Abstracts

New Mexico Geological Society spring meeting

The New Mexico Geological Society annual spring meeting was held on April 15, 2005, at New Mexico Institute of Mining and Technology, Socorro. Following are the abstracts from all sessions given at that meeting.

SESSION 1—GEOLOGY AND HYDROLOGY OF THE JEMEZ MOUNTAINS

RECENT DEVELOPMENTS IN OUR UNDERSTANDING OF VOLCANISM IN THE JEMEZ MOUNTAINS, NEW MEXICO, *Shari A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *K. A. Kempter*, 2623 Via Caballero del Norte, Santa Fe, New Mexico 87505; *J. R. Lawrence*, 2321 Elizabeth Street NE, Albuquerque, New Mexico 87112; and *G. R. Osburn*, Department of Earth and Planetary Science, Washington University, St. Louis, Missouri 63130

New 1:24,000 scale mapping in the Jemez Mountains outside the Valles caldera is revealing previously undescribed volcanic units and/or stratigraphic relationships. We have identified several major Tschicoma flows and centers in the northern Jemez Mountains, including the massive Rendija lava flow in northern Los Alamos County. We recognize a general trend in the age of volcanism across the northern Jemez volcanic field. Lobato basalt, andesite, and dacite are 9–10 Ma in the eastern part of the field and 7–8 Ma toward the west. Tschicoma andesite and dacite are 7–8 Ma in the west and 3–5 Ma toward the east. We also observe Tschicoma-type dacite lava and pumice interbedded with or underlying 9–10 Ma Lobato Formation basalt. Miocene (9–10 Ma) basalt is present in both the northern (Lobato) and southern (Paliza Canyon) parts of the field. Basaltic centers (Lobato) with few interbedded sediments prevail to the north, whereas 1–5-m-thick basalt flows (Paliza Canyon) with approximately 10–15 m of interbedded volcaniclastic sediments are common to the south, suggesting proximal and distal portions of the same volcanic system. We have identified a unit that covers much of the northeastern quadrant of the Jemez Mountains that consists of pumice and a < 0.1-m-thick lithic-rich tuff resting on Puye Formation gravels. This unit may be related to the Otowi Member of the Bandelier Tuff or San Diego Canyon Tuff. Shards of obsidian are also common in this area. The observations listed here are representative of the exciting work to be discussed in this special session.

MEGABRECCIAS, EARLY LAKES, AND DURATION OF RESURGENCE RECORDED IN VALLES CALDERA, NEW MEXICO, *Fraser Goff*, *C. J. Goff*, candf@swcp.com, 5515 Quemazon, Los Alamos, New Mexico 87544; *E. H. Phillips*, ehp@nmt.edu, *Philip Kyle*, and *William C. McIntosh*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

New 1:24,000 scale geologic mapping combined with $^{40}Ar/^{39}Ar$ studies are revealing significant new findings on intracaldera stratigraphy and structure, initial development of intracaldera lakes, and the duration of resurgence within the ca 1.25 Ma Valles caldera. The caldera is about 22 km in diameter, containing a resurgent dome that was uplifted more than 1,000 m. Uplift and faulting have exposed large, rootless megabreccia blocks composed of precaldera rocks submerged in densely welded, intracaldera upper Bandelier Tuff. The largest blocks are 0.2–2.0 km long, consisting of Pennsylvanian through Quaternary rocks. Evidence that an initial lake developed within the caldera depression is preserved in finely laminated lacustrine beds and interbedded rhyolitic, hydromagmatic tuffs that contain accretionary lapilli. Earliest post-caldera rhyolite lavas (Deer Canyon Member) display occasional pepperite and pillow textures. The combined evidence indicates that this first Valles lake was widespread and relatively shallow.

$^{40}Ar/^{39}Ar$ dating of Deer Canyon and Redondo Creek rhyolites yields ages that are statistically indistinguishable from the age of underlying upper Bandelier Tuff (1.256 ± 0.010 Ma, 2σ). These results indicate that the intracaldera lake developed immediately after the caldera formed and that the resurgent dome rose out of a lake. In contrast, initial rhyolite lavas of the first post-caldera moat complex, Cerro del Medio (about 1.229 ± 0.017 Ma) show no apparent deformation due to resurgence, providing an upper time constraint on uplift. Thus, $^{40}Ar/^{39}Ar$ dates indicate that resurgence lasted 27 ± 27 ka, taking place within 54 ka. Resurgence averages 3.7 cm/yr and probably not less than 1.9 cm/yr.

BEARHEAD BASIN: RIO GRANDE RIFT STRUCTURE MEETS THE JEMEZ LINEAMENT WITHIN THE SOUTHERN JEMEZ VOLCANIC FIELD, *Gary A. Smith*, gsmith@unm.edu, Department of Earth and Planetary Sciences, MSC03 2040, University of New Mexico, Albuquerque, New Mexico 87131; and *Scott D. Lynch*, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Recently completed geologic mapping of the Cañada 7.5-min quadrangle corroborates previous preliminary interpretations of rift faults continuing northward from the Santo Domingo Basin into the southern Jemez Mountains. Most notable are the continuation of the Camada and Peralta faults to form the western margin of the Bearhead Basin, the full extent of which is now mapped. The Bearhead Basin is a 7-km-wide, north-northwest-striking, west-tilted asymmetric basin bounded by the Peralta fault (west) and the Media Dia fault (east). Northeast-striking Jemez lineament faults also played an important role in the basin formation and subsequent uplift and dissection of the basin fill.

Although basin-margin and intrabasinal faults locally displace the Pleistocene Bandelier Tuff by at least 80 m, basin subsidence primarily occurred in the late Miocene. This period of basin subsidence is documented by the accommodation of at least 700 m of Peralta Tuff Member of the Bearhead Rhyolite and Cochiti Formation strata with depositional ages between approximately 7.0 and 6.2 Ma, based on $^{40}Ar/^{39}Ar$ ages of rhyolitic tephra. Correlative strata are thin to absent adjacent to the western and eastern margins of the basin. Contemporaneous rhyolite intrusion and extrusion to form the Bearhead Rhyolite was locally focused along basin-bounding faults and along northeast-striking intrabasinal faults. The basin terminates to the north in a region of poorly exposed and largely older intrusive rocks that contain screens of pre-Jemez sedimentary rocks. These relationships imply the presence of one or more northeast-striking, down-to-the south faults that form a northern structural margin to the basin.

UPPER MIOCENE CLASTIC DEPOSITS ADJACENT TO THE NORTHEASTERN AND EASTERN FLANKS OF THE JEMEZ MOUNTAINS, NORTH-CENTRAL NEW MEXICO—PRELIMINARY RESULTS, *Daniel J. Koning*, dkoning@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *D. E. Broxton*, *D. T. Vaniman*, *Giday WoldeGabriel*, Hydrology, Geochemistry, and Geology Group, P.O. Box 1663, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; and *K. A. Kempter*, 2623 Via Caballero del Norte, Santa Fe, New Mexico 87505

On-going investigations continue to elucidate the upper Miocene basin fill stratigraphy of the western Española Basin. Three lithostratigraphic units are recognized under Los Alamos using well data. The youngest deposit is 120 m thick and composed of tuffaceous, fine sand ($^{40}Ar/^{39}Ar$ ages of 7.0–7.5 Ma). Below this fine unit lies 420–500 m of alluvial fan deposits consisting of coarse, volcaniclastic sandy gravel shed from the Jemez Mountains. Intercalated basalts have $^{40}Ar/^{39}Ar$ ages between 8.45 and 8.97 Ma. An older fine unit, consisting of silty sand with minor volcanic pebble beds, contains basalt flows with $^{40}Ar/^{39}Ar$ ages of 10.9–13.1 Ma.

West of Española, three new members of the Chamita Formation are recognized. The Hernandez Member (400–450 m thick) consists of broad channel complexes of sandy gravel (volcanic clasts with 2–27% quartzite) intercalated with floodplain deposits. Upsection there are increases in the concentration of quartzite, the relative proportion of coarse channel deposits, and clast size. The Hernandez Member (6–12 Ma) was deposited by a south-southeast flowing river draining the Tusas Mountains and Abiquiu embayment. The Hernandez Member interfingers to the east with the Cejita Member, a unit deposited by a river draining the Peñasco embayment and the San Luis Basin. The Vallito Member generally underlies these other two members and consists of fluvial, fine to medium sand and minor eolian deposits. Sparse pebbles consist of volcanic clasts. The Vallito Member may correlate with part of the older-fine unit under Los Alamos because of its overall texture, clast composition, and interpreted age (~ 9.5–13 Ma).

HYDROGEOCHEMICAL INVESTIGATION AND STATISTICAL ANALYSES OF BACKGROUND SUBSURFACE WATERS NEAR LOS ALAMOS NATIONAL LABORATORY, *P. Longmire*, plongmire@lanl.gov, Los Alamos National Laboratory, Earth and Environmental Sciences Division, MS D469, Los Alamos, New Mexico 87545; *Fraser Goff*, 5515 Quemazon, Los Alamos, New Mexico 87544; *R. Ryti*, Neptune and Company, Inc., 1505 15th Street, Los Alamos, New Mexico 87544; *Dale A. Counce*, Los Alamos National Laboratory, Earth and Environmental Sciences Division, MS D469, Los Alamos, New Mexico 87545; *D. Bergfeld*, U.S. Geological Survey, MS 434, 345 Middlefield Road, Menlo Park, California 94025; and *M. Dale*, New Mexico Environment Department, DOE Oversight Bureau, 134 State Road 4, Suite A, White Rock, New Mexico 87544

Background hydrogeochemical data with corresponding statistical information are required to distinguish between contaminated and noncontaminated ground water at Los Alamos National Laboratory, New Mexico. Results of this investigation provide a comprehensive, validated database of inorganic, selected organic, stable isotope, and radionuclide analyses of up to 568 ground water samples collected from fifteen background springs and wells. The region extends from the western edge of the Jemez Mountains eastward to the Rio Grande and from Frijoles Canyon northward to Garcia Canyon. Eleven springs and four wells are separated into three aquifer types: alluvium, perched intermediate (depth) volcanic rocks (Bandelier Tuff, Tschicoma Formation, phreatic-magmatic deposits, and Cerros del Rio basalt), and the regional aquifer (Puye Formation and Santa Fe Group sediments). Filtered and non-filtered water samples, with turbidity values less than five Nephelometric turbidity units, were collected and analyzed for chemical constituents in 1997, 1998, 1999, and 2000 during six sampling events. Inorganic analytes include major ions, minor elements, and trace elements; naturally occurring humic substances and small-molecular weight organic compounds; and natural and fallout-derived radionuclides. Ground waters sampled as part of this investigation have low concentrations of major ion and trace elements (chloride, nitrate, perchlorate, sulfate, barium, boron, and natural uranium) and relatively low concentrations of tritium. Results of statistical analyses are provided for nine major ion species; thirty-nine trace elements; stable isotopes of hydrogen, nitrogen, and oxygen; tritium; hydrophobic and hydrophilic organic compounds; and eleven radiological isotopes in addition to gross alpha, gross beta, and gross gamma.

DEEP CORING IN THE VALLES CALDERA, NEW MEXICO, TO OBTAIN A LONG-TERM PALEOCLIMATIC RECORD, *Peter J. Fawcett*, fawcett@unm.edu, *Fraser Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *Jeff Heikoop*, Earth and Environmental Sciences Division, EES-6, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; *Craig D. Allen*, U.S.G.S., Fort Collins Science Center, Jemez Mountain Field Station, Los Alamos, New Mexico 87544; *Linda L. Donohoo-Hurley*, *John W. Geissman*, *Tim F. Wawrzyniec*, *Catrina Johnson*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *Julianna Fessenden-Rahn*, *Giday WoldeGabriel*, Earth and Environmental Sciences Division, EES-6, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; and *Douglas Schnurrenberger*, Limnological Research Center, University of Minnesota, Minneapolis, Minnesota 55455

The Valles caldera in the Jemez Mountains contains a thick sequence of lacustrine sediments and hydromagmatic deposits that date from the inception of the caldera (ca 1.25 Ma). Lakes formed in the caldera immediately after its formation and existed for some period of time before the caldera wall was breached. Another lake formed during the middle Pleistocene in the Valle Grande when a post-caldera eruption (ca 520 ka) filled the drainage to San Diego Canyon.

To determine their paleoclimatic significance, the deposits of this ancient lake were cored in May 2004 (GLAD 5). Hole VC-3 achieved a total depth of 81 m recovering a complete section of ~75 m of volcaniclastic lacustrine mud and silts and gravels. Preliminary analyses show considerable down-core variability in magnetic susceptibility, gamma-ray density, and sedimentary facies. Pumice sands and gravels at the core base grade up into variably laminated and bioturbated diatom-rich silty muds. Several turbidites interrupt the lower laminated mud sequences, and in some sections, thick diatomites occur and are indicative of surface eutrophication in the lake. Higher in the core, thin sand lenses indicate periods of enhanced runoff into the lake, and occasional dropstones are observed. In the middle sequence, a brecciated, diatom-poor facies correlates with high magnetic susceptibility. Rapid vertical facies changes and intervals with well-developed mudcracks indicate multiple lake level changes over the middle Pleistocene lake history that probably spans tens of thousands of years. Future work on the core will include pollen, diatom, stable isotope and other geochemical and geophysical analyses.

