INTRODUCTION

Atlantis, Easter Islanders, Minoans, Mound Builders – lost civilizations provide us with great mysteries. We ask: What were these people like? Why did they disappear and to where did they go? Could the same thing happen to us?

The disappearance of the Maya civilization has provided us with similar questions. The Maya as Native Central Americans have been documented archaeologically to at least 14,000 years BC. During those years they lived as small, isolated groups. In about 2,000 years BC they began to build villages located in the Yucatan Peninsula of Mexico, Guatemala, Belize, and the Honduras (Figure 1). Many of the villages and the important cultural centers are in the northern part of the Yucatan Peninsula. This northern area was called the Maya Lowlands because the land was flat and near sea level. The time period from 800 BC to 250 AD was known as the Maya Preclassic Period and building intensified. During the Pre-classic Period there were two times when the cultural centers became relatively empty for about 10 years; these times (280 and 380 AD) were known as the Preclassic Collapses. The time of greatest population growth was from about 400 AD until 950 AD, known as the Maya Classic Period, and many impressive buildings monuments and step pyramids (such as at Tikal, Figure 2) were built during this time period.

![Figure 1(left): Map of the Maya cultural region, showing the Maya Lowland in the north of the Yucatan Peninsula, and areas mentioned in this activity. Source: Google Earth, accessed September 15, 2008.](http://www.cadastoria.com/americas/tikal/450pe-tikal.png)

![Figure 2(right): A step pyramid at Tikal, named Temple 1—the funerary pyramid of Hasaw Chan K’awil. Source: http://www.cadastoria.com/americas/tikal/450pe-tikal.png, accessed September 15, 2008.](http://www.cadastoria.com/americas/tikal/450pe-tikal.png)
Between 750 and 910 AD, something very drastic happened in the Northern Yucatan Peninsula. The population for the Maya Lowlands in 750 AD has been estimated to have ranged from 3 million to 14 million people. By 910 AD, the population had been reduced to 1 million people at most. That means that between 67% and 93% of the population died—a true catastrophe of suffering (Gill, 2000). The Maya Lowlands and its beautiful cultural centers were abandoned and forgotten until witnessed by Fray Antonio de Cuidad Real in 1588 and explored by John Lloyd Stephens and Frederick Catherwood in 1839 to 1842 (Coe, 1999).

What caused this disaster? Although archaeologists can date the cultural center abandonments in the Maya Lowlands, they have had little idea of the cause. Traditional hypotheses to explain this abandonment mostly considered cultural problems including: poor government, poor agricultural practices that exhausted the soil, frequent wars, or a social organization that could not deal with the high population (Gill, 2000). But in 1988 an archaeologist named Richardson Gill proposed another cause: a catastrophic drought had caused famine and death of the Maya to such a degree that they could no longer maintain the large cultural centers (Gill, 2000).

In this activity you will observe how geochemical data—a mud core taken from the ocean bottom near Venezuela—provides evidence for this drought. Another core taken from a fresh water cenote will provide additional independent geochemical data. You will use and improve your skills using a graphing software package such as Microsoft Excel to evaluate this data.

Before reading further and doing the activity, please view parts 1 and 2 of “Ancient Apocalypse - The Maya Collapse” on YouTube:

Part.1 http://www.youtube.com/watch?v=81U5c2sBdKk...feature=related
Part.2 http://www.youtube.com/watch?v=kabfOADnZUc...feature=related

Part 3. http://www.youtube.com/watch?v=QB-N4Cz8N5o

**ODP Core 1002D**

In 1996 the research vessel JOIDES Resolution drilled a mud core from offshore Venezuela in a deep ocean basin called the Cariaco Basin (see Figure 3 for the location). The Cariaco Basin was drilled as part of the Ocean Drilling Program (ODP) Leg 165.

Scientific ocean drilling is used to recover cores—long cylinders of ocean sediment and rock for scientific research. During drilling, the drill pipe is lowered to the seafloor. It is attached to a special drill bit, which cuts through layers of sediments and rocks without breaking them up. Cores of the material beneath the seafloor are collected in an inner core barrel inside the drill pipe by a wire cable that travels down the center of the drill pipe. Once the cores are acquired they are returned to the ship inside the drill pipe. Scientists analyze the cores to reconstruct the climatic, environmental, biologic and geologic history of our planet that is preserved in ocean sediments. They use that information to expand our knowledge of Earth’s crust.

In the twenty first century scientific ocean drilling is carried out by the Integrated Ocean Drilling Program (IODP), an international research program that uses advanced technology to explore the history and structure of the Earth by studying the sediments and rocks beneath the seafloor. IODP began in October 2003 and builds
upon the legacy of two earlier scientific drilling programs, the Deep Sea Drilling Project (1968-1983) and the Ocean Drilling Program (ODP) (1985-2003), which together revolutionized our view of Earth history, climate change, natural hazards, and geobiology.

