NATIONAL CAVE & KARST RESEARCH INSTITUTE

2019 - 2020

ANNUAL REPORT

www.nckri.org

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Cover Photo

Caver Adam McLeod on rope in one of the longest caves in Great Smokey Mountains National Park. This is one of many premier photos on the National Park Service (NPS) cave and karst website, developed through the new NPS-NCKRI liaison program (see report on pages 29–30). Photo courtesy of Matt Tomlinson.

Back Cover Photo

The ancient Maya saw this column and surrounding stalactites in Grutas de Balankanche, Mexico, as "The World Tree," which shored up the heavens to release rain and support the cycle of life. Caves were sacred to the Maya, as shown in one of this year's projects (see report on pages 4–5). NCKRI photo by George Veni.

NATIONAL CAVE & KARST RESEARCH INSTITUTE

Vision and Values

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

Organization and Mission

NCKRI was created by the US Congress in 1998 in partnership with the National Park Service, State of New Mexico, and the City of Carlsbad. Federal and state funding for NCKRI is administered by the New Mexico Institute of Mining and Technology (a.k.a. New Mexico Tech or NMT). Funds not produced by agreements through NMT are accepted directly by NCKRI, Inc., our non-profit, 501(c)(3) affiliate.

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

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

NCKRI Annual Report Series

NCKRI produced this publication as part of its annual reporting of activities. The reporting period covers NCKRI's fiscal year, from July 1, 2019 to June 30, 2020. Digital copies of this, previous annual reports, and other NCKRI reports are available for free at www.nckri.org.

NCKRI is a proud institute of:

NEW MEXICO TECH
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EXECUTIVE DIRECTOR'S REPORT

Photo courtesy of Allan Cobb.

I first visited the ancient Maya city of Chichén Itzá as a tourist in 1988 as I drove to Belize for a caving expedition. I remember looking up at the Osario, reading on a sign that a hole at the top of the temple led to a cave below, never dreaming that 31 years later I would rappel down through the temple and conduct the first hydrogeologic assessment of the cave.

It is now a year after that trip, and I recall thinking what a fabulous portent that study was of more great things to come as NCKRI had just started its fiscal new year. Sadly, it didn't work out quite that way. I've often joked, "It's bad luck to be superstitious," and some projects, plans, activities, and dreams for NCKRI were canceled or postponed by the COVID-19 virus.

I always write these Executive Director's reports after collecting and reviewing all the other annual report material. While we did suffer some disappointments and losses, after looking through these pages it is clear we actually had a great year. Most importantly, everyone still has their health and jobs, which tragically can't be said for millions of others. This edition of the annual report has packed in more news on projects and programs than ever before. We eliminated our usual staff biographies at the end to make room, and this is still our longest annual report to date!

In last year's annual report, I predicted good things for this year, thanks in large part to a major boost in our federal support. We hired more staff and acquired much needed equipment. Our new team members quickly climbed beyond their learning curves and are now splendidly productive in both the quality and amount of their accomplishments.

The following pages document the growing diversity in NCKRI's projects as well as its national and international scope. Two new sections were added to this annual report. The first covers our new research grant program. The second is on our liaison role with the National Park Service, assisting with and coordinating its national level cave and karst programs.

Certainly, COVID-19 is mentioned in this report where it affected some projects and programs, but not nearly to the degree many would expect. NCKRI is stronger than ever and will continue to excel as the world recovers from this pandemic. We are humbled by the support we have received from so many people during these difficult times, boosting our confidence that we'll come through this stronger still.

On behalf of everyone at NCKRI, we send you our best hopes for your good health, safety, and success throughout and long after this global crisis passes.

George Veni, Ph.D.

NCKRI'S NEW LOOK

We are excited to announce two important projects led by NCKRI's Education Director, Dianne Joop: our new logo and upcoming new website. You may have noticed some changes with the look of our Annual Report. The new logo is on the cover and inside, with minor variations in color to fit the white or backgrounds. We believe our new look better matches what we've become since our founding in 1998—an institute promoting and facilitating cave and karst research, education, and sustainability.

So, why the new look? From the beginning, our Congressional mandates have driven NCKRI's work and direction. Our first Executive Director, Dr. Louise Hose, oversaw NCKRI as a research facility within the National Park Service and laid the groundwork for NCKRI to be established within the New Mexico Institute of Mining and Technology (NMT). In 2003 she led the development of NCKRI's first logo (see below), illustrating the major thematic elements of water connecting the surface and subsurface aspects of karst.

Our current Executive Director, Dr. George Veni, envisioned NCKRI becoming the world's premier cave and karst institute. With our move out of the National Park Service and into NMT, a new logo seemed appropriate and in 2008 we transferred the themes of the original logo into a more abstract form that has served us well for the past 12 years (see below).

With the year 2020 approaching, we began looking inward, assessing actions we could take to sharpen our focus and update our brand. We asked if our logo resonates with our audience and communicates who we are and where we are going. The impetus of a new website further pushed our decision to refresh the NCKRI logo. We considered more than 40 options with our design team. After polling our many constituents, partners, and staff for feedback we agreed on a revised look based on our 2008 logo.

It was crucial that our new logo concisely convey caves, karst, and everything that NCKRI stands for, while resonating with the scientific and academic communities as well as the general public. We wanted to respect the success we've achieved in the first twenty-two years of operations while looking ahead and planning for our future. Simplicity was essential for us while revitalizing a recognizable brand and logo. We feel the new logo stays true to our roots, while reflecting NCKRI's evolution, and will help raise NCKRI's profile as the national authority on caves and karst. The new logo is shown on the next page with explanations of some considerations in its design.

Launching Our New Identity

"*Vision without action is just a dream, action without vision just passes the time, and vision with action can change the world.*"
Nelson Mandela and Joel A. Barker

Our logo is our face, but our website is our window to the world. In thinking about how vision with action can change the world, we view our website as a vital tool to help us improve the world for caves and karst and improve the world by educating it about caves and karst. We see the website as a vehicle to achieve our vision; as a catalyst for the advancement of cave and karst knowledge.

We need to elevate our website to raise our profile as the go-to source on caves and karst. Our current content falls short. To do better requires updated software and state-of-the art information. Our Education Director, Dianne Joop, is leading the charge.

This year she worked with our design team and staff to rebuild NCKRI's website with engaging content and layout, while offering a better user experience. We wrote dozens of new pages of in-depth materials on the origins and types of caves and karst, and their many values, to inform the world about these amazing places —illustrated with dozens of stunning photos.

We are so excited about the new website and can't wait to launch it this upcoming year to elevate the world's knowledge of caves and karst.

NCKRI

National Cave and Karst Research Institute

Stylized stalactites for better recognition of a cave element

New water color to represent karst groundwater. By not using a typical "blue" to represent water, we hope to communicate that karst waterways are different from lakes and oceans.

NATIONAL
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Our "C" ties cave and karst together by representing water flowing through a cave entrance.

Most people outside of the caver audience, refer to us as "Cave/Karst," the two tone text speaks strongly to what we are about, while still recognizing that we are a National Research Institute.

NCKRI RESEARCH

Geoarchaeological Studies of Caves and Karst at Chichén Itzá

The Maya Mesoamerican region extends across Belize, Guatemala, and parts of El Salvador, Honduras, and Mexico. Approximately 70% of this area is karst, characterized by caves and little to no surface water. With most access to water being through caves and related features like cenotes (large sinkhole collapses that expose the water table) and springs, the importance of caves to ancient Maya culture has long been recognized.

Caves were used by the Maya as sources of water and for religious, calendric, ascension, and other rituals (see back cover). Especially sacred areas of caves were frequently hidden or obstructed by constructed walls. The most famous such cave is Grutas de Balankanche near the archaeological site of Chichén Itzá, in Yucatan, Mexico.

Caves have also been identified as significant elements in the sacred symbolic geography and layout of major structures in Mayan communities, even to the extreme degree that some communities have excavated tunnels to create the cultural equivalent of caves where natural caves do not exist. Further, studies of some chultuns, constructed cavities initially envisioned for water storage, found them impractical or unable to hold water and are reinterpreted as another form of artificial cave—even in cavernous areas—for the sacred value they give to a site.

In August 2019 Projecto Gran Acuífero Maya (GAM) invited NCKRI's Dr. George Veni to conduct a preliminary geoarchaeological investigation of known and newly found caves and karst features and archaeological sites in and around Chichén Itzá. Dr. Veni is well known for his many years of research of caves of the Maya region. He was assisted by his long-time colleague and Maya cave expert Mr. Allan Cobb. Their work and access to field sites was facilitated by GAM directors Dr. Guillermo de Anda and Dr. Jim Brady, with assistance from Pedro Almada, Ana Celis, Karla Ortega, and other GAM members. The following are sites visited, and their preliminary findings.

NCKRI photo by George Veni.

Like many ritually important caves in the Maya area, Grutas de Balankanche was once sealed and hidden. A tourist trail now cuts through the ancient wall.

Cueva del Osario (Cave of the Ossuary)

This cave is one of the longest known caves in the area, first reported in 1897. Our study was the first time a karst hydrogeologist examined the cave. The cave's entrance is under El Osario, a flat-topped pyramid that is 24 m long at its base and about 9 m tall. The cave is accessed through a 1-m square shaft at the top of the pyramid that drops through the core of the structure to the cave (see Executive Director's report for a photo of Dr. Veni rappelling into the cave at the top of the temple).

Below the pyramid, the natural entrance is a 2-m deep pit with steps built into one side to give access to the narrow top of a 12-m deep pit. At the bottom is a small room with geologic and airflow corrosion features pointing to where excavation may lead to new passages.

Cueva Xtoloc

Drs. Jim Brady, Kevin Thuesen, and George Veni surveyed this cave in 1992, which was revisited during this study. The cave is in the wall of Cenote Xtoloc, about 20 m down from the top of the cenote and 6 m above its lake. The depth of the cenote's lake is not known. The cave averages 1 to 1.3 m high by 2 m wide. The entrance passage goes west 5 m to a "T" intersection. In each direction the cave extends about 80 m. During this project, the 1992 survey was extended overland to the lake, the rim of the cenote, and some exposed structures within the cenote.

The cave's origin predates the cenote. The direction of groundwater flow that created the cave is not clear, possibly because of a flow reversal when the cenote collapsed, allowing water to drain from the entrance. The entrance passage was enlarged by the Maya to gain access to the main part of the cave.

Given the historic long-time easy

NCKRI photo by George Veni.
Ana Celis, of Projecto Gran Acuífero Maya, in Cueva Xtoloc next to pockets of probably rare gray-green attapulgite clay in the cave wall.

access to the cave, any significant cultural materials in the cave were probably looted long ago. What may be a partial constructed wall exists in the southwest part of the cave and may have once blocked access to a short side passage. Throughout the cave is a gray-green clay not found in most caves. It appears to be attapulgite, also known palygorskite, a magnesium aluminum phyllosilicate clay known for use by the Maya for "Maya Blue" pigment and medicinally for its anti-diarrheal properties; it is an active ingredient in several modern medicines. It is possible this clay was more abundant and excavated from the cave, but there is no direct evidence to support this hypothesis at this time.

Balamku

Balamku (Yucatec Maya for "Jaguar God") is a newly re-discovered cave that contains multiple caches of incense burners and other ceramic vessels. Within about 15 m from the entrance, the cave reaches a depth of about 12 m and maintains that approximate depth throughout its surveyed length of about 500 m. The passages range from 0.4 to 3 m high and wide and formed below the water table. Elevated levels of carbon dioxide occur throughout the cave.

The primary reason for studying this cave was to assess the potential for additional sacred passages hidden by the Maya. The considerable effort and difficulty to carry the large ceramic vessels throughout the known small passages with high levels of carbon dioxide, and with relatively little resulting damage, requires the consideration of a possible hidden entrance. While all passages were not explored, the cave's morphology, description, and map of unvisited areas suggest no additional entrances are likely. Much of the area over the cave was walked and two depressions were discovered above the cave's current southern limit but excavation by GAM did not reveal entrances.

Geologic observations suggest at least one area where a hidden passage may be located. Additionally, the weathering pattern on a roughly-carved 1-m long probable stalactite in the entrance room suggests it was brought in from a cenote or rejollada (a large collapsed sinkhole like a cenote, except with a dry floor) where the stalactite grew in an environment open to surface weathering. Other karst features were found in the area that might contain Maya artifacts if excavated.

Grutas de Balankanche

A short visit was made to this famous show cave (see back cover photo) as a comparison to Balamku. Morphologically, the caves are quite similar, except that passages in Balankanche are much larger. Both caves have high levels of carbon dioxide and drain to the south, suggesting a subtle structural control of cave development in the area that would require highly detailed and precise geologic mapping to confirm. At its southern limit, Balankanche turns along an east-west trend, suggesting Balamku may also turn and drain to the east beyond its current limit of exploration.

Like Balankanche, Balamku becomes wet at its southern end. At this point Balamku is only muddy and no significant pools are known. The description of the end of Balamku is conflicting; it is not clear if the cave ends or continues so small it can only be traversed with difficulty. Pools, that would have been sacred to the Maya, probably exist beyond the current limit of exploration. If they are humanly accessible, then notable cultural materials may be present.

Summary Results

The several conclusions and recommendations from this study are summarized here into four groups:

1. A variety of karst features and areas within caves are suggested for excavation as likely areas for containing undiscovered cultural materials.
2. Geophysical surveys will identify additional unknown culturally important caves, but also yield important insights to cave and aquifer development in the region.
3. While this study focused on geoarchaeological insights for the Chichén Itzá area, not regional hydrogeology, those insights produced recommendations for local to regional aquifer studies.
4. Mineralogical studies of several geological materials in the area will advance both geological and cultural understanding of the caves and their use.

We thank GAM for their invitation and support and look forward to working with them again.

NCKRI photo by George Veni.
Balamku contains caches of ceramic vessels, especially incense burners, some still holding incense ash burned in the cave hundreds of years ago.

Cave Management and Conservation in the Philippines

Since 2014, Philippine and American cave experts have worked to document and understand a large region of tropical karst and caves in Sultan Kudarat Province on Mindanao Island, in the southern Philippines. The international team has worked very closely with local governments and provincial leaders up to the governor. These government offices have provided tremendous support to the project, including vehicles, accommodations, food and supplies that have made the work in Sultan Kudarat possible.

The expeditions have also worked with the local people to map and photodocument the caves and to initiate other projects in the area. A key partner has been the Saranganai Bay Area Outdoor Club. These cavers lead the trips with great organizational and communication skills. They organize food, transportation, accommodation, guides, drivers and much more. Education and outreach are a big part of the project with many training and educational seminars offered by the American and Philippine team. Presentations to the local towns happen nightly during the expeditions with hundreds of Philippine residents attending each evening.

NCKRI's Cave and Karst Management Scientist, Joel Despain, visited the Philippines in January 2020 as part of the fifth Philippine-American expedition to the caves of Sultan Kudarat Province. The caves of the region are most often long, sinuous underground rivers with rapids and waterfalls (see photo on the next page of Agsamosan River Cave). There are also many pits in the area and some of the longer caves have pit entrances, which add another dimension to the caves.

