New Mexico Geological Society

Proceedings Volume
Caves and Karst in New Mexico,
Fort Stanton Cave Science Conference
2022 Annual Spring Meeting
New Mexico Tech
Socorro, NM

New Mexico Geological Society

NEW MEXICO GEOLOGICAL SOCIETY

Thursday, April 7th, 2022 – Ft. Stanton Cave Science Conference
Friday, April 8th, 2022 – NMGS Spring Meeting
Saturday, April 9th, 2022 – Ft. Stanton Cave Science Conference Fieldtrip

NMGS EXECUTIVE COMMITTEE

President: Scott Baldridge
Vice President: Brian Hampton
Treasurer: Kevin Hobbs
Secretary: Johanna M. Blake
Past President: Dan Cadol

2022 SPRING MEETING COMMITTEE

General and Technical Program Chairs: Talon Newton and Dan Cadol
Registration Chair: Connie Apache

Web Support: Adam Read

Thursday, April 7, 2022

Greetings and Introduction

Auditorium: *8:00 AM - 8:10 AM*

Fort Stanton Cave Science Conference: Morning Session:

Auditorium: *8:00 AM - 12:15 PM*
Chair: Mike Spilde & Johanna Blake

REGIONAL GEOLOGY OF THE NORTHEASTERN SACRAMENTO MOUNTAINS, LINCOLN AND OTERO COUNTIES, NEW MEXICO
— Geoffrey Rawling
8:10 AM - 8:30 AM

GEOLOGY, STRATIGRAPHY, AND GEOMORPHOLOGY OF THE PERMIAN SAN ANDRES LIMESTONE AND THE SNOWY RIVER PASSAGE OF THE FORT STANTON-SNOWY RIVER CAVE SYSTEM, LINCOLN COUNTY, NEW MEXICO
— Christina L. Ferguson and Keely E. Miltenberger
8:30 AM - 8:50 AM

FORT STANTON CAVE AND THE NORTHERN SACRAMENTO MOUNTAINS: REGIONAL GEOLOGIC AND HYDROLOGIC CONTEXT
— Lewis Land
8:50 AM - 9:10 AM

HYDROGEOLOGY OF SNOWY RIVER PASSAGE, FORT STANTON CAVE, NEW MEXICO
— Brad Talon Newton
9:10 AM - 9:30 AM

A RESERVOIR MODEL FOR SNOWY RIVER FLOODING
— Stephen S. Peerman
9:30 AM - 9:50 AM

Morning Break (snacks)

Lobby: *9:50 AM - 10:20 AM*

THE TWO INDEPENDENT WATER SYSTEMS IN FORT STANTON CAVE
— Henry Schneiker
10:20 AM - 10:40 AM

GEOCHEMICAL FINGERPRINTING OF SOURCE WATER TO THE SNOWY RIVER DEPOSIT
— Johanna M. Blake, Christina Ferguson, and Keely Miltenberger
10:40 AM - 11:00 AM

A DECADE OF DATA LOGGING IN FORT STANTON CAVE AND SNOWY RIVER
— Pete Lindsley
11:00 AM - 11:20 AM

Continuous Measurement of Evaporation in High-humidity Caves: A Case Study in Fort Stanton Cave, New Mexico
— Jake Collison, Talon Newton, and Scott Christenson
11:20 AM - 11:40 AM

Navigating the BLM Proposal Submission Process to Gain Scientific Entries to Fort Stanton Cave
— Knutt Peterson
11:40 AM - 12:00 PM

Lunch

On your own: *12:00 PM - 1:30 PM*

Fort Stanton Cave Science Conference: Afternoon Session:

Auditorium: *1:30 PM - 5:40 PM*
Chair: Mike Spilde & Johanna Blake

Monitoring Bats on the Fort Stanton – Snowy River Cave National Conservation Area
— Debbie C. Buecher and Diana E. Northup
1:30 PM - 1:50 PM

Contrasting Microbial Communities in Cave Ferromanganese Deposits With Overlying Surface Soils
— Diana E. Northup, Jason C. Kimble, Ara S. Winter, and Robert L. Sinsabaugh
1:50 PM - 2:10 PM

Microbe-Mineral Interactions in Caves
— Daniel S. Jones, Diana E. Northup, and Penelope J. Boston
2:10 PM - 2:30 PM

The Snowy River Calcite Formation Records a Complex History in Fort Stanton Cave
— Michael N. Spilde, Keely E. Miltenberger, Christina L. Ferguson, and Johanna M. Blake
2:30 PM - 2:50 PM

Key speleothem paleoclimate results from Fort Stanton Cave
— Victor J. Polyak, Yemane Asmerom, and Matthew S. Lachniet
2:50 PM - 3:10 PM

Afternoon Break

Lobby: *3:10 PM - 3:40 PM*

Discovery, Exploration, Surveying, and Cartography in Fort Stanton Cave
— John J. Corcoran
3:40 PM - 4:00 PM

THE FIRST DECADE IN SNOWY RIVER: STALKING THE MAMMOTH CAVE OF THE WEST
— Donald G. Davis
4:00 PM - 4:20 PM

SNOWY RIVER'S SECOND DECADE: CHAOS PREVAILS
— John T. M. Lyles
4:20 PM - 4:40 PM

RESISTIVITY MEASUREMENTS AT FORT STANTON CAVE NEW MEXICO
— John S. McLean
4:40 PM - 5:00 PM

FORT STANTON CAVE FORMATION REPAIR AND RESTORATION PROJECT
— Michael C. Mansur
5:00 PM - 5:20 PM

3-D MODELING OF FORT STANTON CAVE USING MAPS, LIDAR, PHOTOGRAMMETRY, AND GAMING ENGINES
— Ronald J. Lipinski
5:20 PM - 5:40 PM

Social Hour

Lobby: *5:40 PM - 6:30 PM*

Friday, April 8, 2022

NMGS Business Meeting and awards

Auditorium: *8:15 AM - 9:00 AM*

Keynote Talk- Dr. Penny Boston:

Auditorium: *9:00 AM - 9:30 AM*

NEW MEXICO UNDERGROUND: SPECTACULAR SUBSURFACE SYSTEMS FOR INTERDISCIPLINARY SCIENCE AND EXPLORATION
— Penelope J. Boston
9:00 AM - 9:30 AM

Caves and Karst:

Auditorium: *9:30 AM - 10:00 AM*
Chair: Talon Newton

SULFURIC ACID SPELEOGENESIS IN THE FRASASSI CAVE SYSTEM, ITALY, AND POSSIBLE IMPLICATIONS FOR GUADALUPE MOUNTAIN CAVES
— Daniel S. Jones

9:30 AM - 9:45 AM

SPELUNKING INTO THE VIROSPHERE: CHARACTERIZING VIRAL COMMUNTIES FROM CARLSBAD CAVERNS NATIONAL PARK
— Joseph Ulbrich, Daniel S. Jones, and Thomas L. Kieft
9:45 AM - 10:00 AM

Morning break

Lobby: *10:00 AM - 10:30 AM*

Cave and Karst II:

Auditorium: *10:30 AM - 11:30 AM*
Chair: Talon Newton

GEOSCIENCE OUTREACH IN THE INTERNATIONAL YEAR OF CAVES AND KARST
— George Veni
10:30 AM - 10:45 AM

USING ELECTRICAL RESISTIVITY METHODS TO MAP CAVE PASSAGES AND CONDUITS IN THE SAN SOLOMON SPRINGS KARSTIC AQUIFER SYSTEM, WEST TEXAS, USA
— Lewis Land and George Veni
10:45 AM - 11:00 AM

CAVES IN THE UPPER PECOS WATERSHED
— Dennis McQuillan
11:00 AM - 11:15 AM

GYPSUM SEDIMENTS IN LEHMAN CAVES, GREAT BASIN NATIONAL PARK, NV, USA.
— Zoe E. Havlena, Daniel S. Jones, Louise D. Hose, Harvey R. DuChene, Amanda L. Labrado, and Benjamin Brunner
11:15 AM - 11:30 AM

Environmental Geology and Hydrology:

Auditorium: *11:30 AM - 12:30 PM*
Chair: Amy Galanter

SIX YEARS OF SEDIMENT DATA COLLECTION FROM A NEW MEXICAN ARROYO
— Kyle Stark and Daniel Cadol
11:30 AM - 11:45 AM

SEISMIC MONITORING OF FLASH FLOODS—SEDIMENT TRANSPORT, FLOOD DETECTION, AND FLOW CHARACTERISTICS INFERRED FROM SEISMIC SIGNALS IN AN EPHEMERAL WATERSHED
— John Mitchell McLaughlin, Susan Bilek, and Daniel Cadol
11:45 AM - 12:00 PM

CONNECTIVITY AND RAINFALL-RUNOFF RELATIONSHIPS IN FLASHY EPHEMERAL SYSTEMS
— Sandra Glasgo

12:00 PM - 12:15 PM

CONTROLS ON FLOW CONVEYANCE LOSSES IN THE SAN ACACIA REACH OF THE MIDDLE RIO GRANDE
— Katie McLain
12:15 PM - 12:30 PM

Paleontology:

Galena Room: *11:30 AM - 12:30 PM*
Chair: Brian Hampton

AN EARLY PERMIAN FOSSIL FLORA FROM THE ARROYO DE ALAMILLO FORMATION OF THE YESO GROUP, SOCORRO COUNTY, NM
— Paul May, Spencer G. Lucas, Hans Kerp, William A. DiMichele, and John B. Rogers
11:30 AM - 11:45 AM

THE TRACE FOSSIL ZOOPHYCOS FROM THE SHALLOW WATER FACIES OF THE MIDDLE PENNSYLVANIAN SANDIA FORMATION, JEMEZ MOUNTAINS, NEW MEXICO
— Patrick James Carey, Spencer G. Lucas, Karl Krainer, Deborah Petrak Green, and Paul May
11:45 AM - 12:00 PM

PRELIMINARY ESTIMATES OF DINOSAUR SIZE AND SPEED AT THE EARLY CRETACEOUS CLAYTON LAKE DINOSAUR TRACKSITE, UNION COUNTY, NEW MEXICO
— John B. Rogers, Michael A. Kvasnak, and Spencer G. Lucas
12:00 PM - 12:15 PM

THE PLATYSTERNID TURTLE *CARDICHELYON* FROM THE PALEOCENE NACIMIENTO FORMATION, NEW MEXICO, USA
— Asher Jacob Lichtig and Spencer G. Lucas
12:15 PM - 12:30 PM

Lunch Break

On your own: *12:30 PM - 2:00 PM*

Geophysics and Geochronology:

Auditorium: *2:00 PM - 3:00 PM*
Chair: Dr. Matt Heizler

AUDIO-MAGNETOTELLURIC AND TRANSIENT-ELECTROMAGNETIC INVESTIGATION OF THE SALT BASIN, SOUTH-CENTRAL NEW MEXICO
— Shari Kelley
2:00 PM - 2:15 PM

NEW EVIDENCE CONFIRMS THE ~250 K.Y. DURATION FOR DEPOSITION OF THE PALEOCENE OJO ALAMO SANDSTONE IN THE SOUTHERN SAN JUAN BASIN, NEW MEXICO
— James E. Fassett

2:15 PM - 2:30 PM

THE DOUBLE-EDGED SWORD OF ULTRA-HIGH PRECISION ^{40}AR/^{39}AR GEOCHRONOLOGY: INVESTIGATING PREVIOUSLY UNRESOLVED COMPLEXITIES IN SANIDINE AGE DISTRIBUTIONS
— Tyler B. Cantrell, Matthew T. Heizler, and Jake Ross
2:30 PM - 2:45 PM

^{40}AR/^{39}AR GEOCHRONOLOGY NEAR RIO GRANDE-RED RIVER CONFLUENCE REVEAL A LATIR VOLCANIC FIELD SOURCE FOR 4.5 TO 1.2 MA FLUVIAL DEPOSITS AND A <1.2 MA CARVING OF THE TAOS GORGE
— Jacob R. Gehrz, Matthew T. Heizler, Karl E. Karlstrom, Matthew J. Zimmerer, and Kevin M. Hobbs
2:45 PM - 3:00 PM

Stratigraphy, Volcanology and Sedimentology:

Galena Room: *2:00 PM - 3:00 PM*
Chair: Dan Koning

ORIGIN OF ARCHAEOLOGICALLY SIGNIFICANT GRAVEL AND LAG DEPOSITS ON SOUTHWESTERN HORACE MESA, MOUNT TAYLOR REGION, NEW MEXICO
— Fraser Goff and M. Steven Shackley
2:00 PM - 2:15 PM

CONTRASTING GEOLOGIC AND GEOARCHAEOLOGICAL VIEWS OF GRANTS RIDGE OBSIDIAN DEPOSITS, MOUNT TAYLOR VOLCANIC FIELD, NEW MEXICO
— Steven Shackley and Fraser Goff
2:15 PM - 2:30 PM

STONEMAN LAKE, AZ, SEDIMENTS ARCHIVE SOUTHWESTERN NORTH AMERICA SURFACE PROCESSES OVER THE LAST TWO GLACIAL CYCLES (AND BEYOND)
— Spencer E. Staley, Peter J. Fawcett, R. Scott Anderson, Gonzalo Jimenez-Moreno, Vera Markgraf, and Erik Brown
2:30 PM - 2:45 PM

THE EOCENE BACA FORMATION, WEST-CENTRAL NEW MEXICO, WAS NOT DEPOSITED IN A LAKE
— Spencer G. Lucas and Lawrence H. Tanner
2:45 PM - 3:00 PM

Poster Session:

Lobby: *3:00 PM - 4:30 PM*

FIRST REPORT OF THE LATE CRETACEOUS (CAMPANIAN) HETEROMORPH AMMONITE *HARESICERAS* (*HARESICERAS*) *MONTANAENSE* (REESIDE, 1927) FROM NEW MEXICO
— Paul L. Sealey and Spencer G. Lucas
Booth: *1*

PENNSYLVANIAN STRATIGRAPHIC ARCHITECTURE, LITHOSTRATIGRAPHY AND TECTONISM IN NEW MEXICO
— Spencer G. Lucas and Karl Krainer
Booth: *2*

UNUSUAL TRACE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS PAGUATE MEMBER OF THE DAKOTA FORMATION IN THE OJITO WILDERNESS, SANDOVAL COUNTY, NEW MEXICO
— Paul May, Spencer G. Lucas, and John B. Rogers
Booth: *3*

THE FIRST REPORT OF *PLANOLITES* IN THE MOJADO FORMATION, CERRO DE CRISTO REY, SUNLAND PARK, NEW MEXICO
— Oskar N/A Alvarez and Eric J. Kappus
Booth: *4*

SEDIMENT TRANSPORT IN EPHEMERAL CHANNELS: VALIDATION OF PHYSICS-BASED MODEL AND DEVELOPMENT OF DATA-DRIVEN MODEL
— Loc Luong, Daniel Cadol, Susan Bilek, and John Mitchell McLaughlin
Booth: *5*

A FIRST REPORT OF THE ICHNOGENUS *CURVOLITHUS* FROM THE MOJADO FORMATION, CERRO DE CRISTO REY, SUNLAND PARK, NEW MEXICO.
— Jahir Sanchez and Eric Kappus
Booth: *6*

A NEW SPECIMEN OF THE EUBAENINE TURTLE *GOLEREMYS MCKENNAI* FROM THE PALEOCENE NACIMIENTO FORMATION OF NORTHWESTERN NEW MEXICO
— Asher Jacob Lichtig and Spencer G. Lucas
Booth: *7*

LATE CRETACEOUS (CENOMANIAN-CAMPANIAN) AMMONITE ZONES IN THE CHAMA BASIN, RIO ARRIBA COUNTY, NEW MEXICO
— Paul L. Sealey and Spencer G. Lucas
Booth: *8*

THREE-DIMENSIONAL GEOLOGIC FRAMEWORK MODEL OF THE RIO SAN JOSE GROUNDWATER BASIN AND ADJACENT AREAS, NEW MEXICO
— Donald S. Sweetkind, Amy E. Galanter, and Andre Ritchie
Booth: *9*

THE FIRST RECORD OF THE RARE AMMONITE GENUS *MASIAPOSITES* IN THE UPPER CRETACEOUS (TURONIAN) OF NEW MEXICO
— Michael P. Foley and Spencer G. Lucas
Booth: *10*

EVALUATING METHODS FOR REMOTE MEASUREMENT OF STREAM FLOW VELOCITY IN EPHEMERAL FLASH FLOOD ENVIRONMENTS
— Zachary Chavez, Daniel Cadol, Kyle Stark, and Jonathan B. Laronne
Booth: *11*

PHOTOGRAMMETRIC ANALYSIS OF THE CLAYTON LAKE DINOSAUR TRACKSITE, EARLY CRETACEOUS OF NORTHEASTERN NEW MEXICO

— Michael A. Kvasnak, John B. Rogers, and Spencer G. Lucas

Booth: *12*

APPLYING SANDSTONE MODAL COMPOSITION AND *IMAGEJ* ANALYSIS TO CONSTRAIN FELDSPAR ALTERATION IN EARLY PERMIAN (WOLFCAMPIAN) NONMARINE STRATA IN NEW MEXICO

— Justin Matthew Friend, Brian A. Hampton, and Alicia L. Bonar

Booth: *13*

MONITORING SEDIMENT EROSION AND DEPOSITION IN THE ARROYO DE LOS PINOS THROUGH STRUCTURE FROM MOTION (SFM) PHOTOGRAMMETRY

— Rebecca Moskal and Daniel Cadol

Booth: *14*

A SIMPLE NUMERICAL MODEL OF THE RIO GRANDE RIFT EXTENSION: IMPLICATIONS ON SURFACE HYDROLOGY

— Kyungdoe Han and John Wilson

Booth: *15*

EARLY PLEISTOCENE (LATE BLANCAN) VERTEBRATES FROM SIMON CANYON, SOCORRO COUNTY, CENTRAL NEW MEXICO

— Gary S. Morgan, Daniel J. Koning, M. Steven Shackley, David W. Love, Kevin M. Hobbs, and Andrew P. Jochems

Booth: *16*

REE IN COALBEDS IN THE SAN JUAN RIVER - RATON COAL BASINS

— Megan N. Badonie and Virginia T. McLemore

Booth: *17*

GEOLOGY OF THE CAMBRIAN-ORDOVICIAN LEMITAR CARBONATITES, SOCORRO COUNTY, NEW MEXICO: REVISITED

— Ethan B. Haft, Virginia T. McLemore, O. Tapani RÃ¤mÃ¶, and Jonas Kaare-Rasmussen

Booth: *18*

EXTREMOPHILIC MICROORGANISMS FROM SULFUR-RICH SPRINGS AND FUMAROLES IN THE VALLES CALDERA VOLCANIC COMPLEX, NEW MEXICO

— Abigail Rose Brown, Brianna Green, and Daniel S. Jones

Booth: *19*

SANTA FE GROUP AQUIFER INVESTIGATIONS IN THE NORTHWESTERN ALBUQUERQUE BASIN, NEW MEXICO

— Daniel J. Koning, Amanda Doherty, Ethan Mamer, and Laila Sturgis

Booth: *20*

MULTIPLE MODES OF DEFORMATION IN FAULT ZONE JUXTAPOSING DISSIMILAR ROCK TYPES, SOUTHERN CHUPADERA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO

— Kevin M. Hobbs

Booth: *21*

MEASURING MICROPLASTICS IN THE MIDDLE RIO GRANDE THROUGH ALBUQUERQUE, NEW MEXICO
— Raven Longwolf Alcott, Alexandra Hurst, Sofia Jenkins-Nieto, Sarah Ann Polsin, and Gary Weissmann
Booth: *22*

GEOCHEMISTRY OF THE TAJO GRANITE, SOCORRO COUNTY, NEW MEXICO
— Haley Dietz and Virginia T. McLemore
Booth: *23*

ELUCIDATING THE STRUCTURAL GEOMETRY AND MAJOR FAULTS OF THE SAN MARCIAL BASIN, SOCORRO COUNTY, USING TOTAL BOUGUER GRAVITY ANOMALY DATA.
— Kyle K. Gallant, Alex J. Rinehart, Daniel J. Koning, and Andrew P. Jochems
Booth: *24*

SOURCE TRACKING ANALYSIS OF ALUMINUM, ARSENIC, AND LEAD ENTERING THE SAN JUAN RIVER IN THE FOUR CORNERS REGION, USA.
— Rachel L. Mixon, Johanna M. Blake, Jeb E. Brown, Shaleene Chavarria, Christina L. Ferguson, and Douglass B. Yager
Booth: *25*

CHARACTERIZATION AND ORIGIN OF THE REE-BEARING MAGMATIC-HYDROTHERMAL BRECCIA PIPES IN THE GALLINAS MOUNTAINS, LINCOLN COUNTY, NEW MEXICO
— Stellah Cherotich and Virginia McLemore
Booth: *26*

GEOCHEMICAL NICHES OF EXTREMOPHILE COMMUNITIES IN AN EPHEMERAL ACID ROCK DRAINAGE
— Mackenzie B. Best and Daniel S. Jones
Booth: *27*

MINERAL RESOURCE POTENTIAL OF LAND PARCELS IN SOUTHWEST NEW MEXICO
— Kyle T. Stafford and Virginia T. McLemore
Booth: *28*

REEVALUATING THE EMPLACEMENT HISTORY OF THE CORNUDAS MOUNTAINS
— Mason N. Woodard, Nels A. Iverson, Virginia T. McLemore, and Laura E. Waters
Booth: *29*

QUANTIFYING GROUNDWATER TO SURFACE WATER EXCHANGES IN THE BELEN REACH OF THE MRGCD
— Ethan Williams, Daniel Cadol, Lin Ma, and Alex Rinehart
Booth: *30*

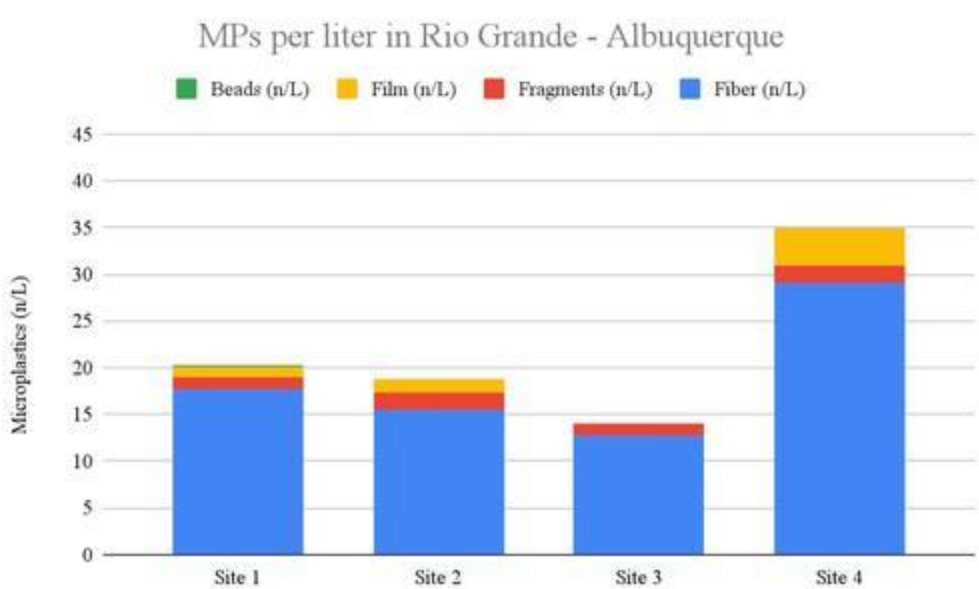
LITHOGEOCHEMICAL VECTORS AND MINERAL PARAGENESIS OF HYDROTHERMAL REE-BEARING FLUORITE VEINS AND BRECCIAS IN THE GALLINAS MOUNTAINS, NEW MEXICO
— Evan J. Owen, Alexander P. Gysi, Virginia T. McLemore, and Nicole Hurtig
Booth: *31*

MEASURING MICROPLASTICS IN THE MIDDLE RIO GRANDE THROUGH ALBUQUERQUE, NEW MEXICO

Raven Longwolf Alcott[1], Alexandra Hurst, Sofia Jenkins-Nieto, Sarah Ann Polsin and Gary Weissmann

[1] ravenlal@unm.edu

The vast production of plastics has resulted in an increase of microplastics (MPs) in the environment. MPs are found in water and food systems, and we demonstrate that MPs are present in the Rio Grande near Albuquerque. In this project, we collected samples from four sites on the Rio Grande in Albuquerque. At each site, we collected water and sediment samples in non-plastic containers to reduce the risk of cross-contamination. Density separation methods were used to float MPs and separate the MPs from sediment, and the MPs were decanted into a vacuum filter. Our procedure for sediment sample processing did not produce reasonable results, therefore these samples were not analyzed or assessed. MPs were manually picked from water sample filter paper using microscopes and tweezers. The primary finding of this project indicates that MPs are present in the Rio Grande. At the upstream site we observed 20 MPs/L, at the first intermediate site there were 19 MPs/L, at the second intermediate site 14 MPs/L were found, and at the site downstream from Albuquerque's water treatment plant 32 MPs/L were found. Although MPs were identified in the Rio Grande and an increase in MPs down river through Albuquerque was observed, we consider these results to be preliminary. Significant uncertainty and variability in our processing approaches exist, therefore additional samples should be collected to verify the results.



