NEW MEXICO GEOLOGICAL SOCIETY
2013 SPRING MEETING

Friday, April 12, 2013
Macey Center
New Mexico Institute of Mining and Technology
Socorro, New Mexico

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Technical Program Chairs: Fred Phillips, John Wilson, Sam Fernald, Peggy Johnson
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ORAL SESSION CHAIRS:
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THE COURT CASE FROM HELL: AAMODT AS SOCIAL DRAMA

Michael Agar

Ethknoworks LLC, 7 Avenida Vista Grande B7, #465, Santa Fe, NJ, 87508, magar@umd.edu

New Mexico water governance is more complicated than anything presenter has anthropologically attempted. One part of the NM water story is an ongoing case, referred to as “Aamodt” after the first in a list of hundreds of names involved in the adjudication of water rights in the Pojaque river basin just north of Santa Fe. Ironically enough, the case, first filed in 1966, was brought about by the availability of new water with the San Juan/Chama tunnel connection between the Colorado and Rio Grande river basins. In the spirit of Victor Turner’s “social drama," the case can be viewed as “breach” and “crisis” that makes explicit centuries of accumulated contradictions that have made contemporary efforts at water policy in the face of increasing population and decreasing supply a political box canyon. The case makes clear how Turner’s third stage, “redressive action,” has remained contentious for decades and how his “reintegration” has been blocked by the intersection of ancient, historical and contemporary conflicting interests. The ultimate goal of the ongoing anthropological research, of which the Aamodt case is a buidling block, is to model the sort of environmental governance that would enable a more productive approach to the dilemma of more water on paper than water in the river, the latter diminishing with climate change. Time permitting, a few revisions of the principles of the traditional "Law of the River" will be proposed.

Covariability and Interannual Variability of June Wild Fires and Atmospheric Aerosols

Lucas J Barrett[1] and David S Gutzler[1]

[1] Department of Earth and Planetary Science, University of New Mexico, Albuquerque, NM, 87131, xantose@unm.edu

The purpose of this study is to assess the hypothesis that atmospheric aerosol from late spring forest fires depresses precipitation in the subsequent monsoon season in the Southwest. To assess this hypothesis I examined the covariability of observed interannual variability of June forest fires and atmospheric aerosols. I obtained fire data including acres burned, dates, and locations of major fires and total number of fires in New Mexico and Arizona, and satellite-derived estimate of aerosol concentrations for the period of 2005-2012. Using these data I calculated correlations on maps, create and analyzed 3D graphs, calculated the linear correlation between forest fires and the aerosol thickness. Interannual correlation between forest fires in New Mexico and aerosol thicknesses in New Mexico is 0.67, provides support for the hypothesis. In this short period of record, however, this correlation is mostly due to a single year, 2011, when aerosols increased from a high increase in forest fires. Removing this highly anomalous year from the data set reduced the correlation between forest fires and aerosol thicknesses in remaining years to 0.12. Therefore, this study was not definitive on whether or not aerosols produced by late spring forest fires generally depress precipitation in the successive monsoon season in the Southwest. With only one big variation in the aerosols and forest fires in 2011 out of the 8 years it is hard to see if there is a true regression.

URANIUM IN WATERS OF THE OJO CALIENTE AREA, TAOS COUNTY, NEW MEXICO

Tony Benson[1] and Ron Gervason[1]

[1] Taos Soil and Water Conservation District, P.O. Box 2787, Ranchos de Taos, NM, 87557, benson1@newmex.com

Uranium dissolved in stream water of the Rio Ojo Caliente in southwestern Taos County and groundwater recharging from it approach or exceed the Federal and State drinking water standards. Nearly all domestic and public water wells in the area approach or exceed the NM drinking water standard of 30ppb. The source of uranium and other trace ions appears to be deep-sourced hot springs emanating from faults at the base of La Madera Mountains to the north in Rio Arriba County. These hot springs have been depositing travertine terraces over the past 100,000 years. Uranium concentrations in these travertine deposits approach 250ppm, comparable to the levels mined in the Hopi Buttes volcanic maar fields in northeastern Arizona. Solution weathering of the travertine releases uranium ions to the Rio Ojo Caliente which recharges ground water downstream in the Ojo Caliente area. Additional uranium and other elements are added to groundwater from the Ojo Caleinte Hot Springs, raising ion levels downstream to the south in Rio Arriba County.

Paleomagnetic, Anisotropy of Magnetic Susceptibility, and Structural Data Bearing on Magma Emplacement and the growth of the Miocene, Cinder Cone

Adam Ray Brister[1] and Michael Petronas[1]

[1] New Mexico Highlands University, Box 9000, Las Vegas, NM, 87701, abrister@live.nmhu.edu

The Trosky Volcano is a monogenic cinder-spatter cone associated with the middle Miocene Jicin Volcanic field of northeast Czech Republic. The intent of this research is to map the Trosky Volcano subvolcanic deformation, magma plumbing system geometries, eruptive dynamics, and cinder cone morphology using paleomagnetic, anisotropy of magnetic susceptibility (AMS), and structural data. The results from this study will be used to compare and contrast three other monogenic volcanoes that exhibit exposed magma feeders systems. We hypothesize that cinder cones conceal multiple magma conduits as opposed to a single conduit as envisioned for many volcanic constructs. By comparing the results from three other monogenic volcanic centers 1) Cienega Volcano, NM, 2) several quarried volcanoes in the Raton-Clayton volcanic field, NM, (future study) and 3) Lemptégy Volcano, France to the data from the Trosky Volcano should enhance our understanding of both ancient and active intra-rift volcanic systems. Preliminary results are encouraging with high values of magnetic susceptibility, single component demagnetization response, and pseudosingle domain grain size. The data obtained will enhance our understanding of subsurface magma transport to the eruptive vent and provide insight into subvolcanic deformation processes. These data should further allow us to provide insight into the growth and hazards associated with active volcanic systems worldwide.

The Early Permian Gallina Well Vertebrate and Trace Fossil Site in Socorro County, New Mexico

Amanda Kaye Cantrell[1], Thomas L. Suazo[1], David S Berman[2], Justin A. Spielmann[1], Spencer G. Lucas[1], Amy C. Henrici[2] and Larry F. Rinehart[1]

[1] New Mexico Museum of Natural History, University of New Mexico, Acantr5@unm.edu

[2] Carnegie Museum of Natural History,

The Gallina Well locality is a Lower Permian vertebrate body and trace fossil site located approximately 20 km northeast of Socorro, New Mexico in the Joyita uplift. The locality is stratigraphically low in the Scholle Member of the Abo Formation and is Coyotean in age. The fossiliferous beds are reddish-brown, fluvially-deposited, calcrete-pebble conglomerates and mudrock. Vertebrate body fossils from the site include paleoniscoid fish;the temnospondyl amphibians *Eryops* sp., *Trimerorhachis* sp., *Platyhystrix* sp., and *Zatrachys* sp.; a skull fragment of the lepospondyl *Diplocaulus* sp.; postcrania of the diadectid *Diadectes* sp.; a captorhinid skull and postcranial skeleton; and specimens of the eupelycosaurs *Ophiacodon* sp., *Sphenacodon* sp. and *Dimetrodon* sp. The coprolite ichno-assemblage includes *Dakyronocopros arroyoensis*, *Alococopros triassicus*, *Heteropolacopros texaniensis* and amorphous coprolites. The Gallina Well locality yields the most diverse and extensive vertebrate body fossil and coprolite assemblage of Early Permian age known from southern New Mexico. Its basic composition differs little from the pelycosaur-dominated assemblages found to the north, indicating some uniformity of the Coyotean vertebrate fauna across New Mexico.

Toward Standardization of Phanerozoic Stratigraphic Nomenclature in New Mexico

Steven M. Cather[1], Kate E. Zeigler[2], Greg H. Mack[3] and Shari A. Kelley[1]

[1] New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Pl., Socorro, NM, 87801, scather@nmbg.nmt.edu

[2] Department of Natural Resources Management, New Mexico Highlands University, Las Vegas, NM, 87701,

[3] Department of Geological Sciences, New Mexico State University, Las Cruces, NM, 88003,

Recent decades have seen an unprecedented rate of change in the Phanerozoic stratigraphic nomenclature of New Mexico. At the same time, the state has experienced a dramatic resurgence of geologic quadrangle mapping, primarily facilitated by the National Geologic Mapping Act of 1992, which enabled the STATEMAP and EDMAP programs. The utility of the new stratigraphic nomenclature has not yet been adequately tested, and in some cases has been opposed by other researchers. Despite a lack of consensus among stratigraphers, it is desirable to have an agreed-upon nomenclature for the purpose of ongoing geologic mapping. We present here, from our perspective as geologic mappers, revisions to the Phanerozoic stratigraphic nomenclature of New Mexico. We hope our discussion will eventually lead to adoption of a standardized nomenclature, for the purposes of mapping, by the New Mexico Bureau of Geology and Mineral Resources, which administers the STATEMAP and EDMAP programs in New Mexico.

Here we criticize, and suggest alternatives to, aspects of recent nomenclatural changes for Pennsylvanian, Permian, Triassic, Jurassic, and Paleogene strata. Specifically, we disagree with: (1) the application of the terms Gray Mesa Formation and Atrasado Formation to Pennsylvanian strata of southern New Mexico; (2) raising of the Lower Permian Yeso Formation to group rank; (3) replacement of the term Meseta Blanca Member with Arroyo de Alamillo Formation in the Yeso; (4) raising the Los Vallos and San Ysidro members of the Yeso to formation rank; (5) the mapping utility of some formation-rank units of the Upper Triassic Chinle Group; (6) the replacement of the term Dockum by Chinle in eastern New Mexico; (7) replacement of the term Westwater Canyon Member of the Jurassic Morrison Formation with Salt Wash Member; and (8) the replacement of the term Baca Formation by the Hart Mine Formation for middle Eocene strata in eastern Socorro County.

TIMING OF THE GROWTH OF DEEP PHREATIC SPELEOTHEMS AND THEIR RELATION TO LANDSCAPE EVOLUTION IN THE SOUTHWESTERN UNITED STATES

David D. Decker[1], Victor J. Polyak[1] and Yemane Asmerom[1]

[1] University of New Mexico, Department of Earth and Planetary Sciences, Northrop Hall, MSC03 2040, Albuquerque, NM, 87114, dave.decker@caves.org

Understanding the interplay between magmatic and associated tectonic events and lithospheric response is critically important in our understanding of landscape evolution. This is particularly true in regions with multiple imprints of contrasting tectonic forces. For example, the timing of the rise of the Guadalupe Mountains located in the southeastern Rio Grande and southern Laramide tectonic provinces is likely multi-modal. One model suggests one kilometer of the Guadalupe block uplift was relatively recent (over the last 14 – 12 My) during the Rio Grande rifting (Polyak et al., 1998). Another model suggests that the area arose primarily during the Laramide Orogeny (DuChene and Cunningham, 2006). A third model suggests there were three instances of mountain building (the two previously mentioned and an earlier one when the area first emerged from the Permian sea), and a combination of the three led to the present two kilometer-plus height of the Guadalupe Mountains (Palmer and Palmer, 2000). In this study, I report the ages of 15 cave spar samples (large euhedral calcite crystals lining geode-like caves) collected from various locations in the Guadalupe Mountains. The ages are based on U-Pb geochronology and show multi-modal ranges: 28 – 30 Ma, 33 – 35 Ma and 50 – 55 Ma. There are several outliers as well. The first two modes correlate well with known magmatic pulses in the region and are likely related to the beginning of the basin and range province. The third mode has not been temporally linked to any known magmatic activity; however it dates to the end of the Laramide. Further work will be required to unambiguously link the cave spar with these geologic episodes and this continuing work will make a significant contribution to the knowledge of the landscape evolution of the Guadalupe Mountains region. More importantly, it will test the feasibility of using cave spar formed deep in the phreatic zone to constrain the timing of uplift and subsidence histories of landscape by establishing links between tectonic events and landscape evolution.

Structural Analysis of 1.1 Ga Diabase Intrusions: Burro Mountains, New Mexico

Cassidy W. Dimitroff[1], Sean Gaynor[1] and Jeffrey Amato[1]

[1] Department of Geological Sciences, New Mexico State University, Las Cruces, NM, 88003, USA,

~1.1 Ga diabase dike swarms cut Paleoproterozoic units throughout the southwestern region of Laurentia. Howard (1991) noted that many of these intruded as horizontal sheets cutting existing subvertical fabrics. Exposures of these intrusions in the southern Mazatzal Province in New Mexico have not been dated, but recent dating of similar dikes in Arizona yielded ages of ~1080–1094 Ma (Bright et al., 2012). The source of this late stage Grenville magmatism remains controversial.

The Burro Mountains, located in southwestern New Mexico, exposes an abundance of cross-cutting diabase intrusions cutting ~1.4 Ga intrusive rocks and ~1.6 Ga metamorphic rocks. In this study, we measured the planar contact orientations of the diabase dikes, and then analyzed orientations in an attempt to determine the structural significance of the diabase swarm and the post-emplacement tilting. Dike orientations were rotated 25° SW about a horizontal axis of 300°, based on orientation of NE-dipping Cretaceous Beartooth Quartzite which uncomformably overlies 1.46 Ga granite. We postulated that the intrusions would be intruded as either vertical dikes, related to horizontal extension, or horizontal sheets as described by Howard (1991).

After rotation, a large percentage of the dikes have a subhorizontal dip, with most having dips of <30° and no consistent strike orientation. This suggests that the majority of the intrusions were originally intruded as horizontal sheets. Some of the dikes have steeper orientations with E-W strike and these might be feeder dikes to the subhorizontal sheets. No regional folding of the dikes was observed based on the plotted orientations, but some of the scatter is likely related to tilting on faults related to Tertiary extension in the region.

Intrusions with distinct zoning represent syntaxial dike intrusions suggesting that the emplacement process was not geologically instantaneous. Chilled margins are not present in dikes cutting ~1.4 Ga intrusive rocks, indicating that the country rock was at an elevated temperature at the time of diabase intrusion. However, the diabasic texture indicates hypabyssal intrusive depths. These intrusions are likely coeval with 1.08 Ga felsic intrusions mapped in the nearby Little Hatchet Mountains (Amato and Mack, 2012) and coeval with Grenville-age magmatism throughout the southwest U.S.

References:

1. Amato, J. M., and Mack, G. H., 2012, Detrital zircon geochronology from the Cambrian-Ordovician Bliss Sandstone, southwest New Mexico: Evidence for contrasting source regions on opposite sides of the Transcontinental Arch: GSA Bulletin, v. 124, p. 1826-1840.

2. Bright, R., Amato, J. M., Denyszyn, S. W., and Ernst, R. E., 2012, U-Pb geochronology and isotope geochemistry of ~1.1 Ga diabase dikes and sills in the southwest U.S.: Implications for Rodinia reconstructions, GSA Rocky Mountain Section Meeting, Abstracts with Programs, v. 44, no. 6, p. 9.

3. Howard, K. A., 1991, Intrusion of horizontal dikes: Tectonic significance of Middle Proterozoic diabase sheets widespread in the upper crust of the southwestern United States: Journal of Geophysical Research, v. 96, p. 12461-12478.

Corrections to Ages of Paleomagnetic Reversals and Ammonite Zone Boundaries from Those Reported in the Gradstein et al. 2012 Time Scale for K-Pg Boundary Rocks, San Juan Basin, New Mexico

James E. Fassett

USGS, retired and Independent Research Geologist, 552 Los Nidos Drive, Santa Fe, NM, 87501, jimgeology@qwest.net ph: 505 983-6011

Geologic time scales such as those by Gradstein et al. (2004) and Gradstein et al. (2012) are valuable reference tools for all geologists involved in geochronologic studies. Unfortunately the Gradstein et al. 2012 Time Scale has failed to include important published geochronologic data for latest Cretaceous strata generated in the San Juan Basin, New Mexico. Fassett and Steiner (1997) published 40Ar/39Ar sanidine ages for multiple altered volcanic ash beds from uppermost Cretaceous strata in the San Juan Basin, New Mexico. Five of these ash beds were in a 21-km long area of bedrock exposure in the southwest part of the San Juan Basin. Two independent paleomagnetic traverses had been obtained in the same area and both contained the paleomagnetic reversal from magnetochron C33n to C32r. With three precise 40Ar/39Ar ages below this reversal and two above, it was thus possible to precisely date this reversal as 73.50 ± 0.18 Ma. Fassett (2000) added an additional 40Ar/39Ar age and recalculated the reversal at exactly the same age. The Gradstein et al. (2004) paper ignored these two publications and gave the C33n-C32r paleomagnetic reversal an age of 73.577 Ma. Fassett (2009) addressed the incorrect age for the C33n-C32r reversal in Gradstein et al. (2004) and published a corrected time scale for uppermost Cretaceous magnetochrons from C33n to C28n. In this paper Fassett also recalibrated Western Interior Ammonite zone (WIAZ) boundaries that were also shown incorrectly in the Gradstein et al (2004) report. Gradstein et al. (2012) ignored all of these publications and assigned an age of 74.309 Ma to this reversal determined by projections and extrapolations vs. the actual, precise recalibrated age of 74.22 Ma and also showed outdated and incorrect WIAZ boundary ages. The correct ages for these important boundaries are in Fassett (2009) but must be recalibrated to current standards.

