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BIOLOGY

ULTRAVIOLET RADIATION SENSITIVITY IN CAVE BACTERIA VERSUS SURFACE BACTERIA

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Previous studies have shown that subsurface bacteria are not more sensitive to ultraviolet (UV) light than surface bacteria. However, earlier studies from our lab have shown that cave bacteria are more sensitive to UV light than surface bacteria. In order to quantify starting material and to have a more quantitatively accurate assessment of differences between surface and cave bacteria exposed to UV light, we measured number of colony forming units per millimeter using cell counting and series dilution counts. Cave bacteria from Left Hand Tunnel in Carlsbad Caverns, New Mexico and surface bacteria from the surface above Carlsbad Caverns were grown on low nutrient (R2A) medium, were exposed to 0 seconds, 50 seconds or 100 seconds of UV light (200µWatts/cm²/s), were incubated at 15°C for 6 days and colonies were counted. In addition, DNA repair capacity was quantified by exposing the organisms to various doses of UV-C radiation and measuring survivability. Results were compared to *Escherichia coli* and *Pseudomonas aeruginosa*. Gram status and pigmentation were also determined. Surface bacteria are predominately pigmented and gram positive, while the cave bacteria do not show either of these predominances. Preliminary results seem to agree with the earlier results from our lab, but survivability data suggest that cave microbes have not lost all of their capacity to repair UV-damaged DNA. Cave bacteria appear to have adapted to the absence of UV light in the cave environment and have lost traits that protect them from UV, such as thicker cell walls and pigmentation.

SCANNING ELECTRON MICROSCOPY ANALYSIS OF LECHUGUILLA CAVE FERROMANGANESE ENRICHMENT CULTURES

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Ferromanganese deposits (FMD) in Lechuguilla Cave (Carlsbad Caverns National Park) contain a diverse community of microorganisms with unique bacterial and mineralogical morphologies. To investigate whether similar morphologies are seen in culture, scanning electron microscopy (SEM) analysis was performed on sloppy agar gradient tubes containing a carpet tack (reduced Fe) and inoculated with FMD and punk rock from the EA Survey and PHD Room of Lechuguilla Cave in 1999. Cultures were incubated in a dark, 15°C incubator for seven years. Some samples had reddish tubercles formed on the surface of the tack, while other regions had solid, mineral-like formations. Samples of aseptically extracted tubercles and mineral deposits were dried either by vacuum or ethanol/HMDS and sputter coated with gold-palladium (Au-Pd). With SEM we observed coccoid cells and biofilms in samples dried via both methods. Many cells appeared to have attachment-like structures. Cells ranged in diameter from about 0.5µm to about 1.5µm. Using energy dispersive spectroscopy, larger cell formations were found to have high Fe and oxygen (O) peaks and lower carbon (C) peaks. Conversely, smaller cells had C peaks

greater than Fe peaks. In addition, ropy biofilms were seen coating many of the cells. Mineralogical formations, such as FeO stars found in samples taken from caves, were found also in the cultures. This preliminary study shows that punk rock material inoculated into Fe-gradient tubes is able to oxidize Fe to form mineralogical structures, similar to those seen in caves, and tubercles containing actively growing bacteria.

DIVERSITY COMPARISONS BETWEEN MICROBIAL MATS AND ENDOSYMBIONT GUT COMMUNITIES ASSOCIATED WITH THE CAVE-DWELLING *ANDRONISCUS DENTIGER* (ISOPODA: ONISCIDAE) FROM THE FRASASSI CAVES, ITALY

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Because symbiosis is a pervasive driver of evolution and adaptation, it is important to understand the functional relationships between symbiont and host. The 16S rRNA gene sequence diversity of microbial mats (as a food source) from the Frasassi Caves (Grotta Grande del Vento – Grotta del Fiume), Italy, and endosymbiont communities from the guts of *Androniscus dentiger* isopods were analyzed to test the hypothesis that constant ingestion of the microbial mats supplants gut community bacterial populations. Molecular analyses of microbial mats from sulfidic cave stream segments revealed the prevalence of *Epsilonproteobacteria* (45% of clones screened), and low taxonomic diversity overall based on the number of diagnosed taxonomic affiliations and nearly saturated rarefaction curve estimates of clone libraries. Other notable taxa included the *Deltaproteobacteria* (20%), *Bacteroidetes* (19%), *Verrucomicrobia* (5%), *Gammaproteobacteria* (3%), *Betaproteobacteria* (3%), *Chloroflexus* (2%), *Planctomycetes* (2%), and the candidate division OP-11 (1%). Members of the *Bacteroidetes* are commonly associated with animal gut flora, and some of the mat organisms are also closely related to other species identified from the deep-sea hydrothermal vents. Although the *A. dentiger* gut communities are currently being assessed, *Desulfotomaculum* spp. have been found in the gut of *Procellio scaber*, a cousin to *A. dentiger*. In the mats, only *Desulfocapsa thiozymogenes* was found and the isopods could be acquiring and retaining *D. thiozymogenes*. This is the first study to explore the possible ecological significance of microbial mat communities, not just as a food source for cave-dwelling organisms, but in the establishment of endosymbiotic communities.

EPSILONPROTEOBACTERIA IN TERRESTRIAL CAVES AND SPRINGS WITH SULFIDIC WATERS

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Recently an outburst of research has centered on testing the long-standing dogma that microbes are distributed everywhere because of their overwhelming abundance, metabolic tenacity, and small size aiding in widespread dispersal. Many biogeography studies, however, have been conducted in habitats with high connectivity (e.g., marine habitats), and there have been relatively few studies to characterize microbes living in habitats where dispersal is assumed to be limited. Hypothetically, microbes from the terrestrial subsurface, and specifically caves and karst settings, would have less opportunity to exchange genetic information because of barriers (e.g., hydrologic, geologic, or stratigraphic) to gene flow. Toward rigorously testing the concept of microbial biogeography, we studied *Epsilonproteobacteria* from sulfidic terrestrial habitats (6 caves and 12 springs). Based on the diversity of retrieved 16S rRNA sequences, we identified novel groups that immediately supplement the current knowledge of environmental *Epsilonproteobacteria*. At 99% sequence similarity, there were >35 lineages identified. Cave systems had more lineage diversity compared to springs, which tended to have <3 lineages present. High diversity, even within a site, may be explained by the fact that sequenced genomes from the *Epsilonproteobacteria* lack DNA mutation repair genes. This is an interesting evolutionary caveat because genetic variation may enhance the adaptability of these bacteria to geochemically changing or stressful conditions. In contrast, however, sequences from one lineage were retrieved from 8 geographically-disparate sites, suggesting that rampant mutation was not occurring and that modern geographic isolation may not be a driving factor in speciation.

DOES BAD TAXONOMY SERVE CONSERVATION PURPOSES? THE CASE OF THE *CICURINA CUEVA* COMPLEX (ARANEAE: DICTYNIDAE) IN THE VICINITY OF AUSTIN (TRAVIS CO.), TEXAS

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Urban development in central Texas is a threat to many habitats, especially caves. About a dozen cave-restricted arthropod species are protected by the Endangered Species Act, while many others are classified as species of concern. The latter category includes *Cicurina cueva* Gertsch, an eyeless spider known from only two caves in the vicinity of Austin. A proposition for a new highway threatens the ecological integrity of Flint Ridge Cave, one of the two known localities for *C. cueva*. Correctly assessing the distribution and species limits of this taxon appears crucial for any conservation decisions. An intense sampling effort resulted in the collection of *Cicurina* spp. from ~70 caves in Travis, Hays, and Williamson counties. About 1kb of mtDNA (COI) was sequenced for 170 spiders and the phylogenetic approach of Paquin & Hedin (2004) was used to assign species names to juveniles. Likelihood and Bayesian analysis gave similar results and extended the occurrence of *C. cueva* from two to ~20 adjacent caves. These results suggest that *C. cueva*, *C. bandida* and *C. reyesi* are the same biological entity. Furthermore, spermathecal variation is not correlated with geography or mtDNA phylogeny, providing further support for synonymy. The genetic structure of *C. cueva* populations shows restricted gene flow between caves. Inadequate taxonomy or lack of collections that artificially increases the biological uniqueness of caves or species rarity is not a sound basis for conservation purposes. Long-term strategies require adequate taxonomic basis and knowledge, which is still, unfortunately, largely deficient.

THE FLUX AND DISTRIBUTION OF ORGANIC CARBON IN CAVES - A CONCEPTUAL MODEL AND PRELIMINARY DATA

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In general, there are three sources of organic carbon in cave waters. The first are sinking streams entering caves. These streams, in terms of carbon flux, are not very different from highly oligotrophic, unproductive desert streams - nearly all of the carbon comes from outside such as leaf fall in the desert and the transport of leaves into the cave in streams. The second source is exchange with groundwater. However, not all cave streams intersect groundwater and the direction of exchange is also unclear. These problems are also common to surface streams via the hyporheic. Finally, water percolating through soil and epikarst brings organic carbon into the cave. We focus our attention on the carbon brought in by sinking streams and epikarst percolation. Using Organ Cave in West Virginia and Postojna Cave in Slovenia as examples, we attempt to measure these fluxes. We also note differences in spatial distribution of the two fluxes, with sinking streams being very patchy in their effect relative to the comparatively ubiquitous percolating water. Finally we show that most of the organic carbon entering through percolating water is dissolved organic carbon, which is at least an order of magnitude greater than the flux due to copepods and other invertebrates coming in through drips. This is in spite of the fact that the flux of animals can be greater than one animal per drip per day. A careful consideration of carbon fluxes may require a modification of the commonly held view that caves are food poor.

A BIOLOGICAL ASSESSMENT OF CAVES IN LAVA BEDS NATIONAL MONUMENT, CALIFORNIA

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Lava Beds National Monument contains more than 500 lava tube caves and features, with more than 28 miles of passages that are home to a variety of cave-adapted organisms. We studied cavernicolous invertebrates in 29 caves between 2 June and 4 August 2005. Most of these caves had a dark zone varying from just above freezing to about 12 °C, where relative humidity varied from about 85 to 100%. In 193 biological samples, 1,511 specimens were recorded. Of the animals recorded, 22.6% were flies (Diptera), 19.3% were springtails (Collembola), 16% were spiders (Araneae), 12.2% were millipedes (Diplopoda), 11.7% were mites (Acari), and 5.3% were diplurans (Diplura). A variety of other animal taxa make up the remaining 12.9%.

Two common, large troglotic invertebrates are the millipede *Plumatyla humerosa* and the dipluran *Haplocampa* sp. Common and nearly ubiquitous springtails of the family Tomoceridae (probably *Tomocerus* spp.) are important members of the Lava Beds cave community, and account for more than half of all springtails. Woodrats (*Neotoma* spp.) and bats (Vespertilionidae) are especially important in bringing nutrients into these caves, and bacteria and fungi growing on their feces provide energy to other cave animals.

Notable taxa include a terrestrial troglotic isopod (Trichoniscidae), which was rarely encountered, and a troglotic pseudoscorpion (Arachnida), which is almost certainly new to science. Richness of the taxa showed no discernable patterns with respect to their association with different lava flows, vegetation zones, or elevation.

