Climate Change & Ancient Maya Society

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The Abdus Salam International Centre for Theoretical Physics

Mesoamerican chronology

Terminal Classic AD 750 – 900

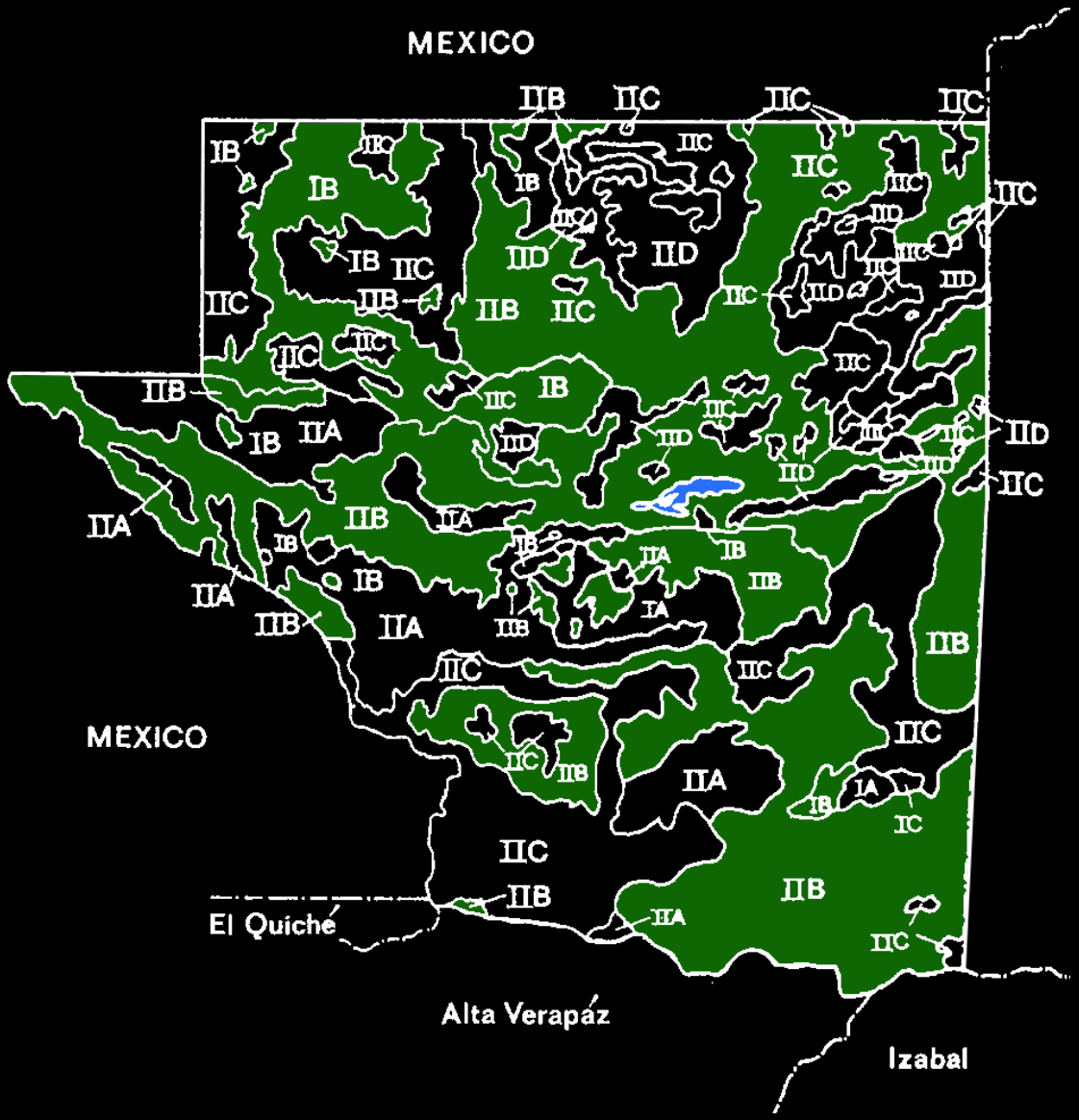
Period	Age
Early Preclassic	2000 - 1000 b.C.
Middle Preclassic	1000 - 400 b.C.
Late Preclassic	400 b.C. – 200 AD
Early Classic	200 – 600 AD
Late Classic	600 - 800 AD
Terminal Classic	**750 – 900 AD**
Early Postclassic	900-1200 AD
Late Classic	1200-1519 AD

Chronology of the Maya area

Over two millennia of history: 1000 BC – AD 1500

Early Culture Ecology models

Soils of Success and Stress



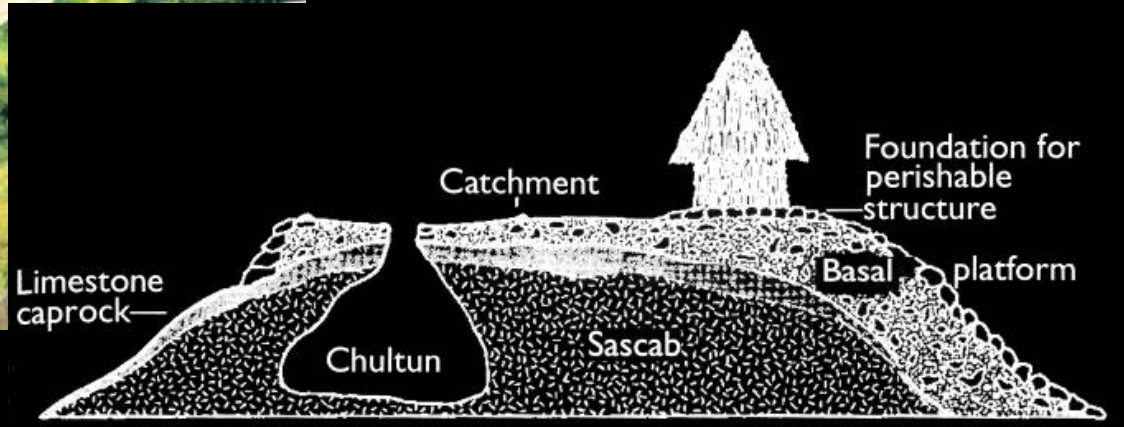
Tropical soils:

Poorly drained
Moderate fertility
Shallow

Sanders 1977

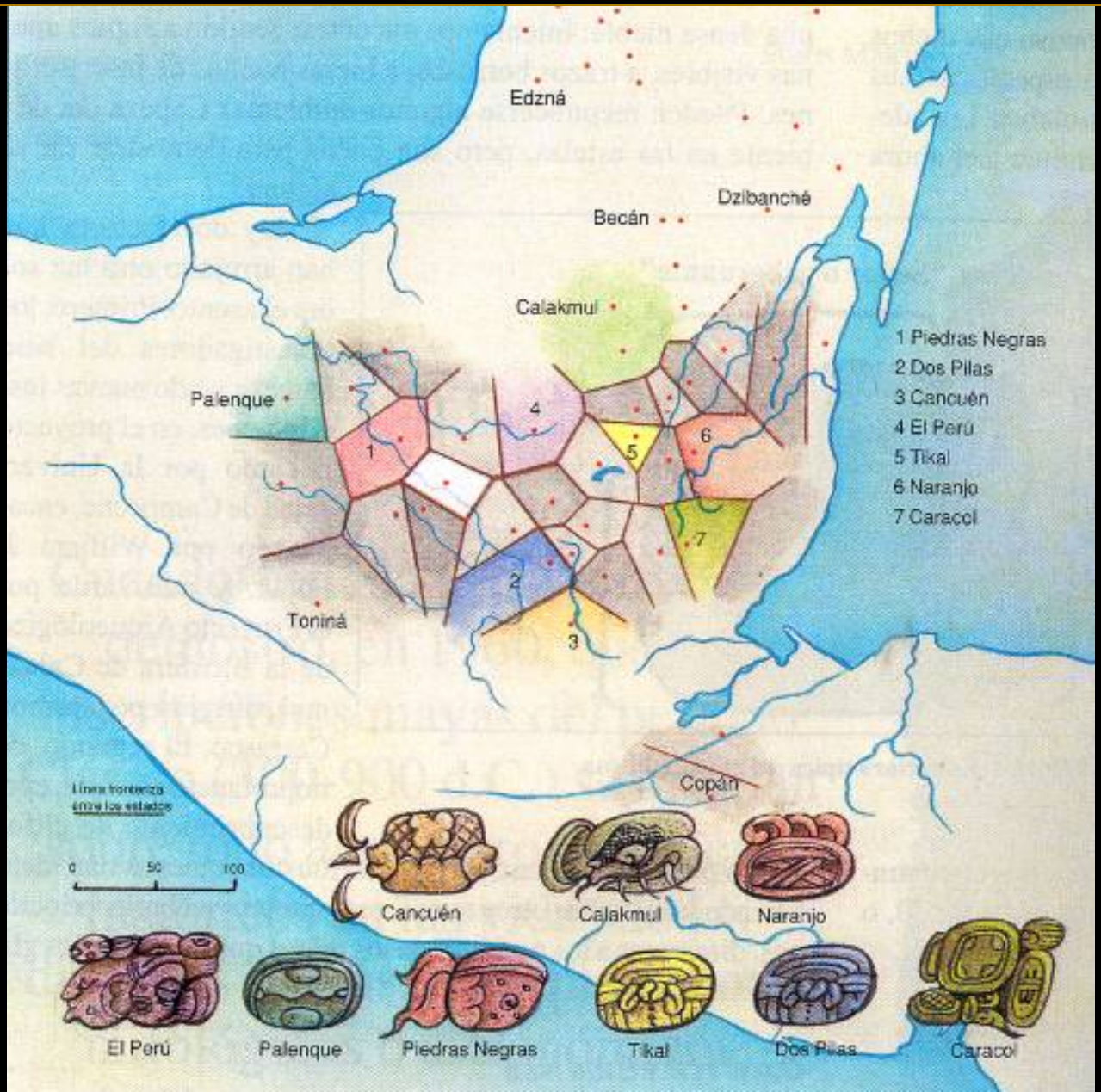
Early Culture Ecology models

Soils of Success and Stress



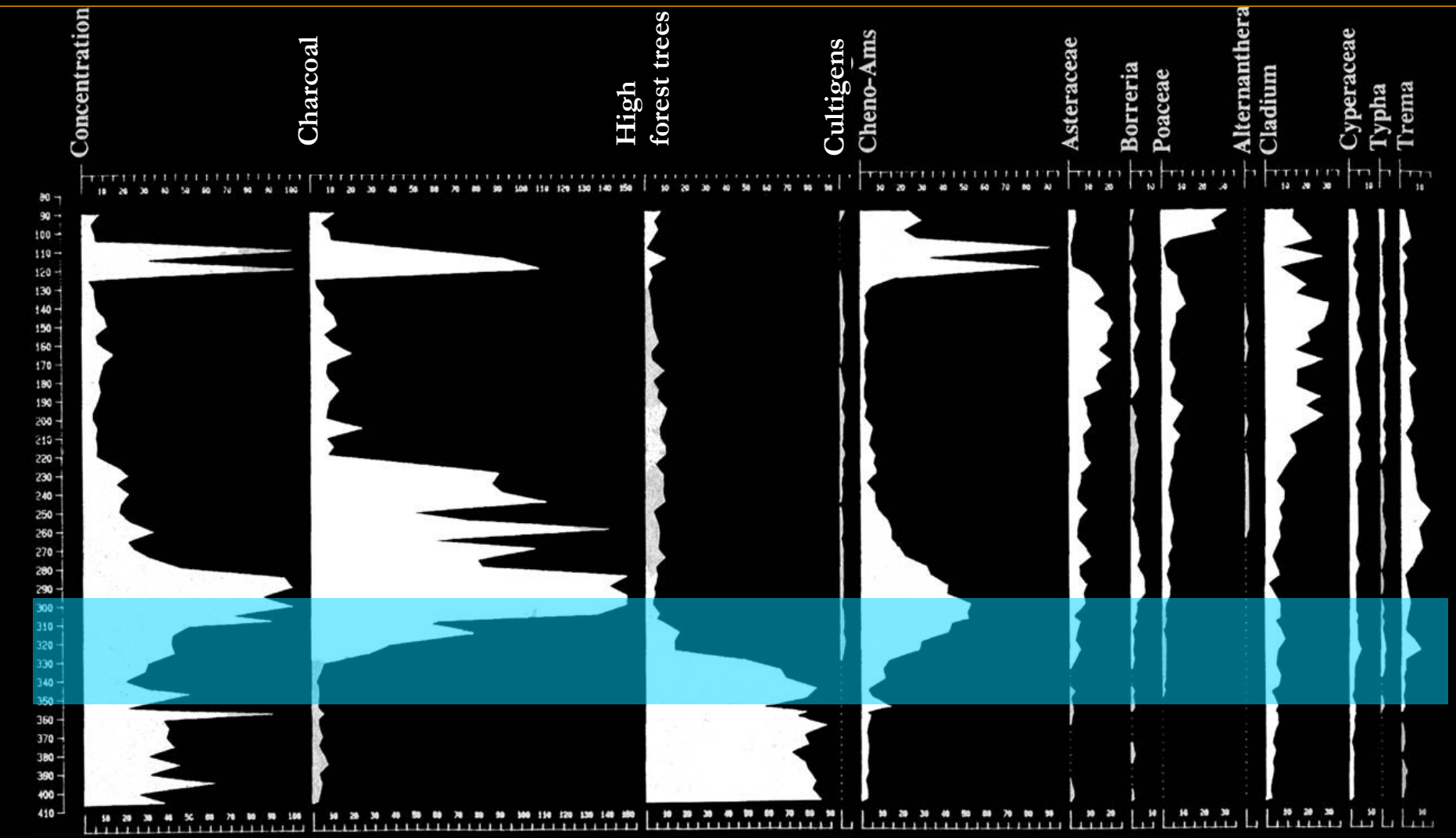
City-states

Peer-polities (Mathews 1989)



Early human impact on Peten

Pollen diagram; Cob Swamp, n. Belize



(after Pohl et al. 1996: Figure 4)

maize & manioc pollen by ca. 3400 BC

increase in forest disturbance after 2500 BC

increase in maize pollen after 2400 BC

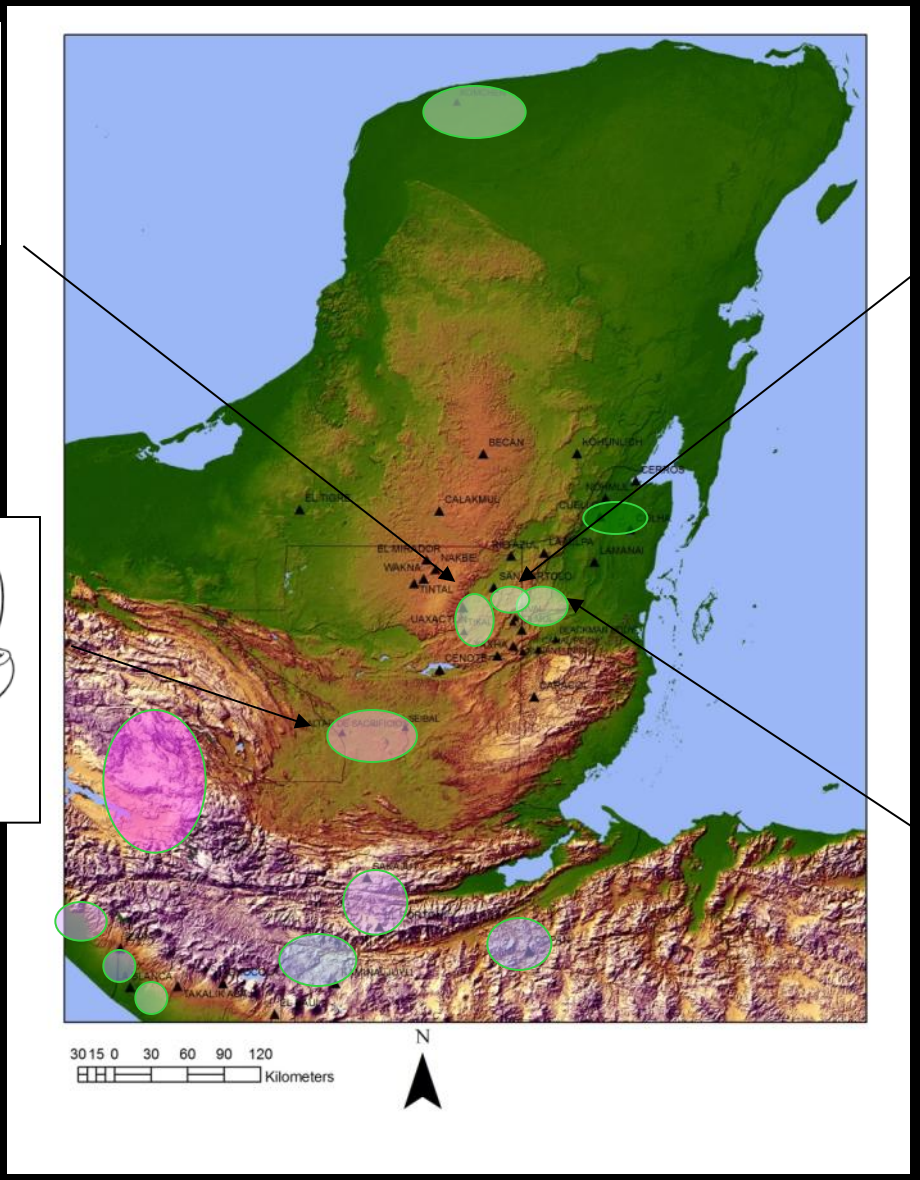
Early Preceramic (3400-1900 BC)

Early sedentism in Peten

1200-900 BC

EB Group
Tikal, Uaxactun

Real Xe
Seibal, Altar de Sacrificios

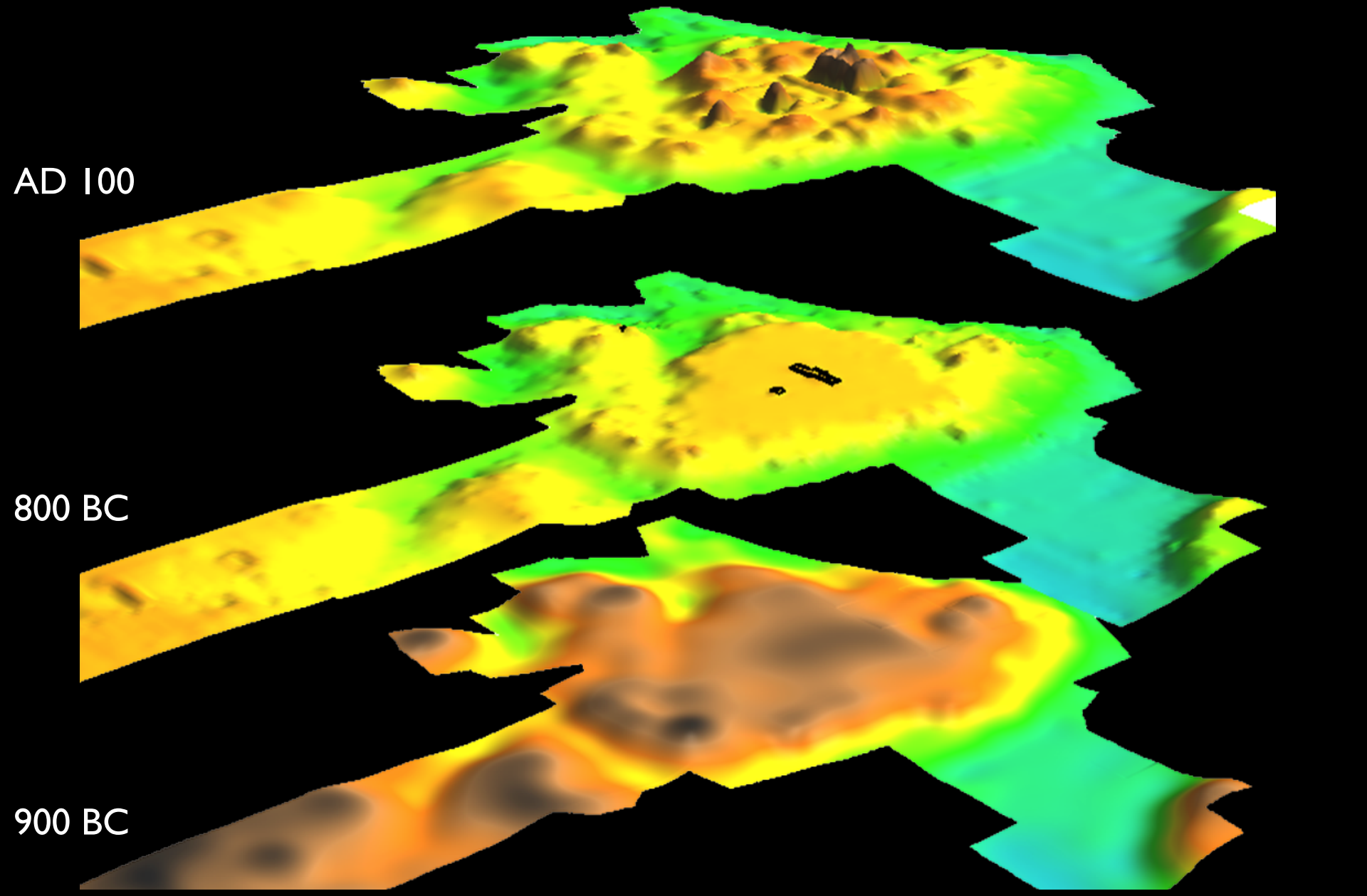


Holmul/Cival Group

Cunil Group
Belize

Major landscape modifications

Cival; 900-800 BC



Early monumentality

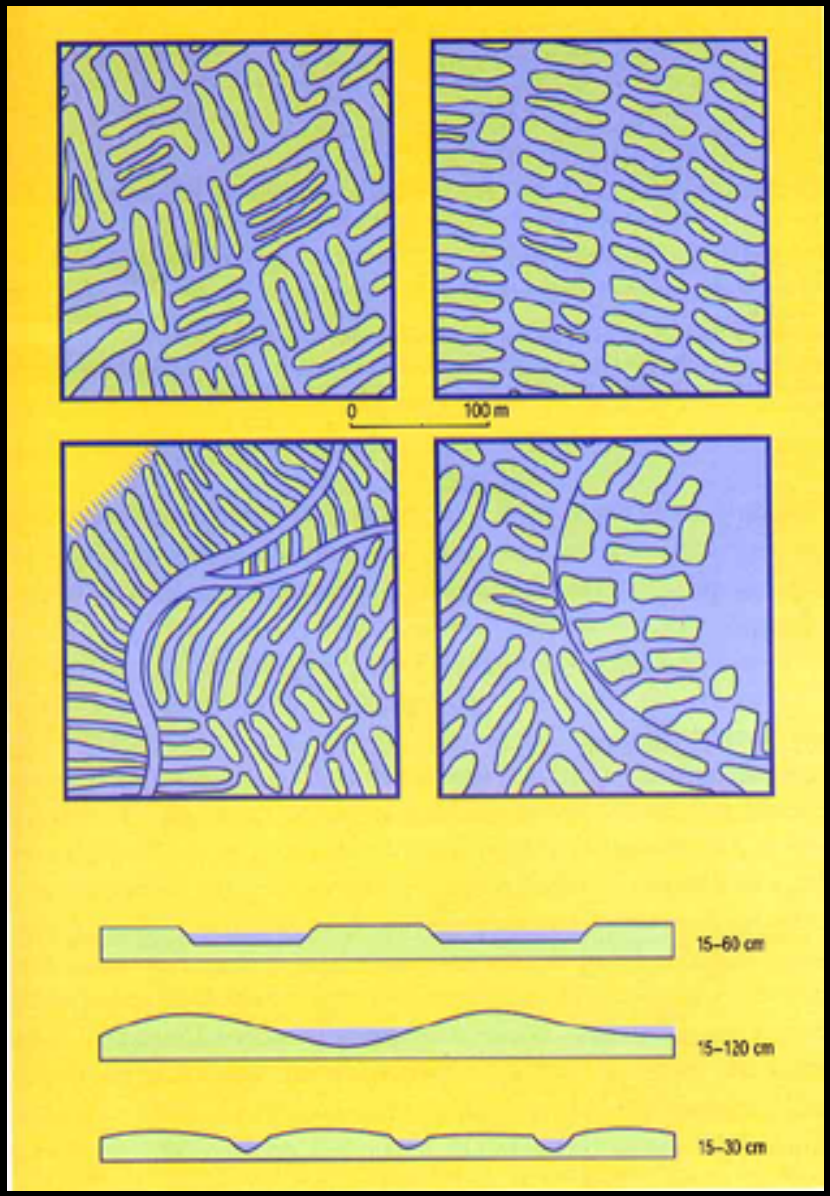
Ceibal; Massive constructions and caching

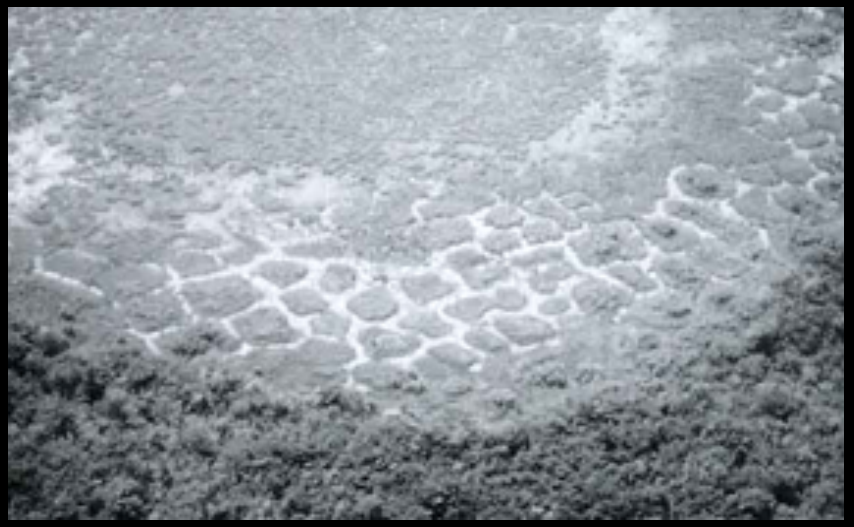
Long distance trade

Cival cache 4; 800-700 BC

Intensive farming techniques

More productive subsistence systems





Pulltrowser Swamp, Belize

Hereditary kingship

San Bartolo murals; West Wall, part 3

Monumentality, hierarchy, and centralization

El Mirador; 200 BC – AD 150

Grouped pyramid plaza complexes

Political hierarchy

Water Reservoirs

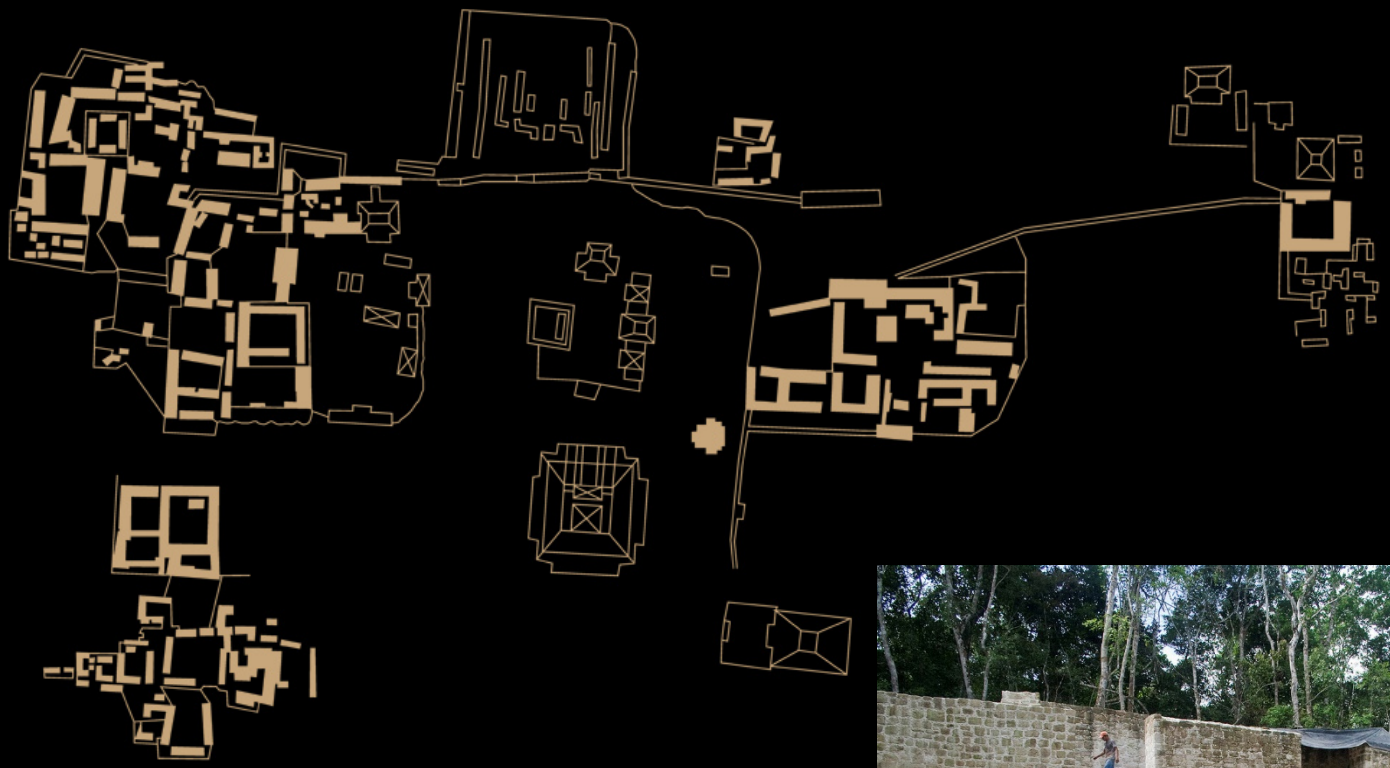
Elite residences and courtyards

Densely Populated

Elevated Causeways

Palaces

Calakmul

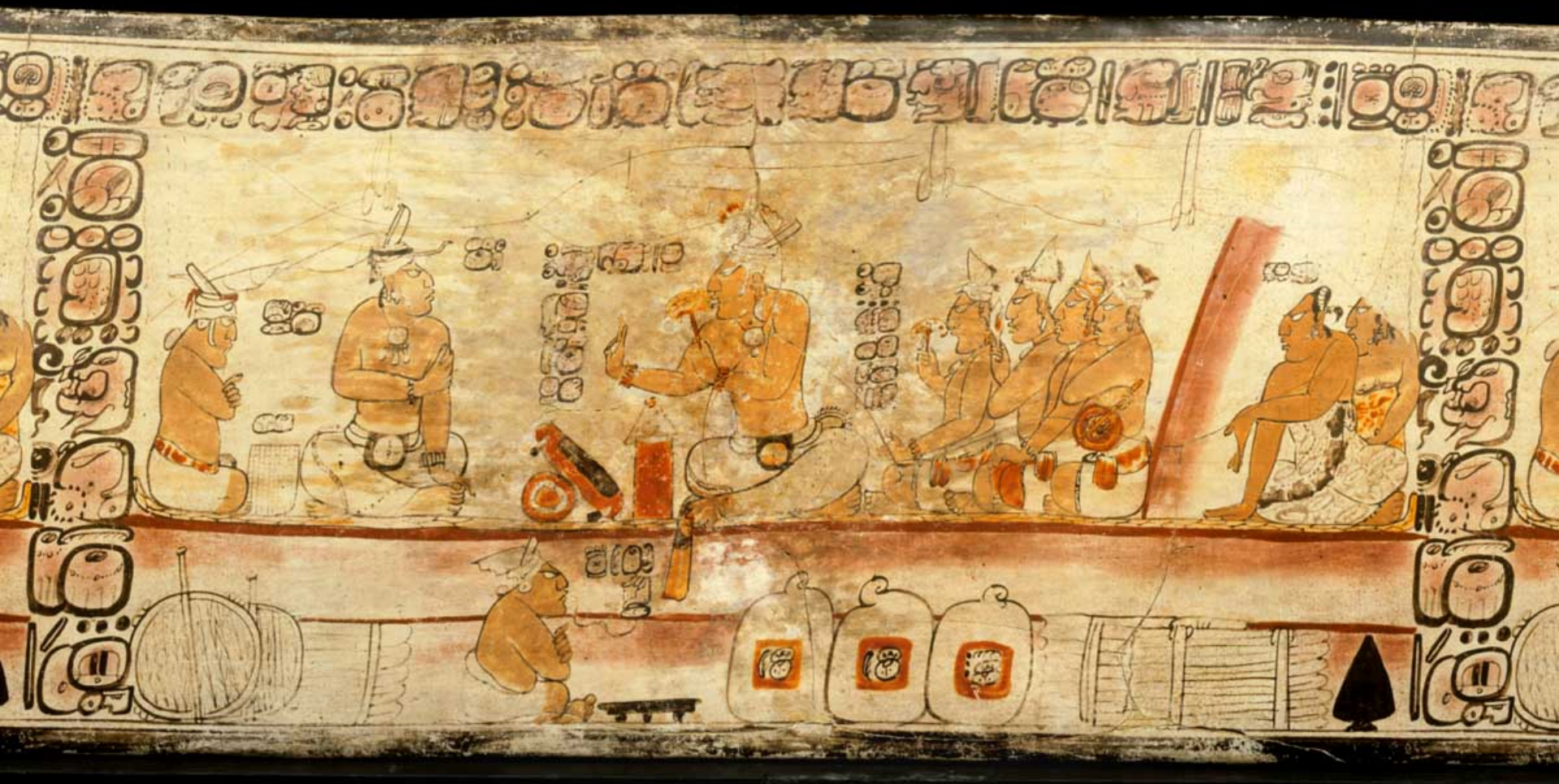


0 500m

Images courtesy of Simon Martin

Centralized government

Royal courts: more than a collection of nobles



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Markets and festivals

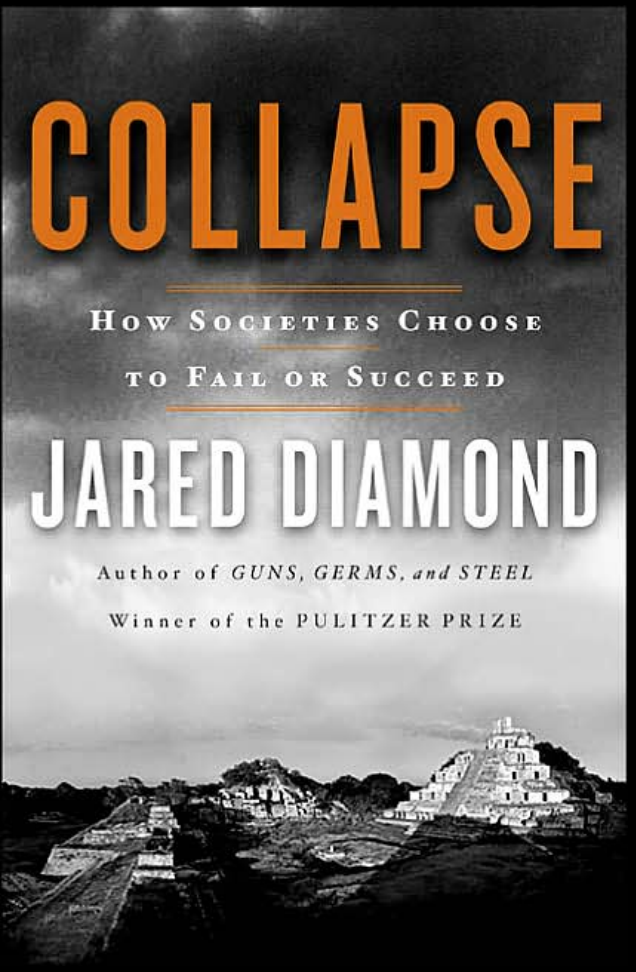
Chiik Nahb in Calakmul

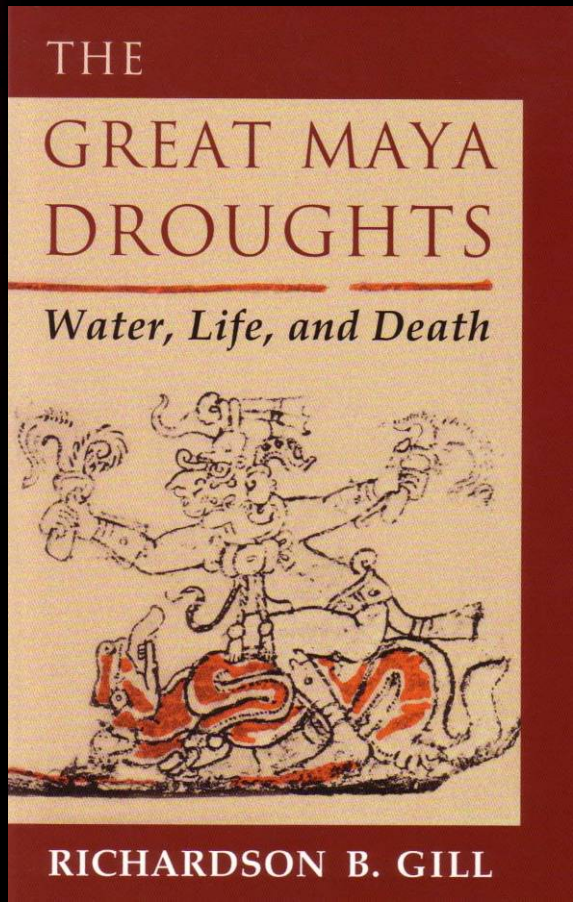
Chronology of the Maya area

Over two millennia of history: 1000 BC – AD 1500

Drought & Collapse

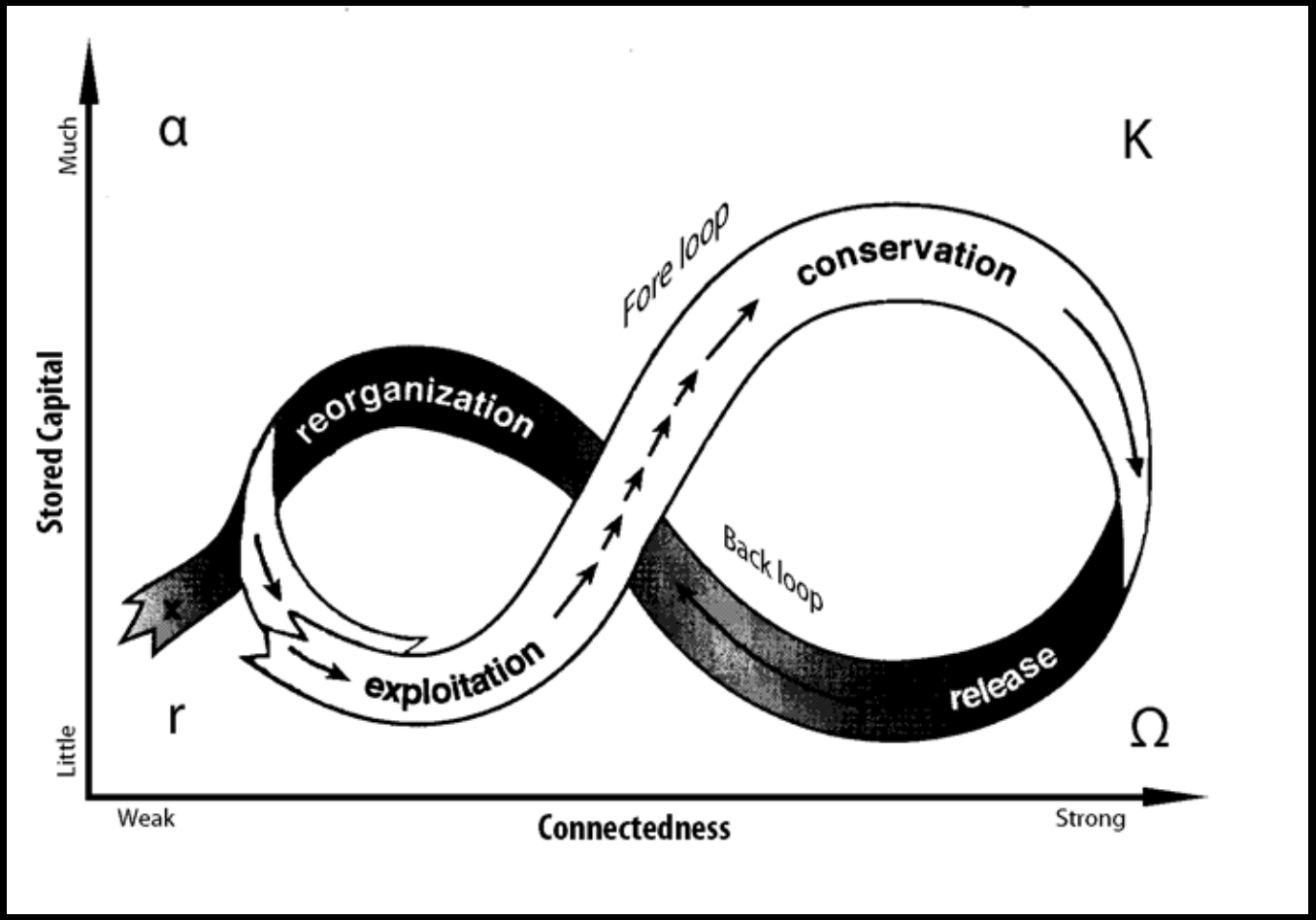
When, where, what?





