

SELECTED ABSTRACTS FROM THE 2004 NATIONAL SPELEOLOGICAL SOCIETY CONVENTION IN MARQUETTE, MICHIGAN

BIOLOGY

THE NATIONAL CAVE AND KARST RESEARCH INSTITUTE: EARLY HISTORY, EVOLUTION, AND CURRENT PROGRESS

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Several Acts of Congress between 1988 and 1998 led to the creation of the National Cave and Karst Research Institute under the initial direction of the National Park Service. In July 2000, an Interim Director was hired to begin development of the Institute and to build collaborative relationships with a variety of federal agencies and other organizations. New Mexico Institute of Mining and Technology and the City of Carlsbad formed a partnership with National Park Service to establish the Institute. A Federal Working Group was created with representatives from six federal agencies to provide recommendations for Institute goals and priorities. Through contracts and cooperative agreements, the Institute began supporting cave and karst research projects. The National Cave and Karst Research Institute is intended to be a multidisciplinary institute, covering all aspects of cave and karst science. Many of the early projects were in geology and hydrology, but some biology projects were sponsored. In December 2002, a permanent director was hired. Extensive contacts with government agencies, universities, and non-profit organizations continued, and in October 2003, representatives of all these interests participated in a Vision Building Workshop to discuss the Institute's operational and administrative future. Near future administrative plans for the Institute include construction of a new building in Carlsbad, movement toward a New Mexico Institute of Mining and Technology-administered operation, and creation of a corporation with a board of directors. The future of biological research and data compilation through the National Cave and Karst Research Institute will depend on input from biologists.

STUDIES OF BACTERIAL COMMUNITIES FROM FOUR WINDOWS CAVE, EL MALPAIS NATIONAL MONUMENT, NEW MEXICO

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One of the striking features of some lava tubes is the extensive bacterial mats that cover the walls. In Four Windows Cave, these bacterial mats occur in the twilight zone adjacent to algal mats and in the dark zone. In an effort to phylogenetically characterize bacterial community members, we extracted DNA from wall rock communities, using a soil DNA extraction technique developed at Los Alamos National Laboratories. The DNA was purified, the 16S rRNA gene was amplified using PCR, amplification products were cloned, and 30 clones were sequenced in their entirety. Comparison of our sequences with those in the Ribosomal Database II revealed that the Four Windows bacterial sequences group with actinomycetes, *Acidobacterium*, *Verrucomicrobia*, *Betaproteobacteria*, *Gammaproteobacteria*, *Flexibacter*, *Planctomyces*, and *Leptospiillum/Nitrospira* groups. These results reveal a diverse community of bacteria and the presence of several novel bacterial species. To test whether these bacteria had lost their resistance to ultra-violet radiation, we cultured mat and surface bacteria on to R2A and subjected cultures to ultra-violet radiation in a biological safety cabinet. Bacteria cultured from these mats and surface soils on R2A medium showed a general trend in

which microbes isolated from the lava tube were much more ultra-violet sensitive than the microbes isolated from the surface.

DISTURBED VERSUS PRISTINE MICROBIAL COMMUNITIES IN TIMPANOGOS CAVE NATIONAL MONUMENT

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Timpanogos Cave National Monument is studying how visitation within its confined cave trail is affecting the cave's microbial communities. Samples have been collected from the disturbed areas near the cave's tourist trail and pristine non-impacted areas such as buried cave sediments and imputing water drips. Relative microbial community diversity and abundance are being evaluated using molecular techniques based on isolation of 16S rDNA from environmental DNA extractions. Preliminary data indicate that disturbed sites are dominated by *Gammaproteobacteria* and *Acidobacteria* sequences, although representatives from *Alphaproteobacteria*, *Nitrospira*, *Planctomyces*, and the *Bacteroidetes/Chlorobi* group were also retrieved. Additionally, a large mat community of an environmental species of *Yersinia* was found associated with discarded food found near the trail. Once these microbial communities have been characterized, the impacts from tourism can be monitored and restoration techniques be can be evaluated.

PHYLOGENETIC INFERENCES OF THE PARASITIC BAT FLIES STREBLIDAE AND NYCTERIBIIDAE (DIPTERA: BRACHYCERA: CALYPTRATAE)

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A phylogenetic study of the evolution of the parasitic bat flies, Streblidae and Nycteribiidae, has been initiated. The relationships within and among these families has been investigated using molecular data from the nuclear 18S rDNA gene and the mitochondrial 16S, cytochrome oxidase II, and cytochrome B genes, for a total of 3048 molecular characters. Phylogenetic trees were reconstructed using maximum parsimony, maximum likelihood, and Bayesian methods. Some previous hypotheses indicate that streblids and nycteribiids are sister families, with the nycteribiids, which exhibit more extreme morphological changes associated with the parasitic lifestyle (i.e. loss of wings, dorsally shifted head and leg insertion), as the older lineage of the two. However, the results of these analyses indicate that the streblids are the older group, and that the nycteribiids are nested within the streblid clade. Additionally, the nycteribiids remain a monophyletic group. While support for the nodes delineating relationships of the three main clades of bat flies (nycteribiids, Old World streblids, and New World streblids) is poorly supported, there remains evidence for two independent invasions of this group into the New World, once within the nycteribiid lineage, and once in the paraphyletic streblid lineage (subfamilies Nyctyerophilinae, Streblinae, Trichobiinae). Future research will compare the evolution of this group with the radiation of the bat hosts.

SPEODESMUS

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Speodesmus millipedes are small, white, troglitic polydesmids, probably descended from soil-burrowing forms that inhabited mesic, southwestern forests in the past. Currently there are four described species: *S. echinourus* Loomis, 1939, from central Texas; *S. tujanbius* (Chamberlin 1952), re-described by Shear (1974), from New Mexico and West Texas; *S. bicornourus* Causey, 1959, from central Texas; and *S. aquiliensis* Shear, 1984, from Colorado.

Elliott's 1976 morphometric study of numerous specimens from Texas employed extensive multivariate analyses in search of species-specific characters. As in most millipedes, the male gonopods provide good characters, because of their lock-and-key relation to the female genitalia. Females have extensible cyphopods. Some small species (7-10 mm long) still burrow in soil, while large species (20 mm) evolved gigantism in humid cave environments. Large and small morphs of *S. bicornourus* are geologically isolated from each other. *Speodesmus* has speciated many times into interesting biogeographic patterns related to karst areas bounded by faults, streams and lithologic changes.

