bsReport on speleothem work for Xcoch Archaeology Project

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Introduction

This speleothem study has attempted to provide a detailed climate reconstruction for the Xcoch and Puuc Region of the Yucatan, Mexico. The period of interest was the Terminal Classic Period, 800-950 C.E. or 1200-1050 year BP (before present). The BP chronological terminology will be used hereafter. In 2010 speleothems were initially collected from Xcoch Cave below the archaeological site. Upon closer examination, these formations were found to be portions of stalagmites and other secondary calcite deposits which could not be used for paleoclimate reconstruction. After corresponding with Dr Michael Smyth, new speleothems were collected from a nearby cave, Vaca Perdida Cueva (VP). These three stalagmites were of varying size and the two of complete speleothems were selected for the paleoclimate study. The samples were then analyzed for their periods of deposition and stable isotope composition. It was hoped that this analysis could shed light of how the climate varied in this region and whether any abrupt climate shifts may have been partially responsible added pressure to the Maya people of this region.

Study Area

Figure 1 shows the location of the Xcoch study area in the Yucatan Peninsula, Mexico. The other locations shown are those that are also archaeological sites or where paleoclimate studies have already been conducted. Of particular interest are Tecoh Cave and Lake Chichanacanab which will both serve as records that will help create a chronology for our speleothem record and its interpretation.

Methods

Sample Selection

The two stalagmites, VP-10-1 and VP-10-2 were collected from Vaca Perdida Cave which is ~11.04 km east of Xcoch Cave. The cave is entered through an 8 m shaft which ends in a large chamber where many of the speleothems had been removed or damaged by the Maya. These two formations appeared to be active in that water was dripping of their terminuses. VP-10-1 is ~450 mm in length and was located 60 m from the entrance and appeared to have recent deposition as evidenced by the presence of a white calcite cap and water droplets. VP-10-2 is a boss stalagmite ~ 150 mm long and was collected 23 m from the entrance. In the laboratory each speleothem was cut along its c-axis, and then polished. Fourteen and seven 300 mg samples of calcite were removed along each growth axis of VP-10-1 and VP-10-2 respectively, using a computer-controlled micro-drill equipped with a dental burr. These samples were then analyzed for their ages using U-series dating (see below section). The same micro-drill was then used to remove 200 μg samples at 5 mm intervals along the growth axis for each speleothem. These were needed for stable isotope analysis.

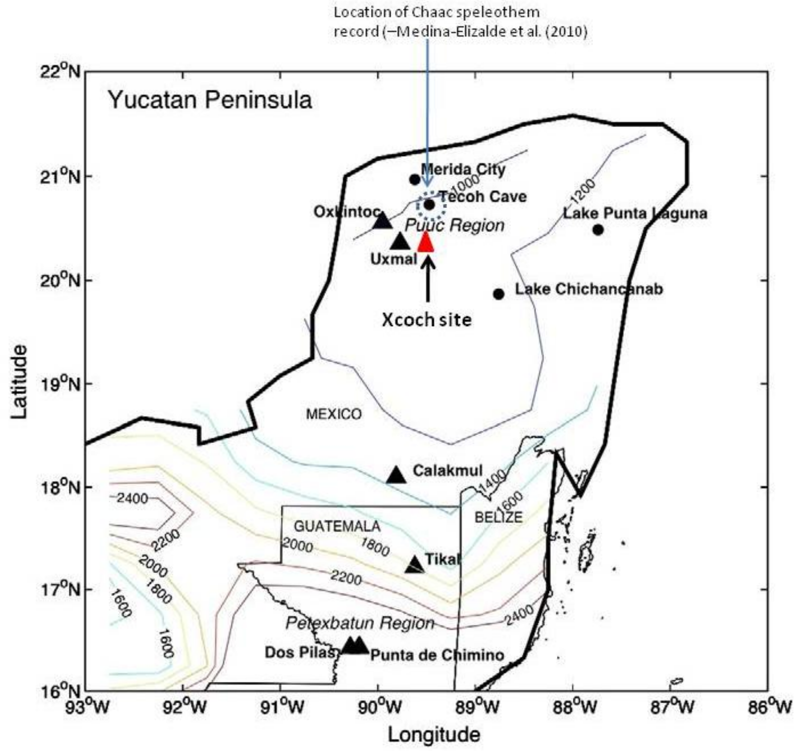


Fig. 1. Location of Xcoch and other sites used in paleoclimate comparison

Dating Techniques

Uranium series dating techniques, specifically ^{234}U-^{230}Th, were used in order to determine accurate dates for each speleothem and completed at the Radiogenic Isotope Laboratory at the University of New Mexico. 50-150 mg of carbonate powder for the samples were dissolved in nitric acid and spiked with a solution of ^{233}U and ^{229}Th of known concentration. These were then dried, redissolved in nitric acid and perchloric acid. The samples were again dried, dissolved in nitric acid, and added to anion resin columns to separate the thorium and uranium. Once separated, the thorium and uranium from each sample was run through the ICP-MS. Due to the low counts of ^{234}U and ^{230}Th, the more sensitive SEM is used to measure the amounts of these isotopes.

