Does Climate make History?

Climate and the Decay of the Maya Culture

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The relative stability of Holocene climate, at least when compared to the rapid, large-amplitude climate excursions of the last ice age, has contributed to a view that the road to modern human civilization has been little affected by climate road-bumps. However, significant variations in regional Holocene climate have now been recognized, with some having had clear societal impacts. Here we summarize recently reported new data from what has become a well-known paleoclimate archive, the annually-laminated sediment record of the anoxic Cariaco Basin off northern Venezuela. Using a new method for the measurement of bulk sediment chemistry, we have shown the ability to develop a record of varying river-derived inputs to Cariaco Basin having roughly bimonthly resolution (50 µm sample spacing) for the period AD 700 to 950 (Haug et al., 2003). Over this time interval one of the most dramatic events in human history occurred in Mesoamerica, the Terminal Collapse of the Classic Maya civilization in the lowlands of the Yucatan Peninsula (Figure 1). Our new record of riverine input to Ocean Drilling Program (ODP) Site 1002 shows in unprecedented detail evidence for a link between regional drought and the demise of Maya culture.

Paired light-dark laminations preserved in the anoxic, non-bioturbated sediments of Cariaco Basin are the direct result of large regional changes in rainfall and trade wind strength driven by seasonal shifts in the position of the Intertropical Convergence Zone (ITCZ; Figure 1) and its associated convection (Peterson et al., 2000; Haug et al., 2001). Light-colored laminae consist mostly of biogenic components deposit-

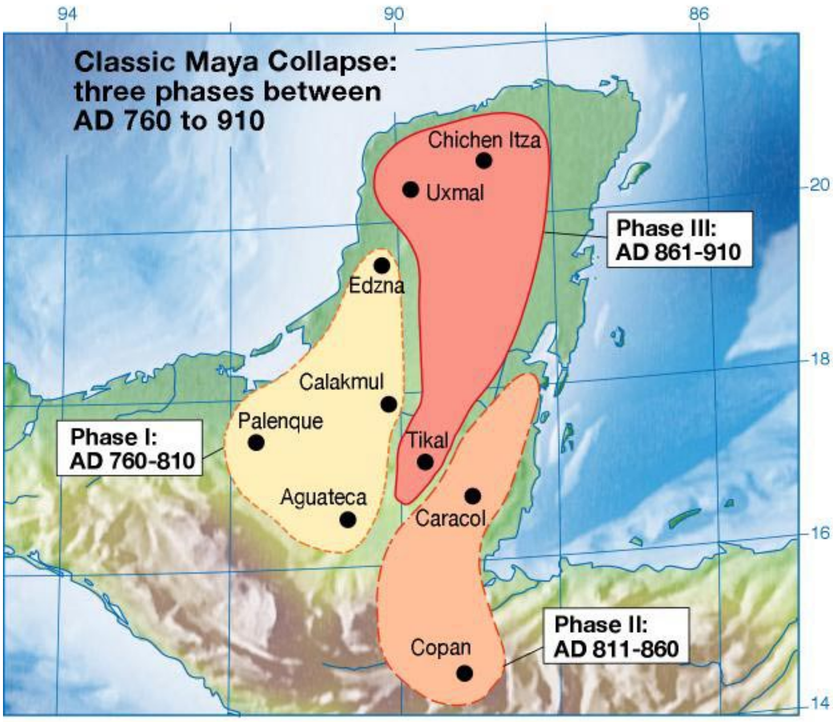

***Fig. 1:** Archaeological information compiled by Gill (2000) suggests three distinct phases for the ‘Terminal Classic Collapse’ of Mayan civilization between ~AD 760 and 910. Phase I led to initial abandonment of the western lowlands, where groundwater is scarce and rainfall was the primary source of water for Mayan cities. Phase II was characterized by abandonment of the southeastern lowlands, a region where freshwater lagoons provided at least some surface water supply. Finally, Phase III of the Terminal Collapse led to large-scale abandonment of remaining cities in the central lowlands and in the north. (Figure modified from Gill, 2000).*

ed during the dry winter-spring upwelling season, when the ITCZ is located at its southernmost position and trade winds along the Venezuelan coast are strong. In contrast, dark laminae are deposited during the regional rainy season (summer-fall) when the ITCZ migrates to its most northerly position, nearly overhead Cariaco Basin. Individual dark laminae are rich in terrigenous grains and contain higher quantities of titanium (Ti) and other lithophilic elements. Our interpretation of bulk Ti content as an index of regional hydrologic change, reflecting variations of the mean ITCZ position with time, is supported by comparison of the Holocene Cariaco record with independent paleoclimatic data from the region.

