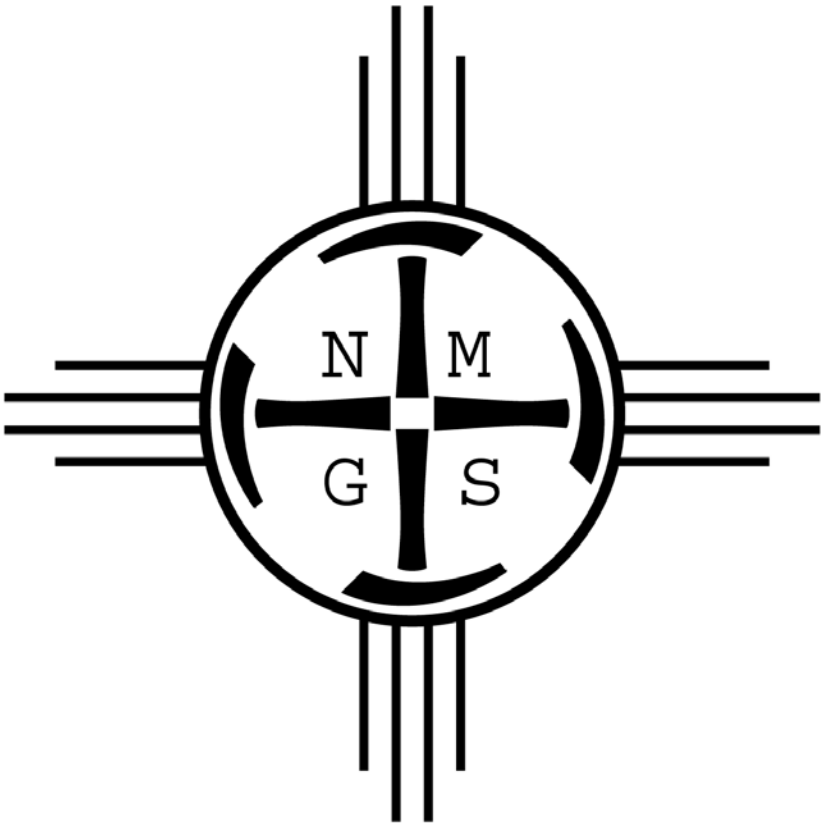
New Mexico Geological Society



Proceedings Volume

2015 Annual Spring Meeting

Macey Center

New Mexico Tech

Socorro, NM

NEW MEXICO GEOLOGICAL SOCIETY

2015 SPRING MEETING

Friday, April 24, 2015
Macey Center
NM Tech Campus
Socorro, New Mexico 87801

NMGS EXECUTIVE COMMITTEE

President:	Mary Dowse
Vice President:	David Ennis
Treasurer:	Matthew Heizler
Secretary:	Susan Lucas Kamat
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2015 SPRING MEETING COMMITTEE

General Chair:	Matthew Heizler
Technical Program Chair:	Peter Fawcett
Registration Chair:	Connie Apache

ON-SITE REGISTRATION

Connie Apache

WEB SUPPORT

Adam Read

ORAL SESSION CHAIRS

Peter Fawcett, Matt Zimmerer, Lewis Land, Spencer Lucas, Matt Heizler

Session 1: Theme Session - Paleoclimate: Is the Past the Key to the Future?

Auditorium: *8:45 AM - 10:45 AM*
Chair: Peter Fawcett

GLOBAL ICE AGES, REGIONAL TECTONISM AND LATE PALEOZOIC SEDIMENTATION IN NEW MEXICO
— Spencer G. Lucas and Karl Krainer
8:45 AM - 9:00 AM

URANIUM ISOTOPE EVIDENCE FOR PERVASIVE MARINE ANOXIA DURING THE LATE ORDOVICIAN MASS EXTINCTION.
— Rickey W Bartlett, Maya Elrick, Yemane Asmerom, Viorel Atudorei, and Victor Polyak
9:00 AM - 9:15 AM

FAUNAL AND FLORAL DYNAMICS DURING THE EARLY PALEOCENE: THE RECORD FROM THE SAN JUAN BASIN, NEW MEXICO
— Thomas E. Williamson, Daniel J Peppe, Ross Secord, Matthew T. Heizler, Stephen L. Brusatte, Sarah Shelley, and Sarah Shelley
9:15 AM - 9:30 AM

BOUQUETS FROM THE PAST: PLANT BIOMINERALS AS PALEOCLIMATE INDICATORS
— K. Daisy Morgan Edel, Penelope J. Boston, and Michael N. Spilde
9:30 AM - 9:45 AM

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

MIOCENE AND MODERN CLIMATE IN THE CALIFORNIA SIERRA NEVADA AND IMPLICATIONS FOR STABLE ISOTOPE-BASED PALEOALTIMETRY
— Lauren Wheeler, Joseph Galewsky, Matthew Huber, and Nicholas Herold
10:15 AM - 10:30 AM

COUPLED WARMING AND ARIDITY IN NEW MEXICO DURING MID-PLEISTOCENE INTERGLACIALS AND MILLENNIAL SCALE CLIMATE VARIABILITY DURING GLACIALS: THE VALLES CALDERA RECORD
— Peter J Fawcett, Joseph P Werne, Scott Anderson, Erik T Brown, Jeffrey M Heikoop, Justin P Dodd, and Zachary D Sharp
10:30 AM - 10:45 AM

Session 2: Volcanology and Proterozoic Tectonics:

Galena Room: *8:45 AM - 10:45 AM*
Chair: Matthew Zimmerer

U-PB GEOCHRONOLOGY OF ASH FALL TUFFS IN THE MCRAE FORMATION (UPPER CRETACEOUS), SOUTH-CENTRAL NEW MEXICO
— Greg Mack, Jeffrey M. Amato, and Garland R. Upchurch
8:45 AM - 9:00 AM

TIMING, GEOCHEMISTRY, AND DISTRIBUTION OF MAGMATISM IN THE RIO GRANDE RIFT
— Rediet Abera, Brad Sion, Jolante van Wijk, Gary Axen, Dan Koning, Richard Chamberlin, Evan Gragg, Kyle Murray, and Jeff Dobbins
9:00 AM - 9:15 AM

N-S EXTENSION AND BIMODAL MAGMATISM DURING EARLY RIO GRANDE RIFTING: INSIGHTS FROM E-W STRIKING DIKES AT FAULKNER CANYON, SOUTH CENTRAL NEW MEXICO
— Cory Christian Paliewicz
9:15 AM - 9:30 AM

VENT MIGRATION PATTERNS OF LATE QUATERNARY BASALTIC VOLCANISM WITHIN THE RIO GRANDE RIFT AND ALONG THE JEMEZ LINEAMENT
— Matthew J. Zimmerer
9:30 AM - 9:45 AM

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

REVISED LOCATION FOR THE YAVAPAI-MAZATZAL CRUSTAL PROVINCE BOUNDARY IN NEW MEXICO: HF ISOTOPIC DATA FROM PROTEROZOIC ROCKS OF THE NACIMIENTO MOUNTAINS
— Tyler A Grambling, Mark E Holland, Karl E Karlstrom, George E Gehrels, and Mark Pecha
10:15 AM - 10:30 AM

U-PB GEOCHRONOLOGY AND TECTONIC SIGNIFICANCE OF ARC-RELATED PROTEROZOIC ROCKS IN SOUTHERN NEW MEXICO
— Chelsea F Ottenfeld and Jeff M Amato
10:30 AM - 10:45 AM

Session 3: Keynote Talk and Awards Ceremony:
Auditorium: *10:45 AM - 11:45 AM*
Chair: Mary Dowse and Peter Fawcett

PALEODROUGHTS: ANALOGUES FOR THE FUTURE?
Connie Woodhouse
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: Rio Grande Rift - Geophysics, Rivers and Sedimentation:

Auditorium: *1:15 PM - 3:00 PM*
Chair: Matthew Heizler

THE ACTIVE RIO GRANDE RIFT: SUMMARIZING OUR CURRENT UNDERSTANDING OF PRESENT-DAY DEFORMATION FROM GEODETIC AND STRESS MEASUREMENTS
— Kyle Dennis Murray, Jeff Dobbins, Mark Murray, Jolante van Wijk, and Gary Axen
1:15 PM - 1:30 PM

CHANGES IN RIO GRANDE RIFT TECTONISM AS INFERRED FROM SUBSIDENCE CURVES
— Evan Gragg, Dan Koning, Jolante van Wijk, Gary Axen, Brad Sion, Rediet Abera, Kyle Murray, Jeff Dobbins, Mark Murray, and Richard Chamberlin
1:30 PM - 1:45 PM

CONFIGURATION AND CORRELATION OF FLUVIAL TERRACE DEPOSITS IN THE LOWER RIO SALADO VALLEY
— Bradley D Sion, Gary J Axen, Fred M Phillips, and Bruce Harrison
1:45 PM - 2:00 PM

LATE HOLOCENE ALLUVIATION IN THE PALOMAS BASIN, SOUTH-CENTRAL NEW MEXICO
— Andy Jochems, Daniel Koning, Curtis Monger, and Dave Love
2:00 PM - 2:15 PM

Session 5: Sedimentology / Stratigraphy:

Galena Room: *1:15 PM - 2:15 PM*
Chair: Lewis Land

DEPOSITIONAL SETTING AND SEQUENCE STRATIGRAPHIC FRAMEWORK OF THE LOWER PERMIAN (WOLFCAMPIAN) HUECO FORMATION (UPPER-MIDDLE AND GASTROPOD MEMBERS). ROBLEDO SHELF, WESTERN OROGRANDE BASIN, NEW MEXICO
— Matthew Harder, Katherine Giles, and Gregory Mack
1:15 PM - 1:30 PM

A PRECISE NEW AGE FOR THE C33N/C32R PALEOMAGNETIC REVERSAL AS DETERMINED IN THE SOUTHERN SAN JUAN BASIN, NEW MEXICO
— James E. Fassett and Matthew T. Heizler
1:30 PM - 1:45 PM

GEOCHEMICAL EXPLORATION FOR OIL AND GAS IN THE ROCKIES: STRATEGIES FOR SUCCESS
— Dietmar (Deet) Schumacher
1:45 PM - 2:00 PM

ROLLALONG RESISTIVITY SURVEYS REVEAL KARSTIC PALEOTOPOGRAPHY DEVELOPED ON NEAR-SURFACE GYPSUM BEDROCK: LAKEWOOD, NEW MEXICO
— Lewis Land and Lasha Asanidze
2:00 PM - 2:15 PM

Session 4: Rio Grande Rift - Geophysics, Rivers and Sedimentation
Continued

REASSESSMENT OF FEATURES IN THE ADEN CRATER LAVA FLOWS, DONA ANA CO., NEW MEXICO
— René De Hon and Richard Earl
2:15 PM - 2:30 PM

RELATING CA. 5 MA COARSE SEDIMENTATION IN THE RIO GRANDE RIFT TO TECTONICS, CLIMATE, AND INTER-BASIN FLUVIAL SPILLOVER OF THE ANCESTRAL RIO GRANDE
— Daniel J. Koning, Scott B. Aby, Andy Jochems, Richard Chamberlin, Virgil Lueth, and Lisa Peters
2:30 PM - 2:45 PM

BIRTH AND EVOLUTION OF THE RIO GRANDE FLUVIAL SYSTEM: NEW INSIGHTS FROM RIVER GRAVEL PROVENANCE STUDIES AND ^{40}AR/^{39}AR DATED PALEOPROFILES
— Marisa Nicole Repasch, Karl Karlstrom, and Matt Heizler
2:45 PM - 3:00 PM

Session 6: Paleontology

Galena Room: *2:15 PM - 3:30 PM*
Chair: Spencer Lucas

FOSSIL TURTLES OF THE CRETACEOUS MENEFEE FORMATION, NORTHERN NEW MEXICO
— Asher Jacob Lichtig and Spencer G Lucas
2:15 PM - 2:30 PM

ANALYSIS OF MORPHOLOGICAL DIFFERENCES BETWEEN TWO EARLY EOCENE HORSES: *MINIPPUS JICARILLAI* OF NEW MEXICO AND *SIFRHIPPUS SANDRAE* OF WYOMING
— Julie E Rej and Spencer G Lucas
2:30 PM - 2:45 PM

NEW MEXICO'S PALEOCLIMATE AND ITS AFFECT ON PLESIADAPIFORM BIOGEOGRAPHIC DISPERSAL – A STUDY OF FOSSIL GEOGRAPHIC RANGE COMPARED WITH ESTIMATED BODY MASS FOR THESE STEM PRIMATES
— Clayton Dean Pilbro
2:45 PM - 3:00 PM

ARTHROPOD BIODIVERSITY HIGHER THAN FORMERLY THOUGHT AT THE LATE PENNSYLVANIAN (MIDDLE MISSOURIAN: KASIMOVIAN) KINNEY BRICK QUARRY LAGERSTATTE, CENTRAL NM, USA
— Amanda Kaye Cantrell, Thomas Lee Suazo, Spencer G Lucas, and Jörg Schneider
3:00 PM - 3:15 PM

PRELIMINARY DESCRIPTION OF AN IANTHASAURUS-LIKE EDAPHOSAURID FROM THE LOWER PERMIAN BURSUM FORMATION, OTERO COUNTY, NEW MEXICO
— Thomas Lee Suazo, Amanda Kaye Cantrell, and Spencer G Lucas
3:15 PM - 3:30 PM

Session 7: Posters
Mezzanine: *8:30 AM - 5:00 PM*

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

THE NOTABLE NEW MEXICO GEOLOGISTS (ONLINE) PROJECT
— Abbey Chesebrough, Makala Hannagan, Magella Honeyfield, NancyElma Dale Proctor, Emily McClenahan, and Steve W Simpson
Booth: *1*

GROUNDWATER LEVEL VARIATIONS OVER THE PAST 60 YEARS IN THE SUNSHINE VALLEY, TAOS COUNTY, NEW MEXICO
— Tony Benson and Ron Gervason
Booth: *2*

HIGH-RESOLUTION STATEWIDE MODELING OF GROUNDWATER RECHARGE IN NEW MEXICO
— David G. Ketchum, Talon Newton, and Fred Phillips
Booth: *3*

PALEO-HYDROLOGIC RECONSTRUCTION OF THE JORNADA BASIN, NEW MEXICO USING U AND SR ISOTOPES IN PEDOGENIC CARBONATES
— Syprose Nyachoti, Lin Ma, Thomas E Gill, and Curtis Monger
Booth: *4*

QUANTIFYING THE EFFECT OF THINNING VEGETATION ON EVAPOTRANSPIRATION IN A MOUNTAINOUS WATERSHED THROUGH REMOTE SENSING
— Peter M ReVelle, Jan M. H. Hendrickx, and B. Talon Newton
Booth: *5*

PRELIMINARY INTERPRETATION OF WATER CHEMISTRY AND GROUNDWATER LEVELS IN THE EASTERN SAN AGUSTIN PLAINS AND UPPER ALAMOSA CREEK, N.M.
— Alex Rinehart, Ethan Mamer, Stacy Timmons, and Daniel Koning
Booth: *6*

URANIUM SPECIFIC FILTERS FOR REMOVAL FROM GROUNDWATER AND DRINKING WATER
— Samantha Saville
Booth: *7*

APPLICATION OF HYDROGEOSPHERE TO MODEL THREE-DIMENSIONAL HYDROLOGICAL PROCESSES IN THE VALLES CALDERA WATERSHED, NEW MEXICO: PRELIMINARY RESULTS
— Michael Louis Wine and Daniel Cadol
Booth: *8*

GEOCHEMISTRY OF AQUIFER RECHARGE PROJECTS IN NEW MEXICO
— Christopher Wolf, Bob Marley, and Amy Ewing
Booth: *9*

THE TRANSITION TO WETTER LATE HOLOCENE CLIMATE IN SOUTHWESTERN NORTH AMERICA FROM SPELEOTHEM DATA
— Chrissy Allen, Yemane Asmerom, Victor Polyak, and Matthew Lachniet
Booth: *10*

PALEOMONSOONAL PRECIPITATION AND HYDROCLIMATE VARIABILITY FROM GLACIAL TO INTERGLACIAL CLIMATES IN THE SOUTHWEST: THE STONEMAN LAKE, ARIZONA RECORD
— Dylan J Garcia, Peter J Fawcett, and R Scott Anderson
Booth: *11*

DEFINING THE RESPONSE OF SOUTHWESTERN NORTH AMERICAN CLIMATE TO ABRUPT NORTHERN HEMISPHERE CLIMATE CHANGE EVENTS DURING THE LAST GLACIAL PERIOD
— Justin Grant Peinado, Yemane Asmerom, Victor Polyak, and Matt Lachniet
Booth: *12*

RECENT IMPROVEMENTS IN REGIONAL STRATIGRAPHY OF PENNSYLVANIAN STRATA PROMISES BETTER CHARACTERIZATION OF THE GEOLOGY AND GEOLOGIC HISTORY OF THE EAST SIDE OF THE SANDIA UPLIFT (EAST MOUNTAINS AREA), CENTRAL NEW MEXICO
— Bruce D. Allen, Spencer G. Lucas, and Karl Krainer
Booth: *13*

SEDIMENT ANALYSIS FROM CERRO MEDIO DRAINAGE, JEMEZ MOUNTAINS, NM: ASSESSING CAUSES OF COLOR CHANGES IN THE VERTICAL PROFILE
— Angelica K Gallegos and Jennifer Lindline
Booth: *14*

COLLECTION AND ANALYSIS OF DUST AND SOIL SAMPLES ADJACENT TO THE JACKPILE MINE, LAGUNA PUEBLO, NEW MEXICO
— Susan F.B. Little, Daniel Cadol, and Bonnie Frey
Booth: *15*

EXPLORING SODA DAM TRAVERTINE MINERALOGY THROUGH X-RAY DIFFRACTION FOR A BETTER INSIGHT INTO PALEOHYDROLOGY, PALEOCLIMATOLGY AND GEOTHERMAL HISTORY
— Graham King Thomas, Eric Peterson, Laura J Crossey, Karl Karlstrom, and April Jean
Booth: *16*

U/TH AND ^{40}AR/^{39}AR DATING PROVIDES ERUPTION AGES AND MAGMATIC EVOLUTION FOR THE EAST FORK MEMBER OF THE VALLES RHYOLITE
— John N. Lafferty and Matthew J. Zimmerer
Booth: *17*

TIMING AND EMPLACEMENT SETTING OF THE TURKEY MOUNTAIN LACCOLITH, MORA COUNTY, NEW MEXICO
— Ryan Mann, Jennifer Lindline, Matthew Heizler, and Lynn Heizler
Booth: *18*

AGE OF CARVING OF THE WESTERNMOST GRAND CANYON: CONFLICTS AND POTENTIAL RESOLUTIONS THAT RECONCILE GEOLOGIC AND THERMOCHRONOLOGIC DATA
— Carmen Winn, Karl Karlstrom, Shari Kelley, David Shuster, and Matt Fox
Booth: *19*

USING MULTIPLE TRACERS TO EVALUATE HYDROTHERMAL AND METEORIC WATER MIXING IN NORTH-CENTRAL NEW MEXICO
— Valerie J Blomgren, Laura J Crossey, Karl E Karlstrom, Paul Bauer, Peggy Johnson, Tobias Fischer, and Marisa Repasch
Booth: *20*

GEOCHEMISTRY OF WHITE ROCK CANYON SPRINGS, NORTHERN NEW MEXICO
— Tanner K Grulke, Laura J Crossey, Karl E Karlstrom, and Valerie Blomgren
Booth: *21*

THE SUSTAINABILITY AND MANAGEMENT OF THE TRUTH OR CONSEQUENCES, NEW MEXICO GEOTHERMAL RESOURCE
— Jeff D. Pepin, Mark A. Person, Shari A. Kelley, Stacy S. Timmons, and Fred M. Phillips
Booth: *22*

HYDROGEOLOGIC WINDOWS: DETECTION OF BLIND AND TRADITIONAL GEOTHERMAL PLAY FAIRWAYS IN SOUTHWESTERN NEW MEXICO
— James Witcher, Mark Person, Shari Kelley, Richard Kelley, Jeffrey Bielicki, Glenn Sutula, and Richard Middleton
Booth: *23*

STRUCTURAL ANALYSIS OF SPECTACULAR EOCENE SOFT-SEDIMENT DEFORMATION IN THE SAWTOOTH MOUNTAINS, WESTERN NEW MEXICO
— Jeffrey Dobbins, Gary Axen, Steven Cather, and Peter Mozley
Booth: *24*

PRELIMINARY ANALYSIS OF THE GEOLOGIC STRUCTURE OF THE EASTERN SAN AGUSTIN PLAINS, N.M.
— Daniel J. Koning and Alex Rinehart
Booth: *25*

