New Mexico Geological Society

# Proceedings Volume
# 2023 Annual Spring Meeting

## *Geological Responses to Wildfires*

**Macey Center**
**New Mexico Tech**
**Socorro, NM**

**Friday, April 21, 2023**

# NEW MEXICO GEOLOGICAL SOCIETY

**2023 Spring Meeting**
**Friday, April 21, 2023**
**Macey Center**
**New Mexico Tech**
**Socorro, New Mexico**

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## Friday, April 21, 2023

***Check-in and Packet Pick-up***

**Lower Lobby:** *7:00 AM - 10:00 AM*

***NMGS Annual Business Meeting and Presentation of Student Awards***

**Auditorium:** *8:00 AM - 8:30 AM*

***NMBGMR Presentation of Earth Science Achievement Award to Kent Condie***

**Auditorium:** *8:30 AM - 8:45 AM*

## Keynote Address

# THE ROLE OF GEOLOGY AND LEGACY MINES IN POST-WILDFIRE WATER QUALITY

Sheila F. Murphy
United States Geological Survey

**Auditorium:** *8:45 AM - 9:45 AM*
**Chair:** Johanna M. Blake

# ORAL PRESENTATIONS

(9:45 A.M. to 3:55 P.M.)

## Paleontology in New Mexico

**Galena Room:** *9:45 AM - 10:40 AM*
**Chair:** Spencer Lucas

**FROM OLD POOP TO THE REAL SCOOP: THE TRUTH ABOUT LAKE BALLS**
— David M. Rachal and Jim Mead
*9:50 AM - 10:10 AM*

**PENNSYLVANIAN SILICIFICATION OF SHALLOW MARINE FOSSILS IN THE JEMEZ MOUNTAINS, NEW MEXICO**
— Patrick James Carey and Deborah Petrak Green
*10:10 AM - 10:25 AM*

**A DINOSAUR REGURGITITE FROM THE PALEOCENE OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO**
— James E. Fassett
*10:25 AM - 10:40 AM*

## Water and Wildfires I

**Auditorium:** *9:45 AM - 10:35 AM*
**Chair:** Johanna Blake

~~**MODELING POST-WILDFIRE HYDROLOGIC AND WATER QUALITY RESPONSE: REVIEW AND FUTURE DIRECTIONS**~~
~~— Zach Shephard, Brian A. Ebel, Michelle A. Walvoord, Sheila F. Murphy, Trevor F. Partridge, and Kim S. Perkins~~
~~*9:50 AM - 10:05 AM*~~ *[withdrawn]*

**FLUVIAL PROPAGATION OF WILDFIRE DISTURBANCES FROM THE LARGEST WILDFIRE RECORDED IN NEW MEXICO**
— Justin Rae Nichols, Asmita Kaphle, Paige Tunby, Dave Van Horne, and Ricardo Gonzalez-Pinzon
*10:05 AM - 10:20 AM*

**MONITORING THE IMPACTS OF THE 2022 HERMITS PEAK/CALF CANYON FIRE ON THE UPPER PECOS RIVER WATER QUALITY**
— Jennifer Lindline, Megan Begay, and Letisha Mailboy
*10:20 AM - 10:35 AM*

# *Morning Break*

**Upper Lobby:** *10:30 AM - 11:00 AM*

Drinks, snacks, and conversation

## Sedimentology and Stratigraphy

**Galena Room:** *11:00 AM - 11:50 AM*
**Chair:** Dan Koning

**HYDROSTRATIGRAPHIC FRAMEWORK AND ASSESSMENTS OF PERMEABILITY AND TDS FOR THE SANTA FE GROUP AQUIFER IN THE NORTHWESTERN ALBUQUERQUE BASIN, RIO GRANDE RIFT, NM**
— Daniel J. Koning, Luke Martin, Matthew Zimmerer, Ethan Mamer, Amanda Doherty, and Laila Sturgis
*11:05 AM - 11:20 AM*

**STRATIGRAPHY OF THE EARLY PERMIAN DECHELLY ERG IN NEW MEXICO**
— Spencer G. Lucas and Karl Krainer
*11:20 AM - 11:35 AM*

**APPLYING $^{40}$AR/$^{39}$AR DETRITAL SANIDINE GEOCHRONOLOGY TO CONSTRAIN STRATIGRAPHIC AGES FROM *PROBOSCIDEAN*-BEARING STRATA OF THE PLIO-PLEISTOCENE CAMP RICE FORMATION, SOUTHERN NEW MEXICO**
— Brian A. Hampton, Peter Houde, Matthew T. Heizler, and Julia Ricci
*11:35 AM - 11:50 AM*

## Water and Wildfires II

**Auditorium:** *11:00 AM - 12:00 PM*
**Chair:** Laila Sturgis

**POTENTIAL POST-WILDFIRE WATER QUALITY EFFECTS IN URANIUM-RICH REGIONS**
— Johanna M. Blake, Sheila Murphy, Elizabeth Tomaszewski, and Michelle Hornberger
*11:00 AM - 11:15 AM*

**BED SEDIMENT METAL CONCENTRATIONS AS INDICATORS OF ECOSYSTEM RECOVERY IN THE GALLINAS CREEK WATERSHED**
— Michelle Hornberger, Sheila Murphy, Elizabeth Tomaszewski, and Johanna Blake
*11:15 AM - 11:30 AM*

**GROUNDWATER SIGNATURES AND MIXING PATTERNS AROUND EL PASO DEL NORTE AREA OF THE RIO GRANDE AQUIFER SYSTEM USING ENVIRONMENTAL TRACERS**
— Astrid Y. Lozano Acosta
*11:30 AM - 11:45 AM*

**LINKING GENOMES AND GEOCHEMISTRY IN EXTREME ENVIRONMENTS ACROSS THE GREATER VALLES CALDERA ECOSYSTEM, NEW MEXICO**
— Daniel S. Jones, Abigail Brown, Mackenzie B. Best, Raymond R. Castillo, Evita A. Chee, Angeline Noelle I. Diongson, Katelyn Green, Elaena L. Hann, Zoë Havlena, Willie A. Hughes, Nathaniel E. Jobe, Damilola M. Odumade, Andre J. Ortiz, Lama Ramadan, and Cassandra H. Skaar
*11:45 AM - 12:00 PM*

## *Student/Professional Mixer Luncheon (ticket required)*

**Copper Room:** *12:00 PM - 1:15 PM*

## *Lunch Break*

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

## Economic Geology and Geologic Resources

**Galena Room:** *1:30 PM - 3:35 PM*
**Chair:** Virginia McLemore & Evan Owen

**CRITICAL MINERALS IN NEW MEXICO**
— Virginia T. McLemore
*1:35 PM - 1:50 PM*

**HELIUM – RELATIONSHIPS TO OTHER RESERVOIR GASES AND IMPLICATIONS FOR EXPLORATION: THE NEW MEXICO EXAMPLE**
— Ronald F. Broadhead
*1:50 PM - 2:05 PM*

**THE SOLUBILITY OF TELLURIUM DIOXIDE IN WATER VAPOR AT 250°C**
— Jonathan Reed Adams, Nicole C. Hurtig, Alexander P. Gysi, and Artaches Migdissov
*2:05 PM - 2:20 PM*

**A REVIEW OF LITHIUM AS A CRITICAL INDUSTRIAL MATERIAL AND ENGAGEMENT PROSPECTS IN NEW MEXICO.**
— Mark R. Leo-Russell and Virginia T. McLemore
*2:20 PM - 2:35 PM*

**MICROTEXTURAL RELATIONSHIPS OF ARSENIDE FIVE-ELEMENT VEINS IN THE BLACK HAWK DISTRICT, GRANT COUNTY, NEW MEXICO**
— Zohreh Kazemi Motlagh, William X. Chávez, Virginia T. McLemore, Evan J. Owen, and Jakob Newcomer
*2:35 PM - 2:50 PM*

**LITHOGEOCHEMICAL VECTORS AND MINERAL PARAGENESIS OF HYDROTHERMAL REE-F-BEARING VEINS AND BRECCIAS IN THE GALLINAS MOUNTAINS, NEW MEXICO**
— Evan J. Owen, Alexander Gysi, Virginia McLemore, Nicole Hurtig, and Katharina Pfaff
*2:50 PM - 3:05 PM*

**RARE EARTH ELEMENTS AND CRITICAL MINERALS IN COAL AND RELATED STRATA IN THE SAN JUAN BASIN IN NORTHERN NEW MEXICO**
— Megan N. Badonie and Virginia T. McLemore
*3:05 PM - 3:20 PM*

**CHARACTERIZATION AND ORIGIN OF THE REE-BEARING MAGMATIC-HYDROTHERMAL BRECCIA PIPES IN THE GALLINAS MOUNTAINS, LINCOLN COUNTY,NEW MEXICO**
— Stellah Cherotich and Virginia T. McLemore
*3:20 PM - 3:35 PM*

## Water and Wildfires III

**Auditorium:** *1:30 PM - 2:15 PM*
**Chair:** Rachel Hobbs

**RESTORE: ADDRESSING DECADE-LONG WATER ISSUES IN THE NAVAJO NATION**
— Darlene Wilson, Abhishek RoyChowdhury, Bonnie Frey, and Jianjia Yu
*1:30 PM - 1:45 PM*

**NM WATER DATA INITIATIVE PROJECT: GROUNDWATER LEVEL MONITORING NETWORK PLANNING**
— Stacy Timmons, Rob Pine, Jake Ross, Geoff Rawling, Rachel Hobbs, and Talon Newton
*1:45 PM - 2:00 PM*

**THE NEW MEXICO WATER DATA INITIATIVE: BUILDING COLLABORATIVE DATA SHARING FOR WATER MANAGEMENT ALONG THE PECOS RIVER, NEW MEXICO**
— Rachel Hobbs, Christopher Cox, Jake Ross, and Stacy Timmons
*2:00 PM - 2:15 PM*

## Geomorphology

**Auditorium:** *2:15 PM - 3:05 PM*
**Chair:** Dan Cadol

**INTERWEAVING RECURRING SLOPE LINEAE IN RAGA CRATER, MARS AND THEIR APPLICABILITY TO HILLSLOPE MONITORING THROUGHOUT NEW MEXICO**
— Dan Mason and Lou Scuderi
*2:20 PM - 2:35 PM*

**IMPROVING SOIL MAPS OF RANGELANDS THROUGH IDENTIFICATION OF PATTERNS IN SOIL VARIABILITY IMPOSED BY GEOMORPHIC PROCESSES**
— Bruce Harrison
*2:35 PM - 2:50 PM*

**FACTORS AFFECTING THE RUNOFF RESPONSE OF AN EPHEMERAL WATERSHED TO HIGH-INTENSITY RAIN: ARROYO DE LOS PINOS, NM**
— Daniel Cadol, Loc Luong, Sandra Glasgo, and Madeline Richards
*2:50 PM - 3:05 PM*

## Structural Geology and Volcanology

**Auditorium:** *3:05 PM - 3:55 PM*
**Chair:** Snir Attia

**DOCUMENTING FRACTURE NETWORKS IN PROTEROZOIC GRANITE, ARROYO DEL TAJO, NEW MEXICO**
— Shari Kelley
*3:10 PM - 3:25 PM*

**GEOMETRY, KINEMATICS, AND TIMING OF PROTEROZOIC SHEAR ZONES IN NEW MEXICO AND NORTHWESTERN ARIZONA: A RECORD OF MULTIPLE OROGENIC PULSES?**
— John M. Bailey
*3:25 PM - 3:40 PM*

**THE CALM BEFORE THE VOLCANIC STORM**
— Matthew J. Zimmerer, Peter W. Lipman, and Nicholas F. Meszaros
*3:40 PM - 3:55 PM*

## Posters, afternoon snacks, and cash bar:

**Upper Lobby:** *3:30 PM - 5:00 PM*

**GEOCHEMISTRY OF CRITICAL MINERALS IN MINE WASTES AT HILLSBORO AND STEEPLE ROCK DISTRICTS, NEW MEXICO.**
— Abena Serwah Acheampong-Mensah and Virginia T. McLemore
**Booth:** *1*

**MILLENNIAL-SCALE CLIMATE CHANGE IN THE VALLES CALDERA SEDIMENT CORE DURING GLACIAL PERIOD MIS 12**
— Raven Longwolf Alcott and Peter Fawcett
**Booth:** *2*

**BEDROCK AND NEOTECTONIC CHARACTERIZATION OF AN UNNAMED RANGE-BOUNDING RIO GRANDE RIFT FAULT SOUTH OF SOCORRO, NEW MEXICO**
— Jonathan Anaya, Kyle Gallant, Daniel Runyan, Antonio Chavez, Riley Heath, and Veronica B. Prush
**Booth:** *3*

**UNEARTHING THE MID-CENOZOIC CORDILLERAN MAGMATIC PERIPHERY OF EASTERN NEW MEXICO**
— Snir Attia and Julia Ricci
**Booth:** *4*

**TIMING AND ORIGIN OF HREE-ENRICHED FLUORITE MINERALIZATION IN WEST TEXAS AND SOUTHERN NEW MEXICO, INCLUDING SIERRA BLANCA AND THE FRANKLIN MOUNTAINS**
— James Barker, Muriel Sandoval, Ali Mahar, Jay Chapman, Phillip Goodell, and Antonio Arribas
**Booth:** *5*

**WESTERN ALPINE HIGH POTENTIAL, WEST FLANK DELAWARE BASIN, TEXAS**
— Anthony Benson and Edward Benson
**Booth:** *6*

**TAOS VALLEY GROUNDWATER STRUCTURE**
— Tony Benson, Shannon Williams, Sam Fire, and Grace Powell
**Booth:** *7*

**HYDROLOGIC RESPONSE OF THE GALLINAS RIVER TO 2023 SPRING SNOWMELT POST-2022 HERMITS PEAK/CALF CANYON FIRE**
— Mary Frances Bibb and Jennifer Lindline
**Booth:** *8*

**Petrography and Economical Potential of Banded Iron Formation of the Neoproterozoic-Age Buem Formation, Ghana**
— Ernest Brakohiapa
**Booth:** *9*

**Magdalena Science Café Water Resources Science Project**
— Kassidy Brunson, Jeremiah Alvarez, Zeb Apachito, Cade Brunson, Tristin Alvarez, Jim Sauer, Bonnie Frey, Nicole Hurtig, and Laila Sturgis
**Booth:** *10*

**Geometry of Major Normal Faults in the Sevilleta National Wildlife Refuge, Rio Grande Rift, Constrained By Total Bouguer Gravity Anomaly Data**
— Antonio Chavez, Richard Chamberlin, and Alex Rinehart
**Booth:** *11*

**Metagenome-assembled Genomes from Extremophilic Microbial Communities In and Around Valles Caldera National Preserve, New Mexico**
— Angeline Noelle I. Diongson, Abigail Brown, Mackenzie B. Best, Raymond R. Castillo, Evita A. Chee, Katelyn Green, Elaena L. Hann, Zoë E. Havlena, Willie A. Hughes, Nathaniel E. Jobe, Damilola M. Odumade, Andre J. Ortiz, Lama Ramadan, Cassandra H. Skaar, and Daniel S. Jones
**Booth:** *12*

**Plagioclase Mineral Chemistry of Basalt Rocks from the Black Mountain-Santo Thomas Chain in the Potrillo Volcanic Field**
— Teresa Dominguez and Jennifer Thines
**Booth:** *13*

**Olivine Mineral Chemistry of Volcanic Flows in the Northeastern Potrillo Volcanic Field**
— Mikayla Earnest and Jennifer Thines
**Booth:** *14*

**The First Record of the Echinoid Genus *Mecaster* From the Turonian (Upper Cretaceous) of New Mexico**
— Michael P. Foley and Spencer G. Lucas
**Booth:** *15*

**From the Laramide to Now: Mapping the Tectonic Evolution of Central New Mexico in the Northern Fra Cristobal Range**
— Kyle K. Gallant and Veronica B. Prush
**Booth:** *16*

**Exceptional Trace Fossils and Fossil Plants From a New Locality in the upper part of the Abo Formation (lower Permian), Socorro County, New Mexico**
— Susan K. Harris, Spencer G. Lucas, William A. DiMichele, and Paul T. May
**Booth:** *17*

**The Uvas Basaltic Andesite: a Large-Volume Volcanic Field Erupted During the Initiation of the Southern Rio Grande Rift**
— Lee H. Hughes and Jeffery M. Amato
**Booth:** *18*

**Permian tetrapod fossils reworked into the Eocene Baca Formation northeast of Socorro, New Mexico: resolving a forgotten discrepancy in the work of N. H. Darton**
— Adrian P. Hunt, Susan K. Harris, Paul T. May, and Spencer G. Lucas
**Booth:** *19*

**Observations on Subsurface Stratigraphy at the I&W Brine Site in Carlsbad, New Mexico**
— Eric D. Koenig and Michael L. Rucker
**Booth:** *20*

**A Cryptic Miocene Occurrence of an Ultramafic Dike in the Interior of the San Juan Basin: Composition, Age, and Tectonic Interpretations**
— Jon M. Krupnick, Kevin M. Hobbs, and Luke Martin
**Booth:** *21*

**Surface Water and Snowpack Modeling With Emphasis on Post-Wildfire Hydrologic Impacts in the Santa Fe Watershed, NM**
— Joseph Kuljis
**Booth:** *22*

**Rare Earth Elements in Humates Mined in the San Juan Basin**
— John Lempke, Bonnie Frey, Brent Goehring, and Virginia McLemore
**Booth:** *23*

**Environmental Fate of Sulfur in Sulphur Creek, Valles Caldera, NM: Implications for Water Quality and Metal Transport**
— Daniel Lavery, Laura J. Crossey, and Abdulmehdi Ali
**Booth:** *24*
**Revisions to the Pensylvanian-Permian Lithostratigraphic Nomenclature in the Southern Sangre de Cristo Mountains, New Mexico**
— Spencer G. Lucas and Karl Krainer
**Booth:** *25*

**Quantifying bedload transport in ephemeral channels using seismic methods**
— Loc Luong and Daniel Cadol
**Booth:** *26*

**AMMONITES OF THE UPPER CRETACEOUS TWOWELLS MEMBER OF THE DAKOTA SANDSTONE, OJITO WILDERNESS AREA, SANDOVAL COUNTY, NEW MEXICO**
— Paul T. May and Spencer G. Lucas
**Booth:** *27*

**COMPARISON OF MEASURED BEDLOAD WITH PREDICTIONS FROM TRANSPORT EQUATIONS IN AN UNARMORED EPHEMERAL CHANNEL**
— Rebecca Moskal and Daniel Cadol
**Booth:** *28*

**THE MINERALOGY OF THE BLACK HAWK ARSENIDE 5-ELEMENT DEPOSIT**
— Jakob Newcomer, Virginia McLemore, Zohreh Kazemi Motlagh, Evan Owen, and Nicole Hurtig
**Booth:** *29*

**COMPLETE FISH FOSSIL FROM THE UPPER CRETACEOUS MANCOS SHALE NEAR TIERRA AMARILLA, RIO ARRIBA COUNTY, NEW MEXICO**
— Randy Pence, Paul T. May, Paul L. Sealey, Joe D. Stewart, and Spencer G. Lucas
**Booth:** *30*

**EVALUATING SEGMENTATION BEHAVIOR ALONG THE ALAMOGORDO FAULT USING REMOTE SENSING AND FIELD-BASED DATASETS**
— George Pharris, Veronica Prush, and John Naliboff
**Booth:** *31*

**INVESTIGATING THE GEOMETRY OF AN UNNAMED FAULT SYSTEM SOUTH OF SOCORRO, NEW MEXICO, USING AN INTEGRATED GEOPHYSICAL AND REMOTE SENSING APPROACH**
— George Pharris, Riley Heath, Victoria Jones, Veronica Prush, Isabel Morris, Lindsay Worthington, Collin Brandl, Sarah Rysanek, Jillian Podmore, and Jonathan Anaya
**Booth:** *32*

**PHYLOGENETIC ANALYSIS OF AMMONIA MONOOXYGENASE (AMOA) GENES FROM DESERT CAVES**
— Kenyan Pius Phlieger, Katelyn Green, and Daniel Jones
**Booth:** *33*

**TECTONIC GEOMORPHOLOGY OF THE JEMEZ SYSTEM: RESOLVING QUATERNARY RIVER RESPONSE TO DYNAMIC LANDSCAPES USING $^{40}$AR/$^{39}$AR GEOCHRONOLOGY**
— Cameron Reed, Karl Karlstrom, Matthew Heizler, Benjamin Rodriguez, Julia Ricci, and Laura Crossey
**Booth:** *34*

**Utilizing Benthic Macroinvertebrates to Assess the Impacts of the Hermits Peak/Calf Canyon Fire on Water Quality in Regional Watersheds**
— Kennis Romero, Mary Frances Bibb, Daryl Williams, Jennifer Lindline, and Sebastian Medina
**Booth:** *35*

**Determining surface water and groundwater returns from Bosque del Apache National Wildlife Refuge to the Rio Grande**
— Stephanie Roussel, Zachary Shephard, Fletcher Brinkerhoff, and Rebecca Travis
**Booth:** *36*

**Mineral Paragenesis and Fluid Evolution at the Magmatic-Hydrothermal Transition of the Lemitar Carbonatite, NM**
— Eric L. Ruggles, Nicole Hurtig, Alexander Gysi, and Virginia McLemore
**Booth:** *37*

**High-Magnesium Dolomites in South-Central New Mexico**
— Daniel M. Runyan, Virginia T. McLemore, Evan J. Owen, and Ethan B. Haft
**Booth:** *38*

**New U-Pb Detrital Zircon Geochronology From the Eocene San Jose Formation, Eastern San Juan Basin, Northwestern New Mexico**
— Nicole Joy Salladin, Thomas A. Valenzuela, Brian A. Hampton, and Kevin M. Hobbs
**Booth:** *39*

**Applying U-Pb Detrital Zircon Geochronology to Constrain Oligocene-Miocene closed-basin Rio Grande Rift sedimentation in the Palomas and Jornada del Muerto Basins, Southern New Mexico**
— Ethan J. Schneider and Brian A. Hampton
**Booth:** *40*

**A Summary of Late Cretaceous Ammonites and Molluscan Zones, Eastern San Juan Basin, Rio Arriba County, New Mexico**
— Paul L. Sealey and Spencer G. Lucas
**Booth:** *41*

**The Nautiloid *Eutrephoceras* Sp. From the Cretaceous of New Mexico Likely Represents Multiple Species**
— Paul L. Sealey and Spencer G. Lucas
**Booth:** *42*

**Alteration and geochemistry of Clinkers in the San Juan Basin, New Mexico**
— Devlon R. Shaver, Virginia T. McLemore, and Evan Owen
**Booth:** *43*

**Tracking REE formation with fluid inclusions from the Gallinas Mountains, NM**
— Teagan Skinner, Nicole C. Hurtig, Alexander P. Gysi, and Virginia McLemore
**Booth:** *44*

**The Hydroclimate and Environmental Response to Warming in the Southwestern US: A Study Across the Mid-Miocene Climate Optimum**
— Sianin Spaur, Jeremy Caves Rugenstein, Daniel J. Koning, and Scott Aby
**Booth:** *45*

**Laramide Porphyry Systems of New Mexico: Geochronology and Critical Mineral Potential**
— Kyle T. Stafford, Virginia T. McLemore, and Nels A. Iverson
**Booth:** *46*

**Hydrochemistry of an Alpine Karst System, Northern New Mexico: Las Huertas**
— Kambray Townsend, Laura J. Crossey, Karl Karlstrom, Brittany Griego, and Livia Crowley
**Booth:** *47*

**Droning on at NMSU: Exploring Integration of Geologic and UAS Workflows**
— Thomas Valenzuela, Nicole Salladin, Alexis Salmeron, Michael Murphy, Joseph Wilcox, and Casey James Duncan
**Booth:** *48*

# GEOCHEMISTRY OF CRITICAL MINERALS IN MINE WASTES AT HILLSBORO AND STEEPLE ROCK DISTRICTS, NEW MEXICO.

**Abena Serwah Acheampong-Mensah[1] and Virginia T. McLemore[2]**

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There are tens of thousands of inactive or abandoned mine features in 274 mining districts in New Mexico (NM) (including coal, uranium, metals, and industrial minerals districts) with about 15,000 abandoned legacy mine features varying from shallow prospect pits to deep mine shafts in the state. There is a need to classify these wastes or "abandoned deposits" to understand their composition, properly estimates the quantity and evaluate the potential economic value. Since most of the earlier operations and exploitation was focused on heavy metals, it would be good to now turn our attention to examine these wastes for potential critical minerals. Hence this project seeks to 1) characterize and estimate the critical mineral endowment of mine wastes in three mining districts in New Mexico (Copper Flat at Hillsboro, Black Hawk in Burro Mountains, and Carlisle-Center mines in Steeple Rock district) and 2) "beta-test" USGS procedures and provide feedback. Potential critical minerals at these deposits include As, Bi, Te, Zn, , Co, Ni, Mg, Mn, and fluorite.

It is necessary to perform paste pH test and particle size analysis on samples collected since these factors can affect weathering and the migration of heavy metals. Also, acid rock drainage (ARD) is a huge concern for mine waste management and soil pH is an effective indicator for ARD. Paste Ph conducted on samples collected from the waste rock piles ranged from 3.66 to 5.67 and are mostly indicative of fine-grained pyrite or sulfide oxidation. The samples collected from the tailings however showed a slightly different pattern in pH, ranging from 6.30 to 8.62 probably due to the presence of carbonates. Difference in particle size fractions and its distribution along the slope are generally influenced by natural occurrences (e.g., gravity and pre-mining hydrothermal alteration) and operational activities such as material piling or dumping. This in turn also affects the general slope stability and possibly mineralogy distribution within the waste dump.

The benefits of this project are to ensure prospects for critical minerals in the New Mexico state are not lost to urbanization, settlement or other land use. This project would ensure that there are data and archived samples for future studies and advance research as these mine features may not be accessible after reclamation. Future mining of mine wastes that potentially contain critical minerals will directly benefit the economy of New Mexico. Possible re-mining of mine wastes could clean up these sites and pay for reclamation.