Stable Isotope Measurements

Once the calcite samples were collected from the speleothems, they were weighed to ~200 µg for stable oxygen isotopic analyses. The calcite was then placed in individual reaction vessels, subjected to anhydrous phosphoric acid in the Keil III carbonate-extraction system coupled to a ThermoFinnigan DeltaPlus XL mass spectrometer. The standard used with conjunction with the cave calcite was the NBS-19 standard which allowed a precision of <0.1‰.

Results

U-series dates

The ICP-MS ages for each speleothem are given in Table 1. Despite the best efforts of Anna Leech (my research assistant) and Dr. Victor Polyak (UNM), accurate ages for the speleothems could not be obtained. However, the top and base dates for VP-10-1 appeared to be usable due to the low detrital Th and the fact that they were chronological order with one another. The top date for this speleothem also agreed with the top date of VP-10-2, hence this was used for the date that the speleothems ceased growing. With the poor chronological control, a comparison to another, well dated, nearby speleothem record (Tecoh Cave, Medina-Elizalde et al. 2010) was used to check our age model. The construction of the age model for VP-10-1 was simply based on the linear interpolation between the top and base dates. This age model was then used to create a time series for the VP-10-1 stable isotopes values (see Fig. 2).

Table 1. ICPMS ages for VP-10-1 and VP-10-2.

Speleothem	Distance from Top (mm)	Age (yr BP)
VP-10-1	3	589± 224
	30	278± 273
	57	-2± 364
	91	2791± 1746
	121	-6363± 5293
	140	1703± 221
	173	2346± 327
	182	975± 232
	217	801± 262
	257	816± 218
	339	551±476
	425	449±346
	435	811±144
	450	2026± 387
VP-10-2	27	580± 88
	43	-19607± 9306
	58	1616± 1242
	89	-14644± 9715
	106	319± 156
	127	298± 99
	153	1677± 215

Oxygen isotope record for VP-10-1

Figure 2 show the time series for the oxygen isotopes for VP-10-1. The $\delta^{18}O$ values for speleothems in the tropics and this region have been found to record changes in precipitation. The cause of this variability in the $\delta^{18}O$ is due to the amount effect (Lachniet et al. 2004). Consequently, more (less) depleted values in the speleothem are indicative of wetter (drier) conditions. As found in the speleothem c-axis profile, there were numerous hiatuses in the top third of growth. The more prominent of these are marked on Figure 2. H^2 and H^3 are two very pronounced events where two and three hiatuses occurred in rapid succession. Cessation in deposition is normally induced by drought conditions.

