# New Mexico Geological Society

# Proceedings Volume
## *Our Common Future: Reliability, Robustness, and Resiliency for Effective Risk Management*
**2021 Annual Spring Meeting**
**Virtual Format**
**New Mexico Tech**
**Socorro, NM**
**New Mexico Geological Society**

# NEW MEXICO GEOLOGICAL SOCIETY
# 2021 SPRING MEETING
## Thursday, April 15, 2021
## Friday, April 16, 2021

## Virtual Format

## NMGS EXECUTIVE COMMITTEE

President: Dan Cadol
Vice President: Scott Baldridge
Treasurer: Brian Hampton
Secretary: Kevin Hobbs
Past President: Shannon Williams

## 2021 SPRING MEETING COMMITTEE

General and Technical Program Chairs: Diane Agnew & Susan Lucas Kamat
Registration Chair: Connie Apache
Web Support: Adam Read

## *Welcome*

**Virtual – Zoom Link Day 1:** *10:30 AM - 11:00 AM*

## *NMGS Business Meeting and Student Awards Ceremony*

**Virtual – Zoom Link Day 1:** *11:00 AM - 11:30 AM*

## *An Update on the NMGS Foundation*

**Virtual – Zoom Link Day 1:** *11:30 AM - 11:45 AM*

## *Lunch*

**Offline:** *11:45 AM - 12:30 PM*

## Oral Presentations Session 1: Environmental Geology and Hydrology:

**Virtual – Zoom Link Day 1:** *12:30 PM - 2:00 PM*
**Chair:** Diane Agnew

**SOUTHEASTERN NEW MEXICO SUBSURFACE MAPPING PROJECT**
— Alyssa Renee Baca, Keith Diegel, Robert Pine, Colin Cikoski, Katie Zemlick, and Stacy Timmons
*12:30 PM - 12:45 PM*

**QUANTITATIVE, QUALITATIVE, AND SPATIAL EVALUATION OF GROUNDWATER RECHARGE IN THE SALT BASIN, NM/TX**
— Beth Ann Eberle and Daniel Cadol
*12:45 PM - 1:00 PM*

**GLOBAL CONTEXT OF SEDIMENT TRANSPORT RATES FROM A NEW MEXICAN EPHEMERAL CHANNEL**
— Kyle Anderson Stark and Daniel Cadol
*1:00 PM - 1:15 PM*

**ASSESSMENT OF SAFE AQUIFER YIELDS WITHIN THE SALT BASIN IN NM AND TX.**
— Elizabeth Evenocheck, Gilbert Barth, Jessica Rogers, and Mark Person
*1:15 PM - 1:30 PM*

**MIDDLE-LATE PLEISTOCENE GEOMORPHIC EVOLUTION OF THE EASTERN SAN MARCIAL BASIN, SOUTHERN RIO GRANDE RIFT, NEW MEXICO**
— Daniel J. Koning, David W. Love, Brad D. Sion, Kevin M. Hobbs, Andrew P. Jochems, and Kristin S. Pearthree
*1:30 PM - 1:45 PM*

**DETRITAL ZIRCON PROVENANCE TRENDS ACROSS THE PLIO-PLEISTOCENE UPPER SANTA FE GROUP, IMPLICATIONS FOR DRAINAGE EVOLUTION OF THE ANCESTRAL RIO GRANDE FLUVIAL SYSTEM**
— Shay P. Ridl, Brian A. Hampton, and Rita L. Adamec
*1:45 PM - 2:00 PM*

## *Break*

**Offline:** *2:00 PM - 2:15 PM*

## Oral Presentations Session 2: Structural and Economic Geology:

**Virtual – Zoom Link Day 1:** *2:15 PM - 3:15 PM*
**Chair:** Diane Agnew

**HOW DID THE GUADALUPE MOUNTAINS CAVE- AND KARST SYSTEM FORM?**
— Keith Diegel, Jolante Van Wijk, and Ronald Broadhead
*2:15 PM - 2:30 PM*

**MINERAL-RESOURCE POTENTIAL IN NEW MEXICO**
— Virginia T McLemore
*2:30 PM - 2:45 PM*

**DETAILED INVESTIGATIONS OF RENDIJA CANYON RHYODACITE, A COMPLICATED VOLCANIC COMPLEX IN THE SIERRA DE LOS VALLES, JEMEZ MOUNTAINS VOLCANIC FIELD, NEW MEXICO**
— Fraser Goff, Matthew Zimmerer, Donathon Krier, Cathy J Goff, M Steven Shackley, Jacob Gehrz, and Siobhan Niklasson
*2:45 PM - 3:00 PM*

**STRUCTURAL EVOLUTION OF THE RESERVE GRABEN, NEW MEXICO: IMPLICATIONS FOR EXTENSIONAL TECTONICS AT THE JUNCTION OF THE RIO GRANDE RIFT, BASIN AND RANGE, AND COLORADO PLATEAU**
— Samuel Martin, Gary Axen, Jolante van Wijk, Daniel Koning, Matthew Heizler, and Connor Whitman
*3:00 PM - 3:15 PM*

## *Socializing Shuffle*

**Virtual - Zoom Link TBD:** *3:15 PM - 3:45 PM*

## Poster Session 1:

**Virtual – Zoom Link Day 1:** *4:00 PM - 4:45 PM*
**Chair:** Susan Lucas Kamat

**THE HETEROMORPH AMMONITE *HOPLOSCAPHITES* AFF. *H. NODOSUS* (OWEN, 1852) FROM THE UPPER CRETACEOUS (CAMPANIAN) OF NEW MEXICO AND ITS SIGNIFICANCE**
— Paul L. Sealey and Spencer G. Lucas
**Booth:** *1*

**VERTEBRATE MICRO-FAUNAL ASSEMBLAGES OF *POGONOMYRMEX RUGOSUS* (HARVESTER ANT) HILLS IN THE TOCITO SANDSTONE (LATE CRETACEOUS, CONIACIAN) OF SANDOVAL COUNTY, NEW MEXICO**

— Paul May, Randy Pence, and Spencer G. Lucas
**Booth:** *2*

**EXTENSIVE LATE CRETACEOUS (CONIACIAN), MOSTLY MARINE VERTEBRATE FOSSIL ASSEMBLAGES FROM THE SOUTHEASTERN SAN JUAN BASIN, NEW MEXICO**
— Randy Pence, Paul May, and Spencer G. Lucas
**Booth:** *3*

**A NEW TESTUDINOID TURTLE FROM THE UPPER CRETACEOUS (CAMPANIAN) FRUITLAND FORMATION, SAN JUAN BASIN, NEW MEXICO**
— Asher Jacob Lichtig and Spencer G Lucas
**Booth:** *4*

## *Closing Remarks*

**Virtual - Zoom Link Day 1:** *2:45 PM - 3:00 PM*

## *Welcome*

**Virtual - Zoom Link Day 2:** *8:00 AM – 8:30 AM*

## *Keynote Address*

## You Don’t Look Like a Geologist

### Deborah Green

**Virtual - Zoom Link Day 2:** *8:30 AM – 10:00 AM*

## Oral Presentations Session 3:

**Virtual - Zoom Link Day 2:** *10:00 AM - 10:30 AM*
**Chair:** Diane Agnew

**A "SYSTEM OF SYSTEMS" APPROACH TO REGIONAL WORKFORCE DEVELOPMENT**
— Dorian G. Newton
*10:00 AM - 10:15 AM*

**ENVIRONMENTAL RISK COMMUNICATION AND ENGAGEMENT**
— Dennis McQuillan and Adria Bodour
*10:15 AM - 10:30 AM*

## *Day 2 Break*

**Offline:** *10:30 AM - 10:45 AM*

## Oral Presentations Session 4: Paleontology of Clayton Lake:

**Virtual - Zoom Link Day 2:** *10:45 AM - 12:00 PM*
**Chair:** Diane Agnew

**THE EARLY CRETACEOUS DINOSAUR TRACKSITE AT CLAYTON LAKE: OVERVIEW AND PREVIOUS STUDIES**
— Spencer G. Lucas, Althea M. Atherton, Bryan Burns, Melodi King, Michael A. Kvasnak, Amber Palmer, Michael Pitula, Tara Spurlock, John Beltran, John B. Rogers, Richard P. Watson, and Theresa Watson
*10:45 AM - 11:00 AM*

**THE EARLY CRETACEOUS DINOSAUR TRACKSITE AT CLAYTON LAKE: SEDIMENTOLOGICAL OBSERVATIONS ON THE MAIN TRACK LEVEL**
— John B. Rogers, Althea M. Atherton, Bryan Burns, Melodi King, Michael A. Kvasnak, Amber Palmer, Michael Pitula, Tara Spurlock, John Beltran, Spencer G. Lucas, Richard P. Watson, and Theresa Watson
*11:15 AM - 11:30 AM*

**CLAYTON LAKE DINOSAUR TRACKSITE PROJECT: PALEONTOLOGY BY DRONE**
— Michael A. Kvasnak, Althea M. Atherton, Bryan Burns, Melodi King, Amber Palmer, Michael Pitula, Tara Spurlock, John Beltran, Spencer G. Lucas, John B. Rogers, Richard P. Watson, and Theresa Watson
*11:30 AM - 11:45 AM*

**CLAYTON LAKE DINOSAUR TRACKWAY PROJECT (CLDTP): UAS APPLICATIONS IN DATA COLLECTION**
— John M. Beltran, Althea M. Atherton, Bryan Burns, Melodi King, Michael A. Kvasnak, Amber Palmer, Michael Pitula, Tara Spurlock, Spencer G. Lucas, John B. Rogers, Richard P. Watson, and Theresa Watson
*11:45 AM - 12:00 PM*

## *Lunch*

**Offline:** *12:00 PM - 12:30 PM*

## Oral Presentations Session 5: Paleontology:

**Virtual - Zoom Link Day 2:** *12:30 PM - 1:45 PM*
**Chair:** Susan Lucas Kamat

**GEOARCHAEOLOGY OF WWII AIRCRAFT IN NEW MEXICO, USA**
— Adrian P Hunt
*12:30 PM - 12:45 PM*

**BIOSTRATIGRAPHY/ECOSTRATIGRAPHY OF THE EARLY PENNSYLVANIAN OSHA CANYON FORMATION AT GUADALUPE BOX, JEMEZ MOUNTAINS, NEW MEXICO**
— Patrick James Carey, Spencer Lucas, and Deborah Petrak Green
*12:45 PM - 1:00 PM*

**THE AMADO EVENT—A GLACIO-EUSTATIC SIGNAL ACROSS THE MIDDLE-LATE PENNSYLVANIAN BOUNDARY IN CENTRAL AND SOUTHERN NEW MEXICO**
— Spencer G. Lucas, Karl Krainer, James E. Barrick, Bruce D. Allen, William A. DiMichele, and Daniel Vachard
*1:00 PM - 1:15 PM*

**THE IMPORTANCE OF THE LATE PENNSYLVANIAN KINNEY BRICK QUARRY LAGERSTÄTTE OF CENTRAL NEW MEXICO FOR THE DEVELOPMENT OF THE STUDY OF VERTEBRATE CONSUMULITES AND OTHER BROMALITES**
— Adrian P Hunt and Spencer G Lucas
*1:15 PM - 1:30 PM*

**FOSSIL TURTLES OF NEW MEXICO**
— Asher Jacob Lichtig and Spencer G Lucas
*1:30 PM - 1:45 PM*

**REVISITING THE PALEOCENE DINOSAURS OF THE SAN JUAN BASIN IN VIEW OF NAYSAYING FROM THE VERTEBRATE-PALEONTOLOGIST COMMUNITY**
— James E. Fassett
*1:45 PM - 2:00 PM*

## Poster Session 2:

**Virtual - Zoom Link Day 2:** *2:00 PM – 3:00 PM*
**Chair:** Diane Agnew

**A STUDY OF ABANDONED MINE LANDS IN NEW MEXICO**
— Nicholas G. Harrison, Virginia T. McLemore, Marcus E. Silva, Navid Mojtabai, and John Asafo-Akowuah
**Booth:** *5*

**EXAMINING POTENTIAL GEOCHEMICAL INDICATORS OF FENITIZATION IN SOIL SAMPLES COLLECTED FROM THE GALLINAS MOUNTAINS, LINCOLN COUNTY, NEW MEXICO**
— Keith Diegel and Virginia T. McLemore
**Booth:** *6*

**FLOW CONNECTIVITY AND SEDIMENT TRANSPORT MODELING IN FLASHY EPHEMERAL CHANNEL NETWORKS**
— Sandra Glasgo, Daniel Cadol, Kyle Stark, Madeline Richards, and Jonathan Laronne
**Booth:** *7*