Photo courtesy of Dave Bunnell.

Small petal-like splattermites are in front of the caver in a speleothem wall in Lagbasan Cave.

Photo courtesy of Dave Bunnell.

Spathite in Makioman Cave. This rare speleothem is about 0.5 m long.

Many of the region's caves are highly scenic with big rooms and passages, well-decorated with large speleothems such as stalactites and stalagmites. Some caves also contain rarer types of speleothems such as splattermites. These form when splattering water makes fin-like crystalline projections that grow on the side of other speleothems such as stalagmites. Small examples are in the photo to the left.

Spathites (see photo above) also occur in the Sultan Kudarat caves. These rare stalactites form with a high content of the mineral aragonite, which gives spathites an odd twisted shape with small inverted cups that hold over-sized drops of water.

Overall to date the project has mapped more than 25 km of cave passages in more than 50 caves, completed approximately a dozen cave maps, taken hundreds of photos, completed more than 30 presentations on the project and caves, published numerous articles on the caves and the project, and initiated biologic, geologic and hydrologic research.

Lagbasan Cave is an excep-

Photo courtesy of Shane Fryer.

Mapping in Agsamosan River Cave in January 2020.

tion to the river caves in Sultan Kudarat Province. It is dry, very old, and the passages are huge—more than 50 m wide (see photo below). But it is what is inside of the passages that especially gets peoples' attention. The cave contains many huge speleothems, including stalactites tens of meters long and stalagmites tens of meters tall. Lagbasan has what may be some of the largest splattermites on Earth.

Curiously, beneath the many giant speleothems in Lagbasan Cave are older broken speleothems often lying on their sides with new speleothems growing on top. What caused these broken masses of calcite crystals is unknown but earthquakes are suspected. Speleothems have been documented breaking in response to earthquakes and the Philippines is a tectonically active country with many temblors.

During the January 2020 trip, Mr. Despain launched a book project on the caves of the area to be published by NCKRI. He also assisted with important management decisions for Lagbasan Cave. Lagbasan could be a significant economic asset to the region as a show cave. He of course assisted with the mapping and geologic assessments of several caves in the area and organized a photo trip to Lagbasan Cave, which was not easy since the cave was a 9-hour drive away. He made 11 presentations to various government officials, ranging from the Governor to teachers and small-town mayors, about the caves, the book project, and cave management for Lagbasan Cave.

Since the end of the trip, Mr. Despain has completed multiple reports for government officials in the area concerning the results of the expedition and on Lagbasan Cave. He and Dr. Patricia Kambesis, from Western Kentucky University, have been invited back to teach a class on cave management to government staff and university students at the local college after the COVID-19 pandemic.

Meanwhile, the *Treasures of the Sultan: The Amazing Caves of Sultan Kudarat Province* book project is off and running with multiple completed articles, dozens of high-quality photos and layout for the first 50 pages completed. Authors include both Philippine and American writers, photographers and cartographers with sections on peoples' lives and experiences in association with the caves, the caves themselves, and cave science and management. Publication is slated for 2021, during the International Year of Caves and Karst.

Plans for the 6th expedition, when the pandemic is over, are under review by Philippine government officials. With the expeditions, book, and educational effort, it is hoped that the caves and karst of the region will be well managed and respected, and become internationally appreciated. With good management and science from NCKRI and our partners in the Philippines and the USA, the caves and karst of the Sultan Kudarat will benefit the local people for generations to come.

Photo courtesy of Dave Bunnell.

Beautiful and profuse speleothems inside the massive Lagbasan Cave.

Geophysics and Chemistry of the San Solomon Springs' Aquifer

Over the past year, work continued in the area around Balmorhea, Texas, on a large-scale study of the hydrology of the San Solomon Spring Group, a series of six karst springs that discharge groundwater from Cretaceous limestones along the northeast flank of the Davis Mountains in West Texas. This work is funded by Apache Corporation, a Houston-based oil company that is developing a new oil and gas discovery in the vicinity of Balmorhea.

The springs provide habitat for several federally listed endangered species, including the Comanche Springs pupfish and Pecos gambusia. They also provide water resources for much of the agricultural activity in southern Reeves County, Texas. The most upgradient spring discharges from Phantom Lake Spring Cave, currently the deepest underwater cave in the United States. The main San Solomon Spring flows into the swimming pool at Balmorhea State Park.

The San Solomon Springs Group is discussed by the US Geological Survey in several reports on the Edwards-Trinity Aquifer. However, regional conceptual models developed by researchers at The University of Texas at Austin suggest that baseflow from the San Solomon Springs originates from groundwater recharge in alluvial basins over 70 km to the west. That groundwater then flows through Permian-age carbonates of the Capitan Reef Complex in the Apache Mountains, and into Cretaceous-age rocks which they contact along faults underground, ultimately discharging from the six San Solomon springs.

NCKRI photo by Lewis Land.
Groundwater discharge from San Solomon Spring at Balmorhea State Park flows northeast through an irrigation canal within the village of Balmorhea.

In 2013 NCKRI personnel conducted a dye trace of the system and established a connection between Phantom Lake Spring Cave and groundwater discharging into the pool at Balmorhea State Park. That dye trace demonstrated that groundwater flows through karstic conduits in Cretaceous limestone from the cave to the park at a rate of approximately 1,000 m/day.

Geophysical investigations of the San Solomon Spring system began in April 2019. The pace of these investigations increased during the last year when NCKRI personnel, assisted by staff of the New Mexico Bureau of Geology and Mineral Resources, conducted electrical resistivity (ER) surveys of selected springs in August and November 2019, and March 2020. A principal focus of these surveys in 2019 was the area around Balmorhea State Park.

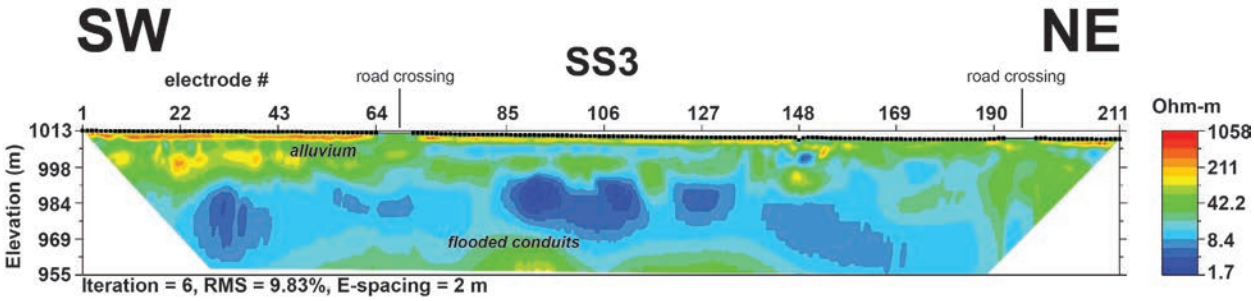
Electrical resistivity surveys are a common and effective geophysical method for the detection of subsurface voids and karstic conduits. The basic procedure involves generating a direct current between two metal electrodes (stainless steel stakes) implanted in the ground that measure differences in electrical flow and voltage drop between the electrodes, from which subsurface electrical resistivity can be determined and mapped.

Modern resistivity surveys employ an array of multiple electrodes connected with electrical cable. Over the course of a survey, pairs of electrodes are activated by means of an electromechanical switchbox and a resistivity meter. Specialized software is used to process the data and generate resistivity profiles that illustrate vertical and lateral variations in subsurface resistivity. The presence or absence of electrically conductive water or water-saturated soil or bedrock is one of the most significant factors influencing the results of an ER survey. Air- or water-filled caves and conduits in the survey area will thus display as zones of higher or lower resistivity, respectively, on ER profiles relative to the surrounding bedrock.

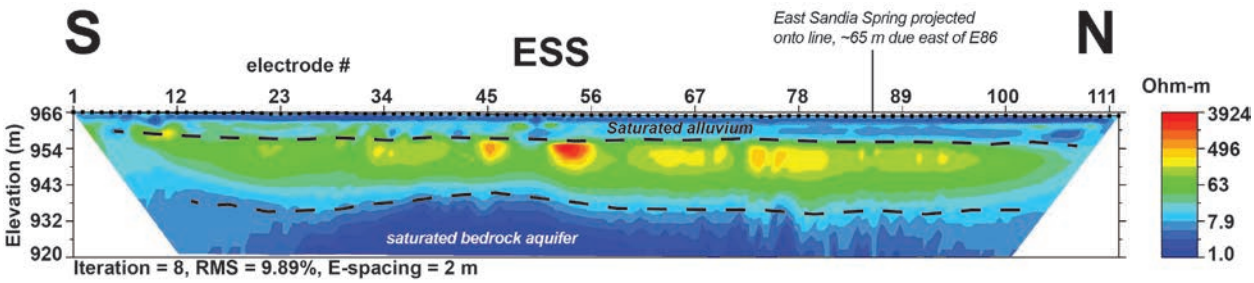
Seven ER surveys were completed in the area of Balmorhea State Park. Their most distinctive features were an irregular zone of low resistivity below ~995 m elevation, including several discrete low resistivity pods. These indicate conduits in the Buda Limestone flooded with brackish water formed. Their presence supports the conceptual model and dye trace results of groundwater flow through karstic conduits. On some of the surveys, the ER images also suggest upward leakage of brackish water from these conduits into overlying alluvium. One profile from this area is shown at the top of the next page.

An additional six ER surveys

NCKRI photo by George Veni.
Stainless steel stakes work as electrodes when connected to specially designed cables for electrical resistivity surveys.



Electrical resistivity survey near Balmorhea State Park. Dark blue areas are likely karst conduits filled with brackish water.



Electrical resistivity survey near East Sandia Spring shows a different stratification from the Balmorhea State Park surveys.

were conducted at East and West Sandia springs, the farthest downgradient springs of the San Solomon Spring Group (see above). These springs rise in a low-relief wetland preserve. All the ER surveys conducted in this area show a distinctive three-layer stratification:

- a near-surface electrically conductive layer extending continuously across the top of the profile;
- an underlying higher resistivity layer; and
- a near-continuous electrically conductive layer extending across the bottom of the profile.

The near surface conductive layer reflects that the surveys were in a grassy wetland area surrounding the springs, where the substrate consists of moist soil partially saturated with brackish water. We interpret the deeper horizon along the bottom of the profile to represent a saturated bedrock aquifer formed in the Buda Limestone. The intermediate higher resistivity layer probably represents a fine-grained confining unit between the shallow perched aquifer in the wetland area and the deeper bedrock aquifer.

Confirming these interpretations requires well data for the underlying strata, but few wells in the area of our surveys penetrate bedrock. Well logs in the area report alluvium ranging from 23-120 m thick.

In addition to the geophysical research, in November and December 2019 NCKRI began a new phase of the study by installing automatic water samplers at four of the six San Solomon springs. Water samples were collected at regular intervals into March 2020 and analyzed for general chemistry, trace metals, stable isotopes, and potential contaminants as part of an effort to better characterize the hydrochemical properties of the aquifer.

Preliminary results include the observation that total dissolved solids, nitrate, and uranium levels in the farthest downgradient East Sandia Spring are considerably higher than in the upgradient Giffin and San Solomon springs. In addition, measurements of spring discharge show that in spite of their proximity, Giffin and San Solomon Springs respond very differently to rainfall. Flow from San Solomon Spring increases within hours of a storm, whereas the response of Giffin Spring is much slower and less obvious. The reasons for this difference are unclear but invite speculation about the complex nature of the karst aquifer which feeds these springs. Almost certainly related to this, dye from NCKRI's 2013 dye trace only appeared in San Solomon Spring, in spite of the fact that Giffin Spring is just 260 m away.

NCKRI photo by Lewis Land.

The second largest of five pools created by East Sandia Spring. With West Sandia Spring, it is part of a planned wetland nature center managed by The City of Balmorhea.

Conglomerate Karst Hydrologic Study: Black River

In May 2020, NCKRI personnel began conducting a Phase 1 dye trace investigation in the Upper Black River Basin as a part of a contract with the US Bureau of Land Management (BLM). The purpose of the project is to begin determining how groundwater flows to the springs that feed the river, which is one of the southernmost tributaries of the Pecos River in New Mexico.

BLM's interest in the Black River stems from it providing a significant percentage of the water in the State's southern section of the Pecos River, which contributes to New Mexico's stream flow obligations to the downstream State of Texas. The Black River also provides the only habitat in New Mexico for the Texas Hornshell Mussel (*Popenaias popeii*), a species listed as endangered by the US Fish and Wildlife Service in 2018.

Most of the stream flow in the Black River comes from a series of springs that discharge from a well-cemented karstic limestone conglomerate, commonly referred to as the Quaternary Gravel Aquifer.

NCKRI photo by Michael Jones.

Dr. George Veni injects uranine dye into the sinking Black River; the riverbed was dry only 100 m downstream. The disposable protective clothing is to prevent accidental spread of the dye which could cause false positive results.

These gravels were deposited during Pliocene through Pleistocene time in a large alluvial fan originating from Slaughter Canyon in the Guadalupe Mountains. Sinkholes in the Upper Black River Basin probably contribute to recharge to the Quaternary Gravel Aquifer, although the details of this conceptual model are not well-understood.

NCKRI's interest in this study is in part to better understand the groundwater system that is economically important to the region, and essential to the survival of its endangered species of mussel. However, NCKRI's scientific interest rises from the fact that while karst aquifers formed in limestone conglomerates are known around the world, they have seen little study. This project may be the first dye trace in such an aquifer.

On 7 May 2020, NCKRI personnel injected eosine dye where Black River sinks upstream from BLM's Cottonwood Day Use Area, where the river reappears briefly, and uranine dye a short distance downstream of Cottonwood where the river sinks a final time. Monitoring stations were established at four downgradient springs and two private wells. These sites are sampled every two weeks using passive dye detectors, which adsorb dye present in the water during that period.

Neither of the non-toxic dyes have been found at the time this report is being prepared. This is not surprising. The dry climate of the region will result in slower groundwater velocities than in areas where most dye traces are done in wetter climates. Next year's annual report will include the results of this study.

NCKRI photo by Michael Jones.

Michael Jones collects a dye detector from the outflow of Rattlesnake Spring.

Searching for Desert Groundwater Fauna

A great thing about NCKRI's location in Carlsbad, New Mexico, is the opportunity to conduct research easily on new or little-studied karst topics. Karst in desert environments has seen relatively little research, especially the study of life in desert karst aquifers.

Carlsbad's location is no accident. It occurs along the Pecos River which is dry or too saline to drink for much of its length in New Mexico. But one area of freshwater springs along the river discharges water from the Capitan Aquifer, recharged in the karstic Guadalupe Mountains to the southwest. These springs made life possible for a city. If the springs can support life on the surface, might they support life in the Capitan Aquifer?

Karst aquifers are often home to a rich fauna that tells us a great deal about the history of life in those regions—above and below ground. The Carlsbad Springs are located about 4 km upstream of NCKRI Headquarters. In 2014, with the help of then-student intern Lasha Asanidze, we conducted a preliminary study of groundwater fauna in the region. Afterward, we didn't have a chance or the staff time to continue his work, until this year.

