



2022 - 2023 ANNUAL REPORT

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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, 2022 to June 30, 2023. Digital copies of this and previous reports are available for free at www.nckri.org.



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Cover Photo

Tongass Genomics expedition particpant, Sam Littman, with NCKRI Education Program Manager Devra Heyer and UROCK participants Celeste Flores and Antonio Chavez exit Cavern Lake Cave in the Tongass National Forest, Prince of Wales Island, Alaska. Photo courtesy of Riley Drake.

Back Cover Photo

Lake Cave, Carlsbad Caverns National Park, Carlsbad, New Mexico. Photo courtesy of Devra Heyer.

VISION

The National Cave and Karst Research Institute will catalyze the advancement of cave and karst knowledge.

MISSION

NCKRI promotes and facilitates cave and karst research, education, and sustainability.

Organizational Information

The National Cave and Karst Research Institute (NCKRI) is located in Carlsbad, NM; and is a research center of New Mexico Institute of Mining and Technology (NMT or NM Tech). 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 to be a nexus of research, stewardship, information and outreach for caves and karst while fostering interdisciplinary collaborations.

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;
- 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.





DIRECTOR'S REPORT



This has been a year of transition at NCKRI. As Interim Director, I have been fortunate to work with the NCKRI team to continue the important work of promoting cave and karst research, education, and sustainability. I am excited for the future as NCKRI begins the search for a new Director.

My name is Valerie Davis, and in April 2023 I was invited to serve an additional role at NCKRI – that of Interim Director due to the retirement of NCKRI's previous leader, Dr. George Veni, at the end of April 2023. This spring and summer, NCKRI's leadership at New Mexico Tech began the process of preparing for and starting the national search for next Director of NCKRI. I am currently serving two roles, the Operations Division Director, and the Interim Director. In both roles, my efforts focus on supporting

NCKRI's infrastructure, enhancing processes, and ensuring the sustainability of the NCKRI National Headquarters building in Carlsbad, NM. Furthermore, I am continuing to support and facilitate the work of our excellent team of professionals who continue their mandate-focused work promoting and facilitating cave and karst research, education, and sustainability. George's tenure at NCKRI provided a foundation upon which NCKRI and NM Tech will continue work building the brightest future possible for the organization and the people we serve.

I would like to acknowledge the important contributions made by George during his tenure at NCKRI. George transitioned from a career as a consulting karst hydrologist in San Antonio, Texas to take the helm of the Cave and Karst Research Institute in 2007. He began his work during a pivotal period in the Institute's history. It was during this time that NCKRI transitioned from a division of the National Park Service to an entity within New Mexico Tech's Research Division. His guidance during that challenging process remains one of his important early contributions to our organization. We should also acknowledge that our current headquarters building was completed largely because of George's work during the design and construction process. NCKRI's physical presence in Carlsbad is due to a collaborative effort of its partners and stakeholders, and George's guidance proved pivotal during that process. Because of this multi-partner collaboration, the NCKRI Headquarters has a home in Carlsbad - a place of deep roots, connection, and inspiration. A place where staff and stakeholders can collaborate, communicate, and perform the important work to fulfill our state and federal mandates. You will find Dr. Veni's outgoing message as NCKRI's past director later in this report.

The 2022-2023 annual report highlights our focus on educational outreach development and implementation of STEAM (Science, Technology, Engineering, Art, Mathematics) outreach and engagement, while building connections with NCKRI's partner agencies. NCKRI has also formed valuable new partnerships within the Carlsbad community such as Southeast New Mexico College, as well as Inspired by Science, a Carlsbad-based charitable organization whose purpose is to promote STEM education for elementary school aged young scientists through hands-on activities, many of these with parents as their science partners.

Readers will also read about significant highlights from the past year including an update from the Cave and Karst Studies Program, along with the report of a completed multi-year research study of lampenflora in partnership with nearby Carlsbad Caverns National Park. We also feature updates on the use of speleothems to give clues to past climates of the Eastern Mediterranean. NCKRI's work also progresses this year with an extramural funded dye trace project located near Fort Stanton, New Mexico, as we continue renewing partnerships with regional offices of federal agencies.

I would like to take a moment to note that the posting of the Carlsbad-based NCKRI Director position can be found on the NM Tech Human Resources website: <u>https://www.nmt.edu/hr/docs/hr/jobs/Director%20Position%20</u> <u>Profile%20Updated%209-1-2023NCKRI.pdf</u> If you are interested in applying, or know someone who may be, please feel free to share the position posting information.

In closing, I would like to extend my gratitude to NCKRI's valuable partners, the City of Carlsbad, the National Park Service, and the State of New Mexico for their support and advocacy of NCKRI's important mission. I am additionally grateful for the team of excellent professionals that comprise our NCKRI team, and the administration and staff of NM Tech for their guidance and oversight as we work together to create a vibrant future for NCKRI and the cave and karst community we serve. Together, we work to achieve outstanding results and continue our efforts to fulfill the NCKRI vision of catalyzing the advancement of cave and karst knowledge.

NCKRI RESEARCH

New Mexico Tech and NCKRI Investigate the Lampenflora Problem at Carlsbad Cavern

Caves in their natural condition are, of course, devoid of light, so photosynthetic organisms don't occur naturally in caves except near the entrances and the twilight zone. However, it was reported in the pages of Science in 1946 that a "greenish cast" had appeared in Carlsbad Cavern, New Mexico, at a site about 230 m below the elevation of the entrance. The green color was from algae and cyanobacteria that were gaining energy from an electric light over the elevator doors. Actually, electric lights were first installed in the cave in 1926 and so photosynthetic biofilms, termed "lampenflora" by speleologists, probably began to colonize the cave at that time. The lampenflora problem is not unique to Carlsbad, and in fact occurs in lighted show caves throughout the world. Besides being unnatural and unsightly, the biofilms can cause damage by staining speleothems and by dissolving underlying rock. Therefore, the National Park Service

(NPS) and other cave managers have long sought a means to limit lampenflora growth. The current approach at Carlsbad Cavern is to apply a household bleach solution to biofilms when the photopigments have accumulated to an unacceptable level, but other tactics are needed.

In 2012, the NPS replaced all of the lighting in Carlsbad Cavern with LED lamps that can be adjusted to control the wavelengths of light used to illuminate the cave. This led to the NPS funding a two-phase study by NCKRI and New Mexico Tech (NMT).

The first phase, led by NMT graduate student Zoë Havlena under the guidance of NMT Biology Professor Dr. Tom Kieft, focused on the effects of light intensity and wavelength as well as mineral texture on the communities of microbes inhabiting speleothems in the cave. The mix of wavelengths of light can be quantified as color temperature (units: degrees K). Zoë collected biofilm samples from speleothems in the Big Room in Carlsbad Cavern on five different dates, extracted



New Mexico Tech graduate student Zoë Havlena collecting biofilm samples from speleothems in Carlsbad Cavern.

Photo courtesy of George Veni.

DNA, and used high-throughput DNA sequencing of a phylogenetically useful gene (the small subunit ribosomal RNA gene) to identify the microbes present and to calculate the relative abundances of various taxonomic groups. DNA sequence analysis is a culture-independent approach that can fully characterize microbial communities; it is not subject to culture bias, which comes about because the majority of microorganisms cannot be cultivated in the lab by currently available methods.

In addition to DNA sequence analysis, Zoë also used reflected light spectrophotometry to characterize photopigments in the cave. Ms. Havlena found that lampenflora biofilm communities include diverse species of Cyanobacteria (photosynthetic bacteria) as well as green and brown algae (Chlorophyta and Ochrophyta, respectively) and many species of heterotrophic (organic carbon-metabolizing) bacteria. Cyanobacteria are especially successful, being able to colonize and grow more rapidly than the eukaryotic algae. Common cyanobacterial genera included Gloeotrichia, Scytonema, and Leptolyngbya.

The results of Zoë's study, published in 2021 in Applied and Environmental Microbiology (https://doi. org/10.1128/ AEM.02695-20), show that all three factors (color temperature, light intensity, and mineral texture) affect the makeup of the biofilm communities. Changing color temperature from 3500 K to a "warmer" 2700 K by reducing blue light results in somewhat diminished growth, but this is less than a panacea. One could perhaps eliminate all photosynthetically active blue and red light, but the resulting yellow-togreen light is thought to be aesthetically unpleasing and is not being considered. Indeed, Carlsbad Cavern has never used wildly colored lights



Zoë Havlena examining biofilm sample in the laboratory at New Mexico Tech. Photo courtesy of New Mexico Tech Marketing and Communications.

to illuminate cave formations, although some commercial show caves have these. Green lights, though garish, could minimize lampenflora growth. Zoë's study is useful in that it provides a detailed depiction of the microbes present in the photosynthetic biofilms and it confirms that the quantity and quality of artificial light can influence lampenflora development. But it is mostly a descriptive study (albeit by modern, quantitative DNA analysis) and does not provide definitive answers for how to eliminate or prevent photosynthetic biofilms in caves.

For the second phase of the project, Dr. Kieft and seven NMT students set out to test physical and chemical means of mitigating lampenflora formation, with an eye to these possibly being useful in Carlsbad Cavern. The results of this study were published in Geoheritage. The project began with a literature search, which revealed that a great many chemical agents have been tested in caves and also tested on the related problem of biodeterioration of buildings and monuments. It's not hard to find effective biocides; the challenge is finding a "magic bullet" that can kill the lampenflora without damaging the underlying rock and without harming non-target organisms. As stewards of precious and fragile ecosystems, NPS cave managers are conscious of the dictum to do no harm. Following their search of the literature, Kieft and his students decided to try one chemical agent, the quaternary ammonium compound benzalkonium chloride (BAC), and one physical agent, germicidal ultraviolet light (UV-C).

Tests of biocidal agents were performed in the lab under controlled, reproducible conditions rather than testing in the field. Undergraduate student Isabelle Lakis devised an experimental protocol in which a mixed culture of algae and cyanobacteria derived from Carlsbad Cavern biofilms was inoculated onto flat, smooth calcium carbonate tiles and then incubated under fluorescent lights. Students treated the inoculated tiles with BAC or UV-C in experiments intended to mimic their potential application in the cave. Replicate tiles were used for each treatment. Lampenflora development was monitored by reflected light spectrophotometry and also by visually examining the tiles and scoring them for amounts of photopigment.

BAC was considered as a candidate for use in caves based on its longtime use as a preservative in cosmetics and personal care products, e.g., eyewashes. If it can be applied to the human eye (don't try this with bleach!), then how bad can it be for a cave ecosystem? BAC was also used to mitigate biodeterioration of ancient paintings in Lascaux Cave in France. Experiments showed that a 1% BAC solution could prevent growth for at least 12 days and that repeated treatments with a 1% solution could remove preformed photosynthetic biofilms. This is a relatively high concentration that one might not want to use on a regular or widespread basis in a cave, but it could perhaps be used as an alternative to bleach. BAC can be biodegraded, but somewhat slowly, so accumulated residue could be a problem. Resistance can also develop, as happened with the Lascaux Cave example. Finally, toxicologists are now questioning the safety of BAC in products for humans, so environmental use may be contraindicated as well.

UV-C is an attractive lampenflora mitigation candidate because



Fig. 2 Calcium carbonate tiles in Petri dishes inoculated with lampenflora enrichment cultures for biocide experiments. The Petri dish lids were removed for UV-C irradiation and for photocarabing. The lide were real-aced during incubation under fluores.

cent lighting. The filter paper was moistened to maintain nearly saturated relative humidity. The relative amount of photopigment was scored 0 through 3

Calcite tiles inoculated with lampenflora. Figure from Kieft et al. 2023, Geoheritage, <u>https://doi.org/10.1007/s12371-023-00839-4</u>)

it's a purely physical treatment, so it leaves no chemical residue other than dead cells. An experiment with tiles in the laboratory was performed in which six hours of UV-C treatment was alternated with periods of visible light exposure, simulating a scenario in which speleothems are irradiated with UV-C during the night and then exposed to visible light during the hours when the cave is open to tourists. This resulted in a significant decrease in green pigment, as indicated by reflected light spectrophotometry. A similar experiment in which tiles with lampenflora growth were irradiated at weekly intervals was performed with a range of UV-C dosages. High doses (3200 to 12800 mJ/cm²) resulted in nearly complete elimination of photopigments: however, lower doses had little to no effect.

These lab experiments suggest that UV-C could be a means for lampenflora mitigation. UV-C lamps could be installed in the same locations as the LED lamps in Carlsbad Cavern and turned on at night when tourists are absent. This is certainly feasible since the sites are already wired for electricity. However, the cost of acquiring UV-C lamps could be an issue. An alternative approach requiring fewer UV-C lamps would be to deploy them temporarily at sites where photosynthetic biofilms have accumulated. These could be placed on stands and turned on only at night, perhaps with signage for tourists to explain their purpose.

A legitimate concern regarding any lampenflora mitigation scheme is the extent to which it may harm indigenous cave animals. In the case of BAC and UV-C, the dosages found to be effective in these lab experiments would indeed harm any cave animals directly exposed along with the lampenflora, probably lethally. However, the affected animals would be only those that are attracted to and habituating the photosynthetic biofilms. These animals in the vicinity of the lampenflora could be termed "lampenfauna." The cave species that are drawn to the added organic matter of the lampenflora and that fall prey to this mitigation measure would thus be more adversely impacted. In any case, the areas of cave habitat that



would be affected would be miniscule compared to the entire volume of Carlsbad Cavern. Moreover, the lethal effect would be no more than and probably less than that of the currently widely used bleach.

The results of this NPS-funded project fall short of finding a final solution to the lampenflora problem, but they add to the growing body of information on this issue. Support is lent to at least one possible approach, i.e., UV-C irradiation, but there is clearly no single answer to the problem. Instead, a combination of approaches is called for. This could include:

1) moderating the quantity of light energy delivered by adjusting the intensity, duration, and spectra of light;

 irradiation with germicidal UV light on a scheduled or sporadic basis; and

3) judicious application of chemical biocides and bleaching agents to the most heavily colonized sites.