ENVIRONMENTAL MAGNETIC RECORD OF LACUSTRINE SEDIMENTS OF THE VALLES CALDERA, NEW MEXICO, *Linda L. Donohoo-Hurley*, ldonohoo@unm.edu, *John W. Geissman*, *P. F. Fawcett*, *Tim F. Wawrzyniec*, and *F. Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The Valle Grande lacustrine system, Jemez Mountains, New Mexico, formed after the collapse of the Valles caldera (VC), 1.25 Ma, and eventually drained via San Diego Canyon. One of the youngest lake systems in the caldera formed after the South Mountain rhyolite eruption at ca 520 ka, which dammed the East Fork Jemez River. Unlike other lake basins in the American Southwest, termination of sediment deposition in the Valle Grande was not due specifically to drier climates. Therefore the most recent lake low stand was due to the morphology of the basin and not climatically controlled conditions. Approximately 80 m of lacustrine sediments were recovered from the Valle Grande during a drilling experiment conducted in mid-May, 2004. Initial paleomagnetic data (typical NRM intensity of 4.0 mA/m) and rock magnetic results (mean destructive field of 35 mT in alternating field demagnetization) indicate that fine-grained (single-domain and pseudo-single domain) magnetite is the primary contributor to the overall magnetization and that well-defined magnetizations are readily obtainable from these materials. Because the source area for these sediments remains constant over time (primarily rhyolitic rocks of VC), downhole variations in magnetic properties and changes in texture and lithology will be used to help resolve the nature of interactions between surficial, hydrological, and volcanic processes. Eventually the results of this study will be integrated with those of other workers to compile a regional climate model for northern New Mexico over the late Quaternary time interval sampled by the VC-3 hole.

QUATERNARY INCISION HISTORY OF THE UPPER REACHES OF THE JEMEZ RIVER, *C. Cox*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *Shari A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Karl E. Karlstrom*, *L. Crossey*, *M. Dillon*, and *D. Newell*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The Jemez River system drains the geologically active Valles caldera; understanding its incision history may provide insight into tectonic forces within the Jemez Mountains and along the Jemez lineament. The modern river profile is complex and shows two major knickpoints. The first is located just downstream from San Antonio Hot Springs and the second in the vicinity of Spence Hot Springs. These knickpoints reflect bedrock lithology in part (Abo sandstones and Banco Bonito flows, respectively), but may also be providing information on drainage reorganization following young (~50 ka) volcanism. Gravels beneath the Bandelier ash flows give an idea of the profile of the ancestral Jemez. The shape of these profiles is very similar to the current river profile. The ash flows filled a valley offset to the west of the modern valley.

Geologic information was superimposed on the river profile to calculate average incision rates for various time intervals during the past 1.8 m.y. In the vicinity of the Guadalupe River confluence, bedrock incision rate averaged 145 m/m.y. from 1.6 m.y. to present; 90 m/m.y. from 1.6 to 0.6 Ma, and 230 m/m.y. from 0.6 Ma to present, indicating increased bedrock incision in the late Quaternary. Compared to the Rio Ojo Caliente north of the Jemez Mountains, late Quaternary rates are similar, but early Quaternary rates are higher in the Jemez Mountains.

ASSESSING MOUNTAIN-BLOCK RECHARGE IN JEMEZ MOUNTAINS VIA HIGH-RESOLUTION HILLSLOPE HYDROLOGIC MODELING, *Huade Guan*, and *John L. Wilson*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

In arid and semiarid regions, mountains provide most of the freshwater to the surrounding basins. Mountain-block recharge (MBR) is an important component of basin ground water replenishment. Previous studies show that MBR in the volcanic San Juan Mountains can be as much as 38% of annual precipitation. With highly permeable volcanic non-welded tuff and fractured welded tuff, the Jemez Mountains should have similar or even larger rate of MBR. MBR starts with water partitioning on the mountain hillslopes. In this presentation, both specific and generic high-resolution hillslope hydrologic simulations were conducted to understand hillslope water partitioning. With a given bedrock hydraulic property, soil type, and vegetation coverage, the water partitioning is primarily controlled by topography-modified local climate conditions, measured by the ratio of annual potential evapotranspiration (PET) to precipitation (P). Based on these results, potential distributed MBR (or the maximum possible MBR) was estimated as the function of PET/P. Similarly, the total water yield, defined as P – ET, was estimated as a function of PET and P.

Finally, maps of potential distributed MBR and total water yield were constructed for the Jemez Mountains based on the PET and P maps. PET was estimated from the maximum and minimum daily temperatures by topography-corrected Hargreaves equation. A newly developed geostatistic model (ASOADeK) was applied to produce the precipitation map.

ASSESSING GROUND WATER RECHARGE THROUGH THE PAJARITO FAULT ZONE, UPPER PAJARITO CANYON, LOS ALAMOS, NEW MEXICO, *M. Dale*, mdale@lanl.gov, NMED DOE Oversight Bureau, 134 State Road 4, Suite A, White Rock, New Mexico 87544; *Fraser Goff*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *K. Granzow*, NMED DOE Oversight Bureau, 134 State Road 4, Suite A, White Rock, New Mexico 87544; *P. Longmire*, and *Dale A. Counce*, Los Alamos National Laboratory, EES Division, MS D469, Los Alamos, New Mexico 87545

Limited knowledge exists concerning the role of the Pajarito fault zone (PFZ) as a ground water recharge mechanism (conduit and/or barrier) within the Los Alamos region. Consequently, the NMED DOE Oversight Bureau initiated a study to determine if surface water loss in upper Pajarito Canyon is occurring within the PFZ. General hydrologic conditions include a perennial surface-water reach flowing west to east for approximately 2.4 km upstream of the PFZ. This reach is supplied by seeps and springs at about 2,740 m. Approximately 1.9 km downstream of PA-10.6, three perennial springs discharge from horizontal fractures and/or surge beds at approximately 2,330 m. Recharge and discharge (water balance) measurements were nearly equivalent. From 1997 through 2003, hydrogeochemical parameters were obtained at PA-10.6 and the springs. Isotopic data suggest that two of the three aforementioned springs (Homestead and Starmer Springs) are chemically and isotopically similar to the PA-10.6 waters. The third spring (Bulldog Spring) contains elevated concentrations of ^{3}H and major ions and is slightly enriched in δD and $\delta^{18}O$ compared to water at PA-10.6, suggesting a different recharge source. Solutes produced from the Cerro Grande fire (May 2000) introduced tracers that show direct links between water at PA-10.6 and the downgradient springs. Subsequent summer monsoon flooding in the upper reach of Pajarito Canyon impacted water quality at PA-10.6. The combined data indicate that some springs are supplied by waters that percolate into the PFZ (Homestead and Starmer) whereas other nearby springs are recharged independent of the PFZ (Bulldog).

ANALYSIS OF A LONG-TERM AQUIFER TEST USING MULTIPLE OBSERVATION WELLS, *S. G. McLin*, sgm@lanl.gov, Los Alamos National Laboratory, P.O. Box 1663, MS-K497, Los Alamos, New Mexico 87545

A 25-day aquifer test was conducted at a constant discharge rate of 1,249 gpm during the winter of 2003 at a municipal water supply well located in Los Alamos County. Continuous water level responses from many observation wells demonstrate that the regional aquifer displays pronounced resistance to vertical propagation of drawdown at shallower depths (i.e., hydraulic conductivity anisotropy). The aquifer also behaves like a semi-confined aquifer at depth with leaky units located above a highly conductive layer that averages approximately 850 ft thick. Drawdown in the highly permeable unit was recorded more than 8,800 ft away from the pumping well, whereas drawdown only 1,225 ft away in a multiple-screened observation well was directly related to individual screen depths. This test has demonstrated a remarkably complex aquifer response that is not easily interpreted without a combination of fully penetrating and multiple-screened observation wells, along with a dynamic spinner log from a second supply well. These data also suggest that an alternative conceptual model may represent the regional aquifer in the central plateau area. This second leaky-confined model consists of alternating high and low hydraulic conductivity layers within the regional aquifer. Here the low-conductive layers within the alternating aquifer sequence are the leaky source beds that are adjacent to high-conductive layers, and the overlying units at the top of the regional aquifer are not a significant source of water to the municipal supply wells. Differentiation between alternative conceptual models has obvious implications for monitoring potential contaminant migration in the regional system.

SESSION 2—PALEONTOLOGY AND STRATIGRAPHY

A NEW EARLY PENNSYLVANIAN (MORROWAN) FAUNA FROM THE NACIMIENTO MOUNTAINS, NORTH-CENTRAL NEW MEXICO, *Barry S. Kues*, Department of Earth and Planetary Sciences, MSC03 2040, University of New Mexico, Albuquerque, New Mexico 87131

Lithology and marine invertebrates from an 8-m-thick gray shale/limestone sequence along U.S.F.R. 376, 6 km north of Guadalupe Box, indicate that this is the upper part of the Osha Canyon Formation, not the younger Madera Formation as mapped by previous workers. These strata directly overlie reddish Precambrian granite, indicating that lower Osha Canyon and underlying Mississippian strata are missing at this locality. The fauna of the upper Osha Canyon here (based on 4,000+ specimens) is dominated by well-preserved brachiopods, with crinoids, bryozoans, and solitary rugose corals as important subsidiary elements; molluscs are uncommon. Brachiopods are represented by 27 species, especially *Neochonetes platynotus* (59% of total brachiopod specimens), *Punctospirifer morrowensis* (8%), *Hustedia gibbosa*? (7%), *Anthracospirifer newberryi* (5%), *Parajuresania pustulosa* (5%), and *Linoproductus nodosus* (3%). These and less common age-diagnostic species (e.g., *Antiquatonia coloradoensis, Plicochonetes arkansanus*) indicate a late Morrowan age, based on well-defined Morrowan zones elsewhere in New Mexico and in Arkansas and Oklahoma. Two new species (of *Beecheria* and *Nucleospira*) are present. *Nucleospira* is rare in the Pennsylvanian of North America, and this is the first report in the southwestern U.S. The fauna at this locality adds considerably to that present at the Osha Canyon type section in Guadalupe Box. Some elements of this fauna are present in the lower Osha Canyon, but the two faunas differ in composition and relative abundance of common taxa. This is not related to age but to a change from high-energy carbonate environments of the lower limestones, to lower-energy, more highly siliciclastic substrates of the upper Osha Canyon.

HUECO GROUP STRATIGRAPHY IN THE DOÑA ANA MOUNTAINS, NEW MEXICO, AND THE EARLY PERMIAN PALEOGEOGRAPHY OF THE ROBLEDO SHELF, *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and *Karl Krainer*, Institute of Geology and Paleontology, University of Innsbruck, Innrain 52, Innsbruck A-6020 AUSTRIA

Hueco Group strata in the Doña Ana Mountains were previously assigned to the Bursum(?), lower Hueco, middle Hueco, gastropod-bearing member, and Abo Tongue of a "shelf facies," and to a supposedly equivalent "basin facies" exposed east of the shelf facies. This lithostratigraphy identified a downwarp across the northwestern margin of the Orogrande Basin dividing Robledo shelf into western and eastern segments. However, a careful reexamination of

Hueco Group stratigraphy in the Doña Ana Mountains does not support this lithostratigraphy. No Bursum Formation is present, and Hueco Group strata are the: (1) Shalem Colony Formation, ~ 63 m thick, mostly dark gray, bioclastic wackestone-mudstone and shale; (2) Community Pit Formation, at least 108 m thick, mostly shale and brownish-weathered lime mudstones; and (3) Robledo Mountains Formation, at least 156 m thick, mostly red bed siltstones and fine sandstones, shale and marine limestones. These are the "shelf facies" of previous workers. Their "basin facies" is faulted strata of the Community Pit Formation or strata of the Panther Seep Formation, which underlies the Shalem Colony Formation in the Doña Ana Mountains. These Panther Seep strata are at least 64 m thick and consist of thick shale slopes interbedded with thin-bedded limestones, sandy limestones, and thin intraformational conglomerates. These facies (especially the peritidal limestones) closely resemble Panther Seep strata in the San Andres and Jarilla Mountains. The absence of a Hueco "basin facies" in the Doña Ana Mountains indicates general continuity of the Robledo shelf from the Robledo Mountains to the San Andres Mountains.

THE LATE TRIASSIC ARCHOSAUROMORPH *TRILOPHOSAURUS* AS AN ARBOREAL CLIMBER, *Justin A. Spielmann*, Justin.A.Spielmann@dartmouth.edu, Dartmouth College, Hinman Box 4571, Hanover, New Hampshire 03755; *Andrew B. Heckert*, and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Two species of the unusual archosauromorph *Trilophosaurus*, *T. buettneri* Case and *T. jacobsi* Murry, are known from diverse localities in the Upper Triassic Chinle Group in the southwestern U.S. Both species likely occupied similar ecological niches, based on morphological similarities in the postcrania, which are essentially identical. *Trilophosaurus* occurrences in the Chinle Group are relatively rare, but individual sites are exceptionally rich, suggesting that *Trilophosaurus* lived in a different paleoenvironment than more typical Chinle vertebrates, which lived in or near streams (phytosaurs, metoposaurs) or on floodplains (aetosaurs, rauisuchians, and dinosaurs). Two potential interpretations are that *Trilophosaurus* was either an arboreal climber or a fossorial digger. However, the gross skeletal features of *Trilophosaurus* are not compatible with a fossorial mode of life: the limbs are too long and gracile, proximal limb elements are longer than distal ones, and the claws are laterally compressed, not transversely broadened. The intermittent study of *Trilophosaurus* has caused the theory of it being arboreal, originally proposed by Gregory, to receive little mention in subsequent studies. We reexamined the functional morphology of *Trilophosaurus* using a qualitative functional morphological analysis of the skeleton, a quantitative examination of claw curvature, and a quantitative examination of manus/trunk and pes/trunk ratios. Claw morphology of *Trilophosaurus* shows similarities to the arboreal drepanosaurs *Drepanosaurus* and *Megalancosaurus*. Our analysis provides ample evidence to suggest that *Trilophosaurus* was arboreal. We reconstruct *Trilophosaurus* as using the less mobile forelimbs for anchoring itself, the powerfully built hindlimbs for propulsion, and the large tail for retaining balance.

