SELECTED ABSTRACTS FROM THE 1998 NATIONAL SPELEOLOGICAL SOCIETY CONVENTION IN SEWANEE, TENNESSEE

BAT CONSERVATION INTERNATIONAL SESSION

COOPERATIVE IDENTIFICATION AND CONSERVATION OF ENDANGERED BAT CAVES IN TENNESSEE

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Since 1995, The Nature Conservancy (TNC), Tennessee Field Office has conducted its Tennessee Caves Initiative to identify and protect critical endangered bat caves across the state. By collecting information from cave, bat, and herpetological experts representing over a dozen organizations and agencies, TNC began the process by ranking caves in need of protection according to each site's rare species, threats, and current landowner situations. The resulting list of highly threatened caves is now used by TNC for prioritizing ecological site mapping, landowner outreach and education, and the ensuing obtainment of management agreements, conservation easements, and/or outright purchases of biologically significant caves. The cooperation and enthusiasm of other nonprofit groups, state and federal agencies and local grottos have been key to the initiative's success.

BAT CONSERVATION AND MANAGEMENT IN PENNSYLVANIA

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Pennsylvania has maintained an active program of bat conservation, management and education since about 1985. Surveys are conducted during the winter in caves, mines, and abandoned tunnels to assess the overwintering population of bats. Twelve sites have been designated as monitoring sites, and surveys are conducted annually or semi-annually. Several hundred additional sites have been surveyed 1 - 3 times each. A few of the most important caves and mines have been gated. These typically have had an increase in bat populations and, in one case, Indiana bats have re-colonized a historic site. Harp trapping at cave and mine entrances has produced two new locations of the Indiana bat as well. Summer work includes maternity roost surveys, mist netting, bat house construction and monitoring, and the purchase of a church that is home to over 15,000 little brown bats and at least a few Indiana bats. Much bat house experimentation and development has taken place. Of the 33 bat houses currently monitored, 30 are being used by bats. A "Bat Condo" was constructed, which may hold over 4000 bats at capacity, and in 1997 over 700 bats were using it. A second Bat Condo was constructed in 1998. Pennsylvania has also been working in cooperation with Bat Conservation International for the past four years, hosting 2 one-week seminars each fall. These seminars offer hands-on instruction, and have been attended by people from across the United States.

ON-GOING SURVEY OF PAST BAT USAGE AT MAMMOTH CAVE, MAMMOTH CAVE NATIONAL PARK, KENTUCKY

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The past usage of Mammoth Cave by bats is of considerable interest from the standpoints of bat conservation, cave management, paleontological resource protection, paleoecology, biogeography, and interpretation. This interest has led to a cooperative project between the Illinois State Museum and Mammoth Cave National Park that seeks to document past usage by inventorying and analyzing bat remains and signs of bat utilization in the cave. We are in the first year of the project.

The inventory has focused on areas near the Historic entrance of the cave and along one of the main tour routes. During the inventory, museum personnel and volunteers identify, evaluate, map, and photograph bat remains. In addition, some remains are being dated in order to help understand temporal patterns of bat usage. Preliminary work has documented that a larger variety of bat species used the cave in the past. In addition, our analysis has confirmed historic accounts that indicated much more intense bat usage of the cave before major modification by historic activities.

The project continues and will make contributions to the following efforts: 1) understanding the effects of entrance and passage modification, 2) mitigating modification effects, and 3) re-establishing colonial usage of the cave by some bat species.

BAT CAVE MANAGEMENT IN MISSOURI

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The Missouri Department of Conservation (MDC) and other agencies became more involved in bat cave management in the late 1970s after the failed attempt by the U.S. Army Corps of Engineers to construct the Meramec Lake. This proposed reservoir would have flooded numerous bat caves harboring Indiana and gray bats. In the 1980s, MDC began to acquire critical bat roosts for protection of hibernating Indiana and gray bats and maternity colonies of grays. Various types of gates, fences, monitoring, and management plans have been tried and modified. Large half gates for gray bats have been successful usually, but Indiana bats are generally declining despite good gates. Ozark big-eared bats are now thought to be absent from the state, but one caver has made a possible sighting in southern Missouri. Temperature and light data loggers are used in some caves.

INFRARED PHOTO-MONITORING OF MEXICAN FREE-TAILED BATS ROOSTING IN CARLSBAD CAVERN

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Carlsbad Cavern hosts a colony of several hundred thousand Mexican free-tailed bats (*Tadarida brasiliensis mexicana*). Investigators have estimated bat colony size using a variety of methods ranging from gross ocular counts, to video and still photography. However, few methods have provided a measure of statistical precision. Colony size, roost geography, repeatability of methods, and cost efficiency are all concerns when determining appropriate methods for estimating abundance. Investigators and managers need a variety of procedures to choose from so that consistent and useable data can be obtained. This inventory and monitoring method involves taking repeated infrared photographs from fixed points under the roost. Colony size is then estimated from the area of cave ceiling covered by bats. The development of reflective infrared photo-monitoring has provided a means of estimating colony size and assessing long-term trends at Carlsbad Caverns National Park.

BIOLOGY SESSION

THE CAVE FAUNA OF MISSOURI

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Missouri has at least 5,600 caves containing more than 400 recorded species. Important populations of two cave crayfish and endangered Indiana bats, gray bats, and Ozark cave fish occur in the southern part of the state. Gardner systematically reported on the fauna of 436 caves and 10 springs in 1986. Craig, Hubricht, Lewis, Martin, Nicholas, Pflieger, Sutton, and others have added to the state fauna list. To date, at least 39 troglobitic species have been identified, but many more probably will be found as more invertebrates are sampled. Accurate identification of species as troglophiles or troglobites depends on good biogeographic and taxonomic data. The declining pool of

invertebrate taxonomists has made the basic task of identification and description more difficult.

SNAPSHOTS OF SUBTERRANEAN BIODIVERSITY: 1888, 1960, AND 1997

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In 1888, A.S. Packard gave a complete list of known stygobites and troglobites, with their distribution. Brother Nicholas Sullivan did the same in 1960, as did Hobbs and Culver in 1997. In 1888, 13 counties were reported as having at least one obligate cave species. In 1960, this number was 176, and in 1997 it was 630, ~ 20% of all U.S. counties. Mean number of species, due to more counties with at least one species, actually declined from a high of 6.7 in 1888 to 4.7 in 1997. Overall, the distribution became more skewed with time. An analysis of the 13 counties known to have an obligate subterranean species in 1888 declined to 3.8 in 1960 and rose to 11.6 in 1997. The original decline was the result of Packard's tendency to believe every cave inhabitant was cave-limited. Nowhere was this more pronounced than in Mammoth Cave.

PRELIMINARY REPORT ON THE BIOLOGY OF CUEVA DE VILLA LUZ, TABASCO, MEXICO

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We present a preliminary overview of the biology of Cueva de Villa Luz in Tapijulapa, Tabasco, Mexico. Much of the cave is a stream passage,the water milky-white with sulfur. Many passages in the cave have very high levels of H_2S, varying from 0 to 57-127 ppm. Most passages were above 10 ppm. The pH of the environment was generally more acidic than typically found in a limestone cave. Exceptionally low pHs were associated with"snottites" or microbial veils (pH 0.3-0.7), and in one area we identified a deposit of bat guano mixed with gypsum paste which had a pH of 0.0. Sulfate-reducing bacteria were present in very high numbers (105-106 +) in all sediments. Coliform bacteria survived in the mainstream passage, but were not detected in springs entering the cave. Microbial involvement is evident in the formation of white filaments in the cave stream and in microbial veils suspended from gypsum, possibly in association with webs of spiders or fungus gnats. The most abundant organisms are the midges, *Tendipes fulvipilus*, which are the main prey for the molly, *Poecilia sphaenops*, which consumes both the aquatic larvae and adults. The fish are in turn preyed upon by a hemipteran (not identified). There was a very high density of predatory invertebrates throughout the cave, particularly spiders, fungus gnat larvae, and amblypygids. We found little evidence for terrestrial troglobites, with the possible exception of a spider and nematodes found in highly acidic vermiculations.

DISTRIBUTION AND ABUNDANCE OF CAVE CRICKETS IN MAMMOTH CAVE NATIONAL PARK DUE TO WEATHER FROM 1995 TO 1997 AND ENTRANCE RETROFITTING IN 1996

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Five out of 9 entrances were retrofitted in 1996 to stop air movement. Two of these entrances had existing steel doors that slowed air movement and 2 had antiquated open gates. All retrofitted entrances incorporated exit/entry tubes for animal movement in their designs. We censused 4 to 16 10-m transects, depending on cave size and decline in animal abundance away from the entrance, 2-4 times per year in 1995 and 1996 and bimonthly in 1996-1997. Except for one cave, where the positions and lengths of the exit tubes were not conducive to cave cricket use, there were no negative effects of retrofitting on animals other than pipistrelles. Air movement, but not winter temperature gradient, was also eliminated with the retrofits. There was a slow increase in cave cricket numbers from 1995 through 1997 correlated with short-term winter weather but not with average or extreme monthly temperatures. From 1995 to 1997 there were fewer and shorter periods with temperatures remaining below 5°C and more short respites of 2-3 days when temperatures remained above 10°C due to light rain. On these favorable nights, after many days or even weeks with no foraging, cave crickets exited in synchrony and foraged in large numbers. In summer there were no temperature constraints and cave crickets exited every night. Exiting was asynchronous with the usual 9-12 days between the summer foraging bouts.

CAVE CRICKETS AT MAMMOTH CAVE NATIONAL PARK: YOU ARE WHAT YOU EAT

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What do cave crickets eat? In aquaria with single food types, crickets do not gain weight on partially decomposed leaf litter with fungal hyphae, moss, lichens, leaves, or live earthworms and other litter organisms. Crickets gain 5-35% of crop empty live weight (CELW) on overripe fruit, fresh mushrooms, and deer fecal pellets. Crickets gain 70-120% of CELW on rotting mushrooms. But, crickets gain 100-250% of CELW on both our 'high quality' canned cat food baits and 'low quality' wet cereal or metamucil mush that they readily locate in the field. The mystery is that high quality foods seem to be rare in the field whether we use extensive walking surveys of mushrooms and deer pellets or intensive 1 m^2 searches for mouse and invertebrate feces or small carrion. Nonetheless, crickets gain as much weight foraging on natural foods as they do when feeding on our artificial bait patches. Certainly crickets are better at finding quality items than we are, using their acute olfactory senses. However, the low Na/K ratios and low caloric density of their crop contents suggests they are not getting much carrion, even though we have seen them quickly locate and carry off horseflies killed at cave entrances.

CORROSION RESIDUES FROM LECHUGUILLA CAVE: COZY HOME OR LIVING HELL FOR MICROBES?

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Many ceiling and wall areas of Lechuguilla Cave, New Mexico, exhibit deposits called "corrosion residues'' (CRs) which appear to be breakdown products of several minerals. These CRs may be colored black, gray, pink, orange, red, or ocher and are distributed throughout the cave. Geologists have hypothesized that Lechuguilla's extensive CRs are the long-term result of upwelling corrosive air. Using enrichment cultures and Scanning Electron Microscopy, Cunningham and Northup discovered extensive bacterial and fungal communities in CRs. Preliminary evidence, including the presence of presumptive bacterial filaments in pits in the wall rock underlying CRs, implies that microorganisms may play an active role in corrosion of parent rock. Potentially, microorganisms could oxidize reduced compounds from the atmosphere or wall rock. The resulting acidity and other redox effects could consequently degrade the rock substrate. Our molecular phylogenetic studies are identifying the nature of this microbial community. Energy Dispersive X-Ray (EDX) analyses of these residues and underlying wall rock reveals the presence of a heterogeneous makeup including the presence of iron and manganese oxides, as previously shown by Cunningham, along with phosphorus, clays, and sulfur. We have also identified rare earth elements, probably associated with apatite in the original limestone, and vanadium in some of the CRs. We are investigating the possible association of these potential inorganic energy sources with microorganisms present.

