Abstracts

New Mexico Geological Society spring meeting

The New Mexico Geological Society annual spring meeting was held on April 27, 2012, at the Macey Center, New Mexico Tech, Socorro. Following are the abstracts from all sessions given at that meeting.

KEYNOTE

THE DISTRIBUTIVE FLUVIAL SYSTEM (DFS) PARADIGM: RE-EVALUATING FLUVIAL FACIES MODELS BASED ON OBSERVATIONS FROM MODERN CONTINENTAL SEDIMENTARY BASINS, *G. S. Weissmann*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *A. Hartley*, Department of Geology and Petroleum Geology, School of Geosciences, University of Aberdeen, Aberdeen, AB24 3UE, United Kingdom; *G. Nichols*, Department of Geology, Royal Holloway, University of London, Egham, Surrey, TW20 0EX, United Kingdom; and *L. Scuderi*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

When we think of fluvial systems and associated soils and their preservation in the rock record, we typically draw upon our experiences with tributary rivers, which are the most common in the world. Indeed, most facies models that we use to interpret the rock record have been developed on tributary rivers that exist outside active sedimentary basins or, if the river system studied lies within a sedimentary basin, the models developed typically do not place the studied reach into the context of the basin. A review of more than 700 modern continental sedimentary basins around the world showed that rivers in active sedimentary basins are generally deposited either (1) as distributive fluvial systems (DFS), variously called megafans, fluvial fans, and even alluvial fans in the literature, or (2) as tributary systems in an axial position that parallel the basin trend or in an interfan area between the large megafans, with the vast majority of sedimentation in the basin occurring on the DFS. In these continental sedimentary basins, we have identified more than 400 fluvial megafans (> 30 km in length), with countless smaller DFS filling the basins. These observations have implications for the interpretation of ancient fluvial deposits and the soils that form on these deposits. Rivers on DFS differ from rivers in degradational settings in many potentially significant ways, including (1) a radial pattern of channels away from an apex (or intersection point) exists on DFS, (2) channel systems commonly decrease in width and discharge and thus cross-sectional area distally, (3) rivers on DFS do not lie within valleys unless the system is in an incised phase, (4) meanderbelts tend to be more laterally mobile on the open DFS, forming "simple" meanderbelts rather than "amalgamated" meanderbelts during aggradational phases on the DFS, (5) floodplain deposits on DFS are often dominated by avulsion deposits, especially in distal portions of the DFS, (6) greater preservation of floodplain deposits appears to occur on DFS dominated by braided streams than found in braided streams of tributary systems, and (7) axial streams in a basin, if confined laterally, and rivers that are incised into the DFS appear to be similar in character to tributary systems. We also expect soil morphology to vary with position on DFS, with different soil types found in proximal, medial, and distal locations as well as laterally away from the active channel belt. Additionally, cycles of incision and aggradation should develop characteristic soil distributions. We believe that this alternative view to fluvial facies distributions can lead to advances in facies distribution prediction based on paleosol character and channel belt geometries on DFS.

SESSION 1—EVALUATING HOW CONTINENTAL SEDIMENTARY BASINS FILL: DEVELOPMENT AND PRESERVATION OF SEDIMENTARY SUCCESSIONS

GEOMORPHIC CHARACTERIZATION OF THE GILBERT RIVER DISTRIBUTIVE FLUVIAL SYSTEM (DFS) AND IMPLICATIONS FOR CRETACEOUS COASTAL FLUVIAL SUCCESSIONS, *K. C. McNamara*, kelsey82@unm.edu, and *G. S. Weissmann*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The Gilbert River distributive fluvial system (DFS) of Queensland, Australia, flanks the Gulf of Carpentaria, an epeiric sea that occupies a slowly subsiding intracratonic basin. Approximately 13 km of progradation has occurred over the last 6 ka, largely due to high sedimentation rates, low regional slope, and a slight sea level fall. This system exhibits the same depositional patterns as purely continental DFSs: (1) a radial channel pattern, (2) a down-DFS decrease in both channel and grain size (the latter inferred), (3) a lack of lateral channel confinement, (4) a broad fan shape, and (5) a down-DFS increase in floodplain/channel area. The coastal plain portion (influenced by sea level changes) is characterized by: (a) a contact between DFS and marginal-marine deposits, (b) channel incision, confinement, and lateral movement, (c) increased channel width due to tidal influence, (d) sediment redistribution (spits, small-scale deltas), and (e) evidence of shoreline progradation (wave-cut platforms and beach ridges). Other coastal DFSs are present in passive-margin settings in Australia, India, and Africa. Few modern examples of DFS spanning the terrestrial to marine realm exist, as: (1) modern coastlines are presently flooded due to high-amplitude Quaternary sea level fluctuations, (2) many rivers are incised into large valleys (Mississippi River) or incised into pre-existing coastal DFS deposits (Canterbury Plains of New Zealand, Texas Gulf coastal plain), and (3) anthropogenic modification conceals surface expressions and hinders natural channel behavior (Godhavari River of India). Geomorphic observations on these systems ultimately lead to sedimentologic and stratigraphic predictions regarding coastal DFS deposits that cross the fluvial-marine interface, such as the Cretaceous Williams Fork Formation of Colorado. A purely progradational succession should be characterized by basal shoreface strata cut into by tidally influenced channels, and exhibit an upsection increase in grain size, sand:mud ratios, and channel amalgamation, with a corresponding decrease in tidal influence and coals. The DFS concept may explain common patterns (e.g., upsection changes in sand:mud, sandbody thickness, and architecture) observed in Cretaceous rock record examples and is valuable in reservoir modeling at the basin scale.

GEOCHRONOLOGIC HISTORY OF DEPOSITION OF THE UPPER CRETACEOUS PICTURED CLIFFS SANDSTONE, FRUITLAND FORMATION, AND KIRTLAND FORMATION, SAN JUAN BASIN, NEW MEXICO AND COLORADO, *J. E. Fassett*, jimgeology@qwest.net, Independent Research Geologist, 552 Los Nidos Drive, Santa Fe, New Mexico 87501

For about 25 m.y., the Western Interior Seaway bisected the North American continent, withdrawing and disappearing from most of the area during Late Cretaceous time. In the San Juan Basin area of New Mexico and Colorado, the final regression of the western shoreline of the seaway was accompanied by deposition of the shoreface Pictured Cliffs Sandstone. Precise $^{40}Ar/^{39}Ar$ ages for sanidine crystals from eight altered volcanic ash beds precisely dated this regression across the San Juan Basin as beginning 76.28 Ma when the shoreline was in the southwest part of the basin and ending 73.55 Ma when the shoreline left the northeast part of the basin. (These ages are corrected from those reported in Fassett 2000, per Kuiper et al. 2008; these authors assigned an age of 66.95 Ma to the K-Pg boundary versus an age of 66.5 Ma that had been assigned earlier.) The Pictured Cliffs regression across the basin covered a distance of 145 km and took 2.73 m.y. The stratigraphic rise of the Pictured Cliffs across the basin was 384 m and thus the thickness of rock concurrently deposited was also 384 m.

These precise geochronologic data make it possible to calculate the sedimentation and regression rates during the retreat of the Pictured Cliffs shoreline across the San Juan Basin.The overall average rate of sedimentation during that time, based on rock thickness, was thus about 140 m/m.y., and the average rate of regression of the shoreline was about 53 km/m.y. The decompacted 380-m rock thickness is 702 m yielding a corrected sedimentation rate of 257 m/m.y. These rates are averages, but because there are eight dated ash beds in this stratigraphic section, the rock thicknesses and time durations between these dated ashes can each be used to determine the variable rates of sediment accumulation and shoreline regression during the 2.73 m.y. it took for the Pictured Cliffs to regress across the basin. These data also make it possible to estimate the rate of tectonic subsidence and the creation of accommodation space during the PC regression; that is 114 m/m.y.

COMPLEX SEDIMENT PRESERVATION AND REMOVAL IN THE NORTHERN AND CENTRAL TULAROSA BASIN, NEW MEXICO, DUE TO DEFLATION, BASE LEVEL CHANGES, DOWN-WIND ACCUMULATIONS, AND RECYCLING, *D. W. Love*, dave@gis.nmt.edu, *B. D. Allen*, and *D. J. Koning*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *R. G. Myers*, U.S. Army, IMWE-WSM-PW-E-ES, White Sands Missile Range, New Mexico 88002

On the floor of the Tularosa Basin, deflation has repeatedly controlled local base levels and related eolian, playa, and alluvial geomorphic features, with eolian sediment being an important contributor to aggradation on eastern basin margins. Modern surface water transports fine

sediment and dissolved salts to the lowest parts of the basin in deflated, non-integrated playas such as modern Lake Lucero (base elevation 1,183 m, 44 m below the drainage divide to the south). Shallow ground water controls depths of deflation, which in turn determine local base levels. Deflation basins scoured and partially filled episodically, so alluvial terraces are preserved at several intermediate levels between the maximum level of basin fill and present streams. At one of these levels (locally ~ 17 m below the level of maximum fill; 2–11 m above Salt Creek) an inactive gypsum-marsh deposit covers > 50 km^2. Radiocarbon ages of 10,900 to 10,300 yr bracket as much as 1.5 m of gypsum-marsh deposition. At least two intermediate levels of terrace-alluvium lie between the marsh and the level of maximum basin fill. Three levels of Holocene alluvium are inset below the marsh, reflecting short-term aggradation between deflation episodes and erosion by Salt Creek. During Holocene time, between the San Andres Mountain front and Alkali Flat, alluvial-fan drainages that had been graded to the edge of Pleistocene Lake Otero cut downward and planed laterally following 20 m of base-level fall during lake-bed deflation.

Deflated sediment was transported primarily to the northeast. Lunette dunes formed immediately downwind of many blowout areas; White Sands dune field accumulated beyond Lake Lucero and Alkali Flat. Farther downwind, clay- to sand-sized gypsum episodically formed broad sheets. An unknown (presumably large) component of clay to fine sand, including gypsum, is (and was) carried eastward to the alluvial fans and slopes of the Sacramento Mountains. Holocene runoff has reworked components of that sediment back onto the alluvial fans. Most late Quaternary sediment preservation is on the eastern and western alluvial fans, in the proximal hanging walls of active normal faults, but episodic deflation precludes long-term sediment preservation in the basin center.

COMPARISON OF MIOCENE TECTONISM AND PALEOCLIMATE WITH RIFT-BASIN SEDIMENTATION AND DRAINAGE POSITIONS, ESPAÑOLA BASIN, NEW MEXICO, *D. J. Koning*, dkoning@nmbg.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *S. D. Connell*, New Mexico Bureau of Geology and Mineral Resources—Albuquerque Office, New Mexico Institute of Mining and Technology, Albuquerque, New Mexico 87106

We summarize Miocene clastic deposition in the Española Basin (EB) and examine how drainage systems may respond to tectonic and paleoclimatic controls. The EB is a half-graben tilted west toward the Embudo–Santa Clara–Pajarito fault system (ESPFS). An arm of the EB, called the Cañada Ancha graben (CAG), extends southeast away from the ESPFS. A faulted structural platform lies northwest of the ESPFS. Syn-rift deposits of the Santa Fe Group are particularly well exposed in the EB, and we could readily map western alluvial slope, central basin floor, and eastern alluvial slope lithofacies assemblages. Abundant tephra and fossils provide exceptional age control. Previous studies documented an increase in ESPFS throw rates at 15–11 Ma and decreased subsidence rates in the CAG after 13.5–13.0 Ma. Paleodrainage changes included: (1) coarsening ca. 13.2 Ma; (2) progressive westward progradation of the eastern alluvial slope during 18–10 Ma and a narrowing of the basin floor, with a particularly rapid advance at 13.5–11 Ma; (3) development of a gravel-bearing ancestral Rio Chama by 12 Ma; and (4) shifting of the axial river onto the northwest structural platform after 11 Ma, at least episodically. The progradation of the eastern alluvial slope is interpreted to be controlled by increased activity along the basin master fault (ESPFS) and slower subsidence in the CAG. Poorly constrained middle Miocene progradation also occurred for eastern alluvial slope deposits in the San Luis Basin to the north, and streams of the western alluvial slope carried coarser bedload at ~ 14 Ma. These observations imply a paleoclimatic influence for the rapid 13.5–11 Ma progradation, driven by increased discharge and stream competence. Increased precipitation, higher subsidence rates along the ESPFS, and emergence of the nearby Jemez volcanic field perhaps facilitated integration and headward elaboration of streams draining the Colorado Plateau, forming a single river roughly coincident with the location of the modern Rio Chama. High throw rates on a fault west of the ESPFS at 11–8 Ma facilitated the shift of the San Luis Basin-draining, axial river onto the northwest structural platform. But another driver for this westward shift may be larger sediment delivery from streams draining the eastern alluvial slope compared to the western alluvial slope and axial river.