New species recognized by Elliott include six from Texas, one from Arizona, and one possible from Nevada. Elliott has in-press descriptions of four of the new Texas species: Species c from Fort Hood, Bell and Coryell counties; Species f from Camp Bullis, north central Bexar County; Species r from Government Canyon State Natural Area, Helotes and other points in northwestern Bexar and northeastern Medina counties; and Species i from Camp Bullis and San Antonio, Bexar County, and Comal County. The closest relative of Species c is *S. bicornourus*, from caves in Williamson, Travis, and Burnet counties, Texas. Species f and r are relatives of *S. echinourus*, which is distributed across the Edwards Plateau and parts of the Balcones Escarpment. Species i is a soil-burrowing form, similar to a new species from Val Verde County. Another new species from Hays and southern Travis counties is a more troglomorphic relative of *S. echinourus*. Preanal setae, previously thought to distinguish species groups of *Speodesmus*, are somewhat variable. Gonopods remain the most suitable structures for separating species groups until DNA studies can be employed.

GEOLOGY

SPELEOTHEMIC MINERAL DEPOSITS FROM FUMES AND STEAM, 1919 LAVA FLOW, KILAUEA CALDERA, HAWAII

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The 1919 "Postal Rift" lava flow in Kilauea Caldera contains about 200 caves. Included are lava tube caves, hollow tumulus caves, drained flow lobe caves, and others. While a single body of magma is believed to underlie the entire caldera, significant differences in the fumes of different areas are detectable by human senses, on and beneath the surface. A significant minority of its caves are at least intermittently hyperthermal, with varied patterns of steam and fume emissions and varied speleothem deposition along hot cracks and in other locations on ceilings, walls, floors, and lava speleothems. Working conditions include up to 100% relative humidity and temperatures up to 55° C, but as a result of thermostratification, temperatures as high as about 80° C can be measured in speleothemic areas. Sulfates, chlorides, and (rarely) elemental sulfur are believed to be present. An initial project of mineral identification foundered with the termination of the position of Cave Specialist at Hawaii Volcanoes National Park. A new project is strongly indicated.

MAZE DEVELOPMENT IN HAWAII LAVA TUBES: A STATISTICAL ANALYSIS

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Over the past two decades, the Hawaii Speleological Society has documented more than 1,000 cave entrances and accumulated nearly 200 miles of survey. Twenty of these caves range from 1 to 40 miles in length. These form the study group for the project. Many are rather simple straight-line drainage tubes, while others form extremely complicated maze systems. Cavers have long wondered why there is such a radical difference in caves that are all formed by the same volcanoes.

This study uses the Compass cave program to analyze a line plot of each cave. Two separate analytical techniques placed the sample caves into three distinctive groups: Linear, Transitional, and Maze. The next step in the study was to correlate each cave with the characteristics of the individual flow unit within which it occurred. The intent was to establish the major criteria that influenced maze development. Six characteristics were tested:

Geologic Age

Volcano—Hualalai, Mauna Loa, Kilauea

Slope—average angle of incline

Volume—average passage diameter

Environment—rift zone, caldera, or cinder cone

Morphology—shielded vs. open air

Maze development was most strongly correlated with large volume flow events. These are more common along rift zones on the taller, steep-sided mountains of Hualalai and Mauna Loa. There is also the impression that maze development formed in relatively short, open-air events.

MICROBIAL CONTROLS ON SULFURIC ACID SPELEOGENESIS

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The sulfuric acid speleogenesis model, proposed in the early 1970s from observations of Lower Kane Cave, Wyoming, considered a cave-enlargement process that was based almost entirely on chemical oxidation of H₂S to sulfuric acid. Sulfuric acid reacted with limestone at the water table or on subaerially exposed cave-wall surfaces where gypsum replaced the limestone. Reduced sulfur compounds (e.g., H₂S), however, also serve as energy sources for microorganisms living in these caves, including Lower Kane Cave. Using uniquely applied geochemical and microbiological methods, a surprisingly complex consortium of microorganisms was found to form thick subaqueous microbial mats in the cave. Several evolutionary lineages within the class "Epsilonproteobacteria" dominate the mats. Compared to the total flux of sulfide into the cave, little H₂S volatilizes into the cave atmosphere or oxidizes abiotically in the anaerobic spring water. Instead, the primary sulfide loss mechanism is from subaqueous microbial sulfide oxidation. Despite the cave waters being slightly supersaturated with respect to calcite, the "Epsilonproteobacteria" generate sulfuric acid as a metabolic byproduct, depressing pH at the limestone surfaces. This acts to focus carbonate dissolution near the attached filament, locally changing the saturation index. The H₂S that volatilizes into the cave air is oxidized at the walls where interactions between cave-wall microbiological (biofilms development) and physicochemical (biofilms hydrophobicity) factors influence subaerial speleogenesis. The recognition of the geomicrobiological contributions to subaqueous and subaerial carbonate dissolution fundamentally changes the model for sulfuric acid speleogenesis and the mechanisms for subsurface porosity development.

BIOVERMICULATIONS: LIVING, VERMICULATION-LIKE DEPOSITS IN CUEVA DE VILLA LUZ, MÉXICO

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Black, grey, brown, beige, blue, and purple wall and ceiling coatings comprising bacteria, fungi, and minor amounts of sub-aerially deposited clay in the sulfide-rich Cueva de Villa Luz, Tabasco, México, visually resemble vermiculations. The mushy colonies occur ubiquitously on exposed, sub-aerial limestone that is not subjected to flowing water. They manifest in a variety of forms ranging from dendritic to discrete spots to massive mats, mimicking all vermiculation morphologies documented by Parenzan (1961), and more. The biovermiculations exhibit pH values from 3.0 to 7.5. The colonies disappear near entrances during the dry season, leaving only an extremely thin layer of gypsum and/or clay, and re-grow during the wet summer and fall seasons. A 3-by 3-centimeter patch within a massive deposit was scraped to bare limestone in 1998. Biovermiculation colonies re-populated with "pimple-like spot" biovermiculations within weeks. The patch continues to fill in with "elongate spots" and by the edges of the massive deposit extending inward.

Epifluorescent microscopy of samples stained with acridine orange revealed a variety of bacterial shapes including large, cigar-shaped rods, stalked bacteria, and cocci. DNA extracted from these deposits demonstrated the presence of fungi and different kinds of bacteria, including *Acidobacterium* and actinobacteria.

While vermiculations occur in a variety of caves worldwide, they are particularly common in active and formerly sulfide-rich environments. These observations suggest that some "mud and clay" vermiculations formed as sub-aerial clay particles accumulated onto the sticky surfaces of active biovermiculations in a manner similar to stromatolite deposits.

