# The Impact of the Geologic History of the Yucatán Peninsula on the Present Day Aquifer

Marcio L. Teixeira

Physical Geology Term Paper, Fall 2004
Front Range Community College, Fort Collins, Colorado

**Abstract:** This paper surveys research on the geology of the Yucatán peninsula and presents a historical view of the region from the Cretaceous to the present. Following a discussion of the peninsula's general geography and geology, we trace the effects of the K-T asteroid impact to the modern hydrology of the region and the resulting consequences on the potable water supply of Merida, the region's most populated urban center.

## 1 Introduction

The Yucatan peninsula, in the southeastern part of Mexico, is an expansive, low-lying carbonate platform that projects into the Gulf of Mexico (see figure 1). It covers an area of approximately 3,500,000 square kilometers and rises fifteen meters above sea level in its northern part (Escolero). The peninsula is a mature karst system consisting mostly of pure limestones and dolostones deposited during and after the Eocene (Escolero, Perry).

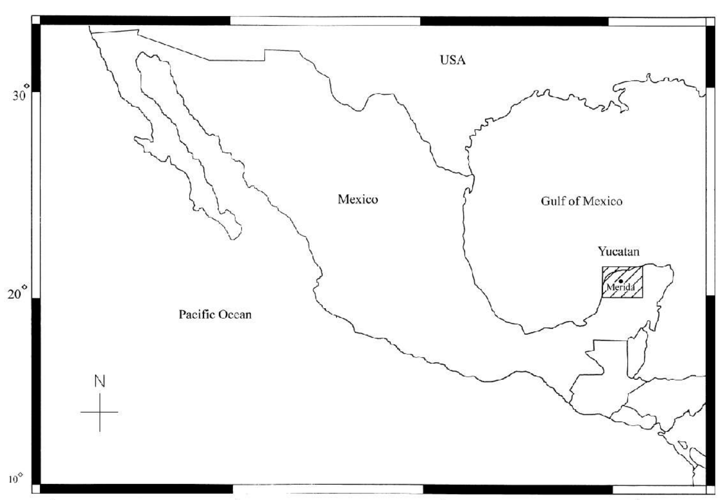


*Figure 1: Location of Yucatán Peninsula (Source: Escolero)*

As shown in figure 2, the major geographic features of the peninsula are the Sierrita de Tecul and the Ring of Cenotes (RC). The RC is a 180 kilometer diameter semi-circular band of water-filled sinkholes centered on the coastal city of Chicxulub Puerto (Perry). The Sierrita de Tecul is a range of low hills that runs tangent to the southwestern part of the RC and has an average elevation of 150 meters above sea level (Perry, Escolero).

## 2 Chicxulub Structure

The RC coincides with the buried Chicxulub structure, which is thought to be a large crater caused by the impact of an asteroid at the end of the Cretaceous period, sixty-five million years ago (Perry, Hildebrand). The primary evidence for the impact is a layer of iridium-rich sediment that marks the Cretaceous-Tertiary (K-T) boundary and is found at sites throughout the globe. Iridium is a rare element in the Earth's crust, but is found in large quantities in meteorites and comets (Hildebrand). From the amount of iridium deposited globally, Hildebrand (1991) cites an estimate that the impact was caused by a meteorite about five miles in diameter, which would have released some 200,000 tons of iridium into the atmosphere. The impact would have been colossal and is thought to have ended the reign of the dinosaurs.

In their 1991 paper, Hildebrand and Boynton document their search for the then unknown crater. By analyzing the mineral composition of the sediment layer of impact ejecta, they determined that the sediment contained both continental and oceanic rocks and that the collision took place at a coastal basin. In Haiti, they found the K-T boundary sediment layer was nearly twenty-five times as thick as in other sites and was rich in tektites, small elongated grains that form as molten rock is expelled from the site of a meteoritic impact. Evidence of large ocean waves during the late Cretaceous at several sites in the Gulf of Mexico collaborated the team's conclusion that the most likely site of impact was the northern coast of the Yucatan peninsula, north of the town of Merida.

## 3 Ring of Cenotes

As pointed out by Perry (1995), a direct geologic study of the Chicxulub structure is impossible, as the crater is now buried by 300 meters to 1 kilometer of Tertiary rocks. Furthermore, the Yucatan peninsula is made up of horizontal sedimentary beds with no exposed outcrops to study, and has a highly weathered, low-relief surface. Thus, much of the evidence for the Chicxulub structure is indirect (Perry). In their 1995 study, Hildebrand and his team measured minute gravitational variations at various closely spaced locations at the surface and used their results to formulate a model of the underground crater. Their model suggested slump faults at the rim of the crater. These coincide with the band of water-filled sinkholes that make up the RC. The authors conclude that extensive fracturing of rocks underneath the surface has increased the permeability of the ring to groundwater and has led to the erosion of sinkholes at the surface.

