

SELECTED ABSTRACTS FROM THE 2002 NATIONAL SPELEOLOGICAL SOCIETY CONVENTION IN CAMDEN, MAINE

BIOSELEOLOGY

UNIQUE MICROBIAL DIVERSITY IN AN APHOTIC CAVE HOT SPRING

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Glenwood Hot Springs, Colorado, a sulfide-rich hot-spring system, issues from numerous springs before eventually flowing into a commercialized pool. To examine the effect of light energy on microbial community structure in such a sulfide-rich environment, we examined microbial communities from two of these springs; the photic 'drinking spring' and the aphotic 'dark-zone,' which flows through a cave. Both of these springs contain white, filamentous microbial communities, and the water flowing through them is chemically and physically identical. Molecular-phylogenetic analysis using 16S rRNA, revealed significant differences in community structure between the photic and aphotic filament communities. The filaments from the photic 'drinking spring' consisted predominantly of a single phylotype, an Epsilon-Proteobacteria related to a hydrothermal-vent symbiot. In the aphotic 'dark zone', the filamentous community displayed significant microbial diversity, with 58 phlotypes representing 7 domains of the Bacteria, including the Proteobacteria, Green non-sulfur and OP11 divisions. In addition, Archaeal species not previously identified under the conditions of temperature and pH found in the hot spring were identified only in the aphotic spring. The results suggest that the absence of light has a profound influence on microbial community structure, presumably through the development of complex metabolic networks required for chemolithotrophic energy conservation. This may suggest a higher degree of complexity in sulfur cycling by aphotic, subterranean communities.

TROGLOMORPHY IN THE CAVE FISH *POECILLIA MEXICANA*, FROM CUEVA DE VILLA LUZ, TABASCO, MEXICO

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The cave fish *Poecillia mexicana*, a type of molly, is found only in Cueva de Villa Luz (aka Cueva de las Sardinias) in Tabasco, Mexico. The cave has mixed energy inputs from sulfur, bats, and through multiple skylights. This rich food base supports an amazing density of the cave fish. Studies done in the 1950s and 1960s stated that the fish showed increasing troglomorphic adaptations and less hybridization with surface forms deeper into the cave. However, the previous data show considerable variation and overlap of characteristics by sample location, and no statistical analyses were done. We wanted to determine if fish in remote areas of the cave had smaller eyes than those in areas near the surface stream. We used a Polaroid camera to take pictures of captured fish for measurements and analysis. Our results show variation in troglomorphy, but no statistical differences in fish from any part of the cave. The rich food base in this cave may reduce pressure to develop troglomorphy.

METABOLIC AND ISOTOPIC DIVERSITY OF CHEMOAUTOTROPHIC SULFUR-OXIDIZING BACTERIA FROM LOWER KANE CAVE, WYOMING

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Microbial communities from Lower Kane Cave (Wyoming) were investigated using phylogenetic analyses of 16S rRNA gene sequences and detailed isotopic surveys. Microbial mats from three sulfidic spring locations were discretely sampled along flow transects, from anaerobic waters in the spring orifices through the aerobic discharge channels, with mats extending 10-15 m from the orifices. Dense mats were 3-10 cm thick, and had short (<1 cm) and

long (>10 cm) white filaments interconnected with white web-like films on the surface, and a gray-brown gel of filaments underneath. Discontinuous patches of yellow biofilms also intermixed with short filaments. Most of the microorganisms identified from the mats were sulfur-oxidizing bacteria. *Thiobacillus* spp. were detected from yellow patches, and short filaments along the stream channels were closely related to *Thiothrix unzii*. The most abundant bacterial populations in all the filamentous samples belonged to an uncharacterized group of sulfur-oxidizing bacteria within the epsilon-Proteobacteria class. Similar organisms have been found in other sulfidic systems, including Cesspool Cave (VA) and Parker Cave (KY). Microbial mats from Lower Kane had an average $\delta^{13}\text{C}$ value of -36‰, demonstrating chemoautotrophic fractionation against ^{13}C from an inorganic carbon reservoir (cave water was -8.9‰). Each of the sulfur-oxidizing bacterial morphotypes, however, had distinct carbon isotope compositions, indicating that pathways for obtaining carbon may be slightly different. These complex populations provide energy for the cave ecosystem as chemoautotrophs, while driving speleogenesis due to sulfide oxidation and the production of sulfuric acid.

CAVE DIPLURA OF GEORGIA

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Examination of 27 collections of campodeid diplurans from 20 caves in northwestern Georgia revealed five distinct species belonging to the genus *Litocampa*. Each species belongs to a different species group. The *cookei* group is represented by the widely dispersed *L. cookei*, having been found in Howards Waterfall Cave in Dade County. The *henroti* species group is represented by an undescribed species known from caves in Dade and Walker counties, and from other caves in Tennessee and Alabama. The *valentinei* and *pucketti* species groups are each represented by an undescribed species, having been found in caves in Chattooga County and Walker County, and Dade County and Walker County, respectively. Both of these species are also known from neighboring Alabama caves. Lastly, a new undescribed species belonging to the primitive *condei* species group was collected from a cave in Bartow County. The discovery of this new species offers further support for the hypothesis that the ancestral home for most of the cavernicolous species of *Litocampa* in the United States was the highlands of southeastern Tennessee.

ANOTHER CHAPTER IN THE BIOSPELEOLOGICAL INVENTORY OF VIRGINIA CAVES

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Since the publication of Holsinger & Culver's 1988 work on the cave invertebrates of Virginia and northeastern Tennessee, biospeleological inventories of cave invertebrates have continued. Their work included records of invertebrate fauna from 319 of 2377 Virginia caves known in 1988. From late 1989 to 2000, a total of 317 Virginia caves have yielded new records from identified collections of cave invertebrates in 25 of the 26 solutional cave-bearing counties in the Virginia Valley and Ridge province, and solutional caves in one county each in the Virginia Blue Ridge and Piedmont provinces. No new identifications were made in Frederick County. Records from caves in Bedford (Blue Ridge province), Clarke, and Loudoun (Piedmont province) are the first cave invertebrate records from these counties. Of the 317 caves reported in this study, 83 were included in the earlier study but have yielded addition records. The two studies have yielded identified cave invertebrates in 553 caves out of the 3884 Virginia caves known in 2001. Both studies include other caves from which no collections were made, or from which collections have not been identified.

In addition to a better understanding of the biological resources of Virginia caves, these studies have saved some caves from destruction or minimized impacts of roads and other land-use changes. Regrettably, Virginia caves continue to be affected by land-use changes. In some cases, we now know that biological resources have been lost by habitat destruction or cave destruction.

DISTRIBUTION AND ABUNDANCE OF THE MIDGE *GOELDICHIRONOMUS FULVIPILUS*, IN CUEVA DE VILLA LUZ, TABASCO, MEXICO

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The terrestrial and aquatic ecosystems in Cueva de Villa Luz (aka Cueva de las Sardinas) in southern Tabasco, Mexico, are based on energy inputs of both organic material and sulfur. Sulfur bacteria in the stream are a major source of food for the chironomid larvae of *Goeldichironomus fulvipilus* (formerly *Tendipes*, then *Chironomus*). Several aspects of the life history of this midge have been studied. Adults lay abundant egg cases just at the waterline, which hatch into minute red larvae. The larvae live in cases, with the highest density found in rapidly flowing water. When they pupate, the adult midges emerge from the water. Adults do not feed, but often reach such high densities that they produce an audible buzzing sound, as noted in the naming of the Buzzing Passage and the Other Buzzing Passage. Adult midges are initially red from larval hemoglobin, but change to a green color within 24 hours. The ratio of red to green midges is significantly different in different parts of the cave. Capture of emerging midges also shows a variable distribution, with productivity ranging from < 1/m² per day in silt-bottomed areas of the cave, to several hundred per m² per day in riffle areas. The productivity determines the ratio of red to green adults. The midges are an important source of food for the cave fish in the stream and support large numbers of spiders in the terrestrial system.

A SYSTEMATIC APPROACH TO SAMPLING THE ARTHROPOD ASSEMBLAGE OF GREGORYS CAVE, GREAT SMOKY MOUNTAINS NATIONAL PARK

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Recent extensive bioinventories such as the All Taxa Biodiversity Inventory (ATBI) in progress in Great Smoky Mountains National Park (GSMNP) have spawned several studies both above and below ground. Though faunal inventories are common in biospeleology, quantitative sampling techniques for cave arthropod populations are few, and studies of this nature in GSMNP are non-existent. In this study, a systematic sampling approach with standardized, repeatable methods determined population sizes and spatial distributions of 11 arthropod taxa in Gregorys Cave, and a comprehensive species list was compiled. Monthly sampling trips, from May 2000 to April 2001, yielded 46 arthropod species representing 35 families, 16 orders, and 5 classes. Of these, 29 were new records for the cave, with two being undescribed species and at least one a new record for GSMNP. Of the 11 taxa studied in detail, all but two showed significant fluctuations, both of their monthly population and their distribution within the cave relative to the entrance. Aquatic arthropod populations were also monitored, and their presence and abundance compared to factors influencing the water table. Richness and dissimilarity indices were calculated for the 12 months of sampling. The greatest numbers of species were observed during November 2000, December 2000, and February 2001, and the peak changes in taxon composition occurred between May 2000 and June 2000. I propose that epigeal weather parameters brought on by seasonal change greatly influence the arthropod community in Gregorys Cave.