THE AQUATIC COMMUNITY OF TUMBLING CREEK CAVE (TANEY COUNTY, MISSOURI): RESULTS OF A DECADE OF MONITORING

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A stratified sampling scheme was developed and initiated in 1996 to monitor the Tumbling Creek Cavesnail (Gastropoda: Hydrobiidae: *Antrobia culveri*), in Tumbling Creek Cave, Taney County, Missouri. An evident decrease in snail numbers in the late 1980s prompted concern for this snail endemic to a single cave in southwest Missouri. This report summarizes a decade of observations on the population status of the cavesnail and the other members of the cave stream community within the study transect. Thirty-two monitoring trips have provided data that support our concern that the cavesnail population has been decreasing. No snail has been seen in the transect area since the fall of 2002, although individuals still occur in an isolated area upstream from the study area. We hypothesize that surface land-management activities and the associated increase in erosion and subsequent silt deposition in the streambed have had a major negative impact on snail populations. However, populations of stygophilic and stygobitic crustaceans (amphipods and isopods) have fluctuated without distinct trends throughout the period of monitoring. Stygophilic limpets (*Ferrisia fragilis*) have experienced “boom and bust” population profiles during the study. Surface snails (*Physa* sp.), absent for several years, seem to be repopulating the cave stream. Surface land use within the cave recharge zone has been altered, surface restoration is in progress, and we continue to conduct cave stream monitoring trips twice yearly.

CAVES OF NATIONAL PARKS AND PUBLIC LANDS

BUGS, LIGHTS, AND MAPS AT GREAT BASIN NATIONAL PARK

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Over the past five years, several projects have been conducted at Great Basin National Park to better understand and manage caves. In addition to Lehman Caves, which is open to the public, the park contains 45 additional caves, including the highest elevation, deepest, and longest caves in Nevada. From 2002–2004, 36 of these were mapped and inventoried for physical resources. In 2003, biological inventories were conducted at 10 caves, with two new species found. The results of these mapping and inventory trips, plus past data, were compiled into a Cave Resource Condition Report. Current cave projects include biological inventories of 15 additional caves and a relighting project in Lehman Caves to reduce lampflora and improve the cave lighting.

MAPPING SURFACE GEOLOGY TO PROTECT CAVE AND KARST RESOURCES

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Jewel Cave is a vast cave system in the Mississippian Madison Formation in the southern Black Hills of South Dakota. Strong barometric winds in the cave have demonstrated that the 228 km presently known represent only about 3% of the total volume. Maps of cave passages overlain by detailed surface geologic maps have demonstrated a spatial relationship between cave passages and geologic contacts, providing a general indication of where undiscovered passages are likely to exist. Hydrologic connections from the surface into the cave are related to the surface exposure of two permeable subunits in the lower part of the overlying Minnelusa Formation. These infiltration zones are areas where the cave is susceptible to impacts from surface activities. Cave potential and vulnerability maps have been used as a predictive tool to anticipate where the undiscovered portions of the cave might be found and where potential impacts to the cave may occur. This information has been used to facilitate cave protection by land exchanges, mineral withdrawals, and recommendations for highway realignment.

QUANTIFICATION OF BACTERIAL DNA IN CLASTIC SEDIMENTS AND ON ARTIFICIAL SUBSTRATES IN MAMMOTH CAVE AQUIFERS

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Bacterial DNA concentrations in clastic sediments at the Charon's Cascade study site and in biofilms on artificial substrates at Eyeless Fish Trail, Mystic River, Owl Cave, Roaring River, and the Hawkins-Logsdon River confluence were determined with quantitative Real-Time PCR. Homogeneous fine sandy sediment like that found at Charon's Cascade can be found in streams throughout Mammoth Cave and affords a homogeneous substrate for comparative measurements of native bacterial DNA concentration wherever it has been deposited. Artificial substrates consisting of ceramic beads composed partially of crushed limestone were deployed in triplicate at five study sites to capture bacterial biofilm growth over a one year period in cave streams. Triplicate qRT-PCR reactions were performed to amplify eubacterial 16S SSU-DNA from each DNA extract and compared to a standard curve consisting of triplicate reactions on *E. coli* genomic DNA of accurately known concentration. Results were normalized by calculating the total yield of DNA per gram of sediment or substrate. Bacterial DNA concentrations in saturated sediments at Charon's Cascade averaged 1261 ng/g with a standard error of $\pm 11\%$. Artificial substrates at Eyeless Fish Trail yielded 476 ± 81 ng/g, Mystic River yielded 6.3 ± 1.6 ng/g, Owl Cave yielded 3463 ± 258 ng/g, Roaring River yielded 1398 ± 114 ng/g, and Hawkins/Logsdon River yielded 5136 ± 2152 ng/g. The same technique can be used with DNA extracted from filters to determine the concentration of bacterial DNA in water over the range of 2–20,000 ng/L (parts per trillion).

THE 2006 MEMORANDUM OF UNDERSTANDING BETWEEN THE BUREAU OF LAND MANAGEMENT, THE NATIONAL SPELEOLOGICAL SOCIETY, AND THE CAVE RESEARCH FOUNDATION: ITS ORIGINS, PURPOSE AND POSSIBILITIES

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The United States Bureau of Land Management (BLM) is a multiple-use land management agency administering more than 1.1 million km² of federal lands and resources in the Western states. Those resources include thousands of caves ranging from the small to the highly significant, and millions of acres of karst lands. The mission of the BLM has grown over the years, and has included positive input from the National Speleological Society (NSS) and Cave Research Foundation (CRF) back to the early 1960s, relating to cave and karst protection and management. The BLM's ability to manage land for its cave and karst resources is largely due to the long term partnerships we have enjoyed. For over four decades, the BLM has worked with the NSS and CRF, organizations dedicated to the preservation and scientific investigation of caves. These organizations have worked on national laws and found, mapped, and shared scientific knowledge about caves and karst lands. NSS and CRF volunteers helped develop Leave No Trace cave safety and ethics brochures and videos and have worked on conservation and restoration activities in and around caves. An Memorandum of Understanding (MOU) between the BLM, CRF, and the NSS is part of the ongoing long-term commitment to recognizing all aspects of speleology and the best management of our valued cave and karst lands. Other assistance agreements can be tiered off of the MOU, such as Cooperative Management Agreements, Cooperative Agreements, Challenge Cost Share Projects, and Volunteer Agreements.

NEW CAVE INVERTEBRATES: INVENTORY RESULTS AT SEQUOIA/ KINGS CANYON NATIONAL PARKS

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From 2002 to 2004, park staff aided scientists from Zara Environmental in conducting a biologic inventory in 31 of the park's 240 known caves. As many as 50 different species were found in individual caves. The ranges of many species were extended, and 27 entirely new species were identified. Park staff are now planning a monitoring phase of this project in order to better understand these species.

MANAGING MULTIDISCIPLINARY CAVE AND KARST RESEARCH AT CARLSBAD CAVERNS NATIONAL PARK

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There is a wide range of multidisciplinary cave and karst research being conducted in Carlsbad Caverns National Park. The park actively supports research by identifying research needs, streamlining environmental compliance, and obtaining funding for projects. In order to prevent the loss of institutional memory, the park has developed a system for tracking and archiving samples as well as keeping track of monitoring equipment and data in park caves. Geological, mineralogical, and speleological inventory data are collected during survey and exploration of all park caves and stored in a digital database to assist researchers in locating appropriate sample sites. Interim and final reports are tracked and archived so that it will be easy for park managers and future researchers to see what work has been done, what data are available, and identify research needs. This model for managing research has proved very successful to both park managers and researchers and could easily be applied to other parks, agencies, and groups managing large and small cave and karst projects.

SYSTEMATIC INVENTORY AND SURVEY OF THE CAVES IN GRAND CANYON — PARASHANT NATIONAL MONUMENT, ARIZONA

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Cave resources of Grand Canyon Parashant National Monument are virtually unknown. During summer 2005 and early-spring 2006, we surveyed all 26 known caves on the Monument. Systematic procedures for mapping and inventorying geological, hydrological, paleontological, archeological and biological resources were developed and refined. Our study was the first regional systematic survey of caves in Arizona. Geologically, caves were found within Permian Kaibab limestone, Mississippian Redwall limestone, sandstone and basalt. We also documented airflow in 10 caves. Several caves may offer great opportunities for paleoenvironmental reconstruction. Two potentially significant archaeological sites were identified, and most caves were used during prehistoric and historic times. Several of the caves act as swallets and may be significant aquifer recharge points. We also inventoried vertebrates and invertebrates. Data collected during this study should be considered baseline data, which will be useful in identifying additional research needs on the monument. These data will also be used in developing cave resource management plans for these caves. The protocols developed may be useful for cave inventory throughout the state.

ENVIRONMENTAL DNA ANALYSIS TECHNIQUES FOR MICROBIAL STUDIES AT OREGON CAVES NATIONAL MONUMENT

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A variety of DNA analysis techniques were evaluated to provide a means for monitoring bacteria and fungi at Oregon Caves National Monument. Sediment samples from study quadrants clustered at the South End of the cave were taken directly from impacted tourist trails and from areas in the same quadrants some distance off the trails. DNA was extracted from the sediments and amplified using bacterial- or fungal-specific primers in PCR reactions to produce copies of 16S or 18S SSU-DNA fragments, respectively, for molecular analysis. Bacterial amplifications were carried out with universal eubacterial 16S primers substantially documented in the literature and routinely used for molecular studies of bacterial communities by many investigators. Fungal amplifications were initially attempted with some eukaryotic primer combinations found in the literature, but those conditions proved either too nonspecific or too limited in taxonomic range for environmental studies. Therefore, conditions were optimized using other primers and reaction conditions until an improved fungal protocol was demonstrated. Fluorescent fragment analysis was considered as a means for broad but indeterminate viewing of bacterial communities and was considered uninformative without prior identification of species. Quantitative Real-Time PCR was used successfully to determine the quantity of bacterial

or fungal DNA extracted from a given mass of sediment; however, inconsistent physical and geochemical parameters such as particle size, surface area, and matrix consistency made site-to-site comparisons irrelevant. Ultimately, cloning and sequencing of bacterial DNA from sediments and fungal tissue from cave surfaces led to likely classifications for many bacteria, fungi, and protozoans.

CAVE CONSERVATION & MANAGEMENT SESSION

MANAGEMENT SUCCESSES AT NUTTY PUTTY CAVE, UTAH

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The recent number of cave rescues and the increased awareness of potential caving dangers have caused the Utah State Trust Lands Administration to consider various options regarding Nutty Putty Cave, including potential permanent closure to prevent a future fatality. Since its discovery, Nutty Putty Cave has required four full callout rescues; two of these rescues were over Labor Day Weekend 2004. The Trust Lands Administration had hoped to enter into a proposed lease arrangement in 2005 with several different organizations which had interest in managing the cave, but those efforts failed for various reasons. The drowning of four people in a Provo cave in 2005 likely affected those organizations' decision not to further consider a lease. The Trust Lands Administration has since signed a Memorandum of Understanding with the Timpanogos Grotto to gate the cave and implement a new management plan to improve training, safety, and resource protection.

