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CLIMATE CHANGE RESEARCH

Workshop on "Palaeoclimate and Human Dispersal during Marine Isotope Stage 3" Chennai, 12.-17.12.2011

MIS 3 Climate Variability Recorded in Speleothems

Dominik Fleitmann
Institute of Geological Sciences and Oeschger Centre for Climate Change Research
University of Bern, Switzerland

The Arabian Peninsula

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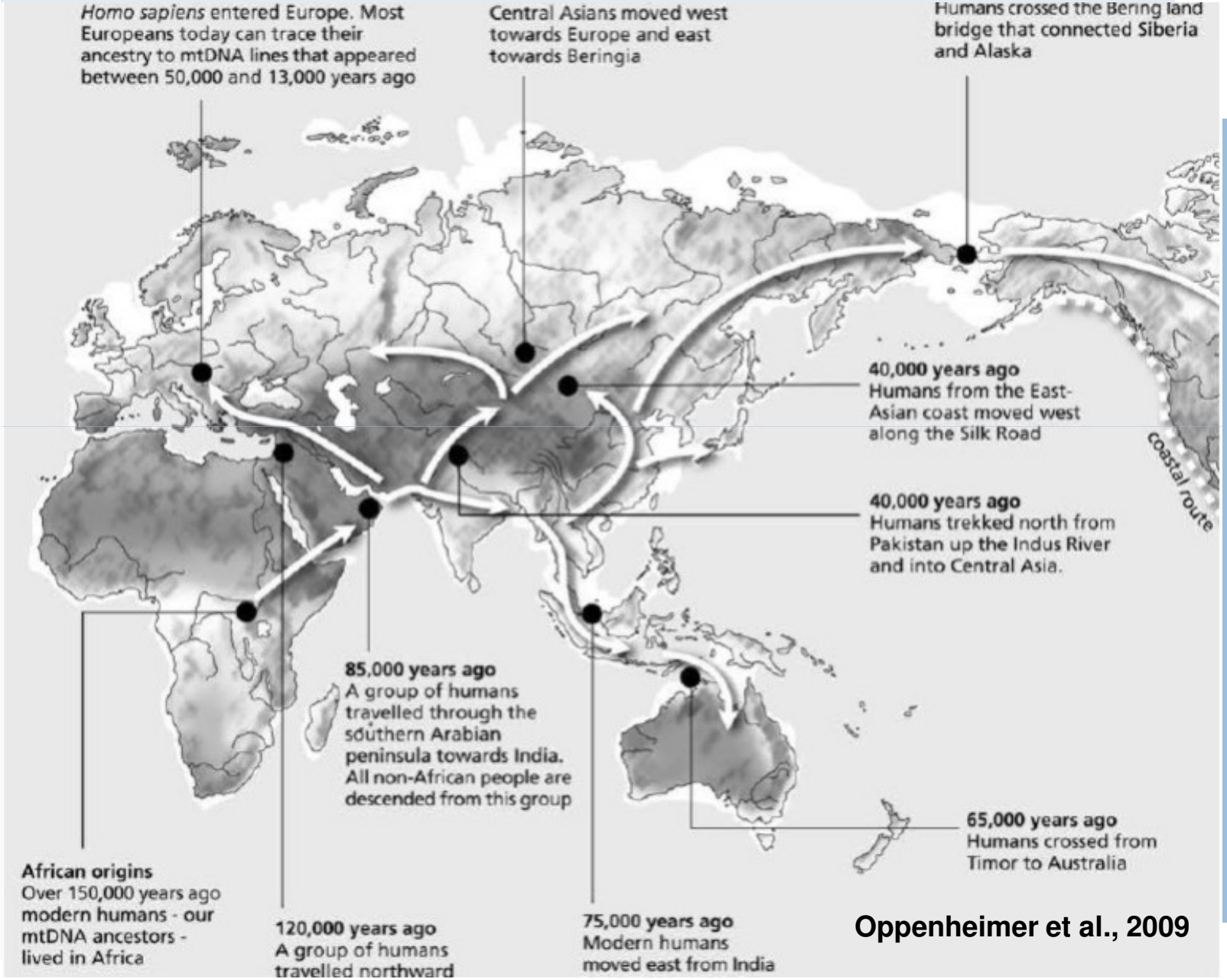

Oppenheimer et al., 2009

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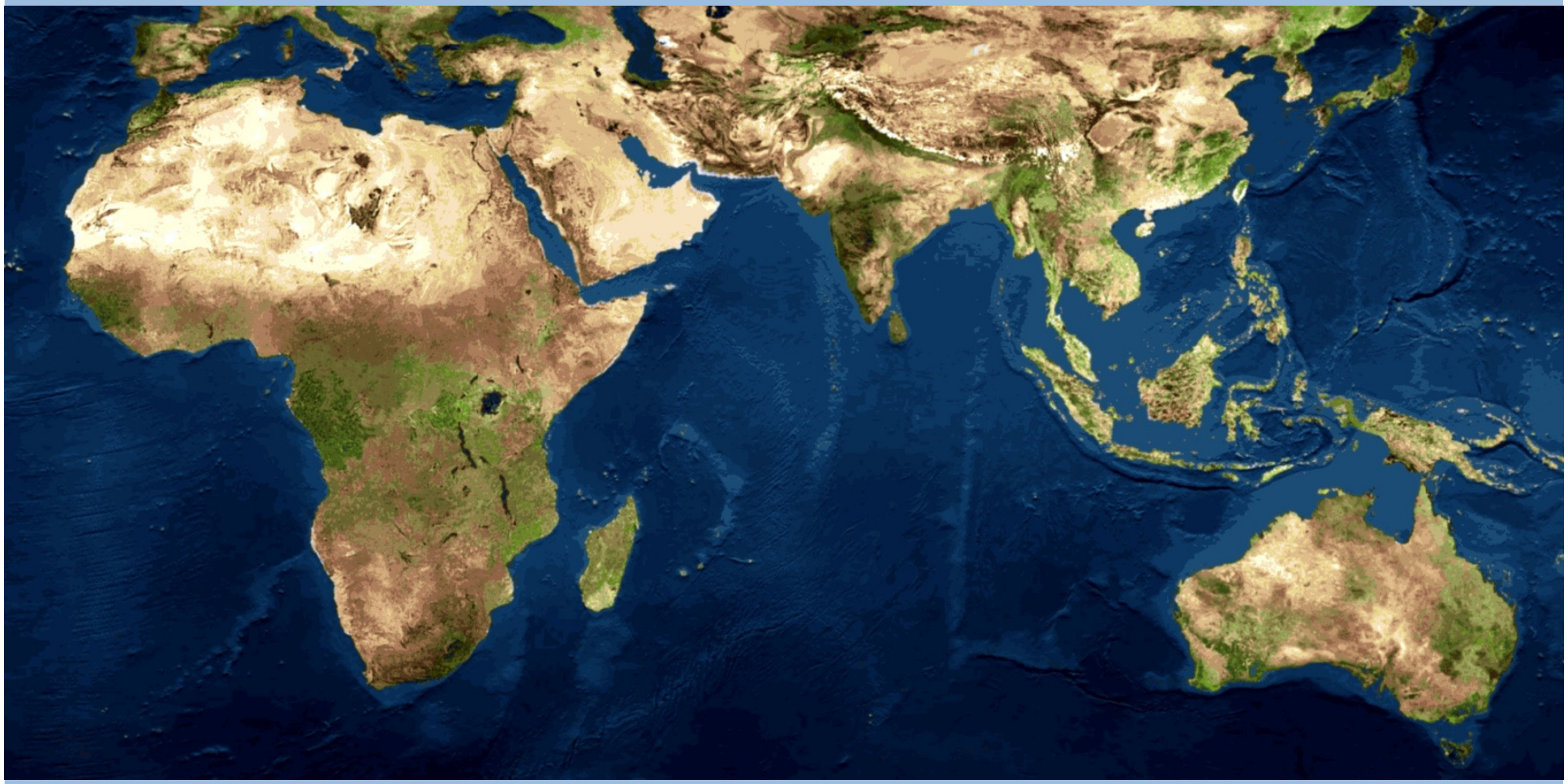

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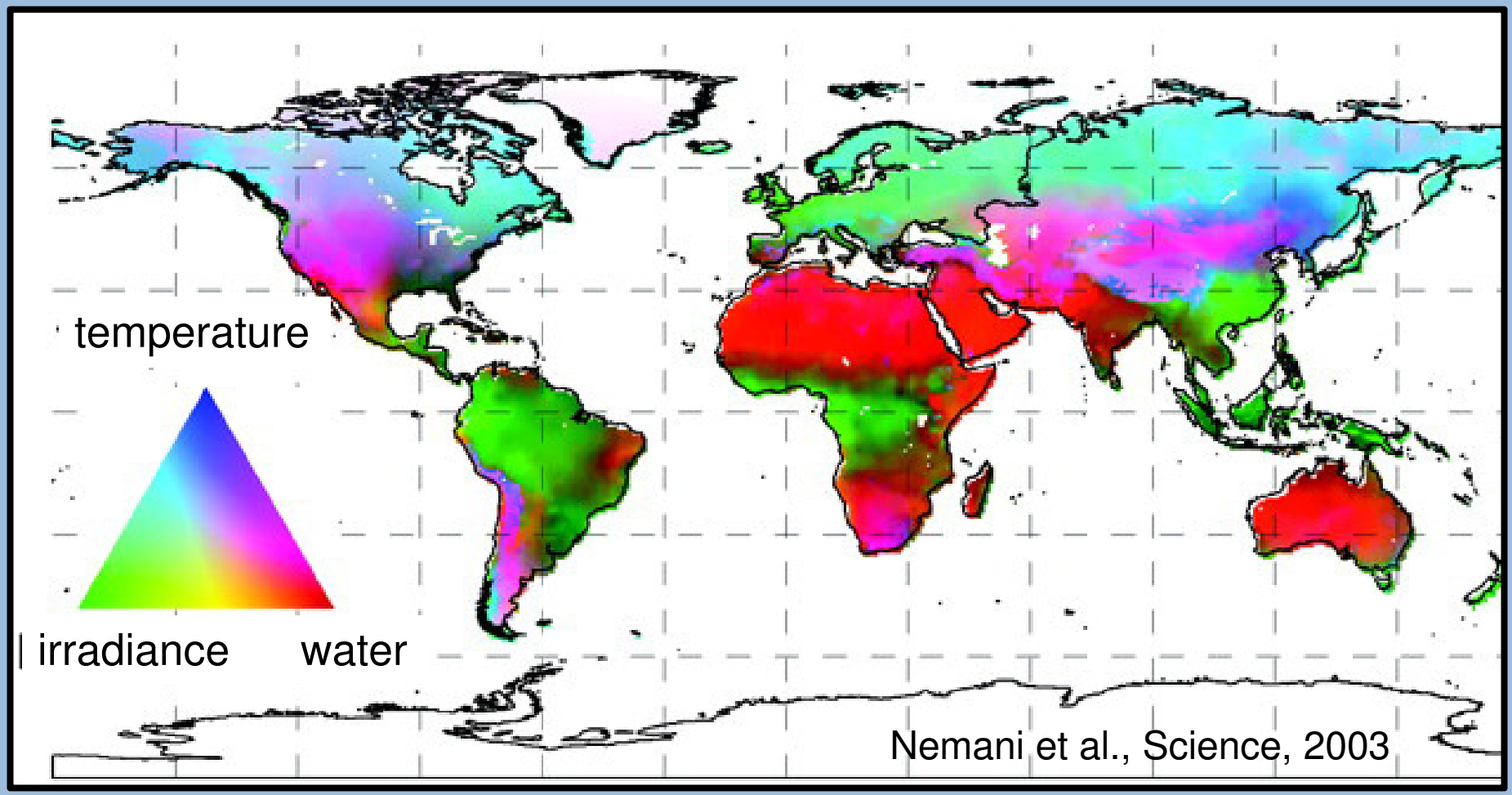
Vegetation



Periods of Favorable Climatic Conditions for Human Dispersal

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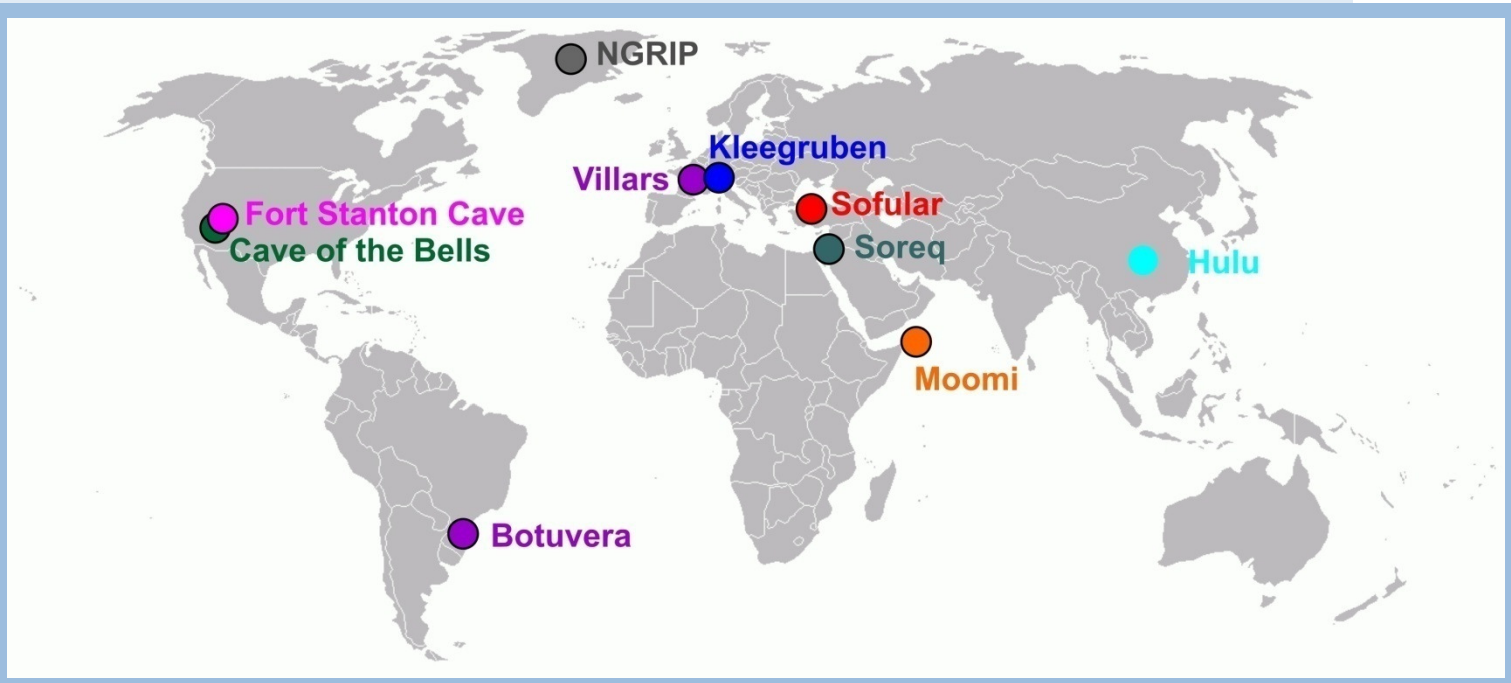
Absolutely-dated speleothem records covering MIS 3



Villar Cave, France: Genty et al., Nature, 2003
Kleegruben Cave, Austria: Spotl et al., QSR, 2006
Sofular Cave, Turkey: Fleitmann et al., GRL, 2009; Badertscher et al., Nature Geosci., 2011; Fleitmann et al., in prep.
Hulu Cave, China: Wang et al., Science, 2001
Fort Stanton Cave, USA: Asmerom et al., Nature Geosci., 2010
Cave of the Bells, USA: Wagner et al., Nature Geosci., 2010
Moomi Cave, Yemen: Burns et al., Science, 2003; Shakun et al., 2007
Botuvera Cave, Brasil: Wang et al., QSR, 2006