THE MICROVERTEBRATE FAUNA OF THE UPPER TRIASSIC *TRILOPHOSAURUS* QUARRY, COLORADO CITY FORMATION (OTISCHALKIAN: CARNIAN), WEST TEXAS, *Andrew B. Heckert*, aheckert @nmmnh.state.nm.us, *Spencer G. Lucas*, and *S. P. Bednarski*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The Colorado City Formation of west Texas preserves the oldest extensive Late Triassic vertebrate fauna in the southwestern U.S., a fauna that is the basis of the Otischalkian land-vertebrate faunachron. The richest and most diverse vertebrate fauna found in the Colorado City Formation is the assemblage from *Trilophosaurus* quarry 1. We report here significant additions to this fauna as a result of continued screenwashing and picking of the matrix from the spoil pile at the quarry. New records from the quarry we report here include possible semionotid fish, diverse archosauriform teeth, a possible cynodont, a probable sauropodomorph, and a sphenodontian. The cynodont is fragmentary but potentially represents the oldest known from the Chinle Group. The sauropodomorph is a probable prosauropod, based on two teeth that appear relatively advanced ("*Azendohsaurus*-grade") and are the oldest such fossils known. The sphenodontid is represented by two jaw fragments and is the oldest sphenodontian from North America. Dozens of fragmentary reptilian vertebrae recovered doubtless represent other new or poorly known taxa. Another significant fossil recovered is an extremely small (near hatchling) dentulous maxillary(?) fragment of *T. buettneri* that further demonstrates that *T. buettneri* and *T. jacobsi* are distinct species. The fauna as a whole is dominated by amniotes (~ 79% of catalogued specimens), followed by osteichthyans (14.4%) and amphibians (5–6%) with chondrichthyans (1.1%) an extremely minor component. This is the oldest Late Triassic microvertebrate fauna in North America and suggests that dinosaurs and sphenodonts both have evolutionary origins in the Ladinian.

AN UNUSUAL *PENTACERATOPS* FROM NEW MEXICO, *J. A. Smith* and *Thomas E. Williamson*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Pentaceratops sternbergi is a large chasmosaurine ceratopsid dinosaur found only in the Upper Cretaceous (Campanian) Fruitland and lower Kirtland Formations of New Mexico, well represented by at least 12 skulls and partial to nearly complete skeletons. It is characterized by a large, keyhole-shaped medial embayment surrounded by four large epoccipitals on the dorsal margin of the parietosquamosal frill. In 1998 the New Mexico Museum of Natural History (NMMNH) collected a partial skull and associated partial skeleton of *P. sternbergi* (NMMNH P-27468) from the Hunter Wash Member, Kirtland Formation in the Bisti/De-na-zin Wilderness area. Recovered skull elements include a largely complete parietal, one of the most complete known for this taxon, incomplete left and right squamosals, and a right jugal. We refer this specimen to *P. sternbergi* because it preserves the diagnostic medial embayment and associated epoccipitals on the parietal. However, the specimen also shows features that are unusual for *P. sternbergi*. The parietal of P-27468 is small compared to all other specimens. Also, the parietal differs from other specimens in the unusual laterally constricted shape and small size of the dorsal medial embayment and the aberrant positioning of the adjacent epoccipitals away from their usual location. We propose two hypotheses (not mutually exclusive) to explain the unique conformation of this specimen; first, that the parietal of P-27468 is pathologic, and second, that it represents an early ontogenetic stage not previously documented.

NEW PACHYCEPHALOSAUR SPECIMENS FROM THE LATE CRETACEOUS OF NEW MEXICO, *Thomas E. Williamson*, twilliamson @nmmnh.state.nm.us, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and *T. D. Carr*, tyrannosauroidea@hotmail.com, Department of Biology, Carthage College, 2001 Alford Park Drive, Kenosha, Wisconsin 53140

Pachycephalosaurs are a rare component in Late Cretaceous faunas of New Mexico. Previously, two pachycephalosaur partial skulls were recovered from the De-na-zin Member, Kirtland Formation, one pachycephalosaur frontoparietal was recovered from the Fruitland Formation, and two specimens including a frontoparietal and a lower jaw and parts of lateral skull roofing bones were recovered from the Hunter Wash and Farmington Sandstone Members of the Kirtland Formation, respectively. We report two new specimens from the De-na-zin Member that include frontoparietals.

NMMNH P-41020 is a partial frontoparietal from NMMNH locality L-5400. Breaks that border the fragment occurred before burial and show abrasion due to transport. The lateral surface includes parts of the sutural contacts for the left supraorbitals I and II. A part of the dorsal surface of the frontoparietal exhibits the pitted texture that is characteristic of Pachycephalosauria.

NMMNH P-41135 is a partial frontoparietal from locality L-3921. It is weathered but largely complete. The frontoparietal is large (preserved length = 140 mm, preserved width = 116 mm) and high-domed (maximum preserved thickness = 95 mm). The ventral surface preserves parts of the ceilings of the adductor chambers. These are closely spaced medially and inclined as in Pachycephalosaurinae.

Both new pachycephalosaur specimens are too fragmentary to allow identification to genus and were found in proximity (< 1 km) to the locality that yielded the holotype of *Sphaerotholus goodwini* (P-27403).

THE USE OF THE LATE CRETACEOUS SELACHIANS *PTYCHODUS* AND *SQUALICORAX* AS BIOSTRATIGRAPHIC INDICATORS IN NEW MEXICO, *Sally C. Williams* and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

A comprehensive biostratigraphy using selachians can be constructed for the Cretaceous Interior Seaway. There are seven selachian faunachrons defined for the Cretaceous Interior Seaway: middle Cenomanian–middle Turonian *Ptychodus anonymous–Odontaspis* faunachron, middle Turonian *P. anonymous–P. whipplei* faunachron, middle Turonian–middle Coniacian, *P. whipplei*, *Squalicorax falcatus* faunachron, middle Coniacian *P. mortoni–S. falcatus* faunachron, middle Coniacian–late Santonian *P. mortoni–S. kaupi* faunachron, early Campanian–middle Campanian *S. kaupi–S. pristodus* faunachron, and the middle–late Campanian *S. pristodus–Cretodus* faunachron. The primary species that define the faunachrons belong to the genera *Ptychodus* and *Squalicorax*. These species turn over nearly in step throughout the Late Cretaceous. So, they define both long time intervals from the middle Cenomanian to the middle Turonian, where both S*qualicorax falcatus* and *Ptychodus anonymous* are present. They are common members of the *P. anonymous–Odontaspis* faunachron. There also are very short time intervals, such as the *anonymous–whipplei* faunachron, where there are overlapping *Ptychodus* species in the middle Turonian. This biochronological unit is a very short amount of time, spanning just about the length of the deposition of the Juana Lopez Member of the Mancos Shale. A slightly longer, yet relatively short, selachian faunachron is in the middle Coniacian; this is a short span of time during the deposition of the El Vado Member of the Mancos Shale and of the Gallup Sandstone. This biochronological unit is determined by the presence of *S. falcatus* and *P. mortoni*. Thus, nearly all of the selachian faunachrons are defined by the presence of species of *Squalicorax* and *Ptychodus*.

PLIOCENE (BLANCAN) VERTEBRATE FAUNAS FROM THE PALOMAS FORMATION NEAR ELEPHANT BUTTE LAKE, SIERRA COUNTY, SOUTH-CENTRAL NEW MEXICO, *Gary S. Morgan*, gmorgan@nmmnh.state.nm.us, and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Pliocene (Blancan) vertebrate fossils are common in the Palomas Formation near Elephant Butte Lake (EBL), Sierra County, south-central New Mexico. There are four Blancan local faunas (LF) from this region: Elephant Butte Lake LF, from sites around EBL; Cuchillo Negro Creek LF, 6 km west of EBL; Truth or Consequences (TC) LF, 1 km west of TC ; and Palomas Creek LF, 5 km southwest of TC. These sites are mostly composed of large mammals derived from axial river gravels; however, the TC LF has produced a diverse microvertebrate fauna from mudstones. Age-diagnostic large mammals from the vicinity of EBL include: horse (*Equus simplicidens*), giant camel (*Gigantocamelus spatula*), and gomphothere (*Stegomastodon primitivus = S. rexroadensis*) from the EBL LF; borophagine canid (*Borophagus hilli*), *E. simplicidens*, camel (*Camelops*), and *S. primitivus* from the Cuchillo Negro Creek LF; and two horses (*Nannippus peninsulatus, E. cumminsii*) and mastodont (*Mammut raki*) from the Palomas Creek LF. Small mammals from the TC LF (lagomorphs—*Hypolagus vetus*, *Notolagus lepusculus*; rodents—*Geomys minor, Neotoma quadriplicata*) indicate an early Blancan age. K-Ar dates of 4.5 Ma on a basalt from the lower Palomas Formation and 2.9 Ma on the Mitchell Point basalt from above most of the fossil sites constrain the age of the EBL faunas to early Blancan (2.7–4.9 Ma). The biostratigraphic ranges of certain mammals (*B. hilli*, *H. vetus*, *N. lepusculus*, *G. minor*, *N. quadriplicata*, *N. peninsulatus*, *E. simplicidens, S. primitivus*) further restrict the age of these sites to late early (= medial) Blancan (~ 3.0–3.6 Ma).

SESSION 3—GEOPHYSICS, VOLCANOLOGY, AND CLIMATE

COMPARING THE THERMAL REGIMES AND THE SEISMOGENIC LAYERS ALONG THE SAN ANDREAS FAULT NEAR PARKFIELD, CALIFORNIA, AND ALONG THE COYOTE FAULT NEAR SOCORRO, NEW MEXICO, *Marshall, Reiter*, mreiter@nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

The subsurface temperature regime is an important factor influencing the base of the continental seismogenic layer; and probably the depth interval of the seismogenic layer as well. Heat flow measurements are the best way to estimate the subsurface thermal regime. However, there are few heat flow measurements within several kilometers of epicenters with well-determined hypocenter depths. In this study two widely separated locations in very different geological environments are considered. The locations are along the San Andreas fault near Parkfield, California, and along the Coyote fault near Socorro, New Mexico. The San Andreas fault is a major strike-slip fault between the Pacific and North American plates. The Coyote fault along the eastern boundary of the Rio Grande rift is a normal fault; interestingly, first motion studies of recent seismic swarms suggest primarily strike-slip events. The hypocenter depth of the main event at Arroyo del Coyote is the same as the hypocenter depth of the two most recent magnitude 6 events near Parkfield. Heat flow at the 1966 magnitude 6 event site just north of Parkfield and the value near Arroyo del Coyote suggest the main events at both locations are occurring at temperatures of ~ 270 ± ~ 30°C. This temperature range is in the upper part of the temperature field for the semi-brittle zone of wet quartz; a region where crustal strength is suggested to decrease. Is this a coincidence or does it suggest that strike-slip events at the two locations similarly depend on temperatures and strain rates?

PARTIAL MELTING, FRACTIONATION, CONTAMINATION, AND ERUPTION OF THE CARRIZOZO LAVA FLOW, SOUTH CENTRAL NEW MEXICO, *J. Z. Williams, C. W. Davis*, and *Nancy J. McMillan*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

The 75-km-long Carrizozo basalt flow is one of the longest subaerial lava flows in the United States. The flow has an estimated total volume of 4.3 km^3, covering 330 km^2 with depths of 10–15 m (Allen 1952).

Two transects across the flow were sampled, based on Renault's (1970) early work: across the distal end (lower flow), where three lobes are present, and across the proximal region (upper flow), where two lobes are present. The first lobe has the lowest SiO_2 concentrations and the highest concentrations of incompatible elements; SiO_2 is higher and incompatible element concentrations are lower in each subsequent flow unit.

Geochemical correlation of the distal lobes with the proximal lobes can be achieved through the addition of crustal melts to mantle-derived basaltic melts. Our model incorporates 3% crustal melt of a gneissic xenolith from Kilbourne Hole (Beard et al. 1993), followed by 2–4% olivine fractional crystallization to produce the composition of the proximal lobes. Consequently, we propose that five batch-melting events occurred in the mantle. For the first three batches (lower flow), heating of the lower crust occurred, yet not significantly enough to cause crustal melting. When the final two batches (upper flow) passed through the lower crust, contamination occurred because the crustal rocks had reached their solidi. Surprisingly, estimates of the duration of flow range between a few months (Zimbelman and Johnston 2002) and three decades (Keszthelyi and Pieri 1993), suggesting that melting and differentiation processes were geologically rapid.