Finally, it should be recognized that some lighting is essential for a national treasure as heavily visited as Carlsbad Cavern, and so lampenflora will never be eliminated but merely kept in check.

The results of this study were published in Kieft, T.L., Del Curto, D., Havlena, Z. et al. Potential for Mitigation of Cave Lampenflora Using Benzalkonium Chloride or UV-C. *Geoheritage* 15, 68 (2023). https://doi.org/10.1007/s12371-023-00839-4

Impact of UV light on lampenflora. Figure from Kieft et al. 2023, Geoheritage, https://doi.org/10.1007/s12371-023-00839-4)

Using Speleothems to Date Past Climates of the Eastern Mediterranean

There are many gaps in the climate history of the Middle East, including the nation of Lebanon. It is important to undertake such studies in Lebanon owing to its location and variable climate in the eastern Mediterranean. Because of its location and mountainous nature. Lebanon is affected by major climatic systems from Africa, Asia and Europe. Lebanon has also been a crossroads of major human societies throughout history. Studying the paleoclimate in Lebanon can provide valuable information not only on climate but also on human migration and settlement.

Lebanon is situated in the central Eastern Mediterranean region. Its geomorphology, various climatic environments, and different air mass origins make it challenging to characterize the precipitation isotopically. This generates diversity in the quantity, isotopic composition and chemical properties of the precipitation.

El-Kassarat cave is located in Nabay village, only 100 m above sea level, in the coastal area of Mount Lebanon, Metn caza (provincial subdivision), in the Antelias River Valley. The cave is located approximately 2.7 km inland, in Jurassic rocks of the Keserouane Formation. El-Kassarat cave is 4,748 m long, with ceiling height reaching nearly 30 m in some locations.

The first round of dating and isotope analyses on the stalagmite collected from that cave was done at the Neptune Isotope Lab, Division of Marine Geology & Geophysics, University of Miami. The second round of dating was conducted by Drs. Issam Bou Jaoude and Victor Polyak at the Radiogenic Isotope Lab, University of New Mexico, and provided more detailed chronology. The oldest age dated was 62,000 years and the youngest was 400 years. Two major hiatus



Map showing locations of El-Kassarat Cave and other important caves in the eastern Mediterranean.

Image courtesy of Issam Bou Jaoude.

periods were documented, one between 14,000 and 1800 years and one much older, between 32,000 and 59,00 years. The first hiatus is consistent with the one in Jeita cave, located a few kilometers to the north, but lasted much longer, and may be related to a change in weather conditions or possibly a shift in source water due to an earthquake. The growth rate in all stages of development is the same at 0.2 mm/year, showing that the source is quite consistent.

The upper portion of the stalagmite, known as the candlestick, was isotopically studied, providing valuable information on the Holocene period. A cold period of around 3200 years was documented that is consistent with a glacial period and a drop in global temperature by at least 1°C, and a lowering of the Mediterranean Sea by about one meter. From 18,000 to 20,000 years, isotopic data are consistent with the last Glacial Maximum, with lowering of temperature by as much as 10°C. This study provides valuable insight into Holocene paleoclimate in the eastern Mediterranean and globally.



Stable isotope and radiometric dating analysis of the stalagmite from El-Kassarat Cave, northern Lebanon.

Image courtesy of Issam Bou Jaoude.

Guano Thickness and Cave Length: Insights from Electrical Resistivity Studies

Fifteen electrical resistivity (ER) survey lines have been conducted around Natural Bridge Caverns and Bracken Cave near San Antonio, Texas, since 2014. The work was initiated with Bat Conservation International (BCI) in an attempt to define the thickness of the bat guano in Bracken Cave, which holds the world's largest bat colony. The project then developed into a more elaborate one, not only to try to define the thickness of the guano but also to define the extent of the cave beyond its known passage. Electrical resistivity surveys also began at Natural Bridge Cavern, which is only one kilometer away, to better understand its extent but primarily for comparison with Bracken. The caves are geologically identical except that Bracken contains a large volume of bat guano while Natural Bridge Cavern does not. The fieldwork for this project was completed in 2022 and the data are currently being analyzed.

ER surveys are a common and effective geophysical method for detection of subsurface voids, but this study is the first to use ER methods to define the thickness of guano deposits in caves. The basic operating principal for an ER survey involves generating a direct current between two metal electrodes 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.



Resistivity line above the Dungeon section of Natural Bridge Caverns. Photo courtesy of Issam Bou Jaoude.

Measuring thickness of guano

With the assistance of BCI and many volunteers, primarily from the Bexar Grotto of the National Speleological Society, 11 ER surveys were conducted inside and outside of Bracken Cave since 2014 to define the thickness of the guano deposit and the possible extension of the cave. Identifying the thickness of the guano helps scientists locate the best sampling/coring point. In addition, a core of the bat guano will reveal important paleoclimate and ecological information for the area.

Bracken Cave is 130 m in length, 15-20 m wide, and 10-15 m high. The cave houses 16 million bats, but in winter most bats migrate south, during which time NCKRI personnel and assistants have a window to conduct the ER surveys. Previous ER surveys were done inside the cave to directly measure the guano, but this survey was done from the surface to compare the images with similar ER surveys over parts of Natural Bridge Caverns that contain no guano. That comparison is in progress. Bracken Cave

Guano Comparison and Cave Extent

Natural Bridge Caverns (NBC) is a world-renowned show cave and the largest cave by volume known in Texas. The cave has a surveyed length of 5.8 km, and several passages remain to be explored. Natural Bridge Caverns was not included in the initial study of bat guano in Bracken Cave, but it became apparent that ER surveys of NBC could provide valuable comparisons.

The first survey began over the Dungeon, the largest side passage in the cave. Following that survey, and as additional blind comparisons, ER surveys were conducted beyond the known extent of the Dungeon and the cave's main passage. Those surveys will not only be useful in comparing resistivity profiles where significant guano deposits are known and absent, but will also help guide further exploration and study of NBC. Initial results are promising; data processing and analysis are ongoing.



During this fiscal year, an electrical resistivity survey was conducted over Bracken Cave. Next year this image will be compared with surveys over Natural Bridge Caverns to determine if the guano deposit in Bracken Cave is identifiable from the surface.

NCKRI COLLABORATIONS AND PARTNERSHIPS

Cave Pollution: Identification, Remediation, and Prevention

The widespread use of caves as garbage dumps goes back centuries, but accelerated during the past century as modern society produced more disposable items while community solid waste disposal was unavailable or impractical for many people to use. As a result, nearby "empty holes in the ground" were seen as convenient dump sites. While this practice has lessened as access to proper waste disposal has improved, it is still common internationally.

NCKRI was contacted by Dr. Jure Tičar of Slovenia's Anton Melik Geographical Institute to partner on an international cave pollution study. His PhD dissertation examined the types and distribution of polluted cave sites in Slovenia, and he wanted a broader perspective on the problem to develop effective remediation methods.

In April 2023, Dr. Tičar visited New Mexico with Dr. Matija Zorn, Director of the Anton Melik Institute, as part of a larger visit of polluted caves and sinkholes in the USA. NCKRI's Dr. Issam Bou Jaoude arranged a series of site visits and meetings to show them the diversity of this problem, beyond just trash, in the Carlsbad area and elsewhere. Those meetings and field sites included: • A visit to El Malpais National Park.

• Large, trash-filled sinkholes on Bureau of Land Management lands and sites of current clean-up efforts.

• Management of trash and other impacts of visitors at Carlsbad Caverns National Park.

• Actual and potential impacts of oil and gas drilling, pipelines, and associated activities on karst terrane.

Discussion of these and other activities focused on identifying the reasons for these problems, and successes and failures in developing remediation and prevention methods. This visit will serve as the basis for later developing a closer and more detailed joint investigation of cave pollution and how to prevent it.



Staff from the Anton Melik Geographical Institute, U.S. Bureau of Land Management, and NCKRI examine a large trashfilled sinkhole that the Bureau has scheduled for cleaning.

Photo courtesy of George Veni.

International Year of Caves and Karst

The International Year of Caves and Karst (IYCK) was 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 was to teach the public, educators, land managers, scientists, and lawmakers about the many benefits, and some of the challenges, caves and karst present to humanity.

NCKRI was one of 263 partner organizations in the International Year from 51 countries. NCKRI was a global leader in the International Year given our close relationship with the UIS (NCKRI's Executive Director, Dr. George Veni, was serving as the UIS President) and through our activities. In total, about 1,100 International Year events were organized by the partners worldwide reaching tens of millions of people. This included lectures, workshops, books, news media reports and interviews, demonstrations of caving skills, field trips, conferences, and clean-ups of trash dumped in caves and sinkholes.

In 2021, NCKRI was featured in the most significant event in the history of cave and karst exploration and science. The United Nations Educational, Scientific, and Cultural Organization (UNE-SCO) invited the UIS to celebrate the International Year at UNESCO Headquarters in Paris, France. The success of that event was proven when Dr. Veni was invited to organize a UIS event for the United Nations' first Groundwater Summit in 2022, which was also held at **UNESCO Headquarters: Karst** Aquifers: the Most Prolific, Vulnerable, and Misunderstood.

While organized on behalf of the UIS, NCKRI again held a prominent role through Dr. Veni's affiliation. The event was praised by many attendees as the most useful of the entire Summit by presenting practical and valuable information, and especially on a topic that applies to about 700 million worldwide, but about which most governmental leaders and groundwater managers are unfamiliar. During the event:

•Dr. Aleš Bizjak, Ministry of the Environment and Spatial Planning of the Republic of Slovenia, welcomed everyone and introduced the topic of karst groundwater and its importance to the world.

•Dr. Nadja Zupan Hajna, UIS President, Senior Research Karst Geoscientist with the Karst Research Institute in Slovenia, introduced the UIS, International Year, and the basic principles of cave and karst hydrogeology to make people aware of the special needs, benefits, and problems with groundwater in karst.

•Dr. Ros Fatihah Muhammad, Professor of Geology specializing in karst, and Malaysia's Delegate to the UIS, discussed how karst aquifers are vital water supplies worldwide, are contaminated easily, and how easily they can be drained of water. She also described the challenges of building dams on karst terrane.

•Dr. George Veni, UIS Past President, karst hydrogeologist, and NCKRI's Executive Director, presented basic solutions to groundwater management problems in karst.

Since this major event occurred at the United Nations Groundwater Summit in December 2022, near the close of the International Year, it was able to launch a growing awareness and understanding of karst groundwater at high governmental levels, and NCKRI was seen as an important player in building that future.



(L-R) Drs. George Veni, Nadja Zupan Hajna, Ros Fatihah Muhammad, and Aleš Bizjak at the United Nations first Groundwater Summit where they presented the event, Karst Aquifers: the Most Prolific, Vulnerable, and Misunderstood, as part of the International Year of Caves and Karst.

Photo courtesy of George Veni.

KARST INFORMATION PORTAL

The Karst Information Portal (KIP) is a one-stop shop for open, online access to cave and karst research in all fields of study and exploration. KIP is a NCKRI project in partnership with the University of South Florida (USF) Libraries, University of New Mexico (UNM), and the International Union of Speleology (UIS). With the assistance of Michael Jones, former NCKRI employee and now karst student, NCKRI sends spreadsheets of citations to the USF Libraries team, which does copyright clearance on these items to determine which ones can be posted with full-text and which need to just be citations. The University of New Mexico and International Union of Speleology provide other support as needed. Metadata is created for each item, and these are uploaded to the KIP portal. This year, we added 665 items, bringing us to a total of

9,073 in the portal. The decrease in the overall number of items is the result of a previous workflow issue that resulted in duplicate items being loaded into the portal. We are working on deduplicating the collection now.

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. The Karst Information Portal (KIP) is hosted on the Digital Commons at University of South Florida platform: https://digitalcommons.usf. edu/kip/.

The Karst Information Portal usage is measured through the Digital Commons Dashboard. This year there were 37,577 full text item downloads and 18,083 metadata page hits. Digital Commons has automated their statistics platform to ensure all reported usage is actual use by excluding duplicate loads or probable robot traffic from the numbers. KIP usage is coming from 180 countries, with most of the usage being in the United States, followed by Brazil and France. KIP is truly reaching a worldwide audience! The image below shows the top 15 countries of usage for the Karst Information Portal, with these countries representing 79% of the total usage. Remaining countries are grouped in a category of "other."



KIP Downloads by Country

NCKRI RESEARCH GRANT PROGRAM

In 2019, NCKRI initiated three 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 encourage new principal investigators to enter the field.

• The NCKRI Scholar Fellowship Program supports cave and karst research by exceptional graduate and undergraduate students across the country.

• 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.

• NCKRI's research grant program is managed by Dr. Daniel Jones. Application and other information is posted at <u>https://www.nmt.</u> edu/research/organizations/nckri. php. In 2022, we supported two new National Seed Grants. We start below with reports from two seed grant projects that were selected for funding in the 2021 cycle, for which the work and reports were completed during the last fiscal year.

NCKRI National Seed Grants – Reports from previously funded seed grants

Late Holocene climate variability from ice caves in Hawaii Bogdan P. Onac

University of South Florida, Tampa, FL 33620

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 precip-

itation chemistry, come from polar and alpine ice cores. Ice deposits in caves and lava tubes may allow for detailed paleoenvironmental reconstructions, which are extremely important in regions where no other records exist. The ratios of naturally occurring oxygen and hydrogen isotopes in ice samples can provide important information about temperature, source of moisture, and evaporation. Thus, climate changes can be characterized for the time period spanned by the ice core record by precisely measuring the oxygen and hydrogen stable isotope variations, denoted as δ^{18} O and δ^{2} H, respectively.

