Special Report

The Arrival of Humans on the Yucatan Peninsula: Evidence from Submerged Caves in the State of Quintana Roo, Mexico

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Submerged caves near Tulum in the Mexican state of Quintana Roo, on the Yucatan peninsula, contain a diverse megafaunal assemblage of latest Pleistocene age. Abundant coeval prehistoric evidence (e.g., hearths with burned bones, artifacts) indicates that human settlement in the region also reaches back to the end of the Pleistocene. Among the highlights of our ongoing multidisciplinary research are three human skeletons of preceramic age, 70–90 percent complete and mostly articulated. These corpses, which skeletized in situ, appear to have been intentionally buried at a time when the caves were still dry, i.e., prior to the early-Holocene rise of sea level. The three individuals are the oldest skeletons found so far in southeastern Mexico and are among the oldest known from the American continent.

The northern part of the Yucatan peninsula is one of the most inhospitable regions in the world as a result of the paucity of fertile soil, scarcity of drinking water, and shortage of other natural resources. Except for cenote sinkholes and caves with groundwater, most of Yucatan would be a waterless plain. Neverthe-

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less, one of the sophisticated pre-Columbian civilizations, the Maya, adapted to and survived under these adverse environmental conditions. Recent archaeological discoveries in the Mexican state of Quintana Roo suggest that humans occupied the region during the Archaic period, several thousand years prior to the classic Mayan civilization. Evidence for an even older settlement in northern Yucatan was absent, however, and it was generally accepted that groups of preceramic foragers never reached the area (García-Bárcena, pers. comm. 2000).

This situation has profoundly changed in recent years, as a consequence of advances in scuba diving. This technological progress now allows for relatively safe access to the subaqueous system of caves and cenotes on the Yucatan peninsula and has resulted in a boom in cenote diving activities. The cave system is explored by scuba divers and underwater speleologists from all over the world. On one hand, the new technologies now allow archaeologists and paleoanthropologists to explore sites previously inaccessible. But on the other hand, the new situation threatens the preservation of these sites, which are now accessible by inexperienced laymen and exposed to vandalism and robbery.

A completely unexpected result of the systematic exploration of the Yucatan system of submerged caves and rivers by cave divers such as James Coke and members of the Quintana Roo Speleological Survey is a significant record of the recent geological, paleontological, and cultural history of the area. These explorations have yielded, besides colonial and Mayan artifacts and human skeletons, materials dating to the beginning of the Holocene and before 10,000 RCYBP, to the Pleistocene. In this paper we present materials recovered from some of these first explorations, specifically those from Aktun Ha, La Chimenea, Naranjal Cave System (Naharon and Las Palmas), and El Templo.

Background: Geology of the Yucatan Peninsula

The Yucatan peninsula forms a single physiographic province that includes the Mexican states of Quintana Roo, Yucatan, and Campeche, as well as Belize and parts of northern Guatemala in Central America (Figure 1). The geology of the region is homogenous and relatively simple, mostly consisting of a 3000-m-thick sequence of shallow-water limestone of early- to late-Cretaceous to

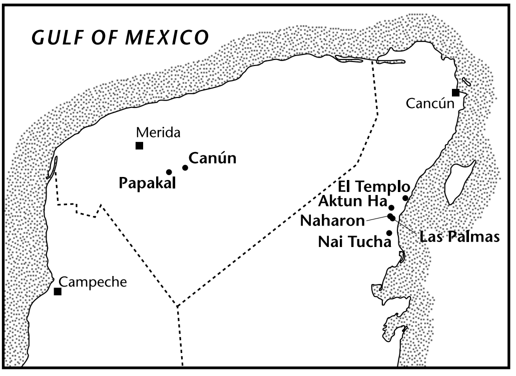

Figure 1. Location of submerged caves containing prehistoric evidence near the east coast of the Yucatan peninsula, state of Quintana Roo and Yucatan, Mexico.

subrecent age, overlying a metamorphic basement detected in the subsurface (Lopez Ramos 1983; Ward et al. 1985, 1995).

Except for a few isolated faults (e.g., Ticul fault, Rio Hondo fault, Chetumal graben), the sediment sequence of northern Yucatan (the Mexican part) is unaffected by tectonic uplift or compression, and strata remain in an almost horizontal position, with a dip of < 2 percent to the north and northeast. Young sediments of Mio-Pliocene or even Pleistocene age are therefore found in this area, whereas the oldest rocks of Cretaceous age outcrop to the south, in northern Guatemala and Belize. As a consequence of the almost horizontal position of the strata, much of northeastern Yucatan is a flat plateau. In the Mexican part of the peninsula, maximum elevations reach 150 m in the Sierrita de Ticul and 300 m in eastern Campeche, but most of Quintana Roo is elevated just a few meters above sea level.

Karst develops because limestone is soluble in water charged with carbon dioxide gas (Figure 2). Owing to the predominance of carbonate lithologies, the tropical climate, high precipitation, and important changes in past sea

Figure 2. Entrance to Naitucha cave. The sedimentary rock is typical of karst topography.

level, mostly during the Pleistocene, the Yucatan peninsula has suffered significant karstification. In the northern and eastern part of the peninsula, the major surface karst phenomena are circular collapsed sinkholes with vertical or funnel-shaped walls, locally known as *cenotes* (a Mayan term). They are the entrances to one of the most extensive cave systems known to date. The majority of these caves are submerged. For instance, an underground river system in the municipality of Solidaridad in Quintana Roo, more than 638 km long, includes 161 underwater caves and 529 cenotes. Among these are the four longest subterraneous rivers known on Earth and the longest cave known in the Mexican Republic (QRSS 2007).[1]

Instead of running off on the surface, water almost instantaneously infiltrates the permeable carbonate bedrock and percolates downward into underlying strata, reaching phreatic levels only a few meters below surface. From here groundwater is rapidly discharged, directed towards the coast. Consequently, even though annual precipitation is high (1000–1500 mm [Back 1985]), the enormous degree of karstification and limestone permeability prevents the existence of surface rivers in the region, except for Rio Hondo east of Chetumal and some minor tributaries.

Origin of the Yucatan Cenote System

The cenote system of northern Yucatan was formed during periglacial periods of the Pleistocene when sea level was low and the Mio-Pliocene carbonate sequence was exposed to subaerial erosion. Groundwater must then have passed through very low levels of the cave system. Since rainwater infiltrated the karstic surface instantaneously, much of the peninsula must have been a waterless plain, completely devoid of surface rivers and lakes. Even the upper levels of caves were mostly dry and probably decorated by speleothems (Figure 3). Indeed, stationary fossil water levels of possible Pleistocene age are occa-

Figure 3. Typical underwater cave landscape, with abundant speleothem decoration. These could only be formed when the cave was dry.

[1] Data published by the Quintana Roo Speleological Survey (QRSS). Underground rivers are cave systems with two or more openings, whereas caves only present a single access to the surface. Cenotes are collapsed sinkholes that give access to caves and subterraneous river systems.

sionally recognized at various levels of depth in the caves by color changes on the cave walls.