SESSION 2—PALEONTOLOGY

VERTEBRATE COPROLITES FROM THE LOWER PERMIAN (LOWER WOLFCAMPIAN) GALLINA WELL LOCALITY, JOYITA HILLS, SOCORRO COUNTY, NEW MEXICO, *A. K. Cantrell*, *T. L. Suazo*, *J. A. Spielmann*, and *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Vertebrate coprolites are the most common trace fossils found at the Lower Permian (middle Wolfcampian) Gallina Well locality in Socorro County, New Mexico (NMMNH locality 4668). Despite the relative abundance of coprolites at the locality, little attention has been paid to the coprolite ichno-assemblage. This ichnoassemblage includes the first occurrence of *Dakyronocopros arroyoensis* in New Mexico, the earliest appearance of *Alococopros triassicus* and occurrences of *Heteropolacopros texaniensis* and amorphous coprolites. The age and faunal associations of *Alococopros triassicus* from the Gallina Well locality refute earlier assertions that longitudinally striated coprolite forms were produced by stem archosauromorphs and are restricted to the Mesozoic and Cenozoic Eras.

ECOLOGY OF EARLY EOCENE SAN JUAN BASIN, NEW MEXICO, *PHENACOLEMUR JEPSENI* WITH *PHENACOLEMUR CITATUS* AND *PHENACOLEMUR PRAECOX* FROM BIGHORN BASIN, WYOMING—A STUDY OF MICROWEAR AND DENTAL VARIATION AS A PROXY FOR EOCENE CLIMATE CHANGE, *C. D. Pilbro*, cpilbro@unm.edu, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Phenacolemur was a widespread genus of Plesiadapiforms (primate-like animals) that lived from the late Paleocene to early Eocene of North America and Europe. Members of this genus were small, varying in size from that of a mouse (121 grams for *Phenacolemur jepseni*) to that of a large squirrel (414 grams for *Phenacolemur praecox*). *Phenacolemur* developed enlarged incisors and a reduced dentition. *Phenacolemur* species superficially appear to have a strong similarity in their dental characteristics but with closer observation, it becomes clear there is significant variation in tooth number, morphology, and dental wear between *Phenacolemur* species. These variations can be interpreted to be adaptations for different diets and evidence of evolutionary adaption to paleoenvironments. Teeth are involved in food acquisition and their morphology reflects food acquisition strategy. Using SEM dental microwear analysis, along with dental morphology and statistical analysis, I show distinctions between three of the closely related species (*P. jepseni*, *P. citatus*, and *P. praecox*). These differences in dentition between *Phenacolemur* species reflect differences in diet, and indicate paleoenvironmental/evolutionary adaptions in this early primate that permitted closely related (basal and derived) *Phenacolemur* species to live in the same areas of the San Juan Basin, New Mexico, and Bighorn Basin, Wyoming, concurrently.

A STUDY OF THE HOLOTYPE OF *ALLOTRIOCERAS* FLOWER 1955, *J. H. McDonnell*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Allotrioceras is an enigmatic fossil from the Middle Ordovician of the Champlain Valley named and described by Dr. Rousseau Flower (1955) and assigned to the cephalopod order Endocerida as type species for a new family, the Allotrioceratidae. Since that time no new study on this fossil is known to have been made, prior to that here.

A close examination of the holotype, and only know specimen of *Allotrioceras*, P-42726 of the New Mexico Museum of Natural History and Science indicates that it is not a cephalopod and that its resemblance to the siphuncle of the Endocerida is strictly superficial.

Allotrioceras consists of a narrow tubular structure of which there is 76 mm and a separate asymmetrically bilateral terminus. The tubular structure is referred to as the stem, the terminus as the calyx. Narrow structures diverge at the opposite end of the stem from that are not simply the remnants of some mostly eroded shell. While cephalopods, including their endosiphuncles, show a distinct bilateral symmetry with one side the mirror image of the other, this is not found in *Allotrioceras* where the two halves are distinctly different internally.

***AETOSAURUS* FROM THE UPPER TRIASSIC BULL CANYON FORMATION, QUAY COUNTY, NEW MEXICO, AND ITS BIOCHRONOLOGICAL SIGNIFICANCE**, *T. L. Suazo*, *A. K. Cantrell*, *S. G. Lucas*, and *J. A. Spielmann*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Aetosaurus is an Upper Triassic genus of relatively small and inornate aetosaurs known from three species: *A. ferratus*, *A. crassicauda*, and *A. arcuatus*. A record of *A. arcuatus* from the Bull Canyon Formation of the Chinle Group in east-central New Mexico correlates these strata to *Aetosaurus*-bearing strata in the eastern United States, Italy, Greenland, and Germany. The genus has been stated to be a reliable tetrapod index fossil for the Revueltian (Norian), making the specimens of *A. arcuatus* from the Bull Canyon Formation in Quay County, New Mexico, which are part of the characteristic Revueltian tetrapod assemblage, important to Late Triassic tetrapod biochronology. While many specimens have been collected from the *Aetosaurus* locality in the Bull Canyon Formation (NMMNH L-501), only the most diagnostic have been previously reported. Here we describe additional aetosaurian material in the collection of the New Mexico Museum of Natural History from L-501, including a partial skeleton, numerous paramedian and lateral scutes, lateral appendage scutes, vertebral fragments, and various limb and hip elements. After *Typothorax*, *Aetosaurus* is the second most common aetosaur in the Bull Canyon Formation. The distribution of *Aetosaurus* in Chinle Group strata includes records in the Rock Point Formation, well documented from the Eagle Basin of Colorado. These records indicate that the Revueltian–Apachean boundary is not, as previously assumed, coincident with the base of the Rock Point lithosome, but instead is at least locally above its base.

SESSION 3—VOLCANICS AND TECTONICS

URANIUM-SERIES DATING OF TRAVERTINE FROM SODA DAM, NEW MEXICO: CONSTRUCTING A HISTORY OF DEPOSITION, WITH IMPLICATIONS FOR LANDSCAPE EVOLUTION, PALEOHYDROLOGY, AND PALEOCLIMATOLOGY, *A. J. Tafoya*, *L. J. Crossey*, *K. E. Karlstrom*, *V. Polyak*, *Y. Asmerom*, and *C. Cox*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

High precision uranium-series geochronology at Soda Dam, New Mexico, provides a record of paleohydrology and incision history for the upper reaches of the Jemez River over the last 700 ka. Active travertine-depositing hot springs occur along the intersection of the Soda Dam fault, and the Jemez River; new dates on active and extinct deposits provide improved geochronologic and geologic context with respect to the timing of travertine accumulation. The largest volume-accumulation, Deposit A, yields ages ranging from > 700 ka to 259.6 ± 14.5 ka. The oldest ancestral Jemez River gravels are preserved beneath Deposit A, at a maximum elevation of 132 m above the modern river; efforts to date pumice clasts are ongoing, but model ages of ~ 700 ka provide an estimate of 188 m/Ma over the last 700 ka. This agrees with longer term bedrock incision rates of 200 m/Ma, from the base of the 1.1 Ma Bandelier Tuff. Inset into Deposit A, Deposit A1, contains travertine-coated Jemez River gravels with a strath 30 m above the modern river; these yield an age of 200.6 ± 2.1 ka, giving a bedrock incision rate of 150 m/Ma over the last 200 ka. A crosscutting vein, at the same elevation as the 200 ka sample, yields an age of 110.9 ± 1.5 ka, suggesting substantial artesian head during the 5e substage of the Eemian interglacial. Deposit B, at lower elevations, developed on a banded central fissure ridge; combined ages from the fissure and mound accumulation indicate the system was active from 138–78 ka, a 60,000 yr interval spanning the transitional period during termination II. Deposit C, at 23 and 16.5 m above the modern river, respectively, yielded ages of 103.2 ± 0.5 ka and 101.7 ± 0.5 ka, giving a river incision rate of 160 m/Ma over the last 100 ka. Our results suggest semi-steady bedrock river incision since ~ 1 Ma with episodic travertine deposition along the Soda Dam fault system at 400–700 ka, 260–360 ka, 134–96 ka, and < 5 ka; reflecting the changes in climate, regional volcanic processes, and the existence of the Valles caldera paleolakes. Stable isotope values of the dated travertines range from $\delta^{18}O = -19$ to -6.5 per mil (PDB), reflecting variations in local spring chemistry and temperature. Compared to global travertine data, Soda Dam travertines have relatively positive C isotope values of +1.4 to +11.7, suggesting degassing of CO_2 in the hydrothermal system.

CALCITE-FILLED FRACTURES IN TRAVERTINE USED TO CONSTRAIN THE TIMING AND ORIENTATION OF QUATERNARY EXTENSION ALONG THE WESTERN MARGIN OF THE RIO GRANDE RIFT, CENTRAL NEW MEXICO, *J. W. Ricketts*, *A. Priewisch*, *M. Kolomaznik*, and *K. E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Large-volume travertine deposits in the Lucero uplift provide an excellent opportunity to understand and quantify Quaternary extension along the western boundary of the Rio Grande rift. Vertical quarried faces expose travertine mounds that have been subsequently cut by multiple systems of extensional fractures. We focus on three quarry sites (Temple Cream, Scheherazade, and Vista Grande), as well as a fourth location, Red Hill, in an attempt to understand the timing and implications of fracture formation.

At each of the quarry sites, at least three fracture sets were observed and measured. Crosscutting relationships at Temple Cream and Scheherazade indicate that a set of horizontal sills are younger than vertical ~NS–~NE-SW trending and ~EW–~NW-SE trending fractures. Vista Grande exposes a more complex history, where vertical and horizontal fractures repeatedly crosscut one another. Red Hill is a small mesa of Permian sandstone and siltstone capped by travertine. NE-SW trending extensional fractures similar to those observed at the quarry sites cut the Permian rocks and acted as conduits for fluid flow, feeding the overlying travertine deposit. In addition, small-scale (< 1 m) normal faults cut the Permian rocks. Preliminary U-series dating of the travertine mound at Scheherazade indicates it was deposited ~ 750–650 ka. The extensional fractures and sills observed at each of the four locations are thus younger than ~ 600 ka.

NS and NE-SW trending fractures observed at all study sites (as well as NE-trending normal faults at Red Hill) indicate ~EW–NW-SE oriented extension that, although of small magnitude, are compatible with Quaternary far field extension related to continued development of the Rio Grande rift. A prominent set of late horizontal sills overprints the subvertical faults and is not consistent with this E-W extension. Instead, these reflect subvertical least compressive stress and suggest a regime of high fluid pressure that reduced the effective normal stress and caused rotation of regional stress fields. This was likely due to upward movement of deeply sourced CO_2-rich fluids to the surface from Socorro Magma Body-like chambers. We conclude that Quaternary far field extension is ongoing, and stress fields are modified in the region of the Socorro Magma Body by ascending CO_2-rich fluids.

