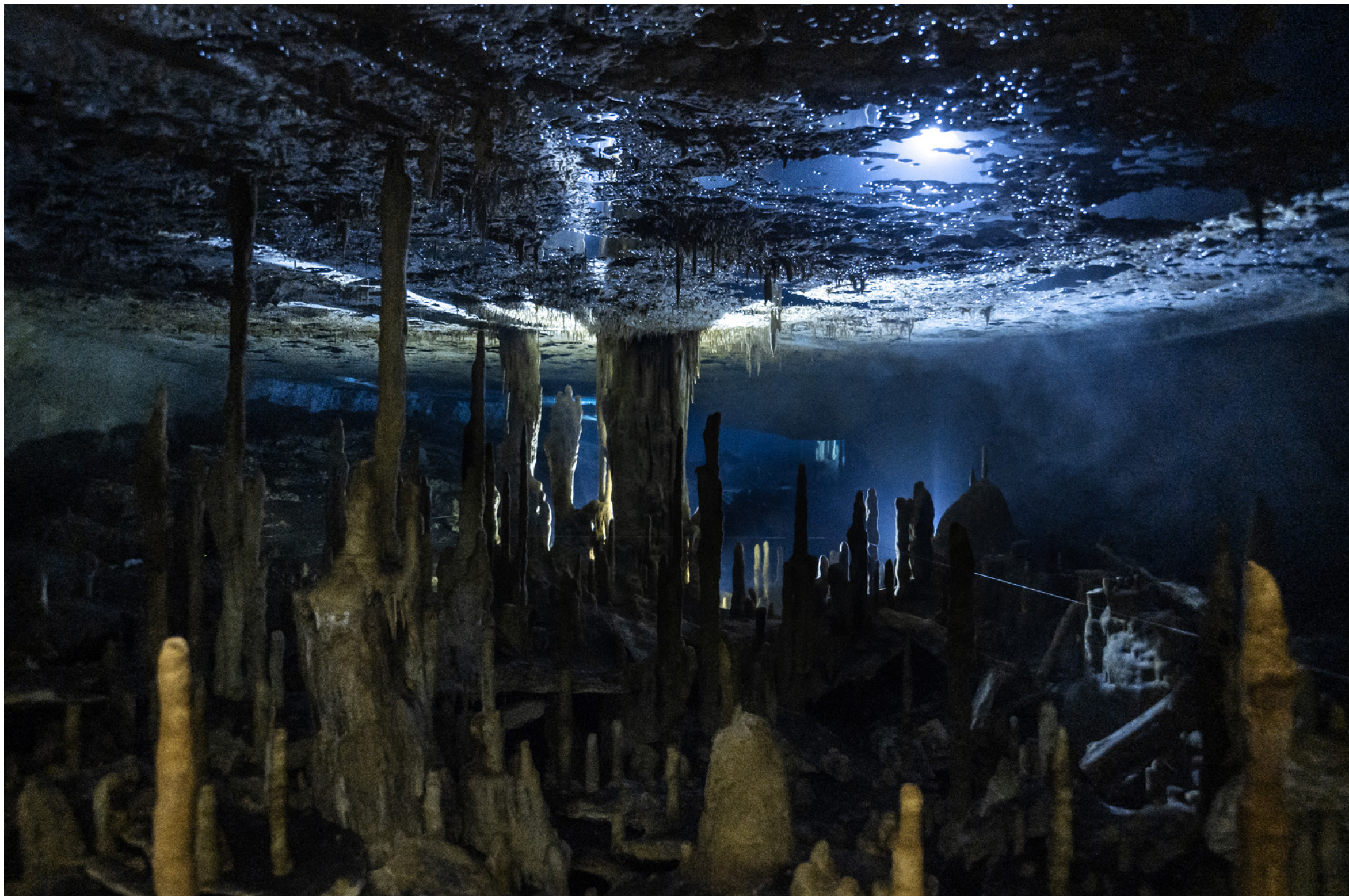


Caves & Cenotes





Page 23: Looking for cenotes at Ciudad Mayakoba across the highway from the resort. This promising cavern turned out not to go very far. Pictured are Matt and Kelvin Davidson, the owner of Third Dimension, a cave and technical diving operation in Tulum where Ivo also works.

Left: The “big room” near the front of Burrodromo. The very flat ceiling and remarkable forest of stalagmites made a striking impression when we first visited.

