

Karst Features in Maya Region of Yucatan Peninsula, Mexico

ROBERT R. SHROCK, Massachusetts Institute of Technology

It is the purpose of this brief article to discuss a few interesting karst features of the recently elevated, low limestone plateau which constitutes the northern part of the Yucatan Peninsula (Fig. 1). The features are located at and near the ancient Maya cities of Chichen Itzá and Uxmal. The observations on which this article are based were made during the spring of 1944 while doing geological reconnaissance in northern Yucatan. The writer was accompanied by Dr. Walter L. Whitehead, Massachusetts Institute of Technology, with whom he was fortunate to discuss the subject matter presented here.

Nature of Surface.—The peninsula of Yucatan has special interest for the student of geomorphology because of its youthful stage in the subterranean drainage cycle. It is a recently elevated plain, developed on fairly soft, flat-lying, chalky limestones of late Tertiary age, which rises gently southward from the Gulf of Mexico, where it stands only a few tens of feet above sea level, to over 500 feet above sea level in the jungle country of northern Campeche and northwestern Quintana Roo (Fig. 1). The region to be discussed in this article is probably not over 150 to 200 feet above sea level except for the prominent northwest-southeast trending ridge a short distance north of Uxmal (Fig. 1). There is a very interesting karst plain on the southerly backslope of this ridge,

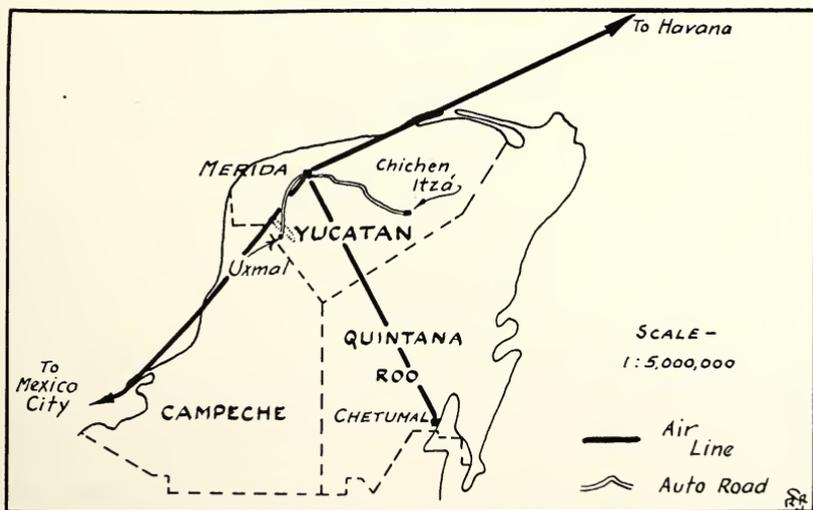


Fig. 1. Outline map of Yucatan Peninsula showing cities and towns mentioned in text.

which appears to be a fault block tipped to the south and scarped on the north side. Red residual soil has washed from this plain through gullies in the crest of the ridge and has been spread out on the north side of the scarp in the form of red alluvial fans which are quite apparent from the air. There is also an abundance of small caves and sinks in this same ridge. These have been very interestingly described by Mercer (1896), who explored a number of them in search for remains of aboriginal culture.

Between Mérida and Chichen Itzá to the east and Uxmal to the south, there is a gentle undulating surface of isolated and interconnected shallow basins of solution separated by low rounded knolls and ridges of limestone. Morris (1931, p. 2) aptly described the surface when he wrote as follows about an automobile trip from Mérida to Chichen Itzá "We moved as upon the back of a great measuring worm, now up, now down across the alternate sequence of swales and hummocks." Many of the depressions have a thin accumulation of red residual soil derived by solution from the surrounding limestone and concentrated in the lower part of the basin through surface wash. When viewed from the air, the red soil areas have a pattern like that of a jig-saw puzzle (Fig. 2). The actual area covered by soil never exceeds 50 per cent

