New Mexico Institute of Mining and Technology

TWO-STAGE LANDSLIDE EMBLACEMENT ON THE ALLUVIAL APRON OF AN EOCENE STRATOVOCANO
Ochrios, Michael, M.S.

The Sawtooth Mountains, western New Mexico, comprise erodionally isolated klippen of an initially contiguous landslide complex that developed on the alluvial apron of an Eocene stratovolcano during late Laramide volcanic-tectonic activity. Volcanogenic siltstone, alluvial sandstone and conglomerate of the lower Spears Group were deposited on mainly fine-grained Baca Formation (fluvial flood-plain facies). The klippen are underlain by a locally exposed, low-angle fault within fine-grained, laminated basal Spears strata (distal fan). The lower fault is overlain by a sheet 7–100 m thick of sandy volcanogenic sandstone (Volcaniclastic Unit of Largo Creek, mid-fan facies) that is strongly deformed by large-scale soft-sediment structures. Another low-angle fault caps this sheet, and carries less-deformed conglomerates (Dog Springs Formation, proximal fan facies).

The lower fault, where exposed has a poorly developed fault core, locally comprised of floury or foliated gouge, and surrounded by a thin, poorly developed fractured damage zone. The upper fault has a well-developed cataclasite core, 0.12–0.40 m thick, with 1–3 primary slip surfaces, rare pseudotachylite, and local cataclastic injections into the upper plate. Striations on both faults are widely dispersed but cluster in two directions, NNE and ESE. The main structure in the upper plate is an E-verticne monocline.

We conclude that the landslide complex was emplaced in two events, first N-directed sliding down the alluvial apron, while the sediments were poorly consolidated. Most soft-sediment deformation probably occurred in this event, due to loading and shear transmitted down from the upper plate and causing liquefaction. The second event was likely due to W-side-up uplift on the Laramide Hickman Fault, located west of the field area, likely triggered by an earthquake, and occurred at seismogenic slip rates, forming pseudotachylite and injections, after the sediments were partially lithified.

ASSESSING THE RINCON GEOTHERMAL SYSTEM USING TRANSIENT ELECTROMAGNETIC SURVEYS AND HYDROTHERMAL MODELING
Horne, Melinda, M.S.

The Rincon geothermal system (RGS) is one of the highest temperature geothermal resources in New Mexico, with bottom hole temperatures reaching 99 °C. This blind geothermal system has no surface expression other than opal deposits. In 1993, a geothermal slim hole (SLH-1) was drilled. The temperature-depth profile in SLH-1 was overturned, suggesting transient geothermal behavior. We remeasured the temperature in SLH-1 in September 2018 and found nearly unchanged in the intervening 25 years, suggesting steady state.

To test if the system is transient or steady state, we developed a suite of cross-sectional models of groundwater flow, heat, and solute transport for the Rincon upflow zone. Steady state hydrothermal modeling was able to recreate the SLH-1 temperature profile given a basal fault zone temperature of 120 °C and flux of 300 m²/yr, and an out-of-the-plane temperature of 9.6 °C and flux of 0.01 m²/yr within a confined aquifer. However, it failed to match the lower portion of the SLH-1 profile. Transient modeling provided a good fit after 100 years of flow with a basal fault zone temperature of 150 °C and flux of 200 m²/yr. But computed temperature differences between 100 and 120 years were too large to be consistent with the minimal changes in SLH-1 between 1993 and 2018.

We electrically imaged the RGS using transient electromagnetics (TEM) to gain understanding of the size and extent of the upflow zone. Between 2016-2018 we collected 14 transient electromagnetic soundings, revealing a relatively low (4 ohm-m) formation resistivity layer at a depth of about 100 m with an upper surface that corresponds to the position of the water table. The 30 m thick electrically conductive layer is underlain and overlain by more electrically resistive sediments with resistivities ranging between 25 to 80 ohm-m. Ultimately, it was unclear whether TEM can image an electrically conductive upflow zone.

