NATIONAL CAVE & KARST RESEARCH INSTITUTE

2021 - 2022

ANNUAL REPORT

www.nckri.org

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Cover Photo

UNESCO celebrated the International Year of Caves and Karst at its headquarters in France this year. Grotte du Mas d'Azil is a French cave that exemplifies some of the values of caves as an important archaeological, paleontological, and groundwater site. NCKRI photo by George Veni.

Back Cover Photo

NCKRI teamed up with the Bureau of Land Management and the Southwestern Region of the National Speleological Society to begin a project cleaning trash out of cave entrances and sinkholes in New Mexico. This project was inspired by and part of the International Year of Caves and Karst. NCKRI photo by George Veni.

NATIONAL CAVE & KARST RESEARCH INSTITUTE

Vision and Values

The National Cave and Karst Research Institute (NCKRI) will be the world's premier cave and karst research organization. NCKRI promotes and performs projects of national and international application, of the highest quality and integrity, through dedicated staff and partners.

Organization and Mission

NCKRI was created by the US Congress in 1998 in partnership with the National Park Service, State of New Mexico, and the City of Carlsbad. Federal and state funding for NCKRI is administered by the New Mexico Institute of Mining and Technology (a.k.a. New Mexico Tech or NMT).

NCKRI's enabling legislation, the National Cave and Karst Research Institute Act of 1998, 16 U.S.C. §4310, identifies NCKRI's mission as to:

1) further the science of speleology;
2) centralize and standardize speleological information;
3) foster interdisciplinary cooperation in cave and karst research programs;
4) promote public education;
5) promote national and international cooperation in protecting the environment for the benefit of cave and karst landforms; and
6) promote and develop environmentally sound and sustainable resource management practices.

NCKRI Annual Report Series

NCKRI produced this publication as part of its annual reporting of activities. The reporting period covers NCKRI's fiscal year, from July 1, 2021 to June 30, 2022. Funding of this report is supported by the National Park Service through Cooperative Agreement P19AC00954. Digital copies of this and previous reports are available for free at www.nckri.org.

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NEW MEXICO TECH
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EXECUTIVE DIRECTOR'S REPORT

Since I began working for NCKRI, I've emphasized that we want to cooperate with others, not compete. There are too many things that need attention in caves and karst. Organizations like ours shouldn't waste time trying to outdo each other when we could do more working together. I've been honored to work with many excellent partners during my time at NCKRI, including those in the photo below. I've also been just as honored to work with many excellent staff at NCKRI.

My report last year focused on staff transitions. We had a major turnover as some personnel retired, one left for graduate school to specialize in cave science, and two found other good opportunities for themselves and their families. As that report went to press, we had filled one position, and I happily introduced you to Dr. Patricia Seiser. In this report I'm just as happy to introduce you to the rest of our new team.

Valerie Davis and Devra Heyer started working at NCKRI on August 2nd. Valerie is our new Operations Division Director. She is my trusted and reliable right hand. Her work is focused on NCKRI's administrative and financial needs to keep us operational and to continue building our efficiency and capacity.

Devra serves as our Education Program Manager. She started here with the mammoth job of completing, stabilizing, and upgrading our many educational and outreach programs. She has fabulously accomplished and is completing those tasks and more, and is preparing us for new opportunities ahead.

Lisa Ryan joined us in September as our new Office Manager. She has also improved our overall operations, expanded our online system for conference registrations and purchases, and coordinating event room rentals as they resume after COVID. Lisa is also the friendly face and voice of NCKRI when people come to visit or call.

Dr. Issam Bou Jaoude joined us a couple months later near the end of 2021 as our new Cave and Karst Science Specialist. His high level of knowledge and experience has allowed him to accomplish tasks beyond what was envisioned for his position.

Much of this year was spent orienting the majority of our team to NCKRI and their new jobs. The quality and quantity of their performance has exceeded expectations. Combining new staff with existing team members, Drs. Jones, Land, and Seiser, and everyone's cooperative team spirit, I can only expect great things in the years ahead.

George Veni, Ph.D.

Photo courtesy of George Veni.

Presidents from the local to international level gather to tour the construction of a new section of Natural Bridge Caverns (Texas, USA) opening for tourism. The tour was part of the 2021 National Cave and Karst Management Symposium. Left to right: Brad Wuest (President of Natural Bridge Caverns, Inc. and the International Show Caves Association), Dr. George Veni (NCKRI Executive Director and President of the International Union of Speleology), Geary Schindel (President of the National Speleological Society), and Jessica Gordon (President of the Texas Speleological Association).

INTERNATIONAL YEAR OF CAVES AND KARST

The International Year of Caves and Karst is a global outreach and education effort, led by the International Union of Speleology (UIS). Originally planned for 2021, it was extended through 2022 due to the COVID-19 pandemic. The purpose of the International Year is to teach the public, students, educators, land managers, scientists, policymakers—everyone, about the many benefits, and some of the challenges, caves and karst present to humanity.

As of the end of June 2022, NCKRI is one of 262 partner organizations in the International Year from 51 countries, including 23 international organizations. NCKRI has been a global leader in the year given our close relationship with the UIS (NCKRI's Executive Director, Dr. George Veni, is also the UIS President through July 2022) and through our activities.

The many speeches, lectures, interviews, and programs given by NCKRI staff for the International Year are listed in the Guest Lectures, Media, and Publications sections of this report. We also teamed with the Bureau of Land Management and Southwestern Region of the National Speleological Society for what we plan will be a long-term project that cleans trash out of sinkholes and cave entrances in southeast New Mexico (see page 35 and back cover photo). One of the goals of the International Year is to spur activities that will continue to educate people and benefit caves and karst long after the International Year has passed.

As this report is written, nearly 630 events have been organized for the International Year, reaching tens of millions of people. This includes lectures, workshops, demonstrations of caving skills, field trips, classes, contests, and conferences. NCKRI was instrumental in Michelle Lujan Grishan, Governor of the State of New Mexico, signing a proclamation that recognized the International Year and its significance.

NCKRI was also featured in the most significant event in the history of cave and karst exploration and science. The United Nations Educational, Scientific, and Cultural Organization (UNESCO) invited the UIS to celebrate the International Year at UNESCO's headquarters in Paris, France. Never before have caves and karst had an audience in front of dozens of governmental leaders from around the globe! As UIS President, Dr. Veni opened the celebration and had several meetings afterward in Paris and online to maintain and grow those relationships.

We hope you will find large or small ways to support the International Year and caves and karst beyond 2022. Every effort helps. For more information about caves and karst, the International Year, and how to support the Year as a partner and with events and activities, visit www.iyck2021.org.

Photo courtesy of Satoshi Goto.

Representing 13 countries, the UIS Bureau (governing board) and friends at UNESCO during the celebration of the International Year of Caves and Karst. NCKRI's Dr. Veni is second from the right in the front row.

NCKRI RESEARCH

New Mexico Governor Celebrates Sinkhole Prevention Project at NCKRI

NCKRI was honored as the site where New Mexico Governor Michelle Lujan Grisham celebrated the completion of a multi-year project to prevent the collapse of a brine well cavity in the City of Carlsbad. NCKRI's conference room was filled with dignitaries and media for the event. Had the collapse occurred, it would have resulted in an estimated $1 billion in damages and economic losses for the region.

Three brine well cavities collapsed in southeast New Mexico and west Texas in 2008-2009. They created sinkholes measuring about 100 m in diameter and 40 m deep (see NCKRI's 2008-2009, 2009-2010, and 2017-2018 Annual Reports). The cavities were formed by injecting fresh water into deep salt beds, thus dissolving the salt and pumping out the resulting brine for oil field drilling.

Another brine well cavity was then identified in Carlsbad near the intersection of two highways, an irrigation canal, and a railroad. It was found to be unstable, and its operations were closed by the state. NCKRI conducted a geophysical survey of the cavity (available in Report of Investigation 2 at https://www.nckri.org/publications/reports-of-investigation/). We also assisted the State of New Mexico in several other ways, including educating the public about the cavity though guest lectures and meetings, co-leading the state's Technical Advisory Committee to develop a remediation plan, and testimony and technical assistance to the state legislature to fund first, an engineering solution to the problem, and second, to implement that solution.

To be clear, while NCKRI played an important role in these efforts, we were part of a large partnership of governmental and private organizations, private citizens, and political leaders who made the funding a reality. NCKRI was honored to be part of this team.

The remediation effort occurred in two phases. First, a viscous grout was injected into the thick pile of rubble covering the floor of the cavity to stabilize it and support the weight of a more fluid grout that filled the space between the rubble and ceiling. Second, in a different part of the cavity, sand was injected first to settle into and fill voids in the rubble and then to fill the space above to the ceiling.

While filling the cavity seems an intuitive and easy solution, it was a complex and delicate operation. The brine in the cavity was helping to hold up the ceiling! Injection of grout and sand was executed carefully so the volume of material going into the cavity equaled the volume of brine pushed out to maintain a constant brine pressure. Over-pressurizing or underpressurizing the cavity could stress the ceiling and result in catastrophic collapse.

The filling of the cavity was justifiably celebrated but monitoring continues. The potential for catastrophic collapse has been eliminated yet the potential for minor subsidence remains. Little or no subsidence is expected, but the site will continue to be monitored by the state for potential subsidence for the next two years.

NCKRI photo by Issam Bou Jaoude.

New Mexico Governor Michelle Lujan Grisham announces completion of filling the brine well cavity. She was joined, seated left-to-right at the front, by NCKRI's Executive Director Dr. George Veni, Secretary of New Mexico Energy and Natural Resources Department Sarah Cottrell Propst, and Eddy County Manager Al Davis.

No Bats Yet! Update on NCKRI's Bat Roost

After 11 years, the NCKRI bat roost still doesn't have bats. Where are they? We have done everything we could, haven't we?

When construction of NCKRI Headquarters was completed in 2011, we had built a first of its kind bat roost, designed as part of a building. It would be used for research, education, and conservation in giving bats a place to live.

Jointly designed with Bat Conservation International (BCI), the NCKRI bat roost was developed as a state-of-the-art structure that bats would love to claim as home. BCI's research shows that bats typically need 2-5 years to find a roost once it becomes available. That time has passed. There was a drought in the area that decreased populations and the need to find a new roost. The drought has passed. We don't know why these small nocturnal mammals have not joined us at NCKRI, but we can ask the following questions:

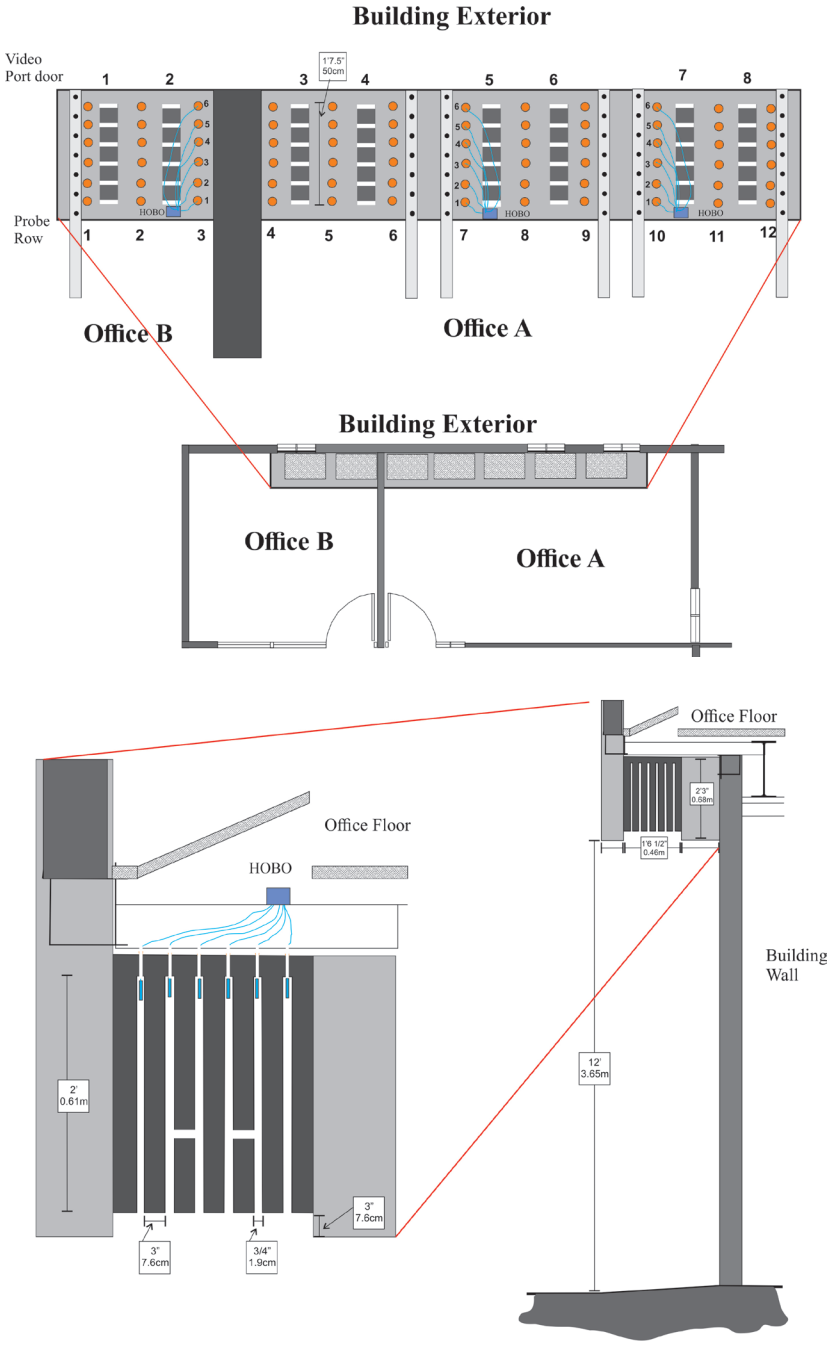
- Is it a problem with the roost temperature or humidity?
- Is the roost area too noisy?
- We discovered another bat roost nearby. Does that roost make the NCKRI roost unnecessary or is there some other issue, such as competition if the roosts are too close to each other?
- What about the streetlights for public safety outside NCKRI Headquarters? Do they make the area too bright for the bats?

To answer these questions, we have a committee of expert bat biologists assisting us. We have compiled our research results to share with them, and hope they will have answers, or at least recommendations on what we can do next to evaluate our situation and find bats in our roost soon.

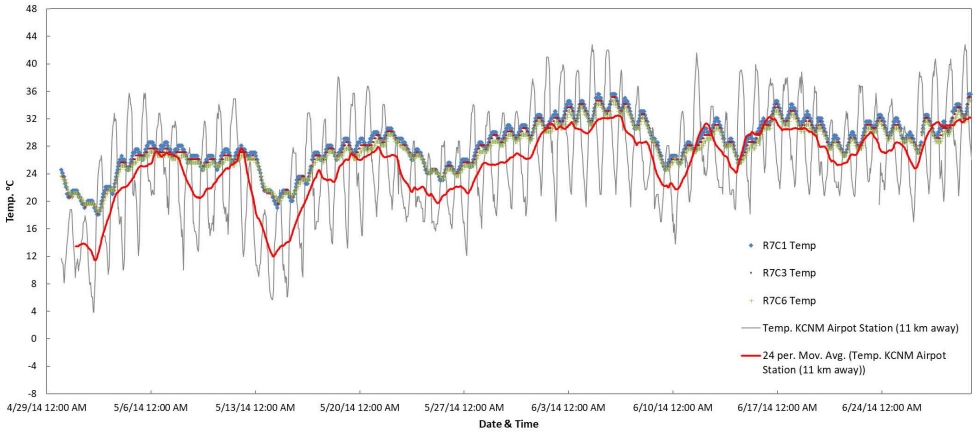
The bat roost was designed to offer flexibility for study and education. For that, two types of monitoring systems were installed. An infrared motion sensor camera was set at each end of the underside of the roost where bats would be seen flying in and out. Our second monitoring system involves 18 temperature and humidity sensors along the 6.7-m long by 0.46-m wide roost.

Reviewing the extensive recordings from 11 years of motion sensor video revealed a lot of visits by birds and flying insects. There was only one brief, 15-minute, visit by a bat on 9 July 2019. The bat stayed outside the main roost in the landing area and left swiftly.

The temperature and humidity monitoring data were collected in two phases. Phase 1 occurred between 2011 and 2018 when iButton Dallas Semiconductor DS1923



Top: Map-view drawing of the NCKRI bat roost, located under two offices; orange circles are ports for dataloggers. Bottom: Profile view of the bat roost.



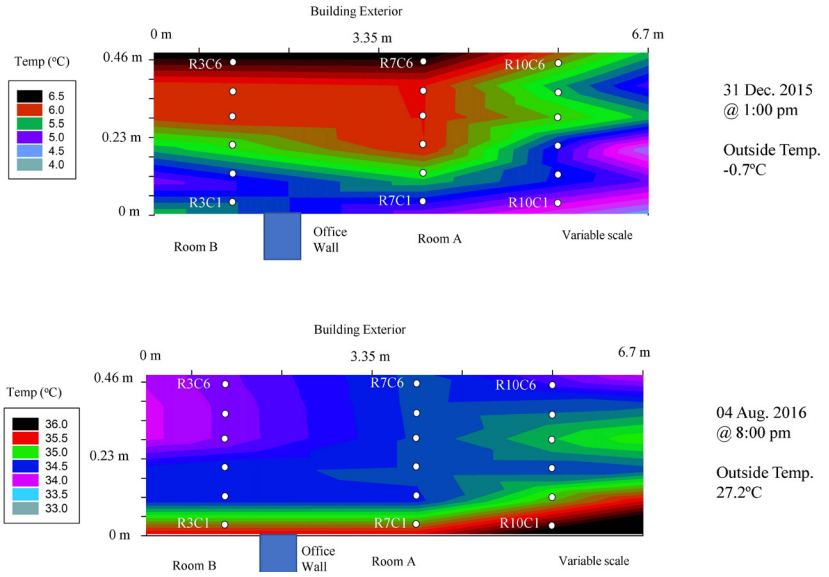
This plot shows temperature variations in the NCKRI bat roost from late April to late June 2014. The closely-spaced blue, red, and green dots (they look like a fuzzy blue-green line) are hourly temperatures at three points in the roost. The black line is the temperature at the Carlsbad Air Terminal and the red line is its moving 10-day average temperature.

probes where installed. Phase 2 extends from 2018 until the present when, thanks to financial support from our Adopt-A-Bat Program, Hobo temperature/RH smart Sensor (S-THB-M002) data loggers replaced the iButtons. The new data loggers are connected to a HOBO RX3000 Remote Monitoring Station which collects and stores the data remotely for immediate access and processing.

The high density of 18 humidity and temperature monitoring points is split into three rows of crevices designed for bat occupation. The monitoring probes are inserted into the top of the roost utilizing built-in access ports. They collect data hourly. Comparing roost temperature to the outside temperature from the Carlsbad Air Terminal monitoring station 11 km away, we see similar variations between day, night, and seasonal temperatures, but the average roost temperature is slightly higher. Temperature maps were also constructed to show the variation in the temperature of the bat roost, especially between the outer and inner roost during different seasons. As for humidity, similar variations between day, night, and seasons were observed but the average bat roost humidity is slightly lower.

In two important ways, the lack of bats is a good thing. First, we now have a clear and detailed record of environmental conditions in the roost before it is occupied by bats. This will allow us to measure the precise changes that will occur in the roost once the bats move in. Second, a major goal of the roost is to better understand bat needs and preferences. Based on extensive experience with prior roosts, this roost has it all: best materials, design, location, orientation relative to the sun, and nearby sources of abundant food and water. But something about the roost is not attractive to bats. Finding out what that is will be important to the design and success of future roosts. We don't want to do anything artificial to attract bats. Instead, we want to eliminate whatever is unattractive so they will join us at NCKRI.