PATTERNS OF STRUCTURAL SEGMENTS AND THEIR INFLUENCE ON PASSAGE MORPHOLOGY IN FRIARS HOLE CAVE SYSTEM, WEST VIRGINIA

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Early flow paths in caves can follow single fractures, fracture intercepts, or zones of closely-spaced fractures. Inferred early fracture conduits (structural segments) can be identified in many kilometers of passages in the Greenbrier caves of West Virginia, especially in Friars Hole Cave System. Detailed three-dimensional mapping of the structural segments shows that the patterns of the early segments exert significant influences on modern passage morphology in certain hydrogeologic settings, particularly in those in which early tubes and fissures were preserved in the ceilings of passages which underwent significant entrenchment by low-volume vadose streams. In plan view, segments and groups of segments exhibit the following common patterns: linear (mostly joint and bed-joint segments); sinuous (bed and fault segments); en echelon (N 60-75 E set joints); and offset (where flow switches segment types, e.g., joint to bed to joint). In profile view, segments exhibit three-dimensional looping, primarily on systematic joints or thrust faults. The details of the fracture geometry and the geometry of the early conduits strongly influence the subsequent growth and morphology of the canyons and tubes that constitute the modern passages. For example, many passages consist of sequences of alternating tubes and isolated vadose trenches. Two additional significant factors affecting the growth and morphology of the passages are (1) minor variations in lithology and (2) the introduction of armoring clastic sediments. Impure units impede entrenchment and can lead to wider lower parts of canyons, or to vertical offsets in canyon profiles where passages change levels and headward erosion is impeded.

MORPHOLOGY AND CLASSIFICATION OF CONDUITS IN THE UNCONFINED FLORIDAN AQUIFER SYSTEM OF WEST-CENTRAL FLORIDA

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Conduits within the unconfined Floridan Aquifer of west-central Florida include both horizontal and vertical components. Vertical portions of conduits visually correlate to fractures, and these fractures dominate conduit directionality as shown by a collection of several Florida cave maps. Length-weighted rose diagrams of passage directions reveal a northwest-southeast and northeast-southwest pattern of conduit directions statistically similar to results found in remote sensing studies. Horizontal elements occur at consistent horizons as shown by cave surveys and observations at quarries. These patterns further demonstrate that horizontal solution features can be pervasive and laterally continuous. Their control is presently unknown but is potentially the result of some combination of lithology, fracture density, and water-table position.

Conduit morphology is traditionally classified from observations in telogenetic karst. In telogenetic karst aquifers, matrix permeability is low, and secondary permeability is provided by fractures and bedding planes. Classification is based upon the type of recharge to the aquifer (allogenic or hypogenic) and whether conduits are controlled by fractures or bedding planes. Recent observations in eogenetic karst (for example, Bahamas) do not fit these classifications. In eogenetic karst, matrix permeability is high—up to four orders of magnitude greater than in telogenetic karst. We suggest that a more appropriate classification scheme of karst would incorporate diagenetic maturity of the rock, as well as recharge type and fracture density. In such a scheme, conduits of the unconfined Floridan Aquifer represent a mid-point in a range between Plio-Pleistocene karst on young carbonate islands and Paleozoic karst in the Appalachian lowlands.

HYDROGEOLOGY OF THE SINKING VALLEY KARST AND THE NSS TYTOONA CAVE NATURE PRESERVE.

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Sinking Valley, Blair County, Pennsylvania, is a 17-kilometer-long anticlinal valley. It has the shape of an inverted V, open to the northeast and bounded on the east and west sides by Brush Mountain which follows the plunging fold of the anticline to form the apex of the V. The northern boundary, crossing the open end of the V, is the Little Juniata River which crosses the struc-

ture at right angles and defines regional base level. Upper Ordovician cavernous limestone outcrops along the base of the mountain. Mountain runoff sinks along the perimeter and drains internally to Arch Spring, the head of Sinking Run. Tytoona Cave is a master trunk consisting of segments of open channel connected by sumps. Dye tracing shows a connection between Tytoona Cave and Arch Spring and also a connection directly to the Juniata River. Analysis of surface drainage, channel and cave profiles, the dye trace, and reports of divers, indicate a complex history for Tytoona Cave: first a master conduit, then an abandoned upper level, then reactivation to its present use as an overflow route. Evidence for a previous dry phase is provided by stumps of massive stalagmites now nearly buried in the sediment of the active stream. Divers have found the final sump to descend to at least 25 meters, close to regional base level. A lower level flooded conduit is predicted, extending to the Juniata River, 3 kilometers away. What seemed to be a simple master trunk system has a much more complex history.

PLEISTOCENE MIXING ZONE CAVES IN A CARBONATE EOLIANITE PENINSULA, VARADERO BEACH, CUBA

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Varadero beach, on the northwestern coast of Cuba, extends approximately 20 kilometers northeast into the Straits of Florida and averages 1 kilometer wide. North-northeasterly winds have deposited carbonate eolianites, composed primarily of bioclasts derived from the erosion of fringing coral reefs. In addition to near-beach active eolianites, the core of the peninsula is composed of late Pleistocene eolianites reaching elevations of 5 to 8 meters.

We documented notches and four caves within these eolianites. Many of the notches and all of the caves display the morphologies and distribution typical of flank margin-style caves formed in freshwater-saltwater mixing zone environments seen in carbonate eolianites of carbonate islands. One of the caves, Cueva Ambrosio, is at least partially fracture-controlled.

Because of the intimate physical association of the karst with the large hotels on the peninsula, the interplay of the tourism industry and the karst features is dramatic. Some notches and possible caves have been extensively developed for use as storage closets and break rooms or converted to fountains by hotels. One flank margin cave, Cueva de Pirata, is presently used as a cabaret bar. Nearby Cueva de Musulmanes and Cueva Ambrosio are protected on an ecological preserve.

These caves represent the only documented flank margin style caves observed on Cuba thus far. The absence of an overlying paleosol-dune package and the presence of large caves in the dune lead us to speculate that these eolianites represent deposition during the oxygen isotope substage 5e transgression.

HYDROLOGIC STUDY OF THE COLDWATER CAVE GROUNDWATER BASIN

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The Coldwater Cave groundwater basin is located within a highly karstified landscape where water moves directly and at high velocities into the groundwater system. Land use practices include farming and livestock. Individual farm residences use shallow septic systems for human waste disposal. The basin under study encompasses 80 square kilometers in northeast Winneshiek County, Iowa, and southeast Fillmore County, Minnesota. The rock units containing this hydrologic system form the Galena Aquifer, which is one of the major agricultural water sources for most of the region. The Coldwater Cave system is the major conduit for the groundwater basin. The cave system, which is dendritic in nature, is developed in the Ordovician-aged Dunlieth Formation and has been mapped to 27 kilometers with survey work in progress. The groundwater basin underlies the Pine Creek and Cold Water Creek watersheds. Streams from both of the watersheds lose water to the subterranean drainage system. Numerous sinkholes in the study area may also contribute water to the groundwater basin. The subterranean stream resurges into Cold Water Creek via Coldwater Spring, which has a discharge rate of 33,500 liters per minute during base flow conditions. Cold Water Creek flows into the Upper Iowa River located a kilometer to the southeast. The Upper Iowa River flows to the northeast and eventually joins the Mississippi River

located 60 kilometers southeast of the study area. The combination of surface and subsurface drainage in the Coldwater Cave drainage basin shows a complex interaction between the surface and subsurface streams.