The Timpanogos Grotto gated the cave on May 24, 2006, and is allowing access only to sufficiently prepared cavers. If this approach can eliminate the safety problems in Nutty Putty Cave, the threat of the cave's total closure will be avoided. With over 6000 visitors per year, the successes or failures at Nutty Putty Cave could largely affect how caves are managed throughout the state.

BAT CONSERVATION IN THE BORDERLANDS

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Bat protection enjoys many successes in the United States, but what happens to our migratory bats when they head south of the border? The situation in Mexico is very different, where subsistence-level living creates unique environmental pressures on wildlife and habitats. Bats, in particular, are greatly misunderstood and often feared; thus entire colonies of mixed species may be destroyed in the mistaken belief that they are all vampires. In addition, caves harboring some of the largest colonies in the world are often inadvertently damaged through inappropriate guano mining techniques. Bat Conservation International and its partners have instigated the documentation of bat caves in Mexico's northern states (Tamaulipas, Nuevo León, Coahuila, Chihuahua, and Sonora) in order to discover new colonies and assist in the conservation and management of these sites. To date, almost 90 caves have been visited. The data suggest that the top 19 sites may have held over 40 million bats, but have slightly over 18 million, a decline of 56%. In addition, BCI and its partners provide local outreach and assistance through meetings with local conservationists, landowners, and community leaders. By utilizing BCI-produced materials such as the book *Murciélagos Cavernícolas del Norte de México*, we are able to reach large numbers of local people with little previous bat education. Through this work we are setting more realistic conservation priorities, and are better able to assist with the successful management of our shared resources.

GEOLOGY AND GEOGRAPHY

KARST WATERFALLS – FEATURES OF GROWING INTEREST

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Spectacular karst waterfalls — actually very large and complex tufa dams, occur in Croatia (Plitvice Lakes), China (Jiuzhaigou), and elsewhere. Scenic and spectacular, these waterfalls are actually growing taller as the tufa accumulates around the roots of trees and shrubs. Some reach heights of 30–50m, widths of 200–300m, and impound beautiful lakes behind them. Carbonate deposition is caused by a complex of physical and biological processes. The water issues from cold water springs and quickly becomes oversaturated in respect to carbonate. Partial pressure is lowered to atmospheric and the water warms. Plants extract large amounts of CO₂ from the water, playing a major, probably dominant, role in carbonate precipitation. In North America (Texas examples are Capote Falls and Gorman Falls), biological processes play little or no role in tufa deposition on waterfalls. Elsewhere are tufa deposits at waterfalls on major rivers such as Haungguoshu Waterfall and the Nine Dragon Waterfall Group in China that occur in much higher energy environments. Chinese examples are further complicated by the fact that the gorges below some waterfalls originated as cave passages that are now unroofed. Detailed study of Haungguoshu reveals that stream piracy occurred there. Although clearly the net result of long-term scarp retreat and erosion, including the pirating of river flow through a cave system and its subsequent unroofing to form a spectacular box gorge, the lip of the waterfall is mantled by 5–8 m of tufa that is actively being deposited today.

CAVE LEVELS IN FLORIDA

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The concept of cave level is fundamental for understanding the geomorphic evolution of karst landscapes. In the Paleozoic limestones of Mammoth Cave, passage levels formed in response to base level changes of the Green River. Within the Cenozoic carbonates of Florida, sea level determines base level. Forty years ago, Florida hydrogeologists proposed, without data, that cavernous porosity in the Floridan Aquifer formed during sea-level still stands during the Quaternary. Our data affirm this hypothesis, and suggest a variety of paleo-water table elevations. In air-filled caves, recent data from cave surveys and existing cave maps reveal levels at 5m, 12–15 m, 21 m, and 30 m above sea level over broad areas. The levels do not follow the large-scale structure of the Floridan aquifer. They do align with nearby, coastal marine terraces formed during times when sea level, and thus the water table, was higher than present. Data from well-cavities (e.g., bit drops) and existing maps of underwater Florida caves demonstrate passage levels at depths of 15 m, 40 m, 70 m, and 90–120 m below the modern water table. These below water table levels generally match the depth below sea level of distant submerged terraces and paleoshoreline features identified using multibeam bathymetric data in the Gulf of Mexico.

GEOPHYSICAL SURVEYS UP-FLOW OF GYPSUM CAVE, IDAHO

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Idaho's 4023-m long Gypsum Cave lava tube was created by a flow that came from an eruptive source over 15 km away. The entrance is at the distal end of a collapse sink. Reasoning that a continuation may be present up-flow from the entrance, a magnetometer survey was conducted in 1999. A well-shaped, negative, linear magnetic anomaly of as much as 5200 nano-teslas (nt) and 26-m wide crest-to-crest was present for over 25 m. Total field in this area is 54,000 nT. To better define the anomaly, a gradient-array resistivity survey was conducted. Prior experience dictated that the huge magnetic anomaly would yield an impressively high resistivity anomaly. Instead, values of less than 150 ohm-meters were found over the anomaly accompanied by 1500 ohm-meters at each side, the exact opposite of what was expected. One explanation is for the cavity to be filled to the ceiling with conductive salts. In 2004, the

magnetometer survey was continued with an unambiguous negative anomaly traced for one kilometer. One part of the anomaly, surveyed for 110 m, measured over 7500 nt deep, and 35 m wide crest-to-crest. In 2005, gradient-array and dipole-dipole resistivity surveys conducted over a section ~0.5 km upflow from the entrance gave the same results as before - nearly a "short-circuit" over the magnetic anomaly. Surveys are continuing to find a suitable place to enter this prospect and to find an explanation for the anomalous resistivity results.

GEOLOGY OF A MYSTERY MICROBE: RETICULATED FILAMENTS IN SPELEOTHEMS

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Some carbonate speleothems commonly host fossil microbial filaments. We report herein on a new form of reticulated filament found in a variety of speleothems worldwide. Reticulated filaments are usually found inside speleothems by etching with weak (5–10%) hydrochloric acid before imaging in a scanning electron microscope (SEM). They often show a higher concentration of carbon, which apparently allows them to resist the acid etching. We currently have imaged 134 individual filaments from six different caves and one surface sample. Most come from pool precipitates in Carlsbad Cavern, Hidden, Cottonwood, and Endless Caves, Guadalupe Mountains, NM. Additional examples are found in cave pearls from Tabasco, Mexico, a lava tube in the Cape Verde Islands and one example in desert varnish from NM. Reticulate filaments are 1–75 µm in length. Two populations overlap in size, one averaging 0.5 µm and a second averaging 0.9 µm in diameter. The reticulated pattern resembles an open fish-net tube. Two varieties occur, one with diamond-shaped chambers that spiral, and a more common one with hexagonal-shaped chambers in a line. Some filaments are hollow, others are solid; a few samples are collapsed or even torn open. We hypothesize that reticulated filaments are the fossilized remains of an unknown microbe that is apparently common in damp cave environments. Efforts to identify living examples have so far failed, but cave microbes are notoriously difficult to culture. We are interested if finding out if anyone else has observed these filaments in living or fossil cave systems.

GROUND WATER TRACING IN RUTHERFORD COUNTY, TENNESSEE, WITH EMPHASIS ON THE BFI LANDFILL AREA

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Rutherford County is located in the Central Basin and is underlain primarily by the cavernous Ridley Limestone of Ordovician age. The focus point of the investigation was around the BFI landfill in Walterhill, which is a large regional landfill seeking a permit for expansion. Dye tracing was also conducted from two sinkholes near the MTSU Coliseum and from a sinkhole near Dillton. Eight successful traces were conducted defining flow paths to six springs. Prior to this investigation, there was no information regarding the recharge area of five of these springs. The results have shown that significant areas around Walterhill cannot suffer from ground water contamination from the landfill if it were to leak pollutants to the subsurface. A trace near the Miller Coliseum shows that ground water from parts of this MTSU property moves to the stream in Black Fox Cave and then emerges at a large spring on the VA Hospital property. This spring is impounded to form a small lake containing a large trout population. Thus, a spill or leak at the Coliseum could endanger the fish. All of the springs at these two areas of investigation contribute water to surface water supply intakes for the City of Murfreesboro and the Consolidated Utility District. These intakes are located on impounded waters of the East Fork below the Walterhill Dam. Finally, one trace was successful in delineating a significant portion of Black Fox Spring, which is the headwaters of a TWRA protected wetlands.

MICROBIAALLY ENHANCED CARBONATE DISSOLUTION IN THE EDWARDS AQUIFER OF CENTRAL TEXAS

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The eastern boundary of the Edwards Aquifer in Central Texas (USA) is marked by a transition to saline, anaerobic to disaerobic, H₂S-rich "bad-water" (BW). Down-hole video-logs from the Edwards Aquifer Authority (San Antonio) of uncased BW wells (depths from 100 - 400 m) reveal a complex network of fractures, solution pockets, and conduits, but also white colloids and filaments in the water column and thick biofilms coating the rocks. Despite some regional stratigraphic and structural variability, the BW is supersaturated with respect to calcite and undersaturated with respect to gypsum. *In situ* microcosms consisting of ~1 cm³ calcite chips (totaling 10 g) were deployed in four BW wells for three months. Both sterile (excluding microbes from colonizing the chips) and non-sterile (allowing microcosms to colonize) microcosms were used to test if calcite dissolution was enhanced by microbes. Non-sterile chips lost ~3-5X as much weight as sterile chips in water supersaturated with respect to calcite; surfaces were also heavily weathered and had a variety of microbial cell morphologies on them. Gypsum occurred in some biofilms, despite the waters being undersaturated with respect to gypsum. These results indicate that surfaces were not in equilibrium with the surrounding waters and that microbes locally mediated both calcite dissolution and gypsum precipitation. Various microbial groups can generate acidity metabolically; genetic characterization identified *Epsilonproteobacteria*, sulfur-oxidizers that produce sulfuric acid. This study provides insight into the unique BW habitat and the potential role of microbes in deep subsurface carbonate weathering and karstification.

AQUEOUS GEOCHEMICAL STUDY OF Tufa CREEK, SHANNON COUNTY, MISSOURI

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Carbon dioxide off-gassing due to agitation as Tufa Creek gradually falls 25 m in elevation over a 583 m stream reach is the principal mechanism for calcite deposition along this fen-fed stream. Water chemistry results support this conclusion. The stream water warmed from 14° to 19° C. The pH increased from 7.02 to 7.96 standard units. Specific conductivity decreased from 0.570 to 0.488 millimhos/cm. Alkalinity decreased from 368 to 321 mg/L. Dissolved calcium decreased from 157 mg/L to 117 mg/L. Magnesium decreased only marginally from 156 to 148 mg/L. Total hardness (calcium and magnesium) decreased from 313 to 265 mg/L. Chloride remained statistically unchanged from 7.6 to 7.5 ppm. Sulfate decreased from 5.7 to 4.7 ppm. Calcite saturation increased from -0.03 to 0.85. PCO₂ equilibrated from -1.51 to -2.56, but did not achieve atmospheric (-3.5) before entering the river. Biological mediation perturbs water quality data at a sedge-muck section of the forested fen. Tufa formation correlates with elevation drop. Comparing Tufa Creek data to nearby Ebb and Flow Spring, and Thompson Creek reveals that sufficient stream mineralization and optimal stream geometry are needed for freshwater calcite deposition. Tufa deposition rates along Tufa Creek are less than those predicted by the Plummer-Wigley-Parkhurst rate law. We speculate this is due to inhibiting effects of dissolved Mg²⁺ or rate changes effected due to periodic gravel scour on the stream.