If you would like to support NCKRI's bat roost research, join our Adopt-A-Bat program. Adopting a bat only costs $25 and includes a Certificate of Adoption, information about bats, and your own cuddly stuffed toy bat. All proceeds go to maintenance and equipment for the bat roost. For more information on how to help or to adopt a bat, go to www.nckri.org or call 575-887-5518.



These maps show how temperatures vary in the NCKRI bat roost from the exterior to the interior of the building. The upper map shows daytime winter temperatures and the bottom map is evening summer temperatures.

Are Playa Lakes in Karst Areas Karst Features? A Geophysical Evaluation

In June 2019, Dr. Lewis Land and Michael Jones spent one week working on a series of near-surface geophysical surveys of playa lakes and gypsum caves in the Burton Flats area, about 26 km northeast of Carlsbad, New Mexico, collaborating with Dr. Dave Decker of Southwest Geophysical Consulting and Dr. Barbara Luke of the University of Nevada-Las Vegas. Their research tools included NCKRI's electrical resistivity system, Dr. Decker's ground penetrating radar, and Dr. Luke's seismic refraction equipment. The intent of these surveys was to evaluate the possible karstic origin of some of the playas in the Burton Flats area.

Playa lakes are shallow, usually dry depressions. In the Delaware Basin region of southeastern New Mexico and west Texas, they are typically found in soils above gypsum bedrock. Many of these shallow depressions are only noticeable because they host either an abundance of salt-tolerant plant life or, in some cases, no plant life at all. These depressions are of interest because some of them are obviously linked to underground conduits and caves via surface openings (swallets).

The Delaware Basin region has been undergoing rapid infrastructure build-up as petroleum exploration, discovery, and exploitation continue to escalate. For this reason, it is necessary to determine if the playas provide pathways from the surface to underlying aquifers, and if so, to make a case for avoiding them during pipeline and well pad construction, road building, power line installation, and other associated infrastructure development.

Many karst features are already known in the Burton Flats region, including caves, swallets, sinkholes, solution tubes, and springs. The protective buffers recommended for these features are determined by the likelihood of a spill or other contamination making its way to the aquifer. These buffers are currently set at 50 m for smaller karst features, or those with a clogged conduit, and 200 m for larger karst features or those with an open conduit at their base.

Photo courtesy of Dave Decker.

Owl Cave is formed in gypsum and its entrance is about 5 m high.

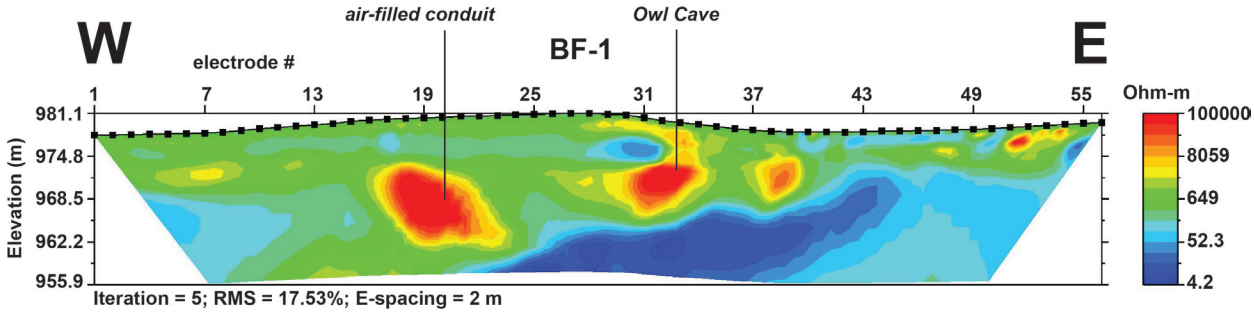
However, it is unclear if the playa lakes are linked to these karst features and why they are so closely associated spatially. If this investigation finds that these playa lakes should be considered karst features, rather than surface hydrologic or wind-eroded depressions, as some researchers have suggested, then they should be given the same protective buffers as other karst features in the region when determining the routing of linear infrastructure and the placement of well pads and ponds for drilling fluids.

Two playa lakes with a known cave, but no visible outlets for surface water, all located in the Burton Flats area, were chosen for this study. The terrain of the area consists of gently rolling hills, flatlands, and occasional cliffs. The area has numerous caves, sinkholes, swallets, and other karst features formed in gypsum and dolomite bedrock of the upper Permian Rustler Formation.

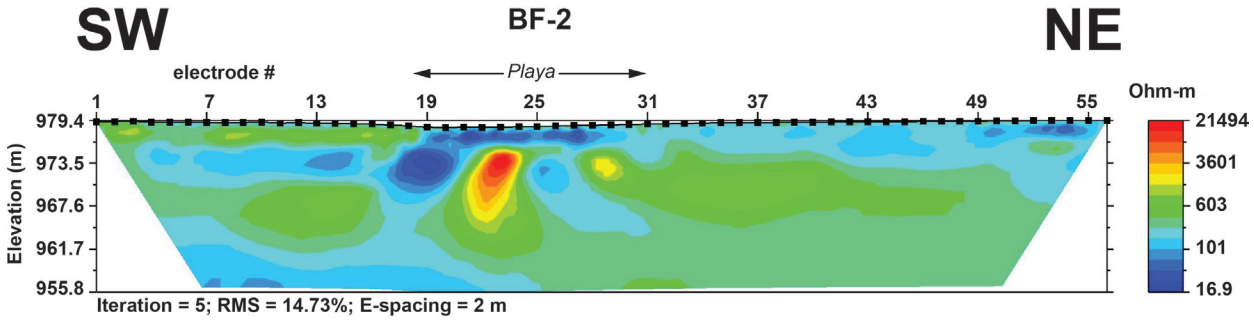
We used a known cave, Owl Cave, as a baseline for all three geophysical methods. The three teams ran identical surveys over the nearby playa lakes to see if there is an identifiable relationship between the playa lakes and other karst features.

The first playa lake (PL-01) was located 130 m east-northeast of Owl Cave. PL-01 is 1 m deep and 23 m in diameter at the location of the resistivity and other surveys. The second playa lake (PL-02) was located 140 m southeast of Owl Cave. PL-02 is only 5 to 10 cm deep and was discernible more by a change in vegetation than topographic relief. In addition, Owl Cave is located on the west edge of a third playa lake.

Electrical resistivity (ER) surveys are a common and effective geophysical method for detection of subsurface voids. The basic operating principal involves generating a direct current



Electrical resistivity survey BF-1, which was conducted directly over Owl Cave. It shows the cave and a possible extension of the cave to the west.



Electrical resistivity BF-2 was over playa lake PL-02. It shows the playa sediments in blue and a possible rubble-filled cave in red.

between two metal electrodes (stainless steel stakes) implanted in the ground, while measuring the ground voltage between two other implanted electrodes. Given the current flow and voltage drop between the electrodes, differences in subsurface electrical resistivity can be determined and mapped. Modern resistivity surveys employ an array of multiple electrodes connected with electrical cable. Over the course of a survey, pairs of electrodes are activated by means of a switchbox and resistivity meter which is programmed with the specific number and spacing of electrodes.

Resistivity profiles display vertical and lateral variations in subsurface resistivity. Air-filled caves or air-filled pore space provide a distinctive high-resistivity signature, because air has near-infinite resistivity, in contrast with the 10 to 15 orders of magnitude more conductive surrounding bedrock.

High resistivity anomalies may thus represent either air-filled void space in the subsurface (caves or potential sinkholes) or brecciated/leached zones in the gypsum bedrock with air-filled pore space. Laterally continuous layers of high or low resistivity may reflect near-surface stratigraphy, such as gypsum or dolomite beds (generally higher resistivity), or mudstone/shale layers (lower resistivity). Very near-surface low resistivity layers may indicate water-saturated fine-grained sediments accumulated in surface depressions.

ER survey BF-1 was conducted directly over Owl Cave and an adjacent playa. The air-filled void space represented by the cave is clearly indicated by a very high resistivity anomaly (>100,000 ohm-m) below electrode 31. Another air-filled cave, or possibly an unsurveyed portion of Owl Cave, is visible about 20 m west of the Owl Cave anomaly. The playa east of Owl Cave has a floor consisting of fine-grained clay and silt, as indicated by the near-surface low resistivity layer in the topographic depression between electrodes 39 and 49.

ER survey BF-2 was conducted over playa lake PL-02. The clay-rich playa floor is indicated by a near-surface low resistivity layer between electrodes 10 and 28, along with a possible fluid-flow conduit dipping down to the southwest along the left margin of the playa. A high resistivity anomaly beneath electrode 23 probably results from air-filled pore space within a rubble-filled conduit that contributed to formation of the playa. These results suggest that the playa formed in part by subsidence associated with subsurface dissolution of gypsum bedrock, as opposed to being a simple wind-eroded basin.

The ER survey results are consistent with the results of the ground-penetrating radar and seismic surveys conducted in the same area by Drs. Decker and Luke. These findings indicate that the playa lakes should be considered karst features and treated as such when planning for future infrastructure development in Burton Flats.

Exploring a Sinkhole Where Sinkholes Should Not Occur

In July 2021, management personnel with Cibola County, New Mexico, reported the occurrence of what appeared to be a small sinkhole ~1.5 m in diameter and 1 m deep. It was located on the north shoulder of County Road 605 in the village of San Mateo. The sinkhole was first identified in mid-April 2021 and was soon filled with compacted soil to a mound several centimeters above the level of the road. A site inspection in June found that over the past two months, the soil mound subsided into a depression roughly 10 cm below ground level.

Features such as this often form in urban settings when aging utility lines in the shallow subsurface collapse. However, a careful examination of the records by Cibola County personnel indicated that the main water line for the village is located 16 m to the south on the other side of CR 605. There are no records of sewer or other utility lines underlying the sinkhole itself, thus it appears natural.

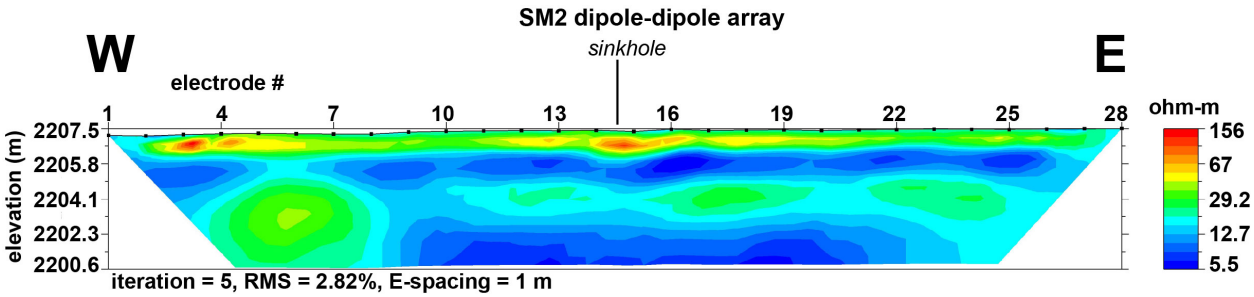
The sinkhole is formed in soil and alluvial material ~8 to 25 m thick overlying upper Cretaceous bedrock of the Menefee Formation, which is composed of non-marine sandstone, shale, and coal beds. This type of rock is not consistent with the formation of typical karst features such as sinkholes. After consultation with Cibola County managers, NCKRI personnel proposed an electrical resistivity survey of the sinkhole to determine if there were any underlying cavities that could cause additional subsidence or catastrophic collapse.

NCKRI staff evaluated the sinkhole on 21 August 2021, which had deepened to 1.3 m. They assumed it was underlain by a subsurface void or air-filled rubble, however the depth of the void space was uncertain. We therefore conducted three electrical resistivity (ER) surveys over and adjacent to the San Mateo sinkhole along the north shoulder of CR 605. Lines SM2 and SM3 were about 1-2 m south of the sinkhole. They used a 28-electrode array at a 1-m electrode spacing, for a target exploration depth of ~5 m. Line SM4 used a 28-electrode array at a 2-m electrode spacing, for a target depth of ~11 m. The center of line SM4 crosses over the center of the sinkhole (see photo below).

ER lines SM2 and SM3 each achieved exploration depths of approximately 7 m. Both profiles display mostly lower resistivity (~100 ohm-m), indicated by blue and green shading in the ER profiles, which is typical of fine-grained alluvium. The center of the SM2 profile shows a pod of slightly higher resistivity coinciding

NCKRI photo by George Veni.

A white measuring tape is draped across the 1.5-m wide San Mateo sinkhole from electrode to electrode while the yellow electrical resistivity cable wraps around the sinkhole. County Road 605 is visible nearby. The concrete barriers were set by Cibola County to prevent people from accidentally driving into the sinkhole.



Electrical resistivity survey profile that shows the San Mateo sinkhole but no underlying cavity to explain its origin.

with the position of the sinkhole, extending from the surface to about 1-2 m below the surface. That pod of higher resistivity is not visible on line SM3, which is offset two meters south of the sinkhole. Another shallow region of higher resistivity is visible at the west end of both profiles, and probably represents air-filled porosity in soil and alluvium. Both profiles are dominated by two low resistivity (<10 ohm-m) layers shown by blue shading. These layers probably reflect lower resistivity clay and silt material within the alluvium.

ER line SM4 crosses directly over the sinkhole and achieved an exploration depth of about 14 m. The maximum resistivity shown on this profile is only 100 ohm-m, and includes a pod of slightly higher resistivity between electrodes 14 and 15, coinciding with the position of the sinkhole. This higher-resistivity zone extends to a depth of ~1.5 m below ground level and is underlain by more electrically conductive material. Higher resistivity zones at greater depth at the west end of the profile probably represent air-filled porosity within coarser-grained sand and gravel in the alluvium and would not result in the collapse.

Based on results of the ER surveys, there is no indication of a large cavity beneath the sinkhole that could cause catastrophic collapse and destruction of private property and transportation infrastructure. It is possible that some artificial feature, such as an abandoned septic tank, may be contributing to the continued subsidence, although no such feature is indicated on the ER profiles. These results, while unremarkable, demonstrate that not all sinkholes are underlain by vast and deep caverns, a conclusion no doubt pleasing to Cibola County's management and highway engineers.

The complete details of this study, including recommendations to identify the cause of the collapse, are available in NCKRI Report of Investigation 13.

NCKRI photo by George Veni.

The electrodes and cable for electrical resistivity line SM2 (see profile above) 2 m south of the San Mateo sinkhole.

NCKRI Expedition Flies the Explorers Club Flag

The Explorers Club was founded in 1904 with the goal of scientifically exploring the world, all that is in it, and beyond. Its members have reached the poles, the bottom of the ocean, the highest mountains, and even the Moon. NCKRI's Executive Director, Dr. George Veni, is one of its members.

Expeditions with members who carry the Explorers Club flag are prestigious activities. Dr. Veni's unique NCKRI research at Bracken Cave was granted "flag status" in 2017. The initial phases of this project were highlighted in NCKRI's 2013-2014, 2015-2016, and 2016-2017 annual reports. The purpose of the study is to conduct the world's first geophysical survey of bat guano in the world's largest bat colony, Bracken Cave, near San Antonio, Texas, USA.

Bracken Cave is owned by Bat Conservation International (BCI), which would like to remove a core of the guano to study past environmental and ecological conditions in the cave and region. The geophysics will identify the best place to drill for the deepest core of guano.

Dr. Veni received flag status for NCKRI's project following the 2017 survey, but a return to the cave was delayed by field conditions that would not produce the best quality data, and then by the COVID-19 pandemic. Finally, he returned twice in early 2022, assisted by NCKRI's Cave and Karst Science Specialist Dr. Issam Bou Jaoude, and volunteers from BCI, St. Mary's University, The University of Texas at San Antonio (UTSA), and the Bexar Grotto of the National Speleological Society.

Electrical resistivity was used primarily for this study (our friends from UTSA conducted an electromagnetic survey in the cave and surface along one of our resistivity lines for comparison). Most of the surveys this year were not done in the cave. Comparative data were needed to evaluate geologically identical resistivity imagery of cave passages and their floors, to see if there is a difference between a cave floor covered in a deep layer of guano and other caves where guano is absent. We identified what may be the northward extent of Bracken Cave, currently blocked by collapse at the entrance, and we also surveyed next door over Natural Bridge Caverns, a show cave which is formed in the same rocks and by the same processes, but is not filled with guano.

Results from this study will be presented next year following a little more field work to complete the project.

NCKRI photo courtesy of George Veni.

NCKRI team of volunteers with the Explorers Club flag at the entrance to Bracken Cave after getting good electrical resistivity results inside.

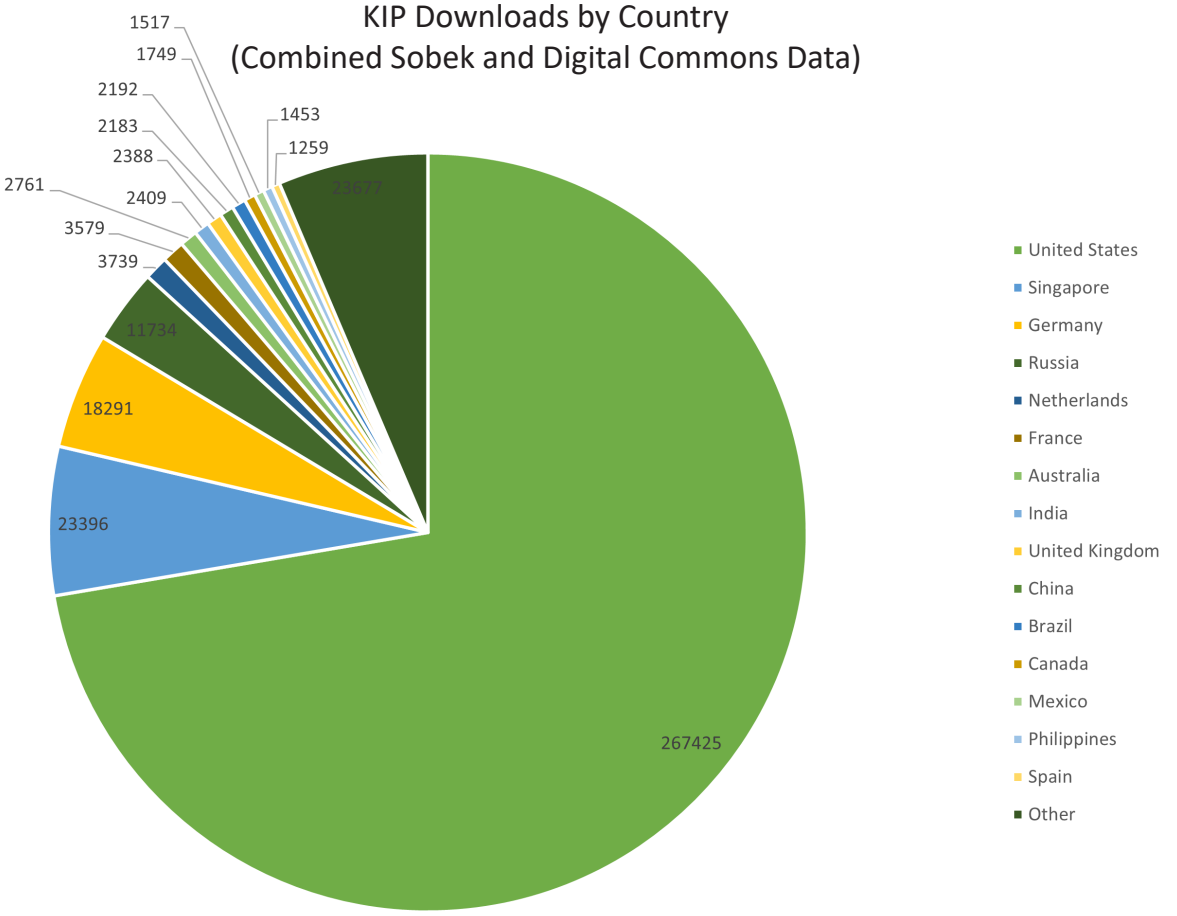
Karst Information Portal

The big news this year for the Karst Information Portal (KIP) is that it has a new home! KIP has migrated from its former location on the Digital Collections platform to Digital Commons at University of South Florida (USF): https://digitalcommons.usf.edu/kip/. Some of you are already familiar with this platform (formerly branded as Scholar Commons), where the University of South Florida hosted the proceedings for the Sinkhole Conference and other NCKRI meetings. We are still working on data cleanup, but the new platform should be easier to search and navigate. Discoverability is optimized through the bepress Digital Commons platform.