Tropical Hawaii harbors high-elevation lava tubes with perennial ice; these ice deposits have only become accessible to science over the last decade. This small-scale project focuses on the investigation of ice cores recovered from two lava tubes formed during different eruption events just below the Mauna Loa Volcano summit. Following the rules imposed by the Department of Land and Natural Resources (Mauna Loa Forest Reserve), the location of caves and photographs should not be provided in reports and publications or any other social media posts without approval from the above mentioned organization. Therefore, in this report the studied lava tubes will be described as "Lava Tube 1" and "Lava Tube 2". Although these Hawaiian lava tubes are at almost 4000 m in elevation, the ice accumulations in them are not immune to current climate warming. In fact, glaciological observations carried out over the past 10 years in one of the



Comparison between the oxygen isotopic record from Lava Tube 1 and Lava Tube 2, showing climate changes over a few thousand years.

lava tubes indicate the ice is rapidly disappearing. The 2022 eruption of Mauna Loa Volcano apparently filled or covered one of the lava tubes, and the preservation of the ice block in the other tube remains uncertain.

The field activities were conducted between March 31 and April 9, 2022, when the PI (Onac), a PhD student (Lucia) from the University of Nevada in Las Vegas, and two cavers (Drs. Stephen Smith and Andreas Pflitsch) entered two lava tubes known to host ice accumulations. The ice core from Lava Tube 1 is only 49 cm long, whereas the one from Lava Tube 2 is 92 cm in length. Both were recovered using a 1-m long and 7.25 cm diameter Kovacs Mark 3 barrel.

The ice cores were photographed, described (stratigraphy, ice features, color, transparency, etc.), and sub-sampled while in the cave to prevent melting. Micro-ice cores (0.8 mm in diameter and 1 cm long) were drilled perpendicular from each of the two cores and transferred into zipped plastic bags for stable isotope analyses. The remainder of the ice cores were then divided in slabs at 1-cm resolution and every individual ice slab was placed in a zipped bag and allowed to melt at room temperature. After the ice melted, each water sample was transferred into high-density polyethylene bottles (8 mL for stable isotope and 125 mL for dating/geochemical analyses) and shipped to the USF Stable Isotope/Geochemical Lab in Tampa, FL.

Because we could not easily see any organic material trapped in the ice, our next attempt was to send melted ice samples from different depths in each of the cores to the Radiogenic Lab at the University of New Mexico in Albuquerque for U-series dating. Unfortunately, the concentration of uranium was too low to obtain absolute ages. Because establishing a reliable chronology is essential in any paleoclimatic study,



Dr. Onac and his team collecting an ice core in a cave in Romania.

we filtered 15 melted ice samples using 0.7 μ m Whatman TCLP glass microfibre filters, allowed them to dry, and then we sent these filters to the Center for Applied Isotope Studies at the University of Georgia for radiocarbon dating, which showed that the cores cover a nearly 3000year record. With these new results, we constructed age-depth models that will allow a better interpretation of the isotopic signal.

The stable isotope analysis of all ice-melted water samples has been completed using the Stable Isotope Lab at University of South Florida (Onac) as well as the Las Vegas Isotope Science Laboratory (Lucia). The δ^{18} O and δ^{2} H values range from -12.6 to -2.5‰ and -92.7 to -43.3‰, respectively. To be valid, a comparison between oxygen isotope curves requires a common time-scale, which is still in progress for our cores. From our preliminary age data, it is now clear that the two ice records overlap for a short period of time.

The amplitude of the single most important isotope shift is 5.4‰, which suggests a significant temperature change, in the order of at least 3-4°C. At the same time the oxygen isotopic values seem to indicate frequent and intense La Niña events, during which greater rainfall and cooler temperatures are expected in Hawaii. We are still working to generate precise isotope time series, in order to indicate when such events occurred and what triggered the isotopic shifts.

The PI presented preliminary results from this research during the International Workshop on Ice Caves held in Liptovsky Mikulas (Slovakia) in May 2022 and in three oral communications (seminars for the Emil G. Racovita Institute for Study of Life in Extreme Conditions and El Malpais National Monument, as well as at the 4th International Planetary Caves Conference held in Lanzarote, Spain in May 2023) focused on highlighting the potential of ice and other mineral deposits in lava tubes as paleoclimatic indicators.

I am happy and grateful to NCK-RI for providing me the necessary financial support to travel and recover the ice cores from these lava tubes in April 2022, as it is unclear whether LT1 and LT2 still host ice or will ever be accessible again.

Bogdan P. Onac

Utilizing Stalagmites from the Philippines (USPS): Quantifying and understanding interannual hydroclimate variability in the Philippines through cave monitoring and stalagmite analyses Dr. Daniel E. Ibarra and Dr. Natasha Sekhon

Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912

Developing nations that contribute least towards global greenhouse gas emissions are anticipated to face the brunt of anthropogenic climate change. Countries within the Maritime Continent such as the Philippines have experienced multiple severe droughts and floods associated with the El Niño Southern Oscillation, monsoon, and typhoons, which are anticipated to change in frequency, timing, and intensity. In addition, water resources in tropical island nations are projected to rapidly decrease as a consequence of already limited resources, an increase in demand, and future changes in climate. Drs. Sekhon and Ibarra utilized seed funding from NCKRI to establish a continuous multi-year monitoring network of multiple cave systems across the Philippines (Figure 1) in close collaboration with Puerto Princesa Subterranean National Park, a UNESCO world heritage site, Biak Na Bato National Park, and Sierra Madre Outdoor Club. The long-term goal of the project is to develop speleothem records from the Philippines to investigate how abrupt climate change events initiated in the Northern Hemisphere impact tropical and extra-tropical hydroclimates through the Quaternary. However, in order to develop terrestrial paleoclimate hydroclimate records from speleothems, a robust understanding of the modern relationship between climate parameters and geochemical proxies (e.g., stable isotopes, trace elements) is paramount. Further, a multi-proxy approach will help fingerprint local and regional changes in the hydroclimate. As such, NCKRI seed grant funding was also used to study matrix versus non-matrix matched calibration of trace elements using a Laser Ablation Inductively Coupled Plasma Mass Spectrometry setup with far reaching implications for



FIGURE 1: a) Location of the newly monitored network of cave systems across the Philippines, b) pCO₂ concentration results from Manningning Cave, Biak Na Bato National Park, c) surface-air temperature, daily rainfall, wind rose, d) pressure and wind speed from weather station closest to the cave, e) drip rate and f) cave-air temperature data for the two sites monitored within the cave.

accurate laser-based carbonate geochemistry measurements.

Preliminary results from our cave monitoring efforts suggest that the geochemistry of the speleothems retrieved will reflect hydroclimate variability. We are monitoring multiple parameters such as cave-air temperature, drip rate variation, and pCO₂ (Figure 1b-f). The spike in drip rate for our site in Biak-Na-Bato following major rainfall events highlights that the cave conditions reflect climate outside the cave. The low variation in cave-air temperature and high pCO₂ concentrations are prime conditions for speleothem growth recording hydroclimate variability. Trace element and stable isotope analysis of cave drip water and farmed cave calcite suggest that establishing an empirical relationship between modern observations (rainfall amount) and variations in geochemical proxies will be crucial to provide quantitative estimates of changes in the hydroclimate.

We collected multiple broken speleothem samples from the caves that we are monitoring across the Philippines. Currently, we are in the process of polishing and imaging the samples before we commence geochemical work. Rather than relying on a single proxy, we will develop a multiple-proxy (stable isotopes, trace elements, and magnetic data) record of past climate to understand past changes in the hydroclimate. Following this we will produce some of the first for the region, high-resolution terrestrial paleoclimate data using the distribution of detritus input in U-Th dated speleothems. In addition, we will also compare our results with new and existing high-resolution isotope-enabled climate model simulations. The newly designed LA-ICP-MS sample holder that we set up has the capability to analyze carbonate and non-carbonate samples using both matrix and non-matrix matched standards. Our monitoring



LA-ICP-MS sample cell holder with matrix (SPLT-NP, JC-T-NP, MACS3) and non-matrix (NIST612) matched standards as the pressed pellets. A cut sample from the Philippines which was used in the standardization study. Clockwise: broken speleothem samples collected from Gypsum Galleries chamber in PPS-RNP, Bangalau cave in STC, and Gaia Passage chamber in PPSRNP.

of extreme hydroclimate events such as fires and typhoons will allow for process-based understanding of extreme events. Further, our new high-resolution speleothem records from the Philippines will ultimately provide insight into the frequency and intensity of extreme weather events.

The team has presented this work at multiple conferences and are writing up the results for multiple publications as well as writing larger grants to the US National Science Foundation. Additionally, as part of the interpreting modern hydroclimate conditions, the team has published the following papers using modern discharge and rainfall datasets from the Philippines:

• Sekhon, N., C.P.C. David, M.C.M. Geronia, M.J.G. Custado & D.E. Ibarra, 2022, "Investigating the response of hydrological processes to El Niño events using a 100-year dataset from the western Pacific Ocean." *Journal of Hydrology: Regional Studies* DOI: doi. org/10.1016/j.ejrh.2022.101174

• David, C.P., M.J., Custado, N. Sekhon & D.E. Ibarra, 2022, "Forecasting tropical EN-SO-induced drought conditions using sea surface heights in the Western Pacific." <u>All Earth</u>. DOI: 10.1080/27669645.2022.2089484

This work has involved two undergraduates, Celia Kong-Johnson and Annabelle Gao, as well collaborators Prof. C.P.C. David and Mart Geronia at the University of Philippines, Diliman, Khylle Tabujara and Jones Tabujara at PPSRNP, Javrald V Gatdula at BNBNP, and Nida Santos Dela Cruz at STC. Dr. Sekhon aims to continue this work when she starts her new position as an Assistant Professor at Occidental College in Spring 2024. Dr. Ibarra and Brown University colleague Dr. Kim Cobb have recruited a new graduate student (starting fall 2023) to also continue work on aspects of this work.

NCKRI National Seed Grants – New seed grants selected for funding in 2022

The Shoshone Canyon Conduit Cave: A Greater Yellowstone Ecosystem Sulfur Cave

John R. Spear Department of Civil and Environmental Engineering, Colorado School of Mines (Mines), Golden, Colorado 80401

Five miles west of Cody, Wyoming and ~25 miles east of Yellowstone National Park lies the Shoshone Conduit Cave. Bisecting Cedar Mountain, an irrigation tunnel built by the Bureau of Reclamation (BoR), managed by the Heart Mountain Irrigation District, delivers water from the BoR Buffalo Bill Reservoir to more than 30,000 acres of irrigated lands in and around Cody. During the construction of that tunnel in the late 1940's, a cave was discovered and the tunnel was made to travel though. The cave is rich in sulfides and sulfur deposits with unique speleothems. In this work, we will conduct a preliminary survey of both the geochemistry and microbiology of this sulfur cave on its speleothems, mineral deposits and waters. To date, this cave has had no such work completed on any kind of science in the cave, though a team of Colorado cavers has been in the cave twice to complete an initial survey. What makes this cave unique and sets it apart is that it is a typical limestone dissolution cave that happens to be dominated by sulfur compounds. Elemental sulfur is present in and on everything and the cave has strong sulfide odors that likely emanate from geothermal



Exotic sulfur speleothems from Shoshone Canyon Cave. Photo courtesy of John R. Spear.

hot springs in the deep subsurface beneath the cave. Access is highly restricted due to the fact that the irrigation tunnel is running most of the year.

John Spear, along with Colorado School of Mines NSS Caving Grotto members, completed a sampling trip to the Shoshone Canyon Conduit Cave, west of Cody, Wyoming in March of 2023. The trip was quite successful for photogrammetry work, high resolution survey, sampling for geochemistry, microbiology, and petrography/mineralogy. Work is ongoing in the laboratory this summer and fall to analyze acquired samples and data. The team are also going to be able to extend their work to nearby Sulphur Cave, Steamboat Springs, which was recently designated as National Natural Landmark.

Developing open-source tools to simulate reactive and non-reactive contaminant transport in karst aquifers

Chloé Fandel

Geology Department, Carleton College. Northfield, MN, 55057

The goal of this project is to improve our ability to simulate how groundwater and contaminants move through karst landscapes. Numerical computer models are powerful simulation tools that allow us to play out various scenarios before they actually happen, so that we can develop wise groundwater protection strategies. However, simulating karst aquifers is significantly more challenging than simulating more common porous aquifers. Numerical modeling in karst is an emerging area of research with many promising new developments, but these are currently somewhat disconnected and the barriers to using them are high.

This study is linked to other ongoing projects by research teams in Minnesota, Switzerland, and Germany, all working on different aspects of groundwater flow and contaminant transport modeling in karst. Fandel's team will focus on developing open-source, well-documented, and reproducible example code linking these disconnected projects, with a particular emphasis on creating training materials that can be used by several generations of undergraduate student researchers.

Future work will then build from these resources to investigate three major anthropogenic contaminants: nitrate in agricultural settings, chloride in urban settings, and heat near geothermal wellfields.

Groundwater susceptibility to surface contamination in Minnesota, highlighting high-risk karst regions that will be the focus of this study.

Map: Minnesota Dept. of Natural Resources.

Sinkhole plain near Fountain, MN. The satellite imagery highlights key interconnected features of the study area: high sinkhole density, extensive agricultural land use, and a surface stream network.