THE POTENTIAL EXTENT OF THE JEWEL CAVE SYSTEM

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Research at Jewel Cave has shown a direct relationship between airflow at the entrance and the prevailing atmospheric pressure. A previous study of this barometric airflow estimated a total minimum cave volume of 1.1 × 10⁸ m³ (4 × 10⁹ ft³), of which less than three percent has been discovered. This study estimates the extent of undiscovered cave passages for Jewel Cave, as well as that of nearby Wind Cave. The estimate is based on: 1) the thickness and distribution of the Madison Limestone; 2) the potentiometric surface of the Madison aquifer; 3) the location and extent of potential geological obstacles; 4) the three-dimensional distribution of the cave systems within the host rock; and 5) the "cave density" at Jewel Cave and Wind Cave. Based on the minimum cave volumes and an estimated 9.3 × 10¹⁰ m³ (3.3 × 10¹² ft³) of available limestone,

the overall cave-to-rock ratio is 0.18%. This is at the low end of the range of known "cave density" values for Jewel Cave and Wind Cave, 0.15–0.59%.

A more recent airflow study indicates a larger minimum cave volume of at least 2.0 × 10⁸ m³ (7 × 10⁹ ft³). With that value, the overall ratio of cave to rock volume would be nearly the same as the average "cave density" for the known portions of Jewel Cave and Wind Cave. Most of Jewel Cave's volume extends toward Wind Cave, and vice versa, and the data support the possibility that the two volumes could be part of one large cave system.

CAVE DETECTION ON MARS

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Exploration of the Martian subterranean environment offers a unique avenue for: (1) investigating promising localities to search for extinct and/or extant life; (2) identifying areas likely to contain subterranean water-ice; (3) evaluating the suitability of caves for the establishment of human habitation areas; and, (4) investigating subsurface geologic materials. On Mars, use of remote sensing will be the most efficient means of cave detection. Due to the long and widespread volcanic history of Mars, the low gravity, possible low seismicity, and low rates of processes that could collapse or fill in caves, lava tubes are expected to be common and widespread. Their detection on Mars involves: (a) development and interpretation of thermal dynamic models of caves to identify the thermal sensor requirements for detection; (b) evaluation of available imagery of both Earth and Mars for their utility in cave detection; and, (c) collection, analysis and interpretation of ground-based measurements of thermal dynamics of terrestrial caves (and then relating these data to detection of Martian caves). Our models suggest detectability will be influenced by time of day and geologic substrate. Certain bands in THEMIS IR satellite data are best for cave detection and we have examined cave size in relation to thermal detectability. Thermal data from terrestrial caves support model results indicating imagery capture at the appropriate time of day is critical to detection. These data also reveal numerous interesting thermal characteristics of caves, which will improve our understanding of thermal properties of caves on both Earth and Mars.

SPELEOTHEMS IN NON-SPELEAN ENVIRONMENTS

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In 2005, members of the Southern California Grotto discovered features typical of California speleothems in an abandoned mine near Los Angeles. Because they are in a mine rather than a cave, they do not fit the long-standing definition of *speleothem*. In the 50+ years since its definition in the *NSS News*, this definition has become increasingly awkward. We propose that the term be redefined in a refereed journal, clarifying that 1) speleothems are characteristic of caves but not limited to them; and 2) morphology, not mineralogy, determines whether a feature is or is not a speleothem.

ATMOSPHERIC CONDITIONS AT TWO ENTRANCES OF A GYPSUM CAVE

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This study was conducted to determine the relative difference in the atmospheric conditions (temperature and humidity) at the surface, at two entrances, and in a passage 15 m from each entrance of a gypsum cave near

Carlsbad, New Mexico. The higher entrance and passage is walking size, the lower entrance and passage is stooping size. The hypothesis was that there exists a relative difference in atmospheric conditions. At the entrance the temperature and the humidity would be higher than the passage, which would be cooler and less humid. The size of the passage would affect the temperature and humidity. The bigger the passage, the hotter and more humid it will be. Data were collected using wet-bulb/dry-bulb on the surface, at the entrances and 15 m down passage from each entrance. There was no pattern to changes in temperature and humidity between each entrance and associated passage. Nor was there any correlation in changes between upper and lower entrances and associated passage temperatures and humidity. Possible factors that might have influenced the atmospheric conditions include: additional entrances, cave configuration (it is a maze cave), impact of human presence, and faulty data collection techniques.

SPELEAN HISTORY

HISTORY OF THE CASCADE GROTTO: THE FIRST THIRTY-FIVE YEARS

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The Cascade Grotto's application to become an Internal Organization was signed May 21, 1951 by ten National Speleological Society members, mostly living in the Seattle area. In those days of two-lane highways, no limestone cave was known in western Washington. Oregon Cave was a fourteen-hour drive from Seattle. The lava tube caves of Mount St. Helens and Mount Adams were believed to be few and hidden deep in wilderness forests. And the closest cave in Canada was believed to be Nakimu Cave in Glacier National Park. Diligent searches by the new group began to unearth limestone caves south of Mount Baker and high above Snoqualmie Pass, but the obstacles were too great and the grotto became inactive around 1955 after publishing just six issues of *Cascade Cave Report*. Almost at once, however, new cavers and new access produced a spectacular rejuvenation with a strong international orientation. A new publication, *The Cascade Caver*, appeared in 1961. The grotto subsequently emphasized international vulcanospeleology. It also pioneered American glaciopedology, but its studies of the summit geothermal caves of Mount Baker were cut short by the 1980 eruptions of Mount St. Helens. There the Cascade Grotto undertook twenty follow-up trips to study the caves and pseudokarsts in the "Red Zone".

SCHROEDER'S PANTS CAVE

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In the fall of 1947, brothers George and Lyndon Lyon, along with Herb Schroeder, discovered a beautifully decorated cave in New York that they would explore and lead school groups into for the next 18 years. On one of those explorations, Herb Schroeder wound up pants-less due to his size and the tightness of some of the squeezes. The cave would become known the world over as Schroeder's Pants Cave. It was featured in numerous NSS News articles in the late 1940s and early 1950s, and talked about throughout the Northeastern Grottos. Twenty-three year old James Gentry Mitchell of Waterville, Ohio, who was living and working in the Boston area, came to Dolgeville, New York on 13 February 1965, with two inexperienced cavers from the Boston Grotto. The three men began exploring the cave to the point where James was lowered into a seventy foot (21.33 m) bell-shaped room. Freezing water was pouring on him at this point and eventually led to his death. The National Capital Rescue Team was called to the scene but ultimately, and not without controversy, determined that it was not possible to get the body out. The cave was dynamited shut. In June of 2006, a group of experts, along with James Gentry Mitchell's brother, made a return trip to the cave to finally retrieve the remains of James for burial at Mitchell Lake, Ohio.

TWO 1851 ACCOUNTS OF GROTTA DEL CANE

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Located in the Phlegrean Fields volcanic area near Naples, Italy, Grotta del Cane contains a concentration of CO₂ sufficient to anesthetize dogs (hence

the name Cave of Dogs). As such it long was touted as a tourist curiosity. Recently the authors encountered two 1851 English-language observations which occurred a few days apart. Information gleaned from these accounts, including both relevant published information, and the important unpublished data of Rosario Varriato, suggest that the cave is artificial. It was probably excavated in a Greek colony during pre-Roman times, in pyroclastic material, as a "sudatorium" (excavated sauna). An illustration in A. Kircher's 18th Century "Mundus Subterraneus" showing the cave as an unroofed space in a travertine basin reflects imagination by the illustrator. Later, probably in Roman times, the cave was invaded by anesthetizing levels of CO₂. This was demonstrated with dogs until about 1930. The cave was closed from 1970 to 1998 as a safety measure. In 2001 it was reopened and cleaned. Currently, the cave is T-shaped. The entrance is 1.9 m high and 0.9 m wide. Its passage slopes downward at 20° to the middle of a rectangular space about 3 m high and 9 m long. A hole in this room extends to the ceiling but is choked. The midpoint temperature is about 45° C, and the cave is hotter farther inside. Current CO₂ concentration data are not available.

HUMAN AND MEDICAL SCIENCES

CAVING-RELATED FEARS PART 2: BEHAVIORAL CAUSES AND POTENTIAL SOLUTIONS

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Anxieties and/or fears are common in caving, from brief situational heart-rate acceleration (due to, for example, significant exposure, hairy climbs, or long tight squeezes) to actual panic attacks (from challenging one's claustrophobia, acrophobia [fear of heights], or potamophobia [fear of rivers or running water]). Some people are reticent to even try caving because of the fear of becoming anxious. The development of most anxiety and its related fears can be appreciated with behavioral or learning theory (the advanced version of the commonly understood reward system). By understanding the basic principles by which anxiety and fears form, it is much easier to intervene in the system that is creating, maintaining, and/or worsening these fears, and provide relief for the affected caver. When a caver wishes to better manage anxiety or overcome a significantly interfering caving situation that intrudes on the caver's ability to enjoy the sport (e.g., tight crawls, hairy climb up or climb downs), there are strategies to address these anxieties, and allow cavers to participate more fully and enjoyably in their sport.

THE CAVING EXPERIENCE

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New and experienced cavers in Arkansas and New York were interviewed and observed concerning what attracts them to their pursuit and how they go about caving and preparing to cave. The research approach, methods, and preliminary findings concerning the discovery, access, social relations, adventure, risk, and sensory appeal of caving are presented here before the final study is complete in an effort to share preliminary results as soon as possible. Theories in leisure and recreational user research and theories of place connectedness, introduced here, are important additions to the environmental social study of caves. Findings from this project are intended to contribute to the literature concerning the experience of a recreational user of the natural environment, particularly cavers. Furthermore, documenting and analyzing cavers' actions and beliefs can add to the development of conservation policies that impact the recreational use of natural environments.

WHY WE LOVE AND HATE CAVES

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Caves harbored nearly all symbols for at least 80% of our existence. Language may have begun in caves, as our two earliest concepts may have been light/dark and above/below, simple dualities made most vivid and memorable in caves via many states of consciousness. Caves soon exemplified ecologic reciprocity with spirits by mediating female/male, life/death, old/new, be-

ing/becoming, mortal/immortal, horizontal/vertical, community/ individual, physical/mental, dreaming/awakeness, and cyclic timelessness/linear change. Based on archeology, whatever prompted cave importance via symbolic systems or otherwise remained intact from at least 78,000 to 14,000 years ago. The value of caves declined in the Middle East when social stratification and writing 6,000 years ago reduced reciprocity with nature and tolerance of consciousness diversity. When the concept of absolute good and evil spread in late Roman times, the negative view of caves dominated as they were most distant from sky gods, of low material value, and didn't serve leaders. Except for some caves blessed by saints, there was little cave use for a thousand years in the West or in Islamic areas. By the Renaissance, an unintended result of the desanctification of worlds below the sky was to promote capitalism, science, and democracy rather than fear-based theocracies. The Romantic sublime united cave fear and beauty. By the mid-1800s, these world views helped make caves as interesting to visit as they had been during the birth of our subspecies.