In early 2020, the City of Carlsbad drained Lake Carlsbad for maintenance and improvement of its dam. With the lake drained, the Carlsbad Springs became more accessible again for research. During February and March, Michael Jones, NCKRI's Cave and Karst Science Specialist, lodged special traps into the main Carlsbad Spring outlets to catch aquatic macroinvertebrates.

Most people in Carlsbad think the Pecos flows from "the Carlsbad Spring." Easily found in a city park, this spring forms a small stream that bubbles up through sand and gravel. However, most of the Pecos River's flow comes from a little-known spring about 200 m downstream, hidden by tall weeds and under the water of Lake Carlsbad. This "main" Carlsbad Spring rises from two conduits, almost big enough for a person and certainly large enough for tiny aquifer animals.

Mr. Jones collected traps from the main spring's conduits on a weekly basis for several weeks. He brought them to the NCKRI Laboratory to sort the specimens into sample bottles with preservative. The bottles were labeled with sample location, and date of collection. Next year, NCKRI will consult with experts in the field of subterranean aquatic biology to determine if macroinvertebrates collected at the main Carlsbad Spring are groundwater species or not.

In April 2020, the City of Carlsbad completed maintenance of its dam and refilled Lake Carlsbad. The city plans to drain the lake again in 3–5 years for continued maintenance. Information gathered while taking advantage of the drained lake will add to the body of knowledge of the Capitan Aquifer.

NCKRI's biomonitoring at Carlsbad Spring is an unfunded but inexpensive project. As time and resources become available, NCKRI plans to expand its biomonitoring to other karst springs, cave streams, and water wells in southeastern New Mexico and West Texas. We expect to learn about the types of aquifer habitats in the region, which will give us useful information on the area's karst aquifers to better understand and manage them sustainably for the needs of human and non-human species.

NCKRI photo by Michael Jones.

Normally under the water of Lake Carlsbad, one of the outlets of the main Carlsbad Spring rises from a hole that may be home to a unique ecosystem.

New Data Loggers in NCKRI Bat Roost

NCKRI Headquarters is the only building in the world designed to include a home for bats. It was designed by Mylea Bayless, Artificial Roosts Coordinator for Bat Conservation International (BCI), and Dr. George Veni, NCKRI's Executive Director. NCA Architects adjusted that design to accommodate construction and attachment to the building.

The roost has an optimal design for bats and offers flexibility for study and education. It is made of concrete and has six crevices to serve as bat living quarters. Each crevice is 60 cm high, 6.7 m long and 1.9 cm wide. The crevices are divided by 3-cm thick panels. Horizontal slots near the bottom of the panels let bats move from crevice to crevice without leaving the roost, where they could be exposed to predators. The outer walls extend 10 cm below the roost and serve as landing pads for bats to easily access the roost.

During the Fall of 2019, NCKRI's bat roost was upgraded with new temperature and relative humidity dataloggers. ONSET HOBO Ethernet Remote Monitoring Stations were installed and equipped with 18 temperature/relative humidity sensors located in three locations in each of the six crevices. This improvement allows for the bat roost temperature and relative humidity data to be continuously logged, saved to the NCKRI server, and uploaded to the HOBOlink cloud for immediate remote access and processing.

Additionally, the new data loggers run on AC power, another big improvement in saving time—eliminating the need to change out batteries and manually save data on a periodic basis. With the new data loggers tapping into the building's power, and making continuous measurements, or as close to continuous as possible at 5-minute intervals, we can now also see small differences between the sampling sites which will be useful to understand how temperature and humidity change throughout the roost.

As we wait for the bats to hang out with us, NCKRI staff have been analyzing eight years worth of temperature and relative humidity data from the old dataloggers, which were also in three locations in each of the six crevices. While it will be great when the bats arrive, developing a good record of roost conditions before their occupation is valuable to the roost's long-term study. This will be useful in better understanding roost conditions after bats move in. Michael Jones is leading the analysis of the roost data, which we hope might tell us why bats haven't moved in yet.

NCKRI photo by Dianne Joop.

Michael Jones installs new data loggers into the bat roost, located in the floor behind the desk of our Operations Division Director, Vicky Gonzales.

NCKRI photo by Dianne Joop.

Data loggers extend into a crevice below each hole. Corked holes in the background are for future dataloggers, and the inset rectangular slots will one day hold cameras to look into the crevices and video bat activity.

Once the roost is occupied, NCKRI will conduct more public education and research about our bats and bats in general. Data, video, and sounds from the roost will be included as one of NCKRI's museum exhibits, and you will be able to watch the bats on our website!

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

Karst Information Portal

The Karst Information Portal (www.karstportal.org) is a NCKRI project in partnership with the University of South Florida Libraries (USF), University of New Mexico, and the International Union of Speleology. The Portal is part of the USF Libraries Digital Collections interface and serves as a one-stop shop for open, online access to cave and karst research.

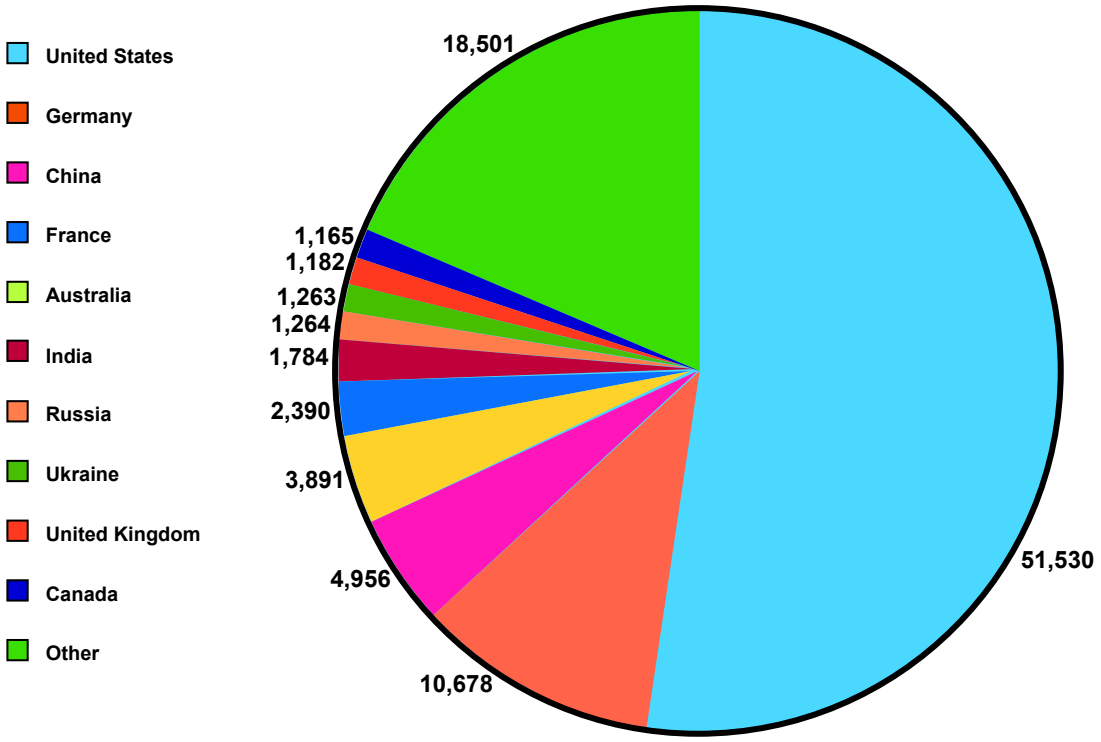
NCKRI has been sending documents, links, and spreadsheets of citations to the USF Libraries team over the course of the past year. Once received, the USF Libraries staff do copyright clearance on these items to determine which ones can be posted with full-text and which need to just be citations. Metadata are created for each item, and these are uploaded to the Portal. This year, we have added 989 items to the Portal, bringing the total to 5,212.

The USF programmer for the interface, Richard Bernardy, developed a new Windows application, nicknamed "KIPcat," to programmatically build data packages for submission into the incoming processing queue for the system. The app accesses the Google Sheets spreadsheets/sheets (via API) which contains the metadata created by the USF Libraries cross-department metadata team. This team is comprised of students and staff from multiple USF departments, led by digital collections cataloger Xiying Mi, with initial metadata originally gathered by Alex Onac. Automating the process has allowed USF to jump ahead and begin to catch up on the backlog of items waiting to be entered into the Portal.

The repository software for Digital Collections/KIP is in continual development. The design/functionality review committee for the interface meets monthly to provide feedback and guidance. An updated version of the software (using the open-source software SobekCM, with our custom alternative public interface) is installed at least monthly. The Digital Collections repository on which the Portal is hosted has been migrated to the Amazon Web Services platform this year to allow more flexibility in development and storage capacity.

The Karst Information Portal's usage is measured through Google Analytics and other tools. Usage of the Portal continues to increase. Items in the Portal have been downloaded a record 322,195 times this past year. Of those uses, 206,191 uses came from 67 different search engines in 25 countries that have discovered the Portal. KIP usage by human users is coming from 177 of 195 countries, with most of the usage being in the United States, followed by Germany and China. The Karst Information Portal is truly reaching a worldwide audience! The chart below shows the top 10 countries' usage for the Portal in the past year.

Useage of the Karst Information Portal by Country



Installing NCKRI's Laboratory

Thanks to our federal funding boost from the previous year, this year NCKRI purchased a wide variety of equipment and supplies to convert NCKRI's empty lab room space into a functioning laboratory.

Dr. Dan Jones took the lead on identifying and purchasing the necessary lab equipment. He identified not just NCKRI's needs but consulted with cave and karst scientists around the country who often conduct research in the Carlsbad area so our lab could also assist their efforts.

As the materials arrived, Michael Jones organized the supplies steadfastly but set some aside to focus on assembly of our lab furniture and fume hood. The two large lab benches were positioned in their appropriate locations, their sinks added and attached to the drains (specially designed for chemicals), spacers installed to attach the cabinetry, and the acid-resistant counter tops were leveled precisely and epoxied in place. Meanwhile the fume hood, an older but fully working unit provided by New Mexico Tech, was cleaned and repainted.

Meanwhile, amid the arrival and assembly of materials, the lab has been used partially to rinse sample bottles using our new DI/RO water filtration system, and for field work preparation. The acid-resistant sinks have already been useful to acid wash sample bottles for research. Additionally, the lab houses a new refrigerator which preserves samples from ongoing groundwater and biological monitoring projects.

Currently, countertop shelves and drying racks are being installed above the lab benches. By the time you read this, the fume hood will be installed, and all equipment organized. The set-up of the NCKRI Laboratory will soon be complete!

Mapping Endangered Karst Species

In 1988 and 1993, the US Fish and Wildlife Service (USFWS) listed a total of seven invertebrate karst species as endangered. These species are only known to occur in the Austin, Texas, area in Travis and Williamson counties. These counties were being urbanized rapidly and many caves were at risk of being sealed, destroyed, or adversely affected by degraded water quality and other impacts.

Following the listings, USFWS developed maps that outlined "karst fauna regions," which contain similar and likely interconnected underground ecosystems, and "karst zones," which identify the probability of encountering the listed species in any particular area. The "region" maps have been used extensively to better manage and set recovery standards for the species. The "zone" maps are attached to various regulatory needs and are the primary tool to help guide urbanization away from sensitive areas, allowing opportunities for purchase and protection of the karst by governmental and private organizations.

As new information has become available, NCKRI was contracted to update the mapping. This work involves study and analysis of the distribution of the seven listed species, plus 32 non-listed species, in 479 caves and karst features in seven counties to fully constrain the limits where the listed species might occur. This study is using powerful GIS tools not available during the initial mapping in 1992, which will assure the boundaries are as accurate as possible. The report will be complete by the end of 2020, and should serve as a template for developing biogeographic management strategies in other karst regions.

For more information about the endangered karst species in Texas and to see the current region and zone mapping, visit https://www.fws.gov/southwest/es/AustinTexas/ESA_Sp_KarstInverts.html#Karst_zones.

Photo courtesy of Dr. Jean Krejca.

Tartarocreagris texana, the Tooth Cave pseudoscorpion, is known only from five caves on the Jollyville Plateau on the west side of Austin, Texas. This fascinating tiny creature is one of seven endangered karst invertebrates NCKRI is studying for the USFWS.

NCKRI photo by George Veni.

The NCKRI laboratory is equipped and getting assembled.

Cave Geomorphology of the Klamath Mountains, California

Joel Despain is leading a research project examining the caves of the McCloud Limestone, found between Redding and McCloud California in the eastern Klamath Mountains. Here, two distinct groups of caves have formed. One set lies low on the landscape and often contains streams. The other group is far above the McCloud River and contains multiple vertical passages, large rooms, sudden passage terminations, phreatic bedrock features, and many large speleothems. It is believed that these caves are much older than the first group and that they formed hypogenically.

Hypogene caves form by rising water, often with unusual chemistries, from deep within the Earth. What causes such water to rise and make caves? In the case of the McCloud caves, the suspect is the active 4,322-m tall Mount Shasta Volcano through "volcanogenic karstification." This process increases sulfur compounds and carbon dioxide in groundwater, creating acidic solutions potentially much stronger than those found in the development of normal cave streams.

To investigate these caves Despain and colleagues Dr. Patricia Kambesis, from Western Kentucky University, and Dr. Jonathan Sumrall, from Fort Hays State University in Kansas, completed and continue to work on a series of projects. Local karst springs were sampled to determine if any are currently rich in sulfate or other indications of hypogene origins. The caves of the area were mapped carefully in detail, allowing the use of fractal analysis to compare the shapes of the caves and mathematically differentiate them by origin. The McCloud limestone has numerous dikes of diorite. These have been heavily weathered in the caves by hot and chemically reactive fluids that may indicate the nature of the water that made the caves. These rocks have been sampled and are being thin-sectioned and analyzed to answer the question. The team hopes to publish its research in 2021.

Photo courtesy of Heather Veerkamp.
Joel Despain collecting a water sample from a karst spring in the McCloud Limestone, Shasta County, California.

National Cave Sample Archive

Two years ago, NCKRI received a fabulous donation of 1,056 cave minerals from Dr. William B. White as the seeds for NCKRI's National Cave Sample Archive. The purpose of the archive is to collect and preserve any type of material from caves and karst, and their associated analyses, and make them available to qualified scientists for study.

Thousands of samples have been collected from caves and some are at risk of loss for lack of adequate or permanent storage facilities. Additionally, many caves are needlessly resampled for materials when specimens already exist but are not known to the greater scientific community. The National Cave Sample Archive will reduce and hopefully one day eliminate those problems.

During the past year, NCKRI received a major and vital donation of 20 surplus sample storage cabinets from the US Geological Survey. With these in place we can now begin to convert the boxes of specimens into a proper archive for research and broad use.

However, prior to moving the physical collection from the temporary shipping containers into proper archival storage cabinets, NCKRI is developing sample management standards that comply with National Park Service (NPS) protocols. NCKRI hopes to become a NPS-accredited or accepted archive, which should also qualify us for other accreditations. Our standards must also offer flexibility where needed, where NPS protocols do not apply to us and/or unnecessarily restrict us, yet without violating any protocols when NPS materials are concerned.