SCIENTISTS IN PARKS INTERNSHIP

This year, NCKRI staff were fortunate to be able to mentor interns through the National Park Service's Scientists in Parks (SIP) program. The SIP program is a joint internship program between the National Park Service, Conservation Legacy's Stewards Individual Placement Program, the Geological Society of America, and the Ecological Society of America. SIP interns gain new skills, experience, and connections while helping the NPS achieve their mission. In May 2023, four SIP interns joined Dr. Jones' Geobiology Lab. Two of the SIP interns, Anika Baloun and Joseph Hoberg started working on a cave inventory and geobiology survey at Capulin Volcano National Monument, and two others, Jimmy Swift and Abigail Brown, started a new project related to upcoming restoration work in the Sulfur Springs area of Valles Caldera National Preserve and in travertine springs around the Preserve. Stay tuned for updates! Several of our most popular national parks are based around caves, and caves and karst are present in many National Parks, Monuments, Preserves, Historic Sites, Parkways, and other NPS sites. Students interested in the SIP program should consider visiting the website below and browse for different opportunities in the National Park System:

https://www.nps.gov/subjects/ science/scientists-in-parks.htm



(Above) Jimmy Swift and Abigail Brown sampling microbial communities in mudpots and gypsum precipitates in Valles Caldera National Preserve.(Below) SIP Interns Jimmy Swift, Anika Baloun, and Joseph Hoberg (left to right)



EDUCATION AND OUTREACH PROGRAM

NCKRI was founded on several guiding principles, with one major tenet being education, through promoting public education to best practices for cave and karst management. NCKRI's efforts to work cooperatively with multiple agencies helps provide a central location for finding cave and karst information through diverse initiatives and multiple platforms. From local family events to online resources that are available around the world, NCKRI works to support the greater community and further our knowledge of speleology.

Science Communications Intern

May 22, 2023 marked the start of another new event for NCKRI, our first Science Communications Intern through the National Park Service's Scientists in Parks (SIP) program, Raquel Lugo. So far Raquel has been helping with outreach events, working on projects such as the decontamination station comics and the Cave & Karst Word of the Week social media posts. NCKRI is excited to have her here and looks forward to seeing her future accomplishments.

"Interning at NCKRI has given me the opportunity to learn about various educational efforts that the institution produces as well as help in creating social media posts and a junior bat biology activity book. It has also shown me the importance of bringing relevant science information to the public and having multiple ways of doing that. I hope to keep learning on how to be an effective science



Example Cave & Karst Word of the Week social media post.

communicator and create educational materials that will be helpful for cave and karst conservation."- Raquel Lugo

Social Media

October 2022 saw the beginning of a new online initiative for NCK-RI, the Cave and Karst Word of the Week. The purpose of this initiative was to make cave and karst jargon more accessible while highlighting the interdisciplinary nature of the subject matter and teaching conservation ethos. For each word an image or diagram is created with interpretive text that shares the etymology of the word while providing relevance to the reader. NCKRI volunteer Riannon Colton started this initiative and continued creating educational



NPS Sciencitists in Parks, Science Communications Intern, Raquel Lugo teaches children about karst during the Inspired by Science Summer Camp STEM night. Photo courtesy of diagrams with text until June 1st. Riannon just started working on her masters at the University of Arkansas looking at airflow within caves, which inspired the posts for " circulating convective airflow", "chimney effect", "barometric" and "radon". Since this initiative has begun, we have seen a 60% increase in Facebook followers, and a 200% increase in Instagram followers. NCKRI's total reach for Facebook for the 2022-2023 fiscal year was over 44,000 and for Instagram 4,500. The top posts on Facebook were related to the Word of the Week Initiative, Cave Week and funding opportunities such as the NCKRI seed grant.

Our Twitter and LinkedIn online presence shares different resources. LinkedIn mostly shares NCKRI related news and professional opportunities such as funding sources and NCKRI-hosted conferences. There was a 37% increase in followers on LinkedIn, which can probably be attributed to the increase of posting frequency of at least one post per month. Our Twitter account is more focused on highlighting NMT's Cave and Karst Academic Program, funding resources and other educational/professional opportunities.

Photo courtesy of Devra Heyer.

NCKRI News

NCKRI news has undergone a couple of changes this year. The issue sent out in March of 2022 was the first time using an online mailing platform. This platform helped us create a template to better organize information while providing an easier way for our readers to interact with the material. Currently the NCKRI news is being sent out on the second Tuesday of each month and includes upcoming deadlines, professional opportunities and the current events happening with NCK-RI and our partners. As we get more feedback, we hope to increase the ease of accessing and sharing cave and karst news. If you would like to join the NCKRI mailing list you can either go to the NCKRI website (nckri.org) and click on the "JOIN" button or use the QR code on the inside cover.

Website

Last year saw the unveiling of the new website, and there have been even more changes this year. Each year we update the website with publications, events, resources and initiatives. Most of the users are looking for information about types of caves and how they are formed. There are 2000-3000 website sessions per month during the fall and spring with drop-offs that correspond to seasonal closings of schools.

One of the new pages includes https://nckri.org/events/sinkholecleanup/ which shares information about the sinkhole cleanups that are being done around the Roswell and Carlsbad area by the Bureau of Land Management, and the relationship between these sinkholes and the local water systems.

Education Initiatives at NCKRI Headquarters Collections and Interpretive Displays

Several years ago, Will White donated karst specimens to NCKRI from all over the United States. 300 specimens from Kentucky have been inventoried with many more to go. These specimens have also been curated and put on display at NCKRI headquarters. Another collection recently curated originated from Tom Bemis, named the "Nightmare" collection. This 100-item collection mostly features gear that has failed in a cave or was retired due to wear. There are several interpretive displays in various stages of development at NCKRI headquarters with themes from the evolution of caving technology to the relationship between art and caves. Whether you are going to a training, family event or just want to say "hi", check out our displays and learn more about our connection and history with caves.



Education Program Manager, Devra Heyer instructing students during Cave Night at NCKRI headquarters.

Photo courtesy of Valerie Davis.

Headquarters Events

There were several events held at NCKRI headquarters with some of our local partners. One of these partners is Carlsbad Caverns National Park, which is celebrating its centennial. Not only does Carlsbad Caverns use NCKRI headquarters for training but they had one of the Centennial Guest speakers, Ron Kerbo, give a presentation. Another event in partnership with Carlsbad Caverns was having Drs. Jure Tičar and Matija Zorn, from the Research Center of the Slovenian Academy of Science and Arts, Anton Melik Geographical Institute, give two lectures for the public at NCKRI Headquarters: Cave Tourism in Slovenia—Between Mass Tourism and the Protection of Geoheritage, and Pollution of Karst Caves in Selected Slovenian Regions.

One of our local community partners is Inspired by Science, a New Mexico based charitable educational organization established in 2013 by native-Carlsbad community members Deena and Mike Antiporda. Inspired by Science promotes and provides supplemental STEM educational activities and day camps at the local and regional level for elementary school age youth. There were several events held in partnership with them, including Cave Night on June 6th, during Cave Week and their STEM summer camp. At this event students and their families practiced reading a cave map, learned magnetic properties, how to use a compass and how to build their own compass using a paper clip.

Outreach Events

Each year NCKRI participates in outreach events and conferences that reach diverse communities, ranging from the Rocky Mountain Geobiology Symposium to the International Union of Speleology to Cave Week to the New Mexico Science Teachers Association. The combined total of people in attendance at all of these outreach events is over 16,000, with over 5,000 pieces of outreach materials given out, which helps us estimate the number of people NCKRI has directly interacted with in the last year.

School and Family Events

NCKRI strives to be a presence in the Carlsbad community by participating in community events with the city of Carlsbad, Southeast New Mexico College, and Inspired by Science by participating in STEM/ STEAM or cave-themed events. During Bat Fest, NCKRI shared the diversity of bats by having participants make bat head bands while learning about how so many of our foods depend on bats to pollinate, disperse seeds or protect from insects. At STEM night with Inspired by Science, NCKRI shared how friction aids in our technical devices and gives knots their various properties. At each event NCKRI shares with the community how the local economy, infrastructure and water resources are intimately connected to the karst environment.

Conservation and Cave Education Initiatives Decontamination Station at NSS Convention

NCKRI sponsored the 2023 National Speleological Society (NSS) Annual Convention Decon (decontamination) Station in Elkins, West Virginia from June 25th to 30th. Convention participants have recreational, educational and even resource management experiences in caves as part of the annual event. NCKRI partnered with the NSS convention volunteers, US Forest Service, Bureau of Land Management and National Park Service to educate and provide this amenity for convention goers, and to build a station that could remain onsite for years to come. The convention site is near many caves on public land with sensitive resources and bats. Each year, the site is utilized by 1000-2000 cavers for various events. This initiative trained site members in how to build and maintain a decontamination station while providing a needed resource for the convention participants. The station was frequented through out the day by convention attendees before they visited new caves. Local cave rescuers even used the station to decon communal gear before going back to the regional gear cache. The station was also utilized to clean gear and as an information booth for decon procedures.



Use of the decontamination station at the National Speleological Society's annual conference in West Virginia. Photo courtesy of Devra Heyer.

Local Cave and Karst Cleanup Events

One of the conservation outreach events that NCKRI participated in was Riverblitz, a Pecos River cleanup event located in Carlsbad, NM. This year there were multiple Sinkhole Clean-Ups led by the Roswell and Carlsbad offices of the Bureau of Land management, including two events held on Earth Day. With point source pollution being such a concern with karst environments, NCKRI is not only spreading the word about this issue, but also participating and helping organize events to help mitigate it.

Online Events

There are multiple online events that provide education and outreach opportunities. The main events that NCKRI participates in are Cave Week, Bat Week and Earth Science Week. Our contributions to each event are tailored to the audience and the message. This year NCKRI staff helped facilitate Cave Week by assisting in writing the communications plan; and creating and organizing the Cave Week toolkit that provided educational resources and templates. If you would like to participate in Cave Week next year feel free to join the cave week mailing list for a link to the Cave Week toolkit.

NCKRI also contributed to the Earth Science Week Toolkit put on by the American Geosciences Institute (AGI) with an educational card. The Earth Science Week Toolkits go out to over 8000 teachers and educators with a range of instructional materials from posters, to lessons to stickers.



Texas Science Teacher Elene Heyer holds up the NCKRI educational flyer from the Earth Science Week Toolkit. Photo courtesy of Elene Heyer.

STUDENT ACTIVITIES

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

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 also in engineering, chemistry, robotics, and other fields. 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

NMT-NCKRI Geobiology Lab

This has been another exciting year for Dr. Jones and the students of his geobiology lab group. In July and August, 2022, Dan, three students and several colleagues went on a research expedition to the Frasassi Cave System, Italy to continue their NASA-funded fieldwork on acidic gypsum deposits. In addition, new students joined the group, and Dr. Jones received two new grants to support his research. He received an NSF CAREER grant for research in the sulfidic Frasassi cave system and Carlsbad Caverns National Park (hyperlink: https://www.nsf.gov/ awardsearch/showAward?AWD_ ID=2239710), and he also received a new award from NASA's Planetary Protection Research program that will support new research in planetary analog environments at Valles Caldera National Preserve and Carlsbad Caverns National Park.



Several members of the Geobiology group on a field trip to Valles Caldera in the Jemez Mountains, 2022. Left to right, Kenyan Phlieger, Brianna Martin, Katherine Krizek, Kathryn Hobart, Katelyn Green, Abigail Brown, and Calyssa Huff.



(left) NMT graduate student Zoë Havlena collects gypsum samples in Frasassi Cave with collaborators Heather Graham (left) and Jennifer Stern (right) from NASA's Goddard Space Flight Center.



Zoë Havlena at the GSA awards reception with NMT's former president, Dr. Stephen Wells

Graduate Student Research

Zoë Havlena is a Ph.D. candidate in Geobiology, in her 5th year. This year, Zoë presented her research on gypsum deposits in the Frasassi Caves in Italy at multiple national and regional meetings including the Geological Society of America fall conference in Denver, CO, and the Astrobiology Graduate Conference in La Jolla. CA. At GSA, Zoë was awarded the William B. & Dorothy Heroy Research Grant, and she received two additional fellowships to support her astrobiology research: the NASA Astrobiology Early Career Collaboration Award, and the New Mexico Space Grant Consortium Graduate Research Fellowship. Earlier this year, she was featured in an NMT press release about her many research awards (https://www. nmt.edu/news/2023/havlena-research-awards.php).

Mackenzie Best is a Ph.D. candidate in Geobiology, in her third year. Mackenzie passed her Candidacy Exam in fall, 2022, and presented her research on nitrogen cycling by cave microorganisms at national and regional conferences including the Geological Society of America fall conference in Denver, CO, and the Rocky Mountain Geobiology Symposium in Denver, CO. This year, Mackenzie was nominated for and accepted a position on the Young Leaders Committee for the Society for Mining, Metallurgy & Exploration, where she serves as a representative for the SME Environmental Division. She also continues to serve as student trustee of the New Mexico Tech Foundation (the philanthropic branch of NMT) and as President of the AAUW student club. This spring, Mackenzie received two research fellowships: the New Mexico Space Grant Consortium Graduate Research Fellowship and a Graduate Grant-in-Aid award from the New Mexico Geologic Society. She was recently notified that



she was awarded NMT's prestigious "Rising Star" award!

Kathryn Hobart defended their Ph.D. in September, 2022, and is now at the United States Geological Survey in Reston, VA, as a Mendenhall Postdoctoral Fellow. In the last year, Kathryn submitted two manuscripts, one of which was recently accepted for publication, and presented at several national conferences. Kathryn was a Ph.D. candidate in Geobiology that was co-advised by Dr. Jones at the University of Minnesota.

Katelyn Green just finished the first year of her graduate program at NMT. Her research is on nitrogen-cycling cave microbial communities, and her main project is using high-throughput DNA sequencing to test hypotheses about nitrogen fixer diversity in the Frasassi cave system, Italy. She participated in her first cave field expedition in July and August, 2022, and this spring she presented her research at NMT's student research symposium and the Rocky Mountain Geobiology Symposium in Denver, CO.