STRUCTURAL-DEPOSITIONAL FEEDBACKS IN A FEATURE-CHALLENGED LANDSCAPE: THE BLACK BUTTE 7.5-MINUTE QUADRANGLE
— Alex Rinehart, David W. Love, and Phil L Miller
Booth: *26*

A PROLIFIC NEW VERTEBRATE COPROLITE LOCALITY FROM THE PENNSYLVANIAN OF CENTRAL NEW MEXICO AND AN ECOLOGICAL TRANSECT OF MISSOURIAN BROMALITE ICHNOFAUNAS
— Adrian P. Hunt and Spencer G. Lucas
Booth: *27*

THE TURTLE ADOCUS FROM THE UPPER CRETACEOUS CREVASSE CANYON FORMATION, SIERRA COUNTY, NEW MEXICO
— Asher Jacob Lichtig, Thomas L. Suazo, Amanda K. Cantrell, and Spencer G. Lucas
Booth: *28*

THE TRACE FOSSIL *ASTHENOPODICHNIUM* FROM THE UPPER CRETACEOUS OF NORTHWESTERN NEW MEXICO
— Spencer G. Lucas, Robert M. Sullivan, Robert F. Robinson, Michael Foley, Amanda K. Cantrell, and Thomas L. Suazo
Booth: *29*

THE UPPER PALEOZOIC SANGRE DE CRISTO FORMATION, SOUTHWESTERN SAN MIGUEL COUNTY, NEW MEXICO: STRATIGRAPHY, AGE AND SEDIMENTOLOGY
— Spencer G. Lucas, Karl Krainer, William A. DiMichele, Sebastian Voigt, David Berman, Amy C. Henrici, Lawrence H. Tanner, Dan S. Chaney, Scott D. Elrick, W. John Nelson, and Larry F. Rinehart
Booth: *30*

DIVERSE, SELACHIAN-DOMINATED FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS TOCITO SANDSTONE, SANDOVAL COUNTY, NEW MEXICO
— Randy Pence, Spencer G. Lucas, Paul L. Sealey, Amanda K. Cantrell, and Thomas L. Suazo
Booth: *31*

NEW STRATIGRAPHY AND VERTEBRATE PALEONTOLOGY FROM PALEOLAKE OTERO, WHITE SANDS MISSILE RANGE
— David Rachal, Kate Zeigler, John Taylor-Montoya, Christopher Goodwin, Charlotte Pevny, Peter Reser, and Stanley Berryman
Booth: *32*

FIRST KNOWN OCCURRENCE OF THE AMMONOID *PARAPUZOSIA* (*AUSTINICERAS*) IN THE CENOMANIAN OF NORTH AMERICA
— Paul L. Sealey and Spencer G. Lucas
Booth: *33*

TIMING, GEOCHEMISTRY, AND DISTRIBUTION OF MAGMATISM IN THE RIO GRANDE RIFT

Rediet Abera[1], Brad Sion, Jolante van Wijk, Gary Axen, Dan Koning, Richard Chamberlin, Evan Gragg, Kyle Murray and Jeff Dobbins

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We have updated previous analyses of the timing, geochemistry and distribution of magmatism within the Rio Grande rift with datasets that have become available in the last decade, and compare the results with new tomographic images and tectonism. It is well understood that two major pulses of magmatism occurred in and around the Rio Grande rift: an early stage following Laramide subduction of the Farallon plate, and a later stage related to extension of the Basin and Range. These pulses can be distinguished using major element, trace element and isotopic compositions of igneous rocks.

Our new analysis supports earlier work showing that the well-documented shift from intermediate-rhyolitic compositions in the Oligocene to predominantly basalt, with minor intermediate and rhyolitic magmas, in the middle Miocene, records the transition from a lithospheric melt source to a predominantly asthenosphere-derived source. This is supported by a shift in K2O/NaO2 ratios that indicate a transition from relatively evolved magmas in the Oligocene to more juvenile magmas from Pliocene to Holocene. The concentration of magmatism along the Jemez lineament in New Mexico during the middle Miocene to Pleistocene is apparent. The Jemez Lineament is underlain by low seismic wave velocity upper mantle and we suggest that it results from shear-driven upwelling and decompression melting in small-scale convection cells that formed along the Colorado Plateau keel as the keel became more pronounced in the early Miocene. The Jemez Lineament extents into the Great Plains (Ocate and Clayton volcanic fields), and also this can be explained with the shear-driven small scale convection model.

We find that, contrary to previous interpretations based on fewer data or on inclusion of basaltic andesite with basalt, a truly bimodal distribution of dominantly basaltic and rhyolite volcanic rocks is observed only in Pleistocene volcanic rocks of the Jemez field. Rhyolites were erupted as ignimbrites at 1.6 and 1.2 Ma and domes from ~1.6 Ma to ~40 ka from the Valles caldera.
The lack of spatial correlation between volcanic centers and the rift itself throughout much of the rift history is intriguing. Volcanism occurs within and westward of the rift, and is largely absent east of the rift. The Rio Grande rift beneath westernmost Texas-southcentral New Mexico and Mexico has been devoid of any magmatic activity since the Oligocene. This region is underlain by fast seismic wave velocities in the upper mantle, and may reflect colder or compositionally different remnants resulting from Farallon subduction that have inhibited partial melting.

RECENT IMPROVEMENTS IN REGIONAL STRATIGRAPHY OF PENNSYLVANIAN STRATA PROMISES BETTER CHARACTERIZATION OF THE GEOLOGY AND GEOLOGIC HISTORY OF THE EAST SIDE OF THE SANDIA UPLIFT (EAST MOUNTAINS AREA), CENTRAL NEW MEXICO

Bruce D. Allen[1], Spencer G. Lucas[2] and Karl Krainer[3]

[1]New Mexico Bureau of Geology and Mineral Resources, NM Tech, 801 Leroy Place, Socorro, NM, 87801, allenb@nmbg.nmt.edu
[2]New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM, 87104
[3]Institute of Geology and Paleontology, University of Innsbruck, Innrain 52, Innsbruck, A-6020, Austria

The geology in areas underlain by Middle to Upper Pennsylvanian sedimentary rocks along the eastern sides of the Sandia and northern Manzano (Manzanita) Mountains has been depicted in contemporary geologic maps using an informal and very loosely applied stratigraphic nomenclature that has seen little change since the mid-20th century. For instance, recent STATEMAP efforts in the Sandia Mountains have tended to treat the marine to marginal-marine Pennsylvanian section as consisting of a relatively thin basal sequence of siliciclastic-dominated deposits (Sandia Formation), and a considerably thicker, overlying succession of undifferentiated limestone and silciclastic deposits (Madera Formation or Group). In recent years the stratigraphy of correlative strata elsewhere in New Mexico has been subjected to intensive study on a regional scale, and a reference section for rocks of Pennsylvanian age has been established nearby in the Manzanita Mountains near Tijeras, New Mexico at Cedro Peak (see Lucas et al., 2014: New Mexico Geology, v. 36, no.1). We have recently begun work to characterize the stratigraphy of Pennsylvanian strata 14 km to the north of Cedro Peak, in the Sandia Mountains, with initial results indicating that the formation-rank, and in most cases the member-level nomenclature that has been established to the south is readily applied to these rocks. Thus, the Sandia, Gray Mesa, Atrasado, and Bursum formation lithostratigraphic units of the "new" nomenclature may now be applied in the Sandia uplift. Geologic mapping of a small area (~4 km^2) along Highway 536 (Sandia Crest road) conducted during visits last year show that this nomenclature is amenable to 1:24,000 scale mapping, and that significant improvements in the interpretation and depiction of geologic structures in the East Mountains should be possible through an awareness and willingness to apply the results of recent stratigraphic studies of the Pennsylvanian System in New Mexico. Work is underway to provide a detailed characterization of the stratigraphy of these rocks in the Sandia Mountains including lithostratigraphy, biostratigraphy (age), and associated interpretations (e.g., inferences regarding tectonic vs. glacioeustatic controls over mid- to late-Pennsylvanian deposition in the region).

THE TRANSITION TO WETTER LATE HOLOCENE CLIMATE IN SOUTHWESTERN NORTH AMERICA FROM SPELEOTHEM DATA

Chrissy Allen[1], Yemane Asmerom[1], Victor Polyak[1] and Matthew Lachniet[2]

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[2]University of Nevada, Las Vegas

Semi-arid, moisture-limited regions such as southwestern North America are particularly susceptible to drought effects due to variations in climate. A shift from a warm and dry Middle Holocene to cooler and wetter Late Holocene that correlates with a shift in intensity of solar insolation has been documented globally (Renssen, 2012), but the timing, character, and resolution of climate shifts such as in effective moisture in southwestern North America over the last 7000 years have not been well established. Thus it is necessary to construct a high-resolution continuous record that encapsulates these climate transitions to better understand the mechanisms that drive them. Such a record is necessary to be able to model and predict the effects of future climate variability in this region. In order to determine possible underlying causes for this these transitions a high-resolution speleothem climate record will be used in conjunction with previously published data. Speleothems are excellent repositories of climate. This study uses multiple stalagmites from multiple caves in the Guadalupe Mountains. Stable isotope time-series from these stalagmites will be combined to construct a 7000-year continuous high-resolution record from which climate variability and important climatic transitions will be identified and analyzed.

References:

Polyak, V., J., and Asmerom, Y., 2001, Late Holocene climate and cultural changes in the Southwestern United States: Science, v. 294, p. 148.

Renssen, H., Seppa, H., Crosta, X., Goosse, H. and Roche, D.M., 2012, Global characterization of the Holocene Thermal Maximum: Quaternary Science Reviews, v. 48, p. 7-19.

Keywords:

Holocene climate, speleothem

URANIUM ISOTOPE EVIDENCE FOR PERVASIVE MARINE ANOXIA DURING THE LATE ORDOVICIAN MASS EXTINCTION.

Rickey W Bartlett[1], Maya Elrick[1], Yemane Asmerom[1], Viorel Atudorei[1] and Victor Polyak[1]

[1]University of New Mexico, MSC 03 2040, Albuquerque, NM, 87131

The Ordovician witnessed an explosion in marine biodiversity followed by the first of the 'big-five' Phanerozoic mass extinctions, the Late Ordovician mass extinction (LOME). The LOME consists of two discrete faunal turnovers; the first coincident with the onset of Hirnantian glaciation and the second with end-Hirnantian deglaciation. Lithologic and geochemical evidence suggests widespread marine anoxia triggered the second faunal turnover; however, these redox proxies only speak to the bottom water or porewater conditions present at the site of deposition. Uranium isotopic ratios preserved in marine carbonates record global seawater conditions due to the fact that the ocean residence time for uranium (~500 ky) is significantly longer than ocean mixing times. Bulk carbonate samples from the Upper Ordovician of Anticosti Island, Canada were analyzed to evaluate global marine redox patterns across the LOME. The Anticosti section was chosen because of its well-studied sequence and biostratigraphy and the fact that it has not been subjected to deep burial or tectonic processes. Isotopic analysis of bulk carbonates record relatively uniform values of ~0.1 per mil across the Katian-Hirnantian boundary and into the mid-Hirnantian. The values then exhibit an abrupt negative shift to ~-0.4 per mil in the Late-Hirnantian, followed by a return to values of ~0.1 per mil in the early Rhuddanian. This negative shift is roughly coincident with the second faunal turnover and is similar in magnitude to the shift reported across the end-Permian extinction. These results support earlier interpretations of widespread marine anoxia associated with the second faunal turnover; however they are at odds with recent interpretations of an intense anoxic event in the late Hirnantian-early Rhuddanian.

Keywords:

Ordovician, Uranium, Mass Extinction, Anoxia, Hirnantion

GROUNDWATER LEVEL VARIATIONS OVER THE PAST 60 YEARS IN THE SUNSHINE VALLEY, TAOS COUNTY, NEW MEXICO

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Water table levels have been monitored at least yearly in 5 to 10 wells in the Sunshine Valley of northern Taos County since 1955 by the USGS, NMOSE and TSWCD. Water level was lowest in 1955, rose significantly in the decades of the seventies and eighties and has declined slightly since the mid nineties. These wells had water tables at approximately 50 to 200 feet below the ground level, from aquifers mostly in Q – T fan and alluvial clastics. They are located one to five miles west of the Sangre de Cristo mountain-front. The water table slopes gently westward at less than 100 feet/mile from the mountain front recharge area to the Rio Grande gorge. Precipitation has been gauged near the town of Red River, 10 miles east of Sunshine Valley, for the last 60 years. The precipitation record shows a low period in the fifties and sixties, followed by increased precipitation in the seventies and eighties, and a decrease since the mid-nineties. Thus the groundwater levels appear to reflect twenty-year climate changes seen in the recharge area. No groundwater age dates are available in the area of these wells, but an analogy to the Taos Valley to the south suggest residence time should be less than ten years. C14 dates from springs and wells near the Rio Grande have ages greater than 1000 years, suggesting a mix with much older ground waters from west of the Rio Grande and/or local recharge sources in the western Sunshine Valley. Abrupt level changes in individual wells are caused by cessation or resumption of irrigation. Recent well irrigation in the northern Sunshine Valley does not seem to lower the water levels. Acequia irrigation near Cerro and Costilla may be helping to maintain groundwater at higher than expected levels. Water table mapping in 1959 and 2009 appear similar and long-term changes are within the 50-foot contour intervals used in both.

USING MULTIPLE TRACERS TO EVALUATE HYDROTHERMAL AND METEORIC WATER MIXING IN NORTH-CENTRAL NEW MEXICO

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Mantle helium has been identified within surface and shallow groundwater in the Colorado Rockies, Jemez Mountains, and northern New Mexico in several previous studies. We examine a suite of springs in the southern San Luis basin and surrounding areas and categorize them based on geochemistry of both water and gas. Consideration of multiple chemical tracers (including gases) will help to better understand the nature of the regional geothermal systems. The springs and thermal wells of northern New Mexico have been grouped by geologic setting (major fault structures and hydrostratigraphic units) and we use multiple tracers to identify end member chemistry. Our methods include major ion chemistry, stable isotopes, gas abundance, and helium isotope analysis. Each tracer aids in understanding mixing between shallow and geothermal sources.

Our preliminary results show mixing trends using major ion compositions, non-reactive gas and helium isotope diagrams, with deeply-circulated fluid end members defined by Ojo Caliente and Ponce de Leon geothermal springs. The major ion compositions show two possible deep end members, Ojo Caliente, Na-HCO_3 waters, and Ponce de Leon, Na-SO_4 waters. Gas abundances, in particular the non-reactive gases Ar-N_2-He, compare dissolved gases in spring samples to air. Deeply derived end members typically have higher helium relative abundances. Our springs show water mixing ranging from deeply derived sources to air-like compositions, with Ponce de Leon along the mixing line. Helium isotope analysis reveals the presence of a mantle component. Several of our samples show 3-4% mantle derived helium assuming a MORB and crustal end member of 8 and 0.02 RA (where RA is the $^3He/^4He$ ratio of air). Our initial conclusions are that Ojo Caliente is a carbonic spring with mantle derived volatiles, and springs along the Embudo fault have similar R_c/R_a values as Ojo Caliente but are not carbonic suggesting different geothermal end members. The use of multiple tracers will allow us to make further conclusions concerning proportions of mixing, groundwater quality degradation, and to apply the gas compositional and isotopic results to better understand geothermal influences on surface systems of the southwestern US.

Keywords:

Hydrothermal, mixing

ARTHROPOD BIODIVERSITY HIGHER THAN FORMERLY THOUGHT AT THE LATE PENNSYLVANIAN (MIDDLE MISSOURIAN: KASIMOVIAN) KINNEY BRICK QUARRY LAGERSTATTE, CENTRAL NM, USA

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The Kinney Brick Quarry Lagerstätte (KBQL) in the Manzanita Mountains of central New Mexico is a world-famous locality for Late Pennsylvanian fossil plants, invertebrates and vertebrates in the Missourian Tinajas Member of the Atrasado Formation.The KBQL is a classic Konservat Lagerstätte, which preserves soft tissues and other delicate structures. It yields palynomorphs, a diverse, conifer-rich megaflora, a shelly marine invertebrate assemblage that includes a few cephalopods, the very common brackish pectinacean bivalve *Dunbarella*, lingulid and other brachiopods, and several syncarid and hoplocarid crustaceans, ostracods, conchostracans, eurypterids, and terrestrial arthropods, mostly insects and rare diplopods, a diverse assemblage of fishes, mostly acanthodians and palaeoniscoids, some marine sharks and rare branchiosaurid amphibians, as well as coprolites and "fish eggs." The depositional setting of the KBQL is an estuary fed by a river delta that was filled by continental fluvial clastics. A renewed interest in large-scale collecting at the KBQL adds several new specimens to the record of terrestrial and aquatic arthropod fossils from the site. Arthropod groups previously represented at the KBQL include myriapods (centipedes and millipedes), insects (blattoids and a possible brodiid), chelicerates (eurypterids and a trigonotarbid) and crustaceans (branchiopods, ostracods and syncarids). Here we round out the five major arthropod groups (myriapods, insects, chelicerates crustaceans and trilobites) by adding the pygidium of a trilobite, *Ditomopyge* cf. *D. scitula* (NMMNH [NM Museum of Natural History] P-69194), to the KBQL record. This specimen closely resembles *Ditomopyge scitula* specimens found at Cedro Canyon and Jemez Springs, NM. Additional arthropod specimens include several blattoids and crustaceans, two myriapods, two eurypterids, a palaeodictyopterid and an exceptionally well preserved mesothele spider, which is the oldest known. The spider (NMMNH P-71523) is the first from the Atrasado Formation of New Mexico and is an important addition to the sparse global fossil record of early aranids. The insect fauna of the KBQL is important in two relationships. First, the co-occurrence of the cockroachoid spiloblattinid insect-zone species together with marine zone fossils, e.g., conodonts, in the KBQL enabled the direct link of nonmarine cockroachoid-bearing deposits, which are widespread in Late Paleozoic Euramerica, to the global marine scale.Second, the KBQL assemblage preserves a coastal insect fauna. As is typical of the Late Pennsylvanian and Early Permian, it is dominated by cockroachoids. However, the entomofauna of the KBQL seems to be much more diverse than those of the contemporaneous inland faunas far from the sea. This compares well to the highly diverse nearshore marine insect localities of the Namurian from Ningxia in China and Hagen-Vorhalle in Germany as well as to the Early Permian coastal plain locality, Carrizo Arroyo, in New Mexico. The addition of so many new terrestrial and aquatic arthropod specimens to the KBQL record suggests that biodiversity was much higher than formerly thought. This supports the idea that nearshore environments such as the KBQL may be not only evolutionary hot spots for the earliest terrestrialisation of arthropods during the Early Paleozoic but for the later diversification of insects, too.

Keywords:

Kinney, arthropod, trilobite, spider, insect

THE NOTABLE NEW MEXICO GEOLOGISTS (ONLINE) PROJECT

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In this interactive poster presentation, we report on the Notable New Mexico Geologists (Online) project, an ongoing collaboration between the New Mexico Geological Society (NMGS) and the Technical Communication program at New Mexico Tech. Since spring 2013, students in a popular science writing class have worked on an online supplement to Kues, Lewis, and Lueth's (2014) special publication, *A Brief History of Geological Studies in New Mexico*, hosted on the NMGS website. Students in the course research and interview active and retired New Mexico scientists and engineers who have made significant contributions to our knowledge of geology, hydrology, geosciences, planetary science, mining, and so on. Students then create lively profiles for the website telling the stories of these scientists' life and work. Current and in-progress profiles include Wolf Elston, Penny Boston, Kent Condie, Ginger McLemore, and more. (See profile page: http://nmgs.nmt.edu/notablegeologists/home.html).

The project's primary goals are twofold: To recognize the contributions of notable scientists, mentors, and colleagues and preserve their stories for future generations of geologists; and to provide students with authentic opportunities to practice principles learned in the class and to publish their work. This project also aligns with current discussions among scientists and science communicators about the important role of storytelling in engaging non-specialist audiences. (See for example Dahlstrom [2014]; also refer to the MIT / Culture Kettle public engagement initiative: http://www.cultureofscienceengagement.net/initiative/culturekettle/). Thus, this project has the potential to supplement efforts to introduce broader audiences of teachers, students and inquisitive residents to New Mexico geology.

Students from the spring 2015 Science Writing class will present this poster with the class instructor and will be available to collect future profile suggestions from conference attendees. Attendees may also contribute their own stories about their professors, mentors, collaborators, and colleagues to the project at the "Story Swap" table near the poster.