Resiliency theory

Periods of Rapid Change



Environmental shifts

Demographic pressure

Resource scarcity (economic or ecosystem services)

Social inequality

"Deus ex machina"

Cultural conceptions of climate change

Climate is what we expect,
weather is what we get.
Mark Twain

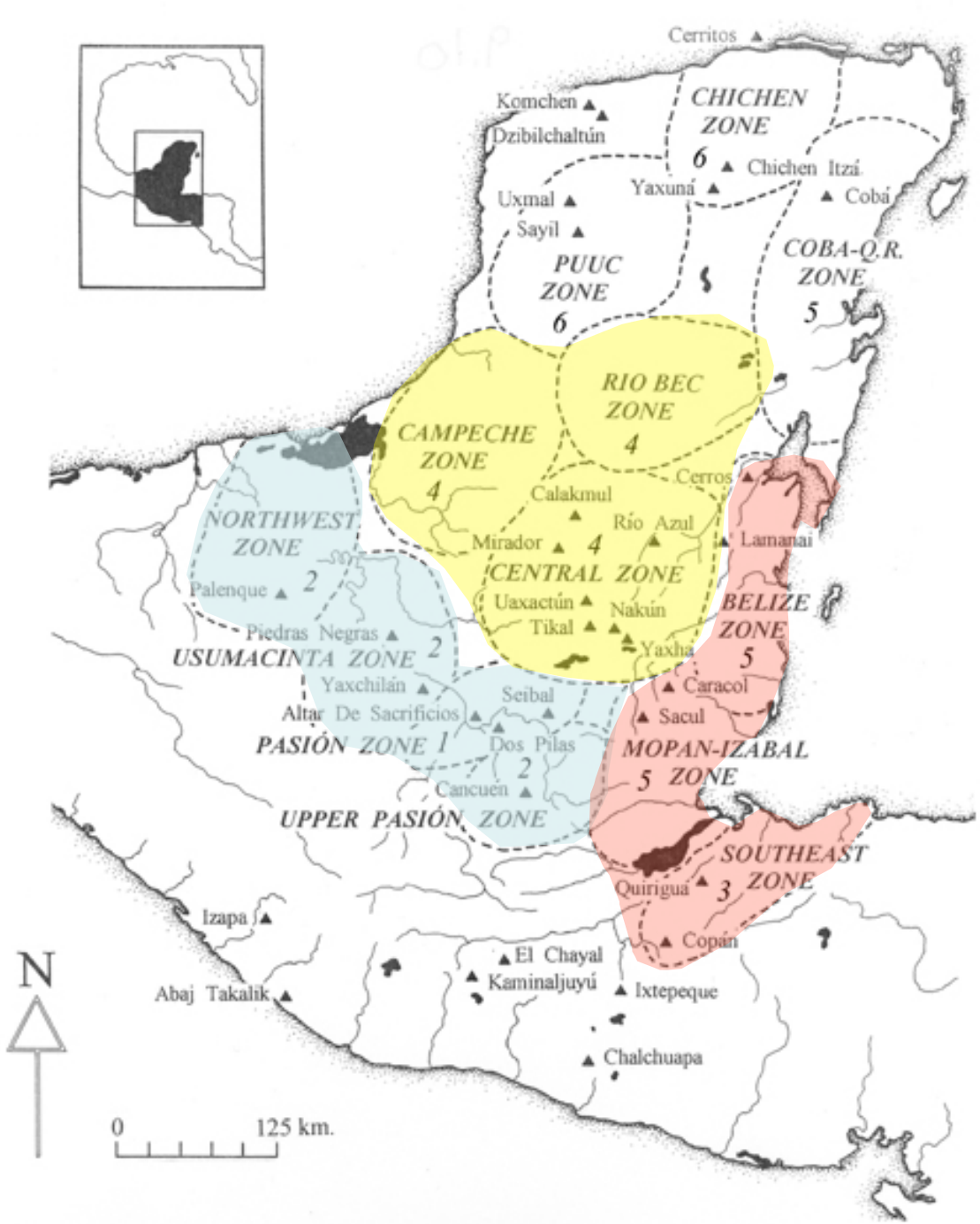
Where, When, and What

Parameterize the "Maya Collapse"

- Where
  - Pasion / Usumacinta / Tabasco plain
  - Central karstic uplands
  - Eastern lowlands
- When
  - 750-850 (Late Classic)
  - 800-1000 (Terminal Classic)
- What
  - Political system
  - Population

Where

Three major regions



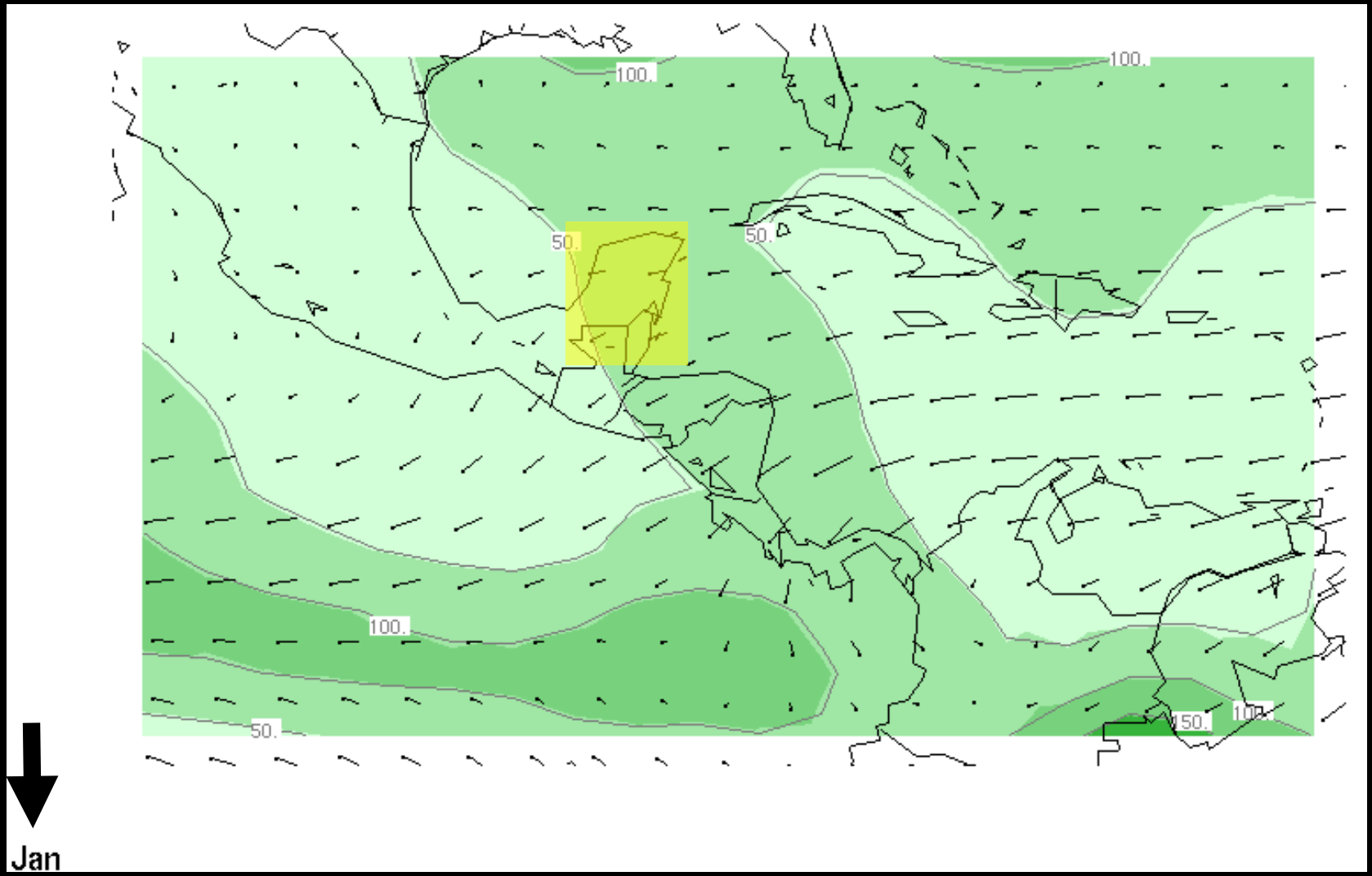
Pasion
Usumacinta
Tabasco plain

Central karstic uplands

Eastern lowlands

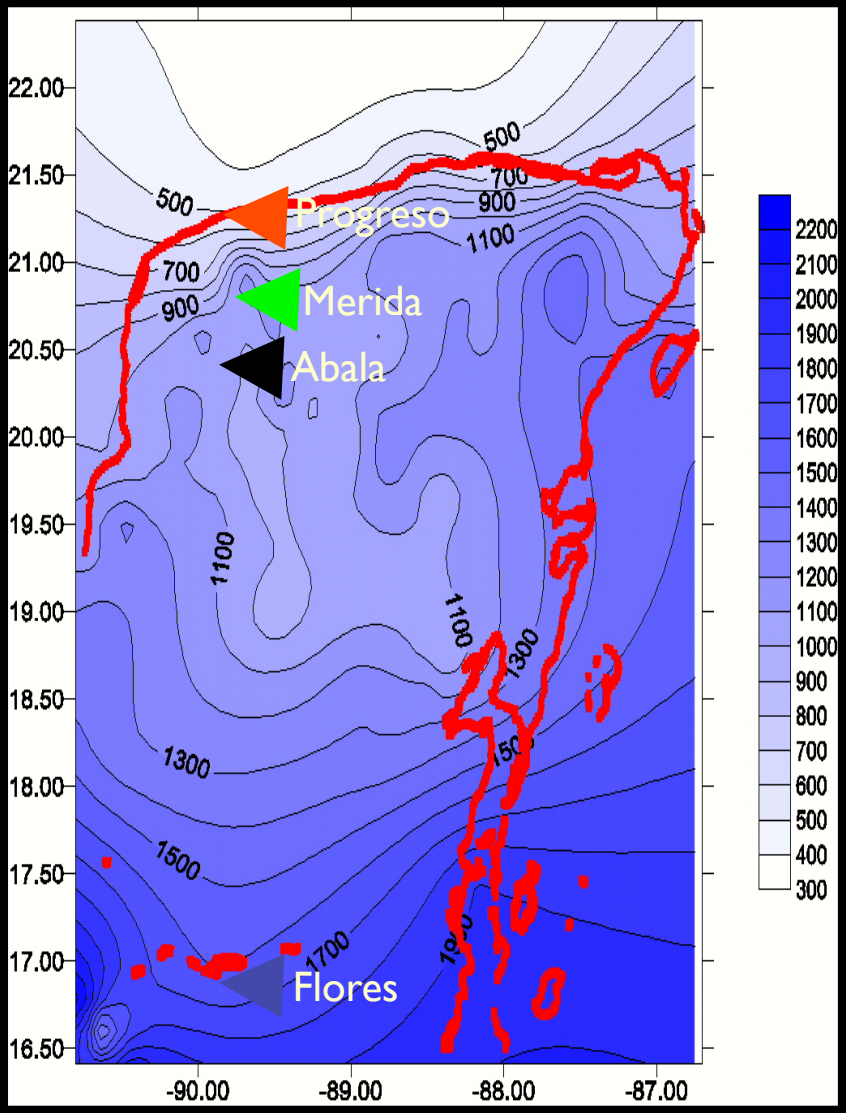
Climate of Maya lowlands

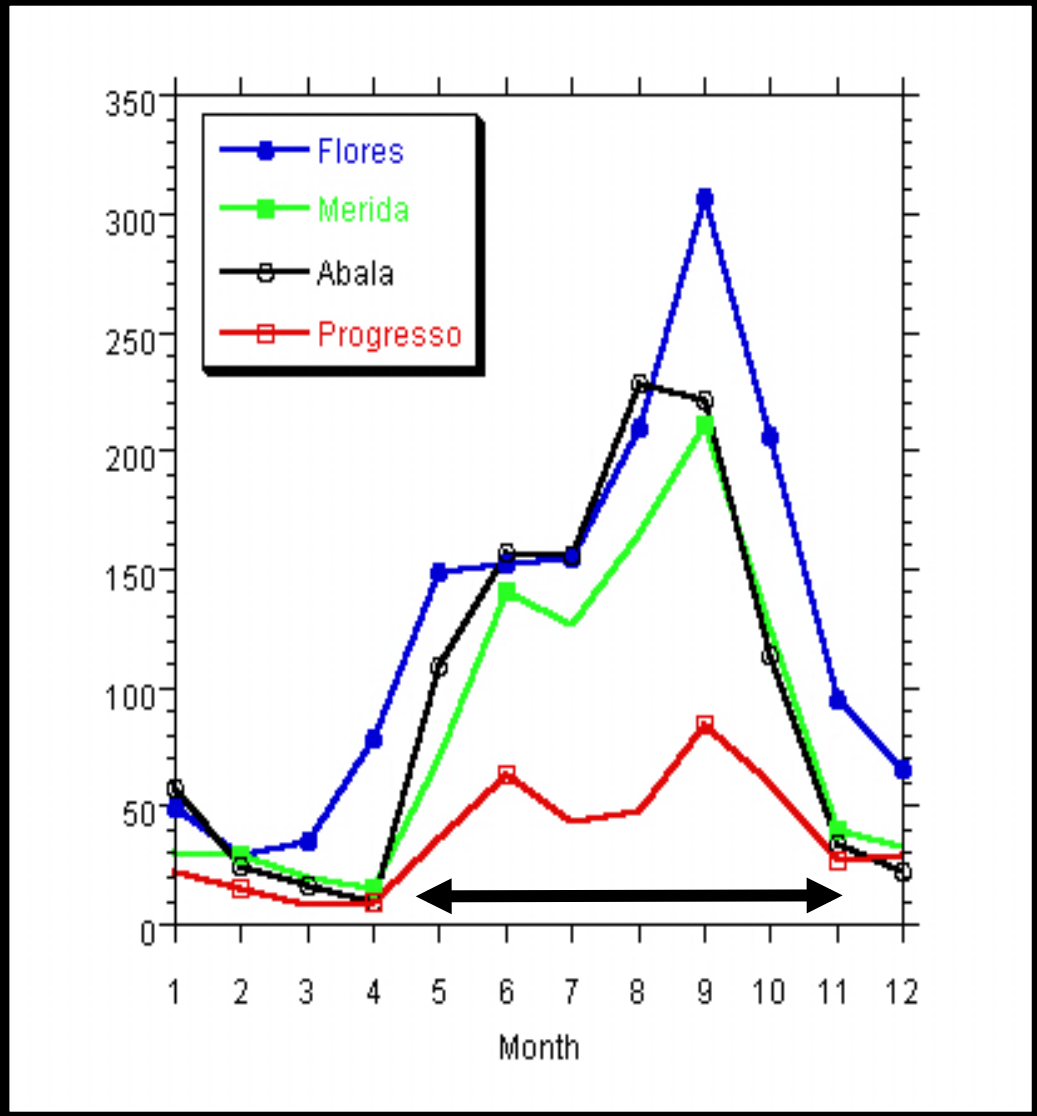
Inter-Tropical Convergence Zone (ITCZ)



Precipitation of Maya lowlands

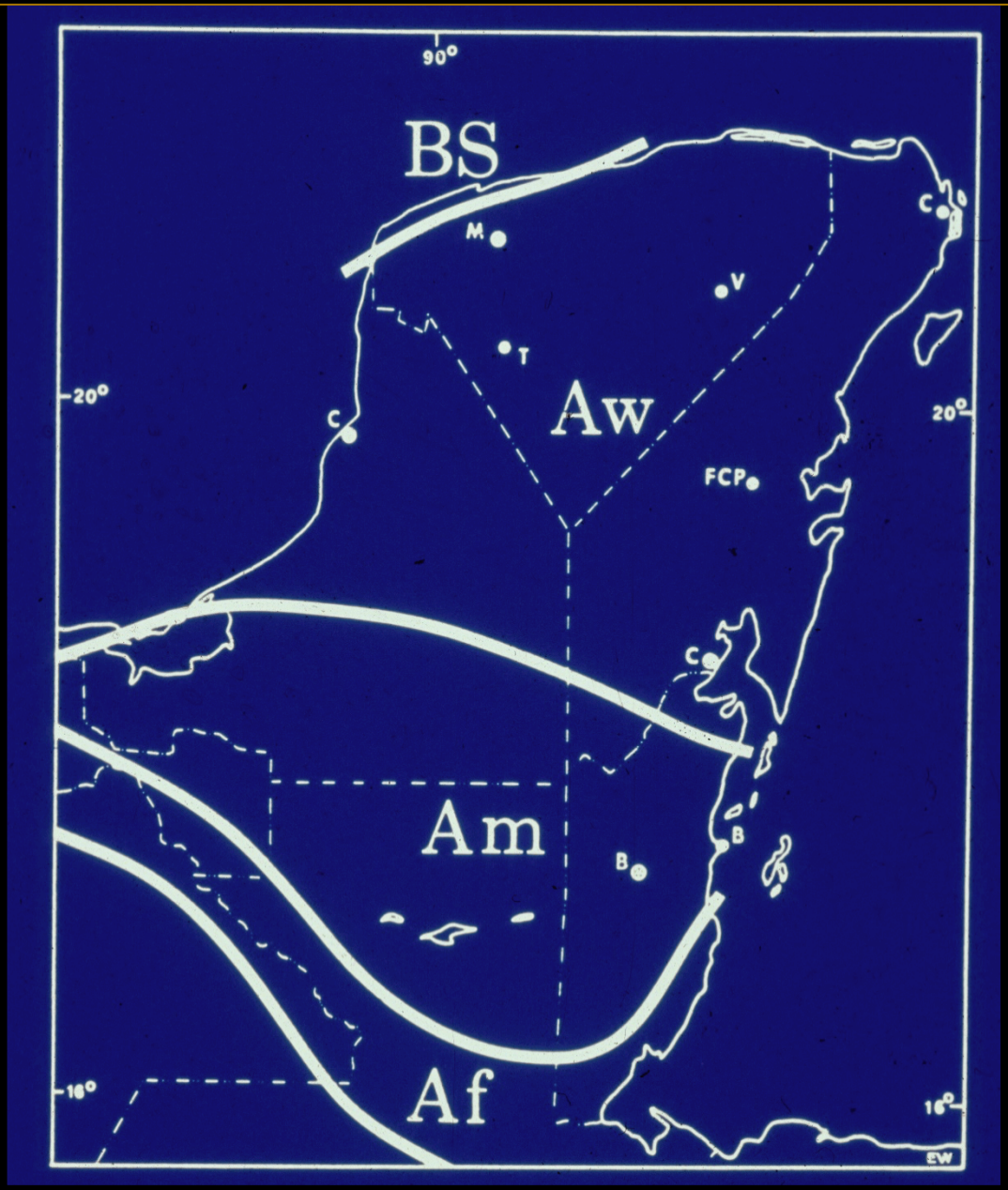
Precipitation patterns (mm/yr)





Climate of Maya lowlands

Koppen Climate Classification



BS
semi-arid

Aw
seasonal tropical w/ winter dry season

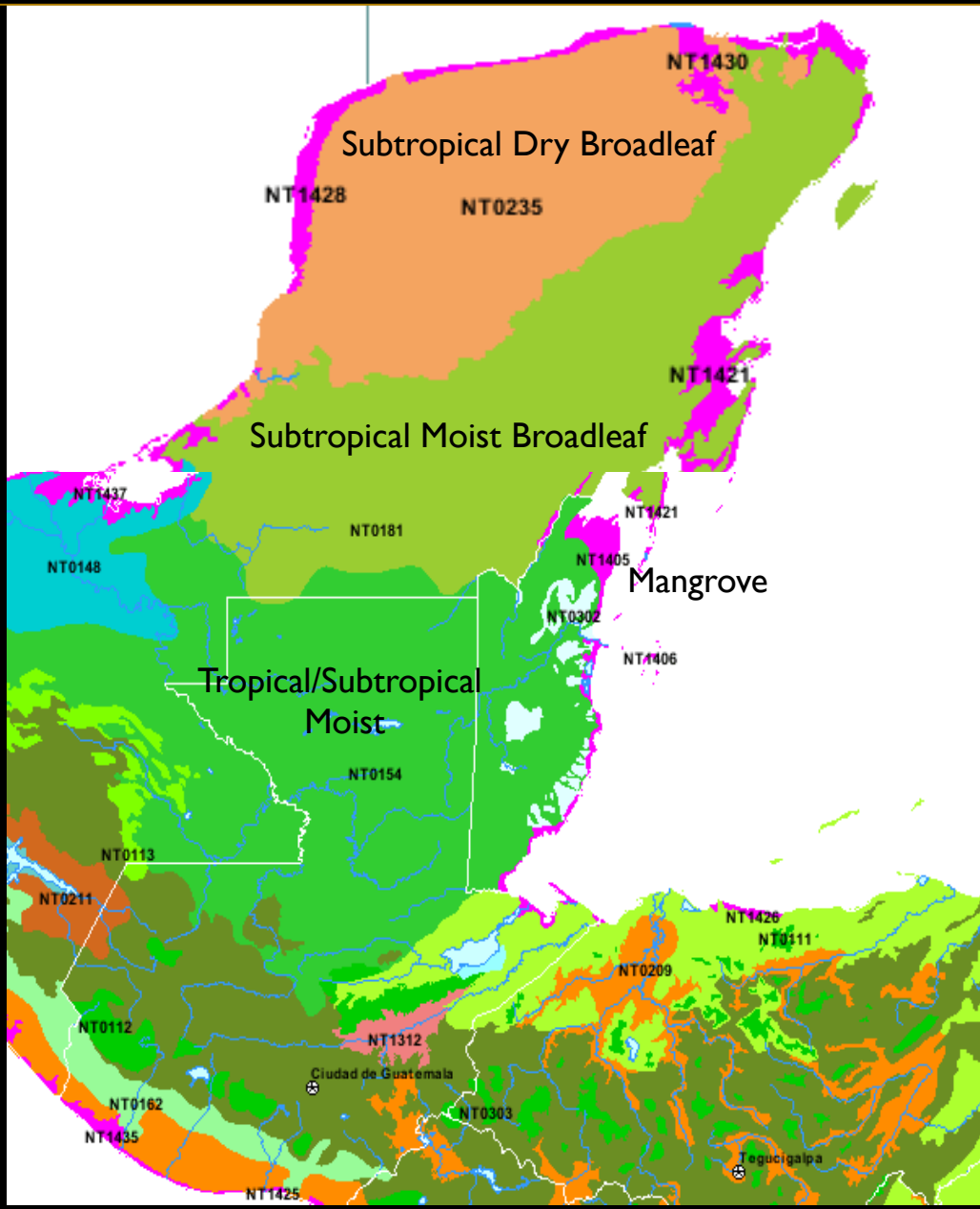
Am
tropical monsoon

Af
tropical rainforest

Wilson (1980)

Environment of Maya lowlands

Vegetation zones



When

Terminal Classic; AD 750-850

Bone inscription mentions drought/famine

Comalcalco; AD 763

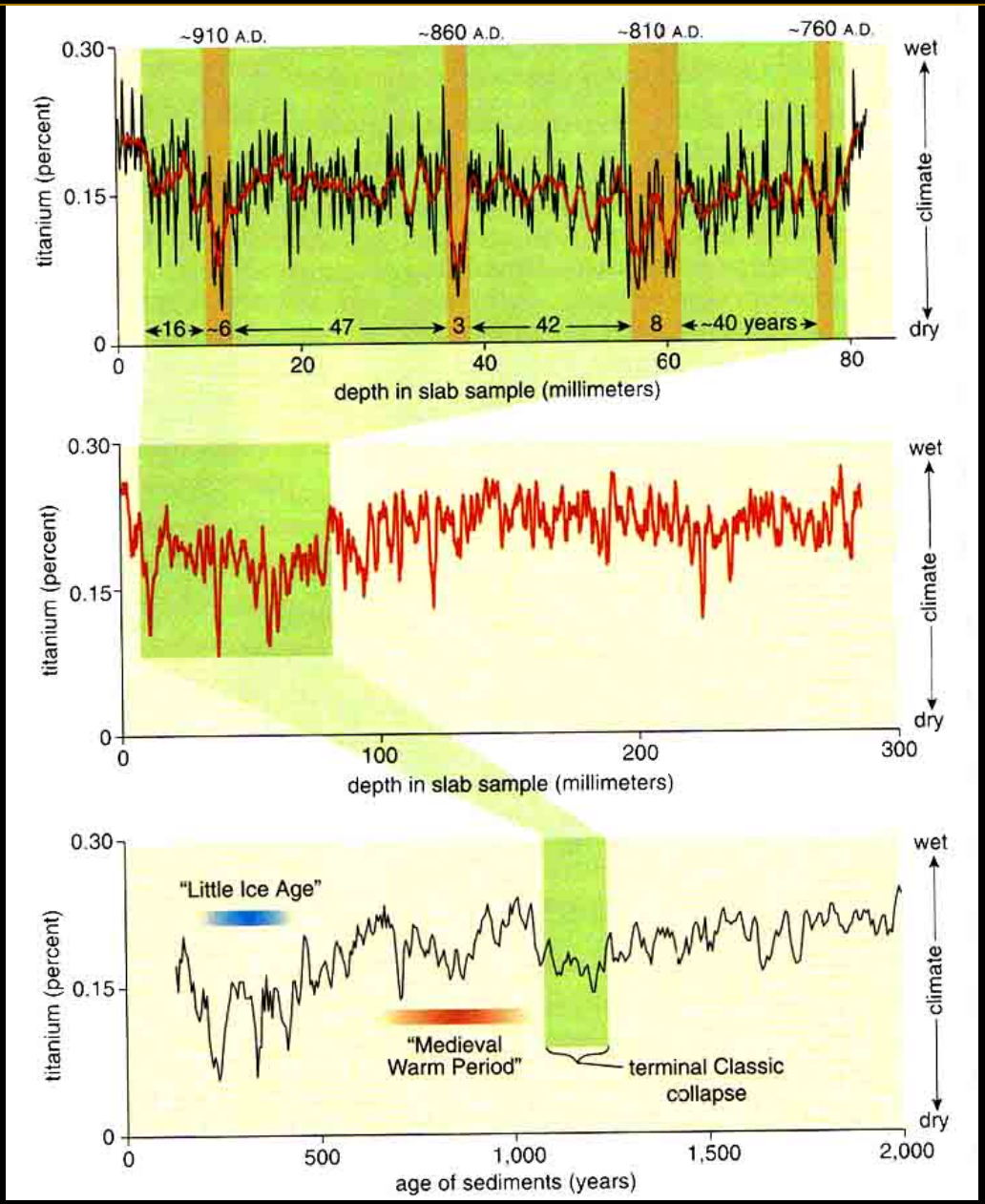
k'intuun / wi'nail

Paleoclimate records

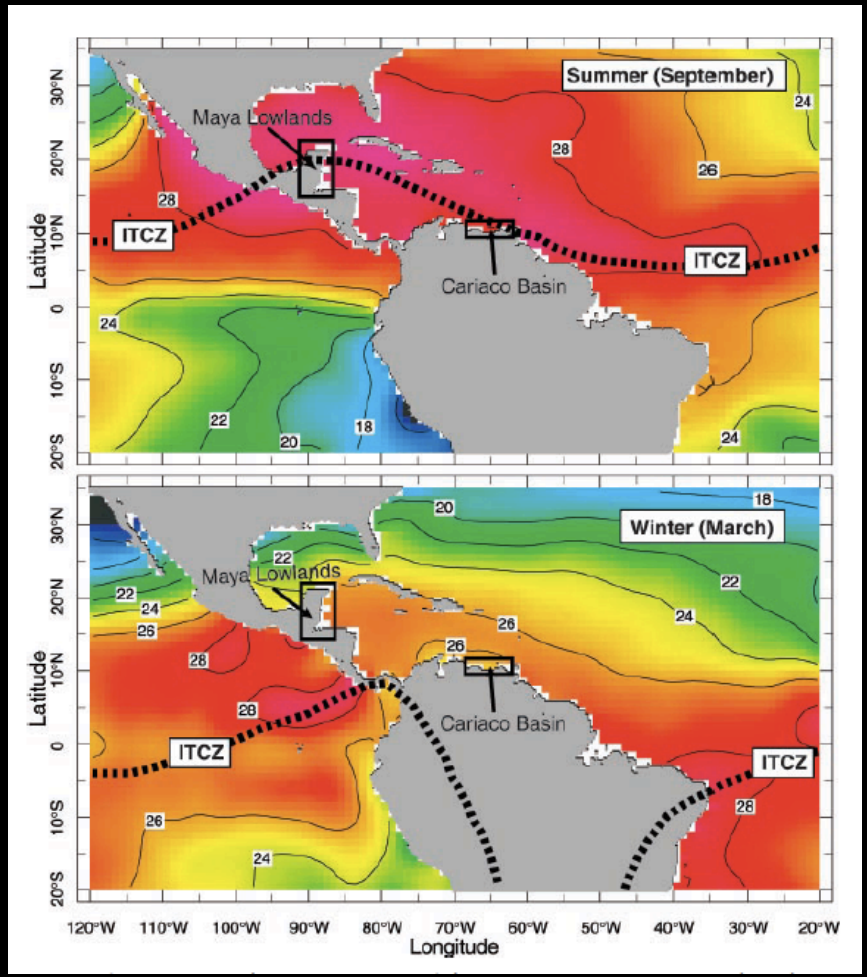
Maya area

1) Cariaco Basin

Haug et al. 2003

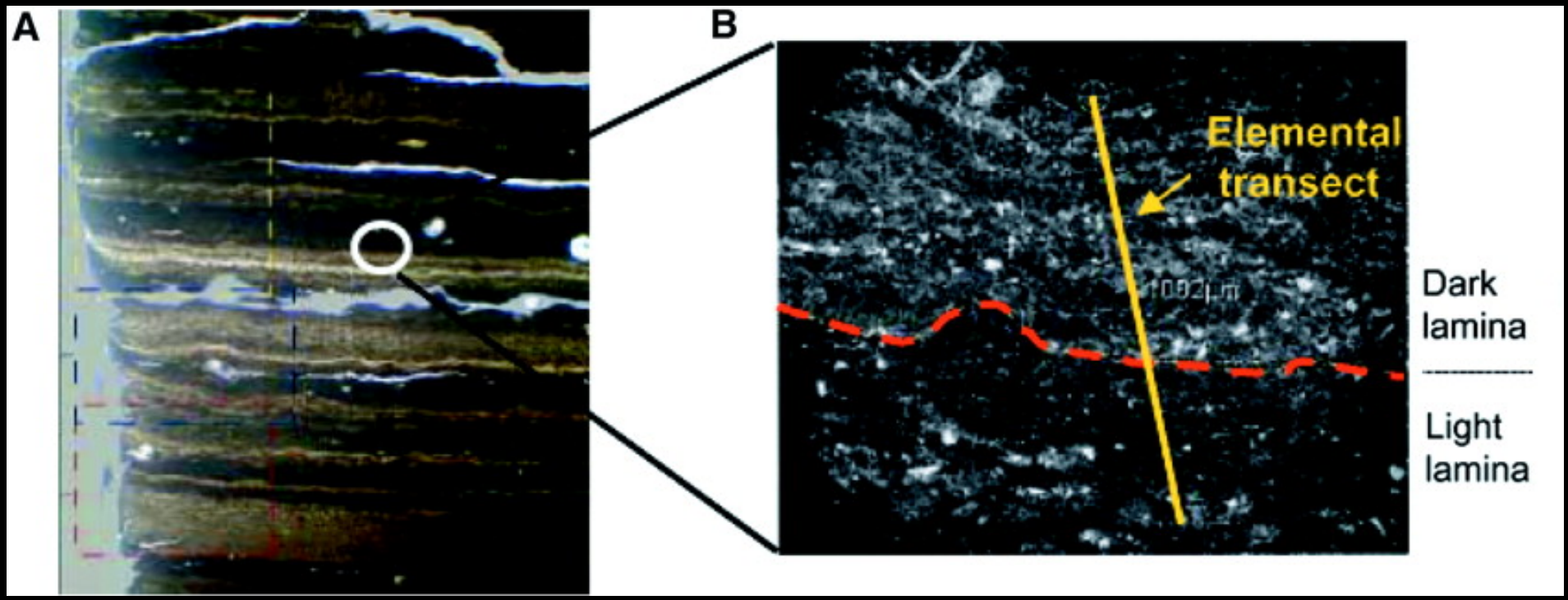


Inter-Tropical Convergence Zone (ITCZ)