RECENT KARST HYDROLOGY INVESTIGATIONS IN PULASKI AND MONTGOMERY COUNTIES, VIRGINIA

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Dye trace studies were performed in Pulaski County and Montgomery County, Virginia, to determine potential impacts to conservation sites containing caves with globally-ranked, critically imperiled fauna. GIS-based "Consites" provide details for environmental planners and managers regarding at-risk conservation areas while safeguarding sensitive information including cave entrance locations.

Between March and August 2003, an investigation was performed to determine the subsurface flow paths of storm water discharge from the New River Valley Commerce Park in Pulaski County. Numerous sinkholes, sinking streams, caves, and springs surround the Park. Activated charcoal samplers were placed at 16 locations—including nine springs, one cave stream, and several surface streams—and background fluorescence was determined. One pound each of Eosine, Fluorescein, and Rhodamine WT was injected into three sinking streams receiving New River Valley Commerce Park storm water. All three dyes were recovered within two days on charcoal samplers and in water samples from Railroad Spring, approximately 6.5 kilometers east of the injection sites.

Another dye-tracing project performed between January and March 2004 provided data for defining boundaries of the Slussers Chapel Conservation Site. Charcoal samplers were placed at 19 sites—including seven springs, three cave streams, and several surface streams—and background fluorescence was determined. One-half pound of Eosine injected into the stream in Fred Bull #2 Cave and one pound of Fluorescein injected into a nearby sinking stream were recovered one kilometer to the east in the trunk stream in Slussers Chapel Cave before flowing southeast an additional two kilometers and emerging from Mill Creek Cave Spring two days later.

GROUND WATER TRACING IN LA VERGNE, TENNESSEE, TO HELP SOLVE SINKHOLE FLOODING PROBLEMS

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La Vergne is located in the Central Basin with sinkholes and springs developed on the very gently folded Ordovician-aged Lebanon Limestone. Serious sinkhole flooding occurs in some areas of the city nearly every year. Ten successful ground water traces were conducted for the purpose of understanding direction of ground water flow and delineation of ground water (spring) basin size. Four separate spring basins were delineated. Two traces went a distance of nearly two miles. Some travel times exceeded one mile per day. With the tracing results and site visits to areas prone to flooding, methods to reduce or eliminate flooding have been investigated. A few injection wells exist in the area, but were constructed at ground level and thus have largely filled with sediment. Cleaning of these Class V injection wells and constructing standpipes and filtration fabric to eliminate sediment and debris inflow should significantly help these areas. At a few other sites, the sinkholes drain poorly due to being clogged by debris and trash. After cleaning these out, Class V injection wells could be constructed to allow more rapid drainage. A novel approach is being investigated in one area where a major sinking stream is the cause of numerous sinkholes flooding immediately down-gradient of the sink point. It appears to be possible to construct a narrow dam approximately 10 feet high and 30 feet wide across the sinking stream channel to return the drainage back to surface flow which existed prior to geologically recent, subterranean stream piracy.

GIS INVESTIGATION OF POTENTIAL KARST IMPACTS AMONG PROPOSED I-66 ALIGNMENTS IN SOMERSET, KENTUCKY

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The Southern Kentucky Corridor (I-66) is a proposed interstate identified by Congress to be a high priority corridor. The ultimate construction of this interstate along any alignment will have serious consequences to the environment. The project area of this study focuses on three proposed alignments of this interstate from the terminus of the northern bypass of Somerset to Laurel County, Kentucky.

The project area contains portions of the Daniel Boone National Forest along the Cumberland Escarpment. This forest contains undeveloped woodlands and gorges along the Rockcastle River and Buck Creek. The region is highly karstified with tremendous bio-diversity. Regional geology is composed of horizontal bedded units. The lowermost is the Borden Formation of Mississippian age, a non-karstic shale/limestone. Above the Borden are several highly karstified Mississippian limestones. The uppermost Mississippian age rock is the non-karstic Pennington Shale. Numerous sandstones of Pennsylvanian age prevent karstification in the ridges.

We digitized geologic maps and corridor alignments, and used existing digital data and data created during this study to analyze the differences among the three proposed alignments of I-66 within the project area. We calculated impacted areas, lengths, and numbers of features and normalized them to the total within the project area. Criteria and weighting factors afforded a means by which to compute relative impacts of each alignment. Based upon our results, the southernmost of the three proposed alignments has the least potential impact to the environment; however, the Highway 80 alignment would utilize existing roads which have already impacted the environment.

AN OVERVIEW OF KARST MAPPING IN VIRGINIA

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Karst mapping in Virginia has evolved over the past 40 years with changes in perception of karst both to map makers and map audience. Although the Virginia Cave Survey plotted cave entrances and carbonate boundaries, their focus was caves rather than karst. Some geologic maps used a symbol for sinkholes and hachured groups of sinkholes as representing karst. The first Virginia karst maps were of regional scale and define the extent of karst and relative degree of karstification by plotting carbonate rock boundaries along with sinkhole and cave entrance features. The intended map audience included geologists, government officials, and the public. A major goal was to convey that sinkhole dumping was an important cause of karst groundwater pollution in addition to defining the extent of sinkhole collapse hazards.

The expansion in interest from sinkhole collapse to karst groundwater contamination initiated a shift in focus from features to karst processes. Many individuals inappropriately remain fixated on sinkholes, rather than the less visible karst processes responsible for the array of karst hazards. The misapplication of regional information for site-specific details continues. Digital mapping and GIS have enhanced karst mapping opportunities as well as enabled sinkhole information to be misused at inappropriate scales and purposes.

Detailed geological mapping in the Timberville area contributed to the recognition of geologic and process linked surficial karst units mapable at the 7.5-minute topographic map scale, which include: flood-prone karst, karren karst, ledge karst, pavement karst, pinnacle karst, subsidence karst, travertine-marl deposits, and generalized karst.

