GO THERE—CENOTES: THE CONNECTION BETWEEN MAYANS AND DINOSAURS

FLY to the small town of *Chichi, Mexico* and **ZOOM OUT** to an **EYE ELEVATION** somewhere between 300 and 400 miles. If you have the **BORDERS LAYER** active in your view, you will see that *Chichi* is a small town near the center of one of the 31 *United Mexican States*. This southeastern most lobe of land jutting northward into the *Gulf of Mexico*, forms the southernmost boundary for the Gulf, separating the *Gulf* from the *Caribbean Sea*. This is most easily observed by **ZOOMING OUT** to between 800-1300 miles **EYE ALTITUDE**. Collectively, the three states of this lobe of land, or peninsula, are named after the northernmost state in which *Chichi* is found. What is the name of the peninsula?

ZOOM IN to around 150-250 miles **EYE ALTITUDE**. Can you infer what the general climate of the peninsula is based on visual evidence? What is the evidence for your inference, based on your observations of this view from **GOOGLE EARTH**?

Why are there north-south trending, rectangular variations in color in this view, and what do you think they represent?

As another byline, based on your observations of this particular view, which area (based on its name) is the most heavily populated in the State? What "natural" color is a heavily populated area and why do you think that "natural" color is an indication of populated areas?

Using the **MEASURE TOOL** in this **VIEW**, determine the average width of this densely populated area., and record it here. **CLEAR** your tool after you are finished.

ZOOM back in to an ***EYE ALTITUDE*** between 30,000 and 50,000 feet, still centered over *Chichi*. Three, semicircular spots about 2 miles east-southeast of *Chichi* are visible in this view. What do you suppose they are, based on their coloration, size, and shape?
The three landforms in this view are called *cenotes*, and were named by the *Yucatec Mayans*. The *Yucatec* built their *Mayan* civilization around the *cenotes*, and not around other features that cultures use for determining where to build towns, cities, and population centers. Which natural resource is most important for building population centers?
ZOOM OUT again in increments to around 180 miles ***EYE ELEVATION***. Make sure that the ***WATER BODIES LAYER*** is Active. Pay close attention and determine the number of rivers, streams and larger lakes you observe in this area. Record that number here.
What does the number of visible rivers, etc. indicate about the importance of the smaller *cenotes* to the *Yucatec Mayans*?
What is the origin of the *cenotes*, and why do you think that the level of the water that fills them is always slightly below their surface?

ZOOM IN again to an ***EYE ALTITUDE*** between 30000 and 50000 feet. Do the three *cenotes* just east of *Chichi* have any apparent sources of water with which they are filled (e.g. rivers, streams, creeks, or man made canals)?
Is the water in these *cenotes* murky with suspended sediments, or is it clear? What visual evidence do you have to support your hypothesis?
Using ***WIKIPEDIA***, search for *cenote* (http://en.wikipedia.org/wiki/Cenotes). How does the brief description of a *cenote* in ***WIKIPEDIA*** compare with your observations?
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Water from deep *cenotes* in the central *Yucatan* is typically layered. The uppermost layer is fresh, but water from the bottom of deep cenotes (between 150 and about 300 feet deep) is typically saline, with a salinity that approaches that of seawater. This boundary, called a halocline occurs throughout the *Yucatan*. It is typically slightly closer to the surface in cenotes near the coast, and is deepest near the center of the peninsula. What do you suppose is the origin of this layer of salt water? What does the halocline and stratified water systems in *cenotes* tell you about the relative density of the saline water at bottom of the cenote and the true source of that saline water?

