6 THE CLIMATIC CONTEXT FOR THE FORMATION AND DECLINE OF MAYA SOCIETIES IN THE BELIZE RIVER VALLEY

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This paper reviews paleoclimate proxy data from the Maya lowlands to provide a framework for understanding the human-environment dynamics that influenced the growth and decline of ancient Maya societies across the Belize River Valley. Patterns in paleoclimate data suggest that Belize Valley communities experienced the impacts of climate change as early as the Preclassic, when a multi-century drought coincides with archaeological evidence for the initial appearance of Early Preclassic (1200-900 BC) agricultural villages across the sub-region. Wetter conditions likely fostered the centralization of expanding Middle Preclassic populations and the formation of large regional polities, which continued to grow despite an extended drought at the end of the Late Preclassic (AD 150-300). At least two major Terminal Classic (AD 750-900/1000) droughts appear to have had variable impacts on Belize Valley polities. While some are abandoned as early as AD 850, large-scale depopulation only occurs at others by the beginning of the 11th century, suggesting that drought in addition to other socio-political factors influenced these developments. Locally focused comparisons of paleoclimate and archaeological data can help us to develop testable hypotheses about the role of climate in these cultural developments in the Belize River Valley and beyond.

Introduction

The ancient Maya were one of only a few prehistoric societies to build massive cities that supported vast populations within a tropical forest environment. Archaeologists are placing a growing emphasis on the role of the environment, and specifically climate conditions, in the initial development and eventual demise of these complex groups. While paleoclimate research has focused primarily on the "collapse" of lowland Maya polities during the Terminal Classic period (~AD 750-900/1000; e.g., Akers et al. 2016; Kennett et al. 2012; Medina-Elizalde et al. 2010), more recent studies also demonstrate that the establishment and growth of the earliest Maya communities was also significantly impacted by climatic change (e.g., Ebert et al. 2017; Medina-Elizalde et al. 2016; Nooren et al. 2018). This accumulating body of research indicates that severe and protracted droughts – ranging in scale from multi-decadal to multi-century – impacted the entire Maya region (and much of Mesoamerica; e.g., Kennett and Marwan 2015; Stark and Eschbach 2018) from the Preclassic through Terminal Classic periods.

While climate has been recognized as an important factor in influencing cultural changes throughout the Maya lowlands, archaeological research has revealed high levels of temporal and spatial variability in the development and decline of polities between and within different sub-regions of the lowlands (Aimers and Iannone 2014; Douglas et al. 2016b). This paper

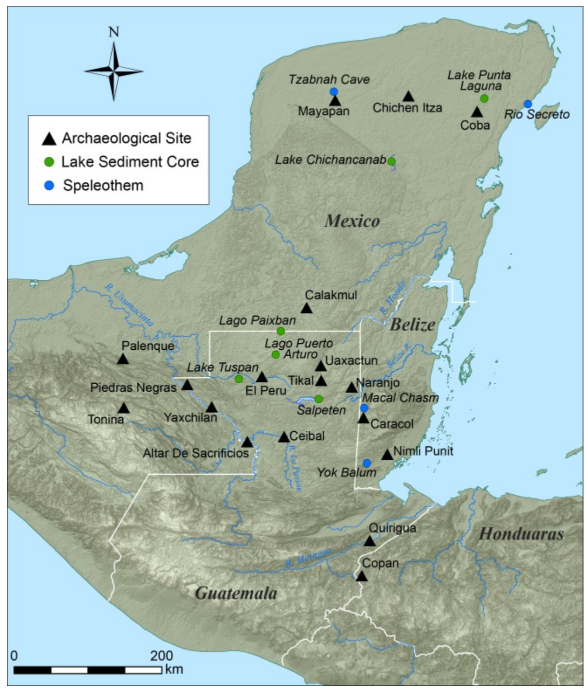

Figure 1. Map of Maya lowlands showing major sites and locations of paleoclimate records discussed in the text.

reviews regional paleoclimate proxy data and archaeological evidence from the Maya lowlands (Figure 1), focusing on the upper Belize River Valley of west-central Belize (Figure 2), to provide a foundation for understanding the complex human-environment dynamics that influenced localized adaptations to climate change. The upper Belize Valley extends approximately 30 km eastward and downriver from the ancient Maya center of Xunantunich and terminates at the site of