NCKRI photo by George Veni.
Michael Jones installs NCKRI's newly donated archival sample cabinets.

As development of our National Cave Sample Archive Protocols nears completion, we will soon begin the digital and physical archiving of the collection. The digital archive will be integrated with other digital databases involving cave samples.

Lastly, as we are now getting off the ground with our archive, if you have suggestions on potential collaborations we may be able to join or assist with, please let us know. NCKRI is continuing discussion with other scientists who are considering preserving their materials with us. If you would like to discuss contributing cave samples to the archive or collaborating on this project in other ways, please contact Dr. George Veni at gveni@nckri.org or by calling 575-887-5517.

NCKRI RESEARCH GRANT PROGRAM

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

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

NCKRI's research grant program is managed by Dr. Daniel Jones. Application and other information is posted at https://www.nmt.edu/research/organizations/nckri.php.

Following are the recipients of the first NCKRI grants with descriptions of their research projects.

NCKRI National Seed Grants

Dr. Elizabeth Hasenmueller: Quantifying Microplastic Debris Transport and Sourcing for a Karst Aquifer

Karst aquifers are unique habitats and important drinking water sources, but high connectivity between the surface and subsurface in these systems makes them susceptible to contamination. Agricultural runoff and leaking wastewater infrastructure can impair karst aquifers with biological (fecal bacteria) and chemical (nutrients and toxic metal) pollutants, but they may also be significant sources of emerging contaminants like microplastics (plastics smaller than 5 mm in diameter).

Plastic debris can cause significant harm to aquatic life when organisms become entangled in the plastics or consume them. Little is known about the transport and sourcing of microplastic contamination in karst aquifers, with only a single previous study noting the presence of microplastics in karst groundwater during periods of low flow. Further research on microplastic contamination of karst is therefore critical given that karst aquifers experience rapid changes in flow during flood events, are highly connected to the surface where pollutants are sourced, offer unique habitats, and provide drinking water.

Dr. Hasenmueller is an Associate Professor in the Department of Earth and Atmospheric Sciences at Saint Louis University, Missouri. She and her students propose to quantify and characterize microplastics (including their size, shape, and polymer type) in a karst aquifer under variable flow conditions. They hypothesize that microplastic loads increase during flood events as higher flows mobilize materials from the surface into the aquifer and, potentially, from stores within the aquifer.

Photo courtesy by Elizabeth Hasenmueller.

Dr. Elizabeth Hasenmueller and her students collect microplastics samples during a flood in Cliff Cave, an urban cave system in St. Louis, Missouri.

Dr. Hasenmueller and her students will use sediment characteristics and dissolved organic carbon concentrations to establish if microplastics are sourced from the surface and/or remobilized from within the aquifer. Additionally, they will test if microplastics co-occur with chemical tracers indicative of human inputs from agriculture, wastewater, or roads.

The study also intends to help resolve an ongoing need in the microplastics community to standardize procedures for monitoring microplastic debris, especially for groundwater systems where there is very limited prior work and a lack of quality control measures. Their research will provide a baseline for future work related to the transport and fate of microplastics in karst and groundwater environments and can be used to inform debris mitigation strategies.

Dr. Dylan Ward and Mx. Rachel Bosch: Stream Capture from Below: Formation of the Sinkhole Plain, Kentucky, Through the Lens of Relict Topography

In areas with many closely spaced sinkholes, such as the Sinkhole Plain near Mammoth Cave in Kentucky, surface river networks cannot develop because streams encounter sinkholes and their water and sediment are carried into the subsurface system of cave passages. As younger limestone layers are revealed by erosion of

river networks in higher elevation areas, those river networks become increasingly disrupted by development of sinkholes in the underlying limestone. Progressively more of the sediment is eroded from overlying rock layers and must be transported through the developing network of karst conduits.

Dr. Ward is an Associate Professor in the Department of Geology at the University of Cincinnati, Ohio, and Mx. Bosch is a PhD candidate at the university. In their study area of central Kentucky, multiple tributaries to the Barren River were cut off from below by the development of sinkholes and cave passages in the Sinkhole Plain. This process diverted flow to the Green River and, over time, migrated the drainage basin boundary between the Barren and Green watersheds westward.

This project will use modern geomorphic tools to evaluate the quantity of rock that must have been removed from the landscape via sinkholes and karst passages to form the modern Sinkhole Plain, the time over which this occurred, and the consequences for the regional river systems.

Photo courtesy of Dylan Ward.
Rachel Bosch samples modern stream sediment from Little Sinking Creek, which sinks into the Sinkhole Plain.

NCKRI Scholar Fellowships

Heidi Aronson: Geochemical and Cultivation-Based Investigation of Gypsum-Hosted Microbial Communities in the Frasassi Caves, Italy

Ms. Aronson is a PhD candidate at the University of Southern California. Her research is focused on the karst at Frasassi, Italy, which hosts a dynamic sulfur cycle that powers microbial chemolithotrophy—a process where microbes consume the bedrock to obtain energy. While many geochemical niches at Frasassi have been studied extensively, much less is known about the geochemistry and microbial communities associated with gypsum deposits.

Ms. Aronson is measuring the concentrations of sulfide, thiosulfate, sulfite, elemental sulfur, polysulfides, and calcium within the gypsum deposits. These concentrations will be used to calculate the energetic yields of reduction-oxidation reactions involving sulfur to determine which reactions could power microbial metabolisms. One reaction, sulfur comproportionation (the reaction of sulfate and sulfide to form elemental sulfur), is a novel microbial metabolism that has not yet been discovered in the environment. It is thermodynamically favorable within Frasassi gypsum and could plausibly be an energy source for microorganisms.

Ms. Aronson is designing a cultivation medium using *in situ* geochemical conditions to enrich for and isolate a sulfur comproportionator from the gypsum. Her work will contribute to revealing the contributions of gypsum-associated microbial communities to the overall sulfur cycle at Frasassi, and how their metabolism may impact cave formation.

Photo courtesy of Heidi Aronson.
Heidi Aronson in the Frasassi Gorge, Italy.

William Coleman: Variance in Genetic Diversity of an Endangered Freshwater Beetle Before and After an Adverse Climatic Event

Mr. Coleman is a PhD candidate at Texas State University. His research focuses on the effects of adverse climatic events, such as severe droughts, on aquatic ecosystems. He hypothesizes that for animals restricted to habitats, such as karst spring complexes, prolonged droughts may result in decreases in population size and a rapid loss of genetic diversity, reducing fitness in the springs' populations.

Mr. Coleman's study is investigating the potential impacts of severe drought on an aquatic endangered species known from only two karst spring complexes in Central Texas which discharge from the Edwards (Balcones Fault Zone) Aquifer.

He is characterizing and comparing genetic diversity of the Comal Springs riffle beetle (*Heterelmis comalensis*) in the Comal Springs complex, before and after a 2010-2015 drought.

Photo courtesy of William Coleman.
The endangered Comal Springs riffle beetle.

During this drought, different spring openings in the complex experienced partial or complete drying, based on the spring openings' elevations.

Mr. Coleman is also investigating changes in genetic diversity in the San Marcos Springs' population over approximately the same timescale. This spring complex is at the base of the aquifer, located about 30 km northeast of Comal Springs and at a lower elevation, so it experienced less severe drought effects.

The data from this investigation will first allow Mr. Coleman to quantify temporal variance in genetic diversity within and among populations at individual spring openings, and within and among populations at the Comal and San Marcos spring complexes.

Secondly, Mr. Coleman will then use next-generation DNA sequencing to generate the genomic data, which will be used to quantify changes in effective population size for the aquatic beetle. The information from this study is needed to understand the effects of adverse climatic events on endangered karst spring endemic organisms, and to inform effective conservation and management programs.

Natasha Sekhon: Decoding Dry and Wet Conditions in Semi-Arid New Mexico by Studying the Mineral Deposits in a Cave

Ms. Sekhon is a PhD candidate at The University of Texas at Austin who is conducting her research in New Mexico. Recent studies show a drastic decrease in the water levels of the Rio Grande and the rapid temperature increase in New Mexico as it becomes the 6th warmest US state. The interplay between climate and hydrology of the region dictates the oscillation between drought and non-drought periods. Instrument records, going back to the early 20th century, allow her to study dry and wet periods for that time period. In order to glean pre-instrumental climate change, which would advance understanding of the regional climate, she is studying the chemistry of cave deposits.

Ms. Sekhon's research is largely focused on understanding how pre-instrumental dry and wet periods have changed through time by investigating the various mineral concentrations of cave deposits in southeastern New Mexico. Trickling rainwater, carrying surface minerals, flows through the rock above caves. The rainwater eventually makes its way underground where it is deposited as stalagmites and stalactites over tens to hundreds of years. Similar to tree-rings, as stalagmites grow, each stalagmite growth layer encapsulates important chemical clues on what the climate was like above the cave.

By looking at numerous mineral concentrations in the growth rings, Ms. Sekhon will establish a paleoclimate record on how dry and wet periods have changed through time in that drought-sensitive region. Her first step will investigate stalagmites that grew at a time that overlaps with instrumental data, permitting her to develop robust relationships between the chemical clues and known instrumental data. On establishing this relationship, she will then look at stalagmites that grew well before the instrumental period (pre-1930s), thereby, developing tools to investigate hydroclimatic trends through time.

Photo courtesy of Natasha Sekhon.
Stalagmite in Sitting Bull Falls Cave, New Mexico, that holds hundreds of years' worth of geochemical data.

NCKRI-NMT Internal Seed Grants

Dr. Thomas Kieft: Culture-Independent, High-Throughput Analysis of Viral Communities in Carlsbad Cavern Pools

The biology of caves has received considerable attention from the scientific community, particularly with regard to cave microorganisms and animals. However, very few cave studies have focused on viruses, which are the most common biological entities on Earth. Viruses that infect bacteria (bacteriophages) are likely to be the most numerous in caves. Characterization of the viruses in caves will increase our knowledge of cave biodiversity and will also further our understanding of nutrient cycling. Viruses breakdown host cells, thereby releasing nutrients for uptake by other cells.

Dr. Kieft is a professor in the Biology Department at New Mexico Tech. He proposes to quantify viral particles in cave pools relative to bacterial cells, to generate a large database of cave pool viral sequences, and to test for human impacts on cave pools as evidenced by the viral communities. He hypothesizes that viral abundance is ten-fold higher than prokaryotic cell abundance in cave pools, that cave pools contain novel viral sequences, and that viral communities in pools from portions of a cave developed for tourism are distinct from those of pools in parts of the same cave not visited by tourists. Dr. Kieft and his students are sampling water from pools in Carlsbad Cavern, New Mexico, and using DNA sequencing to analyze the viral communities.

Photo courtesy of Tom Kieft.
NMT Master's student Joseph Ulbrich collecting water samples at a pool in Lower Cave in Carlsbad Cavern.

Dr. Talon Newton and Scott Christenson: Estimating the Local Water Balance in Snowy River Passage, Fort Stanton Cave, New Mexico

This study aims to increase our understanding of the hydrogeology of Fort Stanton Cave by assessing the local water balance for a flood event in the Snowy River Passage. Since the discovery of the Snowy River Passage in 2001, Fort Stanton Cave, located in southern New Mexico, has become a world-class cave. There are many exceptional aspects of Snowy River, including the crystalline white calcite formation that lines the stream bed along most of the known length of the passage, making it the longest speleothem in the world.

Over the last twenty years, cave explorers and researchers have been collecting geologic, hydrologic and geochemical data, with the objective of identifying the water source(s) associated with several ephemeral floods that have been observed in Snowy River. Recently, researchers from New Mexico Tech, the University of New Mexico, and the US Geological Survey have constructed a preliminary hydrogeologic conceptual model of Snowy River based on existing data sets.

According to this model, Eagle Creek is the primary source of water that periodically floods the Snowy River Passage. During times of high stream discharge in Eagle Creek, enough water infiltrates through sinkholes and stream sediments to initiate flooding in the passage. Much of this water ends up discharging at Government Spring and flows into the Rio Bonito. Water in the Snowy River stream is also lost to downward leakage and evaporation.

Photo courtesy of Knutt Peterson.
Dr. Talon Newton (right) and Dr. Jacob Collison (left) pose with the new pan evaporimeter in Fort Stanton Cave.

Dr. Newton is a hydrogeologist and Mr. Christenson is hydrogeological field technician, both with the New Mexico Bureau of Geology and Mineral Resources. Their objective is to examine hydrogeologic processes in the Snowy River Passage by analysis of individual flood events. Additionally, they will perform water balance calculations to help test their current conceptual model and constrain a two-dimensional hydrologic flow model that is being developed.

Another objective is to build a pan evaporimeter (see photo above) that records continuous data in the cave to accurately estimate evaporation rates in high-humidity caves. This instrument will be a useful tool to study microclimates in other caves in semi-arid regions, presenting opportunities for future collaborative projects. Monitoring evaporation rates in humid caves in semi-arid areas can provide information about the effects of climate change on cave microclimates.

EDUCATION PROGRAM

Many have daydreamed about our planet's recovery to a pre-industrial world. We think about clean air and water and long for our critical ecosystems to be recognized and protected. When the US Congress formed NCKRI in 1998, it provided an unprecedented opportunity for the cave and karst community to advance research, education, communication, and resource management focused on cave and karst landscapes.

NCKRI's Education Program works toward our mission in two ways. First, we develop projects and programs that educate and inform people about caves and karst landscapes. Second, by managing and promoting NCKRI's brand, educating people about the Institute and its vision, mission, and activities. Below are highlights of this year's Education Program activities.

Cave Exploratorium: NCKRI's Science Center

NCKRI is developing the Cave Exploratorium, a cave-centric science center that will offer fun ways for people to learn and interact with cave and karst science topics. We love caves and want to inspire others, as well. It is our passion for cave and karst resources that drives our design concepts for unique, diverse, and informative museum experiences.

Why a science center? When NCKRI formed, the founding partners agreed our headquarters should include a museum. A science center is a big step up from that concept. Science centers focus on emotional and intellectual engagement. They communicate complex science topics, sometimes using somewhat exaggerated and theatrical methods so children can understand. Gaining a comfort level with science can motivate visitors to develop a greater interest and desire to learn more. Science center visitors expect active learning, participating in actions, discussions, and to reflect on their experiences.

We know that cave and karst science is an intensely active and sometimes sporty process, which makes it an exciting prospect in connecting with the general public. The mission of the Cave Exploratorium is to inspire the citizens of and visitors to the City of Carlsbad to learn about cave and karst natural and cultural resources. The Cave Exploratorium will promote and nurture an appreciation of these valuable resources through high quality and easily accessible exhibitions, programs, publications, and other educational experiences.

