4) phase transition. Within these categories, we fit known speleogenetic mechanisms while accommodating possible unique extraterrestrial caves (e.g., cryovolcanic icetubes, Martian ground-ice sapping voids, and others).

Genesis & sedimentation of Windy Mouth Cave, West Virginia

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Windy Mouth Cave is an 11-kmlong abandoned spring conduit formed within the Hillsdale and Sinks Grove Limestone adjacent to the Greenbrier River. The cave contains complex clastic (fluvial) sediments, which were sampled throughout the cave from gravel bars, floor deposits in domes, and main trunk passages. Particle size distributions revealed 2 end members: a high percentage of gravel, lacking mud and sand, or a high percentage of mud, with no gravel or sand. Four of the 16 samples were intermediate between the two. Chert dominated the samples, with the gravel size fractions averaging 75%. Quartz (as determined by XRD) dominated the clay fraction lithology. Grain shape percentage among size fractions >2.00 mm and >1.00 mm both contained high amounts of sub-rounded to sub-angular grains. Sediments found in the cave are locally derived from rocks of the Greenbrier Group and Maccrady Shale.

Sinkhole inputs from the surface feed different branches of the cave. Most sinkholes have very limited catchment in the present environment, and are underfit in relation to the paleodischarges recorded in the sediments within the conduits. Chaotic gravel deposits indicate periods of intense, probably pipe-full, water flow. Fine-grained deposits relate to low flow conditions caused either by lack of recharge or obstruction of the conduit outlet. An ill-defined magnetic reversal found in sediments near the Waterfall Room suggests an age of >760,000 years for deposition of those materials. This is consistent with the height of the cave above present-day base level (30 m).

A hidden speleothem: Elongated concretions in Colorado cave sands

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While digging out ancient sediment chokes to extend 4 partially filled caves in Colorado (Cave of the Winds, Sandite Cave, and Cave of the Swirling Mists in Williams Canyon; Lost Mascot Cave in the Fulford district), cavers have unearthed hidden deposits of elongated concretions of calcified sand (informally called “sandites” by the diggers), embedded in otherwise unconsolidated sand. These are of circular to flattened cross-section, sometimes curving gently or splitting into parallel forks, and may have either rounded or pointed ends. They are up to ~60 cm long and from 6 mm to 5 cm or more wide. Many are isolated and unattached; others are prong-like extensions of larger, irregular calcified masses. In most locations, they parallel the axis of the filled passage in a slanting to subhorizontal attitude, and may cut across bedding layers. They probably grew when the sand in filled sumps was locally saturated with calcite-rich water, but not necessarily below the regional water table. Similar growths have been reported in Australian caves, but not, to our knowledge, in other American ones. Deposits of comparable elongated concretions have also been found in non-cave sands and sandstones in the U.S. and Italy. The calcite-deposition mechanism is undetermined, but the cave examples seem to confirm one conclusion published by researchers of the non-cave concretions: The long axes tend to be aligned along the groundwater flow direction.

Hydrogeology of Spencer Mountain: Lick Branch Karst investigation

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Karst hydrogeology investigations continue around Spencer Mountain in Van Buren County, Tennessee. The court-ordered settlement regarding treated effluent from the City of Spencer’s wastewater treatment plant required a karst investigation of the Lick Branch to Pennywinkle Spring drainage basin. A temporary discharge of treated effluent is allowed into the Pennywinkle drainage while a pipeline is built to the Caney Fork River. The purpose of the karst study is to determine the potential for treated effluent to reach water supply wells and sensitive cave ecosystems.

The Tennessee Dept. of Environment and Conservation requested that the U.S. EPA Science and Ecosystem Support Division lead the study. Members of the National Speleological Society provided volunteer assistance, and K2 GeoEnvironmental provided specialized analytical services.

A June 2002 dye study used field and laboratory fluorometry analyses of water and passive receptors. Base flow conditions existed at the start and end of the study with 3.94 cm rainfall 12 hrs following initial dye injection. The study confirms that water in Lick Branch flows underground through Lick Branch Cave. The water resurges on the Hartselle Formation, flows over a waterfall, and sinks in the Monteagle Limestone. The water resurges again at Pennywinkle Spring in a distributary spring fashion. Sampling and analysis of area water supply wells did not confirm the presence of dye in any drinking water system. Dye mass recovery at Pennywinkle Spring was 97.5%. Another dye trace showed that Lost Cove (a karst valley) water flows through the Monteagle Limestone to Pennywinkle Spring.