**GEOCHEMISTRY OF THE U-TH-REE MINERALIZED TAJO GRANITE, SOCORRO COUNTY, NEW MEXICO**

— Haley Dietz and Virginia T McLemore
**Booth:** *8*

**EVALUATING THE TECTONIC SIGNIFICANCE OF THE MOORE GULCH SHEAR ZONE, CENTRAL ARIZONA WITH GEOCHRONOLOGIC, GEOCHEMICAL, AND ISOTOPIC ANALYSIS OF PALEOPROTEROZOIC PLUTONIC ROCKS**
— Jason Adam Velasquez, Mark Edward Holland, and Sean P Regan
**Booth:** *9*

**PROVENANCE TRENDS FROM MODERN TRIBUTARIES ALONG THE WESTERN MARGIN OF THE RIO GRANDE RIFT, IMPLICATIONS FOR DRAINAGE DEVELOPMENT POST ~1 MA**
— Rita L Adamec, Brian A Hampton, and Shay P Ridl
**Booth:** *10*

**IDENTIFYING FACTORS CONTROLLING FLOW CONVEYANCE LOSSES IN THE MIDDLE RIO GRANDE**
— Katie McLain, Marina Hein, Daniel Cadol, Talon Newton, and Benjamin Duval
**Booth:** *11*

**REFINING THE AGE OF THE RESERVE GRABEN, WEST-CENTRAL NEW MEXICO, WITH 40AR/39AR DATING.**
— Connor J Whitman, Sam Martin, Gary Axen, Jolante van Wijk, Matthew Heizler, and Dan Koning
**Booth:** *12*

**RESULTS FROM ONGOING WATER QUALITY MONITORING (FEBRUARY 2020 TO PRESENT) OF THE UPPER PECOS RIVER**
— Megan Begay, Letisha Mailboy, Kate Diem, Ezekiel Tapia, and Jennifer Lindline
**Booth:** *13*

## *Day 2 Closing Remarks*

**Virtual - Zoom Link Day 2:** *3:00 PM - 3:15 PM*

# PROVENANCE TRENDS FROM MODERN TRIBUTARIES ALONG THE WESTERN MARGIN OF THE RIO GRANDE RIFT, IMPLICATIONS FOR DRAINAGE DEVELOPMENT POST ~1 MA

**Rita L Adamec[1], Brian A Hampton and Shay P Ridl**

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Provenance data from modern sediment in headwater streams of the Rio Grande provide insight on how these drainages developed over the last ~1 million. Summarized here are new U-Pb detrital zircon ages (N=1186) from the modern Jemez, Rio Puerco, and Rio Salado drainages along the western margin of the Rio Grande Rift in the Santa Domingo, Albuquerque, and Socorro basins in central and southern New Mexico.

The Jemez River is the furthest upstream locality in this study and records peak ages at 1725, 1686, 1441, 1089, 223, 165, 87, and 36 Ma. The Rio Puerco and Rio Salado are south of the Jemez River and samples collected above the confluence of the Rio Puerco and Rio San Jose exhibit peak ages at 1729, 1685, 1425, 1160, 419, 165, 93, and 74 Ma. Samples collected below the confluence of the Rio Puerco and Rio San Jose exhibit peak ages of 1731, 1669, 1437, 1133, 556, 414, 166, and 95 Ma. The Rio Salado is the southernmost locality in this study and exhibits peak ages at 1739, 1678, 1637, 1432, 1067, 218, 165, and 95 Ma. Peak ages from all samples overlap with Precambrian source areas of the Yavapai-Mazatzal, A-type granite, and Grenville provinces as well as with portions of the Mesozoic Cordilleran arc and Eocene-Oligocene volcanic fields in northern New Mexico.

Although peak ages are similar across all three basins, there are down-system spatial changes in percent occurrence of zircon populations among tributaries. The highest occurrences of Jurassic–Cretaceous aged zircons occur in central New Mexico in the Rio Puerco and Rio Salado drainages. Zircons that overlap in age with Eocene–Oligocene volcanic fields in New Mexico are rare, and occur only in the Jemez, and Rio Salado drainages. Plio-Pleistocene zircons are absent in the Rio Puerco and Rio Salado and are limited to a single occurrence in the Jemez River. A comparison of these data with previously published detrital zircon ages from Plio–Pleistocene strata from the ancestral Rio Grande show upsection changes in provenance and evolution of drainage development since the last ~1 million years.

# SOUTHEASTERN NEW MEXICO SUBSURFACE MAPPING PROJECT

**Alyssa Renee Baca[1], Keith Diegel[2], Robert Pine[3], Colin Cikoski[4], Katie Zemlick[5] and Stacy Timmons[6]**

[1]NMBGMR, 801 Leroy Pl #2424, Socorro, NM, 87801, alybaca@gmail.com
[2]NMT, 59 La Entrada, PO #2519, Los Lunas, NM, 87031
[3]Office of the State Engineer/Hydrology Bureau, 130 South Capitol Street Concha Ortiz y Pino Building P.O. Box 25102, Santa Fe, NM, 87504
[4]Wyoming Department of Environmental Quality - Land Quality Division, 510 Meadowview Dr., Lander, WY, 82520
[5]Office of the State Engineer/Hydrology Bureau, 130 South Capitol Street Concha Ortiz y Pino Building P.O. Box 25102, Santa Fe, NM, 87504
[6]NMBGMR, 801 Leroy Pl, Socorro, NM, 87801

The Permian Basin is currently seeing an oil boom of historic proportions. This oil boom is in large part due to technological advances, namely horizontal drilling and hydraulic fracturing that enable petroleum recovery from low porosity and low permeability formations such as shale. However, this type of production relies on large quantities of water: millions of gallons are required to drill and complete these wells. While there is increasing use of produced water to help meet this need, the oil well boom has been matched by a fresh water well boom. The number of applications for both new groundwater appropriations and wells has been rapidly increasing in the past few years, as have the quantities being requested. This has created management challenges for the Office of the State Engineer, in part because no administrative groundwater model exists for a large portion of this region. Having a better 3-dimensional understanding of the geology and, ultimately, the hydrology of the basin will allow for the construction of an administrative numerical model for the Capitan Basin and greatly improve management and decision making.

The New Mexico Bureau of Geology & Mineral Resources Aquifer Mapping Program and the Office of the State Engineer Hydrology Bureau are jointly funding this project to review gamma logs from oil and gas wells at a target density of one gamma log per section to map the tops of the Rustler, Dewey Lake, Santa Rosa and Tecovas Formations. The New Mexico Oil Conservation Division (NM OCD) collects and maintains gamma logs in their online imaging system. Distinctive gamma signatures of these lithologies are known but can be difficult to discern in many gamma logs. A process for correlating these lithologies across multiple logs was developed using ArcGIS. The results of this work will generate subsurface geology and eventually be used to create layers for an administrative groundwater model. There have been other attempts at mapping the subsurface in this region using gamma logs, but not at the density pursued by this project. The 3-dimensional data generated will be made available to the public.

# RESULTS FROM ONGOING WATER QUALITY MONITORING (FEBRUARY 2020 TO PRESENT) OF THE UPPER PECOS RIVER

**Megan Begay[1], Letisha Mailboy[1], Kate Diem[1], Ezekiel Tapia[1] and Jennifer Lindline[1]**

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Since February 2020, NMHU Environmental Geology students have been collecting biweekly water quality data for the Upper Pecos River (UPR) to establish baseline conditions and determine if waters are meeting water quality standards (WQS) for the Upper Pecos River's high-quality cold-water designation (NMAC 20.6.4). The team established five monitoring sites along a 25 km stretch at approximately equal distances to capture conditions above an historic mine site (UPR 5 Willow Creek), at the confluence of a tributary downslope of a proposed exploratory hard rock drilling site (UPR 3 Macho Creek), and at several high-use recreation areas (UPR 4 Terrero Village, UPR 2 Dalton Canyon, and UPR1 Pecos Village). The team collected bi-weekly in-the-field physical-chemical parameters (pH, temperature, dissolved oxygen, electrical conductivity) using a USI 556 Multi Probe and collected grab water samples for turbidity analysis in the NMHU Water Resources laboratory using a Hach TL2300 turbidimeter. The majority (99%) of reported turbidity values fell below the 10 NTU threshold. Electrical conductivity increased downstream along the study stretch but remained within the 300 µS/cm threshold. Temperature increased downstream and throughout the summer months but remained below the 23°C (73°F) segment-specific criterion. Dissolved oxygen values were ≥ 6.00 mg/L in accordance with WQS for most sites throughout the sampling period. The Pecos Village site had < 6.00 mg/L dissolved oxygen on 5 days between June and September corresponding to high stream temperature days. The pH values varied greatly between sites and throughout the study period with average pH values ranging between 6.4-6.8. The pH values showed moderate negative correlations with streamflow and generally decreased downstream possibly reflecting input from natural sulfide-bearing bedrock and historic mine workings. We report that the Upper Pecos River is in good health for its domestic water supply, fish culture, high quality cold-water aquatic life, and other designated uses. Minimizing recreation, reducing trampling, and increasing streamside vegetation along the river banks at the Pecos Village site could decrease temperature and increase dissolved oxygen and overall maintain and improve the health of the river.

## References:

New Mexico Administrative Code Title 20 Environmental Protection, Chapter 6 Water Quality, Part 4 Standards for Interstate and Intrastate Surface Waters.

## Keywords:

water quality, Upper Pecos River, pH, turbidity, temperature

# BIOSTRATIGRAPHY/ECOSTRATIGRAPHY OF THE EARLY PENNSYLVANIAN OSHA CANYON FORMATION AT GUADALUPE BOX, JEMEZ MOUNTAINS, NEW MEXICO

**Patrick James Carey[1], Spencer Lucas[2] and Deborah Petrak Green**

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In 2005, Krainer and Lucas redefined the Morrowan Osha Canyon Formation to include an additional 5 m of fossiliferous limestone and shale that had been assigned to the overlying, Atokan Sandia Formation by DuChene et al. in 1977. With these added strata, the Osha Canyon Formation in the main area of outcrop, at and just north of Guadalupe Box, can be divided into three informal members based on stratigraphy and invertebrate fossil assemblages. The upper member equals beds 14-15 of Krainer and Lucas, i.e., the uppermost limestone bed and shale below it that were not included in the original formation definition. In this stratigraphic interval, the brachiopods *Anthracospirifer, Derbyia* and *Linoproductus* are prominent at over 15% abundance. *Echinaria* and the trace fossil *Zoophycus* are also present. *Neochonetes, Hustedia, Punctospirifer*, and *Sandia* are all less than 1% abundant.

The middle member encompasses beds 10-13 of Krainer and Lucas, while, in the original stratigraphy of Duchene et al., this member is probably represented by beds 5-8. Here, *Anthracospirifer, Derbyia,* and *Linoproductus* are less than 5% abundant. *Composita* is dominant at over 50% abundance. *Hustedia* becomes fairly common at about 10% abundance, and *Punctospirifer* and *Sandia* each occur at about 5%. In both the upper and middle members, *Parajuresania* is present at less than 1%. This is not true in the lower member, which includes beds 1-9 of Krainer and Lucas and beds 1-4 of the original stratigraphy of Duchene et al. *Parajuresania* is dominant at 40% abundance, followed closely by *Composita* at about 28%. *Linoproductus* is fairly common at about 6%, but *Neochonetes, Punctospirifer, Hustedia*, and *Sandia* are all less than 1% abundant. *Schizophoria oklahomae* is especially abundant at the type section. The changes in relative abundances of brachiopods and other taxa through the Osha Canyon Formation section are, in part, tied to lithologic changes that suggest ecological factors (water depth, temperature?) drove these changes, but the entire assemblage does not change in taxonomic composition through the section.

The "West Hill" exposure is situated just northwest of the main area of outcrop, on the west side of FR-376, on both sides of an arroyo that crosses the road via a culvert. A collection of 140 specimens, principally from the north side of the arroyo, suggests a fauna that most resembles that of the upper member. The fauna of the very productive roadcut exposure located about 5 km north of the main exposure on FR-376 was described by Kues in 2005. It most resembles the middle member exposed farther to the south but does contain a rather high percentage (15%) of *Parajuresania*, the signature genus of the lower member.

Some of the invertebrate fossils in the Osha Canyon Formation are silicified, usually only partially and frequently in the form of beekite rings. The most extensive silicification (90% of the *Composita* shells) occurs at the FR-376 roadcut about 5 kilometers north of the main exposure. At the main outcrop, the upper and lower members are the least silicified.

# GEOCHEMISTRY OF THE U-TH-REE MINERALIZED TAJO GRANITE, SOCORRO COUNTY, NEW MEXICO

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

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[2]New Mexico Bureau of Geology and Mineral Resources, 807 Leroy Place, Socorro, NM, 87801

The Proterozoic Tajo granite consists of six outliers along two northwest-trending faults east of Socorro. The area was originally examined for uranium, but fluorite and rare earth elements (REE) were reported as well. REE consist of the 15 lanthanide elements and includes scandium and yttrium. While common in the crust, REE do not often occur in economically viable amounts, and are fundamental to a wide variety of technologies including electric cars, energy-efficient lights, and smart devices. Considering America's heavy reliance on other countries for REE supplies, identifying, analyzing, and categorizing potential REE deposits could serve as a considerable independent, economic, and strategic interest. Some Proterozoic granites, including the Tajo granite in New Mexico, contain uranium and REE, but their economic resource potential is unknown. Preliminary petrographic and geochemical analyses of the Tajo granite indicate that it is medium-to coarse-grained, peraluminas granite, but is relatively low in REE and uranium. Geochemical comparisons of the Tajo granite to other granites found in New Mexico show that Tajo has an unusual composition. It is enriched in Rb, U and Th compared to most Proterozoic granites, and depleted in CaO, Na2O, and Sr. Future studies need to further analyze petrographic and geochemical samples to determine what depleted the REE and characterize petrogenesis.

