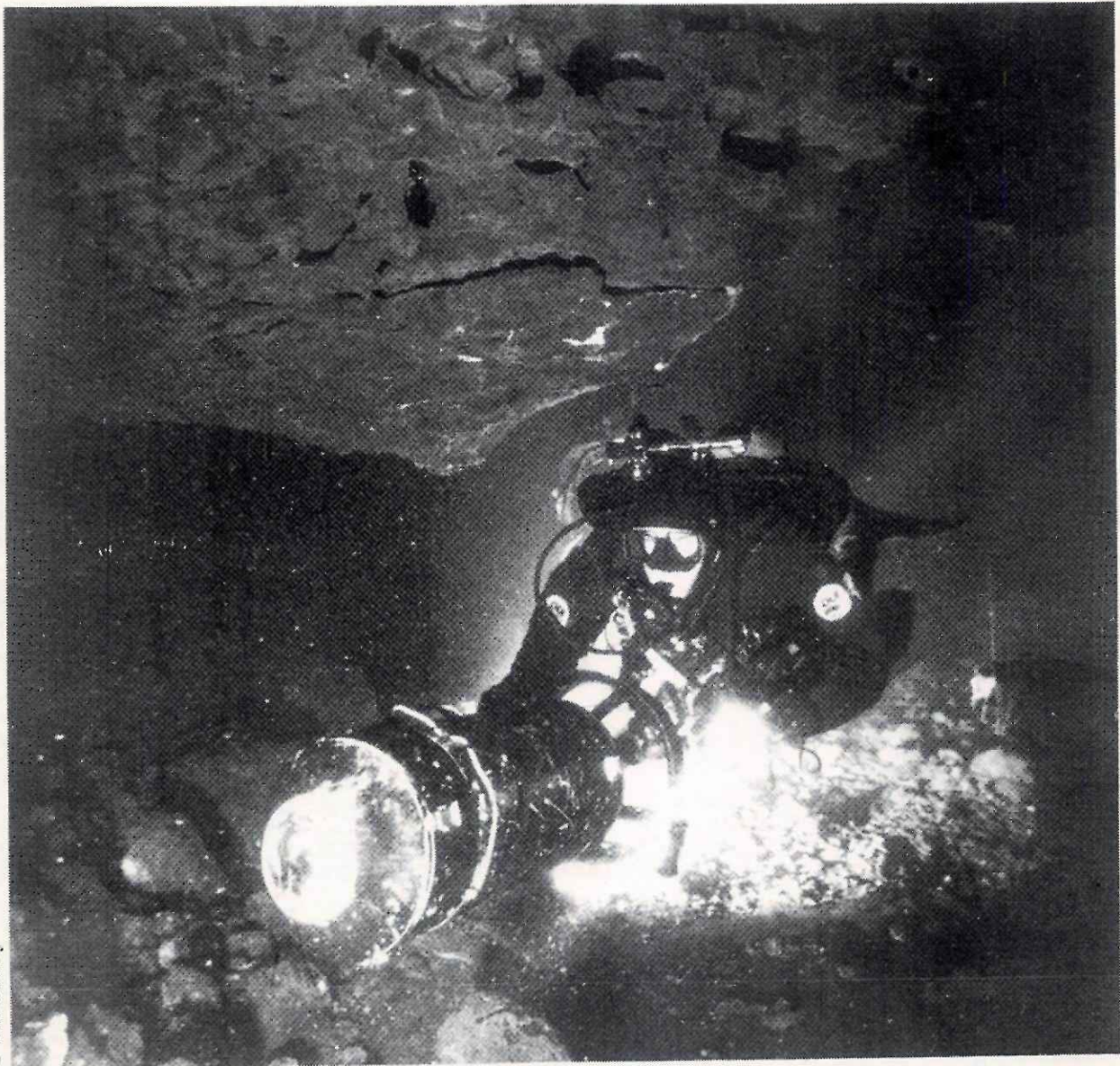


Underwater Speleology

January/February 1995

Volume 22 Number 1



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Manatee Springs Exploration: A New North American Record

Inside this Issue:

**Exploring the Most Remote Place Under the Earth:
the San Agustín Sump**

by Barbara Anne am Ende

Peacock Steps Completed

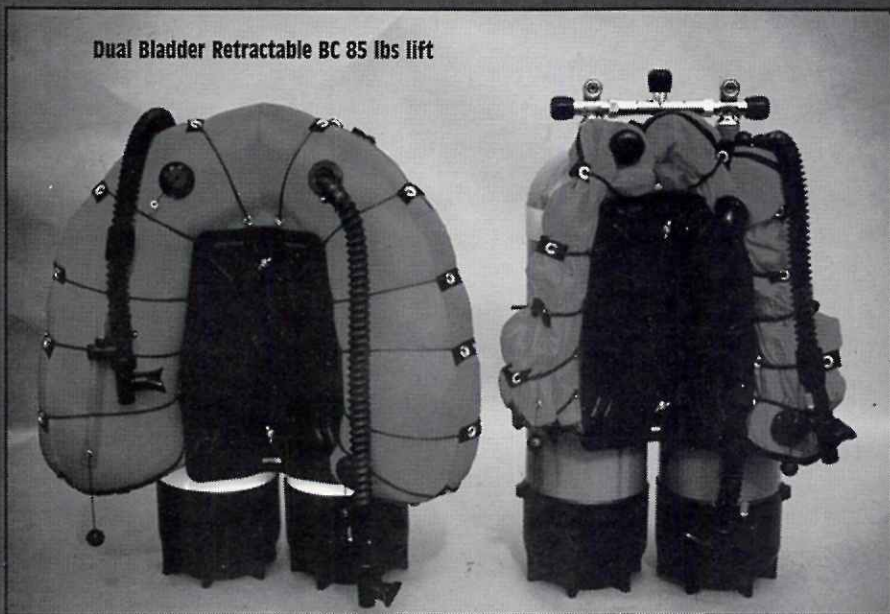
by Eric Tasso



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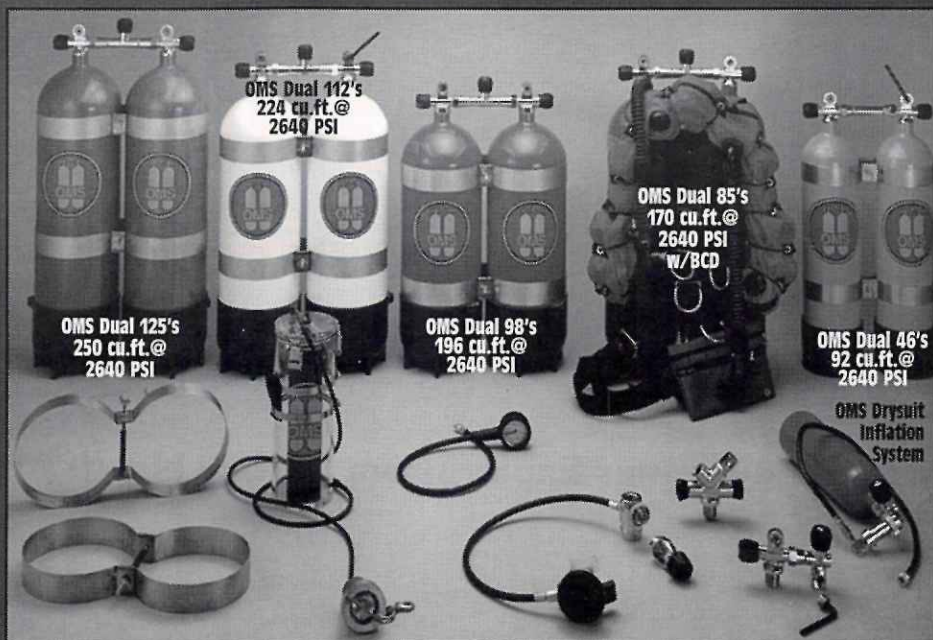
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Submissions

UWS welcomes your submission. *UWS* assumes that anyone submitting photos and/or graphics has obtained proper permission from the cartographer/photographer for reproduction of such material in *UWS*. We prefer prints to slides, but can accept both. All submissions are subject to standard magazine editorial practices. Unfortunately, we cannot publish everything we receive. If you have an idea for an article but are unsure if it is suitable for *UWS*, please feel free to contact the editor.

Submission Deadlines

March/April.....	February 20
May/June.....	April 20
July/Aug.....	June 20
Sept/Oct.....	August 20
Nov/Dec.....	October 20

NSS-CDS BBS System

24 hours a day
813-648-9400
Up to 14,400 Baud
PC Board 15.0
8 data bits; 1 stop bit; no parity

Events

New Board Elected

In the highest return of ballots in CDS history, three new BoD members were elected. More than 50 percent of NSS-CDS members returned their ballots, including members from Switzerland and Saudia Arabia. Elected were Gene Broome, Woody Jasper, and Wayne Marshall. The new Board will meet at 6:30PM on Saturday, February 4, at Ginnie Springs to assign new positions (Chairman, Treasurer, Secretary, etc). The Board looks forward to your input. ❖

CDS Workshop Plans

Workshop Chair Gene Broome is actively soliciting your input for the 1995 CDS Workshop. Please drop him a line at address below with ideas for activities, speakers, or to volunteer. ❖

CDS Social: Ginnie Springs

On February 25th, we are gathering at the new Devil's Eye Pavilion at Ginnie Springs Resort to go diving. We will be there at 8AM on Saturday morning to set up the booth for the CDS with t-shirts, maps and books for sale. Come whether you have a buddy or not—there will be plenty of people to dive with. There will also be canoeing and volleyball for the kids and non-diving partners.

Starting around 7PM we will be having a big party at the pavilion. A keg has been generously donated to the cause and there will be a bonfire as long as the wood lasts. We'll even be having a weenie roast! If you plan to indulge, please keep in mind that there is overnight camping at Ginnie Springs. Hope to see you there! ❖

Joint Instructor Workshop

The joint NACD/NSS-CDS Workshop scheduled for December 3-4 has been postponed until February 18-19. Poor conditions at Indian Springs dictated the postponement of the workshop.

Speakers for the Workshop include Dr. Chuck Mills, Tom Morris, Curt Bowen, Lloyd Bailey and Arnold Jackson.

The Workshop will be held at Indian Spring in Tallahassee, Florida. Instructors must attend all seminars to dive Indian Spring. The cost to pre-register is \$30; at the door the cost will be \$35 (some meals are included in this price). To pre-register, send a check for \$30 by February 1st made out to the NSS-CDS to Elena Casson at the address listed in the calendar below. ❖

Events continues on page 31...

Calendar

February

18-19

Joint NACD/CDS Indian Springs Instructor Workshop, Tallahassee, Florida. To pre-register, contact Elena Casson, c/o Lloyd Bailey's Scuba, 3500-F NW 97th Blvd., Gainesville FL 32606, (904) 392-2619 or e-mail ElenaC8114@aol.com.

25

CDS Social beginning at 9AM at Ginnie Springs, High Springs Florida. Contact Bruce Ryan (813) 528-4202 or Annette Korn (904) 728-6536 for more information.

May

26-29

The 1995 CDS Spring Workshop, Branford, Florida. Gene Broome, Workshop Chairman, is actively seeking volunteers and suggestions. Please contact him at: NSS-CDS Workshop, PO Box 950, Branford FL 32008. Phone and/or Fax him at (904) 935-1141.

July

17-21

NSS Convention, Blacksburg, Virginia. Contact Carol Tideman, 7600 Pindell School Road, Fulton MD 20759, (410) 792-0742.

Peacock Steps Complete

By Eric Tasso—CDS Treasurer

Those of you who have been around for a while will remember the days when driving up to Peacock literally meant up to the spring entrance. You might also remember making a dive at 11PM and decompressing by moonlight. Well, those days are long behind us. All of you reading this newsletter will remember the days when climbing down the makeshift steps was probably the most dangerous part of the dive. Yet the days of makeshift steps are also long behind us at Peacock Springs. On October 9, 1994 the Peacock Steps Project was completed. For some of us this was the realization of a long-time dream. The work was delayed by weather but project supervisor Bill Rennaker was not going to let himself be stopped by a little water. The completion of this project could not even have come to this were it not for some key people. First of all, thanks to Bill Rennaker and Dale Motes, the Project Coordinators. Thanks also to Bill Dooley, Mark Meadows, Tony Pate, and Mike Poucher who gave unselfishly of their time. Thanks also to Joe McGrath and Richard West, the two park rangers at Peacock; Jerry Metzger for the use of his generator and consulting; and Ray Greene for the use of his trailer. A heartfelt thank you must also go to the many members of the CDS Board of Directors who have dealt with the endless bureaucracy in order to complete this effort. And last but certainly not least, thanks to the people listed below who made a financial contribution which without all we would have is a blueprint and a vision:

Accounting Offices of North Florida
Kim Anway
Billy Baxter



Steve Berman
Richard Brady
Jack Brightwell
John Burdiss
Kevin J. Denlay
Susan Drake
Donn Ellerbrock
Terence Fails, Jr.
Steve & Marianne Gamble
Jeff Johnson
Larry Kirby
J. Scott Landon
Stacey & Linda Mills
Ira Potter
Joe Prosser
Jim Robinson
Peter Schulz
John Staub
Tim & Jane Tye

The following is a summary of the Peacock Springs Steps Fund income and expenses:

Income:	
Members contributions:	\$2155.00
CDS Contributions:	1225.00
Total Income:	\$3380.00
Expenses:	
Engineering Expenses:	\$370.00
Engineering revision:	75.00
Wood and nails:	3362.42
Materials (concrete, etc)	624.60
Total expenses:	\$4432.02

As you can see we are still **\$1,050** short of covering our expenses. I would like to suggest that each member make a tax deductible contribution to the project. A \$20 contribution is the cost of one day's diving at many commercial springs. With the current size of our membership, \$20 per member would not only cover our shortfall but allow us to get started on the next project: **The Olsen Steps Project**. With your contribution, we can make the treacherous descent into Olsen a memory. ❖

Manatee Springs:

by Jarrod Jablonski

On June 6, 1994 Todd Kincaid and Jarrod Jablonski marshaled a great deal of support, borrowed some ambition, and explored an additional 800' of siphon tunnel located within the cave system at Manatee Springs State Park. This dive, which required nearly nine hours of submersion and measureless support, was ended at 11,074', establishing a new North American record.

The simplicity with which this was related doesn't begin to do credit to the numerous people and arduous hours logged within the years of the project's existence. To truly credit the numerous divers that have challenged Manatee's interior would be impossible. However, this article will attempt to recap the years of exploration and research that has set Manatee Springs apart as North America's longest underwater cave.

Location

Manatee Springs is located in Manatee Springs State Park roughly six miles WNW of Chiefland, Florida. Manatee Spring is located on the Manatee Spring Quadrangle in SW 1/4, SE 1/4, sec.26, T. 11 S., R. 14 E. All five openings (four of which are passable to cave divers) occur along a fracture zone trending in a SW direction approximately 1800' from Manatee Springs to Friedman's Sink.

The Beginning

Many cave diving legends have assaulted Manatee's interior and all were met with a raging flow and limited visibility. Manatee is a first magnitude spring with an average discharge of 181 cfs (nearly 120 mgd). The daunting force of this flow, coupled with the early years of undependable scooters, made early exploration a monumental undertaking. Cave diving experts like John Harper, Bob Friedman, Court Smith, Sheck Exley, John Zumrick, Bill Main, and Bill Gavin all battled against these challenging conditions. Sheck Exley

was perhaps the most consistent contributor to these efforts and found himself obsessed with the multitude of Manatee's secrets. The author was fortunate to have known and dove with Sheck and thereby gained some information from the storehouse of history within his mind. In this article I will review and try to answer some of the questions Sheck strove to conquer during his many years of exploration within Manatee Springs.

Early Exploration 1961-1981

Manatee Springs does, in fact, have an interesting history of exploration. For example, the first recorded traverse between two submerged cave entrances was completed from Manatee Springs to Catfish Hotel as early as January 1961. As with many of the local cave systems, Sheck Exley played a crucial role in the evolution of thought and action within the Manatee system. Sheck discovered Friedman's Sink (named for his friend and co-explorer Bob Friedman) in March 1973. The sink was at this time merely a solution pipe a few scant inches in diameter. Lewis Holtzendorff then located this hole on the surface and the team began an excavation that many of us today take quite for granted. Although small, this roughly three-foot diameter opening remains the farthest upstream entrance and is therefore a valuable exploratory and research aid.

During the years to follow, numerous dives were conducted within the Manatee Springs cave system extending the breadth of knowledge and cave available for scrutiny. On May 1975 Exley, Holtzendorff and Smith dramatically extended the volume of explored passage by nearly 1300', quite an accomplishment for the time which continued to support the assumption that Manatee Springs predominantly consisted of one major trunk passage with parallel meanders that return back to the main tunnel.

