Geo^2

Volume 29, Number 3-4, 2002

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Marcus O. Gary, John M. Sharp Jr., Robin S. Havens, **The University of Texas at Austin;**
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IDENTIFYING THE CONNECTION BETWEEN VOLCANIC ACTIVITY AND HYPOGENIC KARST IN A HYDROTHERMAL PHREATIC CAVE SYSTEM

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Sistema Zacatón is one of the most unique, actively forming karst systems in the world. There has been a rich history of underwater cave exploration here, culminating in the 1994 world record dive by Jim Bowden to 289 meters of depth, and simultaneously, the tragic loss of THE cave diving pioneer, Sheck Exley (Gilliam, 1995). Bowden and Exley attempted to reach the bottom of the deepest known phreatic cave in the world, Él Zacatón. (figure 1), but fell short of this ambitious goal. Their efforts pushed the envelope of

(continued on page 4)

Figure 1. The water surface of Él Zacatón, the second deepest phreatic sinkhole in the world. The water is a minimum of 330 meters deep here, and the bottom has not been identified yet. The floating grass islands known as zacate can be seen on the surface. White "clouds" of precipitated elemental sulfur appear in the water at the far side of the sinkhole between some of the zacate (Photo by Ann Kristovich).

Geo²

Volume 29, Numbers 1 and 2, 2002

Section of Cave Geology and Geography of the National Speleological Society

GEO² (ISSN 0735-0511) is the official publication of the Section of Cave Geology and Geography of the National Speleological Society (NSS). It is published in February, June, and October of each year. One need not be a member of the NSS to belong to the Section, although such affiliation is encouraged. The Section is dedicated to the advancement of research and education, and to the fostering of interaction and information exchange among cave and karst researchers. Members and nonmembers who are interested in cave geology and geography are urged to participate in Section activities and contribute to our publications. The annual meeting of the Section is held at the NSS Convention, where a business meeting, paper sessions, field trips, and special activities are set up for Section members.

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Dear Geo^2 Subscribers,

Things are doing well around here-- a few compliments on the new format, but no complaints, so I trust that you are enjoying the new format.

One of the proposals for the annual meeting is to make Geo^2 available online, on our website, under a password protected link. One advantage to this in getting the newsletter to you is that Gail and I would no longer have to traverse the path littered with out of date email addresses. Unlike street addresses which normally change on a less frequent basis, email addresses seem almost disposable these days-- you change employment, graduate, or find a new ISP provider, and suddenly Geo^2 gets lost. Unlike the post office, there are few provisions for email forwarding.

Another advantage is: although the .pdf format condenses files by herculean amounts (the 486K file of the first .pdf contained 22 MB of Pagemaker file) there can be nothing more frustrating that receiving a large file when you need to log on and log off in a hurry. Posting on the website would leave the retrieval time up to you. (I would still send out notification that it has been posted via email and probably one or two other forums.)

Think about it. And keep those articles and news items coming. We can't put a Geo^2 together without YOU!

best,
Jo Schaper

NEXT GEO^2 Deadline:
September 1, 2003
(Help Us Get back on Track--
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human endurance at those great depths, and it became apparent that unlocking the secrets of Zacatón would require much more than traditional cave diving methods.

Gary writes: "*After witnessing the emotional events of 1994 (I was Bowden's engineer and one of his support divers), the mysteries of these amazing cenotes in northeastern Mexico began to eat away at the back of my mind. I kept asking myself, why are they so deep? How can the waters seem so different, yet be so close together? Are the cenotes connected? Why is the water so warm? Where do the wispy white clouds in the water column come from? Since at that time I only had a background in commercial diving and no training in geology, these were questions that would go unanswered for some time. In 1998, I returned to college at The University of Texas at Austin and began studying for a bachelor's degree in hydrogeology, driven by the continued nagging in my mind to understand Sistema Zacatón. Since then, I completed undergraduate work, and went directly into pursuit of a PhD, solely to study the dynamics and processes of formation that have shaped what is to me, the most incredible cave system on Earth.*"

Over the last three years, we have begun to document the unique properties of Sistema Zacatón using both traditional hydrogeologic methods and also incorporating state of the art techniques in 3-D mapping. Several expeditions each year headed by Gary and Havens have yielded substantial preliminary information to support the hypothesis that this deep phreatic cave system has been shaped by volcanic activity that powers accelerated karstification. A number of individuals have joined expeditions and contribute immensely to our study. These include: Jim Bowden and Ann Kristovich (diving support), Jack Sharp (research support), Jean Krejca and Vivian Loftin (dry cave survey), Art and Peggy Palmer (dry cave survey and hydrogeologic support), Bill Stone (3D mapping), Alan Riggs (hydrogeologic and diving support, Giorgio Caramana (diving support), Mark Helper (terrestrial survey and geologic mapping). The list of contributors goes on, and their help has been crucial to the success of this project.

Geologic history. Sistema Zacatón has formed in Mid- to Late- Cretaceous carbonate rocks that were deposited as the ancestral Gulf of Mexico covered the area in a shallow sea (Goldhammer, 1999; Enos, 1989). Following eastward regression of the sea, the limestone beds were aerially exposed and uplifted as a result of late Laramide orogenic tectonics. The Zacatón cenotes lie in the foothills of the Sierra de Tamaulipas, which is the expression of the Tamaulipas Arch, a 200-kilometer long, domal anticline that formed in the Gulf coastal plain east of the fold and thrust belt of the Sierra Madre Oriental. The axial trace of this structure is immediately west of Zacatón and the other cenotes in the system. Volcanic intrusive rocks began to erupt in the Sierra de Tamaulipas during the Oligocene, and this type of explosive volcanism continued through the Miocene. By the late Pliocene, substantial basalt flows and extrusive volcanic activity (andesites and basalts) became the dominant local geomorphic process (Camacho, 1993), and formed the Aldama Volcanic Complex, which lies immediately to the east of the study area (Figure. 2). It is inferred that volcanic processes have had significant influence on karstification of these Cretaceous limestones and play a significant factor in the formation of the deep phreatic shafts of Sistema Zacatón.

Hydrogeology. The groundwater system involved in forming the large karst features of the area is complex and relatively unstudied. Recharge to the aquifer apparently occurs primarily in the Sierra de Tamaulipas, where water enters the ground through discrete locations and, in some instances, where entire streams disappear into a single opening on the surface. Once underground, water flows through a complex system of conduits and caves expressed on the surface as a north-south line of cenotes and dry caves formed by the collapse of large underground cavities dissolved from circulating groundwater. This north-south trend in sinkhole development is likely due to structural weaknesses formed in association with the Tamaulipas Arch uplift.

Water reaches a relative flow barrier of the large, extrusive Aldama Volcanic Complex. Here a groundwater interaction zone is hypothesized where local hydrothermal water and regional meteoric water mix to produce a state of chemical disequilibrium with

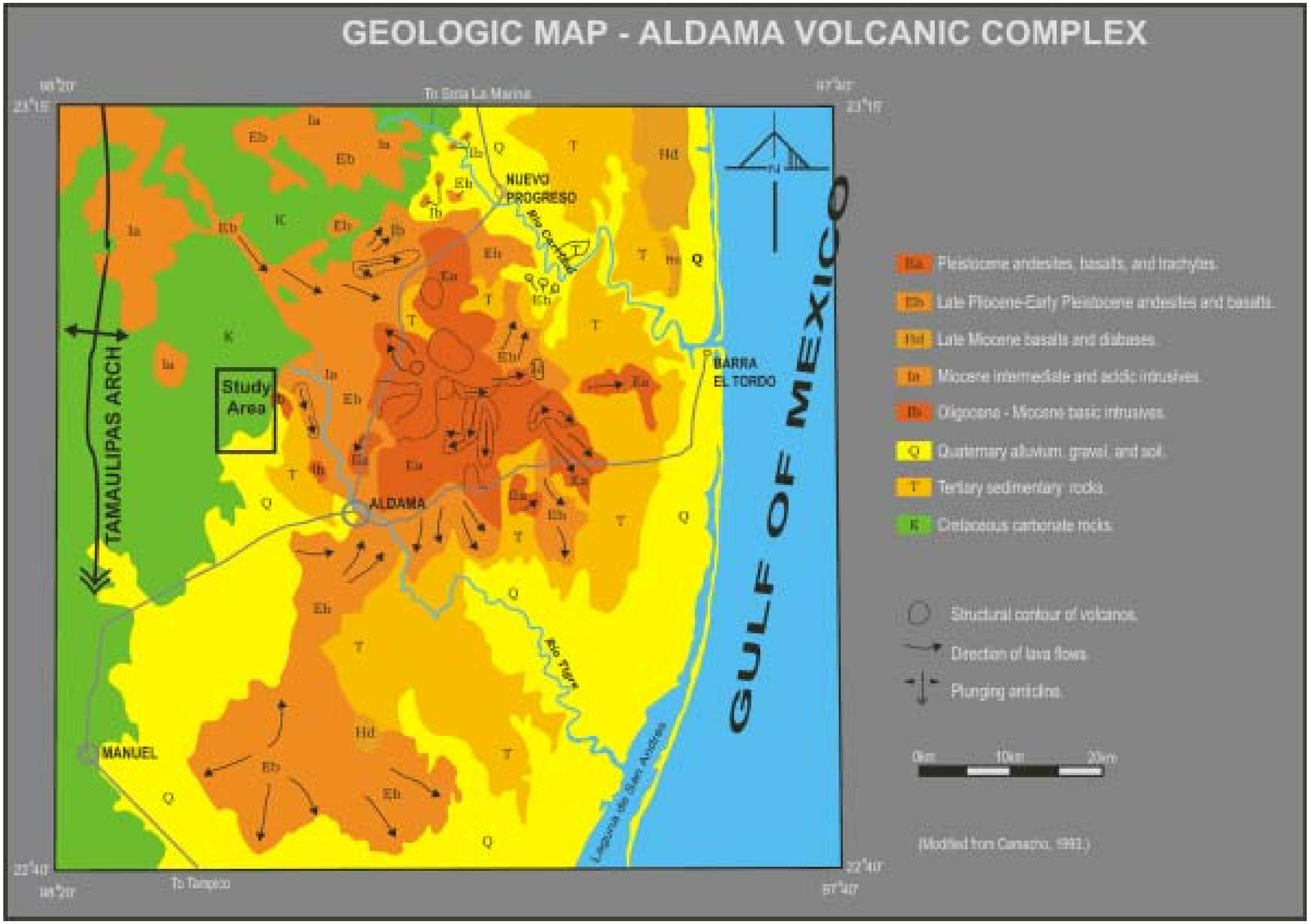

Figure 2. Geologic map of the Aldama Volcanic Complex indicates that the study area exists at the contact between Cretaceous carbonates and Pleistocene basalt flows (from Camacho, 1993).