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Revised Geochronology and Paleomagnetic Interpretations of Uppermost Cretaceous and Lowermost Paleocene Rocks in the Southern San Juan Basin, New Mexico

James E. Fassett

USGS, retired and Independent Research Geologist, 552 Los Nidos Drive, Santa Fe, NM, 87501,
jimgeology@qwest.net ph: 505 983-6011

A 40Ar/39Ar age for an altered volcanic ash bed from the Nacimiento Formation at Mesa de Cuba in the southern San Juan Basin was reported in Fassett et al. (2010). This 40Ar/39Ar single-sanidine-crystal age of 64.0 ± 0.4 Ma was determined relative to the Fish Canyon Sanidine (FCS) age of 28.02 Ma. A recent publication (Renee et al., 2013) has revised the FCS age to 28.294 Ma making the revised age of the Nacimiento ash bed 64.63 Ma. This new age for the Nacimiento ash bed plus adjustments to the levels of the top and base of magnetochron C29n moves the base of C29n from near the base (as shown in Fassett et al., 2010) to the top of the Ojo Alamo Sandstone. The base of C29n is 65.76 Ma (cf. Gradstein et al., 2012) and the top of the Ojo Alamo Sandstone is approximately this same age. This means that the Ojo Alamo Sandstone was deposited between 66.04 Ma (Renee et al., 2013) and 65.76 Ma. At a rate of deposition of 57 m/m.y. (obtained for the lower part of the Nacimiento Formation) for the overlying Nacimiento to to the base of the Eocene San Jose Formation, results in an age for the top of the Nacimiento of 61.1 Ma. Because the Paleocene-Eocene contact is 56.34 Ma, a hiatus of at least 4.8 m.y. must exist at the Paleocene-Eocene contact at Mesa de Cuba (assuming there are no significant intervening unconformities present in Nacimiento strata overlying the dated ash bed). Puercan and (or) Torrejonian mammal fossils have been identified in the Nacimiento Formation at numerous localities in the southern San Juan Basin, including at Mesa de Cuba. The boundary between these land-mammal stages is estimated to be at about the top of magnetochron C29n with an age of 65.06 Ma making the duration of the Puercan Stage in the southern San Juan Basin about 1 m.y. These revisions indicate that paleomagnetic data no longer confirm the Paleocene age of the Ojo Alamo Sandstone. However, robust palynologic data still strongly support the Paleocene age of the Ojo Alamo Sandstone and its contained dinosaur fossils.

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Cambrian-Ordovician(?) Rare Earth Element (REE)-bearing Episyenites in the Caballo and Burro Mountains, Southern New Mexico: Insights into a metasomatic origin

Kwame B Frempong[1], Virginia T McLemore[2], Nelia Dunbar[2] and Annie Riggins[3]

[1] NMT, Department of Mineral Engineering, 801 Leroy Place, Socorro, NM, 87801, boafofrempong@gmail.com ph: 5755189034
[2] NMBGMR, 801 Leroy Place,, Socorro, NM, 87801, ginger@nmbg.nmt.edu
[3] NMT, Department of Earth and Environmental Sciences, 801 Leroy Place,, Socorro,, NM, 87801, anneliseriggins@gmail.com

Numerous occurrences of brick-red, K-feldspar-rich rocks, called episyenites, were discovered in the Caballo and Burro Mountains during exploration for U in the 1950s and 1960s. The term episyenite, as used by Leroy (1978), describes rocks that were desilicated and metasomatized by alkali-rich fluids solutions, possibly related to alkaline or carbonatite magmas. The episyenites in the Caballo and Burro Mountains replace the original Proterozoic igneous granites, granodiorites, and gneissic granites, and contain as much as 16% K2O and have higher concentrations of REE (<1378 ppm total REE), Th (<9721 ppm) and U (<2329 ppm) than most igneous rocks. Field observations and mapping indicate that these episyenites are typically found as flat-lying pods or lenses (<300 m in diameter), pipe-like bodies, and dike-like bodies (<2 m wide and 400 m long). They consist of K-feldspar with varying amounts of quartz, muscovite, hematite/goethite, chlorite, and plagioclase. Accessory minerals include apatite, zircon, calcite, fluorite, limonite, magnetite, barite, and malachite. Some areas have numerous small episyenite bodies in a geographically restricted area, suggesting fracture or fault control. The contacts between the episyenite bodies and the host rocks vary from location to location, from very sharp to distinctly gradational. In places where the contacts are sharp, the episyenites could be interpreted as intrusive primary igneous rocks. However, gradational contacts are more typical. A striking example is the episyenite body located in the Jack Creek rapakivi granite, in the Ramsey Saddle area of the Burro Mountains, which exhibits a strongly gradational contact, transitioning from the buff-colored host rapakivi granite to brick-red episyenite over a distance of 10s of meters. The large rapikivi feldspar crystals, diagnostic of the host granite, are overprinted by the brick-red episyenite, indicating that a fluid-driven metasomatic process was responsible. Similar replacement relationships are observed in other localities, and are reinforced by microbeam observations of feldspar crystal texture and composition (see Riggins et al., this volume). Although multiple origins for episyenite are possible (i.e., igneous and metasomatic), the simplest explanation for the field relationships is that these similar occurrences of brick-red episyenites are all metasomatic in origin. In other geological occurrences of similar types of metasomatic alteration elsewhere in the world, alkaline or carbonatite magmas are thought to be the origin of the REE-bearing metasomatic fluids. Elsewhere in New Mexico, episyenites are found in the Nacimiento Mountains, Pedernal Hills, Lobo Hill, and Zuni Mountains. Cambrian-Ordovician carbonatites are found in the Lemitar and Chupadera Mountains, Lobo Hill, Monte Largo (Sandia Mountains) and southern Colorado (Wet Mountains and Iron Mountain); and Cambrian-Ordovician alkali syenites are found in the Florida Mountains. It is possible that all of the episyenites are related to alkaline or carbonatite plutons at depth and are possibly related to the widespread Cambrian-Ordovician magmatic event that occurred throughout New Mexico and southern Colorado (McMillan and McLemore, 2004).

Diurnal Fluctuations of Arsenic Concentrations and Physiochemical Parameters along the Jemez River, New Mexico

Lorraine Garcia[1], Daryl Williams[1] and Edward Martinez[1]

[1] Department of Natural Resource Management, Mexico Highlands University, Las Vegas, NM, lgarci85@live.nmhu.edu

Snow pack dominated rivers and streams across the Southwestern United States have been feeling the effects of global climate change, which mainly include increasing temperatures and decreasing amounts of precipitation, especially precipitation in the form of snow. Over the past 50 years the Jemez River regions has experienced a 2oF increase in ambient air temperature, as well as a 40% decrease in stream discharge. Spanning roughly 129 km and contributing more than 50,000,000 cubic meters of water to the Rio Grande River annually, the Jemez River is the largest tributary to the Middle Rio Grande Basin. Further complicating matters, the surrounding geology of the Jemez River is of volcanic origin which is responsible for the many hydrothermal springs and seeps in the area, which allow for introduction of heavy metals, especially arsenic into the Jemez River. A 72-study was conducted to determine how total and dissolved arsenic concentrations fluctuate diurnally, and also to determine what physiochemical and site parameters dictate the fluctuations. The study demonstrates that the arsenic concentrations fluctuated up to 60% between night and day, and that a variety of physiochemical parameters, including dissolved oxygen, pH, conductivity, and stream discharge are closely correlated to the fluctuation in arsenic, and also fluctuate diurnally, providing insight to long term changes that the river may experience in the future due to climate change impacts. As the regional climate changes with a continual increase in temperature and decreased precipitation, it is highly probable that arsenic concentrations will rise in the river; possibly high enough to impact downstream users and the water quality of the Rio Grande River.

^{40}Ar/^{39}Ar Muscovite Thermochronology Of Petaca District Pegmatites, Northern, NM

Lisa A. Gaston[1] and Matthew T. Heizler[2]

[1] NMT, 801 Leroy Pl., Socorro, NM, 87801, lgaston.geo@gmail.com

[2] New Mexico Bureau of Geology, NMT, matt@nmt.edu

^{40}Ar/^{39}Ar muscovite dates from pegmatites of the Petaca District in the Tusas Mts, NM reveal cooling ages between 1390 and 1334 Ma. The Petaca District is located along the eastern boundary of Rio Arriba County in northern NM. A once heavily mined area due to the abundance of muscovite; the Petaca district contains more than 200 pegmatites that may also contain important concentrations of REE minerals. We hypothesize that the coarse-grained muscovite will have ^{40}Ar* closure temperatures in excess of 400°C, and depending upon crustal emplacement depth, they might record the intrusion age of the pegmatites. We test this hypothesis by comparing ages of coarse-grained muscovite to ages of finer grained muscovite within metamorphic host rocks. The pegmatite muscovites from 13 samples have overall flat age spectra with integrated ages between 1390 and 1334 Ma and broadly group at 1390, 1370, 1360 and 1335 Ma. The finer grained host rock muscovites from three samples have integrated dates of 1346 and 1332 Ma. Because the basement muscovites are younger than the pegmatite muscovites, we cannot readily conclude that the pegmatite muscovites record intrusion ages. End-member interpretations range from all pegmatites being emplaced at 1390 Ma or older with all ages equaling cooling ages versus each age recording an intrusion over a ~60 Ma duration. Similar muscovite grain size with variable apparent age would argue that ^{40}Ar* closure temperature is not a simple function of physical grain size. We expect to employ in situ ^{40}Ar/^{39}Ar dating and electron microprobe monazite U+Th/Pb dating to better establish intrusion age. Regionally, the muscovite data contribute to the thermochronology database of New Mexico and ca. 1.4-1.35 Ga dates fit well with existing Tusas Mt. data. Expansion of pegmatite dating to more southern and cooler 1.4 Ga basement should identify where muscovite thermochronology can well approximate intrusion ages.

PROTEROZOIC ZONED INTRUSIVE SUITES: DETERMINING THE SURFICIAL RELATIONSHIPS AND EMPLACEMENT MECHANISMS OF THE BURRO MOUNTAIN INTRUSIVE SUITE

Sean Gaynor[1] and Jeff Amato[2]

[1] New Mexico State University, 1255 N. Horseshoe St., Las Cruces, NM, 88003, seanpg@nmsu.edu

The Burro Mountains expose a Proterozoic intrusive suite of ~1.4 Ga granitic plutons, cutting Paleoproterozoic rocks of the southern Mazatzal province. It is part of the vast ~1.4 Ga granite/rhyolite province that stretches across Laurentia. Mapping of the pluton has revealed significant compositional and textural variations. The intrusive body ranges from a coarse grained, biotite-hornblende granodiorite to fine-grained muscovite leucogranite. New mapping has revealed both gradational and sharp contacts between compositional phases of the pluton, redefining previous surficial mapping into four intrusive units: the Jack Creek Granodiorite, Burro Mountain Granite, Langford Mountains Granite and Separ Granite. The Jack Creek Granodiorite, combining previous mapping of the Jack Creek Granite and the granodiorite unit, is a coarse-grained, megacrystic granodiorite. It is the only unit with deformation, ranging from mild foliation to mylonitic grain reduction and migmatite production. These deformational fabrics are concentrated to two orthogonal shear zones, indicative of an extensional tectonic regime coeval to the emplacement of the Jack Creek Granodiorite. This tectonic regime confirms recent research suggesting ~1.4 Ga extension through rapid cooling thermochronology.

What was formerly mapped as the Burro Mountain Granite is now broken down into three units. The Burro Mountain Granite is defined as moderate-grained biotite granite. The Langford Mountains Granite and the Separ Granite are luecogranites separated by textural differences. All phases of the intrusive suite are cut by aplite and pegmatite dikes. Cross-cutting relationships and the presence of xenoliths have established relative ages for the units, in order of oldest to youngest: Jack Creek Granodiorite, Burro Mountain Granite, Langford Mountains Granite and the Separ Granite. An additional unit of ~1.4 Ga magmatism was also identified through field studies, the Spring Creek Diorite. The Spring Creek Diorite is a fine grained mafic rock, marked by megacrystic feldspars. Initially, it appeared to be a younger unit cutting both the Jack Creek Granodiorite and Separ Granite; however it is found foliated within regions of unfoliated Jack Creek Granodiorite, demonstrating that it is the oldest unit. It is not mappable through this project, as it does not have any large scale outcrops.

Division into these units is confirmed through major element geochemistry, specifically the addition of the Langford Mountains Granite and the Separ Granite, as the two units plot in a unique region. The Jack Creek Granodiorite spans a broad geochemical range, matching other large-scale granodiorite such as the Half Dome Granodiorite of the Tuolumne Intrusive Suite.

Field relations indicate that the Burro Mountain Intrusive Suite was emplaced through two distinct periods of different emplacement mechanisms: (1) antitaxial crack-seal emplacement of the Jack Creek Granodiorite and initial emplacement of the Burro Mountain Granite (2) syntaxial crack-seal emplacement of the continued emplacement of Burro Mountain Granite, and the subsequent Langford Mountains Granite and Separ Granite. These were determined through the presence of xenoliths, patterns in textural variations and gradational contacts.

LOW-ANGLE NORMAL FAULTS WITHIN EVAPORITE-RICH PERMIAN STRATA, SIERRA LARGA, NM

Mark W Green[1], Gary Axen[1] and Steven M. Cather[2]

[1] New Mexico Tech, 603 Neel Ave, E&ES Department, Socorro, NM, 87801, misisipimark@hotmail.com

[2] NMBGMR, 801 Leroy Place, Socorro, NM, 87801,

Low-angle normal faults (detachments; LANFs; dip <30°) within evaporate-rich Permian strata are widespread along the eastern flank of the Rio Grande rift near Socorro, New Mexico. First recognized by Smith (1983), this fault system has gone largely unstudied due to the complex structure and stratigraphy in the area. It is the only known LANF system in the Rio Grande rift that initiated at low angles; others appear to have been rotated to gentle dips. The system is composed of younger-on-older faults with stratigraphically-controlled flats (commonly in gypsum-rich intervals) and upper- and lower-plate ramps, most of which cut down section to the east, consistent with top to the east slip. The faults are generally confined to the upper Yeso formation but some also occur in the stratigraphically higher Glorieta and San Andres formations. The detachments excise stratigraphy and, in many places, juxtapose broadly-warped hanging-wall rocks over foot-wall rocks that are folded on much shorter wavelengths. New detailed mapping shows that the detachment system continues along the N and E flanks of the Sierra Larga in the most extensive known upper-plate flat. The internally extended upper-plate, as shown by roll-over anticlines, is limited to the western Sierra Larga and areas farther W. Reconnaissance suggests the system likely extends 30-40 km E, where relatively undeformed Permian strata overlie older tightly-folded and over-thickened Yeso rocks in the Chupadera anticline.

This fault system may have originated as a Laramide thrust and/or gravity slide decollement, as suggested by tightly folded and locally thrust-faulted and overturned strata in the gypsiferous units of the Yeso Formation. These folds are cut by intermediate dikes, one of which, in western Sierra Larga, yields an Oligocene ($^{40}Ar/^{39}Ar$ total gas age of 34.68 +/- 0.11 Ma). This dike is, in turn, cut by detachment-related faults. Traced S, the detachment merges with the E-down, listric Bustos normal fault, which cuts rocks as young as late Oligocene, suggesting that the detachment system was reactivated by normal-sense slip, which explains the many reverse-drag roll-over anticlines in the upper plate. The detachment system is commonly cut by younger, steeper normal faults.

Alternatively, the fault system may have formed from spreading related to synvolcanic loading beneath the volcanic edifices that developed along the Sierra uplift in the middle Eocene-late Oligocene. The presently known N-S extent of the detachments is similar to that of the broad Prairie Spring and Chupadera anticlines and a subsurface halite "tongue" in the Yeso Formation to the east. Salt casts and dissolution structures within Yeso outcrops suggest the halite "tongue" may have extended farther W, providing a weaker medium for slip than gypsum or anhydrite. The over-thickened Yeso within broad folds to the E may represent the blind "toe" of a gravity driven slide.