Abigail Brown has been working with Dr. Jones as an undergraduate since 2020, studying extreme microbial communities in and around Valles Caldera National Preserve in New Mexico. She recently accepted a position as a Master's student in Biology at NMT, and is completing her research on acid-adapted com-

Katelyn Green, Mackenzie Best, and Zoë Havlena (left to right) after a long day in the Ramo Sulfureo passage in the Frasassi Caves, with Italian colleagues Maurizio Mainiero (left) and Stefano Recanatini (right).

munities in the Preserve as well as sulfur-cycling communities at Soda Dam, a fascinating travertine structure that is one of many volcanically-influenced carbonate hot springs in the greater Valles Caldera region. Abigail presented her research at the Rocky Mountain Geobiology Symposium in Denver, CO, and was awarded the Lucille H. Pipkin Undergraduate Research Award by the New Mexico Geological Society.

Calyssa Huff started working with Dr. Jones as an undergraduate in 2022 on a NASA-funded project quantifying microbial bioburden in NASA clean rooms. She gave a presentation on her research at the Planetary Protection in Practice virtual workshop in October, 2022, and presented at the Rocky Mountain Geobiology Symposium in Denver, CO. We are pleased to say that she was recently accepted into NMT's graduate program, and will continue working with Dr. Jones as a Master's student.

Other members of the Geobiology group include undergraduates Kenyan Phlieger (NMT Earth Science) and Katherine Krizek (NMT Psychology). Kenyan worked on a project involving phylogenetic analysis of ammonia oxidation genes from cave communities, and Katherine studied low biomass cave gypsum. Kenyan and Katherine presented their research at the New Mexico Geological Society Annual Spring Conference, Socorro, NM, and the Rocky Mountain Geobiology Symposium in Denver, CO, respectively.

As an extension of the 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 on schedule and a couple of conference papers have been published.

Cave and Karst Research Fellowships for NMT Undergraduates New opportunity: Field research in the Tongass National Forest

From July 24 to August 1, 2022, two undergraduate students from New Mexico Tech (NMT), Antonio Chavez (Environmental Science major) and Celeste Flores (double major in Mechanical Engineering and Physics), joined a cave science expedition to the Tongass National Forest. This opportunity was a new



Antonio Chavez scrapes moonmilk off a cave wall in the Tongass National Forest.

Photo courtesy of Riley Drake



Celeste Flores and Riley Drake collect moonmilk samples in the Tongass National Forest.

model for the Undergraduate Research Opportunities in Caves and Karst (UROCK) program, which was started in 2019 and is designed to facilitate research experiences in cave and karst science at New Mexico Tech in connection with the Cave and Karst Studies (CKS) program.

This special opportunity was different from previous UROCK awards. Instead of students developing and proposing their own project with a faculty or research mentor, students applied to participate in a planned cave research program. The research expedition, called the Tongass Genomics Initiative, was led by Riley Drake, a cave scientist and graduate student at Massachusetts Institute of Technology (MIT). The students traveled with Devra Heyer, NCKRI's Education Program Manager, out to the remote North Prince of Wales Island (a ferry from Ketchikan, and then a long drive, hike, and rowboat trip to the island). There they joined Ms. Drake and another undergraduate (Samuel Littman, Tufts University) and collected samples to assist with the program's scientific goals of assessing groundwater microbiology, evaluating

Photo courtesy of Devra Heyer. speleothem microbial community recovery from damaged versus pristine moonmilk, and exploring the invertebrate fauna of caves in the region. A major component of this opportunity was to prepare students for remote environments, and Devra worked closely with the students to ensure that they were physically and mentally prepared for the fieldwork. One of the outcomes from incorporating these elements is that we were able to engage undergraduate students from diverse academic and experiential backgrounds into caves. The UROCK students walked away with not only an understanding of cave environments, sampling techniques, and conservation ethos but also a better understanding of life skills such as project management, communication strategies, self-advocacy, and self-reliance.

The program was a success, and both NMT students are continuing with research or communication projects stemming from the trip. We may continue this as a new model for creating new research opportunities for NMT students through the UROCK program.

CONFERENCES AND MEETINGS

17th 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. The 17th Sinkhole Conference was held in partnership with the University of South Florida's School of Geosciences in Tampa, USA, on 27-31 March 2023. Nearly 170 people registered for the conference, and they were treated to four new features.

First, unlike previous conferences in this series, all short courses were included in the price of registration to encourage more attendance, especially by students since the conference was held at a university. This decision was very popular as two of the courses sold out, the remaining two nearly reached maximum capacity, and overall attendance was above average.

Second, a livestreaming option was offered for those who could not attend in person. While those online could not communicate directly with those giving presentations, questions could be put into the chat function to be read by the moderator to the presenters.

Third, as often happens at conferences, some people can't write papers by the deadline for publication in the proceedings, and thus cannot present their research. To accommodate them, as well as researchers with newly developing projects for which they'd like some feedback, we offered "Karst Clips." Given in the style of "lightning talks," 22 five-minute-long presentations were squeezed into the schedule.



Fourth, we realized that a huge amount of useful information is shared during the conference field trips, which is lost afterward in memories and often in the scattered papers handed out. Since NCKRI recently developed a Field Guide publication series, Field Guide 3 provided detailed descriptions of the Sinkhole Conference field sites, richly supplemented with many maps and photos. Like the conference proceedings and all NCKRI reports, only a few copies of the field guides were printed but they are available for free download from the NCKRI website.

The conference began on Monday, March 27th, with a full day field trip though the Tampa-to-Gainesville area to see the variety of karst landscape features characteristic of central Florida. The trip was organized by Sam Upchurch, Tom Scott, Roger Portell, Michael Alfieri, and Christopher Williams. Unfortunately, illness kept Upchurch and Scott at home, but Clint Kromhout did a supurb job stepping in to help. Devil's Millhopper Geological State Park was the first stop on the trip, where a large sinkhole occurs within the city limits of Gainesville, 40 m deep and 150 m in diameter, that extends to the water table. The

sinkhole is primarily formed in the lower to middle Miocene Hawthorne Group and is floored by Eocene-age Ocala limestone. The sinkhole formed when Hawthorne sediments collapsed into solution cavities in the underlying Ocala limestone.

The second stop on the trip was Haile Quarry, which contains rich and important bone deposits in the sediments that fill many sinkholes exposed by quarrying operations. The quarry owner, Limestone Products, has supported their study and discovery of bone deposits dating from the Eocene (55 million years ago) to the Pleistocene (10,000 years ago).

The third stop was at Rainbow Springs State Park at the head of the Rainbow River. Rainbow Spring is Florida's fourth largest spring, and one of the largest spring runs in the world, with an average discharge of more than 1.5 million cubic meters (400 million gallons) of water per day.

The second day of the meeting was dedicated to short courses, taught by leading experts in their field. The courses offered at this year's conference included:

- Stormwater Management in Karst—A Regional Perspective, by Robert K. Denton Jr.
- GIS Approaches with LIDAR



and Imaging Technologies for Sinkhole Documentation and Analysis, by Benjamin Mittler and Jorge Gonzalez

- Designing and Conducting Tracer Studies in Karst—With Emphasis on Sites with Actual or Potential Contaminant Releases, by Dr. Ralph Ewers and Keith Whit
- Conducting Geotechnical Investigations in Karst, by Michael J. Byle

Research presentations ran from Wednesday morning until noon on Friday. The presentations began with addresses from Florida State Geologist Guy "Harley" Means and the Florida State Geotechnical Materials Engineer, David Horhota. Dr. Jonathan Martin, University of Florida, gave the keynote lecture, The Carbonate Critical Zone: Impacts from Recharge, Reversing Springs, Residence Times, and Redox Reactions, a topic that will have major implications on karst environmental and engineering issues as our climate continues to change. Wednesday also included a lunchtime meeting of the Karst Commission of the International Association of Hydrogeologists and ended with a poster session and planning meeting for the next Sinkhole Conference.

Thursday continued with presentations, which wrapped up with a panel discussion by members of ASTM's Karst Subcommittee, a newly formed team, about their work and how it applies to engineering and environmental impacts in karst. In the break after the panel discussion, the Silent Auction closed and final purchases were made. The auction was sponsored by members of the Sinkhole Conference's Organizing Committee and others who provided a wide variety of items for sale to raise money for the Barry F. Beck (founder of the conference series) Student Award. This year the auction raised nearly

\$2,100. The award includes free registration to the conference and field trips, and reimbursement for up to \$1,000 in travel expenses. During that evening's banquet, the six student awardees were formally recognized: Giorgi Chartolani, Kyle Compare, Heidi Harwick, Isabella Serena Liso, Olanrewaju Muili, and Lillian Smith.

Jim Griswold, senior hydrologist and assistant to the Director of the Oil Conservation Division, New Mexico Energy, Minerals and Natural Resources Department presented the Thursday evening banquet lecture, *The Sinkhole That Wasn t*, which recounted the history of the collapse of brine well cavities in southeastern New Mexico, and remediation of one in Carlsbad to prevent its collapse.

Following final presentations and lunch on Friday, Jason LaRouche, Robin Speidel, and David DeWitt, all from the Southwest Florida Water Management District, led a halfday trip to the Morris Bridge Sinks complex and the Peck Sink Preserve to discuss the role of karst in flood control and water supply management in west-central Florida.

The 18th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts on Karst is tentatively planned for Upstate New York. This will be the first time the conference is hosted in a glaciated karst terrain. There was great excitement at the Tampa location for New York, and a great deal of support has been offered from organizations in the Upstate area.

To learn more about the conference, the Beck Student Fund, or how to donate or apply for the Beck Fund, visit <u>http://www.sinkholeconference.com/</u>. The conference would not be possible without the support of our Organizing Committee, who are listed individually in the Volunteers section of this report. We also thank this year's generous sponsors: P.E. LaMoreaux and Associates, MicroSeismic, Southwest Geophysical Consulting, Arcadis, and the Barton Springs/Edwards Aquifer Conservation District.



Rainbow Spring. The vivid crystal blue waters distract from the potential for groundwater pollution from increased land use in its watershed.

NATIONAL PARK SERVICE – NCKRI LIAISON PROGRAM

Dr. Patricia Seiser, NCKRI Cave and Karst Management Science Director, currently serves as the National Park Service (NPS) National Cave and Karst Program Coordinator, where she embedded at the NPS Geologic Resources Division (GRD) offices in Lakewood, Colorado. Projects and accomplishments include the following:

Resource Stewardship Strategy

A Resource Stewardship Strategy (RSS) is a long-range planning guidance document created to aid a national park unit in achieving its desired natural and cultural resources conditions. These conditions are identified in a park's foundation document, general management plan and other park plans, as well as NPS policies and relevant laws.

A Resource Stewardship team is comprised of Subject Matter Experts (SME). This team evaluates the status and trends in the condition of the park's resources. This information is used to provide a basis for making decisions for the long-term protection of park resources. It also identifies resources within other agencies, organizations and the public that can aid in these efforts.

This year Dr. Seiser served as the cave and karst SME for two RSS projects. White Sands National Park contains the largest gypsum dunefield in the world. It is also the location of human and animal footprints that tell a story dating back to the time of the last ice age. Its karst landscape creates potential concerns for infrastructure and historic buildings. The second project was Russell Cave National Monument. Russell Cave is an archeological site containing evidence of over 11,000 years of human occupation. The Monument has seen extensive excavation activity as well as changes in philosophy of how to interpret the cave. A significant outcome for the caving community was the re-connection of the National Speleological Society (NSS) with Russell Cave National Monument. NSS cavers may be able to assist the Monument



RSS team at Russell Cave National Monument reviewing status of past archeological digs. Photo courtesy of Patricia E. Seiser.



in achieving some of its identified restoration and preservation goals.

NPS Technical Assistance Requests

National Park units may request assistance for projects that exceed their staff's ability to address. The Technical Assistance Requests (TARs) submitted to the GRD range from technical solutions to knowledge-based expertise for inventories or infrastructure changes. Natchez Trace National Parkway is developing plans for the replacement of the John Coffee Memorial Bridge across the Tennessee river. The TAR involves Dr. Seiser serving as the SME for planning and development meetings, as well as upcoming mapping and inventory efforts for several caves in the Parkway. Capulin Volcano National Monument submitted a TAR to conduct a cave inventory for the park. This work was done in conjunction with a geomicrobiology study being conducted by Dr. Daniel Jones and his SIP interns.

Cave and Karst Resources Inventory Tracker (CKRIT) Database Update

A critical need for the National Park Service was the development of a geocentric cave and karst inventory database that would meet the management needs of individual park units, maintain security, and provide non-sensitive data to upper management and the public. Last year, GRD funded a master's program position to create this database. Denver University geographic information science (GISc) graduate student and project caver Georgia Schneider has now completed her first year of school and work on the database. During this time, she has resolved significant security concerns and has begun the development of a Survey 123 inventory form which will be used to populate the database. Ms Schneider has been testing a Survey 123 form during the cave and karst inventories for Capulin Volcano National Monument and Yellowstone National Park. The CKRIT database is scheduled to be finished at the end of Denver University's spring 2024 quarter. The next step will be to test the database at several cave park units for their review and input.



Georgia Schneider, NPS graduate research assistant, staffs the NCKRI booth during the 2022 Geological Society of America annual meeting in Denver, Colorado.

Photo courtesy of Patricia Seiser.

Denver Museum of Nature and Science: Digital Earth Caves

Dr. Seiser was a guest speaker at the Denver Museum of Nature and Science (DMNS) Digital Earth Caves presentations in January and May. Digital Earth is an ongoing DMNS program developed to present visualizations of the universe in the digital dome.

The Digital Earth Caves presentation was on Carlsbad Caverns National Park and consisted of views from the visitor trail in Carlsbad Cavern. Originally planned as one showing in January, tickets sold out. The Museum put out an announcement for a second showing and it too sold out. The National Park Service Natural Resource Stewardship and Science Directorate, of which GRD is a part, asked for a special showing in May for their "All Hands" meeting. Two showings were scheduled for NPS employees with the remaining seats for the public. In both cases tickets sold out. That week vignettes of Digital Earth Caves were also presented to attendees of the 2023 American Alliance of Museums annual meeting held in Denver.