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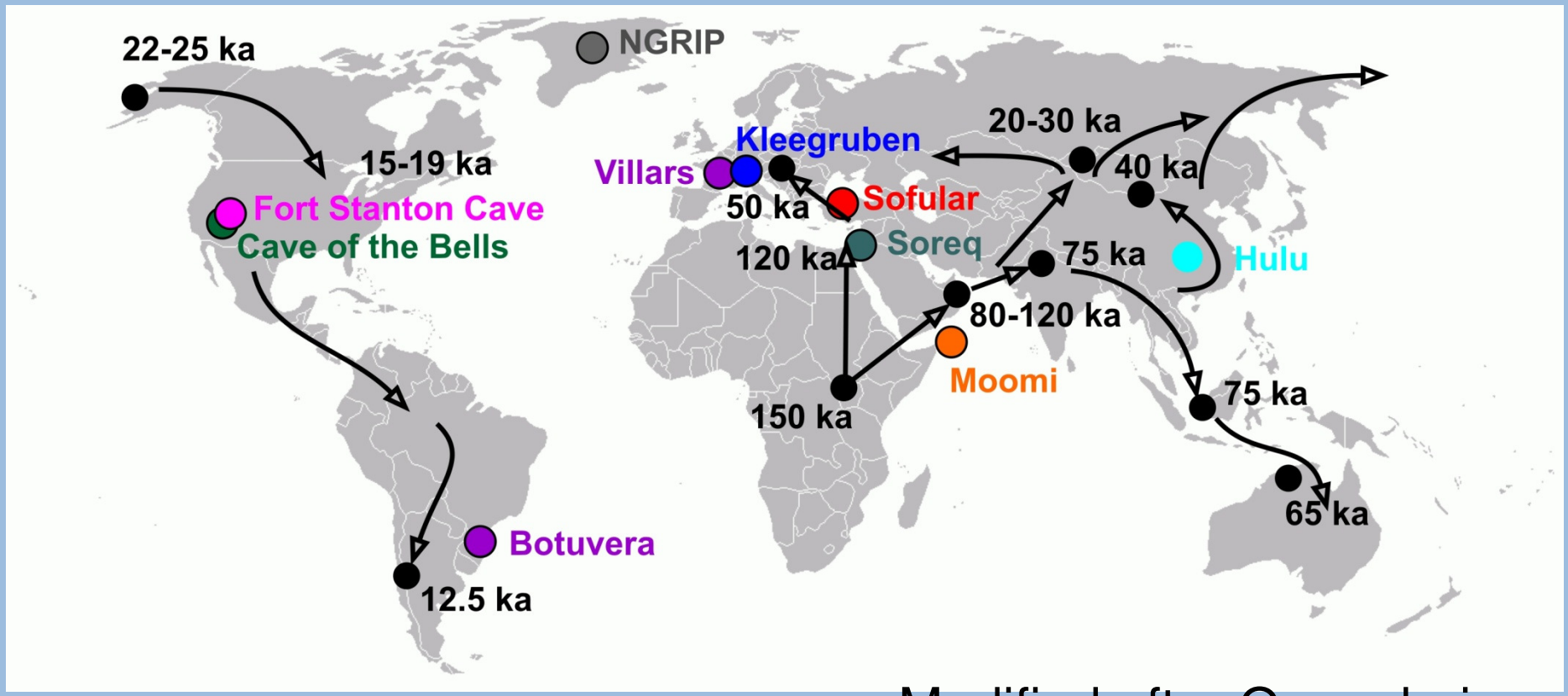
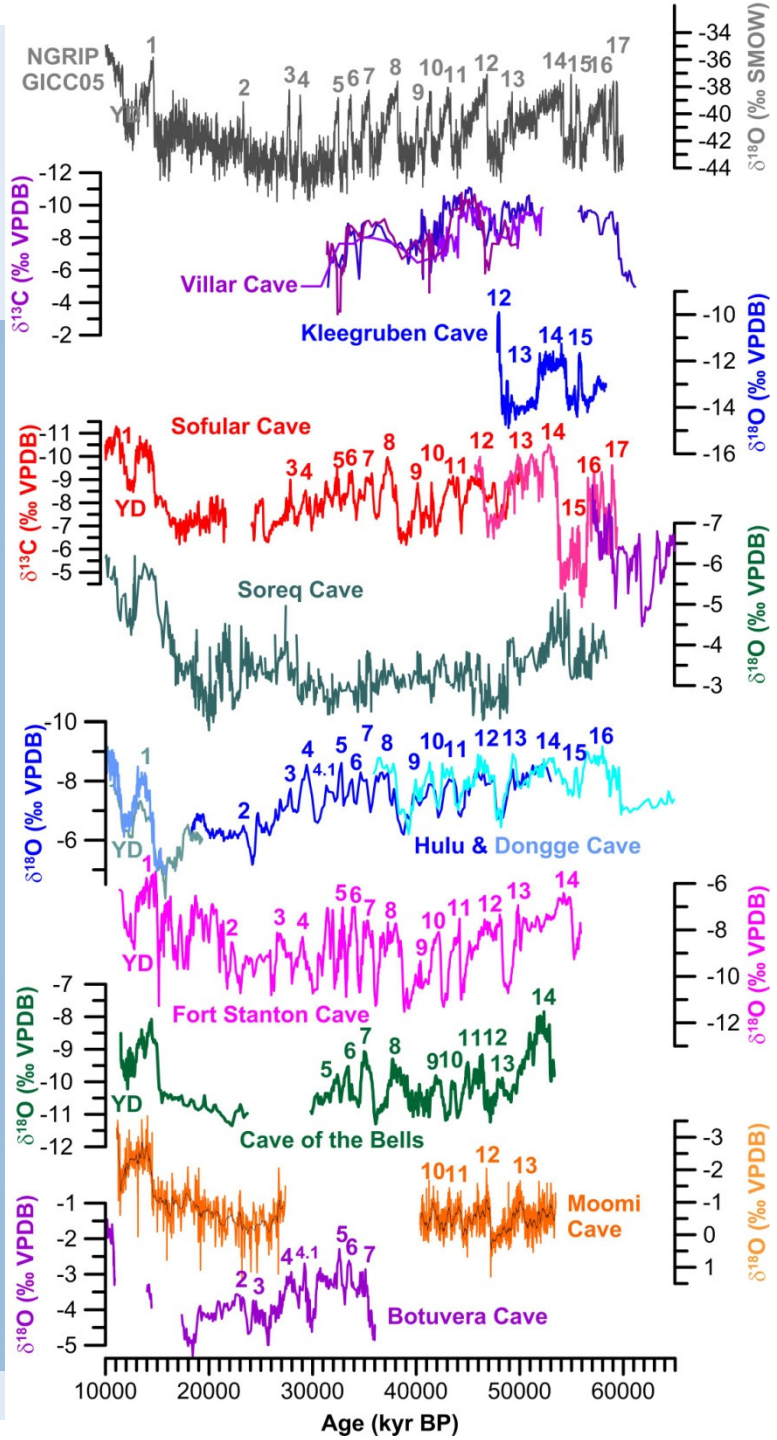


Modified after Oppenheimer

Speleothem records

Timing of D-O events!



Speleothems

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Speleothems

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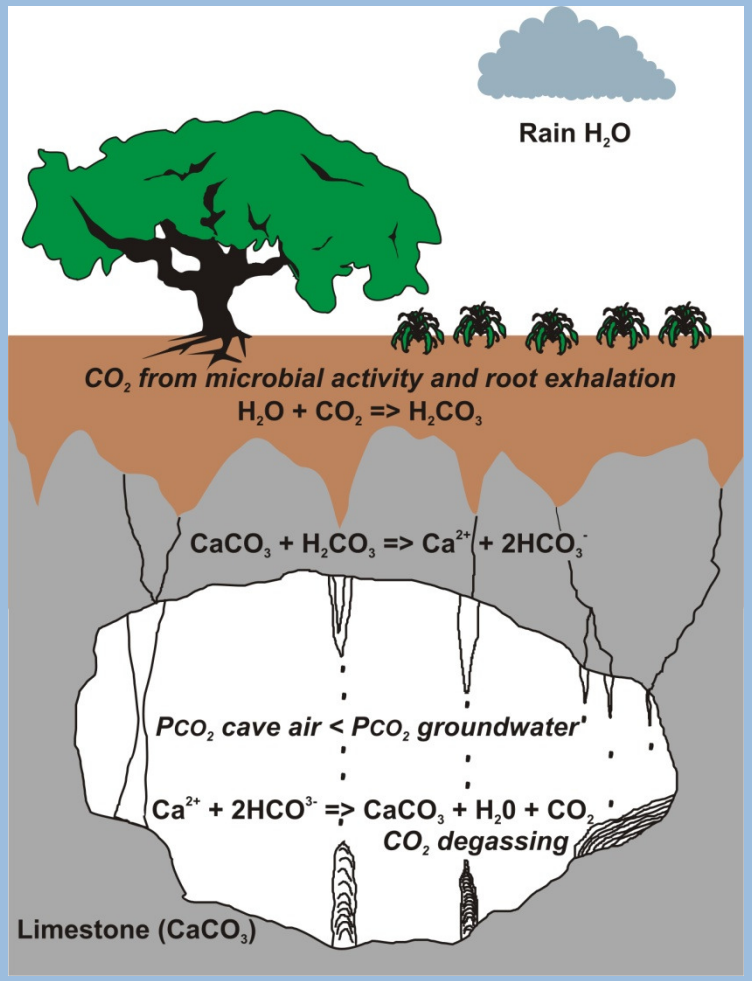

Fleitmann *et al.*, 2004

Climatic & Biological Signals

Rainfall

Temperature

Vegetation

SOILWATER

↓

AQUIFER

↓

DRIPWATER

↓

SPELEOTHEM

Speleothem-based Paleoclimate Reconstructions

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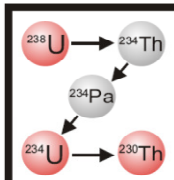


Uranium Series Dating

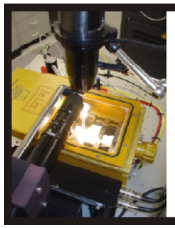
Back to ~400.000 kyr B.P. (Before Present)
Absolute ages
Small age uncertainties

Oxygen and carbon isotopes

$\delta^{18}O$
$\delta^{13}C$

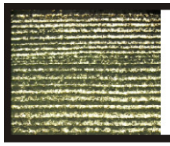
“Environmental isotopes”
Oxygen isotope ratios in speleothems directly reflect climate (e.g., Amount of rainfall)

Carbon isotope ratios often reflect the type of vegetation above the cave



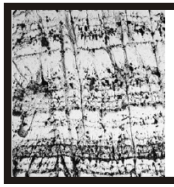
Trace Elements

Sub-monthly resolution possible
Mg, Na, K, Sr, Ba concentrations in speleothem calcite often reflect climate
S reflects atmospheric sulfur contents of the atmosphere



Annual Band Thickness

“Tree rings”
Thickness reflects amount of precipitation



Speleothem Fluid Inclusions

Trapped groundwater and precipitation
Noble gas concentrations and Hydrogen isotopic compositon.
Paleotemperatures & Atmospheric gas conc.

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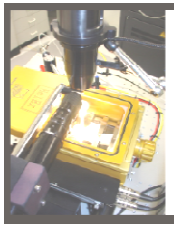

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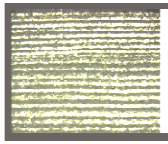

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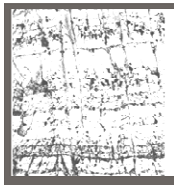

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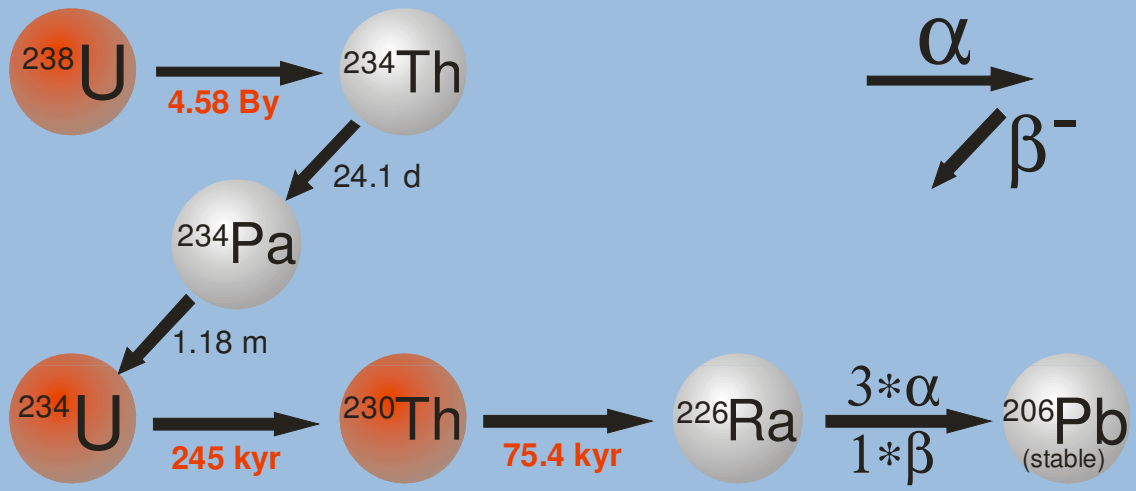
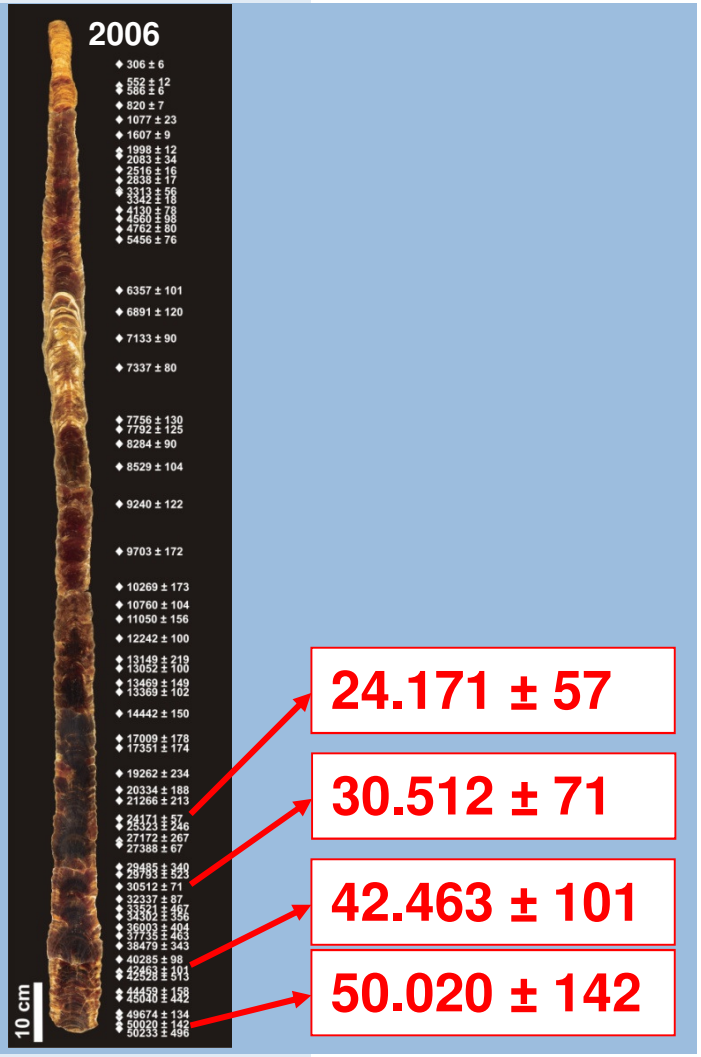


Absolute ages

Small age uncertainties

(typically 0.5 – 2% of the absolute age)



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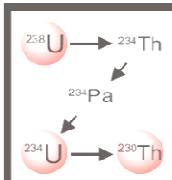

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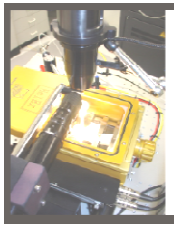

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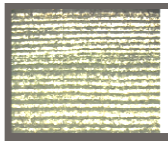

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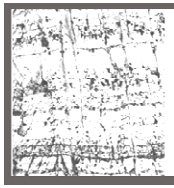

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$\delta^{18}O$: Source of Moisture, Northern Oman

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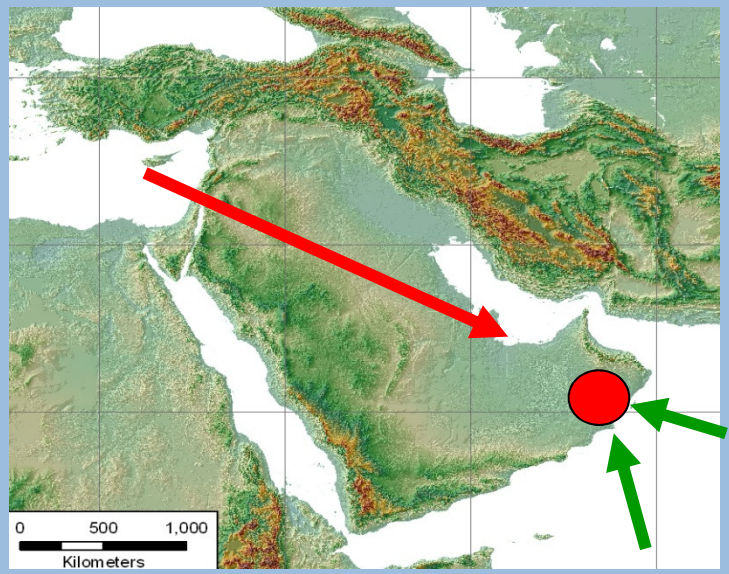

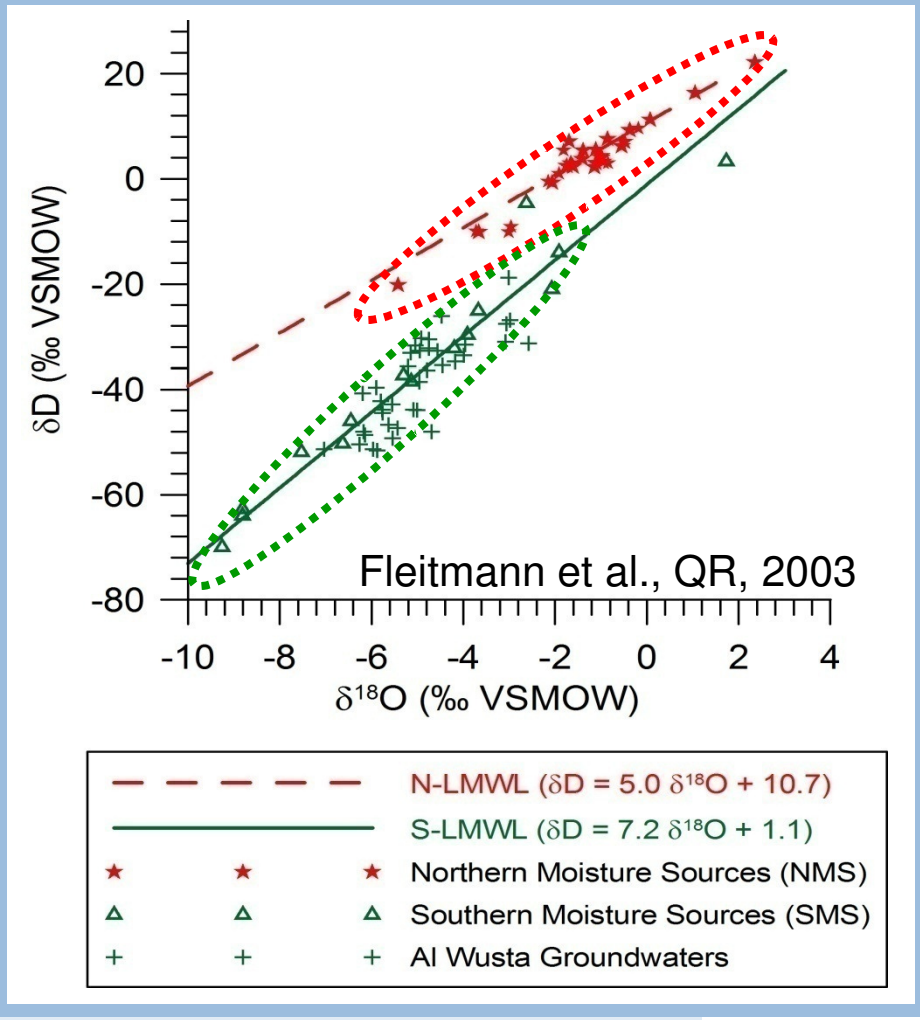

$\delta^{18}O$: Source of Moisture, Hoti Cave, Oman

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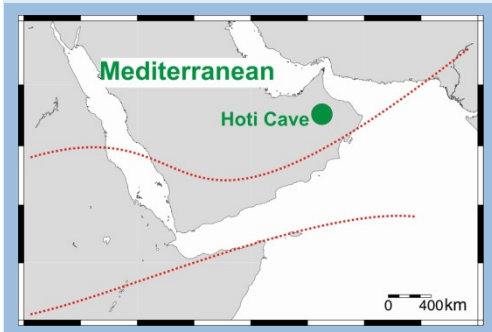