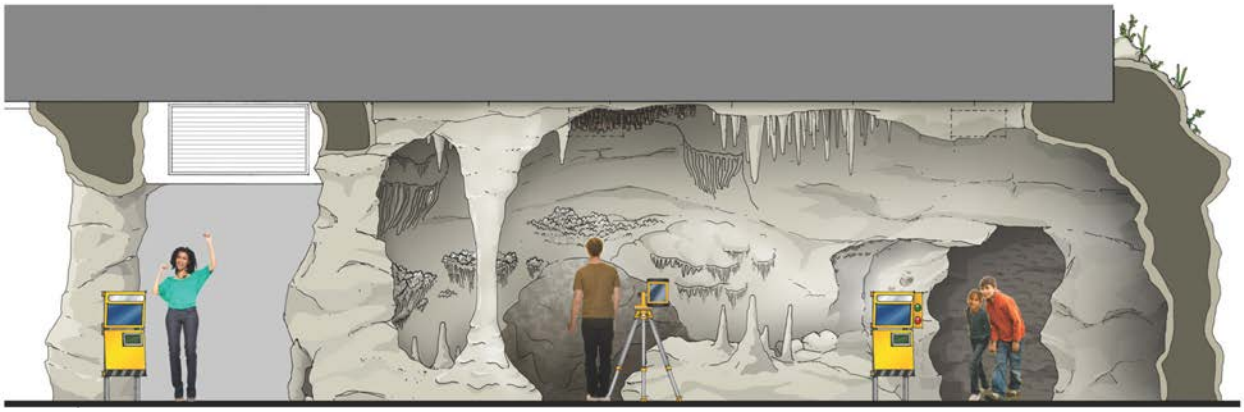
This year we focused on completing the design of our first Cave Exploratorium exhibit—the DropZone!

The DropZone at the Cave Exploratorium

The DropZone will be outside NCKRI Headquarters, filling NCKRI's courtyard, as a 9-m tall simulated cave. Visitors to the DropZone will immerse themselves in vertical cave exploration techniques. They will learn rope climbing, rappelling, and other methods used to explore and study caves. Associated exhibits at ground level will show how theories developed by Newton and Galileo help cavers discover unexplored worlds deep underground.

Construction of the DropZone awaits easing of COVID-19 restrictions. Once the pandemic is over, the DropZone will open to the public to inspire visitors to learn about caves and karst landscapes. The DropZone will also be open to cave, fire, and other rescue teams to practice and further develop their techniques.

This special experience would not have been possible without the generous donation of a City of Carlsbad, New Mexico, Lodgers Tax Grant of over $255,000! Additional support came from New Mexico Tech. The superb exhibit and ropes course designs (see bottom of next page) were created by Storyline Studios and Aerial Designs.



NCKRI's Cave Exploratorium will be an engaging, hands-on, fun, learning experience. This image is part of a detailed design, currently seeking funding for construction.

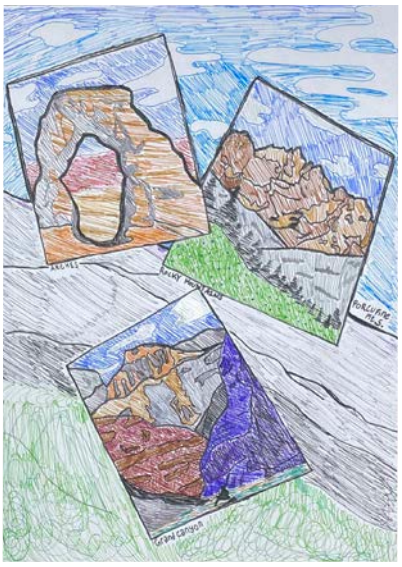
Guadalupe Mountains National Park 4th Annual Youth Poster Contest

Public lands are the best places to enjoy the great outdoors. Whether hiking above or below ground, we at NCKRI believe cave and karst landscapes offer excellent recreational opportunities for everyone, young and old, to connect with nature and these vital and revitalizing resources.

Reflecting on the success of the 3rd Annual Youth Poster Contest, which had caves as the theme and was hosted last year at NCKRI Headquarters, NCKRI again partnered with Guadalupe Mountains National Park for the 4th Annual Youth Poster Contest. The theme for this year's contest was "Recreation for All."

Our Education Director, Dianne Joop, worked closely with Guadalupe Mountains National Park staff to expand the scope of the contest. She developed educational workshops and curriculum, and planned an exciting public judging event and show of the artwork that would be attended by schools from the City of Carlsbad and nearby communities. Sadly, this project was significantly diminished by the COVID-19 pandemic.

Public safety guidelines required us to cancel our workshops, field trips, and classroom visits. However, we proceeded with the contest. We extended the deadline



for contest entries, and offered an option for electronic submissions to accommodate the rapidly changing situation across the country imposed by the pandemic.

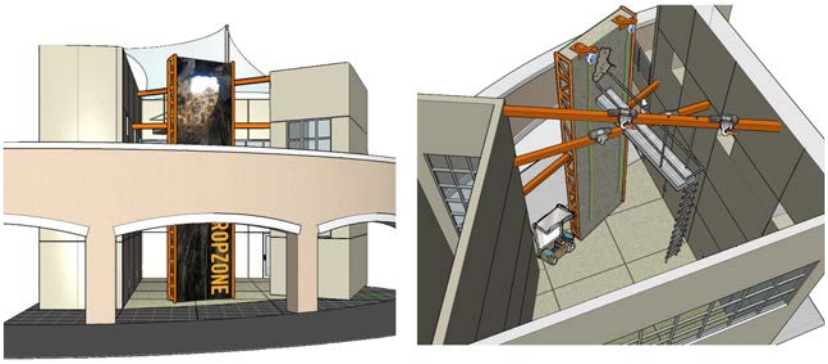
We received entries from nine states, coast to coast. Instead of the public judging event, as originally planned, our judges met in a small group with Carlsbad Mayor Dale Janway to select the winning entries. We had winners in multiple categories.

This year's Cave and Karst NCKRI's Choice Winner was created by 13-year old Mara Van Wagner and is shown above. She also wrote: "People should get out to national parks because it's cool to see how the land was formed and just to look at new things." We couldn't agree more!

NCKRI Educational Tools

NCKRI has developed two new educational tools. Our "Make Your Own Speleothem" activity sheet and attached coloring page (shown below) are fun ways for youngsters (and the young at heart) to learn about caves and their "formations," which are properly called speleothems.

Our second new tool addresses many people's need for a karst map of the US. The US Geological Survey (USGS) produced a detailed updated map for the country in 2014. However, some of the map information was too detailed for easy public use. Responding to requests, NCKRI created a new version of the USGS map for easier public use and in a color-blind friendly way (shown below). Both the map and speleothem activity sheet will soon be available for free download from NCKRI's upgraded website.



This architect's view shows the DropZone as it will appear looking toward NCKRI Headquarters (left) and downward into the courtyard from above (right).

National Workshops

Interpretation is both a communication skill and an art form. Good interpretive programs connect audiences to natural and cultural resources and inspire people to protect those resources. Show cave interpretation is a particularly good avenue to lead the way for cave and karst protection. It can inspire visitors touring show cave sites to care about and protect caves everywhere.

NCKRI's Dianne Joop is working closely with the National Caves Association (NCA) to develop a series of workshops for cave guide training. The NCA is a non-profit organization of show cave owners from across the US who promote the show cave industry to the public and share information and ideas. This project was launched by a workshop presented by Ms. Joop and the NCA Education Committee during the 2019 NCA Annual Convention in Chattanooga, Tennessee.

As part of two courses, and combining aspects of NCKRI's Education and Academic programs, Dr. Dan Jones developed a new science communication activity in partnership with the website Sciworthy (https://www.sciworthy.com), an initiative of the nonprofit organization, Blue Marble Space. Students selected a paper from the scientific literature published in the last year, and wrote news-style layperson articles. Articles of sufficient quality were submitted for publication on Sciworthy, and students were given opportunities to revise their pieces with feedback from Dr. Jones. Articles published by students in Geomicrobiology and Special Topics in Cave and Karst Processes include:

- A special kind of bacteria lets cement fix itself
- Mining with acid-generating bacteria
- Scientists discover cockroach fossils from the dinosaur age
- Strange microbes found living in caves of sulfuric acid

International Workshops

Much of the 3rd Asian Trans-Disciplinary Karst Conference was designed around a series of educational cave and karst workshops taught by international experts from the International Union of Speleology (UIS). As a leading expert and UIS President, NCKRI's Dr. George Veni taught the seminar, *Introduction to Cave and Karst Hydrogeology*.

Other members of the UIS Bureau taught workshops on cave biology, environmental protection, cave photography, the history of cave exploration, and other topics. The conference was held in Panglao, Bohol, Philippines, in September 2019.

NCKRI photo by George Veni.

The Chocolate Hills of the Bohol are a world-famous cone karst and the site of impromptu lectures as part of the Philippines karst workshop.

NCKRI photo from Dianne Joop.

Dianne Joop presenting the "Cave Interpretive Techniques" workshop at the NCA 2019 Annual Convention.

NCKRI PARTNERS AND FRIENDS

Membership

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

NCKRI Partners

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

Founding Partners

NCKRI's Founding Partners played a crucial role in the creation of the Institute and continue to serve as major supporting partners. Each founding partner maintains one permanent position on NCKRI, Inc.'s, Board.

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

Institutional Partners

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

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

NCKRI Affiliates

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

- Bat Conservation International
- Carlsbad Chamber of Commerce
- Carlsbad Municipal Schools

NCKRI photo by George Veni.

The Texas Speleological Survey (TSS) donated a truck full of caving association newsletters dating back as far as 60 years to the NCKRI library. TSS directors (left to right) Merydith Turner, Logan McNatt, and Ron Ralph sit on the loaded truck's tailgate.

- Edwards Aquifer Authority
- Fort Stanton Cave Study Project
- Karst Waters Institute
- Living Desert Zoo & Botanical Gardens State Park
- National Caves Association
- National Speleological Society
- NASA
- US Bureau of Land Management
- US Fish and Wildlife Service

Annual Giving

Our Annual Giving Program recognizes those individuals and organizations who joined as members or provided goods, services, and/or financial gifts during FY 2019-2020 in support of NCKRI programs:

- Dr. Calvin Alexander
- Bert Ashbrook
- David Bednar
- Josh Brewer
- Representative Cathrynn Brown
- Dr. Philip Carpenter
- Richard Cervantes
- Lora Chiehowsky
- Jim Coke
- Paul & Sandra Cosand
- Dr. David Decker
- Harvey Duchene
- William Ellis
- Jim Evatt
- Friends of Bitter Lake
- Larry and Signe Henderson
- Megan Jones
- Ted Lee
- Dr. Penny Lukin
- Frank and Judy Marks
- Pecos Valley Grotto
- Gary Poole
- Richard and Rodney Raber

- Bru Randall
- Renee Reece
- Jesse Richardson
- Todd Roberts
- Jo Schaper
- John Scheltens
- Hayley Schmitt
- Michael Shelton
- Lawrence Shore
- Kay and Dr. Stan Sides
- Texas Speleological Survey
- THG Geophysics
- US Geological Survey
- Eugene Vale
- Edward Vanscotter
- Dr. George and Karen Veni

NCKRI Volunteers

Many of our programs and projects rely on the help of our volunteers. We thank the following individuals for supporting NCKRI through their kind and inspirational efforts over the past year:

- Dr. Calvin Alexander
- James Berglund
- Tyrone Black
- Rusty Branch
- Michael Byle
- Connie Campbell Brashear
- Dr. Daniel Doctor
- Dr. Joseph A. Fischer
- Dr. Yongli Gao
- Brian Hunt
- Peter Hutchinson
- Clint Kromhout
- Dr. Jim LaMoreaux
- Ricardo Lopez-Ruiz
- Bashir Memon
- Dr. Boo Hyun Nam
- Dr. Ingrid Padilla
- Gheorghe Ponta
- Steve Rice
- Dr. Ira Sasowsky
- Dr. Brian Smith
- J. Brad Stephenson
- Simeon B. Suter
- Karen Veni
- Dr. Dorothy Vesper
- Dave Weary
- Keith White
- Sidney Woods
- Dr. Ming Ye
- Dr. Wanfang Zhou

CONFERENCES AND MEETINGS

16th Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst

Work continues on the Sixteenth "Sinkhole Conference." This conference series, which has been ongoing since 1984, was placed under NCKRI's oversight in 2011. The meeting was scheduled to be held in April 2020 in San Juan, Puerto Rico, and would be the first Sinkhole Conference held outside the continental United States, on an island that is world famous for its cockpit karst type sinkholes.

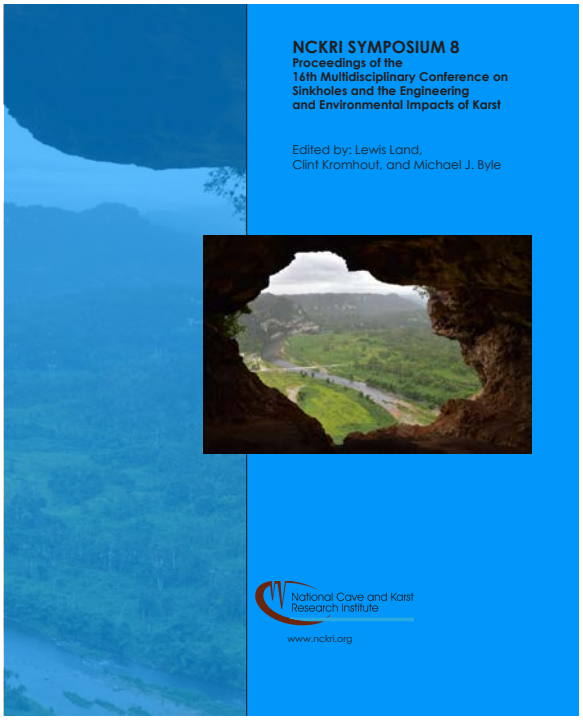
Because of travel restrictions related to the global coronavirus pandemic, the Organizing Committee of the Sinkhole Conference (included in our list of volunteers to the left) made the difficult decision to postpone the conference until 12-16 April 2021. In the meantime, NCKRI has published the conference proceedings volume. Dr. Lewis Land is the senior editor for the conference proceedings (see below).

To register for the conference and for other details, visit http://www.sinkholeconference.com/. To download the proceedings and other NCKRI publications, visit www.nckri.org.

Rentals

NCKRI Headquarters is normally available for private event rentals. We have a large conference room and a smaller board room for week-long corporate meetings, parties, luncheons, and training workshops. We also have six cubicles for those seeking temporary or long-term office space.

Funds collected through the rentals help us buy much needed equipment and boost our programs with resources to give our visitors a full experience in learning about the importance of caves and karst. However, rentals are on hold until the COVID-19 pandemic is over.



STUDENT ACTIVITIES

Cave and Karst Studies at NMT

Cave and Karst Studies at New Mexico Tech (NMT) is NCKRI's Academic Program, and this was another exciting year for the program. Dr. Daniel Jones, NCKRI's Academic Director, taught classes on Earth History, Geomicrobiology, Special Topics in Cave and Karst Processes, and supervised various student independent studies.

Dr. Jones continued his research program, and recently was awarded a grant from NASA to study biosignatures in gypsum deposits in the Frasassi Caves, Italy. He and his students did fieldwork in Frasassi last summer and are continuing their research on cave geomicrobiology and extremophiles from different environments. Below are some details on NCKRI's Academic Program and the students and programs it is supporting.