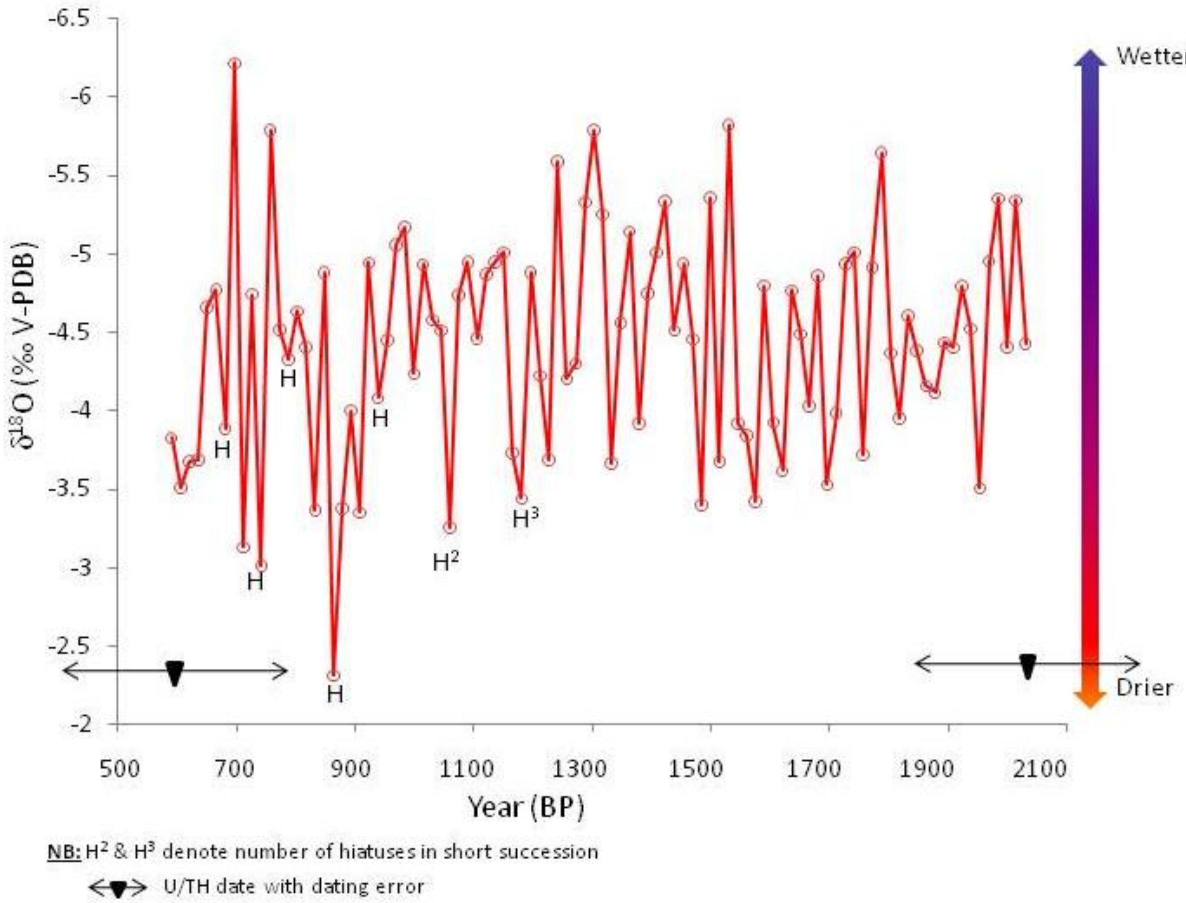
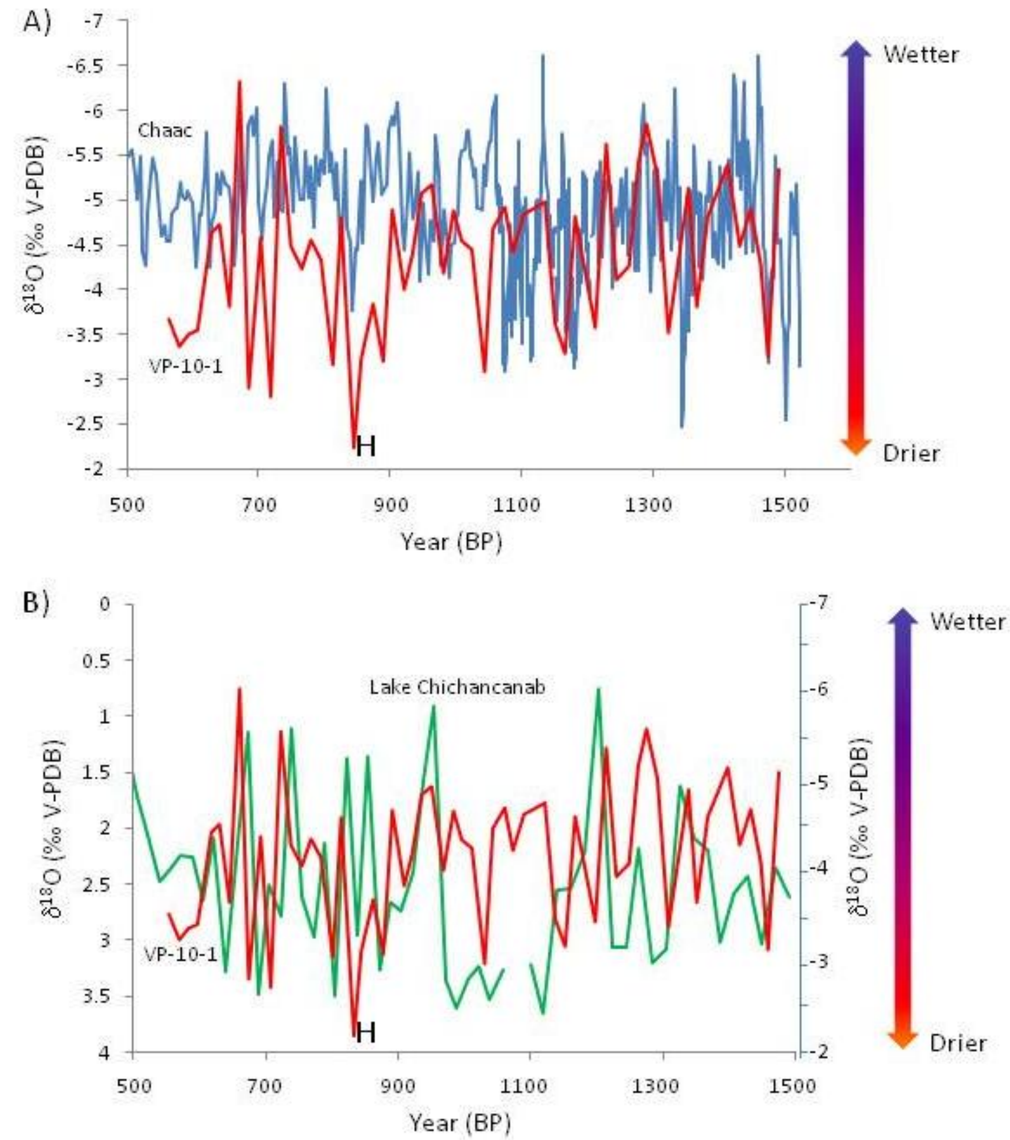


