PRELIMINARY INVESTIGATIONS IN ANCHIALINE CAVES OF CUBA

Jeffrey Bozanic
1 Island Caves Research Center, Inc.
5385 Sandlake, Melbourne, FL 32934

A series of scuba dives conducted in fifteen anchialine caves in two distinct regions of Cuba in September 1992 resulted in the collection of a new gastropod species, a new Remipedia (Crustacea) species, as well as other cave adapted organisms. Caves in the extreme west area of Cuba were Aston type collapses similar to the sinkholes of Florida and blue holes of the Bahamas, while those in the Bay of Pigs area were slumping fracture cracks like those on Andros Island. In conjunction with the scientific studies, Cuban cave diving researchers were assisted with equipment development and evaluation, and with training in techniques utilized by American cave divers.

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During the symposium, one day was taken to travel to Maria de Gorda to conduct an evaluation of the caves in that vicinity. Three American divers were joined by two Cuban cave divers for the three hour drive from Vignales to the western shore of Cuba. Three dives were conducted in two sites in this area.

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Diving for Science...1993

the Yucatan peninsula (Yager, 1987b). Because of similarities in the geology and geographic location of Cuba, we expected to find them in Cuba as well. Nineteen dives in nine sites were conducted in Bay of Pigs caves.

Logistics

Infrastructure: As the exchange of currency in Cuba is restricted by the government of the United States, ICRC participants were required to obtain visas from the Department of State to attend the sessions. Scientists conducting or involved in professional activities are eligible for such visas upon demonstration of need. Permission was eventually granted, with the necessary paperwork arriving less than twenty-four hours before departure. All applications were handled by Marazul Tours, the travel agency authorized to organize the excursions.

Due to the poor economy in Cuba, the availability of commercial electricity for charging batteries was uncertain. In Vignales, where the conference was held, the community reportedly has only four hours a week of electricity commercially available. Conducting effective research while cave diving requires adequate lighting, so the ability to recharge the high capacity batteries is critical.

Gasoline is a rationed commodity in Cuba. This limited travel within the country, and prevented the team from investigating several sites which, based on the information available, had high potential for significant biological findings. Due to the rationing, some sites were accessed on foot (distances up to 4 kilometers), and others were visited by bicycle (distances to 15 kilometers). In these cases standard equipment configurations were altered to make the mode of travel viable.

Diving Equipment: The availability of scuba equipment and extent of supporting infrastructure in Cuba was unknown before the group left the United States. To save on excess baggage fees ($2.00 per pound for each pound over 44 pounds, including carry-on baggage) the divers carried only three sets of cave diving equipment, plus their personal wetsuits, masks, and fins. This meant that everyone shared major equipment, and were not able to dive simultaneously.

The cylinders used in Cuba are all equipped with DIN fittings, so the team used compatible Poseidon and Sherwood regulators. The tanks were configured as dual singles on standard backplates, negating the need to install dual valve manifolds. This also saved weight for the plane flight, and provided an additional level of redundancy should an air system failure occur.

Because of concerns about availability of 120-volt alternating current, several 7.2-volt wet cell nicad lighting systems were carried. These batteries can be charged from any available 12-volt automobiles, and thus provided a level of flexibility otherwise unavailable. Three Dive Rite Manufacturing Star Bright 12-volt lights, which recharge from 120 volt alternating current or 12-volt automobile systems, were also utilized.

Aladin Pro (50% of all dives) and Parkway (15%) dive computers and US Navy dive tables (35%) were used to regulate dive profiles.

Biological Sampling and Data Collection: Swimming crustaceans, including amphipods, remipeds, and shrimp, were collected using Sket bottles and plastic bags. Hand towed plankton nets were utilized to collect copepods, mysids, and planktonic organisms. Fish were collected by hand with plastic bags. Gastropods and sessile organisms, such as clams and mussels, were hand sampled. Bacteria colonies suspended in the water column were collected using plastic bags. Information on general collection
techniques is described by Bozanic (1985).