Student Research Projects

Zoë Havlena is a PhD student in the Earth and Environmental Sciences Department at New Mexico Tech. As part of her PhD research, she is studying Lehman Caves in Great Basin National Park, Nevada.

Some of the world's largest and most spectacular limestone caves, including Carlsbad Cavern and Lechuguilla Cave in New Mexico, were formed by a process known as "sulfuric acid speleogenesis" (cave formation by sulfuric acid). These caves form where groundwaters charged with hydrogen sulfide (H_2S) are exposed to oxygen in cave air or in fresh surface waters. Hydrogen sulfide is the gas that gives rotten eggs their "rotten" smell and is an especially reactive form of sulfur that is unstable in the presence of oxygen. As this hydrogen sulfide is exposed to oxygen, it reacts to form sulfuric acid, thus:

- $H_2S + 2O_2 \rightarrow H_2SO_4$ (hydrogen sulfide + oxygen → sulfuric acid)
- $H_2SO_4 + CaCO_3 + H_2O \rightarrow CaSO_4{\bullet}2H_2O + CO_2$ (sulfuric acid + limestone + water → gypsum + carbon dioxide)

Lehman Caves may have formed by sulfuric acid speleogenesis several million years ago, and some passages preserve features consistent with this process. Until recently, little was known about the geological history and evolution of the cave system, and the geomicrobiological processes that affect the modern cave have not been explored

Ms. Havlena is applying isotopic and mineralogical analytical techniques to help understand Lehman's past and is using molecular tools to explore how microorganisms may continue to impact the cave today. She presented some of her research at the 2019 Geological Society of America Convention.

In addition to her work on Lehman Cave, she is studying microbial communities associated with gypsum in Italy's Frasassi Caves and is trying to understand how gypsum could be used as a microbial habitat and might preserve biosignatures of ancient microbial life.

Mackenzie Best is a Master's student in the Earth and Environmental Sciences Department at New Mexico Tech. For her Master's research, she is studying extreme acid-adapted microbes from sulfidic caves.

Sulfidic caves are hotspots for life in Earth's subsurface. These caves are fed by hydrogen sulfide gas (H_2S), which supports chemosynthetic microorganisms that "eat" hydrogen sulfide in the same way

NCKRI photo from Dan Jones.

NCKRI Cave and Karst Studies students Zoë Havlena (left) and Mackenzie Best (center) in the Frasassi Caves, Italy, with Dr. Dan Jones (right).

humans eat organic carbon. These organisms form the base of a food web that supports entire chemosynthetic ecosystems in these caves, and often include invertebrate and even vertebrate animals.

Some of the most remarkable microbial communities in these caves are known as "snottites." These rubbery biofilms hang from cave walls and ceilings and are formed by microorganisms that live off hydrogen sulfide gas in the cave air. They are also extremely acidic, pH 0-1, similar to battery acid. Some of the organisms found in cave snottites are the most acid-tolerant microorganisms known and have important biotechnological applications for bioremediation and biomining.

Ms. Best has grown several strains of a bacteria known as *Acidithiobacillus*. She is testing them to determine how they make their living and to explore the limits of their acid tolerance. She is also sequencing their genomes and using a technique called metagenomics to explore other extreme acidophiles in the snottites. Metagenomics is genome sequencing of a whole microbial community directly from an environmental sample, and she is using those data to probe the potential metabolisms of the abundant and rare members of the community. Ms. Best presented her research at the 2019 Geological Society of America Convention.

After she completes her Master's degree, Ms. Best is planning to stay at New Mexico Tech to continue working with Dr. Daniel Jones for her PhD. In addition to her cave research, she has worked as both an exploration and an ore-control production geologist at polymetallic base metal mines in the Democratic Republic of the Congo and Peru. She also worked as a geology consultant on a project using remote sensing and machine learning techniques to identify uranium mines and estimate their production.

Cave and Karst Research Fellowships for NMT Undergraduates

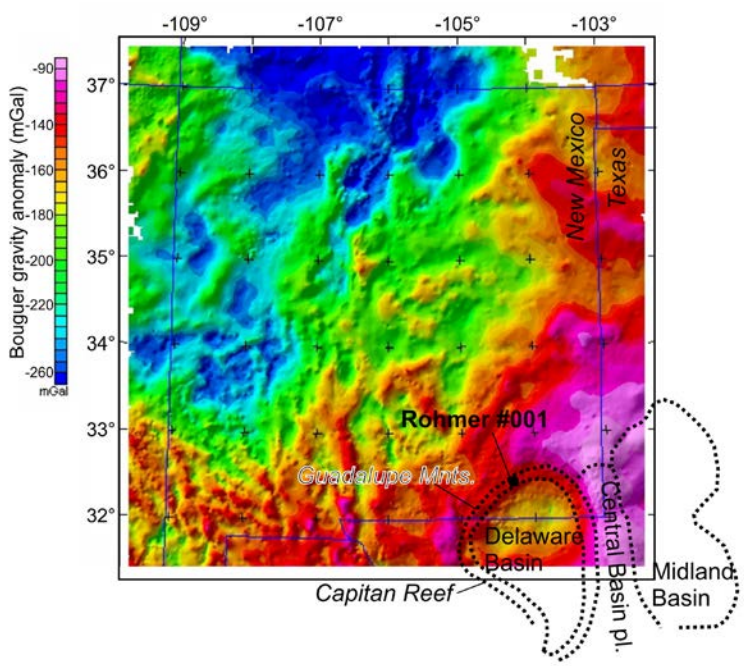
This year we initiated the Undergraduate Research Opportunities in Caves and Karst ("UROCK") fellowship program at NMT. Student awardees ("UROCK Fellows") receive a fellowship to work with a faculty member on a cave and karst research project during the academic year or over the summer. This program is designed to create undergraduate research opportunities in cave and karst science at NMT and is open to undergraduates in any department. We awarded three UROCK fellowships during the 2019/2020 academic year.

Keith Diegel: ***Cave Development in the Guadalupe Mountains***

Undergraduate student Keith Diegel was awarded a UROCK fellowship to work with Dr. Jolante Van Wijk (Earth and Environmental Sciences). His research is in developing a new conceptual model for the formation of the Guadalupe Mountains cave and karst system. In his model, sulfur involved with cave and karst formation originated from a shallow petroleum source rock in the Delaware Basin that matured in recent geologic times (late Paleogene-Miocene). Heat needed to mature this shallow source rock originated in the Eocene Trans-Pecos volcanic field, located in the southern Delaware Basin and extends south.

Mr. Diegel used well data from New Mexico's petroleum wells database to calculate if the Eocene Trans-Pecos volcanic field generated enough heat to mature shallow source rocks. The well Rohmer #001 (figure below) was drilled through the Capitan Reef, making it a suitable well to do this analysis. His modeling results were exciting; he found that source rocks as shallow as the Bell Canyon formation (now at ~900 m depth in some places) possibly matured.

Follow-up research includes extending the thermal analysis to other wells within the Delaware Basin, and chemical study of shallow source rocks in the basin to document their potential for a likely source for hydrogen sulfide.



Map courtesy of Keith Diegel.

Location of the Rohmer #001 well in the Capitan Reef of the Delaware Basin. Colors show Bouguer gravity anomalies. The Delaware Basin is visible as a gravity anomaly-low, caused by the relatively low density of the basin sediments.

Brianna Green:
Extremophile Microorganisms

Ms. Brianna Green was awarded a UROCK fellowship to work with Dr. Daniel Jones (Earth and Environmental Sciences and NCKRI) studying extremophilic microorganisms in carbonate environments. Extremophiles are microorganisms that thrive at the extreme limits for life, such as in very hot or highly acidic environments. During her research, she worked on two projects related to extremophilic microorganisms.

In one project, Ms. Green developed new laboratory methods to enrich and culture acid-adapted microorganisms from the Frasassi Caves in Italy (photo below). She enriched acidic cave samples using various organic carbon sources in media that was pH 0.5. She grew acid-tolerant microorganisms, including unusual fungi found in highly acidic biofilms on the walls of the Frasassi Caves. Unfortunately, her work was interrupted when NMT partially closed in response to COVID-19, but Dr. Jones and his other students will carry on the culturing work that she started.

In a second project, Ms. Green performed geochemical and microbiological analyses of microbial biofilms from travertine hot springs at Soda Dam and other volcanically influenced waters near the town of Jemez Springs, New Mexico (photo below). The hot springs' temperatures were between 42-70 degrees Celsius with circumneutral pH values and sulfide concentrations between 12-25 µM. Free energy calculations show that partial and complete sulfide oxidation is favorable across most sites. She prepared DNA samples for microbial community analysis, which will allow her to explore how microbial diversity varies among these and other volcanically influenced groundwaters in the region.

Ms. Green was preparing to present her research at the Rocky Mountain Geobiology Symposium in April 2020, but unfortunately that conference was canceled because of COVID-19. However, we are pleased to say that she will continue her career as a geobiologist as a graduate student at the University of Tennessee Knoxville in the fall of 2020!

Ethan Haft:
Cone-in-Cone Structures

Mr. Ethan Haft was awarded a UROCK fellowship to work with Dr. Ryan Leary (Earth and Environmental Sciences) on the formation of unusual carbonate features known as "cone-in-cone" structures. For his project, *Origin of Cone-in-Cone Structures in Limestone from Central New Mexico*, he used petrographic and geochemical techniques to explore the origin of some of these fascinating "cones" that he discovered in Cretaceous rocks in Socorro County.

Cone-in-cone structures are known from the rock record, and have been discovered in limestone, marlstone, and shale, and may be associated with the minerals calcite, gypsum, siderite, and pyrite. Mr. Haft showed that the cones from the Cretaceous Mancos Shale are composed of calcite and quartz, and contain microscopic void spaces that may imply past fluid injection. The cones have a self-similar structure at all scales, meaning that larger-scale textures mimic the microscopic fabric (see photos on the next page).

NCKRI photo by Dan Jones.
Brianna Green working in NMT's Geobiology lab.

NCKRI photo by Dan Jones.
Colorful microbial biofilms surround a travertine spring near Soda Dam, New Mexico.

Most previous studies have attributed cone-in-cone structures to diagenesis (the physical and chemical changes from the conversion of sediment to rock), but there is no consensus on how they form. To investigate the process(es) responsible for New Mexico's cone-in-cone structures, Mr. Haft is continuing his geochemical work, including stable isotopic analyses to determine the C^{12}/C^{13} and O^{16}/O^{18} ratios, and he is hoping to study similar structures from other parts of New Mexico, including along the Rio Salado and in the San Juan Basin.

Mr. Haft presented his work at the NMT Student Research Symposium in April 2020 and is planning to continue working to understand these enigmatic features. He will be starting his junior year at NMT in the fall of 2020.

Photo courtesy of Ryan Leary and Ethan Haft.

Thin section photomicrograph showing cone-in-cone structures that occur at a microscopic scale.

Photo courtesy of Ethan Haft.

Cone-in-cone structures in the Cretaceous Mancos Shale, Socorro County.

NCKRI Seminar Series at NMT

We had two excellent speakers in the NCKRI Seminar Series in the fall of 2019. Dr. Jennifer Macalady from The Pennsylvania State University gave a talk on *The Subsurface Biofilm Factory* on September 19th, and Dr. Diana Northup from the University of New Mexico presented on *Microbes that Masquerade as Minerals in Earth's Lava Caves: Enhancing Life Detection on Extraterrestrial Bodies* on November 14th.

All the NCKRI seminars are well attended by students and faculty from throughout the NMT campus, and followed by receptions, hosted by Dr. Daniel Jones, to connect students with the guest speakers and promote fellowship and research collaborations.

NCKRI photo by Dan Jones.

Dr, Diana Northup gives her invited seminar at New Mexico Tech.

Student Opportunities at NMT

New Mexico Tech is highly ranked among US universities in several important categories. It focuses on STEM (Science, Technology, Engineering, and Mathematics) programs, which makes it an ideal home for NCKRI.

For students interested in caves and karst, great opportunities exist not just in geology and biology but engineering, chemistry, robotics, and other fields. 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.

NATIONAL PARK SERVICE – NCKRI LIAISON PROGRAM

During our previous fiscal year, NCKRI received a major boost in its federal funding. As part of this boost, the National Park Service (NPS) initiated a new partnership program. The NPS Cave and Karst Program Coordinator had retired recently and the NPS filled that position with a new NCKRI position made possible by the funding increase. At the close of the last fiscal year, Joel Despain was hired as NCKRI's Cave and Karst Management Scientist, where 75% of his time would be spent as the NPS Cave and Karst Program Coordinator and 25% working on cave and karst management projects for NCKRI.

Mr. Despain undertook a wide variety of activities with the NPS this year. First, he established a NCKRI satellite office at Whiskeytown National Recreation Area in California to expand NCKRI's national outreach. He then conducted introductory administrative trips to the NPS Geologic Resources Division offices in Denver, Colorado, and brief site visits to Mesa Verde National Park in Colorado, and Bandelier National Monument, El Malpais National Monument, and White Sands National Monument in New Mexico, to engage park staff on cave and karst issues in those parks.

NCKRI photo by George Veni.
Joel Despain (right) visits with an NPS ranger in Step House, a large culturally important shelter cave, in Mesa Verde National Park, Colorado.

Mr. Despain began his year at the annual convention of the National Speleological Society, where he and Dr. Veni met with several NPS cave managers to introduce the new NPS-NCKRI Liaison Program. Mr. Despain built on this meeting by hosting a series of regularly scheduled calls and e-mails to NPS staff concerning cave and karst issues that included news on webinars, job opportunities, requests for reports and articles, and discussions on managing COVID-19, updates on programs and activities, and as well as issues and needs specific to certain parks. He also facilitated the renewal of memoranda of understanding between the NPS and the Cave Research Foundation and National Speleological Society.

Other work for park units and the NPS in general ranged from reviewing the new edition of the NPS Cave and Karst Junior Ranger program book, National Natural Landmark nominations, and geologic and paleontological resources reports, to assisting with cave search and rescue training, an urgent sinkhole collapse problem, and with a transition in cave management after a crucial staff member passed away at one park.

This new liaison program is a great opportunity for both the NPS and NCKRI to expand their abilities in meeting their goals for improved cave and karst research, management, and education. In addition to the above tasks, some of the more notable NPS-related accomplishments from Mr. Despain's first year as NCKRI's Cave and Karst Management Scientist are summarized below (his other NCKRI-specific activities are described elsewhere in this report).

Technical Assistance Requests

Technical Assistance Requests (TAR) are requests from national parks for assistance from the NPS national office. They cover a huge range of issues and may be submitted for a wide range of reasons.

About 200 national park units have or potentially contain caves and karst features but most parks do not have a staff specialist in cave and karst management and resources. TARs are commonly submitted by parks that need assistance with cave and karst issues. Examples include assessing impacts from a neighboring stockyard operation on park caves, groundwater and biological resources downstream, tour cave light and trail studies and projects, biological inventories, visitor preference studies, and much more.

TARs are submitted into the NPS STAR database, designed specifically for this purpose. Mr. Despain began managing the database by cleaning up the data, removing or canceling old projects, dating back to 2014, that are resolved, completed or otherwise no longer needed, including some projects at Mammoth Cave, Buffalo National River and other locations. Other TAR projects have continued, and a number of new requests came into the database during this year.