POPULATION STUDIES OF THE AQUATIC SNAIL *PHYSA SPELUNCA* (GASTROPODA: PHYSIDAE) FROM LOWER KANE CAVE, WYOMING

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Most cave ecosystems are energetically limited, depending on the transport of organic materials into the system from the surface. In contrast, Lower Kane Cave, Wyoming, contains sulfidic waters that support abundant communities of sulfur-oxidizing microbes, which use chemical energy to produce food. Other cave systems containing comparable microbial communities have abundant and diverse invertebrate fauna associated with this type of sulfur-based production (e.g., Movile Cave, Romania; Frasassi Caves, Italy). While its invertebrate fauna assemblage is not as diverse as similar systems, Lower Kane Cave contains an extremely abundant aquatic snail, *Physa spelunca*. Stable isotope analyses show that *P. spelunca* sampled from within the cave feed on the microbial mats, with both $\delta^{15}\text{N}$ (7.5‰) and $\delta^{13}\text{C}$ (-36‰) values exhibiting typical trophic effects. In contrast, snails collected from the

entrance of the cave had $\delta^{13}\text{C}$ values (-26‰) typical from terrestrial C3 photosynthesis, indicating a shift to surface productivity. The abundant microbial food source has led to extremely high population densities in the immediate vicinity of the mats, with estimates as high as 6800 individuals/m². Although *P. spelunca* was originally described as exhibiting classic troglomorphic features (i.e., eye reduction and pigment loss), observations of the Lower Kane Cave population indicate that there are at least two other color morphs present (red and black). Preliminary investigations into the genetics of this unusual cave population have been initiated based on internal transcribed spacer gene regions, in order to estimate genetic diversity and evaluate population structure.

WHEN CAVE FISH SEE THE LIGHT: REACTION NORM TO LIGHT EXPOSURE DURING DEVELOPMENT IN EPIGEAN, TROGLOMORPHIC, AND HYBRIDS OF *ASTYANAX FASCIATUS* (CHARACIDAE)

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The study of phenotypic plasticity among hypogean fauna has been virtually ignored. Anecdotal accounts suggested that the development of troglomorphic features such as blindness and depigmentation could be epigenetically influenced by exposure to light. We conducted a series of experiments to ascertain the reaction norm to light on eyes, pigmentation, and behavior among epigeal (eyed, pigmented), troglomorphic (blind, depigmented), and hybrids (epigeal X troglomorphic) individuals of *Astyanax fasciatus* (Pisces: Characidae). Results show that light (or its absence) can strongly influence the development of pigmentation in the regressed eye and swimming behavior of different stocks of this fish species. These results may have important implications in the understanding of the reduction or loss of features during evolution. The ability to respond to changes in light regimes may explain the different phenotypes among many taxa that can be found in the hypogean environment. Further, this phenotypic plasticity may be an adaptive feature on which natural selection acts to determine survivability in the cave environment.

PRELIMINARY REPORT ON INVESTIGATIONS OF RED IMPORTED FIRE ANT (*SOLENOPSIS INVICTA*) IMPACTS ON KARST INVERTEBRATE COMMUNITIES AT FORT HOOD, TEXAS

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Red Imported Fire Ant (RIFA), *Solenopsis invicta*, predation upon karst invertebrate communities in central Texas has been reported in studies by Elliott, Reddell, and Cokendolpher. We have begun a year-long study of 6 caves that seeks to quantify aspects of this phenomenon. The study sites are at Fort Hood (Bell and Coryell counties, Texas), near the northern limit of the Edwards Plateau. Caves there harbor a variety of troglomorphic macroinvertebrates, including several narrowly endemic taxa. Above ground, we use timed bait censusing to measure RIFA foraging activity on a grid of points centered over cave entrances and conduct mound counts within the study plots. Inside the caves, timed RIFA bait traps are placed along an in-cave transect. Visual censusing in a 0.1 m² quadrat frame quantifies diversity and abundance of cavernicoles along the in-cave transect. Preliminary results corroborate earlier observations, in that RIFA mound density and foraging activity are higher at disturbed, open sites. RIFA foraging on the troglomorph *Ceuthophilus secretus* in and outside of caves suggests that the interactions between these two species could have a negative impact on cave communities. We have observed an active RIFA foraging trail in the dark zone of a cave (2 cm soil temperature 17.0°C) while epigeal 2 cm soil temperatures were too low for surface foraging by RIFA (average 12.8°C), demonstrating that RIFA can use the cave community as a food source when temperatures near the surface are too low for foraging.

CAVE RESCUE

FALL FACTORS AND COW'S TAILS: THE DANGERS OF USING STATIC AND DYNAMIC ROPES FOR COWS TAILS

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Static rope should NEVER be used for cow's tails or other applications where it may be required to catch a fall. Any slack between the climber and the anchor when using static rope can be fatal if the climber falls. Static rope is not capable of absorbing energy. The different forces that affect a fall can be seriously underestimated on short falls, such as one might experience when falling on a cow's tail. Falling 4 feet on 2 feet of static rope creates a fall factor that significantly exceeds the maximum fall factor of 2, and can cause anchors, carabiners, and harnesses to fail. It can also cause serious injury or death. Dynamic rope is a safer alternative for cow's tails but still must be treated with caution. The ability of a dynamic rope to absorb the energy of a fall is primarily a function of how much rope is between the climber and the anchor.

Cavers should try to keep possible falls below a fall factor of 1. The easiest way to do that is to make sure that the anchor is always kept above the point where the cow's tail attaches to the harness, and to use a dynamic attachment. A two-foot fall on two feet of dynamic rope creates a fall factor of 1. This fall is half as hard as a fall factor of 2. Commercial available products like the Zyper and sewn cow's tails are the safest alternative, as they are designed to absorb considerable energy in case of a fall. Traversing should never be done with cow's tail alone. An ascender must always be on the rope as well.

CREATING A PREPLAN FOR CAVE RESCUE

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A previously prepared plan for a cave rescue helps with activities during a stressful time. As a trip leader, you may have to send an inexperienced person to call for help. A PrePlan gives that person a checklist and resource list so when they reach the surface, they don't have to depend on memory. It also helps the first arriving rescuers, since they are probably not trained cave rescuers. Fire Departments live by SOGs, Suggested Operating Guidelines, and SOPs, Suggested Operating Procedures, so one doesn't have to depend on memory during a stressful event. Giving the commanding officers SOPs or SOGs is giving them a road map, and turning an event that was an unknown quantity into something understandable.

Including a rescue PrePlan in a cave management plan allows people to determine the potential trouble spots. Then you can assign the resources needed to move patients in various conditions from those spots to the surface. You can also determine what extreme measures, such as bolting formations or passage modification, might be needed and acceptable. Thom Engel created an excellent rescue PrePlan as part of the management plan for the Knox Cave Preserve.

COMMUNICATIONS AND ELECTRONICS

OPERATING LED HEAD LAMPS AT THREE VOLTS AND BELOW

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A 24 LED head lamp operating from a single LiSO₂ D cell with a 7.5 AH capacity is a good combination for use in expedition caving. It can operate at maximum brightness for 12 hours. This is made possible by the addition of a low-dropout, 3-terminal voltage regulator to a LED head lamp that uses a switching supply based on the MAX1698 integrated circuit. Efficient operation is possible over a range of 2 to 9 volts, but the battery voltage must be at least 2.6 volts for the light to start operating. Operation is also possible using other battery combinations including 3 to 6 NiMH cells or even 6-volt gel cells. Over 4 hours of light at maximum output is possible with 4 rechargeable 1.8 AH AA NiMH cells. By adjusting the light output to only what is needed, the light can operate for well over 8 hours.

WATER TRACING EXPERIMENTS IN BELIZE USING AN INEXPENSIVE TOTAL DISSOLVED SOLIDS METER

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A low-cost (\$39 US), pocket-sized, temperature-compensated, digital Total Dissolved Solids (TDS) meter and an alcohol/glass thermometer were used to collect data from several water sources in the Barton Creek Cave system and from associated insurgences, springs, and surface streams. A TDS meter measures electrical conductivity, corrected for temperature, but is typically calibrated in parts per million (ppm) of calcium carbonate. The data collection and dye tracing were part of the 2002 Barton Creek Cave Mapping pro-

ject, under the auspices of the Western Belize Regional Cave Project directed by Jaime Awe for the Belize Department of Archaeology.

Several insights resulted from these simple measurements. We concluded that 3 streams (120 ppm/21.4°C; 127 ppm/22.2°C; and 367 ppm/24.4°C) found near the terminal breakdown in Barton Creek Cave come from separate sources. Our on-site guess was that the Slate Creek insurgence (18 ppm/21.1°C on the surface) was the main source of the first stream and the insurgence in the "Vega" near Mountain Equestrian Trails (45 ppm/22.2°C) was part of the source of the second stream. Dye tracing, with materials and analysis generously donated by Nicholas Crawford of Western Kentucky University, later proved these guesses to be correct. The third stream comes from a large crystal clear siphon. It may not be a good bet for diving because the TDS and temperature suggests that the water has been underground for a long time and may come from diffuse sources in the karst aquifer.

CONSERVATION AND MANAGEMENT

LA CUEVA DE LAS BARRANCAS, PROTOTYPE SITE FOR MARS STUDIES

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La Cueva de las Barrancas, a desert cave first entered in 1991, is managed as a pristine subterranean laboratory for speleological research. The cave management prescription, approved by the US Forest Service in 1999, prioritizes scientific investigation in the cave. In Barrancas, science goes first, before exploration, survey, or cartography. Sampling and investigation for microbial life are initiated in each new passage before other scientists or cavers are allowed to enter. Some areas are left untainted by human entry, preserved as virgin sites for future studies.

Because this cave offers a protected environment for scientific study, the management plan contains innovative features describing limits of acceptable change and protocols for exploration, survey, and research. Included in the plan is a Minimum Impact Code of Conduct for cavers and scientists entering the cave, and Barrancas is managed cooperatively through a "Memorandum of Understanding" with cavers who assisted in writing the management plan.