**YOUR TASK**

Imagine that you are a scientist on ODP Leg 165 and that you are using part of ODP Core 1002D to test the hypothesis that drought may have contributed to the collapse of the Mayan culture. In order to conduct this test, you’ll need to make several assumptions.

Assumption 1: That the climate was the same in the Mayan Lowlands and in Venezuela – meaning that rainfall amounts could be compared between the two areas separated by hundreds of miles.

Assumption 2: That the layers of core sediment could be used as “tree-rings” to measure the climate and date those measurements.

Assumption 3: That the concentration of the element **titanium (Ti)** in sediment layers can indicate the relative amount of rain that fell in a sedimentary layer.

**The Rain’s the Same?**

Can you assume that the rain amounts were the same in two distant areas? Look at the climate today and observe that both the Maya Lowlands and the northern coast of Venezuela (where the sediments in the Cariaco Basin come from) are located a similar distance from the Intertropical Convergence Zone (ITCZ). The ITCZ is a line of convergent weather patterns. Areas that are an equidistant from it will have similar weather patterns. During summer rainy seasons large amounts of sediment are washed from the coast of Venezuela to be deposited in the Cariaco Basin. In the winter there is less rain so less sediment is deposited in the Cariaco Basin.

Visit the following URLs to see animations of the ITCZ migration throughout the year.

(1) [http://daphne.palomar.edu/pdeen/Animations/23_WeatherPat.swf](http://daphne.palomar.edu/pdeen/Animations/23_WeatherPat.swf)
(2) [http://cimss.ssec.wisc.edu/satmet/modules/stewards/global/cmoll.html](http://cimss.ssec.wisc.edu/satmet/modules/stewards/global/cmoll.html)
Figure 4. Location of the Mayan Lowlands and the Cariaco Basin, showing the seasonal location of the ITCZ (From Haug et al., 2003)
**Mud “Tree Rings”**

The core taken from the Cariaco Basin is **laminated**, meaning that there are very fine alternating layers of light and dark sediments. The light sediments are from times when there was little sediment coming from the land (i.e., dry periods), and are mostly composed of organic material (remains of once-living organisms. The dark sediments are from times when there was more sediment washing from the land (i.e., wet periods). Each year of sediment deposition is thus represented by a pair of layers: light for the dry season and dark for the wet season. Geoscientists count the layers from the top (youngest layers) to the bottom (older layers). Geoscientists on ODP Leg 165 who studied Core 1002D took samples from some layers and dated them with radiocarbon isotopes to verify the dates they were using.

**Why Bad is Good**

The Cariaco Basin is an **anoxic** basin, meaning there is little or no oxygen near the seafloor where sediments are being deposited. Such an environment is very bad for living creatures, because almost all organisms need oxygen to survive. But animals are constantly burrowing in the sea bottom and the mud within sea sediments after they are deposited. That mixing of sediments is termed **bioturbation**. In an anoxic basin the sediments are undisturbed and retain their fine layering. That is why the Cariaco Basin was a good place to take a core for this study.
Why Ti?

Titanium (Ti) is a metal that is valuable due to its strength. The primary sources of Ti are the minerals ilmenite (iron titanium oxide, \( \text{TiFeO}_3 \)) and rutile (titanium dioxide, \( \text{TiO}_2 \)), which are both forms of Ti ore. These minerals have several properties that are important for this study. First, they are common minerals in the Earth’s crust. Second, they are “heavy” (detrital) minerals. This means that they do not wash off the land with light rain – they are more concentrated during heavy water runoff (this is why these dark minerals are common in beach sands). Finally, these minerals are very non-reactive, which means they do not change easily and therefore do not weather or break down in sea water but are buried unchanged. They are thus buried as they are. For these reasons, ilmenite and rutile can be used to show the relative amount and energy of the rain that washed them off the continent (Emsley, 2001).

References


MAYA STUDENT WORKSHEET 1 (REVIEW QUESTIONS)

NAME: ________________________ DATE: ________________________

The following questions are to help you review the material contained in the Student Information handout, and parts 1 and 2 of Ancient Apocalypse - The Maya Collapse, in order to help you prepare for the Maya Example Activity.