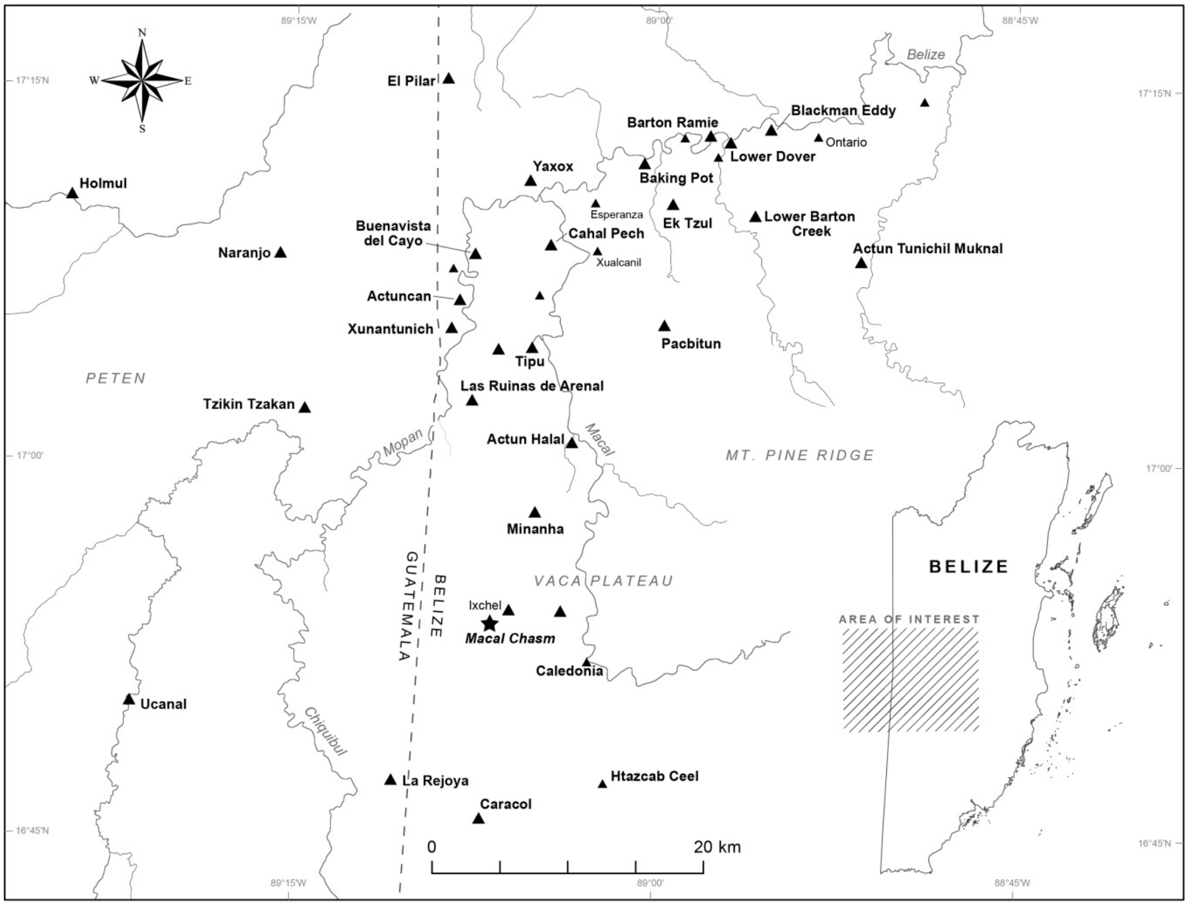

Figure 2. Map of western Belize showing sites mentioned in text.

Blackman Eddy. The region is characterized by a series of limestone escarpments that border fertile alluvial bottomlands located along the Belize River and its tributaries. These are some of the most agriculturally productive soils in the Maya lowlands, and evidence for occupation by farming communities extends over 2000 years from the Early Preclassic through Terminal Classic periods (~1200 BC-AD 900/1000).

Comparing paleoclimate datasets with archaeological data from the Belize Valley sub-region of the lowlands allows us examine the ways that local communities adapted (or did not adapt) to new or fluctuating environmental conditions. Our discussion examines broad, general trends in contemporaneous cultural developments and climatic conditions during the occupational history of the Belize Valley, focusing primarily on major drought. We do not suggest that drought alone, or any other climate/environmental conditions, can account for the establishment, growth, or disintegration of complex societies in the Belize Valley, or elsewhere in the Maya lowlands (Aimers and Hodell 2011). Instead, comparisons provide a new perspective on the role of climate as one important factor in the resilience and vulnerability of ancient Maya communities throughout their developmental trajectory. Examining correlations between socio-political and demographic changes and climatic events can aid archaeologists in developing hypotheses about causation that can be tested against additional archaeological, paleoenvironmental, and epigraphic datasets.

Paleoclimate Datasets from the Maya Lowlands: What They Are and How to Interpret Them

An important component for interpreting paleoclimate records from the Maya region is the analysis of stable oxygen isotopes. Oxygen

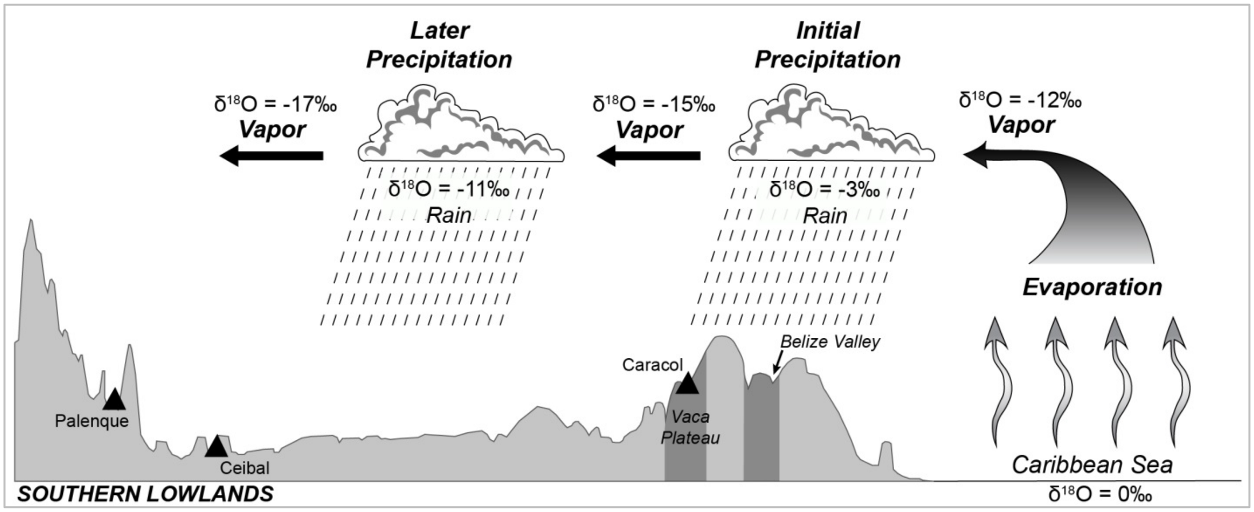

Figure 3. Predicted oxygen isotope values for the southern Maya lowlands based on the amount effect (adapted from Douglas et al. 2016a: Figure 3).

Table 1. Major lake core and speleothem paleoclimate proxy records for Maya lowlands, discussed in text. Date ranges are rounded to the nearest 5 years.

