SELECTED ABSTRACTS FROM THE 1996 NATIONAL SPELEOLOGICAL SOCIETY NATIONAL CONVENTION IN SALIDA, COLORADO

ANTHROPOLOGY AND ARCHEOLOGY SESSION

Session Chair: Jerald Jay Johnson

Leaky Tank, A GypKaP (New Mexico) Archeological Study Site

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GypKaP participants are trying to expand the knowledge of our project caving area by studying as many related fields as possible. Archeology is intriguing, partly because the area has been largely omitted in studies. Participants in this project, while mainly interested in finding and documenting caves, are trying to understand the entire caving area through multi-faceted studies. We have found Native American cultural remains throughout the area and are documenting them and attempting to learn who these people were who previously used these areas and who may have occasionally used the caves.

Studies of the artifacts scattered at the Leaky Tank surface site, combined with a lot of research, are coming up with some rather interesting results. I am proposing that this is a Jumano traders site, possibly developing out of Mogollon roots. Jumano peoples were documented as tradesmen, guides, and hunters by the Spanish explorers and missionaries, but have been ignored by most classic archeological studies.

Caver Recognition of Cultural Context: Did Native Americans Use This Cave?

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Caves were used by prehistoric Native Americans for a variety of purposes. The recognition and documentation of these uses is important to the archaeological, Native American, and speleological communities. Yet, the vast majority of the known caves have never been examined by professional archaeologists, let along professionals experienced in cave archaeology, for evidence of cave resource utilization. Many cave archaeological sites were first discovered by cavers. In Virginia, caver- recognized “dark zone” prehistoric sites include: burial, ceremonial (mud glyph and pictograph), hunting (hibernating bear), lithic quarrying, and mineral collection sites. The important contribution of the experienced caver is the recognition of non-natural or unusual modifications to the cave that may evidence the past activities of man, a cultural context!

One of the most important clues to identifying prehistoric caving activities is the presence of charcoal from torches. To date only pine and native cane charcoal has been noted and dated at our Virginia sites. Other lighting material may include the bark of the shagbark hickory, other woody materials, or wick and tallow lamps. Unfortunately, historic pine charcoal cannot be distinguished from prehistoric pine charcoal without testing or other associated evidence. Careful attention to not damaging the charcoal, watching for prehistoric footprints, and looking for traces of what activities were conducted on these ancient cave trips is too much to ask of cavers without professional help. If you find evidence of prehistoric caving activities, retreat and offer your help to a cave experienced archaeologist. See the professional for verification and documentation before you accidentally damage what might be a significant archaeological site.

Artifacts Made From Calcite and Marble Quarried by Native Americans in Central California 3000 to 4500 Years Ago

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Native American miners acquired calcite and marble from caves in the Mother Lode of the Sierra Nevada in central California between 3000 and 4500 years ago. They manufactured these into pipes, charmstones, beads, and pendants, and traded them to the west into the lower Sacramento and San Joaquin valleys and delta where they were probably exchanged for shell beads and ornaments that had been derived from the Pacific coastal region. The trade of artifacts from cave resources into the great valley to the west apparently ended by 2500 years ago with some use of these materials persisting as offerings left in vertical burial caves in the higher foothills until as late as 2000 years ago.

Evidence exists in several caves of past Native American quarrying activity including battered and sometimes shaped hammerstones and broken stalagmites and stalactites. The focus of this presentation, however, is on the artifacts which were produced from the materials acquired during the mining activities of various Native American populations.

Ponderosa Cave, A Possible Prehistoric Calcite Quarry in the Sierra Nevada in Central California 3000 to 4500 Years Ago

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Ponderosa Cave was mapped by members of the Mother Lode Grotto of the NSS in the winter and spring of 1996. During this activity, the bases of at least four stalagmites were noted that appeared to have been broken off and battered a long time in the past. A few stone artifacts and a possible bone artifact were also noted. Two archaeologists from California State University, Sacramento, who are members of the Mother Lode Grotto visited the site with the authors and noted one large flattened elongated stone which had been battered, a bone artifact, obsidian flake and a shell bead. These artifacts are all of Native American origin and the bead type dates before 3000 years ago. The artifact assemblage, cave characteristics and environment will be compared to several other quarry caves previously identified in the Mother Lode of the Central Sierra Nevada in California.

Fern Cave . . . A Pictographic Recording of the Supernova of 1054 AD?

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A recent regional held by the Western Region of the NSS at Lava Beds National Monument afforded a first-time visit to Fern Cave. This cave is known to have the best display of pictographs in the monument, and perhaps the most concentrated display on the whole of the Modoc Plateau.

A discussion of the discovery and archaeological investigation of the cave and an interpretation of a particular pictograph in this site will be presented. This will be compared and contrasted with other pictographs in caves and on canyon walls in the southwest. A further discussion of the problems of conservation and preservation of this site will also be given.

BIOLOGY SESSION

Session Chair: Ed Lisowski

Temporal Variations in the Emergence Flights of *Myotis velifer*

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Bats are nocturnal mammals and many North American species spend their days resting/sleeping in caves which provide a stable temperature, humidity and protection from predators. Bats that live in total darkness in a cave or mine depend upon a circadian rhythm to trigger their daily arousal and initial departure (emergence) from the roost area. They can then fine-tune this activity pattern with light testing in the entrance area of the site until the light intensity matches that characteristic of the species for their evening emergence. Many of the insectivorous bat species have an emergence pattern that is parallel with the time of sunset. A maternity roost of *Myotis velifer* in Kansas studied by others in the 1970s and this current study in Arizona both reflect an interesting deviation from this "standard" emergence pattern. *Myotis velifer* appears to emerge sooner in the early spring and autumn than in late spring and summer. Besides this variation in the time of emergence, the character of the outflight also changes through the summer period. An explanation for these emergence pattern variations could be the reproductive condition of the females in the maternity roost. Other factors such as ambient temperature may also play a role. Probably no one element is the trigger for emergence, but a rather a combination of factors.

A Comparison of Aquatic Cave Communities in Horse Cave and L&N Railroad Cave: Are They Converging as Horse Cave Recovers?

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The east and south branches of Hidden River were devastated by point source pollution before 1990. L&N Railroad Cave stream has escaped this destruction by being perched 20 meters above the level of Hidden River upstream from the major pollutant inputs. Total nitrogen levels in L&N are high (greater than 3000 mg/L). This suggests continued enrichment of the watershed, probably due to fertilizers and inadequate septic systems. The community structure of the troglobitic and troglophilic aquatic fauna of L&N Cave has remained consistent for three years. Water quality of Hidden River has improved substantially in the last five years. Illegal dumping, washout of toxin-laden sediments, and the time lag recovery of the natural buffering systems probably account for the variations in water quality that continue.

Significant changes have occurred in the community structure of Hidden River. An apparent single cohort of comprised 21 of the 29 fish observed in 1993. No troglobitic fish were observed in the south branch until 1995. The reproducing (?) population of troglophilic crayfish (had poor recruitment in 1994), and the number of individuals observed dropped from 39 in 1994 to three in 1995. High levels of recruitment continue in both troglobitic isopods and crayfish (Recovery of the troglobitic community has been facilitated by movement of adults and recruits from the east branch to the south branch of Hidden River. The resilience of this devastated aquatic cave community provides hope that future successes in cave conservation and reclamation are within our grasp.

On the Roles of Phylogeny and Stochasticity in the Evolution of Perennibranchiate Troglobitic Salamanders

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In general, a variety of different traits characterize the morphology and physiology of troglobitic organisms. These include absent or reduced eyes, elongated appendages, loss of pigmentation, decreased metabolic rates, increased longevity, and delayed reproduction. In addition to many of these characteristics, most troglobitic salamanders are also paedomorphic.

The evolution of paedomorphic troglobitic salamanders is often discussed implicitly as a deterministic process in which metamorphosing, epigean ancestral salamanders enter caves, and their descendants subsequently evolve a suit of morphological characters, including paedomorphosis, which provide a selective advantage in the cave environment. Alternatively, we suggest that paedomorphosis in troglobitic salamanders is the result of historical processes and was present in the ancestors of troglobitic salamanders, rather than an adaptation to the cave environment. Furthermore, the frequency of paedomorphosis in troglobitic salamanders may be the result of stochastic entrapment of epigean species that were polymorphic for paedomorphosis. Once trapped in a cave environment additional characteristics evolved that provided additional selective advantage, including some of the more conventional adaptations noted above. Finally, we describe the first instance of paedomorphic, apparently reproducing, cave dwelling tiger salamanders (that may represent an intermediate stage in the evolution of obligately troglobitic salamanders.

CONSERVATION AND MANAGEMENT SESSION

Session Chair: George Huppert

Protecting Caves From Road Construction

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In 1995, a spokesman for the Mayor of Hawaii County, HI, announced plans to collapse segments of Kazumura Cave, Keala Cave, and other world-class lava tube caves in upgrading a subdivision road. Kazumura Cave is the world's longest lava tube cave with a variety of spelean resources and values. Protests on an international scale were necessary to obtain protection for these important caves. On the other hand, a program of active cooperation had already begun with the Hawaii State Highway Department. With the possible exception of the National Park Service, no standards for protection of caves from roads (and vice versa) seem to exist. This is a nationwide problem which should be addressed by the National Speleological Society.

The Southeastern Cave Conservancy

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The Southeastern Cave Conservancy (SCC) is a relatively new organization designed to acquire and manage caves for scientific study, speleology education, and conservation of caves. It is modeled after other organizations with similar purposes but is specifically concerned with cavers' interests. Although concentrating in Tennessee, Alabama and Georgia, the SCC enjoys a wide membership base throughout the United States. There are still many cavers who are unaware of the SCC and its mission. This presentation will review the Conservancy's purpose and goals, management, education and monitoring programs, properties acquired, and future plans.

Global Cave Conservation Education Via the Medium of the Poster

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Messages may be presented to the general public in many different ways. Posters are one of the most common media used to advertise show caves and to influence the public's image of and attitudes toward their protection. This is, most likely, due to the fact that this is one of the cheapest methods to present a message to the greatest number of people.

Cave Entrance Stewardship at Mammoth Cave National Park

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In terms of access and security, cave entrances are the door to the bank vault. In terms of physical, biological, and energy exchange, they are primary portals between the surface and underground world. Structures installed in cave entrances must: 1) provide an adequate deterrent to illegal entry, which is to say that extraordinary means beyond hand tools are required to gain access, and 2) they must allow natural exchange rates of air, water, organic matter, and commuting wildlife. These characteristics are vital for conservation of cave adapted communities, cultural resources, and even minerals. Changes in cave temperatures, humidity, water flow, and input of organic material can have consequences equal in severity to illegal entry.

Airflow Bat Gates designed by the American Cave Conservation Association and approved by the US Fish and Wildlife Service have been installed at Long, Lee, Bat, Dixon, and White Lightning caves, plus the Colossal, Proctor, Salts, and Historic entrances to Mammoth Cave. Airlocks have been

installed on artificial entrances to Mammoth Cave (including the Frozen Niagara, New, Carmichael, Violet City, Elevator, Doyel Valley, and Austin entrances). We custom fitted gates to Wondering Woods Cave and Bedquilt Entrance to Mammoth Cave and reinforced Crystal Cave's gate.

What's next? The Historic Entrance ecotone in Mammoth Cave is the target of a three year ecological restoration project to begin reactivation of this formerly major bat hibernaculum.

Puerto Rico's Karst, An SOS

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Puerto Rico has a great variety of landforms developed by dissolution of limestone under tropical climatic conditions. The most developed karst area is in the northern and northwestern parts of the island, which are underlain by thick Oligocene and Miocene limestone formations. Using Watson Monroe's words, "Although the areas of karst terrans are not large compared to other countries, they have aroused the interest of karst specialists, especially from Europe, because of the excellent examples of cone and tower karst, well developed cuestas and many features not known elsewhere." Our most spectacular caves are within the northern Puerto Rico karst area, including the world's longest known traversable underground river (16.9 km) to date. The region contains about 50% of the privately owned forests, which are the habitat of many endangered species of flora and fauna, and it is the most important area of recharge to our largest aquifer and to several wetlands.

The rapidly growing population in other portions of Puerto Rico has brought massive residential, commercial, and industrial expansion to the northern portion of the karst lands. The nature of this construction frequently involves extensive deforestation, landform obliteration, and water diversion and contamination.

ELECTRONICS AND COMMUNICATIONS

Session Chair: Frank Reid

Improving the Accuracy of Cave Radio Locations

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A cave radio was used to provide independent verification of target locations inside Kartchner Caverns prior to tunnel construction. A "Single Blind" technique allowed a separate determination of the accuracy of the cave radio locations. Points were located to an accuracy of ±8 in (±20 cm) at depths of 170 ft (52 m). This high degree of accuracy was confirmed by comparison to a precise theodolite survey of the cave. Additional tests were done to demonstrate the accuracy of depth determination with the cave radio.

