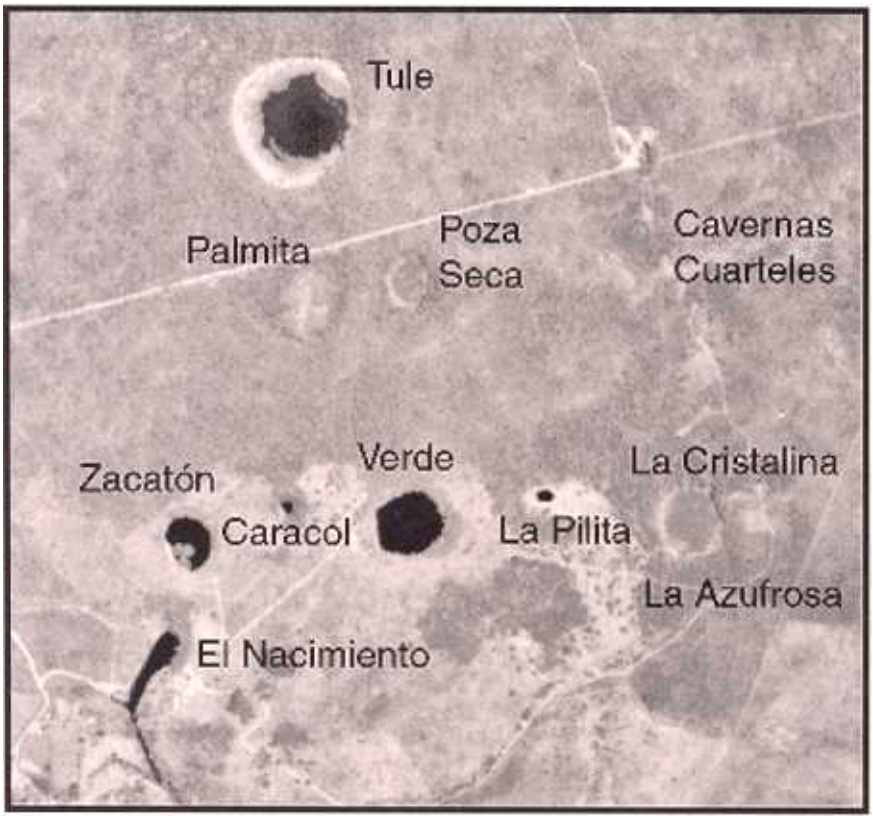
LOS CENOTES DE RANCHO LA AZUFROSA

Marcus Gary

My first visit to Rancho La Azufrosa, Tamaulipas, seven years ago was a time I'll never forget. Jim Bowden and Sheck Exley were preparing to try to reach the bottom of Zacatón, possibly the deepest water-filled pit in the world. Ann Kristovich, Karen Hohle, Mary Ellen Eckhoff, and I made up the support team. (See *AMCS Activities Newsletter* 21.) Diving in the incredible cenotes on the ranch amazed me every time I ventured into their waters. The curiosity I developed that first month at Azufrosa has had a great influence on my life ever since.

The Proyecto de Buceo Espeleológico México y America Central is a small group of explorers that continues to work in the area. Most recently, expeditions have focused on scientific research aimed at describing the incredible karst features at the ranch. This line of hydrothermal springs and pools displays characteristics of a hypogenic karst system, one that forms when deep groundwater is the agent for rapid rock dissolution. Their location is unique, stemming from a combination of geologic conditions that has provided the perfect setting for the formation of deep pits. Karstification processes continue today, as water strips away the limestone and redeposits the material in the form of massive travertine formations. Four expeditions since January 2000 have been intended primarily to collect data to support theories on the speleogenesis of Zacatón and the surrounding cenotes.

The Cenotes de Rancho La Azufrosa, from an aerial photograph by INEGI.



After celebrating the new millennium in Xilitla at Las Pozas, the Birdhouse, with a multitude of other cavers, I joined the rest of our team in camp at Rancho La Azufrosa. The January 2000 group included Jim Bowden, Ann Kristovich, Karen Hohle, Liz Hunt, and Mellie Price. We spent six days on the ranch diving, collecting water data, and searching for undocumented karst features. Most of the diving on this trip was done at La Pilita, a 110-meter-deep cenote on the ranch. The shore of this water-filled pit is also the site of our camp on all expeditions. Warm, 88-degree F water made for wonderful swimming in the cool winter temperatures experienced during the week. Bowden, Kristovich, and Hunt all made deep dives here, reaching the bottom several times. These were primarily training dives intended to build up nitrogen-narcosis tolerance.