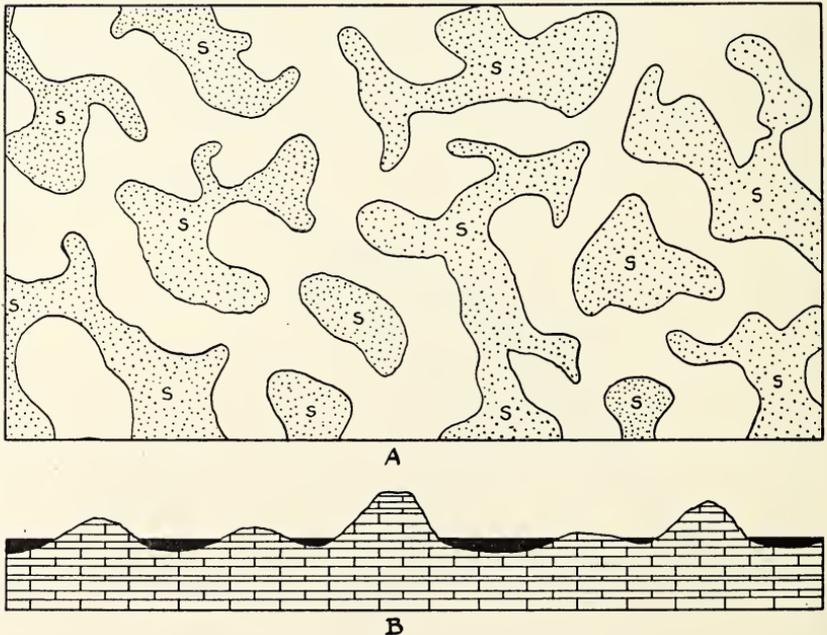


Fig. 2. Karst topography in Mérida region. A. Ground plan of soil-covered basins (s) and intervening ridges as seen from air and ground; the area is about one-half mile wide and one mile long. The area of red soil varies from 10%-50% of the total surface and the soil itself is rarely over five feet thick. B. Cross-section along bottom edge of A showing basins and ridges. The limestone ridges range in height from 1 to 50 feet and usually are covered by rubble.

of the total surface area and probably averages nearer 25 to 30 per cent. No soil deposits greater than five feet in thickness were seen.

There are no continuous channels or surface drainage. Water which falls washes down the bare limestone slopes, carrying to the bottoms of the intervening depressions whatever residual soil has accumulated in the crevices of the weathered rock, and then sinks through the porous residual soil mantle into the limestone beneath. The crevices and holes into which the downward moving water flows are not commonly conspicuous, but at a few places well-like sinks called *cenotes* have developed as a result of subterranean drainage and subsequent collapse of the cavern roof. It is an interesting fact that these *cenotes* do not lie in the center of shallow depressions, as they should if they represented outlets for sinkhole drainage, but rather on flat limestone surfaces.

The most notorious of the *cenotes* is the celebrated "Sacred Cenote" at the ancient Maya city of Chichen Itzá, but there are many other equally interesting ones in the general Mérida region. The writer counted a dozen circular ponds scattered over the karst plateau southeast of Mérida en route by plane to Chetumal and these are presumed to be *cenotes* similar to those seen on the ground. Brief references to some of the better known of these *cenotes* are made by Berlin (1898), Schenck (1906), and Willard (1926), who refer to them incidentally in discussing various aspects of the Maya civilization which flourished in the Yucatan region many centuries ago. Mercer, in his work on the hill caves of Yucatan referred to on a previous page, shows by diagrammatic cross-sections the relations of a number of *cenotes* to the underground caverns which he explored.

Vegetation.—A dense, almost impenetrable jungle of vines, bushes and low trees covers the Yucatan plateau except where the inhabitants have cleared the land for cultivation. Corn is the usual crop raised on the less rocky red soil areas and henequen (sisal), the chief crop of commerce which is cultivated for its hemplike fibre, flourishes on the rocky slopes.

