New Mexico Geological Society

Proceedings Volume

Recent Advances in Geophysics in New Mexico

2019 Annual Spring Meeting

Macey Center

New Mexico Tech

Socorro, NM

New Mexico Geological Society

NEW MEXICO GEOLOGICAL SOCIETY
2019 SPRING MEETING
Friday, April 12, 2019
Macey Center
New Mexico Tech Campus
Socorro, New Mexico 87801

NMGS EXECUTIVE COMMITTEE
President: Dan Koning
Vice President: Shannon Williams
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2018 SPRING MEETING COMMITTEE
General and Technical Program Chairs: Shari Kelley & Alex Rinehart
Registration Chair: Connie Apache
Web Support: Adam Read

Registration

Lobby: *7:30 AM - 12:00 PM*

NMGS Business Meeting and Student Awards Ceremony

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

NMBGMR Presentation of Earth Science Achievement Award to Barry Kues

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

Keynote Address

The Tectonics of the Central Rio Grande Rift: Results from an Integrated Geophysical and Geological Approach

W. Scott Baldridge

LANL and SAGE

Auditorium: *8:45 AM - 9:30 AM*
Chair: Shari Kelley

Break I: Networking and coffee break

Visit with vendors!

Lobby: *9:30 AM – 9:45 AM*

ORAL PRESENTATIONS

Geophysics I

Auditorium: *9:45 AM – 11:15 AM*
Moderator: Alex Rinehart

APPLICATION OF SELF POTENTIAL (SP) SURVEYS AND SHALLOW TEMPERATURE GRADIENT MEASUREMENTS AT A WARM SPRING AREA NEAR HILLSBORO, NEW MEXICO
— James C. Witcher and Howard P. Ross
9:45 AM - 10:00 AM

SINKHOLES AS TRANSPORTATION AND INFRASTRUCTURE GEOHAZARDS IN MIXED EVAPORITE-SILICICLASTIC BEDROCK, SOUTHEASTERN NEW MEXICO
— Lewis Land, Colin Cikoski, George Veni, and David McCraw
10:00 AM - 10:15 AM

SEDIMENT FLUX AND THE ACOUSTIC CHARACTERISTICS OF BEDLOAD IN THE ARROYO DE LOS PIÑOS, NM
— Kyle Anderson Stark, Daniel Cadol, Jonathan B. Laronne, and Madeline Richards
10:15 AM - 10:30 AM

SIGNALS OF FOCUSED RECHARGE ALONG AN EPHEMERAL WASH BY REPEAT MICROGRAVITY SURVEYS, ARROYO DE LOS PIÑOS, NM
— Alex J. Rinehart, Jeffrey Kennedy, Daniel Cadol, Shari Kelley, Madeline Richards, and Kyle Stark
10:30 AM - 10:45 AM

REPEAT MICROGRAVITY MONITORING OF RIO GRANDE RIVER SEEPAGE AND GROUNDWATER WITHDRAWALS IN THE MESILLA VALLEY, NEW MEXICO
— Libby Kahler, Meghan Bell, Andrew Roberston, and Jeffrey Kennedy
11:00 AM - 11:15 AM

A SPACE-BASED GEOFLUIDS OBSERVATORY FOR NEW MEXICO
— Ronni Grapenthin, Alex Rinehart, Shari Kelley, Mark Person, and Emily Graves
10:45 AM - 11:00 AM

Paleontology, Stratigraphy, Volcanology and Sedimentology

Galena Room: *9:45 AM - 11:15 AM*
Moderator: Gary Morgan

SELACHIAN-DOMINATED VERTEBRATE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS TOCITO SANDSTONE, SOUTHEASTERN SAN JUAN BASISN, NEW MEXICO
— Randy J. Pence and Spencer G. Lucas
9:45 AM - 10:00 AM

THE PALEOECOLOGY OF THE LATE CRETACEOUS TURTLE *BASILEMYS*
— Asher J. Lichtig and Spencer G. Lucas
10:00 AM - 10:15 AM

OPEN
10:15 AM - 10:30 AM

PENNSYLVANIAN STRATIGRAPHY IN THE MANZANO-MANZANITA MOUNTAINS, CENTRAL NEW MEXICO
— Spencer G. Lucas, Karl Krainer, and Bruce D. Allen
10:30 AM - 10:45 AM

ADEN LAVA FLOWS, DOÑA ANA COUNTY, NEW MEXICO
— Rene A. De Hon and Richard A. Earl
10:45 AM - 11:00 AM

SPECTACULAR SOFT SEDIMENT DEFORMATION IN EOCENE LANDSLIDE KLIPPEN: SINGLE OR MULTI-STAGE SLIP HISTORY? SAWTOOTH MOUNTAINS, WESTERN NEW MEXICO
— Michael G. Chirigos and Gary Axen
11:00 AM - 11:15 AM

Break II: Networking and coffee break
Visit with vendors!
Lobby: *11:15 AM - 11:30 AM*

Geophysics II

Auditorium: *11:30 AM – 12:30 pm*
Moderator: Alex Rinehart

AN OVERVIEW OF THE ALBUQUERQUE SEISMOLOGICAL LABORATORY AND RECENT ADVANCES IN SEISMIC INSTRUMENTATION
— Robert E. Anthony, Adam T. Ringler, and David C. Wilson
11:30 AM - 11:45 AM

SEISMICITY CHARACTERISTICS ABOVE THE SOCORRO MAGMA BODY, CENTRAL NEW MEXICO
— Susan L. Bilek
12:00 PM - 12:15 PM

FIELD-SCALE FAULT-ZONE CEMENTATION FROM GEOLOGICALLY GROUND-TRUTHED ELECTRICAL RESISTIVITY
— Glenn A. Spinelli, Heather Barnes, Peter S. Mozley, and Johnny Hinojosa
12:15 PM - 12:30 PM

SEISMIC ACTIVITY IN THE PERMIAN BASIN IN NEW MEXICO
— Mairi M. Litherland
12:15 PM - 12:30 PM

Environmental Geology and Hydrology

Galena Room: *11:30 AM - 12:30 PM*
Moderator: Dan Cadol

SOIL MAPPING USING NEAR REMOTE SENSING IN SW UNITED STATES
— Theodore Miller and J. Bruce Harrison
11:30 AM - 11:45 AM

GEOCHRONOLOGIC AND PALEOCLIMATOLOGIC INTERPRETATIONS OF PLIOCENE INTERTRAPPEAN PALEOSOLS, TAOS PLATEAU, NEW MEXICO
— Gage Richards Lamborn, Victor French, and Kevin M. Hobbs
11:45 AM - 12:00 PM

OBSERVING A DIMINISHING SNOWMELT PERIOD IN THE HEADWATERS OF THE RIO GRANDE AND THE CORRELATIONS TO RISING GLOBAL AIR TEMPERATURES
— Max Fajardo
12:00 PM - 12:15 PM

MAPPING SOIL WATER HOLDING CAPACITY IN THE STATE OF NEW MEXICO: A MODEL-BASED APPROACH.
— Gabriel Edwin Lee Parrish, Jan M. H. Hendrickx, Fred M. Phillips, and Daniel Cadol
12:15 PM - 12:30 PM

LUNCH BREAK

Lunch - Student / Professional Mixer ***(ticket required)***

Copper Room (lower level): *12:30 PM* **-** *1:45 PM*

Thank you to donors to the Student/Professional Lunch Mixer

W. Scott Baldridge
James Cearley
Paul Drakos
Michaella Gorospe
Nicolas Harrison
Michael Herman
Fred Hinker
Colleen Hinker
Larry Kemp
Jack Oviatt
Paul Schwering

Other Spring Meeting Contributors

Robert Newcomer
Nicolas Harrison
Eric Kappus
Robert Couch

Structural and Economic Geology

Auditorium: *1:45 PM - 3:30 PM*
Chair: Karl Karlstrom

FARALLON FLAT-SLAB SUBDUCTION AND NEW MEXICO GEOLOGY
— Jolante van Wijk, Gary Axen, and Claire Currie
1:45 PM - 2:00 PM

TIMING OF LARAMIDE DEFORMATION ONSET IN NORTHERN ARIZONA-NEW MEXICO AND ITS TECTONIC IMPLICATIONS
— Jacob Oliver Thacker, Shari A. Kelley, Karl E. Karlstrom, Jerry J. Kendall, and Ryan S. Crow
2:00 PM - 2:15 PM

COOLING HISTORIES OF EXHUMED FOOTWALL FAULT BLOCKS FROM THE SOUTHERN RIO GRANDE RIFT AND EASTERN BASIN AND RANGE USING U-TH/HE THERMOCHRONOLOGY
— Michelle M. Gavel, Jeffrey M. Amato, Jason W. Ricketts, and Shari A. Kelley
2:15 PM - 2:30 PM

NEW ^{40}AR/^{39}AR DATES IN RIO MORA, NM: REGIONAL CONTEXT AND EVIDENCE FOR AN OROGENIC PLATEAU BUILT DURING THE PICURIS OROGENY
— Daniel Joseph Young, Lisa Gaston, Matt Heizler, and Karl Karlstrom
2:30 PM - 2:45 PM

VARIATIONS IN CHALCOCITE TRACE ELEMENT COMPOSITIONS: COMPARISON OF HYPOGENE AND SUPERGENE SULFIDE ENVIRONMENTS
— Bright Duah and William X. Chavez Jr.
2:45 PM - 3:00 PM

BIOTITE AND CHLORITE GEOTHERMOMETRY OF THE LOMAS BAYAS PORPHYRY COPPER DEPOSIT IN NORTHERN CHILÉ
— Ryan Joseph Helms
3:00 PM - 3:15 PM

MINERALOGICAL CHARACTERIZATION AND AN INSIGHT ON THE SILVER DISTRIBUTION ON SULFIDES AT LAS LUCES VOLCANIC HOSTED CU-AG DEPOSIT, CHILE
— Dante Padilla and William X. Chavez Jr.
3:15 PM - 3:30 PM

Environmental Geology and Hydrology II

Galena Room: *1:45 PM - 3:15 PM*
Moderator: Dan Cadol

WELL TESTING INVESTIGATION OF FAULTS AS COMPLEX SUBSURFACE FLOW BARRIERS
— Tyler Sproule, Glenn Spinelli, John Wilson, Michael Fort, Peter Mozley, Johnny Hinojosa, and Jared Ciarico
1:45 PM - 2:00 PM

MAPPING SUITABILITY FOR MANAGED AQUIFER RECHARGE IN ALBUQUERQUE, NEW MEXICO
— Daniel J. Koning, Colin T. Cikoski, Andrew P. Jochems, and Alex J. Rinehart
2:00 PM - 2:15 PM

EFFECTS OF MINERALOGY AND LIXIVIANT COMPOSITION ON URANIUM LEACHING
— Alexandra Rose Pearce, Kierran C. Maher, and Karissa G. Rosenberger
2:15 PM - 2:30 PM

EXPLORING THE RINCON GEOTHERMAL SYSTEM
— Melinda Horne, Mark Person, Shari Kelley, James Witcher, and Matthew Folsom
2:30 PM - 2:45 PM

HYDROGEOLOGY AND WATER BUDGET OF THE SUNSHINE VALLEY REGION, TAOS COUNTY, NEW MEXICO
— Geoffrey Rawling and Shari Kelley
2:45 PM - 3:00 PM

NATURAL SALINIZATION OF THE JEMEZ RIVER, NEW MEXICO: AN INSIGHT FROM TRACE METAL GEOCHEMISTRY
— Jon K. Golla, Laura J. Crossey, Karl E. Karlstrom, and Abdul-Mehdi S. Ali
3:00 PM - 3:15 PM

Poster session, cash bar and afternoon snacks

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

Vendor booths in upper lobby

Sundance
Consulting Inc.

Society of Economic Geologists

POSTERS

A COLLECTION OF HISTORIC SEISMIC INSTRUMENTATION PHOTOGRAPHS AT THE ALBUQUERQUE SEISMOLOGICAL LABORATORY
— Sabrina V. Moore, Charles R. Hutt, Robert E. Anthony, Adam T. Ringler, Alexis C. B. Alejandro, and David C. Wilson
Booth: *1*

TOWARDS UNDERSTANDING THE EFFECTS OF ATMOSPHERIC PRESSURE VARIATIONS ON LONG-PERIOD HORIZONTAL SEISMIC DATA: A CASE STUDY
— Alexis C. B. Alejandro, Adam T. Ringler, David C. Wilson, Robert E. Anthony, and Sabrina V. Moore
Booth: *2*

INSAR ANALYSIS OF SOUTHEASTERN NEW MEXICO: EXPLORING SURFACE DEFORMATION DUE TO WASTEWATER REINJECTION AND MUNICIPAL AND AGRICULTURAL GROUNDWATER USE
— Emily Jo Graves and Ronni Grapenthin
Booth: *3*

EXPLORING THE PLUMBING OF THE TRUTH OR CONSEQUENCES, NEW MEXICO GEOTHERMAL SYSTEM BY USING MAGNETOTELLURIC SURVEYS, FRACTURE ANALYSIS, AND AQUIFER TESTING
— Jeffrey Pepin, Jared Peacock, Mark Person, Brad Sion, Shari Kelley, and J.J. Butler
Booth: *4*

ABANDONED MINE LANDS IN THE NORTH MAGDALENA DISTRICT, SOCORRO COUNTY, NEW MEXICO
— Nicholas G. Harrison and Virginia T. McLemore
Booth: *5*

2018-19 WATER QUANTITY AND QUALITY STUDY OF THE LOWER SANTA FE RIVER, SANTA FE COUNTY, NM: PROGRESS REPORT
— Ryan Mann and Jennifer Lindline
Booth: *6*

RAINFALL-RUNOFF RELATIONSHIPS COMPLEMENTING PREVIOUS SEDIMENT TRANSPORT STUDIES AT THE ARROYO DE LOS PIÑOS, SOCORRO, NEW MEXICO
— Madeline A. Richards, Daniel Cadol, Kyle Stark, Jonathan Laronne, and David Varyu
Booth: *7*

HYDROGEOCHEMICAL ANALYSIS OF THE SANDIA AND MANZANO MOUNTAINS, NEW MEXICO
— Brittany Lyn Griego, Laura Crossey, Livia Crowley, Abigail Axness, Ryan Webb, and Adrian Marziliano
Booth: *8*

HISTORICAL TRENDS IN PHYSICAL PROPERTIES OF THE SURFICIAL AQUIFER IN VALENCIA COUNTY, NEW MEXICO
— Cory A. Griego, Victor E. French, and Kevin M. Hobbs
Booth: *9*

EVALUATION OF A NEW AQUIFER STORAGE AND RECOVERY (ASR) WELL FOR THE ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY, ALBUQUERQUE, NEW MEXICO
— Christopher Wolf, Amy Ewing, Elizabeth Bastien, and Katherine Yuhas
Booth: *10*

IDEALIZED MODELING OF SUBSURFACE FLOW BARRIER SENSITIVITIES
— Tyler Sproule, John Wilson, Glenn Spinelli, Michael Fort, Peter Mozley, and Johnny Hinojosa
Booth: *11*

ANALYZING STORM WATER RUNOFF IN DOWNTOWN SILVER CITY, NEW MEXICO
— Raven Jackson
Booth: *12*

A COMPARISON OF U-PB DETRITAL GEOCHRONOLOGIC PROVENANCE TRENDS FROM UPPER CRETACEOUS NONMARINE STRATA OF THE DAKOTA GROUP ACROSS NORTHERN, CENTRAL, AND SOUTHERN NEW MEXICO
— Brian A. Hampton, Samantha R. Bartnik, Greg H. Mack, and Cody J. Stopka
Booth: *13*

AN UPDATE ON THE MICROBIALLY-INDUCED SEDIMENTARY STRUCTURES (MISS) OF THE PRECAMBRIAN (STENIAN) CASTNER FORMATION, NORTHERN FRANKLIN MOUNTAINS, EL PASO, TEXAS
— Eric J. Kappus, Anthony Alvarez, Joe Cancellare, and Spencer G. Lucas
Booth: *14*

U-PB DETRITAL GEOCHRONOLOGY AND PROVENANCE COMPARISONS FROM NONMARINE STRATA OF THE DAKOTA GROUP, LYTLE SANDSTONE, AND MORRISON FORMATION IN NORTHEASTERN NEW MEXICO
— Samantha R. Bartnik, Brian A. Hampton, and Greg H. Mack
Booth: *15*

MANTLE SOURCE IDENTIFICATION FOR MIDDLE MIOCENE MAGMATISM ON EASTERN FLANKS OF THE RIO GRANDE RIFT, NORTHERN NEW MEXICO
— Jennifer Lindline, Richard Pratt, and Michael Petronis
Booth: *16*

DISTRIBUTION AND STRATIGRAPHY OF UPPER PENNSYLVANIAN ROCKS IN THE TIJERAS CANYON AREA, CENTRAL NEW MEXICO
— Bruce D. Allen, Spencer G. Lucas, Karl Krainer, Filiberto Gomez, Mauro Torres, and Chris Hurren
Booth: *17*

THE PENNSYLVANIAN SECTION AT BISHOP CAP, DOÑA ANA COUNTY, NEW MEXICO
— Karl Krainer, Spencer G. Lucas, and James E. Barrick
Booth: *18*

THE TORTOISE *CAUDOCHELYS* FROM THE MIOCENE TESUQUE FORMATION OF THE ESPAÑOLA BASIN, NEW MEXICO
— Asher J. Lichtig and Spencer G. Lucas
Booth: *19*

A COPROLITE OF THE BONE-CRACKING DOG *BOROPHAGUS* FROM THE PLIOCENE OF SOUTHWESTERN NEW MEXICO AND A REVIEW OF PLIO-PLEISTOCENE COPROLITES OF LARGE VERTEBRATES FROM THE STATE
— Adrian P. Hunt and Spencer G. Lucas
Booth: *20*

AN ASSEMBLAGE OF FRESHWATER INVERTEBRATES AND OTHER FOSSILS FROM THE UPPER CRETACEOUS FOSSIL FOREST MEMBER OF THE FRUITLAND FORMATION, FOSSIL FOREST RESEARCH NATURAL AREA, SAN JUAN COUNTY, NEW MEXICO
— Charles A. Turner, Asher Jacob Lichtig, Spencer G. Lucas, and Adrian P. Hunt
Booth: *21*

NEW RECORDS FROM NEW MEXICO OF THE CRETACEOUS AMMONITE *PLACENTICERAS* EXTEND ITS BIOSTRATIGRAPHIC RANGE IN THE WESTERN INTERIOR
— Paul L. Sealey and Spencer G. Lucas
Booth: *22*

EXTREMELY RARE COLOR PATTERN IN AN EXCEPTIONALLY WELL PRESERVED INOCERAMID BIVALVE FROM THE UPPER CRETACEOUS PIERRE SHALE OF NEW MEXICO
— Paul L. Sealey and Spencer G. Lucas
Booth: *23*

PREPARATION AND DESCRIPTION OF SEVERAL CRANIAL ELEMENTS OF THE FOSSIL ELEPHANT *GOMPHOTHERIUM PRODUCTUM* (PROBOSCIDEA) FROM THE MIDDLE MIOCENE (LATE BARSTOVIAN) OF THE ESPAÑOLA BASIN OF NORTHERN NEW MEXICO
— Timothy James and Gary Morgan
Booth: *24*

TOWARDS UNDERSTANDING THE EFFECTS OF ATMOSPHERIC PRESSURE VARIATIONS ON LONG-PERIOD HORIZONTAL SEISMIC DATA: A CASE STUDY

Alexis C. B. Alejandro[1], Adam T. Ringler[1], David C. Wilson[1], Robert E. Anthony[1] and Sabrina V. Moore[1]

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Incoherent noise generated by seismometer tilt caused by atmospheric pressure variations often limits seismological studies utilizing long-period (>10 s period), horizontal-component seismic records. Several case studies have suggested methodologies for correcting these unwanted signals using collocated pressure records. However, it is unclear if these corrections are applicable to a variety of different geologic settings and installation types (e.g., vault vs. posthole). To better understand how long-period, pressure-induced noise changes with time and emplacement, we examine the coherence of signals recorded on collocated seismometers and barometers at five different Global Seismographic Network (GSN) stations. We also examine three Streckeisen STS-2 broadband seismometers collocated with a barometer at the Albuquerque Seismological Laboratory (ASL).