U.S. GEOLOGICAL SURVEY PROGRESS TOWARD A NEW NATIONAL KARST MAP

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The U.S. Geological Survey (USGS) Karst Applied Research Studies Through geologic mapping (KARST) Project is compiling a new national karst map as part of geologic mapping and karst hydrogeologic activities for the National Geologic Mapping Program. Support by the Program, National Park Service, and National Cave and Karst Research Institute enabled us to hold workshops, which were attended by representatives from 16 states, the

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National Park Service, and other organizations. The outcomes of these meetings include the establishment of personal contacts, offers of data support, suggestions for construction of the map, and regional perspectives on karst-related issues. Initial products of the KARST Project include a GIS version of "The Engineering Aspects of Karst" map by Davies and others (1984). These data are available on the web at the National Map, <http://nationalmap.usgs.gov/>, as the current national-scale karst GIS layer. In addition, a digital karst map of Puerto Rico is in publication, and will be available on the web soon. Furthermore, as a prototype for the National Karst Map, a 1:1,000,000 scale digital karst map of the Appalachian Highland states has been constructed, and is in an initial review stage. Maps of the individual states are available for public review and comment at: the following website: http://geology.er.usgs.gov/eespteam/EESPT_Projects.html. Data for additional states and territories will be added as they become available.

IMPLEMENTING THE NATIONAL CAVE AND KARST RESEARCH INSTITUTE VISION
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The National Park Service and New Mexico Institute of Mining and Technology convened a two-day Vision Building Workshop in October 2003, culminating a nearly year-long effort to seek diverse cave and karst community input. The 26 invited participants represented six federal agencies, five academic institutes, two state programs, and five non-profit organizations. A professional facilitator led the group through discussions relevant to the development of the National Cave and Karst Research Institute, including its Congressional mandate, the needs and opportunities in the discipline, and the appropriate range of activities. The second day focused on how to most effectively structure the Institute.

Efforts in 2004 have concentrated on implementing the prevailing vision provided by the community and its mandate. The National Park Service is moving the National Cave and Karst Research Institute towards a "jointly administered" structure in which New Mexico Institute of Mining and Technology will plan, coordinate, and administer the Institute and its programs while the National Park Service will have ultimate responsibility and retain indirect control. A National Cave and Karst Research Institute corporation with a governing board composed of representatives from partner organizations will likely be established over the next year.

The National Cave and Karst Research Institute's third primary partner, the City of Carlsbad, plans to begin construction of the Institute headquarters in summer 2004 and complete the project about 18 months later. Over \$4 million has been appropriated or pledged towards the building.

GIS APPLICATIONS IN MANAGING KARST GROUNDWATER AND BIOLOGICAL RESOURCES

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Multiple complex factors must be weighed in managing water and biological resources in karst regions. Their relationships are sometimes not apparent. GIS is an effective tool in correlating these factors to identify known or potential problems and delineate zones for effective management. Geologic and hydrologic data must first be considered for their effects on aquifer recharge, development, and transmission of groundwater to wells and springs. Drainage basins for caves are delineated based on surface water flowing into their entrances and groundwater derived from other areas. Caves with rare or endangered species are identified and categorized to determine the species' distribution relative to potential hydrogeologic barriers. By combining the data, management zones can be established to identify areas best suited for protection or in greatest need of protection, and to map the probable distribution of rare species. Such mapping can be used to redirect urban development away from environmentally vulnerable areas and enhance resource protection efforts. Examples from the central Texas area will be used that include the Edwards and associated aquifers, and cave-dwelling invertebrate species that are federally listed as endangered.

ASSESSING CAVE AND KARST TOURISM ASSETS IN THE SULTANATE OF OMAN
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American caving teams participated in three trips to the Sultanate of Oman to assess the potential use of cave and karst resources to enhance tourism. The Omani Ministry of Information sponsored the first trip in June 2000. The second two trips (August 2001 and January 2002) were sponsored by the Omani Directorate General of Tourism and the National Geographic Society.

The 11.5-kilometer long, 385-meter deep Selma Cave System, in northern Oman, incongruently lies in an ~11 km², arid catchment basin. Large pits in the bottom of normally dry wadis drop between 250 and 300 meters from the four distinctly separated entrance areas. The four entrance rooms constitute the largest (up to ~80 by 200 meters and 70 meters high) chambers in the system. Dramatically more constricted passages depart each entrance chamber at ~1,000 meters msl, following regional dip towards the east. These lower passages merge into a larger trunk passage, which leads to a resurgence cave with an intermittent stream. The entire system carries water during uncommon storms.

Nearby Majlis Al Jinn consists of a huge (3.9x10⁶ m³) chamber. A ubiquitous veneer of calcite coats the smooth walls of the broad, dome-shaped room. The floor is mostly covered with insoluble residue from the clastic-rich, Middle Eocene Seeb Formation bedrock. The cave's three entrances near the top of a hill provide no evidence that the huge room has ever received significant surface inflow.

The teams also visited Tawi Attair, Al Hota/Al Fallah, Muqal, Al Marnif, and other caves.

PRIEST GROTTA, WESTERN UKRAINE

Chris Nicola

In spring 1942, as the Nazis intensified their hold on Eastern Europe, four Jewish families disappeared into the vast underground labyrinths of the western Ukraine. The group included a 75-year-old grandmother and a three-year-old girl, and for almost two years, they lived, worked, ate, and slept directly under the feet of those who would send them to their deaths. 344 days later, on April 12, 1944, every one of the original 38 people who entered the cave that previous spring crawled out from Priest Grotto alive, setting a world record for the longest period of time any human being has survived underground.

In 1963, local cavers, exploring the cave for the first time, discovered several small lanterns and a 150-pound millstone just off the cave's main tunnel. But by that point there was no one around who could remember what had actually happened there. For 60 years their story was forgotten until a leading American caver came across the remnants of the Jews' underground sanctuary inside of Ozernaya, the world's 10th longest cave.

SINO-U.S. EXPEDITION TO HUNAN PROVINCE, PEOPLES REPUBLIC OF CHINA
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In March and April 2004 a team of cavers sponsored by the Hoffman Environmental Research Institute and the Guilin Institute of Karst and Geology did reconnaissance and karst assessment work in the Xiangzi area, a remote section of the Guizhou Plateau in northwest Hunan Province. The Dalong Cave system, which drains this section of the plateau, resurges into the Xiangzi River via a 300-meter waterfall. Sumped passages at the upstream end of the cave system were explored and mapped. The recharge area for this cave system encompasses 200 km² of tower karst. A number of fault-controlled shafts and caves located on top of the plateau were explored and mapped.

MULTIYEAR PROJECT TO MAP CAVES FOR THE BELIZE INSTITUTE OF ARCHAEOLOGY

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In February and March 2004, a group of 13 cavers from the U.S. traveled to Belize to finish mapping Barton Creek Cave and to map several other caves for the Belize Institute of Archeology. The resurgence sump of Barton Creek

Cave was mapped by cave divers. The divers connected St. Hermans Cave to the Blue Hole in Blue Hole National Park and began mapping another cave in the park, Mountain Cow Cave. A 98-foot (30 m) dive was done in Yaxteel Ahauto, a cave in the Roaring River Valley. Thousand-year-old pots filled with calcite were found on a upper level of that cave.