Blanchon and Shaw (1995) calculate the difference between recent and late-Pleistocene (13,000 RCYBP) sea level, based on the presence of *Acropora palmata* in fossil reefs on the shelf surrounding the Yucatan coast. *Acropora palmata,* a dominant component of recent reefs in the Caribbean Sea, usually forms monotypic colonies in waters < 5 m in depth to a maximum depth of 17 m (Blanchon and Shaw 1995). The sea level of the Quintana Roo coastline may have been > 100 m below recent sea level, based on karstification reaching this depth. The eustatic rise of sea level, caused by deglaciation at the end of the Pleistocene between 13,000 and 7600 RCYBP, was considered "catastrophic" by Blanchon and Shaw (1995). Sea level reached present-day levels around 7600 RCYBP (about 8400 CALYBP) (Figure 4).

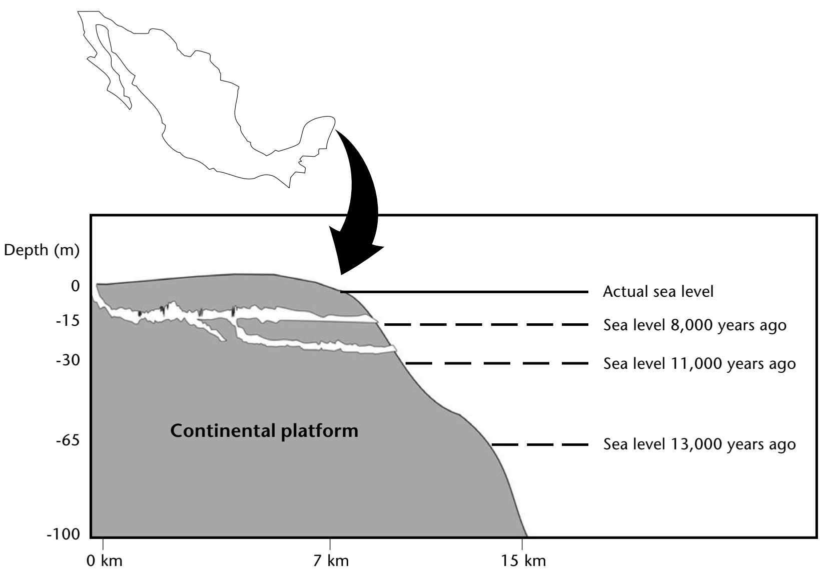

Figure 4. Minimum sea levels and their relation with Quintana Roo caves on the oriental coast (modified from Blanchon and Shaw 1995).

The late-Pleistocene coastline of Yucatan was also different from today. Low sea level exposed the continental shelf towards the north and west of the peninsula (the Campeche Bank off the states of Campeche and Quintana Roo). In sharp contrast to the broad shelf or bank in the Gulf of Mexico, the Caribbean shelf on the eastern margin of the peninsula (Quintana Roo, Belize) is very narrow, frequently only 5–10 km wide, and a depth of > 500 m is rapidly reached in the Yucatan Channel.

The Origins of Native Americans

How and when the first groups of humans arrived on the American continent remains highly polemic and is a question of multidisciplinary debate among paleoanthropologists, archaeologists, and geoscientists from different fields (e.g., paleontologists, geologists, geochemists). Models based on archaeological, anthropophysical, genetic, and linguistic evidence explain the origin and also the number of migrations. The Clovis-first theory suggests ancestral Native Americans came from central Siberia, then crossed Beringia and arrived in North America about 13,500 to 13,000 CALYBP, after a trek between the recently separated Canadian ice sheets (e.g., Fiedel 2006; Haynes 2006). Evidence for this hypothesis is the ubiquitous Clovis fluted point, found throughout Canada and the U.S., and the stylistically derivative Fishtail points of Mexico and Central and South America (Fiedel 2006; Morrow and Morrow 1999).

Other theories postulate multiple pre-Clovis migrations, including trans-Pacific (Rivet 1945), trans-Atlantic (cf. Straus 2000) or coastal (Fladmark 1979) voyages through ice-free corridors by the ancestors of modern Mongolians, Siberians, Australians, Melanesians, or Ainu (Avila 1940; Chatters 2000; González-José et al. 2005) (Figure 5). These new hypotheses are based on archaeological finds in Chile and Brazil as well as on new analyses of crania and molecular data (e.g., Bate and Terrazas 2002; Powell and Neves 1999;

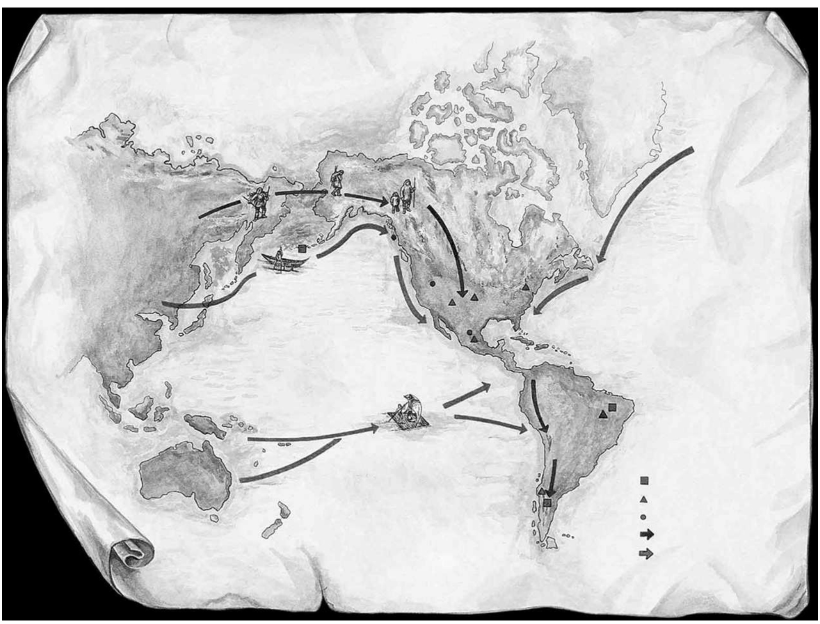

Figure 5. Possible migration routes for the first Americans.

Pucciarelli 2004). In such scenarios, the Americas were colonized thousands of years earlier than Clovis and by several waves of migration. For instance, a human campsite at Monte Verde in southern Chile contains human artifacts and gomphothere bones suggesting an age of 14,000–14,500 (MV II) or even 33,000 CALYBP (MV I) for this prehistoric site (Dillehay 1997, 2002), and human occupations as early as 50,000 CALYBP have been claimed at Pedra Furada in Brazil (Guidon and Delibrias 1986). The anthropological evidence from these sites and their ages, however, remain highly controversial and are considered dubious by many archaeologists, especially from North America (e.g., Fiedel 2006).

Soon after the arrival of Paleoamericans, a massive extinction of megafauna is recognized on the North American continent, now dated to the short period between 13,300 and 12,900 CALYBP (e.g., Fiedel and Haynes 2004). These end-Pleistocene extinctions were abrupt and highly selective, essentially terminating large mammals such as the well-known *Glyptotherium, Glossotherium/Paramylodon, Smilodon, Tapirus, Equus, Camelops, Hemiauchenia, Mammuthus,* and *Gomphotherium,* among many others. Current theories suggest that the ultimate cause for these selective extinctions may have been a combination of repeated rapid climate shifts and human hunting that led to ecosystem instability and population collapse, but there is no unambiguous proof for that (Haynes 2006).