We calculate the mean magnitude-squared coherence between seismic and pressure signals from collocated sensors to determine the relationship between them as a function of both frequency and time. In addition to these two varying parameters, coherence levels vary greatly even on collocated seismic instruments. This suggests that tilt-generated signals are highly sensitive to very local (<10 m) site effects, making it difficult to apply pressure corrections to horizontal component seismic data unless the effects of the pressure changes are greater than those from the local site. Additionally, the frequency dependence of the coherence suggests that some corrections may only be applicable over a limited range of frequencies. Using this information, we hope to be able to identify locations that are highly susceptible to pressure-induced horizontal noise, identify locations in a vault where tilt effects can be mitigated, and understand the optimal frequency bands for applying pressure corrections.

Keywords:

seismometer, long period, atmospheric pressure

Distribution and Stratigraphy of Upper Pennsylvanian Rocks in the Tijeras Canyon Area, Central New Mexico

Bruce D. Allen[1], Spencer G. Lucas[2], Karl Krainer[3], Filiberto Gomez[4], Mauro Torres[4] and Chris Hurren[4]

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[2]New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, NM, 87104
[3]Institute of Geology, University of Innsbruck, Innrain 52, A-6020, Innsbruck, Austria
[4]GCC Rio Grande Inc., P.O. Box 100, 11783 State Highway 337, South Tijeras, NM, 87059

Investigations of the Pennsylvanian System in central New Mexico during the past two decades have led to a stratigraphic nomenclature that appears to be applicable over a large area of the state, from the Sierra Oscura of Socorro County northward to the Sandia Mountains of Bernalillo County, a transect of about 150 km. Thus, Middle and Upper Pennsylvanian (Atokan-Virgilian) marine and marginal-marine strata are assigned to the Sandia Formation (containing a relative abundance of siliciclastic deposits), the overlying Gray Mesa Formation (dominantly carbonate facies), and the Atrasado Formation (alternating siliciclastic- and carbonate-dominated intervals). A number of intraformational units (members) have been identified, with eight members in the Middle-Upper Pennsylvanian Atrasado Formation presently recognized. An uninterrupted section of the Pennsylvanian System is exposed in Tijeras Canyon east of Albuquerque, NM, along a prominent, NE-SW trending ridge ("Tijeras hogback"), which runs along the eastern side of the Tijeras fault zone for approximately 5 km to the east of I-40 and south of Seven Springs. Because these rocks have provided the raw material for the production of Portland cement since the 1950s, geologists at the cement plant in Tijeras, NM, have long had a practical incentive to characterize and delineate the distribution of Pennsylvanian stratigraphic units in a 10 km^2 area extending south of the village. The cement quarries are developed in the Atrasado Formation, and the informal lithostratigraphic scheme developed by geologists at the cement plant is similar to the formal, eight-member division of the Atrasado Formation in current use (the industrial classification consists of nine lithostratigraphic members, rather than eight). Geologic mapping by geologists at the cement plant beginning in the late 1950s produced a detailed interpretation of the distribution of Upper Pennsylvanian strata in the vicinity of the quarries, thus providing basic structural information for an area to the east of the Tijeras fault zone that has received little detailed attention in published map compilations. A measured section of the Pennsylvanian succession across the Tijeras hogback yields a thickness estimate of 356 meters (Sandia- 56 m, Gray Mesa- 68 m, Atrasado- 232 m). Mississippian? redbeds and dolomitic mudstone (~20 m thick) are present between the Sandia Formation and Proterozoic basement on the steep western side of the hogback, and the Atrasado Formation is overlain by siliciclastic and carbonate facies of the transitional Pennsylvanian-Permian Bursum Formation in exposures along Highway 337 near the Tijeras ranger station and in a quarry a few hundred meters southwest of the cement plant ovens. The fact that industry geologists independently developed an internal lithostratigraphic classification of the Atrasado Formation essentially identical to the subdivisions recognized by university and museum geologists is confirmation of the ready recognition and utility of these subdivisions in regional stratigraphy, mapping and economic geology.

AN OVERVIEW OF THE ALBUQUERQUE SEISMOLOGICAL LABORATORY AND RECENT ADVANCES IN SEISMIC INSTRUMENTATION

Robert E. Anthony[1], Adam T. Ringler[2] and David C. Wilson[2]

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[2]U.S. Geological Survey, Albuquerque Seismological Laboratory, Target Road 10002 Isleta SE, Albuqueruqe, NM, 87117

The Albuquerque Seismological Laboratory (ASL) was established in 1961 in one of the seismically quietest regions in the country in order to test seismometers for what is now the U.S. Geological Survey (USGS). In the subsequent decades, that mission has expanded to include the operation and management of the Global Seismographic Network, the Advanced National Seismic System, and numerous regional and aftershock networks. Data from these networks are utilized by the USGS to rapidly characterize earthquakes both within the United States and across the globe. In this presentation, we will provide a brief overview of the ASL and present some of our work quantifying the performance of recently developed seismic instrumentation. We will present results on sensors which enable unique observations of ground motion such as rotational seismometers developed by Applied Technology Associates in Albuquerque, as well as new low-cost instruments such as the Fairfield Nodal Z-land sensors and Raspberry Shake seismographs.

TECTONICS OF THE CENTRAL RIO GRANDE RIFT: RESULTS FROM AN INTEGRATED GEOPHYSICAL AND GEOLOGICAL APPROACH

W. Scott Baldridge

Los Alamos National Laboratory, Earth and Environmental Sciences Division, Los Alamos National Labs MS T003, Los Alamos, NM, 87545, United States, sbaldridge@lanl.gov

Structural connections ("accommodation zones") between basins in continental rifts are of different types, typically with different orientations even within a single rift. They play an important role in controlling distribution and facies of syntectonic sediments and magmatic rocks, and therefore resources such as groundwater, hydrocarbons, and minerals. Because these zones are commonly buried beneath rift-filling sediments, geophysical methods are of paramount importance in characterizing and understanding them. In the *Summer of Applied Geophysical Experience* (SAGE) program we focused on the eastern part of the complex "Santo Domingo accommodation zone," a major structural zone of the central Rio Grande rift. This margin comprises a right-echelon stepover from the southern Española basin (EB) to the larger Albuquerque basin (AB) to the south. Within this zone, recent and currently active structures are superimposed across those of earlier periods of deformation (e. g., Laramide). We integrated existing geological mapping and borehole information with geophysical data acquired by industry surveys and by SAGE to understand timing and kinematic development of this complex zone.

The eastern margin of the broad Santo Domingo zone comprises at least three right-stepping relay faults (La Bajada, San Francisco, and Rincon faults), separated by plunging ramps trending parallel with the axes of the major basins and progressively downthrown toward the rift axis. These faults "relay" extension between the main EB and AB. From our data we tentatively estimate that ~3.2 km of vertical offset and an unknown amount of lateral slip has occurred on the prominent La Bajada fault zone. Significant flexural uplift has occurred on the footwall of the fault, producing shoulder uplift adjacent to the Española basin. On the San Francisco fault >1 km of vertical slip has occurred where imaged within the basin, but offset increases southward. We estimate that extension across these two faults is at least 2.5 km. Uplift of the Sandia block, combined with overlap of the La Bajada and San Francisco faults and greater vertical offset along the southern San Francisco fault, created a narrow, northward-plunging synform (Hagan basin) on the hanging wall of the La Bajada fault. West of the San Francisco and Rincon faults lies the deep Santo Domingo basin, which gravity data suggest may be 6 km deep. We find no evidence in the Santo Domingo accommodation zone for any significant northeast trending faults, in contrast with the prominent Embudo fault zone separating the San Luis and Española basins. Because lower Tertiary sedimentary rocks in the Hagan basin are deformed concordantly with underlying Paleozoic and Mesozoic rocks, we infer that structures in the accommodation zone formed together in the middle to late Tertiary, concurrently with uplift of the Sandia Mountains ~15-10 Ma. Growth over a substantial period of time is compatible with vertical offset along the La Bajada fault of ~3200 m on Precambrian rocks but only 200-300 m on 2.8 my old basalt. The pattern of relay faulting expressed within the Santo Domingo accommodation zone is compatible with left-lateral shearing along the axis of the Rio Grande rift.

U-PB DETRITAL GEOCHRONOLOGY AND PROVENANCE COMPARISONS FROM NONMARINE STRATA OF THE DAKOTA GROUP, LYTLE SANDSTONE, AND MORRISON FORMATION IN NORTHEASTERN NEW MEXICO

Samantha R. Bartnik[1], Brian A. Hampton[1] and Greg H. Mack[1]

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U-Pb detrital zircon ages from nonmarine sedimentary rocks of the Early–Late Cretaceous (Albian–Cenomanian) Dakota Group, Late Jurassic–Early Cretaceous(?) Lytle Sandstone, and Late Jurassic (Tithonian) Morrison Formation in northeastern New Mexico provide new geochronologic and provenance constraints on the age range and source of detritus delivered to the Cordilleran foreland basin during Jurassic–Cretaceous time. Presented here are four U-Pb detrital zircon age spectra (n=978 analyses) from detrital zircons extracted from the Pajarito Formation and Mesa Rica Sandstone members of the Dakota Group and underlying Lytle Sandstone in the western Dry Cimarron Valley east of Raton, New Mexico, as well as the uppermost part of the Morrison Formation exposed in the Crestone anticline near Las Vegas, New Mexico. All four stratigraphic units share strong similarities in occurrences of Paleo-Mesoproterozoic zircon ages with the majority falling between 1800–1600 (Yavapai-Mazatzal provinces), 1450–1350 (A-type granitoids), and 1300–1000 Ma (Grenville province). Neoproteozoic–Jurassic peak ages are also similar across each unit with primary peaks occurring between 625–595, 430–415, and 190–150 Ma. Neoproteozoic and early Paleozoic ages overlap with recycled Mesozoic eolianites of the Colorado Plateau, whereas Jurassic ages overlap with magmatic sources of the Cordilleran arc. We note, however, that although the Mesa Rica Sandstone and Pajarito Formation both contain elevated occurrences of Cretaceous-age zircons with similar peak ages between 105–95 and 125–120 Ma, there are no occurrences of zircons younger than Late Jurassic in either the Morrison Formation or Lytle Sandstone. The nine youngest ages from the Morrison Formation fall between Early–Late Cretaceous (between ~190–150 Ma), whereas the nine youngest ages from the Lytle are between Middle–Late Jurassic (~172–150 Ma). The nine youngest ages from overlying strata of the Mesa Rica Sandstone and Pajarito Formation are all Late Cretaceous (Cenomanian–earliest Turonian) and occur between ~100–92 Ma. The youngest detrital zircon ages from the Morrison Formation and Lytle Sandstone support a Late Jurassic (Tithonian) age for both of these units, whereas the youngest ages from both members of the Dakota Group indicate an age of earliest Late Cretaceous (Cenomanian). The youngest ages from the Dakota Group and Morrison Formation overlap with previously reported biostratigraphic age constraints from these units. It is important to note that although our new geochronologic constraint from the Lytle Sandstone supports a latest Late Jurassic age for these strata, there are scenarios where the Lytle could be interpreted to be younger in age than Late Jurassic (i.e., Early Cretaceous). It is certainly possible that Late Cretaceous zircons in the Dakota Group represent reworked, air-fall tuffs from the Cordilleran arc (rather than fluvial, water-laid deposits), thus absences of these young Cretaceous grains in the Lytle could be interpreted as a temporary hiatus in air-fall material to the Lytle during the Early Cretaceous. In this scenario, the similarity in zircon ages and provenance between the Lytle and Morrison could be explained by later reworking and recycling of Morrison detritus into the Lytle during the Early Cretaceous.

SEISMICITY CHARACTERISTICS ABOVE THE SOCORRO MAGMA BODY, CENTRAL NEW MEXICO

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Seismicity within the central New Mexico, USA region is dominated by deformation processes associated with the Socorro Magma Body (SMB), a large mid-crustal continental magma body at 19-km depth within the Rio Grande Rift. Seismicity has been monitored in this region for decades by a permanent short period network operated by New Mexico Tech, and the resulting catalogs show long-term seismic activity punctuated by discrete earthquake swarms. Waveform characteristics, notably the observation of reflected phases arising from the magma body recorded on this sparse network, led to the discovery of the SMB and estimates of its spatial extent. Here I provide an overview of the seismic observations made with the permanent seismic network, as well as more recent temporary deployments. This includes analysis of the long-term seismicity patterns, including spatial and temporal variations in earthquake swarms, earthquake depth distributions, as well as a review of the observations used to assess spatial extent of the magma body at depth.

SPECTACULAR SOFT SEDIMENT DEFORMATION IN EOCENE LANDSLIDE KLIPPEN: SINGLE OR MULTI-STAGE SLIP HISTORY? SAWTOOTH MOUNTAINS, WESTERN NEW MEXICO

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The Sawtooth Mountains are the erosional remnants of large-scale Eocene mass movement deposits. The landslides occurred in volcaniclastic sandstones and conglomerates of Eocene lower Spears Group, deposited on the sedimentary apron of a stratovolcano. Two subhorizontal faults bound the bases of two slide sheets. The lower, poorly exposed, fault overlies fine-grained lowest Spears siltstones above Baca Formation. The sheet above it displays spectacular soft-sediment folds and granular faults and is bounded above by a fault with 15-60 cm of catclasite and ultracataclasite. Conglomerates above are mostly subhorizontal but become vertically dipping and east-facing in the east. The purpose of this study is to constrain the rate, direction, and the number of slip events that formed these composite landslide deposits, using geologic mapping, cliff-face mapping, structural and petrographic analyses.

Sparse clastic injections, and fault rock samples that show mainly randomly oriented grains, minor clay, and locally foliated ultracataclasite, suggest rapid transport. Sparse striations in the eastern parts of the study area are scattered from N to ESE and compatible with northward slip down the sedimentary apron or ESE slip from a Laramide reverse fault (Dobbins, 2016). Many new kinematic data (striations and from Reidel shear orientations) also cluster in N and ESE directions, with much scatter. Overturned fold hinges also exhibited scatter in both attitude and vergence, showing clustering only locally. Sparse evidence for multiple movements was observed, including folding of the upper detachment, clasts of fault rock mixed into basal hanging wall, clasts of cataclasite within cataclasite, and E-trending striations cross-cutting N-trending ones. We interpret that transport to the north, down the sedimentary apron, was followed by transport to the ESE from the Laramide reverse fault. Future research will focus on understanding the relationship between these landslide deposits and similar deposits in the neighboring Datil and Gallinas Mountains.

ADEN LAVA FLOWS, DOÑA ANA COUNTY, NEW MEXICO

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Aden Crater is a small, volcanic shield in the Potrillo volcanic field approximately 40 km southwest of Las Cruces. The Aden lavas cover 63 km2 superposed on the La Mesa surface composed of Camp Rice sediments and the older Gardner-Afton lavas. The shield and surrounding flow field consist of volcanic physiographic facies determined by the rheology of the lava. Flow thicknesses vary from as little as one meter to as much as five meters. Thick flows were emplaced as thin, fluid flows which developed a strong outer crust that eventually retarded forward advance. Once stopped, the flows inflated to form steep, blocky-margined, flat-topped plateaus. Early attempts to thicken failed as fluid lava broke through weakened margins of early-formed inflation plateaus. Lava escaping from failed inflation plateaus allowed the plateau surface to subside and form blocky-rimmed pits. The flow field is a rugged accumulation of inflation plateaus in which opposing flow margins form deep intervening ravines. The Aden shield was formed as viscosity increased to the point that the lavas began to accumulate over the vent. The shield has a basal diameter of 2.5 km and a height of 50 m. The shield facies consist of basal thin, scabby flows; very low sloping, lobate flows; and an upper slope of steeper, channeled flows that spilled out of a lava lake in the 350-m-wide crater atop the shield. The crater is bound by a three-meter-high spatter lava rampart. The interior contains the remnants of the lava lake; an inner collapse pit formed by lava withdrawal; and a late stage spatter cone.