The late 70's and early 80's found Manatee Springs on center stage vying for the world's longest underwater cave. Once again Exley and company were at the forefront of these long push dives into the raging depths of Manatee Springs. In August 1981 Exley and Pitcairn extended Manatee out to a total penetration of 7,667' where they reached an impenetrable restriction. Later that year Bill Main and Bill Gavin were to follow another route from that of Exley and extend Manatee's penetration to nearly 7,800'. Manatee Springs was to remain the world's longest underwater cave for another seven years until Exley's mammoth dive in Chip's Hole in which he extended the record out to over 10,000'.

Exploration 1990-1994

Manatee Springs, the site of so many years of scrutiny and hours of bottom time, was soon forgotten, leaving many of her secrets shrouded within her raging depths. However, old habits die hard and January of 1990 found Jerry Messick and Jarrod Jablonski once again probing the mysteries of Manatee's interior.

An attempt to refine some long penetration techniques and some general curiosity found these divers rekindling the light within Manatee's long forgotten corridors. It had been nearly nine years since light had touched these surfaces and at nearly 8000' one could gain a true perspective on the tenacity that allowed those long swimming penetrations so many years earlier.

Following a review of both the Exley/Pitcairn and Main/Gavin lines, the duo began their exit. During the long trek out the team noticed a large siphon tunnel at approximately 6,000' and returned two days later for closer review. Immediately upon entering the large siphon tunnel it became apparent that this would become quite a discovery. The main tunnel, which is fairly small with a floor to ceiling height of 5' and a diameter of roughly 6', suddenly

A New World Record

balloons to more than three times that size. Following the exploration of nearly 1500' of this new lead the flow conditions became even more adverse and the exploration was postponed in favor of more favorable exploration conditions in other regions.

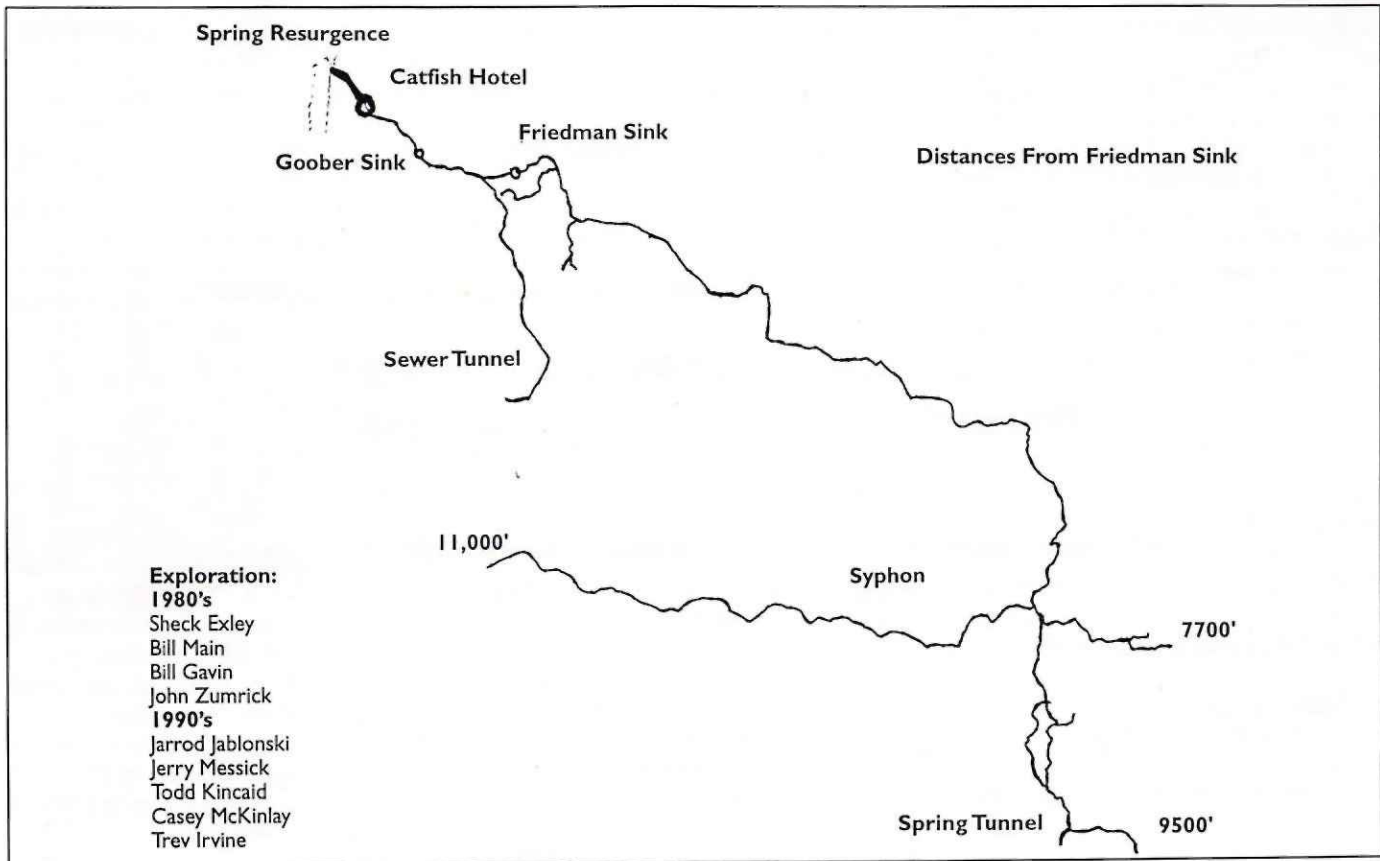
March of 1991 found Messick and Jablonski taking advantage of a lower flow period to search for other promising leads. The divers were suspicious about the lack of flow present near the end of the upstream passage. It became apparent the earlier teams must have missed the main flow (a feat easy to do on a nearly 8000' swimming penetration of Manatee Springs). Hopefully the improved scooter technology would make a closer look more feasible and reveal more passable cave. Once again Manatee responded with an astounding surprise. While the team searched the main corridor Messick found a small

lead that broke into a large cave passage. The next several dives revealed more than three thousand feet of remarkable cave before the increasing flow and the decreasing size of the tunnel called for a recess in the exploration efforts.

The nature of the Manatee dives obviously called for some significant logistical considerations. Both divers relied heavily on the clean Hogarthian style that was developed by Bill Main and refined by Bill Gavin. In addition, large 95 stage bottles were used in some sections of the cave to reduce the number of bottles necessary. The distance traveled also required the staging of scooters via a system designed by Lamar English and George Irvine. Once the silt had cleared, Messick and Jablonski had reached a total penetration of more than 10,000'.

The Next Assault

A review of the past dives and future exploratory plans forced the team to reconsider the safety of the mainline present within Manatee Springs. Long-time cave diving friends Todd Kincaid, Sherwood Schile, Casey McKinlay, and George Irvine joined the exploration efforts and it was decided to remove the mass of multiple threads that had heretofore passed as a main line and replace them with one continuous line. Lamar Hires was contacted and he made arrangements for the NSS-CDS to donate some line for this project. The removal of the tangled mass of lines (in some places as many as four main lines) required nearly a dozen dives and a great deal of patience. It was also decided to place line arrows with distance markers throughout the cave to facilitate the logistics of research and exploration dives.



New map of Manatee Springs with Sewer Tunnel and Syphon

Manatee Continues...

The group agreed that a more refined and scientific approach to the exploration was called for and it was decided to manage Manatee's exploration during poor Woodville Karst Plain Project (WKPP) Tallahassee exploration. The group began to amass as much information as possible on the particular nature of Manatee's structure, striving to expand the breadth of knowledge as well as the extent of cave passage.

The first goal the team tackled was to explore the relationship of the large siphon tunnel discovered by Messick and Jablonski. The advent of Bill Gavin's superscooters, which were well tested in the depths of Tallahassee, greatly facilitated this project. The group has found from experience that most dives of significant range must be as effective as possible, often with multiple tasks being conducted on each dive. Every dive done must not only accomplish some task, but should in some way facilitate the following dive. A team of dedicated divers can in this way accomplish nearly any task.

In March of 1994 George Irvine and Casey McKinlay began the series of dives that would allow maximum efficiency in the team's newest project. Their upstream trek to the 6000' siphon tunnel was designed to place stage and safety bottles for a later push dive. Running efficiently, they managed to accomplish all their objectives and still find time to push through a restriction at 7,500', exploring an additional 900' of cave passage. Their report was promising and the group readied itself for a series of challenging dives.

While the team prepared for the next assault numerous logistical considerations began to become apparent. The large siphon tunnel was located beyond

6000' and necessitated the negotiation of roughly 2000' of restricted cave, making air and scooters more difficult to transport. In addition, the cave repressed efficient travel with a powerful flow that repelled one's efforts for the spring tunnel portion and inhaled divers in an uneasy inflow for the second leg of the long journey. Furthermore, while the siphon tunnel had continued beyond the original restriction encountered by Messick and Jablonski, it continued to intersect numerous sections of cave collapse, creating an impediment to both efficiency and safety. Air calculations also demanded astute care while confronting a raging siphon that begins at over 6000'.

With the safety considerations in place and the dive plan well orchestrated, the team began the siphon tunnel pushes. Todd Kincaid and Jarrod Jablonski began the pushes by leapfrogging through the cave on bottles placed on previous setup dives. The divers retrieved the full bottles placed at 7,500' by Irvine and McKinlay on the previous push. The full bottles were then brought to the end of the current line and left for either emergency air or the next push. Thanks to very careful planning, efficient travel and perhaps a bit of luck, the push went well and the team

unaided by pulling techniques. In addition, the cave continued its tendency of intersecting paleosink debris that greatly impeded the team's progress. As if to further complicate matters the siphon tunnel visibility rapidly began to decline as other tunnels high in particulate content intersected the siphon tunnel's path.

The cave flow continued to increase as the region's lower surface water content slowly removed its shackles. With increased flow the dives magnified in complexity and bottom time. The average depth of 90' made Manatee an excellent Nitrox dive, greatly enhancing the team's safety and efficiency. Yet, as the dives increased in complexity and cumulative dive time, the team began to become more concerned about CNS toxicity. Decompression sickness was considered to be far more favorable than the incapacitating effects of a seizure, yet the bottom times now in excess of 200 minutes certainly called for some relief. George Irvine contacted Dr. Bill Hamilton, WKPP's most frequent source of physiological information, who helped construct dive profiles to reduce toxicity risk. Technical advice was also gained from the generous assistance of Arnold Jackson (American Underwater Lighting).

Armed with this new information, the team decided on one last push before the flow became unmanageable. Again Kincaid and Jablonski began a push made possible by

"At 11,074' the team had established a new North American record, yet the hardest part still remained."

explored nearly 1500 feet of new siphon tunnel without incident.

The dives began to increase in complexity as the siphon flow was greater than anticipated and became a noticeable impediment to efficient exit. The cave was very brittle, forcing a diver to take on the daunting flow

this dedicated team. Our usual group of divers was then joined by cave divers Tyler Moon, Bill Mee, Pat Hare, and Barry Miller who all provided assistance and support. With all stage bottles in place, Kincaid and Jablonski began the last push of the season and were immediately met with a daunting flow

and settled in for a long dive. At the siphon tunnel the duo was already nearly 30 minutes behind schedule and not even at the halfway mark. Nearly 120 minutes of penetration later, they finally reached the end of the current line and began the exploration, choosing to survey as the exploration continued. The cave almost immediately hit a long section of significant debris and continued to increase in flow while becoming much lower and wider. The cave passage became relatively undefined and exploration was further slowed. As the team worked through restriction after restriction in now less than 10' of visibility they reached the end of available penetration air and began the arduous exit. At 11,074' the team had established a new North American record, yet the hardest part still remained.

Immediately upon turning, the team ran into a zero visibility restriction that seemed impassable. Common sense won out over appearances and the exit route was established. However, the exit would continue to be slow with a flow not soon to be forgotten. Furthermore, the duo had decided to try to remove all equipment from the cave to prevent any further equipment damage in the aggressive Manatee water. In retrospect this violation of the group's policy was a poor decision and proved to be costly. Laden with six stage bottles and three scooters each, the exit was all but efficient. People often pay when policies are violated and this penalty would be a day of submersion.

As the distant glow of the exit became evident, the bottom time crept toward 300 minutes. Nearly nine hours later the two divers again breathed the sweet air of open space and made necessary apologies to the support crew who made all this possible. Joining our other valuable members were John Denizmen, Kendal Fountain, and Richard Hisert, all geologists of true character and incredible patience. As we exited the park—two hungry, prune-looking divers—I thought of Sheck

Exley and his many years of contribution. I wished that he were around to call to review the dive with and, most of all, to compare notes on this labyrinth of daunting surprises called Manatee Springs.

Future Assaults

As the exploration of Manatee Springs continues and more of her secrets are revealed, our group is determined to learn as much as possible about this mysterious cave. One of the questions Sheck strove to answer revolved around the classification of Manatee Springs. Is Manatee an exsurgence fed almost entirely by seepage waters from the surrounding karst, or is it a resurgence supplied by the sinking of surface streams? Manatee Springs certainly resists simple classification. For example, it has no apparent sinking streams in the general vicinity, nor does local rainfall seem to immediately impact the spring flow, leading one to classify it as an exsurgence. However, Manatee does retain a high discharge and is predominantly composed of a single trunk of impressive penetration, indicating a possible resurgence.

In truth, Manatee is probably a cave of multiple identities. While the data remains under evaluation, it appears that the cave may pass under the Waccasassa River Drainage Basin and show the Suwannee to be pirating another river's drainage basin (a concept considered by Exley as early as 1976). The tremendous extent of the large siphon tunnel trending directly for the Suwannee River may be the primary route of this pirated water as it discharges into the Suwannee River. This tunnel may help to explain the high particulate content within Manatee's water and the consistent existence and nature of the tunnels on the southeast side of the corridor. The presence of Long Pond and other surface features may also indicate the possibility of an old karst lineament preferentially draining the area. The lack of surface input on the west side may

explain the clearer, less-extensive tunnels located herein and help to produce some of the signs of exsurgence-dominated cave systems.

Furthermore, the apparently high organic content of the Manatee water is of particular interest when one considers the recent pollution problems present within the region's water supply. The nearby trailer park is fighting a battle against a polluted water supply with the course still in question. Several sources may be considered, yet it is conceivable that Manatee's conduit system plays some role in these local problems. Future research will hopefully include water quality tests and sediment samples.

In addition, several of the passages under exploration contain numerous mammalian remains of questionable age and origin. It is highly unlikely that the remains were brought in from the nearest known exit, roughly 10,000' away. The numerous collapse features, coupled with the frequent impassable sinkholes within Manatee Park, make it likely that some of these sinks were at one time passable. Future attempts will be made to video these artifacts and gain a better understanding of their origin. The remains await the learned knowledge of a very serious cave diving anthropologist. Know any?

Conclusion

This long journey has taken us back to the gargantuan efforts of Manatee's early explorers through the evolution of technology and penetration technique, and back to the ancient remains of some long ago stray mammals. It has been a long journey that will continue while there is cave in which to wonder how things were and how they may be. The secrets of Manatee Springs have, to be sure, only begun to come to light. As we slowly edge forward, pushing back the blackness with our feeble sphere of light, let us hope that we can maintain the reason and intellect to safely continue our quest. ❖

Off The Mainline!

by **Barbara Anne am Ende**

I've been exploring caves (dry ones) for 20 years and during that time I've done a lot of vertical work. But nothing I'd ever done was on the scale of the 1994 San Agustín expedition. I knew there were exciting discoveries being made in Mexico, but I never thought I would go there. Through an unusual stroke of luck (chance?) I got a personal introduction to the project while on a cave rescue in West Virginia in the fall of 1992. One of the other members of the rescue party was Bill Stone, the leader of the expedition. Over the next several months I participated in a number of vertical caving trips with Stone and several other individuals well known in Mexican caving—Bill Steele and Jim Smith. Soon after, I saw a flier for a scuba class at the University of North Carolina where I go to school. I thought "Jim and Bill are cave divers, and I've always meant to get certified (it would be a logical thing considering my dissertation is on marine geochemistry); so now's the perfect opportunity." It turned out that I was giving a presentation at a geology meeting in Tallahassee the same time the 1993 training mission for the expedition was starting in Marianna. Everything meshed and I signed on as a team member. By the time the '94 expedition started, I'd completed my Full Cave Diving Certification and had 30+ training hours on rebreathers. Because of my limited experience it was agreed that I would not be doing any exploration dives, but my real interest lay in exploration of the dry passage beyond.