The Prehistoric Record of Southern Mexico

Hammond (1982) suggests that the first settlers could have reached the southern Mexico peninsula by about 11,000 RCYBP, during the so-called "first migration" beginning 30,000–15,000 RCYBP. Archaeological materials associated with this period are Fishtail points of early-Cenolithic age (11,500–9000 RCYBP) from Los Grifos cave in Chiapas, and of late-Cenolithic age (9000–4500 RCYBP) from a number of sites (García-Bárcena 2001). Prehistoric sites with preceramic ages in the proximity of the Yucatan peninsula are also known from the Loltún cave in the state of Yucatan and Santa Marta cave in Chiapas, as well as Los Tapiales in Guatemala and several sites in eastern Belize (MacNeish et al. 1980). At Loltún, fossil bones of American horse (*Equus conversidens*) and extinct bison *(Bison antiquus)* were recovered from layers that also contain lithic tools (Álvarez and Polaco 1982). At San Martha, ancient hearths were identified and dated to 9280 and 9330 RCYBP (García-Bárcena 1976). Organic matter from Los Grifos also yielded ^{14}C ages of 8930 to 9300 RCYBP (García-Bárcena 1978, 1980). Los Tapiales, located in Quiché valley in the Tierras Altas of western Guatemala, was interpreted to be a campsite for hunters. The base of a fluted point from this site was indirectly ^{14}C-dated to 10,700 RCYBP (Brown 1980; Gruhn et al. 1977; Stross et al. 1977). Along the coast of Belize, MacNeish et al. (1980) located several sites with ages between 11,000 and 4000 RCYBP. None of these sites, however, contained human bone material.

Prehistoric Evidence from Yucatan

Until recent years it was believed that the first humans to reach Yucatan were the Mayas. Older archaeological evidence was not known to exist. It was thought that Pleistocene fossils or human bones from preceramic periods could not have been preserved on the surface of the Yucatan peninsula because of dense jungle vegetation, high rate of precipitation, and humic acids from decomposing vegetation. Moreover, the thick limestone bedrock prevents the generation of soil and the flat surface topography is absent of depressions necessary for depositing sediment. The combination of these factors truly impedes the preservation of fossils.

The report of fossil bones found during diving activities, however, and the fact that the Yucatan peninsula forms the heartland of Mayan civilization caught the attention of the Instituto Nacional de Antropología y Historia (INAH), which in Mexico regulates all archaeological, paleoanthropological, and paleontological activities. In 2000, INAH initiated a project to explore the Yucatan cenotes and register important fossil and archaeological sites in the cave system ("Atlas Arqueológico Subacuático para el Registro, Estudio y Protección de los Cenotes en la Península de Yucatán"). So far, seven sites have been identified in the area containing prehistoric evidence associated with early human settlement; four additional sites contain only Pleistocene fossils. The material collected for the prehistoric part of the "Atlas" includes fossil animal bones of late-Pleistocene to early-Holocene age, lithic tools, sediment samples, and charcoal, as well as three nearly complete human skeletons of preceramic age. The human remains are the oldest known from southern Mexico and Central America, and could even be among the oldest known from the American continent. They are thus of special importance in evaluating the age of arrival and migration routes of the first Americans.

All fossil, archaeological, and paleoanthropological remains are housed in the collections of INAH, Mexico City. The three human skeletons were brought to the Área de Prehistoria y Evolución Humana en el Instituto de Investigaciones Antropológicas of the Universidad Autónoma de México (UNAM), Mexico City.

Methods

Despite advances in technology, cave diving remains dangerous. Divers easily lose their orientation in the dark or by stirred-up sediment, or get stuck in narrow openings or between speleothems. Consequently, underwater archaeology in submerged caves is a difficult and logistically complex task that requires many safety measures. A dive partner who can provide assistance in a difficult situation is obligatory, as are redundant tanks, masks, and air provision. The dive is discussed in detail before commencing. When exploring underwater, strings called base lines are unrolled that indicate the direction and distance towards the next exit. The time researchers remain on site is extremely restricted and varies greatly according to the distance from the cave entrance and depth of the immersion. In deep sites (water depth > 25 m), most of the time is used for decompression on the way up, which reduces the amount of time at the archaeological site to just a few minutes.

For the present project, methodologies were implemented that allowed us to improve the effectiveness of dives and increase the amount of time on location. Evidence was first registered and documented using base lines for three-dimensional mapping of the caves. To minimize the stirring-up of sediment and resulting low visibility, bones covered by fine-grained sediment were excavated and registered at the end of a dive. Evidence was collected sequentially during separate dives. For documentation, underwater digital cameras, video cameras, and 35-mm photography were used (Figure 6). These technologies considerably improved our scientific output, since evidence could be analyzed on television screens immediately on completing a dive. This procedure partly compensated for the limited amount of time on site and the limited number of researchers that could enter the narrow caves. For collecting we used water-filled boxes that were closed immediately after taking a sample. This procedure assured that the geochemical composition of the water remained unchanged. For example, samples of archaeological materials taken from salt water may decompose on contact with fresh water. Upon arrival at the laboratory, samples were hardened and stabilized using a mixture of formaldehyde and distilled water.

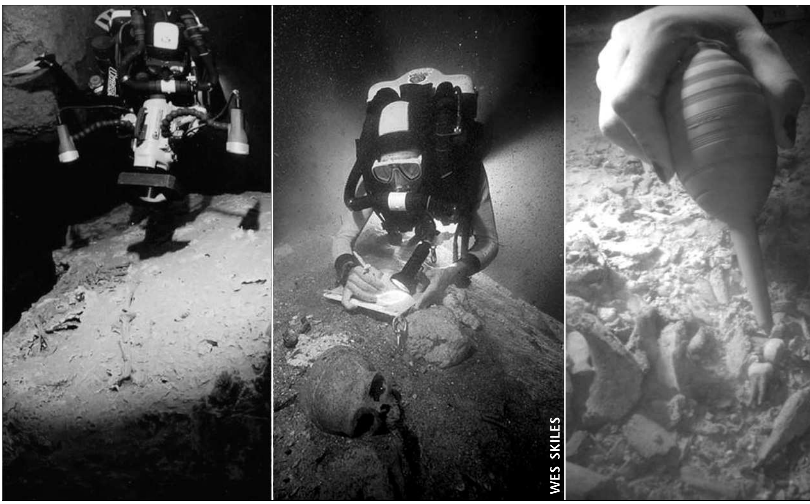

Figure 6. Methodologies for interpreting archaeological context (film, drawings, and excavation).

Results

During our ongoing research, prehistoric sites containing human evidence (skeletons, hearths, rare artifacts) and associated early-Holocene and Pleistocene faunal elements were identified mainly in submerged caves in the Mexican state of Quintana Roo. This concentration, however, may be a consequence of a higher concentration of cenote diving activities and casual discoveries by amateurs around the tourist centers in this region (e.g., Cancun, Playa del Carmen, Cozumel, Tulum). So far, our explorations have been concentrated on sites from which evidence was reported to us (Figure 7).

Aktun Ha

The Aktun Ha cenote is located 8 km west of the intersection that connects Tulum and Coba. The Aktun Ha cave system was formed in limestone bedrock of Miocene age. It is approximately 60 m long in a north-south direction and up to 15 m wide. Two entrances exist, located on the longitudinal ends of the cenote.