Keywords:

Aden crater, Crater, Inflation plateau, Lava flow, Potrillo Volcanic Field, Shield, Volcano

VARIATIONS IN CHALCOCITE TRACE ELEMENT COMPOSITIONS: COMPARISON OF HYPOGENE AND SUPERGENE SULFIDE ENVIRONMENTS

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A preliminary study of chalcocites representing hypogene and supergene geochemical environments was undertaken to determine variations in trace elements that characterize weathering-derived (supergene) vs. hypogene chalcocite. The objective is to determine those elements which might be useful in distinguishing these geochemical environments and therefore assist in assessing the nature of copper sulfides in exploration for copper ore deposits.

For this initial study, polished ore samples were prepared representing andesite-hosted Cu-Ag, copper vein, porphyry Cu-Mo systems, and carbonate replacement deposits. The polished samples were described, emphasizing copper mineralogy, textural relationships, and mineral paragenesis. Samples were then analyzed using standard electron microprobe methods, with quantitative analyses for Cu, Fe, S, Ag, As, and Bi. This suite of elements was selected because they permit discrimination of chalcocite formed from hypogene processes vs. that developed from the weathering of hypogene copper occurrences.

In similar studies of copper sulfides (e.g., see Cook et al. 2011 for a study of minor elements in bornites), researchers note that partitioning of Ag and Bi into some copper sulfides may be significant, suggesting that silver contents may be substantial contributors to the net value of a copper ore. In this study, we examine copper ores to determine whether certain trace elements are diagnostic in defining the geochemical origin of chalcocite, with subordinate interest also in covellite. For each sample we analyzed, the assessment of whether the chalcocite represented hypogene or supergene environments was initially based on spatial location within a given ore deposit, mineral textures, and ore mineral associations.

Our study shows that silver and iron are enriched in chalcocites of hypogene derivation but are generally very scant in supergene chalcocites. Supergene chalcocites are uniformly low in As and Bi, probably reflecting the limited mobility of these elements in the supergene environment in the presence of oxidized iron. Because Ag and Fe substitute for copper in most copper sulfides at hypogene temperatures (e.g., Yund and Kullerud, 1966; see also Chávez, 1985; Craig and Vaughan, 1994), the supergene chalcocites are found to be uniformly low in with respect to Ag and Fe contents. Our initial results suggest that discrimination of supergene and hypogene chalcocites, and very likely, associated covellites, is possible using the trace elements Ag and Fe; analyses of other trace elements, notably Co and Zn, would likely improve our ability to distinguish between hypogene and supergene copper sulfides. Application of such determinations would enhance interpretation of copper and silver geochemical exploration survey data when engaged in ore search for, and economic evaluation of, copper deposits modified by weathering-related processes.

OBSERVING A DIMINISHING SNOWMELT PERIOD IN THE HEADWATERS OF THE RIO GRANDE AND THE CORRELATIONS TO RISING GLOBAL AIR TEMPERATURES

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Climate models continue to illustrate a future with lesser water flux in the Southwestern United States. Along with diminishing reservoirs of water and anomalous fluxes in precipitation, the southwest is experiencing sooner than expected peak snowmelt runoff on the order of days. With the sooner snowmelt runoff peak, the less time the snowpack has to accumulate over the cold winter months. Hence we seek to demonstrate the relationship between global air temperature and receding peak runoff values. The data used are from the Rio Grande headwaters stream flux provided by NOAA. Through the research we seek to present numerically modelled recessions in peak snowmelt runoff; moreover, we find that peak runoff timing is getting earlier in the year and it's not clear that there is a direct relationship with global air temperature models. Thus, there is currently research in progress on the principal causes of the shifting peak snow runoff date. The methods of research are nonlinear algorithm writing and k-clustering machine learning using Python and its accompanying libraries.

Cooling Histories of Exhumed Footwall Fault Blocks from the Southern Rio Grande Rift and Eastern Basin and Range Using U-Th/He Thermochronology

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The Basin and Range province and Rio Grande rift (RGR) form a complex region that records a major transition in the tectonic history of North America from Laramide shortening to Cenozoic crustal extension. Driving mechanisms for this episode are still highly debated and include changes in stress field, widespread small-scale mantle convection, and growth of the San Andreas transform boundary. A suite of apatite (AHe) and zircon (ZHe) (U-Th)/He and apatite fission-track (AFT) dates have been collected from across southern New Mexico and easternmost Arizona. These data were modeled with the program HeFTy to constrain the cooling history of fault-block uplifts that form the physiographic transition zone between the Basin and Range and Rio Grande rift. AHe ages range from 3–22 Ma, ZHe ages range from 2–649 Ma, and AFT ages range from 10–34 Ma with average track length distributions of 10.8–14.1μm.

Time-temperature models created from combining AHe, AFT, and ZHe data were used to delineate the spatial pattern of the timing of rapid extension in each of the locations sampled across southern New Mexico. The Chiricahua Mountains and Burro Mountains have an onset of rapid (cooling rates exceeding 15°C/My) extension at ca. 29–17 Ma, whereas in the Cooke's Range a similar period of rapid extension is observed at ca. 19–7 Ma. In the San Andres Mountains, Caballo Mountains, and Fra Cristobal range, rapid extension is observed ca. 23–9 Ma. Measured average track lengths are longer in Rio Grande rift samples and ZHe ages of >40 Ma have only been observed west of the Cooke's range, suggesting different exhumation conditions of the zircon partial retention zone and the AFT partial annealing zone. This supports onset of Basin and Range extension that both precedes and overlaps with the main phase of opening of the Rio Grande rift along its entire length beginning ca. 25 Ma. Additional work is being done to evaluate the impact of Mogollon-Datil and other Paleogene volcanism on samples in the Burro, Chiricahua, and Florida Mountains.

Natural Salinization of the Jemez River, New Mexico: an Insight from Trace Metal Geochemistry

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The Jemez River (JR), a tributary of the Rio Grande, receives thermal water input from the geofluids of the Valles Caldera (VC), an active, high-temperature ($\leq 300^{\circ}C$), liquid-dominated geothermal system. We focus on a ~50-km portion of the northern JR, spanning a segment from the East Fork JR headwaters to the town of San Ysidro. Previous decadal work during low-flow conditions (~10-20 cfs) has characterized significant major-solute contributions from two outflow expressions of the VC, Soda Dam Springs and Jemez Hot Springs, and two major tributaries, Rio San Antonio and Rio Guadalupe. Generally, there is a net ~500 ppm increase from above the thermal springs to the end of the study reach. This research extends the suite of measured dissolved elemental species by including trace metals (like As, Pb, and U). We discern between conservative behavior, marked by changes in downstream concentrations exclusively attributed to mixing, and non-conservative behavior, which may be a result of removal processes such as co-precipitation and adsorption. To identify and understand these potential secondary reactions, we supplement solute chemistry data with spatial surveys of physiochemical parameters (pH, dissolved oxygen, temperature, oxidation-reduction potential, and turbidity) with regular 1-km spacing and denser (50-m) sampling along sites with complete aqueous chemistry.

Keywords:

aqueous geochemistry, Valles Caldera, geothermal

A SPACE-BASED GEOFLUIDS OBSERVATORY FOR NEW MEXICO

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Sustainable use of groundwater resources and a detailed understanding of aquifer structure, dynamics and long-term evolution are of importance to all aspects of human life, particularly in arid regions with limited recharge. Aquifers are generally monitored via hydraulic head changes in monitoring wells. Similarly, hydrocarbon production and reinjection of brine byproducts are often reported and monitored but, just like groundwater estimates, they are limited to point observations, limiting insight into reservoir dynamics. Assessments of geofluid storage capacities, heterogeneities in their structure and composition, and evolution necessarily involve a large degree of interpolation between observation points based on often uncertain geologic data; frequently requiring extrapolation.

Space geodetic measurements such as GPS, radar interferometry (InSAR), and satellite gravimetry (GRACE) have long been used to study motion induced by effects in the hydrosphere such as groundwater pumping and aquifer recovery. The measurements quantify elastic and permanent deformation due to pore pressure changes and mass redistributions. The most promising strategy for future basin and sub-basin scale geofluid studies is a combination of InSAR and GRACE time series due to freely available data and global coverage.

Here we present an outlook on a project to characterize New Mexico's geofluid activity due to municipal and irrigation pumping, hydrocarbon production, brine reinjection and magma transport and develop methods to better quantify subsurface mass and volume changes via InSAR and GRACE integration. Capabilities of the methods are presented as an example of InSAR-mapped surface deformation in the Buckman well field near Santa Fe. Here, we reveal decadal-scale aquifer dynamics using 25-years of InSAR data, which in combination with recent ground water temperature observations and conceptual modeling, reveal structural complexities. Furthermore, we present initial analyses of GPS and InSAR observations for the Mesilla Basin around Las Cruces, NM, where we exploit irrigation pumping as a basin-wide pump test for basin characterization in a tectonically relatively stable environment.

Keywords:

Hydrogeodesy, InSAR, Aquifer, deformation, subsidence

InSAR Analysis of Southeastern New Mexico: Exploring Surface Deformation due to Wastewater Reinjection and Municipal and Agricultural Groundwater Use

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Geodesists began utilizing interferometric synthetic aperture radar (InSAR) and time series analysis to observe deformation of the Earth's surface during the 1990s. In southeast New Mexico, municipal and agricultural production of groundwater, as well as brine reinjection after oil and gas production, are potential sources of surface deformation.

We aim to discover the extent of deformation and resolve the locations and depths of well sites and the volume of fluid injected and extracted by using InSAR to image this region. We use SAR scenes obtained by the European Space Agency's Sentinel -1A and 1B platforms, operational from 2014 and 2016 respectively, retrieved from the Alaska Satellite Facility's data portal. These freely available data provide full coverage of the region every ~12 days along different flight paths.

We utilize GMTSAR software for the interferometric analysis of individual SAR scenes dating as far back in time as October 2014. The resulting interferograms, all referenced to the same master image, are then analysed with various time series techniques to reduce the noise in the individual interferograms and recover smaller amplitude signals. From the deformation observed at the Earth's surface, we recover the locations and volume of the injected wastewater and extracted groundwater using Bayesian inverse methods for pressure point sources embedded in an elastic half space.

Through the analysis of surface deformation, our preliminary work provides insight into dynamic processes at shallow depths such as the evolution of groundwater resources or the resultant propagation of injection plumes. Characterizing these dynamic processes with short lag-times is vital in making informed resource management decisions.

Keywords:

InSAR, Groundwater, Deformation

HYDROGEOCHEMICAL ANALYSIS OF THE SANDIA AND MANZANO MOUNTAINS, NEW MEXICO

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Springs are an important water resource both for anthropogenic use and support of ecosystems in the arid Southwest. During times of drought, the sustainability of these groundwater systems is a major concern for effective water resource management. During 2017-2019, several springs were visited in the Sandia and Manzano Mountains to perform an inventory of the springs and the surrounding environment. This work is part of an ongoing collaboration between students and faculty at UNM and the US Forest Service (Cibola National Forest).

We collected water samples for water quality analysis (major ions and stable isotopes), and field water quality parameters such as pH, total dissolved solids (TDS), dissolved oxygen (DO), and discharge. We also analyzed snowpack samples from 2019. Spring samples primarily consist of calcium bicarbonate and calcium magnesium chloride sulfate waters. Trends in solute distribution are interpreted to reflect different water-rock interactions on groundwater flow paths. Our results show two distinct trends between spring waters that are interpreted to have undergone silicate weathering and those undergoing carbonate dissolution. Carbonate dissolution occurs in waters traveling through the Madera Limestone aquifer system while silicate weathering occurs as waters travel through faults within the Sandia Granite. Stable isotope analyses show that winter snowpack is the primary recharge mechanism of the majority of these waters.

In addition to data collection and analyses, we have made major efforts in compiling all datasets into a regional database (Springs Stewardship Database) to preserve valuable information, make the data accessible to others, and provide important baselines for future comparison.

HISTORICAL TRENDS IN PHYSICAL PROPERTIES OF THE SURFICIAL AQUIFER IN VALENCIA COUNTY, NEW MEXICO

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The central Rio Grande Valley in Valencia County, New Mexico, is marked by shallow water tables (~1-5 m depth), flat topography dominated by agricultural use, and a complex system of acequias (irrigation canals) that distribute Rio Grande water out of the river and onto fields on the floodplain. These three factors, among others, can lead to rapid and complex changes in surficial aquifer conditions in this region. The focus of this project is to illustrate chemical, biological, and physical properties of the groundwater at two specific locations in Valencia County: Whitfield Wildlife Conservation Area (WWCA), a former commercial dairy; and the University of New Mexico-Valencia campus, which contains large parking lots and building footprints leading to significant runoff during rain events. The water table depth and pH in wells at WWCA have been monitored monthly for approximately 10 years since their installation in 2009. Baseline geochemical data from these wells were collected in December 2009. Our study seeks to better understand the effects of land use on local aquifer properties; to include developing a partnership with the community for future research opportunities; and to understand the timing of effects of land use and management on our local groundwater. We have analyzed groundwater from these wells for the presence of bacteria in low concentrations; our results show that bacteria are present in several wells and we have identified them via DNA isolation and metagenomic analysis. We re-analyzed geochemical properties of the WWCA wells in early 2019 and present here the decade-long change in surficial aquifer geochemistry in this protected natural area. Our work has included the chemical and physical monitoring of local wells, mathematical analysis of well hydrological data, and comparison to climate, weather, water depth history, and irrigation data.

A COMPARISON OF U-PB DETRITAL GEOCHRONOLOGIC PROVENANCE TRENDS FROM UPPER CRETACEOUS NONMARINE STRATA OF THE DAKOTA GROUP ACROSS NORTHERN, CENTRAL, AND SOUTHERN NEW MEXICO

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Late Cretaceous (Albian–Cenomanian) strata crop out throughout parts of northern, central, and southern New Mexico and are thought to record the final phase of sedimentation associated with normal subduction of the Farallon plate beneath western North America, and resultant deformation and volcanism linked with the Sevier fold-thrust belt and Cordilleran arc, respectively. Presented here are U-Pb detrital zircon ages from N=7 samples (n=2046 total analyses) collected from across northern New Mexico (eastern margin of the San Juan basin in the San Ysidro region and western margin of the Great Plains near the Dry Cimarron Valley and Creston regions), central New Mexico (Socorro-Carthage region), and southern New Mexico (Mescal Canyon near the Truth or Consequences region).Detrital zircon spectra from sample localities in northern New Mexico have range of Archean–Mesozoic ages with the majority of primary and secondary peaks occurring between 1800–1600 (Yavapai-Mazatzal provinces), 1450–1350 (A-type granitoids), 1300–1000 (Grenville province) 625–595 and 430–415 (recycled Mesozoic eolianites of the Colorado Plateau), as well as 190–92 Ma (Cordilleran arc). The youngest group of zircon grains from nonmarine members of the Dakota Group in northern New Mexico range from ~100–92 Ma suggesting a youngest age of early Late Cretaceous (Cenomanian–earliest Turonian). We note that there are several samples collected from established Dakota stratigraphy where occurrences of young Cretaceous-age zircon are sparse to entirely absent. Primary and secondary peak ages from the Dakota Sandstone in central New Mexico occur primarily between 1800–1600 (Yavapai-Mazatzal provinces), 1450–1350 (A-type granitoids), 1300–1000 (Grenville province), and 240–94 Ma (Cordilleran arc and possibly older, recycled Paleozoic–Mesozoic strata). The youngest group of zircon grains from the Dakota Sandstone in central New Mexico range from ~110–94 Ma with a calculated latest Early Cretaceous (late Albian) maximum depositional age (MDA) of 102.7+/-1.1 Ma. Strata in central New Mexico have elevated occurrences of Triassic-age zircon that may reflect a combined recycled source from the underlying Chinle Formation as well as from Triassic portions of the Cordilleran arc. The Dakota Sandstone in south-central New Mexico exhibits primary and secondary peak ages very similar to the Dakota Group in northern New Mexico that occur primarily between 1800–1600, 1450–1350, 1300–1000, 625–595, 430–415, and 190–92 Ma. The youngest group of zircon grains from nonmarine portions of the Dakota in southern New Mexico range from ~107–99 Ma with a calculated Early Cretaceous (late Albian) MDA of 103.5+/-1.7 Ma. Although the sample locality in southern New Mexico is more proximal to our central New Mexico locality, there is no evidence of elevated Triassic-age zircon in this region.

Keywords:

Cretaceous, Dakota Group, Cordilleran foreland, Provenance, U-Pb detrital zircon

ABANDONED MINE LANDS IN THE NORTH MAGDALENA DISTRICT, SOCORRO COUNTY, NEW MEXICO

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The North Magdalena district in Socorro County, NM contains a number of abandoned mines. Our objective was to examine two features and perform soil petrography and paste pH analyses on collected samples. The two features examined consisted of a pit (NMSO0832) and the Silver Hill mine (NMSO0809), a shaft with collapsed head frame. Abandoned mine lands (AML) are lands that were excavated, left un-reclaimed, where no individual or company has reclamation responsibility, and there is no closure plan in effect. They include mines and mine features left unreclaimed on federal, state, private and Native American lands because the current owner was not legally responsible for reclamation at the time the mine was created. Government agencies reclaiming AML sites in the past have just reclaimed the physical hazards without any characterization of the material they use to determine if they have any acid generating potential material or elements of environmental concern that could cause environmental issues, especially to groundwater. This project is part of an effort to test a procedure developed by the AML team at NMIMT to inventory mine features and quickly, effectively, and cheaply characterize mine wastes within the North Magdalena mining district. This district was specifically chosen because it is small enough to perform the inventory and complete the characterization within a reasonable time frame.