Science in Barrancas has progressed from doing initial baseline studies of subsurface microbial life to establishing the site as a prototype for subterranean studies on Mars and other planets. Grants awarded by the NASA Institute for Advanced Concepts support using Barrancas as a test environment to develop low-impact operational logistics and no-impact *in situ* techniques for the study of microbial life in sensitive environments. These efforts will advance the study of other pristine and previously impacted cave sites, as well as the study of fragile surface environments.

CONSERVATION EFFORTS AT SPENCER MOUNTAIN, VAN BUREN COUNTY, TENNESSEE

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Tennessee State rules protect streams determined to be "High Quality" against degradation by pollutants or the removal of habitat. A decision to allow the discharge of treated wastewater into Dry Fork Creek, a karstic High Quality stream that flows through Fall Creek Falls State Park, prompted a hydrogeologic study in the Spencer Mountain area of Van Buren County. The study, carried out in summer and fall of 2000, defined major subsurface flow paths and delineated groundwater basins. The results are available to the permitting agency, the permit applicant, environmental advocacy groups, and the Tennessee Water Quality Control Board to help decision-makers evaluate potential impacts of the proposed wastewater discharge and identify discharge alternatives.

A coalition of environmental groups was formed to encourage Spencer and the permitting agencies to protect the stream and associated cave system. The coalition cooperated with US Environmental Protection Agency to study alternatives to the stream discharge. A biologic survey found 24 cave-dwelling species, including 19 unique or rare species. The US Fish and Wildlife Service filed for emergency listing of species at risk and asked the state not to allow the discharge. In order to use public opinion for political leverage, the discharge issue and existence of the caves beneath Spencer were revealed to the news media. The coalition found significant deficiencies with implementation of federal and state environmental protection laws. The issue was heard by the

state Water Quality Control Board, and lawsuits are filed in state and federal courts. Final resolution is pending.

THE BECKIS PROJECT - ESTABLISHING A GIS FOR CAVE AND KARST CONSERVATION IN BERMUDA

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The islands of Bermuda, located in the Western Atlantic Ocean ~1000 km off the coast of North Carolina, contain many significant caves. Bermuda is a densely populated country with ~65,000 inhabitants and a land area of roughly 57 km². Approximately 150 caves have been discovered in Bermuda, many of them profusely decorated with delicate and unique speleothems. Many caves include passages that extend to sea level and contain deep anchialine pools and extensive underwater networks. A large variety of cave-adapted life, including previously unknown species, has been found in these underwater caves. Of the species identified in Bermuda's caves, 25 are currently on the critically endangered species list. The high population density and resultant development pressures, vandalism, pollution, and other negative factors have had a significant impact, and continue to threaten Bermuda's unique cave resources.

In early 2002, the Bermuda Cave and Karst Information System (BeCKIS) project was established, with the primary goals of increasing public awareness of Bermuda's caves and cave life, increasing awareness of negative impacts on these resources, and promoting the scientific study of Bermuda caves. The BeCKIS uses GIS software to maintain a database and inventory of cave locations, and incorporates field observations and other measurements along with both dry cave and submerged cave survey data and maps. GIS maps have been used to establish baseline quality information from past observations, and additional GIS projects are proposed.

CAVE ASSESSMENT, MAPPING, AND CAVE POLICY FORMULATION RESEARCH PROJECT IN SIX BARNAGAYS OF RAJAH SIKATUNA NATIONAL PARK, BOHOL, PHILIPPINES

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An 8-month cave exploration and mapping policy formulation research project was carried out in 6 barangays containing part of Rajah Sikatuna National Park in Sierra Bullones, Bohol, Philippines, from June 2001 to February 2002. The research project had 2 parts: technical exploration and mapping and the development of cave management guidelines and policies. All aspects of the research were carried out with the active participation of local barangay residents. A total of 26 caves with horizontal entrances were explored and mapped in the study. Information collected included surface vegetation, cave features, resources inventories, flora and fauna inside the cave, extent of damage and evidence of treasure hunting, and cave history. A cave coding system was instituted. Thirteen different speleothem types were observed. Resources in the caves included guano, rock phosphate, sand, speleothems, water, and bird nests. Six caves showed evidence of treasure hunting. All data and results were presented to individual participant barangays. A workshop was held on policy and cave management guidelines. The study caves were classified for eco-tourism (show and wild caving), resource use (guano, water, swift nests), and scientific value. Ten strategies for proper cave use were formulated. The research showed local residents can explore, map, and determine management policies and strategies, if given proper guidance and training. Further studies are underway at the site.

CAVE PERMIT SYSTEM OF GUADALUPE RANGER DISTRICT, LINCOLN NATIONAL FOREST

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The Lincoln National Forest, New Mexico, implemented a closure order in 1972, restricting cave access to those with a permit. Over the years, the permitting process has evolved to provide enhanced protection for cave resources, while still allowing recreational use of most of the Guadalupe Ranger District caves.

Following policy and direction set in the Forest Service Manual, Lincoln National Forest Plan, the Federal Cave Resources Protection Act of 1988, and Lincoln National Forest Cave Ecosystem Management Direction, the Lincoln National Forest caves are managed as nonrenewable resources to maintain

their geologic, scenic, educational, cultural, biological, hydrologic, paleontological, and recreational values. Caves have been assigned management classifications, based on visitor potential impact on the caves' ecosystems. Management classifications range from Class 1 to Class 6. Class 1 defines a cave as highly developed, and Class 2, 3, and 4 as undeveloped. Class 5 and 6 caves are closed to recreational use.

Management Class 2 caves may be visited with a guide or approved Trip Leader. To allow more people to visit Management Class 2 caves, a Trip Leader program was developed. Cavers become approved Trip Leaders when they participate in restoration projects within a certain cave, or when they complete in-cave Trip Leader training.

A Cave Steward program is being considered. Cave Stewards would work under Volunteer Agreements and receive in-depth training to protect cave resources while leading visitors on recreational trips.

CONSERVATION AND RESTORATION

TOURISTS AND ENTREPRENEURS: CAVE PRESERVATION IN THE 19TH CENTURY UNITED STATES

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The first impulse toward preserving underground natural spaces came from visitors who feared that the aesthetic qualities of caves were jeopardized by vandalism and other threats to these important cultural spaces. This anxiety led to informal efforts to create new behavioral norms for tourists and, in the remarkable case of Horace Martin, a call for government protection of America's most important cave, Mammoth Cave of Kentucky. A second group, cave entrepreneurs, also supported cave preservation, though they were motivated by overriding pecuniary interests and implemented an approach based on regulating the behavior of tourists. Neither visitors nor proprietors recognized other threats to caves, such as extractive mining or industrialization of karstlands. Aesthetic preservation, still the dominant thrust of cave conservation today, was the primary basis for nascent efforts at protection, while biological, geologic, and historic preservation were non-existent. Compared to other environments, cave preservation was late in arriving and generally ineffective until the 20th century.

GEOLOGY AND GEOGRAPHY

APPLICATIONS OF CAVE DEPOSITS TO TEMPORAL HYDROLOGIC AND ENVIRONMENTAL CHANGE

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Cave deposits can preserve physical, biologic, and chemical records of the temporal and spatial scales of the processes involved in the development of aquifers and landscapes. Studies of growth rates, trace elements, and isotopes illustrate uncertainties involved and the novel advances that can be made with these methods. In central Texas karst (CTK), stalagmite growth rates correspond to glacial periods over the past 70 ka, as determined by 2 independent U-series dating methods. These results are consistent with wetter climates during glacial periods in this region. Based on faunal successions in cave sediments, a hypothesized major CTK soil erosion episode starting in the early Holocene is supported by a new application of Sr isotopes to estimate changes in ancient soil thickness. Paleoclimate studies infer temporal changes in drip water temperature and rainfall composition, using the temperature dependence of trace element and stable isotope partitioning into calcite. This approach assumes that equilibrium precipitation of calcite occurs and that other processes do not significantly affect trace element variations. These assumptions are tested in CTK by examining Mg and Sr variations in modern water samples from soil, vadose, and phreatic environments, reflecting increasing reaction with aquifer limestone. Geochemical variability in soils exerts a first-order control on regional and local water compositions. These effects are much larger than estimates of temperature control. Isotopic equilibrium is being tested by analysis of coexisting water and calcite pairs in CTK and Barbados aquifers. Modern aquifer systems provide important constraints for interpretation of paleo-environmental records derived from cave deposits.

USING CONTINUOUS DYE INJECTION TO SIMULATE CONTAMINANT TRANSPORT DURING PRECIPITATION EVENTS IN A KARST AQUIFER, FORT KNOX, KENTUCKY

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Traditional single-pulse dye injections effectively simulate the movement of a contaminant mass released immediately into a groundwater system. However, they do not address the movement of long-term, slow-release point source contaminants to the environment (e.g., leaking underground storage tanks). Accounting for both release modes would help develop a more effective groundwater monitoring program. This project developed a continuous dye injection program to simulate a potential long-term contaminant release to groundwater. Methodology included the continuous injection of dye, at a constant rate and concentration, over several weeks to establish baseline concentrations of dye at resurgent springs. Once the baseline was established, changes in dye concentration caused by precipitation events could be observed. Two trials were conducted in separate drainage basins under different hydrologic conditions. Dye concentrations showed similar behavior during the initial response to storm events; however, concentrations during post-storm monitoring varied significantly between the 2 trials. In trial 1, the dye returned to its baseline concentration as discharge returned to pre-storm volumes, suggesting uniform transport through the system with minimal residence time. Trial 2 concentrations did not return to baseline values but increased 5-fold and remained elevated for long periods, indicating that a majority of the dye was stored in the aquifer until mobilized by a storm event. Using dye as an analog for contaminant transport through a karst aquifer, the variations in dye concentration from this study demonstrate a need to develop more detailed groundwater sampling protocols to account for slow-release contaminants.