The entrance at the Aktun Ha cenote opens into an underwater chamber locally known as the "Chamber of Ancestors," whose entrance is approxi-

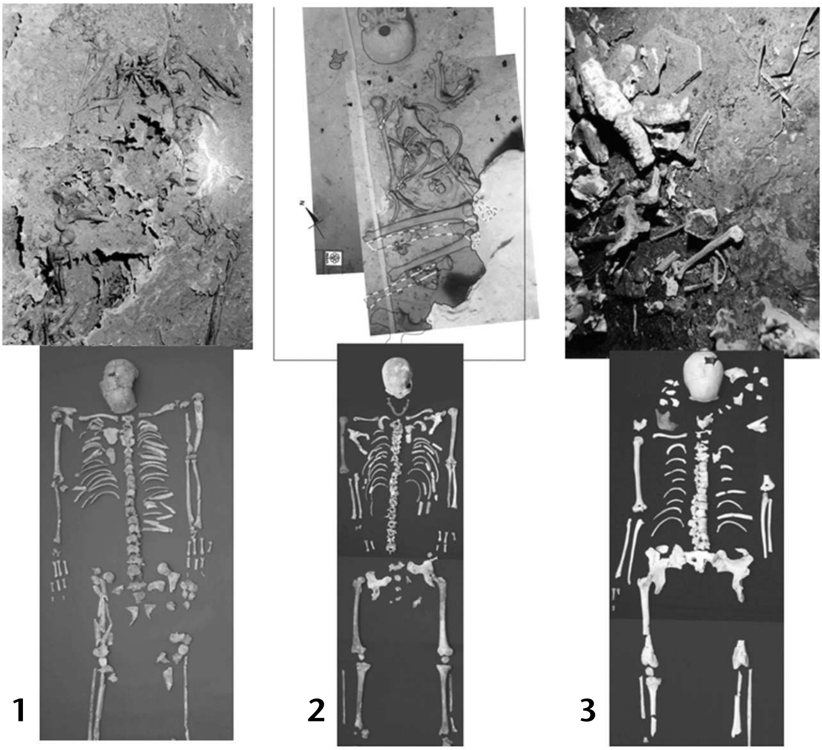

Figure 7. Preceramic skeletons: **1,** El Templo; **2,** Las Palmas; **3,** Naharon. These are from the oldest and most complete collection for southeast Mexico and among the oldest for the American continent.

mately 130 m from the entrance of the cenote, on the right side of a large decorated room. Access is through a small hole covered by heavy decoration (e.g., stalagmites). A small tunnel about 4 m long within the halocline is passable by only one diver at a time. The chamber is 70 m long, up to 30 m wide and 10 m high, with the lowest cave levels reached at a depth of approximately 27 m.

Charcoal concentrations were identified in various places within this chamber. The most interesting feature within this chamber is a small cavity, located about 60 cm above the cave floor, in a tear-shaped limestone rock approximately 2 m high located near the center of the cave (Figure 8). The cavity is approximately 40 cm wide, 40 cm high, and 35 cm deep. Charcoal composition in this niche varied from ash size to pieces up to 10 cm in diameter. In addition, partially burnt wood remains are present. The situation clearly suggests that this charcoal concentration is intentional, the residue from a human hearth. It appears unlikely to us that partially burnt wood and coals could have floated in from the outside and then concentrated in a specific niche, 60 cm above the surface of the cave floor, in a single chamber of the cave system (Figure 9).

Four charcoal samples were collected and dated: Beta-1666199 and UGA-

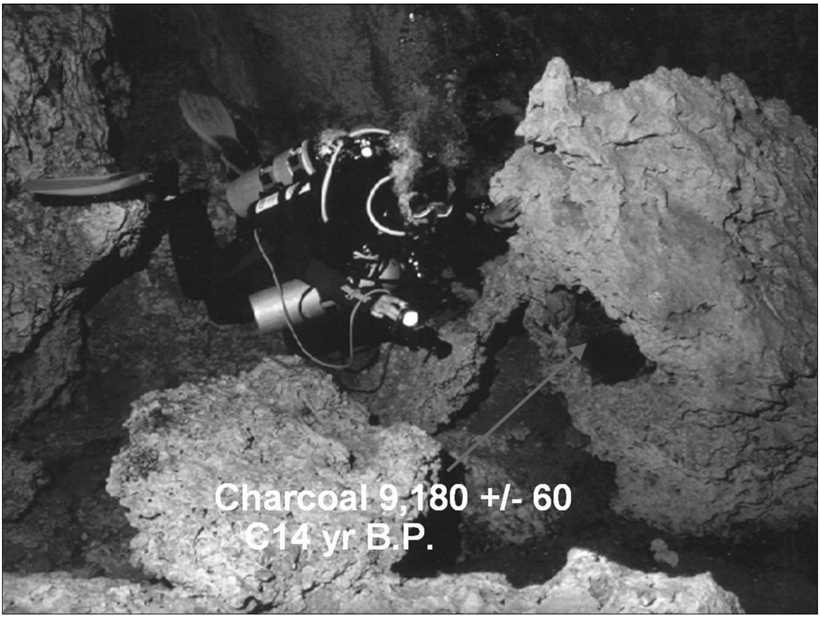

Figure 8. "Chamber of Ancestors" at Aktun Ha, showing a niche in which charcoal was found, indicating the presence of an ancient fireplace.

6637 by AMS ^{14}C, and INAH-2009 and INAH-2011 conventionally. Resulting ages are 9180 ± 60 (Beta-1666199), 9318 ± 37 (INAH-2009), 9139 ± 23 (INAH-2011), and 9524 ± 84 (UGA-6637) RCYBP. They clearly show that the hearth dates to the earliest Holocene.

Associated with the hearth in this "Chamber of Ancestors" at Aktun Ha were possible lithic tools (González et al. 2001, 2002, 2003a).

La Chimenea

The La Chimenea site, which forms part of the Taj Mahal cenote and cave system, is located 26.5 km south of Playa del Carmen, 19 km north of Tulúm, and west of Xpuha in the state of Quintana Roo. Taj Mahal is a well-advertised tourist site on federal road 307 that offers a variety of snorkel and cave diving facilities. The cave system is up to 27.7 m deep, but mostly near the 10 m level, and the halocline is at a depth of 11 m. Water temperatures are about 25°C for fresh water and 27°C for salt water. Access to the La Chimenea prehistoric site is from the Taj Mahal cenote via a complex system of tunnels and chambers, as well as a restriction of approximately 7 m. Base lines are placed, but two jumps are necessary. Swimming to the site, a distance of approximately 130 m, takes about 10 minutes.