Amount of microplastics found at 4 sites along the MRG

THE FIRST REPORT OF *PLANOLITES* IN THE MOJADO FORMATION, CERRO DE CRISTO REY, SUNLAND PARK, NEW MEXICO

Oskar N/A Alvarez[1] and Eric J. Kappus[2]

[1] 2429 John Cox, El Paso, TX, 79936, United States, oalvarez8@miners.utep.edu
[2]Southwest University at El Paso, 1414 Geronimo Dr., El Paso, TX, 79925, USA

Current fieldwork in the lowermost Albian-Cenomanian Mojado Formation (Sarten member) has produced several new invertebrate trace fossil discoveries. Reported here is the third documented occurrence of *Planolites* isp. in the Washita Group at Cerro de Cristo Rey Sunland Park, New Mexico, and the first record of this trace in the Mojado Formation. *Planolites* is a simple, sub-horizontal, cylindrical trace with fill that is different than the host rock. It is interpreted as a domichnia (dwelling trace) or fodichnia (feeding trace) with several possible tracemakers. It is preserved in most environmental settings including marine and continental, from the Ediacaran to Recent. At this locality this trace is associated with *Arthrophycus*, *Thalassinoides*, and *Curvolithus*, so we tentatively assign this ichnoassemblage to the Cruziana ichnofacies. Although ichnoassemblages attributed to the Cruziana ichnofacies have been described a few meters below in the Mesilla Valley Formation, these differ from the low-diversity ichnoassemblage in the Mojado Formation. This change in ichnoassemblage may in the future be used to define the lower contact of the Mojado Formationat Cristo Rey.

Keywords: invertebrate ichnology, trace fossils, Cerro de Cristo Rey, Mojado formation, *Planolites*, Cruziana ichnofacies

References:

Keighley, D.G. and Pickerill, R.K., 1995. Commentary: the ichnotaxa Palaeophycus and Planolites: historical perspectives and recommendations.

Lucas, S.G.,Krainer, K.,Spielmann, J.A. andDurney, K., 2010. Cretaceous stratigraphy, paleontology, petrography, depositional environments, and cycle stratigraphy at Cerro de Cristo Rey, Doña Ana County, NM. New Mexico Geology, 32(4), pp.103-130

Núñez-Useche, F.,Barragán, R., Moreno-Bedmar, J.A. andCanet, C., 2014. Mexican archives for the major Cretaceous oceanic anoxic events. Boletínde la Sociedad Geológica Mexicana, 66(3), pp.491-505.

Pemberton, S.G. and Frey, R.W., 1982. Trace fossil nomenclature and the Planolites-Palaeophycus dilemma. Journal of Paleontology, pp.843-881.

Riahi, S. and Uthman, A., 2022. Ichnology of Lower Cretaceousprodeltaand delta front deposits of the Sidi Khalif Formation, Central Tunisia. Facies, 68(1), pp.1-28.

Keywords:

invertebrate ichnology, trace fossils, Cerro de Cristo Rey, Mojado formation, Planolites, Cruziana ichnofacies

REE IN COALBEDS IN THE SAN JUAN RIVER - RATON COAL BASINS

Megan N. Badonie[1] and Virginia T. McLemore[2]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, Megan.Badonie@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801

Rare earth elements (REE) and critical minerals have recently become of great economic interest because of the advent of new technologies and recent geopolitical unrest affecting supply of resources. The San Juan and Raton basins in northern New Mexico are two structural coal basins that contain elevated concentrations of REE and critical minerals. Concentrations of REE and other critical minerals found in coal deposits are significantly lower than those found in economical deposits. A potential by-product of these minerals is enabled through large amounts of coal that is produced from the electrical plant's coal production. These two New Mexican coal basins will be assessed geochemically and petrographically to quantify mineral enrichment. Coalbeds, coal seams, overlying, and underlying rock units will be sampled and characterized to determine any economic viability. The first step is to describe the drill core stored at NMBGMR. Historic data also will be compiled into a new and comprehensive coal geochemical database, which will grow with new analyses, and serve as the dataset for this project; this coal resource database will be made available to the public.

Keywords:

Coal, San Juan Basin, Raton Basin, Northern New Mexico, REE, Critical Minerals

GEOCHEMICAL NICHES OF EXTREMOPHILE COMMUNITIES IN AN EPHEMERAL ACID ROCK DRAINAGE

Mackenzie B. Best[1] and Daniel S. Jones[1]

[1]New Mexico Institute of Mining and Technology, Earth and Environmental Science, 801 Leroy Pl., Socorro, NM, 87801, mackenzie.best@student.nmt.edu

Acid rock drainage (ARD) occurs when metal sulfide minerals are exposed to surface conditions and begin to oxidize. This creates high concentrations of dissolved iron, other metals, and sulfuric acid, creating orange streams, seeps, and pools. These acidic, metal-rich sites host diverse microbial communities that includes extremophilic iron and sulfur oxidizers that take advantage of the abundant chemical energy from sulfide minerals and dissolved iron, and have adapted to extreme acidity and high metal concentrations. The Copper Flat mine is a historic copper mine located in the Hillsboro mining district in south-central New Mexico. It is a low-grade porphyry deposit where the primary copper mineralization is in the form of chalcopyrite veinlets. The mine operated at full production for 3 months in 1982, and was then placed on a care and maintenance plan to await an increase in the market price of copper, but was eventually decommissioned in the 1990s. At this site, there are two extremely acidic seeps that run only once or twice per year for no more than several weeks at a time, depending on monsoon precipitation. Year after year, a vibrant microbial community springs up when these seeps are actively running. However, we know little about the microorganisms that colonize these seeps, and how the ecology, biogeochemistry, and fate and transport of metals change during these seasonal wetting and drying cycles.

Here we present preliminary data the microbial communities present in one of the seeps that was running in June 2020. pH and specific conductivity of the seep varied from 1.54-1.95 and 9.01-6.32 mS/cm, respectively. Based on rRNA gene libraries from nine exploratory samples, seep sediments were dominated by populations related to known lithotrophic iron-and sulfur-oxidizing bacteria, acidophilic organoheterotrophs, diverse algae, and novel Proteobacteria and Thermoplasmatales-group Archaea that varied with the pH and salinity gradients in the seep. Bacteria and archaea related to *Leptospirillum*, *Acidiphilum, Acidibacter*, *Ferrithrix, Cuniculiplasma*, and *Ferrimicrobium* were consistently more abundant at the more acidic site, while *Acidicapsa*, *Acidobacterium*, and *Alicyclobacillus* dominated at the less acidic location. We hypothesize that these differences in community composition are due to differences in pH and metal content of the waste stream, which may represent the tolerances for each population with respect to their preferred geochemical niches in these ephemeral seeps. Future work aimed at understanding the ecological and geochemical constraints on these organisms can help us to better design passive remediation strategies and understand elemental cycling in ARD environments.

Keywords:

geomicrobiology, acid rock drainage, mining

GEOCHEMICAL FINGERPRINTING OF SOURCE WATER TO THE SNOWY RIVER DEPOSIT

Johanna M. Blake[1], Christina Ferguson[1] and Keely Miltenberger[1]

[1]U.S. Geological Survey, 6700 Edith Blvd. NE, Albuquerque, NM, 87113, jmtblake@usgs.gov

The Snowy River deposit, located in the Fort Stanton-Snowy River Cave System near Capitan, New Mexico, is a unique calcite deposit within the Permian San Andres Formation. Because of its rare and delicate nature, its preservation is of great importance to cave and natural resource managers. The deposit resembles a white riverbed and has been surveyed and mapped up to 12 cave miles. The source of water to the Snowy River deposit is not known. Flooding of the Snowy River portion of the cave has been roughly correlated to large precipitation and run-off events within the local watershed. A geochemical fingerprinting approach rather than a dye tracer allowed for an understanding of the source of water without potential effects to microbial communities in the cave. Four potential sources of water to the deposit were evaluated: surface water from Eagle Creek, Little Creek, Rio Bonito, and local groundwater. Using geochemical tracers including major and trace elements, stable isotopes of water, and strontium isotopes, Eagle Creek, Rio Bonito, and local groundwater were identified as the primary sources of water to the calcite deposit. Analyses included Piper diagrams, principal component analysis, and geochemical modeling to identify unique fingerprints of the potential source waters and waters collected within the cave. However, given the length of the deposit, sources of water appear to change depending on the location in the cave. This information can help land and cave managers to identify potential sources of any adversely effected water to enter the cave.

New Mexico Underground: Spectacular Subsurface Systems for Interdisciplinary Science and Exploration

Penelope J. Boston

NASA Ames Research Center, Moffett Field, CA, 94035, penelope.j.boston@nasa.gov

In New Mexico, we enjoy many magnificent landscapes and varieties of geology and wildlife. But beneath our feet, there is a wondrous hidden wilderness that few people experience other than possibly via trips to Carlsbad Caverns National Park or the lava caves at El Malpais National Monument. Our state is graced by a wide variety of subsurface terrains with distinct geological settings, origin mechanisms, mineralogy, microbiology, and wildlife. Functioning as integrated systems, subsurface cavities and associated rock fracture networks are a significant part of hydrological systems, and even possess their own micrometeorological behavior. Although beneath the surface, caves are significantly coupled to the surface by both matter and energy exchanges making them an important part of Earth's Critical Zone (CZ). This was defined in a landmark National Research Council study (2001) as the heterogenous, surface and near subsurface environment of rock, soil, water, air, and biota that engage in complex interactions that regulate natural habitats, thus determining access to resources that sustain life including our own.

The fundamental nature of geology and geochemistry combined with surface climate over time has produced each cave, and governs its resulting structural and mineralogical properties. Cave minerals worldwide currently number more than 300, many of which are found only in caves, and some of which are found only in a single cave (White 2016; Hill & Forti, 1997). And this tally does not include many unusual organic minerals produced in caves with bat, bird, and other biological organic contributors.

Microorganisms and some larger organisms act as geological agents further helping to catalyze, enhance, transform, and even sometimes impede the geological processes of cave systems. Thus, in order to truly understand the subterranean realm, an integrated interdisciplinary approach involving all of the relevant natural sciences is essential. This understanding is further enhanced by the paleontological and anthropological materials contained within many cave systems that often preserve these finds in exquisite condition.

As an example of a highly successful interdisciplinary approach, a mere 1½ hours drive east of Socorro is Ft. Stanton Cave, which has been known and used by Native Americans, white settlers, and today for recreational cave trips. In 2001, Ft. Stanton yielded a new secret buried at her heart…a gleaming "frozen" river of crystalline calcite in a previously unknown passage, Snowy River. In the 20 years since elapsed, extensive work has been carried out by many explorers, mappers, diggers, scientists, cartographers, photographers, and others (FSCSP 2017).

I will present a handful of examples of the diverse cave systems in New Mexico, a summary of their most striking properties, and pose scientific questions that often cross-cut all of these systems in our community's efforts to understand them.

References:

Ft. Stanton Cave Study Project, 2017. *12 Miles from Daylight.* 310pp.
Hill, C.A. and Forti, P. (1997) *Cave Minerals of the World*. 2nd Ed., Nat. Speleological Soc., Huntsville, AL.
NRC, 2001. *Basic Research Opportunities in Earth Science.* Nat. Academies Press. doi:10.17226/9981.
White W. 2015. Chemistry and karst. *Acta Carsologica* 44(3):349-362. Postojna, Slovenia.

EXTREMOPHILIC MICROORGANISMS FROM SULFUR-RICH SPRINGS AND FUMAROLES IN THE VALLES CALDERA VOLCANIC COMPLEX, NEW MEXICO

Abigail Rose Brown[1], Brianna Green[2] and Daniel S. Jones[1]

[1]Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, abigail.brown@student.nmt.edu
[2]Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, Knoxville, TN

The Valles Caldera is a large volcanic feature in Northern New Mexico that has had geothermal activity since its formation at 1.25 Ma. Volcanic H2S is currently emitted along the western margin of the Caldera through fumaroles and in natural and artificial hot springs. We explored the microbial communities and processes associated with volcanically-influenced surface waters in the Sulfur Springs and Alamo Canyon area of Valles Caldera National Preserve, and in hot springs along the Jemez River to the south. Surface waters impacted by fumarolic gases in the Alamo Canyon and Sulfur Springs areas had pH values between 1.1 to 3.5, with dissolved sulfide concentrations from 10 μM up to 1 mM in areas with the most intense fumarolic activity. In contrast, hot springs at Soda Dam and an artificial spring in the town of Jemez Springs had temperatures between 37-70ºC, circumneutral pH values, and sulfide concentrations between 5-25 μM. Small subunit rRNA gene libraries from Alamo Bog had diverse eukaryotic algae and a wide variety of bacteria related to known chemoautotrophic sulfur oxidizers, including Sulfurimonas spp., Sulfuriferula spp., Halothiobacillus spp., and Thiomonas spp. The more acidic sites in Sulfur Springs are dominated by the bacterial and archaeal genera Acidithiobacillus, Sulfobacillus, Acidiphilium, and Acidiplasma. Green and white streamers from the Soda Dam springs were dominated by Sulfurovum, Thiofaba, Thiothrix, and several cyanobacterial taxa. The most acidic samples were the least diverse, but there was not a strong correlation between microbial diversity and pH. Diversity was also negatively correlated with dissolved sulfide concentration. Future work will continue to explore how geochemical factors influence microbial communities across the strong pH and temperature gradients in the Valles Caldera region.

MONITORING BATS ON THE FORT STANTON – SNOWY RIVER CAVE NATIONAL CONSERVATION AREA

Debbie C. Buecher[1] and Diana E. Northup[2]

[1]Buecher Biological Consulting, 7050 E Katchina Ct, Tucson, AZ, 85715-3323, US, dbuecher@comcast.net
[2]Biology Department, University of New Mexico, MSC03 2020, Albuquerque, NM, 87131

Resources that limit distribution of bats include: appropriate food resources, access to drinking water, and availability of roost sites with suitable temperatures and relative humidity. Fort Stanton – Snowy River Cave National Conservation Area (NCA) has invaluable habitat for bats. The Rio Bonito Creek, with its rich cottonwood gallery and herbaceous understory, threads through the NCA offering bats access to water and insect prey. The NCA has assorted roost sites including: caves and crevices; tree foliage and dead snags; and abandoned buildings. We have conducted mist netting along the Rio Bonito Creek since 2005 to develop a bat species list on the NCA, supplementing netting with acoustic monitoring. We have documented 12 bat species, although additional sampling might add species. NCA bat species are insectivorous and each bat will eat over ½ its body mass in insects nightly, making them the major predators of nocturnal insects.

Summer roosts chosen by reproductive female bats are generally warmer than typical caves and have higher relative humidity than the surface. These conditions ensure the rapid growth of young bats. The NCA has a summer maternity colony of Townsend's big-eared bats (Townsends) along Rio Bonito Creek. We conducted numerous emergence counts outside the cave to monitor the colony health. We monitored roost conditions with programmable loggers showing that cave temperatures range from 12.4ºC to 13.2ºC. Despite the arid surface conditions, the cave RH varies between 78% and 85%.

Winter hibernacula, on the other hand, must be within species-specific cold temperatures and often nearly saturated air for bats to survive months in hibernation, while living off fat reserves accumulated in the fall. Fort Stanton Cave is a significant hibernaculum for Townsends. Winter census counts have been conducted since 1978. The lowest count was 371 bats in 1980 but recently the number of bats has been increasing and the 2022 census count was 1,113 Townsends. Surprisingly Townsends hibernate in a highly variable microclimate, which not all bat species can tolerate. The hibernaculum temperatures typically range between 1.0ºC to 4.5ºC and the RH varies between 50% and 100%.

Recently our work on the NCA has been monitoring for the presence of an invasive fungal pathogen responsible for the bat disease, white-nose syndrome (WNS). *Pseudogymnoascus destructans* (*Pd*) is a psychrophilic fungus that has caused the death of over 6 million hibernating bats in the U.S. and Canada. In 2012 we began swabbing NCA bats to determine the naturally occurring microbiomes across different species. We found a number of Actinobacteria on bats that inhibit the growth of *Pd*. Unfortunately, we have discovered from our microclimate analysis that Ft. Stanton's hibernaculum has appropriate conditions for the growth of *Pd*, were it introduced into the cave. Because of concern for possible *Pd* in NCA caves, we swab bats immediately after hibernation to test for *Pd* spores and visually assess the bats for lesions on wings and tail membranes, resulting from *Pd* infection. To date, we have not detected *Pd* on NCA bats.

THE DOUBLE-EDGED SWORD OF ULTRA-HIGH PRECISION $^{40}Ar/^{39}Ar$ GEOCHRONOLOGY: INVESTIGATING PREVIOUSLY UNRESOLVED COMPLEXITIES IN SANIDINE AGE DISTRIBUTIONS

Tyler B. Cantrell[1], Matthew T. Heizler[1] and Jake Ross[1]

[1]New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801

Improvement in the precision of $^{40}Ar/^{39}Ar$ sanidine geochronology has demonstrated that single crystal sanidine dates from ignimbrites are dispersed, leading to ambiguous interpretations of eruption ages. This inhibits interpretation of temporally closely spaced geologic events such as nearly coeval caldera forming eruptions, paleomagnetic reversals, extinction events, etc. Possible age dispersion sources related to (1) neutron dose differences between individual sanidine grains, (2) mineral and melt inclusion variations between grains, and (3) mass spectrometry and data reduction details have been evaluated via detailed laboratory experiments on multiple sanidine bearing ignimbrites. The accuracy of derived eruption ages is cross validated through stratigraphically constrained 27 – 28 Ma ignimbrites from the San Juan Volcanic Field that may differ in age by less than 15 ka.

The $^{40}Ar/^{39}Ar$ method is based on irradiating a sample to convert ^{39}K to ^{39}Ar with the $^{40}Ar/^{39}Ar$ value being proportional to age. However, multifarious neutron flux, spatially and temporally, leads to no two grains receiving the same neutron dose, thus, variation in grain-to-grain dosage is a possible source of age dispersion. Irradiation of Fish Canyon tuff sanidine (FC-2) grains in a tightly spaced geometry significantly reduced dispersion from the typical grain-to-grain date range of up to ca. 100 ka to as low as ca. 30 ka. Although better constraining the irradiation geometry demonstrated that neutron flux variation is a large source of age dispersion, in detail, populations still show excess dispersion that likely correlates to geologic complexities.

Geologic dispersion is evaluated by handpicking inclusion-free and inclusion-rich sanidine grains. Inclusion-rich grains are characterized by having visible melt and mineral inclusions when viewed under a microscope. Detailed experiments of FC-2 revealed no significant age difference or degree of dispersion between populations with and without inclusions. Numerous other mid-Tertiary ignimbrite samples were analyzed in the same manner and yield results comparable to FC-2. Although inclusion-rich grains revealed more chemical variability, the general observation is that there is no significant difference between inclusion-free and inclusion-rich grains.

The ability of the mass spectrometer and associated analytical methods to yield a normal distribution of dates is evaluated by two methods: (1) a standard gas with an argon isotopic composition similar to typical sanidine and (2) by crushing coarse-grained sanidine crystals to construct a homogeneous geologic sample. Standard gas ultra-high precision analyses yields normally distributed isotopic measurements, indicating that when provided with a homogeneous sample, a homogeneous result can be achieved. Crushed and homogenized FC-2 aliquots yield normally distributed ultra-precise results, reinforcing the robustness of the mass spectrometer when dating a geologic sample and supporting that analytical protocols are not a major cause of single crystal age dispersion.

Experiments on temporally equivalent volcanic eruptions indicate that mid-Tertiary units that differ by as little as 10-20 ka can be accurately delineated, however, challenges remain in determining what part, if any, of a dispersed dataset yields an accurate eruption age.

THE TRACE FOSSIL ZOOPHYCOS FROM THE SHALLOW WATER FACIES OF THE MIDDLE PENNSYLVANIAN SANDIA FORMATION, JEMEZ MOUNTAINS, NEW MEXICO

Patrick James Carey[1], Spencer G. Lucas[1], Karl Krainer[2], Deborah Petrak Green[1] and Paul May[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM, 87104, raglandcarey@aol.com
[2]Institute of Geology, Innsbruck University, Insbruck A-6020, Austria

Zoophycos is a large, distinctive trace fossil that is found in marine deposits throughout the Phanerozoic, but has rarely been reported from New Mexico. It has been usually interpreted as the deposit-feeding trace of a marine worm. *Zoophycos* also gives its name to an archetypal ichnofacies characterized by Seilacher in 1967 as being deposited in deep or at least dysaerobic bottom water. Later it was realized that deep water sediments were not consistently associated with *Zoophycos* in Paleozoic rocks. The large deposit of *Zoophycos* traces described here from the Sandia Formation at Guadalupe Box was originally mentioned by DuChene in 1974 and initially described by Kues in 2005. Based on lithology and associated fossils, it was deposited in shallow water, but below wave base, the same environment as was reported for the most recent New Mexico report of *Zoophycos*, from the Middle Pennsylvanian of Sierra County.

At Guadalupe Box, dozens of *Zoophycos* traces occur in a bed of fine-grained sandstone 28 meters above the base of the 60--meter thick Sandia Formation. Approximately 20 centimeters in thickness, the trace-bearing layer is sporadically exposed to the north for at least 300 meters. At the best exposure, approximately 5 square meters of trace-bearing surface is visible. Beds are close to horizontal and 3-5 cm thick, each with numerous, closely packed *Zoophycos* traces, 15 to 20 centimeters across. The sandstone is fine-grained and contains a high amount of matrix (32-52%) together with monocrystalline quartz grains, minor polycrystalline quartz grains, and rare detrital feldspar grains. A thin bed of fusulinid packstone limestone two meters above the *Zoophycos* bed contains *Fusulinella,* indicative of an Atokan age.

The *Zoophycus* bed is near the top of a large exposure of the lower Sandia Formation. This sequence represents a well-developed fining-upward succession that can be divided into three units, based on lithology. The lower unit, nine meters thick and composed mostly of coarse sandstone, is interpreted to be fluvial. The middle unit, 18 meters of interlayered shale and siltstone, was initially deposited on a coastal plain that became inundated as sea level rose. The upper unit, eight meters of intercalated gray calcareous shale, limestone, and sandstone, was deposited below sea level. The lowermost bed of the upper unit, a grained-supported crinoidal limestone, documents the continuation of transgression, and was deposited in a shallow, open marine setting under moderate to high turbulence. Deepening continued as deposition dropped below wave base, producing limestones with a muddy texture and a diverse fossil assemblage, pointing to deposition in a low energy, but shallow marine environment as long as siliciclastic input was absent. During periods of terrigenous input, calcareous shale was deposited. The *Zoophycos* bed, and the other thin, fine-grained sandstone strata, may represent distal storm layers. Further study is needed to estimate the degree of oxygenation in these unusual *Zoophycos*-bearing beds.

Evaluating Methods for Remote Measurement of Stream Flow Velocity in Ephemeral Flash Flood Environments

Zachary Chavez[1], Daniel Cadol[1], Kyle Stark[1] and Jonathan B. Laronne[2]

[1]New Mexico Tech, NM, zachary.chavez@student.nmt.edu
[2]Ben Gurion University of the Negev

Obtaining measurements of water velocity during flash flooding events is both difficult and dangerous. Safety is of the utmost importance when conducting research in the field, particularly in remote areas with limited vehicle and support access. Traditional methods of measuring water velocity are insufficient, especially when considering the unpredictability of shot-lived ephemeral flash floods. New, automated methods should be evaluated for their accuracy.

We evaluated two methods to measure surface water velocity: Doppler velocity radar and Large-Scale Particle Image Velocimetry (LSPIV). The Doppler radar records an average of the surface velocity by directing a beam of radio wave energy at an approaching target. The frequency shift of the reflected energy is proportional to the radial velocity of the target object relative to the velocimeter. LSPIV analysis consists of recording a video of a flood and analyzing each frame for changes in the water surface. Individual particle tracking produces an array of surface velocity vectors. Using cross section and reference target surveys, continuously monitored stage data, and estimates of the ratio of depth-averaged velocity to surface water velocity for a given relative roughness, continuous cross-section-average velocity can be estimated for the flood event, and from this the entire discharge hydrograph.

The Arroyo de los Pinos is an ephemeral tributary to the Rio Grande. In the 2021 flood season we have collected velocity measurements, both video and radar, across a large range (32- 125 cm) of water depths. To test the accuracy of our two remote methods, we have compared between them and to measurements made in the channel using an electromagnetic velocity meter. The LSPIV was able to calculate velocities that are within the accepted values in hydrometry. A drawback to using LSPIV occurs with lighting. We recorded one flood this season at nighttime with illumination from vehicle headlights, which does not initially appear sufficient for particle tracking with the LSPIV software. However, we hope to address this issue with stronger standard and infrared lighting in hopes that this program will allow for a safer collection of previously unavailable velocity data for ephemeral rivers worldwide.

Keywords:

LSPIV, Surface velocity, Flash flood

Characterization and Origin of the REE-bearing Magmatic-hydrothermal breccia pipes in the Gallinas Mountains, Lincoln County, New Mexico

Stellah Cherotich[1] and Virginia McLemore[2]

[1]New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801, stellah.cherotich@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Pl., Socorro, NM, 87801

Breccia pipes are a common host of many precious and base metal and rare earth elements (REE) mineral deposits because they provide conduits for fluid flow and open spaces for mineral precipitation, hence are a focus area for exploration.The Gallinas Mountains district in Lincoln County, New Mexico has produced copper, lead, silver, fluorite, iron, REE (as bastnaesite), and gold from 1902 to 1980, but no production has been reported from the breccia pipes. However, some magmatic-hydrothermal breccia pipes in the Gallinas Mountains host high concentrations of fluorite-REE and gold. Previous studies have described the occurrence of REE in breccia pipes, but the controls for their transportation and deposition are still unclear. The purpose of this research is to characterize the magmatic-hydrothermal breccia pipes in order to understand the geochemical and physical conditions of deposition of REE and gold in the breccia pipes found in the Gallinas Mountains.