A Brief History

Bill Stone first dove the San Agustín Sump in 1981. It's a difficult place to get to; the sump is 2824' vertically below the closest entrance (Sotano de San Agustín) in the Huautla cave system of southern Mexico. The goal of the dive was to find dry passage on the far side and continue exploring in this very deep cave. He reached 935' penetration and 92' depth, but was unable to reach air-filled passage. In fact he made a wrong turn at 590' penetration in the poor visibility and accidentally

began to return the way he'd come. Further diving was not possible due to the difficult logistics of hauling equipment to this remote site. All of the known entrances to the cave system are located high up on the Huautla Plateau. The stream at the bottom of Sistema Huautla must flow somewhere, and it was presumed that the stream ultimately rose in one of the springs that emerge in the Río Santo Domingo. The exciting news was that if the path of the water could be followed, Sistema Huautla would be the deepest cave in the world. So, in 1984, an expedition was fielded to the Peña Colorada, a fossil resurgence cave near the active spring in which it was hoped that a bypass could be found to much of the flooded passage and allow explorers to proceed upstream toward the San Agustín sump. You can read about the details in an article entitled "Huautla, Exploration of la Peña Colorada" by Noel Sloan, in the October 1985 issue of the *NSS News*. Eventually the logistics stopped exploration in Sump 7, 2.6 miles from the entrance. During the push, a total 72 high pressure composite tanks were used.

In 1988 Jim Smith successfully dye-traced the water to the active resurgence in the Santo Domingo Canyon at river level. That spring was investigated by Noel Sloan during 1984. However, the visibility was so poor that he soon wandered into rocky alcoves and aborted the attempt.

No matter how you look at it, logistics are tough. Sistema Huautla just doesn't fit into the mold of Florida cave diving where you can drive up and dump as many stage bottles as necessary into the spring. So, Bill Stone decided to develop a rebreather that would be suitable for cave diving. Existing military units lacked fundamental safety features that cave divers require, so the task was not one of simply modifying existing hardware. If you're not familiar with rebreathers, they recycle a diver's exhaled breath, add oxygen to make up for the amount metabolized, and scrub out the carbon dioxide exhaled. They are much more efficient than open circuit scuba gear and substantially reduce the weight that must be carried in the cave. To read more

about rebreathers (including the model used in this project), check out issue number 7 of *aquaCorps* journal.

Developing a rebreather is not simple. It took many years and the involvement of numerous engineers, programmers, and physiologists to get to the stage where the MK4 was ready for use at the San Agustín sump and a number of overlapping years to train explorers to use the equipment. You can read about this phase of the project in the *Association for Mexican Cave Studies Newsletter 20* (AMCS, PO Box 7672 UT Station, Austin TX 78712). It took ten years to get to the point of returning to Mexico and diving the San Agustín sump.

Cracking the Sump

The core members of an international exploration team left Maryland on February 15, 1994 where we'd spent nearly a month upgrading the rebreathers which basically meant re-assembling them from their individual components. It was a *big* job and took longer than we expected. But with several hundred pieces per backpack (not counting the electronics), you can imagine it was no simple task. Rather than immediately racing to Mexico, we detoured to Florida where we spent several days at Ginnie Springs leak testing the rigs and checking out the new software. Then after a brief stop in San Antonio, Texas, where we met up with some of the other team members, we finally arrived on March 1st in the tiny Mexican village of San Agustín.

The entrance to the cave is an enormous, verdant sinkhole. The first pitch is a 300' rappel down a 70-degree incline dubbed the "Jungle Drop" due to the extensive vegetation. Immediately below is the "Slip and Slide" which is rappelled down, but used as a handline coming up. Then at the top of the "Dirt Slope" one enters the "Fool's Day Extension" which has a series of 23 short vertical drops and horizontal traverses. This brings you to the top of the Bowl Hole Series, consisting of several significantly longer pitches. The first is 360' deep and the last is 250'. That

San Agustín Sump, Mexico —

final drop deposits one in “Tommy’s Borehole” at the -2066’ level in the cave. Shortly beyond that, Tommy’s Borehole intersects the Upper Gorge which is a canyon passage with a large stream. Follow that downstream for 12 rope drops and 18 tranverse lines to where the gradient levels out at what’s called “The Metro.” A little farther downstream take a left turn and climb back up another 150’ to Camp 3 perched atop a mountain of breakdown in a very large room.

Camp 3 is a palacial (speleologically speaking) underground camp where much of the gear hauling and support services were based. However, it was still a long way from the sump where we set Camp 5. To get to the sump from Camp 3, one must traverse the Lower Gorge, another stream passage that starts out as a crawlway and soon progresses to a steep canyon where 90% of its half mile length must be traversed on rope. After rappelling down beside a final waterfall, one arrives at the lake which ultimately becomes the sump. Since there is no “land,” camp was set on platforms hung above the water. The main platform was 4 x 12’ in size and was suspended 10’ above the lake. Another 4 x 4’ platform was placed just above water level and was used for rebreather prepping. Hammocks for sleeping were hung above the upper platform, but sleeping was difficult because of the deafening roar of the waterfall about 50’ away. Two people standing next to one another would have to shout to be heard.

The first diving push began on March 23, the day after Noel Sloan, Steve Porter and Ian Rolland reached Camp 5. Ian was the first person to dive. Following the roof, he surfaced into a large airbell at approximately 200’ penetration, hoping to find a dry bypass to the remainder of the sump. Unfortunately there was no continuation in that direction. Further progress was hampered when silt in the vicinity of the airbell was stirred up as he broke the surface, significantly reducing the visibility. So Ian returned to Camp 5 and later that morning Noel made a dive. He followed Ian’s line to its final tie-off point, clipped on a new reel, and spooled out.



San Agustín Sump Expedition, Huautla, Mexico

Shortly ahead, the passage widened. The visibility was poor to begin with, but became worse when Noel had to struggle to disentangle one of his fins from the line. Steve made the third dive of the day, but again the poor visibility made him call the dive before he could make any significant progress.

The next day Ian followed the line to where Steve had left his reel. He tried to follow the passage upward, but to no avail. Exploration farther down was again terminated due to extremely limited visibility and Ian called his dive. Steve and Noel also dove that day, but had little luck in finding the way on due to limited visibility in what was apparently a fairly large breakdown chamber at a depth of 60’.

On March 25th, Ian once again returned to the limit of exploration, now at a penetration of 750’. Unfortunately, soon after he began exploring, his breathing became labored and he developed a headache. He aborted the mission and safely returned to dive base on closed circuit. Apparently after six hours of diving the CO₂ absorbent (anhydrous lithium hydroxide) in the rig was spent. This was somewhat unexpected since we

usually had seven to eight hours for each charge of absorbent during our Florida training missions (but there, the absorbent had longer regeneration times between dives). By now the enthusiasm of these explorers had been taxed. The dives were “no picnic.” Worst of all were the conditions at Camp 5. The constant nerve-racking roar of the waterfall, the poor toilet facilities, the lack of immediate success, and all the other stress-creating factors including the awareness of their location at the bottom of 10,000 feet of rope convinced the three to return to Camp 3 to unwind and to discuss the situation with the other members of the team.

The next day (after a more comfortable night at Camp 3) we discussed the configuration of the flooded tunnel and Bill drew a map based on the reports of all the divers and his own recollection from diving there 13 years before. Then Ian returned to the sump with Kenny Broad. That afternoon, after recharging the CO₂ absorbent canister, Kenny laid 280’ of line. The pow-wow we had must have helped, because Kenny felt he had “going passage” estimated to be 30–50’ wide, 45’ high, and a maximum floor depth of 110’.

San Agustin Continues...

The following morning Ian continued on where Kenny had tied off, and laid another 250' of line. Both lines had been laid on a due south bearing toward the springs. Kenny dove again, and after a little more than an additional 100', he surfaced in a large air-filled passage. In his log Kenny wrote, "Ceiling sloped upwards for about 130' until it broke into open water and the mercury-like reflection of the surface sent a shiver down my already shivering spine. While underwater I disabled the oxygen injector (in software), shut off the manual control box valve and surfaced. I removed the regulator and sat on my knees in the mud, breathed the warm humid air and was in awe. The passage was 40' to 50' wide, 40' high. Several shallow (one to three foot) sandbars broke the still surface. There was no perceptible water or air movement and I heard no noise." Because he wasn't as experienced in dry caving, Kenny returned to base and Ian went to check out the new tunnel. Unfortunately Ian didn't return.

According to the pre-arranged plan, Kenny left the sump for Camp 3 to "call out the cavalry" at 10PM. When he arrived we discussed the situation with much input from Don Broussard, the other diabetic on the expedition. The next morning at five, everyone set about specific rescue-related tasks and by about noon, Kenny entered the water with a second rebreather, configured that morning. To everyone's great disappointment Ian was not awaiting rescue in the airbell; he was found in nine feet of water under the airbell. The next morning Bill recovered the body back to Camp 5. An accident report is presented in an accompanying article which concludes the cause of death was apparently due to a hypoglycemic reaction related to his diabetes. Ian's death was especially sad because he was one of the strongest members of the team, exceptionally knowledgeable, a wonderful husband and father, and an all around nice guy. It was learned during the recovery that Kenny had, in fact, broken into an airbell rather than continuing river passage and that the tunnel sumped again.

It took six days to recover the body to the surface. We were grateful to have help from a number of British cavers during the recovery as well as significant help from the Mexican members of the team (Sergio Zambrano and Angel Soto) in dealing with the authorities. There were changes in personnel at this point with several people leaving and others arriving. Those remaining planned a break from the unhappiness due to the loss of our friend. We would take two rebreathers down to the resurgence in the Santo Domingo Canyon for a photo shoot and to get a "lay of the land." A video crew was scheduled to arrive in about a week so we put off our trip to the canyon until then (we later learned that the video people had unfortunate legal problems through no fault of their own and could not make it). In the interim, the newcomers did some acclimatization trips while two other team members hit the beach. That left Bill and myself. I'd gotten to know Bill pretty well and I knew before he said anything that he wasn't the type to sit idly by and wait for the rest of the expedition to restart in a week. As for me, the beach sounded appealing, but I'd come a long way from North Carolina to do a job, so the two of us headed into the cave. On April 8th, Bill Stone finally was able to take off his expedition leader hat and put on his explorer's wetsuit hood (the initial dives were conducted in dry suits to ward off the 64°F chill; later dives were made in wetsuits when the duration of the dives was better anticipated). He had two aborted dives in the morning due to what we finally determined was a leaking BC. With the help of some patching material and some AquaSeal, he was back in the water at 3PM, with a BC good as new.

I had an anxious time there at Camp 5 waiting for Bill to return. A visitor made a sight-seeing trip to the sump from Camp 3 and brought the news about Sheck Exley's death, then left me alone at -2824'. It was not something I cared to hear while waiting the five hours during which Bill was gone. But one's perspective can be skewed under such difficult conditions. In

reality cave diving can and has been done very safely (and we were running very conservative dives given the range of the rebreathers). At 8PM, Bill returned from an incredibly successful trip. He dove into the sump, returned to the airbell, then laid two reels of line through the second sump where he broke into air-filled passage. He explored an estimated half mile in new passage that was at least 20' high before turning back. There were more sumps, but Bill was able to bypass them in dry passage. He saw several leads along the way, but turned around when each was more technically challenging than he cared to attempt with no rope and no partner. In summary, the first sump is 1400' long with a maximum depth of 78'. The second sump is 560' long and only 28' deep. During all 14 exploration dives only 25 cu ft of oxygen and 65 cu ft of diluent were used, which attests to the remarkable efficiency of the rebreather.

Back on the surface we made preparations for our trip to the canyon. The day we hiked down was a sweltering 100° F. There were 5,000' of vertical relief and several miles horizontally to traverse. But when we arrived, we all decided that the hike was worth it. The canyon was beautiful and the river was delightful. We were pleasantly surprised to find that the visibility in the resurgence was greatly improved and commensurate with that in the sump. Instead of just photographing the rebreathers, line was laid by Bill Farr, Kenny Broad, Paul Smith, and Steve Porter. Most of these dives were on open circuit gear (originally brought along for use by the photographers), but the final and longest dive was done with a rebreather. A total of 800' of line was laid, and the passage continues north toward San Agustin at a depth of 55' below river level. However, we had to leave because the burros and drivers we hired to haul the tanks and rebreathers returned. We didn't want to haul the diving gear out on our backs in addition to the personal gear we'd carried down.

The Final Push

Although Bill did a pace and compass survey of the newly discovered passage, it was insufficient for an accurate map. Two people were needed to do a tape and compass survey, so on April 29th Bill, Noel, and I returned to the sump after three days of staging from Camp 3. I had originally expected to be supporting Noel and Bill, but in the end Noel decided not to dive and he helped Bill and me.

On the 30th we were prepping the two rigs when we heard a loud "POP"! It sounded like a loud disconnect of a BC inflator hose, but we couldn't determine the sound's origin. I jumped in the water to have a little time becoming comfortable with the dive while Bill was kitting up. We immediately learned what caused the noise. The first stage regulator of one of the diluent tanks had blown! There was a steady stream of bubbles pouring out. Yikes! This was disconcerting to say the least since each rig had been equipped with new DIN regulators in February. Bill knew there was an O₂ regulator back at the Camp 3 dive depot, but was it worth the effort for one regulator? What if we had another problem on the other side of the sump? No one wanted to have to return to the surface for another regulator. While we considered the options I remembered there was an Acurex tank with a regulator back up at the -2060' level. Bill was our fastest caver, so he flew like the wind, picked up both regs and returned in just two hours (it would have taken me six). Noel promptly went to work putting in the new regulator and we packed the second as a spare for beyond the sump.

I was back in the water that afternoon swimming around close to the dive deck while Bill was kitting up. I soon discovered another problem. The computer said the depth was 0 feet no matter where I was in the water. I was diving the rig Ian was

on when he died, and after the recovery Bill had replaced the computer board that had the "black box" that stored Ian's dive profile so it could be downloaded on the surface. Unfortunately Bill hadn't done a depth calibration on the replacement board. When I got out of the water he started to calibrate the sensor, but accidentally hooked up a high pressure hose to the fitting and blew the sensor. However, due to the careful forethought of Ian, a spare depth sensor had been packed in the parts kit we had there at the sump. Bill replaced it and finished the calibration. Everything was finally ready to do the dive, but at that late hour, we decided to wait until morning and to get a good night's sleep first. The rigs were now working properly, but we had one other problem. All the gear we planned to take to the far side of the sump was packed in a giant duffle bag. Bill had packed it tightly and had carefully added lead to make it neutral before kitting up. We had to unpack the duffle to retrieve our sleeping bags for one more night at Camp 5. One of the Nalgene bottles containing our bags didn't have the lid screwed on properly

"The enormous dry passage we had been following (up to 300 feet wide at one point) was headed steeply down and eventually filled with water."

and had leaked! I tried crawling in the sleeping bag and drying it with my body heat, but the bag was just too wet. I was tired, cold, and soaked. I like to think I'll put up with almost any kind of adverse conditions, but I hate being cold and wet. Noel and Bill finally kicked me out of the bag and dried it over a stove while I dozed in another bag. Finally, around 11PM, we turned out our lights.

Bill and I woke up early on the morning of the 1st. We sat in our hammocks in the faint glow of a carbide lamp and discussed

the dive. The day before I was really looking forward to going beyond the sump and setting Camp 6. But after the two delays in getting the rig running, a poor night's sleep, and the penetrating chill, my enthusiasm had taken a nose dive. The motivating (or perhaps more accurately the de-motivating) factors were a little different for Bill and me, and there was a distinct possibility we wouldn't make the dive. But the facts of the matter were that a) ten years of design and construction had gone into the rebreather specifically for this project, b) we'd just spent three months of intense effort under very difficult conditions, and c.) Ian died giving his all for the success of the project. In the end, neither Bill nor I could accept defeat. We would make the dive. During our training mission the year before, Ian and I both agreed that when you go cave diving, all thoughts vanish except for your awareness of what you're doing to make a successful dive. Bill's perspective here was correct, too. Once you submerge and start your dive in San Agustín, it's just like any one of dozens in Florida, except the visibility isn't quite as good. I went very

slowly (in the past I've been known to dust my buddies). I really wanted to pay exquisite attention to how the rig was operating. For instance, at Devil's Eye in February I got a splitting headache from CO₂ buildup when I didn't breathe

deeply enough while swimming against the current. Here there isn't a current, but still I didn't want to leave anything to chance. I checked my wrist display (which gives analog readings of the three O₂ sensors) frequently and the values corresponded exactly with the data displayed by the computers. All in all, the rig worked perfectly and the dive went very smoothly. It took about an hour to get to the far side of Sump 2 although about 15 minutes were spent talking and slowly traversing the airbell where we crawled on

our knees over the partially submerged sand bar. It would have been much faster and easier to swim the surface of the lake in the airbell, but it was a good opportunity to discuss how the dive was progressing.