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21ST CENTURY STREAMFLOWS IN NEW MEXICO

David S Gutzler

University of New Mexico, Dept of Earth & Planetary Sciences, MSC03-2040, Albuquerque, NM, 87131, gutzler@unm.edu

The current drought is just the most recent in a long sequence of multi-year drought and pluvial episodes that characterize the hydroclimate of southwestern North America. The current deficits of snowpack, precipitation and streamflow are occurring within a context of increasing temperature that is projected to continue into the foreseeable future. So what is the future of streamflow in New Mexico? Hydrologic models forced by global climate models provide us with a powerful, but still limited, means for making projections of streamflow on seasonal and longer time scales. We will present an overview of the projected future of streamflows in the major snow-fed rivers of New Mexico in the 21st Century, looking backward in time to assess the models and forward in time to examine scenarios of the future.

TROUBLED TIME

Matthew T. Heizler

NMBG, New Mexico Tech, Socorro, NM, 87801, matt@nmt.edu

Geochronology precision is undergoing a revolutionary increase that allows incredible insight into complex geological processes. However, each incremental improvement in precision is not necessarily linked to an incremental improvement in accuracy. For relative rate or superposition questions, high or ultrahigh-precision data that determines differences is a hugely powerful tool, however accuracy between different methods and between laboratories hinders direct comparison and correlations between high precision data sets. The geochronology community is working diligently to overcome accuracy issues and great strides are being made. For instance, the noble gas community will soon circulate a traveling gas standard of known composition to first evaluate lab-to-lab differences and then to take action towards normalization of these differences. This is affectionately known as the "Smoking from the same pipe experiment". In the mean time, geochronology must go on and a potential short-term solution will be for individual labs to calibrate to known geological boundaries, such as the K-Pg boundary. The New Mexico Geochronology Research Laboratory (NMGRL) has recently installed state of the art Thermo-fisher ARGUS VI multi-collector mass spectrometers that are equipped with low noise amplifiers that are unique to our facility alone. We are applying this technology to a variety of geological problems and the K-Pg boundary is a priority target. In contrast to the recently published Science article of Renne et al. (2013), that yielded normally distributed $^{40}Ar/^{39}Ar$ sanidine ages (66.0 Ma) for K-Pg boundary ashes from Montana, NMGRL data from a Denver basin K-Pg ash reveals substantial scatter in sanidine ages that cannot be detected on older instrumentation. Preliminary data indicate that the NMGRL calibration for the K-Pg could be nearer to 66.2 Ma and this offset has important implications for chronostratigraphy studies such as those from the San Juan Basin, NM. This apparently small difference in absolute time placement of the K-Pg is actually a barrier in deciphering important chronostratigraphy problems such as timing and recovery rates from mass extinctions and auxiliary questions such as the debate surrounding Paleocene dinosaurs. Ultra-high precision measurements also challenges the common view that $^{40}Ar/^{39}Ar$ sanidine geochronology stringently abides by simple argon systematics. We are detecting subtle variations between grains assumed to be equal in age, and the variations call into question the accuracy of lower precision mean ages commonly reported for ash horizons. We do not view this as a negative for the geochronology community, but rather a positive in that we will be capable of resolving geologically important variations once we develop the conceptual tools to fully embrace ultrahigh precision data.

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Acquiring and Georeferencing Coal Mine Maps: San Juan Basin, NM

Gretchen K. Hoffman[1] and Maureen Wilks[1]

[1] New Mexico Bureau of Geology, NM Tech, 801 Leroy Place, Socorro, NM, 87801, gretchen@nmbg.nmt.edu

Coal mining in New Mexico began in 1803, but it was not until the early 1880's with the development of railroads that large scale coal mining began in Gallup and Monero. The railroads and smelters in the Southwest were major markets for New Mexico coal and kept underground mines throughout the San Juan Basin open until after World War II. Many coal mines closed in the 1950's when railroads changed to diesel and natural gas became the primary home heating fuel. A few coal mines continued to provide fuel to local markets until the early 1970's when more stringent regulations caused most of the small coal operations in New Mexico closed.

Passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977 introduced new regulations and a fee on active mines supporting the Abandoned Mine Reclamation Fund. To evaluate areas in need of reclamation, New Mexico state agencies conducted a survey of the abandoned mine lands (AML) created by past coal mining. Geologists at the New Mexico Bureau of Geology participated in this project, locating mine adits in the field, collecting coal mine maps and historical data, and assessing needed remediation. One hundred years of coal mining in the San Juan Basin, New Mexico (Nickelson, 1989) is a compilation of this work for northwest New Mexico.

The San Juan Basin is one of the largest coal areas in New Mexico with 19 recognized coal fields. This area is the focus of our investigation, partially funded by the Office of Surface Mining and Reclamation. Nickelson's publication, the original AML study notes, and maps are the basis of our mine digital database. Production data, geologic references, photographs and maps from NMBG digital archives were related to mines within the database. Local museums, individuals, city and county agencies were contacted to acquire additional data, principally mine maps. Newly acquired mine maps were scanned and georeferenced into the ArcMap project. Point locations for the mines, where available, were projected into ArcMap along with geologic, topographic, and ownership layers.

Depending on the location, many of these old underground mines are within city limits and underlie housing tracts, schools, and shopping centers. Other abandoned mines are near major highways and may impact future development. Existing and future urban growth above these underground coal mines creates numerous environmental and public safety issues. Areas between Farmington and Shiprock along US Highway 64 and the city of Gallup are examples where future development may be impacted by abandoned underground mines. Subsidence and coal fires in underground mines are issues to consider. Determining accurate locations of mine openings, shafts, and extent of workings is crucial to enable regulatory agencies, developers and concerned citizens to address specific safety and environmental concerns.

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Groundwater and Surface Water Interactions in the El Rito Creek, New Mexico

Junhao Hu[1], Lani Tsinnajinnie[1] and Marty Frisbee[1]

[1] New Mexico Tech, jhu@nmt.edu

The El Rito watershed is a snow-dominated watershed, located in Northern New Mexico, that drains part of the Tusas Mountains and supplies flow to the Rio Chama. Synoptic sampling and stream gauging were conducted to monitor groundwater and surface water interactions along the El Rito Creek. It is hypothesized that geologic structures strongly control streamflow and groundwater-surface water interactions in El Rito Creek. Analyses of vertical hydraulic gradients and solute concentrations from stream and mini-piezometer samples, as well as discharge data, indicate a decrease in streamflow in reaches downstream of a fault that crosses the creek. Future work will be conducted to examine what role the fault has in streamflow processes of El Rito Creek and to examine how other factors, such as land use changes, contribute to the discharge pattern observed. These interpretations of groundwater and surface water interactions will be used in the development of a fully coupled groundwater-surface water model of the El Rito watershed.

Groundwater-Fed Wetlands in the La Cienega Area, Santa Fe County, New Mexico

Peggy S. Johnson[1], Daniel J. Koning[1] and Stacy Timmons[1]

[1] New Mexico Bureau of Geology & Mineral Resources, 801 Leroy Place, Socorro, NM, 87801, USA, peggy@nmbg.nmt.edu

Groundwater-fed wetlands in semi-arid landscapes that form large cienega complexes are among the most diminished and threatened ecosystems in the Southwest. Groundwater-fed wetlands on saturated slopes and adjacent to streams cover 384 acres in the La Cienega area and are threatened by dwindling, disrupted or erratic water flows. A collaborative, multi-agency (NMED, NMOSE, NM Bureau of Geology, Santa Fe County, U.S. Fish & Wildlife Service) study of the wetlands completed in December 2012 reveals that a complex interaction between geology, groundwater, and surface flows controls the location and condition of the wetlands.

Groundwater discharging from the Ancha Formation of the Santa Fe Group aquifer feeds the cienegas. As the aquifer thins and pinches out over underlying, low permeability units, groundwater is forced to the surface to discharge in spring-wetland zones and adjacent streams. Storage of groundwater in the Ancha is controlled by three factors: (1) permeability contrasts between the Ancha and sub-Ancha formations; (2) topography of the erosion surface at the base of the Ancha; and (3) recharge to the Ancha.

Paleo-valleys eroded into the surface of the Tesuque Formation and filled with coarse Ancha deposits create altitude-dependent drains that gather groundwater, concentrate flow, and direct discharge to spring-wetland zones. The El Dorado paleo-valley controls locations for large spring-wetland zones on eastern slopes and tributaries of Cienega Creek (Guicu Creek, Canorita de las Bacas, Leonora Curtin Preserve). Sunrise Springs and wetlands along the western slopes of Arroyo Hondo are controlled by the ancestral Santa Fe River paleo-valley. Unique chemistry, isotope, and age (14C and 3H) characteristics between wetland zones east and west of Cienega Creek verify that multiple groundwater sources feed the cienegas and include mixtures, in various proportions, between groundwater from deep regional flow paths through the Tesuque and groundwater from local to intermediate flow paths within the Ancha.

Seasonal water levels in 38 shallow wells show an increase in winter levels of +0.77 ft (average) in wetland zones. A hydrograph and thermograph of continuous measurements from October 2011 to October 2012 in a wetland well show inverse, synchronized changes in water level and temperature in November and April corresponding to transitions between growing and dormant seasons, illustrating the hydrologic response of shallow groundwater to seasonal changes in evapotranspiration. Water levels measured in 22 wells between 2004 and 2012 show water-level declines of 5.03 to -0.10 ft east of the La Cienega wetlands. Thirty-year hydrographs from area wells show a persistent trend of declining levels and, where the measurement frequency is sufficient, also show the cumulative effects of seasonal water-level variations (winter highs, summer lows) and recharge events (spring 2005) superimposed on the effects of pumping and long-term withdrawals. Results suggest that long-term reduction in aquifer storage in the Ancha poses a significant threat to wetland condition.

STRUCTURAL CONTROL OF WARM SPRINGS IN THE HILLSBORO-LAKE VALLEY AREA

Shari Kelley[1], Mussie Tewelde[2], James Witcher[3] and Mark Person[2]

[1] New Mexico Bureau of Geology & Mineral Resources, New Mexico Tech, Socorro, NM, 87801, sakelley@nmbg.nmt.edu ph: 505-412-9269

[2] Earth and Environmental Science Department, New Mexico Tech, Socorro, NM, 87801,

[3] Witcher and Associates, P.O. Box 3124, Las Cruces, NM, 88003,

Subsurface fluid flow and heat transport in the Animas graben and Animas horst between Hillsboro and Lake Valley in south-central New Mexico are evaluated using older industry and new temperature gradient data, and published and new water chemistry and isotopic data. Thermal manifestations include warm springs (31-38°C) and a borehole with a high geothermal gradient (80°C at 74 m) near Hillsboro. In addition, three shallow water wells drilled during the past decade near Lake Valley have encountered warm water (31-38°C) at shallow depth (<24 m). These warm waters and a nearby warm spring indicate the presence of a previously undocumented geothermal system north of Lake Valley along Berrenda Creek where the creek crosses the Animas horst. A hydrogeologic model, using temperature as a groundwater tracer, was constructed to test the hypothesis that groundwater originating from the Black Range flows eastward, circulates to depths up to 4 km to be heated, and flows upward to discharge along the western boundary faults of the Animas horst, particularly the north-striking Berrenda normal fault. Although the steady-state hydrogeologic model does produce elevated temperatures along the Berrenda fault, the temperature-depth profiles predicted by the model do not match the observed data. Instead, the shapes of the measured temperature-depth profiles from the Hillsboro area are more consistent with a shorter lived, dynamic hydrothermal system, with hot water leaking up along the Berrenda fault and associated buried faults to the west. The warm water along Berrenda Creek just north of Lake Valley is leaking up along a fault zone located about 300 m to the east of the main strand of the Berrenda fault. The estimated reservoir temperatures at Hillsboro using the chalcedony and quartz geothermometers from springs and wells is 73 to 137°C and 68 to 161°C, respectively, compared to a temperature of 300°C at 4 km predicted by the model. The estimated reservoir temperature near Lake Valley using the chalcedony geothermometer is 64 to 83°C. Most of the sampled groundwater has similar chemistry and a meteoric water isotopic composition. Exceptions are waters from wells near Hillsboro, which have elevated sulphate and low magnesium and calcium concentrations compared other groundwater in the area.

THE ANCHA FORMATION IN THE SANTA FE EMBAYMENT: STRATIGRAPHY, TEXTURE AND THICKNESS VARIATIONS, AND GEOMETRY OF THE UNDERLYING MIO-PLIOCENE UNCONFORMITY

Daniel J. Koning[1] and Peggy S. Johnson[1]

[1] New Mexico Bureau of Geology & Mineral Resources, N.M. Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, dkoning@nmbg.nmt.edu ph: 575-835-6950

The Ancha Formation (late Pliocene-early Pleistocene) underlies the Santa Fe embayment between Santa Fe and Galisteo Creek. Where saturated, this relatively coarse deposit constitutes an important aquifer. We use lithologic information from wells and outcrops to evaluate the geometry of its basal contact and spatial variations in its thickness and texture, which can then be used to assess aquifer thicknesses and groundwater flow paths.

The base of the Ancha Formation is a scoured angular unconformity. Bedrock units that lie beneath the Ancha Formation in the southern embaymen include the Espinaso and Galisteo Formations plus Mesozoic and Paleozoic strata. Northward of 35°31.5' N latitude, volcaniclastic Tesuque Fm units are present and then arkosic Tesuque sediment derived from the southernmost Sangre de Cristo Mountains. These older strata are 1 to 4 orders of magnitude less permeable to groundwater than the Ancha Formation, with the Tesuque Formation being more permeable than older strata.

We subdivide the Ancha Formation into two lithofacies assemblages. One was deposited by a southwest-flowing, ancestral Santa Fe River and is consistently coarse-grained in a downstream direction. Santa River deposits are as much as 70 m thick 1-2 km south-southwest of Agua Fria, but thin westward to 19-30 m under the Caja del Rio Plateau. North and south of the ancestral Santa Fe River deposits are alluvial slope assemblages deposited by smaller, west-flowing, ephemeral streams. The northern alluvial slope deposits pinch out northward and northeastwards against the Santa Fe uplands. The southern alluvial slope deposits are generally 15-45 m thick but thicken to 70-90 m in the center of the embayment. There is also a relatively thick (50-70 m), northwest-trending zone near El Dorado and Seton Village. The lower 10-40 m of the southern alluvial slope deposits is generally coarse-grained (sand and gravel). In overlying strata, sandy gravel dominates near the Sangre de Cristo Mountain front but gross texture fines westward to clayey-silty fine sand.

We attribute thickness variability to tectonics and pre-Ancha (late Miocene-early Pliocene) erosion. Footwall unloading along the La Bajada fault to the west may explain the eastward thickening of the Ancha Formation in the western embayment. The Ancha Formation also thickens over paleotopographic lows created by pre-Ancha erosion. The thick zone of Ancha Formation near El Dorado is underlain by Tesuque Formation that was likely preferentially eroded. Erosion also carved 5-15 m-deep paleovalleys (locally as much as 30 m deep). Although locally observed in outcrop, paleovalleys are defined regionally by contouring the elevations of the Ancha Formation base. Two paleovalleys are especially noteworthy. The northern is associated with the ancestral Santa Fe River and trends southwest near Arroyo de los Chamisos. The southern one trends west and then northwest from the Eldorado area. These two paleovalleys join 2 km east of La Cienega, and the downstream paleovalley roughly follows the course of the modern Santa Fe River, deviating to the south ~2.5 km southwest of La Cienega. The paleovalleys are hydrologically important because they may hold thick (up to 30 m) accumulations of saturated Ancha Formation.