# THE SOLUBILITY OF TELLURIUM DIOXIDE IN WATER VAPOR AT 250°C

**Jonathan Reed Adams[1], Nicole C. Hurtig[1], Alexander P. Gysi[2] and Artaches Migdissov[3]**

[1]New Mexico Institute of Mining and Technology, 801 Leroy Pl, Socorro, NM, 87801, United States, jonathan.adams@student.nmt.edu
[2]New Mexico Bureau of Geology and Mineral Resources, 801 Leroy Place, Soc, NM, 87801, USA
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Tellurium is a critical mineral of increasing importance in green energy technologies. Numerical simulations using previous thermodynamic data predict up to ~0.1 ppm in epithermal vapor with $H_2Te(g)$ as the dominant vapor species [1]. However, fluid inclusion studies show up to hundreds of ppm Te in vapor inclusions from epithermal ore deposits [2]. In this study, we measured experimentally the solubility of tellurium in hydrothermal vapors to determine the hydrated tellurium speciation in water vapor. Hydration is the effect of water vapor molecules binding to a metal, greatly increasing its solubility [3]. Experiments were conducted in batch-type Ti Parr reactors at 250°C and a range of water vapor pressures ($P_{H2O}$) using several different oxygen buffers (e.g., $MoO_2$-$MoO_3$, $WO_2$-$WO_3$ and Ni-NiO). Kinetic experiments were conducted between 1-25 days at 250°C and 20 bar and at different redox conditions. At oxidizing conditions, equilibrium conditions were reached after ~10 days with 1.33 ±0.01 ppm dissolved Te, whereas in $N_2$-degassed experiments equilibrium was reached after ~22 days with 0.669 ±0.004 ppm dissolved Te, indicating slower reaction kinetics and reduced solubility at lower redox conditions. Experiments at 250°C and log*f*$O_2$ of -24 ($MoO_2$-$MoO_3$ buffer), show increasing Te solubility with increasing $P_{H2O}$ ranging from 1-3 ppm between 15-25 bar to 12.27±0.01 ppm Te at 35 bar. The $MoO_2$-$MoO_3$ buffered experiments overlap in concentrations with results from the kinetic series at oxidizing conditions. Experiments at 250°C and log*f*$O_2$ of -39.37 ($WO_2$-$WO_3$ buffer), show an increase in Te solubility between 15-35 bar from 14.51 ppm up to 15.45±0.01 ppm. Previous experimental work has shown enhanced solubility of $TeO_2$ in water vapor due to the formation of $TeO_2*xH_2O$ with $x$ = 1 and 2 [1,4-5], whereas in this study Te shows higher hydration numbers similar to other metals [3]. Our results demonstrate the significant role of $P_{H2O}$ on Tesolubility in low density fluids as wellas a strong redox control based on results from the $WO_2$-$WO_3$ buffered experiment. The experimental data generated can be applied in thermodynamic models to discern tellurium mobility in hydrothermal systems.

## References:

[1] Grundler et al., (2013) *Geochim. et Cosmochim. Acta***120**, 298–325.
[2] Wallier et al., (2006) *Economic Geology***101**, 923–954.
[3] Hurtig et al., (2021) *Economic Geology* **116,** *1599-1624.*
[4] Glemser et al., (1964) *Z. anorg. allg. Chem.* **329,** 51-55.
[5] Glemser et al., (1966) *Omagiu Raluca Ripan*, Editura Acedemiei Republici Socialiste Romania,Bucarest, 253-262.

# MILLENNIAL-SCALE CLIMATE CHANGE IN THE VALLES CALDERA SEDIMENT CORE DURING GLACIAL PERIOD MIS 12

**Raven Longwolf Alcott[1] and Peter Fawcett[1]**

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The mid-Pleistocene sedimentary record from the Valles Caldera preserved 14 millennial-scale climate oscillations that were assessed for Total Organic Carbon (TOC), Total Organic Nitrogen (TON), carbon isotopes, nitrogen isotopes and C/N ratios. The in-depth geochemical analysis of these sediments helped determine the relative proportions of terrestrial (higher C/N values) to aquatic productivity (lower C/N values) contributions to the lacustrine organic matter over the abrupt climate change events. The warmer to colder climate oscillations during the MIS 12 glacial period allowed an assessment of changes in productivity and what the relative contributions were from land plants vs. aquatic algae. Meanwhile, examination of the carbon isotopes helped determine whether there were more C4 grasses (which prefer warmer and drier conditions) around the lake during the brief warmer episodes. Data collected and analyzed showed that organic carbon was algae derived and that C4 grasses did not occur during brief warm episodes in the glacial period. Further investigation of the abrupt climate changes using lake sediments can provide a window to the past that allows us better to understand a future that will be heavily influenced by anthropogenic warming.

## References:

Contreras, S., Werne, J. P., Brown, E. T., Anderson, R. S., and Fawcett, P. J. (2016). A molecular isotope record of climate variability and vegetation response in southwestern North America during mid-Pleistocene glacial/interglacial cycles. Palaeogeography. Palaeoclimatology, Palaeoecology, v. 459, p. 338-347.

Fawcett, P. J., Scott Anderson, R., Brown, E. T., Werne, J. P., Contreras, S., Smith, S. J., Heikoop, J. M., and Allen, C. D. (2021) Millennial-scale climate change during a mid-Pleistocene glacial (MIS 12): a lacustrine record from the Valles Caldera, NM. Quaternary Science Reviews.

Fawcett, P. J., Werne, J. P., Anderson, R. S., Heikoop, J. M., Brown, E. T., Berke, M. A., Smith, S., Goff, F., Donohoo-Hurley, L. L., Cisneros-Dozal, L.M., Schouten, S., Goff, F. (2009). Valles Caldera, A Geologic History. University of New Mexico Press.

Fawcett, P.J., Heitkoop, J., Goff, F., Anderson, R. S., Donohoo-Hurley, L., Geissman, J. W., WoldeGabriel, G., Allen, C. D., Johnson, C. M., and Smith, S. J. (2007). Two middle Pleistocene glacial-interglacial cycles from the Valle Grande, Jemez Mountains, northern New Mexico. Field Conference-New Mexico Society Guidebook, 409.

Meyers, P. A. and Lallier-Verges, E. (1998). Lacustrine sedimentary organic matter records of Late Quaternary paleoclimates. Journal of Paleolimnology, v. 21, p. 345-372.

## Keywords:

paleoclimate, lake sediments, climate change

# Bedrock and Neotectonic Characterization of an Unnamed Range-Bounding Rio Grande Rift Fault South of Socorro, New Mexico

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Active rift systems accommodate deformation through the development of normal fault systems. The Rio Grande rift (RGR) in central New Mexico consists of a north-south-trending zone of intracontinental extension and is characterized by a series of normal fault zones bounding half-graben basins. Extension in the RGR is thought to have started during the late Oligocene-Miocene. Fault scarps offsetting recent deposits indicate that deformation has been ongoing through the Quaternary. Rupture along these structures poses a potential danger to local communities and infrastructure; however, the slip histories of many of the fault systems in the RGR are understudied. The Socorro Canyon Fault Zone (SCFZ) is one of several normal faults that demarcate the western boundary of the Socorro basin, a Miocene half-graben basin associated with the development of the RGR. Although the SCFZ is one of the best-studied fault systems within the RGR, the role of surrounding structures in accommodating deformation of bedrock and Quaternary deposits is not as well-constrained. In conjunction with a companion geophysical study, we show that an unnamed series of normal and oblique faults, ~5 km west of the SCFZ, play an important role in accommodating RGR deformation. Our study area is composed of a series of north-northwest normal faults and secondary east-west strike-slip faults offsetting the Oligocene-Miocene volcanic successions of the Hells Mesa tuff, the Miocene Popotosa Formation, and Quaternary deposits. A primary bedrock fault consists of a ~11m damage zone that incorporates lenses of volcanic rocks surrounded by fault gouge, breccia, and cataclasite. Our neotectonic map and soil profile analysis demonstrate how the fault system deforms Quaternary deposits, as evidenced by scarps and tilted Quaternary strata. The development of pedogenic carbonate horizons above deformed Quaternary alluvial fans helps to constrain the timing of deformation along this system. Our study sheds light on the complexity of faulting and strain partitioning in rift systems and how deformation occurs in intracontinental extensional settings. Future work will integrate microstructural observations to constrain how deformation is accommodated at the microscopic level.

**Keywords:**

Rio Grande rift, Socorro Canyon Fault Zone, intracontinental deformation, Quaternary faulting

# Unearthing the mid-Cenozoic Cordilleran magmatic periphery of eastern New Mexico

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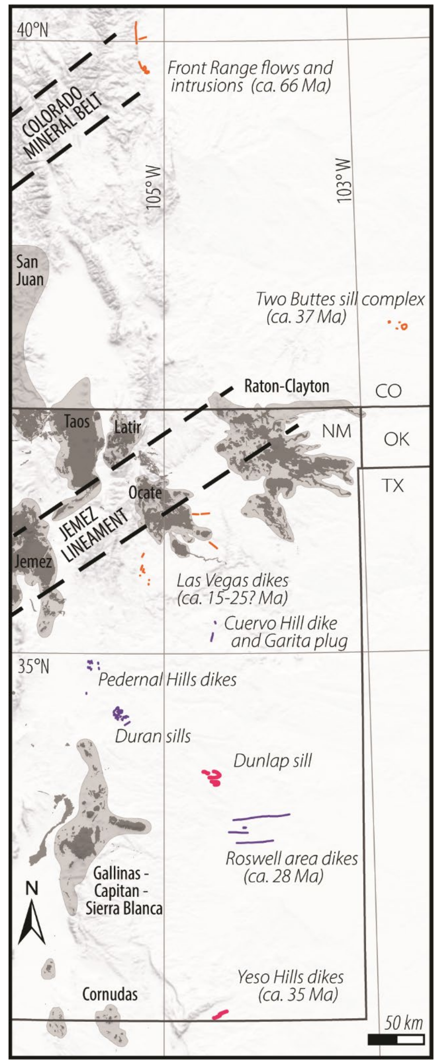


Figure Caption: Distal alkaline igneous occurrences in New Mexico and Colorado. Magmatic periphery in purple, speculative parts in orange, and current mapping targets in pink. Cenozoic igneous rocks in dark grey with magmatic centers in light grey from Geologic Map of New Mexico.

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The North American alkaline magmatic belt has long been recognized as a first-order feature of the western North American Cordillera. Even more distal, small-volume alkaline igneous occurrences are found in the far inboard Cordillera along the western edge of the Great Plains from Texas to northernmost Montana. In eastern New Mexico and southeastern Colorado, distal intrusions of mid-Cenozoic age are emplaced into little deformed Permian to Cretaceous strata, some 50 to 200 kilometers east of the nearest major alkaline magmatic centers. About ten late Eocene to mid-Miocene igneous occurrences stretching from the Yeso Hills dikes (Eddy County, NM) to the northeastern end of the Jemez lineament form the Cordilleran magmatic periphery of eastern New Mexico. Isolated minor dikes, sills, and plugs are generally alkaline and mafic to intermediate in composition, though data and descriptions are presently limited. These peripheral igneous occurrences may simply be far-travelled lateral offshoots of the alkaline magmatic centers in axial New Mexico. Alternatively, distal intrusions may represent transcrustal magmatic systems related to small-volume melting beneath the westernmost Great Plains. In the latter case, these minor alkaline igneous occurrences would constitute a coherent ‘Cordilleran magmatic peripheral belt’ distinct from the major magmatic centers of the North American alkaline magmatic belt emplaced into Laramide structures and rift flank uplifts to the west. We highlight the potential constitutive elements of the Cordilleran magmatic periphery of eastern New Mexico and future research to study these occurrences.

**Keywords:**

alkaline magmatism, intrusions, Cenozoic, Great Plains, intracontinental magmatism

# Rare Earth Elements and Critical Minerals in Coal and Related Strata in the San Juan Basin in Northern New Mexico

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Rare earth elements (REE) and critical minerals (CM) have become of great economic interest because of the advent of new technologies and recent geopolitical unrest affecting the supply of resources. With the continuous development of extracting REE and CM from secondary and non-conventional sources such as coal and its related strata, there is a push to study the relationship between coal, REE, and CM. Extracting REE and CM from coal and coal ash could become feasible because of the large volumes of coal burned for electricity and the resulting storage facilities of coal ash. The San Juan Basin in northern New Mexico is a structural basin that contains coal and related stratigraphic units with elevated concentrations of REE and CM. This basin is being assessed geochemically through whole-rock and coal ash analysis to determine if there is REE and CM enrichment. The San Juan Basin contains three major coal-bearing sequences, ascending in oldest to youngest stratigraphic order: Crevasse Canyon, Menefee, and Fruitland formations. There are 22 individual coalfields within the San Juan basin, eight are Crevasse Canyon formation coalfields, 11 are Menefee formation coalfields, and four are Fruitland formation coalfields. 23 individual holes of legacy drill core from the San Juan Basin have been logged and photographed. They have been logged to record basic geological characteristics of the coal seams and related strata observed. Samples of coalbeds, coal seams, overlying, and underlying rock units continue to be collected and characterized to determine any economic viability. Coal ash samples from the San Juan Basin have shown a greater than 200 ppm total REE, which is considered enriched for these rocks. CM in coal samples from the Salt Lake and Star Lake coalfields show Li and Zr having slightly elevated concentrations when compared to the other San Juan Basin coal samples and average crustal abundance. Historic data has been collected and compiled into a new comprehensive coal geochemical database with the new chemical analyses. This database will grow with additional analysis and serves as the dataset for this project. To determine the economic viability, the coal volume resource potential has been calculated using estimated resource figures defined by NMBGMR and USGS. REE and CM have been applied to these calculations to estimate the resource potential in the San Juan Basin.

**Keywords:**

Rare Earth Elements, Critical Minerals, REE, CM, Coal, San Juan Basin, New Mexico

# Geometry, kinematics, and timing of Proterozoic shear zones in New Mexico and northwestern Arizona: a record of multiple orogenic pulses?

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Proterozoic shear zones are key features of southwestern North America's orogenic belts that extend over 1,000 km along strike from Mexico to eastern Canada. The dominant fabric of these shear zones is a subvertical, northeast-trending foliation expressed in a wide range of temperature regimes, from migmatites to mylonites to pseudotachylytes, that have previously been envisioned to have formed during the Paleoproterozoic (1.7-1.6 Ga Yavapai and Mazatzal orogenies). An emerging addendum is that the lower temperature shearing possibly represents reactivation of earlier shear zones during the later deformation such as the ~1.45 Ga Picuris and ~1.1 Ga Grenville orogenies. The research plan for this project is to use $^{40}Ar/^{39}Ar$ thermochronology to date fine-grained mica found in the grain-reduced shear zones as well as coarse-grained mica from the coarser grained shear zones to attempt to parse 1.65 versus ~1.45 Ga, or younger, tectonites. Previous studies have found that Paleoproterozoic shear zones in the Manzano Mountains of New Mexico may have been reactivates. Other ultramylonites in areas, away from the center of Picuris-age deformation in the Picuris Mountains, such as in the Cimmaron Range, remain undated. This study will date in-hand samples from shear zones in the Cimmaron Range and Manzano Mountains at the New Mexico Geochronology Lab to test the sensitivity of this methodology. This methodology will also be applied more regionally to an important tectonic boundary between the Mojave and Yavapai provinces that is present in the Lower Granite Gorge of the Western Grand Canyon where discrete mylonite – ultramylonite zones, some with pseudotachylyte, are embedded within the ~13-km-wide higher temperature Gneiss Canyon shear zone. For the Lower Granite Gorge shear zones, we plan to integrate U-Th-Pb monazite and xenotime in-situ geochronology to help parse out high temperature versus low temperature deformation. Using these combined field laboratories, the nature and timing of regional shear zone reactivation and this $^{40}Ar/^{39}Ar$ methodology will be tested.

**Keywords:**

Proterozoic, Shear Zones, Tectonics, Geo-Thermochronology

# Timing and Origin of HREE-Enriched Fluorite Mineralization in West Texas and Southern New Mexico, Including Sierra Blanca and the Franklin Mountains

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The main goal of this study is to determine the mineralization timing and origin of the unique Y+HREE (heavy rare earth element) deposit hosted by Round Top Mountain in the Sierra Blanca laccolith cluster in west Texas and compare it to fluorite deposits elsewhere in west Texas and southern New Mexico. Initial operations at the Round Top deposit are underway and the project is estimated to have a mine life of >20 years. Whole-rock geochemistry reveals that the magmatic rocks at the Sierra Blanca cluster are high-K, metaluminous rhyolites. A detailed mineralogical review shows that most of the Y + HREEs reside within the Ca-deficient yttrofluoride, yttrocerite, fluocerite, xenotime and cheralite. New zircon and xenotime U-Pb LA-ICP-MS geochronology data from the Sierra Blanca area indicate magmatism occurred from 38-34 Ma. Inherited zircon show a cluster of ~1.1 Ga dates, which suggest the involvement of granitic basement similar to the 1.1 Ga Red Bluff Granite exposed in the Franklin Mountains. Zircon Lu-Hf (-4 to -10 $\varepsilon Hf_t$) and zircon $\delta^{18}O$ (5.5-6.5 ‰) isotopic data from the Sierra Blanca area suggest enriched mantle-derived magma sources. Fluorite from the Organ Mountains caldera (ca. 36 Ma) and the Red Bluff Granite was investigated using LA-ICP-MS for U-Pb dating and REE concentrations to compare with the Round Top deposit. Fluorite from the Organ Mountains contained significant common Pb and did not yield reliable ages, but the data suggests that mineralization occurred during the Cenozoic. Fluorite from the Red Bluff Granite is significantly more enriched in REE (~9000 ppm REE+Y) than the Organ Mountains fluorite (~400 ppm REE+Y). In addition to fluorite, another purple-colored, REE-bearing mineral was identified in the Red Bluff Granite that is tentatively thought to be hydrothermal zircon with up to 10 wt. % REE=Y. U-Pb analysis of this mineral yields an age of 1.05 ± 0.05 Ga. These new data and our ongoing investigations will help provide a more comprehensive understanding of the genesis of the Round Top HREEs deposit and the generation of REE-enriched fluorite mineralization throughout the region.

# WESTERN ALPINE HIGH POTENTIAL, WEST FLANK DELAWARE BASIN, TEXAS

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The Alpine High gas field discovery was announced by Apache in September, 2016, touting gas reserves of 75 TCF, mainly from the Mississippian Barnett and Devonian Woodford shales (Apache website, 2016) as posted by Benson (2017). Low gas prices and lack of pipeline infrastructure have delayed much development, but was scheduled to resume in the fall, 2022. The authors are part of a team of energy specialists, put together for the JMB company, to evaluate their Hovey Ranches and surrounding areas to assess the total energy potential in Brewster and Jeff Davis Counties.

The original Apache acreage block of over 200,000 acres, mostly in western Reeves County appears to follow a paper published by Swift et al., (1994), whose outline showed potential conventional gas plays in Reeves County based on Woodford structure map and reprocessed 1970s vintage 2-D seismic data. The major up-to-the-west reverse fault No.1, lies just west of the Jeff Davis County line. A previous interpretation by Pearson (1985) mapped the Capitan Permian reef thick overlying the northwest trending Devonian shelf. A Permian thick was mapped in the subsurface by Standen et al., (2009, Figure 18).

An Ellenberger high was mapped under Alpine and trending northwest by Ammon (1981, Figure 11). Deep Ellenberger gas was found at Gomez field and other large fields in the 1960s causing the oil pipeline to be diverted back to California for natural gas consumption. The structural high is covered by the Star Mountain rhyolite (37 myo) portrayed regionally by McLeod (2009). A quarter mile wide by 200-foot-high ridge of Star Mountain rhyolite extends nearly 10 miles southeast from Little Star Mountain (probable vent) just west of fault No. 1, mapped at Woodford shale depth. It is interpreted that this dike extends at depth, following fault fractures and may have heated the Barnett and Woodford shales during the introduction of hydrocarbon expulsion. These areas should be avoided in future drilling.

Six wells have been drilled by Coterra, formerly Cabot Oil and Gas, and affiliates over the past four years, along this Star Mountain trend, including two 4000 foot horizontal laterals. They have been fraced in the Woodford, but no results are available. Coterra acreage leases have been dropped.

Northwest trending faults were mapped by King (1930) in the Glass Mountains. The Woodford produces oil in the Marathon fold belt (Reed and Strickler, 1990). Will high gas prices rejuvenate the unconventional plays on the west side of the Delaware Basin? Late timing of hydrocarbon generation may allow a vast area of unconventional hydrocarbon exploration.

**Keywords:**

Alpine High, Delaware Basin, gas, hydrocarbon exploration

# TAOS VALLEY GROUNDWATER STRUCTURE

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The groundwater structure was calculated at top of the Servilleta basalt. Taos Valley is sourced from streams fed by mountain snowmelt. Recent watershed management actions, including forest thinning projects and deep drilling required by the Taos Pueblo Water Rights Settlement Agreement ("Abeyta Settlement"), provide additional information to better understand Taos' regional aquifer dynamics.

Geological structural data was compiled from water wells located by the Taos Soil and Water Conservation District (TSWCD) and NM Bureau of Geology and Mineral Resources (NMBGR). These data are herein plotted at 1:24,000 scale to allow well location by reference number using topographic maps. Drillers logs accurately depict hard basalt versus soft clastic formations. Structural cross-sections show lateral offsets by faults that frequently affect water levels. Warm, saline waters often rise along fault planes to precipitate minerals that seal the faults, noted first at hot springs in the county.

The origin of numerous north-south faults is pull-apart rifting of the Rio Grande Basin at top of Servilleta basalt dated at approximately 2 MYA. Obvious faults in the Los Cordovas outcrop system and continuing northwards are displayed intermittently at the surface across the Gorge Arch. Other faults occur eastwards under Taos but are buried deeper with less well control for basalt tops. The Gorge Arch continues northeast as an accommodation zone to El Salto. The lack of historic earthquakes suggests diminished faulting, although adobe houses may remain at risk. Faults continue to west of the Gorge Arch, including one under the gorge bridge. South near the Picuris front, young "flower" structures can be seen along the highway 68 "horseshoe" curve.

Recent deep well control data coupled with high resolution aeromagnetic surveys completed by TSWCD and USGS have enabled better definition of faulting and the compartmentalization of the deep aquifer. A 2500 foot well drilled by the Town of Taos in 2001 produces from the unconsolidated Ojo Caliente dune sand at Los Cordovas. Pressure drops during testing revealed nearby low permeability fault barriers. A new deep well is currently drilling 1 mile south of the producing well and will likely encounter a partially depleted reservoir.

Numerous studies have identified an associated problem with deep well water quality where some solutes can exceed EPA levels for drinking water. Arsenic, beryllium, fluoride, and uranium can occur in deep waters and require removal in a public water supply.

Taos SWCD has prepared community groundwater summaries that are now available to the public via their website, www.tswcd.org . These summaries show well control at 1:24,000 scale that allows well locations, water depth, faults, and chemistry to be illustrated for public interest.

**Keywords:**

Taos, groundwater, hydrogeology, deep well, faulting

# Hydrologic Response of the Gallinas River to 2023 Spring Snowmelt Post-2022 Hermits Peak/calf Canyon Fire

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Forest fires are well known to impact the quality of water in a watershed from hillside erosion and fire sedimentation as well as the quantity of water entering the system from decreased soil infiltration, lessened vegetation interception, and increased catchment evapotranspiration. The Gallinas Watershed in northern New Mexico was impacted by the 2022 Hermits Peak/Calf Canyon (HP/CC) Fire, the largest wildfire in New Mexico's history (>340,000 acres). Approximately 115,542 acres burned in the Headwaters Gallinas River Watershed, 21% of which were classified by the USFS Burned Area Emergency Response team as high burn severity. As of April 8, 2023, the snow water equivalent (SWE) data from the NRCS Wesner Springs snow monitoring station at the Gallinas River's source (Elk Mountain; 11,151 feet) stands at 17.0 in, which is trending at 142% higher than the 30-year median of 12.0 in. The above-average snowpack raises concerns for increased snowmelt in the watersheds, with heightened concern for earlier onset and higher levels of peak flows due to post-fire watershed conditions. This undergraduate study consists of monitoring in near real-time the SWE, air temperature, and soil moisture at Wesner Springs and comparing these to both historic and 2023 Gallinas River discharge with emphasis on the period during the spring snowmelt (March through May) to test what if any impact the 2022 HP/CC forest fire is having on hydrologic conditions. Historically, the hydrographs for Gallinas Creek near Montezuma, NM (USGS 08380500) show broad, diffuse, and moderate increases in discharge from March to May from snow melt in contrast to the narrow, sharp, and marked increases in discharges from June to August from monsoon rains. Review of the Gallinas River streamflow data from March 2023 to present shows a flashy spring discharge with narrow and sharp peaks at 4 to 7 times above average similar to monsoonal precipitation response rather than snowmelt response. These data suggest that the snowmelt is running off the burned hillsides rather than infiltrating the subsurface. The NRCS has calculated a forecast volume (50% exceedance probability) of 215% of the 30-year median at Gallinas Creek near Montezuma. Historically, peak discharge on the Gallinas occurs around May 15th based on the 96-year record, but has been occurring earlier during the millennium drought. This year, with the higher SWE and post-fire conditions, monitoring in near real-time is imperative to forecast flood stages, manage fire sedimentation, and protect water supplies.

**Keywords:**

Hermits Peak/Calf Canyon, discharge, Headwaters Gallinas Watershed, snow water equivalent, flood

# POTENTIAL POST-WILDFIRE WATER QUALITY EFFECTS IN URANIUM-RICH REGIONS

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Uranium is found in numerous deposits in New Mexico and globally. While many uranium deposits have been geochemically characterized, little is known about the effects of wildfire on uranium biogeochemistry in watersheds. With the changing climate in the western United States, wildfire frequency and severity have increased and therefore understanding geochemical changes and ecological risk related to wildfire is increasingly important. Uranium can be found in local bedrock, mines, waste rock, stream sediments, plants, and water, which can all be eroded and transported to streams during storm events after wildfires. Due to uranium's redox and pH sensitivity, uranium compounds may be geochemically altered during the wildfire or after delivery to water bodies. While the link between wildfires and aqueous uranium has not been extensively explored, after a fire in Portugal, U-238 was identified in vegetation and ash, and during a fire in Idaho, radiation levels in the air spiked around nearby abandoned uranium mines. After the Cerro Grande Fire burned a large area around Los Alamos National Laboratory, an area known for radionuclide resources and legacy radioactive contamination in nearby stream sediments, total uranium concentrations in unfiltered surface water in the region increased one to two orders of magnitude over 4 years. These examples suggest some effects on uranium during and after wildfire. Concepts of potential effects to uranium aqueous and solid phase geochemistry during and after wildfire will be explored. The recent Calf Canyon/Hermit's Peak fire, in northern New Mexico, burned the Gallinas Creek watershed, which contains several uranium-bearing pegmatite deposits. Ongoing investigations in the Gallinas Creek watershed will apply these concepts.