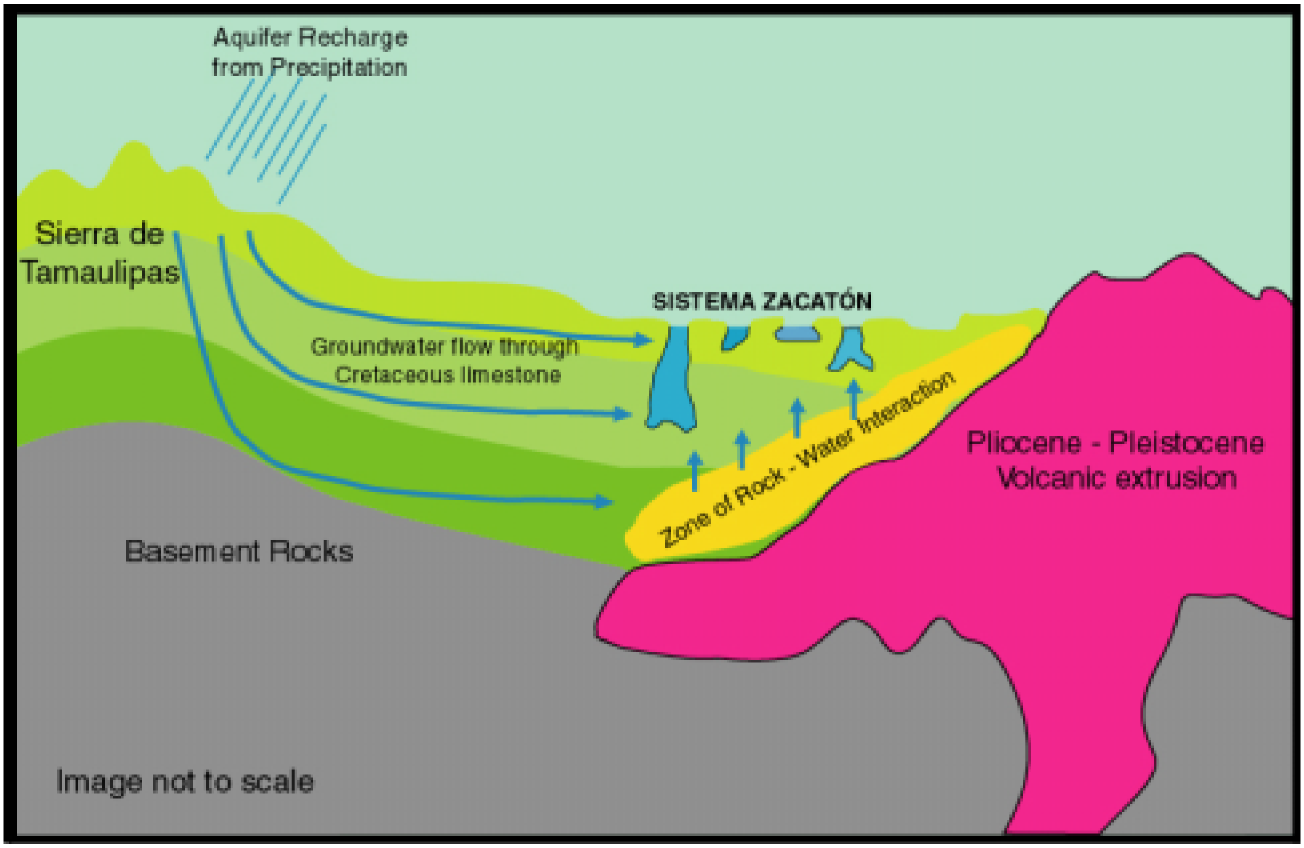

Figure 3. A conceptualized cross-section and simplified groundwater flow path indicates the primary geologic setting in which the deep karst features of Sistema Zacatón have formed. This figure represents the basic model used to form the hypothesis that hydrothermal activity play s a major role in the karstification of the area. (Gary, 2002)

respect to the calcite matrix (Fig. 3). This location is where the deepest cenotes, including Zacatón, have developed. Zacatón reaches at least 100 meters below sea level, indicating that deep phreatic cave development is occurring. The presence of the Cenozoic volcanic activity in the area indicates the potential for CO2 and H2S dissolution at depth as a process in deep cave formation (Dublyansky, 2000). During the period of recent active volcanism, thick deposits of travertine were precipitated from springs discharging hydrothermal, mineralized water (Gary, 2002). This is consistent with the hypothesis that hydrothermal activity associated with recent volcanism is the controlling factor to form these deep hypogenic caves.

Water Properties. Preliminary data collection of field parameters (pH, dissolved oxygen, and temperature) were measured at each of the cenotes using a multi-parameter sonde (Figure 4). Vertical depth profiles of these characteristics indicate that the bodies of water are extremely homogeneous, showing little to no variation throughout the water column. Verde is the only cenote that exhibits stratification of physical parameters as it has thermoclines and chemoclines that fluctuate seasonally (Gary, 2002). Water samples collected at each of the cenotes and analyzed for major anion and cation concentrations show that the hydrochemical facies (Back, 1966) of all the waters is calcium-bicarbonate, except at Tule, which has a sodium-chloride facies. Sulfide (H2S) has been measured in both Caracol and Azufrosa at levels of 1.6 ppm and 1.04 ppm, respectively. In Zacatón, no sulfide was detected; however, the volume of water is at least 3.14 million cubic meters, so the dilution of sulfide anions may affect the measurement, which has a detection limit of 10 parts per billion (Figure 5). The cenotes with measurable sulfide represent extreme reducing environments that are important to consider in interpreting the geochemistry of the system. The temperatures of the waters are variable throughout the system and appear to be linked to the physical morphology of each cenote. For instance, Zacatón, Caracol, and La Pilita directly access the deeper zones of the aquifer and remain at a nearly constant temperature of 31 °C, which is substantially above the mean average temperature of the region (25 ^{o}C). Shallower cenotes such as Verde, Alameda, and Tule are cooler (22-28 °C), and reflect seasonal fluctuations in temperature. Initial water level surveys of the cenotes in the south section of the study area (Figure 6) indicate that the head flux in deeper cenotes varies much less than the shallow cenotes and is less responsive to climatic perturbations. It is proposed that this bimodal characterization of the system (shallow versus deep) is directly linked to the physical morphology of each sinkhole, particularly with respect to massive travertine structures present in many of the cenotes.

Figure 4. Marcus Gary drops a datalogger to the bottom of Él Zacatón (300+ meters) to measure parameters of temperature, pH, specific conductance, dissolved oxygen, and oxygen redox potential. Vertical profiles taken in this cenote reveal that the water is homogonous from top to bottom. (Photo by Robin Havens).

Travertine structures. The 18 karst features that are included in the Zacatón system are primarily a series of circular sinkholes that exist within a 6-kilometer linear distance (Figure 6). Of these sinkholes, eight have developed into shallow dolines that have floors of travertine. The origin of the travertine in these locations is hypothesized to be associated with Pleistocene volcanism that was quite active just to the east of the study area (Camacho, 1993). Rapid dissolution of limestone host rocks may have occurred as meteoric groundwater mixed with hydrothermal waters adjacent to the volcanic extrusion. The closed cenotes were once open, deep sinkholes that were most likely water-filled. In this scenario, following a

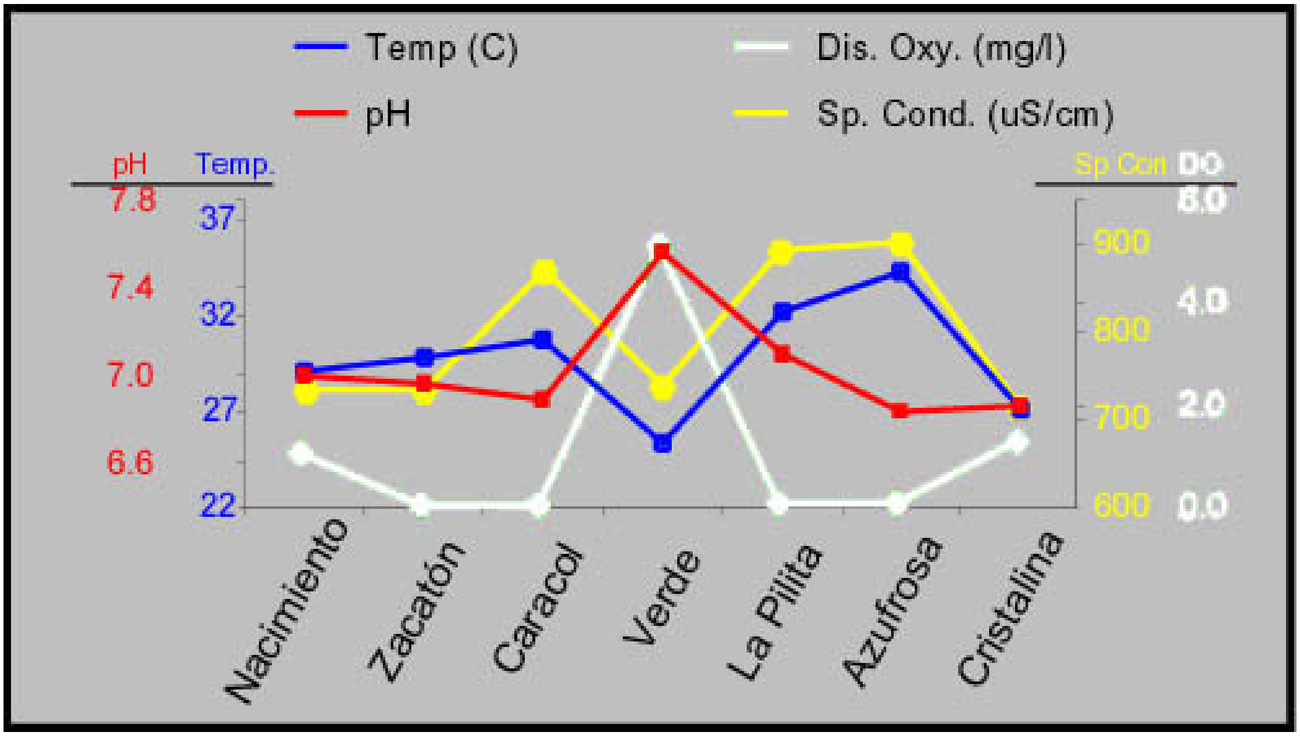

Figure 5. Graph of basic water quality parameters indicates the water of Verde is isolated from the deep, hydrothermal aquifer that is connected to the other cenotes. Note: Cristalina is a small spring cave near Azufrosa.

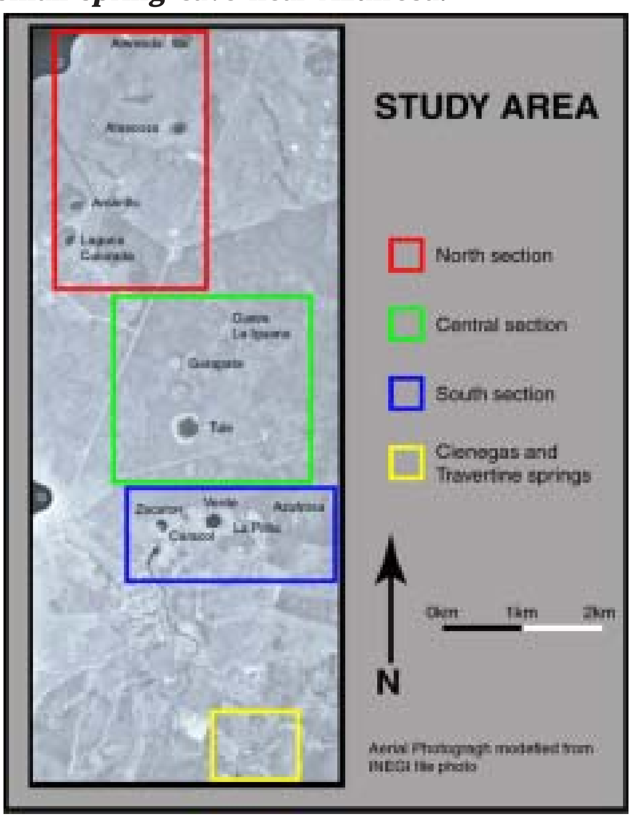

Figure 6. Sistema Zacatón is made up of 18 circular karst features that lie in a north-south trend. Some cenotes (primarily in the central section) have formed travertine "lids" and appear to be filled in. These lids are thought to exist up to 50 meters below the water surface in some cenotes, and define the level of the water table during paleo-climatic conditions.

shift in the local geochemistry, mobilized calcium carbonate may have reached the surface as carbon dioxide equilibrated with the atmosphere, causing precipitation of calcite in the form of thick lids of travertine (Figure 7). Large travertine deposits are typical of hydrothermal systems found in carbonate host rocks (Ford, 1989). Similar occurrences of massive travertine deposition have been documented in the travertine mounds in Italy (Soligo, 2002). Many of the travertine deposits at other locations have massive mounding morphologies, but the "lids" of Sistema Zacatón appear to be quite unique in their morphology.

Figure 7. Team members Bruce Mills and Ann Walthers lower a decompression habitat used for deep diving into La Pilita. The 1.5 meter thick travertine "lid" of the cenote is clearly visible, and is growing in the zone of water table fluctuation (Photo by Marcus Gary).

The travertine floors (or lids) are most common at the present day water tables at Sistema Zacatón, but could also have formed at lower, paleo-water levels. The cenote, Verde, has an extremely flat floor that is currently at 45 meters of depth. Such a level surface is atypical at the bottom of a large collapse structure, and may instead be a travertine floor that formed at such time when climatic conditions forced a much lower water table (Figure 8). The anomalous water properties of Verde from its nearby neighbors of Caracol and La Pilita could be explained from this travertine structure. The cooler temperatures, higher pH, and significantly higher dissolved oxygen levels of Verde may be the result of shallow meteoric groundwater that is separated from the deep hydrothermal groundwater seen in the other cenotes by a substantial travertine barrier similar to those now seen at the surface of other sinkholes in the area (Figure 9) (Gary, 2002).