# QUANTITATIVE, QUALITATIVE, AND SPATIAL EVALUATION OF GROUNDWATER RECHARGE IN THE SALT BASIN, NM/TX

**Beth Ann Eberle[1] and Daniel Cadol[1]**

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

The Salt Basin is a 13,034 square kilometer (5,033 $mi^2$) hydrologically closed basin shared between southeastern New Mexico and western Texas. Due to the semi-arid nature of the Salt Basin, the local water resources are vital to the future of the basin, and potentially, of surrounding areas as well. The ongoing, two-year, three-part project is intended to evaluate the groundwater availability in the Salt Basin, help assess the local sustainability of current groundwater usage, and indicate the implications for future development. In doing so, the project aims to fill data gaps with geophysical analysis and new data collection, expand and update a groundwater model, and improve the understanding of the regional water budget. The water budget in this semi-arid context is strongly connected to the amount of groundwater recharging the local aquifer. Throughout the past sixty years, there have been numerous recharge estimates that range from 6,000 to 240,000 acre-feet per year. To constrain these estimates, geochemistry analyses from sampled well waters are utilized to visualize major flow paths, chemical evolution of waters, and velocities of the groundwater in the Salt Basin. Overall basin trends are evident when the major ion concentrations from the water wells are spatially mapped onto the basin. These evolutionary trends are also visualized and categorized with Piper diagrams and a matrix of pair-wise correlation plots. The velocities of the groundwater flow paths are estimated based on the corrected radiocarbon age dates of the waters. Evolution and speed of the water can be used to determine the quantity of groundwater moving throughout the system and infiltrating into the aquifer. This recharge estimate based on chemistry can be corroborated with a soil water balance model, the Python Recharge Assessment for New Mexico Aquifers (PyRANA). The soil water balance model approximates evapotranspiration (ET) and runoff, and subtracts those from precipitation, giving a net input into the system based on local climate, ecology, and topography. A proportion of the runoff may infiltrate into the beds of the ephemeral channels of the Salt Basin and produce additional recharge. However, constraining this proportion requires additional information, such as discharge measurements. Further, the chloride mass balance method will utilize the spatial geochemistry data for chloride and bromide to produce a recharge rate and another estimate of recharge. Independent of this recharge/geochemistry subproject, a groundwater flow model is being created to produce another recharge estimate utilizing Blaney-Criddle evapotranspiration estimates for consumptive use for active agriculture in the Salt Basin. These four groundwater recharge estimates from the overall project are expected to constrain the 234,000 acre-feet range of recharge estimates from previous studies in the Salt Basin. This project is funded by the U.S. Bureau of Reclamation and is being fulfilled by collaboration between students, faculty, and staff from the Earth and Environmental Science Department and New Mexico Bureau of Geology and Mineral Resources' Aquifer Mapping Program.

## References:

https://urldefense.proofpoint.com/v2/url?u=https-3A__geoinfo.nmt.edu_geoscience_research_home.cfml-3Fid-3D98&d=DwIGAg&c=Xk3HT0PclLbx0YEZpz9tYQ&r=39qX4-

TSyCNx97DXGmkIgUrSNP0njUkJaqg9xYoD71o&m=ObOutNqjHzfRN5VQmNZyU7-nvzvUdJ1Ey85MveC9Hgs&s=kS3KEu7u7HMAGVi5R-oSEv3VCkK2vM3PEQ6ivYMPcwQ&e=

## Keywords:

Salt Basin, groundwater recharge estimate

# ASSESSMENT OF SAFE AQUIFER YIELDS WITHIN THE SALT BASIN IN NM AND TX.

**Elizabeth Evenocheck[1] and Mark Person[2]**

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The Bureau of Reclamation and the New Mexico Interstate Stream Committee is trying to assess the available groundwater resources within the Salt Basin. This basin is situated to the east of the Rio Grande extending from southern New Mexico into northwestern Texas. It is a large, sparsely populated, semi-arid, and hydrologically closed basin. The goals of this study are to determine the water budget and how much water can be sustainably pumped. A secondary goal is to determine if a new well field on the New Mexico side of the basin can maintain safe aquifer yields. A three-dimensional numerical groundwater flow model is being developed to answer these questions. Currently, a steady-state model is being calibrated to observed water levels and stream fluxes. Once the steady-state calibration is complete, a transient model will be developed, and finally scenarios will be run to determine safe aquifer yields. Prior studies have estimated recharge to range between 29,000 acre-feet/year to 142,112 acre-feet/year. These discrepancies are similar for evaporative discharge and hydraulic conductivities. Our work aims to more accurately define recharge, evapotranspiration and hydraulic conductivity using inverse modeling.

# REVISITING THE PALEOCENE DINOSAURS OF THE SAN JUAN BASIN IN VIEW OF NAYSAYING FROM THE VERTEBRATE-PALEONTOLOGIST COMMUNITY

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In his *News in Depth* comment "Does fossil site record dino-killing impact" (5 April, 2019, p. 10) Colin Barras writes "Geologists have theorized that the impact, near what is now the town of Chicxulub on Mexico's Yucatan Peninsula, played a role in the mass extinction at the end of the Cretaceous period, when all the dinosaurs (except birds) and much other life on Earth vanished." This is just one example, both in the popular press and in scientific-journal articles, where overwhelming Paleocene-dinosaur-data presented in my Palaeontologia Electronica (PE) paper (Fassett, 2009) was ignored or disputed. My 146-page paper included a massive and detailed appendix on the palynology of the K-Pg boundary rocks in the San Juan Basin. These data showed conclusively that the dinosaur-bearing Ojo Alamo Sandstone was Paleocene in age throughout its extent in the San Juan Basin demonstrating that some dinosaurs in the San Juan Basin area survived the K-Pg asteroid-impact event. Most naysayers – chiefly vertebrate paleontologists – did not (and still do not) accept the findings of my PE paper primarily based on: 1) Incorrect claims that the dinosaur-bearing Ojo Alamo Sandstone consists of two members: a lower, dinosaur-bearing, Cretaceous member and an upper member of Paleocene age, and 2) Overwhelming palynologic data proving that the dinosaur-bearing Ojo Alamo Sandstone is Paleocene in its entirety throughout the San Juan Basin. As for number 1, not one of the naysayers has ever provided justification or any evidence, via geologic mapping or correlation of stratigraphic columns, to support their two-part Ojo Alamo thesis. As for claim number 2, there is not a single legitimate instance where any of the palynologic data presented in my PE paper has been falsified. All index palynomorphs identified from Ojo Alamo Sandstone samples listed in the PE paper from numerous collecting localities across the San Juan Basin are Paleocene in age. Not one single sample from the Ojo Alamo Sandstone has ever been found to be Cretaceous in age (other than a few, rare, reworked palynomorphs). In addition, false claims that there are Maastrichtian strata in the Cretaceous rocks underlying the Ojo Alamo was disproven in my PE paper. In that paper, palynologic data conclusively proved that the entire Maastrichtian and probably the uppermost part of the underlying Campanian are missing throughout the San Juan Basin. Those who have maintained otherwise have exercised poor scholarship in not referencing my PE paper. In short, no evidence has ever been provided by naysayers that has falsified any of the hard data in my PE paper.

## References:

Fassett, J.E., 2009, New geochronologic and stratigraphic evidence confirms the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone and Animas Formation in the San Juan Basin, New Mexico and Colorado: Paleontologia Electronica, v. 12, no. 1, 146 p. (on-line pub. at https://urldefense.proofpoint.com/v2/url?u=http-3A__palaeo-2Delectronica.org_splash_index12-5F1.html&d=DwIGAg&c=Xk3HT0PclLbx0YEZpz9tYQ&r=39qX4-TSyCNx97DXGmkIgUrSNP0njUkJaqg9xYoD71o&m=ObOutNqjHzfRN5VQmNZyU7-nvzvUdJ1Ey85MveC9Hgs&s=Krgb0wNdSVVi1qh32Trf3GE92mzqQCTVFaCDGIDl5Zc&e= ).

**Keywords:**

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

# FLOW CONNECTIVITY AND SEDIMENT TRANSPORT MODELING IN FLASHY EPHEMERAL CHANNEL NETWORKS

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In large river systems such as the Rio Grande, sediment influx and water delivery from ephemeral streams is difficult to quantify and track. Yet is has major management implications to such diverse issues as reservoir sedimentation, sediment plugs and avulsions, flooding, and additions to streamflow. In the Arroyo de los Pinos watershed, one such ephemeral system, we have been monitoring discharge at 18 different points for two years in an effort to quantify water and sediment delivery from the ephemeral channels. The data collected in the past, present, and future will allow for a better understanding of how the network connects across a range of precipitation intensities and magnitudes, and how these interactions control water and sediment delivery to the watershed outlet. Preliminary data support the prevailing understanding that the primary controls on local runoff generation are rainfall intensity, lithology, and sub-basin size (Richards, 2020).

To investigate how these flow events influence sediment discharge, my proposed work will focus on building open channel flow models with sediment transport capability. The first step will be to build a model framework for a reach where sediment flux is monitored near the confluence of the Pinos and Rio Grande (Stark, 2018). Discharge, bedload, and topographic data collected during the monsoon seasons of 2018, 2020, and – if there are floods – 2021 will be used to calibrate open channel flow models with sediment transport capability. Initially we will utilize the sediment transport simulation capabilities within the Bureau of Reclamation's BORAMEP model, because Reclamation has supported work at the Pinos and is interested in evaluating their model's performance. Modeled sediment flux will be compared against monitored sediment flux near the confluence of the Pinos and Rio Grande. If successful, we will then be able to model sediment transport using the calibrated sediment parameters in other upstream reaches in the channel network. Combined with our flow connectivity data, this would enable an unprecedented quantification of sediment transport connectivity, and potentially disconnectivity, within ephemeral fluvial systems.

# DETAILED INVESTIGATIONS OF RENDIJA CANYON RHYODACITE, A COMPLICATED VOLCANIC COMPLEX IN THE SIERRA DE LOS VALLES, JEMEZ MOUNTAINS VOLCANIC FIELD, NEW MEXICO

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The Rendija Canyon rhyodacite (RCR) of the Tschicoma Formation is one of many dome and flow complexes in the Sierra de los Valles of the Jemez Mountains volcanic field, New Mexico. The RCR has few previously published ages and was mapped as a lumped geologic unit primarily consisting of coarse porphyritic, quartz-bearing lavas containing additional phenocrysts of alkali feldspar, plagioclase, biotite, clinopyroxene, and hornblende. In 2020 we began a new research effort to remap and date individual eruptive units in the RCR to better characterize 1) the timescale of silicic dome complexes and 2) the source provenances of ongoing detrital sanidine studies. Thus far we have obtained 6 ultra high-precision $^{40}Ar/^{39}Ar$ ages of sanidine, ~50 thin sections, ~40 EDXRF analyses of broken rock surfaces and 10 XRF/ICPMS whole rock major and trace element analyses.

From these and previous data, we have subdivided the original RCR into 7 map units as follows (oldest to youngest): Upper Guaje Canyon rhyodacite (5.381 ±0.004 Ma), "classic" RCR (4 dates that range 5.062 ±0.006 to 5.038 ±0.003 Ma), Upper Pueblo Canyon rhyolite (UPCR, undated), Vallecito Canyon rhyodacite (4.881 ±0.003 Ma), Garcia Canyon rhyodacite (undated), Skyline rhyodacite (4.69 ±0.17 Ma), and Cañada Bonita dacite (3.52 ±0.23 Ma). Each of these 7 units is texturally, mineralogically and chemically distinct. UPCR is unique because it is fine-grained and forms a small intrusive lens within RCR. Four of the 7 units contain conspicuous mafic enclaves. Importantly, "classic" RCR contains no obvious mafic enclaves, a great aid during field identification.

New work allows us to break out at least 3 subunits of "classic" RCR erupted in a 24 ±7 ka period of activity. Two of the subunits are found at the top and bottom of a large unnamed hill interlayered with ±35 m of debris flow breccia (5.038 ±0.003 and 5.045 ±0.003 Ma, respectively), suggesting a relatively short 7 ±4 ka eruptive hiatus between flows. The debris flow unit appears to consist entirely of eroded RCR. At this time, we can't unequivocally say that individual subunits of "classic" RCR are mineralogically and/or chemically distinct. "Classic" RCR contains ±7% phenocrysts of clear quartz, large white anorthoclase, smaller sanidine and plagioclase, minor augite, biotite, opaque oxides, and sparse hornblende in a fine-grained gray to black groundmass. In thin sections, quartz is typically resorbed and larger plagioclase is

commonly myrmekitic. The groundmass contains abundant acicular orthopyroxene and clinopyroxene ≤0.5 mm long, and rare to very rare tiny crystals of apatite, titanite, and zircon. Vesicular samples often contain secondary vapor-phase tridymite and display severe oxidation of mafic phases. Acicular groundmass pyroxenes are not found in the 6 newly described map units of the original RCR.

