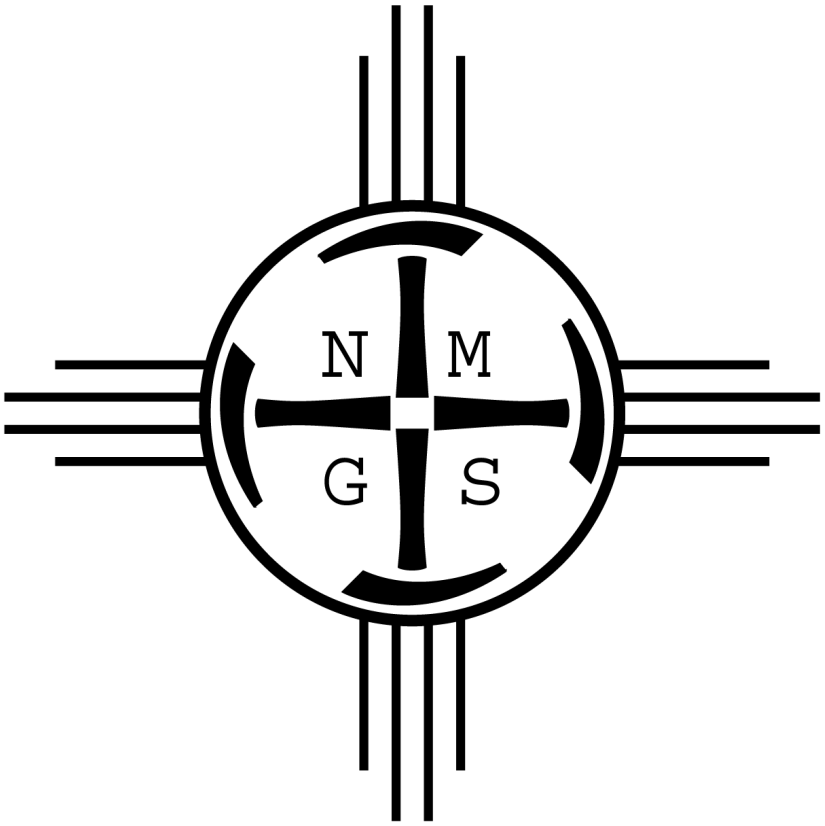
New Mexico Geological Society



Proceedings Volume

2016 Annual Spring Meeting

Macey Center

New Mexico Tech

Socorro, NM

NEW MEXICO GEOLOGICAL SOCIETY

2016 SPRING MEETING

Friday, April 8, 2016
Macey Center
NM Tech Campus
Socorro, New Mexico 87801

NMGS EXECUTIVE COMMITTEE

President:	David Ennis
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Adam Read

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Elaine Jacobs, Matt Heizler, Spencer Lucas, Dan Koning, Giday Woldegabriel, Gary Axen

Session 1: Geohazards in New Mexico and adjacent areas:

Auditorium: *8:30 AM - 10:45 AM*
Chair: Elaine Jacobs

EXAMINATION OF THE ANIMAS RIVER ALLUVIAL AQUIFER HYDRAULICS AFTER THE GKM SPILL
— Ethan A. Mamer and Stacy Timmons
8:30 AM - 8:45 AM

MONITORING GROUNDWATER CHEMISTRY IN THE ANIMAS RIVER ALLUVIAL AQUIFER AFTER THE GOLD KING MINE 2015 MINE-WATER RELEASE
— Stacy S. Timmons, Ethan Mamer, and Cathryn Pokorny
8:45 AM - 9:00 AM

WHAT HAVE WE LEARNED FROM MINE ACCIDENTS AND FAILURES IN NEW MEXICO?
— Virginia T McLemore
9:00 AM - 9:15 AM

GEOLOGISTS MUST REPOSSESS GEOLOGIC REPOSITORIES
— Norbert T Rempe
9:15 AM - 9:30 AM

THE ALLISON MINE SINKHOLE – CAUSES, CONSEQUENCES, AND CORRECTIVE ACTIONS
— Alan K Kuhn, Edward Loescher, Meghan McDonald, and David Hyndman
9:30 AM - 9:45 AM

Poster Viewing and Morning Break
Mezzanine: *9:45 AM - 10:15 AM*

INFLUENCE OF DEPOSITIONAL ENVIRONMENT ON DISSOLVED-PHASE PLUME MIGRATION AT THE KIRTLAND AIR FORCE BASE BULK FUELS FACILITY LEAK SITE
— Diane Agnew, Colin Plank, John Gillespie, Adria Bodour, and Dennis McQuillan
10:15 AM – 10:30 AM

SINKHOLES AS TRANSPORTATION AND INFRASTRUCTURE GEOHAZARDS IN SOUTHEASTERN NEW MEXICO
— Lewis Land
10:30 AM - 10:45 AM

Session 2: Paleontology, Modeling & Petroleum:

Galena Room: *8:30 AM - 10:45 AM*
Chair: Spencer Lucas & Gary Axen

FIRST RECORD OF A TYRANNOSAURID THEROPOD (DINOSAURIA) FROM THE LOWER CAMPANIAN MENEFEE FORMATION, NEW MEXICO
— Sebastian G. Dalman, Amanda K. Cantrell, Thomas L. Suazo, and Spencer G. Lucas
8:30 AM - 8:45 AM

A NEW SPECIES OF NEURANKYLUS FROM THE PALEOCENE OF NEW MEXICO
— Asher Jacob Lichtig, Steven E. Jasinski, and Spencer G. Lucas
8:45 AM - 9:00 AM

AGE AND CORRELATION OF THE LOWER PERMIAN ABO FORMATION AND YESO GROUP, CENTRAL AND SOUTHERN NEW MEXICO
— Spencer G. Lucas, Karl Krainer, and Daniel Vachard
9:00 AM - 9:15 AM

GEOARCHAEOLOGICAL SIGNIFICANCE OF A YOUNGER DRYAS AGED BLACK MAT, TULAROSA BASIN, SOUTHERN NEW MEXICO
— David M. Rachal, John Taylor-Montoya, Stanely Berryman, and James Bowman
9:15 AM - 9:30 AM

MODELING OF SURFACE UPLIFT PATTERN DUE TO THERMAL EXPANSION ABOVE THE SOCORRO MAGMA BODY
— Shuoyu Yao, Jolante van Wijk, Gary Axen, and Rediet Abera
9:30 AM - 9:45 AM

Poster Viewing and Morning Break
Mezzanine: *9:45 AM - 10:15 AM*

PETROLEUM SYSTEM MODELING IN THE WESTERN ANADARKO BASIN: IMPLICATIONS FOR CARBON STORAGE
— Evan Gragg, Jolante van Wijk, and Robert Balch
10:15 AM - 10:30 AM

RESERVOIR CHARACTERIZATION OF THE MORROW SANDSTONE USING THE WINLAND R35 METHOD.
— Dylan Henry Rose-Coss
10:30 AM - 10:45 AM

Session 3: Keynote Talk and Awards Ceremony:
Auditorium: *10:45 AM - 11:45 AM*
Chair: David Ennis and Elaine Jacobs

WILL THE ENVIRONMENTAL LEGACY OF HISTORIC MINING IN THE MOUNTAIN WEST EVER BE BEHIND US? LESSONS FROM THE ANIMAS RIVER SPILL
John Ridley
11:05 AM - 11:45 AM

Lunch 11:45 AM-1:15 PM

New Mexico Geological Society Business Meeting 12:45 PM -1:15 PM Auditorium

Session 4: Geohazards: New Mexico and adjacent areas - Part II:
Auditorium: *1:15 PM - 3:30 PM*
Chair: Elaine Jacobs

NEW MEXICO WEB MAPPING APPLICATION AT THE NM BUREAU OF GEOLOGY AND MINERAL RESOURCES: COAL AND GROUNDWATER QUALITY DATA
— Chang-Heng (Hank) Yang, Gretchen Hoffman, and Stacy Timmons
1:15 PM - 1:30 PM

PRESENCE OF PHARMACEUTICALS IN GROUNDWATER AND SURFACE WATER, LOS ALAMOS, NEW MEXICO
— Patrick Longmire, David Fellenz, Kim Granzow, Michael Dale, Megan Green, and Stephen Yanicak
1:30 PM - 1:45 PM

THE IMPORTANCE OF CAPTURING TOPOGRAPHIC VARIABILITY FOR MODELING FLOW AND TRANSPORT IN MOUNTAINOUS TERRAINS
— Chao Wang, Jesus D. Gomez-Velez, and John L. Wilson
1:45 PM - 2:00 PM

Session 5: Geochronology, Rivers & Groundwater:

Galena Room: *1:15 PM - 3:30 PM*
Chair: Matt Heizler & Dan Koning

THE GREAT PLAINS PROVINCE; INSIGHTS INTO MANTLE PROCESSES FROM THE RATON-CLAYTON VOLCANIC FIELD
— Sid Pinkerton
1:15 PM - 1:30 PM

A GEOCHRONOLOGIC VIEW OF THE YAVAPAI-MAZATZAL TRANSITION ZONE: PAIRED ZIRCON U-PB/HF ISOTOPE EVIDENCE FOR THE PRESENCE OF CRUSTAL MIXING AND DISTINCT HF ISOTOPE DOMAINS IN CENTRAL NEW MEXICO
— Tyler A Grambling, Mark E Holland, Karl E Karlstrom, George E Gehrels, and Mark Pecha
1:30 PM - 1:45 PM

^{40}AR/^{39}AR DATING OF THE OGALLALA FORMATION OF THE LLANO ESTACADO, SOUTHEASTERN NEW MEXICO.
— Kevin Henry, Matthew T. Heizler, and Steve Cather
1:45 PM - 2:00 PM

Session 4: Geohazards: New Mexico and adjacent areas – Part II: Continued

EFFECT OF INTERMITTENT FLOW ON THE MOBILITY OF METALS FROM ABANDONED URANIUM MINE WASTE SITES ON NATIVE AMERICAN LAND.
— Sumant Avasarala, Abdul Mehdi Ali, Peter Lichtner, Ricardo Gonzales Pinzon, and Jose Cerrato
2:00 PM - 2:15 PM

MICROBIOLOGY OF A RECLAIMED URANIUM MINE, LAGUNA PUEBLO, NEW MEXICO
— Olivia Raquel Chavez, Tom Lamar Kieft, Bonnie Frey, Dan Cadol, Reid Brown, Anitha Sundararajan, and Thiru Ramaraj
2:15 PM - 2:30 PM

AEOLIAN TRANSPORT OF DUST-BORNE URANIUM
— Reid Brown, Dan Cadol, and Bonnie Frey
2:30 PM - 2:45 PM

THE EL CAJETE ERUPTION AND ITS SIGNIFICANCE TO VOLCANIC HAZARD ASSESSMENT IN NORTH-CENTRAL NEW MEXICO
— Giday Woldegabriel, Rick Kelley, Elizabeth Miller, and Emily Schultz-Fellenz
2:45 PM - 3:00 PM

VOLCANIC HAZARDS AT THE SOUTHWEST'S SUPERVOLCANO: ONGOING EFFORTS TO TEMPORALLY DISSECT THE ERUPTIVE AND MAGMATIC HISTORY OF THE VALLES CALDERA
— Matthew J. Zimmerer, John Lafferty, and Frank C. Ramos
3:00 PM - 3:15 PM

Session 5: Geochronology, Rivers & Groundwater: Continued

UNRAVELING THE 5 MA BIRTH AND YOUNG EVOLUTION OF THE RIO GRANDE FLUVIAL SYSTEM
— Marisa Nicole Repasch, Karl Karlstrom, and Matt Heizler
2:00 PM - 2:15 PM

STRATIGRAPHY AND AGE CONTROL BRACKETING THE EARLY DEVELOPMENT OF THE PALEO-RIO CHAMA
— Daniel J. Koning, Giday WoldeGabriel, and David E. Broxton
2:15 PM - 2:30 PM

PRELIMINARY OBSERVATIONS OF THE PLIO-PLEISTOCENE DEVELOPMENT OF THE SOUTHERN ENGLE BASIN OF THE RIO GRANDE RIFT
— Colin Cikoski
2:30 PM - 2:45 PM

INFLUENCE OF THE VALLES CALDERA IN SUPPLYING GEOTHERMAL CHEMICAL COMPONENTS TO SPRINGS IN NORTHERN NEW MEXICO
— Valerie J Blomgren, Laura J Crossey, Karl E Karlstrom, Tobias Fischer, and Hyunwoo Lee
2:45 PM - 3:00 PM

CARBONIC SPRINGS AS DISTAL MANIFESTATIONS OF THE JEMEZ GEOTHERMAL SYSTEM, SAN YSIDRO, NEW MEXICO, HIGHLIGHTING THE IMPORTANCE OF FAULT PATHWAYS AND HYDROCHEMICAL MIXING.
— Chris McGibbon, Laura Crossey, and Karl Karlstom
3:00 PM - 3:15 PM

Session 6: Posters
Mezzanine: *8:30 AM - 5:00 PM*

Formal Poster Viewing
Cash Bar and Afternoon Snacks 3:00 PM – 5:00 PM

THE ANIMAS RIVER TOXIC SPILL: USING CURRENT EVENTS TO TEACH GEOLOGY, GEOCHEMISTRY, AND PRESENTATION SKILLS TO UNDERGRADUATE GEOLOGY MAJORS AT FORT LEWIS COLLEGE, DURANGO, CO.
— R Kenny, M D Bachrodt, E A Hedrick, M L Jiang, A J Kirkpatrick, P O Leysens, R L Martinez, J A Mason, K C Poisson, M S Vandervert, and B M Whidden
Booth: *1*

SURFACE-WATER QUALITY IN NORTHWESTERN NEW MEXICO AFTER THE GOLD KING MINE RELEASE
— Johanna M Blake, Laura Bexfield, and Jeb Brown
Booth: *2*

HYDRAULIC CONDUCTIVITY ESTIMATES FROM PARTICLE SIZE DISTRIBUTIONS OF SEDIMENTS FROM LOS ALAMOS CHROMIUM PLUME
— Rose Harris, Paul Reimus, and Mei Ding
Booth: *3*

EVALUATION OF THE ACCUMULATION OF TRACE METALS (AS, U, CU, CR, PB, ZN) ON IRON-MANGANESE COATINGS ON IN SITU STREAM PEBBLES AND EMPLACED SUBSTRATES
— Margaret Marie Turpin, Johanna Blake, Abdulmehdi Ali, and Laura Crossey
Booth: *4*

EVALUATION OF LEACHING TESTS ON URANIUM BEARING WASTE ROCKS FROM GRANTS MINERAL DISTRICT, NEW MEXICO
— Yitian Li, Ingar F Walder, and Bonnie Frey
Booth: *5*

NEAR-SHORE TAILINGS DEPOSITION IN BALLANGEN FJORD, NORWAY: A LOOK INTO NI AND OTHER TOXIC ELEMENT RELEASE RATE IN A SHALLOW SEA ENVIRONMENT AND ITS POTENTIAL FOR NI RECOVERY
— Rodrigo Frayna Embile, Jr., Ingar Walder, and Jenna Lee Donatelli
Booth: *6*

ON THE DEVELOPMENT OF A RETROACTIVE WATER BALANCE DERIVED FROM HISTORICAL WATER QUALITY AND FLOW DATA, MALMBERGET/VITÅFORS IRON MINE, NORRBOTTEN COUNTY, SWEDEN
— Susan F.B. Little, Ingar Walder, and Daniel Cadol
Booth: *7*

GEOCHEMISTRY OF SINKHOLES IN THE SANTA ROSA, NM AREA
— Mariah Jan Kelly, Laura Crossey, Rebecca Frus, and Abdulmehdi Ali
Booth: *8*

THE LIFECYCLE OF THE OLIGOCENE SCHOOLHOUSE MOUNTAIN CALDERA, SOUTHWEST NEW MEXICO
— Vanessa M Swenton, Jeffrey Amato, and William McIntosh
Booth: *9*

USING MULTIPLE GEOCHEMICAL TRACERS TO EXAMINE POTENTIAL LOW TEMPERATURE GEOTHERMAL RESERVOIRS IN NEW MEXICO
— Tanner K Grulke, Laura Crossey, Valerie Blomgren, Karl Karlstrom, Victor Polyak, and Yemane Asmerom
Booth: *10*

VOLATILE CONTENTS AND PRE-ERUPTIVE CONDITIONS OF RHYOLITIC MAGMAS FROM THE ORGAN CALDERA, SOUTHERN NM
— Jenna Lente and Emily Johnson
Booth: *11*

PROVENANCE AND SEDIMENT DISPERSAL TRENDS FROM UPPER CRETACEOUS NONMARINE STRATA IN SOUTHERN NEW MEXICO
— Cody J. Stopka, Brian A. Hampton, and Greg H. Mack
Booth: *12*

STRUCTURAL ANALYSIS OF SPECTACULAR LATE EOCENE SOFT-SEDIMENT DEFORMATION IN THE LOWER SPEARS GROUP, SAWTOOTH MOUNTAINS, WESTERN NEW MEXICO
— Jeffrey Dobbins, Gary Axen, Steven Cather, and Peter Mozley
Booth: *13*

THE LOS ALAMOS SEISMIC NETWORK (LASN): CURRENT NETWORK STATUS AND UPDATED NORTH-CENTRAL NEW MEXICO SEISMICITY
— Peter M Roberts, Elaine P Jacobs, James A Ten Cate, and Leigh S House
Booth: *14*

PRELIMINARY ANALYSIS OF SURFACE REBOUND RECORDED BY INSAR AND TEMPORAL VARIATIONS IN SUBSURFACE TEMPERATURES RECORDED AT THE BUCKMAN WELL FIELD, SANTA FE COUNTY, NEW MEXICO
— Matthew Folsom and Shari Kelley
Booth: *15*

THE ROLE OF THE LATITE DIKES AT THE COPPER FLAT HYDROTHERMAL SYSTEM
— Chaneil Jermaine Wallace and Kierran Maher
Booth: *16*

MIDDLE MIOCENE MAGMATISM ON THE EASTERN FLANK OF THE RIO GRANDE RIFT, NORTHEASTERN NEW MEXICO
— Sarah Shields, Jennifer Lindline, John Lynch, and Michael Petronis
Booth: *17*

MAGMA EMPLACEMENT PROCESSES OF THE OLIGOCENE ZAKUPY AND MIOCENE MERUNICE DIATREMES, CZECH REPUBLIC: REVEALED VIA PETROGRAPHY, ANISOTROPY OF MAGNETIC SUSCEPTIBILITY AND GROUND MAGNETOMETRY DATA
— Sarah F Shields, Michael S Petronis, Vladislav Rapprich, and Jan Valenta
Booth: *18*

THE CERRO COLORADO CINDER CONE, CERROS DEL RIO VOLCANIC FIELD; A STUDY OF MELT EVOLUTION AND PLUMBING SYSTEM DYNAMICS
— Joao Lages, Jeffrey Falance, Daniel Grondin, Jennifer Lindline, and Michael Petronis
Booth: *19*

PRELIMINARY HYDROGEOLOGIC DATA FROM EASTERN MORA COUNTY
— Kate Zeigler, Ryan Mann, and Stephanie Moore
Booth: *20*

PRELIMINARY GROUNDWATER STORAGE CHANGES FROM 1950S TO PRESENT IN NEW MEXICO ALLUVIAL AQUIFERS USING A SEMI-AUTOMATED WORKFLOW
— Alex J. Rinehart, Ethan Mamer, Brigitte Felix, and Trevor Kludt
Booth: *21*

CONSTRAINTS ON THE TIMING OF EXTENSION IN THE FRANKLIN MOUNTAINS FROM APATITE (U-TH)/HE THERMOCHRONOLOGY, EL PASO, TEXAS
— Rafael Andres Delfin and Dr. Jason Ricketts
Booth: *22*

TESTING A MARINE SIGNATURE FOR THE NEOPROTEROZOIC CHUAR GROUP OF GRAND CANYON USING SR ISOTOPIC DATA
— Jordan Curtis Anderson, Karl Karlstrom, and Laura Crossey
Booth: *23*

HYDROCHEMISTRY OF SULPHUR AND ALAMO CREEK, VALLES CALDERA: EFFECT OF GEOTHERMAL SYSTEMS ON SURFACE WATER QUALITY OF THE JEMEZ RIVER.
— Graham Thomas, Tanner Grulke, Laura Crossey, Karl Karlstrom, Valerie Blomgren, and Jared Smith
Booth: *24*

CHARACTERISTICS OF GROUNDWATER NEAR THE TIJERAS FAULT COMPLEX
— Alexandra J Minitrez and Laura J Crossey
Booth: *25*

DEGASSING OF CO2 ALONG FAULT NETWORKS FROM THE VALLES CALDERA AND INTO THE ALBUQUERQUE BASIN: CENTRAL RIO GRANDE RIFT, NEW MEXICO
— Jared R. Smith, Laura Crossey, Karl Karlstrom Tobias Fischer, Hyunwoo Lee and Christopher McGibbon
Minitrez and Laura J Crossey
Booth: *26*

TETRAPOD FOOTPRINTS FROM THE LOWER PERMIAN ABO FORMATION NEAR JEMEZ SPRINGS, SANDOVAL COUNTY, NEW MEXICO
— Spencer G. Lucas, Amanda K. Cantell, and Thomas L. Suazo
Booth: *27*

FREDERIC BREWSTER LOOMIS' 1924 AMHERST COLLEGE PALEONTOLOGICAL EXPEDITION TO THE SAN JUAN BASIN, NEW MEXICO
— Sebastian G. Dalman and Spencer G. Lucas
Booth: *28*

ICHNOLOGY OF THE CRETACEOUS (ALBIAN) MESILLA VALLEY FORMATION, CERRO DE CRISTO REY, SOUTHERN NM
— Eric J Kappus and Spencer G Lucas
Booth: *29*

A NEW ICHNOSPECIES OF *CARDIOICHNUS* FROM THE CRETACEOUS (ALBIAN) OF NEW MEXICO
— Eric J Kappus and Spencer G Lucas
Booth: *30*

A PEDAGOGY FOR THE CERRO DE CRISTO REY DINOSAUR TRACKSITE: HIKING TRAILS, SELF-GUIDED TOURS, AND VIRTUAL VISITS
— Eric J Kappus and Paul Galvan
Booth: *31*

AMMONITE ZONES IN THE SOUTHEASTERN SAN JUAN BASIN, SANDOVAL COUNTY, NEW MEXICO
— Paul L. Sealey and Spencer G. Lucas
Booth: *32*

DETECTING PENNSYLVANIAN MILLENNIAL-SCALE CLIMATE CHANGES USING POLLEN ANALYSIS OF MARINE LIMESTONE-SHALE RHYTHMITES
— William Eldridge Ganter
Booth: *33*

***CAMPYLOPRION* (CHONDRICHTHYES, EDESTOIDEA) FROM THE UPPER PENNSYLVANIAN OF SOCORRO COUNTY, NEW MEXICO**
— Wayne M. Itano and Spencer G. Lucas
Booth: *34*

***HOPLOCHELYS,* A DERMATEMYDID TURTLE FROM THE PALEOCENE OF NEW MEXICO**
— Asher Jacob Lichtig, Steven E. Jasinski, and Spencer G. Lucas
Booth: *35*

A NEW SPECIMEN OF *TRIISODON CRASSICUSPIS* (COPE, 1882) PROVIDES INSIGHT ON TRIISODONTID TAXONOMY AND PHYLOGENY
— Thomas E. Williamson, Sarah L. Shelley, and Stephen L. Brusatte
Booth: *36*

DIVERSE VERTEBRATE COPROLITE LOCALITY FROM THE UPPER PENNSYLVANIAN OF CENTRAL NEW MEXICO PROVIDES DATA ON THE TEMPORAL DISTRIBUTION AND ECOLOGICAL CONTEXT OF THE SHARK SURPLUS PARADOX
— Adrian P. Hunt and Spencer G Lucas
Booth: *37*

TYPE SPECIMENS OF FOSSIL VERTEBRATES IN THE NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE PALEONTOLOGY COLLECTION
— Amanda Kaye Cantrell and Spencer Lucas
Booth: *38*

INFLUENCE OF DEPOSITIONAL ENVIRONMENT ON DISSOLVED-PHASE PLUME MIGRATION AT THE KIRTLAND AIR FORCE BASE BULK FUELS FACILITY LEAK SITE

Diane Agnew[1], Colin Plank[2], John Gillespie[3], Adria Bodour[3] and Dennis McQuillan[4]

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[4]New Mexico Environment Department, 1190 St Francis Dr, Santa Fe, NM, 87505

Kirtland Air Force Base discovered a leak at the former fuel offloading rack in 1999, leading to a soil and groundwater investigation to determine the nature and extent of contamination resulting from the release of aviation gas into the environment. The majority of contamination is limited to the source area on the Air Force base with dissolved constituents extending off-base. Ethylene dibromide (EDB) is the primary risk driver for the site, with the dissolved phase plume extending approximately 7,000 feet down gradient towards the Albuquerque Bernalillo County Water Utility Authority Ridgecrest water supply wells. Depth to groundwater at the site is betwen 460 to 480 feet and flows to the north-northeast towards a cone of depression located near the Ridgecrest well field.