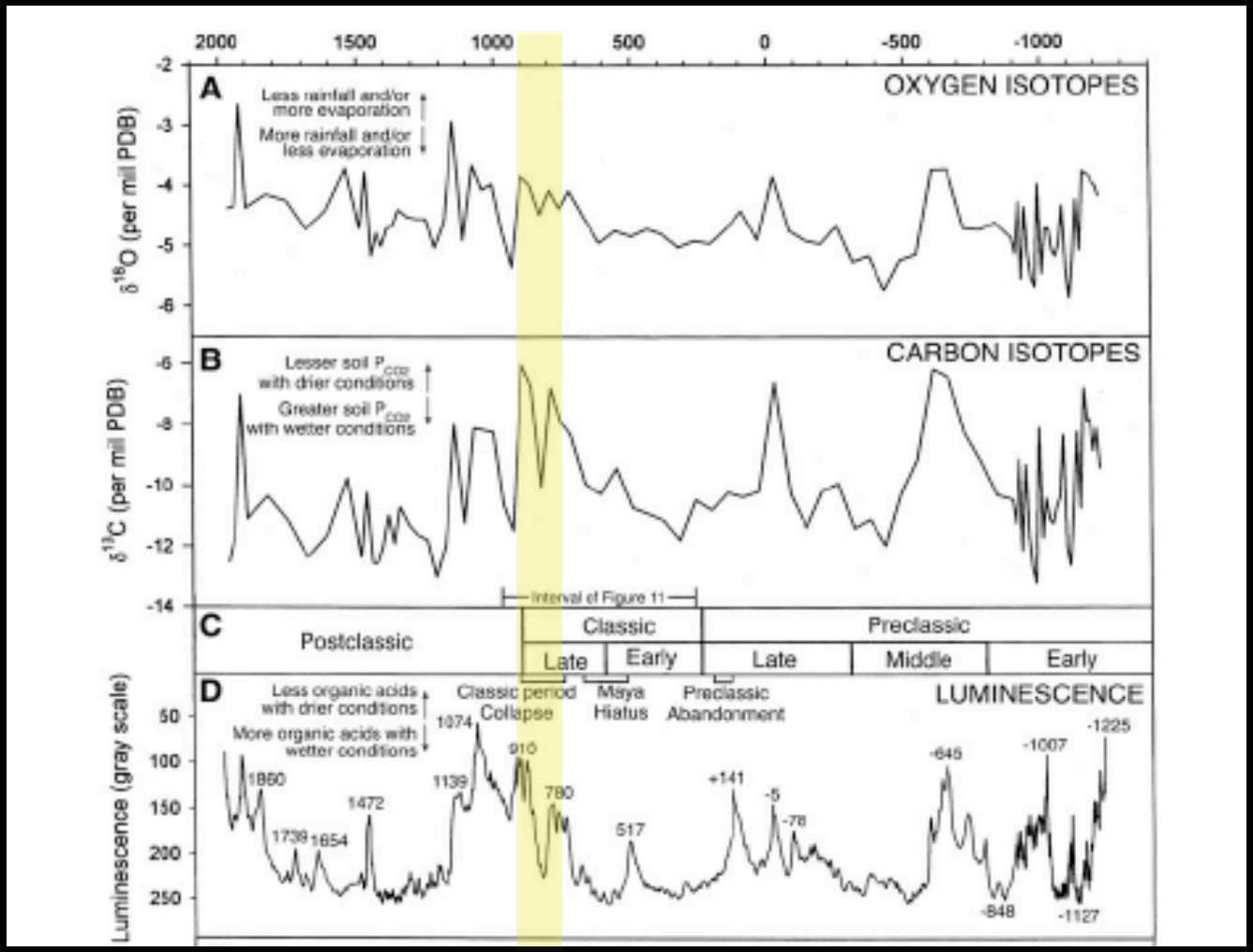
1) Cariaco Basin

Haug et al. 2003



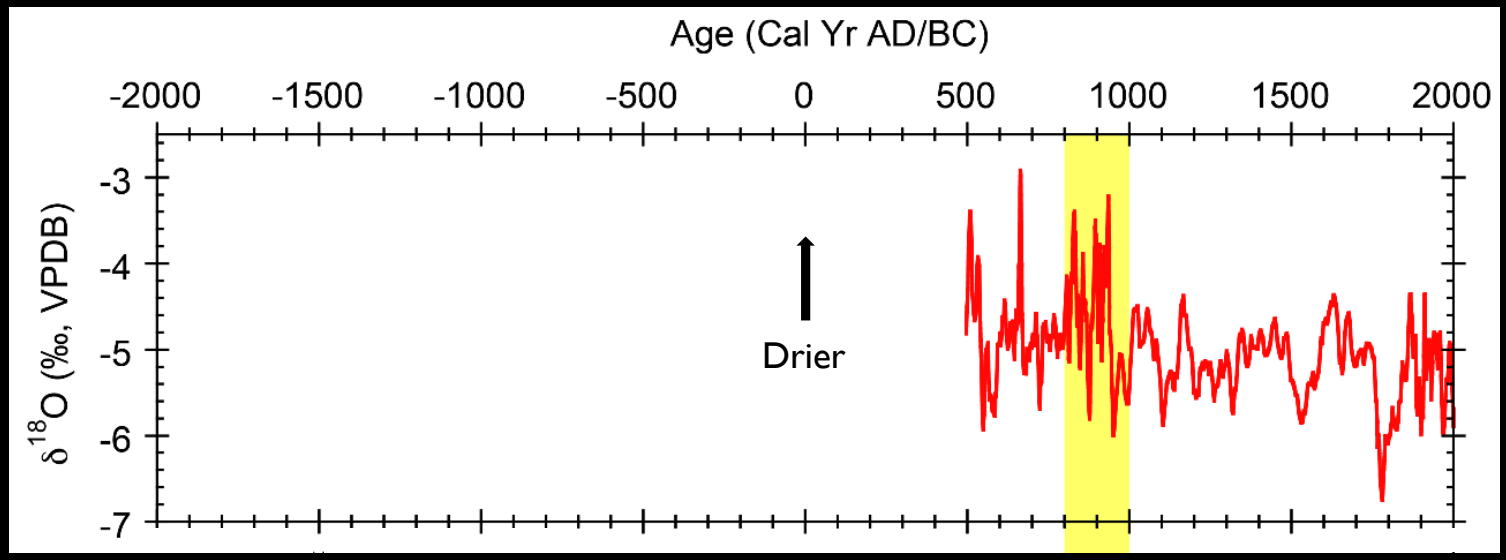
2) Machal Chasm speleothem, Belize

Webster et al. 2007



3) Tecoh Cave, Yucatan

Medina-Elizalde et al. 2010, 2012



Droughts

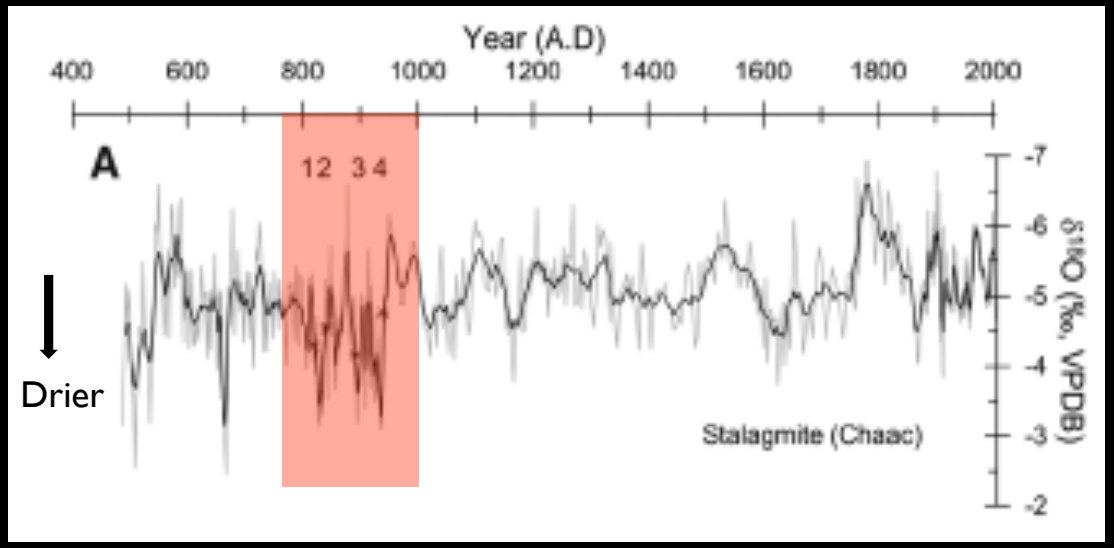
AD 500

AD 666

AD 771

AD 820-990

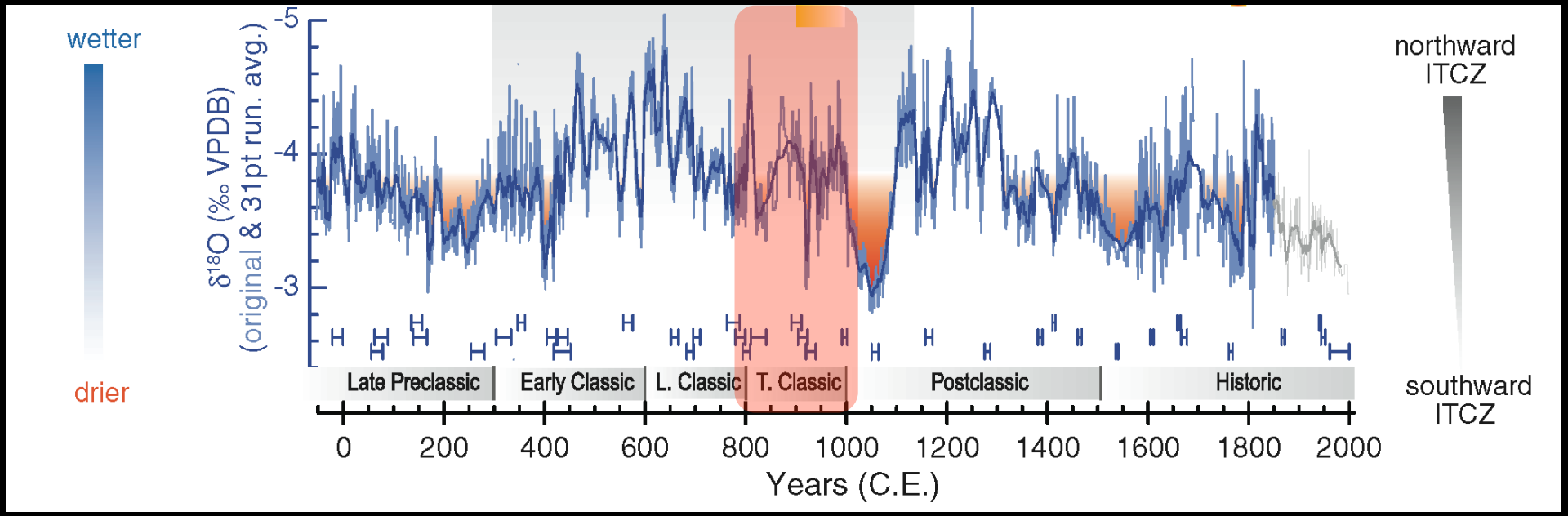
(842, 857, 895, 909, 925, 937)



4) Yok Balum Cave, southern Belize

Kennett et al. 2012

AD 0-100	wet
AD 100-400	dry
AD 400-800	wet
AD 800-1000	mixed
AD 1000-1200	dry



Grayed out tail that reflects the last 200 years is ENTIRELY inconsistent with historically known precipitation records

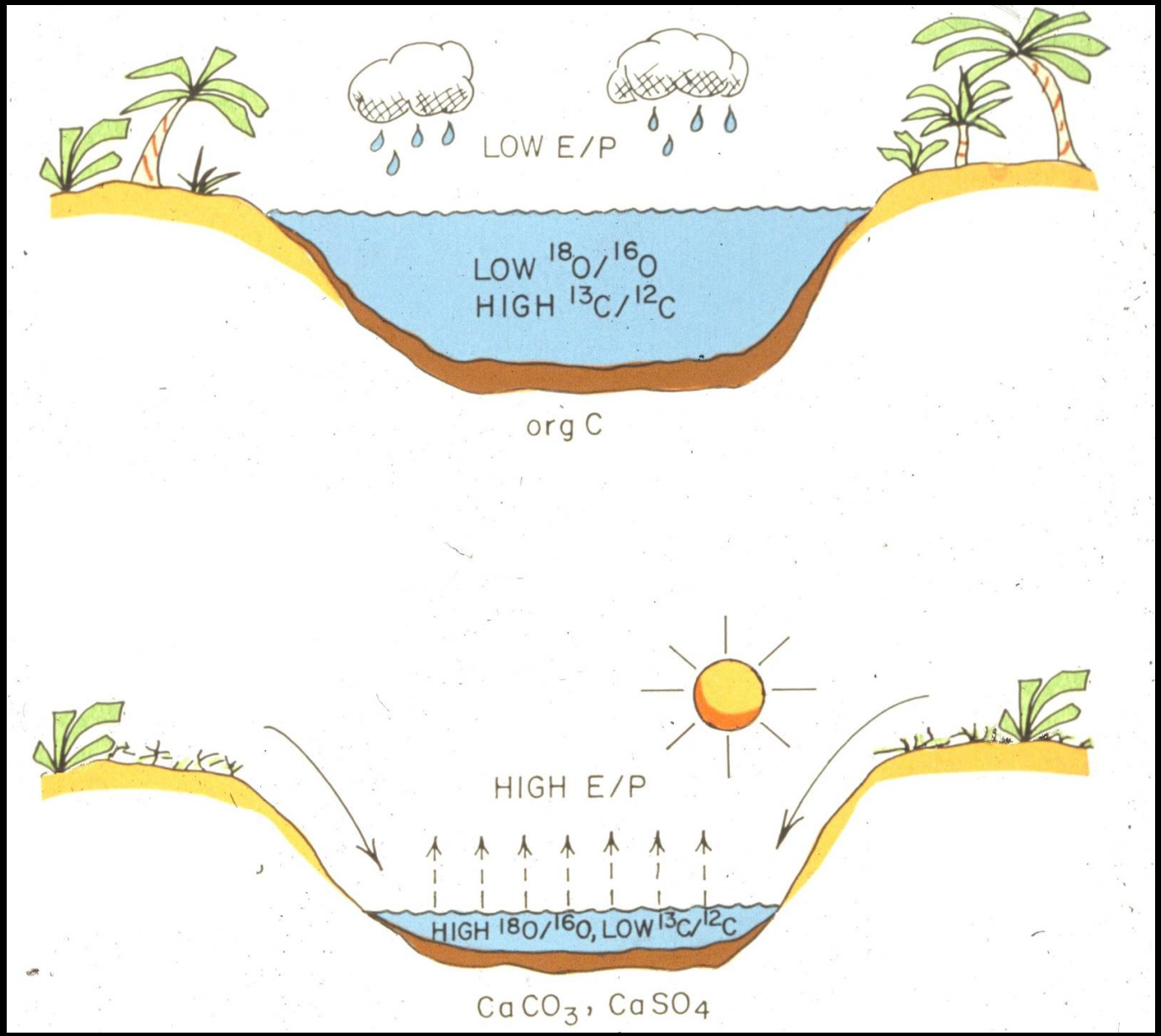
Groundwater–to–speleothem transfer is unclear and suspiciously wrong in known historical contexts

5) Lake Chichancanab, c. Yucatan

Closed basin lake

Lake core records

Lake levels reflect precipitation levels

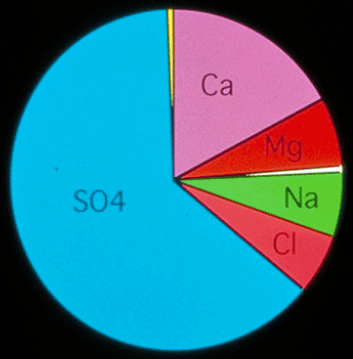


Wet climate:
High lake level

Drought:
Low lake level

5) Lake Chichancanab, c. Yucatan

Gypsum deposits

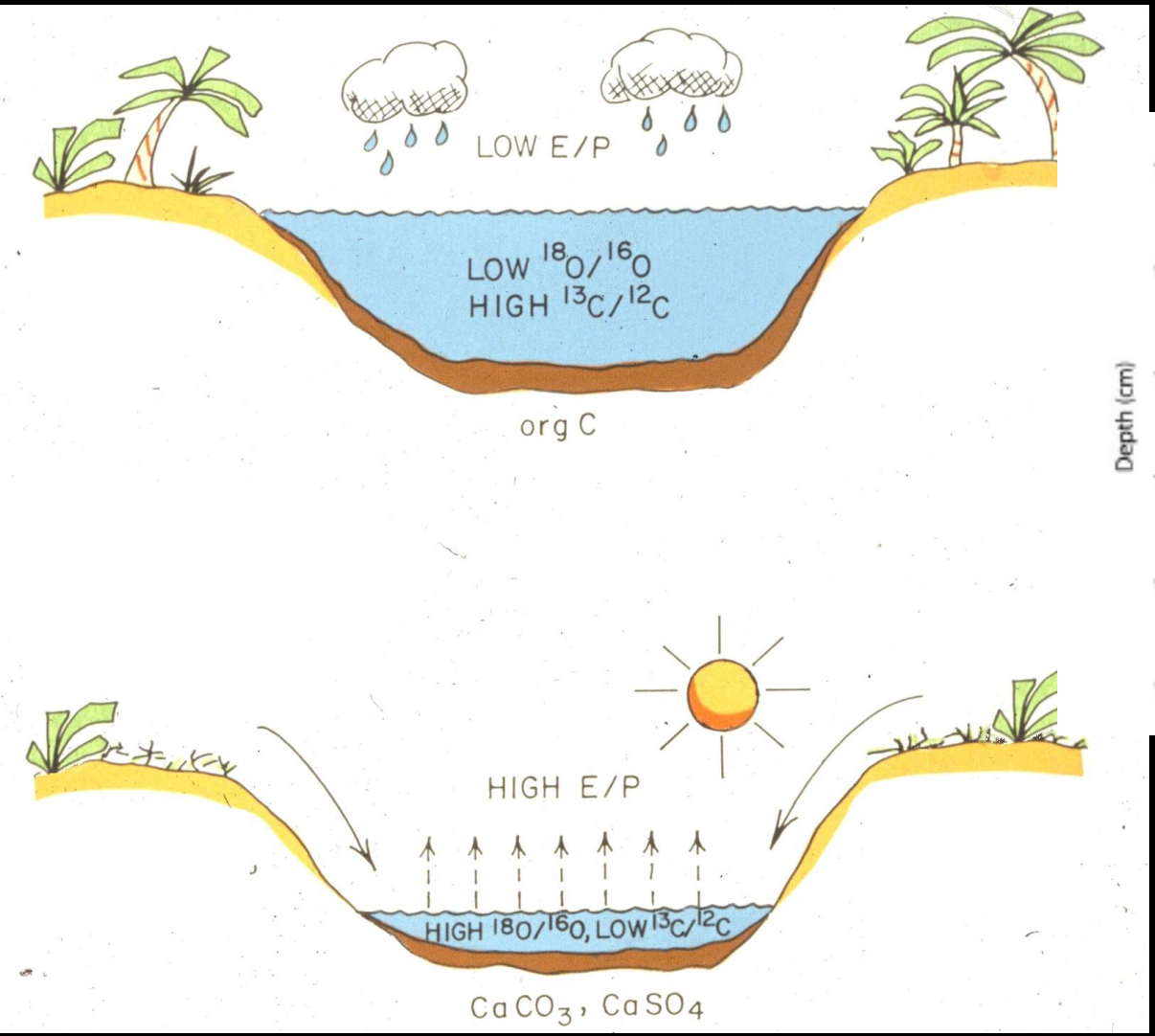


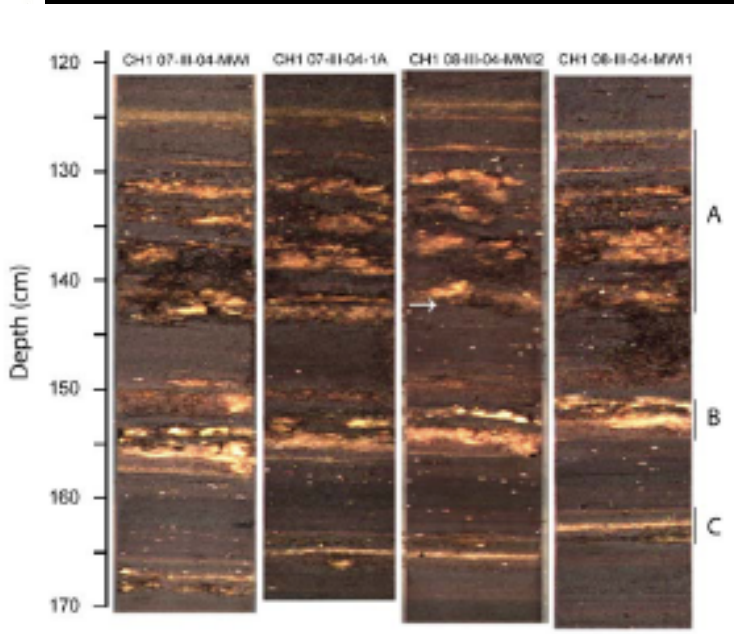
- Ca 693 mg/L
- Mg 257 mg/L
- K 14 mg/L
- Na 250 mg/L
- Cl 234 mg/L
- SO_4 2545 mg/L
- HCO_3 18 mg/L
- Total 4011 mg/L

Gypsum $CaSO_4$ nH_2O

Problems with lake core records

Lake levels MIGHT NOT reflect precipitation levels

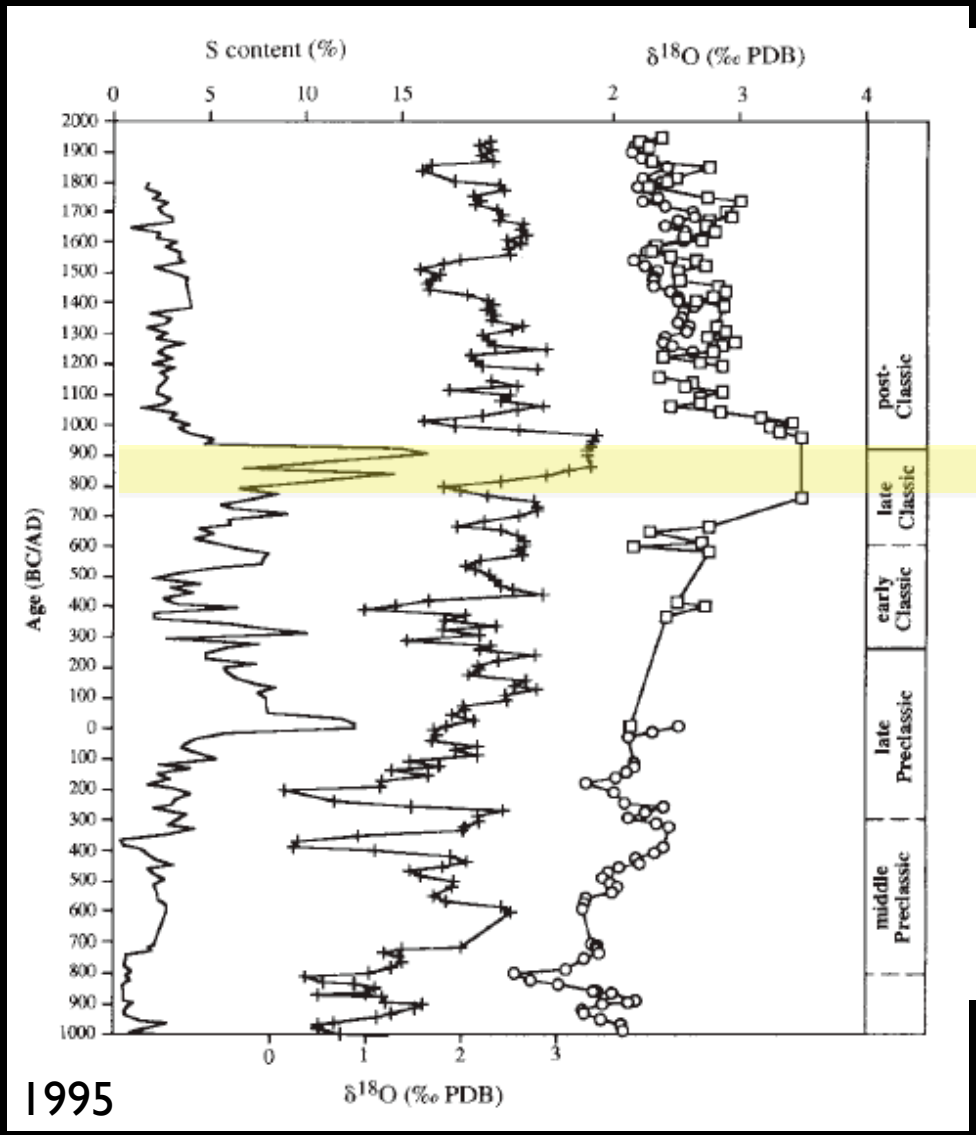




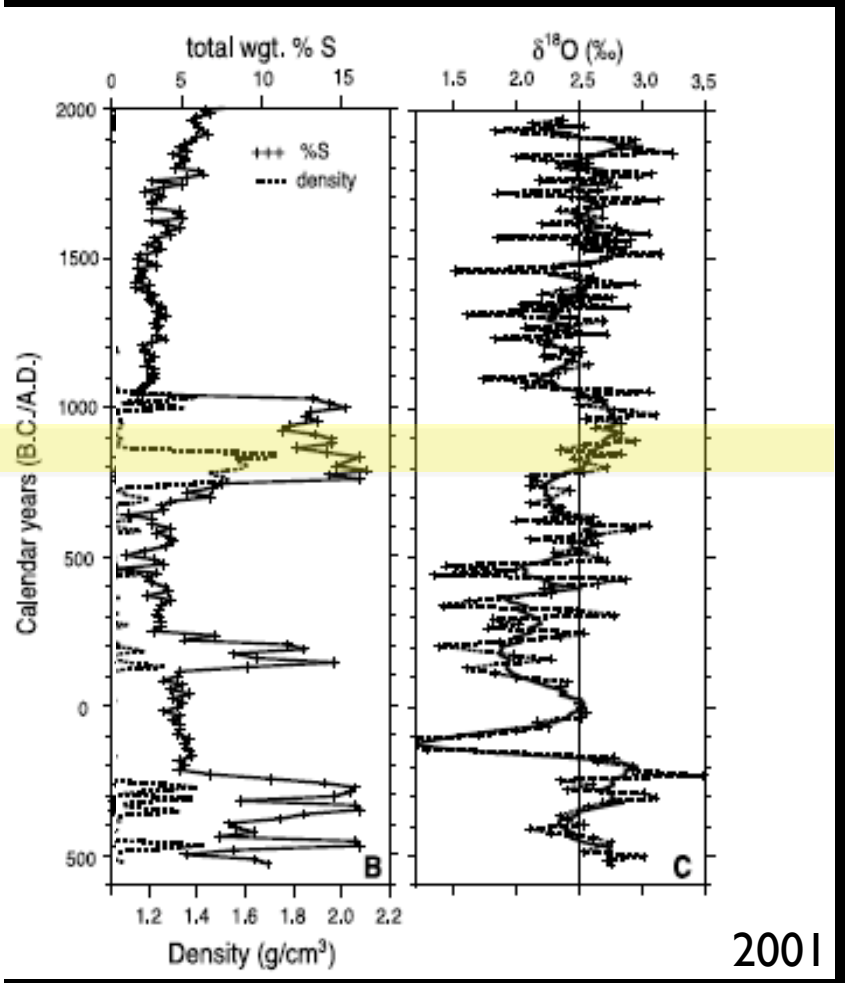
5) Lake Chichancanab, c. Yucatan

Hodell et al. 1995, 2001

major pulse of gypsum deposition from AD 750 to 1000



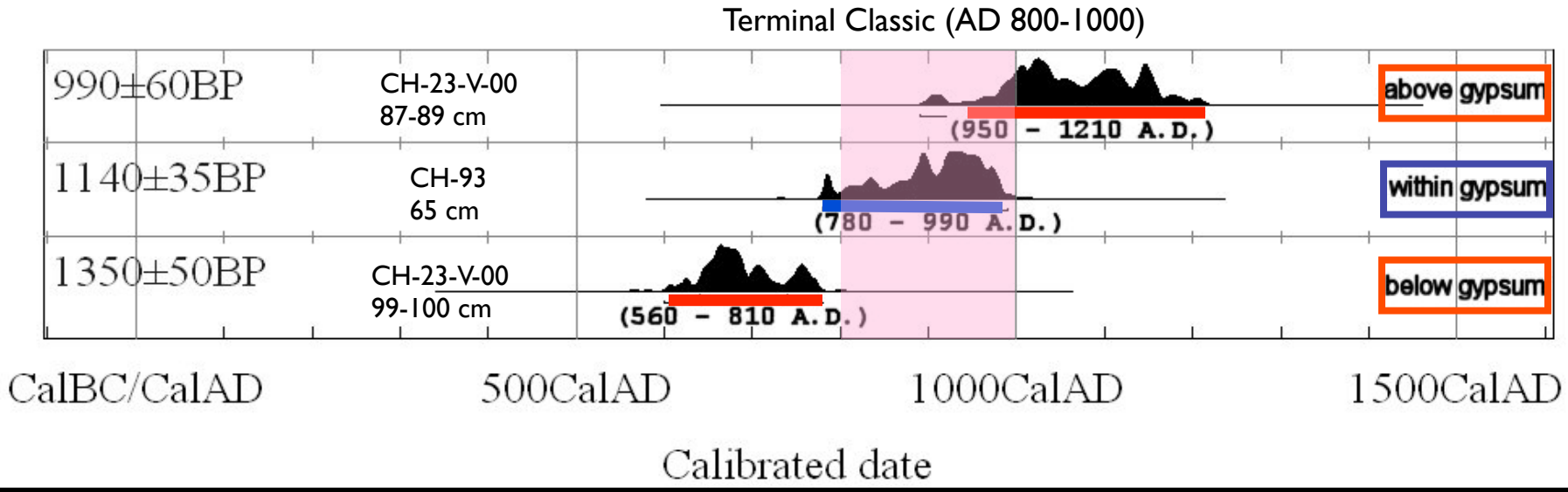
1995

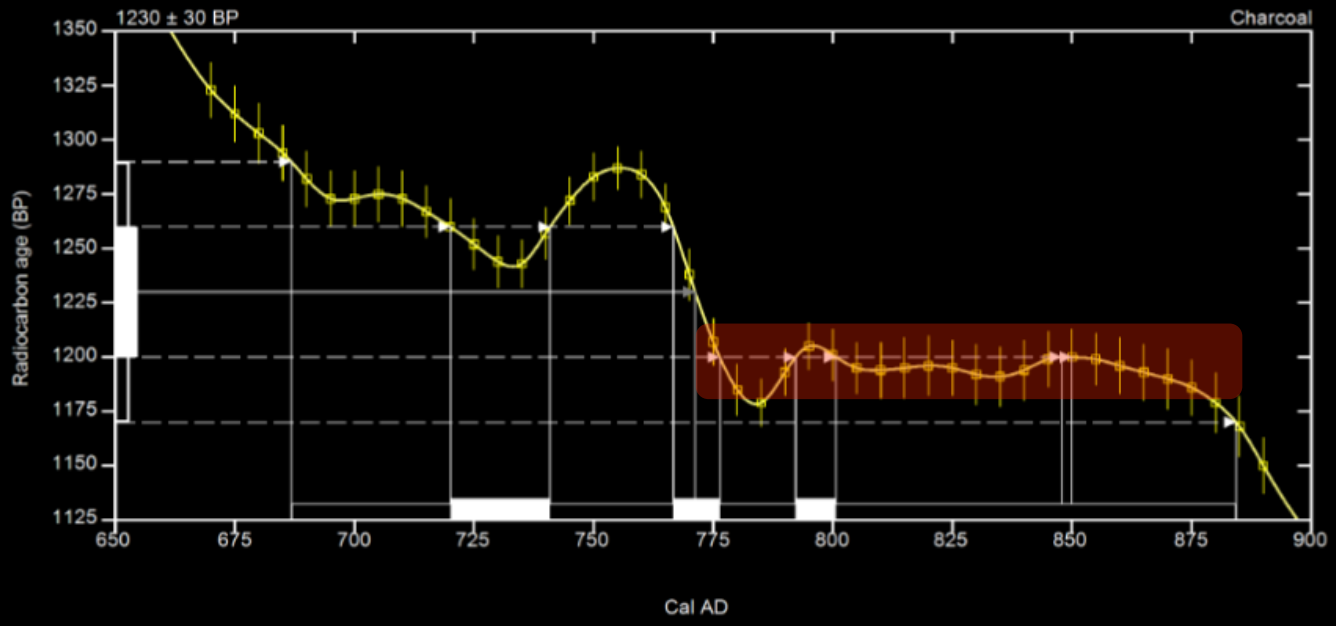


2001

5) Lake Chichancanab, c. Yucatan

Dating of gypsum layers



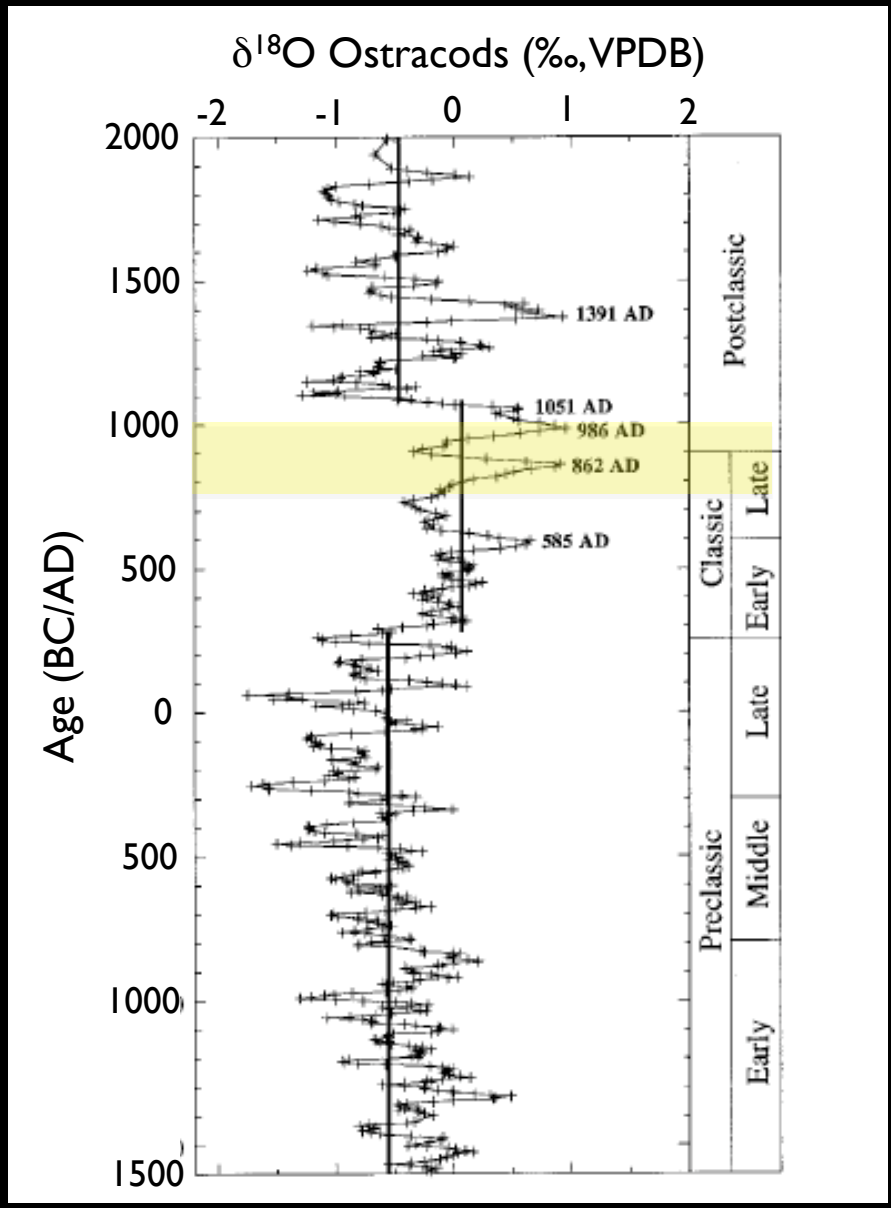


AD 775-885:

C14 calibration curve is flat

6) Lake Punta Laguna, ne Yucatan

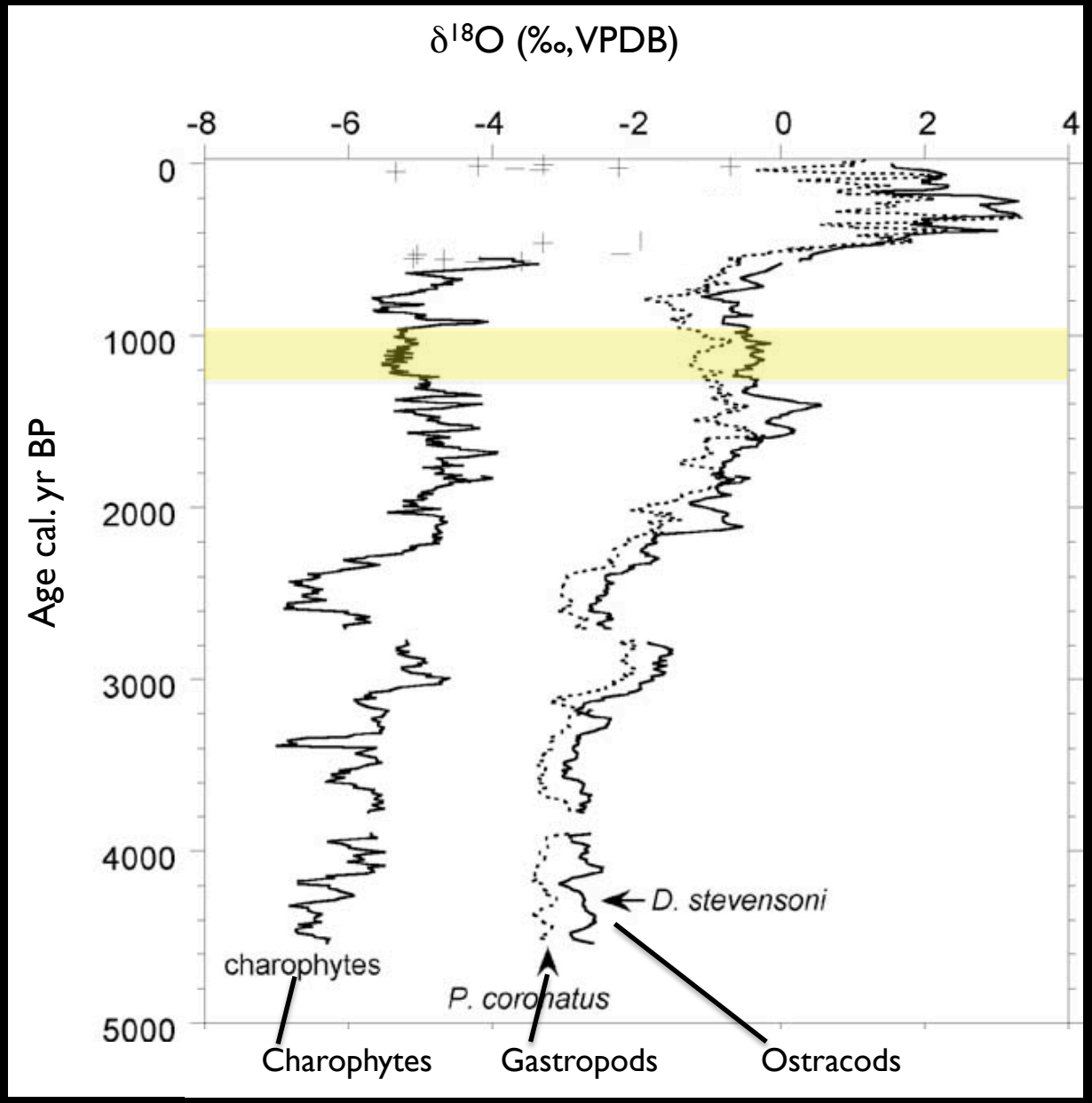
Curtis et al. 1996



7) Aguada X'Caanal, nw Yucatan

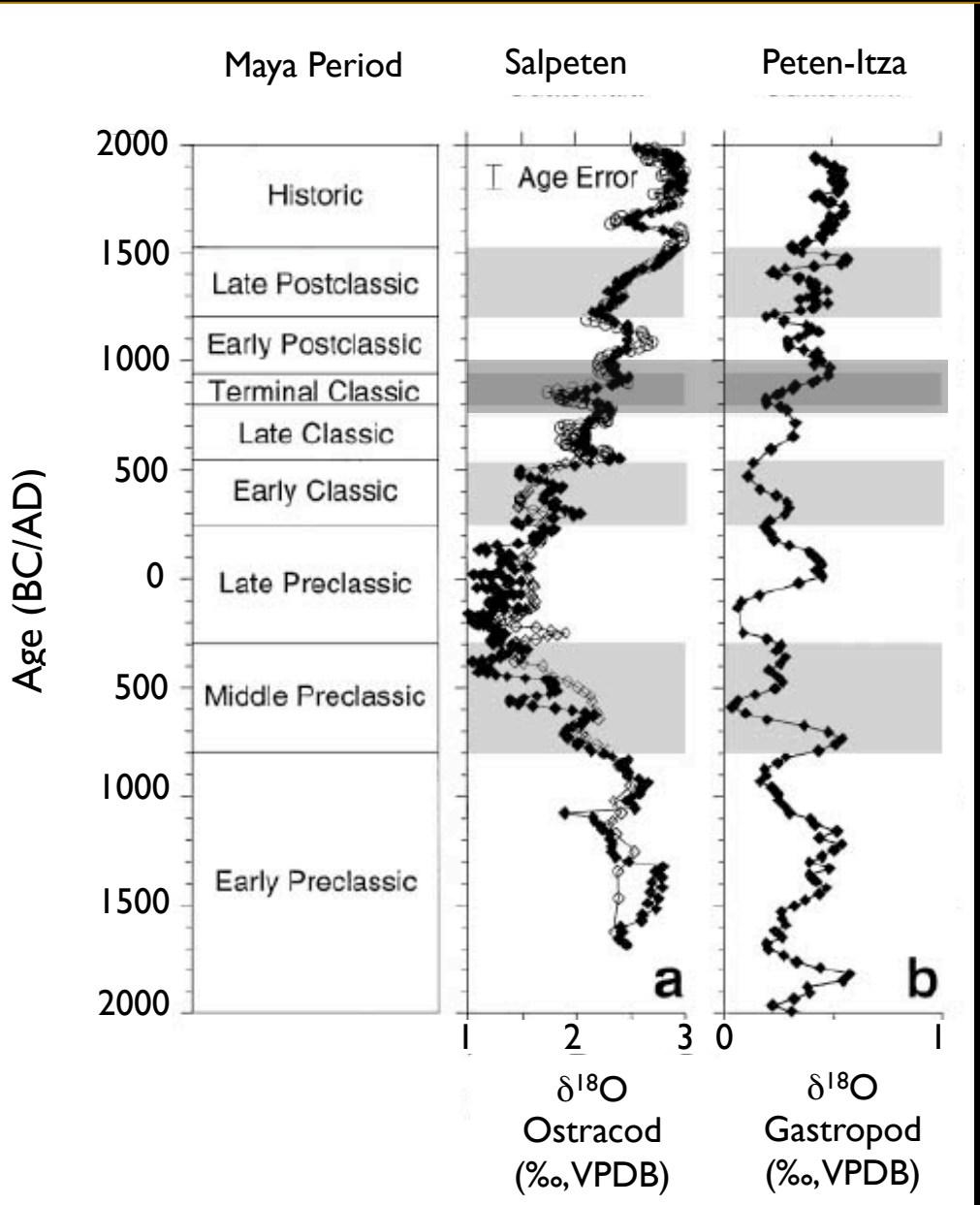
Hodell et al. 2005

No dry period



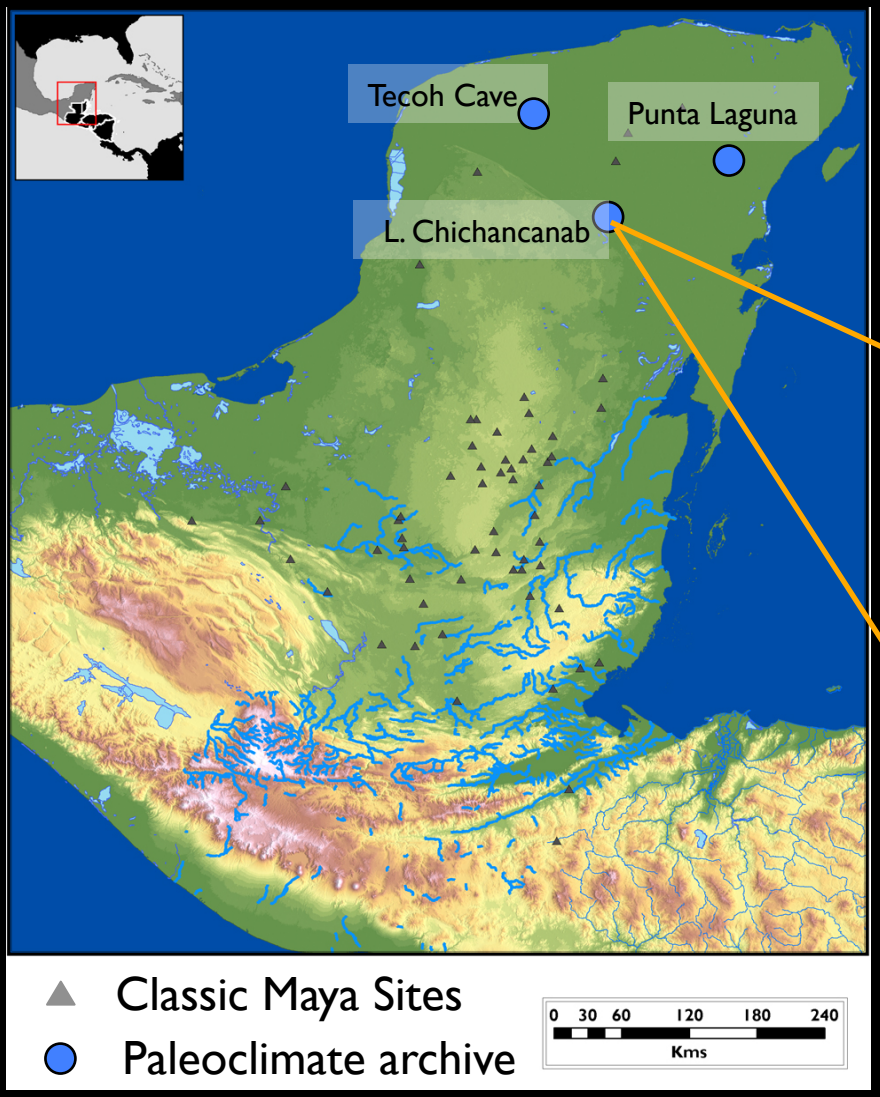
8) Peten lakes, Guatemala

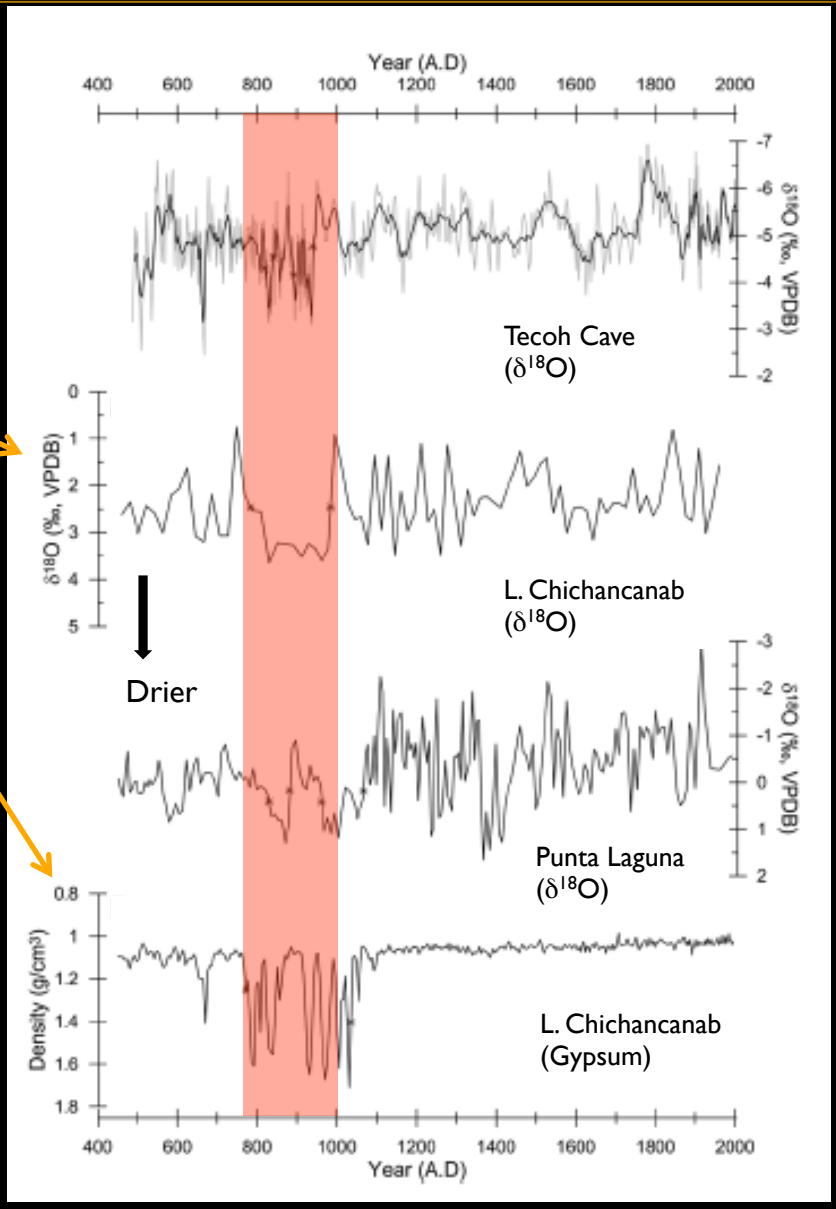
Curtis et al. 1998; Rosenmeier et al. 2002



Comparison of n. Yucatan archives

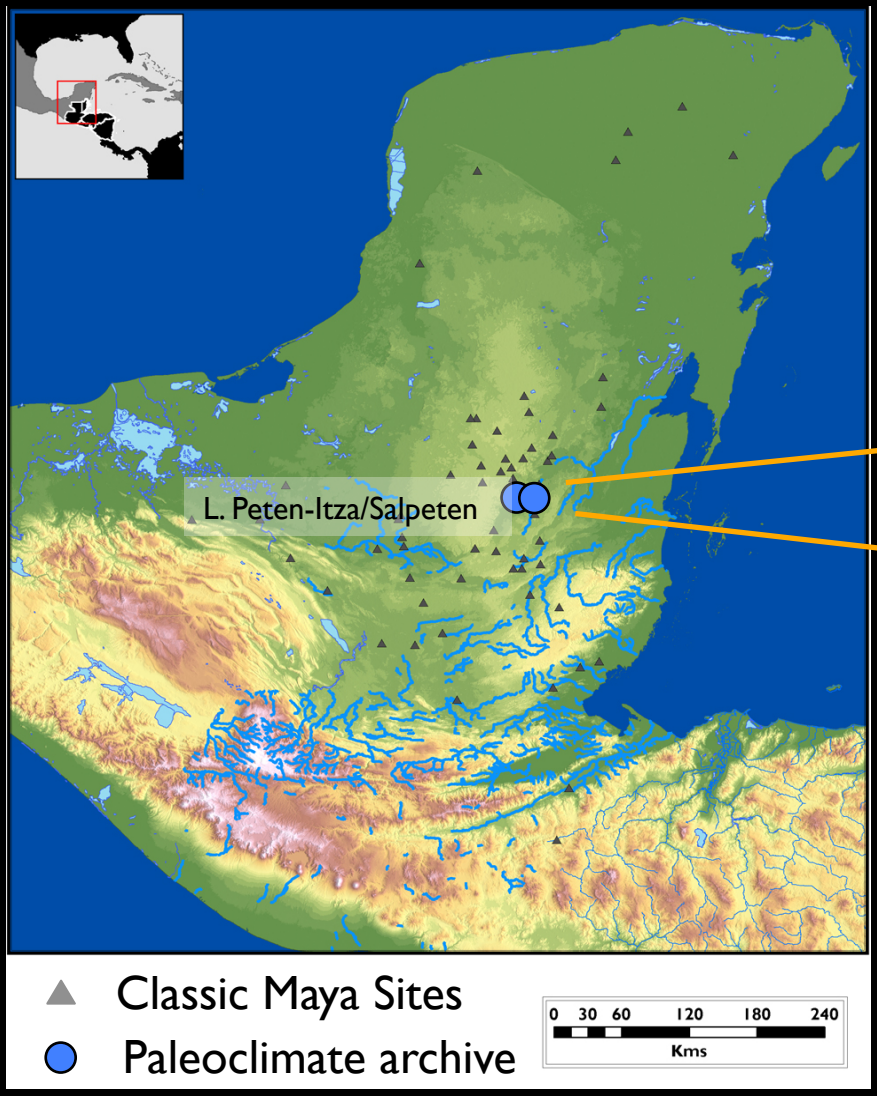
Some concordance at AD 800-1000

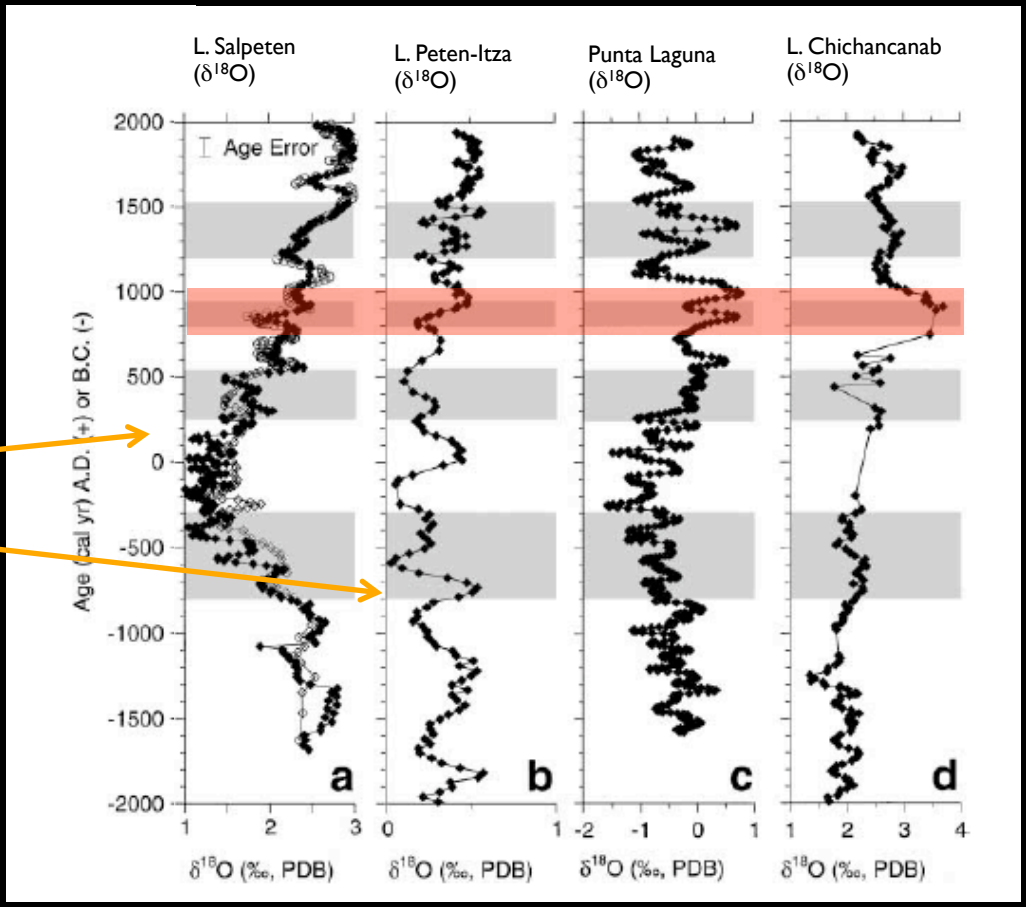




Comparison of c. Peten achives

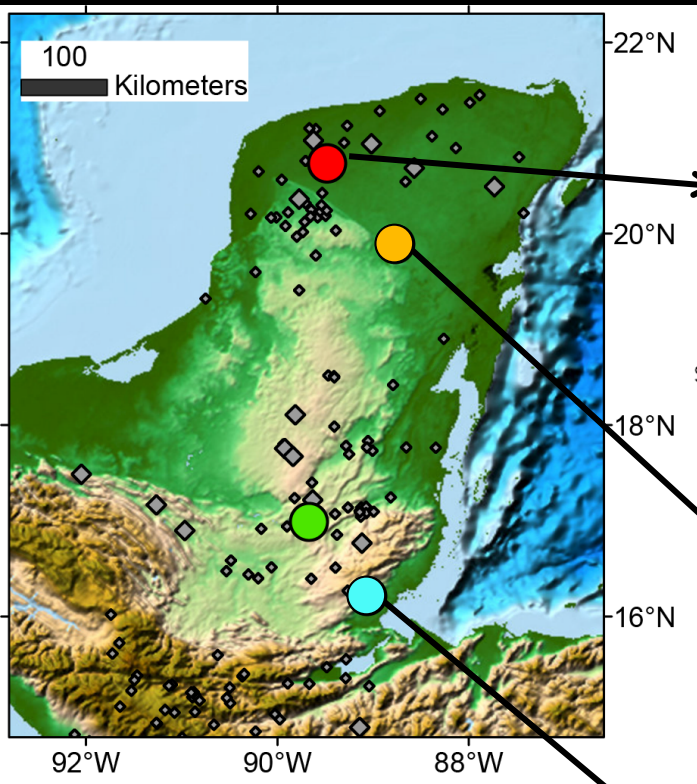
No real signal evident





AD 800-1000 Climate signals

1) Strong but not maximum; 2) Maximum and unique; 3) None

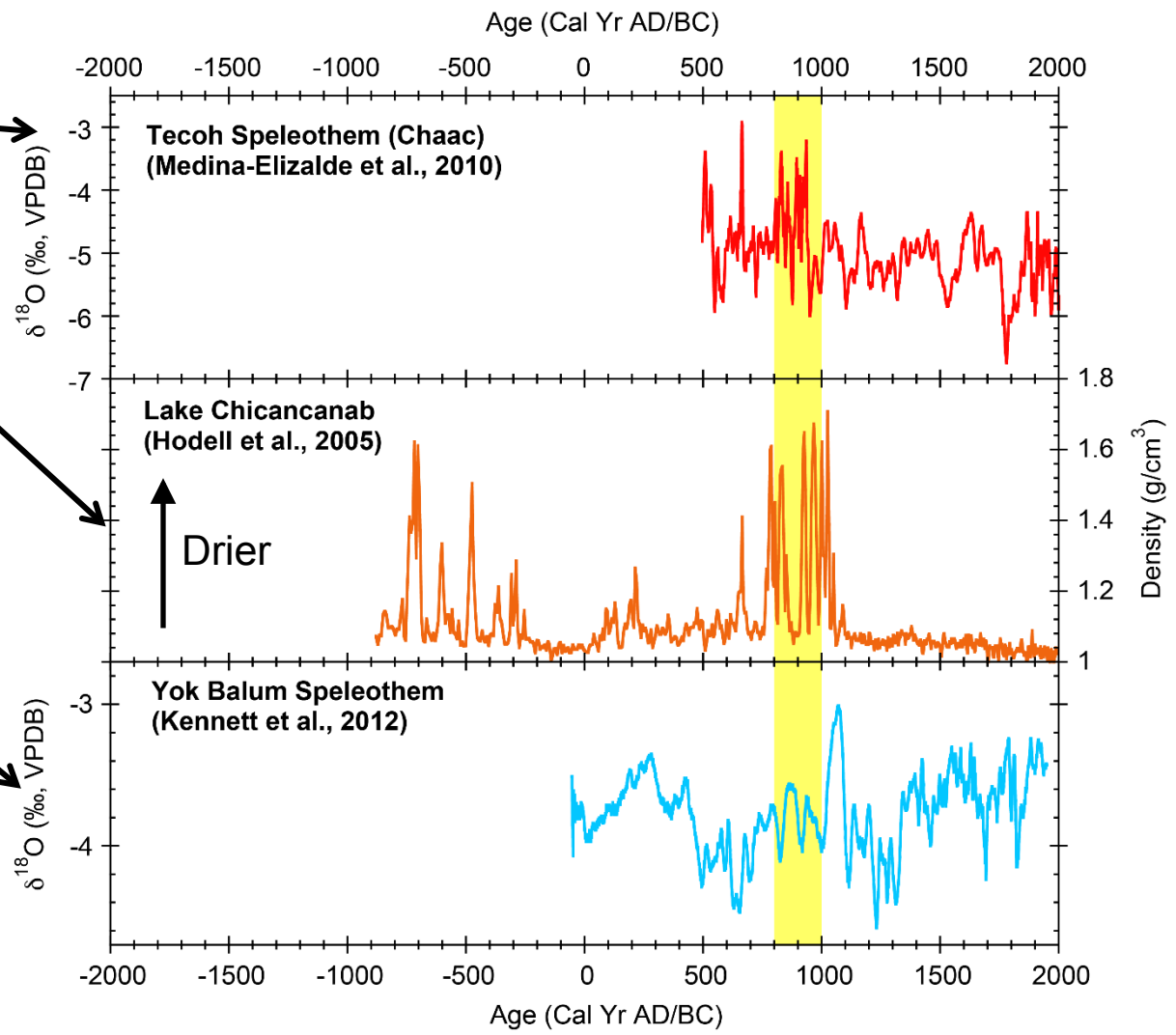


Climate Archives

- L. Chichancanab
- L. Salpeten
- Tecoh Cave
- Yok Balum Cave

Maya Centers

- Rank 1
- Rank 2



New multi-location proxy

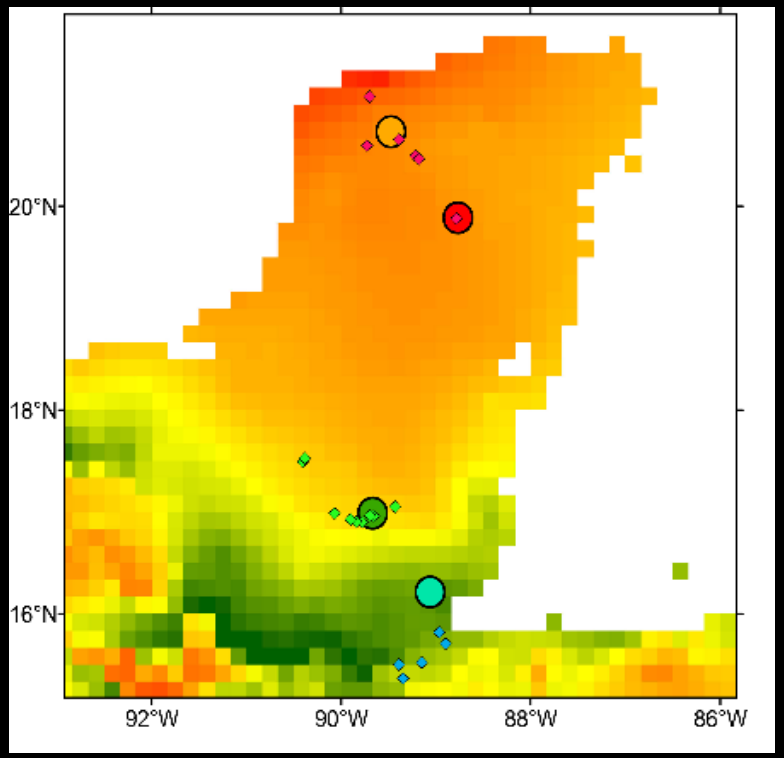
N-alkanes (plant waxes)

PNAS

Drought, agricultural adaptation, and sociopolitical collapse in the Maya Lowlands

Peter M. J. Douglas[a,1,2], Mark Pagani[a], Marcello A. Canuto[b], Mark Brenner[c], David A. Hodell[d], Timothy I. Eglinton[e,f], and Jason H. Curtis[c]

[a]Department of Geology and Geophysics, Yale University, New Haven, CT 06520; [b]Middle American Research Institute, Tulane University, New Orleans, LA 70118; [c]Department of Geological Sciences & Land Use and Environmental Change Institute, University of Florida, Gainesville, FL 32611; [d]Godwin Laboratory for Paleoclimate Research, Department of Earth Sciences, Cambridge University, Cambridge CB2 3EQ, United Kingdom; [e]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA 02543; and [f]Geological Institute, ETH Zurich, 8092 Zurich, Switzerland



Climate Archives

- L. Chichancanab
- L. Salpeten
- Tecoh Cave
- Yok Balum Cave

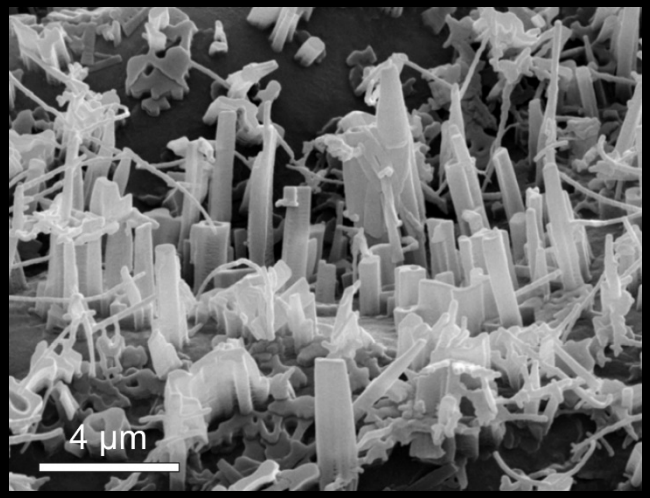
Annual Precipitation (mm)

4900

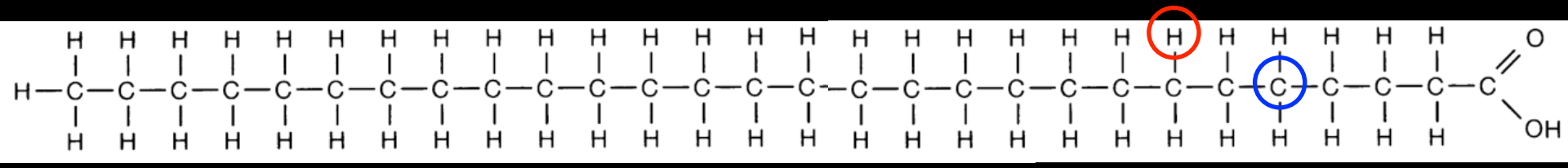
600

Plant Wax Lipids

Climatological cause



Cabbage Leaf (Koch, 2010)



C_{28} *n*-alkanoic acid

D/H, ^{13}C, ^{14}C

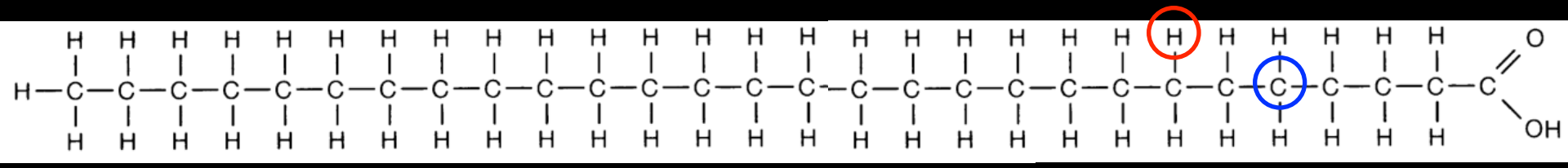
Plant Wax Lipids

A new proxy

Chronology/Carbon-cycling
^{14}C

Hydroclimate Change
H/D; hydrogen/deuterium

Vegetation/Land Use Change
^{13}C

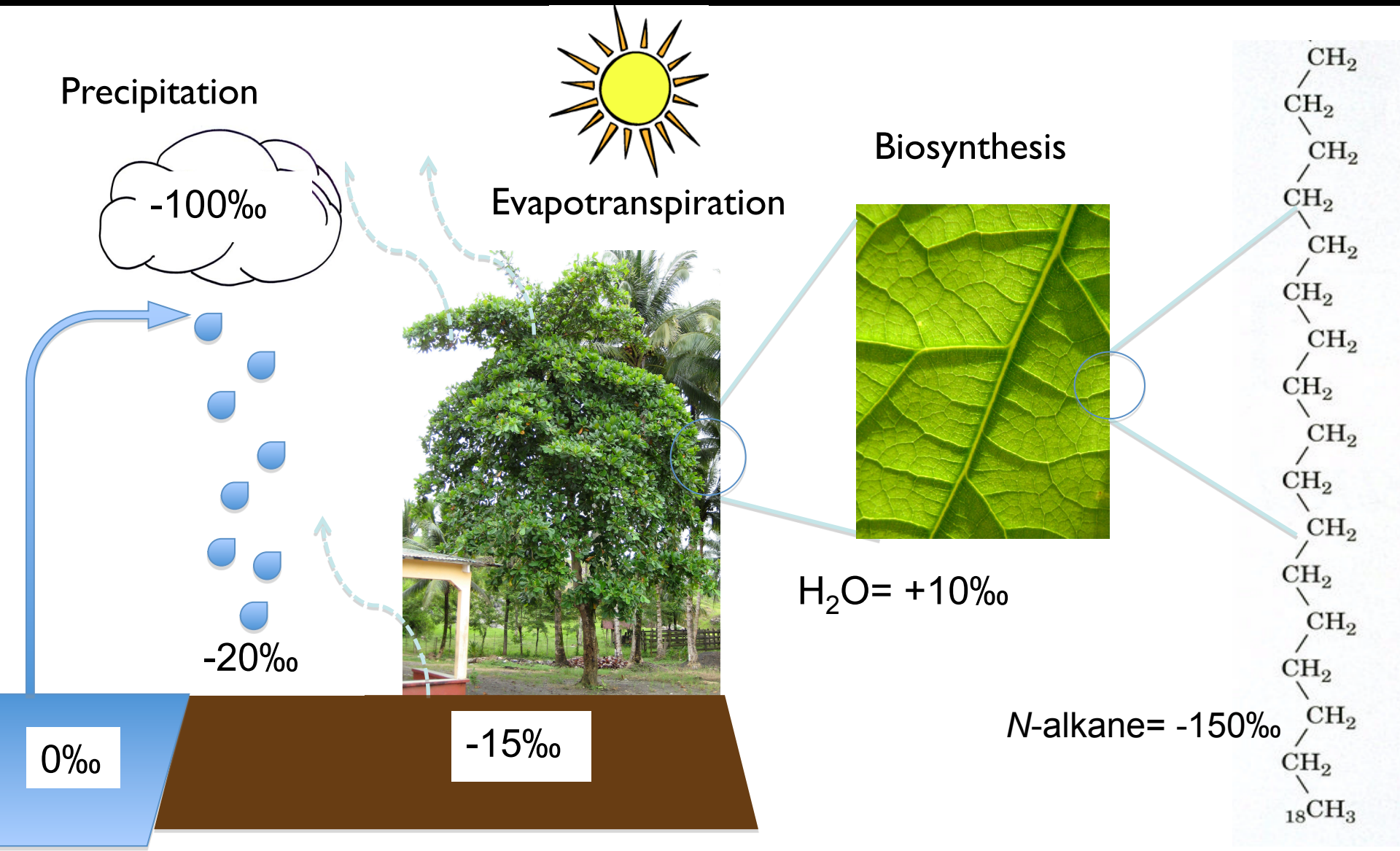


C_{28} *n*-alkanoic acid

D/H, ^{13}C, ^{14}C

Plant Wax Lipids

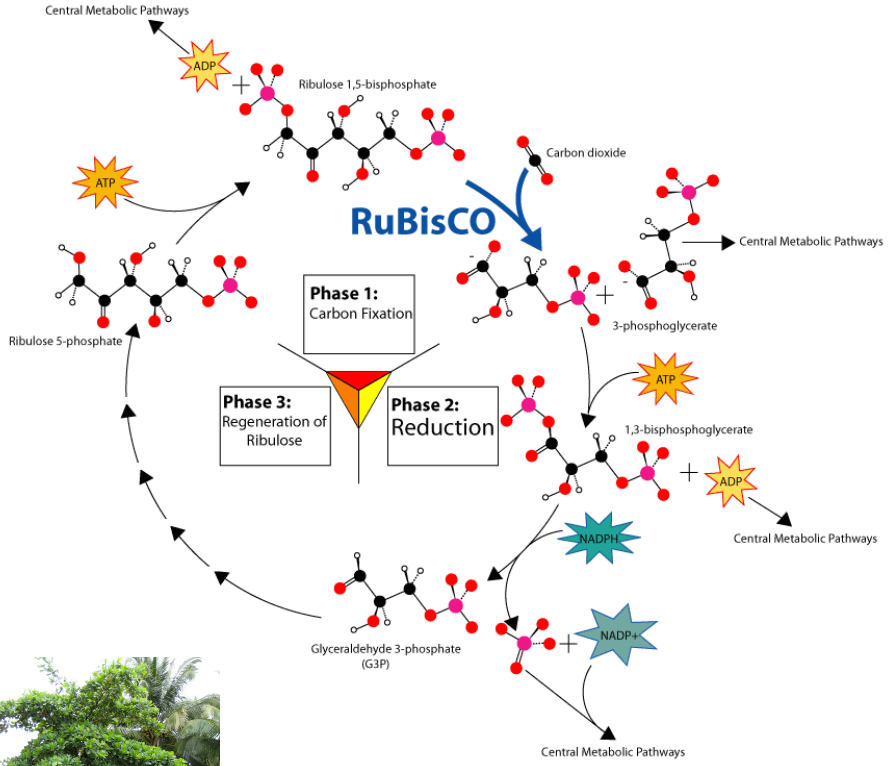
Hydrogen isotopes – Deuterium / Hydrogen