The NPS and NCKRI wish to thank Dr. KaChun Yu, Bob Raynolds, and Eric Hanson for suggesting a Digital Earth Caves presentation and doing the technical work to make the presentation possible. Special thanks goes to Erin Lynch, Cave Resources Specialist at Carlsbad Caverns National Park, for not only facilitating the permit process, but also for her guidance in assuring that no part of the cave was damaged during the photogrammetry and documentation work. And, as always, a shout out to the National Park Service for protecting our national treasures and aiding in sharing these treasures with others outside of visits to the parks.

Junior Bat Biologist Booklet

US State Department-sponsored volunteer interns, Miranda Axelson and Joanna Lam, completed their portion of the Junior Bat Biologist Booklet last fall. Under the guidance of Pat Seiser and Devra Heyer, as well as input from numerous bat experts from around the country, the two created the booklet about bats for the NPS Junior Ranger Program. Currently Devra Heyer and SIP Intern Raquel Lugo have been working on the formatting of the booklet to ensure it meets all final production needs, slipping in the work between time-critical projects. When completed, the goal is to have a PDF available for download and eventually printed booklets for distribution as requested. Following the release of the English version, a Spanish version will be finalized and released.

Cave Week Celebration

The celebration of Cave Week was unexpectedly bumped up to the national level this year when Dan Pawlak, Ranger at Grand Canyon National Park, reached out for help. Dan's work responsibilities and limited internet at Grand Canyon made it difficult to continue running the Cave Week program on his own. Dan dreamed of promoting cave parks through the various social media platforms, hoping that it would bring caves to the attention of the public and promote cave parks large and small. Dan created Cave Week in 2018 by calling all NPS units with "cave" in their name. That was such a success that the next year NPS GRD provided support, including creating a website for Cave Week. Dan reached out to various organizations and agencies, drawing in the US Bureau of Land Management, the US Forest Service, NPS National Natural Landmarks, Parks Canada and others to create a truly North American week celebrating caves.

Dan will continue to be part of Cave Week, providing support as his job and location will allow. Many thanks to Dan for putting so much time and effort into creating this awesome program.

This year Lima Soto, US Forest Service Cave and Karst lead, and Dr. Seiser organized an online meeting with federal, state, local and private cave-related organizations to explain and promote Cave Week. This generated additional support for the program. We'll be continuing these efforts in the future. preparedness is an important component of cave management. Dr. Seiser served as an instructor for level one students at the weeklong training in Virginia.

International Union for Conservation of Nature

The International Union for Conservation of Nature (IUCN) is a global authority on the status of the natural world and the measures that need to be taken to protect and preserve it. A wide variety of commissions are based in the IUCN, each with an assortment of



Dr. Pat Seiser teaching about psychological concerns at NCRC workshop.

National Cave Rescue Commission

The National Cave Rescue Commission (NCRC) is a charter of the National Speleological Society. It is a volunteer group developed to train and track cave rescue resources throughout the United States. NCRC trains cavers as well as federal, state and local agency personnel from around the country in the art and science of cave rescue. Such training ensures that cave rescue expertise can be found throughout the country, as well as aids in rescuers learning how to protect cave resources while conducting rescue efforts. Several NPS cave resources specialists are NCRC national level instructors. NCRC provides an excellent opportunity for NPS personnel to teach and/or train together. Cave rescue



Dr Patricia Seiser at the UIS. Photo courtesy of Alan Caton.

working groups. Dr. Seiser currently serves on two working groups for the World Commission of Protected Areas (WCPA): the Geoheritage Working Group and the Cave and Karst Working Group.

Professional Meetings 18th International Congress of Speleology, Savoie, France

The International Congress is held every four years throughout the world. The conference is supported by the International Union of Speleology (UIS), of which NCKRI is an affiliated organization. The conference allows for cavers, cave managers and speleological researchers from around the world to meet, learn and engage in a manner not possible via the internet. While attending the conference Dr. Seiser gave a presentation on cave wilderness and what it means for cave resources protection, and was elected by UIS delegates to serve a four-year term as one of seven adjunct secretaries on the UIS board.

80th National Speleological Society Convention – Elkins, West Virginia

While attending the National Convention Dr. Seiser participated in the Federal Cave and Karst Meeting, a meeting of all federal cave resources personnel in attendance at the NSS Convention. Dr. Seiser also attended the National Cave and Karst Management Symposium (NCKMS) Board Meeting, where she represents NCKRI as an NCKMS Board Member; and participated in a Meet the Feds panel discussion during the Conservation and Management Session.

PAST DIRECTOR'S MESSAGE

I'm writing this report in my first days of retirement. Working for NCKRI for more than 16 years, especially as Executive Director, has been an incredible privilege and honor. During this time, NCKRI has grown from a little-known institute to an internationally respected leader in cave and karst research, management, and education. We started with a couple of rented offices and are now based in offices at New Mexico Tech in Socorro and Albuquerque, New Mexico; National Park Service offices in Lakewood, Colorado; and in our splendid and spacious headquarters in Carlsbad, New Mexico. These are not self-congratulatory comments, but statements of fact that resulted thanks to NCKRI's dedicated staff. partners, and volunteers.

NCKRI has faced many challenges along the way. The global economic recession of 2008 and the COVID-19 pandemic certainly slowed our progress. Our biggest challenge was and remains fulfilling the many mandates given us by Congress with a still small staff. However, as our number of employees and partners grows, achieving those goals becomes easier and more productive.

NCKRI's progress and projects are tracked in our annual reports. Along with all other NCKRI reports, they are available for free download from our website. As I look back into these reports, I celebrate the successes which have established a firm foundation for NCKRI to continue its growth. My hope is that NCKRI will grow to join the list of distinguished research institutes whose names are familiar to much of the general public. And why not? Twenty-five percent of the US is karst and associated terrains. Everyone should understand karst and recognize and respect the country's national institute on that topic.



Caves and karst have been my life for the past 47 years. A casual visit as a tourist to Carlsbad Cavern in December 1975 opened my eyes to the wonders underground. I began to read all I could about caves as I connected to the caving club in my hometown in San Antonio, Texas. Becoming a caver led to cave science, and eventually full circle back to Carlsbad when I started work at NCKRI in February 2007.

This past year I've gone full circle in other ways. Most notably, I retired from serving as President of the International Union of Speleology after 5 years. My photo on this page is from another full circle event, where I stand for the first time at the Lépineux Entrance to the Pierre St. Martin Cave System along the French-Spanish border. Before entering another cave, after my first visit to Carlsbad Cavern, I read about the exploration of this 334-m deep shaft and the massive cave system below. Those tales inspired me further to explore caves physically, scientifically, and culturally. Reading about a tragic accident in that shaft in 1952 taught me that such exploration must be done with the utmost care, not just for myself and other explorers, but to also protect the caves.

Standing at that entrance, I reflected on my nearly half-century of cave exploration and study. It strengthened my conviction that those were years well spent. Knowing I would be retiring soon, that reflection

strengthened my resolve to continue supporting NCKRI from afar in whatever way I can. Similarly, I hope this annual report will strengthen your resolve and conviction to support NCKRI, and whoever will be its new Executive Director, far into the future.

~ Den

NCKRI PARTNERS AND FRIENDS

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

NCKRI Affiliates

Organizations that demonstrate meaningful support for NCKRI and its goals, or their intent to do so, but without a formal defining agreement. 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
- Inspired By Science
- Living Desert Zoo & Botanical Gardens State Park
- National Caves Association
- National Speleological Society
- NASA
- Roots In Karst
- Southeast New Mexico College
- US Bureau of Land Management
- US Fish and Wildlife 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 Forest Service
- US Geological Survey
- University of New Mexico
- University of South Florida

Annual Giving

Our Annual Giving Program recognizes those individuals and organizations provided goods, services, and/or financial gifts to NCKRI or its conferences during FY 2022-2023. We especially thank the following considering the financial difficulties imposed by the pandemic over the past few years.

- Advanced Geosciences, Inc.
- Jack Angelone

- Arcadis
- Associação de Estudos Subterrâneos e Defensa do Ambiente
- Barton Springs/Edwards Aquifer Conservation District
- Dr. Pavel Bella
- Kathryn Brown
- Maaz Fareedi
- Meghan Forbes
- Dr. Paolo Forti
- Deza Frega
- Gyula Hegedűs
- International Union of Speleology
- Dr. Richard Maire
- MicroSeismic
- Zdenek Motyčka
- Dr. Ros Fatihah Muhammad
- David Mundt
- Bru Randall
- Jesse Richardson
- Shishir Sarker
- Thierry Schneider
- Southwest Geophysical Consultants
- University of South Florida School of Geosciences
- Liviu Vălenaș
- Dr. George and Karen Veni
- Kathleen Von Hoene
- Caleb Watson



During the 2023 Sinkhole Conference in Tampa Florida, Dr. Calvin Alexander, Beck Award Coordinator, and Dr. George Veni, Conference co-chair, flank three of the six Beck Student Awardees: (L-R) Isabella Serena Liso, Lillian Smith, and Kyle Compare.

NCKRI Volunteers

Many of our programs and projects rely on the help of our volunteers. We thank the following individuals for supporting NCKRI, most of whom worked on the Sinkhole Conference series:

- Dr. Calvin Alexander
- Michael Alfieri
- Mike and Deena Antiporda
- Tyrone Black
- Connie Campbell Brashear
- Eamon Brennan
- Michael Byle
- Jesse Chadwick
- Riannon Colton
- Jon Davis
- Dr. David Decker
- Robert Denton
- Joel Despain
- David DeWitt
- Dr. Ralph Ewers
- Jen Foote
- Dr. Yongli Gao
- Tristen Gleason
- Jorge Gonzalez
- David Harro
- Chad Harrold
- Peter Hutchinson
- Dr. Said Iravani
- Michael Jones
- Debbie Koenigs
- Clint Kromhout
- Hunter Klein
- Dr. Jim LaMoreaux
- Jason LaRouche
- Kevin Liow
- Erin Lynch
- Mike Mansur

- Anthony Mazzucco
- Benjamin Mittler
- Dr. Bogdan Onac
- Knutt Peterson
- Gheorghe Ponta
- Roger Portell
- Ethan Reuter
- Steve Rice
- Rachel Saker
- Dr. Ira Sasowsky
- Georgia Schneider
- Dr. Thomas Scott
- Dr. Brian Smith
- Pat Smith
- · Southeast New Mexico College
- Lima Soto
- Robin Speidel
- J. Brad Stephenson
- Deanna Stever
- Chris Stroud
- Simeon B. Suter
- Ellen Trautner
- Samuel Upchurch
- Kyle Voyles
- Keith White
- Christopher Williams
- · Devlin Willingham
- Dr. Wanfang Zhou

Rentals

NCKRI Headquarters has a large conference room and a smaller boardroom, which have hosted week-long corporate meetings, graduation and birthday parties, baby showers, luncheons, training workshops, family reunions, and holiday parties. We also have six cubicles for those seeking temporary

> Science Communication intern Raquel Lugo (left) and NCKRI volunteer Riannon Colton (right) stand in front of a display at NCKRI headquarters.

Photo courtesy of Devra Heyer.

or long-term office space. Funds collected through the rentals help us buy needed equipment and boost our programs with resources which will ultimately give our visitors a full experience in learning about the importance of caves and karst.

Professional Partnerships

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 that we've highlighted elsewhere in this report, we highlight here NCKRI's partnerships with the International Union of Speleology (UIS) and ASTM International.

NCKRI and UIS have collaborated on many projects over the past 16 years: International Journal of Speleology, International Year of Caves and Karst, and the Karst Information Portal, to name some prominent projects. Much of this was spurred through Dr. Veni's role on the UIS Bureau (governing board) and as UIS President. In July 2022, Dr. Veni decided to retire from the UIS and not seek reelection. This opened the door for another person from the USA to serve on the Bureau (no country can have more than one person on the Bureau). The UIS General Assembly elected NCKRI's Dr. Patricia Seiser as a UIS Adjunct Secretary, continuing representation from the US and NCKRI. We look forward to the new joint projects Dr. Seiser will develop between NCKRI and UIS.

NCKRI is a member of the global standardization organization, ASTM International. Dr. Veni created ASTM Subcommittee D18.27 on karst in 2020, which he chaired. During the past year, the subcommittee met in San Antonio, Texas, in January 2023, and in person in Denver, Colorado, in June 2023. The San Antonio meeting was unique in ASTM history because several



events focused on karst. Dr. Veni was invited to present the ASTM lunch workshop, where he gave an introductory review of karst, what it is, how it functions, and how it applies to ASTM. That evening, he led the first underground field trip for ASTM, taking them into Natural Bridge Caverns to show how ASTM standards can be put into practice. Later that week he led another field trip for ASTM's Karst Subcommittee members to examine karst environmental problems and management practices in more detail.