ROME TROUGH TECTONICS IN PULASKI COUNTY, KENTUCKY: KARST INDICATORS

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Karstification of Mississippian carbonates in southern Pulaski County, Kentucky, is extensive. The location and orientation of the passages and flow paths of several major karst conduits within the study area are independent of surface drainage patterns, suggesting a dependence on geologic structure. Geologic, geomorphic, speleogenetic, and statistical evidence gathered from within Jugonot, Coral, and other regional caves, as well as nearby surface features, represents probable faulting below the study area. Further evidence suggests this faulting is related to the Rome Trough structure formed during Iapetan rifting in the Late Precambrian to Middle Cambrian. Fractures and lineaments generated by minor reactivation of this fault system have propagated upward through Mississippian and Pennsylvanian strata as fracture swarms. To date, 5.4 km of passages have been mapped in Jugonot Cave, with a vertical span of 81 m. The nearby Coral Cave System has a current total length of 42 km (36 km connected), with a vertical span of 100 m. Evidence gathered from this study compared with seismic data provided by the Kentucky Geological Survey confirms the presence of a basement fault with a maximum offset of 880 m. This fault was previously hypothesized from magnetic and gravity-anomaly data. The surface expression of this fault is a lineament, mapped using surface and subsurface data, ~3 km wide, 20 km long, and oriented at ~065°. Structural, depositional, and geophysical evidence points toward 3 sub-parallel, right-lateral, oblique-slip faults in the Precambrian and Cambrian strata of Pulaski County related to Rome Trough tectonism.

SANNUR CAVERN, EGYPT, AND FORMATION CAVE, IDAHO, AS ROOFED GOURS

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Depositional carbonate caves ("travertine caves") are a neglected part of speleology. A considerable variety of morphologies is evident. One interesting type is represented by Sannur Cavern, in the Eastern Desert of Egypt, and by Formation Cave, in southeastern Idaho, USA. Although enormously different in size and in geomorphic settings, both caves are characterized by a half-moon horizontal section with a nearly horizontal floor, a near-vertical inner wall, and a backward-curved outer wall, which forms the roof as part of its curve. Thus, both appear to be large roofed gours. Additional studies are needed of depositional carbonate caves, in general, and of any additional roofed gour caverns that can be identified.

REGIONAL KARST MAPPING OF VIRGINIA'S VALLEY AND RIDGE PROVINCE COMPLETED

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The last regional karst maps of Virginia's Valley and Ridge physiographic province is published. The 1:250,000 scale maps include carbonate outcrop areas for 254 different 7.5-minute quadrangles, and were mapped from 1980 through 2001. All three maps include sinkhole and cave entrance locations plotted on a cultural base with geologic map units of limestones, interbedded limestones and dolostones, and non-carbonate rocks. The southern map, the third in the series, includes spring and resurgence features. The mapping of specific features conveys a sense of the relative degree of karst development throughout the province, but on a scale that minimizes their inappropriate use as site specific data. Sinkholes, springs, and resurgences were remotely sensed by stereographic viewing of leaf-off, low altitude (~3600 m), panchromatic aerial photography. Sinkholes (includes all karst depressions) range from a minimum size of 9 m to the 6.8 km long Dungannon polje. A total of 31,239 sinkholes are located on the southern map; the series map includes 48,807 sinkholes. Cave locations were provided as proprietary data for disclosure only at this regional map scale by Virginia Speleological Survey. Karst development increases markedly from north to south. By quadrangle, the maximum number of sinkholes observed for the three maps were: 501 on the Harrisonburg quadrangle, 776 on the Radford North quadrangle, and 1350 on the Crockett quadrangle for the northern, central, and southern maps, respectively. These maps define the extent of karst in the province and convey a relative degree of karst hazard potential.

VERMICULATIONS AND ASSOCIATED DEPOSITS IN SNEDEGARS CAVE, WEST VIRGINIA

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Vermiculations are deposits of incoherent materials made primarily of clays and silts. In Snedegars Cave, vermiculations are unusually abundant on walls of canyons in the Saltpetre Maze and on the ceiling of the Trunk Continuation passage. The vermiculations and associated deposits take a variety of forms. These include relatively uniform ceiling, wall, and ledge coatings, elongated spots and patches, isolated spots and stringers with well-developed haloes, interconnected stringers that locally resemble dendritic vermiculations, ledge undercut deposits, and rill coatings deposited in rill trails associated with descending condensation waters. Many vermiculations undergo annual wetting and drying cycles associated with abundant summer condensation and winter drying. However, detailed observations and repeated photography at selected locations have failed to detect active growth of vermiculations or major changes in vermiculation patterns since 1986.

At least four types of materials form the vermiculations. Red/brown clayey silts may be derived from similar deposits found on ledges, in plugged ceiling tubes, in anastomoses, as crack infillings on canyon walls, and on the surface in sinkholes. Brown/black clayey silts and clays occur primarily near the Saltpetre maze entrance and may be derived in part from forest soils and from the red/brown clayey silts. Gray/tan clays may include aeolian material plating out on surfaces moistened by condensation. Brown/red clayey silts may have coated the ceiling of the Trunk Continuation during waning stages of floods and may be derived from both the red/brown clayey silts and more recent suspended fluvial sediments carried by Cove Run into the cave.

INFLUENCE OF SOILS ON CAVE DRIPWATER GEOCHEMISTRY IN THE EDWARDS AQUIFER OF CENTRAL TEXAS

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Systematic differences in the geochemistry of cave dripwaters in the Edwards aquifer of central Texas are traceable to local soil variability. The Edwards aquifer is developed in karstified Cretaceous limestone and is well-suited to examination of groundwater evolution processes using vadose groundwaters (i.e., cave dripwaters), phreatic groundwaters, and soil leachates. Variations in Sr isotopes and Mg/Ca and Sr/Ca ratios offer insight into the influence of soils on groundwater geochemistry, sources of dissolved constituents in groundwater, water-rock interaction processes, and groundwater residence time. Samples from multiple caves across the region provide the potential to distinguish between local (e.g., within a single cave) versus regional effects.

Variations in Sr isotope values likely reflect changes in the relative Sr flux from soils versus carbonate host rocks, which varies in response to residence time and the corresponding extent of water-rock interaction. Strontium isotope values for cave dripwaters correlate inversely with both Mg/Ca and Sr/Ca ratios. Mass-balance modeling suggests that variations in fluid compositions are regionally controlled by groundwater residence times and water-rock interaction with overlying soils and host aquifer carbonate rocks. Local geochemical differences in dripwaters between individual caves are similar to differences in leachates of soils overlying the caves. These differences in the soils determine the starting point of a fluid evolution model, in which waters evolve along a compositional pathway from soil water, to vadose dripwaters, to phreatic groundwaters. Although soils affect local dripwater variability, the controlling processes on dripwater geochemistry and groundwater evolution are regionally extensive.

SUBAERIAL BEDROCK ALTERATION IN HIGH-CO₂ CAVE ENVIRONMENTS

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Subaerial dissolution of bedrock in a high-CO₂ environment produces pasty or fluffy material, which falls to the floor and onto ledges as irregular layers under smooth, corroded ceilings. Such deposits are most common in caves in dry climates, where through-flow of meteoric water is limited. These deposits and their mineral assemblages can help define past chemical and hydrologic conditions. Most of this material eventually solidifies into a hard rocky material, which can be misidentified as flowstone or bedrock. In many places the unconsolidated paste has flowed down the walls before solidifying. Where the weathered paste falls into wet areas, evaporation forces calcite and aragonite to precipitate, concentrating other ions such as magnesium. The carbonate ion activity also rises, because evaporative enrichment offsets its loss to the precipitating minerals. As evaporation proceeds, fractionation causes rarer minerals such as huntite, hydromagnesite, magnesite, and dolomite to crystallize. The exact assemblage depends on the initial magnesium concentration and the extent of evaporation. Solidified paste is often recognizable as opaque, white, very finely crystalline material. It provides evidence for intense condensation corrosion in the past, even in caves that no longer support such an environment.

HYDROLOGIC, LAND USE, AND HISTORIC CONCERNS RELATIVE TO THE ROSENDALE MINING INDUSTRY

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The Rosendale and Kingston district in southeastern New York State, USA, was the natural cement capital of the world from 1825 to about 1950. It is important to document the world-class historic value of this major economic industry before significant industrial artifacts are lost. Relict features remaining today include vast mines, kilns used to produce high grade hydraulic cement, and a canal and transportation network. The limestone belt worked by early miners is riddled with abandoned limestone mines. There is no comprehensive inventory of these features.

Limestone (i.e., karst) aquifers are particularly vulnerable to contaminant inputs because no natural cleansing occurs. Formerly discrete karst aquifer systems were often integrated when mining operations discordantly cut across them. Today, extensive water-filled portions of these mines, strategically situated near or at the furthest downstream end of Rosendale and Kingston area karst aquifers, represent vast untapped groundwater reservoirs. Consideration of both mine and hydrologic features are important first steps in natural resource protection. Tracer investigations have been initiated.

Our research strives to document and portray these features via a GIS data base. Work being conducted includes a field-based GPS inventory of mines, mills, kilns, springs, caves, and karst features. Aerial photography is also being used to locate vertically bedded mines. Digitized mine maps, a digital photography library, and GIS maps are being produced to graphically depict information and make it accessible to the community. We envision that this information will be useful as a tool to further community planning, to enhance ecotourism, and to protect groundwater resources.