CHARACTERIZING HYDRAULIC PERMEABILITY WITH ELECTROMAGNETIC GEOPHYSICS AND HYDROLOGIC MODELING
Pepin, Jeff, Ph.D.

Advancement in the geothermal industry can be accelerated by the development of new and innovative tools to prospect, characterize, and evaluate geothermal resources. This work describes our efforts to develop two new approaches to studying geothermal systems. Additionally, electrical resistivity and hydrothermal modeling are used in conjunction to refine the conceptual model of crystalline-basement hosted geothermal resources in tectonically-active rift environments. We begin by attempting to improve our ability to estimate subsurface hydraulic permeability patterns. Crustal permeability has profound implications on geothermal resource development potential and sustainability. We examine if incorporating magnetotelluric (MT) geophysical observations into hydrothermal model calibration has potential to estimate permeability on a regional scale. This is done by modeling the electrical resistivity of a simplified regional groundwater flow system and then converting the results to MT data, which are directly sensitive to crustal fluids over a dynamic range of depths. All transport regimes and permeabilities considered yield distinctly different MT responses, which indicates that MT data is systematically affected by crustal permeability. By using a combination of hydrologic, forward MT, and inverse MT modeling, we conclude that electrical resistivity from MT data can likely estimate permeability by being integrated into hydrologic model calibration. Successful implementation of this approach hinges on having adequate control of subsurface porosity, mineralogy, and solute reaction rates.

The tectonically-active Rio Grande rift of New Mexico is believed to contain extensively-fractured and permeable crystalline basement rocks in select regions, which permit deep groundwater circulation. This deeply circulating groundwater ascends through gaps in overlying confining units and along faults to give rise to shallow geothermal resources. We combined forward hydrothermal modeling with MT and transient electromagnetic (TEM) geophysics to image a deep (6 to 10 km) crystalline basement-hosted groundwater flow system that is associated with the Truth or Consequences (T or C) geothermal resource along the central Rio Grande rift. Previously published hydrothermal models indicate that the effective hydraulic permeability of the crystalline basement in the T or C watershed must be unusually high (10⁻¹² m²) to explain measured hot-spring temperatures (41°C), geothermometer reservoir temperature estimates (167°C), vertical specific discharge rates (3 to 6 m/yr), and mean carbon-14 groundwater residence times (7,292 yr). We further evaluate this conceptual model using electrical resistivity and aquifer testing. Regional subsurface resistivity patterns imply the presence of a single-pass and deeply circulating regional groundwater flow system between the upland recharge area to the west and the T or C hot-springs district near the Rio Grande to the southeast. The resistivity of the crystalline basement is observed to be between 100 and 200 ohm-m to depths of 10 km, which is typical of highly-weathered and saturated igneous
and metamorphic rocks and is much more conductive than typical unweathered crystalline rocks. The homogeneity of basement resistivities indicates that fractures at depth are likely to be well-connected and prevalent throughout much of the watershed. Regional faults do not appear to compartmentalize the groundwater system but may serve as conduits for upwelling fluids. There is also a conductive (50 ohm-m) feature at 6 to 10 km depth below the T or C hot-springs district that may represent upwelling brackish geothermal fluids. This feature is reproduced well by hydrothermal models that we use to simulate electrical resistivity patterns. Aquifer testing carried out within the T or C hot-springs district estimate local crystalline basement permeability to be on the order of 4 x 10^{-10} m^2. Overall, these results indicate the likely presence of extremely permeable crystalline rocks on a regional scale that permit groundwater circulation to depths of up to 10 km within this watershed. This work provides evidence that seismically active rift settings with prolonged tectonic histories may contain extensive regions of highly-fractured crystalline rocks that facilitate groundwater circulation to great depth.