Yellow Springs Instruments (YSI) of Yellow Springs, Ohio provided a prototype
device which would record salinity, conductivity, dissolved oxygen, redox potential,
temperature, and depth throughout the dives on which it was carried. The information
was later uploaded into an IBM-compatible personal computer for analysis. The unit itself
was a cylinder about 15 cm in diameter, and approximately 60 cm long. It was carried by
the divers on the back of the cylinders, nestled in the hollow between the two tanks.
This was the first time this instrument has been carried by scuba divers, and YSI was
provided with an evaluation of its performance and problems experienced. Salinity
measurements were checked using a temperature corrected refractometer, and dissolved
oxygen values were confirmed in situ using Chemetrix indicator ampules.

Underwater photography was accomplished using Nikonos cameras and Ikelite
strobes. Only a limited amount of underwater photography was conducted because of
the nature of the excursions.

Site Descriptions and Findings

The following is a brief summary of the caves examined by the group, along with a site
description and collections. The caves are organized by the two regions of Cuba in
which they exist. Maximum cave depths observed (in meters of sea water (msw) and feet
of sea water (fsw)), salinities (in parts per thousand (o/oo)), and depths of density
interfaces (D1)/haloclines (fsw) are summarized in Table 1.

Maria de Gorda Caves

Pozo de Juan Claro--This cave is located at the shoreline, about 20 km north of
the Maria la Gorda resort on the Gulf of Guanahacabibes. It is a fairly typical reversing
current blue hole, like those described by Williams (1978). The blue hole empties into a
small lagoon which is connected to the sea via a small ria. This cave was accessed during
the excurrent cycle, to maximize diver safety. The site had been previously explored by
a French Expedition in 1991. Maximum penetration was about 200 meters. One species
of white shrimp, currently unidentified, was collected. The cave was biologically very
sterile in comparison to undisturbed ocean blue holes in the Bahamas. To the south
another smaller surface boil was sighted, but not investigated.

Pozo Azul--This cave is located about a 4 km walk from the village of
Guana. It is a typical Aston-collapse type sinkhole with expected bellshaped walls and
breakdown pile in the center, as described in Zumrick, et al (1988). The surface pool was
about 100 m in diameter. Entry was a 6 m giant stride into the water. Collections
included the blind cave fish Lucifuga dentatus, cave adapted shrimp Troglocubanus sp.,
another as yet unidentified shrimp, copepods, planarians, sponges, and cirrolanid
isopods. All collections were made in diffuse light from the surface, as no lightless
passages were found.

Bay of Pigs Caves

All of the remaining dive sites were on the eastern side of the Bay of
Pigs. With the exception of Caleta Buena, geomorphically they all appear to be slumping
fracture cracks comparable to those seen on Andros Island (Palmer and Williams, 1984).
They are oriented approximately parallel to the shoreline. Typical expression of the cave
is a completely submerged, extremely tall (often 60 meters) and narrow (1-3 meters) wide
crack which extends sometimes for several hundred meters in either direction from the surface pool. The surface pools were generally linear ponds where the crack was open at its ceiling. Elevations were typically 0.5 to 4 m above water level. Visibility ranged from zero to over a hundred meters. Murky sediments were common, as were hydrogen sulfide (H2S) layers and soft bottom silts. The walls were usually very durable, and often were coated with flowstone. Drapery and other speleothems were seen in many of the caves. Boulders wedged in the cracks, and areas where the crack narrowed to the point where a diver could not pass made these a two-dimensional maze oriented perpendicular to the Earth's surface. Water temperatures ranged from about 25-28°C.

Ilona Cave--Collected two species of shrimp, amphipods, copepods. An American bomb from the Bay of Pigs invasion lies at 40 fsw.

