NMT Assay Report

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Special Issue: International Year of Caves and Karst

"Karst is a type of landscape where the dissolving of the bedrock has created sinkholes, sinking streams, caves, springs, and other characteristic features. Karst is associated with soluble rock types such as limestone, marble, and gypsum. In general, a typical karst landscape forms when much of the water falling on the surface interacts with and enters the subsurface through cracks, fractures, and holes that have been dissolved into the bedrock. After traveling underground, sometimes for long distances, this water is then discharged from springs, many of which are cave entrances." National Park Service, https://www.nps.gov/subjects/caves/karst-landscapes.htm

Exploring Caves and Making Discoveries

A Conversation with President Stephen G. Wells

BY LISA MAJKOWSKI

If you watched ***Ghost Stories with Dr. Wells*** *during the 2020 49ers, you learned that he was a caver on the team that connected Mammoth Cave with the Flint Ridge Cave System, making it the longest cave system in the world (photo, right). In honor of the 2021 International Year of Caves and Karst, Dr. Wells has shared more details about his interest in caves, karst research, and the spirit of exploration.*

The connection group after exiting Mammoth Cave on September 9, 1972. *Back (L-R): John Wilcox, Richard Zoph,* ***Stephen Wells****, and Cleve Pinnix. Front (L-R): Gary Eller and Pat Crowther. Photo: National Park Service, https://www.nps.gov/articles/000/exploring-the-worlds-longest-known-cave.htm*

When did you first become interested in caves?

As a young teen I visited some of the caves in Indiana state parks with my best friend and his family. My family visited Wyandotte Cave in Crawford County, Indiana, and I was hooked. There are numerous caves in Indiana and my middle school friends and I would explore them around the city of Bloomington.

Four of us decided that we needed to learn some professional caving techniques such as underground climbing and rope-work. We practiced climbing up and down ropes from the upper level of a barn. My interest in caving continued through high school and into college. I was the president of the Spelunking (Caving) Club at Indiana University and continued to explore caves throughout the U.S., Mexico, Central America, and Europe.

What type of cave research did you conduct during college?

I did my undergraduate degree at Indiana University where I blended a geology degree with cave research. Another student and I would spend weekends rappelling down vertical cave shafts throughout southern Indiana, measuring and describing the geologic sequences. From this data, we would produce a stratigraphic column of the cave shaft which I would then share with staff geologist Richard Powell of the Indiana Geological Survey. I blended caving and science in a research paper on cave sediments for my sedimentology class, where I measured sections and interpreted past sediment transport regimes in abandoned cave sections.

Exploring Caves and Making Discoveries (continued)

My master's thesis at the University of Cincinnati (*"Geomorphology of the sinkhole plain in the Pennyroyal Plateau of the Central Kentucky Karst"*) involved a blend of hydrology and geomorphology, assessing the regional groundwater flow patterns surrounding Mammoth Cave National Park. I studied sinking streams using groundwater dye tracing and determined that the sources of groundwater flowing through the national park were unprotected and any potential pollution could harm the national park resources.

As a result of this research I became an advocate for cave and karst conservation, working with the Nature Conservancy to protect groundwater systems. Another interesting outcome of my research was that I determined that over geologic time the divide between two large groundwater basins had changed significantly under the sinkhole plain.

What are your favorite caves?

There are several but at the top are Mammoth Cave in Kentucky, which is immense and complex, with a long-term geologic and cultural history. And Parker Cave in Indiana, which is a very challenging cave with a difficult rappel and tight squeezes. However, it had the potential for a large discovery.

What is one of your most memorable caving experiences?

One year to the day after the discovery of the connection between Mammoth Cave and the Flint Ridge cave system, we were exploring a cave under Joppa Ridge in Mammoth Cave National Park, getting ready to descend a very wet vertical shaft. To get there was a long crawl to the distal parts of the cave and we had to tie our bags with all our climbing gear to our ankles, dragging them behind us as bellycrawled through the passages. When we arrived, we saw water running down the shaft and knew we would definitely get wet during the rappel.

So before committing to rappelling and getting very wet, we decided to explore around some ancient cave collapse (breakdown) before going down the shaft. This led to the team discovering an opening into a huge "trunk" cave passage – like a subway tunnel. It was 30 to 40 feet wide and about 30 feet high. There were no footprints or tracks, which meant we were the first humans there. The feeling of walking where no other human has been is very hard to describe. Ultimately, this cave was connected to the Mammoth Cave system.