INFLUENCE OF ELEPHANT BUTTE RESERVOIR ON THE PACIFIC DECADAL OSCILLATION SIGNAL SEEN IN CHLORIDE CONCENTRATION IN THE RIO GRANDE AT EL PASO, TEXAS, *H. Lacey*, hlacey@nmt.edu, and *F. M. Phillips*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Fasong Yuan and Seiichi Miyamoto (2004) published a paper that demonstrated a negative correlation between chloride concentration in the Rio Grande measured at El Paso, Texas, and the Pacific Decadal Oscillation (PDO). By analyzing historical data they concluded that the chloride concentration at El Paso is largely determined by the amount of stream discharge in the middle Rio Grande basin that is associated with the PDO. They did not explore in their paper the effect of Elephant Butte Reservoir (EBR) on the PDO signal at El Paso, nor did they offer an explanation for the correlation of chloride concentration with discharge.

We have analyzed chloride and discharge data from the Rio Grande above EBR at San Marcial in order to determine the influence of EBR on the PDO signal at El Paso. We compared data from 1950 to 1980 when the reservoir level was low and data from 1980 to 1990s when reservoir level was high to the PDO index. We determined first, that the PDO signal is detectable at San Marcial and second, that EBR serves to dampen, rather than enhance, the PDO signal at El Paso when the reservoir level is high.

Furthermore, we have concluded that during times when the PDO index is negative and discharge in the river is low, chloride is likely stored in the vadose zone and shallow ground water of the agricultural system in the Rio Grande basin, and then is flushed out when the PDO index increases and discharge is higher.

SESSION 4—GEOLOGY OF QUESTA MINE ROCK PILES

MAPPING THE INTERIOR OF A MINE ROCK PILE: TRENCHES IN GOAT HILL NORTH, MOLYCORP MINE, QUESTA, NEW MEXICO, *Patrick Walsh, Virginia T. McLemore, Kelly M. Donahue, S. Tachie-Menson, L. A. F. Gutierrez, H. R. Shannon*, and *Glen E. Jones*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Mapping of seven trenches during the deconstruction of the Goathill North mine rock pile in 2004 identified several consistently correlatable units downward through approximately 200 ft of mined material. Trench construction typically consisted of four benches approximately 5 ft long and 4 ft deep, and mapping units were identified based on grain size, color, and other physical properties. Unit boundaries ranged from horizontal to vertical, but most dipped between 20° and 40° westward to northwestward. At the top of the rock pile, a 10–15-ft, nearly horizontal traffic surface unconformably overlies dipping units. Mapped units ranged in thickness from 0.5 to 15 ft.

Team members identified and mapped units primarily on trench walls because benches were usually covered with a thin (6–12 in) traffic surface created by bulldozer movement. Section drawings and lateral measurements of unit boundaries provided data to make maps of each trench. Maps of individual trenches show a "v-shape" indicating the westward dipping beds on each bench with an apparent offset between benches due to the vertical walls separating benches. Thin units pinched out or graded vertically and laterally. Unit boundaries have been projected onto east-west cross sections to show the vertical extent of units within the rock pile.

Detailed and generalized versions of trench maps, projected cross sections, and contoured unit boundaries provide a structural framework for conceptual and numerical models in other parts of this study. Analysis of samples and measurements within each unit provide physical properties and boundary conditions for the models.

VARIATION OF TEMPERATURE AND PORE OXYGEN AND CARBON DIOXIDE IN ROCK PILES AT THE MOLYCORP QUESTA MINE, NEW MEXICO, *S. Tachie-Menson, T. White*, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro New Mexico 87801; *Virginia T. McLemore, Virgil. W. Lueth*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *B. M. Walker*, Molycorp Inc., P.O. Box 469, Questa, New Mexico 87556

Nine boreholes were drilled in four rock piles at the Molycorp Questa molybdenum mine as part of a characterization study in 1999. Temperature and concentrations of pore oxygen and carbon dioxide were monitored in the holes over a 5-yr period at monthly intervals. The data collected over the 5-yr period were analyzed with plots of each of the three parameters against time and depth profiles of mean monthly values.

Oxygen concentrations were lower but carbon dioxide concentrations were higher than ambient values. Concentrations of oxygen and carbon dioxide had a negative correlation in both the depth profiles and time plots. The highest oxygen and lowest carbon dioxide concentrations were in the colder months. Temperatures varied with the seasons at depths above 20–30 ft. Below 30 ft, temperatures did not show seasonal variations but decreased by as much as 10°F over the 5-yr period. Over the same period, mean oxygen concentrations increased by as much as 10% and carbon dioxide decreased by 1%. These observations suggest that air enters the piles through the toe and flows upward. Oxygen is used up by oxidation processes and carbon dioxide is produced by decomposition of carbonates, which produces heat in the piles. With time, the chemical processes slow due to depletion of reactants, resulting in decreasing temperatures and carbon dioxide concentrations and increasing oxygen concentrations. The flow of air into the pile is partly controlled by the difference in temperature between ambient air and the interior of the pile and, therefore, there is greater influx of air during the colder months.

SOIL PETROGRAPHY OF A SAMPLE TRAVERSE FROM A PART OF THE GOATHILL NORTH ROCK PILE, QUESTA MINE, NEW MEXICO, *E. H. Phillips*, ehp@nmt.edu, *Virgil W. Lueth*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Andrew Campbell*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Virginia T. McLemore*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *B. M. Walker,* Molycorp, Inc., P.O. Box 469, Questa, New Mexico 87556; and *S. Tachie-Menson*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Petrographic examination of a series of soil samples collected during deconstruction of a rock pile at the Questa mine reveals differences in characteristics such as color and mineralogy. Twenty-one soil samples were collected at 5-ft intervals along one bench. This traverse crosses eight different mappable units, defined primarily by color, stratigraphic position, and grain size. Two of these units are classified as oxidized, one is intermediate, and five are unoxidized. The color of secondary iron oxide minerals is variable among the twenty-one samples and includes black, orange, red, yellow, and brown material.

Gypsum is present in all of the soils and is found in different habits. Stable isotope studies demonstrate that this petrographic observation can be used to distinguish gypsum as either detrital or authigenic. A preponderance of clear, prismatic, authigenic gypsum grains is an indicator of sulfide weathering after the material was emplaced in the mine rock pile.

Variations in the abundance of carbonate in the soil samples exist, and preliminary data suggest a positive correlation between carbonate abundance and paste pH values. Seven samples contain no detectable carbonate and have paste pH values between 2.2 and 3.7, whereas four samples contain abundant carbonate and have paste pH values between 8.4 and 9.6. The remaining ten samples contain trace to minor amounts of carbonate and have paste pH values ranging from 3.3 to 9.6. All four samples with abundant carbonate are from unoxidized units.

POSTER SESSION 1—GEOLOGY AND HYDROLOGY OF THE JEMEZ MOUNTAINS

GEOLOGIC MAP OF THE CAÑADA 7.5-MIN QUADRANGLE, SOUTHERN JEMEZ MOUNTAINS, NEW MEXICO, *Scott D. Lynch*, lynch@nmt.edu, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Gary A. Smith* and *A. J. Kuhle*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The Cañada quadrangle is located at the boundary between the Jemez volcanic field and Santo Domingo Basin. The northern two-thirds of the quadrangle is Keres Group volcanic rocks and Bandelier Tuff, and the southern one-third is volcaniclastic basin-fill sediments and pediment gravels of the Santa Fe Group. The oldest volcanic unit is a 12.4 Ma Canovas Canyon Rhyolite flow. Intercalated andesite and dacite flows, domes, and volcaniclastic deposits of the Paliza Canyon Formation (11–7 Ma) are widespread. Bearhead Rhyolite lava flows, domes, and the associated pyroclastic and sedimentary strata of the Peralta Tuff Member erupted 7–6 Ma. An intrusive center that was coeval with Keres Group volcanism is exposed in uplifted blocks north of Bearhead Peak, where Bearhead Rhyolite dikes and stocks intrude Paliza Canyon Formation hypabyssal rocks. The Cochiti Formation gradationally overlies the Peralta Tuff and consists of volcaniclastic sediment eroded from Keres Group rocks after the cessation of most or all Keres Group volcanism.

Normal faults in the quadrangle trend north-south or northeast-southwest and dip 65– 80° to the east. Displacement in Keres Group rocks is at least 300 m. Several faults offset upper Pliocene pediment gravels, and a few displace the 1.22 Ma Bandelier Tuff. The Pajarito fault cuts a middle Pleistocene terrace gravel and displaces the Bandelier Tuff by 80 m. The Medio Dia and Peralta fault zones define the Bearhead Basin, which accommodates a 500-m-thick section of Peralta Tuff that is absent east and west of the basin, indicating deposition during basin subsidence.

GEOLOGY OF REDONDO PEAK QUADRANGLE, JEMEZ MOUNTAINS, NEW MEXICO, *Fraser Goff*, candf@swcp.com, 5515 Quemazon, Los Alamos, New Mexico 87544; *Jamie N. Gardner, S. L. Reneau*, Earth and Environmental Sciences Division, Los Alamos National Laboratory, Los Alamos, New Mexico 87545; and *C. J. Goff*, 5515 Quemazon, Los Alamos, New Mexico 87544

A new 1:24,000 scale geologic map of Redondo Peak quadrangle (RPQ) has been completed for the New Mexico State Map Program. RPQ overlies the southern boundary between the Valles caldera (ca 1.25 Ma) and precaldera volcanic rocks of the Jemez Mountains. Three geologic domains make up the quadrangle: the southern resurgent dome, the southern moat, and the southern caldera margin. The resurgent dome consists of upper Bandelier Tuff, earliest post-caldera eruptives and interbedded debris flows, fluvial deposits, and lacustrine rocks. Uplift is at least 1,000 m, and the resurgent dome is broken into a multitude of fault blocks. The southern moat consists of latest post-caldera rhyolite domes, flows, and tuffs interbedded with fluvial and minor lacustrine deposits. Very little faulting is observed in the southern moat. The southern caldera margin consists of mafic to silicic domes and flows (Keres Group, 6–13 Ma), partially covered with lower Bandelier Tuff (1.62 Ma) and extensively mantled with fall deposits of El Cajete Pumice (50–60 ka). This zone is broken into a series of north-trending fault blocks (Cañada de Cochiti fault zone) that are primarily down to the east toward the Rio Grande rift. The western fault blocks are underlain by the Santa Fe Group (roughly 10–17 Ma) and by the upper Abiquiu Formation (21 Ma). The eastern fault blocks display extensive hydrothermal alteration (quartz-calcite-smectite ± illite ± chlorite ± zeolite ± pyrite ± epidote) mostly caused by intrusive activity related to the Bearhead Rhyolite (6–7 Ma).

GEOLOGY OF CERRO DEL GRANT QUADRANGLE, JEMEZ MOUNTAINS, NEW MEXICO, *J. R. Lawrence*, 2321 Elizabeth Street NE, Albuquerque, New Mexico 87112; *S. A. Kelley*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *M. Rampey*, Department of Earth and Planetary Sciences, 425 EPS Building, University of Tennessee, Knoxville, Tennessee 37996

Recent geologic mapping (1:24,000) of the Cerro del Grant 7.5-min quadrangle (CdGQ) was completed under the New Mexico State Map Program. CdGQ encompasses an area north of the Valles caldera and includes two geologic terranes: (1) a western zone of Late Triassic to Pliocene sedimentary rocks and (2) a zone of volcanic rocks (~ 8–1.2 Ma) exposed in the higher elevations on La Grulla Plateau. Uniformly east dipping sedimentary strata include shale, sandstone, conglomerate, evaporite deposits, and chert. These are locally overlain by volcanic rocks of the Polvadera and Tewa Groups. Volcanic activity began with earliest basalt flows (8.67 Ma) that appear interbedded with Ojo Caliente Sandstone of the Santa Fe Group in Cañones Canyon. Effusive eruptions, preserved in a series of Lobato Formation (locally 7.85–7.90 Ma) andesite flows exposed in the escarpment at Encino Lookout, issued onto an east-sloping surface beveled on Santa Fe Group. Remnants of a dissected shield cone occur west of the escarpment. The flow series is locally intruded by a mass of Lobato dacite. Deposition of the Tschicoma Formation, informally subdivided here into two subunits, closely followed Lobato volcanism. Voluminous lower member two-pyroxene andesites cover much of La Grulla Plateau. Upper member hornblende ± biotite dacites (7.63–7.27 Ma) occur as discontinuous, stratigraphically overlying domes and limited flows conspicuously aligned along the east plateau margin, bordering Cañones Creek. Structural control of Tschicoma dacite eruptive centers is apparent. Rhyolitic ignimbrites of the Bandelier Tuff (1.62–1.22 Ma) occur in local remnant outcrops following extensive Pleistocene erosion. Post- and syn-volcanic normal fault movement is evident.