Professional Meetings

NCKRI again attended and/or sponsored many conferences during the past year, both in person and virtually:

- ASTM International Committee Week Conference, Denver, Colorado, USA
- ASTM International Committee Week Conference, San Antonio, Texas, USA
- CaveMAB Network: Best Practices in Protecting and Managing Cave and Karst Waters (virtual)
- 2023 Grading Conference (virtual)
- Planetary Protection in Practice, NASA and Lunar and Planetary Institute (virtual)
- Clay Mineral Society Convention, Austin, Texas, USA
- New Mexico Geological Society Fall Field Conference, Socorro, New Mexico, USA
- New Mexico Geological Society Spring Meeting, Socorro, New Mexico, USA
- Geological Society of America Convention, Denver, Colorado, USA
- International Congress of Speleology, Le Bourget du Lac, France
- National Speleological Society Convention, Elkins, West Virginia, USA
- International Show Caves Association and National Caves Association Congress, San Antonio,

Texas, USA

- International Symposium on Volcanospeleology, Vietnam (virtual)
- New Mexico Northern Wetlands Roundtable (virtual)
- New Mexico Southern Wetlands Roundtable (virtual)
- United Nations Groundwater Summit, Paris, France

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

- ASTM International Committee Week, San Antonio, Texas, USA (Dr. George Veni, workshop instructor and organizer of two field trips)
- Clay Mineral Society, Austin, Texas, USA (Dr. George Veni, karst sediments field trip co-organizer)
- International Show Caves Association and National Caves Association Congress, San Antonio, Texas, USA (Dr. George Veni, Organizing Committee Member and pre-congress field trip organizer)
- 17th Multidisciplinary Conferences on Sinkholes and the Engineering and Environmental Impacts on Karst, Tampa, Florida, USA (Dr. Lewis Land, Proceedings Editor; Dr. Issam Bou Jaoude, Associate Proceedings Editor; Dr. George Veni, Conference Co-Chair)
- 3rd International Congress of Karst, Speleology and Enhancement of Natural Heritage, Rabat, Morocco (Dr. George Veni, Scientific Committee Member)
- United Nations Groundwater Summit, Karst Aquifers: the Most Prolific, Vulnerable, and Misunderstood. United Nations Educational Scientific, and Cultural Organization, Paris, France, 2022.
- New Frontiers in Cave and Karst Research: In Honor of the International Year of Caves and Karst (with Lewis Land, Patricia Kambesis, Rachel Bosch,

Jason Polk, Sarah Arpin, Natasha Sekhon, Louise Hose) at the GSA Fall Meeting in Denver, CO.

• Karst Processes and Speleology (Posters) (with Patricia Kambesis and Rachel Bosch) at the GSA Fall Meeting in Denver, CO.

Guest Lectures and Seminars by NCKRI

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

Devra Heyer:

- A Summer in the Tongass: An example of NMT undergraduate research opportunities in cave and karst, while experiencing remote cave environments. Science Café, New Mexico Bureau of Geology and Mineral Resources, Socorro, New Mexico.
- Enchanting Landscapes: A look at the importance of cave and karst education in New Mexico and the United States. Spring Meeting, New Mexico Science Teachers Association, Socorro, NM.
- *Caving in the Tongass National Forest*. National Speleological Society, Pecos Valley grotto meeting, Carlsbad, NM.
- Sinkhole Cleanup in New Mexico

 Initiation, Implementation & Communication (with Knutt Peterson, Michael Moffit, and Issam Bou Jaoude). Annual Convention, National Speleological Society, Elkins, West Virginia
- Enchanting Landscapes: A look at the importance of cave and karst education in New Mexico and the United States (with Issam Bou Jaoude). February Meeting, Albuquerque Wildlife Federation (online).
- Introduction to Cave Week 2023 (with Lima Soto, Patricia Seiser, Dan Pawlak, and Georgia Schneider) (online). <u>https://www. youtube.com/watch?v=ICVEbQvc9zg&pp=ygUZaW50cm9kdWN0aW9uIHRvIGNhdmUgd-</u>

<u>2Vlaw%3D%3D</u>

Dr. Dan Jones:

- *Mercury cycling and methylmercury*. BIOL 451 (Microbial Ecology), University of New Mexico, Albuquerque, NM.
- Dr. Lewis Land:
- Anthropogenic karst geohazards in southeastern New Mexico and west Texas. National Speleological Society, Sandia Grotto meeting, Albuquerque, NM.
- Dr. Patricia Seiser:
- Paleontology for the Curious Caver – Speleology for Cavers Class. National Speleological Society Convention, Elkins, WV.
- Dr. George Veni:
- Around the world with NCK-RI. International Show Caves Association and National Caves Association Congress, San Antonio, Texas.
- ASTM D18.27: the Karst Subcommittee, origin, and scope.
 ASTM panel discussion. Program with Abstracts, 17th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impact of Karst, National Cave and Karst Research Institute Symposium 8. Carlsbad, New Mexico, p. 21.
- From you to the world: Barton Springs and the International Year of Caves and Karst. Barton Springs University Day, Save Our Springs Alliance, Austin, Texas.
- The importance and state-of-theart of the International Year of Caves and Karst. Importance, State of the Art, and Prospective of Utilization and Protection of Resources in Karst, Belgrade, Serbia, virtual lecture.
- Importance of exploration and cave science: explore, understand, protect. International Show Caves Association and National Caves Association Congress, San Antonio, Texas.
- Introduction to NCKRI and karst. Permian Basin Climate

Justice Coalition, Carlsbad, New Mexico.

- Solutions to karst groundwater problems. Karst Aquifers: the Most Prolific, Vulnerable, and Misunderstood side event, United Nations Groundwater Summit, United Nations Educational Scientific, and Cultural Organization, Paris, France, 2022.
- The International Year of Caves and Karst: confluence of the geosciences. Applied Karst Hydrogeology class, The University of Texas at Austin, virtual presentation.
- The world below: an introduction to caves and karst, a Sigma Xi Distinguished Lecture. India Chapter of Sigma Xi, virtual presentation.
- *UIS update: 2017-2022.* International Show Caves Association and National Caves Association Congress, San Antonio, Texas.

NMT Courses taught

Dr. Dan Jones:

- Geomicrobiology (GEOB 515), 3 cr., New Mexico Tech, Fall Semester, 2022
- Earth History (GEOL 206), 4 cr., New Mexico Tech, Spring Semester, 2023
- Earth History (ST 589), 2 cr., Master of Science for Teachers, New Mexico Tech, Spring Semester, 2023
- Metagenomic Analysis (GEOB 589), 3 cr., New Mexico Tech, Spring Semester, 2023

International Involvement

NCKRI is an Affiliated Organization of the International Union of Speleology (UIS) where in July 2022 Dr. George Veni completed a five-year term as UIS President and Dr. Patricia Seiser was elected as a UIS Adjunct Secretary. The goals of NCKRI and UIS overlap, resulting in mutually supportive projects. Our longstanding joint project is with the Karst Information Portal, and we recently completed work on 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 elevate cave and karst issues within 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 NCK-RI on the Steering Committee for the National Cave and Karst Management Symposium, which is held every two years.
- Devra Heyer is not only NCK-RI's Education Program Manager but is also the Education Division Chief of the National Speleological Society, building synergy to better support both organizations.
- 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 Geological Society of America's Karst Division: Dr. Lewis Land, Past-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. We have hosted the monthly meetings of the Pecos Valley Grotto of the National Speleological Society for 12 years 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:

- Partnered with the US Bureau of Land Management and the Southwest Region of the National Speleological Society on sinkhole clean-up projects on public lands.
- Devra Heyer organized a series of survey and mapping meetups for the Pecos Valley Grotto, with assistance from Dr. Issam Bou Jaoude.
- 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.
- Worked with the Pecos Valley Grotto to clean up part of the Pecos River during the City of Carlsbad's annual RiverBlitz campaign.

Media

NCKRI staff were interviewed and featured in media this year:

- Carlsbad Current-Argus, 27 September, p. 1A, 2A, 'Cave envy' felt as global group seeks solutions from Carlsbad Caverns to manage resources. Adrian Hedden, <u>https://www.currentargus.com/story/news/2022/09/23/</u> <u>global-group-seeks-solutions-</u> <u>from-carlsbad-caverns-to-manage-resources/69506289007/</u>
- Cavern discovered on a ranch in Medina County. Jerry Clayton, Texas Public Radio, 16 October, <u>https://www.tpr.org/news/2022-</u> <u>10-16/cavern-discovered-on-a-</u> <u>ranch-in-medina-county</u>
- Medina County couple find an underground cavern on their property. Gabriel Romero, MySA.com, 18 October, <u>https://</u><u>www.mysanantonio.com/news/</u><u>local/article/medina-county-mas-</u>

sive-cave-17514585.php

- Karst country. Christina Selby, New Mexico Magazine, November, p. 30-35, <u>https://www. newmexicomagazine.org/blog/ post/karst-country-southeastern-new-mexico/</u>
- City of Carlsbad lifts ban on property development near former Brine Well site. Mike Smith, Carlsbad Current-Argus, 29 December, p. 1A, 2A.
- Awards Recognize New Mexico Tech Grad Student's Research. NMT press release, January 3rd, 2023: <u>https://www.nmt.</u> <u>edu/news/2023/havlena-re-</u> <u>search-awards.php</u>
- Awards Recognize Tech Student's Research. El Defensor Chieftain, January 5th, 2023: <u>https://</u> <u>dchieftain.com/awards-recog-</u> <u>nize-tech-students-research/</u>
- Happy retirement Mr. Shoemaker and Dr. Veni. Mayor Dale Janway, Carlsbad Current-Argus, 17 March, <u>https://www.currentargus. com/story/opinion/2023/03/16/</u> happy-retirement-mr-shoemakerand-dr-veni/70012385007/?utm_ source=currentargus-DailyBriefing&utm_medium=email&utm_ campaign=daily_briefing&utm_ term=list_article_headline&utm_ content=PNM5-1278CA-E-NLETTER65
- An amazing discovery was found, hidden at the bottom of a 630-foot deep sinkhole. Explored Planet, 2 June, <u>https://www.</u> <u>exploredplanet.com/guides/amazing-sinkhole-discovery-in-chi-</u> na/?view-all&edg-c=1
- New Mexico Tech Students Write To Promote Science Knowledge. NMT press release, July 6th, 2023: <u>https://www.nmt.edu/</u> news/2022/sciworthy-stories.php
- Tech students use class assignment to promote science knowledge. El Defensor Chieftain, July 6th: <u>https://dchieftain.com/tech-</u> students-use-class-assignment-topromote-science-knowledge/

NCKRI STAFF

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

Valerie Davis, MBA

Interim Director and Operations Division Director

- Dr. George Veni (retired 1 May 2023) Executive Director Karst Hydrogeologist
- 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 Raquel Lugo

NPS Scientists in Parks, Science Communications

Continuing Education

NCKRI staff polish and expand their skills whenever possible. Formal training during the past year included:

- *Ethics in Geosciences*, an annual course required by the Texas Board of Professional Geologists for Dr. Veni and others to maintain their Professional Geoscientist licenses.
- Stormwater Management in Karst—A Regional Perspective, by Robert K. Denton Jr., and Conducting Geotechnical Investigations in Karst, by Michael J. Byle, were short courses taught at the 17th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst and attended by Dr. Lewis Land.
- GIS Approaches with LIDAR and Imaging Technologies for Sinkhole Documentation and Anal-

ysis, by Benjamin Mittler and Jorge Gonzalez, and Designing and Conducting Tracer Studies in Karst—With Emphasis on Sites with Actual or Potential Contaminant Releases, by Dr. Ralph Ewers and Keith White, were short courses taught at the 17th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst and attended by Dr. Issam Bou Jaoude.

Staff Publications Refereed Papers Journal Papers

- Jones, D., Polyak, V., DuChene, H., <u>Veni</u>, G. 2022. New Mexico's sulfuric acid caves. Earth Matters, New Mexico Bureau of Geology and Mineral Resources, Summer: 1-5, <u>https://geoinfo.</u> <u>nmt.edu/publications/periodicals/</u> <u>earthmatters/22/n2/em_v22_</u> <u>n2.pdf</u>.
- Capo E, Peterson BD, Kim M, Jones DS, Acinas SG, Amyot M, Bertilsson S, Björn E, Buck M, Cosio C et al. 2022. A consensus protocol for the recovery of mercury methylation genes from metagenomes. Molecular Ecology Resources 23: 190-204. <u>https://doi.org/10.1111/1755-0998.13687</u>
- Kieft TL, Del Curto D, Havlena Z, Hettiarachchi E, Lakis I, Nourse E, Skaar C, Ulbrich J, <u>Veni</u> G. 2023. Potential for mitigation of cave lampenflora using benzalkonium chloride or UV-C. Geoheritage 15(68), <u>https://doi. org/10.1007/s12371-023-00839-4</u>
- Hobart KK, Greensky Z, Hernandez K, Feinberg JM, Bailey JV, Jones DS. 2023.
 Microbial communities from weathered outcrops of a sulfide-rich ultramafic intrusion, and implications for mine waste management. Environmental Microbiology (In press. Preprint available on *bioRxiv*

2022.10.03.510692; https://doi. org/10.1101/2022.10.03.510692)

 Jones DS, Schaperdoth I, Northup DE, Gómez-Cruz R, Macalady JL. 2023. Convergent community assembly among globally separated acidic cave biofilms. Applied Environmental Microbiology 89: e01575-22 <u>https://doi.</u> org/10.1128/aem.01575-22

Conference Proceedings Papers

- Land L, Jones M. 2023. Exploring the upper limits of electrical resistivity profiling: Carlsbad Caverns National Park, New Mexico, USA. In: Land L, Kromhout C, Suter S. 2023, editors. Proceedings of the Seventeenth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impact of Karst (first edition): National Cave and Karst Research Institute Symposium 9. Carlsbad (NM): National Cave and Karst Research Institute: p. 102-106.
- <u>Seiser</u> PE. 2023. What will Cave Wilderness mean for Resource Protection and Management Concerns? 18th International Congress of Speleology - Savoie Mont Blanc 2022 Vol. I - Karstologia Mémoires no. 21 - SYM-POSIUM 01 - Karst, heritage and resources: p. 145-148.
- <u>Veni</u> G. 2022. Initial geoarcheological survey of caves at Chichén Itzá, Yucatan, Mexico. Proceedings of the International Congress of Speleology, Le Bourget du Lac, France, vol. 5, p 283-286; Bexar Grotto, National Speleological Society, San Antonio, Texas.
- <u>Veni</u>, G. 2022. The International Year of Caves and Karst: history, purpose, plans, and predictions. Proceedings of the International Congress of Speleology, Le Bourget du Lac, France, vol. 1, p 389-392; Pecos Valley Grotto, National Speleological Society, Carlsbad, New Mexico.