## Keywords:

Rendija Canyon, rhyodacite, 40Ar/39Ar, XRF, volcanic domes, Jemez Mountains volcanic field

# YOU DON'T LOOK LIKE A GEOLOGIST – A CONVERSATION ON DIVERSITY (OR THE LACK THEREOF) IN OUR PROFESSION

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Too many times as a young geologist I was told, "You don't look like a geologist," often by clients and even by my own company's managers. I haven't heard that comment in some years, and I hope that speaks to the fact that more women are studying geology and going on to careers in our field, so the face of a geologist isn't necessarily male anymore. According to statistics from the American Geosciences Institute (AGI) in the Status of Recent Geoscience Graduates report (Wilson, 2017), at least forty percent of geology graduates are women. However, we are still an overwhelmingly white profession (the same report indicates less than twelve percent of geology graduates identify themselves as belonging to underrepresented minority groups). There will be some statistics, but they'll be a starting point to talk about *why* there is so little diversity in our field. Increasing diversity would expand the points of view team members bring to projects and enrich the perspectives we use to solve the problems facing us. There is science that shows diverse teams do better work. Increasing diversity, equity, and inclusion in our workplaces is not only the right thing to do (which, of course, it is), it is also the smart thing to do. This presentation will be a conversation in which we all participate, exploring the reasons why the geosciences are the least diverse of the STEM fields in the U.S.

# A STUDY OF ABANDONED MINE LANDS IN NEW MEXICO

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Abandoned mine lands (AML) are sites that were mined and left unreclaimed where no individual or company has reclamation responsibility and there is no closure plan in effect. The New Mexico Bureau of Geology and Mineral Resources and the Mineral Engineering Department at New Mexico Tech are conducting research to develop a better procedure to inventory and characterize legacy, inactive, or abandoned mine features in New Mexico. The object of this study was to inventory a number of abandoned mine features in several mining districts throughout New Mexico. This inventory was conducted by means of recording field observations according to the procedure already used by the program, soil petrography of composite dump samples, and paste pH analysis of said samples. This work served to identify environmental hazards in the two districts, which contributed to the goals of the AML program. The procedure developed for the project involves field examination of the mines features and collecting data on the mine features. Samples are collected to determine total whole rock geochemistry, mineralogical, physical, and engineering properties, acid-base accounting, hydrologic conditions, particle size analyses, soil classification, and prioritization for remediation, including hazard ranking.

A field inventory form was designed to collect data on all mine features during the field examination, which were later entered into the New Mexico Mines Database. Composite dump samples were collected and subjected to soil petrography, paste pH analysis, and geochemical testing, for evaluation of major and trace elements.

Samples that have higher concentrations of pyrite are more likely to have a higher acid generation capacity.

A few mine sites examined have the potential to generate acid drainage and additional mine sites are physically dangerous and require proper safeguarding.

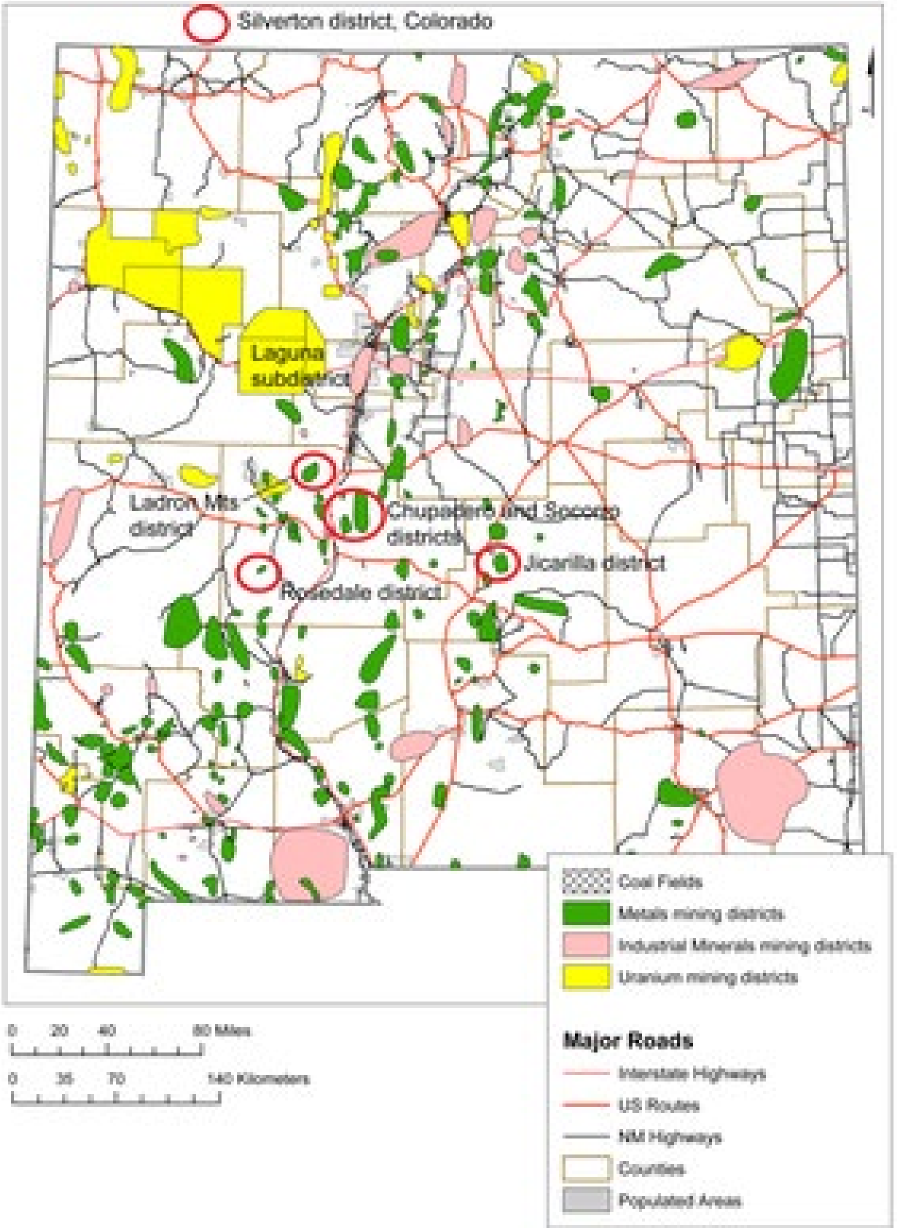

Figure 1. Location of mining districts examined during this study

**Keywords:**

Abandoned Mine Lands, paste pH

# GEOARCHAEOLOGY OF WWII AIRCRAFT IN NEW MEXICO, USA

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Before 1941 there were only a handful of fatal aircraft crashes in New Mexico every year. During World War II (WWII) more than 7,100 fatal air crashes involving United States Army Air Force (USAAF) aircraft occurred on American soil. Collectively these crashes resulted in the loss of over 15,500 lives. The majority of these crashes involved training flights. In New Mexico there were three locations for the Second Air Force – Alamogordo, Clovis and Kirtland Field – and five for the Army Air Forces Training Command – Carlsbad, Deming, Fort Sumner, Hobbs and Roswell. As a result of ramped up training, air crashes in New Mexico rose from about 10 in 1941 to over 450 in 1944. A large number of largely non-fatal crashes occurred in the vicinity of airfields, such as 115 from 1942-1945 around Alamogordo Army Air Field.

A number of crashes occurred in mountainous terrane throughout New Mexico. For example, on April 22nd 1942 a B-24D Liberator (four engine bomber) hit Trail Peak near Cimarron within what is now the Philmont Scout Ranch. Later that year on October 15th a B-17E Flying Fortress, another four engine bomber, struck North Baldy Peak near Magdalena.

Other impacts occurred in a wide range of environments. A USAAF Consolidated 0A-10 (Army designation for Navy PBY-5A Catalina flying boat) crashed in what is now El Malpais National Monument on August 1st, 1945. The aircraft crashed after having feathered one propeller (indicating an engine failure).

A smaller number of aircraft disintegrated at altitude including a B-17F east of Medio on January 1st, 1943 and a B-17E on August 23rd 1942 near Las Cruces. Mid-air collisions were not uncommon in training such as one between a Cessna AT-17 and an AT-17B on January 10th 1943 near Roswell.

Geologic factors influence not only the location of many crash sites but also their preservational potential. The large number of WWII crashes in New Mexico provide potential for a significant geoarcheological dataset in aviation archeology.

**Keywords:**

Geoarcheology, World War Two, aviation archeology, New Mexico

# THE IMPORTANCE OF THE LATE PENNSYLVANIAN KINNEY BRICK QUARRY LAGERSTÄTTE OF CENTRAL NEW MEXICO FOR THE DEVELOPMENT OF THE STUDY OF VERTEBRATE CONSUMULITES AND OTHER BROMALITES

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In 1992, a review of coprolites from the Kinney Brick Quarry Lagerstätte by APH introduced the term bromalite for trace fossils to refer to fossil food material regurgitated, defecated or maintained within the body cavity. Bromalite has been widely accepted and utilized. The same study coined the term regurgitalite for regurgitated food remains and this has also been widely used. APH and SGL coined the term consumulite in 2012 for food remains preserved within body cavities.

Vertebrate consumulites are bromalites preserved within the body cavity and include oralites (oral cavity), esophogalites (GI tract anterior to stomach), gastrolites (stomach), cololites (GI tract posterior to stomach), intestinelites (intestines) and enterospira (spiral valve). Evisceralites are preserved segments of infilled fossilized intestines preserved independent of, or exterior to, a carcass. Vertebrate consumulites have an extensive Devonian-Quaternary fossil record and are principally associated with articulated skeletons. Most articulated skeletons are from aquatic environments, and so are most consumulites. Consumulites are most common in fine-grained deposits of low energy environments. They are also prevalent in Lagerstätten--e.g., Cleveland Shale (Devonian), Holzmaden (Jurassic), Solnhofen (Jurassic), Jehol (Cretaceous), and Messel (Eocene). Most consumulites represent carnivorous animals because plant material is usually finely macerated during digestion and more difficult to recognize as fossils than bone. Large body size favors the recognition of consumulites, so there is an extensive record of consumulites in Mesozoic marine vertebrates, notably ichthyosaurs, plesiosaurs and mosasaurs. Consumulites preserve a wide range of organic elements with a poor fossil record, from lepidopteran wings to hair to embryos. Consumulites, themselves, represent Lagerstätten. Systematic study of consumulites will yield significant records of rare fossils (see, for example, the recent focus on coprolite contents).

The Kinney Brick Quarry Lagerstätte is an important Konservat Lagerstätte in the Manzanita Mountains of central New Mexico. Fossils at Kinney occur in the lower part of the Tinajas Member of the Atrasado Formation of Missourian (Late Pennsylvanian) age. The first three named non-evisceralite consumulites are from this locality - *Werneburgichnus kinneyensis, W. varius* from branchiosaur-like amphibians and *Chondripilula zideki* from chondrichthyans. The Lagerstätte also yields the non-consumulite bromalites *Huberobromus ovatus*, *Maculacoprus ateri*, *Virgacoprus brevis*, *Kinneybromus jurgenai*, *Conchobromus kinneyensis* and four unnamed morphotypes. Contemporaneous bromalite ichnofaunas from New Mexico yield an ecological transect from lagoonal to shallow marine (Tinajas Lagerstätte, Kinney Brick Quarry Lagerstätte, Erickson site, Sacramento site). The Kinney bromalite ichnofauna is significant because: (1) it contains the most studied bromalites of any Paleozoic ichnofauna and includes the highest number of named ichnotaxa; (2) its study stimulated the development of a synthetic nomenclature, with the introduction of the terms bromalite and regurgitalite; (3) it includes the first named non-eviscerалite consumulite taxa; and (4) the Kinney ichnofauna provides a reference for bromalites in lagoonal and estuarine/deltaic environments.