At La Chimenea, charcoal is concentrated at a depth of 23 m. Associated with the charcoal we recovered molars, a large fragment of a mandible, vertebrae, and several large fractured bones of a camelid (*Hemiauchenia macrocephala*). The fossil material is partly burnt, and several bones show cutmarks, parallel grooves

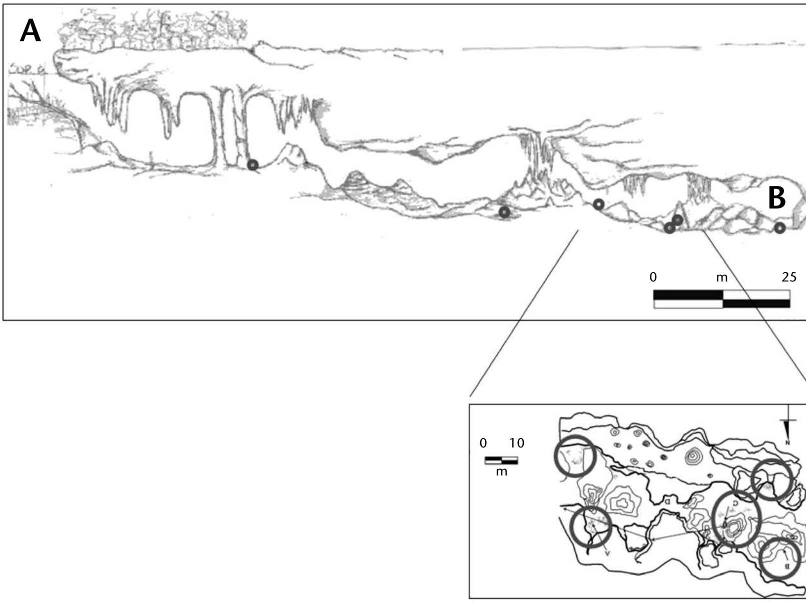

Figure 9. Aktun Ha cave and the location of the "Chamber of Ancestors," where charcoal from an ancient fireplace was found. **A,** cave opening; **B,** "Chamber of Ancestors." Drawing by Octavio del Rio.

3–4 cm long apparently made by a lithic instrument. Unfortunately, stabilizing this material has taken longer than expected, which to date has prevented verifying the issues. A fireplace was found containing charcoal and bones covered with a thin layer of white sediment. The situation is clear evidence for an ancient fireplace in which a camelid was cooked and consumed by humans. It is important to note that *Hemiauchenia macrocephala* is among the mammals considered to have disappeared near the end of the Pleistocene approximately 13,300–12,900 CALYBP (Fiedel and Haynes 2004) (Figure 5). The evidence suggests that humans were possibly present at La Chimenea before the extinction event, during at least the latest Pleistocene.

The Naranjal Cave System

This fully submerged cave system (more than 20 km explored at present) is located about 4.5 km southwest of the city of Tulum, extending for at least 3 km in a northwest-southeast direction north and south of the road connecting Tulum with Chetumal. Eight entrances to the system are known, among them the Naharon, Mayan Blue, and Las Palmas cenotes, which are used for cave diving by local diving schools. The system varies between 10 and 25 m deep, with the halocline at 12 to 16 m, and is well decorated with stalagmites and stalactites.

Naharon. Naharon cave, also called "Crystal Cave," lies 4.5 km southwest of Tulum, west of the Tulum-Felipe Carrillo road, approximately 128 km south of Cancún and 6 km from the coastal line. The Naharon cenote is a large sinkhole 30–45 m in diameter. The skeleton of a woman, covered by 3–5 cm of fine-grain lime mud, was found 368 m north of the cenote on the surface of the cave floor at a depth of 22.6 m.

The skeleton, more than 80 percent complete, is well preserved although fragmented (Figure 10). The female was 20–30 years old at time of death and stood approximately 140 cm tall, judging by the size of the left radius and right humerus. Her weight was calculated at 53 kg (Terrazas and Benavente 2006). Bones were dispersed over an area of 3 by 3 m; only a few articulated vertebrae remained in their anatomically correct positions. It appears that the archaeological context was altered by cave divers who disturbed some of the bones, since water currents in the cave are not strong enough to move the bones, let alone fine-grain sediment.

The remains of this individual were AMS ^{14}C dated to 11,670 ± 60 RCYBP (UCR-4000/CAMS-87301), about 14,500 CALYBP. Analyses by other laboratories, however, have not been able to confirm this date owing to the absence of sufficiently preserved organic material.

Las Palmas. A second skeleton was found in the Naharon system 369 m west of the Las Palmas cenote (also called "Jail House"), in the lowermost levels of a large chamber at a depth of 22.6 m (Figure 11). It was covered by a layer of fine lime mud 1–6 cm thick. At a distance of 15 m from the skeleton we identified a charcoal deposit covering an area of approximately 7m^2.

The Las Palmas skeleton is > 90 percent complete and in excellent condi-

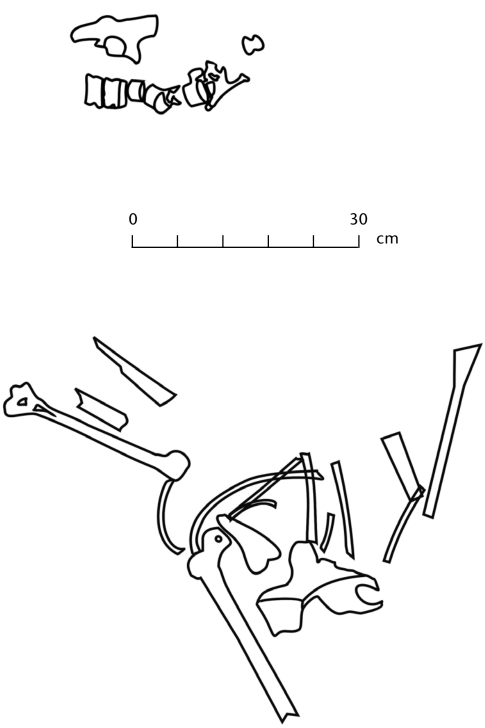

Figure 10. The Naharon skeleton.

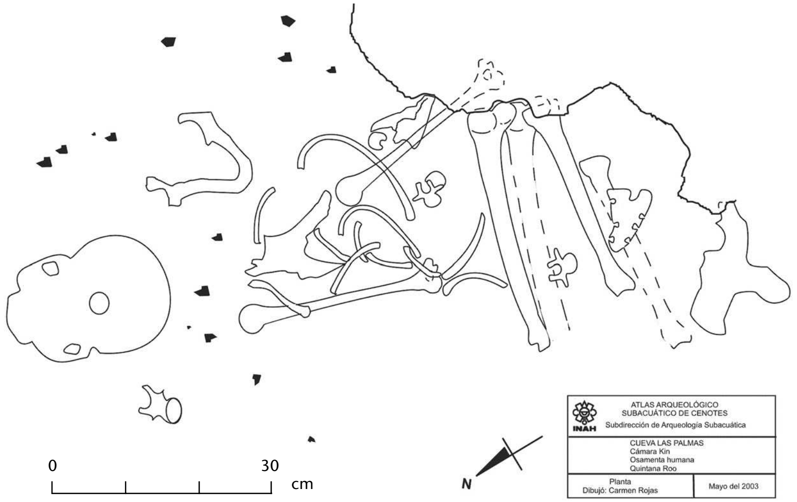

Figure 11. The Las Palmas skeleton.

tion. The bones have a light brown color, and the individual is mostly articulated, with only minor disintegration owing to the effects of gravity. The skeleton was found next to the cave wall in a lying position, bent to the left, with arms and legs angled and drawn towards the body (Figure 12). This situation strongly suggests that the original position of the body was upright and seated against the cave wall, possibly wrapped in a mortuary shroud