THE PENNSYLVANIAN SANDIA FORMATION IN NORTHERN AND CENTRAL NEW MEXICO

Karl Krainer[1] and Spencer G. Lucas[2]

[1] University of Innsbruck, Innrain 52, Innsbruck, A-6020, AUSTRIA, Karl.Krainer@uibk.ac.at ph: +43-512-507-5585

[2] New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM, 87104, spencer.lucas@state.nm.us

Across much of northern and central New Mexico, the Sandia Formation forms the base of the Pennsylvanian succession and represents early synorogenic deposits associated with the initiation of the Ancestral Rocky Mountains (ARM) orogeny. The Sandia Formation was first named in 1900 and rapidly became part of the New Mexico lithostratigraphic chart. In northern and central New Mexico the Sandia Formation is a mixed siliciclastic and carbonate succession, particularly characterized by thick beds of quartz-rich sandstone, conglomeratic sandstone and conglomerate. The high amount of siliciclastic sediment was derived from tectonically active local ARM uplifts composed of Proterozoic basement rocks.Thickness of the Sandia Formation in central New Mexico ranges from 7 to162 m, with the thinner sections close to the ARM highlands. At most places the Sandia Formation rests on Proterozoic basement with an angular unconformity. Locally it overlies Mississippian or Lower Pennsylvanian sedimentary rocks. At most places the dominantly or entirely siliciclastic sediments of the Sandia Formation are conformably overlain by thicker limestone/cherty limestone units of the Gray Mesa Formation. In northern New Mexico sandstone of the Sandia Formation is commonly subarkose, whereas to the south most sandstones are quartzarenites. Towards southern New Mexico (Fra Cristobal, Caballo Mountains) the Sandia Formation interfingers with the Red House Formation.Limestones of the Sandia Formation are composed of various microfacies types including phylloid algal wackestone, bioclastic mudstone, wackestone, floatstone and grainstone to rudstone containing a diverse fossil assemblage. The depositional environment of siliciclastic sediments ranges from fluvial to fluvio-deltaic, coastal swamp and brackish, to coarse-grained high-energy nearshore (storm dominated shelf) and fine-grained middle-outer shelf deposits. Limestone containing a low-diverse fossil assemblage indicates deposition in a restricted shallow marine shelf environment. Limestone types with a diverse fossil assemblage accumulated in open, normal marine shallow shelf settings of low to high energy.The Sandia Formation yields abundant fossils of nonmarine (plants and amphibians) to fully marine (especially algae, foraminifers including fusulinids, brachiopods, crinoids, bryozoans and sharks teeth) organisms. Fusulinids and limited conodont records indicate that the Sandia Formation is mostly of Atokan age, but locally the lower part of the formation is late Morrowan.The Sandia Formation was deposited as part of the extensive Absarokan marine transgression and is characterized by distinct lateral changes in thickness and facies as a result of the ARM deformation. Cycles are present within the dominantly marine successions of the Sandia Formation, but cannot be traced laterally over long distances, so we assume that the formation of the cycles was caused mainly by tectonic movements of the ARM, although some glacio-eustatic influence cannot be ruled out.

HYDROLOGIC IMPACTS OF BURN SEVERITY ON NUTRIENT CONCENTRATIONS IN SURFACE WATER RUNOFF AND SOILS FROM THE LAS CONCHAS FIRE, JEMEZ MOUNTAINS NEW MEXICO

Anita Lavadie[1], Edward Martinez[1], Sara Brown[1] and Joseph Zebrowski[1]

[1] New Mexico Highlands University, alavadie@live.nmhu.edu

Climate change is expected to increase wildfire severity in the Southwest. Following large fires, surface water runoff and soils contributes high concentrations of nutrients to water bodies and has the potential to impair surface water quality and terrestrial systems. Although there is a considerable amount of research on the effects of nutrients in surface water runoff and soils following a fire, the need to directly investigate nutrient levels transported from various severity classes is required. The purpose of this study is to investigate the contributions of nitrite-nitrogen (NO^{2-}), nitrate-nitrogen (NO^{3-}) orthophosphate (OP) levels from surface water runoff originating from various wildfire severity classes from the Las Conchas fire in the Jemez Mountains, New Mexico. To complete this task NO^{2-}, NO^{3-}, and (OP) concentrations will be determined from surface water runoff and soils originating from predetermined high, moderate, low, mixed, and control (unburned site) fire severity types. Fire severity site qualification was determined in a previous study. We hypothesize that our results from the high severity burn area will have the least contribution of NO^{2-}, NO^{3-}, and (OP) and control will have the highest.

Paleoenvironmental Preferences and Distribution of Late Cretaceous Turtles in the San Juan Basin, New Mexico

Asher Jacob Lichtig[1] and Spencer G Lucas[1]

[1] New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM, 87104, ajlichtig@aol.com

The Upper Cretaceous (upper Campanian) Fruitland and Kirtland formations in the San Juan Basin contain an extensive fossil record of turtles (Sullivan et al., 2012). These formations represent a transect from coastal plain and swamp (Fruitland) to inland flood plain facies (upper Kirtland), and thus allow analysis of how their fossil turtles have varied with respect to paleoenvironments.

We used two methods to infer the paleoenvironmental preferences of the Fruitland-Kirtland turtles. First, the methods of Benson et al. (2011) provided a general guide. Second, we compared carapace maximum width to plastron width behind the bridge, finding that a ratio ≤ 1.5 is indicative of a terrestrial turtle. Terrestrial is defined as spending a considerable amount of time on land, such as extant Glyptemys insculpta.

Based on these analyses, Basilemys is terrestrial based on the low bridge height and the wide plastron. Denazinemys and Scabremys are highly aquatic given the wide low plastron and resemblance to modern river turtles, particularly the podocnemids. Neurankylus bauri shows some resemblance to modern map turtles, and resided in a fluvial environment. Boremys and Thescelus appear to fall in the middle-- neither fully aquatic nor terrestrial-- possibly similar to modern pond turtles (i.e. Psuedemys) given their midrange in shape. Aspideretoides are soft shell turtles with habits similar to modern trionychids in being aquatic and using their soft shell to burrow in the substrate.

These turtles show a variation in relative abundances in fossil finds across the Fruitland and Kirtland formations. The abundance of trionychids is highest in the De-na-zin Member of the Kirtland Formation (and Naashoibito Members of the Ojo Alamo Formation). Adocus and Denazinemys dominate the Fossil Forest and Hunter Wash members of the Fruitland and Kirtland formations.

The diversity of turtles appears higher in the Fruitland and Hunter Wash Member of the Kirtland Formation than in the upper members of the Kirtland Formation. This likely resulted from a higher diversity of environments near the coast with swamp channels in addition to the flood plain deposits also seen in the stratigraphically higher units. Basilemys is a prime example, being known from the Fossil Forest Member of the Fruitland Formation and the Naashoibito Member of the Ojo Alamo Formation. Presence of a swamp environment during Fruitland deposition may have resulted in the increase in the abundance of Basilemys by creating an area where the terrestrial species came into proximity with channels and floods, which increased the possibility of preservation.

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U-PB GEOCHRONOLOGY OF PROTEROZOIC GRANITOIDS IN THE SOUTHERN SANGRE DE CRISTO MOUNTAINS, NEW MEXICO

Jennifer Lindline[1], Danielle Cedillo[2] and Andrew Romero[3]

[1] New Mexico Highlands University, P.O. Box 9000, Las Vegas, NM, 87701, lindlinej@nmhu.edu

The Hermit's Peak batholith, a Proterozoic metamorphic-plutonic massif in the southern Santa Fe Range of the southern Sangre de Cristo Mountains, is located in the tectonic transition zone between the Yavapai and Mazatzal Precambrian provinces. We conducted U-Pb zircon geochronology on five previously undated Hermit's Peak batholith intrusions to establish the timing of magmatism relative to Proterozoic deformation events. The Gallinas Canyon felsite is a fine- to medium-grained quartzofeldspathic gneiss that yielded a date of 1.705±0.017 Ga (n=24). The felsite displays a strong penetrative steeply dipping east-northeast trending schistocity and gneissic layering that is parallel to the axial surface of tight to isoclinal folds. The felsite is frequently interlayered with fine- to medium-grained amphibolite and commonly intruded by K-feldspar megacrystic alaskite pegmatites. The approximately 30 km^2 Hermit's Peak granite is a coarse equigranular and variably foliated granite. At some locations the granite displays a strong solid-state foliation, in others a modest submagmatic to magmatic foliation, and a lack of a foliation in others. A weakly foliated sample of the Hermit's Peak granite from Porvenir Canyon yielded a date of 1.700±12.1 Ga (n=24). The Evergreen Valley tonalite is a coarse equigranular strongly foliated garnet-bearing hornblende-biotite tonalite that crystallized at 1.736±0.014 Ga (n=24). The tonalite was intruded by the Evergreen Valley granite-gabbro complex which yielded ages of 1.448±0.012 Ga (n=43) and 1.450±11.9 Ga (n=32), respectively. The granite-gabbro complex is layered on the macroscale but lacks an internal fabric. Both the gabbro and granite are coarse equigranular and display isotropic petrofabrics. Our results illustrate the episodic nature of magmatism in the Hermit's Peak batholith at circa 1.7 Ga and 1.4 Ga as well as the prevalence of pre-1.45 Ga deformation. Our ongoing studies are addressing the structural relationship between the Hermit's Peak granite and its host rocks as well as the petrogenesis of the Evergreen Valley gabbro-granite complex to further understand the tectonic setting of 1.7 Ga and 1.4 Ga magmatism in the Santa Fe Range.

A MAJOR LANDSLIDE INVOLVING AN INVERTED PALEOCHANNEL IN SIERRA COUNTY, NEW MEXICO

Gerald P. Lindsey

(retired), 5801 Lowell, NE, 28C, Albuquerque, NM, 87111, geojerryl@comcast.net

A landslide that probably dates to the end of the Pleistocene has been found adjacent to the the New Mexico Spaceport. The feature consists of three subparallel segments partitioned by southeast trending drainages, covering an area about 8 km wide and 10 km long. It lies just off Sierra County road A013 and Apache Gap road near the entrance to the spaceport site. The head of the slide deposits consist of a northeast trending truncated paleochannel forming an inverted topographic ridge. The best view of the slide are satellite photos that show the offset of the paleochannel and the transverse ridges and swales pattern comprising the bulk of the slide body. The head of the slide is partly underlain by the Cretaceous Crevasse Canyon Formation and the Tertiary Love Ranch Formation. The slide plane is approximated as the unconformable contact between these two formations and likely facilitated by a clay stratum near the base of the the Tertiary deposits. The paleochannel deposits, with some rounded intrusive rock boulders with sizes up to 1.5 meters diameter, indicate a very high flow rate. A series of northwest trending faults have acted as shear zones separating and truncating the landslide segments. The western segment has been washed away leaving only trace evidence of the slide body. A low slide plane angle of less than one percent suggests a seismic trigger.

HYDROCHEMISTRY OF LAVA TUBE SPRING AND THE RIO GRANDE, TAOS COUNTY, NEW MEXICO

Patrick Longmire[1], Michael Dale[2], Kim Granzow[1], Donald Carlson[1], Benjamin Wear[2], Jerzy Kulis[2], George Perkins[3] and Michael Rearick[3]

[1] New Mexico Environment Department-DOE Oversight Bureau, 1183 Diamond Drive Suite B, Los Alamos, NM, 87544, plongmire@lanl.gov

[2] New Mexico Environment Department-Hazardous Waste Bureau, 1183 Diamond Drive Suite B, Los Alamos, NM, 87544,

[3] Los Alamos National Laboratory, Earth and Environmental Sciences Division, MS D469, Los Alamos, NM, 87545,

Lava Tube spring is a subaqueous spring that discharges from the Servilleta Basalt directly beneath the Rio Grande 21 km northwest of Questa, New Mexico. Lava Tube spring is the largest single active spring in New Mexico, with a discharge rate of approximately 22,680 L/min (6000 gal/min). Additional springs discharging within the study area are characterized by low flow rates (<150 L/min, <40 gal/min). Water samples collected upstream, at Lava Tube spring, and downstream along the Rio Grande on July 12, 2012 were analyzed for major ions, trace metals, tritium, and stable isotopes of hydrogen and oxygen. The upstream and downstream stations are 273 m north and 182 m south of Lava Tube spring, respectively. Surface-water flow rates average 1.90 cms (67 cfs) upstream of Lava Tube spring and 2.69 cms (95 cfs) downstream of the spring during sampling. Surface-water flow velocities averaged 0.16 and 0.27 m/sec (0.38 and 0.87 ft/sec) upstream and downstream of Lava Tube spring, respectively. Groundwater discharging from Lava Tube spring mixes with the Rio Grande surface water and constitutes between 32 and 38 percent of chemical tracers measured in the Rio Grande below the spring in the study area. Mixing calculations are based on concentration differences of chloride, sulfate, and uranium, tritium activity, and $\delta^{18}O$ and $\delta^{2}H$ values. Lava Tube spring and the Rio Grande are oxidizing with respect to Fe and dissolved oxygen concentrations range from 8.84 to 9.77 mg/L during sampling. Rio Grande surface water and groundwater discharging from Lava Tube spring are characterized by a Na-Ca-HCO_3 composition, with higher concentrations of major ions and selected trace elements (As, B, Mn, Mo, and Sr) and tritium activities measured in surface water. Lava Tube spring $\delta^{18}O$ and $\delta^{2}H$ values are more negative than Rio Grande surface water, possibly reflecting recharge at higher elevation. Lava Tube spring and the Rio Grande are undersaturated with respect to calcite and amorphous silica and oversaturated with respect to albite, gibbsite, and chalcedony, based on geochemical calculations using the computer program PHREEQC. Lava Tube spring approaches equilibrium with respect to Na- and K-saponite and analcime most likely produced from hydrolysis reactions with Servilleta basaltic glass. Concentrations of dissolved U(VI) below 10^{-8} molal are stable as $UO_2(CO_3)_2^{2-}$ and $UO_2(CO_3)_3^{4-}$ based on geochemical modeling simulations. Speciation calculations suggest that concentrations of dissolved As(V) below 10^{-7} molal are dominantly stable as $HAsO_4^{2-}$.

IMPLICATIONS OF THE EASTERN EXTENT OF ANCESTRAL RIO GRANDE DEPOSITS, NORTHWESTERN EXTENT OF FANS FROM THE EASTERN RIFT SHOULDER, AND PRESERVATION OF INSET TERRACES, SOUTHEASTERN ALBUQUERQUE BASIN

David W Love[1], Alex Rinehart[2], Gary Morgan[3], Bruce Allen[1] and David McCraw[1]

[1] New Mexico Bureau of Geology & Mineral Resouces, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, NM, 87801, USA, davel@nmbg.nmt.edu ph: 575 835-5146

[2] Earth and Environmental Science Department, New Mexico Tech, 801 Leroy Place, Socorro, NM, 87801,

[3] New Mexico Museum of Natural History and Science, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM, 87104, USA,

During the past few million years, tectonism and Rio Grande aggradation and erosion have controlled the dynamics of landscape evolution in the southeastern Albuquerque basin of the Rio Grande rift. Landscape elevations, courses of the Rio Grande, and paths of large tributaries are controlled by tectonic uplift and subsidence, and sediment erosion and aggradation. Sediment transport and storage along the Rio Grande and tributaries are related to episodic fluctuations in climate-determined discharge. The basin-scale interplay of tectonics and sediment storage is reflected in the geometry of alluvial fans, the maximum level of aggradation, and the eastern extent of Rio Grande deposits.

Quaternary tectonism is suggested by paths of tributaries, and the broad removal and contrasting burial of equivalent Pliocene deposits. The south-trending Rio Puerco hooks eastward near Bernardo. Southeastern tributaries trend northwest toward Bernardo, joining the Rio Grande in upstream directions. High-level (Pliocene?) alluvial deposits west of the southern Los Pinos Mountains are poorly preserved south of the Palo Duro-Cibola divide. Equivalent-aged Pliocene rift sediments are buried or at lowest exposures along the Rio Grande valley, indicating a steeper slope between uplifts and basins. These observations suggest the southern Albuquerque basin subsided while the rift flanks uplifted during Quaternary time despite the paucity of observed fault scarps.

Elevations of maximum aggradation of Rio Grande well-rounded mixed-gravel deposits as high as 1,554 m (114 m above the river) are exposed in Abo Arroyo to Turututu (Black Butte) to the headwaters of Pascual Arroyo (east of Contreras). Rio Grande deposits continue south along the west flank of Joyita Hills. These deposits contain clasts of 1.4-Ma Rabbit Mountain obsidian and rare clasts of Bandelier Tuff (Tshirege Mbr). The deposits extend approximately 10 km east and southeast from the modern Rio Grande channel, 3 km farther east and 34 m higher than previously mapped.

The previously interpreted top of basin fill at 81 m above the Rio Grande floodplain is interpreted now as an inset terrace tread. Exposures in Abo Arroyo show two bluff-line unconformities of inset terraces with the two western middle Pleistocene straths closely spaced (instead of one) approximately 39-43 m above the present Rio Grande. The oldest bluff line is between cemented Rio Grande deposits and a package of uncemented strath of Rio Grande channel and floodplain deposits overlain by Abo Arroyo fan deposits. The cemented Rio Grande deposits contain the Blancan camel *Hemiauchenia gracilis* and horse *Equus cumminsii*. The second bluff line and package of similar facies is approximately 15 m west, and the basal strath gravel is 1.5-2 m below the strath to the east. Abo Arroyo also exposes a higher, more gravelly terrace (?) above the cemented unit and a lower, extensive terrace near Veguita with a tread 29 m above the floodplain similar to terraces mapped farther south.