Record Type	*Record Name*	*Location*	*Date Range (years BC/AD)*	*Dating Method*	*Resolution*	*Citation*
Lake Sediment Cores	Lake Punta Laguna	Quintana Roo, Mexico	1600 BC-AD 1990	^{14}C	5 years	Curtis et al. 1996
	Lake Chichancanab	Yucatán, Mexico	860 BC-AD 1995	^{14}C	20 years	Hodell et al. 2005
	Lake Tuspan	Petén, Guatemala	4200 BC-AD 1570	^{14}C	60-70 years	Nooren et al. 2018
	Lago Puerto Arturo	Petén, Guatemala	6760 BC-AD 1500	^{14}C	35 years	Wahl et al. 2014
Speleothems	Macal Chasm (MC01)	Cayo District, Belize	3300 BC-AD 1990	U-Th	4-15 years for Classic; 24-51 years for Prelcassic	Akers et al. 2016; Webster et al. 2007
	Yok Balum Cave (YOK-I)	Toledo District, Belize	15 BC-AD 2005	U-Th	Sub-annual	Kennett et al. 2012
	Tzabnah Cave (Chaac)	Tecoh, Yucatán, Mexico	AD 490-2005	U-Th	2.3 years	Medina-Elizalde et al. 2010
	Rio Secreto (Itzamna)	Playa del Carmen, Quintana Roo, Mexico	1040 BC-AD 400	U-Th	8-10 years	Medina-Elizalde et al. 2016

has three stable isotopes that naturally occur at varying abundances: ^{16}O (99.63%), ^{17}O (0.0375%), and ^{18}O (0.1995%). Measurement of the ratio of the stable isotopes ^{18}O to ^{16}O (denoted as $\delta^{18}O$) records the isotopic characteristics of paleoclimate records, with more positive values associated with dry conditions and negative values indicating increased precipitation levels.

There are two main factors that control the isotopic composition of precipitation at a given location (Dansgaard 1964). In world regions where the temperature of precipitation varies seasonally, $\delta^{18}O$ decreases as temperature decreases (i.e., the “temperature effect”). In the tropics of the Maya lowlands, however, seasonal temperature fluctuations have remained minimal from prehistoric times to the present (Hodell et al. 2012). The degree of rainout of air masses, known as the "amount effect", instead has the greatest impact on lowland Maya paleoclimate datasets (Douglas et al. 2016a). Precipitation is always enriched in ^{18}O (the heavier isotope) relative to water vapor. Progressive rain-out as clouds move across the Maya lowlands from the Caribbean into the Petén, Guatemala and Chiapas, Mexico causes successive rain storms to become increasingly lighter (i.e., they lose the heavy oxygen isotope early on; Dansgaard 1964). The amount of rain then is negatively correlated with δ^{18}O values, effecting tropical areas with seasonal periods of heavy rainfall (Figure 3). Analysis of the isotopic composition of various paleoclimate records, therefore, facilities the tracking periods of high rainfall and drought through time. While available data indicate that droughts were not identical in timing, frequency, or severity across the Maya lowlands, comparison of all records demonstrate clear and synchronous long-term climate trends in oxygen isotope data within the limits of dating errors of individual records.

Two primary types of paleoclimate archives are available to help interpret past climate conditions across the Maya lowlands (Table 1; Douglas et al. 2016a). The first are lake sediment records document temporal variations in sedimentation rates, evaporation, precipitation based on oxygen isotopes (δ^{18}O) of ostracods, gastropods, and diatoms (Figure 4). These aquatic and marine shelled organisms record evidence for past environmental conditions, with the chemical make of their shells reflecting water chemistry at the time they were formed (Ruiz et al. 2013). In the northern Yucatán Peninsula, lake core records of gastropods and ostracods from Lake Punta Laguna (Curtis et al. 1996) and a sediment density record from Lake Chichancanab (Hodell et al. 2005) were the earliest paleoclimate proxy records to document trends in alternating wet and dry conditions from the Preclassic through Postclassic. The most extended and severe droughts identified in these northern lowland records correlate closely with the end of the Classic period, when dry conditions likely influenced the Terminal Classic Maya "collapse" (~AD 750-900/1000). More recently lake sediment core records analyzed from the southern lowlands, including records from Lago Puerto Arturo (Wahl et al. 2014) and Lake Tuspan (Nooren et al. 2018), both in the Petén region of Guatemala. These records show similar dry conditions prevailing. The Lago Puerto Arturo record has a resolution of ~35 years and also spans from the Preclassic through Postclassic period, and shows additional dry periods during throughout the Prelcassic (Wahl et al. 2014). The diatom record from Lake Tuspan, which uses lake salinity documented in diatoms as a proxy to document dry conditions every ~60-70 years, also documents earlier periods of drought during the transition from the Archaic and Early Preclassic (~1800-1000 BC), with wetter conditions prevailing during the beginning of the Middle Preclassic (Nooren et al. 2018).

Speleothems, or calcium carbonate mineral deposits formed from groundwater within underground caverns (Harmon et al. 2007), have produced some of the highest-resolution paleoclimate datasets for the Maya lowlands. Analysis of speleothem proxy records is beginning to clarify the timing of shorter-term pulses in climate trends compared to the more coarsely resolved lake sediment records (Figure 5). The "Itzamna" speleothem record from Río Secreto, Playa del Carmen in Yucatán, Mexico provides the highest resolution dataset for northern lowlands during the Preclassic period, documenting rainfall every 8-10 years (Medina-Elizalde et al. 2016). The record indicates the occurrence of several major droughts during Late Preclassic, with rainfall reduction between 35-50% compared to average occur during the more humid Middle Preclassic period. A more prolonged dry period characterized Late Preclassic climatic regimes, especially during the period between approximately AD 100 and AD 300.

To understand role of climate change in the Belize Valley, we concentrate the remainder of our discussion primarily on two speleothem records from Belize, and compare them to other localized southern lowlands records when appropriate. First is the MC01 speleothem record from the site of Macal Chasm, located 22 km southeast of the Belize Valley in the Vaca Plateau of western Belize. The MC01 record has a resolution of resolution of 24-51 years for

