

SELECTED SCIENTIFIC ABSTRACTS FROM THE 2005 NATIONAL SPELEOLOGICAL SOCIETY CONVENTION IN HUNTSVILLE, ALABAMA

ARCHAEOLOGY

THE ARCHAEOLOGY OF A NINETEENTH CENTURY SALTPETER MINING SITE: CAGLE SALTPETRE CAVE, VAN BUREN COUNTY, TENNESSEE
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Since the foundation of the first colonies, the struggle for both survival and self-sufficiency made gunpowder a critical substance in frontier America. Consequently, the domestic production of saltpeter, the principal ingredient in gunpowder, became an important early industry. A natural and reliable source of saltpeter, the numerous limestone caves throughout Tennessee played a significant role in both the country's military history and the early industrial development of the region. During the nineteenth century, the second war with Britain coupled with the War of the Rebellion led to both large- and small-scale saltpeter mining operations in caves throughout the State. Fortunately, the dry environment of these caves allows for excellent preservation of the material record, thus many of these sites still contain the equipment used in the mining operations, much of it still in context. Despite the high rate of preservation, little scientific research has been undertaken at specific saltpeter-mining sites. Historic documentation of mining activities within these caves is scarce, thus a systematic study of the extant archaeological record can be integral in enhancing our understanding of this early extractive industry. An archaeological examination of extant artifacts and features at one such site, Cagle Saltpetre Cave, in Van Buren County, Tennessee, is focused on providing insight into the production process, the results of which are presented.

TORCHES IN THE DARK: LATE MISSISSIPPIAN EXPLORATION OF HUBBLE POST OFFICE CAVE, TENNESSEE

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In late 2003, during a Southport Chronic Cavers Grotto survey project, Lynn Roebuck discovered evidence for prehistoric people visiting Hubble Post Office Cave, in the form of cane torch stoke marks. Brian Roebuck confirmed the initial identification. While the cave, located in the middle Duck River drainage, was known to be an important paleontological site, it was not known to contain archaeological material. A subsequent research trip by the authors in early 2004 examined in detail the extant evidence. The locations of cane torch stoke marks and cane charcoal deposits were recorded, a sample of cane torch charcoal was collected, and the site was examined for evidence of resource removal, mortuary activity, or ceremonial use. The results of the research reveal that prehistoric people explored the majority of the cave, but there was no indication of any usage of the cave environment except simple exploration. This conforms to what is known about prehistoric cave use in the region, as exploration-only sites are the most common of all deep cave archaeological sites in Tennessee. A single radiocarbon date was obtained, using AMS technology, which revealed that the exploration of the cave occurred in the early- to mid-15th century, placing the activity in the Late Mississippian period. While comparatively little is known about the Late Mississippian in the middle Duck River drainage, it is clear that the cultural tradition of exploring caves long persisted in the area, despite the relatively light population density at the time.

PREHISTORIC CAVE ART IN 44TH UNNAMED CAVE, TENNESSEE

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Recently discovered prehistoric cave art in 44th Unnamed Cave (Tennessee) is discussed. The cave contains more than two dozen pictographs, petroglyphs, and possibly mud glyphs in a dark zone context. The art is associated with a long, intensive, occupation sequence in the vestibule and ritual

human interments in the cave interior. The artwork is classically Mississippian in subject matter (ca. AD 1100–1500) and quite resembles certain distinctive design elements found on shell gorgets in the immediate region of the cave. 44th Unnamed Cave brings to fifty the known assemblage of prehistoric art caves. Because it is owned by the State of Tennessee, the site presents a unique opportunity to allow public viewing of prehistoric southeastern cave art under controlled and protected conditions.

WOODLAND AND MISSISSIPPIAN CAVE ARCHAEOLOGY IN FLORIDA: HOW DOES IT FIT INTO THE SOUTHEAST PICTURE?

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Cave archaeology in the southeast has made monumental contributions to the understanding of prehistoric cultures due to their optimal preservation of organic remains in the subsurface environment. More than four decades of research in caves of the southeast United States demonstrates extensive use by many indigenous groups of the Paleo-Indian, Archaic, Woodland, and Mississippian periods. We know that the range of these indigenous groups was widespread; however, our current perception of archaeological research in caves is based mostly upon studies in south-central Kentucky and surrounding regions, and primarily limited to the Woodland and Mississippian periods.

Less research has been conducted on the periphery of this region despite many of the shared characteristics that these cultures have with other indigenous groups that live on karst terrains during the Woodland and Mississippian time periods. Likewise, little research has been conducted on how cave use in northwest Florida relates to cave use in other regions of the southeast. Florida's younger geology, geographic location, and coastal influences offer archaeologists a unique opportunity to examine variation in underground prehistoric activities. This paper synthesizes previous research conducted in the southeast, reviews prior research in northwest Florida, and explores future research directions for Florida cave archaeology.

BIOLOGY

GUANO INVERTEBRATE COMMUNITIES IN A HIGHLY ACIDIC CAVE

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Cueva de Villa Luz in Tabasco, Mexico, is a cave with a complicated energetic base including inputs of sulfur energy from spring and detrital energy from skylights and bats. Sulfuric acid is a waste product of the metabolism of chemoautotrophic bacteria in the cave, and as a consequence, everything in the cave is highly acidic. There are two areas in the cave with large numbers of bats and significant guano accumulations; Casa de los Murcielagos and the Bat House. Guano samples collected from each location were analyzed to determine pH, percent moisture, % organics and % ash. The Kcal/g dry mass was calculated. Guano samples were also assayed for ppt sodium, calcium, iron, potassium, magnesium, and total nitrogen. 100 cc samples of guano were destructively sampled for invertebrates, and smaller 1 cc subsamples for mites. Differences in the types of species found were noted between the two locations, which may be due to proximity to the nearest entrance. Species diversity and abundance were much lower than expected compared to other studies of guano invertebrate community structure. As expected, mites were the most abundant type of invertebrate collected. Three of 12 samples had no invertebrates at all, and two only had mites. The greatest biological diversity was in samples from the Casa de los Murcielagos area which also had the most narrow pH range of 2.2–4.0, and percent moisture ranging from 13.7% to 22.3%. Bat House guano ranged in pH from 1.6 to 4.6. Trying to relate the distribution of species to any of the measured physical characteristics is not simple. In general, samples with very low pH (<pH 2) had the lowest diversity. Samples

with the highest moisture (>50%) also had low diversity regardless of pH. There were no strong correlations between guano pH or percent moisture for any of the minerals or for organic content. In this study, guano pH, percent moisture, and proximity to entrances, are the best predictors of guano invertebrate community diversity.

PRELIMINARY EVALUATION OF THE INVERTEBRATE FAUNA OF AN ARTIFICIAL BAT CAVE IN TEXAS

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We began the study of colonization of bat guano in a new environment. The Bambergers have built a man-made bat cave on their Selah ranch in central Texas. Consisting of two large domes 40 ft and 20 ft in diameter, the Chiroptorium has had mixed success in attracting bats. Guano covers the floor in both chambers. A visual census of the guano during January 2005 shows a very minimal fauna in terms of numbers and diversity. The most abundant invertebrates are spiders that are common on the walls of the chambers. Interpretation of results will be complicated by importation of about 100 lbs of guano from Bracken Bat Cave. This project will be conducted over the next five years, in cooperation with a study of the bats.

MACRO-INVERTEBRATE SURVEY OF THE TIMPANOGOS CAVE

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Under the funding of the National Park Service's Inventory and Monitoring Program, Dr. Riley Nelson of Brigham Young University was contacted to perform a 2-year survey to identify the macro-invertebrate species of the Timpanogos Cave system, Utah. Species were collected in 87 pitfall traps placed throughout the entire cave system. These traps were collected every 2 weeks, sorted, and identified. Preliminary results show that a total of 29 taxa were collected, most from Sciaridae, Mycetophilidae, and Anobiidae. From this study, indicator species will be selected for monitoring the health, or vital signs, of the cave.

BIOINVENTORY OF SEQUOIA, KING'S CANYON AND YOSEMITE NATIONAL PARK CAVES

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The goals of this study were to create faunal lists for developing cave management plans, and to provide park staff with the tools to maintain a cave species monitoring system. Thirty-five caves were visited over four field sessions of three weeks each in Sequoia, King's Canyon and Yosemite National Parks. During this investigation, approximately 1600 collections were made and they are being shipped to specialists for identification. Already several taxa have been recognized that represent new species. Additionally, a database is being created with a specialized format for managing in-cave biological survey data. This format links species observations to cave survey stations and searcher effort, in order to facilitate analysis of relative abundance and precise spatial distribution of species over time. The database also incorporates the U.S. Department of Agriculture's Integrated Taxonomic Information System (ITIS) nomenclature and taxon identifiers, and is compatible with the National Park Service's Natural Resource Database Template. This format which is already being used in many parks across the country will allow all of these data to be searchable on the web. The format of the database and field identification aids, including color photographs of live specimens provided in a report, will help park staff maintain long-term monitoring of cave species.

A BIOLOGICAL SURVEY OF CAVES AT FORT LEONARD WOOD, MISSOURI

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We surveyed the aquatic and terrestrial fauna of 74 sites, mostly caves, at Fort Leonard Wood, a 71,000 acre (28,700 hectare) military installation located near the northern boarder of the Ozark Plateau (Pulaski County) in central Missouri in 2003 and 2004. All but one of the known caves were sampled, and all taxa, including entrance taxa, accidentals, troglodiles, and vertebrates were noted, thus providing a fairly complete picture of the cave fauna of the northern Ozarks. Using a variety of sampling methods (pitfall trapping, baited aquatic traps, hand collections, vacuum samples, leaf litter samples, and sight records) we recorded more than 2,200 taxon occurrences, representing almost 14,000 specimens. Using species accumulation curves we examined the extent to which our sampling protocol sampled the taxa within the caves. Substrate temperature, relative humidity, and substrate type are correlated with the presence of particular taxa, such as diplurans. Several interesting taxa were recorded including cave-adapted flatworms, terrestrial isopods (*Brackenridgia* sp.), Symphyla, and sometimes quite abundant diplurans. In combination with a concurrent archeological study and cave mapping, the results of this study facilitate informed management of caves by military natural resources personnel.

THE DISTRIBUTION OF AMPHIBIANS AND REPTILES IN WEST VIRGINIA CAVES

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There are over 4000 caves in West Virginia, which provide potential habitat and refuge for a variety of amphibians and reptiles. In 2002 and 2003 herpetological inventories were conducted in 25 caves in the Greenbrier Valley, resulting in 40 new species encounter records. These inventory results were combined with encounter records from literature, museum collections, and communications with researchers and cavers to produce to most comprehensive account to date. Thirty amphibian and 13 reptile species have been documented in West Virginia cave habitats. Of the over 500 species encounter records, 86% are Plethodontid salamanders. Specifically, Cave Salamanders, *Eurycea lucifuga*, and Spring Salamanders, *Gyrinophilus porphyriticus*, are the most frequently documented salamanders from West Virginia caves. This research was supported by grants from the WVDNR Wildlife Diversity Program and the West Virginia Association for Cave Studies.

BIOLOGICAL INVENTORY OF CAVES OF TENNESSEE'S CUMBERLAND PLATEAU

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In 2003 The Nature Conservancy (TNC) of Tennessee undertook a biological inventory of caves associated with the Cumberland Plateau in the east-central part of the state. The Plateau region was chosen for the study because of the high number of caves, previous biological study, and because the area corresponds to TNC's Northern and Southern Cumberlands Project Areas. This large area is a conservation priority for TNC due to the remarkable biodiversity of its forests and aquatic systems. Caves and karst features represent a significant component of the Cumberland Plateau landscape, though the species diversity of the cave systems was not well-known. Building on the pioneering work of Dr. Thomas Barr in the 1950s, Lewis & Associates began conducting bioinventories and gathering data in Tennessee starting with an evaluation of the Rumbling Falls Cave System (Van Buren County) in 2001 and a follow-up project in Van Buren and White counties in 2002. To date 115 taxa classified as obligate subterranean (troglobitic/stygobitic) species have been recorded from over 100 caves sampled. These include 17 crustaceans (3 copepods, 6 isopods, 7 amphipods, 1 crayfish), 22 arachnids (8 spiders, 12 pseudoscorpions, 2 harvestmen), 18 millipeds, 12 collembolans and 41 insects (6 diplurans, 21 carabids, 4 leiodids, 9 pselaphids, 1 dipteran).

EVOLUTIONARY HISTORY AND CONSERVATION STATUS OF CAVE CRAYFISHES ALONG THE CUMBERLAND PLATEAU

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Obligate cave-dwelling crayfish species are found only in southeastern United States, Mexico, and Cuba. Most species are considered to be endangered because of surface pollution threats to ground-water and small geographic distributions, not from in-depth biologic research. As currently recognized, there are three morphologically-similar subterranean species of the

genus *Orconectes* found along the Cumberland Plateau, a worldwide hotspot of cave biodiversity. The objectives of this study are to: 1) delineate species' boundaries using molecular genetic data in a phylogenetic framework, 2) examine evolutionary history of each species using Nested Clade Analysis, and 3) assess conservation status of each endangered cave crayfish species using measures of effective population size and genetic diversity.

This research project has uncovered a new species of cave crayfish along the border of Tennessee and Kentucky, an area previously thought to have "intergrades" between two subspecies of *O. australis*. Additionally, *O. a. packardii* will be elevated to species status, which tallies five stygobitic *Orconectes* species on the Plateau. It appears that *Cambarus gentryi*, a surface-dwelling burrowing species, is the closest living ancestor to the cave *Orconectes* assemblage on the Plateau. The origin appears to be Eastern Kentucky around 70 million years ago, with range expansions occurring southward down the Plateau in small leading-edge steps. Although controversial, these cave species exhibit high levels of genetic diversity, especially in comparison to common surface-dwellers. Conservation efforts should focus on protecting 'high-traffic' areas to maintain gene flow and prevent isolation.

CRUISING IN THE BAT-MOBILE: BACTERIAL ENDOSYMBIONTS AND ENTOMOPATHOGENIC BACTERIA IN BAT-ECTOPARASITES—INSIGHTS TO GENERAL TRENDS OF HOST-PARASITE/ENDOSYMBIONT-HABITAT RELATIONSHIPS

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Symbiotic relationships between bacteria and insect hosts are common, with more than 10% of insect species relying upon intracellular bacteria for their development and survival. These symbionts can stem from an obligatory association [primary (P-) endosymbionts]. Besides P-endosymbionts, most bacteria contain a heterogeneous assemblage of bacteria called secondary (S-) endosymbionts. Usually, little is known regarding the evolutionary role and importance of S-endosymbionts, and the boundaries between an endosymbiotic and a parasitic lifestyle are hard to define. Additionally, there are entomopathogenic bacteria with specific affinities to certain insects, and most of these bacteria are phylogenetically closely related to S-endosymbionts. The main goals of this project are to characterize the diversity of endosymbiont and entomopathogenic fauna within the ectoparasitic batflies and reconstruct a robust phylogeny of all involved bacteria. The resulting topology will be used to address the following questions: (1) What is the position of those bacteria within the Gammaproteobacteria, and what are the phylogenetic relationships between endosymbionts and entomopathogenic bacteria?, (2) What is the strain diversity within discernable groups of bacteria?, (3) Which evolutionary hypothesis (co-evolution vs. horizontal transmission) does the phylogeny support for the different groups?, and (4) Is there a geographical pattern of the bacterial fauna in respect to their hosts (Old World vs. New World batflies) and can this pattern be related to general trends in the evolution of batflies, bats and their habitat? This work will provide insight to the evolutionary events between hosts and bacteria in general, and batflies and bacteria in particular, and increase our knowledge about host-bacterial endosymbiont relationships.