LATE CRETACEOUS U-Pb TUFF AGES FROM THE LARAMIDE SKUNK RANCH FORMATION, LITTLE HATCHET MOUNTAINS, SOUTHWESTERN NEW MEXICO, *G. R. Jennings*, and *T. F. Lawton*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003; *C. A. Clinkscales*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003 and ConocoPhillips Company, Houston, Texas 77079

New LA-ICP-MS U-Pb ages on zircon crystals from airfall tuff beds within the Skunk Ranch Formation, a Laramide synorogenic unit exposed in the Little Hatchet Mountains, southwestern New Mexico, indicate a chronostratigraphic age of 71–70 Ma. Ranging from 374 m thick in its southern exposures to 738 m in northern exposures near Playas Peak, the Skunk Ranch Formation is divided into three informal members including a lower conglomerate member, a middle member of lacustrine shale and basaltic-andesite flows, and an upper member of conglomerate and sandstone. Near Playas Peak, the Skunk Ranch Formation overlies a thick section of the Campanian Ringbone Formation, but south of the Mojado thrust fault, the lower member unconformably overlies Albian carbonate strata. The Mojado thrust cuts the lower member and terminates in a fault-tip anticline in the middle member, which thus provides a minimum age on fault movement. Three tuff beds from the middle member were dated and yielded stratigraphically consistent ages. The stratigraphically lowest sample yielded a weighted mean age of 71.4 ± 0.5 Ma (n = 81; MSWD = 0.89). The middle tuff bed has a weighted age of 70.6 ± 0.7 Ma (n = 32; MSWD = 0.39). The stratigraphically highest tuff bed yielded a weighted mean age of 70.4 ± 0.5 Ma (n = 60; MSWD = 1.04). The new ages indicate that the Skunk Ranch is Campanian–Maastrichtian in age, rather than Eocene as previously interpreted on the basis of ostracodes and that it is correlative with the Hidalgo Formation, a thick section of andesitic flows and flow breccias. The Skunk Ranch Formation was formerly interpreted to record the second phase of a two-stage history of Laramide deformation in southwestern New Mexico. In addition to significantly improving stratigraphic correlation of Laramide strata, the new radiometric ages indicate that Laramide deformation in the Little Hatchet Mountains likely was restricted to the latest Cretaceous.

NOGAL CANYON CALDERA, SOUTHERN SAN MATEO MOUNTAINS, SOCORRO COUNTY, NEW MEXICO; A PROGRESS REPORT, *V. T. McLemore*, ginger@gis.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The Nogal Canyon caldera is the southernmost caldera that formed the San Mateo Mountains. Mt. Withington (27.4 Ma) and Bear Trap Canyon (24.4 Ma) calderas are north of the Nogal Canyon caldera. Six peaks in the southern range exceed 3,000 m in elevation: Vicks Peak (3,287 m), San Mateo Mountain (3,092 m), San Mateo Peak (3,090 m), West Blue Mountain (3,287 m), Blue Mountain (3,142 m), and Apache Kid Peak (3,063 m) and are remnants of the resurgent Nogal Canyon caldera. The Vicks Peak Tuff (28.4 Ma), granite intrusions, and associated rhyolite and quartz latite flows and domes erupted from this caldera. The Vicks Peak Tuff is > 490 m thick and is overlain by > 550 m of rhyolite (Lynch 2003). The estimated diameter of the caldera is 25 km, and Lynch (2003) estimated the total volume of the Vicks Peak Tuff as 1,816 km^3. Re-interpretation of past studies and recent mapping by this author in the southern San Mateo Mountains has refined the history of the caldera. Some of the northern parts of the caldera remain unmapped.

Stratigraphic relationships indicate that the eruption of the Vicks Peak Tuff was followed by intrusion of the granite of Kelley Canyon and rhyolite of Alamosa Canyon, within < 0.42 Ma (Lynch 2003) in the western part of the caldera. Geochemical studies confirm they were from the same source. The Springtime Canyon Formation overlies the Vicks Peak Tuff and consists of rhyolite, quartz latite and latite flows, and associated tuffs erupted along the eastern boundary, probably during this time period, but dating is required. Rhyolite dikes and small rhyolite domes erupted along the southern and northern boundaries and could be related to the caldera. The northern boundary of the caldera is partially concealed by the formation of the Mt. Withington caldera and eruption of the Vicks Peak Tuff and younger rhyolites. However, San Juan Peak is along the northeastern boundary, where an undated peralkaline rhyolite flow and dikes overlies Vicks Peak Tuff, and probably is one of the last eruptions associated with the caldera. The caldera was offset locally by younger Basin and Range faults (i.e., Rock Springs–Priest, Indian Peaks, Rhyolite, Dark Canyon, Bell Mountain faults). The San Jose mining district (Au, Ag, Cu) lies within the caldera along these Basin and Range faults, and associated hydrothermal alteration has made stratigraphic correlations difficult.

IDENTIFYING THE MAGMA SOURCE(S) OF THE CARRIZOZO LAVA FLOW, SOUTH-CENTRAL NEW MEXICO, *E. Gladish*, sumatra@nmsu.edu, *F. C. Ramos*, and *N. J. McMillan*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003; *M. C. Rowe*, School of Earth and Environmental Sciences, Washington State University, Pullman, Washington 99164

The Carrizozo lava flow, located in south-central New Mexico, is a young (~ 5,000 ka) tholeiitic basalt flow erupted in the Rio Grande rift, which consists of separate upper and lower flows. Whole rock data for six lobes of the lower flow and three lobes of the upper flow indicate a minimal role for fractional crystallization within the flows. Melting of heterogeneous mantle sources or magma mixing/assimilation can account for variations of major and trace elements and $^{87}Sr/^{86}Sr$ ratios of whole rocks. Six lobes of the lower flow encompass ~ 2% SiO_2 variation and < 1% MgO variation and slight K_2O and Al_2O_3 variations, which suggest little, if any, olivine or plagioclase fractionation. ~ 1% magnetite fractionation can account for decreasing Fe_2O_3 contents but cannot account for a 2% increase in SiO_2. These lobes define a linear trend in $^{87}Sr/^{86}Sr$–1/Sr indicating two component mixing of which one component has higher Sr and lower $^{87}Sr/^{86}Sr$ ratios and the other, lower Sr and higher $^{87}Sr/^{86}Sr$ ratios. Additionally, both Sr and Zr increase with decreasing SiO_2, which is inconsistent with fractionation.

For the three lobes of the upper flow, $^{87}Sr/^{86}Sr$–1/Sr does not define a linear correlation, thus mixing may not have occurred. However, 3.5% olivine fractionation can account for observed decreasing MgO contents, although K_2O and Na_2O contents are lower than expected while Fe_2O_3, TiO_2 and SiO_2 are higher than expected. Assimilation of a mafic source, occurring during fractionation, could account for variations in these major elements.

U-Pb ZIRCON AND SR-ISOTOPE CONSTRAINTS ON AGE AND CONTAMINATION OF PALEOGENE VOLCANIC ROCKS OF THE BURRO MOUNTAINS, SOUTHWEST NEW MEXICO, *T. N. Jonell*, tjonell@nmsu.edu, *J. M. Amato*, and *F. C. Ramos*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

The Burro Mountains of New Mexico lie at the southernmost edge of the Mogollon–Datil volcanic field. New U-Pb zircon ages from intermediate and felsic lava flows, hypabyssal intrusions, and ash-flow tuffs provide new age constraints on timing of magmatism in the Burro Mountains. The youngest andesite lava flow was analyzed for Sr-isotope compositions to determine degree of and source of contamination by country rock.

U-Pb LA-MC-ICPMS and SHRIMP zircon ages of volcanic rocks in the Saddlerock area of the Burro Mountains indicate a compositional transition at ~ 34 Ma from intermediate stratocone magmatism to felsic magmatism of the Schoolhouse Mountain caldera. Weighted mean ages for Saddle Rock Canyon Formation andesite lava flows ranged from 33.5 to 35.3 Ma. Andesite breccias interfingered with the first overlying rhyolite ash-flow tuff and tuff-breccia of the Kerr Canyon Formation, which yielded an age of 34.3 ± 0.4 Ma. The Kerr Canyon latite yielded an age of 34 ± 0.98 Ma, and flow-banded rhyolite plug, which intruded the latite, an age of 34.7 ± 1.6 Ma. A rhyolite dike, which crosscut an andesite dike (33.5 ± 0.3 Ma), yielded an age of 33.7 ± 0.4 Ma. Another dike, mapped previously as an Oligocene rhyolite, yielded a weighted mean age of 75 ± 1.3 Ma. Current mapping and geochronology suggest that ~ 75 Ma magmatism in the Burro Mountains was more extensive than previously determined and provided moderate xenocrystic zircon contamination in Paleogene volcanic rocks.

Single-crystal TIMS analysis of seven plagioclase crystals from the youngest Mangas Creek andesite lava flow have $(^{87}Sr/^{86}Sr)_o$ values from 0.7074 to 0.7079 when age-corrected to a U-Pb LA-MC-ICPMS zircon age of 33.8 ± 0.7 Ma. Eruption of the andesite lava through thick intracaldera deposits and lack of assimilation of Proterozoic basement rock can explain the $(^{87}Sr/^{86}Sr)_o$ signatures observed.

PENNSYLVANIAN STRATA AND ANCESTRAL ROCKY MOUNTAIN TECTONISM IN SIERRA COUNTY, NEW MEXICO, *S. G. Lucas*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *K. Krainer*, Institute of Geology and Paleontology, Innsbruck University, Innrain 62, Innsbruck A-6020, Austria; *W. J. Nelson*, Illinois State Geological Survey, 615 East Peabody Drive, Champaign, Illinois 61820; and *J. A. Spielmann*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Pennsylvanian strata are well exposed in the San Andres, Fra Cristobal, Caballo, and Mud Springs Mountains in Sierra County, New Mexico. The oldest of these strata are the Morrowan–Atokan Red House Formation, a mixed siliciclastic-carbonate unit (shale, sandstone, and limestone) as much as 50 m thick. The overlying Pennsylvanian lithosome is dominated by cyclically bedded cherty limestone, nodular limestone, and shale, the Atokan–Desmoinesian Gray Mesa Formation (Nakaye Formation and Lead Camp Limestone are unnecessary synonyms) as much as 388 m thick. Member-level subdivisions of the Gray Mesa Formation—Elephant Butte, Whiskey Canyon, and Garcia members—can be recognized in some sections, but not in others, due to substantial lateral facies changes. The youngest Pennsylvanian lithosome is more regionally complex, and is the relatively thin (up to ~ 63 m at Bar-B Draw) Bar-B (Missourian–Virgilian) and (up to 120 m) Bursum (lower Wolfcampian) formations to the west and the very thick (up to 1,000 m) Panther Seep Formation (Missourian–early Wolfcampian) to the east. This lithosome is mixed clastic and carbonate strata within which the Bursum base has a demonstrably disconformable contact on older strata. A comprehensive analysis of lithostratigraphy, facies, and biostratigraphy allows us to construct a tectonostratigraphy of the Pennsylvanian strata in Sierra County that identifies three pulses of the ancestral Rocky Mountain (ARM) orogeny: (1) onset of the ARM at about the end of Morrowan time with initial synorogenic Red House clastics deposited unconformably on older Paleozoic strata; (2) a pulse close to the beginning of the Missourian, indicated by basal Missourian conglomerates and/or the relatively thin (locally absent) Missourian section; and (3) a latest Pennsylvanian pulse indicated by the sub-Bursum unconformity. Although eustasy can be invoked to explain some of the stratigraphic architecture of the Pennsylvanian System in Sierra County, much more of it is explicable by ARM tectonism, particularly by a local Caballo uplift (centered near the Derry Hills?) present and tectonically active intermittently during the Pennsylvanian.

SESSION 4—GEOCHEMISTRY, GEOMORPHOLOGY, AND GEOTHERMAL

HOW TREES INTERACT WITH THEIR ENVIRONMENT: A STABLE ISOTOPE STUDY, *C. G. Gierek*, cgierke@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *B. T. Newton*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The Sacramento Mountain Watershed Study is designed to assess the effects of tree thinning in mountain watersheds as an effective method of increasing ground water recharge. The project employs a soil water balance to quantify the partitioning of local precipitation before and after tree thinning. We are using the stable isotopes of oxygen and hydrogen to identify tree water sources. The study is being conducted in a first order watershed with no perennial outflow stream where vegetation is dominated by Douglas-fir (*Pseudotsuga Menziesii*). Ridges are capped with San Andres Limestone, whereas lower slopes and the valley bottom are underlain by the Yeso Formation. From March to November 2011, we collected several soil and twig samples from which water was extracted by cryogenic vacuum distillation. Mobile soil water was sampled with passive capillary samplers (PCAPS) placed in soil profiles.

The isotopic composition of bulk soil water appears to be controlled by evaporation of snowmelt stored within the soil matrix. The isotopic composition of mobile soil water is a result of mixing of non-evaporated rainfall and evaporated bulk soil water. As the monsoon season progressed and cumulative rainfall increased, the isotopic composition of mobile soil water evolved toward that of local precipitation. The isotopic composition of twig water samples from March and July resembled that of bulk soil water. In August and September, twig water isotope values appeared to have both bulk soil water and mobile soil water contributions.