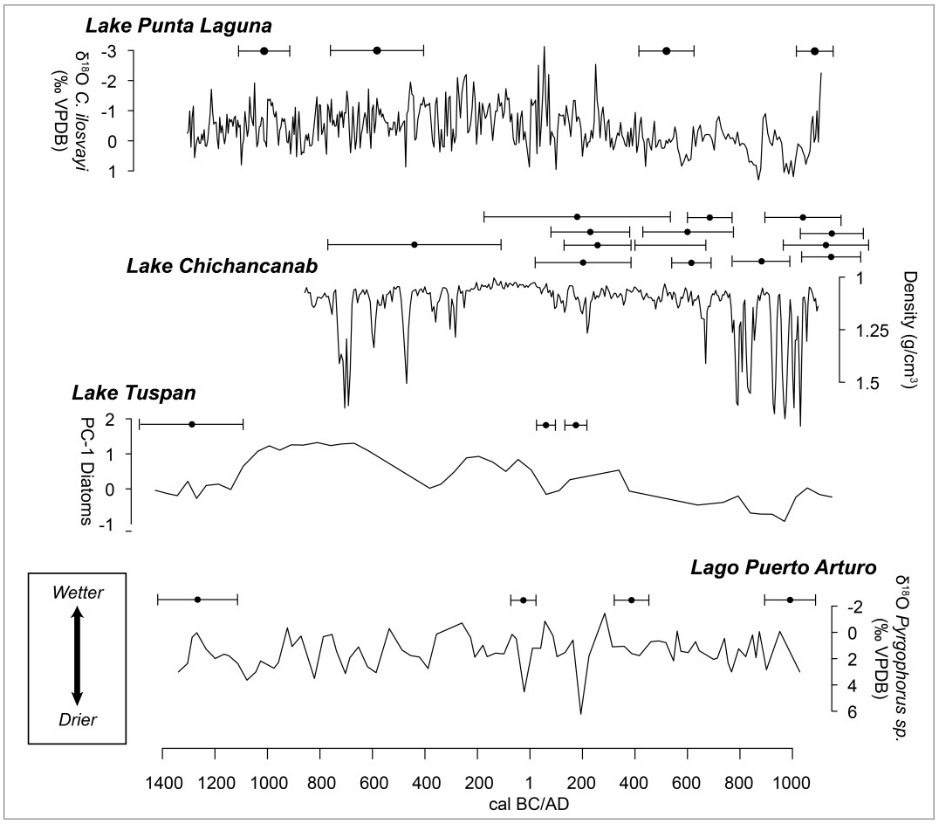

Figure 4. Lake sediment core records from the northern and southern Maya lowlands including Lake Punta Laguna ostracod δ18O record (Curtis et al. 1996), Lake Chichancanab sediment density record (Hodell et al. 2005), Lake Tuspan diatom record (Nooren et al. 2018), and Lago Puerto Arturo gastropod δ18O record (Wahl et al. 2014).

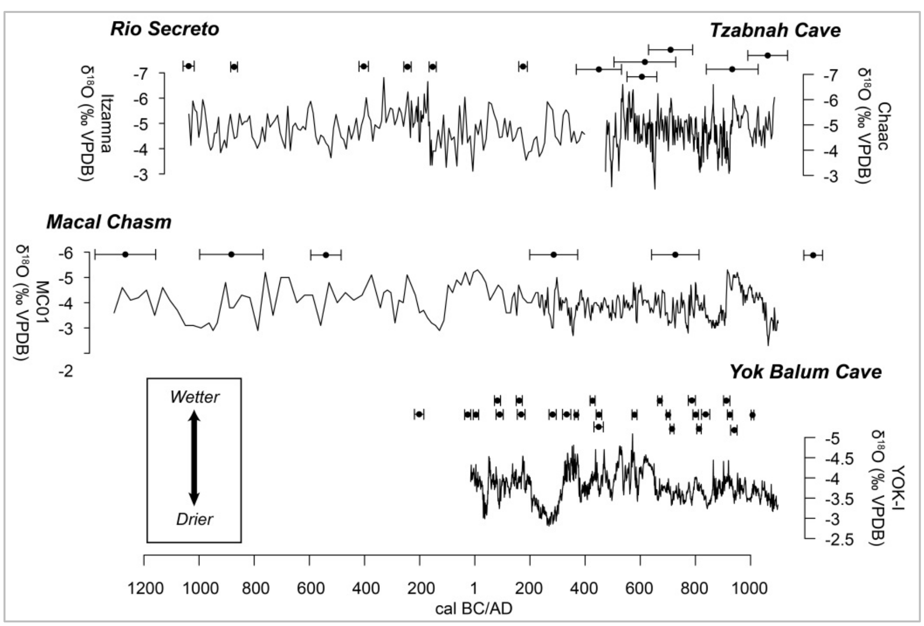

Figure 5. Speleothem δ18O records from the Maya lowlands including the Río Secreto "Itzamna" record (Medina-Elizalde et al. 2016), Tzabnah Cave "Chaac" record (Medina-Elizalde et al. 2010), Macal Chasm (MC01) record (Akers et al. 2016), and Yok Balum Cave (YOK-I) record (Kennett et al. 2012).

the Preclassic section of the record, with higher precision of 4-15 years for the Classic period (Akers et al., 2016; Webster et al., 2007). The second speleothem record comes from Yok Balum Cave in the Toledo District of southern Belize (Kennett et al. 2012). The YOK-I speleothem record is the highest-resolution record currently published for the Maya lowlands with sub-annual resolution. While the YOK-I record covers the period from the Late Preclassic through Postclassic, the Macal Chasm record spans from the Archaic through Postclassic periods.

Cultural and Climatic Trends in the Belize River Valley

Early to Late Preclassic (~1200 BC-AD 300)

The transition from mobile foraging to sedentary farming lifestyles is one of the most important evolutionary developments in Maya prehistory. During the end of the Early Preclassic (~1200/1100-900 BC) archaeological data indicates that people aggregated into settlements in the alluvial plains of the Belize Valley or on the margins of *bajos*, natural depressions that hold shallow lakes and perennial wetlands, in other parts of the lowlands (Awe 1992; Clark and Cheetham 2002; Ebert et al. 2017; Estrada-Belli 2011; Inomata 2017; Inomata et al. 2013, 2017; Lohse 2010). Radiocarbon dating places the initial settlement of several Belize Valley sites during this critical interval, including Actuncan, Barton Ramie, Blackman Eddy, Cahal Pech, Pacbitun, and Xunantunich (see Figure 6). Accompanying the transition to sedentism in the lowlands was an increasing commitment to maize agriculture, the adoption of regionally distinctive ceramic technologies, and intensification of long-distance exchange with other groups in Mesoamerica (Chase and Chase 2012).