After arriving on the far side of Sump 2, we hiked up to a rock ledge and stashed the rebreathers (we didn't want to leave them near the water in case of a flood which might wash them away while we were off on a survey trip). If Camp 5 seemed spartan, Camp 6 was more so (but quieter and on land). Our damp wetsuits placed inside plastic trash bags provided padding under our sleeping bags. These and the fleecewear we wore under our wetsuits comprised our worldly comforts. Camp 6 was the base used for the exploration of the most remote parts of the cave over the next six days. In several places, the passage sumped again but fortunately dry bypasses were found. On many occasions there were cold swims down to sumped passages before we found the going dry passage. However, we were finally stopped by a giant sump. The enormous dry passage we had been following (up to 300' wide at one point) was headed steeply down, and eventually filled with water. The walls of the big tunnel were scoured for side leads in hopes of bypassing this sump (#9), but none of them did. At two miles beyond the original two sumps, and with no back-up, the prospect of carrying a rebreather and continuing exploration was out of the question, so we made our way back. At 3AM (towards the end of our 22 hour push) we stopped to do a perimeter survey in a leviathan room we named Perseverence Hall. The scope of the chamber was difficult to grasp, especially with our tiny carbide lights. The survey showed it to be 400' long and 600' wide!

Sitting in the water preparing for the return dive, we found out what the rigors of hauling equipment down those two miles of rope can do to diving equipment. The electrical cord to the LCD display on Bill's rig had partially unscrewed and water shorted out the computer. If memory serves, "S—t!" was the precise utterance at the time. After the initial shock, Bill

remembered that he'd designed the rig to be redundant in all sorts of useful ways—including having three computers. So, the second and third computers spontaneously did a "start dive" at 5' depth, voted out the errant computer, and he was able to monitor the automatic running of his dive by using the Head's Up Display (HUD). Of course, he could have done the dive by operating the rig manually, but it was satisfying to know he didn't have to.

When we arrived that night at Camp 3, we were anxiously greeted by Noel and Don. They'd been busy hauling up what gear they could (such as dead batteries and empty tanks). We had a joyous time that evening, but the next day we had to get back to work. It took three weeks to haul out the gear and de-rig the cave. Fortunately along the way, we got some additional help. But nonetheless, it was a *lot* of work hauling an estimated one ton of gear up 2824 vertical feet.

The Upshot

The 1994 San Agustín expedition was an awesome adventure. We faced some serious setbacks and daunting goals. We were successful in finally cracking the San Agustín Sump and exploring a substantial amount of virgin passage beyond. The rebreathers that were designed specifically for this project worked extremely well. The depth of the cave was extended to —4838', which makes it the deepest cave in the Western Hemisphere and presently the fifth deepest in the world.

Nevertheless, there's still passage yet to be explored between Sump 9 and the resurgence. So, to paraphrase Arnold, "We'll be back!" ❖

Thanks!

The expedition was sponsored by 56 corporations and non-profit institutions, and also by numerous private individuals. To all of those, and in particular the NSS-CDS, which made a generous grant to help cover operating expenses, we express our most sincere gratitude:

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Accident Analysis

by Bill Stone and Kenny Broad

Sotano de San Agustín, Oaxaca, Mexico

Background

From February 1 through May 31, 1994, a multi-national expedition was fielded to the Huautla Cave System in southern Mexico. The objective of this project was to pass an underwater tunnel known as the San Agustín sump at the bottom of the system and push on to greater depths in air filled tunnels presumed to lie beyond. The dive site was 3000' vertically below and three miles distant from the nearest entrance. During the month of March, some two miles of rope were rigged on more than 60 shafts and 30 traverses to reach this location. Two underground camps were used: Camp 3 was located at a depth of 2500' while Camp 5 was suspended near the canyon roof over the sump. Previous attempts to pass this sump with high pressure composite open circuit diving apparatus in 1981 and in 1984 failed due to logistics and the inefficiency of the diving gear. Experimental closed circuit apparatus (Cis-Lunar MK4) was used for the present effort. Team members rehearsed for the expedition with the MK4 (and its predecessors) for two months each in 1992 and 1993, and most of the lead divers had in excess of 50 hours dive time logged on closed circuit equipment.

During the first three weeks of March Camp 5 was set and three divers, Noel Sloan (USA), Steve Porter (USA), and Ian Rolland (Scotland), carried out an initial series of seven exploratory dives that reached 750' penetration at 80' depth. Visibility averaged five to ten feet. This, and the presence of a complex breakdown chamber, accounted for the difficulty in route finding. The water temperature was 64°F. Due to the monumental effort involved with transporting diving apparatus and consumables to the sump, as well as the established risks associated with buddy diving in poor visibility, all exploratory diving operations were conducted solo. Each diver carried 170 cu ft of open circuit bailout gas.^[1]

The dive site was situated within 50' of a relatively large cascade, and the resulting sound level was deafening. After four days the reconnaissance team

retreated to Camp 3 to escape the noise. During their initial effort, they expended approximately 13 cu ft of oxygen, 30 cu ft of heliox 86/14 diluent, and three pounds of lithium hydroxide (carbon dioxide removal agent) for the conduct of seven dives. There were no software or mechanical problems with the diving apparatus. However, the last dive, by Rolland, was aborted due to exhaustion of the CO₂ absorbent canister at approximately seven hours of use. The reliable canister life with a new charge of lithium hydroxide was agreed during subsequent discussions at Camp 3 to be approximately six hours under the conditions encountered during exploration of the sump. In training missions in Florida it had been common to get seven to eight hours, but this had been in warmer water with significant time between dives, during which partial regeneration of absorbent occurred.

On March 26, Kenny Broad (USA) and Ian Rolland returned to Camp 5 for what was planned to be a single dive for Broad with Rolland serving in support. Broad subsequently laid one reel of line (approximately 280') to the south to where the floor appeared to be rising. Emboldened by this progress Rolland kitted up at 8AM the morning of March 27 and, using the same apparatus, laid out a second reel, reaching a point 1200' from dive base at less than 30' depth. At noon, Broad again dove and within 200' broke surface in an air-filled tunnel measuring 60' wide by 40' tall. It extended beyond the range of his diving lights. The floor was mostly one large lake broken by two long thin sandbars oriented north-south down the center of the tunnel. He did not pursue further exploration due to a time-line agreement previously made with Rolland. Upon Broad's return, Rolland decided to conduct a solo reconnaissance of the new chamber before the two returned to Camp 3 with the news. They switched out gas cylinders, but the CO₂ absorbent canister, with only three hours of use, was left intact. The rig was verified to be working properly during a pre-dive checkout. Rolland left Camp 5 at 4PM, anticipating a four-hour trip. At 10PM, when he had not returned, Broad suited

up and ascended to Camp 3 to organize a rescue party in accordance with a pre-existing plan with Rolland.

At the time it was presumed that there were a number of non-fatal scenarios that would account for Ian's delay including an open-circuit abort from maximum penetration on 86/14 heliox that led to excessive decompression, a climbing accident in dry passage, or a diabetic complication. Approximately 16 months prior to the expedition, Ian (29) had been diagnosed diabetic. Initially this was controlled by diet, but by the summer of 1993 he had become insulin-dependent, requiring daily injections. On the morning of the 27, he had eaten a normal (for Camp 5) breakfast of freeze-dried food and potatoes, but had a mild case of diarrhea. It is unknown whether or not he had taken his insulin dose. In his dive pouch he carried two high-carbohydrate *Power Bars*. Following discussions at Camp 3 with Don Broussard (USA), a 40-year diabetic, it was thought that the diabetes-related scenario was most likely, and that if he correctly sensed a problem (the most serious being hypoglycemia onset) that he would be waiting in the airbell for help. In view of this a rescue kit consisting of a glucagon injection, several *Power Bars*, and bivouac supplies was packaged in a small dry tube for transport through the sump.

At 5AM on March 28, a team consisting of Bill Stone (USA), Jim Brown (USA), Rick Stanton (UK), Paul Whybro (UK), and Kenny Broad descended to the sump. A second rebreather unit was assembled and checked, and at 12:15PM, March 28 Broad entered the water. At 12:45PM he reached the airbell and upon his return reported the following:

"I turned off my Acurex and my control box switches and searched the passage with my primary light. I saw footprints heading up over the sandbar and swam/crawled around and followed their path back into shallow water and up over another sandbar. The water that the sandbar sloped into was clear and I could see a slightly disturbed bottom. The bottom dropped to about ten feet and I swam about 50' into the passage

Analysis Continues...

on the surface at which point I saw Ian motionless on the bottom. His red "Buddy" light was visible and there was no sediment in the water, nor was there any silt on his body. All gauges were full; no sign of a struggle. LCD PPO₂ I believe was 0.17 [atmospheres]. All gear was in place except the mouthpiece. He was lying on his right side facing into the passage with the line reel less than ten feet away. I did not have a slate. I followed Ian's line reel to the left [east] wall and to the original tie off point about 50 feet toward the passage entrance [north]. Both Ian and the line were in open water with no obstruction to the surface. I did not turn off the computer for fear of erasing information. I left everything as I found it."

The following morning, March 29, at 8:37AM Stone returned to the airbell using the same rig used by Broad and began a two hour investigation. His underground log reads:

"There were two narrow sandbars running north/south along the center of the room. I did not detect any water flow. As planned I ditched the Acurex tank and clipped it to the end of the line then swam/crawled down the right side of the room where Kenny had said the water would be deeper. The last sandbar ended about 30m beyond the line tie off for Sump 1. There I inflated my BC and floated on the surface another 20m before I spotted Ian. As planned I dropped down to him, took out the slates and recorded the information listed in the Rig H dive log." [See Appendix A].

"Most importantly, the computer was still fired up. I could see the Buddy Display flashing red from 10m away. He was at exactly nine feet of depth. Kenny had reported all bottles full when he was there. However, by the time I arrived (almost 21 hours later) the onboard diluent was empty. This would easily be accounted for by the fact that the auto diluent switch was enabled and was set to onboard gas. Since the mouthpiece was out and in closed circuit mode the counterlung would gradually contract as gas trickled out. This collapse would then trigger further gas addition until the tank was emptied. There were bubbles coming out of the mouthpiece when I

got there. I took him back to the far sandbar, ditched the onboard diluent bottle and swapped in the offboard diluent bottle. Using this I inflated him to see if I could get him neutral in the water. The stack was obviously flooded. There was, incidentally, no indication of a struggle. Both bailout regulators functioned and were in place and the mouthpiece had not been switched to open circuit. Notably, the solenoid cutoff valve was in the "off" position. Kenny said Ian often did that to save oxygen after surfacing from a dive. The PPO₂ on the LCD registered 0.17, 0.17, 0.19."

By 11:30AM Stone had returned to Camp 5 with both Ian and the rebreather. Prior to commencing what was to be a six-day recovery effort to ascend the cave with the body, Rig H, Ian's rebreather, was inspected. Present for this were Kenny Broad, Jim Brown, Paul Whybro, Rick Stanton, and Bill Stone. Stone's underground log entry reads:

"With these two (Whybro and Stanton, in addition to Brown and Broad) in attendance as witnesses we went through all of Ian's gear. As previously mentioned the rig was functioning properly. We set his Suunto dive computer aside to be taken out so that his profile could be downloaded^[2]. More importantly, we need to download Rig-H to get the black box log that includes all commands, warnings, and PPO₂s, but that will have to take place later. We later drained the stack (it had flooded as a consequence of the mouth bit being in the water for 40+ hours in closed circuit position), blew off the oxygen sensors, and it fired up correctly with the solenoid injecting gas as programmed^[3]. When purged with diluent the average PPO₂ reading was 0.15 [atmospheres] (exact [calibrated heliox 86/14] mix was 0.14) and when purged with pure oxygen the average read 0.99 [atmospheres] (exact would be around 1.0). I used the menu and there was nothing wrong there either. We opened his zippered pouch and found, among his usual stuff (bailout tables etc.), two unopened *Power Bars*, the ones Kenny had been concerned about. Given a) the strenuous work over there in the airbell; b) the lack of recently

ingested food and c) diarrhea, would this have caused insulin shock, or even simple dizziness or light-headedness? There was no way to do a blood sugar analysis at this stage."

Although the gas processor "stack" had been flooded, the replaceable internal canister which contained the lithium hydroxide absorbent material (which removes carbon dioxide), was not. It had been specifically designed to tolerate flooding and the mechanisms designed to prevent flooding had not been breached; there was no alkaline slickness to the water drained from the stack which would have been evidence of such a failure. As stated above, the canister had three hours of usage prior to Ian's departure from the dive base. At most, this canister would have seen three hours and thirty-five minutes of cumulative use prior to Ian's dive into Sump 2. This was well below the six-hour minimum range of the canister. Therefore, it is extremely unlikely that there was any residual CO₂ buildup in the breathing circuit at any time during Ian's mission.

An autopsy was performed in Oaxaca City the week of April 3, approximately eight days following the accident. The clinical cause of death was determined to be "asphyxia due to immersion in water." No water was found in Ian's lungs and the diagnosis was not "drowning." Drowning has been defined as "Suffocation and death resulting from filling the lungs with water or other substance or fluid, so that gas exchange becomes impossible" (*Dorland's Illustrated Medical Dictionary*). However, ten to twenty percent of victims develop laryngospasm after the first gulp and never aspirate water, for which the term "dry drowning" has been applied (*Current Emergency Diagnosis and Treatment*). This appears to be one of several explanations applicable to Ian's situation. Further discussion on this subject is presented below.

On June 4, following the return of the expedition to the United States, the "black box" memory chip resident in Ian's rig was downloaded. Unfortunately, there were complications. Due to the rig being left on for more than 40

hours the log (memory chip) filled up. The software prevents over-writing of the data in this event. Recording therefore stopped at 6:24AM, March 28, approximately six hours prior to Broad's arrival in the airbell. Further complications arose due to the fact that data logging commenced automatically during efforts to download the data. This logging was over-ridden via manual software control within three and a half minutes. Because the memory chip was completely full, this meant that the first three and a half minutes of Ian's fatal dive were possibly over-written. It is likely that less than this amount was lost, since data-logging in the MK4 is event driven. That is, nothing is recorded after the initial scan unless a change has taken place. During an actual dive more data is logged since sensor readings are actively changing. The significance of this is discussed below.

Analysis

Five possible causes exist:

- 1 Hardware malfunction of the rebreather
- 2 Software malfunction of the rebreather
- 3 Hypoglycemia related to Diabetes mellitus
- 4 "Pilot Error"
- 5 Tripping while walking with the rig and being knocked unconscious

First, the issue of clinical asphyxia must be addressed. This could occur under only two circumstances: a) an hypoxic blackout as a result of low oxygen content in the breathing bag or b) the diver going into a state of unconsciousness due to some other cause.

Case a) could occur because of scenarios 1, 2, or 4 above. Case b) could occur because of scenarios 3 and 5 above. Scenarios 1 and 2 were quickly ruled out at dive base as a result of the witnessed tests of Rig H (Ian's rig). It is important to recognize that Rig H was subsequently used by Barbara am Ende to traverse both Sump 1 and Sump 2 (1400' and 560' in length, respectively) on two occasions, on May 1 and later on May 6th. In both instances the rig operated automatically with no complications.

Scenario 5, that of tripping, is not possible either, given the location of the body some 50' from the sandbar and in open water at least 25' from the nearest

wall. As both east and west walls were undercut at the lake surface, there is no possibility of leaving the water and subsequently falling back in. As observed by both Broad and Stone, Rolland had entered the sump and swam to the east wall some 30' to the southeast and tied off the line on a solution hole approximately one to two feet below water level. This could easily have been done while floating on the surface. The line then continued south an additional 50' where it was tied a second time to the east wall at about the same depth. Beneath this wall the main underwater tunnel expands to the east and into Sump 2. However, Ian's guideline then made an abrupt change in direction at the second tie off and led back towards the sand bar. Some 30' were spooled out to where the reel was dropped. The body was approximately eight feet away and closer to the end of the sand bar. This suggests Ian realized that there was a problem and he was returning to the sand bar to resolve it at the time he passed out.

At this stage only two scenarios, "pilot error" and hypoglycemia, remain. The question of pilot error arises for the following reason: the accident investigation showed that the flow of oxygen from the computer controlled solenoid valve to the breathing circuit had been manually disabled by closing a cutoff valve on the manual control box. This valve is present to permit the user to stop uncontrolled flow of pure oxygen into the breathing loop in the rare event of the failure of the solenoid valve in the open position. This is a failure scenario that has been known to occur in the Navy Mark 16, and the ability to isolate this feed line was considered essential by the team during the development of the MK4 and its predecessors. The normal position for the cutoff valve is in the open position. Rolland and several other members of the team, including Broad, used this feature to save oxygen upon surfacing after a dive.

To understand why one might consider it advantageous to close the solenoid cutoff valve, it is necessary to provide some background information on how the MK4 control system works.

The user, employing a software menu system, may select an oxygen control "setpoint" at any time before, during, or after a dive, provided the computer system is turned on. Setpoint is a target value, expressed in absolute atmospheres of pure oxygen, that the control system will attempt to maintain until instructed to do otherwise. It does so as follows: oxygen sensor readings are taken from three independent oxygen sensors that are embedded in the process loop, which includes the mouthpiece, breathing hoses, carbon dioxide absorbent canister, and a flexible breathing bag known as a counterlung. When the oxygen partial pressure falls a specified amount below setpoint (0.01 atmospheres is typical) the computer will initiate a solenoid-firing sequence that leads to a slug of pressurized oxygen being injected into the system. This process in the MK4 is carried out every eight seconds, and if the measured oxygen partial pressure remains below setpoint the system will fire the solenoid every eight seconds until it achieves setpoint.