ULTRAVIOLET RADIATION SENSITIVITY IN CAVE BACTERIA VERSUS SURFACE BACTERIA

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With no sunlight penetration into the subsurface environment, many cave organisms have experienced the loss of skin pigmentation, a protective trait needed to survive the harmful effects of ultraviolet (UV) radiation, which can cause DNA dimerization, mutation and even death. However, the loss of UV resistance traits has rarely been studied in cave microorganisms. In this study, we build on previous results comparing growth of surface and cave isolates after UV treatment and extend the investigations to the loss of pigmentation, protective cell wall components, and bacterial repair mechanisms. Subsurface bacteria from Left Hand Tunnel of Carlsbad Caverns and surface bacteria were isolated and grown on both high (LB) and low nutrient (R2A) mediums. Samples were exposed to 0 seconds, 50 seconds or 100 seconds of UV light (200 μ Watts/cm²), incubated at 15° C for 6 days, and surface area growth was measured to determine the growth inhibition from UV damage. Degree of pigmentation, Gram stain status, and presence or absence of *recA*, the gene encoding the RecA protein involved in UV repair, were determined. Cave bac-

teria were more sensitive to UV exposure and less able to repair UV damage than surface bacteria. Subsurface bacteria were equally distributed among high, low, and no pigmentation while surface bacteria were predominately pigmented. Cave bacteria were predominately Gram negative (75%), while surface bacteria were equally distributed between Gram negative and positive. Preliminary results suggest that surface and cave bacteria have both retained *recA*.

MICROBIAL COMMUNITY FINGERPRINTING OF CAVE FERROMANGANESE DEPOSITS USING DGGE

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Geochemical studies of cave ferromanganese deposits (FMD) have shown a good correlation between color of the deposit and the mineral composition; however, limited trends have been observed in the microbial compositions of the Lechuguilla and Spider Cave sites previously studied with molecular phylogenetic techniques. To further elucidate the nature of the FMD microbial community and to search for correlations between FMD color and microbial community composition, we undertook a community fingerprinting study using denaturing gradient gel electrophoresis (DGGE). FMD samples of different colors (pink, red, medium brown, chocolate brown, steel gray on calcite deposits, and black) were taken aseptically from the Grand Canyon area of Spider Cave in Carlsbad Caverns National Park. DNA was extracted from the samples using the MoBio Ultraclean Soil DNA extraction kit and an approximately 550 bp fragment of the 16S rRNA gene was amplified using DGGE primers 338F-GC (bacterial specific) and 907R (universal). The same techniques were also applied to enrichment cultures targeting manganese-oxidizing bacteria that were obtained by inoculating Mn-enriched media with FMD from Lechuguilla Cave. DGGE patterns showed the presence of dominant organisms across all colors of FMD.

MANGANESE AND IRON INTERACTIONS: CAVE AND SURFACE ROCK VARNISH COMMUNITIES AND PROCESSES COMPARED

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In both arid land caves and surface desert environments, microbial communities appear to interact extensively with iron and manganese, yielding deposits of intimately associated Fe and Mn oxides. In many cases, the geological context and bedrock composition of caves and overlying surficial outcrops are similar, but the differences between surface and subsurface environmental conditions are significant, e.g. humidity levels, or presence or absence of weathering. The manner of microorganism interaction with the rock environment may reflect these differences and be reflected in the resulting mineral deposits, although the underlying biological oxidation mechanisms of Mn and Fe may be similar.

We are analyzing the Mn and Fe deposition in the rock mineral coatings in caves and in surface rock varnish, identifying minerals that are potentially biogenic, and isolating organisms capable of mediating some of these processes. Synchrotron XRD and EXAFS measurements have revealed differences in the coating mineralogy (e.g. u-XAS and u-EXAFS measurements have revealed the presence of layer- (birmessite) and tunnel-structure (todorokite) Mn oxides in both environmental samples and cultured isolates). Electron microprobe analysis has revealed differences in trace element composition.

We are examining biodiversity in these communities by molecular phylogenetic techniques and have successfully induced production of biominerals

similar to those found in caves, by laboratory isolates. The ultimate goal is to determine the degree of microbial responsibility for the secondary mineral deposits observed and the potential role of these communities in both dissolution of bedrock and deposition of surface oxide coatings in caves and rock varnish on surface materials.

CAVE RESTORATION FORUM

HIGH GUADS RESTORATION PROJECT

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The High Guads Restoration Project (HGRP) is a monthly volunteer project on the Guadalupe Ranger District of the Lincoln National Forest (LNF) in Southeastern New Mexico. The project provides restoration in caves on the district that have suffered impact from 40-plus years of use. In the mid-1990s, the United States Department of Agriculture Forest Service (USDA-FS) stopped issuing recreational permits to most of the popular caves on the Guadalupe District. They took this action after recognizing significant negative impact in these caves from both regular overuse and intentional vandalism. A stipulation evolved from the closing-the caves would receive large scale restoration work before being reopened to recreational cavers. Due to lack of funding, the FS proposed charging fees for caving tours and permits. Recognizing the dangers and increased negative impacts that wild cave tours would incur, cavers proposed to provide the restoration work themselves in lieu of fees. A figure of \$100,000 annually in volunteer work was negotiated between cavers and USDA-FS officials. This number includes work done by caver volunteers annually on both the LNF in New Mexico and the Coronado Forest in Arizona. HGRP formed in 1998 and has donated over \$350,000 in volunteer value and materials to the USDA-FS on the LNF alone. In 2005, 70 volunteers from eight states donated \$60,000 in work and materials. In addition to restoration work, volunteers also survey, prepare step logs, and monitor recreational caves for visible negative impact. The group meets the last weekend of every month except December.

CAVE CONSERVATION & MANAGEMENT

THE CAVES OF SINKING VALLEY

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The Caves of Sinking Valley have been surveyed and studied by hydrologists for over 30 years, yet new caves have been found within the last year. The 33-mi² drainage basin is not only a mother lode of caves, but during flood surges it can also be a force of nature. With the possible routing of I-66 over the most vulnerable section of the master conduit, it is imperative to understand how the road and other development could affect the cave and how the cave could affect the road.

FINDING THE LOST RIVER OF ONONDAGA CAVE

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Onondaga Cave State Park is located in the north central portion of the Ozarks near Leasburg, Missouri. The park is known for two extensive cave systems, Onondaga Cave and Cathedral Cave. Both of these cave systems have large streams (1–2 cfs at baseflow) which have unknown recharge areas. As a management consideration, a series of dye traces has been initiated to delineate the recharge areas of the caves. The project was started in winter 2003, with coordination between state and federal agencies. Standard dye tracing techniques were followed using three different dyes in order to maximize the number of potential injection points per round. It was necessary to work with surrounding landowners and other agencies in order to properly conduct the dye traces, as most of the recharge area lies outside the boundaries of the State Park. To date, Onondaga Cave has had three successful hydrologic connections to surface injection sites. A conservative estimate of the size of the Onondaga recharge area is about 8–10 mi², but dye-tracing work is on-going and will likely change this estimate. However, Cathedral Cave has eluded all attempts to connect it hydrologically to nearby surface streams. Information found thus far is now being incorporated into a cave management plan for the park to potentially aid in future management and possible future land acquisition.

STUDYING CAVE VISITATION TRENDS AT TIMPANOGOS CAVE NATIONAL MONUMENT & NUTTY PUTTY CAVE

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Visitation data is vital for properly managing the use of caves. This presentation will show how visitation information has been collected, organized, and analyzed for the tours at Timpanogos Cave National Monument, as well as for uncontrolled visitation problems of nearby Nutty Putty Cave.

Size, time, and date for each tour are recorded at Timpanogos Cave National Monument. The data was used to graph tour size frequency, seasonal and daily visitation fluxes, and the variability between tours sold and tours given.

At Nutty Putty Cave, a StowAway light intensity datalogger was used to record the maximum light exposures over 15-min intervals. This method collected high-resolution visitation data used to graph visitation by season, week, days of the week, and time of day.

At Nutty Putty Cave, a surface register was used to collect visitation demographics. The data showed that local Boy Scouts troops were the largest visiting group with 17% of the total visitation and that NSS grottos were the smallest visiting groups of 1% of the total visitation.

Visitation data is a useful tool that can drive management decisions and policy changes. At Timpanogos Cave National Monument, we are currently associating resource violations (such as touching formations, littering, and leaving tours) with visitation trends to reduce visitation impacts. At Nutty Putty Cave, visitation information helped convince the Utah State Trust Lands that better management practices are needed. Visitation information is vital toward creating valuable management data to support conservation decisions for these two heavily used caves.

MISSOURI CAVES AND KARST CONSERVANCY

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The Missouri Caves and Karst Conservancy (MCKC) was founded in 1993 on the mission statement of cave conservation through ownership, management, and education.

The MCKC purchased Skaggs Cave, a 5,895-ft cavern in Pulaski County, in 1995. This cave is known for its speleothem displays, and is home to rare cave dwelling creatures. MCKC assisted the Ozark Regional Land Trust (ORLT) with the purchase and management of Sarcoxie Cave in Jasper County. Sarcoxie is home to the Ozark cavefish (*Amblyopsis rosae*) and the endangered Arkansas darter. Crystal Cavern, in Barry County, was leased by MCKC in 1996. The cave was once commercialized, and is now located in the center of a 125-ac parcel of land that has been logged. It is now almost surrounded by development. Plans for the cavern include improving the entrance and walkways, and developing it as an educational resource. MCKC manages 6,000-ft Dream Cave in Ozark County, in cooperation with ORLT and Ozark Highlands Grotto. Dream features unique geology and a significant population of rare bats.

MCKC continues its goals by helping other karst conservancies such as the Carroll Cave Conservancy, and assisting the USDA-FS in gating and patrolling other important Missouri caverns. Perkins and Bruce Caves are two others recently adopted by the MCKC. Future goals include the purchase of at least one additional significant cave, and the realization of our educational program in Crystal. You can help by becoming a member and/ or helping us find that special cave in need of preservation.

KARST EDUCATION: WORKING WITH DEVELOPERS TO PROTECT NATURAL RESOURCES

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Development is expanding into more and more sensitive areas; the more difficult areas have been left for later because they pose additional challenges to engineers. Karst is included. There is tremendous need for conservation and development communities to work together in protecting natural resources. The gaps between the two must be narrowed. Education can be vital to the process; it can be seen as nonthreatening and balanced. A good place to start is on middle or common ground where both sides can agree and strike a balance between environmental, social, and economic concerns to achieve sustainability. Once the parties come to terms, all can move forward from recommendation to implementation. The City of Bloomington, Indiana is engaged in the karst education endeavor through their Environmental Commission and

related commissions, agencies, and community partners. Their example can be used as a model for other areas. During the presentation, an overview of developer education will be discussed along with a few success stories.

CONSIDERATIONS FOR CAVE RESCUE PLANNING: A CASE STUDY OF THE 2004 RESCUE PREPLAN FOR LECHUGUILLA

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Resource managers, cavers, and caves benefit from rescue planning by cave rescue experts. Rescue plans address personnel and equipment needed, management structures, interfacing with cavers, rigging challenges and obstacles. Plans identify sensitive areas of the cave to mitigate damage. Effective rescue planning prioritizes main routes and hazards, and identifies and prepares for high probability scenarios. A cave rigged with rescue in mind is easier and safer to travel, and in the event of a rescue incident, vastly improves evacuation time while minimizing resource damage. Lechuguilla presents unique challenges for cave rescue planning due to the sensitive physical and biological environments. We offer it as a case study on rescue planning and rigging for contingencies.

CAVE AND KARST RESOURCES OF THE VIRGINIA DEPARTMENT OF CONSERVATION AND RECREATION NATURAL AREA PRESERVE SYSTEM

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The Virginia Natural Area Preserve System serves to protect 45 natural areas, covering more than 38,500 ac across the Commonwealth of Virginia. The Virginia Natural Areas Preserves Act, passed in 1989, directed the Department of Conservation and Recreation (DCR) to establish a nature preserve system to ensure the permanent protection of these unique assets. Acquisition, dedication, and stewardship of natural areas in the Virginia Natural Area Preserve System are the responsibility of the DCR Natural Heritage Program. A wide variety of natural communities and habitat are represented in the system, including nine natural area preserves in Virginia's Ridge and Valley Physiographic Province containing significant caves and other karst resources.

Unthanks Cave and the Cedars Natural Area Preserves in Lee County support several species of cave-dwelling fauna that are federally listed as endangered or are globally rare species of concern. It should be noted that the Virginia Chapter of The Nature Conservancy generously gave the Unthanks Cave Preserve to DCR. Stay High Cave, in the recently purchased Clover Hollow Natural Area Preserve in Giles County, contains several globally rare cave obligate invertebrates that are species of concern. Unique soils and moisture conditions associated with karst provide habitat for globally rare flora and fauna species. Cleveland Barrens and Pinnacle Natural Area Preserves (NAPs) in Russell County, Pedlar Hills NAP in Montgomery County, Mount Joy Pond and Folly Mills Creek Fen NAPs in Augusta County, and Deep Run Ponds NAP in Rockingham County are all situated on karst terrane.

TOURISM, DROUGHT, AND CLIMATE CHANGES AT KARTCHNER CAVERNS (ARIZONA, USA)

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Kartchner Caverns is a recently developed show cave in southeastern Arizona. One tour opened to the public in November 1999 and another opened in 2003. These openings followed more than 11 years of work in predevelopment studies, planning, and construction, carried out by the Arizona State Parks. Monitoring was initiated during the earliest studies and continues today.

The monitoring includes cave microclimate parameters (temperature, humidity, evaporation, CO₂, and radon), surface climate, and groundwater levels in adjacent aquifers. Some changes in temperature and humidity have been detected. Mean temperatures have risen by up to 2° C, and mean relative humidity has decreased by up to 2.5%. The amount of change varies within the cave, but generally, changes are most extreme in the most intensively developed areas. Comparison of the changes at Kartchner Caverns with some undeveloped caves, with local and regional surface climate data, and with groundwater data in the vicinity suggests that much of the change seen at Kartchner can be attributed to regional changes in climate; however, data show that

development and tourism are also factors. Arizona State Parks continues to study and monitor Kartchner Caverns both to better understand the interaction of the various factors in the cave's climate and to be able to respond to changes as needed.