Who are the people who most inspired your interest in caves?

Art and Peggy Palmer - leading experts in true cave geology
Derrick Ford from Canada - a great cave geologist/hydrologist
William White from Penn State University – another cave scientist
Pete Lyndsey - expert in New Mexico and Texas caves
Bill and Sarah Bishop - great leaders, great at mentoring young people

What caves would you recommend that families visit?

Any of the caves in the national parks. Carlsbad Caverns in New Mexico for the size and wonder; its beauty is unparalleled. Mammoth Cave in Kentucky for the history of human exploration. Wind Cave in South Dakota with its boxwork calcite formations.

It's human nature to explore and discover, and visiting places such as Carlsbad Caverns and Mammoth Cave National Parks can play an important role in nurturing our desire to explore. We should always remember that

this should be part of young people's mental development, driving creativity and innovation. Although it is becoming harder to discover new places that are unique or untouched, we must never forget the importance of the spirit of discovery.

Looking to the future, I cannot wait for humans to travel to other planets, opening up whole new worlds to be explored.

Karst - the Hidden Landscape

Introduction by Dr. George Veni, Executive Director of the National Cave and Karst Research Institute (NCKRI)

Karst covers 25% of our country, ~20% of the land surface of the planet, and most people don't know what it is!

What is karst?

Karst is a landscape formed by dissolving away the bedrock, which happens over thousands and thousands of years. It's hard for people to visualize because karst looks different in different locations. There is an area we call the Classical Karst, where it was first described (in modern day Slovenia), but the karst in Slovenia looks very different from the karst in New Mexico which looks very different from the karst in Kentucky (where we have the world's longest cave) which looks very different from the karst in China. It's a matter of understanding the deeper connection of how karst functions.

Not all caves are karstic – even though the longest, largest, deepest caves tend to be karst. There are, however, many incredibly significant and large and important caves that are not karst.

What's the importance of karst?

Caves and karst impact everyone. Many communities receive their drinking water from streams that are fed by springs from karst areas. If the karst springs become polluted, or go dry because they're over-pumped, then the streams become polluted or go dry. About 700 million people around the world depend on karst aquifers as their primary drinking water supply. Karst aquifers are the most vulnerable to contamination. As a researcher, I often say I've been swimming in many people's water supplies. I'm a giant contaminant. If I'm not getting filtered out of the aquifer, what about things that are a lot tinier than me – oils, grease, chemicals, bacteria? Many people have become very ill or died because of groundwater contamination in karst aquifers. Many of these incidents were preventable if people understood karst. We need to go the extra mile to really protect these systems.

Allan Cobb at Hills and Dales Pit. Muddy water floods unfiltered down a cave entrance into a karst aquifer. *Photo: George Veni, NCKRI.*

Enjoy a margarita now and then? Thank a cave-dwelling bat. They're the primary pollinators of the agave plant that is used to make tequila for your margaritas. There's about 450 different foods, medicines, and industrial products that are directly or indirectly the result of bats.

Some of the most important cultural sites preserving our collective world

Karst - the Hidden Landscape (continued)

history are coming out of high-and-dry caves! Very recently, in a cave in Israel, archaeologists found a basket that is over 10,000 years old. It's so well preserved they could determine the maker was left-handed from its method of assembly.

Climate scientists are recognizing that the best record of past earth climate is from caves. I can go into a cave in my area and get very specific and diverse data about what happened in that area. If we can get data points from all around the continents, we could really understand in detail not just temperature, humidity, and rainfall, but what plants and animals existed, groundwater conditions, and more. We can look at not just the archeology but the paleontology – bone deposits of animals that existed at the time. There's so much we could work out to tell us what these past climates were like and their repercussions.

The ***International Year of Cave and Karst (IYCK)*** website has two main parts – one a description of what caves and karst are, to help teach the public, and the other is the events. The events tab includes announcements of both year-long and one-time activities and event results with a link to a recording or description of the activity. Explore at (https://iyck2021.org).

Our goal, at the end of IYCK, it to compile all the information from every lecture, workshop, and other activity into a document for anyone to access. It will provide an archive to show how many people were involved and the level of international support. We expect that document will be used internationally to get support for research, exploration, or better laws and protection of water supplies.