On an exploratory dive of the type done in Huautla, an operating setpoint of between 1.0 and 1.4 atm was typically used, depending on diver preference and desire to eliminate decompression. During the final stages of ascent a mixture with a partial pressure of oxygen of 1.0 at ten feet, a value typical on most dives logged through Sump 1, will drop to a PPO₂ of only 0.77 when the diver reaches the surface due to the ambient pressure reduction. Under these circumstances, the solenoid will begin firing every eight seconds. When a diver reaches the surface, standard procedure with the MK4 (and most other rebreathers) is to throw a switch in the mouthpiece that closes the process loop so that water cannot enter. Oxygen that is injected begins to inflate the counterlung at this point until an overpressure checkvalve vents the excess gas overboard. Under such conditions it can be shown that the system will approach but never achieve 1.0 atm PPO₂ at the surface, and thus the solenoid will continue to fire.

The quickest method of stopping excess oxygen dumping on the MK4 is to reach to the manual control box and

Analysis Continues...

turn the cutoff valve 90 degrees. At this point the user can enter the software menu system and perform a "stop dive," which stops all active control mechanisms including the solenoid. Under normal conditions a software "stop dive" is all that is required since the volumes involved are only on the order of a few liters. However, given the precious nature of all diving gases at the San Agustín sump, Ian apparently considered those extra few shots of gas to be worth saving, and he closed the cutoff valve.

Normal procedure when beginning a dive at Sump 2 under the above circumstances would be to re-open the solenoid cutoff valve, set the gas selectors for oxygen and diluent to "onboard" gas (there were two sources of each gas in the MK4), and perform a pre-dive checkout to verify that the rig was operating correctly. The final act before submerging generally consisted of setting the desired setpoint, then preloading the counterlung with oxygen to a level near setpoint if setpoint was not achievable on the surface, or slightly beyond setpoint if the setpoint was well below 1.0 atm. The diver would then use the menu to perform a "start dive," which re-activates the solenoid on the electronics side. If not manually started, the system itself will initiate active control at a depth of five feet.

For reasons that will become evident later, we know Ian did perform a manual start dive on the surface before entering Sump 2. He also changed his setpoint to 0.5 atmospheres from the 1.4 value that had been used in Sump 1. This is common practice by users of the MK4 when it is known or believed that the depth will be shallow for some time. The reason is that it is impossible to maintain a 1.4 atmosphere PPO₂ at any depth less than 13'. The common solution is to select an initially lower value of setpoint and reset to a higher level once the depth increases. Another standard procedure in such a case to prevent unnecessary firing of the solenoid (in an effort to conserve battery power) is to preload the counterlung with oxygen to some level above the lower setpoint. For a setpoint of 0.5 atm

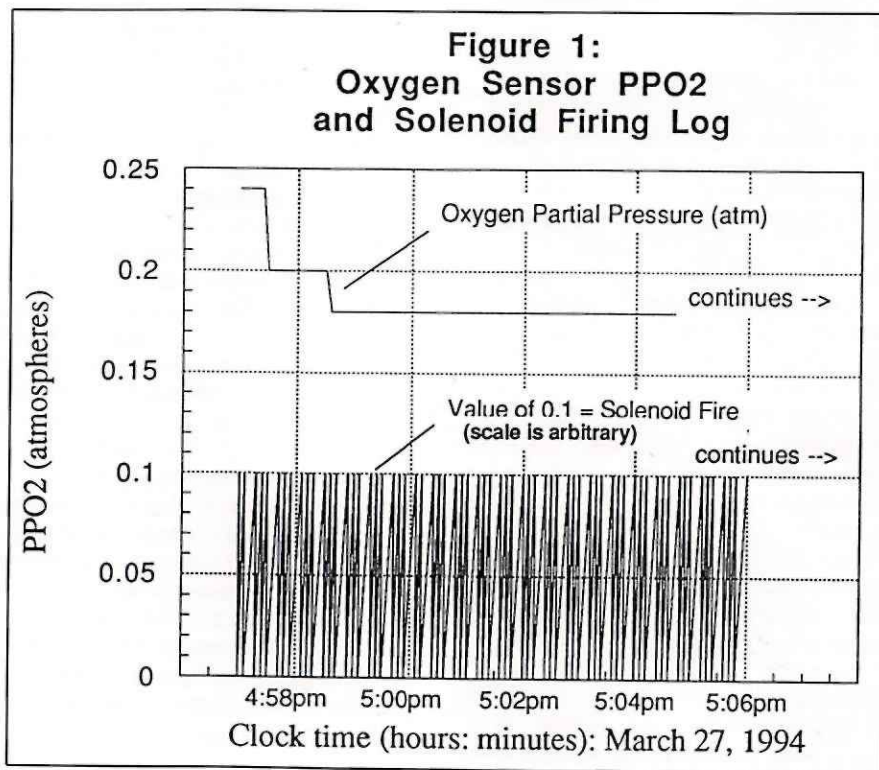
it would not be uncommon to preload the rig to a PPO₂ somewhere between 0.6 to 0.8 atm, which is relatively easy to achieve by bag-purging on the surface. If Ian was using a setpoint of 1.4 atm in Sump 1, as he had on all previous dives, then the residual PPO₂ in the breathing loop was almost certainly at the high end of this range (i.e. 0.7 to 0.9 atm) even without preloading. The significance of this will be discussed below.

With the exception of the solenoid cutoff valve being closed, all other aspects of the rig used by Ian when he entered Sump 2 were normal. Why then did he never re-open it during his pre-dive checkout at the head of Sump 2? There are two widely held opinions: 1) that he was too excited about the upcoming exploration to check the valve settings on the manual control box or 2) that he was under the effects of hypoglycemia. The other remote possibility was "bad air" in the airbell, but this was eliminated based on the experiences of Broad, am Ende, and Stone, who subsequently traversed this chamber on numerous occasions without

observing anything unusual (e.g., high CO₂ etc.). The topic of hypoglycemia is discussed in the May/June 1994 issue of *Alert Diver*. In an article concerning a survey on diabetes and diving, Dr. Guy Dear wrote:

"The controversy about diabetes and diving is due to the fact that a mismatch between insulin and sugar during or after exercise can result in hypoglycemia (low blood sugar). The onset of hypoglycemia is not always easy to predict, especially during exercise. Low blood sugar can cause many symptoms including unconsciousness or seizures—not particularly desirable events for Scuba divers. . . . low blood sugar while diving. . . . can have a serious impact on divers and their buddies. Divers with significantly low blood sugar may not be able to function well under demanding diving situations."^[4]

The traverse of the airbell with a 140 lb backpack was a particularly strenuous undertaking due to the soft sand and shallow water and must be considered a factor in the analysis. Ian's weight, for comparison, was only five pounds more than the backpack.

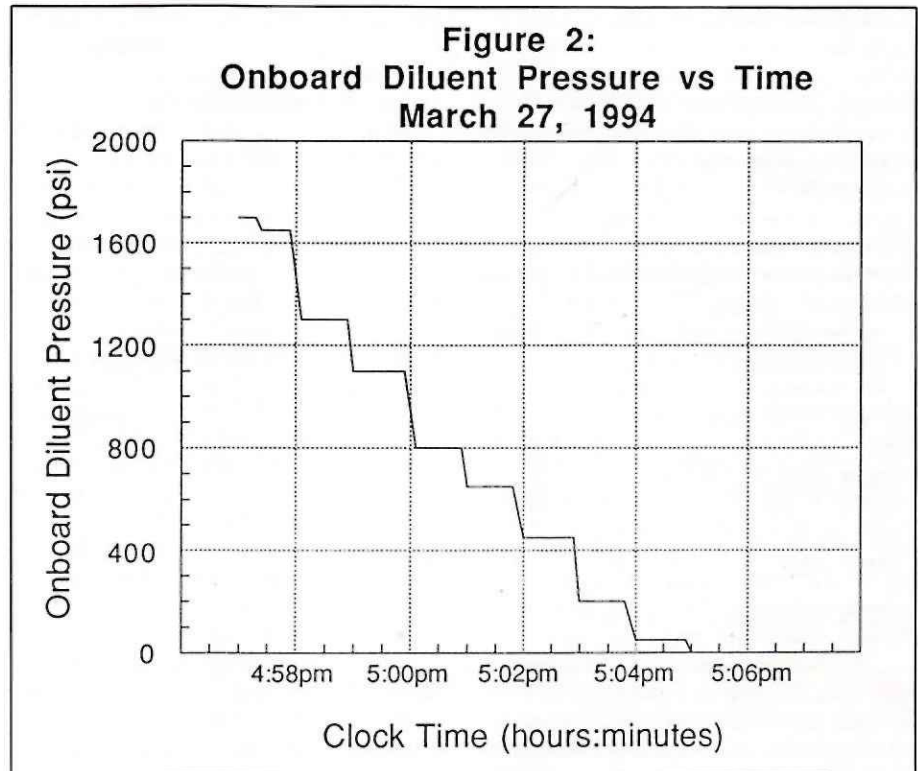


Other factors that are pertinent to the following discussion are that the HUD (Head-Up Display) system was found deployed in front of Ian's mask in such a fashion that it would not have been ignored by an alert diver trained in the use of the MK4. Of particular importance is a multi-state LED in the HUD that is used to convey oxygen partial pressure status. If the PPO_2 is within 0.2 atm of setpoint the HUD oxygen indicator is solid green; if the PPO_2 is between 0.2 atm absolute and 0.2 atm below setpoint, the indicator is flashing yellow; if the PPO_2 is below 0.2 atm absolute the indicator is flashing red. The HUD on Ian's rig was operating correctly 41 hours after the accident and was flashing red for a measured PPO_2 of 0.17 atmospheres, which is the final value reported by both Broad and Stone. A flashing red HUD oxygen light is an unmistakable "wake up call" to anyone using the MK4. This is an emergency situation and the standard procedure is to abort to open circuit bailout gas and then determine why the system had developed such a low PPO_2 .

As previously stated, the mouthpiece was in closed circuit mode (a 90 degree rotation of the mouthpiece valve would have converted it to open circuit operation) and both bailout regulators were still stowed. Thus, either Ian had blacked out prior to the "Red Oxygen" status or he was impaired enough by some other factor as to ignore it. It has been shown on numerous bench dives conducted with the MK4 that an average individual will not experience the dizzy symptoms commonly associated with hypoxia until the PPO_2 drops to between 0.05 to 0.07 atm. Thus, even if an individual has a flashing red HUD oxygen light, there is still significant time available to plan an abort maneuver. The subject of hypoxia threshold is discussed in greater detail in Appendix C.

Appendix B presents a timeline considered by Broad, am Ende, and Stone (who collectively conducted four traverses of Sump 1 and the airbell during the expedition) to be most likely to have occurred during Ian's fatal trip.

The final clock time shown in Appendix B, 4:58PM, coincides with the time at which the black box recorded a



descent from the surface to 9 feet. This can be presumed to be the time of death, since no subsequent changes take place in the partial pressure of oxygen that would indicate an attempt to use the apparatus. Pertinent data recorded in the black box are shown in Figures 1, 2, and 3 (pages 18, 19, and 20 respectively). Of critical importance, Figure 1 shows that at 4:57PM the breathing gas in the system had an average PPO_2 of 0.24 atm, i.e. greater oxygen content than in air at the surface. Over the next several minutes this value drops, and eventually stabilizes to 0.17 atm. This value is maintained until the termination of the log at 6:24AM, March 28. The depth at this time is initially zero, meaning that at 4:56PM Ian was on the surface. Further, from Figure 1 it can be seen that the computer control system was firing the solenoid every eight seconds continuously. For clarity the logs shown in Figures 1 through 3 are terminated at 5:06PM. The states shown at 5:06PM were maintained until termination of the log at 6:24AM, March 28.

The fact that the solenoid was firing at a depth of zero means that Ian initiated a manual start dive prior to entering the water. The fact that it continued to fire produces two other pieces of information:

1) The PPO_2 fell below 0.49 atm and initiated automatic firing of the solenoid. This meant he was breathing on the rig in closed circuit mode and that the system was functioning properly.

2) Given that the solenoid cutoff was in the closed position and given the fact that the PPO_2 continued to drop to 0.24 atm, it is highly unlikely that Ian used the manual control system to manually add oxygen at any time during the dive, as this would have resulted in a higher PPO_2 than 0.24 atm at the recorded time.

Statement 2) above can be further understood by examining Figure 4 (page 21) which shows PPO_2 decay times to 0.24 atm for various PPO_2 precharges and various VO_2 (metabolic oxygen uptake rate) values. For reference, a VO_2 value of 0.5 liters per minute can routinely be maintained by a fit individual

Analysis Continues...

during decompression; a value of 1.0 liters/minute would be likely to exist at a nominal swimming rate of 60 feet/minute. Given the strenuous trip across the airbell, it is almost certain that Ian rested prior to beginning the dive while donning his fins and mask. Since both line tieoffs were reachable from the surface he was likely floating and therefore not exercising hard. It is therefore most likely that his VO_2 during the dive into Sump 2 never exceeded 0.75 liters/minute and quite likely was closer to 0.5 liters/minute.

Of interest are the roughly six minutes that it would have taken him to carry out the tasks listed in Appendix B after leaving the southern limit of the sandbar in the airbell. Even a precharge value marginally above setpoint for a VO_2 of 0.5 would account for the logged PPO_2 of 0.24 atm at 4:57PM without any subsequent oxygen being added to the system. Other scenarios, such as a slightly higher metabolic uptake rate and a slightly higher precharge, also account for the observed PPO_2 without any requirement for manual interven-

tion. Precision in the above discussion is not required. It demonstrates that for a range of conditions it is highly probable that Ian never manually added gas to his system throughout the entire dive.

At a value of 0.24 atm with a setpoint of 0.5 atm the HUD oxygen indicator would have been flashing yellow. An alert user would not permit this condition to exist long before taking three steps: manually adding oxygen, checking the backup PPO_2 display to insure that the PPO_2 was within the desired control range, and then checking the valve selector positions on the manual control box as well as tank pressures to verify that oxygen was reaching the automatic control system. Under normal conditions, this is a reflexive maneuver to anyone who has used the MK4 for more than a few hours. Both of the above paragraphs suggest a level of mental impairment that could not be accounted for by "exploration fever."

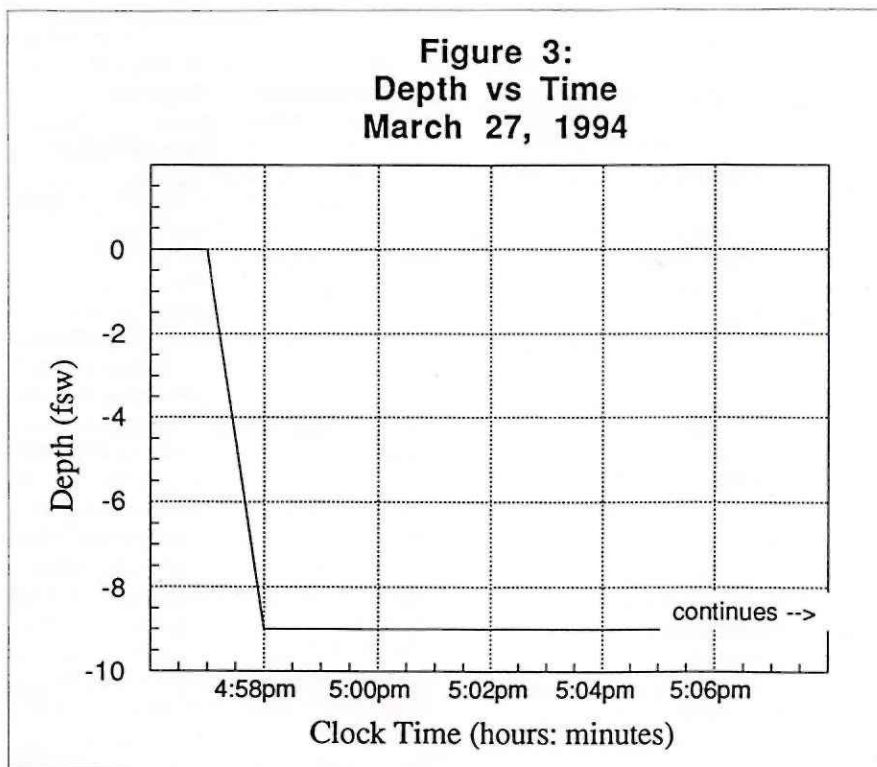
At 4:58PM the depth sensor logged a descent to nine feet. Coincident with this is the linear decay of the onboard diluent gas pressure (Figure 2—above).