Make sure the ***BORDERS*** and ***LABELS LAYERS*** are active. Using the ***PAN TOOL*** (i.e. the "***HAND***"), ***PAN*** almost due west about 13 miles to the small town of *Poccheinå*, and ***CENTER*** your view over this town. About a mile south of *Poccheinå* are the ruins of the pre-Columbian *Mayapan*, the capital of the pre-Columbian Mayan Empire from around 1220 to 1440 AD. *Mayapan's* population is estimated to have peaked around 15000, prior to being sacked and burned from warring Mayan city-states like those of *Chichen-Itza* to the east. ***ZOOM OUT*** slightly to an ***EYE ALTITUDE*** between 50000 feet and 12 miles. About 4 miles south of *Poccheinå*, numerous *cenotes* are visible in the view. Describe their orientation and occurrence in this view. You may want to ***ZOOM OUT*** slightly to verify their arrangement.
According to what you understand about the origin of *cenotes*, what does their arrangement in this area suggest about the nature of the rock in which they occur?
Follow the trend suggested by the arrangement of the cenotes in this towards the east by ***PANNING*** the view, until you encounter the three cenotes you first observed just east of *ChiChi*. Describe the arrangement of the cenotes from both of these areas in the space below.
Continue following the trend to the east. The closest larger cenotes east of *Chichi* are visible just about five miles east of *Kantunil* and slightly north of *Hulca*. You should probably ***ZOOM OUT*** to an ***EYE ELEVATION*** of 30 to 40 miles. Using the ***MEASURE TOO***l, make a ***PATH*** from the cenotes south of *Poccheinå* to those just east of *Chichi*, and connect that ***PATH*** with the *cenotes* just north of *Hulca*. Continue elongating this path, connecting the line of *cenotes*, effectively dividing the *cenote*-less land to the north northwest from the cenotes to the south

and east.
This is a little tricky, and will help you master the *NAVIGATION TOOLS* of *GOOGLE EARTH*. It may involve some *ZOOMING IN* and *OUT*, as well as using the *NAVIGATION TOOL*s in the upper right corner of the *VIEW WINDOW.* One good trick is to use the wheel in the center of your mouse to *ZOOM IN* and *OUT*, as you manipulate the *NAVIGATIONAL JOYSTICK* in the view window.

A few of the more visible cenotes occur in the following general regions of the *Yucatan*:

- Three miles east-northeast of *Cauca*
- Slightly east of *Zucuna*
- Near *Buctzotz*
- Near *Chunyaxnic*

The line of cenotes you have connected should disappear into the *Gulf of Mexico* near the town of *Chunyaxnic*.

Now, *ZOOM OUT* and observe the *PATH* you have created by connecting these cenotes. Describe the general shape of your measured path of aligned *cenotes*, and record its length below.

CLEAR the *MEASURED PATH* and close the *MEASURE TOOL*. Using the *ADD PATH TOOL*, start a *PATH* where the trend of your cenote-line disappears under the *Gulf of Mexico* near *Chunyaxnic*. This will open a *PATH BOX* titled *NEW*. You can move this box to the side or corner of your screen, but it must be open to create a new path. The path you create will be listed in the *PLACE MENU*. If you don't name it, it will be labeled "*UNTITLED PATH.*"

It is probably best to complete this analysis at an *EYE ALTITUDE* averaging around 10 miles, *ZOOMING IN* and *OUT* as necessary with the *CLICK WHEEL*.

Now, retrace the trend you just observed and measured by *CLICKING* on cenotes you previously observed along that trend. You will have to use the navigational skills you developed in the last step. Additionally, you can reposition any points along your path, if desired by *CLICKING* them. The *ACTIVE POINT* is blue, set points are red. Placing the *CROSSHAIR* over that point will cause it to become the *"FINGER"* or *SELECT TOOL*. *LEFT-CLICKING* will allow you to *DRAG-AND-DROP* the point to a new position. *RIGHT-CLICKING* will delete the point from the path.

When you reach the cenotes just south of *Poccheinǻ*, follow the trend to the west, connecting the *cenotes* and dividing the cenote-less land to the north and now northeast from the area to the south and west.