The timing of these developments in relation to changing environmental conditions remains poorly understood (Clark and Cheetham 2002; Lohse 2010). While many paleoclimate proxy records from the northern and southern lowlands span the duration of Archaic-to-Preclassic period transition (Figure 7), less research has been devoted to understanding climate cycles during this time to gauge the influence of precipitation variability on

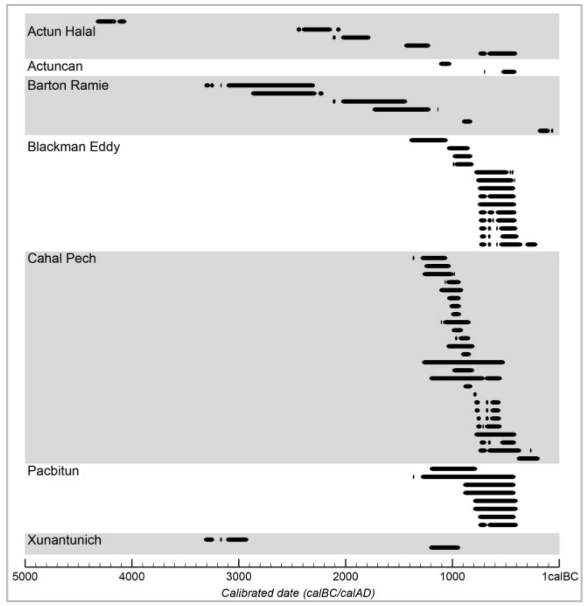

Figure 6. Calibrated 14C dates (2σ ranges) for early Belize Valley sites. From top to bottom: Actun Halal (Lohse 2010), Actuncan (LeCount et al. 2017) Barton Ramie (Hammond 1976, Hoggarth et al. n.d.; Willey et al. 1965), Blackman Eddy (Garber et al. 2002, Brown and Garber 2005) Cahal Pech (Awe 1992, Ebert et al. 2017; Sullivan and Awe 2013), Pacbitun (Healy 1990), and Xunantunich (Brown et al. 2012).

subsistence and settlement change. A multi-century dry period, characterized by smaller punctuated droughts of varying lengths and intensities, is documented in Macal Chasm speleothem between 1100-900 BC, as well as in the Puerto Arturo and Tuspan lake core records in the Petén (Figure 7; Akers et al. 2016; Hodell et al. 1995; Medina-Elizalde et al. 2016; Wahl et al. 2014). Compared to northern lowland records, it appears that there is stronger evidence for drought in the central Maya lowlands of the Petén and Belize during the Early Preclassic (Douglas et al. 2016b).

How did climate impact the development of the earliest farming communities in the Belize Valley? Current settlement data suggest that population levels in the Belize Valley were likely very low at this time, offering little competition in the resource-rich alluvial valley and surrounding zones, so that climate change may not have been an important factor in settlement (Ebert et al. 2017). Alternatively, initial settlement within small communities may represent a type of risk management aimed at pooling resources to combat impacts of dry

