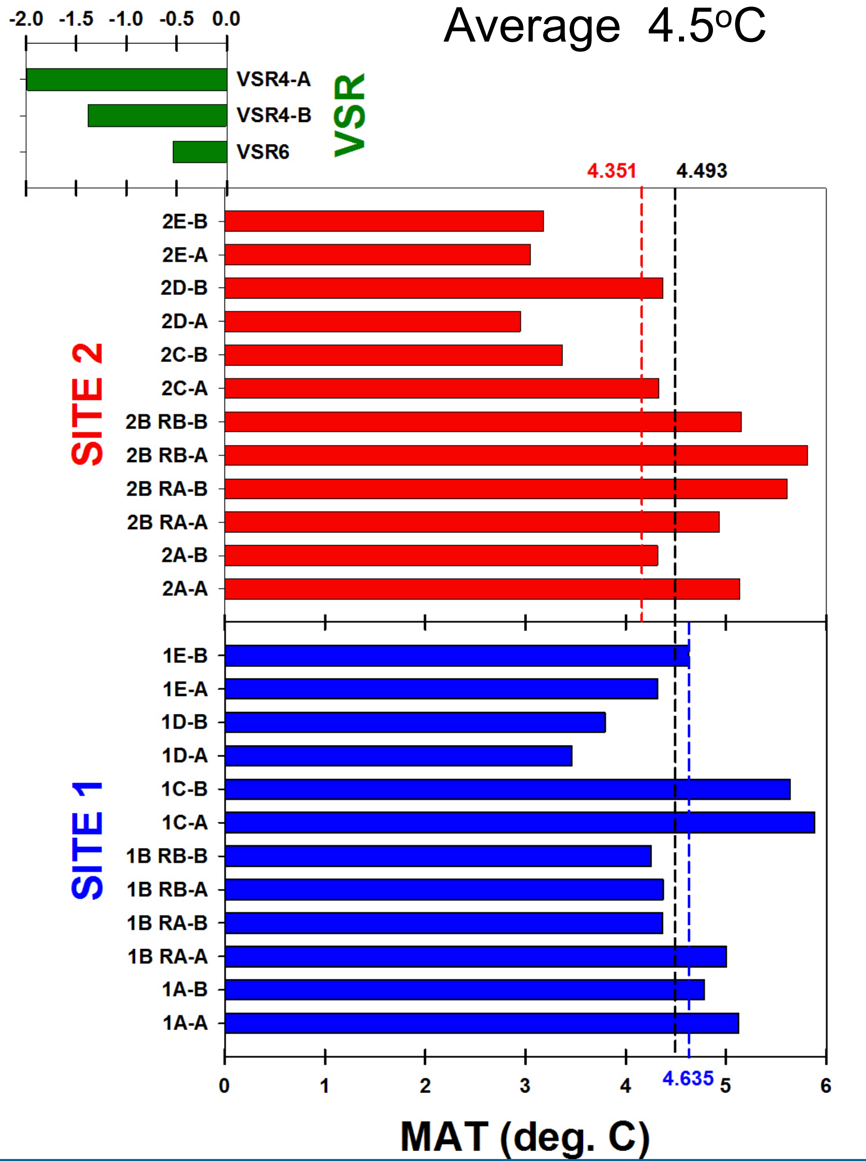
- Extended periods of climatic aridity occur during the warmest phases of the interglacials (MIS 11 and MIS 13)

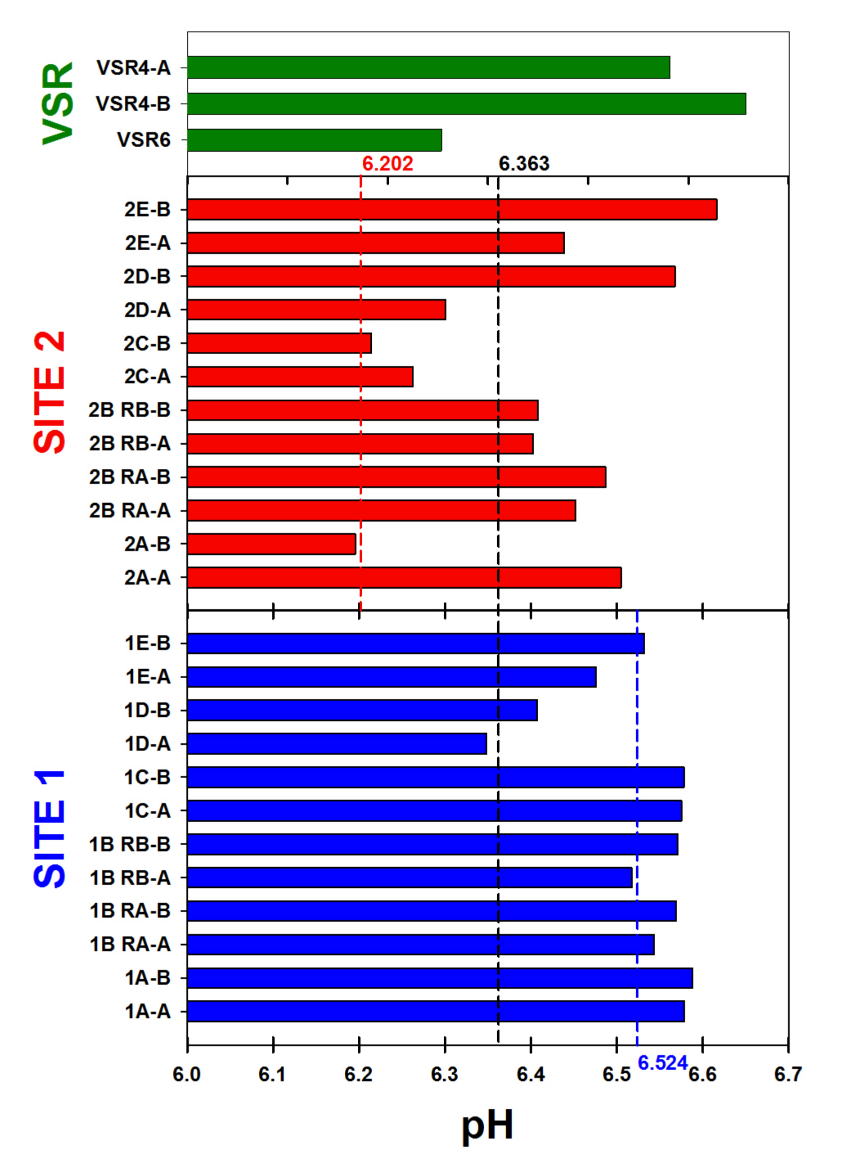
- Natural analog supports projections of "dust bowl-like" conditions resulting from anthropogenic warming – primarily decrease in winter precipitation