**Keywords:**

Bromalite, consumulite, Kinney Brick Quarry, Pennsylvanian, vertebrate, coprolite

# MIDDLE-LATE PLEISTOCENE GEOMORPHIC EVOLUTION OF THE EASTERN SAN MARCIAL BASIN, SOUTHERN RIO GRANDE RIFT, NEW MEXICO

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Completion of recent STATEMAP geologic mapping and preliminary age control allow constraints on the Quaternary landscape evolution of the eastern San Marcial basin. Particular effort was taken to understand the correlation of deposits under a prominent geomorphic surface that projects to ~25-40 m above the Rio Grande floodplain. Detailed mapping indicates that this geomorphic surface is comprised of 3 closely spaced (by 1-6 vertical m) surfaces underlain by three allostratigraphic units (Qs1, Qs2, and Qs3). Near the modern Rio Grande, each allostratigraphic unit contains a common suite of facies that include axial sands and floodplain deposits overlain by westerly-derived alluvial fans. This suite grades laterally northwestward into gravelly piedmont deposits. The youngest unit, Qs1, is the thickest and includes at least two cycles of an axial-to-distal fan upward facies progression. Qs1 has capping soils exhibiting stage II+ to III+ carbonate morphology, a typical tread height of 21-25 m and a strath height ranging from buried to 9 m above the modern Rio Grande floodplain. It is correlated to the Matanza Formation near Socorro, which has a ca. 70 ka surface (Sion et al., 2020), and we infer that the deposit age is 130-70 ka. The middle unit, Qs2, has a strath and tread height of 20-24 m and 27-35 m, respectively, and the older unit (Qs3) has strath and tread heights of 27-30 m and 40-42 m. Both Qs2 and Qs3 are associated with capping soils having stage III to IV carbonate morphologies. A preliminary surface age (Be-10) and depositional age (OSL, multi-grain K-feldspars using post-IRIR protocol) of Qs2 are 135-240 ka and 322 ± 35 ka, respectively, suggesting a period of prolonged deposition between ~140-320 ka. The age of Qs3 is not constrained but likely in the range of 330-650 ka. Mapping of these allostratigraphic units in tributary canyons to the northwest of the modern floodplain, away from axial terrace deposits, indicates that they merge into a compound deposit where the individual units are difficult to differentiate. The relative differences in tributary-terrace tread heights also decrease upstream so that they become practically indistinguishable above the compound piedmont deposit. Interestingly, a younger, intermediate-level terrace deposit, inferred to correlate to the Jaral Largo terrace in Socorro (27-29 ka surface age, Sion et al., 2020), is ubiquitously inset several meters below the top of Qs1 and Qs2 near the Rio Grande but can be correlated to the northwest to a distinctive piedmont deposit that locally overlies the surface of the compound deposit. This indicates that proximal-middle piedmont deposition has continued into the late Pleistocene >6-7 km northwest of the Rio Grande. Also, the notable upstream convergence of the three units shows that base level is strongly controlled by the Rio Grande, and for small drainages its base level fluctuations are muted >6-7 km away from the river.

## References:

Sion, B.D., Phillips, F.M., Axen, G.J., Harrison, J.B.J., Love, D.W., and Zimmerer, M.J., 2020, Chronology of terraces in the Rio Grande rift, Socorro basin, New Mexico: Implications for terrace formation: Geosphere, v. 16, p. 1-22.

## Keywords:

San Marcial, basin, Quaternary, landscape evolution, terraces, base level, Rio Grande rift, terrace facies, geomorphic surfaces

# CLAYTON LAKE DINOSAUR TRACKSITE PROJECT: PALEONTOLOGY BY DRONE

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The use of small unmanned aerial systems (sUAS), i.e., drones and photogrammetry, in the fields of paleontology, archeology, and geology are relatively recent developments. The commoditization of drone technology over the past five or so years combined with now readily available structure-from-motion, photogrammetry, and three-dimensional (3-D) modeling software has led to the ability to improve the scientific collection of field data and then create 3-D models of these natural features. In the Spring of 2019 a team of students from Central New Mexico Community College (CNM) and scientists from the New Mexico Museum of Natural History and Science (NMMNH) and CNM, spent a week at Clayton Lake State Park and Dinosaur Trackways in an effort to extend the work of Dr. Spencer Lucas of NMMNH and try new techniques in photogrammatic data collection developed by Dr. Richard Watson of CNM.

During the five days of on-site work, three types of image data were collected: drone, terrestrial, and LiDAR. The data were then processed through photogrammetry software to create 3-D densified mesh models and a high precision digital surface model (DSM) of the dinosaur tracksite. A unique aspect of this project was the creation of a website to showcase and visualize these dinosaur tracks and tracksite, to expand public awareness and education about the site and aid in developing future research directions.

At Clayton Lake in Union County, northeastern New Mexico, an extensive dinosaur tracksite is exposed in the dam spillway. Tracks are present at four stratigraphic levels across the contact of the Lower Cretaceous (upper Albian) Mesa Rica and Pajarito formations. The main track level is on the top sandstone bedding surface of the Mesa Rica Formation. Previous studies have counted 200-300 dinosaur tracks at this level that are mostly of ornithopods (Caririchnium), but that also include two kinds of theropod tracks (Magnoavipes, cf. Irenesauripus) and a single quadrupedal trackway of an ankylosaur? (Deltapodus). The associated invertebrate ichnoassemblage is shallow burrows assigned to Arenicoilites, Planolites, Taenidium and Thalassinoides, representative of the Scoyenia ichnofacies. The paleoenvironment of the tracksite is broadly interpreted as a sandflat at or very near the shoreline of the Western Interior seaway.

The fusion of the image data collected of these dinosaur tracks at multiple heights and resolutions with geospatial reference data has resulted in a highly accurate orthophotograph and DSM of the entire tracksite. From this DSM and orthophoto additional tracks not originally observed in the previous site surveys are now apparent. Current efforts are on-going to process the tens of gigabytes of images and produce scaled 3-D models of the tracks and identify additional potential tracks. These models can then be used to determine the size, weight, and stride length of the individual creating the track. Additionally, 3-D models suitable for website viewing and 3-D printing are being created.

# A NEW TESTUDINOID TURTLE FROM THE UPPER CRETACEOUS (CAMPANIAN) FRUITLAND FORMATION, SAN JUAN BASIN, NEW MEXICO

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A mostly complete turtle shell from the neurals to the edge of the carapace from the Upper Cretaceous (Campanian) Fruitland Formation in the San Juan Basin, northwestern New Mexico, and recently prepared. In addition, the remainder of the shell, a cervical vertebra and a skull fragment are fractured and stacked in the adjacent rock. This fossil is identified as a testudinoid turtle because it lacks the mesoplastron characteristic of either a pleurodire or a baenid turtle. The neural bone lacks the costiform process characteristic of either chelydrid or kinosternoid turtles.

This turtle has hexagonal neurals with the short sides anterior. The costal bones are of near equal width along their entire length. The anterior of the carapace has a deep cephalic emargination similar to that of *Cardichelyon*. The bridge of the plastron is solidly sutured to the carapace. The cervical scute is either absent or extremely narrow. The plastron has a large caudal embayment, and the xiphiplastron terminates in angular points.

This is the oldest testudinoid in North America, the previous oldest record being the early Paleocene Puercan *Cardichelyon*. This Late Cretaceous turtle indicates that testudinoids entered North America significantly earlier than previously believed. Furthermore, both this specimen and *Cardichelyon* appear to be from the emydid-platysternid branch of the Testudinidae. This suggests the possibility that this early split in the Testudinoidea may be vicariant--the emydid-platysternid branch originating in North America, and the Geoemydidae-Testudinidae branch that originated from those groups remaining in Asia. Later periods of connectivity between Asia and North America would then provide a mechanism for the interchange of these two groups seen more recently.

# FOSSIL TURTLES OF NEW MEXICO

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New Mexico has an extensive record of fossil turtles ranging from the Triassic to the Pleistocene. The Late Triassic *Chinlechelys* from the Bull canyon Formation of the Chinle Group in east-central New Mexico is the oldest turtle in North America. The Upper Jurassic Morrison Formation of north-central New Mexico yielded the pleurosternid *Glyptops*. The Cretaceous of New Mexico host a diversity of turtles starting with trionychids in almost all marine units. The only marine turtle in New Mexico is a carapace fragment in the late Campanian interval of the Pierre Shale in northeastern New Mexico with surface sculpture similar to *Archelon*. The most diverse Cretaceous turtle assemblages in New Mexico are the Campanian Menefee, Fruitland and Kirtland formations in the San Juan Basin. The Menefee Formation has produced fossils of at least five families of turtles, none of which have been identified below the family level. The Fruitland and Kirtland formations contain at least 17 species of turtles, mostly baenids and trionychoidians. More rarely bothremydid and compsemydid turtles have also been found. The Paleocene Nacimiento Formation of northwestern New Mexico has a diverse turtle fauna of at least five families, including some of the oldest testudinoids in North America, *Cardichelyon*. At least 28 species have been described from the Nacimiento Formation to date, but this number is likely inflated by over splitting of trionychid and dermatemydid turtles. The lower Eocene San Jose Formation in the San Juan Basin hosts a diverse turtle fauna including the oldest known fossil testudinid, *Hadrianus majusculus*. Its turtle assemblage is further differentiated from earlier units by the near absence of baenid turtles, a common component of the Cretaceous and Paleocene turtle assemblages of New Mexico. The late Eocene (Chadronian) Palm Park Formation of soiuth-central New Mexico has yielded fragmentary fossils of tortoises (cf. *Stylemys*). The Miocene strata of New Mexico hosts a largely modern turtle fauna lacking paracryptiodires and all non-trionychid trionychoideans. The turtles from these deposits differ from the extant New Mexico turtle fauna in the prevalence of large tortoises, which are absent in the extant fauna. The Plio-Pleistocene record is similarly composed of various tortoises (Testudinidae) and more rarely kinosternid and emydid turtles, including New Mexico's oldest box turtles. These final comparisons to the extant fauna are somewhat obscured by the historic anthropogenic removal of New Mexico’s surviving tortoises for food. Absent this, there would likely be one Testudinidae species left, and the turtle fauna would be more similar to that of the Plio-Pleistocene.

# THE AMADO EVENT—A GLACIO-EUSTATIC SIGNAL ACROSS THE MIDDLE-LATE PENNSYLVANIAN BOUNDARY IN CENTRAL AND SOUTHERN NEW MEXICO

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The Late Paleozoic ice ages of the Pennsylvanian-early Permian have long been seen as primary drivers of global sea level and of cyclical marine deposition in the Pangean tropics. However, in the American Southwest, particularly in New Mexico, the tectonism of the ancestral Rocky Mountain (ARM) orogeny, principally caused by the collision of Gondwana and Laurussia that assembled Pangea, is also an important driver of sedimentation. Further complications are introduced by classic autocyclic drivers of sedimentation, including local and regional climates, productivity fluctuations in the carbonate factory and chaotic aspects of sediment discharge. In the New Mexico Pennsylvanian-early Permian section, most claims of glacio-eustatically driven sedimentary cycles do not stand up to critical scrutiny. Nevertheless, detailed correlations and facies analysis along an ~ 250 km transect from the Sacramento Mountains in Otero County through the northern Sandia Mountains in southern Sandoval County identify the sedimentary signal of a substantial eustatic event across the Middle-Late Pennsylvanian (Desmoinesian-Missourian) boundary. Correlations are based primarily on conodont biostratigraphy supplemented by biostratigraphy based on fusulinids and other forams. This event is seen in the Sacramento Mountains in the Alamo clastic trough, a structure created by ARM tectonism, as deposition shifted from clastic-dominated to platform carbonates that cross the Desmoinesian-Missourian boundary. To the north, this event is correlated to the carbonate-dominated Desmoinesian/Missourian Amado Member within the clastic-dominated lower part of the Atrasado Formation at numerous localities in Socorro, Valencia, Bernalillo and southern Sandoval counties. We thus term this the "Amado event," a substantial glacio-eustatic event essentially equivalent to the Swope cyclothem of the Midcontinent. Strata above and below the Amado event interval are mixed siliciclastic and carbonate sediments that generally lack organized facies stacking and show great lateral variations in thickness and facies. Their stratigraphic architecture suggests that an allocyclic driver such as eustasy was not the primary driver of deposition. The laterally extensive limestones of the Amado Member are composed of muddy microfacies (mostly wackestone to floatstone) and have a diverse fauna of brachiopods, crinoids, bryozoans and other invertebrates. These limestones were deposited in a normal-marine, low-energy shelf environment. There are almost no high-energy sediments (grainstone, rudstone), which means that the Amado interval was deposited during a period of relative tectonic inactivity on a broad marine shelf. The Amado event marks the onset of a major global environmental event during the Kasimovian/Missourian interval, possibly a large-scale

deglaciation in Gondwana, a huge event that would have affected global sea level and climate in the Pangean tropics.