VADOSE ZONE CHARACTERIZATION AND MONITORING BENEATH WASTE DISPOSAL PITS USING HORIZONTAL BOREHOLES, *S. G. McLin*, sgm@lanl.gov, Los Alamos National Laboratory, P.O. Box 1663, MS-K497, Los Alamos, New Mexico 87545; *B. D. Newman*, bnewman@lanl.gov, Los Alamos National Laboratory, P.O. Box 1663, MS-J495, Los Alamos, New Mexico 87545; and *D. E. Broxton*, broxton@lanl.gov, Los Alamos National Laboratory, P.O. Box 1663, MS-T003, Los Alamos, New Mexico 87545

Vadose zone characterization and monitoring immediately below landfills using horizontal boreholes is an emerging technology. However, this topic has received little attention in the peer-reviewed literature. The value of this approach is that activities are conducted below the waste, providing clear and rapid verification of containment. Here we report on two studies that examined the utility of horizontal boreholes for environmental characterization and monitoring under radioactive waste disposal pits. Both studies used core sample analyses to determine the presence of various radionuclides, organic compounds, or metals. At one borehole site, water content and pore-water chloride concentrations were also used to interpret vadose zone behavior. At another site, we examined the feasibility of using flexible membrane liners in uncased boreholes for periodic monitoring. For this demonstration, these retrievable liners were air-injected into boreholes on multiple occasions carrying different instrument packages for environmental surveillance. These included a neutron logging device to measure volumetric water at regular intervals, high-absorbency collectors that wicked available water from borehole walls, or vent tubes that were used to measure air permeability and collect air samples. The flexible and retrievable liner system was an effective way to monitor water content and measure in situ air permeability. The high-absorbency collectors were efficient at extracting liquid water for contaminant analyses even at volumetric water contents below 10%, and revealed tritium migration below one disposal pit. Both demonstration studies proved that effective characterization and periodic monitoring in horizontal boreholes is both feasible and adaptable to many waste disposal problems and locations.

AN UPDATE ON THE SURFICIAL WATER RESOURCES IN THE LOS ALAMOS AREA, NEW MEXICO, *M. R. Dale*, mdale @lanl.gov, *K. P. Granzow*, NMED DOE Oversight Bureau, 134 State Road 4, Suite A, White Rock, New Mexico 87544; *D. E. Englert*, NMED DOE Oversight Bureau, 2905 Rodeo Park Drive East, Bldg. 1, Santa Fe, New Mexico 87505; *S. M. Yanicak*, NMED DOE Oversight Bureau, 134 State Road 4, Suite A, White Rock, New Mexico 87544; *R. E. Ford-Schmid*, NMED DOE Oversight Bureau, 2905 Rodeo Park Drive East, Bldg. 1, Santa Fe, New Mexico 87505, *P. A. Longmire*, and *Dale A. Counce*, Los Alamos National Laboratory, Earth and Environmental Sciences Division, MS D469, Los Alamos, New Mexco 87545

During the mid 1990s, New Mexico Environment Department's Department of Energy Oversight Bureau (the bureau) recognized that there was not an adequate inventory and characterization of local springs and surface water resources in the Los Alamos area. The bureau identified surficial water resources extending from Guaje Canyon to Frijoles Canyon. The survey resulted in the discovery of 89 undocumented perennial and ephemeral springs. Perennial surface water flow from both newly discovered and previously identified springs were documented and monitored to determine changes in flow rates and stream conditions in response to wet and dry periods. A variety of information and data were collected including coordinates, geologic discharge units, field chemistry parameters, and, in some cases, water-quality constituents, tritium, and stable isotopes. Spring discharge is from shallow, intermediate, and deep aquifers composed of sedimentary and volcanic rock units. The shallow perched perennial springs primarily reside in the western part of the Pajarito Plateau and the Sierra de los Valles. Ground water ages vary within each aquifer; however, the youthful waters tend to be shallow versus older waters occurring at greater depths. Estimated recharge or area of precipitation elevations, as indicated by stable-isotope data, for the shallow perched and intermediate/regional springs range from approximately 2,300 to 2,900 m and from 2,100 to 2,400 m, respectively. As a result of this work, a more complete and accurate understanding of hydrologic conditions in the Los Alamos area has been gained, which is critical to the management and protection of water resources.

POSTER SESSION 2—ENVIRONMENTAL GEOLOGY AND PALEOCLIMATE

QUANTIFYING THE INFLUENCE OF CALCIUM CARBONATE ACCUMULATION ON THE HYDRAULIC PROPERTIES OF SEMIARID SOILS: SEVILLETA NATIONAL WILDLIFE REFUGE AND FITE RANCH, NEW MEXICO, *Ryan McLin*, Department of Earth and Environmental Science, New Mexico Institute on Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Soil properties have a major influence on the partitioning of rainfall into infiltration and runoff. Hence, they determine the water available for aquifer recharge, stream flow, and ecosystem processes. Quantifying hydraulic properties for soils requires the use of pedotransfer functions; however, no previous functions have taken into account calcium carbonate accumulation at depth and how the calcium carbonate accumulation affects the rate of water movement into the soil. The accumulation of calcium carbonate in semiarid soils increases with age and produces systematic morphological changes in calcic horizons. Studies have recognized six stages of calcic horizon development recording the gradual accumulation of calcium carbonate cementing the matrix of soils until eventually producing an impermeable layer within the soil profile. Two semiarid sites in the Sevilleta National Wildlife Refuge, New

Mexico, and one semiarid site at Fite Ranch, New Mexico, have been excavated gradually with each soil horizon characterized hydrologically using a tension infiltrometer. Carbonate concentration and bulk density was also measured for each horizon. Preliminary results indicate that as the calcium carbonate accumulates with depth and fills in the pore spaces of the soil substrate, the water flow decreases as reflected by a reduction in hydraulic conductivity. To determine the changes in soil hydraulic properties due to calcium carbonate alone, we use pedotransfer functions based on the measured soil texture assuming that the measured hydrologic properties deviate from that indicated by the pedotransfer functions. This difference represents the changes due to calcium carbonate accumulation.

SOURCING ARSENIC IN THE NORTHERN GALLINAS WATERSHED, *Valerie Duran*, *Catherine Tabe-Ebob*, *Justin Johns-Kaysing*, *Millie Running Eagle*, and *Jennifer Lindline*, lindlinej@nmhu.edu, Environmental Geology Program, New Mexico Highlands University, P.O. Box 9000, Las Vegas, New Mexico 87701

The Gallinas River is the primary source of water for Las Vegas, New Mexico (population 18,000), providing 95% of its domestic water supply. Additional surface water is diverted to the Storrie Lake Water Project and divided among multiple users. Growing demands for water necessitate that the Gallinas River be managed to ensure adequate supply and quality. Water quality studies show that the river contains elevated concentrations of arsenic (0.039 ppm) during periods of elevated flow ($1.98 m^3/s$). These results exceed the USEPA drinking water standard of 0.010 ppm. Total recoverable arsenic in water samples is strongly correlated with total suspended solids (R^2 = 0.98) and is hypothesized to come from a natural source. We collected twenty-three rock and twenty-six soil samples from major geologic units underlying the Gallinas watershed and analyzed them for arsenic content. The results show that most of the geologic units contain arsenic concentrations less than 1 ppm, except for shales of the Lower Pennsylvanian Madera and Cretaceous Niobrara–Carlile Formations, which exhibit arsenic concentrations between 7 and 10 ppm. All soils show arsenic values >20 ppm; soils from the shale outcrops have especially high arsenic concentrations of >50 ppm. The Cretaceous shales contain pyrite, which has been correlated with high arsenic values in rock. The weathering of pyrite may release arsenic into soils, which is then introduced into the river during storm events as suspended solids. These results call for further studies to examine the relationship between arsenic source areas and impacted surface and ground water.

A SYNOPSIS OF SALINE GROUND WATER RESOURCES IN NEW MEXICO, *G. F. Huff*, gfhuff@usgs.gov, U.S. Geological Survey, New Mexico State University, Dept. 3ARP, Las Cruces, New Mexico 88003

Increasing demand on limited potable ground water supplies in New Mexico has stimulated interest in the use of saline ground water resources. Saline water contains dissolved solids concentrations equal to or greater than 1,000 mg/L. Saline ground water can be used to augment potable water supplies after being treated to reduce concentrations of dissolved solids. Aquifers in the Albuquerque Basin, San Juan Basin, Roswell Basin, Capitan Reef, Estancia Basin, and the Tularosa/Salt Basin contain substantial amounts of saline ground water. The feasibility of using saline ground water from these aquifers will be influenced by the hydraulic characteristics of the aquifers, the amount of saline water stored in the aquifers, the pumping depths of saline ground water within the aquifers, the rates of recharge to the aquifers, and the characteristics of regional and local saline ground water flow systems.

PROKARYOTIC DIVERSITY AND BIOGEOCHEMICAL CYCLING IN THE MIDDLE RIO GRANDE AQUIFER, NEW MEXICO, *S. Caldwell*, *L. 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

Previous research has shown an increase in microbial activity with decreased oxygen availability in the shallow alluvial aquifer associated with the middle Rio Grande. The change in ground water flow from being parallel with the river to flowing from channel to riverside drain has increased Darcian flow velocity and the flux of sulfate, dissolved organic carbon, and nutrients to aquifer sediments. Chemoautotrophic microorganisms substitute terminal electron-accepting processes in the absence of oxygen to drive more thermodynamically favorable mineral changes as they oxidize organic matter. Geochemical evidence of associated ground water in the middle Rio Grande from Vinson et al. shows authigenic mineral formation as a result of microbial competitive relationships in sulfidic aquifers. Filamentous phosphate growth and increased bicarbonate concentrations from river to drain further suggest active microbial respiration. Biomolecular analysis of ground water in the San Antonio oxbow, Albuquerque, New Mexico, is used in this study to identify the dominant functional groups and overall diversity of microorganisms in this environment.

DNA was extracted from ground water samples using a sucrose lysis method and amplified by the polymerase chain reaction (PCR). Unique PCR products were separated by denaturing-gradient gel electrophoresis (DGGE) and will be identified by sequencing. Preliminary results of the DGGE indicate potentially high bacterial diversity and low heterogeneity within the shallow alluvial ground water adjacent to the middle Rio Grande.

EXPERIMENTAL DETERMINATION OF THE BIOGENICITY OF MOONMILK, AND THE CHARACTERIZATION OF MOONMILK AND ITS DEPOSITIONAL ENVIRONMENT IN SPIDER CAVE, CARLSBAD CAVERNS NATIONAL PARK, NEW MEXICO, *M. Perrone*, mperrone@nmsu.edu, *K. Giles*, Department of Geological Sciences, New Mexico State University, Breland Hall, Rm. 129, Las Cruces, New Mexico 88003; *P. J. Boston*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *D. E. Northup*, Department of Biology, University of New Mexico, Centennial Science and Engineering Library, MSC05 3020, Albuquerque, New Mexico 87131; and *M. N. Spilde*, Institute of Meteoritics, University of New Mexico, Northrop Hall, MSC03-2050, Albuquerque, New Mexico 87131

Microbe/rock interactions within caves may play a role in the formation of speleothems, such as moonmilk (a two-phase system of calcite and water). Moonmilk is interpreted as forming by either primary deposition (subaqueous or subaerial) or secondary deposition (degradation product). Moonmilk (known as "Crisco") from Spider Cave of Carlsbad Caverns National Park, New Mexico, was analyzed to determine the fabric, depositional setting and extent of biogenicity. Crisco moonmilk is composed of filamentous, calcitic $CaCO_3$ associated with microbes. Crisco is no longer growing and has a thick, detrital silt surface coating, rendering the present day cave environment inadequate for determining the depositional environment. Microbes derived from Crisco were cultured using four types of media to study their precipitates. Moonmilk samples were analyzed using SEM and thin sections stained with Alizarin Red S.

All media types show bacterial and fungal growth, but none have produced visible precipitates. SEM examination at low magnification shows a smooth, curd-like, biofilm-like texture and at high magnification shows an organic filamentous fabric with calcite coatings and calcite rhombohedrons. Thin sections show three types of crystalline fabrics: 1) laminations varying in thickness and degree of stain absorption; 2) irregular and mottled laminations; and 3) recrystallized fabric. Within the cave, moonmilk is associated with cave rafts (thin layers of $CaCO_3$ that form at the air/water interface). The relative timing of moonmilk versus cave raft deposition is currently uncertain but indicates subaqueous deposition if concurrent. Preliminary results suggest there is a biotic component to moonmilk formation, and deposition was accretionary and primary.

CAVE RESPONSE TO SURFACE CLIMATE VARIABILITY: HIGH-RESOLUTION DRIP RATE DATA FROM BAT CAVE PASSAGE, CARLSBAD CAVERN, *J. B. T. Rasmussen*, jbtoledo@unm.edu, *V. J. Polyak*, and *Y. Asmerom*, Department Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

A number of paleoclimate studies depend on high-resolution stalagmite data as proxies for climate change. For stalagmite records at or near annual resolution it has become important to evaluate the delay, if any, transmitted from climate changes above the cave to the stalagmites recording climate variability. For this study three drip sites were chosen at the entrance to Bat Cave passage of Carlsbad Cavern, and drip rate monitors were installed at each site. Two years of continuous hourly drip rate data and hourly temperature, atmospheric pressure, and relative humidity data were collected between 2002 and 2004. Individual response at each drip site varied; however, results show the same seasonal trend of faster drip rates in the summer and slower rates in the winter. When compared to the daily temperature and precipitation data for the city of Carlsbad and Carlsbad Caverns, this trend reflects the surface precipitation cycle of wetter summers and drier winters. When compared to the other parameters measured inside the cave, an interesting relationship was observed between drip rate and pressure. Drip rate was well correlated to cave pressure and exhibited a strong diurnal cycle, suggesting that while the availability of water from meteoric precipitation may be the dominant factor controlling drip rate from year to year, other factors should be considered when evaluating variability on shorter timescales. Results of this study show the cave to be responsive at the sub-annual scale, supporting the use of annually resolved stalagmite records as proxies for climate change.