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REASSESSMENT OF FEATURES IN THE ADEN CRATER LAVA FLOWS, DONA ANA CO., NEW MEXICO

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Aden Crater lava field, encompassing 75 sq km in south central New Mexico, offers excellent examples of features of relatively young (18.2-17.5 ka), low viscosity basalt flows associated with an Icelandic-type shield cone. Improved images and recent field examination allow re-evaluation of the lava field's surface features. The cone consists of an upper channeled flow facies that passes into a lobate flow facies. The outer flanks are characterized by a scabby facies consisting of intercalated thin flows. The bulk of the lava field consists of inflated flows extending across the surrounding surface. These distal flows consist of many inflation plateaus characterized by steep flow margins with peripheral fractures, and flat, level upper surfaces.

The current re-examination of the pits at Aden recognizes four types: inflation pits on inflated flows; simple collapse pits; rootless shield cones; and irregular collapsed tumuli. Collapse pits occur on the upper flanks of the cone and result from removal of still liquid lava from beneath a thin lava crust. The crust was too thin to support itself once the mobile interior flowed away, and the crust collapsed into the depression. The result is a minor depression lined by broken lava crustal fragments. Rootless shield cones are formed by local tumuli on the flow surface that lift the semi-hardened crust in to a positive relief dome. Lava extrusion from the dome flows away from the central pit crater in all directions forming radial lava channels. Rootless shield central pits range from 3-10 meters in diameter. The cones rise 2-4 meters above the surrounding flow. The interior of the pit crater atop the cone is usually filled with broken lava—suggesting that a lava crust may have formed over the pit and collapsed as lava was withdrawn. Collapse tumuli are the largest of the pits on the flanks of the cone. They are unique in that they are irregularly shaped in plan view and surrounded by a raise rim of blocky basalt. The floors are either blocky lava or relative smooth slabs of lava much like the surrounding surface outside the pits. Smooth floor material is crossed by large, intersecting clefts. Previously interpreted as explosion pits based on the presence of blocky raised rims, these irregularly shaped pits are reassessed as collapsed lava-rise tumuli that were too weak to develop as inflation plateaus. Upon close examination, the blocky rim has a double crest with and intervening trough. Blocky rim material over-lies both smooth floor and floor fractures. Lava channels are found draining away from the pits. We propose that the pits with raised, blocky rims are collapsed large tumuli that spilled lava to the surface in much the same manner as rootless shield cones. The blocky raised rims are simply shattered remnants of a thin lava crust that could not support itself after removal of the under-lying lava.

Keywords:

Aden Crater, collapse tumuli, inflation plateau, rootless vents, shield cone

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

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Spectacular soft-sediment deformation in mid- to upper Eocene (40-37 Ma) rocks of the Sawtooth Mountains of west-central New Mexico records gigantic slumping event(s), and provides geologists with an opportunity to study similar processes that may pose future hazards to human lives and property. The Sawtooth Mountains have been mapped in reconnaissance, but this study is the first detailed analysis of their deformation.

To better understand the geometry of deformation, 1:6000-scale geologic mapping and cliff mapping were done. Cliff mapping involved drawing bedding and fault planes on cliff photos while observing them from different perspectives in the field. Riedel shear and detachment fault orientations were collected and used to determine slip direction(s) along the detachment. Samples were collected for thin section petrographic and microprobe analysis. Petrography serves two purposes, (1) estimating permeability differences between the lower and upper plate to test whether the upper plate or cataclastic detachment surface acted as an impermeable seal to the lower plate, preventing dewatering, reducing effective normal stress, and aiding deformation, and (2) describing microstructures within the fault zone and deformed sections of the plates to determine slip direction(s) and whether deformation occurred once or multiple times and catastrophically or slowly.

In the field area, chaotically-bedded argillaceous sandstones of the volcaniclastic unit of Largo Creek (VLC) conformably overlie the undeformed fluvio-lacustrine Baca Formation. The lower plate VLC is separated from the upper plate Dog Springs debris-flow breccias by an extensive detachment fault. Detachment faults may also be present within the VLC and at the Baca-VLC contact in some areas. Geologic mapping reveals different bedding orientations in the upper plate. Western peaks display sub-horizontal bedding that is sub-parallel to the detachment whereas eastern peaks have sub-vertical bedding that strike north. A large ENE-trending anticline is present in one of the western peaks. Cliff mapping has revealed VLC plastic deformation expressed as chaotic, folded bedding and Dog Springs brittle deformation expressed as coherent blocks with faults and fractures. One of the eastern peaks displays fault drag and Riedel shears that imply eastward slip of the upper plate Dog Springs. However, the angle between upper plate bedding and the detachment on the same peak implies westward slip of the upper plate assuming original detachment faulting was part of a slump event. Hand samples are currently being prepared for petrographic and microprobe analyses.

In the eastern peaks, the upper plate possibly underwent two slip events in opposite directions, an initial slip to the west followed by slip to the east. Differences in upper plate bedding orientations suggest that deformation occurred as multiple events or is more complex than currently understood. Preliminary observations of clastic dikes and lithologic differences between the lower and upper plate suggest liquefaction helped to enable deformation.

Keywords:

soft-sediment deformation, detachment faulting, slumping, sawtooth mountains, structural geology

A PRECISE NEW AGE FOR THE C33N/C32R PALEOMAGNETIC REVERSAL AS DETERMINED IN THE SOUTHERN SAN JUAN BASIN, NEW MEXICO

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Global time scales, beginning with Harland, et al. (1989), followed by Gradstein et al. (2004) and Gradstein et al. (2012) have been based primarily on a combination of radiometric ages as related to paleomagnetic reversals (and more recently by orbitally tuned rock sequences) in rock strata throughout the world. These time scales have grown more precise as more radiometric ages have become available to fill in gaps present in earlier time scales. Unfortunately, rocks that can be dated using radiometric methods have not always been present in the same stratigraphic sequences where good paleomagnetic data have been obtained and vice versa. In an effort to improve on the precision of the age of one paleomagnetic reversal Fassett (2000) presented paleomagnetic data for a rock sequence in the southern San Juan Basin that included the uppermost Cretaceous Fruitland and Kirtland Formations. The paleomagnetic reversal from C33n to C32r was found in the upper part of this sequence. Within these same strata, eight altered volcanic ash beds were discovered and sanidine crystals from those ashes yielded relatively precise $^{40}Ar/^{39}Ar$ ages – six of these ash beds were below the C33n/C32r reversal and two were above it. Based on these ages, it was determined that this paleomagnetic reversal had an age of 73.50±0.19 Ma. The uncertainty for these eight ash-bed ages ranged from 0.13- 0.41 Ma. In 2008, some of the ash beds dated by Fassett (2000) were recollected in order to use modern mass spectrometry to more precisely determine the age of the C33n/C32r paleomagnetic reversal. Two of the recollected ash beds below the reversal yielded much more precise results compared to previous data yielding ages of 76.42±0.04 Ma and 75.24±0.04 Ma; an ash bed above the boundary had an age of 73.36±0.025 Ma. Based on these bracketing ages, and assuming a linear deposition rate, the age of the C33n/C32r reversal was found to be 73.782 Ma. The age for this reversal in Gradstein et al. (2012) is reported to be74.309 Ma – about 0.5 m.y. older than our newer and more precise age. We recommend that our new age of 73.782 for the C33n/C32r paleomagnetic reversal become the established age for this reversal used in future global time scales.

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Keywords:

Paleomagnetic reversal, C33n/C32r, 40Ar/39Ar dating, global time scales

COUPLED WARMING AND ARIDITY IN NEW MEXICO DURING MID-PLEISTOCENE INTERGLACIALS AND MILLENNIAL SCALE CLIMATE VARIABILITY DURING GLACIALS: THE VALLES CALDERA RECORD

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We present a high-resolution lacustrine paleoclimate record from the Valles Caldera, New Mexico, which spans 200,000 years across the mid-Pleistocene (Marine Isotope Stages (MIS) 14 to 10). Within this record, periods of climatic aridity (megadroughts) lasting centuries to millennia occurred during the warmest parts of the long interglacials (MIS 13 and 11) and were climatically similar to projected future aridity in the southwest. We used the MBT/CBT index to reconstruct mean annual temperatures downcore and found that the warmest phases of interglacial periods were also the driest, as shown by the presence of mudcracks and elevated calcite concentrations. During these episodes, MATs were similar to, or higher than modern MATs. Three warm peaks with amplitudes of 2^{o}C occur during MIS 11, an interglacial with an orbital configuration similar to the Holocene, and appear to correspond to the low amplitude precessional cycles within MIS 11. Much of interglacial MIS 13 was warmer than MIS 11 and larger amplitude variations in MAT (4 to 6^{o}C) during this interval when precessional cycle amplitudes were larger suggests that local insolation variations were important to southwestern interglacial climate variability.

The glacial periods represented in the Valles Caldera record exhibit Dansgaard-Oeschger like variability, especially during MIS 12, one of the coldest glacial periods in the Pleistocene. High-resolution analysis of proxies from the VC-3 core show the occurrence of approximately 23 millennial-scale oscillations with an average duration of ~2,200 years. Many of these oscillations are characterized by relatively gradual coolings that are followed by abrupt warmings of up to 6^{o}C, similar to the D-O events in the Geenland ice core record. Stadials in the VC record correlate with high percentages of boreal pollen taxa (*Picea*, *Abies*) while interstadials have lower percentages of boreal pollen but have local maxima in *Juniperus* and *Quercus* pollen. Proxy data, including diatom $\delta^{18}O$, show significant changes in the watershed hydrology from stadials to interstadials. We argue that MIS 12 glacial climatic variability in northern New Mexico was driven by changes in continental temperature as well as changes in the strength and track of the winter polar jet, which affected the local hydrologic cycle and isotopic composition of precipitation.

Keywords:

Paleoclimate Valles Caldera New Mexico

SEDIMENT ANALYSIS FROM CERRO MEDIO DRAINAGE, JEMEZ MOUNTAINS, NM: ASSESSING CAUSES OF COLOR CHANGES IN THE VERTICAL PROFILE

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The Cerro del Medio drainage in the Jemez Mountains contains more than 10 laterally continuous alternating light-dark sediment bands. This study hypothesizes that color variations reflect changes in organic matter which in turn reflects repeated cycles of forest fire sedimentation. To test this hypothesis, we are characterizing sediment samples from dark and light bands to test for changes in the mineralogy and in the size, shape, and sorting of the grains that could correlate to changing sediment source and/or depositional environment. Foundational results indicate that grain type and size were consistent within and between the bands throughout the profile indicating an unchanging sediment source and depositional environment through time. The fine to medium sediment size indicates that the depositional environment was one of a low to moderate energy, i.e. low gradient stream. The sub-rounded to sub-angular grain shape indicates that the sediment was not far traveled from the source region. The high amount of quartz and feldspar in the samples is consistent with the sediment eroding from the Cerro del Medio rhyolite dome. The high amount of organic matter in alternating dark bands suggests that the source region was repeatedly replenished with organic material and is consistent with forest fire cycles.

PALEOMONSOONAL PRECIPITATION AND HYDROCLIMATE VARIABILITY FROM GLACIAL TO INTERGLACIAL CLIMATES IN THE SOUTHWEST: THE STONEMAN LAKE, ARIZONA RECORD

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Two lacustrine sediment cores (70 m deep and 30 m deep respectively) were recovered from Stoneman Lake, northern Arizona in October of 2014. With these cores we plan to use multiple methods to determine regional hydroclimate variability between the Pleistocene-Holocene glacial transition ca. 14 ka. The geochemical analyses of these two cores have not yet been explored, but will provide us with invaluable information regarding age control, sources of precipitation to the basin (Gulf of Mexico vs North Pacific), and paleoprecipitation variability. I plan to use diatom oxygen isotope values to constrain precipitation source region changes to the southwest on glacial to interglacial timescales and to determine if the onset of paleomonsoonal precipitation occurs at the glacial termination (Leng and Barker, 2006, Dodd et al., in review). Other lacustrine cores from the southwest, such as the Valles Caldera, New Mexico record (Dodd et al., in review; Fawcett et al., 2011), will allow us to determine if the timing of the monsoon onset is similar in both locations, relative to the glacial termination, or if there is a lead or lag going from northern NM to north central AZ. The longitudinal extent (through NM and AZ) of the monsoon and the amount of monsoonal contribution to the glacial precipitation in Arizona (if any) can also be constrained. Other supporting data to be collected will include pollen and charcoal, total organic carbon, the $\delta^{13}C$ of bulk organic matter and $\delta^{15}N$ of total organic matter, C/N ratios, AMS radiocarbon dating, argon-argon dating, and XRF elemental information. By collecting data from this lacustrine sediment, we will be able to better reconstruct atmospheric paleocirculation patterns of the southwestern United States.

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Keywords:

paleoclimate, oxygen isotopes, biogenic silica, monsoon, glacial, interglacial, precipitation, lacustrine, arizona, southwest

CHANGES IN RIO GRANDE RIFT TECTONISM AS INFERRED FROM SUBSIDENCE CURVES

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Basins of the Rio Grande Rift (RGR) have been studied extensively, but relatively few studies have focused on changes in basin subsidence rates. This study has analyzed the tectonic subsidence of the RGR in ten locations: two in the southern San Luis Basin, four in the Española Basin, three in the Albuquerque Basin, and one in the Lemitar Mountains area. Six of the ten locations are wells and four are measured stratigraphic sections. We selected locations for which we had good subsurface age controls. The subsurface units were differentiated based on age control and lithologic differences. Parameters for these subsurface units (such as porosity depth coefficients, surface porosities, and bulk densities) were estimated using their lithologic descriptions and published estimates for similar lithologies.

We use the backstripping method to calculate tectonic subsidence. This is a technique that decompacts and successively removes sediment load driven subsidence using Airy isostasy. Interpretations need to consider that the backstripping method treats unconformities as periods of zero tectonic subsidence whereas in reality unconformities may coincide with times of uplift or possibly subsidence. With that caveat, we argue that these ten tectonic subsidence curves allow a comparison of subsidence rates along the rift on both inter- and intra-basin scales.

All but one of the subsidence curves with sufficient data follow a trend characterized by rapid tectonic subsidence rates of ~25-65 mm/Ka in the Miocene, followed by an unconformity, and slower tectonic subsidence in the Plio-Pleistocene. Post-unconformity rates of subsidence are ~10 mm/Ka between about 5 Ma and 2 Ma in all basins. This indicates the rift was still opening in Plio-Pleistocene time but much slower than in the Miocene. On well doesn't follow these tectonic subsidence trends because it lies on a relatively deep half-graben developed on the immediate hanging wall of the active Parijtio Fault system, which has maintained high slip rates through the Pliocene. Our study confirms that the unconformity is a rift-wide feature. We also explore several literature models which our subsidence curves compliment that may explain the unconformity, including climate, tectonic processes and dynamic uplift.

Keywords:

Rio Grande Rift, Tectonism, Subsidence, Basin Modeling

REVISED LOCATION FOR THE YAVAPAI-MAZATZAL CRUSTAL PROVINCE BOUNDARY IN NEW MEXICO: HF ISOTOPIC DATA FROM PROTEROZOIC ROCKS OF THE NACIMIENTO MOUNTAINS

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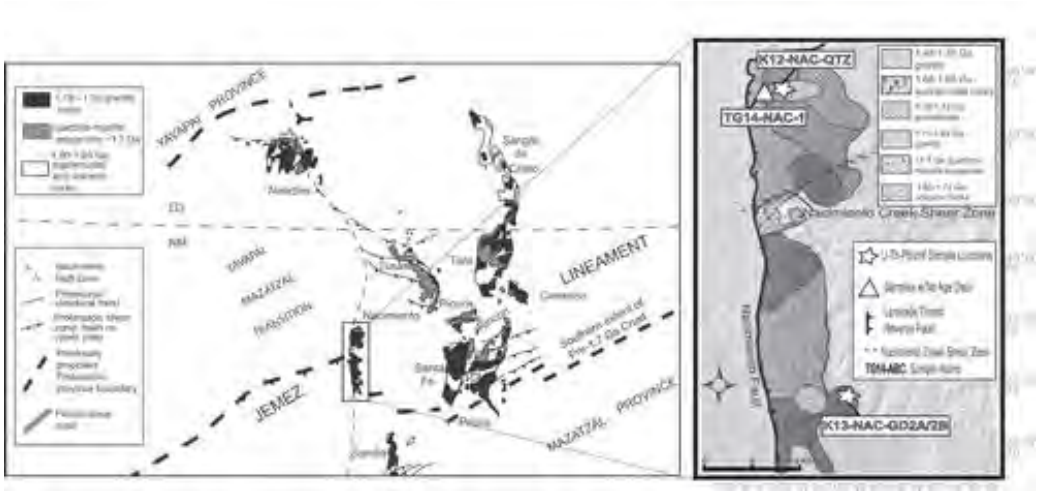
Lithospheric growth of southwestern Laurentia during the Paleoproterozoic has been hypothesized to have involved addition of two dominantly juvenile crustal provinces: the 1.8-1.7 Ga Yavapai province and the 1.7-1.6 Ga Mazatzal province. Timing of assembly of these two crustal provinces has been stated to have occurred during the 1.72-1.68 Ga Yavapai orogeny and 1.65-1.60 Ga Mazatzal orogeny, with both undergoing high temperature deformation and metamorphism at middle crustal depths accompanying Mesoproterozoic intrusions from 1.45-1.35 Ga. The boundary between provinces remains poorly understood, but has been inferred to lie along the northern edge of the Jemez volcanic lineament and through the Nacimiento uplift in northern New Mexico. This basement-cored Laramide uplift exposes a 53-km-long N-S transect dominated by Paleoproterozoic and Mesoproterozoic granite, providing an ideal locality to examine age and origin of continental lithosphere across this proposed boundary on a local scale. A quartzite metasedimentary unit from the northern Nacimiento that is intruded by ca. 1696 Ma granite was analyzed with U-Pb and Hf isotopic analyses of zircons. The detrital zircon data show a narrow unimodal age peak at 1720 Ma and a maximum depositional age of ~1.7 Ga. Detrital zircons from this sample yield initial epsilon Hf values ranging from +6.4 to +14.2 suggesting an isotopically juvenile ca. 1.7-1.8 Ga source region for the quartzites. Detrital zircon ages suggest correlation with the greater Hondo Group and equivalents of northern New Mexico.
A 1449 ±12 Ma granite from the southern Nacimiento Mountains has initial epsilon Hf values of +2.6 to +10.5 suggesting that the lower crustal melt source region contained 1.7-1.8 Ga (Yavapai) crust that was partially melted by and may have mixed with juvenile 1.4 Ga melt. Together these data suggest that >1.7 Ga (Yavapai) crustal province rocks extend in the subsurface south of the Nacimiento Mountains.



Generalized regional geologic map of southern edge of Yavapai-aged terrane in New Mexico. Inset map details geology of Nacimiento uplift and locations of samples collected for this study.

Keywords:
Yavapai, Mazatzal, Hafnium, U-Pb, Geochronology, Precambrian, Zircon, Proterozoic

GEOCHEMISTRY OF WHITE ROCK CANYON SPRINGS, NORTHERN NEW MEXICO

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The Rio Grande runs through White Rock Canyon in North-Central New Mexico. White Rock Canyon is positioned on the East flank of the Jemez Mountains on the edge of Pajarito Plateau and exposes volcanic rocks related to both the Bandelier tuff eruptions and basalts of the Cerros del Rio volcanic field. Numerous springs emerge along the Rio Grande and along canyon tributaries. Previous workers examined spring water chemistry to inspect the possibility of environmental contamination from anthropogenic activities on the Pajarito Plateau. The purpose of this study was to resample springs and gases at selected sites to deduce likely groundwater flow paths based on geochemical parameters. This study is part of a regional examination of the extent of the Valles Caldera geothermal system and regional fault zones in influencing ground and surface water quality. We also compare results to previous studies. Samples were taken in March, 2015. The samples were analyzed for major ions, trace elements, and stable isotopes of water. In addition to the examination of this chemistry, gas chemistry will also be analyzed. Spring temperatures ranged from 11 to 20 degrees C. The pH ranged from 6.2 to 8.35 and total dissolved solids (TDS) are generally low (100-300 mg/L). Alkalinity ranges from a low of 80 ppm to a high of over 200 ppm as bicarbonate. The springs are uniformly higher in Br, F and silica concentration relative to the Rio Grande, although Li concentrations are similar. Sulfate concentrations are uniformly low in the spring waters relative to the Rio Grande. As gas and stable isotope data become available, multiple tracers can be applied to examine reasonable end-member mixing models to ascertain whether the waters mix with a geothermal component. Preliminary examination of major ion chemistry indicates that the waters are calcium-bicarbonate dominated and dominated by meteoric recharge.