KIP is part of the USF Libraries Digital Collections interface and serves as a one-stop shop for open, online access to cave and karst research. KIP is a NCKRI project in partnership with the USF Libraries, University of New Mexico, and the International Union of Speleology. NCKRI volunteer and former staff member Michael Jones sends spreadsheets of citations to the USF Libraries team. The USF staff conducts copyright clearance on these items to determine which can be posted with full-text and which will only be citations. Metadata are created for each item and uploaded to the Portal. This year, we added 1,388 items, bringing us to a total of 9,948 in the Karst Information Portal—a 16.2% increase over last year, even in the middle of migrating to a new platform.

The Karst Information Portal usage is measured through Google Analytics and other tools. Usage of the Portal continues to increase, growing 11.4% this year, from 326,351 downloads in FY 2020-2021 to 363,590 in FY 2021-2022. (Much of this was bot activity, with 230,011 uses from bots and 133,579 downloads from human users.) Additionally, there were 6,458 downloads on the Digital Commons platform. KIP usage is coming from every country in the world, with most being in the United States, followed by Singapore and Germany. KIP is truly reaching a worldwide audience! The image below shows the top 15 countries by usage, combining numbers from both platforms.

Do you want to share your cave or karst newsletter, journal, thesis, or other maps and reports with the world? Send them to the Karst Information Portal for posting! We will not post anything without clear, explicit, permission. If you have questions, contact us through the Portal or at info@nckri.org.



NCKRI RESEARCH GRANT PROGRAM

In 2019, NCKRI initiated three new grant programs designed to facilitate and support cave and karst research at academic and research institutions across the United States:

- The NCKRI National Seed Grant Program is designed to enable investigators to initiate new cave and karst research as well as encouraging new principal investigators to enter the field.
- The NCKRI Scholar Fellowship Program supports cave and karst research by exceptional graduate and undergraduate students.
- The NCKRI-NMT Internal Seed Grant Program creates opportunities for investigators at NCKRI and New Mexico Tech (NMT) to initiate new cave and karst research. It also expands NCKRI's research footprint by enhancing collaborations with NMT faculty and students.

In 2021, we supported two new National Seed Grants and four NCKRI Scholar Fellowships, two to graduate students and two to undergraduate students. Reports on those grants follow below after reports on three previously funded seed grant projects.

NCKRI's research grant program is managed by Dr. Daniel Jones. Application and other information is posted at https://www.nmt.edu/research/organizations/nckri.php. The National Park Service is the primary financial supporter of NCKRI's grant program.

NCKRI National Seed Grants

Dr. Thomas Kieft and Joseph Ulrich, report: *Culture-independent high-throughput analysis of viral communities in Carlsbad Cavern pools*

Cave ecosystems are well known to harbor diverse communities of organisms, including many unique, indigenous species of bacteria, archaea, and eukarya (protists, invertebrates, and vertebrates). However, while all three of these evolutionary domains of life have been well studied in caves, the characterization of viruses, the most numerous biological entities on Earth, has barely been addressed in caves. The few studies of viruses in caves have mostly examined viruses associated with bats and humans, the latter used primarily as indicators of human contamination. The majority of viruses in caves are likely phages (viruses that infect bacteria) and they most likely far outnumber their microbial hosts.

The total abundance of viruses on Earth is estimated to be 10^{31} or ~10 times the number of prokaryotic cells (bacteria and archaea). Phages have been studied most extensively in the ocean, where they number ~10^7 viruses/ml and are responsible for death of about 20% of marine bacteria every day. The lysis of host cells releases nutrients for uptake by other cells, a phenomenon known as the "viral shunt." Some phages also confer useful genetically encoded functions to their hosts. The same principles governing bacterial host-phage relations likely apply in cave environments, as well.

Until recently, most viral studies have focused on isolation of viruses using host species (a culture-dependent approach). Polymerase chain reaction (PCR)-based studies have also been used to amplify nucleic acids from viruses, but these rely on primers with homology to known viruses. These approaches are extremely limiting. There is no single gene present in all viruses and many viruses infect uncultivated microbes, so-called "microbial dark matter," and thus they constitute "viral dark matter." More recently, high-throughput shotgun metagenomic sequencing has enabled characterization of the viruses in an environment (the virome). In this approach, viruses are physically separated from all cells by filtration and then concentrated; DNA is then extracted and sequenced. Since nearly all bacteriophages are double-stranded DNA viruses, this DNA approach recovers the majority of viral sequences.

As a first attempt at high-throughput viral sequencing in a cave, a NCKRI-New Mexico Tech Internal Seed Grant project led by Dr. Thomas Kieft was awarded to study viruses in cave pools in Carlsbad Cavern, Carlsbad Caverns National Park, USA. Although cave pools have relatively low organic matter contents, they do contain significant abundance as well as diversity of bacteria, ~10^4-10^5 cells/ml of pool water in karstic caves in South Dakota, USA, and Switzerland. This suggests that viral abundance could be in the range of 10^5 to 10^6 viruses/ml of pool water.

The objectives of this NCKRI -funded study were to: (1) quantify viral particles in cave pools relative to prokaryotic cells, (2) generate a large database of cave pool viral sequences, and (3) test for human impacts on cave pools as evidenced by the viral communities. The following hypotheses were tested: (1) viral abundance is ~10-fold higher than prokaryotic cell abundance in cave pools, (2) pools contain novel viral sequences, and

Photo courtesy of Joseph Ulrich.
New Mexico Tech graduate student Joseph Ulrich filtering pool water in Carlsbad Cavern.

(3) communities in pools from portions of a cave developed for tourism are distinct from those of pools in undeveloped parts of the same cave.

New Mexico Tech graduate student Joseph Ulbrich carried out this project under the direction of Dr. Kieft and received bio-informatics help from NCKRI Academic Director Dr. Dan Jones. Ulbrich collected samples and concentrated viruses from two pools in well-visited areas of the Big Room (Green Lake and Longfellow's Bathtub) and two less visited pools (Iron Pool in Left-Hand Tunnel and Lower Cave Pool in Lower Cave). Microscopic counts of bacteria averaged ~1 x 10^4 cells/ml and viral counts averaged ~2 x 10^5 virus-like particles/ml. These data are in rough agreement with those of other environments, e.g., seawater, and they support the first hypothesis.

High-throughput sequencing generated more than 80 million DNA reads. Bioinformatic analyses identified more than 700 viruses, most of them phages, and many of them previously unknown; thus, they add to our knowledge of "viral dark matter" and support the project's second hypothesis of novel viruses. The third hypothesis, that viral communities of pools in developed and undeveloped cave areas would differ significantly, was not supported. Even though Green Lake and Longfellow's Bathtub share characteristics of heavy tourist traffic and artificial lighting (and associated lampenflora microbes including photosynthetic cyanobacteria), cluster analysis did not show their viral communities were closely related.

This first ever metagenomic study of cave viruses revealed diverse and novel viruses that infect cave pool bacteria. The discovery of these hitherto unstudied biological entities in a cave should pave the way for future studies of viruses in cave and karst environments. Metagenomic surveys of viruses should be extended to cave sediments and biofilms, in addition to caves with varied physical and chemical conditions as these are apt to yield more new viruses. Studies that link viruses to their specific hosts and that determine the possible negative and positive effects on those hosts will take cave virus studies to a new level. Better understanding of the role of viruses in caves may even have implications for management of cave resources.

Dr. Georgina Lukoczki and Dr. Benjamin W. Tobin, report: ***Controls of dolomitization on matrix porosity and its effect on cave passage formation as inferred from numerical simulations based on geochemical and experimental analyses***

Drs. Gina Lukoczki and Ben Tobin, of the Kentucky Geological Survey, USA, conducted their seed grant project in Kentucky's Flint-Mammoth and Edwards Mountain Cave systems to explore the relationship between cave passage development and diagenetic processes, particularly dolomitization. While it is well-understood that conduit development in karst is typically organized along bedding planes, faults, and fractures, the role of diagenetic evolution of rock porosity and permeability in controlling groundwater flow is understudied.

The central question of this project is, why the presence of dolomite layers, in a succession of alternating limestone and dolomite, does not have a consistent relationship with cave passage development? Previous observations in various caves found that some passages preferentially develop in dolomite layers, in other cases dolomite and dolomitic layers are more resistant to cave passage development than the surrounding limestone, and in yet other cases dolomite has no apparent influence on cave morphology.

Drs. Lukoczki and Tobin sampled various parts of the Flint-Mammoth Cave System, including Crystal Cave and the areas covered by the Half-day Tour and the Historic Tour with the help of National Park Service staff and volunteers. Assisted by faculty from Western Kentucky University, the team also sampled surface outcrops near the Flint-Mammoth Cave System in Warren and Barren counties. Samples for the Edward Mountain System, located near Monticello in Wayne County, were collected in collaboration with Dr. Lee Florea and Sarah Asha Burgess, who provided insight into the prevalence of irregular dolomite bodies that protrude into cave passages. Field observations, as well as petrographic and geochemical data, suggest that the dolomite beds in the Flint-Mammoth Cave System and the dolomite bodies in a cave of the Edward Mountain System have differing origins and evolutionary histories, as discussed below.

In the Flint-Mammoth Cave System, the studied dolomites

are stratiform dolomudstones and partially dolomitized grainstones and wackestones. The fine crystal size, the stratiform occurrence of dolomites, and the prevailing semiarid-arid climate during the Mississippian have led researchers to propose these dolomites formed in tidal flat environments, probably similar to those along the shores of the Persian Gulf, either by sabkha dolomitization and/or reflux dolomitization. Both dolomitization models invoke the circulation of highly saline, evaporatively concentrated brines as the dolomitizing agent. However, the oxygen isotope values measured on samples from the Flint-Mammoth Cave System are several per mil lower than what is expected for dolomites formed from evaporatively concentrated Mississippian-age seawater. These data, coupled with unequivocal signs of high-temperature dolomite-forming fluids in the form of well-developed saddle dolomite cements lining the walls of vug-pores and fill fractures, clearly indicate a relatively late-diagenetic, high-temperature event.

A possible explanation for the discrepancy between the previously proposed dolomitization mechanism and data collected for this project is recrystallization, a process during which a metastable dolomite transforms into a more stable dolomite via dissolution and re-precipitation. During recrystallization, dolomites that originally formed shortly after deposition in near-surface settings, typically with higher porosity and permeability than the over- and underlying limestones, are transformed during burial as high-temperature fluids migrate through and interact with dolomites within these permeable layers.

Depending on fluid composition, this recrystallization may change both the texture and dolomite geochemistry, including the oxygen isotope composition, while leaving other characteristics apparently intact. While the isotope data can best be explained by burial recrystallization, it is currently unclear whether the diagenetic porosity-permeability evolution of the dolomitized layers contributed to the lack of noteworthy morphological differences between dolomites and limestones in the studied passages. Further studies are needed to establish the reason for the lack of apparent genetic connection between cave passage development and the diagenetic evolution of the host carbonates.

The Edward Mountain System contains elongated, irregularly shaped dolomite bodies that cross-cut bedding in the same Mississippian-age formations as those that host the Flint-Mammoth Cave System. Survey data and field observations show that many passages have fault-controlled morphology and orientation, suggesting strong structural control on speleogenesis. However, there is a complex relationship between the spatial distribution of dolomite bodies and cave passage morphology. Drs. Lukoczki and Tobin's data suggest a paleokarst-related origin of these dolomite bodies. Eogenetic caves likely developed during relative sea-level lowstands following the deposition of the Ste. Genevieve Limestone. Subsequent sea-level rise renewed carbonate sedimentation and filled these cavities with lime mud. Later dolomitization was restricted to the paleokarst-fill, likely because of porosity and permeability contrasts between the cave-filling sediment and the surrounding limestone (bioclastic wackestone and bioclastic/ooid grainstone), resulting in porous dolomite bodies encased in tight limestone. The presence of crinoid fragments and minor detrital quartz grains in the otherwise fabric-destructive planar-euhedral matrix dolomite support this scenario. Dolomitization likely occurred in a tidal flat setting similar to other Mississippian penecontemporaneous dolomites during the next regression following the deposition of the marine carbonate sediments.

However, the low carbon and oxygen isotope values of the dolomites seem to record meteoric recrystallization of these dolomites rather than the original

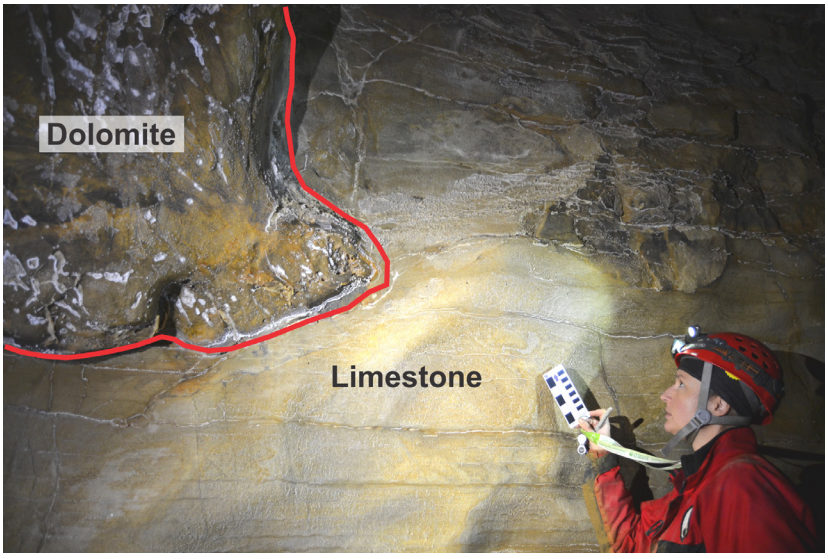


Photo courtesy of Dr. Gina Lukoczki.

Dr. Lukoczki looking at the contact between a dolomite body and the surrounding limestone in the Edward Mountain Cave System. The red line highlights the border between the differing rock types.

dolomitization mechanism, the latter of which is expected to be represented by higher oxygen and carbon isotope values. Meteoric recrystallization is further supported by the spatial distribution of dedolomites, i.e., dolomites that were pseudomorphically replaced by calcite. Dedolomites appear to be more abundant near the top of the dolomite bodies suggesting meteoric flushing during subaerial exposure, likely during the Late Mississippian or Pennsylvanian. Later, likely in a more deeply buried setting, the intercrystal pore spaces in the dolomite bodies were filled with non-ferroan and ferroan calcite. This late calcite cementation rendered the dolomite tightly cemented and, coupled with the lower solubility of dolomite compared to calcite, more resistant to cave-passage formation than the surrounding limestone. The differences in protrusion between two studied dolomite bodies in a cave of the Edward Mountain System are likely caused by differences in weathering resistance between the softer wackestone (more receded) and the harder grainstone (less receded) surrounding the dolomite bodies.

To further assess the cave wall morphology and its relation to the lithology, Drs. Lukoczki and Tobin used photogrammetry to provide 3-D imagery of the cave passages. They collected a minimum of 250 images of each cave passage wall in their study. These images encompassed both the dolomite bodies and surrounding limestone in two sections of the Edwards Mountain Cave System. The photographs were used to create a digital elevation model (DEM) of each wall with 1-cm resolution. These DEMs were analyzed for variability between cells to determine areas with the greatest variability.

The DEMs show distinct differences in surface texture variability, with the dolomite body showing highly variable surface texture, and the surrounding limestone showing a relatively consistent texture. This textural variability is likely a result of the mixed mineralogy (varying proportions of dolomite and calcite) in the dolomite bodies, which in turn resulted in differential dissolution during cave passage development. This is due to the difference in solubility between the less soluble, rock-forming dolomite, the more soluble, intercrystal calcite cement, and the dedolomite resulting in a rough surface in the dolomite body. Dr. Lukoczki, with collaborators in Canada, will further characterize the solubility of selected samples.

Even though both caves are hosted in Mississippian carbonates of the St. Louis and Ste. Genevieve Limestones, they are located on opposite sides of the Cincinnati Arch, a paleogeographic/structural feature separating the Illinois and Appalachian basins. During the time of deposition of the cave-hosting carbonates, the depositional environments were generally similar over the area of the Cincinnati Arch with lower depositional thicknesses and truncation surfaces on the eastern side. However, later tectonic movements resulted in a divergence in the burial history and corresponding diagenetic evolution of the Mississippian carbonates on opposing sides of the Cincinnati Arch. Dolomites in the Mammoth Cave area likely recrystallized during burial by warm/hot fluids, whereas on the other side of the Cincinnati Arch, dolomites recrystallized by cold meteoric fluids during relative sea-level lowstand accompanied by extensive calcite cementation. The porosity-permeability contrast between the dolomite and the surrounding limestone appears to be a more important factor in the development of larger-scale, cave-wall morphology compared to mineralogy, the latter of which seems to have a stronger influence on the finer-scale texture of the cave-wall.

The team has given two professional presentations, related to findings of this work:

- Lukoczki, G., Burgess, S.A., Tobin, B.W., Florea, L. 2020. Evolution of matrix porosity and its effect on cave passage development. Geological Society of America Abstracts with Programs, v. 53, no. 6, https://doi.org/10.1130/abs/2021AM-367738
- Florea, L., Burgess, S.A., Lukoczki, G., Tobin, B.W. 2021. Toward a more comprehensive model of karst development in the U.S. Midcontinent. Geological Society of America Abstracts with Programs, v. 54, no. 4, https://doi.org/10.1130/abs/2022NC-374598

Dr. Tobin has also used this NCKRI grant to work with the Education Division of the National Speleological Society developing education materials, designed for non-technical audiences, like school children and public enthusiasts.

Dr. Dylan Ward and Dr. Rachel Bosch, report: *Stream capture from below: formation of the Sinkhole Plain, Kentucky, through the lens of relict topography*

In Drs. Ward and Bosch's study area of central Kentucky, USA, multiple tributaries to the Barren River were cut off from below by the development of sinkholes and cave passages in the Sinkhole Plain, and diverted to flow to the Green River, migrating the drainage basin boundary between the Barren and Green watersheds westward over time. This is part of a larger pattern of erosional response to downcutting of the Green and Barren rivers during the Quaternary, wherein sinkholes develop and deepen to reflect increased erosion potential of the subsurface network that drains to these rivers. This investigation focused on Crystal Onyx Cave in Prewitts Knob, Cave City, Kentucky,

to investigate the landscape evolution and drainage history of the Sinkhole Plain in the context of the established chronology of the incision of the Green River using burial ages for the Mammoth Cave system.