PROTECTING UNDERGROUND CULTURAL RESOURCES: CAGLE SALTPETER CAVE, TENNESSEE

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In 2003 cave resources specialists and the management of Fall Creek Falls State Park decided that proactive protection of the historic cultural resources in Cagle Saltpeter Cave might be needed. The cave is a well-preserved antebellum industrial landscape, and historical consultants verified its importance and vulnerability. While investigating the cave's historic resources it was discovered to be an important prehistoric site as well. To facilitate its preservation, partnerships were established between the Park (the State of Tennessee), the University of Tennessee Cave Archaeology Research Team, Friends of Fall Creek Falls, The Nature Conservancy, the Upper Cumberland Grotto, and individual cavers. Caver and conservationist Kristen Bobo agreed to design and build an appropriate gate for the site, funds were raised, supplies acquired, and site preparation was undertaken throughout the spring and summer of 2004. In designing protection for the site, consideration was also given to the cave's important biological resources, including significant new biological research on site. In the fall of 2004 the various partners came together and constructed a bat (and invertebrate) friendly gate, using standard ACCA specifications, thus dovetailing the protection of underground historic, prehistoric, and biological resources.

THE EVOLUTION OF THE BECKIS PROJECT FOR CAVE INVENTORY AND CONSERVATION IN BERMUDA

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The Bermuda Cave and Karst Information System (BeCKIS) project has been an ongoing project for three years, and serves to increase public awareness of Bermuda's caves and cave life, increase awareness of negative impacts on these resources, and promote the scientific study of Bermuda caves. A countrywide GIS database has been established to serve these goals, and to maintain an inventory of locations, field observations, cave survey data, and maps. This system incorporates data collected over 25 years, and has been used to examine changes in various measured cave parameters over time, the effects of development and land use practices, and as a communications tool for public awareness and scientific study. A workshop in February brought scientists and cavers from across the globe together with government agencies and local research organizations to examine progress thus far, and to leverage these experiences forward to new project areas and goals.

HUALALAI RANCH – A CAVE TO BE CONSERVED FOR ALL AND ALL TIME

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The size and significance of Hualalai Ranch Cave in Hawaii County, Hawaii is becoming more and more evident with each expedition. It appears to be a world class cave in many respects, and it merits protection and management appropriate to its importance as a significant cave.

Nevin Davis has reported that the cave has 15.72 mi of mapped passage, as of January 2005. This qualifies it as the longest cave in west Hawaii. Besides length and depth, it exhibits unique, significant geology, aesthetics, biology, and archaeology. Hualalai Ranch Cave is a multi-level maze with many parallel branching and braided passages. One can find all the usual lava formations found in other lava caves. It has an abundance of puka entrances, so one can enter the system at many different places. Fountain grass, a nonnative species, dominates the surface at lower elevations, and goats have destroyed most of the native plants. However, a few pukas have such steep walls that the threatened native plants in them have so far survived. The higher elevations have a dryland forest composed of a mixture of native and introduced species. It is home to several threatened bird species, including the Hawaiian hawk and owl.

Several areas of the cave are exceptional for their secondary mineral deposition. These areas of HRC are not awe-inspiring in the way that portions of Lechuguilla Cave can inspire with massive formations, but rather in an understated aesthetic way that requires one to stop and get close. A person who is not paying attention to detail might go through Puffball Hall and not think anything more about it than that it is whiter than most lava caves. Closer exam-

ination has revealed numerous unusual minerals, such as gypsum beards. In addition, a portion of the cave contains a wide exposure of xenoliths in the cave wall. The cave also has significant archaeological sites. Portions of the cave were used for short-term occupation, refuge, and possibly for ritual purposes.

GEOLOGY AND GEOGRAPHY

GEOLOGY AND GEOGRAPHY POSTER ABSTRACTS

COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS

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Rota, like the other islands in the Mariana Arc in the western Pacific, was created primarily by Late Eocene to Early Oligocene volcanism. Rota is mantled by limestone, but has some outcrops of volcanic rocks. The interactions of highly permeable eogenetic limestone, low permeability volcanics, tectonically-driven uplift, and eustatic sea level changes have created an assemblage of caves on Rota distinct from the cave assemblages documented on Guam, Aguijan, Tinian and Saipan, the other islands in the Mariana Arc on which caves have been investigated. As predicted by the Carbonate Island Karst Model, Rota has a large number of flank margin caves, developed by mixing dissolution under diffuse-flow conditions at the edge of the fresh-water lens. Rota also has a significant number of mixing-zone fracture caves developed by mixing dissolution as water from the lens discharged along pre-existing fractures (*i.e.* sea level springs). Rota has a few hydrologically important contact caves. Two extensive zones of vertical fissures were also found on Rota, among them is the deepest cave on the island. Although caves have been found on Rota from sea level to within a few meters of the summit at 496 m, fewer caves have been found at higher elevations. This is probably the result of a combination of more difficult exploration at higher elevations due to thick jungle cover, and destruction of older/higher caves by dissolution and mass wasting of the hill slopes and cliffs that contain the caves.

THE SPELEOGENESIS OF LARGE FLANK MARGIN CAVES OF THE BAHAMAS

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Flank margin caves are abundant in the Bahamas, where they are believed to have developed by mixing dissolution during the last interglacial sea-level highstand, Oxygen Isotope Substage (OIS) 5e. The tight spatial and temporal controls that govern their genesis and evolution—formation in the margin of a freshwater lens, under the flank of the enclosing landmass, in approximately 12,000 years—explain for the most part their size and location, 2–7 m above modern sea level. Several large flank margin caves on Eleuthera, Long, Crooked and San Salvador islands stretch these constraints to the limit. These voids have areal footprints between 1,000 and 10,000 m², some have phreatic dissolutional ceilings that are well over 10 m in elevation, and often show evidence of reinvasion by a freshwater lens. Here we investigate whether these incongruities with the current model can be explained as effects of local geological and hydrological conditions, or if a more widespread mechanism needs to be invoked. Their large size can be explained by the intersection of small or medium-sized voids, the high phreatic ceilings can be caused by perching of the water table by relatively impermeable paleosol calcretes, and the speleothem etching could have occurred intra-OIS 5e. The alternative is formation during a pre-OIS 5e highstand, the most likely candidate being OIS 11, a prolonged period of warmth and possible very high sea level. This would address the problems, but the evidence of such a highstand is scarce and unconvincing throughout the Bahamas and the world.

GEOLOGIC AND HYDROLOGIC OBSERVATIONS FROM WANHUAYAN CAVE, HUNAN, CHINA

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Wanhuyan Cave is a world-class show cave located just outside of the city of Chenzhou in Hunan Province. Our group to Wanhuyan was sponsored by the Hoffman Environmental Research Institute, Karst Geology Institute Guilin, and Wanhuyan Cave Company to do a detailed resource inventory and resurvey of the developed section of the cave, determine the recharge area of the system, and to make in-cave geologic observations and measurements. In order to accomplish the task of delineating the recharge area, two dye traces were completed that linked Songja (6 km away) and Zhenyan caves (1 km away; both are major insurgences) to the main stream in Wanhuyan Cave. Structural geology measurements were taken in the cave that identified four joint sets and a bedding plane that strikes to the southwest and dips to the north. A sample of the bedrock was also taken to make a thin-section to identify the lithology and petrology of the Mississippian-aged carbonate, since the rock may be marble instead of limestone. Also, granite boulders greater than 1 m in diameter are located in the cave stream, indicating a source for allogenic recharge in close proximity. This is also interesting considering that the presence of numerous speleothems, and cave streams with a pH of 8, are indicative of autogenic recharge. A final interesting note is the grussy floor, weathered granite, and elevated temperatures found in Zhenyan Cave, which is located on the northern end of Wanhuyan's groundwater basin.

MULTI-TRACER APPROACH FOR EVALUATING THE TRANSPORT OF WHIRLING DISEASE TO MAMMOTH CREEK FISH HATCHERY SPRINGS, UTAH

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The Utah Division of Wildlife Resources has been concerned about the vulnerability of selected spring-fed fish hatcheries to whirling disease, caused by a microscopic parasite that infects species of trout and salmon. Whirling disease can potentially migrate along underground pathways in areas where aquifer permeability is high, such as in volcanic and karstic terrains, and where ground-water movement is rapid enough to allow passage and survival of the spores. Mammoth Creek fish hatchery in southwestern Utah tested positive for whirling disease in 2002. Because a nearby losing stream also tested positive, a study was begun to evaluate potential hydrologic connections between the stream and the hatchery springs.

Fluorescent dye-tracer studies indicate that water lost through the channel of Mammoth Creek discharges from the hatchery springs. Ground-water time of travel through the basalt aquifer was about 8 hours over a distance of 3,000 ft, and well within the two-week timeframe of viability of whirling disease spores. However, results of studies using soil bacteria and club moss (*Lycopodium*) spores as surrogate particle tracers to simulate the size (up to 100 μ m) of the parasite indicate that the potential for transport through the fractured basalt may be low. Substantial losses of particles occurred during streambed infiltration and within the aquifer. Bacteria concentrations were generally below reporting limits, and club moss spores were recovered from only a few samples. However, peak concentrations for the bacteria and club moss spores in water from the east hatchery spring coincided with peak dye recovery.

POSSIBLE SOURCE OF HYDROGEN SULFIDE GAS IN CUEVA DE VILLA LUZ, TABASCO, MEXICO

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Cueva de Villa Luz, in Tabasco, Mexico, is an active hypogenic cave system producing prodigious quantities of hydrogen sulfide (300–500 mg/L) from many of its more than twenty springs. Sporadic and rapid gas outbursts exhibit concentrations of H₂S rising from <30 ppm to >200 ppm within a few minutes. Three potential sources exist for spring water H₂S: 1) the Villahermosa petroleum basin, ~65 km to the north, 2) the El Chichon volcano (~50 km to the west), or 3) microbial sulfate reduction taking place in Cretaceous evaporite beds below the cave. Water analyses from four cave springs yield remarkably similar results, despite clear differences in oxidation/reduction potential of discharge water. A spring gas sample contained CO₂, H₂S, N₂, He, and CH₄,

minor Ar, H₂ and O₂, but no measurable CO. The N₂/He (4500) and He/Ar (0.9) of the sample indicate a mantle component. Helium isotope ratios (R/R_A = 1.8 where R_A = ³He/⁴He of air) are significantly higher than crustal values (~0.02–0.05 RA) but lower than pure magmatic gas (8 RA), suggesting that a mixture containing about 22% magmatic He is discharging into the cave. Comparison of cave water with hydrothermal fluid derived from El Chichon yields a mixture of mostly meteoric water with a hydrothermal contribution of 16%. Light sulfur isotopic values of H₂S and high sulfate content of the water suggest that much of the H₂S could be derived from microbial sulfate reduction taking place along the flow-path before water enters the cave.

CAVES AND MESOCAVERNS AS SHELTERS DURING THE END-CRETACEOUS EXTINCTION

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Writing in GSA Bulletin Volume 116 (2004), Robertson *et al.* proposed natural cavities as one of two principal mechanisms of vertebrate survival during the end-Cretaceous (K-T) extinction. Yet these investigators almost completely excluded caves and mesocaverns in their reasoning. Further, they focused their considerations on birds. Present knowledge of small Cretaceous and Paleocene mammals and of distribution of late Cretaceous karsts and potentially cavernous pseudokarsts are reviewed in the context of subsurface habitats of modern analogues and relevant genetic concepts. It is hypothesized that late Cretaceous mammals included important spelean populations likely to have survived the K-T extinction. Further study of Cretaceous/Paleocene paleokarsts and of crevice fills and breccias is proposed to test this hypothesis. Biospeleologists should be included in interdisciplinary teams studying such survivals.

GEOLOGY AND GEOGRAPHY ORAL SESSION ABSTRACTS

CHINESE KARST TERMINOLOGY

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Many things about Chinese culture are confusing to westerners (and vice versa), and their karst literature is no exception. Western descriptions of tropical karst focus on hill and depression morphology distinguishing between the steepness of hillside slopes. Tower karst has steep, cliffy slopes while cone karst has lower slope angles. Classic Chinese descriptions distinguish on the basis of the degree of separation of the adjacent hills.

Two end-members are defined in the Guilin-Yangshuo area as:

1. Fenglin (pronounced fung-lin), peak-forest karst, where isolated peaks rise from a flat plane. Isolated, near-vertical towers rise like tree trunks in a forest from the surrounding fields. These landforms appear very similar to tower karst in Western literature, but the concept behind the classification is different. Foot caves in tower bases are characteristic of fenglin karst.
2. Fengcong (pronounced fung-sung), peak-cluster karst, is formed by clustered towers with a common base. The bases of adjacent steep-sided (usually cone-shaped) hills merge to form clusters of hills. These landforms appear very similar to cone karst or cockpit karst in Western literature, but the concept behind the classification is different.

Most of the high-relief karst in the world falls into the Chinese category of fengcong karst. In contrast, 90% of the fenglin karst in the world occurs in China, and most of that is in the Guilin-Yangshuo area. The Chinese have defined numerous subcategories of these two karst types that translate as margin-type peak-forest plain karst, peak-cluster gorge karst, intervalley peak-cluster karst, and many more.

THE GEOLOGY OF NATURAL STONE BRIDGE & CAVES, POTTERSVILLE, NEW YORK

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Natural Stone Bridge & Caves is a series of hydrologically-related caves formed in highly metamorphosed, crystalline, Grenville-age marble. The caves result from the sinking and resurgence of Trout Brook. The drainage area upstream from the sink is 230 km² (90 mi²). The water is almost entirely allogenic in origin.

The caves are well adjusted to the local drainage. Presumed derangement by Pleistocene glaciation would suggest that the caves are post-glacial in age. The basin relief ratio and water chemistry seem to support this conclusion. The

caves have large cross-sections by New York standards, though they are short. The largest cave in the group has an entrance 50.5 m (166 ft) wide by 10 m (32 ft) high.

GEOLOGY OF OREGON CAVE REVISITED

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No refereed report on the geology of Oregon Cave has been published, and much misinformation is in print. My 1969 *NSS Bulletin* account of the cave contained an accurate account of its geology in terms of then-current concepts. But knowledge of western caves in marble and of the geomorphic history of such marbles has expanded vastly. Oregon Cave now is seen as a fairly small example of a dissolution cave of the Lilburn Cave type, characterized by an extraordinarily rapid dissolution rate and by development of a complex three-dimensional braided network of passages in a limited vertical range below steep feeder routes. The marble is part of a melange which may represent subduction metamorphism of a continental fringing reef or part of the process of accretion of a terrane or "string continent". This is irrelevant to speleogenesis, and discussions of the geology of the cave must be differentiated from those of the geology of its surroundings in Oregon Caves National Monument. As in many of the marble caves of the Klamath Mountains and Sierra Nevada, the cave extends to the edge of its marble body. The non-calcareous rocks exposed by such speleogenesis are not part of the cave.