GEOLOGY AND GEOGRAPHY SESSIONS

Session Chair: George Veni

Comparison of Physical and Chemical Discharge to Determine the Relationship of Two Springs at Woodlawn Memorial Park, Nashville, Tennessee

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Springs in karst terranes can be either a single discharge point or a distributary system. In this study two springs discharging from the same hillside were studied to determine if they drain the same or separate basins.

Sampling strategies were implemented to accurately record the chemical and physical qualities of both springs in relationship to a rain event. Discharge volume, pH, conductivity, and temperature were monitored at approximately 12-hour intervals before, during, and after a rain event. A V-notch weir and a bucket and stop-watch method were employed to measure the discharge volume of the springs. Other qualities of the springs were monitored with a pH meter, a conductivity meter, and a thermometer.

The data were plotted on graphs for comparison. Results in discharge volume, conductivity, pH, and temperature indicated that the two springs had different quantitative and qualitative responses to the same rain event.

The chemical and physical response of the two springs to a rain event indicated that they drain different groundwater basins.

Spring Creek Dye Tracing: Greenbrier County, West Virginia

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Spring Creek, West Virginia, is ~24 mi (~39 km) long and flows south from the south flank of Droop Mountain to the Greenbrier River. Large springs rise along the creek and include cave streams from some of West Virginia's longest caves. The Buckeye Basin overlies the underground Culverson stream, and is located between that basin and Spring Creek. Both the Culverson and Buckeye basins, their caves and the Buckeye resurgence, are in the Union Limestone. The four Culverson resurgences are in the Patton Limestone, which is below the Union Limestone and the 20 ft thick Taggard Shale. It is not known where or how the subterranean Culverson Creek crosses through this shale.

Beginning in 1994, 17 dye traces were completed in the Buckeye Basin, nine in the Culverson Basin, and seven to Spring Creek. In the Buckeye Basin, Fuells Fruit Cave resurgences in the adjacent valley of Turner Hollow to the northwest; the Turner Pit #2 water appears at Apple Spring; the

Baber Pit and Sissler Sink water resurge at Callisons Pond Cave, and all three of these waters reappear at Rubble Spring on Spring Creek. All of the upper Buckeye Basin insurgences breach the Taggard Shale and resurge at the four Culverson springs. The southernmost sink in the Buckeye Basin, the Reynolds Swallowhole, flows into the Boggs Bluehole, the uppermost of The Hole resurgences.

In the Culverson Basin, Plastic Bag Cave System and the two AWOL insurgences resurge at Picnic Cave, Poorfarm Cave resurges at the Scout Camp North Spring, and Stove Cave resurges at Briar Patch Spring. On Spring Creek, two streams in the Boarhole and the entrance stream of The Portal reappear at Cannon Hole, the resurgence for Friars Hole. This estavelle is located on Spring Creek between the Culverson and Buckeye resurgences, just upstream of the Spring Creek Cenotes.

Scanning Electron Microscopy of Fine-grained Sediment From Movile Cave, Southern Dobrogea, Romania

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Since its discovery in 1986, Movile Cave, Romania, has been of interest to scientists. The main foci for investigations have been the chemoautotrophically based ecosystem and the troglomorphic terrestrial and aquatic organisms. This is the first detailed examination of scanning electron microscopy images highlighting Movile Cave sediment.

Sediment samples were collected from passage walls, ledge accumulations, and from pits dug into the cave floor. Sediment was analyzed by SEM (with EDAX) and X-ray diffraction (XRD). Based on the mineralogy of the sediment, two populations of cave sediment exist—allochthonous and autochthonous. The first has clay minerals of mostly mixed-layer silicates, specifically illite-smectite, kaolinite-smectite, and lesser chlorite-smectite. Additionally, 0.5-4.0 mm grains of goethite, quartz, muscovite, and minor concentrations of mafic minerals are also associated with these accumulations. SEM images of bulk sediment and grain mounts show these detrital minerals are abundant (roughly 85%) in clay and fine-grained sediment. The second type of sediment resembles the carbonate bedrock. Dolomite, with trace amounts of illite (and possibly kaolinite), is in the <2.0 µm sediment fraction. Calcite rarely occurs in the sediment, but is the major component of bicarbonate crusts and calcite laminae within the bedrock. XRD analyses of powdered bedrock and sediment prove that the major constituents of the autochthonous sediment are dolomitic ooids. SEM images reveal tiny (0.5-2.0 µm) zoned dolomite rhombs on the outer surfaces of ooids. Some dolomite crystal faces have an abundance of adhering, spherical single and chained bacteria. The average diameter of the chained spheres is 1.0 µm, with a connecting filament of approximately 1.0 µm of length. Bacteria chains, up to 20 µm long, rest in dents and depressions on dolomite crystal faces.

Stratigraphy and Sedimentology of GypKaP Caves

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Thousands of solution caves have developed in sequences of evaporites and carbonates of the Permian San Andres Formation that crop out between Vaughn and Roswell, New Mexico. These “gypsum caves” afford an extraordinary opportunity to examine the evaporite rocks. As part of the ongoing Gypsum Karst Project (GypKaP), we have conducted geologic studies in several gypsum caves since 1992. Thus far, stratigraphic sections have been measured in 13 caves scattered over a 1000 square mile area.

Gypsum textures exposed in the caves include massive, nodular, and laminar types. While cavers generally refer to them as “gypsum caves”, gypsum is by no means the only rock type exposed in the caves. Some cave passages are developed in thick dolostone units intercalated with or overlain by gypsum beds.

As a result of the contrast in solubility and hardness between gypsum and dolostone, the stratigraphic sequence in a particular cave exerts a profound effect on cave geometry and passage cross-section. Many passages have gypsum walls and a dolostone or limestone floor. Many passages are confined to a single stratigraphic unit for hundreds of feet prior to breaching of the resistant carbonate floor at a vertical shaft or climb-down. Dolostone beds in gypsum caves occupy a similar position with respect to cave development as the chert beds in limestone caves of the eastern US. Although many of the cave passages flood completely during major storm events, the stairstep profile of most of the caves is indicative of speleogenesis that has occurred predominantly within the vadose zone.

A New Technique for Dating Allogenic Cave Sediments Using Cosmogenic Nuclides

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The concentrations of and in allogenic quartz cave sediment can be used to date sediment deposition over a time span of 0.2 to 4 Ma. Near the ground surface, radioactive (half-life=0.7 Ma) and (half-life=1.5 Ma) are produced in quartz at a ratio of 6:1 by nuclear reactions with secondary cosmic ray neutrons and muons. These cosmic rays are absorbed by rock, so and production in caves is negligible. In quartz sediment which was once exposed at the ground surface but is now buried in a cave, radioactive decay decreases the ratio of to over time. The ratio of to can therefore be used to date sediment burial.

I have used this technique to date river gravels preserved in five caves above the New River, Virginia. Over time, the river has incised through bedrock, so that caves which once opened

onto the riverbed and received gravel sediment are now in cliffs high above the river. Sediment emplacement times range from 0.3±0.09 Ma to 1.52±0.18 Ma, and show that the river has incised at a rate of 20-30 meters/Ma.

Genesis of Hydraulic Conduits in Karst Aquifers: A Two Dimensional Modeling Approach

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Geochemical modeling of the development of conduits and caves in karst systems is an area of active research. One of the goals of geochemical modeling is to estimate the time scales required for the development of hydraulic pathways. Such modeling efforts thus offer a useful tool for exploring different hypotheses on cave development.

Several previous studies have examined the enlargement of conduits in one-dimensional flows. It is our impression that natural fracture planes which lead to the development of conduits are better viewed as two dimensional flow systems. In two-dimensional flows, there is an opportunity for instabilities and preferential flow paths to develop, which can accelerate conduit growth significantly.

A two-dimensional computer modeling approach is used to describe flow, calcite dissolution, transport and wall retreat within an idealized fissure of a karst aquifer. Industry standard groundwater models MODFLOW and MT3D are used to describe the flow and transport within the fissure.

Contaminant Case Studies in Virginia Karst

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Natural processes active in karst result in three types of natural hazards: subsidence, sinkhole flooding, and groundwater pollution. Traditionally, subsidence has been the natural hazard of greatest concern to karstland residents. With continued development and population growth in karstlands, local residents are becoming aware of the high susceptibility of karst groundwater to pollution. Cavers have long been aware that the caves under-draining sinkholes, sinking streams, and other surface water access points, are conduits along which travel is possible for long distances through the subsurface. Liquid contaminants or the leachates of solid wastes typically follow the same solutional conduit pathways as surface water and precipitation in recharging the karstland aquifers. Subsurface flow is through solutionally enlarged fractures and partings in the folded and faulted Valley and Ridge province carbonate rocks. These conduits comprise both storage and flow path components of the karstland aquifers in these otherwise tight rocks. Contaminants that have fouled the Commonwealth of Virginia's karst include spills or leaks of petroleum products, herbicides, sheep and cattle dip, solvents, fertilizers, sewage, milk, and the leachate of improperly disposed waste materials. Remediation of contaminated groundwater is costly and rarely completely effective. The best long term management tools for karstland groundwater resources are: 1) the education of the karstland residents about the nature of karst and the proper handling and disposal of potential pollutants; and 2) protecting the recharge areas through quality control of recharge inputs including the storm-water drainage systems.

Enlargement of Lava Tubes by Downcutting and Breakdown

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Pahoehoe lava forms extensive tubes, through which lava is conveyed over large distances. Throughout the active time of such a tube, many processes act to alter its initial tubular appearance. Comparative studies in several major tube systems on Hawaii (Keala Cave, total length 8.60 km; Keauhou Trail System, length of all segments >2.5 km; Clague's Cave, total length ca. 2 km; Charcoal System, total length of all segments ca. 2 km; and Earthquake System, total length 338 m) illustrate the importance of these processes. All of the mentioned tubes show evidence of active downcutting. This downcutting appears to be largely associated with the backcutting of lava falls and is most probably purely mechanical. Several lava falls may move upslope simultaneously, creating tall, canyon-like passages. Very often voluminous plunge pool rooms develop below lava falls. The downcutting is often associated with the undercutting of sidewalls, resulting in a meandering of the passage and causing breakdown to occur.

A Condensation-Evaporation Model for the Origin of Some Types of Speleothems

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Some hollow gypsum speleothems, studied in Kugitangtou caves, may form by permanent evaporation-condensation processes. This mechanism demonstrates high heat and mass transportation efficiency. A physical model and the prominent factors of these processes as well as kinetics of the growth and a stability of these aggregates are discussed. Peculiarities in morphology and structure of some types of crusts and newly described speleothems "hornet nests" may be explained by an evapo-condensation water feeding model.

It is proposed that growth of "hollow gypsum stalagmites", a rare speleothem, is initiated by a cavity of any origin in gypsum deposits, and is controlled by cave air temperature along a vertical gradient. They grow in conditions balanced between

seeping and evapo-condensation water feeding, which renders them highly stable. Seasonal changes in the humidity and temperature gradients in caves appears to affect the morphology of these aggregates.

Although attractive, this model has internal contradictions and is an incomplete explanation of this speleothem type.

Gypsum Speleothems of Glacial Origin

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Seasonal permafrost affects the development of gypsum speleothems in caves of the Pinega area, northwestern Russia, including two previously undescribed types of deposits.

One type, called gypsum "ezh" (porcupine) grows in dense clay sediments within a high supersaturation environment. Originally growing in the direction away from the freezing front, they later enlarge almost symmetrically. Their shape and peculiarities are dependent on various factors and provide interesting comparisons with gypsum "roses" from arid regions. A second type, a very rare gypsum speleothem, appears to be produced from concretions of gypsum "powder" accumulated in cavities within a powerful underground glacier. Recrystallization of the gypsum is controlled by fluctuating local temperature and seasonal permafrost in an environment of low supersaturation.

A Possible Influence of the Earth's Rotation on Speleogenesis

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The morphologies of sub-latitudinal (east-west oriented) and sub- longitudinal (north-south oriented) cave stream channels in sub- polar regions of northwestern Russia show differences in cross-section. This effect has been observed in both gypsum and limestone caves. Sub latitudinal passages are commonly almost symmetrical. Sub-longitudinal passages often have a consistent pattern of clearly visible asymmetry.

On the basis of these observations, it is hypothesized that the Earth's rotation (Coriolis force) influences cave morphology. Different mechanisms influencing channel development depend on surficial and underground streams, and local conditions for speleogenesis.