There are more than 20 exposed breccia pipes that intrude the Yeso Formation, Glorieta Sandstone, trachyte, and syenite, forming a northeast-trending belt, approximately 3–5 kilometers long in a fault block northwest of the Pride fault. The breccia pipes are gray to brown and consist of angular to subrounded fragments of granite, granitic gneiss, sandstone, shale, limestone, trachyte, and syenite that are as much as 1 m in diameter. The majority of the breccia pipes are matrix-supported with a groundmass of feldspar and quartz, along with small crystals of other minerals and rock fragments. Significant number of these breccia pipes are altered and weathered, consisting of secondary hematite and local calcite, quartz, and fluorite. Some rock fragments are silicified around their edges and other fragments are surrounded and cut by fluorite veins. Fragments of magnetite-hematite ore are found in several breccia pipes.

Chemically, the breccia pipes exhibit light REE-enriched chondrite-normalized patterns. Samples with high fluorine also have high REE and some have high gold concentrations. Some breccia pipes contain as much as 28,485 ppm total REE and 121 ppb Au. Preliminary studies suggest that the breccia pipes are magmatic and intruded into the host rocks and, subsequently, hydrothermal fluids precipitated fluorite-REE and gold along the edges of some breccia pipes. Additional studies are underway to further test this hypothesis.

References:

McLemore, V.T., Kelley, S. Zimmerer, M. Owen, E. Haft, E. Cantrell .T, Gysi. A Trivitt, A. 2021, Geology and Mineral Deposits of the Gallinas
Mountains, Lincoln and Torrance Counties, New Mexico, Open-file Report 617, Volume 1

CONTINUOUS MEASUREMENT OF EVAPORATION IN HIGH-HUMIDITY CAVES: A CASE STUDY IN FORT STANTON CAVE, NEW MEXICO

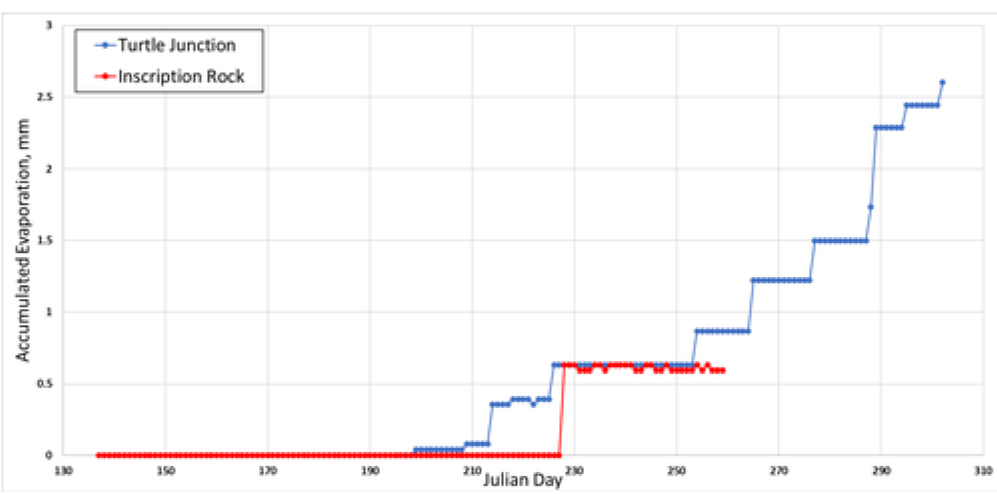
Jake Collison[1], Talon Newton[2] and Scott Christenson[2]

[1]UNM: Civil, Construction & Environmental Engineering Department, jakec@unm.edu
[2]NM Bureau of Geology and Mineral Resources

Monitoring evaporation rates in humid caves in arid areas may provide information about a variety of cave features and processes, including speleothem formation and growth, cave biota and their habitats, the effects of climate change on cave microclimates, and seasonally changing ventilation patterns within the cave. With funding from the National Cave and Karst Research Institute, a cave evaporimeter was designed and deployed at two different locations within Fort Stanton Cave. The evaporimeter consists of an aluminum container where the water level within the container is monitored by a linear potentiometer that records a water level change of 0.24 mm to a data logger.

The initial deployment of the cave evaporimeter at Inscription Rock within Conrad's Branch recorded 0.65 mm of evaporation over a period of 124 days, 5/15/2020 through 9/15/2020, with the first 92 days showing no appreciable evaporation. The second deployment of the cave evaporimeter at Turtle Junction recorded 2.60 mm of evaporation over a period of 110 days, 7/12/2021 through 10/29/2021. The results are displayed in the figure below.

The most predominant driving force of evaporation within a cave is the exchange of near-fully saturated air within the cave with minimally saturated air outside the cave. This exchange of air is driven primarily by barometric pressure differences inside and outside the cave, with the current understanding that evaporation near the cave entrance will be greater than farther inside the cave. Although the data collected was not concurrent, it was collected during similar seasons one year apart. Contrary to what was expected, the evaporation rate deeper within Fort Stanton Cave was four times greater than that near the entrance. These results lead to the following question: what's driving the higher evaporation rate at Snowy River?



Accumulated evaporation at Inscription Rock 2020 (red) and Turtle Junction 2021 (blue).

Keywords: Evaporation, Snowy River

DISCOVERY, EXPLORATION, SURVEYING, AND CARTOGRAPHY IN FORT STANTON CAVE

John J. Corcoran

FSCSP, 510 Montego Dr SE, Rio Rancho, NM, 87124-3081, United States, JohnJC3X@outlook.com

This presentation summarizes the general history of discovery and cartography as related to Fort Stanton Cave, Lincoln County, New Mexico. Evidence show that native Americans visited the cave sometime between 1100 AD and 1800 AD. The cave was rediscovered by U.S. Army soldiers in 1855 who began visiting the cave often through the late eighteenth and early nineteenth centuries. In addition to historic graffiti left in the cave, such as signatures, a scattering of newspaper articles were written about their experiences in the cave. In 1877, the U.S. Army documented the cave with a report and the first map. Soldiers from Fort Stanton and local civilians explored the cave gradually from 1855 through the 1890s and even through the 1950s when modern cave explorers started more methodical exploration, surveys, and cartography that expanded on previous knowledge. In 2001 a major discovery was made of the Snowy River Passage and associated complex of side passages. As of April 2022, the length of surveyed passages has reach 42.32 miles in length.

Surveying and Cartography has gradually evolved from 1877 through the present. Instruments, techniques, and Technology have been adapted to suit the cave environment and standards needed to produce quality surveys and maps over the last 167 years.

Keywords:

History, Cartography

THE FIRST DECADE IN SNOWY RIVER: STALKING THE MAMMOTH CAVE OF THE WEST

Donald G. Davis

Fort Stanton Cave Study Project, 441 S Kearney St, Denver, CO, 80224-1237, dgdavis@nyx.net

I first visited Fort Stanton Cave as a young caver in 1960, and as I wandered along its level, winding, river-system galleries, I thought "this is just like what I've read about Mammoth Cave!" I was hooked, and joining with organized cavers, I explored FSC from time to time from then until the century turned. A Wheeler Survey team had surveyed ~2.12 miles in 1877. By 2000, our efforts digging through breakdowns had earned enough virgin passage to bring the length to ~8.52 miles. But digging continued in an intimidating collapse called Priority 7 in northern FSC. On Sept. 1, 2001, four diggers broke through into a short, muddy, windy passage that led eastward to a junction with a horizontal walkway leading NE and S. The floor hosted a dry streambed lined with a pristine white calcite deposit such as no one had ever seen.

No one stepped onto it, following a BLM directive that required an environmental impact statement in the event of a major discovery. That took two years, but in 2003, the first cavers walked onto Snowy River. We had feared that the calcite surface might be very fragile, and had even devised padded "snowshoes" to test it with, but the central path proved to be thick and strong as a sidewalk. Teams began surveys NE toward the Bonito Valley and S into the hills. The valleyward direction led about half a mile to a short dropoff where a small spring, Crystal Creek, fed a meandering streamlet running across a mud-floored chamber ending in a sump. One major side passage, the Metro, climbed up to the south into an undulating paleo-gallery that ended in a massive breakdown.

The south proved to be the ongoing direction. Three increments of survey got us to station SRS108 along Snowy River South in Oct. 2003, where breezy passage 20 feet wide and two feet high (start of the "Crawl from Hell") continued. Various interesting places were named along the route. Then another delay took place because BLM had declared the Priority 7 route unsafe. A side passage W from SRS23 had proved to end under the E wall of Don Sawyer Memorial Hall in the historic cave. The project dug a 45-foot bypass shaft that broke through in 2007, whereupon Snowy River was seen flowing for the first time. Via this safer, easier approach, survey was resumed in 2008-2009, crossing two major breakdowns (with a puzzling side passage, Sandy River, looping most of the way around them but ending in a sand choke), an intermittent muddy sump (Mud Lizard), another miserable crawl, then thousands of feet including the Underground Railroad, an upper-level loop (Fallen Arrows Corridor), and more large borehole, crossing the Mount Airy collapse-pass, and an unusually delicate stretch of calcite which triggered another hiatus until 2011, when one trip brought the cave to SRS383, still going big under the Ruidoso airport. The survey had reached 15.58 miles. At this point John Lyles takes up the story.

GEOCHEMISTRY OF THE TAJO GRANITE, SOCORRO COUNTY, NEW MEXICO

Haley Dietz[1] and Virginia T. McLemore[2]

[1]New Mexico Institute of Mining and Technology, 911 Bursum Place, Socorro, NM, 87801, haley.dietz@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801

The Proterozoic Tajo granite consists of six outcrops along two northwest-striking faults east of Socorro, New Mexico. The area was originally examined for uranium, but fluorite and rare earth elements (REE) are reported as well. REE consist of the 15 lanthanide elements, including scandium and yttrium, are critical minerals, and are fundamental to modern society. REE deposits are rare in the world. Some Proterozoic granites in New Mexico, including the Tajo granite, contain uranium and REE, but their mineral-resource potential is unknown. We conducted a petrographic and geochemical study of the Tajo granite to determine the mineral-resource potential. The Tajo granite is medium-to coarse-grained, peraluminous, A-type granite, but it is relatively low in REE and uranium concentrations and not economic at this time. Geochemical comparisons of the Tajo granite to other Proterozoic granites found in central New Mexico, including Proterozoic granites found in the Gallinas and Los Pinos Mountains show that Tajo granite has an unusual composition. The Tajo granite is enriched in Rb, U and Th compared to the other Proterozoic granites, and depleted in CaO, Na_2O, and Sr. Future studies are needed to determine why the Tajo granite is depleted in REEs.

NEW EVIDENCE CONFIRMS THE ~250 K.Y. DURATION FOR DEPOSITION OF THE PALEOCENE OJO ALAMO SANDSTONE IN THE SOUTHERN SAN JUAN BASIN, NEW MEXICO

James E. Fassett

USGS Retired, Independent Research Geologist, 552 Los Nidos Dr, Santa Fe, 87501, jimgeology@aol.com

The dinosaur-bearing Ojo Alamo Sandstone (OAS) of the San Juan Basin (SJB), NM and CO, is earliest Paleocene based on palynologic data from multiple localities. An unconformity of 7-8 m.y. separates the Paleocene OAS from underlying Cretaceous strata in the southern SJB – Maastrichtian-age strata are absent there. Previous publications show that OAS dinosaur bones were not reworked but were fossilized in place. The OAS averages 15-30 m thick in the southern SJB and is up to 130 m thick further north in the basin. The first altered volcanic ash bed ever found in the Nacimiento Fm. was discovered in the southeast SJB 64 m above the top of the OAS near Cuba, NM. Sanidine grains from this ash bed had a $^{40}Ar/^{39}Ar$ age of 64.60 Ma (adjusted). Based on an estimated rate of deposition for the lower Nacimiento Fm., the age for the top of the underlying OAS was determined to be 65.7 Ma. Subsequently, a second Nacimiento ash bed was found only 10.5 m above the top of the Ojo Alamo with a reported $^{40}Ar/^{39}Ar$ sanidine age of 65.49 Ma . This ash bed was found near De-na-zin Arroyo in the southwest part of the SJB. Again, based on an estimated rate of deposition for the lowermost Nacimiento Fm, the top of the underlying OAS was calculated to be 65.7 Ma. In addition, a detrital sanidine age for the top of the OAS in the southern part of Cuba, NM was reported to be 65.67 Ma, in agreement with the ages above. And a very recent paper (2020) discussing the paleomagnetism of the Nacimiento Fm., suggests an age of 65.67 Ma for the base of magnetochron C29n, a few meters above the top of the OAS. These new data also support an age of 65.7 Ma for the top of the OAS in the southern SJB. Previous publications have estimated the base of the OAS to be ~65.95 Ma, thus the duration of OAS deposition in the southern SJB must have been ~250 k.y. This duration of OAS deposition in the southern SJB of about a quarter-million years is thus confirmed by recent data. It must be cautioned that in those parts of the basin to the north, where the OAS is thicker, the time interval for its deposition could have been proportionally greater and have a younger upper boundary.

Some workers (mostly vertebrate paleontologists) have suggested that the OAS consists of two members: a lower, dinosaur-bearing member of Cretaceous age separated from the upper part by an imagined unconformity of millions of years. This report shows that the undivided OAS was deposited over about 250 k.y. in the southern SJB. There is no stratigraphic evidence on OAS outcrops around the basin for a significant break in deposition within this formation; indeed, OAS outcrop observations clearly show otherwise. Voluminous palynologic data, published heretofore, unequivocally support the top-to-bottom Paleocene age for the dinosaur-bearing OAS throughout the SJB. None of these data have ever been falsified.

Keywords:

Duration of Ojo Alamo Sandstone deposition, Paleocene dinosaurs

GEOLOGY, STRATIGRAPHY, AND GEOMORPHOLOGY OF THE PERMIAN SAN ANDRES LIMESTONE AND THE SNOWY RIVER PASSAGE OF THE FORT STANTON-SNOWY RIVER CAVE SYSTEM, LINCOLN COUNTY, NEW MEXICO

Christina L. Ferguson[1] and Keely E. Miltenberger[1]

[1]USGS-New Mexico Water Science Center, 6700 Edith Blvd NE, Albuquerque, NM, 87113, cryssferg83@gmail.com

The Snowy River calcite deposit within the Fort Stanton-Snowy River Cave System is unique. The source of the water that creates this 12-mile-long speleothem is not well understood. One way to better understand this source is to determine where the cave lies stratigraphically within the Permian San Andres Limestone. In the Fort Stanton area, the San Andres Limestone has four members: the Glorieta Sandstone, the Rio Bonito Member, the Bonney Canyon Member, and the Fourmile Draw Member. In the study area, the oldest and most prominent member, and the one that the cave is likely developed within, is the Rio Bonito Member. This member consists of alternating thin and thick beds of limestone which are variably fossiliferous, vuggy, and dolomitized. Some beds of limestone contain nodules of extremely dense, sometimes siliceous limestone; the distinct morphology of these nodules makes them easily recognizable in the formation. These same nodules may be seen in the Snowy River Passage portion of the cave at Independence Hall, and the identification, if confirmed, will aid in correlation of the stratigraphy outside of the cave with that inside the cave. Correlating the stratigraphy is an important step in understanding where water may be infiltrating to the subsurface. Another important step to understanding the Fort Stanton Cave system is understanding the geomorphic history of the cave and the sediments within it. In the Snowy River Passage, remnant clastic sediments cover the walls and lie beneath the Snowy River calcite layer. Pebbles and crossbedding within those sediments suggest a higher depositional energy than what is present today. These observations suggest that there may have been a subterranean stream in the Snowy River Passage, prior to precipitation of the Snowy River calcite, which has been dated to be approximately 830 years old. Work beginning in summer of 2022 will distinguish depositional packages of sediment, characterize sediment, and collect samples for optically stimulated luminescence age-dating.

THE FIRST RECORD OF THE RARE AMMONITE GENUS *MASIAPOSITES* IN THE UPPER CRETACEOUS (TURONIAN) OF NEW MEXICO

Michael P. Foley[1] and Spencer G. Lucas[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, *(submitting author)*

Masiaposites is a rare genus of Late Cretaceous ammonite, composed of two species that until now have only been described from deposits of Turonian age in Madagascar and Europe (e.g., Collignon, 1965; Amédro et al., 2016). We report a recently collected specimen of *Masiaposites* from the middle shale interval of the Juana Lopez Member of the Mancos Shale in Sandoval County, New Mexico. It was recovered from the *Coilopoceras inflatum* subzone in the upper part of the *Prionocyclus macombi* zone. The specimen is an incomplete but well preserved phragmocone with smooth, concave flanks, and a narrow, deep umbilicus. Diagnostic features of *Masiaposites* include the smooth carinate venter, the lack of ornamentation, and the rounded flanks that are swollen and convex around the umbilicus but concave to flat toward the shoulders. Initial comparisons reveal that our specimen shares more characteristics with the Madagascan species *M. carinatus* (Collignon, 1965) than with the European species *M. kennedyi* (Amédro and Devalque, 2014), but further study is needed to determine the species assignment of our specimen. The recently discovered specimen of *Masiaposites* is the first record of the genus in North America. It expands the Late Cretaceous paleogeographic range of the genus from Madagascar and western Europe to the Western Interior seaway.

References:

Amédro, F. and Devalque, C., 2014, Les Ammonites; *in* Robaszynski, F., Amédro, F., Devalque, C. and Matrion B., Le Turonien des massifs d'Uchaux et de la Cèze (S.E. France). Migration globale d'ammonites et conséquences sur la zonation internationale, rudistes et corrélations entre les massifs : Académie Royale de Belgique, Mémoires de la Classe des Sciences, Bruxelles, v. 2, 197 p.

Amédro, F., Robaszynsk,i F., Matrion, B. and Devalque, C., 2016, A North American ammonite fauna from the late Middle Turonian of Vaucluse and Gard, southern France: the *Romaniceras mexicanum*, *Prionocyclus hyatti* and *Coilopoceras* cf. *springeri* association: Acta Geologica Polonica, v. 66, p. 729 -736.

Collignon, M., 1965, Atlas des fossiles caracteristiques de Madagascar (Ammonites), XII (Turonien): Service Geologique, Tananarive, 82 p.

APPLYING SANDSTONE MODAL COMPOSITION AND *IMAGEJ* ANALYSIS TO CONSTRAIN FELDSPAR ALTERATION IN EARLY PERMIAN (WOLFCAMPIAN) NONMARINE STRATA IN NEW MEXICO

Justin Matthew Friend[1], Brian A. Hampton[1] and Alicia L. Bonar[2]

[1]Department of Geological Sciences, New Mexico State University, Las Cruces, NM, 88003, United States, jmfriend@nmsu.edu
[2]ConocoPhillips School of Geology and Geophysics, University of Oklahoma, Norman, OK, 73019, United States

Petrographic analysis of Early Permian, nonmarine strata of the Abo Formation (and equivalent strata) reveal a wide range in plagioclase and K-feldspar percentages and highly variable feldspar alteration trends throughout northern, central, and southern New Mexico. Sandstone modal composition trends show a significant decrease in detrital K-feldspar and increase in plagioclase as you compare percentages from northern (P=53%; K=47%), central (P=85%; K=15%), and southern New Mexico (P=97%; K=3%). In addition, elevated occurrences of diagenetic albite are in higher abundance in these strata in central and southern New Mexico compared to northern New Mexico.

Feldspar alteration is common during the diagenesis of felsic, arkosic sedimentary strata and often involves the process of sodium metasomatism associated with deep basin brines. At depth in a sedimentary basin, the onset of albitization of K-feldspar occurs at temperatures between 60–70°C (near depths of ~2500 m) when formation waters transition out of the stability field of K-feldspar and begin to approach the stability field of albite. At the basin surface and at shallower basin depths, evaporative concentration of salts in the groundwater of a closed basin will yield Na-rich brines that can react with detrital silicates to develop authigenic albite. In locations and basin conditions where felsic sedimentary strata react with available saline fluids, silt- and sand-size K-feldspar and plagioclase are partially-to-completely replaced by albite at a specific range of depth and temperature conditions in a basin. Feldspar can also undergo hydrothermal diagenesis that occurs in part during interaction of subsurface strata with magmatic systems and associated hydrothermal fluids.

In order to better constrain the extent and degree of feldspar alteration in Permian strata throughout New Mexico, data were collected from three field transects that were selected based on geologic and tectonic criteria that included (1) near and far from Laramide and Rio Grande rift structures, (2) near and far from shallow rift igneous systems, and (3) near and far from the Permian paleoshoreline and younger Permian evaporite strata throughout New Mexico.

In addition to applying traditional point-counting methods to determine standard detrital modes (e.g., Q-F-L, Qm-P-K, Lv-Lm-Ls), during the point-counting process, photomicrographs of all feldspar counts are collected in order to better isolate the degree and range of alteration in plagioclase and K-feldspar grains from each field locality. For this added approach, after completing a count for a sample, each feldspar photomicrograph is imported into *ImageJ* (Java-based image processing program) where the degree of alteration can be initially imaged and then quantified into a percent-of-alteration/grain value for each sample. Preliminary image analyses reveal a wide range of alteration in both plagioclase and K-feldspar from these strata.

The primary goal of this study is to constrain the extent and degree of feldspar alteration in Early Permian strata throughout New Mexico and observe whether trends are more regional and likely related to normal diagenesis, or whether trends are more isolated and focused in regions of high heat flow and near faults associated with the Rio Grande rift and/or Laramide orogeny in New Mexico.

ELUCIDATING THE STRUCTURAL GEOMETRY AND MAJOR FAULTS OF THE SAN MARCIAL BASIN, SOCORRO COUNTY, USING TOTAL BOUGUER GRAVITY ANOMALY DATA.

Kyle K. Gallant[1], Alex J. Rinehart[1], Daniel J. Koning[2] and Andrew P. Jochems[2]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Pl, Socorro, NM, 87801, kyle.gallant@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801

Gravity surveys are an effective way to aid in interpretation of subsurface bedrock variations in sedimentary basins. A gravity survey was conducted in the San Marcial basin, Socorro County, New Mexico over the summer of 2021 in order to clarify general basin geometry and structural complexities that could not otherwise be discerned by field mapping. The San Marcial basin was formed as part of the Rio Grande rift, which produced several extensional sedimentary basins from southern Colorado through New Mexico. In this study, approximately 100 new gravity measurements were tied to National Geospatial-Intelligence Agency (NGA) benchmarks. At each location, gravity and GPS measurements were taken, with GPS coordinates measured to a resolution of 10cm horizontal and 5cm vertical. Reviewing the processed data indicated two significant, linear-trending, terrain-corrected Bouguer gravity anomalies in the south-central and eastern part of the basin. The western anomaly is correlated to the down-to-the-east Black Hill fault, which strikes NW and forms fault scarps on select middle Pleistocene surfaces. The eastern anomaly is a pronounced west-down gravity gradient that strikes NNE, which we interpret as a west-down fault. This eastern anomaly, here named the Lava fault, coincides with a laid-back escarpment east of the Rio Grande. The Lava fault projects southwards to 5 km east of the northern end of the Fra Cristobal Mountains. To the north, it may possibly link with the Little San Pascual fault system immediately east of Mesa del Contadero. The lack of noteworthy footwall uplifts along either fault, especially when compared to the prominent Fra Cristobal Mountain footwall uplift on the Walnut Springs fault to the south, may be due to a northward partitioning of extensional strain from the Walnut Springs fault towards the Black Hill and Lava faults. The decreased displacement on either fault resulted in low vertical displacement rates that could not outpace long-term erosion rates or burial by sedimentation.

^{40}Ar/^{39}Ar Geochronology Near Rio Grande-Red River Confluence Reveal a Latir Volcanic Field Source for 4.5 to 1.2 Ma Fluvial Deposits and a <1.2 Ma Carving of the Taos Gorge

Jacob R. Gehrz[1], Matthew T. Heizler[1], Karl E. Karlstrom[2], Matthew J. Zimmerer[1] and Kevin M. Hobbs[1]

[1]New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, jacob.gehrz@student.nmt.edu
[2]Department of Earth and Planetary Sciences, University of New Mexico, 221 Yale Blvd NE, Albuquerque, NM, 87131

The Rio Grande, in conjunction with its associated landscapes, such as the Taos Gorge, provide an ideal environment to study important geomorphic processes that have shaped the region over the past 5 million years. ^{40}Ar/^{39}Ar geochronology of paleoriver deposits and lava flows can help test competing hypotheses for the evolution of the Rio Grande. Wells et al. (1987) suggest that the Ancestral Rio Grande had its headwaters in the modern Red River drainage until 600-300 ka. More recently, Machette et al. (2013) proposed that the upper Rio Grande was only integrated into its modern configuration following spillover of the Ancestral Lake Alamosa at ~400 ka. Repasch et al. (2017) hypothesize that the Ancestral Rio Grande was established as a through-going river at least as far south as the Socorro area by ~5 Ma, with headwaters both in the San Juan Volcanic Field (SJVF) and Latir Volcanic Field (LVF). Furthermore, Lake Alamosa spillover, and geomorphic resolution of other river-damming episodes related to Servilleta lava eruptions between about 4.5 and 2.5 Ma, represent reintegration of the Rio Grande.