SPELEOGENESIS WITHIN AN ANTICLINAL VALLEY: HELLHOLE CAVE, WEST VIRGINIA

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Hellhole is an extensive (32 km) cave system developed within Germany Valley (Pendleton County, West Virginia) on the flank of the Wills Mountain Anticline. It is the most extensive of several mapped caves in the area (others include Memorial Day Cave and Schoolhouse Cave). Hellhole is the deepest cave in the valley (158 m). The upper bounding lithology is the McGlone Limestone. The cave penetrates through the Big Valley Formation and into the New Market Limestone, a high purity unit that tends to form large rooms. Faulting and folding are prominently exposed in several passages, but did not affect passage development in a noticeable way. The entrance sinkhole opens into a large room, but the catchment for the sinkhole is limited, suggesting that the room formed the entrance by collapse. Passage orientation and strike of the bedrock are nearly identical (025°). Lower passages are generally down dip from upper (older) passages. Three hundred measurements of wall scallops show that paleowaters in the historical section flowed north and west (2.5 m³/s). Paleoflow from the southern portion of the cave flowed northward (2.3 m³/s), and flow in the northern section flowed southward (1.4 m³/s). Most passages are 50 to 100 m below the present land surface. Most of the cave appears to have formed under phreatic conditions, but the presence of thick clastic sediments in some locations attests to vadose invasion.

THE CAVES AND CONE KARST OF ABACO ISLAND, BAHAMAS

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Flank margin caves are a common feature of the Pleistocene eolianite ridges of Abaco Island, Bahamas, where they are proxies for past interglacial sea-level highstands. It has been accepted in the tectonically-stable Bahamas that the highest cave-forming sea-level highstand of the Pleistocene was the +6 m of the last interglacial, OIS5e ~125 ka. Southern Abaco, however, has an eolianite ridge with a series of apparent flank margin caves at an elevation of ~15 m, calling earlier dogma into question.

Abaco also has landforms that bear a striking resemblance to tropical cone karst, features not known from other Bahamian islands. These hills are symmetrical in shape, range in height from 6–20 m, and are formed from the erosional dissection of eolianite ridges. One slope of the hill follows the dip of the foreset beds while the other slopes are formed by truncation of the beds to form a nearly symmetrical cone. The absence of surface streams on Abaco implies that meteoric subaerial dissolution is the dominant process. One element of meteoric dissolution is pit cave formation, which causes slope failure on the periphery of the hills. The land surface is further mobilized by forest

fire-induced exfoliation of the eolianites. As eolian ridges initiate with high relief, rock loosened by fire and epikarst processes mass-wastes downslope to create the relative symmetry of the hills. Abaco is the only Bahamian Island that has both the high eolian relief and climate with a large positive water budget necessary for the observed erosion.

ANTHROPOGENIC EXHUMATION OF KARST: RESIDUAL ORE MINING IN SOUTHWEST VIRGINIA

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Recent work inventorying and classifying mine features for a GIS-compatible mineral resource database has resulted in a reappraisal of the origin and nature of mineral resource deposits in Virginia karst. The exhumed pinnacles and subsoil karren forms comprise the most significant assemblage of the normally covered karst features known in the state, and the distribution of the mines and prospects conveys much about the nature of the deposits and the evolution or succession of karst geomorphology. Some of the barite deposits are true residual ore deposits concentrated in small karst traps as the barite is freed from its carbonate host. Most of the iron and manganese deposits located in Virginia's karst are essentially replacement ores that were concentrated in the active karst belt. The karst-associated lead and zinc ores are even more interesting and result from the dissolution of carbonate rocks hosting Mississippi Valley sulfide deposits. Alteration and secondary formation of lead and zinc deposits as rinds on carbonate pinnacle surfaces were mined by open-pits and by shafts, which were sunk through cover sediments to the secondary ores mantling karst pinnacles. Miners stripped the secondary ores from the flanks of the covered bedrock pinnacles. The resulting karst is one modified by anthropogenic exhumation of normally covered karst and sinkholes formed by the collapse of karst cover into mined voids overlying ancient karst. In some cases, the mining appears to have allowed ore-clogged karst to reactivate and once again take water.

RARE CAVE MINERALS AND FEATURES OF HIBASHI CAVE, SAUDI ARABIA

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Ghar Al Hibashi is a lava tube situated in a field of vesicular basaltic lava flows located east of Makkah, Saudi Arabia. The cave has 581 m of mainly rectilinear passages containing a bed of loess up to 1.5 m deep, optically stimulated luminescence-dated at 5.8 ± 0.5 ka BP at its lowest level, as well as many bones and the desiccated scat of hyenas, wolves, foxes, bats, etc., well preserved due to a temperature of 20–21 °C and humidity of 48%. Phytoliths have been found inside plant material preserved in samples of this scat. A human skull, 425 years old, and the remains of an old wall indicate a potential for historical or archaeological studies. The loess bed is under study for testing microrobotic designs to navigate inside lava tubes on Mars.

Nineteen minerals were detected in samples collected, mostly related to the biogenic mineralization of bones and guano deposits. Three of them, pyroproite, pyrophosphite and arhemite are extremely rare organic compounds strictly related to bat guano combustion, observed until now only in a few caves in Africa. Hibashi Cave may be one of the richest mineralogical shelters of the Arabian Peninsula, and has been included in the list of the ten mineralogically most important lava caves in the world.

SECONDARY MINERALS IN VOLCANIC CAVES: DATA FROM HAWAII

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Lava tube caves contain a surprising variety of secondary minerals formed by seepage waters extracting components from the overlying rock and depositing them as crusts, crystals, and small speleothems in the underlying tube. Some 50 specimens were collected in the course of a reconnaissance of a selection of caves on Hawaii. Many of these were from caves at low elevation near the coast where the cave environment is wet and at ambient temperature. Some were from a cave at 2900 m on Mauna Loa where conditions were much drier. Minerals in hot fumarole caves in the Kilauea Caldera were observed but not sampled. Mineral identifications were made by X-ray diffraction with some assistance from a scanning electron microscope with energy dispersive X-ray detector for bulk chemistry analysis. Calcite is surprisingly common, appearing in the form of small coralloids and other crusts and

coatings. Gypsum is common as crusts and as "puffballs." Other sulfate salts such as thenardite and mirabilite were identified. Two unusual occurrences were the transition metal ions vanadium and copper. The vanadate ion was responsible for yellow-green patches on the floor of Lama Lua Cave, and copper salts formed the bright blue-green coatings on lava stalactites in the Kapuka Kanohina System.

PHYSICS-BASED MICROMETEOROLOGICAL MODELING OF IDEALIZED CAVES: PREDICTIONS AND APPLICATIONS TO CARLSBAD CAVERN, NM, USA

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Cave micrometeorological processes may contribute to the formation and subsequent enlargement of caves and control some of the details of secondary mineral deposition. For example, airflow has been suggested as a possible factor controlling occurrences of cave popcorn, and convective-cell-driven condensation hypothesized as the cause of Fe/Mn corrosion residue deposits in caves like Lechuguilla Cave, New Mexico.

We have modeled the internal fluid-thermal dynamics of geometrically idealized air-filled caves (focusing on buoyancy and natural convection due to geothermal heating) by creating two-dimensional computer models using FEMLAB multiphysics computer software. Thermal properties of limestone and air and geothermal flux were incorporated. The models couple the incompressible Navier-Stokes equations with the thermal energy convection and conduction equation using the finite element method. We have developed a variant Rayleigh number for this application.

Although the constructed models are limited in scale and have highly simplified geometries compared to real caves, they have identified important factors that may influence internal cave dynamics. Predicted phenomena include natural convection cells, insulation effects of air-filled cavities, thermal effects of speleothems, effects on airflow patterns resulting from chamber and passage aspect ratios, effects of size of entrance passage, and modifications of all of these with the presence of multiple entrances especially at different elevations.

Using Carlsbad Cavern as a test case, we have applied model predictions in an attempt to explain permanent airflow, temperature, and humidity data. These experiments show that modeling can be a powerful tool to understand the internal dynamics of caves.

QUANTITATIVE EVALUATION OF DATA QUALITY IN ELECTRONIC DATA LOGGING OF KARST FLOW SYSTEMS

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A characteristic of many karst flow systems is rapid variation in the flow and water chemistry conditions that govern system evolution and function. Recently progress has been made with the use of electronic probes and digital data loggers in understanding the details of these processes. Some parameters can be measured directly, while others can be statistically related to direct observations, and from these a variety of useful quantities can be derived. A challenge in this work, however, lies in the quantitative evaluation of data quality.

We report here our effort underway within Cave Spring Caverns, Kentucky to rigorously define the practical limits of reported precision (associated with the reproducibility of a result) and accuracy (conformity with the true value of the measured parameter) in karst water monitoring by working under essentially ideal conditions of easy access, equipment security and available electricity. After measuring flow through a tipping bucket rain gauge to develop a rating curve, water from an underground waterfall is monitored for temperature, pH, and SpC by three independent probe/data logger (Campbell CR10X) systems with two-minute resolution. This redundancy reduces the probability of data loss by equipment malfunction and allows calculation of a standard deviation to quantify measurement precision. Early

results show that data can be obtained within one standard deviation of $<0.2^{\circ}$ C for temperature, $<4 \mu\text{S}/\text{cm}$ at 25° C for specific conductance, and <0.01 unit for pH. We continue to evaluate accuracy issues, especially for pH with highly precise measurements complicated by instrument differences and carbon dioxide degassing.

GEOLOGICAL FACTORS AFFECTING THE DISTRIBUTION OF CAVE-DWELLING SPECIES AND THEIR IMPLICATIONS ON THE EVOLUTION OF KARST LANDSCAPES
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Karst and some non-karst cavernous areas provide habitat to species adapted to spending their entire lives underground. Many of these species are rare and some endangered. These areas occur across diverse biomes, climates, topographies, and geologies, and have even more complex ecological, climatic, and geological histories. These factors are usually intertwined in how they impact and sometimes dictate the distribution and evolution of cave-dwelling species. Six basic geological factors influence and determine subterranean biodiversity: lithology, structure, burial, hydrology, climate, and landscape evolution. Their overall effect is to provide potential habitat for cave-dwelling species, connectivity between populations, and restrictions and barriers to gene flow. Speciation often results when populations become isolated. Genetic isolation can be complete, a barrier to species' distribution, or partial, a restriction to their distribution. In the case of restrictions, gene flow occurs through relatively small areas and/or areas traversable only for relatively short periods of time. While geological factors can be used to predict species distribution, species distribution can also be used to reconstruct past landscapes and groundwater hydrologies. Areas with genetically identical populations suggest geologic continuity. However, the degree of difference between populations may show not only geological discontinuities, such as erosion or faulting separating areas of cavernous rock, but reflect when those discontinuities developed. Studies of aquatic fauna are particularly useful in assessing current and previous hydrological connections in karst aquifers.

STYGOBITE PHYLOGENETICS AS A TOOL FOR DETERMINING AQUIFER EVOLUTION
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The use of aquifer-dwelling organisms (stygobites) for learning about past and present subterranean hydrologic connections was evaluated in the Edwards (Balcones Fault Zone), Trinity, and Edwards-Trinity (Plateau) aquifers of Texas and adjacent areas in north Mexico, an area with complex karst groundwater flow and sociopolitical problems stemming from overuse and contamination. Using likelihood and parsimony based comparisons, *Cirolanides* (Isopoda: *Cirolanidae*) were found to have a phylogenetic history congruent with *a priori* predictions of subterranean hydrogeologic history in its terminal nodes. Branches of the phylogenetic tree originating from basal nodes had similar terminal taxa, but their placement was not as predicted by hydrogeologic history, a phenomenon that may be indicative of a lack of hydrogeologic understanding of the area. *Lirceolus* (Isopoda: Asellidae) had a phylogenetic history congruent with an alternate hypothesis, patterns of surface drainages. This difference of patterns for two species that both live in the aquifer is probably related to their evolutionary history, with *Cirolanides* having invaded the cave habitat as a single marine population and *Lirceolus* invading the cave habitat as a freshwater migrant with possible pre-existing genetic structure determined by surface drainages. This study pioneers the testing of *a priori* biogeographic hypotheses using phylogenies of aquifer organisms and the creation of hydrogeologic histories in a karst setting, and supports the use of similar methods to aid in understanding biogeography and aquifer evolution.

TRACING FLOWPATHS IN THE BALCONES FAULT ZONE SECTION OF THE EDWARDS AQUIFER IN SOUTH-CENTRAL TEXAS

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The Edwards Aquifer Authority performed a series of tracer tests in the Edwards Aquifer Recharge Zone in northern Bexar County, south-central Texas. The tests were performed as part of the Authority's Focused Flow Path

Studies to determine: ground-water flow paths, the effect of major faulting in controlling groundwater flow in the recharge zone, the relationship between recharge and discharge/monitoring sites, and to determine ground-water velocities. Tests were performed in the Panther Springs Creek ground-water basin. Panther Springs Creek, a small ephemeral stream, flows north to south across the width of the recharge zone.

Seven tracer tests were performed in the northern Bexar County area. Sixteen monitoring, irrigation, and municipal water supply wells, completed in the Edwards and underlying Trinity Aquifer, were sampled for dye. Dyes injected into both the Edwards Limestone and Upper Glen Rose Limestone moved from north to south toward the Edwards Aquifer Artesian Zone. The dyes from the tracer tests crossed as many as six major faults, some with displacements of over 30 m. Ground-water velocities ranged from 24 to more than 4,000 m/day, and tracer test distances ranged from 600 to more than 7,600 m. Tracer test data showed that groundwater from the Glen Rose Limestone (Trinity Aquifer) is flowing into the Edwards Limestone (Edwards Aquifer) where the formations have been juxtaposed by faulting. These data have important implications related to the Edwards' water budget as well as protection of water quality.

DIGITAL COMPILATION OF TENNESSEE GROUND WATER (DYE) TRACES

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It is estimated that more than 300 ground-water (dye) traces have been conducted in Tennessee, but the results are scattered throughout many reports and publications and thus, not readily assessable to State agencies that need to respond immediately to a hazardous materials spill or toxic release. Such tracing data are also needed by consulting firms working on new sites, counties experiencing sinkhole flooding problems, and cavers looking for caves. Through a grant from the TDEC-Ground Water Management Section, over 250 ground-water traces have been placed, to date, onto a digital GIS database with topographic overlays. The ground-water tracing results were gathered from personal interviews, in addition to publications.

The traces were digitized with a Summagraphics digitizing table, Arc/Info GIS, and ArcView GIS 3.3 software. Delorme 3-D Topo Quads 2.0 software was used to find the latitude and longitude for each point in decimal degrees. Attributes for each point include the following: 1) record (trace) #, 2) type of point: injection or detection, 3) topographic map of the trace, 4) geologic age and formation of the trace, 5) reference to the source of information (if published), 6) county of trace, and 7) latitude and longitude of the injection/detection points. After attributes were added, the traces were registered to real world coordinates. Digitizing and attribute errors were eliminated, and spatial accuracy was assessed. The tracing information will soon be placed onto the State's server for easy access by all potential users.