Filamentary Gypsum Crystals From the Cupp-Coutunn Cave

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Various types of gypsum filamentary crystals and their aggregates are widespread in the caves of the Cupp-Coutunn system. These speleothems include flowers, beards, wool, hair, needles on and inside clay, and satin spar veins in clay.

After examination of their structure, substratal peculiarities, and other features of the environment, simple calculations show that the usual model explaining their growth from a solution seeping through porous substrates doesn't work. Impossible pressures are needed and fibers' diameter/length relation dispersion shows the absence of uni-directional seeping.

The only mechanism, suitable for the observed properties, is a short-cycle (seasonal) substratal wetting-drying cycle caused by condensation evaporation. In several cases, there is direct evidence as growth proceeds on isolated pieces of pure carbonate substrates. The only local sulfate source here is the gas from the air, driven into the substrate pores by condensing water.

Some unusual aggregates (quasi-epitaxial gypsum overgrowths on the ends of calcite-aragonite quill anthodites) preserve their original orientation as gypsum hair.

Gypsum needles start as filamentary crystals extruding from clays. They pass through the zones of split growth and skeleton growth. Competition between the pores causes high oversaturation. Crystallization pressure blocks most of the pores, squeezing the solution into the surviving ones and creating strong oversaturation barriers.

New Levels in the Minor Mineral Bodies Hierarchy

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Common classification systems for minor mineral bodies include 1st order populations (crystals, grains), 2nd order populations (skeleton crystals, split crystals, dendrites), aggregates, and upper level minor mineral bodies (for example, veins). This is adequate for "usual" mineralogy. However, caves, with their peculiar environments, display several well-recognized hierarchical levels above aggregates.

Further, needed classifications include: a) multi-aggregates—syngenetic, regular intergrowths of different aggregates (thus, demonstrating that the paragenesis conception may be used with aggregates); b) crusts—unions of all the crystallization products generated during an interval of simultaneous crystallization (extension of the "weathering crusts" conception); c) ensembles—unions of crusts, resulting from prolonged, monotonous crystallization stages.

Unique aggregate and multi-aggregate interrelated activities also results from peculiarities of cave environments. In the usual case, the mass transportation symmetry (and the derived aggregates' texture symmetry) is exclusively controlled by the physics of the crystallization environment. In the interactive case (i.e. helictites), the crystallization environment symmetry is "controlled back" by the growth's peculiarities. So, in this

case we must speak not only about the aggregate's structure and texture, but also about their new property—"behavior".

Stable cave environments may also generate upper levels of mineral populations (single-phase generated mineral bodies, started from a single embryo, and having a complete structure). In Cupp-Coutunn Cave, there are 3rd order gypsum individuals (split skeleton screw crystals).

Subaqueous Helictites, Virgin Cave, New Mexico

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Subaqueous helictites have been discovered in a small pool in Virgin Cave, Lincoln National Forest, New Mexico. Previously, the only known occurrences have been within Lechuguilla Cave, Carlsbad Caverns National Park. The helictites extend into a shallow, water-filled pool from a narrow (<1 cm) leading margin of thin, translucent shelfstone. Although the most centered helictite extends to a length of 4 cm and has a diameter of nearly 0.5 cm, most helictites are about a centimeter in length and less than a millimeter in diameter. Submerged, unbroken cave rafts, which are only rarely associated with these unusual speleothems, occur at the bottom of the pool. A gypsum block, approximately 0.5 m in diameter, is situated on wet flowstone which slopes toward the pool. Also, on the slope leading directly to the pool, there are remnant "tufts" of another gypsum block which has not been completely dissolved. The presence of this remnant gypsum supports the theory that subaqueous helictites precipitate in response to the common-ion effect.

The Relationship of Structure and Stratigraphy to Cave Formation in the Fourmile Draw Member, San Andres Formation, Eastern New Mexico

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The gypsum caves on the eastern plains of New Mexico provide a unique window through which to view the structure and stratigraphy of the Fourmile Draw Member of the Permian San Andres Formation. Since 1992, the stratigraphy of a number of gypsum caves has been studied by members of the Gypsum Karst Project (GypKaP) of the NSS. The strata exposed in the caves consists primarily of gypsum, dolostone, and clastic beds deposited along a broad continental ocean shelf during Permian time. When deposits such as these are exposed at the surface they are typically highly weathered. However, in the caves studied, periodic flooding has provided relatively fresh surfaces with extensive lateral exposure, enabling our study to be more comprehensive than one would usually expect in evaporites.

Correlation of beds exposed in different caves has enabling us to infer the regional geologic structure. A number of oil, gas, and water wells have been drilled in the area, and correlation of the logs from these wells has helped in the analysis of the deeper beds not reached by the caves. The larger, more vertically developed caves appear to be forming along structural highs. Analysis of well logs and the stratigraphy exposed in the caves indicates the possible presence of several anticlines in the study area, and that the larger caves are developed near the crests of these folds.

Comparison of Joint, Sinkhole, Photo-lineament, and Cave Segment Orientations for Predicting Contaminant Transport Direction in the Central Basin of Tennessee

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Orientation measurements were made of 979 joints, 260 photo- lineaments, 318 sinkholes, and 247 straight cave segments within the upper Ordovician carbonates of Cannon and Rutherford counties, which are located on the southern flank of the Nashville Dome, Tennessee. Large caves of particular interest for the study were Snail Shell, Espey, Robinson Ridge, and Pleasant Ridge caves. Together, these caves contain over 22 mi (35 km) of passage. Three dominant cave passage orientations were observed with scatter around the following average trends: N55°W, N40°E, and N5°W. Most passages are developed along the N55°W trend and the least along N5°W. Very similar joint orientations were observed in the shaly beds. In the more massive carbonate rock units, the N5°W trend was generally absent. The sinkhole and photo-lineament orientations matched the N55°W and the N40°E trends well, but again the N5°W trend was nearly absent. Although there is some scatter of the data, with this information contaminant transport direction from a spill or leak can better be predicted using sinkhole, joint, and/or photo-lineament orientations where cave data do not exist.

Crystallization of Calcite and Aragonite

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Controversy persists over what controls calcite vs. aragonite precipitation and the morphology of calcite crystals. In caves, averaged measurements of pool chemistry correlate poorly with mineralogy and crystal shapes. However, increases in pH with depth are common in certain cave pools, especially during rapid infiltration, which indicate steep gradients and rapid degassing. Pools with the highest degassing rates contain calcite needles. Those with moderate degassing rates contain blade-shaped calcite, commonly in V-shaped twins. Low degassing rates produce shingled calcite rhombs, and pools with rather static contain unshingled calcite rhombs. Lab experiments are being conducted to clarify these relation-

ships and to determine the influence of dissolved solids on mineralogy and crystal morphology is bubbled through distilled water to achieve PCO_2 levels up to 1 atm, and reagent-grade calcite is dissolved in the solutions to just below saturation. Some bottles are spiked with salts of Ca, Mg, Na, Cl, and samples are allowed to lose at various rates, while pH, ionic composition, and saturation indices for calcite, aragonite, and vaterite are determined with time. Similar studies are performed with spring water. Preliminary results show that degassing rates of roughly >0.01 atm/day produce both aragonite and calcite, accompanied by vaterite when degassing is most rapid, whereas slower rates produce only calcite, independent of the presence of other ions. In Mg-rich water, low-Mg calcite forms on the bottom, while calcite rafts are high in Mg but revert with time to low-Mg calcite. High-sulfate solutions produce very low-Mg calcite.

Dolomite Cave Rafts: Evidence of Dolomitization in Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico

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A sample of cave rafts from the floor at the Rusticles in Lechuguilla Cave consists of dolomite. Petrographic examination of the sample reveals a pseudospar crystal fabric which does not conform to the crystal arrangement common in cave rafts, and therefore suggests replacement of calcite by dolomite. A relict texture of rhombohedral crystal terminations, observed in a thin section of the sample, provides convincing evidence that the rafts originally formed as calcite and were later replaced by dolomite.

The Rusticles area exhibits iron-rich stalactites (the Rusticles), small potholes (partially filled with goethite-rich sediment) formed by corrosion drip waters, and abundant dolomite crusts and aragonite frostwork. The diagenetic history of the cave rafts yields information about the evolution of the pool water chemistry in the vicinity of the Rusticles. Study of the cave rafts may also explain the origin of the iron rich stalactites.

Geochemistry of Lechuguilla Cave Pool Water

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Like other caves in the Guadalupe Mountains of New Mexico, Lechuguilla is believed to have been formed by sulfuric acid dissolution of limestone bedrock. This history is responsible for many of the spectacular sulfate speleothems for which the cave is known, and for distinctive patterns in water chemistry. Since the main cave's discovery in 1986, over 100 water samples from pools throughout much of its known extent have been collected and analyzed for major and trace element chemistry, and in some cases, isotopes including deuterium, and tritium.

Analysis results provide insight into geochemical processes occurring within the cave. Major ion chemistry is controlled by the carbonate bedrock that hosts the cave, but is modified by in- cave processes, including evaporation, condensation, and dissolution and precipitation of secondary cave minerals, including calcite, aragonite, and gypsum. In particular, dissolution of magnesium-containing calcite or dolomite bedrock followed by precipitation of secondary calcite or aragonite within the cave has resulted in increased magnesium: calcium ratios in solution; most Lechuguilla pool waters have a Mg:Ca molar ratio greater than 1. Local groundwater, most of which presumably did not undergo cave processes during recharge, has a Mg:Ca ratio around 0.6.

Two of the more unusual speleothems found in the cave probably owe their origin to common-ion effect precipitation. As previously demonstrated, the subaqueous helictites in Pellucidar and elsewhere reflect carbonate precipitation caused by the addition of gypsum to a solution already saturated with calcite. The exact opposite process may explain the selenite precipitation taking place in the Dilithium Pool, where water saturated with gypsum encounters carbonates and other minerals.

Tritium in Lechuguilla Pool Water: Implications for Recharge Processes

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Numerous isolated pools of various size are found throughout Lechuguilla Cave, fed only by water seeping through the overlying limestone. The pools thus permit direct sampling of locally perched vadose zone water beneath the arid Chihuahuan desert of southeastern New Mexico. Over 20 pool water samples have been collected for low-level tritium analysis. For comparison, a sample of local groundwater was also collected from a nearby well.

Nuclear weapons testing in the 1950s and 1960s released large amounts of tritium into the atmosphere, which was then slowly removed by precipitation. The "bomb-pulse" tritium profile obtained by measuring tritium concentrations at different depths in the cave provides insight into the character and rate of recharge processes in the region.

Our results show that elevated tritium levels are confined to pools within the upper 900 ft of Lechuguilla Cave. Maximum tritium concentrations are an order of magnitude lower than predicted using a piston-flow recharge model. The data can be

fit far better using a well-mixed reservoir model for the vadose-zone. Using this model, the data indicate a mean recharge velocity of roughly one ft/yr, which is reasonable considering estimates of local precipitation, evapotranspiration, and vadose-zone moisture content.

The observed variability in tritium concentrations within the cave hints at the complexity of recharge processes occurring. Variations in surface topography and drainage, preferential pathways along fractures in the overlying bedrock, hydrodynamic dispersion in the vadose zone, and vapor phase advection and diffusion both within and above the cave may all play significant roles in producing the observed tritium profile.

A Geologic Reconnaissance of the Cerro Blanco Karst, Chiapas, Mexico

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The Cerro Blanco karst is situated in north-central Chiapas, Mexico, within the Sierra Madre del Sur, and includes roughly the area northeast from the town of Pueblo Nuevo Jolistahuacan within the Arroyo Seco and Río Colorado drainage basins. Recent exploration has discovered the first major cave systems known in the mountains of Mexico not formed in Cretaceous limestone. The caves are developed in the Oligocene Mompuyil Formation, a marine platform limestone composed largely of calcarenites and terrigenous clastics. The Simojovel Formation, a suite of littoral sand, silt, and some interbedded limestone, is described as conformably overlying the Mompuyil, but the contact is clearly karstified in some areas. The occurrence of gypsum speleothems in several caves indicates the presence of pyrite or other sulfate- yielding minerals within the clastics. Quartz-rich sands, eroded from the Simojovel, cover the floors of many cave passages. However, surface erosion due to recent deforestation has filled and nearly-filled some passages with soil deposits over 10 m deep.

Three major cave systems are known: Cueva del Arroyo Grande (10.2 km long, 292 m deep), Sima Soconusco (8.7 km long, 510 m deep), and Cueva del Aire Fresco (8.6 km long, 280 m deep). Arroyo Grande is a fossil phreatic maze formed under a low hydraulic gradient that existed prior to the incision of the modern valleys. Soconusco and Aire Fresco formed more recently in response to that incision, and Aire Fresco probably pirated flow from Arroyo Grande. Soconusco is a system of hydrologically active vadose shafts and passages formed along the retreating margin of the Simojovel Formation. They feed into the large base level conduits of Aire Fresco, which is collapsed at its downgradient end and forms a roughly 200-m-long valley. This yet-to-be-connected group of caves discharges with an estimated baseflow of 1 m3/s through rubble at the lower end of the valley. Most passages in the area are stratigraphically and structurally controlled: perched on sandstone beds and running down the 14-19° dip. The geometry of the base level passages, and their volume of peak flow discharge (as suggested by sediment deposition and flow features) and baseflow discharge indicate that most of the cave system has yet to be found.