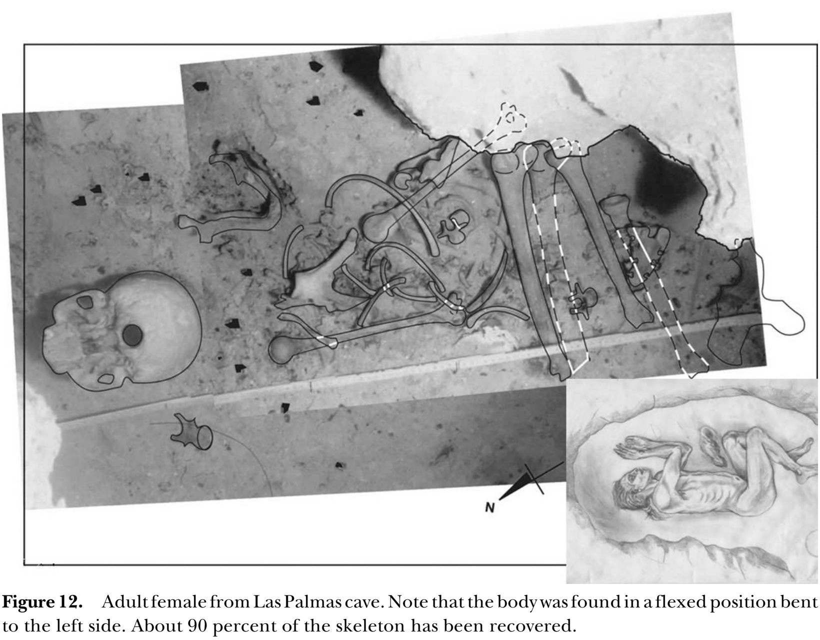

Figure 12. Adult female from Las Palmas cave. Note that the body was found in a flexed position bent to the left side. About 90 percent of the skeleton has been recovered.

(sack). This interpretation indicates an intentional funerary deposit because in a natural death in place, “rigor mortem” would have caused stretching of the corpse, contrary to the flexed position encountered here. Morphometric measurements by Terrazas and Benavente (2006) suggest the Las Palmas skeleton is that of a female 152 cm tall and weighing 58 kg, who was between 44 and 50 years at time of death.

Initial radiometric ages were obtained using both AMS ^{14}C and Uranium-Thorium (U/Th) techniques. Direct AMS dating of the bone (UGA-6828) yielded an age of 8050 ± 130 RCYBP (about 8587–9305 CALYBP). U/Th dating of the bone at Oxford University yielded an age of 10,000–12,000 CALYBP (A. Pike, pers. comm. 2004).

At a distance of 15 m from the skeleton and separated by a natural wall, there is a dense concentration of charcoal and the cave-floor sediment changes to a dark color. The charcoal stain strongly indicates the presence of an ancient hearth and thus suggests human occupation of the cave. Two charcoal samples conventionally ^{14}C-dated at the INAH laboratory in Mexico City yielded ages of 8941 ± 39 (INAH-2123) and 7740 ± 39 RCYBP (INAH-2119). Calibration using Calib Rev 5.1 yields 2-sigma intervals of 9916 –10,205 CALYBP and 8432–8590 CALYBP, respectively.

We recovered the remains of a small fox, *Urocyon cinereoargenteus*, 17 m from the human skeleton. No artifacts have been found in association with the Las Palmas human skeleton.

El Templo

A third skeleton was discovered in El Templo cave, located 18 km north of Tulum and 1.5 km south of Chemuyil. Access to this site is through a low cavern with a floor covered by a few centimeters of water. This “cat walk” cavern leads to the entrance of a submerged wide cave, from there into a tunnel 2 m high and 2.5 m wide. Navigation is made relatively simple by a white-knotted base line that initiates at the roof of the cave entrance. No jumps are needed. The maximum depth reached during submersion is 17 m, mean depth is around 14 m, and the halocline is at a depth of 11 m. Water temperatures are around 25°C in fresh water and 27°C in salt water. Distance from the entrance to the prehistoric site is approximately 185 m.

The El Templo skeleton (Figure 13) was found 185.5 m from the cenote entrance at a depth of 23.5 m. Registering and collecting this individual took us more than 20 submersions over a period of nine months. Difficulties resulted from a peculiar aggressive dissolution of the limestone underlying the bones, producing a soft vesicular surface resembling swiss cheese. Not only were most of the bones fragile and fragmented, they were spread out at the edge of a natural step about 1 m deep. The El Templo individual is a male 25 to 30 years old at time of death (Terrazas and Benavente 2006) (Figure 9). The skeleton was mostly articulated and in an extended position. Remains, however, are poorly preserved as a result of saltwater erosion. Bones are very light, fragmented in situ, and superficially dissolved, with almost the entire organic material lost. Although approximately 70 percent of the skeleton was recovered, the poor preservation prevents ^{14}C dating.

Figure 13. The El Templo skeleton.

Sites with Paleontological Evidence Unrelated to Human Activity

Literature on the Pleistocene faunal assemblage of the Yucatan peninsula is scarce. The few existing reports come from dry caves and cenotes. Mercer (1975), Hatt et al. (1953) and Ray (1957) report on discoveries of *Equus conversidens* and the giant sloth, *Paramylodon* sp. Alvarez (1983), in an unpublished INAH report, mentions the presence of fossil marsupials, insectivores, lagomorphs, carnivores, and perissodactyls, among them abundant *Equus conversidens* from Loltún cave in the state of Yucatán. Polaco (1998) described the first proboscidian gomphothere from this locality.

As we know now, the submerged cenotes and caves of Quintana Roo and the state of Yucatan are rich in fossil remains of late-Pleistocene age, although it remains difficult to establish a direct correlation between them and human occupations. For example, at Nai Tucha, a cenote of the Tuhx Cubaxa system located 19 km north of Tulum in the municipality of Solidaridad, Quintana Roo, we located the articulated remains of a proboscidean (*Gomphotherium* sp.) and a tapir *(Tapirus bairdii)*. Interestingly, the gomphothere bones are partially covered by a stalagmite. At Taj Mahal, we identified remains of the American horse (*Equus conversidens*). At Papakal, in the state of Yucatan, the fossil assemblage includes camelid (*Hemiauchenia* sp.), giant armadillo (*Glyptotherium* cf. *G. floridanum*), American horse (*Equus conversidens*), and rabbit (*Sylvilagus* sp.) (Polaco et al. 2002).

Discussion: Arrival of Humans on the Yucatan Peninsula

When was Yucatan settled? Prior to this research the oldest artifacts and human remains known from the region belonged to Mayan or pre-Mayan civilizations and were assigned ages of between 2000 and 3500 RCYBP. Nevertheless, a much earlier settlement during the so-called "first migration," about 11,000 RCYBP, was theoretically thought possible (Hammond 1982). Now we know that evidence for this hypothesis is preserved in the submerged caves of Quintana Roo. With the new results at hand, it becomes clear that humans did arrive in Yucatan early, during the late Pleistocene or earliest Holocene. There are several lines of evidence for this interpretation, as reviewed below.

Decoration of the Subterraneous Chambers. The submerged caves and cenotes of Quintana Roo are fully decorated by stalactites and stalagmites from near surface levels down to at least 40 m. The presence of these kinds of speleothems clearly indicates that caves must have been dry for many thousands of years. From the geological situation it is clear that the cave system formed during periods of low sea level, i.e., during glacial periods of the Pleistocene. The system was subsequently drowned during the early Holocene between 13,000 and 7600 RCYBP, as sea level rose with melting of ice caps in the Northern Hemisphere. The presence of gomphothere bones with stalagmitic overgrowth (e.g., at Nai Tucha) clearly suggests that these fossils date from the dry phase of the case, with a minimum age of 7600 RCYBP (about 8200 CALYBP).