Selected waste rock piles at the sites were mapped using a handheld GPS and/or measuring tape. Sketches of selected mines and associated waste rock piles were compiled. Composite samples of waste rock piles were collected and soil petrography and paste pH analyses were measured for each sample. The samples were examined to determine alteration type, any notable weathering features, and overall mineralogy. The grain shape was noted, after which the sample was moistened with distilled water and its color was determined. The samples were then tested to determine their paste pH. Fine grains from the sample were placed in a beaker with distilled water and the mixture was stirred until it formed a paste, the probe from the pH meter was dipped into the paste, and the data was recorded.

Soil petrography revealed that the soil was composed of 75% fine sand, silt and clay, loosely packed. The individual grains were mostly angular and poorly sorted. An acid test revealed the presence of some carbonates, probably calcite. The samples contained a small amount of organic material, such as grass and seeds. Minerals found at the sites included malachite, chrysocolla, calcite, quartz, and iron oxides. Paste pH of the samples revealed an average reading of 8.25, indicating the soil is slightly alkaline with non-acid forming potential. The Silver Hill mine is an open shaft and therefore presents physical hazard.

Keywords:

Abandoned Mines, paste pH

BIOTITE AND CHLORITE GEOTHERMOMETRY OF THE LOMAS BAYAS PORPHYRY COPPER DEPOSIT IN NORTHERN CHILÉ

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The Lomas Bayas porphyry copper deposit is located in northern Chilé approximately 110 km northeast of the port city of Antofagasta. The deposit is hosted by a Paleocene granodiorite which has been intruded by a feldspar porphyry (Chávez, 1998). The predominant alteration present is a weak K-silicate constructive potassic alteration characterized by biotite + K feldspar + quartz with biotite replacement of magmatic mafic minerals. This has been overprinted by incipient – weak chloritization. The purpose of this study is to determine the temperature of formation of the hydrothermal alteration at Lomas Bayas by using electron microprobe analyses of hydrothermal biotite and chlorite grains for use as a vectoring tool in exploration, focusing on the Ti and Mg# (Mg/Mg+Fe) relationships as a function of temperature described by (Henry et al., 2002; Henry et al., 2005; Wu and Chen, 2015) as well as the tetrahedral Al-Si relationship in chlorite related to temperature (Cathelineau, 1988; Caritat et al., 1993).

EXPLORING THE RINCON GEOTHERMAL SYSTEM

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The Rincon geothermal system is one of the highest temperature geothermal systems in New Mexico with a water table temperature of 81°C. This hydrothermal system is located within the discharge area of the Jornada del Muerto proximal to the Rio Grande. It is a blind system, having no surface expression other than opal deposits. Rincon was discovered with the use of shallow thermal wells, self-potential surveys, and radon soil-gas surveys, all of which had anomalies relating to a geothermal system. A geothermal exploration borehole (SLH-1) was drilled in 1993 to a depth of 371 m and a bottom hole temperature of 99 °C. Its temperature-depth profile did not display typical linear characteristics of steady-state geothermal systems; instead, it had higher temperatures at shallower depths, which suggested a short-term high-flow-rate transient system.

We remeasured temperature in SLH-1 in Sept. 2018 and found the temperature fully equilibrated from lost drilling fluid, but otherwise unchanged in the intervening 25 years. We hypothesize that the temperature overturn in SLH-1 is due to three-dimensional flow effects related to the interaction of the geothermal upflow zone and the regional flow field. We have built a three-dimensional groundwater flow and heat transport model of the Rincon upflow zone to test our hypothesis. We also completed three transects of transient electromagnetics (TEM), which provide vertical profiles of formation resistivity up to 500 m depth. The TEM surveys reveal a zone of high formation electrical conductivity at the water table that correspond to the geothermal system.

Keywords:

geothermal; geophysics; temperature

A COPROLITE OF THE BONE-CRACKING DOG *BOROPHAGUS* FROM THE PLIOCENE OF SOUTHWESTERN NEW MEXICO AND A REVIEW OF PLIO-PLEISTOCENE COPROLITES OF LARGE VERTEBRATES FROM THE STATE

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The upper part of the Pliocene Gila Group is exposed on Pearson Mesa, south of Virden in Hidalgo County, New Mexico. Here, there are two late Blancan vertebrate faunas from the fluvial Pearson Mesa Formation: early late Blancan Pearson Mesa LF from the lower 15 m of the section and the latest Blancan Virden LF 30 m higher in the section. NMMNH (New Mexico Museum of Natural History) P-33202 is a bone-bearing segment of a coprolite of a large carnivore from the Pearson Mesa LF (NMMNH locality 4596). The segment is off-white in color and highly apatitic in composition. It has a sub-rounded cross section with one side more flattened. The maximum width is 35 mm, and the length is 25 mm. One end is slightly concave and reveals two large, angular bone fragments. The other end is a rounded, slightly-irregular cone. We identify this specimen as representing a posterior conical segment of a borophagid coprolite based on: (1) composition; (2) morphology; (3) size; (4) bone content; and (5) age. Borophagid coprolites are currently only identified from the latest Miocene Mehrten Formation in California. *Borophagus*, the bone-crushing dog or hyena-like dog, is rare in New Mexico, represented by only five specimens from four faunas of early Blancan age. Skeletal remains of this taxon do not occur at Pearson Mesa.

This is the only vertebrate coprolite currently reported from the Pliocene of New Mexico. The most numerous coprolites from the Pleistocene of the state represent small taxa, notably rodent coprolites from neotomalites (fossil packrat middens) and chiropteraguanolite (fossil bat guano). Coprolites of large vertebrates occur at three localities in the Pleistocene of New Mexico and consist principally of specimens of *Castrocopros martini* produced by the ground sloth *Nothrotheriops shastensis*. Aden Crater is one of two localities of sloth coprolites in Doña Ana County in southern New Mexico. A narrow opening on the eastern side of the crater leads to a near vertical fumarole that formed a pitfall trap. The bottom of the shaft has extensive deposits of chiroptoguanalite in which was partially buried an incompletely mummified sub-adult skeleton of *Nothrotheriops shastensis* and an associated coprolite. Shelter Cave (Bishop Cap Cave) is west of Aden Crater on Bishop's Cap, a southern outlier of the Organ Mountains. The cave yielded seven specimens of *Castrocopros martini*. The coprolites from Aden Crater and Shelter Cave have yielded radiometric dates of late Rancholabrean age. Carlsbad Caverns National Park in Eddy County is well known for its extensive deposits of chiropteraguanolite. Sloth coprolites also occur at the park. The taphonomy of large Plio-Pleistocene coprolites of New Mexico is consistent with other localities in the Southwest. The majority of coprolites occur in caves, and these coprofaunas are dominated by herbivores. Carnivore coprolites are most common in fluvial environments.

ANALYZING STORM WATER RUNOFF IN DOWNTOWN SILVER CITY, NEW MEXICO

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Downtown Silver City, New Mexico has longstanding problems with storm water runoff, especially during high-intensity monsoon storms that occur annually from June to September. As storm water flows through an urbanized area it collects and transports heavy metal contaminants. The Environmental Protection Agency (EPA) recognizes urban runoff as one of the leading causes of water quality issues ("National Water Quality Inventory: 1998 Report to Congress", 2013). Urban runoff is especially concerning when it is discharged into a natural body of surface water, as is the case in the study area for this project. The storm water runoff from the study area is diverted into San Vicente Arroyo, which recharges the aquifer downstream that Silver City uses for municipal water.

Heavy metal contaminants pose varying degrees of risk to human health and the presence of multiple heavy metals in the same water source can be detrimental (Ma, 2016). The scope of this project focuses on analyzing the hydrology of downtown Silver City in order to understand to what extent storm water runoff over the urbanized study area affects soil and water quality. The pollutants that are being investigated in this study are copper, lead, and zinc. The working hypothesis is that as the storm water runoff flows down-gradient, the concentration of heavy metal contaminants will increase near the lower portion of the drainage pattern along San Vicente Arroyo.

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Preparation and Description of Several Cranial Elements of the Fossil Elephant *Gomphotherium productum* (Proboscidea) From the Middle Miocene (late Barstovian) of the Española Basin of Northern New Mexico

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Excavations in the Chamita and Tesuque Formations from Española basin in northern New Mexico yield exceptionally preserved fossil elephants (Order Proboscidea; Family Gomphotheriidae). While most mammal genera geologic lifespans are ~2 million years, the New Mexican Miocene *Gomphotherium productum* occurred for 7+ million years (~7-14 Ma) despite shifting paleoenvironmental conditions. Thus, *G. productum* may possess unique ecological adaptations that allowed it to persist or *G. productum* may represent multiple species. To test these hypotheses, *G. productum* fossils were prepared using microscribes and dental picks at the New Mexico Museum of Natural History (NMMNH), and the fossils were described and measured. These fossils represent among the oldest, best-preserved record of middle Miocene (late Barstovian; 13-14 Ma) proboscideans. Ontogenetic stages for several *G. productum* crania and partial mandibles from the Chamita and Tesuque Formations were compared. We examined and measured a juvenile maxilla and mandible (NMMNH P-25280); an abnormally small, adult cranium and mandibles (P-19204) with fragmentary tooth rows; a young adult (P-28972) with associated mandibles and complete tooth row; and a complete adult cranium (P-63875), maxillary tooth row, and right tusk. Our preliminary results include quantitative comparative measurements and qualitative visual comparisons of these specimens to assess whether they represent multiple species or possess unique ecomorphological adaptations such as mandible procumbency.

REPEAT MICROGRAVITY MONITORING OF RIO GRANDE RIVER SEEPAGE AND GROUNDWATER WITHDRAWALS IN THE MESILLA VALLEY, NEW MEXICO

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Increasing water demand for public supply and irrigation coupled with limited surface-water supplies have resulted in increased groundwater withdrawals in the Mesilla Basin in south-central New Mexico. In 1987, the U.S. Geological Survey established the Mesilla Basin Monitoring Program in cooperation with several federal, state and local agencies to document the hydrologic conditions within the basin and to create a long-term database to permit the quantitative evaluation of the groundwater-flow system and stream-aquifer relations.

As part of the monitoring program, a pilot microgravity study was carried out with two to three surveys per year at 20 stations from 2016 to 2018. The network of gravity stations was designed to identify recharge occurring through a losing reach of the Rio Grande, with additional monitoring near a reach where recharge was not expected. Other stations were placed in agricultural areas, and the timing of the monitoring was designed to detect changes due to annual patterns of pumping for irrigation. Where feasible, gravity stations were collocated with wells to enable estimates of specific yield.

By precisely measuring the change in the acceleration due to gravity through time, it is possible to estimate the change in groundwater storage underneath the gravity meter through a simple linear relation (4.2 x 10-7 m/s2 equals 1 m of free-standing water). This relation is independent of the depth to water or porosity of the aquifer. Closely-spaced stations allow the total volume of groundwater-storage change to be interpolated. Furthermore, if gravity stations are collocated with monitoring wells, the relation between storage change (derived from gravity data) and groundwater-level change can be used to estimate specific yield. Changes in storage measured using repeat microgravity represent a 1-dimensional thickness of free-standing water; the equivalent change in groundwater level is the storage change divided by the specific yield

Overall, changes in gravity corresponded with the irrigation regime, with increases in groundwater storage of up to 0.52 m observed during the summer season and decreases of up to 0.64 m during other parts of the year. Most sites collocated with wells showed good correlation between gravity-derived changes in storage and changes in groundwater levels, resulting in estimates for specific yield ranging from 0.17 to 0.34. At five sites, storage changes were insufficiently small to estimate specific yield.

An update on the Microbially-Induced Sedimentary Structures (MISS) of the Precambrian (Stenian) Castner Formation, Northern Franklin Mountains, El Paso, Texas

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The Castner Formation of El Paso, Texas is the oldest Precambrian rock unit (Stenian, ~1260Ma) exposed in the Franklin Mountains of West Texas. This unit is now marble, but was initially a carbonate/clastic sedimentary succession and has been metamorphosed to hornblende-hornfels facies. Originally named by Harbour (1960) as the "Castner Limestone," it contains exquisitely preserved bedding structures, including soft sediment deformation, imbricated edgewise conglomerates, and two types of stromatolites. Microbial Induced Sedimentary Structures (MISS) were first recognized in the Castner Formation by Pittenger (1994), who reported cryptalgal laminites. We describe several other MISS not associated with the previously described stromatolites. These MISS include gas domes, syneresis cracks, and possible discoidal microbial communities. In addition, we also offer an alternative hypothesis for the formation of edgewise conglomerates, namely that they may have formed due to microbial binding of individual beds, which has been reported elsewhere (i.e., Van Kranendonk et al., 2003).

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Keywords:

MISS, Proterozoic, Castner

MAPPING SUITABILITY FOR MANAGED AQUIFER RECHARGE IN ALBUQUERQUE, NEW MEXICO

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We used weighted overlay analyses to map suitability for managed aquifer recharge (MAR) by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA). The study area extends from the Rio Grande eastward to the Sandia Mountains, and from Sandia Pueblo southward to ~2 km south of Tijeras Arroyo. The subsurface Santa Fe Group stratigraphy consists of axial-fluvial sediment that interfingers westward with the Rio Puerco distributive fan system and eastward with piedmont sediment from the Sandia Mountains. The Santa Fe Group is overlain by up to 51 m of weakly consolidated mid- to late Quaternary piedmont alluvium, Rio Grande terrace deposits, and valley fills. Long-term pumping by the city has created a large, trough-like cone of depression centered in the study area, with up to 120 m of unsaturated, relatively permeable sediment that could be used to store excess surface water allotted to ABCWUA from the San Juan-Chama Drinking Water Project. We produced two suitability maps with a grid cell resolution of 100x100 m: one showing the suitability for deep (saturated zone) injection recharge and the other for shallow (infiltration or vadose zone injection) recharge. Unsuitability buffers were *a priori* assigned to fault zones (due to potential barrier effects), the Rio Grande floodplain (due to potential for injected water to reach the river or induce swamping), and 1/2 mile around known groundwater contamination sites. Initial steps included: (1) compiling hydraulic data from pump and infiltration tests; (2) studying outcrop analogs of lithologic units comprising the aquifer units; (3) drawing structural contours of 10 lithologic units under and near the study area; (4) assessing the proportions of sand, clayey sand, and clay layers for these units (primarily using interpretation of wireline logs); and (5) using ArcGIS tools to construct a 3-D geologic model. For the weighted overlay analyses, we considered several criteria that could impact MAR. For deep injection recharge, these include transmissivity, the typical storage zone thickness (thickness of permeable beds between clay layers), allowable injection rates, water table gradient, density of ABCWUA and non-ABCWUA wells, and distance to existing water pipelines. For shallow recharge, criteria include surface soil characteristics (hydraulic conductivity and drainage classes from NRCS soil maps), surface slope, depth to groundwater, percolation time to reach the water table, and the proportion of clay layers. Each criterion were subdivided into classes (binned), which were ranked from 0 to 2 based on their impact to MAR (2 being most favorable and 0 being least). For criteria that vary with geologic unit (e.g., transmissivity, storage zone thickness), each individual geologic unit's score was thickness- and depth-weighted, summed, then normalized to between 0 and 2 at each grid cell location to produce a single score. All criteria at each cell were then weighted, summed, and normalized (to 0–2) to produce an overall rating. We compared the overall ratings to previous maps and known locations of MAR-suitable sites, and then used histogram analysis to translate the scores to qualitative MAR suitability ratings. A separate map showing soil hydrocompaction susceptibility will also be produced.

Keywords: managed aquifer recharge, artificial recharge, aquifer storage and recovery, geologic model, Albuquerque, New Mexico, weighted overlay, San Juan-Chama Drinking Water Project, hydrocompaction, collapsible soils

THE PENNSYLVANIAN SECTION AT BISHOP CAP, DOÑA ANA COUNTY, NEW MEXICO

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Bishop Cap is a miter-shaped peak that is a fault block outlier between the Organ and Franklin mountains in south-central Doña Ana County. Pennsylvanian strata form most of the peak, and previous workers assigned them to the La Tuna and overlying Berino formations, units originally defined in the Franklin Mountains. We reassign these strata to the Horquilla Formation and regard the La Tuna and Berino as possible members of the Horquilla. The Horquilla section at Bishop Cap is 256 m thick and rests disconformably on shale of the Mississippian Helms Formation. We divide this section into five informal units: A (= La Tuna Formation) overlain by B-E (= Berino Formation). Unit A is an ~ 80 m thick, cliff-forming interval of massive to indistinctly bedded limestone units that alternate with thin- to medium-, even- and wavy-bedded limestone intervals and covered intervals. One crossbedded, lenticular sandstone approximately 20 m above the base contains terrestrial plant debris. Most limestone beds contain chert nodules and thin chert lenses. Limestone has muddy textures throughout the unit, some of the limestone intervals are bioturbated, and many limestone beds contain crinoidal debris. Thick-bedded to massive limestone units contain solitary corals and brachiopods, and *Chaetetes* is present in a few intervals. One bed contains small coral colonies. Unit B is an ~ 84-m-thick, slope-forming unit of limestone intervals alternating with abundant covered (shale) intervals. Limestone intervals are thin to medium bedded and mostly < 2 m thick. Even-bedded limestone commonly contains abundant crinoidal debris and rare chert. Wavy-bedded to nodular limestone is mostly cherty and rarely contains crinoid fragments and solitary corals. A distinctive fusulinid bed (*Fusulinella*) is intercalated in the lower part. One conglomerate bed in the upper part contains limestone clasts, abundant crinoid fragments and fragments of solitary corals and brachiopods. Unit C is ~ 23 m of cliff-forming, indistinctly medium- to thick-bedded and massive limestone containing abundant crinoidal fragments with intercalated wavy-bedded to nodular limestone and a few thin covered intervals. Solitary corals are present in the basal nodular limestone unit, and brachiopods are present in a crinoidal limestone in the upper part. Chert is rare. Unit D is ~49 m of slope-forming cover/shale intercalated with thin- to medium-bedded limestone intervals and beds. Even-bedded limestone commonly contains abundant crinoid fragments, and wavy-bedded to nodular limestone is mostly cherty. Brachiopods and solitary corals are rare. Unit E is the summit of Bishop Cap and is ~ 21 m of mostly cherty nodular limestone and interbedded crinoidal limestone locally containing corals and brachiopods. Conodont biostratigraphy shows that the upper part of unit A (~65 m above base) is early Atokan, based on the presence of *Neognathodus nataliae.* The lowest Desmoinesian fauna, indicated by the appearance of *N. bothrops,* occurs ~60 m above the base of Unit B. Early Desmoinesian (Cherokee) conodonts range through Unit C and as least as high as the lower 10 m of Unit D. Less diagnostic Desmoinesian conodonts occur in the upper part of Unit D and Unit E.