One day was spent diving into Zacatón, but water conditions were less than ideal. Visibility in Pasaje de la Tortuga Muerta, which leads to the deep cenote, was less than three meters. Bowden and

Kristovich dove through the cave and surfaced in Zacatón. There, they discovered visibility to be poor, but they still made a dive to 85 meters depth. On their return trip through the Tortuga Muerta passage, dive lines were removed for safety reasons.

Basic water-quality parameters were collected at Rancho La Azufrosa during a two-day period, using a Hydrolab multiprobe instrument. This is a versatile piece of equipment that can be used in a wide range of conditions, and it proved ideal for data collection in the cenotes. Readings were taken at all of the major cenotes—Zacatón, Caracol, Poza Verde, La Pilita, La Azufrosa, and Cristalina—as well as the resurgence from Zacatón, El Nacimiento. The measurements confirmed that the water in all but Verde is acidic and substantially warm. The lack of dissolved oxygen in the acidic waters was also seen in this first set of data.

On a reconnaissance trip in the northern part of the ranch, our team discovered a new large cenote, but this one had a solid travertine floor. Karen Hohle and her husky Mante found the sinkhole after dodging a rotting goat corpse. Since we had no idea what the local name of the feature was, we temporarily called it Cabra Muerta. Later, we discovered the true name was Poza Seco, or Dry Well. It truly is a dry well, as only a small pool of water less than a meter in diameter exists here. Liz Hunt and I later returned to collect information on the water in the cenote, and as we walked across the flat floor around the perimeter, it sounded hollow, with a thumping sound.

In March 2000, our team returned to Rancho La Azufrosa with some new faces. Four cavers from the University of Texas Grotto joined Bowden, Kristovich, and me to help with the work here. Aimee Beveridge, Andy Grubbs, Robin Havens, and David Turner were primarily interested in surveying the dry cave passages that are nearby. Cavernas Cuarteles lies in the northeastern corner of the ranch and is a relatively level series of rooms and tunnels, frequently interrupted by skylights. After three days of surveying, over 700 meters of passage had been surveyed in Cuarteles. Huge collapsed rooms where *higueron* trees grow up through the openings characterize the upstream portion of the cave. Downstream the cave gradually narrows, although it was still walking passage as far as the survey went during this trip.

Cavernas Cuarteles appears to be heading directly toward La Cristalina, a crystal-clear pool along the edge of Cenote Azufrosa. La Cristalina was dived by Bowden and Gary Walten in 1990, but the passage soon closed to small dimensions that limited exploration to only 50 meters. It seems quite likely that La Cristalina is a discharge feature of a shallow groundwater system that incorporates Cavernas Cuarteles.

Marcus Gary collecting water-chemistry data at Caracol with a Hydrolab multiprobe. *Robin Havens.*

While surveying was being conducted in Cuarteles, Bowden, Kristovich, and I made preparations for a deep dive in Zacatón. Jim planned a dive in the 170-to-200-meter-depth range, since conditions looked much better than they had during the previous trip. Two days were spent in camp at La Pilita configuring gear, running decompression tables, and making acclimation dives to 100 meters.

On our third full day, equipment was ready to transport to Zacatón. Ann and I dove through the Pasaje de la Tortuga Muerta and surfaced in Zacatón. Jim lowered his stage bottles from atop the 20-meter cliff that separates the water from the land surface. Grubbs and Turner assisted him, while Beveridge and Havens helped with gear transfers on the water surface, paddling a kayak that had been lowered into the pit past a massive killer-bee hive. Luckily, only one bee sting was experienced, and we were able to ready all the diving equipment. A down-line was dropped past a depth of 200 meters, and then Ann and I placed decompression stage bottles down the line at various depths for Bowden to use the next day on his deep dive.

With everything in place, Bowden made a deep, mixed-gas dive into Zacatón the next day. He made it to –170 meters, where observations of the rock walls were made. No problems occurred during decompression, and Jim surfaced after being underwater just less than four hours.