PHYLOGENETIC ANALYSIS OF BACTERIAL COMMUNITIES ISOLATED FROM FOUR WINDOWS CAVE: ARE THEY ACTINOMYCETES?

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Silvery clusters of bacteria pepper the limestone walls of Four Windows Cave in El Malpais National Monument, New Mexico. In an effort to identify the types of bacteria in these colonies, we have utilized techniques developed at Los Alamos National Laboratory to extract DNA from colonies on wall rock. From this DNA, we utilized polymerase chain reaction (PCR) amplification and cloning to generate a library of 16S ribosomal RNA gene (rDNA) clones of the organisms present. Comparison of rDNA sequences from 30 of the clones with sequences available in the Ribosomal Database Project (RDP) revealed considerable genetic diversity. Many sequences were most closely related to those of actinomycetes, including *Actinosynnema, Nocardia* and *Frankia* sp., while some clones show relatedness to rDNAs of unknown organisms recovered from soils. Actinomycetes are a group of related bacteria that produce filaments during their development. These bacteria break down com-

plex organic matter and thrive in environments where nutrients are sparse and conditions extreme. This description fits well the phenotype and habitat of this sample community.

SPECIAL BIOLOGY SYMPOSIUM: *New Frontiers of Biospeleology*

THE CAVE LOACHES OF THAILAND: PHYLOGENETIC RELATIONSHIPS AMONG POPULATIONS AND SPECIES

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Five of the seven known cave fishes in Thailand are balitorid river loaches, a family common in the surface waters. The evolutionary relationships among species and genera in this family are unknown. Samples of the five troglobitic and 20 epigean Thai balitorids are under study using DNA fingerprint markers generated with AP-PCR techniques. AP-PCR data show genetic relatedness of populations and species and will be used to reconstruct the phylogenetic relationships of the Thai species and to study their population genetics. All eight cave populations studied (including species of *Schistura, Noemacheilus* and ("*Homaloptera*") have lower genetic variation than populations of surface balitorids, reflecting their isolation and reduced effective population sizes. Inter-populational variations among four populations of *Schisturaoedipus* from Mae Hong Son were also studied. Although the four cave systems are isolated from one another, the populations are genetically similar, suggesting gene flow among populations, perhaps through surface waters. The waterfall climbing cave leach, *Homaloptera thamicola*, is clearly different from *H. zollingeri* and *H. smithi* at the level of DNA fingerprint, and probably incorrectly placed in *Homaloptera*. In fact, it does not closely resemble any of the six genera examined. A new cave fish of uncertain relationship from Tham Phra Wang Daeng, near Phitsanoluk, was examined. It clusters more closely with *Schistura* rather than *Noemacheilus.*

BIOSPELEOLOGY AS THE BASIS OF GROUNDWATER MANAGEMENT

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Current research using new techniques in microscopy and mass spectrometry have allowed an Ozark cave stream ecosystem (Cave Springs Cave, Arkansas) to be described fully for the first time, enabling better management practices for the recovery of the threatened Ozark cave fish (*Amblyopsis rosae*). The use of direct counts of microbial abundance by epifluourescence microscopy allows a good estimate to be made of total numbers of viable microbial cells in an aquatic ecosystem. Thus, the microbial community may be used as a bio-indicator of disturbance, especially in the form of organic loadings or intoxication. Furthermore, microbial biomass may be estimated from this technique, allowing a more complete carbon budget to be made or measurements of the bio-availability of organics present. The use of stable isotope assays allow a cave food web to be described completely, can determine which organic matter source (guano, agricultural waste, etc.) feeds the food web, and can identify pollution sources. Dye tracing, water-table contouring, photo-lineament studies, and other hydrogeologic methods have determined the recharge area for this cave stream, and the use of a geographical information system (GIS) has enabled a visual as well as statistical synthesis of the information relating to this spring complex. Once a groundwater ecosystem has been fully described, including energy and organic matter flux, trophic relationships, hydrogeologic characteristics, pollution threats, etc., it can be monitored and managed as an entire ecosystem.

MOLECULAR PHYLOGENETIC CHARACTERIZATION OF UNUSUAL MICROBIAL COMMUNITIES ASSOCIATED WITH CORROSION RESIDUES FROM LECHUGUILLA CAVE

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In order to more fully characterize the microbial community associated with corrosion residues (CRs), we are utilizing molecular phylogenetic techniques to avoid sampling biases introduced by enrichment cultures. Using techniques developed at Los Alamos National Laboratory for soil, we have extracted DNA from CR samples from Lechuguilla Cave. Polymerase chain reaction (PCR) amplification of extracted DNA with primers specific for small subunit ribosomal RNA genes indicates the presence of bacteria, Archaea and Eucarya in both CRs. We have begun to analyze a clone library generated from these PCR products. A restriction fragment length polymorphism (RFLP) analysis of 16 clones from this extracted DNA demonstrated that 14 of 16 clones were unique, revealing the existence of a diverse microbial community. Preliminary results from the phylogenetic analysis of the small-subunit ribosomal RNA (rRNA) gene from two clones showed that the nearest relatives of one clone are *Crenarchaeota*. The existence of this type of low-temperature Archaea has only been discovered in the last five years. Little is known about the metabolic properties of these Archaea due to the present inability to culture them. The other sequenced clone's closest relatives are gram positive bacteria. Both sequences are very dissimilar (less than 0.5 similarity, 0-1.0 scale) to any other known 16S rDNA sequences.

PRIMARY PRODUCTIVITY ESTIMATES FROM A CHEMOAUTOTROPHIC MICROBIAL COMMUNITY IN MOVILE CAVE, ROMANIA

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Since its inception, the Movile Cave Project has focused primarily on describing ecosystem energy and organic carbon sources. Previous research has documented microbial chemolithoautotrophy as the energetic base of the diverse and abundant invertebrate food web in Movile Cave. Preliminary studies show that the microbial community contains sulfide-oxidizing, sulfate-reducing, methanotrophic, and heterotrophic bacteria. Current research is based on constructing an ecosystem energy budget by quantifying energy flow within the food web. As a first approximation of energy flow, primary productivity of the microbial community was examined. To estimate primary productivity in Movile Cave, time-course incorporation experiments were conducted using [^{14}C] bicarbonate as a radiolabeled inorganic substrate. Preliminary results indicate that primary productivity in Movile Cave (~129.3 g C/m^2/yr) is similar to published values for the open ocean and mesotrophic lakes, but is an order of magnitude greater than values estimated for deep-sea hydrothermal vents. Productivity estimates will be used in constructing a complete carbon budget for the Movile Cave microbial community. Continuing experiments focus on estimating microbial respiration and excretion.

CAVE CRICKETS AT MAMMOTH CAVE NATIONAL PARK: SOURCE AND SINK POPULATION DYNAMICS

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Congruent increases in population size among nine entrances from 1995 to 1997 suggest that cave crickets inside Mammoth Cave National Park do not exist as a meta-population. Great differences in relative abundance of four size classes of crickets shows that there are both source and sink populations. In clear source entrances (3 out of 9 censused) small sizes are much more abundant than adults, so populations are increasing. But all other entrances (6 out of 9 censused) are sinks where adults outnumber or greatly out number small size classes. These populations are presumably maintained by immigration from sources. There was no correlation between population size and source entrances. The source entrances have some but not all of the following attributes: 1) close proximity of entrance roosts to reproductive areas; 2) ceiling pocket refuges from winter influxes of cold, dry air just inside the entrance; and 3) mesic summer microclimate with presumed better foraging opportunities in sinkholes and/or late successional forest outside the entrance.

HAWAII'S LAVA TUBES: NATURAL LABORATORIES FOR THE STUDY OF EVOLUTION AND LINEAGE DIVERSIFICATION IN TROGLOBITES

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This project utilizes molecular population genetics data coupled with behavioral and geological information to elucidate patterns of speciation and relationships between populations in the cave-adapted plant hopper species complex *Oliarus polyphemus*. This species complex on the island of Hawaii occupies lava tubes in volcanically active regions of the island. As a result of its volcanic habitat, *O. polyphemus* populations have undergone repeated expansion, contraction, and isolation events during their relatively short history on the island. Preliminary information has demonstrated significant differ-

ences in the mating calls of geographically close populations. While this behavioral information clearly demonstrates significant divergence between populations, it cannot distinguish the historical relationships of populations to one another. My work, therefore, uses genetic data to determine basic parameters of gene flow and to construct an intraspecific cladistic network in order to clarify the relationships of the populations. Genetic data (including sequence data and AFLP's) are being used to test the hypothesis that *O. polyphemus* is not limited to humanly accessible caves, but is distributed continuously throughout the millions of tiny voids in the lava substrate. This analysis will also help to better understand how habitat fragmentations have influenced the evolutionary history of *O. polyphemus*. Finally, this genetic information, when coupled with song data, can address basic issues of species status in the *O. polyphemus* complex. Because the identification of unique populations of *O. polyphemus* is likely to reflect similar patterns in other cave and surface organisms, conclusions of this study will identify crucial biological regions for conservation efforts.

SPATIAL AND TEMPORAL PATTERNS OF CARBON, NUTRIENT AND MICROBIAL TRANSPORT IN A KARST AQUIFER

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Aquifer physical structure and water flow patterns constrain energy input and distribution in karst groundwater ecosystems. Consequently, carbon availability and microbial biofilms may vary spatially by aquifer structural zone and temporally with hydrologic stage. To test this, we examined carbon and bacterial flux from aquifer input to output during two months in the Dorvan-Cleyzieu aquifer, France. Both months included low water followed by one or more floods. Dissolved organic carbon increased from input to output ($p<0.01$) but did not vary temporally ($p>0.05$). In contrast, microbial drift and activity (respiratory and hydrolytic) were not significantly different between structural zones ($p>0.05$), but changed significantly over time ($p<0.001$). In all zones, during initial floods total bacterial drift was high (86-130 x 10^3 bacteria/ml) then decreased during flood recession (24-32 x 10^3 bacteria/ml). Conversely, respiring bacterial drift was low at the peak of the first flood (5-17 x 10^3 bacteria/ml) then increased during flood recession (10-26 x 10^3 bacteria/ml). Although initial floods after low water caused consistent changes in microbial drift, the drift patterns differed between structural zones during subsequent floods.

SPECIAL BIOLOGY SYMPOSIUM: *Taxonomy and Systematics of Cave Organisms in the 21st Century: A Look Ahead*

PROGRESS IN CAVE COLLEMBOLAN TAXONOMY AND BIOGEOGRAPHY IN THE NEXT 30 YEARS

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Cave biogeography has a great need for more knowledge concerning the phylogeny of cave Collembola and the relationship between this and the microgeographic distribution of species. What will biospeleological Collembola taxonomy be like in the next 30 years? Various scenarios come to mind and I shall present two extremes. 1) General funding for taxonomy increases as the biological community realizes that this is the essential first step for any ecological or evolutionary analysis. This combined with relatively cheap and easily used molecular techniques, as well as increased facility in using computer scanning techniques for taxonomic analysis, results in a melding of genetic, morphological and behavioral information to develop a new sound and widely accepted picture of cave species as groups of evolutionarily and genetically united taxa. 2) Funding for taxonomy continues to focus more and more on genetic studies. Eventually this leads to a relatively static or diminishing knowledge of alpha and beta taxonomy of many groups such as Collembola. At the same time there is a much greater facility for genetic analyses and funding for such studies. The inability to match this information with troglomorphic features leads to a characterization of cave populations solely on the basis of genetic structure and the move towards abandoning of binomial nomenclature in favor of characterization of populations and eventually species as clusters of genetic formulae, stored and analyzed in computers. The result is a diminished interest in cave microarthropods such as Collembola as model systems for evolutionary and ecological study.