Drs. Bosch and Ward prepared a variety of samples for geochronological analysis, including cosmogenic isotope measurements on surface stream sediments from the Sinkhole Plain, as well as cosmogenic burial dating of allochthonous cave sediments in Crystal Onyx Cave, a cave set in Prewitts Knob, one of many remnant "knobs" (local term for certain hills), rising about 60 m above the modern Sinkhole Plain surface. The caves within these remnant knobs may act as just local drainage. However, they hypothesize that Crystal Onyx Cave may have been a part of an integrated karst drainage network including other knob caves, and perhaps connected with older levels of Mammoth Cave.

Crystal Onyx Cave, with its upper entrance at 268 m and lower entrance at 249 m above mean sea level, is just one example of many knob caves. First, they considered the age of development of the passages that comprise Crystal Onyx Cave, with a focus on the lower level, presumably the youngest passage. It would be similar in age to level B Mammoth Cave passages if it was lithologically controlled. It may be consistent with or even higher than level A because the elevation of Crystal Onyx is quite a bit higher than level A. Or, perhaps, it was an isolated cave that never connected to the Mammoth Cave system.

Crystal Onyx Cave exhibits two consistent horizontal levels. Both levels have more clastic sediment than would be expected if these were isolated drainages that received sediment sourced from only the present-day knob. These deposits do not demonstrate any consistent sedimentary structures that indicate the directions of past groundwater flow. Additionally, scallops have been observed throughout the cave, but it was concluded by prior researchers that they do not yield sufficient information to reconstruct the paleohydrological setting of this cave.

Sand and sandstone from a breccia deposit were collected from a ledge in a lower-level passage of Crystal Onyx Cave for burial $^{26}Al/^{10}Be$ cosmogenic dating to determine where and when Crystal Onyx Cave fits within the geomorphic and hydrologic history of the Sinkhole Plain. Additionally, silt and sand from a cut bank and modern sand from a point bar were collected from Little Sinking Creek for exposure ^{10}Be analysis to determine basin-wide averaged erosion rates.

Photo courtesy of Rachel Bosch.

Clastic sediments in Crystal Onyx Cave were examined to unravel the evolution of karst development in the Sinkhole Plain.

Results from the $^{26}Al/^{10}Be$ burial dating revealed a burial age of 5.1 ± 0.7 million years, consistent with the chronology established for Mammoth Cave. This sample from Crystal Onyx is quite a bit older and plots within the same range of erosional rates, verifying that it is within the same landscape. It is thus reasonable to presume that Crystal Onyx Cave could have been part of the Mammoth Cave system since a linear trend can be regressed through the burial data from Crystal Onyx Cave. The slope of that line yields an erosional rate of about 25 m/million years for the Green River's incision rate.

The ^{10}Be surface exposure results from the cut bank material gave a basin-wide averaged erosion rate of ~4.4 m/million years and the modern sand yielded a rate of ~4.6 m/million years. This is quite slow compared with the Green River incision deduced from the burial ages, leading to the inference the Sinkhole Plain has not kept pace erosionally with the Green River. This dramatic difference in erosion rates could explain the high elevation of the Sinkhole Plain relative to the Green River.

There are several possible explanations for the age of the lower level of Crystal Onyx Cave and how it fits in with the regional landscape. It is significantly older than level B of Mammoth Cave which tells us that its development was probably not lithologically controlled. It could have been formed contemporaneously with level A, but abandoned by sedimentation earlier than level A, in which case level A may have experienced subsequent erosion and aggradation. Or it could be it could be an older level of the same system that drained to the Green River and there's nothing left further north and west from this level. A final possibility is that it was hydrologically completely different than modern day Mammoth Cave; it may have drained west to the Barren River.

Considering the burial age of Crystal Onyx Cave in combination with the Mammoth Cave burial ages, the average estimated rate for the Green River incision is 25 m/million years. Whereas, distributing the ~5 million year age for Crystal Onyx Cave over the relief of Crystal

Onyx Cave relative to the Sinkhole Plain, yields an average erosional rate of 15 m/million years. Lastly, the slowest overall erosion rate is provided by analysis of the sediments from Little Sinking Creek, at ~4.5 m/million years.

Questions for future research include whether knob caves at similar elevations to Crystal Onyx Cave throughout the Sinkhole Plain contain clastic sediments that could be interpreted and dated. Do they have other paleo flow indicators within them such as scallops that could inform reconstruction of the Pennyroyal Plateau prior to the denudation of today's Sinkhole Plain?

This study supported Rachel Bosch's 2021 PhD dissertation, *Landscape Evolution of the Central Kentucky Karst, Doctoral Dissertation*, University of Cincinnati, http://rave.ohiolink.edu/etdc/view?acc_num=ucin1627665906577779. Its results were shared at the 2022 joint North-Central - Southeastern Geological Society of America meeting in Cincinnati, Ohio, USA (https://doi.org/10.1130/abs/2022NC-375448), and are in preparation for scientific journal publication.

Dr. Daniel Ibarra and Dr. Natasha Sekhon: ***Utilizing stalagmites from the Philippines: quantifying and understanding interannual hydroclimate variability in the Philippines through cave monitoring and stalagmite analyses***

The Philippines, located in southeast Asia, are extremely vulnerable to the impacts of climate change. The Intergovernmental Panel on Climate Change projects an increase of hydroclimate hazards such as floods, droughts, and tropical cyclones for southeast Asia. At the same time, global climate drivers that affect the spatial and temporal response of these hazards are poorly understood. Oscillating between El-Niño and La-Niña conditions, El-Niño Southern Oscillation (ENSO) is a fundamental feature of the global climate system and originates in the central and eastern Pacific Ocean. However, it is still not widely understood how ENSO affects rainfall, and by extension droughts and floods, in the Philippines. Available instrumental (satellite and weather station) data, on average cover the past 50 years, and have provided a baseline knowledge that El-Niño conditions exacerbated local droughts. But, recent instrumental data-based studies have demonstrated that this generalization cannot be used for the entire country, let alone the entire region. Further, limited instrumental data fall short of capturing enough ENSO events (every 2-7 years).

Photo courtesy of Dr. Daniel Ibarra.
Polished cross section of a stalagmite from a cave on Bohol Island, Philippines. Analysis of the growth layers will reveal information about paleoclimatic conditions in the Philippines.

The geochemical trends retrieved from stalagmite growth layers in caves from the Philippines can help us better understand how hydroclimate variability changed before the availability of instrumental data. The geochemistry of stalagmite growth layers holds clues of the climate above the cave. Through actively monitoring the cave by collecting, for example, stalactite drip waters and cave air temperature, the relationship between the climate signal and the geochemical clue recorded in the stalagmite is better understood. In this project, Drs. Ibarra and Sekhon will develop new stalagmite records through the Holocene, together with modern (instrumental and monitoring) data to investigate hydroclimate (flood and drought) variability in the deep tropics as modulated through ENSO. With local collaborators and partnerships, they will also set up some of the first ever regular cave monitoring field sites in the Philippines.

Dr. Bogdan Onac: ***The last ice caves in Hawaii***

Much of the information about past climate and environmental conditions on timescales from decades to hundreds of millennia, and the most direct and highest temporal resolution record of past atmospheric and precipitation chemistry come from polar and alpine ice cores. Ice deposits in caves store a record of past climate, particularly important in the absence of other paleoclimate proxies in the region. The ratios of naturally occurring oxygen and hydrogen isotopes in ice samples can provide significant information relative to temperature, distance from source water, and evaporation. Thus, climate changes can be detected for the time period spanned by the ice core record by precise mea-

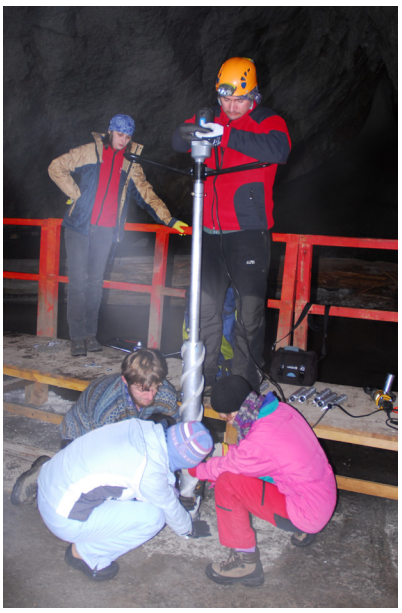


Photo courtesy of Dr. Bogdan Onac.
Dr. Onac's team retrieves an ice core from a cave in Romania.

surements of oxygen and hydrogen isotope variations.

Tropical Hawaii, USA, harbors high-elevation lava tubes with perennial ice. These ice deposits have only become accessible to science over the last decade. Dr. Onac proposes to core and investigate the ice deposits in lava tubes on Mauna Loa volcano that have the potential to significantly expand our knowledge of the environment and climate evolution of the region. With this perspective, he believes high-resolution isotopic records from the targeted ice caves would provide low-latitude, high elevation counterparts to the mid-to-high latitude ice core records. These ice deposits are of further interest for the microbial lifeforms that prevail under these Mars-analog environments.

The ice accumulations in Hawaiian lava tubes are threatened by climate warming as well as a potential eruption of Mauna Loa volcano. This project will have benefits beyond the location in Hawaii Volcanoes National Park by further contributing climatic data that can be used to test various space- and time-dependent climatic models.

NCKRI Scholar Fellowships, Graduate Students

Jeremy Vandenberg: *Characterizing diet, summer movements, and roost habitat of Townsend's big-eared bats* (Corynorhinus townsendii) *in northern Arizona*

Mr. Vandenberg is a masters degree student in the Cave Ecology Lab, Department of Biological Sciences, at Northern Arizona University, USA.

Wildlife managers have limited knowledge concerning the diet, landscape use, and summer habitat of Townsend's big-eared bat (*Corynorhinus townsendii*) in northern Arizona. This study will investigate these knowledge gaps in two main ways. First, tracking bats using high-frequency radio transmitters will determine how they are using the landscape in the summer for foraging, roosting, and raising young. Second, DNA analysis of bat feces will determine the breadth and content of their diet during the summer season.

The importance of this research is emphasized by the impending impacts of climate change and White-nose Syndrome on bat populations in northern Arizona. Mr. Vandenberg's results will enable regional land managers to protect important roosting and foraging habitat of Townsend's big-eared bat, facilitate further study of population trends, and better understand the ecology of cave-roosting bats in northern Arizona.

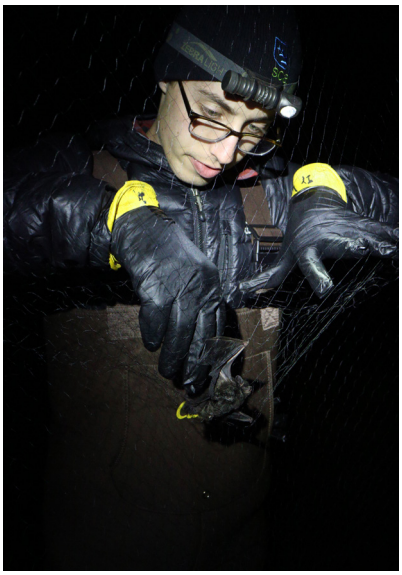


Photo courtesy of Jeremy Vandenberg.
Jeremy Vandenberg gently retrieves a bat from a mist net for study.

Brendan Cramphorn: *Phylogeography, speciation, and cryptic diversity in* Pseudosinella *cave springtails (Entomobryomorpha: Entomobryidae) of the Interior Low Plateau and Appalachian Valley and Ridge karst regions*

Mr. Cramphorn is a biology masters degree student at The University of Alabama in Huntsville, USA.

Caves offer a unique opportunity to study the ecology and evolution of life in extreme environments. Many different groups of invertebrates and vertebrates have evolved similar adaptations to living in habitats that lack light and generally have limited energy resources. However, the same processes that drive diversification in subterranean fauna can also obscure true levels of biodiversity. Traditional taxonomy of most subterranean organisms has relied heavily on morphology. However, several molecular studies in recent years have uncovered high levels of cryptic diversity in some subterranean organisms. More widely distributed species that were delimited using morphology are comprised of multiple, genetically distinct lineages. However, many subterranean species remain to be genetically studied.

In this project, Mr. Cramphorn examines the potential for cryptic speciation in three cave springtails of the genus *Pseudosinella* (*P. christianseni*, *P. hirsuta*, and *P. spinosa*) that are broadly distributed in the Interior Low Plateau and Appalachian Valley and Ridge karst

Photo courtesy of Matthew Niemiller.
A Pseudosinella hirsute springtail from a cave in Jackson County, Alabama. These tiny cave animals are often overlooked since they are only a few millimeters in size.

regions of the eastern United States. He will integrate morphological and genomic approaches to determine true levels of species and genetic diversity and investigate factors that shape genetic structure and species distributions. Outreach activities will include the development of species profiles for the Cave Bio data portal and cave springtail-focused teaching and learning modules for summer camps. This project will assist in conservation efforts of this overlooked invertebrate group and expand our knowledge of the factors that drive cryptic speciation in subterranean organisms.

NCKRI Scholar Fellowships, Undergraduate Students

Aspen Huseman: *Analysis of a Presumptive Chemoautotrophic Cave Ecosystem*

Ms. Huseman is a junior biology major at Henderson State University, in Arkadelphia, Arkansas, USA. Her research focuses on the ecology of a unique cave in the Highland Rim Geological Region of Central Tennessee, USA, which is being explored and has a currently mapped length of over 24 km. The cave is referred to by the pseudonym "Secret Squirrel Cave," to protect it from unwanted disturbance.

While most caves are formed by water descending from the surface creating the passages (epigenic caves), this system appears to be at least partially formed by sulfuric acid speleogenesis, a process where hydrogen sulfide from below the cave is converted by microbes to sulfuric acid that then erode away the limestone, often leaving gypsum behind. Lechuguilla Cave and Carlsbad Cavern are two better known examples of such caves.

Ms. Huseman's study site has been named the "Petroleum Passage," for its pervasive petroleum smell. There, an active stream pool with "mini-vents," occasionally expels globules of an oily substance. These mini vents are surrounded by concentric colored rings of sediment. At times, this

Photo courtesy of Kaylie Wheeless.
Aspen Huseman shows a sample she collected for her research.

passage holds dense populations of cave salamanders and cave-adapted millipedes. Ms. Huseman hypothesizes that these organisms are supported by microbial action, without the input of the products of photosynthesis on the surface. She plans on furthering her research using 16S rRNA gene sequencing to expand her team's understanding of the composition of the microbial community, and stable isotope analysis to track the movement of energy from the microbes to the invertebrates and vertebrates, predicting that the higher organisms will be "isotopically light," a finding that would support the hypothesis that the system is functioning without, or without much, input from photosynthesis. Such subterranean systems have been suggested as models for potential life in subsurface environments on Mars.

Cody Kisner: *Assessing Growth of fungus on rope strength in Lechuguilla Cave*

Mr. Kisner is working on an undergraduate degree in biology at the University of Cincinnati, Ohio, USA, and volunteers in the study of the blind Mexican cave fish, *Astyanax mexicanus*.

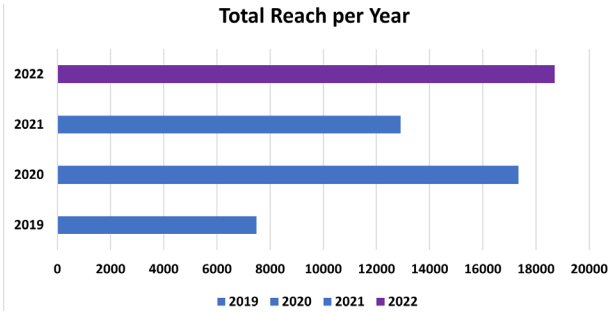
Fungi reside in almost every habitat on earth. One of the many ecological functions of fungi are as decomposers and recyclers of organic material. In Lechuguilla Cave, Carlsbad Caverns National Park, New Mexico, USA, fungi have been observed growing on the nylon sheathing of newer ropes that are rigged permanently in the cave. Given that nylon is a recalcitrant polymer, it still has an organic chemical structure, and it is uncertain whether fungal growth has an effect on rope strength. In this project, Mr. Kisner will test the strength of nylon fibers exposed to fungus from the cave. The results could provide valuable information to the National Park Service on rope management in caves.

Photo courtesy of Andy Armstrong, National Park Service.
A rope left in Lechuguilla Cave for 10 months. Fungus is visible on the rope in a thick, hazy, green/white layering.

EDUCATION PROGRAM

Since the start of August 2021 there have been many changes to NCKRI's Education Program, beginning with the hiring of Education Program Manager Devra Heyer. Upgrading a program is always challenging and the current program goals are to:

- Act as nexus for education and outreach endeavors between various entities and public lands.
- Provide interdisciplinary resources aligned to national standards for educators and academic entities that are related to caves, karst, and the multitude of disciplines that intersect this sensitive environment.
- Offer multiple means by which to interact with the public such as an online presence through websites and social media, outreach/ tables at public events, creating interactive interpretive exhibits, public and guest speaking.
- Support academic programs and educators that further the knowledge or conservation ethos of caves and karst.



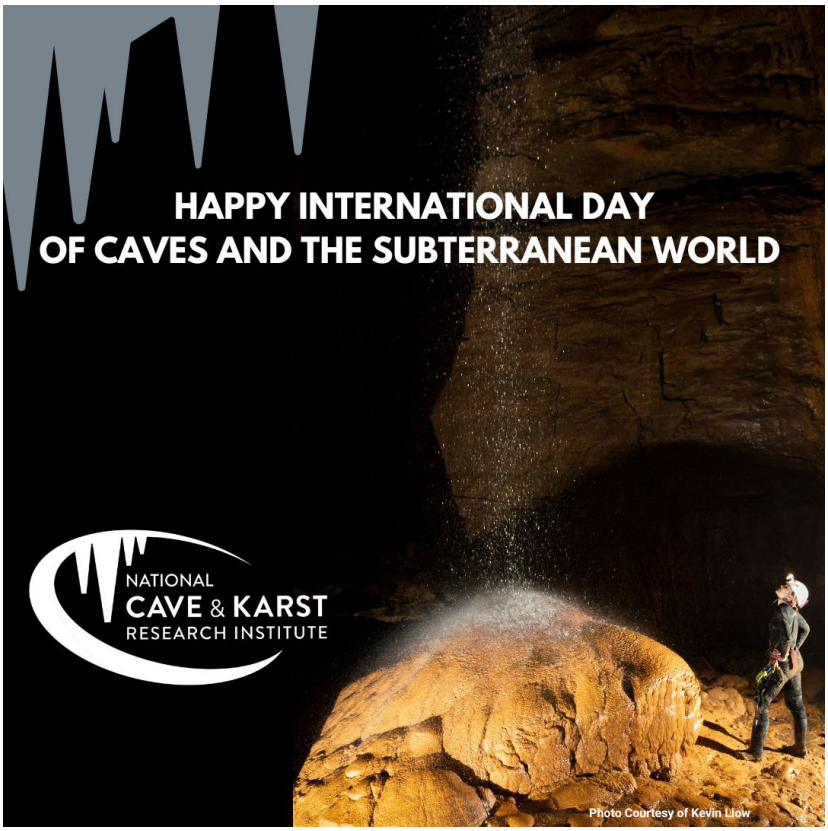
NCKRI's social media makeover has resulted in reaching more people in just the first six months of 2022 than in any of the previous three years!

NCKRI Website and Social Media

Devra Heyer's first major task as Education Program Manager was to complete the upgrade, launch, and transition to NCKRI's new website design. She made improvements large and small throughout the site, most notably adding an easy-to-find and navigate Publications page, where all NCKRI's reports are available for free download. If you haven't seen the new website with all its new features and information, visit it at: www.nckri.org.