RISKS TO CAVERS AND CAVE WORKERS FROM EXPOSURES TO LOW-LEVEL IONIZING A RADIATION FROM ^{222}Rn DECAY IN CAVES

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Human health risks posed by exposure to elevated levels of ^{222}Rn in caves are not well documented. Various studies throughout the world have detailed the often very high ^{222}Rn gas concentrations in caves and exposures to cavers and commercial tour guides and other employees, but without a consequent assessment of the overall impact on human health. Although ^{222}Rn concentrations in caves are considered high relative to most above ground dwellings, the levels identified are also considered to be low for ionizing α radiation. Low-level ionizing radiation impacts on human health are deduced by application of the linear no-threshold theory (LNT) of radiation carcinogenesis. Comprehensive reviews of the published literature and an understanding of exposure time suggests that commercial cave workers (e.g., tour guides) and commercial ^{238}U -mine workers are both exposed for the same number of hours per month (~170 h), but cave workers are exposed to much lower ^{222}Rn concentrations than are mine workers. Cavers will generally be exposed for a smaller number of hours per month. Risk estimates suggest that cavers will likely be subject to insignificant risks, but that cave workers may be subject to low-level risks of developing lung cancers from elevated levels of ^{222}Rn gas concentrations in caves.

THE PETZL S61 NEST RESCUE STRETCHER

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While rarely seen in North America, the Petzl S61 NEST rescue stretcher is the dominant caving stretcher in Europe. It was developed in cooperation with Speleo Secours Français, the French cave rescue group. It is highly adapted for rescue from the narrow vertical caves predominant in alpine regions. An integral harness and PVC flaps contain the patient. The stretcher design assists in spinal stabilization. His position is maintained by adjustable leg stirrups with integral support blocks for the feet. A flexible plastic skid plate protects caver and stretcher during evacuation through low ceiling passages. Multiple carry handles and lifting straps permit horizontal or vertical evacuation. It weighs 11.5 kg and measures 1.9 m long by 0.5 m wide, and can be further reduced in volume by removing rigid support slats and a shoulder-level metal stay. Thus configured the stretcher may be rolled for transport. It may also be folded along its long axis. With a price of nearly US\$2000 (as of early 2006) the S61 NEST is a highly specialized device best suited to specialist cave rescue teams rather than general caving and wilderness rescue.

INTERNATIONAL EXPLORATION

HOUPING 2006 - EXPLORATION IN SOUTH-WESTERN CHINA

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A multi-national team of six returned to the Houping karst area situated in the mountainous Chongqing Provincial Municipality in southwest China, where previous expeditions had partially explored segments of an extensive karst system. Despite multiple illnesses, the team surveyed more than 10 km of new passage in Er Wang Dong and San Wang Dong, taking advantage of the dry season to push multiple shaft series down to the flood-prone active stream

levels of the caves. A complex network of large draughting streamways was explored and left continuing at the end of the expedition, in some cases heading off our maps. The combined flow of the currently documented streams accounts for only a small fraction of the six cumecs of water that flows from the area's primary resurgence. The cultural (and gastro-intestinal) adventures of rural Chinese village life, made our subterranean discoveries all the more memorable, and the hospitality of the people of Er Wang Dong Village and the government of Wulong County was amazing. Attempts to connect Er Wang Dong and San Wang Dong were unsuccessful in 2006, however newly discovered passages in both caves present exiting possibilities for a connection during a future expedition. Such a connection would result in a system more than 40 km in length, and one of the great caves of the world.

SOUTH CHINA - XILIAN '05 AND NANDAN '06

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The China-based, Hong Meigui Cave Exploration Society and international cavers conducted an expedition to Xilian in 2005 and Nandan in 2006. Xilian is located on the north edge of Hunan Province. The potential of this area was seen as so good, a planned trip to the Zhangjiajie area was canceled and the team rode five additional hours north where 7.4 km of nice cave was mapped in 6 days. Nandan is a small city in northwest Guangxi Province. Just east of the city, the Nandan River disappears into the edge of a cone karst plateau, creating great river passages and giant paleo borehole. Undocumented caves are so numerous in the area that one hardly knows where to start. On Hong Meigui's 4th Nandan expedition, 9.8 kilometers of cave were surveyed bringing the area total to just shy of 40 km. With each of these trips, our fascination with China has grown. The caves delight in both quality and quantity amid a culture of endless surprises. The Chinese view of karst in very practical terms makes any research into better understanding the hydrology a welcome enterprise. From a pure caving perspective, we're exploring and documenting world-class cave development.

XIBALBA MAPPING AND EXPLORATION TEAM: BELIZE, 2006

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Over 30 cavers from 12 states worked in Belize for a month during February-March of 2006. This is the 6th consecutive year we have worked there under the auspices of the Institute of Archaeology of Belize (Dr. Jaime Aiwe, Director). Efforts were concentrated this year in 4 caves: Painted, Chapat, Yaxteel (Yaxteel Ahau) and Blue Hole #3 (Jaguar) Cave. Mapping was completed in Painted and Blue Hole #3 and the main passages of Chapat were delineated. Above-water survey in lower Yaxteel was completed. There was significant archaeological support work done by our team in Painted and Upper Yaxteel. A dye trace and underwater survey were started in Lower Yaxteel. Several days were spent laying groundwork for the 2007 trip, and one member spent significant time cataloging the Institute's library and a large photo collection compiled from past expedition members' pictures. Work in the Chiquibul System, one of our initial objectives, was deferred to another year due to concerns about safety and security. These are nearly all large river caves, voluminous, and well decorated in places, and the dry passages frequently contain quantities of Mayan artifacts.

SENSITIVE ECOLOGICAL AREAS AND SPECIES INVENTORY OF ACTUN CHAPAT CAVE, VACA PLATEAU, BELIZE

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This project is the first effort to synthesize information on both invertebrate and vertebrate observations from a Belize cave. Based on limited field research and a review of literature, we identified two ecologically sensitive areas, and developed a species inventory list containing 41 vertebrate and invertebrate morphospecies in Actun Chapat, Vaca Plateau, west-central Belize. Actun Chapat contains two ecologically sensitive areas: (1) a large multiple species bat roost, and (2) a subterranean pool containing troglobites and stygobites. The inventory list is a product of sporadic research conducted between

1973 and 2001. Ecological research in this cave system remains incomplete. An intensive systematic ecological survey of Actun Chapat, with data collection over multiple seasons using a suite of survey techniques, will provide a more complete inventory list. To minimize human disturbance to the ecologically sensitive areas, associated with ecotourism, we recommend limited to no access in the areas identified as "sensitive."

2004 EXPEDITION OF THE SANGKULIRANG PENINSULA IN EASTERN KALIMANTAN

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In the August 2004 Cyndie Walck and Shane Fryer assisted a Nature Conservancy expedition to Eastern Kalimantan to assess future protective status for four karst areas that included orangutan habitat on the Sangkulirang peninsula. The multidisciplinary expedition involved geographers, entomologist, arborist, biologist, archeologist and geologist just to name a few. A large effort was placed on understanding cave development, cave biological communities and hydrologic systems of the areas.

ECOTOURIST CAVING IN GUANGXI PROVINCE, CHINA

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China is home to half the world's karst, and Guangxi province is renowned for its spectacular fengcong and fenglin tower karst. Several organizations are now offering ecotourist-type cave trips to this region, and three of us from the USA spent two weeks in October with one of them, visiting a dozen caves in Leye and Fengshan provinces, several of them unsurveyed, and conferring with the Karst Institute of Guilin about a program of American expeditions. Our guides were local cavers, including the Flycats club in Leye. Until recently, harvesting formations for sale was rampant in some of these caves until the government outlawed it. Ecotourism in the caves provides an alternative means of income for the local people and may offer the best protection for them yet. Cave-for-pay in undeveloped caves is a mixed bag, and we made numerous suggestions for better conservation (especially flagging routes through areas of delicate floors). But most of the caves are large and spectacular and very easy to explore, and could result in less overall impact when led by those with a stake in the cave's resources. China also has many spectacular show caves ranging from small operations controlled by local villages, to large tourist meccas with carved marble walkways and interestingly translated signs.

ENTERING THE JAGUAR'S REALM: DISCOVERY OF PICTOGRAPHS AND GLYPHS IN A BELIZEAN CAVE

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The recent discovery of Painted Cave is significant, as it represents only the ninth cave known to contain painted Maya writing and the first to be found in Belize. The Painted Cave corpus is unique as the glyphs are large and executed entirely in red. A rare depiction of a jaguar, a symbol of Maya royalty and common occupant of cave entrances, accompanies the text.

NATIONAL KARST DATABASE INITIATIVES

SUBTERRANEAN BIODIVERSITY DATABASES: DATA ACQUISITION AND QUALITY CONTROL

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There are several problems associated with data acquisition, including (1) intellectual property rights, (2) issues of security and accessibility, and (3) data compatibility. Each data entry is typically the result of considerable effort both in the field and in the laboratory, and there are typically hundreds if not thousands of entries from dozens of scientists and collectors. A great deal of concern has been raised about accessibility of data, but little advantage has been taken of the possibilities of making location information less precise than would be needed to find the cave. Different researchers have proposed often elaborate database structures whose complexity is often in inverse proportion to the amount of data collected. A minimum database was proposed at a workshop on mapping subterranean biodiversity sponsored by the Karst Waters Institute and the Laboratoire Souterrain. A major problem with most lists of location information is the relatively high rate of errors resulting from transcription errors from maps and failure to indicate which datum (*e.g.*, 1927 North American Datum) is being used. Another problem is how to treat undescribed species or specimens that could not be identified to species with certainty. Finally, the problem of taxonomic synonymies is an especially vexing one.

THE NATIONAL KARST MAP AND ITS RELATIONSHIP TO KARST FEATURE DATABASES

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The U.S. Geological Survey KARST Project is producing a new national karst map of the United States. This map is being compiled in a GIS at a resolution of 1:1 million. The new data are being generated in several phases. A first approximation of karst areas is provided by isolation of soluble bedrock units derived primarily from state geologic maps. The potential karst areas are then subdivided into karst types reflecting regional styles of karstification. Criteria being considered include: geologic setting, physiography, and the distribution and density of caves, sinkholes, and other karst features. Other variables such as ecoregions and the known geographic distribution of cave organisms may also be considered. The compilation and classification process is complicated by: 1) unevenness in spatial precision and classification of lithologic units between the various geologic maps; 2) lack of easily obtainable statewide and region-wide karst data, especially cave locations; and, 3) recognition of key, non-lithologic factors affecting the development and expression of karst features. Because of differences in scale and scope, the National Karst Map dataset will have a top-down relationship to other karst databases. This relationship can be thought of as somewhat analogous to the relationship of metadata to data. The new Karst Information Portal (KIP) offers a potential framework for integration of data sets of all resolutions from national to local scales.