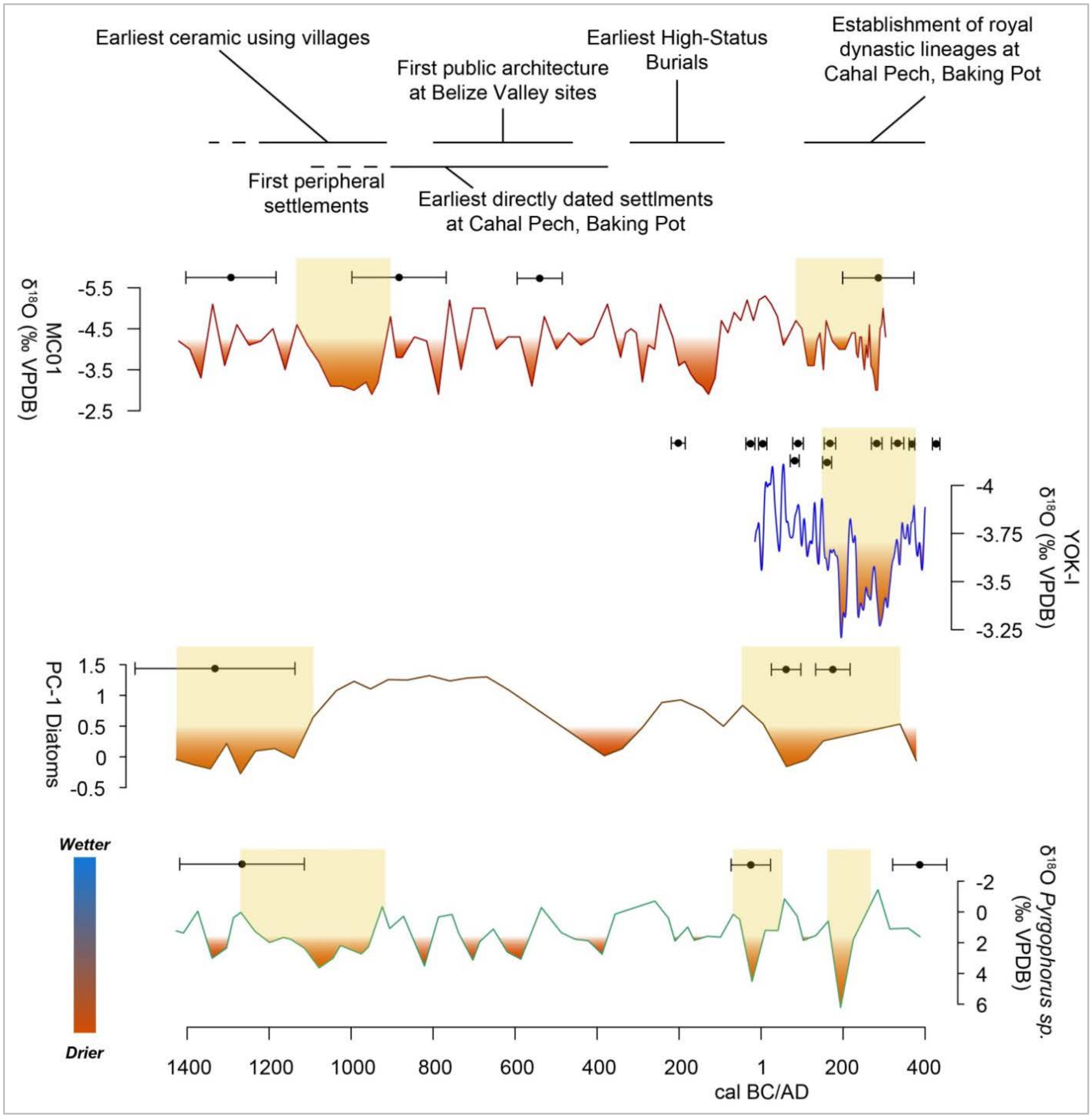

Figure 7. Preclassic period timeline with paleoclimate records for Belize and the Petén, including the Macal Chasm (MC01) δ18O speleothem record (Akers et al. 2016), the Lake Tuspan diatom record (Nooren et al. 2018), and the Lago Puerto Arturo δ18O gastropod record (Wahl et al. 2014). Major droughts discussed in text are highlighted in yellow. Directly dated historical events (2σ calibrated radiocarbon ranges) are indicated at top (dates after Ebert 2017; Ebert et al. 2017; Hoggarth et al. 2014).

conditions on agricultural food production (Morgan et al. 2017). While additional data is needed to address this hypothesis, we would expect Archaic and Preclassic contexts to be separate, discrete components, since climate likely played a role in the adoption of agriculture later in time likely shifted settlement patterns to focus on access arable lands.

Climate conditions became more humid beginning in the Middle Preclassic (900-300 BC). This period represents one of the wettest and least impacted by drought in ancient Maya history (Douglas et al. 2016b). Nooren and colleagues (2018) suggest that wetter conditions recorded in the Lake Tuspan record, among others, would not have been favorable to the expansion of agricultural production, and thus influenced a "delayed development" of lowland Maya societies until the Classic period. High frequencies of climatic volatility (i.e., relatively rapid fluctuations between wet and dry conditions; Kennett and Marwan 2015) are documented in the southern lowlands paleoclimate records from ~900 BC to 500 BC. Alternating wet and dry conditions may have provided a challenging context for early farming communities, with drought posing serious risks in particular to agricultural production that formed the foundation of Maya communities.

However, the construction of the first monumental buildings and expansion of populations in many parts of the Maya lowlands first starts at the beginning of the Middle Preclassic, when Belize Valley sites (Awe 1992; Brown et al. 2013; Ebert et al. 2017) and those elsewhere in the lowlands experienced a fluorescence (e.g., Pasion at Ceibal, Inomata et al. 2017; Petén, Doyle 2017, Hansen 1998). At Cahal Pech, for example, increased frequencies of radiocarbon dated construction phases in the monumental epicenter indicate that the site's inhabitants began to construct increasingly larger public architecture after AD 700-500, which would have required a labor force beyond the level of the household, despite possibly unfavorable climatic conditions impacting agricultural production (Awe 1992; Ebert et al. 2017). During this time several large round platforms, temples, and an E-Group architectural assemblage were constructed at the site (Awe 1992; Peniche May 2016; Ebert 2018). The earliest components of peripheral settlements at Cahal Pech also date to the Middle Preclassic, suggesting relatively substantial population growth supported by agricultural production (Ebert et al. 2016a, 2017). Similar developments occurred across the Belize Valley in the Middle Preclassic, when the inhabitants of Blackman Eddy (Garber et al. 2004), Pacbitun (Powis et al. 2017), and Xunantunich (Brown et al. 2013) also constructed plastered platforms, pyramidal temples, and E-Group assemblages that may have been used for public functions. Based on these data we suggest, contrary to Nooren and colleagues (2018), that wet phases of the Middle Preclassic likely allowed Maya farmers to increasingly exploit productive soils for more intensive maize agriculture (Dunning et al. 1998, 2002; Luzzadder-Beach et al. 2012), providing a context for the growth of many polities.

The climate of the Late Preclassic is characterized by a drying trend beginning around AD 1, culminating in an extended period of drought at the end of the Late Preclassic from approximately AD 100-300. The Macal Chasm speleothem record shows the driest period at the end of the Late Preclassic occurring between AD 250-300 (Akers et al. 2016), while the Yok Balum record shows two major droughts, the second of which was the most extreme and lasted over a century from AD 200-300 (Kennett et al. 2012). Though lake core records from the Petén have lower temporal resolution for this period, similar dry conditions are documented at both Lago Puerto Arturo (Wahl et al. 2014) and Lake Tuspan (Nooren et al. 2018). During this major dry event at end of the Preclassic, which impacted both the southern and northern lowlands, precipitation was reduced by up to 65-75% in some sub-regions of the Maya area (e.g., the northern lowlands, Medina-Elizalde et al. 2016).

Late Preclassic drought conditions have been linked to population decline and abandonment of some major Maya centers in the Petén (e.g., Nakbe and El Mirador), as well as a hiatus in construction activity in some parts of the southern lowlands (see Dunning et al. 2014; Ebert et al. 2017). Large-scale abandonment during the end of the Late Preclassic, however, was not universal (Aimers and Iannone 2014). Evidence of formally organized civic centers and continued construction monumental appears in Late Preclassic contexts at sites throughout the Belize Valley. At Cahal Pech, the construction of elaborate tombs and offerings within monumental temple architecture appeared at Cahal Pech, signaling the development of a royal lineage at the site (Awe and Zender 2016; Novotny et al. 2018). Baking Pot also experienced growth during this period when elite plaza and courtyards were expended and large temples were constructed around 100 BC-AD 250 (Audet 2006; Hoggarth et al. 2014). Excavations at Barton Ramie and the residential settlement around the Lower Dover civic-ceremonial core have similarly revealed evidence for Late Preclassic growth (Petrozza 2015; Walden et al. 2017). Their location in the productive environments of the Belize Valley likely made them more resistant to drought, allowing for the persistence of polities and their constituent populations into the Classic period.