NCKRI and NMT

Dr. George Veni, Executive Director of National Cave and Karst Research Institute (NCKRI)

What's the history of NCKRI and how is it connected to New Mexico Tech?

The idea of NCKRI was born in the early 1980's in New Mexico; a team of federal cave and karst resource managers, all based in Carlsbad, thought it would be good to have a federal agency focused on caves and karst. After they worked with people at local, state, and federal levels, the US Congress, in partnership with the State of New Mexico (through NMT) and the City of Carlsbad, created the National Cave and Karst Research Institute (NCKRI) in 1998.

NCKRI's congressional mandates go beyond the initial vision and we work with any organization around the country, not just federal ones, and with partners around the world. NCKRI was placed as a New Mexico Tech research partner so the university would administer NCKRI and its funds from state, federal, and private sources.

What sort of research programs does NCRKI have with New Mexico Tech?

About three years ago, NCKRI's federal funding received a boost. They set some of the increase aside for research grants to support NMT students and faculty as well as scientists nationwide (NCKRI is a national research institute, after all). Dr. Daniel Jones administers that program.

Dr. Daniel Jones, Academic Director of NCKRI

In addition to being tenure-track faculty in the NMT E&ES department, Dr. Jones is also Academic Director for

NCKRI and NMT (continued)

NCKRI, running the Cave & Karst studies program at NMT. Plans include expanding the program by recruiting more NMT students to conduct cave and karst research and creating incentives and opportunities for his colleagues to take on cave and karst research projects with NMT students.

One opportunity funded through this program is ***NMT UROCK*** (Undergraduate Research Opportunities in Cave and Karst), with fellowships offered each semester; the funding supports students to work 10 hours per week with NMT faculty. Five students have been funded so far to work with four professors.

A second opportunity, established in honor of the International Year of Caves and Karst, is being piloted this summer. The ***NCIP*** (NCKRI Communications Internship Program), in partnership with the Blue Marble Space Institute of Science (BMSIS, https://www.bmsis.org/) and led by Dan and Dr. Graham Lau of BMSIS, is seeking NMT undergraduate students interested in making science accessible while developing their communication skills.

NCKRI Seed Grants

A second program involves seed grants funded by NCKRI - two national (up to) $25K grants and one internal seed grant open to NMT faculty only. The program is designed to assist a researcher in getting an idea they've come up with in their head to the bench or lab. Historically NCKRI has had a long relationship with the NMT E&ES department and has done a lot of work with the NMT Biology department. The NMT faculty grant is a way to help increase collaborations between NCKRI and other NMT departments. For example, they recently awarded funding to Dr. Kooktae Lee (Mechanical Engineering, https://sites.google.com/view/kooktaelee/research), who is investigating the potential use of drones in cave exploration, first on earth and someday on the moon and Mars.

NCKRI Speaker Series

A third program Dr. Jones has worked on since starting at NMT is bringing two NCKRI researchers to campus each semester as part of the E&ES Speaker Series. They brought in four cave and karst science researchers to discuss their work and projects before the pandemic put the program on pause.

Future plans include expanding the NCRKI seminar series beyond NMT; a NCKRI Distinguished Lectureship would sponsor a researcher (NMT or otherwise) to travel to multiple institutions to give talks. That would increase awareness of NCRKI's and NMT's programs and provide opportunities for future collaborations.

Inspiring the Future

Dr. George Veni

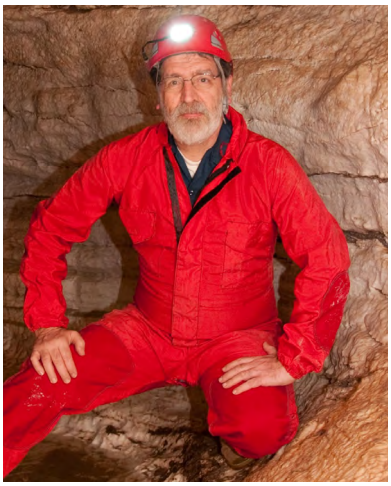
Check out INTERNATIONAL YEAR OF CAVES AND KARST events, announcements, and results at https://iyck2021.org. One of our hopes, through the IYCK, is that someday in the not too distant future we won't have to explain what karst is. Through NCKRI, I want people to know that caves and karst are important, that they're highly vulnerable to damage, and they need to be properly protected and managed.