COOPERATIVE DATABASES

William R. Elliott

Missouri Department of Conservation

My experience includes creating and managing cave and cave life databases for the Texas Speleological Survey, Texas Parks & Wildlife Department, Balcones Habitat Conservation Plan (Texas), and the Missouri Department of Conservation. I also contribute to and borrow data from the Missouri Speleological Survey. My discussion is derived from the perspectives of cavers, cave surveys, conservationists, researchers, and bureaucrats. In my opinion, a national cave or karst database will be unpopular unless state cave surveys are invited to participate. There are two key questions: 1) Will cave names and precise cave locations be available to the public or only to qualified researchers? 2) Who owns the data, or who controls it? The Missouri Cave Life Database (CLD) is a cooperative project of 12 partners that I developed. It contains no permanent tables of cave coordinates, but it has cave name, county, and MSS accession number. This avoids political/legal problems. When needed for GIS work and analysis, a special table of "biocaves" from the MSS can be related.

About 17% of the 6,100 caves in Missouri are “biocaves.” The end products are maps with cave symbols generalized to diameters of 3-10 mi. (5-15 km). Decimal degree coordinates provide several advantages over other systems. A national cave life database is achievable. The CLD is adaptable to other states and countries. It draws on published literature and observations by multiple partners. It allows fauna lists to be produced for a cave or an area, and it provides for biodiversity analysis.

THE FUNCTIONS AND FRUSTRATIONS OF STATE AND REGIONAL SPELEOLOGICAL SURVEYS

George Veni

President, Texas Speleological Survey

The Texas Speleological Survey (TSS) “is organized for scientific, educational, and conservation purposes, with the specific objectives to collect, organize, and maintain information on Texas caves and karst, and to generally make that information available to responsible persons and organizations. [It] reserves the right not to distribute certain information if it could result in the exploitation or degradation of cave or karst resources [and] will work with caving organizations to make science an important part of all cave-related activities.” Speleological surveys around the world are created with the same general goals as the TSS. They share the often conflicting challenges of collecting, archiving, and disseminating cave data, while protecting the data and ultimately the caves from misuse and harm. Methods vary from having membership to non-membership organizations, free to fee-based data access, and access based on personal acquaintance to contractual agreements. The methods appropriate to one region may not be completely effective elsewhere. Most data collection and data-basing methods have arisen independently. International standardization methods have yet to become popular due to language barriers, cultural differences, rapid changes in software, cumbersome communication methods, and different needs and types of information gathered. Many of these obstacles are breaking down and more cave surveys are also beginning to archive information on karst features. Growing pains will occur, but multi-regional and international speleological surveys will inevitably develop as communication between regional surveys increases.

DEVELOPMENT OF A KARST INFORMATION PORTAL (KIP): THE IMPORTANCE OF KARST DATABASES

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The University of New Mexico, the National Cave and Karst Research Institute, Los Alamos National Laboratory, and the University of South Florida are partnering to develop the Karst Information Portal (KIP) to promote open access to karst, cave, and aquifer information and linkages among karst scientists. Our purpose is to advance karst knowledge by: (1) facilitating access to and preservation of karst information both published and unpublished, (2) developing linkages and communication amongst the karst community, (3) promoting knowledge-discovery to help develop solutions to problems in karst, (4) developing interactive databases of information of ongoing karst research in different disciplines, (5) enriching fundamental multidisciplinary and interdisciplinary science, and (6) facilitating collection of new data about karst. The KIP project is currently (1) transforming *A Guide to Speleological Literature of the English Language 1794-1996* into the portal's first searchable on-line database and (2) creating an institutional repository of scanning electron micrographs from research in caves that includes social software to promote linkages among karst scientists. In addition to these initial databasing efforts, KIP organizers hope to stimulate the development of new karst-related databases and the inclusion of existing ones.

CONSERVATION & RESTORATION

ROBBER BARON CAVE, TEXAS: SURFACE RESTORATION AND MANAGEMENT FOR SUBSURFACE SPECIES

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Known since the 1910s, Robber Baron Cave is a former show cave that developed a rich history as San Antonio, Texas, grew around it. Vandalism resulting from the cave's urban location resulted in the construction of a series of four gates beginning in 1980, each more secure than the last, until the placement of an impenetrable five-ton concrete bunker. However, this bunker restricted airflow and nutrients into the Robber Baron Cave, which contains six endemic invertebrate species of which two are federally listed as endangered. The Texas Cave Management Association (TCMA) has since acquired the cave and also a grant from the U.S. Fish and Wildlife Service to improve the species' habitat. Originally, TCMA planned to modify the bunker, but structural instabilities were discovered that required its complete removal. This allowed restoration of the entrance to its near-original state, with a secure but ecological sound gate that allows the natural passage of air, water, nutrients, and organisms. Restoration work currently in progress includes new fencing, trails, and sinkhole stabilization. Additionally, exotic vegetation has been removed and native vegetation will be planted to support some non-listed yet ecologically key cave species that exit at night to forage. The use of native plants will obviate the need for watering and chemical treatment, while supporting the cave's endangered species. When restoration is complete, signage and a kiosk will be installed so the landscape over the cave can serve as an educational resource for the community.

GOT CAVE? NO BATS? WE CAN HELP WITH THAT: BAT CONSERVATION INTERNATIONAL'S SEARCH FOR RESTORATION SITES

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The traditional approach to cave conservation for bats has been to identify caves with populations and then to limit access during the critical season, either by voluntary closure or by gating if necessary. However, recent discoveries have shown that many of these protected caves are only marginally suitable. In 2005, based on the research of Dr. Merlin D. Tuttle, Bat Conservation International initiated a project to locate and survey caves that may contain evidence of previous habitation. In 2005–2006, a team of cavers led by Cat Kennedy visited 39 caves in Indiana and Kentucky during six weeks of field work. Assistance was also provided by caving organizations, state authorities, cavers and local landowners. As a result, BCI has identified 10 key sites that combined would have housed millions of bats. Our next step is to further evaluate each site for restoration to its former, more suitable conditions. One example is Saltpetre Pit in Kentucky, which currently serves as a home for the third largest known colony of Rafinesque's Big Eared Bats in the world. The 22-meter pit entrance to this cave was more than half filled with household trash and debris. The American Cave Conservation Association and BCI conducted a sinkhole cleanup in July 2006, to remove the entrance flight zone obstructions. BCI continues to lead field work to document these sites and make management recommendations in order to restore bat populations, especially for the endangered Indiana bat.

CREATIVE FUNDING OF GRAY BAT PROTECTION IN SOUTHWESTERN VIRGINIA

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Virginia Speleological Survey Director Jim West observed clustering bats in Bacon Cave, Lee County, Virginia, in 2002 while surveying. The Virginia Department of Conservation and Recreation (DCR) and Department of Game and Inland Fisheries documented a resident bachelor colony of up to

4000 federally listed endangered Gray bats (*Myotis grisescens*). The cave's entrances are in a cliff face along the Powell River, a tributary of the Upper Tennessee River. Trash, fire pits, and excavations made by pothunters and parties indicated the need for a cave gate. Grigsby Cave in Scott County hosts a transient population of Gray bats from April through June, ranging from a handful of individuals to several thousand bats. Over the last decade, cavers documented increased guano accumulation rates and new roosting sites in the cave, suggesting possible maternity use. Evidence of ongoing disturbance by spelunkers made clear the need for a gate. Interagency coordination between DCR, Department of Game and Inland Fisheries, and the Department of Mines Minerals and Energy arranged for Paramount Coal Company to fund gating of Bacon Cave by the American Cave Conservation Association (ACCA) as compensatory mitigation for closure of an unstable mine portal in Wise County used by a small population of *Myotis liebigii*. ACCA worked with the US Fish and Wildlife Service to gate Grigsby Cave, using the \$14,000 Paramount settlement as matching funds. Other conservation partners included Bat Conservation International, The Nature Conservancy, and NSS cavers. Bacon was gated in August 2005, and Grigsby in June 2006.

CAVING AND THE BOY SCOUTS – OH THE HORROR! REACHING OUT TO THE FUTURE OF A KARST COMMUNITY VIA A SPELEO VENTURE CREW PROGRAM

Patricia E. Seiser

Cave Stewardship Research Volunteer

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The NSS has worked hard to develop guidelines for youth group caving activities. Initial reaction to forming a caving-based Venture Crew, a youth group associated with the Boy Scouts, was negative. Supporting the organization of such a group was needed for the following conservation reasons: the community was located in a karst region, dependent on karst based industries (oil, gas, and cave tourism), and those kids who stayed in the region as adults would be faced with karst land-use decisions. Support for future cave and karst stewardship is dependent on the kids we take caving today. The Carlsbad Speleo Venture Crew teens learn how to cave responsibly and are exposed to various aspects of speleology and cave conservation. We anticipate that participation will increase their understanding of cave environments and ecosystems, as well as karst systems in general, so they can become responsible cavers now, and be responsible cave neighbors and managers in the future.

CAVE BIOTA—AN EVOLVING “WEBUMENTARY”

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Media can be a successful partner in cave conservation. Newspaper, film, and the Internet can help inform the public on land use practices that affect cave life and that are general indicators of environmental conditions such as water quality. There is a direct correlation between the number of informed public and the quality of cave stewardship. The Hoosier National Forest, Indiana Karst Conservancy, and National Speleological Society are sponsoring a cave biology video produced by Ravenswood Media of Chicago, Illinois. Various clips are currently available on northern cavefish, cave salamanders, bats, pseudoscorpions, and macroinvertebrates, and more are in the works. The clips will be edited into a thirty-minute video for distribution and use by individuals and organizations. Educational components that relate to general academic standards and integrate with cave education programs such as Project Underground, Project Wet, and Project Wild have been developed. The project is being considered for television production. For more information, see: www.cavebiota.com.

CONTAINING HUMAN-INTRODUCED DEBRIS ALONG THE PUBLIC TOUR ROUTE IN OREGON CAVES

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More than 53,000 visitors touring Oregon Caves each year bring in debris such as dirt, lint, hair, and shoe material. Many show caves contain and/or remove such material because of its ecologic and visual impact. The effectiveness debris mitigation depends on the environment and tour route design. Oregon Caves has a higher ratio of natural versus introduced organics than

many dry caves. This reduces ecologic impacts, but dripping water increases organic decay and reduces the effectiveness of traditional lint removal. Water also spreads organic material to areas beyond the trail areas. Clear, vinyl tarps were ordered to size with grommets and installed in Oregon Caves below stairs and grated walkways. On tarps below stairs, debris and water flow into basins fitted with filters that retain debris and release water. Fittings mounted in tarps below horizontal bridges and walkways allow drainage into buckets with filters. The tarps are periodically rinsed with cave water to flush collected debris into the filters, and the filters on the buckets and basins are cleaned regularly. The tarps likely mitigate much of the impacts of human-introduced debris on cave biota.