MAPPING BIODIVERSITY OF CAVE ORGANISMS

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Protection and education about cave organisms can best come about with a detailed understanding of their distribution. An ongoing project, in conjunction with The Nature Conservancy, aims to provide a list of cave-limited species, by county. Data on more than 1,000 species and subspecies are included in the database. Analysis of patterns suggests that the biggest gap in our knowledge is for non-cave subsurface habitats, especially small-cavity habitats such as the underflow of rivers. These species comprise less than 10% of the aquatic fauna. In Europe, they are often the majority. Most geographic areas are well covered, but data for the Ozarks, especially Arkansas, are not as complete as elsewhere. While counties are not a natural boundary, most data are listed by county, rather than by drainage basin. Lists by cave, while obviously more detailed, are more difficult to map.

SPECIES AND SPECIATION IN CAVE ANIMALS

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Animals with long evolutionary histories in caves share a morphological syndrome termed troglomorphy. The troglomorphic pattern includes reduced or lost features, such as eyes and pigmentation, and elaborated features, most notably enhanced extra-optic sensory structures and elongated appendages. The fact that the troglomorphic pattern is shared by distantly related taxa (e. g., cave-dwelling vertebrates and invertebrates) and by similar but geographically distant taxa (e. g., cave-dwelling carabid beetles of Europe and North America) suggests that troglomorphy is a consequence of a considerable amount of parallel and convergent evolution. Convergence and parallelism provide difficulties for systematists because features that have evolved in this manner do not reflect shared evolutionary history. In fact, phylogenetic studies using biochemical and molecular characters have shown that populations presumed to be conspecific on the basis of morphological features are actually much more distantly related. This raises the possibility that convergence and parallelism may be important processes even on very local geographic scales, and that many presumptive cave species may in fact be species complexes, despite being morphologically very similar. Genetic data on several cave inhabiting species, including the cave fish *Typhlichthys subterraneus*, the amphipod *Gammarus minus* and several species of trechine carabid beetles indicate substantial differentiation among populations deemed conspecific on morphological grounds. These data clearly indicate lack of gene flow among these populations and are at least consistent with the view that the evolution of troglomorphic features within these supposed species may be polyphyletic.

THE FUTURE FOR CAVE FISHES

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The first cave dwelling fish was discovered in the 1820s and the first named species(*Amblyopsis spelaea*) was described from Mammoth Cave in 1842. Since then, cave fishes have been discovered in 27 countries world wide and there are now 79 described species. What will happen to these in the next few decades and how might these numbers change? It seems certain that the number of known species will increase. In 1960 there were 27 species, 1970 (35), 1980 (39), and 1990 (59) and in 1998 (79). If this rate of discovery remains constant there will be 85 species by 2000, 125 by 2010 and 200 by 2020. At the same time, it is possible that known species will become extinct.

Three species (*Clarias cavernicola*, Namibia; *Speoplatyrhinus poulsoni*, USA; *Glossogobius ankaranensis*, Madagascar) are assessed as critically endangered by IUCN. Two are assessed as endangered (*Prietella phreatophila* and *Ophisternon infernale*, both in Mexico) and no less than 46 as vulnerable. This is 63% of all known species. One of the critical needs of the next few years, therefore, is for conservation assessments so that conservation effort is directed to the right places. A central plank of this must be accurate population

assessment. A second will be an examination of the molecular genetics of demes.

Over 50% of all known species are from only five countries (China, Mexico, Brazil, USA and Thailand) and in all of these, human population pressure will continue to increase.

TAXONOMIC GAPS AMONG CAVE-DWELLING MILLIPEDS (SPEODESMUS) AND MITES (RHAGIDIIDAE), WITH NOTES ON THINGS THAT AREN'T

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The polydesmoid genus, *Speodesmus*, which is troglobitic, contains four described species from Texas, New Mexico, and Colorado. At least six new species in two species groups are known from Central Texas, and new populations have been found in West Texas and Utah. Numerous genera and species of cavernicolous rhagidiids are known from caves in the USA and Mexico. Some of the populations are relicts of arctic and boreal litter-dwelling ancestors, but there are unexplained gaps in Texas and other cave areas. Other arthropod groups are inexplicably scarce or absence from regional cave faunas in the USA; two examples are rhaphidophorid crickets in California and carabid beetles in Missouri.

A LIMITED INVENTORY OF INVERTEBRATE CAVE FAUNA OF COLORADO

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Finding little information on the cave fauna of Colorado, arrangements were made to inventory the invertebrate cave fauna in some Colorado caves before, during, and after the 1996 NSS Convention in Salida, CO. Collections were made in 6 of 7 caves visited in Williams Canyon in El Paso County, Canon City area of Fremont County, and the White River Plateau in Garfield and Rio Blanco Counties.

Taxa collected included amphipods, beetles, book lice, centipedes, copepods, diplurans, harvestmen, millipeds, mites, pseudoscorpions, spiders, and springtails. Preliminary identifications indicate that the collections included new species of amphipods, diplurans, millipeds, pseudoscorpions, springtails, and possibly a spider. The most significant discovery was two specimens of a minute, troglobitic chordeumatid milliped from Spring Cave, Rio Blanco County. Initially they were thought to represent a new family of milliped, until further study revealed critical anatomical details and they were assigned to the Family Tingupidae. *Blancosoma scaturgo* Shear and Hubbard, 1998 was described as a new genus and a new species. Results of this limited cave inventory indicate a diverse and significant invertebrate cave fauna exists in the caves of Colorado.

CONSERVATION AND RESTORATION SESSION

THE GOOD, THE BAD, AND THE UGLY: MICROBIAL LIFE IN CAVES

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Microbes. Who ARE these annoying, invisible little things? Why are we making such a fuss about them? How do they fit into the normal world of the caver? The admittedly complex answers to these questions can be simplified for, understood by, and dealt with by cavers armed with a little knowledge and a little caution.

First, we consider the Good Microbes, those fascinating tiny bits of life that can live in weird places and eat weird things. In their minuscule bodies, they contain the promise of an immense wealth of biological insight that has biologists enraptured.

Secondly, we will turn our attention to the Bad Microbes. These guys (known commonly as "germs") can and do make us sick. They have been the companions of humans for a very long time, and we bring them into caves ourselves. Who are they and what can we do about them?

Lastly, we will examine the murky realm of the Ugly Microbes. These organisms are native to caves and they MIGHT be able to make us VERY sick. Cavers already know about histoplasmosis. What about caves as a source of "new," really nasty emerging diseases like Ebola virus? Should we be alarmed? Should we ignore the whole issue?

THE USE OF INVENTORY DATA AS A TOOL FOR PLANNING CAVE RESTORATION PROJECTS

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Inventory is a useful tool for identifying and locating important features in a cave prior to commencing a restoration project. Inventory is used to catalog geological, mineralogical, paleontological, speleogenetic, biological and archeological information, as well as assessing the impacts of human use. Inventory data, coupled with photographic monitoring, can be collected at selected survey stations to keep track of changes to the cave caused by use over time.

The following steps may be required prior to commencing restoration. 1.) Survey the cave prior to gathering inventory information. This is true in caves that have never been surveyed, or where stations from previous surveys cannot be recognized. When conducting a survey prior to an inventory and restoration project, it is desirable to place unobtrusive permanent survey markers to facilitate later work. 2.) Collect a comprehensive list of important features during a scientific reconnaissance of the cave. 3.) Record a list of features by category on reproducible pages that will fit in a survey notebook. 4.) A team visits the area to be restored and uses the notebook pages to record all features near each survey station. 5.) Inventory data is plotted on a map of the area to be restored for use as a training and planning tool.

Inventory data should be archived. The use of computer database management software simplifies this process, particularly when the data can be coupled with cave mapping software. Using the computer simplifies the storage and manipulation of survey and inventory information, and provides a format for monitoring changes to the cave.

PROBLEMS WITH THE FCRPA IN UTAH AND NEVADA

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Lack of continuity and communication has recently caused the cave management successors to the Forest Service in Utah to reveal the nature and location of caves to people walking into the office from off the street. The cave information was given to the Forest Service only because of the Federal Cave Resource Protection Act (FCRPA).

In Nevada, one huge BLM district with many very significant caves has declined to implement any protection to the caves as provided by the FCRPA. The District has no cave management plan. Cave file information is not kept confidential. New, very sensitive discoveries desperately need attention by the land managers but cavers are reluctant to get involved with them under present circumstances.

EEEK!! I KILLED A MICROBE: CONFESSIONS OF A CAVE EXPLORER

Diana E. Northup, Biology Department, University of New Mexico

Recent studies of microbial populations in Lechuguilla Cave (New Mexico, USA) and Cueva de Villa Luz (Tabasco, Mexico) are demonstrating the rich potential for identifying new microbial species in caves. In both caves we find abundant microbial habitats, secondary mineral deposits of iron or manganese oxides, sulfur deposits, and, in Lechuguilla, pristine pools. When people enter caves, we introduce exotic organisms. More importantly, in caves lacking extensive organic nutrients, we leave behind organic matter in the form of skin, hair, urine, lint, and feces. Exotic microbes and organic carbons, plus physical damage such as soil compaction or introduction of contaminants from agriculture and other human activities, can compromise and damage microbial communities in caves. A case study of human impact in Lechuguilla Cave has shown that impact on microbial communities can be minimized.

IMPACT MAPPING: TECHNIQUE FOR IMPACT INVENTORY

Jerry Trout, USFS National Cave Coordinator

Impact mapping can be an effective means of documenting specific cave damage for inventory and monitoring purposes. Impact maps can be useful conservation tools for cave managers; they can provide valuable data for making decisions concerning acceptable limits of change, numbers of permits or visitors, areas in need of restoration, areas that might be defined as off-limits, and areas that show no appreciable change. Once accomplished, impact maps can be easily updated to record changes in the condition of the cave.

KARST HYDROLOGY IN CAVE PROTECTION AND RESTORATION

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Hydrologic protection of caves requires at least a basic understanding of how the caves in question have formed, and of the drainage area from which they capture water. Caves develop from a variety of processes and conditions such as in sinking streams, by backflooding, from rising hydrogen sulfide gases, and from rapidly-flowing to nearly-ponded waters. Knowledge of a cave's origin is critical in projecting its probable extent beyond the limits of exploration, and also into unexplorable micro-conduits and enlarged fractures. This insight in turn is critical to estimating the cave's drainage area. Dye tracing is a powerful tool in drainage basin delineation, yet it may not be feasible in some cases. Then the basin must be estimated based on the cave's hydrogeologic origin.

Cavers usually do a fine job protecting cave hydrologic systems from pollutants within the caves. Cavers clean trash from inside caves and entrance sinkholes. Feces and urine are often removed and low-impact methods are used to remove graffiti and algae. However, in many cases, caves are adversely impacted far more by outside activities in their drainage basins. Cavers must develop locally effective methods of protecting and restoring caves from rural impacts such as feedlot runoff, pesticides, fertilizers, and septic systems, and from urban impacts like roadway runoff, sewer leaks, leaking underground storage tanks, and sedimentation from construction projects. Close cooperation with land owners and regulatory agencies will often be needed.

EXPLORATION SESSION: UNITED STATES

HISTORY OF EXPLORATION AND SURVEY IN HURRICANE CAVE, DADE COUNTY, GEORGIA

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Hurricane Cave, Dade County, Georgia has a long history of exploration and survey. Since Hurricane Cave's first known exploration in 1964, there have always been indications that it had additional potential. Its name is derived from the rush of air that often issues from the Air Chute, a body sized hole that stopped the original explorers. Virgin passage had been left for years because of the grimness of the Air Chute and the passages beyond. During the late 1980s, some of the passages beyond the Air Chute were explored and mapped. But it wasn't until the mid-1990s, during a re-survey of the cave, that almost a third of the currently known passages in Hurricane Cave were discovered. Recent discoveries have helped better understand the relation of this cave to other smaller caves on the mountain. As of April 1998, the cave had 2,080 m of surveyed passage, with a vertical extent of 76 m making it one of the ten deepest caves in Georgia. The project is still in progress.