USING APATITIC CONODONTS AS A PROXY FOR PALEOCLIMATE CHANGE, *M. R. Emms* and *Maya B. Elrick,* Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

$\delta^{18}O$ values from calcareous foraminifera are routinely used to determine ancient climatic features such as seawater temperature, and the rise and fall of sea level is a well-documented and effective tool for understanding paleoclimate. Their use in pre-Cenozoic deposits is usually not possible because calcite is highly susceptible to diagenetic alteration. Conodonts make a good proxy for older rocks (Paleozoic–Mesozoic) because they are made of apatite as opposed to calcite and are not prone to alteration by diagenic processes. The Gray Mesa Formation at Mesa Sarca displays well-preserved Pennsylvanian (Desmoinesian) age rock that shows trends of transgression and regression on meter scales (cycles) and 40–80-m scales (sequences). In this study, conodonts are used as a proxy to determine whether the transgression and regression sequences (40–80-m thick) from the Gray Mesa Formation at Mesa Sarca are due to glacial eustasy. This will be determined by using the $\delta^{18}O$ values from the conodonts. Glacial eustasy as a mechanism will leave greater $\delta^{18}O$ values at the base of the unit and smaller $\delta^{18}O$ values at the top of the sequence.

POSTER SESSION 3—GEOLOGY OF QUESTA MINE ROCK PILES

NEAR SURFACE GEOPHYSICS FOR THE STRUCTURAL ANALYSIS OF A MINE ROCK PILE, NORTHERN NEW MEXICO, *R. L. Van Dam*, rvd@nmt.edu, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *L. A. Gutierrez*, Department of Mineral Engineering, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Virginia T. McLemore*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *G. W. Wilson*, Department of Mining Engineering, University of British Columbia, Vancouver, B.C., Canada V6T1Z4; *J. M. H. Hendrickx*, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *B. M. Walker*, Molycorp Inc., Questa, New Mexico 87556

A rock pile in northern New Mexico has been investigated by a multi-disciplinary research team to define pile characteristics and weathering behavior. Geophysical techniques and trenches were used to assess the internal structure of the material for the Goathill North rock pile. Electromagnetic (EM) induction was used to measure the spatial variability in bulk apparent electrical conductivity of the rock pile, whereas ground penetrating radar (GPR) was applied to image the internal structures of the rock pile. Seven trenches were excavated for analysis of the stratigraphy and material properties.

The measurements show the characteristics of the top 5–8 m of the rock pile. The electrical conductivities varied typically around 6 mS/m, but on the southwestern part of the rock pile anomalously high values as much as 30 mS/m were found. These high values can be explained by a different texture, mineralogy or pore-water composition, or a higher water content. In this area the penetration depth of the GPR waves is significantly reduced, and the reflection configuration is dominated by sub-horizontal reflections. In general, the GPR results have a character of reflectors whose dip directions and angles reflect the rock-pile deposition. The trench data show excellent correlation with the GPR survey.

CLAY MINERALOGY OF ALTERATION SCARS AND ROCK PILES, QUESTA AREA, NEW MEXICO, *Kelly M. Donahue*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *P. L. Hauff*, Spectral International, Arvada, Colorado; *Nelia D. Dunbar, Virgil W. Lueth, Virginia T. McLemore*, and *Lynn Heizler*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Clay mineral analysis by X-ray diffraction and near-IR spectroscopy for the Questa mine rock piles and nearby natural alteration scars indicate the presence of four different secondary phyllosilicate minerals: kaolinite, smectite, illite (mica), and chlorite. The abundance of these clay minerals varies significantly from the different sample localities. Kaolinite is most abundant in samples where the host rock is a feldspar-rich lithology (e.g. Amalia tuff) that has not been propylitically altered and is a minor component in samples from within the rock piles (predominantly andesite). Chlorite is common to the volumetrically most abundant propylitically altered andesites.

Analysis of materials from the alteration scars indicates sillite, smectite, and chlorite as the major clay minerals, with mixed layer illite/smectite and kaolinite as minor components. Veinlets of halloysite clay have been identified in some zones within the alteration scars.

Within the rock piles, yellow-orange brown oxidized zones (most common on the outer edges) contain more abundant illite and smectite. Chlorite is of greater abundance within darker brown to gray units more common to the center of the rock piles, removed from the oxidized zones. The distribution of clay minerals within the rock piles and alteration scars suggests the formation of illite and smectite in zones that are the most weathered. Chlorite is most abundant away from the oxidizing/weathering surface of the rock piles and may represent a less oxidized type of weathering within the piles or a clay phase inherent to the premined propylitically altered andesite.

POSTER SESSION 4—STRUCTURAL GEOLOGY AND STRATIGRAPHY

CONSTRAINTS ON ANCESTRAL ROCKY MOUNTAIN AND LARAMIDE DEXTRAL-OBLIQUE DEFORMATION IN NORTH-CENTRAL NEW MEXICO USING REGIONAL AEROMAGNETIC PATTERNS AND STRUCTURAL BALANCING CONSIDERATIONS, *Steve M. Cather*, steve@gis.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; and *Karl E. Karlstrom,* Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

The regional aeromagnetic map of north-central New Mexico was cut along prominent structural trends, then reassembled by rematching aeromagnetic anomalies and by restoring shortening along major contractile structures of Ancestral Rocky Mountain (ARM) and Laramide age. This reconstruction indicates dextral separations on the Picuris–Pecos fault (~ 40 km) and the Tusas–Picuris fault (~ 15 km) that are compatible with previous studies. Approximately 22 km of dextral slip on the Nacimiento fault system, restored subparallel to the Gallina fault, rematches aeromagnetic patterns and predicts ~ 7 km of shortening along the front of the Nacimiento–Peñasco uplift, similar to that proposed by Pollock et al. (2004, NMBGMR Bull. 160). Approximately 12 km of shortening in the Sangre de Cristo uplift is balanced by dextral slip on the Tijeras–Cañoncito fault. The latter fault serves to transfer slip northeastward from the Montosa and Paloma faults. Dextral components on the thrust faults of the eastern Sangre de Cristo Mountains may range between ~ 5 and 10 km, depending on the obliquity of shortening. This simplistic model predicts ~ 22 km of shortening in the southern Rockies near the latitude of Santa Fe. At least ~ 55 km and as much as ~ 90 km of dextral separation may be present on north-striking faults. Net dextral separation thus may be two to four times greater than contraction in north-central New Mexico. Dextral separations probably result mostly from ARM and Laramide tectonism, as no other known Proterozoic or Phanerozoic deformation can be inferred to have produced major dextral slip.

TIMING AND STYLE OF DEFORMATION OF THE SOUTHERN MAZATZAL PROVINCE, SAN ANDRES MOUNTAINS, NEW MEXICO, *A. Serna* and *Jeffrey M. Amato,* Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003

The Proterozoic deformational history in the San Andres Mountains is being determined through field mapping and ongoing geochronology. The oldest rock type is a deformed granitic gneiss that has been dated at 1.63 Ga (Roths 1991). Amphibolite dikes are both older and younger than undeformed granitic plutons dated at 1.46 Ga (Roths, 1991). Amphibolite is boudinaged suggesting extensional deformation. Based upon field data extension was in an east-west direction, emplacing the amphibolite, and then in a north-south direction to form the boudins. Within the boudins a foliation exists that occurred concurrently with boudin formation. Smaller younger granites crosscut the boudins and will be dated to constrain emplacement and deformation. Metasedimentary rocks include quartzite and phyllite. The orthogneiss has been subjected to deformation producing the gneissic banding and a second event that folded this earlier fabric. The metasedimentary rocks are deformed and appear to have been affected by the same events that produced the gneiss. Preliminary results from U-Pb of detrital zircons from the quartzite suggest that the sediments were locally derived from the 1.6 Ga plutons. The younger undeformed plutonic rocks provide constraints on the timing of deformation.

GEOLOGIC MAP OF EASTERN GRAND CANYON, ARIZONA: DOCUMENTING MULTI-PHASE LATE PROTEROZOIC DEFORMATION AND LARAMIDE REACTIVATION IN THE SOUTHWESTERN UNITED STATES, *J. Michael Timmons*, mtimmons@gis.nmt.edu, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801; *Karl E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; *Joel Pederson*, and *Matt Anders*, Department of Geology, Utah State University, Logan Utah 84321

The geologic map of eastern Grand Canyon includes ~ 670 km^2 of northeastern Grand Canyon National Park, Kaibab National Forest, and Navajo Nation Reservation. It consists of parts of the Point Imperial, Nankoweap Mesa, Walhalla Plateau, Cape Solitude, Cape Royal, and Desert View 7.5-min quadrangles.

Rocks exposed in the area include Paleoproterozoic basement rocks of the Granite Gorge Metamorphic Suite, the Grand Canyon Supergroup, including the Late Mesoproterozoic Unkar and Neoproterozoic Chuar Groups, relatively flat lying and mildly deformed Paleozoic strata, and Quaternary surficial deposits. Of particular focus in this map is new mapping in the Grand Canyon Supergroup and the structures related to supergroup deposition, deformation, and preservation.

The Grand Canyon Supergroup is one of the best-preserved remnants of Late Proterozoic sedimentary rocks in the southwestern United States. It provides an exceptional record of protracted, multi-phase deformation and intracratonic basin formation. The 1,255–1,100 Ma Unkar Group records syn-sedimentary, northwest-directed shortening and penecontemporaneous, orthogonal, northeast-southwest directed extension that are kinematically linked to "Grenville-age" tectonism. The 800–742 Ma Chuar Group records east-west directed extension on north-striking normal faults that are kinematically linked to the incipient rifting of western North America in the Late Neoproterozoic.

Paleozoic rocks in the map area underwent deformation associated with the development of monoclines during the Laramide orogeny. Laramide-age monoclines preferentially reactivate Proterozoic-age normal faults within the map area. We postulate that Laramide monocline development in the Colorado Plateau region may reflect inversion of Proterozoic normal faults.

CONSTRAINTS ON TIMING OF MAGMATISM AND DEFORMATION IN PROTEROZOIC PLUTONS OF THE BURRO MOUNTAINS, SOUTHWESTERN NEW MEXICO, *Andre Boullion*, *Jeffrey M. Amato*, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003; *George Gehrels*, Department of Geosciences, University of Arizona, Tucson, Arizona 85721; *Matthew T. Heizler* and *Richard P. Esser*, New Mexico Bureau of Geology and Mineral Resources, New Mexico Institute of Mining and Technology, 801 Leroy Place, Socorro, New Mexico 87801

Proterozoic intrusions in the Burro Mountains of the Mazatzal province, southern New Mexico were dated using laser ablation multiple collector inductively coupled plasma mass spectrometry (LA–MC–ICPMS). A pervasively deformed granodiorite from the northern Burro Mountains yielded an age of 1,625 ± 53 Ma. An undeformed two-mica granite from the Bullard Peak quadrangle yielded an intrusive age of 1,441 ± 41 Ma (17 grains). Twenty-seven cores and rims were dated from an undeformed coarse-grained granodiorite. Two older core ages are inherited grains from a ~1.67 Ga intrusion. The younger grains represent intrusion at 1,427 ± 23 Ma. Two samples of undeformed fine-grained biotite granite mapped as the Burro Mountain granite were dated. One sample (25 cores and rims) from this unit yielded an intrusive age of 1,431 ± 24 with inheritance at 1,650 ± 33 Ma. The other (21 cores and rims) intruded at 1,416 ± 18 with inheritance at ~1.68 Ga.

Monazite dating of pervasively deformed ~1.6 Ga metasedimentary rocks of the Bullard Peak Series of the Burro Mountain region has placed the main events of metamorphism of these units at 1,470 ± 16 Ma and 1,415 ± 14 Ma (Sanders 2003). An $^{40}Ar/^{39}Ar$ date on an amphibolite in this region records metamorphism of this unit at 1,419 ± 6 Ma. None of the ~ 1.4 Ga plutons of the region are deformed, suggesting emplacement of these units produced a thermal event only. This suggests that in southern New Mexico, the main episode of Proterozoic deformation occurred sometime between 1.63 and 1.47 Ga.

OPPORTUNITY FOR DIRECT DATING OF ~1.65 GA QUARTZITE-RHYOLITE SUCCESSION: WERE THERE TWO QUARTZITE-RHYOLITE "EVENTS" DURING CRUSTAL ASSEMBLY OF THE SOUTHWESTERN UNITED STATES?, *Amy Luther* and *Karl E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131

Paleoproterozoic quartzite-rhyolite assemblages remain an enigmatic and poorly dated tectonic feature of the 1.70–1.65 Ga crustal assembly of southern Laurentia. An understanding of these sequences will provide insight into the processes involved in the formation of continental lithosphere. 1–2-km-thick quartz arenites with greater than 95% quartz are found throughout the Southwest and are likely associated with the Yavapai and Mazatzal orogenies. Due to the lack of modern analogs, the depositional and tectonic settings of these first-cycle quartzites remain controversial.

Two distinctive suites of these sequences have been identified based on U-Pb geochronology; ~ 1.70 Ga and ~ 1.66 Ga. This study focuses on one of the younger of the quartzite-rhyolite assemblages, located in the Manzano Mountains of central New Mexico. In this locality, the rhyolites are stratigraphically above and below the Manzano Group quartzite, allowing a unique opportunity to precisely date these quartzites. Previously, a wide range of dates have been found for the Manzano area rhyolites, from 1,662 ± 1 to 1,680 ± 20 Ma (Shastri 1993), 1,680 ± 20 Ma (Bowring et al. 1983), and 1,700 ± 20 Ma (Unruh unpublished data). Using detrital zircons and monazites from the quartzite, and zircons from the rhyolite, new dates will tightly constrain the timing of deposition, timing of deformation, and the provenance of the quartzite. These data, along with field mapping and comparative studies between correlative quartzite-rhyolite sequences in Arizona and elsewhere in the Southwest, will provide essential information for understanding the tectonic evolution of continental lithosphere.