A few of the more visible cenotes west of *Poccheinǻ* occur in the following general regions of the *Yucatan*:

- about two miles southwest of *Abala*
- about three miles northeast of *Kapoma*
- about ten miles northeast of *Maxcanu*
- about two miles south of *Altamira*
- about three miles northeast of *San Matias*
- about three miles southeast of *Bella Flor*

As you navigate through this region, cloud shadows often look like water bodies, but can be distinguished from the cenotes by observing their cloud source, which is typically shaped similar to the shadow about ½ mile to the southeast.

The line of cenotes you have just connected should disappear into the *Gulf of Mexico* about 18 to 19 miles northwest of *Bella Flor*.

Now, ***ZOOM OUT*** and observe the ***PATH*** you have created by connecting these *cenotes*. Based on the pattern you have outlined, what type of process could have produced fractured limestone bedrock that promotes the flow of groundwater to make the cenotes arranged in an almost semicircular pattern? What can you conclude about the force necessary to produce such a large semicircular fracture, and how does that relate to your hypothesis for the origin of the pattern of aligned cenotes?

Based on your hypothesis above, what might you expect to find in the shallow seafloor north of the coast of *Yucatan* that is coincident with the pattern you established with the *cenotes*?

CLICK "OK" when done to close the ***ADD PATH BOX***. Now, use the ***RULER TOOL*** to determine the rough diameter of observed portion of this "circular object. ***MEASURE*** the rough diameter from where it disappears under the *Gulf of Mexico* in the west to where it disappears under the *Gulf* in the east, and record its diameter below. Also, ***PRINT*** this view and attach it to the last page of the exercise.

The limestone bedrock of the northern *Yucatan* peninsula is primarily horizontally stratified limestone slightly over 3000 feet thick. The youngest limestones at the top of this stack of stratified rock formed in the Cenozoic Era, and indicate that shallow warm seas have existed in this area for about 65 Ma or about 65 million years. Fossils derived from drilling through the lowermost Cenozoic limestone beds indicate that those limestones started forming in the oldest time Epoch of the Cenozoic Era (i.e. Paleocene) about 65 Ma or about 65 million years ago, just after the dinosaurs and many other creatures became extinct. The Cenozoic limestones of the Yucatan are only broken slightly along the trend of the Cenotes, indicating some form of post-depositional settling in a ring-like depression at the hedges of the hemispherical trend we have just described. Essentially this is similar to the kind of settling observed in the development of a "giant" sinkhole.

The Cenozoic limestone sits directly on over 1500 feet of breccia and andesitic glass characterized by crustal melting that also contains shocked quartz, a mineral that forms only under the intense pressure associated with impact of large objects.

The rock below the glass and breccia is predominantly limestone—limestone that also formed in warm shallow seas during the age of the dinosaurs. This limestone contains latest Cretaceous marine index fossils just below the breccia, and is also intensely fractured.

Based on the nature of the rock sequence described above for the northern Yucatan, when did the fracturing of rock below this semicircular structure occur.

ADD a ***"PLACEMARK"*** (pushpin marker) to the approximate center of this semicircular pattern. Make sure you ***CLICK*** ***"OK"*** after you have positioned it. The ***MARKER*** should be about eight to ten miles north of the small town of ______________________ (nine letters, starting with C and ending with B). Objects such as this are typically named for unique named geographic features in the area in which they are located, and the small town you just identified is the name sake for this "crater".

Look up ______________________Crater in ***WIKIPEDIA*** (http://en.wikipedia.org). In the space below, describe how your analyses and hypotheses relate to the reported information documented in the ***WIKIPEDIA*** article.

Craters such as this can be formed from the impacts of extraterrestrial objects. Several scientists have studied the relationships between the characteristics of a "projectile" and its "target" for large planetary-modifying collisions. Those parameters include: projectile composition/density, projectile diameter, projectile velocity, impacting angle, target density, and target composition. Now lets determine some of those parameters, in order to figure out how big the object was that formed this feature and caused global ecosystem change about 65 Ma.