The Paleontological Assemblage. A late-Pleistocene age is clearly indicated for the assemblage of fossil mammals found in the cave system of Quintana Roo and Yucatan. We identified American horse (*Equus conversidens*), camelids (*Hemiauchenia* sp.), giant armadillo (*Glyptotherium* cf. *G. floridanum*), tapir (*Tapirus bairdii*), and proboscidians (*Gomphoterium* sp.). Some of these remains have been dated radiometrically using U-Th isotopes (A. Pike, Oxford, pers. comm.). For instance, *Tapirus bairdii* and *Gomphotherium* sp., both collected at Nai Tucha, were dated by U-Th to approximately 40,000 CALYBP, and the camelid *Hemiauchenia* sp. from Papakal may even be as old as 150,000 CALYBP. These animals disappeared from the American continent 13,300-12,900 CALYBP (Fiedel and Haynes 2004) during a massive extinction event near the end of the Pleistocene.

Although a direct correlation with coeval human occupation of the caves is difficult to establish at present, indirect evidence exists. For instance, at La Chimenea cenote charcoal is concentrated at a depth of 23 m, suggesting an ancient hearth. The charcoal is associated with molars and bones of the camelid *Hemiauchenia macrocephala.* According to our initial research, the fossil bones are partially burned, and some of these bones show possible cutmarks, indicating that the animal may have been cooked and consumed by humans. Thus in the Yucatan cenotes a possible correlation exists between the presence of humans and *Hemiauchenia macrocephala*, a species that disappeared at the end of the Pleistocene.

The assemblage of fossil mammals identified during our research also suggests that the surface of Yucatan was considerably dryer during the late Pleistocene. Horses (*Equus conversidens*), camelids (*Hemiauchenia* sp.), giant armadillos (*Glyptotherium* cf. *G. floridanum*), and proboscideans (*Gomphoterium* sp.), all widely known from coeval strata of the American continent, are regularly associated with open grassland or shrub vegetation, clearly unlike the low jungle of today (Alvarez 1983) (Figure 14).

Taphonomy. The human skeletons of El Templo, Las Palmas, and Naharon are found at depths of 20–30 m of the cave system, levels that were flooded during early stages of the Holocene sea-level rise, and at distances of 160 m to almost 400 m from the nearest entrance. Could bodies have floated to their present locations during the transgression or later? To us, this scenario is unlikely. It

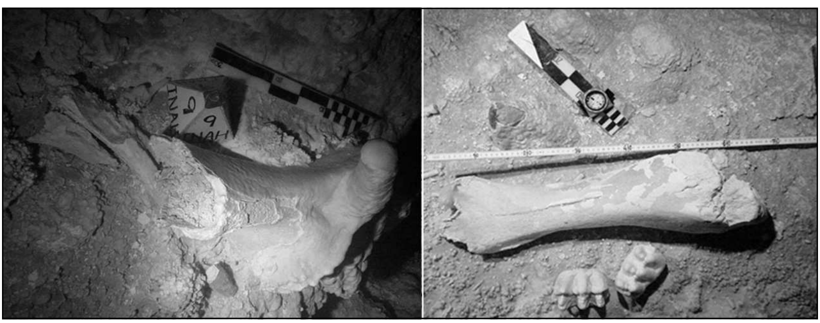

Figure 14. Underwater collection of a proboscidean at Nai Tucha, likely a gomphothere. Late-Pleistocene faunal evidence from Nai Tucha has not yet been related to human activity.

would mean that individuals, after floating for several hundred meters through a cave system of tunnels and open galleries decorated with speleothems, were subsequently deposited almost intact, without major disintegration of bones. At least the Las Palmas and the El Templo skeletons are almost fully articulated, even with the anatomical connections of hand carpals and foot tarsals in their corresponding positions. These structures are the first to disintegrate and fall off a body floating in water for a long period of time (Haglund 1993). Their remarkable state of preservation clearly indicates an in situ skeletization of the bodies that could only have occurred in a dry cave. Although amateur cave divers appear to have altered the position of some bones of the Naharon skeleton and removed some of them, making it difficult to interpret anatomical positions, the otherwise remarkable condition of the Naharon skeleton begs a similar interpretation as for the Las Palmas and the El Templo skeletons.

Some cenotes in Quintana Roo and Yucatan also contain abundant Mayan skeletons; however, these were deposited differently. These later individuals were thrown into the water, where they floated for some time and finally sank to the ground and became deposited. These bodies are always disintegrated, and cranial, foot, and finger bones are usually dispersed over a large area (González González et al. 2006).

The flexed position of the Las Palmas woman even suggests an intentional situation, likely a funeral, in which the corpse was likely wrapped in a sack. This is suggested by the angled position of the legs and arms, which were drawn to the body, and the originally upward position. A funeral would clearly require a place which was dry at the time when the bodies were placed. In the deep parts of the Yucatan cave system (below 20 m depth) these conditions only existed during the late Pleistocene and initial stages of the early-Holocene sea-level transgression.

Radiometric Ages. The human skeletons of Las Palmas and Naharon have been dated by AMS ^{14}C techniques by laboratories of the University of California at Riverside, University of Georgia at Atlanta, Beta Analytic, and Instituto Nacional de Antropología e Historia. U/Th analyses were completed at University of Liverpool and Oxford University. The U/Th analyses were presented in the 2nd International Symposium "El Hombre temprano en América" in Mexico City, September 6–10, 2004. Results are compiled in Table 1. These preliminary ages, ranging from 7740 ± 39 to 11,670 ± 60 RCYBP,

Table 1. Radiocarbon ages obtained by analyses of samples from submerged caves on the Yucatan península. Ages were calibrated based on data presented by Bronk Ramsey (1995, 2001). Laboratories: University of California at Riverside (UCR) University of Georgia (UGA), Instituto Nacional de Antropología e Historia, Mexico City (INAH), and Beta Analytic, Florida (Beta).

Cave	Sample	Material	Radiocarbon age (RCYBP)	Calibrated age (CALYBP) 1 sigma	2 sigma
Naharon	UCR-4000	Human bone	11,670 ± 60	13,610–13,430	13,700–13,370
Las Palmas	UGA-6828	Human bone	8050 ± 130	9130–8710	9400–8550
	INAH-2123	Charcoal	8941 ± 39	10,200–9940	10,210–9910
	INAH-2119	Charcoal	7740 ± 39	8560–8450	8600–8430
Aktun Ha	Beta-1666199	Charcoal	9180 ± 60	10,410–10,250	10,500–10,230
	INAH-2009	Charcoal	9318 ± 37	10,580–10,440	10,660–10,400
	INAH-2011	Charcoal	9139 ± 23	10,285–10,235	10,390–10,230
	UGA-6637	Charcoal	9524 ± 84	11,080–10,690	11,150–10,550

suggest an early settlement of Yucatan during the latest Pleistocene or earliest Holocene, placing the skeletons among the oldest from southeastern Mexico. Caution is required, however, in the case of the Naharon skeleton (11,670 RCYBP), as bone material used for this analysis almost entirely lacked collagenous organic tissue. This date may be too old.