Early Classic to Late Classic (AD 300-750)

Paleoclimate records for the Maya lowlands generally have higher temporal resolution for the Classic period, which has been the main focus for paleoclimate research in this region of the world. During the Early Classic (AD 300-600), higher-resolution speleothem records from Belize indicate a shift to generally more humid conditions (Figure 8). The Yok Balum speleothem shows highly anomalous rainfall between AD 425 and AD 500 (Kennett et al. 2012), coincident with the establishment of some of the largest polities in the Maya region (e.g., Tikal, Calakmul, Caracol, and Naranjo). The more localized Macal Chasm record shows more climatic variability throughout the Early Classic, though generally wetter conditions prevailed in western Belize compared to the Late Preclassic. Settlement data from across the Belize Valley suggest a substantial increase in population beginning in the Early Classic period (e.g., Barton Ramie, Willey et al. 1965; see also Awe and Helmke 2005; Hoggarth et al. n.d). Construction activity also is evident at several sites including Cahal Pech (Awe and Helmke 2005), Buenavista (Ball and Taschek 2004), and Pacbitun (Healey et al. 2004). At Cahal Pech, several structures within Plaza A were remodeled, large public plazas grew substantially through the construction of new buildings, and the first phase of the eastern ball court was erected (Awe 1992; Awe and Helmke 2005: Table 1). Some of the most elaborate royal burials from the site date to the Early Classic period based on ceramic associations (Awe 2013). Settlement research and AMS ^{14}C dating document the establishment of several new residential groups during the Early Classic around the Cahal Pech site core (Ebert et al. 2016a, 2017). Other large centers were first established in the Belize Valley at the end of the Early Classic. Radiocarbon dating of human remains from one of the largest temple structures at the site of Lower Dover indicate that the building was constructed in a single event sometime between cal AD 470-640 (Guerra and Awe 2017). Excavations from the site document similar trends for large scale construction, while earlier Preclassic components are largely absent in the monumental epicenter. Because the expansion of these Belize Valley sites is coincident with much higher precipitation recorded in both the Macal Chasm and Yok Balum speleothem data, this likely indicates that increased average rainfall amounts favored stable environmental conditions and fostered agricultural production, population expansion, and aggregation at large Belize Valley sites.

Decreasing precipitation appears in the Macal Chasm and Yok Balum records during the Late Classic (AD 600-750). In the Macal record, droughts become more prolonged and severe beginning around AD 700. The Yok Balum shows a similar drying trend, with decreased precipitation levels occurring as early as AD 650. Despite unfavorable conditions, Belize Valley polities continued to expand. Settlement research programs at sites including Baking Pot, (Hoggarth 2012), Barton Ramie (Willey et al. 1965), Cahal Pech (Ebert et al. 2016b) and Xunantunich (Yaeger 2008) suggest that most Belize Valley centers reached their demographic peak in the Late Classic, and did not begin got decline until after AD 800 (Hoggarth et al. n.d.). Mortuary activity also increases throughout the Late Classic (Hoggarth et al. n.d.), showing no apparent correlations with drying conditions.

Terminal Classic (AD 750-900/1000)

Climatic instability during the 8th century culminated in some of the most severe droughts in lowland Maya paleoclimate records. A recent synthesis by Douglas and colleagues (2016) indicates that the droughts during this period were extraordinary both in terms of frequency and intensity, compared to the preceding 1,800 years of Maya history (Douglas et al. 2016b: 625). Most lowlands paleoclimate records indicate the presence of at least two distinct dry periods (Douglas et al. 2016b). The Macal Chasm record shows a major drought between AD 750-900, followed by another two droughts from approximately AD 1050-1280. Similarly acute dry intervals are also present in the Yok