Utilizing geologist soil boring logs, continuous cores, and geophysical analyses, environmental sequence stratigraphy cross-sections have been developed at regional and plume scales. These cross-sections are consistent with the geologic understanding of the Abuquerque Basin synthesized by Connell (2008). Regional cross sections show that the EDB plume migrates within the portion of the groundwater system comprised of braided river deposits of the Ancestral Rio Grande, one of three primary depositional systems that filled the Rio Grande Rift Basins over time (Champion et al., 2015). Plume scale sections show that the coarse channel-fill and bar sediments are interbedded with silts and clays deposited in overbank and incipient floodplain settings (Champion et al., 2016). The depositional morphology of these fluvial deposits appears to influence plume hydraulics, resulting in the lateral spreading of the plume parallel and perpendicular to the regional hydraulic gradient.

Understanding the basin geology, specifically the orientation and extent of the braided channel deposits, at a variety of scales is critical for the design and implementation of the remediation technologies used to address EDB in groundwater. Locations of extraction wells for the ongoing EDB plume collapse interim measure were largely informed by the site stratigraphy and the simulation of plume capture using three-dimensional fate and transport models.

References:

Champion, Tom et al., 2015. Regional Geology and Cross Sections, Kirtland Air Force Base. Albuquerque, NM: Technical Memorandum.

Champion, Tom et al., 2016. Plume and Water-table scale Cross Sections, Kirtland Air Force Base. Albuquerque, NM: Technical Memorandum

Connell, Sean D., 2008. Preliminary Geologic Map of the Albuquerque-Rio Ranch Metropolitan Area and Vicinity, Bernalillo and Sandoval Counties, New Mexico Socorro, NM: New Mexico Bureau of Geology and Mineral Resources

Keywords:

Environmental sequence stratigraphy, EDB, Aviation gas, Plume migration

TESTING A MARINE SIGNATURE FOR THE NEOPROTEROZOIC CHUAR GROUP OF GRAND CANYON USING SR ISOTOPIC DATA

Jordan Curtis Anderson[1], Karl Karlstrom[1] and Laura Crossey[1]

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The goal of this research is to further test the depositional environment of the Grand Canyon's Chuar Group through $^{87}Sr/^{86}Sr$ analyses. The Chuar Group was deposited during a dynamic time in Earth's history between 780 and 742 Ma. This was just before some of the most dramatic changes in geology and biology in Earth's history: the breakup of the supercontinent of Rodinia, the Snowball Earth episodes, and the evolutionary commencement leading to multicellular life. The Chuar Group is a 1600-meter-thick, apparently conformable, microfossiliferous, unmetamorphosed succession that is composed of dominantly mudrock with subordinate but recurring sandstone and carbonate beds. Carbon isotopic studies have documented large 15 ‰ excursions in organic carbon in black mudrocks that, if marine, represent some of the largest positive excursion in Earth history. This is why it is critical to determine the depositional environment of the Chuar. If all or part of it was not deposited in the Neoproterozoic ocean then any data recovered from its sediments may not be relevant to the ocean chemistry of this time. Previous studies by Carol Dehler have inferred a shallow marine depositional environment based on sedimentary structures, marine microfossils and large swings in $\delta 13C$, which are recognized in all Neoproterozoic sections worldwide. To test for diagenesis we found the elemental concentrations of Sr, Fe, Mn and Mg for each sample. Samples with high Sr and low Fe/Sr, Mn/Sr and Mg/Sr were considered least altered and used for $^{87}Sr/^{86}Sr$ analysis.

We analyzed 36 samples for their elemental concentrations to determine if they had been significantly altered. 19 of the least altered samples were then analyzed to find their $^{87}Sr/^{86}Sr$ ratios. In the upper Chuar (Wallcott and Awatubi members) we found what we interpret to be primary Neoproterozoic marine $^{87}Sr/^{86}Sr$ values in 7 samples ranging from 0.706961 to 0.707219. We also found 4 samples that had radiogenic $^{87}Sr/^{86}Sr$ values from 0.702705-0.7084803 that we interpret to be altered based on the elemental concentrations. In contrast, in the lower Chuar (Tanner, Jupiter and Carbon Canyon Members) all 8 of our samples had apparently non-marine $^{87}Sr/^{86}Sr$ values from 0.7078137-0.7099816. These radiogenic samples from the lower Chuar have elemental concentrations similar to the samples with primary marine signatures in the upper Chuar suggesting that their $^{87}Sr/^{86}Sr$ values may be primary and non-marine. We conclude that lower Chuar Group rocks (Galleros Formation) may be non-marine or had an intermittent marine connection whereas the upper Chuar Group (Kwagunt Formation) is marine.

Keywords:

Grand Canyon, Chuar, Strontium, Neoproterozoic

EFFECT OF INTERMITTENT FLOW ON THE MOBILITY OF METALS FROM ABANDONED URANIUM MINE WASTE SITES ON NATIVE AMERICAN LAND.

Sumant Avasarala[1], Abdul Mehdi Ali[2], Peter Lichtner[2], Ricardo Gonzales Pinzon[1] and Jose Cerrato[1]

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Column experiments were conducted to study the effect of intermittent flow on the mobility of metals from abandoned uranium mine waste sites in Blue Gap Tachee (BGT), AZ and Laguna, NM. Intermittent flow represent the rainfall patterns in the southwestern United States, involving alternate wet and dry cycles. In order to simulate these rainfall patterns shorter wet periods of 15, 30, 60, 120 and 360 minutes, followed by longer dry periods of 24 hours, were adopted for the column experiments. The experiment involved sequential leaching of sediments from Laguna and BGT with 18MΩ water (pH 5.4), Synthetic Rain Water (SRW, pH 5.6), 10mM bicarbonate solution (pH 7.9) and 10mM acetic acid (pH 3.4) solution that represent the environmentally relevant conditions as witnessed in BGT water samples (pH 3.8 and 7.4). These reagents were specifically chosen to target most metal species through various transport mechanisms which include advective-dispersive forces, ion-exchange, desorption and dissolution. With just 18MΩ water and SRW almost 90 μg/L of U, 4500 μg/L of V and 20 μg/L of As were released from BGT mine waste while the Laguna sample showed the release of 380 μg/L of U, 2 μg/L of V and 40 μg/L of As. The released U concentrations were 3-13 times its EPA MCL for U which under natural circumstances could threaten the proximate communities. Bicarbonate and acetic acid extractions on the other hand released 3500-6000 μg/L of U, 50–3000 μg/L of V and 14-35 μg/L of As from both Laguna and BGT mine waste respectively. Based on our previously published results, U and V from the uranyl-vanadate (U-V) species within BGT mine waste samples were only partially released with bicarbonate unlike the column experiments where almost all of the U and V from the U-V species were dissolved and released using 10mM bicarbonate solution. For reference, the columns were also leached continuously with bicarbonate and acetic acid for a week (each), to identify if the phases were kinetically or thermodynamically controlled. A 1D reactive transport model is also being applied to better interpret the role of these interplaying mechanisms.

SURFACE-WATER QUALITY IN NORTHWESTERN NEW MEXICO AFTER THE GOLD KING MINE RELEASE

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The Gold King Mine Release of August 5, 2015 mobilized three million gallons of water and sediment into a tributary of the Animas River, which flows south from Colorado into New Mexico. The Animas enters the San Juan River at Farmington, New Mexico, the sixth largest city in the state and one of several communities that rely on the Animas and San Juan rivers for drinking water and (or) crop irrigation. Mines such as the Gold King are sources of metals and acidity to streams of the area, leading to concerns regarding the effects of the release on water quality. Potential problem constituents such as lead and arsenic (among others) were analyzed in surface water and sediment samples collected by the U.S. Geological Survey (USGS) in August 2015. Surface-water samples collected from the San Juan River at Farmington on August 8, 2015 (a time when the orange color indicative of the release was observed) had concentrations in whole water (unfiltered) samples of 552 μg/L lead and 26.3 μg/L arsenic. The concentrations of lead and arsenic were above the lead action level of 15 μg/L and the maximum contaminant level of 10 μg/L for arsenic, as set by the U.S. Environmental Protection Agency for drinking water. In contrast, the dissolved concentrations (0.45 μm filter) of these elements at the same site and time (lead <0.04 μg/L and arsenic 0.23 μg/L) were about two to three orders of magnitude below drinking-water standards and three to 5 orders of magnitude below the whole water sample concentrations. At the San Juan River at Farmington streamgage, located approximately two river miles downstream from the Animas River at Farmington streamgage, concentrations measured in whole water samples collected 4 hours after the samples on the Animas River ranged from 122 μg/L for lead, and 7.89 μg/L for arsenic. These concentrations were likely affected by dilution from the San Juan River which had discharge on August 8, 2015 of about 1,300 cfs, whereas discharge on the Animas River at Farmington was about 800 cfs.

Based on the results for total and dissolved water samples, constituents of concern generally were associated with particulates in the water. Bed sediment samples collected from the Animas River at Farmington on August 12, 2015 had lead concentrations ranging from 33.0 to 179 mg/kg and arsenic concentrations ranging from 3 to 11 mg/kg (n =4). Concentrations of these constituents in bed sediments were generally lower at the San Juan River at Farmington, similar to the trend in water-quality data for the same sites. Concern related to suspended particulates and bed sediment in these rivers continues months after the release. Continuous monitoring of pH, temperature, specific conductance, and turbidity is expected to help to understand the current geochemical interactions in the rivers. Additionally, water-quality sampling during snowmelt and storm events will provide valuable information about sediment and metal mobility during high-discharge events in the Animas and San Juan Rivers.

Keywords:

Gold King Mine, arsenic, lead, Animas River, San Juan River

INFLUENCE OF THE VALLES CALDERA IN SUPPLYING GEOTHERMAL CHEMICAL COMPONENTS TO SPRINGS IN NORTHERN NEW MEXICO

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Carbonic warm and hot springs extend NE of the Valles Caldera toward Taos, NM. The Valles Caldera had major eruptions 1.6 and 1.25 Ma, subsequent rhyolite eruptions lasting until 40-60 ka, and now hosts an active magmatically driven geothermal system. From studying spring chemistries at a range of distances from the Valles Caldera, we found that the Valles geothermal system influences water and gas chemistry at Ojo Caliente via a geothermal outflow plume (possible lateral transport) along the Embudo- Ojo Caliente fault systems of the Jemez lineament. This finding is supported by external carbon (C_{ext} – carbon from carbonates removed) concentrations of 0.04 mol/L and $\delta^{13}C$ of -3.5‰ (corresponding with Valles Caldera values), $^{87}Sr/^{86}Sr$ ratios of 0.747, Sr abundances of 1.35 ppm and higher ^{4}He concentrations than the Valles Caldera (suggesting long lateral transport through granitic bedrock), Na concentrations at 983 ppm and lithium at 4.3 ppm.

Our second finding is that regional fault systems provide conduits for both lateral and vertical migration of deep gases and solutes to rise and mix with meteoric fluids; this is verified by helium and carbon isotopes. Throughout the study site helium isotope analysis reveals the presence of a mantle component of 0.13 to 0.32 Rc/Ra, hence 1.6 to 4.0% MORB, assuming a MORB end member of 8 Rc/RA (Ra = $^{3}He/^{4}He$ ratio of air; Rc is air-corrected value). Carbon isotopes throughout the site have $\delta^{13}C$ values ranging from -9.05 to -3.5‰ showing mixing among an endogenic source, at -3.5 (Goff et al., 2000), and an organic source, typically -28‰.

Our third finding is that the eastern Rio Grande Rift springs have different chemistry than Ojo Caliente and La Madera springs (springs on the western side of the Rift) due to less lower world influence, meaning the eastern springs are mainly influenced by small geothermal input coming vertically upwards along faults rather than laterally from the Valles Caldera. We argue this because the eastern springs have lower C_{ext} concentrations of 0.001 to 0.004 mol/L, and they plot closer to the epigenic end member on mixing lines, in particular trace element and non-reactive gas plots.

In addition to these regional trends we discovered extensive degassing on a smaller geographic scale from Ojo Caliente to La Madera and Statue springs. The $\delta^{13}C$ values at La Madera and Statue springs range from 3.6 to 8.6‰ and have similar C_{ext} concentrations to Ojo Caliente at 0.03 to 0.04 mol/L. La Madera values can be modeled by using degassing Rayleigh fractionation equations, with an alpha for HCO_3 to CO_2, starting the degassing trend from Ojo Caliente values. The driver for CO_2 degassing is the fault network at Ojo Caliente where there is an intersection of NW and NE faults.

We conclude that Ojo Caliente springs underwent mixing with endogenic fluids derived in part from the Valles Caldera whereas eastern Rio Grande Rift springs are more meteoric, but still have $^{3}He/^{4}He$ ratios suggesting mantle or deep crustal degassing mostly from vertical transport along deeply penetrating faults.

AEOLIAN TRANSPORT OF DUST-BORNE URANIUM

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Closed mines pose significant risks to environmental and human health. While some work has been done on uranium mine waste contamination of surface water, ground water, and soil, little has been done to investigate the health risks to humans and wildlife from the aeolian transport of contaminated dust particles. In arid environments this is of particular concern due to the frequency of dust storms. At the Jackpile mine in Laguna Pueblo, NM, 15 sets of dust traps have been installed on vertical posts at heights of 0.25 m, 0.5 m, 1.0 m. and 1.5 m above the ground surface. The dust traps were installed at a range of distances from the source, from within the mine pit to approximately 4 km away. Soil samples have been collected at each site and dust samples will be collected every other month as well as collected after individual windstorm events. Soil and dust samples will be sieved into different size classes using 2 mm, 1.5 mm, 1.00 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.09 mm and 0.063 mm sieves. The samples will then be digested and uranium content will be analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). First, we will analyze our samples for correlation between dust and soil contamination to 1) evaluate if soil contamination can be used as an indicator for the risk of airborne contamination, and 2) gain insight into the possibility that dust is the source of soil contamination. Secondly, we will investigate whether uranium has an affinity for a particular size class of dust. Of special interest are the particles small enough to be completely inhaled by humans.

Preliminary results show that surface concentrations of uranium vary substantially across the landscape. Distance from the pit shows no correlation with concentration of uranium in the upper 5 cm of soil, however, vegetation height does. This correlation suggests that vegetation height and density may influence dust transport across the land surface. Uranium concentrations in the top 5 cm of soil tend to be higher at sites with 1.0 m or greater vegetation compared to the majority of sites with 30 cm grass. This work will be a step forward in closing the gap of knowledge in this area of potential human health risk.

Keywords:

Uranium, Dust transport, Soil

TYPE SPECIMENS OF FOSSIL VERTEBRATES IN THE NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE PALEONTOLOGY COLLECTION

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The New Mexico Museum of Natural History and Science (NMMNH) in Albuquerque, New Mexico, has one of the most scientifically significant fossil collections in the United States (Spielmann and Lucas, 2006). The collection holds world-class assemblages of Late Pennsylvanian fossils, Permian tracks, Triassic vertebrates, Late Cretaceous dinosaurs and Paleocene mammals, among others. The NMMNH was founded in 1980 by an act of the Legislature of the State of New Mexico, with the paleontology collection being established in 1983. In the last 32 years, the collection has grown to more than 70,000 cataloged specimens and more than 10,000 fossil localities. Museum staff, adjunct researchers, students and volunteers have collected the majority of NMMNH fossils, with the remainder coming from other institutions as orphaned collections (Morgan and Lucas, 2000). The vertebrate paleontology type collection includes a diverse array of specimens, from the 3535 kg (11,600 lb.) block with some of the dorsal vertebrae of the Jurassic sauropod dinosaur "*Seismosaurus" hallorum*, to a tooth of the Cretaceous eutherian mammal *Gypsonictops clemensi* that fits on the head of a pin. The vertebrate paleontology type collection of the NMMNH consists of 129 primary type specimens—81 holotypes and 48 paratypes. Of the 81 holotypes, 35 are genoholotypes; 68 of the 81 holotypes are from New Mexico, with the remaining 13 from Texas, Wyoming, Montana and Alabama. The number of holotype specimens by geologic time period is:Mississippian (1), Pennsylvanian (14), Permian (2), Triassic (26), Jurassic (1), Cretaceous (18), Paleocene (15), and Eocene (4). The following classes are represented in the NMMNH vertebrate paleontology type collection: Chondrichthyes (9), Acanthodii (1), Osteichthyes (4), Amphibia (2), Reptilia (32) and Mammalia (20).

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Keywords:

type specimens, New Mexico Museum of Natural History, collection

MICROBIOLOGY OF A RECLAIMED URANIUM MINE, LAGUNA PUEBLO, NEW MEXICO

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The Jackpile Mine near Laguna Pueblo is located in the New Mexico uranium belt and was once the world's largest open pit uranium mine. After the mine closed, it was reclaimed by the addition of soil on top of the mine tailings and leftover ore. This study aims to characterize the microbial communities in the soil, in relation to uranium concentrations and radioactivity levels. Soil was sampled aseptically, DNA was extracted and high-throughput metagenomic sequencing was performed at the National Center for Genome Resources. The resulting sequences give an overview of the inhabitant bacteria, eukarya and archaea. The results show a wide range of typical soil microbes, and also a strong representation from metal reducers, e.g., *Geobacter* spp. Importantly, the metal reducers include species bacteria that can reduce uranium from a mobile to an immobile state. Results suggest that the small amounts of uranium contamination (2.245 mg/kg to 15.191 mg/kg) have selected for bacteria capable of reducing metals, including uranium.

Keywords:

metagenome, microbiology

PRELIMINARY OBSERVATIONS OF THE PLIO-PLEISTOCENE DEVELOPMENT OF THE SOUTHERN ENGLE BASIN OF THE RIO GRANDE RIFT

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On-going STATEMAP geologic mapping of the Black Bluffs 7.5-minute quadrangle provides an opportunity to study the interrelated sedimentary, volcanic, and structural evolution of the southern portion of the east-tilted Engle basin of the southern Rio Grande rift. Mapping efforts to date have focused on the northern portion of the quadrangle around Mitchell Point along Elephant Butte Lake (EBL) eastward toward the Fra Cristobal Mountains (FCM), which lay in the footwall of the Walnut Springs fault (WSf) and bounds the basin on the east. All rift basin-fill sedimentary strata in the studied area belong to the Plio-Pleistocene Palomas Formation (Santa Fe Group), and include axial-fluvial pebbly sands/sandstones interfingering with piedmont sediments derived from the FCM to the east and several highlands to the west. Sedimentary rocks intercalate with locally-erupted basaltic flows and pyroclastic volcanics. The exposed rift basin-fill stratigraphy can be divided into four sequences based on the lateral extent of axial facies sediments and intercalated volcanics. Sequence (1) [oldest] is marked by sand-dominated axial-fluvial sediments occurring notably further east of axial sediments of later sequences. Axial sandstones of sequence (1) are found within 600 m of the FCM, as opposed to the ~2.5 km closest distance of later sequences. Piedmont sediments from the FCM then prograded westward, and sequence (2) axial-fluvial sediments occur only from the eastern margin of EBL on the east to at least 2 km west of EBL on the west. Sequence (3) is marked by intercalated basaltic flows and pyroclastic deposits. At the surface, volcanics are concentrated spatially to the east of EBL, with vents generally along intrabasinal and basin-bounding faults, and concentrated stratigraphically to a discrete interval as opposed to occurring throughout the Palomas Formation section. Toward the end of this volcanic period, piedmont sediments from the west prograded eastward toward EBL, and sequence (4) is marked by axial-fluvial sediments restricted to the area around EBL. The sharp contact between sequence (1) and (2) and basaltic flows in sequence (3) were used to estimate vertical offsets across the intrabasinal Hackberry fault (Hf) and the basin-bounding WSf. The Hf offsets the (1)-(2) contact by 60 m and various basaltic flows of sequence (3) by 10 to 42 m, with offsets decreasing to the north and/or up-section. The WSf offsets various basaltic flows of sequence (3) by 26 to 35 m. Axial-fluvial sandstones of sequence (1) do not cross the WSf, but the significantly greater eastward extent of axial sediments during this time relative to later sequences may be a reflection of significant activity along this basin-bounding structure during or preceding deposition of sequence (1).