The final day was spent breaking down equipment in camp and collecting water-chemistry data. Andy Grubbs and I made measurements

The flat travertine floor of Poza Seca is densely covered with an *acacia* shrub. *Marcus Gary.*

Large *higueron* trees near the entrance to Cavernas Cuarteles. *Robin Havens.*

with a Hydrolab minisonde at Zacatón, Caracol, Verde, and Azufrosa. Data were collected at intervals of 10 meters depth, and a bottom was reached at all locations except Zacatón, where we reached the instrument's limits at 200 meters depth. These measurements revealed that the waters of Zacatón and Caracol are primarily homogeneous, with only a thin surface layer showing any difference from the rest of the water column. Except at the surface, virtually no dissolved oxygen is present, the temperatures are constant (29°C at Zacatón and 30°C at Caracol), and pH is a slightly acidic 6.9.

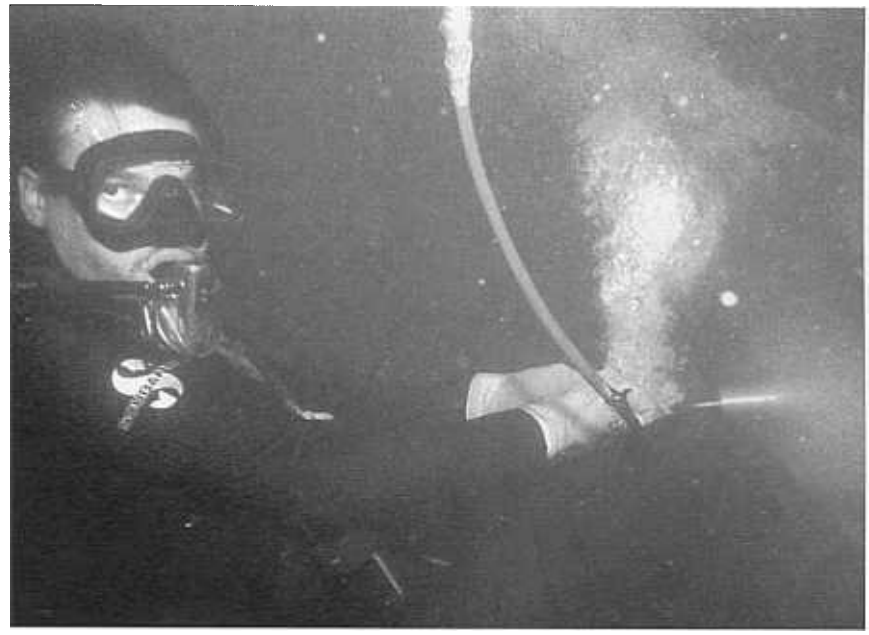
Verde is substantially different, much more like a typical body of water. Significant changes are encountered, as dissolved oxygen is quite high at the surface and gradually decreases with depth. Small thermoclines are encountered, and the pH is a much more basic 7.6. Azufrosa proved to be the warmest cenote, even though it is only a small pool 1 meter deep. Like at Zacatón and Caracol, the water is acidic and anoxic, and it has a strong odor of sulfur. La Pilita was measured the next day, as we were packing up camp. The water there is most similar to Zacatón and Caracol, being homogeneous from the surface to the bottom at –114 meters.

Following a series of last-minute changes of plans, a small team made it to Rancho La Azufrosa in January 2001. Jean "Creature" Krejca, Vivian Loftin, Robin Havens, and I arrived at the ranch ready to get to work. Since Creature and Viv would be able to stay only a few days and they had hauled most of the tanks and compressor, we decided to do most of our diving at the beginning of the trip. One of my primary objectives on this trip was to collect some underwater core samples of the travertine surrounding La Pilita. This process involves using a drill powered by air from scuba tanks to turn a diamond-tipped coring bit that is 5 centimeters in diameter and 50 centimeters long. Two cores were drilled, one at 1 meter and one at 6 meters, and successfully recovered.

The first week was unseasonably cool, so the four of us took a day out of the water to return to Cavernas Cuarteles. Here we completed the survey, adding another 260 meters. At the end of the surveyed passage, one more room remains unexplored because it was inhabited by thousand of free-tail bats, making the air quality very poor. During the survey, the positions of the skylights in Cuarteles were determined from above using a Garmin GPS receiver.