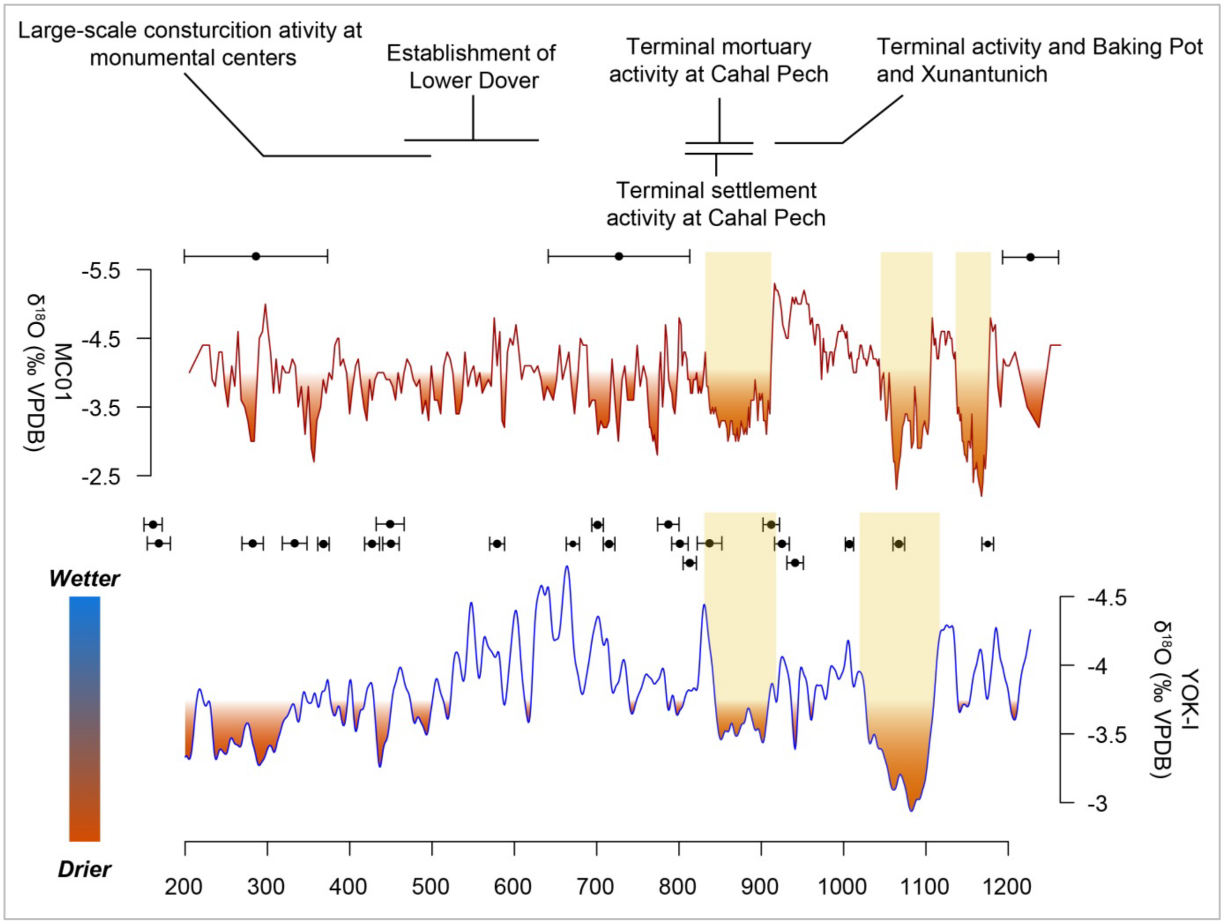

Figure 8. Classic to Early Postclassic timeline with paleoclimate records for Belize, including the Macal Chasm (MC01) δ18O speleothem record (Akers et al. 2016) and the Yok Balum δ18O speleothem record (Kennett et al. 2012). Major droughts discussed in text are highlighted in yellow. Directly dated historical events (2σ calibrated ranges) are indicated at top (dates after Ebert 2017; Ebert et al. 2017; Hoggarth et al. 2014).

Balum record around the same times, suggesting that drought impacted most of the Maya lowlands during the Terminal Classic. A multi-decadal drought in between the Yok Balum record AD 820-870 was part of a broader regional drying trend at the end of the Classic period, which culminated in the most pronounced drought from ~AD 1000-1100. Several studies have found temporal overlap between these droughts and increased warfare, the disintegration of political systems based on divine dynastic rulership, and demographic declines across the Maya lowlands (e.g., Ebert et al. 2014; Hoggarth et al. 2016; Kennett et al. 2012; Medina-Elizalde et al. 2010; Nooren et al. 2018). The impacts of shifting climate regimes also influenced the adaptive capacity of Maya agricultural systems to absorb disturbance in the face of anthropogenic landscape disturbance and population expansion (Beach et al. 2015; Ebert 2017; Kennett and Beach 2013).

In the Belize Valley, the timing of Terminal Classic political and demographic changes appears more variable. Epigraphic evidence from dated stone monuments indicate that the site of Xunantunich (Lecount et al. 2002) and Caracol (Chase and Chase 2004; Martin and Grube 2008) experienced a brief surge in elite activity between AD 820 and AD 860. On the other hand, some large polities like Cahal Pech (Awe 1992, 2006) and Buenavista (Ball and Taschek 2004) may have been abandoned as early as AD 850 (Awe and Helmke 2007). Only one high-status burial has been associated with Terminal Classic contexts at Cahal Pech (Burial H1 in Plaza H; Awe

2013), indicating a decline in elite mortuary activity in the site core at the end of the Late Classic Period. Settlement excavations also show variable timing in the cessation of construction and mortuary activities at households. Radiocarbon dating from Cahal Pech indicates that some of the largest elite households may have also been abandoned as early as AD 850. Recent ^{14}C dating of burials from Baking Pot document a hiatus in mortuary activity at that site much later, beginning in the Early Postclassic (cal AD 900–1200) with subsequent reoccupation in the Late Postclassic (cal AD 1280–1420; Hoggarth et al. 2014). If drought played a role in the abandonment of centers and demographic decline during the Terminal Classic, why is the timing of these events asynchronous between Belize Valley centers? Climatic stress during the latter half of the eighth century, followed by severe multi-decadal droughts throughout most of the ninth century, contributed to existing political and economic stress. Understanding changing social, political, and population dynamics at the site level within the broader climatic context, however, is essential to discerning the specific events of the Classic Maya collapse in the Belize Valley.

Conclusions

Archaeological and paleoclimate studies document variability in human responses to climate change as an important driver of the episodic rise and decline of Maya society from the Preclassic through Terminal Classic periods (e.g., Akers et al. 2016; Curtis et al. 1996; Hodell et al. 1995, 2005; Kennett et al. 2012; Medina-Elizalde et al. 2010, 2016). These studies suggest that severe and protracted droughts impacted the entire Maya region, and posed serious risks to agricultural production, and resulted in the disintegration of polities during the Terminal Classic period. While most of these studies have been large-scale in nature, examining trends across the entire Maya lowlands, more localized, sub-regional studies can help archaeologists and paleoclimate scientists develop and test hypotheses about the relationships between socio-political and population dynamics with climate change.

In this paper we compared general climatic trends documented in lake sediment core and speleothem paleoclimate proxy records from the southern Maya lowlands with cultural developments in the Belize River Valley. While current data suggests that wetter conditions likely promoted the growth of communities during the Preclassic and the Classic periods, drier conditions appear to have influenced development and disintegration of Maya communities differently. Three important questions arise from our comparisons, and warrant future research by Belize Valley archaeologists. First, how did climate impact the development of earliest farming communities in the Belize Valley? Based on the earliest direct dates from farming communities in the region, initial settlement coincides with drought conditions. Additional identification and chronological assessment of these earliest settlement context can help clarify these developments. The second questions is why were the impacts of the Terminal Classic drought more dramatic compared to Late Preclassic climate change? What allowed some earlier Maya communities to be more resilient in the face of climate change? Related to this is the final question is if drought played a role in the abandonment of centers and demographic decline during the Terminal Classic, why is there temporal and spatial variability of these events within the Belize Valley sub-region? Archaeological and epigraphic analyses have indicated that societal collapse began much earlier in some sub-regions of the lowlands compared others. However, drought conditions would be expected to impact sites within a smaller region like Belize Valley relatively equally. Current radiocarbon and ceramic data suggest the socio-political disintegration occurred earlier at Cahal Pech (~AD 850), compared to other centers like Baking Pot or Xunantunich. These data indicate that while drought was one possible (and likely) mechanism stimulating cultural change in the Belize Valley, other factors also influenced these developments. While there is now a relatively large body of paleoclimate proxy data that can help clarify climate conditions in the Belize Valley, there is a need for higher resolution archaeological datasets comparable to climatic datasets. Revised, site specific archaeological chronologies can help interpret smaller scale developments that made communities both sensitive to drought and increasingly unstable during the Terminal Classic period, in addition to preceding eras. Closer collaboration between archaeologists and paleoclimate scientists will help clarify the relationships between climate variability and the rise of fall of Maya communities in the Belize River Valley and beyond.

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