^{40}Ar/^{39}Ar detrital sanidine (DS) geochronology yield maximum deposition ages (MDA) of river deposits, and lava geochronology bracket the age of river deposits between lavas. In addition, DS dates and associated K/Ca values yield sediment provenance that delineate source material derived from the SJVF versus the LVF. Published and new DS analysis on a river deposit collected between underlying 4.52 ± 0.20 Ma and overlying 3.57 ± 0.02 Ma Servilleta lavas near the confluence of the Rio Grande and Red River at La Junta Point show a dominance of dates between 26 and 20 Ma. Based on age and K/Ca values, this distribution correlates to a LVF source. The DS distribution did not reproduce published detrital zircon (DZ) data that had a significant 40–27 Ma mode; thought to be most consistent with detritus from the SJVF. A gravel deposit sample collected 1.3 km north of the confluence along the Rio Grande Gorge that overlies a 3.57 ± 0.02 Ma lava, yields a youngest single grain MDA of 1.21 ± 0.20 Ma and also contains a strong mode between 26 and 20 Ma. This current DS dataset supports a Red River headwaters for the Ancestral Rio Grande in this area between ~4 Ma and 1.2 Ma, but does not explain the published older DZ ages. Importantly, the DS-derived 1.21 Ma MDA for the gravel defining the present surface at La Junta Point indicates that the modern Taos Gorge formed after 1.21 Ma and constrains a minimum average river incision rate of ~230 m/Ma. The DS-derived timing for Taos Gorge carving is consistent with the Machette et al. (2013) estimate. Ongoing geochronology will further constrain the complex interplay of volcanism and Rio Grande drainage evolution in the iconic landscape of northern New Mexico and other comparable areas of global interest.

Connectivity and Rainfall-Runoff Relationships in Flashy Ephemeral Systems

Sandra Glasgo

New Mexico Tech, 507 6th St North A, Socorro, NM, 87801, sandra.glasgo@student.nmt.edu

In large river systems such as the Rio Grande, water delivery from ephemeral tributaries is difficult to quantify and track. In the Arroyo de los Pinos watershed (32 km^2) draining a variety of lithologies, we have been monitoring rainfall at five locations and discharge at 12-18 locations since 2018 to quantify flow patterns in ephemeral channel networks. These data allow for a better understanding of how the network connects across a range of rainfall intensities, magnitudes, spatial distributions, and storm track. These interactions are expected to control water and sediment delivery to the watershed outlet. Initial data support the prevailing understanding that the primary controls on local runoff generation are lithology, sub-basin size, and rainfall intensity. For monsoon storms that do not cover the full watershed, the lithology of the area experiencing rain largely controls whether runoff reaches the Rio Grande or becomes transmission loss.

Connectivity of a watershed describes how efficiently water and sediment are transmitted between geomorphic systems such as hillslopes and river networks. Flow generation is the primary indicator of the hydrologic connectivity or disconnectivity of a watershed and is controlled by the same factors – lithology, basin size, etc. Knowledge of the size and lithologies of the tributaries and sub-basins combined with the rainfall-runoff data will enable quantification of connectivity across scales. Analysis of three flood events with similar North-South storm track in the month of July 2021 illustrates the diversity of rainfall events and connectivity within the Arroyo de los Pinos.

Keywords:

Flash floods, Ephemeral, Rainfall, Runoff

ORIGIN OF ARCHAEOLOGICALLY SIGNIFICANT GRAVEL AND LAG DEPOSITS ON SOUTHWESTERN HORACE MESA, MOUNT TAYLOR REGION, NEW MEXICO

Fraser Goff[1] and M. Steven Shackley[2]

[1]Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, candf@swcp.com
[2]University of California Berkeley, Geoarchaeological XRF Laboratory, 8100 Wyonming Blvd NE, Albuquerque, NM, 87113

Previous and on-going archaeological investigations in and around Lobo Canyon in the Mount Taylor volcano region have identified an important source of obsidian nodules used by Puebloan and Pre-Puebloan inhabitants. The obsidian nodules are found in thin gravel and lag deposits 0-1.5 m thick on the top of the southwesterly part of the northern edge of Horace Mesa over a linear distance of roughly 2.5 km. The obsidian-bearing deposits (OBD) extend as much as 300 m south and east from the mesa edge and are partially traversed by Forest Service 193. The east portion of the OBD grades into and mixes with thicker, non-obsidian bearing volcaniclastic deposits that are shed from the Mount Taylor stratovolcano located 10 to 15 km to the east. The OBD overlie clinopyroxene-phyric basalt dated at 2.64 ±0.01 Ma on the west. In addition to obsidian, the OBD contain relatively aphyric devitrified rhyolite, rare chert and rare Precambrian crystalline fragments. Most of the OBD rocks are subangular to angular, and are poorly sorted. Nodule sizes generally vary from 1 to 10 cm; a few are larger. Outer surfaces of the nodules are moderately oxidized and some are slightly etched.

Obsidian in OBD is extremely aphyric and visually resembles obsidian lithic fragments in the upper ignimbrite of Grants Ridge (GR) rhyolite tuff. Previous work shows that GR obsidians (≥3.28 Ma) are chemically distinct and older than Mount Taylor rhyolites (≤3.03 Ma). We obtained a composite chemical analysis of cleaned and crushed obsidian nodules from the OBD and compared results with analyses of cleaned and crushed obsidian lithic fragments from two different locations in the upper GR ignimbrite. The three analyses are virtually identical in major and trace elements, and in contents of F and Cl (about 4700 and 720 ppm, respectively). Relatively high F and Cl concentrations are characteristic of rhyolite and obsidian from GR volcanics. We also compared the $^{40}Ar/^{39}Ar$ age of nodules in OBD to obsidian lithics in one of the upper GR ignimbrite locations. Three homogenized nodules from the OBD produced an age of 3.462 ±0.008 Ma whereas the GR obsidian lithics dated several years ago returned an age of 3.28 ±0.04 Ma. A sample of obsidian from the NE flank of GR rhyolite center yielded an age of 3.498 ±0.003 Ma (all ages recalculated using the FC-2 sanidine monitor age where necessary). However, the latter obsidian is different in texture than the others. The three dates suggest that the obsidians within OBD and GR deposits originated from GR rhyolitic volcanism over a span of ≤200 kyr. Present-day Lobo Canyon is 2225 m deep near GR rhyolite center, and is laterally separated from the OBD deposits on Horace Mesa (2440 m) by about 4 to 5 km. Because the OBD deposits overlie a young basalt flanking Lobo Canyon at Horace Mesa, we speculate that ≥215 m of volcanic and sedimentary rock was carved out of Lobo Canyon in the last 2.64 Myr.

Keywords:

Mount Taylor, Grants Ridge, Horace Mesa, obsidian, Geology, Geoarchaeology, geochemistry, Ar/Ar dating, landscape evolution

GEOLOGY OF THE CAMBRIAN-ORDOVICIAN LEMITAR CARBONATITES, SOCORRO COUNTY, NEW MEXICO: REVISITED

Ethan B. Haft[1], Virginia T. McLemore[2], O. Tapani RÃ¤mÃ¶[3] and Jonas Kaare-Rasmussen[4]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Pl, Socorro, NM, 87801, ethan.haft@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Pl, Socorro, NM, 87801
[3]Department of Geosciences and Geography, Geology and Geophysics Research Program, University of Helsinki, Finland
[4]Department of Earth Science, University of California, Santa Barbara, CA, 93106

Carbonatites are igneous rocks of magmatic origin that are composed of more than 50% carbonate minerals, less than 20% SiO_2, and they can form economic deposits containing significant amounts of rare earth elements (REE), barite (Ba), fluorite (F), and niobium (Nb). REE are critical minerals and are critical to the functioning of information-age technologies because of their unique properties, i.e., high electric conductivity, strong magnetism, fluorescence, and luminescence. Carbonatites are currently the principal source of REE in the world. Carbonatites in the Lemitar Mountains are light REE enriched and contain as much as ~1% total rare earth elements (TREE). While previously described, new analytical techniques have allowed for additional and more precise description, age, and model of their origin. The Lemitar carbonatites from both $^{40}Ar/^{39}Ar$ and U/Pb methods are ~515 Ma. Petrographic observations combined with whole-rock geochemical and isotope data indicate the Lemitar carbonatites are mantle-derived and related to the regional Cambrian-Ordovician belt of alkaline igneous rocks and carbonatites in southern Colorado and New Mexico. The Lemitar carbonatites are not economic at the present time because of small tonnage and low grades. However, drilling is required to determine if they increase in REE and Nb concentrations at depth (1.1% total REE in one sample is significant). Detailed geophysics are required to determine if the Lemitar Mountains could have a larger carbonatite emplaced in the subsurface.

Keywords:

Lemitar, carbonatite, carbonatites, silicocarbonatite, rare earth elements, REE, geology, Socorro county, New Mexico, Cambrian, Ordovician

A SIMPLE NUMERICAL MODEL OF THE RIO GRANDE RIFT EXTENSION: IMPLICATIONS ON SURFACE HYDROLOGY

Kyungdoe Han[1] and John Wilson[1]

[1]Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, kyungdoe.han@student.nmt.edu

Tectonic extension of the Earth's crust significantly alters the surface hydrology in the region by disorganizing the established connections. On the contrary, the extension also promotes the development of a new hydrologic regime by opening basins and providing topographic relief to the basins. The Rio Grande Rift (RGR) is an excellent example of an east-west tectonic extension with a large, modern axial river flowing through multiple basins, retaining the history of long-term hydrologic changes associated with the complex tectonic activities in the past. Dozens of references on the development of the gross architecture of the RGR recognized the history of the succession of the Rio Grande and its subbasins. However, there is less consensus on how surface hydrologic systems have responded to the tectonic movement in the RGR. Thus, we focus on surface hydrologic changes associated with rift tectonics and river incision. This study put forth an overarching goal: to reconstruct the history of surface hydrologic connections among basins in RGR during rift evolution. We created simple rift opening scenarios that model the Oligocene to Miocene opening of the RGR to the present. Here, we demonstrate the preliminary results of our modeling practices, and they will be further developed to reconstruct the history of hydrologic connectivity during both syn-tectonic and post-tectonic periods of the RGR.

GYPSUM SEDIMENTS IN LEHMAN CAVES, GREAT BASIN NATIONAL PARK, NV, USA.

Zoe E. Havlena[1], Daniel S. Jones[1], Louise D. Hose[2], Harvey R. DuChene[3], Amanda L. Labrado[4] and Benjamin Brunner[4]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Pl., Socorro, NM, 87801, zoe.havlena@student.nmt.edu
[2]Department of Geological Sciences and Engineering, University of Nevada-Reno, Reno, NV
[3]Karst Waters Institute, Lake City, CO
[4]Department of Earth, Environmental, and Resource Sciences, The University of Texas at El Paso, El Paso, TX

Lehman Caves is set in mylonitic marble in the Southern Snake Range of Eastern Nevada, USA, and is part of Great Basin National Park. Recent morphological evidence described by Hose et al.[1] indicate abundant features within the Gypsum Annex consistent with a hypogenic and sulfuric acid origin, in contrast with earlier and limited descriptions of the cave. Hose et al. propose a two-stage speleogenetic model with sulfuric acid speleogenesis (SAS) as the initial dissolution event followed by later stage epigenic overprinting in most of the cave. We sought to determine if sediments in the Gypsum Annex could be part of the proposed sulfuric acid origin versus a later-phase feature, and to compare these sediments to speleogenetic gypsum from other known SAS caves such as Carlsbad Cavern in New Mexico and the Frasassi Caves in Italy. We first characterized the mineralogy of the sediments throughout Lehman using powdered X-ray diffraction (pXRD) and, for select samples, scanning electron microscopy and energy dispersive X-ray spectroscopy (SEM-EDS). To determine if the white sediments (gypsum and calcite) found in the Gypsum Annex were related to an SAS phase or if they precipitated during a later phase of speleogenesis, we examined the $\delta^{34}S$ values of gypsum and carbonate associated sulfate. We then sought to determine if these sediments host microbial life and how they compare to microbial communities, which are observed in active SAS systems. Microbial biomass in most of the sediments is very low, although 16S rRNA gene libraries suggest segregation of microbial species within different passages of the cave, and that inorganic N compounds are important energy resources for extant cave communities. Petrographic analysis of thin sections, in progress, will be used to evaluate diagenetic processes in the white deposits and look for potential traces of past life

References:

1. **Hose, L.D.,** DuChene, H.R., Jones, D., Baker, G.M., Havlena, Z., Sweetkind, D., and Powell, D., 2021, Hypogenic karst of the Great Basin, *in* Florsheim, J., Koeberl, C., McKay, M.P., and Riggs, N., eds., 2021 GSA Section Meeting Guides: Geological Society of America Field Guide 61.

Keywords:

Caves, Nevada, Gypsum, Sulfuric Acid Speleogenesis

MULTIPLE MODES OF DEFORMATION IN FAULT ZONE JUXTAPOSING DISSIMILAR ROCK TYPES, SOUTHERN CHUPADERA MOUNTAINS, SOCORRO COUNTY, NEW MEXICO

Kevin M. Hobbs

NMBGMR, 801 Leroy Place, Socorro, NM, 87801, kevin.hobbs@nmt.edu

In the southernmost outcrop of pre-Quaternary rock in the Chupadera Mountains, Socorro County, New Mexico, a down-to-the-south normal fault is exposed in a bedrock quarry just east of New Mexico State Road 1. Physical characteristics of this fault zone grant insight into timing and methods of faulting in the San Marcial basin, a Rio Grande rift sub-basin that contains few fault outcrops. This quarry exposes silty sandstones of the Spears Group and the Andesite of Willow Springs, which are of similar upper Eocene age. The east wall of the quarry exposes the fault, where both the hanging and foot walls comprise andesite in a ~20 m-wide fault zone around a 1.5 m-wide fault core. Outcrop geometry suggests that the Spears Group sedimentary rocks are no more than ~10 m below the fault outcrop. Nearly all fractures in the fault zone are filled with cataclasized sediments showing physical and mineralogical similarities to the sedimentary rocks of the Spears Group. Cataclasites at the study site contain clasts with a smaller average diameter than the nearby Spear Group sediments, and microtextural observations suggest grain-to-grain comminution during faulting likely caused quartz spalling. While the majority of cataclasite in the fault zone appears to have been transported into fractures via particulate flow processes, interpreted here to represent faulting prior to lithification or during poorly-lithified conditions, the presence of angular clasts of sandstones within the fault zone also suggests that portions of the Spears Group also exhibited cohesive behavior during faulting, interpreted to represent relatively well-lithified sands. Other features in the fault zone include zones of oxide clast concentration within cataclasites and post-faulting calcite vein mineralization. Because the San Marcial basin lack a topographically-expressed uplifted footwall block or basin-bounding horsts, little is known about timing and styles of faulting during the basin's tectonic and sedimentary evolution. This fault is the most basin-central known fault in the San Marcial basin and therefore offers insight into increasing understanding of its tectonic history.

MICROBE-MINERAL INTERACTIONS IN CAVES

Daniel S. Jones[1], Diana E. Northup[2] and Penelope J. Boston[3]

[1]Earth and Environmental Science Department, New Mexico Institute of Mining and Technology, and National Cave and Karst Research Institute, Socorro, NM, 87801, daniel.s.jones@nmt.edu
[2]Department of Biology, University of New Mexico, Albuquerque, NM, 87131
[3]Earth and Environmental Science Department, New Mexico Institute of Mining and Technology, and NASA Ames Research Center, Socorro, NM

Microorganisms are crucial catalysts for elemental cycling in most of Earth's environments, and caves are no exception. Because photosynthesis is limited to the entrance and twilight zones, cave ecosystems either depend on allochthonous inputs of surface organics, or primary production by chemosynthetic microorganisms that can take advantage of in situ mineral resources or other energy-rich inorganic compounds. These microorganisms are geological agents that can contribute to cave formation by producing acids and corroding bedrock. In other cases, microorganisms form secondary mineral deposits by catalyzing metal oxidation, creating sulfate precipitates, and inducing carbonate precipitation. Further complicating analysis, mineral precipitation can also be nucleated passively on microbial communities, even sometimes forming on dead organisms. In this presentation, we will review energy resources for cave life, highlight the diversity of microbial habitats within caves, and describe case studies in which microorganisms play direct roles in limestone corrosion and speleothem formation in order to provide context for the microbial interactions with sulfur, iron, and manganese minerals that occur in Fort Stanton Cave. Caves are windows through which we can study the ubiquitous and globally distributed subterranean microbiota that not only play an active role in the evolution of karst, but in subsurface environments across the globe.

Sulfuric Acid Speleogenesis in the Frasassi Cave System, Italy, and Possible Implications for Guadalupe Mountain Caves

Daniel S. Jones

Earth and Environmental Science Department, New Mexico Institute of Mining and Technology, and National Cave and Karst Research Institute, Socorro, NM, 87801, daniel.s.jones@nmt.edu

Cave formation by sulfuric acid, known as "sulfuric acid speleogenesis," is responsible for some of the world's largest and most spectacular caves. In actively forming caves, sulfuric acid is produced at the water table where anoxic, hydrogen sulfide (H_2S)-rich groundwaters are exposed to oxygen, usually in fresh surface waters or cave air. Because sulfide oxidation represents a rich source of chemical energy, sulfuric acid caves support robust communities of chemosynthetic microorganisms that speed up acid production and limestone dissolution, and support entire sulfide-based ecosystems that include invertebrate and sometimes even vertebrate life. Although they are rare, these "active" sulfuric acid caves are important analogues that allow us to directly observe the processes responsible for ancient sulfuric acid caves, such as those that occurred in New Mexico's Guadalupe Mountains between 4-12 million years ago. My talk will focus on the the Frasassi cave system in central Italy, a spectacular example of an active sulfuric acid cave. I will discuss biogeochemical sulfur cycling at the cave water table, the role of microorganisms in inorganic sulfur transformation and limestone dissolution, and how the secondary minerals and passage morphologies are overprinted as cave levels are removed from the sulfidic aquifer through tectonic uplift.

AUDIO-MAGNETOTELLURIC AND TRANSIENT-ELECTROMAGNETIC INVESTIGATION OF THE SALT BASIN, SOUTH-CENTRAL NEW MEXICO

Shari Kelley

New Mexico Bureau of Geology & Mineral Resources, New Mexico Tech, Socorro, NM, 87801, shari.kelley@nmt.edu

As part of an extensive study of the groundwater resources in the Salt Basin in south-central New Mexico, geophysical surveys that measure both natural and induced electrical and magnetic signals were used to explore the subsurface of the region. Audio-magnetotelluric (AMT) data were collected at twenty eight sites in the study area. The AMT technique utilizes naturally-occurring electromagnetic waves generated by lightning (high frequency) and the interaction of solar winds with the Earth's magnetosphere (low frequency). Transient electromagnetic (TEM) data was collected at twelve sites. The TEM method measures the electrical resistivity of the subsurface using an applied current. The subsurface resistivity measured by both methods is affected by rock type, porosity, and groundwater salinity. Saline water, clays, and mineralized rocks conduct electric currents well (i.e., are conductive), whereas fresh water, dry anhydrite, and bedrock with little permeability or porosity are poor conductors (i.e., are resistive). The study was focused on Crow Flats and Otero Mesa in New Mexico. Crow Flats is underlain by gypsum-rich playa deposits. The water table is close to the surface and both the AMT and TEM data indicate that the shallow groundwater is conductive, consistent with the high total dissolved solids (TDS) content of the groundwater measured during previous water-quality studies. The geologic and hydrologic interpretation of the AMT data from Otero Mesa was more challenging because, as mentioned above, many factors besides TDS affect the resistivity of the subsurface. The data indicate that limestone in the shallow subsurface (<300 m) is resistive and probably contains fresh water. The interpretation is trickier at depths below 300 m, where at many sites, a conductive zone is recorded in the AMT data. The conductive zone could be associated with a clay-rich rock type (i.e., the Abo Formation) or brackish water. Luckily, several oil wells have been drilled in the Salt Basin and geophysical well logs and rock cuttings from those wells are on file at the New Mexico Bureau of Geology and Mineral Resources. Careful examination of the logs and cuttings revealed that in some instances, the conductive zone correlates nicely with the Abo Formation. However, in other cases, the conductive zone is in the overlying Yeso Formation, a unit that contains anhydrite, which is not conductive unless the calcium sulfate goes into solution. Thus, using evidence derived from the oil wells and AMT data, we hypothesize that brackish aquifers can be identified in the Yeso Formation using this combined approach. This investigation was reconnaissance in nature; the AMT sites were scattered over an area of about 250 km^2. Given the encouraging results, the next step is to conduct more focused experiments near the oil wells to test the interpretation.

Keywords:

Salt Basin, audio-magnetotelluric, transient electromagnetic, subsurface

SANTA FE GROUP AQUIFER INVESTIGATIONS IN THE NORTHWESTERN ALBUQUERQUE BASIN, NEW MEXICO

Daniel J. Koning[1], Amanda Doherty[1], Ethan Mamer[1] and Laila Sturgis[1]

[1]New Mexico Bureau of Geology & Mineral Resources, New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801, dan.koning@nmt.edu

In order to better understand and manage their groundwater, the City of Rio Rancho funded a study to: 1) map the 3D distribution of the Santa Fe Group aquifer, including internal hydrostratigraphic units, in the northwestern Albuquerque Basin, and 2) assess permeability differences within and between hydrostratigraphic units in the aquifer. An ancillary goal was to assess spatial trends of TDS and radiocarbon ages. Four stratigraphic units were recognized based on their texture and composition which were inferred to possess unique hydrogeologic properties: the Upper Rio Rancho (URR), Middle Rio Rancho (MRR), Lower Rio Rancho (LRR), and Zia hydrostratigraphic units (HSUs). Contacts separating these units are exposed on the land surface north and west of Rio Rancho. These contacts were projected into the subsurface, guided by subsurface picks in well data (made using geophysical logs and archived cuttings), via drawing of structural contours in ArcMAP. Structural contours were also digitally drawn for dipping fault planes of major faults (with >100 m vertical offset). Gridded raster files were created with the ArcGIS tool called Topo to Raster, where the inputs were the structural contours and the elevations of the picked contacts in wells. Isopach maps for each HSU were made by subtracting the top and base of a given HSU. A visualization of the 3D model was rendered in ArcScene using the gridded raster surfaces and fault structural contours. We also created 2D images that display geologic features of the model in an intuitive format. To further aid visualization of the Santa Fe Group aquifer, we made a 3D block model using two orthogonal cross sections and a Google Earth-derived land surface.

All four HSUs thicken to the southeast, and are slightly thicker northward between the Zia and Coronado fault zones. The URR and MRR HSUs thin over a north-trending Ziana horst. Correlating hydraulic pump-test data with HSU (based on screened depths of a given well) indicate that the URR and possibly LRR have higher permeabilities (by a factor of 2-3) compared to the MRR. However, the extent and relatively large saturated thickness of the MRR means it plays an important role in providing groundwater for the City. Available pumping test data suggest that hydraulic conductivities in the MRR are slightly higher in the southwest part of the study area, perhaps due to the proportionally high sand bedload of the Benevidez Member of the Cerro Conejo Formation, but more well data are needed to confirm this apparent lateral trend.

The youngest C-14 values in the groundwater are found to the east, near the Rio Grande, in the URR. The highest TDS values are found in the LRR HSU on or immediately adjacent to the Ziana horst, consistent with earlier hydrogeologic studies by Glorieta Geoscience Inc. Fault zones bounding the Ziana horst may be conduits for expelling poor-quality water from fractured bedrock at depth, and the structurally high, relatively permeable LRR may act as a pathway in transmitting this lower-quality water southwards into the study area.

Keywords:

Albuquerque basin, aquifer, Rio Rancho, Santa Fe Group, model, hydrostratigraphic units

Photogrammetric Analysis of the Clayton Lake Dinosaur Tracksite, Early Cretaceous of Northeastern New Mexico

Michael A. Kvasnak[1], John B. Rogers[2] and Spencer G. Lucas[3]

[1]Central New Mexico Community College, 900 University Blvd. SE, Albuquerque, NM, 87106, mkvasnak@cnm.edu
[2] 900 University Blvd. SE
[3]New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM, 87104

At the NMGS Spring Meeting in April of 2021, our CNM/NMMNH team made a presentation on the use of drones to aid in the collection of paleontological data. Our specific project was to collect data on the Early Cretaceous dinosaur tracksite at Clayton Lake, NM. At the time of the 2021 Spring Meeting, the data had been collected, but processing of the dataset had just begun. Those data consist of 3,632 files containing 29.9 gigabytes of terrestrial and drone imagery. Pix4D, the leading photogrammetry software for professional drone mapping, was used to create three-dimensional computer models in fbx format. Processing was time consuming; for example, "terrestrial" images, taken by camera to produce 3-D models of individual tracks and other features, took 12-20 hours of computer processing per model. The processing resulted in an additional 1.9 gigabytes of data in 32 files. As of the Spring Meeting in 2022, all of the data have been processed, and we can present the results. The photogrammetric data have been used to create a map/orthophoto of the tracksite with mm-scale contours that can serve as a baseline for future management and monitoring of tracksite changes due to erosion and weathering. The fine-scaled imagery allows a variety of metric analyses of the tracksite to be undertaken to evaluate the taphonomic history and dynamics of the tracks. Approximately 533 dinosaur tracks have been identified and documented. Of these, 182 can be grouped into 28 trackways. For these trackways we can estimate the hip height, speed, and bearing of the trackmaker. The photogrammetric data also reveal the complexity and defects of the Clayton Lake dinosaur tracks, which represent multiple episodes of footprint formation on substrates of diverse viscosity so that track quality is relatively low, and there is extensive extramorphological variation of the tracks. The photogrammetric data and the resulting maps and models of the tracks allow for detailed exploration and analysis directly on the researchers' computers in their offices. However, some very fine details, specifically tracks with positives and tracks that have been trampled over, are difficult or impossible to see in the contour data. For these details several on-site visits were conducted to the tracksite to verify the map and anchor the detailed analysis of the trackmakers' hip heights, speed, and bearing of movement.

