New Mexico graduate student abstracts

New Mexico Geology recognizes the important research of graduate students working in M.S. and Ph.D. programs. The following abstracts are from M.S. theses and Ph.D. dissertations completed in the last 12 months that pertain to the geology of New Mexico and neighboring states.

New Mexico Institute of Mining and Technology

GEOCHEMISTRY AND TRANSPORT OF URANIUM-BEARING DUST AT JACKPILE MINE, LAGUNA, NEW MEXICO

Brown, Reid Douglas, M.S.

Closed mines pose significant risks to the environment and human health. Uranium mine contamination of surface water, groundwater and soil have received moderate attention, but few studies have investigated dust transport of uranium. The latter has immediate implications for remediation efforts and environmental/human health regulators. Frequent dust storms intensify aeolian transport of uranium in arid settings. At the Jackpile Mine in Laguna Pueblo, New Mexico, 15 sets of dust traps have been installed at heights of 0.25 m, 0.5 m, 1.0 m and 1.5 m above the soil surface. Some of these traps are within the mine pit, while others are up to 4 km away; dust from these sites was collected every two months. In addition, soil samples from each site were collected and sieved into eight size classes. All samples were acid digested, and the uranium content analyzed using Inductively Coupled Plasma Mass Spectrometry. We investigate whether uranium has an affinity for a particular particle size class, with interest centered on particles small enough to be completely inhaled by humans. Results show that surface concentrations of uranium vary substantially across the landscape. Distance from the pit shows no correlation with uranium in the upper 5 cm of soil. Other factors appear to control accumulation, such as vegetation height and density and topographic relief, which are known to have a significant impact on wind speeds, soil erosion and dust deposition. Our study site has over 150 m of relief and intricate topography that lead to a range of wind speeds between sites. The soil uranium content determined at 15 sites has been compared to site elevation and vegetation height. Analysis suggests that elevation and vegetation height may impact local erosion and deposition of uranium contamination. Dust mass was collected at each height and converted into a flux (g/d/m2). The relationship between mass flux and height above ground followed a power law relationship as supported by previous research (Zingg 1953; Butterfield 1999; Dong et al 2003; Dong et al 2004a, 2004b). Particle size fractionation during aeolian transport led to an increase in metal concentrations in 4 of 6 metals of concern in the dust compared to the soil.

LITHOFACIES ANALYSIS OF THE SIERRA LADRONES FORMATION, SOUTHERN ALBUQUERQUE BASIN, N.M.: IMPLICATIONS FOR CLIFF FAULT ACTIVITY DURING THE EARLY PLEISTOCENE

Celep, Eda, M.S.

This study uses stratigraphic relations to interpret tectonic activity of the Cliff fault during the early Pleistocene. The north-striking, 60° west-dipping, ~13 km-long Cliff fault is the easternmost of three exposed Quaternary normal faults in the southwestern Albuquerque Basin of the Rio Grande rift. Previous studies have suggested that the Cliff fault was active during the late and middle Pleistocene, but early Pleistocene activity is conjectural. The other two Quaternary normal faults in the study area are the Loma Blanca and Loma Pelada faults. Comparing the long-term displacement history of the three faults allows us to determine if extensional strain has focused inward in this part of the rift, as inferred in the Española and Palomas-Winston basins of the Rio Grande rift. In addition, analyzing displacement gradients of the Cliff fault along strike allows inferences regarding fault structure and continuity of this fault to the south, where it is buried by Quaternary deposits.

The strata on the footwall of the Cliff fault are the Sierra Ladrones Formation; a Pliocene-early Pleistocene deposit composed mainly of sand with minor gravel and clay-silt. The footwall provides information on Sierra Ladrones stratigraphic units away from the potential fault related sedimentation on the immediate hanging wall of the Cliff fault. The footwall units also allow correlation of stratigraphic units between the footwall and hanging wall to obtain fault throw estimates. The footwall sediments were grouped into two different lithofacies assemblages: basin floor and distal alluvial fan. The basin floor lithofacies assemblage is subdivided into three different lithofacies; the Rio Puerco channel fill, Rio Salado channel fill and floodplain lithofacies. The alluvial fan lithofacies assemblage is very minor and consists of hyper-concentrated flow deposits from the Rio Salado drainage. In addition to these lithofacies assemblages, eolian lithofacies and some paleosols were observed with Stage I to II calcium carbonate accumulation.