Cueva XXXV Anniversario--High densities of Eliotris (a type of fish commonly found in anchialine caves) in the surface pool, and an unidentified shrimp were found in the cave. In some cases there were in excess of 20 shrimp per square meter of wall. Collected Eliotris sp., shrimp (four different species), mussels, sea stars, a form of Cyclostrearna (a small snail) as yet undescribed (Cosman, 1993), and rock boring clams. A new species of land snail was also collected from inside the cave, which is currently waiting description (Cosman, 1993). Walls were highly decorated with flowstone.

Casimba el Brinco--This cave is the only one seen in this area which had an aerial expression of the slumping fracture crack, with the sides of the crack extending about five meters above the water level. The entry is from a cement platform in a small cavern, formed by these walls, and is a two meter jump into water 60 m deep. Visibility in this system is in excess of 100 m. The entire east side of the cave is an intact fossil reef, complete with corals, sponges, etc., which has been left behind after the surrounding matrix was preferentially dissolved away. Flowstone coats the other side of the cave. This cave has significant potential for further paleontological and geological research, but is extremely prone to damage by careless dives as described by Bozanic (1992). Collected mysids, copepods, an eyed cirrolanid isopod, and three species of shrimp, including one Macrobrachium.

Casimba Susanna--The surface water layer is a greenish, tannic water with 1 m visibility. The 3-6 m (10-20 ft) layer is a very red tannic layer. The 6-15 m (20-50 ft) layer contains clouds of dissolved H2S, dissolved O2 levels exceeding 1 ppm, colonial bacteria suspended in the water column, and numerous shrimp in clear water. The deepest layer has about 15-m visibility, with lower dissolved O2 levels (<0.05 ppm). Collected bacteria, shrimp, thermosbaenaceans, and Lucifuga dentatus. Cave extends in excess of 100 m in both directions.

Laguna Larga--Large lake, with several small caverns. Two caverns too small for a diver to enter. One additional cavern has a 12 m tunnel extending from the end. Large breakdown blocks line the bottom. It might be possible to find going passage under some of this breakdown, given sufficient effort. Low visibility H2S water layer seen at deepest point in lake.

Humo--Cave extends about 40 m in at 294°, and 50 m at 108° (the other side of the pool). H2S layer at 12 msw (41 fsw). The top of the talus mound was at 22.5 msw (75 fsw) in surface pool, with the floor extending to greater than 40 msw (120 fsw) in the southeast passage. Collected shrimp (three species), cirrolanid isopods, medusae, copepods, hadziid amphipods, copepods, and thermosbaenaceans.

Casimba Juan Jose--A shallow, muddy collapse with no going passage. Located near the Caleta Buena Restaurant.

Tarpon Cave--Another small collapse northeast of Casimba Juan Jose. Two 50 cm
Bozanic: Preliminary Investigations in Anchialine Caves of Cuba

tarpon seen. No significant cave passage seen, although a small possibility exists that passage could be found in this site.

Caleta Buena--This cave is anomalous for this region, as it is not a slumping fracture type cave. This cave resembles those of the Yucatan Peninsula and Cozumel (Bozanic, 1984), in which a continuous excurrent emerges from a low oval passage (1.5 m high by 2 m wide). In the Yucatan caves, the lower water layer is typically marine, the flow of which tidally reverses. While only a cursory examination of this cave was made, this appeared to be true in this site as well. According to the Cuban divers, the cave extends approximately 150 m from the entrance before becoming too small for divers to pass (Nieto, 1992).

Cueva del Trueno--This was the first time this cave had been dove using scuba, according to the Cubans. The water has extremely high H2S concentrations at depths of 6-20 msw (21-67 fsw). The dive was turned based on planned bottom time at a talus mound which might indicate another surface opening, at a penetration distance of 170 m in going passage. Visibility about one meter. Collected one mysid.