Fig. 2. Speleothem VP-10-1 $\delta^{18}O$ (‰) record

Comparison with other Yucatan paleoclimate records

To check the accuracy of the VP-10-1 chronology and our reconstruction of precipitation variability, two different proxies were used. The first is a speleothem from Tecoh Cave (Chaac $\delta^{18}O$ record, Fig. 3a) which is north of our field site (Fig.1). Once again, more depleted $\delta^{18}O$ isotope values are wetter conditions. Both speleothems are plotted on the same y-axis and possess not only very similar $\delta^{18}O$ values but also similar amplitudes. Consequently, our linear interpolation for VP-10-1 appears to be quite accurate when compared to the well dated Chaac chronology. Any differences in the timing of abrupt changes in the $\delta^{18}O$ values can be attributed to both the frequent hiatuses in our speleothem, and different growth rates and data resolutions between each sample. The Lake Chichanacanab $\delta^{18}O$ record (Hodell et al. 2001) further solidifies both the accuracy of our chronology and our precipitation reconstruction (Fig. 3b).



Data: Chaac $\delta^{18}O$ - Medina-Elizalde et al. (2010); Lake Chichancanab Pyrgophorus sp $\delta^{18}O$ (‰) - Hodell et al. (2001)

Fig . 3. a) Yucatan speleothem oxygen Isotope records from ... (VP-10-1) and Tecoh (Tzabnah) Cave (Chaac); b) VP-10-1 and the Lake Chichancanab (Yucatan) Pyrgophorus sp $\delta^{18}O$ (‰) records.

Terminal Classic Period (TCP)

The TCP has drawn much scientific attention from paleoclimatologists over the last several decades since it was suggested that major droughts may have contributed to the *Maya collapse* during this interval. Medina-Elizalde et al. (2010), while no means the first study to investigate this question, is however the most detailed and quatitative of any work yet. They demonstrated the possible impact of decreasing precipitation on the Maya in their region of the

Yucatan. They suggest precipitation may have been 300 mm below the long term average for their region (Fig. 4).