The hanging wall strata are studied to find direct evidence of fault-related angular unconformities, upward splaying of stratal tilts, or fault scarp colluvium, or indirect evidence relate to sedimentation patterns. The hanging-wall strata are well-exposed in three topographic bowls. The strata consist of stream-flow gravels, that are clast supported and imbricated, and hyper-concentrated flow deposits on the toe of the Rio Salado alluvial fan, fault scarp colluvium, and playa deposits. In addition, there are paleosols with Stage-II and Stage-III calcium carbonate accumulation. Six layer-cake stratal units on the hanging wall are recognized. These range from 3 m to 30 m thickness and are called Hanging wall-1 to Hanging wall-6 (oldest to youngest). In the southernmost part of the study area, in Hanging wall-1, cemented conglomerate stratigraphy is similar to footwall Rio Salado channel fill. This gives a minimum throw of 46 m for that part of the fault.

Only the Hanging wall-6 sediment package was studied in detail to assess evidence for syn-depositional fault displacement. Eleven lithostratigraphic units were recognized

in the Hanging wall-6 layer-cake unit. These subunits are (listed from bottom to top): the lower gray subunit (Qslg), lower red sediment (Qslr), well-sorted sand (Qsws), lower brown sediment (Qslb), upper red sediment (Qsur), copper-colored gravelly sand sediment (Qsc), gray gravel sediment (Qsgg), upper brown sediment (Qsub), double soil (Qsds), tan sediment (Qst), and upper gray gravel sediment (Qsug). Inferred paleodepositional environments for the Hanging wall-6 sediment package includes playa, intra-fan depositional lobes (some oriented parallel to the Cliff fault), fault scarp colluvium and slope wash sediments.

There are indications for early Pleistocene movement of the Cliff fault in the Hanging wall-6 layer-cake unit. These include local upward splaying of stratal tilts, lateral facies variations and paleoflow parallel to the fault, thickness changes, local lateral coarsening trends towards the fault, and fault scarp colluvium. An abrupt upward splaying of stratal tilts (from 5° to 2° degrees), occurring across a 3 m thick wedge-shaped, internally massive unit, is present in the middle bowl. The presence of fan deposits transitioning south-to-north into playa deposits suggests a topographic obstruction on the east-sloping Rio Salado fan, consistent with a fault scarp. In the middle topographic bowl, pebbly to clayey sand of the copper unit and the double soil unit thicken towards the fault and pinch out towards the west. The upper brown unit in the northern topographic bowl -composed of clay, silt, and sand (inferred playa facies)- becomes coarser towards the fault. The uppermost two units, interpreted to be scarp-abutment fans elongated parallel to the fault scarp, exhibit southwest paleoflow. These two units also thin and become finer-grained to the south. The copper-colored and lower alluvial fan units interfinger with interpreted fault scarp colluvium and slope wash sediments. Colluvium sediments include cemented conglomerates and pebbles with calcium carbonate accumulation on their surface - interpreted to be reworked from the footwall. These observations provide evidence for early Pleistocene activity of the Cliff fault.

The hanging wall lithofacies assemblages differ from footwall lithofacies assemblages. Very short-distance fault-scarp derived debris and slope-wash sediments are observed. They interfinger with sediments that were carried by small fan and alluvial fan drainages. These sediments consist of playa and sand mixed sediments. The paleoflow and deposition history of alluvial –playa sedimentation on the hanging wall provides evidence for fault activity because the hanging wall preserves deposits from fault-deflected drainages (scarp abutment fans). Paleoflow data show that the paleoflow history starts with easterly- southeasterly directed small-fan, mixed-sand deposits and playa muds. Then, small fan drainages flow to the northeast. Next, flow is toward the southwest; these drainages were deflected by the fault scarp. In addition, at least six soils were developed on the hanging wall, implying that the landscape was stable between periods of deposition. There was fault activity during and between depositions of some of the units.