Consequences of low pH, cave-wall condensation & biofilm development to sulfuric acid speleogenesis

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Volatilization and oxidation of H_2S to sulfuric acid on cave-wall surfaces causes aggressive carbonate rock dissolution and replacement by gypsum during sulfuric acid speleogenesis. Reddish-brown crusts cover the gypsum in Lower Kane Cave (Wyoming,). The crusts are composed principally of C, O, and Si, with abundant microorganisms and euhedral quartz microcrystals. Condensation droplets hang from cave-wall surfaces and average droplet pH was 1.7, ranging from pH 1.25 on crust to 2.92 on gypsum. Droplets on crust had contact angles >90° (avg. 121.6°), indicating hydrophobicity. Droplets with pH < 2 were undersaturated with respect to gypsum, while droplets with pH > 2 were in equilibrium. Condensate solutions on gypsum will approach pH 2, but typically not exceed it, due to buffering by the bisulfate-sulfate weak acid/base pair (pK = 1.92) combined with the gypsum-sulfate. Droplets on crusts had pH values below the critical HSO_4^-:SO_4^{2-} pK as a result of crust hydrophobicity and acid-producing bacteria. Therefore, armoring of the cave walls by gypsum and biofilms fundamentally impacts how a cave enlarges during sulfuric acid speleogenesis. Microbial colonization of the low pH, moist gypsum habitat forms an organic film that eventually becomes impermeable. Condensation becomes separated and out of equilibrium with respect to the underlying gypsum, precluding diffusion of sulfuric acid through the gypsum to the underlying limestone, limiting or shutting-off sulfuric acid dissolution completely. Only when fresh limestone is exposed will subaerial speleogenesis be reinitiated, and the replacement-colonization cycle start again.

Paleosols & paleokarst: A key to paleoclimate interpretation in carbonate islands

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Bahamian paleosols carry a paleoclimatic signal. Paleosol development is dependent on: climate, vegetation, soil organisms, parent material, topography, and time. The Bahamian parent material is Late Quaternary carbonates, and soil developed is therefore linked to epikarst processes. Not only should the paleosol carry a paleoclimatic signal, but the nature of the paleosol/paleokarst contact should also reflect climate: *e.g.*, wetter conditions creating a more complex paleokarst surface that is infilled with more highly weathered paleosol material. Vegetation and soil organisms are a function of climate; the parent material is uniform, so the remaining variables are topography and time. Topography can be factored out by taking sample transects from hills though valleys. Paleomagnetic analysis (secular variation) of the paleosol and geochronology of the parent material can address the time factor. Bahamian carbonates are ~100% $CaCO_3$, and the insoluble components of the soils are not residual, but are eolian additives as Saharan dust; so the starting materials are known. Bahamian paleosols in some outcrops are developed on a planar, unkarstified carbonate surface, suggesting arid conditions, while others form over a well-developed epikarst surface with significant relief, suggesting wet conditions. Forming soils can fill epikarst voids and harden. Carbonate dissolution removes the weaker parent rock, leaving hardened paleosols, and soil-filled pipes as positive residual structures, inverting topography. Soil infiltration can infill caves and resist surface destruction; such fills in Cueva del Aleman, Isla de Mona, are at least 1.6 Ma old.

Water tracing using fluorescent dyes to delineate groundwater flow paths in Lee County, Virginia

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Two groundwater traces using fluorescent dyes were performed in Lee County, VA. The first trace was to determine the hydrologic relationship between 2 caves near the Cedars Natural Area Preserve. Both caves contain populations of the federally listed endangered Lee County Cave Isopod, *Lirceus usdagalun*. The study was part of an investigation by the Virginia Dept. of Conservation and Recreation in support of the U.S. Fish & Wildlife Service recovery plan for *Lirceus usdagalun*. Background fluorescence levels were established at various sampling sites; charcoal samplers were replaced in the stream in Thompson Cedar Cave and at sampling points in nearby springs. Eight ounces of eosine dye were injected into the stream in an unnamed cave 500 m from Thompson Cedar Cave. Ozark Underground Laboratory analyzed the charcoal samplers. Charcoal samplers from Thompson Cedar Cave contained eosine dye, thus demonstrating a hydrologic connection between the 2 caves.

The second dye trace sought to determine the relationship of an actively subsiding sinkhole with nearby springs and wells. Analysis of background charcoal samplers by the investigator using a luminescence spectrometer found no detectable levels of rhodamine WT in sampled springs. During a significant rain event, one pound of rhodamine WT tracer dye was injected into the intermittent stream flowing into the sinkhole. Post-injection analysis of charcoal samplers found dye on one charcoal sampler, thus demonstrating a hydrologic connection between the sinkhole and Jones-Flannary Spring, which is located 200 m south of the sink-point. No connection with other sampled springs or wells was demonstrated.