GROUNDWATER FLOW VELOCITIES FOR THE DEEP ARTESIAN PORTION OF THE EDWARDS AQUIFER, NEAR COMAL SPRINGS, TEXAS
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Two tracer tests assessed groundwater flow velocities and flowpath relationships between the deep artesian and recharge zones of the Edwards Aquifer at Comal Springs, TX. Results of the tests will help calibrate flow models of the Edwards, design an improved ambient water quality monitoring program, and improve response to hazardous material spills. Comal Springs, the largest in the southwestern United States, with an average discharge of 8.5 m³/s, emerge from hundreds of individual locations and form the 1.2-km-long Landa Lake in New Braunfels, TX. The Comal Springs "complex" is located on the 250-m-displacement Comal Springs Fault, which juxtaposes the aquifer's recharge and deep artesian zones.

Over 80 participants, representing 4 countries and >15 public and private entities, monitored 30 surface sites and 3 municipal wells and collected and analyzed over 1600 water samples. A trace from the 200 m deep flowing artesian well (with a head about 5 m above ground level) yielded flow velocities of 290 m/d to springs 350-750 m away, and demonstrated conduit flow in the deep artesian zone. The dye emerged from rise points in a 400 m stretch of the middle of Landa Lake in an "underground delta" pattern. Dye was also detected in a municipal well 300 m from the dye-injection point. A second dye, simultaneously injected into a 25-m-deep well on the up thrown side of the fault, moved at 1400 m/d to a separate set of rise points at the springs.

ESTIMATING THE EFFECTS OF SEEDING-INDUCED RAINFALL ON KARST AQUIFERS

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Texas has one of the fastest-growing populations in the nation. With much of the state located in arid to semi-arid climates, cloud seeding is examined for its potential to replenish surface and groundwater supplies. Satellite interpretation of cloud structure is used in this study to identify clouds most suited for seeding, and probable seeding-induced rainfall (SIR) is calculated, based on limited ground calibration. The effects of SIR versus unseeded rainfall on groundwater were calculated primarily from mean recharge rates. However, most published recharge rates for Texas karst aquifers probably underestimate recharge, in some cases by nearly an order of magnitude. Recharge rates are better estimated by water balance calculations than by general permeability and porosity values that often do not account for karstic conditions. SIR was found to have high potential to significantly recharge karst aquifers. Due to the rapid discharge and flow-through rates in karst, SIR would be most effective in artesian aquifers with slower mean velocities and greater potential residence times through fracture and diffuse storage. Broad, aerially extensive unconfined karst aquifers with long distances to springs may also benefit from SIR. Small, narrow unconfined aquifers would probably rapidly discharge the enhanced recharge and not appreciably benefit from SIR. A comparison of SIR-enhanced Edwards Aquifer recharge versus diminished groundwater pumping following SIR over the city of San Antonio showed that the volume in pumping reduction would be 6 to 13 times less than the hypothetical volume of recharge from an equal size portion of the aquifer's recharge zone.

QUADRANGLES AS PIXELS: A PROPOSED TECHNIQUE FOR MAPPING CAVE DEVELOPMENT AT SMALL SCALES

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Preparing small-scale maps of karst areas at the State scale of 1:500,000 or a national scale of 1:7,500,000, poses unique challenges to the map maker's art. Existing karst maps typically display the outcrop pattern of karstic rock-limestones, dolostones, and gypsum. One of the most important measures of karst development is the extent of cave development. Although cave maps can be prepared at scales in the range of 1:100 to 1:1000 and "stick maps" can represent large caves at scales of 1:10,000 and below, representation at still smaller scales is difficult. The scheme of representing each cave by a dot fails to account for cave lengths. There may also be objections to maps that show

exact locations of caves.

The overall cave length per unit area is a better indicator of cave development than the number of caves per unit area. The USGS 7.5' quadrangle map is a useful, fundamental unit of area. Pennsylvania, a roughly rectangular, medium-sized state, is 40 quads east to west and 18 quads north to south. The total surveyed cave length within each quadrangle can be color coded on a logarithmic scale. A state map of cave length distribution is then shown as a mosaic of colored rectangles. Such a cave length representation lends itself to computer manipulation of database information and is adaptable to GIS formats. The colored quadrangle display gives a good sense of cave length distribution, but no indication of how many individual caves are present or where they are located.

CAPTURE ZONE ASSESSMENT FOR CONTAMINATED MUNICIPAL WELLS IN A CARBONATE AQUIFER

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Seven people died and about 2300 people became ill at Walkerton, Ontario, in May 2000 from contamination of the municipal water supply by pathogenic bacteria. Hydrogeological investigations have since sought to establish potential source areas, pathways, and travel times for this contamination.

A major hydrogeological investigation was conducted on behalf of the town of Walkerton in the summer of 2000. A numerical model of flow, incorporating the results of this investigation (assuming an equivalent porous medium and using MODFLOW), indicated that the 30-day time-of-travel capture zones extended up to 300 m from each of the 3 municipal wells. In February 2001, the hydrogeologic results obtained by the town of Walkerton were presented to a judicial inquiry. The author of this paper suggested that the carbonate aquifer at Walkerton was in fact karstified, implying that groundwater velocities could be far greater than the MODFLOW results indicated. This hypothesis was tested by convergent flow tracer testing to 1 well, which showed that groundwater velocities were about 80x faster than indicated by the MODFLOW simulation.

These rapid groundwater velocities show that the potential source area for the pathogenic bacteria extended far beyond the one farm initially implicated as the source of bacteria. These results vividly demonstrate both the importance of a precautionary approach in carbonate aquifers, in which karstic conduits may be present, as well as the usefulness of actually measuring groundwater velocities by means of tracer testing.

GEOLOGY - SPECIAL SYMPOSIUM ON PSEUDOKARST

THE ANVIL POINTS CLAYSTONE CAVE COMPLEX: WORLD'S LONGEST DRYLANDS PIPING CAVE?

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In recent years, a number of significant pseudokarstic piping caves have been documented in badland areas of northwestern Colorado. These typically occur in mixed claystone/sandstone debris-flow material along contacts with bedrock and resemble vadose solution caves in pattern and morphology. Their development is facilitated by high porosity in the matrix, a considerable content of shrinking/swelling clay, and high exchangeable sodium percentage. The Anvil Points claystone cave complex in Garfield County, in the Eocene Wahsatch Formation, is the most extensive thus far surveyed. It includes 3 genetically related caves, of which the longest is 625 m, 55 m of vertical relief, and 166 m maximum linear extent. The system is dendritic; a complicated sinkhole terrain feeds intermittent influx into several tributaries that converge into a discharge trunk. Passages are well-defined, with up to 12 m of overburden and with widely varying cross-sections, from crawlways to 6-m-high tubes and winding canyons. Breakdown chambers up to 9 m wide occur at 2 passage junctions. Internal piracy has diverted flow from some conduits. In one respect, these caves resemble ice and snow thermokarst: the roofs slowly sag, cycling surface material into the drains. In the process, bubble-like breakdown chambers may be formed above the stream level and migrate surfaceward. Such piping caves may exist on extraterrestrial planets like Mars, where weathering and intermittent water flow have occurred, but which have not necessarily been hospitable to carbonate solution cycles.

PSEUDOKARST: AN HISTORICAL OVERVIEW

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Pseudokarstic forms in loess were observed and described in China perhaps 2300 years ago. Roman writings mentioned lava tube caves on Mt. Etna. The presence of large talus, crevice, and glacier caves must have been known locally from early times.

During the early 20th Century, the specific terms "pseudokarst" and "pseudokarstification" originated several times, in several languages, and for several types of features. This created controversies that are still not completely resolved. Most of these pioneer reports described features remote from centers of learning, and their writers were not academics. They were commonly in obscure publications, and many were in languages that were not widely read, thus creating gaps in communications.

The German geologist von Knebel (1908) was apparently the first to use any of these specific terms. Beginning around 1927, Russian geologists pioneered the study of karst-like features in permafrost and poorly soluble rocks. In 1941, the title of a significant Italian paper used the term "fenomeno pseudokarstico," and Malaurie used the term in French in 1948.

In the 1950s, the term became commonplace in speleological publications in central European languages and began to appear in the American geological and speleological literatures. Late in the 20th Century, symposia on pseudokarst developed independently in central Europe and in the USA, and a IUS Commission for Pseudokarst now correlates advances in this rapidly growing branch of speleology.

CAROLINA PSEUDOKARST: AN OVERVIEW OF ITS MULTIFACETED SPELEOLOGICAL SIGNIFICANCE

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As of January, 2002, the files of the Carolina Cave Survey listed ~1525 caves. The vast majority of these North and South Carolina caves are pseudokarstic. These non-solutional caves in the Carolinas include such features as large stream-worn potholes, rock shelters, and waterfall alcoves formed by erosion and breakdown. Also of interest are small tafoni caves created by honeycomb weathering. There are numerous soil pipes and suffosion caves formed by the piping of underground water along weak zones of decomposing granite. The most extensive caves include mechanically produced talus and tectonic caves formed by joint enlargement through frost action, block creep due to exfoliation, cliff spalling, and more massive gravity sliding phenomena. The most prevalent rock types include sand- and siltstones, quartzites, granites, schists, and gneisses.

ROCK-CITY CAVES: DISTRIBUTION, MORPHOLOGY, AND GENESIS

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There are several categories of pseudokarstic caves, formed largely by processes other than dissolution of bedrock. These include 'accidental caves' those formed through the juxtaposition of rocks, such as the accumulation of talus or the falling away of a lower section of a cliff, leaving an overhang or a shelter cave. Rock-city caves result from the displacement of blocks of rock that have separated from bedrock. Rock-city caves differ from most other accidental caves because of their systematic movement of blocks in a uniform direction.