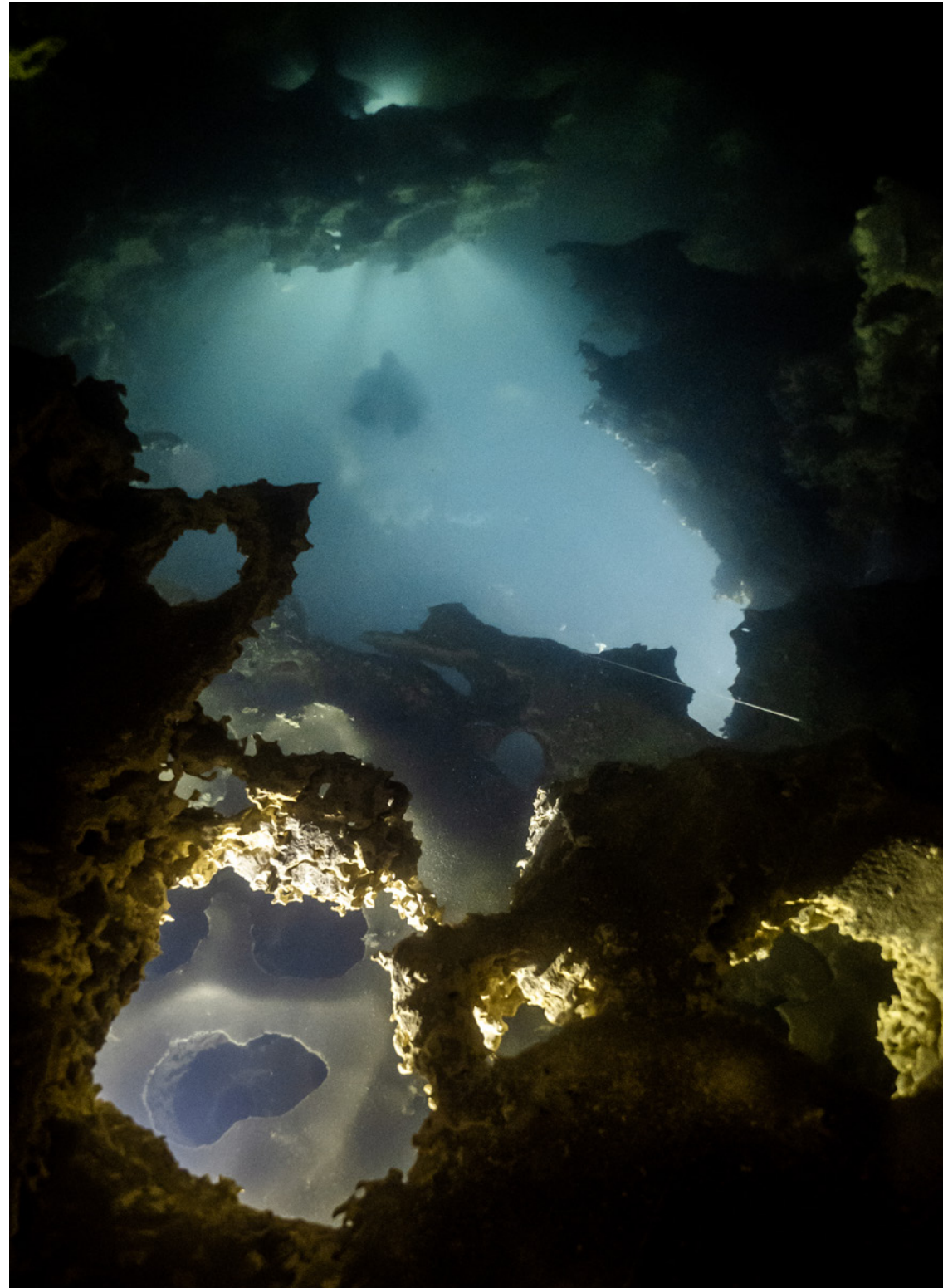
Caves form in many types of rocks during a process called *speleogenesis*. But the largest caves, and those most frequently found, are formed in limestone when the natural acid in water dissolves away the solid bedrock platform, leaving behind cave passages which can continue to develop over time through chemical and physical processes. Caves of this type are called *solution caves*, and the porous limestone environment that supports them is called *karst*. Karst exists in most parts of the world to some degree and is a prominent feature of places like the Nullarbor Plain in Australia, Southern China, the Southeastern United States, and Mexico in the Yucatán Peninsula.