# Petrography and Economical Potential of Banded Iron Formation of the Neoproterozoic-Age Buem Formation, Ghana

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Historically, Ghana has relied mostly on gold, bauxite, and manganese as the major contributors to the domestic economy. Further investigation into other minerals to transform the mining sector in Ghana focused on detailed geologic field mapping and sampling. The Buem Formation of eastern Ghana, previously unrecognized as a potential source for ore deposits, was found to host banded iron formation. Banded Iron Formations ('BIFs') are chemical precipitates characterized by the presence of alternating layers of iron-rich and amorphous silica-rich layers. The Buem Group comprises a complex series of metasedimentary, volcaniclastic, and volcanic rock units, including poorly-defined banded iron formation occurrences. This study reports our initial petrographic observations and economic assessment of the Gyamurume – Wawase Range, one of the host regions for BIF. Petrographic studies show that stratigraphic contacts between dominantly hematitic ferruginous horizons and siliceous strata are distinctly sharp and abrupt. Most hematite comprises micron-scale, irregular grains interstitial to granular, undulatory-extinction quartz; cross-cutting coarse quartz veinlets are barren of iron oxides. Although some BIF strata show former magnetite skeletal textures, even cm-scale ferruginous strata show only trace residual or relic magnetite. Initial studies of the mineralogical composition of Beum Formation BIF show that hematite is abundant, with nominal or no magnetite. No other silicate minerals are observed. Continued studies will assess the trace element contents of Beum Formation iron minerals, with emphasis on the P and Ti contents on hematite-dominant strata as a means of distinguishing low-contaminant, potentially economic horizons.

# HELIUM – RELATIONSHIPS TO OTHER RESERVOIR GASES AND IMPLICATIONS FOR EXPLORATION: THE NEW MEXICO EXAMPLE

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Helium is the second most abundant element in the universe after hydrogen but is relatively rare on earth. Helium occurs as two stable isotopes, $^3He$ and $^4He$. $^4He$ is the dominant isotope in crustal gases and is a radiogenic decay product of uranium and thorium mainly in granitic basement rocks.$^3He$ is dominantly primordial and primarily originates from the earth's mantle. $^3He$ may also be formed by radiogenic decay of $^6Li$ which may be found in argillaceous sediments deposited in evaporitic settings. Although He occurs in most natural gases, it almost always occurs in extremely low, subeconomic concentrations, less than 0.1%. It is rare in concentrations more than 1%. A very few small reservoirs have gases with more than 7% helium.

Other gases that constitute the dominant components of helium-bearing natural gases are hydrocarbons (HC's), carbon dioxide ($CO_2$), and nitrogen ($N_2$). The highest He concentrations occur where the dominant gas is $N_2$ but most He has historically been produced as a byproduct where the dominant gases are HC's. HC's are generated from petroleum source rocks. Their presence in a reservoir is dependent upon the presence of a mature source rock in the basin and a migration path between the source rock and the reservoir. Large accumulations of $CO_2$ in the southwestern U.S. resulted from the degassing of rising Tertiary magmas and subsequent migration of the gases into reservoirs. $N_2$ appears to originate mostly from degassing of the mantle but may also be formed by the thermal maturation of coals and subsequent the degradation of ammonia in pore waters.

The presence of economic concentrations of He in reservoir gases is dependent not only on an adequate source of $^4He$ generated from granitic basement rocks but also on accommodating flux rates of HC's, $CO_2$ and $N_2$. These gases differ in their origins, places of generation and rates of generation. Economic concentrations of He occur where the reservoir is incompletely filled with either HC's or $CO_2$. These reservoirs contain elevated concentrations of $N_2$ in addition to the elevated concentrations of He.

Exploratory drilling for He on Chupadera Mesa in the late 1990's and early 2000's encountered He-rich gases in Lower Permian and underlying Pennsylvanian clastic strata. Isotopic analyses suggest that 94% of Chupadera Mesa He originated from radiogenic decay in crustal rocks while 6% is derived from the mantle or possibly evaporitic Permian shales. Marked differences in the $CO_2$ concentrations in different strata indicate that some strata acted as carrier beds for $CO_2$ while $N_2$-rich and $CO_2$-poor reservoirs were isolated from $CO_2$ sources. Identification of $CO_2$ carrier beds is therefore pertinent to exploration in regions with substantial Tertiary or Quaternary volcanic activity.

# MAGDALENA SCIENCE CAFÉ WATER RESOURCES SCIENCE PROJECT

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The Teen Science Cafe began participating in the New Mexico Tech Water Resource Education Program in April 2022. Water samples were collected from two areas around Magdalena. Area One included three sample locations between the Magdalena and San Mateo mountains (Forest, Big Crow and New Wilson wells, pipe and stock tanks). Area Two included one sample from the Alamo Reservation (Apachito well) and two north of the reservation, but south of I-40 (House and Oro wells and stock tanks).

The pH, specific conductivity, hardness, and dissolved oxygen were measured in the field using a YSI-meter and the LaMotte AQ-2 Chemical Analysis Kit. Other samples were put in plastic bottles and analyzed later in the analytical laboratory at the New Mexico Bureau of Geology and Mineral Resources. Major ions and minor trace metals, specific conductivity, and alkalinity were tested using a Agilent 5900, Agilent 7900 and Dionex ICS-5000, a Metrohm titrator and a conductivity meter. Hardness and total dissolved solids were calculated from the major ion measurements.

Water sources in Area One have good water quality with the exception of an elevated fluoride concentration at one of the sources (Big Crow). Hardness, total dissolved solids and conductivity are also below safe drinking cautions. Water sources in Area Two have high values in hardness, conductivity, and total dissolved solids. A high value in uranium (Apachito) has been measured. Sulfates are also a concern. The US Environmental Protection Agency has proposed a non-regulatory Health-Based Screening Level of 10 µg/L for lithium. All of our testing sites, with the exception of Oro, is above this limitation. When sampling a tank, we know that as water evaporates it leaves behind the chemicals suspended or dissolved in the water. This can increase values of water quality constituents such as hardness, fluoride, sulfates, chloride, etc. We don't have this problem when testing wells or pipes.

**Keywords:**

water quality, Magdalena, stock tanks

# FACTORS AFFECTING THE RUNOFF RESPONSE OF AN EPHEMERAL WATERSHED TO HIGH-INTENSITY RAIN: ARROYO DE LOS PINOS, NM

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The relative influence of rainfall and watershed characteristics in controlling runoff in ephemeral channel systems is difficult to interrogate with current field datasets. First, runoff-producing rainstorms are rare in the environments that host ephemeral channels. Compounding this, there are at least three dimensions of variability in rainfall that affect runoff: rainfall intensity, total depth of high-intensity rainfall (or, equivalently, duration of high-intensity rainfall), and spatial extent of high-intensity rainfall. As a result, there is rarely enough field data to fully cover this variable space. Beyond this, influences such as lithology, vegetation, and soil and their effect on infiltration – both on hillslopes and in channels – are difficult to incorporate.

We are developing a new runoff and rainfall monitoring dataset for the Arroyo de los Pinos watershed in central New Mexico to help bridge this gap. Our goal is to use the diverse geology of the basin to advance understanding of runoff generation and channel conveyance loss. The 32 $km^2$ watershed has three important lithologic classes: limestone bedrock, sandstone-shale bedrock, and weakly-lithified alluvial basin fill. Here, we present two years of monitoring data from this watershed. Runoff only occurs during the summer monsoon season, in instances when high-intensity thunderstorms linger long enough over the watershed. An approximate 15-minute intensity threshold for runoff production is 0.2 mm/min. Runoff is produced most readily in limestone sub-basins, followed by sandstone, and least readily in alluvial fill, a pattern that is consistent with the increasing hydraulic conductivity of the three lithologies. Rainfall intensity is a stronger predictor of the runoff ratio than rainfall depth, particularly in smaller subbasins and in limestone-dominated subbasins. This is consistent with observations of infiltration-excess overland flow throughout the watershed during high-intensity storms. In general, larger subbasins have lower runoff ratios, due to high transmission losses as bed infiltration in the ephemeral channel network. However, the mix of lithologies in the larger subbasins complicates the interpretation.

# PENNSYLVANIAN SILICIFICATION OF SHALLOW MARINE FOSSILS IN THE JEMEZ MOUNTAINS, NEW MEXICO

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The frequently red silicification of northern New Mexican Pennsylvanian fossils, especially brachiopods, is well-known to collectors but, as of yet, has not been described in detail or explained in the geological literature of New Mexico. In general, the process is interpreted as early, shallow burial, replacement diagenesis produced in calcite skeletons surrounded by marine water enriched in dissolved silica. Usually, fossil shells in limestones are silicified, while the enclosing calcite matrix is not. This is because replacement silicification is favored in the microscopic environments in the shell that contain organic matter, which upon decay, produces the more acidic conditions necessary for silica precipitation concomitant with calcite dissolution. Pore-water enrichment is ascribed to episodic increases in dissolved silica, principally produced either by variations in the delivery of primary silica by rivers or by changes in the delivery of wind-blown dust, which could be climatically controlled. Two occurrences that have been linked to red silicfication at other localities are not petrographically abundant in these rocks, namely sponge spicules or pyrite.

All four of the Pennsylvanian formations exposed in the Jemez Mountains contain silicified fossils in concentrations that vary between 15% and 25% of total specimens. Usually, only some of each calcite shell or skeletal part is replaced by silica. Silicification that is just below the outer layer of a brachiopod shell is usually red. If it is within the shell's outer layer, it is light gray and produces distortion of the shell's surface, frequently in the form of beekite rings. When shells were partially crushed by differential compaction, silicification preceded shell breakage. The red color of the silicification that is dominant in The Virgilian Jemez Springs Shale is ascribed to the presence of ferric iron in the silica, of unclear origin. Older Pennsylvanian formations in the Jemez Mountains contain about an equal number of gray-silicified as compared to red-silcified fossils, in both shale and limestone lithologies. Along with brachiopod shells, crinoid stems and sea urchin spines are commonly silicified. Rare mollusk shells are not silicified.

Silicification of these fossils during the Pennsylvanian occurred in diverse environments, especially if it is assumed that changing water depth was the dominant influence on sediment deposition in norhern New Mexico. In these Jemez Mountain rocks, it is not true that fossil silicification is more common in limestones than in shales. In fact, in three cycles of alternating shale and limestone in the Morrowan Osha Canyon Formation, the average percentage of silicified specimens is 15% in the shales, but only 3% in the limestones, However, the level of silicification is greater in the marly (shallower?) southern exposures of the Jemez Springs Shale than it is eight kilometers to the north. It is unclear, therefore, if water depth has any effect on silicification. Further research is needed to answer this and other questions, such as the connection between fossil silicification and chert formation or whether there are any signs of cyclicity during the Pennsylvanian Period in northern New Mexican rocks.

# Geometry of Major Normal Faults in the Sevilleta National Wildlife Refuge, Rio Grande Rift, Constrained By Total Bouguer Gravity Anomaly Data

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During the summer of 2022, we conducted 0.05 mGal resolution relative gravity surveys along two W-E lines in the western Sevilleta National Wildlife Refuge. Gravity data can provide a test of rift models, which include deep-seated listric faulting (Ricketts et al., 2015) or multiple generations of cross-cutting, planar-rotational normal faults, initially formed at steep dips (Chamberlin and Love, 2016).
Our survey had 74 new relative gravity stations. At each station, GPS coordinates were collected with a Trimble RTX to a 10-cm horizontal and 5-cm vertical accuracy. We used a ZLS Burris Gravity Meter with 5 μGal resolution for relative gravity measurements. Stations along each profile were at a spacing of 0.25 to 1 km. We re-occupied a subset of stations multiple times to correct for drift and to tie to NGA absolute benchmarks. Data was reduced to the mean measured gravity and manually drift corrected. The total Bouguer anomaly was calculated assuming a crustal density of 2.65 g/cm$^3$.
The northern survey, from the base of Ladron Peak to Bernardo along the AT&T road, reveals some unexpected variations in gravity anomalies. The western end, at the foot of Ladron Peak, shows a gentle eastward gradient above the low-angle Silver Creek fault. At two km from the mountain front, a steep eastward gradient (40 mGal/km) offsets this gentle gradient. The gravity profile is then again gently eastward sloping for the next 9 km. A small eastward gradient (2 Mgal) is observed down dip of the Loma Pelada (aka. Coyote) fault trace. This is much less than expected, since seismic reflection data indicate over 2 km of east-down displacement on the Coyote fault. Three km further east the flat gradients steepen to 10 mGal/km eastward and then reverse to 15 mGal/km westward for the final 2 km.
The southern profile along Alamillo Road begins at a gravity low in the westerly tilted Plio-Pleistocene La Jencia Basin. From this low, gravity observations increase eastward at about 5 mGal/km toward the crest of the west-tilted basin block where it is truncated by the low-angle Silver Creek fault. A gentle and narrow eastward gradient (1mGal) is observed 1 km east of the Silver Creek fault trace. This gradient then turns westward above another west tilted basin block floored by volcanic rocks at Cerritos de las Minas. The profile maximum occurs on the south flank of Cerrito de las Minas. At the south end of the Loma Pelada fault, basin-fill strata reverse dip direction to 30º east. Here the gravity gradient also changes direction and slopes uniformly at 5 mGal/km eastward across a possible relay ramp structure.

Geologic map plus gravity data demonstrate that the Miocene low-angle Silver Creek fault is displaced 400m down-to-the east by a Pliocene rift fault that dips 70º to the SE.

# Characterization and Origin of the REE-bearing Magmatic-Hydrothermal Breccia Pipes in the Gallinas Mountains, Lincoln County,New Mexico

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Breccia pipes are a common host of many precious metals, 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 produced copper, lead, silver, fluorite, iron, REE (as Bastnäsite) 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.

A total of 66 samples were subjected to various analysis, chemically, the breccia pipes exhibit light REE-enriched chondrite-normalized patterns, some host high concentrations of REE (80,500 ppm total REE) and Au (175 ppb).

These breccia pipe can be classified into three groups, group one has low concentration of REE and Au and contains mostly unaltered primary magmatic minerals, group two has low concentration REE and elevated concentration of Au, most sample in this group are slightly altered with some evidence of hydrothermal fluids being introduced into the system leading to some alterations minerals. The third group host high concentrations of REE, they are filled with hematite, fluorite, calcite and REE bearing minerals, mostly bastnäsite. In conclusion, the magmatic breccia pipe was formed followed by a younger carbonate-rich hydrothermal fluids precipitated F-REE and Au along the edges of some breccia pipes.

## References:

Clifford.(2022).Rare Earth Elements. *Indiana Journal of Earth Sciences*, 4: https://igws.indiana.edu/outreach/news/research/REE

Corbett, 2018, short course manual, Chapter 4; Breccia, single page 18 (2-18): https://corbettgeology.com/wp-content/uploads/2018/02/Chapter-4-Breccias-single-page18-2-18_-interactive.pdf

Kelley, V.C., 1949, Geology and economics of New Mexico iron ore deposits: University of New Mexico, Publications in Geology, no. 2, 246 p.

Kelley, V.C., Rothrock, H.E., and Smalley, R.G., 1946, Geology and mineral deposits of the Gallinas district, Lincoln County, New Mexico: U.S. Geological Survey, Strategic Minerals Investigation Preliminary Map 3-211, scale 1:62, 50.

McLemore, V.T., 1991b, Gallinas Mountains mining district, New Mexico: New Mexico Geological Society, Guidebook 42, p. 62-63.

McLemore, V.T., 1996, Great Plains Margin (alkalic-related) gold deposits in New Mexico; in Cyner, A.R. and Fahey, P.L. (eds.), Geology and ore deposits of the American Cordillera: Geological Society of Nevada Symposium Proceedings, Reno/Sparks, Nevada, April 1995, p. 935-950.

McLemore, V.T., Kelley, S. Zimmerer, M. Owen, E. Haft, E. Cantrell ,T. Gysi, A. Cherotich, S. Trivitt, A, 2021, Geology and Mineral Deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico, Open-file Report 617, 164p., https://geoinfo.nmt.edu/publications/openfile/details.cfml?Volume=617

Schreiner, R.A., 1993, Mineral investigation of the rare-earth-element-bearing deposits, Red Cloud Mining district, Gallinas Mountains, Lincoln County, New Mexico: U.S. Bureau of Mines, MLA 99-93, 189 p.

# METAGENOME-ASSEMBLED GENOMES FROM EXTREMOPHILIC MICROBIAL COMMUNITIES IN AND AROUND VALLES CALDERA NATIONAL PRESERVE, NEW MEXICO

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Valles Caldera is an active caldera in Northern New Mexico that formed 1.25 million years ago. Most of the caldera is within a National Preserve that, according to the National Park Service, is visited by 30,000-76,000 visitors each year. The western margin of the Preserve contains an area where $CO_2$ and $H_2S$-rich volcanic gases are emitted through fumaroles that sometimes interact with surface waters, creating acidic and sulfidic springs, streams, and lakes that support diverse acidophilic microbial communities. The greater Valles Caldera ecosystem also includes natural and artificial hot springs along the Jemez River to the south. Soda Dam is one of these travertine springs, in which sulfidic, volcanically-heated waters host robust microbial biofilms where dissolved volcanic gases are exposed to light and oxygen. We characterized metagenome-assembled genomes from six samples collected in acidic streams, lakes, and mudpots in the Sulfur Springs and Alamo Canyon region of the Preserve, and two samples from circumneutral springs at Soda Dam. We will share metagenomic insights into the extremophilic microbial communities in the region, including metagenome-assembled genomes from known extremophilic sulfur-oxidizing bacterial and archaeal genera including *Acidithiobacillus*, *Halothiobacillus*, *Acidianus*, *Ferroplasma*, and *Sulfurovum*, as well as currently undescribed microorganisms such as family "RAAP-2" in the Actinobacteriota, family "UBA5754" in the Desulfobacterota, and unnamed groups in the order Thermoplasmatales. We will discuss how these novel microorganisms fit into the ecological niches present in the volcanically-influenced landscape, and how they might impact sulfur and carbon biogeochemistry in the region.

The metagenomic analysis for this project is being conducted as part of a research-based class at New Mexico Tech, Metagenomic Analysis (GEOB 589-01/BIOL 589-01, Spring 2023). All students in the course contributed to the analysis of these datasets, and are included as co-authors.

# PLAGIOCLASE MINERAL CHEMISTRY OF BASALT ROCKS FROM THE BLACK MOUNTAIN-SANTO THOMAS CHAIN IN THE POTRILLO VOLCANIC FIELD

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In his 1971 study, Hoffer offered two hypotheses (1) the magma which erupted from the Black Mountain-Santo Thomas chain originated from the same source, and (2) after crystallization, olivine and plagioclase crystals had enough time to sit in the melt and separate with olivine settling and plagioclase floating before eruption. The Black Mountain-Santo Thomas Chain is a series of cinder cones and flows in the Potrillo Volcanic Field which includes Black Mountain, Little Black Mountain, San Miguel, and Santo Thomas. These cinder cones and flows are isolated from the rest of the Potrillo Volcanic Field, at about 13 km away from the nearest Potrillo Volcanic Field vents and other closely spaced cones. Minimal research has been conducted on this suite of cinder cones and flows, thus their relationship to each other and to the rest of the Potrillo Volcanic Field is poorly constrained. We collected samples from Black Mountain, Little Black Mountain, and Santo Thomas to analyze the plagioclase mineral chemistry and assess the mineral-melt equilibria. This strategy is two-fold: (1) analyzing the mineral chemistry of these two minerals provides information about the magma source, and (2) this new data will be compared to existing mineral data from the rest of the Potrillo Volcanic Field. Feldspar crystals separated from two samples at each location were analyzed using an electron probe microanalyzer (EPMA) from the University of Iowa. The anorthite contents of the plagioclase minerals range from $An_{56}$ to $An_{76}$. While the existing feldspar mineral chemistry dataset is very sparse for the Potrillo Volcanic Field, these anorthite contents are very different from the existing range of $An_{27}$ to $An_{48}$. Occasional reversed zonation observed in the plagioclase reflects a changing composition as the magma cooled before eruption and could suggest a recharge event or the incorporation of xenocrysts prior to eruption. The data was plotted against a feldspar equilibrium curve on a Rhodes Diagram. The diagram shows most of the plagioclase crystals did not grow in equilibrium and were above the equilibrium curve which suggests crystal accumulation. This supports Hoffer's second hypothesis of the olivine crystals settling at the bottom of the melt, leaving the plagioclase crystals to accumulate at the top melt and suggests that the plagioclase crystals spent a significant amount of time in the melt before erupting. More data would need to be collected to determine whether the magma originated from the same source. This study aids our understanding of young volcanism in New Mexico and allows for questions such as does the melt in the Socorro magma body have enough time to slow and settle before eruption and whether young magmatism in the region is characterized by longer residence times prior to eruption.

## References:

Hoffer, J.M., 1971, Mineralogy and petrology of the Santo Tomas-Black Mountain Basalt Field, Potrillo Volcanics, south-central New Mexico: GSA Bulletin, v. 82, p. 603-612.

# OLIVINE MINERAL CHEMISTRY OF VOLCANIC FLOWS IN THE NORTHEASTERN POTRILLO VOLCANIC FIELD

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The Potrillo Volcanic Field (PVF), located to southwest of Las Cruces, covers approximately one thousand square kilometers in southern New Mexico. The relatively young volcanic field (≤500 ka) lies along the western boundary of the Rio Grande Rift. Few studies have been conducted on cones and flows in the northeastern region of the Potrillo Volcanic Field, notably the Little Black Mountain, Black Mountain, and Santo Tomas basalts. Hoffer (1971) hypothesized that these basalts were sourced from a common magma chamber that is distinct from other young features in the PFV. This study aims to assess the mineral-melt equilibria of these basalts and compare the olivine mineral chemistry to compositions of the greater PVF to determine if all flows within the PVF came from the same magma body.

The forsterite values range approximately from 75% to 84%, with the Santo Tomas flow demonstrating the lowest average forsterite concentrations. Initial results indicate that the olivines are in disequilibrium with the melt. Both normal zoning and reverse zoning are observed. The compositions of olivine from Little Black Mountain, Black Mountain and Santo Tomas are similar to published values from cinder cones in the PVF. Therefore, based on available data, Black Mountain, Little Black Mountain, and Santo Tomas likely originate from the same magma body but one which differs from the rest of the PVF. The equilibrium state of olivines in these basalts has implications for the timing of crystal settling and the rate of magma assembly prior to eruption. An active magma body is located below Socorro, New Mexico, and assessing the assembly history of PVF magmas has implications for the central New Mexico community. Determining if the magma body has time to crystalize and settle (seen in zoning) or erupts quickly can provide an indication of how quickly the magma body in the Socorro region may generate and erupt.

## References:

Hoffer, J.M., 1971, Mineralogy and petrology of the Santo Tomas-Black Mountain Basalt Field, Potrillo Volcanics, south-central New Mexico: GSA Bulletin, v. 82, p. 603-612.

# A Dinosaur Regurgitite From the Paleocene Ojo Alamo Sandstone, San Juan Basin, New Mexico

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The San Juan Basin (SJB) is a Laramide structural basin in northwest New Mexico and southwest Colorado. The rocks outcropping in the central basin comprise Late Cretaceous through Paleogene strata. The Cretaceous-Paleogene (K-Pg) boundary is well exposed and lies between the Cretaceous Fruitland-Kirtland Formations (FK) and the Paleocene Ojo Alamo Sandstone (OA). The OA rests on an unconformable erosion surface that truncated underlying Cretaceous strata. The basal OA hiatus is about 7 m.y. in the south-central part of the basin with the entire Maastrichtian absent. Dinosaur fossils are present in both the Cretaceous FK and the Paleocene OA strata in the SJB. The presence of dinosaur fossils in the Paleocene OA was once thought to possibly be due to reworking of K fossils into Pg strata, but that possibility was proved untrue by the discovery of multiple fossils of a single animal in a small group in the OA. In addition, chemical fingerprinting of K and Pg fossils shows that K and Pg fossils have distinctly different chemical compositions. Field work near the multiple-fossil site above resulted in the discovery in the OA of an assemblage of dinosaur bone fragments concentrated within an envelope of iron cemented sandstone. This site is at the top of the lower of two beds of OA about 5 m above the base of the OA. The sandstone envelope is elliptical, measuring 28 x 35 cm. The larger bone fragments are about 10 cm in size and are in the upper central part of the assemblage. Frill bones and a single limb-bone end are identifiable; the other bone fragments are not diagnostic. There are about 50 bone fragments in this assemblage with most of the largest ones within the outline of the envelope and some of the smaller ones outside the envelope. It is apparent that all the bone fragments were originally within the envelope, but recent erosion has moved the smaller, lighter fragments a short distance outside their original position. The only logical explanation for this bone-fragment assemblage is that it represents the regurgitated remains (regurgitite) of the meal of a carnivorous dinosaur. Based on the presence of frill bone fragments, this meal could have been of a juvenile ceratopsian. All the fragments have sharp broken edges making it unlikely that they moved all the way through the digestive system of a carnivore, thus the most obvious solution is that they were regurgitated. The sandstone envelope containing the bone fragments is red-brown sandstone that must have resulted from the iron-rich mucous of the host causing the bone-containing package to cement the sandstone in its present compact shape. Owl pellets are a modern analog of regurgitate produced by an animal carnivore containing the undigestible bones of prey. This bone assemblage is another example of Paleocene dinosaur bones from the OA that could not have been reworked from underlying Cretaceous strata.

**Keywords:**

Regurgitite, Paleocene dinosaurs, Ojo Alamo Sandstone, San Juan Basin

# THE FIRST RECORD OF THE ECHINOID GENUS *MECASTER* FROM THE TURONIAN (UPPER CRETACEOUS) OF NEW MEXICO

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Echinoid fossils are extremely rare in the Upper Cretaceous strata of the Western Interior, where fewer than 60 unique occurrences are known to date, most of them represented by only a few tests or isolated spines (Hook and Cobban, 2017). Five new echinoid specimens, belonging to the genus *Mecaster,* have recently been recovered from the Upper Cretaceous (Turonian) *Prionocyclus hyatti* Ammonite Zone, within the Semilla Sandstone Member of the Carlile Shale near Cabezon (NMMNH locality 13149) in the southeastern San Juan Basin of northwestern New Mexico. These New Mexican specimens compare well with *Mecaster* in having a small to medium sized test that is broad and tall relative to length, with an abrupt truncation in the rear and a slight to moderate sinus in the front. The ambulachral areas are moderately depressed, and the interambulachral spaces are prominent. These newly discovered echinoid specimens are the stratigraphically youngest record of *Mecaster* in New Mexico, as well as the first to be recorded from the Turonian of New Mexico. Further work with these specimens is needed to be able to assign them to a species.

## References:

Hook, S.C., and Cobban, W.A., 2017, *Mecaster batnensis* (Coquand, 1862), a late Cenomanian echinoid from New Mexico, with a compilation of Late Cretaceous echinoid records in the Western Interior of the United States and Canada: Acta Geologica Polonica, v. 67, p. 1–30.