EXPLORATION OF THE RORAIMA SUR CAVE, BOLIVAR STATE, VENEZUELA, THE LONGEST QUARTZITE CAVE IN THE WORLD

(EXPLORACIÓN DE LA CUEVA RORAIMA SUR, ESTADO BOLÍVAR, VENEZUELA, LA MAYOR CAVERNA DEL MUNDO EN CUARCITAS)

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The Roraima Sur Cave is located at the summit of Roraima tepuy, a Venezuelan table mountain, near the border with Brazil and Guyana. The cavern is composed of a complex framework of horizontal galleries with numerous low ceiling passages. This system was formed in the weaker strata of the Roraima Group sandstone. With more than 5 kilometers of development, Roraima Sur Cave surpasses the documented 4.7-kilometer length of Brazil's Gruta do Centenario, which was, until now, the world's longest cave in quartzite rock.

The recent Venezuelan Speleological Society (SVE) expedition surveyed approximately 5.5 kilometers of galleries, with a depth of 50 meters. The Society also connected a previously explored passage to a neighboring cave, doubling the total cave length measured by a previous Czech and Slovak caving team.

Roraima Sur Cave exhibits several peculiar geomorphologic characteristics. With its extensive system of horizontal galleries, it defies the typical vertical profile of most caves in the Venezuelan Guiana Shield karst. The abundance of highly developed opal stalactites, found deep in the cave, is a unique phenomenon that had only been previously reported in Sarisariñama's Sima de la Lluvia, but as much less abundant and smaller. These stalactites are also peculiarly slanted, evidence of the presence of a consistent air current through the cave system.

PHOTOGRAPHY

EXTENDING YOUR DYNAMIC RANGE: GETTING THE MOST FROM YOUR HIGHLIGHTS AND SHADOWS IN POST PROCESSING

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Dynamic range refers to the range of detail we can capture in an image from the brightest to darkest. In cave photography, we are constantly dealing with this issue. Ideally, all of our flashes would be placed perfectly to give uniform exposure throughout. Because caves contain subjects ranging from near black to white or clear, we inevitably end up with photos with burnt-out highlights or shadow areas that are too dark. Even more problematic are photos incorporating natural light in which we want to light the cave within as well. This is an even greater problem with digital, which has less dynamic range than film. This talk focuses on techniques in Photoshop to eke more detail from highlights and shadows from individual photos, and on approaches where combining two or more photos at different exposures can solve problems not possible in a single exposure. A typical sequence involves adjustment of color balance (many digitals, especially when using the onboard flash, are cyan-heavy), global shifts in tonal range, sharpening, then localized adjustment of highlight and/or shadow. Advantages of working in CMYK color space include having an extra color channel to adjust that is basically grayscale information, and ability to sharpen just the black channel, which enhances detail without giving an oversharpened look. Finally, the processed files are saved as `originalname_r.jpg` and the originals preserved. If you typically rename files, it is better to do that before processing if you use such a naming convention, so you can easily reference your originals. Files that will require several saves are first converted to the lossless Tiff format. Photoshop 7 even allows adjustments to be saved in a reversible manner with adjustment layers, especially nice when preparing digital images for any type of output (print, slide) where subsequent corrections might be needed to get optimal saturation and brightness.

ENVISIONING "THE CAVE" IN CENTRAL PARK, NEW YORK CITY, THROUGH ARCHIVAL PHOTOGRAPHY

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Sadly, many caves have been destroyed in whole or in part through landscape modification, construction, or quarrying. As a result, the only way most of these caves may be documented is through contemporary written descriptions, primitive sketches, or vintage photographs.

"The Cave" in Central Park, on Manhattan Island in the New York City is an excellent example of how archival materials can lead to a fairly accurate depiction, even though a map of the cave is not known to exist. The Cave was a "fanciful creation" of the two principle designers and architects of Central Park, Frederick Law Olmstead and Calvert Vaux. During the construction of the park in the 1850s and 1860s, they had a natural cleft in outcrops of bedrock roofed over with boulders, creating a short, tunnel-like cave. In the 1920s the Park administration had The Cave sealed with stone and concrete, as it had become the "haunt of tramps and vagrants" and was considered dangerous. Several postcards and over a dozen stereopticon views were published during the interval that The Cave was open to visitors. These are indispensable for describing the features in some detail. A composite map may be constructed from these archival photographs.

SPELEAN HISTORY

CAVE HOAXES AND NINETEENTH CENTURY ARCHAEOLOGICAL THEORY

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American archaeology in the 19th century was dominated by the Mound Builder myth, which held that the tens of thousands of earthen mounds in North America were constructed by a superior vanished race unrelated to the Indians. Several distinctive Mound Builder motifs appear in the nationally propagated Nesmith Cave hoax of 1866-67, which was based on an actual cave, Chutes Cave, in Minneapolis, Minnesota. Specifically, there are close parallels between details in the cave hoax and Ancient Monuments of the Mississippi Valley, a classic of American archaeology and the first publication (1848) of the newly founded Smithsonian Institution. The authors, Ephraim Squier and Edwin Davis, were squarely in the Mound Builder tradition. In excavating mounds they found stone coffins, skeletons that crumbled to powder, and sacrificial altars with calcined bones, all of which were also supposedly found in the hoax cave by the fictitious Mr. Nesmith. The latter concludes, as Squier and Davis had earlier, that "the relics found are not at all aboriginal in character, and may have been the work of a people existing long before even these prairies were the hunting grounds of the Indians."

THE APPLICATION OF BACK'S PRINCIPLE TO CAVE HISTORY

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William Back, in his 1981 article, "Hydromythology and Ethnohydrology in the New World," wrote "[i]f used with caution, mythology can sometimes extend historical and archeological interpretation further back in time." This paper applies the principle to Minnesota cave history. According to early missionaries, the indigenous Dakota people believed that the junction of the Minnesota and Mississippi Rivers was the center of the Earth, positioned directly under the center of the heavens. Nearby was the dwelling place of Unktahe, Dakota god of waters and of the underworld, who was often depicted as a serpent. Mary Eastman, in her 1849 book, *Dahcotah, or Life and Legends of the Sioux around Fort Snelling*, wrote that "Unktahe, the god of the waters, is much revered by the Dahcotahs. Morgan's Bluff, near Fort Snelling, is called 'God's House' by the Dahcotahs; they say it is the residence of Unktahe, and under the hill is a subterranean passage, through which they say the water-god passes when he enters the St. Peter's [Minnesota River]. He is said to be as large as a white man's house." Taken at face value, the myth of the subterranean god, Unktahe, constitutes the oldest cave reference for Minnesota, antedating the accounts of explorers such as LeSueur (1700) and Carver (1778).