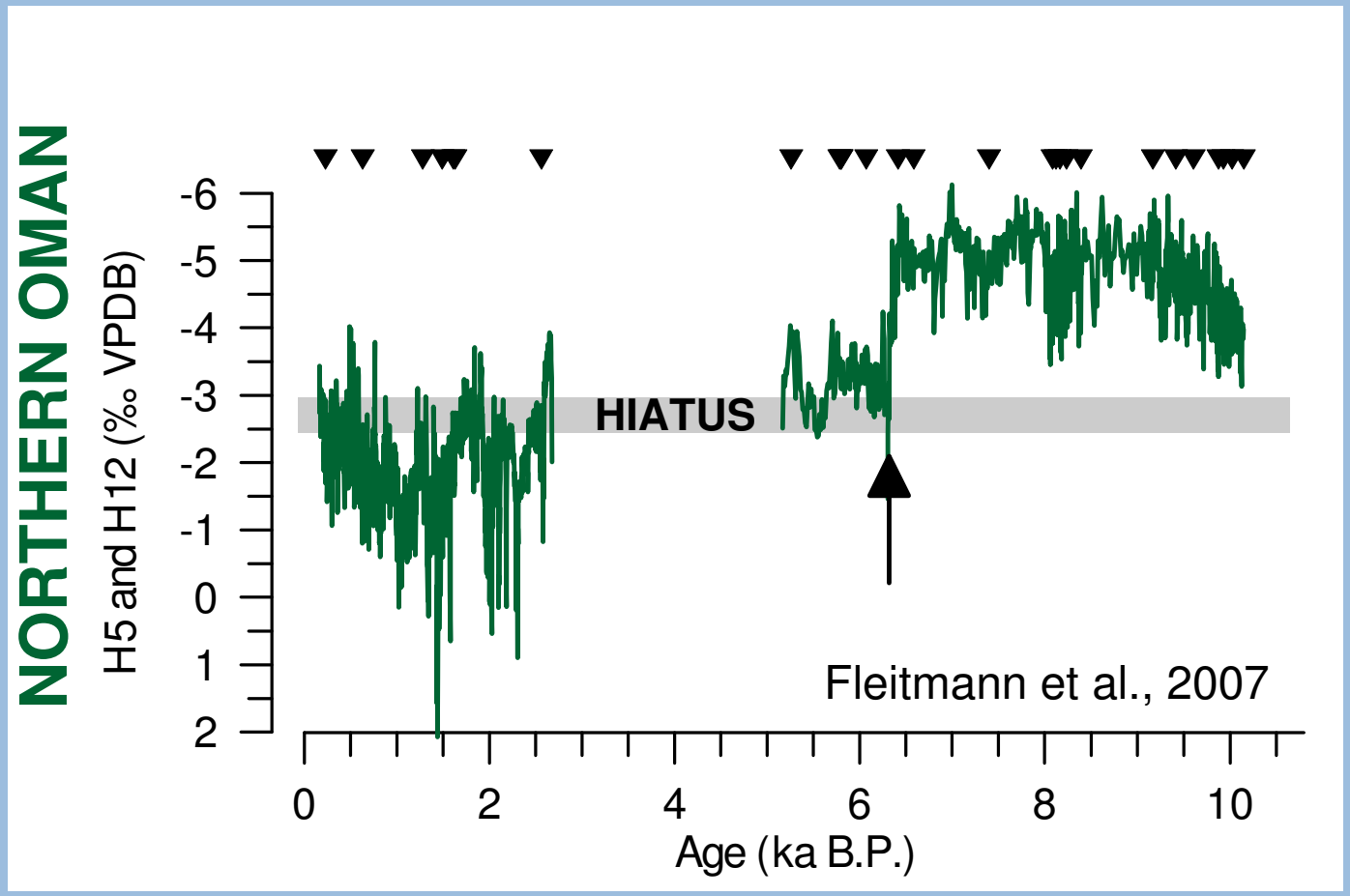

$\delta^{18}O$: Amount of Rainfall („Amount Effect“)

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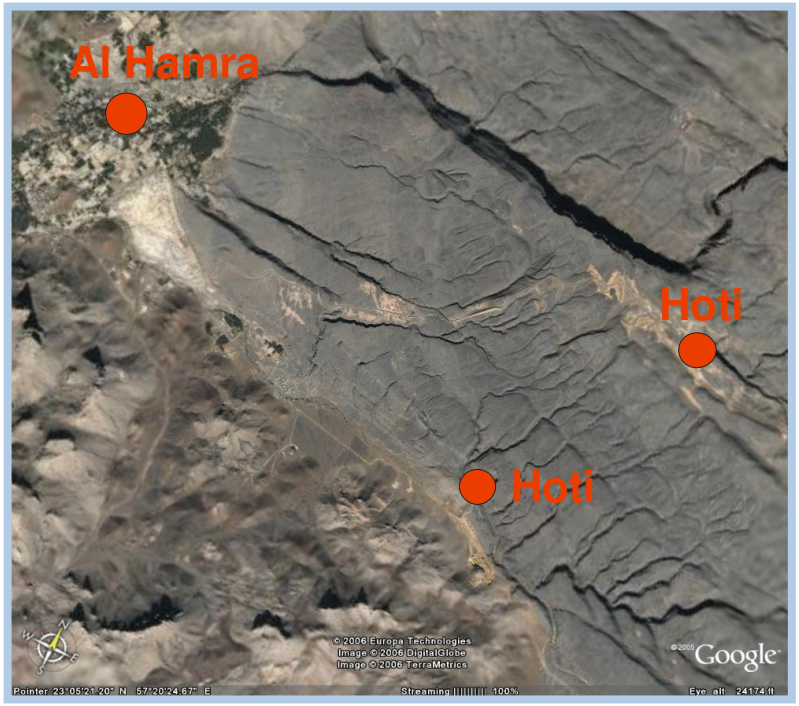
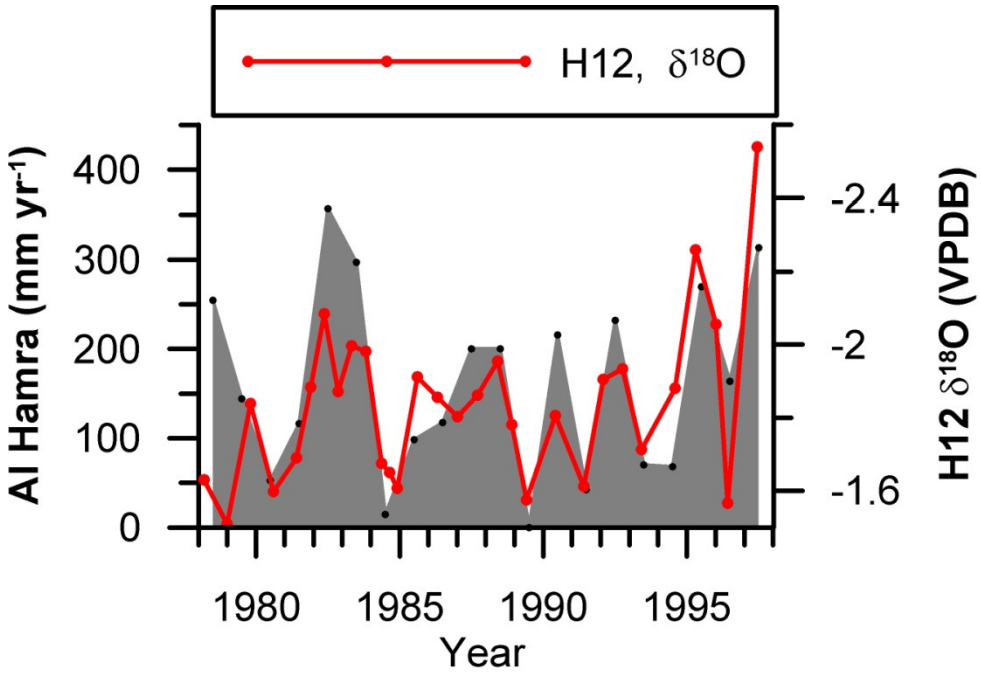
Stalagmite H12, Hoti Cave (Northern Oman)





More negative oxygen isotope values = Higher precipitation

$\delta^{18}O$: Amount of Rainfall („Amount Effect“)

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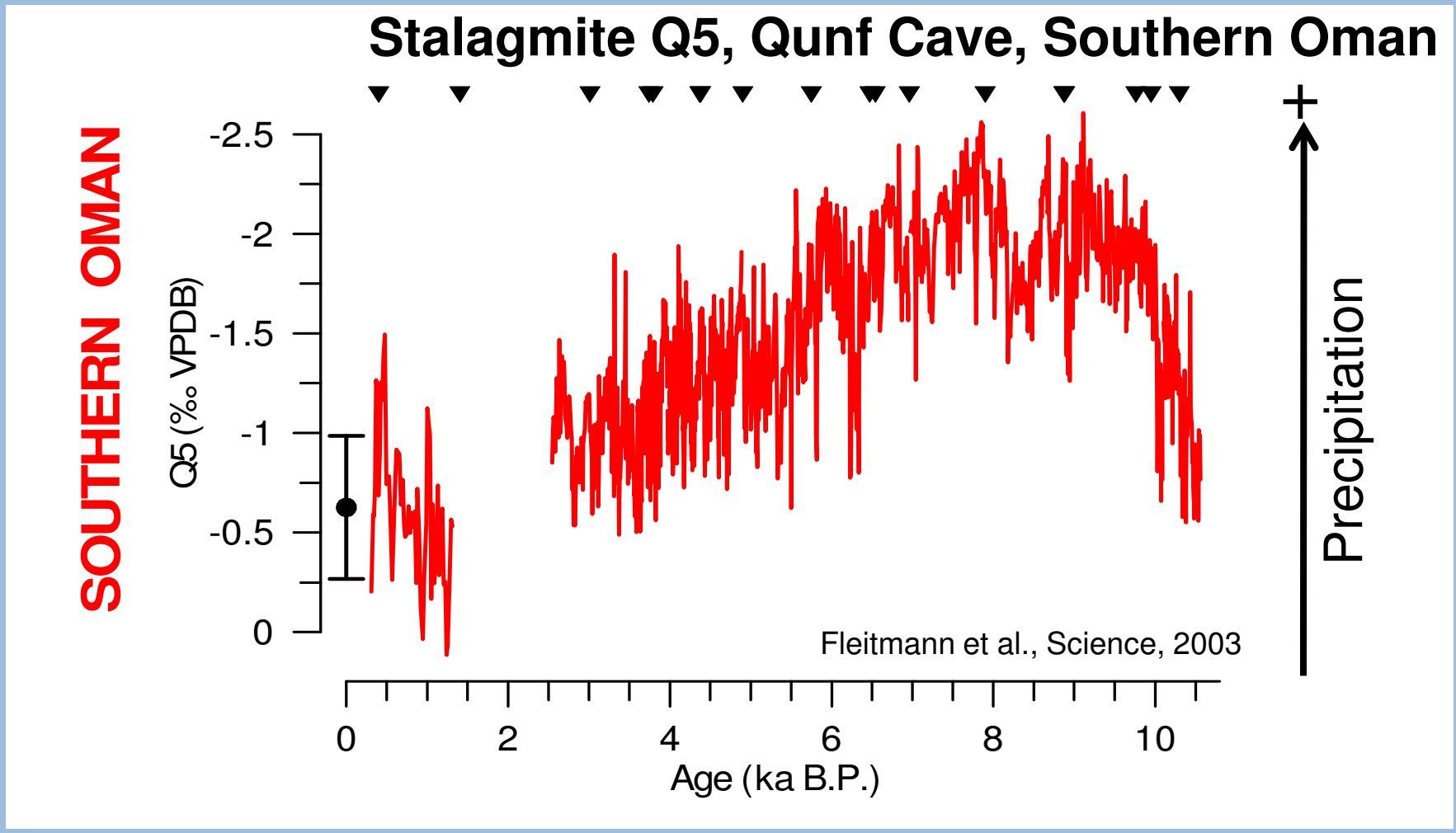

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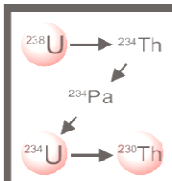

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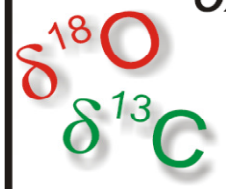

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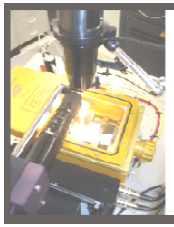

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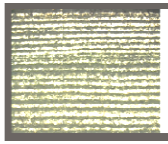

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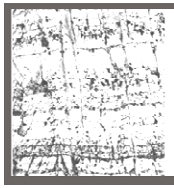

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$\delta^{13}C$ in Speleothems

C3 plants (trees and shrubs)

Soil CO_2: -26 and 20 ‰ (PDB)

$\delta^{13}C_{calcite}$: ~ -13‰

C4 plants (grasses)

Soil CO_2: -12 and 8‰ (PDB)

$\delta^{13}C_{calcite}$: ~ -6‰

- **Proportion of C3/C4 plants**
- **Recharge conditions (open/closed system conditions)**
- **Biological activity in the soil**
- **Degree of interaction with limestone bedrock**
- **Rate of CO_2-degassing of cave drip water**

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Sofular Cave, Northern Turkey

Annual rainfall: around 1200 mm yr^{-1}

Weak seasonality of precipitation

Cave air temperature: 11.8 ± 0.1 °C

Vegetation: predominantely C3-type vegetation

Sofular Cave: Stalagmite So-1

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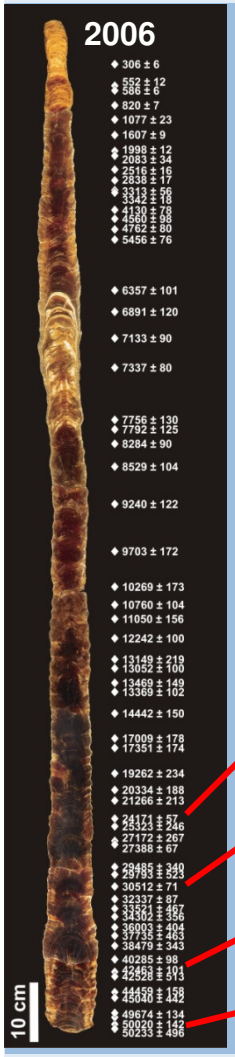

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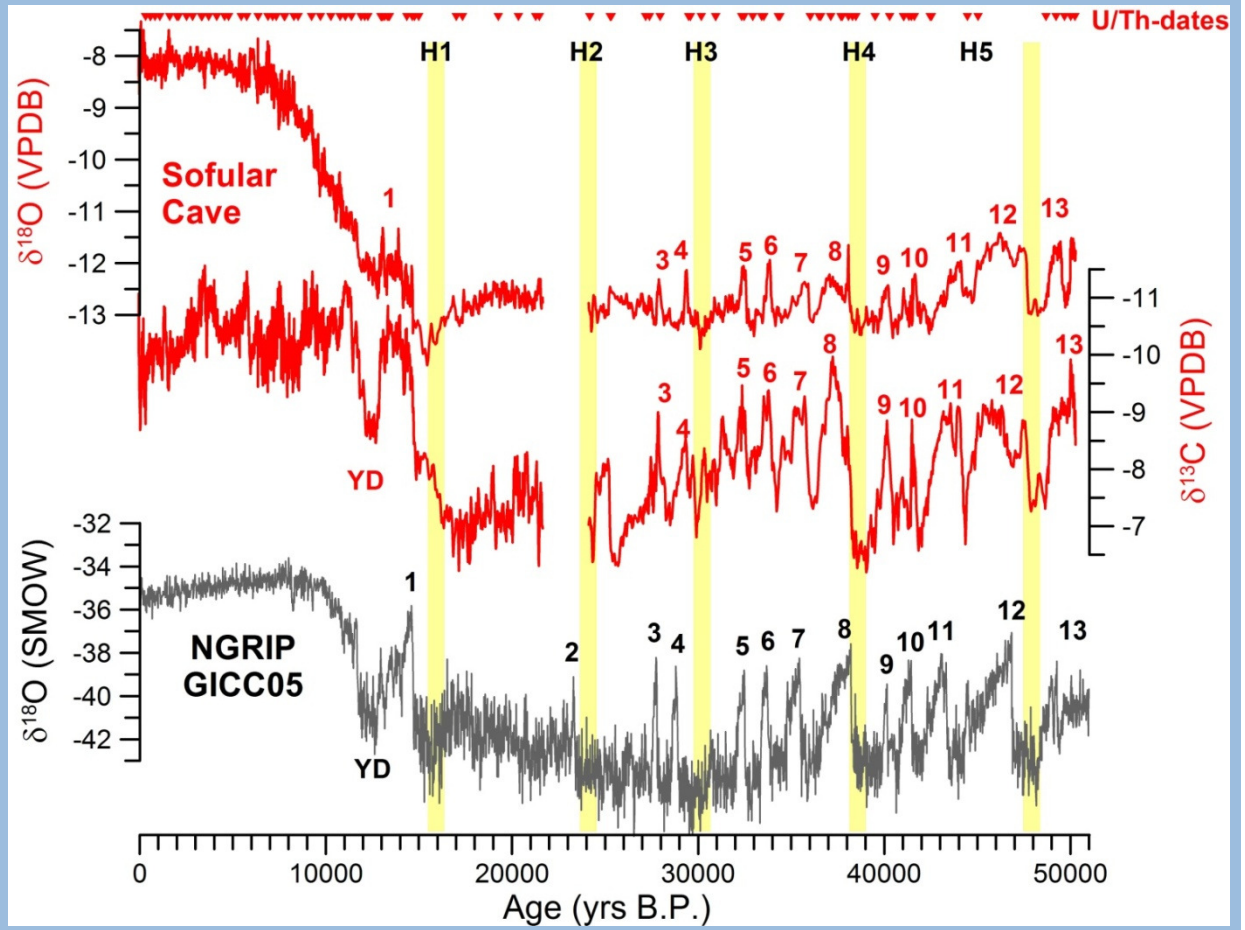