Dr. Daniel Jones

Involving young people in caving can be a great way to encourage them to explore and investigate. New Mexico has one of the most spectacular "show" caves in the world, Carlsbad Caverns, that permits self-guided tours. The best way to try "wild" caving is to reach out to a local cavers' club (aka, grotto; NMT has a student-led grotto); you can find a local group through the National Speleological Society (https://caves.org).

Meet the People of NCKRI and NMT

Dr. George Veni, Executive Director of the National Cave and Karst Research Institute



Executive Director of NCKRI since 2007, Dr. Veni is an internationally recognized hydrogeologist specializing in caves and karst terrains.

How did you discover caves and karst and get to where you are now?

Many, many years ago (November, 1975) in San Antonio, Texas I was interested in mountain climbing, even though I didn't know anything about it. I went to Guadalupe Mountains National Park (in west Texas) to find mountains. It's amazing I didn't kill myself. After I climbed some mountains, there was this place called Carlsbad Caverns National Park next door. I thought, "It's a national park; it must be something cool." I went there and I fell in love.

That's where my cave story began. I became a cave explorer where I would jump in a cave, run to the end, run out, say that was fun. But then I began mapping and studying caves, which slowed me down. I remember one moment in 1978, before I took any geology classes, when I was sketching a cave and it popped out at me – "I know how this cave formed." That led me to become a cave scientist, which eventually led me to my job with NCKRI, which brought me full circle back to Carlsbad.

Before I joined NCKRI, I was invited to serve on the Bureau (governing board) of the Union Internationale de Spéléologie (UIS). In 2015, during the UIS's 50th Anniversary, the Bureau contacted all 55 member countries and voted to hold the **International Year of Caves and Karst** in 2021. I took a lead position on that; in 2017 I was elected President of the UIS, a position I still hold.

Dr. Daniel Jones, Assistant Professor of Geobiology, NMT Earth & Environmental Science Department, and Academic Director, NCKRI

As an undergraduate, Dr. Daniel Jones took a course in geomicrobiology and became really interested in the subject. He then did a summer research undergraduate experience (REU) with his future Ph.D. advisor. That summer he got into caving through the science, later enjoying caving as a recreational sport.

Formerly with the University of Minnesota, he started at NMT in January, 2019. In addition to being tenure-track faculty in the NMT E&ES department, Dr. Jones is also Academic Director for NCKRI, running the Cave & Karst studies program at NMT.

As a geomicrobiologist, Dr. Jones' research areas are microbial interactions with the environment and how microorganisms contribute to cave geochemistry and ecosystems. One area of study for him and his students is sulfuric-producing microbes and how they contribute to cave formation.

One memorable cave exploration for him was an early visit to the Frasassi cave system in Italy. The water coming in was hot (~45°C / 113°F) and had an abudance of sulfide in it, so there was a lot of sulfuric acid production in this very active cave. Bacteria and other microbes use it as an energy source, producing acid in the process, so this cave (compared to most caves) has a lot of energy and supported a robust microbial system.

The cave itself wasn't hot until the water table was reached - getting there, cavers got covered in a sort of limestone powder coating. Once at the water table, everything was steamy and atmospheric and there were

drips of water coming down from the ceiling. As they hit the limestone powder coating the cavers' suits, the drops of water would sizzle; meanwhile, pieces of limestone gypsum were also falling off the walls. He notes, "You could see the cave forming around you."

Dr. Jones took his students there in 2019, but the water table had dropped after a big earthquake in 2017 that changed the hydrology of the area. Although that particular passage with the really active stream and acid production had dried up, it provided them the unexpected opportunity to study how a cave evolves once the sulfide source is shut off – one of his students is pursuing funding to continue that research.

In the Frasassi cave system, Italy, in 2019 (l to r) Zoë Havlena, Mackenzie Best, and advisor Dr. Daniel Jones. *Photo Daniel Jones*

Zoë Havlena, Ph.D. Candidate

Zoë Havlena has strong, deep ties to NMT. She's the daughter of an alum (Jeffrey Havlena, *B.S. Geology, 1983, and M.S. Hydrology, 1988*), she earned her B.S. (*Biology, 2017*) and M.S. (*Biology, 2019*) degrees through the NMT 5-year program, and she's now a Ph.D. candidate.