# FROM THE LARAMIDE TO NOW: MAPPING THE TECTONIC EVOLUTION OF CENTRAL NEW MEXICO IN THE NORTHERN FRA CRISTOBAL RANGE

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The Fra Cristobal range is a north-south oriented horst block situated between the San Marcial and Engle basins to the west and the Jornada del Muerto basin to the east. Towards the southern part of the range, Precambrian basement rocks (~1.5 Ga granites; Condie, 1981) are overlain by the Phanerozoic section of central New Mexico, including syn-Laramide Love Ranch basin fill (Seager et al., 1997). Within our study region at the northernmost point of the range, the Phanerozoic section has been stripped and the Precambrian basement is in contact with the Cretaceous McRae formation, resulting in 7000 ft (~2100 m) of eroded stratigraphy. Previous authors have interpreted this contact relationship as either depositional or due to normal fault offset (McCleary, 1960; Nelson, 1986). We use high-resolution (1:5000) geologic mapping to reexamine this contact relationship. Mapping efforts reveal: i) volcanic tuffs and previously unrecognized limestones, ii) a silicate geothermal system that has hydrothermally altered much of the lithology, and iii) a stratigraphic relationship that implies thick-skinned thrusting of Precambrian basement over Paleozoic(?) sedimentary rocks. Our results suggest that previous models for the development of the northern Fra Cristobal range may not capture its true structural complexity. We hypothesize that the thick-skinned thrust fault formed during the Laramide orogeny (~75 Ma; Seager et al., 1997). The volcanic tuff was emplaced after cessation of thrust faulting, followed by deposition of syn-Laramide McRae formation. Hydrothermal alteration followed McRae deposition. Regional thermochronological constraints (e.g. Gavel et al., 2021) and a close association with local mineralized fault planes suggest that hydrothermal alteration occurred during Rio Grande rift extension. Preliminary conclusions from this study include: i) evidence of thick-skinned thrust faulting ~10 km north of currently mapped north-south-striking, west-verging thrust faults associated with Laramide orogenesis (Nelson, 1986) and ii) evidence for widespread geothermal alteration of basement rocks and Phanerozoic cover, with significant implications for regional thermochronological studies. Reexamination of the ages proposed for the evolution of the study area will be necessary to better constrain the timing of the range's evolution.

## References:

Condie, K.C., 1981, Precambrian rocks of the southwestern United States and adjacent areas of Mexico. NMBGMR Resource Map 13, scale 1:1,500,000.

Gavel, M.M. et al., 2021, Thermochronological transect across the Basin and Range/Rio Grande rift transition: Contrasting cooling histories in contiguous extensional provinces: Geosphere, v. 17, p. 1807–1839, doi:10.1130/GES02381.1.

McCleary, J.T., 1960, Geology of the Northern Part of the Fra Cristobal Range, Sierra and Socorro Counties, New Mexico: [M.S. Thesis]: Albuquerque, University of New Mexico.

Nelson, E.P., 1986, Geology of the Fra Cristobal Range, south-central New Mexico, in R.E. Clemons, W.E. King, G.H. Mack, eds., NMGS 37th Fall Field Conference Guidebook, Truth or Consequences Region, NMGS, p. 83–91, doi:10.56577/FFC-37.83.

Seager, W.R. et al., 1997, Structural kinematics and depositional history of a Laramide uplift-basin pair in southern New Mexico: Implications for development of intraforeland basins: GSAB, v. 109, pg. 1389-1401.

# APPLYING $^{40}$AR/$^{39}$AR DETRITAL SANIDINE GEOCHRONOLOGY TO CONSTRAIN STRATIGRAPHIC AGES FROM *PROBOSCIDEAN*-BEARING STRATA OF THE PLIO-PLEISTOCENE CAMP RICE FORMATION, SOUTHERN NEW MEXICO

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Strata of the uppermost Santa Fe Group are exposed along the axis of the Rio Grande rift throughout central New Mexico and record sedimentation associated with the Plio-Pleistocene integration of the ancestral Rio Grande fluvial system. In southernmost New Mexico, these strata are referred to as the Camp Rice Formation and preserve a rich record of proboscidean megafauna (elephant relatives; i.e., mastodons, gomphotheres, and mammoths) as well as many other Plio-Pleistocene mammalian fossils. The Camp Rice Formation records sedimentation from ~5.0–0.8 Ma in southernmost New Mexico, however while fossil occurrences are abundant, radiometric age constraints are sparce for the strata. In an attempt to place new age constraint on stratigraphic horizons where known gomphothere fossils occur, N=6 samples were collected throughout Doña Ana County for 40Ar/39Ar detrital sanidine analysis. The primary goal for each sample was to analyze ca. 300 sanidine grains with the aim of using the youngest ages as a maximum depositional age (MDA) for each stratigraphic horizon.

The MDAs for each sample fall between ~3–1 Ma and break out into several distinct age groups. The oldest MDAs from this study are 2.779±0.023, 2.752±0.008, and 2.745±0.010 Ma with n=2, 5, and 3 sanidine ages used to determine MDAs, respectively. The youngest three ages from the study are 1.997±0.039, 1.331±0.035, and 1.252±0.003 Ma with n= 12, 2, and 82 used to calculate MDAs for each sample, respectively. We caution that MDA determination does not preclude these samples from being younger than the ages listed above (i.e., younger sanidine grains could occur in each sample). We also note that the transport mechanism for sanidine grains into these strata could include fluvial transport and/or tephra erupted from distal sources.

The youngest MDA at 1.252±0.003 Ma likely is sourced from the Upper Bandolier Tuff of the Valles Caldera in north-central New Mexico and is tentatively interpreted to represent the true age of the stratigraphic horizon of the Camp Rice Formation where it was collected. The detrital sanidine grains defining the older MDAs do not overlap with known volcanic sources from the Valles Caldera and may represent distal tephra input from other local or regional late Cenozoic volcanic fields and caldera systems. For instance, the ca. 2 Ma sanidines could be from the Huckleberry Ridge tuff in Yellowstone and the ca. 2.75 grains could be derived from Mount Taylor. The lack of ubiquitous Upper and Lower Bandelier grains in these samples could support the MDA's as actual depositional ages.

The large number of ages supporting the youngest MDA are suggestive of an eruption that could have been coincident with or led to the death of an adult but yet undated Cuvieronius gomphothere recovered from this stratum. Cuvieronius is believed to have been replaced temporally by Stegomastodon and in turn by mammoths, reflecting differences in diet imposed by aridification of the Ancient Rio Grande Valley. Nevertheless, both gomphotheres are reported from Middle Blancan to Irvingtonian NALMA in southern New Mexico.

**Keywords:**

Rio Grande Rift, Plio-Pleistocene, 40Ar/39Ar detrital sanidine, Proboscidean, Camp Rice

# EXCEPTIONAL TRACE FOSSILS AND FOSSIL PLANTS FROM A NEW LOCALITY IN THE UPPER PART OF THE ABO FORMATION (LOWER PERMIAN), SOCORRO COUNTY, NEW MEXICO

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A recently discovered tracksite in the Abo Formation in the Quebradas region of Socorro County is distinguished by unusually high ichnodiversity and exceptional preservation. This site, NMMNH (New Mexico Museum of Natural History) locality 12617, is north of Tinajas Arroyo in the Cañon de Espinoso Member of the Abo Formation, about 9 meters below the base of the overlying Yeso Group, placing it in the *Dromopus* biochron, only about 4 meters below its contact with the overlying *Erpetopus* biochron boundary. The fossil-bearing stratum is a 0.7-1.5 m thick interval of thin-bedded, ripple-laminated, very fine sandstone with extensive mudcracks. Tetrapod ichnotaxa from locality 12617 with at least one assignable track include *Dromopus*, *Batrachichnus*, *Limnopus*, *Varanopus*, *Dimetropus*, *Amphisauropus* and *Ichniotherium*. The invertebrate traces include the arthropod trace *Monomorphichnus*, reported here from the Abo Formation of Socorro County for the first time. Plant specimens consist of the conifer *Walchia*, the peltasperm *Supaia* and the callipterid *Autunia conferta*. *Walchia* and *Supaia* are typical of the Abo Formation throughout its extent; most Abo Formation fossil plant sites are dominated by conifer remains of several types, but some fewer by *Supaia*. Mixed assemblages are uncommon. *Autunia conferta*, of the small-pinnule type, is common only in the upper Abo Formation (Cañon de Espinoso Member). At locality 12617, many surfaces with trace fossils have microbially induced sedimentary structures (MISS), and microbial mediation of preservation likely caused some of the exceptional ichnofossil preservation at this site. The ichnofaunal composition at NMMNH locality 12617, which includes *Limnopus*, *Ichniotherium* and *Dimetropus*, is very different from that of the *Erpetopus* biochron only 4 meters above it. This is consistent with data from North America and Europe that identify a substantial change in the composition of footprint ichnoassemblages at the beginning of the *Erpetopus* biochron (close to the beginning of the Leonardian) due to the diversification of sauropsid reptiles, likely driven by climate changes (drying) across much of Pangea.

## IMPROVING SOIL MAPS OF RANGELANDS THROUGH IDENTIFICATION OF PATTERNS IN SOIL VARIABILITY IMPOSED BY GEOMORPHIC PROCESSES

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Soil maps of rangeland soils which make up approximately 80% of the landsurface in the US show that all the soils have been mapped and often have very detailed soil analyses associated with them. However, published soil maps consist mainly of poorly characterized soil mapping units which contain one or more soil taxonomic units making it difficult to locate and identify soils in the field. This is a result of the lack of a perceived economic benefit associated with more accurate soils data However, with the impacts climate change being acknowledged, there is increasing need to better understand how soil landscapes will respond to changing environmental conditions.

Detailed soil maps are logistically expensive to produce with the current soil mapping programs. More accurate soil data will require a combination of remote sensing, digital soil mapping, machine learning and an understanding of the controls of pedogenic processes. Soil landscapes reflect the actions of geomorphic processes (past and present) that develop distinctive patterns of soil variability and the proxy data that can be used to identify them. These patterns should be used to inform the remote sensing and digital soil mapping approaches to developing new soil maps of nonagricultural areas.

# THE NEW MEXICO WATER DATA INITIATIVE: BUILDING COLLABORATIVE DATA SHARING FOR WATER MANAGEMENT ALONG THE PECOS RIVER, NEW MEXICO

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The New Mexico Water Data Initiative (WDI) is a multi-year effort to build a streamlined data infrastructure for water data in New Mexico (newmexicowaterdata.org). This collaborative effort is convened by the New Mexico Bureau of Geology and Mineral Resources, and includes the New Mexico Office of the State Engineer, the Interstate Stream Commission, the Energy Minerals and Natural Resources Department, and the Environment Department.

The goal of WDI is to improve how water data in New Mexico are managed, shared, and integrated. One way to work towards this broad goal is to focus on regional projects with specific data needs, providing opportunities to learn and improve New Mexico's data infrastructure. For one such project, WDI is currently collaborating with the Pecos Valley Artesian Conservancy District (PVACD) on a WaterSMART grant from US Bureau of Reclamation. Following the installation of telemetry-equipped, real-time water level monitoring devices, WDI is building two web-based applications to modernize data management and sharing. Both applications are being developed iteratively with a focus on user testing and feedback. In addition, WDI is working to make many local datasets available through the program's data catalog (catalog.newmexicowaterdata.org).

One application in development enables the PVACD to enhance their ongoing water data management activities by leveraging modern, open source software. Furthermore, an integrated API helps improve coordination and data sharing with the regional Water Master at the Office of the State Engineer. Another tool WDI is developing with PVACD is a simple, clean user interface for the PVACD team and local collaborators to see quick visualizations of groundwater change over time. This tool, the PVACD Groundwater Dashboard shows both real-time and historic water level data for ten groundwater monitoring wells within the conservancy district. This dashboard also provides integrated monitoring data for nearby wells monitored by other agencies, including the New Mexico Office of the State Engineer, US Geological Survey, and the New Mexico Bureau of Geology.

# BED SEDIMENT METAL CONCENTRATIONS AS INDICATORS OF ECOSYSTEM RECOVERY IN THE GALLINAS CREEK WATERSHED

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Measures of post-wildfire effects and recovery often include constituent-based approaches that identify natural and/or anthropogenic disturbance. Water quality and bed sediment studies are two such examples in assessing trends associated with mobilization and transport. In 2022, the Calf Canyon/Hermits Peak Wildfire burned 95% of the Gallinas Creek watershed. Because the El Porvenir Mining District (Quartz-Pegmatite vein) lies within the watershed, metal concentrations were used to establish a baseline of "post-fire condition" with a goal of evaluating recovery over space and time. Bed sediment samples from Gallinas Creek and several tributaries were collected 5 months post fire. Samples were sieved to <63 µm to reduce grainsize bias and allow for spatial comparisons relative to legacy mining activities, and analyzed for arsenic, cadmium, and copper concentrations. In Gallinas Creek, arsenic concentrations were lowest at the most upstream station (Gallinas Creek at Oak Flat, 4.1 ± 1.1 µg/g) and greatest at the most downstream station (Gallinas Creek near Montezuma, 5.3 ± 0.3 µg/g). Arsenic concentrations in streams in the Beaver Creek sub-watershed were up to twofold higher than in the Gallinas, ranging from 6-10 µg/g. Cadmium concentrations followed a similar pattern: concentrations were lowest in the most upstream station on the Gallinas (0.2 ± 0.1 µg/g) and three-fold higher at the downstream station (0.6 ± 0.2 µg/g). Concentrations of cadmium in Beaver Creek, and intermittent streams, were variable, ranging from 0.4-0.7 µg/g. Unlike arsenic and cadmium, there was no unidirectional downstream decline of copper in the Gallinas, and concentrations were low (14-25 µg/g) at all sites apart from a sediment deposit near the mouth of the Hermits Peak Mine adit (100-443 µg/g), likely due to the proximity to legacy mining activities. Although abiotic indicators are key in identifying metal sources, biological effects associated with elevated metal concentrations can only be inferred. Tissue residue studies using resident aquatic organisms measure bioavailability and provide a direct link between chemical exposure and biological effects. Benthic macroinvertebrates were not present at any of the sediment monitoring stations, likely due to the physical disturbance (e.g., high turbidity, scour, debris flows) caused by the wildfire. However, as habitat conditions improve, aquatic insects will recolonize, and, as part of this study, allow for tissue metal analysis and biological assessment of ecosystem recovery.

**Keywords:**

sediment, metals, environmental risk

# THE UVAS BASALTIC ANDESITE: A LARGE-VOLUME VOLCANIC FIELD ERUPTED DURING THE INITIATION OF THE SOUTHERN RIO GRANDE RIFT

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The Uvas Volcanic Field (UVF) is a large-volume dominantly mafic volcanic field representing the earliest (~27 Ma) significant mafic magmatism in the southern Rio Grande rift (RGR). It consists of lava flows, dikes, and domes with compositions ranging from basalt to trachyandesite. In this study, we will use $^{40}Ar/^{39}Ar$ dating, isotope (Nd and Pb) and whole-rock geochemistry, and geothermometry (olivine-liquid) to evaluate magma sources during the early stages of crustal extension in the southern RGR.

We collected 32 samples over a broad area of the UVF, including the Sierra De Las Uvas Mtns, Goodsight Mtns., and Southern Caballo Mtns. Alteration is ubiquitous; to ensure accurate results, 10 of the least altered samples were subjected to ultrasonic leaching, crystal picking, and magnetic separation.

Thin-sections from 16 samples show an assemblage mainly consisting of microlitic plagioclase, magnetite, and clinopyroxene, and medium-grained olivine and pyroxene phenocrysts. The samples show extensive alteration, with widespread secondary replacement of olivine and pyroxene, extensive clay development within plagioclase, and calcite-filled amygdules.

Whole-rock geochemistry of 10 samples reveals a sub-alkaline character for the UVF with variations in $SiO_2$ (50–58 wt.%), $Na_2O$ (2.9–3.8 wt.%), and $K_2O$ (0.5–2.4 wt.%). Magma evolution was influenced by olivine and pyroxene fractionation, resulting in lower MgO, FeO, and CaO concentrations with increasing $SiO_2$. Eight out of the ten samples generally show a depletion of high field-strength elements and an abundance of large-ion lithophile elements. The enrichment in mobile elements like Sr, Ba, and Pb, along with non-mobile elements such as Rb, despite being basaltic in composition, suggests significant crustal assimilation.

Most UVF samples resemble basalts that come from modified sub-continental lithospheric mantle melting, similar to the Mogollon-Datil Volcanic field connected to the Cenozoic ignimbrite flare-up (~37–23 million years ago). Two samples from a location 30 km away (Southern Caballo Mtns.) from the main central domal uplift have an Ocean Island Basalt (OIB)-like composition, suggesting a different magma source. The origin of these samples, whether from a less-contaminated magma or a later pulse from a deeper source related to rapid extension in the Rio Grande rift beginning around 27 million years ago, remains uncertain. More radiogenic isotope analysis and precise dating will help clarify this.

We will assess whether UVF's composition corresponds to the onset of rifting. By merging geochemical data with accurate $^{40}Ar/^{39}Ar$ dating, we aim to determine whether radiogenic isotope and geochemical signatures suggest a more primitive magma, as expected during widespread stretching in the eruptive period. Identifying a clear geochemical change from lithospheric mantle melting through conductive heating to asthenospheric melting through decompression melting would offer strong evidence for the onset of rifting around ~27 Ma. Our research will help improve existing models of magma generation during the early stages of the Rio Grande rift.

**Keywords:**

Rio Grande rift, Geochemistry, Early continental extension, Isotope Geochemistry, Geothermometry, Ar/Ar dating

# Permian tetrapod fossils reworked into the Eocene Baca Formation northeast of Socorro, New Mexico: resolving a forgotten discrepancy in the work of N. H. Darton

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In 1928, N. H. Darton reported tetrapod fossils collected by E. C. Case in the bank of the Arroyo de la Parida east of Socorro in central New Mexico. Although Case had earlier, in 1916, identified these bones as representing taxa of "Permo-Carboniferous" age, Darton concluded that they came from Triassic strata and thus must be reworked. Here, we resolve the evident contradiction—Permian bones in supposed Triassic strata—by demonstrating that Darton erred in his stratigraphy but was correct that the bones were reworked. Darton (1928) provided three kinds of information about the fossil locality that made relocating it possible: (1) he stated that "the bones were mainly in a conglomerate of dark red pebbles, lying on green, blue, and drab shales in the bank of the Arroyo de la Parida at a point not far below the mouth of Canyoncito Colorado…." (2) Darton published a photograph of the fossil site, and, though a century of erosion has modified the landscape, the location can still be recognized; and (3) Darton published a reconnaissance geologic map of part of central New Mexico that shows a Triassic outcrop along the Arroyo de la Parida that encompasses the location described and photographed.

The vertebrate fossils from the site are in the collection of the University of Michigan Museum of Paleontology, where Case was a professor. They include the proximal end of a rib of a diadectid; a complete femur pertaining to the temnospondyl *Eryops*; and various specimens either pertaining to the eupelycosaur *Sphenacodon* (a femur; a fragment of jaw), or possibly pertaining to the genus (the distal end of a scapula; the distal end of a large scapula; fragments of a large pelvis). These are characteristic early Permian tetrapod fossils of taxa well known locally from the lower Permian Abo Formation.

Darton's mapping around the fossil site is very accurate but he mistook as Triassic the siliciclastic red beds of the Eocene Baca Formation in which the bones are reworked. At the fossil site, these Baca strata are scoured into underlying Middle Triassic Moenkopi red beds and comprise a 65-m-thick section of red-bed mudrock and intercalated conglomerates, some of which have limestone boulders up to 1 m in diameter. We conclude that the bones Case collected and described are of early Permian age, and they were reworked as Darton concluded, but reworked into Eocene, not Triassic red beds. What is most unusual is that the reworked Permian bones are not particularly abraded/damaged and that they remained in close proximity to each other while being reworked and redeposited.

## References:

Case, E. C., 1916, Further evidence bearing on the age of the red beds in the Rio Grande Valley: Science, new series, v. 44, p. 708-709.

Darton, N. H., 1928, "Redbeds" and associated formations in New Mexico: U. S. Geological Survey, Bulletin 794, 356 p.

# Linking Genomes and Geochemistry in Extreme Environments Across the Greater Valles Caldera Ecosystem, New Mexico

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Valles Caldera is an active volcanic caldera in the Jemez Mountains, Northern New Mexico. Most of the caldera is within a 363 $km^2$ National Preserve, but the greater Valles Caldera ecosystem also includes natural and artificial hot springs such as those along the Jemez River to the south. Interactions among volcanic gases, volcanically-influenced groundwaters, and surface waters results in strong geochemical gradients, from extremely acidic surface springs, streams, and lakes where $CO_2$ and $H_2S$-rich volcanic gases mix with surface waters, to circumneutral travertine springs formed by sulfidic, volcanically-heated groundwaters. The chemical disequilibrium that results as these volcanic gases are exposed to light and oxygen provides energy for diverse chemosynthetic microbial communities that thrive on reduced volcanic gases and contribute to the biogeochemical cycling of sulfur, carbon, and other elements. We are exploring the microorganisms and microbial biogeochemical processes in acidic, sulfidic streams and lakes in the Sulfur Springs and Alamo Canyon areas of Valles Caldera National Preserve, and at Soda Dam, a large travertine hot spring near Jemez Springs, NM. Preliminary culture-independent analysis using high-throughput 16S rRNA gene sequencing and fluorescence *in situ* hybridization (FISH) showed that microbial communities contain eukaryotic algae and a wide variety of known chemoautotrophic sulfur oxidizers, as well as several undescribed groups of bacteria and archaea. We will discuss how the chemical, pH and temperature gradients in the region affect the diversity and types of microorganisms present, and describe new results from a research-based class at New Mexico Tech (Metagenomic Analysis, GEOB 589-01/BIOL 589-01, Spring 2023), where we are using metagenomic sequencing to discover the metabolic capabilities of some of these novel extremophiles and explore their potential biogeochemical roles in the volcanically-influenced springs and streams.

# MICROTEXTURAL RELATIONSHIPS OF ARSENIDE FIVE-ELEMENT VEINS IN THE BLACK HAWK DISTRICT, GRANT COUNTY, NEW MEXICO

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Arsenide five-element vein deposits are Ag-Co-Ni-Bi-As bearing vein systems with local elements such as U, Cu, Pb, Zn, Sb, Hg and others. Many of these elements are critical minerals. Critical minerals are nonfuel mineral commodities that are essential to the economic and national security of the United States, and is from a supply chain that is vulnerable to global and national disruption. The arsenide five-element vein deposits are unusual deposits and consist of high-grade silver (1000's g/t Ag), but are low tonnage (<1 Mt). These elements have different chemical properties and aren't normally found in the same environment. Ag, Bi, and As occur as native elements and Co and Ni as arsenides and/or sulfides. Ag in most other types of deposits are typically found with Cu and Au, which are rare in these deposits. Carbonates such as calcite and siderite are the most common gangue (non-economic) minerals, although barite, quartz and fluorite are locally present. Our study characterizes the arsenide five-element vein deposits in the Black Hawk district in the Burro Mountains in Grant County, New México. From 1881 to 1960 the district produced approximately 1,286,000 million ounces Ag, along with 1000 lbs Cu, 4000 lbs Pb, 1000 oz Au, and some tungsten and fluorite. The Black Hawk deposits are hosted within north-trending faults in Mesoproterozoic calc-alkaline granites and metamorphic rocks and comprises open-space fillings within numerous fissure-style veins and breccias, typically in zones having strike lengths of more than 30 m and widths of less than 1 meter with a vertical extent of 183 m. A sample of altered material adjacent to a vein was dated as 65.3±1.2 Ma (K-Ar, Gerwe, 1986). A 100 lb sample taken from below the 8$^{th}$ level of the Black Hawk mine assayed 8.82% Ni, 0.9% Co, 8.8% Zn, and 2,542 oz/ton Ag (H. Schmidt, unpublished report, 1/7/1958). Early studies in the district identified Ni, Co, Ag, and U minerals. Major minerals observed in our study suggests a preliminary paragenesis of early, brecciated pyrite, locally as black, reduced clasts. Sulfides, which formed during the earliest mineralization satge, are represented mainly by pyrite, chalcopyrite, sphalerite, and galena. Fluorite is present as local, pre-sulfide, euhedral microcrysts. Following brecciation, pyrite is surrounded and partially replaced by a series of Ag minerals and, locally, Ni- and Co-arsenides. The deposit represent an environment with Ag, which is represent as pure metal and incorporated in otherphases such as sulfides (e.g., acanthite and jalpaite) and sulfosalts (e.g., freibergite). At least two generations of native silver are observed, with acanthite as the primary phase. Skutterudite and acanthite display replacement textures showing that Co-Ni-Ag-As-S activities alternated substantially following early pyrite development and prior to latest vein brecciation and banded, multi-stage carbonate precipitation.Our efforts contribute to the understanding of mineralogy and geochemistry of these potentially-important sources of critical minerals.

**Keywords:**

Arsenide Five-Element veins, Black Hawk district,

# DOCUMENTING FRACTURE NETWORKS IN PROTEROZOIC GRANITE, ARROYO DEL TAJO, NEW MEXICO

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Recent model-based studies of two geothermal systems in New Mexico (Socorro and Truth or Consequences) suggest that the measured temperatures and chemical compositions of the fluids in these systems are best explained by deep (4–8 km) circulation of groundwater within permeable ($10^{-14}$ to $10^{-12}$ $m^2$) fractured Proterozoic basement. A detailed investigation of joint density and connectivity in the Proterozoic Tajo Granite in the Quebradas Backcountry Byway area east of Socorro was initiated to determine if circulation of fluids in fractured Proterozoic crystalline rocks is an important geothermal process. The southernmost outcrop, which is incised by the southern tributary of Arroyo del Tajo, is the focus of this presentation. The Great Unconformity, which separates the granite from the Pennsylvanian Sandia Formation, forms the eastern boundary of the outcrop and the Quaternary Coyote fault forms the western boundary. Fractures in this 1 km (N-S) by 0.35 km (E-W) granite outcrop that are visible on Google Earth images were evaluated. In addition, 16 areas within the exposure near some of the larger fractures were examined in detail. North-northwest striking joints are common 40 to 70 m to the east of the Coyote fault and many of these fractures are filled with fluorite, barite, and quartz. Fracture density is 22 to 27/m within 4 m of the fault zone, dropping to 12/m at a distance of 18 m west of the fault zone. Most of these fractures near the fault zone are short, only 2.6 to 10.8 m long. Connectivity, which is based on the number of systematic joint intersections (nodes) in a square meter, ranges from 42 to 23/$m^2$ in this same area. In contrast to the relatively short fractures near the fault zone, several E-striking fractures that can be traced 60 to 270 m are common in the southern 0.27 km of the exposure. The spacing between these long, continuous fractures along the southern edge of the exposure ranges from 5.5 to 18.7 m. Northeasterly strikes are more common in the northern half of the exposure and northwesterly strikes are found throughout the outcrop. A NE-striking (65–75°) zone located approximately 0.15 km south of the northern tip of the exposure appears to cut across NW-striking (330–340°) fractures on the Google Earth images; the zone is 40–50 m wide. Field data support this observation; NE-striking iron oxide, calcite, and quartz veins cut the NW-striking fractures and cm-scale offsets across the NW-striking fractures were noted in this area. Iron-rich fluids clearly flowed through fractures in the Tajo Granite throughout the exposure, suggesting that fluids do move through fractured crystalline basement. The spatially variable fracture patterns in this large exposure of granite are related to the fact that the this fault block is rotated to the east above an east-vergent reverse fault along the eastern margin of the Laramide Sierra uplift (perhaps opening the E-striking structures) that was subsequently cut by Rio Grande rift extensional faults.