DEPOSITIONAL SETTING AND SEQUENCE STRATIGRAPHIC FRAMEWORK OF THE LOWER PERMIAN (WOLFCAMPIAN) HUECO FORMATION (UPPER-MIDDLE AND GASTROPOD MEMBERS). ROBLEDO SHELF, WESTERN OROGRANDE BASIN, NEW MEXICO

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In recent years, the Lower Permian Wolfcamp Shale of Texas and New Mexico has become one of the most prolific onshore unconventional hydrocarbon plays in the United States. Understanding how sea level change, paleoclimate, and tectonic subsidence interact to control these basinal facies can enhance the predictability of both lateral and vertical changes in reservoir attributes. In this study we develop a depositional facies and sequence stratigraphic framework for the up dip equivalent Hueco Formation which can be utilized to increase predictability of subsurface play elements in the Wolfcamp Shale.

The Upper-middle member and Gastropod member are age-equivalent subunits of the Hueco Formation that form a mixed carbonate and siliciclastic succession found in the Robledo and Doña Ana mountains of southern New Mexico. These members contain depth-sensitive lithofacies that allow paleogeographic reconstruction and delineation of sea-level cycles on the Robledo Shelf and the western margin of the Orogrande Basin at the time of deposition. A broad range of carbonate and siliciclastic lithofacies are documented including fluvial siltstones, supratidal to open marine carbonates, and basinal shales. A total of 19 fifth-order cycles were correlated out of a thickness of 50m in the Robledo Mountains and 65m in the Doña Ana Mountains. The duration of each cycle was approximately 100,000 years and deposited an average of 2.5 m of carbonate and siliciclastic sediment. These fifth-order cycles took place between two third-order cycles which saw subaerial exposure and fluvial siliciclastic deposition. The frequency and amplitude of these sea-level changes is evidence of a glacio-eustatic control for both third and fifth-order cycles.

Despite their relatively similar position on a carbonate ramp depositional profile, the Upper-middle and Gastropod members have different facies in outcrop. The Upper-middle member is dominantly restricted tidal dolomites and semi-restricted limestones with some normal marine limestone and thin shale units. The Gastropod member is mostly basinal shale and normal marine limestones, with occasional semi-restricted limestones and fluvial siltstones, no dolomite was found in the Gastropod member of the Doña Ana Mountains. The presence of both carbonate and siliciclastic lithofacies is likely related to glacio-eustatic sea-level changes, differences in the restriction of each location, and paleoclimate shifts whereby carbonates were deposited during arid periods associated with sea-level lowstands and siliciclastics during more humid periods associated with sea-level highstands.

A PROLIFIC NEW VERTEBRATE COPROLITE LOCALITY FROM THE PENNSYLVANIAN OF CENTRAL NEW MEXICO AND AN ECOLOGICAL TRANSECT OF MISSOURIAN BROMALITE ICHNOFAUNAS

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The Upper Pennsylvanian Tinajas Member of the Atrasado Formation is of Missourian age and yields vertebrate coprolites from the Kinney Brick Quarry Lagerstätte in the Manzanita Mountains of Bernalillo County and the Tinajas Lagerstätte in the Cerros de Amado of Socorro County. A new locality (NMMN locality L-9096), also in the Cerros de Amado, contains a very large sample of coprolites. Most 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 majority of coprolites are spiral in morphology (heteropolar, amphipolar, scroll). Five ichnotaxa are heteropolar spiral in morphology and include *Crassocoprus mcallesteri*, *Kalocoprus oteroensis*, two ichnospecies of *Heteropolacopros* and ?*Speirocoprus* isp. There are numerous specimens of *Crassocoprus mcallesteri*, which was previously only known from one specimen from the Tinajas Lagerstätte. Heteropolar microspiral coprolites are assigned to *Heteropolacopros*, but there is a need for an ichnotaxonomic review of this ichnogenus. Amphipolar coprolites are represented by *Hyronocopros amphipola*. There are several specimens of the scroll coprolite *Bibliocoprus beemanensis*, which is identified beyond its type locality for the first time. 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) NMMN locality L-9096 – nearshore marine; and (4) Sacramento Mountains – offshore marine. The Kinney ichnofauna preserves a diverse bromalite ichnoassemblage comprising seven morphotypes of coprolites, regurgitalites and a consumulite. Most specimens are sub-ovoid, laterally compressed, non-spiral in morphology and preserved in matrix. The sample size from the Tinajas Lagerstätte is smaller but it yields 12 morphotypes of bromalites (11 coprolites, 1 regurgitalite) including *Conchobromus kinneyensis*, *Crassocoprus mcallesteri, Spierocoprus socorroensis, Elongatocoprus amadoensis*, *Elacacoprus williamsi* and *Crustacoprus tinajaensis*. Most specimens are preserved in matrix, and a higher percentage are of spiral morphology than at Kinney. The Sacramento Mountains ichnofauna derives from the Beeman Formation and consists entirely of spiral coprolites that have weathered out of shale. Beeman specimens represent *Liassocoprus hawkinsi, Heteropolacopros texaniensis, Hyronocoprus amphipola, Kalocoprus oteroensis, Bibliocoprus beemanensis* and unassigned morphotypes. There are clear trends through these ichnofaunas (Kinney-Tinajas-L-9096-Sacramentos); (1) flattened preservation in matrix to isolated three dimensional; (2) diverse bromalites to only coprolites; and (3) increasing proportion of spiral coprolites. The new locality is transitional in all these aspects between Tinajas and the Sacramentos. The ichnofauna of the Beeman Formation is representative of the Shark Surplus Paradox, in which there is an apparent disproportionate diversity and abundance of spiral (probably chondrichthyan) coprolites relative to the fish fauna (preserved or inferred). The ichnofaunas from the Missourian of New Mexico are potentially important for understanding the causes of the Shark Surplus Paradox.

LATE HOLOCENE ALLUVIATION IN THE PALOMAS BASIN, SOUTH-CENTRAL NEW MEXICO

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The origins of late Holocene alluvial deposits in the American Southwest have long been debated, with climate variability being the most commonly hypothesized driver of episodic valley-fill aggradation and incision. Deposits that are correlative over multiple drainage basins are thought to form by alluviation occurring in drier periods with infrequent floods. Conversely, larger and/or more common flood events during wetter intervals permit streams to incise their valley bottoms. Such shifts between aggradation and incision have resulted in both deeply cut arroyos and low-lying alluvial benches over the past ~4000 yr or longer.

The Palomas basin of south-central New Mexico is an east-tilted half graben in the southern Rio Grande rift. Here, late Holocene valley fill occurs in three allostratigraphic units along both arroyos and perennial streams. We mapped and described these units in Rio Grande tributaries: alluvium underlying Las Animas Creek (unit Qahan) and terrace deposits along ephemeral Cañada Honda (units Qay1 and Qay2). Charcoal collected from each deposit was radiocarbon dated, and the interpreted record of tributary aggradation and incision was compared to alluvial records of the Rio Grande and the middle part of Cañada Alamosa, a Rio Grande tributary in the northernmost Palomas basin.

Radiocarbon dates constrain late Holocene aggradation in Las Animas Creek and Cañada Honda to the last ~2500 yr. The upper 1.5 m of valley floor alluvium of Las Animas Creek (unit Qahan) is incised into middle-late Holocene alluvial fans, and returned ages of 300-250 and 140-55 yr BP. The high terrace deposit in Cañada Honda (Qay1) returned an age of 2720-2385 yr BP, whereas the low-lying deposit there (unit Qay2) aggraded at 630-515 yr BP and incised shortly thereafter. Qay2 is similar in age to post-incision valley floor alluvium in Cañada Alamosa dated at 550-350 yr BP. Previous workers also used radiocarbon ages to constrain alluviation (and/or stability) along the mainstem Rio Grande in the Palomas basin at ~5000-760 and 550-260 yr BP; incision events are estimated at 760-550 and just after 260 yr BP.

Late Holocene alluviation was generally synchronous across the Palomas basin, with basin-wide aggradation at ~550-500 yr BP suggesting a common climatic driver. Regional precipitation reconstructions from tree-ring chronologies indicate the onset of sustained, interseasonal drought at that time. Incision was also consistent between the mainstem Rio Grande and Cañada Alamosa prior to 550 yr BP. Cañada Honda incised after 530 yr BP, perhaps a result of the upstream propagation of baselevel fall from the Rio Grande. Such signals appear muted in the larger Las Animas Creek drainage, where greater sediment flux could have obscured incision events related to baselevel fall. Mainstem Rio Grande incision after 260 yr BP is not observed in its Palomas basin tributaries, and may have been related to external climatic events in its headwaters (i.e. the Little Ice Age). Understanding the complex origins of these allostratigraphic units is critical for investigators who seek to understand how climate variability influences alluviation and valley cutting at the basin scale in arid and semi-arid settings.

Keywords:

late Holocene, climate variability, alluviation, incision, radiocarbon

HIGH-RESOLUTION STATEWIDE MODELING OF GROUNDWATER RECHARGE IN NEW MEXICO

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The rate and distribution of groundwater recharge to New Mexico's aquifers is the least understood aspect of the state's water budget. Despite a history of precise and distributed measurements quantifying surface water flow, water table elevations, precipitation amounts, as well as current models that describe evapotranspiration, a statewide assessment of recharge has not been completed. While recharge estimates and studies of recharge processes have been conducted, the effort to date has been on the basin scale, or by county or water planning region. With a long-term goal of estimating groundwater recharge on a statewide scale, we have undertaken recharge modeling based on the soil water balance approach in order to represent relevant physical parameters affecting the rate of recharge. We use raster grids representing spatially distributed physical parameters including precipitation, soils, geology, reference evapotranspiration, and vegetation as inputs to the model. Implementing methodology developed by the United Nations Food and Agriculture Program, we calculate actual evapotranspiration and tabulate a daily soil water depletion from three one-dimensional soil layers. We then calculate recharge based on modeled soil saturation and saturated bedrock hydraulic conductivity. With support from the New Mexico Water Resources Research Institute's Statewide Water Assessment we have compiled recharge estimates from around the state and have constructed our recharge model. We plan on using funds provided by NMGS to field-verify this model using the chloride mass balance technique.

RELATING CA. 5 MA COARSE SEDIMENTATION IN THE RIO GRANDE RIFT TO TECTONICS, CLIMATE, AND INTER-BASIN FLUVIAL SPILLOVER OF THE ANCESTRAL RIO GRANDE

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Previous and new age control indicates coarse sedimentation in the Rio Grande rift ca. 5 Ma. We describe three sites illustrating this coarse sedimentation and discuss how it could be due to tectonics, climate, and inter-basin fluvial spillover.

The first site lies in northern New Mexico at the structural high between the Española and San Luis basins. Here, a 1-25 m thick package of 4.7 to 5.0(?) Ma sand and gravel unconformably overlies Late Miocene sandy strata with 1-5% pebbles. The former consists primarily of medium- to very coarse-grained sand, pebbles, and subordinate cobbles that were deposited by three west- to southwest flowing paleodrainages sourced in the southern Taos Range and Picuris Mountains. The northern two paleodrainages merged westward to form the ancestral Rio Grande (ARG), whose associated clasts were reworked in 4.0-4.6 Ma maar deposits 5 km east of Ojo Caliente.

The second site consists of a 1200 ft-deep well in the west-central Socorro basin, which penetrated the entire Plio-Pleistocene ARG sedimentary package and bottomed in 30 ft of clayey playa deposits. There is a coarsening-upward trend from 1170 to 1050 ft, and sediment is particularly coarse between 802 and 1050 ft (common well-rounded quartzite and granite clasts). We suggest that the 1050-1170 ft interval reflects initial Rio Grande sedimentation in a semi-closed basin.

The third site lies at the structural high between the Palomas and Engle basins near downtown Truth or Consequences (TRC). Here, the basal scoured erosion surface of ARG sediment overlies finer, locally derived piedmont sediment. The lower 20-25 m of the ARG is markedly coarse, containing many cobbly-bouldery beds that are lacking or very sparse in higher strata. An $^{40}Ar/^{39}Ar$ age of 4.8 Ma (from cryptomelene) projects 9-13 m above the base of the unit. The lowermost 3 m of the ARG deposit consists largely of limestone pebbles-boulders from the Mud Springs Mountains, and elsewhere in the lower coarse package are abundant cobbly beds whose gravel were derived from mountains to the west or northwest.

We agree with Gragg et al. (this vol.) that a decrease in rift tectonic extension rates occurred near the Mio-Pliocene boundary, which would promote fluvial spillover and southward expansion of the Rio Grande (Connell et al., 2005, 2012). At the first site, a decrease in tectonic subsidence rates would be conducive to progradation of coarse, footwall-derived sediment across the southern San Luis basin. However, hanging wall sediment also coarsened in the eastern Española basin half graben between 5 and 7 Ma, which is is not readily explained solely by decreased tilt rates. Previous studies indicate climatic changes at about this time, which can account for the increased competency of streams irrespective of tectono-structural position as well as suggestions of increased spring discharges in the TRC area ca. 5 Ma. High initial slopes on the downstream side of inter-basin paleotopographic highs would promote temporarily high stream power and coarse sedimentation associated with fluvial spillover, but increased stream competency of tributaries at the third site is probably best explained by climatic factors.

Keywords:

Ancestral Rio Grande, Ancestral Rio Grande evolution, Ancestral Rio Grande spillover, Rio Grande rift sedimentation

PRELIMINARY ANALYSIS OF THE GEOLOGIC STRUCTURE OF THE EASTERN SAN AGUSTIN PLAINS, N.M.

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We use borehole data, Bouguer gravity data, and previous geologic mapping of surrounding mountains to preliminarily characterize the geologic structure underneath the eastern San Agustin Plains. Home to the Very Large Array, the eastern San Agustin Plains occupies the 1400 km^2 basin east of Datil. It is surrounded by the Datil Mountains and Gallinas Mountains to the northwest and northeast, respectively, Tres Montosas to the east, and the Mount Withington area of the northern San Mateo Mountains to the southeast. The 14 km-wide C-N embayment on the southwest side of the basin extends 16 km between the Luera and northern San Mateo Mountains. Sandy basin-fill correlative to the Santa Fe Group underlies most of the eastern San Agustin Plains, whereas the surrounding mountains are composed of ignimbrites, volcaniclastic sediment, and lava flows of the Mogollon-Datil volcanic field.

We interpret at least two, possibly three, structural grabens underneath the eastern San Agustin Plains. Some of the faults bounding these grabens have experienced Quaternary activity. A subsurface bedrock high trends northeast across the center of the eastern San Agustin Plains, separating the North graben to the north from the C-N graben to the south. This bedrock high is manifested in the gravity data and collaborated by borehole lithologic data near the VLA headquarters. Southeast of the eastern extension of this bedrock high, relatively low gravity values suggest a third possible fault-bounded graben, which we call the White Lake graben, between Tres Montosas and Mount Withington.

The North graben is an east-tilted half-graben, tilted towards a north-northeast striking, 3 km-wide fault located 8-9 km east of Datil. A deep exploratory borehole indicates at least 3500 ft of basin-fill immediately east of this master fault zone. Although west-down, northwest-trending faults are present on the east side of North graben, their respective throws are relatively minor and do not produce notable gravity gradients. On the north end of North graben, the North Lake playa lies in a minor graben between two of these eastern faults.

The C-N graben underlies the northern C-N embayment. Rather than a simple half-graben, we interpret a northeast-elongated, fully-fault bounded graben. Its northern bounding fault corresponds to a previously inferred, northeast-striking, normal or normal-oblique fault that bounds the southern side of the aforementioned subsurface bedrock high. Its eastern bounding fault corresponds to the VLA fault, which has formed 40 m-tall scarps in middle Pleistocene alluvium. The gravity anomally associated with the C-N graben is similar to that of the western North graben, so we infer similar basin-fill thicknesses of 3500-4000 ft.

These grabens formed over the past 30 Ma during west-east extension associated with Rio Grande rifting. The rectangular shape of the C-N graben suggests a pull-apart structure created by oblique slip along its northeast-striking, north bounding fault. This fault was likely a reactivation of earlier structures associated with the northeast-trending San Agustine lineament of Chapin (1971), which approximates the northwestern boundary of the Laramide-age Morenci uplift of Cather and Johnson (1984).

Keywords:

San Agustin Plains, San Augustine Plains, San Agustin Plains structure, San Augustine Plains structure

U/TH AND ^{40}AR/^{39}AR DATING PROVIDES ERUPTION AGES AND MAGMATIC EVOLUTION FOR THE EAST FORK MEMBER OF THE VALLES RHYOLITE

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U/Th and Ar/Ar dating was conducted to determine the age of the youngest eruptions at the Valles caldera. The youngest series of eruptions, collectively known as the East Fork Member of the Valles Rhyolite, includes the co-erupted El Cajete pumice and Battleship Rock ignimbrite, and overlying Banco Bonito lava flow. Despite the importance for hazard assessment, previous geochronology investigations have not produced conclusive eruption ages for these units. Ages range from less than 30 ka to more than 1 Ma. Ar/Ar dating was conducted using the high-sensitivity ARGUS VI mass spectrometer, which is capable of dating late Quaternary samples with the single crystal method. Ar/Ar ages indicate that the El Cajete pumice and Battleship Rock ignimbrite erupted at 74.7 ± 1.3 ka, whereas the Banco Bonito lava erupted at 68.3 ± 1.5 ka. To test the reproducibility of these eruption ages, as well as to investigate the crystallization of the East Fork Member, the U/Th method was used to date zircon. Unpolished zircon surfaces were dated using the high-spatial resolving power of the SHRIMP-RG. By analyzing the surface of zircon crystals we are able to determine the timing of crystal growth immediately prior to eruption. U/Th ages indicate that the youngest phase of crystal growth occurred at 70 ± 4 ka for the El Cajete pumice and Battleship Rock ignimbrite, and 68 ± 4 ka for the Banco Bonito lava flow. These ages agree with the Ar/Ar eruption ages. In addition to zircon that crystallized near the time of eruption, U/Th ages indicate an abundance of inherited crystals. Most antecrystic or xenocrystic zircon yield ages ranging from near the eruption age to 97 ± 11 ka, and from 149 ± 16 ka to 160 ± 20 ka. These older zircon populations reveal a previously unknown period of protracted magmatism prior to the eruption of East Fork Member.

Keywords:

volcanology, Valles Caldera, geochronology

ROLLALONG RESISTIVITY SURVEYS REVEAL KARSTIC PALEOTOPOGRAPHY DEVELOPED ON NEAR-SURFACE GYPSUM BEDROCK: LAKEWOOD, NEW MEXICO

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Following flooding in September 2013, several areas in northern Eddy County, New Mexico were damaged by multiple sinkhole collapses. We conducted rollalong electrical resistivity (ER) surveys for subsurface cavities parallel to roads within and near the community of Lakewood, NM to guide road repairs. The rollalong method allowed us to generate exceptionally long, continuous ER profiles of the survey area. ER surveys attained a maximum exploration depth of 55 to 62 meters over a lateral extent of ~1000 meters, revealing an unconformable surface developed on gypsum bedrock, punctuated by shallow depressions. Subsurface stratigraphy, including clay-rich valley fill sediments, and mudstone and gypsum of the underlying Seven Rivers Formation, can be identified by vertical and lateral variations in electrical resistivity. The irregular bedrock surface of the Seven Rivers Formation reflects paleotopography developed on that surface prior to its burial by floodplain sediment. Some of the negative paleotopographic features are probably filled sinkholes, which may be associated with shallower karstic features not imaged on the profiles.

Keywords:

sinkholes, electrical resistivity

THE TURTLE ADOCUS FROM THE UPPER CRETACEOUS CREVASSE CANYON FORMATION, SIERRA COUNTY, NEW MEXICO

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A partial shell of the well-known Upper Cretaceous turtle *Adocus* was collected in the Crevasse Canyon Formation, east of the Caballo Mountains in Sierra County, New Mexico. It was found stratigraphically low in the Crevasse Canyon Formation, so its age is close to the Coniacian-Santonian boundary (approximately 86 Ma). This is the southernmost known occurrence of an *Adocus* in North America and may be the oldest North American record of the genus. A fragmentary specimen was previously reported from Santonian strata in Utah and tentatively assigned to the genus based on surface sculpture.

The specimen from the Crevasse Canyon Formation is the anterior half of the plastron as well as most of the free edge of the anterior half of the carapace. This includes a partial nuchal bone missing a portion of its left half. In addition to this, are many isolated shell fragments of indeterminate placement. The Crevasse Canyon specimen has several features that justify assigning it to the genus *Adocus*: (1) the characteristic surface sculpture of pits oriented in lines across the shell; and (2) a mosaic of characteristics seen in Campanian *A. bossi* and A. *kirtlandicus*. These include the structure of the bridge, which is similar to that observed in *A. bossi* from the upper Campanian Kirtland Formation of northwestern New Mexico. The cervical scute is trapezoidal, narrowing posteriorly, as in *A. bossi*. The bridge of this specimen displays a longitudinal sulcus, as in *A. kirtlandicus*. Unlike *A. bossi*, the free edge of the carapace of the Crevasse Canyon *Adocus* ends in a thick, rounded shape rather than coming to a pointed edge. The gular scute meets the humeral-pectoral sulcus just ahead of the posterior end of the gular scutes. We conclude that the Crevasse Canyon specimen is likely a new species of *Adocus*, possibly ancestral to the Campanian-age *Adocus* of northwestern New Mexico.