SPECIAL SYMPOSIUM ON GEOLOGY OF THE GUADALUPE MOUNTAINS

Session Chairs: Harvey R. DuChene & Donald G. Davis

Extraordinary Features of Lechuguilla Cave, New Mexico

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Lechuguilla Cave is remarkable for a characteristic suite of geologic features: some of them virtually unique to this cave, others previously known but much better-developed and/or more abundant here than elsewhere. These features, which fall into several classes listed below, will be illustrated and concisely explained.

SPELEOGENS: Acid lake basins, Subterranean karren fields

SPELEOGENETIC DEPOSITS: Gypsum “glaciers”, Sulfur masses

ATMOSPHERIC SPELEOFACTS: Corrosion residue, Rimmed vents, Horizontal corrosion/evaporation lines

SPELEOTHEMS OF UNORTHODOX ORIGIN: Biothems: Rusticles, Pool finger complex;

COMMON-ION-EFFECT SPELEOTHEMS: Common-ion-effect stalactites, Subaqueous helictites; Evaporative speleothems: “Chandelier” stalactites and stalagmites, Giant gypsum hairs, Hydromagnesite fronds, Folia, Raft accumulations and cones, “Silticles”, Splash rings

Permian (Guadalupian) Stratigraphy of the Guadalupe Mountains

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The limestone, dolomite and sandstone beds of the Guadalupe Mountains are part of the Permian (Guadalupian)-age Capitan Reef Complex of New Mexico and west Texas. The Capitan Reef Complex is divided into three major depositional areas: 1) reef, 2) lagoon, (also called “backreef”), and 3) basin. The rocks in each area have distinct stratigraphic characteristics. In the reef, clean, highly fossiliferous limestones and dolomites predominate. On the landward side, lagoonal sediments consist mostly of limestone and dolomite and a few interbedded layers of sandstone. Carbonate rocks become progressively more evaporitic and less fossiliferous toward land. On the seaward side, there is a steep debris slope composed of material that eroded off the reef. Near the base of this slope, reef debris interfingers with dark gray, poorly fossiliferous

limestones and fine-grained sandstones of the Delaware basin.

There are two reefs in the Guadalupe Mountains, the older Goat Seep Formation and the younger Capitan Formation. The Artesia Group includes five formations composed mostly of backreef sediments. From oldest to youngest, they are the Grayburg, Queen, Seven Rivers, Yates and Tansill. The Queen and the younger part of the Grayburg formations are equivalent to the Goat Seep Formation. The Seven Rivers, Yates and Tansill are equivalent to the Capitan Formation. In the Delaware basin, the Cherry Canyon Formation is equivalent to the Goat Seep, and the Bell Canyon Formation is equivalent to the Capitan.

Most caves in the Guadalupe Mountains are located in the Capitan, Yates and Seven Rivers Formations. Understanding the stratigraphy of the Permian rocks of the Guadalupes helps cavers understand the origin of known caves as well providing clues to the location of undiscovered caves.

The Lechuguilla Cave Mineralogical and Geological Inventory Project

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In 1992, at the start of the Lechuguilla Cave Mineralogical and Geological Inventory Project (LMIP), a method for the capture and recovery of geologic information was needed. It was suggested that a series of relational databases using software for the Personal Computer (PC) would be a good solution for the problem. With the help of cavers familiar with Lechuguilla, a series of databases covering 146 parameters in the cave was developed. The databases are 1) aragonite speleothems, 2) calcite speleothems, 3) sulfate speleothems, 4) miscellaneous minerals, 5) water, 6) Pleistocene and Permian paleontology, 7) bedrock features, and 8) speleogenetic features.

Inventory data is keyed to survey stations within Lechuguilla. A team of cavers follows a specific survey, stopping at each station to record geological and mineralogical information on standardized inventory forms. Data from the completed forms is entered into FOXPRO, a relational database manager.

Once data is entered, new databases can be created within FOXPRO for a specific feature or set of features in the cave. The new database is exported to a mapping program that displays all of the survey stations in the cave. Survey stations with features listed in the new database are shown in a different color, and their distribution in the three-dimensional cave system is easily seen.

What is the use of inventory? Scientists, cave managers and explorers all use the information to better understand speleothem distribution, speleogenesis, environment and ecology in Lechuguilla. However, the most important benefit of the LMIP may be increased awareness of the underground environment by explorers who learn by collecting data that a cave is more than a hole in the ground surrounded by rock.

Geochemistry of Carlsbad Cavern Pool Waters

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Water samples from 10 pools throughout Carlsbad Cavern have been collected and analyzed on a quarterly basis for pH, temperature, electrical conductivity, alkalinity, and the concentrations of major and trace inorganic solutes. The temperature, relative humidity, and carbon dioxide concentration of the cave air adjacent to each of the pools were also measured.

Different pools vary markedly in chemical composition from one another. The waters range from very fresh (TDS 300 mg/L) to saline (TDS 10,000 mg/L). The salinity of the pool waters does not correlate with depth beneath the land surface, and the pool at the lowest elevation in the cave (Lake of the Clouds) is among the pools containing the lowest concentrations of dissolved solutes. The most dilute pool waters are of the calcium-magnesium-bicarbonate type, whereas the most saline pool (Iron Pool) contains a magnesium-sulfate water. Based on computer model simulations, most pools are saturated or supersaturated with respect to calcite, and a few pools are also saturated with gypsum or hydromagnesite.

A geochemical tracer study was initiated to assess the leakage rate of water from the pools. The results indicate that bromide concentrations have been declining only slowly following tracer introduction. This suggests that the pools are not leaking at a significant rate during this time period. The low dissolved solute concentrations observed in most of the pools, coupled with the apparent long residence time for the bromide tracer, indicate that the pools are recharged periodically by infrequent precipitation events separated by long quiescent periods of slow evaporation with minimal leakage.

Geology of the Delaware Basin

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A brief background survey of the geology of the Delaware Basin is presented in order to help the caver understand how the caves of the Guadalupe Mountains relate to a regional geological setting. Four episodes of karsting have occurred in the Guadalupe Mountains: Stage 1 fissure karst (Late Permian), Stage 2 spongework karst (Mesozoic), Stage 3 thermal karst (Miocene), and Stage 4 sulfuric acid karst (late Miocene to present). Stage 1 fissure karst is developed along joints and is filled with breccia and a mudstone and/or spar matrix; Stage 2 spongework karst forms a spongework (small holes) matrix in the bedrock; Stage 3 thermal karst is lined with large calcite (dogtooth) spar crystals; and Stage 4 sulfuric acid karst forms the large, explorable, cave passages such as in Carlsbad Cavern and Lechuguilla Cave.

Stage 4 sulfuric acid caves are genetically related to hydrocarbons and economic sulfur deposits (e.g., Culverson sulfur

mine) in the basin, and to Mississippi Valley-type lead-zinc deposits (e.g., Queen of Guadalupes gossan) in the reef by a series of sulfur-redox reactions. Caves also occur in the Capitan Limestone of the Apache and Glass Mountain sections of the Delaware Basin. Caves in the Glass Mountains are known to be sulfuric acid caves like those in the Guadalupe Mountains.

History of Sulfuric Acid Theory of Speleogenesis in the Guadalupe Mountains

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Steven Egemeier, in a 1971 report to Carlsbad Caverns National Park, first suggested that the large rooms of Carlsbad Cavern may be the result of solution by sulfuric acid. Egemeier's thesis, published in 1973 at Stanford University, again mentioned the possibility of sulfuric acid origin based on his replacement-solution, sulfuric acid theory for the Kane Caves, Wyoming. Based on field work completed in 1973, and completely independent of Egemeier, David Jagnow published his MS Thesis in 1977, proposing a sulfuric acid origin for the Guadalupe caves. Jagnow attributed the source of the sulfuric acid to oxidation of pyrite in the overlying Yates Formation during uplift of the Guadalupe block. In 1979, Carol Hill did the first sulfur isotope determination on gypsum blocks in the Big Room of Carlsbad Cavern, proving that the gypsum was not derived from the Castille gypsum in the Permian Basin. Hill also determined that endellite was formed under sulfuric acid conditions. In 1979 and 1980, Donald Davis was the first to propose a hydrocarbon source for the hydrogen-sulfide/sulfuric acid origin for gypsum and sulfur.

Since the early 1980s, the theory of sulfuric acid solution for the Guadalupe caves has been largely accepted. Additional studies of endellite, silica deposits, isotopically light gypsum and sulfur, the presence of alunite, natroalunite, tyuyamunite, and other unique minerals all point to basinal degassing of hydrogen sulfide as the most likely source of the sulfuric acid solution. Debate continues over the migration routes of the gases or brines derived from the underlying formations. This unique origin is the reason the Guadalupe Mountains contain spectacular world-class caves.

Hydrology of the Capitan Aquifer: Past and Present

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The Capitan Aquifer, consisting of the Capitan and Goat Seep Limestones and associated carbonate rocks in the San Andres Limestone, supplies large quantities of water to wells used by the City of Carlsbad and associatedirrigation areas. Some wells have produced more than 4,000 gpm. Three stages can be identified in the evolution of this productive aquifer: 1) initial uplift and erosion exposed the aquifer and allowed rainfall to enter and replace or dilute the saline water in the aquifer; 2) leakage through overlying sediments lowered water levels in the aquifer, created breccia pipes, and allowed increased inflow of fresh rainwater; 3) the Pecos River eroded sediments overlying the aquifer, established Carlsbad Springs, and increased circulation, and thus transmissivity, in the aquifer west of the Pecos.

The large caves in the Guadalupes appear to have formed independently of the preexisting trends in transmissivity of the aquifer. Increased groundwater circulation created a zone of very large transmissivity extending from east of the town of Carlsbad to the Dark Canyon well field. Near Whites City, the aquifer is less transmissive, and in the vicinity of Lechuguilla Cave, an increased hydraulic gradient, water-level fluctuations in the cave, and a single test well indicate that the transmissivity may be further reduced.

Much of the recharge to the aquifer takes place north of the Guadalupe Mountains by infiltration of surface runoff and by leakage from perched aquifers in the back-reef sediments. In the Guadalupe Mountains, caves allow observation of the principal mechanisms as infiltration directly along fractures, drainage from perched aquifers, and capillary water slowly moving through the rock matrix.

Canary-Yellow Cave Precipitates: Late-Stage Hydrated Uranyl Vanadate, Uranyl Silicate, and Iron Sulfate Cave Minerals

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Many occurrences of yellow cave deposits have been erroneously or prematurely identified as elemental sulfur. The recent discovery of metatyuyamunite in Spider Cave, Carlsbad Caverns National Park, New Mexico, has prompted more careful examination of these yellow minerals in caves of the Guadalupe Mountains. In addition, similar canary-yellow minerals sites have been investigated in Horsethief Cave, Wyoming, Porcupine Cave, Colorado and a cave in northern Chihuahua, Mexico.

Canary-yellow minerals identified from six different caves by x-ray diffraction analysis and electron microscopy include metatyuyamunite, tyuyamunite, carnotite, boltwoodite, copiapite, coquimbite, and roemerite. Metatyuyamunite, tyuyamunite, carnotite and boltwoodite are all uranium minerals. Copiapite and coquimbite are hydrated iron sulfates; roemerite, usually lavender but sometimes yellow, is also a hydrated iron sulfate. Carnotite, boltwoodite, copiapite, and roemerite have not previously been identified as cave minerals.

Cave Patterns in the Guadalupe Mountains

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Caves in the Guadalupe Mountains have distinctive patterns shared by few caves elsewhere. These patterns reflect an interplay between sulfuric acid speleogenesis and the local geologic setting. The typical Guadalupe cave has a ramifying pattern with branches emanating at various levels from central areas. However, parts of many caves exhibit network or sponge-work patterns and some consist of simple widening of fissures.

The ramifying pattern is typical of caves formed by the oxidation of rising hydrogen sulfide. It entered the caves through presently sediment- choked fissures that extend below major cave levels up to 50 m deep. Such rifts narrow downward and are typically vertical or inclined at angles up to 40°. Large domed rooms are located where oxidation has persisted at the same site for a long time. Outflow from these areas took place through lateral conduits to the most efficient available outlet. Altitudes of lateral passages decreased as the local base level dropped. Because the location of available outlets changed with time, it is common for lateral conduits to extend in a variety of directions. Many of these passages are nearly horizontal but are discordant to bedding, so they almost certainly represent former water tables. Some upper-level passages are not horizontal, but rise in a series of arcs toward former outlets above the present cave levels. This configuration shows that mixing of oxygen-rich water with water must have taken place well below the water table and continued over vertical distances as great as 250 m.