Lastly, we use principal component analysis (PCA) and k-means clustering to explore distinguishing characteristics between known-geothermal resources (KGRs) in southwest New Mexico. We then use those characteristics to outline a sub-region of higher geothermal potential and then prospect this sub-region by identifying non-KGR locations that are similar to its KGRs. Twenty geological, thermal, geochemical, and hydrologic datasets are incorporated into this analysis. Our approach indicates that geothermal resources in this area are distinguishable by their physiographic/tectonic province (e.g. Rio Grande rift, Basin and Range) and identifies two primary exploration areas that are related to classic forced-convection geothermal systems and secondary fracture permeability resources, respectively. The secondary permeability region is comprised primarily of low-temperature hot spring systems. The forced-convection region contains some of the hottest liquid-dominated resources in New Mexico. Further analysis of this hotter region indicates that the southeast portion of the study area is most likely to yield new economically-viable geothermal resources. Areas near Lordsburg, Las Cruces, Deming, and south of Socorro are believed to be particularly promising due to their strong relation to developed moderate/high temperature geothermal resources within the study area. These target areas agree well with a recently published geothermal prospectivity map of the region. The PCA and clustering framework used in this study is most applicable to the preliminary and exploration phases of geothermal resource discovery, as it was able to classify KGRs on a regional scale, while also identifying regions of elevated geothermal potential.

New Mexico State University

**PROVENANCE AND SEDIMENT DISPERAL TRENDS FROM LOWER–UPPER CRETACEOUS NONMARINE STRATA OF THE CORDILLERAN FORELAND BASIN IN NORTHERN NEW MEXICO**

Bartnik, Samantha Rae, M.S.

Lower–Upper Cretaceous (Albian–Cenomanian) strata of the Cordilleran foreland basin outcrop throughout parts of northern New Mexico and are thought to record the final phase of sedimentation associated with normal subduction of the Farallón plate beneath western North America, and resultant deformation and volcanism linked with the Sevier fold/thrust belt and Cordilleran arc, respectively. Presented here are sandstone modal composition trends (N=22) and U-Pb detrital zircon ages (N=6; n=1760) from fluvial deposits of the Lower Cretaceous (?) Lytle Sandstone and Lower–Upper Cretaceous (latest Albian–Cenomanian) Dakota Group sampled from across northern New Mexico (eastern margin of the San Juan basin and western margin of the Great Plains). Sandstone modal composition trends from Lower–Upper Cretaceous strata are dominated by abundant quartz (98%), lesser lithics (~1%), and rarefeldspar (~1%). The Lytle Sandstone is dominated by monocrystalline and polycrystalline quartz (99%) with few chert and lithic grains (1%). The nonmarine portions of the Dakota Group are similar and are composed of monocrystalline and polycrystalline quartz (99%) and sparse lithic and feldspar grains (1%). All stratigraphic units show strong similarities in the distribution of Paleo–Mesoproterozoic zircon ages with the majority falling between 1800–1600 (Yavapai and Mazatzal provinces), 1450–1350 (A-type granitoids), and 1300–1000 Ma (Grenville province). Neoproterozoic–Jurassic peak ages also occur across all units with primary peaks occurring between 625–595, 430–415, and 190–150 Ma. Neoproterozoic and early Paleozoic ages overlap with recycled Mesozoic eolianites of the Colorado Plateau, whereas Jurassic ages overlap with magmatic sources of the Cordilleran arc.

Although most strata from the Dakota Group contain elevated occurrences of Early–Late Cretaceous-age zircons with peak ages between 105–95 and 125–120 Ma, there are no zircons younger than Late Jurassic in either the Lytle Sandstone or the Encinal Canyon member of the Dakota Group. The oldest zircon ages from strata of the Dakota Group are ~104–93 Ma. The youngest detrital zircon ages from Lytle Sandstone and Encinal Canyon member support a Late Jurassic (Tithonian) age for these units, whereas the youngest ages from both members of the Dakota Group indicate an age of latest Early Cretaceous (Albian)–earliest Late Cretaceous (Cenomanian). However, it is certainly possible, and previous studies support, that the youngest Cretaceous zircons in the Dakota Group originated from reworked, ash-fall tuffs (rather than fluvial, water-laid deposits), thus the absence of these Cretaceous grains in the Lytle Sandstone and Dakota Group could have resulted from a temporary hiatus in deposition of ash-fall material to these units during the Early Cretaceous.