Keywords:

Rio Grande rift, Palomas Formation, rift basins

FIRST RECORD OF A TYRANNOSAURID THEROPOD (DINOSAURIA) FROM THE LOWER CAMPANIAN MENEFEE FORMATION, NEW MEXICO

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We report an isolated complete lateral tooth, nearly complete right metatarsal II and right thoracic rib pertaining to a tyrannosaurid theropod from the Menefee Formation near Cuba in northwestern New Mexico. The Menefee Formation is an early Campanian terrestrial unit that yields diverse vertebrate fossil assemblage, notably of turtles and dinosaurs. The overall morphology of the isolated tyrannosaurid tooth, including small, block-shaped anterior and posterior denticles and the labiolingually twisted anterior carina, closely resembles the teeth of other tyrannosaurids from younger, Upper Cretaceous terrestrail deposits of Alberta and Montana. The presence of the isolated tyrannosaurid tooth in the Menefee Formation marks one of the earliest occurrences of these iconic theropods in the southwestern part of North America and adds to the previous assumption of the origin of Tyrannosauridae in Late Cretaceous Laramidia. Further, the tooth is labioligually compressed, unlike the bullet-shaped teeth of *Tyrannosaurus rex*, which provides new information about the dental morphology of tyrannosaurids. The right metatarsal II preserves most of the shaft and nearly complete distal condyles. The shaft is not exceptionally well-preserved; however,, it maintains its original morphology, which is identical to that of other tyrannosaurids, including a large, teardrop-shaped articular surface for metatarsal III. Both distal condyles are clearly visible; however, the lateral is only partially preserved, missing the entire lateral surface. The medial condyle is nearly complete. The ligament pit is shallow but extensive. Ventral to the ligament pit is a characteristic medioventral notch that lies nearly on the long axis of the ligament pit. This characteristic medioventral notch is present in the metatarsal II of the albertosaurine tyrannosaurids *Albertosaurus sarcophagus* and *Gorgosaurus libratus* and also in Appalachian taxa such as *Appalachiosaurus montgomeriensis*. The isolated thoracic rib is missing the head and part of the anterior and posterior shaft. However, the preserved shaft has a characteristic tyrannosaurid morphology, which includes a deep intercostal groove and prominent flange-like structure located on the anterolateral side of the shaft. At present, the genus-level taxonomic identity of the tooth, metatarsal II and the thoracic rib cannot be ascertained because other skeletal elements are unknown. However, given their relatively small size, the bones most likely belong to a juvenile animal.

FREDERIC BREWSTER LOOMIS' 1924 AMHERST COLLEGE PALEONTOLOGICAL EXPEDITION TO THE SAN JUAN BASIN, NEW MEXICO

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In 1924, a paleontological expedition from Amherst College in Massachusetts led by Dr. Frederic Brewster Loomis explored the Upper Cretaceous deposits in the San Juan Basin in northwestern New Mexico. This expedition has been overlooked by various workers on San Juan Basin paleontology, and, indeed, none of the fossils Loomis collected have been described in print. From 1917 to 1937, Loomis was a professor of biology and geology at Amherst College. He led many successful paleontological expeditions around the country and collected numerous important vertebrate fossils, which today are a part of the collections of Amherst College and the Springfield Science Museum, Massachusetts. The 1924 expedition to the San Juan Basin collected several partial but exceptionally well-preserved isolated bones and partial skeletons of dinosaurs and other vertebrates, including two species of turtles, Adocus bossi and Denazinemys nodosa. The dinosaur specimens include Ankylosauridae, Ceratopsidae, Hadrosauridae, Titanosauridae, and Tyrannosauridae. The ceratopsian skeletal materials are identified only to the family level, because their fragmentary preservation, whereas bones of other dinosaurs are identified to the genus and species level and include *Glyptodontopelta mimus*, the hadrosaurid *Kritosaurus navajovius*, and the titanosaurid sauropod *Alamosaurus sanjuanensis*. The tyrannosaurid skeletal material consists of an isolated, diagnostic right dentary, which may represent a new taxon. No field notes of this important expedition can be located, and only a brief report exists that does not specify the exact locality of the dinosaur bones and in what formation they were collected, beyond the designation "Ojo Alamo Formation." However, based on their preservation, the ceratopsian, hadrosaurid, and tyrannosaurid were probably collected from the De-na-zin Member of the Kirtland Formation, whereas a large, nearly complete left humerus of *Alamosaurus* and a cluster of osteoderms of *Glyptodontopelta* were collected from the Naashoibito Member of the Ojo Alamo Formation. The discovery of these specimens has historical and paleontological significance, because the Amherst College expedition and the specimens were largely forgotten and never described in the literature. The left humerus of *Alamosaurus* is the first and the most complete humerus of this giant sauropod recovered from the Upper Cretaceous deposits of New Mexico and provides new and important anatomical information. The identification of a possibly new tyrannosaurid adds to the growing record and diversity of tyrant reptiles in North America.

CONSTRAINTS ON THE TIMING OF EXTENSION IN THE FRANKLIN MOUNTAINS FROM APATITE (U-TH)/HE THERMOCHRONOLOGY, EL PASO, TEXAS

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The Rio Grande rift extends north-south for approximately 1,000 km from central Colorado to at least southern New Mexico and western Texas, and possibly farther into northern Mexico. Structurally the rift is a relatively narrow feature that is composed of a series of north-south-trending flank uplifts that lie in the footwalls of major rift-related normal faults. In southern New Mexico, however, the physiographic expression of the rift widens and becomes more similar to the adjacent Basin and Range Province. In the narrow segment of the rift in Colorado and northern New Mexico, the timing of extension in many localities has been constrained utilizing apatite fission-track (AFT) and (U-Th)/He (AHe) thermochronologic methods, but very little thermochronologic data yet exists for the southern Rio Grande rift in southern New Mexico or western Texas.

To extend the existing thermochronologic database to the south, five samples were collected from the eastern flank of the Franklin Mountains of western Texas for AHe thermochronology. Samples were collected from the Proterozoic Red Bluff granite at varying elevations. A total of 26 single-grain AHe dates were obtained from these five samples, with ages ranging from 7.9 ± 2 Ma to 40 ± 4.0 Ma. eU values for these samples are very restricted from 4-27 ppm such that correlations between AHe age and eU are not observed. Thermal history models were produced for four of the samples; the fifth sample is not suitable for modeling because of a range of AHe ages that cannot be explained by different eU concentrations. Based on thermal history modeling constraints, one sample remained at temperatures above 40 °C until 23 Ma and cooled to near-surface temperatures by 10 Ma, two samples remained at temperatures above 40 °C until 18 Ma and cooled by 8 Ma, and the fourth sample remained at temperatures above 40 °C until 15 Ma and cooled by 8 Ma. Although these timing constraints are rough and could be improved with the addition of higher-temperature thermochronologic data, the AHe ages and thermal history models are consistent with results from the northern and central segments of the rift that preserve a strong pulse of exhumation from 25-10 Ma.

These data, when viewed within the context of existing AFT and AHe data from Colorado and New Mexico, indicate that the southern Rio Grande rift of western Texas evolved coevally with the more well-defined central and northern segments of the rift. These data do not support models of a northward-propagating rift or rotation of the Colorado Plateau as a primary driver of extension. Rather, models to explain the rift must account for synchronous extension along its length from northern Colorado to Texas as indicated by thermochronologic data.

STRUCTURAL ANALYSIS OF SPECTACULAR LATE EOCENE SOFT-SEDIMENT DEFORMATION IN THE LOWER SPEARS GROUP, SAWTOOTH MOUNTAINS, WESTERN NEW MEXICO

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Spectacular soft-sediment deformation (≤150-m thick) in the upper Eocene lower Spears Group is exposed along the northern periphery of the Mogollon Datil volcanic field (MDVF) in the Sawtooth, Datil, and Gallinas Mountains of western New Mexico. Despite detailed studies of the stratigraphy, geochronology, and geochemistry of volcanic and volcaniclastic rocks in the MDVF, no thorough structural analysis of widespread soft-sediment deformation has been undertaken. The present study exploits excellent exposures in the Sawtooth Mountains to reconstruct the late Eocene deformational history of the northern MDVF.

Four methods were used to analyze lower Spears Group deformation: (1) 1:6000 scale geologic mapping on enlarged 1:24,000 USGS topographic quadrangle base maps, (2) mapping fault and bedding traces on oblique photos of cliff exposures, (3) measuring and describing slip and separation indicators such as Riedel shears, fault-plane striations, drag folds, and displaced contacts, and (4) analyzing thin sections of cataclasite and undeformed rock samples.

A structural stack with five distinct levels is present throughout the study area. The lowest level exposed is the middle to late Eocene Baca Formation with gently east-dipping bedding. A detachment fault sub-parallel to underlying bedding is present in some locations at the upper Baca contact and in others less than five meters above a depositional contact. Above the Baca, the volcaniclastic unit of Largo Creek (VLC) of the lower Spears Group forms a sheet (0-150 m thickness) of variably contorted sandstones. In thicker sections, localized listric faults in lower exposures are truncated above by a zone of up to five sub-horizontal faults bounding deformed VLC sandstones. The upper VLC contact is an extensive gently- to moderately-dipping (5º-30º) detachment fault with indicators suggesting the upper plate slipped east or southeast. Overlying Dog Springs Formation (lower Spears Group) debris-flow deposits are sub-horizontal and parallel to the subjacent detachment in western peaks, but in eastern peaks dip steeply east (75º-85º) with stratigraphy facing east. South- and southwest-striking reverse-dextral faults offset the stack down to the east.

Analyzing the structural stack and incorporating previous investigators' findings resulted in multiple spatial and temporal interpretations by the author. Cataclasite rip-ups within a cataclasite layer subjacent to the detachment imply multiple cataclasis events. The detachment fault separating the Dog Springs from underlying units formed during one or more mass movements, possibly landsliding or block spreading events. The upper plate detached from a western source, most likely an unstable topographic feature formed by the Hickman fault zone. In eastern lower Spears Group exposures outside the study area, exotic non-volcanic blocks were likely derived from eastern or southern sources. Crosscutting relationships between faults provide a timeline of deformation events. Following deposition of the lower Spears from 37-40 Ma, localized slumping and thrusting formed listric faults in the VLC. One or more large blocks of Dog Springs deposits detached from a western source and moved eastward over VLC deposits. Reverse-dextral faults offset the detachment fault down to the east, probably during late-Laramide transpression, which ended approximately 36 Ma, providing a minimum age constraint on deformation in the Sawtooth Mountains.

Keywords:

soft-sediment deformation, detachment fault, mass movement, Spears Group, Sawtooth Mountains, Mogollon Datil volcanic field

NEAR-SHORE TAILINGS DEPOSITION IN BALLANGEN FJORD, NORWAY: A LOOK INTO NI AND OTHER TOXIC ELEMENT RELEASE RATE IN A SHALLOW SEA ENVIRONMENT AND ITS POTENTIAL FOR NI RECOVERY

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In Ballangen, Norway, mine tailings from the closed Råna Nickel-olivine mine were discharged in the nearby Ballangen Fjord, covering old high sulfide containing mine tailings from a massive sulfide deposit. A tailings dam was built in the inner part of the fjord filling the old tidal flats that also contain an older tailings deposit. The leaching of metals especially Ni and other toxic elements into the fjord is a major threat to shallow sea and bottom dwelling organisms in the area. To determine the rate of release of Ni and other potential toxic elements into the surrounding ecosystem, column experiments using the old tailings obtained from a depth of 8 to 40 cm from different locations within the tailings deposit, beach sand, and stream bed sample from a nearby creek were conducted for 40 weeks. A column containing the same material that has been running for over 150 weeks was also used to compare long-term reaction rates. Initial results from the recent kinetic testing show that the beach sediments have the highest and almost constant TDS followed by the middle portion of the dumpsite and the stream sediment sample. Tailings on the west side have clearly higher pH in the range of 5 to 7 while those on the east side are more acidic with pH of 3 to 4. All the metals analyzed (Ni, Cu, Mn and Fe) decrease in concentration in time. Current data suggests Cu and Mn are highest in the stream sediment, while the middle part of the dumpsite close to the stream has elevated Ni and Fe. Elevated Mg concentration in the leachates collected suggests significant weathering of olivine. Based on the long-term data for 150 weeks it was observed that Ni release generally increased as pH decreased. From the Ni leaching rates observed, the possibility for Ni recovery from mine tailings is not unlikely. The interplay of spatial variation, mineralogy of the material and groundwater movement play a significant role in the resulting leachate chemistry.

PRELIMINARY ANALYSIS OF SURFACE REBOUND RECORDED BY INSAR AND TEMPORAL VARIATIONS IN SUBSURFACE TEMPERATURES RECORDED AT THE BUCKMAN WELL FIELD, SANTA FE COUNTY, NEW MEXICO

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The Buckman well field (BWF) experienced substantial drawdowns and ground subsidence recorded by InSAR between 1993 and 2000. Subsequent changes in well field management resulted in dramatic recovery of water levels starting in 2007. Newly processed InSAR data from 2007-2010 show ground uplift across a 12 km^2 area in the field, with uplift rates as high as 50 mm/yr. Modeling using an inverse Mogi method suggests that a net increase of volume of ca. 4 x 10-4 km^3 (324 acre-ft. equivalent) at a depth of 1200 m can explain the observed signal; this is approximately the depth of crystalline basement. This uplift is interpreted as an elastic response of rock units to increased pore pressures, and its magnitude is unexpected. Also imaged is a bimodal pattern of both subsidence and uplift that is most pronounced during the period 2009 – 2010. The sharp discontinuity observed between the two phases in the 2007-2010 data was previously imaged in the 1993-2000 data.

This discontinuity is also recorded in repeat temperature measurements in the BWF. Students attending the Summer of Applied Geophysical Experience (SAGE) field school had a unique opportunity to measure temperature profiles in monitoring wells in the BWF between 2013 and 2015. Repeat measurements of thermal profiles and well discharge temperatures indicate that aquifer temperatures are dynamic in some areas, while aquifer temperatures elsewhere remain fairly constant.

Here we focus on data from three monitoring wells (SF2b, SF3a, SF4a) and three production wells (Buckman 1, 6 and 8) near the Rio Grande. SF2b has a geothermal gradient of 38°C/km above 120 m and 54.4°C/km below 120 m; this increase of gradient with depth likely corresponds to a change from sandy deposits at shallow levels to finer-grained deposits at depth. The temperature in SF2b between 200 and 235 m has been warming gradually since 2008. The 2008 temperature was 0.5°C lower than our 2013 measurement and the 2015 temperature was 0.2°C higher than the 2013 measurement. The elevated thermal gradients measured in SF3a and SF4a of 72 and 79 C°/km are only 300 m west of SF2b; repeat thermal profiles measured in both wells between 2013 and 2014 are identical. Discharge temperatures and water levels in Buckman 1 and 6 have slowly been rising since 2008. Analysis of discharge temperatures collected during the summer months in Buckman 1 reveals that the well draws in cooler water during times of high and prolonged production. The discharge temperatures in Buckman 8 show no temporal trend.

Differences in thermal gradient, water chemistry and the response of water levels to pumping at Buckman 1 indicate a discontinuity between the aquifers sampled by the SF2 and the SF3/4 piezometer nests. The exact reason remains a mystery. Possibilities include (1) changes in aquifer thermal properties related to ground subsidence across the discontinuity imaged by InSAR; (2) thermal changes caused by long-term production in the well field; and (3) elevation of gradients by upwelling of warm fluids by the regional-scale flow system.

Keywords:

Buckman well field, InSAR, temperatures

DETECTING PENNSYLVANIAN MILLENNIAL-SCALE CLIMATE CHANGES USING POLLEN ANALYSIS OF MARINE LIMESTONE-SHALE RHYTHMITES

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Deep-water "rhythmites" are characterized by thin, rhythmically interbedded limestone layers alternating with shale layers. They are common in Precambrian through Cenozoic poorly oxygenated offshore marine deposits. Previous studies report that individual limestone-shale couplets represent 1000-3000 years and are the result of millennial-scale wetter to drier climate changes with shale layers indicating wetter climates and limestone layers representing drier climates. I am testing this millennial-scale climate change hypothesis by comparing the characteristics of eolian-derived pollen assemblages in limestone versus shale interbeds from two different Middle Pennsylvanian rhythmite successions in central New Mexico. If the pollen-producing terrestrial plant community changed in response to these climate changes, then the pollen diversity and abundance might be reflected in offshore deposits and different pollen morphotypes and abundances would occur in the limestone versus shale layers.

Preliminary results from a single section in the southern Sandia Mountains show four statistically significant pollen morphotypes including bissicate, alete, periporate, and trilete. Of these morphologies, bissicates are the most common in shale layers, whereas limestone layers contain greater abundances of the other three morphotypes. Additional samples from a coeval northern Sandia Mountain location are being processed to further substantiate these trends. If both locations record distinctly similar pollen abundances and diversity trends, then this research suggests that Paleozoic rhythmites as primary depositional features and millennial-scale climate changes affected both terrestrial vegetation patterns and offshore sediment input.

PETROLEUM SYSTEM MODELING IN THE WESTERN ANADARKO BASIN: IMPLICATIONS FOR CARBON STORAGE

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We use Petroleum System Modeling techniques to support ongoing and potential future carbon storage and utilization efforts in the western Anadarko Basin. Petroleum system characterization models are developed to better understand regional migration risks of CO_2, as well as hydrocarbon sources and fluid properties. This research is part of ongoing field scale characterization conducted by the Southwest Regional Partnership on Carbon Sequestration at Farnsworth Unit's large scale carbon capture, utilization and storage operation in the pandhandle of Texas. The goal of this project is to evaluate the injection and storage of 1 million metric tons of 100% anthropogenic sourced CO_2 as part of a CO_2-Enhanced Oil Recovery operation. Carbon stored by EOR operations can help minimize the impact of carbon emissions on the climate system while meeting energy demands.

2D reflection seismic data, well log and core data were interpreted and integrated into three Petroleum System Models across the northeast Texas panhandle. Results highlight three key issues: (1) the regional migration risk of CO_2 is towards the northwest and northeast, and appears low, (2) upper Morrowan reservoir hydrocarbons in the region are not dominantly sourced locally, and are most likely sourced from the Thirteen Finger and upper Morrowan black shales deeper in the Anadarko Basin, (3) Petroleum System Models are useful aids in characterizing CO_2 migration patterns and risk, seal bypass systems, and potential additional reservoirs for CO_2 storage. In order for carbon storage technology to make a measurable impact on emissions, its implementation would need to expand greatly across the globe. Petroleum System Modeling techniques appear to work well as a 1st order characterization tool for many vital geologic aspects of carbon storage. Decision makers could use this information to aid ranking and selection of future regions if the technology is to be deployed on increasing scales.

Keywords:

Morrowan, Anadarko Basin, Carbon Storage, Petroleum System Modeling, CO2-EOR, Farnsworth Unit, SWP, Climate Change, Characterization

A GEOCHRONOLOGIC VIEW OF THE YAVAPAI-MAZATZAL TRANSITION ZONE: PAIRED ZIRCON U-PB/HF ISOTOPE EVIDENCE FOR THE PRESENCE OF CRUSTAL MIXING AND DISTINCT HF ISOTOPE DOMAINS IN CENTRAL NEW MEXICO

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The preferred model for growth of continental lithosphere along the southwest margin of Laurentia from 1.80 Ga to 1.60 Ga involves accretion of juvenile arc terranes in a continental arc or back arc environment. Addition of continental lithosphere during this time is interpreted to have occurred during two major orogenic events, the Yavapai and Mazatzal orogenies. The former affecting 1.80-1.70 Ga juvenile crust between 1.71 and 1.68 Ga, and the latter influencing 1.68-1.60 Ga juvenile crust from 1.66-1.60 Ga. Each event resulted in crustal provinces that, in addition to delineation based on structural and geophysical properties, have distinct zircon Hf isotopic domains reminiscent of the age of their respective terrane. Recent studies have shifted previous interpretations of the discreet boundary between the Yavapai and Mazatzal provinces, but did not fully address the transition zone between each province or offer a more concrete interpretation of where geochronologic data would indicated this zone to lie. Comparisons of paired U-Pb/Hf isotopic data from both igneous and detrital zircon collected from the Nacimiento, Zuni, Sandia, and Manzano Mountains indicate the presence of purely Yavapai-derived crust present in the southern Nacimiento Mountains, zones of mixed Yavapai and Mazatzal-derived crust in the Zuni and Sandia Mountains, with the central Manzano Mountains representing the first appearance of solely Mazatzal-derived crust in the region of study. This data indicates that there is an geochronologically distinct Yavapai-Mazatzal transition zone that approximately coincides with the transition zone described by Whitmeyer and Karlstrom in 2007. Additionally, this data adds temporal support for the notion that assembly of Yavapai-age crust ceased at approximately 1.7 Ga and resumption of accretion occurred at approximately 1.68 Ga, with evidence of recycling portions of Yavapai-age crust into juvenile Mazatzal blocks during the early stages of the Mazatzal orogeny and cessation of this Yavapai influence on Mazatzal terrane by 1.65 Ga. This allows for more detailed interpretation of the timing of, and subduction regimes dominant during, Paleoproterozoic growth of the North American continent.

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Keywords:

Basement, Tectonics, Precambrian, Proterozoic, Zircon, Hf, U-Pb, Geochronology, Yavapai, Mazatzal, Crustal Provinces

USING MULTIPLE GEOCHEMICAL TRACERS TO EXAMINE POTENTIAL LOW TEMPERATURE GEOTHERMAL RESERVOIRS IN NEW MEXICO

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Geochemical tracers can be very useful in investigating solute sources, mixing of ground and surface waters, and tracking geothermal inputs in any given system. There are many different geochemical tracers that can be applied to a system depending on the inputs and water-rock interactions that affect the system. The geochemical tracers used in this study include major ion chemistry, trace element chemistry, and stable and radiogenic isotope signatures. We analyzed spring and well waters from several different regions in New Mexico and apply geochemical models to estimate subsurface temperatures (geothermometry), as well as mixing models to quantitatively test flowpath hypotheses. When combined at a single system or study area, these tracers can prove to be immensely powerful tools in analyzing surface and groundwater.

Chemical geothermometers take advantage of temperature dependent water-rock reactions. The geothermometers applied in this study used concentrations of dissolved silica, Na, K, Ca, Mg, and Li. Geothermometers can be used to assess possible reservoir temperatures from chemical data of surface waters. Geothermometers have some limitations when solute concentrations are affected by processes such as: mixing with other waters, dissolution or precipitation, ion exchange with surrounding materials, and residence time. We use models compiled by Powell and Cumming (2010) to estimate subsurface fluid reservoir temperatures and equilibration state.

Preliminary tools used for identifying site-specific mixing trends and potential solute sources were ternary diagrams (Cl-SO4-HCO3 and Na-K-Mg), Piper diagrams and variation diagrams. We analyzed a subset of waters in the Jemez river system (including springs and wells) for radiogenic strontium as well as uranium isotopic composition to test specific subsurface flowpath models.