LATE CRETACEOUS (MIDDLE CENOMANIAN) AMMONOIDS FROM THE MANCOS FORMATION, BIG BURRO MOUNTAINS, GRANT COUNTY, NEW MEXICO

Spencer G. Lucas[1] and Sarah E. Machin[2]

[1] New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, spencer.lucas@state.nm.us

[2] Department of Geological Sciences, New Mexico State University, Las Cruces, NM, smachin@nmsu.edu

An approximately 335-m thick section of the Mancos Formation (= "Colorado Shale") is exposed on the southwestern flank of the Big Burro Mountains just north of Redrock in Grant County, New Mexico. Here, the Mancos Formation overlies strata traditionally termed Beartooth Formation with evident, transgressive disconformity. Thus, the topmost bed of the Beartooth Formation is coarse-grained sandstone capped by a dark, hematitic crust that locally contains a matrix-supported conglomerate of mostly siliceous pebbles. The base of the Mancos Formation is very finely laminated shale with some silty/sandy interbeds. In the lower 5 m of the Mancos Formation we have collected a sparse but age-diagnostic assemblage of ammonoids in nodular limestone concretions in shale. Three ammonoid taxa are present: *Acanthoceras amphibolum* Morrow, *Tarrantoceras sellardsi* (Adkins) and *Desmoceras* sp. These ammonoids identify the *Acanthoceras amphibolum* zone of middle Cenomanian age, so this is (within resolution) the age of the base of the Mancos Formation in this part of the Big Burro Mountains. This is an age consistent with previous ammonoid-based determinations of the age of the base of the Mancos Formation in southwestern New Mexico. A volcanic ash bed in the Big Burro Mountains at the ammonoid localities, ~ 14 m above the base of the Mancos Shale, has a zircon U/Pb age of 96.3 ±1.3 Ma. This numerical age just above middle Cenomanian ammonoids is consistent with current numerical calibration of the Cenomanian Stage.

PRIMITIVE MAMMOTH JAW FROM LOWER PLEISTOCENE RIO GRANDE SEDIMENTS, SOCORRO, NEW MEXICO

Spencer G. Lucas[1], Gary Morgan[1], Craig Bejnar[2], Nelia Dunbar[3], Richard Chamberlin[3] and David Love[3]

[1] New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, spencer.lucas@state.nm.us

[2] Socorro, NM, 87801

[3] New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, NM, 87801

A mammoth jaw found as a large clast reworked from ancestral Rio Grande (ARG) deposits in Matanza Arroyo at Socorro, New Mexico, is from one of the geologically oldest and most primitive North American mammoths. Thin, cross-bedded layers of pumice above the jaw-bearing bed are geochemically identical to Group II pumices in ARG sediments between 1.2 and 1.6 million years in age (Cerro Toledo eruptions of Jemez volcanic field) studied in Hell Canyon. The ARG deposits underlie thick fan deposits of Qvo3, which forms the surface at the Socorro County fairgrounds and airport. This fan surface is traceable down the arroyo to ancestral Rio Grande terrace deposits, 30 m above the modern Rio Grande floodplain and is traceable up Matanza Arroyo to a terrace along Socorro Canyon Arroyo. In 2003, Phillips et al. determined a ^{36}Cl age of 122 ± 18 ka for this terrace. Although the upper surface and shallow deposits of Qvo3 likely are equivalent to the age of the Qvo3 terrace in Socorro Canyon, the stratigraphy of the alluvium and soils between the jaw and the fan surface suggests a long history of erosion, deposition, and stability.

The mammoth fossil, catalogued as New Mexico Museum of Natural History P-67371, is a left dentary fragment with incomplete m2-3. It has a short symphysis, relatively low and narrow horizontal ramus and, what remains of the ascending ramus suggests it was relatively low and inclined posteriorly. The left m2 is fully erupted, moderately worn and preserves 6.5 plates (the anterior 1-2 plates are missing), for a plate count of 7-8. The tooth is relatively small (length = 150 mm, width = 70 mm), has a low plate ratio of 6 and very thick enamel (average thickness = 3.8 mm). The m3 is beginning to erupt and preserves 6.5 similar plates with very thick enamel. The small size of the molars, very thick enamel and shape of the dentary identify NMMNH P-67371 as a very primitive mammoth, *Mammuthus meridionalis*.

Three other early Pleistocene (early Irvingtonian North American land-mammal "age," ~1.6-1.0 Ma) mammoths are found in New Mexico. The most complete specimen is a pair of lower jaws from the Sierra Ladrones Formation in Tijeras Arroyo, Bernalillo County. The Tijeras Arroyo mammoth was referred to *Mammuthus meridionalis* based on the low plate count and thick enamel of the m3 and shape of the dentary, all similar to the Matanza Arroyo mammoth. A partial skull with both tusks and an M3 of *M. meridionalis* were collected from the Adobe Ranch fauna in the Camp Rice Formation, Doña Ana County. Both the Tijeras Arroyo and Adobe Ranch records of *M. meridionalis* are associated with Ar/Ar dated volcanic ashes, indicating an age range of 1.6–1.2 Ma. Several isolated teeth of the more advanced mammoth *M. imperator* are known from the Tortugas Mountain fauna east of Las Cruces in the Camp Rice Formation, Doña Ana County. The association of the Tortugas Mountain *Mammuthus* with the gomphothere *Stegomastodon* suggests an age older than 1.2 Ma.

REDEFINITION OF THE BASE OF THE PERMIAN

Spencer G. Lucas

New Mexico Museum of Natural History, 1801 Mountain Road N.W., Albuquerque, NM, 87104, spencer.lucas@state.nm.us

For more than 70 years, the base of the Permian was recognized by a fusulinid biostratigraphic datum, the first occurrence (FO) of "*Schwagerina,*" which to many meant the FO of the inflated schwagerinids. In 1998, the base of the Permian was defined by the FO of the conodont *Streptognathodus isolatus* at the GSSP located at Aidaralash Creek in western Kazakstan approximately coeval with the FO of the fusulinid *Sphaeroschwagerinafusiformis*. However, it is now clear that with respect to longstanding fusulinid biostratigraphy, the FO of *S. isolatus* is diachronous, with the GSSP being among the youngest known FOs of the species, and that the taxonomy and evolution of *S. isolatus* are not agreed on. This calls into question the conodont-based definition of the base of the Permian. In North America, the base of the Permian had been identified as the base of the Wolfcampian Series since about 1939, based on the FO of *Schwagerina* in the North American sense. However, longstanding and widely accepted fusulinid correlations indicate that the conodont-defined Permian base at the Aidaralash GSSP is younger than the Wolfcampian base, and corresponds closely to the early-middle Wolfcampian boundary. This has created much confusion with respect to the base of the Permian in North America, particularly with regard to a vast literature developed for an oil industry understanding of the greater Permian basin. It also fueled an unnecessary debate over whether a new stage, "Bursumian," was needed in the North American provincial chronostratigraphy to equal early Wolfcampian time, so that the system boundary would not be within a provincial "stage," but correspond to a "stage" boundary. Instead, we need to reconsider the position of the base of the Permian and its current GSSP, and reposition the base of the Permian so as to respect longstanding usage and produce the most correlateable boundary. No conodont-based definition obviously meets these criteria, but a fusulinid-based definition does. Two choices are available--the LO of North American *Schwagerina s. str.* (= *Thompsonites* Bensh?),which defines the base of the Wolfcampian, or the LO of an inflated schwagerinid taxon, which defines the beginning of the middle Wolfcampian and is closer to the original base of the Asselian. I favor the FO of North American *Schwagerina* sensu stricto because it also marks a major biological event—the beginning of the explosive diversification of schwagerinids--and it retains longstanding and extensive North American usage that equates the base of the Wolfcampian with the base of the Permian. In New Mexico, the section of the Horquilla Formation at New Well Peak in the Big Hatchet Mountains of Hidalgo County provides an excellent place to undertake such redefinition because of its unparalleled fusulinid record through the Pennsylvanian-Permian boundary. A fusulinid-defined base of the Permian respects longstanding usage and produces a correlateable Permian base that is synchronous within current levels of biostratigraphic resolution.

USING URANIUM ISOTOPES TO DETERMINE SALINITY SOURCES IN RIO GRANDE WATERS

Lin Ma[1], Anna Szynkiewicz[1], David Borrok[1] and Jennifer C. McIntosh[2]

[1] Department of Geological Sciences, University of Texas at El Paso, 500 W. University Ave, El Paso, TX, 79968, lma@utep.edu

[2] Department of Hydrology and Water Resources, University of Arizona, Tucson, AZ, 85721, mcintosh@hwr.arizona.edu

The Rio Grande flows from Southern Colorado through New Mexico and West Texas down to the Gulf of Mexico. It serves as an important water supply for agricutural and municipal needs. In Rio Grande waters, total dissolved solids (TDS) increase from ~40 mg/L at the headwaters to 500-1500 mg/L at El Paso, Texas. The elevated TDS values in downstream water cause various problems such as reduction in crop productivity and deterioration of soil quality due to salt loading. A number of natural and anthropogenic factors may lead to increased salinity, so the exact sources and their relative contributions to the salt load remain unclear. U isotopes (e.g., ^{234}U and ^{238}U) fractionate naturally when released from rocks to waters during chemical weathering processes at Earth's surface. It has been suggested that the degree of U isotope fractionation depends largely on local lithology and climate conditions, which affect chemical weathering and U release rates. U isotopes in natural waters thus have great potential to serve as natural tracers for chemical weathering processes, which in turn can help to determine the origins of dissolved solids (i.e., salts) and their history.

Here, we measured the U concentrations and isotope ratios for water samples collected along a ~ 1000 km stretch of Rio Grande (from the headwaters in Colorado to El Paso, Texas), as well as from streams and springs in the Jemez Mountains, a small drainage basin that recharges to Rio Grande in northern New Mexico. The comparison of these two case studies reveals different evolution histories for U in surface waters. In the Jemez Mountain region where human impacts are minimal, U isotope ratios in surface waters are largely controlled by rhyolite weathering, and both U concentrations (0.01-0.19 ppb) and ($^{234}U/^{238}U$) activity ratios (1.5-3.0) vary systematically with elevation (2600-2900 m). Here, solutes in streams largely represent mixing of two sources: young surface water (e.g., several months old) with low U concentrations and high ($^{234}U/^{238}U$) ratios and relatively old shallow groundwater that has higher U concentrations and lower ($^{234}U/^{238}U$) ratios. Similar ranges of U concentrations and ($^{234}U/^{238}U$) ratios are observed for the headwater regions of the Rio Grande. U concentrations in the Rio Grande increase significantly downstream (0.12 to 5.97 ppb) and correlate well with Ca^{2+}, Mg^{2+}, and HCO_3^- ions, revealing a control of carbonate dissolution/precipitation on river water chemistry. This is probaly due to a change of lithology. In addition, both ($^{234}U/^{238}U$) ratios (1.6-2.1) and U concentrations in the Rio Grande waters show strong seasonal patterns, reflecting the human impacts on river chemistry, such as the regulation of river flows by reservoirs and dams, agricultural irrigation return flows, and pumping of cold/geothermal aquifer waters.

THE AGE OF THE ENCINAL CANYON MEMBER OF THE DAKOTA FORMATION: NEW INSIGHTS INTO THE EARLY-LATE CRETACEOUS TRANSGRESSION OF THE WESTERN INTERIOR SEAWAY INTO NORTH-CENTRAL NEW MEXICO

Sarah Machin[1], Jeffrey Amato[1] and Spencer Lucas[2]

[1] New Mexico State University, Department of Geological Sciences, MSC 3AB, P.O. Box 30001, Las Cruces, NM, 88003, smachin@nmsu.edu

[2] New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, NM, 87104,

The transgression of the Western Interior seaway into North America is widely accepted as occurring in the Early-Late Cretaceous; however, the precise age of the marine incursion into northern New Mexico is not well understood. As the seaway migrated southwestward, rocks generally termed the Dakota Formation were deposited as its paralic facies throughout the Western Interior. Distal rivers to the west and southwest of the encroaching shoreline backfilled as base level rose, and in north-central New Mexico, stream aggradation in pre-Dakota incised valleys resulted in deposition of the lowest part of the Dakota Formation–the Encinal Canyon Member.

The age of the fluvial Encinal Canyon Member – and thus the shoreline position of the Western Interior seaway during Encinal Canyon deposition – has long been unclear for a lack of age data, though some workers posited a late Early Cretaceous (late Albian) age based on regional stratigraphy and limited palynological data. In northern NM, the Encinal Canyon Member is a discontinuous fluvial sandstone, 0-75 m thick, that has not yielded age-diagnostic fossils and directly overlies a regional unconformity with the Upper Jurassic Jackpile Member of the Morrison Formation. The marine Oak Canyon Member of the Dakota Formation disconformably overlies the Encinal Canyon Member, and was deposited as shallow marine and marginal marine sands when the seaway transgressed over the region. It is mid-Cenomanian in age based on ammonoid biostratigraphy. New U-Pb zircon geochronology resolves the timing of the transition from continental to marine deposition represented by these basal Dakota members associated with the initial transgression of the Western Interior seaway.

U-Pb zircon geochronology of the Encinal Canyon Member at outcrops on the northern flank of the Sandia uplift in Bernalillo County, NM, yields a maximum depositional age of 99.4 ±1.6 Ma (earliest Cenomanian). An ash bed (ash "A") in the middle of the overlying Oak Canyon Member at the edge of the Albuquerque basin in Sandoval County, NM, provides an igneous age of 97.6 ±1.3 Ma. In addition, the Oak Canyon contains fossils of the mid-Cenomanian Conlinoceras tarrantense ammonoid zone. Both the fossil zone and the ash are laterally continuous throughout the region and greatly improve age resolution of the early marine incursion into northern New Mexico during the Early-Late Cretaceous.

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Here We Go Again

Thomas Maddock III

Department of Hydrology and Water Resources, University of Arizona, 1033 E James E. Rogers Way, Tucson, AZ, 85721, USA, tmaddock3@comcast.net

In 2003, the state of Texas threatened to file suit against New Mexico because New Mexico was not protecting releases of Rio Grande Project supply from Elephant Butte reservoir that were destined for an irrigation district in Texas. In 2008, the Bureau of Reclamation and the two irrigation districts reached a settlement on how water between the two districts in the Project would be divided and how the Texas district would be guaranteed its Project releases. On February 14, 2012, the New Mexico Attorney General filed suit in federal district court in New Mexico seeking to overturn the Operating Agreement Settlement claiming it was unfair to New Mexico. On 4 January 2013, the state of Texas responded by filing a motion in the U.S. Supreme Court seeking permission to file a complaint stating that New Mexico was depleting surface waters of the Rio Grande from Elephant Butte Dam to the New Mexico-Texas state line, causing substantial and irreparable injury to Texas. This talk will give an abbreviated history of the Rio Grande Project, and discuss the origins of the dispute that led to the Supreme Court action. It will also discuss the Operating Agreement that is the heart of this controversy including New Mexico farmers' supplemental pumping and the ramifications of carry-over storage for the two districts.