GEOCHRONOLOGIC AND PALEOCLIMATOLOGIC INTERPRETATIONS OF PLIOCENE INTERTRAPPEAN PALEOSOLS, TAOS PLATEAU, NEW MEXICO

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In northern New Mexico on the Taos Plateau there are a series of basalt lava flows that formed at ~4 Ma. Atop some of these lava flows, sediments were deposited and over time soils formed in these sediments. These soils were subsequently buried by later lava flows, becoming encased and incorporated into the rock record as paleosols. In this study, our goal is to determine the climate conditions under which these soils formed, the duration of pedogenesis, and the overall geomorphic setting of the Taos Plateau during the Pliocene epoch. To do this, we analyzed the elemental composition of the paleosols with XRF spectroscopy and color indexed the paleosols using the Munsell soil color chart. We then used these data to perform a geochemical climate analysis on the samples, the results of which are incongruent with all other paleosol characteristics. In addition to this, we obtained thin-sections of the paleosols and used a polarizing light microscope to investigate the individual grains so that we could study the mineral composition and micromorphological features found within the paleosols. Paleosol B horizons are dominated by silt-sized quartz and sand-sized primary minerals ranging from 20μm – 1mm in diameter, respectively. Since quartz is unlikely to be formed in the silicate series for basalt, we interpret these grains to have been delivered via eolian processes during pedogenesis. Our results suggest that these paleosols formed in a semi-arid environment, similar to what is found in present day New Mexico. The presence of stage III-V pedogenic carbonate horizons suggest a duration of pedogenesis of up to 10^6 years under reasonably stable semi-arid paleoclimate conditions. Within several of the paleosol layers we observed inflationary horizons with well-preserved desert pavement. Radiometric dating of encapsulating basalts will provide further constraints on duration of pedogenesis and timing of pedogenic events.

SINKHOLES AS TRANSPORTATION AND INFRASTRUCTURE GEOHAZARDS IN MIXED EVAPORITE-SILICICLASTIC BEDROCK, SOUTHEASTERN NEW MEXICO

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Personnel with the National Cave and Karst Research Institute and the New Mexico Bureau of Geology and Mineral Resources conducted an assessment of karst geohazards southeast of Carlsbad, New Mexico, USA. The US Highway 285 corridor in this area is subject to high levels of oilfield traffic, and is particularly prone to sinkholes because of the presence of gypsum bedrock of the Rustler Formation at or near the surface throughout much of the study area. These features pose a geohazard for the transportation and pipeline network in this part of the state. The geotechnical properties of the Rustler Formation are influenced by soluble gypsum strata interbedded with mechanically weak mudstone and siltstone and more rigid dolomite beds. Surface geologic mapping and near-surface electrical resistivity (ER) surveys indicate that most sinkholes formed in the Rustler are relatively shallow (<3 m), without deep roots, probably due to the mixed lithology of soluble and insoluble bedrock. However, longer-array ER surveys have identified additional cavities at greater depths that do not breach the surface.

THE PALEOECOLOGY OF THE LATE CRETACEOUS TURTLE *BASILEMYS*

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The fossil turtle *Basilemys* is known from the Upper Cretaceous of the Western Interior of North America, including the San Juan Basin of northwestern New Mexico. We analyze its paleoecology based on shell proportions, forelimb proportions and femur morphology. *B. variolosa* from Alberta has a shape unlike any living turtle: it has a carapace-width-to-plastron-width ratio of 1.36 and a length-to-height ratio of 13.48. *B. gaffneyi* from New Mexico is similar in age to *B. variolosa* but has a distinctly taller carapace with a length-to-height ratio of ~2.6 and a slightly higher carapace-width-to-plastron-width ratio of ~1.6. *B. morrinensis* from Alberta has a carapace-to-plastron-width ratio of 1.64 and a length-to-height ratio of 3.4. All of these ratios suggest an aquatic habitus in the various *Basilemys* species.

Basilemys has a very broad plastron relative to its carapace width compared to most aquatic turtles. The only living turtles that approach these ratios are *Emydoideablandingii*, *Cuoraaurocapitata*, *C. pani*, *C. trifasciata*, and *Terrapene coahuila*. These are all swamp dwellers that live in shallow bodies of water comingled with land. Thus, they need to travel over land more often than other aquatic turtles, bringing them additional exposure to predation, both in and out of the water. If *Basilemys* was a resident of these marginal waterways it also might explain its high degree of dorsoventral compression, as this would help keep a turtle submerged in shallower grazing areas and thus less noticeable to terrestrial predators. Given the large size of *Basilemys*, and its environment, the added strength of a domed carapace may not have been needed. Such shallow water would be an unsuitable hunting ground for larger predators.

The articulated limbs of a complete *Basilemys variolosa* has the bottoms of the manus and pes covered in osteoderms, and the posterior opening of the shell filled with more osteoderms. The lateral ridges on the unguals are larger on the manus than the pes. This might indicate they were used in forelimb digging. These unguals are similar in shape to those of the burrowing synapsid *Varanops*. This supports earlier suggestions of *Basilemys* as a burrower. If *Basilemys* inhabited shallow, often ephemeral, bodies of water, burrowing ability may have played a role in surviving prolonged dry periods. The two fore limbs measured average 49% humerus length, 21% ulna length and 30% hand length. These measurements most closely match the fore limb proportions of semi-aquatic, extant emydids and lead to the inference of a habitus in small or stagnant bodies of water. A *Basilemys* femur from the Dinosaur Park Formation of Alberta has a ratio of the intertrochanteric fossa length to femur length of ~0.13. This most closely approaches that seen in *Chelydra serpentina*, *Kinosternonbaueri* and *Terrapene coahuila*. This is consistent with an aquatic habitus, as all of these species are bottom walkers generally found in shallow water. Thus, we conclude that *Basilemys* were aquatic turtles that frequently had to cross land.

THE TORTOISE *CAUDOCHELYS* FROM THE MIOCENE TESUQUE FORMATION OF THE ESPAÑOLA BASIN, NEW MEXICO

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There is an extensive fossil record of Neogene tortoises in New Mexico, but they have received little study to date. *Caudochelys* is a genus of North American giant tortoises (family Testudinidae) primarily known from the Miocene of Texas and the Pleistocene of Florida. Here, we present the first report of *Caudochelys* in New Mexico, which includes some specimens that had previously been called *Hesperotestudo* sp. *Hesperotestudo* is the only other genus of giant tortoises recognized from the Neogene of North America.

Two skulls from the Tesuque Formation in "First Wash," in the Barstovian Pojoaque Member of the Tesuque Formation, one of which has associated postcrania, are referable to *Caudochelys* and provide some insight into the cranial anatomy of this genus. These skulls differ from *Hesperotestudo* in the lack of a second lingual ridge and the presence of a large medial septum of the palatines. The fenestra subtemporalis is significantly larger, particularly medio-laterally, than in *H. impensa* and *H. osbornia*. This indicates increased size of the jaw closing muscles in *Caudochelys*. This, combined with the tuberculate rather than striated morphology of the labial triturating surface, leads us to conclude the New Mexico *Caudochelys* likely consumed a tougher, more fibrous diet than the *Hesperotestudo* examined. This suggests possible niche partitioning using different food sources for each genus, reducing competition.

The postcranium associated with one of the skulls of *Caudochelys* includes ungual- shaped osteoderms similar to those seen in *Hesperotestudo osbornia*. Among living turtles these are only seen in *Manouria* and have no previously suggested function. The presence of these osteoderms fits with the previous idea that *Hesperotestudo* and *Caudochelys* are sister lineages. Furthermore, this raises the question, given this shared unique trait, is *Manouria*, the Asian Forest Tortoise, more closely related to North American giant tortoises than previously thought? The gulars of the New Mexican *Caudochelys* individual have a more pronounced lateral constriction than some of the other Tesuque Formation tortoise fossils, which we interpret to indicate that it is likely a male. Anterior lobes of Miocene New Mexico giant tortoises are generally less constricted at the gular-humeral sulcus than younger individuals previously assigned to *Hesperotestudo*. Thus, it is important to realize that the Miocene and Pliocene giant tortoises of New Mexico may not be members of the same lineage. The westward expansion of the range of *Caudochelys* further expands the geographic overlap of *Hesperotestudo* and *Caudochelys*.

MANTLE SOURCE IDENTIFICATION FOR MIDDLE MIOCENE MAGMATISM ON EASTERN FLANKS OF THE RIO GRANDE RIFT, NORTHERN NEW MEXICO

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Middle Miocene magmatic rocks in the Las Vegas region represent a volumetrically small but regionally significant collection of mafic dikes, plugs, and stocks that represent an episode of igneous intrusive activity on the east flank of the Rio Grande rift to the east of the Sangre de Cristo Mountain front. The intrusions consist of hornblende + plagioclase + augite ± olivine with variable amounts of hydrothermal alteration. The dikes (n=14) range in size from meters to decimeters in width and meters to kilometers in length. One of the dikes, the 5-km-long Buena Vista intrusion, is a composite intrusion consisting primarily of gabbro with a differentiated plagioclase-rich central portion. The smaller intrusions include the 55 m-wide Reed Ranch plug, and the 25 m-wide Milton Ranch stocks. We propose that the eastern shoulder of the Rio Grande rift in the Las Vegas region is underlain by fertile subcontinental lithosphere influenced by subduction related processes, from the accretion of Proterozoic terrains to the subduction of the Farallon plate. The hydrous nature of the parent mafic melt, implied by the high proportion of hornblende, as well as the presence of boron (a large-ion lithophile element), indicated by accessory tourmaline, are hallmarks of a dehydrating slab fluid-enriched system. An alternative hypothesis proposes that the high volatile content of the Las Vegas region intrusions is an inherent feature of asthenosphere melt generated by foundering of the Farallon plate. To distinguish mantle source regions, we conducted a geochemical study of the Las Vegas mafic suite, including trace element and isotope makeup, to compare to known mantle source regions of subcontinental lithosphere with upper- and lower-crustal contamination and asthenosphere with insignificant crustal contamination. Ten samples were taken from the regional intrusions, including 6 from the Buena Vista intrusion. The samples were crushed and powdered at New Mexico Highlands University and taken to the Czech Academy of Sciences (Prague) for isotope separation and Thermal Ionization Mass Spectrometer (TIMS) analysis. $^{87}Sr/^{86}Sr$ values for 9 of the samples with SiO_2 weight percent less than 48.60 range from 0.70395-0.70430 (average 0.70412). One sample, taken from the plagioclase-rich core of the Buena Vista intrusion (SiO_2 weight percent = 60.48) shows an elevated $^{87}Sr/^{86}Sr$ value of 0.70608. The Sr isotopic data for the majority of the Las Vegas intrusions suggest derivation from an enriched mantle source or an asthenospheric mantle source with crustal contamination. An enriched mantle source is more likely, as the rocks also show enrichment in the light rare earth elements relative to the heavy rare earth elements $(La/Yb)_N$=29-37 and selective enrichments in the incompatible elements Ba, Th, K, Nb, and Ta, which are characteristic of melts originating in the subcontinental lithosphere enriched by arc fluids or hydrous mafic magmas. Thus, mafic magmatism in the Las Vegas area originated from a fertile fluid-modified lithospheric mantle during a mid-Miocene period of extension focused east of the Sangre de Cristo Mountains.

Seismic Activity in the Permian Basin in New Mexico

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While most earthquakes in New Mexico are due to tectonic forces associated with the Rio Grande Rift and the Socorro Magma Body, in recent years seismic activity has increased in areas where fluid injection is ongoing, raising the possibility that these earthquakes are induced by human activity. The two regions of New Mexico that have seen the largest rise in activity are the Raton Basin, which spans the New Mexico-Colorado border in northeastern New Mexico, and the Permian Basin, which spans the New Mexico-Texas border in southeastern New Mexico. I will discuss the recorded history of seismicity in the Permian Basin in New Mexico, as well as past and ongoing efforts to better understand its causes.

Earthquake monitoring in New Mexico began in the 1960s in the area around the Socorro Magma Body, and a network in southeastern New Mexico began operating in 1998 to monitor the Waste Isolation Pilot Plant (WIPP), a nuclear waste storage facility located southeast of Carlsbad. The WIPP network currently consists of nine short-period sensors and is able to detect many of the potentially induced seismic events in the Permian Basin, making it invaluable for studying the long-term history of seismicity in the region. Temporary seismic networks, including the 3-component broadband SIEDCAR campaign, have also been used to study seismicity in the region.

The largest concentration of seismic activity in the Permian Basin in New Mexico occurred in the Dagger Draw oil field, northwest of Carlsbad. Seismic activity began to increase in 2001, 5 years after peak fluid injection in 1996, suggesting significant fluid migration occurred. Seismic activity at Dagger Draw has since decreased, and activity in other parts of the Permian Basin in New Mexico has generally been moderate. While seismic activity in the Permian Basin has increased dramatically in the past few years, most of the increase has occurred in the Texas portion of the Permian Basin, while up to this point the earthquakes occurring in New Mexico have generally been less frequent and smaller than M2. However, it is important to continue to study the entire region to better understand the causes of induced seismicity and how to mitigate it.

PENNSYLVANIAN STRATIGRAPHY IN THE MANZANO-MANZANITA MOUNTAINS, CENTRAL NEW MEXICO

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Pennsylvanian strata overlie Proterozoic basement along the crest and dipslope of the Manzano and Manzanita Mountains in Valencia, Torrance and Bernalillo counties, New Mexico. However, locally, along the Tijeras Hogback Ridge in the northernmost Manzanita Mountains, the Pennsylvanian sits on 16-21 m of Mississippian red beds. Study of Pennsylvanian successions at Priest Canyon, Sol se Mete Peak, Cedro Peak and Tijeras Hogback Ridge, as well as other less complete successions, indicates that the Pennsylvanian strata in the Manzano-Manzanitas can be assigned to the (ascending order) Sandia, Gray Mesa and Atrasado formations. The Sandia Formation is interbedded shale, quartz-rich sandstone, limestone and conglomerate, mostly in depositional contact with the Proterozoic basement. Sandia Formation thickness ranges from 14 to 70 m, largely because of the paleotopography upon which it was deposited at the local onset of the ancestral Rocky Mountain orogeny. The Gray Mesa Formation (= Los Moyos Limestone) is 67-192 m thick and can be divided into three members (ascending): Elephant Butte Member, 20-47 m of limestone and shale; (2) Whiskey Canyon Member, 30-84 m of cherty limestone; and (3) Garcia Member, 18-84 m of non-cherty limestone and shale with lesser amounts of cherty limestone, sandstone and conglomerate. The Atrasado Formation (=Wild Cow Formation) is 200-272 m thick and divided into eight members (ascending): (1) Bartolo Member, 28-66 m of slope-forming shale with thin beds of sandstone, limestone and conglomerate; (2) Amado Member, 9-19 m of bedded, cherty, brachiopod-rich limestone; (3) Tinajas Member, 45-115 m of shale with interbedded limestone and sandstone; (4) Council Spring Member, 7-23 m of mostly algal limestone without chert; (5) Burrego Member, 23-63 m of arkosic red beds and limestone; (6) Story Member, 6-22 m of limestone; (7) Del Cuerto Member, 9-26 m of arkosic red beds and limestone; and (8) Moya Member, 5-11 m of bedded limestone and shale. The Atrasado Formation is overlain by the transitional Pennsylvanian-lower Permian (Wolfcampian) Bursum Formation, which is 30-90 m of interbedded red-bed mudstone, sandstone, conglomerate and limestone. The continuity of Atrasado Formation stratigraphic architecture reflects tectonic events in the Pedernal highland and adjacent basin over a distance of at least 150 km, from the northern Oscura Mountains of Socorro County to the northern Manzanitas. The Pennsylvanian section at Priest Canyon includes the type sections of units named by Myers and long applied to Pennsylvanian strata throughout the Manzano-Manzanita mountains. It is very similar to the Pennsylvanian section in the Cerros de Amado, ~60 km to the SW, and the stratigraphic nomenclature used in Socorro County can be applied to the Gray Mesa and Atrasado formations throughout the Manzano-Manzanita mountains. We thus abandon all of Myers' Pennsylvanian lithostratigraphic terms because they are either synonyms of earlier named units or do not identify useful lithostratigraphic units. In the Manzano-Manzanita Mountains, fusulinid and conodont biostratigraphies indicate that the Sandia Formation is late Atokan-earliest Desmoinesian, the Gray Mesa Formation is early-middle Desmoinesian and the Atrasado Formation is late Desmoinesian-middle Virgilian.