Fleitmann et al., GRL, 2009:
Badertscher et al., Nature Geoscience, 2011

Proxy Quality of $\delta^{13}C$ in stalagmites from Sofular Cave

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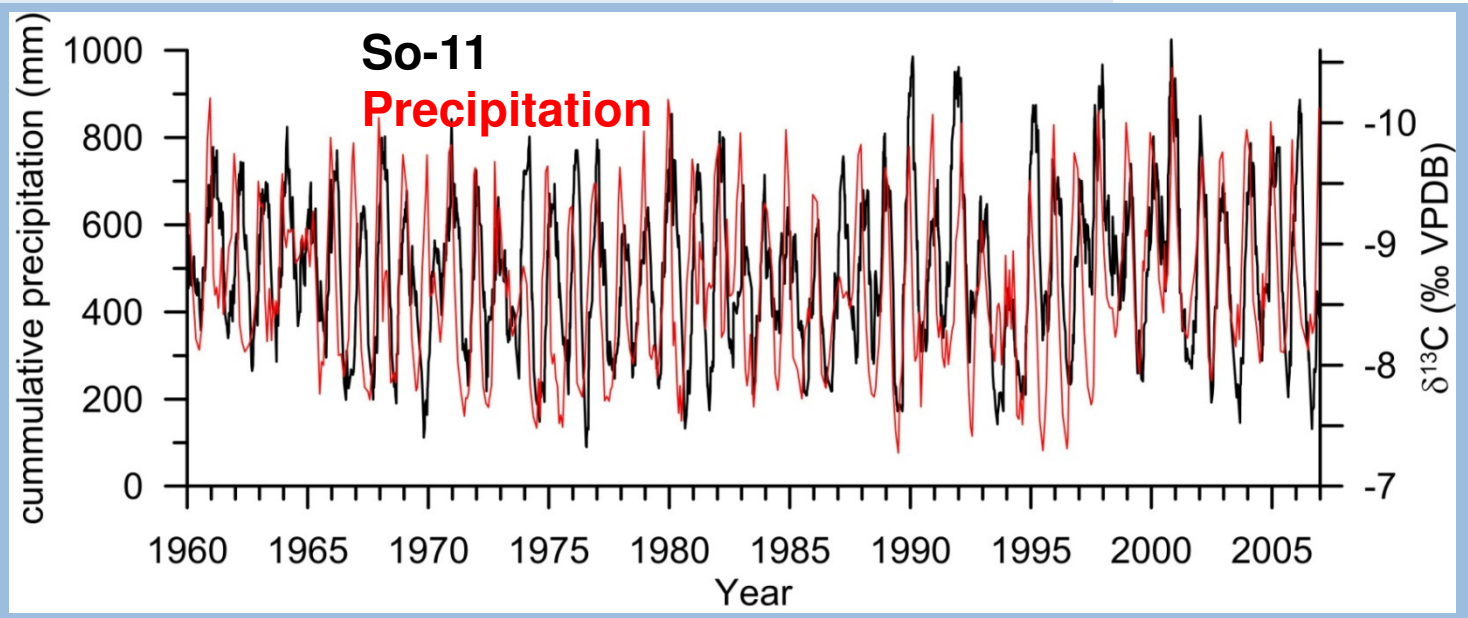

Stalagmite $\delta^{13}C$ values are closely related to the drip rate

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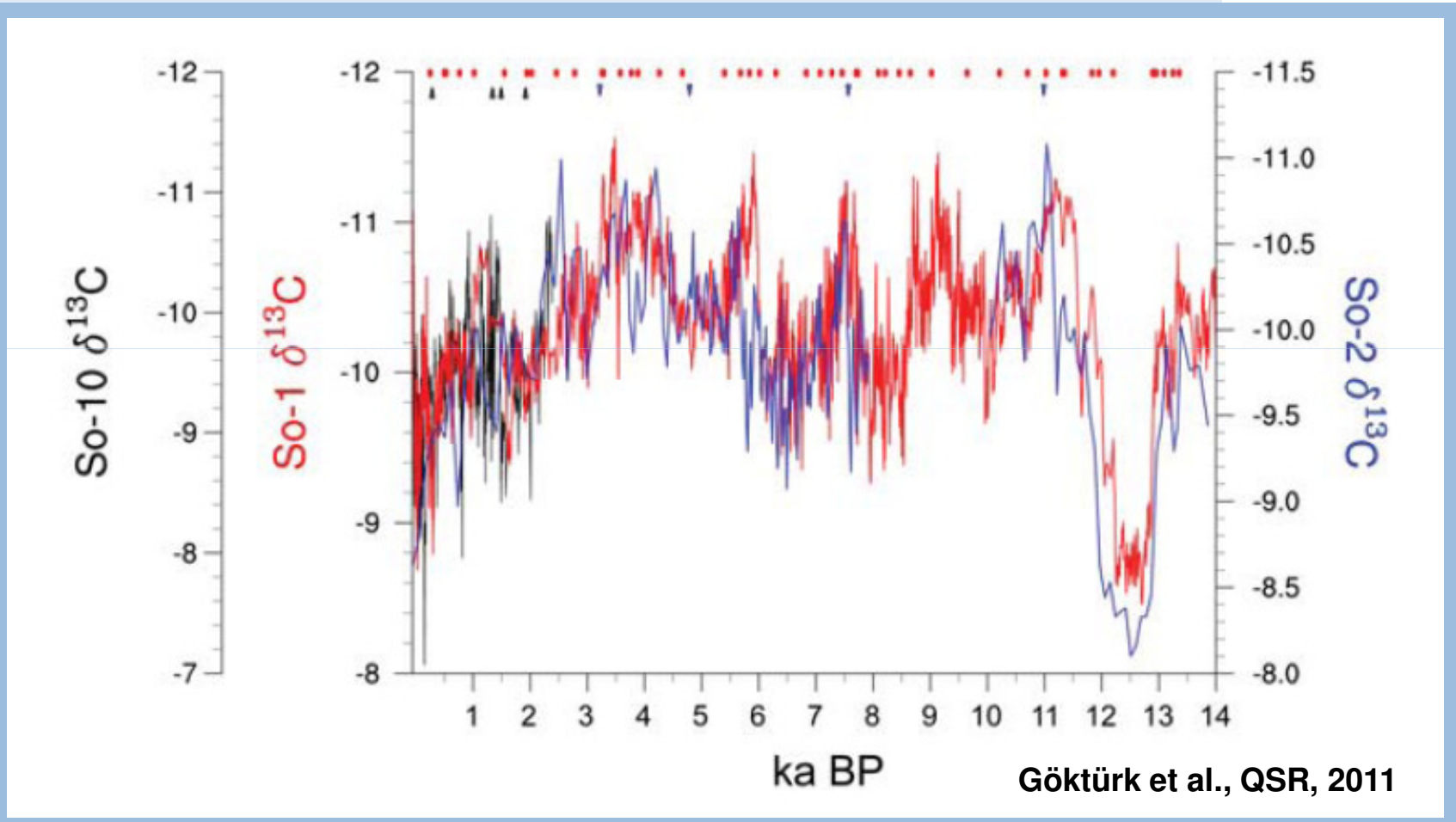
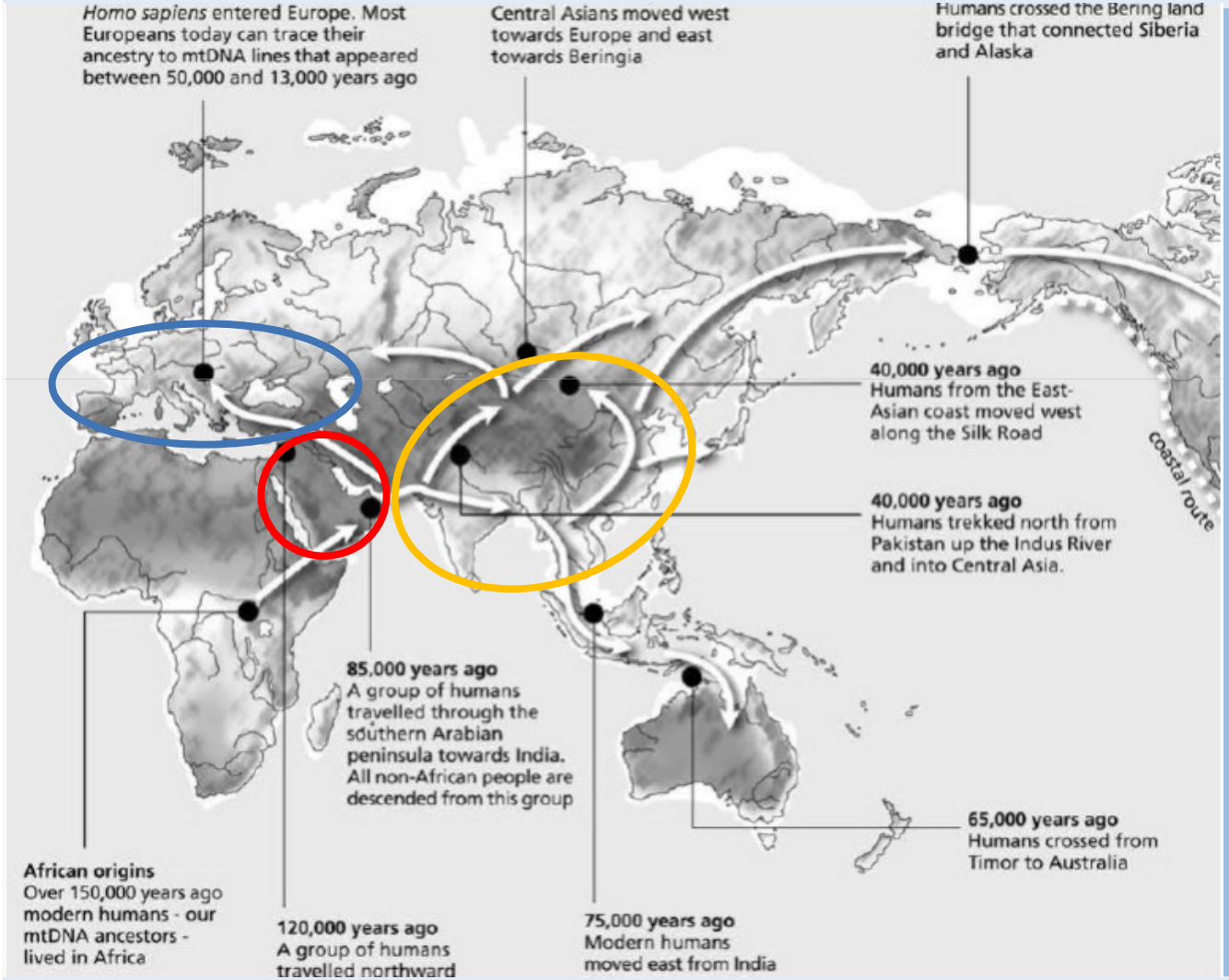


Göktürk et al., QSR, 2011

$\delta^{13}C$ records from Sofular Cave stalagmites are reproduceable!

Human dispersal („Out of Africa II“)



Oppenheimer,
Quaternary International, 2009

Study Sites in Arabia

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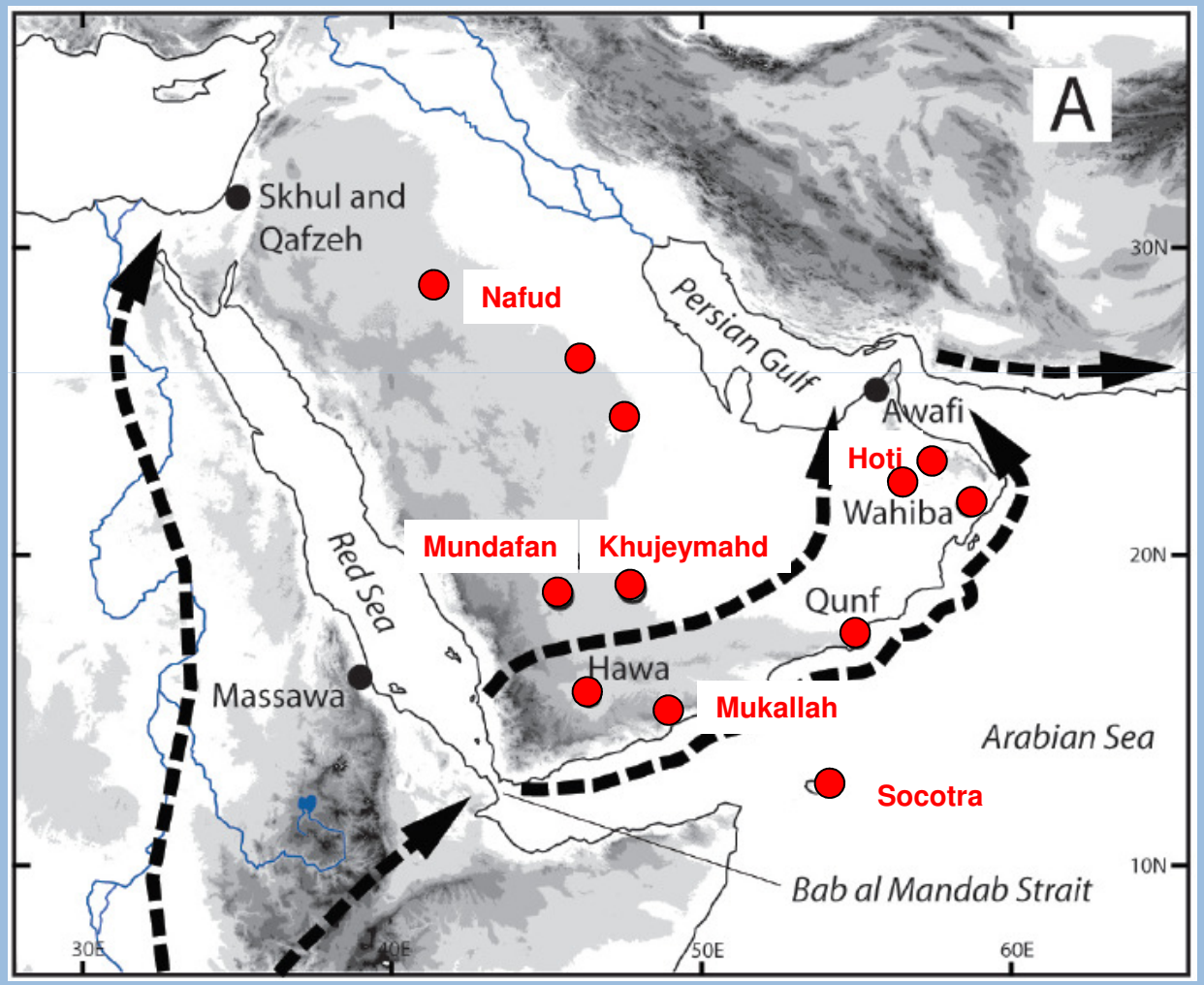

Rosenberg et al., Geology, 2011

Lacustrine Sediments

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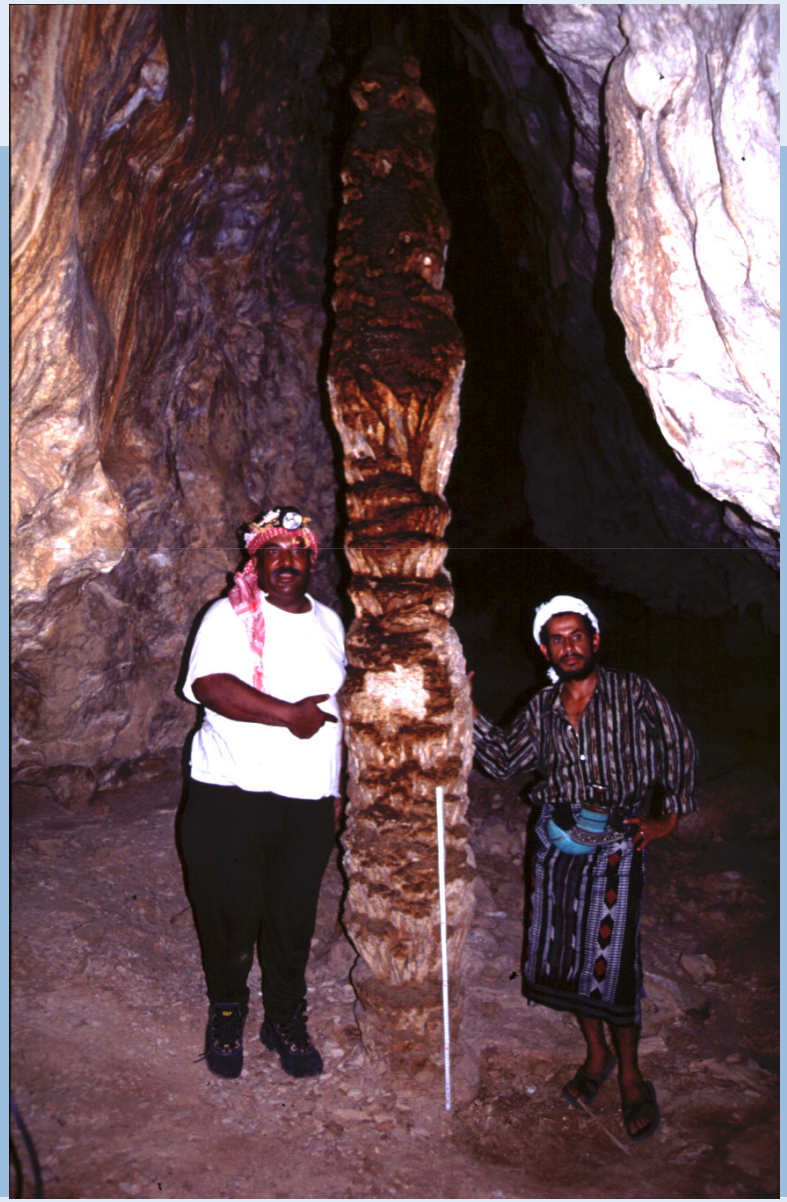