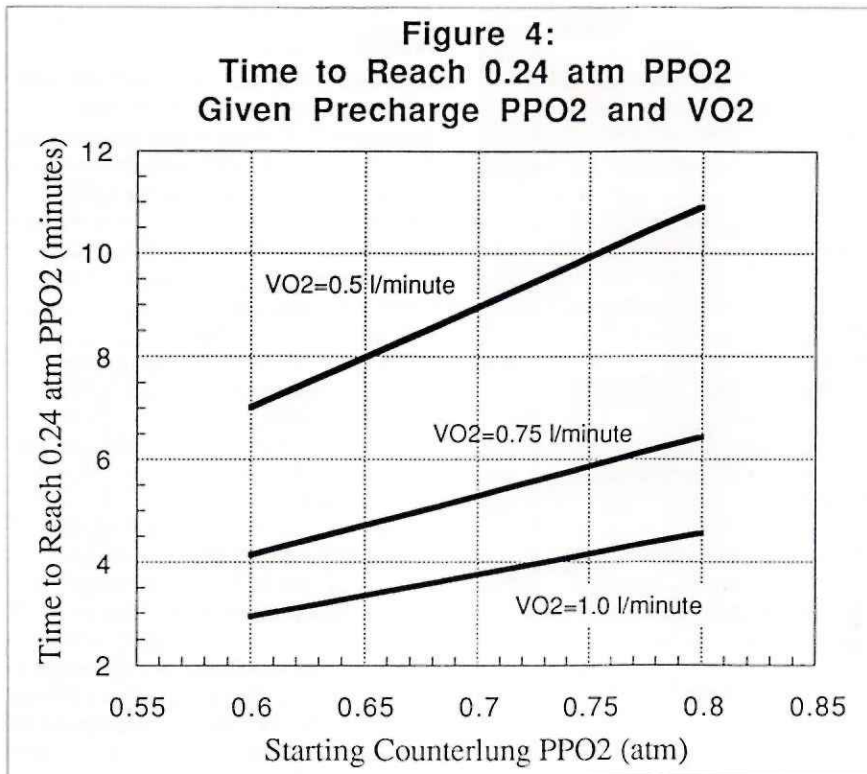
Given that the mouthpiece block was found in closed circuit mode, the only way this pressure could have dropped was by triggering of the automatic diluent addition valve. This special valve adds gas to the system upon collapse of the counterlung bags during descent to maintain lung volume. A descent to nine feet under normal circumstances would have represented no more than a ten psi pressure drop for this cylinder. The only explanation consistent with the observed state is that the mouthpiece, in closed circuit position, dropped from Ian's mouth. At this point gas would have been forced through the mouthpiece by the hydrostatic pressure exerted on the counterlungs. Coincident with this collapse of the counterlung two things would have happened: 1) the auto diluent valve would have gone into a constant flow condition due to the fact that there was no back pressure at the mouthpiece; and 2) the collapse of the counterlung (which represented up to 15 lbs of lift) would have reduced buoyancy dramatically causing him to sink to the floor at nine foot depth fairly rapidly.

At 4:59PM the black box log shows that the PPO_2 was fluctuating between 0.16 and 0.20 atm. The value ultimately observed by Broad and Stone was 0.17 atm. The above black box values were recorded coincident with the purging of the process stack by the emptying of the onboard diluent bottle. Heliox 86/14 has a PPO_2 level of 0.17 atm at nine feet underwater at 2300' elevation (the level of the San Agustin sump). From this we can conclude that at no time during the dive did the gas mixture in the rig go hypoxic (see Appendix C for further discussion).

Let us play Devil's Advocate. Suppose that during the three minutes of data that are missing from the black box log that the mix went hypoxic and he blacked out. If that were the case the PPO_2 , as mentioned above, would have to be reduced to at least 0.07 atm. The solenoid cutoff valve was closed and therefore the system could not automatically add oxygen. Likewise, an unconscious individual could not be expected to depress the manual oxygen addition

**Figure 3:
Depth vs Time
March 27, 1994**





switch. This scenario is therefore inconsistent with the recorded data, since there would be no means to return to the 0.24 atm level recorded at 4:56PM.

A final observation should be made concerning the apparent discrepancy between the onboard diluent tank pressures observed by Broad and as recorded by Stone in a later detailed investigation. Broad had glanced at the primary LCD display on Ian's rig and seen the bar graphs that present the pressures of the oxygen and diluent tanks as "gas gauges." He saw both bars to be full or nearly full. Stone had taken the specific digital pressures and written down four psi for the same diluent tank. Analysis of the log shows that at approximately 7PM on the evening of March 27, after some 800 solenoid firings, each of which consumes power, the battery voltage momentarily dropped sufficiently to cause the LCD microprocessor to reset. The MK4 system is a redundant processor design that permits failure and recovery of any of its nodes. When the LCD microprocessor came

back online it read that the depth was greater than five feet and therefore presumed that a dive had just been initiated. The software is presently coded so that in such a case the system takes the current tank pressures and makes them read full-scale on the bar graph. This permits multiple dives on the same tank while giving one the ability to manage each dive by the rule of thirds. In this particular instance the bar graph was full when Broad read it, but in fact the contents were four psi.

Discussion

The sequence of events during the last minutes seems to have begun when he stopped tying the line and headed back toward the beach. This might have been based on an awareness or premonition of trouble. This is suggested from the location of the line and the reel. About halfway back he apparently dropped straight to the bottom. There was no evidence in the silt that he had struggled, nor was there any silt on his body. When found, the apparatus was

functioning normally. It is not likely that the setting on the cutoff valve was of concern to Ian at this point, because a simple 90-degree rotation would have been easy for him to accomplish had he been aware that it was off. Furthermore, he had three sources of open-circuit gas available to him within easy reach.

When found, Ian did not have the mouthpiece in his mouth. The system would have had a slight positive pressure as he was using it, and further there was a little "spring" on the hoses tending to pull the mouthpiece out. Thus, all he would have to do is relax or become inattentive in order to lose it. When the mouthpiece is removed intentionally, it is normal to close it off with a lever, which in the case of the MK4 converts it to an open-circuit second stage; if this is not done, as the gas escapes the unit will attempt to fill with diluent. As the bags lose their gas their buoyancy is reduced, by as much as 15 pounds, so once the mouthpiece was lost Ian would have immediately begun to sink unless he had taken corrective action. If he had been in a weakened condition or severely disoriented he might have been unable to avoid sinking even if not totally unconscious.

Possible Causes of Unconsciousness

What are the possible reasons for Ian to pass out? Of the candidate reasons by far the leading choice is hypoglycemia as a result of diabetes with the additional combined effects of exertion, a long time since eating, and diarrhea.

Another speculation is hypoxia. Under the right circumstances this is a possibility with any type of rebreather. In this case, however, there are two dominant factors that render this unlikely as a primary cause. First, as mentioned, the record stored in the computer showed that the lowest PO_2 value even remotely likely to have occurred before he lost the mouthpiece and began to descend from the surface was 0.24 atm, because with the oxygen solenoid cutoff turned off there was no way it could get back up to that value

Analysis Continues...

had it gone lower. This conclusion of course depends on the reliability of the log recording function, but there is no reason to doubt this in view of the normal post-accident checkout and continued use of the rebreather.

The second important factor arguing against hypoxia was that the diluent gas was 14% oxygen. This gas is perfectly safe to breathe at the surface. It is roughly equivalent to breathing air at 12,500' altitude. At an altitude of 2300' it would be slightly more stressful ($PO_2 = 0.13$ atm), and although it would be hypoxic enough to cause mountain sickness in some individuals after several hours of exposure, performance decrements at this level of hypoxia are so slight that they are hard to measure. Breathing 14% oxygen at 2300' altitude could reduce night vision and would cause some decrement in mental ability, but normal people are most unlikely to become unconscious on sudden exposure to this PO_2 . This mixture would have been even less hypoxic at the depth of the bottom where Ian was found, a PO_2 of 0.17 atm. This assumes that Ian was in fact exposed to this gas, but the record shows his oxygen exposure was most likely to have been above 0.24 atm until the final descent. The abrupt drop in oxygen level during the descent with no subsequent variations indicates that the drop was due to purging of the system with diluent mix, rather than due to its being "breathed down" by heavy exertion.

Cause of Death

When Ian was found the mouthpiece was out and there was no sign of a struggle. Autopsy performed more than a week later said the cause of death was "asphyxia due to immersion in water." It was not listed as drowning because there was no water in the lungs. This is of little significance in any case, but particularly since the body was carried out through five kilometers of cave, hauled up 3 kilometers of rope, and not autopsied until eight days after death. "Asphyxia" implies both a lack of oxygen and an accumulation of CO_2 , as might occur on breathing in and out of a closed bag, or being strangled or

choked, but there would be no way in this autopsy to make this determination. As stated earlier, it is extremely unlikely, given the functional state of the absorbent canister, that high CO_2 was involved at any time during Ian's dive. Although the mechanism is not known precisely, some 10% to 20% of drowning victims are found without water in the lungs; this is known as "dry drowning," and its occurrence is well accepted.

If Ian were merely unconscious but otherwise essentially normal and sank into the water without a mouthpiece and breathing gas, even though underwater he would in due course when the gases in the blood reached the "breaking point," have attempted to breathe, involuntarily. This was fresh water, so a leading possibility for explaining the lack of water in the lungs is that some water that could have been in the lungs was absorbed; this is known to occur to the extent that if circulation continues, as much as half the blood volume of water can be absorbed into the blood from the lungs.

Another group of possibilities are the hypoglycemia-related problems such as heart arrhythmias or a seizure. Almost any of the normal physiological steps in drowning can be exacerbated by hypoglycemia. Arrhythmias could cause the heart to be completely dysfunctional, and drowning is known to cause vagal inhibition of the heart and arrhythmias even without hypoglycemia. Respiratory movements would stop shortly thereafter. There can also be a reflex constriction of peripheral airways and pulmonary vasoconstriction leading to a ventilation-perfusion imbalance in the lungs and further hypoxia. Much of this would not have been detectable in autopsy.

Another physiologic event occasionally mentioned about dry drowning is laryngeal spasm. This is a constriction of the larynx as a result of being stimulated by water (a vagal reflex). Laryngospasm is not likely to be a cause of death in itself, because by the time the victim is unconscious and becoming hypoxic the spasm tends to relax. The resulting hypoxia can lead to the heart or seizure problems just mentioned.

Conclusions and Reflections

The most probable chain of events was that Ian began a second dive after traversing the first sump and sandbar, and that he passed out, sank, and drowned after performing shallow work tying lines. The most probable cause of his passing out was from diabetic hypoglycemia, exacerbated by recent exercise, several hours of fasting, and diarrhea.

There are other responses to hypoglycemia that could have been factors in this incident: it can lead to cardiac arrhythmias (rhythm disturbances that can in effect be like a heart attack) and seizures as well as altered consciousness. Despite the fact that the oxygen cutoff valve was turned off, hypoxia in the breathing rig seems highly unlikely to have been involved.

Ian was a man of consummate technical skill with rebreathers. His approach to cave diving was rigorous, precise, and conservative. Under normal circumstances the failure to re-open the oxygen cutoff valve would have been construed as "pilot error." However, rather than being the cause of the drowning, it was a symptom of the fact that his thinking was impaired by hypoglycemia before he even entered the water at Sump 2. Of the experts with whom we consulted on diabetes and diving, all indicated that impaired consciousness as a result of hypoglycemia can be insidious in that its onset is very difficult to detect by the affected individual.

For a man like Ian, who devoted nine years of his life to the San Agustín Expedition and was the quintessential Renaissance Man in the cave exploration world—practiced at many complex skills—the thought of quitting, after being diagnosed with diabetes a year before expedition departure, was unacceptable. He made a conscious decision to press on, regardless, and accept the risk. He was one of the strongest team members at San Agustín. There are two recommendations we feel that should be drawn from this incident:

1) Diabetics should not be banned from diving. Rather, such individuals, with the open understanding and consent of their peers, should have the right to assume risk and to pursue the course in life that they feel they must.

2) Because exercise is a factor in hypoglycemic onset, and because once underwater there are few options for dealing with a problem of this nature, it is incumbent on diabetic divers to more closely track their blood glucose levels. At a minimum it appears logical that this should be done immediately prior to each and every dive. However, there is substantial merit to also monitoring these levels immediately after diving as a means of developing a calibration for one's metabolism. This becomes particularly important if long duration and/or technical diving is involved.

This report is intended to present the facts of the accident. In no way does it touch upon the sorrow felt by members of the expedition. Ian was a man who experienced life to its fullest potential, literally to the last minute. His spirit and drive were fueled in large part by caving and mountaineering—even more so, however, by the love for his wife, Erica, their three children and close friends. Words cannot express our loss and our sadness.

Acknowledgement

The authors would like to express their gratitude to Dr. Bill Hamilton, Dr. Tom Neuman, and Dr. Hugh Greer for their review of this document. Their detailed comments were both constructive and informative and were incorporated into the final report. Dr. Hamilton is a hyperbaric medicine specialist well known to the technical diving community; Dr. Neuman is an ex-USN diving medical officer, a lung specialist, and a hyperbaricist; Dr. Greer is a diving neurologist who has a special interest in diabetes.

Footnotes

[1] Bailout gas consisted of Heliox 86/14 which was available via three independent tanks and regulators (100 cu ft Acurex composite bailout, and two 30 cu ft aluminum bottles pumped to

3500 psi to give 35 cu ft each). These latter two tanks were also used for diluent makeup in the closed circuit unit and for buoyancy compensation. Additional 100 cu ft Acurex composite stage bottles of oxygen and Heliox 86/14 were located at 300 and 750 feet into the sump, respectively, to permit an open circuit abort from maximum penetration.

[2] The depth-time down load from Ian's Suunto dive computer showed no data for his dive at Sump 2. This can be attributed to a memory overflow as a result of the instrument being at a depth of nine feet for more than 40 hours. It logs continuously every three minutes when the depth is greater than one foot. The recovery dive through Sump 1 on March 29 was recorded correctly. Other than providing an approximate transit time for Sump 1 this data does not shed any further light on the events of March 27.

[3] When the system senses that the average PPO₂ in the breathing loop has fallen 0.01 atmospheres below the user-defined setpoint it initiates firing of the oxygen solenoid every eight seconds until the average reading exceeds setpoint. Several experiments were conducted at the dive deck and on each occasion, for various setpoints and with the solenoid cutoff valve re-set to its proper "open" configuration, the valve fired gas into the breathing bag on queue. Based on these tests a hypoxic blackout resulting from hardware or software failure in the rig was ruled out as a cause of death.

[4] On May 4th Don Broussard was found unconscious following a convulsion at Camp 3 after a heavy day's work. It took Noel Sloan, the expedition physician, nearly an hour and a half to revive him from his unconscious state by placing glucose solution under his tongue while Bill Steele propped him up. He was, by Sloan's estimate, "not far from death." Broussard had been a meticulous planner for his diabetes, taking several blood sugar measurements a day and had not had an incident for 20 years (he was now 50). None of the team members can recall Rolland

taking such measurements and no instrumentation of the type required to do so was found in his personal effects at Camp 5. ❖

Appendix A: Data Obtained at Accident Site

The following information was recorded by Stone at the accident site from 9–11 AM, March 29:

Dividing Gas:

Onboard Oxygen: 2550 psi (approx. 13 cu.ft.); valve open, back 1/4 turn

Onboard Diluent: 0004 psi (empty) valve open, back 1/4 turn

Offboard Oxygen: 2000 psi (approx. 9 cu.ft.); valve on, back 1/4 turn

Offboard Diluent: 3000 psi (approx. 30 cu.ft.); valve on, back 1/4 turn

Acurex Bailout: 5000 psi (approx. 105 cu.ft.); valve on, back 1/4 turn

LCD Display Messages: "PPO₂ Low" (occurs when PPO₂ is less than 0.2 atm below setpoint) "Diluent Tank Empty" (occurs when dil. pressure <200psi)

Suunto Dive Computer: In place. Read 9' depth, no decompression. Later attempts on the surface to download the data failed. The length of the last dive (more than 40 hours) apparently could not be handled by the available storage which logged depth every three minutes. It did record the return dive through Sump 1 at 34 minutes with a maximum depth of 81' but this is not of specific importance other than to re-affirm the approximate transit time for Sump 1 shown in Appendix B.

Setpoint:

0.5 atmospheres (default is 1.0, so this value represented a user over-ride)

Max Depth: 9.4 feet

Current Depth: 9.0 feet

Dive Time:

16:17 hours:minutes, colon blinking, on Tuesday, March 29, approx. 9:07AM) [the system "wraps" every 24 hours so the actual run time was 24:00 + 16:17 for a total "on" time of 40:17, thus the computer was still operational from the moment Ian began the dive].

Oxygen Sensors: 0.17, 0.17, 0.19 atmospheres, digital display

Analysis Continues...