We applied these tracers in several locations in New Mexico, but we will be looking in detail at the waters sourced from the Valles Caldera system and the upper Jemez river system. We present a combined tracer model (eg., Cl concentration and Sr isotopic composition) that shows excellent agreement for flowpath and mixing. This encourages the use of multiple tracers in order to better define complex subsurface flowpaths.

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HYDRAULIC CONDUCTIVITY ESTIMATES FROM PARTICLE SIZE DISTRIBUTIONS OF SEDIMENTS FROM LOS ALAMOS CHROMIUM PLUME

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Chromium used in Los Alamos National laboratory cooling towers was released as effluent onto laboratory property between 1956 and 1972. As a result, the underlying regional aquifer is contaminated with chromium (VI), a toxin and carcinogen. The highest concentration of chromium is ~1 ppm in monitoring well R-42, exceeding the New Mexico drinking water standard of 50 ppb. The chromium plume is currently being investigated to identify an effective remediation method. Geologic heterogeneity within the aquifer causes the hydraulic conductivity within the plume to be spatially variable. This variability, particularly with depth, is crucial for predicting plume transport behavior. Though pump tests are useful for obtaining estimates of site specific hydraulic conductivity, they tend to interrogate hydraulic properties of only the most conductive strata. Variations in particle size distribution as a function of depth can complement pump test data by providing estimates of vertical variations in hydraulic conductivity. Samples were collected from five different sonically-drilled core holes within the chromium plume at depths ranging from 732'-1125' below the surface. To obtain particle size distributions, the samples were sieved into six different fractions from the fine sands to gravel range (>4 mm, 2-4 mm, 1.4-2 mm, 0.355-1.4 mm, 180-355 μm, and smaller than 180 μm). The Kozeny-Carmen equation ((δg/μ) *(d_m^2)/180 * (Ø^3/(1-Ø^2))), was used to estimate permeability from the particle size distribution data. Pump tests estimated a hydraulic conductivity varying between 1 and 50 feet per day. The Kozeny-Carmen equation narrowed this estimate down to an average value of 2.635 feet per day for the samples analyzed, with a range of 0.971 ft/day to 6.069 ft/day. The results of this study show that the Kozeny-Carmen equation provides quite specific estimates of hydraulic conductivity in the Los Alamos aquifer. More importantly, it provides pertinent information on the expected variations with depth in hydraulic conductivity not obtainable from pump tests. This information is a prerequisite for modeling the spatial variation of the chromium plume and formulate remediation strategies.

^{40}Ar/^{39}Ar DATING OF THE OGALLALA FORMATION OF THE LLANO ESTACADO, SOUTHEASTERN NEW MEXICO

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Despite the potential for the use of the Ogallala Formation as a constraint on the sedimentary response to uplift of the Southern Rocky Mountains during the Tertiary; primary data on the age and provenance of the New Mexico Ogallala Formation are sparse. The current age of the southern Ogallala is ~13-5 Ma based on vertebrate biochronology in the northeastern part of the Llano Estacado in Texas. In an effort to improve the age constraints and correct this deficit, this study applied ^{40}Ar/^{39}Ar geochronology analysis to detrital sanidine (DS) from samples collected along the western escarpment of the Llano Estacado. By comparing the K/Ca ratios (determined from measuring ^{39}Ar/^{37}Ar) and ages of detrital sanidines to known K/Ca values and ages of regional volcanic units, the age and provenance of the Ogallala can be improved. This information is utilized to better understand the evolution of the Pecos River system.

The results for samples taken along the SW Llano Estacado (that part bounded on the west by Mescalero Ridge) suggest a Trans Pecos Volcanic Field source and perhaps a contribution from the Mogollon-Datil Volcanic Field as well. This supports paleocurrent data that implies that the paleo-Pecos river system flowed north (cf. Cather, 2011). While the SW Llano Estacado exhibits a significant population of Oligocene and Eocene DS, no crystals are younger than 26.6 Ma. These older ages do not improve our knowledge of the Ogallala depositional age. A study of outcrops and digital elevation data of the SW Llano Estacado shows both a steeper topographic gradient and different lithology compared to the typical northern Ogallala sections (i.e., north of Roswell). Northern Ogallala outcrops commonly contain fluvial deposits and reworked eolian sand and silt. SW Llano Estacado outcrops have very sparse fluvial deposits and are instead almost entirely eolian. These topographic and lithological differences may imply the existence of a here-to-fore unrecognized Oligocene formation in the SW Llano Estacado that is older than the Ogallala Formation and dominated by eolianites.

Samples from several outcrops currently mapped as Ogallala in east-central New Mexico have lower and upper Bandelier tuff (~1.6 and 1.2 Ma) represented in the DS age distributions. These samples are clearly too young to be Ogallala and will require changes to existing geological maps to coincide with these new DS data.

DIVERSE VERTEBRATE COPROLITE LOCALITY FROM THE UPPER PENNSYLVANIAN OF CENTRAL NEW MEXICO PROVIDES DATA ON THE TEMPORAL DISTRIBUTION AND ECOLOGICAL CONTEXT OF THE SHARK SURPLUS PARADOX

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The Tinajas Member of the Atrasado Formation (Upper Pennsylvanian: Missourian) yields vertebrate coprolites from the Kinney Brick Quarry and the Tinajas Lagerstätten in central New Mexico, but the largest coprofauna from these strata derives from a locality in the Cerros de Amado of Socorro County (NMMNH locality L-9096). Here, most coprolite specimens are found as a weathering lag that eroded from a shale, although a small number of specimens occur in situ in thin limestone beds. The coprolites are preserved in a low energy, shallow marine environment.

The majority of coprolites are spiral in morphology--heteropolar, amphipolar and scroll. Five ichnotaxa are heteropolar spiral in morphology and include *Crassocoprus mcallesteri*, *Kalocoprus oteroensis*, two ichnospecies of *Heteropolacopros* and ?*Speirocoprus* isp. The most common ichnotaxon is *Crassocoprus mcallesteri*. Heteropolar microspiral coprolites are assigned to *Heteropolacopros*. There is a need for an ichnotaxonomic review of this widespread ichnogenus, which was originally named for a Triassic morphotype. This is the only occurrence of *Kalocoprus oteroensis* outside the Beeman Formation of Otero County, NM. Amphipolar coprolites are represented by *Hyronocopros amphipola*. There are several specimens of the scroll coprolite *Bibliocoprus beemanensis*. Diverse vertebrate bones occur elsewhere in the Tinajas Member, but not at this locality.

The majority of large coprofaunas from shallow marine strata are dominated by spiral morphologies. During the Mesozoic and Cenozoic, spiral coprolites are clearly attributable to chondrichthyans. Thus, there is clearly a disparity between the high taxonomic diversity of fish faunas of these ages and the low diversity of chondrichthyan-dominated coprolite ichnofaunas; this has been termed the Shark Surplus Paradox. Coprolite assemblages from the Devonian-Permian also yield abundant spiral forms, although in ichnofaunas of these ages there are more candidates for producers. The Cerros de Amado locality provides information on the distribution and ecological context of the Shark Surplus Paradox during the Paleozoic.

Distribution: Arguably the best record of Late Paleozoic vertebrate coprolites is preserved in Scotland where spiral morphotypes become abundant by the Early Devonian. However, large samples from discrete ichnofaunas are rare, so the Cerro de Amado locality documents a Late Pennsylvanian data point of a high percentage of spiral forms in an assemblage from a shallow marine environment.

Ecology: Four bromalite faunas of Missourian age in New Mexico represent an ecological transect from estuarine to shallow marine: (1) Kinney Brick Quarry Lagerstätte – estuarine; (2) Tinajas Lagerstätte – lagoonal ; (3) Cerros de Amado – nearshore marine; and (4) Sacramento Mountains – offshore marine. There are trends through these ichnofaunas (Kinney-Tinajas- Cerros de Amado-Sacramentos); (1) flattened preservation in matrix to isolated three dimensional; (2) diverse bromalites to only coprolites; and (3) increasing proportion of spiral coprolites. The ichnofauna of the Cerro de Amado locality provides evidence that at least during the Missourian the Shark Surplus Paradox is a phenomenon of shallow marine environments.

Keywords:

coprolites, Pennsylvanian, Tinajas, New Mexico, shark surplus paradox

CAMPYLOPRION (CHONDRICHTHYES, EDESTOIDEA) FROM THE UPPER PENNSYLVANIAN OF SOCORRO COUNTY, NEW MEXICO

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A partial symphyseal tooth whorl of *Campyloprion* sp., comprising five teeth, is reported from the Tinajas Member of the Atrasado Formation of Socorro County, southern New Mexico. The age is constrained by both fusulinid and conodont biostratigraphy to the Missourian Stage (Upper Pennsylvanian). The holotype of *Campyloprion annectans*, the type species of *Campyloprion*, is of unknown provenance, although it has been presumed to be from the Upper Pennsylvanian of Midwestern North America. Tooth whorls of *Campyloprion* are more loosely coiled than those of the better-known edestoid *Helicoprion*; the tooth whorls of both genera are shaped like logarithmic spirals. The parameter that characterizes a logarithmic spiral, the angle between a tangent to the spiral and a radius from the center, is about 60° for *Campyloprion* versus about 82° for *Helicoprion*. The New Mexico specimen is not complete enough for this angle to be determined. Determination of the genus is therefore based on the morphology of the individual teeth, particularly the serrations, which compare closely to those of the holotype of *Campyloprion ivanovi* from the Upper Pennsylvanian of Russia. This is the first record of *Campyloprion* from New Mexico, and the most complete edestoid fossil known from New Mexico.

Keywords:

Pennsylvanian, chondrichthyes, edestoid, shark

A NEW ICHNOSPECIES OF *CARDIOICHNUS* FROM THE CRETACEOUS (ALBIAN) OF NEW MEXICO

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A new ichnospecies of *Cardioichnus* is documented and proposed from the Mesilla Valley Formation, Cerro de Cristo Rey, southern NM. Invertebrate trace fossils are common in these shallow marine strata of Cretaceous (late Albian) age. One bioclastic wackestone/packstone in this formation contains many specimens of *Cardioichnus*. The proposed ichnospecies is a heart-shaped resting trace (cubichnia) with a bilobate terminus, and is preserved exclusively in convex epirelief. It differs from described ichnospecies of *Cardioichnus* in its preservation, geometry, implied behavior, and host sediment. Several specimens are also associated with *Scolicia* burrows. The tracemaker is a spatangoid echinoid, most likely *Heteraster* d'Orbigny, 1853, which has been described from this formation. This is a part of an ongoing study of trace fossils from Albian strata at Cerro de Cristo Rey in southern New Mexico.

Keywords:

Cardioichnus, cubichnia, resting trace, spatangoid echinoid, Cretaceous, New Mexico

A PEDAGOGY FOR THE CERRO DE CRISTO REY DINOSAUR TRACKSITE: HIKING TRAILS, SELF-GUIDED TOURS, AND VIRTUAL VISITS

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The Cerro de Cristo Rey dinosaur tracksite was discovered in 2002 on a local hillside regularly used for informal geoscience education. Although quickly preserved, the site has not been developed. We designed and constructed 7km (4.3mi) of interpretive trails covering over 200 acres, and installed 20 plaques with QR codes, linking visitors and their cell phones to educational content about the geology and history of the area. Virtual visitors can also see these same trails using Google Earth® software on their personal computer, tablet, or cell phone. Each of the trail stops contains content which interprets the view at that spot, instilling a greater understanding of the El Paso urban area, and stimulating a sense of place and belonging. This trail system compliments the Catholic trail up to the top of Cerro de Cristo Rey, which receives over 50,000 visitors annually and is one of the most important cultural landmarks of the El Paso region. The trails have been promoted through field trips, presentations, and teacher workshops. There is still need for further development at the Cerro de Cristo Rey dinosaur tracksite and for protection for the dinosaur tracks, which have now been preserved for 13 years.

Keywords:

Cerro de Cristo Rey, Informal Geoscience Education, Pedagogy, Google Earth, place-based education

ICHNOLOGY OF THE CRETACEOUS (ALBIAN) MESILLA VALLEY FORMATION, CERRO DE CRISTO REY, SOUTHERN NM

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Invertebrate trace fossils have been identified from shallow marine facies of the Mesilla Valley Formation (Washita Group) at Cerro de Cristo Rey, Sunland Park, NM. Ichnotaxa described here include the invertebrate traces *Ancorichnus, Arenicolites, Bergaueria, Cardioichnus, Chondrites, Cochlichnus, Cruziana, Fuersichnus, Helicodromites, Lockeia, Muensteria?, Ophiomorpha, Palaeophycus tubularis, Palaeophycus striatus*, *Planolites* isp., *Planolites hebertii, Planolites montanus, Scolicia, Scoyenia, Skolithos, Spongeliomorpha, Taenidium, Teichichnus*, and *Thalassinoides*, as well as arthropod resting traces, a chimney structure, and the biofilm "Kinneyia." This is the first report on the invertebrate ichnology of the shallow marine units at Cerro de Cristo Rey. This is a medium/high diversity ichnoassemblage, including fugichnia (i.e., *Skolithos*), fodichnia (i.e., *Chondrites*), domichnia (i.e., *Ophiomorpha*, *Thalassinoides*), repichnia (i.e., *Cruziana*), paschichnia (i.e., *Palaeophycus*), and cubichnia (i.e., *Cardioichnus*, *Lockeia*), The ichnoassemblage was preserved in tempestites (storm deposits) from below wave base, on the upper/middle continental shelf and contains ichnotaxa representative of the *Cruziana* ichnofacies.

Keywords:

invertebrate ichnology, trace fossils, Cerro de Cristo Rey, Mesilla Valley formation, Cruziana ichnofacies

GEOCHEMISTRY OF SINKHOLES IN THE SANTA ROSA, NM AREA

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In Santa Rosa, NM there are several bodies of water known as sinkholes, fed by an artesian aquifer (the Permian Artesia Group). The sinkholes are perennial water sources that both host endemic species as well as provide water to the Pecos River. We examine ten locations, including four sinkholes, two Pecos River locations, one tributary to the Pecos River and three water wells to compare the different water chemistries and parameters to identify connections and processes occurring between the diverse water locations.

Data collected from the surface water and from wells are acquired by standard water sampling protocols. Samples that are collected from warm water vents at depths lower than 10 meters were taken using an original technique necessitated by the specific condition of the deep locations. We report temperature, pH, conductance, and major ion solute concentrations. All of the waters (sinkhole data (~18 °C, 7.3 pH, 3085μS); spring data (~18 °C, 5.7pH, 2530μS); Pecos River data (~17°C, 6.5pH, 2690 μS)) have a strong geochemical similarity to the regional aquifer (aquifer data (~18 °C, 6.8 pH, 2010 μS)). Additional effects on the waters include evaporation and mineral precipitation/dissolution. We use geochemical modelling codes to indicate the major ions composition and distribution as well as the saturation state with respect to minerals such as calcite and gypsum. The contribution of these artesian groundwater outflows is significant to the Pecos River, and take on additional importance given the projections of diminished stream flows in the future.

THE ANIMAS RIVER TOXIC SPILL: USING CURRENT EVENTS TO TEACH GEOLOGY, GEOCHEMISTRY, AND PRESENTATION SKILLS TO UNDERGRADUATE GEOLOGY MAJORS AT FORT LEWIS COLLEGE, DURANGO, CO.

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The toxic spill generated by the Gold King Mine (GKM) blowout north of Silverton, Colorado traveled ~60 river miles along the Animas River and reached the City of Durango by 8:00pm on August 6, 2015 carrying elevated levels of heavy metals as both dissolved load and colloids. On August 15, 2015, the EPA determined, based on on-going analyses of river samples that the water quality of the Animas River had returned to pre-spill levels. Contaminated water and colloid samples were collected by the authors using standard EPA protocol during peak spill and toxicity levels, from August 7-13, 2015. Water samples from six Animas River locations and sludge samples from eight river and canal locations, were independently analyzed at an EPA and State of Colorado Certified Laboratory with funding provided by Fort Lewis College (FLC) Provost Barbara Morris. Nine undergraduate geology majors, as part of an upper-level undergraduate Geology course, were charged with undertaking a comparative geochemical analysis of water quality data collected by the EPA and the Geosciences Department at FLC. Each student was assigned specific tasks; all students collaborated and worked together to produce a final PowerPoint® presentation. The students addressed the geologic setting of the Silverton Caldera, mining history, historic mine releases, water quality concerns, bulkhead construction and benefits, and generated suitable GIS maps. Field outings to the Silverton area were conducted in August to discuss and geochemically distinguish between AMD and ARD sites. Historic cross-sections and high wall plans of the GKM were graciously provided by the Colorado Division of Reclamation, Mining, and Safety (Abandoned Mines Division). Spatially-referenced data from ArcMap® was imported into Vulcan® (Maptek) software, and a 3D model of the GKM underground workings was generated: (1) to illustrate the geologic and hydrologic complexity of the mine; and, (2) to investigate possible hydrologic connectivity that could possibly explain the elevated flow volumes observed during the blowout. In addition to the educational benefits of the study, the goals of the study were to provide the public with a more complete understanding of the GKM, and help explain why metal concentrations in streams vary by sample location, discharge levels, and time of day. The students presented their work at public forums.

Keywords:

Gold King Mine, undergraduate education, hydrogeochemistry, Animas River

STRATIGRAPHY AND AGE CONTROL BRACKETING THE EARLY DEVELOPMENT OF THE PALEO-RIO CHAMA

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The Rio Chama is a major headwater of the Rio Grande, so deciphering its fluvial record is critical for understanding the evolution of the Rio Grande fluvial system. In this paper, we present evidence that early Rio Chama deposits are represented by the Hernandez Member of the Chamita Formation in the Española Basin, and the maximum age of this member lies between 12.3-11.5 Ma. The Hernandez Member is characterized by its light gray color and relatively abundant gravelly channel fills containing very coarse pebbles and cobbles. Gravels are subrounded to rounded and include high proportions of dark-colored dacites and andesites, together with minor amounts of rhyolite, welded tuff, and ≤26% quartzite.

The geographic and stratigraphic position of the Hernandez Member is consistent with a paleo-Rio Chama. This member is mapped between the modern Rio Grande and the Jemez Mountains in the south-central Española Basin as well as along the northern flank of the Jemez Mountains. Paleocurrent data west of Española are to the southeast, consistent with a southeast-flowing paleo-Rio Chama wrapping southward around the northeastern Jemez Mountains. As would be expected for a paleo-Rio Chama, the Hernandez Member interfingers eastward with sandy fluvial deposits derived from the southern San Luis Basin (Vallito Member of Chamita Formation) and westward with relatively monolithic, angular volcaniclastic detritus derived from the Jemez Mountains volcanic field.

Two Hernandez Member clast types are useful for identifying provenance. The dark-colored intermediate volcanic gravels are interpreted to be derived from the southwestern San Juan volcanic field. They are very similar to those seen in Quaternary Rio Chama deposits and are not observed in Miocene-Quaternary fluvial deposits derived from the San Luis basin. The dark-colored intermediate volcanic clast have returned $^{40}Ar/^{39}Ar$ ages of 29.98±0.09 Ma and 29.08±0.13 Ma (latter from Kempter et al., 2007). These ages are consistent with derivation from the San Juan volcanic field but are too old to be sourced in the Latir or Jemez volcanic fields. The Jemez Mountains lack quartzite, so the quartzite clasts likely are derived from the Tusas Mountains.

Radiometric age controls (primarily $^{40}Ar/^{39}Ar$) in exposures and/or wells at 5 sites indicate the paleo-Rio Chama began 12.3-11.5 Ma. Near Española, the river subsequently shifted northeastward due to development of ca. 10 Ma volcanic edifices associated with the Lobato Formation of the Jemez volcanic field.

We attribute the initiation of the paleo-Rio Chama to development of the early Jemez volcanic field and shifting of tectonic strain from major normal faults near Abiquiu towards the Pajarito fault. The build-up of topographic highs in the volcanic field effectively blocked previously southeast-flowing streams heading in the eastern Colorado Plateau. These blocked streams converged into a single, high-competency river that flowed around the north end of the Jemez volcanic field. A shifting of strain to the Pajarito fault facilitated development of paleovalleys (up to 60 m deep) observed north of the Jemez Mountains. These paleovalleys may have migrated headward towards the Colorado Plateau, and ensuing stream-capture there may have resulted in further consolidation of discharge to the paleo-Rio Chama.

Keywords:

Rio Chama, Hernandez Member, Chamita Formation, ancestral Rio Grande

THE ALLISON MINE SINKHOLE – CAUSES, CONSEQUENCES, AND CORRECTIVE ACTIONS

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In early August, 2015 a large sinkhole opened suddenly at ground surface above the abandoned Allison Mine on the west side of Gallup, NM. The mine is located in a tributary valley of the Rio Puerco. A paleovalley, filled with alluvium and not visible at ground surface, underlies the present valley. The sinkhole is within the alluvial fill of the paleovalley and lies along the channel of the present valley.

This underground room-and-pillar coal mine operated from the late 1800s to 1939. Two coal seams of the Gibson Coal Member of the Mesaverde Formation were mined, one at 80-100 feet depth and the other at 140-165 feet depth. When it closed, most entries to the mine were sealed and surface facilities were removed, but no backfilling or other stabilization of underground workings was performed.

When notified of the sinkhole, the Abandoned Mine Land Program of the New Mexico EMNRD immediately initiated an emergency response. A team of geologists, geophysicists, engineers and surveyors was assembled and began a fast-track investigation to determine the shape and extent of the sinkhole, its cause(s), and possible remedial measures to arrest sinkhole expansion and to protect public safety and impacted property. Historical records were collected and reviewed at the same time that field investigations were initiated. Mine records were fragmentary but useful in locating mine workings in the vicinity of the sinkhole. Anecdotal information from local residents was especially helpful in locating adits and shafts and enabled the team to more precisely position the mine workings map in relation to present ground features. Field investigations included land surveying, subsidence monitoring, mapping of surface features, aerial photography, geophysical surveys, and exploratory drilling.

These investigations revealed that the upper coal seam had been eroded from the paleovalley, leaving the eroded edge of the upper seam buried in alluvium approximately 60 feet west of the center of the sinkhole. During mining, an exploratory drift was advanced along the upper seam and into the alluvium. Over time, the timber supports of the drift deteriorated, and overburden progressively caved into the drift. Caving was accompanied by high-angle cracking that propagated to ground surface, and some of these cracks intercepted the present-day arroyo channel. Runoff entered these cracks and followed them into the collapsing drift, eroding alluvium along the way and forming an underground erosional chamber. Once it daylighted at ground surface, the sinkhole expanded rapidly in runoff-induced increments to more than twice the original size in less than four months.