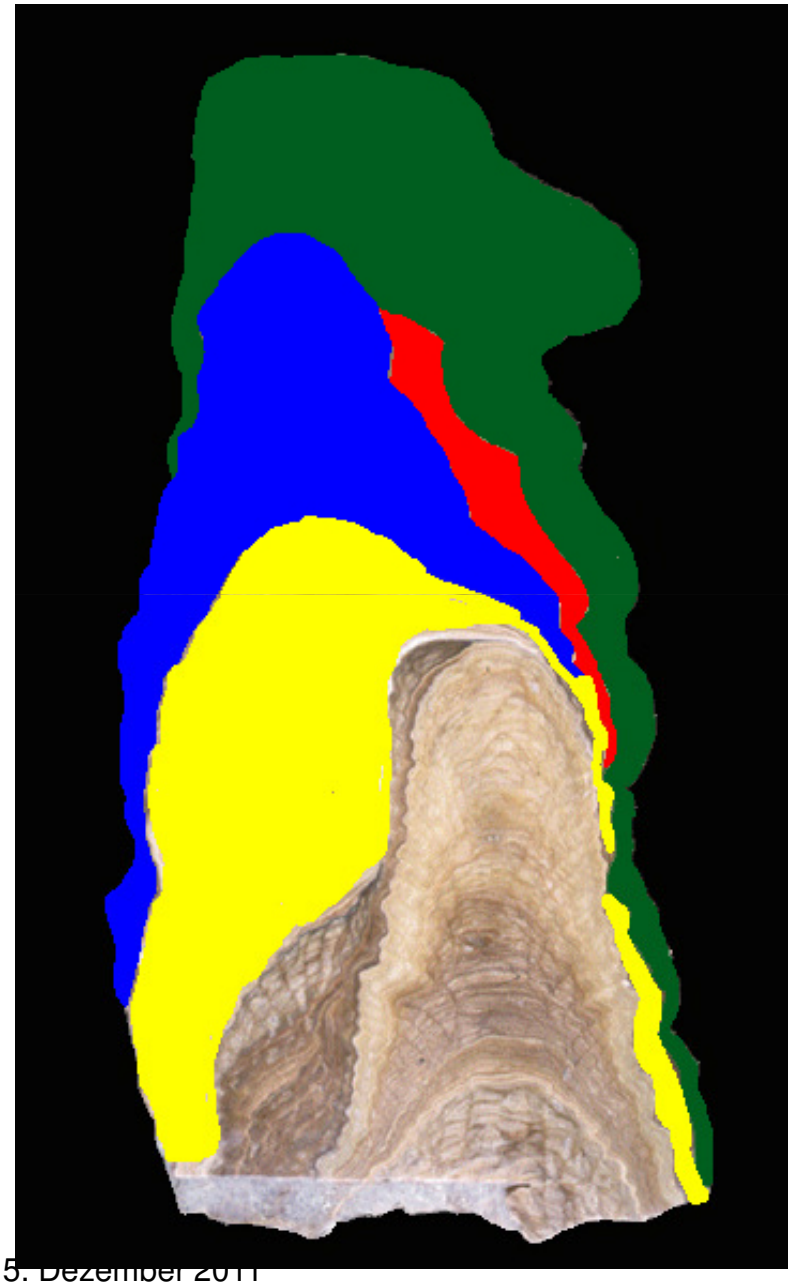

130.000 - 120.000 yrs BP

205.000 - 195.000 yrs BP

230.000 - 220.000 yrs BP

330.000 - 300.000 yrs BP

Fleitmann et al., Quaternary Science Reviews, 2011

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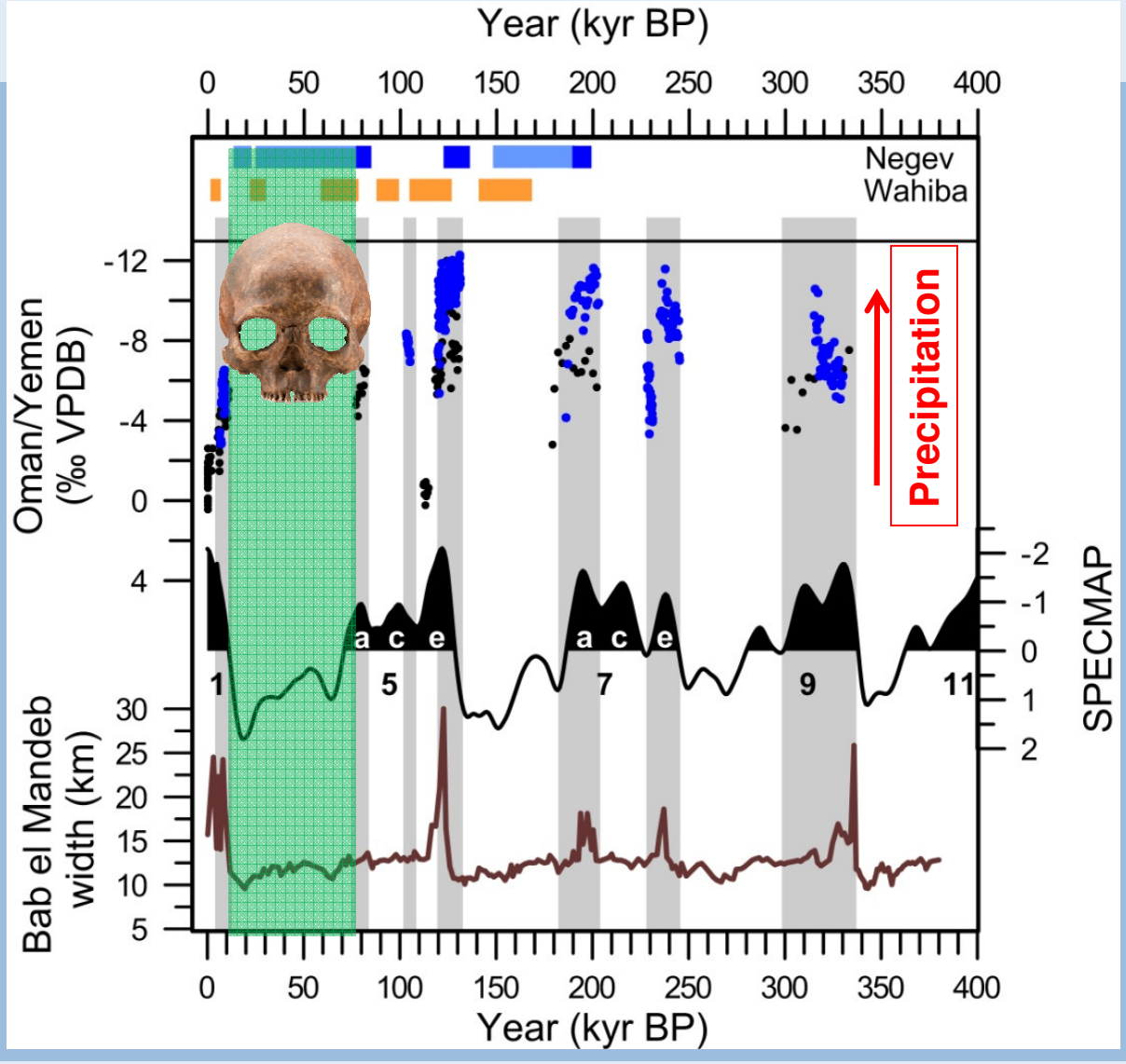
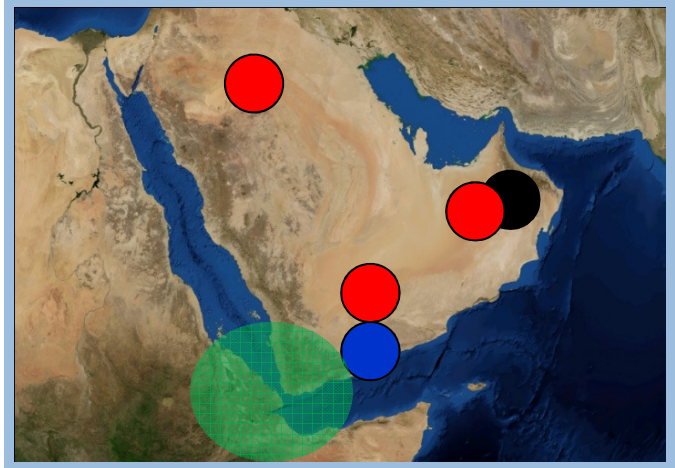
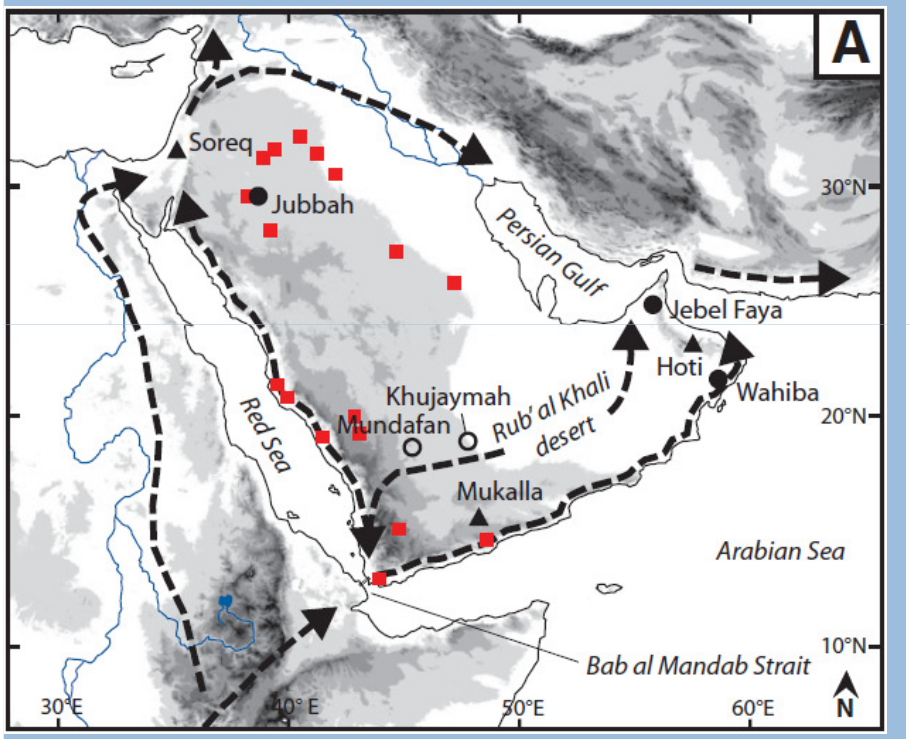
Pluvial Periods in Arabia

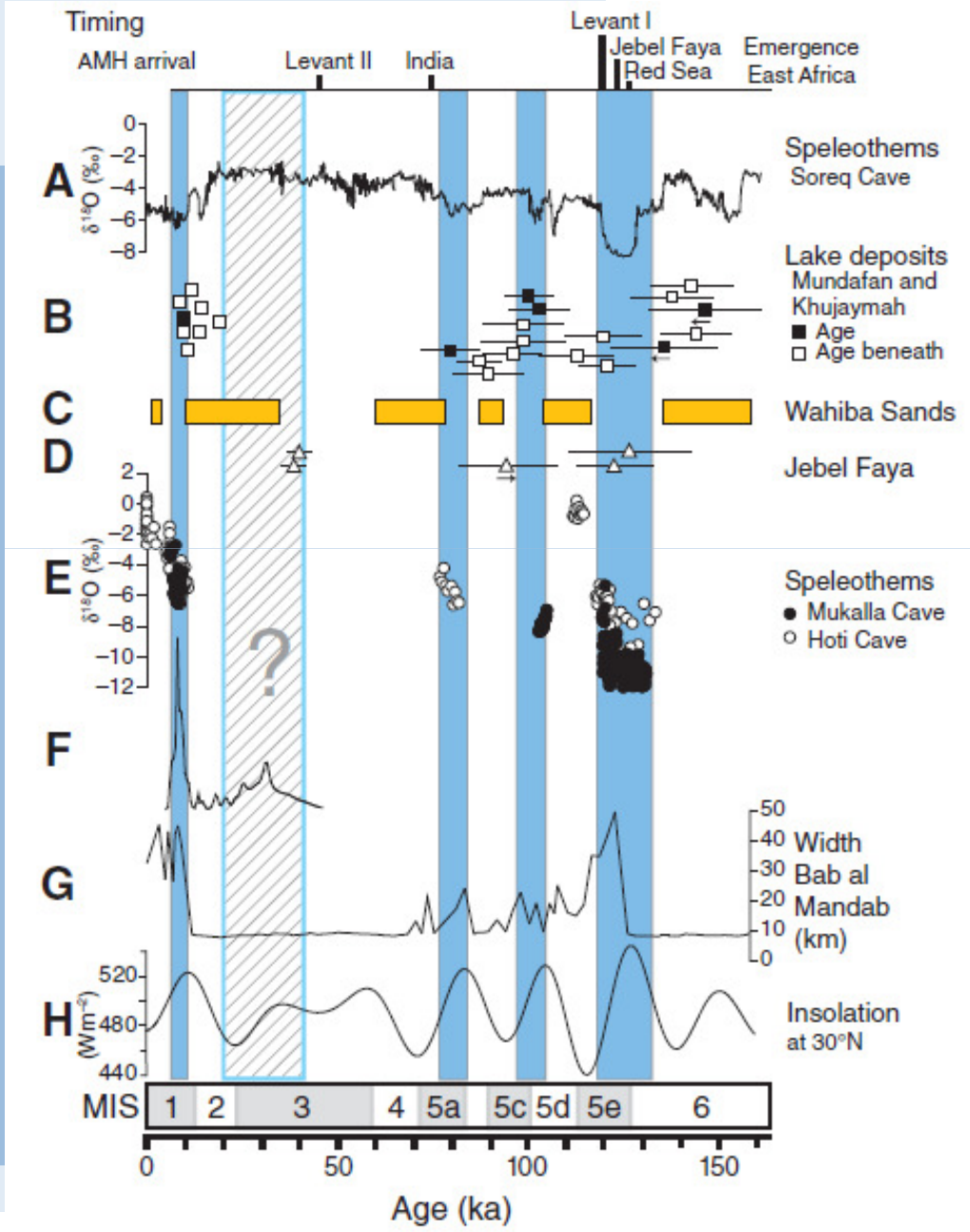




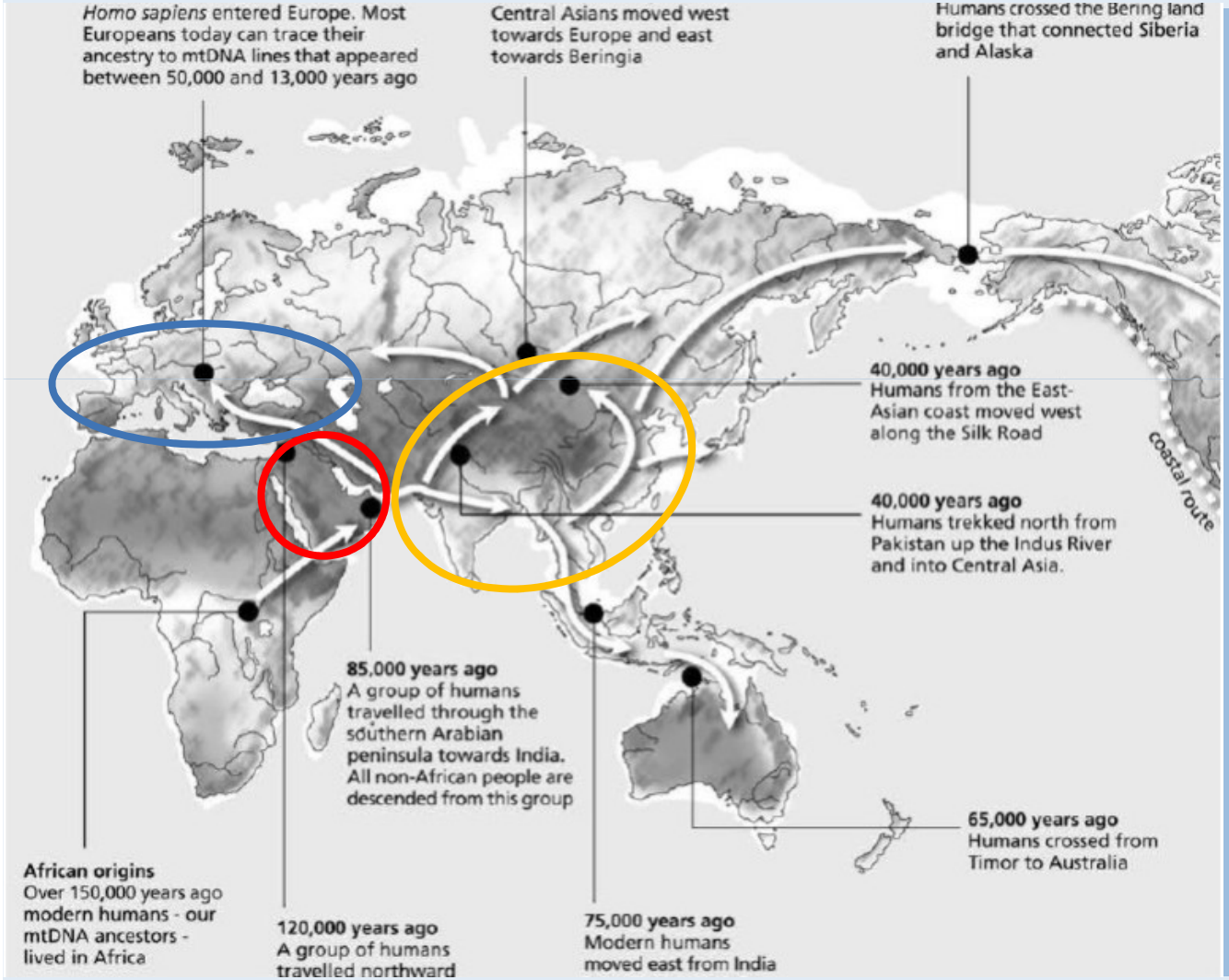
Pluvial Periods in Arabia



Rosenberg et al., Geology, 2011



Human dispersal („Out of Africa II“)