Solenoid: not verified insitu (could not hear valve clicking, possibly due to my solenoid making it difficult to discern which was firing, possibly because the cutoff valve was closed (see below). [Later verified working during witnessed test at Camp 5].

Body Position: On right side, face down, head facing south. Floor was undisturbed; no signs of a struggle.

Buoyancy Compensator:

Empty, but both inflator and deflator worked properly.

Mouthpiece: In closed circuit position. [mouthbit was not in victim's mouth]

Primary Dive Light:

Dive Rite "Huautila" Light. Battery functioning, switch on, light head dead (burned out filament).

Backup Lights: Two UK SL4s: in on position, both dead.

One UK2L: Off position, still working.

Primary Reel: On floor 8 feet to east, lock nut free (i.e. he was laying line)

Gap reel: Stowed, unused.

Drop Weight: Stowed, on right d-ring.

Mask: In place, flooded.

Backup mask:

Stowed, reversed on neck (standard).

Knives: Two, in place, stowed.

Harness:

Properly secured, buckles in place.

Bailout Gas: Acurex bottle in place, stowed properly, second stage clipped as per standard procedure: Not used.

Offboard diluent regulator was also stowed properly and was also unused.

At the time of the accident he was certain to have had available in excess of 150 cu ft of surface breathable gas in open circuit mode.

Manual Control Box:

Oxygen Select: Onboard.

Diluent Select: Onboard.

Oxygen Cutoff Valve: Closed [normal position at all times is "open"].

Dive Pouch: Contents: 2 unopened

Power Bars, backup fin strap, UK2L backup light (working), bailout decompression tables, 3 carabiners.

Exposure Suit:

6mm farmer john, jacket, hood, short leg long john undergarment.

Head-Up Display: Deployed in front of mask; oxygen: flashing red; CO₂: green;

Appendix B: Likely Timeline Followed by Ian Rolland on March 27, 1994

Task:	Task Time:	Clock Time:
1. Mission start		4:00PM
2. Swim through Sump I	34 minutes	4:34
3. Complete software stop dive, disable O ₂ solenoid, disable auto diluent valve, remove fins and stow mask for foot travel	4 minutes	4:38
4. Walk/swim/crawl across sand bars	5 minutes	4:43
5. Put fins and mask back on, sort primary line reel, rest.	3 minutes	4:46
6. Do pre-dive check in software. Reset PPO ₂ setpoint to 0.5 atm. Re-enable autodiluent select valve to onboard; purge bag to 0.6 to 0.8 atmospheres prior to commencing dive. Verify PPO ₂ with wrist display. Initiate "start dive" (software).	4 minutes	4:50
7. Swim to east wall and locate line tie off	1 minute	4:51
8. Tie line off twice, 50 feet apart	5 minutes	4:56
9. Recognize something is wrong, begin swimming back to sandbar (50' distant)	1 minute	4:57
10. Uncontrolled descent to 9 feet of depth		4:58PM

Decompression: green; Battery: green. Flashing red for oxygen means PPO₂ is less than 0.2 atmospheres absolute.

Appendix C: General Comments on Hypoxia

There has been some speculation that the cause of Ian's becoming unconscious was hypoxia as a result of his breathing the diluent mixture. The

discussion above of the sequence of events as reconstructed shows that it was most unlikely that this could have occurred, but because this remains as a concern the consequences of breathing diluent mix should be examined. The diluent was 14% oxygen, balance helium. At an altitude of 2300' the oxygen in the diluent would have a partial pressure of 0.1285 atm, equivalent to breathing 13% oxygen at sea level, or air at an altitude of 12,500'.

A breathing mixture of 13% oxygen is a hypoxic mixture; a person breathing this gas would be "hypoxic" by definition. The oxygen level in the end-expiratory gas (P_{EtO_2}) would be expected to be about 62mm Hg, predicting an arterial blood oxygen partial pressure (P_{aO_2}) of about 60mmHg (0.079 atm or 8.0 kPa). This would be expected to produce a hemoglobin saturation from 80 to 90% (Lambertson, 1974; Parker and West, 1973).

However, this degree of hypoxia is known from vast experience in the aviation and altitude literature to be right on the edge of measurable performance decrement. A fraction of people so exposed would have no detectable performance decrement in mental ability, but in some individuals it would be possible to detect a deficit. Most people exposed to this degree of hypoxia would show some decrement in night vision, and many would get acute altitude sickness or mountain sickness after a few hours of exposure. A composite diagram shows the relationship (Parker

and West, 1973; page 24). It can be seen on the diagram that a P_{aO_2} of around 25 mmHg or a hemoglobin saturation of around 50% would be necessary for a normal individual to become unconscious from a short exposure.

A recent series of studies by the U.S. Navy on fire-retardant atmospheres have confirmed some of these classical data. These involved 8 subjects breathing 13 percent oxygen (among others; the balance was nitrogen) for several days (Knight et.al. 1987; 1990; 1991). The investigators were unable to show a difference in performance on a paced arithmetic test at both 12 and 13 percent oxygen except at high levels of exercise. The hemoglobin saturation in these 13 percent subjects was measured at 77 to 88 percent. Their subjects at 12 and 13 percent oxygen were a long way from becoming unconscious.

Thus the classical data and recent experiments both provide strong support to the interpretation that even if Ian had breathed the diluent alone it would have been extremely unlikely that this would

cause him to pass out. There is a possibility that a value of oxygen slightly higher than the levels in the diagram, say a PO_2 of 30mmHg or a saturation of 60 percent, could cause unconsciousness in a severely hypoglycemic person, but the positive interaction between hypoxia and hypoglycemia is only a speculation, and the necessary oxygen levels are still unrealistically low for the situation as reconstructed.

Hypoxia References:

Knight, D.R., Luria, S.M., Socks J.F., and Rogers, W. (1987), Effect of nitrogen-based, fire-retardant atmospheres on visual and mental performance. In: Bove AA, Bachrach AJ, Greenbaum LJ Jr., eds. *Underwater and Hyperbaric Physiology IX*. Bethesda, MD: Undersea and Hyperbaric Medical society, pp 521-534.

Knight, D.R., Schlichting C.L., Fulco C.S., Cymerman A. (1990), Mental performance during submaximal exercise in 13 and 17 percent oxygen. *Undersea Biomed Res* 17(3):223-230. May, 1990.

Knight D.R., Schlichting C., Dougherty J.H., Messier A.A., Tappan D.V. (1991), Effect of hypoxia on psychomotor performance during graded exercise. *Aviat. Space Environmental Med* 62(3): 228-232. March, 1991.

Lambertsen, C.J. (1974), Altitude, anoxia, and acclimatization. In: Mountcastle VB. *Medical Physiology*, Vol. 2, Part XI, Chapter 65. St. Louis, MO.

Parker JF, VR West, eds. (1973), *Bioastronautics data book*. NASA SP-3006, Washington. National Aeronautics and Space Administration. ❖

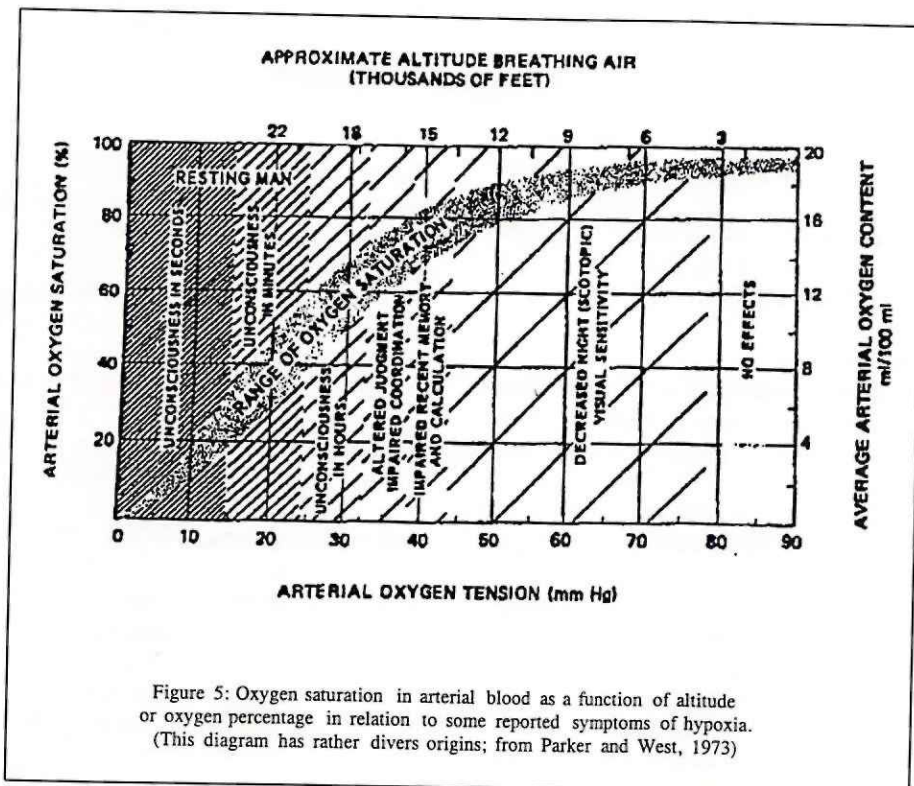


Figure 5

Techniques

SCHwing—By Jeff H. Carson

SCHwing is the memory word that comes to mind when I think of o-rings. The first three letters stand for Size, Compound and Hardness. With a good working knowledge of these three parameters you can easily purchase and utilize the proper o-ring for each application.

Recently on a trip to Ginnie Springs I heard a large air leak coming from the tank valve belonging to the person at a picnic table next to mine. (I filed all the appropriate papers and Yes, the table *is* mine!) After the valve was shut off the guy said, "That was a brand new o-ring; I just put that thing in!" I asked him what kind of o-ring he was using and he said, "Huh? The one they gave me." That conversation got me to do some research on those little rubber (sometimes) rings that so many of us take for granted.

As an example of how important o-rings are to a safe cave dive, let's review how many o-rings a typical cave diver might have. As you can see from Figure 1, for the diver using doubles, a manifold, two regulators, one pressure gauge, one primary light and two backups, the dive depends on between 44 and 48 o-rings working properly per diver. In the paragraphs that follow I have tried to provide the essential information necessary to make an informed choice when buying o-rings.

Schwing

The **S** stands for size. The size of an o-ring from an engineering perspective consists of Inside Diameter (ID), Outside Diameter (OD), and the Cross Sectional Diameter, also called the Width (W). For the cave diver who wants to order the correct size o-ring, a sizing chart with the American Standard Uniform Dash Number will get you the right size. A copy of the AS o-ring size chart

can be obtained by calling 1-800-255-7597; the cost is \$19.95 plus tax and shipping. To use the chart just place the old ring on the chart. First check Width(W) in the lower left hand corner.

Each (W) has its own page: 1/16, 3/32, 1/8, etc. One more item regarding size: if you have an application that requires an odd size,

consider o-ring cord and o-ring tape. O-ring cord looks like string made of o-ring material. This "string" can be cut to any length and glued together to make an on-the-spot custom o-ring. I have found this to be very useful for the large o-rings found in scooters and primary light canisters. The Arnold Jackson scooter, for example, uses 1/8 inch o-rings so I always carry about three feet of 1/8 inch (W) o-ring chord to cover emergencies. O-ring tape works the same way, except tape is flat instead of round. The next time you see someone with a Dacor scooter, look at the red o-ring that seals the two body halves together: that is o-ring tape.

sChwing

The **C** stands for Compound. There are several o-ring compounds that you should be familiar with: Buna, Fluorocarbon and Silicone. Unless you specify, you're probably "gonna get Buna." Fluorocarbon is typically recognized by the DuPont tradename "Viton." Viton o-rings are used in nitrox, trimix and oxygen applications. Because oxygen is extremely flammable, it must be used in an oxygen-clean environment and in contact with materials that are not

very prone to flash fire. The third compound which is commonly used is Silicone. According to the *Parker O-ring Handbook*, "As a group the silicones have poor tensile strength,

Equipment Name	Number of O-rings	Comments
tanks	2	one per tank
manifold	7 to 9	DIN w/ isolator
regulators	13 each	Cyclon 300
pressure gauge	2 each	size 003
lights	5 to 7	primary light
backups	1 each	UK Q-3

Figure 1

tear resistance, and abrasion resistance" (Parker Hannifin Corporation, Cleveland, OH 1992, page A3-6; 1-800-272-7537). This family of polymers is typically noted for their ability to function at extreme temperatures and their resilience after compression. Silicone o-rings have been used as yoke face seals with good success. However, Buna and Viton rings appear to provide better seal characteristics for diving applications.

schwing

The **H** stands for Hardness. The hardness of an o-ring is measured by an instrument called a durometer. Durometer is also a way to specify the hardness of the ring you want to buy. The hardest rings typically used in diving are 90 durometer. According to the graph on page A4-2 of the *Parker O-Ring Handbook*, "a 90 durometer ring is designed to withstand pressures up to 10,000 psig, the 80 durometer ring is designed to function up to 6,000 psig and the 70 durometer ring up to 3,000 psig. Remember the guy with the blown o-ring at Ginnie earlier? Question: What kind of o-ring do you think he got? What kind of o-ring do you think he wanted if his

continues next page. . .

The Safety Line

tanks were not oxygen clean and are typically pumped to 3,100 psig? What if the tanks were oxygen clean and typically pumped to 2,460 psig? Answer these three questions (Yes! There *is* a test at the end so *pay attention!*) If you can answer these using **SCH**wing, you've got all it takes to get the correct o-ring for the job and you wouldn't hold up everyone else or cause everyone in the parking lot to look at you like they were in an E.F. Hutton commercial.

"It's My Collection"

(for bonus points, name the underwater movie that line comes from) Creating your own o-ring collection is really simple. Go through all your gear after you have an o-ring chart and make a list of all the **Sizes**, **Compounds** and **Hardnesses** you use in your gear. Order only the ones that you will replace often. Also you can order different **Sizes**, **Compounds**, and **Hardnesses** in various colors for easy identification. You could also write ring sizes on dive bin lids or directly on the equipment.

SCHwing Lubrication

Buna and Silicone rings should be lubricated with a very small amount of Silicone grease and Viton rings with any of the commercially available oxygen-compatible lubricants such as "Krytox™," "Christolube," or Ivory soap if you're in a pinch. ❖

Durometer (max working pressure)	Extrusion Rate
90	10,000psig
80	6,000psig
70	3,000psig

Extrusion Rates for Commonly Used O-rings

What is a Safe Cave Dive? by Wendy Short

One part of my job as Safety Coordinator is to present the Abe Davis Safety Awards at the workshop to those individuals who have made at least 100 safe cave dives. This doesn't mean a survival dive, nor a lucky dive. It means exactly what it says: a safe dive. But what constitutes a safe dive? Frank Lavallee's article in *Underwater Speleology* a while back addresses this very question. His article (November/December 1993, Volume 20, Number 6, page 11) shared two different dives that he survived but considered not safe. I appreciate his comments and would like to elaborate further on this subject.

I think if a rule is blatantly broken, the dive is no longer safe, even if everything went off smoothly. Maybe you were just lucky. Examples of this would be diving beyond your level of training, neglecting to properly plan the dive, or failure to double check you life support equipment.

Sometimes things do go wrong. But if the dive was planned well and proper precautions were taken then you as a safety-minded diver have a better chance to correct the situation and live to dive another day. Though the situation may have put you in

harm's way, if you used sound mature judgement and learned a valuable lesson, the dive could be considered safe, relatively speaking.

Then there are those "grey" areas

where safety could be considered questionable by different people. How do you evaluate a long stage dive in a cave you have never been in and know relatively little about? Or two people scootering to some far-reaching passage when one person has penetrated it without the scooter and knows his air requirements and the other person has not? Would encouraging this scootering situation be any worse than a full cave diver encouraging a basic cave diver to do a system where multiple jumps and doubles are required? Rules are the mechanism to a safe cave dive. Common sense is the method to which the rules are applied.

Past experience also plays a role and what is safe for one individual may be unsafe for another. For instance, going through tight restrictions may not be a problem to a seasoned cave diver, but to a "novice" restrictions can be very intimidating. A dive you make one day may be hazardous a different day (conditions could change, for example).

If you are applying for the Safety Award, keep all this in mind when you are filling out your log and you are wondering if the dive you made was safe. The Cave Diving Section has worked to promote safety. You are the Section. A safe cave dive is one that has been properly executed according to CDS standards. That leaves it up to you to encourage safe cave diving principles by word and by example. ❖

CDS Board of Directors

The members present were: Joe Odom, Chairman; Gene Broome, Secretary; Eric Tasso, Treasurer; Watson Boxley, Vice-Chairman; and by proxy: Jerri Broome for Van Flowers; Watson Boxley for Rick Wolfe; and Joe Odom for Lamar Hires.

The meeting was called to order at 7:58PM at Ginnie Springs.