With NCKRI's new logo from the previous year and website branding, Devra next focused on giving NCKRI's social media presence a makeover. A new Facebook page, and a restructure of our Twitter and Instagram pages allow the general public and our partners to interact with us more effectively and with more information.

As of the end of June 2022, the new Facebook page had only 600 followers, but it already had reached more people than the old page with its 1,800 followers. As our friends switch to our new Facebook, we expect to surpass the number of previous followers soon. NCKRI has also partnered with outreach initiatives such as World Migratory Bird Day, Bat Week, Earth Day, Earth Science Week, and other large-scale initiatives to help gain exposure and send out our message. Our most liked posts are related to job opportunities such as the National Park Service's Scientist In Park program and outreach events such as Cave Day, Earth Day, and Migratory Bird Day.



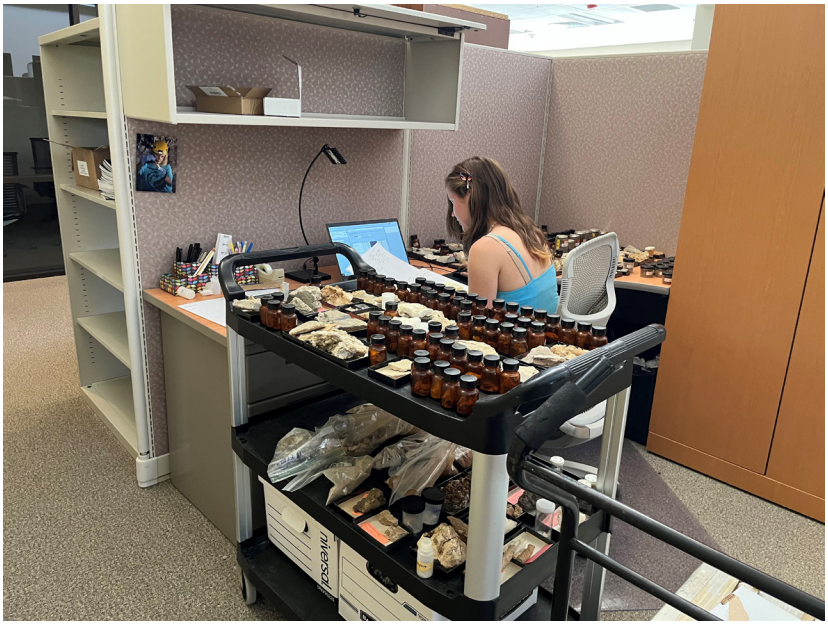
NCKRI's social media makeover includes the work of a new team of excellent cave photographers who are graciously allowing us to use some of their images, such as this social media graphic featuring a photo from Kevin Liow.

DropZone and Exhibits: Opening Soon

The DropZone is outside NCKRI Headquarters and fills our courtyard. It is a 9-m tall exhibit where visitors will immerse themselves in vertical cave exploration. They will learn rope climbing, rappelling, rock climbing, and other techniques used to explore and study caves. Mobile exhibits at ground level offer information about caves and karst, and some of the basic scientific principles in their exploration.

In preparation for the opening of the DropZone, NCKRI staff visited the Roswell UFO Museum to learn more about museum exhibit creation, manufacturing, what works with different audiences, and gift shop strategies and management. Our thanks go to museum Board Chair Jack Swickard and Executive Director Karen Jaramillo for their gracious and eye-opening informative tour.

Following delays by the COVID-19 pandemic, DropZone construction is complete. NCKRI staff were trained by Aerial Designs, the DropZone's ropes course designer, in the special features and safe use of the DropZone. Devra Heyer is now leading the effort to develop a safety and training manual for the DropZone. She is also creating temporary indoor exhibits for when the DropZone opens to the public next year.



NCKRI photo by Devra Heyer.

Riannon Colton curates and organizes mineral and speleothems samples from NCKRI's National Cave Sample Archive.

The DropZone would not have been possible without the generous donation of a City of Carlsbad New Mexico Lodgers Tax grant of over $255,000, and support from New Mexico Tech.

Devra's efforts have been supported by two fabulous volunteers. Geologist Riannon Colton is working on the inventory and curation of our National Cave Sample Archive specimens for use in our research and education programs. Meanwhile, Mike Mansur started building our display cases, which will be installed with interpretive signage showing different karst regions, speleothem types, methods of cave restoration, and the progression of cave exploration technology. We thank them both for their excellent work!

NCKRI photo by Devra Heyer.

Mike Mansur drove nearly 5 hours from Albuquerque, New Mexico, to begin construction of exhibit display cases at NCKRI Headquarters.

Local to International Education and Outreach

NCKRI continues to work closely with the local community. Most of the activities are described later in this report in the Community Involvement section. Notable local education outreach included the creation of a new posters, stickers, and other outreach pieces for Earth Day and STEM Night, hosted by Southeast New Mexico College in Carlsbad. Devra Heyer and Dr. Bou Jaoude are also teaching members of the Pecos Valley Grotto of the National Speleological Society how to map caves.

Moving a little further from Carlsbad, NCKRI's Education Program worked with NCKRI's Academic Program to take Dr. Dan Jones' students underground (see the photo on the next page in the Cave and Karst Studies Program section of this report) to study caves and karst features in southwest New Mexico's Black Range.

The COVID-19 pandemic continued to affect some of our educational outreach but NCKRI staff were invited to give classes, seminars, and educational lectures virtually. Most are listed in the Guest Lecture and Seminar section of this report. NCKRI staff did present two virtual classroom-focused seminars:

- Dr. Daniel Jones: *A STEM introduction to caves, karst, and the geosciences*. 2021 Annual Virtual STEM Education Conference, the Americas Conference of Universities.
- Dr. George Veni: *Cave conservation during and after the International Year of Caves and Karst*. Summer School of Speleothem Science, virtual presentation.

We also supported two in-person national workshops:

- NCKRI sponsored the CaveSim traveling cave exhibit to visit Jewel Cave National Monument, Wind Cave National Park, and the National Speleological Society Convention, all in South Dakota, USA. This interactive STEM education program teaches caving ethics, physics related to caves and karst, and allows people to test their ability in safely traversing a simulated cave environment.

NCKRI photo by Devra Heyer.

Thousands of children and adults climb and crawl through CaveSim each year. This artificial cave provides a safe and fun environment to learn about caves. It also offers other outside educational exhibits and activities. NCKRI sponsored a two-week program by CaveSim this year.

NCKRI photo by Valerie Davis.

Education Program Manager Devra Heyer prepared a groundwater model, karstified rocks, and other instructional materials, plus brochures, stickers, pens, and other items about caves, karst and NCKRI for STEM Night at Southeast New Mexico College. Visitors could take home many of these items to continue learning about caves.

- NCKRI set up a booth and an educational tour of the geology and natural history Devils Sinkhole State Natural Area, Texas, USA, when the National Park Service, Texas Parks and Wildlife Department, and Devils Sinkhole Society celebrated the 50th anniversary of the immense cave chamber's recognition as a National Natural Landmark.
- Drs. Veni and Bou Jaoude traveled to Caverns of Sonora, Texas, to give the guides a special tour and field training on caves, and specifically on the complex origin of their show cave, so they can offer their visitors the most accurate and current information.
- Dr. Patricia Seiser participated in a Denver Museum of Nature and Science public education event, Dia del Niños, which focused on connecting cultural environments to physical ones, including caves and karst.

STUDENT ACTIVITES

Cave and Karst Studies at NMT

Cave and Karst Studies at New Mexico Tech (NMT) is NCKRI's Academic Program, directed by Dr. Daniel Jones. It is designed to provide specialized undergraduate and graduate instruction for students interested in or pursuing a career in the cave and karst sciences.

This was another exciting time for the Cave and Karst Studies program. Over the last year, we supported several new undergraduate research fellowships, and piloted a new Science Communication summer program. With the COVID-19 pandemic decreasing, we also created opportunities for students to learn about cave science through new course offerings and field trips.

Riana Foley and Daniel Runyan were NCKRI's first science communication scholars. Over the summer and early fall of 2021, they participated in a new science communication program, developed by Dr. Jones in partnership with Dr. Graham Lau and the Blue Marble Space Institute of Science's Young Scientist Program. Over the summer, Riana and Daniel interacted with other science communication scholars and participated in communications and ethics training, interviewed professional scientists, and produced several articles. You can see some of their writings at the links below:

- http://sciworthy.com/the-first-climbing-robot-for-mars/
- https://www.bmsis.org/bmsis-scientist-feature-dr-jim-cleaves/
- https://www.bmsis.org/caves-and-culture-el-malpais-national-monument/
- https://sciworthy.com/hawaiian-caves-invaded-by-rats/

Dr. Jones taught classes in Geomicrobiology, Earth History, and a new cave science course called *Introduction to Caves and Karst*. His classes took advantage of New Mexico's amazing geology for field trips to travertine springs, carbonate stratigraphy, and nearby caves. We're lucky to have incredible and diverse geology right in our backyard that allowed us to safely continue class field trips throughout the pandemic. Students in his classes also honed their science communication skills by writing summaries of recent primary literature articles for the website Sciworthy. You can see a sampling of their articles linked below, and read a press release about Jones' science communication class activity here: https://www.nmt.edu/news/2022/sciworthy-stories.php

- https://www.sciworthy.com/could-there-be-ice-in-caves-on-mars/
- https://www.sciworthy.com/antibiotic-resistant-bacteria-are-way-older-than-penicillin/
- https://www.sciworthy.com/what-did-the-ancient-maya-do-to-their-teeth/

More reports are at https://www.sciworthy.com/category/ppp/nmt-caves/

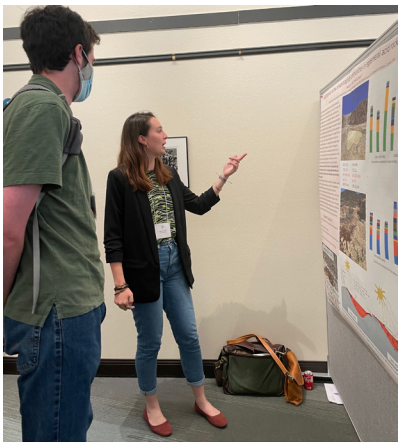
As an extension of NCKRI's Academic Program, Dr. George Veni continued his appointment as a committee member at the Aristotle University of Thessaloniki in Greece for Despina Dora's doctoral dissertation, *Cave morphometric analysis: a contribution to the study and classification of Greek karst caves*. Her dissertation is progressing well and is on schedule. She will soon have some insightful research papers ready for publication.

NCKRI photo by Dan Jones.

NMT students on a field trip to Robinson's Cave in New Mexico's Black Range led by NCKRI's Dr. Dan Jones and Devra Heyer, with assistance from Steve Peerman.

Graduate Student Research

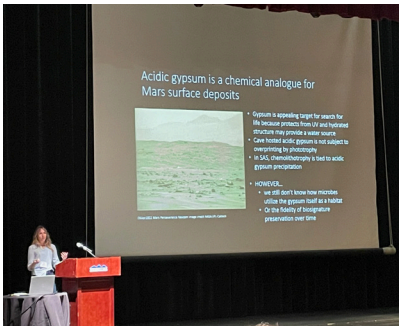
Mackenzie Best is a PhD student in Geobiology, in her second year. She presented her research on extreme acid-adapted microorganisms from Mexico's Cueva de Villa Luz and other areas at several national and regional conferences, including the Geological Society of America and the Astrobiology Science Conference. She was also invited to give a presentation on extremophilic cave microorganisms at the convention for New Mexico's chapter of American Association of University Women (AAUW). In addition to her research, Mackenzie serves as President of the AAUW student club, is on the board for the New Mexico chapter of Quail Forever, and was recently elected as the student trustee of the New Mexico Tech Foundation (the philanthropic branch of NMT).



NCKRI photo by Dan Jones.

Mackenzie Best describes the research in her poster at a conference.

Zoë Havlena is a PhD candidate in Geobiology, in her third year. Zoë presented her research on Lehman Caves in Great Basin National Park, Nevada, USA, and in the Frasassi Caves in Italy, at multiple national and regional meetings including the Geological Society of America fall conference in Portland, Oregon, and the Astrobiology Science Conference (AbSciCon) in Atlanta, Georgia. Zoë received the William B. & Dorothy Heroy Research



NCKRI photo by Dan Jones.

Zoë Havlena presents her research at the New Mexico Geological Society Annual Spring Meeting, where she won Best Student Presentation!

Grant from the Geological Society of America and received NMT's prestigious "Rising Star" award in the fall of 2021 (https://www.nmt.edu/advancement/award_recipients.php). She was also featured in a Scientific American article (https://www.scientificamerican.com/article/how-scientists-could-tell-the-world-if-they-find-alien-life/), and in a NMT press release about a NASA award that she received earlier in the year (https://www.nmt.edu/news/2021/havlena_nasa_grant.php).

Kathryn Hobart is a PhD candidate in Geobiology at the University of Minnesota (UMN), USA, who is co-advised by Dr. Jones and is notable member of his lab team. Kathryn spent the last year teaching as a Visiting Assistant Professor at the University of Minnesota Duluth, supported by a fellowship from the UMN Community of Scholars Program Pre-Doctoral Teaching Fellowship program while she completes her dissertation. She was awarded a prestigious Mendenhall postdoctoral fellowship to work at the US Geological Survey in Reston, Virginia, after she defends her dissertation in the fall of 2022.

NMT-NCKRI Geobiology Lab

This has been a busy year for Dr. Daniel Jones' geobiology lab group at NMT as they returned to the laboratory after the pandemic shut-down and initiating new research. In addition to the exciting student accomplishments above, Dr. Jones and his group published several new papers, and Dr. Jones received new

Photo courtesy of Kathryn Hobart.

Dr. Jones' lab group, summer, 2022. Top, left to right: Zoë Havlena, Katherine Krizek, Katelyn Green, Abigail Brown. Bottom, left to right: Calyssa Huff, Kathyn Hobart, Mackenzie Best. Not in the picture: Dr. Jones, who was social distancing while waiting for a COVID test result.

grants from NASA and the National Science Foundation to work on planetary protection research and to bring new analytical instruments to NMT.

Dr. Jones and his group had a research expedition to the Frasassi Cave System, Italy, in October and November 2021. This NASA-funded fieldwork was conducted to continue their research on acidic gypsum deposits in the cave. They are also pleased that Katelyn Green has joined the lab as a graduate student. Ms. Green graduated with a Bachelor of Science in Biology in spring 2022, and started her Master's research with Dr. Jones during the summer.

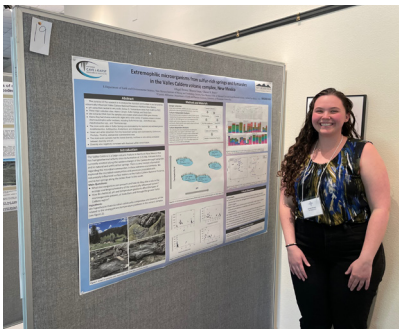
Cave and Karst Research Fellowships for NMT Undergraduates

This was a big year for the Undergraduate Research Opportunities in Caves and Karst (UROCK) fellowship program. We are pleased to say that we were able to support six UROCK scholars from three different departments at NMT during the past year. We present them below starting with a report on a project from a previous year's fellowship recipient.

Abigail Brown, report: *Analysis of extremophilic microorganisms in sulfur-rich travertine springs at Soda Dam, northern New Mexico*.

Ms. Brown continued her work with Dr. Daniel Jones (Earth and Environmental Sciences Department and NCKRI) studying extremophilic microorganisms associated with travertine hot spring deposits at Soda Dam, a fascinating carbonate structure near Jemez Springs, New Mexico. The water flowing from these springs is rich with hydrogen sulfide, which provides energy that supports microbial mat communities that thrive in the springs.

Her microbial and geochemical analyses examine the relationship between the geochemical gradients throughout the hot springs and the microbial communities present. 16S rRNA gene sequencing showed that green and white streamers from the Soda Dam springs were dominated by sulfide-oxidizing microorganisms from the genera *Sulfurovum*, *Thiofaba*, *Thiothrix*, as well as several different types of cyanobacteria, photosynthetic bacteria that thrive in the warm water of the springs.



NCKRI photo by Dan Jones.

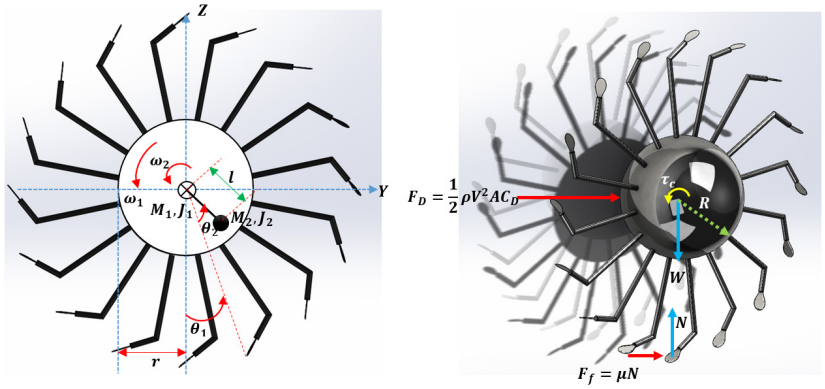
Abigail Brown presenting her award-winning poster at the 2022 New Mexico Geological Society annual spring meeting.

Based on multivariate analyses, Ms. Brown showed that the water temperature and the amount of dissolved hydrogen sulfide and oxygen were the main geochemical factors driving diversity in the Soda Dam springs. Through this work, she identified several interesting extremophilic microorganisms which are known to inhabit similar travertine springs, but for which we know little about how they make their living or their role in stream biogeochemistry. Ms. Brown is continuing to explore the genomic potential of these and other organisms from the site.

Ms. Brown is also studying extremophilic communities in other sulfide rich springs in nearby Valles Caldera National Preserve and comparing them to the Soda Dam communities. She presented her research at three different meetings over the last year, the Rocky Mountain Geobiology Conference in Denver, Colorado; New Mexico Tech's student research symposium; and the New Mexico Geological Society (NMGS) annual spring conference. She won best student poster presentation at the NMGS conference and was featured in the Academic Affairs newsletter for her student research symposium presentation. Ms. Brown is planning to continue on to pursue a Master's degree and obtain her teaching license to pursue a career in secondary education.

Cole Dunning: *Development of a Golden Wheel spider-inspired drone for cave exploration*.

Mr. Dunning is working with Dr. Mostafa Hassanalian (NMT Mechanical Engineering) to develop a new concept for a drone that can autonomously operate in harsh and confined subterranean spaces, based on the Golden Wheel spider's characteristics with rolling,



Graphic courtesy of Cole Dunning.

Cole Dunning's rolling drone concept based on the Golden Wheel spider.

jumping, and folding capabilities. Mr. Dunning's UROCK research resulted in three publications to date:

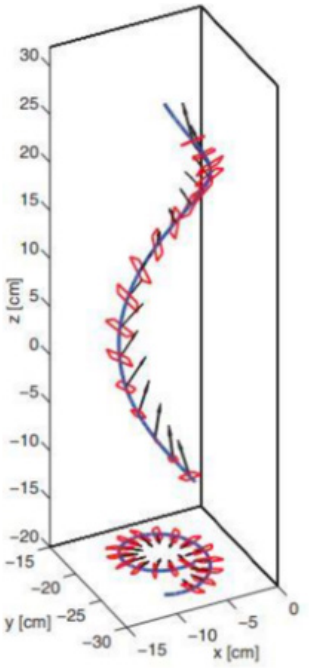
- Dunning, C., Cervantes, R., Velasquez, L., Western, A., Sherman, M., and Hassanalian, M. 2021. Design and manufacturing of a bioinspired spider rolling robot for Mars exploration. AIAA SciTech Forum, Virtual Event.
- Fill, D., Strauss, E., Dunning, C., Western, A., and Hassanalian, M. 2021. Amphibious bioinspired robots for ocean objects identification. In: AIAA Aviation 2021 Forum, p. 2781, Virtual Event, 2–6 August 2021.
- Western, A., Cervantes, R., Dunning, C., Haghshenas Jaryani, M. and Hassanalian, M. 2021. Bioinspired robot with walking, rolling, and jumping capabilities for planetary exploration. In: AIAA Aviation 2021 Forum, p. 2784, Virtual Event, 2–6 August 2021.

