Abstracts

New Mexico Geological Society spring meeting

The New Mexico Geological Society annual spring meeting was held on April 13, 2007, at New Mexico Institute of Mining and Technology, Socorro. Following are the abstracts from all sessions given at that meeting.

KEYNOTE

GEOTHERMAL RESOURCES OF NEW MEXICO: NATURE OF OCCURRENCE, CURRENT AND FUTURE USES, *J. C. Witcher*, jimwitcher@zianet.com, Witcher and Associates, P.O. Box 3142, Las Cruces, New Mexico 88003

The physiographic diversity of New Mexico is accompanied by different thermal regimes, hydrology, and structures that are conducive to practically the entire gamut of possible geothermal manifestations. User demand, economics, accessibility, technology, and awareness determine the types of geothermal resources that are placed in service. Shallow convective systems in fractured bedrock are the focus of current geothermal utilization. The shallow reservoirs are the result of rapid upward topography-forced leakage from deep hot regional bedrock ground water flow or seepage systems. Large and deep confined aquifers with conductive thermal regimes also have potential for use as energy demand, technology, economics, and awareness converge. Upper crust magma heat sources are not required for either the forced-convective or the conductive resource categories; although, high regional heat flow from the mantle and deeper crust is favorable. Geothermal heat may be converted to electricity or the heat may be used directly without energy conversion. New Mexico leads the nation in geothermal direct-use for heating greenhouses. The Masson Radium Springs Farm geothermal greenhouse provides an example with significant energy savings. The operation is the largest business in northern Doña Ana County with annual cash receipts exceeding $10 million and more than 100 employees. Several technologies are applied in the operation to save fresh water, prevent corrosion, and sustain the geothermal resource. The New Mexico geothermal future may include small-scale electrical power generation, desalination, and many industrial and agricultural direct-use applications. In fact, geothermal could complement petroleum production by using hot produced fluids with high water cut for small-scale power production.

INVITED SPEAKER

ENVIRONMENTAL AND SAFETY ISSUES IN GEOTHERMAL DEVELOPMENT, *F. Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *C. J. Goff*, candf@swcp.com, Consultant, 5515 Quemazon, Los Alamos, New Mexico 87544.

Geothermal installations are relatively benign compared to most conventional power schemes. For example, geothermal power plants release ≤7% of the CO_2 released by an equivalent natural gas-fired plant. However, any large-scale geothermal construction project produces visual impacts on the landscape, creates noise and wastes, and may adversely affect local hot spring systems. The following list of environmental and safety issues are usually addressed during development stages of geothermal resources: 1) H_2S pollution of atmosphere, 2) brine pollution of ground water, 3) impacts on hot spring systems and potential for hydrothermal explosions, 4) landslides, 5) reservoir interference and depletion, 6) ground subsidence, 7) inducted seismicity, and 8) earthquake and volcanic hazards. Items 2, 3, and 5 are probably the most important issues in low- to intermediate-temperature geothermal developments (<170°C) such as resort use, fish farming, and green housing, which are common geothermal applications in New Mexico. All items are important issues at high-temperature developments (>170°C) in Quaternary volcanic regions such as The Geysers, California, and would be considered at any future development in the Valles caldera, New Mexico. Proactive measures to mitigate potential environmental problems are beneficial to the long-term health and financial well being of commercial geothermal developments.

SESSION 1—ALTERNATIVE ENERGY: GEOTHERMAL RESOURCES OF NEW MEXICO

GEOPHYSICAL STUDIES RELATING TO REGIONAL GEOTHERMAL RESOURCES IN NEW MEXICO, *M. Reiter*, mreiter@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Heat flow and subsurface temperature gradient data are considered along with seismic and gravity studies for several large regions with geothermal resource potential. In the north-central and northeastern San Juan Basin heat flows and geothermal gradients become elevated approaching the San Juan volcanic field and the associated large-scale negative Bouguer gravity anomaly. These geothermal data are near the perimeter of a regional upper mantle low shear wave velocity centered at Alamosa, Colorado, having a diameter of several hundred kilometers. Just south of Alamosa, a slow P wave anomaly at 100 kilometers depth extends southward for 60 km along the Rio Grande rift in southern Colorado and northern New Mexico. Two nearby heat flow values just to the south-southwest of this anomaly are elevated. P wave tomography at 100 km depth indicates a large slow-velocity region of the order of 100 km on a side associated with the Jemez caldera. Preliminary geothermal gradient data suggest a change in very elevated gradients to normal gradients over a distance of ~20–40 km, implying observable geothermal resources are in the uppermost crust. In the Datil–Mogollon volcanic field a large slow P wave anomaly at 100 km coincides with a relatively large negative Bouguer gravity anomaly and estimated high geothermal gradients. Large batholiths modeled in the San Juan and Datil–Mogollon volcanic fields would have dissipated their heat over the past ~25–35 m.y. since caldera eruptions. This and the above data imply thermal source replenishment over time. Temperature gradients near the San Juan and Datil–Mogollon volcanic fields are as elevated as higher gradients along the Rio Grande rift.

LARAMIDE AND OLDER STRUCTURES AS POSSIBLE PRIMARY CONTROLS ON THE OCCURRENCE OF CONVECTIVE GEOTHERMAL SYSTEMS IN THE RIO GRANDE RIFT AND ADJACENT AREAS, *J. C. Witcher*, jimwitcher@zianet.com, Witcher and Associates, P.O. Box 3142, Las Cruces, New Mexico 88003

Most convective geothermal systems in the Rio Grande rift have fractured Precambrian, Paleozoic, or lower Mesozoic reservoir hosts, and the discharge for most systems occurs where regional Mesozoic and Tertiary aquitards are tectonically or erosionally stripped to form hydrogeologic windows. A spatial affinity to Laramide or older structural highs is apparent when the systems are plotted on a Tertiary subcrop map. A closer examination shows that many overlie the vergent margins of Laramide basement-cored, north- and northwest-striking uplifts. Geothermal systems at Montezuma Hot Springs, Salado Warm Springs, Truth or Consequences, Derry Warm Springs, Lake Valley, Rincon, San Diego Mountain, and Radium Springs are examples. Elsewhere, core drilling of the geothermal system at McGregor Range encountered a thrust fault slicing a large overturned fold that has either late Paleozoic or Laramide affinity. The Lightning Dock system straddles a major west-northwest striking zone that shows evidence for tectonic inversion of a Jurassic extensional fault zone during Laramide compression. Confirmed reservoir temperatures and aqueous chemical geothermometry imply typical water circulation depths greater than 3 km. Considering the temperatures and high mass flow rates for some of the systems, a very deeply penetrating and extensive fracture permeability network is required. Forelimb domain deformation in the hanging wall of a large-scale basement-cored reverse fault and fold structure would provide the shattered volume and depth penetration necessary to create geothermal system plumbing. Any contemporaneous Laramide transpression components and later mid-Tertiary volcanotectonic features and Neogene rift faults act to enhance and sustain the older permeability. Impermeable reverse fault cores or gouge zones and folded aquitards on the footwall would direct flow vertically in the fractured domain and facilitate discharge or recharge.

CENOZOIC UPLIFT, MAGMATISM, AND MANTLE TO SURFACE FLUID INTERCONNECTIONS ASSOCIATED WITH THE ASPEN ANOMALY OF CENTRAL COLORADO: THE CREST EXPERIMENT (COLORADO ROCKIES EXPERIMENT AND SEISMIC TRANSECTS), *K. E. Karlstrom*,

Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *K. G. Dueker*, Department of Geology and Geophysics, University of Wyoming, Laramie, Wyoming 82071; *R. Aster, J. MacCarthy* Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *L. Crossey*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *M. T. Heizler*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Teleseismic studies indicate that the upper mantle beneath the Colorado Rocky Mountains has low seismic velocity and is at a temperature consistent with the presence of a small percentage of partial melt. The lowest mantle velocity feature in the region, the Aspen Anomaly, coincides with the intersection of the northeast-trending Proterozoic Colorado mineral belt and the north-northwest-trending extension of the Rio Grande rift. This anomaly is similar in spatial scale to low-velocity anomalies in the Yellowstone and Rio Grande rift regions and is characterized by very sharp velocity transitions. Its interpreted association with both a dipping Proterozoic paleosuture zone in the lithosphere and with the Cenozoic San Juan volcanic field and Rio Grande rift systems suggests feedbacks between Cenozoic asthenospheric small-scale convection and ancient lithospheric compositional and rheologic heterogeneities.

The geometry and tectonic history of the Aspen Anomaly are being evaluated through an integrated experiment involving: 1) passive IRIS PASSCAL-supported imaging (~70 stations), with data collection planned for 2008–2009; 2) geologic and thermochronologic studies of the uplift history of the highest elevation region of the Colorado Rockies; and 3) studies of mantle to surface interconnections via mantle degassing, hydrochemistry, and neotectonics. The provocative time-space correlations between Cenozoic rock uplift and denudation patterns, magmatism, modern hydrothermal systems, and the modern-day mantle anomaly indicate that the Aspen Anomaly may have been an active tectonic feature of the southern Rockies throughout the Cenozoic. The highest peaks of the Colorado Rockies are located above, and major drainage is radial away, the mantle anomaly suggesting broad mantle-driven epeirogenic surface uplift. Quaternary faults in Colorado follow both rift-related north-northwest trends and northeast trends suggesting that epeirogenic uplift may be expressed in the crust as block movements in a segmented lithosphere above the buoyant mantle domain. Mantle degassing (CO_2 and ^3He) and high heat flow through hot springs and CO_2 springs indicate continued mantle devolatilization. The emerging data and the ongoing experiment offer rich potential for understanding interconnections and feedbacks between the mantle and the near-surface systems.

HOT SPRINGS REVISITED: A REVIEW OF DATA FROM THE C. V. THEIS STUDY "THERMAL WATERS OF THE HOT SPRINGS ARTESIAN BASIN," *C. Winters*, craigwin@rmi.net, Department of Civil Engineering, New Mexico State University, Las Cruces, New Mexico 88003

In 1939 Charles V. Theis, George C. Taylor, Jr., and C. Richard Murray investigated the thermal waters of the Hot Springs, New Mexico (now named Truth or Consequences), to determine how much development of the hot mineral water can take place without lowering the temperature or reducing the flow of water. Their work included two pumping tests, which were analyzed with curve matching methods, and show variations in the transmissivity of the aquifer depending on the direction between the pumping well and observation well. These variations were described as having maximum transmissivity parallel to the strike line of the thermal water-bearing Magdalena limestone formation and are aligned to the grain of the formation.

This study reanalyzes the published data from these pumping tests using the Hantush–Jacob method to verify the directional sensitivity of transmissivity and investigate the cause of this directionality. The conclusion is that there is systematic variation in the computed transmissivity of the Hot Springs thermal aquifer. This study considers it highly significant that the direction of maximum transmissivity is perpendicular to the isopotential lines of the piezometric surface, therefore, in the direction of ground water flow, but is at a 30° angle to the strike line. It was considered that variation results from horizontal flow within the aquifer distorting the cone of depression of the pumped well, but a MODFLOW analysis suggests that the transmissivity represents actual variations in the conductivity of the water-bearing formation. The alignment of peak transmissivity with the direction of flow could result from piping as the heated water dissolves rock and enlarges channels as it flows toward an identified point of high natural discharge. Additional pump testing from a different location is suggested for a conclusive determination.

VALLES CALDERA (BACA) GEOTHERMAL SYSTEM, NEW MEXICO, *C. J. Goff*, candf@swcp.com, Consultant, 5515 Quemazon, Los Alamos, New Mexico 87544; and *F. Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Valles caldera is a 22-km-diameter resurgent cauldron that formed 1.25 Ma with eruption of the upper Bandelier Tuff. Continued post-caldera volcanism to roughly 40 ka provides potent, shallow heat for long-lived hydrothermal activity. A generalized model of the geothermal system includes recharge of cold meteoric water in the north and east caldera moat, convective rise of hydrothermal fluids beneath the southwestern resurgent dome, and lateral discharge of an outflow plume southwest of the caldera. Geochemical studies and drilling data indicate that hydrothermal fluids in the caldera are parent fluids for hot springs discharged in San Diego Canyon. The present geothermal system (260–300°C) occupies two structural zones within the resurgent dome. The Redondo Creek subsystem, located in a graben that bisects the resurgent dome, was drilled by 19 wells, of which only seven were considered viable for electricity production. Steep terrain and landslides restrict drilling sites. Two geochemically distinct fluids indicate lack of connectivity in the faulted reservoir. The Sulphur Springs subsystem on the west side of the resurgent dome was penetrated by eight subcommercial wells. In 1983 geothermal development of the Redondo Creek subsystem ceased due to insufficient quantities of fluid to supply a planned 50 MWe power plant. Only 20–30 MWe of capacity were proven. After the Valles Caldera National Preserve was created in 2000, a "hold out" owner of Baca mineral rights declared an interest in renewing geothermal development, but as of early 2007 no further exploration or drilling has been conducted.