Joel Despain made two TAR site visits during the year. The first was to California's Golden Gate National Recreation Area to assist park staff, and Paul Burger from the Alaska Regional Office, with assessing and documenting the sea caves in the park in October 2019.

Sea caves are specialized biological habitat and can host rare species in this otherwise urban landscape. Accompanied by the park lifeguards, the research team

spent three days on small boats (see photo below) in San Francisco Bay and along the neighboring Pacific coast in the park. They documented the caves, including their locations, depths, and photographed the caves' entrances. Rough surf kept the team from entering most caves, so additional work is still needed, but some caves were entered and biologically inventoried.

Mr. Despain's second TAR site visit was to Oregon Caves National Monument. He was there for four days to help the park initiate several new projects. In meetings with the superintendent and several members of the park staff, the group laid out plans for:

1. a new lighting system for the cave;
2. research and investigation of a cave in the monument named, the Cave Next Door; and
3. a karst watershed and drainage investigation and delineation study designed to inform a wild and scenic river process in the park.

Since the visit in December 2019, the park and Mr. Despain have been working to bring these projects to fruition through multiple phone meetings and consultations. Once COVID-19 restrictions are removed, the work can begin in earnest and will likely include more site visits to the monument.

NPS Web Pages

The theme for Cave Week 2020 was, "Why do we go into caves?" Joel Despain researched and wrote three articles on bats and their use of caves, recent cave exploration in the national parks, and on the upcoming International Year of Caves and Karst in 2021 for the NPS Cave Week website. He also tracked down cave photographers to provide photos for the pages (see cover photo).

Mr. Despain expanded the Park Resources section of the NPS web page with articles and graphics on solution cave and lava tube geomorphology in the national parks. The graphics show multiple stages in the formation and geology of a lava tube.

Additionally, he led a new NPS initiative to develop cave photo galleries, including single photographer and park galleries as well as more articles for the NPS web pages. This was done by soliciting cavers to write articles and submit photos about their projects in the national parks. The 13 photo galleries have been posted. The first article is by Dr. Mark Minton about efforts to climb and fully explore the complex ceiling of the Mystery Room in Carlsbad Cavern. The article will appear in *Inside Earth*, the NPS Cave and Karst Program newsletter. Mr. Despain has worked to revise and revive it as an online series with multiple articles per edition. A new editor has been selected, Chelsea Ballard from Mammoth Cave National Park, and the first five articles for the first new edition have been completed with Mr. Despain writing two of the articles.

Photo courtesy of the National Park Service.

Joel Despain (on right) with NPS staff before setting out to inventory sea caves at Golden Gate National Recreation Area.

COVID-19 NPS Cave Response Management

During the COVID-19 pandemic there has been a great deal of concern for cave management in NPS show caves and recreational caves. Caves are difficult places for social distancing and disinfection. To meet the need for information within the NPS cave management community, Joel Despain hosted two sets of virtual meetings for NPS staff. The first video-calls were for superintendents and senior park staff. Four calls were held over three weeks and discussions included decontamination protocols, bats and COVID-19, employee concerns and safety, messaging and signs for visitors, and much more.

The second call grew out of the quarterly NPS cave management calls hosted by Mr. Despain. This call was focused on cave and resource management staff at parks but included representatives from privately owned show caves and cave scientists. These calls were held every two weeks and six have been held to date. Discussions included the latest published literature on COVID-19 in the natural environment, specific decontamination fluids and materials, cave reopening specifics, and employee concerns and fears.

While the NPS-NCKRI Liaison Program and NCKRI's Cave and Karst Management Scientist position were not created to manage a pandemic, we are pleased they were established in time to help with effective national-level communication and response to this crisis within the cave management and research community.

OUTREACH

International Year of Caves and Karst

In the coming months, 2021 will be celebrated as the International Year of Caves and Karst (IYCK) to teach the world about the importance of caves and karst. The IYCK is a project led by the International Union of Speleology, of which NCKRI is a partner and NCKRI's Executive Director, Dr. George Veni, is president.

Dozens of local to international organizations are involved in the IYCK to educate not just the general public, but lawmakers, land managers, scientists, teachers, business leaders—everyone—about the crucial worldwide benefits provided by these often hidden and poorly understood natural resources.

Like all IYCK partners, NCKRI's initial plans for the year were scrapped by the COVID-19 pandemic. Also like other partners, at the time of this writing NCKRI is planning to develop a series of remote or virtual events for at least the first half of 2021, with potential in-person activities for the second half of the year if allowed by the status of the pandemic.

Our most noted work so far, by Joel Despain, is the job description for a Virtual Student Federal Service intern for the NPS Cave and Karst Program. This intern will assist the NPS with the IYCK, Cave Week 2021, and other NPS web media. We encourage you to get involved with the IYCK and to get more information at www.iyck2021.org.

NCKRI News

Perhaps NCKRI's most popular and best-known service is its e-mail list. About 2-3 times each month we send cave and karst news and announcements directly to thousands of people around the world, including by their request the e-mail lists of cavers in six countries. This news isn't just from NCKRI but from friends and partners internationally. The messages include announcements about cave and karst conferences, job and grant opportunities, books, training, and other diverse topics. We don't sell our list or send junk mail to anyone, and there is no pressure or cost to join. If you would like to be added, simply e-mail us your request at info@nckri.org.

Professional Partnerships and Karst Standards

NCKRI values its partnerships with many organizations around the world, and the sincere friendships we've built with scores of their members. In addition to the projects and events with partners that we've highlighted elsewhere in this report, we highlight our new partnership with ASTM International.

NCKRI is a member of the global standardization organization, ASTM International. At the June 2019 ASTM meeting, ASTM and NCKRI began organizing a karst subcommittee that would work on effective standards for cave and karst research. Based on the high degree of interest in the topic, during the February 2020 meeting ASTM created Subcommittee D18.27 on karst, chaired by NCKRI's Dr. George Veni. The scope of the subcommittee is below. To join the subcommittee, whether an ASTM member or not, contact Dr. Veni at gveni@nckri.org.

It shall be the responsibility of Subcommittee D18.27 to develop standards that assist and/or guide the protection of karst and pseudokarst resources and that assist in the understanding of geohazards accompanying those systems (further use of "karst" in this scope includes pseudokarst). This responsibility includes standards relating to the classification, characterization, and properties of karst systems and processes. Standards involving associated site characterization, geologic, hydrogeologic, and geotechnical aspects associated with potential and/or actual ground instability are also included. The subcommittee will coordinate standards development with other committees and subcommittees where overlap in activities might occur.

Professional Meetings

NCKRI again attended, sponsored and/or had a booth at many conferences during the past year:

- 3rd Asian Trans-Disciplinary Karst Conference: Panglao, Bohol, Philippines
- ASTM International Conference; Atlanta, Georgia, USA, and virtually
- Geological Society of America Convention; Phoenix, Arizona, USA
- Mayors' Energy Summit; Carlsbad, New Mexico, USA
- National Cave and Karst Management Symposium; Bristol, Virginia, USA
- National Caves Association Annual Meeting; Chattanooga, Tennessee, USA
- New Mexico Southern Wetlands Roundtable; virtual, USA
- New Mexico Tech Research Colloquium; Socorro, New Mexico, USA
- Society of Exploration Geophysicists; San Antonio, Texas, USA
- Public Lands Alliance Conference; Washington, DC, USA

- Southwestern Region of the National Speleological Society, Winter Technical Meeting; Las Cruces, New Mexico, USA
- White-nose Syndrome National Webinar; virtual, USA

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

- *Biogeochemical Interactions in Caves and Karst Session*, Geological Society of America Convention; Phoenix, Arizona (Dr. Daniel Jones, with Dr. Laura Rosales Lagarde)
- *Caverns of Sonora Field Trip*, New Mexico Tech Alumni Association, Sonora, Texas, USA, (Drs. Daniel Jones and George Veni)
- *Evaporite Karst in the Greater Permian Evaporite Basin of Texas, New Mexico, Oklahoma, Kansas, and Colorado Session*, Geological Society of America Convention; Phoenix, Arizona (Dr. Lewis Land, with Dr. David Decker and Kenneth Johnson)
- *Karst Hydrology and Hydrogeology Session*, Geological Society of America Convention; Phoenix, Arizona (Dr. Daniel Jones)
- *New Voices in Geobiology Session*, Geological Society of America Convention; Phoenix, Arizona (Dr. Daniel Jones)
- *The 16th Multidisciplinary Conferences on Sinkholes and the Engineering and Environmental Impacts on Karst*, to be held in San Juan, Puerto Rico, USA, postponed to 2021 (Dianne Joop and Drs. Lewis Land and George Veni)

Guest Lectures by NCKRI

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

Joel Despain:

- *Cave and Karst Resource Management*. Office of the Governor, Sultan Kudarat Province, Philippines, (presented with Dr. Patricia N. Kambesis).
- *Cave and Karst Resource Management Course Proposal*. Office of the Governor, Sultan Kudarat Province, Philippines, (presented with Dr. Patricia N. Kambesis).
- *New status of the National Park Service Cave and Karst Program*. Nationwide webinar for the National Park Service.
- *The resources and management of Lagbasan Cave*. Sultan Kudarat Province, Philippines.
- *Sultan Kudarat Cave and Karst Project Update*. Sultan Kudarat Province, Philippines.

Dr. Dan Jones:

- *Energy, life, and speleogenesis in the sulfidic Frasassi cave system*. Sandia Grotto of the National Speleological Society, Albuquerque, New Mexico, USA.
- *Hypotheses for the origin of life*. New Mexico Tech Environmental Microbiology Class, Socorro, New Mexico, USA.
- *Life in the Archean*. New Mexico Tech Environmental Microbiology Class, Socorro, New Mexico, USA.
- *Microbes, minerals and mining: unique microbial communities and microbe-mineral interactions in sulfidic mine waste from Minnesota's Duluth Complex*. New Mexico Tech, Chemistry Department, Socorro, New Mexico, USA; The University of Texas El Paso, Department of Geosciences, El Paso, Texas, USA.
- *Sulfuric acid speleogenesis in the Frasassi cave system, Italy, and lessons for Carlsbad Caverns*. Geology of New Mexico, University of New Mexico Valencia Campus, USA.

Michael Jones:

- *Hydrologic models of regional groundwater flow patterns and groundwater withdrawals within the La Jencia and Socorro basins: Eagle Picher TCE contaminant plume, Socorro, New Mexico*, Groundwater Hydrology Class, New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA.

Dr. Lewis Land:

- *Evaluation of groundwater residence time in a high mountain aquifer system (Sacramento Mountains, USA): Insights gained from use of multiple environmental tracers*. American Nuclear Society, Carlsbad, New Mexico, Chapter, USA.
- Invited panelist presentation on NCKRI's research on the regional aquifer system that feeds the San Solomon Springs, Texas. Town hall meeting, Balmorhea, Texas, USA.

Dr. George Veni:

- *Karst aquifers in the San Antonio area: Beyond the Edwards Aquifer*. GIS in Geology Class, The University of Texas at San Antonio, Texas; Bexar Grotto, San Antonio, Texas; Edwards Aquifer Authority Brownbag lecturer, San Antonio, Texas, USA.
- *Karst: Living in a cavernous environment extending from New Mexico to around the World*. Friends of Bitter Lake National Wildlife Refuge, Roswell, New Mexico, USA

International Involvement

NCKRI is an Affiliated Organization of the International Union of Speleology (UIS) where Dr. George Veni is serving a four-year term as UIS President. The goals of NCKRI and UIS overlap, resulting in mutually supportive projects. Our longstanding joint project is with the Karst Information Portal (see page 13), and our new joint project is the International Year of Caves and Karst (see page 31).

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 Conser-

vation of Nature's (IUCN) Cave and Karst Specialist and Geoheritage groups. While caves are clearly an established priority for the IUCN, NCKRI and UIS are working to bring cave and karst issues to the United Nations.

National Involvement

- NCKRI is an Associated Society of the American Geosciences Institute and the Geological Society of America and meets with those organizations regularly.
- NCKRI staff serve three major positions in the Karst Division of the Geological Society of America Karst Division: Dr. Lewis Land, Vice-Chair; Dr. Daniel Jones, Secretary; Dr. George Veni, Advisor.
- NCKRI has a position on the Steering Committee for the National Cave and Karst Management Symposium, which is held every two years. The next meeting will be in San Marcos, Texas, USA, in October 2021.
- NCKRI is an organizational member of the US Fish and Wildlife Service's White-nose Syndrome Stakeholder Committee.
- Joel Despain represented NCKRI at the 2019 National Fossil Day celebrations at Grand Canyon National Park, which included public and management meetings and activities.

Community Involvement

NCKRI is always excited to show community support and stays involved in many ways. For several years we have hosted the monthly meetings of the Pecos Valley Grotto of the National Speleological Society on the third Thursday of each month at 7 p.m. Since the temporary closing of NCKRI Headquarters to the public due to COVID-19, NCKRI now hosts the meetings by Zoom. Anyone interested in cave exploration and cave research is welcome to attend.

NCKRI staff also:

- Participated in the Carlsbad Chamber of Commerce's annual Bat Brigade. This delegation of community leaders visits leaders of New Mexico government at the state capitol to raise their awareness and support for issues in the City of Carlsbad and Eddy County.
- Regularly attended board meetings of the Carlsbad Chamber of Commerce, and its Government Affairs, Education, and Tourism Committees, Carlsbad Department of Development, and participated in related activities supporting new businesses and community leaders.
- Serve on the Creative Carlsbad Arts Council, HeritageFest and Night of Lights Planning teams, and on the Leadership Eddy County Committee.
- Continued supporting the brine well cavity remediation by co-chairing the State's Brine Well Authority's Technical Committee and educating the public about the situation.
- Attended the Carlsbad Mayor's Energy Summit, an annual event focused on the impact of the oil and gas industry in southeastern New Mexico, and staffed a booth providing information about NCKRI's activities and opportunities for collaboration.
- Supported Explora, a science museum in Albuquerque, New Mexico, when Dr. Lewis Land was interviewed about career paths in the geosciences.

Media

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

- Dr. Daniel Jones interviewed by Dr. Keith Parnell on KTEP for radio/podcast broadcast, 8 December 2019, https://www.ktep.org/post/science-studio-dr-dan-jones
- *Park Service acquires Sulphur Springs site*. Tom Oates, Frontiers in Ecology and the Environment, 2 March 2020, https://esajournals.onlinelibrary.wiley.com/doi/10.1002/fee.2166
- *The river ran green: scientists use dye to trace the Black River's flow in Eddy County*. Adrian Hedden, Carlsbad Current-Argus, 15 May 2020, 1A, 6A, https://www.currentargus.com/story/news/local/2020/05/12/eddy-county-black-river-dyed-green-scientists-study-flow/3108056001/
- *Why the hunt for alien life is under way far beneath Earth's surface?* Donna Lu, New Scientist, 13 November 2019, https://www.newscientist.com/article/mg24432560-800-why-the-hunt-for-alien-life-is-under-way-far-beneath-earths-surface/

In addition to being contacted by the media, NCKRI developed a media initiative of its own. Information Matrix is a short-form documentary series broadcast on Public Television stations in all 50 states. It is hosted by movie star Lawrence Fishburne. Working with the Information Matrix team, NCKRI developed a 6.5-minute short documentary focused on sinkhole collapse and NCKRI as the national institute studying them and related phenomena. Drs. Lewis Land and George Veni were interviewed, with appearances by Michael Jones and Dianne Joop.