THE WIND CAVE PROJECT, WIND CAVE NATIONAL PARK, SOUTH DAKOTA

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The Wind Cave Project began in the Spring of 1990 when a new flagged-trail system had been instituted at the Park. This system allowed cavers to effectively help with the huge amount of survey and inventory work needed to be done. Since that time, project weekends have taken place on a monthly basis. In 1997, 3.1 km of new survey was completed, along with 2.8 km of inventoried passage. Presently, 58% of Wind Cave's 19,933 stations have been inventoried and recent work has led to the discovery of two significant areas: the Lunatic Fringe and Navidad. Both of these areas were discovered by cavers attempting to push through the present Western boundary of the cave.

BLACK HOUSE MOUNTAIN CAVE SYSTEM, FENTRESS COUNTY, TENNESSEE

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As of March 1998, the Black House Mountain Cave System consists of four multiple entrance caves: Cornstarch at 5.8 km, Alastor at 2.1 km, Red Bud at 1.6 km, and Temple Falls at 1.6 km, plus many associated smaller caves and karst features. During the past year our group continued to push the frontiers of the various caves, attempting to connect them. The dreaded Water World crawl in Red Bud finally opened up into a 27 m dome, with many leads in the area. We hope to span the 120 m gap between Red Bud and Temple Falls and possibly discover upper levels in Red Bud as well. The connection of the dry upper level April Fools entrance to Temple Falls through the Butt Crack avoids the dangerous Wet Wang water crawl. The 1.6 km wide tip of a major ridge of Black House Mountain tantalizes us with the potential of large passage between Walter World (not the same as Water World) in the south end of Cornstarch and the 30 m high multi-level breakdown trunk in April Fools / Temple Falls. Cornstarch has crossed under the creek separating it from Alastor, but differences in levels continue to frustrate a connection of these two caves. Finally, the 2.4 km of karst ridge between Alastor and the field house hints at a vast extension to the west.

THE CAVE IS SQUARE NO MORE: THE DISCOVERY OF SOUTHERN COMFORT IN WIND CAVE, WIND CAVE NATIONAL PARK, SOUTH DAKOTA

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Prior to 1991, the 96 km of Wind Cave, South Dakota were entirely underneath one almost perfectly square mile (1.6 km). On September 9, 1991, three cavers chased a tantalizing wind through an overlooked crawlway in the Silent Expressway, known since the early eighties. On that trip, they mapped 300 m of passage with a couple of small rooms. This new discovery was heading south, out of the square outline of the cave. On the next trip, cavers pushed through another 90 m of crawls into Southern Comfort, a room more than 150 m long, and averaging 15 m wide. The room trended almost due south and the cave was square no more. Over the next year, exploration continued. The Southern Comfort area of Wind was marked by large passages separated by long crawls, squeezes, and sharp breakdown, and had passed 8 km by November, 1992. Then Wind Cave slammed shut. Most of the side leads dwindled into squeezes, too tight to continue or into impenetrable breakdown. In October 1997, cavers returned to one of the tight passages at the end of Route 66, near the southwestern edge of Southern Comfort. After more than 100 m of squeezing, chipping, and shredding of clothes, the cave opened up into a 120 m long hand-and-knees crawl with airflow. On the next trip, they found a crawlway leading from the top of a tall canyon passage. The crawl broke into a series of canyons and decent-sized rooms where Southern Comfort continues.

1998 RIO ENCANTADO EXPEDITION, FLORIDA, PUERTO RICO

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The Rio Encantado Karst Basin remains a huge puzzle, with several world class caves and potential for much more exploration. Although the main system river passage is traversable for 15.9 km, a world record, there are surprisingly few side passages. This seems to be the result of both structural conditions and a series of complex stream piracies that have left major paleo-trunk and in-feeders to the system scattered throughout the mogote hills. Finding these missing pieces has proven productive and enlightening as a more complete picture of the past and present mega-system slowly emerges. Potential for major extensions and connections is high, but not without challenge. Typically, during the last days of the 1998 expedition, significant new caves were found and going surveys were left at several points. The project is also working to assist in land preservation efforts, as the development and deforestation of large areas of the karst is rapidly accelerating.

SEARCH FOR THE MISSING LINK: ONGOING EXPLORATION OF THE COBLESKILL PLATEAU, SCHOHARIE COUNTY, NEW YORK

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Approximately 7.2 km of cave theoretically lies between Howe Caverns and McFails Cave, based on dye tracing and water flow estimates. With the discovery in 1992 of Barrack Zourie slightly west of McFail's, yielding 5.1 km of passage, digging activity has stepped up. Several potential entrances to the fabled Missing Link have since been opened, including Pasture Cave, Chevy Cave and Peggys Hole.

Espey Cave, Cannon County, Tennessee

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Espey Cave is one of the largest caves in Cannon County, Tennessee. Well-known to area residents, the cave was possibly visited as early as 1840 and was mined for saltpeter during the Civil War. Written records also mention that its cave stream was used to power a mill a few yards below its only entrance. Although several survey attempts were made over a 30-year time span by modern cavers (the first in 1956), none were ever completed. The Tennessee Cave Survey (TCS) officially listed the length of the cave as ~3.2 km, which was based on the results of previous survey attempts. After the discovery of a large extension in 1990, a new survey was begun by members of the TCS and the Tennessee Central Basin Grotto (TCBG). Surveying together in Espey, the members formed a new cave survey group that would eventually be called HR3, the purpose of which is to actively explore and survey Tennessee's Highland Rim caves. After a total of 66 survey trips from 1990 to 1996, the survey of the cave was completed at just over 9.7 km long, making the cave the second longest in Cannon County.

Exploration and Survey of Fox Hole, Van Buren County, Tennessee

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Fox Hole has been known locally and the entrance area of the cave visited for many years. The southern historic portion of the cave was first penetrated by NSS members Eric Morgan, Dave Van Fleet, and William Chambley in December 1962, when 520 m of cave was explored. The cave was re-discovered by Jim Hodson and Ron Tramel on January 12, 1974, and further exploration and survey began. On June 3, 1974, during a survey of the cave, Jean and John Smyre dug open a passage that led into the extensive north section. A grade-5 survey by Jean and John and many other Tennessee cavers was completed on September 29, 1984, with 3.1 km mapped. On May 6, 1995, during an exploration trip to the southern portion of the cave, Bill Walter and Hal Love discovered a small hole in the ceiling of an obscure crawlway with very good airflow. The following weekend, Hal, Joel Buckner, and Jason Wyatt enlarged the hole and broke into large passage. They were stopped by a 15 m sediment wall after 91 m. The following week, a large crew returned and tunneled through the sediment into more cave. A new survey project was started, with nearly 8 km mapped as of May, 1998. At least 3 km of cave remain to be mapped, with good potential for much more.

1998 Isla de Mona Expedition

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Isla de Mona is a small uninhabited island 80 km off the coast of Puerto Rico. The island is entirely carbonate and is literally hollow with caves. To date little exploration or survey work has been done. The 1998 Isla de Mona expedition consisted of sixteen cavers from the US who spent fourteen days on the island. They concentrated their efforts on the survey and exploration of Cuervo Lirio and searching the north shore for new caves. Many kilometers of cave were surveyed and many new caves were discovered.

Yell Cave, Bedford County, Tennessee

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Yell Caves Number 1 and 2 are located in Bedford County, Tennessee, and have recently been connected to yield a single cave that is the fourth longest in the county. Historically, this cave has been used for moonshine production and also as a source of local water which continues to this day. Although well known to locals, this cave had (until recently) been protected from visitation by its former owners. Three years ago, members of the Tennessee Highland Rim Survey gained permission to explore and survey the cave and, in the process, they established a good relationship with the owners. The cave has been the object of intense survey trips for the past three years. Since the discovery of a maternity colony of gray bats (*Myotis grisescens*) during the first winter of surveying, we have only been able to enter Yell Cave during the winter months. We are currently working with the landowners and the local authorities to protect the bat colony from future disturbances. Bat experts have estimated the colony size at 5,000 to 9,000 bats during one emergence count in the summer of 1997. In addition, possible extinct jaguar remains were found by Marbry Hardin during a survey trip at the cave's furthest extent. The cave has a surveyed length of over 2900 m consisting of mostly stream passage. When the survey is completed, we expect the total length of the cave to be approximately 3800 m. There have been 15 survey trips into the cave to date.

Burns Cave, Bath County, Virginia

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A recent breakthrough in Burns Cave is one of the latest exciting discoveries in Burnsville, Virginia. After 30 years of hard pushing and digging, cavers have gained access to a long hypothesized lower level of the cave and have been given a glimpse of the main drainage for a large karst valley. The cave is one segment of a major cave system underlying Burnsville Cove. This system is complex in nature and not yet fully understood, even though several caves within this complex contain more than 60 km of passage. Burns Cave is a significant piece of this underground puzzle. The extreme nature of the entrance series has proven to be a major obstacle limiting not only the number of people who enter the cave, but also the frequency of the trips. An elusive wind and the possibility of further breakthroughs continue to draw a small group of cavers back to the cave's horror. At -240 m, Burns Cave is Virginia's deepest and possibly most difficult cave.

The Exploration and Mapping of Montague Cave and Russell Cave, Jackson County, Alabama

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Recent explorations from 1988 to present in Montague Cave and Russell Cave, Jackson County, Alabama, have yielded two new vertically extensive caves 124 m and 103 m deep respectively. The 1988 exploration of Montague Cave included repeating the aid climb of Thunderfalls, a 42 m tall dome first climbed by Don Davison, and rediscovering 915 m of passage. Revisiting Davison's exploration yielded an additional 3,659 m of passage and the 84 m tall "Storm Shaft." Stopped by overhanging chert, the original climb ended 49 m high on the wall. In 1994, a new route on the other side of the Storm Shaft, the "Rebelay Wall," was completed to the top of the dome in 4 pitches, but with no continuation. To date, 6,800 m) of passage has been surveyed. Continuing the work begun by Bill Torode, exploration of the upper level domes in Russell Cave began in 1995 and was finished in 1996. Domes of 38 m ("Guillotine Wall") and 11 m were climbed to reach a new high point in the cave at +103 m.

Snake Dance Entrance to Bull Cave, Great Smoky Mountains National Park, Tennessee

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In the summer of 1996, cavers in east Tennessee discovered a cave entrance on Rich Mountain in the Great Smoky Mountains National Park. In the initial exploration by a group of five local cavers, the cave was surveyed down seven pits to a depth of 121 m below the entrance. This find was reported to the National Park and a cave exploration permit was obtained for the Tennessee Cave Survey to coordinate the continued exploration and survey during the 1997 caving season. During the summer of 1997, 25 different cavers from 5 states participated in the project. The cave was surveyed down another series of 6 pits to a horizontal borehole level at -180 m. The horizontal passage extended 200 m and ended with two more pits. A narrow passage then led 114 m to connect to the previously known lower stream passage of Bull Cave at a depth of 248 m. A re-survey of the lower stream passage showed the low point sump to be 282 m below the new entrance. This project surveyed 1.66 km of new cave, increased the cave length from 2.24 km to 3.66 km, and increased the cave depth from 226 m to 282 m. This route to the cave bottom requires negotiating 14 pits, the deepest of which is 43.6 m.

Jewel Cave Exploration, Jewel Cave National Monument, South Dakota

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Jewel Cave is one of America's oldest national monuments, established by Theodore Roosevelt in 1908, and incorporated into the National Park Service in 1928. Although it has been known for about 100 years, most of its exploration has taken place since 1959, particularly as a result of the efforts of Herb

and Jan Conn. Since then, exploration has progressed at a modest average of 4 km a year. This has been accomplished by volunteers working closely with the Park Service. Known for its barometric breezes, the cave's airflow has been the most valuable tool for discovering new passages. In late 1991, a strong breeze encouraged the excavation of "The Stopper," leading to the discovery of nearly 48.3 km of new cave, including larger rooms and passages than any previously known. Today, that breakthrough point is less than halfway to the end of the cave.