It has been suggested that recurrent patterns of drought played an important role in the complex history of the Maya (Hodell et al., 2001; Gill, 2000). Maya civilization developed in a seasonal desert and was highly dependent on a consistent cycle of rainfall to support agricultural production. Most of the rain available to the Maya falls during the summer, when the ITCZ sits at its northernmost position over the Yucatan. During the winter, the ITCZ is located south of the lowlands and the climate is dry. Hence, the center of Maya civilization was located in the same climatic regime as Cariaco Basin, with both areas near the northern limit of seasonal ITCZ motion.

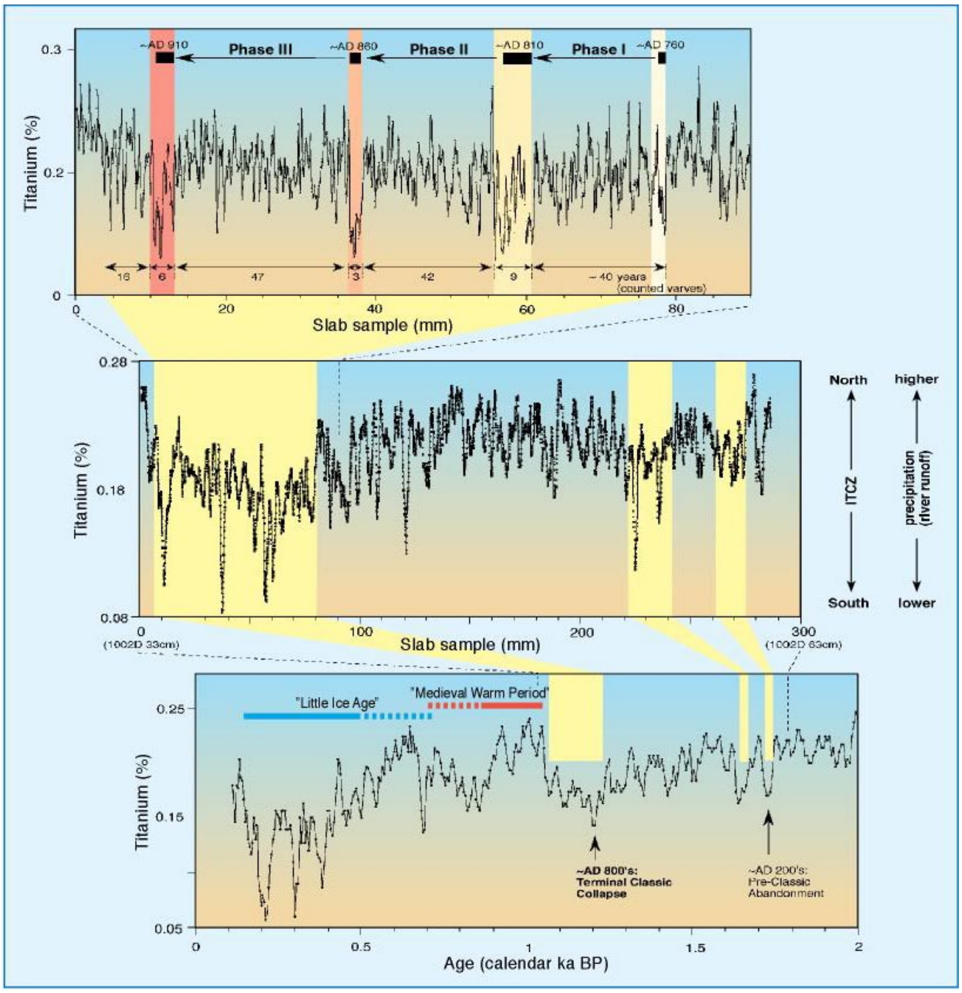

Fig. 2: *Bottom panel: Bulk Ti content (3-point running mean of 2mm resolution measurements; Haug et al., 2001) of sediments from ODP Hole 1002C in the Cariaco Basin during the last 2000 years. The timing of well-known climate events (e.g., Little Ice Age) and major events in Mayan civilization history are shown. The 'Pre-Classic abandonment' and the 'Terminal Classic Collapse' of Mayan culture coincided with phases of low riverine-derived Ti input to Cariaco Basin and inferred dry conditions in the region.*

Middle panel: Bulk Ti content (30-point running mean of 50µm resolution analyses) of a 30-cm long slab sample from companion ODP Hole 1002D in the time interval ~1.8 to 1.0 ka confirm these trends and show increased detail.

Top panel: Bulk Ti content (3-point running mean of 50µm resolution analyses) centered on the time interval of the 'Terminal Classic Collapse' of Mayan civilization (~AD 760 to 910). Within the limits of chronological uncertainties, the three phases of Maya Collapse identified by Gill (2000) at ~AD 810, 860 and 910 coincide with distinct intervals of low Ti input and inferred regional drought.