More diving was done the next day, as Krejca and I swam into Zacatón through the Pasaje de la Tortuga Muerta. Once there, we observed the colorful biomats that coat the walls of this massive sinkhole. After returning back through

Marcus Gary drillling cores in the travertine surrounding La Pilita. *Robin Havens.*



the passage, we met Havens and Loftin, who had been diving in the basin and entrance of the resurgence.

Creature and Viv returned to Texas the next day, leaving only Robin and me. For such a small team, we were able to get a lot accomplished in the next eight days. One of our first tasks was to collect GPS data on all the important karst features. The perimeters of each of the cenotes were traced, either on foot on by kayak, and GPS positions were collected at 10-meter intervals. This information is important for creating accurate digital maps. These maps can then be used with other information, such as satellite imagery, that is referenced to geographical coordinates. The gathering of the GPS data was spread over the rest of the trip.

One day the resident ranch hand, Nacho, gave us a tour of the entire 37,000-hectare ranch on horseback. During a day in the saddle, many new discoveries were made. A beautiful *ciénega*, or wetland, lies on the southern part of the ranch. Here, crystal-clear springs emerge from old travertine deposits, and the water flows into broad swamps filled with many species of waterfowl. One of the springs seemed a promising dive site, since there was a substantial volume of water flowing from a cave entrance. We noted its location and continued on our equestrian tour.

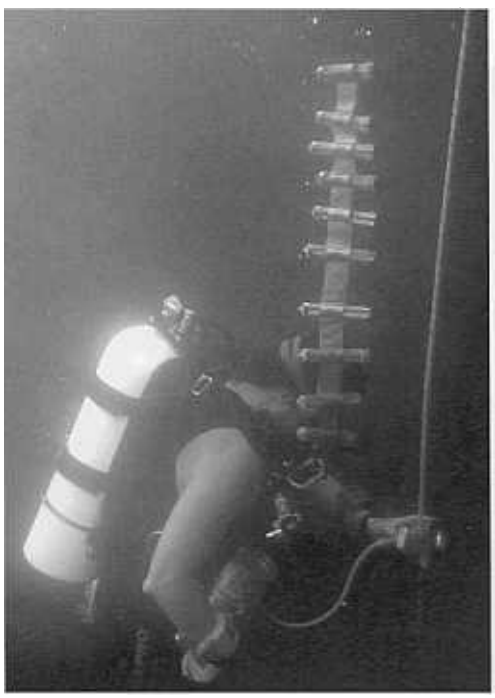
The next major event of the day was a visit to Cenote Tule, which lies on the ranch directly north of Rancho La Azufrosa. Nacho led us over the fence and down a trail to the largest sinkhole, in surface area, that I have ever seen. A huge fortress of spiked acacia shrubs and dense reeds surrounds the large body of water in the center, however. We chopped our way around the northern perimeter of the cenote until the vegetation got so thick it was virtually impassible. It was time to turn around and get the horses back to the ranch anyway, so we headed back.

Marcus Gary surveying at the entrance to Caverna Travertina. *Robin Havens.*

The next day, we returned to the spring at the *ciénega* with some diving gear. Unfortunately, Creature and Viv had left with most of the tanks, and there was only 450 pounds pressure left in one of my tanks. But it was enough to get in a dive in the entrance. Here, the ceiling and floors were nothing but massive travertine structures of stalactites, stalagmites, and flowstone. The walls pinched off 15 meters back into cracks that I could not pass with my back-mounted tank. I went out and let Robin go in for a brief look. The visibility had remained quite good even with our swimming around in the tight room, so I looked forward to returning with side-mounted tanks to explore a little more thoroughly.

The last few days of this trip were spent collecting water samples and taking field measurements at each of the cenotes. Samples were later analyzed in the lab for major dissolved elements. The level of dissolved sulfide in the water was also measured in the field. Azufrosa, 0.36 parts per million, and Caracol, 1.02 ppm, were the only two that had levels within our detection range.

Ann Kristovich collecting water samples for sulfide analysis at La Pilita. *Marcus Gary.*



Two months later, in March 2001, I returned to Rancho La Azufrosa with Robin Havens, Jim Bowden, Ann Kristovich, and Karen Hohle. We spent a relatively relaxed five days diving and collecting data. One of the main accomplishments during the week was acquiring vertical sulfide concentration profiles in Caracol and La Pilita. Caracol showed a peak concentration at –60 meters, and sulfide was not detected in La Pilita down to –70 meters, which was as deep as the water was sampled. Although we did not measure sulfide at La Pilita, the smell of rotten eggs at the surface is a good indication that hydrogen sulfide is being outgassed. A higher-resolution instrument will be needed to quantify the level of dissolved sulfur here.