1. Give the two time periods recognized by archaeologists for the Maya Preclassic Collapses.

2. Define ITCZ.

3. Give one reason that traditional archaeologists have given for the Maya Collapses.

4. Define IODP

5. Why are laminated sediments important to this study?

6. In what year did Richardson Gill publish his book on the theory of the Maya Collapse?

7. Give the formulas for ilmenite and rutile.

8. Where is the Cariaco Basin located?

9. Who is buried in Temple 1 at Tikal? (His name means “Lord Chocolate”!!)

10. Who was the first Spaniard to see the ruins in the Yucatan Lowlands in 1588?
THE MAYA STUDENT WORKSHEET 2 (ACTIVITY PROCEDURES AND QUESTIONS)

NAME:              DATE:

Materials:
Computer with graphing software such as Excel and printer
Pencil
Colored pencils

Procedure:
1) Download/Upload Maya Activity from the server
2) Double click on Excel file Maya Activity
3) Sheet 1 shows several columns labeled A-I. These are:
   A. The original radiocarbon dates of Core 1002D layers in years BP (before present).
   B. The dates in column A have been changed to years BC/AD (BC is a negative number) to
      make them easier for your to understand
   C, D, E. The percent (%) Ti measured – measurements are recorded for every 50 years, 22
      years and 5 years.
   F. The population at the Maya Three Rivers Center.
   G, H, I. Dates and data from Hodell et al., giving percent CaCO$_3$ and percent S from CaSO$_4$.
4) Open Chart 1 from the bottom left tab. This chart already has a graph of the Ti data plotted
   for every 50 years. Notice on the Y axis that a lower Y value represents drier conditions (less Ti)
   and a greater Y value represents wetter conditions (more Ti). Remember that Ti is a proxy for
   rainfall. Therefore, these measurements represent relative rainfall amounts, not actual
   centimeters of rain.
5) Now plot the data for plot of the Ti% for every 22 years, using a different color. If you can add
   this graph to chart 1, do so. If not, create a new chart. Note: you can put the pointer on
   individual points to get the data of each point.

Question 1: In general, what are the differences between the 50-year plot line and the 22-year plot
line? Note five differences between the 22-year and 50-year plot lines – give the dates.
6) If you plotted the **22-year** data on the same chart, delete the 22-year line. Note: if you delete the wrong line, go to Edit and select Undo delete.
7) Go back to the Chart and, if you can, Add Data for the 5-year values, to plot the data for Ti% as the geologists on Leg 165 measured it – approximately every 5 years. If you cannot insert this plot into Chart 1, then create a new chart to show the plot line for the 5-year data. Compare the two plot lines.

**Question 2:** What differences do you see in the data plotted every 50 years versus that plotted every 5 years? What dry periods would you have missed if you only had data for every 50 years?

**Question 3:** Look at the dry period that happened at around 280 AD. How long did that dry period last?

8) If you have two plot lines on the same chart, remove the 50-year plot line (blue) by selecting it and pressing delete. This will leave you with only the plot line representing the data for every 5 years. Or, if you have created separate charts for each, then return to the chart showing the plot line for the data for every 5 years.

9) Put your pointer within the light blue Plot Area (make certain you are in the chart area and not on any lines). Use the Fill Effects button to insert an image into the chart area. Choose History 1 background.tiff within your Maya Activity folder to display this as the new background for the chart.

NOTE: do NOT click insert picture from right click – the picture will not fill the space correctly.

This background now displays the times of the Mayan city abandonment in a darker shade of blue, along with a plot of the estimated population of the Three Rivers area (see Figure 1 for the location of this area). Notice the population variation during the dry periods and city abandonment. Notice also that the population plot is logarithmic, meaning the variation is much larger than it looks.

**Question 4:** After noting the population drop in the Three Rivers area from the 750 AD maximum to 900 AD, what percent of the population was left in 900 AD?

Although some of the population of this area and the entire Maya Lowlands was able to migrate to the south and west, most of this population decrease may have resulted from famine deaths caused by the lengthy drought. This was a major disaster, from which the Maya people never recovered, although there are still Maya in the area today.
10) Select Chart 2. This chart shows some data taken at Lake Chichancanab in the Yucatan Peninsula (Figure 1) by another research team (Hodell et al., 1995). The data was again taken from a laminated core, but this one was from fresh water. In Lake Chichancanab during wet years there was some calcite (CaCO\(_3\)) precipitated at the bottom of the lake in the laminations. During dry years this precipitation shifted to gypsum (CaSO\(_4\)). So years with high sulphur percentage (sulphur is found in gypsum but not calcite) represent dry years at Lake Chichancanab. A print out is provided.

11) Compare the Lake Chichancanab plot to the Ti data that you plotted. Note that the Drier – Wetter label is reversed because as it gets drier, the % sulphur in the cores increases. In the previous charts, the amount of Ti in the cores increased with the amount of rainfall.

**Question 5:** Which droughts are documented by both the Ti data and this new data? Which are not?

**Question 6:** After having looked at this data, do you think that droughts may have had a major influence on the abandonment of the Maya cities?

**Question 7:** In your future reading of news or science articles, what information would you be interested in about the Maya Culture city abandonment?

12) Look at the period from 1500 AD to 1900 AD. In Europe this time period was marked by very cold climate and was known as the Little Ice Age.