In the private executive meeting, Broome read a letter to the Board from Van Flowers since he was not able to be in attendance. He discussed several issues of concern for the Board, some being the status of *UWS* and also some status reports on advertising in the current and past issues. It was reported by Flowers that he had a signed contract from OMS for one year's advertising at the previous rate and it was discussed relating to the commitment for the advertising even though the rates have risen. Broome moved with a second by Boxley that we officially accept that contract from OMS and the resulting vote was unanimous in the affirmative.

Chairman Odom stated that he wanted to recognize publicly to the Board that he is most pleased and well satisfied with the first issue just completed by the new editor of *UWS*, Shannon Sikes. Boxley and Tasso both agreed.

Odom began a discussion on Flowers' status as editor of *UWS*. He stated that with the many problems and areas of concern with the various issues, he was compelled to advise the Board of the need to solve them. He stated that after discussion with the Board members via telephone and the resulting votes cast by them to replace Flowers, that he did notify Flowers by E-Mail of the decision to terminate his editorship. Broome felt that since Flowers was not contacted for his input and vote,

that possibly the vote was not a valid one in accordance with the ByLaws. He suggested that the Board actually call for a motion and vote to keep it proper. Odom as proxy for Hires made the motion to replace Flowers with Sikes and a second was provided by Boxley. The resulting vote was 6 to 1 with the nay vote being cast as per the instructions for his proxy, Jerri Broome. The motion carried by majority.

The Board further instructed that the future issues of *UWS* would be reviewed before printing by the Chairman. He will review for potential problems for the issue and will advise Sikes of any areas of concern.

The next item for discussion was the Section's bulletin board computer. It was determined that the Board needed to know as to the usage of the system to verify that it is being used to the Section's maximum benefit since the Section pays the phone bill and related costs and it is the property of the Section. The Board asked Tasso to get the usage report from Wayne Maples, who handles the Bulletin Board Service. Tasso stated that he had previously asked for the report and, so far, has not received it. The Board further instructed Tasso to get a budget for 1995 relative to the BBS' funding needs. Tasso is to follow up immediately and upon the information received, will determine the usefulness of the BBS and if the usage warrants, the Board will continue its use.

Odom addressed the Workshop for 1995 and the issue of its Chairman. There was some discussion as to the Workshop this year and some problems and areas of concern that the Board does not wish to recur. Broome was asked if he would be willing to Chair the event and he

responded that he would. But he emphasized that he would be utilizing many people in that effort and the Board members would be involved as well. He indicated that he felt that more members should be included in the effort of the Workshop and that more could be experienced with good potential for future workshops. Tasso moved with a second from Boxley to appoint Broome the 1995 Spring Workshop Chairman. The resulting vote was unanimous in the affirmative. The Workshop will be held Memorial Day weekend.

At this point, 9:05PM, Shannon Sikes and Jennifer Andes Brown joined the open meeting of the Board.

Odom began a discussion of *Underwater Speleology* with Sikes. Sikes reported that she had just gotten the new issue out and it was complete with mailings for a cost of \$700. This represents a savings of about the same amount as spent. She also stated that we had an additional cost of \$115 for the Exley Memorial inserts that were printed. This cost will be borne over two issues since the printing was for 2,000 copies of the insert.

Broome asked Sikes if there would be any additional cost for a photo for the cover instead of a map. She explained that we could have a photo at no additional cost. The Board encouraged her to have photos for the cover in the future issues. Odom also stated that the Section's Logo needed to be on the cover as well. Sikes stated that there simply was no room for it this time and will abide by that direction in the future. Boxley complimented Sikes for the issue.

Odom questioned Sikes as to the number of times she has used the Federal Express account in the printing and mailing of this issue.

Meeting Minutes: October 1—

She replied that she did not use it at all. This certainly will reduce the costs associated with the issues as well. Broome moved with a second from Boxley to allow Tasso to decide when to use the Federal Express account on *UWS*. The resulting vote was unanimous in the affirmative. Sikes noted, however, that she will be hand-delivering the materials directly to the printer, thereby avoiding the need to mail them and protect their content. This will provide more safeguards in this respect.

There was some discussion as to the status of the payment of advertising in the current and previous issues of *UWS*. It appears that the advertising has not always been paid for prior to the printing of the issues and there is sometimes a delay in the payments being received. It was further reported that the Section has not received its advertising revenues from the current issue's advertisers. Tasso is to look into this. Sikes was instructed not to run any advertising for anyone that is not first paid for. Sikes is to draw up an advertising contract to be used and submit it to the Board for their approval and it will be required in all instances for advertisers. The classified advertising will be at the end of the issue and will be in much smaller print.

The Board directed Broome to contact Flowers and check on the monies due from OMS as well as their contract that Flowers says he has in his possession. Also, Broome will question Flowers as to the status of the Membership Manual as Sikes stated that she has none of the materials for same. Flowers had reported in his letter that he had it completed and would be forwarding copies to the Board for their review before its being sent to the printer. Since there have been so many problems with the advertising

monies and the amount of effort that takes, there was discussion on ceasing all advertisement in the issues except the rear cover. Broome moved with a second being provided by Tasso to cease the paid advertisement except the rear cover which is to be rotated on a first-paid/first advertised manner with no one having rear cover advertising in two consecutive issues. The resulting vote was 6 to 1, with Boxley being the only dissenting vote. The motion passed by majority.

Sikes was informed by Odom that the Board wished the Chairman to review each issue of *UWS* prior to its being sent to the printers. Sikes reported that she had no problem with that arrangement. Schedules and deadlines will be addressed and handled accordingly. He will review for types of articles submitted. Once they are approved, they may go to print. He further noted that articles containing questionable information, etc. would require a disclaimer inside the article. The Board agreed that there would be no equipment reviews nor recommendations of same to be presented in *UWS*. If a press release is sent in by a manufacturer, then it can be run without problems in this area. There will be no editing of this type of material, but it will be run as sent in. Odom stated that he did not want the vehicle of *UWS* to create a demigod. Broome questioned one article in the current issue wherein the recommendation was made to "intentionally silt out a passage" of a cave. The Board agreed that we cannot encourage anyone to do such and in so doing, this would not only be contrary to our views on cave conservation, but would be possibly causing someone to endanger themselves in such an environment.

Broome was questioned as to the plans for the upcoming elections for the Board. As was stated in the current *UWS*, nominations should be received by October 15th. So far, there have been two people nominated. Once that date passes, it was discussed that the Board wants candidates' platform statements to accompany the ballots to the membership for the members to consider. Boxley moved with a second from Broome that this procedure be followed. The resulting vote was unanimous in the affirmative. Broome indicated that he will follow this direction from the Board as he is responsible for the handling of this matter.

Broome presented a proposal from Ken Helinski on providing the Section with an additional revenue source potential. Helinski is in the CD publishing profession and is interested in providing some CDs for resale by the Section of a video game on cave diving as well as other types of publishing materials that could generate funds for the Section. The Board instructed Broome to advise Helinski to provide further information to the Board with actual products and descriptions that can become Section offerings. It may very well add another dimension to our library of revenue sources and the price seems to be very attractive.

There being no further business, Jerri Broome as proxy for Flowers moved with a second from Tasso to adjourn. The meeting was adjourned at 11:44PM. ❖

Respectfully Submitted,
Gene Broome
Secretary, NSS-CDS

Return To Atlantida Tunnel —

by R.D. Milhollin

The fourth installment of an ongoing research project at the Atlantida Tunnel on the island of Lanzarote took place from May 26 through June 10. The study is being conducted by Dr. Tom Iliffe, a Texas A&M University professor of Marine Biology and a CDS cave instructor. The project is now in its eleventh year, and is concerned with faunal composition, the source of the cave's food web, and the relationship of similar cave species on each side of the Atlantic Ocean. The 1994 trip was sponsored with grants from the National Geographic Society and the Texas Institute of Oceanography.

I was asked to participate as safety diver and research assistant and, in this position, walk in the shoes (fins?) of several fine North American cave divers who have participated in previous trips. The itinerary for travel is across the Atlantic on an eight-hour flight to Madrid, and then a two and a half hour connection flight to Lanzarote, one of the Canary Islands. The climate is surprisingly cool for the latitude and the sea water is a cool 64° F (18°C). The island is volcanic in origin; in fact, the cones and flows marking previous eruptions define the landscape.

For our stay, Dr. Iliffe booked accommodations at an apartment house in the seaside village of Arrieta, about forty minutes north of the principal town of Arriçife ("Reef" in Spanish). From the apartment the view is dominated by the cone of Monte Corona, or Crown Mountain, which geologists estimate last erupted about three thousand years ago. During that time several lava flows extended the island eastward, and under one of these flows a gigantic lava tube formed. Approximately five miles (eight kilometers) long from volcano to the measured end, the tube has in some places three distinct levels, with a combined height approaching 60 feet where the levels have collapsed into one huge tunnel. Inland there are numerous collapses where the tunnel is exposed to the surface, but the most dramatic are located where the tunnel meets the sea. Here, three of the sinks (or "Jameos" in the local terminology) have been developed by the island

government into a national park, the Jameos del Agua. Two of the entrances were modified by celebrated island architect and artist Cesar Manrique into a huge public facility, seating close to 150 people for dinner and more for dancing and drinks. At the upstream end an acoustically perfect concert hall was fit into the cavern entrance, and at the downstream end the restroom patrons and lost diners can view the tunnel making its descent into the sea down a rough boulder pile sloping steeply to a quiet pool whose water levels fluctuate two meters with the tides.

This is where it gets interesting. To dive the Tunnel one must crawl over the handrail, feel with your feet for a small set of stairs that descend beneath a huge basalt overhang with not really enough clearance for tanks on your back. A belay rope was attached to boulders at the top of the slope for handling the heavy loads, and a small wooden platform left behind by a previous Spanish team allowed some room for gear to be assembled at low tide. This is the best time to dive the tunnel, for as the tide begins to rise toward the end of the dive, the current surging toward the entrance will aid the diver in returning. The water continues to flow beyond the entrance pool through the porous rock breakdown, upon which the dining room and bar are built, and into a continuation of the tunnel not accessible to casual tourists, the Cueva de los Lagos. Water not only moves through the breakdown, it allows the inhabitants of the cave to migrate from one area to another. The most celebrated of such inhabitants is the troglobitic decapod crab *Munidopsis polymorpha*, found only in this cave and affectionately known locally as "Jameito."

Over the two weeks spent on the island, Dr. Tom and I completed a series of six dives in the tunnel, penetrating as far as a sand mountain marking the approximate halfway point in the 1.4 km (.88 mile) long passage. The end was reached and the tunnel surveyed and mapped in 1992 by Sheck Exley, Paul DeLoach, and Mary Ellen Eckhoff. Our objective this trip was not exploration per se, but biological sampling. This was accomplished via a diver-towed plankton net, the use of baited

traps set at specified locations throughout the cave, and manual specimen collection using clear bottles. In addition, at the end of a dive a pneumatically powered water pump would be set to filter cave water for particulate matter, a good use for leftover scuba air. A typical dive would include Dr. Tom entering with a plankton net deployed and myself following with a bag full of collecting bottles. The return trip would take us to retrieve traps placed on a previous dive. Each dive was different, and the repeated failure of a primary light due to a hidden tear in the power cord and a Poseidon Odin's pilot valve failure added at times to the excitement when diving a quarter of the way around the world.

Born from the flow of molten rock, the Atlantida Tunnel is decorated in a different fashion than caves formed from the dissolution of limestone. The speleogens along the cave run from upstream to downstream, and are sometimes in the form of "benches," or remnants of flowing lava that cooled in place as the flow abated. These formations can be from two to six feet (0.6 to 2 m) high, might project two to three feet (0.6 to 1 m) from the side walls, and could run as long as 40 feet (12 m). In some locations, lava stalactites have formed hanging from the ceiling or upper parts of the walls. The areas where the different levels of the cave have collapsed into one another provide for spectacularly tall chambers, and the tremendous size of the breakdown boulders making up much of the floor is awe-inspiring in itself. In one of the upper level passages the cave surfaces above the sea level into a quiet air-filled chamber dubbed "Lago Escondido," the Hidden Lake.

Much of the scientific work carried out at the Atlantida Tunnel is of an ongoing nature and will not be concluded for some years to come. Each visit is made with the goal of adding a little more to what is known of this type of environment and how it is similar or different from other oceanic habitats. I am glad to have been able to participate in a project of this importance and uniqueness, and hope to be invited to continue to assist in the future. ❖

Speleo Things

CDS Giftshop



Description	Item #	Nonmember	Member
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Events continues. . .

New Caving Section on CIS

There is now a new caving section on the CompuServe network. In addition to the Cave/Wreck/Cavern section of the Scuba Forum, the "Outside" Forum now hosts a section devoted to caving, both wet and dry. Covers the world over meet here to discuss caves and caving. Available in the section's library are various cave-related articles of interest, including cave mapping software, ready for you to download. Look forward to seeing you there! ❖

CDS-BBS Still Up and Running

For those of you who have been wondering, the CDS BBS, run by Wayne Maples, is still functioning. Some have been having trouble connecting lately, but please try again. The parameters for connection are specified on page 3 of this issue: 8 data bits; 1 stop bit; no parity. Look forward to seeing you there! ❖

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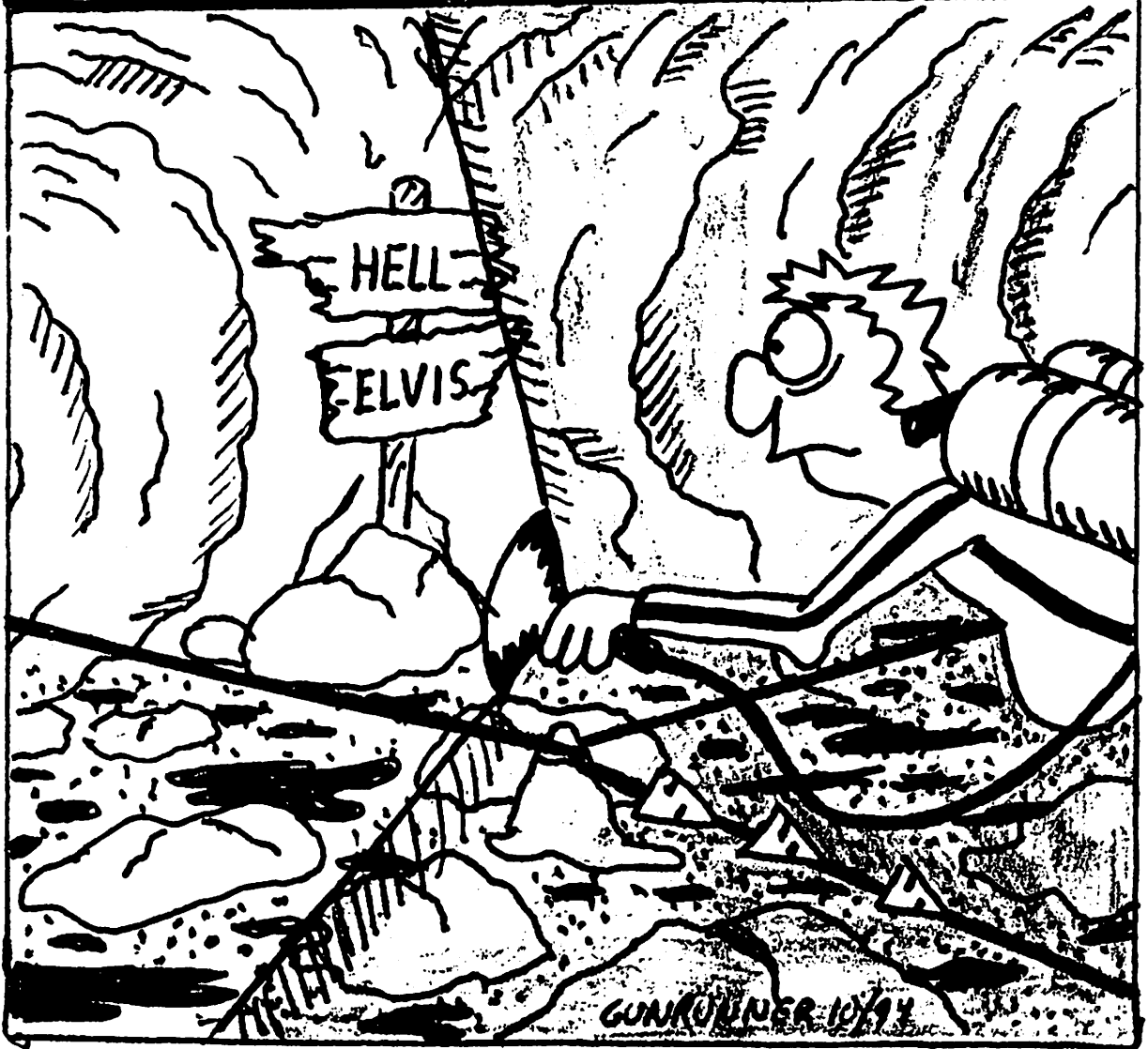
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