Keywords:

Adocus, Turtle, Crevasse Canyon,

FOSSIL TURTLES OF THE CRETACEOUS MENEFEE FORMATION, NORTHERN NEW MEXICO

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The Upper Cretaceous (Campanian) Menefee Formation is a dominantly nonmarine formation, which contains a wide variety of incomplete turtle fossils, including remains of adocids, trionychids, baenids, bothremydids, and the solemydid turtle *Naomichelys.* Two specimens of *Denazinemys* and one refered to aff. *Denazinemys* have been recovered from the Menefee Formation. Additionally, mixed in are five pieces that appear to be from a turtle pelvic girdle. These may represent the first girdle material associated with a specimen of *Denazinemys*. Additional indeterminate baenid specimens include specimen NMMNH [NM Museum of Natural History] P-70340, which includes two large pieces of the lateral edge of the anterior plastral lobe. The one specimen of the solemydid turtle *Naomichelys* is a small, ~4 cm diameter piece of turtle shell bone with the characteristic pattern of raised circles seen in this genus. This represents the only record of *Naomichelys* from New Mexico. Trionychids in the Menefee Formation are represented by a variety of shell fragments. One nearly complete costal, likely between the 3rd and 5th, has been collected (NMMNH P-25053). Additional trionychid specimens, including NMMNH P-70339 and P-70336, are recognized based on their characteristic surface pattern. The largest of the fragments clearly show the plywood structure discussed by Scheyer et al. in 2007. Pelomedusids in the Menefee Formation are represented by one specimen that includes a ~70% complete plastron and associated carapace fragments, CHCU [Chaco Culture National Historical Park] 81269, referred to the bothremyid, *Elochelys* cf. *E. perfecta*. This plastron is missing the anterior lobe, and the specimen is heavily weathered. The femoral-anal sulcus meets the medial sulcus at an "S"-shaped juncture in the center of the abdominal lobe. The two sulci are indistinguishable for ~1 cm. The placement of the hypo-xiphoplastral suture and the pattern of the sulci are similar to that seen on bothremydid turtles. In the middle portion of the plastron the sutures surrounding the narrow mesoplastron show a pattern that is diagnostic of bothremydid turtles. In addition to the plastron, parts of two sutured costals and one incomplete nuchal are present. The nuchal bone is nearly flat, with the anterior left edge of the carapace preserved. The medial edge of the preserved portion includes a cervical scute with a teardrop shape that comes to a point just beyond the right edge of the fragment. The sulci on the posterior lobe of the plastron are similar to those seen on *Chedighaii* and *Elochelys* in the "S"-shaped meeting of the midline and femoral-anal sulcus. The preserved portions of *E. perfecta* are largely consistent with what is found on this new specimen. This is the oldest bothremydid turtle in New Mexico and only the second specimen known from New Mexico. Diverse, and arguably understudied, Cretaceous turtle faunas exist outside the San Juan Basin in New Mexico. The turtle assemblage of the Menefee Formation is the second most diverse after the Fruitland and Kirtland formations in New Mexico. Diversity of turtles in the nonmarine strata of New Mexico mirrors the collecting effort expended on these units.

Keywords:

Menefee Formation, turtle, testudines

COLLECTION AND ANALYSIS OF DUST AND SOIL SAMPLES ADJACENT TO THE JACKPILE MINE, LAGUNA PUEBLO, NEW MEXICO

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Uranium mines and mills present a number of potential hazards to the local environment. Of particular relevance is the containment of contamination associated with these sites. If not properly maintained, tailings piles and ponds, and even the abandoned mines and mills themselves, may affect the surrounding communities and ecosystems.

This study aims to understand the migration of uranium from one such site, the Jackpile uranium mine and mill. By investigating the spatial, temporal, and chemical characteristics of this migration, and through the comparison of dust and soil samples, the proposed research will advance our understanding of risks related to legacy uranium mining and milling sites.

Fifteen Big Spring No. 8 (BSNE) stems (Custom Products and Consulting, Big Spring, TX) have been installed in the vicinity of the Jackpile uranium mine. Each stem has been outfitted with four BSNE sediment traps placed at heights of 0.25, 0.5, 1.0, and 1.5m. The locations of the sediment trap arrangements vary so as to address a number of issues related to vegetation density, topography, and distance from the mine.

Collected samples will be sieved into their respective size fractions. The size fractions will consist of 2mm to 0.18mm (10 to 80 mesh), 0.18mm to 0.09mm (80 to 170 mesh), 0.09mm to 0.02mm (170 to 635 mesh), and <0.02mm (-635 mesh). Once sieved, the samples will be split, and a fraction of the sample will be digested using a method involving the use of a hydrofluoric acid mixture and a hot block. Once total digestion has been achieved, each sample will then be processed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) to determine total uranium content.

Outlined here is the methodology and timeline for the remainder of this research, including the collection of dust samples and the analysis of both soil and dust samples. Also included is a discussion of previously used techniques as they apply to this study.

Keywords:

uranium, dust, aeolian, transport, mining

THE TRACE FOSSIL *ASTHENOPODICHNIUM* FROM THE UPPER CRETACEOUS OF NORTHWESTERN NEW MEXICO

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Asthenopodichnium is a trace fossil consisting of aligned and overlapping, lozenge- or pouch-shaped borings or cavities in wood, bone or coal substrates known from a handful of Cretaceous and Cenozoic records and attributed to either mayfly nymph boring or fungal rot. We add to the sparse record of this trace fossil two new occurrences, in the Campanian Menefee and Kirtland formations in northwestern New Mexico. The Menefee record is from the lower Campanian Allison Member in the Piedra Lumbre Arroyo drainage in Sandoval County. The Kirtland specimens are from the upper Campanian Hunter Wash Member in the Chaco River drainage. These traces are dense concentrations of aligned and variously overlapping, lozenge-shaped chambers in the wood xylem that we assign to *Asthenopodichnium lignorum* Genise et al. The *Asthenopodichnium* traces suggest freshwater, humid and subaerial conditions at the time of their formation. The presence of *Asthenopodichnium* in the Kirtland and Menefee formations is thus an important paleoecological indicator of freshwater deposition in systems that were deposited near the shoreline of the Cretaceous Western Interior seaway. They are also the first published evidence of wood-rotting fungi (the most likely tracemaker from the Kirtland and Menefee formations). Further work on trace fossils in wood in the Upper Cretaceous strata of northwestern New Mexico will no doubt reveal greater diversity and provide additional paleoecological information.

GLOBAL ICE AGES, REGIONAL TECTONISM AND LATE PALEOZOIC SEDIMENTATION IN NEW MEXICO

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The late Paleozoic (Carboniferous-Permian) ice ages took place when New Mexico was located in the equatorial tropics of western Pangea. Two potential primary drivers of Pennsylvanian-Permian sedimentation in New Mexico have been identified: (1) global, glacio-eustatically driven sea-level cycles, a farfield effect of the ice sheets that waxed and waned in southern Gondwana; and (2) the regional, ancestral Rocky Mountain orogeny (ARM). Most sedimentologists advocate glacio-eustasy as the primary driver of late Paleozoic sedimentation in New Mexico, but new analyses of stratigraphic architecture, facies and biostratigraphy do not support that conclusion. The classic template for understanding late Paleozoic glacio-eustatically-driven sedimentation is in the Midcontinent, where cyclothems accumulated in a quiescent tectonic setting. They are inferred to record glacio-eustatic cycles that were orbitally forced by 100 and 400 kyr eccentricity cycles. Counting Midcontinent cycles indicates that the Desmoinesian, Missourian and Virgilian comprise 44, 23 and 50 cycles, each with an inferred duration of 100 kyr, which suggests durations of 4.4, 2.3 and 5.0 million years for each of these stages. Radioisotopic chronology agrees reasonably well with these astrochronological estimates. The Wolfcampian is more difficult to calibrate astrochronologically, but it represents at least 20 cycles inferred to represent 400-ka-eccentricity, so it has a minimum duration of about 8 million years. In the New Mexico sections, strata with good biostratigraphic age control contain far less cycles than do correlative strata in the Midcontinent. Examples include well studied Pennsylvanian sections in Sierra, Socorro, Valencia and Bernalillo counties, where cyclostratigraphy identifies between 25-50% the number of cycles. Particularly significant are recent precise biostratigraphic data from the Bursum Formation at Carrizo Arroyo in the Lucero uplift of Valencia County. Here, the Bursum Formation has too few cycles to be matched to the succession of Midcontinent cyclothems, and this is prima facie evidence that regional tectonic events of the ARM exerted a greater control over the creation and preservation of Bursum depositional sequences than did eustatic events. The large Gondwana ice sheets collapsed during the Early Permian (Sakmarian = middle Wolfcampian), and subsequent Permian ice fields were too small to have driven global eustasy. Yet, recent work continues to advocate a glacio-eustatic driver of sedimentation in some younger Permian rocks in New Mexico, such as late Sakmarian and Artinskian strata in the Robledo Mountains of Doña Ana County. The cycles these studies identify are better interpreted as autocyclic shifts along the topographically complex Early Permian seacoast. Eustatic farfield effects are present in some parts of the New Mexico upper Paleozoic section, as shallowing upward cycles correlated to actual cyclothemic events thought to reflect the drawdown of global sea level during ice-sheet expansion. However, these cycles are the minority of cycles seen in most sections. Instead, the majority of the late Paleozoic section has a disorganized stratigraphic architecture and a lack of completeness (hiatuses) indicative of prolonged, repeated and/or complex tectonic events. Thus, ARM tectonism, not glacio-eustasy, was the primary driver of late Paleozoic sedimentation in New Mexico.

THE UPPER PALEOZOIC SANGRE DE CRISTO FORMATION, SOUTHWESTERN SAN MIGUEL COUNTY, NEW MEXICO: STRATIGRAPHY, AGE AND SEDIMENTOLOGY

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In southwestern San Miguel County, New Mexico, the upper Paleozoic Sangre de Cristo Formation is ~ 300 m thick. Most of the lower-middle parts of the formation are poorly exposed, but the base of the formation crops out as extrabasinal conglomerate resting with evident disconformity on the Middle Pennsylvanian Porvenir Formation. The upper 160 m of the Sangre de Cristo Formation are continuously exposed, and are mostly red-bed, non-fissile mudstone, and less common sandstone, conglomerate and calcrete. We can divide these strata into two intervals, a lower unit A, about 60-80 m thick, and an upper unit B, about 50-80 m thick. Units A and B are distinguished by the relative abundance in unit B of thin, laterally extensive sheet sandstone bodies that display abundant climbing ripple lamination. Unit A, which is composed of mudstone with intercalated crossbedded conglomerate and sandstone, contains the majority of known fossil bone localities, whereas the tetrapod footprint and fossil plant localities are from unit B. Most of the sandstones of the Sangre de Cristo Formation are subarkose to arkose, and a few sandstones and pebbly sandstones containing abundant reworked carbonate grains are classified as lithic arenites. The contact of Yeso Group strata on Sangre de Cristo Formation strata is conformable, as is the Abo-Yeso contact to the south. The Sangre de Cristo grades laterally southward to finer grained red beds of the Abo Formation. Trace fossils of invertebrates and vertebrates (mostly arthropod and tetrapod walking traces) are locally common in the upper part of the Sangre de Cristo Formation. The tetrapod ichnofauna is quite similar to vertebrate trace fossil assemblages described from the Abo Formation of central New Mexico. Plant fossils are sparse in the Sangre de Cristo Formation and are mostly macrofossil foliar remains preserved as impressions. The flora of the Sangre de Cristo Formation red beds appears to be much the same as its finer grained equivalents (Abo and Robledo Mountains formations) to the south, and likely indicates seasonally dry climates and that much of Early Permian New Mexico was covered with conifer forests of great extent and low biodiversity. The fossil vertebrate assemblage from the upper Sangre de Cristo Formation encompasses xenacanth sharks, lungfishes, lepospondyl and temnospondyl amphibians, diadectomorphs and eupelycosaurs and represents a mixture of aquatic, semi-aquatic, semi-terrestrial and terrestrial fauna. The tetrapod footprints and vertebrate body fossils indicate a late Wolfcampian age. The Sangre de Cristo Formation comprises sediments that were deposited on a broad alluvial plain in response to tectonic movements of the Ancestral Rocky Mountain deformation. In southwestern San Miguel County, these sediments are nonmarine red beds dominated by fine-grained deposits of the overbank environment and subordinately composed of coarser deposits of sandstone sheets that represent isolated broad, shallow channels of low gradient and low stream power.

U-PB GEOCHRONOLOGY OF ASH FALL TUFFS IN THE MCRAE FORMATION (UPPER CRETACEOUS), SOUTH-CENTRAL NEW MEXICO

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The Upper Cretaceous McRae Formation was deposited in the Laramide (latest Cretaceous-Eocene) Love Ranch basin and is most widely exposed in the Cutter Sag, northeast of Truth or Consequences, south-central New Mexico. Primarily fluvial in origin, the McRae Formation is divided into the lower Jose Creek Member, which contains leaf fossil sites and at least 50 petrified stumps in growth positions, and the upper Hall Lake Member. A Maastrichtian age for the McRae has been based on the presence of two dinosaur fossils, which have poorly constrained stratigraphic positions in the Hall Lake Member because of faulting and Quaternary cover. Presented here are U-Pb-zircon dates from previously undated ash fall tuffs, including three in the middle and upper part of the Jose Creek Member and the "pink" tuff located nine meters above the base of the Hall Lake Member. The fine-grained, felsic tuffs were dated using laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS). Between 11 and 17 zircons in each sample were dated, and no inherited cores were observed or analyzed. The stratigraphically lowest tuff yielded the oldest $^{206}Pb/^{238}Pb$ age (75.2 Ma) and the highest tuff yielded the youngest age (74.0 Ma), with the intermediate-level tuffs yielding ages of 74.7 Ma and 74.9 Ma. However, all four tuffs have the same age within the two-sigma uncertainty level (0.5-1.5 Ma). Taking into consideration the maximum uncertainties, the tuffs erupted between 73.0 and 76.7 Ma, making them late Campanian in age. These new dates for the lower McRae Formation indicate that the onset of Laramide sedimentation in the Love Ranch basin was contemporaneous with that in the Laramide Ringbone and San Juan basins in New Mexico, and they provide a more accurate comparison of the Jose Creek paleoflora with coeval paleoflora elsewhere in the Western Interior of North America.

Keywords:

Cretaceous, Tuffs, McRae Formation, New Mexico

TIMING AND EMPLACEMENT SETTING OF THE TURKEY MOUNTAIN LACCOLITH, MORA COUNTY, NEW MEXICO

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This study focused on igneous intrusions of the Turkey Mountains, Mora County, New Mexico, to relate the igneous structures and age of crystallization to the regional tectonomagmatic setting. The Turkey Mountains are a 365 km^2 wooded massif situated on the Southern High Plains physiographic province 5 km northeast of Fort Union National Monument. The main mass is a laccolith while subsidiary dikes, stocks, and plugs intrude the sedimentary rock cover. Because the laccolith intrusion is not exposed at the surface, well log and well cuttings from Union Land and Grazing #1 Fort Union were studied to characterize the igneous rocks that encompass the laccolith. Igneous rock was encountered at six discrete intervals within the Upper Pennsylvanian Madera Group at depths of 843-856 m, 930-980 m, 994-1012 m, 1078-1103 m, 1185-1197 m, and 1225-1239 m. The igneous rock cuttings were white colored, homogeneous, very fine grained, concoidally fractured, and dull lustered. They classified as porphyritic rhyolite based on the presence of sanidine and quartz microlites in a highly siliceous matrix. We report two new $^{40}Ar/^{39}Ar$ cooling age spectra from a middle-level (1078-1103 m) and lowest-level bulk well cutting samples. Both have classic saddle shapes that indicate excess argon. Taking the youngest part of the youngest age spectra, we interpret the sills as having a maximum crystallization age of 30.5± 0.2 Ma. This age is significantly older than the Middle Miocene lamprophyre dikes, stocks, and plugs that intrude the Turkey Mountains as well as Late Miocene to Pleistocene extrusions of the Mora-Ocate volcanic field. We submit that the Turkey Mountain granitic laccolith was emplaced within a compressive stress regime related to the waning stages of the Laramide orogeny.

BOUQUETS FROM THE PAST: PLANT BIOMINERALS AS PALEOCLIMATE INDICATORS

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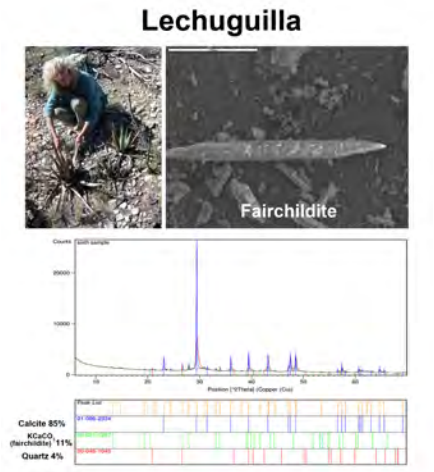
Many plants use available elements in the soil, such as silica and calcium, to make biominerals called phytoliths, which can provide structure, aid in defense against predation, and provide mechanisms to deal with environmental stressors. Some plants manufacture morphologically or chemically unique phytoliths and they can be used to identify plant families or species. Pollen, sponge spicules, diatoms, and other biogenic silicate materials have been used as paleoclimate proxies and phytoliths provide a new diagnostic tool to help reconstruct past ecological conditions. These microfossils can be recovered from modern plants, soils, sediments, lacustrine deposits, eolian deposits, archaeological sites, plant fossils, and allochthonous sediment deposits in caves. North American phytolith research is limited, especially in arid regimes. Phytoliths from arid land plants are often of calcic composition, e.g. calcium oxalates, calcite, etc., thus have significantly different properties than their silicate counterparts.

Modern plants from several ecological zones and habitat types in New Mexico and Arizona were collected and analyzed to create a phytolith reference library. Desert plants like cacti, creosote, and yucca yielded several different phytolith morphologies, with primarily calcic minerals. Riparian indicator species such as horsetail, Maximilian's sunflower, and mulberry manufactured primarily amorphous silica phytoliths with diverse morphologies and smaller amounts of other minerals.

Phytoliths are released into the environment through vegetative decay, fire, herbivore usage. They can then be buried or transported by wind, water, animals, or geological events, and usually some amount of weathering takes place along the way. We simulated mechanical weathering of the phytoliths to understand how abrasion would affect the identifiable morphological features and if chemical makeup was a factor in preservability from abrasion. Despite alterations of surface features, most phytoliths of all chemical compositions were still identifiable after the simulated weathering experiments indicating long term preservation potential.



Lechuguilla, a Chihuahuan Desert endemic species, produces phytoliths of 3 different mineralogies: calcite, fairchildite, and quartz. A lath-shaped fairchildite crystal with a length of 200 microns is pictured in the SEM. Phytoliths with these mineralogies have a good chance of being preserved.

Keywords:

phytoliths, biominerals, paleoclimate, new mexico, lechuguilla, desert, riparian

THE ACTIVE RIO GRANDE RIFT: SUMMARIZING OUR CURRENT UNDERSTANDING OF PRESENT-DAY DEFORMATION FROM GEODETIC AND STRESS MEASUREMENTS

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Geodetic and stress-field studies of the Rio Grande rift (RGR; Aldrich et al., 1986; Kreemer et al., 2010; Berglund et al., 2012) have aimed at precisely measuring active crustal deformation and understanding the associated dynamic processes and stresses. How is deformation distributed spatially across a large area spanning the RGR from the Great Plains to the Basin and Range province and how does this relate to lithospheric structure and the stress field? We review results and interpretations from previous studies and provide a summary of our current knowledge of the active tectonics related to the RGR.

With sufficiently long time series and noise characterization, modern techniques for processing Global Positioning System (GPS) phase data allow us to estimate a GPS receiver's relative horizontal position and velocity with sub-millimeter accuracy. Spatially differentiating these velocities along a given profile gives the strain rate in that dimension. With respect to stable North America, a low, westward velocity gradient exists from near zero velocity in the Great Plains up to ~4 mm/yr just west of the Colorado Plateau. Average station velocities within the basin-bounding normal faults of the RGR are just above 1 mm/yr. This results in an average strain-rate of ~1.2 nanostrain/yr along five ~1000 km long east-west profiles. We used a statistical F-test to determine whether or not strain in these profiles is better described using a single linear model, or if introducing more parameters in a segmented model is a better statistical fit to the data. We found that a single two-parameter regression was a better statistical representation than any of the segmented models, which supports previous studies' conclusion that strain is broadly distributed across a large area extending well beyond the surface expression of the RGR.