The conceptual model that we have developed to explain this phenomenon relies on differences in how snowmelt and monsoon precipitation enter the subsurface, which determines where each water source is stored. Snowmelt infiltrates soil and is stored in the matrix, whereas water from short duration, intense rainstorms preferentially flows through macropores and quickly flushes through soil profiles to shallow epikarst features in the underlying bedrock. In the spring and early summer, trees use soil water. During monsoon season when epikarst storage increases, a secondary root system is able to begin exploiting this newly available source. The contribution of this secondary source manifests in tree water as an integrated mixture of bulk soil water and epikarst water.

RECONSTRUCTING QUATERNARY PLUVIAL EPISODES USING TRAVERTINES OF EGYPT'S WESTERN DESERT, *G. Jimenez*, jimenezg@unm.edu, *L. J. Crossey*, *K. E. Karlstrom*, *J. W. Ricketts*, and *A. J. Tafoya*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *T. Anan*, and *A. Mohammed*, Department of Geosciences, Western Michigan University, Kalamazoo, Michigan 49008

Quaternary climate in North Africa was marked by multiple pluvial periods overprinting extreme aridity, but pluvial drivers, as well as their timing and geographic extent, are poorly constrained. We address these factors in the first comprehensive analysis of travertine from Egypt's Western Desert, which represents a unique and under-utilized sedimentary record of paleoclimate and paleohydrology. We focus on correlating travertine deposition either to glacial cycles or to more specific orbital forcings, particularly precession, acting on the North African summer monsoon. An age-probability plot of published U-series ages shows no obvious correlation between travertine occurrence and glacial cycles (the dominant literature conclusion), so that forcings remain enigmatic. Following previous workers, we assume that large-scale travertine accumulations reflect pluvial episodes, via raised ground water head supplying adequate water for travertine precipitation from CO_2-rich oasis springs. We collected ~ 60 additional geologically and volumetrically well-constrained samples in January 2012, sampling deposit tops and bottoms to resolve inception and termination of pluvials as well as regional aggradation/incision patterns, and also banded feeder vein systems to establish finer-scale wet/dry fluctuations. Our goal is to contribute to an understanding of low-latitude climate and monsoon dynamics, as well as Western Desert hydrology, with implications for modern water management.

GEOTHERMAL EXPLORATION OF THE WINSTON GRABEN, CENTRAL NEW MEXICO, USA, *M. J. Sophy*, mjsophy@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *S. A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The geothermal potential of the Winston graben (WG) is evaluated using well temperature logs, gravity and magnetic data, water chemistry, and water table measurements. The WG is a late Cenozoic rift basin, part of the Rio Grande rift, which is bordered by the Black Range (BR) to the west and is separated from the Rio Grande valley by the Sierra Cuchillo (SC), a horst block composed of Proterozoic–Paleozoic rocks intruded by an Oligocene laccolith. Two low-temperature warm springs, Ojo Caliente and Chise, indicate that hot water may be present at depth.

Geothermal gradients from wells range from 20°C/km to 60°C/km, with higher gradients located on the eastern side of the SC horst, coincident with both warm springs. The Chise warm spring occurs at the intersection of the eastern boundary fault of the SC and a northeast-striking accommodation zone called the Chise lineament. Gravity highs and magnetic anomalies coincide with the Morenci and Chise volcanic lineaments along the northern and southern ends of the graben.

Water chemistry data from recharge (BR) and discharge areas (Chise warm spring) show a trend of calcium to sodium and carbonate to chloride-dominated waters. Water table data suggest both along axis and cross axis flow direction within the basin. This chemical trend may be the result of ion exchange along a deep, long-lived west to east flowpath. Carbon 14 dating at Ojo Caliente yielded ground water ages in excess of 13 ka. Mineral solubility simulations (carbonate and silicate) indicate that chemistry from the Chise and Ojo Caliente warm springs were in thermal equilibrium at temperatures between 70 and 100°C.

Because the temperature anomalies trend east-west and water table gradients trend both east-west and north-south, a two component hydrogeologic system is proposed. The deeper system consists of ground water flowing from the BR eastward below the WG, where the water is heated by high background heat flow. The warm water continues to flow eastward through the SC, emerging within and to the east of the horst.

GEOTHERMAL POTENTIAL OF THE SOUTHERN RATON BASIN, NEW MEXICO, *S. A. Kelley*, and *R. Broadhead*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *R. E. Salaz*, and *M. Tewelde*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The geothermal potential of the southern Raton Basin (SRB) is evaluated using equilibrium (ET), bottom hole (BHT), and wireline (WT) temperature data. ET logs are generally from shallow wells (< 600 m); interval geothermal gradients generally correspond to lithology, which is indicative of conductive heat flow. Interval geothermal gradients in the Paleogene Raton and Poison Canyon formations and in Cretaceous shales (Pierre, Carlile, Graneros) are on the order of 40–60°C/km. In contrast, interval gradients in the Cretaceous Trinidad Sandstone and in other sandy units are 20–30°C/km.

BHT data constrain the deeper thermal structure of the basin. High BHTs were measured in the Stubblefield Canyon gas field near the Colorado border; the maximum uncorrected BHT is 135°C at a depth of 2,160 m and associated geothermal gradients are 50–80°C/km. BHTs in the Las Vegas Basin (LVB) to the south are cooler (85°C at 3,091 m) compared to those in the SRB to the north at similar depths. This study focuses on wells with two or more BHT readings. Four wells with multiple BHTs in the Castle Rock Park gas field show a distinct decrease in temperature between measurements in the Trinidad Sandstone and measurements in the underlying Pierre Shale. This pattern implies lateral flow of warm (~ 45°C) water in the Trinidad Sandstone in this area.

WT logs can provide good thermal data if used with caution. WT logs are obtained by oil companies to look for zones of fluid flow or to gauge the quality of a cement job. WT logs measured in air are noisy. WT logs measured in air drilled holes and filled with formation water before measurement yield thermal data of a quality similar to equilibrium logs.

Temperatures of 150°C at depths of ~ 3 km are present in the Colorado part of the Raton just north of the border. ET data from the Stubblefield Canyon area just south of the state line yield published heat flow values of 89–120 mW/m^2. If the elevated gradients derived from ET, BHT, and WT data from Stubblefield Canyon are extrapolated to depth, then a temperature of 150°C is reached at 3 km, comparable to the depths on the Colorado side of the border. The difference in temperature between the SRB and the LVB is attributed to (1) elevated heat flow associated with low velocity mantle beneath the SRB, and (2) erosion of low thermal conductivity Cretaceous shales from the LVB.

SESSION 5—POSTER SESSION

PRELIMINARY RESULTS FROM A LATE PLEISTOCENE TO HOLOCENE PALEOCLIMATE STUDY OF THE LAKE SEDIMENT CORES, NORTHERN NEW MEXICO, *A. R. Brister*, abrister@live.nmhu.edu, and *M. S. Petronis*, Environmental Geology Program, Natural Resource Management Department, New Mexico Highlands University, Las Vegas, New Mexico 87701

The geography of the Las Vegas National Wildlife Refuge (LVNWR) and surrounding region has changed dramatically since the late Pleistocene in response to the expansion and contraction of alpine glaciers activity and associated climate change. During the late Pleistocene, we hypothesize that the area just east of the Sangre de Cristo Mountains at the latitude of Las Vegas, New Mexico, consisted of several or a network of interconnected lacustrine systems. Following the end of glacial activity, these lacustrine systems shrank to their current condition of minor low-volume isolated lakes and numerous playas and pluvial bodies. Preliminary data from an integrated, paleoclimatic study of sediment cores collected from three playa lakes provide insight into late Pleistocene to Holocene paleoclimatic variations in northeastern New Mexico. Sedimentologic, midge fossil, and rock magnetic data acquired from the sediment cores is used to characterize the materials, identify stratigraphic changes, document shifting lake levels, assess temperature changes, and infer paleoclimate conditions. Data collected from McAllister and Wallace Lake are encouraging and reveal depth dependent changes in fossil assemblages, grain size, and rock magnetic properties that have been interpreted to reflect climatic driven variations impacting the depositional system. Bulk low-field magnetic susceptibility decreases by an order of magnitude from the surface to the base of the measured core suggesting a change in detrital magnetic influx into the lacustrian system. Curie point estimates indicate that the dominant magnetic mineral in all samples is cubic, low-Ti titanomagnetite phase. An environmental magnetism study of sediment from the LVNWR and surrounding playas can help provide an invaluable and untapped record of late Pleistocene to Holocene climatic change. Additional data are being collected that will aid with interpreting the evolution of the lacustrine system. We postulate that concurrent with alpine glacial activity during the Pleistocene, the LVNWR and the transitional Great Plains region to the northeast were an expansive single lake or interconnected lake system, analogous to the Pleistocene lakes of the Estancia Basin (Lake Estancia) and the Tularosa Basin (Lake Otero) of central and southern New Mexico.

LARGE-VOLUME QUATERNARY TRAVERTINE DEPOSITS IN THE RIO GRANDE RIFT AND JEMEZ LINEAMENT, NEW MEXICO AND ARIZONA: IMPLICATIONS FOR PALEOCLIMATE, LANDSCAPE EVOLUTION, AND NEOTECTONICS, *A. Priewisch*, *L. J. Crossey*, *E. Embid*, *K. E. Karlstrom*, *V. Polyak*, *Y. Asmerom*, *J. Ricketts*, and *A. Nereson*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

New Mexico and Arizona host several large-volume (0.2–0.9 km^3) travertine deposits with surface areas of 10–40 km^2 and thicknesses ranging from 5 to more than 60 m. They are present both along the northeast-trending Jemez lineament and north-south-trending Rio Grande rift and record natural CO_2 leakage related to Quaternary magmatic CO_2 degassing. U-series data show that travertine deposition overlapped temporally from place to place. High volume deposition was not steady, but occurred episodically at 36–100 ka, 200–380 ka, and 520–660 ka. Stable isotope analyses from the travertines overlap substantially, exhibiting high $\delta^{13}C$ values, +2.0‰ to +8.3‰, and $\delta^{18}O$ values that range between −13.5‰ to −4‰. High $\delta^{13}C$ values are interpreted to be caused by rapid CO_2 degassing, whereas the range of $\delta^{18}O$ values is interpreted to represent changing water temperatures and mixing trends of ground water. Times of high accumulation rates are interpreted as times of high ground water flow and hence as a proxy for regional paleohydrology/paleoclimate control, whereas the primary control on the spatial localization of large-volume travertine is high tectonic CO_2 flux in areas of mantle upwelling, crustal magma chambers, and fault conduits. Large-volume travertine occurrences are important indicators of the extent of past natural CO_2 leakage that can inform carbon sequestration models. By analogy to the active Springerville CO_2 gas field in Arizona, the large volumes and similar platform geometries of the travertine occurrences in New Mexico are interpreted to record extinct or dormant CO_2 fields. Travertine platforms now occupy positions high in the landscape (inverted topography) and also provide data on the scales and timing of regional landscape evolution. Erosion rates measured from travertine-capped mesas reveal differential denudation across the study areas and may have implications for Quaternary uplift associated with the Jemez lineament.