References:

Kvasnak, M. et al., 2021, Clayton Lake Dinosaur Tracksite Project: Paleontology by Drone, NMGS Spring Meeting 2021

Rogers, J. et al., 2022, Preliminary Estimates of Dinosaur Size and Speed at the Early Cretaceous Clayton Lake Dinosaur Tracksite, Union County, New Mexico, NMGS Spring Meeting 2022

FORT STANTON CAVE AND THE NORTHERN SACRAMENTO MOUNTAINS: REGIONAL GEOLOGIC AND HYDROLOGIC CONTEXT

Lewis Land

National Cave and Karst Research Institute, 1015 Tijeras Ave NW, suite 200, Albuquerque, NM, 87102, United States, lland@nckri.org

Fort Stanton Cave, located in the northern Sacramento Mountains of south-central New Mexico, is formed in the middle Permian San Andres limestone. The cave is situated on the west flank of the Mescalero Arch, a broad structural divide separating the gently dipping eastern slopes of the mountains from structurally low areas of the Tularosa and Sierra Blanca Basins to the west. Fort Stanton Cave is located downgradient from extensive outcrops of siliciclastic sedimentary rocks as well as igneous and volcanic rock exposed at higher elevations in the Sierra Blanca Basin. This complex geologic setting results in surface drainage systems that originate on non-carbonate bedrock and are thus probably undersaturated with respect to calcium carbonate, making downstream dissolution and cave formation more likely. Evidence of both accretionary and dissolutional processes are widespread in the region. Tufa mounds associated with active and relict springs are a common feature in the southern Sacramentos. The most distinctive accretionary feature in Fort Stanton Cave is the Snowy River formation, a pool deposit composed of white calcite that coats the floor of the Snowy River passage, and currently extends >17 km with its southern terminus still undefined. Core samples collected from the Snowy River deposit reveal a laminated internal structure, indicating episodic deposition of sub-millimeter scale calcite laminae during periods when the passage stream is activated. The age of the basal layer has been determined to be only 820 years old, suggesting an abrupt change in climatic or hydrochemical conditions within the past millennium. The origin of water flow in the Snowy River passage is unknown, but appears to be associated with extreme summer precipitation events or heavy winter snowfall in the northern Sacramento Mountains. Field observations and hydrograph records support a point source or sources for water in the Snowy River passage via sinkholes or losing streams upgradient from the southwesternmost mapped stations in the cave.

USING ELECTRICAL RESISTIVITY METHODS TO MAP CAVE PASSAGES AND CONDUITS IN THE SAN SOLOMON SPRINGS KARSTIC AQUIFER SYSTEM, WEST TEXAS, USA

Lewis Land[1] and George Veni[1]

[1]National Cave & Karst Research Institute, 1015 Tijeras Ave. NW, suite 200, Albuquerque, NM, 87102, United States, lland@nckri.org

Personnel with the National Cave and Karst Research Institute have conducted a series of electrical resistivity (ER) surveys over and beyond mapped portions of Phantom Lake Spring Cave, currently the deepest underwater cave in the United States, and one component of the San Solomon Springs group, a network of karstic springs in far west Texas. Most of the cave is partially or completely flooded with brackish water, and displays on ER profiles as a zone of low electrical resistivity. ER surveys show electrically conductive zones indicative of a flooded conduit more than 400 m beyond the farthest downgradient station in the mapped portion of the cave. A dye trace study conducted in 2013 indicates that water in Phantom Lake Spring Cave flows at a rate of ~1000 m/day through conduits formed in Cretaceous limestone, eventually discharging from San Solomon Spring at Balmorhea State Park, six kilometers east of the cave entrance. Low resistivity anomalies identified on ER surveys conducted west and east of the park probably represent those flooded karstic conduits, supporting the hydrologic link between Phantom Lake Spring Cave and San Solomon Spring.

A NEW SPECIMEN OF THE EUBAENINE TURTLE *GOLEREMYS MCKENNAI* FROM THE PALEOCENE NACIMIENTO FORMATION OF NORTHWESTERN NEW MEXICO

Asher Jacob Lichtig[1] and Spencer G. Lucas[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Rd. NW, Albuquerque, NM, 87124, ajlichtig@gmail.com

A skull and associated postcrania found in the Paleocene Nacimiento Formation are the first specimensof the eubaenine turtle *Goleremys mckennai* identified east of the Sierra Nevada Mountains. The skull of NMMNH (New Mexico Museum of Natural History) P-9067 is from the Torrejonian, in the West flank of Torrejon Wash. It matches the diagnostic characters listed by Hutchison (2004) for the taxon, including the moiety or divide between the triturating surfaces growing larger posteriorly, a short unconstructed rostrum and the jugal restricted to the posterior of the orbit. Conversely, the nasal may be slightly separated from the maxilla or just barely touching, and this is likely individual variation. In addition, NMMNH P-9067 has the small triangular parietals added to the diagnosis in Joyce and Lyson's revision of the taxon. The right mandible is superficially similar to that of *Neurankylus torrejonensis*, but shorter and with an anteriorly widening triturating surface. The associated postcrania give the first look at this animal's forelimbs and carapace. The carapace is thick and fully fused, indicating this was an adult individual. This animal is likely aquatic as other baenids are inferred to be. Interestingly, the posteriorly widening moiety resembles those of the extant *Trachemys scripta*, which contribute to the flexible diet of these turtles. Thus, we infer that *Goleremys* may have had a similarly diverse tolerance for varied food sources. This could contribute to its wide geographic range as it is the only baenid known west of the Sierra Nevada Mountains.

References:

Hutchison, J. H. 2004. A new eubaenine, Goleremys mckennai, gen. et sp. n.,(Baenidae: Testudines) from the Paleocene of California.Bulletin of the Carnegie Museum of Natural History 36:91–96.

Joyce, W. G. and Lyson, T. R., 2015, A review of the fossil record of turtles of the clade Baenidae. Bulletin of the Peabody Museum of Natural History, v. *56*(2), p. 147-183.

THE PLATYSTERNID TURTLE *CARDICHELYON* FROM THE PALEOCENE NACIMIENTO FORMATION, NEW MEXICO, USA

Asher Jacob Lichtig[1] and Spencer G. Lucas[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Rd. NW, Albuquerque, NM, 87124, ajlichtig@gmail.com

New specimens, including a complete skull and limb material, from the Paleocene Nacimiento Formation, San Juan Basin, New Mexico, extend our knowledge of the morphology of the platysternid turtle *Cardichelyon*. This skull is very similar to that of extant *Platysternon megacephalum* though smaller relative to the size of the carapace. Similarities to *Platysternon* include: skull is about as long as wide with a pronounced hook, forward placed orbits and broad and thick parietals. The broad triturating surfaces may indicate a relatively durophagus diet, which, combined with the hook, leads to the inference that *Cardichelyon* consumed motile invertebrates. This skull adds to the evidence that a platysternid turtle distinct from emydids and other testudinoids existed in North America in the early Paleocene. This suggests that the split of tesugirids from emydids and platysternids must have happened during or before the early Paleocene, perhaps as far back as the Cretaceous. Combined with another new specimen that appears to be emydid like from the Late Cretaceous (Campanian) Fruitland Formation, we suggest that emydids and platysternids were present in North America relatively early compared to the testugurid clade, which is not known before the Eocene. We speculate that this may indicate that the emydid-platysternid from testugurid split was the result of a vicariant split of testudinoids between North America and Asia, with each group originating on the respective landmass.

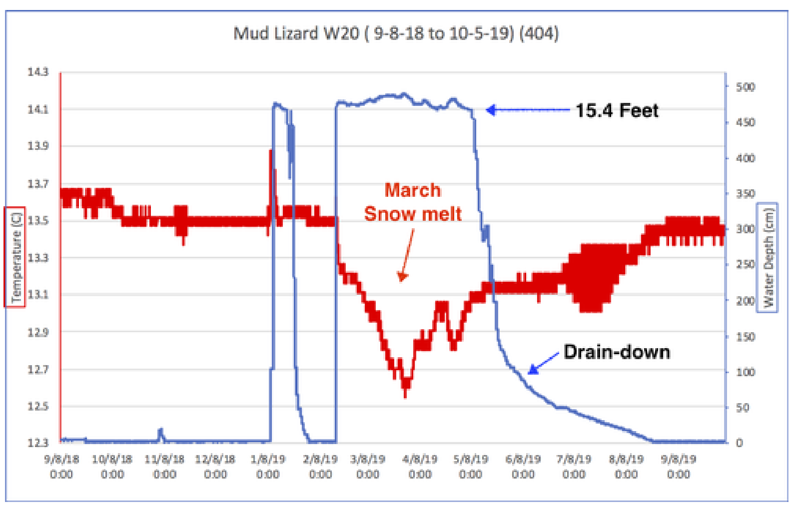
A DECADE OF DATA LOGGING IN FORT STANTON CAVE AND SNOWY RIVER

Pete Lindsley

Fort Stanton Cave Study Project, 1 Whispering Winds Trail, Placitas, NM, 87043-8861, caverpete@gmail.com

Snowy River Passage in Fort Stanton Cave was discovered in 2001, and would extend the known passages another 8 miles towards the Sierra Blanca peak, 20 miles to the southwest. The 1 cfs intermittent flow of Snowy River created a unique white calcite deposit along its sinuous route. To better understand the source of this intermittent flow, multiple data loggers were deployed by 4-member exploration teams to sites that are over 11 miles from daylight. This presentation summarizes the data logging effort and gives an example of the data being obtained, such as that in the example figure. This "Mud Lizard" site shows that starting in January 2019, the water flow created a 15-foot deep sump in a passage only 4-feet high for about 3 weeks. Two weeks later the passage again sumped for another 5 months before slowly draining back to an air-filled passage. Temperature data suggests the 2nd flow was due to snow melt on Sierra Blanca.

A summary of the equipment and site requirements is presented with map information showing the complexity of this study. Continuing studies are now focused on correlating discharge measurement sites that are not accessible during Snowy River flows, as well as establishing selected surface sites that will become part of future analyses that will relate the flows to unpredictable weather on the surface above the exploration teams. The area hydrology includes springs and three surface streams with intermittent flows. Exploration continues. Additional data is available at [http://fscsp.org/data_logger_sites.html].



References:

Lindsley, P., 2011, *Snowy River Water Flow*, Unpublished paper by Fort Stanton Cave Study Project, June 7, 2011, 15 pp.

Lindsley, P., 2022, *A Decade of Data Logging in Fort Stanton Cave and Snowy River*, Fort Stanton Cave Study Project, Special Report, March 30, 2021, 139 pp.

Keywords:

Fort Stanton Cave, Snowy River, hydrology, data loggers, flow timing, depth and temperature

3-D MODELING OF FORT STANTON CAVE USING MAPS, LIDAR, PHOTOGRAMMETRY, AND GAMING ENGINES

Ronald J. Lipinski

Fort Stanton Cave Study Project, 12904 Manitoba Dr NE, Albuquerque, NM, 87111, rjlipin@msn.com

A half mile of Fort Stanton Cave's Snowy River has been modeled in 3-D using Lidar point clouds to define the walls and photos of the floor, wall and ceiling along that entire length to map onto the wall mesh. The Unity gaming engine was used to allow easy exploration and inspection of this 3-D model on a PC, Mac, or Linux computer, either as a first-person viewer, or as an avatar. This tool (Caver Quest) is available for free on the Fort Stanton Cave Study Project web site (www.FSCSP.org).

The half mile of Snowy River in Caver Quest also has been deployed to the Meta Quest 2 virtual reality headset ("Caver Trek: Snowy River"). This highly-immersive tool allows for more detailed inspection of this section of the cave. A Quest 2 headset will be available at the conference for experiencing this simulation.

An additional four miles of passage in the historic section of the cave has been modeled with lidar-determined walls in Caver Quest. To reduce the file size, generic wall textures from photos in the local area are used instead of actual photos along the entire seven-mile stretch. Caver Quest can be used to familiarize researchers with the structure of the cave and estimate travel times to distant locations for sampling.

Keywords:

3-D Model, Virtual Reality, Snowy River

PENNSYLVANIAN STRATIGRAPHIC ARCHITECTURE, LITHOSTRATIGRAPHY AND TECTONISM IN NEW MEXICO

Spencer G. Lucas[1] and Karl Krainer[2]

[1]New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, spencer.lucas@state.nm.us
[2]Institute of Geology, Innsbruck University, Innsbruck, A-6020, Austria

Pennsylvanian strata are present on the surface and in the subsurface across most of New Mexico and can be divided into two broad lithosomes. The northern lithosome crops out across much of northern and central New Mexico and has an overall three part stratigraphic architecture of: (1) a basal, siliciclastic-dominated unit, which includes quartzose, coarse-grained sandstone and conglomerate of Morrowan (locally), Atokan (mostly) and early Desmoinesian (locally) age, the Sandia, Red House and Gobbler formations; (2) a medial, limestone-dominated, apparently cyclical unit with very few coarse-grained siliciclastic intercalations, the Porvenir Formation and the Gray Mesa Formation (= Nakaye Formation, = most of the Lead Camp Limestone, = Bug Scuffle Member of Gobbler Formation), primarily of Desmoinesian age; and (3) an upper interval of mixed siliciclastic and carbonate strata, including various beds of coarse-grained clastics, of late Desmoinesian-Virgilian age, the Alamitos, Atrasado, Bar-B, Beeman and Holder formations. This three part architecture is not evident in the Pennsylvanian strata of southern New Mexico, which are cyclically bedded (apparently) limestone with calcareous shale interbeds and lack any significant coarse-grained siliciclastic intercalations. Age data (primarily from fusulinids) indicate that these strata encompass essentially all of Pennsylvanian time where they are thick and well exposed, as in the Big Hatchet Mountains of Hidalgo County. Thus, these southern New Mexico strata are broadly equivalent temporally to the northern strata. We assign the southern lithosome strata to the Horquilla Formation because the type Horquilla Formation of southeastern Arizona is of similar lithology—limestone dominated, few coarse-grained clastic beds--and it is correlative based on fusulinid biostratigraphy.

In a simple sense, we can thus view the Pennsylvanian strata of New Mexico as comprising two lithosomes, a northern New Mexico lithosome with coarse-grained clastic beds in its lower and upper strata, and a southern New Mexico lithosome almost entirely made of limestone with very few coarse-grained siliciclastic beds. The northern lithosome crops out as far south as the Black Range, Caballo Mountains and Derry Hills of Sierra County and in the Sacramento Mountains of Otero County. It reflects Ancestral Rocky Mountain tectonics with the local onset of tectonic movements in late Morrowan-Atokan time, and a second interval of elevated tectonism during the Late Pennsylvanian. Glacio-eustasy was a minor driver of deposition of the northern lithosome, whereas it was a more important driver of the cyclically bedded Horquilla strata of southern New Mexico that were evidently deposited with less influence from local/regional tectonism.

THE EOCENE BACA FORMATION, WEST-CENTRAL NEW MEXICO, WAS NOT DEPOSITED IN A LAKE

Spencer G. Lucas[1] and Lawrence H. Tanner[2]

[1]New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, spencer.lucas@state.nm.us
[2]Department of Biological Sciences, LeMoyne College, Syracuse, NY, 13214

Strata of the Baca Formation in west-central and south-central New Mexico are Eocene siliciclastic strata deposited late in the Laramide orogeny. Although initially described as fluvial deposits in the 1970s, in the 1980s Baca deposition was reinterpreted as having taken place in a closed lake basin, a conclusion not questioned since. A re-evaluation of Baca sedimentation, however, indicates no evidence for deposition in a lake basin but instead in a fluvial system that flowed to the east.

Previous interpretations of Baca deposition as lacustrine identified Gilbert deltas, lacustrine mudrock, extremely thick Baca strata near the lake basin center (Gallinas-Bear mountains) with paleoflow from the east draining off of a Laramide Sierra uplift. None of these conclusions stands up to a critical re-evaluation.

So-called Gilbert delta deposits in the Baca Formation are alluvial deposits consisting of fluvial channel and floodplain deposits. Fluvial channel geometry consists of single- to multi-storey channels with flat to heavily scoured bases, locally with abundant mudstone rip-up lag deposits. Individual storeys display multiple beds of planar to trough cross-bedded and plane-bedded sandstone.

Baca mudstones mostly display evidence of pedogenesis to varying degrees. Where the mudstones are well exposed, they are gray to red, commonly mottled, with wedge to blocky peds with well-developed clay cutans on the ped surfaces, or crumb fabric in places. Root traces are common, sometimes but not always drab. Good mudstone exposures at Dog Springs Canyon in the Gallinas Mountains include paleosol profiles with clear A and B horizons and silty mudstone near the top with prominent drab root traces and blocky fabric. Exposures in the Bear Mountains, supposedly at/near the lake center, display mature calcretes with partially to fully coalesced nodular ledges (Bk horizons) with flat upper surfaces and gradational lower boundaries in which nodule size and frequency decrease downward. Clearly, the bulk of the mudstones record deposition on an alluvial plain subject to vegetation and pedogenesis. Deposits of laminated and organic-rich mudstones occur locally, but these have limited vertical and lateral distribution. Hence, we interpret these as evidence of local ponding on the alluvial plain.

Maximum Baca thickness on outcrop is about 354 m, though average thickness is 150-200 m, much less than the 520 m thickness claimed near the basin center. Paleoflow of Baca rivers from the east was based on a small set of crossbed measurements in the Bear Mountains that, when combined with additional paleoflow measurements (e.g., gravel imbrication), do not indicate westward paleoflow.

As concluded in the 1970s, Baca deposition took place in a fluvial system that flowed east, not in a closed basin with flow into a lake near the basin center. This re-evaluation of Baca sedimentation also calls into question the existence of a Laramide Sierra uplift and of a Laramide Carthage-La Joya basin.

SEDIMENT TRANSPORT IN EPHEMERAL CHANNELS: VALIDATION OF PHYSICS-BASED MODEL AND DEVELOPMENT OF DATA-DRIVEN MODEL

Loc Luong[1], Daniel Cadol[1], Susan Bilek[1] and John Mitchell McLaughlin[1]

[1]New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801, loc.luong@student.nmt.edu

Quantitatively understanding fluvial sediment movement has been an important topic studied for nearly a century. Notably, quantifying the sediment driven by flood events in ephemeral channels is notoriously difficult because of the scarcity, irregular nature, and high intensity of flash floods. Due to practical limitations of directly measuring sediment flux in rivers, there needs to be a method to evaluate sediment flux indirectly and continuously. Acoustic and seismic methods arise as promising techniques for tackling such problems.

The Arroyo de Los Pinos is one of the few monitoring stations where sediment and water flow are monitored using a variety of instrumentation. We deployed three Reid-type slot samplers for direct bedload measurement in 2018, in conjunction with pipe-microphones imbedded in the channel that record sediment impacts just upstream of the samplers, and pressure transducers that record flow depth. Four broadband seismic stations we installed in 2019. Over 70 nodal seismometers (compact, all-in-one seismic sensors) are deployed along the channel banks every monsoon season. And in 2020, we deployed two hydrophones to record the acoustic signals within the water column. This combination of direct and surrogate methods will help us understand the movement of sediment better, validate existing sediment transport models, and develop new frameworks of data- driven models. Recently, some physical models have been proposed in the literature to relate the sediment flux to seismic power and acoustic noise. Data collected from every monsoon season will be used to validate these existing models and potentially improve them.

The purpose of this research is to continue operating the Arroyo de Los Pinos station to effectively collect the data for the 2022 monsoon season. This requires a huge effort from a team of graduate and undergraduate students. High-quality data collected will then be used to validate Tsai et al. 's model, a physical model for seismic noise generation from sediment transportation. As part of this research, a data-driven sediment transport model will be developed based on our seismic and hydrologic data using machine learning techniques. The goal is to be able to deploy a seismic node and a pressure transducer at any channel, and to use the resulting data with our model to accurately estimate bedload transport during that time. In addition to that, data recorded from the monitoring site will enable government agencies to improve their modeling and forecasting efforts in the Middle Rio Grande region, as well as elsewhere in dry and semi-arid regions. Validation of physical models and development of data-driven models with the data obtained from the station is expected to advance the understanding of sediment transportation, river morphology and dynamics.

References:

Gimbert, Florent, Victor C. Tsai, and Michael P. Lamb. "A physical model for seismic noise generation by turbulent flow in rivers." *Journal of Geophysical Research: Earth Surface*119, no. 10 (2014): 2209-2238.

Tsai, Victor C., Brent Minchew, Michael P. Lamb, and Jean?Paul Ampuero. "A physical model for seismic noise generation from sediment transport in rivers." *Geophysical Research Letters* 39, no. 2 (2012).

SNOWY RIVER'S SECOND DECADE: CHAOS PREVAILS

John T. M. Lyles

PO Box 95, Los Alamos, NM, 87544, jtml@vla.com

By 2012 the growing upstream Snowy River trend had doubled Fort Stanton Cave's length with 15.58 miles of surveyed passages. It continued south following a general bearing of 220 degrees, and at eight miles from the entrance cavers encountered a lengthy difficult region covered in collapsed breakdown that was named Rough Country. This required changing from clean Snowy River attire into dirty gear. Finger Lake provided the first drinking water on Snowy River. Survey teams were vetted from experienced cavers with requisite stamina as they traveled these long distances with ultra-light gear, earning the moniker "strong and light" cavers. During a burst of activity from 2012-2014 they found a complex of passages off Snowy River. A major infeeder from the southeast was discovered at Midnight Junction, ten miles from the entrance. New chambers decorated with speleothems were found and names such as Harmony Hall, Velvet Underground, No Cave for Old Men, Red Velvet Passage, La Culebra Passage and Borderlands were added to the complex cave development near the southern frontier. This added 15.3 additional miles to the length of the cave. Just when the going was good, a multi-year flood began that prevented further upstream exploration. This allowed focus on other projects including digs at promising surface prospects as well as inside Fort Stanton Cave. A resurvey of much of the historic part of the cave was underway. By 2018 the timing of drier periods coincided with the summer and fall expeditions, but flooding remained further upstream. A team returned to Rough Country to discover Alchemy Canyon while establishing a second camp in the cave. A new interest in climbs out of middle Snowy River intersected upper paleo passages, essentially parallel routes trending NE to SW that intersect Snowy River. The longest of these, Bliss, rejoined Snowy River at Rough Country, three miles away from the starting climb. The last major breakout started in the same development of Bliss, but meandered the opposite direction towards the historic cave. Cavers found an astounding complex of passages starting with Gold Rush, followed by a tight crawl through Donner Pass to Cripple Creek, Scorched Earth and Capitan Caverns. Gypsum beards, directional aragonite bushes and significant dripstone were discovered in this series of boreholes. The terminus is only hundreds of feet beyond an airy breakdown pile in Lincoln Caverns in the historic part of the cave. This near connection resolved the mystery of this blowing passage. Teams continue to make significant discoveries, while survey trips have increased in difficulty. Camps are established in several locations to improve safety and productivity of exploration and survey, as the earlier 'day' trips had extended beyond 35 hours. The mapped cave of 42.3 miles has grown beyond the boundaries of the designated National Conservation Area and has even extended beyond the jurisdictional area of the Bureau of Land Management. Even at the ends of present exploration in multiple locations, going leads continue to tease our strong and light explorers with airflow heading into the unknown.

Keywords:

exploration, survey, caving

FORT STANTON CAVE FORMATION REPAIR AND RESTORATION PROJECT

Michael C. Mansur

Chair of the Southwestern Region of the National Speleologocal Society, P.O. Box 1117, Tajique, NM, 87016, mcmansur@zoho.com

The goal of the Fort Stanton Cave Formation Repair and Restoration Project is to repair and restore damaged speleothems in Fort Stanton Cave so they can be viewed and photographed by future generations. Damage to speleothems in Fort Stanton Cave is documented as far back as 1855, based on a signature and date in the historical section of the cave where hundreds of broken formations are found. We found more than 90 formations with chisel or hammer marks, which are inferred to be the cause of much of the breakage. In six trips since 2020, we repaired 38 broken stalactites and stalagmitesusing new devices, tools, and procedures that were created for this purpose. This presentation highlights the work and new tools that were used to achieve this goal.

AN EARLY PERMIAN FOSSIL FLORA FROM THE ARROYO DE ALAMILLO FORMATION OF THE YESO GROUP, SOCORRO COUNTY, NM

Paul May[1], Spencer G. Lucas[1], Hans Kerp[2], William A. DiMichele[3] and John B. Rogers[4]

[1]New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, *(submitting author)*
[2]WestfÃ¤lische Wilhelms-UniversitÃ¤t Muenster, Muenster, 48149, Germany
[3]NMNH Smithsonian Institution, Washington, DC, 20560
[4]Central New Mexico Community College, Albuquerque, NM, 87106

Few fossil remains of any kind have been reported from the Arroyo de Alamillo Formation of the Yeso Group, a lithologic succession of siltstone, sandstone and minor dolostone and gypsum of early Permian (Leonardian/Kungurian) age, formed under a semi-arid to arid climate regime on a vast coastal plain, conditions generally unfavorable for the preservation of fossil remains. Here we report a fossil plant assemblage from Socorro County, NM, ~ 14 m above the base of the Arroyo de Alamillo Formation. The plant remains occur in a 0.5 m thick, fine-grained sandstone bed of local areal extent. Planar bedded and lacking trough cross bedding, with climbing ripples, we interpret this deposit as a small-scale sheet flood (unchannelized flow) into a standing water pond, possibly an oasis on an otherwise arid, sand-rich landscape. The fossil flora occurs in a small area approximately 2 m in width and 30 cm in depth, its length limited by the erosional boundaries of the outcrop to about 3 m. With the exception of a few specimens, all plant remains can be assigned to the peltasperm (callipterid) *Autunia naumanii*. Single specimens are tentatively identified as the peltasperm *Arnhardtia scheibei*, the filicalean fern *Oligocarpia* sp., and some small seeds. The specimens are preserved as large fragments, leading us to suspect that had the hard, resistant enclosing rock matrix been more susceptible to splitting along large surfaces, much larger, possibly even entire, fronds might have been recovered. The dominant plant, *Autunia naumannii* has been widely reported across tropical Pangea, from the easternmost regions (China) to the west (New Mexico) and many areas in between. It is associated with environmental indicators of moisture seasonality, but still with moderate soil moisture. The material found in the Yeso deposit appears to have had small, forked fronds bearing multilobed pinnules and small, rounded intercalary pinnules. It deviates to some degree from typical *A. naumannii* in having more rounded pinnule lobes than is typical for the species; in this trait it might be considered a subspecies or even a new species. This is the youngest occurrence of plant fossils so far reported in the early Permian of far western Pangea.