However, we cannot disregard the clear anomalies present in both GPS and stress measurements. We find localized velocity and strain anomalies in or near the RGR. For example, a zone of possible east-west contraction east of the RGR in southern Colorado and northern New Mexico corresponds spatially to ~NNE horizontal minimum stress orientations (S_h) defined by aligned Plio-Quaternary volcanic vents in the eastern Jemez lineament. These differ markedly from generally east-west extension and S_h in and near the rift, and the paleostress field suggests this situation has existed for a few million years. These may reflect E-W contraction and compressional horizontal stress caused by lithospheric flexure due to buoyant mantle or magma emplacement in the eastern Jemez Lineament. The E-W oriented S_h closer to the center of the rift provides evidence of rift-related extension beyond its surface expression which is congruent with both geodetic results and tomographic images of the lower crust and mantle. In addition, the best-fit E-W velocity gradient in parts of the rift is higher than in adjacent Colorado Plateau or Great Plains, but error is larger due to low station density (3 or 4 in each transect). Longer observation times and higher station density is required to resolve if the rift does correspond to measurably higher E-W velocity gradients.

Keywords:

Rio, Grande, rift, geodesy, GPS, geophysics, strain, extension, stress

PALEO-HYDROLOGIC RECONSTRUCTION OF THE JORNADA BASIN, NEW MEXICO USING U AND SR ISOTOPES IN PEDOGENIC CARBONATES

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Pedogenic carbonates in arid and semi-arid soils could be used as a proxy indicator of Quaternary paleo-environmental conditions. Previous studies have utilized C and O isotopic compositions in pedogenic carbonates of the desert southwest USA to reconstruct paleo-vegetation and paleo-precipitation. Climatic changes affect hydrological budgets thus prediction of water balances in future climates within the arid Southwest. However, due to inconsistency of paleo-climate information revealed from various proxies, constraining the timing of Quaternary climatic oscillations in the Southwest remains a challenge. Uranium and Sr isotopes are co-precipitated with Ca in carbonates. Here, we use Sr and U-series isotopes in stage V pedogenic carbonates at the La Mesa geomorphic surface within the Jornada Basin, New Mexico to: (1) identify Ca sources, (2) determine carbonate ages, and (3) infer paleo-hydrologic soil conditions during their formation in soils. We analyzed calcareous soil (H1, at 40 cm depth from surface), pedogenic carbonate/ caliche (H2 and H3, at 60 and 200 cm depths respectively) obtained along a soil profile, and modern dust collected within the basin. $^{87}Sr/^{86}Sr$ of the labile fraction of H1, H2, and modern dust showed ratios between 0.7086 and 0.709. This suggests significant contribution of dust-sourced Sr to the formation of young carbonates in shallow soils, assuming a constant dust composition since H2 carbonate formation with atmospheric circulations similar to modern conditions.H3 labile fraction in the deep, old carbonates showed slightly radiogenic $^{87}Sr/^{86}Sr$ ratios (0.711), suggesting a source of highly radiogenic dust (derived from areas different from modern dust source regions). Uranium concentrations in bulk caliche and soils range from 1.00 to 3.67 ppm and the $(^{234}U/^{238}U)$ activity ratios (UAR) range from 0.91 to 1.34. The depth profiles of [U] and UAR suggests surface addition of uranium probably from dust. H3 and H2 carbonates yielded U-series ages ranging from 145.7 ± 3.6 to 5.94 ± 0.1 ka (2σ) and initial $(^{234}U/^{238}U)_0$ between 0.95 and 1.35 (±7‰, 2σ). The calcareous soils (H1) did not yield any reliable age, but had a calculated $(^{234}U/^{238}U)_0$ of 0.92. These ages represent a mixture of old and younger carbonate at respective depths and show a general decreasing trend towards surface consistent with the carbonate growth history inferred from the stratigraphic relationship. The $(^{234}U/^{238}U)_0$ could be used as a proxy for soil paleo-waters during carbonate formation and shows considerable variations with depth in the soil profile. If the $(^{234}U/^{238}U)_0$ ratios vary based on soil moisture availability, these observations suggest that H2 carbonates were formed during a relatively wet period while H1 and H3 carbonates formed under dry periods. This study demonstrates the relevance of radiogenic isotopes in reconstructing Quaternary paleo-hydrologic events as well as shedding light on formation of pedogenic carbonates and paleoclimates of New Mexico.

U-Pb Geochronology and Tectonic Significance of Arc-Related Proterozoic Rocks in Southern New Mexico

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The Mazatzal province is thought to be a juvenile arc terrane that accreted onto southern Laurentia during the ~1.65 Ga Mazatzal orogeny (Karlstrom et al., 2004). Thermal overprinting and deformation during the emplacement of A-type granites at ~1.46 Ga has made it difficult to date Proterozoic fabrics. U-Pb ages were obtained by LA-MC-ICPMS from four localities in southern New Mexico. These dates will be used to constrain the timing of deformation and the relationship of these rocks to the arc magmatism.

A weakly deformed quartzite from the Caballo Mountains yields the youngest maximum depositional age (MDA) of 1629 ± 27 Ma (2s); a similar quartzite in the San Andres Mountains yielded an MDA of 1657 ± 11 Ma. Phyllites from the San Andres yielded MDAs of 1664 ± 19 Ma and 1669 ± 16 Ma. Schist from the San Andres yielded an MDA of 1651 ± 14 Ma. Quartz-rich amphibolite (possibly sedimentary) from Mud Springs Mountain yielded a MDA of 1655 ± 17 Ma and a sphene U-Pb metamorphic age of 1427 ± 20 Ma. A low-grade conglomerate from the Kingston District yielded a MDA of 1661 ± 21 Ma, and a metasedimentary rock from there yields the oldest MDA of 1670 ± 30 Ma.

A gneissic granite from the Caballo Mountains intruded at 1667 ± 27 Ma. An undeformed granophyre from the Kingston District yielded an age of 1659 ± 21 Ma. Granites from the San Andres yielded ages of 1654 ± 14 Ma and 1667 ± 30 Ma. A boudinaged amphibolite intruding orthogneiss yielded an age of 1629 ± 13 Ma; a granitic dike that cuts the amphibolite had zircons with ages of 1463 ± 44 Ma and 1646 ± 16 Ma. These are interpreted as representing inherited zircons at 1.65 Ga and igneous zircons at 1.46 Ga.

These new ages combined with previously published ages from the Mazatzal province in New Mexico yield MDA's ranging from 1629–1670 Ma and igneous ages of 1623–1684 Ma. Thus, deposition seems to be synchronous with magmatism in the province, suggesting it occurred prior to arc-continent collision. In the Kingston District, rocks have apparently escaped significant deformation, whereas ~30 km east in the Caballo Mountains rocks are highly deformed. In the San Andres Mountains, rocks range from undeformed to weakly deformed quartzite to highly deformed orthogneiss. Contact metamorphism near ~1.6 Ga plutons has yielded large garnet growth. The pluton that likely caused the garnet growth is mostly undeformed but has discrete shear zones. The age of these shear zones is unknown. Presence and intensity of deformation does not appear to be related to age of the protolith or location within the Mazatzal province. We suggest that the end of Mazatzal arc magmatism occurred at 1645 Ma, prior to final collision and the subsequent onset of bimodal, possibly extensional magmatism that occurred around 1630 Ma in southern New Mexico.

References:

Karlstrom et al., 2004, NMGS Special Publication 11, p. 1-34

N-S EXTENSION AND BIMODAL MAGMATISM DURING EARLY RIO GRANDE RIFTING: INSIGHTS FROM E-W STRIKING DIKES AT FAULKNER CANYON, SOUTH CENTRAL NEW MEXICO

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North-northeast extension and bimodal magmatism during early Rio Grande rifting is recorded by the emplacement histories of two suites of dikes and associated plugs at Faulkner Canyon. Whole-rock geochemistry and 40Ar/39Ar data suggest that alkalic trachybasalts (34.7 +/- 1.1 Ma) and trachydacites (35.96 +/- 0.09 Ma) were emplaced first and were followed by the emplacement of two petrogenetically distinct groups of calc-alkaline magmas consisting of basaltic andesite and andesite. Major and trace element compositions from these two suites indicate that Ne-normative trachybasalts (Nb/Ba = 0.057-0.026) were likely derived from the asthenosphere and evolved to Qtz-normative trachydacitic compositions by assimilation and fractional crystallization (AFC) of mid-lower crust. Calc-alkaline magmas (Nb/Ba = 0.006-0.013), however, were likely sourced from an enriched lithospheric mantle source and evolved independently. Spatial zonation of hypabyssal units suggest that magmas were emplaced by a series of laccolithic bodies that may have been elongated from a previously existing zone of structural weakness possibly associated with the Texas Lineament. Although previous works suggest that early Rio Grande rift extension was oriented generally E-W during hypabyssal emplacement, localized stresses from the intrusions initially deformed the overlying Eocene Palm Park Formation into a broadly folded E-W trending anticline and sub-parallel joints that were filled by alkaline and calc-alkaline magmas.

Keywords:

Rio Grande rift, igneous petrology, structural geology

DEFINING THE RESPONSE OF SOUTHWESTERN NORTH AMERICAN CLIMATE TO ABRUPT NORTHERN HEMISPHERE CLIMATE CHANGE EVENTS DURING THE LAST GLACIAL PERIOD

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There are well-established reoccurring climate change events during the last glacial period in the Northern Hemisphere as seen in Greenland ice core records. These events preserved in the ice cores are defined as Greenland stadials (GS) and interstadials (GI), and led to or were associated with reorganization of atmosphere temperature-pressure and ocean circulation surface temperature gradients in the Northern Hemisphere. However, to what extent they represent changes in effective moisture and temperature at regional scales remains unknown. The aim of this project is to provide constraints on what extent the changes seen in the Greenland ice core records represent changes in moisture and temperature in southwestern North America (SWNA). To determine this, we will use a speleothem from Carlsbad Cavern in the Guadalupe Mountains that was collected from a site that is thought to be sensitive to changes in temperature and moisture because of the short connection to the surface. Precise ages on the speleothem will be obtained using uranium (U)-series radiometric dating to establish a high-resolution chronology for a period between 50 and 30 ka. Stable isotopic values of $d^{18}O$ and $d^{13}C$ have been obtained for stalagmite CaCa-BC5, which was collected in the Main Corridor in Bat Cave Passage. The stable isotope time-series will be used to make interpretations regarding regional temperature, effective moisture, and precipitation variability. Some preliminary strontium (Sr)-isotope paleothermometry work will be included in this study to help in determining regional temperatures. Furthermore, comparisons with other speleothem records and continental proxies will provide additional framework for determining the SWNA regional climate response.

Keywords:

Paleoclimate, Carlsbad Caverns, Speleothem

DIVERSE, SELACHIAN-DOMINATED FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS TOCITO SANDSTONE, SANDOVAL COUNTY, NEW MEXICO

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Near Cabezon in west-central Sandoval County, New Mexico, lenses of the coarse-grained sandstones of the Upper Cretaceous (Coniacian) Tocito Sandstone produce abundant quantities of selachian teeth and other fossils. The vast majority, picked from sieved anthills, are 5 mm or less in size, with a few larger fossils found adjacent to the anthills. The Tocito Sandstone is sandwiched between a lower tongue of the Mulatto Member of the Mancos Shale and an upper tongue of the Mulatto, and the inoceramid bivalves in the Mulatto both above and below the Tocito near Cabezon indicate an early Coniacian age. The Tocito has been interpreted as offshore sands deposited parallel to the coastline of the Western Interior Seaway. The most common of the Tocito selachians are from the order Lamniformes, representing the two families Odontaspididae (*Cretolamna appendiculata*) and Mitsukurinidae (*Scapanorhynchus* sp.). Other taxa present include *Hybodus* sp., *Polyacrodus* sp., *Ptychodus mortoni*, *Squalicorax* sp., cf. *Scindocorax* sp., *Cantoscyllium* sp., *Ptychotrygon* sp., *Texatrygon* sp. (possible new species), as well as other selachians yet to be identified. Non-selachian fish include cf. *Micropycnodon kansasensis*, cf. *Coelodus stantoni*, and at least one other teleost. One gar (represented by a single scale) that apparently washed down from a freshwater source, has been identified. In addition to the fishes, reptiles (crocodilians), cephalopods (ammonoids), inoceramid clams and various gastropods have also been documented. This assemblage has both increased the Coniacian vertebrate taxa known from New Mexico and extended the ranges (stratigraphic and geographic) of some of these species.

THE SUSTAINABILITY AND MANAGEMENT OF THE TRUTH OR CONSEQUENCES, NEW MEXICO GEOTHERMAL RESOURCE

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Deterioration of geothermal resources due to overexploitation often results from the lack of a comprehensive water management system. We have investigated the sustainability and water management practices of the Truth or Consequences, New Mexico, hot-spring system in the southern Rio Grande Rift. There are currently ten commercial spa resorts and an estimated 158 geothermal production wells utilizing the relatively hot (~ 41 °C) groundwater within the town's 0.6 km^2 historic hot-springs district. Over the last seven decades there has been an estimated 285% increase in the number of geothermal wells in this area. Theis et al. (1941) provided measurements of borehole discharge temperature, water-table elevation, artesian pressure heads, water chemistry and natural hot-spring discharge. We replicated these measurements between October 1, 2012 and September 30, 2013 for comparison to gain insight into the system's response to development. We also estimated current water consumption and characterized diurnal temperature and pressure patterns to guide resource management.

We found that there has been virtually no change in water chemistry between 1941 and 2013. However, silica and cation-based geothermometry indicates that deep reservoir temperatures may have increased by 10 to 14%; this might be a result of drawing water from greater depths due to increased pumping in the area. Spatial discharge and temperature patterns have shifted, while temperature magnitudes show little change (~ 1 °C decline). The temperature decline is most likely due to changes in well depth, as current wells are typically 40% shallower than those of 1941. The spatial pattern of water-table elevation has changed very little, while the magnitude of mean water-table elevation has declined by approximately 0.4 meters. Additionally, artesian pressures appear to have dropped, although data are very limited. The estimated amount of natural geothermal discharge has declined by approximately 13% to 7.14 x 10^{-2} m^3s^{-1}. Overall, the evidenced changes are marginal considering the aggressive development that has taken place since 1941; thereby suggesting the system is reasonably healthy. Our analysis of daily water-table elevations and discharge temperatures in the hot-springs district indicates that fluctuations of these parameters are largely controlled by human water demand. Measured values decline during periods of high demand and recover when demand diminishes. The periods of daily recovery are believed to play an important role in mitigating long-term adverse effects of development. Data on water consumption limit our ability to make inferences about future development, as only 6.3% of appropriated water is accounted for in the current reporting system regulated by the State. While evidence suggests that the system is currently not overexploited, it is imperative that a comprehensive monitoring program and water usage reporting system be emplaced before the resource is further developed.

Keywords:

Geothermal, sustainability, hot springs

NEW MEXICO'S PALEOCLIMATE AND ITS AFFECT ON PLESIADAPIFORM BIOGEOGRAPHIC DISPERSAL – A STUDY OF FOSSIL GEOGRAPHIC RANGE COMPARED WITH ESTIMATED BODY MASS FOR THESE STEM PRIMATES

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Plesiadapiformes (possible stem-primates) proliferatedaround the world during the Paleocene-Eocene with a large sample found in the San Juan Basin of New Mexico.The Paleocene-Eocene Thermal Maximum (PETM) occurred 56 million years ago, and is considered the most extreme change in the Earth's climate during the Cenozoic Era. This global warming event is linked to the extinction of many plesiadapiformes, and the rise of "true" primates (euprimates).Geographic range has a strong effect on extant primate species. Dispersal can be estimated for plesiadapiformes by using fossil localities. Estimates suggest a positive correlation between geographic range and generic diversity at the clade-level for larger plesiadapiforms (ex. plesiadapids r= .764, n= 12, p= .004). However, there is no correlation in smaller plesiadapiforms (i.e. paromomyids, picrodontids, palaechtonids, and microsyopids). Plesiadapiformes were a highly diverse order with >9 families and >150 genera. These basal primates varied in size from small, mouse-like species (7 gram Micromomysvossae) to that of cat-sized species (3,055 gram Plesiadapiscookei).To better understandplesiadapiform paleogeographic-dispersal and climate adaptations, it is necessary to have an extant, analogous species to compare them to. This study will look at anumber of living species: metatherian phalangeriformes (Trichosurus vulpecula, Didelphis orientalis, and Petaurusbreviceps), rodents (Sciurusspecies), dermoptera (Galeopterus variegatus), and prosimians (Microcebus species). New correlations (comparing m1 area body massand microwear dietary types) provide insights into dispersal regression models that failed to correlate between range and fossil genus biodiversity.New Mexico fossil data suggests that small plesiadapiforms' geographic dispersal was highly controlled by size and diet (both factors highly affected by the PETM).Plesiadapiform groups that showed no correlation (ex. paromomyids r= .292, n= 27, p= .139) now show a positive correlation between body mass, diet type, and paleogeographic-dispersal (r= .690, n= 9, p= .05).

NEW STRATIGRAPHY AND VERTEBRATE PALEONTOLOGY FROM PALEOLAKE OTERO, WHITE SANDS MISSILE RANGE

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Archaeological and paleontological studies in the Tularosa Basin have revealed the possibility of artifacts in association with the fossil remains of a mastodon and a series of vertebrate trackways. Preliminary excavation of the site recovered fragments of a molar, a partial tusk and bone fragments belonging to a juvenile mastodon. A partial ulna from a woodpecker and a partial femur from a mouse were also recovered from the same unit.The vertebrate trackways were composed of camlids, proboscidean, and canid tracks. Print, step, and stride length measurements of the tracks indicate that these large mammals had a walking speed that ranged from 2.3 km/h to 4.2 km/hr. Radiocarbon dates indicate that the mastodon fossil remains are no younger than 35 kya, while the trackways were made between ~35 kya to ~25.7 kya. Paleoenvironmental reconstruction of the site indicates that the mastodon was living near a wetland environment, while the formation of the trackways coincides with more arid conditions for the region. The results from this study indicate that the fossil remains and footprints are associated with lake margin deposits that predate the last glacial maximum and the arrival of humans in New Mexico. One explanation for the presence of lithic flakes found around the fossil remains is that they could have been washed in from an upslope archaeological site. Fieldwork will continue in 2015 to develop a more detailed assessment of the stratigraphy, paleoclimate, vertebrate paleontology and archaeology for the Tularosa Basin and Paleolake Otero.

Keywords:

Lake Otero, paleoclimate, mastodon

ANALYSIS OF MORPHOLOGICAL DIFFERENCES BETWEEN TWO EARLY EOCENE HORSES: *MINIPPUS JICARILLAI* OF NEW MEXICO AND *SIFRHIPPUS SANDRAE* OF WYOMING

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Hyracotherium is the earliest (Eocene, Wasatchian) known taxon of Equidae and is well represented by fossils from the San Jose Formation, San Juan Basin, New Mexico. In 2001, Froehlich proposed a cladotaxonomy that subdivided *Hyracotherium* into nine new genera by using cladistic analysis of 121 morphological characteristics. We analyzed nine supposedly diagnostic characteristics of the lower molars as well as individual tooth sizes of two of the genera named by Froehlich, *Sifrhippus* (*S. sandrae*) and *Minippus* (*M. jicarillai*). These are two of the smallest and most primitive species of equids. Compared to *M. jicarillai*, *S. sandrae's* lower molars have an anterior fovea, which is created by the paracristid curving up the metaconid. Also, *S. sandrae* has comparatively weak lophids. The specimens involved in this study were the *M. jicarrillai* holotype (NMMNH [New Mexico Museum of Natural History] 9239), four *M. jicarrillai* paratypes (AMNH [American Museum of Natural History]: 4637, 16761, 48022, 48069), and a cast of the holotype of *S. sandrae* (UM [University of Michigan] 83567). These specimens did not show the "diagnostic" characteristics consistently; some characteristics were difficult to measure, and others were quite subjective. Also, characteristics were sometimes unobservable due to wear and weathering. The size of each tooth falls within or close to the size range previously proposed for *S. sandrae*. It is difficult to distinguish the anterior fovea, and the lophid seems relatively the same on all specimens with only very minor variation. Overall, the holotype and paratypes of *M. jicarillai* appear no different from *S. sandrae.* The differences are very minor and arguably due to individual variation. We thus conclude that the supposedly "diagnostic" characteristics show intraspecific variation rather than taxonomically significant variation, so *S. sandrae* and *M. jicarillai* are the same species. Past studies show that speciation of *Hyracotherium* is due to body size, and while tooth characteristics vary, they are rarely consistent within a single species. The other small species of *Hyracotherium*, *H. index*, was not analyzed in this study; however, this species is likely not taxonomically different from *M. jicarillai* or *S. sandrae*. *Sifrhippus*, *Minippus*, and the other genera created by Froehlich are not separate taxa, and all should be classified under the genus *Hyracotherium*.