Exploration trips had always been done in a single long day. With trip times approaching 20 hours, and round trip distances as long as 16 km, it became apparent that camping would be necessary for continued exploration of the farthest reaches. A trial camp, conducted in June 1997, led to the development of a camping policy and the establishment of a permanent camp in November 1997. Since then, four-day trips have become common. Strong breezes recently led to a second breakthrough, and it is beyond the restriction known as "The End" that most of the cave is expected to be found.

EXPLORATION SESSION: INTERNATIONAL

BEYOND THE SAN AGUSTIN SUMP - HUAUTLA

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In 1994, an international team of cavers mounted an expedition to explore beyond the San Agustín Sump in Sistema Huautla, in southern Mexico. A total of 44 people participated, including a dozen divers. After a month of assembling diving gear in the states, three months were spent in Huautla. Initial attempts were made on the sump resulting in the discovery of an airbell 425 m in. Another 180 m sump led from the southern extent of the airbell to dry borehole. Two people established Camp 6 beyond the second sump. During the following six days, 3.2 km of dry passage were explored and surveyed. At 2.4 km from Camp 6, the San Agustín river joined another river, presumably the Río Iglesia, quadrupling the downstream flow and forming the "Main Drain". About 800 m downstream from the Río Iglesia junction, the combined flow floods the passage in a 50 m wide by 25 m long sump. Exploration ended there, still 7 km from the resurgence at 1,475 m (now the deepest cave in the Americas). The resurgence is 1,639 m below the Nita Nanta entrance. However, in 1995 the resurgence was explored to a depth of 60 m below the spring level, and continuing down, at a distance of 1 km north of the mouth. This suggests a minimum overall depth potential of 1,700 m for Sistema Huautla.

1998 VACA PLATEAU, BELIZE

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Since 1990, multidisciplinary research encompassing geology, hydrology, speleology and geoarchaeology has been conducted in a 25 km^2 portion of the northern Vaca Plateau in Western Belize. Dr. Philip Reeder, a geographer at the University of Nebraska at Omaha, manages the project. In March 1998, a team of 6 cavers spent 2 weeks at a remote jungle camp on the Mayan terraces of Ix Chel, a large temple complex in the study area. The team focused on geology, water and sediment collection and analysis, a small in-cave excavation, pottery assemblage and drawing, ridge walking for more caves and Mayan structures, and surface surveying. A detailed survey was completed of Macal Chasm with its 53 m entrance shaft located just east of Ix Chel's main plaza. Much time was spent completing a detailed survey of a significant burial cave. As a result of looting of the archaeological sites and caves in the area, valuable information about the Maya has been lost.

SPELEOLOGICAL POTENTIAL OF EGYPT

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Egypt is located between Libya and the Arabian Peninsula, both of which have well-known caves and karst. The Underground Atlas dismisses its karst as "not considered of interest to speleologists." A National Geographic Society map shows caves of major archeological importance. As expected, Gezireh Grotto in Cairo is an artificial pleasure grotto but information obtained on limestone, gypsum and sandstone karst features warrants further investigation.

RECENT EXPLORATION IN THE PURIFICACION KARST

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Recent exploration in Mexico's Sistema Purificacion has added 5 km to the system, making it 90.5 kilometers long. In December 1996, a base camp in the World Beyond section produced 2.3 km of new survey, including the promising Batwing Boulevard, which may lead up to a higher entrance. In March 1997, another camp was put in via the Infiernillo entrance and added more survey. An aid climb up Napoleons Dome led to a new section of cave which pinched before a sump bypass could be realized. Above the system, a long term dig in Sótano de la Cuchilla broke through the grim Hurricane Crawl resulting in several hundred meters of new passage to yet another dig. Five kilometers to the west of the system, a promising new cave was explored in the Tinajas Valley. Sima Chupacable was pushed down a series of long pitches to a sump at -400 m. In the southern part of the area, the formerly sumped wet weather resurgence at Ojo Encantado was found to be open and was explored up several waterfall climbs and continues. This trip was part of an ongoing search across northern Mexico for blind catfish of the genus *Prietella*. While none were found here, the catfish team has had good success at other localities in Tamaulipas and Coahuila.

UKRAINIAN CAVES; GEOLOGICAL ASPECTS AND EXPLORATION TECHNIQUES

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The Dnestr-Black Sea (DBS) and Crimea regions of Ukraine are two of the country's major caving areas. The DBS region is best known for its remarkable gypsum caves around Podoliya. The longest gypsum cave in the world, Optimisticheskaya (191.5 km), lies in close proximity to Ozernaya (111 km). The existence of a connection between these two caves has often been suggested, but results of recent work now indicate that a connection is most unlikely to exist. The gypsum cave of Zolushka currently has a length of 89.5 km. New exploration has also extended the mapped passages of Kristalnaya (22 km), Mlynki (23 km), and Slavka (8.2 km). The Black Sea's mountainous Crimean peninsula is home to many limestone caves. Krasnaya cave (13.7 km) remains the longest, while the Soldatskaya shaft is the deepest at 500 m. In recent years, new sections have been discovered in Emine-Bair-Cola (950 m) and Emine-Bair-Khosar (1,460 m) caves. In addition, the phreatic complex of the Chernaya (1,160 m), as well as Mramornay cave (2,055 m), has been surveyed to ever-increasing lengths. Deeper explorations include those of the Kaskadnay (-400 m), and Druzhba (-270 m) shaft systems.

GEOLOGY & GEOGRAPHY SESSION

MICROBES IN CARBONATE THERMAL SPRINGS: HOT SPRINGS NATIONAL PARK, ARKANSAS

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As part of a long-term study of possible terrestrial analogs to biogenic features in Martian meteorite ALH 84001, the authors are studying carbonate mineral deposits in subterranean hot springs located in Hot Springs National Park, Arkansas, USA. The hot springs, which are ~65°C at a nearly neutral pH of -7.3, precipitate aragonite and calcite at and below water surfaces. Although previous studies had termed the water "naturally sterile," bacteria are in fact commonly preserved in the carbonates, including 1-2 µm rods, and unusual filaments of 0.1 µm (or 100 nm) in diameter and up to 6 µm long. The waters also deposit orange films of amorphous Fe-Si-O material which is associated with a distinctive biota: spherical bacteria 5-15 µm in diameter, rod-shaped bacteria 0.5 - 1 µm long, and spherical shapes, interpreted as nanobacteria, less than 0.5 µm in diameter. The carbonates appear to be precipitated abiogenically, and early experiments indicate that the orange films, while clearly associated with biota, can be formed independently of biological action.

BELLEFONTAINE OUTLIER, OHIO: ITS FORMATION AND SUBSEQUENT CAVERN DEVELOPMENT

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The Bellefontaine Outlier lies on the Cincinnati/Findlay Arch structure in the central half of Logan County, Ohio. The Outlier consists of middle Devonian limestone capped by the Ohio Black Shale. The Bellefontaine Outlier is surrounded by older Silurian limestones and shales. The nearest

other Devonian outcrop begins 75 to 100 km to the east, and trends north-northeast. The whole Bellefontaine Outlier is a karst-dominated feature consisting of sinkholes being filled for the past 10-15 Ka by recent glacial till. Many of these sinkholes dot the landscape and need to be investigated. Zane Shawnee Caverns is developed in an east-west fissure with the south side opening down the stream valley. This allows the Black Shale to fill the top of the fissure, where it is cemented in place as a cap over the underlying chasm. The lower levels are dominated by a very small stream and passage system. They trend from the north and empty into the adjoining valley as small seeps. Presently, only Zanes and Ohio Caverns have been investigated, showing the upper levels are fracture controlled and the lower levels are vadose controlled.

BELL HOLE MORPHOLOGY: SPECULATIONS ON GENESIS

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Bell holes are conical to cylindrical dissolutional features in cave ceilings, displaying elongated vertical axes. The origin of bell holes is controversial with several mechanisms (phreatic and vadose) proposed for their origin. Phreatic mechanisms include floodwater, mixing-corrosion, and convection cells; vadose mechanisms are condensation corrosion and biogenic.

Few data on bell hole dimensions are available, and a quantitatively based definition of their morphometry is lacking. To evaluate proposed formational mechanisms, detailed morphological analysis was performed in Lighthouse Cave (30 bell holes) and Majors Cave (16) on San Salvador Island, Bahamas; Cueva de los Parajos (30) on Isla de Mona, Puerto Rico; and Roppel Cave (30) and Saltpetre Cave (16) in Kentucky; plus additional data from New York caves (8). Bell holes were profiled at 2 cm intervals along X and Y axes. Observations regarding rock texture, structure, and lithology were recorded along with a survey to determine bell hole relative positions.

Aggregate bell hole analysis indicates two major categories: cylinders, and cones. Height to width ratios range from 1.93 to 0.44. Bell holes with the greatest vertical development occur in the youngest caves, implying that vadose exposure does not correlate with bell hole development and making the vadose models unlikely. The uniformity of bell hole widths between various caves argues against mixing corrosion. The flank margin speleogenesis of the island caves eliminates floodwater hypothesis. As such, phreatic convection cells as a genetic mechanism appear favored.

A METHOD FOR ANALYZING MORPHOLOGICAL VARIATIONS OF CAVE DISSOLUTIONAL FEATURES

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Quantitative studies of cave dissolutional features (e.g., scallops, wall pockets) have yielded a wealth of speleogenetic information. However, analyses of other dissolutional features (e.g., bell holes, cusps, etc.) are mainly qualitative, making their speleogenetic implications mostly speculative. One difficulty in studying these features is developing a means of analysis that identifies morphological variations between populations. An ongoing study of bell hole morphology required development of such a method. The resulting methodology could easily be adapted to study other types of dissolutional features and similarly shaped non-cave features (e.g. stream potholes).

Data collection entailed profiling (2-4 cm interval) of the bell holes along two perpendicular axes normal to the vertical axis. These profiles are analogous to an inverted stream profile. A statistically significant sample (n = 15-30) was collected from each cave studied. A survey of bell hole locations facilitated analysis of packing distribution and spatial patterns of morphological variation.

Data analysis began with identification of inflection points in each profile to determine the boundary between the bell hole and ceiling. For each cave, measurements of percent height versus percent width for each bell hole were plotted. Comparison of these plots with ideal shape plots (e.g., cones, cylinders, hemispheres, etc.) identified patterns in bell hole morphology. Regression analysis of these data allowed creation of an aggregate shape plot using mean bell hole dimensions. The aggregate shape plots enable comparison of morphological variations between caves and geological settings.

VARIATION IN CAVE TEMPERATURES ON SAN SALVADOR ISLAND, BAHAMAS: A PRELIMINARY ANALYSIS

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Horizontal and vertical temperature profiles between a non-tidal and tidal cave were recorded on San Salvador Island, Bahamas. Temperatures were measured and recorded approximately every 5 minutes for a 3-, and a 5-day period, using Hobo™ temperature data loggers. Temperature observations indicated that for the non-tidal cave, temperature increased from the entrance of the cave to the back (entrance mean temperature 22.0°C, back mean temperature 23.8°C). The variance in temperature observations decreased from the entrance of the cave to the back. For the vertical temperature profile in the non-tidal cave, temperature increased with height above the floor (floor mean temperature 22.5°C, ceiling mean temperature 24.1°C).

The thermal environment of the tidal cave is different from the non-tidal cave. Temperature increased from the entrance of the cave to the back along the horizontal profile (entrance mean temperature 25.0°C, back mean temperature 25.6°C), while variation of temperature observations decreased from the entrance to the back of the cave. Temperatures decreased from the floor of the cave to the top of the bell hole (tidal pool mean temperature 27.5°C, ceiling mean temperature 26.1°C). In addition, temperatures directly above and below the tidal water surface displayed a symmetrical, cyclical component that coincided with the tidal cycle. Temperatures rose at high tide, and decreased at low tide. These observations suggest tidal water inside a cave may enhance atmospheric instability. Such instability may support the dissolution process of condensation-corrosion.