**Keywords:**

geothermal, fracture networks, Proterozoic crystalline rocks

# OBSERVATIONS ON SUBSURFACE STRATIGRAPHY AT THE I&W BRINE SITE IN CARLSBAD, NEW MEXICO

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The City of Carlsbad, NM is on the northern edge of the Delaware Basin, a fore reef basin mostly encircled by the Capitan Reef and containing thick sequences of evaporites deposited in the Ochoan Age of the Permian Period.

Collection of subsurface rock core samples and downhole geophysical logging within Carlsbad are rare due to ordinances prohibiting oil and gas drilling within city limits. Thus, investigations and geotechnical remediation of the brine well cavity at the I&W Site provided opportunities for direct observation of local stratigraphic, structural and diagenetic changes, as well as comparison with stratigraphy of collapsed brine well sites on the north side (back reef basin) of the Capitan Reef. Several microseismic sensor array installation coreholes, ranging in depth from 400 to 700 feet, penetrated the Salado and the uppermost part of the Castile Formations.

Findings from the geotechnical investigation include:

Collapse breccias, comprising relatively insoluble clays and gypsum, and massive gypsum horizons in the uppermost Salado Formation that occurred as a result of dissolution of the youngest Permian halite layers from inundation of the area during development of the Ancestral Pecos River Valley since the Late Cretaceous or Early Paleogene. This contrasts with the profile in the Loco Hills area (site of a brine cavity collapse sinkhole), north of the Capitan Reef, where the upper Permian halite layers still exist with intermittent, interbedded claystone and sulfate (anhydrite) horizons.

Likely cyclical dehydration of gypsum into anhydrite during the Permian Period, followed by rehydration into gypsum with fresh groundwater inundation and during the Cenozoic formation of the Ancestral Pecos River Valley , á la R. C. Murray's 1964 model, is evidenced by relict anhydrite horizons at the base of a thick, massive gypsum layer in the upper Salado above the shallowest Salado Fm halite.

Accumulation and consolidation of relatively insoluble remnants of dissolved halite layers and formation of massive gypsum layers above the halite at the I&W Site likely imparted additional strength to the roof of the brine well solution mining cavity, and delayed a full collapse that would have affected highway and city infrastructure in Carlsbad. This contrasts with the brine well operations at Loco Hills and Jim's Water Service to the north, where the lack of halite dissolution by groundwater caused no such formation to occur; and the roofs of those cavities collapsed, leaving large sinkholes.

## References:


Murray, R.C. (1964), *Origin and Diagenesis of Gypsum and Anhydrite,* Journal of Sedimentary Petrology, Vol. 34, No. 3, pp. 512-523

Rucker, Michael L. (2018), *Technical Memorandum, Conceptual Design & Modeling, Carlsbad Brine Well Remediation, Carlsbad, New Mexico,* Memorandum submitted to the Energy, Minerals, and Natural Resources Department by Wood Environment & Infrastructure Solutions, Inc, November 2018



## Keywords:

brine, brine well, brinewell, I&W, Salado, Castile, Carlsbad, solution mining, sinkhole, halite dissolution

# HYDROSTRATIGRAPHIC FRAMEWORK AND ASSESSMENTS OF PERMEABILITY AND TDS FOR THE SANTA FE GROUP AQUIFER IN THE NORTHWESTERN ALBUQUERQUE BASIN, RIO GRANDE RIFT, NM

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This study differentiates four hydrostratigraphic units (HSUs) in the northwestern Albuquerque basin: the Upper, Middle, and Lower Rio Rancho HSUs underlain by the Zia HSU. This area hosts Rio Rancho (population of 104,000), which relies solely on groundwater for its municipal needs. We mapped these HSUs in the subsurface and assessed spatial trends in permeability and TDS. The study entailed constructing a 3D, geologic model showing the elevations of the bounding surfaces of these HSUs, and this model explicitly includes major faults. The HSUs exhibit layer-cake geometry, thicken towards the southeast, and thin over the Ziana horst in the northern part of Rio Rancho. Hydraulic conductivity data compiled from pumping tests indicate that the Upper Rio Rancho (RR) HSU has higher values compared to the Middle RR HSU: 1.1-6.4 ft/day, median of 2.9, vs. 3.2-21 ft/day, median of 9.3 (xx-xx = 10-90 percentile range). However, the thick, saturated portions of the Upper RR HSU are only found east of the Tamaya fault and in the southeastern part of the study area. The saturated Middle RR HSU is over 1,000 ft thick across most of the study area, including a north-trending prong between the Ziana horst and the Zia fault. Several wells indicate a coarsening upward trend in the Middle RR HSU, so areas where its upper part is saturated are more favorable than where just its lower part is saturated. There are no strong lateral permeability trends across the Middle RR HSU over most of the study area, but hydraulic conductivities from two pumping tests suggest higher permeability values in the southwest part of the study area, within 8 km northwest of the western end of Paseo del Norte. A northward increase in sand proportions also occurs north of the approximate latitude of well RRU-9 (35°20’0”), suggesting an increase in permeability that remains to be confirmed by pumping-test data. TDS values are 205-412 ppm in the Upper RR HSU, (excluding one well at 1,100 ppm) and 190-530 ppm in the Middle RR HSU, with the highest values in the latter occurring over the Ziana horst. The Lower RR HSU is mainly penetrated by wells on the Ziana horst, where it exhibits relatively high TDS values (478-1,400 ppm); the EPA recommends treatment for TDS >500 ppm. Various well-based permeability proxies and a single pumping test, in agreement with field observations, indicates it has relatively high permeability. The Lower RR HSU extends across the northern 2/3 of the study area, but may become finer-grained (corresponding to lower permeability) south of Southern Boulevard. The lower-middle Zia HSU is notably sandy, based on outcrop observations and wildcat oil well data. Its relatively higher elevation on the Ziana horst may possibly provide an accessible deep-water aquifer, but economical methods for water blending or desalinization would need to be formulated. The 3D geologic model along with maps of the potentiometric surface and TDS will

be useful for managing groundwater resources in Rio Rancho and for potential groundwater-flow models of the area.

**Keywords:**

Rio Rancho, northwest Albuquerque basin, Santa Fe Group, aquifer, hydrostratigraphic, hydrogeology, groundwater, potentiometric surface, water table, TDS

# A CRYPTIC MIOCENE OCCURRENCE OF AN ULTRAMAFIC DIKE IN THE INTERIOR OF THE SAN JUAN BASIN: COMPOSITION, AGE, AND TECTONIC INTERPRETATIONS

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This field study presents the physical, geochemical, geochronological, and mineralogical properties of the informally named Pemada Canyon dike that is found 15 km east of Aztec, New Mexico. The geographical isolation of this dike merits investigation into its relationship to nearby igneous features and Cenozoic stress orientations in the San Juan basin. Surface exposures of this 3.8 km-long dike are found intruded into thick sequences of basin fill arenites, wackes, and mudstones of the Eocene San Jose Formation. It is 76 to 173 cm-thick, has measured outcrop strikes ranging from 355° to 012° (average strike 003°), and dips ranging from 83° to 90°. There are at least two left-stepping en echelon features in the dike. Bulk geochemical analysis of the dike indicates a low silica (37%), low alumina (9.5%), and high magnesium (12%) composition similar to some transitional minette/katungite dikes of the Navajo volcanic field (Nowell, 1994) but dissimilar to nearby dikes of the Dulce dike swarm (Lipman and Zimmerer, 2019). XRD analysis indicates a primary mineral composition of diopside, phlogopite, sanidine, and pigeonite with minor chamosite, hinting at more mineralogical affinity to the Navajo volcanic field than to the Dulce dike swarm. $^{40}Ar/^{39}Ar$ dating of dike groundmass suggests an early to middle Miocene age (20 to 12 Ma).

The Pemada Canyon dike's accordance with regional fracture patterns in the San Jose Formation and subjacent formations, along with its Miocene age, give new insight into the history of stress orientations in the San Juan basin—it shows that the least compressive stress in the Miocene was east-west and horizontal. This study's dataset allows further interpretation of the timing and development of documented north-south fracture sets within stratigraphy of the San Juan basin including the Dakota Formation and Mesaverde Group (e.g., Lorenz and Cooper, 2003), Mancos Shale/Niobrara Formation (e.g., Nelson and Sonnenberg, 2021), and Ojo Alamo Formation (e.g., Hobbs and Thacker, 2021). The age and composition of the Pemada Canyon dike suggests relation to late-stage Navajo volcanic field magmatism as opposed to magmatism from the Platoro caldera complex and associated Dulce dike swarm of the Southern Rocky Mountain volcanic field. This interpretation of the Pemada Canyon dike extends the eastern boundary of the Navajo volcanic field approximately 50 km to the east into the interior of the San Juan basin.

# Surface Water and Snowpack Modeling With Emphasis on Post-Wildfire Hydrologic Impacts in the Santa Fe Watershed, NM

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The Santa Fe Municipal Watershed is an important source of drinking water and water storage for the City of Santa Fe and these water resources are believed to be at considerable risk from high severity wildfires. This hydrologic modeling project intends to develop a coupled snowpack-surface water model for the Santa Fe Municipal Watershed that will be useful for predicting wildfire risk scenarios. Preliminary work has so far included watershed characterization, instrumentation planning, and model selection. Project plans are that surface water modeling will begin in HEC-HMS, while the SnowModel model package will be used to track seasonal snowpack evolution and provide meltwater inputs to HEC-HMS. It is believed that the coupling of these models will provide more reliable runoff and water yield estimates than with less complex snow modeling modules. Models will then be parameterized with different wildfire and forest management scenarios to provide insight into hydrologic vulnerability and resilience in the Santa Fe Municipal Watershed. Field data will be collected to parameterize and validate the model – sap flow measurements for determining transpiration rates in dominant tree species, and soil moisture content measurements. Other data will come from weather stations (SNOTEL, RAWS) and USGS streamgages.

# ENVIRONMENTAL FATE OF SULFUR IN SULPHUR CREEK, VALLES CALDERA, NM: IMPLICATIONS FOR WATER QUALITY AND METAL TRANSPORT

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The 1.2 Ma Valles Caldera in northern New Mexico hosts a hydrothermal system that has been characterized by Goff and Janik, 2000 and references therein as consistent with a young igneous model. This study aims to determine the geochemical processes that govern the attenuation of chemical components released by hydrothermal activity in streams draining the Jemez mountains. The Sulphur Springs are the primary vents of the Valles acid-sulfate hydrothermal system, emitting waters with pH <3 and high concentrations of Al (60-800 mg/L) and $SO_4^{2-}$ (1,800-10,000 mg/L). Sulphur Springs discharges into Sulphur Creek, imparting a similarly low-pH, high-Al, high-$SO_4^{2-}$ signature. Further downstream, these signatures are attenuated by the interaction of Sulphur Creek with the similarly low-pH Redondo Creek and the circumneutral, snowmelt-fed Río San Antonio. The Sulphur Creek field area is a particularly useful natural laboratory to conduct this study due to the wide range of in-stream pH and salinity conditions. Additionally, Sulphur Creek waters mix with waters of diverse composition of both hydrothermal and meteoric origin at multiple confluences along its run. The wide range of conditions found in this field area make it possible to discriminate between many processes that control attenuation.

This study uses major ion and stable isotope compositions and field parameters of collected water samples as geochemical tracers to identify attenuation processes. Due to the low pH of many of the samples, charge balancing of the waters required additional steps, including partitioning total sulfate species into $SO_4^{2-}$ and $HSO_4^-$ and geochemical modelling using software such as PhreeqC. Data collected for this study suggests the importance of dilution and pH-changes in attenuating high concentrations of dissolved solids. Mixing analysis at the many confluences Sulphur Creek has along its flowpath is required to identify attenuation on a more granular level. Furthermore, additional investigation is needed to identify seasonal changes in the geochemistry of the system that may have an impact on the attenuation of the hydrothermal components. Hydrothermally-affected waters from the Yellowstone caldera are used for comparison with Valles waters in this study.

## References:

Goff, F. and Janik, C, 2000, Geothermal Systems: Encyclopedia of Volcanoes, p. 817-834.
McCleskey, R.B., Nordstrom, D.K., Susong, D.D., Ball, J.W., Holloway, J.M., 2010a, Source and fate of inorganic solutes

in the Gibbon River, Yellowstone National Park, Wyoming, USA: I. Low-flow discharge and major solute chemistry: Journal of Volcanology and Geothermal Research, v. 193, p. 189-202.

McCleskey, R.B., Nordstrom, D.K., Susong, D.D., Taylor, H.E., 2010b, Source and fate of inorganic solutes in the Gibbon River, Yellowstone National Park, Wyoming, USA. II. Trace element chemistry: Journal of Volcanology and Geothermal Research, v. 196, p. 139-155.
Nordstrom, D.K., McCleskey, R.B., and Ball, J.W., 2009 Sulfur geochemistry of hydrothermal waters in Yellowstone National Park: IV Acid-sulfate waters: Applied Geochemistry, v. 24, p. 191-207.

## Keywords:

Valles Caldera, acid-sulfate, geothermal, water quality, contaminant fate

# RARE EARTH ELEMENTS IN HUMATES MINED IN THE SAN JUAN BASIN

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Rare earth elements (REE) are of economic importance today because of modern-day technologies, including magnets, electrical components, and industrial components needed for national defense. Humates are organic compounds containing humus, which is known to be available in soil and coal byproducts. These products are abundant, low-cost, and are sold commercially for use in several products, including nutrients for soil for better plant growth, cosmetics, filtration, and other uses. Although the concentrations of REE are relatively low in coal and humates (<600 ppm total REE), the volumes of coal and humate produced is large and makes them an attractive source for potential by-product REE production. The Menefee mine in northern New Mexico processes humates with average concentrations of total REE (TREE) from 113-179 ppm. In this study, five humate samples from two different mines were analyzed using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) to quantify REE. The metals were extracted using two methods, RO (reverse osmosis) extraction and acid digestion (via microwave). Before extraction, samples were prepared by oven drying the samples, grinding them using mortar and pestle and then sieving them through a 45-micron sieve. During RO extraction, the samples were mixed one-part humate to five parts RO water, shaken continuously for an hour, then centrifuged. One sample was shaken for a total of 72 hours to compare TREE extracted to shaking for one hour. The samples were filtered with Whatman funnel filters before analysis. Before acid digestion, samples were split into smaller aliquots (about 0.25 gram) using a riffler splitter. The acid digestion was conducted using 5 mL nitric acid and 2 mL hydrofluoric acid, and samples were filtered with Whatman funnel filters and diluted to about 1% acid before analysis. The solutions from the two methods of extraction were then analyzed by ICP-MS at the New Mexico Bureau of Geology and Mineral Resources Analytical Laboratory. The TREE concentrations were generally low for these samples. A high ratio of LREE (light rare earth element) to HREE (heavy rare earth element) was observed. A longer shaking step resulted in higher TREE concentrations. An elevated concentration of TREE was also present in a white filtrate produced after the hydrofluoric acid step in the microwave digestion.

# A Review of Lithium as a Critical Industrial Material and Engagement Prospects in New Mexico.

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Lithium. The name appears on our batteries and electronic devices. But what is Lithium? What makes this element work in our power supplies? Where does it come from and how do we get it? And, what about Lithium in New Mexico?

Lithium is a critical mineral used in lubricants, metal alloys, medical products, ceramics and glass, and most commonly, batteries. As we move to alternative energy and electric vehicles, the uses and demand for Lithium is increasing. Global production of Lithium rose over 11-fold from 1995 to 2021 growing from 9.5 kTonnes to 106 kTonnes annually.

Lithium is the lightest of all metals. It has a single electron in its valence shell which is readily given up to form a cation in reactions. This makes it a very reactive metal that must be stored away from air and water but gives Lithium its good thermal and electrical conductivity—key properties for use in batteries.

Economically-viable deposits of Lithium occur in three major categories: in pegmatites typically as the minerals spodumene and lepidolite ($LiAlSi_2O_6$ and $K(Li,Al)_3(Si,Al)_4O_{10}(F,OH)_2$); in volcanic clays as hectorite, montimorillonite and bentonite ($Na_{0.33}(MgLi)_3Si_4O_{10}(F,OH)_2$, $(Na,Ca)_{0.33}(Al,Mg)_2Si_4O_{10}(OH)_2 \cdot nH_2O$); and from brine and geothermal deposits which includes solar evaporates, playa lakes, and extracted subsurface brines from petroleum and geothermal production.

Although currently not in production in New Mexico, we accounted for about 10% of US Lithium output from 1920 to 1950. Most of that production came from the Harding Pegmatite Mine in the Picuris District, Taos County. Since 1950 no Lithium has been mined in New Mexico but work is currently underway exploring sources of Lithium in the state that could be economically produced. There are several known Lithium sources from pegmatites in north-central New Mexico but these are not likely to be developed in the near future. Volcanic clays occur across many parts of the state and a few have potential for development in the near-term. The Popotosa Formation of the Rio Grande Rift has notable amounts of Lithium in its tuff layers. Diatomite and zeolite deposits in the Gila Conglomerate in the Buckhorn area near Silver City offer another potential source of Lithium. Brine and hydrothermal/geothermal deposits offer some of the best sources of Lithium and other minerals in the short term. The Lordsburg, Tularosa, and Estancia basins all have measurable amounts of Lithium that make them potential development areas.

At the Bureau of Geology we have several projects exploring critical minerals in the state, including Lithium. Sampling and analyses are being conducted on porphyry deposits, carbonatites, mine wastes, and coal-related materials looking for viable sources of critical industrial minerals such as Lithium. A recent grant from the State of New Mexico to research our state's geothermal resources may also include examining the potential to co-produce Lithium and other minerals from geothermal fluids in a manner similar to current work being done at the Salton Sea in southeast California.

**Keywords:**

lithium, batteries, electronic devices, alternative energy, electric vehicles, pegmatities, volcanic clays, brine, geothermal, New Mexico

# MONITORING THE IMPACTS OF THE 2022 HERMITS PEAK/CALF CANYON FIRE ON THE UPPER PECOS RIVER WATER QUALITY

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The Upper Pecos Watershed (UPW), part of the Rio Grande Basin, extends from the headwaters of the Pecos River in the Sangre de Cristo Mountains (elevation > 12,000 ft) to its confluences with Cow Creek and El Rito (elevation ~ 6,000 ft). The Upper Pecos River supports recreation, agriculture, cattle grazing, tourism, and other uses. It is one of the most ecologically diverse and culturally significant waters of New Mexico. The UPW, along with nearby regional watersheds, was impacted by the 2022 Hermits Peak/Calf Canyon Fire, the largest wildfire in New Mexico's history (>340,000 acres). Approximately 40,150 acres burned in the UPW, 34% of which were classified by the USFS Burned Area Emergency Response (BAER) team as high burn severity. Such classification raised concerns for post-fire impacts to water quality from increased river discharge, hillside erosion, and fire sedimentation. We collected weekly in-the-field physical-chemical parameters (conductivity, temperature, dissolved oxygen, and pH) using a YSI 556 Multi Probe and grab water samples for turbidity analysis using a Hach TL2300 turbidimeter throughout Summer 2022 to assess the after-effects of the wildfire. These data were compared to water quality data collected by our team in Summer 2020 and 2021 to determine if and how much the water quality departed from baseline values. From the onset of the monsoon rains (mid-June), ash and floating debris were observed in the stream, along with high turbidity and low dissolved oxygen values both in exceedance of the NMAC 20.6.4.900 water quality threshold (> 10.00 NTU and 6 mg/L respectively). Values of pH ranged between 3.79-7.69 with the lowest values corresponding roughly to high discharge events. Temperature and electrical conductivity met water quality standards for the Upper Pecos River's high-quality cold-water designation (NMAC 20.6.2). We continue to monitor the river, as water quality in the system sets the basis for the rest of ecosystem health.

**Keywords:**

Upper Pecos River, Hermits Peak/Calf Canyon fire, water quality, turbidity, dissolved oxygen

# GROUNDWATER SIGNATURES AND MIXING PATTERNS AROUND EL PASO DEL NORTE AREA OF THE RIO GRANDE AQUIFER SYSTEM USING ENVIRONMENTAL TRACERS

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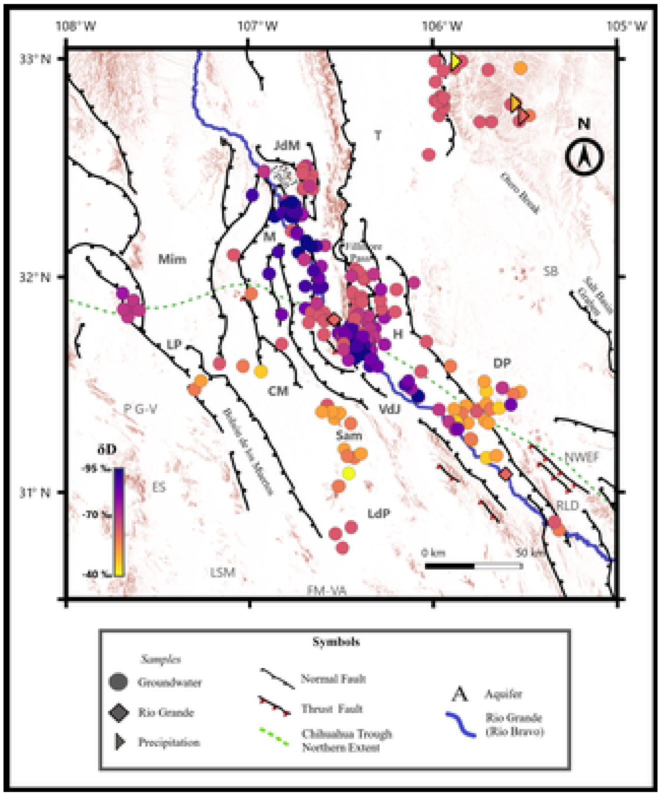


Regional map showing structural features of the basins and the distribution of deuterium values for groundwater and surface samples around El Paso del Norte area. Initials in bold refer to aquifers included in this study.

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Geochemical and isotopic data from the literature for aquifers around El Paso del Norte area is gathered and analyzed to identify mixing patterns and study their hydraulic connectivity. Most of the aquifers are recognized as part of the Rio Grande aquifer system and represent an interlinked series of basins. Existing information on groundwater flow direction and interbasin flow help interpret the data. Using environmental tracers, groundwater groups were identified and characterized, including possible instances of mixing among them. The results were then compared to dendrograms produced from a multivariate analysis of the data as well as to published classification schemes. This study specifically identifies a number of samples in the Valle de Juárez aquifer that match the signature of groundwater groups found near the Jornada-Mesilla divide as well as mixing with the Hueco Bolson endmembers. Groundwater from Conejos-Médanos resembles a mix of at least two distinct water types identified in the Laguna de Patos aquifer; their similarities with a number of samples in the Mesilla Basin, Diablo Plateau, and southern Hueco Bolson suggest mixing and/or a common source or lithology. Springs from the Diablo Plateau and Red Light Draw located at normal faults along the southeastern Hueco boundary are discharging groundwater with similar characteristics. A number of regional geochemical trends were also identified. The results illustrate aquifer dynamics and highlight the importance of data integration for the analysis of regional and local systems, which has implications for water management, quality, and availability topics.

**Keywords:**

groundwater, environmental tracers, Rio Grande aquifer system, interbasin flow, multivariate analysis, transboundary aquifers

# REVISIONS TO THE PENSYLVANIAN-PERMIAN LITHOSTRATIGRAPHIC NOMENCLATURE IN THE SOUTHERN SANGRE DE CRISTO MOUNTAINS, NEW MEXICO

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Carboniferous strata were first identified in the southern Sangre de Cristo Mountains in the 1870s, and, in 1928, Darton referred them to the Magdalena group overlain by the Abo sandstone capped by the Chupadera formation. In the 1940s, U. S. Geological Survey mappers brought the Pennsylvanian lithostratigraphic nomenclature used to the south into the Sangre de Cristo Mountains, and referred to the overlying red beds as Sangre de Cristo Formation. Thus, they assigned the lower part of the Pennsylvanian section to the Sandia Formation and most of the overlying Pennsylvanian strata to the Madera Limestone divided into a lower, gray limestone member and an upper, arkosic limestone member. In the 1960s-1970s, Sutherland proposed new lithostratigraphy, the La Pasada Formation (south) and equivalent Flechado Formation (north) correlated to the Sandia Formation and gray limestone member of the Madera Limestone, overlain by the Alamitos Formation, in part equivalent to and overlain by the Sangre de Cristo Formation. In the 1980s-1990s, Baltz and Myers proposed an alternative lithostratigraphic nomenclature that recognized the Sandia Formation overlain by the Madera Group composed of the Porvenir and Alamitos formations, unconformably overlain by the Sangre de Cristo Formation.

Sutherland stated that no consistent criteria could be identified by which to separate the Sandia from the Madera formations, but the Sandia-Madera contact south of the Sapello River is the same as it is to the south in the Sandia uplift. So, Sutherland's La Pasada Formation is a composite unit made up of the Sandia and Gray Mesa formations, and it should be abandoned. The Porvenir Formation type section near Las Vegas is mostly limestone with a few thin quartzose sandstone interbeds and a shaley interval in its upper half. Baltz and Myers identified three facies of the Porvenir Formation: (1) in the south, a dominantly carbonate facies, including the formation type section; (2) in the north, a thicker more shaley facies; and (3) farther north, more arkosic sandstone. The carbonate facies is simply Gray Mesa Formation, so Porvenir is a synonym of Gray Mesa. Porvenir strata to the north can be assigned to the Flechado Formation.