Geomicrobiology. Biomats coating the walls of Zacatón, Caracol, and La Pilita appear as a thin, purple-red blanket, with some white areas (Figures 10 and 11), and are commonly underlain by dissolved calcium carbonate rock (Cretaceous limestone or Pleistocene travertine). These mats are likely composed of algae and bacteria that exist on the walls of the cenotes and may represent autotrophic, photosynthetic purple bacteria. The immense cenotes of Sistema Zacatón have likely formed with aid from geomicrobial processes that have accelerated the karstification process, and the conditions observed in Zacatón, Caracol, and La Pilita indicate that this is the case. Hydrogen sulfide is hypothesized to originate from the deep, hydrothermal contact zone created by local Pleistocene volcanism. This H_2S rises through the water column and reacts with the purple sulfur bacteria that coat the calcium carbonate walls. Sulfuric acid may be produced as bacteria consume available oxygen and H_2S. Low dissolved oxygen values in the three cenotes reflect this reaction. The calcium carbonate substrate is exposed to a hyper-acidic environment as the sulfuric acid disassociates into the sulfate anion and hydrogen protons, dropping the pH

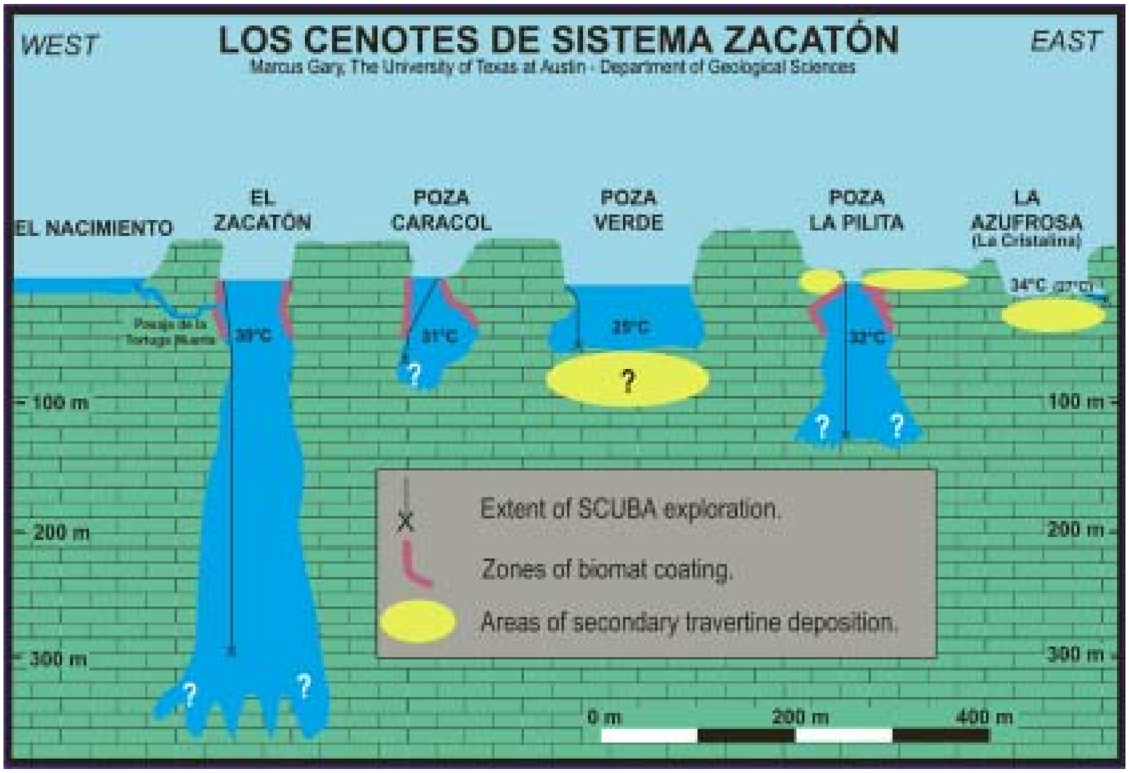

Figure 8. A cross-section of the south cenotes in Sistema Zacatón shows the relative locations of important features. The general physical expression of the system can also be observed.

to levels lower than would be expected in a limestone aquifer.

Three-Dimensional Mapping. Channelized karst aquifers represent some of the most complex hydrogeological features known. Charting such three-dimensional labyrinths and interpreting the various geological and hydrological relationships, particularly between sub-surface and surficial features, has been extraordinarily difficult. Two recent technologies-LADAR and phased array sonar-in conjunction with improved earth resistivity techniques promise the ability to model such features in a fully three-dimensional capacity and to link metadata to the model through the use of immersive interactive graphics.

Zacatón, likely the deepest cenote in the world, has a sub-aquatic void space exceeding 7.5 x 106 cubic meters (and likely much larger), and is the focus of this study in which we are creating a detailed 3D map of the entire system. The interactive map, when completed, will include data from above the ground surface, beneath the water table, in the rock matrix itself, and will be used to gain more accurate knowledge of the extent of these immense karst features and to interpret the geologic processes that formed them.

Phase 1 of the research, completed in January of 2002, involved high resolution (20 mm) LADAR scanning of surficial features, including four of the largest cenotes in the complex. Advantages to using LADAR, a ground-based, static mount equivalent to aerial platform based LIDAR imagery, include imaging under tree canopies, manmade structures, or within overhung rock structures (Figure 12). Scan locations — selected to achieve full feature coverage once registered — were established atop surface benchmarks whose UTM coordinates were established using GPS and Total Stations. The combined datasets will be meshed to form a geo-registered TIN that will represent surface features down to water level inside the cenotes.

Phase 2 began in January 2003 and entails subsurface imaging using Earth resistivity geo-physi-

Figure 9. This sinkhole has been named "Garapata" (Spanish for tick) by the research team since no local name appears to exist. The bottom has yet to be explored, but a distinctive flat floor covered with tule (reed type vegitation for which the large cenote just south of this one is named) is hypothesized to have formed from travertine similar to that in La Pilita (figrue 8). Photo by Marcus Gary.

cal methods. Spatial data from this technique will identify other void spaces isolated from open flow conduits and large variations in water chemistry (Figure 13). The most innovative aspect of this project will be Phase 3, during which the team will acquire high-resolution imagery of the underwater voids. We plan to modify the 3D Digital Wall Mapper used to image the deep Floridian aquifer in 1999 during a National Geographic expedition and produce a detailed TIN of the Zacatón phreatic zone.

Conclusion. Sistema Zacatón still remains relatively unstudied, and as we try to understand the details about its physical expression and processes of formation, more questions arise than begin to be answered. The first three years of geologic research has collected information that is now being used to form the hypothesis that volcanic activity plays a key role in the speleogenesis of deep phreatic cave systems. Hydrothermal karst systems are proposed to create some of the world's largest single pores, phreatic karst conduits,

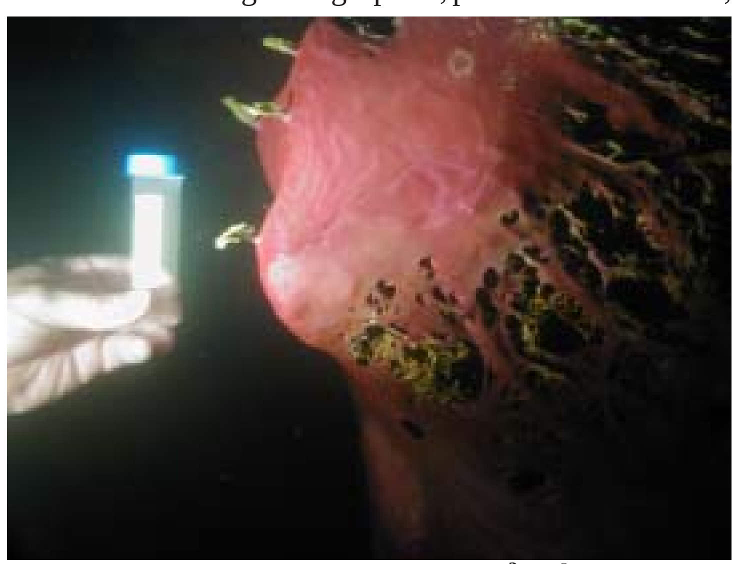

Figure 10. Biomat coating on the phreatic walls of the cenote Caracol. The water in this sinkhole is the most sulfurous in the system, and what appears to be precipitated elemental sulfur can be seen as a white powdery layer on the biomat film (Photo by Robin Havens).

and mega-sinkholes. We hypothesize that the formation of these systems is strongly influenced by volcanic activity proximal to thick, relatively uniform carbonate strata. Two of the world's three mega-sinkholes over 1000 feet (~300 m) of depth (water-filled) meet this criteria. They are: Pozzo del Merro, Italy, (392 m) (Caramana, 2002), and Zacatón, Mexico (over 330 m). We have started collaboration with Giorgio Caramana, who has spearheaded the research at the Merro Well, and a detailed, direct comparison of these two deepest underwater caves (Knab, 2003) is planned for the future. This research will evaluate the geochemical conditions and morphological history of Sistema Zacatón, which is perhaps the deepest accessible mega-sinkhole in the world.

Among the key scientific questions about El Sistema Zacatón (and other similar systems) are: What are its subsurface dimensions and how did it form? To address these questions, we integrate four approaches that have shown preliminary success at Zacatón and Pozza del Merro:

* Sonar subsurface imaging, tied to an existing 3-D spatial data base of surface and cave morphology;
* Geosphysical probing beneath suspected travertines that may cover unrealized mega-sinkholes;
* Hydrogeologic quantification of the physical and chemical nature of the groundwater system; and
* Isotopic analyses to: 1) test the hypothesis that volcanic processes play a key role in the karstification and 2) date the travertines and speleothems.

This project will offer fundamental insight into the geometry of these mega-sinkholes, how they are formed, and when they formed.

For more information, check the website: www.geo.utexas.edu/zacaton

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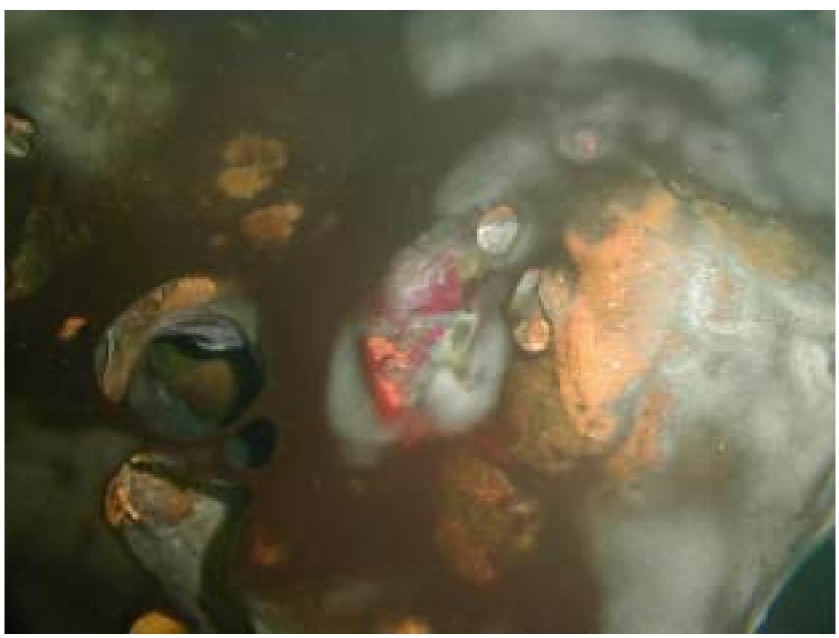

Figure 11. Biomat coating on the phreatic walls of La Pilita covers all the rock from the water surface to a depth of approximately 40 meters (Photo by Robin Havens).