PRELIMINARY ANALYSIS OF A DYE TRACE IN THE UNSATURATED ZONE ABOVE CARLSBAD CAVERN, CARLSBAD CAVERNS NATIONAL PARK, NEW MEXICO
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In early 2001, over 94,000 L of water containing fluorescein dye (80 ppm) was poured into Bat Cave Draw, a small valley overlying Carlsbad Cavern at the edge of the Visitor Center parking lot. For four years, activated charcoal traps have been collected periodically from 23 sites throughout the cave, ranging from every two weeks to every three months. Traps placed prior to the test showed that there was some fluorescein in the system prior to the test, likely the result of antifreeze contamination from the Visitor Center and Bat Cave Draw parking lots. The data show distinct concentration spikes rather than smooth breakthrough curves. In order to differentiate the injected dye from the existing fluorescein in the system, the concentration data were treated as flow data and analyzed using stream baseflow analysis. The data show good correlation between periods of relatively intense rainfall and spikes in dye concentration, but not necessarily individual rainstorms. These analyses will help to estimate travel times and identify flowpaths for dye as an analog for contaminants from the Bat Cave Draw parking lot for contaminants from the Bat Cave Draw parking lot.

HYDROLOGIC CHARACTERIZATION OF TWO KARST RECHARGE AREAS IN BOONE COUNTY, MISSOURI

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The Bonne Femme watershed, located in central Missouri, is a rapidly urbanizing area, and this study was undertaken to characterize the hydrology of two karst aquifers within this watershed before significant increases in impervious surface occur. The objectives of this study were to: 1) delineate the recharge area for Hunters Cave (HC); 2) quantify stream discharge at the resurgence of HC and Devils Icebox (DI) caves; and 3) characterize the chemical and physical status of the cave streams. The quantity and quality of the water at the resurgence of both cave streams were monitored from April 1999 to March 2002. Both recharge areas were determined to be of similar size (33.3 km² for HC and 34.0 km² for DI) and were formed in the same geologic strata. Average annual discharge was 1,900,000 m³ at DI and 1,170,000 m³ at HC. Average monthly discharge was 97,700 m³ at HC and 158,000 m³ at DI. However, median instantaneous discharge over the three years was 18% higher at HC (74 m³/h) compared to DI (63 m³/h). Turbidity and pH showed the largest differences between sites, reflecting the greater magnitude and duration of runoff events and the higher row-cropping intensity in the DI recharge area. The HC recharge area is characterized by limited sub-surface conduit development, small conduits, short flow paths from surface to resurgence, and predominantly allogenic recharge. The DI recharge area is characterized by extensive sub-surface conduit development, large conduits, long flow paths to the resurgence, and autogenic and allogenic recharge.

GEOLOGY OF TAG CAVES

KARST HYDROGEOLOGY OF LOOKOUT MOUNTAIN, A SYNCLINAL MOUNTAIN IN THE FOLDED APPALACHIAN MOUNTAINS OF SOUTH-CENTRAL TENNESSEE

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The objective of this research is to investigate the hydrogeology of Lookout Mountain, Tennessee, funded by the National Park Service to better understand karst ground-water under its 12 km² park and the possible effect of nearby urban development on karst and groundwater quality. Major karst flow routes under Lookout Mountain have been identified, and the drainage basins for the major cave streams and springs have been delineated. If a major spill of toxic material were to occur on Lookout Mountain, as happened in 1996, the NPS must be able to track the contaminant movement. Lookout Mountain is a synclinal mountain in the folded Appalachians with the same stratigraphy as the Cumberland Plateau. Caves are mainly oriented along the strike, with vertical shafts where cave streams drop through resistant strata. Dye tracing and cave exploration and mapping were used to investigate the hydrogeology. A hydrologic inventory was conducted on and around the base of Lookout Mountain, and charcoal dye receptors were placed at all springs and streams, and at several locations inside caves. Four different dyes were simultaneously injected into karst sinks on three separate occasions. The results show that cave streams are trapped by the synclinal structure of Lookout Mountain and flow along the strike. Cave streams have a stair-step pattern as they breach perching layers and descend through the Pennington, Bangor, and Monteagle Limestones. The deepest vertical shaft, Mystery Falls (85.6 m), was formed as a cave stream dropped off the perching Hartselle Formation into the Monteagle.

GEOLOGY AND HYDROGEOLOGY OF TUMBLING ROCK CAVE, JACKSON COUNTY, ALABAMA

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Tumbling Rock Cave is a valley-wall conduit that has developed along the Cumberland Plateau Escarpment of northeast Alabama. Recent dye tracing

confirms that the cave functions as a drain for Round Cove, a closed depression at the head of Mud Creek Valley. However, only a small percentage of the injected dye was recovered, which suggests that the cave and surrounding area are hydrologically more complex than originally thought. The main stream passage in Tumbling Rock trends subparallel to and within the eastern wall of the Mud Creek Valley, which suggests that flow paths were guided by stress-relief fracturing. The cave contains multiple levels of passage development. Some of those levels are associated with the allogenic paleo and modern stream within the cave. Higher passage levels, including the Topless Dome, which reaches 120 m in height, are associated with an epikarst aquifer.

PERCHING LAYERS, VADOSE TUBES, AND EXPLORATION IN MAMMOTH CAVE, KENTUCKY

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While the Mammoth Cave area is famous for being ruled by river-controlled phreatic tube levels, many parts of the cave are heavily controlled by the path that vadose water takes from its point of entry to some far-off base level destination. A big factor affecting these pathways is the presence of perching layers, which may be chert or dolomite. Vadose water flowing on these perching layers results in the formation of vadose tubes, or vadose passages which have a surprisingly significant tube aspect to their shapes. Vadose tubes can be many thousands of feet long, and form an important backbone of the connected cave system. Many passages that are considered to be base level are well above the true regional base level, and owe their continuity to perching layers. A poster-child example of a vadose tube is Canis Minor and Canis Major in Sides Cave. These passages, which start as two branches and then merge into one, originally took water from Cooper Spring Hollow on a horizontal journey of approximately 900 m, finally dumping into a dome at its far east end. The passage later experienced up to six successive piracys, working gradually west toward its origin. Vadose tubes make us look at exploration prospects differently: (1) Upstream is as good as downstream; (2) Leads at the tops of domes are often very promising; and (3) Major passages can exist independently at each level, with little interaction between levels. The same principles apply to many caves throughout the Southeast.

AN OVERVIEW OF KARST DEVELOPMENT ALONG THE CUMBERLAND PLATEAU ESCARPMENT OF TENNESSEE, ALABAMA, AND GEORGIA

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Surface streams flowing off the sandstone caprock of the Cumberland Plateau onto the underlying carbonates tend to invade the subsurface, creating caves that take a stair-step route to resurge as springs at the escarpment's base. Surface streams usually sink upon flowing onto the Bangor Limestone. They then tend to drop down vertical shafts until they hit the Hartselle Formation, which is primarily sandstone and shale. Bangor cave streams often resurge along the Hartselle Bench about half way down the escarpment and drop as spectacular waterfalls into large sinkholes in the underlying Monteagle Limestone. The cave streams then tend to take a stair-step route down through the Monteagle and St. Louis Limestones to finally resurge in the upper Warsaw Formation near the escarpment base. Many cave streams in the Bangor breach the Hartselle Formation behind the escarpment along stress-relief fractures, thus creating the deep vertical shafts and spectacular underground waterfalls for which TAG caves are noted. In places, even relatively large rivers (such as the Caney Fork and Cane Creek) sink into the Monteagle and St. Louis Limestones, creating large caves (such as Camps Gulf Cave) and then resurge further downstream. Also, large karst valleys (such as Grassy Cove) have formed where surface streams have breached the sandstone caprock, often along structural highs, several kilometers from the edge of the escarpment. As the sandstone caprock is removed by slope retreat, it leaves behind a sinkhole plain that follows the retreating escarpment.

STRUCTURAL CONTROLS ON KARST DEVELOPMENT AND GROUNDWATER FLOW, REDSTONE ARSENAL, HUNTSVILLE, ALABAMA

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Redstone Arsenal covers 154 km² in Huntsville, Alabama and contains 424 identified springs, 1886 mapped sinkholes, a highly evolved epikarst,

solution cavities in ~70% of bedrock boreholes, and 26 mapped caves. It is situated on the south flank of the Nashville Dome where geologic structure is usually assumed to consist of gently southward-dipping beds of Mississippian-age carbonates overlying the Chattanooga Shale. Five distinct hydrogeologic regimes have been identified, and a generalized network of subsurface conduits is inferred from a structural-stratigraphic model. Recently the Army completed nearly 50 km of reflection seismic surveys, nine dye traces, and 32 deep coreholes, documenting significantly more complex structure than previously imagined, with block faulting superimposed on the regional dip. Faulting apparently played a significant role in development of shallow karst aquifers, as shown by dye tracing, and may also have facilitated deep karst development. Drilling revealed transmissive solutional voids up 6 cm thick below the Tennessee River base level in the lower Tusculum limestone and Fort Payne formations. These strata host natural hydrocarbons that are probably related to block faulting. Ground-water in deep strata is rich in Na-SO₄, grading into Na-Cl water downward toward the Chattanooga Shale. Pyrite and gypsum infilling in deep cores, H₂S and methane at depth, and the distinct water chemistries may suggest a hypogenic origin for the deep karst development. The faulting may be responsible for the juxtaposition of all of these conditions, and for the karst and caves as well.

SPELEOGENESIS IN THE CUMBERLAND PLATEAU OF NORTHEASTERN ALABAMA

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Caves are numerous along the Highland Rim Section of the Cumberland Plateau Province, but they are not exceptionally long, despite propitious lithology. The majority of caves form along the escarpment front where streams flow off the protective caprock onto limestone, to emerge close by at the escarpment foot. Such caves tend to be abandoned and destroyed as the escarpment retreats. In a few cases, caves have developed in inliers of limestone. The associated closed depressions become fragmented as they develop, although a substantial trunk conduit may persist beneath a protective caprock. The longest caves in the region tend to parallel valley sides, and there has been some debate concerning the origin of such "Cumberland" type caves. The landscape in northeastern Alabama has been disrupted by cycles of river incision and aggradation, and by epochs of delivery of excessive sediment loads from the escarpment. River incision leads to stimulation of cave development, abandonment of high level routes and development of links concordant with lowered base level. Subsequent rise in base level has caused burial of sinks and springs and obstructed deeper passages. Clastic sediments have choked sinkholes and redirected surface streams. Large alluvial fans formed in valley heads, probably several million years ago. These fans have redirected surface drainage and appear to have stimulated development of Cumberland type caves along their margins.

STABLE BASE LEVELS, VALLEY UNDERDRAINS, CATCHMENT AREAS, AND TIME: THE INTERPLAY RESPONSIBLE FOR THE MASTER TRUNK CAVES OF THE CUMBERLAND PLATEAU

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The Cumberland Plateau in central Tennessee and northern Alabama is blessed with a rich population of caves of many lengths, passage sizes and origins. The calculations described here address the large-cross-section trunk passages that form either active or paleo master drains. The coves of the Cumberland Plateau are incised into the sandstone-capped upland. High-gradient streams descend the walls of the coves, often by underground routes with much vertical development. Valley bottoms also provide the gradient for even lower-gradient master trunk development. The volume of trunks represents the tradeoff between rate of conduit development and time of stable base level. Cosmogenic isotope dating of sediment in master trunks by Anthony and Granger has provided a time scale into which cave development must be fitted. With chemical data on active drainage systems as a reference, combined with models for rates of passage development, the calculated time scale for development of master trunk drains is in the range of 10,000–50,000 years. Rapid development of master drains with low hydraulic resistance results in underdraining of valleys. Calculated development times are shorter by an order of magnitude than periods of stable base level indicated by the Anthony and Granger dates. Reconciliation of these data requires a damping effect on

cave development probably due to sediment infilling and by the development of protective barrier layers on cave walls. Evidence for the latter is provided by the observed transmission of low-pH acid mine water.

GEOLOGIC CONTROLS ON THE "DEEP" CAVES OF TAG

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TAG (Tennessee, Alabama and Georgia) is home to a significant number of vertical caves. In this region, caves that have a vertical extent of a hundred meters or more are considered deep. Approximately 1% of all TAG caves fall into this category. Many deep caves are characterized by shafts that are separated by long crawlways and short stretches of borehole before reaching base level. Other deep caves consist of multiple shaft routes to base level. Some deep caves have significant lateral as well as vertical extent that reflect major changes in base level over time. And some deep caves attain their vertical extent from epikarstic domes that have fortuitously intersected paleo-trunk passages. The morphology, lateral extent and vertical extent of deep TAG caves are a function of stratigraphic, structural, hydrologic and geomorphic controls. These controls vary across the physiographic provinces that typify the TAG region and between the two major watersheds that drain it.

HUMAN SCIENCES

THE KOWALLIS CAVE HAZARDS RATING SYSTEM

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The Kowallis Cave Hazards Rating System was designed out of an informal request of some of the local cavers and scouts. This rating system is established as a general guide to help people know before hand the degree of difficulty and hazards they may encounter as they enter each cave. It is in reference to the entire cave and not to specific areas. This system is not made to measure the ease or difficulty of a rescue. Numbers are based on how hazards compare to one another. The rating system is based on numerical values assigned to each hazard based on its seriousness and frequency of occurrence, which are based on US cave accident reports published by the NSS. Although several caves have already been rated via various equations based on cave-related data, the system is set up so that anyone can enter the caving hazards data for any cave so that the spreadsheet can produce a value that is then assigned a rating. The development of the data analytic system and spreadsheet will be discussed.

VERTICAL SKILLS CHECKLIST

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In light of recent alpine discoveries, and in order to remedy inconsistencies in vertical proficiency and assure that necessary rope skills are not overlooked among its members, the Timpanogos Grotto has developed a Vertical Skills Checklist. The list is based on a mix of European and American techniques. It was carefully designed to create the most efficient vertical training and to avoid liability through its designation as a checklist rather than a qualification guide. Creating the checklist and designing it to apply to a wide variety of vertical techniques and to be helpful to a broad sample of cavers was a challenging task that will be discussed in detail in this presentation.

CAVING PROJECTS: DEALING WITH PEOPLE YOU CAN'T STAND

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Every caving project, whether major or minor, includes a variety of personalities, some of which are more easily dealt with than others. Even simply organized caving trips may have members who make the trips less than enjoyable because of their behavior or attitudes. Dealing with difficult people slows down projects and irritates project members. However, learning how to get along with such people, or learning how to deal with others if you are one of these people, will improve the quality of interactions of caving projects. Difficult persons can be identified in several ways. Tank-confrontational, angry, pushy, and aggressive. Sniper-using rude comments, sarcasm, or eye-rolling, this person strives to make you look foolish. Grenade-after a brief period of calm, this person explodes into an unfocused tirade about unrelated material. Know-It-All-this person is seldom in doubt, with a low tolerance for

correction and contradiction. Think-They-Know-It-All-can fool enough of the people all of the time, all for the sake of getting some attention. Yes Person-these people agree to nearly anything to avoid confrontation. They overcommit until they have no time for themselves, and they become resentful. Maybe Person-in a moment of decision, this person procrastinates in the hope that a better choice will present itself. Nothing Person-no verbal feedback, no non-verbal feedback, nothing is provided. No Person-this person defeats big ideas with a single syllable. Whiner-this person feels helpless and overwhelmed by an unfair world. Offering solutions makes you bad company, so their whining escalates.