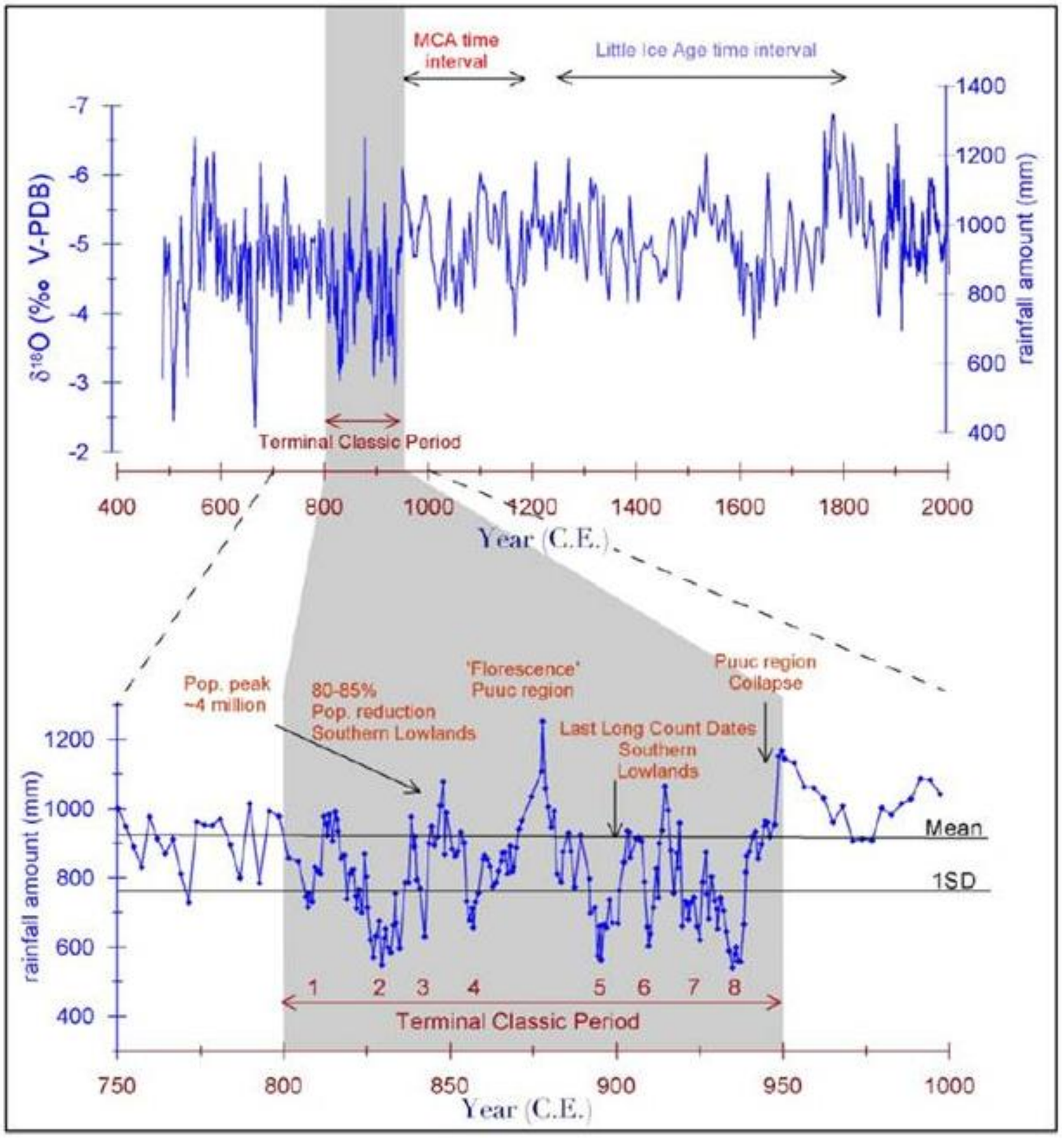


Fig. 4. Medina-Elizalde et al. (2010) depiction of precipitation during the Terminal Classic Period

A subsection of the Chaac speleothem record is highlighted in Figure 4 showing precipitation changes for the Tecoh Cave region during the TCP. Medina-Elizalde et al. (2010) detailed depiction of the TCP portrays both rapid changes in precipitation and pronounced droughts, which coincide with pivotal demographic changes for the Maya. One overlying objective of this study is to determine whether these abrupt shifts in precipitation shown above were localized or more widespread. Precipitation amounts vary greatly, even across relatively short distances. In addition, even if the same climate shift occurred across the Yucatan, would its magnitude be uniform or vary locally? For example, could a locale in the same geographic area, such as the Yucatan, experience a different magnitude of change in rainfall compared to another?