Keywords:

Equidae, Hyracotherium, Sifrhippus, Minippus

BIRTH AND EVOLUTION OF THE RIO GRANDE FLUVIAL SYSTEM: NEW INSIGHTS FROM RIVER GRAVEL PROVENANCE STUDIES AND ^{40}AR/^{39}AR DATED PALEOPROFILES

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Fluvial systems are sensitive, yet complex gauges of active tectonic processes. The Rio Grande through northern New Mexico provides an ideal location to evaluate neotectonic influences on river integration and incision. Rio Grande axial rivers did not reach southern rift basins until 4-5 Ma and did not reach the Gulf of Mexico until after 1 Ma; instead, upstream drainage was divided among several intermittently connected, internally drained basins. The processes that influenced hydrologic integration of Rio Grande rift basins, and timing of integration of sub-basins, remain incompletely understood. This study aims to reconstruct the birth of this continental scale river system, understand the time evolution of its integration, and study differential incision of the northern Rio Grande/Chama system over the last ~5 Ma.

Detrital zircon and detrital sanidine dating of modern and ancestral Rio Grande river sands, combined with ^{40}Ar/^{39}Ar dating of adjacent basalt flows, is underway to add new data to ongoing studies of the provenance for various paleoriver deposits. Thirteen detrital grain samples have been collected from paleoriver deposits that range in age from 4.5 Ma to modern sands. Progress to-date to constrain the ages of the paleoriver deposits and associated paleoprofiles includes eight new ^{40}Ar/^{39}Ar ages on basalts that overlie or underlie the deposits. Ages are reported at 2σ uncertainty relative to FC-2 at 28.201 Ma and 40K total decay constant of 5.543e-10/a. At the Red River confluence 4 new basalt ages listed in stratigraphic order (bottom to top) are 4.93± 0.03 Ma (lower Servilleta flow), 4.85± 0.03 Ma and 4.79± 0.08 Ma (middle Servilleta flow), and 3.43± 0.08 Ma (upper Servilleta flow at this location). The distinctly older ages for the middle/lower Servilleta basalts indicates a ~1.4 Ma time gap between the lower/middle and upper Servilleta flows. The middle/lower Servilleta ages at the Red River confluence are nearly analytically identical and likely represent several flows emplaced over a ~100 ka interval. Pilar Mesa basalts have stratigraphically constrained ages (bottom to top) of 3.48± 0.12 Ma, 3.36± 0.06 Ma, and 3.09 ±0.10 Ma, which correspond to the age of the upper Servilleta flow at the Red River confluence.

A new basalt age at Black Mesa of 4.51±0.03 Ma, interpreted with respect to existing ages of ~3.5 (Ar-Ar) Ma and a 2.85 Ma age (K-Ar) leads to a testable hypothesis that Black Mesa basalt flows record a longer history of basalt flows than previously known. The observed river deposits under basalts of 4.5 and 3.5 Ma, suggest that basalts likely flowed down ancestral paleorivers (e.g. possible paleo Rio Grande, paleo Rio Ojo, or paleo Rio Embudo) at several times during the overall aggradational accumulation of Servilleta basalts on the Taos Plateau from 4.8 to 2.8 Ma. Possible local vent sources for the flows needs to be investigated, and provenance of underlying deposits clarified, but the indication of multiple ages of basalt flows at Black Mesa raises the possibility of elucidating fluvial connectivity between the Espanola basin and upstream headwaters from 4.5 to perhaps 2.85.

QUANTIFYING THE EFFECT OF THINNING VEGETATION ON EVAPOTRANSPIRATION IN A MOUNTAINOUS WATERSHED THROUGH REMOTE SENSING

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A long-term water balance study in an experimental watershed of the Sacramento Mountains monitors the impact of thinning vegetation on groundwater recharge. The study objective is to evaluate if the tree thinning will increase groundwater recharge in the mountains to provide larger regional flows to aquifers in surrounding basins. In the semi-arid Southwest, evapotranspiration (ET) makes up 75 to 95 % or more of the total water budget. The standard methods for its quantification have large uncertainties, especially for heterogeneous land surfaces. The variability of daily vegetation transpiration and solar radiation with time of year and the effects of complex terrain on the amount of solar radiation reaching sloped land surfaces of different aspects create a seasonal and spatial variability of ET that is not well quantified in mountainous regions.

Through applying the remote sensing model METRIC (Mapping Evapotranspiration with high Resolution and Internalized Calibration) to satellite imagery from the LANDSAT satellite, we calculate high-resolution maps of ET for the Sacramento Mountains watershed area to quantify spatially-distributed estimates of ET before and after thinning. METRIC calculates ET through applying an energy balance that is calculated spatially across an image to estimate ET for each pixel that represent an area 30 meters by 30 meters. In the Sacramento Mountains watershed there are 4 sets of paired plots consisting of a control plot adjacent to the thinned plot. Differences in ET are calculated between thinned and control plots in the watershed before and after thinning. To determine the net impact of thinning on ET for an image and account for differences not due to thinning, pre-thinning ET differences between each pair of control and thinned plots are subtracted from the post-thinning differences between that same pair of control and thinned plots.

Estimates of ET from METRIC indicate a significant net decrease in ET in the first year after thinning for all of the thinned plots but show significant variability between areas with different terrain characteristics. Future analysis with more images over the course of the season in later years will help to more precisely evaluate the time-scale and rate of change of the effect of thinning on ET. Future insights based on such estimates could also help in identifying areas that have the largest response to land management practices such as tree thinning.

Keywords:

evapotranspiration, experimental watershed studies, Sacramento Mountains, vegetation thinning, remote sensing, land cover changes, water-balance

PRELIMINARY INTERPRETATION OF WATER CHEMISTRY AND GROUNDWATER LEVELS IN THE EASTERN SAN AGUSTIN PLAINS AND UPPER ALAMOSA CREEK, N.M.

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We present a compilation of water chemistry and groundwater level measurements from the eastern San Agustin Plains and the upper Alamosa Creek, NM. The San Agustin Plains forms a closed surface water basin with poorly constrained groundwater connections to neighboring basins. This basin is surrounded by the Datil Mountains to the northwest, the Gallinas Mountains to the northeast, Tres Montosa to the east and the northern San Mateo Mountains to the southeast. The C-N embayment of the eastern San Agustin Plains extends between the Luera and northern San Mateo Mountains. A low surface water divide separates the C-N embayment and the upper Alamosa Creek drainage. We define upper Alamosa Creek from its headwaters at the surface divide with the C-N embayment to just beyond the Monticello Box upstream of the village of Monticello.Both the eastern San Agustin Plains and upper Alamosa Creek occupy normal-fault bounded basins. The uppermost units of the San Agustin Plains consist of sandy basin fill, with thick playa-lacustrine deposits in the C-N embayment. The primary aquifers of Alamosa Creek are shallow alluvial aquifers. Uplands surrounding these basins are underlain by a series of ignimbrites, volcaniclastic sediment and lava flows associated with the Mogollon-Datil volcanic field, which locally may have high transmissivity fractured zones. Nested calderas are present near the boundary of the C-N embayment and upper Alamosa Creek.We sampled groundwater levels, major ion and trace metal chemistry, and environmental tracers including stable isotopes (O and H), carbon-14 and tritium. Groundwater levels have very low gradients in the eastern San Agustin Plains. However, between the C-N embayment and upper Alamosa creek, there is a steep southward groundwater gradient. In the upper Alamosa Creek, groundwater levels are generally shallow and mimic topography. The transition suggests a very low transmissivity zone in the aquifer under the upper Alamosa Creek and the C-N embayment boundary.Trace metal and major ion chemistry suggests there is little connection between the San Agustin Plains and the Alamosa Creek basins. Major ion chemistry results have dominant Ca to Na and HCO_3 to SO_4 concentrations with slightly lower Ca and higher Na concentrations in the eastern San Agustin Plains, relative to the Alamosa Creek drainage. Concentrations of trace metals appear to be spatially correlated with faults and caldera margins in the eastern San Agustin Plains. They have generally low concentrations both in the central basin and in the upper Alamosa Creek.

The ^{14}C groundwater ages show relatively “old” water (>10,000 years on average) in the eastern San Agustin Plains, while the waters in upper Alamosa Creek are dominantly younger. This is further supported by the presence of tritium in the upper Alamosa Creek waters (groundwater ages <50 y) and the general lack of tritium from water samples from the eastern San Agustin Plains. The isolation of the shallow aquifers of the eastern San Agustin Plains from Alamosa Creek is further supported by snow-dominated lighter $\delta^{18}O$ values in the San Agustin Plains groundwater, and heavier $\delta^{18}O$ values in the Alamosa Creek groundwater.

STRUCTURAL-DEPOSITIONAL FEEDBACKS IN A FEATURE-CHALLENGED LANDSCAPE: THE BLACK BUTTE 7.5-MINUTE QUADRANGLE

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The Black Butte 7.5-minute quadrangle in the SE part of the Albuquerque Basin of the Rio Grande rift reveals a complex geologic history of structurally-controlled fluvial and alluvial deposition and incision that is masked by low relief. The quadrangle extends eastward from the Rio Grande valley across uplands toward Abo Canyon and the northern Los Pinos Mountains. Drainages entering the southern basin all turn toward Veguita, NM, down a gravity gradient towards a regional gravity low. The dominant topographic feature on the quadrangle is Black Butte (Turututu), a horst of Oligocene-lower Miocene basaltic andesite lava flows underlain by three ash-flow tuffs. The majority of the quadrangle area is composed of subplanar Quaternary sediments, including the top and terraces of the ancestral Rio Grande, alluvial fans, local tributaries, their terraces, and Holocene valley fills. The distinctive suites of clast compositions are (1) ancestral Rio Grande (ARG) pebbly sands, sandstones, and gravels from the north that include 1.4-Ma obsidian; (2) broad constructional and inset fans of the Abo drainage; (3) broad constructional fans from the Palo Duro drainage; (4) inset fans of Pino Draw; and (5) smaller alluvial fans and inset fans from Los Pinos Mountains. Smaller drainages rework sediments from these sources. Alluvial fans and inset fans from the Abo drainage dominate the eastern half of the quadrangle and along the northern part parallel to the present Abo valley. Palo Duro fans dominate the southwestern part of the quadrangle. Smaller fans dominate the southeastern corner. ARG-sourced pebbly sand covers nearly horizontal steps and slopes on the west and west-central parts of the quadrangle. Subtle north-northeast-trending topographic steps from Maes Arroyo to Abo Arroyo are Quaternary normal fault scarps eroded to form laid-back gentle slopes. Three strands within the down-to-the-west Maes-Abo (normal) fault zone (MAFZ) drop planar levels of ARG deposits. The prominent north-northeast-trending down-to-the east Military Road (normal) fault zone (MRFZ) cuts SW from the modern Abo drainage through Abo fan deposits that predate maximum level of Rio Grande aggradation, is cut by Pino Draw, and eventually pinches out or is buried by Palo Duro fan deposits or more recent small Los Pinos piedmont deposits. The MRFZ in the central area of the quadrangle has a young graben at its base that deforms recent small drainages and an intermediate terrace in Abo Arroyo. Deposits from Abo Arroyo spill out around the MRFZ in a set of inset fans, with the youngest levels burying traces of the MAFZ. More recent (post-faulting) alluvial fans are being deposited on ARG surfaces by small drainages that cut through wind-gaps in the MRFZ horst. Terraces of Pino Draw are not preserved through the MRFZ, affecting possible correlations of terraces east and terraces west of the fault. ARG deposits (<1.4 Ma) abut the west side of the MRFZ before being dropped by the MAFZ to the west. This highest level of ARG deposits is likely to be at the maximum level of aggradation that occurred at approximately 800 ka.

URANIUM SPECIFIC FILTERS FOR REMOVAL FROM GROUNDWATER AND DRINKING WATER

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Uranium has a significant impact on life in several Western states including New Mexico. The EPA in 1991 proposed the uranium standard for drinking water to be 30 ppb (EPA 1991) but groundwater in uranium-rich areas can range up to 120 ppb (Langmuir 1997). This creates a large problem in New Mexico because most drinking water comes from sources that can be contaminated with high uranium concentrations. Removal of uranium by binding to a subsequently-separable solid is becoming a highly sought technology in industry and uranium research. Veliscek-Carolan et al (2013) reported that the non-functionalized titania oxide absorbed 20% uranium selectively from a mixed solution of other actinides and lanthanides and radioactive material. They additionally found that with other functional groups the absorption rate increased to 50% selectively to uranium (Veliscek-Carolan 2013).In my project we will be developing potential uranium filters with a new proprietary material that is an inorganic-organic hybrid material on the bases of graphite developed by Dr. Frolova.This is a new material that has recently been prepared and will be patented. The goal of this new material is to create a surface which will specifically absorb uranium, thus significantly reducing uranium concentrations in drinking water as an inexpensive, reusable commercial filter. This will be accomplished by modifying carbon material with organic pendants that have binding characteristics specific to uranium. In our preliminary results we were able to concentrate 91.6% of uranium on our material and 81.98% of uranium when mixed with other common divalent cations.

Keywords:

Uranium, filter

GEOCHEMICAL EXPLORATION FOR OIL AND GAS IN THE ROCKIES: STRATEGIES FOR SUCCESS

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Geochemical exploration for petroleum is the search for surface or near-surface occurrences of hydrocarbons and their alteration products. Geochemical and microbiological surveys document that hydrocarbon microseepage from oil or gas accumulations is common and widespread, is predominantly vertical (with obvious exceptions in certain geologic settings), and is dynamic (responds quickly to changes in reservoir conditions).

FIRST KNOWN OCCURRENCE OF THE AMMONOID *PARAPUZOSIA* (*AUSTINICERAS*) IN THE CENOMANIAN OF NORTH AMERICA

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In North America, species of the ammonoid *Parapuzosia* have previously been reported from the Turonian, Santonian and Campanian (Clark, 1960; Matsumoto, 1988). *Parapuzosia* (*Austiniceras*) *sealei* Clark from the middle Turonian of Texas was the oldest record from North America. A single specimen of a new species of *Parapuzosia* (*Austiniceras*) recently recovered from the middle Cenomanian *Acanthoceras amphibolum* Zone in the upper part of the Paguate Sandstone in Sandoval County, New Mexico, is in the collection of the New Mexico Museum of Natural History (NMMNH P-71327). This is the first record of *Parapuzosia* (*Austiniceras*) in the Cenomanian of North America.

The shell of NMMNH P-71327 is moderately involute, with a low, vertical umbilical wall and a fairly narrowly arched and rounded venter, and weak constrictions are replaced by major ribs that approximate on the latter part of the outer whorl, as in *Parapuzosia* (Wright and Kennedy, 1981). It is compressed and high whorled on the outer whorl, with a convergent whorl section, and has two distinct series of ribbing; long, sinuous primaries and shorter, sinuous intercalatories, as in the type species of *Austiniceras* (Wright and Kennedy, 1984). The NMMNH specimen differs from other species of *Parapuzosia* (*Austiniceras*) in being less involute with a less compressed whorl section, in its smaller size, having coarser ornament, less sinuous ribs with less projection over the venter and substantially fewer intercalated ribs.

Parapuzosia (*Austiniceras*) has previously been reported from the lower Cenomanian to upper Turonian of Europe, middle Turonian of the USA and Coniacian to Campanian of Madagascar; it has a geographic distribution that includes England, France, Germany, Czechoslovakia, Iran, North Africa, Angola, Madagascar, Japan and Texas (Wright and Kennedy, 1981, 1984). The occurrence of the new species of *P.* (*Austiniceras*) in the Paguate Sandstone in Sandoval County, New Mexico, extends the range of the genus *Parapuzosia* and the subgenus *Austiniceras* from the middle Turonian back to the middle Cenomanian in North America. It is also the first occurrence of *Parapuzosia* in New Mexico.

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Keywords:

Parapuzosia,Austiniceras,Cenomanian,Paguate Sandstone,New Mexico

CONFIGURATION AND CORRELATION OF FLUVIAL TERRACE DEPOSITS IN THE LOWER RIO SALADO VALLEY

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The Rio Salado is a western tributary of the Rio Grande whose valley is flanked by six major terrace levels. These terrace levels were documented by previous workers, but have not been thoroughly examined. The terrace mapping in northern, central and southern New Mexico is well documented, but the relation of these terraces to Rio Salado terraces is unknown. Additionally, the presence of several Quaternary rift-related normal faults and an active, deep, mid-crustal sill beneath the Rio Salado valley provide an unusual opportunity to investigate the effects of various modes of tectonic deformation of the terraces.

In this study, Rio Salado terraces were mapped using a commercial high-resolution DEM and digital color stereophotographs on a GIS workstation. The terraces were projected onto a vertical plane to construct longitudinal profiles. Three new soil pits were described to aid terrace correlation. We employed the terrace nomenclature of existing 1:24,000-scale geologic maps, but divide Qte into two distinct terraces (Qte_1 and Qte_2). We estimated terrace ages of 234 ± 35 ka (Qtg), 169 ± 25 ka (Qtf), 97 ± 14 ka (Qte_2), 65 ± 10 ka (Qtd), 42 ± 6 ka (Qtc), and 7 ± 1 ka (Qtb) using a net incision rate of 0.41 ± 0.06 m/ka, inferred from the correlation of Qte_1 to the 122 ± 18 ka Airport surface ~ 25 km south of the Rio Salado. This incision rate is >1.5 times more rapid than estimated rates nearby or in other parts of New Mexico, but results in age estimates that are in agreement with field observations of soil development. We tentatively correlate Qte_1 to the Segundo Alto terrace in Albuquerue, to Qtoc6 in the Rio Ojo Caliente in northern New Mexico, and to Qt5 in Cañada Alamosa in southern New Mexico, based on local age control and height above the stream. We also correlate Qtc to the Primero Alto terrace in Albuquerque, Qtoc7 in Rio Ojo Caliente, and Qt7 in Canada Alamosa based on the relative position of the terraces in the flight. The terrace gradients in the Rio Salado increase through time, indicating either stream response to Rio Grande incision, or footwall tilting from the Quaternary Loma Blanca fault. Additionally, terraces in the LBF hanging wall are back-tilted relative to the footwall, suggesting a listric geometry of the LBF. Two exceptions are terrace levels Qtf and Qtc, which are east-tilted relative to their footwall counterpart. Both Qtf and Qtc merge eastward with the next youngest terrace in the flight. The intermediate Qtc terrace is arched, possibly reflecting surface uplift due to the Socorro magma body (SMB).

This study is a preliminary report on the configuration and correlation of Rio Salado terraces. Future work will involve cosmogenic ^{36}Cl surface exposure dating to obtain a quantitative chronology for the Rio Salado terraces and enable the determination of incision rates and confident correlation with regional terraces. Surface exposure dates will also provide constraints on slip rates of Quaternary faults and the geologic history of the SMB.

PRELIMINARY DESCRIPTION OF AN IANTHASAURUS-LIKE EDAPHOSAURID FROM THE LOWER PERMIAN BURSUM FORMATION, OTERO COUNTY, NEW MEXICO

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An incomplete, articulated skeleton of a medium-sized edaphosaurid from the Early Permian (early Wolfcampian: Newwellian) Bursum Formation in Otero County, New Mexico, likely represents an undescribed taxon. It shares many features with the small and primitive edaphosaurid, *Ianthasaurus hardestii*, especially in the elongate, tubercle-bearing neural spines that form the sail. The specimen (NMMNH [New Mexico Museum of Natural History] P-70796) consists of at least 17 partial and articulated neural spines that bear small, widely and irregularly spaced tubercles along their lateral surfaces. There are between 3 and 5 tubercles per neural spine. The spines are proximally round in cross section and flatten out distally. While the morphology of the tubercles and neural spines is most consistent with those of *Ianthasaurus*, it is unlikely that P-70796 can be referred to that genus. This is based on the typical size of the sail of *Ianthasaurus*, which reconstructions estimate to be approximately 25 cm long with a maximum height of approximately 15 cm. NMMNH P-70796 has a sail with a length of at least 60 cm and a maximum height of at least 30 cm. Thus, NMMNH P-70796 may belong to an undescribed taxon, possibly representing an intermediate group between the small primitive insectivore *Ianthasaurus*, and the larger, more derived herbivore *Edaphosaurus.*

Keywords:

IANTHASAURUS, Otero County, EDAPHOSAURID, Permian

EXPLORING SODA DAM TRAVERTINE MINERALOGY THROUGH X-RAY DIFFRACTION FOR A BETTER INSIGHT INTO PALEOHYDROLOGY, PALEOCLIMATOLGY AND GEOTHERMAL HISTORY

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Travertine deposits from the Soda Dam springs in the Jemez Mountains, northern New Mexico, provide a record of the paleohydrology, paleoclimatology and geothermal history of the area. Travertine deposits occur along the Soda Dam fault just upstream of the village of Jemez Springs along the Jemez River. Travertine deposits here are predominately calcium carbonate precipitates from the Soda Dam hot springs and its precursors. Carbonates are a powerful tool because of the wide variety of information that can be received from slight changes its mineralogy and mineral chemistry. We employed X-ray diffraction to examine a suite of samples from the Soda Dam area. We used the Rietveld method to obtain calcite lattice parameters, magnesium occupancies, and to quantify concentrations of accessory minerals such as quartz, aragonite and dolomite. A goal is to test whether travertine age or stable isotope composition correlates with lattice parameters or mineralogy, and to evaluate whether perhaps temperature is recorded by mineralogic variation such as aragonite (hot) versus calcite (cooler). The calcite deposits also range from spars to micrites, suggesting possible differences in precipitation conditions. The samples analyzed ranged in age from modern deposits to deposits of > 500ka. Modern travertines were collected from deposits associated with waters that ranged from 20-40 C. We also examined laminated samples with alternating textures (e.g., spar and micrite). Preliminary analyses on the textural differences show encouraging results. All samples are composed of calicite. Using lattice parameters, we estimate magnesium content in the calcite ranging up to 5%. Site occupancy information shows a possibility of higher Mg contents. The micrites and spars of different ages also had measurable variations in magnesium content. These results are refined by a rietveld analysis, to take out the error involved with preferred orientation to make the results as accurate as possible. Additional analysis will determine if there is a correlation between trace element concentrations (Mn, Fe, Sr, Ba) and the magnesium content or lattice parameters. We anticipate that systematic examination of stable isotope composition and composition via xrd will allow greater understanding of the relative importance of factors such as fluid mixing and temperature variations in the travertine-depositing system.