The results of this study have two implications of general interest. The paleoseismic history of faulting in the study area suggests that there is inward progression of extensional deformation; faults become younger towards a gravity low and corresponding syncline axis, inferred to be the depocenter of the southernmost Albuquerque basin. Inward progression occurs because the Silver Creek fault became inactive prior to the Quaternary; there is no clear trend of the Loma Pelada, Loma Blanca, and Cliff faults. Second, elevation vs. distance graphs of various lithologic contacts indicates a southward-decreasing displacement gradient of the Cliff fault. This implies two structural scenarios: 1) the Cliff fault in the study area and what was called the Cliff fault in the San Acacia area (to the south) may be linked by a relay ramp, or 2) the Cliff fault does not continue to the San Acacia area as an effectively linked structure, as was interpreted by previous workers.

DEEP RESISTIVITY IMAGING OF THE CENTRAL RIO GRANDE RIFT USING 3-D INVERSE MODELS OF MAGNETOTELLURIC DATA, WITH IMPLICATIONS FOR HYDROLOGIC AND GEOTHERMAL PROCESSES

Folsom, Matthew T., M.S.

A 3-D electrical resistivity model of the central Rio Grande rift, centered over ground surface deformation attributed to the Socorro magma body, has been generated using magnetotelluric data from 17 stations. Resistivity models were constructed using 2-D and 3-D inversion techniques, and results from the different approaches are compared and evaluated. The survey has close station spacing (~ 2 km) along a single east-west transect, but is sparsely populated with data elsewhere in the domain. A surprising result is that the zone of ground surface uplift is found to lie directly over a resistive body (~1600 Ω m) that rises to shallow depths under the Lemitar Mountains and potentially extends greater than 15 km in depth. The shallowest portion of this body lies under and to the south of the center of uplift. The Socorro Basin is found to contain a lens of low-resistivity basinal brines (0.3 – 0.5 Ω m) between 800 m and 1400 m depth, within the lower Santa Fe Group, and compartmentalized between the Loma Pelada Fault and mid-basin Cliff Fault. These structures may play a role in moving quantities of these brines upwards, where they mix with surface waters. Above the lens, the upper 800 m supports fertile agricultural lands with resistivity values ~ 10 Ω m. Although poorly constrained, low-resistivity zones (~ 90 Ω m) persists to mid-crustal depths (~ 30 km) below the Southern Albuquerque Basin and the town of Socorro. 3-D forward modeling is used to explain how 2-D inverse methods can generate spurious conductors at depths > 20 km. The phenomena can be explained solely by complex 3-D geometry of sedimentary basins in the upper 4 km of the Earth's crust.

^{40}AR/^{39}AR DETRITAL SANIDINE DATING OF THE OGALLALA FORMATION, LLANO ESTACADO, SOUTHEASTERN NEW MEXICO AND WEST TEXAS

Henry, Kevin D., M.S.

This study utilizes high precision ^{40}Ar/^{39}Ar geochronology of detrital sanidine (DS) to determine the sedimentary provenance and maximum deposition age for the Ogallala Formation. More than 1000 K-feldspars were dated from 14 samples, which define 4 unique age distributions that correlate