In order to inhabit the Yucatan lowlands and to deal with normal seasonal variations in rainfall, the Maya developed elaborate strategies to accumulate and store water. Cities were designed to catch the water from rainfall, and quarries were converted into water reservoirs. The Maya also built on topographic highs to use the hydraulic gradient to distribute the water from canals into complex irrigation systems. Nevertheless, the human-engineered system, despite its sophistication, ultimately depended on seasonal rainfall as natural groundwater resources are restricted over much of the lowlands.

During the Pre-Classic period prior to about AD 150, Maya culture flourished and the first major cities were built. Between ~AD 150 and 250, the first documented historical crisis hit the lowlands, which led to the 'Pre-Classic abandonment' of major cities (Figure 2). However, populations recovered, cities were reoccupied, and Maya culture blossomed in the following centuries during the so-called 'Classic' period. At the peak of the 'Classic', around AD 750, best estimates for the population of the Maya lowlands range from 3 to 13 million inhabitants.

Between about AD 750 and 950, the Maya experienced a demographic disaster as profound as any in human history. During the ‘Terminal Classic Collapse’, many of the densely populated urban centers were permanently abandoned, and Classic Maya civilization came to an end. What happened? While the Cariaco Basin record cannot provide a complete explanation, it supports the view that changes in rainfall patterns played a critical role.

Using a Micro-XRF technique not previously applied to sediments, we measured the Ti content (at 50µm spacing) of a slab sample from ODP Hole 1002D taken from the stratigraphic interval known to encompass the period of the Terminal Collapse. Further methodological and chronological details can be found in Haug et al. (2003). Within the Hole 1002D slab sample, we observed distinct Ti minima at depths of ~12-mm, 38-mm, 58-mm and 78-mm (Figure 2) which we have interpreted as marking multi-year drought events that began about AD 910, AD 860, AD 810 and AD 760, respectively. These are superimposed on an interval of generally lower Ti content. Not counting the duration of the more severe multi-year droughts, the number of varves between drought events indicates a spacing of approximately 40 to 47 years (± 5), a number that agrees remarkably well with the observation of subpeaks in the well-known Lake Chichancanab sediment density record at about 50 year intervals (Hodell et al., 2001).

Mayanists generally agree that there is strong evidence for regional variability in the Terminal Classic collapse in the archaeological record. Most would also concur that the collapse occurred first in the southern and central Yucatan lowlands, and that many areas of the northern lowlands underwent similar decline a century or so later. A more controversial tripartite pattern of city abandonment (Figure 1) has been proposed by Richardson Gill (2000) based on analysis of the last dates carved into local monuments (stelae). On this basis, Gill has argued for three separate phases of collapse that terminated respectively at ~AD 810, 860, and 910. He further speculated that periods of drought were what triggered the Maya demise. Within the uncertainty of our age model, the proposed end dates for each phase of abandonment match the three most severe drought events inferred from the Cariaco Basin record.

Considerable variability exists in the distribution and quality of natural water sources in the Yucatan lowlands, a factor that would surely come into play during periods of drought. While the northern lowlands are characterized by the lowest amounts of annual average rainfall, collapsed cenotes in this region provide the most direct access to groundwater in the Yucatan. In the central lowlands, some freshwater is available in and around the Petén Lake district. Towards the west and south, access to groundwater is scarce and rainfall was almost certainly the primary source of water for Maya cities. During sustained drought, access to groundwater was likely an important factor in determining which large population centers could survive.

No one archaeological model is likely to capture completely a phenomenon as complex as the Maya decline. Nevertheless, the Cariaco Basin sediment record provides support for the hypothesis that regional drought played an important role in the collapse of Classic Maya civilization, and provides a temporal template against which archaeological data can be compared. Drought conditions may also have been responsible for the earlier Pre-Classic abandonment of Maya cities that occurred between ~AD 150 and 250, intervals similarly marked by low sediment Ti contents. These periods of drought are all likely the result of climatic conditions that prevented the ITCZ and its associated rainfall from penetrating as far north as normal. A southward displacement of the ITCZ, as indicated by low Ti in Cariaco sediments, would be expected to lead to similar rainfall reductions in the Maya lowlands.

We suggest that the rapid expansion of Maya civilization from AD 550 to 750 during climatically favorable (i.e., relatively wet) times resulted in a population operating at the limits of the environment’s carrying capacity, leaving Maya society especially vulnerable to multi-year droughts. Given the perspective of our long sediment time-series, it would appear that the droughts we have highlighted were the most severe to affect this region in the first millennium AD. The intervals of peak drought were brief, each lasting between ~3 and 9 years. However, they occurred during an extended period of reduced overall precipitation that may have already pushed the Maya system to the verge of collapse.

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