Oppenheimer,
Quaternary International, 2009

Sites

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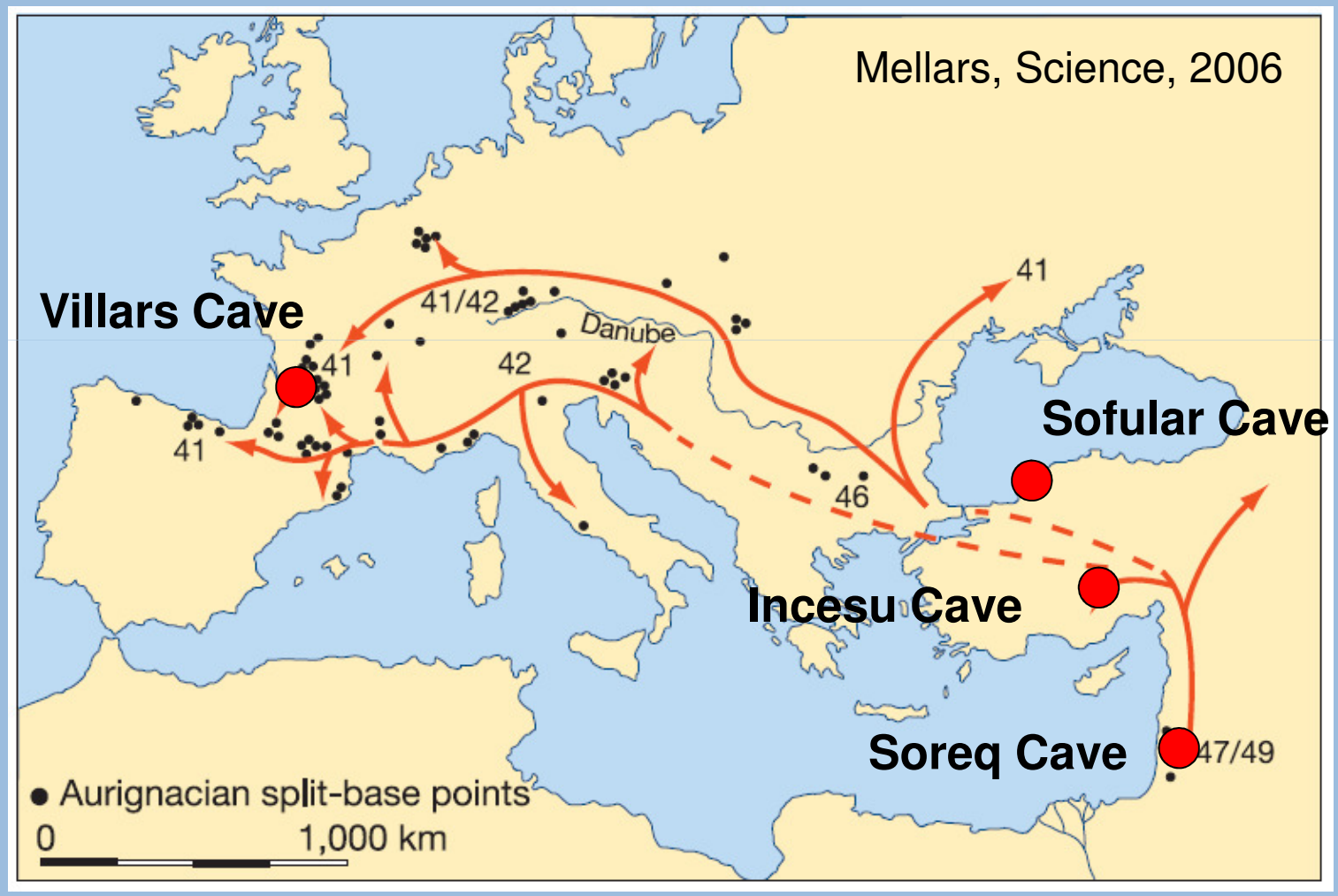

Atmospheric circulation and precipitation in the Mediterranean basin

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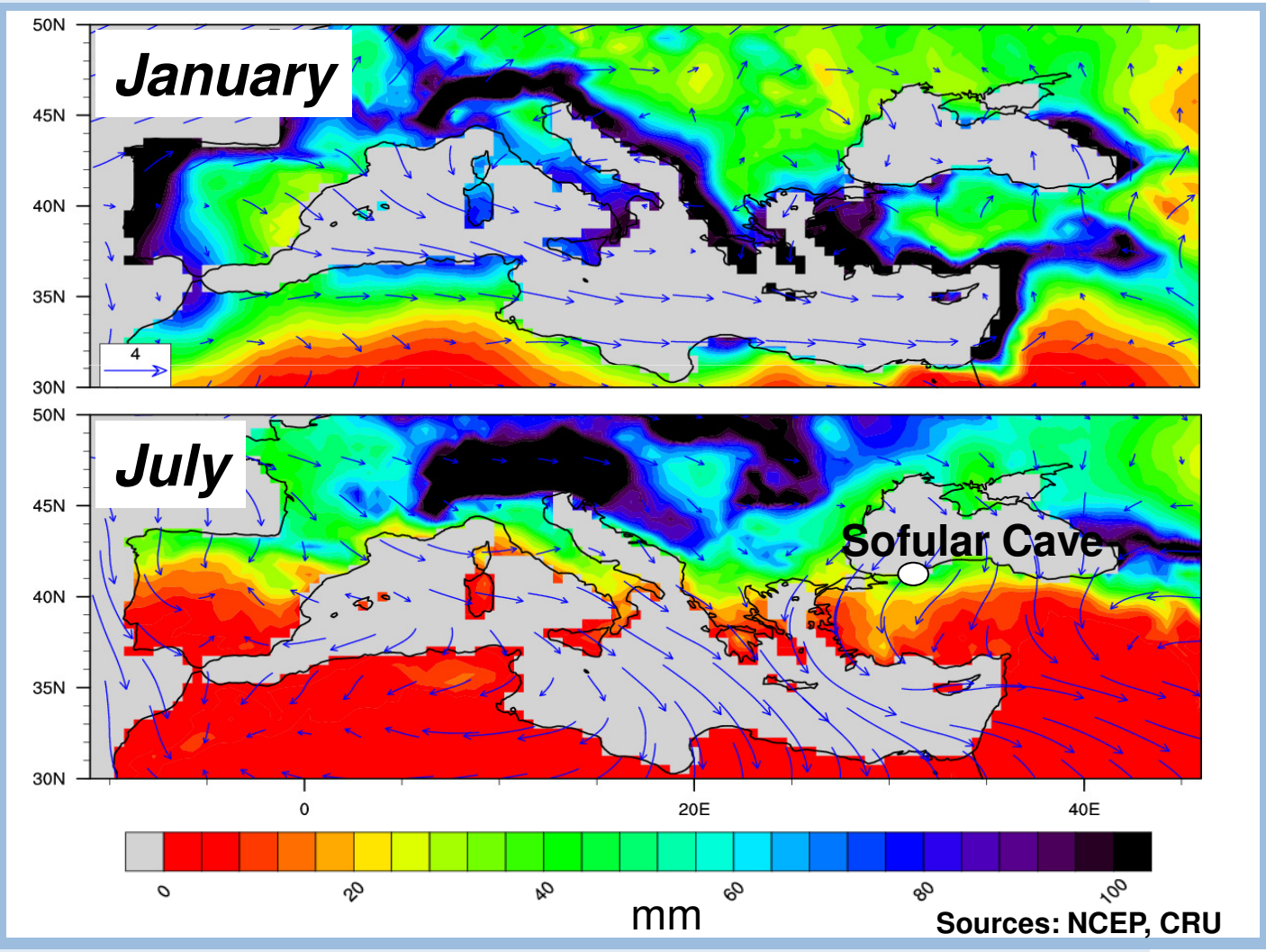

Sofular Cave: Stalagmite So-1

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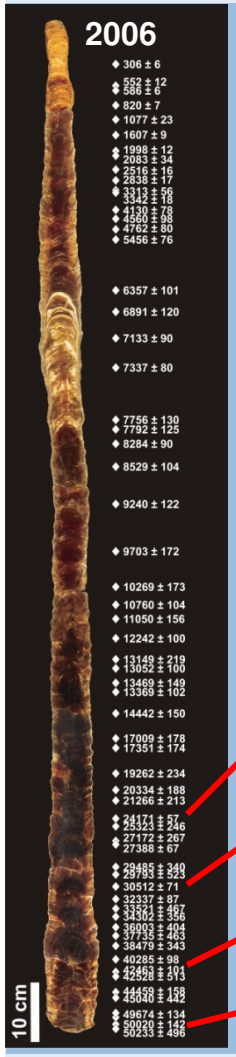
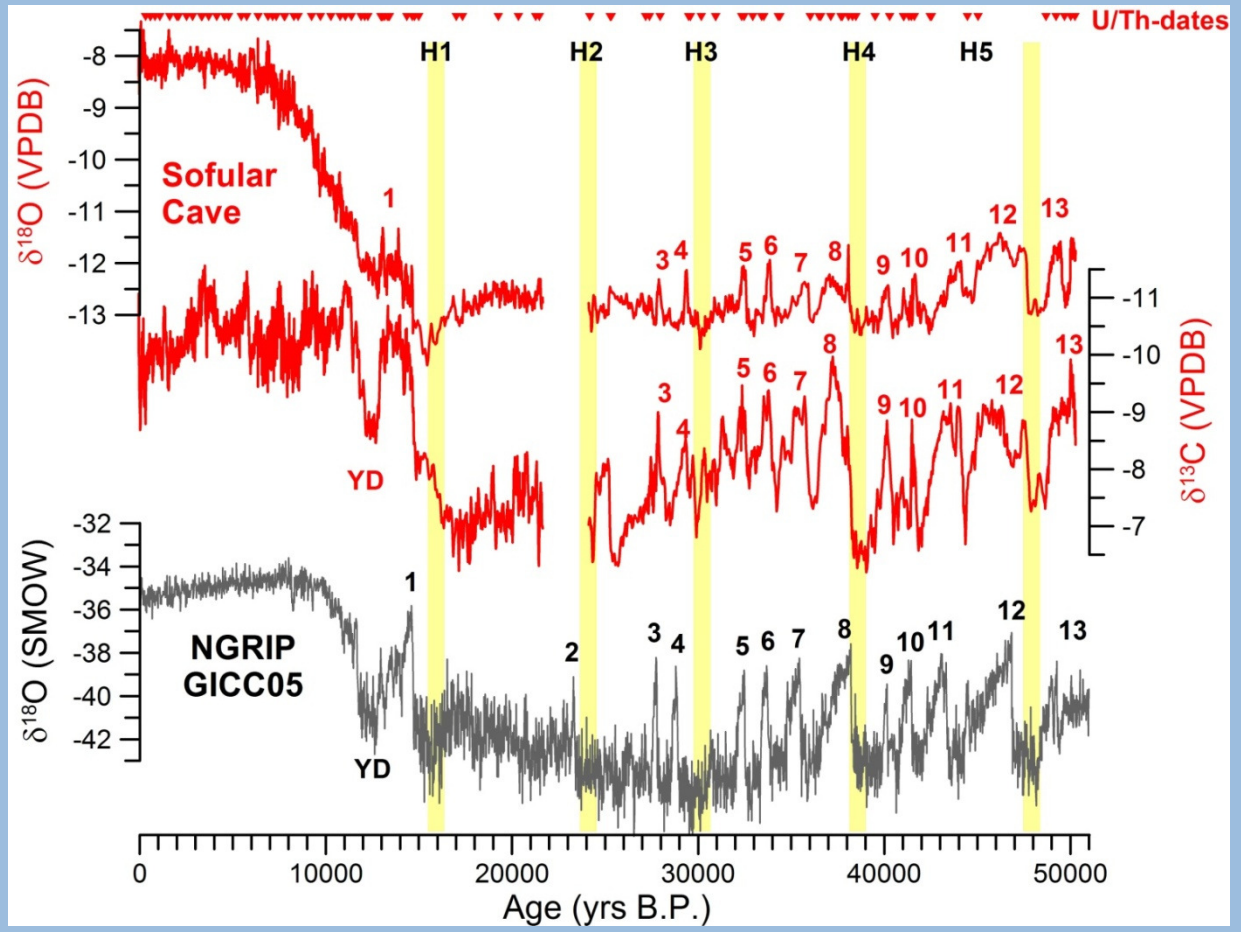


24.171 ± 57

30.512 ± 71

42.463 ± 101

50.020 ± 142



Fleitmann et al., GRL, 2009

Sofular Cave: Stalagmite So-1

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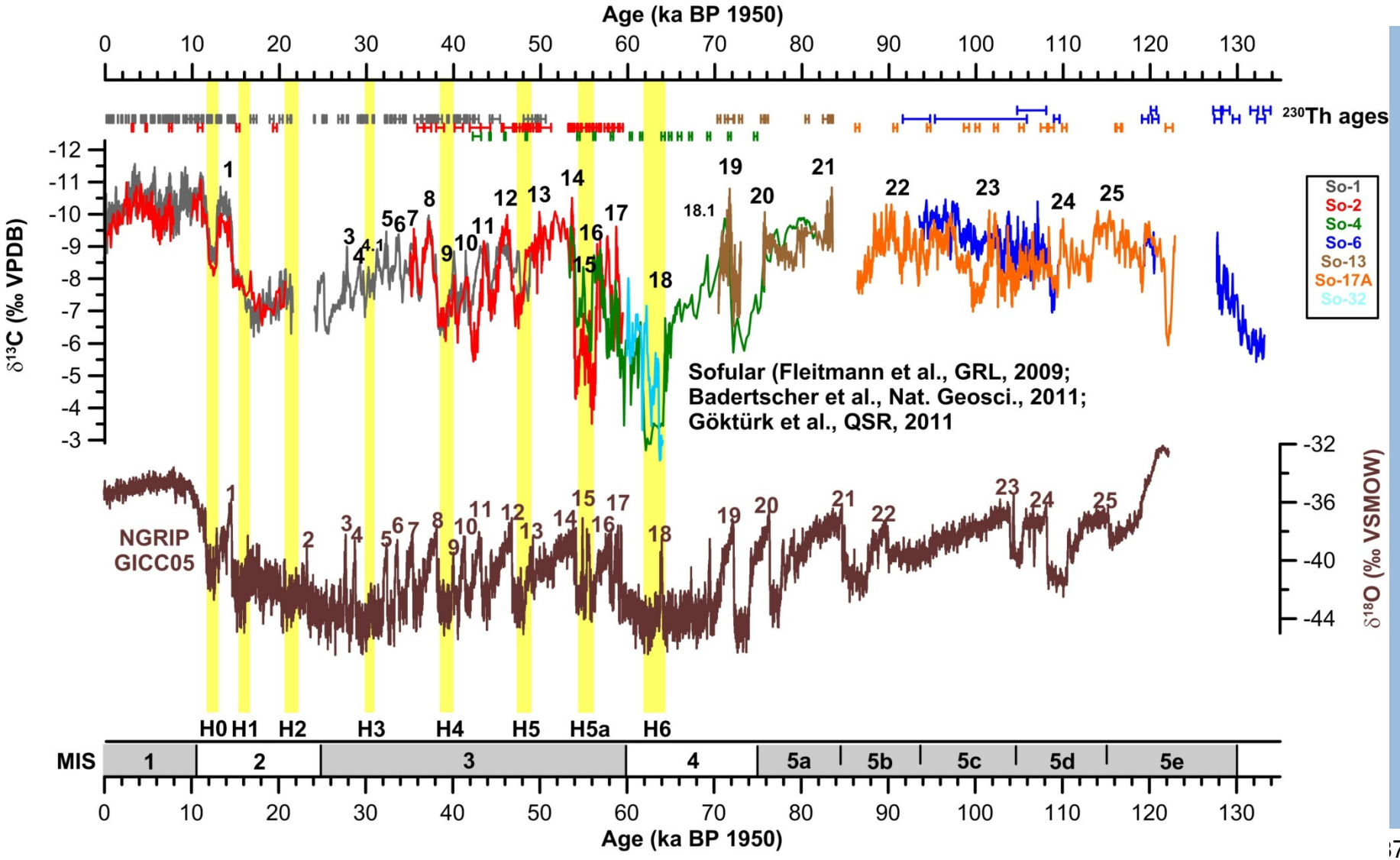

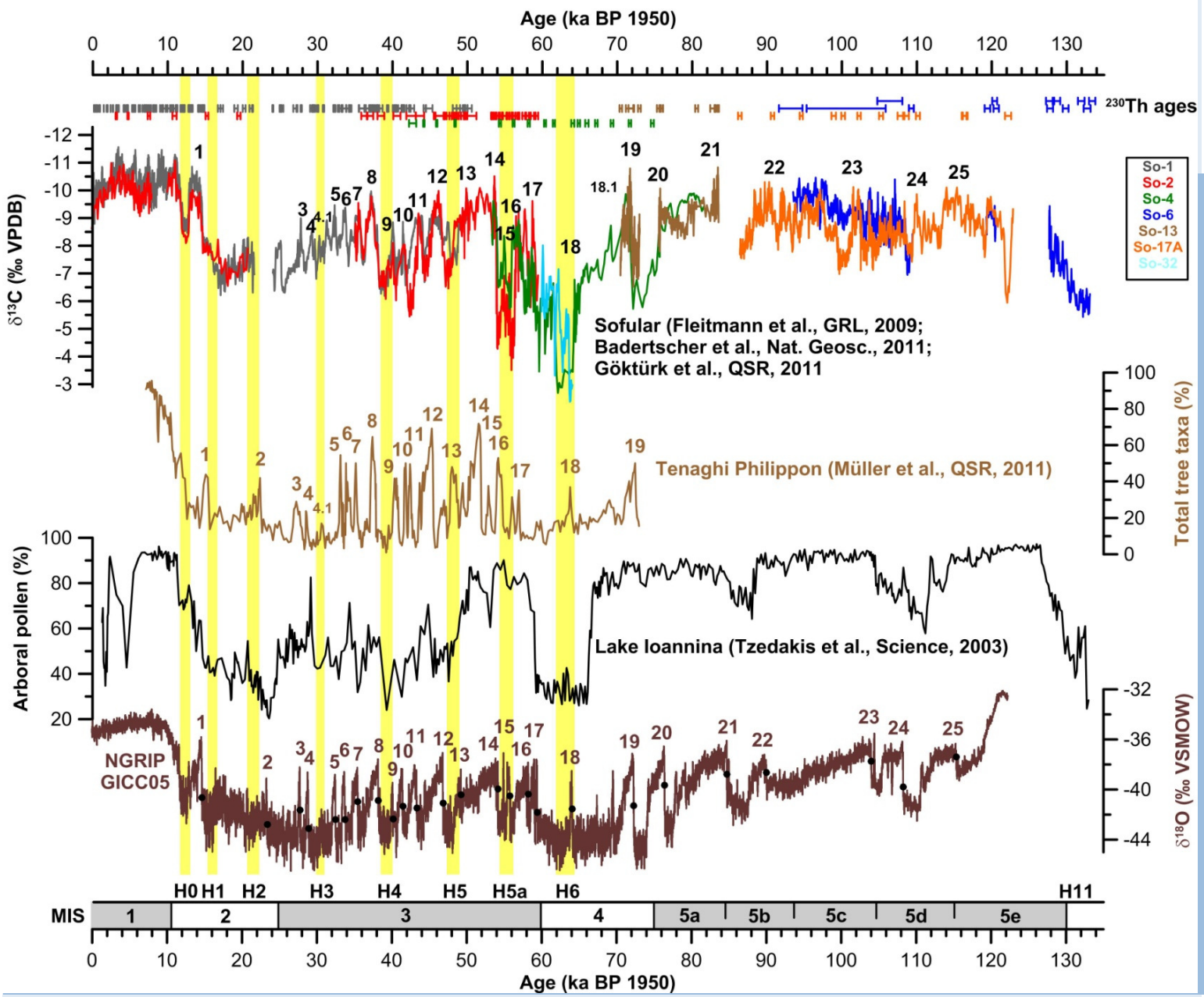
Age (ka BP 1950)
230Th ages
δ13C (‰ VPDB)
So-1
So-2
So-4
So-6
So-13
So-17A
So-32
Sofular (Fleitmann et al., GRL, 2009;
Badertscher et al., Nat. Geosc., 2011;
Göktürk et al., QSR, 2011
Tenaghi Philippon (Müller et al., QSR, 2011)
Total tree taxa (%)
Arboral pollen (%)
Lake Ioannina (Tzedakis et al., Science, 2003)
NGRIP
GICC05
δ18O (‰ VSMOW)
H0 H1 H2 H3 H4 H5 H5a H6 H11
MIS 1 2 3 4 5a 5b 5c 5d 5e
Age (ka BP 1950)