Sedimentation & porosity enhancement in a breached flank margin cave

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San Salvador Island, Bahamas, provides a unique location to study modern sedimentation processes on carbonate platforms. The time span of visible geology is highly compressed to the middle Pleistocene through Holocene (< 500 ka). Altar Cave, formed within an oxygen isotope substage 5e eolianite (~125 ka) of the Grotto Beach Formation, is a classic example of a flank margin cave exposed during hillslope retreat. The nature of Altar Cave (restricted entrance, simplistic morphology, and easy access) allowed association of cave features with current environmental conditions and made a sedimentation study easier to perform. Sediment profiles from trenches at 3 locations show that deposits formed in conjunction with a Holocene strand plain present today between the cave and the present beach. ^{14}C dates show these deposits to be Holocene. Dates from sediment and bedrock from the back of the cave, and XRD and geochemical analyses show the surficial sediment to be recent and that leaching has altered the cave floor bedrock. Petrology of the floor rock has provided the first evidence of autogenic sedimentation in the form of dissolution residuum, most likely drifting downward from the roof, accumulating during void development. Petrographic analyses show that this leaching has resulted in increased bedrock porosity below the soil profile, and introduced organics have contaminated the late Pleistocene bedrock with young carbon, producing a ^{14}C age of 28 ka. These results demonstrate a potential method of porosity enhancement in young carbonates. These porosity-enhanced zones may have implications on understanding recharge to the fresh-water lens on carbonate islands.

The use of electrical geophysical methods to define groundwater flow path impacts in a karst aquifer

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Pollution and alteration of surface and subsurface hydrology increasingly threaten karst areas. In order to protect these fragile and dynamic watersheds, efficient diagnostic methods must be adapted for use in complex karst settings. The use of surface geophysical techniques to delineate possible flow paths of clean water in karst aquifers is a new application of existing technology. This study examines stream loss in a small tributary of the Youghiogheny River known as Hoyes Run in Garrett County, MD. The stream bounds the pit of the Deep Creek limestone quarry, operated by Keystone Lime Company. During low flow, the stream abruptly terminates in a swallet, leaving ~100 m of dry streambed. Multiple resistivity profiles using the SuperSting™ R8 System were generated along the zone of loss and compared with results of ground penetrating radar and electromagnetic conductivity profiles in the same location. A dye trace using Fluorescein™ confirmed the flow path of water from the stream into the quarry. Cavities detected in the study were evaluated based on resistivity signal as to their contents (air or sediment filled) to determine which ones might be involved in groundwater transport. The study suggests that surface geophysics coupled with hydrologic and geologic analysis can locate possible flow paths for groundwater in a karst aquifer, even in the absence of obvious karst surface expression. Borehole confirmation is slated before remediation measures are executed.

Hydrogeologic methods used to predict cavern development: Raders Valley, Greenbrier County, West Virginia

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Conventional hydrogeologic mapping techniques have been combined with several analytical methodologies to predict cavern development in Raders Valley, Greenbrier County, WV. The area is dominated topographically by Brushy Ridge anticline and Muddy Creek syncline, which bound this open karst valley. Numerous karst features give clues to cave development in the valley. A model for cavern development was created based on observing cavern development in other areas of Greenbrier County. The hypothesis was that 4 hydrogeologic conditions should be met to develop a large cave in the area: 1) The Hillsdale Limestone-McCrady (shale) Formation contact would need to be exposed to surface runoff; 2) A large area of surface runoff should go underground at the contact (sink); 3) The limestone would need to be fractured where the runoff is captured; 4) Captured surface water would need to flow unobstructed along a fracture or fault to form the cave.

Surface geologic mapping was used to locate the Hillsdale Limestone-McCrady Formation contact and faults. Topographic maps were used to locate sinkholes and determine inflow locations to the cave system. Map calculus techniques were used to locate areas of fractured limestone and faults. Dye traces were compared with other nearby cave-spring dye traces to indicate whether groundwater flow was obstructed. An integrated interpretation was made to predict the location of the cave system on the west side of Raders Valley between Tolers Sinkhole and the Lower Spring. Field walking resulted in finding Middle Earth Cave near the predicted location.

America's National Cave & Karst Research Institute 2003: The gearing-up phase

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America's National Cave and Karst Research Institute, established by the U.S. Congress, began its "gearing up phase" in December 2002 following a 2.5 year development stage led by Interim Director, Zelda Chapman Bailey. Permanent director Louise Hose has established the Institute office in Carlsbad, New Mexico. The Director's current efforts include initial operational setup, recruiting staff positions, and working with partners to design a permanent building and form a long-term vision.

The Institute operates under a mandate to at least match its current federal funding with non-federal sources. We currently operate under a funding match from the state of New Mexico, which supports collaborative efforts by NM Bureau of Geology–Carlsbad Office hydrogeologist Lewis Land and NM Institute of Mines and Technology (NMT) geomicrobiologist Penny Boston. Land's recent investigations of variations in groundwater discharge from gypsum sinkholes at Bottomless Lakes State Park, NM, has resulted in presentations and a paper to be published this fall in an Oklahoma Geological Survey Circular. NMT created a Cave and Karst Studies Program to provide strong intellectual and educational foundations for the Institute and wider speleological community. Several new Cave and Karst graduate students to be admitted in Fall 2003 under Boston's direction will strengthen NMT's new but aggressive cave and karst research mission.