Sandstone modal composition (N=4) and U-Pb detrital zircon (N=1; n=94) data are also reported from Morrison Formation in northern New Mexico as a means to compare and better constrain the age of the Lytle Sandstone. The Morrison is characterized by a relatively high abundance of quartz (Q=87%), minor amounts offeldspar (F=10%), and trace occurrences oflithics (L=3%). The nine youngest ages from the
Morrison Formation fall between Early–Late Jurassic (between ~190-150 Ma) and support a Late Jurassic age. The Morrison Formation contains similar age distributions to overlying strata of the Lytle Sandstone and Dakota Group. Based on results from this study and previous work, two distinct source areas may be recognized and distinguished in Lower–Upper Cretaceous strata in New Mexico and include direct sources to the Sevier fold/thrust belt in southern Utah and Nevada and to the Cordilleran arc in southeastern California. In addition, there is a third source area that is characterized by third-order recycling of strata (e.g., Mojado Formation) from the relict shoulder of the Bisbee rift in southeastern Arizona and southwestern New Mexico.

Provenance trends described above support a model in which detritus was derived from the Sevier fold/thrust belt as well as from the Permian–Cretaceous Cordilleran arc by ash-fall or by recycling of subcrop strata (e.g., Triassic Chinle Formation and Jurassic Morrison Formation). Elevated occurrences of monocrystalline quartz and minor lithic volcanics indicate likelihood of large contributions from recycled source areas rather than directly sourced volcanic arcs via fluvial systems. There is also evidence that the Dakota Group in northern New Mexico contains recycled detrital contributions from the underlying Lytle Sandstone.

LOW-TEMPERATURE THERMOCHRONOLOGICAL CONSTRAINTS ON NEogene EXTENSION IN THE RIO GRANDE RIFT AND BASIN AND RANGE OF SOUTHERN NEW MEXICO

Gavel, Michelle M., M.S.

The Basin and Range and Rio Grande rift (RGR) are regions of crustal extension in southwestern North America that formed in the Paleogene after Laramide-age shortening. The timing of extension in the area of southern New Mexico where these two provinces blend is uncertain, which also calls in to question the developmental relationship between the two provinces. A suite of 96 apatite and 43 zircon (U-Th)/He dates (AHe and ZHe) and 16 apatite fission track (AFT) dates have been collected from an east-west transect across southern New Mexico and easternmost Arizona to investigate the cooling and exhumation histories of the southeastern Basin and Range, the southern Rio Grande rift, and the transition zone between them. AHe dates range from 3–22 Ma, ZHe dates range from 2-649 Ma, and AFT ages range from 10-34 Ma with average track lengths of 10.8-14.1 µm. First-order spatiotemporal trends in the combined dataset suggest that Basin and Range extension was either contemporaneous with Eocene/Oligocene Mogollon-Datil volcanism or occurred before volcanism that formed in the area. The Chiricahua Mountains and Burro Mountains have an onset of rapid extension, defined as cooling rates in excess of >15 °C/Ma, at ca. 29-17 Ma. In the Cookes Range, a period of rapid extension occurred at ca. 19-7 Ma. In the San Andres Mountains, Franklin Mountains, Caballo Mountains, and Fra Cristobal range, rapid extension at ca. 23-9 Ma. Measured average track lengths are longer in Rio Grande rift samples and ZHe ages of >40 Ma are only present east of the Cookes Range, suggesting different levels of exhumation for the zircon partial retention zone and the AFT partial annealing zone. The main phase of fault-block uplift occurred ca. 22–10 Ma, similar to what is observed in the northern and central sections of the Rio Grande rift. Although rapid cooling occurred throughout southern New Mexico, comparison with spatiotemporal patterns in magmatism suggest it was driven by isothermal relaxation following magmatism in the Basin and Range, whereas in the Rio Grande rift it was driven by fault-related exhumation. Differences in cooling history, crustal thickness, electrical resistivity, sedimentation, and mantle heterogeneity make the Rio Grande rift teconically distinct from the Basin and Range, although the two provinces may have evolved together in the early stages of Cenozoic extension in the western U.S.