Trung Le: ***Aerodynamic stability of a helium-assisted cave research drone***

Mr. Le is assisting Dr. Kooktae Lee (NMT Mechanical Engineering) on his hybrid drone cave exploration project by analyzing the aerodynamics effect on stability and control. Initial flight tests showed that the proposed helium balloon lift system causes some flight instability. Mr. Le will analyze the drone's stability, including through the use of other aerodynamic models, and devise a solution to stabilize it during flight.

Jesse Montano: ***Development of LiDAR data collection software for drone-based cave research***

Mr. Montano is also working with Dr. Kooktae Lee and his graduate student Geronimo Macias on their hybrid drone project. Mr. Montano's portion of the study will involve investigating various



Graphic courtesy of Trung Le.

Trung Le's evaluation of a drifting piece of paper, used to evaluate cave drone stabilization methods.

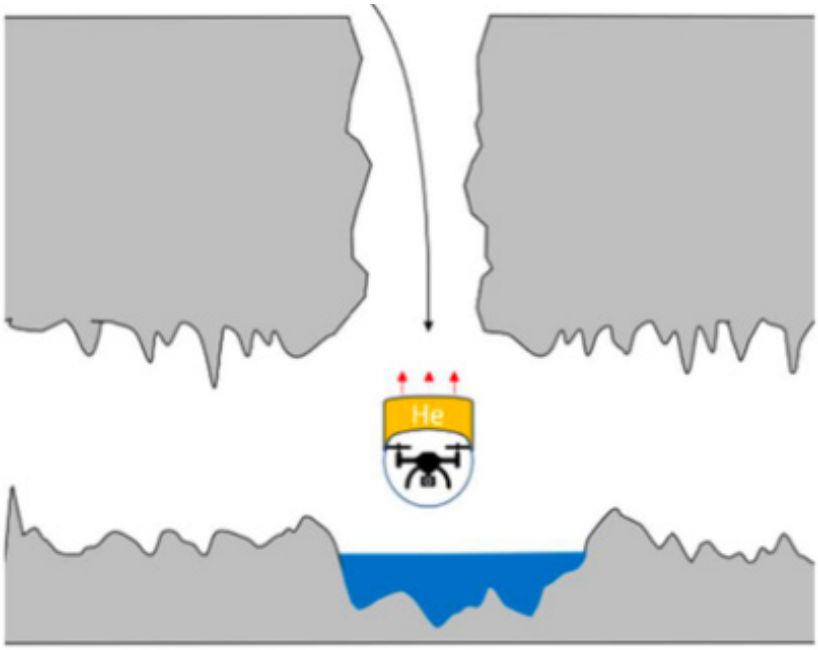
LiDAR technologies and developing software to allow the hybrid drone to collect data for 3D mapping as it travels, thus bolstering its autonomous capabilities.

Emma Piercey: ***Evaluation of carbonate clay ceramic water filters***

Ms. Piercey is working with Dr. Michael Schaefer (NMT Earth and Environmental Science) to study ceramic water filters created out of carbonate-rich clay from Guanajuato, Mexico. Access to safe drinking water is a human right. While karst aquifers are the primary water supply for about 700 million people, they also are some of the most vulnerable to contamination

Ceramic water filters are a low-cost and effective technology used to remove pathogens. A single filter from the company Caminos de Agua, for example, can filter up to 30,000 liters of pathogen-free drinking water supplying drinking water for a family for about 5 years. However, depending on the source material, the firing process can also release harmful elements.

Ms. Piercey will study the geochemical changes that occur when these carbonate-rich clays are fired and evaluate whether and how arsenic, lead, and fluoride are leached from the source material.



Graphic courtesy of Jesse Montano.

This image conceptually illustrates the use of a helium-assisted drone mapping while exploring a cave with LiDAR, with technologies in development by Jesse Montano.

Photo courtesy of Emma Piercey.

A ceramic filter used in leaching experiments for Emma Piercey's water filter research.

Graphic courtesy of Michael Taylor.

Michael Taylor's underground vehicle drone concept is superimposed on a cave photo.

Alexandra Sartori: ***Use of earthquakes to geophysically explore and evaluate caves***

Ms. Sartori was awarded a UROCK fellowship to work with Dr. Susan Bilek (NMT Earth and Environmental Science) on an application of geophysical methods in the study of karst aquifer systems. They will use earthquake signals generated regionally and globally to explore the cave system in O'Leno State Park near Gainesville, Florida, USA.

Ms. Sartori will explore changes in the amplitudes of the seismic waves that are dependent on whether the station was above the conduit or not, to evaluate how seismological activity outside of the immediate vicinity impacts the karst aquifer system and its seismological readings.

Michael Taylor: ***Housing unit development for a drone-based underground vehicle***

Mr. Taylor is working with Dr. Mostafa Hassanalian (NMT Mechanical Engineering) on a project that seeks to combine an underground vehicle (UGV) with a drone. The goal is to merge the payload capacity and battery life of a UGV with the extended field of view and greater maneuverability of a drone, which are critically important to moving through a cave. Mr. Taylor's project focuses on developing the housing unit.

NCKRI photo by George Veni.

The Santa Fe River sinks in Florida's O'Leno State Park into a water-filled cave system, which is the subject of Alexandra Sartori's UROCK geophysical research.

Student Opportunities at NMT

New Mexico Tech is highly ranked among US universities in several important categories. It focuses on STEM (Science, Technology, Engineering, and Mathematics) programs, which makes it an ideal home for NCKRI. For students interested in caves and karst, great opportunities exist not just in geology and biology but engineering, chemistry, robotics, and other fields, as seen here with our diverse UROCK student projects.

For more information, visit www.nmt.edu. To learn more about NCKRI's Cave and Karst Studies Program at NMT, contact Dr. Daniel Jones at daniel.s.jones@nmt.edu

NATIONAL PARK SERVICE – NCKRI LIAISON PROGRAM

The National Park Service (NPS) – NCKRI Liaison Program is where a NCKRI employee works 75% of the time as the NPS Cave and Karst Program Coordinator and 25% on NCKRI caves and karst management projects. Dr. Patricia Seiser conducts this program as NCKRI Cave and Karst Management Science Director. She works in the NPS Geologic Resource Division offices in Lakewood, Colorado. Below are some of her projects and accomplishments over the past year.

Cave and Karst Resources Inventory Tracker (CKRIT) Database

Databases are critical to effective cave research, management, and exploration. Currently each NPS unit maintains it's own database(s) relative to cave, karst and psuedokarst data. What is lacking is a unified system that maintains each park's unique and often sensitive data while offering a consolidation of non-sensitive data for upper management use. Concerns about the security of data on many of the country's most precious caves held back efforts to organize a national database, until now.

This project started by viewing the US Forest Service's (USFS) cave and karst database. Discussions with Lima Soto, USFS Cave and Karst Program Coordinator and Jack Wood, NPS Physical Scientist, helped solidify a description of the database needs and potential issues before kicking it off with the software development team.

The goal of the database was defined to serve as a management tool for park units with caves, karst, and pseudokarst. The database would contain a wide variety of information and links to stored files and NPS records with both restricted and unrestricted access.

The initial database game plan was for a relatively static database with limited GIS capabilities. Upon engaging with NPS cave management personal participating in the development of the database, it was quickly apparent that this initial plan would not meet their needs. A shift was made in the direction of the database program to create a geocentric database that would meet the needs of the various parks and from which non-sensitive information could be passed on to the Washington Office level of the NPS without compromising the security of the cave data.

A Scientist In Parks (SIP) internship was created to test and implement the database as originally envisioned. The individual would need a basic understanding of databases as well as a basic understanding of cave management concerns and database needs.

Georgia Schneider, a Denver caver, was selected for this internship position. Georgia had completed a certificate in GIS and is involved in a variety of cave mapping projects throughout the US and internationally. She brought a level of expertise needed for this project, which was named with the acronym, CKRIT ("secret"), as a reminder of the need for data security.

The change to a geocentric database required changing who and how the cave database would be developed. Georgia was up to the challenge. However, it was recognized that this project went well beyond the purview of an internship and as a result, through an agreement with the University of Denver, a masters program was funded. Georgia will begin graduate school in Fall of 2022 walking into the door with a national project for the NPS. As an added bonus, her advisor worked as a ranger at Carlsbad Caverns National Park in the 1970s. He brings his understanding of cave management needs and understanding of security needs to the project.

The results of the project will be a database built from park units' needs that maintains strict security with the ability to report non-sensitive data for upper management and public information needs. The anticipated completion of the database is the end of 2024.

NCKRI photo by George Veni.

Mammoth Cave National Park, Kentucky, USA, contains not only the world's longest cave, but many other caves and diverse resources. The Snowball Dining Room alone has many important, geologic, and historic resources which the CKRIT database will help to better track, study, and protect, along with other National Park Service cave, karst, and pseudokarst resources.

Timpanogos National Monument Resource Stewardship Strategy

The NPS has a Resource Stewardship Strategy program designed to aid individual park units in meeting their legislative duties including prioritizing resource management needs. The teams included subject matter experts from all resource management concerns including caves and karst. The goal of the program is to create a long-range planning document that aligns with the park unit's foundation document and general management plans. It is a strategic approach to managing and protecting park resources over time.

The Resource Stewardship team evaluates the status and trends in the condition of various national park resources and uses the information to provide a basis for making resource decisions and working with other agencies and the public for the long-term protection of park resources. It also assures the park managers meet the requirements of resource stewardship under law and policy. This approximate six-month effort of meetings with park staff culminates in an onsite meeting to solidify understanding of park issues and staff needs.

This year's project was conducted at Timpanogos Cave National Monument, which protects Timpanogos Cave Historic District and a cave system on Mount Timpanogos in American Fork Canyon in the Wasatch Range, near Highland, Utah, USA. The staff there provide stewardship for a small but amazing cave and karst resource area.

NCKRI photo by Pat Seiser.

The entrance of Timpanogos Cave.

Photo courtesy of Georgia Schneider.

Dr. Pat Seiser at Yellowstone National Park during her first reconnaissance investigation of cave and karst management needs at this iconic park.

Junior Bat Biologist Booklet

During the past year, the NPS and USFS released the Spanish version of the Junior Cave Scientist booklet. Spearheaded by Lima Soto, the USFS Cave and Karst Program Coordinator, this effort inspired the creation of a Junior Bat Biologist booklet in both English and Spanish versions. This program builds on Hot Springs National Monument's, Carlsbad Caverns National Park's, and Lava Beds National Monument's individual Junior Bat Biologist programs.

Two interns, Miranda Axelson and Joanna Lam, volunteered to create this national level booklet. They have met biweekly with personal from NCKRI, NPS, USFS, and Bat Conservation International. After the initial kickoff, Devra Heyer, NCKRI's Education Program Manager, took the lead on this project to ensure it met necessary multi-age educational requirements. We anticipate publication by October 2022 in time for Bat Week, an international celebration of bats.

Yellowstone National Park Technical Assist Review

Yellowstone National Park is evaluating its geological resources to understand obstacles from a wildlife standpoint (bison, bears, and wolves). Dr. Seiser, and her intern Georgia Schneider, conducted reconnaissance trip to plan future visits for inventorying and mapping the park's cave and karst resources.

NCKRI PARTNERS AND FRIENDS

Membership

NCKRI's Annual Membership program is offered to all interested persons wanting to support NCKRI activities. You can join online at www.nckri.org or call us at 575-887-5518. When you become a member, you will receive reduced rates on publications, special presentations, classes, lectures, and facility rentals, and in the future, discounts in the museum store.

NCKRI Partners

NCKRI recognizes four levels of partnership and uses their descriptions below in defining its relationships with NCKRI partners:

Founding Partners

NCKRI's Founding Partners played a crucial role in the creation of the Institute and continue to serve as major supporting partners.

- City of Carlsbad
- New Mexico Institute of Mining and Technology
- US National Park Service

Institutional Partners

Organizations with formally defined, mutually supportive relationships with NCKRI through Memoranda of Agreement, Memoranda of Understanding, contracts, or other written and signed agreements, in effect for periods of at least one year, and which define each party's specific roles and responsibilities.

- American Geosciences Institute
- Carlsbad Caverns National Park
- Emil Racovita Institute of Speleology (Romania)
- Guadalupe Mountains National Park
- International Research Center on Karst (China)
- Instituto do Carste (Brazil)
- International Academy of Karst Sciences
- International Union of Speleology
- Karst Research Institute
- New Mexico Bureau of Geology and Mineral Resources
- US Bureau of Land Management
- US Forest Service
- US Geological Survey
- University of New Mexico
- University of South Florida

NCKRI Affiliates

Organizations that demonstrate meaningful support for NCKRI and its goals, or their intent to do so, but without a formal defining agreement. NCKRI and its Affiliates exchange news and information, and coordinate and/or cooperate with each other in projects and activities. Each organization may also extend other benefits according to their internal rules and abilities.

- Bat Conservation International
- Carlsbad Chamber of Commerce
- Carlsbad Municipal Schools
- Edwards Aquifer Authority
- Fort Stanton Cave Study Project
- Karst Waters Institute
- Living Desert Zoo & Botanical Gardens State Park
- National Caves Association
- National Speleological Society
- NASA
- Southeast New Mexico College
- US Bureau of Land Management
- US Fish and Wildlife Service

NCKRI Volunteers

Many of our programs and projects rely on the help of our volunteers. We thank the following individuals for supporting NCKRI:

- Jennifer Adkins-Schudrowitz
- Dr. Calvin Alexander
- Frank Binney
- Tyrone Black
- Tom Brown
- Pat Bryan
- Connie Campbell Brashear
- Michael Byle
- Jesse Chadwick
- Riannon Colton
- Rick Corbell
- Jon Cradit
- Jon Davis
- Dr. David Decker
- Joel Despain
- Ethan Fagan
- Jim Funk
- Dr. Yongli Gao
- Crystal Grafft
- Wilzave Guzman
- David Harro
- Tobin Hays
- Stephen Hernandez
- Jessica Heyer
- Fran Hutchins
- Peter Hutchinson
- Dr. Said Iravani
- Joel King
- Dr. Mio Kitano
- Clint Kromhout
- Michael Jones
- Niki Lake
- Dr. Jim LaMoreaux
- Kevin Liow
- Alicia Luna
- Mike Mansur
- Jesse McCloskey
- Kurt Menking
- Dr. Evelynn Mitchell
- Michael Moffitt
- Michael Polendo
- Gheorghe Ponta
- Gary Poole
- Ron Ralph
- Marco Ramos
- Steve Rice
- Dr. Ira Sasowsky
- Richard Silver

- Dr. Brian Smith
- Stefan Solowiow
- J. Brad Stephenson
- Chris Stroud
- Simeon B. Suter
- Matthew Taylor
- Mike Tudor
- Dr. Sharon Weaver
- Dr. Blake Weissling
- Keith White
- Dr. Wanfang Zhou

Annual Giving

Our Annual Giving Program recognizes those individuals and organizations who joined as members or provided goods, services, and/or financial gifts to NCKRI during FY 2021-2022. We especially thank the following considering the financial difficulties imposed by the pandemic this year.

- Tom Bemis
- Brecon Estates and Damian Grindley
- Cascade Caverns and Lance Kyle
- Austin Clark
- Paul and Sandra Cosand
- Bob Forrest
- Amy Hourigan
- Ted Lee
- Morghan McCool
- Matthew Mele
- Jessica Peluso
- Bru Randall
- James Reddell
- Jesse Richardson
- Neville Ritchie
- Raj Sam
- Sew What and Liz Thompson
- Texas Speleological Survey
- Dr. George and Karen Veni
- Brooks Willis

Rentals

NCKRI Headquarters is available again for private event rentals. We have a large conference room and a smaller board room which have held a wide variety of meetings and parties. We also have six cubicles for those seeking temporary or long-term office space. Call 575-887-5518 for information!

CONFERENCES AND MEETINGS

Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts on Karst: Tampa, Florida

Commonly called the "Sinkhole Conference," this NCKRI conference series is the longest running international meeting to exchange state-of-art information on engineering and environmental work on all aspects of karst—and not just sinkholes!

Following a delay due to the COVID-19 pandemic, the 17th Sinkhole Conference will be held in partnership with the University of South Florida's School of Geosciences in Tampa, USA, from 27-31 March 2023. Unlike previous conferences in this series, all short courses are included in the price of registration to encourage more registrations, especially by students since we will meet at a university. A livestreaming option will also be offered for the first time for those who cannot attend in person.

The conference will start with a full day field trip and end with a half-day trip. In between there will be many papers, keynote and banquet presentations from prominent experts, two social networking receptions, and a panel discussion on karst environmental assessment and other karst standards under development at ASTM International. Additionally, the Karst Commission of the International Association of Hydrogeologists will have their annual meeting at the conference.

As before, the Beck Student Support Fund will provide free registration, field trips, and short courses for all selected students, plus up to $1,000 in travel expenses. To learn more the conference, register, or to donate or apply for the Beck Student Fund, visit http://www.sinkholeconference.com/. To download the proceedings of the Sinkhole Conferences NCKRI has hosted since 2013, and other NCKRI publications, visit www.nckri.org.

Above is the front half of a postcard used to advertise the Sinkhole Conference. NCKRI organizes the conference with the assistance of an outstanding group of geoscience professionals who volunteer their expertise to expand the world's knowledge on all engineering and environmental karst and sinkhole research and management topics. Our thanks go to Tyrone Black for designing this postcard.

OUTREACH

NCKRI News

Perhaps NCKRI's most popular and best-known service is its e-mail list. About twice each month we send cave and karst news and announcements directly to thousands of people around the world, including by their request the national e-mail list of cavers in seven countries. This news isn't just from NCKRI but from friends and partners internationally. The messages include announcements about cave and karst conferences, job and grant opportunities, books, training, and other diverse topics. We don't sell our list or send junk mail to anyone, and there is no pressure or cost to join. If you would like to be added individually or have your group list added, simply e-mail us your request at info@nckri.org.

Professional Partnerships and Karst Standards

NCKRI values its partnerships with many organizations around the world, and the sincere friendships we've built with scores of their members. In addition to the projects and events with partners we've presented elsewhere in this report, we highlight here NCKRI's partnership with ASTM International. NCKRI is a member of this global standardization organization.

ASTM created Subcommittee D18.27 on karst in 2020, which is chaired by NCKRI's Dr. George Veni. During the past year, the subcommittee met twice, virtually in January 2022 and in person in Seattle, Washington, in June 2022. The subcommittee is focused on karst and pseudokarst properties, characterization, and the prevention and remediation of karst geohazards. Two standards on karst characterization and initial environmental assessments of karst are being balloted as this annual report is being prepared, and other standards are in development.

A major goal of D18.27 is to develop globally recognized guidance for conducting environmental and engineering studies in karst, especially to assist those lacking specific karst training. To join the subcommittee, whether an ASTM member or not, contact Dr. Veni at gveni@nckri.org.