INTERNATIONAL EXPLORATION

MEXICO TECOMAN PROJECT 2005

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In 1999 Peter Ruplinger led a trip to a small community called San Gabriel near Tecoman, Mexico in the state of Colima. On that trip 15 pits were discovered and mapped.

This year we returned to follow up on Poso Cara del Tigre, a pit that left us hanging at about 100 m. Most of the caves in that area are known for their bad air, so this year we took an oxygen meter to measure levels. We found the bottom of the pit at 168 m in 16.3% oxygen. We also discovered a 30-m-deep pit that we called Poso Hermoso.

After finishing up in the San Gabriel area we moved on to Palos Maria, another small community, where the locals showed us a horizontal stream cave called Cueva Canoa; we mapped about 100 m and then pushed upstream another 200 m through waist-deep water with no end in sight. We were going to return the next day to continue surveying, but due to illness were unable.

<http://www.cancaver.ca/int/mexico/zotz/colima/tecoman98.htm>

PROYECTO ESPELEOLOGICO SIERRA OXMOLON, MEXICO

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Located west of Aquismon in the State of San Luis Potosi (Mexico) lies one of the greatest caving areas known. El Sotano de las Golondrinas was discovered by cavers in 1967 and was at that time the deepest single drop in the world. Shortly after, Hoya de las Guaguas and Sotano de Cepilla were discovered, two other world-class vertical pits. Over the years several other large pits were located, marking this area as having the best in large bird pits: green coureus, swifts, and military macaws inhabit many of these large-volume pits.

Speculation about a major system existing there brought about a recon in September 2000. On this first visit five new caves were discovered, one being a 100-m drop. The following November saw the first PESO (Proyecto Espeleologico Sierra Oxmolon) trip into La Brecha de Tanzozob and thus the project was born. Many trips have since been undertaken, growing the list of 20 known caves to over 100. One of the latest finds was in Cueva Linda, already known to be over 500 m long. A short bolt climb led to an additional kilometer of new passage and the beginning of the rumored system.

EXPLORATION OF CAVES USED BY THE MAYA, EL PETÉN, GUATEMALA

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Aguateca was a large Maya urban center located near the modern city of Sayaxche in the northern state of El Petén, occupied from 300 BC to 350 AD, and from 710 AD to 810 AD. The site is currently under investigation under the direction of Dr. Takeshi Inomata of the University of Arizona.

In 2005 three US cavers, Bev Shade (TX), Philip Rykwalder (TN) and Nick Johnson (MN), visited Aguateca to help Reiko Ishihara, a speleoaerchaeology Ph.D. candidate at University of California, Riverside, map caves at the site. Reiko is currently focused on elucidating the Maya use of the large chasms, or grietas, that dominate the Aguateca site. The grietas are deep, linear cracks in the earth that are open to the surface in places, the largest being 1.5-km long and 80-m deep. The grietas are tectonic in nature, but traditional solutional caves and karst features are located in the area.

We cavers were able to make a number of finds at the site. We found all of the caves and many karst features to be heavily littered with Maya artifacts, including fairly intact monochrome and polychrome pottery, axe heads, religious pieces and other artifacts. On the surface, we also explored a few cliff-

side karst features, in one of which a large pot 40–50 cm in diameter was found. A few bolt climbs were also done in order to see if the Maya had placed artifacts on elevated ledges within the caves.

MULTIYEAR PROJECT TO MAP AND PHOTOGRAPH CAVES FOR THE BELIZE INSTITUTE OF ARCHAEOLOGY

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In February and March of 2005, NSS cavers from the US and Canada—an informal group named XMET (Xibalba Mapping and Exploration Team)—made their sixth annual trip to survey caves in Belize under the auspices of the Belize Institute of Archaeology. The Maya made extensive use of the caves during the height of their civilization and many of the caves contain cultural material. Over the course of the project, the cavers of XMET have mapped eight km of passageway in Barton Creek Cave, have done dye tracing to find the source of the water in Barton Creek Cave, and have mapped or are in the process of mapping eight other smaller caves. Cave divers have penetrated sumps at the back of several of the caves and have extended the surveyed length more than a 1000 m.

The caves of Belize have beautiful large rooms, which XMET has photographed while surveying them. In 2005, XMET received permission to visit the Chiquibul System to photograph the second largest room in Central America, the Chiquibul Chamber in Actun Kabal.

The XMET team will return to Belize to continue the project in February, 2006.

CAVES OF DAMAS, COSTA RICA

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The Caves of Damas are located 10 mi north of the town of Quepos and 30 mi south of the town of Jaco. The caves are located on a privately owned 700-ac rainforest, wildlife, and research preserve. The current mapped caverns are 300 m in length. We have explored additional caverns; however, our expertise and equipment have limited our exploration.

The caves contain various species of bats and insects. A particular species of cockroach lives within the caverns, and viewing the full life cycle is amazing. Our group cannot explain how plants are able to grow and produce green leaves in total darkness. Various rock formations lead some to believe the Quepoa Indians were inhabitants of the caves. In addition, within the depths of the River of Damas stone carvings have been photographed. We also have discovered underwater tunnels, which open into caverns.

A National Geographic representative visited the location years ago and felt that up to 13 km of caves may exist. Nearly 20 years ago, when the government of Costa Rica threatened to nationalize the property, the previous landowners dynamited entrances to several tunnels.

A portion of the Caves of Damas tour proceeds is donated to Costa Rica Latin America Schools Supplies, Inc. (CLASS). CLASS is a Florida non-profit, 501(c)(3) corporation with programs to help students of all ages learn to read, write, and speak English in Costa Rica.

<http://www.costariclass.org>

CAVES OF LONG ISLAND, BAHAMAS

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In December of 2004 nine cavers traveled to Long Island, Bahamas to take part in a 10-day expedition led by Dr. John Mylroie of Mississippi State University. The goal of the expedition was to survey as many caves as possible to support the science mission of understanding how these caves formed. Sixteen caves were surveyed, varying in length from 10 m to just over a kilometer in length (second longest in the Bahamas). Many other caves were discovered but not surveyed due to a lack of time. The caves are flank margin caves, similar to those found on other tropical carbonate islands such as Isla de Mona in the Caribbean or Tinian in the Pacific. Typical characteristics include large rooms, plentiful formations, numerous skylights, and bell holes. While most caves are dry, one consists of a single large lake room with water over three m deep. Some pit caves, with depths up to 13 m, were examined. Cave location utilized traditional ridge-walking, but also a boat to reach offshore

cays and remote peninsulas. One cave was used to house a goat herd, and one participant ended up with a "jigger," a type of bot fly larva, in his foot; the first case reported by a caver in the Bahamas.

BOQUERONES AND BEYOND: CONTINUED EXPLORATIONS IN SANCTI SPIRITUS PROVINCE, CUBA

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The joint projects of the NSS Cuba Caves group and the Cuban Speleological society's Grupo Sama over the past four years have finally resulted in a completed map of the Boquerones system at over 9 km in length, and the project is now considered finished (until someone finds a bit more...). Last year's expedition seemed to be wrapping up and all the leads were crossed off until the last day when, as so often happens, new caves and some promising pits were found, all headed into new sectors of this complex multi-level system. This year's work yielded three independent but related caves, several dead-bottom pits and one connection from a new pit series to already mapped sectors of the main cave.

Looking to the future, we have begun exploration and survey of areas along the North coast including some very unusual and extensive flank margin caves in the Lomas de Punta Judas and at Caguanes. Camping in the caves of Punta Judas has proven to be a comfortable base for mapping, and the Loma has yielded almost a kilometer per day in often huge passages. The future in this area is very exciting as the cave density is very high, and the caves seem to be very different types of systems than those seen elsewhere. Other regions in Cuba have been scouted for additional new projects in conjunction with local cavers and clubs. There seems to be endless potential, but considerable effort is still needed to obtain needed permissions from both the US and Cuban governments.

THE LAVA TUBES OF HARRAT KISHB, SAUDI ARABIA

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The first speleological study of lava tubes in Saudi Arabia began in November of 2001 in Harrat Kishb, a lava field located 300 km northeast of Jeddah. The expedition had two goals. One was to investigate a series of collapse holes, visible in airphotos, extending from an extinct volcano named Jebel Hil and suggesting the presence of a lava tube at least three kilometers long. The second goal was to try locating several shorter lava tubes seen in this area by a hunter. A hair-raising climb up Jebel Hil revealed an opening in the side of the crater, presumed to be the upper end of the long lava tube. A ground reconnaissance then gave the coordinates of most of the collapses and indicated the floor of the tube was from 26 to 42 m below the surface.

The shorter lava tubes were found with the help of Bedouins living at the edge of the lava field. One of the tubes, Kahf Al Mut'eb, was surveyed to a length of 165.8 m and was found to contain lava levees, stalactites, animal bones and a plant-fiber rope that may be 8,000 years old. In Ghostly Cave, tall stalagmites of rock-dove guano were found, as well as two L-shaped throwing sticks, thought to be Neolithic.

Saudi Arabia has 89,000 km² of lava fields, suggesting that many more caves will be found in the future.

CAVING IN THE PERUVIAN ANDES: 2004 EXPEDITION

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In 1996, a new high elevation pit area in Peru was discovered. Since then, nearly annual expeditions into the area have occurred. This karst, averaging about 14,000 ft in elevation, proved to have an incredible concentration of deep pits. Of the 23 known limestone open-air pits over 100 m in depth in South America, 18 are in this area. Three of these pits are over 150 m in depth. In July of 2004, Steve led another expedition into this area to reconnoiter further out into the wilderness and examine the potential for caves. A new base camp was established and the group made a number of new cave discoveries, including a multi-drop cave that was pushed to a constriction at -300 m. The caves in this new area were unlike most of the pits previously discovered in that a number of them contained both airflow and water. The group theorizes that the caves feed into a larger main-drain system, and future expeditions are being planned.

2005 SINO-AMERICAN EXPEDITION TO HUNAN PROVINCE, PEOPLES REPUBLIC OF CHINA

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In Spring of 2005, U.S. cavers sponsored by the Hoffman Institute of Western Kentucky University, and cavers and researchers from the Karst Geology Institute of Guilin, worked together in continuing the exploration and survey of Wanhuayan Cave (Cave of 10,000 Flowers), in Hunan Province. The main objective of the expedition was to pursue a waterfall lead, which was originally discovered and documented during a Cave Research Foundation trip in 1988. This lead, which is at the end of a 4 km long side passage, contributes 70% of the water flow in the cave. Dye tracing from other cave entrances in the area showed that the Wanhuayan Cave System is much more extensive than previously expected. Besides exploring and mapping cave leads and doing quite a bit of resurvey and fieldwork, the American team had to deal with the perils of Chinese banqueting and relentless gambe.

CAVING IN MIDDLE EARTH: A PHOTOGRAPHIC SAFARI TO THE CAVES OF NEW ZEALAND

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A group of 12 cavers from the USA were hosted by four New Zealand cavers for three weeks of caving on the South Island of New Zealand. Rather than exploration, our primary goals were to provide our hosts with professionally made photos of their caves and learn about their caves and caving approaches.

Most of the caves on the South Island are in the northwest corner, and roughly divided into three karst regions. The west coast has numerous long, dendritic stream caves, including the 20-km-long Honeycomb Hill, noted for bone deposits of the extinct Moa bird, and Metro. Although on Department of Conservation land, both are used extensively by cave-for-pay concessions, with some significant impact to the caves. The Mount Owen and Mt. Arthur regions have alpine karst housing the longest (Bulmer, 50+ km) and deepest (Nettlebed) systems, as well as the major Czech discovery, Bohemia. The latter contains an immense chamber and an unusually diverse collection of helictites. Takaka Hill, the third region, is intermediate in elevation and contains two large vertical systems, Greenlink-Middle Earth and Harwood's Hole. The latter affords a remarkable vertical through-trip starting with a 186-m rappel.

CAVES OF PANAMA

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Panama, not known as a cave-rich country, does have limestone and caves. A broad-scale approach was taken to try to find caves in many different regions of Panama, instead of focusing on any particular area. About 60 caves were located and surveyed, totaling six km of passage. The longest cave was Ol' Bank Underground at 1.1 km, until the recent British expedition pushed Nibida past 1.4 km. Panama has many karst areas, and at least one zone includes roughly 2,000 km² of karst that has not been explored by any speleologist.

PALEONTOLOGY

HAMILTON CAVE, WEST VIRGINIA PALEONTOLOGY UPDATE

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Continued excavations in Hamilton cave have produced additional fossil vertebrates. Several more parts of the *Miracinonyx inexpectatus* skeleton recovered in the 1980s have been found including parts of the left mandible and a nearly complete right ulna. The ulna is especially important as only the distal end of the left side had been recovered previously. An incisor and several phalanges of *Smilodon cf. S. fatalis* have been found, presumably belonging to a cluster of bones and teeth recovered mostly in the 1980s. In addition, fine screening has produced additional microvertebrates, including the rodents *Mimomys virginianus* and *Phenacomys brachyodus* and the bat *Tadarida* sp.

PLEISTOCENE BEAVER TOOTH IS NEW RECORD FOR WEST VIRGINIA

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An upper cheek tooth of a small beaver has been recovered from Pleistocene age deposits from Hamilton Cave, Pendleton County, West Virginia. The tooth appears to represent the extinct genus *Dipoides* which is best known from the Pliocene. The Hamilton Cave deposit from which the tooth was recovered dates to the Middle Irvingtonian Land Mammal Age, about 850,000 years before present. An apparently similar tooth has been noted from Cumberland Cave, Allegheny County, MD, which is believed to be slightly younger than the Irvingtonian deposits in Hamilton Cave. The living beaver, *Castor canadensis*, is also present in the Hamilton Cave Fauna.

NEW RECORDS OF MAMMUT AMERICANUM (MASTODON) FROM MONROE COUNTY, WEST VIRGINIA

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During several expeditions to Scott Hollow in Monroe County, WV, cavers have recovered seven teeth of the extinct, Pleistocene age, mastodon *Mammuth americanum* as well as other postcranial bones. At least three individuals are represented. This is the largest number of teeth ever recovered from a single locality in the state and brings the total number of known mastodon occurrences to 19. All of the teeth except one are well preserved. Molds and casts have been made of the teeth and deposited in the U.S. Museum of Natural History (Smithsonian) and Carnegie Museum of Natural History. The original teeth are on loan from the owner and on exhibit at the West Virginia Geological Survey Museum. One complete tooth minus roots and one fragment of a humerus were submitted for radiocarbon dating. Both samples were from different parts and levels of a large cave system and are thus not from the same individual. The ^{14}C dates are $11,350 \pm 360$ years BP for the tooth and $21,830 \pm 660$ years BP for the humerus fragment. These are the first ^{14}C dates for mastodon in West Virginia and were made possible through a grant provided by The Robertson Association (TRA).