Plant Wax Lipids

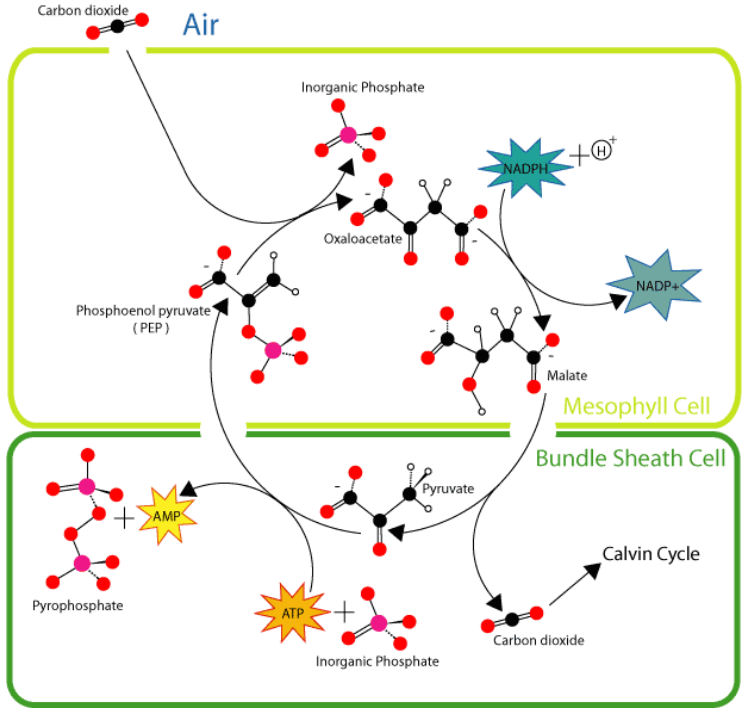
Carbon isotopes – C13 vis-à-vis C3/C4 plants

C_3



~ -35‰
(Angiosperms)

C_4



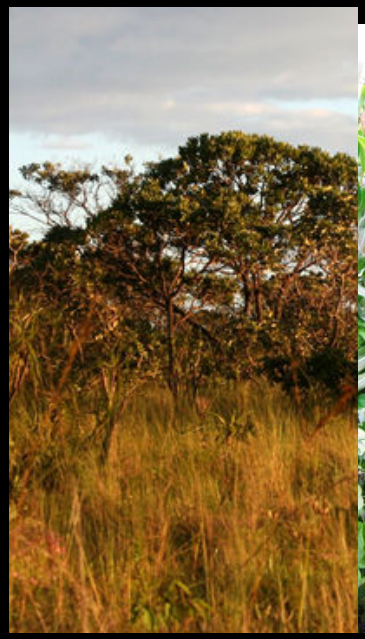
~ -20‰

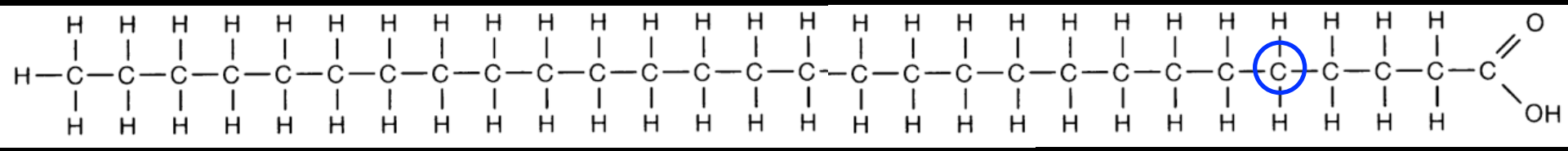
Plant Wax Lipids

Carbon isotopes – C13 vis-à-vis C3/C4 plants

C_3 plants: -31 to -39‰

C_4 plants (Maize) -18 to -24‰





C_{28} *n*-alkanoic acid

^{13}C

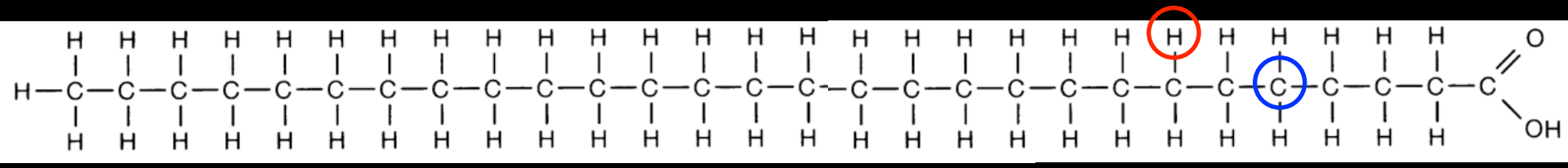
Plant Wax Lipids

A new proxy

Spatial patterns of drought

Longer records (into the Preclassic)

Coupled changes in climate and land use



C_{28} *n*-alkanoic acid

D/H, ^{13}C, ^{14}C

New multi-location proxy

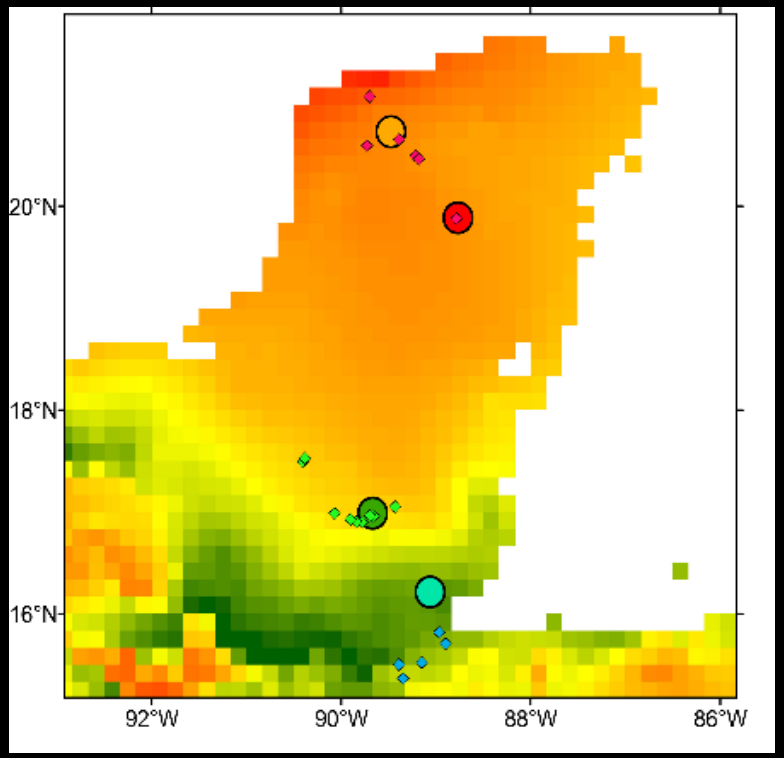
N-alkanes (plant waxes)

PNAS

Drought, agricultural adaptation, and sociopolitical collapse in the Maya Lowlands

Peter M. J. Douglas[a,1,2], Mark Pagani[a], Marcello A. Canuto[b], Mark Brenner[c], David A. Hodell[d], Timothy I. Eglinton[e,f], and Jason H. Curtis[c]

[a]Department of Geology and Geophysics, Yale University, New Haven, CT 06520; [b]Middle American Research Institute, Tulane University, New Orleans, LA 70118; [c]Department of Geological Sciences & Land Use and Environmental Change Institute, University of Florida, Gainesville, FL 32611; [d]Godwin Laboratory for Paleoclimate Research, Department of Earth Sciences, Cambridge University, Cambridge CB2 3EQ, United Kingdom; [e]Department of Marine Chemistry and Geochemistry, Woods Hole Oceanographic Institution, Woods Hole, MA 02543; and [f]Geological Institute, ETH Zurich, 8092 Zurich, Switzerland



Climate Archives

- L. Chichancanab
- L. Salpeten
- Tecoh Cave
- Yok Balum Cave

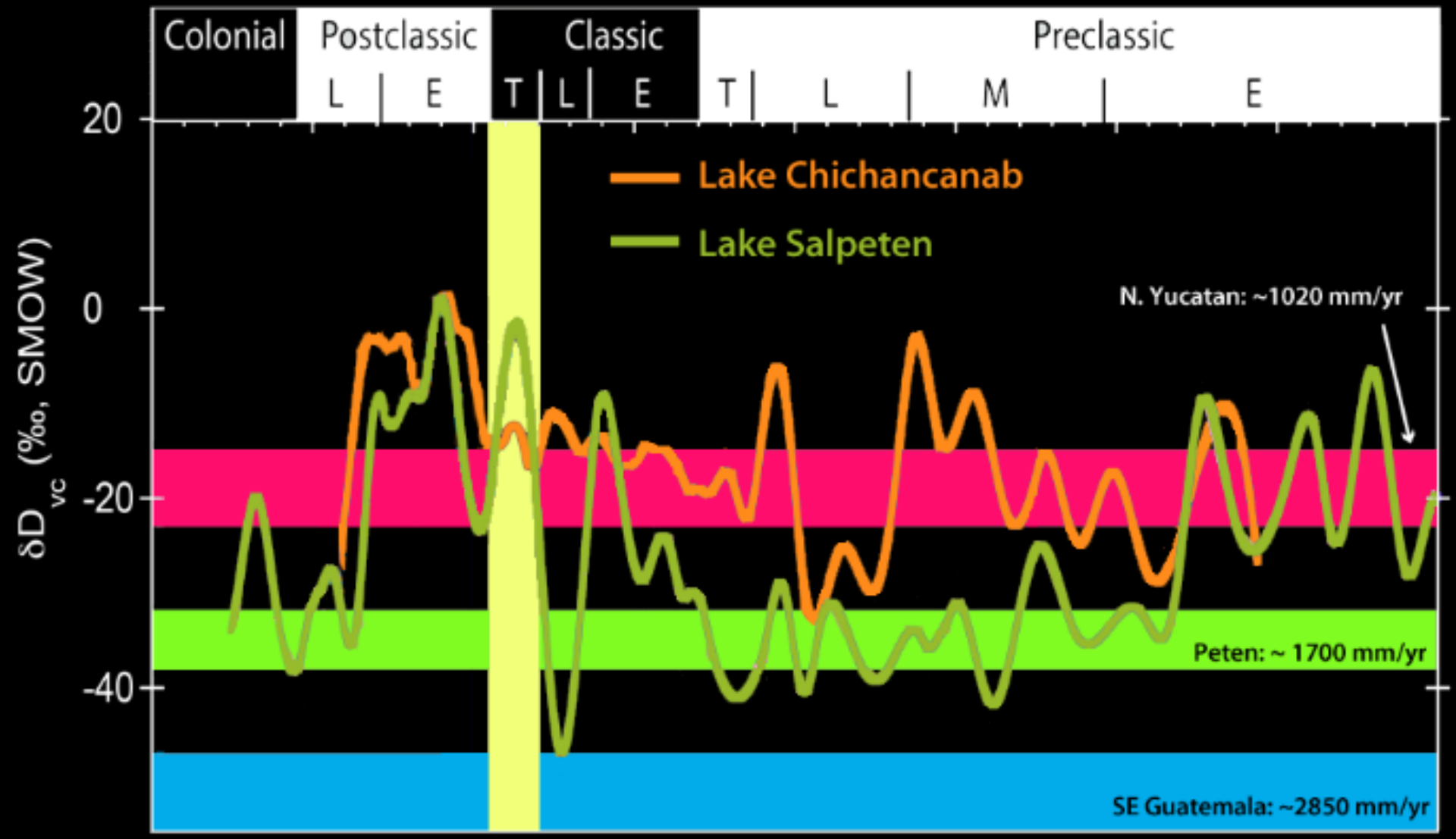
Annual Precipitation (mm)

4900

600

Rainfall patterns for Maya area

Douglas et al. 2015

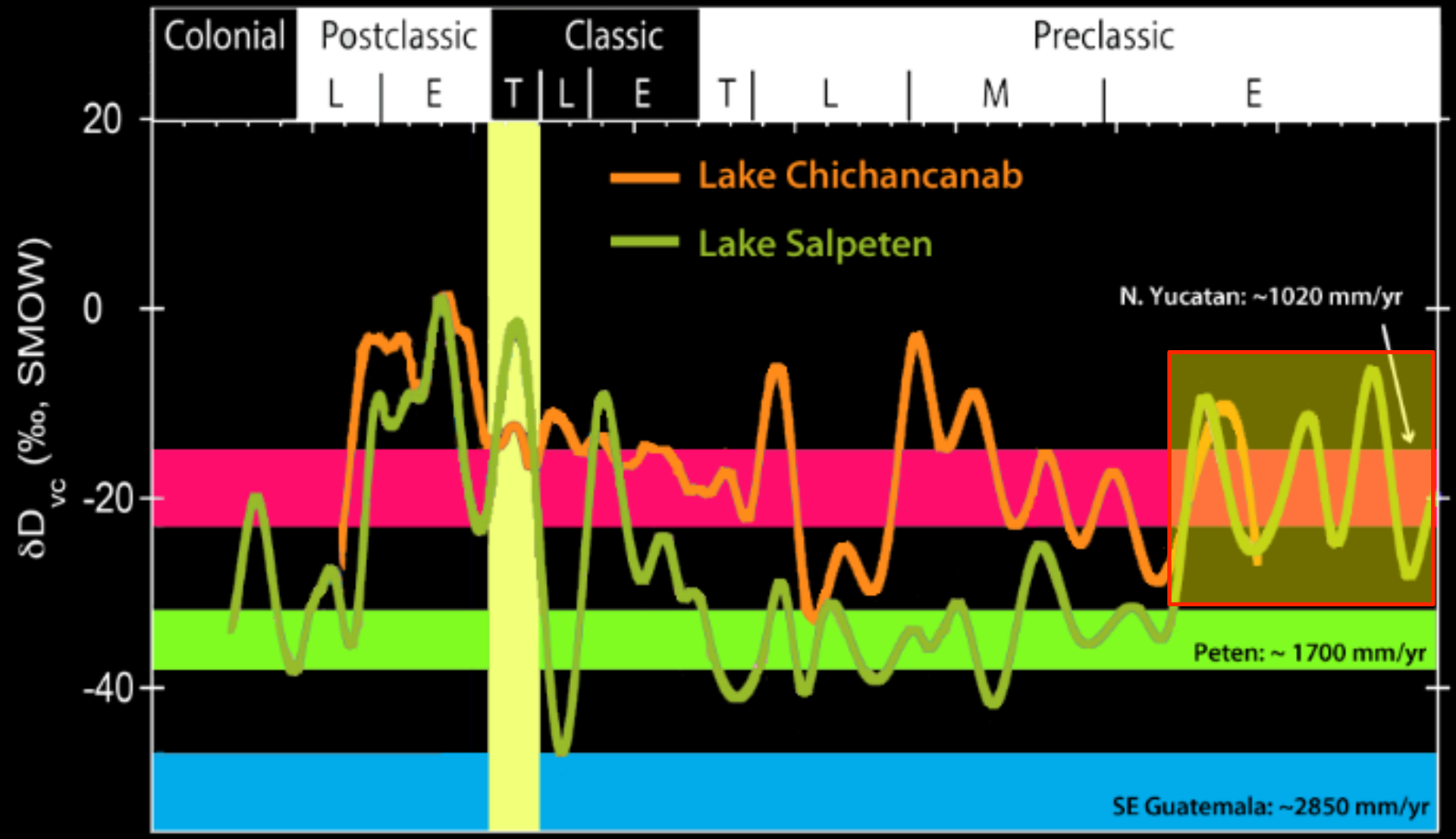


3000 BC – 1500 AD

Dry period #1

2000 – 1200 BC

Douglas 2014



Early Preclassic: *Peten was as dry as n.Yucatan is today*

Late Preceramic estuarine adaptation

2500 – 1500 BC

Gulf / Caribbean / Pacific Coasts

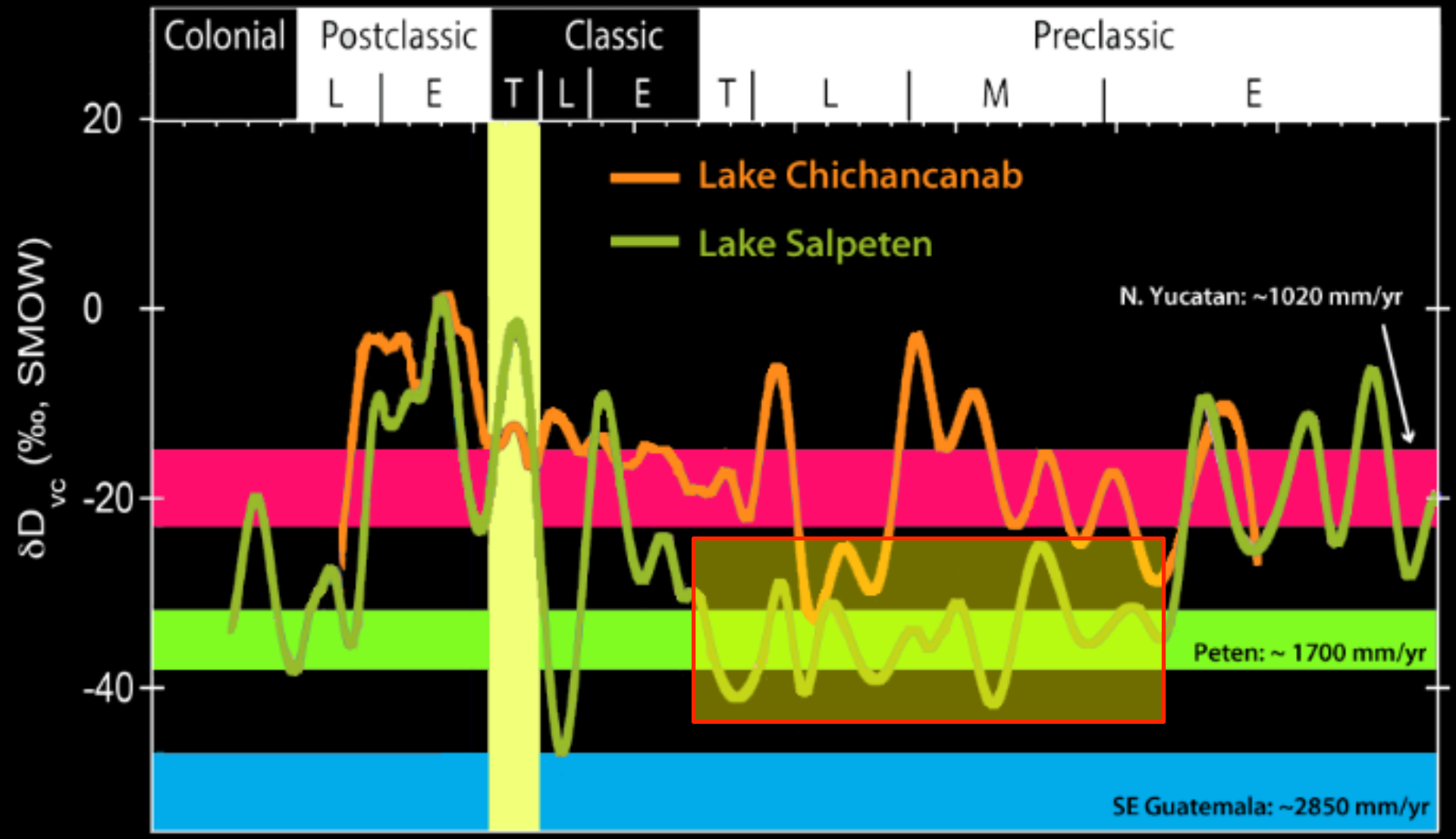
Abundant hunting, fishing, collecting

Semi-permanent settlements along estuaries

Simple pottery production c. 2000 BC

Wet period #1

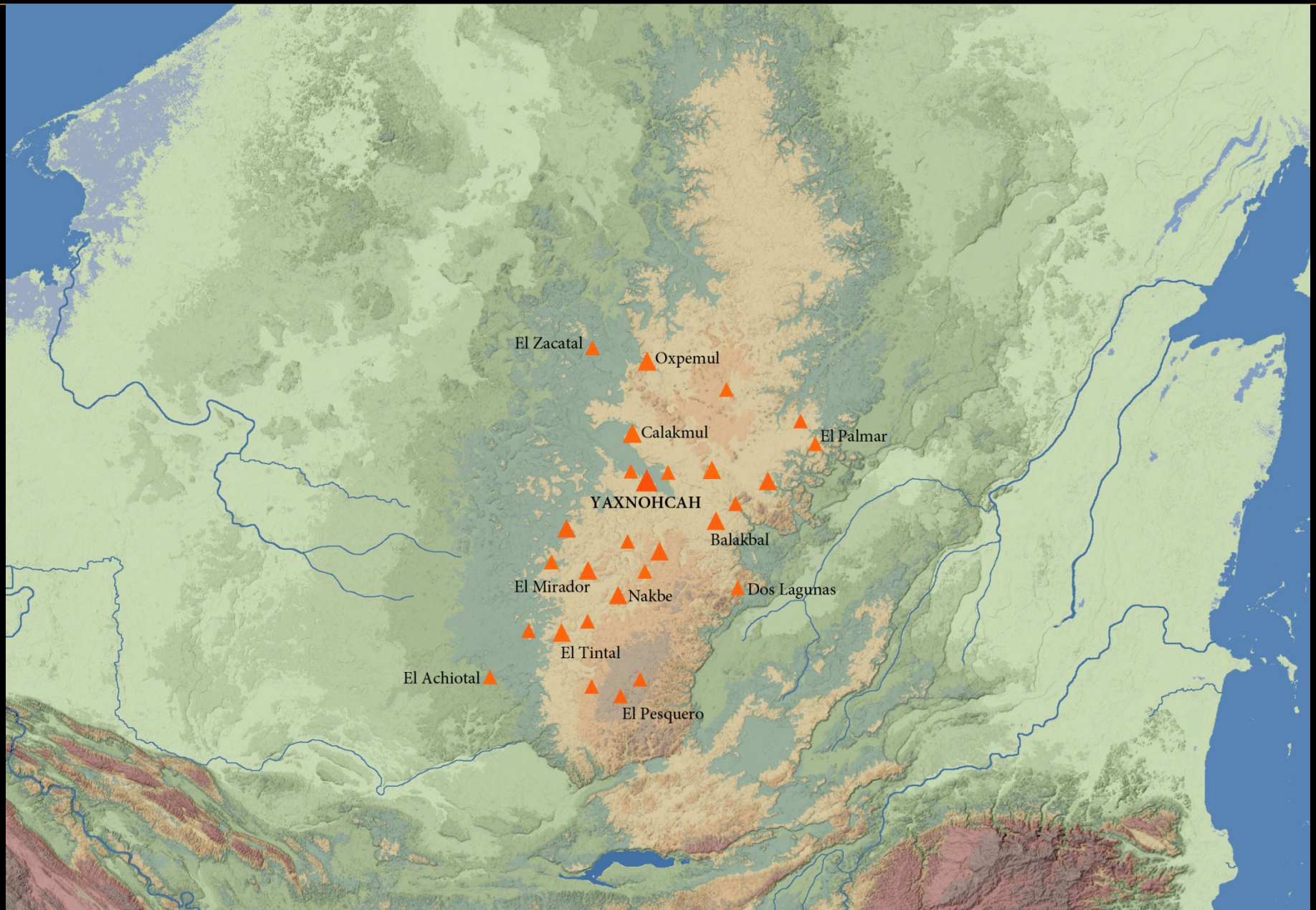
1200 BC – AD 250



Middle and Late Preclassic: *Peten was stable and as wet as today*

Central Karstic Uplands (CKU)

Hub of Late Preclassic centers



Late Preclassic trends

300 BC – AD 250

Specialized centers

Regional economic, administrative, and urban-like centers

Organizational hierarchies

Elite class

Non-farming, full-time specialists

Office of Kingship

Surpluses of labor and food

Massive resource extraction and its environmental effects

Ideology

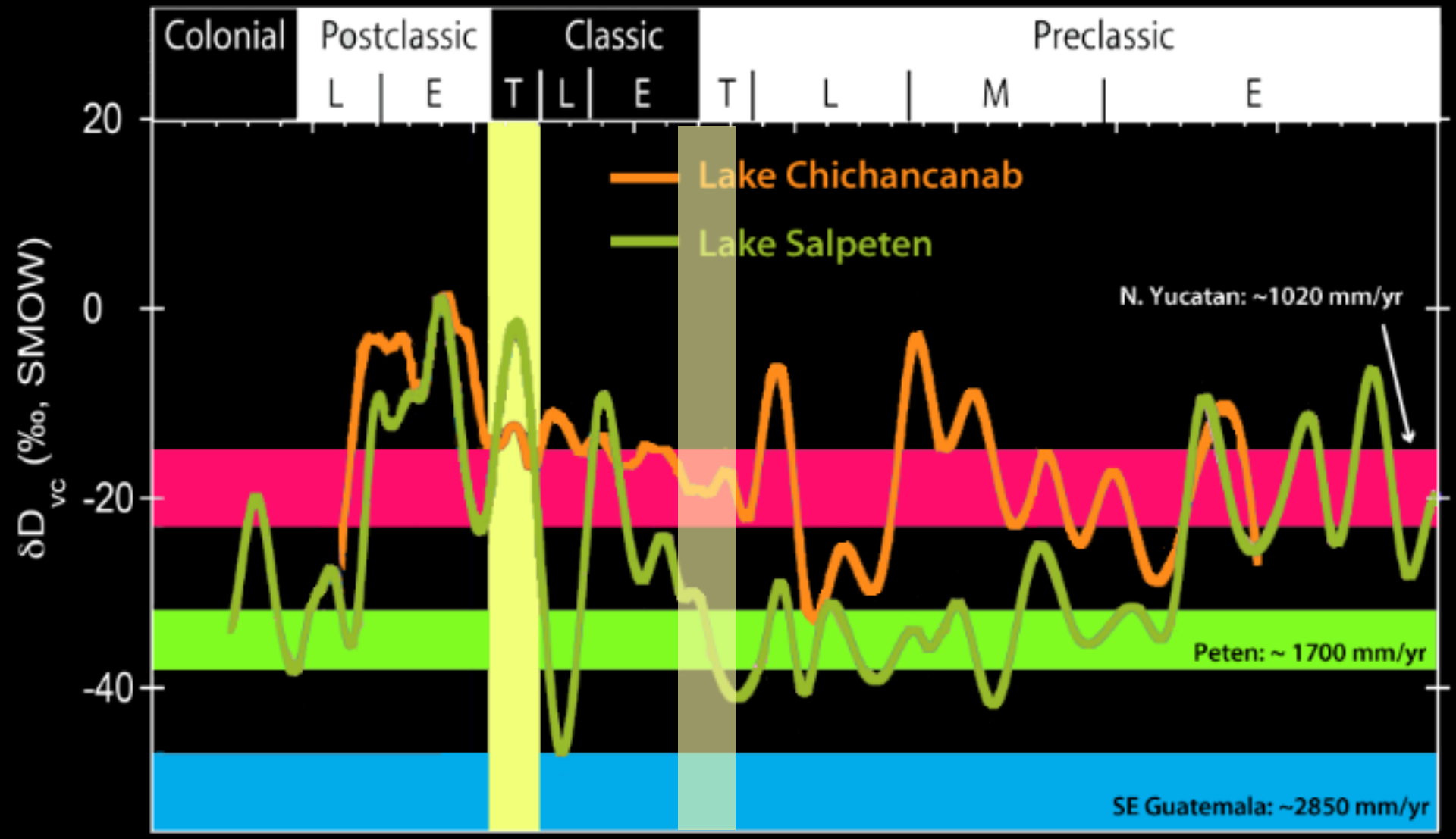
Complex of deities and creation mythology institutionalized

Monumental public architecture

Platform mounds, monumental public art, open plazas

Late Preclassic collapse?

AD 150 – 250



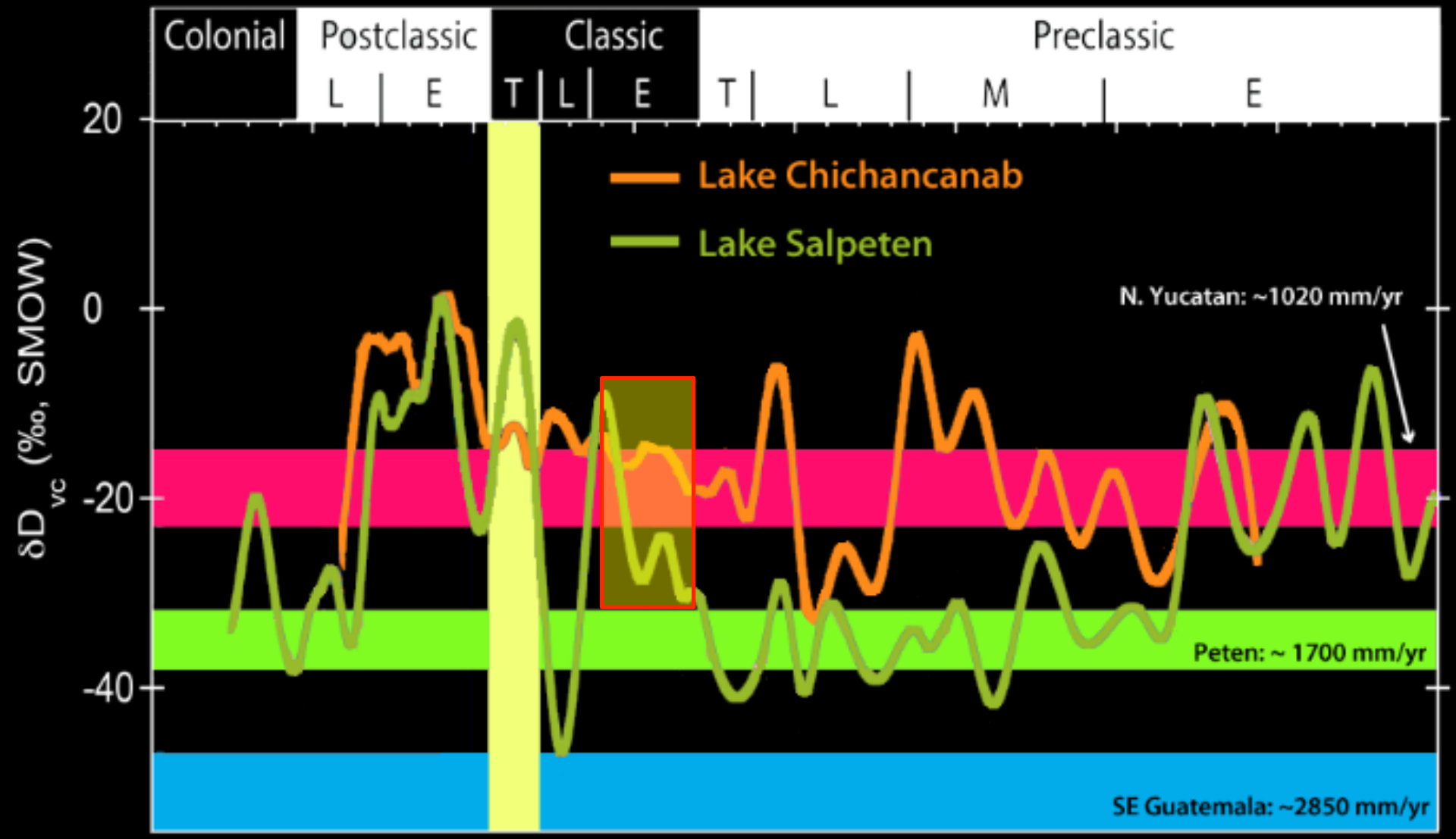
Early Classic: *Peten progressively dried, to modern n.Yucatan levels*

Late Preclassic collapse?

The end of El Mirador

Dry period #2

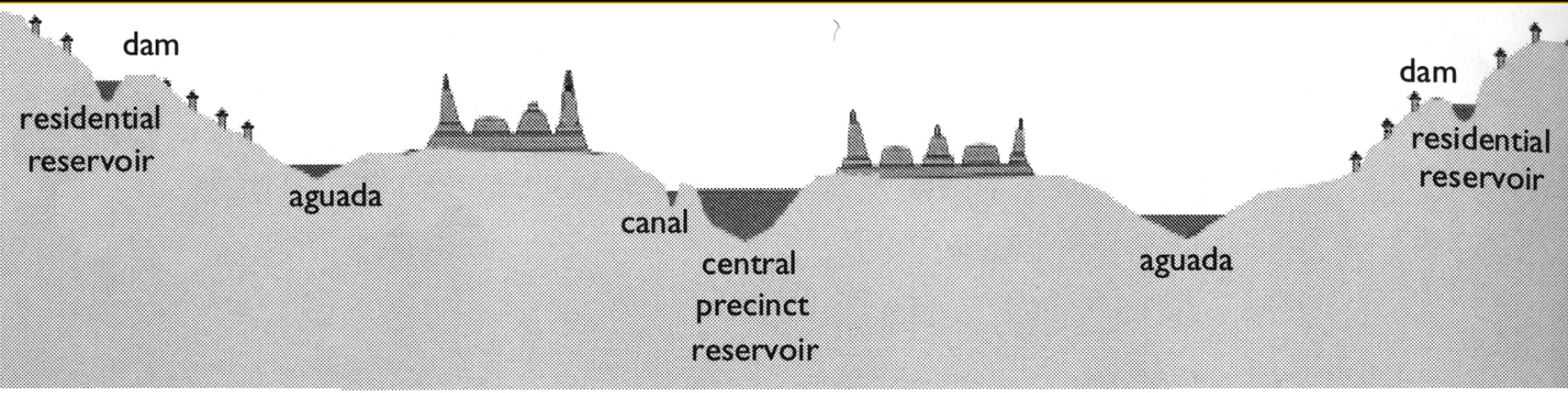
AD 250 – 550



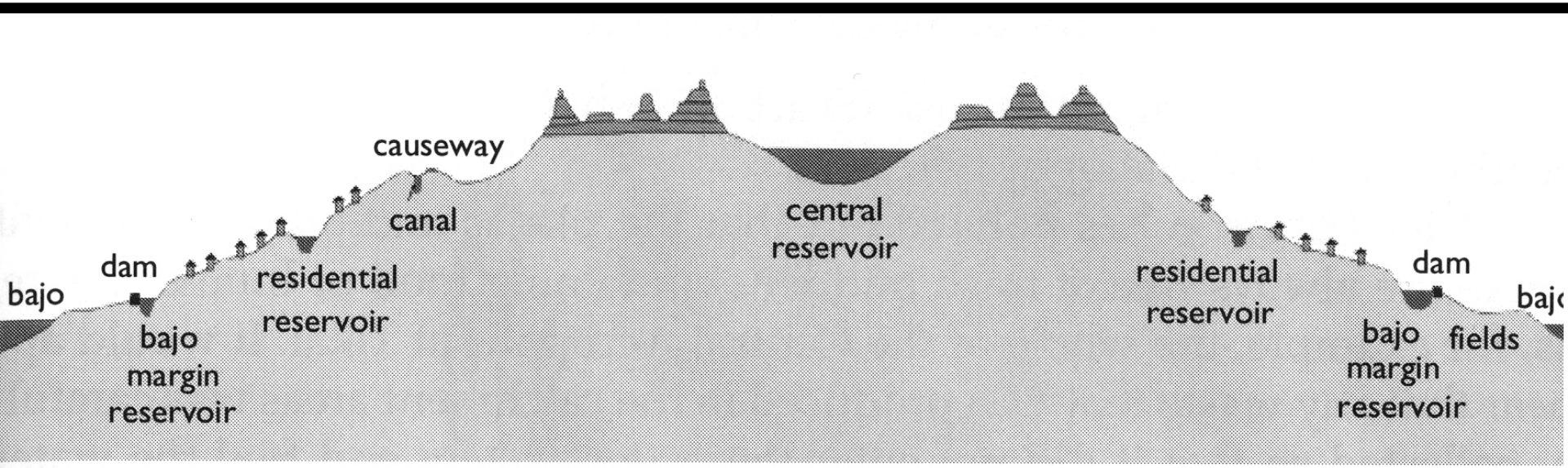
Early Classic: *Peten progressively dried, to modern n.Yucatan levels*