While the documentary is complete, it will not be released until the upgrade of the NCKRI website is finished. At that point it will air for one year with an estimated viewership and reach of 60 million households. A 30-second ad was also created that will play in selected major markets. Our hope is to greatly increase awareness of caves and karst, and certainly of NCKRI to study them.

BOARD OF DIRECTORS CHAIRMAN'S REPORT

Photo courtesy of Jack Swickard.

The National Cave and Karst Research Institute this year has joined the great national and international movement to work remotely, usually from home.

NCKRI's change in work habits began March 19 when New Mexico Governor Michelle Lujan Grisham's administration ordered the shutdown of all but "essential" operations in the state to help ward off the spread of the coronavirus.

New Mexico Tech, NCKRI's parent institution, already had initiated work-at-home rules for faculty and staff. Our Executive Director, Dr. George Veni, quickly put these into effect for the NCKRI staff.

The NCKRI, Inc., Board of Directors met in person on September 25, 2019, at the Geological Society of American Convention in Phoenix, Arizona, and by teleconference in 2020 on January 28, for a March 23 special Board meeting, and then on May 22 for its annual meeting, where the Board approved a major revision of NCKRI, Inc.'s, Bylaws and elected Board members.

Joining the NCKRI Board were Sarah Arpin, Kathryn Bach, Dr. John "Jack" Hess, Dr. Benjamin Schwartz, and Limaris "Lima" Soto. Re-elected to the Board were Dr. Johanna Kovarik and John Scheltens.

Board members retiring this year were Dr. Calvin Alexander, Dr. Lisa Goggin, and Gary Hartwick. All were excellent Board members who will be greatly missed.

Another new member to the NCKRI, Inc., Board is Hal Pranger, who succeeds Dave Steensen as National Park Service (NPS) Board member and Budget Committee chairperson. Hal stepped in and immediately got up to speed after Dave retired from the NPS.

This year the Board is beginning an analysis of its role and its relationship with NCKRI and the program's partners—New Mexico Tech, the National Park Service, and the City of Carlsbad.

All of us at NCKRI wish all of you a healthy, productive year as we all come to terms with the coronavirus pandemic and eagerly await a return to normalcy.

Jack Swickard
NCKRI, Inc., Board Chairperson

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.

Dr. George Veni
Executive Director
Karst Hydrogeologist
Vicky Gonzales, MBA
Operations Division Director
Dr. Daniel Jones
Academic Director
Dianne Joop
Education Director
Certified Interpretive Trainer
Joel Despain
Cave and Karst
Management Scientist
Dr. Lewis Land
Karst Hydrogeologist
Michael Jones
Cave and Karst Science Specialist
Loren Darby
Office Manager

Continuing Education

NCKRI staff polish and expand their skills whenever possible. Training attended by one or more staff members in the past year includes:

- *Early Career Geoscience Faculty Workshop*, Science Education Resource Center, University of Maryland.
- *Ethics and Geosciences*, Becky Johnson, Texas Board of Professional Geologists.
- *Groundwater Hydrology*, New Mexico Institute of Mining and Technology.
- *Hydrological Theory and Field Methods*, New Mexico Institute of Mining and Technology.
- *Orientation to Cave Rescue*, National Cave Rescue Commission.
- *Social Media Design*, National Association for Interpretation.
- *Visual KARSYS: A Web Service for Modelling Karst Aquifers in 3D*, Swiss Institute for Speleology and Karst Studies.

Staff Publications

Refereed Papers

Conference Proceedings Papers

- Best, M.B., Jones, D.S., Northup, D.E., Gómez-Cruz, R. 2019. Comparative metagenomic and culture-based analysis of extremely acidophilic *Acidithiobacillus* spp. from sulfidic cave biofilms. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/338755.
- Despain, J. 2019. Enigmatic speleogenesis, Sequoia and Kings Canyon National Parks, California. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/337311.
- Despain, J.D. 2019. Cave law and regulation in the Philippines. National Cave and Karst Management Symposium, Bristol, Virginia, USA.
- Goldscheider, N., Chen, Z., Auler, A.S., Bakalowicz, M. Broda, S., Drew, D., Hartmann, J., Jiang, G., Moosdorf, N., Stevanovic, Veni, G. 2019. Statistical evaluation of the World Karst Aquifer Map: global distribution of karst aquifers. 46th International Association of Hydrogeologists Conference, Malaga, Spain.
- Havlena, Z.E., Hose, L.D., Jones, D.S. 2019. Reconnaissance geomicrobiology survey of Lehman Cave, Great Basin National Park. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/340348.
- Havlena, Z., Kieft, T.L., Veni, G., Horrocks, R., Jones, D.S. 2019. Photosynthetic biofilms in Carlsbad Cavern: use of *in situ* spectrophotometry and DNA analysis to explore influence of lighting and substrate conditions on growth. Mars Extant Life: What's Next? Carlsbad, New Mexico, USA.
- Havlena, Z., Kieft, T.L., Veni, G., Horrocks, R., Jones, D.S. 2019. Preventing problematic photosynthesis in caves: do lighting methods and substrate affect the development of destructive lampenflora in Carlsbad Cavern? New Mexico Tech Student Symposium, Socorro, New Mexico; American Society for Microbiology, Rio Grande Branch Meeting, Socorro, New Mexico, USA.
- Hobart, K.K., Feinberg, J.M., Bailey, J.V., Jones, D.S. 2020. Determining the rate of microbially-mediated pyrrhotite dissolution using integrated geochemical, magnetic, and genomic analyses. Goldschmidt Conference, Hawaii, USA.
- Hobart, K.K., Feinberg, J.M., Jones, D.S. 2019. Integrating geochemical, magnetic, and genomic analyses to understand strain-specific differences in microbially-mediated pyrrhotite dissolution. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/337355.
- Jones, D., Northup, D.E., Gómez-Cruz, R., Macalady, J.L. 2019. Global biogeography and diversity of extremely acidic cave-dwelling acidophilic communities. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/339909.
- Jones, D.S., Cooper, A., Bakovic, M., Pajovic, G., Borovinic, N., Tostevin, G., Monnier, G. 2020. Applying high-throughput rRNA gene sequencing to assess microbial contamination of a 40-year old exposed archeological profile: North-Central Section of the Geological Society of America, Duluth, Minnesota, USA.
- Jones, D.S., Havlena, Z., Macalady, J.L. 2019. Microbial ecology, evolution, and biosignature preservation potential in chemosynthetic cave ecosystems. Lunar and Planetary Institute Conference: Mars Extant Life: What's Next? Carlsbad, New Mexico, USA.
- Jones, M.D. 2020. Characterizing groundwater flow paths in desert spring-fed wetlands using electrical resistivity tomography: San Solomon Springs Aquifer System, Far West Texas, 2020 Sigma Xi Scientific Research Honor Society Student Scholars Symposium; 2020 New Mexico Tech Student Symposium, New Mexico, USA.
- Jones, M.D., Land, L., Veni, G. 2020. Electrical resistivity surveys: initial steps in characterizing the San Solomon Springs Aquifer, Far West Texas. Geological Society of America South-Central Section, Fort Worth, Texas, USA, https://gsa.confex.com/gsa/2020SC/meetingapp.cgi/Paper/343079.
- Jones, M.D. 2020. Geochemical signatures and aquatic life use monitoring at Rebecca Springs during the critical period of flow in the Hill Country area of South-Central Texas. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/338043.
- Joop, D., Jackson, E. 2019. Connecting karst across state boundaries. Public Lands Alliance Conference, Washington, DC, USA.
- Kambesis, P.N., Despain, J. 2019. Karst development on the southwest peninsula of Haiti. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/341417.

- Lakis, I.M., Kieft, T.L. Havlena, Z, Veni, G. 2019. Mitigation of lampenflora-based environmental biofilms in Carlsbad Caverns National Park. New Mexico Tech Student Research Symposium, Socorro, New Mexico, USA.
- Land L. 2019. Sinkholes as transportation and infrastructure geohazards in southeastern New Mexico. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/333400.
- Land L., Jones, M., Veni G. 2020. Using electrical resistivity methods to map cave passages and conduits in the San Solomon Springs karstic aquifer system, west Texas, USA. In: Land L, Kromhout C, Byle M, editors. Proceedings of the Sixteenth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst: National Cave and Karst Research Institute Symposium 8: p. 93-104, https://scholarcommons.usf.edu/sinkhole_2020/ProceedingswithProgram/Geophysics_Remote_sensing/4/.
- Schwartz, G.E., Gionfriddo, C., Soren, A., Jones, D.S., Elias, D., Gilmour, C. 2019. Abundance and diversity of *hgcAB*$^{+}$ microbes in Chesapeake salt marsh soils—relationships to MeHg and site biogeochemistry. International Conference on Mercury as a Global Pollutant, Poland.
- Veni, G. 2019. Caves: The sacred substrate of Maya Civilization. Geological Society of America Convention, Phoenix, Arizona, USA, https://gsa.confex.com/gsa/2019AM/meetingapp.cgi/Paper/337494.

NCKRI photo by George Veni.
Identification and mitigation of karst geohazards, such as sinkholes along and below roadways, is one of this years' topics of reports by NCKRI staff.

Books and Book Chapters

- Land, L., Kromhout, C., Byle, M., eds. 2020. Proceedings of the Sixteenth Multidisciplinary Conference on Sinkholes and the Engineering and Environmental Impacts of Karst: National Cave and Karst Research Institute Symposium 8. National Cave and Karst Research Institute, https://digital.lib.usf.edu/SFS0070630/00001?search=nckri.
- Land, L. 2020. Bottomless Lakes State Park. In: Scholle P., editor. The geology of southern New Mexico's parks, monuments, and public lands. New Mexico Bureau of Geology and Mineral Resources (NMBGMR): 328-334, https://geoinfo.nmt.edu/publications/guides/nmparks/northern/home.cfml (link also for the next five papers).
- Land, L. 2020. Brantley Lake State Park. In: Scholle P., editor. The geology of southern New Mexico's parks, monuments, and public lands. NMBGMR: 323-327.
- Land, L. 2020. Guadalupe Backcountry Byway. In: Scholle P., editor. The geology of southern New Mexico's parks, monuments, and public lands. NMBGMR: 315-318.
- Land, L. 2020. Living Desert State Park. In: Scholle P., editor. The geology of southern New Mexico's parks, monuments, and public lands. NMBGMR: 319-322.
- McCraw, D., Land, L. 2020. Bitter Lake National Wildlife Refuge. In: Scholle P., editor. The geology of southern New Mexico's parks, monuments, and public lands. NMBGMR: 335-340.
- Northup, D.E., Jones, D.S., Boston, P.J., Spilde, M., Lavaud, M.C. 2019 Microorganismos de la Cueva de Villa Luz, Tacotalpa. In: La biodiversidad en Tabasco. Estudio de Estado v II. conabio, México, pp. 358-361.

Journal Papers

- Goldscheider, N., Chen, Z., Auler, A.S., Bakalowicz, M. Broda, S., Drew, D., Hartmann, J., Jiang, G., Moosdorf, N., Stevanovic, Veni, G. 2020. Global distribution of carbonate rocks and karst water resources. Hydrogeology Journal, 28(5):1661-1677, https://doi.org /10.1007/s10040-020-02139-5.
- Jones, D.S., Walker, G.M., Johnson, N.J., Mitchell, C.P.J., Coleman Wasik, J.K., Bailey, J.V. 2019. Molecular evidence for novel mercury methylating microorganisms in sulfate-impacted lakes. ISME Journal 13: 1659-1675
- Zoss, R., Medina Ferrer, F., Flood, B.E., Jones, D.S., Louw, D.C., Bailey, J.V. 2019. Microbial communities associated with phosphogenic sediments and phosphoclast-associated DNA of the Benguela upwelling system. Geobiology 17: 76-90.

Unrefereed Papers

- Despain, J.D. 2020. Bats and their use of caves. www.nps.gov/articles/bats-in-caves.htm.
- Despain, J.D. 2020. Cave

2019-2020 STATE AND FEDERAL BUDGET

NEW MEXICO TECH
National Cave & Karst Research Institute

Fiscal Year 2020, Year-to-Date Summarized Financials as of June 30, 2020

Revenue		**FY2020 Budget**	**FY2020 Actual**	**Budget to Actual**
State of New Mexico		$ 418,839	$ 398,691	$ 20,148
	Carryforward	$ 325,687	$ 314,435	$ 11,252
National Park Service		$ 794,000	$ 725,859	$ 68,141
Grants & Contracts		$ 185,392	$ 185,392	$ -
Total Revenue		**$ 1,723,918**	**$ 1,624,377**	**$ 99,541**
Expenses		**FY2020 Budget**	**FY2020 Actual**	**Budget to Actual**
State of New Mexico				
	Salary & Fringe	$ 269,999	$ 194,681	$ 75,318
	Expenses	$ 148,840	$ 242,816	$ (93,976)
	Subtotal	$ 418,839	$ 437,497	$ (18,658)
			Carryforward	$ 274,101
National Park Service				
	Salary & Fringe	$ 558,207	$ 549,773	$ 8,434
	Expenses	$ 235,793	$ 302,645	$ (66,852)
	Subtotal	$ 794,000	$ 852,418	$ (58,418)
Contracts & Grants				
	Salary & Fringe	$ 103,917	$ 103,917	$ -
	Expenses	$ 118,495	$ 118,495	$ -
	Subtotal	$ 222,412	$ 222,412	$ -
Total Expenses		**$ 1,435,251**	**$ 1,512,327**	**$ (77,076)**

Exploration in the National Parks. https://www.nps.gov/articles/cave-exploration-in-the-national-parks.htm.

- Despain, J.D. 2020. Report on the Fifth Philippine-American Expedition to Sultan Kudarat, submitted to the Philippines Department of the Environment and Natural Resources.
- Despain, J.D. 2020. Report on Lagbasan & the Fifth Philippine-American Expedition to Sultan Kudarat. Report to the Philippines Department of the Environment and Natural Resources.
- Despain, J.D. 2020. The International Year of Caves and Karst. https://www.nps.gov/articles/the-international-year-of-caves-and-karst.htm.
- Gionfriddo, C.M., Wymore, A.M., Jones, D.S., Wilpiszeski, R.L., Lynes, M.M., Christensen, G.A., Soren, A., Gilmour, C.C., Podar, M., Elias, D.A. 2020. An improved *hgcAB* primer set and direct high-throughput sequencing expand Hg-methylator diversity in nature. bioRxiv: 2020.2003.2010.983866 10.1101/2020.03.10.983866.

National Cave and Karst Research Institute

400-1 Cascades Avenue
Carlsbad, New Mexico 88220 USA

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