AN UPDATE ON VERTEBRATE FOSSIL RESEARCH IN CAVES OF SOUTHEAST ALASKA

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Fossil research in Southeast Alaska has expanded geographically from Prince of Wales Island to other islands and the mainland. In 2002 Enigma Cave and Kit-n-Kaboodle Cave on Dall Island were excavated, with many bear, seal, and bird remains recovered. In 2003 human remains and many artifacts, along with fish, birds, and mammals, were found in Lawyers Cave on the Alaska mainland near Wrangell. Colander, Deer Bone, and Otter Den caves were excavated on Coronation Island. No bones were found exceeding 12,000 years old in any of these caves, but the post-glacial record was well-represented. In 2004 we returned to On Your Knees Cave, Prince of Wales Island, where an excellent record of the Last Glacial Maximum and Middle Wisconsin Interstadial was previously excavated from 1996 to 2000. Deep excavation in the Seal Passage of that cave revealed a large collection of bird, bear, rodent, and other fossils. Dense layers of broken speleothems were also found, and these can be dated to add information to the cave's chronology. The search will continue on other islands to find sites with a fossil record like On Your Knees Cave, especially the islands of the outer coast (Coronation and Dall islands) because they were further from the center of major glaciers.

SOME REMARKABLE NEW PALEONTOLOGICAL FINDS FROM TENNESSEE CAVES

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Tennessee is extremely rich in caves, and where these subterranean shelters occur there is usually evidence of past life, otherwise known as fossils. Two recent discoveries from the state are discussed here. The first is a collection of bones and teeth, (recently donated to the East Tennessee Museum of Natural History) that originated from Guy Wilson Cave, a well known late Pleistocene site in Sullivan County. This material was collected in the early 1970s and had remained in private hands ever since. While this new sample contains many of the extinct species already reported from the cave, like Jefferson's ground sloth (*Megalonyx jeffersonii*), dire wolf (*Canis dirus*), tapir (*Tapirus* sp.), and a large collection of flat-headed peccary (*Platygonus com-*

pressus), it also includes unreported extinct mammals, such as the long-nosed peccary (*Mylohyus nasutus*) and horse (*Equus* sp.). Although this donation spawned interest in doing systematic excavations, the cave is not currently accessible. The second discovery was recorded by cavers a number of years ago, but was not assessed by paleontologists until recently. The cave is in north-central Tennessee and houses some of the most extensive peccary and bear trackways known. In addition, bear claw marks are found throughout the cave, and one location, which also has some black bear (*Ursus americanus*) skeletal remains, appears to have been a denning area. Because of these sensitive and irreplaceable paleontological resources, this cave is in serious need of protection and management.

AN ENIGMATIC TOOTH FROM A PLEISTOCENE DEPOSIT IN GEORGIA—IS IT HUMAN?

Joel M. Sneed, NSS 10137LF

A Pleistocene deposit in a Bartow County cave has yielded over 150 taxa, including fauna both extinct and extirpated, an intermingled fauna with more western affinities, more northern affinities and more southern affinities than those found in the area today. Radiocarbon dates on elements from this deposit include one of $12,470 \pm 50$ years BP from the antler of a deer, *Odocoileus virginianus*, and another of $12,790 \pm 50$ years BP from bone collagen of an extinct peccary, *Mylohyus nasutus*. One tooth recovered from the deposit has eluded identification, despite being examined by several specialists. This tooth, a well-worn molar, was initially identified as being human, commanding the attention of many due to the age of the deposit and its association with extinct fauna. The tooth has been subjected to several tests of its macrostructure and microstructure, including scanning electron microscopy, x-ray, and photomicrography. None of the tests to date has yielded a definitive answer as to whether the tooth is from an animal or human. Interestingly, physical anthropologists that have seen the tooth feel that it must be animal, and zooarchaeologists insist that the tooth matches no animal, living or extinct.

THE GRAY FOSSIL SITE: A LATE MIOCENE SINKHOLE DEPOSIT IN THE SOUTHERN APPALACHIANS

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Because limestones and dolomites are highly soluble and erode away over relatively short periods of geologic time, most fossil-bearing karst deposits in North America are Pleistocene in age. However, the Gray Fossil Site, a recently discovered fossiliferous sinkhole deposit in Washington County, Tennessee, dates to the late Miocene (between 4.5–7 million years old). This age is based on the known temporal and stratigraphic occurrence of the rhino *Teleoceras* and the short-faced bear *Plionarctos* at other localities. Geologic interpretation of the site indicates that a sinkhole acted as a natural trap and/or watering hole that attracted, then possibly trapped, terrestrial vertebrates. The limestone walls of the sinkhole have long since weathered to a loose residuum, leaving behind the more resistant fossil-rich sediments as a topographic high. Core samples show that these sediments cover roughly 4–5 acres and are up to 35–45 meters thick. The highly-laminated, organic-laden, silty sediments are rich in both plant and animal remains. Excavation and surface collection have yielded vertebrate remains such as shovel-tusked "elephant," rhinoceros, tapir, peccary, camel, saber-toothed cat, a new species of badger, a small fox-sized canid, short-faced bear, a new species of red panda, rodent, shrew, alligator, snake, turtle, frog, salamander, and fish. In addition, the site is rich in plant macrofossils and invertebrates such as gastropods, bivalves and ostracodes. Due to a lack of similar-aged deposits in this region, this site offers a unique opportunity to study the paleoecology of southern Appalachia at that time.

SPELEAN HISTORY

CHARLES A. MUEHLBRONNER & JOHN NELSON: HEROES OF MAMMOTH CAVE'S "ECHO RIVER CLUB"

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In January, 1904, the annual convention of the League of Commission Merchants was held in Louisville, Kentucky. As part of their activities, a trip

was organized to visit Mammoth Cave. During the Echo River tour inside the cave, seventeen passengers on guide John Nelson's boat were dumped into the icy water due to the horseplay of one of the men. Only the quick thinking and heroic action of Nelson and Charles A. Muehlbronner, former Pennsylvania state senator from Pittsburgh, saved the group from drowning. Back at the Mammoth Cave Hotel, the grateful passengers formed the Echo River Club with membership limited to those people on the trip. Muehlbronner was elected as President for life. The group held annual reunions in different cities for several years.

ON WHITE FISH AND BLACK MEN: DID STEPHEN BISHOP REALLY DISCOVER THE BLIND CAVE FISH OF MAMMOTH CAVE?

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Some of the chronology of discoveries at Mammoth Cave, KY., is marred by contradictory reports and legends. The first published reference to a blind cave fish ("white fish") in Mammoth Cave appears to be by Robert Davidson in 1840; however, the chronology given in his book is contradictory. We did archival and field research aimed at identifying the first person to have seen (and probably collected) this blind cave fishes at Mammoth Cave. We also researched all the known specimens of the two species of blind cave fish ever found at Mammoth Cave to see if that information could provide evidence of which of the two species was seen first. We conclude that: (1) Davidson's chronology in his book is probably wrong and that he did not visit the cave until 1838 or 1839; (2) it is possible that Bishop was the first person sighting the fish, but others cannot be definitely excluded from having been involved in this discovery; and, (3) that although there are two species of blind cave fish that inhabit the waters of Mammoth Cave, the first one sighted was likely *Amblyopsis spelaea*, also the first one to be recognized in the scientific literature. We finally conclude that the facts surrounding Stephen Bishop's fame need to be further investigated under the perspective of the romantic movement of the mid-nineteenth century that gave rise to the noble savage mythology as well as on the perspective of race in the United States prior to the Civil War.

DIAMOND CAVERNS: JEWEL OF KENTUCKY'S UNDERGROUND

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Salt peter was being mined in Short Cave and Long Cave on the west side of a karst valley near Three Forks, Kentucky during the War of 1812. Beneath this valley was a beautiful cave discovered when landowner Jessie Coats' slave was lowered down a 35 foot pit on July 14, 1859. He saw sparkling calcite that resembled diamonds.

The Kennedy Bridal Party was the first to enter the new show cave a month later. Joseph Rogers Underwood, a renowned Bowling Green lawyer, senator, and managing trustee of the Mammoth Cave Estate, bought Diamond Cave and 156 acres from Jesse Coats. A close relationship existed between Mammoth Cave and Diamond Cave with cave literature describing both caves. Mammoth Cave Railroad opened in 1886 with Diamond a stop.

Amos Fudge of Toledo, Ohio, and his son-in-law, Presbyterian minister Elwood A. Rowsey, purchased Diamond in 1924. The fledgling National Speleological Society organized an expedition to Diamond in October, 1942. Dr. Rowsey and his son, Elwood, and Rowsey's niece, Jan Alexander McDaniel and her husband, Vernon, ran the cave and campground adjacent to Mammoth Cave National Park until 1982. NSS cavers Gary and Susan Berdeaux, Larry and Mayo McCarty, Roger and Carol McClure, Stanley and Kay Sides, and Gordon and Judy Smith purchased the cave on July 7, 1999 to promote the cave as a historic attraction and develop a national show cave museum. Virgin passages have since been discovered and a new cave found on the property.

THE REDISCOVERY OF LE SUEUR'S SALTPETER CAVES IN MINNESOTA

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A 300-year-old mystery in spelean history may recently have been solved. In September 1700, the French fur-trader Pierre-Charles Le Sueur reported

salt peter caves along the shores of Lake Pepin, a widening of the Mississippi River, in what is now Minnesota. This is the earliest record of cave salt peter in the United States. Although these caves have been a topic of discussion at major salt peter symposia, no one has actually searched for them, to the best of our knowledge. In 2004, small, narrow, crevice caves were identified in Ordovician-age Oneota dolomite outcrops along the river bluffs in Goodhue County, Minnesota. The caves match Le Sueur's description as well as could be expected given several centuries of slope-wasting processes. While Le Sueur's journal suggests that he found actual salt peter, rather than petre dirt, no efflorescent salts were seen in the caves. But analyses of floor sediments from these caves and others along the bluffs on both sides of the Mississippi River reveal nitrate concentrations up to over one weight percent-comparable to those of Mammoth Cave.

HISTORY OF EARLY OWNERSHIP AND PASSAGE NAMING IN GRAND CAVERNS, VIRGINIA

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Grand Caverns, in Virginia's Shenandoah Valley, was known as Amonds Cave when it was discovered by Bernet Weyer on Mathias Amond's property in 1804. The cave was commercialized in 1806 and has been operating ever since under a variety of names, including Weyers Cave and Grottoes of the Shenandoah. The cave was modified for trail improvements over the years, but most of the current commercial trail was in place by 1808. The cave's formations and rooms have had a variety of names over the years. Early names were based on parts of a house (the Ballroom and Balcony) and some features were named for political figures (Washington and Jefferson Halls) or religious figures (Solomon's Hall). The names of the features have varied over time, based on the cave owner's whim and, perhaps, political correctness.

STATE CAVE SURVEYS OF THE US

ALABAMA CAVE SURVEY

Jim Hall

The Alabama Cave Survey was started in the 1930s by State Geologist Dr. Walter B Jones. Cavers took charge in the 1970s and our first publication was in 1979. We currently have over 4100 caves on our survey, with maps for about half. In 2003 we started putting maps only on CD-ROM in Adobe Acrobat (PDF) format to reduce use of paper, because our survey book had become over 1000 pages long. The original cave data are still only available on paper copies. The CD-ROM contains only cave maps, cave ID numbers and cave names. The survey has about 50 to 100 members on an average year. Membership is currently \$10, which covers publication costs. The only membership requirement is to be a NSS member for at least two years. To be included in the survey database, a cave must be over 50 ft deep or 50 ft long; have documented biological species; or extends into total darkness. All submitted data are sent to the cave files director. Our web page has report forms and a data key that can be downloaded (www.alacaves.org). Landowner relations are handled by local grottos. Cave locations are specified by either Township and Range or Latitude/Longitude. We accept all cave surveys sent in that have good locations and a description (for instance length, depth, and number of drops).

OVERVIEW OF THE GEORGIA SPELEOLOGICAL SURVEY

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The Georgia Speleological Survey (GSS) is a National Speleological Society (NSS)-affiliated state cave survey with the goal of exploration, documentation, and conservation of Georgia caves. The GSS was founded in 1966 and was active until the mid-1970s, then reformed in the early 1980s. The GSS has documented around 570 caves so far, including 16 caves over a mile long and four deep caves (> 300 feet of vertical extent). About 70% of Georgia caves have at least one map on file. The GSS averages about 80 members and has a very open membership policy, with the requirement that you must be an NSS member to receive the GSS Cave Data Listing. The GSS is very active, hosting ridgewalks and running a project to resurvey Frick's Cave in Walker County, Georgia—in which inexperienced surveyors are encouraged to participate and learn how to survey. The *GSS Bulletin*, which is published annually, contains articles and maps from recent exploration and survey, along with his-

torical accounts of Georgia caves. The GSS Mapbook is now being distributed in an electronic medium that includes a nice Web-browser-based interface for accessing maps and metadata. The GSS also maintains extensive paper and electronic archives containing articles, references, maps, and photos.

THE CAVES OF MISSISSIPPI

Adam Walker, Chris Moore, John Mylroie, Lindsay Walker, Mississippi State University, Department of Geosciences

The survey of Mississippi caves is part of the National Karst Map, funded by the National Cave and Karst Research Institute and the National Park Service. The goal of the project is to create a database of fully surveyed caves as well as a GIS-based digital map of the state. There are a total of 47 known caves in Mississippi, 40 of which are limestone caves. To date, 21 caves in Mississippi have been mapped to modern standards. Most of the state's caves are located in three limestone formations: the Mariana Limestone of the Vicksburg group, running east to west across mid-state; the Ripley Limestone of the Wilcox Group, cutting diagonally across the state from north to south-east; and the Mississippian-Devonian limestone of the Fort Payne Group, occupying the northeast corner of the state. Pseudokarst caves are found in sandstone and quartzitic beds, as well as in loess deposits. Mississippi is not well known for its caves, even to its residents. The most recent publication regarding Mississippi caves, *Caves of Mississippi* (Knight *et al.*, 1974), is 31 years old. In this time, the knowledge of many of Mississippi's caves has become lost or forgotten. No caving organizations currently exist in Mississippi to preserve cave location data or the caves themselves. Deforestation, mining and other land use practices have altered the landscape, resulting in the concealment of some caves, and complete or partial destruction of others. The cave inventory of Mississippi is being accomplished from scratch without an established caver infrastructure.

FLORIDA CAVE SURVEY

Jason Richards

In the last year the Florida Cave Survey has made a paradigm shift from secretive political infighting to an organized, frequently used print and electronic database with more than nine hundred and fifty caves and more than two thousand lines of related data. Almost all of the large data holding organizations have been included in the database from as far back as the mid 1960s. Borrowing from database examples such as the TCS and GSS, the FCS electronic database is indexable by almost every entry field, while retaining a simple and common spreadsheet format, similar in use and appearance to those produced by other southern state cave surveys. The FCS now is in the process of updating our print map book, with more than five hundred maps, to a digital format which can be easily updated and disseminated to cavers across the state. As the organization matures, we hope to continue our mapping efforts across the state, providing a permanent and long-lasting cave record for Florida's caver communities.