PALEONTOLOGY

A PLEISTOCENE TAPIR FROM A VIRGINIA CAVE

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Remains of a Pleistocene tapir have been found in a newly discovered cave in Bath County, Virginia about five hundred meters from the dug open entrance to the cave. The tapir remains include a nearly complete but dorso-ventrally crushed skull, three cervical vertebrae, rib parts, a partial scapula, a humerus and a partial ulna. A metatarsal was found about 3 meters from the main cluster of bones. The skull has deciduous premolars and freshly erupted first molars indicating a juvenile. Based on available measurements, the tapir is identified as *Tapirus veroensis* and is probably late Pleistocene in age. Other vertebrates found near to the tapir include bats, a deer mouse, and a snapping turtle skull.

MISSISSIPPIAN AND PLEISTOCENE VERTEBRATES FROM HAYNES CAVE, WEST VIRGINIA

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Haynes Cave in Monroe County, West Virginia has produced vertebrate fossils from the Mississippian limestone and the Pleistocene sediments in the cave. The Mississippian fossils are represented by the small teeth of two kinds of shark, a xenacanth and a pavement toothed type. The Pleistocene vertebrates include fish, amphibians, reptiles, birds and mammals. The mammals include two large extinct species: a ground sloth, *Megalonyx jeffersonii*, and a peccary, *Mylohyus fossilis*. There are nearly 30 species of small mammals. The fauna includes two rodents, the Cumberland deer mouse and the Trout Cave vole, both extinct species that probably date to the late Irvingtonian land mammal age, about 600,000 years before present. Most of the other species are late Pleistocene in age and include the yellow-cheeked vole, a species that now inhabits northern Canada and Alaska. A partial scapula of the sloth has been radiocarbon dated at nearly 36,000 years before present. Unfortunately Haynes cave was heavily mined for saltpeter, thus making interpretation of the stratigraphy of the sediments difficult.

LET THOSE BONES BE: LESSONS IN PALEONTOLOGICAL CONTEXT AT UNTHANKS CAVE, VIRGINIA

David A. Hubbard, Jr. and Fredrick Grady

Virginia Speleological Survey

In the fall of 1996, a caver called saying he'd passed the notorious Easter Pig Sump in Unthanks Cave. He'd found a borehole passage with a large bone protruding from a mud bank. Concerned that the sump would re-close for another decade or that the bone might wash away before a recovery trip could be made, he packaged and transported the bone beyond the sump in this gated cave. The authors obtained written owner permission, which satisfied our existent blanket paleontological permit, and recovered the limb-bone during the 1996 DOM. The well-packaged tibia was missing its proximal end (knee-end of the lower leg-bone) at a fresh break, and the distal end was too abraded to make a determination. After a discussion on the importance of context and the missing terminus with the caver, he made a return visit and determined that addition bone was present and scheduled a joint visit. In September 1997, a very

modest excavation yielded the missing proximal end and the fragmental fibula of *Arctodus simus*, the greater short-faced bear. The proximal end of the tibia was in contact with bedrock and buried in a sandy gravel deposit underlying an over-bank deposit of clayey silt in a paleo-streambed. The same periodic high-stage flooding events that sent flood waters coursing through the pirated cave stream passage and transported the bones to their location, deposited gravel and a clayey silt layer over the bones, eventually eroded those sediments to partially expose the tibia, and replenished the paleo-stream passage sump. The discovery of the 12,000 year-old short-faced bear of Unthanks Cave provides an important illustrative lesson on context. As initially recovered, the fragmental tibia was unidentifiable, but examination of the bone site allowed full recovery of the specimen, subsequent identification and rationale for radiocarbon dating, and a partial interpretation of how these remains came to rest in Unthanks Cave.

SURVEY & CARTOGRAPHY

SURVEY SHOT LINKING ORDER AS AN INDICATOR OF ACCURACY

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Development of the CMAP survey data reduction program to handle forward references led to having versions that produced three different survey shot linking orders. If the survey network is sufficiently well connected, the different versions produce three relatively independent survey paths to any part of the survey. This small sample provides an indication of the consistency and accuracy of our surveys. For a good survey with blunders having been resurveyed, the different locations of a station fit inside a box whose diagonal is on the order of 3 to 4 percent of the straight-line distance from the entrance. This tends to support the old rule of thumb that the accuracy of a survey is about 2 percent. Of course the linking order does not affect the location of stations after closure adjustment, but the adjustment method does. Locations produced by least-squares and sequential adjustments differ by 0.5 to 1.0 percent. Different weighting factors in the least-squares adjustment affect the locations by less than 0.5 percent. This type of analysis is less effective for non-maze caves.

BASELINE INFORMATION FOR UNDERSTANDING, MANAGING AND PROTECTING CAVES AND KARST

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In order to effectively manage, protect and conserve caves and karst, it is important to have basic knowledge about their physical extent, nature and attributes. Geographic data, resource inventories, and photodocumentation provide the baseline of information necessary to understand cave and karst resources. Synthesis of this information into maps, databases and geographic information systems provides the framework from which to make sound and intelligent resource management decisions. Such baseline data and information is also a starting point for scientific research. Ultimately it is research that will further knowledge and understanding about caves and karst.

HUMAN FACTORS AND CONTROLS – MITIGATION AND DETECTION OF COMMON SOURCES OF PROBLEMS THAT INFLUENCE THE ACCURACY OF CAVE SURVEYS

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In-cave surveys create a perfect storm for errors and blunders. Poor conditions, substandard equipment, and inexperienced and fatigued personnel all contribute to poor-quality surveys. Thirty years of surveying in Mammoth Cave have taught us much about survey techniques and the sources of errors and blunders. Besides the often discussed, albeit general, topic of survey accuracy, we have become aware of common situation occurrences (the human factor) that have the greatest likelihood of creating the bane of surveyors — the blunder. A good understanding of these common causes of errors, and of the in-cave survey-scenarios that can contribute to this problem, offers opportunities to not only prevent survey problems, but also to detect them during post-survey analysis. There are common, blunder-prone survey-scenarios; approaches that have proven to be effective in addressing them; and techniques for analysis to assist in blunder detection.

US EXPLORATION

BLACK CHASM CAVERN: JEWEL OF THE MOTHER LODE

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Black Chasm is a vertical cave developed in Permian-age, recrystallized limestones of the Calaveras group near the gold rush town of Volcano, in Amador County, California. Its passages likely began forming some two million years ago. The earliest written record of the cave dates to 1854, when it was explored by gold miners during the gold rush era, including a perilous rope descent of over 30 meters to the bottom of its main chamber. In the 1950s, local grottos began exploring it, and a group of Sierra Club climbers traversed the main pit and found a room festooned with crystal-clear helictites. Tom Rohrer made a very basic map of the cave in the 1960s, published in *Caves of California*, and one of the cave's deep lakes was dove to 24 meters with scuba gear. The cave was designated a National Natural Landmark in 1976 for its helictites. In 1996 the cave was purchased by Sierra Nevada Recreation for development, and construction of an elevated trail was completed in 2001. In 2003 we began a project to thoroughly survey and photo-document this unusual cave. We located at least one new area and rediscovered a few others. A detailed map produced by Hazel Barton shows 956 meters of passage and 45 meters of depth. Besides the helictites, the cave is notable for its large boxwork and many outstanding examples of pool spar, some of it hexagonal in form.

RECENT EXPLORATION AT JEWEL CAVE

Mike Wiles

Jewel Cave National Monument, 11149 US Highway 16, Custer, SD 57730

Since July 2006, over 4.2 km of passages were discovered and mapped. All but 365 meters were discovered in the southeastern section of the cave on four four-day trips. Several unsuccessful attempts were made to push beyond a linear geologic obstruction that had stopped several passages in the area. Other new mapped passages stopped against a second linear obstruction, but barometric airflow indicates there is much more cave beyond. New discoveries include passages up to 20 m wide and 15 m high, and upper-level passages with tilted bedding. In January, a 1,524 meter loop was closed with only 3 m of closure error. In February, explorers finished mapping the Encore, a room 45 m wide, 75 m long, and 9 meters high, that had been discovered in early 2005. The total surveyed length of Jewel Cave reached 218.2 km and surpassed that of Optymistychna Cave, making Jewel Cave the second-longest cave in the world.

CAVES OF THE 1919 LAVA FLOW IN KILAUEA CALDERA, HAWAII: A PRELIMINARY REPORT ON A 12 YEAR STUDY OF 200+ CAVES

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A 12-year application of speleological techniques documented that the 1919 Postal Rift lava flow in Hawaii's Kilauea Caldera contains more than 200 caves. For this, 167 field trips were conducted in 22 field seasons. Only two caves had been identified here prior to this study. Most of this flow's caves were found to be drainage structures rather than classical lava tube conduits: hollow tumuli, drained flow lobes, tongues, breakouts, etc. Several melt holes were found to have integrated once-individual caves into compound caves. Many of these caves are hyperthermal, with 100% relative humidity. Some are notable for thermostratification and/or changing underground wind currents. These meteorological conditions required development of new exploration techniques. Noxious gas (probably HCl) was encountered only in one tiny cave on the edge of Halemaumau Crater. Two types of CO₂ monitors required for the last five field trips were found to be useless in hyperthermal caves. Hundreds of pages of raw data and individual field trip reports have been submitted to the National Park Service. Processing these data is expected to require many months. Systematic speleological studies are urged for other Kilauea lava flows, especially another 1919 flow in Hawaii Volcanoes National Park. Also, mineralogical studies of these caves begun by Bobby Camara in cooperation with the USGS Hawaiian Volcano Observatory should be completed.

WIND CAVE SURVEY PROJECT UPDATE, 2006

Rodney D. Horrocks

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The first ever Wind Cave Quadrangle book has recently been completed. This Atlas contains 192.45 kilometers of drafted survey drawn on 37 individual Mylar sheets at a scale of 6 m/cm (50 ft/inch). These "quadrangle" maps cover an area of 457 × 305 m (1,500 × 1,000 ft). The atlas contains survey statistics for the entire Wind Cave survey project, including a list of everyone that has gone on more than five survey trips (205 people). During the previous seven years, the Wind Cave survey has grown at an average rate of 7.2 km a year, and this trend is expected to continue into the foreseeable future. Since July 2005, a total of 82 trips resulted in 6.79 km of survey and inventory. The official length of Wind Cave increased from 187.76 to 194.65 km. The most significant discoveries during this time period were the Gas Chamber, Ghost Town, Stalactites Galore, EX survey, Big Fish Canyon, Cow Hoof Lake, & End of the Road areas. On February 13, 2006, the Wind Cave survey passed Hoelloch Cave of Switzerland to become the fourth longest cave in the world. In recognition for 16 years of volunteer service at Wind Cave National Park, The Colorado Grotto was chosen by the Midwest Region of the National Park Service as their nomination for the 2005 George B. Hertzog Volunteer Group Service Award.