Geomorphologists describe rock cities as blocks that have become detached from the bedrock and separated by sliding, so that a network of avenues, often in two mutually orthogonal sets, forms spaces among the blocks. The result is the appearance of a 'city' composed of blocks (buildings) that have canyons (streets) surrounding them. Block gliding is typically facilitated by lithological differences between the moving blocks and the material on which they glide, for example, blocks of sandstone that have slid on an underlying shale. Rock-city caves require that some of the blocks form roofs. This occurs by differential sliding among superimposed strata, by toppling of some blocks, or where separated blocks have become lodged between glided blocks.

Rock-city caves are found in areas where the process of block gliding is common. Some noteworthy examples are found in the eastern states, including New York, Ohio, Pennsylvania, Virginia, and Tennessee. Several rock cities have been developed as tourist attractions or parks.

SEA CAVES OF RHODE ISLAND, USA

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Rhode Island, "The Ocean State," has at least 12 sea caves. Pirate and Conrads Caves in Newport were Victorian-era tourist attractions. The Boston Grotto recently discovered other sea caves; it is very likely that more will be

found. In Newport, 2 smaller sea caves are adjacent to the original Pirate Cave near Brenton Point. In Middletown, there is one sea cave within Purgatory Chasm, a Victorian attraction. In Jamestown, caves are located on Taylor Point, Fort Weatherill, and Lion Head.

Two factors control the location of the sea caves. The primary influence is a high-energy shoreline. Most of the sea caves are on or within 1 km of the Atlantic Ocean. Two small sea caves on Taylor Point, Narragansett Bay, are the furthest (7 km) from the ocean. The second factor that controls sea cave locations is the local structural geology. Faults allow sea caves to form in some of the most resistant rock in Rhode Island. The sea cave in Purgatory Chasm is in the Purgatory Conglomerate, a very tough, cliff-forming metaconglomerate, where a high-angle fault intersects the chasm-forming joint set. The sea cave at Fort Weatherill is in a fault zone within the porphyritic Lily Pond Granite. Better sea cave development occurs where faults and joints further weaken the less-tough meta-siltstones and phyllites of the Newport Neck, Fort Burnside, and Jamestown Formations. At Taylor Point, where the sea caves are 7 km from the ocean, phyllite of the Jamestown Formation contains sea caves at weaknesses related to joints and kink folds.

EROSIONAL AND SOLUTIONAL SEA CAVES OF NAHANT, MASSACHUSETTS, USA

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Nahant, a rock island connected to the mainland by a sand tombolo, has erosional and solutional sea caves. The cave area is on the Atlantic Ocean and 5.5 km from the mainland. It is a southeast-facing, high-energy shore with dramatic rocky cliffs. The cave area has complex geology with structural blocks and hundreds of black mafic intrusions that imprinted colorful contact metamorphism on faulted gray Cambrian strata.

There are 3 erosional caves (Swallows, Devils Cove, and Slime) in Nahant. Swallows Cave, known in colonial times and included in Hauer's Caves of Massachusetts, developed by erosion of a forked basalt dike in the Nahant Gabbro lopolith. The other caves are in the Pulpit Rock structural block. Devils Cove Cave formed in a shattered tholeiitic dolerite sill. Slime Cave, barely worth noting, is in folded and faulted Weymouth Formation meta-sediments.

Three solutional sea caves in Weymouth Formation limestone are unique to New England. The Weymouth is often contact-metamorphosed into colorful, insoluble rocks, but the portion with caves is a 3.6-m-thick unit of unmetamorphosed cherty limestone. The caves, which have oval or rectangular cross-sections, formed because of seawater dissolution of the limestone along joints. Devils Maze is on the north side of Devils Bridge chasm. Devils Chin and Devils Mouth Caves, on the south side of the chasm, go through a rock point. The caves are at different elevations above current sea level. Devils Mouth and Devils Maze are emerged sea caves, while Devils Chin is just above the current high-tide mark.

PSEUDOKARST DEVELOPMENT NEAR BARSTOW, CALIFORNIA

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An area near Barstow, California, which includes Rainbow Basin National Natural Landmark, contains numerous pseudokarst features and several sizable caves. The area is dominated by Tertiary lake-bed deposits and includes other sedimentary and volcanic ash layers. A fault system related to the San Andreas Fault has caused extensive folding and tilting of these layers, resulting in textbook examples of unconformities, anticlines, and synclines.

Runoff has been channelized by numerous faults and folds, and erosion occurs naturally along fractures and weaker beds. Heavy dissection of these sedimentary deposits in some areas has created significant gradients that have further channelized and concentrated runoff, resulting in tunneling and piping. Some areas are dominated by sinkhole-like structures, pits, and numerous small caves. Weathering of less consolidated layers also contributes to the development of small caves. Although the region is arid, seasonal rainfall contributes to these processes today.

CAVES FORMED IN SALT-BEARING ROCKS BY LARGE ANIMAL CONSUMPTION

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In their quest for salt, large animals are known to create cavities or caves in salt-bearing rock formations. Several examples of such caves are described in various publications. An example in Mississippi, Rock House Cave, was

visited by the authors in 1999. It seems to have been formed by deer. Perhaps the most spectacular example is Kitum Cave in Kenya. This cave has been excavated to a length >100 m by elephants. An ancient example is La Cuerva Milodon in Chile, which is reported to have been used by the now extinct Milodon. The several natural caves formed by this animal process constitute a unique class of pseudokarst features.

BRAINERDS CAVE: AN UNUSUAL PSEUDOKARST CAVERN

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Brainerds Cave in Jersey County, Illinois, is probably developed in the Edgewood Limestone of Silurian age. It is a relatively recent geologic addition to the landscape; the crack that formed the cave likely began to widen only a few thousand years ago. The cave is the only example of a "block-creep" cavern known to this author in the Midwest. It was created when a massive block of limestone separated from the high bluff above the Illinois River and began slowly sliding down the talus slope. A spacious cavern 3 m wide, 12 m deep, and 21 m long was formed between the downwardly advancing block and the main limestone massif. Small side passages exist along secondary cracks. The process is still continuing. No solution processes were involved in the genesis of this cave, but water seeping down the walls of the cavity from above adorned the cave with a few small flowstone deposits. Pounded chert nodules hint that prehistoric American Indians explored the cave.

The cave can be entered through a tight opening at the top of the bluff. The caver can chimney down to the bottom of the cave. Use of a handline is advised. Once the haunt of local children, Brainerds Cave is now owned and managed by Pere Marquette State Park. It is the home of a well established colony of little brown bats and numerous other cavern dwelling creatures. Entrance to the cave is currently allowed only with a research permit.

SUFFOSIONAL PSEUDOKARST, GRANITIC WEATHERING, AND SOME IMPERTINENT QUESTIONS CONCERNING THE UNIQUENESS OF KARST LANDFORMS

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Pseudokarst features have the appearance of karst landforms but are formed by processes other than bedrock dissolution. Volcanic landforms are pseudokarst only because of the interest in cave exploration common to karst caves and lava tubes. Glacial caves and surface features are either karst or pseudokarst depending on whether or not one considers the melting of ice to be equivalent to the dissolution of rock. Development of karst requires a pronounced differential dissolution to bring out the relief of sinkhole or pinnacled surface karst or the creation of large cave passages in otherwise solid bedrock. Very rarely is the development of karst a purely dissolutional process. In nearly all karstic rocks, there is a residue to clay, sand, and chert that must be removed by mechanical processes. This, in turn, requires flow velocities much greater than those found in granular aquifers.

Consider two traditional types of pseudokarst: granitic weathering and suffosional pseudokarst. Weathering in fractured granites and occasionally in fractured sandstones can result in pinnacle landforms not visually distinct from karst pinnacles. The differential weathering is dominated by the chemical breakdown of feldspar minerals, with concurrent transport of quartz and other insoluble minerals. Suffosional pseudokarst, which includes caves of substantial size, is found in insoluble but poorly consolidated sediments. Transport is by particles held in suspension by the development of turbulence along certain flow paths. Suffosional pseudokarst also requires high flow velocities and channelized flow. There is no clear-cut boundary between karst and many categories of pseudokarst.

HUMAN SCIENCES

BEEN THERE, GOT THE BUTTON

Steven J. Stokowski, Jr., Stephen Hulbert, John Evans, Anne Fletcher, Morrie Gasser, John Hannon, Gary Lau, Joanne Pacheco, Karen Potter, Sybille Rex, and Chris Taylor, c/o Boston Grotto, P.O. Box 380304, Harvard Square Station, Cambridge, MA 02138-0304 USA, caversteve@aol.com

In 2001, the Boston Grotto helped the Boston Museum of Science market the IMAX film, *Journey into Amazing Caves*. The museum's goals were to increase attendance and interest in the film. The grotto's goals were to support the museum, to attract local individuals in the caving community who are not in the grotto, and to increase club camaraderie. We were specifically not interested in attracting new people to caving or appealing to thrill seekers.

To achieve the goals, the Boston Grotto contributed the following:

- A display of eight large photographs of caves by grotto members
- A display of caving equipment on a mannequin
- Two posters of grotto activities in speleology and caving
- Grotto member attendance in cave suits, gear, and with the BG posters at the Press Preview with Michael Ray Taylor, at the official Saturday opening with Hazel Barton, and at two Saturday "Meet the Cavers" events

We met all the goals. The movie had an extended run of three months beyond the scheduled six. Grotto participants had a good time, showed their cave photographs in a public venue, had a party, met many cavers visiting Boston from other areas, saw the movie, and received a prized Amazing Caves button. All grotto members learned the grotto's achievements. No large numbers of people contacted the grotto to go caving, but we did present our caving message to the public.