CENOZOIC MAGMATISM IN THE RIO GRANDE RIFT: A CASE STUDY FROM THE PREHISTORIC TRACKWAYS NATIONAL MONUMENT, SOUTHERN NEW MEXICO

Richard, Nicholas P., M.S.

The Prehistoric Trackways National Monument (PTNM) is located on the eastern edge of the Robledo Mountains near the western margin of the southern Rio Grande rift in Doña Ana County, New Mexico. The range consists of Permian strata overlain by Paleocene clastic rocks from the Love Ranch Formation, Eocene volcaniclastic rocks of the Palm Park formation, the Plio-Pleistocene Camp Rice Formation, and the focus of this study: late Eocene rhyolites and Miocene basalts. U-Pb dating of zircon from a rhyolite silt within the Prehistoric Trackways National Monument yielded a 206Pb/238U weighted mean age of 34.8 ± 0.1 Ma (all errors at 2σ) which is similar to the rims of the groundmass plagioclase. This suggests that the latest stage of crystal growth of the megacrysts took place in the host basalt.

The initial 87Sr/86Sr isotope ratios of the megacrysts are similar to each other (0.7030). This suggests a similar magma source region for the plagioclase megacrysts. This is unlike the 87Sr/86Sr/Pb/Pb isotope ratio of the whole rock, which is more radiogenic (0.7034). This difference in the 87Sr/86Sr isotope ratios indicates that the megacrysts are derived from a different magma source as the host basalt. In addition, the host basalt magma likely assimilated some continental crust with higher 87Sr/86Sr, such as Proterozoic granite.

The preferred model for magmatism in the PTNM is that an earlier magma sourced from the asthenosphere was injected into the lower crust and stalled. Fractional crystallization as well as crystal settling allowed for the formation of compositionally diverse large plagioclase crystals. These crystals were eventually assimilated as megacrysts by a younger asthenospheric basalt that intruded the lower crust magma. This new melt assimilated minor amounts of country rock with more radiogenic 87Sr/86Sr. Finally,
the melt traveled along normal faults and was emplaced as intrusive bodies in the PTNM.

University of New Mexico

OBSERVED AND PROJECTED SNOWMELT RUNOFF IN THE UPPER RIO GRANDE IN A CHANGING CLIMATE
Bjarke, Nels R., M.S.

As climate has warmed over the past half century, the strength of the covariance between interannual snowpack and streamflow anomalies in the Rio Grande headwaters has decreased. This change has caused an amplification of errors in seasonal streamflow forecasts using traditional statistical forecasting methods, based on the diminishing correlation between peak snow water equivalent (SWE) and subsequent snowmelt runoff. Therefore, at a time when water resources in southwestern North America are becoming more scarce, water supply forecasters need to develop prediction schemes that account for the dynamic nature of the relationship between precipitation, temperature, snowpack, and streamflow. We quantify temporal changes in statistical predictive models of streamflow in the upper Rio Grande basin using observed data, and interpret the results in terms of processes that control runoff season discharge. We then compare these observed changes to corresponding statistics in downscaled global climate models (GCMs), to gain insight into which GCMs most appropriately replicate the dynamics of interannual streamflow variability represented by the hydro-climate parameters in the headwaters of the Rio Grande. We quantify how the correlations among temperature, precipitation, SWE, and streamflow have changed over the last half century within the local climatic and hydrological system. We then assess different long-term GCM-based streamflow projections by their ability to reproduce observed relationships between climate and streamflow, and thereby better constrain projections of future flows as climate warms in the 21st century. In the Rio Grande system, we find that spring season precipitation increasingly contributes to the variability of runoff generation as the contribution of snowpack declines.