Use of Sangre de Cristo Formation in the southern Sangre de Cristo Mountains was largely based on age, because, in Colorado, that unit encompasses Pennsylvanian and lower Permian strata, as it supposedly does in the southern Sangre de Cristos. Nevertheless, the Pennsylvanian-age Sangre de Cristo strata in New Mexico of earlier workers are mostly Alamitos Formation red beds. The Sangre de Cristo Formation in New Mexico lacks the marine interbeds characteristic of the Sangre de Cristo Formation in its type area, and was deposited in a basin separate from the basin in which Sangre de Cristo Formation strata were deposited in Colorado. In southern San Miguel County, the two Abo members recognized to the south (Scholle and Cañon de Espinoso members) can be recognized in the "Sangre de Cristo" strata. Thus, we abandon the name Sangre de Cristo Formation in northern New Mexico in favor of Abo Formation.

# Stratigraphy of the early Permian DeChelly erg in New Mexico

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The early Permian DeChelly Sandstone represents an erg that covered much of the Four Corners region of the American Southwest. Its southeastern edges are in New Mexico, and new stratigraphic data from near Placitas in Sandoval County document its rapid, local pinchout and transition into arid coastal plain deposits of the Arroyo de Alamillo Formation. In New Mexico, the lower lithosome of the Yeso Group was long termed the Meseta Blanca Member of the Yeso Formation, but encompasses two distinct lithofacies—to the north, eolian sandstones (dune and interdune deposits) properly termed DeChelly Sandstone (the type Meseta Blanca Member section in the Jemez Mountains is a section of the DeChelly) and the arid coastal plain deposits of the Arroyo de Alamillo Formation to the south. Prominent outcrops of the DeChelly Sandstone are mostly crossbedded sandstone of eolian origin at: (1) Jemez Mountains (T16N, R2E, Sandoval County), 82 m thick; (2) Zuni Mountains (T9N, R11W, Cibola County), 77 m thick; and (3) Lucero uplift (T7N, R3W, Valencia County), 70 m thick. These are the southernmost outcrops of the DeChelly Sandstone. Lower Yeso strata to the south/southeast are of the Arroyo de Alamillo Formation, a mixture of siltstone and sandstone, the latter often gypsiferous with some thin, local eolian sandstones and minor beds of dolomite and gypsum. These outcrops are at: (1) Mesa del Yeso, type section of the Arroyo de Alamillo Formation (T2S, R2E, Socorro County), 107 m thick; (2) Abo Pass (T3N, R6E, Torrance County), 60 m thick; (3) Fra Cristobal Mountains (T12S, R2W, Sierra County), 81 m thick; and (4) Caballo Mountains (T17S, R3W, Sierra County, 74 m thick.

On the northern end of the Sandia uplift north of Placitas (T13N, R5E, Sandoval County), two stratigraphic sections document over a distance of ~ 1 km the southward gradation and pinchout of the DeChelly Sandstone into the Arroyo de Alamillo Formation. To the north, the lower Yeso lithosome is 59 m thick and almost totally eolian sandstone, and thus assigned to the DeChelly Sandstone. But, about 1 km to the south, the lower Yeso lithosome is 24 m thick and about 50% siltstone and 50% sandstone, the latter often gypsiferous and including some eolian sandstones. To the south of the Sandia uplift, at Tijeras Canyon (T10N, R5E, Bernalillo County), the lower Yeso is strata of the Arroyo de Alamillo Formation. To the east/northeast, on Glorieta Mesa at Rowe (T15N, R12E, San Miguel County), the lower Yeso is a mixture of sandstone of fluvial origin and siltstone with minor beds of conglomerate and dolomite. These rocks differ from strata of the De Chelly or Arroyo de Alamillo formations and may merit a new formation name. Earlier workers, who called the entire lower Yeso lithosome from the Jemez Mountains to the Caballo Mountains the Meseta Blanca Member obscured a substantial facies change from the DeChelly eolian (dune and interdune) deposits to the north that grade southward into arid coastal plain deposits of the Arroyo de Alamillo Formation to the south.

# QUANTIFYING BEDLOAD TRANSPORT IN EPHEMERAL CHANNELS USING SEISMIC METHODS

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The transport of sediment is one of the fundamental geomorphic processes governing the evolution of landscapes. Reliable sediment flux forecasts are necessary for a variety of applications such as sedimentation engineering, river restoration, and flood risk mitigation. Quantifying bedload driven by flood events in ephemeral channels is notoriously difficult because of the scarcity, irregular nature, and high intensity of flash floods. Seismic methods appear to be a promising tool to characterize such fluvial processes, as they continuously record the ground motions caused by bedload and water movement while located outside of the active channel.

We evaluated the performance of the physics-based model estimates of bedload fluxes developed by Tsai et al. (2012) by comparison to continuous monitoring of bedload measurements. The model establishes a mathematical relationship for the power spectral density (PSD) of the Rayleigh waves produced by vertically impulsive impacts from saltating particles based on the rate of impacts of fluvial sediment for a given bedload flux and grain size distribution. As a test of this model, we collected seismic data during flow events and compared the seismically-estimated bedload flux with high-precision bedload flux observations. These data derive from a multi-year campaign of monitoring an ephemeral, sand-and-gravel bedded channel reach of the Arroyo de los Pinos, central New Mexico, USA. Based on seismic data analysis, we find that bedload transport correlates to signals in the 30-80 Hz frequency range, whereas rainfall correlates to signals above 100 Hz. Inverting seismic data for bedload fluxes using the vertical impact model results in overestimates of the observed bedload flux by ~2 orders of magnitude. We investigate three hypotheses that may explain this discrepancy. First, the process of rolling and/or sliding particles, as opposed to saltating particles, may be the predominant cause of model discrepancy. Rolling particles are perhaps a very significant contributor to bedload at this study site. Second, the fine-grained alluvial characteristics of this riverbed, as contrasted to a rigid bedrock substratum used in the model, lead to significant attenuation of seismic energy as a result of the inelastic impact of bedload particles. Third, the bedload impact frequency model may not fully depict the impact of particles onto the riverbed in this environment. By thoroughly examining bedload transport mechanisms and considering alternative impulse functions for seismic noise generation, we intend to construct a new physics-based model within the framework of the existing models to quantify bedload transport in the ephemeral environment.

**Keywords:**

sediment transport, environmental seismology

# INTERWEAVING RECURRING SLOPE LINEAE IN RAGA CRATER, MARS AND THEIR APPLICABILITY TO HILLSLOPE MONITORING THROUGHOUT NEW MEXICO

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Recurring slope lineae (RSL) are unique features on the Martian surface whose formative mechanisms and overall geomorphic expression are still poorly understood [1]. While many appear linear, a small subset— notably in Martian craters such as Raga— display an interweaving morphology. This morphology has not been discussed at length in the literature and raises several questions about the nature of recurring slope lineae; specifically about the geomorphic expression of interweaving RSL. We seek to determine whether interweaving slope lineae can provide insight into the formative nature of RSL, and postulate that the interweaving exhibited by recurring slope lineae does help to further constrain their formative mechanisms as either fully aqueous in form, or as a dry, channelized flow of sediment down sinuous sub-resolution channels. Our research also suggests that changes in slope angle near the bifurcation point of slope lineae are associated with the interweaving patterns seen in RSL, and that higher sinuosity in those channels may influence the interweaving nature of these features.

Approximately 87% (198 of 228) of RSL were found to contain just a single channel. Approximately 10% (23 of 228) had two channels, ~2% (5 of 228) had three channels, and less than 1% (2 of 228) had four channels. Conversely, 4% of channels (10 of 267) were determined to be sinuous; the highest sinuosity ratio found was 1.204. None were classified as meandering. Additionally, most of the channels cataloged as sinuous— six of ten— were found to be part of multi-channel RSL systems. However, only four anabranching RSL contained sinuous channels. Six sinuous channels were part of the four multi-channel lineae, whereas four sinuous channels were part of single-channel lineae.

Of the seventy-seven channel bifurcations measured, approximately 51% (39 of 77) were found on slopes that became shallower in the few meters around the channel bifurcation. By contrast, only around 27% (21 of 77) of channel confluence points were on slopes that became shallower around where the channels reconvened. Slope angle therefore appears to play an integral role in channel bifurcation, reconvening, and in the propensity for RSL interweaving more broadly.

This research is applicable not only to extraterrestrial hillslope processes, but to terrestrial hillslope processes and specifically to hillslope failure— especially in drier, more arid terrestrial regions, such as the desert southwest in the United States. While not a perfect analogue for the Martian surface due in part to the terrestrially higher temperatures and moisture content, states such as New Mexico nonetheless approximate generic Martian conditions more closely than their more vegetated and humid terrestrial counterparts. As such, understanding the downslope movement of material on planets such as Mars can provide geomorphologists, urban planners, and hydrologists with a greater understanding of slope processes in dry, arid environments, informing decisions about environmental hazards and risk mitigation strategies throughout both the state of New Mexico and the region more broadly.

## References:

[1] Stillman, D. E. et al. (2020) *Icarus*, *335* (August 2019), 113420.


## Keywords:

Mars, planetary, RSL, geomorphology, hillslope

# Ammonites of the Upper Cretaceous Twowells Member of the Dakota Sandstone, Ojito Wilderness Area, Sandoval County, New Mexico

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The BLM Ojito Wilderness Area in southern Sandoval County, New Mexico, is located in the southeastern San Juan Basin. Most of the strata exposed in the Ojito are of Jurassic age, but its western third exposes outcrops of the intertongued Dakota-Mancos succession of early Late Cretaceous (Cenomanian) age. At the top of this succession is the Twowells Member of the Dakota Sandstone, a thin (1-4 m thick) unit of laminar or bioturbated sandstone that yields ammonites of the upper Cenomanian *Calycoceras canitaurinum* Zone.

Since W.A. Cobban's 1977 work on the Dakota-Mancos molluscan fauna of west-central New Mexico, no new taxa of mollusks have been reported from the Twowells Member. A recent survey of the Cretaceous strata of the BLM Ojito Wilderness Area produced an impressive molluscan assemblage from the middle Cenomanian, most of it from the Paguate Member of the Dakota Sandstone and the Clay Mesa Member of the Mancos Shale. It also yielded ammonites and other fossils (bivalves, shark teeth) from 16 localities in the Twowells Member over a 5 km outcrop belt along the western boundary of the Ojito Wilderness Area (NMMNH [New Mexico Museum of Natural History] localities 12749-12752, 12755-12760, 12762, 12786-12788, 12790, and 12820). Here, the Twowells Member is a persistent, yellowish-gray glauconitic sandstone bed that overlies a narrow band of the Whitewater Arroyo Member of the Mancos Shale. Within the crossbedded, fossiliferous coarse-grained sandstone are lenses of lag with coquina, shark teeth, pebbles, and occasional bone fragments.

The Twowells Member assemblage of ammonites recovered consists of *Metoicoceras praecox* (Haas), *Calycoceras (Proeucalycoceras) canitaurium* (Haas), and *Cunningtoniceras arizonesis* (Kirkland) as well as the second and third specimens of *Metongococeras* (Hyatt) reported in New Mexico. The *Metengonoceras* are unusual and rare and consist of: (1) NMMNH P-87911 from locality 12755, a three-dimensional sandstone cast of a fragment of a large adult phragmocone/body chamber; and (2) NMMNH P-86638 from locality 12820, a weathered three-dimensional sandstone cast of a phragmocone fragment. We assign these specimens to *Metengonoceras* cf. *M. dumbli* (Cragin). They have only one lateral side well preserved. The shells are compressed, involute and discoidal with nearly flat flanks with faint ribs and a steep umbilical shoulder. Possible primary and secondary ribs are visible, and there are two secondary ribs per primary. The narrow venter become more rounded outward. Under indirect light, faint falcate growth lines are visible. These are the first fully documented *Metengonoceras* reported from New Mexico. The other report is by Cobban in 1987, who briefly mentions a *Metengonoceras* from the Mancos Shale of Socorro County. *M. dumbli* is only known from the middle Cenomanian of the Western Interior, and all Twowells Member ammonites from New

Mexico are from the upper Cenomanian. *M. acutum* is only known from the upper Cenomanian. Due to the rarity of well-preserved specimens, variability of morphology, the historical ambiguity of the nomenclature, and the fact that our specimens exhibit morphological features ascribed to both species, we propose that Cenomanian *Metengonoceras* is only one species: *Metengonoceras dumbli*.

# CRITICAL MINERALS IN NEW MEXICO

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New Mexico has a wealth of mineral resources, including critical minerals. A common definition is "*a critical mineral is a nonfuel mineral commodity that is essential to the economic and national security of the United States, and is from a supply chain that is vulnerable to global and national disruption."* Many critical minerals are 100% imported into the U.S (Fig. 1). The U.S. DOI, DOE, and DOD established a list of critical minerals in 2019 and revised that list in 2022. Copper is not considered a critical mineral because the U.S. produces enough copper for current use and copper is imported from other countries where there are secure trade agreements, so the supply of copper is not considered in jeopardy at this time. Uranium was listed as a critical mineral in 2019 because of its use in Navy nuclear reactors. However, because uranium is used as a fuel for nuclear reactors, it was removed from the list in 2022. The critical minerals list is to be reviewed every 2 to 3 years.

A number of critical minerals are found in NM. Rare earth elements (REE) deposits are found in the Gallinas, Capitan, and Cornudas Mountains and Laughlin Peak-Chico Hills; all are associated with Tertiary alkaline igneous rocks. Disseminated Y-Zr-REE deposits in Proterozoic nepheline syenite are found at Pajarito Mountain (Mescalero Apache Indian Reservation, Ruidoso). Other critical minerals are associated with various mineral deposits in NM. For example, vanadium, molybdenum, selenium, and REE are associated with sandstone uranium deposits in the Grants uranium district. Rhenium is found in porphyry copper and porphyry molybdenum deposits in NM. Coal deposits are abundant in the state and could be source of several critical minerals (REE, Se, V, Li), additional work is underway to fully understand the distribution of critical minerals in NM coal deposits.

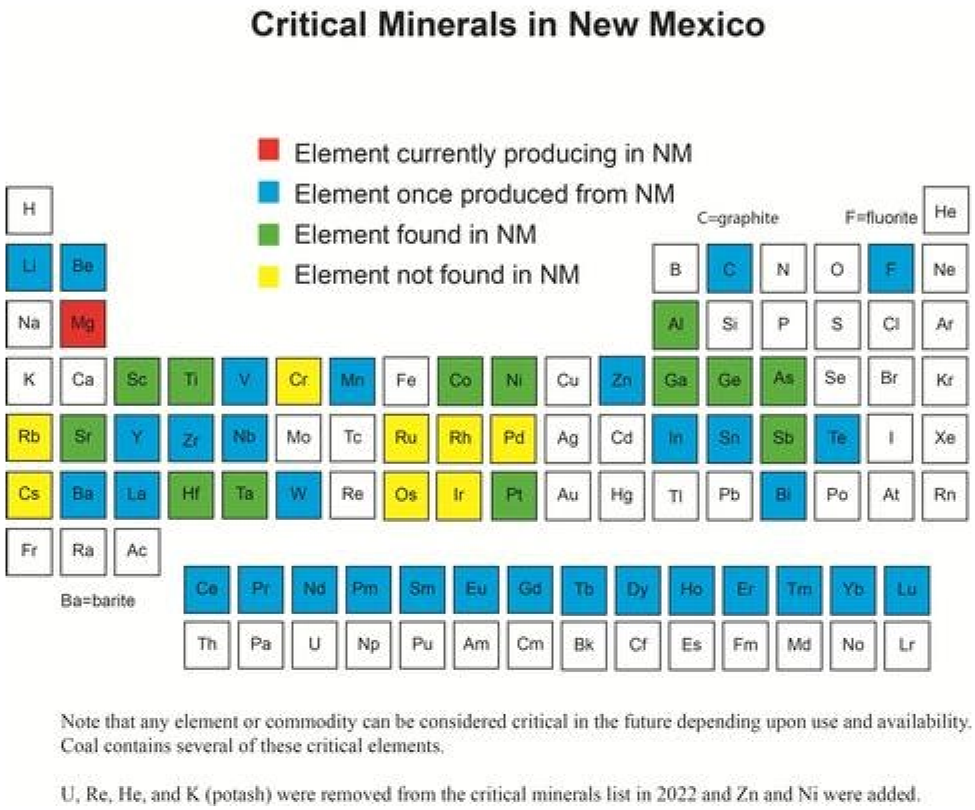


FIGURE 1. Periodic table showing critical minerals in New Mexico.

**Keywords:**

critical minerals, rare earth elements, vanadium, porphyry copper deposits

# COMPARISON OF MEASURED BEDLOAD WITH PREDICTIONS FROM TRANSPORT EQUATIONS IN AN UNARMORED EPHEMERAL CHANNEL

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The Arroyo de los Pinos is a tributary of the Rio Grande that transports relatively coarse sediment into the river annually through flash flood events. This coarse-grained sediment can lead to problems for downstream infrastructure, such as sedimentation in reservoirs and increased channel maintenance requirements for flow conveyance. Over the past five years, a comprehensive database of bedload, suspended sediment, and meteorological-hydrologic measurements have been developed at the confluence of the channel to the Rio Grande. Bedload flux is monitored by three Reid-type slot samplers at 1-minute resolution, flow stage is continuously monitored with pressure transducers, and surface flow velocity is measured periodically using large scale particle imagery velocimetry (LSPIV) to produce a stage-discharge rating curve. Bed material samples have been collected and sieved, and channel geometry has been mapped in detail using drone imagery and structure from motion (SfM) photogrammetry. This dataset enables assessment of predicted bedload using a wide range of well-established equations including Meyer-Peter and Müller, Wilcock and Crowe, Einstein, Parker, Ackers-White, and Engelund-Hansen which are calculated and compared in HEC-RAS and BedloadWeb. Crucially, we can compare the quality of prediction from these methods against the observed bedload transport at a range of flow depths between 5 – 50 cm (discharge at 0.25 – 10 m3/s). The Pinos dataset provides an excellent opportunity to compare a range of transport equations and consider their relative performance in ephemeral, semi-arid, flash flood driven fluvial systems. Successful equation selection will enable the extension of our temporally-limited direct bedload measurements to approximate annual bedload yields from the Arroyos de los Pinos, as well as from other similar ephemeral tributaries to the Rio Grande and elsewhere. The best fitting bedload transport equations for the Arroyo de los Pinos are the Meyer-Peter and Müller and the Wilcock and Crowe equations.

**Keywords:**

flash floods, sediment transport

# THE ROLE OF GEOLOGY AND LEGACY MINES IN POST-WILDFIRE WATER QUALITY

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Wildfires can lead to increased surface runoff, erosion, and conveyance of sediment, ash, pollutants, and debris to surface water during storm events. This can result in decreased water quality, loss of reservoir storage capacity, stream habitat degradation, and increased treatment costs for drinking-water providers. Studies have shown that the range and magnitude of post-wildfire water-quality effects vary widely and that important factors include burn severity, wildfire extent and post-fire precipitation. Less is known about the role of underlying geology and mineralogy. Wildfires have become a common occurrence in the western U.S., a region with a diverse array of underlying geology and mineralogy as well as a large number of legacy mining sites. The intersection of legacy mining and post-wildfire hydrologic response poses an increasing risk to many water supplies in this region due to the risk of increased delivery of metals to water bodies. There are several potential post-wildfire pathways for metal transport to surface water after wildfire: precipitation falling directly onto mine waste surfaces after vegetation on the waste has burned, leading to the dissolution and transport of metals to streams; increased surface runoff and stream flow that erode and transport metal-rich sediment deposits from hillslopes and streambanks to streams; remobilization of the metals from streambeds; and increased flow, and greater fluctuation, of water through underground mine workings and delivery of this water to the stream network. The role of these processes in post-wildfire water quality must be accounted for in different regions across the western U.S. The USGS is working to advance our ability to measure, model and predict potential impacts of wildfires on water supplies.

**Keywords:**

wildfire, water quality, legacy mining, geology, metals

# The Mineralogy of the Black Hawk Arsenide 5-Element Deposit

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The unusual arsenide five-element-vein deposits of the Black Hawk district in the Burro Mountains, Grant County, New Mexico is one of only a few examples of these types of deposits in the United States. These are unusual deposits due to their scarcity, unusual metal association, and uncommon mineral textures. The typical metal assemblage consists of silver-nickel-cobalt-arsenic-bismuth mineralization, with varying amounts of uranium, copper, antimony, mercury, and zinc. These deposits have been long produced for high grades of silver, and more recently cobalt, nickel, and bismuth, but they are not well studied. The Black Hawk deposits appear to be late Cretaceous in age, and occur within faults of Proterozoic granites, diorites, and metamorphics. Production from the Black Hawk district from 1881-1960 amounts to 1,286,000 oz Ag, 3,000 lbs. Cu, 1,000 oz Au, 4,000 lbs. Pb, and minor tungsten and fluorite. The mineralogical and textural relationships are very similar to those observed from the 5-element system in Cobalt, Ontario, Canada. These include early precipitation of dendritic and skeletal native silver, followed by nickel and cobalt arsenides, such as nickeline, skutterudite, nickelskutterudite, safflorite, and rammelsbergite. This is followed by a sulfide stage and precipitation of minor base metals, such as galena, sphalerite, and chalcopyrite. The last minerals to precipitate are gangue minerals, typically calcite or siderite, with some quartz. The Black Hawk district shows early uraninite precipitation, whereas the Cobalt, Ontario system shows no such uranium mineralization. This assembly of highly reduced metallic phases indicates a reducing agent component to precipitation, and it is theorized that methane or other organic fluids could have caused this rapid crystallization, leading to the development of the observed dendritic and uneven vein filling mineral textures. A better understanding of the mineralogy of this deposit in comparison to other 5-element deposits around the world will better inform the pursuit of the critical minerals cobalt, nickel, arsenic, zinc, and bismuth.

# FLUVIAL PROPAGATION OF WILDFIRE DISTURBANCES FROM THE LARGEST WILDFIRE RECORDED IN NEW MEXICO

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Wildfires within the Southwest are expected to increase in frequency and severity, and are known to change terrestrial ecosystems, soil hydrophobicity, and a watershed's runoff response to precipitation. While wildfires' impact on a watershed and its localized effect on nearby stream reaches are well documented, what remains uncertain is how wildfire disturbances on water quality and stream metabolism propagate longitudinally through a fluvial system. To further our understanding of wildfire longitudinal impacts, we utilized five high-frequency in-situ sonde sites downstream of the Hermits Peak Calf Canyon (HPCC) wildfire, the largest wildfire in New Mexico state history, covering 192 km of the Gallinas Creek that included the Las Vegas, NM municipality and Santa Rosa Lake. Our results show a significant increase in turbidity (p-values $< 0.05$) at monitoring sites upstream of Santa Rosa Lake during periods of high discharge. During these periods, a significant reduction was observed in gross primary production at all monitoring sites upstream of Santa Rosa Lake (p-value $< 0.05$). Unlike the monitoring sites upstream of Santa Rosa Lake, the site downstream did not experience a significant change in turbidity (p-value $= 0.12$) and had a significant increase in gross primary production (p-values $<$ 0.05). Stream metabolic fingerprints also indicated increased scouring, DOC, and sediments at sites upstream of Santa Rosa Lake, while the site downstream remained relatively stable. Our novel results demonstrate how a large-scale wildfire can cause localized impacts to water quality and stream metabolism and propagate through a fluvial system spanning multiple stream orders impacting downstream water quality and ecosystem services, and how a large lake was able to buffer those disturbances halting their propagation.

**Keywords:**

Wildfire propagation, fluvial, water quality, stream metabolism

# Lithogeochemical Vectors and Mineral Paragenesis of Hydrothermal REE-F-Bearing Veins and Breccias in the Gallinas Mountains, New Mexico

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The Gallinas Mountains district in New Mexico showcase hydrothermal rare earth element (REE)-bearing fluorite veins and breccias hosted in Permian sedimentary rocks that formed during the emplacement of trachyte/syenite sills, dikes and breccias ~30 Ma ago. This district occurs within the Lincoln County Porphyry Belt and is part of the North American Cordilleran alkaline-igneous belt, which has produced significant amounts of gold and silver, as well as lesser fluorite and REE. The Gallinas Mountains district has recorded production of base and precious metals in the early 1900s, with later fluorite and REE production in the 1950s. The Gallinas Mountains district is a prime location to study hydrothermal REE mobilization in an alkaline system because of the well exposed geology. Rare earth elements are primarily found in the fluorocarbonate mineral bastnäsite-(Ce), which is also the primary ore mineral of several world-class carbonatite REE deposits such as Mountain Pass in California and Bayan Obo in China. In this study, a mineral and vein paragenesis was documented using petrographic observations, scanning electron microscopy (SEM)-based automated mineralogy, cathodoluminescence (CL) microscopy, and backscattered electron (BSE) imaging. Trace element chemistry of fluorite was obtained using laser ablation inductively coupled mass spectrometry (LA-ICP-MS) to characterize different types of fluorite found within crosscutting veins and track the occurrence and distribution of REE in the district. Previously collected whole-rock geochemical data allow the authors to link petrographic observations to deposit- and district-scale features, creating lithogeochemical vectors for REE and related alteration styles that may aid exploration for REE in this and other districts.

Three REE-bearing fluorite vein types have been characterized using optical microscopy, BSE imaging, SEM-based automated mineralogy, and CL microscopy. These are: Type 1 barite-fluorite, Type 2 bastnäsite-fluorite, and Type 3 calcite-fluorite veins. Three distinct fluorite generations (fluorite I-III) with unique CL signatures were distinguished in these veins. Of these, fluorite II, found in Type 2 veins, appears to be most significant for the REE endowment as it forms fine intergrowths with bastnäsite-(Ce) overprinting fluorite I in Type 1 veins. Preliminary LA-ICP-MS analysis on fluorite indicates distinct REE chondrite-normalized profiles for each fluorite type. Fluorite I exhibits a LREE-enriched profile, fluorite II a flat LREE profile depleted in HREE, and fluorite III a LREE-depleted and HREE-enriched profile. Whole rock F and REE concentrations in fluorite veins and breccias display a positive correlation with Ba, which indicates an increase in REE mineralization associated with elevated barite concentration. This relationship corroborates the common, district-wide observation of Type 2 bastnäsite-fluorite veins overprinting earlier Type 1 barite-fluorite veins. These results indicate that F-metasomatism plays a key role in the hydrothermal mobilization and deposition of REE, which needs to be further investigated to develop additional geochemical vectors in this type of REE mineral deposit.