MIOCENE AND MODERN CLIMATE IN THE CALIFORNIA SIERRA NEVADA AND IMPLICATIONS FOR STABLE ISOTOPE-BASED PALEOALTIMETRY

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The objective of this research is to address the inconsistencies between geologic and isotope-based evidence of the timing and elevation of the southern Sierra Nevada Mountains (Sierra) during the Miocene. Geologic evidence suggests that the southern Sierra uplifted ~2000 m in the last 20 Ma, whereas, isotope-based paleoaltimetry studies suggest little to no elevation change in the last 16 Ma. From incision rates in the Sierra, as well as sedimentation rates in the Great Valley, it is hypothesized that there have been two periods of uplift in the last 20 Ma. The first uplift event ca. 20 Ma is thought to be driven by the opening of a slab window. The second occurs post-3.5 Ma and is thought to be the result of mantle delamination beneath the southern Sierra. Isotope-based paleoaltimetry studies rely on the linear relationship between $\Delta\delta^{18}O$ and net elevation. Records of paleometeoric waters from the leeward side of the Sierra show relatively little change in the $\delta^{18}O$ values during the last 16 Ma which are interpreted to suggest that there has been relatively little change in elevation of the southern Sierra during the Miocene. There are several complications with interpreting isotope records for paleoaltimetry, most notably is that modern air trajectories for the Sierra are inconsistent with the underlying 2-D assumptions used in the isotope-based approach. Due to complexities introduced by 3-D flow patterns we suggest that the isotope-based approach may not be able to constrain the uplift history of the southern Sierra during the last 16 Ma.Atmospheric flow over topography can be understood, to a first order, in terms of the nondimensional flow parameter Nh/U; where N is the buoyancy frequency (s^{-1}), h is the mountain height (m), and U is the horizontal wind speed (m/s). Idealized models of flow around a topographic barrier demonstrate that when $Nh/U << 1$, flow is more likely to go over the topographic barrier but when $Nh/U >> 1$, flow is deflected around a topographic barrier. Using General Circulation Models (GCMs) for both Miocene (20 Ma to 14 Ma) and modern climate we characterize the annual average climate climates in terms of Nh/U. For the incoming offshore conditions for the Sierra we find that $N_{modern} < N_{Miocene}$, meaning that in flow is more deflected for Miocene climates. We also find that the annual average U wind profiles are very similar. Trajectory analyses from simulations of flow around an idealized Sierra, assuming that the Miocene Sierra were high, demonstrate that for annual average simulations for the Miocene and modern climate (N and U) that most of the incoming trajectories are deflected around the highest terrain. This suggests that during the Miocene the annual average climate state may not have been different enough from modern to support the underlying assumption of 2-D flow used in isotope-based paleoaltimetry studies.

FAUNAL AND FLORAL DYNAMICS DURING THE EARLY PALEOCENE: THE RECORD FROM THE SAN JUAN BASIN, NEW MEXICO

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The early Paleocene was a time of rapid faunal and floral reorganization following the end-Cretaceous mass extinction. The mammal record is punctuated by intervals of substantial turnover, yet it is unclear if these changes are due to extrinsic factors, such as climate change, or intrinsic factors, such as rapid evolution. The San Juan Basin (SJB) contains one of the best records of early Paleocene mammalian and floral evolution and thus provides an ideal location to examine ecosystem response and change in the first four million years of the Cenozoic.

Dates from magnetostratigraphy and $^{40}Ar/^{39}Ar$ sanidine provide temporal constraints to key fossil horizons and indicate that the type middle and late Puercan faunas occurred within 350 ka and 500 ka of the K-Pg boundary, respectively. These age constraints show that rates of morphological change for some mammals was extremely high. For example, mass estimates for the largest Puercan mammal, *Ectoconusditrigonus*, are up to 100 kg, far exceeding the size of the largest Late Cretaceous mammals (~5 kg for *Bubodens magnus*) – an exceptionally rapid evolutionary increase in body size.
We evaluated the mammalian turnover record based on our revised timescale, taking into consideration possible biases from unequal interval durations, sample sizes, and species richnesses. We corrected for interval duration and sample size, which were significantly correlated with origination or extinction rates. Results indicate that origination rates far outpace extinction rates, with strong peaks of origination in the late Torrejonian (To5 & To6).

We constructed a stable isotopic record (oxygen and carbon) for the early Paleocene from mammalian tooth enamel to use as a barometer for environmental and climate change. Preliminary results of this record indicate relative stability in carbon and oxygen values through most of the early Paleocene except for a significant increase in carbon values in *Tetraclaenodon* from To4 to To5. However, carbon values in *Tetraclaenodon* do not covary with those of *Periptychus* through this interval and there is no clear correlation between climate and faunal change in the SJB.

The SJB preserves a superb early Paleocene floral record that is relatively diverse and dominated by angiosperms. Many taxa appear to be endemic to the SJB and these floras are significantly more diverse than contemporaneous floras from the Northern Great Plains. Analyses from fossil leaves, as with the stable isotope record, show little variability in paleoenvironment or paleoclimate between the Puercan and Torrejonian. However, there is major turnover in plant morphotypes and mammal species between the Puercan and Torrejonian suggesting the possibility of synchronous floral and faunal change between Puercan and earliest Torrejonian time.

In conclusion, our results indicate that ecologically complex mammal and plant communities were present in the SJB within a few hundred thousand years of the K-Pg mass extinction. Both mammalian faunas and floras were relatively short-lived and turned over rapidly. Because similar climates and environments appear to have persisted through the early Paleocene, we suggest that plant and mammal turnover may be related to interspecific competition and/or immigration, rather than significant environmental or climatic change.

Keywords:

Paleocene, Nacimiento Formation, Mammalia, recovery, San Juan Basin

APPLICATION OF HYDROGEOSPHERE TO MODEL THREE-DIMENSIONAL HYDROLOGICAL PROCESSES IN THE VALLES CALDERA WATERSHED, NEW MEXICO: PRELIMINARY RESULTS

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Application of HydroGeoSphere to model three-dimensional hydrological processes in the Valles Caldera watershed, New Mexico: Preliminary results

Mountainous watersheds in northern New Mexico provide an important source of recharge to the hydrologic system in this predominantly water-limited southwestern state. The Valles Caldera watershed in the Jemez Mountains is particularly interesting because of its topoclimatological, edaphic, and geological complexities that together give way to intricately complex surface hydrology that is intimately coupled with equally complex hydrogeologic processes. Precipitation, evaporative demand, and snowmelt dynamics depend strongly on orographic processes along with spatially distributed plant community characteristics. Soil characteristics vary greatly in space due to local geomorphology—from coarse on high-gradient resurgent and extrusive domes to fine in the low-gradient Valle Grande. Underlying the soil lies vastly complex surficial geology resulting from the Caldera's long geologic history of volcanism, uplift, landslides, and lake sediment accumulation.These complex spatially distributed processes and characteristics result in highly three-dimensional hydrologic processes.Modern distributed-parameter, coupled surface-subsurface hydrologic models such as HydroGeoSphere are capable of representing all of the aforementioned spatially variable hydrologic processes—precipitation (including snowmelt), evapotranspiration, variably saturated flow, coupling between surface and subsurface domains, overland flow, and channel flow—thereby fully accounting for the three-dimensionality in complex systems such as Valles Caldera. This presentation describes our strategy and progress in parameterizing and applying the HydroGeoSphere model to the Valles Caldera watershed. Specifically we will present our parameterization scheme, early model output, challenges we have experienced, and future directions.

AGE OF CARVING OF THE WESTERNMOST GRAND CANYON: CONFLICTS AND POTENTIAL RESOLUTIONS THAT RECONCILE GEOLOGIC AND THERMOCHRONOLOGIC DATA

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Conflicting models for the timing of carving Grand Canyon, especially the controversial westernmost Grand Canyon, involve either an "old" 70 Ma segment of Grand Canyon versus a "young" < 5-6 Ma segment. Geologic data such as the late Miocene-Pliocene Muddy Creek constraint, the north-derived Paleogene Hindu fanglomerate, and the 19 Ma Separation Point basalt on the south rim favor the young model. However, thermochronologic data are in conflict between two studies. (U-Th)/He (AHe) data combined with $^{4}He/^{3}He$ modeling of a sample near Separation Canyon suggest river level rocks cooled from ~100 to 30ºC during the Laramide orogeny at 70 Ma. Alternatively, apatite fission track (AFT) combined with AHe data show variable cooling paths in different locations, with some samples cooling steadily since 70 Ma and others remaining at ~40-80ºC until 5-6 Ma. Either model could be compatible with geologic data that show Laramide (90-70 Ma) cooling resulted from northward stripping of the Hualapai Plateau. Variable cooling sample-to-sample is geologically plausible, although perhaps unlikely, such that this study area offers an important test-bed for interpreting the sensitivity of thermochronologic data in areas of slow cooling at relatively shallow (~ 1 km) burial depths.

Recent $^{4}He/^{3}He$ modeling of the Separation Canyon samples suggests a period of 90-70 Ma Laramide cooling, 70-10 Ma post-Laramide residence at ~40-60 ºC, then another period of cooling to surface temperatures at 5-6 Ma. We also summarize all available thermochronologic data from river-level Precambrian basement rocks of westernmost Grand Canyon. New HeFTy modeling of all samples was done considering the Precambrian age and cooling histories of the grains, cooling to near surface temperatures in the Cambrian and Devonian, and then burial by 1-3 km of Phanerozoic strata by 90 Ma (hence 40-140ºC from 90-100 Ma). Our models indicate that most grains underwent substantial pre-Laramide radiation damage, and that peak Laramide burial and associated temperatures may not have been high enough to completely reset the AHe system and anneal out lattice damage. Only some samples record a second 5-6 Ma cooling pulse. Our overall conclusion is that published thermochronologic constraints were not yet able to fully resolve the "old" versus "young" canyon models because 1) most AHe ages are old (> 50 Ma), 2) the Precambrian apatite crystals have variable, often high effective uranium (eU) values and complex radiation damage due to long term burial and insufficient annealing as a result of thin cover (~ 1 km) following the Laramide.

Additional AFT, AHe, and $^{4}He/^{3}He$ modeling on the same samples is underway and will likely define better cooling paths for this complex region. Once cooling paths are better established, geologic interpretations will need to consider: 1) a still unresolved combination of northward stripping of the Phanerozoic section that left less than 1 km of strata above basement rock, 2) fault throw on the Hurricane and other Laramide faults, 3) irregular cliff retreat of the ~1 km high Permian escarpment, and 4) the carving of paleocanyons.

Keywords:

Grand Canyon, Low-temperature thermochronology, apatite

HYDROGEOLOGIC WINDOWS: DETECTION OF BLIND AND TRADITIONAL GEOTHERMAL PLAY FAIRWAYS IN SOUTHWESTERN NEW MEXICO

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We are in the process of creating a methodology to identify blind geothermal resources in southwestern New Mexico and assess the risk associated with the exploration for these resources. The presence or absence of a hydrogeologic window through Paleozoic, Mesozoic, and Paleogene confining units and younger, fine-grained basin fill forms the basis of the play fairway framework. Hydrogeologic windows are zones where regional or local aquitards are breached by faulting, erosion, or intrusions, allowing relatively rapid vertical flow of heated groundwater toward the surface; this heated water might become trapped below fine-grained facies in the basin fill, resulting in a blind system. A variety of data sets including temperature-depth profiles, bottom-hole temperatures, heat flow, subsurface formation tops, aqueous geochemistry, fault location, and earthquake location have been gathered and organized into ArcGIS layers that can be superimposed to identify signatures of known geothermal systems and to use those same signatures to explore for unknown systems. The formation top data are used to create a series of subcrop maps below the basin fill to locate bedrock highs and syndeformational lows that formed during Ancestral Rockies, Jurassic Bisbee rift, Laramide, and Neogene Rio Grande rift deformation. These maps are the key to defining the hydrogeologic windows.

Conservative element tracers that are commonly associated with geothermal systems (e.g., lithium, boron, bromide, chloride) are used to locate geothermal outflow plumes in shallow aquifers, following an approach first used by Neupauer and Wilson (1999) to identify the location of up-gradient contaminant sources using contaminant concentrations in down-gradient wells. This new exploration concept considers the dynamics of fluid flow and geochemical tracer transport. The up-gradient path of conservative ions from each borehole in the Socorro-La Jencia and Albuquerque basins is calculated using water table contours and a simple particle tracking algorithm. The flow vectors based on Darcy law are used to "upwind" particles across the basins. The calculated paths are then compared to Quaternary and older fault ArcGIS layers to try to identify the source of waters with elevated conservative ion concentrations. Several known and previously unknown geothermal areas have been identified using this approach.

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GEOCHEMISTRY OF AQUIFER RECHARGE PROJECTS IN NEW MEXICO

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Managed aquifer recharge is being implemented at sites across New Mexico as an important water resource management tool, to recharge and store surplus water within aquifers, and to recover the water for later use. During the site selection process, potential geochemical reactions that may affect water quality are an important consideration. Several examples from managed recharge sites in New Mexico are presented that illustrate how water quality may be influenced during the aquifer recharge process.
New Mexico has several managed aquifer recharge project sites that are in varying stages of project development, ranging between characterization of hydrogeology and geochemistry, to permitting and operations. Water managers enhance aquifer recharge using surface and subsurface approaches such as:

Surface methods: infiltration galleries, ephemeral stream reaches, and basins
Subsurface techniques: vadose zone wells and ASR wells

Sources of water include bank filtered or treated surface water, reclaimed water, or groundwater. Benefits of enhanced aquifer recharge include maximizing storage capacity, improving management of seasonal surplus water supply, reducing evaporation, avoiding land subsidence, minimizing drawdown and developing drought reserves.
During the aquifer recharge process, water will either infiltrate through the vadose zone to reach the water table or be injected directly into the aquifer. Each method allows for various geochemical reactions to occur between the injected and receiving waters, or injected water and aquifer sediments. Water moving through the vadose zone may react with pore water and minerals in the vadose zone sediments. During injection, the recharge water pushes groundwater away from the well, and this is often conceptualized as a bubble of injected water forming around the wells.

Geochemical compatibility of the injected water with both the receiving water and the aquifer material can be predicted using geochemical models and calculations for binary mixing and saturation indices (SI). A range of potential outcomes can be identified including probable water quality at the time of recovery, treatment requirements, and operational difficulties that should be planned for or potentially avoided through treatment or engineering solutions.Water quality may be improved, maintained, or degraded. The mixing of different water chemistries and aquifer matrix reactions may affect the water quality of the recovered water. Geochemical methods may also be used to trace injected water including using stable isotopes, ion ratios, sulfur hexafluoride (SF_6), and disinfection byproducts. Examples include:

Mixing of water in the Tesuque Formation aquifer: elevated fluoride, arsenic and uranium in groundwater mixing with treated surface water may require treatment upon retrieval
Iron and manganese in the Santa Rosa Sandstone-Chinle Formation aquifer system: potential mobilization of iron and manganese needs to be predicted for the final water quality
Arsenic in the Santa Fe Group aquifer system: reactions between sediments and injected water may dissolve iron coatings on sediments releasing iron and adsorbed arsenic
Tracing injected water in the Santa Fe Group aquifer system: SF_6 was injected into the injection water as a conservative tracer to monitor movement in the aquifer

Keywords:

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PALEODROUGHTS: ANALOGUES FOR THE FUTURE?

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Drought conditions have impacted Rio Grande flows over the past 15 years, and have been highlighted by iconic images of low water levels in Elephant Butte Reservoir. Below average snowpack in the headwaters of the Rio Grande this spring foretell another year of low runoff. The ongoing drought has prompted the question, is this a local manifestation of global climate change, or attributable to natural variability? Given the relatively short instrumental climate records, this question can be difficult to answer. The Rio Grande gage record from the headwaters in Del Norte, Colorado, which extends to 1891, can provide part of the answer. However, to examine the range of conditions that have occurred under natural variability over longer time periods, paleoclimatic records are needed. Tree rings provide one way to investigate past hydroclimatic variability going back centuries to several millennia. A network of tree ring data has been used to develop reconstructions for the Rio Grande region including annual streamflow and monsoon precipitation. Taken together these records suggest the most severe droughts in the instrumental record have been exceeded in prior centuries. In particular, there have been episodes of dry monsoon seasons in the middle Rio Grande region of New Mexico, coupled with low flows in the Rio Grande headwaters. Although the monsoon record is limited to the last four centuries, longer tree-ring records for the San Juan Mountains suggest prolonged periods of drought occurred in the medieval period and in the second century. While these records of persistent droughts of the past may be considered analogues for future droughts, they are likely to be conservative. Recent and projected temperature trends will play an increasingly important role in exacerbating effects of droughts, including the range of drought conditions documented in the tree-ring records.

VENT MIGRATION PATTERNS OF LATE QUATERNARY BASALTIC VOLCANISM WITHIN THE RIO GRANDE RIFT AND ALONG THE JEMEZ LINEAMENT

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Newly determined high-precision $^{40}Ar/^{39}Ar$ ages of basaltic lava flows and cinder cones, in conjunction with previously published low-precision ages, suggest that vent locations within individual volcanic fields of the Rio Grande rift and Jemez lineament have migrated from the west or southwest to the east or northeast during the late Quaternary. Although many volcanic fields in the rift and lineament were active during the late Cenozoic, the migration pattern is only observed in the six fields with eruptions during the last 1 Ma. The vent migration rate and direction for most fields is between 2 to 5 cm/yr to the east or northeast (~ N70°E ± 45°). The pattern of vent migration in some volcanic fields has been fairly regular. For example, the oldest vents in the Zuni Bandera volcanic field are the Chain of Craters, located along the continental divide and in the most western part of the field. Activity here began as early as 783 ka with most eruptions occurring between 260 and 100 ka. Vent locations then migrated eastward to the northwest corner of the present-day El Malpais National Monument and southern Zuni Mountains. Here, at least ten cinder cones erupted between 65 and 11 ka, including the well known Bandera crater and flow. The youngest and most eastern vent erupted the McCartys flow 3.9 ka. Vent migration in other fields has not been constant and continuous, but instead is best characterized by an abrupt, “step-like” jump in vent location. The oldest vents in the Potrillo field are exposed in the West Potrillo Mountains, which were active between 916 and 262 ka. Activity then migrated eastward where at least nine vents erupted between 190 and 17 ka. Both the older, western vent cluster and younger, eastern vent cluster display irregular vent migration patterns. The eastward migration of volcanism is also apparent at fields with infrequent eruptions. The Carrizozo lava flow erupted at 5.2 ka. This Holocene eruption was preceded by two eruptions at 345 and 252 ka from vents 12 km to the west-northwest. The magnitude and direction of vent migration within fields of the rift and lineament is similar to the established migration patterns at other Quaternary fields in the western US. Furthermore, the rift and lineament vent migration patterns are also moderately consistent with the absolute North American plate motion relative to a fixed mantle source. Continued work will focus on quantifying the volcanic hazards and connecting the temporal-spatial patterns of late Quaternary volcanism within the rift and along the lineament with geochemical data that suggest an increasing contribution from an asthenospheric mantle source.