Left unchecked, subsidence would continue as long as runoff could enter the sinkhole and eroded alluvium could be flushed into the vast underground workings. To arrest this process, the sinkhole was backfilled with crushed recycled concrete to provide structural support for the sinkhole, to be followed by grouting to minimize infiltration of surface water. The arroyo channel will be lined across the subsidence area to separate runoff from the sinkhole.

THE CERRO COLORADO CINDER CONE, CERROS DEL RIO VOLCANIC FIELD: A STUDY OF MELT EVOLUTION AND PLUMBING SYSTEM DYNAMICS

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Cerro Colorado is a 2.5-2.6 Ma dissected cinder cone in the Cerros del Rio volcanic field, west of Santa Fe, NM. The volcano stands 2225 m high and includes a well-defined 325 m diameter central vent characterized by inward dipping beds of moderately to strongly welded and highly oxidized scoria deposits and effusive lava flows. These transition sharply to periclinally dipping wall facies composed of vesiculated fragments, oxidized and unoxidized cinders, spatter agglutinate, and lava flows. While Cerro Colorado units follow general cinder cone facies patterns (central crater facies, proximal and distal wall facies) and granularity trends (decreasing cinder size away from summit), exposed sections deviate from the idealized cinder cone models. Several wall facies outcrops show multiple and regular alternations between explosive (pyroclastic falls) and effusive (lava flows) cycles. Pyroclastic deposits are highly vesiculated while lava flows are noticeably non-vesicular. These observations indicate that Cerro Colorado eruptions fluctuated from undegassed to degassed events, implying the existence of a shallow magma storage reservoir and challenging the simple feeder-dike plumbing system cinder cone model. Paleomagnetic data along with physical volcanology observations (volcanic facies distribution, vesicle size and amount; degree of fragmentation) and petrology data (presence of hydrous phases, SiO_2 wt. %, and degree of fractionation) are being collected to characterize and compare the emplacement and timing of effusive versus extrusive units and the formation and deformation of the volcano edifice. Preliminary rock magnetic data indicate the presence of single domain and pseudo single domain Fe-Ti oxide phases; medium-Ti titanomagnetite is the principal magnetic phase carrying both the remanence and anisotropy. The presence of Fe_7S_8 suggests a low temperature magmatic source. The entirety of the dataset will be used to track the degassing, crystallization, and compositional evolution of the Cerro Colorado system over time providing new insight into cinder cone system dynamics.

Outcrop photograph of welded scoria layer (below fracture) followed by a massive flow layer (above fracture) from Cerro Colorado cinder cone wall facies.

Keywords:

cinder cone, Cerro Colorado, Cerros del Rio volcanic field, degassing, plumbing

SINKHOLES AS TRANSPORTATION AND INFRASTRUCTURE GEOHAZARDS IN SOUTHEASTERN NEW MEXICO

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Sinkholes and other surface karst features are naturally-occurring phenomena in regions underlain by soluble bedrock. The lower Pecos region of southeastern New Mexico and west Texas is particularly prone to karst geohazards because of the widespread occurrence of Permian evaporites at or near the surface. Sinkholes in this region occur over a broad spectrum of scales, ranging from less than one to several hundred meters in diameter, and are often associated with human activity such as solution mining or road construction. Depending on thickness and mechanical properties of the overburden, sinkholes may develop slowly as broad subsidence features or rapidly by catastrophic collapse. Sinkholes receive widespread news coverage when they form in densely populated parts of the country such as south Florida or Kentucky. When these features form in more sparsely populated regions such as the desert southwest, they may go unreported for long periods of time. Sinkholes nevertheless pose a significant geohazard for the transportation and pipeline network in southeastern New Mexico; their occurrence is sometimes difficult to predict and remediation is often challenging and expensive.

Keywords:

sinkholes, Pecos valley, gypsum karst

VOLATILE CONTENTS AND PRE-ERUPTIVE CONDITIONS OF RHYOLITIC MAGMAS FROM THE ORGAN CALDERA, SOUTHERN NM

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The Organ caldera in south-central New Mexico formed during eruptions ~36 Ma, and the volcanic deposits and plutonic bodies are now exposed in the Organ Mountains. This research project provides the first analyses of volatile contents and trace and major element concentrations of melt inclusions, and crystallization pressures from the first and last erupted caldera units, the Cueva Tuff and the Squaw Mountain Tuff ignimbrites. Through geochemical analyses of melt inclusions, whole rocks and minerals, information has been obtained regarding pre-eruptive characteristics of the magma chamber including chamber stratification, volatile contents preceding the eruptions, and the volume of the eruptible magma chamber. Previous studies suggested that the three caldera-forming eruptions resulted from a single, stratified magma chamber being repeatedly tapped, and whole-rock geochemistry supports this claim (Seager and McCurry, 1988). However, results thus far show variable volatile contents (~2.2-6.8% H2O) and a narrow range of major elements from the first-erupted Cueva Tuff melt inclusions, suggesting a more homogeneous, convecting magma chamber at depths between ~2 and 10 km. Whole rock analyses from this and previous studies show similar major element composition for the Cueva Tuff. Analyses of volatile contents from melt inclusions from the last-erupted unit, Squaw Mountain Tuff, have been inconclusive, but major element compositions are more heterogeneous than the Cueva Tuff. Both melt inclusion and XRF whole rock data from the Squaw Mountain Tuff span between the Cueva Tuff and West Side Lavas (eruptive unit following the Squaw Mountain) compositions. These data currently suggest the possibility that the injection of the West Side Lavas and the resultant mixing with residual Cueva Tuff helped initiate the eruption of Squaw Mountain Tuff. This hypothesis is further supported by magma mixing or mingling observed in samples of the upper Squaw Mountain Tuff. This hypothesis is being tested through a detailed investigation of mineral chemistry, textures and zoning, which should reveal any mixing prior to eruption. Additionally, a secondary estimate of magma H2O and storage pressures from the Squaw Mountain Tuff is required, as the melt inclusions in Squaw Mountain underwent volatile loss during rehomogenization, resulting in unreliable data. I will use a published hygrometer to determine melt H2O contents from Squaw Mountain Tuff feldspars to provide an estimate of pressures and depths of Squaw Mountain Tuff crystallization. The results of this project provide new insights into the formation and evolution of a large magma body, and processes that occurred prior to the eruptions of Organ caldera.

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EVALUATION OF LEACHING TESTS ON URANIUM BEARING WASTE ROCKS FROM GRANTS MINERAL DISTRICT, NEW MEXICO

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The Grants Mineral District in New Mexico was a major uranium producing area in the world (McLemore, 2010), and it was one of the primary three uranium-mining districts from the 1950s to late 1980s. In the nature, uranium is mobile as uranyl and carbonate complexes, it forms stable minerals in reducing conditions. This is the case in the Morrison Formation; a sandstone unit in the Grants Mineral District shows locally radiation anomalies due to uranium bearing layers. In addition, historic mining and milling of uranium ore has led to widespread contamination of shallow ground water resources (Thomson et.al, 2014). Arroyos in the vicinity of Ambrosia Lake have shown some evidence of uranium contamination. Although the mine site has previously been reclaimed, contamination from the mine site are still occurring (Jaramillo, 2013). In an attempt to determine mineral sources of the contamination and transformations associated with uranium chemistry, we are conducting preliminary leaching tests on the waste rock from Section 11/12 mine, Saint Anthony Mine and the Mt. Taylor Mine to evaluate the geochemical behavior of mining material from the Grants Mining District. Characterizing the wastes to evaluate the current and future leaching potential is essential for the public health.

A series of laboratory experiments are being conducted to assess the mineralogy and geochemistry of the material to estimate the leaching potential, acid generation and neutralization potential. Kinetic Column Tests (KCTs) have been constructed for uranium leaching tests, which provide the closest analogue to the infiltration of water through solids or aquifers (Nordtest, 1995b). The assumption applied to this test is that if the constituent doesn't leach from the waste, then it is not a threat to the groundwater. Therefore, most of the subsequent chemical experiments will be conducted twice, before KCTs and after KCTs, to compare the differences of initial and final metal concentrations and constitute species. In addition, weekly tests for pH, conductivity, Pe, alkalinity, major anions, major cations and trace elements are being conducted on the column leachate. This data is being used to compare changes from week to week to determine points in time where the data stabilizes.

HOPLOCHELYS, A DERMATEMYDID TURTLE FROM THE PALEOCENE OF NEW MEXICO

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Hoplochelys crassa was originally described from the Paleocene Nacimiento Formation of New Mexico in the San Juan Basin, New Mexico. Following the original description, numerous species of the genus were subsequently named based on shells of varying degrees of completeness. Among these was *H. bicarinata,* which has two parallel ridges on each side of the midline rather than one, as in other *Hoplochelys*. In the last 10 years, all *Hoplochelys* species have been synonymized with *H. crassa* with little formal explanation. We suggest that this may have been premature because an examination of the shells in the collections of the New Mexico Museum of Natural History and Science reveals that two distinct morphological groups appear to be present. One has a single ridge and a broad first neural, here termed *Hoplochelys* n. sp., from the Puercan interval of the Nacimiento Formation. This does not correspond to the morphology of any previously published *Hoplochelys*. The other has two distinct double ridges and an elongate first neural that we tentatively refer to *H. crassa*. This has been found in both the Puercan and Torrejonian intervals of the Nacimiento Formation. We thus conclude that the retention of two taxa is justified based on the differences in the proportions of the neural bones. Regarding paleoecology, this may suggest the competitive exclusion principle in these turtles during the Puercan, with only *H. crassa* surviving into the Torrejonian, although non-shell material must be analyzed to confirm or refute this possibility.

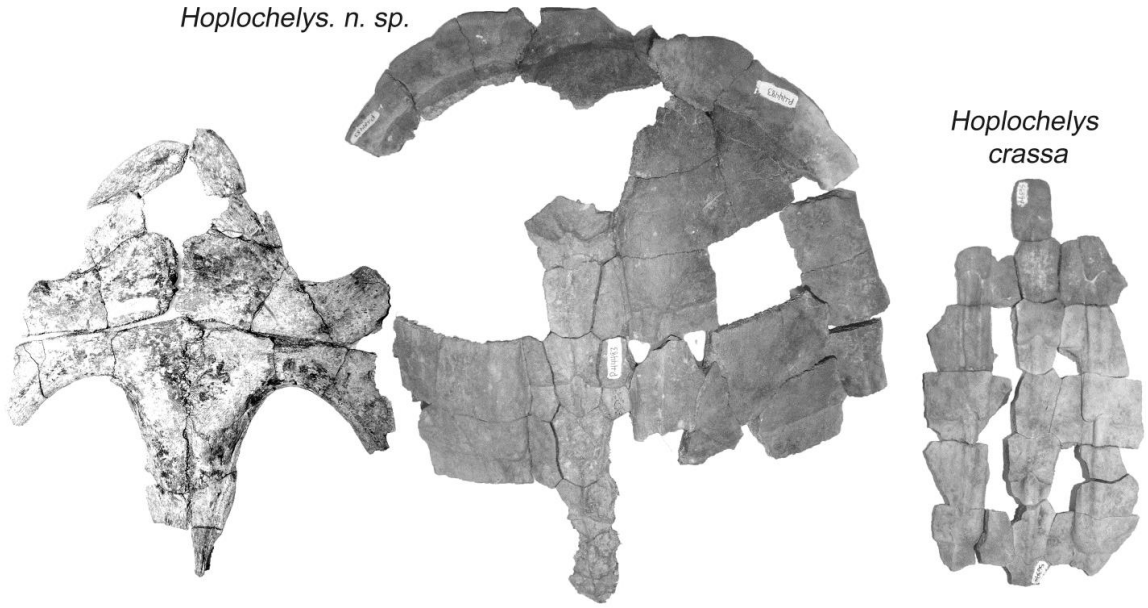

FIGURE 1. Two morphotypes of *Hoplochelys* from the Nacimiento Formation of New Mexico. From left to right, *Hoplochelys* n. sp., plastron and carapace, *Hoplochelys crassa*, incomplete carapace. Neural 1 approximately aligned between the two carapaces.

A NEW SPECIES OF NEURANKYLUS FROM THE PALEOCENE OF NEW MEXICO

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A recently named species of the baenid turtle *Neurankylus* from the Torrejonian interval of the Paleocene Nacimiento Formation of New Mexico shows some significant new morphological features. The skull exhibits larger exoccipitals than are seen in either *N. eximius* or *N. lithographicus*. In addition, the vomer is narrow and elongate, similar to *Trinitichelys,* one of the oldest known baenids. It is also worth mentioning that the jaw structure of this turtle is similar to that of *Baena arenosa*, with a near identical ramii angle and a similar position of the posterior end of the triturating surfaces. Further, in the skull, the jugal takes up a similarly wide portion of the posterior rim of the orbit. The broad, triangular shape of the jugal is similar to that in more basal eubaenids, supporting the basal placement among baenid turtles of the recently named *Neurankylus* species. An associated distal phalanx has a prominent ventral process for muscle attachment. It is similar to that seen in *Terrapene*, *Chelydra*, *Compsemys*, and *Hoplochelys*. We suggest this relates to a bottom walking mode of locomotion, as this process is absent in swimming turtles such as *Trachemys*. Indeed, these muscles would be useful for holding the digits in place, rather than their extension, which would be useful for active swimming. This, as well as the resemblance of the jaw to that of modern chelydrid turtles, suggest a similar habitus as a river-dwelling predator. Additionally, a second posterior lobe of the plastron is included in the original collection, which appears to scale directly from that of the holotype, indicating the presence of a second, similarly-sized individual of the species. The vertebrae are similar to those of *N. baueri* from the older, Upper Cretaceous Fruitland Formation. These similar vertebrae, as well as similarities in the plastral sulci, lead us to suggest a possible anagenetic descent of *Neurankylus* n. sp. from *N. baueri* in northwestern New Mexico.

ON THE DEVELOPMENT OF A RETROACTIVE WATER BALANCE DERIVED FROM HISTORICAL WATER QUALITY AND FLOW DATA, MALMBERGET/VITÅFORS IRON MINE, NORRBOTTEN COUNTY, SWEDEN

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The Malmberget/Vitåfors mining facility, located in Norrbotten County, Sweden, is the world's second largest underground iron ore mine, comprised of roughly 20 steeply dipping magnetite-hematite ore lenses, with an underground area of approximately 5 x 2.5km. Since its' opening in 1892, over 350Mt of ore have been removed from Malberget, and another 350Mt of iron reserves have been declared proven and probable.

The state-owned Swedish mining company, Luossavaara-Kiirunavaara Aktiebolag (LKAB), owns and operates the facility. They have seen an increase in production in the past years, effectively doubling the amount of ore processed at the Vitåfors facility, from 8Mton/year in 1998 to 16Mton/year in 2013, and they intend to maintain this steady increase into the future. Despite these changes, the amount of water used within the system has not increased proportionally, and is not predicted to do so in the future. This is due to increases in process-water recycling, which adds to the demands placed on this water. As the water is reused, the conservative and trace element concentrations grow, affecting the overall water quality. This is of concern, as a portion of this spent process-water is released daily into the local receiving environment, the Lina River.

This discharge to the Lina River represents one of the main losses within the system, and has been sampled with some degree of consistency since 1998. Such is not the case for instances of evaporation and diffuse leakage, both of which have been acknowledged but not quantified. Thus, a water balance for this system is not as straightforward as it may seem. Not only are these losses unknown, but thorough accounting of water use in the mine and processing facility has only been undertaken within the past few years, leaving a number of gaps in the historical record. Additionally, seasonal fluctuations exist in the availability of input water from the primary source: groundwater entering the mine workings. This adds to the complexity of the problem, and highlights the importance of an accurate working model of water use within the system.

This research intends to define and quantify the inputs and losses to the system, as well as determine the degree to which process water recycling impacts overall water consumption. The initial model serves as a foundation for understanding the likely changes that will occur due to seasonal fluctuations and increases in production.

Keywords:

process water, mining, iron, water balance, hematite, magnetite

PRESENCE OF PHARMACEUTICALS IN GROUNDWATER AND SURFACE WATER, LOS ALAMOS, NEW MEXICO

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Endocrine disruptor chemicals (EDC), including pharmaceutical and personal care products (PPCP), are contaminants of significant concern found in aquatic environments worldwide. Numerous EDC and PPCP have been measured in treated and non-treated sanitary sewage effluent throughout the United States and Europe during the past two decades. Since the mid-1940s, Los Alamos National Laboratory (LANL) and Los Alamos County, New Mexico have released sewage effluent to three watersheds that provide recharge to groundwater beneath the Pajarito Plateau. The regional aquifer at Los Alamos is a sole-source aquifer providing high-quality drinking water to the public and LANL. Sampling stations located across the Pajarito Plateau were analyzed for 32 EDC and PPCP with detection limits in the low nanogram/liter range. These include wells screened in alluvial and perched intermediate-depth groundwater and wells and springs pumping or discharging from the regional aquifer. Surface-water sampling locations were selected in two watersheds currently receiving treated sewage and cooling-tower effluent from NPDES outfalls. Analytical results showed EDC and/or PPCP at most of the sampling locations, with variable types and frequency of detections. Commonly detected pharmaceuticals include acetaminophen, caffeine, carbamazepine, DEET, Dilantin, meprobamate, methadone, salicylic acid, and sulfamethoxazole. Acetaminophen, caffeine, and sulfamethoxazole were detected at the highest frequency. Several of the wells containing pharmaceuticals also contain contaminants associated with treated sewage, cooling tower, and industrial-derived effluents such as nitrate, boron, chromate, and tritium. Presence of EDC and PPCP in groundwater at Los Alamos refines the conceptual model for fate and transport of mobile contaminants migrating through the deep vadose zone (305 meters thick) to the regional aquifer.

Keywords:

pharmaceuticals, personal care products, groundwater, contaminants

AGE AND CORRELATION OF THE LOWER PERMIAN ABO FORMATION AND YESO GROUP, CENTRAL AND SOUTHERN NEW MEXICO

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The Abo Formation and overlying Yeso Group comprise most of the Lower Permian stratigraphic section in central and southern New Mexico. Traditionally, the Wolfcampian-Leonardian boundary has been equated with the Abo-Yeso contact, and other correlations of these strata have been similarly imprecise due to a lack of biostratigraphically significant fossils. However, new biostratigraphic data from marine strata below (Bursum Formation) and laterally equivalent (Hueco Group) to the Abo Formation, from marine limestones of the Los Vallos Formation of the Yeso Group and from the overlying San Andres Formation, greatly clarify age determinations and regional correlations (e. g., Lucas et al., 2013, 2015; Vachard et al., 2015). Fusulinid and conodont data indicate that the Bursum Formation straddles the Virgilian-Wolfcampian (Carboniferous-Permian) boundary and is mostly of early Wolfcampian (Newwellian/ early Asselian) age. The base of the Abo Formation is a regional unconformity close in age to the base of the middle Wolfcampian (Nealian/Asselian). In southern New Mexico, the red-bed interval of the Robledo Mountains Formation of the Hueco Group, equivalent to part of the upper Abo Formation (Cañon de Espinoso Member) to the north, is of Leonardian (Hessian/Artinskian) age base on microfossils from interbedded and bracketing marine limestones. This means the Wolfcampian-Leonardian boundary is in the upper part of the Abo Formation, though precise placement in nonmarine sections is not possible with available data. Marine limestone beds of the Los Vallos Formation of the Yeso Group in the Fra Cristobal and Caballo Mountains of Sierra County yield microfossils indicative of a late Leonardian (Cathedralian/early Kungurian) age. The San Andres Formation, above the Yeso Group, contains microfossils of late Leonardian (Cathedralian/middle-late Kungurian) age, consistent with ammonoid and conodont data that indicate that the lower part of the San Andres Formation (only this portion is preserved in central and southern NM) is of late Leonardian age. Applying the current ICS numerical calibration of the standard global chronostratigraphic scale thus indicates Bursum deposition took place close to ~299-301 Ma; Abo deposition occurred in the interval ~298-286 Ma; and Yeso deposition took place ~286-276 Ma.

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TETRAPOD FOOTPRINTS FROM THE LOWER PERMIAN ABO FORMATION NEAR JEMEZ SPRINGS, SANDOVAL COUNTY, NEW MEXICO

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In the canyon of the Jemez River and its tributaries south of Jemez Springs, Sandoval County, New Mexico, the Lower Permian Abo Formation is up to 190 m thick and divided into the lower, mudstone-dominated Scholle Member (100+ m thick), overlain by the Cañon de Espinoso Member (40-60 m thick), which is characterized by numerous sheet sandstone beds. The Scholle Member has long yielded well known vertebrate fossil assemblages of Coyotean (Wolfcampian) age dominated by sphenacodontid eupelycosaurs, diadectomorphs and temnospondyls (Lucas et al., 2012). At the Spanish Queen Mine locality, it also contains a paleoflora dominated by peltasperms and conifers. We report here the first tetrapod footprint assemblage from the Abo Formation in the Jemez Mountains. This assemblage is from New Mexico Museum of Natural History locality 10325, in a 1.3 m-thick bed of ripple-laminated sandstone of the Cañon de Espinoso Member, about 44 m below the upper contact of the Abo Formation with the overlying Meseta Blanca Formation of the Yeso Group. The footprints are associated with walchian conifer impressions and a low diversity invertebrate ichnoassemblage dominated by *Scoyenia*. Most of the footprints are of temnospondyls, small (*Batrachichnus*) and large (cf. *Limnopus*). Rare footprints at the locality can be assigned to cf. *Varanopus* (captorhiniomorph reptile) and *Ichniotherium* (diadectomorph). The occurrence of *Ichniotherium* is significant, as this ichnotaxon is only present in relatively inland localities of the Abo depositional system. The Jemez Springs footprint locality fits that concept, as it was far from the Abo-Hueco shoreline in southern New Mexico. It thus belongs to the *Ichniotherium* sub-ichnocoenosis of the *Batrachichnus* ichnocoenosis of Hunt and Lucas (2006).

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EXAMINATION OF THE ANIMAS RIVER ALLUVIAL AQUIFER HYDRAULICS AFTER THE GKM SPILL

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Following the August 5, 2015 bulkhead breach of the Gold King Mine roughly 3 million gallons of mine waste water and tailings were introduced to a tributary of the Animas River, turning the waters a vivid orange. While the river has since returned to its normal color, there is concern that the toxic metals left on the streambed may begin to seep into the shallow alluvial aquifers and impact the groundwater in the surrounding area. In August 2015, in collaboration with other agencies (USGS, NM OSE, and NMED), groundwater level measurements were collected at over 100 locations along the Animas River. Using the network of wells established in 2015, we developed a groundwater level monitoring program in the Animas River valley utilizing private domestic wells. Future sampling campaigns carried out at different points in the year will help us understand the seasonal fluctuations of the water table and if it will affect the groundwater/ surface water interaction in the area.