Lacrina de Catalina--A very small (2 x 5 m) pool clogged with trees, trash, electrical cable, fishing line, etc. Cave could be seen to go at least another three meters deeper than penetratable by a diver. It is possible that it could be cleaned out, resulting in a diveable site. Located about 150 m behind a group of houses in a community called Giron. Visibility about three meters.

Cueva de los Carboneros--Clear water (50 m visibility), with a new species of remipede found swimming in sight of daylight. This new remipede closely resembles Speleonectes lucayensis (Yager, 1993), but has not yet been described. Also collected were thermosbaenaceans, copepods, blind cave fish, and shrimp. Almost all of the cave animals were found immediately below the 12 m (40 ft) halocline. Large quantities of mung in the cave. Visibility dropped to less than 1 m as a result of bubbles disturbing sediment and bacterial colonies on the roof. Going passage in both directions, explored to distances of about 150 m in each direction.

Cueva 1900--This opening is located in the middle of a swamp, about 200 m from the nearest solid ground and 500 m from Cueva de los Carboneros.

The area consists of a dense growth of mangroves, ferns, and plant life, all growing in water a few centimeters deep. Walking to the site requires wading through mud which is usually ankle to calf deep, and occasionally knee deep. The surface pool appears like any other place in the swamp, except instead of being knee deep the water was 5 m deep. The opening is just larger than one meter in diameter, with the walls and bottom consisting of mud and peat. As there was no solid place to tie off the guideline, it was "secured" to base of three individual ferns. A solid tie was obtained at a depth of 4.5 msw (15 fsw), out of sight of surface light. Water was red in color from tannin on the surface, with visibility of about one meter. There was a weak H2S layer at 10 msw (30 fsw). Remipedes and thermosbaenaceans were found at depths of 18-21 msw (60-70 fsw) and 13-22.5 msw (42-75 fsw) respectively. The cave only goes in one direction, but it may be possible to dig out the other side. We limited the maximum depth to 27 msw (89 fsw) (because of residual nitrogen from previous dives), but could see a minimum of 18 m downward from that point, yielding a maximum depth in excess of 45 msw (150 fsw). As this dive was conducted literally minutes before the group left for Havana to return to the United States, it was not possible to conduct further exploratory dives in this cave.
Table 1--Summary of Salinities and Density Interfaces (DI) of water strata in caves: Asterisks (*) denote data which was not collected, dashes (--) denote information not applicable to that cave.

<table>
<thead>
<tr>
<th>Water Strata (right)</th>
<th>#1 Max Depth</th>
<th>Shallow</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5 Deep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cave Name (below)</td>
<td>fsw $\theta_{100}$</td>
<td>DI</td>
<td>fsw $\theta_{100}$</td>
<td>DI</td>
<td>fsw $\theta_{100}$</td>
</tr>
<tr>
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<td>11.6 38</td>
<td>37</td>
<td>10</td>
<td>37</td>
<td>22.9</td>
<td>4.5</td>
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<td>9.1</td>
<td>1.5</td>
<td>22.9</td>
<td>4.5</td>
<td>28</td>
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<td>1.8</td>
<td>32</td>
<td>37</td>
<td>35</td>
<td>21.3</td>
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<tr>
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<td>66.7 4.5</td>
<td>9.1</td>
<td>37</td>
<td>35</td>
<td>15.2</td>
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<td>12.2</td>
<td>35</td>
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<tr>
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<td>6.1</td>
<td>35</td>
<td>15.2</td>
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<td>*</td>
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<tr>
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<td>14 4</td>
<td>14</td>
<td>*</td>
<td>12.5</td>
<td>37</td>
<td>37</td>
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<tr>
<td>Humo</td>
<td>33.8 2</td>
<td>3.7</td>
<td>*</td>
<td>12.5</td>
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<td>*</td>
<td>12.5</td>
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<tr>
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<td>20.4 *</td>
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<td>*</td>
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DISCUSSION

One of the reasons ICRC personnel were invited to attend the symposium was to assist with the development of scientific cave diving within Cuba. This effort proceeded along two major avenues. First, several lecture style presentations were made as part of a workshop session on underwater speleology. These included presentations on techniques, equipment, and philosophies, and eventually lead to several informal practical training sessions in the pool of the hotel in which the conferees were housed. Second, several teams of Cuban cave divers participated in the research dives with the American visitors.