EARLY MISSISSIPPIAN OCEAN ANOXIA TRIGGERING ORGANIC CARBON BURIAL AND ENHANCING LATE PALEOZOIC ICE AGE ONSET: EVIDENCE FROM URANIUM ISOTOPES OF MARINE LIMESTONES
Cheng, Keyi, M.S.

The Early Mississippian (Tournaisian) positive δ13C excursion (or TICE) is one of the largest recorded in the Phanerozoic and the organic carbon (OC) burial associated with its development is hypothesized to have driven global cooling and increased glaciation. We are testing the hypothesis that expanded ocean euxinia/anoxia drove widespread OC burial and the TICE and we are testing this hypothesis using uranium isotopes (δ238U) of Lower Mississippian marine limestones from southern Nevada as a global seawater redox proxy. δ238U trends record a prominent mid-Tournaisian negative excursion (~0.30‰ magnitude) lasting ~1 My. The lack of correlation among δ238U values and water-depth dependent facies changes, terrestrial influx proxies (Al, Th, wt% carbonate), redox-sensitive metals (U, V, Mo, Re) and diagenetic proxies (Mg/Ca, Mn/Sr) suggests that the δ238U curve represents a global seawater redox signal. The negative δ238U excursion (indicating increased sediment deposition under oxygen-depleted conditions) is coincident with the onset and peak of the first TICE positive excursion supporting the hypothesis that expanded ocean euxinia/anoxia controlled OC burial; we term this the Tournaisian oceanic anoxic event or TOAE. These results provide the first evidence from a global redox proxy that widespread ocean euxinia/anoxia controlled Tournaisian OC burial and enhanced long-term global cooling/glaciation. U modeling results indicate that during the TOAE, the area of euxinic/anoxic seafloor increased by 6x and that the negative δ238U excursion was initially driven by euxinic conditions which waned and was replaced by anoxic/suboxic conditions where OC burial continued, but there was low U fractionation/sequestration. Comparisons between modeled OC burial amounts of the TICE versus the Late Ordovician (Hirnantian) positive δ13C excursion (HICE), which occurred during peak Gondwanan glaciation, indicates that substantially more OC was buried during the TICE and adds strong support that the TOAE ultimately enhanced Tournaisian global cooling and increased glaciation.

In contrast to most Paleozoic and Mesozoic OAEs, the TOAE developed during (and further enhanced) long-term late Paleozoic global cooling. We interpret that the TOAE developed in response to this long-term cooling, which intensified atmospheric and ocean circulation, enhanced upwelling- and eolian-derived nutrient flux, increased productivity and dissolved O₂ consumption, which lead to ocean euxinia/anoxia expansion.

CONSTRAINING THE OXYGEN VALUES OF THE LATE CRETACEOUS WESTERN INTERIOR SEAWAY USING MARINE BIVALVES
Dayer, Camille H., M.S.

The Western Interior Seaway (WIS) remains an oceanographic enigma, including its circulation, similarity to the open ocean, and the fidelty of geochemical proxies to reconstruct paleoenvironments. Across the late Campanian and early Maastrichtian I test whether: 1) the WIS had unique δ18OVPDB compared to other marine settings, 2) increasing oceanographic restriction changed the stable isotope composition, and 3) biases, e.g., taxonomy or diageneis, influenced stable isotope compositions. Results indicate distinct δ18OVPDB in the WIS compared to other marine settings. δ18OVPDB values were stable throughout, suggesting insignificant oceanographic restriction and a maintained open-ocean connection despite marine regression. The spread of δ18OVPDB values suggests that mixing of multiple isotopically distinct water bodies in combination with changing evaporation regimes may strongly influence ocean chemistry. Therefore, interpretation of δ18OVPDB in WIS carbonates as a paleotemperature proxy should be done cautiously and the isotopic composition of mixing water bodies must be considered.