Networks and fissures formed either by dispersed flow rising from below or by local bursts of acidity. Spongework formed by local bursts of acidity in areas of high primary porosity. The large pores in the Capitan limestone favored spongework.

HISTORY SESSION

Session Chair: Susan Holler

The Truth About the Gold of Spanish Cave

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For more than 60 years, newspapers, magazines, books, and television have promulgated tales about a lost Spanish gold mine, with skeletons and ancient relics, concealed in the mysterious depths of Spanish Cave in Colorado's mountains. My research from 1960 to 1995, however, has failed to produce sound confirmation that the Spanish ever saw or entered the cave. The "Spanish" cross and artifacts are more probably attributable to an 1870s colony of German settlers below the mountain.

Music in the Mammoth Cave: An Inquiry into an Important Aspect of 19th Century Cave Tourism

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Music was a significant component of most tourist trips into Mammoth Cave, Kentucky, during the 19th Century. Visitors to the cave often perceived natural and man-made sounds in the cave as musical. Tourists also frequently made their own music while visiting the cave, using voices and instruments. In addition, the guides to the cave typically sang for the tourists during their excursions. Finally, professional musicians, whether members of the Mammoth Cave Hotel band or travelers like Ole Bull, visited the cave and sometimes performed. Although not usually thought of as an important part of caving in the 20th Century, music was an integral part of the cave experience in the 19th Century.

South Carolina's Historic Rockhouse and the Great Flat Rock Revisited

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Two historic South Carolina caves in granitic rock were first described by John Drayton, governor of the Palmetto State, in 1802. In his monumental book entitled A View of South Carolina as Respects Her Natural and Civil Concerns, Drayton paints a romantic description of a large talus cave on Flat Creek, which he refers to as the Rock House. In addition, he refers to "two caverns" located at the base of the Great Flat Rock, now known as Forty Acre Rock. Additional 19th Century literature re-emphasized the significance of these sites.

The latter caves are now part of a Nature Conservancy Preserve and frequently visited, but the location of Rock House Cave has, until recently, been lost with time. While engaged in field work for the Carolina Cave Survey, we mentioned our search for the Rock House to a local hunter, Kenny Henson. After he had read a copy of Drayton's description, he felt that he had come across that very site a short time before. With his excellent directions, we were able to relocated the cave the following day. Indeed, the 19th Century descriptions of the area were not exaggerated: "Upon the whole, the cascade of Juan Fernandez, celebrated by circumnavigators, may be more beautiful; as that of Niagara is more grand and sublime; but still this Rockhouse and cascade would rank high in ornamental gardening with all those..."

Preserving NSS Guidebooks on CD-ROM

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Every year more originals of limited publication guidebooks are lost. The conventional process is to preserve books on microfilm.

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INTERNATIONAL EXPLORATION

Session Chair: Nancy Pistole

Caves of India: Exploration of an Emerging Significant Karst Region

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The Indian subcontinent was not known for its karst until 1992 when cave explorers from Bristol Exploration Club and Orpheus Caving Club, UK recognized for the first time the great potential for cave development in northeastern India. The extensive deposits of limestone, up to 350 m (1160 ft) thick, occur in the state of Meghalaya (The Abode of The Clouds) just north of Bangladesh. The hot and humid summer climate offers on average 12 m (40 ft) of rainfall annually. In fact, the highest rainfall in the world was measured in the Khasi Hills at 26.5 m/year (87 ft/year). The combination of a limestone massif and torrential precipitation, as predicted, created a significant karst.

Expeditions during 1994 and 1995 provided further evidence of extensive river caves of mainly horizontal profile as well as vertical shafts with depths to 60 m (nearly 200 ft). Tetengkol was surveyed to 5.3 km (3.3 mi) to become the longest cave in the Indian subcontinent. Krem Mawmluh (4.5 km; 2.8 mi), a fine river cave with passages up to 30 m wide by 25 m high (100 ft x 83 ft), was partly damaged by cement waste. Siju Dobhakol (Cave of the Bats), her biota, houses in its 4.4 km (2.7 mi) of passages a large bat colony, among other biota. Along with limestone, calcareous sandstone lends itself to speleogenesis in this region. Entirely formed in such sandstone, Krem Dam was surveyed to 1.3 km (0.8 mi) to yield the longest sandstone cave in this part of the world. The three expeditions have now resulted in nearly 33 km (21 mi) of surveyed cave passage with prospects for considerably more.

Caves of the Republic of Mauritius

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Two sizable volcanic islands constitute the bulk of the Republic of Mauritius. Solutional borehole caves up to 1.25 km in length exist beneath a subdued epikarst, in calcarenite, on the island of Rodrigues. Numerous lava tube caves of varying sizes are on the island of Mauritius proper. Some occur along the length of curvilinear systems. The vulcanospeleology of the island of Mauritius is compared to that of the island of Kauai, Hawaii.

The Caves and Karst of the Rio Encantado Area, Northwest Puerto Rico

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Recent exploration and threats to the karst near the Rio Encantado have spurred new interest in this extensive system. The Rio Encantado cave contains a world-class river traversable for over 15.9 km—a subterranean record. Severa l groups have explored the cave over several years. Much of the cave was explored as separate segments and linked together by passing obstacles of different sorts. Each linked segment has its own character ranging from huge wandering canyons to sporting waterfalls and sumps. Several major (and growing) disconnected fragments remain and potential exists for further integration of both the most upstream portions and tributaries. While the new exploration has excited greater interest, the most pressing concern is the very rapid destruction of the karst landforms due to massive development and quarry activities. The destruction of caves and important geologic features (as well as archaeological sites) has inspired renewed work to document the area and provide data for the proposed creation of a karst preserve.

Caving in Cuba: A Taste of the Forbidden Fruit

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Cuba consists of one large island and approximately 1600 smaller ones. The main island measures 1230 km long and 219 km across at its widest point, approximately the size of Pennsylvania. Towering mountains, up to ~200 m above sea level, cover one-fourth of the island, which is over 60% limestone. Although Cuba lies only 146 km off the coast of Florida, few US speleologists have visited due to travel restrictions and a long standing embargo.

Since September 1992, Cato and Susan Holler and a handful of other US cavers have made three expeditions to explore Cuban caves. On their first trip, they were the first US cavers to set foot in the Ancon Valley region of western Cuba. They also visited the world-class, 48 km long Santo Tomas Cave.

In 1993, the couple returned to rejoin some of their Cuban friends for additional exploration in Santo Tomas, and also the 35 km Majaguas—Canteras system. Following a difficult climb up the steep wall of a mogote, they were privileged to visit a special and rarely visited cave named Marilu. With its sparkling crystal walls and outlandish helictites, it is truly reminiscent of Caverns of Sonora.

In a 1995 visit which carried the Explorer's Club flag, Cato and Susan concentrated on the photodocumentation of several caves in the Matanzas province. Ambrosio has incredible pictographs and Santa Catalina displays a forest of stone mushrooms. The discovery of Cuba's first calcite bubbles, a look at geyser stalagmites, and sharing passages with large tarantulas and boa constrictors added interest to the exploration.

Caving in Switzerland Is Not Only Going 1000 m Deep and 100 km Long

Roman Hapka

Surely you know our little, tiny country for its chocolate and cheese and mountains. As you are a real caver, you know also that this little, tiny country has some of the deepest (-330 m in the Siebenhengsten System, 1060 in the Muttseehvhle) and longest (160 km for the Holloch and 140 km for the Sieben...) caves of the world. But our tiny country also has plenty of tiny caves. To date, the members of the Swiss Speleological Society have explored more than 2000 of them. So, even if you don't like chocolate or hate the smell of cheese or have some problems going up in the mountains, you will like Switzerland. Why? Because you are a real caver.

News in the Kugitangtou Caves Exploration

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Kugitangtou Ridge caves are atypical in all the senses. Speleothems are extremely variable, beautiful, and rare. Cave fauna age estimation contradict the known geological history of the area. Along with huge and beautiful chambers' existence, all of the last 15 years of finds (including huge new areas) appear from extensive digging through narrow collapsed mazes that makes exploration doubly hard—both for technical and psychological reasons.

Nowadays, the largest cave is Cupp-Coutunn Main, 61 km. long. Four more large caves (1.5 km, 3.2 km, 4.2 km, 8.5 km) share the same hydrological system. In the other 10-15 systems, no systematic exploration has begun, and only 1-3 km caves are known.

The last scientific studies in the caves show very interesting things: how minor changes in the cave environment (digging through narrow passages) may cause speleothem dissolution or vice versa (fast new speleothem growth).

The last expedition (April 1996) displayed two new ecological problems with the Kugitangtou caves, that are yet to be solved: a) As a result of great economic difficulties in Turkmenistan, the caves are again considered as a source of cheap "marble onyx" souvenirs—striped calcite from flowstones. A new mining project might start in about a year. b) The Provull cave, residence of the troglobitic loach (a unique troglobitic fish), is polluted. In spite of all the efforts for its conservation, declared by the Turkmenistan government, a new sheep farm was located nearby, and this spring several tons of sheep feces were moved by a mudflow into the entrance. It's still unknown whether the blind loaches survived after it.

Continuing Exploration in Cueva Cheve, Oaxaca, Mexico

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Cueva Cheve is located in the Sierra Juarez in northern Oaxaca, and is one of the deepest caves in Mexico at -1,386 meters. It is currently almost 25 km long. In February of 1995, a group of cavers camped at the end of the cave for 12 days and attempted to find a way through the massive breakdown choke that has been preventing progress toward the known resurgence at the Rio Santa Domingo. The group had limited success: they worked their way upward through the breakdown, and finally encountered a solid wall and ceiling. This may help lead the way to more open borehole along a fault system, which has characterized the cave so far.

Soconusco Area, Chiapas, Mexico

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The small town of Soconusco is located in Chiapas, halfway between Tuxtla Gutierrez and Villahermosa. It is part of Proyecto Cerro Blanco, which also includes the Arroyo Grande and Yerba Buena areas. In the last two years, several groups have discovered, explored, and surveyed many new pits and caves, and several known caves have been connected. Of note, a 250 m pit, La Ventana, was discovered in Cueva Dos Puentes. Cueva La Pedrada has a 217 m entrance pit, and then follows a stream for more than a kilometer until a sump is reached. The latest find, Cueva Darwin, begins with a 180 m entrance pit and connects to Cueva Soconusco. The Muleshoe system was also connected to Cueva Soconusco, making the overall system length close to 5 km. There is a great potential for finding more caves in the area.

PALEONTOLOGY

Session Chair: E. Ray Garton

The Paleoecological Record of the Eastern Grand Canyon Prior to the Last Glacial Maximum

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Previous investigations of solutional cave systems in Grand Canyon National Park have revealed extensive deposits of archaeological and paleontological resources. The dry climate and constant temperatures within these caves have resulted in excellent preservation of plant and animal remains that provide considerable information on the paleoecology of Grand Canyon during the Pleistocene Epoch. These caves commonly contain botanical materials preserved in packrat (genus middens that frequently date to the late Pleistocene. Packrat middens often preserve a high-resolution paleoclimatic record of botanical and faunal relationships that existed near the caves during the period of accumulation. The majority of middens found within the Grand Canyon typically date between 10,000 BP (radiocarbon years Before Present) and 13,000 BP, and middens older than 25,000 BP, and thus recording conditions prior to the height of the most recent glacial event, the Wisconsinan glacial maximum, are relatively rare. Here I report 22 new radiocarbon dates on packrat middens collected in 1984 and 1993. The dates on middens collected from cave sites along the river corridor are slightly older than average, falling between 12,830±70 BP and 16,620±110 BP. The exceptions were middens collected from caves in one minor tributary at River Km 80. Six middens yielded a mid-Wisconsinan glacial age, dating from 29,980±300 to 46,370±3270 BP. These are the oldest dates for middens found in the Grand Canyon. These middens will allow examination of mid-Wisconsinan plant communities that were present prior the last glacial maximum. Further, two sequences of dates were obtained from two cave localities, ranging from 13,970±90 to 46,370±3270 BP for Rebound Cave (six dates) and 18,120±100 to 44,480±1700 (five dates) for Crescendo Cave.