Transition time of Dansgaard-Oeschger events: Changepoint calculations

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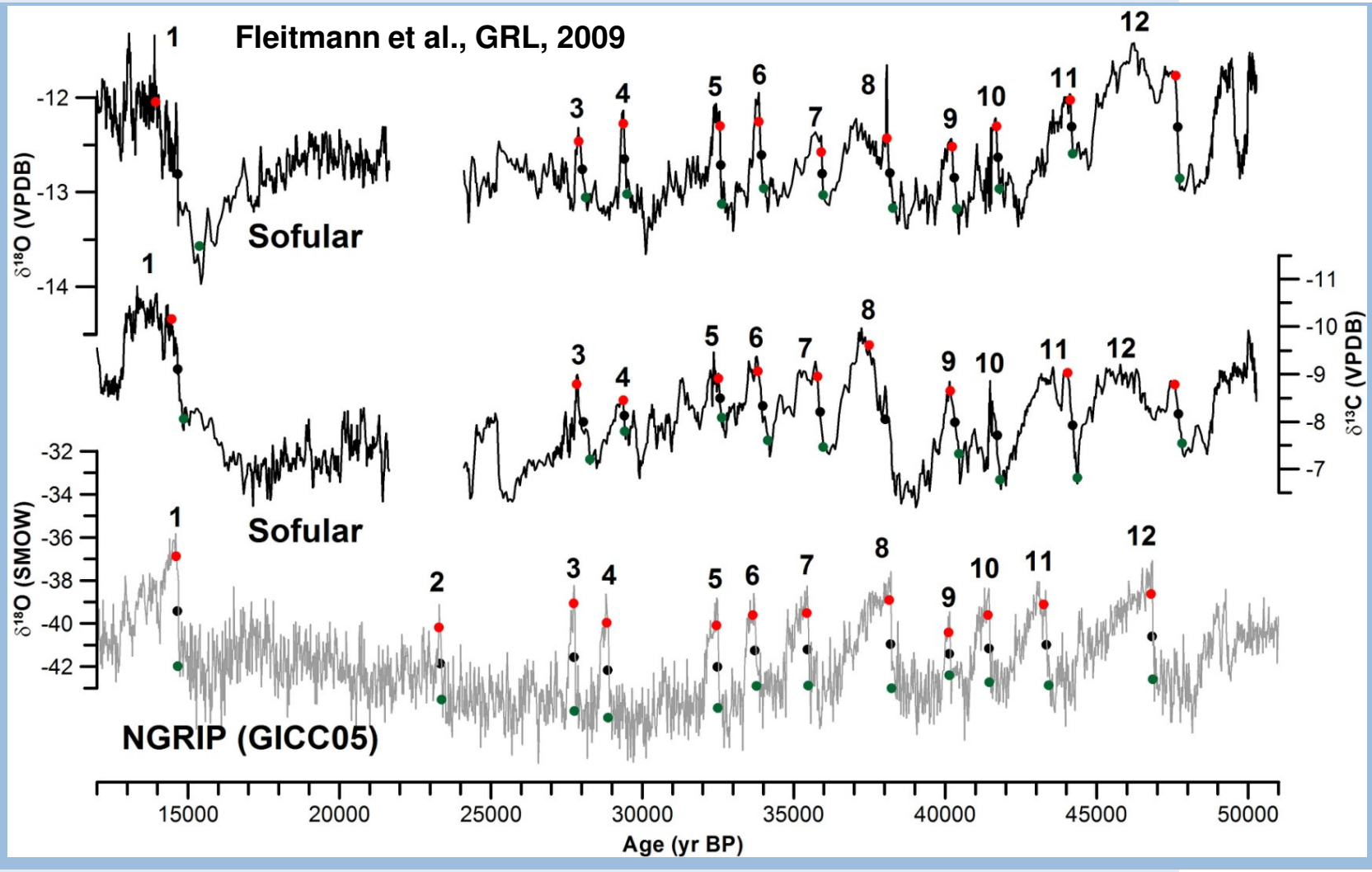

Transition time into D-O Events in Sofular and NGRIP

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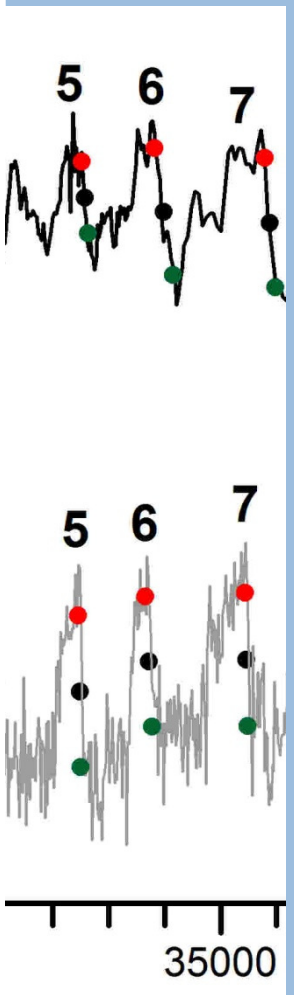

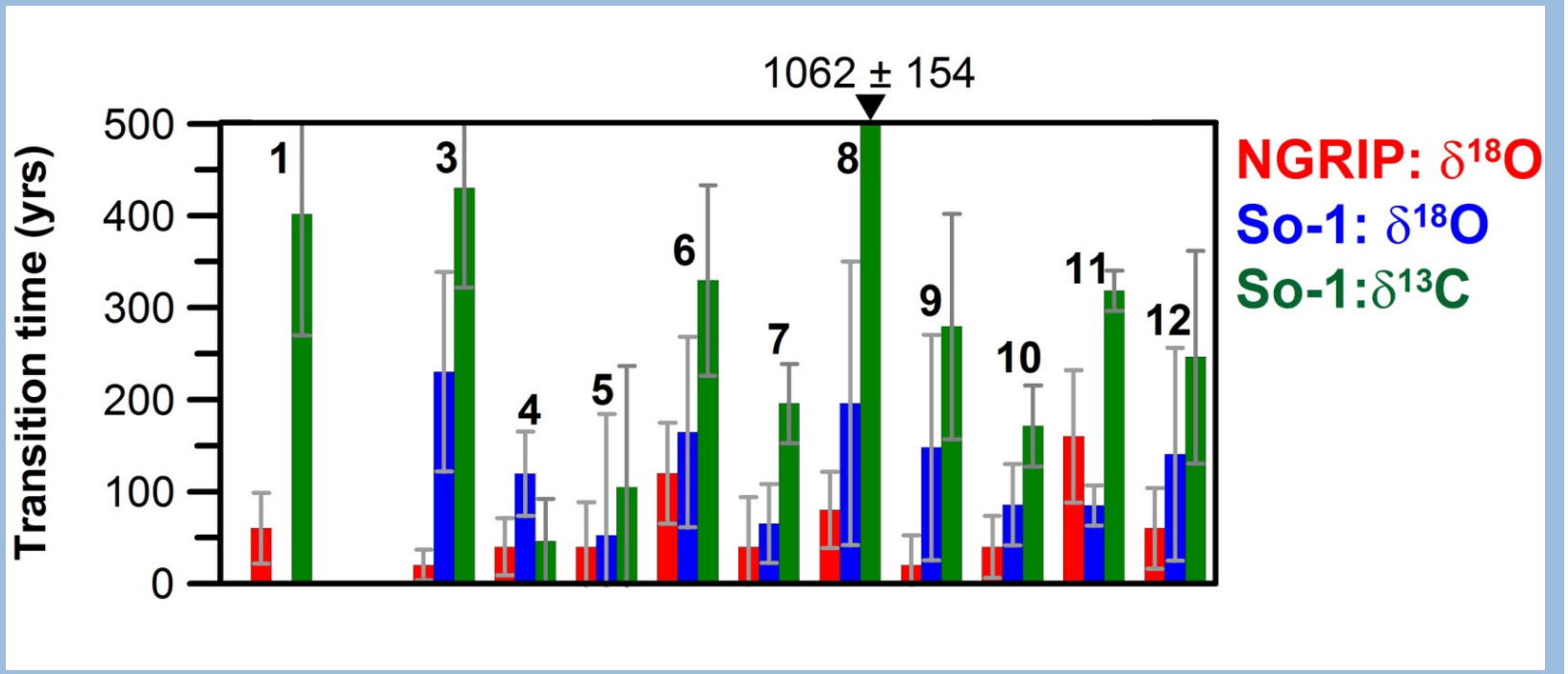

Full transition into a D-O event takes longer in the Sofular $\delta^{13}C$ time series!

Incesu Cave, Turkey

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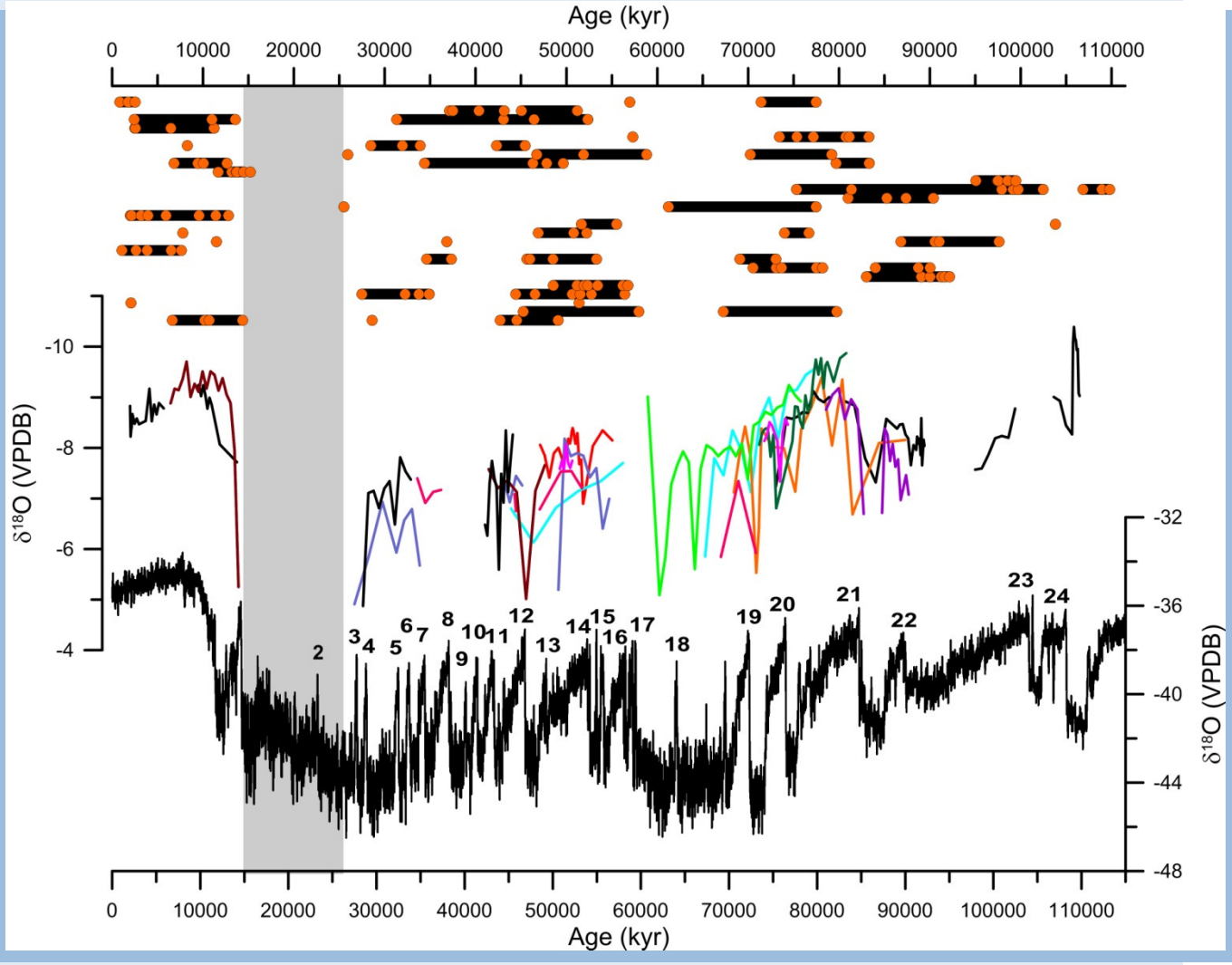

Ice Extent at 60 ka BP

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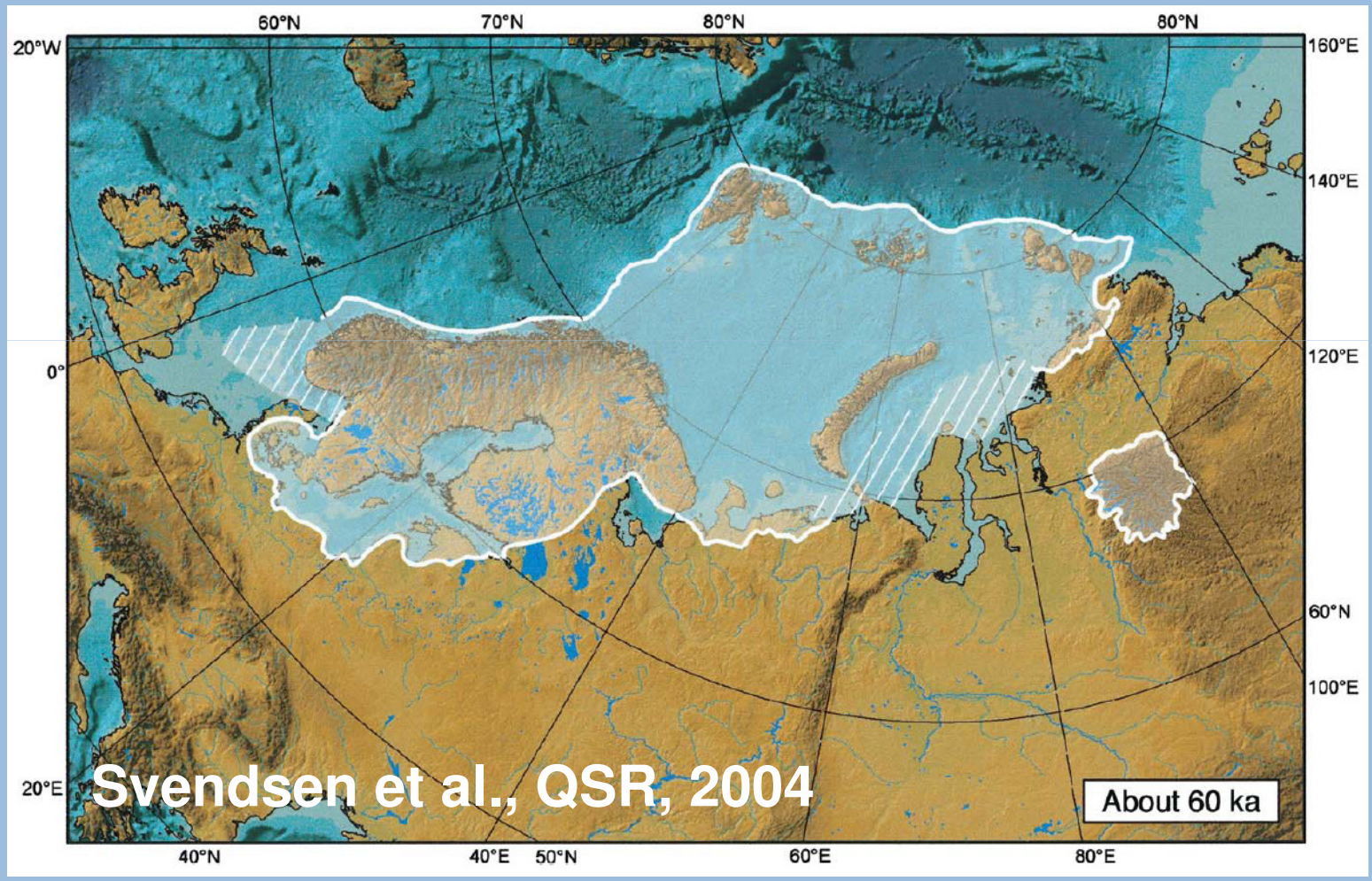