^{40}Ar/^{39}Ar Sanidine Chronostratigraphy of K-Pg Boundary Sediments of the San Juan Basin, NM

Iain Paul Mason[1], Matthew T. Heizler[2] and Thomas E. Williamson[3]

[1] Earth and Environmental Science Department, 801 Leroy Place, Socorro, NM, 87801, imason@nmt.edu

[2] New Mexico Bureau of Geology, NM Tech, Socorro, NM, 87801, matt@nmt.edu

[3] New Mexico Museum of Natural History and Science, 1801 Moutain Rd NW, Albuquerque, NM, 871084,

New ^{40}Ar/^{39}Ar dating of a key ash horizon and detrital sanidines from the San Juan Basin, NM (SJB) demonstrate that the Naashoibito Member of the Kirtland Formation is not older than 66.5.±0.2 Ma thereby revising earlier age estimates by ~2-3 Ma. In addition, a 65.70±0.03 Ma sanidine date from the Nacimiento Formation that stratigraphically overlies a recently reported U/Pb date of a dinosaur bone at 64.8 ± 0.9 Ma challenges the accuracy of the U/Pb system to directly date bones. The SJB strata holds a globally important record of mammal and dinosaur evolution and extinction, but the lack of a precisely and accurately determined chronostratigraphy limits complete understanding of this record. We use a combination of high precision detrital sanidine dates from Cretaceous and Paleocene strata and a newly discovered ash layer to advance our understanding of this record. Three samples of the dinosaur-bearing Naashoibito Member of the Kirtland Formation yield variable detrital sanidine age populations. The youngest group of one sample is 66.5.±0.2 Ma and variations between age populations could indicate unconformities in the Naashoibito sandstone. A depositional age at no greater than 66.5 Ma is consistent with earlier suggestions that the Naashoibito's vertebrate fauna, the Alamo Wash local fauna, is Lancian and thus latest Cretaceous. Three samples (2 sandstones, 1 ash) at stratigraphically similar levels within the Nacimiento Formation in the De-na-zin Wilderness area record concordant ages. The ash is 65.70±0.03 Ma (n=59 of 61 sanidines). The fact that the two sandstone samples contain minimum detrital populations that are equal in age (65.78±0.11, 65.62±0.07 Ma) to the ash demonstrate that detrital sanidine can yield the depositional age of sedimentary rocks. These units are stratigraphically above a U/Pb dated dinosaur bone (64.8 ± 0.9 Ma) and thus are not geologically compatible. We suggest that the U/Pb date is not accurate and the dinosaur bone cannot be younger than 65.7±0.03 Ma. Importantly, this 65.7 Ma ash occurs between the fossil horizons that yield middle and late Puercan age fossils. This places significant and surprisingly old age constraints on Puercan faunas if the K-Pg boundary is 66.0 Ma. At Mesa de Cuba, detrital dating of a layer 61 m above the Ojo Alamo (OA) contact gives a maximum depositional age of 64.2±0.2 Ma. This age and a depositional rate of 25 m/m.y. places the top of the O A at 66.6 Ma and approximately equal to the youngest detrital sanidines in the OA. Ar/Ar data are at 1σ, relative to a ^{40}K total decay constant of 5.543-10/a and Fish Canyon sanidine at 28.294 Ma.

GEOMORPHIC EFFECTS OF A HIGH SEVERITY BURN IN THE LAS CONCHAS FIRE.

Richard P. McNeill[1], Joseph P. Zebrowski[1], Anita Lavadie[1], Dr. Edward Martinez[1], and Dr. Sara Brown[1].

[1]New Mexico Highlands University, P.O. Box 9000, Las Vegas, New Mexico 87701. (juniper.botany@gmail.com)

High fuel loads and extremely dry conditions have led to previously unknown fire behavior and effects. This study investigated the effect runoff from burned areas had on erosion and arroyo formation in the Cerro del Medio drainage within the Valles Caldera National Preserve, which was burned in the Las Conchas Fire in 2011. This drainage is 139 hectares and 2.3 km long. The majority of the drainage was categorized as a moderate or low severity fire. 24 hectares of the drainage were categorized as a high severity fire. The first post-fire monsoon season was slightly above average with 129.79 mm of precipitation in September and October. The first monsoon season's runoff from the high severity patch has resulted in rapid geomorphic change. An arroyo has formed that ranges up to 9.8 m wide and to 2.45 m deep. Upon leaving the constrained drainage it has resulted in an alluvial fan deposit that is 24 hectares in two lobes with the longest lobe 1.9 km long. Changing fire behavior has resulted in larger and more severe fires and this will likely result in rapid and extreme geomorphic changes on a landscape scale with a corresponding impact on human activities.

THE RIO GRANDE: IS THE PAST THE KEY TO THE FUTURE?

Fred M. Phillips

New Mexico Tech, Department of Earth & Env. Science, 801 Leroy Place, SOCORRO, NM, 87801, United States, phillips@nmt.edu ph: 575-835-5540

The Rio Grande Valley receives the large majority of its water supply, both surface and ground water, from its headwaters in Colorado and northern New Mexico. This area constitutes a small fraction of the drainage basin. This hydrological reality imposes severe constraints on the potential supply of water for the inhabitants of the Rio Grande Valley. For most of its history, the inhabitants accommodated themselves to the flood-and-drought vagaries of the river, modifying it in only very minor ways. This changed with the incursion of railroads in New Mexico in the 1870's. The effects of access to distant markets and to modern engineering technology resulted in changes to the Rio Grande that, by the middle of the 20th century, made it scarcely recognizable as the same river that had existed 100 years prior. In many cases, the changes were not intentional, but rather arose from unforeseen outcomes of economic activities. We have now reached the point where water utilization is a zero-sum game. If water is to be put to new uses, it has to be taken away from an existing user. Water availability is the constraining limitation on human activity in the Rio Grande Valley. The question for the 21st century is whether the inhabitants of the Valley will continue to reallocate the water to satisfy blindly accepted societal goals, and suffer the inevitable unintended consequences, or whether they will recognize the limiting role of water supply and try to direct water use toward achieving the best quality of life possible within the water limitation.

High-Resolution X-ray Computed Tomography Scanning of New Mexico Fossils

Clayton Dean Pilbro

University of New Mexico E&PS Department/Office of the Medical Investigator, 12801 Copper Ave NE Apt D37, Albuquerque, NM, 87123, United States, cpilbro@unm.edu

The Office of the Medical Investigator (OMI) in Albuquerque is one of the world's only medical examiners offices with a CT scanner. The OMI offers an exciting possibility to conduct high-resolution scans of NM fossil. To date, the OMI has graciously run free scans on fossil Plesiadapiform teeth and the holotype skull of the Pachycephalosaurid Sphaerotholus goodwini (NMMNH P-27403). These initial scans provide good quality images on specimens >4mm in size. In addition, the UNM Nursing School has allowed access to their MicroCT scanner than provides resolution of specimens <1mm. These two CT scanners provide a chance to make three-dimensional digital models of unique fossil material (such as holotypes) and the ability to share those scans with students and researchers all over the world. The OMI/Nursing School are very interested in being involved in this cutting edge research. Paleontologists are often interested in the size of a creature's brain and the way it was laid out in the skull. CT scans can cut through the rock and answer those questions. CT scans can show tooth roots and canals that run through fossil teeth. This can tell researchers what kind of nerves the animal might have possessed and whether the specimen had special sensor systems on its face. Scans may also provide tantalizing clues about upright posture in animals based on the position of the inner ear structure. Funding must be obtained in order to continue using the OMI/Nursing School scanning equipment. However, the potential new discoveries that such facilities present make the cost worthwhile.

U-SERIES GEOCHRONOLOGY OF LARGE-VOLUME TRAVERTINE DEPOSITS OF THE SOUTHEASTERN COLORADO PLATEAU: EVALUATING EPISODICITY, TECTONIC AND PALEOHYDROLOGIC CONTROLS

Alexandra Priewisch[1], Laura J Crossey[1], Karl E Karlstrom[1], Victor Polyak[1], Yemane Asmerom[1], Alexander Nereson[2] and Jason W. Ricketts[1]

[1] Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM, 87131, arp2301@unm.edu

[2] Earth and Planetary Sciences, University of California Santa Cruz, Santa Cruz, CA, 95064,

Large-volume travertine deposits in the southeastern Colorado Plateau of New Mexico and Arizona, USA, occur along the Jemez lineament and Rio Grande rift. These groundwater discharge deposits reflect the vent locations for mantle-derived CO_2, which was conveyed by deeply-sourced hydrothermal fluid input into springs. U-series dating of stratigraphic sections shows that major aggradation and large-volume (2.5 km^3) deposition took place across the region episodically at 700-500 ka, 350-200 ka, and 100-40 ka. To explore possible tectonic and paleohydrologic controls on the episodicity of travertine formation, we document overlap of these pulses with timing of regional basaltic volcanism and show an association of travertine deposits with underlying low-velocity mantle that could supply the excess CO_2. We use basalt paleosurfaces to calculate rates of landscape denudation, and find that travertine platforms developed on local topographic highs which required artesian head and fault conduits. We conclude that the travertine platforms and apparent episodicity represent conditions when fault conduits, high hydraulic head, and high CO_2 flux within confined aquifer systems were all favorable for facilitating large-volume travertine formation. By analogy to the active Springerville-St. Johns CO_2-gas field, the large volumes and similar platform geometries of travertine occurrences in our study are interpreted to represent extinct CO_2-gas reservoirs that were vents for degassing of mantle volatiles into the near-surface system.

HYDROGEOLOGY OF EAST-CENTRAL UNION COUNTY, NORTHEASTERN NEW MEXICO

Geoffrey Rawling

New Mexico Bureau of Geology and Mineral Resources, 2808 Central Avenue, SE, Albuquerque, NM, 87106, geoff@nmbg.nmt.edu

This study incorporates new and historical geologic and hydrologic data to understand the aquifer system in east-central Union County. The Ogallala formation and upper Dakota group both vary from zero to several hundred feet in thickness and form a complex unconfined aquifer. Deeper levels of the Dakota group, the Morrison formation, and the Entrada sandstone are confined to varying degrees. Shale layers form leaky confining beds amongst these units.

Water level and saturated thickness declines from the mid -1950s to the present have been extensive. Large portions of the Ogallala-Dakota aquifer have been dewatered. There is much variability in well hydrographs spatially and with formation and depth, however, it clear that ground water extraction from all aquifers in the study area is outpacing recharge. Water levels in deep wells recover after irrigation season (generally March to October) ends, but the recoveries are superimposed on long-term declining water-level trends.

With one exception, sampled groundwaters are largely Ca-Mg-HCO_3-SO_4 waters. Based on recalculation of historical analyses, the water chemistry has not changed since the 1950s. Waters from the Morrison formation in the southwest corner of the study area have distinct Na-HCO_3 chemistry that can be explained by cation-exchange processes occurring on clay mineral surfaces. These waters appear to be isolated from the other aquifers by effective confining layers and probably discharge to surface drainages. Stable isotopic compositions of sampled groundwaters have a weak evaporative signature.

Although recharge mechanisms invoked for the southern High Plains are probably operative in the study area, analyses of tritium and ^{14}C in well water samples indicate that there is no significant recharge occurring to the sampled water-bearing zones of the aquifer. This is consistent with the large and ongoing water level declines. Simple seepage velocity calculations support a recharge model in which these waters have traveled tens of miles from recharge areas west of the present study area. The sampled groundwaters were recharged thousands of years ago by rapid infiltration of playa lake waters and precipitation on porous volcanic features, lava flows, and exposed bedrock of the aquifer units. Both the physical mechanism and proposed geographic region of recharge are hypotheses worthy of future study.

A PROPOSAL FOR RESPONDING TO SUSTAINED DROUGHT AS NEW MEXICO'S "NEW NORMAL"

Matthew G. Reynolds

Seventh Judicial District Judge, State of New Mexico, NM, tocdmgr@nmcourts.gov

If current environmental conditions portend a drier and hotter climate for New Mexico, an immediate and costly response must be implemented to ensure the state's vitality. In March 2013, the New Mexico state legislature unanimously approved a joint memorial recognizing that "climate change and drought are having a significant negative impact on available water resources . . . that local, state, and federal laws, policies and ordinances are inadequate for the purpose of proactive water resource management under existing environmental conditions . . . [and] that sustainable economic development is contingent on sustainable water resource management." House Joint Memorial 9. While this joint memorial refers to the Upper Pecos River basin, it could just as well apply to the entire state. To address New Mexico's "new normal" of a significantly reduced water supply, a special legislative session should be convened. First, the legislature should mandate a fundamental change of policy, by establishing experimental and applied hydrology as a fully-funded cornerstone for state action, including using state-of-the art technology for hydrographic surveys and monitoring of compliance throughout all of New Mexico, and incorporating the tools of adaptive management to meet the challenges of the resource's changing circumstances within the framework of the constitutional mandate of the prior appropriation doctrine (public ownership, beneficial use, and the better water right given to earlier appropriators). See Hydrology and Water Law: Bridging the Gap (2006). Second, in order to effectuate a key component of the State Water Plan, the legislature should set the goal of ensuring completion of all current general stream adjudications within ten years. Third, in drafting legislation to govern new adjudications, which should be completed within ten years after commencement, the legislature should examine the Appropriative Rights Model Water Code, adopted by the American Society of Civil Engineers, along with ideas that have already been presented by the State Engineer and the Administrative Office of the Courts and any new suggestions from stakeholders and independent hydrologists. Among other proposed statutes in the Model Code, the legislature should consider adopting the Model Code's requirement for existing water rights (pre-1907) to be declared within one year or be deemed forfeited. In addition to effective mediation mechanisms to be made available to all water rights claimants in a general adjudication, the legislature should set forth procedures for Native American rights to be handled through negotiation rather than litigation, as recommended by the Western Governors Association. Fourth, and most critically, the legislature should submit by joint resolution to New Mexico voters a constitutional amendment to cover the costs of this massive undertaking, of which the expenses of scientific research and adjudications are only a part, namely, an amendment transforming the severance tax permanent fund into the permanent water fund, the income from which would be used solely for water-related matters, and allowing the legislature by three-fourths vote in each house to withdraw a percentage from the corpus of the fund for emergency allocations, which might occur frequently as New Mexico adapts to its changing environment.

GENESIS OF THE CABALLO AND BURRO MOUNTAINS REE-BEARING EPISYENITE

Annelise M Riggins[1], Nelia W Dunbar[2,1], Virginia McLemore[2,1], Kwame Frempong[3], Matt T Heizler[2,1] and William McIntosh[2,1]

[1] NMT, Department of Earth and Environmental Sciences, 801 Leroy Place, Socorro, NM, 87801, anneliseriggins@gmail.com

[2] NMBGMR, 801 Leroy Place, Socorro, NM, 87801

[3]NMT, Department of Mineral Engineering, 801 Leroy Place, Socorro, NM, 87801,

Extraordinarily potassium feldspar-rich rocks, termed “episyenite”, exposed in Proterozoic basement in the Caballo and Burro Mountains, New Mexico, have anomalously high concentrations of U, Th and rare earth elements (REE). Episyenite bodies may have been emplaced as magmatic dikes, or formed by interaction of potassium-rich metasomatic fluids with Proterozoic basement.
Field investigations show that brick-red episyenite tend to occur as clusters of elongate, sub-parallel bodies. Contacts between episyenite and host rock are typically gradational, along which transitional mineralogy, colors and textures are exhibited. Alteration and reddening of host rock has been observed along fractures. Spatial association of episyenites with pegmatite and aplite dikes, mafic xenoliths and complex textural variations in the host rock suggest that episyenites may be emplaced/formed near the margins of older plutons.
Textural, mineralogical and chemical variations between granitic basement, episyenite and transitional rocks were characterized by electron microprobe. Host rocks typically contain unaltered plagioclase, K-feldspar, quartz, biotite and magnetite with accessory zircon and monazite. Plagioclase and K-feldspar both contain patchy perthitic textures and quartz inclusions. Similar original mineralogy can be recognized in transitional samples, but are overprinted by extensive alteration. Many primary plagioclase and K-feldspar are surrounded by rims of secondary K-feldspar. The secondary K-feldspar is significantly less fractured, displays no perthititic textures, and contains micron size hematite inclusions. The most reddened episyenites are composed almost entirely of secondary, interlocking K-feldspar, with vein quartz and accessory amounts of zircon, apatite, rutile and hematite. K-feldspars crystals display no relict igneous textures. In one sample from the Caballo Mountains, a large REE-bearing phase was discovered, possibly the mineral parisite. Qualitative scans show it contains La, Ce, Pr, Nd, Y, Ca and F. In a second sample from the Caballos, a zircon crystal interpreted to be primary has been partially replaced by a REE-bearing alteration rind.
Field and microprobe observations suggest that episyenites are metasomatic in origin, formed by K-rich fluids migrating along fractures in Proterozoic basement, and are not primary igneous intrusions. Origin of the fluid responsible for metasomatism is, at this time, unknown. In the Caballo Mountains, the C-O Bliss Formation truncates episyenites and contains episyenite clasts in its basal transgressive lag, constraining metasomatism to older than late Cambrian. Similar stratigraphic control is not present in the Burro Mountains. Cambrian-Ordovician carbonatite and alkaline magmatism with associated K-metasomatism is well documented in southern Colorado and New Mexico. Though no carbonatite or alkaline intrusions are exposed in the Caballo or Burro Mountains, episyenites may be related to unexposed C-O intrusions at depth. Dating of metasomatic K-feldspars by the Ar/Ar method yield complex age spectra that suggest episyenites have experienced multiple thermal and/or recrystallization events. Apparent ages suggest minimum formation ages of ~460 Ma in the Caballo Mountains, and ~525 Ma in the Burro Mountains.