# THE EARLY CRETACEOUS DINOSAUR TRACKSITE AT CLAYTON LAKE: OVERVIEW AND PREVIOUS STUDIES

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At Clayton Lake in Union County, northeastern New Mexico, an extensive dinosaur tracksite is exposed in the dam spillway. Tracks are present at four stratigraphic levels across the contact of the Lower Cretaceous (upper Albian) Mesa Rica and Pajarito formations. The main track level is on the top sandstone bedding surface of the Mesa Rica Formation. Previous studies have counted 260 to as many as 500 dinosaur tracks at this level that are mostly of ornithopods (*Caririchnium*), but that also include two kinds of theropod tracks (*Magnoavipes*, cf. *Irenesauripus*) and a single quadrupedal trackway of an ankylosaur? (*Deltapodus*). The associated invertebrate ichnoassemblage is shallow burrows assigned to *Arenicolites*, *Planolites*, *Taenidium* and *Thalassinoides*, representative of the *Scoyenia* ichnofacies. The paleoenvironment of the tracksite is broadly interpreted as a sandflat at or very near the shoreline of the Western Interior seaway. Paleontological study of the Clayton Lake tracksite began in 1982, and Gillette and Thomas (1985) published a map of the tracks. This, the only published map of the tracks, was made by standard grid, tape and compass techniques, and identified nearly 500 dinosaur tracks at the site, mostly of ornithopods. Subsequent studies focused on some individual tracks, detailed the statigraphy and geological age of the tracksite or presented short summaries of the tracksite (e. g., Lucas et al., 1986; Gillette and Thomas, 1989; Bennett, 1992; Hunt and Lucas, 1998). Lucas and Dalman (2016) restudied the tracksite without cleaning it, so it was not mapped. They counted 260 dinosaur tracks at the site. Traditional photography, under low angle natural light, was used by Lucas and Dalman to document individual tracks, and some trackways were traced on acetate film to produce trackway maps. Our photogrammetric study in 2019 yields extensive data with which to more accurately interpret the geology and ichnology of the tracksite than was possible by previous studies using traditional field methods.

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# STRUCTURAL EVOLUTION OF THE RESERVE GRABEN, NEW MEXICO: IMPLICATIONS FOR EXTENSIONAL TECTONICS AT THE JUNCTION OF THE RIO GRANDE RIFT, BASIN AND RANGE, AND COLORADO PLATEAU

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History of strain accumulation in the transition zone between the Rio Grande Rift, the southern Basin and Range province, and the Colorado Plateau can inform the late Cenozoic tectonic history of SW North America. Study of basin fill and fault exposures in the Miocene-Quaternary Reserve graben within this transition zone is in progress to assess proposed tectonic models, and to provide additional timing and kinematic constraints on SW US extension in general. An anomalous NE-striking fault system formed the graben, which separates the relatively little-deformed Mogollon Plateau (core of the Mogollon-Datil volcanic field) from the SE Colorado Plateau. Previous workers (e.g., Chapin and Cather, 1994) predicted significant sinistral slip along Reserve graben faults, implying that the southeastern Colorado Plateau moved farther SW than the Mogollon Plateau relative to the stable Great Plains during rifting. Also, a mid-Miocene change from SW to WNW extension has been proposed for the southern and central Basin and Range (e.g., McQuarrie and Wernicke, 2005) and the Rio Grande Rift (Aldrich et al., 1986; Morgan et al., 1986), possibly driven by the evolving Pacific-North America dextral transform plate boundary. This model predicts early oblique or strike-slip on northeast-striking faults of the Reserve graben (dextral or sinistral, depending on relative motions of the Colorado and Mogollon plateaus), followed by dominantly normal dip-slip.

Fault slip-sense indicators and $^{40}$Ar/$^{39}$Ar ages of volcanic and intrusive units in sedimentary basin fill inform the Reserve graben's structural development. New $^{40}$Ar/$^{39}$Ar ages bracket basin subsidence and sedimentation between ~16.4 and ~1.9 Ma (Whitman et al., this meeting). Cross-cutting relationships among kinematic indicators along the main boundary fault system suggest highly oblique dextral-normal slip followed by mainly normal dip-slip, consistent with a regional mid-Miocene change in extension direction. Early dextral kinematics suggest SW-directed Basin and Range extension continued past ~16 Ma. Apparent dextral offset of newly-dated intrusive units along the master fault system (Ratté, 1989) suggests that this change postdated ~14.7 Ma, and that SW-directed extension between the Plains and Mogollon Plateau was greater than that between the Plains and the SE Colorado Plateau. Future $^{40}$Ar/$^{39}$Ar dating will test and refine these results.

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## Keywords:

Rio Grande rift, Basin and Range, Colorado Plateau, tectonics, geochronology, faults

# VERTEBRATE MICRO-FAUNAL ASSEMBLAGES OF *POGONOMYRMEX RUGOSUS* (HARVESTER ANT) HILLS IN THE TOCITO SANDSTONE (LATE CRETACEOUS, CONIACIAN) OF SANDOVAL COUNTY, NEW MEXICO

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Near Cabezon in Sandoval County, two prolific shark-tooth-dominated vertebrate fossil assemblages are present in the Upper Cretaceous (Coniacian) Tocito Sandstone, New Mexico Museum of Natural History (NMMNH) locality 2606 and NMMNH locality 10175. Both assemblages are in the topmost sandstone bed of the Tocito Sandstone, which is 0.2-0.4 m thick and consists of trough cross bedded, very coarse grained, pebbly quartz sandstone. The two fossil sites are about 250 m apart north-south, and the teeth can be directly collected from the sandstone bed and from nearby anthills where the ants have concentrated them.

Anthills have long been a treasure trove for paleontologists and archeologists and call attention to fossil sites of interest. The Harvester Ant, *Pogonomyrmex rugosus* (Emery) is a common high desert denizen. Their telltale discs made of large sand grains blanket the southwestern USA and northern Mexico. These diligent diggers can carry up to twice their body weight alone and work together on large objects. The nest architecture of *P. rugosus* conveniently places the food/trash storage chambers just under the surface debris disc, created by seasonal excavations and foraging. The chambers may be sealed off or periodically emptied of their contents, which expand the debris disc. At these two Tocito Sandstone fossil localities, some of these chambers contain small teeth from inhabitants of the Western Interior Seaway (mostly sharks), ~ 85 Ma. The NMMNH L-2606 anthill is located on an erosion slope 3 meters below the topmost bed of the Tocito Sandstone. The debris disc is small and washing downslope, with a thin crust that has a few small teeth on the surface. The NMMNH L-10175 anthill is located on the very top of a bluff, self-contained in a depression within the topmost bed of the Tocito Sandstone. The debris disc is huge, with a thick crust and numerous small teeth present on the surface. Our work suggests that *P. rugosus* anthills, in the right place, will yield a more extensive and more complete micro-fossil assemblage than a random sampling of the matrix of that site.

# IDENTIFYING FACTORS CONTROLLING FLOW CONVEYANCE LOSSES IN THE MIDDLE RIO GRANDE

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The Middle Rio Grande experiences significant water losses in the reach from San Acacia to Fort Craig. While the quantity of flow loss has been defined in previous studies the relative contribution of the various mechanisms of loss have not been closely studied. It is our goal to investigate the interactions of the topography, hydrological conditions, weather, and vegetation to better define the processes that contribute to this conveyance loss. We plan to use several techniques in our research, such as water table monitoring, by using data loggers in wells, soil moisture monitoring using probes, water quality and field chemistry parameters from surface and ground waters, and vegetation surveys. We intend to deliver information to the Middle Rio Grande Conservancy District that will aid their water management decisions, in particular, what conditions lead to maximum conveyance of flow releases through the reach with minimal transmission losses.

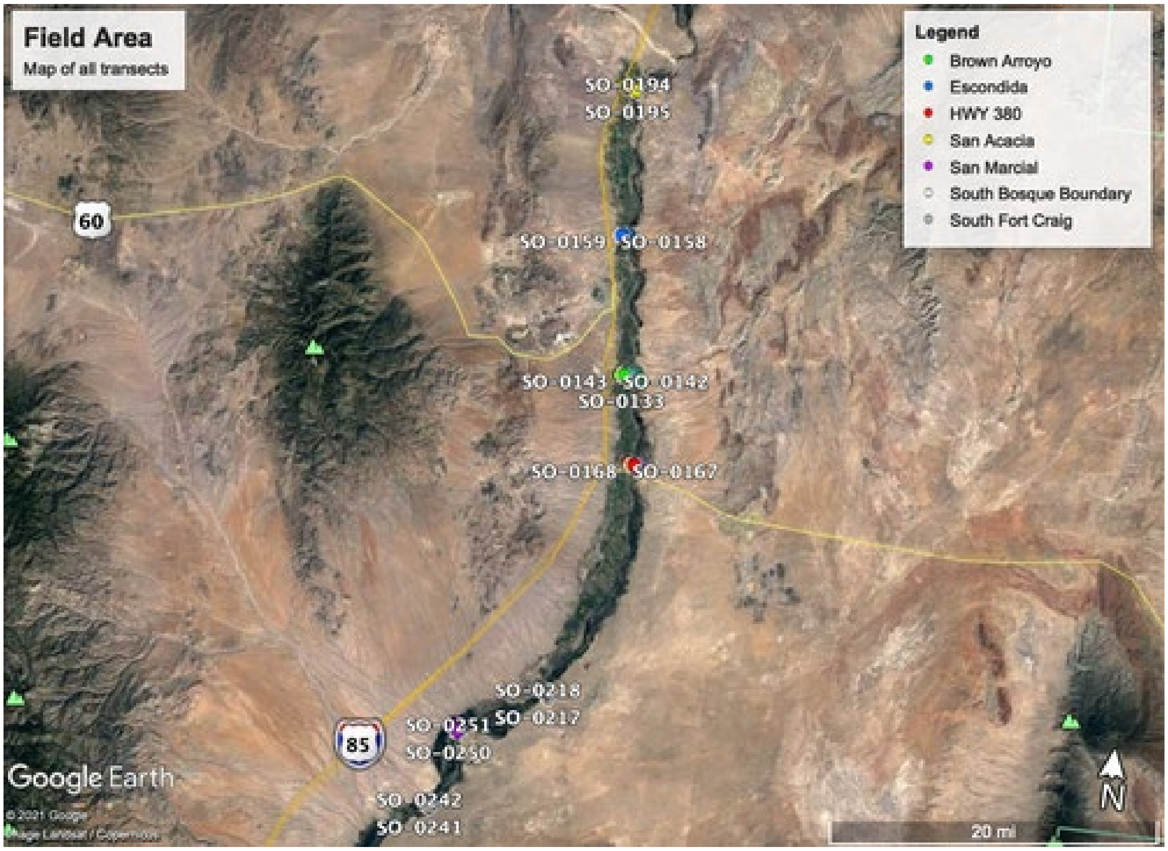

Figure1: Map showing Transects being evaluated in the study.

# EXAMINING POTENTIAL GEOCHEMICAL INDICATORS OF FENITIZATION IN SOIL SAMPLES COLLECTED FROM THE GALLINAS MOUNTAINS, LINCOLN COUNTY, NEW MEXICO

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Fenitization is an alkali metasomatic alteration associated with carbonatite and alkaline intrusions. Typically, fenitization occurs with enrichments of potassium (K), sodium (Na), and rare earth elements (REE). REEs are comprised of the 15 lanthanide elements, yttrium, and scandium. REEs are increasing in demand with their use in smart phones, LED lights, solar technologies and electric vehicles. Occurrences of fenitization associated with REEs, such as at the Gallinas Mountains mining district, Lincoln County, NM, are therefore of considerable economic and strategic interest. In the 1950s some REE, occurring as bastnaesite, were produced from the Gallinas Mountains. Several companies have conducted exploration programs to identify REE potential therein. Four types of deposits are found in the district: epithermal REE-F veins, Cu-REE-F veins, REE-F breccia pipe and iron skarn deposits; all are associated with Tertiary alkaline or alkali-calcic igneous rocks, REEs and fenitization. In 2010 a series of 240 soil/rock chip samples were collected and analyzed with a Bruker handheld XRF instrument. Samples range in K concentrations from 0.7-3.8%, and maximum concentrations of La (2071ppm) and Ce (3547ppm), indicating zones of fenitization and mineralization that need further confirmation. Analytical precision is within +/-10%. Of the REEs, only La, Ce, Nd, and Y were detected by the instrument. Rb shows a very strong positive correlation with potassium, suggesting these elements are in K-feldspar, which could be related to the fenitization. As K-feldspar is a common host of Rb, this is expected. There is no apparent correlation between K and the four REEs tested (Nd, Ce, Y, and La). Further fieldwork has indicated that REE anomalies are concurrent with general alteration and REE veins.