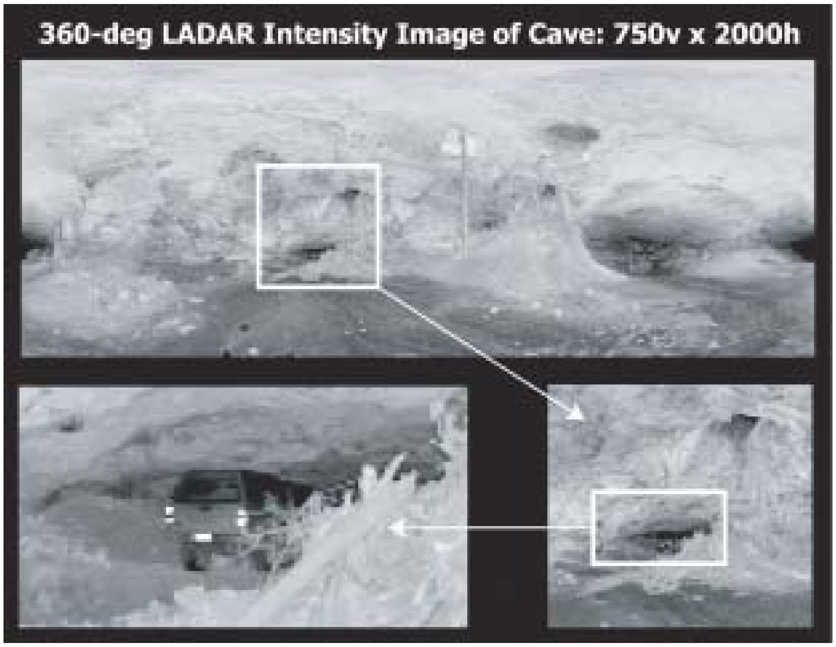

Figure 12. Intensity image acquired from a LADAR scan in the dry cave of Caverna Cuarteles where a junction of three horizontal passages and several skylights exist. The dataset consists of 750 points for each of 2000 vertical scan lines, giving a total of one and a half million data points. The resolution of the spatial data can be seen in this image (the truck was approximately 75 meters from the laser scanner). LADAR scans similar to this one have been made at each of the cenotes in the south section, creating a high-resolution, 3-D model of the

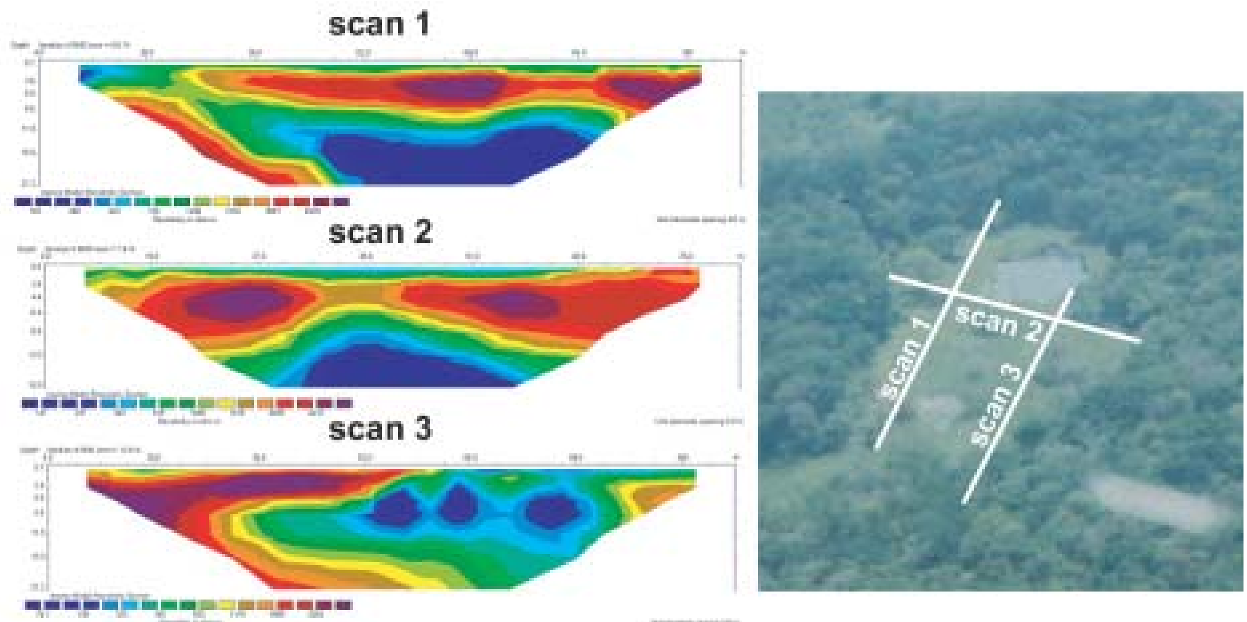

Figure 13. Electrical resistivity pseudosection of a La Pilita was used to normalize the imagery created from this geophysical method, since water filled void spaces can be reached beneath the travertine lid by SCUBA diving. This image clearly displays the applicability of multi-electrode earth resistivity for identifying phreatic voids (blue areas in images – low resistivity), which are hypothesized to exist below travertine lids (reds and purple areas in images – high resistivity) of Poza Seca, Azufrosa, Tule, Garapata, and Verde (data taken by Sharp and Gary, January 2003).

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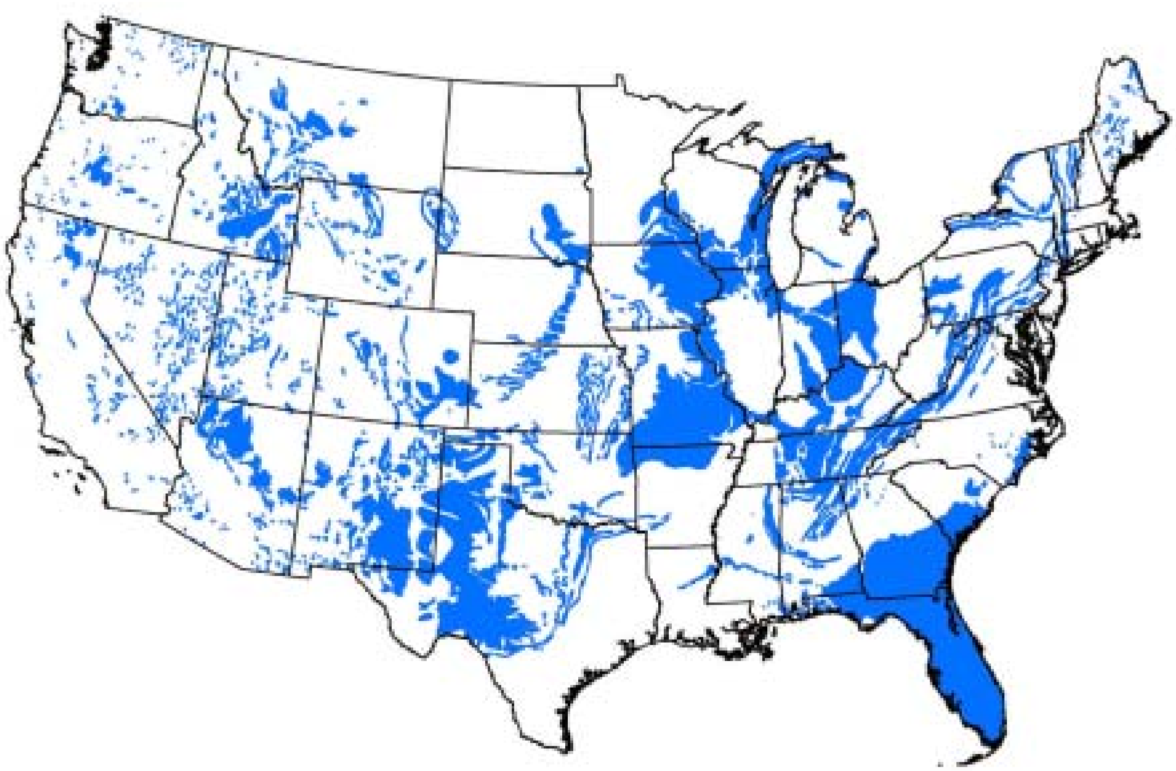
THE NATIONAL KARST MAPPING PROJECT
by David J. Weary, USGS



Federal and State agencies, the speleological community, and academia have repeatedly expressed the need for an accurate and detailed national karst map to better understand the distribution of soluble rocks in the United States. Maps at a variety of scales are needed to educate the public and legislators about karst issues, to provide a basis for cave and karst research, and to aid Federal, State, and local land-use managers in managing karst resources.

During the past two years, a diverse group of karst experts strategized a long-term plan for karst mapping on a national scale. The resultant goal is for the US Geological Survey (USGS) to produce a national karst map in digital form, derived primarily for maps prepared by the individual States, and to link that map on a web-based network to State and local scale maps and related data. The newly formed National Cave and Karst Research Institute (NCKRI; *Louise Hose, Director; 505-234-5561, fax 505-234-3051; lhose@cemrc.org*) will establish a web-based network of karst information that will be used to build the national map.

The National Karst map, which builds upon the "Engineering Aspects of Karst" map by WE Davies and others (1984, scale 1:7,500,000) published in the National Atlas, will be prepared digitally and can be printed at a scale of 1:7,500,000 for educational purposes and 1:2,500,000 for a more detailed view of karst distribution. A digital copy of the map will reside on the NCKRI web site and be linked to individual states and speleological organizations for state karst maps, detailed information, annotated bibliographies, and outreach products.

The USGS will facilitate compilation of the national map by cooperating with State geological surveys to update or produce state karst maps and to establish standards and consistent digital products, and will facilitate the digital compilation and production of the national karst map. Methods of presentation of data in karst maps vary considerably and boundaries of karst between some adjacent states do not match. Some states have a digitized geologic map from which a karst map could be prepared. Outlines of known karst areas, caves and sinkholes, depth of burial of karstic rocks, and areas of “pseudokarst” of several types are among the types of data shown on some maps.

Sinkhole Photo by Jo Schaper

The national map will consider the distribution of carbonate and evaporite units, intrastratal karst, karst beneath surficial overburden, and percentage of area covered by karst. SUPPORT: USGS has initiated programmatic funding for the national karst map, and the ongoing National Cooperative Geologic Mapping Program has long supported mapping in individual states. State geological surveys have provided in-kind match in the National Cooperative Geologic Mapping Program, and some of the resultant mapping has focused on karst. NCKRI is providing program coordination, serving the web network, and funding to supplement the USGS mapping program and states that need additional funding to complete mapping or to convert maps to digital form.

The leader for the national karst map project is David Weary (703)-648-6897 *dweary@usgs.gov.* Weary has and will be contacting individual State Surveys as this effort progresses. 5/24/2003

KWI Interdisciplinary Workshop on Epikarst comes to Shepherdstown, West Virginia

On October 1-4, 2003, in Shepherdstown, West Virginia, KWI is hosting its latest karst science workshop, KWI Interdisciplinary Workshop on Epikarst. Epikarst is defined as that area where the soil meets karst rock. It is that zone where many cave entrances are located and is the cause of sinkholes and other topographical karst features. The workshop will cover topics include the following:

-defining and delimiting epikarst
-geochemistry of epikarst
-evolution of epikarst
-karst soils
-geophysical sensing of epikarst
-biological sampling of epikarst
-hydrology and contaminant transport
-ecology and conservation of epikarst

Speakers scheduled for this event include those from Ukraine, France, China, Slovenia, Canada, Hungary, and various states throughout the U.S. Workshops, as opposed to conferences, also allow for discussion periods where the attendees can interact and discuss each particular topic at the end of each speaker's presentation. There will also be a photographic poster session, and three "Confusion Sessions" where speakers are invited to discuss a 5-minute presentation on any topic with which they are needing insight.

So if you are interested in karst science make your plans to be in West Virginia on October 1-4. For more information or to register for the workshop see: http://www.karstwaters.org/epikarst/epikarst.htm

Kelly Norwood
NSS-KWI Liaison

(From NSS Discussion Board)

Boca di Diablo

by Bruce Rogers

Colour photograph postcard published by Kralendijk Trading Co., Ltd., Bonaire, Netherlands Antilles; postmarked November, 1983, with 50 cent flamingo and 10 cent volcano Nederlandse stamps.

"Bonaire, Netherlands Antilles.
"Devil's mouth — Boca di Diablo. Young girls entering this mouth can only be rescued by a nice young man!"

Yes, well . . . anyway . . .