UNUSUAL TRACE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS PAGUATE MEMBER OF THE DAKOTA FORMATION IN THE OJITO WILDERNESS, SANDOVAL COUNTY, NEW MEXICO

Paul May[1], Spencer G. Lucas[1] and John B. Rogers[2]

[1]New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, massagepaul@gmail.com
[2]Central New Mexico Community College, 525 Buena Vista S. E., Albuquerque, NM, 87106

A recent paleontological inventory of Cretaceous strata in the Ojito Wilderness near San Ysidro, Sandoval County, New Mexico, discovered a slab of sandstone of the Upper Cretaceous (Cenomanian) Paguate Member of the Dakota Formation with a highly unusual ichnoassemblage preserved on the surface. The sandstone is a 0.1 to 0.3 m thick bed that is medium-grained and quartzose. It has symmetrical ripples on the trace-fossil-bearing surface and is from a stratigraphic level ~ 3 m above the base of the Paguate Member. The traces are: (1) abundant *Thalassinoides* that form branching, polygonal networks; (2) several trails of *Cruziana*; (3) four specimens of *Zoophycos;* and (4) an area with undertrack fallout of the horseshoe crab walking trace *Kouphichnium*. Some *Thalassinoides* crosscut *Cruziana* and one of the *Zoophycos* traces, so this suggests at least two episodes of trace formation. This ichnoassemblage from the Paguate Member clearly was preserved in a shallow, well oxygenated marine setting at or slightly above wave base. Indeed, the assemblage can readily be assigned to the *Cruziana* ichnofacies, which is characteristic of shallow marine settings. Nevertheless, *Zoophycos* has long been accepted as an indicator of deep and/or poorly oxygenated marine waters, so it is "out of place" among traces typical of the *Cruziana* ichnofacies. The Paguate ichnoassemblage thus presents evidence that *Zoophycos* is a facies crossing ichnotaxon that should not be associated with an archetypal ichnofacies.

CONTROLS ON FLOW CONVEYANCE LOSSES IN THE SAN ACACIA REACH OF THE MIDDLE RIO GRANDE

Katie McLain

New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, United States, katie.mclain@student.nmt.edu

The San Acacia reach of the Middle Rio Grande experiences high conveyance losses throughout the year that vary greatly based on local features, seasonal flow variability, and regional influences. Variability in loss rates are driven by hydrogeological differences, topographical differences, and vegetative differences throughout the region, with some sub-reaches occasionally gaining flow and some sub reaches frequently losing 100% of flow. Summer drying events provide insight into the most critical reaches, and close analysis of water table trends within these areas can provide further indications of the controlling local features. In addition to these local controls, there is a larger climate-related control on the entire region. During poor water years, flows have higher percentage losses than good water years, minimizing effective conveyances. It becomes difficult to counteract the effects that poor flows have on the water table, which raise hydraulic gradients and increase conveyance losses for extended periods of time. Conveyance losses are controlled by several scales of influence, but outlining them and understanding the interactions between them is a critical challenge for maximizing flow transmission in the future.

Seismic Monitoring of Flash Floods—Sediment Transport, Flood Detection, and Flow Characteristics Inferred from Seismic Signals in an Ephemeral Watershed

John Mitchell McLaughlin[1], Susan Bilek[1] and Daniel Cadol[1]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, United States of America, John.mclaughlin@student.nmt.edu

Ephemeral channels that characterize a large part of New Mexico are a result of powerful, short-duration floods driven by storms largely during the monsoon season of July and August. Due to the nature of these floods and the channels through which they flow, large amounts of sediment are transported as bedload. These large bedload fluxes, combined with erratic storms and fast-rising flows, make quantifying bedload transport challenging and hazardous. Systems designed to directly monitor and sample bedload flux are effective, but only until samplers reach capacity. Additionally, any equipment placed in-channel is subject to damage and maintenance requirements resulting from bedload transport. Since bedload transport involves impacts of rolling, sliding, and saltating grains with the bed, seismic instruments have emerged in recent years as a potential means with which to study bedload transport without hazardous or expensive measurements. Although some work has been done to characterize seismic signals generated by bedload transport in perennial alpine streams, fine-grained gravel bed arroyos have remained largely unexplored.

To investigate seismic signals generated by floods in these arroyos, 5 broadband seismometers and 66 seismic nodes have been deployed at the Arroyo de los Pinos, an ephemeral watershed in central New Mexico, over multiple monsoon seasons encompassing numerous flash flood events. To isolate signals generated by bedload transport, outside sources of seismic noise including rainfall and human activity have been characterized. Additionally, seismic signals emanating from a hydraulic jump have been characterized for the purpose of ruling out its interference with bedload-generated signals. Ongoing research involving both seismic and hydrologic instruments has determined that with outside noise sources characterized and avoided, elevated seismic power at an appropriate range of frequencies is well explained by bedload transport rates. Findings suggest that seismic instruments may be an effective complement to traditional water and sediment-monitoring instruments when these instruments are deemed impractical, insufficient, too expensive, or too invasive to install.

RESISTIVITY MEASUREMENTS AT FORT STANTON CAVE NEW MEXICO

John S. McLean

geospeleo@gmail.com

Earth resistivity measurements near Fort Stanton Cave were begun shortly after the discovery of the Snowy River passage in 2001. Resistive anomalies were frequently detected ahead of the progress of underground exploration and survey of the cave passages, and later shown to represent cave passages when the survey lines passed through the anomalies. Many other anomalies are present between and adjacent to the passages currently known.

The presence of anomalies aligned approximately parallel to major passages in the cave suggest that there are significant passages or passage segments yet to be discovered. Many of these segments may be isolated by collapse and infilling by allogenic sediment, allowing only the air-filled sections to be resolved.

Some of the aligned anomalies may represent passages developed before Snowy River, providing earlier discharge paths to the Rio Bonito or Salado Creek. Others may be local infeeders which have been underdrained, abandoned and partly filled. The abundance of anomalies indicates that cave development and filling is far more extensive than indicated by the passages currently mapped.

Caves in the Upper Pecos Watershed

Dennis McQuillan

High Desert Science, 3 S Hijo de Dios, Santa Fe, NM, NM, 87508-9133, United States,
geologist@highdesertscience.net

Caves formed by dissolution along permeability structures in Paleozoic limestone in the Upper Pecos Watershed are of geological, hydrological, biological, and anthropological interest.

A series of cave entrances are located at the base of a cliff on the south side of Cave Creek in the Pecos Wilderness. Cave Creek flows along the strike of south-dipping limestone, and a portion of the streamflow enters the caves, especially during spring snowmelt runoff. The caves extend a distance of tens of meters under the hillside where water flows into progressively smaller passages.

Terrero Cave is located at the bottom of a cliff on the west side of the Pecos River near the former mining town of Terrero. It contains more than 0.4 km of passages and rooms in westward-dipping limestone. Numerous speleothems have formed, especially where water drips heavily from the cave ceiling. The sound of flowing water can be heard at some locations inside the cavern and water surfaces from a narrow cave tunnel south of the main entrance. Terrero Cave is the type locality of the lampshade spider species *Hypochilus jemez*, and the harvestman species *Sclerobunus jemez*. These arachnids are named in honor of the Pueblo of Jemez for whom Terrero Cave has profound spiritual significance.

Pecos Pueblo, located 21 km south of Terrero Cave, was continuously inhabited from the 1200s until 1838 when the remaining residents migrated to Jemez Pueblo. In his 1776 survey of missions in New Mexico, Fray Francisco Atanasio Dominguez wrote about the church's efforts to prevent native Pueblo residents from using caves "for idolatrous purposes." Archaeologists Edgar Hewett and Alfred Kidder noted in the early 1900s that Jemez Pueblo residents of Pecos ancestry made pilgrimages to visit both the Pecos Pueblo ruins and a sacred cave in its vicinity. In 1925, Kidder's team found "a very deep cave in the hills" extending for "nearly a mile" consisting of "a narrow passage with gangliar chambers," a mud floor and stalactites. Kidder's excavation of Pecos Pueblo discovered the tip of a stalactite in the Kiva 5 niche.

Willa Cather's 1927 history-based novel, *Death Comes for the Archbishop*, includes a secret ceremonial cave used by Pecos Pueblo inside of which "the sound of a great underground river, flowing through a resounding cavern" was heard. Cather visited the Santa Fe area in 1925, during Kidder's 1924-29 Pecos expedition. The cavern in Cather's book is mentioned in Kidder's Pecos Pueblo Archaeological Notes where he states, "Willa Cather must have picked up tales of this sort" for her "delightful" novel.

The Pecos Eagle Society at Jemez Pueblo, a traditional religious group originally from Pecos Pueblo, periodically "returns to its aboriginal homelands at Pecos to perform ceremonial rites at shrines that still exist." In the 1980's, after decades of vandalism, littering and other desecration, the cave entrance was gated and locked by the state at the request of Jemez Pueblo. The gated entrance preserves this sacred cave for pilgrimages by the Pecos Eagle Society and protects the unique arachnids that live inside.

SOURCE TRACKING ANALYSIS OF ALUMINUM, ARSENIC, AND LEAD ENTERING THE SAN JUAN RIVER IN THE FOUR CORNERS REGION, USA.

Rachel L. Mixon[1], Johanna M. Blake[1], Jeb E. Brown[1], Shaleene Chavarria[1], Christina L. Ferguson[1] and Douglass B. Yager[1]

[1]U.S. Geological Survey, 6700 Edith Blvd NE, Albuquerque, NM, 87113, rlmixon@usgs.gov

The San Juan River is a vital source of water for drinking, irrigation, and recreational use for individuals in the arid Four Corners Region, much of which encompasses the Navajo Nation. The Navajo Nation Environmental Protection Agency (NNEPA) discovered elevated concentrations of aluminum, arsenic, and lead in surface water samples from routine monitoring of the San Juan River. Tributaries, most of which are ephemeral, that flow into the San Juan River may be contributing elevated concentrations of aluminum, arsenic, and lead. These metals could come from local oil drilling operations, abandoned uranium mines and mills, agricultural land, natural gas power plants, geology and erosion, illegal dumping of waste, and other sources. In cooperation with the NNEPA, the U.S. Geological Survey (USGS) is working to determine which tributaries are contributing aluminum, arsenic, and lead to the San Juan River, as well as the relative contributions from anthropogenic and natural sources. Thirty-four tributaries and numerous sites on the San Juan River, from Navajo Dam, NM to Mexican Hat, UT are being sampled routinely for surface water and sediments by scientists at the NNEPA and the USGS. Surface water samples are being analyzed for major ions and trace metals, and sediment mineralogy is being analyzed using a scanning electron microscope (SEM) at the University of New Mexico. Water chemistry and sediment mineralogy data analysis is ongoing. Results from a February 2021 baseflow synoptic survey of the San Juan River, and from tributary samples collected in July 2021, show concentrations of aluminum as high as 3.77×10^6 parts per billion (ppb), above the Environmental Protection Agency (EPA) suggested goal for aluminum of 200 ppb. Arsenic results were as high as 27 ppb, above the EPA maximum contaminant level (MCL) for arsenic of 10 ppb. Lead results were as high as 218 ppb, above the EPA MCL for lead of 15 ppb. SEM analysis of sediments collected in August 2021 show a large amount of aluminum in tributary sediments. Arsenic and lead have not been found in SEM analysis, which could be due to their low concentrations, or desorption from sediments. To better determine the effect of tributary chemistry on the San Juan River, USGS scientists are beginning to use aerial imaging to model streamflow so that metal loads can be calculated. Determining the relative contributions of metals to the San Juan River is vital to the public for recreational use, for water managers in the region, and for future scientific inquiry.

EARLY PLEISTOCENE (LATE BLANCAN) VERTEBRATES FROM SIMON CANYON, SOCORRO COUNTY, CENTRAL NEW MEXICO

Gary S. Morgan[1], Daniel J. Koning[2], M. Steven Shackley[3], David W. Love[2], Kevin M. Hobbs[2] and Andrew P. Jochems[2]

[1]New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, gary.morgan1@state.nm.us
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801
[3]Geoarchaeological XRF Laboratory, Albuquerque, NM

A recently discovered assemblage of vertebrate fossils 53 km south-southwest of Socorro, here named the Simon Canyon Local Fauna (LF), is one of the most precisely dated early Pleistocene (late Blancan North American Land Mammal Age – NALMA) faunas in New Mexico. The site is located near the lower (eastern) end of Simon Canyon in the central San Marcial Basin, Socorro County, in central New Mexico. The fossils were collected primarily from two axial-fluvial sand tongues of the Palomas Formation. The lower 4 m of the 12 m-thick, upper sand tongue yielded most of the fossils and also contained pebbles of obsidian. Trace-element analysis of three obsidian clasts, using XRF methods, indicate a close match with the 2.23 ± 0.15 Ma El Rechuelos Rhyolite. A 0.8 m-thick, coarsening-upward, pebble-boulder pumice bed is present 4 m above the top of the upper sand tongue. Its geochemistry supports a correlation with the Otowi Member of the Bandelier Tuff (OMBT), assuming this bed is the same as the Fort Craig pumice. We interpret that this pumice was transported here via a dam-burst flood within thousands of years after the associated Toledo caldera eruption in northern New Mexico at 1.62 Ma. Thus, the age of the upper axial-fluvial sand tongue is bracketed between 2.4 and 1.6 Ma. The Simon Canyon LF consists of 15 species of vertebrates, including seven mammals known from Blancan NALMA vertebrate faunas in New Mexico and elsewhere in the southwestern U.S.: *Glyptotherium texanum* (glyptodont), *Canis* cf. *edwardii* (wolf), *Equusscotti* (large horse), and four camels, *Camelops* sp., *Gigantocamelus spatulus*, *Hemiauchenia* cf. *blancoensis*, and *Hemiauchenia gracilis*. Except for *Equus scotti* and *Camelops* sp., these Blancan vertebrates were collected in the lower third of the upper axial-fluvial sand tongue or within 1 m below it. The most age-diagnostic of these species are *Glyptotherium texanum*, a mammalof South American origin and a participant in the Great American Biotic Interchange that first arrived in New Mexico at the beginning of the late Blancan (~2.7 Ma) and became extinct at the end of the early Irvingtonian NALMA (~1.0 Ma), and *Hemiauchenia gracilis*, a small camel known only from the late Blancan (~1.6–2.5 Ma). Conspicuously absent are Blancan mammals that became extinct at ~2.2 Ma (e.g., *Borophagus*, *Nannippus*) as well as *Mammuthus*, a Eurasian immigrant whose first appearance in North America defines the beginning of the early Irvingtonian at ~1.6 Ma. Thus, the mammalian biochronology of the Simon Canyon LF indicates a latest Blancan age (~1.6-2.2 Ma) for the fauna collected in the upper axial-fluvial sand. This biochronologic age is remarkably consistent with the independent 1.6-2.4 Ma age provided by the overlying OMBT pumice bed and the El Rechuelos Rhyolite obsidian clasts found in the lower part of the upper axial-fluvial sand tongue.

Monitoring Sediment Erosion and Deposition in the Arroyo de los Pinos Through Structure from Motion (SfM) Photogrammetry

Rebecca Moskal[1] and Daniel Cadol[1]

[1]New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801,
rebecca.moskal@student.nmt.edu

The Arroyo de los Pinos is a tributary of the Rio Grande that transports tons of relatively coarse sediment into the river annually through flash flood events. The focus of this research is to determine where sediment erodes and deposits in the arroyo reach leading into our monitoring station and to document how much enters the Rio Grande. If too much sediment deposits downstream it can lead to problems for infrastructure such as sedimentation in reservoirs and increased channel maintenance needed for flow conveyance. To investigate these concerns, we have started using Structure from Motion (SfM) photogrammetry from drone-based air photos. The pictures captured through the drone flight are analyzed in a program called AGISOFT, in conjunction with the coordinates of the control points marked by targets, to create DEMs of the terrain. With those DEMs we can then create a digital elevation model of difference (DoD) in GIS to show the difference between two DEMs of interest and quantify the deposition and erosion. DEMs from previous years compared to our most recent DoD show that deposition has increased in the thalweg of the channel and the higher points in the channel have eroded, leading to a flatter bed surface. A significant amount of sediment has deposited at the mouth of the channel creating a fan that will likely be transported by the Rio Grande as flow increases. The next goal of this research is to compare these results with the sediment transport models BORAMEP and HEC-RAS to determine the best sediment transport equation to use for modeling ephemeral streams.

HYDROGEOLOGY OF SNOWY RIVER PASSAGE, FORT STANTON CAVE, NEW MEXICO

Brad Talon Newton

NM Bureau of Geology, 801 Leroy Place, Socorro, NM, 87801, talon.newton@nmt.edu

Fort Stanton Cave is located in the upper Rio Hondo Basin in the northern Sacramento Mountains in south central New Mexico. Until recently, this cave has been mainly of recreational interest, but in 2001, the Snowy River Passage was discovered due to digging efforts. Since its discovery, the length of the cave has increased from three miles of known passage to over forty miles, making it the second largest cave in New Mexico behind Lechuguilla Cave. There are many exceptional aspects of Snowy River including the white calcite formation that lines the stream bed along most of the known length of the passage. Several ephemeral flooding events in Snowy River Passage over the last 12 years sparked interest by researchers about the local hydrogeology of Fort Stanton Cave, specifically Snowy River. The primary goal of the study is to develop a conceptual model that describes the mechanisms by which water from the surface makes its way into the cave to flood the Snowy River channel based on available hydrologic and geologic data.

Flood hydrographs for Snowy River at Turtle Junction (the main access point to Snowy River Passage) are very interesting and provide clues about important processes in this hydrologic system. The shape and characteristics of these ephemeral hydrographs are peculiar and very different from most ephemeral flood hydrographs. All hydrographs at Turtle Junction show a very steep climbing limb where the depth of water at the measurement location at Turtle Junction increases from zero to over 30 cm in one to four hours. The duration of the observed floods ranged between two months and two years. All floods in Snowy River also exhibit similar shaped recession curves, which appear to be the result of the discontinuation of streamflow and downward drainage of water, rather than a gradual decrease in flow rate. The time that it takes for all of the water to drain from Snowy River ranges from a few days to several weeks. The peak flow, which exists between the climbing limb and the recession curve, usually maintains a depth between 30 and 35 cm, which correlates to the approximate location of the upper edge of the Snowy River calcite deposit.

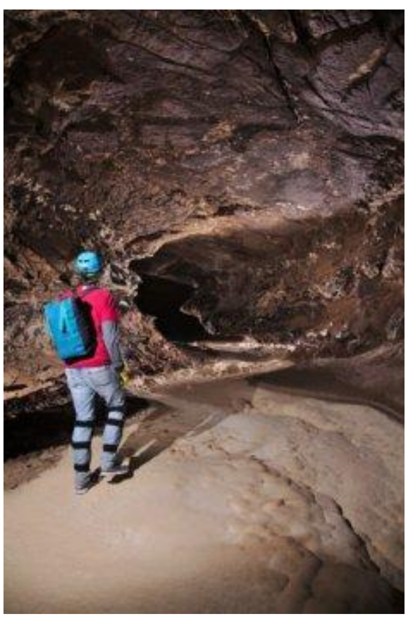
Eagle Creek, an ephemeral stream located within the projected pathway of Snowy River Passage, is about five miles from the current known extent of the Passage. Chemistry and stream discharge data indicate that Eagle Creek is likely the main source of water for Snowy River. Seepage from Eagle Creek recharges a perched aquifer in the fluvial sediments that lie below the Snowy River calcite formation that lines the stream channel. Water in this aquifer leaks downward to recharge the regional aquifer. During periods of high stream discharge in Eagle Creek, when recharge rates exceed leakage rates, a pressure response to the head increase in the recharge area causes the water table to quickly rise above the streambed, initiating stream flow in Snowy River, which ultimately discharges at Government Spring and flows into the Rio Bonito.

Contrasting Microbial Communities in Cave Ferromanganese Deposits With Overlying Surface Soils

Diana E. Northup[1], Jason C. Kimble[1], Ara S. Winter[1] and Robert L. Sinsabaugh[1]

[1]University of New Mexico, Department of Biology, MSC03 2020, Albuquerque, NM, 87131-0001, dnorthup@unm.edu

Arid-land carbonate caves, such as Fort Stanton Cave, receive limited surface input; hence, critical constituents required for microbial communities are often limited. We hypothesized that the microbial communities residing in surface soils would differ from their subsurface counterparts found throughout the Snowy River passage on walls and ceilings in soil-like material (*speleosol*) rich in Fe- and Mn-oxides. Also referred to as ferromanganese deposits (FMDs), these secondary mineral deposits represent low nutrient environments that would likely select for organisms with metabolisms that favor low-nutrient local conditions and may be chemolithotrophic (“rock eaters”). We examined archaeal and bacterial makeup of low-nutrient ferromanganese deposits occurring in Fort Stanton Cave, NM, USA, and in corresponding overlying surface soils. Results of 16S rRNA gene sequencing indicate that bacterial and archaeal communities in the cave are taxonomically significantly dissimilar to their corresponding surface soils. Core microbial constituents of these communities, representing operational taxonomic units (OTUs) occurring in >80% of all samples, determined that there were only 19 and 17 archaeal and bacterial OTUs shared between surface and cave samples, respectively out of the total 1,639 archaeal and 12,051 bacterial OTUs. Surface archaeal communities were primarily represented by the *Thaumarchaeota* class Soil Crenarchaeotic Group (SCG), which play important roles in nitrogen cycling. Dominant archaeal groups in the subsurface included the *Euryarchaeota* class *Thermoplasmata* and *Thaumarchaeota* classes South African Gold Mine Gp 1 (SAGMCG-1), Marine Group I, and AK31. Bacterial cave OTUs significantly different from surface bacteria included *Nitrospirae*, GAL15, *Omnitrophica*, Zixibacteria, *Latescibacteria*, SBR1093, and *Ignavibacteriae*. Results suggest Fort Stanton Cave provides a biological niche for low nutrient/chemolithotrophic bacterial/archaeal groups, several of which are players in critical nutrient cycling (e.g. nitrogen). Community composition is likely driven by depth below the surface and rock geochemistry, which is supported by the high number of reads shared amongst cave core OTUs.



Dark ferromanganese deposits in Snowy River passage, Fort Stanton Cave, New Mexico. Photo by Kenneth Ingham.

LITHOGEOCHEMICAL VECTORS AND MINERAL PARAGENESIS OF HYDROTHERMAL REE-BEARING FLUORITE VEINS AND BRECCIAS IN THE GALLINAS MOUNTAINS, NEW MEXICO

Evan J. Owen[1], Alexander P. Gysi[2], Virginia T. McLemore[2] and Nicole Hurtig[1]

[1]New Mexico Tech, E&ES Department, 801 Leroy Place, Socorro, NM, 87801, evan.owen@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801

The Gallinas Mountains district located in Lincoln and Torrance Counties, New Mexico, is host to hydrothermal REE-bearing fluorite veins and breccias. Rare earth elements (REE) are found in bastnäsite-(Ce) ([Ce,La]CO_3F), which is also the primary ore mineral mined in several important carbonatite deposits (e.g. Mountain Pass in California; Bayan Obo in China). Minor production of REE, fluorite, Cu, Pb, Zn, Ag, and Fe has been recorded in the Gallinas Mountains district between the early 1900s and the 1950s. The REE-bearing fluorite veins and breccias are hosted in Permian sedimentary rocks as well as genetically related trachyte/syenite sills and dikes emplaced between 28-30 Ma. Previous studies have described the REE occurrences in the Gallinas Mountains, but the controls of hydrothermal processes on the transport and deposition of REE in the district remain unclear. In this study, we combine microtextural observations with mineral and whole rock chemistry of hydrothermal REE-bearing fluorite veins and breccias to determine the vein types, alteration styles, and establish a detailed mineral paragenesis. The goal of this study is to determine lithogeochemical vectors towards REE enriched zones in the district by linking thin section and deposit scale observations with mineral and whole rock geochemistry. This district is an exceptional natural laboratory for studying the role of hydrothermal processes for transport/deposition of REE in an alkaline F-rich magmatic-hydrothermal system because very few deposits worldwide have such well-preserved and exposed geology.