A GIANT PHYTOSAUR (REPTILIA: ARCHOSAURIA) SKULL FROM THE GARITA CREEK FORMATION (UPPER TRIASSIC: ADAMANIAN) OF NORTH-CENTRAL NEW MEXICO, *D. C. Bond*, *L. F. Rinehart*, *W. L. Layman*, and *S. G. Lucas*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Phytosaurs are large, semi-aquatic, carnivorous reptiles known from Upper Triassic strata in North America, Brazil, Europe, Turkey, North Africa, Madagascar, India, and Thailand. The Chinle Group of New Mexico yields many phytosaur fossils. A giant skull, mandible, and associated postcranial fossils representing a *Rutiodon*-grade phytosaur, possibly *Leptosuchus*, was collected by the New Mexico Museum of Natural History and Science (NMMNH) in 2009 and 2010. NMMNH locality 1176 in the Garita Creek Formation of the Chinle Group, (Santa Fe County) normally yields metoposaurid amphibian (*Koskinonodon perfectum*) remains in an extensive bone bed designated the Lamy amphibian quarry. In 2009, one of the authors (WLL), discovered a very large phytosaur mandible straigraphically about 1.2 m below the amphibian level. That level is now designated NMMNH locality 8276. The mandible and associated postcrania were subsequently collected and prepared. In 2010, WLL found a nearly complete but badly crushed skull less than 2 m from the mandible. The fossils are from silty mudstone strata representing overbank deposits similar to those of the overlying amphibian bone bed. The mandible as prepared is 1,240 mm long. The skull as measured in the field is approximately 1,390 mm long from the snout tip to the distal squamosals, which were broken, but apparently in life position, and 630 mm across at the widest point (quadratojugals) and is among the largest phytosaur skulls found to date. The relative sizes of the skull and mandible and their close association indicate that they probably belonged to the same individual. Published data and our observations indicate that other giant phytosaur skulls measure between 1,215 mm and 1,420 mm long, with incomplete skulls estimated up to 1,500 mm. The posterior half of the Lamy skull is badly crushed and consists largely of small, disarticulated pieces but an intact connection of bone between the snout tip and quadrates yields an accurate minimum length. Associated paramedian scutes, NMMNH P-61225 and NMMNH P-61238, show healed bite marks. Some duplication of anatomical elements indicates that more than one phytosaur individual is represented by the fossils from locality 8276.

DYNAMIC EARTHQUAKE TRIGGERING ABOVE THE SOCORRO MAGMA BODY, NEW MEXICO, *E. A. Morton*, emorton@nmt.edu, and *S. L. Bilek*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

When earthquakes occur they release energy in the form of waves that cause ground movements. For high magnitude earthquakes, these waves can travel around the world and interact with other faults at great distances from where the earthquake originally occurred. This interaction through ground displacements can alter the stress state on these remote faults, reduce the friction on the faults, and cause them to fail, or trigger another earthquake. This dynamic triggering process can occur in a variety of tectonic settings but particularly occurs in areas characterized by the presence of hot fluids and/or magma. Therefore we hypothesize that triggering should be common within the region above the Socorro Magma Body (SMB) within the Rio Grande rift. To test this, I examined data from 319 large earthquakes from around the world with magnitudes > 6.0 between January 15, 2008, and November 30, 2009, and analyzed the seismograms recorded on seismometers stationed around Socorro, New Mexico, to see if local earthquakes corresponded with the passage of waves from the large earthquake. 93 local events were found corresponding to 66 of the large earthquakes. I have been looking at background rates of seismicity in the area to determine if the amount of local earthquakes increases with the passage of large earthquake waves, indicating that some events are a result of "delayed triggering" rather than being independent of the large earthquake. The majority of local events occur above the Socorro Magma Body, showing that it is more conducive to triggering in New Mexico, but the events can be spread throughout the rift as well. We hypothesized that large earthquake locations would show a region that preferentially triggers events in New Mexico; however, the only clustering of possibly triggering large earthquakes is a reflection of areas naturally more seismically active. I am also looking into triggering and triggering delay dependence on the large earthquake's location and wave amplitude.

TRACE ELEMENTS IN THE COPPER FLAT PORPHYRY DEPOSIT, HILLSBORO MINING DISTRICT, SIERRA COUNTY, NEW MEXICO, *G. Pruthvidhar*, pruthvid@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *V. T. McLemore*, and *N. Dunbar*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Copper Flat deposit is a small porphyry copper deposit in the Hillsboro mining district, New Mexico. Copper Flat has proven and probable reserves of 45.5Mt of ore at a reported grade of 0.45% Cu, 0.14g/t Au, 2.3 g/t Ag, and 0.0015% Mo. The district consists of Cretaceous andesites surrounded by Paleozoic sedimentary rocks and Quaternary alluvial fan deposits. A quartz monzonite stock (74.93 ± 0.66 Ma) with a breccia pipe is located in the center of the district, and a series of latite dikes radiate outward from the quartz monzonite. The quartz monzonite porphyry and the latite dikes are co-genetic. Replacement deposits, which occur near the porphyry deposit, are also genetically related to porphyry deposit.

The Copper Flat porphyry copper deposit consists of Cu, Au, Mo, and Ag disseminations and quartz veins in the breccia pipe. Propagating outward radially from the Copper Flat porphyry are Laramide veins hosted by many of the latite dikes. Chemical analyses range from 8–64,600 ppb Au, < 0.2–590 ppm Ag, 40–57,337 ppm Cu, < 1–475 ppm Mo, 57–8,906 ppm Pb, and 138–17,026 ppm Zn. Carbonate-hosted replacement deposits are found distal from the center. Chemical analyses range from < 5–99 ppb Au, 1–< 50 ppm Ag, 131–173 ppm Cu, 2–140 ppm Mo, 30–> 10,000 ppm Pb, and 123–> 20,000 ppm Zn. As much as 130 ppm Te and 3,400 ppm Bi also are found.

In this study, samples from the Hillsboro district were examined petrographically, and pyrite, chalcopyrite, and molybdenite were identified. Samples were then examined by electron microprobe in order to determine the distribution of elements of economic interest. Initial investigation involved qualitative geochemical analysis using wavelength-dispersive scans and chemical maps of 1.5 × 1.5 cm areas to identify particles with high concentrations of Au, Ag, and Mo. No discrete particles containing Au or Ag were identified, suggesting either that these elements are present at lower concentrations in other minerals or that particles containing these elements are present at low enough concentrations that they were not present in the scanned area. Following qualitative investigation, quantitative analysis for trace elements was carried out, using long count times in order to obtain detection limits below 100 ppm. The results show detectable Au, Ag, Mo, but Te, Se, Cd, Bi are not detected.

COMPARING DETRITAL ZIRCON U-Pb AGE DATA TO DETERMINE PROVENANCE RELATIONSHIPS OF UPPER JURASSIC AND LOWER CRETACEOUS STRATA, SOUTHWEST NEW MEXICO AND SOUTHEAST ARIZONA, *J. C. Gilbert*, and *T. F. Lawton*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

Analysis of detrital zircon U-Pb age data of the Early Cretaceous Hell-to-Finish Formation of the Little Hatchet Mountains in New Mexico and the Late Jurassic Glance Conglomerate and Early Cretaceous Morita Formation of the Huachuca Mountains in Arizona indicates different provenance histories. Formerly, the Hell-to-Finish Formation has been considered genetically similar and correlative with the red beds of the Glance Conglomerate and Morita Formation based on outcrop appearance and stratigraphic position. In the southwest Huachuca Mountains, a detrital zircon sample from a volcanic litharenite high in the Glance Conglomerate contains dominantly Early to Middle Jurassic grains (81 of 96 grains) derived from underlying volcanic rocks. Unconformably overlying the Glance Conglomerate, the lower Morita Formation transitions from nearshore facies rocks at the base to fluvial facies rocks. A detrital zircon sample of 90 grains from a nearshore subarkose contains mostly Triassic (n =12) and Proterozoic grains (n = 60) but only a few Early Jurassic grains (n = 6), reflecting burial or late stage erosion of Jurassic rocks. Higher in the section, a fluvial volcanic litharenite contains abundant Cretaceous grains (ca. 145–120 Ma) from the arrival of volcanic material to the west. In the Little Hatchet Mountains, the lower Hell-to-Finish Formation is fluvial, and the sandstones are litharenites that contain abundant chert and carbonate clasts and no volcanic fragments. A detrital zircon sample of the Hell-to-Finish Formation is composed almost exclusively of pre-Triassic grains (78 of 79 grains) and was sourced from the Burro uplift to the north. In contrast, the Morita Formation received a significant component of material from a western source that is not reflected in the Hell-to-Finish Formation, suggesting the basins were isolated. Material for the Glance Conglomerate was locally derived and is not an input for the Hell-to-Finish Formation.

AR-AR PHLOGOPITE GEOCHRONOLOGY OF THE NAVAJO VOLCANIC FIELD AND THE SHIP ROCK DIATREME OF NORTHWEST NEW MEXICO DEFINE A 1.4 MA PULSE OF POTASSIC MAGMATISM, *J. P. Nybo*, and *W. C. McIntosh*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *S. Semken*, School of Earth and Space Exploration, Arizona State University, Tempe, Arizona 85287

Newly acquired Ar-Ar phlogopite ages indicate a brief but widespread pulse of magmatism at 25.9 to 24.5 Ma in Navajo volcanic field (NVF). Covering approximately 30,000 km^2 of the Four Corners region in the southwestern US, the NVF encompasses numerous diatremes, plugs, dikes, and occasional sills and maars including the well-known Ship Rock diatreme. Petrographically the field is dominated by minette and serpentinized ultramafic microbreccia though outcrops of monchiquite, katungite, and olivine melilitite occur as dikes in small numbers. Published K-Ar ages from the NVF range from 33.9 to 19.4 Ma. Phlogopite separates of six dikes from the Ship Rock diatreme along with two dikes and two plugs from other locations throughout the NVF were analyzed in this study by the Ar-Ar method using CO_2 laser and resistance furnace incremental heating. The resulting age spectra were generally flat, and a selection of the most precise ages range from 25.9 ± 0.1 Ma at Todilto Park, Arizona, to 24.4 ± 0.1 Ma at Ship Rock, New Mexico. The selected samples spatially represent the full breadth of the NVF and span a range 1.4 Ma. The narrow range of ages found in this study contrasts with the much wider range of published ages implying the bulk of the NVF was emplaced by a short pulse of widespread magmatism rather than series of temporally spaced eruptions. Additional geochronology will assess whether additional eruptive pulses occurred in the NVF.

PENNSYLVANIAN SANDIA FORMATION IN THE SIERRA NACIMIENTO, NEW MEXICO: EVIDENCE OF TECTONISM OF THE ARM PEÑASCO UPLIFT, *K. Krainer*, Karl.Krainer@uibk.ac.at, Institute of Geology and Paleontology, University of Innsbruck, Innsbruck A-6020 Austria; *S. G. Lucas*, and *J. A. Spielmann*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and *D. Vachard*, Université des Sciences et Technologies de Lille, 59655 Villeneuve d'Ascq Cédex, France

The Lower-Middle Pennsylvanian (?late Morrowan–early Atokan) Sandia Formation in the Sierra Nacimiento, north-central New Mexico, is characterized by distinct lateral changes in thickness and facies as a result of the ancestral Rocky Mountain (ARM) deformation. In the Sierra Nacimiento, the Sandia Formation is thinner than at the type section in the Sandia Mountains near Albuquerque (124 m). The thickest sections (72 m) are exposed on the eastern side of the Sierra Nacimiento north of Jemez Springs (Soda Dam), where the Sandia Formation rests on Precambrian gneiss and is composed of shale with intercalated sandstone and fossiliferous limestone containing the fusulinids *Millerella*, *Eostaffella*, and *Fusulinella*, indicating an Atokan age. Toward the west and north the Sandia Formation thins and is entirely siliciclastic, composed of alternating shale, siltstone, and sandstone (Mesa Venado, Porter Landing, Rancho de Chaparral). North of Guadalupe Box, the Sandia Formation overlies the Osha Canyon Formation, is 32 m thick, and composed of several fluvial fining-upward cycles and a thin marine horizon at the top. The northernmost outcrops are at Resumidero east of San Pedro Peak where the Sandia Formation is approximately 13 m thick and overlain by Gray Mesa Formation. Locally, near the western and southern margin of the Sierra Nacimiento, the Sandia Formation is absent. At Log Springs near the southern end of the Sierra Nacimiento the Log Springs Formation is unconformably overlain by thin Osha Canyon Formation and Gray Mesa Formation, indicating phases of uplift during Late Mississippian and Early Permian time. At Coyote Flat west of Jemez and at Rio de las Vacas the basement is overlain by the Guadalupe Box Formation, an equivalent of the Atrasado Formation (late Desmoinesian–middle Virgilian). In the area of Camp Zia northwest of Cuba, the Precambrian basement is overlain by red beds of the Abo Formation, indicating that the Peñasco uplift existed there as a positive high during the entire Pennsylvanian. Thus, thickness and facies changes and the distribution of the Sandia Formation in the Sierra Nacimiento can be attributed to ARM tectonic movements of the Peñasco uplift.