**Keywords:**

REE, fenitization, alteration, fenite, Gallinas, Rare Earth Element

# MINERAL-RESOURCE POTENTIAL IN NEW MEXICO

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*Mineral resources* are the naturally occurring concentrations of materials (solids, gas, or liquid) in or on the earth's crust that can be extracted economically under current or future economic conditions. Most of the state's mineral production comes from oil, gas, coal, copper, potash, industrial minerals and aggregates. Oil and gas are the most important extractive industries in New Mexico in terms of production value and revenues generated. Other important commodities include a variety of industrial minerals (potash, perlite, cement, zeolites, etc.), sulfuric acid, molybdenum, gold, uranium, and silver. The *mineral-resource potential* of an area is the probability or likelihood that a mineral will occur in sufficient quantities so that it can be extracted economically under current or future conditions, including the occurrence of undiscovered concentrations of metals, critical minerals, other nonmetals, industrial materials, and energy resources. The mineral-resource potential is not a measure of the quantities of the mineral resources but is a measure of the *potential* of occurrence. Factors that could preclude development of the resource, such as the feasibility of extraction, land ownership, accessibility of the minerals, or the cost of exploration, development, production, processing, or marketing, are not considered in assessing the mineral-resource potential. Evaluations of mineral-resource potential are useful for estimating mineral availability, aid government officials in land-use planning (including potential withdrawal of lands from mineral production), and delineate areas requiring more geologic investigation. Government officials are required to make decisions regarding use, acquisition, and restriction of lands (including land exchanges) that could have known or even suspected mineral-resource potential. The *mineral-resource potential* of an area is the probability or likelihood that a mineral will occur in sufficient quantities so that it can be extracted economically under current or future conditions, including the occurrence of undiscovered concentrations of metals, nonmetals, industrial materials, and energy resources. The mineral-resource potential is not a measure of the quantities of the mineral resources but is a measure of the *potential* of occurrence. Mineral-resource potential is a qualitative judgment of the probability of the existence of a commodity and is classified as very high, high, moderate, low, or no potential according to the availability of geologic data and relative probability of occurrence. Factors that could preclude development of the resource, such as the feasibility of extraction, land ownership, accessibility of the minerals, or the cost of exploration, development, production, processing, or marketing, are not considered in assessing the mineral-resource potential. The evaluation process is complex and involves integration of geologic maps with numerous geologic, mineral, and economic databases. The process is based upon geologic analogy of promising or favorable geologic environments with geologic settings of known economic deposits. Current studies at NMBGMR assesses the mineral-resource potential throughout New Mexico, including critical minerals.

**Keywords:**

mineral-resource potential, critical minerals

# ENVIRONMENTAL RISK COMMUNICATION AND ENGAGEMENT

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Effective stakeholder communication and engagement on environmental risks are important for the design and implementation of holistic efforts to protect public health. Complex sites can involve multiple contaminants, exposure pathways, receptors, regulatory jurisdictions, and differing limits for drinking water, groundwater, surface water, sediment, air, crops, livestock, fish, game animals, wildlife, and humans. A good example is the contaminant lead, which has at least 22 standards and guidelines in various media. Environmental practitioners must clearly explain the applicability of various limits, as well as how differences in sample collection, preparation, analysis, and reporting units can affect the interpretation of test results.

Practitioners must maintain scientific rigor while educating, and creating trust with, the public. Stakeholder engagement should include design of environmental investigations, analysis of risks identified, and selection of corrective actions. Public notice and comment periods for these activities are required by some regulatory programs. Practitioners can exceed these requirements by seeking broad community engagement that addresses local needs and involves citizens in environmental and public health monitoring.

Human-health and ecological risk assessments are often conducted to inform corrective actions at contamination sites. Comparative Risk Assessments (CRAs) are sometimes performed to estimate and compare the potential adverse health effects of multiple risk factors in a geographic area. A CRA for radiological risks in Santa Fe County, for example, could include naturally occurring radium and uranium in well water, indoor radon, tobacco smoking that greatly increases the risk of lung cancer from radon exposure, and transportation of radioactive waste from Los Alamos to Carlsbad. Practitioners and stakeholders should collaborate on holistic risk assessments and mitigation to reduce disease burdens.

Environmental Standards and Guidelines for Lead, Applicable in New Mexico

| | | |
|---|---|---|
| **Water (mg/L)** | | |
| Drinking Water[1] | | |
| | Goal | Zero |
| | Action Level | 0.015 (total) |
| Ground Water[2] | | 0.015 (dissolved) |
| Surface Water[3] | | |
| | Domestic water supply | 0.015 (dissolved) |
| | Aquatic life, acute | 0.14 (dissolved) |
| | Aquatic life, chronic | 0.005 (dissolved) |
| | Irrigation | 5 (dissolved) |
| | Livestock | 0.1 (dissolved) |
| **Sediment/Soil (mg/kg)** | | |
| Migration to Groundwater[4] | | 270 |
| Human Health, Residential[4] | | 400 |
| Human Health, Industrial[4] | | 800 |
| Flora[5] | | 120 |
| Invertebrates[5] | | 1,700 |
| Birds[5] | | 11 |
| Mammals[5] | | 56 |
| Hazardous Waste Characteristics (TCLP rule of 20)[6] | | 100 |
| **Air[7] (ug/$m^3$)** | | |
| Ambient Air | | 0.15 |
| **Food[8] (mg/kg)** | | |
| Fruiting vegetables | | 0.05 |
| Cattle, pig and sheep meat | | 0.1 |
| Fish meat | | 0.3 |
| **Human Blood** | | |
| All Blood Levels[9] | | Notification required |
| Children's Blood[10] (ug/dL) | | 5 |

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# A “SYSTEM OF SYSTEMS” APPROACH TO REGIONAL WORKFORCE DEVELOPMENT

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Background: The mission of the U.S. Department of Energy's Office of Environmental Management, Los Alamos Field Office is to “cleanup of legacy contamination and waste resulting from nuclear weapons development and government-sponsored nuclear research at the Los Alamos National Laboratory.” Newport News Nuclear BWXT Los Alamos (N3B), a limited liability company owned by Huntington Ingalls Industries and BWX Technologies manages the 10-year, $1.38 billion Los Alamos Legacy Cleanup Contract (LLCC) in support of this mission.

To tailor requirements to mission risks and ensure overall mission readiness, N3B must first address attrition levels that may occur in the Northern New Mexico region over the next four to seven years caused in part by unique regional demographics and the following complex-wide human capital issues facing DOE’s national federal and contractor workforce:

- Workforce Maturity: A 2017 NNSA report indicates that over 50% of the workforce in key technician positions is within 5 years of retirement age & less than 7% are under 30 years old.
- Skill Gaps in Technical and Institutional Knowledge: Few employees have the minimum skills required to effectively perform the challenges encountered in working in DOE’s one-of-a-kind facilities, with unique processes that may involve hazardous materials and special machinery and tools that are too often inaccessible for support from commercial industry experts.
- Unskilled Workforce Pool: "Pipelines for key technician positions at DOE sites are weak or non-existent causing significant shortages of qualified applicants as we look to the future."

Case Study - Northern New Mexico’s “System of Systems” Approach: This presents a case study analysis of how N3B continues to use Systems Engineering principles and a “System of Systems” (SOS) approach to build a workforce that is resilient and has the skills and experience required to accomplish EM-LA and DOE’s highly technical mission through:

- Channeling industry expertise and experience to convene partnerships with regional governments, colleges, schools, labor, workforce agencies, community organizations, and other community stakeholders.
- Pooling the capital, resources and capabilities of federal and regional systems (and sub-systems) to create a new, more complex system offering more functionality and performance than simply the sum of the constituent systems.
- Accommodating the needs of industry and community stakeholders within the constructs of larger corporate, regional and national workforce development systems and priorities.

The resulting “system of systems” successfully developed apprenticeship and mentorship programs that provide formal worker training needed to support on-going & anticipated LLCC work through instruction and experience – both theoretical and practical:

- Ensuring scarce private and public resources are not spent on inefficient infrastructure solutions.
- Creating a cost-effective, systematic and repeatable process to address its workforce needs and attrition levels in the Northern New Mexico region over the next four to seven years.

This case study demonstrates by utilizing a “system of systems” approach to create a single, unifying framework utilizing regional system and sub-system architectures industry partners can identify a supporting set of standards, interfaces, best practices, and design guides that are tailorable to address specific workforce needs in any region.

## Keywords:

Workforce Development, Systems Approach, System of Systems, Northern New Mexico, Apprenticeship, Regional, Department of Energy

# EXTENSIVE LATE CRETACEOUS (CONIACIAN), MOSTLY MARINE VERTEBRATE FOSSIL ASSEMBLAGES FROM THE SOUTHEASTERN SAN JUAN BASIN, NEW MEXICO

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An extensive vertebrate faunal assemblage has been collected from anthills that have gathered fossil material from the Upper Cretaceous (Coniacian) Tocito Sandstone. The fossil-bearing deposit is a crossbedded, very coarse grained to pebbly sandstone that was deposited on an offshore bar or barrier island. The fossils mostly represent selachian taxa, are worn and tumbled and thus are allochthonous. This is an ongoing project consisting of sorting and identifying at least 17,000 fossils, and thus far there have been at least 12 selachians, 3 bony fish, four invertebrates, at least two types of reptiles, and one mammal collected. The selachian taxa include *Scapanorhynchus raphiodon, Ptychodus mortoni, Squalicorax* cf. *falcatus, Scindocorax novimexicanus, Cretolamna appendiculata, Ptychotrygon* nov. sp., *Hybodus* sp., *Polyacrodus* aff. *parvidens, Pseudohypolophus ellipsis,* rhynobatoidsp., *Myledaphus* sp.,and *Cantioscyllium decipiens,* as well as yet to be identified species. The bony fishes include *Micropycnodon kansasensis, Anomoeodeus* sp., *Lepidotes* sp.and an unidentified ginglymodian. Inoceramid clams make up the majority of the invertebrates, with the rest being baculites, other ammonites, crinoids (reworked from Paleozoic strata), and gastropods. The reptiles include crocodile, plesiosaur, and mosasaur. The one mammal tooth collected is an incisor of an unknown taxon. Teeth of *Scapanorhynchus* apparently make up the vast majority of the faunal assemblage (though soem of these teeth, many of which are fragmentary, may represent other taxa), while some other taxa are rare, notably *Polyacrodus* aff. *parvidens,* which is known from five or less examples. Almost all of the teeth are very small, less than 10 mm in maximum dimension, but whether this is caused by hydraulic sorting, the ability of the ants to carry material to build up their hills, or the fossil assemblage sourcing a possible shark pupping area is yet to be determined.

# CLAYTON LAKE DINOSAUR TRACKSITE - SURFACE HYDROLOGY ANALYSIS: ESTABLISHING A BASELINE FOR STUDIES OF SURFACE EROSION

**Michael R Pitula**

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At Clayton Lake in Union County, northeastern New Mexico, an extensive dinosaur tracksite is exposed in the dam spillway. Tracks are present at four stratigraphic levels across the contact of the Lower Cretaceous (upper Albian) Mesa Rica and Pajarito formations. Exemplary tracks in the top sandstone bedding surface of the Mesa Rica Formation are exposed and vulnerable to the elements. Rain is infrequent but can be intense, while runoff from snowmelt can also cause impacts. Photogrammetric data gathered at Clayton Lake have been used to establish a baseline characterization of site surface hydrology in order to assess potential threats that flooding, weathering and erosion may present to ongoing preservation of tracks and traces.

Digital survey data collected in May 2019 at sub-centimeter spatial resolution were used to conduct a hydrological analysis of the site topography. UAS imagery collected from a height of 24 m provided a ground sample distance (GSD) of 0.62 cm, superseding the spatial resolution of 10 m DEMs previously available for this site. Pix4DMapper was used to generate an orthomosaic, Digital Surface Model (DSM) and Digital Terrain Model (DTM). ESRI ArcMap 10.6 Modelbuilder and QGIS 3.x were used to conduct a hydrological analysis of the site topography based on the DTM.

This process generated high accuracy feature classes for basins, contours and ephemeral microstream features, all of which permitted a highly detailed characterization of surficial geomorphology across the site. Tracks intersected by surface flow features are potentially the most impacted by runoff because the velocity of runoff is higher in the relatively narrow channels. The analysis determined that about half of the exemplary trackways are intersected by emphemeral microstreams. Many of these are simply grazed by the microstreams, but about 3-4 of them are squarely intersected by drainages that accumulate from significant upstream areas within the watershed. This characterization should assist in the prioritization of tracks for protection against flooding, weathering and erosion. Additionally, the findings of this study provide a baseline for future geologic studies and engineering interventions.

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## Keywords:

Clayton Lake Dinosaur Tracksite, Clayton Lake, Surface Hydrology Analysis, trace fossils

# Clayton Lake Dinosaur Tracksite - Surface Hydrology Analysis: Establishing a Baseline for Studies of Surface Erosion

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At Clayton Lake in Union County, northeastern New Mexico, an extensive dinosaur tracksite is exposed in the dam spillway. Tracks are present at four stratigraphic levels across the contact of the Lower Cretaceous (upper Albian) Mesa Rica and Pajarito formations. Exemplary tracks in the top sandstone bedding surface of the Mesa Rica Formation are exposed and vulnerable to the elements. Rain is infrequent but can be intense, while runoff from snowmelt can also cause impacts. Photogrammetric data gathered at Clayton Lake have been used to establish a baseline characterization of site surface hydrology in order to assess potential threats that flooding, weathering and erosion may present to ongoing preservation of tracks and traces.