to location. The maximum depositional age (MDA) for the Ogallala of the western Llano Estacado of SE New Mexico is 11.44±0.03 Ma and is time equivalent to the upper Couch Formation of the Ogallala Group in Texas. In Yellow House Canyon near Lubbock, TX the Bridwell Formation of the Ogallala Group has a MDA of 6.74±0.02 Ma consistent with the Hemphillian biostratigraphy. In eastern NM, units mapped as Ogallala yielded Pleistocene DS grains, thereby indicating inaccurate mapping. These units are likely part of the Blackwater Draw Formation. The Taiban Mesa had poor sanidine yield and the dated K-feldspars are dominated by Precambrian ages. However, a single DS grain of 8 Ma indicates late Miocene or younger deposition. Most Eocene-Oligocene detrital sanidine grains in the Ogallala are sourced from the Mogollon-Datil volcanic field with a possible minor component from the Trans-Pecos and Sierra Madre Occidental volcanic fields. Mogollon-Datil material likely comes from a Whiter River Group-equivalent rock that has been completely eroded and reworked into the Ogallala. Older DS grains are sourced from reworked underlying Mesozoic strata and if the MDA approximates the deposition age the erosion of these strata occurred prior to ~11.5 Ma in the western Llano Estacado region. The Eocene-Oligocene DS grains yield distinct populations however 65–80 Ma grains cannot be directly correlated to a known volcanic source. These could have been derived from NM and Texas Upper Cretaceous or younger strata or have been eroded from volcanic rocks associated with Laramide Orogeny volcanism in northern Mexico/southern NM. Despite the overall lack of DS grains derived from the Trans-Pecos volcanic field the current data cannot support or rule out a north-flowing ancestral Pecos river during Ogallala deposition.

SOIL EROSION RATES IN THE EVOLUTION OF A FIRST-ORDER CATCHMENT IN CENTRAL NEW MEXICO: INSIGHTS FROM RUNOFF PLOTS AND MEASUREMENT OF DUAL COSMOGENIC NUCLIDES

Ramirez Torres, Carlos Fernando, M.S.

This work is part of a collaborative research on the hillslope aspect influence on the evolution of a drainage basin. It uses both insights from runoff plots and, measurements of a dual cosmogenic nuclides approach, using ^{10}Be and ^{36}Cl, to assess geomorphic histories and the erosional rates differences between the surface of two contrasting vegetated opposite north and south-facing hillslope in Central New Mexico. Apparent cosmogenic nuclide erosion rates of 6 to 21 mm kyr^{-1} were measured with differences between aspect-oriented slopes as high as 33%; evidencing the feedback relationship of aspect and plant coverage on erosion as the more vegetated/moist north-facing slope was more resource conserving than the south-facing slope. Furthermore, the study found that our initial working hypothesis of headward erosion of the trunk drainage was not supported, as the nuclide data indicates downward incision of the entire drainage. In addition an average surface exposure age of 580 ka was obtained for the surface into which our first-order basin was incised and an age range of 60 to 180 ka was indicated as a constraint on the establishment of the current aspect-dependent erosion pattern.

EVAPOTRANSPIRATION IN MOUNTAIN TERRAIN – APPLYING TOPOGRAPHIC-BASED ENERGY CONSTRAINTS TO EVALUATE THE DISTRIBUTION OF WATER FLUXES AND EFFECT OF VEGETATION COVER CHANGE

ReVelle, Peter M., M.S.

Increasing water demands and groundwater pumping rates in semiarid regions have focused attention on improving the understanding of regional water resources and characterizing hydrological processes and quantifying their associated fluxes that ultimately determine short and long-term water supplies. The Sacramento Mountains in southeast New Mexico are a significant source of groundwater recharge for the surrounding Roswell Artesian Basin, Tularosa Basin, and Salt Basin aquifers. Land and forest management officials are interested in understanding the effects of manipulating environmental conditions, through land cover changes and forest management practices, on mountain recharge. This recharge ultimately provides much of the water supply for high water-use areas in surrounding basins. Previous work under the Sacramento Mountains watershed study has investigated various components of the water balance, including the relationship between soil water sources and tall forest vegetation, as well as quantifying runoff and canopy interception. One of the largest, most variable, and most important processes controlling mountain groundwater recharge is the total amount of water that evaporates from the soil surface or through vegetation (evapotranspiration). The focus of the present study is to examine experimental plots that have been thinned, and similar control plots that were not thinned, in order to quantify the amount of water lost to the atmosphere through evapotranspiration, in order to improve estimates of the change in the water-balance and the resulting change in groundwater recharge.