NEW OUTCROPS OF THE UPPER CRETACEOUS "BOQUILLAS FORMATION" IN THE FRANKLIN MOUNTAINS NEAR EL PASO, TEXAS, *S. G. Lucas*, spencer.lucas@state.nm.us, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *K. Krainer*, Institute of Geology and Paleontology, University of Innsbruck, Innsbruck A-6020 Austria; *J. A. Spielmann*, and *B. Cornet*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The "Boquillas Formation" (= Mancos Shale) is shale-dominated strata of Late Cretaceous (middle Cenomanian) age known in New Mexico from outcrops on the northern flank of Cerro de Cristo Rey, Doña Ana County. We report newly discovered outcrops of the Boquillas exposed by excavation of an unpaved road just south of Flag Hill in the Franklin Mountains of El Paso County, Texas (NM Museum of Natural History locality 7730). This outcrop exposes about 4.5 m of Boquillas strata that consist of: (1) thinly laminated (mm-scale) mudstone in which gray mudstone laminae alternate with slightly coarser, silty, brownish mudstone laminae; (2) some thin gypsum layers; (3) fine-grained, laminated carbonate beds that are composed of mudstone containing locally abundant planktic globigerinid foraminifers such as *Hedbergella*, peloids, a few small bivalve shells, gastropods, ostracods, and small echinoderm fragments. These carbonate beds are up to 15 cm thick and contain abundant shells on bed tops. The carbonate beds laterally lense out. Some of the carbonate beds form lenses less than 1 m wide, probably representing the fills of paleotopographic lows. The mudstone also contains ammonites, bivalves, gastropods, and other fossils that are partly fragmented, indicating that the fossils have been transported. These strata are very similar to the Boquillas Formation at Cerro de Cristo Rey, where the exposed thickness is 18.6 m.

Fossils from the Boquillas Formation at the newly discovered outcrop represent the following taxa: unidentified gastropods; the bivalves *Ostrea beloiti* Logan, *Inoceramus arvanus* Stephenson, *I. praefragilis* Stephenson, and *Pinna* sp.; the ammonoids *Acanthoceras amphibolum* Morrow, *Desmoceras* sp./*Moremanoceras* sp., and *Idiohamites* sp. These taxa are also found at Cerro de Cristo Rey and support assignment to the middle Cenomanian *Acanthoceras amphibolum* Zone. In southern New Mexico and west Texas, the name Mancos Formation is best applied to this shale-dominated interval at the base of the Greenhorn cycle of deposition. More parochial stratigraphic names such as Boquillas, Chispa Summit, and Ojinaga are best abandoned to unify the stratigraphic terminology so that it better reflects the regional distribution of this lithosome throughout southern New Mexico, west Texas, and northern Chihuahua.

ERUPTION CHARACTERISTICS OF THE CIENEGA CINDER CONE, CERROS DEL RIO VOLCANIC FIELD, NEW MEXICO, *M. Foucher*, *A. Romero*, and *J. Lindline*, Environmental Geology Program, Natural Resources Management Department, New Mexico Highlands University, Las Vegas, New Mexico 87701

This study describes the eruption characteristics of the Pleistocene Cienega cinder cone. This volcano is located in the southeastern part of the Cerros del Rio volcanic field (CdR) west of Santa Fe, New Mexico. The CdR is the largest (> 700 km^2) of several middle Pliocene to Pleistocene basaltic volcanic fields of the axial Rio Grande rift in northern New Mexico. Eruptive centers are typically central vent volcanoes, ranging from low-relief shields to steep-sided, breached cinder and spatter cone remnants. The Cienega cinder cone is actually a volcanic complex that consists predominantly of tephra fall deposits as well as several vents, multiple intrusions, and numerous lava flow sequences. A slightly eroded northern vent is 230 m in diameter and consists of inward bedded crater facies and periclinally bedded wall facies. A smaller southern vent is 95 m in diameter and composed of steep north-dipping pyroclastic layers that suggest the development of a late-stage shallow cryptodome. Vent facies include vesiculated fragments, oxidized cinders, and spatter agglutinate interbedded with lava flows. Proximal wall facies are moderately sorted with a high proportion of coarse scoria and bombs, whereas the distal wall facies are very well sorted with a high proportion of fine lapilli. Fluvial sand and gravel deposits as well as aeolian sand deposits within some of the pyroclastic layers illustrate the development of stream channels and exposed surfaces in between eruptions. One major north-striking anastomosing dike (> 10 m long by 4 m wide) as well as several minor north-striking dikes (< 2 m long by 1 m wide) intrude the southern complex. Macrostructures (slickenlines, chatter marks, and Reidel shears) consistently show wall rock deformation having a north-sense of shear, indicating south-moving magma toward the inflating southern vent. Samples from all volcanic facies (vent, lava flows, proximal wall, and distal wall) contain major olivine (1–3%), pyroxene (1–3%), and plagioclase (5%) phenocrysts in an aphanitic matrix. Scoria cinders contain 20–50% vesicles in a holohyaline matrix. Our observations show that the Cienega cinder cone is a monogenetic volcanic complex that developed by endogenic and exogenic dome growth with short eruptive events that likely were derived from a rapidly evolving reservoir-conduit system.

AN UNUSUALLY LARGE METOPOSAURID FROM THE SALITRAL FORMATION OF THE CHINLE GROUP (UPPER TRIASSIC: CARNIAN?) ON LANDS BELONGING TO THE PUEBLO OF JEMEZ, *K. M. Madalena*, K373 Buffalo Hill Road, Pueblo of Jemez, New Mexico 87024; *K. E. Zeigler*, Environmental Geology Program, Natural Resources Management Department, New Mexico Highlands University, Las Vegas, New Mexico 87701; and *S. S. Sumida*, California State University-San Bernardino, San Bernardino, California 92407

Lands belonging to the Pueblo of Jemez in north-central New Mexico include sedimentary strata that range in age from Mississippian to Pleistocene, and include excellent exposures of Upper Triassic strata. The Salitral Formation of the lower Chinle Group (Upper Triassic: Carnian) are present in the southeastern corner of the Jemez Reservation in an area that is complexly faulted. Samples for paleomagnetic analyses have been taken from the area in order to clarify the stratigraphic relationships and are currently in progress. Material pertaining to a metoposaurid amphibian was recovered from a grayish-purple calcrete nodule horizon in the lower Salitral Formation, approximately 7–8 m above the underlying Shinarump (= Agua Zarca) Formation. The fossil-bearing horizon is comprised primarily of a poorly consolidated conglomeratic lens dominated by calcareous nodules from 1 to 10 cm diameter. This unit also contains moderately abundant fragments of metoposaur and phytosaur material. Metoposaurid material includes cranial and shoulder girdle elements as well as teeth. Phytosaur material includes teeth and osteoderms with a characteristically high dorsal ridge. The metoposaurid specimens are fragmentary, but are significant for their extraordinary size. A partial interclavicle is conservatively reconstructed as well over 450 cm in width. The largest specimen reported from Texas is 430 cm, and a specimen previously reported as the largest from New Mexico is 400 cm in width. Published sizes of metoposaurid interclavicles from the Chinle Formation of New Mexico and the Dockum Formation of west Texas average 307 cm and 313 cm, respectively. Thus, the Jemez metoposaur is one of the largest ever reported, approximately 47–48% larger than those published averages, and approximately 5% larger than the largest one yet reported. Although measurements of the thickness of dermal elements of the pectoral girdle are not commonly available, the Jemez metoposaur also appears remarkable in this regard, measuring more than 2.5 cm from deep to superficial surfaces.

THE SIPHUNCLE IN A SPECIMEN OF *DOMATOCERAS* FROM THE SAN ANDRES FORMATION, NEW MEXICO, *J. H. McDonnell*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The nautiloid cephalopod *Domatoceras* Hyatt 1891 is well known from the Pennsylvanian and Permian of North America. Descriptions, however, are pretty much limited to the external morphology of the shell as in Bernhard Kummel (1964: Nautiloidea - Nautilida. Treatise on Invertebrate Paleontology Part K) and others. Mention of the siphuncle is limited to its position and the possibility of its being orthochoanitic.

The segments of the siphuncle and part of a fourth are exposed in a break in specimen P 56221 of the New Mexico Museum of Natural History and Science, which have allowed description for perhaps the first time. Segments are 5 mm in length, fusiform, expanding from 2 mm at the septal foremina to as much as 3.5 mm at the midpoint. Septal neck are not recognized; however, the slight expansion suggest that, when present, they were slightly cyrtochoanitic, rather than orthochoanitic as inferred in the literature.

EVALUATING SOLUTE SOURCES IN THE UPPER GILA RIVER, NEW MEXICO, *P. Vakhlamov*, pavel.vakhlamov@gmail.com, and *L. J. Crossey*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *C. N. Dahm*, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131; *V. Acuña*, Catalan Institute for Water Research, Parc-CientíficiTecnològic de la Universitat de Girona, Girona, Spain; and *A. S. Ali*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

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 with many perennial rivers of the American Southwest, deep ground water 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 on a 66.5 mi 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. 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.

ANISOTROPY OF MAGNETIC SUSCEPTIBILITY, ROCK MAGNETIC, AND PALEOMAGNETIC DATA FROM MAFIC DIKES IN THE ESPAÑOLA BASIN, RIO ARRIBA COUNTY, NEW MEXICO, *R. Trujillo*, rhondatrujillo@hotmail.com, *M. S. Petronis*, and *J. Lindline*, Environmental Geology Program, Natural Resource Management Department, New Mexico Highlands University, Las Vegas, New Mexico 87701

This study characterizes a suite of Miocene mafic dikes in the Española Basin, north-central New Mexico, using paleomagnetic, rock magnetic, and field observations. Paleomagnetic data provided constraints on potential components of vertical-axis rotation across structural blocks, between separate dikes, and along strike variations within individual dikes. Anisotropy of magnetic susceptibility (AMS) data and field observations provided information on magma flow patterns within each dike and discernment of any variation in magma flow patterns within the swarm. We tested the following hypotheses: (1) the mafic dikes experienced some degree of vertical axis rotation associated with Rio Grande rifting and (2) the magma flow pattern within the dikes reflects lateral emplacement with flow directed away from the magma ascent location.

Rock magnetic data provided constraints on the magnetic mineralogy responsible for carrying the AMS and the remanence directions. Low-field susceptibility versus temperature experiments yielded a spectrum of results reflecting a thermomagnetic behavior typical of intermediate composition titanomagnetite, whereas others exhibited a more complex behavior with the presence of two or more magnetic phases. Curie point estimates ranged from ~ 100°C to 575°C indicating a range of moderate to low Ti- titanomagnetite compositions as well as the presence of a Fe-sulfide phase. Additional rock magnetic experiments included the Lowrie-Fuller test to estimate the magnetic domain state, acquisition of isothermal remanent magnetization (IRM), and backfield IRM experiments to verify the magnetic mineralogy, domain state, and the coercivity of the remanence. These experiments, as well as other data, indicated that the remanence is likely a primary thermoremanent magnetization acquired during cooling and is thus geologically stable.

The AMS fabric data reveal a combination of both prolate and oblate susceptibility ellipsoids. At several sites, the fabrics are oblate from paired dike margins and reveal a unique magma flow direction. The maximum susceptibility axis (K1) and the imbrications of the magnetic foliation (K1–K2) planes indicate both upward and downward sense of flow, as well as flow toward and away from the likely source region. Susceptibility values are high and consistent with a ferromagnetic phase. Preliminary results indicate that the group mean is discordant in a counter-clockwise sense to the expected Miocene field direction. Additional paleomagnetic experiments are underway and should help further constrain the emplacement of the dikes and tectonic evolution of the study area.

INVESTIGATION OF SOIL POLLUTION SOURCES IN THE EL PASO REGION USING SEM, MAGNETIC SUSCEPTABILITY, AND XRF ANALYSIS, *J. L. Tasker*, *M. Gomez*, and *K. Devaney*, El Paso Community College, Transmountain Campus, El Paso, Texas 79924; and *L. R. Bothern*, El Paso Community College, Transmountain Campus, El Paso, Texas 79924, and Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

In urban area soil pollution is a major concern for the health of residents, development of the land, water usage, and agricultural production. This makes investigation of soils important for maintaining the well-being of people, plants, and animals that reside within the area of study and beyond. In this study, we will investigate soil pollution using three methods: magnetic susceptibility, scanning electron magnification, and X-ray fractionation. Potential sources of pollution in El Paso region include a former artillery range, oil refineries, smelters, power plants, freeways, and other dismantled industry.