INTERNATIONAL EXPLORATION

2002 RÍO DE LA CIDRA EXPEDITION

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The 2002 Río de la Cidra Expedition to the Dominican Republic started a little early on December 29, 2001. We surveyed a maze cave 479 m long, which extended from a hole in the side of the rock shelter that we used as base camp. Several new pictographs were found in the cave. Across the river, we resurveyed another cave, 882 m long, which also contained pictographs. A new pit entrance was discovered. Another 307 m virgin cave containing a large population of bats was surveyed. A rock shelter, not previously known to researchers, was discovered 250 m from base camp and contained 43 pictographs. The biology of the area was studied, and 9 species of bats were verified. Several nasty climbing leads remain in the caves. The extensive karst area, of 5-10 m high jagged pinnacles, lies above the resurgences and remains nearly unchecked. Two obvious entrances beckoned on a distant hillside, but the locals reported that the caves were small. The 14 km return hike to civilization was more difficult than the hike in, due to muddy conditions from earlier rains. Where the trail went through shady forest, the mud was calf-deep. The fog changed to rain, we lost 3 of our group, and it got dark. The challenging adventure worked out in the end, and by 3 AM, everyone was safe, dry, and fed by local farm family.

CAVES OF HOG CAY, SAN SALVADOR, BAHAMAS: SETTING THE BAHAMIAN DRY CAVE DEPTH RECORD

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Majors Cave is a flank-margin cave mapped in 1998 on Hog Cay, San Salvador, Bahamas. Flank-margin caves form at the margin of the freshwater lens on the flanks of eolianite ridges as mixing chambers, not conduits. Their morphologies are large globular chambers with concave dissolution surfaces and undulating ceilings and floors, vertically restricted and clustered like beads on a string. Investigations in 1999, 2000, and 2001 on Hog Cay revealed that many pit caves exist above Majors Cave. Pit caves on carbonate islands develop as vadose fast-flow routes to conduct meteoric recharge from the epikarst of the land surface to the freshwater lens. They are believed to form independently of phreatic features in the lens, such as flank margin caves. Pit caves developed in eolianites can occur in concentrations of over 100/km². They rarely exceed 10 m in depth, but may cross-connect to produce caves with over 50 m of horizontal extent. They have 2 main morphologies: simple vertical shafts, and complex features with horizontal components controlled by subtle changes in lithology. In late December 2001 and early January 2002, an effort was made to map several karst features on Hog Cay. CK1, a complex pit cave, was mapped and connected to Majors Cave, producing the only known pit cave/flank margin connection. This connection produced the deepest known dry cave in the Bahaman Archipelago, at 17.8 m.

SEARCHING FOR TEMPLE CAVES IN THAILAND

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Caves are an integral part of life for many of the peoples of southeast Asia. Consequently, they have modified caves in many ways. Religious shrines are particularly common, especially where Buddhism is the dominant religion, as in Thailand, Laos, and nearby areas. The beauty of Thai architecture has led to the construction of especially notable shrines in its caves. At least two, however, predate the coming of the Thai people. So many shrines exist that no reasonably complete list is known to exist. *Caves of Thailand* lists many of them throughout the country, but is far from complete. *Sacred Rocks and Temple Caves*, the sole book on the subject, considers even fewer. The contents and fame of these temple caves vary greatly. Perhaps the best known are at Phetchaburi and north to northeast of Chiang Mai. Others near Ratchaburi and Kanchanaburi are less famous. Most are known only locally. Thailand is strongly emphasizing caves as ecotourism sites, and some are targets of other special interest tours. In the Ao Luk-Phangna area, and probably in many other regions, local publications and publicity handouts are a good source for information on such caves. In addition to their interest as architectural gems, points of worship and speleological pilgrimage, some are of special interest for lengthy karstic conduits that extend far beyond the areas of religious shrines.

MULTIYEAR PROJECT TO MAP CAVES FOR THE BELIZE DEPARTMENT OF ARCHEOLOGY

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In February and March 2002, a group of 15 cavers from all over the US returned to Belize to resume mapping Barton Creek Cave. The project is under the auspices of the Western Belize Regional Cave Project, directed by Jaime Awe for the Belize Department of Archeology. Dye tracing was done to identify the sources of water in Barton Creek Cave. Slate Creek was determined to be the major source of water in the cave, with two other sources of water identified. A total of 6400 m of passage, some beautifully decorated, has been mapped in Barton Creek Cave. The cave currently ends at 3 sumps that are 3 km from the entrance. Dye tracing has shown that there are potentially 6 km of passage beyond one of the sumps. Small caves near the insurgences were located and mapped. Offering Cave, which like Barton Creek Cave was used by the Maya 1000 years ago, was mapped during the 3 weeks we were in Belize.

CLOSE TO THE EDGE, 2001

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Close to the Edge was discovered from the air in 1985. It is at the top of a cliff east of Prince George, British Columbia. The 255-m entrance pit was not expected, so it took several trips before enough rope was up the mountain. By late 1986, the cave had been explored down a second pit of 32 m to an impassable crack with strong air flow. In 1994, after blasting, exploration continued down short drops to a depth of ~440 m in tight wet passage. Trips in 1995 and 1998 improved the survey and found a drier route into the cave. The 1999 push ended at a depth of 421 m, part way down a large pit named The Abyss. Ice in the entrance prevented a trip in 2000. In September 2001, exploration continued. The rigging from the entrance to The Abyss was improved, and the crack was enlarged to give it a minor axis of ~23 cm. The Abyss was bottomed (68 m), and a 9-m pit was descended to a sump at a depth of 472 m. Horizontal passages discovered below The Abyss included a canyon carrying a stream much larger than any other seen in the cave. This stream flows into the sump, and the passage goes upstream. A number of possible cave entrances were also found on the surface and checked, and GPS readings revealed that the water from the cave resurges ~610 m below the entrance.

PALEONTOLOGY AND CAVE ARCHAEOLOGY

THE PALEONTOLOGICAL RESOURCE INVENTORY OF VIRGINIA CAVES (PRIOVAC): A NEW NSS PROJECT

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The Paleontological Resource Inventory of Virginia Caves (PRIOVAC) is one of the newest NSS Projects, but our initiative dates from 1995. Recognition of how few caves with noteworthy paleontological resources were included in the Virginia Significant Cave List prompted a 1995 convention talk to stimulate awareness of cave paleontological resources. A few interesting fossil records had been discovered in Virginia caves, but the Virginia

Cave Protection law, designed to protect cave resources, also made scientific collections from caves difficult. Before 1995, the Commonwealth of Virginia had issued only one fossil collection permit, which was the result of a lengthy process and our joint efforts. Our solution was a blanket permit that, with owner permission, would allow immediate legal collection status, so cave reports of potentially significant exposed animal remains could be investigated, examined, and collected without a lengthy delay between discovery and laboratory analysis. The first of a series of blanket permits took nine months from application to receipt. The context of the remains is at least as important as the fossils, because it helps us decipher how they came to be in the cave and other information about their nature. Many of Virginia's past cave fossil finds were collected without regard to context. PRIOVAC investigators, working forensically to recover clues to the nature of fossil occurrences, have included studies of many of the known Virginia cave fossil discovery sites and investigations of the new cave finds.

FROM THE PORTALS OF XIBALBA THROUGH THE DOORS OF PERCEPTION: "ENLIGHTENED" INTERPRETATIONS OF ANCIENT MAYA CAVE ART

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Recent investigations by the Western Belize Regional Cave Project revealed a new class of ancient Maya cave art, termed Modified Speleothem Sculpture. This genre of speleothem modification is far more elaborate than the simple petroglyphs previously identified by Maya cave scholars.

PHOTOGRAPHY

MAKING A MULTIMEDIA DISSOLVE PROGRAM FOR THE COMPUTER

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Multi-projector dissolve (MPD) shows are an impressive way to present cave images, usually combined with an audio track. The dark regions inherent in cave images can be used creatively in overlays. But MPDs are incredibly time-consuming to produce and require lots of equipment to show. With the advent of digital projectors, building such a show on the computer is an attractive alternative. Many software packages are designed to present multimedia images, but few seem to offer control of transitions and duration timing on a slide-by-slide basis or the precise mating of audio with the images. Surprisingly few provide a smooth-looking digital dissolve. I discovered a simple yet powerful \$15 shareware program, Slide Show to Go, that allowed me to migrate an existing MPD show to the computer. Useful PhotoShop techniques help prepare images for the show, such as aligning images for overlays.

HOW TO KEEP A CROWD AWAKE IN A QUIET, DARK AND WARM ROOM: SLIDE PRESENTATIONS FOR AN AUDIENCE

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The most important thing one must consider is your audience—who they are and what they will expect of you. This may even dictate the topic of your presentation. Next you must determine how long you have and how long you want the picture portion of your show to be. Now you may consider your selection of media and the use of various "show and tell" objects. Then you will be ready to make the selection of what pictures you want to show. Pay particular attention to beginning your show, and keep it varied, lively and moving along, but do not fear silences. Use humor when you can. Be sure to go through your show ahead of time to get out the kinks, and arrive early enough to be set up and ready to go before the audience arrives. Determine when you want to take questions, and let the audience know this before you are well launched. You can always find a way to mix in a safety and conservation message with your show. Do this. Common pitfalls to avoid include apologies, reading of the text, reversing slides, and inappropriate use of scale.

SAVING AND MANAGING CAVE LANDS WITH NONPROFIT CONSERVANCIES WORKSHOP

CORPORATE STANDARDS AND PRACTICES OF THE LAND TRUST ALLIANCE

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Incorporated cave and karst conservancies arose from the desire of cavers and cave scientists to ensure access to caves and to protect the natural features

of caves. The conservancies have the knowledge and enthusiasm necessary to set reasonable protective policies for management of caves owned, leased, or only managed. However, they seldom start with knowledge and experience in incorporating and managing a non-profit, charitable corporation. The foremost source of support and guidance in those respects is the Land Trust Alliance (LTA, www.lta.org), an umbrella organization for over 1200 conservancies nationwide. In order to ensure a high standard of corporate responsibility and management, which helps to maintain the corporate health, effectiveness and reputations of land trusts everywhere, LTA recommends the adoption of corporate Standards and Practices (S&P). LTA S&Ps concern such topics as incorporation, board development and board member training, financial and asset management, fundraising, training and recognizing volunteers, and much more.