2018-19 Water Quantity and Quality Study of the Lower Santa Fe River, Santa Fe County, NM: Progress Report

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The City of Santa Fe relies heavily on the Santa Fe River for its potable supply. The Santa Fe River originates in the Sangre de Cristo Mountains before being impounded within McClure and Nichols reservoirs until it is called for by the City's municipal and agricultural customers. Stream flows are variable and dependent on winter snowpack and summer monsoonal rains, which provide approximately 40% of the City's water. The remainder comes from the Rio Grande Buckman Direct Diversion and the San Juan-Chama Project. Santa Fe's water refuse is treated at the Wastewater Treatment Plant (WWTP) and discharged back into the lower Santa Fe River, which then flows through the historic communities of La Cienega and La Bajada before entering Cochiti Pueblo. Outputs from the lower Santa Fe River have amplified, with increased development, groundwater pumping, irrigation diversions, and evapotranspiration. Rarely does the river reach its confluence with the Rio Grande, its termination occurring somewhere within Cochiti Pueblo. There is little information about the quantity and quality of the water in the Lower Santa Fe River after its discharge from the WWTP. This project is focusing on the lower Santa Fe River's water budget and chemistry to determine how land usage impacts its instream flow and water quality. Project methods include taking streamflow measurements and water samples at five sites during the 2018-19 water year. Stream flow monitoring results thus far show that flow stage remained steady (0.50-2.25 feet) throughout the winter months and only showed diurnal variations and intermittent storm events throughout the 6-month data-collection period. We anticipate variations in stage height and stream flow during the spring and summer seasons when the river experiences increased inputs from snow melts and monsoonal rains and increased outputs from evapotranspiration and user demands. Stream chemistry results are pending. This water study will constrain the stress on existing supplies and assist with evaluating possible water resource management options to supplement traditional water-supply approaches.

Soil Mapping Using Near Remote Sensing in SW United States

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Current soil mapping methods are time consuming and expensive, especially at small scales and in remote areas. Traditional methods require both aerial photographs and field measurements such as textural and color classifications to be collected and studied by a professional soil scientist (Soil Survey Staff, 2017). After data is collected the scientist will then create a conceptual model of soil formation to predict the soil taxonomy of the surrounding area. Traditional soil mapping methods have high propensity for error (Wilding, 1965; Drohan, 2003). Modern soil surveys produce maps at 1:24,000 or 1:12,000; at these scales one inch on th map is equal to 2,000 feet and 1,000 feet, respectively (Soil Survey Staff, 2017), meaning acres of soils can be missidentified. To create a soil map that is more detailed with current methods is logistically cost prohibitive to undertake, especially in range-land areas.

With the advancement of technology several new approaches have been proposed to create a soil map using differentiation of soil properties (Dobos, 1998; Engle, 2009; Lagacherie, 2006; Lunt, 2003; Mcbratney, 2003; Moran and Bui, 2003; Scull, 2003; Ulaby, 1996). Generally these approaches fall into two categories: digital soil mapping and remote sensing. Physical soil properties such as grain size, organic matter content, and slope influence the residence time of water in the soil (Anderson et al. 2013). Soil moisture can be obtained using electromagnetic induction or moisture probes (Birchak, 1974; Sudduth, 2003), however, these methods are limited to 50 acres and are immobile. Estimates of soil moisture can be made from satellite imagery through radar or energy balance algorithms. This is done either through radar (Ulaby, 1996; Dobos, 1998) or through multispectral bands using energy balance algorithms (Bastiaanssen et al. 1998). Radar is only accurate 0-5cm in depth (Reich, 2014; Dobos, 1998; Suarez, 2010; Scull et al. 2003), while energy balance algorithms predict moisture to root depth (Allen et al. 2009; Bastiaanssen, et al. 1998; Hendrickx 2005, 2009). A limitation of this method is that it relies heavily on satellite data, which has coarse spatial and temporal resolutions and is inhibited by cloud cover.

We hypothesize that an accurate and detailed soil map can be produced using data collected by way of Unmanned Aerial Vehicles (UAVs). We have collected remote imagery data using UAVs before using energy balance algorithms to estimate soil moisture. We then observed the changes in soil moisture estimation over several days and compared these changes to established drying curves, which are correlated to physical properties. Theoretical drying curves are indicative of texture and horizontality (Cosby, 1984; Miller, 1973). We trained the computer to recognize differences in soil types based on soil moisture changes. The result is a soil map with increased temporal and spatial resolution with a reduced misclassification.

A COLLECTION OF HISTORIC SEISMIC INSTRUMENTATION PHOTOGRAPHS AT THE ALBUQUERQUE SEISMOLOGICAL LABORATORY

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The Albuquerque Seismological Laboratory (ASL) has preserved a photograph collection featuring historic seismographic equipment, stations, and drawings used by the U.S. Coast and Geodetic Survey (USC&GS) in the early-to-mid twentieth century. The photographs were transferred to ASL from the U.S. Department of Commerce in Washington, D.C., after ASL became established as a federal facility for seismological research and instrument testing in 1961. The photographs were used in publications dating as far back to the 1920s to document USC&GS activities or used internally to document instrument installation, operation, and components. The historic collection is made up of hundreds of photographs that were originally printed in the 1930s and 1940s. Our hope is that the archival of these records, as well as brief descriptions about their significance, will help preserve some of the knowledge about seismological advances in the United States.

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MINERALOGICAL CHARACTERIZATION AND AN INSIGHT ON THE SILVER DISTRIBUTION ON SULFIDES AT LAS LUCES VOLCANIC HOSTED CU-AG DEPOSIT, CHILE

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Las Luces deposit is a stratabound Jurassic volcanic-hosted Cu-Ag deposit. Geographically located in the western area of the coastal cordillera at 50 km of the Taltal town, Antofagasta region, Chile and metallogenetically, in the south corner of the Tocopilla-Taltal belt (S. Kojima, 2007). Mineralization is mainly hosted in basaltic andesite to andesite Jurassic volcanic-sedimentary piles (Camaraca, Ofícina Viz and La Negra formations). The characteristic mineralization styles are vesicle infill that predominates over other styles, and networks of veinlets (up to ~20 um thickness) that interconnect the major open spaces and inside some breccias as late cement component, sealing remaining open space. Creation and enhancement of open space could be explained by a mixture of the following processes: at lithospheric scale, tectonic inversion in a back-arc basin; at a regional scale, hydraulic fracturing driven by circulating fluids either related or not with the mineralizing fluids; and, finally, molar volume reduction driven by the effects of hydrothermal alteration. The main hydrothermal alterations can be listed as follows: sodic alteration (albite-hematite-~chlorite), chlorite-calcite alteration (accompanied by specular hematite) and a late destructive alteration (white phyllosilicate-clays). The petrographic study identified as the main mineralogy, specular-hematite, pyrite, chalcocite, bornite, digenite and chalcopyrite, covellite as distal-minor phases and based on their textural relationships a paragenesis of the order of the events have been developed (see attached Image). The sequence of events starts with the Sodic Alteration characterized by albite, hematite, staining host rocks, and chlorite from the ferromagnesian phases of the host rocks, interpreted to represent an early low temperature fluid passing through the permeable areas. The second event, Chlorite-Calcite Alteration characterized by quartz, chlorite, calcite, infilling vesicles along with the saturation of specular hematite and a first generation of chalcocite (chalcocite I); it is interpreted to portray fluids of at least higher temperature than the previous event, >~190 ºC to be specular hematite stable (W. Chavez Jr. verbal communication). The third event, Mineralization Stage I is characterized by porous specular hematite, a highly porous bornite (bornite I), digenite and an interpreted undifferentiated chalcocite event. Finally, the fourth event, Mineralization Stage II is characterized by chalcocite (chalcocite II), bornite (bornite II), digenite, fringing hematite and minor chalcopyrite and covellite. Everything considered, there were at least three different mineralization cycles overprinting previously formed mineralization based on the available mineralogical and textural relationships. It can be interpreted that the fluids responsible for each cycle of mineralization were chemically similar, yielding a history of alike mineral assemblages overprinting previously formed phases that ended showing a simple set of mineral associations, even though, with complex paragenetical relationships. Finally, electron probe microanalysis data has shown that the main mineral phases holding silver on their structure are chalcocite (average 0.10 wt% Ag) and bornite (average 0.37 wt% Ag), being the bornite the most important phase for silver, contrary of what it is expected for this set of co-precipitating minerals (Nigel J. Cook, 2011), supported by myrmekitic textures with bismuth concentrations b.l.d.

Keywords:

Las Luces, Chile; Volcanic Hosted Cu-Ag deposits; Petrographic study; Paragenesis; Ag distribution in sulfides.

MAPPING SOIL WATER HOLDING CAPACITY IN THE STATE OF NEW MEXICO: A MODEL-BASED APPROACH.

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Soil Water Holding Capacity (SWHC) within the rooting zone of the soil (RZSWHC) is the most important parameter for calibrating soil-water-balance models. SWHC is also the most difficult parameter to measure, the reason being that SWHC depends on ill-defined concepts such as "soil water capacity at field capacity" and "wilting point" as well as often unknown root water uptake distribution with depth. As such, an indirect method for parameterizing SWHC is necessary, given the paucity of in-situ measurements that are available. We are exploring alternative approaches to estimating SWHC: 1) SWHC is determined as a model fitting parameter, i.e. the SWHC of a soil-water-balance model is varied until agreement is found between 'observations' of evapotranspiration (ET) from an independent energy-balance model and modeled ET from the soil-water-balance model; 2) Using two independent data sets of modeled precipitation and ET, soil-moisture deficits are tracked on a daily basis for 11 years. The largest soil-moisture deficit recorded is taken to be a minimum for the SWHC within the root zone, assuming that there is no change in land cover or Hortonian runoff. We present the resulting maps of RZSWHC within our area of interest and compare their attributes. Additionally, we evaluate the ET estimates produced by the Jet Propulsion Laboratory's energy-balance model that generated the independent ET estimates used to determine RZSWHC.

Keywords:

Soils, Root Zone, Soil Water Holding Capacity

EFFECTS OF MINERALOGY AND LIXIVIANT COMPOSITION ON URANIUM LEACHING

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Northwestern New Mexico holds one of the world's largest reserves of uranium in an approximately 100-mile-long belt of sandstone-hosted deposits in the Jurassic Morrison Formation. Some of these have been identified as amenable for alkaline in-situ recovery (ISR) in terms of geologic setting. Alkaline ISR is a widely-used form of 'solution mining', where an array of injection and extraction wells circulate chemical lixiviants to mobilize (via oxidation) and complex (via carbonate ions) uranium from a water-saturated ore body.

We investigated the behavior of primary- and redistributed-type ores (1% and 0.17% uranium, respectively) from this region when leached with a typical lixiviant (hydrogen peroxide + sodium bicarbonate) of industry-standard specifications and ambient groundwater. Preliminary results from 48-hour batch leaching tests of samples show that samples leached with groundwater (sourced from the Westwater Canyon Fm. aquifer, host formation of many of the deposits) liberated approximately half the uranium that industry standard lixiviant leaching did. In addition, contrary to expectations, a less oxidizing lixiviant (i.e., containing an order-of-magnitude less hydrogen peroxide) liberated as much or more uranium relative to the industry-standard solution, not less. This implies that understanding the mineralogy of the system may be more important on predicting yield than the lixiviant concentration.

Ores from primary-type deposits associated with more organic carbon appeared to liberate a smaller fraction of their bulk uranium than redistributed-type ores (7 % uranium in samples with 3.5 % organic carbon content, versus 49 % released in those containing 0.03 % organic carbon). Lixiviant leaching also released non-target metals arsenic and selenium, which may have implications for groundwater quality and pregnant leach solution processing.

Much of the depositional porosity in the host sandstones of primary-type ores was subsequently reduced by deposition of organic matter and/or calcite, which may render them physically unsuitable for ISR depending on the lixiviant used. Preliminary results from electron microprobe analyses show the uranium mineralogy of primary-type ores to be overwhelmingly carbonaceous, with carnotite-group and pitchblende minerals present in much lower volume. Redistributed-type ores are dominated by pitchblende and carnotite group minerals. Carbonaceous uranium ores may be more resistant to alkaline ISR, but the higher amounts of uranium in them imply a longer mine life.

SELACHIAN-DOMINATED VERTEBRATE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS TOCITO SANDSTONE, SOUTHEASTERN SAN JUAN BASISN, NEW MEXICO

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An extensive fossil vertebrate assemblage collected from a series of anthills on the Tocito Sandstone (Upper Cretaceous, Coniacian), south of the Cabezon Peak volcanic plug in the southeastern San Juan Basin, consists of over 18,000 teeth from a variety of marine animals, the vast majority belonging to the class Chondrichthyes. About 200 pounds of anthill were collected, screen washed, and then picked under a microscope. Preliminary identification of these sharks, sawfish, and rays identifies the families Anacoracidae, Cretoxyrhinidae, Gingymostomatidae, Hybondontidae, Leptostyraxidae, Mitsukurinidae, Orectolobidae, Polyacrodontidae, Ptychodontidae, Rhombodontidae, Rhynobatidae, and Sclerorhynchidae.The vast majority of the teeth belong to the two genera *Scapanorhynchus* and *Cretolamna*, each represented by more than 8,000 teeth. Other faunal elements include baculites and other ammonites, varieties of teleost fish (including gar), at least two types of pycnodontids, crocodilians, gastropods, inoceramid clams, yet to be identified marine reptiles, and one mammal incisor. Reworked fusulinids were found, a result of erosional redeposition, possibly from Pennsylvanian deposits in the nearby Jemez Mountains. Several coprolites were also collected. Due to the fact that very few of the selachians have complete roots, and that the small number of larger teeth are fragmented, we inferred that these teeth were transported and then deposited on offshore sandbars or barrier islands. Of the 16,000 plus teeth assigned to the Mitsurkurinidaeand the Creroxyrhinidae,less than one percent exceed a main cusp height of 8 mm (from the tip of the crown to the base of the root). Why are the majority of the teeth so minuscule? Is this simply due to hydraulic sorting, or could this be evidence of a nearby pupping area for these two families of sharks? It has been established that modern sharks have dedicated nursery areas for their young, and this may be one of the few published examples of a Cretaceous selachian nursery. Another question to be studied is why some scapanorhynchid teeth have labial plications and others do not. Is this due to ontogenetic reasons, as some have posited, or is there another reason? Included in this fauna is a proposed new species of a ptychotrygonid based upon the mesial ornamentation of the teeth. As research continues on this assemblage, further selachian families may be recorded, listed families may be revised, and new species described. It is also possible that more than one species may be discovered within a particular established genus.

Exploring the Plumbing of the Truth or Consequences, New Mexico Geothermal System by using Magnetotelluric Surveys, Fracture Analysis, and Aquifer Testing

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We combined forward hydrothermal modeling with magnetotelluric (MT) and transient electromagnetic (TEM) geophysics to image a deep (4 to 10 km) crystalline-basement-hosted groundwater flow system that is associated with the Truth or Consequences (T or C) geothermal resource along the central Rio Grande rift of New Mexico, USA. Previously published hydrothermal models indicate that the effective hydraulic permeability of the crystalline basement in the T or C watershed must be unusually high (10^{-12} m^2) to explain measured hot-spring temperatures (41°C), geothermometer reservoir temperature estimates (170°C), vertical specific discharge rates (3 to 6 m/yr), and mean uncorrected carbon-14 groundwater residence times (7,000 yr). We further evaluate this conceptual model using electrical resistivity, fracture analysis, and aquifer testing. Regional subsurface resistivity patterns imply the presence of a single-pass and deeply circulating regional groundwater flow system between the upland recharge area to the west and the T or C hot-springs district near the Rio Grande to the southeast. The resistivity of the crystalline basement is observed to be between 100 and 200 ohm-m to depths of 10 km, which is typical of altered, fractured and saturated igneous and metamorphic rocks and is much more conductive than typical intact crystalline rocks. Regional faults do not appear to compartmentalize the groundwater system but may serve as conduits for upwelling fluids. There is also a conductive (50 ohm-m) feature at 6 to 10 km depth below the T or C hot-springs district that may represent upwelling brackish geothermal fluids. This feature is reproduced well by hydrothermal groundwater models that we use to infer electrical resistivity patterns. Aquifer testing carried out within the T or C hot-springs district estimate local crystalline basement permeability to be on the order of 4×10^{-10} m^2. Preliminary analysis of fractures in surface exposures of Proterozoic basement rocks in the Mud Springs Mountains and on the south side T or C reveals local variability in both rock type and fracture density. Rock types include folded metasedimentary and metavolcanic rocks intruded by nonfoliated granite that, in places, contain large xenolithic blocks of the older metamorphic rocks. The T or C outcrops north and west of the Rio Grande have the highest fracture densities (20 to 50 fractures/m). Outcrops in the Mud Springs Mountains commonly have low densities (2 to 10 fractures/m) with local zones of higher density. Interestingly, very few of the fractures observed in the Proterozoic rocks in the Mud Springs Mountains continue above the "Great Unconformity." Fractures in the Mud Springs Mountains predominantly strike northwest. The orientations of fractures in T or C are more variable. Overall, these results indicate the likely presence of permeable crystalline rocks on a regional scale that permit geothermal groundwater circulation to depths of up to 10 km within this geothermal system. This work provides evidence that seismically active rift settings with prolonged tectonic histories may contain extensive regions of highly-fractured crystalline rocks that facilitate groundwater circulation to great depth.

Keywords:

Truth or Consequences, geothermal system, fracture measurement, magnetotelluric data

Hydrogeology and Water Budget of the Sunshine Valley Region, Taos County, New Mexico

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It has been known since the 1920s that there is significant influx of groundwater to the Rio Grande in the reach that bounds the western edge of Sunshine Valley in northern Taos County, New Mexico. This occurs as spring discharge and seepage. The recent Aamodt Settlement Agreement includes a clause stating that 1,752 acre-feet per year of groundwater rights used for irrigation in Sunshine Valley are to be transferred to the Nambe–Pojoaque–Tesuque basin as surface water to be diverted from the Rio Grande. The reasoning is that groundwater not pumped for consumptive use will be available as surface water downstream. Thus this remote, sparsely populated region is of great regional hydrologic significance.