EXPLORATION OF THE LIGHTNING DOCK KGRA, ANIMAS VALLEY AND PYRAMID MOUNTAINS, HIDALGO COUNTY, NEW MEXICO, 1975–78, *W. E. Elston*, welston@unm.edu, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *E. G. Deal*, Montana Bureau of Mines and Geology, 1300 W. Park Street, Butte, Montana 59701

Exploration of the Lightning Dock KGRA, funded by USGS and NM Energy & Minerals Dept., involved geologic mapping (E. G. Deal, Eastern Kentucky Univ., W. E. Elston, UNM); hydrogeochemical and isotopic models (C. Swanberg, NMSU; G. P. Landis, M. J. Logsdon, UNM); and geophysical surveys (G. R. Jiracek, UNM). A summary (Elston et al. 1983, NMBMMR *Circ. 177*, 44 pp., geologic map) concluded that geothermal waters are structurally controlled by an intersection of three geologic features, ~9 km southwest of the present hot wells:

(1) The moat and ring-fracture zone of the late Eocene Muir ignimbrite cauldron, projected westward from the Pyramid Mountains to the Animas Valley. Ground was prepared by fractures related to caldera collapse and resurgence. Base exchange reactions by zeolitized pyroclastic rhyolites of precursor and moat stages may account for purity of geothermal waters.

(2) A northeast-trending alignment of Plio-Pleistocene basalt volcanoes, from the San Bernadino field (southeast Arizona) to Lordsburg. Resistivity and gravity highs and isotherms of KGRA waters follow this trend. An electrically conductive body, detected by magnetotelluric soundings 7 km below the geophysical highs, has been interpreted as mafic (mantle?) rock near the basalt solidus and ultimate heat source.

(3) A recently active north-south fault system. From northern Mexico to the Gila River (200 km), it controls numerous shallow epithermal Mn oxide-fluorite veins. Inclusions in fluorite from the Doubtful (Animas) mine, 3.5 km southeast of the hot wells, indicate former boiling fluids (apparent temp. 137–345°C). The KGRA seems to be a relict of a much larger fault-controlled hydrothermal system.

Geothermal waters were interpreted as mixtures from two sources, both meteoric:

(1) 25%, 10^4-yr-old 250°C water from a deep source, possibly condensed from a vapor phase after boiling, and collected in a reservoir of fractured rocks at ~1.5 km depth.

(2) 75%, ground water in fractured volcanic rocks. Mixing at ~0.5 km results in a 150–170°C reservoir, from which a rising structurally controlled plume mixes with a cool shallow aquifer (Gila Conglomerate?), and disperses northeast.

Today, wells 135–180 m deep produce up to 1,200 gpm of water ≤119°C. Annually, 25 million roses are shipped from the largest (32 acres) geothermal greenhouse complex in the U.S. and millions of tilapia fingerlings are raised in geothermal tanks.

GROUND WATER-SURFACE WATER INTERACTIONS: EFFECTS OF HYDROTHERMAL SPRING INPUTS TO JEMEZ RIVER WATER QUALITY, *J. R. Dyer*, golf72@unm.edu, *L. J. Crossey*, and *A. S. Ali*, Department of Earth and

Planetary Sciences, University of New Mexico, Albuquerque, New Mexico, 87131

The Jemez River drains the Jemez Mountains of northern New Mexico and receives input from a number of hydrothermal features along its reach. A base line study was conducted to determine salt and metal loading effects of spring inputs to Jemez River water quality. Ten sites (stream and springs) were sampled along a 25-km reach of the river through San Diego Canyon and analyzed for major and selected trace element concentrations (Ca, Mg, Na, K, Cl, SO_4, HCO_3, Si, Br, B, Li, Ba, F, and As) under summer and baseflow conditions in 2006. Hydrothermal inputs examined include Soda Dam, Jemez Springs, and Indian Springs, and water chemistry results are consistent with earlier reports (Trainer 1984; Goff, 1994; and Goff and Shevenell 1987). Jemez River water displays a tenfold increase in total dissolved solids (TDS) and metals reflecting hydrothermal inputs between San Antonio Creek and the confluence with the Guadalupe River. Chemical trends for conservative ions (Cl, Br) are consistent with mixing/dilution of a low TDS (<30 ppm) calcium, magnesium-bicarbonate water with approximately 5% of a high TDS (>1,000 ppm) sodium chloride water at typical (baseflow) discharges of 30–40 ft^3/sec. The Guadalupe River dilutes these contributions; however, concentrations again increase along the Jemez River between the Guadalupe River and village of San Ysidro because of additional hydrothermal inputs. Loading calculations for TDS and arsenic under a variety of flow regimes typical of the Jemez River indicate that As levels of approximately 100 ppb and TDS of 500 ppm are likely to occur in the reach between Soda Dam and the Guadalupe River beginning at discharges below 140 ft^3/sec. In 2006 flows measured at the USGS gaging station near Jemez Springs were below this threshold value for all but a few days.

SESSION 2—PALEONTOLOGY

LITHOSTRATIGRAPHIC SUBDIVISION AND VERTEBRATE BIOSTRATIGRAPHY OF THE REDONDA FORMATION, CHINLE GROUP, UPPER TRIASSIC OF EAST-CENTRAL NEW MEXICO, *J. A. Spielmann, S. G. Lucas*, and *A. P. Hunt*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

In the San Jon Hill to the Mesa Redonda region of Quay County, the Upper Triassic Redonda Formation has been divided into four formal members (in ascending order): Red Peak, San Jon Creek, Duke Ranch, and Wallace Ranch Members. The type section of the members is at Red Peak, where the Red Peak Member is 64.4 m thick and disconformably(?) overlies the Upper Triassic Bull Canyon Formation. It is predominantly siltstone, with substantial mudstone, and less common sandstone, limestone, and conglomerate that are very pale orange, moderate red, and reddish brown. The San Jon Creek Member is a 2.6-m-thick bench of pale greenish-yellow, sandy lime mudstone. The Duke Ranch Member is a siltstone-dominated, slope-forming unit that is 20.2 m thick and is mostly siltstone, with colors ranging from pale reddish brown to pale greenish yellow and very pale orange. The Wallace Ranch Member is 7.7 m thick and consists mostly of very fine grained silty sandstone that forms a prominent bench; this sandstone is massive or crossbedded and is pale reddish brown to yellowish brown. Flaggy siltstone at the top of the Wallace Ranch Member is disconformably overlain by the Middle Jurassic Entrada Sandstone. Vertebrate fossils come from high in the Red Peak Member, low in the Duke Ranch Member, in the middle Duke Ranch Member, and in the middle Wallace Ranch Member. The vertebrate fauna from the Redonda Formation is the "type" assemblage of the Apachean land-vertebrate faunachron of Late Triassic (late Norian–Rhaetian?) age.

THE NEW WELL PEAK SECTION OF THE PENNSYLVANIAN–PERMIAN HORQUILLA FORMATION, BIG HATCHET MOUNTAINS, SOUTHWESTERN NEW MEXICO, *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *K. Krainer*, Institute of Geology, University of Innsbruck, Innsbruck, AUSTRIA; *J. Barrick*, Department of Geosciences, Texas Tech University, Lubbock, Texas 79409; *S. Ritter*, Brigham Young University, Provo, Utah 84602; and *J. A. Spielmann*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

At New Well Peak in the Big Hatchet Mountains (sec. 32 T31S R14W and vicinity), an exceptionally thick, well-exposed, nearly homoclinal and almost complete section of the Pennsylvanian–Permian Horquilla Formation is exposed. At New Well Peak, the Horquilla Formation is ~1 km thick, dips 20–30° to the southwest, rests with erosional disconformity on the Mississippian Paradise Formation, and has its top faulted out. Nearby outcrops indicate that the Lower Permian Earp Formation rests disconformably on the Horquilla Formation. The New Well Peak section of the Horquilla Formation comprises three lithologically distinct intervals: (1) lower member of sandy limestones, calcarenites, and oolitic limestones, ~200 m thick; (2) middle member of cherty, thick-bedded limestones, many with silicified *Chaetetes*, ~300 m thick; and (3) an upper member of thin-bedded limestones with especially rich fusulinacean assemblages, ~500 m thick. The only significant structural disruption of the Horquilla Formation at the New Well Peak section occurs low in the middle member in the form of a complex of down-to-the-north normal faults (New Well Peak fault zone), topographically low on the north side of New Well Peak. Conodont biostratigraphy indicates the basal part of the Horquilla Formation at New Well Peak is of Morrowan age. A detailed fusulinid biostratigraphy indicates that the upper part of the lower member is Atokan, the middle member is Atokan–Missourian, and the upper member is Missourian–Wolfcampian. Newly collected conodont data allow correlation of Atokan–Wolfcampian fusulinid and conodont biostratigraphy at New Well Peak and provide an important reference point for the conodont-defined base of the Permian and its relationship to fusulinid biostratigraphy.

THE DOCUMENTATION OF IN-PLACE DINOSAUR FOSSILS IN THE PALEOCENE OJO ALAMO SANDSTONE AND ANIMAS FORMATION IN THE SAN JUAN BASIN OF NEW MEXICO AND COLORADO MANDATES A PARADIGM SHIFT: DINOSAURS CAN NO LONGER BE THOUGHT OF AS ABSOLUTE INDEX FOSSILS FOR END-CRETACEOUS STRATA IN THE WESTERN INTERIOR OF NORTH AMERICA, *J. E. Fassett*, jimgeology@qwest.net, Independent Geologist, 552 Los Nidos Drive, Santa Fe, New Mexico 87501

Extensive geochronologic studies of the rocks adjacent to the Cretaceous–Tertiary (K–T) interface in the San Juan Basin have now provided compelling data attesting to the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone in New Mexico and the Animas Formation in Colorado. These data consist of radiometric age determinations for Cretaceous strata underlying the K–T interface and palynologic, paleomagnetic, and geochemical evidence attesting to the Paleocene age of the strata above the K–T interface. The identification of the paleomagnetic normal interval (C29n) in the dinosaur-bearing lower part of the Ojo Alamo Sandstone in the southern San Juan Basin at multiple localities allows for the precise dating of the last occurrence of Paleocene dinosaurs at the top of chron C29n at 64.432 Ma.

The conventional wisdom (entrenched dogma) among most geologists, and especially among vertebrate paleontologists, has been for more than 100 years that all dinosaurs became extinct at the end of the Cretaceous. Thus, dinosaur bone found in place in a formation provided indisputable evidence that the formation was Cretaceous in age. Now, with the discovery of Paleocene dinosaurs, the paradigm of Cretaceous-only dinosaurs must shift. Let us hope that this paradigm-shift will be a smooth and placid lateral-slip along planar fault blocks rather than a grumbling, rumbling, herky-jerky sliding of jagged-edged, opposing sides past each other. Science must always be conservative and accept such paradigm shifts only on the basis of the most solid evidence; however, when the data do finally speak, the shift must be accepted by all of us who follow the data in the noble pursuit of finding out how the world was made.

SESSION 3—STRUCTURE, TECTONICS, AND VOLCANOLOGY

SEISMIC INVESTIGATION INTO THE CRUSTAL STRUCTURE AND EVOLUTION OF SOUTHERN RIO GRANDE RIFT IN SOUTHERN NEW MEXICO AND FAR WEST TEXAS: THE POTRILLO VOLCANIC FIELD EXPERIMENT, *M. G. Averill*, averill@geo.utep.edu, *K. C. Miller*, and *S. Harder*, Department of Geological Sciences, University of Texas, 500 W. University Avenue, El Paso, Texas 79968

The crustal structure of the Rio Grande rift is an important link to the understanding of mantle, crustal, and surface processes in continental rift environments. The 2003 Potrillo Volcanic Field (PVF) experiment was designed as a detailed seismic investigation of the structure and composition of the southern Rio Grande rift (SRGR) at the PVF, a young and well-known xenolith locality. Our results provide new insights into the structure of the SRGR and PVF. Along the 205-km-long profile, the velocity structure of the upper 3–5 km reflects the basins and ranges of this recently extended area. Basin fill ranges in velocity from 2.5 to 4.5 km/s. In the ranges, velocities are 4.7–5.3 km/s and reflect uplifted Paleozoic sedimentary rock. A middle crust interface that marks the transition from upper to middle crust steps up from ~15 to ~11 km below the PVF leads to thickening of the middle crust in this region. Velocities increase from approximately 6.15–6.4 km/s above this interface to 6.7–7.1 km/s at the base of the crust. Whereas near-vertical incidence records exhibit laminar reflectivity at the Moho, velocity modeling does not show a pronounced lower crust transitional layer. Crustal thickness varies from 35 km near Hachita, New Mexico, to as little as ~30 km beneath El Paso, Texas. Upper mantle velocities decrease west to east from 7.9 to 7.75 km/s, consistent with a warm upper mantle and high heat flow values of 75–125 mW/m^2. We interpret the west to east changes in the middle crust, crustal thickness, and upper mantle velocity as the manifestation of the transition from southern Basin and Range province to the Rio Grande rift proper.

ANALYSIS OF PROXIMAL SYNTECTONIC PENNSYLVANIAN DEPOSITS YIELDS DEFINITIVE EVIDENCE OF MAJOR PHANEROZOIC SLIP ON PICURIS–PECOS FAULT, NORTH-CENTRAL NEW MEXICO, *S. M. Cather*, steve@gis.nmt.edu, *A. S. Read*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *K. Krainer*, Institute for Geology and Paleontology, University of Innsbruck, Inrain 52, Innsbruck, AUSTRIA; *S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *S. A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *B. S. Kues*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *B. D. Allen*, and *J. M. Timmons*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

We studied the provenance, paleocurrents, sedimentary facies, and paleontology of Pennsylvanian coarse-grained, syntectonic deposits immediately east of the Picuris–Pecos fault (PPF) to test hypotheses for the timing of the 37-km dextral separation of Proterozoic lithotypes and structures on the PPF. Near the Rio Chiquito on the northern flank of the Truchas uplift, a well-exposed, 394-m-thick succession of mostly fluvial sandstone, conglomerate, and talus breccia abuts the PPF, and consists entirely of detritus derived from the metasedimentary Hondo Group. These deposits, which we correlate to the Flechado Formation, display southeasterly paleocurrents and fine markedly to the east. We interpret them as fault-scarp deposits. The unit intertongues upsection with marine shales that contain a latest Atokan–early Desmoinesian brachiopod fauna. A limestone 80 m above the top of the Flechado Formation contains the early Desmoinesian fusulinids *Beedeina* and *Wedekindellina*. The nearest potential source terrane for the metasedimentary detritus in the Flechado Formation is in the Picuris Mountains, now dextrally separated from the Rio Chiquito exposures by at least 20 km. Immediately west of the PPF at Rio Chiquito, fine-grained, mostly arkosic Pennsylvanian beds overlie granite-gneiss. These relationships require ≥20 km of post-Atokan dextral slip on the PPF, which is supported by a ~70–90° clockwise rotation of strike of bedding in the Flechado Formation near the fault.