Hand samples of hydrothermal veins and breccias containing fluorite ± calcite ± barite ± bastnäsite-(Ce) were collected from outcrops, prospect pits, and mine dumps. Optical microscopy was used to identify minerals and determine the textural features and crosscutting relationships of the different fluorite veins. Multiple vein generations have been observed: i) early K-feldspar veins; ii) barite-fluorite ± hematite ± quartz veins; iii) bastnäsite-fluorite veins; iv) late quartz and calcite veins. Bastnäsite-(Ce) is commonly found in veins overprinting earlier barite-fluorite veins and contain barite that display dissolution textures (skeletonized crystals). Cathodoluminescence (CL) microscopy reveals at least three distinct fluorite generations with complex overprinting, including a generation intergrown with bastnäsite-(Ce). These textural observations suggest a key control of REE mineralization in the Gallinas Mountains district is by coupled dissolution of barite-fluorite veins and precipitation of later bastnäsite-fluorite veins. LA-ICP-MS analysis was performed on multiple fluorite generations to link fluorite chemistry with textural relationships. At least three distinct chondrite-normalized REE patterns are revealed, including: i) enriched LREE; ii) flat LREE with depleted HREE; iii) depleted LREE with enriched HREE. One fluorite generation seen replacing euhedra contains over 1% total REE. Geochemical whole rock data within the New Mexico Bureau of Geology and Mineral Resources database were analyzed using the IMDEX ioGAS^{TM} program to define geochemical signatures of rock types, alteration styles, and vein types. Preliminary data analysis indicates a positive correlation between Ba, F, and total rare earth oxides (TREO). These trends corroborate with the observed vein microtextures, suggesting that the interaction of a hydrothermal fluid with the barite-fluorite veins represents a key process for defining geochemical vectors in the district.

Keywords: critical minerals, alkaline system, rare earth elements, fluorite, hydrothermal, carbonatite, vectoring, bastnasite, barite

A RESERVOIR MODEL FOR SNOWY RIVER FLOODING

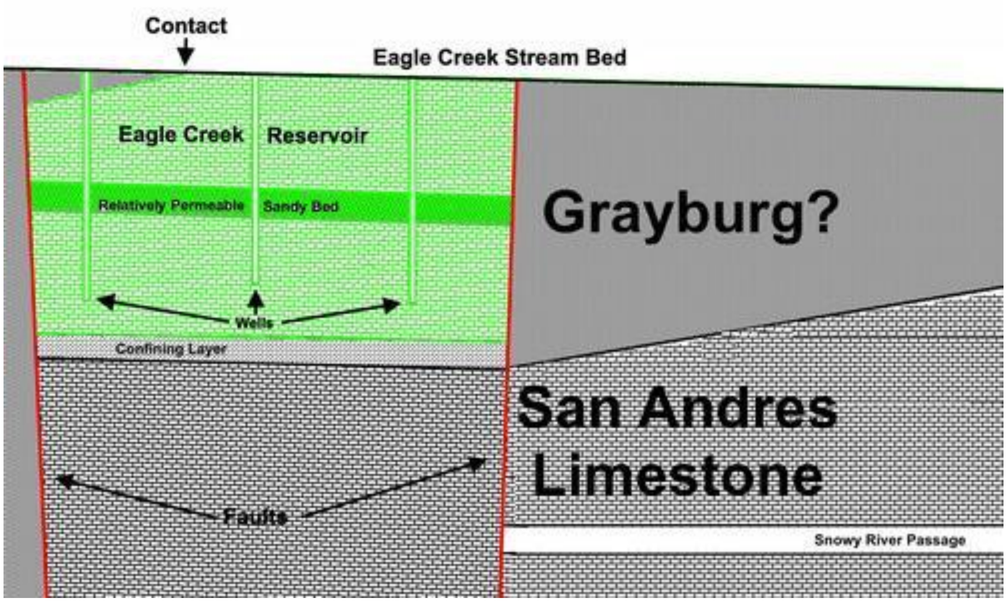
Stephen S. Peerman

Fort Stanton Cave Study Project, 3125 Missouri Ave., Las Cruces, NM, 88011, FSCSP.director@gmail.com

The discovery in 2007 that the Snowy River passage floods periodically and relatively frequently, has led to water flow data logger monitoring at Turtle Junction and other locations in the Snowy River passage, and an additional effort to try and understand the reasons behind the flooding. A numerical model has been developed to provide a mechanism for predicting future flooding events. This Reservoir Model uses discharge data from a USGS gage on Eagle Creek and various parameters to predict flooding events at Turtle Junction.

The model uses an EXCEL spreadsheet with inputs of the daily average discharge from USGS gage 0387600 <https://waterdata.usgs.gov/nm/nwis/uv?site_no=08387600> and a two-state output for each day: 10 indicating that water should be flowing at Turtle Junction; 0 indicating water should not be flowing at Turtle Junction. The model does not predict the status of flooding at other locations in Snowy River, or other passages in the cave.

While this is a numerical model, it can be visualized in terms of a leaky, overflowing, refillable reservoir, as shown in the diagram below.



A conceptual diagram for the Reservoir feeding the Snowy River passage from Eagle Creek.

Keywords:

hydrology, Snowy River, modeling

Navigating the BLM Proposal Submission Process to Gain Scientific Entries to Fort Stanton Cave

Knutt Peterson

BLM Roswell Field Office, 2909W 2nd St, Roswell, NM, 88201, knuttpet@blm.gov

Fort Stanton Cave is a unique environment which offers scientists and researchers the opportunity to discover, study, and explore the unknown.

The Bureau of Land Management's Roswell Field Office Cave Program supports science and research by offering funding opportunities and special access to study the unanswered questions that Fort Stanton Cave has to offer. The first step to conducting research in Fort Stanton Cave is to submit a proposal to the BLM. In the past proposal requirements have been vague and seemingly convoluted, but for the 2023 caving season a new streamlined submission process will be in place.

The Cave and Karst Specialist from the BLM Roswell Field Office will discuss the new proposal submission process and the steps each proposal goes through during the review process.

KEY SPELEOTHEM PALEOCLIMATE RESULTS FROM FORT STANTON CAVE

Victor J. Polyak[1], Yemane Asmerom[1] and Matthew S. Lachniet[2]

[1]Department of Earth and Planetary Geosciences, University of New Mexico, 221 Yale Blvd, Northrop Hall, Albuquerque,, NM, 87131, polyak@unm.edu
[2]Department of Geoscience, University of Nevada, 4505 S. Maryland Pkwy, Las Vegas,, NV, 89154

Stalagmites are the speleothem type primarily used for paleoclimate research. Fort Stanton Cave, New Mexico’s second longest cave, is well-known for its history, cave velvet, and Snowy River. Fort Stanton Cave also hosts exceptional paleoclimate records from its stalagmites and from other speleothem types. The cave is ideally located in the southwestern United States (SW USA) such that cold climatic shifts in the north Atlantic regions during glacial cycles synchronously cause southward sways in the polar storm track that produce climatic oscillations preserved in stalagmites that mimic the north Atlantic climate trends preserved in the Greenland ice sheets. The cave’s position and environment has resulted in speleothem growth occurring only during the last four northern hemisphere (NH) glacial cycles. NH Glacial cycle 1, defined as the Last Glacial Period is well represented in the SW USA by the Estancia basin lacustrine paleoclimate record stretching from ~65 to ~10 ka, where greater effective precipitation during this time not only created Pleistocene Lake Estancia, but also decorated Fort Stanton Cave with calcite speleothems ~55 to ~10 ka. Two Fort Stanton Cave paleoclimate records, one from stalagmite FS-2 and the other from stalagmite FS-AH1 exhibit $\delta^{18}O$ time-series that match the Greenland ice core records remarkably well. The correlation between FS-AH1 and the Greenland ice core $\delta^{18}O$ time-series of $R = 0.64$ (chronologies are independent and untuned) suggests that Fort Stanton Cave stalagmites that grew during previous glacial cycles could serve as synthetic Greenland ice core $\delta^{18}O$ time-series. Growth and non-growth of speleothems in Fort Stanton Cave provide a regional effective moisture index in that speleothem growth takes place only during the glacial cycles, indicating that glacial cycles are pluvial intervals in the SW USA, something alluded to in the literature, but not well resolved for the previous three NH glacial cycles. Growth of stalagmites, and therefore glacial driven pluvial moisture, ends abruptly at glacial terminations. Our results also show that greater thickness of overburden seemingly interferes with the stable isotope signals.

REGIONAL GEOLOGY OF THE NORTHEASTERN SACRAMENTO MOUNTAINS, LINCOLN AND OTERO COUNTIES, NEW MEXICO

Geoffrey Rawling

New Mexico Bureau of Geology and Mineral Resources, 1015 Tijeras Avenue NW, Suite 200, Albuquerque, NM, 87102-2909, US, geoffrey.rawling@nmt.edu

Permian through Eocene sedimentary rocks, and intrusive and extrusive rocks of the Eocene-Oligocene Sierra Blanca volcanic complex and Capitan Pluton are exposed in the northeastern Sacramento Mountains in the vicinity of Ruidoso and Capitan. This region includes the eastern flank of the Laramide-age Sierra Blanca basin. Six contiguous 7.5- minute quadrangles were mapped here with STATEMAP funding from 2003 – 2010 and form the basis for geologic understanding of the area.

The oldest mapped unit is the Permian Yeso Formation, which is well-exposed in rugged terrain north of Ruidoso Downs. Dissolution of evaporites has resulted in intraformational breccias and disharmonic folding within the Yeso, and local collapse of the overlying Permian San Andres Formation. Subdivsions of the San Andres Formation defined in the southeast Sacramento Mountains are not mappable in this area because of the thick forest cover. Karst within the San Andres Formation is indicated by solution cavities and breccias, and terrarossa. Large thickness variations (0 to 135 m) and basal topography of the siltstone and very fine sandstone that comprise the overlying, unconformity-bounded Grayburg Formation suggest that some of the karst is Permian in age. The Triassic Santa Rosa and San Pedro Arroyo Formations are relatively thin and are cut out by the unconformity beneath the Cretaceous Dakota Sandstone in Ruidoso. The same unconformity truncates the Jurassic Morrison Formation near Capitan. Igneous intrusions of all varieties are abundant within the Cretaceous Mancos Shale and Crevasse Canyon Formation sandstones and shales. The Eocene Cub Mountain Formation comprises the Laramide basin fill and occurs in disconnected half-grabens. Syenite of the Bonito stock underlies Monjeau Peak and intrudes dominantly andesite breccias and lavas of the Sierra Blanca volcanic complex. Gravels mantling elongate east- and northeast-trending mesas between Alto and Capitan are western equivalents of the late Miocene to Pliocene Ogallala Formation.

The Ruidoso fault zone forms the eastern boundary of the Sierra Blanca basin in Ruidoso and strikes north to northeast through the mapped area. Maximum throw is at least several thousand feet down-to-the west, near Moon Mountain, where Dakota Sandstone is juxtaposed against San Andres Formation. To the southwest is a complex array of faults near Mescalero Lake. Towards Fort Stanton and Capitan, the fault zone bifurcates into a network of north- to east-striking faults, most of which are buried beneath the gravel-capped mesas, suggesting topographic inversion. Evidence for dextral oblique offset along northeast-striking faults includes sparse shallowly plunging slickenlines, variations in apparent throw along strike, and fold axes nearly perpendicular to adjacent faults. Many of these faults terminate at the Capitan fault, a major east-striking, down-to-the-south normal fault at the south margin of the Capitan Pluton that forms the Capitan Mountains. Fine-grained sedimentary units host abundant igneous intrusions (sills, stocks and laccoliths in the Mancos Shale) and accommodated distributed deformation at fault tip zones (Grayburg Formation). A notable example of the latter occurs along Eagle Creek, where a thick occurrence of Grayburg Formation was deposited in a probable paleokarst depression.

PRELIMINARY ESTIMATES OF DINOSAUR SIZE AND SPEED AT THE EARLY CRETACEOUS CLAYTON LAKE DINOSAUR TRACKSITE, UNION COUNTY, NEW MEXICO

John B. Rogers[1], Michael A. Kvasnak[1] and Spencer G. Lucas[2]

[1]Central New Mexico Community College, 900 University Blvd. SE, Albuquerque, NM, 87106, United States, john.rogers8@comcast.net
[2]New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM, 87104

The Early Cretaceous (late Albian) dinosaur tracksite at Clayton Lake in Union County encompasses approximately 533 dinosaur tracks, 182 of which are organized into 28 trackways. Most of the trackways were made by bipedal ornithopod dinosaurs, but two trackways were made by bipedal theropods, and one was made by a quadrupedal ankylosaur. To estimate dinosaur speeds from the trackways, we employed the methods of Alexander (1976, 1989) and Thulborn (1990) that rely on footprint lengths and strides as the raw data from which to estimate size and speed. On the Clayton tracks, we measured total length and width as highest edge to highest edge (rim to rim) of the maximum track shape. Though not ideal, this approach was dictated by the quality and nature of track preservation and provided a consistent methodology. For deeper tracks, these measurements are similar to the "negative vertical displacement" approach, but less than the "maximum zone of deformation." This approach neither captures the true footprint dimensions nor the full extent of extramorphological variation but does represent the maximum lengths and widths on the bedding plane surface. Track length was measured from the anterior tip of digit III to the base of the "heel" margin, actual or inferred. In some cases, our measured track lengths exceed the true foot length of the trackmaker, and these tracks are unsuitable for size and speed estimates. However, some trackways have a "best" track(s) that exhibit(s) some combination of clear track outline, high angle footwalls, and "impressed" positives. We estimated size and speed for these. The results (using the method of Alexander, 1976) are that all of the ornithopod trackways show walking speeds of ~ 2-to 7 km /hour. The relatively fastest dinosaur speed at Clayton Lake may be the single trackway of a "trotting" ornithomimosaur at an estimated 9.5 km/hour. How foot length is measured and the choice of equations to calculate hip height and speed greatly influence the size and speed of the trackmakers. Furthermore, the Clayton trackways are a good example of how extramorphology and tracksite weathering make it difficult to identify landmarks that enable accurate footprint lengths to be measured so that size and speed estimates are reliable.

References:

Alexander, R. McN., 1976, Estimates of speeds of dinosaurs. Nature, v. 261, p. 129-130.
Alexander, R. McN., 1989, Dynamics of Dinosaurs and Other Extinct Giants. Columbia University Press.
Thulborn, R.A., 1990, Dinosaur Tracks. London, Chapman and Hall.

A First Report of the Ichnogenus *Curvolithus* From the Mojado Formation, Cerro De Cristo Rey, Sunland Park, New Mexico.

Jahir Sanchez[1] and Eric Kappus[2]

[1]El Paso Community College, 14288 Michele Ann Dr, El Paso, TX, 79938, jahirsanchez29@hotmail.com
[2]Southwest University at El Paso, 1414 Geronimo Dr, El Paso, TX, 79925

As part of a continuing investigation of trace fossils from the lower-most, Albian Sarten Member of the Mojado Formation, we report the first description of *Curvolithus simplex* at Cerro de Cristo Rey, Sunland Park, New Mexico. *C.simplex* is a horizontal, three-lobed trace interpreted as a repichnia. Other traces in this ichnoassemblage that are commonly associated with the *Cruziana* ichnofacies include *Thalassinoides, Arthrophycus, Planolities,* scratch marks (and others not yet reported). Our *Curvolithus* specimensare preserved exclusively in convex epirelief on iron-stained, massive sandstones, interbedded with thin grey shales. At this location the lower contact of the Sarten Member is easily distinguishable from the Mesilla Valley Formation below. Although the base of the Mojado Formation was originally defined arbitrarily by the thickness of sandstone interbeds, or a change in sandstone lithology, we see a distinct change in ichnoassemblages between these two Formations, which may be used to define the contact in the future.

References:

Buatois, L.A., Mangano, M.G., Mikuláš, R. and Maples, C.G., 1998. The ichnogenus Curvolithus revisited. Journal of Paleontology, 72(4), pp.758-769.

Chrz?stek, A. and Nowicka, N., 2021. Trace fossils and depositional environments of the middle Turonian sandstones in the Upper Nysa K?odzka Graben (Sudetes, Poland) revisited. Geological Quarterly, 65(1), pp.65-10.

Cornell, W.C., LeMone, D.V. and Norland, W.D., 1991. Albian ophiuroids from Cerro de Cristo Rey, Dona Ana County, New Mexico. Journal of Paleontology, 65(6), pp.1009-1013.

Heinberg, C., 1973. The internal structure of the trace fossils Gyrochorte and Curvolithus. Lethaia, 6(3), pp.227-238.

Lucas, S.G., Krainer, K., Spielmann, J.A. and Durney, K., 2010. Cretaceous stratigraphy, paleontology, petrography, depositional environments, and cycle stratigraphy at Cerro de Cristo Rey, Doña Ana County, NM. New Mexico Geology, 32(4), pp.103-130.

Scott, R.W., Formolo, M., Rush, N., Owens, J.D. and Oboh-Ikuenobe, F., 2013. Upper Albian OAE 1d event in the Chihuahua Trough, New Mexico, USA. Cretaceous Research, 46, pp.136-150.

Keywords:

Invertebrate ichnology, trace fossils, Cerro de Cristo Rey, Mojado Formation, Curvolithus simplex, Cruziana ichnofacies.

THE TWO INDEPENDENT WATER SYSTEMS IN FORT STANTON CAVE

Henry Schneiker

HDS Systems, P.O. Box 42767, Tucson, AZ, 85733, HSchneiker@HdsSystems.com

There are two known water systems in the Fort Stanton Cave system. The first water system flows through the historic section of the cave generally following the main passage between the entrance area and Snowflake Passage. The primary water for this system is hypothesized to originate from west of the cave entrance. The second water system generally follows Snowy River. The primary water for this system is hypothesized to originate from the Eagle Creek drainage while the primary drain is at Government Springs. The current data and observations support the hypothesis that these two water systems are independent and do not interact in any significant way.

The primary water flow through the main passage is limited by flow through sediments and has not been accurately measured. As such, the rate of flow will be low even during high water events. Thus, it is possible such a slow flow rate can follow strata that is below the current Snowy River level and remain undetected. It remains possible that the main passage water exits through Government Spring. For instance, it could be the source for Crystal Spring and the seep below Lincoln's Bathtub.

The data supports a hypothesis that the historic main passage water system did and still can overflow into the Snowy River water system during times of high water in the historic section of the cave. Two different overflow routes have been identified. One route is via the Starry Nights Passage. The other route is via the Mud Turtle Passage. The elevations of both overflow routes have been raised by collapse features along the routes.

A precision elevation survey of the main passageway though Snowflake and North Snowy River is being undertaken. Although the survey is only partially completed at this time, it supports the current hypotheses.

FIRST REPORT OF THE LATE CRETACEOUS (CAMPANIAN) HETEROMORPH AMMONITE *HARESICERAS* (*HARESICERAS*) *MONTANAENSE* (REESIDE, 1927) FROM NEW MEXICO

Paul L. Sealey[1] and Spencer G. Lucas[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, ammonoidea@comcast.net

Two specimens of *Haresiceras* (*Haresiceras*) *montanaense* (Reeside, 1927) were recovered from the Satan Tongue of the Mancos Shale on the eastern side of the San Juan Basin in Rio Arriba County in northern New Mexico. An early form and a late form of the species were found in the lower Campanian *Scaphites leei* III and *S. hippocrepis* I zones, respectively.

The early form, a partial shell, has one lateral half preserving most of the outer whorl and the other half preserving a complete, septate inner whorl. The whorl section is well-compressed, and coiling is very involute with a very small umbilicus exposed on the inner whorl. The venter and flanks are flattened, and, on the inner whorl, they meet to form a sharp, angular ventrolateral shoulder. On the latter half of the inner whorl, sigmoidal ribs strengthen and arch forward on the outer flank, bend slightly backward before the ventrolateral shoulder, connect to tiny ventrolateral nodes, then cross the venter with forward arching. On the body chamber, ornament changes to strong, straight, sharp-edged primaries that connect to small, nodate ventrolateral tubercles and are separated by four straight secondaries. The late form, an inner whorl, differs mainly from the early form in its smaller ventrolateral nodes.

The NMMNH specimen that is the early form is best assigned to *Haresiceras* (*H.*) *montanaense* because the inner whorl is identical to that species, and the chronologic age is the same as the early form of that species. However, the suture is closer to *Haresiceras* (*Mancosiceras*) *mancosense* (Reeside, 1927) in the symmetrical trifid lateral lobe and the less extended second lateral saddle. Also, the venter of the body chamber seems more similar to *H.* (*M.*) *mancosense* than to *H.* (*H.*) *montanaense*. It may be an intermediate form low in the *Scaphites leei* III Zone, or a form resulting from intraspecific variation.

Haresiceras is a rare ammonite that is known only from the Western Interior of the United States. Initially, two specimens, one the holotype of *Haresiceras* (*Mancosiceras*) *mancosense* from the uppermost Santonian *Desmoscaphites bassleri* Zone in the Mancos Shale in San Juan County, were the only known occurrences of the genus from New Mexico (Cobban, 1964). *Haresiceras* (*Mancosiceras*) sp., likely *H.* (*M.*) *mancosense,* was later reported from the *D. bassleri* Zone in the Smoky Hill Member of the Niobrara Formation in Colfax County (Scott et al., 1986). This is the first report of *Haresiceras* (*H.*) *montanaense* from New Mexico.

References:

Cobban, W. A., 1964, The Late Cretaceous cephalopod *Haresiceras* Reeside and its possible origin: U.S. Geological Survey, Professional Paper 454-1, 21 p.

Reeside, J. B., Jr., 1927, The cephalopods of the Eagle Sandstone and related formations in the Western Interior of the United States: U. S. Geological Survey, Professional Paper 151, 87 p.

Scott, G. R., Cobban, W. A. and Merewether, E. A., 1986, Stratigraphy of the Upper Cretaceous Niobrara Formation in the Raton Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 115, 34 p.

Keywords: Haresiceras, ammonite, heteromorph, Cretaceous, Campanian, Mancos Shale,San Juan Basin

LATE CRETACEOUS (CENOMANIAN-CAMPANIAN) AMMONITE ZONES IN THE CHAMA BASIN, RIO ARRIBA COUNTY, NEW MEXICO

Paul L. Sealey[1] and Spencer G. Lucas[1]

[1]New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, ammonoidea@comcast.net

Upper Cretaceous strata exposed in the Chama Basin in Rio Arriba County in northern New Mexico contain ammonites and other marine molluscan fossils that span middle Cenomanian to middle Campanian time. Very few studies have been done on the Upper Cretaceous molluscan fossils in the Chama Basin. Landis and Dane (1967) published a geologic map of the Tierra Amarilla quadrangle with descriptions of geologic units and their fossil content. Muehlberger (1967) published the geology of the Chama quadrangle and also listed fossils from each geologic unit. Doney (1968) published the geology of the Cebolla quadrangle, also describing geology and listing fossils. Landis et al. (1974) published on the Cretaceous rocks and fossils of the Tierra Amarilla coal field. Lucas et al. (2009) documented a small assemblage of invertebrate fossils in the Dakota Sandstone near Ghost Ranch.

The *Acanthoceras amphibolum* Zone in the Paguate Sandstone Tongue of the Dakota Sandstone establishes a middle Cenomanian age for that unit. The *Sciponoceras gracile* biozone is present in the Graneros Shale, thus establishing a late Cenomanian age for that unit. In the Greenhorn Limestone, *Watinoceras coloradoense* indicates the lower Turonian *Vascoceras birchbyi* Zone, and the *Mytiloides mytiloides* inoceramid zone indicates the ammonite zone of *Mammites nodosoides* and thus a latest early Turonian age. The *Collignoniceras woollgari* Zone is present in the lower Carlile Member, establishing an earliest middle Turonian age for that unit, and the middle Turonian *Prionocyclus hyatti* Zone occurs higher in the Carlile. The ammonite zones present in the Juana Lopez Member are the earliest late Turonian *Prionocyclus macombi* Zone, the early late Turonian *Scaphites warreni* and *S. ferronensis* zones and the middle late Turonian *S. whitfieldi* Zone. The middle lower Coniacian *Cremnoceramus crassus inconstans* inoceramid zone is present in the Cooper Arroyo Sandstone Member and is equivalent to the *Scaphites preventricosus* ammonite zone. Santonian age invertebrates have not been collected from the study area. The *Scaphites hippocrepis* I Zone in the Satan Tongue establishes an early Campanian age for part of this unit. The lower middle Campanian zone of *Baculites mclearni* is present in the Lewis Shale.

References:

Doney, H. H., 1968, Geology of the Cebolla quadrangle, Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 92, 114 p.

Landis, E. R., Dane, C. H., and Cobban, W. A., 1974, Cretaceous rocks of the Tierra Amarilla Coal Field and adjacent areas, Rio Arriba County, New Mexico: New Mexico Geological Society, Guidebook 25, p. 231-238.

Landis, E. R., and Dane, C. H., 1967, Geologic map of Tierra Amarilla quadrangle, Rio Arriba County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Geologic Map 19, scale 1:62,500.

Lucas, S. G., Rinehart, L. F. and Kelley, S., 2009, Cenomanian invertebrate assemblage from the Dakota Sandstone near Ghost Ranch, Rio Arriba County, New Mexico: New Mexico Geology, v. 31, p. 59-64.

Muehlberger, W. R., 1967, Geology of Chama quadrangle, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 89, 114 p.