I returned to Caverna Travertina

with small side-mounted tanks to see if any passages existed in the tight cracks of this spring. The flow was much lower than earlier in the year, and a layer of fine silt had collected on the floor of the cave. We had planned to photograph the entrance room, taking advantage of the crystal-clear water, but the easily stirred up silt thwarted that. Diving alone, I squeezed through the travertine formations that make up the entire floor and ceiling. Ahead of me, water clarity was good, with visibility of 1 to 2 meters, and I noticed large turtles flashing by every now and then. Finding a gap in the flowstone formations, I pushed into a domed room about 2 meters in diameter. There, all the turtles that had been buzzing me were huddled together, hovering at the back of the room. When my bright dive-light illuminated them, they scattered and started to swim out in a frenzy. Unfortunately, I was blocking the exit. Only a small space above my head was open, and they aimed for that area. It was a good thing I was wearing a helmet, for more than one of the turtles smacked squarely into my head and violently clawed its way by. I checked out the now-vacated room and saw no passages. No leads were observed anywhere in the cave, and a complete survey will be conducted during higher flow, when visibility is good.

Later in the trip, Kristovich and Bowden dove through El Pasaje de la Tortuga Muerta into Zacatón and made a dive there to 85 meters depth. The goal of this dive was to determine the extent of the biological mats that cover the walls there. The algae and bacteria that make up this biomat appear to be phototropic, as the walls were devoid of coating below –35 meters.

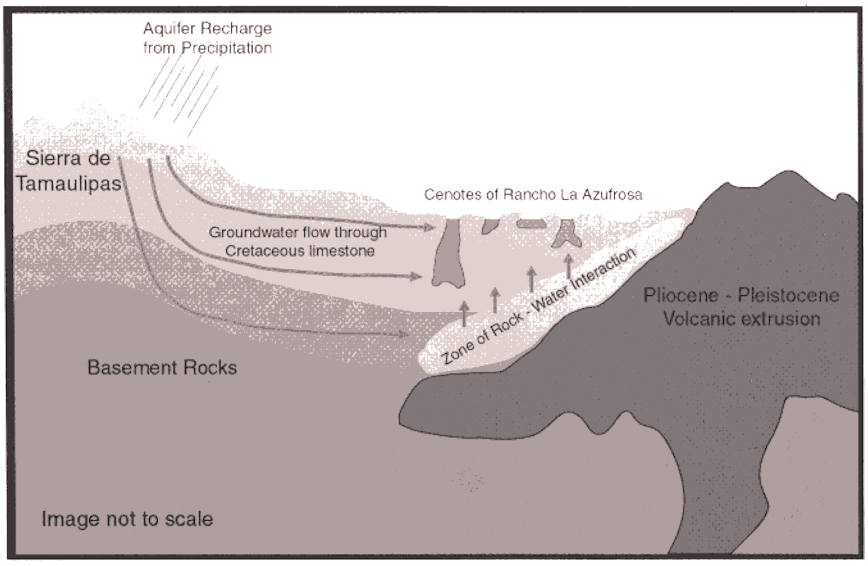
On the way back to Texas, Havens and I stopped in Ciudad Victoria and picked up some aerial photographs at the IENGI office. On them, six unexplored water-filled cenotes and four new travertine-filled cenotes in our area were identified. Of the water-filled group, Tule looks like a promising dive site. A dark, deep area is apparent in the center of this largest sinkhole. Many days of challenging logistics at Tule will test our team's ingenuity and stamina before we will be able to explore its depths.

Robin Havens checking out the *ciénega* at the southern edge of Rancho La Azufrosa. *Marcus Gary.*

The geologic history around Rancho La Azufrosa is favorable for deep-seated karstification. Thick beds of limestone were deposited during the late Cretaceous, when the Gulf of Mexico covered the area. Following aerial exposure and lithification, these limestone beds were uplifted during the Laramide Orogeny, about forty million years ago, forming the Tamaulipas Arch, a 200-kilometer-long domal anticline that makes up the Sierra de Tamaulipas. The axis of this structure is immediately west of Rancho La Azufrosa. By the late Oligocene, volcanic intrusions began to dissect the Sierra de Tamaulipas. Then the extensive volcanic field around Villa Aldama became active in the late Pliocene, producing basaltic lava flows throughout most of the Pleistocene. During this period of volcanism, thick deposits of travertine were deposited from springs discharging hot, mineralized water.