The Sunshine Valley aquifer consists of sand and gravel layers overlying and interbedded with fractured and highly transmissive basalt flows that pinch out to the east. Low-permeability, clay-rich lake deposits in the central valley cause local semi-perched and semi-artesian conditions. Recharge originates largely as winter precipitation in the Sangre de Cristo Mountains to the east of the valley; little recharge occurs across the valley floor. More than half of the recharge moves laterally into the aquifer from the adjacent mountain block, resulting in locally elevated groundwater discharge temperatures and perturbed thermal profiles in wells near young range-front faults. The remaining recharge occurs as infiltration of streamflow and irrigation water derived from streamflow. The very steep range front and extreme relief from the valley floor to the adjacent peaks, recently-active range-front faults, and abundant faults, fractures, and hydrothermal alteration in the mountain block associated with the Questa Caldera all likely play a role in the large amount of lateral ground water movement into the aquifer.

Water budget calculations for the region are constrained by fundamental data limitations, yet they imply that the valley aquifer is approximately in equilibrium, with estimated discharges falling between the estimated upper and lower bounds of recharge. Storage changes calculated from sequential water-level elevation surfaces indicate average storage losses of 1000 – 2000 acre-feet per year since the 1980s, corresponding to average water-level declines of few feet per year.

Cessation of groundwater pumping due to the water-rights transfer will ultimately result in additional discharge to the Rio Grande and Red River on a time scale of a few to several tens of years. Regional trends in precipitation, temperature, and surface water-use are the most likely factors involved in the declining amount of water in storage in the Sunshine Valley aquifer. Continued declines in annual precipitation and streamflow and increases in mean annual temperature will decrease the amount of recharge to and discharge from Sunshine Valley.

RAINFALL-RUNOFF RELATIONSHIPS COMPLEMENTING PREVIOUS SEDIMENT TRANSPORT STUDIES AT THE ARROYO DE LOS PIÑOS, SOCORRO, NEW MEXICO

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In semi-arid climates, sediment influx to large rivers such as the Rio Grande from ephemeral streams is challenging to quantify. These streams are not studied as often as perennial streams because of their erratic nature and the fact that they are usually located in hard to access, remote deserts. The Arroyo de los Piños is currently one of very few study sites collecting data on water velocity and discharge, bedload and suspended sediment, as well as other measurements that may be relevant during a flood event. This study site is located close to the confluence of the arroyo and the Rio Grande, yet data on the contributing watershed are lacking. Gaining a clearer picture of stream connectivity and rainfall-runoff relationships in this channel will be useful for quantifying flow generation as well as aquifer recharge and transmission loss through the stream bed.

Over the past monsoon season seventeen pressure transducers were installed in the Piños watershed (Figure 1). One recording rain gauge was added to the two existing gauges. The placement of the loggers and rain gauges aims to capture geologic heterogeneities within the watershed. Being able to determine the geology that experiences overland flow during an event has implications for the composition of the sediment transported to the monitoring site.

Several floods have been recorded in the arroyo tributaries since the loggers have been installed. Through pressure transducer and rain gauge data we can infer the pathway the storm took, and to some degree the intensity of the storm. We can also document which lithologic units produced flow most readily. We have limited rainfall and runoff data from 2018, but now that pressure transducers and rain gauges are installed, our instrument coverage for the 2019 monsoon season will allow us to better describe rainfall-runoff in the Piños.

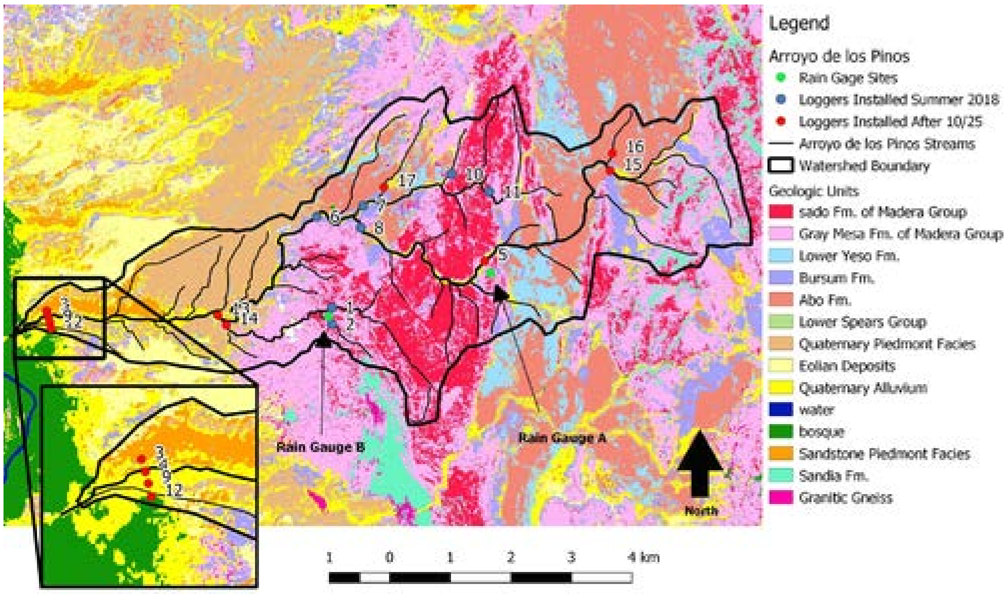

Figure 1: Arroyo de los Piños pressure transducer and rain gauge sites, inset of closely placed pressure transducers in the lower braided reach. Underlying geologic map is from Cather 2005.

Keywords:

Rainfall, Runoff, Aquifer Recharge, Flood

Signals of focused recharge along an ephemeral wash by repeat microgravity surveys, Arroyo de los Piños, NM

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We present preliminary results showing small (10-50-µGal) changes in gravitational acceleration along Arroyo de los Piños, NM east of Socorro following two flow events. These changes in gravity caused by subsurface mass change indicate that repeat microgravity is a viable technique to understand focused recharge along ephemeral streams. In semi-arid regions, ephemeral streams are common and form a significant source of both flow and recharge. However, floods in these streams are commonly violent and sediment-rich, making gaging and recharge estimates difficult. Repeat microgravity measurements do not require boreholes or access to the subsurface, so they are a good candidate for estimating recharge. In Summer 2016, we installed sixteen 0.6 m length Feno survey spike monuments along a 5-km reach of Arroyo de los Piños. Stations were located within a meter of the stream or as near as appeared stable. Stations were located along straight, relatively narrow reaches of the stream to avoid bank cutting and erosion/sedimentation in the stream bed below the station. A reference station, where gravity was assumed to be stable, was installed on a bedrock ridge outside of the catchment. In Summer 2018, we conducted three surveys on June 25-26, July 19-20, and July 28-29. Surveys had multiple occupations of each station with repeat measurements once an hour to correct for drift, and ties of at least three survey stations to the reference station. The June 25-26 survey was after several months of no rain or streamflow. The July 19-20 survey was after a 0.5 m maximum-stage flow on July 16; observations showed that it was bank-full but did not overtop the banks. The July 28-29 survey followed a 1.5-m depth flow on July 26; this flow did overtop the banks and removed two stations. Several other stations were buried by 2 cm to 5 cm of sediment, which was cleared away to a distance 3 m from each monument prior to the gravity survey. Changes in gravity were found relative to the base station and between occupations. For both flow events, there was a positive change in gravity indicating an increase in mass in the subsurface from recharged water. The gravity changes were larger for the narrower, single-trace, sinuous portions of the stream. Downstream, the channel transitions into a braided, mulitiple-thalweg channel, though constrained within a single low channel. Overall, there was a lower gravity change in this portion of the system. These observations argue that the conceptual model of using stream morphology with greater recharge occurring in braided systems than for sinuous systems may not be appropriate in streams like Arroyo de los Piños.

Keywords:

gravity, recharge, Arroyo de los Piños, ephemeral stream

EXTREMELY RARE COLOR PATTERN IN AN EXCEPTIONALLY WELL PRESERVED INOCERAMID BIVALVE FROM THE UPPER CRETACEOUS PIERRE SHALE OF NEW MEXICO

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We report here preservation of an extremely rare inoceramid bivalve color pattern in *Cataceramus*? *glendivensis* Walaszczyk, Cobban and Harries, 2001. This inoceramid was recovered from the upper part of the *Baculites baculus* Zone in the Pierre Shale of northeastern New Mexico. The locality (NMMNH L-12263) is in the upper Pierre, 80 km southwest of Raton near Cimarron, about 40 m below the base of the Trinidad Sandstone.

The very well preserved shell, which has both valves articulated, is large, prosocline, ventroposteriorly elongated, oblique to the long axis, and is equivalved and equilateral. The anterior margin is short, slightly convex, and passes into a long ventral margin. Most of the hinge line and posterior margin are missing. The valves are weakly inflated. The beak is curved anteriorly and projects slightly above the hinge line. Irregularly spaced, rounded rugae weaken ventrally. A fairly deep groove near the posterior end of the shell may be a sublethal, healed injury that caused a growth anomaly. The color pattern consists of alternating dark and light radial bands of varied widths. These bands follow the course of the long axis of the shell. The color banding is best preserved in the umbonal region; starting at the growth axis, the bands are narrow, and bands of the same color are of relatively equal width. In a dorsal direction, the bands begin to widen, and the dorsal-most band is very wide. Also, the bands appear to expand in width ventrally.

This is the first report of a color pattern in *Cataceramus*? *glendivensis*. Inoceramid color patterns are extremely rare, and reports of them are scant.

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Walaszczyk, I., Cobban, W. A. and Harries, P. J., 2001, Inoceramids and inoceramid biostratigraphy of the Campanian and Maastrichtian of the United States Western Interior Basin: Revue de Paléobiologie, v. 20, p. 117-234.

Keywords:

inoceramid,bivalve,color pattern,Cataceramus? glendivensis,Pierre Shale,Upper Cretaceous,New Mexico

NEW RECORDS FROM NEW MEXICO OF THE CRETACEOUS AMMONITE *PLACENTICERAS* EXTEND ITS BIOSTRATIGRAPHIC RANGE IN THE WESTERN INTERIOR

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The chronostratigraphically highest *Placenticeras* previously reported from the Western Interior is *Placenticeras costatum* Hyatt, 1903, from the late Campanian *Baculites reesidei* Zone (Larson et al., 1997; Cobban, 2016). We report here *Placenticeras* as high as the *B. baculus* Zone in the Pierre Shale of northeastern New Mexico. The *B. baculus* Zone is three ammonite zones higher than the *B. reesidei* Zone. *P. costatum* was recovered by us from the *B. reesidei*, *B. jenseni*, and *B. baculus* zones, and *P. meeki* Böhm, 1898 from the *B. baculus* Zone in the Cimarron area. The *B. jenseni* Zone is one ammonite zone higher than the *B. reesidei* Zone. In a postscript, W. J. Kennedy (Cobban, 2016) reported that, in the Western Interior, the youngest species of *Placenticeras, P. costatum,* extends into the lower half of the *B. reesidei* Zone, and *P. meeki* disappears a little lower in that zone. Two well preserved, compressed half whorls of *Placenticeras costatum* with nacreous layer from NMMNH (New Mexico Museum of Natural History) localities 12260 and 12261 are from the *Baculites baculus* Zone. There are five moderately strong, but small, umbilical bullae in the half whorl. The small, weaker, outer lateral nodes are about one-third the distance from the ventrolateral shoulder to the umbilical shoulder. Low, weak flexuous ribs connect the umbilical bullae to the outer lateral nodes and finally to ventrolateral clavi as delicate riblets. The weakly concave venter bears two rows of small, alternating, ventrolateral clavi. Five ventrolateral clavi occur between every two outer lateral nodes (Kennedy et al., 1996, p. 6), and the shells have distinct, sinuous growth striae, both of which are characteristic of *P. costatum* (Cobban, 2016, p. 597). Suture is not visible. One specimen from locality 12259 is a well preserved whorl that is part of a larger *Placenticeras meeki* with iridescent nacreous layer. It has a highly compressed shell with a very narrow, tabulate, concave venter. Fragments of the larger, outer whorl are less compressed with a tabulate venter that becomes less concave on the largest fragment, which is still septate. The shell is completely smooth and unornamented. Suture is not preserved. The occurrence of *Placenticeras costatum* in the upper Campanian *Baculites jenseni* Zone and the lowermost Maastrichtian *B. baculus* Zone, and *P. meeki*, in or a little above the *B. baculus* Zone in the Raton Basin, significantly extends the known presence of *Placenticeras* in the Western Interior.

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Larson, N. L., Jorgensen, S. D., Farrar, R. A. and Larson, P. L., 1997, Ammonites and the other cephalopods of the Pierre Seaway: Tucson, AZ, Geoscience Press, 148 p.

Keywords:

Placenticeras, New Mexico,Pierre Shale, Raton Basin, Cretaceous, Western Interior, Campanian, *Baculites jenseni* Zone,Maastrichtian, *Baculites baculus* Zone

FIELD-SCALE FAULT-ZONE CEMENTATION FROM GEOLOGICALLY GROUND-TRUTHED ELECTRICAL RESISTIVITY

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Fault-zones are an important control on fluid flow, affecting groundwater supply, hydrocarbon/contaminant migration, and waste/carbon storage. However, most current models of fault seal do not consider fault-zone cementation despite the recognition that it is common and can dramatically reduce permeability. As part of a study of field-scale fault-zone permeability and cementation, we examine the variably cemented Loma Blanca fault, a normal fault in the Rio Grande Rift. We collected electrical resistivity data from 15 parallel two-dimensional transects orthogonally crossing the fault, centered on exposures of the fault at the land surface. Inversions of the resistivity data indicate a low resistivity anomaly in the cemented portions of the fault and within the adjacent footwall; these anomalies are present in the unsaturated zone. This low resistivity signature may be an indication of a higher degree of fluid saturation resulting from greater capillary forces, both in the cemented fault (due to reduced pore sizes within the cemented material) and in the footwall (possibly due to smaller grain size). These mechanisms for generating low resistivity anomalies in both the cemented fault zone and in the footwall, suggest that the low resistivity anomalies likely correspond to regions with low permeability. The ability to characterize spatial variations in the degree of fault zone cementation with resistivity has exciting implications for improving predictive models of the hydrogeologic impacts of cementation within faults.

IDEALIZED MODELING OF SUBSURFACE FLOW BARRIER SENSITIVITIES

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We present a series of simple three-dimensional numerical flow models to examine how different barrier types impact the local subsurface flow regime and head distribution. Pumping is simulated near barriers including a linear boundary (similar to image well superposition), conductive fault structure, and laterally opposing facies (i.e. sharp permeability change). For each of these scenarios, vertical barriers (90°) were compared to dipping barrier orientations (45°). Each simulation was run for a duration of 1000 h with a fully penetrating well pumping at 6.3E-03 m^3/s (100 USGPM) under confined aquifer conditions. A finite element method based multiphysics software (COMSOL) was utilized for model mesh generation and flow simulation. Transient average well drawdowns were evaluated for each run. The linear barrier models produced the most substantial average well drawdown, which is attributed to the barrier's impermeability. Opposing facies simulations produced more average drawdown at the well than their conductive fault model counterparts. The impacts of barrier dip angle in late test time were only discernible in the conductive fault model runs. Furthermore, we include preliminary examples of a simple field study analogue where both opposing facies and a conductive fault are present. Additional perturbation analyses that vary both barrier dip and well proximity are likely to provide further insights to the flow regime sensitivity.

Keywords:

numerical flow modeling, fault hydrogeology, flow barriers

WELL TESTING INVESTIGATION OF FAULTS AS COMPLEX SUBSURFACE FLOW BARRIERS

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We are conducting an interdisciplinary geoscientific investigation at the Loma Blanca Fault in central New Mexico. One of our group's key research objectives is to better understand how non-idealized barrier faults impact subsurface flow regimes. Fault zones can act as flow barriers, conduits, or complex barrier-conduit features. Conventional flow theory and modeling packages often represent subsurface flow barriers as perfectly vertically impermeable linear boundaries. However, faults observed in the natural world commonly reveal properties including thickness, dip angle, and anisotropic permeability that violate numerous assumptions implicit in linear boundary representations.

The Loma Blanca Fault was chosen as the candidate for this field study because it deviates dramatically from idealized linear barrier models. The fault strikes north, dips at approximately 45°E, is cemented with abundant calcium carbonate, and has variable thickness ranging from 2 to 5 meters visible in outcrop. The calcium carbonate cement is inferred to act as a local groundwater flow barrier based on its low permeability relative to surrounding host sediments. However, multiple lines of interdisciplinary evidence suggest that the fault cement is discontinuous in the northern portion of the study area. Preliminary findings of a site geologic and depositional reconstruction suggest that a nearby ephemeral stream (Rio Salado) previously scoured the fault cement and surrounding sediments in the northern area. This interpretation creates an even more complex study-area subsurface, as it implies the presence of a cemented flow barrier that terminates perpendicular to a lateral erosional contact.

A series of 21 wells were installed in the study area's shallow unconfined aquifer in order to perform constant rate pumping tests. Time drawdown analysis and pressure derivative diagnostics of pumping and observation well data were processed with nSIGHTS open source software. Preliminary aquifer test analyses reveal extreme differences in hydraulic properties between the north/south study area, attributed to the erosional and depositional history. In addition to the presence of the cemented fault barrier, we propose that contrasting aquifer permeabilities on opposing sides of the inferred erosional contact represent an additional hydrologic boundary at this site.