# Complete Fish Fossil From the Upper Cretaceous Mancos Shale near Tierra Amarilla, Rio Arriba County, New Mexico

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Other than shark's teeth and isolated actinopterygian scales, fossil of fishes are rare in the Upper Cretaceous Mancos Shale of northwestern New Mexico. Therefore, the discovery of a nearly complete fish skeleton is a noteworthy record. This fish skeleton was collected decades ago by persons unknown and donated to the Museum of New Mexico and later transferred to the New Mexico Museum of Natural History (NMMNH). Locality data with the fossil indicate it was collected near Tierra Amarilla in Rio Arriba County from an approximately 0.25 square mile outcrop (NMMNH locality 8277). The stratigraphic interval that contained the fish fossil was mapped by Landis and Dane (1967) as the middle shale unit (Kmm) of the Mancos Shale above the Cooper Arroyo Sandstone Member (Kmc) and below the El Vado Sandstone Member (Kme). King (1974) called the unit equivalent to the middle shale unit the "lower Smoky Hill interval." Two lithologies are apparent at the outcrop where the fish fossil was found: a darker, more indurated shale (Kme) overlies lighter, more friable shale (Kmm). The matrix of the fossil fish matches the lithology of the upper shale, and isolated fish scales are present in the lower shale. Based on King's biostratigraphic data, we can infer that the fish fossil came from one of two zones: the upper middle Coniacian *Volviceramus involutus* inoceramid zone, which is equivalent to the *Scaphites ventricosus* ammonite zone, or the lower upper Coniacian *Magadiceramus subquadratus* inoceramid zone, which is equivalent to the *Scaphites depressus* ammonite zone.

Catalogued as NMMNH P-64787, the Mancos fish fossil is part/counterpart of a nearly complete acanthopterygian fish. It has a standard length of approximately 17.5 cm, which is approximately twice as large as an unnamed taxon of holocentroid that Stewart (1984) described from the upper Santonian Zone of *Clioscaphites chouteauensis* in the Smoky Hill Chalk Member of the Niobrara Chalk in Kansas. Whereas the Mancos fish has scales with ornamentation consisting of subparallel ridges perpendicular to the rear edge of the scale, the unnamed holocentroid taxon has no such scale ornamentation. The scales of the Mancos specimen are generally similar to those of *Caproberyx superbus* from the English Chalk. This is the first U.S. record of a Cretaceous holocentroid outside of Kansas. Both older and younger holocentroid records are known in Kansas.

## References:

King, N. R., 1974, The Carlile-Niobrara contact and lower Niobrara strata near El Vado, New Mexico: New Mexico Geological Society, Guidebook 25, p. 259-266.

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.

Stewart, J. D., 1984, Taxonomy, paleoecology, and stratigraphy of the halecostome-inoceramid associations of the North American Upper Cretaceous epicontinental seaways [Ph.D. dissertation]: Lawrence, University of Kansas, 201 p.

# Evaluating Segmentation Behavior Along the Alamogordo Fault Using Remote Sensing and Field-based Datasets

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Earthquake magnitude scales with the length of the ruptured fault plane (Wells and Coppersmith, 1994). Regional earthquake hazard assessments therefore require an understanding of how individual fault segments may link together to produce large earthquakes. Though fault segmentation's impact on rupture has been explored along strike-slip faults, such as the San Andreas system in California (Schwartz and Coppersmith, 1984, Nishigami, 2000), similar studies along normal faults are limited (DuRoss et al., 2016). The Alamogordo fault is a segmented normal fault in the Tularosa Basin of south-central New Mexico with established seismogenic potential (Koning and Pazzaglia, 2002). A rupture along this fault would threaten critical infrastructure, such as the city of Alamogordo (population >30,000), White Sands Missile Range, and Holloman Air Force Base. Here we assess fault segmentation along the Alamogordo fault using a combination of remote sensing and field-based mapping techniques. Restricted access within the White Sands Missile Range has limited previous mapping efforts, but with the release of new statewide lidar datasets, we are able to conduct more detailed remote sensing-based neotectonic mapping. Our efforts have expanded the mapped extent of the fault by >15 km. Future work will include mapping of offset geomorphic surfaces at the northern and southern ends of the fault to verify remote mapping interpretations and integration of mapped fault geometries into the lithospheric dynamics code ASPECT to create a geodynamic model of the fault zone.

## References:

DuRoss, C.B., Personius, S.F., Crone, A.J., Olig, S.S., Hylland, M.D., Lund, W.R., and Schwartz, D.P., 2016, Fault segmentation: New concepts from the Wasatch Fault Zone, Utah, USA: Journal of Geophysical Research, Solid Earth, v. 121, p. 1131–1157, doi:10.1002/2015jb012519.

Koning, D.J., and Pazzaglia, F. J., 2002, Paleoseismicity of the Alamogordo fault along the Sacramento Mountains, southern Rio Grande rift, New Mexico *in* : Lueth, V., Giles, K.A., Lucas, S.G., Kues, B.S., Myers, R.G., and Ulmer-Scholle, D., eds.,New Mexico Geological Society 53rd Fall Field Conference Guidebook, Geology of White Sands, p. 107–119.

Nishigami, K., 2000, Deep crustal heterogeneity along and around the San Andreas fault system in central California and its relation to the segmentation: Journal of Geophysical Research, v. 105, p. 7983–7998, doi:10.1029/1999jb900381.

Schwartz, D.P., and Coppersmith, K.J., 1984, Fault behavior and characteristic earthquakes: Examples from the Wasatch and San Andreas Fault Zones: Journal of Geophysical Research, v. 89, p. 5681–5698, doi:10.1029/jb089ib07p05681.

Wells, D.L. and Coppersmith, K. J., 1994, New empirical relationships among magnitude, rupture length, rupture width, rupture area, and surface displacement: Bulletin of the Seismological Society of America, v. 84, p. 974–1002.

### Keywords:

Alamogordo fault, segmentation, geodynamic modeling, Tularosa Basin, mapping

# INVESTIGATING THE GEOMETRY OF AN UNNAMED FAULT SYSTEM SOUTH OF SOCORRO, NEW MEXICO, USING AN INTEGRATED GEOPHYSICAL AND REMOTE SENSING APPROACH

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Active faults within continental rift zones, such as the Rio Grande rift (RGR), pose hazards to society. Evaluations of earthquake hazard along active faults require models of subsurface geometry and estimates of fault activity rates. South of the city of Socorro, New Mexico, a series of normal faults – including the Socorro Canyon Fault Zone (SCFZ) – mark the eastern boundary of the Chupadera Mountains in the RGR. Despite the seismic hazard posed by these fault systems to surrounding communities, their subsurface geometry is not well-constrained. Here we use a variety of interdisciplinary geophysical techniques, including ground penetrating radar (GPR) and seismic reflection surveying, to image the subsurface architecture of this complex fault system. We also use recently released high-resolution lidar imagery to relate scarp morphology in unconsolidated alluvial fans to relative fan age in order to establish Quaternary fault activity. Our geophysical imaging surveys show offset of reflectors consistent with normal faulting. Relative fan age estimates and analysis of scarp morphology indicate that this system has remained active throughout the Quaternary. This recent activity warrants further investigation into the seismic hazard posed by this system, including possible linkages between this and surrounding structures in large earthquakes. Future work includes extending the study area along-strike and cosmogenic nuclide dating of alluvial fans to further constrain the slip history of the faults.

**Keywords:**

GPR, seismic reflection, scarp morphology, Socorro Canyon Fault

# PHYLOGENETIC ANALYSIS OF AMMONIA MONOOXYGENASE (AMOA) GENES FROM DESERT CAVES

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Nitrification is the process by which ammonia is oxidized to nitrate, and is an important biogeochemical reaction in the global nitrogen cycle. This process is catalyzed by ammonia monooxygenase (AMO), which is encoded by the amoA gene. Both bacteria (ammonia-oxidizing bacteria, or AOB) and archaea (ammonia-oxidizing archaea, or AOA) are capable of carrying out ammonia oxidation. This project focuses on the phylogenetic analysis of novel amoA genes from microorganisms found in caves. Through this project, amoA genes from two new metagenomes from Lehman Caves in Nevada and Lechuguilla Cave in New Mexico are being analyzed. Other amoA sequences used for phylogenetic comparison are being compiled from the scientific literature, including amoA studies that go back more than 23 years, as well as from metagenomes from other cave systems. At least one bacterial and one archaeal amoA have been identified so far, and preliminary BLAST analysis showed that these likely originated from close relatives of known ammonia oxidizers, including Nitrosomonas spp., and an unknown archaea. Detailed phylogenetic analysis shows that the amoA from the ammonia-oxidizing bacterium is most closely related to Nitrosomonas spp. and to amoA recovered from other caves, as well as several pmoA sequences, indicating potential use of trace methane. We are now performing additional phylogenetic analyses to further classify these new amoA sequences and explore the evolution of ammonia-oxidizing microorganisms in caves, as well as to further explore the potential use of trace methane as an energy resource in desert caves. The work from this project will be used in future research aimed at uncovering new ammonia-oxidizing cave microorganisms and exploring their role in the subterranean nitrogen cycle.

**Keywords:**

ammonia monooxygenase, bacteria, cave, amoA, phylogenetics

# FROM OLD POOP TO THE REAL SCOOP: THE TRUTH ABOUT LAKE BALLS

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*Ruppia cirrhosa (Ruppia)* is an aquatic vascular plant which has been the source for numerous balls of plant material found along the eastern shoreline of Paleolake Otero in the Tularosa Basin in southern New Mexico. Since some of them have been found adjacent to purported human and Ice Age megafauna tracks and trackways, it has been hypothesized by some researchers that they are Pleistocene megafauna coprolites (fossilized feces). An alternative explanation is that the*Ruppia* seed balls are formed by wave action (oscillating back and forth) during late Pleistocene storm events in the littoral zone of the lake. Both the coprolite and lake ball hypotheses were tested by comparing the Paleolake Otero *Ruppia* seed balls to modern and fossil coprolites and other *Ruppia* seed balls that formed by wave action from known analog/modern saline lake locations in North America. The fabric of the seed balls lacked any evidence that the plant material had been inside the gut of a megaherbivore. Instead, the fabric of the seed ball is consistent with the proposition that they are formed by *Ruppia* inflorescences breaking apart, drifting to near shore by wind and being rolled into balls by wave action during late Pleistocene thunderstorms.

# Tectonic Geomorphology of the Jemez System: Resolving Quaternary River Response to Dynamic Landscapes Using $^{40}Ar/^{39}Ar$ Geochronology

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Compilation of new and published incision rate data in the tributaries of the northern Río Grande system, the fourth longest river in the US, show differential incision (at a scale of 100 m/Ma) as rivers cross the Jemez lineament and Southern Rockies at long wavelengths that may reflect mantle buoyancy driving forces. Two major tributaries of the Jemez River, the Río Salado and Río Guadalupe, drain the western margins of the Valles Caldera and Sierra Nacimientos. Unpublished U-series dated travertines along the Río Salado suggest it is one of the fastest incising river systems in the Southern Rockies. Neotectonic forcings that may focus higher river incision at shorter, subregional wavelength include Pleistocene thermal inflation of the Valles Caldera and/or young faulting. The goal of this project is to evaluate the extent to which epeirogenic uplift or local tectonics may be responsible for the differential incision rates. Climatic forcings are minimized by measuring bedrock incision over million-year timescales that average out glacial-interglacial cycles, and by concentrating on this relatively small area.

We sampled five major previously mapped Quaternary Río Salado terraces ($Qt_7$, $Qt_6$, $Qt_5$, $Qt_3$, $Qt_1$) and found few young grains. A shift in tactics targets clasts potentially derived from rhyolite domes of known ages within specific terraces that we correlate 'around the corner' between Tierra Amarilla anticline and Soda Dam. Additional detrital sanidine (DS) geochronology sampling of 'cryptic' ashes from river terraces will provide an age-correlation for $Qt_1$ terraces of the Jemez River system. Newly sampled terraces at the confluence of the Río Guadalupe and Jemez River provide Lava Creek B (640 ka) maximum depositional ages (MDA) that may serve as a benchmark terrace to trace downstream. If DS $^{40}Ar/^{39}Ar$ geochronology supports high incision rates for all these rivers, higher than regional average rates, this may implicate the young (1.61 and 1.23 Ma) Valles Caldera eruptions as the driver of enhanced young surface uplift within a broad region of potential mantle-driven uplift in the Southern Rockies. However, if rates in the Río Salado do not agree with other tributaries and terraces of the Jemez River, this may suggest young reactivation of the Nacimiento fault and neotectonic footwall uplift in its southernmost reaches near the Tierra Amarilla anticline.

**Keywords:**

Geomorphology, Geochronology, Tectonics, Jemez Mountains, river incision, detrital sanidine

# UTILIZING BENTHIC MACROINVERTEBRATES TO ASSESS THE IMPACTS OF THE HERMITS PEAK/CALF CANYON FIRE ON WATER QUALITY IN REGIONAL WATERSHEDS

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Wildfires can have short- and long-term impacts on the health of a watershed. The loss of vegetation, abundance of charred materials, and destabilization of hillsides can increase stream sedimentation and impact water quality. This project assessed the 2022 Hermits Peak/Calf Canyon Wildfire's impact on water health in regional streams using macroinvertebrate numbers and populations as proxies for water quality. Approximately 115,542 acres burned in the Headwaters Gallinas River Watershed, 21% of which were classified USFS Burned Area Emergency Response (BAER) team as high burn severity while approximately 34% of the 40,150 acres burned in the UPW were classified as high burn severity. Such classification raised concerns for post-fire impacts to water quality from increased river discharge, hillside erosion, and fire sedimentation. We followed the NM Water Quality Bureau's SOP for Benthic Macroinvertebrate Sampling; Section 6.1 Wadeable Streams/Rivers and collected samples from two sites along both the Upper Pecos River and Gallinas River over a 6-week period following August 2022 fire containment. The Upper Gallinas Canyon site was at Canovas Canyon (35°41'51''N; 105°25'00''W) and Lower Gallinas Canyon site was at the National Avenue Bridge (35°35'41''N; 105°13'28''W). The Upper Pecos River site was at 35°35'00''N; 105°40'20''W and Lower Pecos River site was at the Village Bridge (35°34'35''N; 105°40'10''W). The Gallinas River was more degraded post-fire than the Upper Pecos River. Macroinvertebrate species observed in the Gallinas River (worms, black flies, scuds, dragon flies, and riffle beetles) were more pollution tolerant, indicating poor to moderate water quality, while those observed in the Upper Pecos River (stoneflies, nymphs-adults, caddis flies, mayflies) were more pollution sensitive, indicating good water quality. Both systems showed decreasing numbers and diversity in macroinvertebrate species from upper to lower sites, indicating diminishing downstream water quality. These observations suggest that (1) the Headwaters Gallinas Watershed shows poorer aquatic ecosystem health relative to the Upper Pecos River Watershed; (2) both systems remain vulnerable to post-fire floods and water quality impairments; and (3) downstream sites in particular should be monitored for water quality health and targeted for stream bank restoration.

**Keywords:**

Hermits Peak/Calf Canyon fire, ecosystem, macroinvertebrates, Headwaters Gallinas Watershed, Upper Pecos Watershed

# Determining surface water and groundwater returns from Bosque del Apache National Wildlife Refuge to the Rio Grande

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Bosque del Apache National Wildlife Refuge (refuge), located along the Rio Grande near San Antonio, New Mexico, provides a critical stopover for migrating waterfowl and is managed by U.S. Fish and Wildlife Service. The 57,331 acre refuge is made up of several different habitats principally defined by their water requirements, including active floodplain, seasonal wetlands, and desert. Understanding the magnitude and variability of different components of the refuge water budget is critical to managing the refuge water use and to achieving the essential mission of protecting wildlife for future generations. The refuge relies on surface water deliveries and on groundwater pumping to create wetland habitat. Unlike traditional agriculture, the refuge irrigates in winter months when evapotranspiration losses are at their lowest for the benefit of migratory birds. Groundwater infiltration and flow are not measured by the refuge's surface water outflow gages, but any unused irrigation returned to the system through the subsurface could augment the refuge's return-flow credit. Measurement of discharge inflows and outflows as well as estimates of groundwater fluxes, evapotranspiration and precipitation are being used to develop the water budget. This study will address specific research questions such as: what is the groundwater flux from the refuge to the main return-flow drainage system, what surface water data gaps exist that may cause potential errors in the water budget estimates, and how might spatial variations in irrigation and in evapotranspiration between different managed and unmanaged habitats contribute to return flows? Along with addressing these specific research questions, the final product will include documentation of a method to calculate consumptive use in a managed riparian wildlife habitat.

# MINERAL PARAGENESIS AND FLUID EVOLUTION AT THE MAGMATIC-HYDROTHERMAL TRANSITION OF THE LEMITAR CARBONATITE, NM

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The Lemitar Carbonatite, located in the Lemitar Mountains, NM, comprises 516.7±0.7 Ma old dikes intruded into Proterozoic mafic rocks [1,2]. This area comprises of more than one hundred surface exposures of carbonatite dikes with grades of up to 1.1% total rare earth element (REE) concentrations that show variable degrees of hydrothermal overprinting. Hydrothermal processes have been shown to be critical for REE mobilization and enrichment to economic levels [3]. This study aims to determine a mineral paragenesis and study fluid inclusions to highlight REE mobility and enrichment at the magmatic-hydrothermal transition in the Lemitar Carbonatite.

Magmatic minerals comprise of calcite, dolomite, phlogopite, magnetite, and apatite [1] overprinted by hydrothermal veins comprising of calcite, fluorite, and quartz. Alteration surrounding carbonatites includes potassic fenitization, hematization, F-Ca-metasomatism, chloritization, and silicification [4]. Cathodoluminescence imaging shows three distinct calcite generations of which calcite-1 is early and likely magmatic, calcite-2 is the early hydrothermal vein calcite and calcite-3 is the latest hydrothermal calcite generation. Apatite occurs in the fine-grained carbonate matrix, exhibits dissolution textures, and is cross-cut by calcite-3. Calcite-2 occurs as euhedral crystals growing on hydrothermal vein walls overgrown and crosscut by calcite-3 and subsequently by quartz and fluorite. Four fluid inclusion types have been observed including: type-1 vapor-poor (5-15 vol% vapor) and type-2 vapor-rich (>30 vol% vapor) liquid-vapor inclusions, type-3 vapor-poor (5-15 vol% vapor) and type-4 vapor-rich (>30 vol% vapor) multiphase inclusions. Apatite displays inclusion types 1, 2, and 4, as well as melt inclusions. Type-1 and 3 inclusions occur in calcite-1, type-1, 2, and 3 inclusions occur in calcite-2, and type-2 and 3 inclusions occur in calcite-3, type 1 and 3 inclusions occur in quartz, and fluorite exclusively exhibits type-1 inclusions. Microthermometric data of fluorite-hosted type-1 inclusions show ice melting temperatures at -1.2±0.1°C, and calcite-3 type-1 inclusions yielding -2.5±0.08°C. Apatite-hosted type-2 and 4 inclusions show melting temperatures from -5.8±0.2°C to -8.6±0.15°C. Salinities are 2.07 wt% NaCl equivalent in type-1 fluorite-hosted inclusions, 4.18 wt% in type-1 calcite-3 hosted inclusions and 8.95 to 12.4 wt.% in apatite-hosted type-2 and 4, respectively. Preliminary data indicate a decrease in salinity and homogenization temperatures for fluid inclusions between apatite and fluorite from early to late in the paragenetic sequence.

## References:

[1] McLemore, 1987, The Journal of Geology, Issue 2, pg. 255-270.

[2] Haft et al., 2022, New Mexico Geological Society, 72nd Annual Fall Field Conference, pg. 365-373.

[3] Perry, E.P., Gysi, A.P., 2018. Rare Earth Elements in Mineral Deposits: Speciation in Hydrothermal Fluids and Partitioning in Calcite. Geofluids 2018, 1–19.

[4] Perry, E.P., 2019. Rare earth element signatures in hydrothermal calcite: insights from numerical modelling, experimental geochemistry, and mineral deposits in New Mexico. PhD. Thesis, 125.

## Keywords:

Rare Earth Elements, Hydrothermal Mobility, Mineral Paragenesis

# HIGH-MAGNESIUM DOLOMITES IN SOUTH-CENTRAL NEW MEXICO

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Magnesium is an important critical mineral used in a wide range of industrial products and materials. It is used in the manufacture of certain medicines, fertilizers, electronics, and batteries. Magnesium is utilized as an alloying agent of aluminum to improve mechanical capabilities; aluminum-magnesium alloys are useful in airplane and car construction, where strong lightweight materials are critical. China has much of the processing capacity and is the largest global producer of both magnesium compounds and magnesium metal. Demand for magnesium has increased because of use in car parts and batteries. Although magnesium is found in many minerals, dolomite, magnesite, brucite, carnallite, and olivine are of major commercial importance. In New Mexico, magnesium is produced solely for fertilizer as langbeinite from the Carlsbad Potash District. At least one company is considering producing magnesium from dolomite near Deming. In addition to providing significant yields of magnesium, dolomites are also used as crushed rock in construction as a soil additive and iron smelting. In order to consider mining dolomites for magnesium, the dolomites need to be "high-purity". We define high-purity dolomites as containing at least 15% MgO. We find that certain dolomites in south-central New Mexico, including those within the Florida and Organ Mountains, contain economically significant grades of magnesium (12-22% MgO). High-purity dolomites exist near Silver City, Deming, and Las Cruces, locations that are feasible for transport and extraction. High-purity dolomite deposits in south-central New Mexico, the mining of which could occur in the future, remain the most plentiful source of magnesium in the state. Research is ongoing as magnesium-rich sites are found and described for any potential future mining activity.

# New U-Pb Detrital Zircon Geochronology From the Eocene San Jose Formation, Eastern San Juan Basin, Northwestern New Mexico

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The San Juan Basin (SJB) of northwest New Mexico has received a considerable amount of study focused on determining the timing of Laramide deformation, provenance, and basin-scale sediment dispersal trends from Jurassic-earliest Paleogene strata. However, little is known about the sources and driving mechanisms for deformation and erosion that resulted in the deposition of Eocene synorogenic strata of the San Jose Formation in the SJB. The San Jose Formation has been subdivided into four units that include: (1) the basal Cuba Mesa Member (sand- and gravel-dominated facies), (2) the overlying silt-dominated Regina Member, (3) the sand-dominated Llaves Member which appears to interfinger with the upper Regina Member, and (4) the youngest (sand and silt dominated) Tapicitos Member. Presented here are N=4 new detrital zircon samples (representing a total of n=769 new U-Pb detrital zircon ages) from each member of the San Jose Formation.

The basal Cuba Mesa Member of the San Jose Formation contains primary peak ages at 1693, 158, and 111 Ma, with secondary peaks at 1406, 231, and 188 Ma. The overlying Regina Member contains peak ages at 1689 and 185 Ma with secondary peaks at 1404 and 86 Ma. The Llaves Member has one primary peak age at 1708 Ma and secondary peaks at 162 and 96 Ma. The Tapicitos Member has primary peak ages at 1702, 163, and 66 Ma with secondary peaks at 1426 and 205 Ma. In addition to the peak ages in the Llaves and Tapicitos Member, these units also contain occurrences of ages that fall between 650-225 and 1200-1000 Ma. Zircons of this age were not present in the lower two members of the San Jose (Cuba Mesa and Regina Members). The youngest ages in all four samples from the San Jose fall between 95-65 Ma.

Detrital zircon ages that fall between 1700-1400 Ma overlap in age with the Mazatzal and Granite-Rhyolite Precambrian provinces and may represent detritus derived from local Laramide uplifts. Mesozoic ages (225-65 Ma) overlap with the Cordilleran arc and likely are recycled. Ages that fall between 1200-1000 Ma overlap with the Grenville province and are likely recycled from parts of the Sevier fold/thrust belt and Mogollon highlands. Although preliminary, U-Pb detrital zircon data from the San Jose Formation support a model where the basal Cuba Mesa and Regina members were derived largely from nearby basement Laramide uplifts, whereas the overlying Llaves and Tapicitos members were derived from these same Laramide uplifts as well as highlands in the Sevier fold/thrust belt and Mogollon highlands.

# APPLYING U-PB DETRITAL ZIRCON GEOCHRONOLOGY TO CONSTRAIN OLIGOCENE-MIOCENE CLOSED-BASIN RIO GRANDE RIFT SEDIMENTATION IN THE PALOMAS AND JORNADA DEL MUERTO BASINS, SOUTHERN NEW MEXICO

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Latest Oligocene–Miocene synorogenic strata of the Hayner Ranch and Rincon Valley formations preserve the early rift history of closed-basin sedimentation in southern New Mexico and crop out along the modern Rio Grande rift (RGR) margin in the Palomas and Jornada del Muerto basins. The RGR preserves a near-continuous record of volcanism and sedimentation from late Eocene–Present, and although a considerable amount of previous work has focused on documenting the onset, extent, and geochemistry of Eocene–Oligocene volcanism during the early stages of the RGR, very little is known about provenance, drainage development, and sediment dispersal during the latest Oligocene–Miocene. Given the unique distribution of bedrock source areas that have been exposed as a result of rift deformation (e.g., Cenozoic volcanic fields, recycled Paleozoic–Mesozoic stratigraphy of the Colorado plateau, and Precambrian basement sources), southern New Mexico is an excellent natural laboratory to carry out this project. Presented here are N=7 new detrital zircon samples representing 972 new U-Pb ages from the Hayner Ranch Formation and 604 new U-Pb ages from the Rincon Valley Formations (1576 new U-Pb ages total from both units).

The basal Hayner Ranch Formation contains one primary peak age at 28 Ma and secondary peak ages at 47 and 36 Ma with isolated ages occurring between 225-150, and 95-55 Ma. In addition to these Phanerozoic ages, the Hayner Ranch also has rare, isolated Precambrian grains that fall between 1500-1400 Ma. The overlying Rincon Valley Formation has one primary peak age at 36 Ma and secondary peak ages at 167, 97, and 49 Ma with isolated age occurrences at 550, 400, and 225 Ma. Precambrian age occurrences are more abundant in the Rincon Valley and fall between 1700-1600, 1500-1400, and 1000-1300 Ma.

Detrital zircon ages that fall between 1700-1400 Ma overlap in age with the Mazatzal and Granite-Rhyolite Precambrian provinces and may represent detritus derived from local basement uplifts (e.g., basement exposed along the western Caballo Mountains front). Ages that fall between 1300-1000 Ma overlap with the Grenville province and are likely recycled from parts of the Dakota Sandstone. Mesozoic ages (225-95 Ma) overlap with the Cordilleran arc and likely are recycled. Zircon ages that occur near 47 and 36 Ma are likely derived from the Palm Park Formation (and equivalent Rubio Peak and Spears Formation) and caldera complexes, respectively. Abundant zircons that fall near 28 Ma overlap in age with the Uvas basaltic andesite and equivalent tuffaceous sandstone of the Thurman Formation. Given the large occurrence of these ages in the Hayner Ranch, these may represent detritus delivered to closed basins via ash-fall tuffs.