CO_2 MEASUREMENTS AND RECENT FLOODING IN THE MAMMOTH CAVE KARST AQUIFER

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Interstitial fluids within the sediments beneath Charons Cascade in the River Styx area of Mammoth Cave were found to have CO_2 pressures an order of magnitude higher than the stream waters flowing on top of the sediments. Dissolution and downward cave growth thus might be occurring beneath these clastic deposits. This has generally been assumed to be negligible.

Intensive study of the Logsdon River, one of Mammoth Cave's and the Turnhole Spring Groundwater Basin's major underground streams, is also underway. There, results indicate the importance of both in-cave and external sources of CO_2, the major control on the water's ability to dissolve limestone. A single storm in March of 1997 (over 20 cm of precipitation in 12 hours), which caused the river level to rise over 28 m in less than 15 hours, has provided bounding conditions for the river's hydrologic and geochemical conditions, and their rates of change. Abandoned conduits within parts of the aquifer that rarely ever see water flooded rapidly, with a maximum rate of about 8 m per hour.

PHREATIC AND VADOSE FEATURES IN VOLCANIC CAVES IN KENYA

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In Kenya, several extensive caves in unusual volcanic rocks present an interesting interface between karst and pseudokarst. Some of the caves have phreatic and vadose features like those of karstic caves. Located in tuff along one wall of a gorge, Gigglers Caves largely consist of an elongated multilevel network, rounded to elliptical in cross-section, with small rounded chambers. Local stream erosion is present, and some minimally developed karren. On Mt. Elgon, some voluminous caves appear to have a similar origin. These include Kitum Cave, Makningen Cave, and at least the upper Chepyanili Cave. Here the bedrock consists of a confusing complex of agglomerate, tuff, and lake bed deposits with extensive organic components and soluble salts. They are used as salt licks by wild and domestic animals. Makningen Cave is especially suitable for speleogenetic study. It is primarily a borehole passage 50-70 m wide and 10-20 m high. A large dome-shaped upper level is present, as are

a small stream channel and a shallow breakdown dome. A vertical lava flow enters its borehole passage from the dome chamber. Depositional features are scant. Only superficial observations have been made in these caves, and intensive speleogenetic studies are needed.

SIDERITE WEATHERING, A RARE SOURCE OF CO_2 FOR CAVE GENESIS: THE EISENSTEIN STOLLEN SYSTEM AND ADJACENT CAVES IN THE IBERG, HARZ MOUNTAINS, GERMANY

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Genesis of limestone caves depends on how and in what amounts CO_2 is available. Probably >90% of cave-generating CO_2 is soil-derived and infiltrates the rock through seepage or river sinks. Internally either mixing-corrosion or, probably more important, the slow kinetics of carbonate dissolution near saturation carry the dissolution potential far into the rock. But other sources of acid anhydrites can be important also. Best known is the example of Carlsbad Cavern where oxidation of ascending H_2S provided dissolution potential.

The investigation of the Eisenstein Stollen System, a labyrinthic 5 km of irregular natural halls connected by short mine passages in isolated Middle Devonian reefal limestones in the southeast corner of Iberg Mountain, Harz Mountains, Germany, illustrates the importance of yet another CO_2-generating process: siderite weathering. When siderite ($FeCO_3$) is oxidized, CO_2 is liberated and the iron oxide mineral goethite forms. The limestone of the Iberg was infiltrated with Mg- and Fe-bearing solutions transforming the limestone partly into dolomite and siderite. The siderite started to weather when the groundwater level sank enough to allow oxygen into the ore body. Due to the *in situ* liberation of CO_2, isolated caves, partly filled with clayey geothite, started to form started to form around the ore bodies. The goethite was mined for iron until the end of the last century. Unconnected Frankenberg Höhle, Biese Schacht, Kernberg Schächte, and Iberger Tropfsteinhoehle, a show cave, add another 3 km of passages, halls and pits.

DISSOLUTION KINETICS OF LIMESTONES AND DOLOMITES FROM ISLA DE MONA, PUERTO RICO, IN RELATION TO CAVE DEVELOPMENT

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Isla de Mona is a 6 km diameter carbonate island located in the Mona Passage between Puerto Rico and the Dominican Republic. The island consists of an upland plateau with sea cliffs on three sides and an escarpment dropping down to small beach areas on the south side. Large flank margin caves have developed near the contact between the limestone and the dolomite. A laboratory investigation was initiated to interpret the distribution of Isla de Mona caves in terms of the dissolution kinetics of the carbonate rocks.

The relative dissolution kinetics of the Lirio Limestone and the Isla de Mona Dolomite were determined by dissolving discs of various samples in CO_2-saturated solutions. Uptake of dissolved carbonate was determined by monitoring pH and specific conductance as a function of time. Initial rates for limestones averaged 12.53 $\mu mol\ m^{-2}\ sec^{-1}$ compared with 8.53 for dolomite. The rate curves had similar shapes. The limestone rates are comparable with those measured on single crystal calcite but the dolomite rates are higher than rates measured on Paleozoic dolomites.

Karstification of the Lirio Limestone takes place rapidly both because of the intrinsic chemistry of the rock and because of the large surface areas due to the porous character of the limestone. Because of the included calcite and perhaps also because of the porous surfaces, the Isla de Mona Dolomite dissolves substantially faster than the impermeable Paleozoic dolomites. Karstification within the Isla de Mona Dolomite would not be excluded from considerations of kinetics alone.

DELINEATION OF GROUNDWATER SPRING BASINS IN RUTHERFORD COUNTY, TENNESSEE: A FIRST STEP IN UNDERSTANDING SINKHOLE FLOODING

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Groundwater tracing was utilized in three spring drainage basins of Rutherford County, Tennessee, for the purpose of understanding present sinkhole flooding problems and planning for future growth. Ten successful dye traces were conducted. Seven traces went to Bushman Spring enabling the calculation of a drainage basin size of 26.4 km^2. One tracer traveled a distance of over 8 km in 3 days. Double Springs is a sub-basin within the larger Bushman Spring Basin. Two dye traces were conducted to Nice Mill Springs yielding a basin size of ~17.4 km^2. The tenth trace was to Compton Spring. More tracing is needed to this large spring to determine the recharge area. In all of the spring basins, groundwater moves through the Ridley Limestone perched above the Pierce Formation. Rapid movement of tracing agents suggests that subsurface cavities have not been clogged by human activities. Constructed geologic and topographic cross-sections, combined with two-foot contour map information, shows the karst water table is very close to the surface. As a result, natural constrictions associated with changes in cave passage size cause storm waters entering the subsurface to back up behind constrictions, resulting in flooding of upgradient sinkholes.

GEOCHEMISTRY OF CUEVA DE VILLA LUZ, MEXICO, AN ACTIVE H_2S CAVE

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Cueva de Villa Luz, Tabasco, Mexico, is in deformed Cretaceous limestone at the foot of the Chiapas highlands. The cave is an outlet for H_2S-rich water interpreted to be from a nearby oil-rich sedimentary basin because of its high Mg, Na, Cl, and SO_4, and low silica. Two water types feed the cave through impassable inlets: (1) H_2S-rich, pH = 6.6, PCO_2 = 0.1 atm, depositing sulfur on adjacent walls, coating surfaces with white filaments of sulfur-oxidizing bacteria; and (2) oxygenated water exposed to aerated conditions upstream from the accessible passages, pH = 7.3, PCO_2 = 0.02 atm, no hydrogen sulfide,precipitating iron hydroxide which recrystallizes to goethite. Cave air around Type 1 inlets has up to 130 ppm H_2S. Suspended droplets of infiltrating water absorb H_2S and O_2, which react to form sulfur and sulfuric acid. Slow drips reach pH values as low as zero. Nearby limestone surfaces convert to gypsum by reaction with the acid. The redox reactions support a bacterial community that forms the base of a complex food chain. Folia of sulfur alternating with organic films may have formed by H_2S degassing below a former water surface. The main cave stream (28°C, 290 L/sec) is cloudy with colloidal sulfur and at saturation with calcite and dolomite, but undersaturated with gypsum. The cave enlarges as gypsum falls into the stream and dissolves. Acidic water also seeps through the gypsum crust into the limestone stream bed, creating rills. In places, the walls and floor are coated with organic-rich muck in which pyrite is forming.

BY-PRODUCTS OF H_2S/H_2SO_4 SPELEOGENESIS

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This paper discusses sulfuric acid indicator by-products of H_2S/H_2SO_4 speleogenesis found in major caves of the Guadalupe Mountains, New Mexico. Some of these speleogenetic materials are gypsum, hydrated halloysite (endellite), alunite, natroalunite, jarosite, quartz, hydrobasaluminite, todorokite, amorphous silica**,** and sulfurous alumina gel. They form as by-products of sulfuric acid reaction with bedrock and internal sediments **(**host rocks**)**. They are found in areas protected from flood or drip waters. Host rocks are limestone and dolostone (calcite and dolomite), and siltstone and internal sediments (quartz, illite, dickite, kaolinite, illite/smectite mixed-layers, montmorillonite-rich-clay, and mica). Montmorillonite-rich clay is common only in solution cavities of Carlsbad Cavern.

Gypsum is the most abundant by-product of H_2S/H_2SO_4 speleogenesis. It replaces dolostone or precipitates from solution both below and above the water table. Alunite, natroalunite, jarosite, and hydrobasaluminite**,** other sulfate by-products**,** formed by sulfuric acid reaction with clay. Sulfur stable isotope values of these sulfates are negative, indicating biogenic hydrogen sulfide derived from hydrocarbons. Silica released during the alteration of clays precipitated as quartz or opal. Todorokite is commonly found as black halos around pockets of altered bedrock. Late-stage secondary minerals, indirect indicators of H_2S/H_2SO_4 speleogenesis, include uranyl vanadates (tyuyamunite and metatyuyamunite), aluminite, gypsum, gibbsite, nordstrandite, amorphous silica, and sulfurous alumina gel. Study of the H_2S/H_2SO_4 speleogenesis of Guadalupe caves provides a general model for similar cave systems worldwide.

REVISED AGE FOR XANADU CAVE, TENNESSEE, AND IMPLICATIONS FOR RIVER INCISION IN THE CUMBERLAND PLATEAU ESCARPMENT

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Xanadu Cave (Fentress County, Tennessee) is a 15 km long system on the Western Cumberland Plateau Escarpment. A minimum age of 0.91 Ma was previously assigned to upper levels of the cave based on paleomagnetic studies. To better constrain the age of the cave, we collected quartz sand for cosmogenic isotope dating, along with detailed paleomagnetic samples, at a site in the cave where a normal to reverse magnetic polarity change was found. Dating of the sand based on radioactive decay of ^{26}Al and ^{10}Be implies with 99% certainty that the sand was deposited prior to 2.7 Ma, and with 95% certainty that the sand was deposited prior to 3.3 Ma. The Obey River, presently 50 m below the sampling site in Xanadu Cave, is therefore downcutting at less than 20 m/Ma. This is comparable to rates obtained for the New River, Virginia, and the Kanawha River, West Virginia, but slower than rates of 30 m/Ma inferred for the Green River near Mammoth Cave, Kentucky, and 45 m/Ma for the Ohio River near Madison, Indiana. Assuming that the sediments were deposited near the river swallet, now 7.7 km upstream, the swallet is migrating upstream at more than an order of magnitude faster than river incision.