Keywords: ammonite zones,Upper Cretaceous,Chama Basin,Rio Arriba County,New Mexico

Contrasting Geologic and Geoarchaeological Views of Grants Ridge Obsidian Deposits, Mount Taylor Volcanic Field, New Mexico

Steven Shackley[1] and Fraser Goff[2]

[1]Department of Anthropology, University of California, Berkeley and, Geoarchaeological XRF Laboratory, Albuquerque, NM, 87122, shackley@berkeley.edu
[2]Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM 87801

In 1993, Julie Stein and Angela Linse published, in a Geological Society of America Special Paper (283), a geological and archaeological examination of concepts of scale in those disciplines (Stein and Linse 1993). In both complementary disciplines the issue of scale is crucial for research. However, in many instances the two disciplines conceive of scale in very different ways. At times in geology the size and resolution of scale is tightly constrained, in other situations much less so. The same in archaeology. The obvious difference is in conceiving geological formations either in structure or composition. Mapping archaeological sites down to the millimeter is quite common for archaeologists, indeed expected. Geologists rarely are concerned about this level of scale in geological mapping. Geoarchaeological mapping of stone sources is often at a finer resolution as well (Shackley 1998; Shackley et al. 2016). Our research on the obsidian sources in the Mount Taylor volcanic field is where the contrasting views of scale intersected. Goff rightly, and with intensive research, characterizes the obsidian at Mount Taylor as derived from the Grants Ridge rhyolite center, which is most certainly correct. However, Shackley has identified two compositionally and structurally different obsidian "sources" that have important archaeological meaning - the scale is different. Called geoarchaeologically "Grants Ridge" or "Horace/La Jara Mesa" obsidian, the former exhibits a more vitrophyric fabric and a less desirable media for stone tool production, while the latter is generally aphyric and a somewhat better media for stone tool production. This difference is reflected in the archaeological record and archaeological contexts in the region. Is the geological definition incorrect? Of course not, but the scale of definition is quite contrasting, and just as meaningful to either discipline. After spending two days field sampling in Goff et al's (2019) geochronologically defined map units in "Grants Ridge rhyolite" a better understanding of scale for both geoarchaeology and geology has become visible. Indeed, some of the map units on Horace Mesa, based on the geoarchaeological examination of the obsidian in those units could be expanded. It's a matter of scale. We present those inferences, both for the Mount Taylor specific example, and as a potential guide for future geological and geoarchaeological research.

References:

Goff, F., Kelley, S.A., Goff, C.J., McCraw, D.J., Osburn, G.R., Lawrence, J.R., Drakos, P.G., and Skotnicki, S.J., 2019, Geologic map of the Mount Taylor Volcano area, New Mexico: New Mexico Bureau of Geology and Mineral Resources Geologic Map 80, scale 1:36,000.

Shackley, M.S., 1998, Geochemical differentiation and prehistoric procurement of obsidian in the Mount Taylor volcanic field, northwest New Mexico. Journal of Archaeological Science, v.25, p. 1073-1082.

Shackley, M.S., Goff, F., and Dolan, S.G., 2016, Geologic origin of the source of Bearhead Rhyolite (Paliza Canyon) obsidian, Jemez Mountains, northern New Mexico. New Mexico Geology v.38, p. 52-65.

Stein, J.K., and Linse, A.R. eds., 1993, Effects of Scale on Archaeological and Geoscientific Perpsectives: Boulder, Colorado, Geological Society of America Special Paper 283, 91 p.

Keywords: Mount Taylor, geology and geoarchaeology, obsidian source provenance, effects of scale

THE SNOWY RIVER CALCITE FORMATION RECORDS A COMPLEX HISTORY IN FORT STANTON CAVE

Michael N. Spilde[1], Keely E. Miltenberger[2], Christina L. Ferguson[3] and Johanna M. Blake[3]

[1]University of New Mexico, Institute of Meteoritics, MSC03 2050, Albuquerque, NM, 87131, mspilde@unm.edu
[2]University of New Mexico, Earth and Planetary Sciences Department, MSC03 2040, Albuquerque, NM, 87131
[3]USGS-New Mexico Water Science Center, 6700 Edith Blvd NE, Albuquerque, NM, 87113

One of the most remarkable features of Fort Stanton Cave is the Snowy River calcite deposit, which is likely the world's longest speleothem (currently over 19.1 km in length). The Snowy River formation is a subaqueous coralloid pool deposit with a very low slope (<0.8 degrees over 7.5 km) that responds quickly to large surface meteoric events, filling within hours, flowing for several months, and then draining and drying over a period of several weeks. The carbonate crust has a cauliflower-like texture on the surface, and in cross section, consists of thin laminae that vary from microns to millimeters in thickness.

Eight drill cores taken in 2008 indicate that the deposit thins from 83-25 mm in thickness in a northerly direction (direction of flow). Two more cores were taken in 2018 for compressional strength analysis and other tests. Muddy layers in the cores are continuous and correlate across all ten cores, enclosing a length of over a km in distance. One core was prepared as a conventional petrographic thin section; the section reveals the presence of 500 individual light and dark lamina. A dark laminae forms as a thin layer of detrital minerals settle out after initial flooding; the light layer of calcite precipitates over the top of it, continuing until the water drains out as the flood event ends. Thus, each dark and light pair forms an apparent couplet recording every flood event. The lamina couplet records a filling-draining event with 250 such events taking place over the period of deposition of 821 (+/-120) years, as determined by uranium-series dating (Land et al. 2010). This yields a calculated average of ~3.6 yrs between filling events, approximating the interval of El Nino-Southern Oscillation events (3-5 yrs) in the southwestern US (Polyak, pers. comm).

In addition to examining the cores, we are conducting a long-term experiment to monitor calcite precipitation by using coupons, placed on the bottom of Snowy River, that are examined after each flooding event. The coupons show a growth rate of calcite of 8-11 um/month during flooding, with thickness apparently dependent on the coupon surface. Data loggers with attached cords, also in the flow path, show a higher rate of growth, upwards of 72 um/month.

Analyses of major and minor elements across one of the cores reveal that the core is a low-Mg calcite, but it is high in sulfate. Generally low in trace elements, the upper 2/3 of the core exhibits a trend of increased Fe, Mn, and Zn. This also correlates with discoloration and an increase of thin mud layers in the upper portion of the core, implying that conditions at Snowy River changed during deposition.

References:

Land L, Polyak V, Newton BT (2010) The Snowy River formation in Fort Stanton Cave, New Mexico—Results from radiometric dating and hydrologic observations of the world's longest speleothem. In: Eaton M, Landres P (eds), Decade of discovery in the National Landscape Conservation System, Proceedings RMRS-P- 000. Fort Collins, Colo., US Dept. of Agriculture.

MINERAL RESOURCE POTENTIAL OF LAND PARCELS IN SOUTHWEST NEW MEXICO

Kyle T. Stafford[1] and Virginia T. McLemore[2]

[1]New Mexico Institute of Mining and Technology, kyle.stafford@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources

The Organ Mountains – Desert Peaks National Monument is a recently established national monument near Las Cruces, New Mexico and is administered by the U.S. Bureau of Land Management (BLM). The NM State Land Office (SLO) is requesting a transfer of NM state lands located in the monument for other BLM lands located in southwestern NM. In order for this land exchange to occur, the mineral-resource potential of these parcels must be established, which is the current work of the authors and the focus of this project. The mineral-resource potential is an area of the probability that a mineral will occur in enough quantity so that it can be extracted economically under current or future economic conditions. It includes the occurrence of undiscovered concentrations of metals, nonmetals, industrial materials, and energy resources. It is a measure of the potential of occurrence, not a measure of quantities of mineral resources. Evaluating mineral resource potential is enhanced by the use of GIS systems such as ESRI ArcMap, previous literature, and other means. Many parcels have high potential for aggregate, and some have various levels of potential for metals, industrial minerals, and other commodities. Additionally, some parcels have no mineral resource potential.

Stoneman Lake, AZ, Sediments Archive Southwestern North America Surface Processes Over the Last Two Glacial Cycles (and Beyond)

Spencer E. Staley[1], Peter J. Fawcett[1], R. Scott Anderson[2], Gonzalo Jimenez-Moreno[3], Vera Markgraf[2] and Erik Brown[4]

[1]University of New Mexico, Albuquerque, NM, 87131, US, sestaley@unm.edu
[2]Northern Arizona University
[3]Universidad de Granada
[4]University of Minnesota, Duluth

Stoneman Lake (Mogollon Rim, central Arizona) is found within a circular, 40 m-deep, 1.2 km-diameter depression on the southwestern edge of the Colorado Plateau. Stratigraphically beneath the lake's 3.5 km^2 basaltic watershed is the Kaibab Limestone, raising the possibility that this depression is one of the largest karstic sinkholes in the region. Taken from the lake's northern depocenter, core STL14 is an ~ 80 m-long, continuous, multi-indicator archive of past climate and associated surface processes since the Early Pleistocene (~ 1.3 Ma). Tephrostratigraphy, radiocarbon dating, sedimentary facies analysis, and palynology indicate consistent sensitivity of the local ecosystem to glacial-interglacial hydroclimatic changes with diverse responses to each of the over 10 glacial cycles contained in the archive. The mid-Pleistocene transition manifests as a glacial intensification after ~ 900 ka.

Quantitative mineralogy (qXRD) and geochemical (XRF) analyses indicate dust exerts significant influence on the composition of catchment soils and lake sediments. In lake stratigraphy containing the last two glacial cycles (Marine Isotope Stages 1 - 7), mineralogy is dominated by quartz and illite indicating consistent dust accumulation in this ecosystem. A time series of catchment erosion rate (ER) is calculated using dry bulk density measurements, our age model, and qXRD of locally derived minerals (albite and ilmenite). Similar terms along with qXRD of allochthonous minerals are used to estimate dust mass accumulation rate (DMAR). Both ER and DMAR exhibit ranges comparable to results from other studies and their timeseries resemble the sawtoothed character of mid-to-late Pleistocene global climate trends. Both measures are roughly an order of magnitude higher during interglacials (*MIS 1 and 5* ER: ~1 – 5 mm/kyr; DMAR: 0.5 – 4 $g/cm^2/kyr$) than during glacials (*MIS 2,3,4, and 6* ER: ~0.1 – 2 mm/kyr; *DMAR*: 0.1 – 1 $g/cm^2/kyr$).

Particle size distributions (PSD) of lake sediments generated by laser granulometry are statistically unmixed into endmember (EM) PSDs representing various sediment sources for the lake. Three EM PSDs account for most of the clastic sediment volume in Stoneman Lake. EM 1 represents local catchment-derived clastics and corresponds to ER, other erosion indicators (Ti_{XRF} and *Glomus*, an arbuscular mycorrhiza indicative of soil erosion), thermophilus tree species, fire frequency (charcoal), and overall drier conditions (lake facies). EM 2 represents fine-grained, far traveled (>100 km) regional atmospheric dust and corresponds to periods of alluvial fan activity in the Mojave and Sonoran Deserts. EM 3 represents coarser-grained short-traveled (10's of km) dusts and more closely follows patterns of regional fluvial aggradation, occurring during wetter glacial periods. Viewing dust accumulation as an integrated signal of upwind regional conditions, dust fluxes in southwestern North America appear to be broadly controlled by sediment availability, greatly enhanced during transitional climatic periods characterized by geomorphic instability. Core STL14 is an archive of Quaternary processes from catchment to regional scale and is uniquely situated to probe surficial behaviors of the desert southwest beyond that which are preserved in geomorphic surfaces.

Keywords:

Quaternary, paleoclimate, geomorphology, surface processes, erosion, dust

Six years of Sediment Data Collection from a New Mexican Arroyo

Kyle Stark[1] and Daniel Cadol[1]

[1]New Mexico Tech, 801 Leroy Pl., Socorro, NM, 87801, United States

We present six years of data collection from the Arroyo de los Pinos, an ephemeral channel in central New Mexico. The Pinos is home to a state-of-the-art sampling station with a large array of sensors to measure hydrologic and sediment data during flash floods. Hydrologic related data include water depth, velocity, and discharge, rainfall rates, and upstream flow patterns. Sediment related data include bed- and suspended load transport rates and grain size distributions. Some sediment related data was also collected using surrogate equipment, instruments that collect data related to the transport of sediment using acoustic and vibration methods while significantly reducing the cost of operation.

Instantaneous bedload fluxes were as high as 12 kg s^{-1} m^{-1}. Suspended sediment concentration was also high, as large as 100,000 mg L^{-1}, with evidence of clockwise hysteresis. Flow events last 3 hours and typical peak flow discharges were 14 m^3 s^{-1}. The Pinos averages 3 – 5 flow events per year but some years (two of the six years thus far) record no flow. These values depict a highly active system with significant sediment transport. Through physical, direct measurements and an extended record using surrogate instruments we estimate that the Pinos transports 0 – 3,400,000 kg of sediment as bedload per year. Total mass transported in suspension is 8x higher, on average.

Our vision for the Arroyo de los Pinos monitoring station is to provide the highest quality direct, physical measurements alongside novel ways to measure sediment in transport. By selecting the Pinos as our observatory, we aim to advance sediment monitoring in rivers with a wide range of grain sizes in transport. Further understanding of sediment transport processes will aid regional decision makers that manage sediment in arid lands.

Keywords:

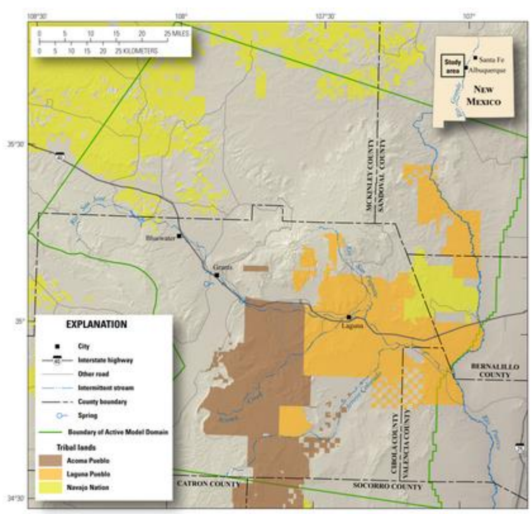
sediment, sediment transport, ephemeral, bedload

THREE-DIMENSIONAL GEOLOGIC FRAMEWORK MODEL OF THE RIO SAN JOSE GROUNDWATER BASIN AND ADJACENT AREAS, NEW MEXICO

Donald S. Sweetkind[1], Amy E. Galanter[2] and Andre Ritchie[2]

[1]U.S. Geological Survey, Geosciences and Environmental Change Science Center, Denver Federal Center MS980, Denver, CO, 80225, United States, dsweetkind@usgs.gov
[2]U.S. Geological Survey, New Mexico Water Science Center, 6700 Edith Blvd NE, Albuquerque, NM, 87113, United States

As part of a U.S. Geological Survey study in cooperation with the Bureau of Reclamation and the Pueblos of Acoma and Laguna, a digital three-dimensional geologic framework model was constructed for the Rio San Jose and its surface-water drainage basin in west-central New Mexico. This model was constructed to define the elevation, thickness, and extent of 18 geologic units for use in a regional numerical hydrologic model. The model includes an undivided Precambrian basement layer, 13 consolidated rock units of Paleozoic and Mesozoic age, and 4 Cenozoic-aged units. Model input data were compiled from published cross sections, well data, structure contour maps, selected geophysical data, and data derived from geologic maps and structural features in the study area. These data were used to construct faulted surfaces that represent the upper and lower subsurface geologic unit boundaries. The digital three-dimensional geologic framework model is constructed through combining faults, the elevation of the tops of each geologic unit, and boundary lines depicting the subsurface extent of each geologic unit. The digital three-dimensional geologic model represents the generalized geometry of the subsurface geologic units, reproduces with reasonable accuracy the input geologic data, and is consistent with previously published subsurface conceptualizations of the region. The geologic framework model is at a scale and resolution appropriate for use as the foundation for a numerical hydrologic model of the study area. The numerical hydrologic model will provide a tool to help support long-term planning and management decisions regarding the basin's surface-water and groundwater resources. The 18 geologic units from the geologic framework model were grouped into 9 hydrogeologic units based on similar age, lithology, and reported hydraulic properties and these hydrogeologic units were used to define the layering in the numerical hydrologic model.



Keywords:

hydrogeology, 3D framework, Rio San Jose

SPELUNKING INTO THE VIROSPHERE: CHARACTERIZING VIRAL COMMUNTIES FROM CARLSBAD CAVERNS NATIONAL PARK

Joseph Ulbrich[1], Daniel S. Jones[2] and Thomas L. Kieft[1]

[1]Biology Department, New Mexico Institute of Mining and Technology, joseph.ulbrich@student.nmt.edu
[2]Earth and Environmental Science Department, New Mexico Institute of Mining and Technology

Viruses are the most abundant biologic entities on Earth, and they play a critical role in the environment and biosphere. Primarily studied in marine environments, viruses, quantified as viral like particles (VLP), have been found to be 10-100 times more prevalent than cells. They contribute to nutrient cycling, regulate microbial populations, and aid in the formation of marine sediments. While most viral research efforts have been focused in oceans, no such investigation has been performed in publicly toured caves. Here, we characterize viral communities in four cavern pools in Carlsbad Caverns National Park to test the hypotheses that i) viral abundance is ten-fold higher than prokaryotic cell abundance in cavern pools, (ii) cavern pools contain novel viral sequences, and (iii) viral communities in pools from developed portions of the cave are distinct from those of pools in undeveloped parts of the same cave. The relationship between viral and microbial abundance was determined through direct epiflorescent microscopy counts. Viral DNA metagenomes were constructed to examine viral diversity among pools and to identify novel viruses. Auxiliary metabolic genes (AMGs) were also identified for pool characterization. VLP and microorganism quantifications determined cave viral-bacteria ratio to be 22:1, aligning with marine findings. Viral abundance was determined to be independent of pool traffic. Pools with higher traffic were found to be more similar to each other than to less visited pools, based on statistical analysis of coverage profiles. Gene-sharing network analysis revealed high viral diversity compared to a reference viral database as well as other aquatic environments. AMG presence showed variation in metabolic potential among the four pools. Overall, Carlsbad Cavern harbors novel viruses with diversity among pools. Future work will investigate viral-host interactions and RNA viruses.

GEOSCIENCE OUTREACH IN THE INTERNATIONAL YEAR OF CAVES AND KARST

George Veni

National Cave and Karst Research Institute, 400-1 Cascades Avenue, Carlsbad, NM, 88220, United States, gveni@nckri.org

The International Year of Caves and Karst is a global effort to teach the world about the benefits and challenges caves and karst offer to humanity. Organized by the International Union of Speleology with 261 partner organizations from 51 countries (all statistics as of 28 March 2022), this effort is targeted at the public, including the educated public, many of whom are ill-informed about caves and karst despite massive strides in recent years.

Of the 462 International Year events to date, approximately 40% have focused on geoscience topics with audiences ranging from children to professionals. Partners include 32 national and international geoscience organizations and 27 UNESCO Global Geoparks and World Heritage sites. As geologic features, much of the outreach, directly or indirectly, provides geoscience education. The COVID-19 pandemic has actually helped the outreach by forcing the production of virtual activities watched worldwide over many months. Conservative estimates, boosted especially through news media outlets, exceed more than 50 million contacts.

The theme of the International Year is “Explore, Understand, Protect.” The goal is that greater understanding will lead to greater funding to support additional research and more effective regulations and guidelines to minimize adverse impacts on karst, and of karst on people. Due to the pandemic, the International Year is extended through 2022, but the benefits and expanded frontiers of the cave and karst geosciences are expected to grow for decades.

QUANTIFYING GROUNDWATER TO SURFACE WATER EXCHANGES IN THE BELEN REACH OF THE MRGCD

Ethan Williams[1], Daniel Cadol[1], Lin Ma[2] and Alex Rinehart[1]

[1]New Mexico Tech, 810 Leroy Place, Socorro, NM, 87801, ethan.williams@student.nmt.edu
[2]University of Texas at El Paso, 500 West University Avenue, El Paso, TX, 79968

Periodic synoptic sampling of surface flows in the southern Albuquerque basin during the 2021 calendar year revealed spatial and temporal variations in the proportion and provenance of groundwater contributions to surface flow. Differential flow gauging and analysis of geochemical tracers (major and minor anions and cations, trace metals, field parameters, $\delta^{18}O$, $\delta^{2}H$, $^{87}Sr/^{86}Sr$) were performed at five riverside irrigation drain locations along a 70-km interval between Bosque Farms and San Acacia, NM, with additional geochemical samples collected from the Rio Grande. Prevailing conceptual models for salinization in the middle Rio Grande focus on the input of deeply sourced brine. However, shallow groundwater with high salinity inherited from interactions with Mesozoic and Paleozoic sediment may be another significant solute source (such as groundwater associated with the Rio Puerco and Abo Arroyo). While these shallow groundwaters are thought to discharge into the river, their influence has not previously been constrained. We consider the chemical, spatial, and temporal variability of groundwater discharge to identify and disaggregate contributions from distinct water sources to understand their individual influence on the riparian system to inform water management decisions, salinization mechanics, and drought resilience. $^{87}Sr/^{86}Sr$ data collected from March and May are consistent with three system endmembers: Rio Grande through-flow ($^{87}Sr/^{86}Sr$ = 0.7096), upwelling sedimentary brine ($^{87}Sr/^{86}Sr \geq 0.7106$), and water influenced by Paleozoic sediment ($^{87}Sr/^{86}Sr$ = 0.7090). Preliminary end-member mixing analysis indicates one or more additional end-member waters could be present. Strontium isotope mass balance showed that sedimentary brine and Paleozoic-influenced water accounted for as much as 5% and 11% of drain flow respectively. The greatest net increase in the Rio Grande's salinity throughout the project area was observed in March, where Cl^- concentration increased from 21.2 to 50.5 mg/l and $^{87}Sr/^{86}Sr$ increased from 0.70955±0.00016 to 0.70996±0.00003 between Bosque Farms and San Acacia, indicating a final composition of 2% Paleozoic-influenced water, 2% brine, and 96% Rio Grande throughflow. Groundwater flux measured in irrigation drains ranged from -13.1 to 21.0 m^3/day/m (4.2 m^3/day/m average). Notable trends in water evolution include increases in specific conductance and a transition from a Ca-HCO_3^- towards a Na-HCO_3^- water type. The rate of change increases with proximity to the basin's terminus. $^{87}Sr/^{86}Sr$ in samples collected near sub-basin structural highs showed locally elevated brine fractions, inconsistent with the general trend. Increases in Na^+/Ca^{2+} did not always correspond to increases in Cl^-, suggesting cation exchange and water mixing have independent influence. These results demonstrate that shallow lateral groundwater flows are a primary source of salinization in addition to upwelling brine.

REEVALUATING THE EMPLACEMENT HISTORY OF THE CORNUDAS MOUNTAINS

Mason N. Woodard[1], Nels A. Iverson[2], Virginia T. McLemore[2] and Laura E. Waters[3]

[1]New Mexico Institute of Mining and Technology, New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801, mason.woodard@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Socorro, NM, 87801
[3]New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801

The Cornudas Mountains are a group of Eocene-Oligocene alkaline laccoliths, plugs, sills, and dikes expressed as nine prominent mountains that straddle the New Mexico-Texas line approximately 60 miles east of El Paso. The intrusions are exposed on the Otero Mesa, situated between the Tularosa and Salt Basins, on the eastern edge of the Rio Grande Rift. The Cornudas Mountains have recently become of interest because of their economic potential for rare earth elements (REEs), as REE-bearing minerals such as eudialyte, bastnaesite and monazite are observed in some intrusions and altered zones. The petrology, mineralogy, and ages of these intrusions were described in detail in the 1970's and 1990's and summarized in McLemore (2018). The purpose of the work is to update these datasets to help guide exploration and understand the emplacement of intrusion.

The lithology of the Cornudas Mountains can be grouped into nepheline syenite to syenite laccoliths and plugs, phonolite sills, and phonolite dikes that are intruded into Permian sediments, which are largely limestone. Many dikes are altered, though pervasive alteration is not found in larger intrusions. The emplacement history of the Cornudas Mountains is not well understood, since only a few of the intrusions were dated using the K-Ar dating method. The previously reported age ranges are 36.8-31.6 Ma. McLemore (2018) provides a new $^{40}Ar/^{39}Ar$ age for Wind Mountain, which is being checked. New $^{40}Ar/^{39}Ar$ ages of the intrusions show an emplacement history of ~12 Ma, from 37.14 to 25.58 Ma, which is longer than those previously reported. These new ages suggest three periods of emplacement: an early laccolith and plug stage (37.14-35.77 Ma), a middle sill stage (32.78-31.07 Ma), and a younger dike stage (32.18-30.16 Ma). One sill (Flat Top, 25.58 Ma) does not follow this progression and is being reassessed.

We incorporate the whole rock and clinopyroxene chemistry of each intrusion into the clinopyroxene-liquid geothermobarometer (Putirka, 2008) to determine the temperatures and pressures of emplacement. Applying the thermometer shows that the syenite intrusions crystallize at higher temperatures (821-1019^{o}C) than the phonolite sills (763-797^{o}C); barometry yields similar pressures within error of the model (1.4-2.7 ± 2kb).

We use the crystallization pressures and a limestone density of 2730 kg/m^3 to calculate emplacement depths (5-11 km). Pairing these depths with the new geochronology, we calculate minimum exhumation rates for intrusions in the Cornudas Mountains that range from 0.1-0.4 mm/y, with faster exhumation rates for younger intrusions. This is faster than the average rate of erosion for a drained part of continents, which could indicate a tectonic component to the exhumation of these intrusions. The timing of the emplacement and exhumation of the Cornudas Mountains could be valuable to understanding the eastern extent of Paleogene extension prior to Rio Grande rifting.

References:

McLemore, V. T. (2018). Rare Earth Elements (REE) Deposits Associated with Great Plain Margin Deposits (Alkaline-Related), Southwestern United States and Eastern Mexico. *Resources*, *7*(1), 8. https://doi.org/10.3390/resources7010008

Putirka, K. D. (2008). Thermometers and Barometers for Volcanic Systems. *Reviews in Mineralogy and Geochemistry*, *69*(1), 61–120. https://doi.org/10.2138/rmg.2008.69.3