There are probably millions of caves on this planet, but we know of just a small fraction. Amidst telescopes and microscopes, satellites, and submarines, we have tools to see big and small and up and down, but we have almost nothing that can allow us to see into the caves. In order to gain that perspective, we must go look for ourselves, a technical challenge that is reserved for a small group of people—divers trained in cave diving who possess the special techniques, equipment, and mindset to do so safely. In a long-range cave exploration project, this can be a process that feels like mounting an expedition to a tall mountain or a trip to the moon.

The Yucatán Peninsula contains a vast coastal aquifer system, in which nearly all fresh water moves below ground, instead of through rivers and streams as is typical in most parts of the world. This coastal aquifer is best described as a series of interconnected underground rivers that form one of the most spectacular and unique features of any environment in the world. Caves in the Yucatán Peninsula form a geological list of superlatives—the longest single submerged cave, the most extensive network of cave systems, and the resting place of the earliest human remains in the Americas, among just a few notable records.

Left: Looking down on divers in the “Hell Hole” of Ma’ Aayin. Named for its darkness and because it is the deepest part of the system, this tunnel leads into a colorful saltwater section of the cave.

Right: Ivo and Matt pointing at an animal skeleton we found in Ma’ Aayin. The skull and vertebrae appear to be from a medium-sized four-legged animal, perhaps a coati. The white dots on the image are small cave-adapted shrimp. Very small and a striking albino-white color, these animals were very populous in the cave.







Left: Ivo and Matt relaxing on the far side of the air chamber we used to bypass the collapse at Burrodromo, about an hour-long swim into the cave.

Center: The crystal-clear pool at Nohoch Nah Chich, a well-known cenote that is part of the longest submerged cave system in the world, Sistema Sac Actun, located near Tulum.

Right: Matt placing tanks for a dive at Cenote Naharon, near Tulum.





Left: Fernanda Montiel, a shaman and Temazcalera, conducting a traditional ceremony at Cenote Senderos.

Right: Drone image of Mayan Blue south of Tulum.





Submerged caves are entered by divers through openings in the limestone bedrock. Around the world, these entrances may be called springs, karst windows, or cenotes, as we refer to them in Mexico. The origin of the word cenote is the Yucatec Maya word *ts'ónot*, which means “well with water.” While cenotes provide the only source of fresh water in the region, this simple definition fails to represent the importance of cenotes to the traditional indigenous cultures of the area. For the Maya, caves and cenotes were sacred spaces, considered to be openings to the underworld, or Xibalba. The Chacs, gods of rain, were believed to live deep in the cenotes, which became ideal spaces in which to make offerings and sacrifices to the gods. Archaeologists and divers have uncovered thousands of pots, stones, and other ritual objects in the cenotes of the Yucatán.

To gain a greater understanding of the spiritual importance of cenotes to some indigenous peoples from the area, Fernanda Montiel, a shaman and Temazcalera, spent a day with us at Cenote Guadalupe and Cenote Senderos to conduct a traditional ceremony. This was a powerful experience, captured in our upcoming documentary film about the project.

Beyond their extreme importance to the environment and the Maya people, cenotes are a fascinating and unique ecotourism attraction. Each year, thousands of people tour cenotes as part of their experience in the Riviera Maya, particularly to the south around Tulum.

For these visitors, cenotes are mostly used for snorkeling and swimming in the crystal-clear pools outside the caves. Recreational divers may also dive in the *cavern zone*, the area at the cave entrance where daylight still reaches. As divers proceed past the natural light zone into the area called the *cave zone*, diving is reserved for the small subset of divers with special training, certification, and equipment to safely navigate an environment with no natural illumination, and no direct path to the surface.

Once in the cave zone, only the lights divers carry allow them to observe and navigate farther. To shoot the photos in this book, we used more than half a dozen lights, outputting more than 60,000 lumen—the equivalent of 30 car headlights.

Because there is no sunlight in the cave, photosynthesis cannot take place to form the bottom of the food chain. Thus, the cave zone is a world with relatively few familiar plants and animals. Instead, caves have their own specialized and highly adapted life forms: plants, animals, and bacteria that can thrive with no natural light, and that can survive in this ultra-low-energy environment.





Left: Two divers swim through a big passage of the K'oox Baal Cave System after entering at Cenote Nai Tucha.

Center: The Blue Abyss, a significant dive in both distance and depth, which at 77 m (235 ft) is one of the deeper pits in the Yucatán Peninsula.

Right: Ancient pottery and bones in a cave south of Tulum.