Resilience built into Classic polities

Better water catchment strategies



CONCAVE MICROWATERSHED



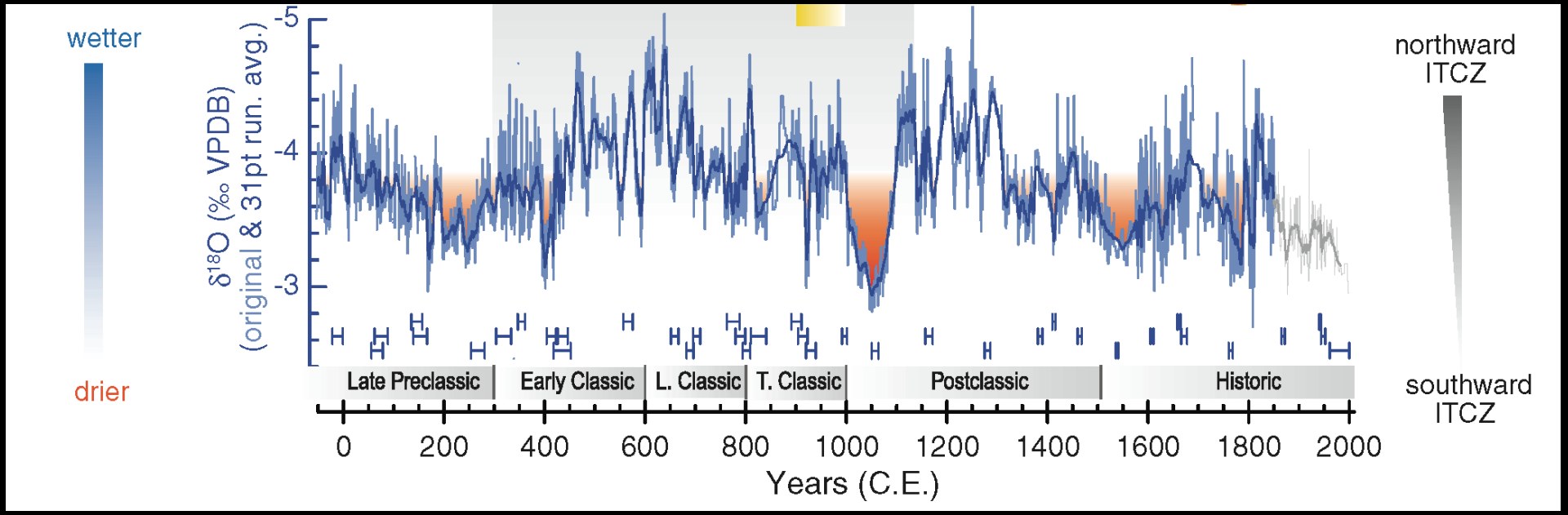
CONVEX MICROWATERSHED

Kaminaljuyu's political collapse

No settlement abandonment

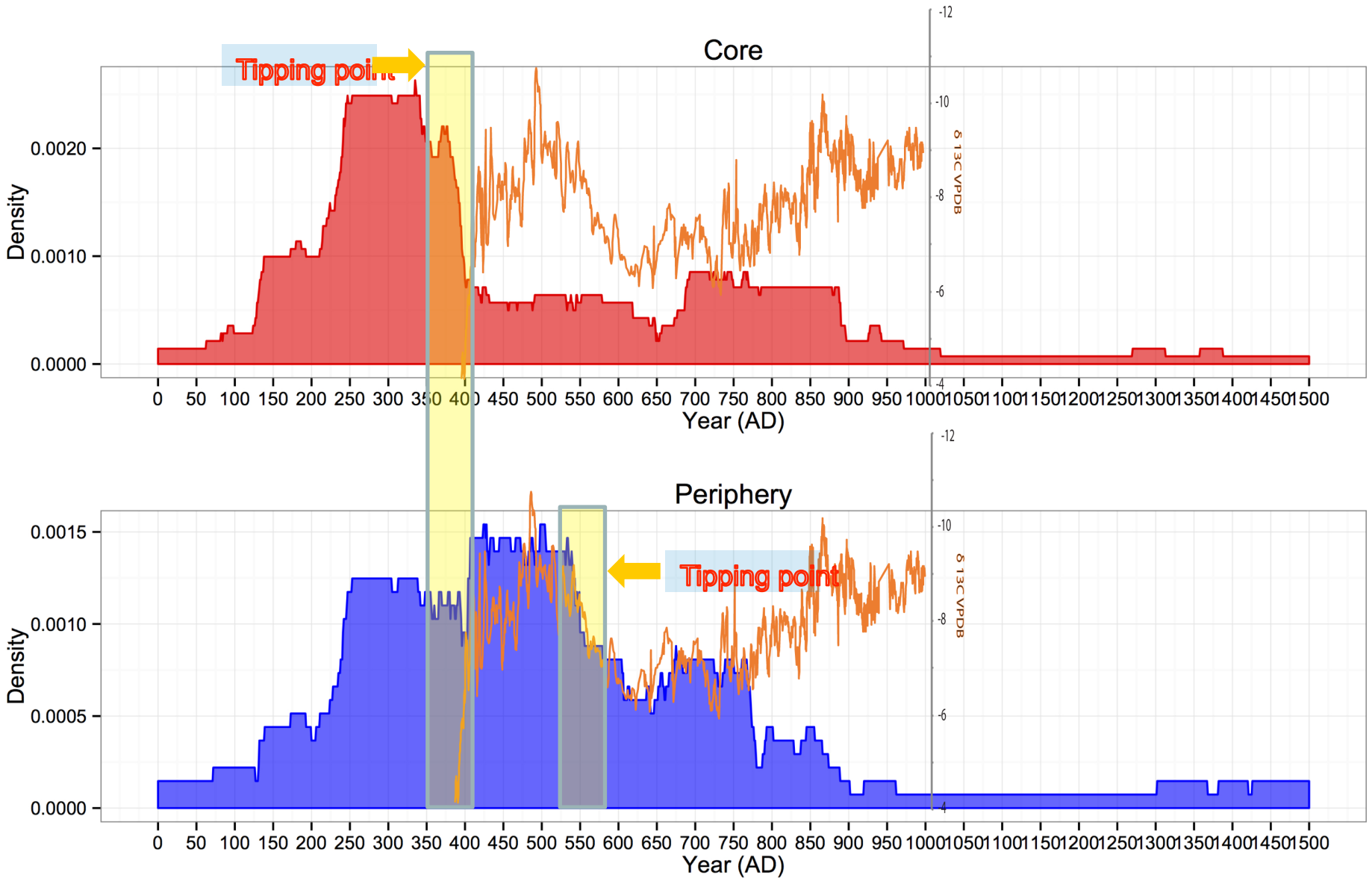
Yok Balum Cave, southern Belize

Kennett et al. 2012



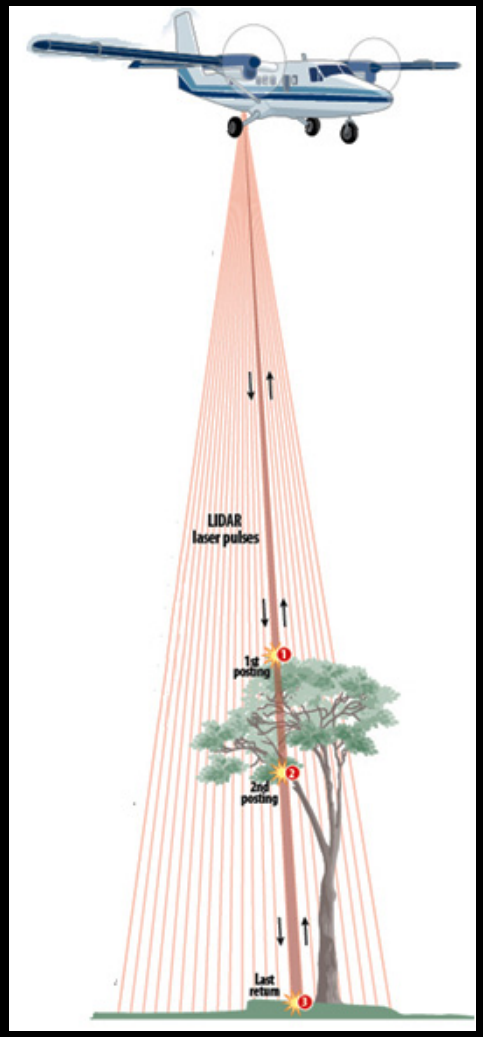
4) Yok Balum Cave, southern Belize

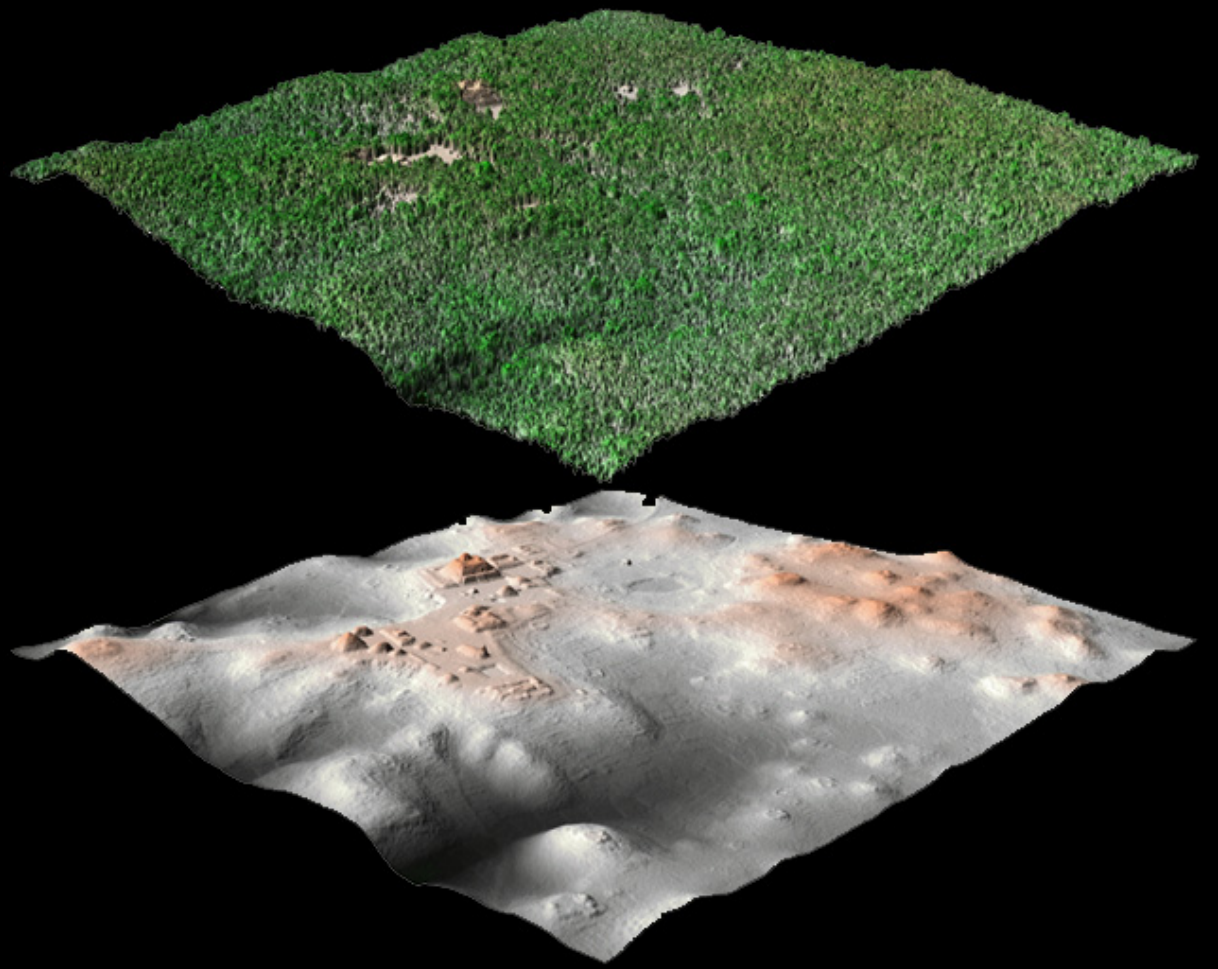
Kennett et al. 2012



LiDAR (Light Detection And Ranging)

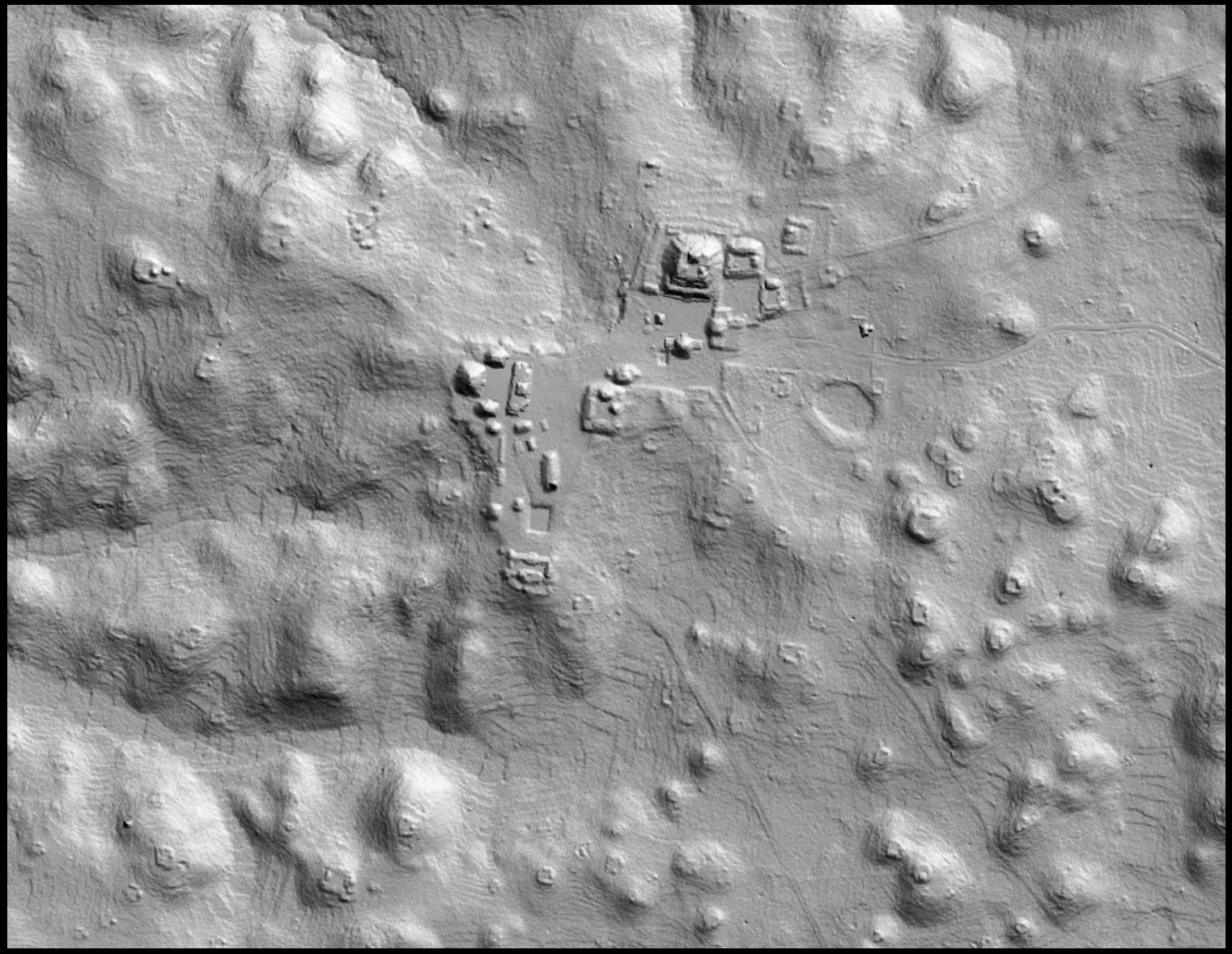
A new sensing technology





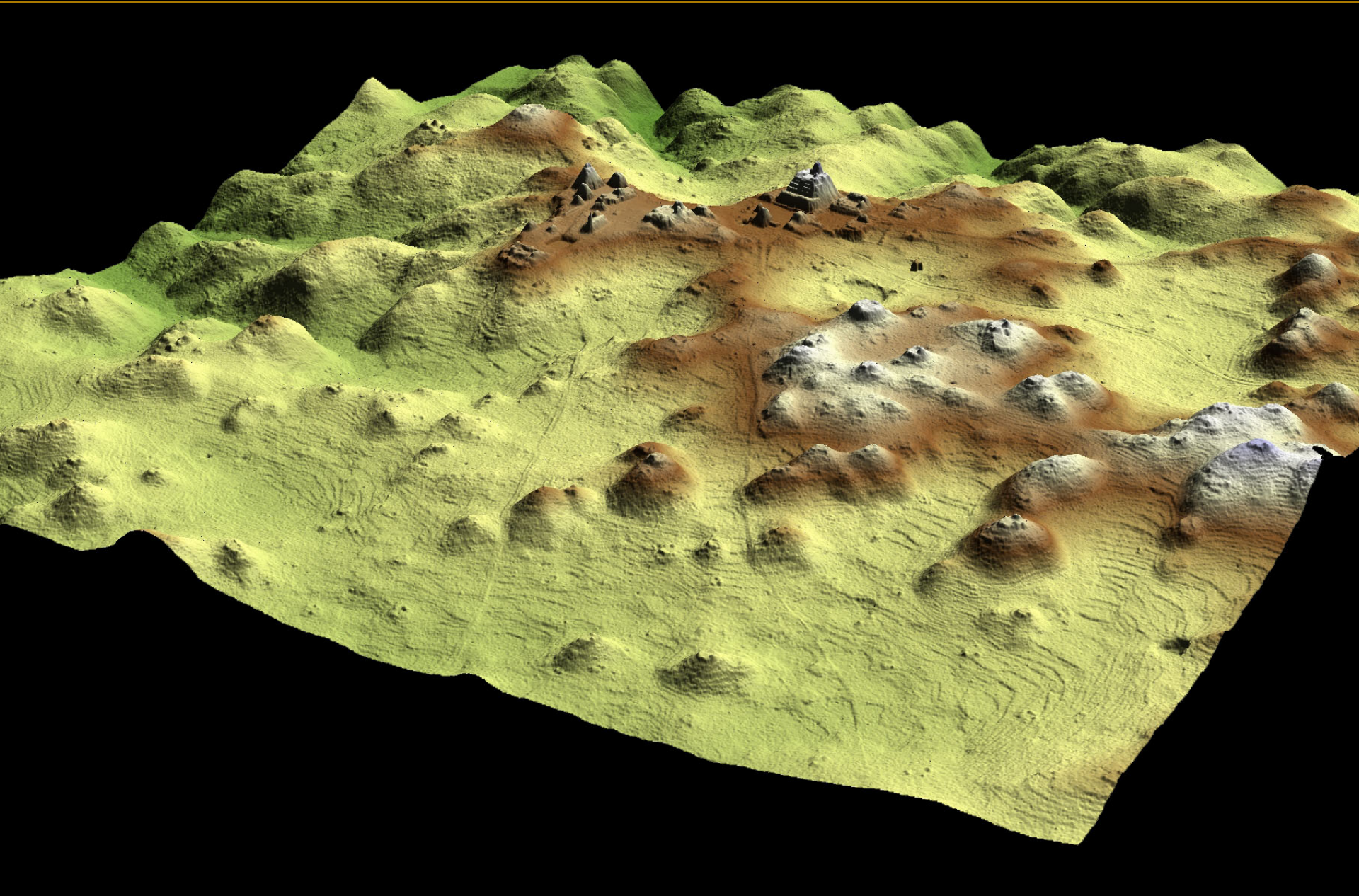
Detection of features and structures

A new sensing technology



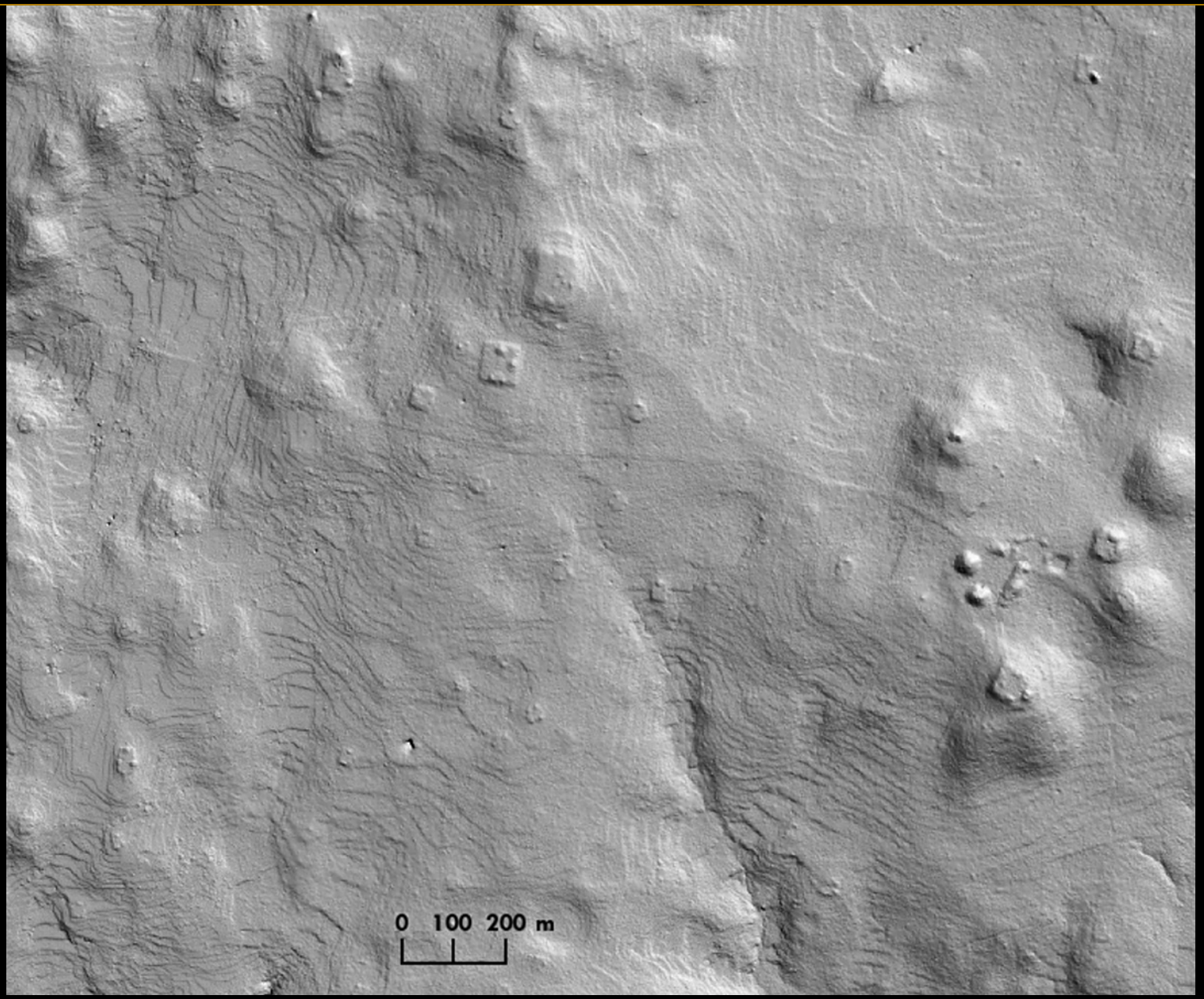
Detection of features and structures

A new sensing technology



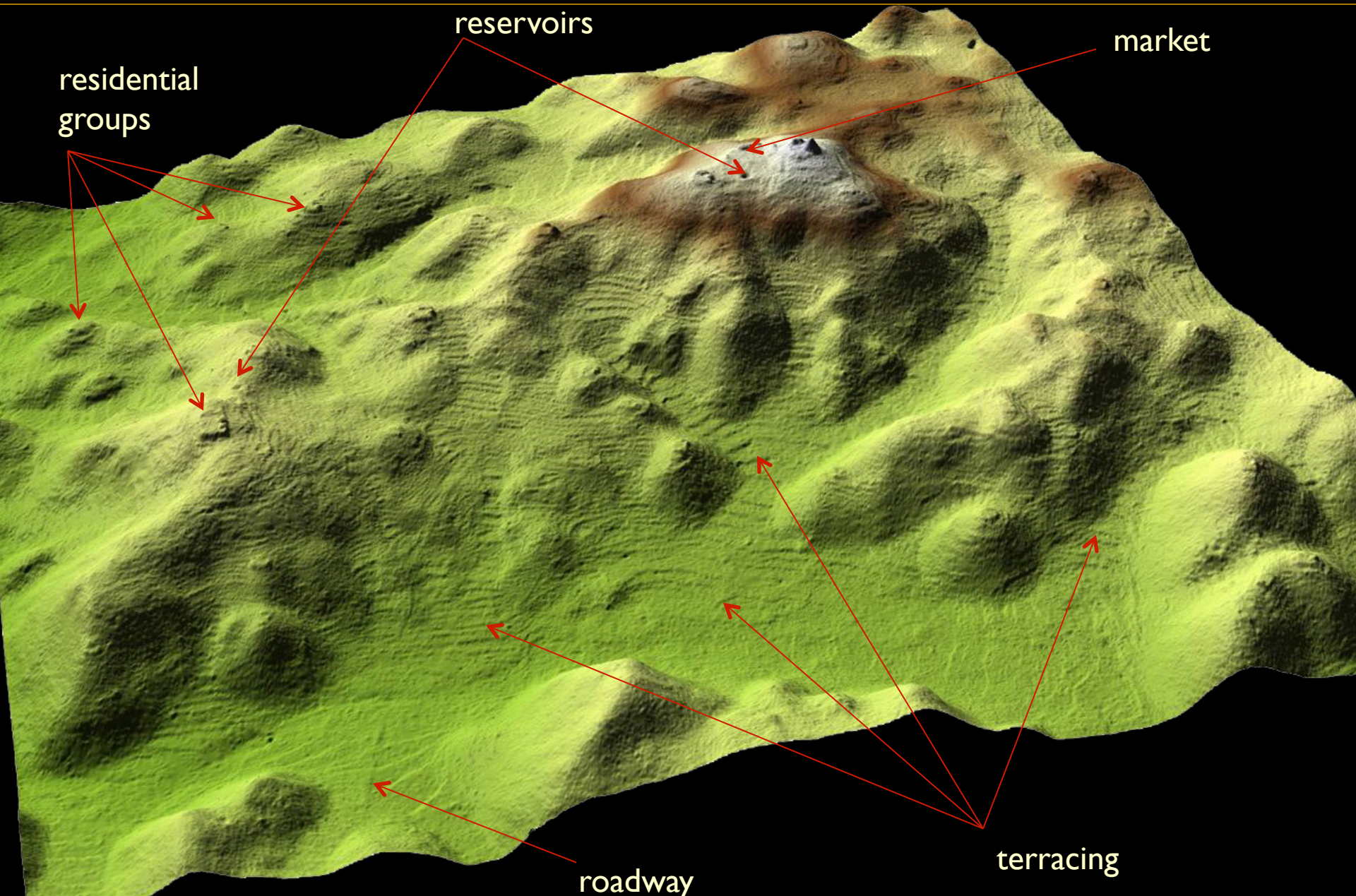
Intensively modified landscape

Extensive terracing



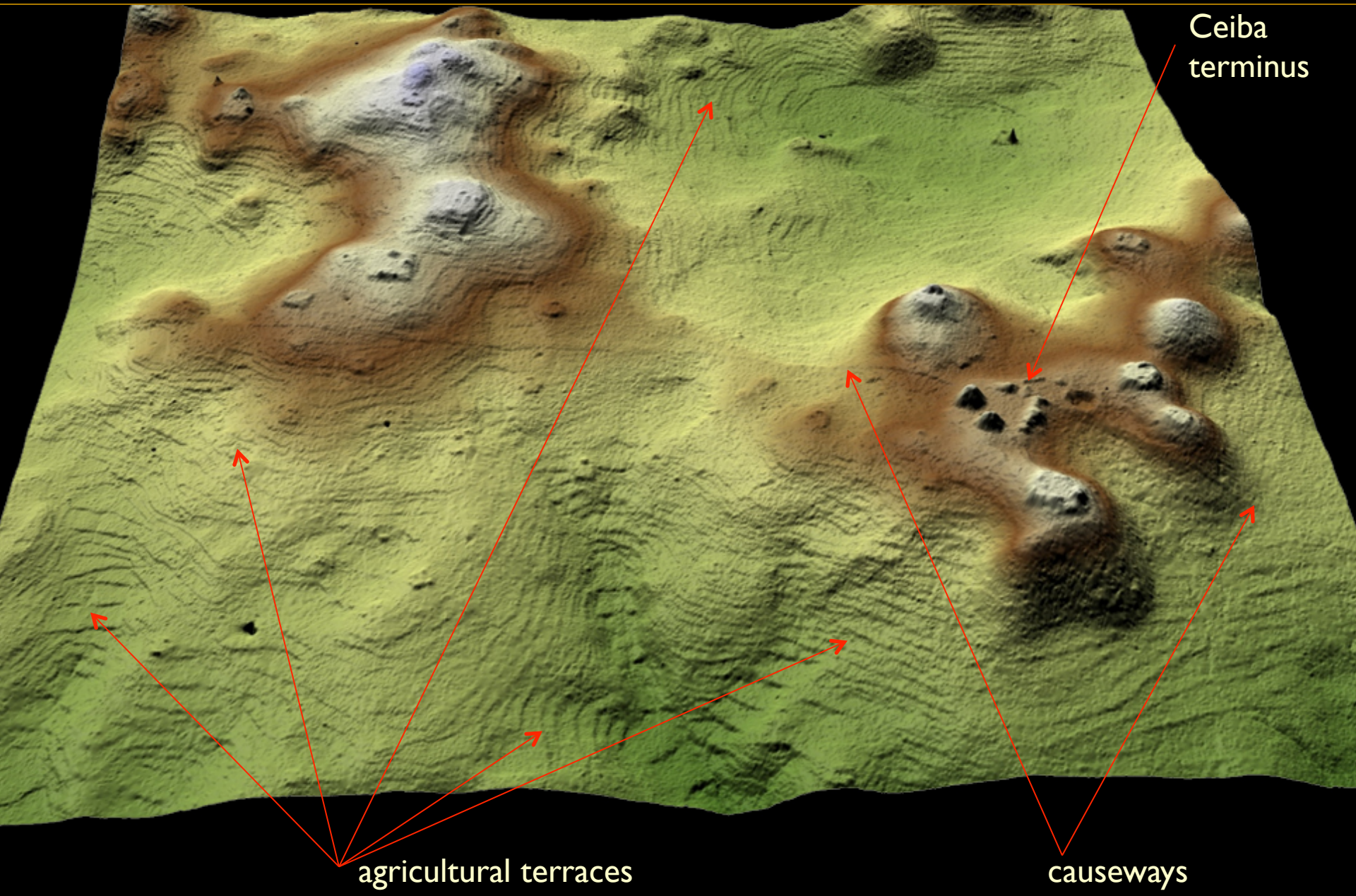
An integrated anthropogenic landscape

Caracol, Late Classic



An integrated anthropogenic landscape

Caracol, Late Classic

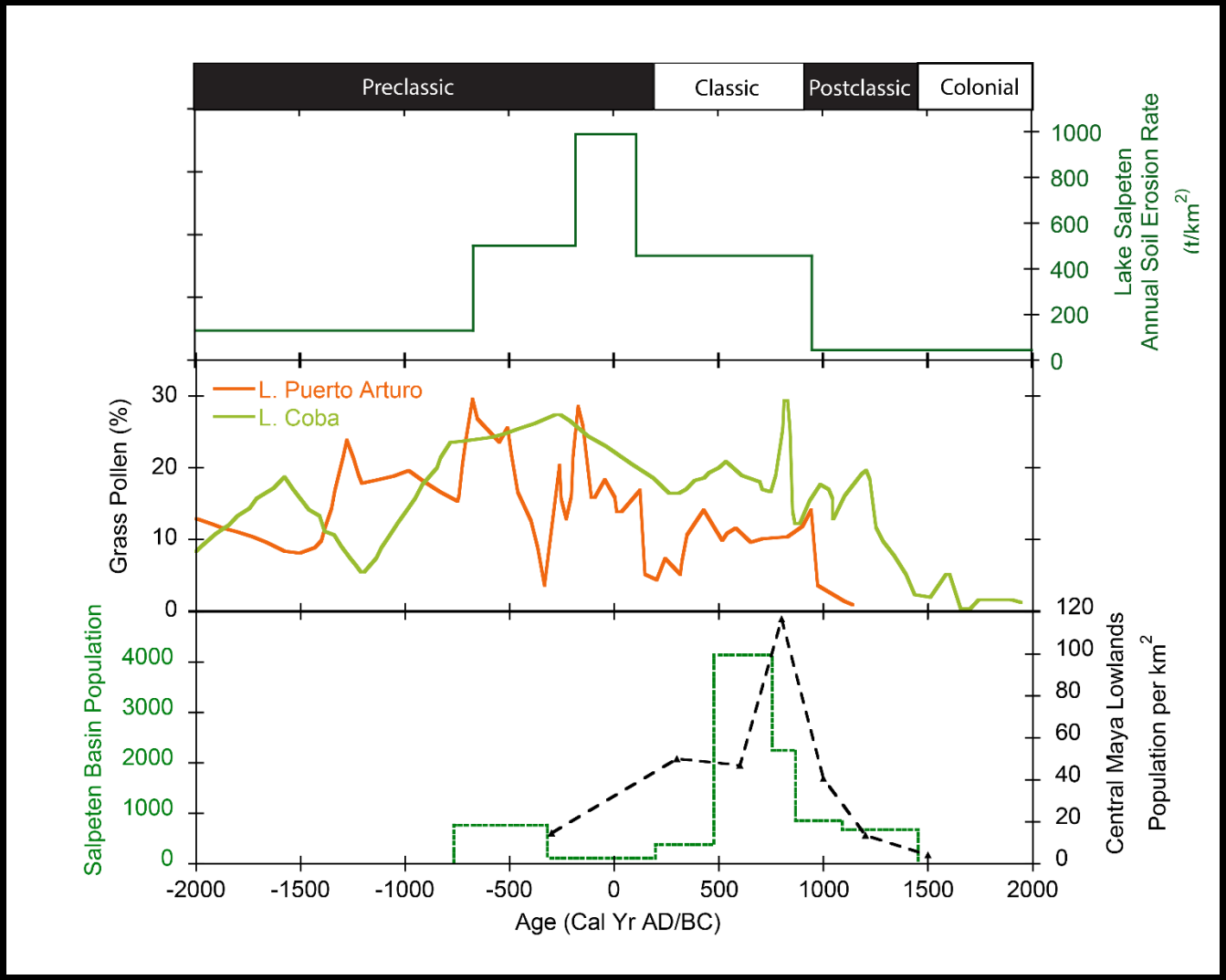


Lowland Maya: dispersed, low-density urbanism

A risk-abatement strategy?

Anthropogenic change to environment

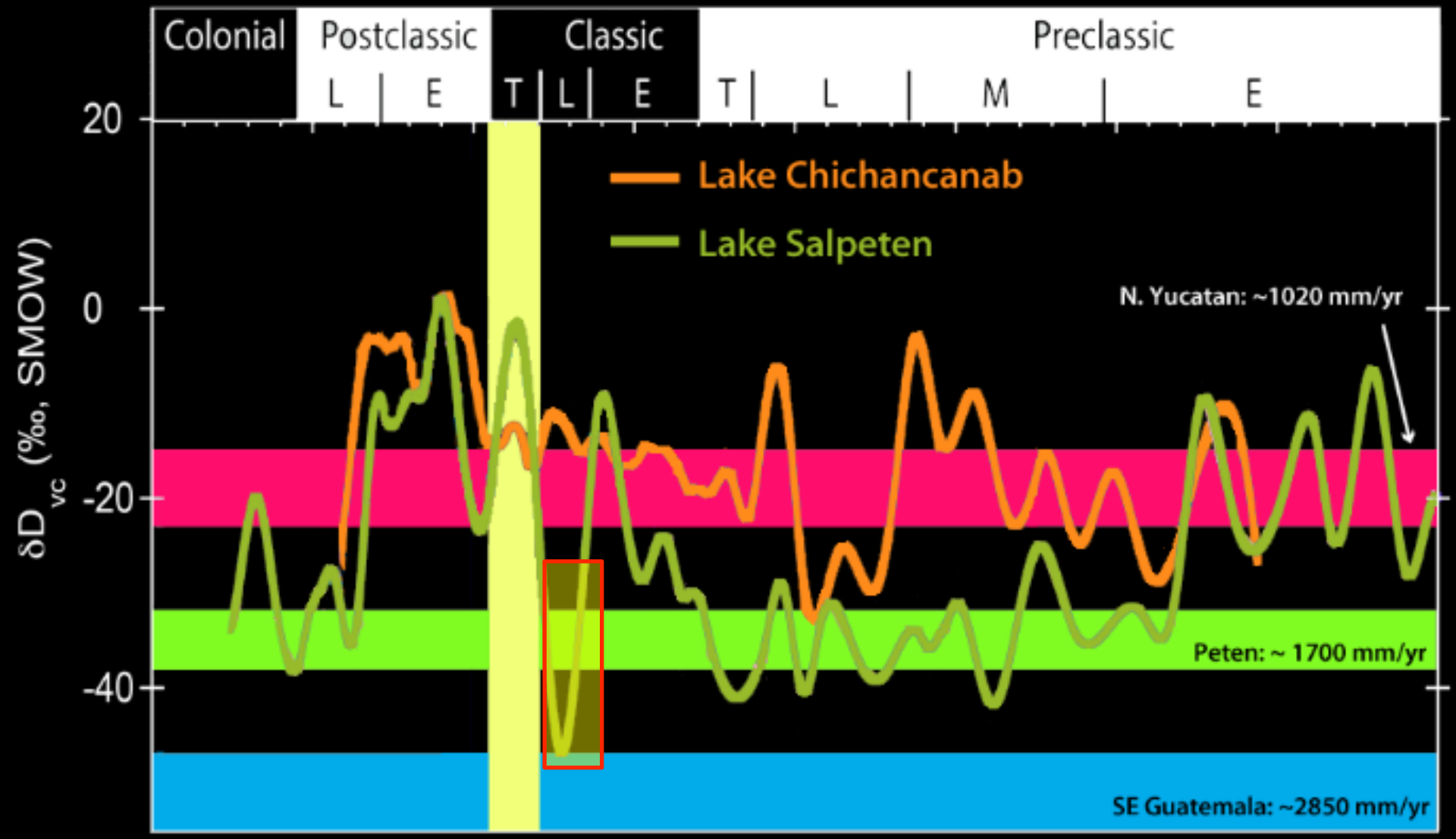
The product of success?