Following our preliminary water level measurements in August 2015, a second round of water level measurements were collected in January 2016. The August water level measurements provided us with a snapshot in time of the flow conditions during the monsoon and irrigation season, when water levels are likely at their highest. The January sampling represents base flow conditions in the river. Of the 70 wells with repeat water level measurements the majority of the wells had a decline in water level of 2.1 ft, on average, between August 2015 and January 2016. In general, the wells north of Aztec show more decline than the wells to the south.

A water table map was delineated using the manually collected water level measurements, and paired with high-resolution model of the Animas River stage. For the most part, the water table map shows the river is a gaining system, where groundwater from the surrounding alluvial valley flows down gradient and discharges into the river. From a regional perspective, this would suggest that water from the Animas River is not seeping into the alluvium. However, in January we found groundwater levels had declined, and river levels had risen. The January water table map showed that in close proximity to the river, the water table contours were almost perpendicular to the river, and even slightly inverted in places. With a neutral water table, fluctuations in the river stage can quickly turn a slightly gaining reach to a slightly losing reach. The degree to which the river is losing is so slight (less than 1 ft) that it is not detected by coarse resolution, regional water table maps. In areas with dense enough sampling we refined the contouring to 5 ft intervals.

CARBONIC SPRINGS AS DISTAL MANIFESTATIONS OF THE JEMEZ GEOTHERMAL SYSTEM, SAN YSIDRO, NEW MEXICO, HIGHLIGHTING THE IMPORTANCE OF FAULT PATHWAYS AND HYDROCHEMICAL MIXING.

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Input of deeply sourced (endogenic) waters can degrade water quality, contributing significant salinity and trace metals to groundwater, with faults acting as conduits for subsurface fluid flow. Understanding source, movement, and chemistry of groundwater is becoming more significant with changing climate and weather patterns. Systematic sampling was carried out on a series of carbonic warm and hot springs in New Mexico, USA: 1) Tierra Amarilla springs near San Ysidro south of Nacimiento Mountains, 2) Penasco Springs along the Nacimiento fault west of the Nacimiento basement mountain block, and 3) Soda Dam, Jemez, and Indian hot springs in San Diego Canyon along the Jemez River. Multiple hydrochemical tracers were applied to quantitatively evaluate possible flow paths and mixing. The goal is to test three hypotheses for source and transport of waters to these carbonic springs: San Juan basin origin, meteoric flow from the Nacimiento high topography, and/or influence from the Valles Caldera geothermal system of the Jemez Mountains. Multiple geochemical plots show that all three carbonic spring groups are very different than meteoric and sedimentary aquifer waters. The springs are warm to hot (20°C-60°C) and many deposit travertine, pH ranges from 5.38-6.94; conductivities range from 3300-20000μS and PCO_2 ranges from -0.94 to 0.93. San Ysidro springs look similar in major ions to Penasco Springs each showing a different range of the same mixing trend. Soda Dam appears to anchor these mixing trends, but itself is part of a broader mixing trend with a Valles Caldera geothermal water end member.

The main tracers that define mixing trends are: major ions, stable isotopes, conservative tracers, temperature, and helium isotope ratios. In all of these tracers, the Tierra Amarilla and Penasco Springs overlap strongly and fall on well-defined mixing trends anchored by geothermal fluids of the Valles system. Stable isotope composition in the San Ysidro and Penasco springs overlap with Soda Dam hot springs and values fall on a mixing line with Valles Caldera geothermal waters. High lithium, boron, and bromine values all show the San Ysidro carbonic springs to have hydrochemical influence from the Jemez hydrothermal system. Similarly, helium isotope data show elevated $^3He/^4He$ values consistent with contributions from the Jemez volcanic system. In San Ysidro and Penasco spring groups, plots of high Li and B versus chloride suggest geothermal waters have acquired Cl from other sources, including salt and gypsum of the Paleozoic and Mesozoic rock aquifers. We interpret these carbonic springs to be distal manifestations of fluid circulation along faults with a mixture of Jemez geothermal waters and waters sourced from either/both San Juan Basin aquifers and meteoric sources. Semi-confined fault conduits, especially of the Jemez and Nacimiento fault zones, provide connectivity between carbonic spring systems and help explain geochemical similarities and mixing trends between Valles Caldera, Soda Dam, and Jemez geothermal waters with more distal San Ysidro and Penasco Spring waters. Penasco Spings are interpreted to reflect a component of outflow from the geothermal system that crosses the Nacimiento Mountain basement block along NE- trending faults.

Keywords:

Valles Caldera, Geothermal, Water-rock interaction, Carbonic Springs

WHAT HAVE WE LEARNED FROM MINE ACCIDENTS AND FAILURES IN NEW MEXICO?

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At the time the General Mining Law of 1872 was written, there was no recognition of the environmental consequences of direct discharge of mine and mill wastes into the nation's rivers and streams or the impact of this activity on the availability of drinking water supplies, and riparian and aquatic habitats. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s and 1970s, although the dumping of mine wastes and mill tailings directly into the nation's rivers was halted by an Executive Order in 1935. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break. In New Mexico, there are tens of thousands of inactive or abandoned mine features in 273 mining districts (including coal, uranium, metals, and industrial minerals districts). Many of them pose only a physical hazard, which is easily but costly to remediate. Although most of these mine features pose little or no environmental or stability threat to the public and environment, many of them have not been inventoried or prioritized for reclamation. During the late 1880s, government agencies began to track mine accidents. Indeed one of the earliest recorded accidents in the west was an explosion at the White Ash coal mine in the Cerrillos district, where 24 men died. Other mine accidents occurred during the late 1800s and early 1900s. Environmental accidents also have occurred at some New Mexico mine sites, mostly before the 1980s. In July 1979, 370,000 cubic meters of radioactive water containing 1,000 tons of contaminated sediment from a failure of the United Nuclear uranium tailings dam traveled 110 km downstream in the Rio Puerco in western New Mexico. Evidence of slope instability at the Goathill North waste rock pile at Questa molybdenum mine was observed as early as 1974, but was not stabilized until 2004. Today, more than three dozen Federal laws environmental laws and regulations cover all aspects of mining in an attempt to prevent such accidents, including the Clean Water Act (CWA), Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or Superfund act), Federal Mine Safety and Health Act of 1977, among others. Mine accidents that were once common in the late 1800s and early 1900s, are rare today, but still occasionally happen. Legacy issues still remain and should be inventoried. Today, one important aspect of mine planning in a modern regulatory setting is the philosophy, actually, the requirement in most cases, that new mines and mine expansions must have plans and designs for closure. This philosophy is relatively new and attempts to prevent environmental accidents common in the past. Mine development of the distant and even not-too-distant past commonly did not consider mine closure, except perhaps to plan for safeguards and contingencies. Mine closure planning is necessary not only for safety reasons, but also for environmental reasons.

Keywords:

mine waste rock piles, abandoned mines

CHARACTERISTICS OF GROUNDWATER NEAR THE TIJERAS FAULT COMPLEX

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Groundwater monitoring well, Coyote Test Field-Monitoring Well 2 (CTF-MW2), is located on Kirtland Air Force Base in Albuquerque, New Mexico and is part of Sandia National Laboratories (SNL) Groundwater Monitoring Program. The well was installed in 2001 as part of an investigation on the potential release from a wastewater system. The borehole was advanced to 190 feet (ft) below ground surface (bgs). During installation, fault breccia was possibly encountered at 145 ft. The well was installed to 135 ft with a screened interval from 110 to 130 ft. CTF-MW2 is also located approximately 1,000 ft east of the Tijeras Fault. Previous analysis of the well revealed bicarbonate alkalinity, along with high calcium, sodium, and arsenic values. The distinct geochemical signature suggests that the fault is allowing an abundance of carbon dioxide (CO_2) to influence the groundwater that results in an increase in calcium, sodium, and arsenic. This necessitates that there is a distinct geochemical signature for the groundwater. A noble gas analysis has shown that there is a mantle component to the CO_2 and that combined geochemistry and gas analysis show the mixing of epigenic and endogenic waters.

THE GREAT PLAINS PROVINCE; INSIGHTS INTO MANTLE PROCESSES FROM THE RATON-CLAYTON VOLCANIC FIELD

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The Raton-Clayton Volcanic Field (RCVF) is located along the eastern edge of the Great Plains province in northwestern New Mexico along the Jemez Lineament. Raton-Clayton volcanics are the eastern-most extent of Cenozoic volcanism until the Mid-Atlantic Ridge. The mechanism that causes melt generation beneath the Great Plains province is unclear. The RCVF offers the best chance to understand the mechanism driving melt generation in the Great Plains. The youngest phase of volcanism in the RCVF is the Capulin phase which ranges from ~1.5 Ma to 0.03 Ma. Only the youngest (~50 ka - ~30 ka) Capulin-phase volcanics were analyzed for this study. Whole-rock and single-crystal geochemical data is used to infer mantle composition and what processes have caused melting beneath the Great Plains province. Capulin-phase volcanics analyzed in this study are typically basalts, with some basaltic andesite and basaltic trachy andesite. Preliminary strontium isotope data suggest mixing between two slightly radiogenic sources (0.7042 and 0.7039) or indicates two separate sources of magma formation. Ratio/ratio plots of incompatible trace elements suggest two sources have contributed to Capulin basalts. Trace element data suggests contribution from both an Ocean Island Basalt (OIB)-like source and an enriched lithosphere source. Capulin-phase basalts show negative niobium anomalies. A mixture of approximately 60% OIB and 40% subduction enriched lithosphere can approximately explain trace element trends in Capulin-phase rocks. Deviations from the mixing trend may be explained by crustal contamination.

GEOARCHAEOLOGICAL SIGNIFICANCE OF A YOUNGER DRYAS AGED BLACK MAT, TULAROSA BASIN, SOUTHERN NEW MEXICO

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The paucity of recorded Paleo-American sites around the margins of Paleolake Otero in the Tularosa Basin has always raised the question of whether the geoarchaeological context for buried, intact Paleo-American sites exists in this locality. Here, we describe an undocumented stratigraphic sequence located on the western lake margin of the paleolake. This sequence contains an organic rich horizon or "black mat" that formed during the Younger Dryas (10,900– 9,800 ^{14}C yrs BP). This black mat is in a sequence of buried geomorphic surfaces dating from ~12,300 to ~9,500 ^{14}C yrs BP. The formation of this black mat is contemporaneous with other geoarchaeological sites that exhibit a Younger Dryas aged black mat that cover portions of the Clovis age landscape where artifacts and Pleistocene megafaunal remains have been recovered in Arizona, west Texas, and New Mexico. The lack of recorded Paleo-American sites in this locality may be more related to lack of visibility because these surfaces are buried rather than to low human population densities along the lake margin during the late Pleistocene– Holocene transition. Although no artifacts or skeletal remains of the Pleistocene megafauna have so far been found in association with the black mat reported here, the geomorphological context is a promising place to focus future research.

GEOLOGISTS MUST REPOSSESS GEOLOGIC REPOSITORIES

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Geologists can draw valuable lessons from the two 2014 WIPP incidents and related "recovery" efforts to date. The continuing WIPP crisis ought to focus geologists' attention on the risk spectrum of nuclear and radioactive processes in geologic time and space. Failure to understand and compare risk from a variety of radioactive and "non-radioactive" sources may otherwise doom prospects for future geologic repositories. Early investigations into the cause of the radiological release focused –without evidence and contrary to reasonable likelihood- on rock mechanical failure scenarios, when a violation of fairly elementary chemical safety precautions was the actual culprit. The radioactive contamination of portions of WIPP excavations then became the almost exclusive concern, while "simple" industrial and occupational risk from actual and proposed remediation efforts continues to be ignored. Thus far, there has been no truly independent and comprehensive (e.g., National Academy of Science or Engineering) review, evaluation, or oversight. This deficiency allows the owner and the operator of WIPP to rely on the expediency of compliance with regulations that were never imagined to cover contamination of an underground environment and that are founded on concepts not based on evidence but irrational fear, political perception, and professional empire preservation. Geologists are uniquely qualified to contribute to the resolution of these issues, but only if they assert the primacy of geology in all matters concerning geologic waste repositories. They must take back ownership of the basic idea of, and justification for, geologic repositories for dangerous -including radioactive- wastes, or the whole concept and its realization may face extinction.

Keywords:

geologic repositories, crisis, geologic time and space, risk, ownership

UNRAVELING THE 5 MA BIRTH AND YOUNG EVOLUTION OF THE RIO GRANDE FLUVIAL SYSTEM

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The Rio Grande-Rio Chama (RG-RC) fluvial system preserves a record of southern Rocky Mountain erosion and sediment transport over the last 8 Ma. During this time the two rivers have evolved dramatically, undergoing channel migrations, drainage capture and integration events, carving and refilling of paleocanyons, and lake spillovers. Volcanism concurrent with the development of the river system provides a unique opportunity to apply multiple geochronometers to the study of its incision and drainage evolution. New $^{40}Ar/^{39}Ar$ basalt ages coupled with new detrital zircon and sanidine age population data for fluvial sediments document the birth of the ancestral RG by 4.8 Ma, with headwaters in the San Juan Mountains and extending to the Palomas Basin.

This paper reports on twelve detrital samples (zircon + sanidine) collected from RG-RC river alluvium ranging from ~8 Ma RC to ~3.5 Ma RG deposits. RC detrital zircon age spectra are distinct from ancestral RG, and are rich in San Juan Basin and San Juan volcanic detritus; this river is interpreted to be the main drainage before 5 Ma. Detrital zircon age spectra for ancestral RG alluvium underlying 4.7-4.5 Ma basalt flows in the Espanola Basin reveal peaks at 21 Ma (Servilleta Plaza volcanics), 28 Ma (southern San Juan Mountains), 30-35 Ma (northern San Juan Mountains), and 70-100 Ma (recycled San Juan Basin sediment). Detrital sanidine grains from these samples reveal similar age peaks at 19.8, 25.4 (Latir Volcanic Field), 28.72, 29.3, and 34.8 Ma. Although the 28 Ma peak could include input from small volume pre-Caldera Latir Field volcanics, and recycling of the Ojo Caliente Sandstone of the Santa Fe Group (5% 37-27 Ma grains) may have resulted in 28 and 35 Ma grains, the larger percentage (10-12%) of 37-27 Ma grains in river sediment at Black Mesa are interpreted to reflect a RG with headwaters in the San Juan Mountains at 4.8 Ma. Building of the Taos Plateau Volcanic Field precluded drainage from the upper San Luis Basin from ~5 Ma until the ~0.430 Ma spillover of Lake Alamosa re-integrated this drainage to the lower RG-RC system. 2.6 Ma ancestral RG sediment downstream of today's RG-RC confluence (Totavi Lentil) has a similar age spectrum to the ancestral RC, while 1.6 Ma Totavi Lentil is more similar to the combined RG-RC, suggesting northward shift of the RG-RC confluence between 2.6 and 1.6 Ma during the building of the Jemez Mountain eruptive center.

This study highlights the influence of magmatic and tectonic processes on major river systems. Building of the Taos Plateau Volcanic Field from 5-3 Ma is interpreted to have driven downward integration of the RG to the Palomas Basin by 4 Ma. River damming events in the RG-RC system were driven by Taos Plateau and Jemez volcanism, while spillover events were driven by continued headwater uplift in the southern Rocky Mountains. Increased amplitudes of glacial and interglacial periods likely contributed to increased discharge and incision rates during latest stages of river evolution, but tectonic drivers dominate over the ~5 Ma time period.

Keywords:

rivers, geochronology, tectonic geomorphology

WILL THE ENVIRONMENTAL LEGACY OF HISTORIC MINING IN THE MOUNTAIN WEST EVER BE BEHIND US? LESSONS FROM THE ANIMAS RIVER SPILL

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The Animas River (Gold King Mine) Spill has been touted as the worst mining related environmental disaster in US history, although was small compared to tailings dam failures elsewhere in the world over the past few years. The estimates are that about 3 million gallons (10 000 tons) of low pH water ponded in the mine workings and 400 tons of metals in solution and as suspended mineral particles, amounts which would normally seep out of the mine over about 6 months, were released in a slug over a period of about two days. With dispersion, the Animas River remained significantly contaminated over a longer period in NW New Mexico.

Although the trend has reversed, the spill took place after years of general improvement to the quality of Animas River water, a result of cessation and mine and mill activity and site-by-site remediation by various groups, including the Animas River Stakeholders Group. Interestingly the Gold King Mine had not originally been identified as a top priority site for treatment. The earlier assessments had been based on steady state metal and acid loading and had not considered failure of blockages or engineered structures, or changes to hydrology and other conditions at mines. The Gold King Mine was relatively large, its ores and wallrock have high acid-producing capacity, and its hydrology had been affected by remediation work at topographically underlying mines.

The metal load in the Animas will reside largely in stream bed precipitates and sediments, presumably along the whole length to Lake Powell, and has the potential to be chemically and physically remobilised. The potential for acid production in mines, waste rock and tailings will remain so long as pyrite is available for oxidative dissolution. Despite the visual prominence of iron-oxide staining, pyrite dissolution in waste rock is slow relative to historic time frames in the climate of the Mountain West. Estimates of reaction rates from natural acid rock drainage and petrology of historical mine waste imply that an order of magnitude drop in rate of acid production requires of order 1000 years. Rates may be different in mine workings as a result of temperature, dissolution into a near stagnant partially deoxygenated mine pool, and other factors, but order of magnitude estimates of metal flux suggest similar time spans for ‘reactive flushing’ of the Gold King Mine workings by through-flow of meteoric waters.

PRELIMINARY GROUNDWATER STORAGE CHANGES FROM 1950S TO PRESENT IN NEW MEXICO ALLUVIAL AQUIFERS USING A SEMI-AUTOMATED WORKFLOW

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In response to increasing needs to understand the water budget of New Mexico, we have constructed estimates of historical groundwater storage change in the shallow (less than 1000 ft), unconfined alluvial aquifers of the state. Shallow, unconfined alluvial aquifers in New Mexico form the major groundwater reservoirs in many of the urbanized and agricultural areas of the state. This collocation means that alluvial aquifers have been commonly used as a major water source over the last 70 years, possibly leading to declines in storage through time. We present preliminary estimates of historical groundwater storage changes in the alluvial aquifers of New Mexico, separated by USGS HUC-8 (hydrologic unit code, level 8) boundaries. These aquifers are mostly in Rio Grande and Basin-and-Range physiographic provinces—they are either in basins with the Rio Grande flowing through them or they are in the closed basins to the east and west of the Rio Grande basins. Our estimates are based on depth-to-water measurements available from the USGS online database, and datasets that conform to USGS measurement standards. Water level measurements affected by pumping or those that were taken during irrigation season were removed, except for locations in rangeland areas with poor data coverage. The measured depths-to-water are then used to determine a correlation length of water levels for each basin for every decade from the 1950s to present. The water levels are then interpolated using both ordinary kriging and inverse-distance-weighting methods. The interpolated fields are restricted to the radius of correlation lengths, and to Quaternary sediments mapped at the 1:500,000 scale.

While our results are preliminary, we see a few patterns beginning to emerge. Groundwater withdrawals in closed basins appear to vary by the proportions of the water balance—pumping rates and locations compared with recharge rates and locations. In open basins, such as the El Paso-Las Cruces HUC or the Albuquerque HUC, the storage changes appear to be linked to the degree of connection of groundwater with the surface water, pumping demands and the presence of mountain-block recharge. Open basins are less sensitive than closed basins to pumping demands as long as (a) there is an initial connection with surface water, and (b) pumping does not lower the water to the point that the groundwater does not respond strongly to annual river flows. The Albuquerque HUC is a case where both of these conditions are met. The Santa Fe HUC and El Paso-Las Cruces HUCs, respectively, are examples of behaviors when (a) and (b) are not met, and groundwater is currently lowering due to greater demand independent of the river. Our results provide a coarse resolution view of groundwater storage in New Mexican alluvial aquifers. They do provide direct examples of how geology, hydrology and society are reflected in our groundwater resources at the basin scale.

Keywords:

groundwater storage change, Rio Grande basin, geostatistical methods, hydrogeology

THE LOS ALAMOS SEISMIC NETWORK (LASN): CURRENT NETWORK STATUS AND UPDATED NORTH-CENTRAL NEW MEXICO SEISMICITY

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From the first data recorded in the fall of 1973 to now, the Los Alamos Seismograph Network (LASN) has operated for almost 43 years. During that time LASN data have been used to locate more than 2,600 earthquakes in north-central New Mexico. The network was installed for seismic verification research and to monitor local earthquakes for the Los Alamos National Laboratory (LANL) Seismic Hazards Program. LASN once included as many as 22 stations spread over a geographic area of 150 km (N-S) by 350 km (E-W), but was downsized to cover only the local area around Los Alamos, roughly 15 km N-S by 15 km E-W, in the mid 1980s. Until 2010, LASN operated only 7 permanent stations. Over the last 6 years, 7 additional microseismic stations have been added, expanding both the spatial coverage and density, as well as utilizing state-of-the-art sensors and digital recording and telemetry technology. An additional digital broadband station is now being installed on LANL property. Currently, 6 of the 14 microseismic stations are old short-period, analog UHF-telemetered stations with 1-Hz geophones. The other 8 stations have digital broadband seismometers with spread-spectrum digital RF telemetry. In addition, a strong-motion vertical array of digital accelerometers was installed in a wellbore on LANL property. All but one station have 3-component (vertical, north-south and east-west) sensors. Also, three forensic strong-motion accelerometers (SMA) are operated at LANL facilities and more are planned. LASN is now capable of monitoring not only local tectonic earthquake activity, but also very small volcano-seismic events associated with the nearby Valles Caldera, due to installation of 3 broadband stations in and around the caldera. We will present a description of the current LASN station, instrumentation and telemetry configurations, as well as the data-acquisition and event-detection software structure used to record events in Earthworm.

More than 2,000 earthquakes were detected and located in north-central New Mexico during the first 11 years of LASN's operation (1973 to 1984). With the subsequent downsizing of the network, about 1-2 earthquakes per month are detected and located within about 150 km radius of Los Alamos. Over 950 of these nearby earthquakes have been located from 1973 to present. We recently updated the LASN earthquake catalog for north-central New Mexico up through 2013 and most of 2014. This involved re-assessing numerous historic locations in the previous catalog. We are also looking at subsets of the catalog that represent earthquake swarms or clusters, as well as tiny events on the Valles Caldera's ring fracture that were not detected before the caldera stations were installed. We will present the most recently updated map of north-central New Mexico seismicity based on these efforts. Many of the events detected by LASN do not appear in other catalogs because the majority of nearby earthquakes have magnitudes less than 1.5 and are not detected by other networks. Since 1973, there have been only a handful of events that were felt locally by Los Alamos residents.