South of the Truchas uplift, ongoing studies of poorly exposed Pennsylvanian conglomeratic strata east of the PPF show a southward transition from quartzarenite (Ortega Quartzite provenance) to arkose (granite-gneiss and metavolcanic provenance) just south of Cave Creek in the Pecos Wilderness. Paleocurrent data indicate that these Pennsylvanian sediments were derived from west of the PPF. The Pennsylvanian quartzarenite–arkose transition approximately overlies the southern limit of the metaquartzite terrane in the subsurface east of the PPF. It thus appears that no dextral fault separation of the southern boundary of the metaquartzite terrane existed in the Early Pennsylvanian.

Our results provide definitive evidence that at least 20 km, and probably all, of the 37-km dextral separation on the PPF occurred after the Early Pennsylvanian.

TRACE ELEMENT AND ND-SR ISOTOPE SYSTEMATICS OF PHONOLITE AND OTHER ROCKS OF THE CHICO SILL COMPLEX, NORTHEAST NEW MEXICO, *L. S. Potter*, lee.potter@uni.edu, Department of Earth Science, University of Northern Iowa, 121 Latham Hall, Cedar Falls, Iowa 50614

Alkaline igneous rocks of Chico sill complex in northeastern New Mexico fall on the trend of the Jemez lineament. These 37–20 Ma intrusive rocks are spatially associated with younger rocks of the Raton–Clayton volcanic field, but clearly sample a different magma source. A subset of the spectrum of intrusive rocks (including phonolite, phonotephrite, trachyte, and lamprophyre dike rocks) is included in this study, and these rocks show overall enrichment in incompatible trace element concentrations. Phonolite is the most common rock type in the southeastern half of the sill complex and is the product of extreme fractional crystallization of a more mafic parent, but may not have evolved from the other lithologies studied. Trace element ratios and normalized-element plots suggest that at least two distinct differentiation trends produced phonolite, titanite fractionation played a role in differentiation, and a subduction component is absent from the phonolite source but may have contributed to other rocks. One odd feature is the enrichment of Zr as compared to other continental alkaline rock suites.

The subset of rocks studied shows initial Sr and Nd isotope ratios that are close to bulk-earth values, with epsilon Nd in the narrow range of 2.1 to –1.5 ($^{143}Nd/^{144}Nd$ between 0.51275 and 0.51256), and initial $^{87}Sr/^{86}Sr$ ratios in the slightly broader, but still clustered range of 0.7039 to 0.7060. These isotope ranges are similar to many ocean-island basalts. The trail of the data toward higher $^{87}Sr/^{86}Sr$ values suggests a probable mixing curve with granitic or sedimentary rocks of the upper crust, although the degree of contamination must have been small and the contaminant is poorly defined.

THE ^{40}AR/^{39}AR GEOCHRONOLOGY AND THERMOCHRONOLOGY OF THE LATIR VOLCANIC FIELD, NEW MEXICO: IMPLICATIONS FOR SILICIC CALDERA VOLCANISM, *M. J. Zimmerer*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico, 87801; *W. C. McIntosh* and *N. W. Dunbar*, Department of Earth and Environmental Science and New Mexico Bureau of Geology, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The Questa caldera of the Latir volcanic field offers an opportunity to study the magmatic cycle of a single caldera from inception to cessation. The unique nature of only one caldera within the field implies that both the volcanic record and cooling history of the plutons were not complicated by later generations of volcanism and plutonism. Preliminary $^{40}Ar/^{39}Ar$ dating of volcanic and plutonic rocks from the Latir volcanic field suggests a prolonged magmatic and cooling history. New ages indicate a ~2 m.y. period of precaldera volcanism followed by a magmatic climax with the eruption of the caldera-forming Amalia Tuff at 25.26 ± 0.01 Ma. Ages determined from the subvolcanic plutons indicate a variety of cooling histories reflecting variable depths of emplacement and uplift.

Single-crystal laser-fusion of sanidine from the tuff of Tetilla Peak indicates that the earliest precaldera volcanism within the Latir field began at 28.15 ± 0.05 Ma. The rhyolite of Cordova Creek, which was previously thought to be a similar age as the tuff of Tetilla Peak based on stratigraphy and K-Ar dating, erupted much later at 25.48 ± 0.03 Ma. The similar stratigraphic position between the two units, along with the new, younger age of the rhyolite of Cordova Creek suggests that the rate of precaldera volcanism was not constant before the eruption of the Questa caldera, but rather culminated in the several hundred thousand years before the eruption of the Amalia Tuff. We hope to test this hypothesis with continued dating of intermediate composition precaldera volcanic rocks that have stratigraphic positions between the rhyolite of Cordova Creek and the Amalia Tuff,.

The exposed plutons within the field, thought to represent the subvolcanic batholith, provide the opportunity to examine the $^{40}Ar/^{39}Ar$ thermochronology of batholiths that underlie calderas. Dates from hornblende, biotite, and K-feldspar (500°C, 350°C, and ~250°C respective closer temperatures) and age spectra from plutonic K-feldspars show that the thermal history of subvolcanic batholiths varies depending on location of emplacement. Ages from the four northern resurgent plutons are between 26.70 ± 0.10 Ma and 24.89 ± 0.03 Ma. Ages older than the Amalia Tuff reflect excess argon within the K-feldspars. Plutons that mark the southern caldera margin were emplaced between 24.77 ± 0.06 Ma and 23.63 ± 0.19 Ma. Age spectra indicate that the southern caldera margin plutons partially reset K-feldspars of the resurgent plutons and they themselves were partially reset by two plutons, Rio Hondo and Lucero Peak, located outside the southern caldera margin. Age spectra from both Rio Hondo and Lucero Peak plutons, suggest a prolonged cooling history in the southern region of the Latir field. We propose to use K-feldspar thermal modeling to better understand the cooling and uplift history of these plutons.

PETROGRAPHY AND GEOCHEMISTRY OF MAFIC DIKES NEAR RILEY, NEW MEXICO: A GUIDE TO MAGMATIC EVOLUTION UNDER A CALDERA CLUSTER OF THE EARLY RIO GRANDE RIFT, *M. I. Dimeo*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *R. M. Chamberlin*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Abundant north-northeast- to north-northwest-trending mafic dikes near Riley, New Mexico, are coeval with and appear to radiate from the Oligocene Socorro–Magdalena caldera cluster (SMCC, 32–24 Ma). The westward migrating SMCC was emplaced in an east-northeast-trending zone (reactivated Laramide Morenci zone) during early opening of the Rio Grande rift. The mafic dikes intrude Cretaceous and Tertiary sandstones, shales, and conglomerates on the southeast margin of the Colorado Plateau.

The mafic dikes are subdivided into three petrographic categories: kersantite (lamprophyric), feldspathoidal, and basaltic. Kersantite dikes contain large (~4 cm) clots of biotite in a groundmass of plagioclase and clinopyroxene. These groundmass phases commonly occur as pseudomorphs that are "replaced" by magmatic (?) carbonate. Feldspathoidal dikes typically lack plagioclase but contain nepheline, titaniferous clinopyroxene, minor phlogopite, and rare microphenocrysts of leucite. Carbonate is usually absent in the feldspathoidal dikes. Basaltic dikes contain clinopyroxene and rare olivine phenocrysts in a groundmass of plagioclase + clinopyroxene ± biotite. Despite differences in petrography, the dikes are chemically similar. When plotted on a total alkali-silica diagram, the dikes fall in the shoshonite, potassic trachybasalt, and basalt fields. Trace element plots, along with age data and spatial relationships, suggest the dikes have a common or similar magma source. Enrichment of HFS elements indicates that this source must be from a small-degree (i.e., small volume) mantle melt or must include a significant crustal component. The large volume of the Oligocene Socorro–Magdalena magmatic system (7,000 km^3) implies that crustal assimilation was a significant factor in its evolution.

INSIGHTS FROM RECENT MAPPING IN THE OJO CALIENTE AND LA MADERA QUADRANGLES, TUSAS MOUNTAINS, NEW MEXICO; KINEMATICS, TIMING, AND RHEOLOGY OF PROTEROZOIC DEFORMATION AND FAULT REACTIVATION, *A. C. Salem*, *K. E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *M. L. Williams*, Geosciences Department, University of Massachusetts, Amherst, Massachusetts 01003; and *D. Koning*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Here we present new mapping, Proterozoic stratigraphy, and structural data from the Ojo Caliente and La Madera quadrangles, New Mexico. These data allow for a revised interpretation of the kinematics and timing of Proterozoic deformational events, and insights into rheology of middle crustal flow. We also examine middle-late Miocene throw along the Vallecitos fault and propose that the location of the fault may be controlled by a Proterozoic shear zone.

Proterozoic units are divided into two groups (in ascending order): 1) the Vadito Group, consisting of aluminous quartzite, schist, metarhyolite, and amphibolite, and 2) the Hondo Group, which includes the Ortega Quartzite. These are intruded by Tres Piedras Granite (~1693 ± 11 Ma). Metamorphic mineral assemblages indicate Proterozoic units experienced greenschist- to amphibolite-grade metamorphism (475–550°C at 12–16 km depth) with metamorphic grade increasing southward. These units experienced three episodes of progressive, ductile deformation D_1, D_2, and D_3. D_1 and D_2 are characterized by folds, fabrics, and shear zones formed as the result of northeast-directed shortening during the Mazatzal orogeny, ca. 1,650 Ma. D_3 is characterized by east-plunging folds formed syntectonically with 1,420 Ma granites, and resulted in continued shortening, triple-point metamorphism, and fabric development. Geometry of the resulting regional composite D_2/D_3 structures is controlled by massive Ortega Quartzite that is folded into overturned synclinoria with shallow plunges. D_1/D_2 in the underlying Vadito Group record intense layer-parallel shear before and during the formation of the large synclines. This rheologic contrast produced different deformation styles in different rock types and allowed shear zone detachments to develop near the base of the quartzite.

Detailed mapping of Proterozoic lithologies suggests that the location of the Miocene-age Vallecitos fault may be controlled by this older Proterozoic shear zone. This shear zone is indicated by low-angle truncation of Vadito Group units. The brittle fault reactivation, associated with Rio Grande rift extension, offsets middle Miocene strata of the Tesuque Formation with west-side-down normal displacement.

SESSION 4—CAVES, HYDROGEOLOGY, AND STRATIGRAPHY

POLYGENETIC SPELEOGENESIS IN THE CASTILE FORMATION: EDDY COUNTY, NEW MEXICO, AND CULBERSON COUNTY, TEXAS, *K. W. Stafford*, kwstafford@juno.com, Cave and Karst Studies, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *P. J. Boston*, Cave and Karst Studies, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801 and National Cave and Karst Research Institute, Carlsbad, New Mexico 88220; and *R. Nance*, Carlsbad High School, Carlsbad, New Mexico 88220

The Permian Castile Formation crops out over an area of ~1,800 km^2 in the western Delaware Basin, where it hosts extensive karst development in laminated, massive, and nodular gypsum fabrics, as well as in selenite, gypsite, and biogenic limestone. Karst development ranges widely, including: sinkholes (filled and open), hypergenic and hypogenic caves, brecciation, and calcitization. Combined field studies and GIS analyses have identified >3,500 surficial karst manifestations and suggest >10,000 are probable; however, less than 10% are open and large enough to be humanly entered for study.

Hypergenic karst is characterized by sinkholes and small caves that are laterally limited with rapid passage width decrease away from insurgences. Hypogenic karst is reflected in larger caves with complex morphologies (e.g., risers, half-tubes, and cupolas) indicative of confined dissolution. More than 1,000 individual calcitized masses (i.e., biogenic limestone produced as a byproduct of bacterial sulfate reduction in the presence of hydrocarbons) have been documented, which indicate cross-formational fluid migration. Native sulfur and selenite masses are commonly found associated with calcitized evaporites.

Intense karst development, biogenic limestone, and selenite commonly occur in clusters, suggesting a speleogenetic correlation between these features. A proposed polygenetic model for speleogenetic evolution is being developed, which includes: 1) calcitization associated with upward migration of fluids along fractures; 2) confined evaporite dissolution associated with fluid migration through brine density convection originating from porous biogenic limestone; 3) selenite precipitation through oxidation of secondary sulfur in the presence of hypergenic fluids; and 4) epigenic overprinting resulting from surface denudation and cave breaching.