# A Summary of Late Cretaceous Ammonites and Molluscan Zones, Eastern San Juan Basin, Rio Arriba County, New Mexico

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Upper Cretaceous strata exposed on the eastern side of the San Juan Basin in Rio Arriba County, New Mexico, contain ammonites and other marine molluscan fossils that date from the Turonian, Coniacian and Campanian stages. The stratigraphic units are Greenhorn Limestone, Carlile, Juana Lopez, El Vado Sandstone and Satan members of the Mancos Shale and Lewis Shale. The *Mytiloides mytiloides* inoceramid zone in the Greenhorn Limestone indicates the ammonite zone of *Mammites nodosoides* and thus a latest early Turonian age. The *Collignoniceras woollgari regulare* Subzone of the *C. woollgari* Zone and the *Prionocyclus hyatti* Zone are present in the Carlile Member. These zones represent the middle Turonian. The *Prionocyclus macombi* Zone is present just below the lower calcarenite of the Juana Lopez Member, and the *Scaphites warreni* and *S. ferronensis* zones occur in the upper calcarenite of the Juana Lopez. The *Coilopoceras colleti* Subzone of the *P. macombi* Zone and the *Inoceramus dimidius* inoceramid zone are also present in the Juana Lopez. The *P. macombi*, *S. warreni* and *S. ferronensis* zones indicate the lower part of the upper Turonian. The inoceramid *Magadiceramus complicatus* (Heine) indicates the *Scaphites depressus* Zone and thus a late Coniacian age for the top of the El Vado Sandstone in the Llaves area. Fossils representative of the Santonian stage have not been collected from the study area. The lowermost Campanian *Scaphites leei* III Zone is present in the upper Satan Tongue near Gallina. The lower Campanian *Scaphites hippocrepis* I Zone is present in the uppermost Satan Tongue near Llaves. Ammonites and inoceramids collected from the upper part of the Lewis Shale in the eastern San Juan Basin are middle to late Campanian in age. The ammonite zones include the lowermost middle Campanian *Baculites obtusus* Zone, the lower middle Campanian *B. mclearni*, *B. asperiformis* and *Baculites* sp. (smooth species) zones, the upper middle Campanian *B. perplexus* and *B. gregoryensis* zones, possibly the upper middle Campanian *B. reduncus* Zone, the uppermost middle Campanian *B. scotti* Zone, the lowermost upper Campanian *Didymoceras nebrascense* Zone, the lower upper Campanian *Exiteloceras jenneyi* and *D. cheyennense* zones and possibly the middle upper Campanian *B. compressus* Zone. Twelve ammonite zones were identified from the Lewis Shale, and a total of 21 ammonite zones are present or indicated in Upper Cretaceous strata in the eastern San Juan Basin in Rio Arriba County.

We report *Placenticeras pseudoplacenta* Hyatt from the *Prionocyclus hyatti* Zone and *Baculites yokoyamai* Tokunaga and Shimizu from the *Scaphites warreni* and *S. ferronensis* zones. *P. pseudoplacenta* and *B. yokoyamai* have not previously been reported from Rio Arriba County. From the Satan Tongue, we report the nautiloid *Eutrephoceras alcesense* Reeside and the ammonites *Menabites* (*Delawarella*) *vanuxemi* (Morton), *P. syrtale* (Morton), *P. placenta* (DeKay), *Glyptoxoceras*, *B. aquilaensis* Reeside, *Scaphites* (*Scaphites*) *hippocrepis* (DeKay) I Cobban and *Haresiceras* (*Haresiceras*) *montanaense* (Reeside). All, except the latter species, have not previously been reported from the eastern San Juan Basin in Rio Arriba County.

**Keywords:**

Cretaceous,ammonites,inoceramids,ammonite zones,inoceramid zones,San Juan Basin,Rio Arriba County,New Mexico

# THE NAUTILOID *EUTREPHOCERAS* SP. FROM THE CRETACEOUS OF NEW MEXICO LIKELY REPRESENTS MULTIPLE SPECIES

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Compared to ammonites, Cretaceous nautiloids are relatively rare in New Mexico, and *Eutrephoceras* sp. is the most common nautiloid of that age in the state. The genus *Eutrephoceras* ranges from the Late Jurassic to the Middle Miocene worldwide. In New Mexico, *Eutrephoceras* sp. has been reported from the Turonian and Campanian (e.g. Scott et al., 1986), Santonian and Campanian (Sealey and Lucas, 2019, 2022), *E. alcesense* Reeside has been reported from the Santonian, and *E. montanaensis* (Meek) from the lowermost Maastrichtian (Sealey and Lucas, 2019, 2022). Morphological features of many New Mexico specimens of *Eutrephoceras* sp. are similar to *Eutrephoceras dekayi*. However, Landman et al. (2018) stated that the lowest occurrence of *E. montanaensis* from the Cedar Creek Anticline in Montana—the uppermost Campanian *Baculites eliasi* Zone or the lower part of the lowermost Maastrichtian *B. baculus* Zone—is below that of *E. dekayi,* and that their ranges may overlap. Given that the stratigraphically highest known specimen of *Eutrephoceras* sp. in New Mexico is from the middle upper Campanian *B. compressus* Zone, specimens from the state are best not assigned to *E. dekayi*. Furthermore, *E. dekayi* has been a "wastebasket" taxon for North American Cretaceous nautiloids (Neal Larson, written communication, 2018).

*Eutrephoceras* sp. is present in the D-Cross Member of the Mancos Shale and Gallup Sandstone in Socorro County, the Satan Tongue of the Mancos Shale in Sandoval County, the Lewis Shale in Rio Arriba and San Juan counties and the Fort Hays Limestone Member of the Niobrara Formation and the Pierre Shale in Colfax County. In New Mexico, *Eutrephoceras* sp. has been found in the upper Turonian *Scaphites ferronensis* and *Prionocyclus quadratus* zones, the lower Campanian *S. hippocrepis* II Zone, the middle Campanian *Baculites gregoryensis* Zone, the upper Campanian *Didymoceras nebrascense*, *Exiteloceras jenneyi*, *D. cheyennense* and *B. compressus* zones and unknown zones. The Satan Tongue occurrences are Santonian in age. These Turonian, Santonian and Campanian occurrences of *Eutrephoceras* sp. from many different ammonite zones in New Mexico likely represent multiple species, and we propose that further study is needed.

## References:

Landman, N. H., Grier, J. W., Cochran, J. K., Grier, J. C., Petersen, J. G. and Towbin, W. H., 2018, Nautilid nurseries: hatchlings and juveniles of *Eutrephoceras dekayi* from the lower Maastrichtian (Upper Cretaceous) Pierre Shale of east-central Montana: Lethaia, vol. 51, p. 48–74.

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.

Sealey, P. L. and Lucas, S. G., 2019, Late Cretaceous (Cenomanian-Campanian) ammonite systematic paleontology and biostratigraphy, southeastern San Juan Basin, Sandoval County, New Mexico: New Mexico Museum of Natural History and Science Bulletin 80, 245 p.

Sealey, P. L. and Lucas, S. G., 2022, Late Cretaceous (Campanian-Maastrichtian) ammonites from the Pierre Shale, Raton Basin, northeastern New Mexico and southeastern Colorado: New Mexico Museum of Natural History and Science Bulletin 91, 183 p.

## Keywords:

Eutrephoceras sp.,nautiloid,Cretaceous,New Mexico

# ALTERATION AND GEOCHEMISTRY OF CLINKERS IN THE SAN JUAN BASIN, NEW MEXICO

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Clinkers are the result of coal seam fires that alter adjacent strata into rocks with a generally red/ orange, brick-like appearance. Coal seam fires burn at temperatures of over 500 degrees C, causing the surrounding rock and minerals within, to be altered, fused, or even melted. Clinker gets its name from the ringing sound it makes when struck, due to glassy, pyro metamorphosed minerals within the rock. Clinkers can be composed of various sedimentary rocks that were bedded with the coal seams during the burning process and include shales, claystone-s, and sandstones. These rocks impart different textures and affect the geochemical compositions of the clinker. Most underground coal fires that result in clinker are caused by wildfires, lightning strikes, or even heat from the oxidation of pyrite or marcasite contained in coal igniting exposed coal seams. Clinker is used as an aggregate in road construction, and is also used in glass production, refractories, and as a soil amendment. Chemical analysis of neighboring unburned coal deposits with a similar composition to the pre-burned clinker would provide insight into whether critical minerals including rare earth elements (REE) have been concentrated, depleted, or altered during the clinker formation. With the recent interest in charactering coal wastes such as ash for their critical mineral potential, trace element chemistry would show if clinkers could be a potential source of critical minerals. All of our samples are from the San Juan Basin in northwestern New Mexico as no clinker deposits are found in the Raton Basin. Comparing the REE profiles of clinker to standards such as average European shale show that the pyro-metamorphosis of coal and adjacent strata into clinker has not caused any significant variation in the concentration of REE. REE in clinkers range from 105-306 ppm total REE. Some samples contain elevated $Fe_2O_3$ concentrations (>50%) as well as elevated $P_2O_5$ (0.03-0.17% $P_2O_5$) concentrations. compared to adjacent coal samples. $P_2O_5$ correlates with the light REE such as lanthanum and cerium This correlation suggests that monazite, a light REE phosphate mineral could be present in the clinker in trace amounts. Only a small number of samples are currently available for analysis and petrographic study, additional samples are needed for more definitive interpretations.

# MODELING POST-WILDFIRE HYDROLOGIC AND WATER QUALITY RESPONSE: REVIEW AND FUTURE DIRECTIONS

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*[abstract withdrawn]*

# TRACKING REE FORMATION WITH FLUID INCLUSIONS FROM THE GALLINAS MOUNTAINS, NM

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Rare earth elements (REE) are mined for use in electronics, from digital cameras and LED lights to electric cars. Large quantities of REE are also used in renewable energy technologies for example solar panels and wind turbines. The future demand for REE for use in technology makes research on REE mineral deposits critical to avoid a supply shortage. The United States is actively searching for more sources of REE in mining and battery recycling. If we understand better how these resources form, we can look for more specific indicators to target REE deposits. Here, we are investigating fluorite-hosted fluid inclusions from the Gallinas Mountains, which is a REE-fluorite-barite vein and hydrothermal/volcanic breccia deposit located in New Mexico. The Gallinas Mountains were re-evaluated for REE in 2010, and bastnaesite and fluorite found in Gallinas breccia pipes were revealed to be REE-rich (McLemore, 2010). The focus of this work is on fluorite-hosted fluid inclusions, which provide information on fluid chemistry and mechanisms of REE transport and precipitation in the REE mineralized veins. This information will provide a better understanding of how REE deposits form and may even provide better strategies for future exploration.

We have found three generations of fluorite using cathodoluminescence (CL) imaging, which are early euhedral green to later euhedral blue, and a cross-cutting fine grained purple fluorite. Two types of two-phase vapor and liquid fluid inclusions were identified. In the green growth zones of the early fluorite, inclusions exhibit 30-40 vol% vapor and in the later, purple fluorite fluid inclusions have 5-15 vol% vapor. Differences in phase proportions (i.e., vapor to liquid ratios) at ambient condition indicate variable entrapment conditions, which generally show a cooling trend from early to late fluorite generations. Next, we will continue conducting microthermometry to determine the salinity of the fluid inclusions hosted in the different fluorite generations and measure the compositions of the fluid and their inclusion using RAMAN spectroscopy.

## References:

McLemore, V., 2010, Geology and nineral deposits of the Gallinas Mountains, Lincoln and Torrance Counties, New Mexico; Preliminary Report: NMBGMR, Open-File Report Of-532, 3 p.

### Keywords:

rare earth elements, fluid inclusions, Gallinas Mountains, fluorite

# The Hydroclimate and Environmental Response to Warming in the Southwestern US: A Study Across the Mid-Miocene Climate Optimum

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Predictions for the effects of modern climate change on the southwestern US tend to suggest increased aridity, which is incompatible with paleoclimate data from other warm, high $pCO_2$ periods. The Mid-Miocene Climate Optimum (MMCO; ~17-14 Ma) represents a period of warm global temperatures and high $pCO_2$ with estimates similar to the projected $pCO_2$ for future decades. We present new stable isotope records of mid-Miocene terrestrial carbonates from the Española basin in northern NM, with $\delta^{18}O$ and $\delta^{13}C$ records recording the extent of the MMCO and the beginning of late Miocene cooling. New $^{40}Ar/^{39}Ar$ ages establish an updated, high-resolution age model for the Tesuque Fm of the Santa Fe Group. We use $\delta^{18}O$ as a measure of the balance between summertime and wintertime precipitation and $\delta^{13}C$ as a reflection of soil productivity. We find evidence for an increasingly winter-wet climate in the southwest US during the MMCO; when compared to modern precipitation $\delta^{18}O$, the carbonate $\delta^{18}O$ record suggests that the region received more westerly-derived, cool-season precipitation than it does today. This indicates that El Niño Southern Oscillation (ENSO) was operating during the MMCO and may have been stronger than today; it seems to have been particularly strong during cooler periods during the MMCO, suggesting that cooler temperatures and high $pCO_2$ may be favorable to ENSO. The $\delta^{18}O$ and $\delta^{13}C$ records are highly correlated, indicating seasonality of precipitation as a main control on soil productivity; increases in soil productivity coincide with increases in cool-season precipitation and with faunal fossils that indicate a wetter environment with large vegetation. Changes in the seasonal hydroclimate and soil productivity agree well with the paleontological record at the site, which show a diverse and dynamic faunal assemblage that evolved with the hydroclimate. During the global cooling immediately following the MMCO Española carbonates display decreasing soil productivity and a more summer-dominant hydroclimate similar to that of the region today, with paleontological records indicating a drier faunal and floral assemblage very different from those that occupied the region during the MMCO. Collectively our data do not support increased aridity in the southwest US during warm, high $pCO_2$ periods, instead suggesting a shift in the hydroclimate towards cool-season, westerly-derived precipitation, driving higher soil productivity and supporting larger vegetation and dynamic faunal assemblages in the region.

# Laramide Porphyry Systems of New Mexico: Geochronology and Critical Mineral Potential

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Southwest New Mexico hosts a number of Laramide age porphyry copper deposits. These deposits are associated with intrusions inferred to be the remnant cores of stratovolcanoes formed by subduction and arc magmatism during the Laramide Orogeny (~75-45 Ma). These porphyry copper deposits are large, low grade (<0.8% Cu), and contain disseminated copper and molybdenum sulfides, breccias, and stockwork veinlets associated with porphyritic intrusions. These deposits also contain many accessory minerals categorized as "critical minerals", such as PGEs (platinum, palladium, rhodium, iridium, osmium, and ruthenium), tellurium, indium, germanium, gallium, and rhenium. These critical minerals were not the main target of these deposits historically, and are recovered from the anode slimes remaining after copper is refined. New detailed geochronology, mineralogy, geochemistry, along with geologic mapping are refining the location of critical minerals within specific systems and will identify porphyry systems with elevated critical minerals that could become economic once again. A new compilation of the geochronology of these copper porphyry and related districts reveals there are two main pulses of arc magmatism in New Mexico that produced mineralized deposits, ~75-71 Ma and ~58-54 Ma. However, many of these deposits and associated Laramide intrusions have very limited geochronology available. Many of these districts were dated with the older and less precise K-Ar method, while others provide conflicting and/or questionable intrusion emplacement ages. Plutons and mineralized portions of these deposits are currently being prepared for modern, high-precision 40Ar/39Ar geochronology. These new ages will provide more accurate and precise emplacement ages for the plutons. A second set of samples from the mineralization areoles will allow us to assess the timing of mineralization, both hypogene and supergene where present. Updated geochronology combined with new whole rock and trace element geochemistry, along with mineral characterization via electron microprobe analysis will identify which phases bear these critical minerals and their abundance. The ultimate goal is to determine a correlation, if one exists, between these critical minerals and the ages of emplacement and mineralization. Districts we have targeted so far include the Hillsboro district, Tres Hermanas district, Camel Mountain – Eagle's Nest district, Black Hawk district, and potentially other districts in the future. These districts have a dire need for updated geochronology, exhibit unique mineralogy, and often have conflicting or poor precision dates.

# NM WATER DATA INITIATIVE PROJECT: GROUNDWATER LEVEL MONITORING NETWORK PLANNING

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Following the 2019 NM Water Data Act statute, multiple agencies in the state are working to integrate water data following a federated data model. The ultimate goal of this effort, commonly called the NM Water Data Initiative, is to make finding water data simple. In this federated model approach, data providers, which include but are not limited to state agencies, provide data through a standardized application programming interface (API).

While working to improve access to data on a statewide level and address data gaps, there are several use-case focused projects to help drive data use and integration. This year, with funding from Thornburg Foundation, we evaluated groundwater level monitoring data in the state. After interviews with state experts on regions of highest priority, 10 regions were selected for a detailed analysis. For each region, we explored water uses, geology and availability of regular, dedicated groundwater level measurements, with data accessible online. Acknowledging that some datasets are not digitally available or online, the majority of the data that were used were compiled from the USGS and NM Bureau of Geology and Mineral Resources, through the Healy Collaborative Groundwater Monitoring Network.

With approximately 270,000 groundwater wells on record with the NM Office of the State Engineer, we found only about 1400 wells statewide with some sort of dedicated groundwater level monitoring, and accessible (online) data. This project provides recommendations for regions where groundwater monitoring could be improved with dedicated monitoring wells.

Using accessible water level data, we also have developed an open-source web-based map application to help communicate the spatial coverage of groundwater monitoring and groundwater level trends. The goal of this web application is to build awareness of regions of NM with groundwater data gaps. The hope is to address these gaps by developing funding sources to drill dedicated monitoring wells and/or develop monitoring projects.

More information about the New Mexico Water Data Initiative can be found at newmexicowaterdata.org, which is a collaborative effort convened by the New Mexico Bureau of Geology and Mineral Resources, working with numerous state agencies on water quality, quantity and uses toward improved water management and planning.

# HYDROCHEMISTRY OF AN ALPINE KARST SYSTEM, NORTHERN NEW MEXICO: LAS HUERTAS

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Persistent drought conditions, increased water use, and anthropogenic modifications of water resources have made wetlands in the southwest vulnerable to a changing climate. Spring-fed waterbodies in mountain recharge zones, such as Las Huertas in the Sandia Mountains, New Mexico, rely on snowmelt and monsoonal input for recharge and often have intermittent groundwater inputs along flow paths. Las Huertas provides water for the surrounding community and is the primary water source for acequias and irrigation for Placitas, New Mexico. Regional climate change models predict decreased snowpack; therefore, increased observation of wetlands, such as Las Huertas, is a management priority for Cibola National Forest. The Las Huertas watershed is in an arid land region, with springs emerging with $CO_2$-rich waters at a high elevation, actively precipitating travertine in some reaches but not others, which may be indicative of variable fluid inputs and geochemistry along the flow path. Presently, connections between surface water and groundwater and the karst aquifer (Madera Limestone) are poorly understood. Methods include major ion chemistry analysis and stable isotope analysis. Geochemical mixing models are used to identify end members and quantitatively determine the relative contributions of annual recharge and older groundwaters.

Stable isotope data indicate that both winter and summer monsoonal precipitation contribute to the regional aquifer recharging these springs. Field observations suggest that travertine precipitation is more active in the watershed's upper reaches, which may indicate the stream's equilibration with lower atmospheric $CO_2$. Spring waters classify as dominantly calcium bicarbonate, with some Na-Cl.

Salinity varies from less than 200 ppm to over 1000 ppm, and individual springs show limited interannual/seasonal variation. Las Huertas and Capulin Springs, headwater springs at high elevation, are the most saline springs observed. This study will fill critical gaps in understanding the flow contributions to Las Huertas Creek, one of the few perennial streams in the Sandia Mountains. Our work will help identify flow contributions to the water source, with implications for its resilience for anticipated changes from climate change.

# DRONING ON AT NMSU: EXPLORING INTEGRATION OF GEOLOGIC AND UAS WORKFLOWS

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Uncrewed Aircraft Systems (UAS/drones) have proven to be valuable tools in geological fieldwork/research. However, collecting ad hoc UAS imagery is time-consuming, generates enormous datasets, and prevents researchers from utilizing imagery to its full potential. UAS can supply geologists with a wide range of data such as elevation models for landforms, geologic structures, geomorphic processes and even geochemical alteration patterns. However, the benefits and limitations of using UAS must be taken into consideration when incorporating them into geoscience workflows. Iterative and intentional workflows provide a method for integrating UAS data collection into research projects by encouraging structured data collection and management plans. In order to conduct UAS research flights in the US, researchers must consider regulatory, logistical, and institutional issues. Flights must comply with FAA regulations and some universities/institutions require all pilots and observers to take additional internal safety courses. Additionally, before a flight can take place, flight planning is essential for promoting a safe and productive operation.

As part of course GEOL 520- Drones in Geosciences at New Mexico State University and to explore the integration of UAS in geology, sites near to Las Cruces, NM, were selected for their specific geologic workflow attributes. Aerial imagery was collected with a DJI Phantom 4 Advanced then processed in *Agisoft Metashape.* Through five case studies presented here, the integration of UAS with geologic fieldwork is explored, including the benefits/limitations and workflow-specific considerations of flight planning, data collection, and processing/interpretation. (1) Near Soledad Canyon, imaging for 3D outcrop modeling was done to resolve m-scale mineralized joint sets, cm-scale igneous flow textures throughout the outcrop, their cross-cutting relationships, and spatial attitudes by calibrating the UAS flight distance and angles necessary to capture images that display these small structures at high resolution. (2) To observe stratigraphic relationships and architecture in the Abo Formation in Lucero Arroyo, UAS images were captured from a distance of 10-15 m from multiple angles (nadir and oblique) to resolve vertical features within the outcrop. (3) When developing a digital outcrop model (in the Bishop Cap Hills) for building a measured section, UAS imagery must provide sufficient resolution to recognize fine bedform features and geometries. Workflows for generating such a model require greater consideration for UAS flight altitudes, image densities, and processing resolution qualities. (4) To refine the understanding of lava flow morphology and resolve flow features at Aden Lava Flow, NM, UAS imagery was collected for creation of orthomosaic maps and 3D outcrop models. (5) Also at Aden Lava Flow, imagery was collected at 50 and 100 m flight altitudes to experimentally calculate the Ground Sampling Distance of the UAS camera and provide guidelines for flight altitudes necessary to resolve fine- vs large-scale geologic features. These examples highlight the wide range of UAS applications in geoscience research and education, and the importance and necessity of integrating UAS workflows at all stages to ensure that flights are conducted in a safe, planned, and integrated manner.

# RESTORE: ADDRESSING DECADE-LONG WATER ISSUES IN THE NAVAJO NATION

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A significant shortage of fresh water is a big challenge throughout the Navajo Nation. Currently, more than 30% of homes lack access to safe and drinkable water. Livestock in the Navajo Nation mainly rely on windmill-pumped groundwater in which naturally elevated arsenic and uranium pose a serious threat to the animals' well-being. The possibility of residual arsenic and uranium in the animal meat and dairy products is an additional risk to humans. To address these challenges, we developed an innovative desalination technology for water remediation using cross-linked polyvinylidene fluoride (CPVDF) hollow-fiber membranes. Laboratory results show salt rejection of >99.9% and > 30 kg/($m^2 \cdot h$) water flux in desalination of brine and groundwater samples from the Navajo Nation. Further, there was no arsenic or uranium detected in the recovered product water. The high specific surface area (>1,000 $m^2/m^3$) of the hollow fiber membrane reduces the footprint of the technology and allows the technology to be easily integrated within a portable skid-mounted system that can be installed at any windmill wellhead for the production of high-quality (TDS<150 mg/L) water free of toxic metals. A team from Navajo Technical University (NTU) and New Mexico Tech (NMT) proposes the NTU-NMT Navajo Nation Water Purification Project ($N^4$WPP) to install these units at remote locations within the Navajo Nation in partnership with Navajo Nation chapter houses. The research involved the collection of water quality samples from local water wells within the Navajo Nation. The wells of interest are those that have the lowest quality water, to effectively test the filtration system. Once wells of interest are identified, the filtration system will be put into place and will be tested for water quality by the students at NTU. The regular data collection will help determine if the filtration system is effective and producing clean water. The overall goal of this project is to reach water quality healthy enough for livestock consumption, as well as human consumption.

# THE CALM BEFORE THE VOLCANIC STORM

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Geochronologic studies of ignimbrite-caldera systems in the Southern Rocky Mountains indicate significant eruptive hiatuses prior to the onset of caldera collapse-related volcanism. Detailed mapping, combined with hundreds of $^{40}Ar/^{39}Ar$ dates, in the Southern Rocky Mountain volcanic field (SRMVF), indicates that precaldera volcanic edifices were largely constructed several hundred ka to a few Ma prior to caldera collapse. For example, near complete growth of the precaldera edifice is documented to have finished ~700 to 400 ka prior to the 33.4 Ma eruption of the Bonanza caldera in the northeastern SRMVF. In the central SRMVF, the 5,000 km$^3$ Fish Canyon Tuff, sourced from the 28.2 Ma La Garita caldera, was preceded by precaldera andesites and dacites, exposed on the caldera rim, that yield ages from 34.5 Ma to as young as 30.5 Ma. Likewise, in the southeastern SRMVF the pre-ignimbrite volcanic edifice was constructed 3.7 to 2.4 Ma prior to the 30.2 Ma onset of polycyclic collapse at the Platoro caldera complex. During this hiatus, multiple dikes were emplaced indicating continued magmatism with little preserved eruptive activity. Prior and ongoing dating of Quaternary caldera-related rocks in the Jemez Mountains volcanic field provides additional constraints on the timing of precaldera activity. Published studies indicate that precaldera volcanic activity of predominantly intermediate composition began perhaps as early as ca. 25 Ma in this field and continued to 2.93 Ma. New ages for the La Cueva Tuff, an initial ignimbrite of at least 1-4 km$^3$ that may have triggered a small-scale caldera collapse, are 1.90 Ma, documenting the onset of rhyolite volcanism after an apparent ca. 1 Ma pause in activity. The field appears to have sat in repose for another 300 ka before eruption of the Otowi Member of the Bandelier Tuff and collapse of the Toledo caldera at 1.61 Ma. Extensive new dating of Cerro Toledo lavas and tephras that were emplaced following the Otowi Member event indicate a ca. 120 to 160 ka eruption hiatus prior to a brief 9 ka period of volcanism before collapse of Valles caldera at 1.23 Ma. In these four examples, minor eruptions may have occurred within the subsided area, but the absence of deposits on caldera rims and flanks suggest that volumes were limited compared to peak growth. These examples suggest that some volcanic fields may transition from extended periods of producing small-volume eruptions to protracted durations (e.g., 0.5 to > 2 Ma) of magma storage and incubation that culminates in large-volume ignimbrites and caldera collapse. This work supports initiatives to closely monitor Quaternary caldera systems, even those that are currently in moderate to long periods of repose.

**Keywords:**

Geochronology, volcanism, hazards, calderas