Data from Anselmetti et al., 2010; Leyden et al., 2002; Wahl et al., 2006; Rice and Rice, 1990; Turner II, 1990

Wet period #2

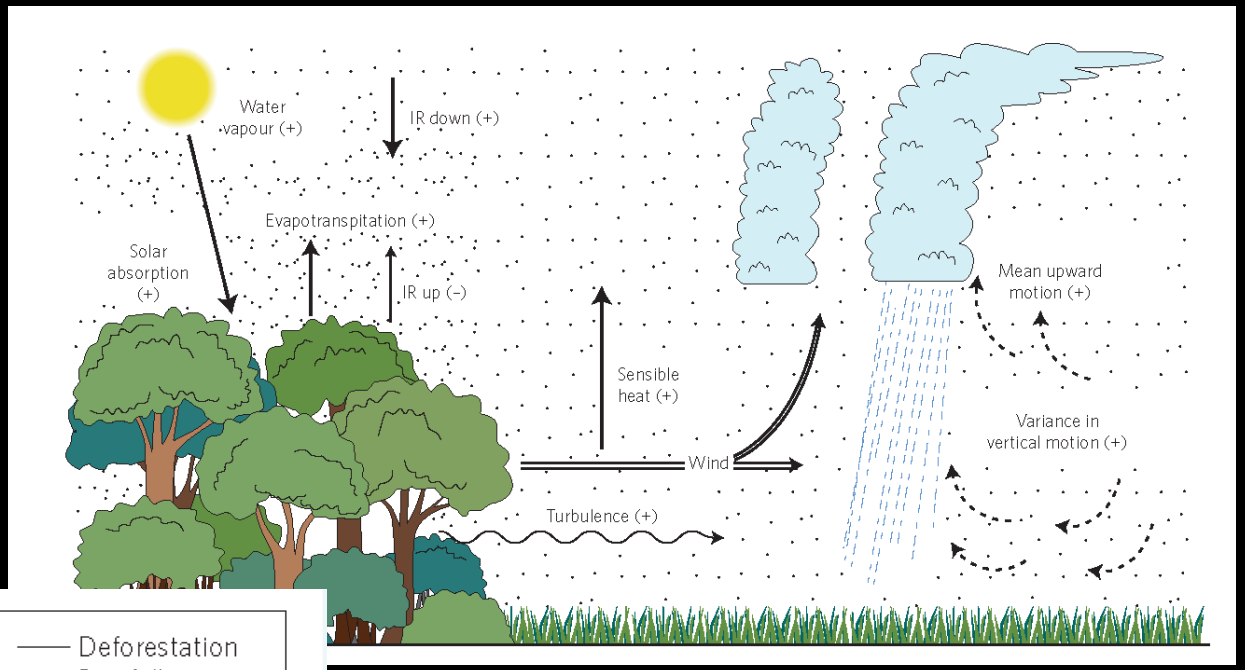
AD 550 – 800

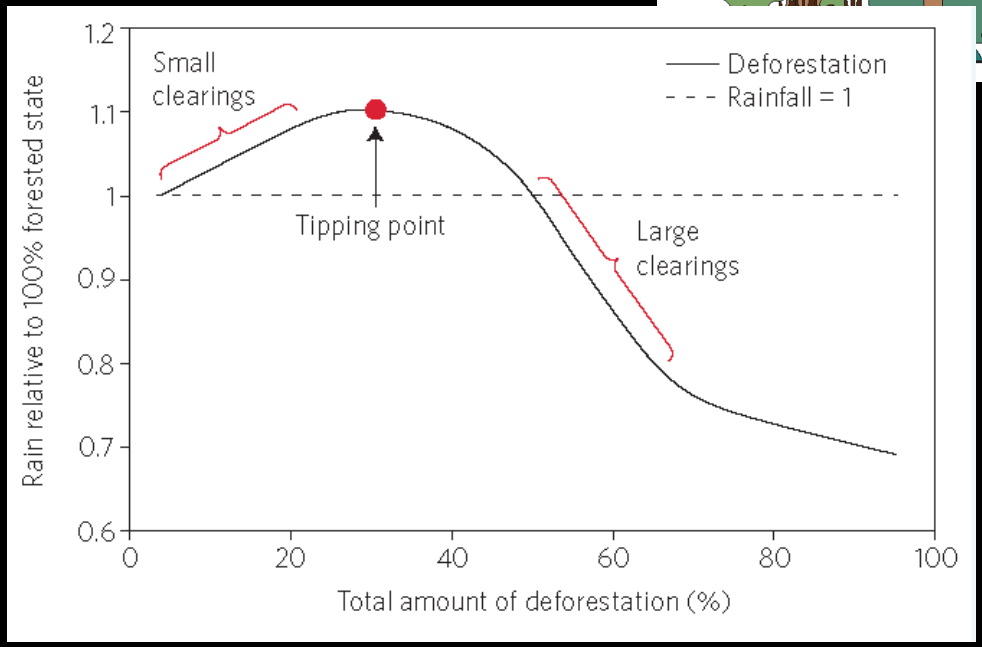


Late Classic: *Peten was wetter than today*

New Studies in deforestation

"Effects of Tropical Deforestation on Climate and Agriculture", Lawrence and Vandecar, 2014, *Nature*





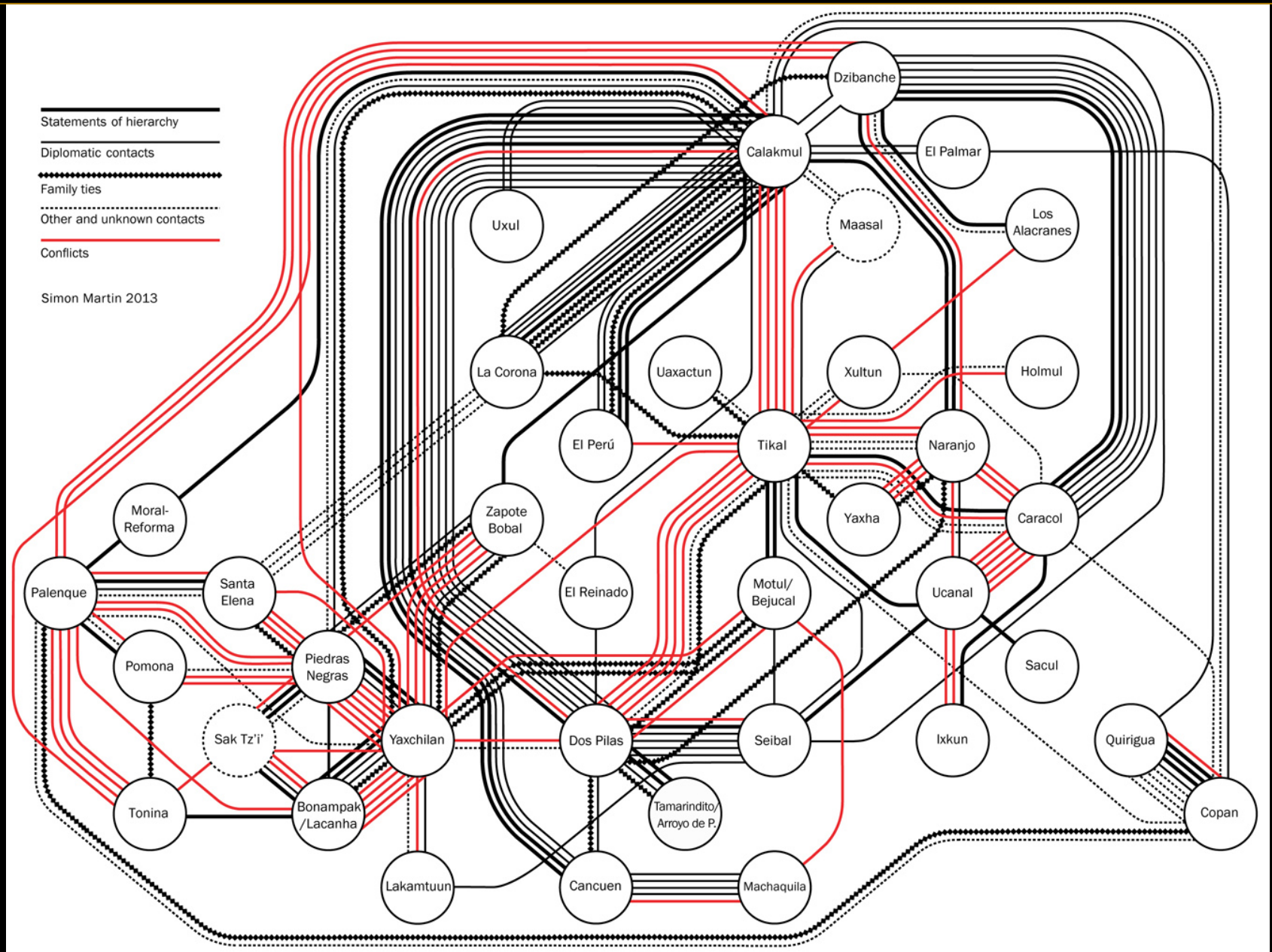
The KAANUL regime

Hegemonic strategies deploying different kinds of power

Image from Simon Martin

Diplomatic relations

Soft vs. Hard power

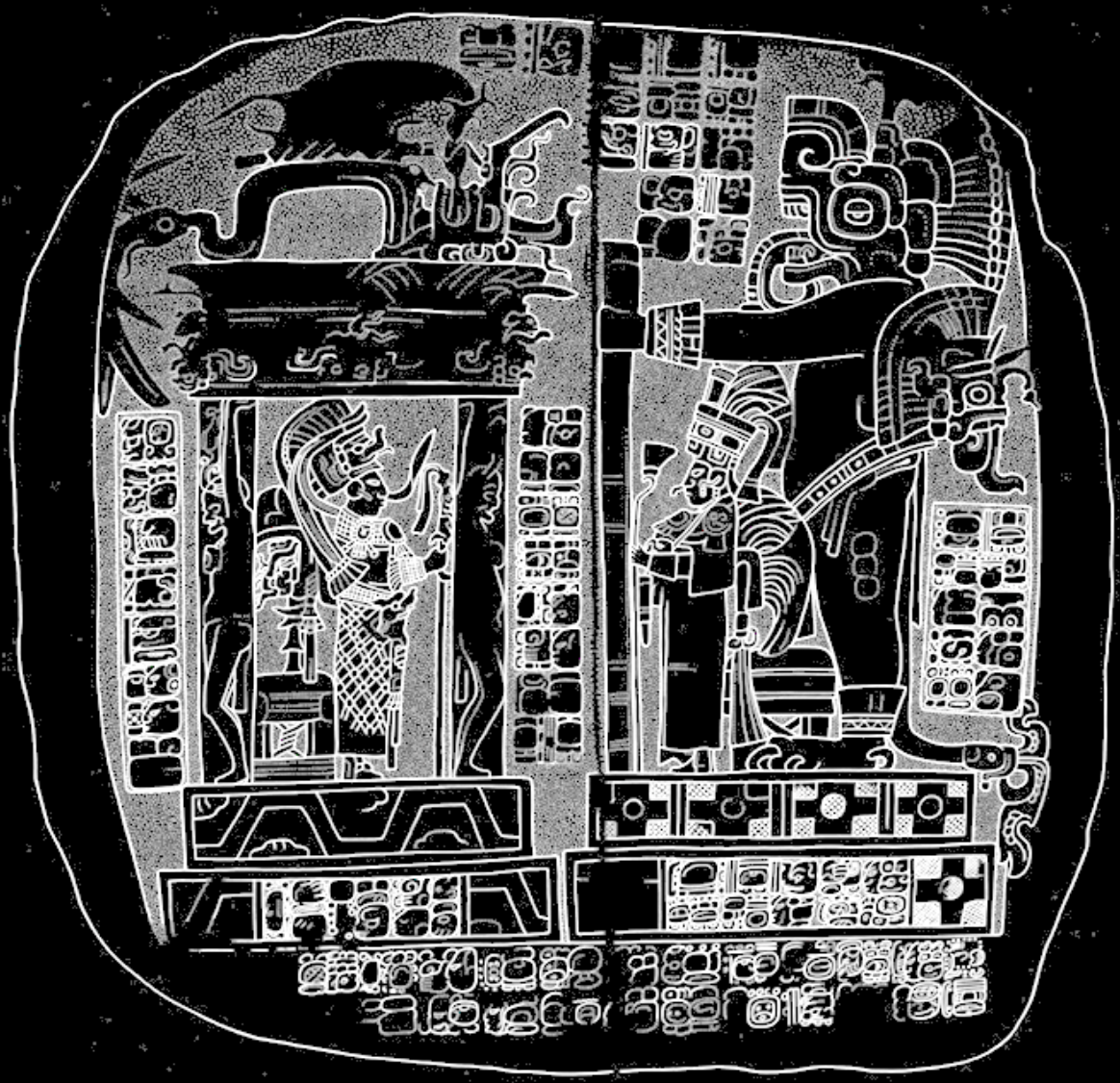


La Corona, Panel 6

Dedicated to three women from the KAANUL kingdom

La Corona, Panel 6

Dedicated to three women from the KAANUL kingdom



Drawing by David Stuart

Panel 6

Dedicated to three women from the KAANUL kingdom

Ix ? naah ek’

AD 520

Drawing by David Stuart

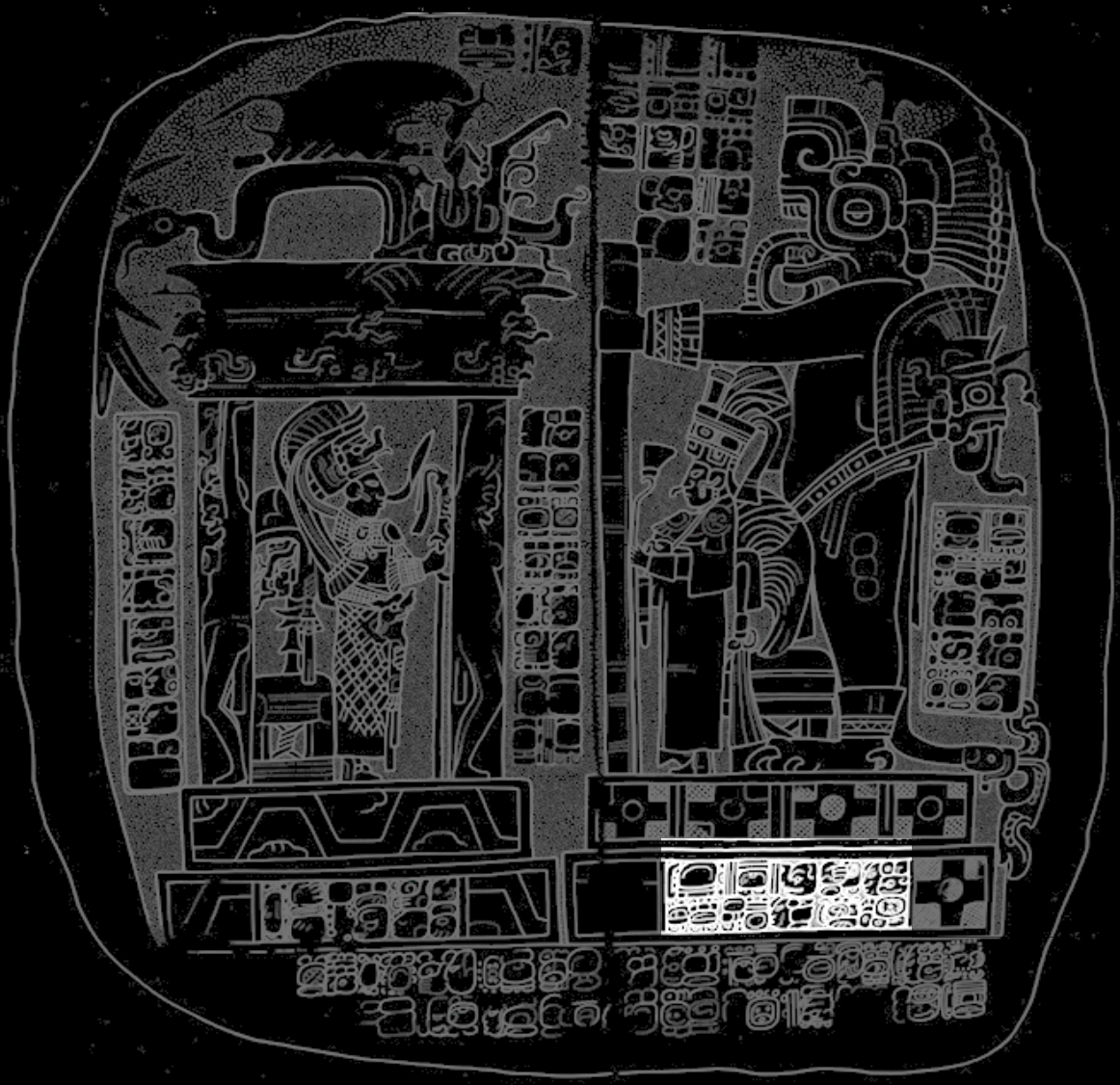
La Corona, Panel 6

9.12.6.16.17 11 Caban 10 Zodz - May 3, 679

Lady Tz'ihb Winik
AD 679

Arrival of
Lady Tz'ihb Winik
of Calakmul

spouse of
K'inich ? Yook
of La Corona



Drawing by David Stuart

A new political order

Absence of *k'ujul ajaw*

Oxpemul

Calakmul

Los Alacranes

Champerico

Uxul

La Corona

Tikal

Yuknoom Ch'een, the Great
(AD 636 – 686)

La Corona, H.S. 2 Block 8

Foto courtesy of Cristina Guirola

A new political order

Expansion of routes to the south

Dzibanche

Calakmul

Uxul

Naachtun

Río Azul

La Corona

Xultun

Palenque

El Perú-Waka

Tikal

El Zotz

Piedras Negras

Naranjo

Zapote Bobal

Yaxchilan

Polol

Caracol

Seibal

Dos Pilas

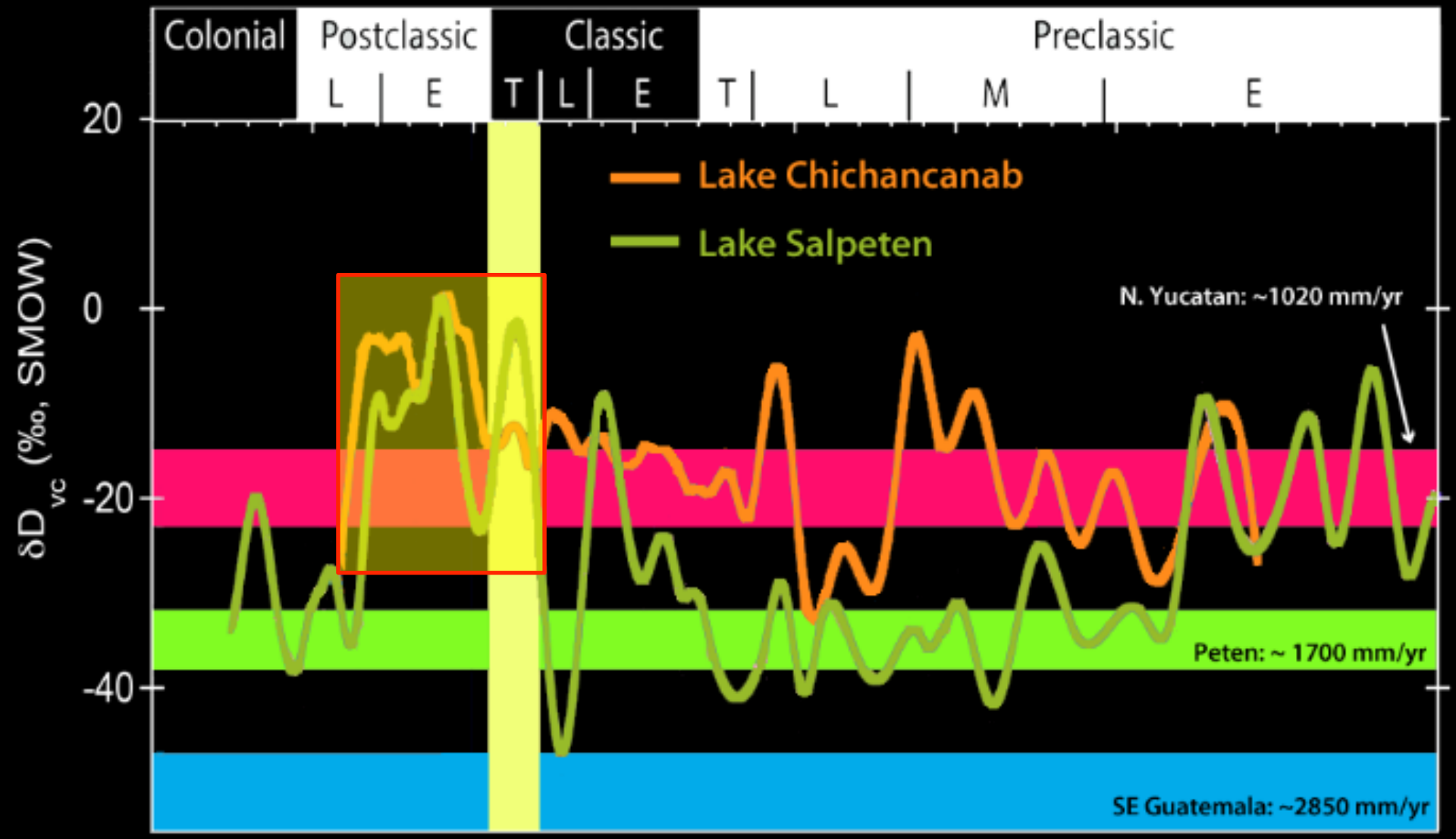
Cancuen

The absence of centralizing authority

Endemic warfare

Dry period #3

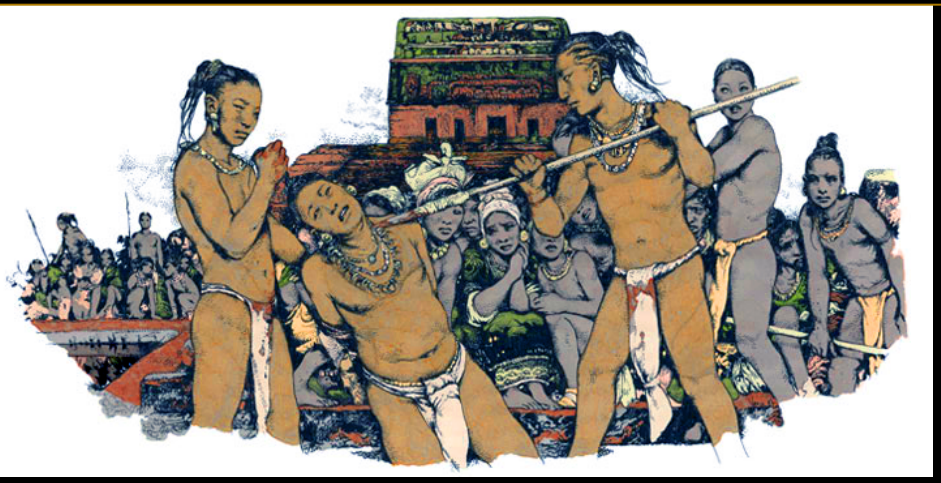
AD 800 – 1500



Terminal Classic and Postclassic: *Peten was drier than modern n Yuc.*

What

The fall of dynastic houses; the end of divine kingship



What

The abandonment of sites; the loss of population

Terminal Classic in central lowlands

Political collapse by AD 850

- Cessation of monumental architecture construction
- Abandonment of palaces and temples in large sites
- Cessation of public monument erection
- Decline in production of hieroglyphic texts
- Reduction in production of elite goods

Copan, Altar L

Terminal Classic in central lowlands

Political collapse by AD 850

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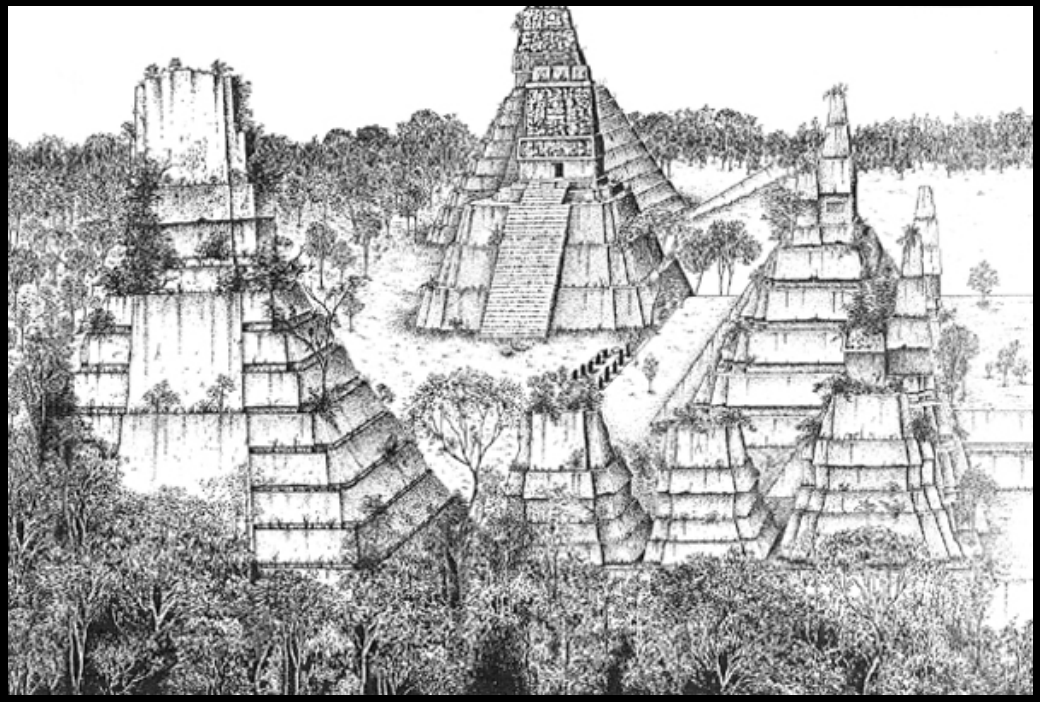

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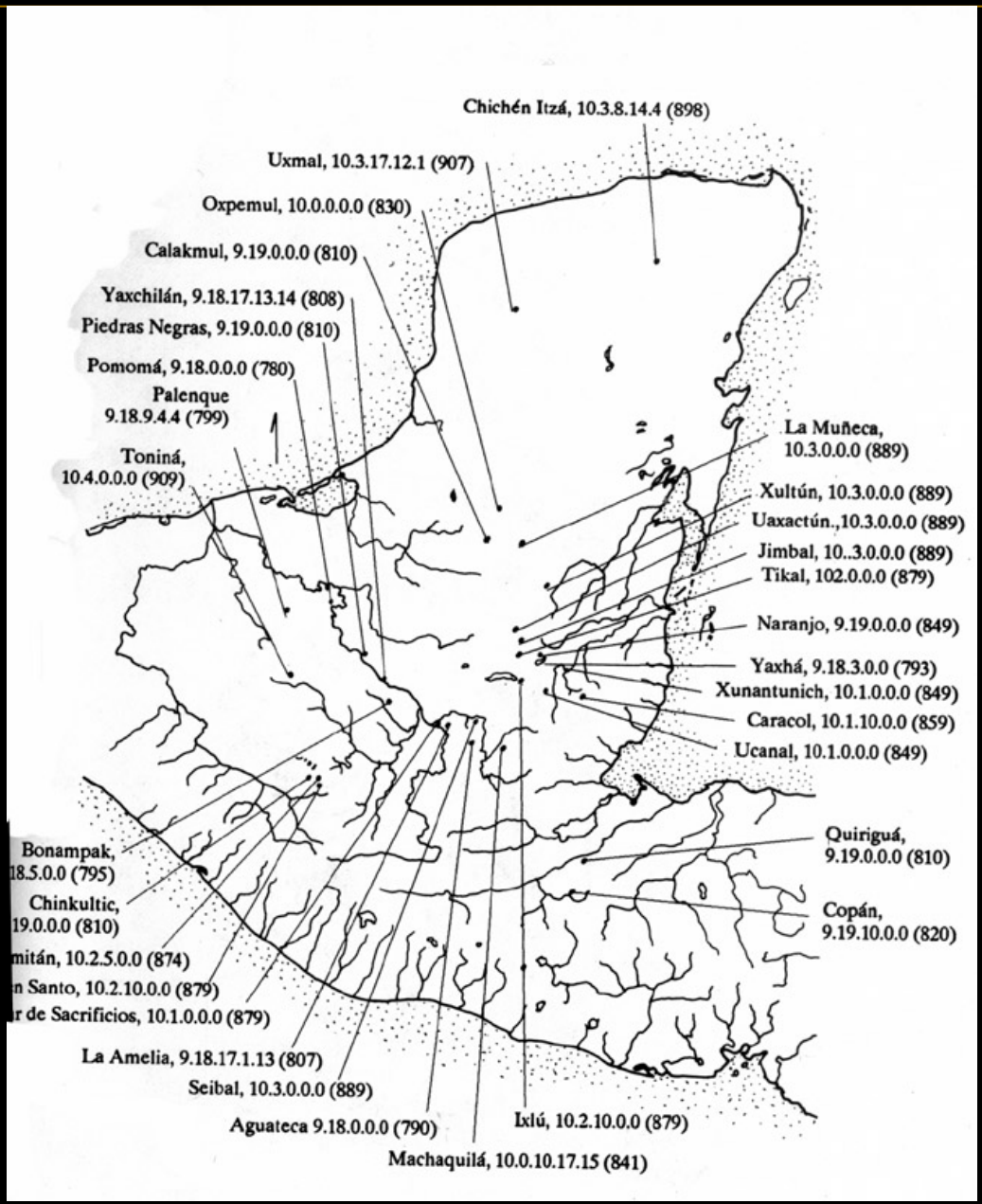

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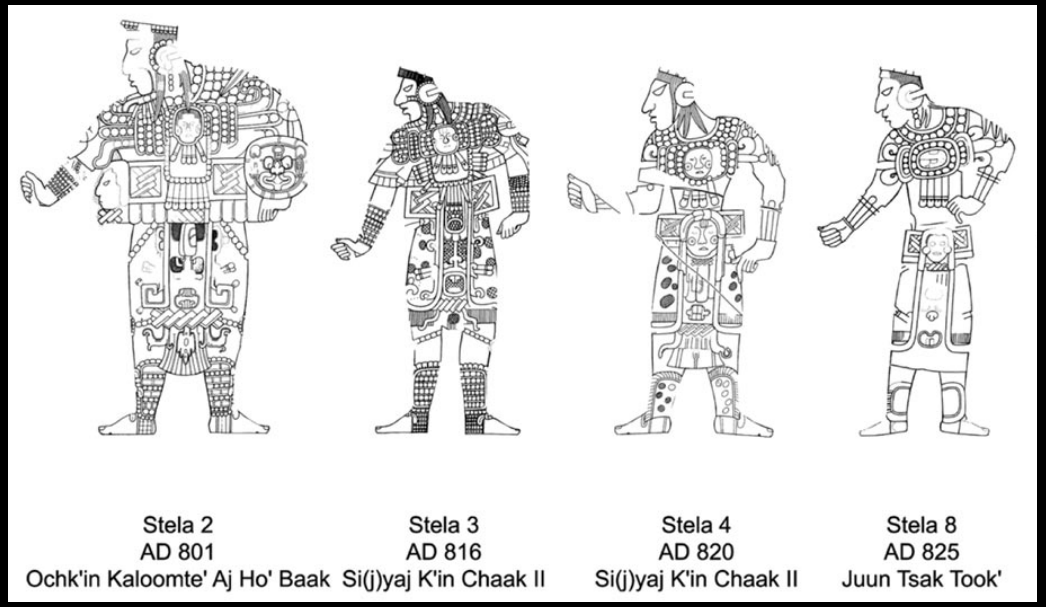

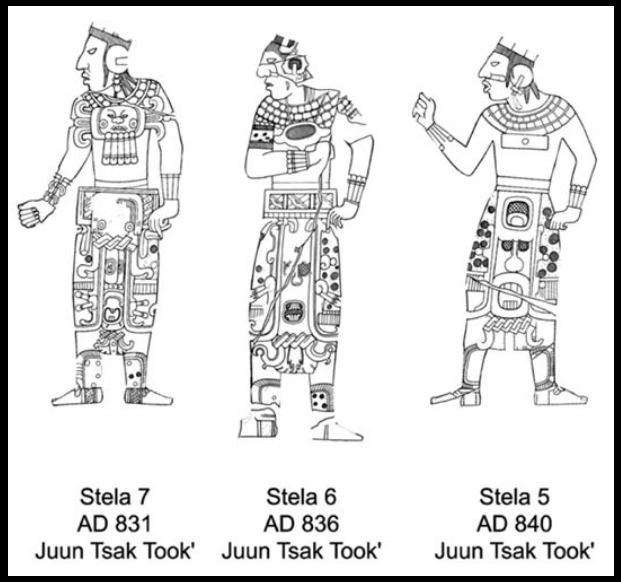

Divine kings,
Stelae erection,
Machaquila

Terminal Classic in central lowlands

Political collapse by AD 850

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- Cessation of public monument erection
- Decline in production of hieroglyphic texts
- Reduction in production of elite goods

Ornaments, Royal pool, Cancuen

Terminal Classic in central lowlands

Socio-economic change: AD 800-1000

- Elite residences abandoned before surrounding settlement
- Squatter occupation of abandoned elite buildings
- Surviving sites located along perennial water sources: *Yaxha, Machaquila, Ceibal*
- New material cultural traditions
- New suite of trade routes

Terminal Classic in central lowlands

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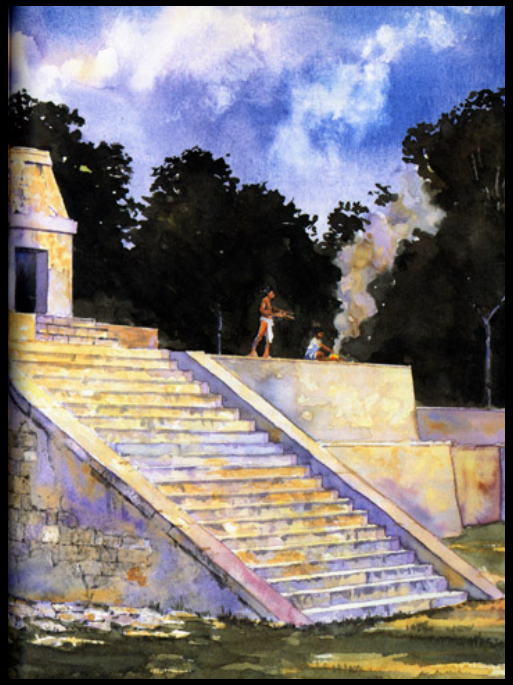

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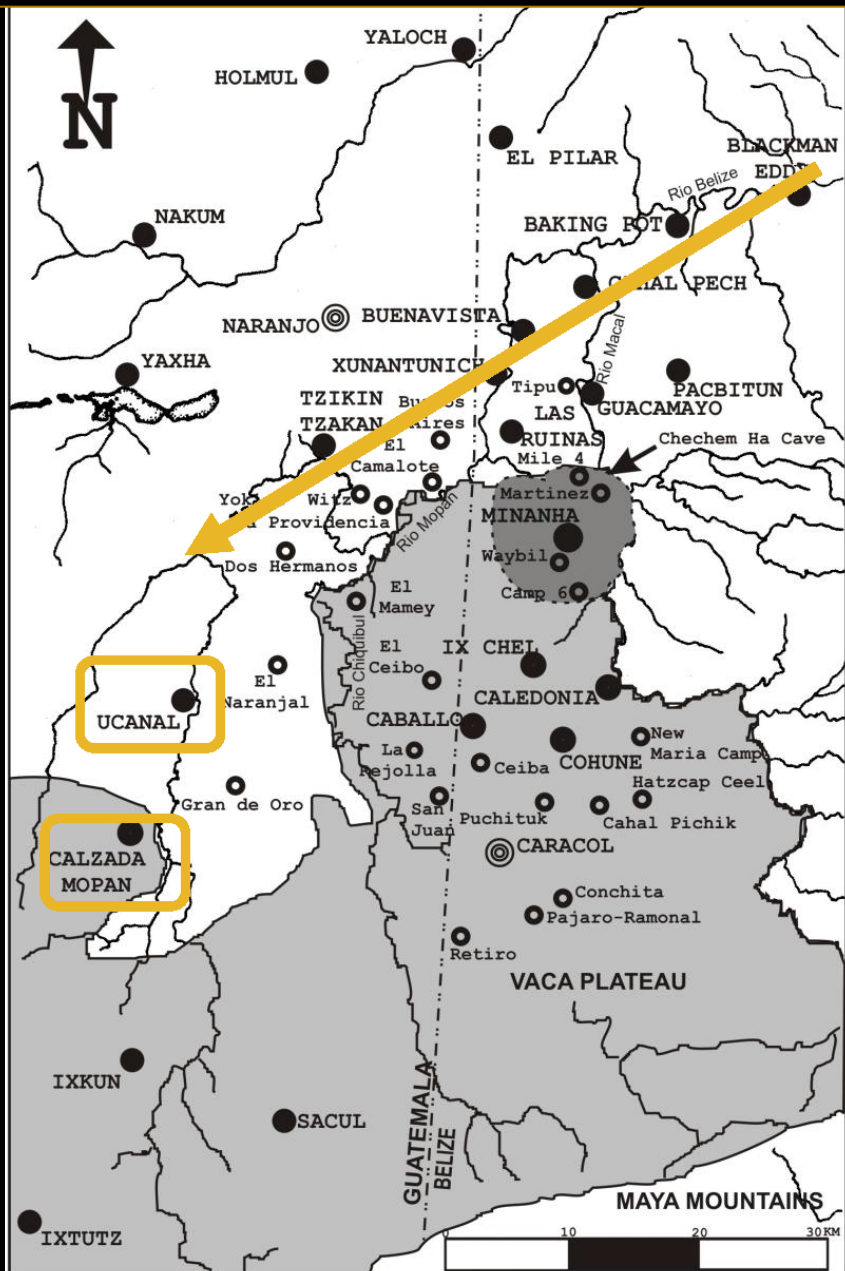