Professional Meetings

NCKRI again attended and/or sponsored many conferences during the past year:

- ASTM International (Winter 2022) Conference (virtual)
- ASTM International (Summer 2022) Conference, Seattle, Washington, USA
- Geological Society of America Convention, Portland, Oregon, USA
- National Cave and Karst Management Symposium, San Marcos, Texas, USA
- National Speleological Society Convention, Rapid City, South Dakota, USA
- New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Conference, Socorro, New Mexico, USA
- New Mexico Northern Wetlands Roundtable (virtual)
- New Mexico Southern Wetlands Roundtable (virtual)
- Southwestern Region of the National Speleological Society, Winter Technical Meeting, Las Cruces, New Mexico, USA
- University of South Florida Near-Surface Geophysics Workshop, Tampa, Florida, USA
- White-nose Syndrome National Meeting (virtual)

NCKRI staff also organized or co-organized the following events:

- Annual Virtual STEM Education Conference, The Americas Conference of Universities (Dr. Daniel Jones, Panel Discussion Chair on *Conducting Research and Higher Education in the Time of COVID)*.
- Astrobiology Science Conference National Meeting, Atlanta, Georgia, USA (Dr. Daniel Jones, Session Chair of *Acidophiles and Their Mineral Habitats* and *Voids as Targets for Astrobiology Science*).
- EuroKarst 2022, Malaga, Spain (Dr. George Veni, Scientific Committee Member).
- Geological Society of America Convention, Portland, Oregon, USA (Dr. Daniel Jones, Session Co-Chair of *New Frontiers in Cave and Karst Research: In Honor of the International Year*

NCKRI photo by George Veni.

Seattle, Washington, is not known for caves but members of the ASTM Karst Subcommittee meeting there got underground. Some of the city's first streets are still accessible but buried under modern roads, and some trigger sinkholes that can be studied for comparison to natural sinkholes.

NCKRI photo by George Veni.

Drs. Pat Seiser and Lewis Land visit with guests to the NCKRI booth at the Geological Society of America Convention in Portland, Oregon.

of Caves and Karst; Dr. Lewis Land, Chair of Karst Division, organizer of division business meeting and awards ceremony).

- Importance, State of the Art, and Prospective of Utilization and Protection of Resources in Karst, Belgrade, Serbia (Dr. George Veni, Honorary Committee Member).
- International Show Caves Association Congress, San Antonio, Texas, USA (Dr. George Veni, Organizing Committee Member).
- 17th Multidisciplinary Conferences on Sinkholes and the Engineering and Environmental Impacts on Karst, Tampa, Florida, USA (Dr. Lewis Land, Proceedings Editor; Dr. George Veni, Conference Co-Chair.
- 23rd National Cave and Karst Management Symposium, San Marcos, Texas (Devra Heyer Session Chair for *Collaboration in Karst*; Dr. George Veni, Field Trip Organizer).
- National Speleological Society, Rapid City, South Dakota, USA (Devra Heyer, Instructor for Junior Speleological Society [JSS] survey and inventory class and JSS field trip leader; Dr. Pat Seiser, Session Chair for *Cave Conservation*).

Guest Lectures and Seminars by NCKRI

NCKRI staff were invited to give the following presentations and lectures.

Dr. Issam Bou Jaoude:

- *An introduction to the karst of Lebanon*. Pecos Valley Grotto of the National Speleological Society, Carlsbad, New Mexico, USA.
- *Dams in karst in Lebanon*. Texas Hydro~Geo Workshop, Cave Without A Name, Texas, USA.

Devra Heyer:

- *Caves of China: a tale of cowboys and weavers journeys into the southeast China karst region from 2010-2016*. Contra Costa Public Library, https://youtu.be/G39UB8TVypY.
- *Groundwater model*. National Speleological Society webinar, https://www.youtube.com/watch?v=J_JerB2q6FY.
- *If you learn how to cave, what else do you learn? What makes a cave expert*. Escabrosa Grotto Inc., of the National Speleological Society.
- *Intro to cave survey and cartography: why do we make cave maps? What to expect*. National Speleological Society 2022 Convention, Rapid City, South Dakota, USA.
- *Science and exploration in caves*. Effingham College & Career Academy.

Dr. Dan Jones:

- *Cave microbiology*, Environmental Microbiology (BIOL 344), New Mexico Tech, USA.
- *Sulfuric acid caves and the microbes that make them*. University of New Mexico, USA, Earth and Planetary Sciences.

Dr. Lewis Land:

- Lesson on the environmental impact of fracking to Ms. Esther Kovari's middle school class in Santa Fe, New Mexico, USA.
- Evaporite karst hydrogeologic field seminar. Students from the University of South Florida, Carlsbad, New Mexico, USA.

Dr. George Veni:

- *An introduction to karst and karst ecosystems in the Camp Bullis Sentinel Landscape*. Invited virtual presentation to the Camp Bullis Sentinel Landscape Partnership, San Antonio, Texas, USA (virtual).
- *Comal County, Texas: opportunities and challenges within the International Year of Caves and Karst*. Comal County Conservation Alliance, New Braunfels, Texas, USA (virtual).

- *Earth science and the International Year of Caves and Karst*. Water Today and for the Future webinar for Earth Science Week, American Geosciences Institute, Alexandria, Virginia, USA (virtual), https://www.americangeosciences.org/webinars/earth-science-and-international-year-caves-and-karst.
- *From the karst of the world to deep in the karst of Texas*. Diving Deep in Karst. Webinar, Wimberley Valley Watershed Association and Trinity Edwards Springs Protection Association, Texas, USA, https://wimberleywatershed.org/2021/09/09/diving-deep-into-karst-webinar/.
- *Geology, karst, and the origin of the Devil's Sinkhole*. 50th National Natural Landmark Anniversary Celebration of Devil's Sinkhole, Texas. Devil's Sinkhole State Natural Area, Texas Parks and Wildlife Department, USA.
- *Opening comments and welcome to the International Year of Caves and Karst*. 2nd Colombian Congress of Speleology, EspeleoCol, Colombia (virtual).
- *Opening comments and welcome to the International Year of Caves and Karst*. 2nd Moroccan National Congress of Speleology, Oujda, Morocco (virtual).
- *Steps in conducting environmental impact assessments in karst*. 1st International Webinar on Karst and Caves, Karstological Study Group, PUC Minas University, Brazil (virtual).
- *The International Union of Speleology and International Association of Hydrogeologists: working together beyond the International Year of Caves and Karst*. International Association of Hydrogeologists Karst Commission meeting, Malaga, Spain (virtual).
- *The International Year of Caves and Karst: the Crossroads of the Geosciences*. NCKRI and Earth and Environmental Sciences Department Seminar Series, New Mexico Tech, Socorro, New Mexico, USA.
- *Welcome address to the International Year of Caves and Karst celebration*. United National Educational, Scientific, and Cultural Organization, Paris, France, https://www.youtube.com/watch?v=6-ylDYpPfjQ.
- *Welcome to the International Year of Caves and Karst*. Invited virtual address to the International academic exchange in cave and karst studies: strengthening alliances between the United States and Mexico through UNESCO scientific programs, Cancun, Mexico, and Bowling Green, Kentucky, USA (virtual).
- *Why an International Year of Caves and Karst? Examples from central Texas*. Alamo Chapter, Air and Waste Management Association, San Antonio, Texas, USA (virtual).
- *You and the Central Ohio Grotto's role in the International Year of Caves and Karst*. Central Ohio Grotto, Columbus, Ohio, USA (virtual).
- *Your Role in the Texas Hydro~Geo Workshop During the International Year of Caves and Karst*. Texas Hydro~Geo Workshop, Cave Without A Name, Texas, USA.

International Involvement

NCKRI is an Affiliated Organization of the International Union of Speleology (UIS) where Dr. George Veni is serving a four-year term as UIS President—extended to five years because of the COVID-19 pandemic. The goals of NCKRI and UIS overlap, resulting in mutually supportive projects. Our longstanding joint project is with the Karst Information Portal, and our current major joint project is the International Year of Caves and Karst, both described earlier in this report.

Related to the UIS, International Year, and other international efforts, NCKRI staff serve on the United Nations Non-Governmental Organizations Major Group and on the International Union for the Conservation of Nature's (IUCN) Cave and Karst Specialist and Geoheritage groups. While caves are clearly an established priority for the IUCN, UIS and NCKRI are working to bring cave and karst issues to the United Nations.

National Involvement

- NCKRI is an Associated Society of the American Geosciences Institute and the Geological Society of America and meets with those organizations regularly.
- Dr. Pat Seiser represents NCKRI on the Steering Committee for the National Cave and Karst Management Symposium, which is held every two years.
- Devra Heyer is not only NCKRI's Education Program Manager but is also the Education Division Chief of the National Speleological Society (NSS), building synergy to better support both organizations. She also serves on the NSS Vertical Training Commission Advisory Board, and hosted three NSS webinars.
- NCKRI is an organizational member of the US Fish and Wildlife Service's White-nose Syndrome Stakeholder Committee.
- NCKRI staff serve three major positions in the Karst Division of the Geological Society of America Karst Division: Dr. Lewis Land, Chair; Dr. Daniel Jones, Secretary; Dr. George Veni, Advisor.

Community Involvement

NCKRI is always excited to show community support and stays involved in many ways. For several years we have hosted the monthly meetings of the Pecos Valley Grotto

of the National Speleological Society on the third Thursday of each month at 7 p.m. Anyone interested in cave exploration and cave research is welcome to attend.

NCKRI also partnered with local cavers and cave management organizations on a variety of projects:

- Worked with the Bureau of Land Management and the Southwestern Region of the National Speleological to initiate a sinkhole clean-up project on public lands. The first event was of course on Earth Day weekend and to celebrate the International Year of Caves and Karst. Approximately 2 tons of metal were recycled and non-recyclables were disposed appropriately.
- Devra Heyer organized a series of survey and mapping meetups for the Pecos Valley Grotto, and recruited assistance from Drs. Issam Bou Jaoude and Patricia Seiser.
- This trio also participated in the Pecos Valley Grotto's annual clean-up of Skyline Road in Carlsbad, a karst landscape on the way to the Living Desert Zoo and Gardens State Park.
- NCKRI personnel also volunteered to assist in native seed collection, speleothem repair in backcountry caves, radon readings, guano sampling, and mapping surveys at Carlsbad Caverns National Park.

Outside of the local caving community, NCKRI staff also:

- Regularly attended board meetings of the Carlsbad Chamber of Commerce Nonprofit Advisory Committee, Carlsbad Department of Development, and participated in related activities supporting new businesses and community leaders.
- Continued supporting the recently completed brine well cavity remediation by co-chairing the State's Brine Well Authority's Technical Committee and educating the public about the situation.

NCKRI photo by Devra Heyer.

NCKRI's Operations Director Valerie Davis, and husband Jon, celebrate Earth Day with Smokey Bear of the US Forest Service.

Media

NCKRI staff were interviewed and featured in local to international media this year, including:

- *Land expert warns about new roads: karst-heavy Kendall County full of swallets*. Zachary-Taylor Wright, The Boerne Star, 6 July 2021, p. 1, 5. https://www.boernestar.com/article/news/land-expert-warns-about-new-roads
- *Texas Parks and Wildlife votes preservation over development for Honey Creek ranch*. Elena Bruess, San Antonio Express-News, 26 August 2021, https://www.expressnews.com/news/local/article/Texas-Parks-Honey-Creek-Ranch-San-Antonio-16414142.php?sid=5ad9eeabcdb7ec63237d-23b4&utm_source=newsletter&utm_medium=email&utm_content=headlines&utm_campaign=SAEN_210Report
- *Devil's Sinkhole celebrates its golden anniversary October 1-2*. Emma Barnebey, Concho Valley Homepage.com, 18 September 2021, https://www.conchovalleyhomepage.com/news/devils-sinkhole-celebrates-its-golden-anniversary-october-1-2/
- *The Caving Podcast: Devra Heyer*. https://www.podomatic.com/podcasts/cavingpodcast/episodes/2021-11-01T08_39_26-07_00
- *Southwest Chapter News*. The Explorers Log, 54(1):15, February 2022.
- *On the lookout for trash: cavers clean century-old contaminants from Edwards Aquifer recharge*. Elena Breuss. San Antonio

Express-News, 14 February 2022, https://www.expressnews.com/news/local/article/Edwards-Aquifer-trash-16918090.php?sid=5b0234ea24c17c5e3d919b81&utm_source=newsletter&utm_medium=email&utm_content=headlines&utm_campaign=SAEN_210Report

- *What lies beneath*. Melissa Gaskill, Texas Highways, 9 March 2022, https://texashighways.com/travel/outdoors/9-caves-in-texas-tour-for-day-of-pure-exploration/
- *Standards enter the cave: new standards promise to increase awareness of karst, the otherworldly topography associated with caves*. Rich Wilhelm, Standardization News, May/June 2022, https://sn.astm.org/?q=features/standards-enter-caves-mj22.html
- *A deep dive: explorers map the recent history of the state's deepest ancient cave*. W.F. Strong, Texas Co-op Power, May 2022, p. 29, https://texascooppower.com/a-deep-dive/
- *Giant sinkhole with a forest inside found in China*. Stephanie Pappas, Live Science, 11 May 2022, https://www.livescience.com/new-sinkhole-discovered-china?utm_source=SmartBrief&utm_medium=email&utm_campaign=368B3745-DDE0-4A69-A2E8-62503D85375D&utm_content=32AADDE9-8C04-4437-8806-D22B3941B400&utm_term=36cfd259-08f4-4230-b806-349e492b61cc
- *Enormous sinkhole with ancient forest inside discovered in China*. Robyn White, Newsweek, 12 May 2022, https://www.newsweek.com/enormous-sinkhole-ancient-forest-discovered-china-1705906
- *China scientists stunned as huge sinkhole found hiding ancient forest: 'Spectacular!'* Antony Ashkenaz, Express, 12 May 2022, https://www.express.co.uk/news/science/1609301/china-sinkhole-ancient-forest-spectacular-karst
- *Guangxi China's giant 630-feet sinkhole secretly houses a lively forest with caves, tall trees*. Ron Jefferson, The Science Times, 12 May 2022, https://www.sciencetimes.com/articles/37633/20220512/guangxi-china-s-giant-630-feet-sinkhole-secretly-houses-lively.htm
- *Explained: What Lies Inside China's Newly Discovered Giant Sinkhole?* Deepanshu Kainthola, Tatsat Chronicle, 13 May 2022, https://tatsatchronicle.com/explained-what-lies-inside-chinas-newly-discovered-giant-sinkhole/
- *Southwest Chapter news*. The Explorers Log, 54(2):18, May 2022.
- *Spelunkers discover a massive sinkhole in southern China—with a forest at the bottom*. Kaleena Fraga, All That's Interesting, 16 May 2022, https://allthatsinteresting.com/china-sinkhole-forest
- *The Sorcerer's Cave is the deepest—and possibly longest—cave in Texas*. W.F. Strong, The Texas Standard, Texas Public Radio, 18 May 2022 https://www.texasstandard.org/stories/the-sorcerers-cave-is-the-deepest-and-possibly-longest-cave-in-texas/
- *Giant sinkhole with ancient, underground forest discovered in China*. USA Today, 18 May, https://www.usatoday.com/videos/news/world/2022/05/18/giant-sinkhole-ancient-underground-forest-discovered-china/9743974002/
- *Cave explorers discover 'heavenly' sinkhole surprise living down below*. Marianne Mizera, AccuWeather, 18 May, https://www.accuweather.com/en/weather-news/cave-explorers-discover-giant-sinkhole-forest-in-china/1188921
- *Chinese scientists find massive 630 ft-deep sinkhole with an entire hidden forest inside*. Stuti Mishra, Yahoo News, 19 May 2022, https://au.news.yahoo.com/chinese-scientists-massive-630ft-deep-063955505.html
- *In a massive Chinese sinkhole, scientists find a secret forest*. Marisa Iati, Washington Post, 19 May 2022, https://www.washingtonpost.com/world/2022/05/19/sinkhole-forest-china/
- Radio interview with Dr. George Veni about a sinkhole discovery in China. Margie Shafer, KCBS Radio San Francisco, 20 May 2022, https://www.audacy.com/kcbsradio
- Internet news interview with Dr. George Veni: *Científicos Chinos encuentran profundo agujero con un bosque primitive*. Andrés Infante, Ecos del Combeinma 790 AM, 20 May 2022, https://www.ecosdelcombeima.com/internacional/nota-191007-descubierta-cueva-en-china-cuyo-interior-sorprendio-los-cientificos
- *Scientists have found hidden caves, forest in a sinkhole*. WKRC Local 12.com, 29 May 2022, https://local12.com/news/offbeat/scientists-have-found-a-hidden-forest-found-in-a-sinkhole-woods-trees-vegetation-karst-geology-science-research-explorers-topography-bedrock-guangxi-zhuang-autonomous-region-leye-cincinnati-ohio
- *Explorers in China find prehistoric forest hidden in giant sinkhole*. The Optimist Daily, 31 May 2022, https://www.optimistdaily.com/2022/05/explorers-in-china-find-prehistoric-forest-hidden-in-giant-sinkhole/
- *Carlsbad Brine Well remediation project completed: National Cave and Karst Research Institute hosts Governor Michelle Lujan Grisham for celebration*. New Mexico Tech News, 2 June 2022, https://www.nmt.edu/news/2022/carlsbad-celebration.php
- *Ancient forest discovered in Chinese sinkhole: researchers say the forest may contain small animal species unknown to scientists*. Margaret Osborne. Smithsonian Magazine, 10 June 2022, https://www.smithsonianmag.com/smart-news/ancient-forest-discovered-in-chinese-sinkhole-180980137/
- *Thanks to those who diligently worked to remediate the Carlsbad Brine Well*. Dale Janway, Carlsbad Current-Argus, 5 June 2022, p. 2A, https://www.currentargus.com/story/opinion/columnists/2022/06/05/thanks-those-who-diligently-worked-remediate-carlsbad-brine-well/7512808001/

NCKRI STAFF

NCKRI has a small, but growing and excellent staff. Following is the list of our staff during this report period, followed by training programs and publications. Biographies are available on the NCKRI website.

Dr. George Veni
Executive Director
Karst Hydrogeologist
Valerie Davis, MBA
Operations Division Director
Dr. Daniel Jones
Academic Director
Dr. Patricia Seiser
Cave and Karst Management Science Director
Dr. Lewis Land
Karst Hydrogeologist
Devra Heyer
Education Program Manager
Dr. Issam Bou Jaoude
Cave and Karst Science Specialist
Lisa Ryan
Office Manager

Continuing Education

NCKRI staff polish and expand their skills whenever possible. We are especially proud to announce that Lisa Ryan received her Associates Degree in Business Office Technology with a focus on accounting.

Other formal training during the past year included, *Ethics Issues in the Practice of Geoscience*, an annual course required by the Texas Board of Professional Geologists for Dr. Veni and others to maintain their Professional Geoscientist licenses. Additionally, Dr. Seiser received READ (Resource Advisors) training through the Wildland Fire Interagency Training Program. With large wildfires on the increase, the need for understanding wildfire issues on cave and karst lands has come to the forefront. This training provides a thorough understanding of what a Resource Advisor's role is during fire suppression, control and mitigation. The value of such training is to provide appropriate guidance for cave and karst resource management fire activities, from suppression to fire recovery.