The Netherlands Antilles are a trio of small Caribbean islands belonging to Holland that are just off the north coast of Venezuela. Composed of terraces of Tertiary limestone deposited on a mid-Cenozoic volcanic rock core, the islands have been upraised and intensely karstified. All the islands are filthy with caves, as are the reefs offshore, plus all those icky fish things. Saba, St. Eustatius, and southern St. Martin Islands some 160 miles east of Puerto Rico are also part of the Dutch presence in the Caribbean Sea.
Bonaire, the easternmost island, is famous for flamingoes and hypersaline lagoons (like the Pekel Meer) where dolomite rock forms being the capitol of the group. Aruba is the western island and famous for scuba diving, flamingoes, and that fact the McClurg family got started caving there sometime in the relatively recent past - now was it just after the Great Flood Waters receded from the island, David?

Boca di Diablo is actually an arch some 12 ft. high and about 20 ft. wide. It's the remnant of a mostly collapse large chamber of a "flank margin" cave. If you look very closely, you'll see some small barrel-shaped cacti on top of the arch itself. Although the islands are only 12 degrees north of the equator, they are very arid and have a remarkably number of plants similar to the American Southwest. Whether or not any nice men rescued young maidens from its depths or not only Mr. McClurg can say . . . and at last count, he's not saying!

Karst Research Calender --

NSS Convention
Porterville, California, 4-8 August 2003
Contact: Peri Frantz, 408-356-8506. Email: a**pfrantz@pwpconsult.com.** Lynn Fielding, 310-533-8627. Email: **lynn@wb6hqk.ampr.org.**

Gypsum Karst Areas in the World
Bologna, Italia, 26-28 August, 2003
Contact: Consorzio do gestione del Parco Naturale dei Gessi Bolognesi e Calanchi, dell'Abbadessa, Via Jussi, 171, 40068 San Lazzaro di Savena (Bologna), Italy. Tel. +39-051-6251934, Fax. +39-05106254521. E-mail: **parcogessi@tin.it.**

Ninth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst™
Practical Applications of Karst Science

Sponsored by the Geo-Institute of the American Society of Civil Engineers, The Association of Ground Water Scientists & Engineers of the National Ground Water Association, and P.E. LaMoreaux & Associates, Inc.
September 6-10, 2003
Huntsville, Alabama, USA
www.asce.org/conferences/karst2003

Symposium on Water Resources in Karst and Hard Rock Formations with Emphasis on Karst Exploration Techniques
Middle Sept. 2003
Esfahan I.R. of Iran
Contact: DR. A. AFRASIABIAN.
DIRECTOR OF NATIONAL KARST STUDY AND RESEARCH CENTER GENERAL SECRETARY.

P, O, and BOX: 15875-3584, TEHRAN IRAN.
FAX: + 98-21-7533186 Tel: + 98-21-7520474.
Email: **Karst @ wrm. Or. ir**

Karst Waters Institute
Interdisciplinary Workshop on Epikarst
Oct 1-4, 2003
Shepherdstown, West Virginia
For more information:
http://www.karstwaters.org/epikarst/epikarst.htm.

16th National Cave and Karst Management Symposium
October 13-17, 2003
Sheraton Hotel-- Gainesville, Florida
http://www.nckms.com/#call
Abstracts or
questions regarding the program should be directed to Michael Poucher, at e-mail:
mpoucher@cavesurvey.com, or by calling at (h) 352-840-0167. The deadline for submitting abstracts and biographical sketches is August 15, 2003.

Have a karst conference announcement?
Please remember we have a 3-4 month lead time, so send in timely manner to :
joschaper@socket.net.

WHERE THE LIMESTONE PROFESSOR MEETS THE LAVA

— William R. Halliday

When the National Speleological Society's annual Convention was held in Yreka, CA, its mottowas "Where the limestone meets the lava" or vice versa.

During the summer of 1915, a noted karstographer-to-be, Willard Rouse Jillson spent several weeks examining "the geology and physiography of the Mt. St. Helens region". Several of his writings about this expedition appeared later in his "Sketches in Geology" (Jillson, 1928).

As seen from the perspective of 21st Century vulcanospeleology, Jillson was especiallyfascinated by the numerous tree molds of this region, and found moderately deteriorated wood at the bottom of one of them, providing insight even then about the age of the lava which had engulfed them. The scientific investigation of tree molds and their caves today is largely a Japanese undertaking, but Jillson's pioneer interest in these landforms should not be overlooked when the history of their study is compiled.

On the other hand, Jillson missed several major opportunities here. Apparently he passed by Ole's Cave without entering it:

" ... at an elevation of 1,351 feet of occurs the lower entrance to the largest of the several lava (caves of the Mt. St. Helens District. It is reported that this cave, which is really an elongate laval (sic) channel, is over a mile in length. This report, though it may be true, is not herewith authenticated."

Not only did Jillson miss his chance to be the father of American vulcanospeleology but he missed the chance to see partially charred, wood in situ near the lower end of nearby Lake Cave. Almost 50 years later, our discovery of this wood in a piping confluent near the lower end of this easy cave provided the first radiocarbon date on the Cave Basalt Lava Flow which dominates the southern slopes of Mount St. Helens. It is at the bottom of one of the tree molds which intrigued him so much.

All in all, however, Jillson's little 1928 book is a delight. it would well be worth reprinting for sale at Mount St. Helens National Volcanic Monument, Mammoth Cave National Park and other famous landmarks where his long-ago studies remain significant in the 21st Century.

Reference:

Jillson, Willard Rouse. 1928. **Sketches in Geology, a group of 22 separate papers on American geology.** Louisville, C.T. Dearing Printing Co.

Lightning Safety For Cavers

by John Gookin
National Outdoor Leadership School

Photo courtesy of John Gookin

These cows made three fatal mistakes.

1) They were in an open area during a storm, exposing themselves to a direct strike.

2) They were near a long conductor, which probably channeled high voltage down from a hillside strike.

3) They naturally had their legs spread far apart (about as far apart as a person laying down), providing significantly more voltage to one leg than the others, which drove ground current in one leg and out the others.

Numerous cavers have been shocked by lightning. The serious injuries have been near cave entrances, especially when metal cables, cable ladders and wires were being used. Cavers walking on the surface, to and from caves, are generally at greater lightning risk than they are while caving. In general, it is much safer to be well inside a cave than on the surface during an electrical storm. But some cave entrance areas appear to be even more dangerous than other places on the surface.

One proviso: Non-cavers often call small overhangs "caves." Small overhangs are especially dangerous. Lightning tends to flash over surfaces, and it easily jumps the gaps of these small pseudocaves, especially when rain water is running. Humans offer better paths for conducting electricity across those gaps. Be sure to tell non-cavers that cave entrances are dangerous during electrical storms, so they will get the message that these "caves" are poor places to be in a thunderstorm.

Real cavers who are underground probably won't even know that a thunderstorm is outside unless someone gets shocked, or unless the water level starts to rise from rain, or unless you are exiting the cave and hear the thunder rumbling at the entrance.

Cavers as far as a mile underground have been shocked by lightning[1]. Those standing in water seem to get shocked more. People standing in water on the surface have been shocked through the water, at the same long distances from strikes. Touching the cave ceiling while standing on the ground will increase your potential to conduct current[2].

But cavers well within a cave don't seem to get more than uncomfortable (or slightly debilitating) shocks. It's the cavers in the entrance pits, on cable ladders or near other metallic lines, that tend to get seriously hurt by lightning. Wet ropes hanging in an entrance can be as dangerous as cables, but have only been observed as lightning conductors in the mountaineering accident data (not in caves, yet.) Metal handrails into showcaves need occasional gaps in the metal to avoid channeling lightning strikes to everyone holding that railing in the cave. These gaps should be feet long, not inches long, and the railings should be well grounded near the surface. Plastic bridges between railings should be in dry locations.

This picture of Wolf Creek Cave shows cave air exhaling, just like it tends to do during a mid-afternoon thunderstorm. Cave air is highly conductive of electricity compared to normal air on the surface. Streams are also highly conductive. The exhaling air and the sinking stream may be related to the fact that some caves seem to attract lightning.

Photo by Dave Bunnell

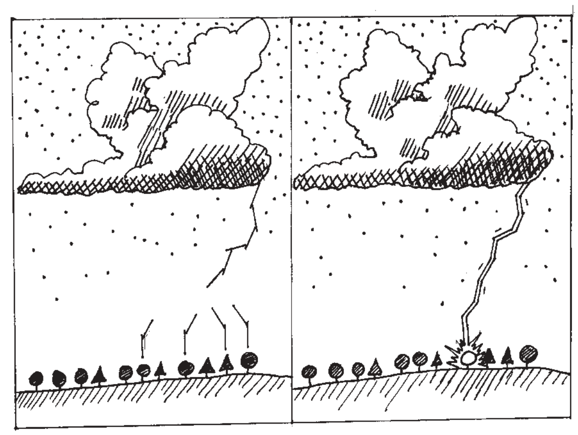
Do caves attract lightning?

Some caves definitely get struck more often than others. This has been well documented in the Pyrenees[3]. This has also been documented via geomagnetic signatures in lava tubes. But why some caves get struck more than others is open to debate. If you don't care why some caves might get struck more than others, skip to "lightning safety guidelines."

Caves tend to be exhaling highly conductive air in the afternoons when lightning tends to strike. Diurnal cave breathing is well documented, but exhaled cave air flows downhill and tends to stay together like a river of air (you can feel it.) The high conductivity of cave air was documented decades ago . This needs further examination by analyzing the cave air itself for ions and by looking for electrical fields above exhaling cave entrances.

Look at Dave Bunnell's photo of Wolf River Cave to see normal cave entrance air movement. Cool dry air is seeping out of the cave below the fog layer. Dry air is actually heavier than moist air: this is counter-intuitive. And cool air is heavier than warm air. At the thermocline between the cave air and the warm moist surface air, fog forms when the cool cave air condenses the moisture from the warm surface air. If a storm was approaching, the dropping barometric pressure would suck huge amounts of cool air out of the cave.

Anatomy of a Lightning Strike



First, a leader moves down from the cloud in 50m steps. When it is close to the ground, it attracts "streamers" from the closest objects.
Second, when the leader connects with the closest streamer, the big "return stroke" travels along its path. Caves would only tend to attract a strike if they had an elevated conductor, like a tree or a column of ionized air, up high where they would connect with more leaders.

A turbulent storm could mix the air more. Some people who study caves and lightning think this air helps attract lightning to caves that breathe a lot of air.

But another important factor to observe in this photo is that the local stream is dropping into the cave. This is a wet spot in the well-drained karst terrain. Eventually this stream connects to the water table, providing an excellent grounding. These diving streams are ex-

cellent conduits for charge to move in or out of the Earth. This charge coming out of the Earth helps develop the “streamers” that help blaze the trail for a significant lightning strike, and it helps channel ground current from a strike. Cavers have been standing in water a mile underground, and been shocked through the stream of water. Observers at the cave entrances have documented that
sometimes the lightning repeatedly strikes an entrance, to shock the cavers underneath . But other observers at cave entrances have noticed that sometimes lightning hits far from the entrance, and still shocks the cavers in the water underneath. The distant strikes that shock cavers are probably connecting to the cave stream via some other stream passage, not via the same entrance the cavers used.

Dale Green is an amateur geophysicist who has been studying lava tubes. While mapping the magnetic fields around lava tubes in Idaho, he has found that the magnetic disturbances caused by lightning strikes are concentrated around entrances of tubes that blow air. These strikes can be detected because intense currents from lightning magnetize the lava and completely alter any previous magnetic field. Away from entrances, lightning strikes were found to be very sparse and randomly placed. The cause for this entrance concentration is unknown but may be due to moisture in the exhaled air. If this seems like a weak scenario, consider that the main place most houses receive direct lightning strikes is through furnace exhaust vents.

We can actually start looking at real lightning strike data at cave entrances in the US (lower 48 States) and much of Canada from the National Lightning Detection Network (NLDN.) The NLDN is run by Vaisala Global Atmospherics Inc (VGAI). To see a real time map of lightning in the US for the past 2 hours, go to <www.lightningstorm.com>. VGAI sells detailed lightning data to anyone who wants it and they can produce color-coded maps showing strike concentrations for specific areas. If you get struck and want to know whether it was a hot strike or a cool one (they can vary from 1-200kA) VGAI can use your exact time and location to tell you more about “your” strike. If you think a local cave is lightning prone, you can hire them to tell you if that location is really a hot spot.