VOLUNTEERS AND CONSERVATION: A VALUABLE PARTNERSHIP

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Non-profit conservation organizations are often faced with financial limitations when planning and implementing protection projects. Volunteer help is essential to the success of conservation efforts, often "making or breaking" a project. The Nature Conservancy has long relied on volunteers for many functions, including cave and karst protection projects. In a general capacity, volunteers routinely offer help with office and fundraising event functions. Volunteer groups, such as Boy or Girl Scouts and corporate volunteer programs, are critical to larger projects. These activities might include trail development and maintenance at preserves, removing exotic plants, or reforesting riparian areas. In Tennessee, volunteers from the caving community have given countless hours in a variety of ways to support conservation of the state's magnificent cave resources. Projects such as sinkhole and cave clean-ups and entrance barrier construction require much volunteer labor. These projects can be incredibly time-consuming, financially draining, and physically exhausting and would be virtually impossible to accomplish without the many members of Tennessee's caving community volunteering their time. The caving community in Tennessee also provides assistance with both the management of biologically significant caves and with biological surveys at these sites. Partnerships between volunteer groups and The Nature Conservancy play an important role in the conservation.

SURVEY AND CARTOGRAPHY

USING A DISTO LASER RANGE FINDER TO SURVEY CAVES IN BELIZE

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The 2002 Barton Creek Cave Mapping Project used 2 different models of Leica Disto rangefinders to measure distances in Barton Creek Cave and other caves in the Cayo District in Belize. By using the Distos, we could accurately measure distances between stations and make left, right, up, and down measurements. These measurements, which would have taken hours or been impossible using a tape, took only minutes with the Distos. In one room of Barton Creek Cave, the ceiling height measured 55 m, and we only had a 30-m-long tape. The sketchers were given accurate measurements from spray shots to the walls and speleothems, rather than estimates of distance. Many of the station-to-station distances exceeded 30 m. Ceiling heights varied from 3 to 55 m. Left and right measurements exceeded 30 m in places. The data from the Disto, plus direction and inclination data, were entered into a laptop computer running Walls, a cave mapping program, to produce an outline map of the cave. At the end of the trip we found another cave. In 90 minutes, we were able to collect survey data for 400 m of cave. It would have taken all day if we had been using a tape to measure the distances.

U.S. EXPLORATION

EXPLORATION OF SCOTT HOLLOW CAVE

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Scott Hollow Cave is a 40 km cave system in Monroe County, WV. The cave has been explored for the last 18 years, and in that time several significant discoveries have been made. These discoveries include Mystic River, Scoop City, prehistoric animal bones, and a large portion of cave that comes close to Windy Mouth Cave, another nearby long cave. Exploration in 2001

and early 2002 focused on the far upstream portions of the cave. The most current exploration has occurred at the opposite end of the system (downstream), in an attempt to find a connection to Windy Mouth Cave. Microblasting and aluminum extension ladders have been effective tools for this exploration.

THE MAINE CAVE SURVEY

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Maine caves can be found in limestone, granite, and sandstone. Although one does not connect caving with Maine, the state does have some very nice small caves of various origins. The Maine Cave Survey gives an in-depth look at the Maine caves that have reached publication and the Maine Cave Protection Act. This survey and the law have been primarily the result of the work of Presque Isle High School students. For years, only a handful of caves were known, with most of these dating back to the 1800s and the Charles Jackson geological survey. Recently, there has been a systematic search to rediscover these historical coastal sea caves and ice caves once used by sailors and loggers. Maine's hiking trails were then searched, resulting in the discovery of many new caves, including sections of the Appalachian Trail that pass through talus caves. Maine's rocky coast has many sea caves with interesting histories. With the increased awareness of Maine's geologic heritage, many new caves have been discovered, including emerged sea caves caused in part by the weight of glacial ice depressing the land near coastal areas, and talus caves formed by the movement of glacial ice causing large rock falls in the granite regions. As the search continues, there are currently just over 200 caves reported in the literature, with the number growing yearly. With increased recreational caving and further systematic exploration of the region, the number of caves in Maine should continue to grow rapidly.

CAVES OF TAYLOR RUN

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The Taylor Run cave survey project has been an ongoing effort since 1994 to explore and map the caves of the Taylor Run region in Randolph County, WV. Meeting monthly, cavers from around the Virginia Region have explored and mapped caves within a 600 hectare parcel of limestone spanning the eastern flanks of Middle Mountain, above Gandy Creek. Accomplishments of the survey include discovery and mapping of 5 large caves with a combined extent of 8 km. The longest single cave exceeds 3.2 km long and spans ~1.5 km of lateral distance. Cumulative depth of all these caves exceeds 107 m.

PEELING THE "ONION": CONTINUED DISCOVERIES IN UNION CAVE, MONROE COUNTY, WEST VIRGINIA

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Before March of 2001, Union Cave in Monroe County, WV, was only known to be ~300 m long. Under the auspices of the Monroe County Cave Survey, a dig was started in 1997, but suspended after the discovery of Hurricane Ridge Cave. The dig was continued in early 2001, yielding major discoveries in March of that year. Many passages of various characteristics were then surveyed, including one containing a large stream that represents a major portion of Dickson Spring, the county's largest spring. The cave is now 7.3 km long.

RECENT EXTENSIONS TO KNOX CAVE

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Located in Albany County, New York, Knox Cave has been known since at least 1787, being shown on a map made that year by Will Cockburn, then the Surveyor-General of New York State. The definitive map of the cave dates back to 1963. The cave has been very popular with cave explorers for perhaps 50 years and is one of the more frequently visited wild caves in New York. Despite those years of visitation and exploration, during a trip in 1995 a mere 20 minutes of relocating rock by hand was all that was required to extend the northern limits of the cave, yielding entry to a previously undiscovered room ~6 by 18 m, but only 30 cm high. A return trip extended the cave into yet another room, and a stream that leaves that room by a low passage ending in a sump after 240 m. Besides the relative significance of extending the cave length by nearly one-third, the stream passage is geologically significant for having formed in the Brayman Dolomite, which is shaly and not typically

known as a cave-forming rock. All other known cave passages located in the Brayman Dolomite have originated in the overlying limestone before cutting down into the Brayman. The second room also contains an unusual formation, of the type informally known as a "dribbler." During periods of adequate water flow, perhaps 10 mL of water collects at the tip of the formation before draining abruptly and then repeating the process.

RUMBLING FALLS CAVE

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In 1983, 2 Western Kentucky University students did several dye traces near Spencer, Tennessee. One trace was to Swamp Spring, 9.7 km to the north, presenting alluring possibilities of then unknown cave passages. In 1991 and 1995 Nashville cavers found segments of the system near the resurgence, yielding the 2-km Thunder Run Cave and 6.4-km Swamp River Cave. They were prevented from continuing south by a sump and massive breakdown.

In 1997, a lone caver found an entrance with a 20-m pit. Returning with a friend, they dropped the pit and explored the passage 150 m up dip, stopping below a waterfall. The discovery was named Rumbling Falls Cave and was recorded by the Tennessee Cave Survey. In July 1998, another caver climbed the waterfall and explored 425 m of virgin passage. Instigating a survey, he returned and on the third trip discovered a 60-m drop into a huge breakdown chamber. This led to a major segment of the hydrologic puzzle, consisting of 24 km of cave. The project remained secret until a conservation issue forced disclosure. Resulting media attention, including a great picture by a Kentucky caver, has made the 1.6+-hectare Rumble Room, and the cave, famous.

MOTHER MAY I SPRING CAVE

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Several cavers found Mother May I Spring Cave while ridgewarding on Mothers Day weekend in 2000. The exploration of this cave was awesome, having just enough of everything: stream crawls, pits, domes, canyons, waterfalls, climbups, and climbdowns. There's even a beautiful side passage 200 m long with one rimstone pool after another. Currently the cave has an estimated total length of ~1 km and a total depth just over 30 m.

Surveying began on the third visit to the cave. During the survey, several archaeologically significant torches were found. Paying more careful attention to the surroundings, the first of several bare human footprints were found in the cave floor. The prints had obviously been there a while. The explorers were then alarmed after finding a mud ball with ancient hand/finger prints mere centimeters away from the fresh boot print of one of the explorers.

Finding and exploring virgin cave is an exciting experience, and it's often tempting to rush through the new discovery to see what has been found, but some aspects of the discovery may be less obvious than others. The moral of this story is that things like this do exist and are likely more abundant than we think. Watch your step!

VIDEO

USING UNCONVENTIONAL LIGHT SOURCES FOR CAVE VIDEO ILLUMINATION

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As part of the 2002 Barton Creek Cave Mapping Project in Belize, I used fluorescent work lights to illuminate the cave passage while shooting video from a canoe. The lights were powered by a 12V battery and 110V inverter. The 3 lights used 125W of power and produced a light intensity equal to a 500W incandescent flood light. The light provided an even illumination of the passage. I was able to light the ceiling at a height of 25 m. Another advantage of the fluorescent lights was that the color temperature was close to daylight, so the white balance did not need to be adjusted going from bright shadow, outside the cave, to the dark zone of the cave, where the only light was supplied by the fluorescent lights. The use of fluorescent lights eliminated the need to carry a generator into the cave.

In another cave, I used torches made from modified propane plumber's torches to illuminate the cave. This light allowed one to see figures that the Maya had carved into flowstone formations. The figures disappear when illuminated with a helmet light or flashlight.