HISTORY OF THE GEORGE WASHINGTON UNIVERSITY STUDENT GROTTO
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The George Washington Student Grotto (GWU Grotto), NSS grotto #134, existed from 1966 to 1974. The first grotto Constitution had five elected officers, including a "Publicity Director." The second Constitution (1969) changed elections to April so that the now three officers could plan the upcoming school year. The GWU Grotto primarily caved in Virginia and West Virginia. From 1966 through 1968, the club mapped caves for "Descriptions of Virginia Caves." The first Chairman, Hugh H. Howard, was the most dynamic. He tried to start the GWU grotto in 1965, but had to first overcome a rule that any on-campus club could not be affiliated with a national organization. The grotto had 54 members in its first year and published *The Colonial Caver*. In the fall of 1967, Warren Broughton was elected Chairman. The club published professional-looking issues of *The Colonial Caver*. Charles Pfunter was elected Chairman for the 1969–70 school year and Leonard LeRoy was elected grotto Chairman for the 1970–71 school year. The Vietnam War affected grotto membership. Paul Stevens was elected Chairman for the 1971–72 and 1972–73 school years. Paul took the grotto by storm, and "The Foggy Bottom Caver" was started. Grotto membership expanded to 35. Steve Stokowski was elected Chairman for the 1973–74 school year. By 1974, all the GWU student members had either graduated or left the university. After considering that advertising for new cavers might result in a cave conservation disaster, Stokowski dissolved the grotto.

THE ROQUEFORT CAVES OF ST. PAUL, MINNESOTA
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The Roquefort caves of France have a history dating back to Classical antiquity. In 1933, Professor Willis Barnes Combs of the University of Minnesota began experimental ripening of a domestic Roquefort cheese in artificial sandstone caves at St. Paul, Minnesota, which he determined had the proper combination of low temperature and high humidity. Combs stated that there was no commercial production of Roquefort in the United States at this time. After spectacular success at the University Cave, he boasted that St. Paul's caves could supply the entire world demand for Roquefort. Made from the more plentiful cow's milk, rather than from sheep's milk as in France, the Minnesota cheese was initially called Roquefort but after complaints by the French Foreign Trade Commission was relabeled Blue Cheese. The production of Minnesota Blue did not really take off until 1940, however, when World War II cut off Roquefort imports from France. Kraft Cheese and Land O'Lakes then rented caves in St. Paul and ripened millions of pounds of blue cheese. For a brief moment, St. Paul was acclaimed the Blue Cheese Capital of the World. The University Cave, which ceased operations in the 1950s, was recently dug open by the author. Filled with debris that was pushed into it with a bulldozer years ago, the cave contains no obvious artifacts from the cheese-making era.

SURVEY AND CARTOGRAPHY

TIPS FOR EFFICIENT CAVE SURVEYING
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This presentation describes some ways that a survey team can improve their productivity and efficiency by "working smart, not hard." Among the techniques described are allocating tasks so that no team member is overloaded or under utilized, defining the responsibilities of each team member, placing stations to facilitate easy shots, taking readings in a consistent order, taking advantage of geometry to make shots easier to read, avoiding reading and recording errors, testing instruments before each trip, agreeing in advance on how dimension data is to be recorded, carrying instruments to facilitate quick use, using a small flashlight to light stations for backshots, and knowing when to quit and head out of the cave.

AN ANALYSIS OF RANDOM AND SYSTEMATIC SURVEYING ERRORS
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An analysis was performed of various types of surveying errors, with the errors falling into two categories, random and systematic. Random errors are

errors that are as likely to be off in one direction as the other, and may be large or small in magnitude. Random errors come from instrument readability (usually on the order of 1–2 degrees) and "blunders" which can be small or large. Systematic errors are errors that are consistently off in one direction. Systematic errors generally come from instrument offset. This analysis concentrated on compass and inclinometer readings in longer passages.

Analysis was performed using statistical methods and by numerical experimentation where 50 shots of actual survey data were taken and errors were assigned to the data. The differences between the data with errors and the data without errors were calculated.

The conclusions were as follows: Random errors caused by instrument readability consistently cancel out in longer passages. Therefore, meticulous matching of the foresight and backsight readings beyond that which serves to catch large blunders is not helpful. Instrument offsets of even half a degree give much larger final errors, even if the instrument offset is smaller than the readability of the instrument. This is because systematic errors accumulate rather than cancel. Fairly frequent blunders of 10 degrees make less difference in the final answer than instrument offset. Aside from preventing major blunders, the best way to improve survey data is to carefully take into account the differences between survey instruments.

ENHANCING WORKFLOW IN DIGITAL CARTOGRAPHY
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While the advent of computer mapping has greatly improved the potential of the cave map, digital maps often sacrifice that timeless humanistic fluidity of a hand-drawn map for machine-like repetitions that make us say, "that's definitely digital." This presentation will focus on various features in Adobe Illustrator that allow you to speed up the cartographic process while creating maps that allow a digital cartographer to keep that timeless hand-drawn appearance. We will use layers to make global changes to specific features, generate brushes to cut time from drawing the minute details, and copy and manipulate forms to create repeating shapes that don't resemble computerized duplicates.

AURIGA, OR TRADING YOUR SURVEY NOTEBOOK FOR A PDA
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The Auriga cave survey software for Palm OS was originally written to assist in the development of an electronic sensor box designed to automatically acquire azimuth and slope measurements, but has now evolved into a smart survey notebook replacement for in-cave use and a lighter weight laptop replacement while at camp. Surveyors can see the cave map on screen while doing their survey, and data does not need to be transcribed later, thus preventing many blunders throughout the process. Despite the smaller screen and slower CPU of Palm devices (vs PCs), Auriga offers graphical and spreadsheet rendition of cave passages, survey stations, and survey shots between them. Thanks to sessions, a concept already present in most cave survey software, surveyors can free their mind of instrument calibration, varying magnetic declination, and mixed measurement units. This allows Auriga to faithfully store survey data exactly as input, only applying corrections and conversions when computing coordinates. Several efficient design aspects provide the cave surveyor with a highly configurable and ergonomic interface, even when operating through a windowed protection box. Once back on the surface, survey data can be sent to other Palm devices through an IR beam or uploaded onto a computer and converted into common cave survey file formats via a software "conduit." The Auriga freeware is under intensive and constant evolution; support for networks of several caves and loop closure are currently in the works, while on-screen freehand sketching of cave walls and details remains the ultimate goal.