- Orbital-scale variability (Precession) noted during MIS 11 with a temperature variation of ~2^{o}C and a strong vegetation response

- Millennial-scale variability strong during glacial stages – up to 6^{o}C temp. variation and a strong vegetation response

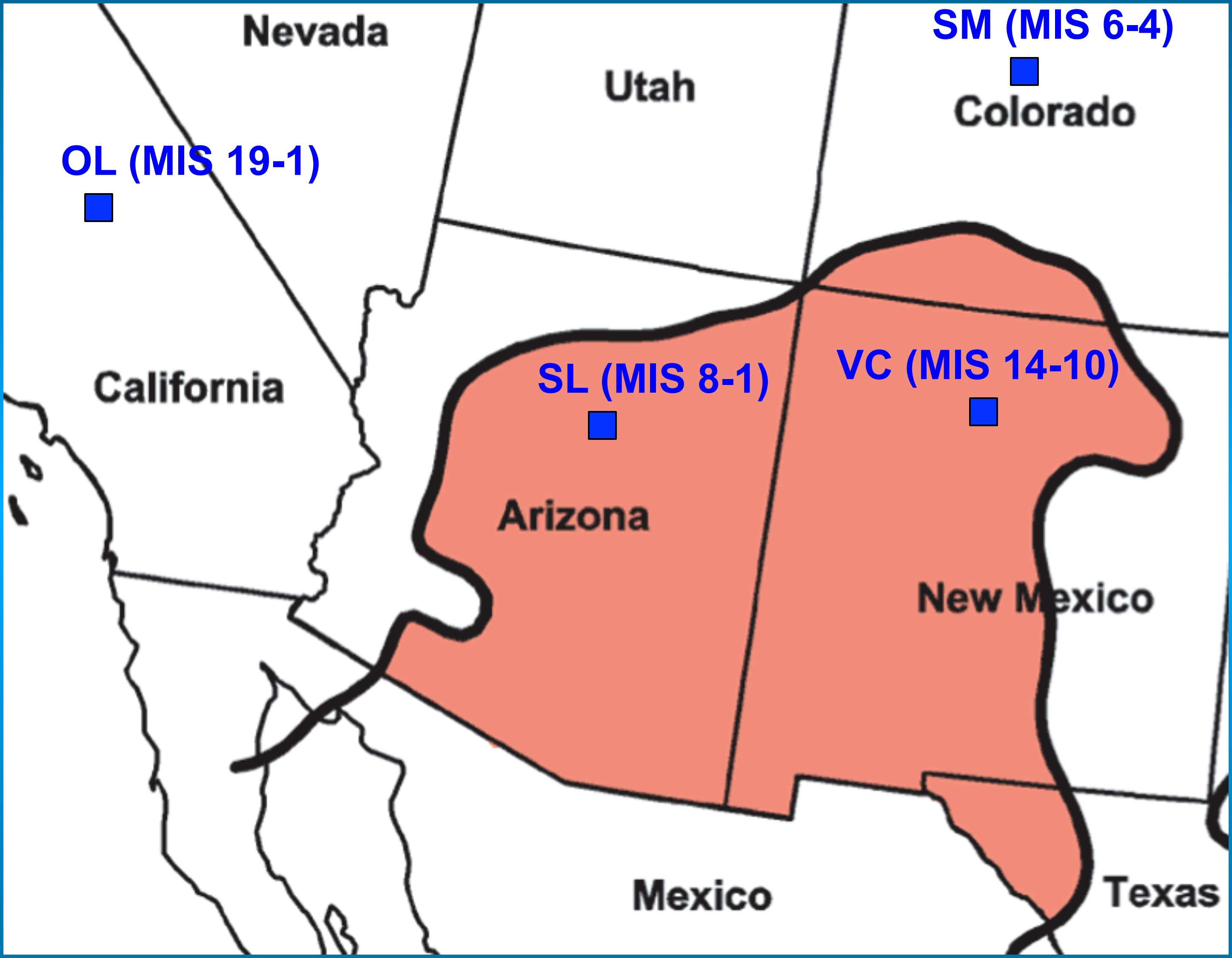
Modern Soil Calibration at VCNP Headquarters: MAT = 4.6°C





Unpublished Data: Sergio Contreras UM-Duluth

Monsoon Region of the SW United States



New Records to test monsoon vs. winter westerly contributions across glacial terminations (glacial to interglacial timescales)