A GEOMICROBIOLOGICAL AND GEOCHEMICAL APPROACH TO THE BIOGENICITY OF MOONMILK FORMATION—SPIDER CAVE AND PAHOEHOE CAVE, NEW MEXICO, THURSDAY MORNING CAVE, COLORADO, AND THRUSH CAVE, ALASKA, *M. Curry, P. J. Boston*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, and National Cave and Karst Research Institute, Carlsbad, New Mexico 88220; and *S. O'Neil*, Department of Biology, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Many secondarily formed deposits within caves (known as speleothems) are the result of primarily physiochemical processes. Moonmilk is a unique speleothem whose origin does not appear to be explainable via the more usual abiotic mechanisms employed to explain traditional speleothems (i.e., stalagmites, stalactites). Moonmilk is exceptional due to its high biomass and water content, highly variable mineralogy, and unusual texture. Moonmilk is currently loosely defined as a microcrystalline aggregate cave deposit composed of one of a variety of possible mineralogies and with a distinguishable texture that is soft, plastic, and pasty when wet, and crumbly and powdery when dry. Visible micropits in bedrock are often associated with microbial bodies, filaments, and hold-fasts. These suggest a microbial role in dissolution of parent material, apparently caused by organism attachment and associated carbonate dissolution via organic acids. Evidence of mineral precipitation by organisms can be seen in encrustation around microbial filaments, and significant overall biofilm content of the material. We hypothesize that such moonmilk is the product of a passive, microbially mediated disaggregation of host rock and reprecipitation of carbonate from bedrock in a ground water seepage-driven evaporative process.

We are investigating calcite and monohydrocalcite moonmilk within four different cave environments in order to help determine the relative importance of biotic versus abiotic mechanisms. Each cave system provides different environmental parameters (e.g., temperature and lithology). We will discuss results to date including 1) organisms isolated from the moonmilk, 2) SEM images and EDS of organisms and their associated minerals, 3) stable isotope analyses of S and C in organisms and resulting mineral precipitation, 4) electron microprobe elemental mapping, and 5) petrography.

CO_2 MOUND SPRINGS OF THE WESTERN U.S.: TOWARD A MODEL FOR CONTINENTAL SMOKERS, *L. J. Crossey*, lcrossey@unm.edu, *K. E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *C. Takacs-Vesbach*, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131; *D. L. Hilton*, Geosciences Research Division, Scripps Institution of Oceanography, La Jolla, California 92093; *J. Hall, C. N. Dahm*, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131; *D. L. Newell*, and *T. F. Fischer*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

CO_2-rich springs of the western U.S. associated with Quaternary travertine and lacustrine carbonate deposits record long-lived interactions of deeply sourced (endogenic) fluids with the near-surface hydrologic regime. Springs occur along faults and fracture zones associated with continental extension (e.g., Rio Grande rift, Basin and Range, Arizona transition zone). Upwelling waters may emerge as springs along basin margins, or they may mix with aquifer waters in the shallow hydrologic system. They represent diffuse degassing and a generally unrecognized flux of CO_2 into regional aquifers, and also impair water quality via high solute loads and the presence of elevated trace metal concentrations (e.g., arsenic). Geochemical mixing models indicate that only a small component of saline, radiogenic, hydrothermal fluid is needed to produce observed spring chemistries. He and C isotopes are suggestive of a deep crustal or mantle origin for the gases, linking them to magmatism and extensional tectonics.

Both cool (20–35ºC) and hot springs (40–80ºC) share geochemical similarities to the chemolithotrophic microbial ecosystems found in oceanic hydrothermal systems related to extensional tectonic settings (black and white smokers at mid-ocean ridges). Microbial community analysis reveals the presence of microorganisms utilizing many of the same metabolic pathways found in oceanic hydrothermal settings. Cloning and sequencing of amplified 16S rRNA genes using universal primers identifies organisms with >95% similarity to marine denitrifiers and thermophiles, as well as novel forms (<90% 16S rRNA gene similarity). Results reveal a microbial community strikingly uncharacteristic of known terrestrial springs. Bacterial communities are similar among sampled locales in Colorado, Arizona, and New Mexico and include many Gamma-proteobacteria sequences that exhibit strong similarity to halophilic and marine bacteria representatives from cold seeps, hydrothermal vents, saline lakes, and Arctic brine ice. Archaeal sequences are dominated by thermophilic Crenarchaeota, detected in marine and terrestrial volcanic environments. These results suggest that the springs harbor microbial communities similar to marine vent systems and seeps because of similarities in the geochemical environment.

WATER COMPOSITION AND MICROBIAL COMMUNITY STRUCTURE ASSOCIATED WITH GROUND WATER UPWELLING IN RIO GRANDE FLOODPLAIN AQUIFERS, SOCORRO BASIN, NEW MEXICO, *M. F. Kirk, L. J. Crossey, D. L. Newell*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *R. S. Bowman*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Chemical analyses of water samples from the northern end of the Socorro Basin demonstrate that deep ground water upwelling there has a considerable influence on water quality and microbial community structure. Samples associated with upwelling are characterized by elevated temperature, conductivity, DOC, HCO_3^-, Cl^-, Br^-, Cl^-/Br^- mass ratio, SO_4^{2-}, Mg^{2+}, Ca^{2+}, K^+, Na^+, Li^+, Sr^{2+}, and dissolved Fe and Mn. Furthermore, the pH and $\delta^{13}C$ of DIC are lower in comparison to the other waters sampled in this study.

We collected six surface water and 23 shallow ground water samples from New Mexico Tech Rio Grande Project transects that cross the Rio Grande floodplain at San Acacia (SAC), Escondida (ESC), and Brown Arroyo (BRN) during February 16–22, 2006. SAC lies just south of the terminus of the Albuquerque Basin and has previously been interpreted to host deep ground water upwelling. The sites farther south, ESC and BRN, show no signs of deep ground water upwelling.

Ground water west of the low-flow conveyance channel (LFCC) at SAC was affected the most. The temperature of the water there ranges from 16.1 to 20.8°C compared to 15.7–17.4°C at ESC and 14.2–17.6°C at BRN. The average conductivity of the water west of the LFCC at SAC ranged from 907 to 6,050 µS compared to 1,099–1,246 µS at ESC and 636–1,246 µS at BRN. Cl/Br mass ratios west of the LFCC at SAC range from 332 to 1,262 compared to 454–655 at ESC and 297–726 BRN.

In contrast to the ground water west of the LFCC, the characteristics of ground water between the Rio Grande and the LFCC at each site varied little and are similar to Rio Grande water. For all three sites, the temperature of the water ranged from 12.1 to 16.3°C, the conductivity ranged from 445 to 597 µS, and the Cl/Br mass ratio ranged from 200 to 367.

The conservative components of all of the surface water and ground water samples fall approximately along a simple binary mixing line. Some samples deviate from this line, however, suggesting that evaporation and other end-member waters may be important. Furthermore, the lower DIC $\delta^{13}C$ and elevated DOC, HCO_3^-, and dissolved Fe and Mn of samples collected west of the LFCC at SAC compared to all other samples suggest that the upwelling waters have enhanced reducing conditions in the shallow aquifer by increasing the availability of energy sources associated with degradation of organic matter.

HOLOCENE FAN SEDIMENTATION AND FIRE ACTIVITY IN SOUTHERN NEW MEXICO, *J. D. Frechette*, jdfrech@unm.edu, and *G. A. Meyer*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

In mountainous terrain, hydrologic processes associated with severe fires are an effective mechanism for rapidly transporting large volumes of sediment. Where fire regimes include severe fire, these processes can have significant geomorphic impacts on millennial timescales. We use alluvial fan deposits from the Sacramento Mountains to investigate the importance of fire-related geomorphic processes in ponderosa pine forests, where fire-scar records suggest recent severe fires are an anomaly.

Consistent with fire-scar reconstructions for the last 400 yrs, the youngest fan deposits in the Sacramentos are generally not fire-related, suggesting severe fires were rare. In contrast, middle Holocene deposits are dominated by charcoal-rich debris-flow facies. These deposits, characteristic of episodic fire-related sedimentation, resulted in rapid fan aggradation. Increased severe fire activity during the middle Holocene was followed by a dramatic decrease in fire-related sedimentation during the early Neoglacial when deposits indicate gradual aggradation and cumulic soil development. During Medieval time and the transition to the Little Ice Age ca. 1,500–500 calendar years B.P. fire-related sedimentation increased again, although it never returned to middle Holocene levels.

Our results indicate that alluvial fan aggradation rates in the Sacramento Mountains are strongly influenced by changes in severe fire occurrence and resulting fire-related sedimentation. This record also demonstrates that short tree-ring chronologies from the Southwest are unlikely to capture the full range of Holocene fire variability, and that severe fire may be an important driver of natural geomorphic change in some ponderosa pine forests.

MAGNETOSTRATIGRAPHY OF THE LOWER CHINLE GROUP (LATE TRIASSIC: CARNIAN–EARLY NORIAN), NORTH-CENTRAL AND CENTRAL NEW MEXICO, *K. E. Zeigler*, bludragon@gmail.com, and *J. W. Geissman*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The Chama Basin of north-central New Mexico and the Zuni Mountains of central New Mexico contain several excellent outcrop exposures of the Upper Triassic Chinle Group. The Shinarump, Salitral, and Poleo Formations, which comprise the lower half of the Chinle Group, encompass the Carnian to early Norian Stages of the Late Triassic, based on vertebrate biostratigraphy. Each of these units was sampled at three localities in the Chama Basin and one locality in the Zuni Mountains. Sites spanning the gradational Shinarump/Salitral Formation contact yielded an in situ grand mean of D = 352.9˚, I = 49.3˚, α_{95} = 20.1˚, *k* = 38.7. Sites in the El Cerrito Bed of the medial Salitral Formation yielded an in situ grand mean of D = 177.4˚, I = 10.7˚, α_{95} = 15.6˚, *k* = 63.5. The Youngsville Member of the Salitral Formation and the Poleo Formation are exclusively of reverse polarity, with an in situ grand mean of D = 188.3˚, I = 16.8˚, α_{95} = 19.4˚, *k* = 23.4 and D = 182.7˚, I = -0.3˚, α_{95} = 5.3˚, *k* = 36.5, respectively. Rock magnetic experiments indicate that the magnetic remanence in these strata is carried by the high coercivity mineral hematite. In general, the lower Chinle Group tends to be dominantly reversed polarity. The Shinarump Formation is noted for intense color mottling and the local occurrence of copper and uranium mineralization. Locally, the lower member of the Salitral Formation (Piedra Lumbre Member) is also very mottled, with colors ranging from whites and yellows through reds, purples, and blues that reflect intense pedogenic alteration of the sediments. Several specimens from different sites in the Shinarump and both members of the Salitral Formation yield incoherent magnetizations, suggesting that pedogenic alteration may have erased any original Late Triassic magnetization. However, the majority of sites sampled yield data of good to excellent quality, and tentative correlations can now be made between the lower Chinle Group and stratigraphic sections of similar age in the Tethys region of southern Europe and in eastern North America.

POSTER SESSION 1—STRUCTURE, TECTONICS, AND VOLCANOLOGY

TESTING HYPOTHESES FOR NET CENOZOIC ROCK UPLIFT OF THE COLORADO PLATEAU USING THE FLEXURAL ISOSTATIC RESPONSE TO EROSION, *C. N. Callahan*, callaha@unm.edu, *M. Roy*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *J. Pederson*, Department of

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The Colorado Plateau physiographic province within North America stands at an average elevation of 2 km and exhibits minimal upper-crustal deformation since Late Cretaceous time. The mechanisms and timing of rock and surface uplift of the Colorado Plateau remain enigmatic and are the subject of ongoing debate. A fundamental constraint on surface and rock uplift may be derived from the observation that coastal sandstones were deposited across the plateau in Late Cretaceous time; therefore, this is the last known time at which the plateau surface was at or near sea level. The post-depositional vertical motion of these shoreline sediments, estimated using geomorphology and stratigraphy, constrains the net Cenozoic rock uplift of the Colorado Plateau to be an average of 2,150 m. Our goal in this study is to quantify how much of this geologically estimated net Cenozoic rock uplift of the Colorado Plateau can be explained by isostatic responses to Cenozoic erosion. We model the isostatic effect of Cenozoic erosion as a flexural response of the lithosphere and show that this mechanism contributes only approximately 405–328 m of mean rock uplift across the plateau, with greater amplitudes toward the center of the plateau. This leaves an average of –1,850 m residual rock uplift to be accounted for by mechanisms other than erosion. These results provide new constraints to previous estimates for rock uplift due to exhumation based on Airy isostasy alone. Furthermore, the average residual rock uplift is uniform across the plateau and is inconsistent with the hypothesis of rock uplift due to crustal thickening by east-directed mid- to lower-crustal flow. Instead, our findings suggest that a regionally uniform post-Laramide process, such as buoyancy modification in the mantle lithosphere, is responsible for most of the rock uplift of the Colorado Plateau.

ROCK MAGNETIC AND PALEOMAGNETIC RESULTS FROM 80 M OF PLEISTOCENE LACUSTRINE SEDIMENT, VALLE GRANDE, VALLES CALDERA, NEW MEXICO, *L. L. Donohoo-Hurley, J. W. Geissman, P. J. Fawcett, T. F. Wawrzyniec*, and *F. Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Sedimentology, carbon isotope data, percent organic carbon, and an Ar/Ar date of 552 ± 3 ka for 78 m depth have been used independently to suggest that 80 m of lacustrine sediment was deposited during glacial terminations VI (522 ka) and V (424 ka). In this study alternating patterns of rock magnetic properties with depth (specimens taken at a minimum of 20 cm) are used as a proxy for climatically controlled changes in lithology. These combined results contribute to a mid-Pleistocene climatic model for northern New Mexico.