Villars Cave

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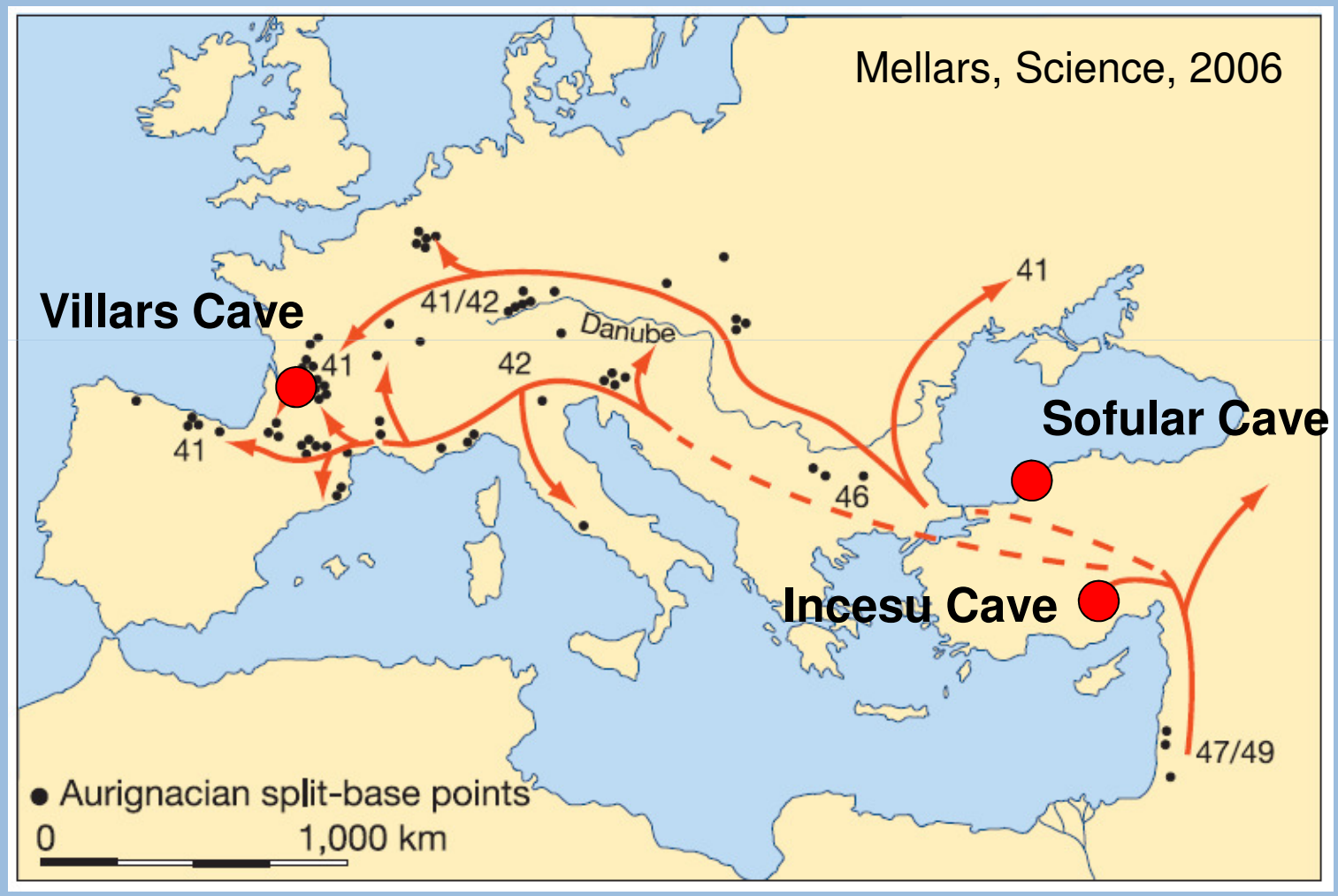

Villars Cave

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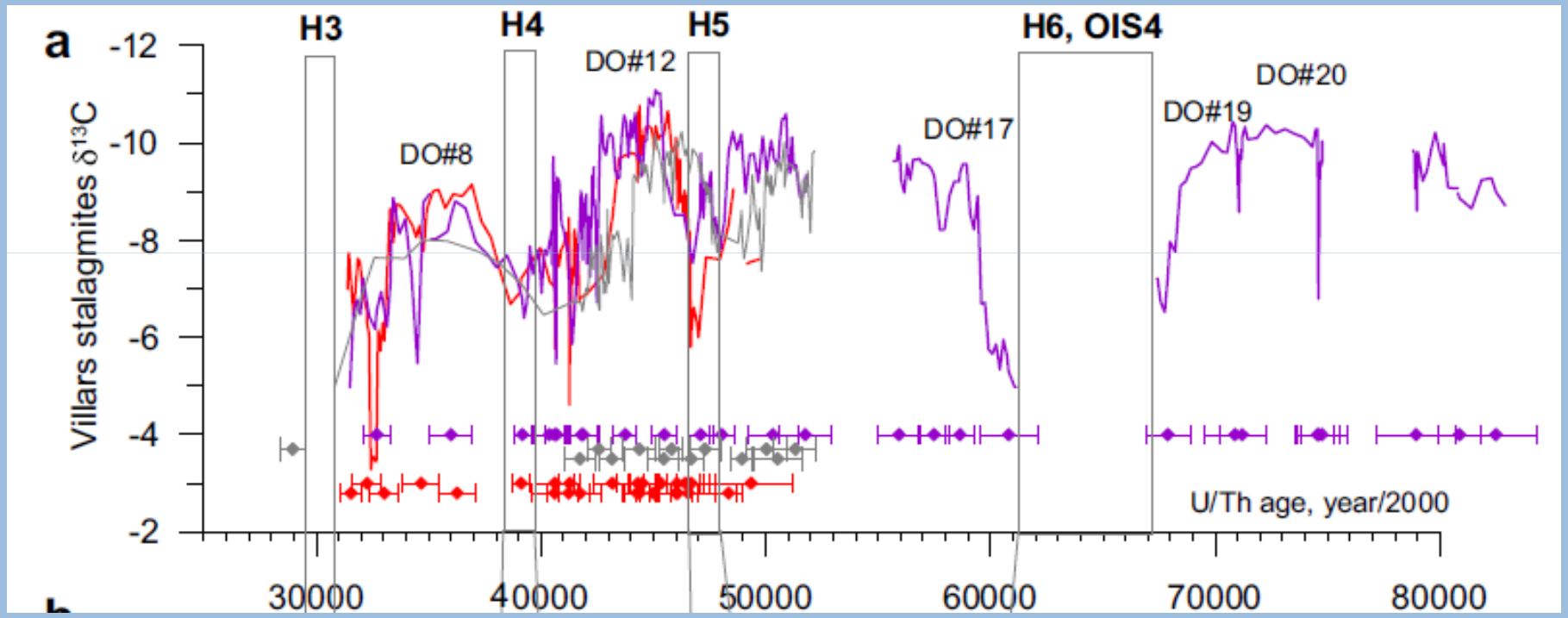

Genty et al., QSR, 2010

Villars and Sofular

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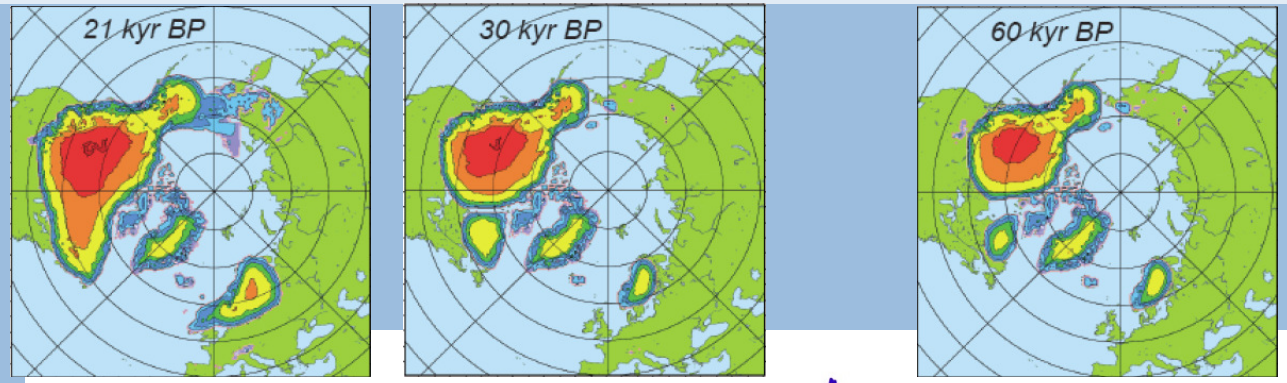

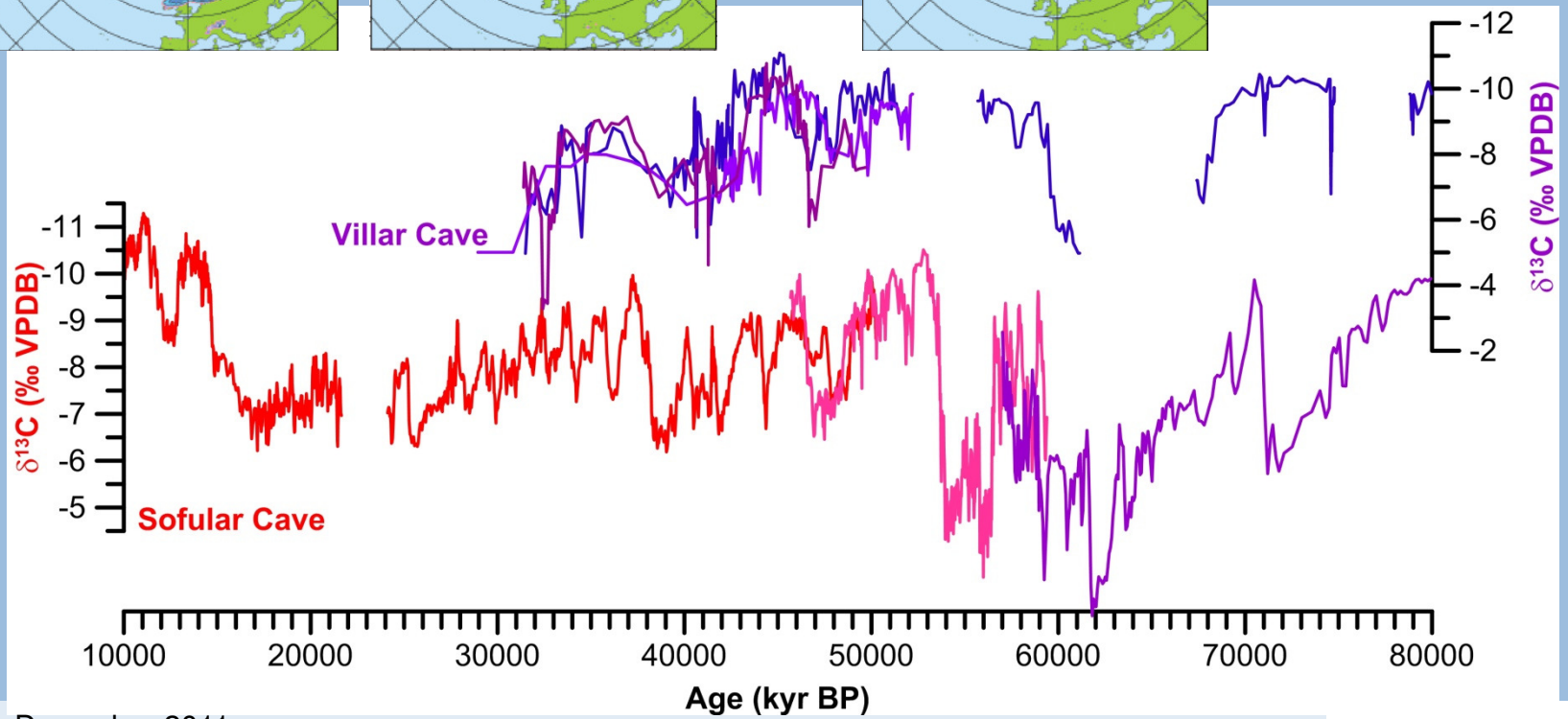

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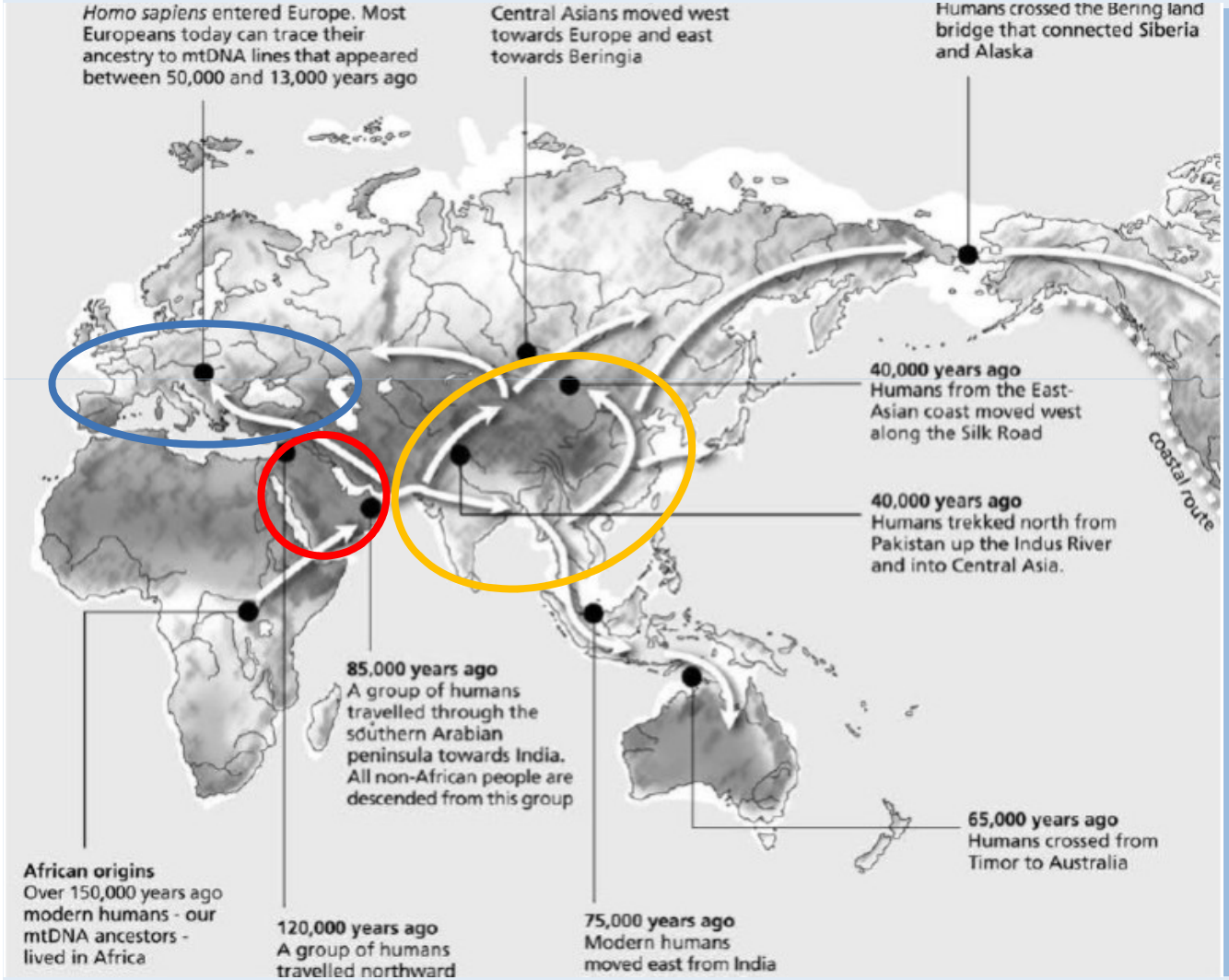

Oppenheimer, Quaternary International, 2009

Hulu Cave, China

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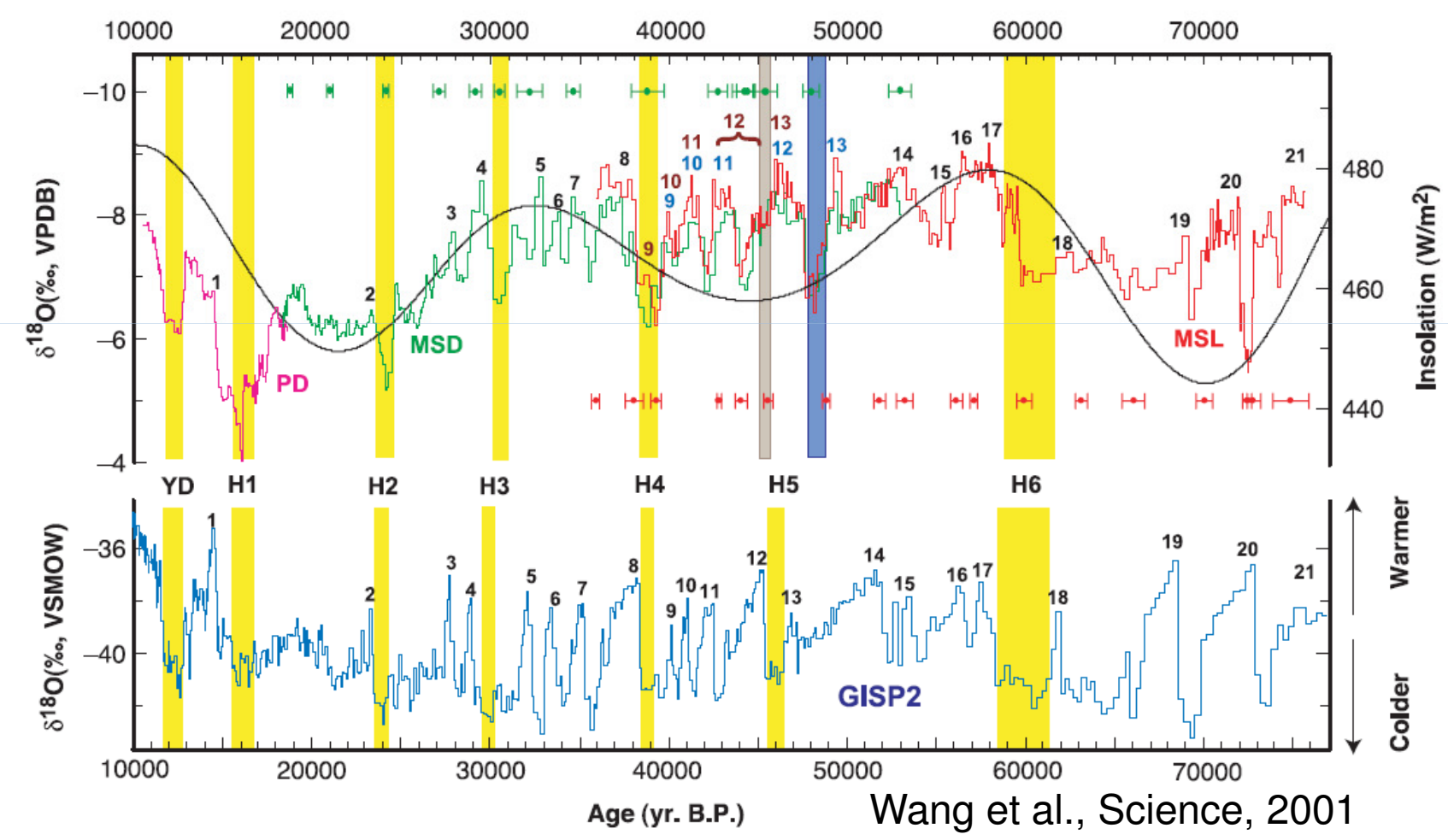

Wang et al., Science, 2001

Thank You!

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