Magnetic susceptibility is a quick, easy method to detect pollution in soils involving simple sample preparation and provides rapid, repeatable analyses. The iron oxides generated through combustion display high magnetic properties that act as a proxy for heavy metal pollution from the source. The scanning electron microscope (SEM) allows for up to 10,000× magnification of samples and also has an X-ray attachment that allows for elemental analyses of specific sample grains. The X-ray fractionation instrument available at New Mexico State University will provide us with detailed analyses of trace elements within soil samples. After collection of samples and analysis of data, we hope to better understand processes involved in heavy metal pollution of sample area soils and identify point sources of the pollutants.

THE BEARTOOTH–MOJADO CONNECTION: USING MID-CRETACEOUS SEDIMENTARY ROCKS TO UNDERSTAND THE TECTONIC HISTORY OF SOUTHWEST NEW MEXICO, *S. E. Machin*, smachin@nmsu.edu, *J. M. Amato*, and *T. F. Lawton*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

Mid-Cretaceous quartzarenites in the Bisbee Basin of southwestern New Mexico record the transition from Late Jurassic–Early Cretaceous rifting to the onset of Laramide shortening in the latest Early Cretaceous. Detrital zircon analyses and measured sections indicate a correlation between late Albian quartzarenites on opposite sides of the relict Bisbee rift basin.

Exposed in the Burro Mountains, along the northern flank of the basin, the Beartooth Formation is a 30-m-thick section of quartzarenite and conglomerate representing a tidal-marginal marine environment. Until this study, the age of the Beartooth Formation remained poorly constrained, but detrital zircon analyses indicate a maximum depositional age of 100 Ma. The Mojado Formation is a 1,245-m-thick sequence of marginal marine quartzarenite in the Little Hatchet Mountains that represents renewed subsidence of the Bisbee Basin in the late Albian. The conformable contact with the underlying, middle Albian U-Bar Formation and the 99 Ma detrital zircon grains from the upper part of the Mojado Formation are evidence of rapid subsidence that exceeds the rate of thermal subsidence, indicating tectonic influence on basin formation. Additionally, an air-fall tuff in the lowermost strata of the overlying Mancos Formation, which represents a marine transgression, is ~ 97 Ma.

Foreland basins that form after relict rift basins are poorly understood. The Cenomanian strata are characteristic of a foreland basin system, with the Mojado Formation deposited in the foredeep and the Beartooth Formation deposited on the forebulge. Rather than attributing the increased accommodation in the late Albian to thermal subsidence of the Bisbee rift basin, an alternative model of a flexural origin for the Mojado–Beartooth section is supplied by the asymmetric geometry of those strata. A foreland basin origin for the uppermost Albian strata in turn provides evidence for earliest Laramide shortening in southwestern New Mexico near the beginning of the Late Cretaceous.

EARLY CAMPANIAN AMMONITES AND OTHER MOLLUSCS FROM THE POINT LOOKOUT SANDSTONE NEAR CABEZON, SANDOVAL COUNTY, NEW MEXICO, *P. L. Sealey*, and *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road, NW, Albuquerque, New Mexico 87104

Ammonites and other molluscs were collected from near the base of the Point Lookout Sandstone near Cabezon, New Mexico. The ammonites *Placenticeras syrtale*, *Baculites* sp. and *Scaphites leei* III, the gastropod *Gyrodes* sp. and other unidentified gastropods, and the bivalves cf. *Tellina* sp., cf. *Siliqua* sp., cf. *Mactra* sp., *Cardium* sp., inoceramids and other bivalve taxa were recovered. In 1917, W. T. Lee reported a locality near Cabezon where the old wagon road crossed the top of the Mancos Shale. He collected a small molluscan fauna from what he called the transitional zone between the uppermost Mancos Shale and the basal Mesaverde. We believe that the horizon we collected—a fossiliferous, calcareous sandstone ~ 6 m above the base of the Point Lookout Sandstone—is the same horizon collected by Lee. Lee's list included the bivalves *Ostrea elegantula*, *Anomia* sp., *Pinna* sp., *Cardium* sp., *Cyprimeria* sp., *Tellina* sp., *Liopistha undata*, *Mactra* sp., and *Corbula* sp. as well as the gastropods *Gyrodes* sp. and *Actaeon* sp. But, he did not report *Scaphites* or *Baculites* from the locality. The only ammonite he reported was *Placenticeras sancarlosense*, a species subsequently synonymized with *P. syrtale*.

P. syrtale also occurs in the Dalton Sandstone in the Cabezon area. It has also been reported from the upper part of the Mancos Shale in the upper Rio Grande valley and along the western side of the Sierra Nacimiento, including the Satan Tongue of the Mancos Shale near La Ventana. *P. syrtale* has been reported to range from the lower Santonian to the lower Campanian. The *Baculites* specimens collected from the Point Lookout Sandstone near Cabezon are closest to variants of *Baculites aquilaensis* in their prominent arcuate nodes on the outer flanks. *B. aquilaensis* var. *obesus* was reported by Reeside from the basal part of the "Mesaverde Formation" east of Cuba, New Mexico. *Scaphites leei* III has also been reported from near the base of the "Mesaverde Formation" east of Cuba and from the Hagan coal field. This would correspond to the base of the Point Lookout Sandstone. *S. leei* III has also been reported from the upper part of the Mancos Shale on the eastern side of the San Juan Basin and from the Ortiz Mountains. *S. leei* III is the lowest Campanian zone taxon. This indicates an earliest Campanian age for the Point Lookout Sandstone near Cabezon.

DIACHRONOUS EPISODES OF CENOZOIC EROSION IN SOUTHWESTERN NORTH AMERICA AND THEIR RELATIONSHIP TO ROCK UPLIFT, PALEOCLIMATE, AND PALEOALTIMETRY, *S. M. Cather*, steve@gis.nmt.edu, *C. E. Chapin*, and *S. A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The history of erosion of southwestern North America and its relationship to uplift processes is a long-standing topic of debate. We use geologic and thermochronometric data to reconstruct the erosion history of southwestern North America. Erosion events occurred mostly in response to rock uplift by tectonism, although important isostatic components of uplift can be demonstrated during the late Miocene–Recent. We recognize four regional episodes of erosion and associated rock uplift: (1) the Laramide orogeny (ca. 75–50 Ma), during which individual uplifts were deeply eroded as a result of uplift above thrusts, but Laramide basins and the Great Plains region remained near sea level as shown by the lack of significant Laramide exhumation in these areas; (2) late middle Eocene erosion (ca. 42–37 Ma) in Wyoming, Montana, and Colorado occurred in response to epeirogenic uplift from rebound that followed the cessation of Laramide dynamic subsidence; (3) late Oligocene–early Miocene deep erosion (ca. 27–15 Ma) that affected a broad region of the southern Cordillera (including the southern Colorado Plateau, southern Great Plains, Trans-Pecos Texas, and northeastern Mexico) that was uplifted in response to increased mantle buoyancy from major concurrent volcanism in the Sierra Madre Occidental and adjacent volcanic fields; (4) late Miocene–Recent erosion (ca. 6–0 Ma) of a broad area of southwestern North America, with a locus of deep erosion in the western Colorado–eastern Utah region that reflects mantle-driven rock uplift as well as an important isostatic component related to deep fluvial erosion. We cannot estimate the amount of rock or surface uplift associated with each erosion episode, but the maximum depth of exhumation for each was broadly similar (typically ~1–3 km). Only the most recent erosion episode is correlated with climate change.

Paleoaltimetric studies, except for those based on leaf physiognomy, are generally compatible with the uplift chronology we propose here. Physiognomy-based paleoelevation data commonly show that near-modern elevations were attained during the Paleogene, but are the only data that uniquely support such interpretations. High Paleogene elevations, however, require a complex uplift/subsidence history for the Front Range and western Great Plains area that is not compatible with regional sedimentation and erosion events. Our results suggest that near-modern surface elevations in southwestern North America were generally not attained until the Neogene, and that these high elevations are the cumulative result of four major episodes of Cenozoic rock uplift of diverse origin, geographic distribution, and timing.

NO EVIDENCE FOR CONFORMABLE CONTACT BETWEEN THE OJO ALAMO SANDSTONE AND THE NACIMIENTO FORMATION, *T. E. Williamson*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *S. L. Brusatte*, American Museum of Natural History, New York, New York 10024; *D. J. Peppe*, Baylor University, Waco, Texas 76798; *R. Secord*, University of Nebraska, Lincoln, Nebraska 68588; and *A. Weil*, Oklahoma State University, Center for Health Sciences, Tulsa, Oklahoma 74107

The San Juan Basin of northwestern New Mexico is a Laramide basin that accumulated sediments through the Cretaceous–Paleogene (K–Pg) boundary. However, the precise age of the Ojo Alamo Sandstone, which lies near the K–Pg boundary in the San Juan Basin, remains controversial. Determining its age is crucial to understanding the tectonic and biotic history near the K–Pg boundary in this area. Based on study of these strata in the Bisti/De-na-zin Wash area (BDNZ) near Barrel Springs, previous workers have argued that the top of the Ojo Alamo Sandstone and the base of the Nacimiento Formation are interfingering and therefore are conformable. Based on this interpretation, most workers have regarded the Ojo Alamo Sandstone (here regarded in the restricted sense; = Kimbeto Member) in the BDNZ to be early Paleocene in age. The base of the Nacimiento Formation has been correlated to C29n and produces early Paleocene mammals. This provides a minimum age for the underlying Ojo Alamo Sandstone. Given this minimum age constraint workers have generally taken one of two positions for the precise age of the Ojo Alamo Sandstone: (1) the Ojo Alamo Sandstone spans the upper part of C29r, or (2) it is restricted to only the lower part of C29n. To resolve this question and to determine a more precise age for the Ojo Alamo Sandstone, we examined the stratigraphic relationships between the Ojo Alamo Sandstone and the overlying Nacimiento Formation in the BDNZ. Contrary to previous interpretations, we find that this formational contact is not conformable. Rather, what other workers have assumed to be the "upper part of Ojo Alamo Sandstone" that interfingers with basal parts of the Nacimiento Formation is actually a remnant of a lenticular channel sandstone of the Nacimiento Formation. This reinterpretation suggests that the formational contact between the Nacimiento Formation and the Ojo Alamo Sandstone may represent a significant hiatus of up to ~ 0.5 Ma separating the Ojo Alamo Sandstone from the base of the Nacimiento Formation in the BDNZ area. Future work should focus on more accurately determining the age and refining the duration of the hiatus at the Ojo Alamo–Nacimiento formational contact.

EVALUATION OF CHEMICAL GEOTHERMOMETERS FOR ESTIMATING RESERVOIR TEMPERATURES OF NEW MEXICO GEOTHERMAL SYSTEMS, *T. H. Schlossnagle*, *F. M. Phillips*, *M. A. Person*, and *A. R. Campbell*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

New Mexico is endowed with relatively high background heat flow and permeable, fractured bedrock. This combination has given rise to numerous low-temperature geothermal systems throughout the state. Conventional geothermometers consistently overestimate temperatures for moderate- to low-temperature geothermal systems. Determination of mineral-saturation indices has been found to produce better estimates of known reservoir temperatures than the use of traditional geothermometers. However, there are few geothermal systems with known reservoir temperatures in New Mexico.

We attempted to determine which geothermometers are best at predicting known geothermal reservoir temperatures, as well as determining the likelihood of each geothermometer producing valid temperature estimates in areas with unknown reservoir temperatures. We applied both traditional geothermometers and the mineral-saturation approach to areas of known temperature. We also applied a statistical filtering process to both nonthermal and thermal data sets to weed out conventional geothermometers predicting unlikely temperatures.

No single geothermometer or suite of geothermometers could be considered highly reliable for predicting reservoir temperatures in New Mexico. Traditional geothermometers such as quartz, chalcedony, Na-K-Ca, and Na-K geothermometers work well for predicting high-temperature resources. The mineral-speciation approach also worked well for predicting high reservoir temperatures. Though this method is more time consuming it is useful when there is no agreement between traditional geothermometers. Our screening process determined that four traditional geothermometers are best suited for estimating low- to moderate-temperature resources: two chalcedony, one Na-K-Ca, and the K-Mg. It is also apparent that the mineral-speciation approach works well with lower temperature systems. However, these lower temperature systems show less convergence and wider range of predicted temperatures. Our screening process identified several regions of known moderate-temperature geothermal resources (Lightning Dock, New Mexico State University, Jemez Springs). We also identified several moderate-temperature systems that have not previously been identified with geothermometry (Montezuma Hot Springs, Hondo Hot Springs).