NATURAL SALINIZATION OF THE JEMEZ RIVER, NEW MEXICO: AN INSIGHT FROM TRACE ELEMENT GEOCHEMISTRY
Golla, Jon K., M.S.

The Jemez River, a tributary of the Rio Grande in north-central New Mexico, receives thermal water input from the geofluids of the Valles Caldera, an active, high-temperature, liquid-dominated geothermal system. We focus on a ~50-km portion of the northern Jemez River. This research extends previous decadal work (Crossey et al., in prep, 2013) on major chemistry in the river by characterizing the response of 16 trace elements to geochemical contributions from geothermal waters (McCauley, Spence, Soda Dam, and Jemez Springs springs and San Ysidro mineral waters), an area with copious hydrothermal degassing (Hummingbird), and two major tributaries (Rio San Antonio and Rio Guadalupe) during a low-flow event (~425 L/s). The greatest known loading (as much as 10⁴ concentration increase) of trace elements to the Jemez River is from Soda Dam ([TDS] = 4700 ppm). Seventy-five percent of analyzed trace elements are coupled with major ions and resemble mostly conservative downstream behavior. Correspondent to their inherently low ionic potential, the alkali (Li, Rb, Cs) and alkali earth (Sr, Ba) metals remain abundantly dissolved. The relative non-reactivity of some transition metals (Fe, Ni, Co, U, V, Cu, Pb), which are sensitive to redox changes and susceptible to sorption, is facilitated by transport as complexed species (predominantly as Fe(OH)₂⁰, HCO₃⁻, UO₂(OH)₄⁰, VO₂OH₂⁻, CuCO₃⁰, PbCO₃⁰). There is no common sink for the latter 25% (As, Al, Mo, Mn), each as is potentially scavenged at different sections of the river by different processes, like oxidation-enhanced adsorption and co-precipitation. The inflowing H₂S and CO₂ gases at Hummingbird impart unique physiochemical conditions that allow some solutes to become non-conservatively solubilized (Cu, Pb, Al) and removed (U, Mo).

CARBON AND NITROGEN STABLE ISOTOPE ISOTOPES IN ORGANIC MATTER FROM LAKE CHALCO, MEXICO: A RECORD OF QUATERNARY HYDROLOGY AND CLIMATE CHANGE
Pearthree, Kristin Sleazak, M.S.

Sediment cores from Lake Chalco, central Mexico, were analyzed to reconstruct paleoclimate in the neotropics. This study employs total organic
disagreements over biogeographic zonation. The has long been the subject of debate, with mass extinction event. The spatiotemporal mode of non-avian dinosaurs and “archaic” mammal subclade, Placentalia), following the annihilation explosive ecomorphological diversification of stage; ~66.04-65.12 Ma). It is typified by the Paleogene period (Paleocene epoch, Danian spanning roughly the first one million years of cican terrestrial biochron of the Cenozoic era, Age (NALMA) is the earliest major North Amer-

EUTHERIAN BIOGEOGRAPHY DURING THE PUERCAN NORTH AMERICAN LAND MAMMAL AGE (PALEOCENE, EARLIEST DANIAN): PROBLEMS AND POTENTIAL SOLUTIONS

Silviria, Jason S., M.S.