Assume that the projectile has about the same density as the target—there is no gravitational/magnetic difference in the crater and there is no indication of preserved fragments of such a "projectile" in the area surrounding the which suggests that the projectile was not one of the iron-nickel meteors

Several other facts help us to model the nature of the impact. First, the rain of debris from the impact appears to be greatest north of the *Yucatan* in *North America*, with very little direct fallout to the south, east or west. Second, small glass tektites are reportedly more abundant in the deep-sea sediments of both the *Gulf of Mexico* and the western *North Atlantic* than in other areas. Third, terrestrial deposits spanning the same time frame in *North America* are characterized by a charcoal-rich horizon, suggesting a tremendous wildfire with accompanying iridium-enriched clay and shocked quartz (both of those materials are produced from impacts). Fourth, the charcoal-enriched and iridium/shocked quartz horizon is capped with a horizon enriched in fern spores, a typical plant that repopulates burned forests. What do these facts collectively suggest about the impact angle of the object that formed the crater?

The highest impact velocities of documented objects in the Solar System capable of impacting Earth is about 72 km/sec (162,000 mph), although typical impact velocities of asteroids is about 17 km/sec (15,750 mph) and cometary impact velocities are about 51 km/s (114,750 mph). Asteroids are generally rocky, not iron-rich, and are capable of producing large concentric fractures and craters. Comets are generally low density, composed of lightweight volatile components and do not pack the punch of large rocky objects. The probable atmospheric explosion of a low-density cometary fragment knocked down over 80 million trees in about an 850 square mile area near the *Tunguska River* of *Siberi*a, leaving no discernable crater. Based on these facts, and remembering that iron-nickel fragments are not prevalent in the fallout associated with the *Yucatan* event, what kind of object do you suppose made the fracture system about 65 Ma in this former land of the Mayan Civilization?

Scientists working for the LPL (Lunar and Planetary) Institute at the University of Arizona have posted an interesting website for modeling planetary impacts at http://www.lpl.arizona.edu/tekton/crater_p.html

Use the following parameters we obtained from our analysis to get a feel for the size of the large body of rock that rocked our Earth 65 Ma.

- Final Crater Diameter (as computed from determining the diameter of the ring of cenotes in this study. Your diameter was in miles, multiply it by 1.6 to obtain the diameter in kilometers)
- Projectile Density: 3000 kg/m^3 for dense rock
- Impact velocity (use the Earth/Moon asteroid impact velocity on the pull-down menu)\
- Impact Angle (use 45 degrees as an estimate)
- Target Density (limestone rock is almost 3000 kg/m^3)
- Gravitational Acceleration (Earth's gravitational acceleration is 9.8 m/sec^2)
- Target type (= liquid water. The area was submerged during impact within the photic zone of the ocean)

What is the size of the asteroidal projectile capable of producing the crater on the Yucatan 65 Ma? Use the results from the Pi Scaling calculation (the "preferred" method in this type of analysis, and list it in the space below. Also use a calculator and convert the diameter in meters to miles (remember that the answer will be in 100's of meters, that one thousand meters is one kilometer, and that one mile is 1.6 kilometers)

Just to put this in perspective, imagine you were a happy dinosaur at the time, minding your own business of everyday life. Both *Triceratops* sp. and *Tyrannosaurus* sp. were common in that time interval. Using another set of calculations that help us to get some clue on the environmental effects of impacts as posted by the LPL institute (http://www.lpl.arizona.edu/impacteffects/), plug in the projectile size, angle, composition, etc. to those calculation forms on the website, and determine what it would have been like to have been a dinosaur at each of the following localities:

1. A place currently called *Hell Creek, Montana*, about 2050 miles (3280 km)currently from ground zero (distance from impact).
2. The area currently between *Farmington* and *Albequerque*, *New Mexico*, about 1500 miles (2400 km) from ground zero (distance from impact).
3. The area in the southernmost tip of *Texas*, about 500 miles (800 km) from ground zero (distance from impact).

List the environmental results for each of those localities in the boxes below, and comment what you would have experienced, had you been there.

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References

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