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# DETRITAL ZIRCON PROVENANCE TRENDS ACROSS THE PLIO-PLEISTOCENE UPPER SANTA FE GROUP, IMPLICATIONS FOR DRAINAGE EVOLUTION OF THE ANCESTRAL RIO GRANDE FLUVIAL SYSTEM

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Axial-fluvial strata exposed throughout the Rio Grande rift (RGR) corridor preserve a ~4 m.y. record of provenance and drainage-network configurations from the Plio-early Pleistocene ancestral Rio Grande river just prior to incision and the arrival of the modern river system at ~1 Ma. Presented here are U-Pb detrital zircon ages from 8 samples (N=2382) collected from the Camp Rice and equivalent Palomas Formation in the Socorro, Hatch/Rincon-Jornada del Muerto, and Mesilla basins in central and southern New Mexico. Samples were collected from the three basins at equivalent stratigraphic horizons (5.0, 3.1, and 1.6 Ma) where known age constraints exist.

The Socorro basin is the furthest upstream locality in this study and records peak ages at 1684, 1442, 1076, 520, 421, 168, 87, 34, and 5 Ma. The Hatch/Rincon-Jornada del Muerto basin is downstream and south of the Socorro basin and exhibits peak ages at 1679, 1431, 1072, 618, 514, 421, 217, 166, 83, 35, 28, and 5 Ma. The Mesilla basin is the southernmost downstream locality in this study and preserves peak ages at 1687, 1432, 1034, 602, 522, 430, 224, 189, 165, 95, 64, 35, and 28 Ma. Peak ages from all samples overlap with Precambrian source areas of the Yavapai-Mazatzal, A-type granite, and Grenville provinces. The strongest Phanerozoic peaks overlap with the Permian–Cretaceous Cordilleran arc and late Eocene–Oligocene calderas of southern New Mexico.

Comparison of detrital zircon trends with previous studies in the northern portion of the RGR provide a spatial and temporally extensive record of drainage configuration during the Plio-Pleistocene phase of drainage development. The oldest stratigraphic intervals of Pliocene axial-fluvial strata (~5.0–4.5 Ma) contain the highest percentage of zircons that overlap in age with late Cenozoic volcanic fields. Recycled Cordilleran arc-derived zircons are rare in the northernmost part of the rift corridor (i.e. southern Colorado and northern New Mexico) but increase in percentage throughout central New Mexico and decrease slightly in southern New Mexico. Younger, Late Pliocene stratigraphic horizons (~3.1–2.6 Ma) throughout New Mexico record decreased contributions of zircons derived from late Cenozoic volcanic fields relative to older axial-fluvial strata. The youngest, (Pleistocene) stratigraphic intervals range in age from 2.0–1.6 Ma and contain some of the highest percentages of recycled Cordilleran arc-derived zircons in the study with much lower percentages of late Cenozoic-age zircons.

Provenance trends across the RGR reflect an upsection transition from initial, caldera-dominated sources available during the Pliocene, to more Colorado Plateau-dominated recycled sources during the Pleistocene stage of drainage development. This trend may reflect denudation of the Colorado Plateau possibly as a result of headward erosion of the Rio Puerco and Rio San Jose during the late Pliocene. The absence of zircons that overlap in age with late Cenozoic volcanic fields at the youngest stratigraphic horizons may reflect hydrologic closure of the Upper San

Luis basin following emplacement of the Taos Plateau volcanic field in northern New Mexico and southern Colorado.

# THE EARLY CRETACEOUS DINOSAUR TRACKSITE AT CLAYTON LAKE: SEDIMENTOLOGICAL OBSERVATIONS ON THE MAIN TRACK LEVEL

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At Clayton Lake in Union County, northeastern New Mexico, an extensive dinosaur tracksite is exposed in the dam spillway. Tracks are present at four stratigraphic levels across the contact of the Lower Cretaceous (upper Albian) Mesa Rica and Pajarito formations. The main track level is on the top sandstone bedding surface of the Mesa Rica Formation. Previous studies have counted 260 to as many as 500 dinosaur tracks at this level that are mostly of ornithopods (*Caririchnium*), but that also include two kinds of theropod tracks (*Magnoavipes*, cf. *Irenesauripus*) and a single quadrupedal trackway of an ankylosaur? (*Deltapodus*). The associated invertebrate ichnoassemblage is shallow burrows assigned to *Arenicolites*, *Planolites*, *Taenidium* and *Thalassinoides*, representative of the *Scoyenia* ichnofacies. The paleoenvironment of the tracksite is broadly interpreted as a sandflat at or very near the shoreline of the Western Interior seaway.

Salient features of the main track-bearing layer include the following:

1) All the dinosaurs tracks are undertracks with some tracks registered in the mudrock above the sandstone track level. There is sandstone infilling of some of the tracks 2) The eastern portion of the tracksite is more deeply impressed demonstrating varying sediment viscosity across the site. 3) The burrows of the invertebrate ichnoassemblage cross cut the tracks. Thus, the traces were made after the track makers. No dinosaur tracks were noted that obliterated invertebrate burrows. Normally these invertebrate traces do not form subaerially, suggesting that the tracks were made in a subaqueous environment with shallow water above sand. A subaqueous environment would explain the generally poor preservation of the dinosaur tracks. 4) Low sandstone mounds are found in the southern/southeastern part of the tracksite. With one exception, footprints appear to go around the mounds. We believe that these mounds are of hydraulic origin, but a possible biogenic origin is also being evaluated. These enigmatic mounds of unclear origin need more study.

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# THE HETEROMORPH AMMONITE *HOPLOSCAPHITES* AFF. *H. NODOSUS* (OWEN, 1852) FROM THE UPPER CRETACEOUS (CAMPANIAN) OF NEW MEXICO AND ITS SIGNIFICANCE

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Three specimens of *Hoploscaphites* aff. *H. nodosus* (Owen, 1852) were recovered from the Pierre Shale in the Raton Basin of northeastern New Mexico. The shells were found at the same stratigraphic level as *Baculites jenseni*, hence they are dated as upper upper Campanian. *H.* aff. *H. nodosus* has previously been reported from the *Nostoceras* (*N.*) *hyatti* Zone in the Coon Creek Tongue of the Ripley Formation in Tennessee (Landman et al., 2010, p. 133, fig. 81). *N.* (*N.*) *hyatti* Stephenson is only known in the Western Interior from the *B. jenseni* Zone in the Pierre Shale near Walsenburg, Huerfano County, Colorado (Kennedy, 1993, p. 105). *H.* aff. *H. nodosus* has also been reported from the *B. reesidei*-*B. jenseni* zones in the Bearpaw Shale in Alberta, Canada and Montana, Nacotoch Sand in Texas, and from the *B. reesidei* Zone in the Lake Creek Shale Member of the Pierre Shale in Kansas, Saratoga Chalk in Arkansas and the Larimer Sandstone Member of the Pierre Shale in Colorado (Landman et al., 2010, fig. 78, p. 125, 127, 133, 135).

The NMMNH specimens are closest to *Hoploscaphites nodosus*, but differ from that species in three respects: 1) they are too large for that species, with the largest specimen (macroconch) having a LMAX of about 117 mm, which would be larger if the phragmocone was complete, 2) the rib density of the specimens is about half that of *H. nodosus* with ribs on the venter of the mid-shaft measuring 3-3.5 per cm, and 3) the flanks are flattened on the body chamber. Forms assigned to *H.* aff. *H. nodosus* are larger, more coarsely ornamented and have flatter flanks than *H. nodosus* (Landman et al., 2010, p. 127, 135). The largest NMMNH specimen has the aperture and apertural lip completely preserved with an aptychus (lower jaw) preserved in close association in the shale covering the outside of the aperture.

The largest NMMNH specimen is significant because ammonite jaws usually occur as isolated elements but jaws inside or closely associated with body chambers are relatively rare. The NMMNH specimens are also important because this is the first report of an aptychus associated with *Hoploscaphites* aff. *H. nodosus* and the first report of this taxon from New Mexico.

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# GLOBAL CONTEXT OF SEDIMENT TRANSPORT RATES FROM A NEW MEXICAN EPHEMERAL CHANNEL

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We present an initial evaluation of sediment transport data collected from ephemeral channels in dryland regions worldwide. These data have been compiled from a wide range channels with differing watershed size, bed material, and aridity. When these channels are activated, bedload transport rates are among the highest recorded anywhere. Their defining features - sparse vegetation cover, lack of baseflow, and unarmored nature - allows these channels to transport material highly efficiently downstream. Of these channels the Arroyo de los Pinos, an ephemeral channel in central New Mexico, ranks among the most efficient at transporting sediment. It's unique properties (a loose, gravel bed with a significant sand content) allows individual grains to mobilize much easier.

This is a first attempt to gather publicly available data from desert channels worldwide. Ephemeral channels in these regions deliver the majority of sediment and runoff to mainstem trunk rivers and over 35% of the earth's landmass is classified as drylands. More than 2 billion people live in these regions. Our goal is to aggregate sediment transport data in the hope to resolve outstanding fundamental questions about how these channels behave and advance the knowledge about these under-studied fluvial systems.

# EVALUATING THE TECTONIC SIGNIFICANCE OF THE MOORE GULCH SHEAR ZONE, CENTRAL ARIZONA WITH GEOCHRONOLOGIC, GEOCHEMICAL, AND ISOTOPIC ANALYSIS OF PALEOPROTEROZOIC PLUTONIC ROCKS

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Proterozoic crust of southwestern Laurentia is widely considered to be an example of continental growth by accretionary processes. In a broadly accepted model, Laurentia grew by the sequential addition of crustal provinces, each having their own distinctive geologic histories. Two key provinces in this model are the ca. 1.8-1.7 Ga Yavapai and ca. 1.7-1.6 Ga Mazatzal provinces, delineated by marked differences in lithology, metamorphic grade, and structural style across the Moore Gulch shear zone in central Arizona. Two endmember hypotheses have been proposed to account for the differences between crustal provinces. In one hypothesis, rocks of the Mazatzal province are allochthonous with respect to the Yavapai province, and were juxtaposed by subduction-related thrusting, with the Moore Gulch shear zone representing a reactivated hinge-zone that marks the approximate crustal boundary. In the other end-member model, rocks of the Mazatzal province were deposited unconformably atop rocks of the Yavapai province, and the difference in lithotectonic character is ascribed to the juxtaposition of different crustal levels across the Moore Gulch shear zone. A crucial test of these opposing hypotheses is evaluating the petrogenetic history of ca. 1.74 Ga plutonic rocks on either side of the Moore Gulch shear zone. We present paired U-Pb zircon geochronology and Hf-isotope analysis and bulk-rock major and trace element geochemistry of intermediate plutonic rocks on either side of the Moore Gulch shear zone. Our results indicate that ca. 1.74 Ga plutonic rocks on both sides of the Moore Gulch shear zone share similar petrogenetic histories. Both suites of rocks have a range of calc-alkalic to calcic major element compositions. Both suites of rocks show enriched high-field strength elements relative to large ion lithophile elements with pronounced negative Nb, Ta, P, and Ti anomalies. Both suites of rocks are isotopically juvenile at ca. 1.74 Ga, with εHf(t) values ranging from ca. +2 to +14. These results favor the second hypothesis, indicating that ca. 1.74 Ga basement characteristic of the Yavapai province is present beneath the Mazatzal province, and that the Mazatzal province is para-autochthonous with respect to the Yavapai province.

# REFINING THE AGE OF THE RESERVE GRABEN, WEST-CENTRAL NEW MEXICO, WITH $^{40}$AR/$^{39}$AR DATING.

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The Reserve Graben is a small rift basin situated between three major tectonic features of the Southwestern United States: the Rio Grande Rift to the east, the Colorado Plateau to the northwest, and the Basin and Range Province to the southwest. The graben's location at the junction of these three features suggests its formation can be tied to their relative motions (Martin et al., this meeting). However, more data are needed on the age and duration of rifting within the graben. In order to refine older, mainly K/Ar ages of graben fill, 11 samples taken from igneous intrusive and extrusive units interlayered with the basin fill have been dated using the 40Ar/39Ar radiometric method. Dated materials include groundmass from 10 basalt flows and biotite/sanidine from a quartz diorite volcanic plug. The oldest basalt, within the deepest sediments near the floor of the basin, yields an age of 16.35 ± 0.04 Ma while the youngest basalt age is 1.89 ± 0.01 Ma. The latter flow crosses the master fault of the graben without offset, providing a minimum age for fault activity, which is slightly older than the previous K/Ar age of 1 Ma (Marvin et al., 1987). Another basalt, previously dated by K/Ar at 19.2 ± 2.5 Ma (Ratté 1980), yields a precise 40Ar/39Ar age of 16.02 ± .04 Ma, consistent with other basalts in the area. These findings suggest that rifting in the Reserve Graben began significantly later than the previously estimated 21 Ma (Crews, 1994). Onset of Reserve Graben subsidence around 16 Ma corresponds closely with a rapid pulse of subsidence in the nearby Rio Grande Rift during early and middle-Miocene time (Chapin & Cather, 1994). This also occurred during the transition from southwest-directed to west-northwest-directed extension in the Basin and Range Province (McQuarrie & Wernicke, 2005). Additional samples are being dated to determine sedimentation rates and constrain better the youngest sedimentation history within the basin.

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