In southern Yucatan and northwestern Quintana Roo the dense jungle, in which is the heart of the chicle country, consists of hilly areas of large, coarse-looking green trees separated by irregular flat tracts of finer textured, lighter colored vegetation. It was later learned that the zapote trees, which are the source of the gum chicle, prefer the rocky hills whereas swamp and marsh vegetation cover the lower flats where the soil is deeper. Karst topography borders the chicle country on the northwest and may also be present beneath the heavy jungle growth but this could not be determined from the air. It was learned, however, that the soil is thicker as one travels southeast from the Uxmal region.

Description of Cenotes (Natural Wells)—The *cenotes*, which appear to be scattered over the Yucatan plateau without a definite pattern, are vertical solution tubes which have been greatly enlarged particularly in the equatorial plane by slump and collapse. The early shape of a typical *cenote* is that of an upright brandy glass without the stem;

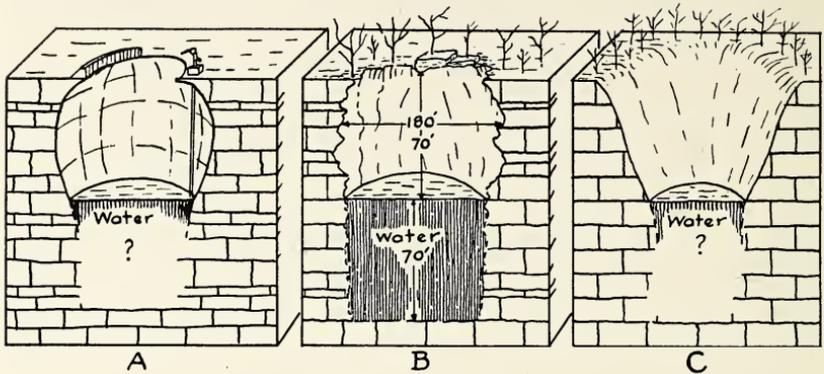


Fig. 3. Cenotes. A. A jug-shaped cenote at Libre Union west of Chichen Itzá. It is about 60 feet deep and 50-60 feet across. Water is pumped from the pool in the bottom to supply the village. The depth of the water could not be ascertained. B. Sacred Cenote at Chichen Itzá. The well has an elliptical opening and the brink overhangs to some extent. The outwardly curved wall has prominent encircling ribs and grooves produced by differential weathering of the flat-lying chalky limestone strata. C. Bowl-shaped cenote observed along the road to Uxmal south of Mérida. The depth appeared to be about 70 feet and the pool in the bottom fairly small. The depth of water was not determined. All diagrams are exaggerated vertically about twice.

i.e., smaller at the surface opening than half way down, and rounded bowl-like in the bottom (Fig. 3A). If the entire rim collapses, the shape is roughly cylindrical (Fig. 3B). Outward migration of the rim produces a bowl-shaped basin with the pool typically occupying most of the bottom (Fig. 3C). Several cenotes of the last type, with circular pools in the bottom, were observed along the road from Mérida to Uxmal.

The local inhabitants, descendants of the ancient Maya, have long depended on the cenote pools as a source of water, hence the name "natural well," and archeologists (Morley 1925, p. 65-66; 1936, p. 622) have concluded that the great Maya cities were located near cenotes for this reason. At the little village of Libre Union, on the road from Mérida to Chichen Itzá, there is a typical cenote about 50-60 feet across and about 60 feet deep. Water from the pool is pumped to the brink and is used locally (Fig. 3A).