**Question 8:** This study was based upon several assumptions. Describe a situation in which one of these assumptions would not be valid.
Question 9: Compare the relative rainfall conditions in Central America during the period from 1500 AD to 1900 AD with those during the Maya Collapse.

13) Look at the map of Texas provided (Source: Texas Water Development Board <http://www.twdb.state.tx.us/mapping/maps/pdf/mtr_34X34.pdf>), which shows the major rivers in Texas.

![Map of Texas](http://www.twdb.state.tx.us/mapping/maps/pdf/mtr_34X34.pdf)

Question 10: If you were looking for evidence of droughts in Texas, where would you drill offshore cores? Describe and/or mark the locations with a colored pencil on the small map (above).
Question 11: Remember that the Cariaco Basin had an unusual property which allowed preservation of the depositional record. What would you need to know about the locations you have selected in light of this requirement?

Optional Activity: Compare the ways a Maya teenager would react to the drought of 750-900 AD with the way a modern teenager would react to a drought in the United States.

Figure 8 (left). A pottery incense burner in the shape of Chac (the long-lipped god) the Mayan god of rain (Coe, 1999)

Figure 9 (right). The Mayan hieroglyph for drought (Gill, 2000)

References


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IF YOU HAVE EXCEL 1997-2003, you may follow the steps given to create your graphs.

Procedure:
1) Download/Upload Maya Activity from the server
2) Double click on Excel file Maya Activity
3) **Sheet 1** shows several columns labeled A-I. These are:
   A. The original radiocarbon dates of Core 1002D layers in years BP (before present).
   B. The dates in column A have been changed to years BC/AD (BC is a negative number) to make them easier for your to understand
   C, D, E. The percent (%) Ti measured – measurements are recorded for every 50 years, 22 years and 5 years.
   G, H, I. Dates and data from Hodell et al., giving CaCO₃ and CaSO₄.
4) Open **Chart 1** from the bottom left tab. This chart already has a graph of the Ti data plotted for every 50 years. Notice on the Y axis that a lower Y value represents drier conditions (less Ti) and a greater Y value represents wetter conditions (more Ti). Remember these represent relative rainfall amounts, not actual centimeters of rain.
5) Go to **Chart** pull down at top of display and click **Add Data**. A dialog box will appear. Do not enter anything in the box – instead select **Sheet 1** tab on the bottom left. On that sheet click on **Column D**, making certain that the entire column is selected. The symbols for that column will appear in the add data dialog box. Click OK on add data box and a plot of the Ti% for every 22 years will appear on the chart in pink. Note: you can put the pointer on individual points to get the data of each point.
6) Click your pointer on the pink 22-year line and press **delete**. This will remove that plot line. Note: if you delete the wrong line, go to **Edit** and select **Undo delete**.
7) Go back to the **Chart** pull down and again click **Add Data**. When the dialog box appears again go to **Sheet 1** but choose **Column E**, and click OK in the dialog box. You have now plotted the data for Ti% as the geologists measured it – approximately every 5 years.
8) Now remove the 50-year plot line (blue) by selecting it and pressing **delete**. This will leave you with only the pink plot line representing the data for every 5 years.
9) Put your pointer within the light blue Plot Area (make certain you are in the blue and not on any lines) and double click. The Plot Area dialog box will appear, click on the Fill Effects button because we are going to change to a picture in the background. Click Picture tab at the top of that box. Click Picture Select button. Choose History 1 background.tif within your Maya Activity folder and click OK. Click OK again to display this new background.

NOTE: do NOT click insert picture from right click – the picture will not fill the space correctly.

This background now displays the times of the Mayan city abandonment in a darker shade of blue, along with a plot of the estimated population of the Three Rivers area (see Figure 1 for the location of this area). Notice the population variation during the dry periods and city abandonment. Notice also that the population plot is logarithmic, meaning the variation is much larger than it looks.

10) Select Chart 2. This chart shows some data taken at Lake Chichancanab in the Yucatan Peninsula (Figure 1) by another research team (Hodell et al., 1995). The data was again taken from a laminated core, but this one was from fresh water. In Lake Chichancanab during wet years there was some calcite (CaCO₃) precipitated at the bottom of the lake in the laminations. During dry years this precipitation shifted to gypsum (CaSO₄). So years with high sulphur percentage (sulphur is found in gypsum but not calcite) represent dry years at Lake Chichancanab. We are now going to superimpose this data upon the 5 year Ti % concentration plot.

11) Go back to the Chart One. Click on Plot Area to change the background again. When the Plot Area dialog box appears, click on the Fill Effects, then Picture, then Picture Select (again, do NOT use right click to insert picture). Choose History 2 Background within your Maya Activity folder and click OK. Click OK again to display this new background.