## 4 Groundwater in the Yucatan Peninsula

Warm and moist tropical breezes bring to the Yucatan peninsula between 500 and 1,500 millimeters of rain a year (Escolero), yet streams or lakes are conspicuously absent from much of the landscape. Surface water quickly makes its way through the porous and fractured surface rocks to the underlying aquifer (Perry 1995). The aquifer is highly permeable, allowing rapid and unimpeded groundwater flow. It forms a buoyant lens of freshwater underlain by a denser salt water intrusion. The watertable is only eight to twelve meters below the surface (Escolero) and is remarkably flat and stable, able to quickly recover from large episodes of rainfall (Perry).

Apparently the buried Chicxulub structure and the RC play a major role in the flow of groundwater in the Yucatan peninsula. Perry and his team found evidence that the RC acts as a large groundwater channel that carries groundwater to the ocean. The first line of evidence is the sinkholes themselves, which Perry suggests may be the result of partially collapsed subterranean cavern systems. Second, his team's examination of wells at various points on the peninsula showed that water levels tend to increase as one moves away from the coast, reaches a maximum, and then falls again as one nears the five kilometer wide band which forms the RC. This suggests that the ring is depleting the surrounding rocks of their groundwater. Third, there is ample freshwater discharge into the ocean at the point where the ring intersects the coast, at the Estuario Celestum and Bocas de Dzilam, the site of several submarine freshwater springs. To bolster their claim that the RC channels groundwater to sea, Perry and his team demonstrated that the mineral composition of the water at the springs was more closely related to water in wells lying further inland on the ring than to the surrounding ocean water.

## 5 A Case Study: The Hydrogeologic Reserve Zone at Merida

Groundwater is a precious resource in many parts of the world and the Yucatan peninsula, with no surface water bodies, is no exception. Merida, the largest city in southeastern Mexico, uses municipal wells to tap the groundwater supply and meet the needs of local industry and agriculture, as well as providing its 600,000 inhabitants with drinking water. Yet, despite the economic and societal importance of this resource, Merida falls short in measures to protect it. The city lacks adequate sewage treatment and many homes dump raw sewage into underground septic tanks, with only a few meters of porous karst rocks to keep the sludge from reaching the watertable. Leaching from landfills, industrial runoff, pesticides and fertilizers compound the problem. Today, the top fifteen meters of the aquifer are contaminated and water-borne diseases account for the majority of deaths in young children (Escolero).