Discussing theories of why some caves are more lightning prone than others is an academic exercise that may eventually help us predict relative risks in certain caves. But it is factual that some caves are more lightning prone than others. When the locals tell us that a certain cave is lightning prone, we should be careful around these entrances by minimizing our time of exposure during storms.

Lightning safety guidelines for cavers
• Time your caving trips to avoid thunderstorms.
• Avoid cave entrances during thunderstorms.
• Avoid long conductors during thunderstorms.
• Avoid water, and touching the wall or ceiling if near the surface during a storm.
• Drop into the lightning position if a lightning hazard exists.

Additional Lightning Safety Guidelines For People On The Surface
• Seek a modern building, car or safer terrain if you hear thunder.
• Avoid high ground if you hear thunder.
• Avoid relatively tall trees if you hear thunder.

Get in the lightning position to reduce risk. Squat or sit, ball up, put feet together, and wrap your arms around your legs.

The Lightning Position
Assume the lightning position when at risk. This will reduce the chances of getting a direct strike and it may reduce the other effects of lightning, but it offers no guarantees. Some scientists argue that it barely helps

protect you; others argue that it is much more valuable because the data says that no one in this position has ever been hurt.

This position includes squatting (or sitting) and balling up so you are as low as possible without getting prone. Wrap your arms around your legs, both to offer a safer path than your torso for electrons to flow from the ground, and to add enough comfort that you will choose to hold the position longer. Close your eyes.

While the prone position is lower, being spread out increases potential for ground current to flow through or across you. Keep your feet together so you don't create potential for current to flow in one foot and out the other. If you have any insulated objects handy, like a foam pad or a soft pack full of clothes, sit on them. Avoid backpacks with frames since the frame may concentrate ground current. Don't touch metallic objects. You won't get a warning that a strike is imminent because the lightning event from cloud to ground and back occurs faster than you can blink an eye, so stay in the lightning position until the storm passes. The lightning position reduces the chances of lightning injuring you as badly, but is no substitute for getting to safer terrain or structure if it is immediately available. If you are concerned enough to assume the lightning position, you should have your group dispersed at least 50 feet apart to reduce the chances of multiple injuries.

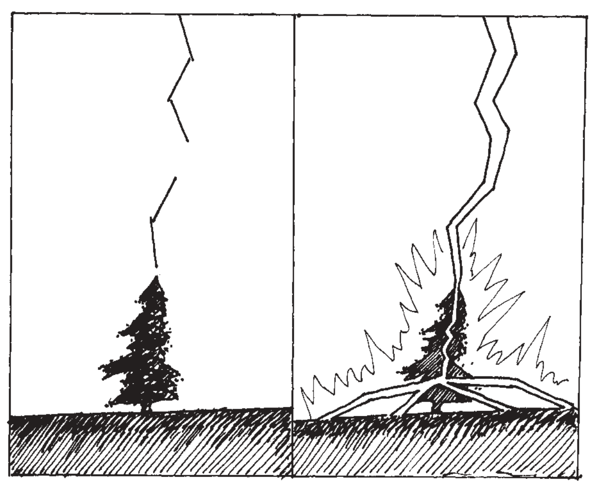
Ground current may spontaneously trigger your leg muscles to jump while in the lightning position, so take care to avoid being near hazards when you drop into this position.

Summary

Cavers are probably at greatest risk walking to and from caves. But cave entrances offer dangerous spots where we need to exercise a high level of caution, moving past them quickly just like when passing under potential rockfall. Inside caves, we are only at moderate risk when near the entrance or in the water. Deep in a cave, on dry ground, we are probably safer than anywhere on the surface. Having said all of that, the leading experts in lightning injury epidemiology say that lightning safety is about 2/3 intelligent behavior and 1/3 luck. Following lightning safety guidelines can eliminate 2/3 of the lightning injuries in the world.

Cavers aren't just cavers: we are outdoorspeople. Knowing how to behave intelligently when lightning threatens can help us in many other activities. Studying up on lightning safety guidelines for other activities we participate in can help us make more informed decisions wherever we are.

When lightning strikes, it emits powerful surface arcs above the ground surface and ground currents under the surface. Most victims are killed by ground currents. Any long conductors, like cables, wet ropes, metal handrails, or streams, tend to channel that ground current as it travels into the Earth. This factor may not make caves *attract* more direct lightning strikes, but it may channel the energy of nearby strikes into more caves.



Resources

• Learn more about backcountry lightning safety at http://research.nols.edu/wild_instructor_pdfs/lightningsafetyguideline.pdf

• Learn more general lightning safety guidelines at <www.uic.edu/‘macooper/faq1htm>.

• Health professionals can learn more about lightning injuries in Mary Ann Cooper MD’s “Lightning Injuries” chapter in Paul Auerbach MD’s Wilderness Medicine: Management Of Wilderness And Environmental Emergencies.

• Sports enthusiasts can see the NCAA lightning safety guidelines at http://www.ncaa.org/sports_sciences/sports_med_handbook/.

Footnotes:

[1]Personal correspondence from Mike Zawada RE an incident in1962.
[2]Personal correspondence from Cindy Heazlit RE an incident in1999.
[3]Choppy, J. “Caves Attract Lightning”. Paris, 1994. See John Gookin for an English translation.
[4]Ibid.
[5]“An Electrifying Incident Beneath the Arbuckles” by R.D. Milhollin, NSS News May 2000.
[6]We used to call this the lightning SAFETY position, but this name easily allows the illusion of safety.

Conference Report:
Symposium on the Application of Geophysics to Engineering and Environmental Problems
Environmental and Engineering Geophysical Society

by George Veni
(all photos by the author)

Introduction

The Environmental and Engineering Geophysical Society (EEGS) is an organization I had peripherally heard of but knew nothing about. The same was true of their “SAGEEP” series, Symposia on the Application of Geophysics to Engineering and Environmental Problems. When I heard they were coming to my hometown of San Antonio, Texas for a convention on 7-10 April 2003, my interest stirred. I couldn’t meet the paper deadline, but was able to attend part of the conference and assist with the field trip. This report focuses on symposium’s karst sessions and the post-conference trip over the Edwards Aquifer.

The Karst Sessions

Officially, the program offered one karst session. But a session on the Edwards Aquifer was, by default, a second karst session. Unfortunately, the planning staff for the symposium didn’t realize this. I arrived on the second day of the symposium to attend the karst session announced in the published schedule. I was sure I was in the right room, but nothing was said about karst. I left to check the master schedule outside of the meeting rooms and found the karst session was moved to the next day and opposite the Edwards session. I never learned what prompted this change, but one author who arrived on the scheduled day to present his paper ended up giving it in a non-karst session since he couldn’t stay until the next day. This was a disappointing introduction to EEGS and SAGEEP.

The next day was better. There was nothing I could do about the scheduling conflict but since I knew the

Edwards Aquifer issues well, I attended the "Karst and Cavities" session instead. Four papers were on the agenda:

1) *Application of wavelet transform in detection of shallow cavities by surface waves* by Parisa Shokouhi, and Gucunski Nenad.

2) *Accuracy of seismic refraction tomography codes at karst sites* by Philip J. Carpenter, I. Camilo Higuera-Diaz, Michael D. Thompson, Shashank Atre, and Wayne Mandell.

3) *Application of a downhole search and rescue camera to karst cavity exploration* by Jonathan E. Nyquist and Mary M. Roth.

4) *Mapping structural pathways for DNAPL transport in karst using induced polarization* by Larry J. Hughes and Norman R. Carlson.

The first two papers dealt primarily with adjusting and improving geophysical instrumentation to certain problems. The karst issues seemed secondary to the papers. I missed the third paper because of the scheduling change mentioned above. The fourth was an interesting application of induced polarization that mapped either clays or TCE migration from a leaking landfill to identify buried, sediment-filled sinkholes. The results were confirmed by drilling, but it wasn't clear if the clay, TCE, or a combination of both was key to the method's success.

Edwards Aquifer Studies Session

Given the conference's location in San Antonio, where the Edwards Aquifer is effectively the sole source of water for about 1.5 million people, a special session on the Edwards was not surprising. Eight papers were presented:

1) *Geologic setting of the Edwards and Trinity aquifers of central and south Texas - interactions among tectonics, carbonate deposition, and groundwater flow* by Susan D. Hovorka.

2) *Hydrological overview of the Edwards/Trinity aquifers* by George Ozuna.

3) *Ground water resource management issues* by John Waugh

4) *Advanced processing and interpretation of the high-resolution aeromagnetic survey data over the central Edwards Aquifer, Texas* by David V. Smith and David Pratt.

5) *Application of audio-magnetotelluric soundings to detect fractures in the Edwards carbonate aquifer near Seco Creek, Medina County, Texas* by Herb A. Pierce, George Elliott, Alex Ingerov, and Rebecca Lambert.

6) *The conductivity structure above Edwards Aquifer, Texas, derived from airborne EM data* by Daniel Sattel and John Slade.

Figure 1--
Caver rappelling into the 44-m-deep entrance pit of Valdina Farms Sinkhole, Medina County, Texas.

Figure 2--
Entrance of Bear Cave, Bexar County, Texas.

7) *Preliminary results, helicopter electromagnetic and magnetic survey of the Seco Creek area, Medina and Uvalde counties, Texas* by Bruce D. Smith, Richard Irvine, Charles Blome, Allan Clark, and David V. Smith.

8) *Identification of electrical anisotropy from helicopter EM data* by Changchun Yin and Greg Hodges.

I missed the first three papers due to the scheduling conflict with the karst session, but since they were primarily introductory papers on topics I'm well familiar with, it was no big loss for me. The Edwards is a highly productive, deep, artesian aquifer formed in Cretaceous carbonates along the Balcones Fault Zone along the southern and eastern margin of the Edwards Plateau in central Texas. It is a complicated system, both hydrogeologically and in its management, due to issues involving water quality and quantity, endangered species, and a growing, but still insufficient knowledge base from which to manage it. Adjacent to the Edwards, the Trinity Aquifer is not one groundwater system but comprised of several distinct aquifers, some karstic and some not. Increasing evidence demonstrates that in some areas, the Trinity contributes water to the Edwards.

The remaining five papers examined large area geophysical mapping of the aquifer. They showed a variety of features, such as volcanic intrusions, major fracture zones, and changes in lithology that play important roles in regional patterns of groundwater movement. Two of the papers focused on the Seco Creek area, in part due to the presence of Valdina Farms Sinkhole (Figure 1). This cave is located about 100 m from the creek. In 1982, the Edwards Underground Water District built a low-head dam across the creek and cut a 4-m-deep by 3-m-wide diversion channel on the upstream side of the dam to the cave to enhance recharge into the aquifer. More than 16 million cubic meters of water have been gauged entering the cave during a single recharge event. However, given the scale of the surveys, the cave was little more than a blip on the geophysical maps.

Edwards Aquifer Field Trip

Geary Schindel, Chief Technical Officer for the Edwards Aquifer Authority (EAA), organized a post conference field trip over the Edwards Aquifer and solicited help from Ron Green (Southwest Research Institute), Susan Hovorka (Bureau of Economic Geology), John Hoyt (EAA), Bruce Smith (USGS), and me (George Veni and Associates).

The trip started with a scenic overlook of San Antonio and the aquifer area. The site was used to provide an overview of the aquifer and its management issues. It proved dramatically educational in an unexpected way when we arrived to new construction roaring and rattling the scene, emphasizing the point that rapid urban growth is occurring over the aquifer recharge zone.

Figure 3--Geary Schindel opens the valve to allow artesian flow from a well that was traced to the Comal Springs, Comal County, Texas.

Figure 4--Geophysicists wait for the results of an electrical resistivity transect near Bracken Bat Cave, Comal County, Texas.

We soon drove to nearby Bear Cave (Figure 2) and Cub Cave. They occur in a 0.85-km^2-area behind a flood control dam that the city recently purchased for parkland. The dam also serves to enhance recharge into the aquifer through Bear, Cub, and other caves in its reservoir. Initially, the caves' location in the reservoir was considered beneficial, but as the drainage area becomes urbanized, there is increasing concern about water quality degradation. Quite a bit of time was spent describing karst for the benefit of most participants, its role in the Edwards and other karst aquifers, its vulnerability to pollution, and geophysical studies conducted at the cave and other Edwards locales. A brief visit was made to nearby Cub Cave, which has the largest entrance in the county at 14 m wide by 6 m high.