The direct dates on human skeletons are supported by dates obtained from anthropogenic charcoal horizons at Aktun Ha and Las Palmas (Table 1). Charcoal at Aktun Ha was discovered approximately 60 cm above the ground surface of the cave in a small niche of an isolated rock. This concentration is clearly anthropogenic in origin. Ages of 9139 ± 23, 9180 ± 60, 9524 ± 84, and 9318 ± 37 RCYBP for the Aktun Ha charcoal and 8941 ± 39 and 7740 ± 39 RCYBP for Las Palmas are well established owing to the great amount of preserved organic matter. These ages, comparable to those obtained from the human skeletons, also indicate that human colonization of Yucatan dates to at least the earliest Holocene.

Cranial Morphology. According to preliminary morphometric analyses (Terrazas and Benavente 2006), cranial morphologies of the three Yucatan skeletons (especially Las Palmas) differ considerably from those of pre- and post-Hispanic Mayas, and from typical prehistoric Native American material known from the U.S. and Mexico. Craniomorphometry rather resembles older (late-Pleistocene/early-Holocene) Paleoamerican skulls from North and South America. Interestingly, the greatest similarities are with individuals recovered from Tc50-5 from Tehuacan Valley in central Mexico, (Anderson 1967) and Upper Cave 3 (China), two generalized skulls considered "premongoloids" (for Upper Cave 3 see Cunningham and Jantz, 2003).

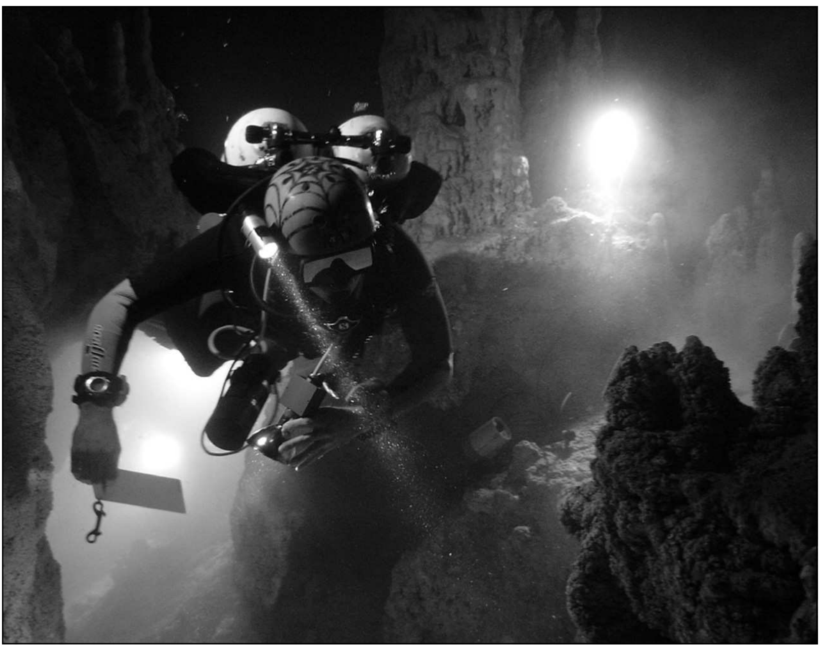

Figure 15. The findings in these caves only show a small part of their real potential. Unfortunately, because of tourist developments, a lot of these sites are being destroyed.

Conclusions

Submerged caves near Tulum in the state of Quintana Roo, southeastern Mexico, are rich in fossil and prehistoric evidence, shedding light on the early settlement of the Yucatan peninsula (Figure 15). Within seven years of our ongoing research, we discovered an abundant and diverse fossil assemblage previously unknown from the region. The association, dating to the late Pleistocene, consists of American horse (*Equus conversidens),* camelids (*Hemiauchenia* sp.), giant armadillo (*Glyptotherium* cf. *G. floridanum*), tapir (*Tapirus bairdii),* and proboscideans (*Gomphoterium* sp.) among others. These mammals became abruptly extinct in other parts of the North American continent in a short period of time, between 13,300 and 12,900 CALYBP (Fiedel and Haynes 2004).

In some cases, a direct correlation was established between the presence of these animals and human occupation of the cave system. At La Chimenea, for example, fossil bones of the camelid *Hemiauchenia macrocephala* are partially burned as a result of cooking in an ancient hearth.

A late-Pleistocene to early-Holocene settlement of Yucatan is also indicated by the presence of other charcoal concentrations interpreted by us as human-produced hearths. At Las Palmas ages range from ca. 9000 to 7700 RCYBP, and at Aktun Ha they date to ca. 9200–9100 RCYBP. Associated with the hearth from Aktun Ha are four possible lithic tools.

Our most important discoveries are three human skeletons, which are almost complete (more than 80 percent of bones recovered) and mostly articulated. The taphonomic circumstances suggest that at least two skeletons, Las Palmas and El Templo, were intentionally interred when the caves were dry. We propose that these skeletons also date to the latest Pleistocene or early Holocene. This interpretation is based on three lines of evidence: (1) radiometric ages, (2) cranial morphology, and (3) taphonomy. The Naharon individual, a female aged 20–30 years, was AMS ^{14}C-dated to ca. 11,670 RCYBP; the Las Palmas individual, a female aged 44–50 years, was AMS ^{14}C-dated to ca. 8100 RCYBP and U/Th dated to 10,000–12,000 CALYBP. The ^{14}C age for Naharon needs to be considered with caution, however, given the poor preservation of the remains. Cranial morphology indicates similarities with other late-Pleistocene/early-Holocene Paleoamerican skulls from central Mexico and South America, and differences with morphologies of pre- and post-Hispanic Mayas and other prehistoric Native American crania. The possible ritual associated with the El Templo and Las Palmas individuals and in situ skeletization of all three bodies must have occurred when the caves were dry, before the early-Holocene sea-level transgression. Present-day levels were reached at about 7600 RCYBP, but the three skeletons were found in deeper levels of the cave system, at depths of between 20 and 30 m. Drowning of these levels of the karstic system must have occurred hundreds or even thousands of years earlier.

Identification and registration of submerged prehistoric caves in Quintana Roo and Yucatan was only possible due to the great support of cave divers of the region. Without their collaboration and dedicated participation in our work, this research would not have been possible. We are especially grateful to James Cook, William Phillips, Robert Schmittner, Roberto Hashimoto, Luis. F. Martínez, Sebastian Genijovich, Flor de Maria Curiel, Marco Rotzinger, Germán Yañez, Octavio del Río, Andreas Mattens, Scott Carnahan, Sergio Granuchi, Karin Boucher, Fernando Rosado, Enrique Soberánes, and Raul González, as well as to our cave diving friends and collaborators from the beginning, Samuel Meachan, and Roberto Chavez. In a multidisciplinary project, the participation and support of academic collaborators from different areas is highly important. We thank Pilar Luna, Luis Alberto Martos, Donald Keith, Larry Murphy, Solveig Turpin, Herb Elling, Adriana Velásquez M, Santiago Analco (†), Guillermo Acosta, Joaquín García-Bárcena, Joaquín Arroyo, Oscar Polaco, Paul Blanchon. Luis Marín, Elva Escobar, Magdalena de los Ríos, Erv Taylor, Alistair Pike, Thomas Highman, Silvia González, José C. Jiménez, Mónica López Portillo, Carlos Serrano, Jorge Juárez, Fernando Sánchez, Sergio Grosejan, Felipe Bate, Ximena Chávez, Fidencio Rojas, Aldo Castro, Rodrigo González, Liliana Pulido, Marianela Fuentes, Susana Xelhuatzin, Paolo Testelli, Froylan

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