A DECADE OF MUD MOVEMENT

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In 1987, a peculiar mud slope in Shine Cave caught the attention of the authors. The slope has striations apparently carved by ceiling irregularities when moving mud squeezed under a step in the ceiling. Also where water drops fall from the ceiling onto the mud slope, a down-slope drip trench exists, rather than a typical drip hole. These circumstances suggested a measurement of the mud movement rate could be made. With that objective, simple plumb bobs were hung from a few points on the ceiling above the slope. Under the point of each bob, where it almost reaches the mud, a stiff vertical wire was pushed into the mud so that the wire initially aligned with the bob. After the mud moves, the wire no longer aligns with the bob and the displacement can be measured. After 4 years, the initial results of periodic measurements were reported in 1991. Measurements have continued through 1997. This decadlong data series shows a higher than typical rate during winter and spring 1991, correlating with an anomalous high rainfall period. From examination of the decade data set, the average rates are: 3 mm/yr from late 1987 through 1990; 40 mm/yr in the first half of 1991; and 3.5 mm/yr from 1992 through 1997. Measurements of the elongation of drip trenches, while not as accurate, confirm the rates from the plumb bob installations.

CAVE MORPHOLOGY AND HYDROLOGY AS MEASURES OF KARST AQUIFER EVOLUTION

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Caves increase in length, volume, vertical extent, and general complexity with time, and thus become better integrated components of their aquifers. These attributes can be regionally examined to determine the evolution of karst aquifers. Two aquifers in south-central Texas were studied. The Lower Glen Rose (LGR) Aquifer is shallow, and mostly gravity drained to the Guadalupe River, with a deeper component that joins the artesian flow of the Edwards (Balcones Fault Zone) Aquifer. Caves are best developed in the central portion of the LGR aquifer where groundwater circulation was first initiated. Groundwater has flowed through that aquifer's eastern and western sections for about the same amount of time, but few significant caves and springs are known in the east, where the water table has been relatively higher and groundwater circulation probably slower. In the Edwards Aquifer, caves change from dendritic conduit networks to isolated chambers from west to east, suggesting the aquifer has grown eastward, accreting major fault blocks as incising streams allow discharge from progressively lower elevations.

The degree of cave extent and complexity in assessing aquifer evolution must be determined relative to the caves in each given area. Hydrologically mature aquifers can sometimes be difficult to assess if a high degree of uniformity exists among the caves, and the nature of conduits related to groundwater piracy or other key hydrologic events is obscured. Conceptual understanding of aquifer development can be useful to groundwater modeling, management, and cave exploration.

HAWAII SESSION

A SUMMARY OF SURVEY ACTIVITIES IN LAVA TUBES TO THE NORTH OF THE NORTHEAST RIFT ZONE OF MAUNA LOA, HAWAII

Dave Bunnell, Doug Medville & Ron Simmons, Hawaii Speleological Survey

On the north side of the Northeast Rift zone on Mauna Loa (elev. 4171 m) on the island of Hawaii, lava flows, ranging in age from historical to about 4 Ka BP, cover an area of about 570 km^2. To date, over 21 km of survey has been conducted in about 50 tubes in 12 flows below and to the north of the NE rift zone. The most productive of these are three historic flows: the 1855 flow (6830 m surveyed in 18 tubes), the 1859 flow (4600 m surveyed in one tube) and the 1935 flow (4200 m surveyed in 5 tubes). The tubes surveyed have ranged in depth from 1.5 to > 15 m below the local surface, and in complexity, from simple unitary conduits to multiple level, braided passages.

CULTURAL RESOURCES IN CAVES AT HAWAII VOLCANOES NATIONAL PARK

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At various times during the last 2000 years, Polynesians from the Marquesas and Tahiti sailed to Hawaii and settled, eventually becoming today's Native Hawaiians. Caves were, and are, viewed by them as part of the resource base of Hawaii, and were extensively used by the people of old. Caves served as temporary or permanent habitation sites and were used for religious purposes, shelters in time of war, and storage places for food, as well as work areas. Water dripping from cave ceilings was collected in gourds or other containers, especially in desert areas. Some caves are paleontologically important, containing the bones of several species of extinct flightless birds endemic to Hawaii. Important caves were named, and political land boundaries often followed the course of large caves. Nearly every large lava tube in Hawaii Volcanoes National Park older than 200 years contains archeologically important cultural remains. These may range from charcoal deposits, to simple arrangements of pebbles used to prop gourds upright, to caves containing hundreds of petroglyphs, to habitation caves with their complement of features.

THE HIGHCASTLE LAVA TUBE - HAWAII VOLCANOES NATIONAL PARK

Bobby Camara, Hawai`i National Park, HI 96718
Jim Kauahikaua & Carl Thornber, U.S.G.S., Hawaiian Volcano Observatory, Hawai`i National Park, HI 96718

The volcanic nature of Hawaii and the kind of lava erupted allows for the formation of sometimes extensive lava tube systems. Lava tubes are more commonly found on the younger, less weathered volcanoes, such as Mauna Loa and Kilauea on the island of Hawaii. The lands that comprise the 97,000 hectares of Hawaii Volcanoes National Park were formed by lava flows from the summits and rift zones of both volcanoes. We have been able to observe and gain some insight as to the formation and evolution of lava tube systems during an ongoing eruption on the east rift zone of Kilauea. A three year old lava tube was entered, mapped, and its features inventoried in the winter of 1997. A suite of unusual secondary minerals was collected and analyzed, and lava features in the cave were described and analyzed. An attempt was made to correlate observations made while the tube was active, and those made during exploration. Location(s) of skylights, size and shape of the tube, locations of mineral deposits and lava features, as well as surface features, were all examined to ascertain if patterns existed which would account for our observations. The youth of Highcastle offered a unique opportunity to focus on the apparently transient features only found in recently formed lava tubes.

HAWAII CAVES 1958-1998

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Systematic speleology began in Hawaii in 1958, with publication of an initial report in the *NSS Bulletin*. The ill-fated fallout shelter program of the 1960s identified and published the locations of numerous caves. In 1970, Frank Howarth and Fred Stone initiated biological studies that radically changed scientific understanding of insect evolution. Later in the 1970s, stud-

ies by mainland and overseas speleologists began to accelerate. Most of the body of knowledge comprising today's mainstream of Hawaiian speleology accumulated following formation of the Hawaii Speleological Survey in 1989. The number of known caves has increased to more than 1,200, including the world's longest lava tube cave (Kazumura Cave, with 60.2 km mapped). More than 100 km of cave passages has been mapped. Collaboration with planetary geologists led to discovery and investigation of a new type of cave at vents for nodules of ultramafic xenoliths. New types of sheet flow caves have been found in Kilauea Caldera, and numerous hollow lava tumuli of several types. The deepest pit in the United States is either on Hualalai Volcano or on Molokai Island (the latter pit is mostly water-filled and re-measurement is needed).

LAVA RISE CAVES IN KILAUEA CALDERA, HAWAII

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A lava rise is a large lava tumulus found on some flow fields of basalt, such as the Kilauea Caldera, Hawaii. Like other tumuli, they result from injection of very fluid lava beneath a deformable plastic crust. Many undergo partial deflation after their margins have solidified, resulting in a central depression or collapse surrounded by a boundary ridge one to several meters high. In some cases, a cavernous space persists within the boundary ridge and between it and the central depression. It can extend several meters outward from the high point of the boundary ridge. Sometimes extensive, complex feeder and/or drain tubes are present. The classical case approximates the shape of a hollow donut, but commonly, only segments of the ring are present. A few of these unusual caves have been investigated and the consistency of their internal structures is not clear. They appear to be more closely related to flow lobe caves than to "ordinary" hollow tumuli, but a deep fissure cave thinly lined with accreted lava in the middle of one central depression raises a question about the route of the lava injection. One of the boundary ridge caves has been mapped to the margin of an unrelated adjoining conical tumulus.

CULTURAL RESOURCES IN NORTH KONA LAVA TUBES

Doug & Hazel Medville, Hawaii Speleological Survey

A variety of structures and artifacts found in lava tubes in the North Kona district, Hawaii are evidence of former and ongoing use by native Hawaiians. These include walls, steps into pukas, rock rings, platforms, and other structures. Tube use is evidenced by offerings placed at entrances, as well as twigs and shells found inside the tubes. Although several of the features observed while surveying in the tubes have been described in the archeological literature, other features, so described, are no longer to be found as a result of their removal from the tubes by unknown persons. As development continues in the North Kona district, cultural features found in the lava tubes are expected to continue to diminish.

HISTORY SESSION

LOST CAVES OF HARRISON AND CRAWFORD COUNTIES, INDIANA

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Harrison and Crawford Counties, bordering the Ohio River in southern Indiana, have long been known to cavers. Some 800+ caves for the side-by-side counties are listed in the Indiana Cave Survey database. Famous show caves, such as Wyandotte and Marengo Cave, are here, as well as the 30+ km Binkley Cave System. At least 18 caves in these counties have been physically closed or "lost" so that present entry by cavers is not possible because of natural cave-in, sealing during highway construction, being bulldozed shut by owners, flooding, quarrying, or inadequate knowledge about the location of the entrance. The existence of these once open caves is documented with newspaper articles, photos, and word of mouth and hand-me-down stories. These caves await rediscovery by persistent cavers. From the known clues, some of the lost caves may prove to be quite extensive and/or very beautiful.

RALPH WALDO EMERSON AND MAMMOTH CAVE

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Although speleohistorians have long known that Ralph Waldo Emerson visited Mammoth Cave sometime in the 1850s, recent research in his journals and letters has yielded additional information about his trip to Kentucky and the cave. Of particular interest is Emerson's lengthy letter to his wife, Lydian, which details his two tours into Mammoth Cave in June 1850. Emerson was impressed by the natural features of the cave as well as the theatrics and other elements of the tour. The Mammoth Cave experience made a lasting impression upon Emerson and provided the seeds of ideas which later emerged in his essay "Illusions."

HISTORIC CAVES OF THE MATTERHORN REVISITED

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Following the 1997 International Congress of Speleology in Switzerland, the author spent some time in Zermatt, climbing and investigating local historic caves.

During an ascent of the Matterhorn, a shallow cave was visited on the east face near the Hornli Ridge, at an elevation of 3,811 m msl. Due to its strategic location, this grotto has been used as a bivouac on numerous occasions by climbers. In 1868, three years after the first ascent of the Matterhorn, a small wooden hut, protected by dry stone walls, was constructed out from the cave mouth to increase the shelter's capacity to accommodate 7 or 8 stranded climbers. Over time, the hut fell into progressive stages of disrepair, and by the turn of the century it was all but gone. In 1915 the Solvay Hut was established 192 m above the cave. This is still the mountain's highest emergency shelter.

A second historic cave, the Gouffre Des Busserailles, a few kilometers south of the mountain across the Italian border, can still be seen for a small fee. It has an impressive narrow, sinuous glacial gorge, and is about 100 m long and 33 m deep. It was first entered in November 1865 by the Alpine guide, Jean-Antoine Carrell, who was lowered by others into the chasm. They soon built a plank walkway so everyone could explore the cave. Edward Whymper was also impressed and referred to the cave in his classic treatise, *Scrambles Amongst the Alps in the Years 1865-69*.

THE SALTPETER MINING HISTORY OF VIRGINIA CAVES: AN INVENTORY AND COMPENDIUM IN PROGRESS

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From the mid-18th century until 1865, many Virginia caves were used for the extraction of saltpeter, with the most intense mining occurring during the Revolution, the War of 1812, and the Civil War. During recent years an active inventory of these caves and their contents has been in progress, using historic documents, oral tradition, and artifacts to rediscover sites. Aspects of the physical remains were recorded, which reveal a wide array of variation in tools used, sediment types exploited, where leaching took place, where water was collected, types of vats used, and sometimes when a passage was worked and by whom. Ongoing research indicates that 94 caves were mined for saltpeter within the present geographic limits of Virginia. This inventory also entails the compilation of previous documentation. Older photographs and slides of mining evidence are sought for duplication and inclusion in the compendium. All saltpeter mining remnants and artifacts are protected by the Code of Virginia.