Keywords:

Seismic network, seismicity, northern New Mexico, Los Alamos

RESERVOIR CHARACTERIZATION OF THE MORROW SANDSTONE USING THE WINLAND R35 METHOD.

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This study presents a field scale reservoir characterization of a late Pennsylvanian clastic reservoir at the Farnsworth Unit (FWU), located in the northeast Texas Panhandle on the northwest shelf of the Anadarko basin. The characterization is undertaken as part of a Phase III CO_2, storage and enhanced oil recovery (EOR) project conducted by Chaparral Energy (LLC) and the Southwest Regional Partnership on Carbon Sequestration (SWP). The target unit is the upper most Morrow sandstone bed (Morrow B Sand). The objective of the current study was to utilize extensive data acquired from FWU to improve previously constructed static and dynamic geologic models used for simulation and prediction of reservoir behavior.

Legacy data included wire-line logs from 151 wells, including 48 with associated cores and 10 with thin sections. Depth converted 3D seismic data in conjunction with the abundant well control was used to define stratigraphic surfaces and structural features within the static model. Three new characterization wells were drilled for the project. Cores and advanced wire-line logs from these wells were analyzed for stratigraphic context, sedimentological character and depositional setting to gain a better understanding of the reservoir. Porosity and permeability trends were sought in order to model flow within the reservoir, an important aspect of the EOR and CO_2 storage efforts at the field.

The Morrow B reservoir was deposited as fluvial low-stand to transgressive clastic fill within an incised valley. It is a subarkosic, brown to grey, sub-angular to sub-rounded, poorly sorted, planar to massively bedded, upper medium to very coarse sand and fine gravel sandstone. Gallagher (2014) demonstrated that primary depositional fabrics have less effect than post depositional diagenetic features do on reservoir performance.

Because of the initial difficulty in describing reservoir heterogeneity using traditional methods the Winland R35 hydraulic flow unit methodology (HFU) was used to characterize and refine porosity permeability relationships within the field. This methodology involves calculating R35 values, an empirically derived estimate of pore throat aperture radius when core samples are 35% saturated during a mercury porosimetry test. The R35 value is believed to be the point at which pores form interconnected networks responsible for flow and often provides an excellent means for correlating porosity and permeability. At FWU using R35 values not only provided a means of categorizing porosity as a function of permeability but also helped illuminate some of the underlying geologic underpinnings of flow characteristics within the reservoir.

It is shown at FWU that low HFU's correspond to areas with occluded intergranular space and only minor intragranular microporosity, whereas increasing HFU's have increasing amounts of intergranular space that is better able to form interconnected flow paths.

The integrated approach illustrated in this study presents an improved methodology in characterizing heterogeneous and complex reservoirs that can be applied to reservoirs with similar geological features.

Future work will focus on tying HFU to associated controls such as clay content and degree cementation, then defining a geologic reason for their abundance and distribution in order to further enhance the geologic modeling process.

AMMONITE ZONES IN THE SOUTHEASTERN SAN JUAN BASIN, SANDOVAL COUNTY, NEW MEXICO

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Twenty-four Upper Cretaceous ammonite zones have been identified in the southeastern San Juan Basin. In ascending order, the zones are: *Conlinoceras tarrantense* in the Oak Canyon Member, *Acanthoceras bellense* in the Cubero Sandstone, *Acanthoceras amphibolum* in the Clay Mesa Member and Paguate Sandstone, *Calycoceras canitaurinum* in the Two Wells Sandstone, *Mammites nodosoides* in the upper Greenhorn Limestone, *Collignoniceras woollgari* and *Prionocyclus hyatti* in the Carlile Member, *Prionocyclus hyatti* in the Semilla Sandstone Member, *Prionocyclus macombi*, *Scaphites warreni*, *Scaphites ferronensis* and *Scaphites whitfieldi* in the Juana Lopez Member, *Scaphites preventricosus* in the Montezuma Valley Member, Gallup Sandstone, Tocito Sandstone Lentil and Mulatto Tongue, *Scaphites ventricosus* in the upper Mulatto Tongue, *Scaphites depressus* in the El Vado Sandstone, *Clioscaphites vermiformis*, *Clioscaphites choteauensis*, *Desmoscaphites erdmanni* and *Desmoscaphites bassleri* from the Satan Tongue, *Scaphites leei* III from the Satan Tongue and lower Point Lookout Sandstone, *Baculites asperiformis* from the La Ventana Tongue of the Cliff House Sandstone, *Baculites perplexus*, *Baculites gregoryensis* and *Baculites scotti* from the Lewis Shale and *Didymoceras stevensoni* from the Pictured Cliffs Sandstone. The *C. tarrantense* Zone is indicated by a molluscan fauna consisting of *Turrilites acutus*, *Arrhoges modesta*, *Exogyra aquillana* and *Pinna petrina*. The *M. nodosoides* Zone is indicated by the *Mytiloides mytiloides* inoceramid zone. The *S. preventricosus* Zone is identified in the Montezuma Valley Member, Gallup Sandstone and Tocito by the *Cremnoceramus deformis erectus* inoceramid zone and in the Mulatto Tongue by the *Cremnoceramus crassus crassus* inoceramid zone. The *S. ventricosus* Zone is indicated by the *Volviceramus involutus* inoceramid zone in the upper Mulatto.

There is a large hiatus in the ammonoid record of the southeastern San Juan Basin that represents most of late Cenomanian and early Turonian time that includes the majority of the *Dunveganoceras problematicum* through *Vascoceras birchbyi* zones. Ammonites diagnostic of the upper Cenomanian zones of *Vascoceras diartianum*, *Euomphaloceras septemseriatum*, *Burroceras clydense*, *Neocardioceras juddii*, and *Nigericeras scotti* have not been collected from this area. However, *Sciponoceras gracile* occurs in the lower Greenhorn Limestone and because it ranges from the *E. septemseriatum* through the *N. juddii* zones, it indicates at least one of these zones. If there was no hiatus, the *D. problematicum* through *V. birchbyi* zones would have to occur in the interval occupied by strata equivalent to the Graneros and Greenhorn members of the Mancos Shale. However, these 11 zones could not possibly fit within so thin of a stratigraphic interval. Also, these members are mostly poorly exposed in the southeastern San Juan Basin, and few fossils have been found in them. Another large hiatus in the ammonoid record from the southeastern San Juan Basin includes the lower Campanian zones of *Scaphites hippocrepis* I, II and III, *Baculites* sp. (smooth) and *Baculites* sp. (weak flank ribs), and the lower middle Campanian zones of *Baculites obtusus* and *Baculites maclearni*. These missing zones, the zones of *S. hippocrepis* I through *B. maclearni*, should occur in the interval occupied by the middle and upper parts of the Point Lookout Sandstone and the overlying, terrestrial Menefee Formation.

Keywords:

ammonite,ammonite zone,San Juan Basin,Cretaceous

MIOCENE MAGMATISM ON THE EASTERN FLANK OF THE RIO GRANDE RIFT, NORTHEASTERN NEW MEXICO

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The Las Vegas Igneous Field (LVIF) is a volumetrically small but regionally significant collection of mid-Miocene mafic dikes, plugs, and stocks that represent a previously undocumented episode of igneous intrusive activity on the east flank of the Rio Grande rift to the east of the Sangre De Cristo Mountain Front Range. The intrusions are all comprised of hornblende + plagioclase + augite ± olivine with variable amounts of hydrothermal alteration. The dikes (n=14) intrude the Carlile Shale and Niobrara Group, strike NNE, and 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 Milton Ranch stocks, each measuring approximately 25 m-wide. The Reed Ranch plug and the Milton Ranch stocks intrude the Graneros Shale and are located just east of Las Vegas and north of the Las Vegas National Wildlife Refuge. Compositionally, they are similar to the Buena Vista intrusion, but contain significantly more olivine forming large glomerocrysts and fractionating to augite. The LVIF basalts are alkaline and fall within the sodic series of the alkali olivine basalt scheme. They have low SiO_2 values (43.59-48.59 wt.%) and moderate MgO values (3.61-6.41 wt.%). They are sufficiently mafic that their incompatible trace element compositions are controlled mainly by their mantle source region(s). The rocks are enriched in the light rare earth elements relative to the heavy rare earth elements $(La/Yb)_N$=29-37. MORB-normalized trace element patterns show selective enrichments in the incompatible elements Ba, Th, K, Nb, and Ta, which are characteristic of melts originating in the subcontinental lithosphere. The LVIF basalts have moderate Ta/Ba and Nb/Ba ratios which are also signatures of the lithospheric mantle, modified by subduction zone fluids. We recognize the LVIF as a mid-Miocene magmatic episode that predates, and is petrographically distinct from, the 8.0-0.8 Ma Mora-Ocate volcanic field. The chemistry of LVIF rocks indicate they originated from a fertile fluid-modified lithospheric mantle during a mid-Miocene period of rapid extension associated with Rio Grande rifting, but focused east of the Sangre de Cristo Mountains. The origin of magmatism associated with the LVIF remains enigmatic; we postulate strain associated with rifting to the west was partitioned eastward beyond the Sangre de Cristo Mountains into the transition zone between the Rocky Mountain Front and the Great Plains.

Keywords:

Rio Grande rift, olivine, subcontinental lithosphere, mantle, source

MAGMA EMPLACEMENT PROCESSES OF THE OLIGOCENE ZAKUPY AND MIOCENE MERUNICE DIATREMES, CZECH REPUBLIC: REVEALED VIA PETROGRAPHY, ANISOTROPY OF MAGNETIC SUSCEPTIBILITY, PALEOMAGNETIC, AND GROUND MAGNETOMETRY DATA

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The emplacement of silica-undersaturated magma in continental rift volcanoes remains poorly understood because the roots of these systems are not often accessible. The Miocene Merunice and Oligocene Zákupy diatremes, Czech Republic, are located within or on the SE shoulder of the Eger Rift. These diatremes provide a unique opportunity to conduct a comparative emplacement study, in near 3-dimensions, of their sub-volcanic magma plumbing systems. Studies across the rift reveal that magma compositions show a temporal evolution trend that coincides with three rift phases, pre-rift (79-49 Ma), syn-rift (42-16 Ma), and late rift (16-0.3 Ma). Here we report data on how varying degrees of alkaline magma generation paired with a dynamic rift stress regime yield unique emplacement mechanisms of presumed monogenetic rift diatremes. Field observations and laboratory data at both diatremes indicate multiple emplacement and eruptive events, as shown by variation in composition, eruptive materials and cross cutting relationships between dikes and sills that reflect different emplacement dynamics. Anisotropy of magnetic susceptibility (AMS) data collected from 25 Zákupy diatreme sites reveal primarily oblate magnetic fabrics suggesting magma flowed up, down, and laterally away from the suspected main conduit but have a NE-W/SW flow trend from a probable NE magma source, that is in accordance with the syn-tectonic rift stress regime (NE-SW). Preliminary paleomagnetic data reveal that the intrusions are of both normal and reversed polarity and show scatter about their respective expected polarity reference directions that could be related to sub-volcanic deformation of the diatreme. Curie point estimates show that the magnetic mineral phases carrying the characteristic remanent magnetization are moderate to high titanomagnetite with ilmenite inclusions in clinopyroxene and diospside. AMS data from the main feeder dikes from the Merunice diatreme display a steep upward NW and NE emplacement trend, suggesting a SW magma source, that follows the same rift trend of NE-SW. Petrologic observations indicate that the rocks are olivine basanites with little to no compositional variation between intrusive and extrusive products. Paleomagnetic data from the Merunice diatreme are underway and should aid with defining subvolcanic deformation during the growth of the diatreme. The results from this multidisciplinary study suggest that these presumed monogenetic systems display characteristics that are better described by a polygenetic emplacement model with a strong structural control dictated by the Eger rift stress configuration.

Keywords:

magma emplacement, paleomagnetism, anisotropy of magnetic susceptibility, Egar Rift

DEGASSING OF CO_2 ALONG FAULT NETWORKS FROM THE VALLES CALDERA AND INTO THE ALBUQUERQUE BASIN: CENTRAL RIO GRANDE RIFT, NEW MEXICO

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Extension rates in the Rio Grande rift (RGR) have slowed since the Miocene within the Albuquerque Basin, and the Valles Caldera geothermal system is presumably cooling, yet large amounts of CO_2 are degassing along active Quaternary faults in these areas. This study measures present day CO_2 flux (g_{CO2}/m^2d) along faults in order to provide evidence that faults are conduits for fluids from deep crustal and magmatic sources. We used a CO_2 flux device (EGM-4 CO_2 gas analyzer; PP Systems, with an accumulation chamber) to measure transects across faults at three sites within the Valles Caldera (Alamo Canyon-AC, Sulphur Springs-SS, and Soda Dam-SD) and near the western and northern borders of the Albuquerque Basin at five sites (Penasco Springs-PS, Zia Pueblo-ZP, San Ysidro-SY, Sand Hill Fault-SHF, and Carrizo Arroyo-CA). These sites (except for ZP) characterize the western RGR faults from the Valles Caldera southward along the rift related Jemez, Nacimiento, Sand Hill, and Comanche fault networks. Mantle He and CO_2 are well documented at 5 of the 8 sites, and decreases in the mantle derived He component is shown by decreasing $^3He/^4He$ ratios away from the Caldera. Targets along these fault systems included carbonic and geothermal springs and cemented faults. The cemented (silica and carbonate) faults demonstrate past fluid migration and CO_2 degassing. Results are as follows: carbonate-cemented faults at Zia Pueblo show little to no CO_2 flux (0-1.2 g_{CO2}/m^2d), indicating an impermeable barrier to cross and up-flow fluid migration. The silica cemented fault associated with the Santa Ana fault network showed a moderate CO_2 flux (9.6 g_{CO2}/m^2d), indicating it is still a conduit for upward and potentially cross-flow fluid migration.

Cumulative probability plots were constructed to distinguish between CO_2 fluxes produced by background (biological and soil), diffuse, and/or endogenic (magmatic or tectonic) sources, also referred to as populations. Active carbonic and geothermal spring sites (AC, SS, SD, PS, and SY) have at least 3 populations, whereas sites with no active springs (ZP, SHF, and CA) have only 2 populations. Our analyses show that background values vary between sites, especially within the Valles Caldera where more vegetation and precipitation occurs. Generally, CO_2 fluxes that range from 0.2 to 8.6 and from 0.2 to 2.5 g_{CO2}/m^2d in the Valles Caldera and Albuquerque Basin, respectively, are considered background. CO_2 fluxes ranging from 2.0-148 g_{CO2}/m^2d are considered diffuse in the Valles Caldera. Sites in the Albuquerque Basin with active carbonic springs (PS and SY) and those without active springs (ZP, SHF, and CA) have diffuse CO_2 flux rates that range from 0.8-35.5 and 1.7-9.6 g_{CO2}/m^2d, respectively. Endogenic fluxes from the Valles Caldera sites range from 100-2,400 (maximum flux detection) g_{CO2}/m^2d. Endogenic fluxes from the Albuquerque Basin sites with active carbonic springs range from 13.2-2,400 g_{CO2}/m^2d, and no endogenic CO_2 was measured at sites that had no active springs. These high flux rates are comparable to Yellowstone and other geothermal systems around the world, and provide evidence that large amounts of CO_2 are contributed to the atmosphere from dormant volcanoes and intercontinental rift systems.

PROVENANCE AND SEDIMENT DISPERSAL TRENDS FROM UPPER CRETACEOUS NONMARINE STRATA IN SOUTHERN NEW MEXICO

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Nearly continuous sections of Upper Cretaceous strata outcrop throughout parts of southern New Mexico. Here, Turonian-Campanian strata are defined from base-to-top by: (1) nonmarine fluvial strata of the Tres Hermanos Formation, (2) lower- and upper-offshore strata of the D-Cross Tongue of the Mancos Shale and lower shoreface strata of the Gallup Sandstone, and (3) nonmarine fluvial strata of the lower member and upper Ash Canyon Member of the Crevasse Canyon Formation. Summarized here are new provenance data (U-Pb detrital zircon geochronology and sandstone modal composition) and paleoflow trends from nonmarine strata that outcrop near Carthage and Truth or Consequences (TorC), New Mexico.

The Tres Hermanos Formation is composed primarily of quartz and lithic fragments (volcanic and metamorphic) with minor amounts of feldspar (Q=63%, F=10%, L=27%). Paleoflow trends show east-directed flow (93°) near TorC and a southeast-directed flow (166°) near Carthage. TorC peak detrital zircons ages include 101, 169, 1127, 1417, and 1698 Ma, with the youngest zircon grain at 92.6 Ma and a calculated maximum depositional age (MDA) of 96 Ma. Carthage peak detrital zircon ages include 94, 151, 1080, 1426, 1712 Ma, with the youngest zircon grain at 89.7 Ma and a calculated MDA of 94 Ma.

The lower member of the Crevasse Canyon is composed primarily of quartz and lithic fragments (volcanic and metamorphic) with minor amounts of feldspar (Q=50%, F=9%, L=41%). Paleoflow trends near TorC show an east-directed flow (100°) and peak detrital zircon ages include 98, 168, 1050, 1406, and 1685 Ma, with the youngest zircon grain at 88.9 Ma and a calculated MDA of 98 Ma. Carthage peak detrital zircon ages include 98, 149, 1069, 1117, 1415, and 1706 Ma, with the youngest zircon grain at 88.5 Ma and a calculated MDA of 91 Ma.

The upper Ash Canyon member of the Crevasse Canyon is composed primarily of quartz and lithic fragments (volcanic and metamorphic) with minor amounts of feldspar (Q=48%, F=6%, L=46%). Paleoflow trends at Carthage show a southeast-directed flow (118°). Peak detrital zircon ages from lower part of Ash Canyon Member near TorC include 94, 150, 171, 1419, and 1687 Ma, with the youngest zircon grain at 79.8 Ma and a calculated MDA of 94 Ma. The upper part of the Ash Canyon Member near TorC has peak detrital zircon ages of 79, 90, 166, 1409, and 1678, with the youngest zircon grain at 78.3 Ma and a calculated MDA of 79 Ma. Carthage peak detrital zircon ages include 91, 98, 152, 171, 1110, 1413, and 1674 Ma, with the youngest zircon grain at 86.6 Ma and a calculated MDA of 91 Ma.

Based on trends summarized above, we favor a sediment dispersal model where the Tres Hermanos and Crevasse Canyon Formations were sourced from recycled orogen and arc source areas that were likely located in the west-southwest parts of the Cordillera. Source areas likely included Mesozoic magmatic systems of the southwestern Cordillera as well as Precambrian sources of the Yavapai and Mazatzal, Grenville, and Mogollon Highland provinces of the southwestern United States.

THE LIFECYCLE OF THE OLIGOCENE SCHOOLHOUSE MOUNTAIN CALDERA, SOUTHWEST NEW MEXICO

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The Oligocene Schoolhouse Mountain Caldera (SMC) in the southernmost Mogollon-Datil volcanic field exposes pre-caldera dacite flows, collapse megabreccias, and a series of mostly undated rhyolite tuffs. The pre-, syn-, and post-caldera volcanic units are preserved within normal-fault blocks, making the SMC an excellent site for a combined field-mapping, geochronology, and geochemistry case study of the lifecycle of a caldera. All thickness estimates are from Finnell (1987). Dacite lava flows are the oldest caldera unit in the area, and these are overlain by rhyolite flows of Saddlerock Canyon, which measure up to 125 m thick. The next unit may represent the collapse of the caldera, which produced the tuffs, flows, and megabreccias of the Kerr Canyon sequence. The megabreccia is up to 220 m thick between Schoolhouse Mountain and Saddle Rock Canyon, and consists of a lithic-rich, highly altered, rhyolitic matrix containing ash, quartz, biotite, sanidine, and plagioclase. Matrix material is stained orange-brown and pale green in areas of great weathering, most significantly in samples with abundant biotite and pumice. Clasts within the matrix consist of rhyolite, flow-banded rhyolite, and pumice ranging in size from 2 cm to ~ 2.5 m. Other clasts are Cretaceous quartzarenite and Proterozoic granite. The largest clasts are composed of crystal-rich rhyolite, containing sanidine, biotite, plagioclase, and quartz phenocrysts that are ≤ 2 mm in size and minimally altered, which is ideal for argon dating. The next unit is the Mangas Creek, largely composed of intermediate to felsic tuffs, and the regionally significant McCauley Ranch Tuff. Individual flows of Mangas Creek measure up to 300 m thick, and the McCauley Ranch Tuff is exposed up to ~ 343 m thick. The Cherokee Canyon Tuff and Greenwood Canyon Tuff are the youngest units postulated to be associated with the SMC. Outflow sheets are located ~ 20 km south of the SMC in the Eye Peak and Knight's Peak regions. These may have been derived from the SMC or from a caldera in the Boot Heel volcanic field. The Kneeling Nun Tuff is interbedded with these tuffs. Results from high-precision, single-crystal 40Ar/39Ar dating on all of the tuffs and on the megabreccia will provide a more precise timeline for the history of this caldera. Dating of sanidine phenocrysts from the large, crystal-rich clasts in the megabreccia can constrain a time window for the possible age of the collapse breccia, which is a critical stage in the volcanic history of the SMC. The entire caldera history is postulated to have occurred within 2-3 million years based on existing geochronology (Jonell, 2012) and regional relationships.

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HYDROCHEMISTRY OF SULPHUR AND ALAMO CREEK, VALLES CALDERA: EFFECT OF GEOTHERMAL SYSTEMS ON SURFACE WATER QUALITY OF THE JEMEZ RIVER.

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The Valles caldera in northern New Mexico is a large, Quaternary silicic volcanic complex (1.25 Ma to 40 ka) containing a liquid-dominated geothermal system. Sulphur Springs and Alamo Canyon in the southwestern part of the caldera contain acidic geothermal features. In this study, we examine the hydrochemistry of the acid-sulfate waters and examine their influence on the surface waters draining the Valles caldera.

We sampled waters of Alamo, Sulphur, San Antonio and Jemez rivers during two campaigns in summer, 2015. To obtain pH, temperature and other initial parameters a field probe was placed in streams. After those are recorded two water samples are collected; one for bicarbonate concentrations and another for anion and cation concentrations. With over 23 samples collected, measurements vary across a wide range: pH ranges from 2.5 (Sulphur Creek) to 7.1 (Jemez River above Soda Dam), temperatures from 10 C° (Alamo Creek) to 22 C° (above Soda Dam), and total dissolved solids concentrations from 30 (Alamo Creek) to 688 (Sulphur Creek) ppm. The acidic geothermal contributions have a major effect on the water quality in streams and shallow groundwater systems; especially pH, T, sulfate and solute content in the upper stream reaches of Alamo and Sulphur creeks. The water quality improves as dilute, circum-neutral waters from Redondo and the East Fork Jemez enter the stream system.