The Puercan North American Land Mammal Age (NALMA) is the earliest major North Amer-
ican terrestrial biochron of the Cenozoic era, spanning roughly the first one million years of the Paleogene period (Paleocene epoch,alian stage; ~66.04-65.12 Ma). It is typified by the explosive ecomorphological diversification of the mammalian clade Eutheria (particularly our subclade, Placentalia), following the annihilation of non-avian dinosaurs and “archaic” mammal groups during the Cretaceous/Paleogene (K-Pg) mass extinction event. The spatiotemporal mode and tempo of Puercan eutherian diversification has long been the subject of debate, with disagreements over biogeographic zonation. The traditional model—based largely on well-sampled, well-constrained eutherian assemblages from Montana and Saskatchewan (Williston Basin), Wyoming (Bighorn Basin), Utah (Paradox Basin), and New Mexico (San Juan Basin)—postulates an increased north/south dichotomy between faunal provinces and higher basin-level endemism in the later Pu2/Pu3 intervals relative to the earlier Pu1 interval, comparable to patterns observed in dinosau-ran and mammalian faunas below the K-Pg boundary (Sloan, 1987; Buckley, 1994; Williamson, 1996). However, since the late 1970s-early 1980s, investigation of Pu1 faunas from the Great Divide and Hanna Basins in Wyoming, as well as the Denver Basin in Colorado, led to the proposal of a heterogeneous “transition- zone”, harboring unusual endemic arctocyonids and periprychids alongside taxa more typical of Pu2/Pu3 “southern” faunas in the Denver, Paradox, and San Juan Basins (Middleton, 1983; Eberle and Lillegren, 1998; McComas and Eberle, 2016). However, the role of lithological and collecting biases in the formulation of these hypotheses has yet to be thoroughly tested.

This study analyzed the ecological biogeography of Puercan eutherian biogeography using force simulated flows to have the same mean and variance as observed flows over a historical baseline period, yielding normalization ratios that can be applied to future flows when water management decisions are unknown. At the gage considered in this study, the effect of the normalization is to reduce all simulated flow values by nearly 72% on average, indicative of the large fraction of natural flow diverted from the river upstream from the gage.

The normalized streamflow scenarios are then implemented as the main boundary condition in a simple water balance model to analyze future policy options, using reservoir storage and downstream releases to compare management choices. It takes four years of twice the average annual inflow to fill Elephant Butte Reservoir to full operating capacity, starting from near-empty initial conditions as occurred in late 2018. In terms of increasing downstream releases and increasing reservoir storage, reducing direct reservoir evaporation was the best option from a strictly hydrologic perspective. Increasing the future inflows by reducing upstream diversions increases reservoir storage and Caballo releases, but there was also an increase in reservoir evaporation. Lastly, maintaining a minimum storage threshold for reservoir storage increases future average storage, but also leads to an increase in reservoir evaporation and a decrease in releases. Water stored in Elephant Butte Reservoir is lost via the positive correlation between increasing reservoir storage, and thus the increased surface area, and the subsequent rise in direct reservoir evaporation. Therefore, the water balance model suggests the most hydraulically efficient policy option involves reducing reservoir evaporation, although the water balance model does not consider the costs of methods to reduce evaporation.

EVALUATING FUTURE RESERVOIR STORAGE IN THE RIO GRANDE USING NORMALIZED CLIMATE PROJECTIONS AND A WATER BALANCE MODEL

Townsend, Nolan T., M.S.

We develop and implement new tools for assessing the future of surface water supplies in downstream reaches of the Rio Grande, for which Elephant Butte Reservoir is the major storage reservoir. First, a normalization procedure is developed to adjust natural Rio Grande streamflows simulated by dynamical models in downstream reaches. The normalization accounts for upstream anthropogenic impairments to flow that are not considered in the model, thereby yielding downstream flows closer to observed values and more appropriate for use in assessments of future flows in downstream reaches. The normalization is applied to assess the potential effects of climate change on future water availability in the Rio Grande Basin at a gage just above Elephant Butte reservoir. Model simulated streamflow values were normalized...