Staff Publications

Refereed Papers

Journals Papers

- Capo, E., Peterson, B.D., Kim, M., Jones, D.S., Acinas, S.G., Amyot, M., et al. 2022. A consensus protocol for the recovery of mercury methylation genes from metagenomes: bioRxiv, p. 2022.2003.2014.484253 (doi: https://doi.org/10.1101/2022.03.14.484253)
- Hobart, K.K., Feinberg, J.M., Volk, M.W., Jones, D.S. 2022. The importance of temperature-dependent diffraction data in understanding magnetic changes across the pyrrhotite λ-transition. *Earth and Space Science Open Archive* 33 (doi: https://doi.org/10.1002/essoar.10507692.1)
- Kieft, T.L., Byrd, E., Veni, G. 2022. Toxicological study of fluorescent hydrologic tracer dye effects on cave bacteria. Groundwater, 60(2):404-409, https://doi.org/10.1111/gwat.13160, https://ngwa.onlinelibrary.wiley.com/doi/10.1111/gwat.13160.
- Veni, G. 2022. Groundwater and the International Year of Caves and Karst: explore, understand, protect. Groundwater, Guest Editorial, 60(2):158-159, https://doi.org/10.1111/gwat.13146

Photo courtesy of Lisa Ryan

Lisa Ryan happily holds her diploma after graduating from New Mexico State University - Carlsbad.

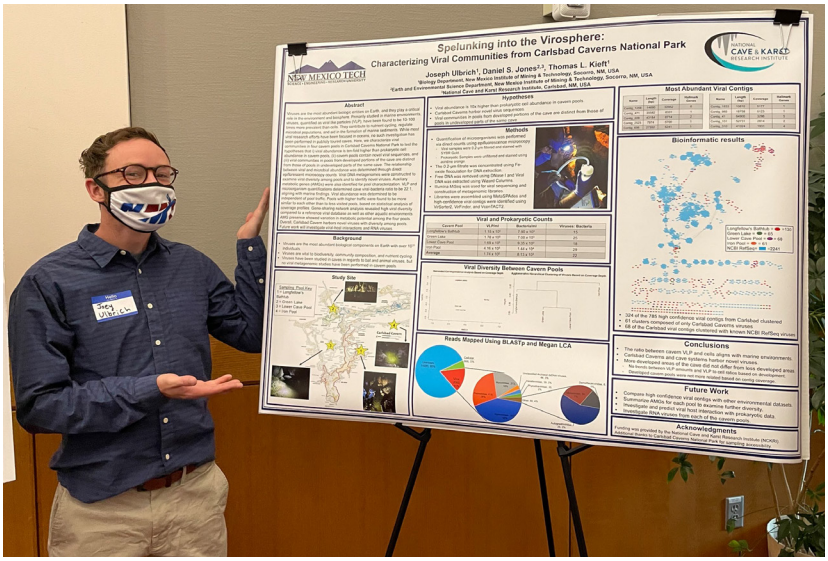
Conference Proceedings Papers

- Best, M.B., Gómez-Cruz, R., Northup, D.E., Jones, D.S. 2022. New insights into extremely acidophilic communities from cave wall biofilms. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Best, M.B., Jones, D.S. 2022. Geochemical niches of extremophile communities in an ephemeral acid rock drainage. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico. USA, 7-9 April.
- Best, M.B., Jones, D.S., Northup, D.E., Gómez-Cruz, R. 2021. Genomic characterization of extremely acidophilic bacteria in acidic cave wall biofilms. Geological Society of America Abstracts with Programs. 53(6), doi: https://doi.org/10.1130/abs/2021AM-368949
- Best, M.B., Jones, D.S., Northup, D.E., Gómez-Cruz, R. 2021. New genomic and physiological insights into

extremely acidophilic bacteria from acidic cave wall biofilms. Rocky Mountain Geobiology Conference, 11 September, Golden, Colorado, USA.

- Bou Jaoude, I. 2022. An introduction to the caves of Lebanon. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 28, https://nss2022.caves.org/index.php/program-guide/
- Bou Jaoude, I. 2022. Why Lebanon is rich in caves. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 43, https://nss2022.caves.org/index.php/program-guide/
- Brown, A., Green, B,, Jones, D.S. 2021. Extremophilic microorganisms in sulfur-rich travertine springs at Soda Dam, Northern New Mexico. Rocky Mountain Geobiology Conference, 11 September, Golden, Colorado, USA.
- Brown, A., Green, B., Jones, D.S. 2022. Extremophilic microorganisms from sulfur-rich springs and fumaroles in the Valles Caldera Volcanic Complex, New Mexico. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico, USA, 7-9 April.
- Graham, H.V., Stern, J.C., Chung, A.H., Wankel, S.D., Havlena, Z.E., Best, M.B., Jones, D.S. 2022. Biosignature preservation in subterranean gypsiferous ecosystems. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Green, K., Best, M.B., Jones, D.S. 2021. Using high-throughput *nifH* sequencing to characterize nitrogen-fixing microorganisms in caves. Rocky Mountain Geobiology Conference, 11 September, Golden, Colorado, USA.
- Havlena, Z.E., Jones, D.S. 2021. Comparing modern and ancient gypsum as a microbial habitat in sulfuric acid caves. Rocky Mountain Geobiology Conference, 11 September, Golden, Colorado, USA.
- Havlena, Z.E., Jones, D.S. 2022 Exploring microbial colonization of acidic gypsum deposits in sulfidic caves. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Havlena, Z.E., Jones, D.S., Hose, L.D., Duchene, H.R., Labrado, A.L., Brunner, B. 2021. Probing the origin and modern microbial colonization of gypsum sediments in Lehman Caves, Great Basin National Park, Nevada, USA. Geological Society of America Abstracts with Programs. 53(6), doi: https://doi.org/10.1130/abs/2021AM-371175
- Havlena, Z.E., Jones, D.S., Hose, L.D., Duchene, H.R., Labrado, A.L., Brunner, B. 2022. Gypsum sediments in Lehman Caves, Great Basin National Park, Nevada, USA. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico, USA, 7-9 April.
- Heyer, D. 2022. If you learn how to cave, what else do you learn: a pedagogical look at caving. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 57, https://nss2022.caves.org/index.php/program-guide/
- Hobart, K.K., Feinberg, J.M., Jones, D.S. 2021. Using integrated magnetic and crystallographic techniques to examine the pyrrhotite lambda transition in natural samples. AGU Fall Meeting, New Orleans, Louisiana, USA, 13-17 December.
- Hobart, K.K., Feinberg, J.M., Jones, D.S. 2022. Magnets, minerals, and microbes: using magnetic techniques to understand microbial pyrrhotite dissolution. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Jones, D.S. 2022. Sulfuric acid speleogenesis in the Frasassi Cave System, Italy, and possible implications for Guadalupe Mountain caves. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico, USA, 7-9 April.
- Jones, D.S., Best, M.B., Mainiero, M., Auch, B.T., Gómez-Cruz, R., Boston, P.J., Northup, D.E. 2022. Improved genome recovery from cave wall metagenomes provides new insights into microbial sulfide oxidation in sulfuric acid caves. Invited paper, American Chemical Society Spring Meeting, San Diego, California, USA, 20-24 March.
- Jones, D.S., Macalady, J.L., Gómez-Cruz, R., Northup, D.E. 2022. Subterranean islands: biogeography of cave-hosted extremophiles. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Jones, D.S., Northup, D.E., Boston, P.J. 2022. Microbe-mineral interactions in caves. Invited paper, New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico, USA.
- Jones, D., Veni, G., Havlena, Z., Labrado, A.L., Brunner, B. 2021. Origin and significance of the sulfate mineral crusts in the Caverns of Sonora, Sutton, County, Texas. Geological Society of America Convention, Portland, Oregon, USA abstract, https://gsa.confex.com/gsa/2021AM/webprogram/Paper368527.html

- Land, L. 2022. Fort Stanton Cave and the northern Sacramento Mountains: regional geologic and hydrologic context. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Conference, Socorro, New Mexico, USA, Program with Abstracts, https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2808
- Land, L. Jones, M. 2021. Water chemistry variations in a karstic aquifer system: San Solomon Springs, far west Texas. Geological Society of America Convention, Portland, Oregon, abstract, https://gsa.confex.com/gsa/2021AM/meetingapp.cgi/Paper/369526
- Land, L., Veni. G. 2022. Using electrical resistivity methods to map cave passages and conduits in the San Solomon Springs karstic aquifer system, west Texas, USA. New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Conference, Socorro, New Mexico, USA, Program with Abstracts, p. 46, https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2835
- Santucci, V.L., Hodnett, J.-P., Tweet, J.S, Wood, J., Seiser, P.E. 2022. National Park Service Cave Paleontology: Inventory, Discovery, and Stewardship. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 64, https://nss2022.caves.org/index.php/program-guide/
- Sarbu, S., Brad, T., Chauveau, C., Flot, J., Galdenzi, S., Galassi, D., Gentile, G., Iepure, S., Jones, D.S., Martin, P., Montanari, A., Stoch, F. 2022. Biodiversity in the sulfidic sections of the Frasassi Caves, Italy. In: Proceedings of the 2nd International Electronic Conference on Diversity—New Insights into the Biodiversity of Plants, Animals and Microbes, 15–31 March, MDPI: Basel, Switzerland, doi: https://doi.org/10.3390/IECD2022-12384
- Sebree, J., Peters, J.P., Sliwinski, M.K., Cable, M.L., Barton, H.A., Blank, J.G., Jones, D.S. 2022. Wind Cave as a terrestrial analog for subsurface liquid reservoirs of icy moons. Astrobiology Science Conference, Atlanta, Georgia, USA, 15-20 May.
- Seiser, P. 2022. Update on status of the NPS Cave and Karst Program and NCKRI's programs. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 64, https://nss2022.caves.org/index.php/program-guide/
- Ulbrich, J., Jones, D.S., Kieft, T.L. 2021-2022. Spelunking into the virosphere: characterizing viral communities from Carlsbad Caverns National Park. Rocky Mountain Geobiology Conference, 11 September, Golden, Colorado, USA; New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Science Conference, Socorro, New Mexico, USA, 7-9 April.
- Veni, G. 2021. Cave and karst management after the International Year of Caves and Karst. Keynote address, 2021 National Cave and Karst Management Symposium Program Guide, San Marcos, Texas, USA, p. 28; National Speleological Society's virtual Out of Bounds Grotto, USA.
- Veni, G. 2021. Geoscience outreach in the International Year of Caves and Karst. Geological Society of America Convention, Portland, Oregon, USA, abstract, https://gsa.confex.com/gsa/2021AM/webprogram/Paper367062.html; New Mexico Geological Society Annual Spring Meeting and Fort Stanton Cave Conference (by request), 2022, Socorro, New Mexico, USA, Program with Abstracts, p. 85, https://nmgs.nmt.edu/meeting/abstracts/view.cfm?aid=2847
- Veni, G. 2021. The International Year of Caves and Karst: Results on the First Six Months and News on What's Next. National Speleological Society Convention, virtual lecture, USA, https://www.youtube.com/watch?v=vPGnqMgeQLA



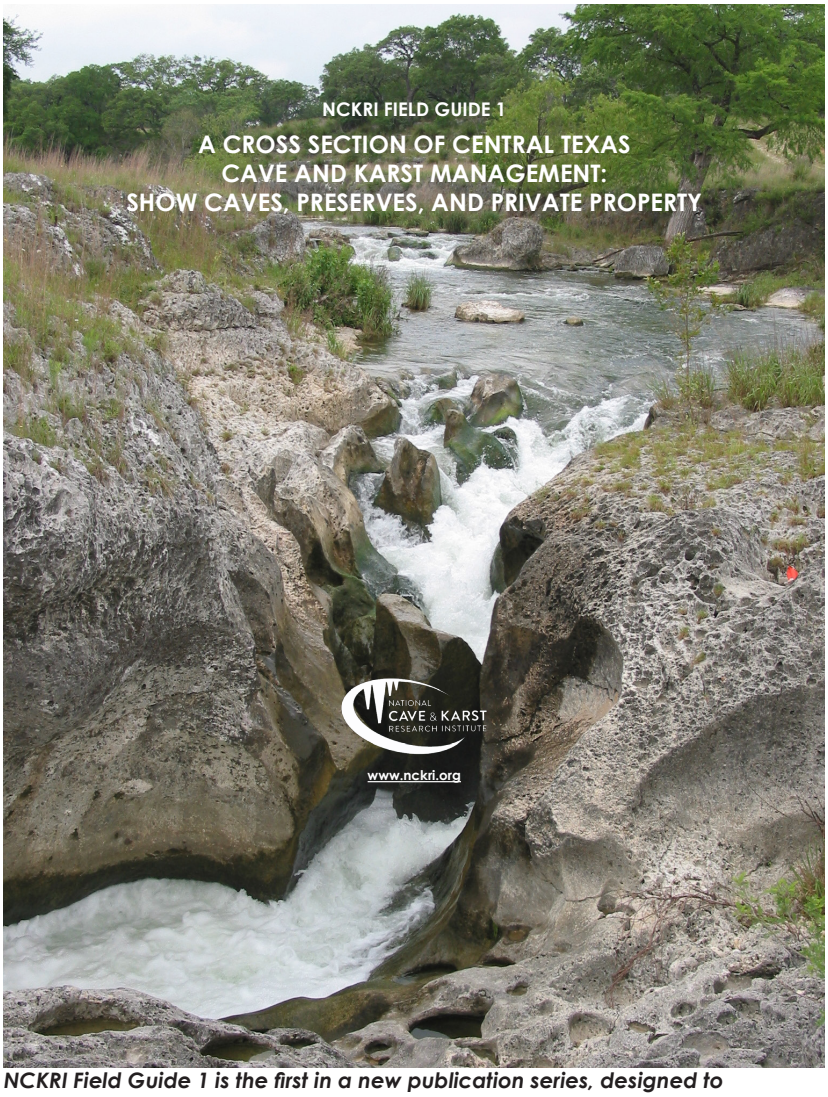
NCKRI photo by Dan Jones.

NCKRI Scholar Joseph Ulbrich at his poster during the New Mexico Geological Society Spring Meeting, displaying his ground-breaking work on cave viruses.

- Wood, J.R., Bilderback, E., Zyatitsky, K., Seiser, P.E. 2022. Taking a crack at it: monitoring and quantifying fracture dynamics within the walls of a lava tube, proximal to an active volcano. 2022 NSS Convention Program Guide, National Speleological Society Convention, Rapid City, South Dakota, USA, p. 47, https://nss2022.caves.org/index.php/program-guide/

Books and Book Chapters

- Hose, L.D., Duchene, H.R., Jones, D.S., Baker, G., Havlena, Z.E., Sweetkind, D., Powell, J.D. 2021. Hypogenic karst of the Great Basin. In: Florsheim, J., Koeberl, C., Riggs, N., and McKay, M.P., eds., GSA Section Meeting Guides: Geological Society of America Field Guide 61, p. 1–38, doi: https://doi.org/10.1130/2020.0061(05)
- Kieft, T.L., Byrd, E., Veni, G. 2021. Toxicological study of fluorescent hydrologic tracer dye effects on cave bacteria. National Cave and Karst Research Institute Report of Investigation 12, Carlsbad, New Mexico, 16 p., https://www.nckri.org/publications/reports-of-investigation/
- Land, L., Jones, M., Veni G. 2021. Phase 1 dye trace investigation of a conglomerate karst aquifer, Black River Basin, Eddy County, New Mexico. National Cave and Karst Research Institute Report of Investigation 12, Carlsbad, New Mexico, 35 p., https://www.nckri.org/publications/reports-of-investigation/
- Land, L, Veni. G. 2021. Electrical resistivity survey of a pseudokarst sinkhole hazard, Village of San Mateo, Cibola County, New Mexico. National Cave and Karst Research Institute Report of Investigation 13, Carlsbad, New Mexico, 9 p., https://www.nckri.org/publications/reports-of-investigation/
- Veni, G. 2021. Foreword. Karst Geology and Ecosystem: Karst Science Popularization in China. International Research Centre on Karst, Guilin, China, p. 1-2.
- Veni, G. 2021. A cross section of central Texas cave and karst management: show caves, preserves, and private property. Guidebook for the 23rd National Cave and Karst Management Symposium National Cave and Karst Research Institute Field Guide 1, Carlsbad, New Mexico, 35 p., https://www.nckri.org/publications/field-guides/
- Veni, G. 2021. Introduction to SpeleoMedit, Mediterranean Speleology. SpeleoMedit, Mediterranean Speleology: panoramic view of caves and karst of Mediterranean countries, Ferdinando Didonna and Francesco Maurano, eds., Società Speleologica Italiana, Bologna, p. 7-9.



NCKRI Field Guide 1 is the first in a new publication series, designed to provide informative guides to caves and karst areas, often in association with conferences. This series is not limited to any topic or field of research, except that they involve caves and/or karst. This one was prepared for the 23rd National Cave and Karst Management Symposium. Like all NCKRI publications, it is available for free download from www.nckri.org.

2021-2022 STATE AND FEDERAL BUDGET

Revenue	Category	FY2022 Budget	FY2022 Actual	Budget to Actual
State of New Mexico		$340,438.00	$341,738.00	($1,300.00)
	Carryforward	$267,037.00	($47,142.00)	$314,179.00
National Park Service		$794,000.00	$792,770.00	$1,230.00
Grants & Contracts		$26,752.00	$26,752.00	$ 0.00
Total Revenue		$1,428,227.00	$1,114,118.00	$314,109.00
Expenses	**Category**	**FY2022 Budget**	**FY2022 Actual**	**Budget to Actual**
State of New Mexico				
	Salary & Fringe	$300,797.00	$167,787.00	$133,010.00
	Expenses	$39,641.00	$126,110.00	($86,469.00)
	Subtotal	$340,438.00	$293,897.00	$46,541.00
National Park Service				
	Salary & Fringe	$513,448.00	$562,787.00	($49,339.00)
	Expenses	$280,552.00	$307,498.00	($26,946.00)
	Subtotal	$794,000.00	$870,285.00	($76,285.00)
Contracts & Grants				
	Salary & Fringe	$20,831.00	$20,831.00	$0.00
	Expenses	$5,921.00	$5,921.00	$0.00
	Subtotal	$26,752.00	$26,752.00	$0.00
Total Expenses		$1,161,190.00	$1,190,934.00	($29,744.00)

*State of New Mexico Actuals includes State Appropriation totals and internal transfers, expense recovery and internal revenue.

- Veni, G. 2021. Preface. Underground Symphony, Philippe Crochet and Annie Guiraud, in fine Publications, p. 5.
- Veni, G. 2021. Prólogo president UIS. Cueva del Puerto: una cueva hipogenica, Calasparra, Murcia, Natursport, Murcia, Spain, p. 5.
- Veni, G. 2022. Foreword. Caves and Karst of Thailand. Department of Mineral Resources, Thailand, p. 5-6.
- Veni, G. 2022. Foreword. Peșterile Munților Bihor: Caves of Bihor Mountains – Romania. Liviu Vălenaș and Eugen Kamp, Clubului de Speologie „Z", 240 p.

Unrefereed Papers

- Jones, M. 2022. Mapping the geography of underground ecosystems. ArcUser, Spring, p. 22-25 (Michael Jones had left NCKRI to attend graduate school when this article he wrote was published on some of his work at NCKRI)
- Veni, G. 2021. NCKRI 2021: a new look. National Speleological Society Southwestern Region Winter Technical Meeting, virtual conference, Southwestern Cavers, 59(6):61.
- Veni, G., Mansur, M. 2021. The First Year of the International Year of Caves and Karst and the Role of the Southwestern Region of the National Speleological Society. National Speleological Society Southwestern Region Winter Technical Meeting, virtual conference, Southwestern Cavers, 59(6):60.

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