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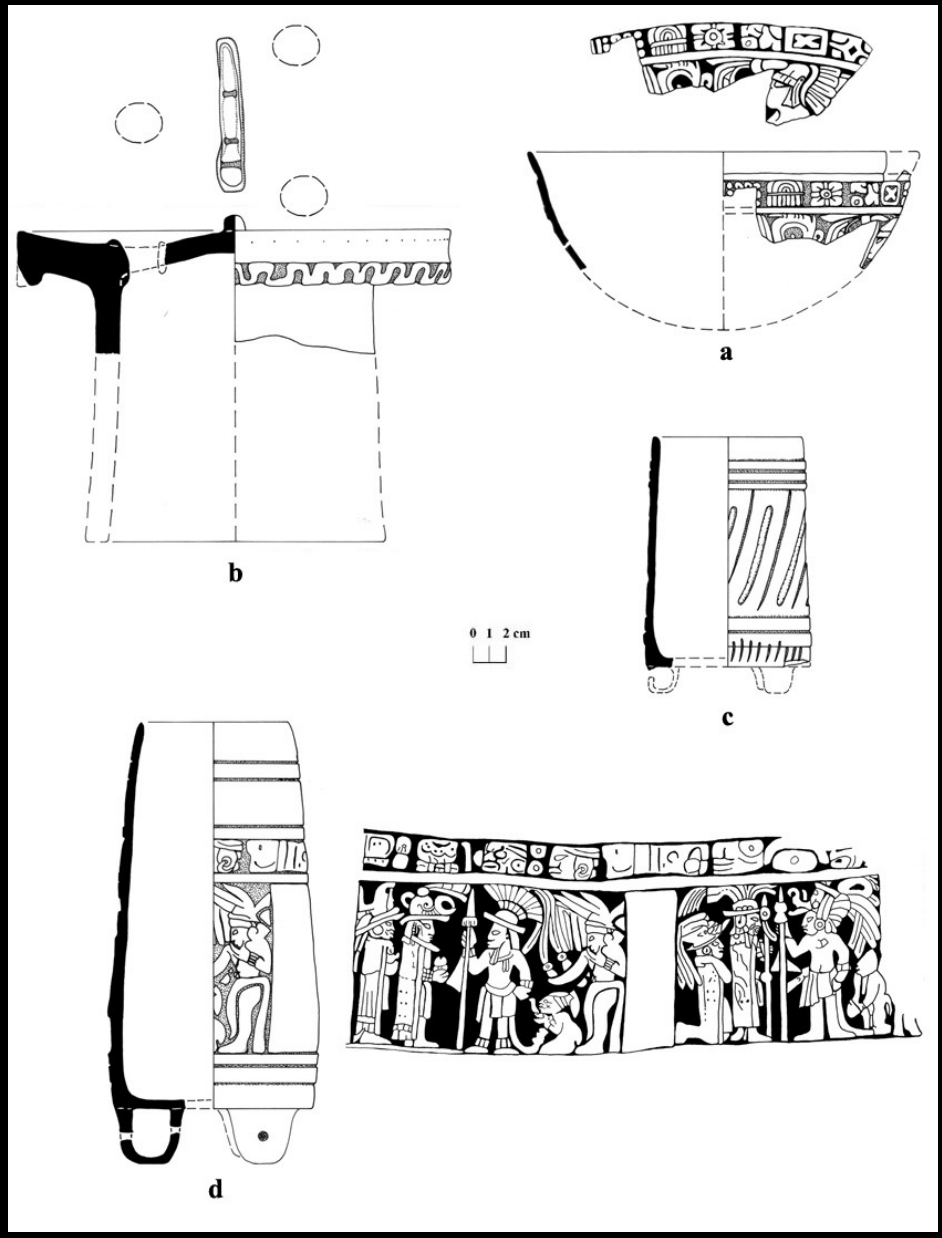

Terminal Classic in central lowlands

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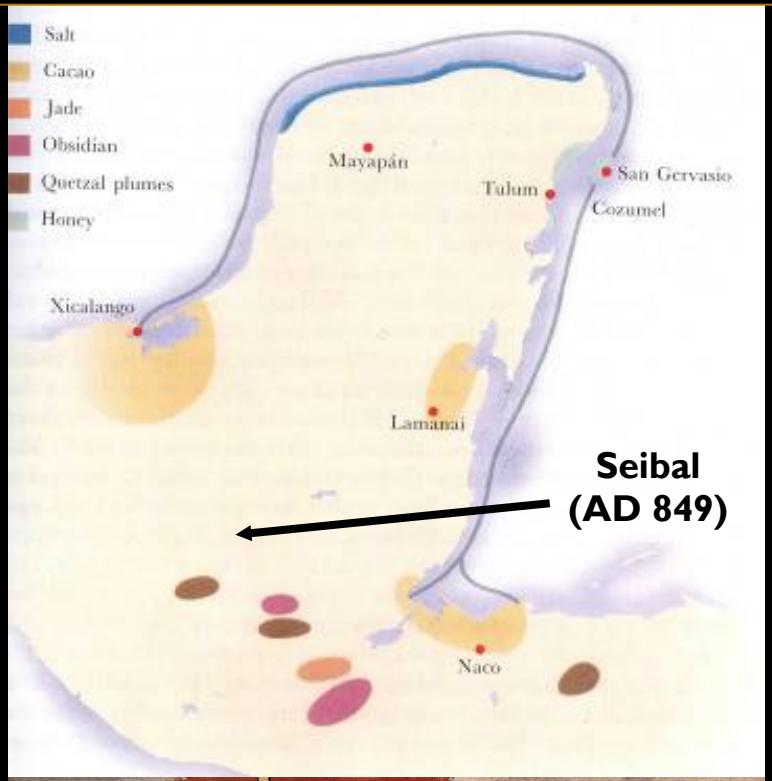
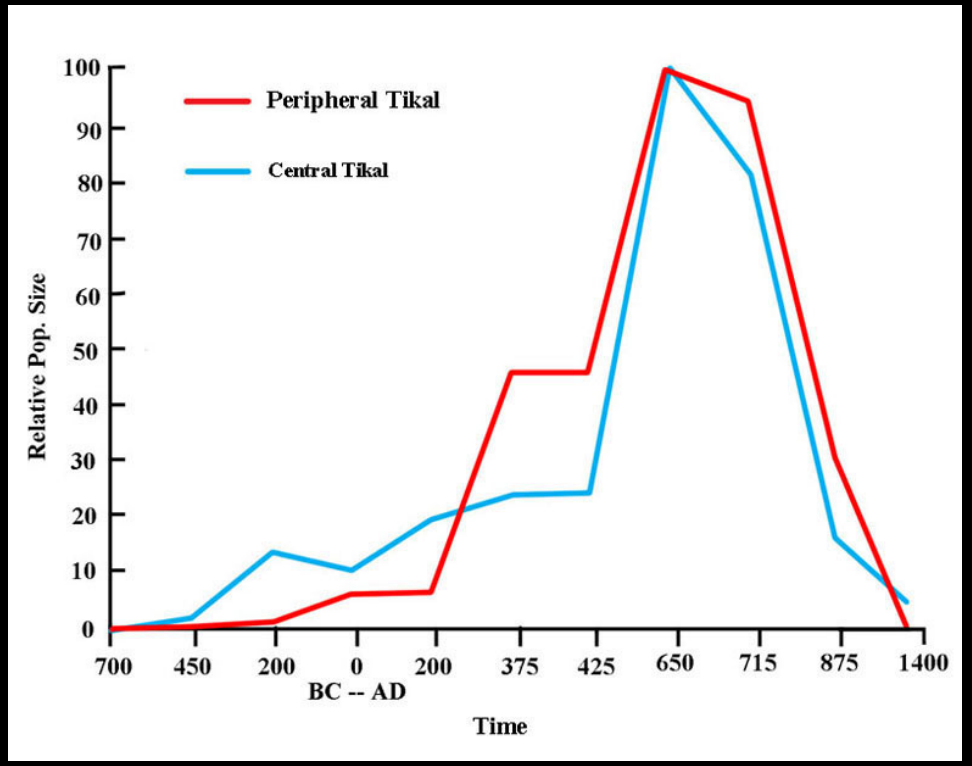


Terminal Classic in central lowlands

Anthropogenic changes to environment: AD 800-1000

- Population overshoot
- Degradation of environment
- Decreasing commoner populations, migrating out of central lowlands



- *Carrying capacity surpassed*

Population health during collapse (c.AD 780-850) was no worse than in earlier periods

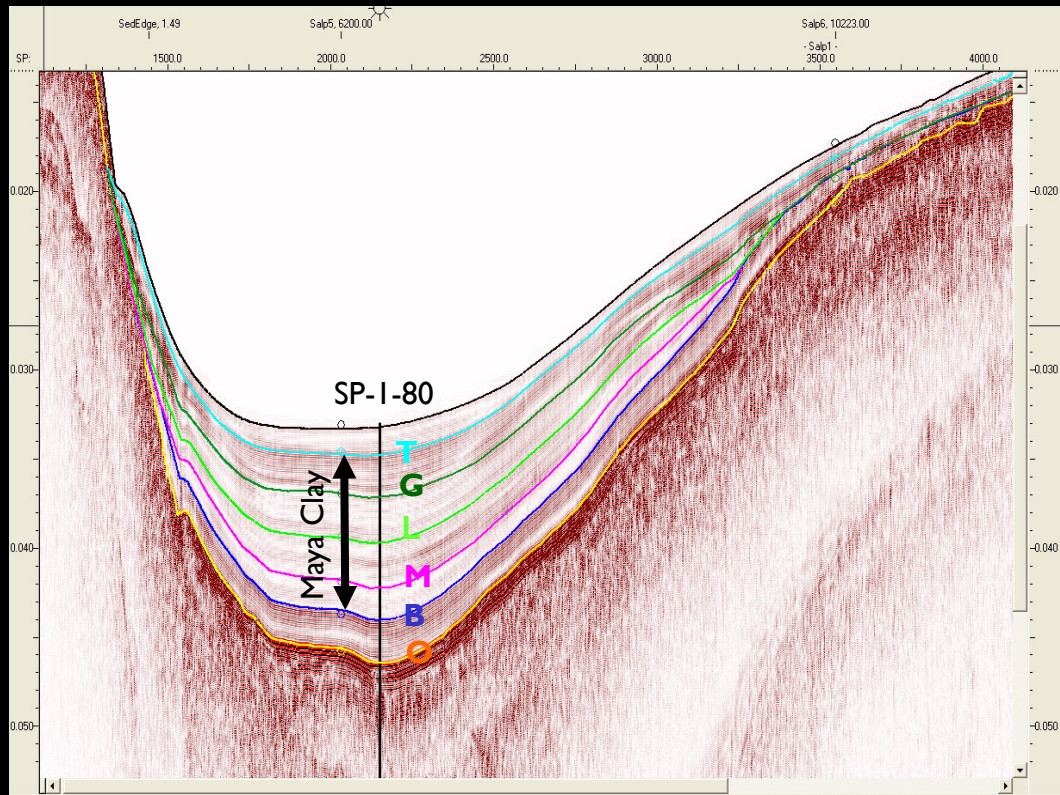
Is this an issue of sample size or chronological control?
Was subsistence failure so slow that people had time to move away & control population?

Terminal Classic in central lowlands

Anthropogenic changes to environment: AD 800-1000

- Population overshoot
- Degradation of environment
- Decreasing commoner populations, migrating out of central lowlands

- *Intensive agricultural measures failed*



Terminal Classic in central lowlands

Anthropogenic changes to environment: AD 800-1000

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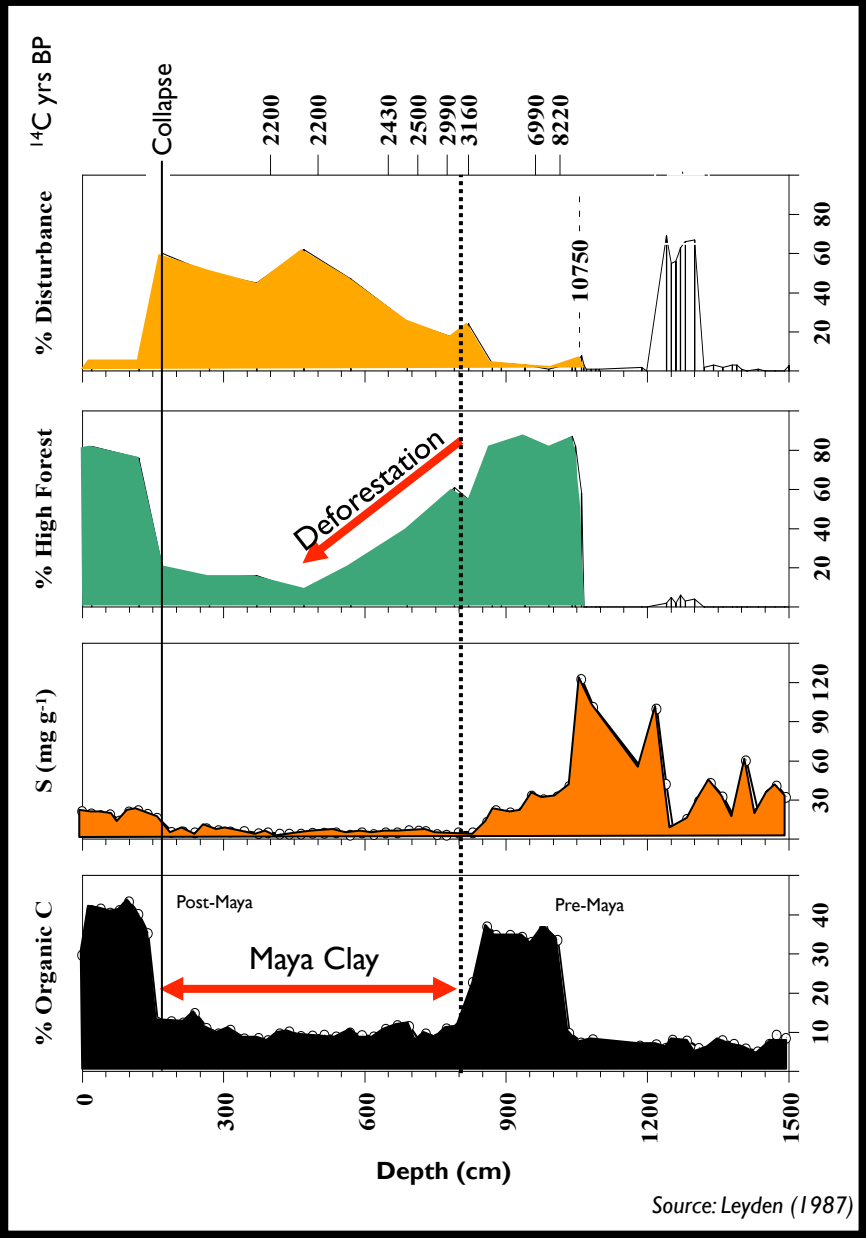


Source: Leyden (1987)

Terminal Classic in central lowlands

Anthropogenic changes to environment: AD 800-1000

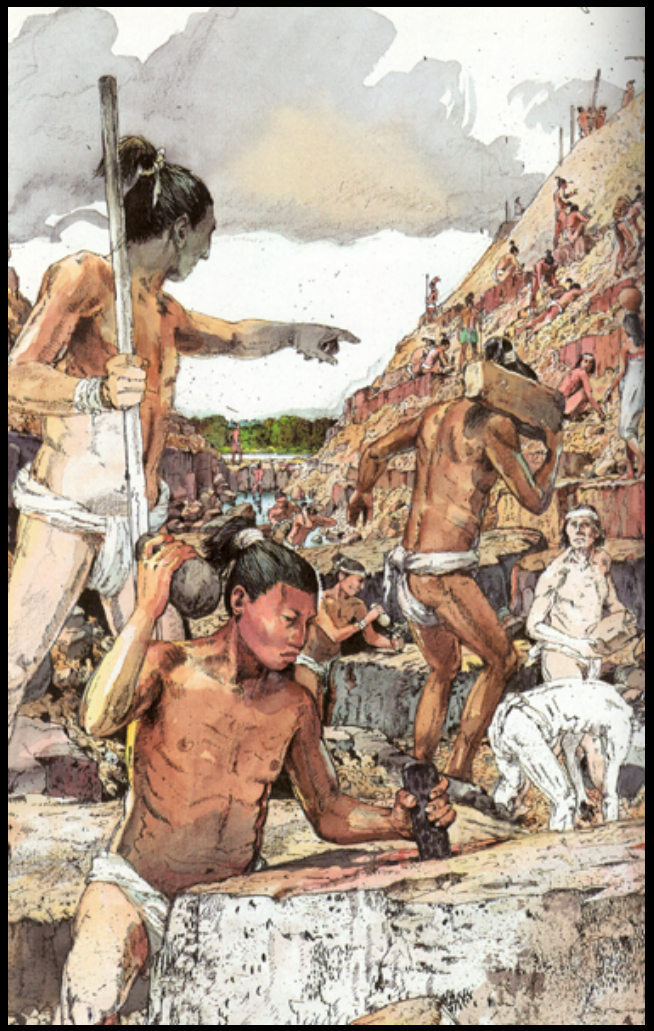
- Population overshoot
- Degradation of environment
- Decreasing commoner populations, migrating out of central lowlands

Van Akkeren 2012

Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
- Invasion from outsiders
- Escalating warfare
- Failure to centralize



- *Crisis of government*
- *Loss in faith of kingship*
- *Ideology of divine lord was abandoned*

Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
- Invasion from outsiders
- Escalating warfare
- Failure to centralize

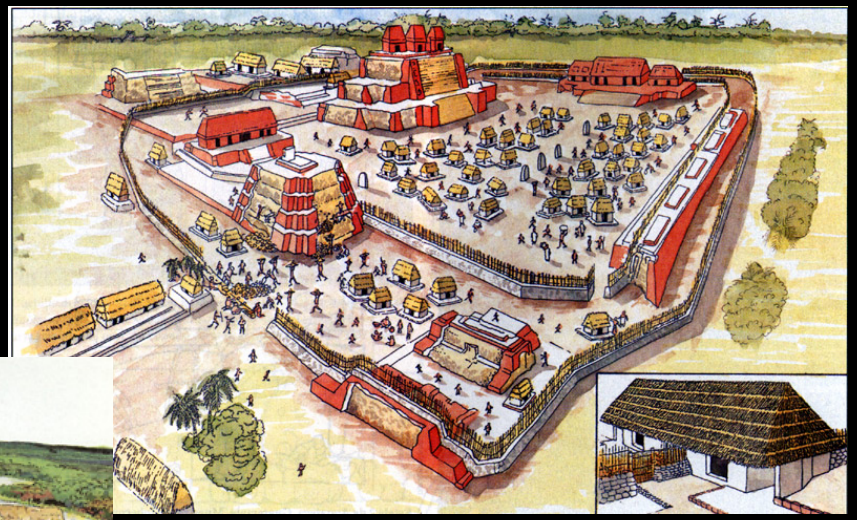
Stela 13
AD 869/889

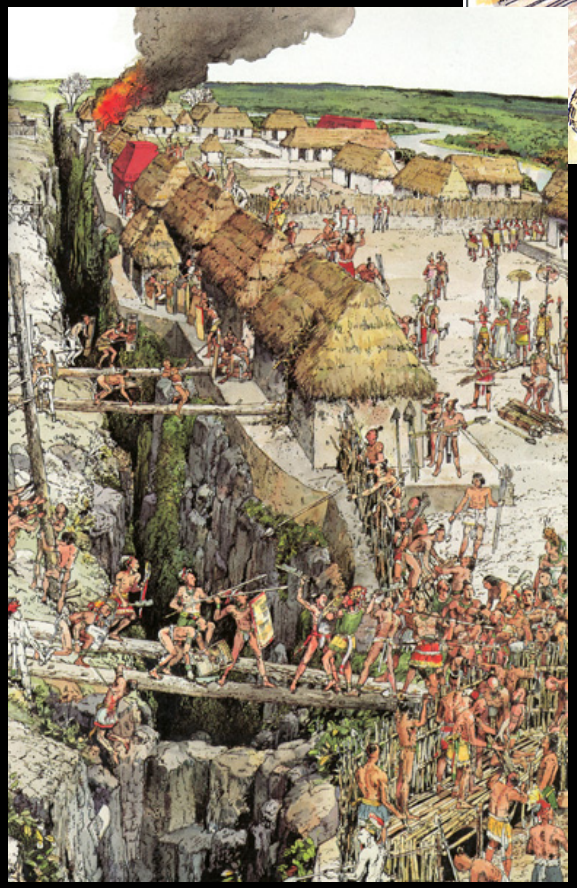
- *"Putun" Maya*
- *Foreigners as kings*
- *New trading routes*

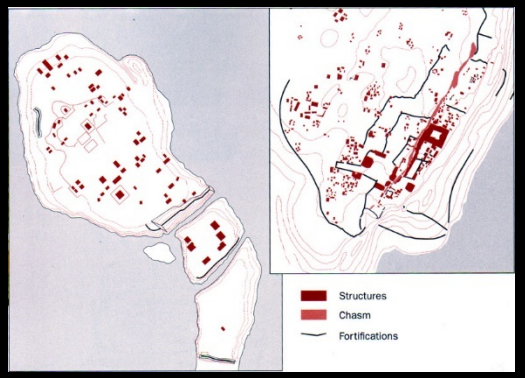
Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
- Invasion from outsiders
- Escalating warfare
- Failure to centralize





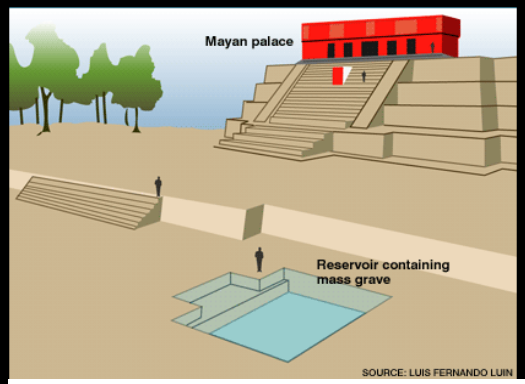


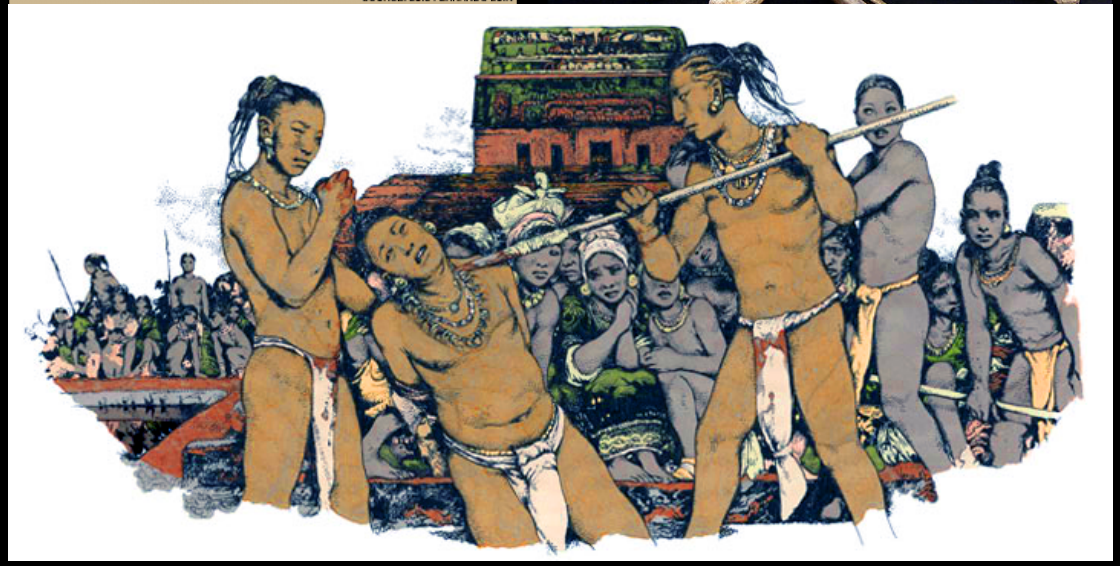
- *Collapse of agricultural production*
- *Disruption of exchange networks*
- *"Emergency" tactics vs. Long-term strategies*

Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
- Invasion from outsiders
- **Escalating warfare**
- Failure to centralize





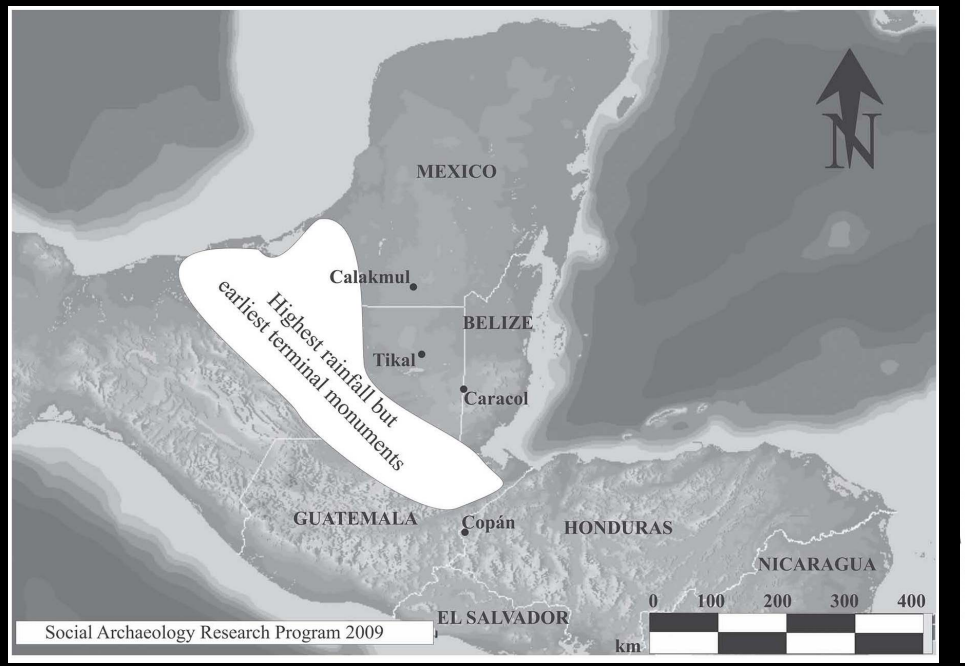
- *Crisis of government*
- *Loss in faith of kingship*
- *Ideology was unsustained*

Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
- Invasion from outsiders
- Escalating warfare
- Failure to centralize

- *How Ajaw dealt with crisis*
- *Lack of regional efficiency*
- *Regionalism as hedge against risk*



Societal response in central lowlands

Evaluating response to changes

- Peasant revolution against elites
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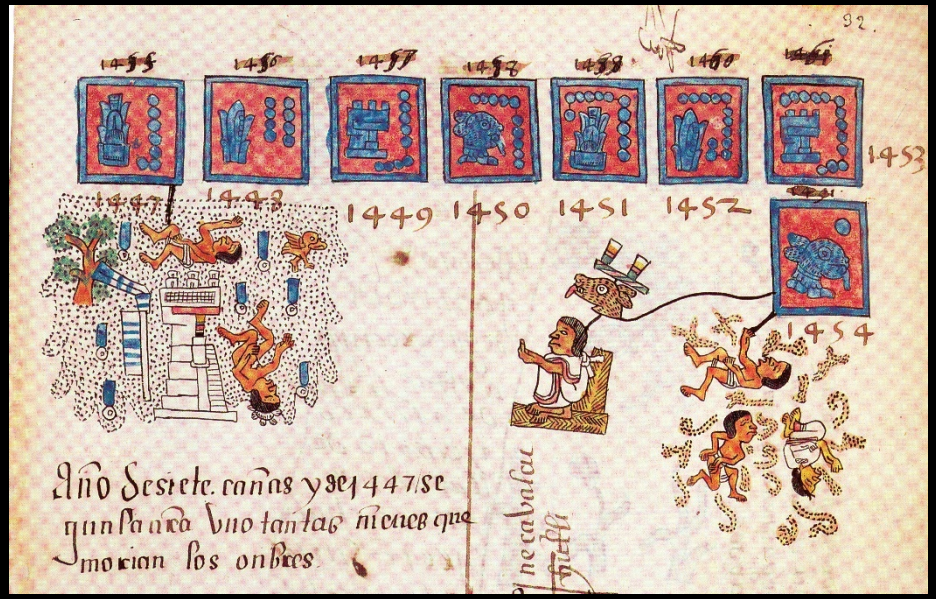
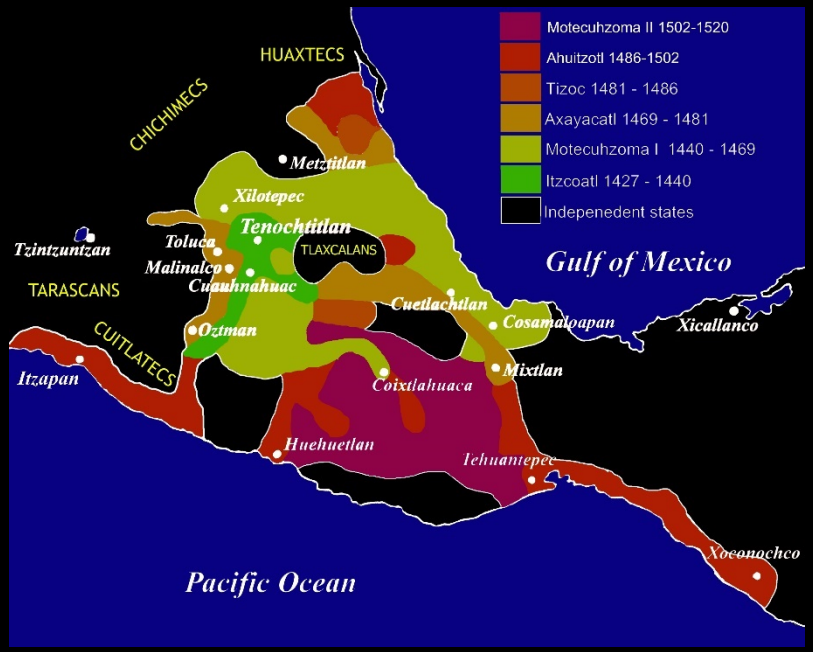
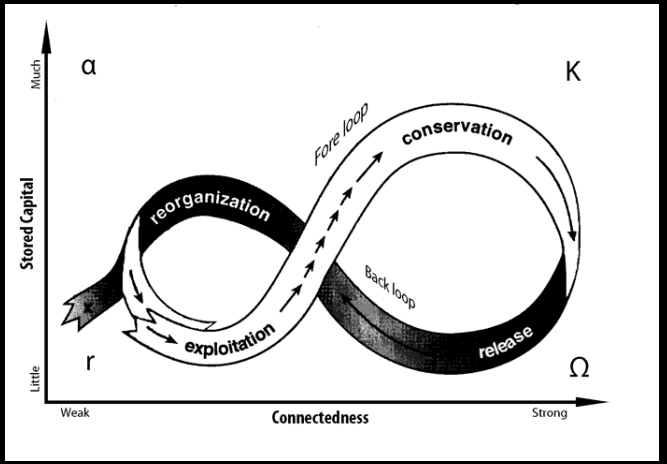




- *How Ajaw dealt with crisis*
- *Lack of regional efficiency*
- *Regionalism as hedge against risk*

Collapse models

Does these models explain decline as well as no recovery?



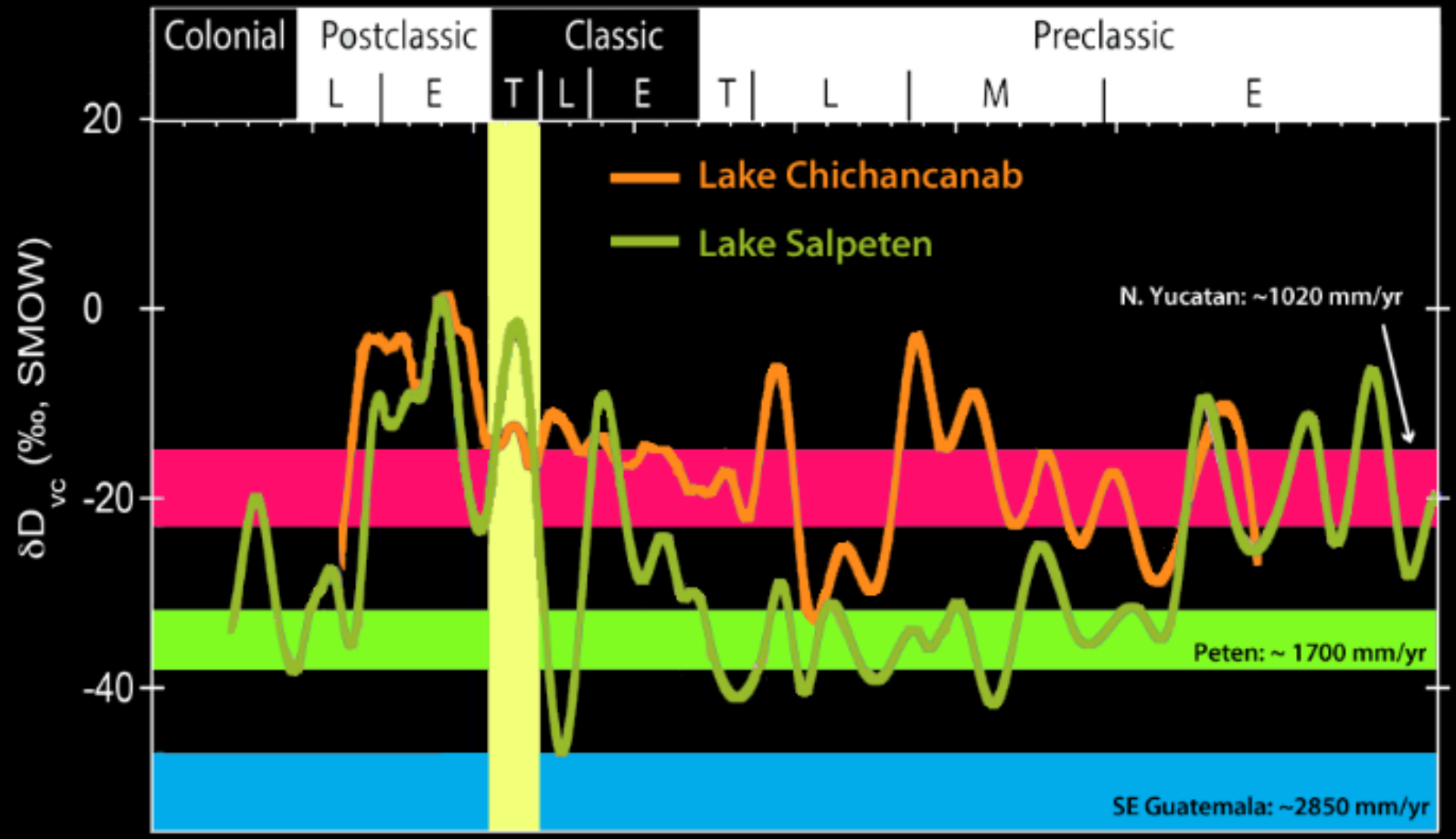
- Political changes
  - *Cessation of monumental architecture construction*
  - *Abandonment of palaces and temples in large sites*
  - *Cessation of public monument erection*
  - *Decline in production of hieroglyphic texts*
  - *Reduction in production of elite goods*
- Socio-economic changes
  - *Elite residences abandoned before surrounding settlement*
  - *Squatter occupation of abandoned elite buildings*
  - *Surviving sites located along perennial water sources:Yaxha, Machaquila, Ceibal*
  - *New material cultural traditions*
  - *New suite of trade routes*
- Environmental changes
  - *Population overshoot*
  - *Degradation of environment*
  - *Decreasing commoner populations, migrating out of central lowlands*

- Societal responses

Peasant revolution against elites
Invasion from outsiders
Escalating warfare
Failure to centralize

Rainfall patterns for Maya area

Douglas et al. 2015



Summary of data correlation

for the Classic Maya Collapse

- Late / Terminal Preclassic crisis
  - First examples of political failures related to climate
  - Not a regional collapse
- Early Classic restructuring
  - Rise of new resilient systems in central karstic uplands
  - Larger roles for State, unitary tendencies
- Late Classic unity/fragmentation
  - Climatologically favorable
  - Expansion of smaller kingdoms counter to hegemonic forces
- Terminal Classic collapse
  - Climatological stress major factor for Central Karstic Uplands
  - Eradication of a political system, no return