THE TOMBIGBEE RAILROAD SURVEY VISITS SALTPETER CAVE

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Inscriptions scratched on a rock in Saltpeter Cave, Lawrence County, Alabama, record a June 8, 1887, visit by the "Tombigbee R. R. Survey". Perhaps drawn by curiosity or a cool escape, this survey party apparently departed from its assigned tasks to view the wonders of this cave with its large entrance. In doing so, the group left a lasting record of its membership on that day. It also marked an event in the fascinating history of transportation problems and opportunities in the corner of Alabama, Mississippi, and Tennessee where the headwaters of the Tombigbee River approach the northward bend in the Tennessee River. Probable identifications for four of the six survey members were made.

THE DEMISE OF SHELAH WATERS

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In 1869, Shelah Waters explored extensively in Higginbotham Cave (now known as Cumberland Caverns) in Warren County, Tennessee. Tom Barr's *Caves of Tennessee* (1961) reported the local folklore that Waters was ambushed and killed in 1870. In 1990, the McGarr-Waters Papers at the

Tennessee State Library and Archives were consulted, which contained documents which clearly proved that Waters was still alive as late as December 9, 1887. Subsequent research by Marion O. Smith resulted in the discovery of Waters' obituary in the February 4, 1894, issue of the *Nashville Daily American*. Based upon this new information, the author located Waters' grave in the Nashville National Cemetery. Waters' house at 407 Fatherland Street in east Nashville is no longer in existence. This past year Shelah Waters' name was found by Joseph C. Douglas in another Warren County grotto, Hubbards Cave.

SPELUNKING SOCIALISTS AND STUDENTS

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Ruskin Cave, Dickson County, Tennessee, has been noted at least since 1808 and 1810, when deeds listed a "great cave" as a landmark of the property. Ruskin was home to a socialist commune in the late 1890s and to Ruskin Cave College (RCC) from 1904 to 1918. Graffiti in the cave shows that it has been visited by numerous people, including some adventurous individuals who belly crawled over 60 m to reach the back portion of the cave. One hundred students and two faculty members from RCC have been identified as traversing the crawl, since their names and/or initials are found past that point. Ten identifiable trips are noted that contain names or initials and a date. Two trips were led by faculty members R. J. Kelly and Virgil B. Hatley. Kelly's group (1 faculty member, 6 students) contained at least 4 females while Hatley's group (1 faculty member, 7 students) consisted of at least 5 females. The socialist commune found its home at Ruskin from 1896 until 1899. The cave was named after the noted British socialist John Ruskin, who never visited the colony. The socialists used the cave entrance extensively for canning, food storage, and dances. Several socialist names appear before and after the crawl. C. W. Broeg, the stonecutter for the commune, chiseled his name before the start of the crawl. Other socialists entered the back of the cave on September 9, 1899, before the colony dissolved and the cave property was sold.

CAVES AND CIVIL WAR ARMIES IN THE CHATTANOOGA REGION

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Some caves in southern Tennessee, northeastern Alabama, and northwestern Georgia relate to movements of Civil War armies. On or near the routes the armies traveled were caves worked by the Confederates for saltpeter or springs with associated passages. Over a dozen of these caves were visited by Union troops during the last half of the war. Some were entered during the Chickamauga-Chattanooga campaign while others were subsequently toured by railroad guards or transient soldiers. Two of the caves, Lookout and Nickajack, received heavy visitation by men from both sides. Many of these military tourists have been identified.

PALEONTOLOGY SESSION

A MODERN AND HOLOCENE BONE SITE IN WHITE CROSS BONE CAVE, TENNESSEE

Frederick Grady, Department of Paleobiology, MRC 121 NHB, Smithsonian Institution, Washington, D.C. 20560; Laurie Adams, 76 Lavale Avenue, Asheville, NC 28806

The surficial deposits in White Cross Bone Cave, Cocke County, Tennessee include 10 species of mammals and several birds. The well preserved nature of the material is suggestive of an owl roost or natural trap. An owl roost is suggested by the dominance of several species including *Sigmodon hispidus* [Hispid cotton rat], *Microtus pinetorum* [pine vole], and *Blarina brevicaduda* [short-tailed shrew], and the shallow depth of the cave such that small animals would likely survive a fall and be able to climb out of the cave. A test pit 30 cm deep reveals a similar fauna though less well preserved. None of the species in White Cross Bone Cave are extinct and all are found in the local area today.

NEW FINDS OF PLEISTOCENE TAPIRS FROM TENNESSEE, VIRGINIA, AND NORTH CAROLINA

Frederick Grady, Department of Paleobiology, MRC 121 NHB, Smithsonian Institution, Washington, D.C. 20560; David A Hubbard, Jr., Virginia Cave Board, PO Box 3667, Charlottesville, VA 22903; Cato Holler, Jr., O Box 100, Old Fort, NC 28762

Six new discoveries of Pleistocene tapirs are all referred to as *Tapirus veroensis* based on size. The Tennessee specimens consist of an upper second molar from Blue Spring Cave, White County, a lower first molar from an unnamed cave in Montgomery County, and the diaphysis of a femur from Upper Buffalo Mountain Cave, Washington County. All are new county records of *Tapirus* in Tennessee. The Virginia specimens consist of an upper fourth premolar or first molar from Slip Sliding Away Cave, Scott County, and an upper first or second molar from Lost Lake Cave also of Scott County. Both Virginia specimens are from newly discovered caves. The North Carolina specimen is a partial upper molar from Blowing Springs Cave, Swain County and is the first cave record of *Tapirus* from the western part of the state. All 5 teeth have had their roots chewed off by rodents, probably *Neotoma magister* [eastern woodrat], and the femur also exhibits evidence of rodent gnawing.

NEW PALEONTOLOGICAL CAVE RESOURCE FINDS IN VIRGINIA

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Frederick Grady, Department of Paleobiology, MRC 121 NHB, Smithsonian Institution, Washington, D.C. 20560

A new inventory of paleontological resources in Virginia caves has yielded significant new records. Records include additional fauna at known paleontological sites and new sites. New sites appear to represent accumulations by wash-in, pit-fall, pack-rat hoarding and visitation. New records of extinct fauna include: *Arctodus simus* [short-faced bear], *Mammut americanum* [mastodon], *Mammuthus primigenius* [woolly mammoth], *Tapirus veroensis* [vero tapir], *Platygonus compressus* [flat-headed peccary], and *Bootherium bombifrons* [musk ox]. Goals of the Paleontological Resource Inventory Of Virginia Caves (PRIOVAC) include: 1) determining the context of deposits; 2) taxa inventory; 3) communicating with fellow cavers about the importance of paleontological resources and appropriate protocols when suspected paleontological resources are discovered. The paleontological resources of Virginia caves are protected by the Code of Virginia.

RESCUE SESSION

THE USAR STRETCHER: A NEW LITTER FOR CAVE RESCUE

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The USAR - Urban Search and Rescue Stretcher- was developed from the Neills-Robertson stretcher. The self-contained unit includes a detachable semi-rigid plastic drag plate, Cordura nylon fabric-covered foam and plastic stretcher body, integral fiber pile exposure bag, removable head support and attached rigging straps for both horizontal and vertical lift of a casualty. It is adjustable to fit a wide range of patient sizes, from children to large adults. It is lightweight (9.9 kg) and compact, rolling down to 25 cm x 76 cm. Placement of a patient in the USAR can be done without rolling the casualty, using as few as two rescuers. The USAR encircles the patient, acting as a full-body splint. It has a very low profile for tight cave passages and can be dragged through mud or over rock and gravel, protected by the plastic drag plate. Vital signs are easily assessed with minimal manipulation of the litter straps. The USAR is x-ray translucent and contains no metal. The USAR is an excellent evacuation aid for caving groups exploring remote cave systems or for rescue caches.

A SELF RESCUE TECHNIQUE FOR DEALING WITH THE EDGE OF A DROP

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One of the challenges of vertical caving is negotiating the edge of a drop. The caver must deal with loose rock, overhangs, and excess friction when the rope touches the rock. These hazards are increased in a self rescue situation. Some of the rescue hazards can be mitigated through proper patient preparation and a special edge technique. In the first phase of the technique, the rescuer prepares the patient by placing them in a chest harness. A quick attachment safety and an ascender are clipped to the patient's seat harness. A carabiner or pulley is clipped to the leg loop of the harness. The main line runs through this entire system. The rescuer also attaches a safety ascender and an ascender to their own harness. In the second phase of the technique, the main line and patient are hauled to the top of the drop. In the third phase, the rescuer clips into the main line with the safety and runs the tail of the line through the harness ascender. The rescuer squats at the edge of the drop, and pulls in as much of the tail as possible. The rescuer then stands up, hauling the patient up.

The patient's seat ascender will capture the upward progress. This procedure is repeated until there is no rope left. At this point the patient should be a least a foot above the edge of the lip. The rescuer can then drag the patient across the lip into a safe area.

SURVEY AND CARTOGRAPHY SESSION

A VERSATILE RANGEFINDER

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Optical range finders based on the parallax method are almost totally worthless in the cave environment because of low light levels. Even with powerful (heavy and bulky) lights, converging the illuminated images does not produce satisfactory results. However, if an object at the distance being measured is illuminated with a spot from a laser beam, the result is astonishingly accurate. Using an instrument with a lens separation of 10 cm, repeatable accuracy of 3 cm is possible up to about 6 m. Accuracy degrades to 5 cm at 9 m, 15 cm to 15 m, 30 cm to 30 m, and about 1.5 m up to 45 m (if you can see the spot). Using this instrument it is possible to make accurate, non-invasive measurements to inaccessible or environmentally sensitive areas.

SPELEOMESHING: A TECHNIQUE FOR HIGH DEFINITION CAVE SURVEYS

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This paper describes a set of novel computer techniques for cave and mine mapping which are collectively referred to as SpeleoMeshing. The process yields detailed volumetrics, dense meshes for structural finite element analysis, and photo-realistic rendering. The techniques are low cost, high in accuracy and suitable for use on personal computers.

The process is composed of three steps: collection of passageway profiles, conversion of the profiles into 3-dimensional models and, optionally, collection and application of texture maps on passageway walls for photo-realistic rendering.

The first step of the process uses a simple pocket laser to outline each passage profile along survey lines for photographic capture. The photograph is subsequently digitized and used to calculate passage profile axiometric distances. In the second step, the resulting axiometric passage profile data is extruded between profiles into a 3-dimensional wire frame mesh. This wire frame mesh data is suitable for high accuracy volumetric analysis and for structural finite element analysis. In a third step, for high quality rendering, the photographs of passageway walls are taken for color and texture definition. The resulting photographs are then texture mapped onto the 3-dimensional model, and computer rendering techniques are used to produce near photo-realistic renditions of the cave.

AUTOMATIC UNDERWATER SURVEYING AND MAPPING

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In October 1998, the U. S. Deep Caving Team will field an expedition to Wakulla Springs, a show cave in The Edward Ball Wakulla Springs State Park south of Tallahassee, Florida. The objectives are to continue the exploration, survey, mapping, and scientific study begun in 1987 by The Wakulla Springs Project and continued by the Woodville Karst Plain Project. Wakulla Springs is an underwater cave exceeding 5 km in length and 100 m in depth.

Surveying will be done automatically by a Digital Wall Mapper (DWM) mounted on a Diver Propulsion Vehicle (DPV). The DWM uses an inertial navigation system for determining the position and orientation of the DPV and a sonar device that simultaneously measures thirty-two wall distances for determining cross sections. Data are gathered several times per second, the resulting spacing of wall points being a fraction of a meter.

Within the DWM, the data from the inertial navigation system, the sonar device, three pressure sensors, and a thermometer are stored in an on-board computer. When the DPV returns to the surface the data are downloaded to a Personal Computer (PC). The PC reformats and writes the data to a zip disk that is then transferred to a Silicon Graphics workstation. Nine separate programs, written in ANSI C and using OpenGL for graphics support, comprise the software suite. A three-dimensional interactive cave map is produced with minimal human intervention.