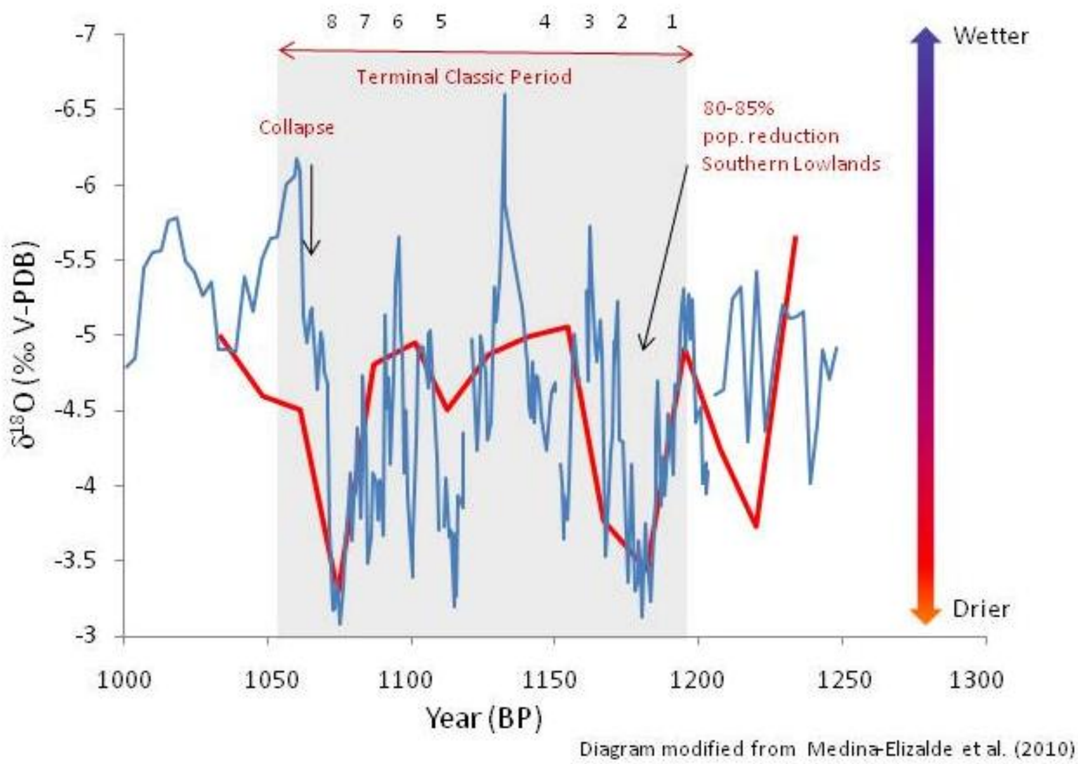


Fig. 5. Chaac and VP-10-1 $\delta^{18}O$ (‰) speleothem records during the Terminal Classic Period

In a preliminary attempt to address these questions, Figure 5 displays the Chaac reconstruction of precipitation compared to that of VP-10-1. It is readily apparent that there is a great difference in the resolution of data between the two records. However, there are still several pertinent observations that can be made from this comparison. First, the major changes in precipitation measured at Tecoh Cave (Chaac), especially the prominent droughts, are also found at Vaca Perdida (VP-10-1). Second, the magnitude of change in rainfall at Vaca Perdida appears to be somewhat subdued when matched with the Chaac record. In a word of caution, this observation may simply be an artifact of the lower resolution of the Vaca Perdida speleothem record.

Summary

The preliminary nature of this pilot study must preclude any firm conclusions about the magnitude and timing of precipitation changes at the Vaca Perdida region of the Yucatan over the last 2000 years. The low resolution of the oxygen isotopic record and the issues with creating a reliable chronology are two major reasons for this tentative approach. However, if the observations outlined in this report have some truth, then an expanded study is warranted. This could entail a higher resolution stable isotope record, possible ^{14}C dating, and even investigating the possibility of annual laminae in the speleothem. This last mode of study can help to create greater precision for the chronology, a technique long undertaken in dendrochronology. There are very clear laminations throughout the speleothem. Consequently, although there are obstacles to overcome, further study may well show subtle, yet potentially important differences in climate change in the Yucatan Peninsula.

References

Hodell, DA, Curtis, HJ, Brenner, M (1995) Possible role of climate in the collapse of Classic Maya civilization. *Nature* 375, 391–394.

Lachniet, MS, Burns, SJ, Poperno, DR, Asmerom, Y, Polyak, VJ, Moy, CM, and Christenson, K. (2004) A 1500-year El-Nino/Southern Oscillation and rainfall history for the Isthmus of Panama from speleothem calcite. *Journal of Geophysical Research* 109: D20117 doi:10.1029/2004JD004694.

Medina-Elizalde, M, Burns, SJ, Lea, DW, Asmerom, Y, von Gunten, L, Polyak, V, Vuille, M, and Karmalkar, A. (2010) High resolution stalagmite climate record from the Yucatán Peninsula spanning theMaya terminal classic period. *Earth and Planetary Science Letters* 298,255–262