Emerging from the caves, whether in Mayakoba or at the more populated cenotes around Tulum, divers often hear the question: “How deep is it?” Submerged caves can be quite deep in some parts of the world, such as in Mexico to the west of the Peninsula, or the Woodville Karst Plain north of Tallahassee Florida. There, vertical water depths may average nearly 100 m (330 ft), creating dives of extraordinary complexity. But in this part of Mexico, most caves are of moderate depth, typically between 5 and 25 m deep (15 to 85 ft), with just a few areas known as pits that can get much deeper.

But what caves in the Peninsula are missing in depth, is made up in length. The caves here are incredibly vast, such as Sistema Sac Actun, where the current recorded length of 369 km (229 mi) makes it Earth’s longest known underwater cave. Just south of Tulum, Sistema Ox Bel Ha, at 319 km (198 mi), is the world’s second longest explored underwater cave. Rather than being composed of a few single passageways, the caves in this region constitute a complex interconnected web of passages that spread out across the entire peninsula.

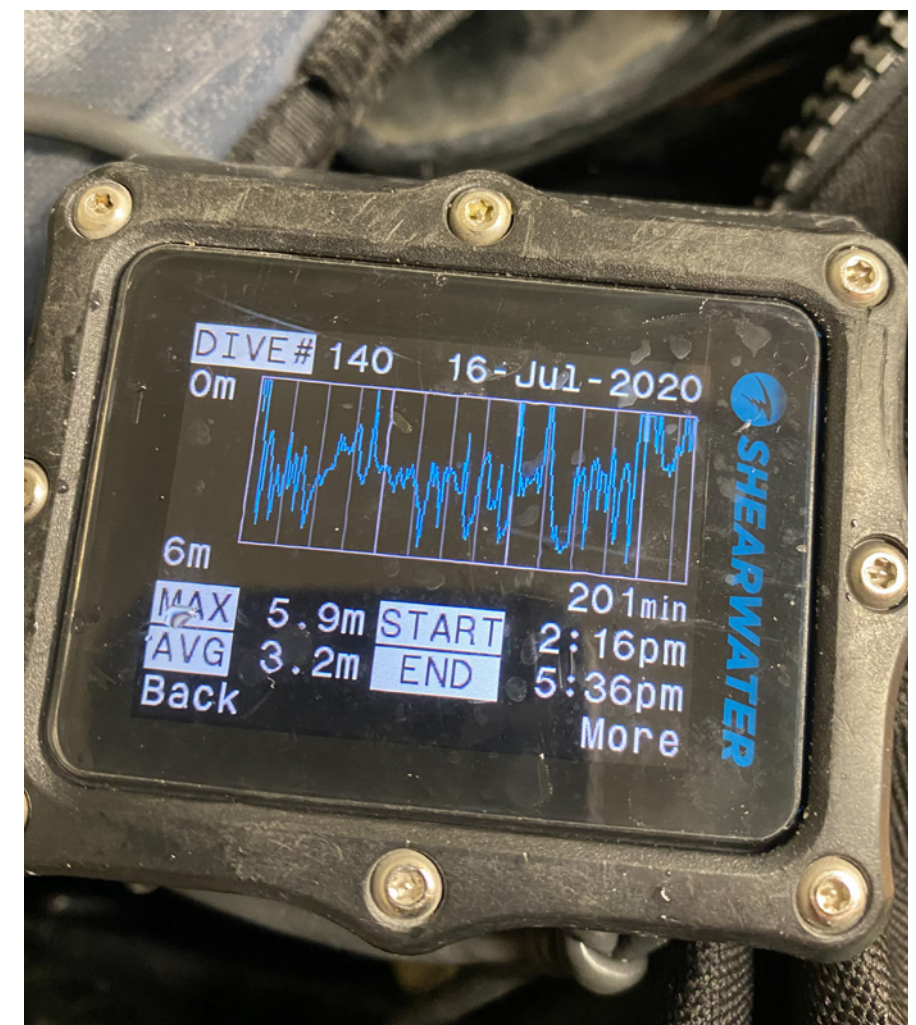
Most caves here have many cenote entrances, and traversing the entire distance of a cave in one dive is likely to be impossible. Working from known passages, divers explore new tunnels over time. This happens incrementally on successive dives, or astonishingly in just one dive where divers discover that two formerly “separate” systems connect through a common cave passage. When caves are “connected” in this way, the combined entity takes the name of the longer system, such as when exploration joined Sistema Dos Ojos to Sistema Sac Actun in 2018.