- <u>Veni</u>, G., Jones, M. 2022. GIS modeling of the ranges of endangered troglobites. Proceedings of the International Congress of Speleology, Le Bourget du Lac, France, vol. 1: 349-352; Pecos Valley Grotto, National Speleological Society, Carlsbad, New Mexico.
- <u>Veni</u> G. 2023. The vital role of speleological databases in karst management. In: Land L, Kromhout C, Suter S, editors. Proceedings of the 17th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impact of Karst: National Cave and Karst Research Institute Symposium 9. Carlsbad, New Mexico, p. 41-48, <u>https://nckri. org/publications/symposia/</u>.

Conference Presentations

- Best MB, Wankel SD, Green K, Graham HV, Stern J, Macalady JL, Jones DS. 2022. Nitrogen sources and signatures in sulfuric acid caves. Geological Society of America Abstracts with Programs. Vol 54, No. 5 (doi: 10.1130/abs/2022AM-380879)
- Best MB, Wankel SD, Graham H, Stern J, Macalady J, Jones <u>DS</u>. 2023. Ammonia-supported ecosystems in sulfidic caves. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- <u>Bou Jaoude</u> I. 2022. Protecting Karst Resources Results in Sustainable Development along the Silk Road – Examples from Lebanon. 2022 Silk Road International Conference on the Cooperation and Integration of Industry, Education, Research, and Application,
- <u>Bou Jaoude</u> I, Khayat Z, 2022. A Preliminary Classification of Karstic Springs of Lebanon. Geological Society of America Abstracts with Programs, v. 54, no. 5. <u>https://doi.org/10.1130/</u> <u>abs/2022AM-377787</u>

- <u>Bou Jaoude</u> I, Karanouh R, Karanouh W. 2022. The History of Lebanon Exposed Through the Darkness of Jeita Cave. Proceedings for the 18th International Congress of Speleology - Savoie Mont Blanc, France, Vol. I - Karstologia Mémoires n 21 - Symposium 01 - Karst, heritage and resources. <u>https://uis-speleo.org/ index.php/proceedings-of-the-international-congress-of-speleology-ics/
 </u>
- <u>Bou Jaoude</u> I, Karanouh R. 2022. EL Kassarat Cave: From Destruction to Protection. Proceedings for the 18th International Congress of Speleology - Savoie Mont Blanc, France, Vol. I - Karstologia Mémoires n 21 - Symposium 01 - Karst, heritage and resources. <u>https://uis-speleo.org/</u> <u>index.php/proceedings-of-the-international-congress-of-speleology-ics/</u>
- <u>Bou Jaoude</u> I, Karanouh R, Karanouh W. 2022. Damming the karst of Lebanon. Proceedings for the 18th International Congress of Speleology - Savoie Mont Blanc, France. Vol. III - Karstologia Mémoires n°23 - Symposium 05 - Karst hydrogeology, physical Chemistry. <u>https://uis-speleo.org/</u> index.php/proceedings-of-the-international-congress-of-speleology-ics/
- <u>Bou Jaoude</u> I, Fayad F, Karnaouh R, Karanouh W. 2022. Exploration and Mapping of Rahoue Cave. Proceedings for the 18th International Congress of Speleology - Savoie Mont Blanc, France. Vol. VI - Karstologia Mémoires n°26 - Symposium 09 - Topography, Mapping, 3D, Documentation. <u>https://uis-speleo.org/index.php/proceedings-of-the-international-congress-of-speleology-ics/
 </u>
- Karanouh R, Hamdan W, Harb S, <u>Bou Jaoude</u> I, 2022. Similarity in the Speleogenesis of Afqa and Roueiss Caves. Proceedings for

the 18th International Congress of Speleology - Savoie Mont Blanc, France Vol. IV - Karstologia Mémoires n°24 - Symposium 04 - Geomorphology and Speleogenesis. <u>https://uis-speleo.org/index.</u> <u>php/proceedings-of-the-interna-</u> <u>tional-congress-of-speleology-ics/</u>

- Brown AR, Green B, Jones DS. 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, NM, April 7-9.
- Brown A, Best MB, Castillo RR, Chee EA, Diongson ANI, Green K, Hann EL, Havlena ZE, Hughes WA, Jobe NE, Odumade DM, Ortiz AJ, Ramadan L, Skaar CH, Jones DS. 2023. Metagenomic insights into extremely acidic, sulfur-cycling microbial communities from Valles Caldera National Preserve, New Mexico. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Diongson ANI, Brown A, Best MB, Castillo RR, Chee EA, Green K, Hann EL, Havlena ZE, Hughes WA, Jobe NE, Odumade DM, Ortiz AJ, Ramadan L, Skaar CH, Jones DS. 2023. Metagenome-assembled Genomes from Extremophilic Microbial Communities In and Around Valles Caldera National Preserve, New Mexico. New Mexico Geological Society Annual Spring Meeting, Socorro, NM, April 21, 2023, https://doi.org/10.56577/SM-2023.2934.
- Dora D, Lazaridis G, Vouvalidis K, Tokmakidis K, <u>Veni</u> G. 2022. Morphometric and statistical analyses of caves in the Lefka Ori massif (Crete, Greece). Abstracts of the XXII International Congress of the Carpathian-Balkan Geological Association, Plovdiv, Bulgaria, p. 167.

- Graham H, Sherwood Lollar B, Mustard J, Rogers K, Jones DS. 2022. Planetary subsurface science and exploration: An integrated approach to understanding subsurface sources of energy and the unique energetics of subsurface life. 44th COSPAR Scientific Assembly. Held 16-24 July, 2022. Available: <u>https://www. cosparathens2022.org/</u> (Abstract B4.3-0009-22).
- Green K, Best MB, Jones DS. 2023. Characterizing nitrogen-fixing microorganisms in caves using high-throughput *nifH* sequencing. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Havlena ZE, Graham HV, Stern J, Chung A, Wankel SD, Jones DS. 2022. Microbial colonization and biosignature preservation potential in acidic gypsum deposits from sulfidic caves. Geological Society of America Abstracts with Programs. Vol 54, No. 5 (doi: 10.1130/abs/2022AM-381363)
- Havlena ZE, Graham HV, Stern JC, Chung AH, Wankel SD, Jones <u>DS</u>. 2023. Examining microbial communities and biosignatures associated with acidic, Mars analog gypsum. Astrobiology Graduate Conference, May 22-25, La Jolla, CA.
- Havlena ZE, Graham HV, Stern JC, Chung AH, Wankel SD, Jones <u>DS</u>. 2023. Exploring biosignature production by acidophilic microbial communities inhabiting secondary mineral deposits from sulfidic cave systems. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Heyer D. 2023. Preparing Future Cave Scientists: Lessons from the incorporation of undergraduate researchers to an expedition

in the Tongass National Forest. Annual Convention, National Speleological Society, Elkins, West Virginia.

- Hobart KK, Feinberg JM, Jones <u>DS</u>. 2022. Strain-specific genomic differences in pyrrhotite oxidizing bacteria isolated from the Duluth Complex, Minnesota. Geological Society of America Abstracts with Programs. Vol 54, No. 5 (doi: 10.1130/ abs/2022AM-383886).
- Huff CJ, Green KM, Regberg AB, Graham HV, Dworkin JP, Lalime EN, Congedo AB, Chung AH, Pugel DE, Jones DS. 2022. Enumeration and Fluorescence In Situ Hybridization of Microbial Bioburdan on Cleanroom Surfaces. Planetary Protection in Practice, held virtually, 18-19 October, 2022. LPI Contribution No. 2710, 2022, id.7017 (link: https://www.hou.usra.edu/ meetings/planetprotection2022/ pdf/7017.pdf)
- Huff CJ, Green KM, Regberg AB, Graham HV, Dworkin JP, Lalime EN, Congedo AB, Chung AH, Pugel DE, Jones DS. 2023. Microbial bioburden on NASA cleanroom surfaces: Cell counting and fluorescence *in situ* hybridization. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Jobe NE, Skaar CH, Kieft T, Jones DS. 2023. Culture-dependent and -independent analysis of deep, ancient viromes from the Moab Khotsong mine in South Africa. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Jones DS, Brown A, Best MB, Castillo RR, Chee EA, Diongson ANI, Green K, Hann EL, Havlena ZE, Hughes WA, Jobe NE, Odumade DM, Ortiz AJ, Ramadan L, Skaar CH. 2023. Linking genomes and geochemistry in extreme environments across the greater Valles Caldera ecosystem,

New Mexico. New Mexico Geological Society Annual Spring Meeting, Socorro, NM, April 21, 2023, <u>https://doi.org/10.56577/</u> <u>SM-2023.2936</u>.

- Krizek K, Havlena ZE, Jones DS. 2023. Microbial inhabitation of relict gypsum deposits from sulfuric acid caves. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Odumade DM, Jones DS, Brown A, Best MB, Castillo RR, Chee EA, Diongson ANI, Green K*, Hann EL, Havlena ZE, Hughes WA, Jobe NE, Odumade DM, Ortiz AJ, Ramadan L, Skaar CH. 2023. Metagenomic analysis of phototrophic and colorless microbial biofilms from a travertine hot spring near the Valles Caldera volcanic complex, New Mexico. Rocky Mountain Geobiology Symposium, April 22nd 2023, Boulder, CO.
- Phlieger KP, Green K, Jones <u>DS</u>. 2023. Phylogenetic analysis of ammonia monooxygenase (amoA) genes from desert caves. New Mexico Geological Society Annual Spring Meeting, Socorro, NM, April 21, 2023, <u>https://doi. org/10.56577/SM-2023.2931</u>
- <u>Seiser PE</u>. 2023. What will Cave Wilderness mean for Resource Protection and Management Concerns? 18th International Congress of Speleology - Savoie Mont Blanc 2022.
- <u>Seiser PE.</u> 2023. Protecting Caves Through Legislation, Regulations, Policy. Meet the Feds Panel, Conservation and Management Session. National Speleological Society Convention, Elkins, WV.
- <u>Seiser PE</u>. 2023. Management of Volcanic Caves in US National Parks. International Symposium on Volcanospeleology, Viet Nam (virtual).

Books and Book Chapters

• Duchene, HR, Palmer AN, <u>Jones</u> DS. 2022. Geology and Speleogenesis. In: Lechuguilla Cave: Discoveries in a Hidden Splendor. (ISBN 978-3-9821714-2-5). Available: <u>https://www.lechu-</u> guilla-cave.info/book/

- <u>Veni</u>, G. 2022. International Show Caves Association pre-congress field trip: the show caves of west Texas and southeast New Mexico. Guidebook for the 9th International Show Caves Association Congress, National Cave and Karst Research Institute Field Guide 2, Carlsbad, New Mexico, 57 p., <u>https://www.nckri.org/publications/field-guides/</u>
- <u>Veni</u> G (editor). 2023. Florida's karst landscapes and roles of karst in flood control and water supply management in west-central Florida. Guidebook for the 17th Multidisciplinary Conference on Sinkholes and the Engineering & Environmental Impacts of Karst, National Cave and Karst Research Institute Field Guide 3, Carlsbad, New Mexico, 53 p., <u>https://www.nckri.org/publications/field-guides/</u>

Unrefereed Papers

- <u>Veni</u> G. 2022. The closing of the International Year of Caves and Karst 2021/22: the opening of new opportunities. UIS Bulletin, 64(2):17.
- <u>Veni</u> G. 2022. UIS at the United Nations Groundwater Summit. UIS Bulletin, 64(2):69-70.
- <u>Veni</u> G. 2022. UIS President's report to the General Assembly: 2017-2022. UIS Bulletin, 64(2):6-7.



Roger Portell explains the origin of the many sediment-filled sinkholes discovered in the walls of Haile Quarry. Photo courtesy of George Veni.

2022-2023 NCKRI FUNDING REPORT

Revenue	Category	FY2022-23 Budget	F	Y2022-23 Expense
State of New Mexico	Carryforward	\$ 308,504.00	\$	-
State of New Mexico		\$ 401,486.00	\$	560,453.53
National Park Service FY22		\$ 380,091.00	\$	113,009.27
National Park Service FY23		\$ 794,000.00	\$	11,176.62
Enterprise Funds	NCKRI Rentals	\$ 21,252.00	\$	-
	Sinkhole Conference	\$ 84,815.00	\$	51,572.30
Total Revenue		\$ 1,990,148.00	\$	736,211.72
Expense Detail				
State of New Mexico				
	Salary & Fringe	\$ 219,432.00	\$	445,140.45
	Expenses	\$ 490,558.00	\$	115,313.08
	Subtotal	\$ 709,990.00	\$	560,453.53
National Park Service				
	Salary & Fringe	\$ 635,023.00	\$	49,692.02
	Expenses	\$ 539,068.00	\$	74,493.87
	Subtotal	\$ 1,174,091.00	\$	124,185.89
Enterprise Funds				
	Expenses	\$ 84,815.00	\$	51,572.30
	Subtotal	\$ 84,815.00	\$	51,572.30

Earth Day Clean Up Saturday April 22, 2023, 10am-2 pm Sacramento Plains BLM Roswell Field Office



RSVP to receive a map to the location: Knutt Peterson: knuttpet@blm.gov

(Above) Sinkhole Clean-Up flyer made in celebration of Earth day.

(Right) Dr. Lewis Land walks along the sinking stream channel of the Peck Sink Preserve during the Sinkhole Conference half-day field trip. Photo courtesy of George Veni.





National Cave and Karst Research Institute

400-1 Cascades Avenue Carlsbad NM 88220 USA