STRATIGRAPHIC ASSOCIATION OF UNCOMPAHGRE GROUP AND THE VALLECITO CONGLOMERATE? INSIGHT INTO PALEOPROTEROZOIC INTRACRATONIC BASIN FORMATION, *Austin Zinsser*, and *Karl E. Karlstrom*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico, 87131

Thick successions of Proterozoic and lower Paleozoic quartz arenite are broadly distributed along the juvenile accretionary margins of southern Laurentia. These packages are anomalous in their maturity, thickness, and purity and are often stratigraphicaly associated with metarhyolites. Recent research in the Southwest has identified what appear to be two distinct pulses of quartzite deposition at ~ 1.70 and ~ 1.66 Ga. The first pulse coincides with the end of the Yavapai orogeny (1.70 Ga) and is characterized by deposition of the rhyolite-quartzite assemblage directly on unroofed basement (Karlstrom et al. 2004). Circa 1.7 Ga quartzites are present throughout Colorado and northern New Mexico, in the Colorado Front Range, Gunnison region, and Sangre de Cristo, Tusas, and Needle Mountains. Whereas the majority of these quartzite packages characteristically overlie metarhyolites, the Uncompahgre Group of the Needle Mountains is in tectonic contact with exhumed 1.78–1.69 Ga basement. Although there is some shearing along the contact, a basal conglomerate and paleosol horizon suggest an original angular unconformable relationship between Yavapai province basement and quartzite "cover." Another question concerns the association of the Uncompahgre Group with the nearby Vallecito Conglomerate. We plan to test whether the Vallecito Conglomerate correlates with the basal facies of the Uncompahgre Group; if so, the Needle Mountains preserve a unique sedimentary succession not seen in other 1.7 Ga quartzite localities. We will evaluate the nature of these relationships through a combination of detailed structural analysis and detrital mineral geochronology in order to refine our understanding of the rhyolite-quartzite phenomenon.

TYPE SECTION OF THE PENNSYLVANIAN SANDIA FORMATION, SANDIA MOUNTAINS, NEW MEXICO, *Karl Krainer*, Institute of Geology and Paleontology, University of Innsbruck, Innrain 52, Innsbruck A-6020 AUSTRIA; and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

In 1900 C. L. Herrick named the "Sandia Series," and we designate a lectostratotype section of the Sandia Formation at Doc Long Campground in the Sandia Mountains (SE ¼ sec. 14 T11N R5E). This well-exposed, fossiliferous and accessible section well represents Herrick's and subsequent workers' concept of the Sandia Formation. At the lectostratotype section, the Sandia Formation rests nonconformably on Proterozoic granite and is disconformably overlain by cherty limestone of the Gray Mesa Formation. The Sandia Formation is ~ 124 m thick and consists of shale (41% of the section), sandstone/conglomerate (36%), and limestone (23%) and can be divided into lower (0–52 m) and upper (53–124 m) parts. The lower part is mostly gray to black shale, one layer yielding fossil plants. Sandstone and conglomerate beds are relatively thin (< 4.2 m thick), arkosic, and ripple laminated or crossbedded. Limestone beds are mostly gray, fossiliferous bioclastic wackestone; some beds contain abundant siliciclastic material. The upper part of the section has less shale with thicker sandstones and limestones. We interpret deposition of the lectostratotype Sandia Formation to have taken place in brackish to marine coastal facies (dark shales with marine fossils), fluvial channels and upper shoreface sand bodies (sandstones/conglomerates), and shallow marine shelf facies (limestones). Irregular stacking of different lithotypes and interbedded coarse nonmarine lithofacies and marine lithofacies indicate syndepositional tectonics influenced sedimentation. The Sandia Formation at the lectostratotype section is thus a synorogenic deposit of the first pulse of the Ancestral Rocky Mountain orogeny in the central New Mexico foreland.

REFINEMENT OF UPPER TRIASSIC CHINLE GROUP BIOSTRATIGRAPHY AND MAGNETOSTRATIGRAPHY, CHAMA BASIN, NORTH-CENTRAL NEW MEXICO, *Kate E. Zeigler*, *John W. Geissman*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131; and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The Chama Basin, north-central New Mexico, contains excellent exposures of Upper Triassic Chinle Group strata that can be used to refine Late Triassic vertebrate biostratigraphy and to develop an improved magnetic reversal chronology for the Late Triassic. Recent fossil discoveries have expanded the known fauna for both the lower Chinle Salitral Formation and the upper Chinle Mesa Montosa Member (Petrified Forest Formation). The addition of the metoposaurid *Buettneria* and the aetosaur *Desmatosuchus* to the Salitral fauna confirms an Adamanian age for these strata. The discovery of material pertaining to *Buettneria*, the aetosaurs *Typothorax coccinarum* and *Paratypothorax*, the archosaur *Vancleavea,* and other fauna confirms a Revueltian age for the Mesa Montosa Member. Paleomagnetic sampling has been concentrated on mudrocks, using a block sampling approach. Block samples typically carry a well-defined, well-grouped magnetization dominated by pigment hematite that is unblocked below about 660°C (e.g., for a single horizon, with six independent samples, Decl. = 185.5°, Incl. = 0.3°, α_{95} = 6.6°, and k = 102.6). Sandstones and siltstones contain pigment hematite and, based on preliminary experiments, contain both detrital hematite and some magnetite. An initial reversal chronology has been developed for Poleo and Petrified Forest strata (middle and upper Chinle Group) in the Chama Basin. The Petrified Forest Formation is characterized by fairly regular reversals, and the Poleo Formation is dominated by reverse polarity.

THE TO2–TO3 TRANSITION IN THE SAN JUAN BASIN, NEW MEXICO, *T. E. Williamson*, twilliamson@nmmnh.state.nm.us, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The Torrejonian North American Land-Mammal "age" (NALMA) was subdivided into "subages" named To1–To3 based largely on the succession of mammals in the Nacimiento Formation, San Juan Basin, New Mexico. The To2 interval is based primarily on the faunas of the "*Deltatherium* zone." The To3 interval is based on the faunas of the *Mixodectes pungens* zone (= "*Pantolambda* zone"). The To2–To3 boundary is marked by the extinction of several genera including *Deltatherium*, *Triisodon*, *Haploconus*, and *Ellipsodon*. Several species making their first appearance include *Mixodectes pungens* and *Pantolambda bathmodon*. Some of the differences between the two faunas can be attributed to a collecting bias as the *M. pungens* zone has been sampled extensively for microvertebrates, and the "*Deltatherium* zone" has not. Also, their is usually a distinct difference in preservation resulting in a taphonomic bias between the two zones. One aspect of this is manifested in the abundant preservation of fossil mollusks in the *M. pungens* zone and their near absence in the underlying "*Deltatherium* zone."

For part of the West Flank of Torreon Wash, however, the distinctive red bed facies of the *M. pungens* zone extends downward to include strata that fall within the "*Deltatherium* zone." This results in the unusual association of typical "*Deltatherium* zone" fossils including *Triisodon* and *Deltatherium* with gastropods. Also, the rare pentacodontid *Pentacodon occultus* is reported from the "*Deltatherium* zone" for the first time based on NMMNH P-44597, a specimen consisting of the lower jaws and teeth of this taxon, from this area.

POSTER SESSION 5—PALEONTOLOGY

FIRST NEW MEXICO RECORD OF *SPHENOTHALLUS* FROM THE UPPER PENNSYLVANIAN (MISSOURIAN) ATRASADO FORMATION OF SOCORRO COUNTY, *Allan J. Lerner* and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Sphenothallus Hall 1847 is a widely distributed invertebrate taxon that ranges in age from Early Cambrian to Permian. Its phylogenetic affinities are problematic. We document the first New Mexico record of *Sphenothallus*, which was collected from NMMNH locality 4667, in the Upper Pennsylvanian (Missourian) strata of the Atrasado Formation, near Tinajas Arroyo in Socorro County. A single specimen (P-37916) assigned to *Sphenothallus* sp. was found in a 4-m-thick unit of thinly laminated, gray shale stratigraphically low in the Atrasado Formation. Deposition of this unit took place within a coastal plain lacustrine environment as indicated by sediments and by conchostracans, insects, and terrestrial plants. *Sphenothallus* is an allochthonous element within the fossil assemblage. P-37916 is preserved as part and counterpart. It consists of an incomplete crushed sphenothallid tube, lacking a basal attachment structure or apertural opening, which has a length of 35 mm and a maximum width of 10 mm. A small segment of the tube is displaced that retains a thickened lateral margin. Many (~ 200) irregularly circular holdfasts are attached to the tube surface. Holdfast diameters range from 0.25 mm to 1 mm, indicating that fastening occurred over a period of time. Although both tube and holdfast morphology is characteristic of the genus *Sphenothallus*, there is insufficient material to make a specific assignment. *Sphenothallus* holdfasts have been reported on various surfaces including brachiopods and crinoids. Historically, *Sphenothallus* has often been misidentified or neglected, which makes it probable that it is more common in New Mexico than has been recognized.

EARLY PERMIAN (WOLFCAMPIAN) MARINE MACROINVERTEBRATE ASSEMBLAGE FROM THE SHALEM COLONY FORMATION (HUECO GROUP), DOÑA ANA MOUNTAINS, NEW MEXICO, *Justin A. Spielmann*, Justin.A.Spielmann@dartmouth.edu, Dartmouth College, Hinman Box 4571, Hanover, New Hampshire 03755; *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104; and *Karl Krainer*, Institute of Geology and Paleontology, University of Innsbruck, Innrain 52, Innsbruck A-6020 AUSTRIA

The marine macroinvertebrate assemblages of the Hueco Group in the Doña Ana Mountains have yet to receive thorough study, although extensive assemblages have been well described from the neighboring Robledo Mountains. We report and illustrate a diverse macroinvertebrate assemblage recently discovered in the

Doña Ana Mountains in a shale bed ~ 15 m below the top of the Shalem Colony Formation and only a few meters below fusulinacean packstones of the *Pseudoschwagerina* zone. This assemblage occurs in the upper part of a 2.7-m-thick shale interval, which is overlain by a 0.4-m-thick, fossiliferous limestone bed containing brachiopods and gastropods. This assemblage consists of brachiopods (*Squamaria moorei*? Muir-Wood & Cooper, *Derbyia* sp., *Composita cracens* Cooper & Grant, *Crurithyris tumibilis* Cooper & Grant), bivalves (*Septimyalina burmai* Newell), nautiloids (Pseudorthoceratidae), gastropods (*Tychonia inexpectata* Kues, *Euphemites* sp.) and bryozoans (*Protoretepora* sp.). The fauna is dominated by *S. moorei*? and bryozoans. The *S. moorei*? are in various states of preservation, including specimens more complete than previously reported from the Robledo Mountains. The Shalem Colony Formation assemblage is indicative of shallow marine, shelf waters with enough energy to move large brachiopod shells. The macroinvertebrate assemblage from the Shalem Colony Formation is less diverse than, but similar in composition and relative abundances to, the more extensive assemblages known from the stratigraphically higher Robledo Mountains Formation in the Robledo Mountains. This suggests chronofaunal stability of the invertebrate macrofauna during much of Hueco Group deposition on the Early Permian Robledo shelf of southern New Mexico.

THE POSTCRANIAL SKELETON OF *REVUELTOSAURUS CALLENDERI* (ARCHOSAURIA: CRUROTARSI) FROM THE UPPER TRIASSIC BULL CANYON FORMATION OF EAST-CENTRAL NEW MEXICO, *Adrian P. Hunt*, ahunt@nmmnh.state.nm.us, and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

In 1986 field parties collected an extensive vertebrate fauna from the Late Triassic (Revueltian lvf: early Norian) Bull Canyon Formation of east-central New Mexico. These included teeth assigned to *Revueltosaurus callenderi,* which was considered to represent an ?ornithischian dinosaur. Other associated remains included a partial skeleton (NMMNH P-16932) and other specimens of an undescribed armored crurotarsan. Preparation of dentulous cranial fragments of NMMNH P-16932 has shown that this animal is *Revueltosaurus* and that it is not an ornithischian dinosaur.

Revueltosaurus is a crurotarsan distinguished by wide rectangular paramedian osteoderms with an irregular pattern of deep pits and no lateral osteoderms, a wide tarsus that has a small astragalar medial process and corresponding medial calcaneal concavity, and teeth that are remarkably convergent on ornithischians.

Many partial osteoderms and one complete osteoderm are in the collection. The complete osteoderm is rectangular and is 64 mm long, 33 mm wide, and 5 mm thick. The dorsal surface is covered by an irregular pattern of deep, rounded pits. The medial end of the osteoderm is thickened. The osteoderm thins at its lateral and anterior margins. A smooth lapet runs along the anterior margin and broadens near the lateral margin.

This taxon represents a crurotarsan because it possesses: (1) a hemicylindrical calcaneal condyle for the fibula; (2) a flexed tibial facet on astragalus; (3) a single articulation between astragalus and calcaneum; and (4) single paramedian osteoderm per vertebra. Further, it is assignable to a clade containing derived crurotarsans on the basis of an advanced “crocodile-normal” tarsus.