SIGNALS OF A CHANGING CLIMATE IN PECOS RIVER STREAMFLOW

Manuel Salgado[1] and David S Gutzler[1]

[1] University of New Mexico, Albuquerque, NM, msal80@unm.edu

The Pecos River is the principal source of surface water for Eastern New Mexico and variability in its flow presents natural and economic challenges. Projections of anthropogenic climate change show increasing temperature year round in the Pecos Valley and decreasing winter precipitation within its upper drainage area. Through analysis of stream gage and SNOTEL data, and monthly temperature and precipitation data from New Mexico Climate Division 2, we attempt to ascertain the degree to which observed climate change in recent decades may have affected Pecos River flows. Interannual variability of precipitation within the upper drainage basin is quite large and strongly tied to the El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). Long term time series of annual flow of the Pecos River at Pecos, NM show large interannual and decadal variations correlated to precipitation, but no significant long term change in the annual flows in the river. However, decadal averages of melt season central timing (MSCT) are at their earliest historically recorded levels despite comparable precipitation deficits in the mid 20th century. Melt season monthly stream flow percentages show a decline in June and an increase in the months of March and April. Changes in streamflow timing may be an indicator that increased air temperatures due to climate change are increasing the speed of the spring snow melt that feeds the river. Increased temperatures for the period of March through June show a significant correlation to early MSCT dates. A linear regression model for the most recent 30 year period (1983-2012) shows reduced amounts of melt season streamflow per unit of winter precipitation when compared to the regression model for the previous 30 year period (1953-1982). The more recent regression model lies outside the 95 percent confidence interval of the previous model and may be an indicator of increased evaporation in the region.

Seasonal Variations in Nutrient and Dissolved Organic Carbon Concentrations of Two Valles Caldera Head Water Streams

Ernesto Sandoval[1], Sebastian Medina[1], Daryl Williams[1] and Edward A. Martinez[1]

[1] Department of Natural Resource Management, New Mexico Highlands University, Las Vegas, NM, 87701, ernsandoval7@yahoo.com

High elevation areas, such as the Valles Caldera National Preserve (VCNP) located in the Jemez Mountains of Northern New Mexico, have been described as exceptionally vulnerable to changes in climate and thus offer an ideal window to monitor temperature changes and their possible implications. In the present study, we examined the effects diurnal and seasonal water temperature changes and discharge have on water quality. Two water sampling regimes (diurnal and grab samples) were employed from May 2010 to May 2012 at four sites along two potentially vulnerable headwater streams located within the VCNP. Concentrations of primary nutrients (nitrate, nitrite, and phosphate), dissolved organic carbon, and other solutes (bromide, chloride, fluoride, and sulfate), along with discharge and physicochemical parameters (conductivity, dissolved oxygen, pH, and turbidity) served as indices of water quality. The results of this study indicated that primary nutrients and other solutes were sensitive to seasonal temperature changes, but that their sensitivity was modulated by the unique characteristics of sample sites. Effects of seasonal water temperature fluctuations on primary nutrient and other solute concentrations can offer a deeper understanding of challenges headwater streams may face as result of anticipated climate changes.

REESIDITES MINIMUS FROM THE JUANA LOPEZ MEMBER OF THE MANCOS SHALE, SANDOVAL COUNTY, NEW MEXICO: A VERY RARE AMMONITE IN NORTH AMERICA

Paul L. Sealey[1] and Spencer G. Lucas[1]

[1] New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, ammonoidea@comcast.net ph: 505-404-8283

Several specimens of the extremely rare (in North America) ammonite *Reesidites minimus* were collected from the upper part of the Upper Cretaceous (Turonian) Juana Lopez Member of the Mancos Shale east of Mesa Prieta, in Sandoval County, New Mexico. These *Reesidites* specimens occur over a stratigraphic interval ~ 10 m thick that ends at the topmost calcarenite bed of the Juana Lopez Member. This bed contains most of the *Reesidites* fossils in an unusually thick lens of dense, bioclastic packstone. Prior to the records documented here, only two specimens of *R. minimus* from North America have been reported in the literature, both from New Mexico. Most of the New Mexico Museum of Natural History specimens of *R. minimus* were found in a bed of calcarenite that also yields fossils of *Scaphites whitfieldi*, *Baculites* cf. *B. yokoyamai*, fragments of *Prionocyclus novimexicanus*, *Inoceramus perplexus* and other bivalves and gastropods. This places *R. minimus* from the Juana Lopez in the study area in the *S. whitfieldi* Zone, which is early late Turonian in age.

The involute shells of the NMMNH specimens of *Reesidites* are very compressed, with small umbilici, and bear low, broad, slightly sinuous primary and secondary ribs that each connect to a ventrolateral clavus and terminate in a siphonal clavus on a fastigiate venter, as has been previously described in *Reesidites minimus*. The great majority of specimens of *R. minimus* from the Juana Lopez Member are juveniles, with only one definite impression of an adult recovered.

The only specimens of *Reesidites minimus* from North America previously illustrated and/or described are USNM (National Museum of Natural History, Smithsonian) 414510 and 414511. USNM 414510 is in the *Scaphites whitfieldi* Zone in the D-Cross Tongue of the Mancos Shale in Socorro County, and USNM 414511 is in the *Scaphites ferronensis* Zone in the Mancos Shale, 18 m above the top of the main upper ledge of the Juana Lopez Member in Valencia County (Cobban and Kennedy, 1988, p. 68; Kennedy et al., 2001, p. 27). The new records we document are thus the first report of *R. minimus* from the Juana Lopez Member and from Sandoval County. Furthermore, they effectively quadruple the known occurrences in North America of this important biostratigraphic indicator. *R. minimus* is best known from Japan, but has also been reported from Armenia, Austria, Tunisia and New Mexico. It is interesting to note that the holotype specimen of *R. minimus* from Hokkaido, Japan was also found in a *Scaphites* bed.

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Campanian Ammonites and Other Molluscs from the Pictured Cliffs Sandstone, Sandoval County, New Mexico

Paul L. Sealey[1], Charles A. Turner[1] and Spencer G. Lucas[1]

[1] New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, ammonoidea@comcast.net

Ammonites and other molluscs were collected from the Pictured Cliffs Sandstone at Mesa Portales, Sandoval County, New Mexico. Here, the Pictured Cliffs Sandstone is ~ 50 m thick and consists largely of friable hematitic and/or clayey sandstone in tabular to massive beds. Contacts with the underlying shale-dominated Lewis Shale and the overlying coaly Fruitland Formation are gradational. Molluscs occur at two stratigraphic levels, a very prolific lower bed ~ 21 m above the base of the Pictured Cliffs Sandstone and a less fossiliferous bed ~ 12 m higher. The moderately diverse fauna (in order of abundance within kind) includes the ammonites *Placenticeras intercalare*, *Didymoceras stevensoni*, *Oxybeloceras crassum* and *Baculites crickmayi*; the gastropods *Lunatia occidentalis*, *Cantharus* (*Cantharulus*) cf. *C*. (*C*.) *lemniscatus*, an unidentified naticid, *Turritella* sp., *Turcicula imperialis*, *Acteon* sp., *Sinum* sp., *Haminea subcylindrica*, and *Pyropsis* sp.; the bivalves *Granocardium whitei*, *Tellina scitula*, *Leptosolen biplicatus*, *Ostrea* sp., *Cyprimeria* sp., *Gervillia* sp., *Corbula* sp., an inoceramid, the scaphopod *Dentalium* sp.; and a solitary coral. This is the first report of these ammonites, and *C*. (*C*.) *lemniscatus*, *T. imperialis*, *Sinum*, *Pyropsis*, *L. biplicatus*, *Cyprimeria*, *Gervillia* and *Dentalium* from the Pictured Cliffs Sandstone.

Very little has been published on fossil invertebrates from the Pictured Cliffs Sandstone. Reeside (1924, p. 19) listed a small molluscan fauna in San Juan County and near Durango, Colorado. Dane (1936, p. 112) reported the bivalves *Cardium* (*Ethmocardium*) *whitei*, *Corbula* sp. and the gastropod *Buccinum*? sp. at Mesa Portales. Fassett (1966) mentioned pelecypods, gastropods and the burrow *Ophiomorpha major* as being abundant at Mesa Portales. Cobban (1973, p. 150) reported on poorly preserved fragments of *Didymoceras* from the lower part of the Pictured Cliffs Sandstone near Barker Dome in northern NM, that could be *D. cheyennense*. *Didymoceras stevensoni* has also been collected in NM from the Pierre Shale near Cimarron and, together with *Baculites crickmayi*, from northwest of Vermejo Park. *Oxybeloceras crassum* is usually associated with *D. stevensoni*. The fossils from the Pictured Cliffs Sandstone at Mesa Portales represent the early late Campanian *D. stevensoni* Zone.

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ANGULITHES FLEURIAUSIANUS FROM THE PAGUATE SANDSTONE, SANDOVAL COUNTY, NEW MEXICO: A VERY RARE NAUTILOID IN NORTH AMERICA

Paul L. Sealey[1] and Spencer G. Lucas[1]

[1] New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM, 87104, ammonoidea@comcast.net ph: 505-404-8283

Together with numerous ammonites, only one specimen of the extremely rare (in North America) nautiloid *Angulithes fleuriausianus* (d'Orbigny, 1840) was recovered from the basal part of the Upper Cretaceous (Cenomanian) Paguate Sandstone southeast of Mesa Prieta, in Sandoval County, New Mexico. Ammonites collected from this interval include *Acanthoceras amphibolum*, *Tarrantoceras sellardsi*, and *Desmoceras* aff. *D. japonicum*. This places *A. fleuriausianus* from the Paguate in the study area in the *A. amphibolum* Zone, which is of middle Cenomanian age.

The shell of this nautiloid specimen has a rounded venter, a small umbilicus, very involute coiling, and a compressed and subtrigonal whorl section, as in *Angulithes fleuriausianus* (Cobban and Kennedy, 1993, p. E2). The slightly sinuous suture extends from the umbilicus, and crosses the flanks with a slight concavity, forming a broad, shallow lobe that then curves forward across the venter to form a shallow ventral saddle.

Cenomanian nautiloids are rare in the Western Interior of the United States. Here, *Angulithes fleuriausianus* is only known from the *Acanthoceras amphibolum* Zone in the Paguate Sandstone. Previous records (three specimens) of *A. fleuriausianus* are from the Paguate Sandstone in Cibola and McKinley counties, New Mexico (Cobban and Kennedy, 1993, p. E1-E2). This is the first report of this nautiloid from Sandoval County. *A. fleuriausianus* has also been reported from the Cenomanian of England, France, Germany, Tunisia and southern India.

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ARE RIO GRANDE AND TRIBUTARY TERRACES DEFLECTED BY THE SOCORRO MAGMA BODY (SMB), INDICATING A LONG HISTORY OF MAGMATIC INFLATION?

Bradley D Sion[1], Fred M Phillips[1], Gary J Axen[1] and Bruce Harrison[1]

[1] New Mexico Tech, Socorro, NM, 87801, brads589@gmail.com

The Socorro Magma Body (SMB) is a deep (~19 km) partly molten sill ~100-150 m thick beneath Socorro, NM that causes active surface uplift at rates up to ~3 mm/yr, as indicated by geodetic data. The duration of uplift is not known however: Is uplift long-lived (>1 ka) due to inflation of a thicker body that is mostly crystalline or to episodic intrusion over time (Majkowski-Taylor 2008), or a recent, one-time event (<1 ka), as inferred from models of a cooling sill (Reiter et al., 2010)? We use Rio Grande and tributary terraces as structural markers to investigate the possible longer-term history of the SMB. Tributary terraces along the Salas Arroyo NE of La Joya, NM and an unnamed tributary W of Luis Lopez, NM were mapped and analyzed based on their elevations above their respective channels. After further mapping, characterization, and preliminary correlation of river terraces within range of the magma body, soil carbonate development and ^{36}Cl cosmogenic dating will be used to infer ages and test correlations. A similar terrace study along the Rio Salado NW of San Acacia, NM concluded that terraces are warped by surface uplift caused by the SMB (Majkowski-Taylor, 2008). Quaternary faults in the area were not observed to cut the young terraces from which this conclusion was drawn. Faults crossing Salas Arroyo and Luis Lopez also do not cut the terraces described here. Such faults complicate the analysis of SMB-related deformation of older terrace remnants. Analysis of terrace elevation profiles in our two study sites does not show clear evidence of SMB-related, along-stream terrace deflections. However, Salas Arroyo runs sub-parallel to contours of equal SMB-related uplift, so is not expected to show differential tilting. There are, however, greater numbers of terraces preserved at Salas Arroyo than at Luis Lopez. This may indicate differential incision between the two areas caused by the SMB. Five distinct terrace levels are observed at Salas Arroyo compared to three levels at Luis Lopez. Terrace levels of 0.5 m, 1 m, and 2 m are observed at Luis Lopez while levels of 1 m, 2 m, 8-10 m, 12-13 m, and 20 m are preserved at Salas Arroyo. The 0.5 m terrace at Luis Lopez represents the modern floodplain and the youngest terrace along the tributary. The lowest terrace at Salas Arroyo sits 1 m above the active channel and comprises the youngest surface at La Joya. We tentatively correlate these two terraces in the absence of soil analyses. This is consistent with greater incision at La Joya, resulting from uplift rates of ~2 mm/yr, than at Luis Lopez, where uplift rates are <0.5 mm/yr (Pearse and Fialko, 2010). Future work will consist of mapping additional terrace remnants along other tributaries and the Rio Grande, performing detailed soil analyses to characterize relative soil ages and carbonate development, which will aid terrace correlation among the various tributaries. ^{36}Cl cosmogenic dating methods will subsequently be implemented to obtain absolute ages for terraces to test the previous correlations based on soil analyses.

JUVENILE SKULL OF THE PHYTOSAUR REDONDASAURUS FROM THE UPPER TRIASSIC CHINLE GROUP AT GHOST RANCH, NEW MEXICO

Justin A. Spielmann[1], Spencer G Lucas[1] and Larry F Rinehart[1]

[1] New Mexico Museum of Natural History and Science, 1801 Mountain Rd. NW, Albuquerque, NM, 87104, justin.spielmann1@state.nm.us

Redondasaurus is the geologically youngest known North American phytosaur and an index fossil of the Apachean land-vertebrate faunachron. In the Rock Point Formation (Chinle Group) at the Whitaker quarry, Ghost Ranch, New Mexico, a nearly complete juvenile skull of *Redondasaurus* was preserved among the many skeletons of the dinosaur *Coelophysis*. Approximately 220 m total length, it is the best preserved and most complete juvenile phytosaur skull of its ontogenetic stage known. The skull and lower jaws are nearly complete, only missing the anterior snout tip and anterior end (symphyseal tip) of the lower jaw. This skull shows that many of the diagnostic cranial features of *Redondasaurus* are present in small specimens and thus not subject to ontogenetic change, including septomaxillae that wrap around the outer margin of the external narial opening, thickened orbital margins, and inflated posterior nasal behind the external narial opening. However, the juvenile skull does not possess some features that diagnose adult *Redondasaurus*, including supratemporal fenestrae concealed in dorsal view and reduced antorbital fenestrae. These differences are attributable to differential growth of selected parts of the skull, particularly the great expansion of the squamosals to conceal the supratemporal fenestrae in the adult. Thus, the juvenile skull of *Redondasaurus* demonstrates that juvenile phytosaurs can be diagnosed and assigned to taxa defined on adult characters. We assembled a growth series of five *Redondasaurus* skulls from which we assessed skull metrics and allometry. Relative growth data for this dataset of *Redondasaurus* skulls, which range in length from 220 to 1205 mm, as log-transformed metrics better fit a linear regression than a polynomial, which indicates simple allometry where shape changes during ontogeny occurred along a single constant trajectory. The allometry of the *Redondasaurus* skull is similar to that of numerous other phytosaur species, except in the postorbital region, which apparently grows in negative allometry as opposed to the positive allometry seen in others. The data thus imply that this is an important ontogeny-based diagnostic character of *Redondasaurus*, but a larger sample size will be required to confirm the hypothesis.