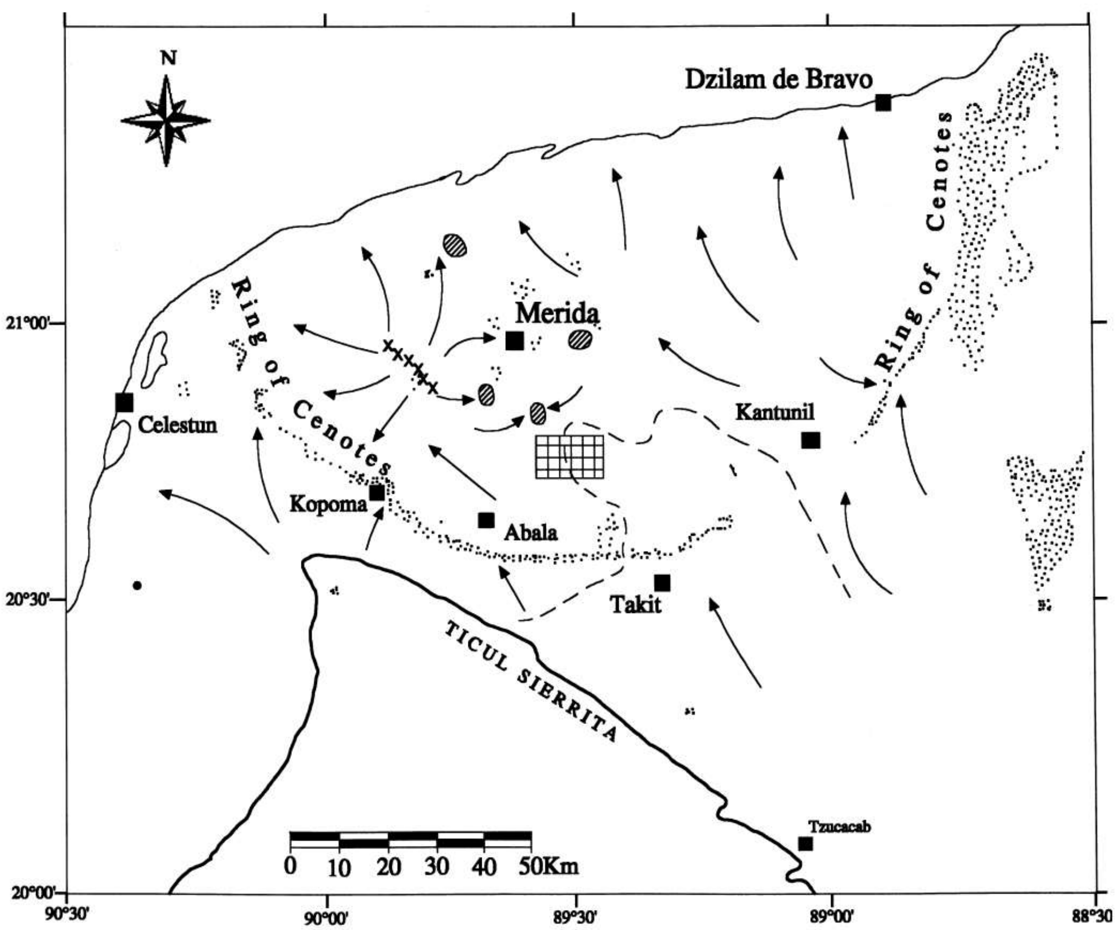


*Figure 2: The major geologic features of the Yucatan peninsula are the Sierrita de Tecul and the Ring of Cenotes (RC). Arrows indicate groundwater flow in the peninsula. The string of X's mark the groundwater divide (Source: Escolero)*

In their research, Escolero and his team explored ways to improve the situation by taking advantage of the the unique patterns of groundwater flow in the Yucatan peninsula. Using their understanding of the local geology, they worked out the ideal location for a Hydrogeologic Reserve Zone (HRZ), a 900 square kilometer area which could be cordoned off for the purpose of providing clean, uncontaminated groundwater to the residents of Merida. They determined that the channeling effect of the RC created an outward flow of groundwater from a region called the groundwater divide, located southwest of Merida, just north of the RC (see figure 2). As groundwater flows radially away from that region, it is uncontaminated and provides an ideal location for pumping out water.

## 6 Conclusion

In this paper we have traced the geologic history of the Yucatan peninsula, starting in the distant past and progressing to the present. We have peered sixty-five million years back to see how an asteroid impact chiseled out the Chicxulub crater and eradicated the dinosaurs. We have learned how geologists have located and studied the buried remnants of this event and seen how the intervening years have eroded away the Ring of Cenotes that now scars the surface of the Yucatan peninsula. Finally, in a remarkable demonstration of how ancient geologic history can affect the present day, we have seen how urban planners have used their knowledge of geology to draft a plan to provide safe and clean drinking water to the residents of Merida well into the future.

## Acknowledgments

The original inspiration for the topic of this paper came from the fictional novel "Domain," by Steve Alten, which dealt in a large part with the limestone foundations of the Yucatan peninsula and its history. Although it is largely a fictionalized work with little hard science, it nonetheless piqued my interest in the Yucatan and provided me with a solid starting point for this paper. I am also indebted to Allie for introducing me to Steve Alten's works.

## Works Cited

Escolero O. A., Marin L. E., Steinich B., Pacheco J., 2000, Delimitation of a hydrogeological reserve for a city within a karstic aquifer: the Merida, Yucatan example, Landscape and Urban Planning 51: Elsevier, pp. 53-62

Hildebrand A.R. and Boynton W.V., 1991, Cretaceous Ground Zero. Natural History 6/91, pp. 46-53

Hildebrand A.R., Pilkington M., Connors M., Ortiz-Aleman C., and Chavez R.E, 1995, Size and structure of the Chicxulub crater revealed by horizontal gravity gradients and cenotes: Nature: v.376, n.6539, pp. 415- 417

Lefticariu M., Perry E., Lefticariu L. and Ward W., 2004, After the Chicxulub Impact: Control on depositional and diagenetic history of the Cenozoic carbonate formations of the northwestern Yucatan Peninsula, Mexico, Lunar and Planetary Science XXXV

Perry E., Marin L., McClain J. and Velázquez G., 1995, Ring of Cenotes (sinkholes), northwest Yucatan, Mexico: Its hydrogeologic characteristics and possible association with the Chicxulub impact crater, Geology v.23, n. 1, pp. 17-20

Smit J., 1999, The Global Stratigraphy of the Cretaceous-Tertiary Boundary Impact Ejecta: Annual Review of Earth & Planetary Sciences; 1999, Vol. 27 Issue 1, pp. 75-113