If you’ve seen a typical dry cave like Mammoth in Kentucky, Hang Son Doong in Vietnam, or Blue Grotto in Italy, you’ve seen an example of a decorated cave. Also called *speleothems*, these decorations are cave formations such as stalactites (the pointy extensions that hang from the ceiling) and stalagmites (those that extend from the floor), along with more exotic shapes like flowstone, helictites, and cave pearls. Cave formations are made primarily of calcite and develop over millions of years as mineral-rich water drips, flows, and pools in the cave, leaving behind condensed mineral formations in beautiful shapes that decorate the caves like crystal palaces.

Not all caves are decorated though. In fact, most submerged caves in Florida, another cave diving hotspot, are missing cave speleothems altogether. This is because formations cannot develop when caves are submerged in water, since mineral condensation can’t occur. Some Florida caves were probably once decorated, but the formations dissolved and eroded over many thousands of years.

Left: Dive computers help monitor depth, runtime, and decompression schedules.

Right: Ancient silt dunes near the third branched intersection (called a “T”) in Burrodromo.









Left: The caves at Mayakoba demonstrate remarkable porosity with layered limestone passages and frequent holes.

Top: Stalactites covered in helictites at Burrodromo. Helictites are delicate formations in which calcite grows away from the vertical plane that is encouraged by gravity. Helictites are likely caused by capillary forces but may also be encouraged by wind or the growth of bacteria.

Bottom: Ma' Áayin's rock formations could be striking. Here, a line placement is made on a rock with the imprinted shape of ancient corrals.



Most of the caves in coastal Yucatán are both flooded and highly decorated. How did this happen? The caves of the Yucatán Peninsula were dry in the last ice age, when the Earth was cooler and the sea level was lower, up until about 15,000 years ago. This dry period created a window in which cave formations were able to grow. But now that the ice caps have melted and the caves have flooded with water, the formations we see are likely all that will ever be created.

Because the caves here were dry in the last ice age, they provided shelter for the earliest humans in the Americas, who contended with many other animals that used the caves too. Now filled with water, the caves have become time capsules, preserving ancient history since they are sealed from weather, sunlight, and almost all visitors.

The earliest human remains ever found in North America were located in a submerged cave called Hoyo Negro, located about 60 km (37 mi) south of our project. One skeleton that explorers found was that of a teenage girl who died around 13,000 years ago, likely after she fell into what was then a deep, dry pit. They called her Naia, after the Greek water nymph, and found her alongside bones from distinct megafauna such as saber-toothed cats, an elephant-like animal called the gomphothere, and the short-faced cave bear.

While complete sets of human remains are relatively rare findings, cave divers regularly see charcoal from the ancient fire rings of early people, as well as impressive animal skeletons from mastodons, tapirs, and giant sloths.

Submerged caves can be filled with fresh water, salt water, or a layered combination of both. For example, caves in Florida's vast aquifer located in the north-central part of the state are nearly entirely fresh water, creating the springs that are famously used for bottled water. When caves exist closer to the ocean, saltwater intrusion occurs, and caves can be entirely saline, as in the sea caves called blue holes, in the Bahamas.

Left: A halocline at Ma' Áayin which separates the freshwater layer from the deeper saltwater layer below. This passage was a frequent area for photos owing to the wispy effect our light made when we illuminated the cave.

Right: A diver piercing a very highly defined halocline boundary. These types of haloclines completely obscure visibility while the diver swims through them.





Right: Matt and Ivo are ready for a dive at Chan Hol south of Tulum.

The caves in the Yucatán Peninsula of Mexico contain a freshwater layer that floats atop a saltwater layer. The saltwater layer starts roughly at a water depth of about 15 m (50 ft) in most coastal caves in the Yucatán Peninsula and goes deeper as the caves get farther from the ocean.

The boundary layer between the freshwater and saltwater layers is called the *halocline*, a part of the water column that creates several interesting effects. Descending upon it, one sees a river of saltwater flowing separately and at a different velocity from the static freshwater above. As you descend through the halocline, puncturing the invisible or slowly undulating boundary with your mask or outstretched hands, light is refracted at different wavelengths which scramble your vision, creating a blurred and strangely colorful experience.

The higher density of the saltwater layer causes a momentary bounce as you struggle to break through, exhaling deeply to counteract your increased buoyancy. With success, you are bathed in noticeably warmer water, and taste the salt as your eyes adjust to the bright iridescent blue and stunning water clarity. Below the halocline, the highly decorated cave formations disappear, changing to pure limestone that may appear like a scalloped tube or an intricate matrix that can conjure what it must feel like to be inside the ribcage of a giant dinosaur skeleton. ♦