The Second Record of the Extinct Armadillo *Dasypus Bellus* from West Virgina

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The discovery of some 100 osteoderms, one cervical vertebra, one tooth, and other bone fragments of the extinct armadillo, *Dasypus bellus*, from Alaina P Cave in Berkeley County represents the second record for this species from West Virginia. The new discovery is about 200 km (120 mi) northeast of the only previous discovery of *Dasypus bellus* in the state, a single band osteoderm from Organ Cave, Greenbrier County. The discovery from Alaina P Cave represents a northeastern range extension for the species. Both movable band and buckler osteoderms are represented in the Alaina P collection along with some as yet unidentified skeletal fragments. Some of the movable band osteoderms are quite large in comparison with the single specimen from Organ Cave. So far, no other species have been found in Alaina P Cave and the age of the *Dasypus bellus* cannot be determined beyond the probability of being middle to late Pleistocene, ca. 500,000 to 12,000 years BP.

Paleontological Investigations at Kartchner Caverns, Southern Arizona

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Kartchner Caverns is being developed as the 26th State Park in Arizona and is in a developmental phase for tourism. In addition to being an ecologically fragile, geologically complex, and actively wet limestone cave system, the cavern has preserved a valuable paleoecological record. A small scale paleontological survey suggests the cavern may have had variable and possibly short-lived entrances during the course of the Pleistocene and Holocene thus accumulating and preserving sediments and faunal remains that could lead to a better understanding of the ecological changes that occurred in the San Pedro Valley over at least the last 200,000 years.

Paleontological salvage and testing has focused in the Echo Passage and Tarantula Room. Remains of a ground sloth have tentatively been ascribed to the Rancholabrean-age Shasta ground sloth. Most of the sloth bones are at least partly cemented in travertine, with exposed portions extremely friable and covered in wet clay. A new type of preservative proved useful in stabilizing and preserving the wet bone. Removing bone from the travertine was not feasible and therefore the objective was to expose, measure, preserve, and photograph as much of the remains as possible. A Uranium-series analysis is pending for the age of the travertine that covered the sloth.

The Tarantula Room will be the staging area for tours in the cave and therefore the removal of large amounts of apparently Holocene-age sediment is planned. Samples from this debris cone are producing microfaunal remains.

Late Pleistocene Paleoecology of the Missouri Ozarks via Mammalian Fauna from Little Beaver Cave, Phelps County, Missouri: A Preliminary Report

Blaine W. Schubert, Quaternary Studies Program, Northern Arizona University, Flagstaff, AZ 86011-5644

Paleontological investigations of caves in the Ozarks have yielded extensive faunal records for the last "Ice Age" or Pleistocene Epoch (1.8 Ma to 11 Ka). However, past analyses of Pleistocene cave deposits in the Ozarks lacked adequate temporal and/or stratigraphic control, due to unsuccessful attempts at radiocarbon dating. Excavations during the summer of 1994 and 1995 (with Russell Graham, Illinois State Museum) confirmed a rich faunal deposit with extinct, extralimital, and locally extant mammals. New techniques in targeting individual amino acids in bone (Tom Stafford, INSTAAR) in conjunction with advanced radiometric dating (accelerator mass spectrometry: AMS) have been utilized to gain temporal control. A total of three AMS 14C dates on bone samples represent the Pleistocene/Holocene boundary (10,000-11,000 yr. BP).

Extralimital species recorded from Little Beaver Cave include the meadow vole (red-backed vole) and porcupine. Extinct species from the cave are Jefferson's ground sloth and the beautiful armadillo. An AMS 14C date of 11,000±60 yr. BP on an armadillo scute represents the youngest directly dated specimen for this Dasypus variant. According to this date, the proposed extinction or possible migration and/or size reduction of did not occur prior to the Pleistocene/Holocene transition in this area of Missouri. In addition, finding a boreal extralimital species associated with the presumed neotropical inferred from helps support the hypothesis that the terminal Pleistocene Ozarks had a more equable climate than today.

SPECIAL PALEONTOLOGY SYMPOSIUM ON PORCUPINE CAVE, PARK COUNTY, COLORADO

Session Chair: E. Ray Garton

Porcupine Cave, Park County, Colorado: The Carnivore Fauna

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At least 20 species of carnivores, eight of which are extinct, are represented in the Porcupine Cave mammalian fauna. They include the oldest record of black-footed ferret (and the first Irvingtonian records in the western United States of a fisher (wolverine (cf. short-faced skunk (and cheetah (cf. The Canidae include coyote, the extinct Edward's wolf, red, kit and gray foxes, and a small unknown species of The are represented by badgers (the most numerous carnivore present), wolverines, two weasels (long-tailed weasel and ermine), mink, black footed ferret, a new species of marten, fisher, three species of skunks (spotted, striped, and short-faced), and otters. Specimens of the are rare, but include the bobcat and an extinct cheetah (including partial skulls of two cheetah kittens). An isolated premolar may represent the coati (a member of the So far there are no bears, saber-toothed cats, or other large cats in the fauna. There were at least 35 species of rodents, lagomorphs and hoofed-animals which provided prey for the carnivores. From the large number of specimens of carnivores (more than 200 specimens were collected in 1994 alone), it seems likely that Porcupine Cave functioned as a carnivore trap during at least part of its long history. Wolves, badgers, skunks and perhaps some other smaller carnivores denned, brought in prey, or died in the cave. Today, eleven extant species of carnivores are found in Park County, and four others have been extirpated within the last 120 years. Remains from ten of these species have been found in Porcupine Cave, thus these carnivores have had a long history in the area.

Porcupine Cave, Park County, Colorado The Irvingtonian Fauna

Elaine Anderson, Research Associate in Zoology, Denver Museum of Natural History, Denver, CO 80107 & Louis H. Taylor, Research Associate in Earth Sciences, Denver Museum of Natural History, Denver, CO 80107

The Irvingtonian fauna from Porcupine Cave was collected from strata distributed through as much as 1.5 million years. Several thousand specimens of land snails, fish, amphibians, reptiles, birds and mammals have been recovered. Fossils occur in a fissure and in several rooms in the cave. Deposits from the areas known as The Pit and Velvet Room are stratified and record major environmental changes—from relatively humid glacial to warmer, dry interglacial conditions.

The fauna (in general) reflects these changes; marmot and pika remains occur within the glacial layers while prairie dogs, ground squirrels, and sagebrush voles are common in the interglacial layers. Fish are rare. Amphibians include frogs, toads, and salamanders. Lizards and snakes, especially garter snakes, are present. The avian fauna includes several raptors, a goose, a grouse, a wader, and many passerines. At least 65 different species of mammals are present, more than at any other Irvingtonian site in North America. Some 35 species of lagomorphs, rodents, and hoofed animals served as prey for the 20+ species of carnivores.

Shrews and bats are rare; rabbits are abundant; and rodents, including many extinct species, are common. Extinct taxa include horses, peccary, camel, antilocaprids, musk-ox, wolf, cheetah, and a mylodont ground sloth. So far, remains of proboscideans, bears, and large cats have not been found in the cave possibly because of their large size or because of an incomplete sampling record.

Porcupine Cave, Park County, Colorado: What Drives Community Reorganization? Implications of Superposed Fauna From Porcupine Cave

Anthony D. Barnosky, Mountain Research Center, Montana State University, Bozeman, MT 59717 & Christopher J. Bell , Museum of Vertebrate Zoology, University of California, Berkeley, CA 94720

Information from a richly fossiliferous, stratified sequence of fossil vertebrates from the Pit locality in Porcupine Cave sheds light on how climate change may or may not drive major reorganizations of vertebrate communities (especially the mammalian component). Biostratigraphic and paleomagnetic dating and correlations suggest that the sequence spans at least one transition from glacial to interglacial times between approximately 365,000 and 487,000 years ago, and that lower parts of the sequence include additional glacial-interglacial transitions that predate the Brunhes-Matuyama boundary. The major transition between glacial and interglacial times corresponds with changes in the mammalian community that include: 1) changes in relative abundance of various taxa, and 2) at least local extirpation of very few taxa. However, the no-analog assemblage of species that existed during the cold time did not disintegrate as the climate shifted to a warmer regime. Community changes that took place in the middle Pleistocene did not approach the magnitude of community changes that took place at the terminal Pleistocene shift from the last glacial into the present interglacial, which included wholesale restructuring of species assemblages through extinction of assemblages. The differences in community response to climate change indicate that the late Pleistocene-Holocene transition is not the universal model for the response of mammals to global warming, and that other transitions should be examined to understand what responses are common to all global warming events, and which responses are unique to specific events.

Porcupine Cave, Park County, Colorado: The Microtine Rodents and the Changing Face of Irvingtonian Microtine Rodent Biochronology

Christopher J. Bell, Museum of Vertebrate Zoology, University of California, Berkeley, CA 94720 & Anthony D. Barnosky, Mountain Research Center, Montana State University, Bozeman, MT 59717

A stratified sequence of sediments in the Pit Locality of Porcupine Cave produced a diverse mammalian assemblage including at least 11 species of microtine rodents. At 2900 meters, Porcupine Cave represents the first high-elevation site to produce an extensive microtine rodent assemblage; the fauna is unique and includes taxa widespread in the Irvingtonian, taxa that are relatively rare, and many associations of taxa that have never previously been found together. Three possible explanations for the associations of these taxa are proposed. The presence of taxa that are elsewhere known only from lower elevations at earlier times suggests that Porcupine Cave may be sampling from a refugium habitat (cf. sp.). The seemingly anomalous occurrence of taxa that are elsewhere known from much later times may indicate that the cave is situated along a dispersal corridor in the Rocky Mountains and therefore samples early populations of presumed immigrant taxa (sp.). Detailed morphological analysis of fossils of one lineage (reveals a gradational change in complexity of both lower and upper molars and suggests that the cave may be sampling a population undergoing speciation. This morphological change does not appear to be correlated with a transition from glacial to interglacial climatic conditions that is reflected in the sediments.

Porcupine Cave, Park County, Colorado: The Biology of Packrats as Cave Dwellers

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To speleologists the packrat (woodrat), genus is one of a host of animals to be found in caves, and one that has drawn increasing interest because of the wide ramifications of its interactions with the outside world. Those species (of that live in caves also are adapted primarily for life outside of caves and bring evidence of their outside activities into caves in the form of food materials and litter; sticks, bones, scat, and other collected items; and nests made of fine fibrous materials in which they raise their young. They also leave on the rock ledges and walls solid dark deposits and urine stains commonly known to cavers as amberat. Curiosity as to the nature of these introduced materials and how they get there can best be answered with some knowledge of the characteristics and behavior of the packrats that are responsible. This presentation will give some of the basic biology of packrats and show how they make use of caves. An understanding of basic Neotoma ecology will also help cavers appreciate how and why packrat deposits and middens are such a unique resource for study of the past history and evolution of life on earth, both outside and inside of caves. The abundant fragments of plant material and predator scats dropped on the middens and rock shelves by packrats provide an excellent record of ecological communities and climatic changes that have occurred outside the den or cave over thousands of years.

Porcupine Cave, Park County, Colorado: The Geomyid Fauna

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Irvingtonian pocket gophers in the Porcupine Cave fauna are of the genus and are represented by at least three species: cf. (extant), cf. (extant), and an indeterminate species. Both of the extant taxa inhabit montane meadows at high elevations in

the western United States. Specimens of the indeterminate taxon are characterized by a narrow, rectangular trigonid on the lower fourth premolar, and are distinct from the other two taxa. Only a single taxon of gopher is present in each of the stratified levels containing gopher fossils in the Denver Museum of Natural History excavation site in the Velvet Room, suggesting that the different species of pocket gophers were not sympatric. The pocket gophers occur in layers with (packrats), (ground squirrels), (prairie dogs), and (rabbits), suggesting that pocket gophers only lived near Porcupine Cave during interglacial episodes.

Porcupine Cave, Park County, Colorado: The Lagomorph Fauna

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Modern rabbits and hares (Family Leporidae) evolved in the early Pleistocene, but due to difficulty in identifying fossil rabbits, little is known about their early speciations. Pikas (Family Ochotonidae) evolved in the Pliocene and, although rare as fossils, are relatively easier to identify. The genera and are present in the Porcupine cave faunas.

Lagomorphs are the most common fossil group in Porcupine Cave; several thousands of specimens have been catalogued (in over 1100 different entries) into the collections of the Denver Museum of Natural History. Morphometric analysis of modern leporids has enabled identification of the fossil rabbit material and will provide insights into the evolutionary history of the Irvingtonian rabbits from Porcupine Cave. The presence of pikas in the Porcupine Cave fossil assemblages is evidence of cold conditions.