Alternating field (AF) demagnetization response yields positive inclination vectors through most of the core, consistent with Brunhes normal polarity. Three short intervals of negative inclination may partially record geomagnetic polarity events at ~410 ka, ~535 ka, and ~565 ka (Big Lost excursion). Remanence in these sediments is carried by multidomain and pseudo-single domain ferrimagnetic particles as shown by rock magnetic data. Paleomagnetic and rock magnetic data all record higher intensity values during glacial times (NRM from ~0.1 mAm, ARM from ~8 mAm, SIRM from ~500, and susceptibility from ~1E-4) and lower intensity values during interglacial times (NRM from ~0.2 mAm, ARM from ~4 mAm, SIRM from ~100, and susceptibility from ~6E-5). This alternating pattern may be due to a combination of an increase in terrigenous sediment during glacial times, or a change in oxidation state. An anomalous interval of high magnetic susceptibility is recorded between ~40 and ~45 m depth and is most likely due to diagenetic or biologic alteration of ferrimagnetic particles.

TRAVERTINES OF THE SPRINGERVILLE AREA, ARIZONA: "CHEMICAL VOLCANOES" LINKING WATER QUALITY, PALEOHYDROLOGY, AND NEOTECTONICS, *E. H. Embid, L. J. Crossey*, and *K. E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Sixty travertine mounds are clustered along the Little Colorado River in the Springerville volcanic field in Arizona near Lyman Lake and along two trends 5–10 km to the west and east of the river. Travertine vents align with previously mapped northwest-trending Quaternary faults and folds that reflect contemporaneous strain at the southern boundary of the Colorado Plateau–Basin and Range transition zone just to the south of the site. Travertine mounds with central vents resemble shield volcanoes and cinder cones in both morphology and mode of accumulation. These travertine deposits provide a natural laboratory for studying the interaction of magmatism, deeply sourced fluids, CO_2 migration and flux, neotectonics, and the evolution of drainages.

Local springs and ground water show appreciable variability in chemistry. The travertine-depositing springs are warmer (18.1°C), have lower pH (6.8), and have higher TDS (1,835 ppm) and trace metal concentrations than waters from nearby ground water wells. Gas composition data from the springs show very high CO_2, active CO_2 degassing, and high $^3He/^4He$ (R_a of 0.58), indicating input of endogenic fluids from below the aquifer.

Studies of the travertines themselves will address several hypotheses. U-Series dating and detailed field studies of relative timing relationships will evaluate the timing of travertine deposition, and whether travertine deposition episodes coincided with either volcanic episodes and/or wet times in the paleoclimate record. Dates on travertine-cemented river gravels offer the potential to date the incision of the river and changes through time of the locus of travertine mound spring deposition and the river.

The Springerville volcanic field is a major center of recent (3.0–0.3 Ma) magmatism at the intersection of the southeastern margin of the Colorado Plateau and the Jemez lineament. Existing data suggests spatial and temporal interconnections betwee Quaternary volcanism and travertine deposition. A swarm of nearly identical upper crustal microearthquakes ranging in magnitude from ~2.0 to ~4.0 occurred directly south of the area in December 2004, indicating active tectonism in the region. The Springerville "chemical volcanoes" may provide a record of continued neotectonic activity.

INFERENCES REGARDING TECTONIC ACTIVITY ALONG RIO GRANDE RIFT, INTRA-BASINAL FAULTS NEAR CLARA PEAK AND ON LOBATO MESA, NORTHERN JEMEZ MOUNTAINS, NEW MEXICO, *D. J. Koning*, dkoning@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *K. Kempter*, 2623 Via Caballero, Santa Fe, New Mexico 87505

We investigate the tectonic history of faults near Clara Peak and a west-down fault system on Lobato Mesa, located 16–22 km west-northwest of Española in the north-central Rio Grande rift. La Cañada del Almagre fault (CdAF) lies northeast of Clara Peak, a late Miocene basaltic eruptive center in the Jemez Mountains, and appears to intersect the Santa Clara fault to the south. Previous studies have determined ~520 m of right-lateral offset of a 9.74 ± 0.21 Ma basalt dike along this fault and greater than 350 m of east-down stratigraphic separation. We compare the relative stratigraphic heights of two contacts on either side of the fault to refine when this fault experienced throw. One contact separates the Ojo Caliente Sandstone and Chama–El Rito Members of the Tesuque Formation. This 13.3–13.5 Ma contact has experienced ~430–480 m of east-down stratigraphic separation. The second contact, corresponding to the base of 9.7–11.0 Ma basalts of the Lobato Formation, has undergone ~60–70 m of east-down stratigraphic separation. Consequently, 370–410 m of the total 430–480 m stratigraphic separation occurred between 13.5 and ~10 Ma, a time of significant tectonic activity along this fault. Oblique-slip continued after ~10 Ma, but the throw component was at a comparably lower rate. Furthermore, the aforementioned basalts fill a 30-m-deep paleovalley on both the footwall and hanging wall of the CdAF. This deep incision implies uplift along the Santa Clara fault on the southern flanks of Clara Peak before 10 Ma.

The Cerritos fault dips to the east and trends north-northwest–south-southeast along the eastern margin of the Los Cerritos dacite center, located ~2.5 km west of Clara Peak. This fault appears to have been active since 9.65 Ma, which is the age of a distinctive Los Cerritos dacite lava flow vertically offset by >50 m across the fault. Older basalts, partly mantled by thick colluvium, appear to be of comparable thickness on either side of the Cerritos fault, suggesting no or very low rates of throw before 9.65 Ma.

A 2.5-km-wide system of west-down, normal faults offsets the ~10 Ma basalts that cap Lobato Mesa by as much as 180 m. However, these do not offset 3–7 Ma Tchicoma dacite flows to the south. We do not know if this fault system was active before 10 Ma, but it is evident that these faults produced significant throw between 10 and ~5 Ma and have not been noticeably active in the Plio–Pleistocene.

MEASUREMENT OF RIO GRANDE RIFT EXTENSION IN NEW MEXICO AND COLORADO USING A GPS NETWORK, *A. L. Luther, M. Roy*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *A. R. Lowry*, Department of Geology, Utah State University, Logan, Utah 84322; *A. Sheehan*, and *S. Nerem*, Department of Geoscience, University of Colorado, Boulder, Colorado 80309

The Rio Grande rift is the easternmost active tectonic feature of the western U.S. To date, rates of extension are estimated to range from sub-millimeter to 5 mm/yr, but uncertainties in these data are as large as the motion itself. The installation of a dense, semi-permanent global positioning system (GPS) network across the rift will provide more accurate measurement of active extension over the next 5 yrs. Integration of these data with other datasets (i.e., seismic velocities in the crust and mantle, gravity, surface heat flow, and geologic data) together with geodynamic models will shed light on processes that control continental rifting.

Over the fall 2006, we installed 21 of 25 planned GPS monuments in New Mexico and Colorado, with field engineering support and equipment from UNAVCO. Each site across the rift was chosen based on the presence of exposed bedrock, and a good sky view. The bedrock location was chosen carefully to minimize movements from freeze-thaw or poroelastic effects (i.e., no shale or pervasive fracturing). Currently, the 21 installed stations are recording continuous data that will be post-processed to be accurate to a millimeter. These data will allow us to determine how far north the rift propagates, its width from north to south, and heterogeneities in spreading rates. We can then begin to answer other questions regarding the seismic hazards of the rift zone, the character of the deformation, and how the rift zone affects surrounding tectonic provinces.

We also present preliminary results from simple numerical experiments on crustal extension using a finite-element model that combines Lagrangian and Eulerian approaches. The finite-element package, GALE v.1.1.1, is designed for long-term tectonic modeling and is distributed and supported by Computational Infrastructure for Geodynamics (CIG). Our models investigate the patterns of strain developed during extensional deformation of simple rheologic analogs for the crust, e.g., a fluid with temperature-dependent viscosity overlain by a brittle-plastic layer. Our models to date are preliminary, and we hope to develop more complex coupled crust-mantle models to help us understand the behavior of the whole lithospheric column during continental rifting.

BRECCIAS OF THE SANGRE DE CRISTO IMPACT SITE NEAR SANTA FE, NEW MEXICO: A PROGRESS REPORT, *T. H. McElvain*, timmcelvain@hotmail.com, 111 Lovato Lane, Santa Fe, New Mexico 87505; *A. S. Read,* New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *E. Tegtmeier, M. T. Peterson*, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131; *W. E. Elston*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *H. E. Newsom*, and *B. A. Cohen*, Institute of Meteoritics, University of New Mexico, Albuquerque, New Mexico 87131

Shatter cones, equal in size to those of the Sudbury (Ontario) and Vredefort (South Africa) impact sites, are exposed in roadcuts along NM–475 in the Sangre de Cristo Mountains, near Santa Fe, New Mexico. Breccias in Proterozoic crystalline basement and Mississippian–Pennsylvanian carbonates are being examined to determine whether their distribution is compatible with the development stages that have been worked out for large impact structures:

Excavation stage: Ejecta blanket, fall-back breccia, in situ breccias of crater wall and floor. Breccia dikes and pseudotachylites, injected into the crater wall and floor subsequent to the shock wave responsible for shatter cones.

Enlargement stage: Landslide blocks and megabreccias (clasts >1 m), from collapse of crater wall.

Outcrops along NM–475, at progressively deeper structural levels, can be interpreted as a traverse from crater margin to subfloor. Distances are in miles, (**tentative interpretations in bold**).

0.0 Santa Fe, intersection of NM–475 and NM–590.

4.1 *Curve*: Matrix-supported megabreccia, crystalline clasts (>1 m), along a fault zone, overlain by unbrecciated Mississippian (?) carbonates. *Near here*: Small fractures (millimeter-wide) in carbonate clasts contain granite fragments with multiple fracture sets in quartz (possible planar deformation features, PDFs): (**ejecta or wall/floor breccias**). Paleozoic–Proterozoic contact appears to be depositional in most places.

4.3 *Cross bridge*: Elongated (max. 10+ m) steeply dipping brecciated granite clasts and m-size clasts of sheared mafic schist. *Down creek 50 m*: Fault-bounded breccia tower with decimeter-to-m clasts of angular granite and sparse rounded mafic schist. Clasts are supported by intracataclastic matrix: (**collapse or wall/floor megabreccia**).

5.9 Shatter cones, centimeter-to-meter size, in mafic schist, granite gneiss, and granite pegmatite; best developed in granite gneiss: (**subfloor**).

PDFs (if confirmed) and shatter cones are widely accepted as impact criteria, but tectonic interpretations of breccias cannot be ruled out. Dimensions of the proposed impact structure remain unknown, but several tectonic events have undoubtedly distorted its geometry. Resolution of age question depends on interpretation of breccias at the contact between Paleozoic rocks and brecciated crystalline basement.

WAVEFORM CROSS-CORRELATION OF EARTHQUAKE CLUSTERS TO DETERMINE LOCI OF ACTIVE PROCESSES WITHIN THE SOCORRO SEISMIC ANOMALY, NEW MEXICO, *J. J. Morton, S. L. Bilek, R. Aster*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *C. A. Rowe*, Los Alamos National Laboratory, Los Alamos, New Mexico 87545

The Socorro Seismic Anomaly is an area of elevated seismicity in central New Mexico responsible for 45% of magnitude >2.5 earthquakes in the state. This may be due to inflation of the Socorro Magma Body, an areally extensive body of magma residing at 19 km depth. Improved source locations for earthquakes within the Socorro Seismic Anomaly have resulted from the addition of two broadband seismic stations to the existing network, and application of waveform cross-correlation (WCC) methods to improve picking consistency among events within earthquake clusters. The catalog of seismic data used for this project includes ~300 locatable events with magnitude greater than –0.9 in the area from September 1, 2004, to the present. The event locations are estimated using data from the permanent, local, eleven-station seismic network as well as two temporary broadband seismic stations (PETR and SNKE) installed during fall 2005 in the Sevilleta National Wildlife Refuge. Data from these new stations lead to more accurate earthquake locations and aid in identification of additional events that may have been missed using only data from the permanent network. WCC allows comparison of seismic waveforms to eliminate inconsistencies in user-defined picks, thus reducing hypocentral scatter. The WCC process has been performed on multiple earthquake clusters within the Socorro Seismic Anomaly. Among the structures resolved is a linear feature very closely following the path of the Rio Salado. In this case, many events were shifted by 1–4 km onto this structure. Depths for the events in this region range from 1.3 to 14.6 km.

STRUCTURAL ANALYSIS OF AN EXTENSIONAL FOLD IN SAN LORENZO CANYON, NORTHERN LEMITAR MOUNTAINS, NEW MEXICO, *C. Robinson*, crobinso@nmt.edu, and *G. Axen*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The San Lorenzo Canyon area is located ~15 km north of Socorro, New Mexico. Seated within the Rio Grande rift, the area has experienced substantial rift-related sedimentation, extension, and related deformation. Detailed geologic mapping (1:24,000) has been done in this area, but a full structural analysis of the San Lorenzo Canyon area has yet to be completed. An interesting aspect of the area is that Tertiary strata describe a faulted anticline of extensional origin. Understanding the structural cause of this fold is a crucial step toward structural analysis of the study area. Since folds are generally found in contractional terrains, the presence of this structure in an extensional terrain is counterintuitive.

The study area is located at the common corner of four quadrangles, of which the San Lorenzo Springs (Chamberlin 2004) and Lemitar (Chamberlin et al. 2001) quadrangles are the most important. The stratigraphy was defined and correlated between the two quadrangles to create a working stratigraphic column. Cross sections drawn from the maps are discussed, in order to eliminate as many hypotheses as possible.