A SKULL OF THE PHYTOSAUR *PSEUDOPALATUS* FROM THE UPPER TRIASSIC (LATE CARNIAN) SANTA ROSA FORMATION OF CENTRAL NEW MEXICO, *Adrian P. Hunt*, ahunt@nmmnh.state.nm.us, and *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Pseudopalatus is a common genus of Late Triassic phytosaur that has biochronologic significance; its an index taxon for the early Norian Revueltian lvf. A skull from the late Carnian of central New Mexico is the first occurrence of this genus before the Norian.

NMMNH P-25745 is from NMMNH locality 3108, which is the type locality of *Typothorax antiquum*. This locality is in the Tres Lagunas Member of the Santa Rosa Formation in Santa Fe County. NMMNH P-25745 is a partial skull represented by the region posterior to the mid point of the orbits. The anterior margin slopes anteriorly such that the lateral temporal fenestrae are preserved on both sides. The skull is slightly flattened dorsoventrally. NMMNH P-25745 can be assigned to *Pseudopalatus* on the basis of: possessing a moderately wide postorbital squamosal bar, supratemporal fenestrae that are short and narrow in dorsal view with narrow anterior margins, and a parietal-supraoccipital complex that has an inverted U shape.

This is the first occurrence of *Pseudopalatus* before the beginning of the Norian. This provides evidence for a refinement of the robust biochronology of the Late Triassic based on land vertebrate biochrons.

THE MICROVERTEBRATE FAUNA OF SHARK TOOTH HILL, REDONDA FORMATION (LATE TRIASSIC:APACHEAN), QUAY COUNTY, NEW MEXICO, *Andrew B. Heckert*, aheckert@nmmnh.state.nm.us, *Spencer G. Lucas*, and *Adrian P. Hunt*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The Upper Triassic Redonda Formation in east-central New Mexico consists of fluvial, lacustrine, and lacustrine-margin strata deposited during latest Triassic time. The macrovertebrate body fossil record of the formation is understudied, but known to include the redfieldiids *Cionichthys* and *Synorichthys stewarti*, the semionotids *Semionotus* and cf. *Hemicalypterus*, the lungfish *Arganodus*, an indeterminate coelacanth, the temnospondyl *Apachesaurus gregorii*, a large cynodont, the archosauromorph *Vancleavea*, the phytosaur *Redondasaurus*, the aetosaur *Redondasuchus*, a giant sphenosuchian, and possible theropod dinosaurs. The microvertebrate fauna is essentially unstudied, but is known to include a broadly similar fish fauna. Screenwashing for microvertebrates at Shark Tooth Hill near San Jon yielded a microvertebrate fauna composed of redfieldiid and semionotid fish, indeterminate reptiles, several morphotypes of archosauriform teeth, small phytosaurs, and possible ornithischians. Chondrichthyans are conspicuously absent. Many of the archosauriform tooth morphotypes are known from much older (Adamanian) taxa, and thus are not age-diagnostic. The microvertebrates do, however, provide some insight into the small-bodied fauna of the Redonda Formation, which appears to have been dominated by small archosauriforms. The putative ornithischian teeth, while fragmentary, constitute the only record of ornithischian body fossils in the Redonda Formation. The diversity from this preliminary sample hints at a large microvertebrate fauna that remains largely undiscovered, and should spur additional interest in the microvertebrate record of the Redonda Formation. Indeed, the Redonda Formation is the most fossiliferous stratigraphic unit of latest Triassic age in western North America, and is clearly the key to understanding latest Triassic vertebrate evolution.

COPROLITES AND COLOLITES FROM THE LATE TRIASSIC THEROPOD DINOSAUR, *COELOPHYSIS BAURI*, WHITAKER QUARRY, RIO ARRIBA COUNTY, NEW MEXICO, *Larry F. Rinehart*, rinehartl@nmmnh.state.nm.us, *Adrian P. Hunt, Spencer G. Lucas*, and *Andrew B. Heckert*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

New Mexico Museum of Natural History's Whitaker (*Coelophysis*) Quarry block (C-8-82) from the Apachean-aged Rock Point Formation of the Chinle Group contains abundant fossils of *Coelophysis bauri*, non-dinosaurian tetrapods, fish, and invertebrates. At least three specimens of *C. bauri* have fossil fecal material directly associated with articulated skeletal material These specimens apparently include material retained within the posterior intestine (cololites) as well as evacuated material (coprolites). The cololites and coprolites occur between the ischia and the proximal caudal vertebrae, and posteroventral to this area. Most of the coprolite material is formless and was apparently somewhat mixed with still-wet mud and silt at or near the time of death. In P-44801, a small amount of coprolite material contains sparse bone fragments. The cololite and/or coprolite material associated with P-42352 is enigmatic; it consists of small bone fragments in a densely packed matrix of small (~1 mm long by ~0.1 mm diameter), rod-shaped material. The coprolitic material associated with P-44552 is copious, formless, and rich in bone fragments. Bone fragments prepared from this material include a distal ulna, an ulnare, and partial phalanges that apparently pertain to juvenile *Coelophysis* and provide further evidence of cannibalism in this dinosaur. Additional material appears to include wrist bones, long-bone and rib fragments, and thin sheets similar to skull or pelvic bone. Few examples of close associations between fecal material and vertebrate fossils are known, and this is a unique occurrence for a dinosaur.

LATE JURASSIC TURTLE FROM THE MORRISON FORMATION IN CENTRAL NEW MEXICO, *Spencer G. Lucas, Larry F. Rinehart, Andrew B. Heckert, Ron Peterson*, and *Rod Peterson*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

The Peterson Quarry, west of Albuquerque in central New Mexico, is a sauropod-dominated, fluvially concentrated bonebed in the Brushy Basin Member of the Upper Jurassic Morrison Formation. We document a recently prepared incomplete plastron and carapace of a turtle from the Peterson Quarry, which is the first non-dinosaurian vertebrate fossil from the quarry and New Mexico's first Jurassic turtle. The specimen consists of parts of the entoplastron, mesoplastra, hypoplastron, six peripherals, and very damaged costals. It is readily assigned to *Glyptops plicatulus* (Cope) based on the following features: carapace low, surface ornamentation consists of tubercles and raised ridges, peripherals not scalloped, mesoplastra meet at midline, and plastron relatively thin. The identifiable suture pattern also well matches that of *G. plicatulus*. *Glyptops* is a characteristic Morrison Formation turtle previously reported from Wyoming, Utah, and Colorado. The Peterson Quarry record of *Glyptops* thus is its southernmost occurrence. We interpret *Glyptops* as a semi-aquatic omnivore that was a regular inhabitant of Morrison streams and stream margins.

FIRST RECORD OF *EOCONODON GAUDRIANUS* IN THE LATE PUERCAN OF NEW MEXICO, *Thomas E. Williamson*, twilliamson @nmmnh.state.nm.us, New Mexico Museum of Natural History, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Two Puercan faunal zones have been recognized in the early Paleocene Nacimiento Formation. These are known as the "*Hemithlaeus kowalevskianus* zone" (= "*Ectoconus* zone") and the "*Taeniolabis* zone." The mammalian faunas from these zones form the primary basis for the recognition of the Pu2 and Pu3 interval zones, respectively. Pu3 is distinguished from Pu2 primarily on the absence of several taxa including the periptychid condylarths *Hemithlaeus kowalevskianus* and *Conacodon entoconus* as well as the presence of the multituberculate *Taeniolabis toaensis*. The two interval zones are also distinguished by the presence/absence of other taxa, especially those that are rare. Reported here is the first record of the triisodontid *Eoconodon gaudrianus* from the *Taeniolabis toaensis* zone.

E. gaudrianus is an uncommon component of the "*H. kowalevskianus* zone." It is represented in the "*Taeniolabis zone*" by a single specimen, United States National Museum (USNM) 405671, a crushed and distorted m1 and an associated partial left dentary with m2 recovered from "Upper Puerco, Barrel Springs Arroyo." The specimen falls within the size range of *E. gaudrianus* from the "*H. kowalevskianus* zone" and possesses the high trigonids with the protoconids and metaconids merging above the trigonid basin that is characteristic of the taxon.

AN UPDATED ELECTRONIC BIBLIOGRAPHY OF NEW MEXICO FOSSIL VERTEBRATES, *Caleb Lewis, Andrew B. Heckert*, and , *Spencer G. Lucas*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

We present here an electronic update of Kues and Lucas' (1993) bibliography of New Mexico fossil vertebrates. The bibliography has been improved by indexing references by taxonomic groups covered as well as geological age (time periods or epochs). References considered to contain only incidental information about New Mexico fossil vertebrates were deleted from the Kues and Lucas bibliography. The current bibliography was assembled using Thomson Reasearchsoft Endnote 7, references for the updated bibliography were compiled from personal Endnote libraries, Kues and Lucas (1993), personal bibliographies and curriculum vitae, Georef, New Mexico Geological Society guidebooks, and New Mexico Museum of Natural History and Science (NMMNHS) bulletins. References from these were compiled into one Endnote library, which will be made available for download on the NMMNHS Geosciences Collection's website (www.nmfossils.org), and a searchable database of the bibliography will be also incorporated into that website.

The bibliography reflects the continued interest in fossil vertebrates from New Mexico, and contains more than 2,000 references, a ~ 30% increase since 1992, the last year indexed by Kues and Lucas (1993). This reflects the ongoing work of the NMMNHS staff, associated volunteers, and University of New Mexico students, as well as researchers outside the state. Areas of particular growth include the upper Paleozoic, particularly the Permian–Pennsylvanian footprint record, Late Triassic nonmarine tetrapod record, Jurassic Morrison Formation (particularly the Peterson Quarry), and the Neogene (particularly the Pliocene–Pleistocene). Cretaceous and Paleocene vertebrates from the San Juan Basin still compose a substantial portion of the bibliography.

"REDISCOVERY" OF THE ROUSSEAU FLOWER COLLECTION AT THE NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE, *Andrew B. Heckert*, aheckert@nmmnh.state.nm.us , *J. McDonnell*, and *R. Traeger*, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Rousseau Flower (1922–1988) is well known for his many contributions to the taxonomy of nautiloid cephalopods (Paleocephalopoda) and to the stratigraphy of the lower Paleozoic in New Mexico and elsewhere. Dr. Flower was senior paleontologist at the then-New Mexico Bureau of Mines and Mineral Resources (NMBMMR) and professor of paleontology at New Mexico Tech from 1951 through 1988. During his professional career he acquired an extensive collection of invertebrate fossils including cephalopods, trilobites, brachiopods, and corals from New Mexico, New York State, and other localities. The New Mexico Museum of Natural History and Science (NMMNH&S) received the bulk of Flower's collection along with the rest of the NMBMMR paleontology collection in 1994. These collections include more than 600 fossils identified and cataloged by Dr. Flower, including almost 300 type specimens. The type and many illustrated specimens have been re-curated, re-cataloged, and added to the NMMNH&S database (www.nmfossils.org), and are now available for study by the scientific community for the first time in nearly two decades.

Many of Flower's type and figured specimens are organized taxonomically and occupy 23 24 x 29" steel drawers for easy access. Uncatalogued specimens are loosely arranged in stratigraphic order and occupy approximately 530 18 x 24" trays in another 24 cabinets, with another ~3 cubic yards of specimens still packed in boxes. The uncatalogued specimens include thousands of fossils from dozens of localities in Paleozoic strata across southern New Mexico and west Texas. Those interested in studying these fossils are encouraged to contact the first author.

NMFOSSILS.ORG—THE NEWEST PALEONTOLOGICAL RESOURCE AND OUTREACH INITIATIVE OF THE NEW MEXICO MUSEUM OF NATURAL HISTORY AND SCIENCE, *Andrew B. Heckert*, aheckert @nmmnh.state.nm.us, New Mexico Museum of Natural History and Science, 1801 Mountain Road NW, Albuquerque, New Mexico 87104

Within 18 months of going live, the New Mexico Museum of Natural History and Science (NMMNH&S) online paleontology database recorded over 150,000 page views from more than 10,000 visitors. Inspired by this success, the scientific, educational outreach, exhibits, and computer specialist staff at the NMMNH&S have accelerated plans to make more information available online to those interested in New Mexico's fossil record. Accordingly, paleontological information ranging in scale and complexity from the aforementioned database to a children's interactive is now available from one centralized site, www.nmfossils.org. The interactive provides diverse information on selected paleontological, mineralogical, and biological specimens. The interactive is designed to be language-independent and allows students to glean basic size, weight, age, and other information on a dozen specimens from the collections. For the professional and interested avocational paleontologist, we also added a digital bibliography of the primary literature on the vertebrate paleontology of the state, as well as many downloadable (.pdf) files based on the collection and related staff research. Many of these files are of publications that are now out of print and thus otherwise nearly unavailable. Perhaps the most intriguing new feature is a "photo gallery" allowing interested parties to browse more than 1,600 digital images of specimens in the collections. Planned additions include an index to the type specimens housed in the collections and improved links highlighting the paleontological wealth, resources, and history of individual counties. Together these online resources should be an invaluable asset for parties ranging from school children to geoscience professionals.

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 $100.00 for best student talk was given to Sammy Tachie-Menson for his presentation "Variation of temperature and pore oxygen and carbon dioxide in rock piles at the Molycorp Questa mine, New Mexico."

For the first time two students tied for first place in the poster competition; both will receive awards of $100.00. The winners are Andre Boullion for "Constraints on timing of magmatism and deformation in Proterozoic plutons of the Burro Mountains, southwestern New Mexico" and Kate Zeigler for "Refinement of Upper Triassic Chinle Group biostratigraphy and magnetostratigraphy, Chama Basin, north-central New Mexico."

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