A PRELIMINARY GEOLOGIC MAP OF THE BULL GAP QUADRANGLE, LINCOLN COUNTY, SOUTHEASTERN NEW MEXICO, *K. E. Zeigler*, zeiglergeo@gmail.com, Environmental Geology Program, Natural Resources Management Department, New Mexico Highlands University, Las Vegas, New Mexico 87701; and *B. D. Allen*, New Mexico Bureau of Geology and Mineral Resources—Albuquerque Office, New Mexico Institute of Mining and Technology, Albuquerque, New Mexico 87106

The Bull Gap quadrangle is located in the northern Tularosa Basin, south of Carrizozo and north of Oscura, New Mexico. The topography is primarily low, rolling country with a long hogback of Cretaceous strata trending north-south in the center of the map, and the Carrizozo lava flow trending northeast-southwest across the quadrangle. Exposures of Permian and Cretaceous strata are present in the center of the map area, and large tracts of modern alluvium and older fan deposits from the Sacramento Mountains cover bedrock geology to the east. The western one-third of the quadrangle lies to the north, south, and east of bedrock uplands, and surficial clastic sediments in this area are classified as piedmont deposits with relative age designations based on inset relationships. The Carrizozo lava flow, ~ 5 ka in age, trends southwest to northeast across the center of the quadrangle. An unnamed Tertiary age (?) conglomerate is locally incised into underlying Cretaceous strata, and its base is an angular unconformity with older strata. Tertiary igneous intrusives occur as both sills and dikes and are presumably related to the Oligocene Sierra Blanca volcanic field. Sills observed in the field area are felsic to intermediate in composition and often have porphyritic textures. Dikes in the map area are oriented east-west to southeast-northwest and tend to be short in length (less than 0.75 km). Permian strata in the Bull Gap area include the San Andres Formation and the overlying Grayburg Formation of the Artesia Group, which are overlain by the Lower to Middle Triassic Moenkopi Formation. Cretaceous strata include the Dakota Sandstone, which forms the distinctive hogback in the center of the map area, the lower tongue of the Mancos Shale, Tres Hermanos Formation, D-Cross Tongue of the Mancos Shale, Gallup Sandstone, and the Crevasse Canyon Formation. The limestones in the lower tongue of the Mancos Shale are the Bridge Creek Beds. Faults in the Bull Gap quadrangle are primarily oblique-slip faults and oriented northwest-southeast to east-west. Both right lateral and left lateral strike slip motion are evident, and slickenline lineations observed at a few localities are steeply inclined. A few faults trend north-south to northeast-southwest and appear to be primarily normal faults. These faults are primarily down to the west and are presumably part of the Neogene extensional structural fabric.

U-SERIES DATING AND STABLE ISOTOPE ANALYSIS OF TRAVERTINE DEPOSITS NEAR PONDEROSA, NEW MEXICO: IMPLICATIONS FOR DEFINING THE EASTERN LIMIT OF THE VALLES OUTFLOW PLUME, *R. E. Salaz*, zeke@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *S. A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *G. WoldeGabriel*, Earth and Environmental Sciences Division, Los Alamos National Laboratory, EES-16/MS D462, Los Alamos, New Mexico 87545; and *M. Albrecht*, TBA Power, Inc, 2825 East Cottonwood Parkway, Suite 500, Salt Lake City, Utah 84121

The well-known Valles caldera hydrothermal outflow plume, which flows along the Jemez fault zone (JFZ) in Cañon de San Diego (CdSD) in the southwest Jemez Mountains, New Mexico, possibly extends to the east of the currently accepted limits. Recent geologic mapping on the Cat Mesa and Jose fault zones (CMFZ and JoFZ), 3–6 km east of the JFZ, has identified several Quaternary hydrothermal features. Also, a hot well with temperatures of 129°C at 829 m depth (AET-4) located just east of the CMFZ implies an eastward extension of the plume. Indications of Quaternary hydrothermal activity include four generations of travertine deposition, goethite/hematite/barite mineralization in fault zones and coating terrace gravels, and one sinter deposit on the JoFZ. The highest elevation and oldest travertine in the area rests on a terrace 190 m above the Jemez River. Stable isotope values for this travertine are $\delta^{13}C$ of 5.18‰ PDB and $\delta^{18}O$ of 23.74‰ SMOW. The other travertine mounds lie on much lower terraces of around 40 m above the Jemez River and have an estimated age of around 155 ka. The sinter deposit

intrudes into the JoFZ contact between Jurassic Entrada Sandstone and Tertiary Zia Formation and is indicative of very high temperature water. The deposit is of an unknown age and appears to be an exhumed vent.

Recent detailed geologic mapping along the JFZ on the Pueblo of Jemez has identified three generations of travertine deposition. The oldest is at an elevation of 44 m above the river and has an age of 233 ka. This travertine deposit rests on fine illite clay that was deposited across the JFZ. After the first travertine deposition, hematite-rich fluids cemented alluvial fan deposits, which were then overlain by a 144 ka travertine deposit. The third travertine occurs near Salt Spring at an elevation of 9 m above the river and has an age of 166 ka. Stable isotope data from these travertines ranges from $\delta^{13}C$ values of 3.47‰–3.73‰ PDB and $\delta^{18}O$ values of 22.40‰–22.52‰ SMOW. These data are fairly consistent with published U-series dates and stable isotope values from Soda Dam. The travertines on Jemez Pueblo are thought to have the same outflow plume origin as Soda Dam. U-series dates and stable isotope data will be evaluated to determine if the outflow plume is responsible for deposition of the CMFZ and JoFZ travertines.

EARLY PERMIAN TETRAPOD ICHNOFAUNA FROM THE SANGRE DE CRISTO FORMATION OF NORTH-CENTRAL NEW MEXICO, *S. Voigt*, sebastian.voigt@state.nm.us, *S. G. Lucas*, and *L. F. Rinehart*, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Early Permian tetrapod footprints from the Sangre de Cristo Formation of the Pecos River valley area in north-central New Mexico have been known for more than two decades. Initial finds from 1989 were the first Paleozoic vertebrate tracks from New Mexico described in detail. Currently, the New Mexico Museum of Natural History stores 167 footprint specimens from seven localities in the upper part of the Sangre de Cristo Formation in San Miguel County. A recent increase of material and knowledge necessitates revision of this ichnofauna. The assemblage comprises tracks of *Batrachichnus* Woodworth, 1900, *Limnopus* Marsh, 1894, *Ichniotherium* Pohlig, 1892, *Dimetropus* Romer and Price, 1940, *Tambachichnium* Müller, 1954, cf. *Hyloidichnus* Gilmore, 1927, and *Dromopus*, Marsh, 1894. They can be referred to temnopspondyl, diadectomorph, "pelycosaur," captorhinid, and araeoscelid trackmakers. This assemblage represents a typical Early Permian red-bed tetrapod ichnofauna. Relatively large (pes length ~ 70 mm) imprints of cf. *Hyloidichnus* referred to moradisaurine captorhinids may indicate a late Early Permian (Artinskian–Kungurian; late Wolfcampian–Leonardian) age of the footprint-bearing strata. The remarkable abundance of *Ichniotherium* (referred to diadectomorphs) and *Tambachichnium* (referred to varanopid "pelycosaurs") suggests that the occurrence represents an inland tetrapod ichnofauna. Such an interpretation coincides with paleogeographic reconstructions locating the study area during the Early Permian in an intramontane foreland basin (Taos trough) of the ancestral Rocky Mountains at least 160 km landward from the nearest marine shoreline. Given the rarity of fossil sites with Paleozoic inland (and upland) tetrapod communities, the Sangre de Cristo tetrapod ichnofauna is of global interest and deserves further research.

REVISION OF *REDONDASAURUS* (ARCHOSAURIA: PARASUCHIDAE) FROM THE UPPER TRIASSIC (APACHEAN) OF THE AMERICAN SOUTHWEST, *J. A. Spielmann* and *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

A recent restudy of Apachean-age phytosaurs, primarily from the Chinle Group of the American Southwest, has allowed for the recognition of at least six new skulls of the Apachean *Redondasaurus*, which when added to previously known cranial material, brings the total number of recognized *Redondasaurus* skulls to ~ 12. With this larger sample size, new taxonomically informative characters have been recognized that further distinguish *Redondasaurus* from closely related phytosaur taxa (e.g., *Pseudopalatus*, *Nicrosaurus*). The primary diagnostic character of *Redondasaurus* has traditionally been supratemporal fenestrae that are hidden in dorsal view. However, now, with a greater sampling of skull characters, the following features are also recognized as diagnostic of *Redondasaurus*: reduced antorbital fenestrae; a prominent pre-infratemporal shelf at the anteroventral margin of the lateral temporal fenestra; septomaxillae that wrap around the outer margin of the external narial opening; a thickened orbital margin (distinguishing it from all other phytosaur except *Coburgosuchus*); and an inflated posterior nasal behind the external narial opening. Based on these newly recognized diagnostic characters *Redondasaurus* is demonstrably distinct from *Pseudopalatus,* and arguments for their synonymy should be abandoned. Further, we interpret *Redondasaurus* as sexually dimorphic, with the males possessing an overall more robust skull with a crest that extends the length of the snout and females with a more gracile skull that lacks a crest, analogous to the sexual dimorphs recognized in *Pseudopalatus*. Given the sexual dimorphism in *Redondasauru*s, the two named species should be synonymized, as the only difference between the two species were sexually dimorphic characters of the crest. Thus, the holotype of *Redondasaurus gregorii* is the female morph, and the holotype of *R. bermani* is the male morph. Given *R. gregorii*'s priority, *R. bermani* should be treated as a junior subjective synonym. The newly recognized diagnostic characters of *Redondasaurus* will hopefully allow additional specimens to be identified and increase the biostratigraphic utility of this taxon.

A JULIFORM MILLIPEDE FROM THE UPPER PENNSYLVANIAN (VIRGILIAN) BURSUM FORMATION, CARRIZO ARROYO, CENTRAL NEW MEXICO, *J. A. Spielmann* and *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Fossil millipedes are rare elements in the Paleozoic assemblages of western North America and when found are often so poorly preserved that distinguishing diagnostic features proves impossible. The presence of a millipede at Carrizo Arroyo (NMMNH locality 3433), a Virgilian locality in the Red Tanks Member of the Bursum Formation with an extensive invertebrate fauna, was initially described as a singular occurrence. However, a recent reexamination of the collected material from Carrizo Arroyo has led to the discovery of five additional millipede specimens. These specimens range in completeness from a dozen midbody segments to a specimen that preserves the first 48 segments of an individual, in part and counterpart, including the individual's head. All millipede specimens share consistent segment morphology and thus pertain to a single taxon. In contrast to modern millipedes, which are diagnosed at the species level based on genital structure, fossil millipedes are distinguished based on segment ornamentation. The Carrizo millipede possesses the following diagnostic characters: a mid-segment ridge running dorsoventrally the height of the segment that serves to separate the prozonite and the metazonite; and no additional ornamentation of the segments. The Carrizo millipede is only one of three examples of Paleozoic millipedes known from western North America; others include material from the Upper Pennsylvanian to Lower Permian limestones of Hamilton County, Kansas, and the Upper Pennsylvanian Kinney brick quarry of central New Mexico. Thus, these new millipede specimens add significantly to our understanding of Paleozoic millipedes and help to fill gaps in the sparse fossil record of this group.

New Mexico Geology thanks the New Mexico Geological Society Foundation for their continuing financial support of the publication of these abstracts.

NMGS spring meeting
Student winners for best presentation

Each year a panel of judges evaluates student oral and poster presentations. Scores are tallied from judging forms. This year the award for best student talk was given to Jason Ricketts for his presentation "Calcite-filled fractures in travertine used to constrain the timing and orientation of Quaternary extension along the western margin of the Rio Grande rift, central New Mexico." The award for best poster presentation was given to Sarah Machin, for "The Beartooth–Mojado connection: using mid-Cretaceous sedimentary rocks to understand the tectonic history of southwest New Mexico."