These conditions have allowed meteoric groundwater to mix with the rock in the Villa Aldama volcanic intrusion, resulting in deep-seated hypogenic karst. The resulting massive collapse structures are nearly circular and lie together within a fairly small area. The cenotes are among the eighteen circular karst features that have been identified in a 7-kilometer distance. Of these sinkholes, eight have evolved into shallow dolines that have floors of travertine. The closed cenotes were once deep, open sinkholes that were most likely water-filled. A shift in the local geochemistry as volcanic activity cooled down caused precipitation of calcite in the form of thick deposits of travertine. These travertine-filled sinkholes are now densely covered with vegetation, which is often flooded during the rainy season.

The karstification processes taking place at the active cenotes includes the action of microbes that may be



processing dissolved sulfide in the water to produce a hyper-acidic zone along the walls. Initial field and laboratory data indicate that these biocoatings may, in fact, contain sulfur-oxidizing bacteria capable of producing sulfuric acid, which then dissolves the limestone host rock. A much more thorough analysis will be required to verify this hypothesis.

Some of the individuals and organizations that have played a critical role in these early stages of research at Rancho La Azufrosa are Jim Bowden, Ann Kristovich, Alejandro Davila, Robin Havens, Becky Sikes, Hydrolab Corporation, Austin Aquasports, and Jack Sharp at the University of Texas Department of Geological Sciences.

Los Cenotes del Rancho La Azufrosa

Desde enero de 2000, el autor ha estudiado la geología y la química de las aguas de estos profundos cenotes en Tamaulipas. El agua es termal y sulfurosa. El diagrama muestra la temperatura, pH y nivel de oxígeno disuelto en los cenotes. Algunos de los cenotes presentan pisos formados por depósitos masivos de travertino. Se piensa que la naturaleza agresiva del agua en estas grandes formas kársticas es debida a la reacción entre las aguas pluviales y rocas volcánicas relatívamente recientes de Villa Aldama. Algunos de los cenotes presentan áreas cubiertas por grandes masas de materia orgánica en las paredes, que pueden incluir bacterias que oxidan el azufre, produciendo ácido que acelera la disolución. Caverna Cuartéles, una cueva fósil en el rancho, presenta muchas claraboyas y tiene cerca de 1 km de largo.

Cenotes of the Riviera Maya. Steve Gerrard. Published by the author, Puerto Aventuras, Quintana Roo, Mexico; 2000. 8.5 by 11 inches, 244 pages, softbound. ISBN 0-9677412-0-3. $49. May be ordered from Riviera Maya, PO Box 768, Placida, Florida 33946; add $4.95 for U. S. shipping, $14.95 outside the U. S.

The short stretch of Quintana Roo's Caribbean coast south of Cozumel, through Akumal and Tulum, is turning out to be one of the most cavernous areas on earth. Virtually all the cave passage in the area is under water, but that has not prevented the exploration and survey of some 350 kilometers of cave, including three systems more than 55 kilometers long. It is hard to keep up with the actual lengths, because it is not uncommon for a project in the area to survey a mile of virgin cave a day. (One suspects, though, that the sketches aren't too wonderful.) Much of the cave passage is well decorated by speleothems deposited when water levels were lower during the ice ages.

This book is a visitors' guide to the caves and their cenote entrances. The descriptions of the sixty-odd caves or cave systems and their many entrances are in outline form, with at most brief descriptions and no cave maps, but the information includes locations and access policies. The book also contains sections on safety and training, as well as analyses of the known cave-diving accidents in Quintana Roo. Probably most attractive to the non-diving caver are the numerous nice color photographs, about one per page, with many full-page or larger. Some cavers may be a bit put off by the fact that the book is obviously intended to promote recreational cave diving in the area, which has hotels, dive shops, guides, and instructors catering to the cave-diving trade. But the cave-diving community, unlike ordinary, dry caving in North America, has a long tradition of professional training, which has significantly reduced the fatality rate, and other commercial involvement.

Not cheap, but worth it for the beautifully illustrated introduction to a spectacular and unusual caving area.—*Bill Mixon*