There is evidence from faulting relationships and angular unconformities in the map area that faulting, tilting, and sedimentation occurred simultaneously with folding. The southern end of the anticline terminates against the generally east-west striking Puerto fault. Possible origins of the fold, such as in a transfer/accommodation zone or a relay ramp, or by listric, antilistric, and/or antithetic domino-block tilting are explored.

PETROGRAPHIC TECHNIQUES USED TO CHARACTERIZE MOLYCORP ROCK PILES, QUESTA, NEW MEXICO, *D. Sweeney*, dsweeney@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *E. Phillips*, Black Hills State University, 1200 University Street, Spearfish, South Dakota, 57799; *V. T. McLemore, K. Donahue, N. W. Dunbar*, and *L. Heizler*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

A full mineralogical characterization of the rock pile material at Molycorp's Questa molybdenum mine in Taos County, New Mexico, required several techniques. This is due to the heterogeneity created by several rock types, supergene alteration, hypogene alteration, and recent weathering since rock pile emplacement. Soil petrography was the primary tool used for characterizing samples. Electron microprobe analysis provided micro-scale observations, and thin section analysis proved useful for select samples. X-ray diffraction was used to obtain relative clay abundances. Finally, X-ray fluorescence provided whole sample chemistry. Normative mineralogy calculations used the XRF data to acquire overall mineral abundances to supplement other techniques. Using a combination of all tools gave a comprehensive view of the rock pile mineralogy and lithologies.

DEFLECTION OF RIO SALADO TERRACES DUE TO UPLIFT OF THE SOCORRO MAGMA BODY, SOCORRO, NEW MEXICO, *L. M. Taylor*, lisamt@nmt.edu, and *J. B. J. Harrison*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The Socorro Magma Body is located in central New Mexico along the intersection of the Socorro fracture zone and the Rio Grande rift. High micro-earthquake activity corresponding to the area of the magma body indicates that it is currently active. Whereas the depth and extent of the magma body have been constrained, the age of the magma body is under debate. Evaluation of the surface disruption caused by the magma body provides clues to the duration of uplift. Specifically, given that the modern rate of vertical deflection can be measured using geodetic techniques, if the amount of deflection of a geomorphic surface above the magma body can be determined, a minimum age for the initiation of deflection can be estimated by dividing the amount of deflection by the modern rate. The modern inflation rate of the magma body has been approximated at 1–5 mm per year based on leveling surveys and INSAR data. The rapid and localized uplift has deflected the Quaternary terrace surfaces along the Rio Salado, which traverses the zone of maximum uplift.

Uplift due to magma inflation will produce vertical displacement of a riverbed and any associated terraces. Assuming that the rate of channel down cutting keeps pace with uplift, the modern longitudinal stream profile should represent the equilibrium state of the drainage. The paleostream profile, constructed based on terraces, deviates from the equilibrium condition, as estimated from the modern longitudinal profile. Comparison of the modern stream profile with the paleostream profile, as indicated by a distinct marker terrace, shows increasing deflection across the zone of maximum uplift.

Correlation of the Quaternary terraces of the Rio Salado was based on the degree of pedogenic $CaCO_3$. Although terrace preservation is poor, there is a terrace that is traceable throughout the length of the research area. This marker terrace is distinguished by being the lowest terrace exhibiting stage III carbonate horizon development. It is bounded below by a terrace showing weak pedogenic $CaCO_3$ (stage I) and above by terraces showing greater pedogenic $CaCO_3$. The marker terrace elevation above the active channel increases progressively downstream along the Rio Salado. The distribution of uplift inferred from the channel deflection is consistent with the uplift distribution based on INSAR data.

THE PETROLOGY OF MAFIC DIKES IN THE TURKEY MOUNTAINS, MORA COUNTY, NEW MEXICO, *R. Trujillo, C. Parson*, and *J. Lindline*, lindlinej@nmhu.edu, Environmental Geology Program, New Mexico Highlands University, P.O. Box 9000, Las Vegas, New Mexico 87701

The Turkey Mountains, a laccolith that was likely produced by a Tertiary intrusion, contains numerous north to northeasterly trending steeply dipping to vertical mafic dikes. The dikes intrude Mesozoic strata and range in size from 0.30 to 1.0 m in thickness and up to 1,200 m length. We examined field relations and hand specimen features to assess the dikes' genesis and relation to magmatism in northeastern New Mexico. We have two working hypotheses for the origin of the dikes: 1) the dikes relate to the granite intrusion that formed the laccolith structure; and 2) the dikes relate to extrusions of the Ocate volcanic field. All dike rocks are gray to dark black in color and display aphanitic to porphyritic textures. One dike contains augite phenocrysts, one contains quartz phenocrysts, and one contains quartz plus olivine phenocrysts. A sample of the Baldy Mountain cinder cone, representing Ocate volcanism, contains quartz plus olivine phenocrysts. All phenocrysts are subhedral to anhedral and relatively small, averaging 0.2 mm in diameter. Most dikes contain vesicles, and some contain amygdaloidal fillings. The Turkey Mountain dikes, together with dikes from the Las Vegas and adjacent quadrangles, show a mean orientation of N20ºE on a rose diagram (n = 26). This trend parallels that of the Jemez lineament, a weakness in the earth's crust that is thought to give surface expression to the 1.65-b.y.-old suture between the southern Yavapai and Mazatzal provinces of the southern Laurentian supercontinent. The concordance of the Turkey Mountain dikes with the Jemez lineament suggests that Turkey Mountain magmatism may be related to this regional magmatic event. We are currently studying the dikes petrographically and geochemically to characterize their source magmas, assess correlations among samples, and test petrogenetic models.

POSTER SESSION 2—PALEONTOLOGY

PENNSYLVANIAN–PERMIAN PETALODONT CHONDRICHTHYAN FROM THE BIG HATCHET MOUNTAINS, SOUTHERN NEW MEXICO, *A. O. Ivanov*, Department of Paleontology, St. Petersburg University, 16 Liniya 29, St. Petersburg 199178, RUSSIA; *S. G. Lucas, L. F. Rinehart*, and *J. A. Spielmann*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Petalodontiform chondrichthyans are very common in the marine Carboniferous and Lower Permian deposits of many regions, especially the USA. They are known mainly by isolated teeth, except for *Janassa*, *Belantsea*, *Netsepoye*, and *Siksika*. Two teeth of *Petalodus* have been recovered in the Upper Pennsylvanian (Missourian-NMMNH locality 6939) and Lower Permian (Wolfcampian: NMMNH locality 6938) strata of the Horquilla Formation in the Big Hatchet Mountains, Hidalgo County, southwestern New Mexico. The complete tooth from locality 6939 has a slightly asymmetrical crown and base. The base is considerably curved labially and thickened in the distal part. The Permian tooth of *Petalodus* is symmetrical, with a very well preserved crown and an incomplete, flattened base. Both teeth are assigned to a group of species that includes *P. ohioensis* Safford and *P. acuminatus* Agassiz. The teeth of *P. acuminatus* differ from those of *P. ohioensis* in the wide, lingually ridged band according to Hansen (1997), and in smaller tooth size and equally short crown and base according to Zidek and Kietzke (1993). However, the lingual band of *P. ohioensis* teeth described by various authors from different localities displays a large variation in width. Such differences could be explained by the position of the teeth in the heterodontous dentition of one *Petalodus* species. Probably, a detailed redescription of Safford and Agassiz's type collections will allow recognition of or synonymy of those species. The crown preservation of the Permian tooth from the Big Hatchet Mountains allows us to suggest a new reconstruction of tooth occlusion in the *Petalodus* dentition with the overlapping of crowns of the teeth from the upper and lower jaws.

FISHES FROM THE UPPER PENNSYLVANIAN (MISSOURIAN) ATRASADO FORMATION OF SOCORRO COUNTY, CENTRAL NEW MEXICO, *A. J. Lerner, S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and *A. O. Ivanov*, Department of Paleontology, St. Petersburg University, 16 Liniya 29, St. Petersburg 199178, RUSSIA

New Mexico Museum of Natural History locality 4667 in the Upper Pennsylvanian (Missourian) strata of the Atrasado Formation of Socorro County contains a 4-m-thick unit of thinly laminated, dark-gray shale that produces a moderately diverse fossil fish assemblage of acanthodians, actinopterygians, and sarcopterygians. The material primarily consists of small groups of scales and isolated bones and teeth, which probably came from carcasses that decomposed while drifting in the water column. The most abundant elements are of palaeonisciforms, which are represented by flank and fulcral scales, skull bones of Elonichthyidae, Haplolepidae, and a deep-bodied form (cf. Platysomidae). One well-preserved fragment consists of a palaeonisciform caudal fin with squamation and fin rays. Less common remains include osteolepiform scales resembling *Megalichthyes* or *Greiserolepis*; rhizodontiform scales, teeth, and a cleithrum probably assignable to *Strepsodus*; as well as rare acanthodian fin spines and a scapula belonging to *Acanthodes*. Abundant ovoid coprolites and less common spiral coprolites and flat ground masses of probable fish origin occur with the fish remains. Other trace fossils are absent, which is likely due to anoxic bottom conditions during deposition. Terrestrial plants, syncarid crustaceans, insect wings, conchostracans, ostracods, a non-marine bivalve (*Anthraconauta*), and a single specimen of the problematic marine invertebrate *Sphenothallus* occur in the same unit as the fish remains. Deposition of this unit as indicated by the sediments, fauna, and flora took place within a fresh to minimally brackish lacustrine setting with access to shallow marine conditions. The fish fauna at locality 4667 is similar to that reported from other Carboniferous lacustrine environments. This occurrence adds to the record of Paleozoic fishes from New Mexico, which is best known from the early Virgilian Kinney Quarry Lagerstätte.

TEMNOSPONDYL? BONE FROM THE MIDDLE PENNSYLVANIAN SANDIA FORMATION—NEW MEXICO'S OLDEST TETRAPOD FOSSIL, *S. G. Lucas, L. Rinehart, J. A. Spielmann*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and

K. Krainer, Institute of Geology, University of Innsbruck, Innsbruck, AUSTRIA

North of Rancho de Chaparral in the Nacimiento Mountains of Sandoval County (sec. 2 T19N R1E), Middle Pennsylvanian (Atokan) strata of the Sandia Formation rest on Precambrian basement. Poorly and incompletely exposed, the Sandia Formation is at least 10 m thick and consists of interbedded greenish gray/brown shale and coarse-grained to conglomeratic, quartzose sandstone. Overlying cherty limestones ("Gray Mesa Formation") contain the fusulinacean *Wedekindellina*, indicative of a Desmoinesian age. In a 0.7-m-thick bed of conglomeratic sandstone that is ~4 m below the top of the Sandia Formation, we recovered an isolated bone that is the first tetrapod fossil from the Sandia Formation and New Mexico's oldest fossil tetrapod. This bone is columnar, incomplete, and ~ 40 mm long with a flat articular end that is 9.5 mm wide. The shaft is slightly bowed on its long axis, shallowly concave on one side, shallowly convex on the other side, and widens toward the less complete articular end. It closely resembles the fibula or possibly a presacral rib of a primitive temnospondyl amphibian such as *Greererpeton*. However, we only tentatively identify the fossil as temnospondyl. Most other Pennsylvanian tetrapod records from New Mexico are of Late Pennsylvanian age (Bursum, El Cobre Canyon, and Atrasado Formations, most notably the Kinney Brick Quarry), and the oldest previously reported record was a captorhinomorph bone from the Desmoinesian Flechado Formation in Taos County. The occurrence of tetrapod bone in the Sandia Formation thus pushes back New Mexico's fossil record of tetrapods into the Atokan.

PALEOCENE PALYNOMORPH ASSEMBLAGES FROM THE NACIMIENTO FORMATION, SAN JUAN BASIN, NEW MEXICO, *T. E. Williamson*, thomas.williamson@state.nm.us, New Mexico Museum of Natural History and Science, 1801 Mountain Road, NW, Albuquerque, New Mexico 87104; and *D. Nichols*, nichols@usgs.gov, Denver Museum of Nature and Science, 2001 Colorado Boulevard, Denver, Colorado 80205

Two palynomorph assemblages were recovered from the Paleocene Nacimiento Formation, San Juan Basin, New Mexico, in Kimbeto Arroyo. The first sample (SJB03-17) is from a carbonaceous mudstone ~1 m below strata of the Puercan (Pu2) NALMA and in a zone of normal magnetic polarity correlated with polarity subchron C29n. It yielded an assemblage including *Arecipites* sp., *Corollina* sp., *Laevigatosporites* sp., *Momipites tenuipolus, Nyssapollenites* spp., *Pityosporites* sp., *Tricolpites angululominosus*, *Tricolpites* spp., and *Ulmipollenites krempii*. The second sample (SJB03-19) is from a carbonaceous mudstone approximately 2 m above strata that yield a basal Torrejonian (To1) NALMA vertebrate fauna and within a succeeding zone of normal magnetic polarity correlated with polarity subchron C28n. It yielded an assemblage including *Cicatricosisporites* sp., *Corollina* sp. [common], *Laevigatosporites* sp., *Momipites triorbicularis* [common], *Pityosporites* spp., *Tricolpites anguloluminosus*, *Ulmipollenites krempii*, and *Zlivisporis novomexicanum*.

SJB03-17 contains *Momipites tenuipolus*, a taxon that is widespread in the lower Paleocene in the Western Interior. Its occurrence in this sample in the Nacimiento Formation is consistent with its known stratigraphic range. SJB03-19 yields *Momipites triorbicularis*, a taxon that indicates a correlation with Paleocene palynostratigraphic Zone P3 (the *Momipites actinus–Aquilapollenites spinulosus* Interval Biozone), a zone identified throughout the lower Paleocene of the Western Interior. The identification of Zone P3 in the Nacimiento Formation closely associated with a To1 vertebrate assemblage firmly establishes a correlation between the Paleocene palynostratigraphic and vertebrate biostratigraphic zonation of the Nacimiento Formation and provides an important biochronologic correlation for the Western Interior.