As a child, she loved the outdoors - biology, environmental studies, earth sciences, etc. During her junior year at NMT she took Environmental Biology with Dr. Thomas Kieft and loved it. He had just taken over a project looking at lampenflora in Carlsbad Caverns (photosynthetic organisms in caves that grow where there's lighting installed). Zoë had gone hobby caving with her family when she was young; she was excited to work with Dr. Kieft studying these lampenflora. Her M.S. research was published January, 2021 in the Journal of Applied and Environmental Microbiology: https://aem.asm.org/content/early/2021/01/12/AEM.02695-20/article-info?versioned=true).

Photo courtesy Zoë Havlena

Her Ph.D. research involves studying the microbiology associated with gypsum deposits in actively forming sulfidic cave systems. This is a bottom-up process where sulfuric groundwater meets oxygenated water or air and forms super corrosive sulfuric acid. This process is mediated by sulfur-oxidizing bacteria, creating a unique ecosystem to study with implications for both early origin of life on Earth and the search for evidence of life on Mars (this is a NASA funded project). Part of her research looks at how evidence of microbial life ("biosignatures") in those systems might be preserved over very long periods of time.

Her work includes two sites – the Frasassi cave system in Italy and the Lehman caves in the Great Basin National Park in Nevada. Due to the pandemic her field work has been severely restricted; she hopes to return to the Lehman caves in summer 2021 and to Italy in Fall 2021. Although Lehman Caves is a National Park, not much research has been done on the cave until recently. Part of Zoë's work in Lehman is interpreting evidence that the cave may have formed through the same sulfidic process that is acting in Frasassi, potentially occurring as long as 5-10 million years ago.

Meet the People (continued)

Her love of the outdoors continues - outside of her academic pursuits, Zoë is the president of the wilderness first responder group "Socorro Search and Rescue" and the youngest person in New Mexico to certify as an Incident Commander with NM Search and Rescue (a volunteer division of the NM Department of Public Safety). She vividly recalls a youthful science experiment with her father – a baking soda volcano they made in the newly renovated family kitchen. She also vividly recalls the resulting explosion covering every surface in the room. She participated in summer science programs for kids, which provided an interdisciplinary exposure showing how one field of science connects to others.

Mackenzie Best, Ph.D Student

Mackenzie "Mac" Best grew up in mining towns around the world due to her father's work (Jeffrey Best, *B.S. Mineral Engineering, 1997*). After spending a year abroad at the University of Canterbury and completing her undergraduate degree (B.A. Geology with a Minor in Biology, Middlebury College, 2018), she wanted to pursue graduate studies in a field that incorporated both geology and biology. At the time she was exploring graduate programs Dr. Daniel Jones, geomicrobiologist, was just starting at New Mexico Tech. Excited by geomicrobiology, she joined his research group in 2019, earning her M.S. (*Geochemistry, 2021*) and starting her Ph.D. program.

Mac's research is conducted in the Frasassi sulfidic cave system in Italy. Dissolved sulfide degasses out of the groundwater into the cave atmosphere where it reacts with oxygen, creating sulfuring acid leading to super rapid cave formation and enlargement. Organisms and microbes can use this sulfide as an energy source. This is a dark, extremely acidic (pH of zero) environment, with stable temperatures and minimal organic input.

One focus of her research, with an astrobiological aspect, is nitrogen cycling of systems in areas with high sulfuric acid. There are extremely isotopically light nitrogen signatures in the actively sulfidic portions of the cave, but heavier signatures away from this area near the entrance of the cave. Mac's research looks at microbial community dynamics and changes, as well as nitrogen source chemistry in different sections of the cave.

Photo courtesy Mackenzie Best

Mac has interned, and worked, at mining operations in Peru and the Democratic Republic of Congo. These were both open pit operations where high grade ores can be processed by electrowinning and smelting, low grade ore is processed differently to keep costs low. One of those methods is heap leaching; it has only relatively recently been discovered that much of this process is dominated by microorganisms. For example, sulfur oxidizing organisms will eat away sulfide minerals, producing their own sulfuric acid that aids in metal leaching. There is a push to adapt this model to electronic waste material (e-waste) recycling, a potentially robust metal resource. Mac's research is focused on using microorganisms from bioleaching operations to aid in metal breakdown and recovery from e-waste.

In 2019 Mac visited the Frasassi cave system and enjoyed the whole experience. It takes a couple of hours of caving to reach the study site, led by local Italian cave guides. After long hours in the caves, an Italian dinner was a perfect end to the day. She's hoping to return to the caves in Fall 2021 with Dr. Jones' research group.

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