Stop 3 was at a roadcut along Loop 337 in New Braunfels, a town about 30 km northeast of San Antonio. In that location the Edwards Limestone is a highly permeable, honeycomb that probably formed at the front of a former fresh water/saline water mixing zone along a major fault. Dissolution and alteration features are evident, such as from preferential dolomitization during deposition of the limestone and later dedolomitization.

Lunch was served nearby in New Braunfels' Landa Park at the Comal Springs. This spring group is the largest issuing from the Edwards Aquifer and discharges from along faults at a mean rate of 8 m^3/s as measured between 1930 to 2000. In March 2002, Geary Schindel conducted two tracer tests to the springs using eosine and uranine. The dyes were injected into nearby wells and one appeared within about 3 hours and the other within about 36 hours. One of the wells is artesian (Figure 3) and required some creativity to inject the tracer, which involved installing a PVC casing that rose above the potentiometric level, then lowering a tube deep into the well and pumping in dye through the tube. About 1,800 samples were analyzed over a two week period and beautifully showed the effects of photodegradation on the fluorescent dyes as the water discharged from the springs into a small, shallow lake. The tracer experiment was important since tracer work is seldom conducted in Texas and several prominent geologists and decision-makers did not previously believe that conduits play a significant role in groundwater flow in the aquifer. Unfortunately, some still don't.

Leaving the springs, we broke into two groups. One returned to the hotel, and the other drove a little south for an early dinner and a trip to Bracken Bat Cave. Bracken contains the world's largest concentration of mammals. It is a maternity colony for Mexican free-tailed bats. During this fieldtrip most of the bats had recently returned pregnant from their winter excursion in Mexico. Since they give birth to an average one pup each, by the summer, their population in the cave will double to an estimated 40 million.

The cave is a single large passage about 130 m long by 15-25 m wide by 10 m high. The entrance is in a 30-m-diameter by 10-m-deep collapse sinkhole, and cavers have long believed that the passage must continue on the other side. Those of us who arrived there early set up a demonstration of the AGI (Advanced Geophysical Instruments) Sting electrical resistivity system to try and detect that void (Figure 4). As we worked, the others arrived and enjoyed watching the spectacular bat emergence. Ron Green led the demonstration, based on prior geophysical work done at the cave by his co-workers at Southwest Research Institute, but this demo didn't turn out as well. In our rush to complete it before the hour became too late, some of the electrodes didn't have good contacts with the ground and there was no time to fix the problem. What seems to be a void appeared on the image produced by the Sting, but the error was too large to consider it reliable.

Summary

Although there were some initial disappointments with this meeting, I'm glad I attended. All conferences have their gaffes, and I expect from the caliber of people attending that those I saw were exceptions, not the rule. The papers I saw in the karst and non-karst sessions seemed insightful, well researched, and useful investigations. While there is a tendency to think of geophysics as something that karst consultants working in applied fields would tend to use, I was impressed with the potential use of geophysics in sound basic research to help us better understand how karst develops and functions. While karst geoscientists would benefit from attending these conferences, the geophysicists would also benefit from our participation. Of the papers I saw and the people I spoke with, it was clear that few had any detailed understanding of karst. Though like myself, many of you reading this love our karst conferences, for us to truly influence the science and management of karst, we need to attend meetings like this to increase their and our education.

The proceedings of this and other SAGEEP conferences are available on CD. To order these and related publications and for more information and EEGS and SAGEEP, visit the EEGS website at: www.eegs.org

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Dear Karst Friends,

In a little over a month, many of us will be meeting in California for the NSS Convention. The Section of Cave Geology and Geography luncheon meeting is scheduled for Wednesday, 6 August. If you plan to be at the meeting, the
tentative agenda below is a reminder/warning that you'll be called on for a report. If you won't be at the meeting, please e-mail me a report that I
can share with the others. If there are any unlisted old or new business items that you want to discuss, let me know and I'll add them to the
agenda.

Should you need to reach in the coming month, keep in mind that I'll be unreachable from 9-21 July while teaching a karst management
seminar in Guatemala.

Thanks,

George

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SCGG MEETING AGENDA

NSS Convention, Porterville, California,
6 August 2003
Treasurer's Report: Gail McCoy
Editor's Report: Jo Schaper
Web Editor's Report: Matt Reece

Committee Reports
Cave Geology: Bette White
KARSTMAP: Jack Epstein/Randy Orndorff/David Weary
Long and deep cave lists: Bob Gulden
Huppert/Quinlan Award: Jameson

Other reports:
AAAS: Dan Chess
AGI: Harvey DuChene
JCKS: editor - Louise Hose
JCKS geoscience: editor -- Ira Sasowsky
KWI: John Mylroie
Thesis list: Betty Wheeler
UIS Commission on Cave Mineralogy: Carol Hill / Will White
Friends of Karst: Will White
NCKRI: Louise Hose
Cave & Karst Encyclopedia: Will White
2003 Convention
GIS workshop/symposium: Bernie Szukalski
Other past meetings/symposia?

Old Business:
New Business:
1) Next year's symposium: Island Karst, Mylroie and Florea?
2) Should Geo2 be-mailed or placed on password-protected website?
Announcements
Elections:
Adjourn

In Review: Proceedings of the 15th NCKMS Symposium

David M. Bednar, Jr.

The 15th National Cave and Karst Management Symposium (NCKMS), dedicated in the memory of Drs. George N Huppert and Randall Tufts, was held from October 16-19, 2001 in Tucson, Arizona. Some of the agencies, universities, and consulting companies represented at the symposium included the National Park Service, Hoffman Environmental Research Institute, Mammoth Cave National Park, Virginia Department of Natural Heritage, Missouri Department of Conservation, Western Kentucky University, SWCA, Inc., Tongass National Forest, and the U.S. Fish and Wildlife Service. The 16th NCKMS will be hosted by The Cave Diving Section of the National Speleological Society in Gainesville, Florida from October 13-17, 2003.

This proceedings volume contains 24 papers and 32 abstracts divided into six sections.

The focus of Section 1 is Management of Karst Areas. Bailey provided a progress report on the activities and projects at the National Cave and Karst Research Institute. One project would result in a booklet entitled Guidelines for Cave and Karst Management for America's Protected Lands. Bowman presented a review of the Cave Management Plan process. Land acquisition problems encountered by the West Virginia Cave Conservancy were discussed by Bray. Buecher provided caving accident statistics and Crawford discussed karst hazards in urban areas.

Ek reported that of the 384 National Park Service units, 73 % (281) contain significant natural resources. Of those, 43 % contain caves and/or karst resources. One item of note in this paper is Elk's definition of karst. Guaranteed, a globally accepted definition of karst does not exist in the literature. Every author defines karst differently using similar terms. Elk defines karst as a process rather than an area of land with distinctive geomorphic and hydrologic features. Additionally, Ek provided a long list of citations (204) used to confirm the presence of cave and karst resources within National Park Service lands. Hamilton-Smith addressed the difficulties encountered when establishing protected areas for karst ecosystems. Groves et al. summarized recent activities by the cooperative scientific program between the Hoffman Institute, the Cave Research Foundation and Chinese Academy of Geological Sciences.

Several brief abstracts follow that addressed topics such as the inadequate management of cave and karst resources along the Ozark National Scenic Karstways (House); a cooperative education program between Western Kentucky University and the National Park Service (Meiman et al.), a model for evaluating three fundamental elements of karst systems, (Kambesis and Grooves), detailed air flow data to better understand cave environments (Schneiker), and human factors in cave resource management (Smith).

Stokes and Griffiths called attention to a four-step karst vulnerability procedure developed for forest management guidelines in British Columbia. The paper by Trout covers outdoor recreation conflicts among opposing user groups and the psychology of the differences. Turner discussed the cave permit system, management classifications for caves, and the Trip Leader Program at the Lincoln National Forest, Guadalupe Ranger District. The last paper of the section by White described the problems with the management of karst in coastal aeolianite ridges (soft rock karst) along the southern and southwestern coast of Australia.

Section 2, Management of Specific Caves, covers a number of issues with respect to the caves of the National Park Service. Papers and abstracts in this section focus on Coyote Cave in Wind Cave National Park (Despain), Skull Ice Cave in Lava Beds National Monument (Fuhrmann), cave protection in Tennessee (Garland), the development of a cave potential map for Wind Cave (Horrocks and Szukalski), development and management of Glenwood Caverns in Colorado (Koper), and the development of a karst education and outreach program at Leonard Springs Nature Park in Bloomington, Indiana (Lindberg).

Other papers in this section include a discussion by Meiman et al. on management issues at Mammoth Cave National Park. Richards presented a detailed description of events that lead to the selection of a stainless steel culvert in Lechuguilla Cave. Werker and Hildreth-Werker provided a very interesting paper about the discovery of La Cueva de las Barrancas cave and its intended use as a study site for the development of astromicrobiological methods.

In Section 3, Geology and Hydrology, Brown presented a status report on House Joint Resolution No. 161 that mandates karst groundwater monitoring in the Shenandoah Valley in Virginia. Ek discussed cave forming mechanisms and proposed a cave geomorphic classification system. Another paper by Fagan and Orndorff summarized Federal, State, and private programs used to help protect and remediate karst resources. Orndorff and Fagan, Peachey, and Serface and Gilli provided information on a sinkhole classification scheme developed by the Virginia Karst Program of the Virginia Division of Natural Heritage, problems with apokryptic karst in southern Arizona, and paleoseismicity in caves in Arizona and New Mexico, respectively. Trout developed a model presentation format to use when discussing karst groundwater resources. An overview of the arid karst of Australia with descriptions of the Gregory Karst and Nullarbor Plain is included at the end of the section (White).

The study of Biological Resources as applied to cave and karst management is covered in Section 4. Buecher reported on the emergence variation of the cave bat in southern Arizona. Crothers et al. described an incidental take permit of karst invertebrates in Bear County, Texas. Other topics of discussion included the relationships between microbes and limestone dissolution kinetics (Oakley et al.), cave surveys in Missouri (Elliott), determination of microbial diversity in caves by DNA fingerprinting techniques (Fowler et al.), the recognition of wildlife uses of caves and mines in the Sonoran desert region of Arizona (Kingsley et al.), and surface preserve size recommendations for cave or cave clusters to help promote species survival (Areca et al.).

The paper by Lewis concentrated on the development of a non-lethal method for estimating populations of the Illinois Cave Amphipod. Olson and Sidner discussed lamp flora and endangered bats at Fort Hauchuca, respectively. White, Carothers, and Berkhouse described the karst fauna region concept concerning invertebrate recovery in Bexar County, Texas.

Section 4, GIS/Mapping, provided examples of how GIS mapping technologies are used to manage cave and karst resources. Three short abstracts in this section concentrate on light detection and ranging technology to assess impacts on the Tongass National Forest (Baichtal and Langendoen), sub-meter accuracy of a handheld GPS unit (Buecher), and the use of cave inventory systems to manage cave resources in Lava Beds National Monument and Wind Cave National Park (Reece). The use of ArcView GIS and LANDSAT data helped Lerch et al. assess the water quality of two karst watersheds in Missouri. A GIS was used to create a cave passage overlay for Jewel Cave to identify passages beneath roads, buildings, and parking lots (Ohms). Truebe describes how raster format GIS can be used to develop a cartographic model to aid in the search for undiscovered caves.

Veni et al. reported on a GIS model that was developed for the City of San Antonio. The model was used to identify tracts of land to purchase within the recharge area of the Edwards Aquifer. Geologic (land slope, faults, caves, sinkholes, and lithology), biologic (endangered species that included karst invertebrates and potential bird habitat), and watershed surrogate (property size and connectivity) data layers were incorporated into the model for subsequent analysis.

Four short abstracts are presented in Section 6, Toxic Materials and Air Studies. Subjects of interest include transport of Atrazine by suspended sediments in Mammoth Cave (Anderson and Meiman), public concern for the proposed Kentucky Trimodal Transpark located between Bowling Green and Mammoth Cave (Glennon et al.), contamination at the Panama Ranch Garbage Dump Cave (Hansen et al.), and a spill retention and runoff filtration structure along I-65 near Mammoth Cave (Olson and Schaefer).

In Review:
Proceedings of the 2001 National Cave and Karst Management Symposium
G. Thomas Rea (ed), USDA-Forest Service, Coronado National Forest, 194 pp.

Reviewed by David M. Bednar, Jr.