Porcupine Cave, Park County, Colorado: Taphonomy of Irvingtonian Fossils

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Porcupine Cave is in a remote part of South Park at an elevation of 9500 ft (2900 m), is the highest Pleistocene vertebrate site in North America, and contains the richest and most diverse Irvingtonian (early and medial Pleistocene) mammalian fauna in North America. During the Irvingtonian, Porcupine Cave had numerous entrances; all were receiving debris which was washed deep into the cave. Some entrances were used by carnivores for dens, some openings were used by marmots and rabbits, and all openings were used by woodrats (packrats) that built extensive middens and nests deep within the cave. Carnivores left the chewed bones of their prey and even their own bones in areas close to the surface; marmots, rabbits, and other small animals left their skeletons when they fell into the cave and were unable to escape; but most of the bones and teeth, many of which were gnawed, were hauled in by the woodrats. The woodrats even carried in carnivore scat and raptor pellets which were loaded with small jaws, bones and teeth. A partial skeleton of a large camel indicates that at least one entrance trapped large mammals. At about 350,000 years ago, all of the entrances became completely plugged and Porcupine Cave was isolated from the outside, even from the woodrats. Porcupine Cave remained sealed until the late 1800s when it was inadvertently opened by prospectors. These prospectors were the first to find fossil bones in the cave, but the Pleistocene age of the fossils was not recognized until almost a century later.

Porcupine Cave, Park County, Colorado: Geologic History of the Cave

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Porcupine Cave is located in Ordovician Manitou carbonates which occur in a prominent N-S ridge along the southwestern part of South Park in central Colorado. Manitou strata dip 30 degrees to the east and the cave system is developed conformably within these tilted beds. Karsting of the Manitou carbonates began in the medial Ordovician during a long period of subaerial exposure and prior to deposition of the overlying transgressive Ordovician Harding Sandstone. The Manitou carbonates were again karsted during vadose and phreatic enlargement of the cave during one or more stages in post-Harding and pre-Laramide time. Numerous cupolas on the ceilings throughout the cave were formed during this time and prior to Laramide tilting (about 50 Ma); their symmetrical hemispherical shapes are now inclined in the same direction as the dipping strata. Subsequent to the final stages of cave enlargement and cupola formation, there was extensive collapse (breakdown) of large blocks from the walls and ceilings (during Laramide tectonism?). This was followed by one or more wet periods during which cave formations developed—prior to the great infilling of clastics during the early and medial Pleistocene (Irvingtonian). Irvingtonian strata are stratified, consist mainly of extensive talus cones, and may contain beds of mud nodules and flowstones. Access by animals existed for one million years or more until the cave was totally sealed from the outside approximately 350,000 years ago. Deposition essentially ceased after the Irvingtonian except for debris from frost- wedging, local ceiling collapse, and evaporation crusts which formed on top of older Pleistocene deposits.

Porcupine Cave, Park County, Colorado: Paleomagnetic Stratigraphy

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Magnetostratigraphic studies in Porcupine Cave were made in the Pit and the Velvet Room. Carbonate-cemented material from the Carnegie Museum excavations in the Pit was analyzed in the late 1980s by Fred Luiszer and Victor Schmidt, and results indicated a probable reversed polarity history. The Denver Museum excavation in the Velvet Room has been sampled annually, beginning in 1993 and was hindered by the strata's dry, unconsolidated character of the strata. All samples were taken from strata at the toe of a talus cone, with the strata dipping approximately 10 degrees. The 1993 sampling effort was unsuccessful because strata in the cubes became disaggregated. In 1994, a large sample of the oldest stratified material was encased in a plaster jacket, dried, and impregnated with epoxy. Of the 29 oriented cubes cut from the block, most preserved the magnetic signal poorly, and only three samples suggested reversed polarity. In 1995, samples were taken using a piston corer/extruder device which was able to obtain tightly packed samples of oriented silty material. Clear reversals were identified. Our present interpretation is that the bulk of the strata in the Velvet Room is reversed and was probably deposited during the Matuyama reversed polarity chron. The majority of the collections from the Velvet Room are thus in excess of 0.78 million years in age. Extinct microtine rodents recovered from the same strata support this interpretation.

Porcupine Cave, Park County, Colorado: Regional Geologic Setting

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The Porcupine Cave area has a remarkable geologic history. The cave bearing Ordovician Manitou dolomite lies disconformably on Precambrian granite and is part of a regionally continuous Paleozoic passive margin succession. Early dissolution and fissure formation in the Manitou is marked by a widespread weathering surface and internal ancient karst features. Burial, erosional and uplift events during the Paleozoic dramatically changed the site's landscape. At the end of the Paleozoic, the cave area was buried by over 10000 ft of marine and fluvial strata (mostly Pennsylvanian and Permian in age). By early Mesozoic time, the area was peneplaned, setting the stage for several marine and non-marine depositional events. During the late Cretaceous, the Western Interior Seaway completely inundated the area. In the latest Cretaceous and earliest Tertiary, the Laramide mountain building episode broke the area into high mountain ranges and intervening basins that mimicked the Ancestral Rockies (formed during the late Paleozoic). By medial Eocene time, the area stood as gently rolling terrain and Porcupine Cave was near the surface for the first time since the early Paleozoic. Late Eocene and Oligocene volcanoes released a series of massive ignimbrite, lava and lahar flows. Drainages were blocked, lakes formed, and the landscape was draped with a thick succession of volcanic, fluvial, lacustrine and ash rich eolian deposits. Miocene uplift rejuvenated the landscape and headward-cutting drainages exhumed the Eocene landscape. Porcupine Cave was again near the surface and during the early Pleistocene was open to the surface.

Porcupine Cave, Park County, Colorado: Response to Climate Change in Dental Remains of Middle Pleistocene Cynomys at Porcupine Cave

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Porcupine Cave, a high elevation (2900 m) middle Pleistocene site in the Colorado Rocky Mountains, contains many chambers with abundant remains of fossil prairie dogs (During the deposition of the fossils, the region experienced a series of transitions between cool, moist glacial conditions and warmer, drier interglacials. Both subgenera of (i.e., white-tailed, [and black- tailed, [are present, appearing in upper strata which include a glacial-interglacial transition. Currently the subgenera are not generally sympatric. Analysis of the climate space now inhabited by the two subgenera suggests that their sympatry at Porcupine Cave during the middle Pleistocene required effectively warmer and/or drier July conditions in order to allow black-tailed prairie dogs to exist in the area. Climatic inferences from another no-analog assemblage, and suggest effectively moister conditions in January; hence, approximately 400,000 years ago the Porcupine Cave area probably experienced wetter winters and drier summers than presently. Analysis of Porcupine Cave specimens over the climate transitions and comparison to other fossil specimens from throughout North America has proceeded with the aid of a computer morphometric program called MORPHOSYS creating analyses of both interpopulational and intrapopulational morphological changes which suggest a complex morphological response to middle Pleistocene climate changes.

Porcupine Cave, Park County, Colorado: The Artiodactyla and Perissodactyla Faunas

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Fossils of the Order from Porcupine Cave are represented by approximately 100 different bones, partial jaws, and teeth which have been curated into the Denver Museum of Natural History (DMNH) collections. This collection indicates the presence of the tayassuid sp. (peccary), cervids sp. (deer) and sp. (elk), antilocaprids (pronghorns), ovibovine bovids (musk-oxen), and the camelid sp. (camel). Two-thirds of these specimens are from the stratified deposits in the DMNH excavation site in the Velvet Room. At this site, antilocaprids, and are present throughout the stratigraphic section, but and have only a single specimen each. The ovibovine is absent at this site but is known elsewhere in the cave in deposits with a similar age—as are all of the other artiodactyls, the ovibovine, and the antilocaprids represent extinct taxa. They are smaller than other known Irvingtonian forms and probably represents a new taxon. The ovibovine most likely also represents a new taxon, and was as large as the living musk-ox. The antilocaprids include two taxa: one larger and one much smaller than the extant genus.

The fauna is represented by a limited number of specimens, many of which are fragmentary. However, several teeth and foot bones and a partial scapula indicate at least two extinct taxa of one of which is close in size to the extant horse.

RESCUE SESSION

Session Chair: Barbara Moss

Developing a Self Rescue Training Curriculum for the Western Region—A Work in Progress

Cindy Heazlit, 5672 Bluegrass Lane, San Jose, CA 95118

Cavers in the Western Region often travel to very remote areas to do their caving. Many of these areas are not serviced by either SAR or cave rescue teams. Outside response to a cave accident could take hours, even days. In the meantime, the caving party must deal with the accident using only the people and equipment at hand. There has been little information available about the techniques needed for this type of rescue. In the Autumn of 1994 several Western Region cavers formed a committee to research and develop these techniques.

SURVEY AND CARTOGRAPHY SESSION

Session Chair: Roger Bartholomew

Methods to Facilitate Faster Sketching

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The speed of the sketcher more often than not determines the speed of the survey crew and, thus, the amount of passage mapped during the trip. Methods for increasing the rate of sketching fall into two categories: devote less time towards non-sketching activities, and simply sketch faster.

The first point seems obvious. Traveling, eating, talking, and digging are non-sketching activities. Standing around, looking at rocks with a book and pencil in hand is also a non-sketching activity—if the pencil is not moving, you are not sketching. Clean hands, teeth marks on the book, bruised elbows, and the ability to efficiently organize a crew are some indicators of a speedy sketcher.

The Berkshire County, Massachusetts Cave Survey Project: An Introduction and Status Report

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The small, marble caves of Berkshire County, Massachusetts represent one of the first focus areas of organized caving in the United States. Despite over 50 years of exploration, these caves have remained largely unsurveyed until recently. A systematic survey of all “significant” solution caves and holes, otherwise deemed to be historically relevant, has been conducted for the purposes of documentation and publication. After three years of effort, the project is estimated to be approximately 80% complete with a total Grade 5 survey length in excess of two miles. Included within this figure is Great Radium Springs Cave, New England’s second longest solution cave. Pettibone Falls Cave, previously assumed to be Massachusetts’ longest cave, has been reassigned to a fourth place position.

Computer Graphics—A Freehand Way to Generate and Display Your Cave Maps

Bob Richards, 1206 Spinnaker Way, Sugar Land, TX 77478

Cave cartographers will be replacing pen and ink with mouse and monitor as home PCs and graphics software packages become cheaper and easier to use. The use of FreeHand software as a fundamental drawing tool is just one such package available to cave cartographers.

Regardless of how powerful an illustration package is, it won’t be useful if you can’t draw with it. FreeHand enables you to draw pristine line art and smooth-as-silk technical drawings. Tasks that use to be exceedingly nerve-wracking or downright unlikely 10 years ago—like getting two thick pen lines to meet and form a perfectly sharp or smooth corner—are a breeze now. With very little effort and not much in the way of experience, one can be drawing cave maps that would have made you bleed, sweat, and cry—were you to approach the task using traditional drafting tools.

FreeHand works its precision magic by looking at artwork in terms of objects, which are independent, mathematically defined lines and shapes. For this reason, drawing programs are sometimes said to be object oriented. Understanding how one’s object—your cave map —is entered, set-up and executed using a variety of FreeHand tools is essential in creating a successful computer generated cave map.

Effects of Blunders on Survey Accuracy

Fred L. Wefer, Butler Cave Conservation Society, 4600 Duke Street #1310, Alexandria, VA 22304 <fwefer@mitre.com> & Rob Kolstad, BSDI, 5575 Tech Center Dr. #110, Colorado Springs, CO 80919 <kolstad@bsdi.com>

A useful way to classify survey errors is based on the predictability of individual error and the statistical distribution of a large number of errors. This yields three basic error types: Random Errors are not predictable and are caused by rounding measurements, the limited graduation on the instruments, etc. They are typically small and normally distributed. Systematic Errors are predictable, hence correctable. They are caused by instrument misalignment, and personal tendencies, for example. They are typically small and follow a pattern.

Blunders are not predictable and have an unknown distribution. They are caused by cold, fatigue, and sloppiness, for example. They typically occur infrequently, follow no specific pattern, can be of either sign, and of almost any magnitude. Seven types of blunders have been identified and studied.

Loop closures are often used to determine survey accuracy. To explore error attributed to instruments or techniques (vs. blunders), we modeled a typical cave that was then "surveyed" perfectly.

These perfect survey numbers were corrupted to simulate standard instruments (e.g., 1o azimuth accuracy). Loop closure results demonstrated an "average loop closure error" due to instruments. Finally, the observations were perturbed using various blunders. Loop closure errors were again studied.

Blunders are difficult to find and nearly impossible to correct. The best strategy is to anticipate and prevent them. Some techniques for obviating blunders are: use equipment graduated in degrees, use an azimuth compass (not bearing), paint over the percent grade scale, set declination to zero and leave it, follow good survey team procedures, use fore and back shots, verify computer input, compare the plotted traverse line with the sketch, and learn all the positions on the survey team.