UNITED STATES EXPLORATION

NON-TRADITIONAL CAVING IN COLORADO
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In addition to its many fine limestone caves, the state of Colorado contains a substantial variety of caves in other media. These include dolomite, tufa, granite, rhyolite, basalt, welded tuff, sandstone, claystone, and gypsum. Many of these caves have only been found in the past few years and include a

cave/crevice complex in sandstone, previously unreported lava tubes, and caves in gypsum.

PAUTLER CAVE SYSTEM, ILLINOIS

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Pautler Cave, located in Monroe County, Illinois, had some history of visitation but was lost to organized caving after the entrance was bulldozed in 1968. By the 1980s no cavers seemed to remember exactly where the entrance had been. No map of the cave was known to exist, but there were biological records and a brief description in the Bretz and Harris 1961 publication, *Caves of Illinois*. In 1996 the entrance was re-discovered and exploration and survey began in earnest. Currently over five miles have passages have been mapped with almost another mile has been documented in disjunct caves within the system.

NORTH COAST KARST, PUERTO RICO

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Puerto Rico is a carbonate island with a volcanic core. The north side of the island contains a belt of carbonate rocks that take the drainage that flows off the volcanic core forming the island's most significant cave systems. The area consists of a variety of karst landforms that include cone and tower karst, alluviated valleys, deep limestone gorges, zanjones (vertical-walled trenches), and active river caves. In addition to the active caves there are many dry segments, which are developed at higher elevations. These are paleo-segments of conduits that drained the basin in the past and are indicative of tectonic uplift of the island and sea level fluctuations. Over the past several years, exploration and survey efforts have concentrated on locating and mapping the dry upper segments, on extending the known cave systems, and in doing reconnaissance in carbonate areas where caves are currently not known.

COLDWATER CAVE—PAST, PRESENT, AND FUTURE

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Coldwater Cave (Winneshiek County, Iowa) is the upper Midwest's longest known cave. Since its discovery in 1967 by Iowa Grotto cave divers Dave Jagnow and Steve Barnett, several generations of cavers have pushed the cave's mapped extent to nearly 17 miles (27.2 km). Coldwater Cave is a dynamic, hydrologically active system that responds rapidly to surface drainage. Many remote areas of the cave are accessible only during periods of low groundwater levels. Because of lower than average rainfall in recent years, extensive survey, exploration and study has taken place in the furthest upstream and downstream reaches of the cave, including some areas that have been inaccessible since the cave's initial exploration.

CUMBERLAND GAP CAVE—CUMBERLAND GAP NATIONAL HISTORICAL PARK

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The Cave Research Foundation manages a multidisciplinary karst study at Cumberland Gap in the political jurisdictions of Virginia, Tennessee, and Kentucky within Cumberland Gap National Historical Park. The southern edge of the Pine Mountain Thrust Sheet rises 600 meters above Powell Valley, exposing 150 meters of Newman (Greenbrier) Limestone dipped 40 degrees northwest. Cudjos Cave Underthrust Fault affects the limestone members from the Gap beyond Lewis Hollow two miles to the northeast. The Gap lies south of the Middlesboro Impact Structure, with a 20-kilometer circumference, and north of several exposed members of tilted Ordovician limestone exhibiting a 120-square-kilometer karst plain. Gap Cave is formed within this complex geologic structure trending along the Newman Limestone strike. The cave has an extensive modern culture related to human use and unique hydrology, geology, and biology. Cartography of Gap Cave has been the major project activity since research began April 2003. The working map exceeds 7 kilometers. Gap Cave exhibits the potential to exceed the 11.25-kilometer known length. While research continues, efforts will be made to connect passage northeast beyond Lewis Hollow where the exposed limestone along Cumberland Mountain continues for more than 25 kilometers.

LECHUGUILLA CAVE EXPEDITION, OCTOBER 2003

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Most of the recent efforts in Lechugilla Cave, New Mexico, have focused on validating and correcting earlier surveys. In October 2003, one team of four cavers spent five days resurveying in the Southwest Branch in an effort to correct several loop closure failures. In the course of resurveying over 600 meters of passage, they identified azimuth errors ranging from 4° to 20°. It is likely that these errors were introduced by the use of a metallic flashlight to illuminate the survey instruments. The team also produced slightly over 130 meters of new survey.

WISCONSIN CAVES: A HISTORICAL TIMELINE FROM EARLY NATIVE AMERICAN USE TO MODERN DAY EXPLORATION

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Wisconsin has hundreds of documented limestone and sandstone caves. Many small sandstone caves and rockshelters are very significant and contain prehistoric rock art. Southwestern Wisconsin is home to one of eastern North America's premier rock art sites, in a cave located in the Lower Wisconsin River watershed. This site was used by Ioway and Ho-Chunk Indians as a religious shrine, beginning at about 300 A.D. through the early 19th century. The lead and zinc mining district of southwestern Wisconsin, located in the unglaciated "Driftless Area," produced about one half of the world's lead consumption in the 19th century. Scientific exploration of Wisconsin's caves began in the late 1800s. Wisconsin's longest natural cave is over 3,000 feet (914 m) long and several caves have over 90 feet (27 m) of vertical relief. The Niagara Escarpment of eastern Wisconsin harbors some of the state's deepest and longest caves. Commercial caves first appeared in Wisconsin in the 1800s. The Wisconsin Speleological Society has been active for over 40 years exploring, surveying, and working to protect these great resources.

THE CHAIN OF PUKAS SYSTEM, HAWAII

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The Chain of Pukas System began with the mapping of A'a Surprise Cave in 1998, an unusual find in an a'a lava flow, following-up on a Doug Medville lead from an aerial photograph showing a distinct line of pukas in an historic flow. The exploration of the chain of pukas commenced in 2003, with a concerted effort to document and tie in all the pukas in this part of the flow. This yielded several new finds, including Beer Barrel Puka, Cave 'Til You Puka, and the best find of the trip: Once A Puka Twice A Cave. In January 2004, the uppermost pukas in the nine-puka chain were explored, yielding Pukas Interruptus, and A'a Demise.

CAVES OF PLAYA PAJAROS, ISLA DE MONA, PUERTO RICO

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Since 1998, the Isla de Mona Project has been exploring and mapping caves, cave systems, and pits on Playa Pajaros, located on the southeast side of the island. The karst on Mona is a world-class example of flank margin cave development. As of June, 2004, all of the caves on Playa Pajaros have been located and mapped. Work will continue on the meseta where more than 30 small pits have been documented to date. A reconnaissance of the northwest side of the island revealed many more large flank-margin caves that need to be mapped.