Using solute concentrations (including sulfate, chloride and bicarbonate) we are able to quantify the mass loading of geothermal constituents to the stream system, and predict the consequences of changes to future snowpack and runoff on water quality in the Jemez river system.

Keywords:

Water Quality, Geothermal, Hydrochemistry, Valles Caldera, Jemez River

MONITORING GROUNDWATER CHEMISTRY IN THE ANIMAS RIVER ALLUVIAL AQUIFER AFTER THE GOLD KING MINE 2015 MINE-WATER RELEASE

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Following the August 2015 mine-water release into Cement Creek and the Animas River, the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) undertook a hydrologic assessment of the Animas River and its alluvial aquifer in New Mexico, from Colorado-state line to Farmington, NM. The purpose of the project is to evaluate seasonal changes to the hydraulic or groundwater quality conditions along the NM-reach of the Animas River.

In August 2015, in collaboration with other agencies including U.S. Geological Survey, NM Office of the State Engineer, and NM Environment Department, we measured groundwater level at over 100 locations along the Animas River. Building from this network of wells, with funding from the NM Environment Department, the NMBGMR developed a repeatable monitoring network in the Animas River valley utilizing private domestic wells. Twenty of these wells were selected for water chemistry sampling as part of our monitoring efforts. Samples were analyzed for cations, anions, trace metals and the stable isotopes of oxygen and hydrogen. We also compiled and evaluated water quality data from groundwater samples collected in August 2015 by the U.S. EPA.

Water chemistry sampling revealed groundwater with elevated levels of Fe, Mn, SO_4, and Al above recommended drinking water standards. From our January 2016 results, the highest observed total iron from a groundwater sample was 4.58 mg/L, which is above the secondary recommendation (0.3 mg/L), and total manganese at 6.4 mg/L, which is also above the health advisory level (1.6 mg/L). We compared results from the January 2016 water chemistry sampling with previous results from samples collected by US EPA in August 2015. Similar to our results, the US EPA samples had elevated levels of Fe, Mn, SO_4, and Al. Most samples collected in January 2016 exhibited higher total manganese and iron levels than those sampled in August 2015.

Maps of the water chemistry results show an increase in ion content and total dissolved solids in groundwater in a down river direction from the Colorado-state line to Farmington. Whereas, the elevated levels of iron and manganese appear to be more common in the Cedar Hill and Inca regions. Results from stable isotopes of hydrogen range from -95.9 to -104.1‰, and oxygen from -13.4 to -14.4‰. The very "light" ranges of these values suggest that groundwater in the Animas River valley is predominantly recharged by winter precipitation.

With long-term environmental, mine-related, and anthropogenic impacts to the water quality along the Animas River, it is not surprising to find groundwater with elevated constituents observed in these limited samples. Continued monitoring of groundwater quality, through consistent and repeated measurements, is the only way to accurately examine any affects to groundwater related to the Gold King Mine or other contaminant concerns over time.

Keywords:

groundwater

EVALUATION OF THE ACCUMULATION OF TRACE METALS (AS, U, CU, CR, PB, ZN) ON IRON-MANGANESE COATINGS ON IN SITU STREAM PEBBLES AND EMPLACED SUBSTRATES

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Exposure to trace metals (As, U, Cr, Cu, Pb, Zn) have potential negative health effects on human populations and wildlife that are exposed. Geothermal waters often have elevated concentrations of trace metals and understanding their geochemical cycling can be challenging. Previous studies have utilized in situ stream pebbles and glass or ceramic substrates to examine the association of trace metals with iron-manganese oxide coatings to understand contamination and chemical cycling. This project's main focus is to develop an extractive method using adsorption onto substrate surfaces in both natural and engineered environments and to characterize the phenomenon of adsorption/coprecipitation between trace metals and these surface coatings. Sampling locations include the Jemez River and Rio San Antonio in northern New Mexico, which have significant geothermal inputs from the Valles Caldera system. Factors such as leachate type, water pH, substrate type, coating accumulation period and leach time were all considered in this experiment. It was found that of the three leachates: aqua regia, 10% aqua regia and hydroxylamine at pH 2, hydroxylamine at pH 2 was the most effective at leaching coatings without dissolving substrates. Samples leached with aqua regia and 10% aqua regia were found to have had a significant weight gain post leaching and then weight and mass loss occurred over the following 5, 7, and 10 day measurements. Glass beads were determined to be more effective than in stream pebbles as accumulation data was more easily controlled and monitored. Substrate samples leached with hydroxylamine for 5, 24, 48 and 72 hour intervals showed little difference in their leachate concentrations, suggesting that leach time has little impact on the concentration of leachate samples. Adsorption rates of metals of copper, lead and zinc had similar values over 3, 5 and 7 week intervals in the Jemez system. Batch experiments to determine trace metal capacity on iron-manganese oxides are in progress. This research aims to find the best method for determining trace metal loading to aid in understanding geochemical cycling.

THE ROLE OF THE LATITE DIKES AT THE COPPER FLAT HYDROTHERMAL SYSTEM

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The Copper Flat Hydrothermal System is located in Hillsboro, New Mexico, USA is a copper porphyry system mostly hosted by a coarsely phaneritic quartz monzonite intrusive body. The mineralization itself is dominantly hosted within an enigmatic breccia. Although the breccia is dominated by quartz monzonite, locally fragments include clasts of rock having a latitic composition and strongly porphyritic texture. Additionally latite dikes are present, but generally not strongly mineralized in most of the system. Because of the low copper concentrations, the latite was not previously considered to be important in the genesis of the deposit. The role of the latite magma relative to brecciation and mineralization has not been considered in prior models of the genesis of the deposit. This is compounded by the fact that not all prior workers differentiated the latite intercepts from the breccia or quartz monzonite. In order to resolve what role the latite played in the formation of the breccia and mineralized system, drill core from the deposit was relogged with the goal to identify latite intercepts and carefully document contact effects due to the latite dikes, including variation in intensity of alteration and mineralization. Drill core relogging was supplemented by thin section petrographic analysis. Assays of the drill core proximal to and including the latite intercepts were examined for evidence of metal gradients away from the latite since any such relationship could imply that the latites brought in at least some of the mineralization in the system. Petrography of the latites sampled demonstrates a commonly present quenched texture that indicates that a fluid was exsolved. The exsolution of a fluid from the latite provides evidence to support a model where the latites produced fluid for alteration and mineralization, and may have been responsible for the generation of the breccia due to volume expansion. The assay review indicates an increase in mineralization near most of the latite contacts studied, also suggesting that the latites brought in mineralization. Based on the combination of observations made in this study, a new genetic model involving the latite dikes in the generation of the breccia body and associated mineralization should be considered.

Keywords:

Copper Flat, Economic Geology, Geochemistry, Thin Sections, Electron Microprobe

THE IMPORTANCE OF CAPTURING TOPOGRAPHIC VARIABILITY FOR MODELING FLOW AND TRANSPORT IN MOUNTAINOUS TERRAINS

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Complex distributed hydrologic models are widely used to understand flow and transport in watersheds and their effects on related physical and biogeochemical processes. These models typically discretize the watershed into elements for numerical simulation; however, this discretization is constrained by computational limitations, for example, the number of elements and their location. In this study, we investigate the effect that capturing key topographic features (e.g. rivers and ridges) has on the modeled flow and transport characteristics of a mountainous watershed. As a starting point, we use a simplified model that assumes steady state flow and a water table that is a subdued replica of the topography (i.e., Tóthian assumption). Then, we use different mesh resolutions, where the level of topography complexity is increased by capturing more stream channels and ridges. Modeled baseflow and residence time were used to quantify differences among complexity levels. Our results show that capturing the river network and ridges has a significant influence on simulated flow and transport patterns. For example, topographic complexity controls the proportion of baseflow generated from local, intermediate and regional flow paths. In particular, ignoring lower order streams diminishes flow through local flow systems and biases high the contribution of regional and intermediate flow paths. The proportion of baseflow from regional flow paths decreases with increasing topographic complexity. Similarly, this has an effect on residence time. The decrease of local flow, due to low topographic resolution, results in low-order streams with baseflow residence times biased high, affecting our ability to interpret environmental tracer data and predict bio- and geo-chemical evolution of water. Future work will relax the Tóthian assumption and include more realistic boundary conditions as well as geological features.

A NEW SPECIMEN OF *TRIISODON CRASSICUSPIS* (COPE, 1882) PROVIDES INSIGHT ON TRIISODONTID TAXONOMY AND PHYLOGENY

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Triisodontids are an archaic group of mammals that possess dental adaptations for carnivory, but are not members of the order Carnivora. They were probably apex mammalian predators for much of the early Paleocene. The wolf-sized species of *Triisodon* were the largest triisodontids and were also among the largest mammals of their time. A new specimen of the poorly known species *Triisodon crassicuspis* clarifies the diversity and evolutionary history of triisodontids and provides new morphological information that helps to untangle triisodontid interrelationships and aids in establishing the place of triisodontids on the mammalian tree of life.

Triisodon crassicuspis is one of the most poorly known mammal taxa named from the lower Paleocene Nacimiento Formation. The type specimen (AMNH 3178) consists of a lower jaw fragment with a partial m2-m3. Another species, *Triisodon rusticus* Cope, 1885, may be a synonym of *T. crassicuspis*, and is also poorly known, represented only by the holotype (AMNH 3225), a lower concreted jaw fragment with an m1-m2. Both specimens were collected by David Baldwin and lack precise provenance information. Some workers have suggested that *T. crassicuspis* should be transferred to the triisodontid genus *Goniacodon*. Williamson and Lucas (1997) described briefly some upper teeth (NMMNH P-19319) from the Chico Springs locale, a P3 and M1 that they referred to *G. crassicuspis*, and argued that the specimen possesses features that support its referral to *Goniacodon*. A new specimen of *T. crassicupsis* allows a reappraisal of this enigmatic taxon.

During the 2015 field season, a partial skull and skeleton (NMMNH P-72096) was recovered from basal Torrejonian age strata of the Nacimiento Formation in Kimbeto Wash. The specimen includes a nearly complete upper dentition (left C, P2-M3 and right C, P3, M1-3) a partial lower dentition (left c, p2, m3 and right c, partial m1, partial m2, m3) and fragments of the postcranial skeleton including a partial humerus, partial radius, and partial ulna.

The preserved lower molars are nearly identical to those of the type specimen of *Triisodon crassicuspis*. The upper teeth are essentially the same as *Triisodon quivirensis*, but about 20 percent smaller. NMMNH P-72096 thus clearly establishes that *T. crassicuspis* is a valid taxon that is referable to *Triisodon* rather than *Goniacodon*. It is also distinctly different from the Chico Springs taxon, which may represent a large species of *Goniacodon*. NMMNH P-72096 is similar in size and closely resembles the holotype specimens of *T. crassicuspis* and *G. rusticus* in preservation and possibly they also were collected from basal Torrejonian strata, which are not generally fossiliferous and poorly sampled.

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Keywords:

early Paleocene, Nacimiento Formation, Torrejonian, Torrejonian, Triisodontidae, triisodontid

THE EL CAJETE ERUPTION AND ITS SIGNIFICANCE TO VOLCANIC HAZARD ASSESSMENT IN NORTH-CENTRAL NEW MEXICO

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Several episodic pulses of volcanic and tectonic activities that climaxed in the Late Miocene make up the Jemez volcanic field in north-central New Mexico. The volcanic field is mostly confined to the shoulder and the adjacent western margin and to the western part of the floor of the Espanola Basin of the Rio Grande rift. The volcanic field, which represents various types of mafic to silicic flows, formed at the intersection of three tectonic features, consisting of the N-S-trending Rio Grande rift, the NE-SW-trending Jemez Lineament, and the Colorado Plateau.

At least five major pulses of volcanic activities that ranged in age from the late Oligocene (25.5 Ma) to the late Pleistocene (68.3 ka) are known within the Jemez volcanic field. Even though andesitic and basaltic rocks of late Miocene ages dominated the volcanic assemblage, it was a series of caldera-forming silicic eruptions that altered the current landscape during the late Pleistocene (≤1.8 Ma). With an estimated volume of 800-950 km^3 silicic pyroclastic products from the Valles-Toledo caldera complex, the Bandelier Tuff (1.2-1.6 Ma) is the dominant rock type within the volcanic field. More localized silicic lava and pyroclastic eruptions continued from domes confined to the Valles caldera ring fracture.

Most of the Valles caldera-bound pyroclastic and lava eruptions do not appear to pose volcanic hazard concerns in north-central New Mexico because they have been inactive for a long time. However, the latest volcanic activity from the southern moat of the Valles caldera is too young to be ignored. The youngest pyroclastic and lava eruptions belong to the East Fork Member, comprised of El Cajete Pyroclastic Beds, the Battleship Rock Ignimbrite, and the Banco Bonito lava that range in age from 74.7 to 68.3 ka. With an estimated eruptive volume of about 10 km^3, outcrops of the El Cajete Pyroclastic Beds were identified ≥30 miles to the southeast of the vent. More than a meter of bedded fallout deposits were identified in topographically protected areas within the northwestern part of the Cerros del Rio volcanic field east of the Rio Grande. Similar deposits, ranging in thicknesses from 0.7 m along a road cut on State Road 502 east of the Rio Grande and up to 2-m thick tephra beds were noted within the southern half of the Pajarito Plateau, including within the Los Alamos National Laboratory boundaries. The current distribution of the El Cajete Pyroclastic Beds provides a valuable conservative estimate for gauging potential impacts of the likelihood of similar-magnitude future tephra eruptions from the Valles caldera.

NEW MEXICO WEB MAPPING APPLICATION AT THE NM BUREAU OF GEOLOGY AND MINERAL RESOURCES: COAL AND GROUNDWATER QUALITY DATA

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A new database-driven web mapping application (the application), is in development using the ArcGIS Javascript API and flask microframework. Along with other geologic features, the application can now map groundwater quality locations and coal mine locations across New Mexico. The application helps effectively communicate diverse types of geologic information to the public through their web browsers and mobile devices. In addition, the application can also provide a deeper and more comprehensive understanding of the relationship between geologic features and water quality in wells across the state.

The New Mexico Bureau of Geology and Mineral Resources initiated an interactive web map in 2014 (maps.nmt.edu). With project funding related to protection of the state's source water from the New Mexico Environment Department, the application will now display groundwater quality data that have been compiled from multiple sources. Data sources include historical water quality reports, the U.S. Geological Survey, New Mexico Environment Department and New Mexico Bureau of Geology and Mineral Resources. Analytes to portray will include Uranium, Fluoride, Total Dissolved Solids, Specific Conductivity, Chloride, Sulfate, Arsenic, Calcium, Sodium, Magnesium and Bicarbonate.

Considering many potential impacts to sources of water for New Mexican communities, the application is designed to display the complexity of water and historical features from coal mine data. For example, each coal mine location can be related to diverse datasets including its production by year, photos and pdf files with more detailed information. The application not only conveys various types of geographic information by visualization, but strengthens the evaluation of potential impacts to water resources under different geologic regimes.

Keywords:

water, coal, ArcGIS Javascript, Web Mapping Application

MODELING OF SURFACE UPLIFT PATTERN DUE TO THERMAL EXPANSION ABOVE THE SOCORRO MAGMA BODY

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The Socorro Magma Body (SMB) is an ~130 m-thick partially molten sill at ~19 km depth below the central Rio Grande Rift. It is oval in shape, ~60 km in E-W width and ~80 km in N-S length. Numerous previous geodetic studies reveal that emplacement of the SMB causes surface uplift of up to ~3 mm/yr in a circular dome-like pattern centered on the northern ~2/3 of the SMB. Study of the SMB will provide insight regarding the mechanisms of deformation and emplacement of mid-crustal magma sills and potential related geo-hazards. We utilize the software ABAQUS© to model the process of magma sill emplacement in a two-dimensional elastic crust. Here we consider only thermal expansion of rocks (thermal expansion coefficient: $1\times10^{-5}K^{-1}$) around the SMB as the cause for surface uplift, in order to isolate the effects of thermal expansion from other processes, such as inflation. Tests with two other thermal expansion coefficients ($5\times10^{-6}K^{-1}$and $3\times10^{-5}K^{-1}$) indicate that the uplift amplitude is proportional to the thermal expansion coefficient. In the model heat is transmitted by conduction (thermal conductivity: 2.6 $Wm^{-1}K^{-1}$) only. Our simulation consists of two stages: the "heating phase," when elements representing the cross sectional area of the SMB are heated from ambient temperature (~510°C) to magmatic temperature (basaltic liquidus, ~1200°C) over 100 yr, and a "cooling phase" of 50,000 yr, while the sill conductively cools. During the "heating phase" the surface uplift can be up to 3.5 m with a nearly constant maximum surface uplift rate of ~30 mm/year, about an order of magnitude faster than current maximum uplift rates. The width of the uplifted surface area is ~twice the width of the sill itself (similar to previous models of inflation of penny-shaped cracks), whereas the diameter of the geodetically measured uplift is similar to the short, E-W dimension of the oval SMB. During the cooling phase the surface uplift rate decreases to values similar to those measured geodetically within a few years but surface uplift continues across the width of the uplifting domain during the entire 50,000 years.

The mismatch in both shape and dimension of the measured uplift relative to the SMB itself suggests that the heat source has a different plan-view shape than the seismically imaged SMB. If heat is supplied across the full E-W width of the SMB, then the times when the model surface uplift is smaller than or comparable to the seismically imaged width are late enough in cooling phase that the slow, outer edges of the uplift pattern fall below the limit of geodetic resolution. The width of the surface uplift shrinks to values similar to those geodetically measured within several years after heat input into the SMB ends. These results suggest that the SMB is in the cooling phase and is no longer actively inflating and increasing its heat content.

Keywords:

Socorro Magma Body, Thermal Expansion of Crust

PRELIMINARY HYDROGEOLOGIC DATA FROM EASTERN MORA COUNTY

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In 2015, the Mora-Wagon Mound Soil and Water Conservation District launched a hydrogeology project designed to partner with the ongoing Union County Hydrogeology Project. These two projects together are aimed at developing a better understanding of regional groundwater relationships in northeastern New Mexico. The Mora-Wagon Mound SWCD covers approximately the eastern two-thirds of Mora County, from the front range of the Sangre de Cristo Mountains to the Canadian River valley. Preliminary data were collected during 2015 and include biannual static water level measurements from 25 wells, basic water chemistry from eight wells, radiocarbon dates from 10 wells and geologic mapping along the I-25 corridor.

Initial water level measurements indicate the presence of three discrete groundwater horizons: a shallow zone at 10-40' below land surface (bls), an intermediate zone 150-300' bls and a deep zone greater than 350' bls. The intermediate zone primarily corresponds to the Cretaceous Dakota Group. After an unusually wet summer, hydrographs for a subset of the wells appear to document recharge into the shallow groundwater horizon.

In order to assess subsurface geologic complexity, five petroleum well geophysical logs from the central part of the SWCD area were examined. Tentative correlation of rock units among these logs suggest the subsurface geology is fairly complex, with structural relief and/or paleotopography developed on the top of the Jurassic Morrison Formation near the village of Wagon Mound. This complexity is also supported by the distribution of radiocarbon dates across the project area and wells that appear to document summer recharge. Preliminary geologic mapping documents extensive fracturing of exposed bedrock of the Dakota Group, yielding information on potential flowpaths for groundwater in areas where the Dakota Group is the primary aquifer in the subsurface.

Earlier work by the New Mexico Environment Department hypothesized that recharge to the Wagon Mound springs, west of the village, is provided by melting snowpack from the Turkey Mountains to the south. The orientation of fractures documented during mapping is dominantly north-south to northwest-southeast, whereas the hinge of the Turkey Mountain anticline (located near the center of the project area) is oriented northeast-southwest. This contrast between a local structural feature and the local fracture patterns raises questions regarding the relationship between Turkey Mountain snowpack and local spring recharge.

VOLCANIC HAZARDS AT THE SOUTHWEST'S SUPERVOLCANO: ONGOING EFFORTS TO TEMPORALLY DISSECT THE ERUPTIVE AND MAGMATIC HISTORY OF THE VALLES CALDERA

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Ar/Ar and U/Th ages of the ring-fracture domes at Valles caldera provides critical information to assess the eruption frequency and related hazards. Although large-volume caldera-forming eruptions are impressive and worthy of investigation, the most likely events at most Quaternary caldera systems, including Valles, are the smaller-volume higher-frequency eruptions that characterize postcaldera volcanism. Geologic mapping, petrology, and geochemistry indicates that following the 1.264 Ma caldera-forming eruption of the Upper Bandelier Tuff as many as 38 lava flows and tuffs erupted from vents on or adjacent to the resurgent dome and along the ring-fracture zone. The limited number of ages for the postcaldera lava flows has lead to a generalized eruptive history and for many of the ring-fracture domes only a single age has been determined. Initial efforts to characterize the eruptive history at Valles caldera have focused on the youngest eruptions, specifically the East Fork Member (i.e., Banco Bonito lava, Battleship Rock ignimbrite, and El Cajete pyroclastic beds), La Jara dome, and South Mountain lavas. Dating of sanidine with and without melt inclusions from La Jara and South Mountain domes illustrates the effects of excess Ar in melt inclusions. Dating of single-crystals without inclusions yields eruptive ages of 533.3 ± 1.2 ka and 533.3 ± 1.3 ka for La Jara dome and the oldest flow exposed at South Mountain, respectively. Detailed geochemistry of the phenocrysts and melt inclusions for these two units will be necessary to assess whether they are coeval or are from two different eruptions with a short repose period. The new Ar/Ar ages for South Mountain, together with previously published ages, suggest that the duration of dome construction was at least ~ 30 ka. Ar/Ar dating of sanidine with melt inclusions from the La Jara and South Mountain lavas yields erroneous eruptions ages of 534.1 ± 1.2 and 539 ± 2 ka, respectively, along with a scattered distribution of older ages. These inaccurate ages are interpreted to reflect excess Ar in melt inclusions. Single-crystal sanidine ages indicate that the Battleship Rock ignimbrite and co-erupted El Cajete pyroclastic beds erupted at 74.4 ± 1.3 ka. The Banco Bonito lava, the youngest eruption at Valles, erupted at 68.3 ± 1.5 ka. Both of these units contain a significant population of xenocrysts (up to 100% of the dated grains) or grains with excess Ar. U/Th SIMS dating of zircon in the East Fork Member yields ages ranging from the eruption age to > 350 ka (i.e., secular equilibrium) indicating that the ~ 450 ka hiatus between the South Mountain and East Fork Member eruptions was not accompanied by magmatic dormancy. Instead, the youngest series of eruptions at Valles caldera were erupted from a magma body with a protracted history, remnants of which may constitute the imaged shallow crustal magma body. Future work will focus on generating high-precision Ar/Ar ages for all the postcaldera units, U/Pb ages for each dome complex, and detailed geochemistry.