LITHOLOGY AND TAPHONOMY OF AN EARLY PERMIAN *SPHENACODON* BONEBED IN CAÑON DEL COBRE, NORTH-CENTRAL NEW MEXICO, *L. F. Rinehart, S. G. Lucas*, and *S. K. Harris*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

A remarkable Early Permian (Seymouran, Wolfcampian) bonebed (New Mexico Museum of Natural History locality 5379) in the upper part of the Arroyo del Agua Formation in Cañon del Cobre, north-central New Mexico, yields principally *Sphenacodon ferox* material. This bonebed is in poorly sorted (vfL to cL), immature, arkosic, slightly laminated, dark reddish-brown sandstone with pale greenish-yellow color banding at ~10-cm intervals. Elongate bones generally trend ~N30E with loose alignment (~ ± 35°), and in situ rhizoliths are common. A single articulated skull was present. The bones represent all three Voorhies Groups, but disarticulated skull and mandible material account for the greatest portion, especially when the original proportions of bone types are considered (i.e., there should be ~50 vertebrae per skull if unsorted).

A preponderance of Voorhies Group III material would indicate a heavily winnowed or a lag deposit, but much of the skull material is disarticulated into relatively flat bones that probably belong to Group I. Both the finely laminated rock and the Voorhies Group abundances indicate a floodplain deposit. Loosely aligned bones with incomplete sorting point to a relatively gentle flow. The Cañon del Cobre *Sphenacodon* bonebed probably accumulated on a floodplain with periodic (possibly annual), low-velocity sheet floods that hydraulically sorted the bones. More data will be acquired to refine the analysis.

MIDDLE CENOMANIAN SELACHIAN ASSEMBLAGE FROM THE CLAY MESA MEMBER OF THE MANCOS SHALE, SANTA FE COUNTY, NEW MEXICO, *J. A. Spielmann, S. G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; *F. J. Varriale*, Johns Hopkins University, School of Medicine, 1830 E. Monument Street, Baltimore, Maryland 21205; and *J. W. Murphy*, Department of Earth and Environmental Science, New Mexico Institite of Mining and Technology, Socorro, New Mexico 87801

Both Late Cretaceous selachians and marine invertebrates have biostratigraphic utility in the North American Western Interior. Here, we report a selachian assemblage (NMMNH locality 5617, SDSM locality V2001-04) from the Clay Mesa Member of the Mancos Shale near the town of Galisteo in Santa Fe County, New Mexico (T13N R10E, near the Cañada Estacada). The selachians and associated marine invertebrates are in a 0.6-m-thick bed of hematitic bioclastic conglomerate in the middle part of the Clay Mesa Member that yields the ammonites *Acanthoceras amphibolum* and *Tarrantoceras sellardsi* and the bivalve *Inoceramus arvanus*. The ammonites place this fauna in the *A. amphibolum* ammonite zone. The selachian fauna consists of *Ptychodus occidentalis, Squalicorax curvatus, Cretoxyrhina mantelli*, and *Cretodus semiplicatus*, further confirming these taxa in the middle Cenomanian. *P. occidentalis* specimens are characterized by their overall square shape and their transverse ridges bifurcating numerous times distally, grading into finer and finer parallel to subparallel ridges. *S. curvatus* specimens have a distinguishing concave labial crown face. *C. mantelli* specimens lack cusplets and a nutrient groove on the lingual root, distinguishing them from *Cretolamna* and *Paranomotodon*. Distinct cusplets that are continuous with the root identify specimens of *C. semiplicatus*. This is the oldest Late Cretaceous selachian assemblage reported from New Mexico.

UPPER CENOMANIAN SELACHIAN ASSEMBLAGE FROM THE BRIDGE CREEK MEMBER OF THE MANCOS SHALE, SOCORRO COUNTY, NEW MEXICO, *J. W. Murphy*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; *S. G. Lucas* and *J. A. Spielmann*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Late Cretaceous selachians provide a marine biostratigraphy throughout the North American Western Interior. Here, we report a selachian assemblage from the Bridge Creek Member of the Mancos Shale near the town of Carthage in Socorro County, New Mexico (sec. 8 T05S R02E). The selachian fossils are in a 0.3–0.6-m-thick bed of sandy limestone/calcarenite at the top of the Bridge Creek Member that yields numerous shells of the bivalves *Ostrea beloiti* and *Mytiloides mytiloides*. This fossil assemblage occurs within the *Sciponoceras gracile* ammonite zone. Specimens of *Ptychodus* dominate the assemblage, with rare and fragmentary remains of blade-shaped shark teeth, some of which can be identified as *Squalicorax* sp. *Ptychodus* specimens belong to *P. occidentalis* and *P. anonymus* and further confirm their presence in upper Cenomanian strata. The *P. occidentalis* specimens are characterized by their overall square shape and their transverse ridges bifurcating numerous times distally, grading into finer and finer parallel to subparallel ridges. The *P. anonymus* specimens are characterized by their transverse ridges that extend down the cusps then divide and curl around as they enter the marginal area. In addition, numerous *P. anonymus* specimens have a prominent cusp that superficially resembles *P. whipplei*, though the presence of transverse ridges that extend down the sides of the cusp confirm these specimens pertain to *P. anonymus*. The lithology of the site indicates deposition in deep water, which suggests that *Ptychodus* had a preference for deep water, as previously noted by other workers.

POSTER SESSION 3— HYDROLOGY, HYDROGEOCHEMISTRY, AND MICROBIOLOGY

INVESTIGATING SPATIAL AND TEMPORAL WATER QUALITY TRENDS IN THE UPPER RIO GRANDE, *E. Bastien*, ebastien@nmt.edu, *F. M. Phillips, H. F. Lacey*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology,

Socorro, New Mexico 87801; and *G. Oelsner*, Department of Hydrology, University of Arizona, Tucson, Arizona 85721

The Rio Grande increases in salinity as it flows from Colorado to Mexico. Previous research has focused on identifying and quantifying sources of the salinity, mainly through modeling of non-reactive solutes, which illustrated the major importance of deep geologic brine. The investigation of reactive solutes leads to further understanding of Rio Grande chemistry. Historically the Rio Grande contained higher solute concentrations, evident in comparisons between 1905–1907, 1934–1953, and 1980–2004 river datasets. All major solute concentrations from the three datasets increase from the headwaters to Ft. Quitman, Texas. In current data, magnesium, calcium, and bicarbonate loads decrease below Elephant Butte Reservoir, which is likely caused by precipitation of carbonate minerals within the reservoir and possibly in irrigated fields below Elephant Butte. The calcium trend correlates well with the bicarbonate trend, indicating similar sources and sinks control these solutes. Irrigation return flow is one factor contributing to reactive solute behavior. Analysis of irrigation and ground water samples coupled with a water mass balance for a representative site (Lemitar, New Mexico) in the middle Rio Grande suggests that mineral dissolution during irrigation releases solutes into the Rio Grande (200 kg/ha/yr of calcium, 1,300 kg/ha/yr bicarbonate, 100 kg/ha/yr of magnesium, 80 kg/ha/yr of sodium, and 240 kg/ha/yr of sulfate). A geochemical mass balance-modeling program (NETPATH) and soil analyses were used to identify subsurface soil reactions. The dissolution of calcite, dolomite, and gypsum as well as cation exchange reactions account for the solute addition to the Rio Grande. The trends observed at the Lemitar site provide insight in understanding compositional differences between current and historic Rio Grande chemistry. The anion data illustrate chemical similarities between current and historic main channel river chemistry to ground water and applied irrigation water from the Lemitar site respectively.

VARIATIONS OF WATER PARTITIONING ON THE NORTH AND SOUTH FACING HILLSLOPES AT THE SEVILLETA NATIONAL WILDLIFE REFUGE, *E. M. Engle* and *J. B. J. Harrison,* Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The partitioning of water into runoff and infiltration is not well understood in the Sevilleta National Wildlife Refuge. Aspect and solar radiation inputs control soil development and the amount and type of vegetation on each hillslope. The differences in the hillslopes are reflected in the runoff processes that control water partitioning, the type of vegetation that is present, and the differences in soil development of each slope. Because of the presence of vegetation and the organisms that live in the islands formed by vegetation, there are higher rates of infiltration on north facing slopes allowing greater infiltration and deep percolation. In contrast, on south facing slopes there is less vegetation, more bare ground, less activity from microorganisms, and consequently, lower infiltration rates. These differences in infiltration and runoff enhance soil development on north slopes and inhibit soil development on south hillslopes. Therefore, it is expected that north slopes will have less runoff due to increased infiltration and decreased distance between flow obstructions. The opposite is true for south hillslopes. Since these processes are intricately coupled, this research project will focus on the influence of hillslope aspect and its controls over slope stability due to differences in infiltration and runoff in a semiarid landscape.

To complete these objectives, several runoff plots will be constructed to observe the amount of runoff and sediment generated during storms. However, data for this poster will come from plots that were constructed and monitored in the summer of 2006. Four plots were constructed, two on the north facing hillslope and two on the south facing hillslope at the Red Tanks area of the Sevilleta National Wildlife Refuge. Bulk runoff samples were collected from these plots for the duration of the summer. Runoff budgets for the hillslopes were determined using the bulk runoff amounts, infiltration rates, and precipitation data also collected at the study hillslopes. These plots will be used to supplement data that will be collected from future runoff plots that will be built in a well-instrumented hillslope. These data will be used to examine the complex relationships of runoff and infiltration on the hillslope scale and to gain a greater understanding of water partitioning in a semiarid environment.

POSSIBLE HYDROTHERMAL SULFATE KARST FEATURES ASSOCIATED WITH IMPACT CRATERS ON MARS, *J. G. Johnston*, jgj@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *P. J. Boston,* Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801 and National Cave and Karst Research Institute, 1400 University Drive, Carlsbad, New Mexico 88220

Preliminary examination of images from the Mars Global Surveyor Mars Orbiter Camera reveals evidence of possible collapse features associated with impact craters >1 km diameter in the mid-latitudes of Mars. A theoretical model developed by Stafford and Boston (2005) and expanded by Johnston and Boston (2006) suggests that the energy associated with the cratering process could supply heat sufficient to melt ground ice and allow it to circulate briefly through the fracture system also created by the impact. In the presence of soluble sulfate minerals, which have been found to be abundant at the surface of Mars, this process could create a hydrothermal karst system capable of providing a protected habitat for indigenous subsurface Mars lifeforms that may be either dormant or even active in the subsurface and released to the aboveground environment by the impact event.

Hydrothermal and karst systems are found in the vicinity of certain Earth impact craters such as Haughton (Devon Island, Nunavut, Canada) and Chicxulub (Yucatan, Mexico) and seem to be preferentially developed along the concentric rather than the radial fractures produced by the impact. A similar pattern seems to be emerging from the examined Mars images. The postulated collapse features are found ringing craters in the middle-latitudes, frequently in combination with gullies on the crater walls. No such features are seen around similar-sized craters in either the equatorial or polar latitudes. This may be explained by the expected distribution of ground ice and permafrost, as outlined by Head et al. (2003). In the absence of permafrost, no ice is available to be melted by the cratering process, whereas in the continuous permafrost zone karst formation is inhibited or obscured by the mantling process.

ORIGIN OF THE CHEMICAL COMPOSITION OF SPRINGS IN THE SAGUACHE CREEK WATERSHED OF THE SAN JUAN MOUNTAINS IN COLORADO, *M. D. Frisbee* and *F. M. Phillips*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The Saguache Creek watershed located in the northern San Luis Valley has been selected for an intensive hydrological study including research into the chemical evolution of spring water. The watershed has an abundant distribution of springs with respect to elevation, and these springs have been sampled for chemical analysis. Samples of snow and snowmelt runoff have also been collected and analyzed. All samples were analyzed for sodium, potassium, magnesium, calcium, chloride, fluoride, nitrate, phosphate, sulfate, silica, temperature, pH, and conductivity. Preliminary data revealed encouraging trends in the chemical compositions of spring water from high to low elevations. Snowmelt runoff showed minimal increases in cation concentrations as compared with the cation concentrations of the snow samples. However, there were more pronounced increases in the anion concentrations of snowmelt runoff, especially with respect to potassium, magnesium, and calcium. Many of these constituents show linear increases in concentration with decreasing elevation (i.e., small concentrations in the high elevation springs trending toward higher concentrations in low elevation springs). It also appears that snowmelt runoff rapidly acquires a silica concentration that is nearly 25% of the silica concentration observed in spring waters. The snowmelt runoff was observed as overland flow, and the rapid acquisition of silica appears to occur within a few minutes of contact with the soil. Electrical conductivity and temperature both increase linearly with decreasing elevation. These trends are encouraging; yet, further research is needed to gain an understanding on the origin of the chemical compositions observed in these springs. Thus, NETPATH, a model used to calculate net geochemical reactions along a flow path, was used to predict the amount of reacted minerals needed along a flow path to acquire the observed chemical composition. NETPATH requires that the user provide chemical constraints and mineral phases based on the geology of the study area through which the geochemical reactions are modeled. This poster will present the findings determined by NETPATH on the origin of the chemical composition of springs in the Saguache Creek watershed of Saguache, Colorado.