Early in 1944 the writer saw a cenote similar to those of Yucatan on the flat karst plain east of Ciudad Trujillo in the Dominican Republic. This feature was described on the spot in the writer's field notes as follows:

"At 37 kilometers east of Ciudad Trujillo, on the north side of the highway, is a remarkable jug-shaped sinkhole known locally as the 'Indian Well' where, it is reported, the ancient inhabitants of this part of the island used to come for water. The cavity is about 25 meters deep, 15 meters in diameter near the bottom and perhaps 10 meters across at the surface opening. Stalactites hang from the walls which flare out

toward the bottom. At the time of our visit (Feb. 4, 1944) a pool of water covered perhaps half of the bottom of the sink.

"Indian Well and the numerous shallow sinkholes observable from the highway between Ciudad Trujillo and San Pedro de Macoris indicate extensive subterranean drainage on the elevated limestone bench along the coast."

The most famous of the Yucatan cenotes is "Sacred Cenote" or the "Well of Sacrifice" in the ancient Maya city of Chichen Itzá. According to archeologists (Morley 1925, p. 80-81; 1936, p. 622 and pls. XVI and XVII), young maidens were hurled into the well in times of great national necessity as living sacrificial victims. At the same time that the girls were thrown in, the Itzá people, who lined the brink during the ceremony, cast their prized possession after her, presumably with the hope of appeasing the gods. These possessions included numerous kinds of jade ornaments, gold and copper bells and rings, carved bones, wooden weapons and pottery.

Many of these articles were recovered about 40 years ago by dredging and are now on display at the Peabody Museum of American Archeology and Ethnology at Harvard University. A detailed description of the dredging operations and of the objects recovered from the bottom muds, which lay beneath over 60 feet of water, will be found in T. A. Willard's interestingly written "The City of the Sacred Well" (The Century Co., New York, 1926).

The Sacred Cenote is about 180 feet across at the top, somewhat larger at about half-depth, and generally cylindrical to the water's edge (Fig. 3B). The water surface of the pool is 65 to 70 feet below the rim of the cenote and the water is reported to be 70 feet deep and never to vary in level. Water level in the second cenote at Chichen Itzá is also about 70 feet below the surface but its depth does not seem to have been determined.

Geomorphological Significance of the Cenotes—The water table at Chichen Itzá stands at about 70 feet below the limestone plateau, but the elevation of the bottom of the cenote (about 140 feet below the surface) is not known. Concerning the depth of the cenotes, Morley (1936, p. 591) states, "The cenotes and modern wells vary in depth directly with the increasing elevation of the land as one withdraws from salt water, from only a few feet at the coast to about 100 feet in the interior. The level of the subterranean water table, however, always remains the same." It has been reported that no salt water is encountered in the cenotes except immediately adjacent to the coast where sea water mingles with fresh water in some of the sinks.

The elevation of the bottoms of the Yucatan cenotes has special significance for the following reason. Accepting the conclusion that the Yucatan Peninsula has recently been elevated, it follows that if the bottoms are now below sea level or above by less than the amount of uplift, subterranean drainage was active at elevations lower than the present water table. This does not mean, necessarily, that the under-

ground features resulting from solution were formed below the water table of the time. It is quite possible that these features were made during the part of the Pleistocene when sea level and water table both were lowered. Precise data on surface and subsurface elevations will have to be obtained, however, before any definite statement can be made about the level at which subterranean drainage developed.

Archeological Interest—The karst plain of Yucatan has special archeological interest because it is one of the regions where the Maya civilization attained a high state of development. Its sparse soil supported a community large enough to raise the great pyramids and temples that are today in partial ruin and the underlying limestone furnished the building materials for the structures. Water used in construction, as well as for domestic purposes, must have come from the natural wells because there seems to have been no other natural source of supply and no evidence remains to conclude that the Maya ever employed catchments and cisterns for water storage.

The archeology of the Yucatan Peninsula has been investigated in considerable detail and has been discussed in many publications but little about the geology has found its way into print. Since the life of the ancient inhabitants was so closely related to the karst features of the terrane, study of the geology offers a very worth-while field of investigation and should be encouraged.

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