The skill level of the Cuban divers was unknown prior to the trip, so part of the initial activities was to informally evaluate them so as to make best use of their abilities during the post-conference excursion. We found that they were very accomplished divers, but were forced to work under severe equipment handicaps, because they could not get modern scuba equipment. As an example, one of the divers tied his [extremely rusty] double cylinders together with rope, lacking any better means of uniting them. Even such things as cave diving line and batteries were coveted, as they simply were not available in Cuba. When we left, we left with them a new edition of the NSS Cave Diving Manual (Zumrick, et al, 1988), all of our remaining line, several back-up lights, two reels, and much miscellaneous equipment.

We also found that skills commonly taught in cave diving courses in the United States, such as anti-silting kicks, weighting and trim, and running reel were often new concepts for Cuban diving speleologists. During the course of research activities, much was taught to these divers, primarily by example. Tentative plans were made to have some of the American participants return to teach a full cave diving course, subject to obtaining governmental permission and funding.

Maximum dive depths in the caves ranged to 66 msw (219 fsw), with a median of 31 msw (104 fsw). On dives below 45 msw (150 fsw), one diver remained at that depth while the other descended to the maximum depth for a bottom time at depth of one minute, enabling collection of data on the YSI probe. 67% of the dives required stage decompression, which was based on either dive computers or US Navy dive tables (at the individual diver's discretion).

Several situations occurred which potentially could have jeopardized the safety of the divers. Two of these were related to waters with high naturally occurring H2S concentrations. Cubans had previously explored Casimba Susanna using 1 cm manila rope as their permanent guideline. It is interesting to note that this line could be easily pinched in half between thumb and finger, due to the corrosive action of the H2S. The rock walls in this cave were noted to be very friable, as evidenced by a very large piece of wall which fell onto one of the divers during a decompression stop. The influence of the H2S in this event is unknown.

The concentration of H2S in Cueva del Trueno was high enough to cause extreme discomfort to divers. Sufficient H2S was absorbed through the skin so they could not see at times because of the burning it caused in the eyes. Had some other problem occurred, this could have contributed to a fatal incident.

Another incident occurred while exploring Cueva de los Carboneros. A new reel was used by the divers on the dive. In the course of their exploration, the end of the guideline on the reel was reached. Normally, the guideline is tied to the reel to prevent its being lost in this situation. This had not been done in this instance by the manufacturer of the reel, resulting in its being left behind the divers as they advanced. Loss of the line
was noted after about 10 m, and a standard lost line search was instituted in the half-meter visibility. The guideline was located, and the divers exited without further incident. This points to the need to check the security of line termination to the reel.

CONCLUSIONS

Preliminary investigations in anchialine caves in Cuba resulted in the collection of several new species of animals, including one mollusk, one remipede, and potentially several other crustaceans. As only a relatively few number of Cuban caves were examined, it seems reasonable to expect that further work would yield other new organisms. In addition, collection of remipedes in Cuba should contribute to understanding the geographic distribution of the class, and possibly of other cave adapted fauna as well. Based on these findings, continued inquiries in these anchialine systems is indicated.

Several potentially hazardous incidents related to waters with naturally high concentrations of H2S were noted. While H2S is known to be toxic to humans, the amount of H2S which is absorbed and the amount which can be safely tolerated by a diver remains unknown. It seems that these amounts would be a function of the concentration, which can vary significantly in natural environments, exposure time, and protective suit utilized. Studies to define safe exposure levels for divers would benefit researchers diving in some anchialine cave environments, as well as those working in the stratified lakes of Palau.

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LITERATURE CITED


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