SNOWY RIVER DISCOVERY IN FORT STANTON CAVE

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Fort Stanton Cave, New Mexico, has 17.7 km of surveyed passage, with large trunk passages and long crawls. Significant portions of the cave have been found through digs. Beginning in 1970 a team of cavers began digging through collapsed breccia, with solid wall on one side and loose breakdown on the other. After five years of difficult work chasing air, they suspended operations at Menacing Dome. This portion of the northern branch of the cave required traversing through deep mud and flooded passage during the 1980s and early 1990s. When the water receded, work resumed in a dig called Priority 7. In 2001, the 140-meter-long dig opened into a stunning trunk that paralleled previously known cave, and was paved for ~2.9 km with a white calcite coating from wall to wall. Methods were developed to minimize impact while studying and surveying the new passage, called Snowy River. In 2003, nearly five kilometers were surveyed in Snowy River and a large parallel paleo-trunk named the Metro. An unexplored stream heads off the map at the northern end of Snowy River. The south end was not pushed due to logistics. In 2005, cavers decided that the risk of sending teams through the challenging Priority 7 route was unacceptable, and a new bypass dig was planned and started. When the new dig is completed, stabilized, and an environmental gate installed, further exploration of Snowy River will continue.

EXPLORATION IN LECHUGUILLA CAVE

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Lechuguilla Cave, New Mexico, was dug open 20 years ago. Rapid exploration of the cave occurred in the first 5 years, but progress has slowed as the frontier has become more remote. Survey expeditions continue to take place in the massive western branch, primarily in the Chandelier Graveyard, Widowmaker, Mirage Room, Hudson Bay, Zombie Zoo, Mother Lode, and Southern Climes. In the southern branch, a big dome above the Prickly Ice Cube Room known since 1988 was climbed 39 meters into an area named Flatlands. Another long, promising climb in Prickly Ice Cube room was started, but not completed. In the eastern branch, a second expedition to Coral Seas found additional passages between Boundary Waters and La Morada room. Teams continued exploration near La Morada and the Outback, finding additional passage at the -404 meter depth. Several teams continued exploration and mapping in day trips near the Rift, fixing loops and sketching errors and discovering some new passages. Since July 2005, cavers have mapped 7.3 km of passage, increasing the cave length to 189.4 km (117.7 mi).

THE DISCOVERY AND EXPLORATION OF RUSSELL'S RESERVE CAVE---BATH COUNTY, VIRGINIA

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Clues pointed to the existence of a large cave in a limestone ridge in southern Bath County, Virginia. The indicators included swallets in the stream bed that resurge many kilometers away, a sandstone capped limestone anticlinal ridge, and blowing fissures. In April of 2005, work began on a strongly blowing

opening more than a meter above the surface stream level. The following October, after digging 26 m through the fissure filled with sandstone breakdown, cavers broke into Russell's Reserve Cave. The cave's passages were found to be on several levels, being generally large and having many classic phreatic features, including a large natural bridge. In some areas, numerous drill holes in the clay deposits exposed bones washed free from ancient sediments. Initial discoveries include a Pleistocene tapir and a remarkably intact black bear skull, also probably of Pleistocene age. Surveyors discovered a sizable stream in the furthest reach of the cave. The stream is flowing in an open passage and headed toward a surface river just 366 m away, but at an elevation nearly 12 meters lower. As of June 2006, 5.9 km have been surveyed.

CAVE HILL: THE BEGINNING OF THE END?

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Major new discoveries have been made over the last two and half years during the Virginia Region's (VAR) survey project at Grand Caverns, the United State's longest continuously operating commercial cave, now a regional park. The cave celebrates its bicentennial this year, and the VAR was asked by the park to create a new map of the cave befitting this milestone. At the 2005 NSS Convention we reported the discovery of a previously-untouched tight crawlway which led to massive virgin cave. Since that time, even more major passage has been found in Grand Caverns. The survey was finally declared finished this year, expanding the cave from 1.1 km (3600 ft) to over 6.1 km (3.82 mi). On other parts of the hill, several more caves have been found, and will be mapped.

LAVA CAVES OF SOUTHERN WASHINGTON

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The lava caves of southern Washington are mostly spread over four flows from two separate mountains. During the last decade, a concentrated effort to locate and map these caves has led to an understanding of the flow dimensions. The two sources are Mount Saint Helens and Lemei Rock. On Mt St Helens, the flow is over 8 km long with over 457 m of elevation change. Lemei Rock is in the Indian Heavens Volcanic Field and has three distinct flows from its center. On the west side is the Fall Creek flow, to the northeast is the Smokey Creek flow and to the southeast is the Trout Lake flow. Each of these flows can be traced over eight kilometers and probably represent many eruption events. Cavers have surveyed over 200 caves totaling nearly 80.5 km of passages. Approximately three quarters of these caves are located within the Gifford Pinchot National Forest. Cavers are working with the Forest Service to record locations, photograph, place monument markers, and incorporate cave survey data into their GIS for all of their significant caves.

UPDATE ON EXPLORATION IN THE OMEGA CAVE SYSTEM: 2000 TO 2006

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Since 2000, the Omega Cave System has grown dramatically in length and complexity. Annual week-long camp trips deep in the system have discovered and mapped more than 16 km of new passage, with no end in sight. The discovery of several large stacked paleo levels above this main stream passage, as well as an extensive paleo infeasible complex from a small surface stream gap, has contributed much of the new passage. The main stream passage in the cave continues upstream and to date has a total length of 8.5 km. The upstream extension of the cave was discovered at the top of a climb bypassing a waterfall. This discovery promises to be just as complex and extensive as the rest of the system. A new cave entrance leading to a stream passage descended a series of wet and muddy shafts and connected to the main system in 2005, bringing the total number of entrances to three. The total length of the Omega System now stands at 36.76 km, with a depth of 385 m. Potential to add additional length and depth remains high. Other caves near Omega have been found, surveyed and explored. Including Omega, nearly 50 km of passage have been surveyed in the past 10 years. Hydrologic studies have been used to aid exploration efforts in the area and are revealing a highly complex system.

EXPLORING THE DEPTHS OF MAIN DRAIN CAVE, UTAH

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In the summer of 2004, a breakthrough in entrance series of Main Drain Cave led to passages reaching a terminal sump at a depth of 358 m, making it Utah's deepest cave. In 2005, exploration continued through an overflow route to another terminal sump at a depth of 374 m. Main Drain Cave now stands as the ninth deepest cave in the United States. There is still potential to bypass this sump and push the cave deeper.

THE WEBSTER CAVE COMPLEX SURVEY GROUP (WCCSG)

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The WCCSG is dedicated to the exploration and survey of the Webster Cave Complex, Breckinridge County, Kentucky. The three known entrances to the system are nestled in Sinking Creek Valley, surrounded by the 243-meter-high ridges. More than a dozen caves make up the Webster Complex. The main passage of this cave is over 5 km long and frequently 12 m in diameter, making it one of the largest continuous trunks in the state. In places, continuous lakes extend for over 800 m with neck deep water from wall to wall. Recently, the WCCSG has started a systematic resurvey and exploration of the known caves of the area. This commenced in May, 2005 with the survey and continued exploration of Webster Cave. The main cave survey is more than 8 km long (including about 1,600 m of newly discovered passage) and has not been fully mapped. Numerous leads remain unexplored. The source and resurgence of this stream are not known, so the potential for additional cave discovery in the areas is high.

CAVES OF THE POHAKULOA TRAINING AREA, U. S. ARMY, BIG ISLAND

HAWAII

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The United States Army has sponsored the study of lava tubes on the Pahokuloa Training Area on the Big Island of Hawaii. Recent efforts to study these features have included the documentation of many kilometers of lava tubes. To date, three major lava flows have been studied. Each flow has distinct characteristics and has resulted in a variety of cave systems. The Delta Cave System is the longest to date, with just over 8 km of accumulated survey. Formation is believed to have happened quickly (days to weeks) within a flow of average volume (probably 1–3 m³/s). The tube is best described as embryonic in nature. Bobcat Trail Cave resulted from a larger flow volume with longer flow duration and has resulted in a more mature type of cave development. Puu Koli (Red Cone) is radically different from either of the other two systems currently under study. The cave is layered or stacked and was the result of a long duration, small volume flow. Extensive downcutting and false floors between levels have built the cave into its current form. This cave is located at higher elevation than the others under study, which has resulted in smaller amounts of water percolation through the system, allowing extensive gypsum deposition within the cave.

THE GREAT CRACK — BIG ISLAND, HAWAII

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The majority of lava caves in Hawaii are formed by very fluid lava flowing down the sides of the mountain to form tubes at shallow depth beneath the surface. Recent exploration on the Big Island has revealed a much more interesting and challenging type of volcanic cave development. Each of the three active mountains is formed on the same basic plan. Three equilateral fault zones radiate outward from a central dominant caldera. In each case, two of the zones are dominant. The third is buried beneath the shoulder of the adjacent mountain. The Southwest Fault Zone of Kilauea Volcano is a nearly continuous single fault that often opens to the surface and can be traced for nearly 48 km along this line. Exploration into this fault system has documented caves more than 183 m deep and up to 800 m long. These primarily tectonic features have also been found to have carried lava flows for distances of up to thirty-two kilometers outward from the center of the volcano. In many cases, these secondary flow events have modified the original crack structure and added a roof to the open crack system. A new term, *crubes*, has been suggested to describe these combined crack-tube features.

EXPLORATION AND MAPPING AT GAP CAVE AND IN THE PINE MOUNTAIN REGION OF KENTUCKY, VIRGINIA, AND TENNESSEE

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The Cave Research Foundation (CRF) Cumberland Gap Project has been conducting a multidisciplinary study at Cumberland Gap National Historical Park in Kentucky, Virginia, and Tennessee. Since 2003, CRF has been mapping Gap Cave, and 50% of the known cave has been surveyed. The cave is currently more than 13 km (8 mi) long and 145.7 m (478 ft) deep. Since the start of the project, 3.7 km (2.3 mi) of virgin passage has been mapped. Cumberland Mountain is the southern edge of an uplifted fault sheet more than 85 km (53 mi) long. The limestone containing the cave is 171 m thick in this area. The northern exposed edge of the uplifted fault sheet, Pine Mountain, is the secondary focus of research. Mapping and exploration of this area has resulted in 56 caves, including Pit-Up Straight Creek. There is high potential for additional cave exploration and research in the area.

FURTHER EXPLORATION IN ROPPEL CAVE, KENTUCKY

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Roppel Cave, Kentucky, was discovered in 1976 and mapped to a length of 79 km before it was connected with Mammoth Cave in 1983, forming a system of 473 km. Since the connection, further work in Roppel has evolved from early, rapid exploration into a systematic, three-dimensional mapping and exploration project. While the areal extent of the cave has not changed a great deal in the ensuing 23 years, an additional 48 km of passage have been explored, including some large passages. New passage has been found in multiple additional levels within only a few meters of known passage. Technical climbing has been used extensively to reach unexplored upper levels. "Micro-camps" during trips longer than 36 hours, as well as camping for up to four days, have been used to explore remote areas. Exploration of other caves in the area has led to the connection of Hoover Cave into the system in 2005. This was the first new natural Mammoth entrance since the 1983 connection. There has been a strong emphasis on survey standards, and the project has been recognized as having the second highest data quality of any large cave project in the world.