OPERATIONAL OVERVIEW OF THE TENNESSEE CAVE SURVEY

Jack Thomison, TCS East Tennessee Co-Chairman

The Tennessee Cave Survey (TCS) is governed by a nine-member Executive Committee including West and East Tennessee Co-Chairmen. Applicants must be cavers recommended by two regular members and approved by two of the Executive Committee. Dues are currently \$6.00/year.

Information about caves is collected using a report form with specified data fields, a narrative description of the cave and its location, and a marked copy of the applicable topographic map. All data is kept both as a hard copy and an electronic file. Cave maps are currently only maintained as hard copy.

The cave database and a county narrative file are published for all Tennessee caves. A map book is produced in an 8 1/2" x 11" format. These publications are available to TCS members at printed cost. A newsletter is published at irregular intervals and is free to TCS members.

The data are not to be distributed to anyone else without permission from the Co-Chairmen or the Executive Committee. No electronic copies are released. For special purposes, limited information may be provided to outsiders for research or to limit damage to caves.

The West Tennessee Co-chairman maintains the data, checks and corrects the report forms, and updates the information in the database and narrative files. The Map Book Director keeps the map files and maintains the map books. The East Tennessee Co-chairman keeps an off-site copy of all electronic files.

AN INTRODUCTION TO THE TEXAS SPELEOLOGICAL SURVEY

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The Texas Speleological Survey (TSS) is a nonprofit corporation dedicated to the management of Texas cave data in support of research, exploration, education, and conservation. It was founded in 1961, and formalized itself with a now 12-member Board of Directors in 1994 and nonprofit status in 1995. The TSS office is housed at The University of Texas at Austin, through the support of the university's Texas Memorial Museum. TSS has produced or co-produced 40 publications on Texas caving regions, plus Kentucky and New Mexico. Currently (April 2005), 8,884 records are in the digital database, of which 3,806 are caves, 2,687 are karst springs, 233 are rockshelters, and 1,282 are sinkholes and other karst features. Hundreds of additional paper files of caves and karst features are being recorded digitally. Access to the data is available through casual requests, where non-sensitive or small amounts of sensitive data are requested (a simple procedure most commonly used by cavers) and formal requests, where large amounts of sensitive data are requested or greater assurance for responsible use is needed (a written request used mostly by consultants). Each method includes procedures to assure, as much as possible, the proper use of the data, protection of cave and karst resources, and the return of new data to TSS.

TSS strives to support Texas cavers and caving projects, while generating more information for its database, through its publications, a regular column in the Texas Speleological Association's newsletter, data-cataloguing sessions, technical workshops, and an active Internet web site: www.txspeleologicalsurvey.org.

VIRGINIA SPELEOLOGICAL SURVEY

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The Virginia Cave Survey became the Virginia Speleological Survey (VSS) in 1974 after the publication *Descriptions of Virginia Caves* (probably the last state-wide publication of cave locations and descriptions). Since then the survey has continued to prosper. Its primary mission has been to gather and archive Virginia cave information, disseminating data when appropriate. Conservation has always been an intrinsic part of the survey.

The VSS's organization has no regular members, but its Board is comprised of both Regional Directors who represent a county or drainage basin and At Large Directors. The in-flow of information comes through directors, county surveys, individuals, publications, and the VSS website. The VSS has contracts/agreements to share information with several governmental and private entities as well as working relationships with others.

VSS data is maintained both in a relational computer database and in hard files. The database has components that contain information about cave owners, maps, reporters, significant caves, closed caves, histories of exploration, karst springs, karst features, cave entrances as well as the main data file. As of April 2005, there are 4260 caves recorded, of which 366 are designated significant. Records of 1624 springs have been established and search of tax records provided 1884 addresses of cave owners.

A quarterly newsletter, The Virginia Cellars, provides cave descriptions, scientific/historical articles, maps and other cave information to subscribers. Cave locations are not published. A new endeavor called the Cave Observation Program is being developed to further document cave features and the various phenomena seen in caves.

SURVEY AND CARTOGRAPHY SESSION

USING GIS TO CREATE THE MAMMOTH CAVE ATLAS

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In the spring of 2005, over 50 years of Cave Research Foundation (CRF) exploration efforts in the Mammoth Cave area were assembled in a Geographic Information System (GIS). Among other tasks, one result of this goal was the initial prototyping and production of The Mammoth Cave Atlas. Maps from different data sources including, pencil on mylar, ink on mylar, Adobe Illustrator, and CAD formats have been combined into one dataset to visualize the world's longest known cave system.

Work continues on this CRF project, but preliminary results indicate that GIS provides an excellent software platform for producing color sheets of var-

ious maps, scales, and themes. A base of maps depicting known cave passage is being assembled as 11x17 sheets in to the +200 page The Mammoth Cave Atlas.

U.S. EXPLORATION

HISTORY OF THE EXPLORATION AND MAPPING OF HELLHOLE, PENDLETON COUNTY, WEST VIRGINIA

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Hellhole is located in Germany Valley, Pendleton County, West Virginia. Hellhole and the NSS have had a long and storied association, dating back to the inception of the NSS. Many of the techniques we now know as Single Rope Technique (SRT) were developed in Hellhole's 154-ft entrance drop and nearby Schoolhouse Cave. As well as being historically significant to the caving community, Hellhole is a hibernaculum site for two endangered species of bats: the Indiana Myotis and over 25% of the world's population of the Virginia Big-Eared.

With the exception of the United States Fish and Wildlife Service (USFWS) sponsored bi-annual bat counts, Hellhole has essentially been closed to the caving community since 1988. In 2002, after prolonged negotiations with Greer Industries (owner and operator of an adjacent limestone quarry), the USFWS, the West Virginia Department of Natural Resources (DNR), the West Virginia Department of Environmental Protection (DEP) and local landowners, the Germany Valley Karst Survey (GVKS) was contracted to survey the extent of the cave. In accordance with USFWS requirements regarding endangered bats, all survey activities must be completed in a 16-week window during the summer months. In three years (44 short weekends) of epic caving, the GVKS has surveyed over 12 mi of virgin passage, increased the length of the cave from 8.5 mi (13,679 m) to 20.3 mi (32,669 m), and revealed the deepest drop in West Virginia of 265 ft (81 m).

EXPLORATION AND SURVEY IN GRAND CAVERNS—AUGUSTA COUNTY, VIRGINIA

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At management's request, the Virginia Region of the NSS is re-surveying Grand Caverns, a commercial cave located in the central Shenandoah Valley of Virginia. The cave is developed in Cambrian limestone/dolomite, and is known for its abundance of shield formations. With completion of the re-survey in the commercial cave (2650.7 m), a 20-cm high passage was pushed, leading to 3023.0 m (current) of unexplored cave. This newly discovered portion of cave is highly decorated with many forms of speleothems, including shields. As in the commercial portion, the northeast two thirds of the new passage is formed along NE-SW-oriented nearly vertical bedding. In the southwest third of the new passage, the bedding moves towards horizontal. The northern portion of the new passage is terminated by the hillside, while the southern portion is terminated by an inferred fault first described by Kass Kastning. The bedding-plane-oriented passages of the north are fairly dry with abundant brilliant white formations, earning it the name New Mexico. The more horizontal bedding in the southern portion of the new cave has led to the creation of a series of large rooms with massive breakdown. The largest of these rooms, Kentucky, is over a hundred meters long by forty meters wide. The highest and lowest points in the cave are found in the new passage. The total relief is 35.5 m. Exploration continues along the fault.

GAP CAVE EXPLORATION BY CAVE RESEARCH FOUNDATION CUMBERLAND GAP

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The Cave Research Foundation Cumberland Gap Project continues a multidisciplinary study at Cumberland Gap National Historical Park (CUGA) in Kentucky, Virginia, and Tennessee. Since 2003 CRF has been mapping Gap Cave. Thirty-five percent of the known cave has been surveyed. Mapped length exceeds 6 miles with 478 ft depth. 1.6 mi of virgin passage has been mapped. Project partner Lincoln Memorial University has improved the Cumberland Mountain Research Center (CMRC). Cave inventory forms, procedures, and training have been developed. All project participants now complete low-impact training and enter a contract to implement it in-cave. The CMRC Powell River Aquatic Research Station has been completed 14 mi south of Cumberland Mountain on the Powell River. Cumberland Mountain presents the 53-m-long edge of an uplifted fault sheet with an exposed lime-

stone member 560 ft thick. The Powell River Valley, encompassing 950 mi² in Virginia and Tennessee, is primarily a karst plain of diverse carbonate structure. The potential for productive cave exploration and research remains high.

RECENT EXPLORATION AT JEWEL CAVE

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In an extensive cave system like Jewel Cave, exploration has evolved into dual purposes: to map as much of the far extents of the cave as possible (pushing the edge), and to map the rest of the passages to a practical level of completeness (mop-up). Both are necessary for increasing knowledge of the entire cave and for protection of cave resources; both known and unknown.

The park's exploration program continues to make use of technology, including a ruggedized laptop at camp, laser distance meters, digital cameras for cave feature inventory, and a joined multi-table database for recording trip reports and relevant statistics. We are also beginning to use inexpensive PDAs for data collection.

Attempts to push past a linear geologic obstruction have not yet been successful. However, geologic mapping has shown that there is no visible offset on the surface, so the lineament may be a fold axis. This is a less severe obstruction than a fault; as it was previously believed to be; and barometric airflow indicates that there is much cave beyond.

NEW DISCOVERIES IN LILBURN CAVE, CALIFORNIA

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Lilburn Cave is formed in a banded marble unit of the Sierra Nevada Mountains in central California. Several new discoveries in the past few years have pushed the length of the cave length to over 20.6 mi. The new areas carry such prosaic names as Southern Comfort, Canyonlands, the Area of Low Hanging Fruit, and the Paris Opera House. Typical passages are narrow, muddy canyons with many intersections, forming complex three-dimensional mazes. The new areas also include some rooms that are relatively large for a California cave. Of particular interest is the discovery of a missing section of Redwood Creek, the stream that is responsible for much of the passage formation in Lilburn Cave. The largest area was reached by an aid climb, while others involved pushing tight crawls through breakdown. Other new discoveries include large deposits of malachite.

RECENT DISCOVERIES IN THE CHESTNUT RIDGE CAVE SYSTEM, BATH CO., VA

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On August 9, 2003 a digging effort by Butler Cave Conservation Society members spanning 12 years on a lead called the Air Blower was rewarded by a significant extension of the cave. To date 3.48 mi (5.6 km.) of passage has been surveyed with a vertical extent of 437 ft. (133 m.) The Boondocks Section of the cave spans lower levels which flood to depths of 90 ft. (27 m.) to large upper paleo levels adorned with exotic world class anthodites. The lower level also contains a stream carrying nearly all of the flow of Cathedral Spring which drains this portion of the system. This is the first time the main flow has been encountered in the cave although many tributaries have been seen. The surveyed length of the system now stands at 17.49 mi. (28.2 km.). Presently explorers are within a few feet of connecting to Burns' Chestnut Ridge Cave which will add another 2.39 miles (3.8 km.) to the Chestnut Ridge Cave System; however, the connection may be challenging.

LECHUGUILLA CAVE: RECENT EXPLORATION HIGHLIGHTS

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Exploration and survey continued in Lechuguilla Cave in the past year. Through methodical examination of obscure leads in fissures, climbs, boneyards, pancake layers, and breakdown, cavers have extended the known length beyond 114 mi. Resurvey in the Western Branch is improving the complex Chandelier Graveyard Quads above the Western Borehole. Survey in the Promised Land was completed; the western edge of the cave is now defined where the 260-m-long Congo trunk abruptly ends. At the southwest edge of the spacious Zanzibar chamber, a tight chimney was pushed to find Zombie Zoo, trending out below the Rainbow Room, the original end of the Western Branch. Paris-Texas continued to meander in horrendous boneyard under the Haupache Highway portion of the Western Borehole. It came close to making a connection to the deeper Frostworks complex. The spectacular Mother Lode

chamber yielded a half dozen new leads, some dropping deep into fissures. Over a 100 m lower, the Widowmaker continued to be explored and mapped. In the southwest, an impact map was made for the Chandelier Ballroom, the most photographed chamber in the cave. In the Eastern Branch, La Morada room was resketched and survey continued in the Outback. In the central Rift of the cave, teams explored both the north and south ends in numerous day trips. There are 2200 surveys recorded, with approximately 27,000 stations in the cave. After 18 years since its discovery, Lechuguilla Cave is far from finished.

MANU NUI CAVE, HAWAII
Peter and Ann Bosted

Manu Nui is a recently explored cave on the Big Island of Hawaii. It is unusual among lava caves in being profusely decorated with long, curved stalactites. Some areas of the cave also contain a rich variety of colors and splash features. The cave follows a very steep gradient, probably resulting in unusually strong chimney effect air currents in at the time of active lava flows. The cave is named for bones of the extinct Manu Nui bird. There are many entrances (pukas) to the system, most of which are named after native species growing near the entrances in this lush rain forest environment. With over 1.5 mi surveyed to date in the system (which also includes Lauu Cave), many leads remain before the exploration can be considered finished.

EXPERIMENTAL RESEARCH USING THERMOGRAPHY TO LOCATE HEAT SIGNATURES FROM CAVES

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Thermal differences between cave entrances and the surrounding landscape have long been known. Cavers traditionally ridgewalked in cave-likely temperate regions in cold mid-winter with a falling barometer in order to visually detect 'fog-plumes' of escaping subterranean air from crevices in order to locate caves. We are experimenting with a high-technology solution to this cave detection method by applying infrared thermography, a useful tool in fire detection, human body location and other building examination remote sensing to the surface of the earth. Early trials during the spring of 2005 with a Therna CAMTM B20 HSV infrared (IR) camera, even under foliage-filled and warm atmospheric conditions, produced promising results in initial trials in New Mexico, Missouri and West Virginia. Further research is underway at Fisher Cave, Franklin County, Missouri.

This research began by documenting temperatures of cave openings and surrounding substrates. Atmospheric, ambient conditions (temperature, relative humidity, specific humidity and dew point) were recorded inside the cave, at the entrance and at intervals up to 183 meters. Normal images were contrasted with thermograms that showed full temperature gradients of the openings. At 118 meters, the opening could no longer be seen with the naked eye. The thermograms showed distinct images of cave openings. Trials continued to 388 meters. In excess of 300 meters, thermograms showed the distinct cave opening of Fisher Cave. At 388 meters, the thermograms showed signatures that could be that of a cave entrance. The initial results indicate that individual cave entrances have separate and unique temperature gradients. Thus, individual cave thermograms are a "fingerprint" or signature of that cave. Thermograms can be used to isolate and identify caves entrances from surrounding terrain. Once standardized procedures are established, thermograms may become an important tool for cave location and exploration.