Identification of rapid groundwater flow to the contaminated municipal wells in the karst aquifer at Walkerton, Ontario

by Steve Worthington

Walkerton is a rural town of 5000 people in south-west Ontario. It's about two hours drive from Toronto and about three hours from Detroit. At the end of a long weekend in May 2000 it made the news headlines across Canada when many people became seriously ill. The town's hospital was soon overwhelmed, and for the news media and many Canadians the defining image of that time is critically ill patients being evacuated by helicopter to larger hospitals. It was soon discovered that the municipal water supply was contaminated, with E. coli O157:H7 and Campylobacter jejuni being the principal pathogens. Seven people died and more than 2000 became ill in all, and three years later many people are still chronically ill.

The provincial Ministry of the Environment ordered the town to carry out studies to determine the cause of what became known as the Walkerton Tragedy, and a public inquiry was organized. The town had been using three wells, Wells 5, 6, and 7. Well 5 was found to be highly contaminated with bacteria and was taken offline, but the other two wells also had bacterial contamination some of the time, and so it was unclear which of the wells had been the source of the contamination. Well 6 was also later taken offline and decommissioned.

Matching of the bacteria in the human cases and in cattle on nearby farms showed a match between about three-quarters of the human cases and the cattle on a farm close to Well 5. In the summer and fall of 2000 a hydrogeological investigation was carried out for the town of Walkerton. This included the drilling of 38 boreholes, surface and downhole geophysics, pumping tests, and the testing of numerous samples for both bacteriological and chemical parameters. The two reports produced on the hydrogeology totaled some 900 pages.

When I first heard about the contaminated water supply at Walkerton my immediate thought was that the aquifer was likely to be limestone or dolostone, since this sounded to be a case of unanticipated rapid karstic flow. On the Tuesday after the May long weekend I checked the geology maps of Walkerton, and was rather puzzled to find that the valley that the town was situated in had about 50 m of overburden above the bedrock. I mistakenly assumed that the wells were in that overburden.

Several months later Chris Smart told me that he had been contacted by the hydrogeology consultants since they were considering doing tracer testing. He had learned that the wells were outside the buried valley, that they were in limestone and dolostone, and that there was a spring close to one well. I obtained a copy of the main hydrogeology report, and found that the bedrock aquifer had been assumed to have a porosity of 5% and to behave like a porous medium. Numerical modeling based on these assumptions showed that groundwater flow would take about a month to travel 200 m. However, if the aquifer were karstic then groundwater velocities could be much faster.

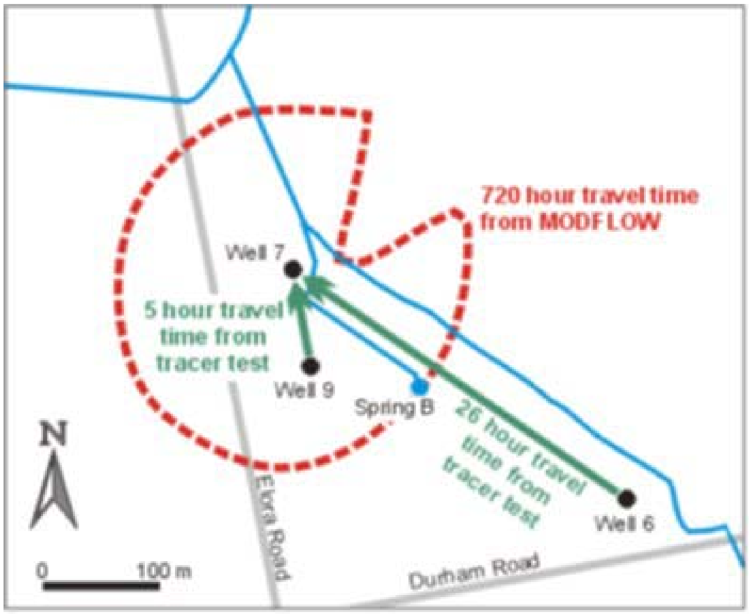
Meanwhile, in October 2000 the public inquiry had started. It heard evidence on many possible contributing factors to the tragedy: how the provincial government had cut back on water supply inspectors in recent years, how inspectors had found earlier that there had been occasional problems with bacteria in the wells, how the directors of the water utility had little awareness of the problems with the water supply, and how staff had failed to keep adequate chlorine residuals in the water supply.

I joined the team helping the citizens' group, Concerned Walkerton Citizens, at the Walkerton Inquiry. In February 2001 I drove the two hours from my home to Walkerton to help with cross-examination on the hydrogeology evidence. My first surprise was to find that the spring only 20 m from Well 5 was flowing at the high rate of about 20 L/s. Clearly this drained a substantial area, and rapid flows through the limestone bedrock to that spring would not be unexpected.

I was even more surprised when I visited Wells 6 and 7. These two wells are 350 m apart, and I found there to be a substantial spring midway between them (Figure 1). The hydrogeology evidence was presented on February 28 2001 by Dr. Robert Gillham of the University of Waterloo, who had been retained by the Walkerton Inquiry to present and explain the hydrogeology evidence. Dr. Gillham stated that he had no doubt that the bedrock aquifer at the Walkerton wells was karstic.

Clearly more work was needed on the implications of the karstic nature of the bedrock, and in the spring of 2001 Chris Smart, Wilf Ruland and I gauged spring discharge and chemistry, conducted downhole conductivity profiling, and analyzed existing data from a karst perspective. In particular the existing downhole video and flow meter data were invaluable, showing that there were discrete inflows to the wells on just a few bedding planes. Horizontal video shots on some of these bedding planes revealed the water to be flowing into the well from elliptical channels a few millimeters to a few centimeters in height - exactly what we expect in karst.

We wrote our findings up in a report and I presented this at the Inquiry in July 2001. What was missing from our work of course was any tracer testing since we had not succeeded over the previous several months in obtaining permission to conduct any. All I could say at the inquiry was that all the evidence pointed to the aquifer behaving like a normal karst aquifer and that groundwater velocities were likely to be far faster than the porous medium model had indicated. The implication of this was that the pathogenic bacteria could have come from a much broader area than had been indicated by the numerical model. Of particular concern was the source for the one quarter of the human illnesses that did not match the cattle from the nearest farm.



In October 2001 the tracing was carried out by the town's consultants, with input from Chris Smart and myself, after the local health unit had approved the use of two non-toxic fluorescent dyes, uranine and eosine. Eosine was injected into one well and uranine into a second. These wells were 100 m and 350 m, respectively, from Well 7, the pumping well. The prediction from the numerical model was that groundwater velocities to Well 7 were about 200 m per month.

I had suggested at the Inquiry that the effective porosity of the aquifer for transport (i.e. the porosity of just the conduit network) was likely to be roughly 0.1% rather than the 5% used in the numerical model. If this were so then tracer velocities would be about 200 m per day, and this turned out to be close to measured velocities. The eosine from the 100 m trace arrived after five hours and peaked after ten hours and the uranine from the 350 m trace arrived after 26 hours and reached a peak after 2-3 days (Figure 2). Calculations showed that these rapid velocities indicated that channels at least several millimeters in diameter must be continuous over distances of at least hundreds of meters, which of course is exactly what karst theory suggests.
Hopefully one legacy of the Walkerton Tragedy will be a greater awareness amongst hydrogeologists of the occurrence of rapid groundwater flow in carbonate aquifers.

Proposed Program Schedule of the 2003 NSS Convention
Cave Geology and Geography Session

13 Poster papers to be presented Monday, 4 August 2003:

America's National Cave and Karst Research Institute 2003: The Gearing Up Phase. Louise D. Hose, Zelda Chapman Bailey, Lewis Land, and Penelope Boston.

Genesis and characteristics of Tumbling Rock Cave, a valley wall conduit in Jackson County, Alabama. Patricia N. Kambesis and Ira D Sasowsky.

Genesis and sedimentation of Windy Mouth Cave, West Virginia. Megan D. Curry, Ira D. Sasowsky, and David A. Shank.

A hidden speleothem: elongated concretions in Colorado cave sands. Donald G. Davis and Frederick G. Luiszer.

Subterranean soil development. Michael N. Spilde, Penelope J. Boston, Diana E. Northup.

Applying statistical analysis to cave maps to infer controls on conduit development in the Edwards aquifer of central and south Texas. Adrien L. Lindley and Susan D. Hovorka.

Guadalupian speleogenesis reinterpreted: new models for old holes. J. Michael Queen.

The Egemeyer Model meets hot air: a vadose convective air-circulation model for the development of boneyard, ceiling pendants, lofts, blind pockets, vents, rims and scallops. J. Michael Queen.

Consequences of low pH, cave-wall condensation and biofilm development to sulfuric acid speleogenesis. Annette Summers Engel*, Libby A. Stern, Philip C. Bennett.

Annual banding in small columnar stalagmites. Victor J. Polyak, Jessica B. T. Rasmussen, and Yemane Asmerom.

Caving on the San Andreas Fault: talus caves in Pinnacles National Monument, California. Bruce W. Rogers, Joel Despain, William Frantz, and John Portillo.

A preliminary mineralogy of talus caves in Pinnacles National Monument, Paicines, California. Bruce W. Rogers.

Extraterrestrial cave-forming mechanisms Penelope J. Boston.

16 Oral papers to be presented Wednesday, 6 August 2003:
0900-0920: The National Cave and Karst Research Institute: how will it address its science mandate? Louise D. Hose and Penelope Boston.

0920-0940: Origin and mineralogy of a tectonic rhyolite cave in Big Bend National Park, Texas. George Veni.

0940-1000: The Carbonate Island Karst Model as applied to Rota (Luta), Tinian, and Aguijan Islands, Commonwealth of the Northern Mariana Islands. T. Montgomery Keel, Kevin W. Stafford, John E. Mylroie, Joan R. Mylroie, and John W. Jenson.

1000-1020: Eogenetic karst development in the Mariana Islands: Aguijan, Rota, and Tinian. Kevin W. Stafford, T. Montgomery Keel, John E. Mylroie, Joan R. Mylroie, and John W. Jenson.

1020-1040: Break

1040-1100: Paleosols and Paleokarst: A Key to Paleoclimate Interpretation in Carbonate Islands. Vasile Ersek, John Mylroie, Joan Mylroie, Bruce Panuska, and James Carew.

1100-1120: Quantitative Footprint of Flank Margin Caves. Monica Roth, Kathryn Zellner, and John Mylroie

1120-1140: Sedimentation and porosity enhancement in a breached flank margin cave. Lee J. Florea, John E. Mylroie, Adam Price.

1140-1200: A decade of process-response observations of a sinkhole collapse cycle in Pebble Pile Creek, Lilburn Cave, California. John C. Tinsley, John W. Hess, David Cowan, Howard Hurtt, and William Farr.

1200-1400: Lunch

1400-1420: On the definition of cavern breakdown: a review of the changing conceptions of breakdown. Roy A. Jameson.

1420-1440: Hydrogeologic methods used to predict cavern development: Rader's Valley, Greenbrier County, West Virginia. Morris Hall.

1440-1500: **Aqueous geochemical study of Tufa Creek, Shannon County, Missouri. J.A. Schaper and C.M. Wicks.**

1500-1520: **The Use of Electrical Geophysical Methods to Define Groundwater Flow Path Impacts in a Karst Aquifer. Paula Grgich and Richard Hammack**

1520-1540: **Break**

1540-1600: **Bit drops (drilled voids) as a measure of karst. Rebecca L. Bixby and Ira D. Sasowsky**

1600-1620: **Recharge area delineations in the Salem Plateau, Illinois. Philip L. Moss.**

1620-1640: **Hydrogeology of Spencer Mountain: Lick Branch karst investigation. John Deatrick, John Hoffelt, and W. Stephen Anderson.**

1640-1700: **Seasonal changes in spring water quality in Rutherford County, Tennessee. Albert E. Ogden, Clay Kennedy, Joe Bales, Rebecca James, John P. DiVincenzo, Monette Rebecca, and Melissa Niese.**

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Inside Geo^2:

SISTEMA ZACATÓN:
IDENTIFYING THE CONNECTION BETWEEN VOLCANIC ACTIVITY AND HYPOGENIC KARST IN A HYDROTHERMAL PHREATIC CAVE SYSTEM

Marcus O. Gary, John M. Sharp Jr., Robin S. Havens, The University of Texas at Austin; William C. Stone, Stone AeroSpace