Vertebrate Body Fossils From The Upper Pennsylvanian (Lower Wolfcampian) Bursum Formation, East Of Socorro, New Mexico

Thomas L. Suazo[1], Amanda K. Cantrell[1] and Spencer G. Lucas[1]

[1] New Mexico Museum of Natural History and Science, University of New Mexico, tsuazo@unm.edu

The Upper Pennsylvanian (lower Wolfcampian) Bursum Formation east of Socorro, New Mexico, has been interpreted as the transition between underlying Upper Pennsylvanian shallow marine carbonate-dominated deposits and overlying Lower Permian continental red beds of the Abo Formation. Composed of interbedded marine carbonates and nonmarine red beds, exposures of the Bursum Formation produce a diverse assemblage of vertebrate body fossils. These include teeth of the dipnoan *Sagenodus*; teeth of the chondrychthians *Deltodus, Hybodus, Acrodus* and *Petalodus;* a partial clavicle of the temnospondyl amphibian *Eryops;* diadectid jaw fragments; a bolosaur? jaw fragment; a partial embolomere centrum; and various cranial and postcranial elements of the sphenacodontid eupelycosaur *Sphenacodon.* Vertebrate-body-fossil-producing beds in the Bursum Formation east of Socorro are stratigraphically high in the formation, occurring in the uppermost 5-10 meters. Facies that yield fossil bone vary from fluvially-deposited mudrocks and sandstones to marine-influenced carbonate conglomerates, with the majority of the fossil bones recovered from the latter. Despite the Bursum Formation being older and having a greater abundance of marine sediments than the Abo Formation, both units produce a tetrapod fauna that includes diadectids and eryopids and that is sphenacodontid dominated. However, the relatively numerous and diverse marine shark's teeth from the Bursum differentiate its vertebrate fauna from that of the Abo Formation. The similarity of tetrapod taxa recovered from the Bursum and Abo formations east of Socorro shows that, despite changes from a mixed marine/nonmarine environment to a fully terrestrial environment, many taxa persisted from the Late Pennsylvanian into the Early Permian.

EVALUATING SOLUTE SOURCES IN THE UPPER GILA RIVER, NM

Pavel Vakhlamov[1], Laura J. Crossey, Cliff N. Dahm, V. Acuña and A. S. Ali

[1] pavel.vakhlamov@gmail.com

The Gila River in southwestern New Mexico is one of the last free flowing rivers in North America. It exhibits a great range of hydrochemical variability across spatial and temporal scales in response to changes in precipitation and temperature. Previous work indicates that during times of monsoonal precipitation, temporal variability in water chemistry of streams in the Gila watershed is largely affected by surface runoff due to variability in landscape cover features, as well as size of the catchment. However during base flow regimes, spring inputs of various magnitudes are the dominant drivers of solute concentrations and variability in this system. There are several influencing factors effecting base flow solute concentrations. In the Gila River, as in many perennial rivers of the American Southwest, deep groundwater and geothermal inputs are determined to be primary contributing sources of solutes. Such waters derive their compositions from being conducted through fault and fracture networks created by tectonic processes. Our primary objective is to quantify contributions of deep water and geothermal inputs to surface water chemistry of the upper Gila stream network and determine annual variability of solute fluxes by utilizing a combination of methods including continuous water quality monitoring sensors and campaign sampling. Preliminary results exhibit substantial spatial variability evident by progressive downstream increases in solute concentrations. We report results of a 120 kilometer reach of the upper Gila River, from Gila Springs to Bill Evans Lake. This is an area of major geologic sources of saline water input into the system. Regional climate change scenarios predict a reduction in precipitation including effects on snowpack melt and runoff contribution to the Gila system. This will significantly increase the occurrence of base flow regime leading to higher salinity. Such conditions are projected to apply stress on a wide range of ecological communities and have negative consequences for water quality for downstream users. Reported results indicate that at times of base flow conditions end member concentrations of solutes and regulated contaminants exceed primary and secondary national drinking water standards. Detailed study of water chemistry of geologic water inputs in the upper Gila watershed provides crucial baseline information for determining the response to climate change and data to distinguish geologic solute concentrations from anthropogenic contributions to the system.

MINERALOGY AND GEOCHEMISTRY OF THE GALLINAS MOUNTAINS, NEW MEXICO

Zachary Vance

New Mexico Tech, NMBMMR, EES, 801 Leroy Place, Socorro, NM, 87801, zrvance@gmail.com

During the past decade, worldwide demand for rare earth elements (REE) has surged; however, the genesis and geochemical characteristics of hydrothermal REE deposits associated with alkalic igneous systems remains poorly understood. This study addresses the genesis of bastnaesite-fluorite breccia deposits and their association with Ag-Pb-Zn sulfide vein and breccia mineralization in the GallinasMountains. The spatial and chemical association between these two types of deposits and the amenability of many ore and gangue minerals to stable isotopic study provides a unique opportunity to examine the history of hydrothermal fluids responsible for mineralization.

Mineral associations, especially products of sulfide weathering (i.e. agardite, an REE bearing mineral), indicate a genetic link between REE and sulfide mineralization in the deposits near RoughMountain. $\delta^{34}S$ isotopic ratios of sulfide and sulfate species vary from -21.1 to 1.5‰ and 9.6 to 13.3‰ vs. CDT, respectively. $\delta^{34}S$ and $\delta^{18}O_{SO4}$ data, barite and galena trace element chemistry, and the overall mineralogy of the Rough Mountain deposits suggest an the presence of an oxidized hydrothermal fluid and that cooling was responsible for large isotopic changes over space and time. These $\delta^{34}S$ and $\delta^{18}O_{SO4}$ data are interpreted as a mixing line between magmatic and regional groundwaters in isotopic equilibrium with the overlying Yeso Formation. Stable isotope geothermometry (bar-gn) yields a temperature of formation of ~380°C in the deeper parts of the system and fluid inclusion temperatures from previous studies indicate a temperature of ~200°C for late sulfide formation in the upper reaches of the system. A model developed from this data suggests that Rough Mountain REE and sulfide deposits were derived from a magmatic source. Stable isotope and fluid inclusion evidence suggests that REE mineralization occurred due to fluid cooling and, in the vicinity of Rough Mountain, mixing occurred. Base and precious metal mineralization continued into the upper reaches of the system until solutions finally became relatively cool near the Yeso contact.

Whole rock and mineral trace element abundances, metal ratios, and mineralogy suggests that the M and E No. 13 is genetically different than the RoughMountain deposits and that mineralization may have been derived from a carbonatite source. Isotopic ratios of carbonate species ($\delta^{13}C$ and $\delta^{18}O$) vary from -11.1 to -3.4‰ vs. PDB and 15.0 to 23.8‰ vs. VSMOW, respectively. $\delta^{13}C$ data from the M and E No. 13 prospect fall within the range of primary carbonatites but $\delta^{18}O$ data fall outside the expected range. These data suggest that calcite mineralization, particularly in the vicinity of the M & E No. 13 prospect was late stage fracture filling and precipitation occurred at low temperatures from a cooled magmatic fluid. Alternatively, dissolution of Yeso carbonate could cause this magnitude of $\delta^{18}O$ enrichment.

This study suggests that the association between bastnaesite (REE) and sulfide mineralization can occur in deposits associated with alkalic igneous activity. The role of a carbonatite magma in the district is less well defined.

Irrigation Efficiency Improvements: Technical, Economic, and Policy Issues

Frank A. Ward

Agricultural Economics and Agricultural Business and Extension Economics, MSC 3169 NMSU, P.O. Box 30003, New Mexico State University, Las Cruces, NM, 88003-8003, USA, fward@nmsu.edu

Climate change and recurrent drought in many of the world's dry places continue to inspire the search for economically attractive measures to conserve water through improvements in irrigation efficiency. Work has been conducted at New Mexico State University that analyzes water conservation practices in irrigated agriculture in the Rio Grande Project Area of southern New Mexico. An approach is described to estimate water savings in irrigated agriculture that result from public subsidies to farmers who convert from surface to drip irrigation. The method accounts for economic incentives affecting farmers' choices on irrigation technology, crop mix, water application, and water depletion. Findings show that farmers will invest in technologies that reduce water applications when faced with lower financial costs for converting to drip irrigation. Subsidies for drip irrigation increase farm income, raise the value of food production, and reduce the amount of water applied to crops, and raise irrigation efficiency. However, an unexpected result is that water conservation subsidies that promote conversion to drip irrigation can increase the demand for water depleted by crops. Our findings show that where water rights exist, water rights administrators will need to guard against increased depletion of the water source in the face of growing subsidies for drip irrigation. Our approach for analyzing water conservation programs can be applied where water is scarce, irrigation is significant, food security is important, and water conservation policies are under debate.

INVERTEBRATE BIO-ACCUMULATION IN A COPPER SULFATE TREATED RESERVOIR

Daryl E Williams[1], Jason Martinez[1] and Edward A Martinez[1]

[1] Natural Resources Management, New Mexico Highlands University, 806 7th Street, Las Vegas, NM, 87701, area52@gmx.com

Copper sulfate has been commonly used as an algaecide to combat cyanobacteria blooms in municipal reservoirs. The United States EPA has classified copper sulfate as a Class I toxic substance with the potency inversely related to the alkalinity and pH of water. Copper can accumulate indefinitely and bind to reservoir sediments until disturbances favor its release into the water column. This study sought to determine the levels of copper in water, sediments, and chironomids as an indicator of reservoir water quality. Samples were collected seasonally at four sites in Peterson Reservoir near Las Vegas, New Mexico. Water was analyzed for temperature, pH, dissolved oxygen, conductivity, turbidity, light intensity, Secchi disk, chlorophyll-a, alkalinity, and total phosphorus. Chironomids, sediment, and water were analyzed for copper using Graphite Furnace Atomic Absorption Spectrometry. Reservoir sediment exhibited relatively high levels of copper (18-34 ppm). Copper concentrations in invertebrates were typically higher than sediments (14-1600 ppm) indicating a bio-accumulation rate of up to 4.5 times that of the surrounding sediment. Due to the high buffering capacity of pH (~9) and alkalinity: (~200), most copper concentrations in the water column were below USEPA MCL standards. However, four sites exceeded USEPA standards (>1.3 ppm) during summer stratification and fall turnover events.

FIELD MAPPING OF THE REDROCK AREA, BURRO MOUNTAINS, SOUTHWEST NEW MEXICO, AND U-PB DATING OF 1.2 GA MAGMATISM AND CONTACT METAMORPHISM OF PALEOPROTEROZOIC METASEDIMENTARY ROCKS

Rosie A. Williams[1], Jeff M. Amato[1] and Sean Gaynor[1]

[1] Department of Geological Sciences, New Mexico State University, Las Cruces, NM, 88003, raw03110@gmail.com

Paleoproterozoic sedimentary rocks in the Burro Mountains, southern Mazatzal province, have an unknown depositional age, depositional setting, and source region, and they were subsequently metamorphosed by one or all of the magmatic events that occurred at 1.63 Ga, 1.46 Ga, and 1.25 Ga. The main goals of this project are to (1) use detrital zircons to evaluate the age and source regions for the protoliths of the Proterozoic metasedimentary rocks exposed in the Redrock area of the northern Burro Mountains, and (2) to determine the timing of magmatism that caused regional and contact metamorphism of these rocks.

Preliminary mapping has identified three main metasedimentary rock types in the Redrock area: (1) a phyllite found in the southern part of the map area, with white mica, biotite, and an aluminosilicate that is probably kyanite based on its blue color; (2) a resistant quartzite found at Lydian Peak that has white mica and biotite; and (3) a mafic quartzite with amphibole and mica, found mainly in the Ash Creek drainage. These rocks are intruded by 1.63 Ga gabbro, 1.46 Ga Jack Creek granite, and 1.25 Ga granitic rocks. There is an intrusive relationship between the 1.63 Ga gabbro and the metasedimentary rocks, as determined by a smaller grain size in the gabbro near the contact, indicating more rapid cooling of the intrusive body at its margins. This contact has been modified by faulting in several locations, probably because of the strong rheological contrast between the rigid gabbro and the weak phyllites. Field observations near the eastern boundary of the study area have revealed an intrusive relationship between the Jack Creek Granite and the Lydian Peak quartzite. Evidence for this includes 2 cm wide dikes of Jack Creek granite observed in several locations along the boundary. The 1.25 Ga intrusive rocks, some of which were dated by Ramo et al. (2003), are the likely cause of contact metamorphism of the metasedimentary rocks.

Within the northern Burro Mountains, there are two phases of the Redrock Granite. The main phase of the granite on the northwestern part of the field area has not previously been dated. LA-ICP-MS zircon dating (n=23) from a granite sampled on the eastern edge of the Redrock area indicate a weighted mean 207Pb/206Pb age of 1227 ± 2.3 Ma (MSWD=2.5). Another dike (~20 m wide) on the eastern edge of the metasedimentary rocks near the contact with the Jack Creek granite was dated (n=21) and it yielded a weighted mean 207Pb/206Pb age of 1228 ± 6.7 Ma (MSWD=0.32). These results suggest that the ~1.2 Ga Redrock pluton extends much further to the east than previously mapped and are also in agreement with the hypothesis that the ~1.2 Ga magmatic event was the cause of the contact metamorphism in the Redrock area.

A NEW VERTEBRATE LOCAL FAUNA FROM THE MENEFEE FORMATION, SAN JUAN BASIN, NEW MEXICO

Thomas E. Williamson[1] and Tara Templeman[2]

[1] New Mexico Museum of Natural History and Science, 1801 Mountain Road, NW, Albuquerque, NM, 87121, thomas.williamson@state.nm.us

[2] Earth and Planetary Sciences, University of New Mexico, 220 Northrop Hall, Albuquerque, NM, 87131,

Few early Campanian terrestrial vertebrate faunas have been described from western North America. Consequently, it is not known if the pattern of high diversity and high provinciality that characterized middle and late Campanian biotas also prevailed in the early Campanian. Here we provide an updated list of a vertebrate assemblage from the Santonian – lower Campanian Menefee Formation from near the southeastern margin of the San Juan Basin, southwest of San Ysidro, New Mexico that we name the Armijo Draw local fauna. This fauna provides new information from a “southern” terrestrial faunal assemblage.

The Armijo Draw local fauna is from a relatively small (< 2 km^2) exposure of Menefee badlands that is bounded by normal faults. Unlike most Menefee exposures, this one is relatively rich in well-preserved vertebrate fossils. New vertebrate fossils were recovered from this locale through a combination of surface prospecting and from screenwashing of bulk samples. New macrovertebrate fossils include a partial ceratopsian braincase, bones of a hadrosauroid, and fragmentary postcrania of a theropod. A microvertate assemblage from NMMNH locality L-8849 includes a “typical” Campanian age biota including osteichthyan scales and teeth representing several taxa (e.g., lepisosteid genus et sp. indet, amiid gen. et sp. indet. and *Paralbula* sp.), teeth representing numerous fresh water chondrichthyan taxa (e.g., *Lissodus* sp., *Hybodus* sp., Orectolobidae gen. et sp. undet., cf. *Myledaphus* sp., *Pseudohypolophus* sp., *Ptychotrygon* sp.), teeth of crocodilians, teeth of ornithischian dinosaurs, and tooth fragments of therian mammals. The Armijo Draw local fauna resembles other Campanian age, coastal plain vertebrate assemblages of western North America.

THE UNION COUNTY HYDROGEOLOGY PROJECT: BUILDING A SCIENTIFIC EFFORT FROM THE GROUND UP

Kate Zeigler[1], Barbara Podzemny[2], Geoff Rawling[3], Gregory Peacock[1], Shannon Williams[4] and Andy Yuhas[5]

[1] Zeigler Geologic Consulting, Albuquerque, NM, 87123, zeiglergeo@gmail.com ph: 505-263-5448

[2] Northeast Soil and Water Conservation District, Clayton, NM,

[3] New Mexico Bureau of Geology and Mineral Resources, Albuquerque, NM,

[4] AMEC, Albuquerque, NM,

[5] Yuhas Geoinformatics, Albuquerque, NM, 87112,

The area around the town of Clayton, in northeastern New Mexico, was not a declared groundwater basin until September of 2005. In the years leading up to 2005, battles over groundwater use began to brew and attempts were made to stop drilling of additional water wells for irrigation and stock use. Because there were no regulations in place and the geology of the area had not been studied in a hydrologic framework since the 1960s, there was no basic information for decisions to be made with regards to drilling new wells and use of groundwater. In 2006, the Northeast Soil and Water Conservation District (NESWCD), based in Clayton, decided that they needed a hydrogeology project similar to the Sacramento Mountains hydrogeology project in Otero County. In 2010, the NM Bureau of Geology and Zeigler Geologic Consulting partnered with the NESWCD to help develop a full-fledged hydrogeologic project. The UC Hydrogeology Project is unique in that this project was initially undertaken by members of the community who developed a program of biannual static water level measurements in wells across the county. In addition, the project has support from the vast majority of land owners in Union County. Previous assumptions were that the primary aquifers being utilized were the Tertiary Ogallala Formation and the Upper Cretaceous Dakota Group. However, evaluation of surface bedrock exposures and well cuttings from petroleum exploration wells drilled in eastern Union County demonstrate that the subsurface geology is more complex than might be expected. This subsurface data, along with initial ^{14}C dates, water chemistry and hydrographs from data recorders installed in a limited number of wells suggest that the aquifer system in Union County is partitioned and substantially more complicated than the “oceans of water” it has often been described as.