Keywords:

faults, hydrogeology, well testing

SEDIMENT FLUX AND THE ACOUSTIC CHARACTERISTICS OF BEDLOAD IN THE ARROYO DE LOS PIÑOS, NM

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The Rio Grande is a crucial part of life in the Southwest U.S.; it and other mainstem perennial rivers allow for development in this semi-arid region. These rivers are often modeled to predict changes and allow for effective management and the largest source of uncertainty in modeling these rivers is associated with the sediment influx from ephemeral tributaries. Studies of ephemeral channels in arid environments are limited; few point measurements, let alone continuous datasets, exist for these flash flood-driven channels. Evaluating sediment transport by conventional means is not possible in flood-driven channels that are typical of large tracts of land in deserts worldwide. Automatic means are required to monitor these channels. To that end, three Reid-type slot samplers have been deployed at the Arroyo de los Piños sediment monitoring station. These samplers collect bedload in a chamber set below the surface of the channel. Sediment falls through a slot of a specified width and a system of pressure transducers measures the accumulated mass in real time. They represent a 9.5 m wide constricted reach of 1.3% slope draining a 32 km^2 basin with presumed high yields of sand and gravel. These are transported directly to the Rio Grande in a few monsoon-season flash floods. The channel bed is unarmored, with coarser pebble–cobble-rich bars and finer-grained thalwegs comprised of sand-rich granules. The channel bed contains about equal proportions of sand, granules (2-8 mm) and coarser particles.

While bedload is measured directly using Reid-type slot samplers, a number of novel surrogate methods are deployed to measure bedload indirectly. Here we present our initial analysis of two pipe microphone impact sensors. Pulses are generated from bedload striking the pipe that causes acoustic noise that is recorded by a microphone sealed within the pipe. If the acoustic power exceeds some predetermined threshold, a pulse is counted.

Five flood events, ranging widely in discharge, have been recorded along the Piños station to date. Initial analyses establish that bedload fluxes are very high by global standards (6.5 – 16.5 kg/m^2; as expected in unarmored, ephemeral channels). Bedload transport is initiated even by shallow flow events (5 – 10 cm water depth). The pipe microphone time series show significant differences both laterally and temporally. At times, the pipe microphone positioned near the left bank received nearly twice as many pulses as the right pipe microphone for a given water depth. These instruments have been successfully used in other channels worldwide; once properly calibrated, pipe microphones can be an effective alternative to painstaking manual measurements of bedload transport required by systems like the Reid slot sampler.

Keywords:

sediment, bedload, ephemeral, acoustic

TIMING OF LARAMIDE DEFORMATION ONSET IN NORTHERN ARIZONA-NEW MEXICO AND ITS TECTONIC IMPLICATIONS

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Observations from the southern Laramide region (Arizona-New Mexico) have figured prominently in deducing the tectonic processes that culminated in the formation of classic Colorado Plateau and Rocky Mountain basement-involved structures ~90-45 million years ago. Previous work has delineated eastwardly migrating magmatism that progressed from the late Cretaceous plate margin in southern Arizona/California to as far inboard as southern New Mexico. This sweeping pattern, and observations by subsequent researchers, has been attributed to flat slab subduction of the Farallon plate that transferred magmatism and orogenic compressional stresses >1000 km from the trench. An inferred eastward sweeping pattern of Laramide deformation has been more difficult to discern, and models suggest both sweeping (directed W-E or SW-NE), sporadic (i.e., lacking pattern), or episodic deformation timing across the region. Thus, the mechanisms that resulted in deformation still need additional testing to evaluate whether subduction processes can completely explain Laramide deformation timing. Here, we address these mechanisms by refining the timing of Laramide deformation onset (when significant deformation began) along a west-to-east transect in northern Arizona and New Mexico. The methods integrate (1) continuous time-temperature path models from a regional dataset of new, published, and unpublished apatite thermochronology data (fission-track and (U-Th)/He) on Laramide arches, (2) stratigraphic accumulation/basin subsidence histories on adjacent basins (San Juan and Raton) where present, and (3) compilation of onset estimates from previous geologic studies. This integrated approach allows for a comprehensive analysis of Laramide deformation timing. Results are consistent with an eastward sweep of deformation onset, originating in westernmost Arizona at the Kingman arch ~90 Ma and progressing to the San Luis-Sangre de Cristo arch and Raton basin in north-central New Mexico by ~75-71 Ma. These data lead to a model for Laramide orogenesis whereby deformation onset regionally migrated east-northeast (consistent with regional kinematic studies), a process that was guided by Farallon flat slab subduction that weakened the stable cratonic interior via progressive dewatering in conjunction with transmission of stresses inboard past the Sevier fold-thrust front. Comparison with transects produced in Montana and Wyoming show a similar onset pattern, though with early (~90-80 Ma) and late (~65-60 Ma) deviations to the onset trend that may be related to preexisting weaknesses within the Wyoming foreland. Later deformation starting ~75 Ma in Grand Canyon is interpreted to have occurred following passage of the conjugate Shatsky Rise, a feature that may have impeded dewatering and cratonic weakening that resulted in lower-amplitude Laramide structures coincident with the modern-day Colorado Plateau.

Keywords:

Laramide, tectonics, thermochronology, stratigraphy, structural geology

AN ASSEMBLAGE OF FRESHWATER INVERTEBRATES AND OTHER FOSSILS FROM THE UPPER CRETACEOUS FOSSIL FOREST MEMBER OF THE FRUITLAND FORMATION, FOSSIL FOREST RESEARCH NATURAL AREA, SAN JUAN COUNTY, NEW MEXICO

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Numerous fossil bivalves in shale/conglomerate were prepared out of several blocks (~227 kg) of sediment that were excavated from the Upper Cretaceous (upper Campanian) Fossil Forest Member of the Fruitland Formation in the Fossil Forest Research Natural Area (T23N, R12W) of San Juan County, northwestern NM. The Fossil Forest is named for an extensive *in situ* stump field preserved as a result of flooding. However, the area also contains numerous vertebrate and invertebrate fossils and other plant fossils. Much of the invertebrate and smaller vertebrate material is concentrated in channel-lag deposits; larger dinosaur and turtle fossils are more broadly distributed. One channel complex, located stratigraphically between the highest thick coal bed (> 1m) and the Bisti Bed, is especially rich in invertebrate specimens. The prepared blocks with bivalves are from this complex. Macerated plant debris and fragments of carbonized wood are common in the blocks. Dozens of shells of freshwater bivalves were preserved in the matrix. These bivalves are disorganized sedimentary clasts, together with inorganic pebbles, wood and bone fragments, suggesting that the fossiliferous sediment is part of a channel-lag deposit. Thus, few of the bivalves were preserved intact; most consist of single (non-articulated) valves. Nevertheless, many valves are in excellent condition, including some with internal nacre. Two species of bivalves were found, of approximately equal abundance. Both species are taxonomically classified within the Order Unionida (Gray); Family Unionidae (Rafinesque).

Commonly referred to as freshwater mussels, unionids are common throughout the world, and the family persisted in similar forms since the Triassic. Mollusks in general, and especially unionids, are variable in overall shell shape (e.g., ecologically plastic in morphology). Minor variations and deformation of the shell can result from environmental conditions, disease, and poor nutrition. Therefore, diagnostic features such as external ribbing and position of the umbo (hinge apex or "beak") are important for species identification. In addition to the genus *Unio*, two other genera of unionids have been documented from the Fruitland Formation: *Proparreysia* and *Plesielliptio*. The two species of bivalves found in this study are identified as *Unio* sp. 1 and sp. 2. *Unio* sp. 1 (very likely *U. baueri* Stanton) is the larger of the two species. Characteristics: average height = 5 cm; average length = 9 cm; subovate in outline; dorsal margin in front of beak descending steeply into a broadly rounded front margin; and very fine concentric ribbing (when preserved). *Unio* sp. 2 (possibly *Proparreysia holmesiana* (White)) is smaller and more ovate than sp. 1, with a more pronounced umbo (beak), and much heavier concentric ribbing. In addition to the bivalves, the following other fossils were present in the matrix: one gastropod, identified as *Campeloma amarillensis* (Stanton); one coprolite, light brown in color and not well mineralized, ~3 cm long, 2 cm wide, with evident plant fiber inclusions; several fragments of trionychid turtle carapace; one crocodile tooth, 4 cm long; and one conifer branchlet, 5 cm long.

FARALLON FLAT-SLAB SUBDUCTION AND NEW MEXICO GEOLOGY

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Flat-slab subduction of the Farallon plate is inferred from western U.S. magmatic and deformation histories which are similar to those observed at modern flat-slab subduction zones. At its maximum extent, the Farallon flat-slab hinge was under present-day New Mexico, affecting lithosphere deformation, magmatism, and the upper mantle. Here we present results of geodynamic models of flat-slab subduction, that form an interpretive framework for the lithosphere and upper mantle structure below New Mexico, as well as patterns of magmatism. Our models show that arc magmatism ended when the Farallon flat slab advanced. This happened because the asthenospheric wedge filled with lowermost lithosphere of the North American plate, which was scraped off by the advancing slab. As the slab flattened, it compressed the North American plate through end loading. This resulted in compressional deformation far east of the slab hinge, into present-day central US.

Slab removal opened the asthenospheric wedge, resulting in magmatism of the San Juan, Mogollon-Datil and Trans-Pecos volcanic fields. It left a step in the lithosphere-asthenosphere boundary which focused Rio Grande rift opening. A keel, consisting of bulldozed material that had been scraped off by the flat slab, is present below southeastern New Mexico, leaving a fast seismic velocity anomaly in the upper mantle that inhibits magmatism.

APPLICATION OF SELF POTENTIAL (SP) SURVEYS AND SHALLOW TEMPERATURE GRADIENT MEASUREMENTS AT A WARM SPRING AREA NEAR HILLSBORO, NEW MEXICO

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The self-potential (SP) method is most useful in early geothermal exploration. SP measures natural voltage differences at the surface and is inexpensive with two persons able to conduct a survey in a short-time frame. Required equipment includes: 1) 1,000 m of light-weight single conductor wire, 2) a high impedance digital voltmeter, and 3) copper-copper sulfate, porous-pot electrodes. One electrode provides a stationary base station, a second, weather-elements protected and stand-alone electrode in the field is for drift corrections, and a third is a roving electrode. In practice, a radial survey allows many measurements at 60-m or less spacing and facilitates anomaly shape and magnitude characterization. Contrasts in subsurface electrical conductivity, high temperature gradients, and moving subsurface fluids can create SP anomalies. Cultural and telluric interference, electrode drift, infiltration from recent precipitation, and very dry soil with poor electrical subsurface connection can contribute to measurement noise. Typically, 2 millivolts (*m*V) data accuracy is possible with survey attention to soil moisture, drift, and brief telluric disturbance. High-precision temperature logs of shallow small-diameter boreholes that are completed with water-filled, small-diameter pipe which is capped on the bottom and the annulus back-filled filled with grout can provide detailed subsurface formation temperature information and be cost effective. Measurement of thermal conductivity of drill core or cuttings allows detailed heat flow calculation. The Hillsboro Warm Springs discharges 38°C, sodium-bicarbonate-sulfate water from a developed spring tank on top of a low mound with siliceous (opal) deposits. Older opal deposits exist beneath thin colluvial cover in an apron surrounding the spring mound that extends laterally to a local and prominent jasperiod exposure of the Berrenda fault east of the springs. Spring aqueous Na-K-Ca and quartz geothermometers of 174 and 161°C and the presence of opal deposits infer potential for an intermediate-temperature geothermal system. The springs discharge is outboard 300 m to the west on the hanging wall of the exposed Berrenda fault on the Animas Mountains western margin. Our SP survey, conducted during November, 1992 and November, 1997, consists of 8.3 line-km with 30 to 60 m spacing over approximately 2 km^2 centered on the warm springs. Positive SP, 0 to 25 *m*V, is recorded adjacent the Berrenda fault at higher elevations. A positive closure of 34 *m*V within this zone overlaps the Warm Spring. A small bipolar minimum anomaly of -10 to -23 *m*V coincides with gradient hole SRC-1124-1 that shows formation up flow with gradients ranging from 400°C/km at 20 m depth to 175°C/km at 74 m depth and a bottom hole temperature of 80.3°C.An area of approximately, 4 km^2 was explored with seven temperature gradient holes by NMSU and funded by Steam Reserve Corporation, Denver in the 1980's. Conductive temperature gradients ranged from 50-to-400°C/km. Using, an estimated thermal conductivity of 1.8 W/m°K, the total heat flux for the Hillsboro Warm Springs system is estimated to be about 8 MWt with a background 90 mWm^2 regional heat flow.

Keywords:

Aqueous geothermometry, heat flow, Hillsboro, SP, temperature gradient, warm springs

EVALUATION OF A NEW AQUIFER STORAGE AND RECOVERY (ASR) WELL FOR THE ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY, ALBUQUERQUE, NEW MEXICO

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The Albuquerque Bernalillo County Water Utility Authority (Water Authority) is implementing an aquifer storage and recovery (ASR) project at their San Juan-Chama Drinking Water Treatment Plant (DWTP) in Albuquerque, New Mexico. The purpose of the project is to provide drought resiliency, while conserving both surface water and groundwater. The project is permitted by the New Mexico Office of the State Engineer (OSE) through the underground storage and recovery program under permit USR-4, and by the New Mexico Environment Department Ground Water Quality Bureau under discharge permit DP-1887.For this project, surface water from the Rio Grande that has been treated to meet drinking water standards at the DWTP will be stored in the Santa Fe Group Aquifer System of the Albuquerque Basin, and later recovered and used. A new well, ASR-01, was installed in 2017 and will be used for both injection of the treated water and extraction of the stored water. After equipping the ASR well with a submersible pump and a Baski flow control valve, a demonstration project began in the Spring of 2019 to develop and improve hydraulics of the well, test operational parameters, and evaluate water quality. Yellow Jacket Drilling of Phoenix, Arizona performed the drilling and testing of ASR-01. Using reverse mud rotary techniques, a 16-inch pilot borehole was drilled to 1,240 feet below ground surface (ft bgs). Lithologic descriptions of the drill cuttings and a borehole geophysics survey were completed using the pilot hole. The geologic units of the Santa Fe Group include the Sierra Ladrones and Ceja Formations. The Sierra Ladrones Formation appeared typical of axial fluvial deposits, and the Ceja Formation appeared typical of alternating floodplain and channel deposits. The pilot hole was reamed to 32-inches before the well was constructed using 20.6-inch diameter, stainless steel, louvered screen and casing manufactured by Roscoe Moss. The screen interval of the well is approximately 400 to 1,200 ft bgs. Filter pack material is silica beads manufactured by Sigmund Linder (SiLi).Following well development at ASR-01, aquifer testing was performed including step-drawdown and constant rate tests. The step-drawdown test had 4 steps of 200 minutes each with rates of 2,500, 3,000, 3,500, and 4,000 gallons per minute (gpm). Specific capacity ranged from 57 gpm per foot of drawdown (gpm/ft) at 2,500 gpm to 51 gpm/ft at 4,000 gpm. The constant rate test was run for 4 days at 3,000 gpm. Water quality of the treated surface water and groundwater are of high quality and meet drinking water standards. As water is injected into the aquifer, chemical reactions may occur that could impact water quality. The chemical compatibility of the treated surface water and groundwater was evaluated using the geochemical models PHREEQC and Geochemists Workbench. Based on the modeling results, the waters are compatible, and no adverse chemical reactions are expected to occur due to mixing of the waters in the aquifer or between the water and aquifer sediments. Extensive water quality sampling is also occurring during the demonstration testing.

Keywords:

Aquifer storage and recovery, ASR, hydrogeology

NEW ^{40}AR/^{39}AR DATES IN RIO MORA, NM: REGIONAL CONTEXT AND EVIDENCE FOR AN OROGENIC PLATEAU BUILT DURING THE PICURIS OROGENY

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Basement rocks in northern New Mexico provide evidence of peak tectonism at ~1.45-1.42 Ga, the Picuris orogeny that overprints older regional metamorphism and deformation at 1.65 Ga, the Mazatzal orogeny in southern Colorado and northern New Mexico. ^{40}Ar/^{39}Ar dates on hornblende and muscovite constrain cooling through ~500 °C and ~350-400 °C, respectively, and provide insight into cooling rates of these amphibolite-grade middle crustal rocks and what was happening tectonically immediately following Picuris orogeny peak deformation, metamorphism and pluton emplacement. New ^{40}Ar/^{39}Ar data from exposures along the Rio Mora in the Sangre de Cristo block from the Vadito, Hondo, and Trampas groups provide plateau cooling ages of 1398 ± 3 Ma, 1381 ± 3 Ma, and 1420 ± 1 Ma in hornblende. Muscovite samples provide cooling ages of 1378.0 ± 2 Ma, 1359 ± 3 Ma, and 1367 ± 5 Ma. This indicates cooling through 350 °C, at likely depths of 15-20 km, about 70-90 million years following peak tectonism. We compile these new data with ^{40}Ar/^{39}Ar cooling data from muscovite from the Petaca pegmatite district (mean age of 1375 ± 10 Ma), and similar ages in neighboring basement exposures in the Santa Fe range, Rincon range, Taos range, Picuris range, and southern Tusas Mountains. We find no evidence of post-Mazatzal cooling preserved in these areas as heating from the Picuris orogeny exceeded 500°C. The data illuminate post-Picuris orogeny cooling and its tectonic implications. Slow cooling from 1420 to 1360 Ma at temperature >350 °C occurred post-amphibolite grade metamorphism during the Picuris orogeny. We propose that an orogenic plateau was present in northern New Mexico following Picuris-aged tectonism. This orogenic plateau would have extended from central New Mexico to southern Colorado and may have been similar in size to the modern Colorado Plateau. The slow erosional removal of this plateau would provide a mechanism to have protracted cooling from >500 to <350 °C between 1420 and 1360 Ma (~70 Ma), and erosion of the region to sea level by ~1.2 Ga in time for deposition of the De Baca Group. A possible orogenic plateau analog would be the construction and eventual erosional removal of the Colorado Plateau from its initial uplift ~90 Ma to its future erosion back to sea level tens of millions of years in the future. In such an analog, erosional removal of a 2 km high Colorado Plateau and progressive 4/5 isostatic rebound would require exhumation of rocks from 10-15 km depths, similar to the aftermath of the Picuris orogeny.