US EXPLORATION

Session Chairs: Stan Allison & Jim Pisarowicz

Diving the Lakes of Lechuguilla

David Bunnell, 320 Brook Rd., Boulder Creek, CA 95006

During the past five years, exploratory cave dives were conducted in three of Lechuguilla's lakes: Blue Giants, Stud Lake, and Castrovalva. All three are perched lakes, well above the water table. While submerged stals are clearly visible from above at Blue Giants, the other lakes proved to have submerged stals as well. Stud Lake also contained subaqueous helictites of a form unique to that locale. Thus, all three lakes were dry for lengthy periods of time before being flooded, probably during the last ice age. In Blue Giants, a steeply sloping tube was followed for 200 ft (60 m) to a flowstone seal at -90 ft (27 m). In Stud Lake, an airbell 60 ft (18 m) wide and a much larger chamber beyond were found. The lake is over 300 ft (90 m) long and up to 30 ft (9 m) deep. At Castrovalva, I was joined by Ron Simmons and we found only small 10-20 ft (3-6 m) long pockets off the main lake, which was never deeper than 25 ft (8 m). We did find a cluster of six large stals coated with mammillary crusts which I'm calling mammillagmites. None of the lakes appears to have any potential for further passages beyond but were awesome cave dives!

The Discovery and Exploration of Barberry Cave

Mike Ficco, 1650 Barnes Mill Rd. Apt. 1211, Marietta, GA 30062-3884 & Ben Schwartz, Justamere Farm, Doe Hill, VA 24433

Barberry Cave is the latest important discovery in the Burnsville Cove area of west-central Virginia. The cave represents a key component of a complex Cave-Sinking Creek System and the Chestnut Ridge Cave System. The discovery and ongoing exploration of Barberry is the result of the persistence and dedication of a handful of individuals who have had to develop unique approaches to overcome the multiple challenges which the cave has presented. The cave has rewarded its explorers with large and sometimes beautifully decorated passages, intermingled with the requisite "Chestnut Ridge horror". The belief that Barberry holds clues to the interconnection of caves in the Burnsville Cove has driven its explorers to take dramatic steps to facilitate exploration of this great Virginia cave.

Hurricane Cave

Mike Frazier, 2207 Hagerman, Colorado Springs, CO 80904

Hurricane cave is an amalgamation cave formed entirely in the 1.0 Ga Pikes Peak Granite. It is located on the drainage of the Pikes Peak monolith, El Paso County, Colorado.

The cave is formed along a fault and takes water from two streams which join together just above the insurgence. Heavy stream down- cutting forms beautiful scalloped chimney passage in some areas. The cave is vertical, wet and involves crawling and squeezing through tight complex boulder piles. Some portions of the cave become impassable during heavy spring run-off.

The cave water is snow-melt that never ranges far above 32º Fahrenheit. In addition to the cold water, a constant wind blows through the cave making hypothermia a constant danger. Other dangers in this cave include possible rockfall and the possibility of becoming disoriented or falling. Current length is 2533 ft (772 m). Current depth is 553 ft (168.64 m). Hurricane is the deepest known granite cave in the world. Source: Atlas Great Caves (Bosted, et al., 1989).

Prospecting for Caves in Utah's House Range

Dale Green, 4230 Sovereign Way, Salt Lake City, UT 84124

The House Range is in west-central Utah, about 40 mi (65 km) east of the Nevada border. The Range is 65 mi (105 km) long, trending from north to south. The northern two-thirds is mostly limestone. As with most other ranges in the Great Basin, the House Range has only one cave of major size and a few smaller ones. Several years of haphazard, random searches for rumored caves produced almost nothing and a great amount of time was wasted in duplication of effort. In order to determine exactly what caves actually existed, a project was undertaken in 1985 to systematically observe all exposed limestone surfaces n the northern 32 mi (52 km) of the Range. Colored geologic maps superimposed on topographic maps were carried and the route and observations were marked directly on them in the hopes of finding other large caves. The main tools used for route finding were a digital altimeter and compass. Binoculars were particularly handy for peering into inaccessible holes and checking shadows. About 2 dozen new caves were found but most of them were small. However, an equal number of digging prospects were located. The elusive second large cave in the House Range is probably behind one of these prospects but the entrance has been filled with packrat debris.

Update, Tongass Cave Project, Southeast Alaska

David M. Klinger, PO Box 537, Leavenworth, WA 98826

Cavers of the Tongass Cave Project continue to find, explore and map an ever increasing number of caves on Prince of Wales Island, Dall Island, Heceta Island, Chichagof Island and other islands of the Alexander Archipelago in southeast Alaska. Especially exciting finds have been made on Heceta Island. Arabica Cave has the possibility of becoming the longest cave in Alaska.

An Update on Exploration in the Mystery-Rimstone Karst Perry County, Missouri

Philip L. Moss, 2621 Columbia Lakes Dr. Apt 2-D, Columbia, IL 62236-2616

The Mystery-Rimstone karst contains about 40 mi of mapped passage to date. Talks and articles have been presented previously of the exploration of Mystery Cave (17 mi/20 km) and Rimstone River Cave (17.5 mi/28.5 km). In he early 1980s, two significant caves were explored and mapped that have added to our understanding of this karst area. These caves are Hot Caverns (3 mi/5 km) and Maple Leaf Cave (2.5 mi/4 km). Hot Caverns is primarily two side passages feeding a short continuation of the main stream of Rimstone River Cave. Maple Leaf Cave is a large, fossil trunk that I have interpreted to have once been a downstream continuation of Mystery Cave and a segment that would have connected it with Rimstone River Cave.

New Mexico Gypsum Karst Project

Steve Peerman, 1757 Defiance Rd., Las Cruces, NM 88001

The New Mexico Gypsum Karst Project (GypKaP), sponsored and organized by the Southwestern Region of the NSS, has been working for the last 9 years in the gypsum karst area of south central New Mexico. We are approaching 150000 ft (45.7 km) of mapped passage in that time in a large number of gypsum caves. While many of these caves are small, others are quite extensive, some over 2 mi (3 km) long. Over that time we have developed a working relationship with a number of private ranch owners and managers in an area the size of the island of Puerto Rico. Landowner relations continue to be a major emphasis of our efforts.

We are now beginning to understand the processes at work there. We continue to make new discoveries, both in the sense of exploration, and in the understanding of the karst area. This presentation will give an overview of the accomplishments of the project along with a photographic "taste" of the New Mexico gypsum cave and karst environment.

Discovery of a Pristine Lava Cave at Trout Lake, Washington

Garry Petrie, 19880 NW Nestucca Dr., Portland, OR 97229-2877

Seventy miles from Portland, the lava flows west of the small town of Trout Lake, Washington continue to yield new discoveries. In 1994, a long, pristine and beautiful cave was discovered. The cave, Chubby Bunny, a.k.a. Fat Rabbit, rivals the flow's other major cave, Dynamited and Deadhorse. Chubby Bunny contains infinitely detailed, vivid red pahoehoe flows, sand formations, lavacicles, and complex passage topology. Unfortunately, the upper end of the cave appears to have been buried by an earlier road building effort. Access to this 7000 ft (~2100 m) long cave is now strictly controlled by the United States Forest Service.

Four Years of Exploration in Wyoming's Gros Ventre Wilderness

Garry Petrie, 19880 NW Nestucca Dr., Portland, OR 97229-2877

Many years ago, the Gros Ventre mountains were forgotten for "not having enough focused drainage" to support cavern development. While a great cave on the scale of Great Ex or Columbine Crawl appears to be absent in the Gros Ventres, the immense limestone deposit has many significant caves. For the

last four successive years, a diverse group of cavers has documented over two dozen caves. The caves include Marmot's Nest, Big Crapper, Initiate Pit, Gray Bird, Pikas Revenge, and Blue Bell. These caves are typical cold and wet alpine caves. With thousands of acres of limestone to explore, more discoveries are expected in the future.

The Discovery and Exploration of Breezeway Cave, Colorado

Richard Rhinehart, 1718 Lorraine Street #B2, Colorado Springs, CO 80906

Fresh from the discovery of the Cave of the Winds' celebrated Silent Splendor, Colorado cavers turned to other promising excavations. While many resulted in modest extensions to the caves of Williams Canyon, nearly a decade passed before another major discovery.

Following instinct, science and luck, cavers excavated an overlooked canyon-side hole. Quickly, they pushed their way through unstable breakdown and climbed into Cowboy Heaven, the first of the great rooms and corridors of Breezeway Cave.

During the first few weeks of exploration, the ever-present breeze was followed past wind-eroded stalactites deep into the mountain. Cavers crossed a series of pools known as the Holy Waters to reach the Celestial City, a chamber frescoed with white beaded helictites reminiscent of Silent Splendor. From there, excavation of clay-filled crawlways opened several spectacular helictite chambers: Vanity Fair, the Elkhorn Chambers and Heavens Gate. Exploration in Breezeway quickly out paced ongoing survey efforts. One major corridor led to Stone River and High Plains, Guadalupian-like chambers filled with pools, flowstone and massive dripstone. Another dropped through a twisty squeeze called the Sidewinder to a precipitous mud-walled canyon known as Rattlesnake.

Several thousand feet were discovered in the cave's lower level, including the beautiful Velvet Underground. In the 18 months since the last major discovery, cavers are continuing excavation efforts to discover new extensions. With a little bit of luck, Breezeway will continue to surprise and delight for decades to come.

Exploration of the Kazumura Cave System, Hawaii

Bob Richards, 1206 Spinnaker Way, Sugar Land, TX 77478

Kazumura is an exciting wild cave—a vast, sinuous tunnel with numerous lava falls and chambers. Kazumura is formed entirely in 500 year old basalt flow on the flank of Kilauea, the world's most active volcano. A 9 person expedition led by Kevin Allred last fall mapped an additional 13 km which extended the cave system to a record 60 km for a lava tube cave. A major breakthrough in the Olaa Cave during the expedition extended the cave to a US depth record of 1099 m. A 42 km, 1000 m deep through trip was accomplished by team members at expedition's end. This marathon trek took 2 days to complete. It is believed that there are many extremely long caves on the island, only a few of which have been entered. The Big Island holds the promise of enormously long lava tube caves, some of which possess the vertical range of the deepest limestone caves. The Kazumura Cave System is just one of them.

Jewel Cave Exploration

Mike Wiles, Jewel Cave National Monument, Custer, SD 57730

Jewel Cave was discovered around 1895, staked as a mining claim in 1900, and became one of the first National Monuments in 1908. Its hundred-year history notwithstanding, most of the cave's exploration has taken place since 1959, particularly because of climbers-turned-cavers, Herb and Jan Conn. Since then, exploration has progressed at a modest average of two-and-a-half mi a year. This has been accomplished by a small group of volunteers working closely with the Park Service.

The cave is a complex maze of phreatic passages ubiquitously lined with calcite crystals, from which it derives its name. In spite of nearly 600 ft (180 m) of vertical relief, exploration requires no vertical work more than handlines and an occasional webbing-ladder. It does require quickness and agility for cavers to negotiate the twists, turns, and tight spots quickly enough to reach the end of the cave with sufficient time to explore. This has resulted in some distinctive caving practices that will be of interest.

Once thought to be a small cave, Jewel now has over 100 mi (160 km) of passages mapped. Barometic winds predict a volume of five billion cubic feet, or about 5000 average-sized mi (8100 km). Regardless of actual size, strong barometric breezes at the far reaches of the cave indicate that most of the cave is still undiscovered.

VERTICAL SESSION

Session Chair: Tray Murphy

The Use of the Counterbalance Lift For Self Rescue

Cindy K. Heazlit, 5672 Bluegrass Lane, San Jose CA 95118-3513

It is sometimes necessary to lift someone up a drop. There are many ways to accomplish this task. One of the easiest methods is the Counterbalance Lift. The lift is quite different from other counterbalance methods. This particular 2:1 lift requires no additional rope, no rerigging of the rope, no special equipment, and can be accomplished by a single person. The lift is so easy that the Western Region Self Rescue Committee has included it in its self rescue curriculum.

Developing a Self Rescue Training Curriculum for the Western Region—A Work in Progress

Cindy Heazlit, 5672 Bluegrass Lane, San Jose, CA 95118-3513

Cavers in the Western Region often travel to very remote areas to do their caving. Many of these areas are not serviced by either SAR or cave rescue teams. Outside response to a cave accident could take hours, even days. In the meantime, the caving party must deal with the accident using only the people and equipment at hand. There has been little information available about the techniques needed for this type of rescue. In the Autumn of 1994 several Western Region cavers formed a committee to research and develop these techniques. The committee developed a curriculum for teaching self rescue to the average caver, and has started to teach classes within the Western Region. The talk will cover the basic needs of the wilderness caver, the specific problems faced by Western Region cavers, the development of a curriculum for self rescue, and the lessons learned during this development work.