GEOCHEMICAL CONTROLS ON MICROBIAL COMMUNITY COMPOSITION FROM VARIED HOT SPRING ENVIRONMENTS, *K. R. Mitchell*, kmass@unm.edu, *B. Cron*, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131; *L. J. Crossey*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *C. Takacs-Vesbach*, Department of Biology, University of New Mexico, Albuquerque, New Mexico 87131

Although microbial studies in hot spring environments are numerous, widespread surveys of the microbial diversity of thermal features are lacking. Many studies of hot spring environments have focused on a single organism or type of spring. In order to expand our knowledge of the extent of thermophilic life, we conducted a microbial inventory of thermal features in Yellowstone National Park that included in-depth geochemical measurements. We have analyzed microbial communities from greater than 40 thermal features from across Yellowstone National Park by 16S rRNA gene analysis of environmental DNA. These samples span the range of temperature and pH (48.9–86.2°C and 2.00–9.19) encountered in the park's thermal features. By combining phylogenetic analyses with geochemical data, we attempt to determine the level of control that the geochemistry of a spring exerts on the microbial communities. The relationship between community and geochemistry is strongest when the microbial communities are compared at the genus level. Temperature and pH are correlated with community structure, but do not alone predict the type of organisms present in a spring. Additional geochemical controls include both putative metabolically informative compounds (i.e., $SO_4^{=}$ and NH_4^+) and trace elements (i.e., F, Sr, Sb). Our geochemical approach includes computation of the state of disequilibrium for coupled redox reactions that represent possible energy-yielding reactions for microbial metabolism. Often, the highest energy yields are for hydrogen and sulfur oxidation: Both pathways are known to be employed by Aquificales that dominate many of the sampled springs. Our ongoing work pairs communities with site-specific energy-yield characteristics. These results suggest niche control over community structure at the genus level. However, the much weaker relationship between geochemistry and species level groups suggests other mechanisms such as dispersal between springs or in situ evolution or mutation is affecting the individual populations that comprise the communities.

CHLORINE-36 IN THE RIO GRANDE, *S. McGee,* Shasta@nmt.edu, *M. D. Frisbee*, and *F. M. Phillips*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Chlorine-36 can be a powerful tool when examining residence times and sources for waters in a river system. In this case, it is known that the $^{36}Cl/Cl$ ratios in the headwaters of the Rio Grande are much higher than the natural deposition resulting from cosmic-ray activation of Ar in the atmosphere. This input is due to the pulse of chlorine-36 produced by nuclear testing during the 1950s. This pulse is being recycled in the biological environment, by trees, based on our recent chlorine-36 analysis of two Rocky Mountain Douglas-fir trees that revealed an average chlorine-36 ratio of 14,516 ($^{36}Cl/10^{15}$ Cl) in the vegetation. Recycling by the biota provides a constant input of chlorine-36 to the headwaters of the Rio Grande. This function will enable future work on tracing the bomb pulse through the subsurface.

Understanding the source of solutes in the Rio Grande has been an increasingly important problem due to the increase in population living in the Rio Grande valley. Up to this point, several studies have been done on the causes of this salinity increase. Recent investigations by our research group indicate that brines are contributing chloride to the Rio Grande at distinct locations that coincide with faults that cross the river. Such brines are characterized by high Cl/Br and low $^{36}Cl/Cl$ ratios. Chlorine-36 results from a synoptic sampling of the Rio Grande performed in 2001 show that the $^{36}Cl/Cl$ ratios decrease while the Cl/Br ratio and chloride concentration increase in the downstream direction. These results support the hypothesis that saline brines are contributing chloride to the Rio Grande.

WATER LEVEL RESPONSES AND PRELIMINARY SPRING CHEMISTRY RESULTS: PROGRESS REPORT ON THE HYDROGEOLOGIC STUDY IN THE SOUTHERN SACRAMENTO MOUNTAINS, NEW MEXICO, *S. Timmons*, stacyt@gis.nmt.edu, *G. C. Rawling, P. S. Johnson, L. Land*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *J. Morse*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

In November 2005 the New Mexico Bureau of Geology and Mineral Resources began a regional geology and hydrology study in the southern Sacramento Mountains. The goal of this study is to characterize ground water aquifers that supply water for domestic and agricultural needs in the Sacramento Mountains. Water level variations in approximately 60 domestic and municipal wells are measured bi-monthly, and eight wells have continuous data loggers installed. So far 28 spring water samples have been collected for general chemistry, stable isotopes, and several relative age-dating analyses, including tritium, chlorofluorocarbons, and carbon-14.

Fractured limestone beds within the Yeso Formation are the primary aquifer for wells in the study area. Initial findings have shown that the abundant precipitation in July through October 2006 increased hydraulic head in the aquifer, elevated water levels in most monitored wells, and induced greater discharge in springs and streams. Water levels in many wells began to rise as early as August, with an average increase in water level of 20 ft. Water levels in most wells rose in response to increased hydraulic head by October. Generally, wells along the crest of the mountain range and the western slope displayed the earliest and largest responses to precipitation.

In spring waters, concentrations of strontium, chloride, and sulfate increase northward, consistent with a north-south trend of increasing abundance of evaporite facies within the Yeso Formation. Lighter ^2H:^1H and ^{18}O:^{16}O ratios from springs at higher elevations, and heavier ratios at lower elevations suggest that shallow ground water is recharged at all elevations along the Sacramento Mountains eastern slope.

FRACTURE EFFECTS ON SURFACE AND GROUND WATER FLOW IN THE SACRAMENTO MOUNTAINS, SOUTHEAST NEW MEXICO, *P. Walsh*, pwalsh@gis.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

Fractures in the southern Sacramento Mountains, south-central New Mexico, influence both surface and ground water flow. Fractures are often assumed to control water movement, but the relationships of stream orientation or spring discharge locations with fractures are rarely quantified. This study combines fracture measurements in the field with GIS analysis to assess fracture control on stream orientations and spring discharge locations. One hundred seventy fractures were measured at 70 sites. They primarily consist of opening mode joints with northeast-southwest and northwest-southeast orientations. These orientations are consistent with previous regional structural interpretations based on fault kinematics (Howell 2003). East dipping strata, at the surface consisting of San Andres Formation limestone and Yeso Formation limestone and mudstone, cause most streams in the study area to flow generally eastward toward the Pecos River. However, about one-third of the stream segments are parallel to one of the two dominant joint sets. The joint-parallel stream segments form prominent peaks on plots of total stream length vs. orientation. In addition, the Sacramento River flows southeast, along the axis of a graben.

Joint-parallel stream segments selected from streams mapped with a DEM are as much as 900 m in length and are parallel to fractures observed in the field. The abundance of surveyed springs throughout the study area decreases logarithmically with distance from joint parallel stream segments. These findings indicate that joints strongly affect surface and ground water flow, and most likely recharge. Future field observations will quantify the effects of fractures on the interaction between surface and ground water by measuring stream flow rates upstream and downstream of joint-parallel stream segments.

POSTER SESSION 4—MAPPING

PRELIMINARY GEOLOGIC MAP OF THE MOUND SPRINGS 7.5-MINUTE QUADRANGLE, LINCOLN, SIERRA, SOCORRO, AND OTERO COUNTIES, NEW MEXICO, *D. W. Love*, dave@gis.nmt.edu, *B. D. Allen*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801; and *R. G. Myers*, U.S. Army, IMSW-WSM-PW-E-ES, White Sands Missile Range, New Mexico 88002

The Mound Springs quadrangle encompasses the northern edge of the Tularosa Basin and southern exposures of the Oscura Mountains. We mapped gypsum-depositing springs and related extinct gypsum-spring deposits in the central and southern part of the area because one of the active springs provides a home for the endangered White Sands pupfish (*Cyprinodon tularosa*). The northern part of the quadrangle includes east-sloping cuestas of highly faulted Pennsylvanian and Permian Madera, Bursum, Abo, and Yeso Formations. The high-angle Laramide (?) faults trend northwest. These are cut by east-west-trending, vertical, mid-Cenozoic diabasic dikes. The bedrock is offset by Quaternary faults at the south end of the Oscura Mountains. One east-west-trending normal fault parallels a diabasic dike and offsets (with a fault scarp) mid-late Quaternary piedmont deposits. Another Quaternary normal fault trends north-northeast and truncates (with a scarp) Quaternary pediments, piedmont gravels, and east-dipping cuestas.

Piedmont landforms and gravelly deposits from the Oscura and San Andres Mountains are classic alluvial aprons with three or more inset levels of channel, fan, and eolian sand-loess-sheet development. Modern channels gather in the north-central part of the quadrangle and continue southwestward toward Salt Spring at the head of the Salt Creek drainage, a perennial saline stream in the northern Tularosa Basin.

The gravel-poor Holocene deposits adjacent to the channels are inset below older gravelly piedmont deposits along the medial parts of dissected fans, but partially bury distal piedmont gravel bars farther out in the basin.

The present-day Mound Springs are crater-topped conical hills of gypsum deposited around the margins of calcium-sulfate-dominated brackish springs. These cratered mounds reach up to 5.5 m high and 50–250 m across. Dozens of extinct cratered mounds occupy the western flank of an earlier and much larger accumulation of discharge-related gypsum, covering an area of at least 16 km^2. Similar extensive fossil discharge deposits are present to the northeast and southwest of the Mound Springs area. These older deposits are pitted with aligned sinkholes more than 8 and perhaps as much as 13 m deep.

Lewis Gillard and Leo Gabaldon helped with the graphic presentation.

PRELIMINARY GEOLOGIC MAP OF THE ABEYTAS QUADRANGLE, SOCORRO COUNTY, NEW MEXICO, *D. J. McCraw*, djmc@nmt.edu, *D. W. Love*, and *S. D. Connell*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The Abeytas quadrangle covers the junction between the Rio Puerco and Rio Grande at the south end of the Albuquerque Basin. Rift-related Plio–Pleistocene basin fill of the Santa Fe Group exposed in the Abeytas quadrangle came from four sources: the Rio Grande from the north, Abo Pass and Los Pinos uplift to the southeast, Rio Puerco and Rio San Jose from the northwest, and Rio Salado from the southwest. Quaternary post-basin-fill episodic entrenchment of the Rio Grande is shown by three major fluvial terraces preserved on the eastern side of the Rio Grande valley and by a correlative high terrace along the Rio Puerco. Local tributaries formed several inset levels of alluvial terraces in response to climate change and episodic downcutting and lateral planation by the Rio Grande. Thick valley fills of the Rio Grande and Rio Puerco are the hallmark of both major streams in this area. Several north-trending Quaternary faults displace deposits from less than one to more than 10 m. The Sabinal fault dies out southward in a monoclinal structure. The West Ceja fault dies out southward as the hanging wall becomes a ramp and joins the footwall at the same elevation. The newly discovered Contreras Cemetery fault offsets the lowest Rio Grande terrace by 2 to more than 4 m and was active at the time of terrace deposition.

GEOLOGY OF THE RUIDOSO AREA, LINCOLN AND OTERO COUNTIES, NEW MEXICO, *G. C. Rawling*, geoff@gis.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, Albuquerque Office, 2808 Central Avenue SE, Albuquerque, New Mexico 87106

A new compilation of recent STATEMAP projects in the Ruidoso area covers the Angus, Fort Stanton, Ruidoso, and Ruidoso Downs quadrangles, an area of New Mexico that has never previously been mapped at a scale of 1:24,000. Permian through Eocene sedimentary rocks and intrusive and extrusive rocks of the Eocene–Oligocene Sierra Blanca volcanic complex are exposed in the mapped area, which covers the eastern flank of the Laramide Sierra Blanca Basin.

The Permian Yeso Formation is the oldest unit in the mapped area and is exposed along the Rio Ruidoso. Evaporite dissolution has resulted in chaotic bedding and disharmonic folding within the Yeso, and local collapse of the overlying San Andres Formation. Paleokarst within the Permian San Andres Formation is indicated by terra rossa and large thickness variations of the overlying Grayburg Formation. Triassic units are thin and are locally cut out by an unconformity beneath the Cretaceous Dakota Sandstone. Dikes, sills, stocks, and irregular igneous masses are abundant within the Cretaceous Mancos Shale and Mesaverde Group sandstones and shales. The Eocene Cub Mountain Formation comprises the Laramide basin fill and occurs in disconnected half-grabens. Syenite of the Bonito stock underlies Monjeau Peak, the highest point in the mapped area, and intrudes andesite breccias of the Sierra Blanca volcanic complex. Mesa-capping gravels are abundant in the Fort Stanton quadrangle and are likely western equivalents of the Ogallala Formation.

The Ruidoso fault zone forms the eastern boundary of the Sierra Blanca Basin and trends southwest-northeast through the mapped area. Maximum throw is at least several thousand feet down-to-the-west, near Moon Mountain. To the southwest is a complex array of faults near Mescalero Lake. Toward Fort Stanton, the zone is composed of numerous intersecting faults, most of which are buried beneath gravel-capped mesas, suggesting topographic inversion. Evidence for dextral-oblique offset along the northeast end o f the fault zone includes sparse shallowly plunging slickenlines, variations in throw along strike of individual faults, and fault-related folding.

The Ruidoso region has experienced serious water supply problems for several years. Improved geologic understanding of this area should prove useful in future ground water studies.

Publication of these abstracts was supported in part by a grant from the New Mexico Geological Society Foundation.

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 of $100 for best student talk was given to Matt Averill for his presentation "Seismic investigation into the crustal structure and evolution of southern Rio Grande rift in southern New Mexico and far west Texas: the Potrillo Volcanic Field experiment." Shasta McGee's poster presentation "Chlorine-36 in the Rio Grande" won the $100 award.

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