Using the remote-sensing algorithm Mapping EvapoTranspiration at high-Resolution with Internal Calibration (METRIC), satellite imagery from Landsat 5 was analyzed to estimate evapotranspiration (ET) for watershed plots for images chosen before and after thinning of the plot areas. Through solving the surface energy balance, METRIC provides spatially distributed ET estimates at 30 meter by 30 meter resolution that account for both soil and vegetation contributions to the amount of water lost as ET. We employed an environmental-impact-type analysis to compare ET estimates from METRIC before and after thinning and quantify the net impact on ET. We used linear regression to evaluate the relationship between changes in canopy cover due to vegetation removal and resulting effects on ET for thinned plots. Additional analyses used multiple linear regression to determine which surface parameters were most important in explaining the variability of the response in ET before and after thinning at the plot scale. Much larger samples across the whole Landsat image extent were also analyzed to examine large-scale distributions and identify patterns and shifts in significance of predictor variables between images. Forest-group types and land-cover classes were examined further by comparing mean ET values using a multi-comparison test that grouped statistically similar ET distributions together. This approach was taken as a way to investigate the ability of METRIC to

identify and separate individual class or group types from one another or combine similar land cover types into groups, given that specific forest group types are not supplied to METRIC. Statistical analysis of ETrF (fraction of reference ET) and associated ET values for the paired plots extracted from maps produced using METRIC show no statistically significant difference in ET (alpha = 0.10) between thinned and respective control plots between pre-thinning images, while indicating significant but variable decreases in ET between images from before and after thinning dates. The net changes in ET determined using a Before-After Control-Impact (BACI) analysis show a net decrease for all thinned plots at a 90% confidence level. Linear regression was applied to determine the relationship between the net changes in ET to the associated changes in canopy cover, showing a good fit with an R-squared value of 0.79. Additional data points were compared from a similar study in a semi-arid upland pine forest using values of canopy cover reduction and the associated effect on ET that showed close agreement to the regression line determined from the present study within a few percent. While thinning extent appears to be the primary control on the effect on ET, multiple linear regression analysis indicates that topography has an important influence on the variability of the magnitude of the effect. Changes in albedo after thinning is also an important contributing factor identified from the multiple regression analysis. The significance of albedo can be related to the physical effect of decreases in canopy cover associated with thinning treatment modifying the surface albedo and resulting net short-wave radiation for thinned plots. Large-scale analysis of ETrF estimates across the entire Landsat image provide evidence for the consistency between ETrF values from METRIC for different image dates and indicate the ability to distinguish forest groups and land cover classes through statistically significant differences in mean ETrF. The results of the ANOVA GLM analysis exhibit the same primary factors contributing to the variability in ETrF, highlighting the consistent and robust nature of METRIC derived ETrF estimates. The range of ETrF values for forest groups are reasonable and compare well with crop coefficients (ETrF) found in the literature. Multiple comparison testing between forest and NLCD groups demonstrates statistically significant differences between many forest and NLCD groups that result in similar grouping between image dates. Differences in grouping between image dates are likely influenced by the effects of varying local meteorological conditions and antecedent soil moisture. The methods utilized in the present study provide a new approach to quantifying changes in ET associated with land cover management practices through remote sensing. The current work illustrates the potential for similar types of approaches. Further analysis utilizing additional images could be applied to advance the understanding of the role of surface parameters in predicting responses in ET resulting from land cover changes through identifying and investigating significant relationships within the meta-scale patterns determined by the complex processes governing them in highly heterogeneous terrain.

ECOLOGICAL DISTURBANCES AND THE WATER BALANCE
HYDROLOGIC SCIENCES, Wine Michael, Ph.D.

As populations rise, understanding how global change impacts future water resource availability on Earth is of paramount importance. While the air temperature-water vapor pressure relationship typically plays a central role in predictions of hydrologic effects of future climate scenarios, ecological changes—including disturbances—also influence water resources. Key anthropogenic drivers of ecological change include atmospheric greenhouse gas induced global warming, long-term changes in grazing paradigms, historic fire suppression, and road construction, which have led to a widespread wildfire deficit. This wildfire deficit has caused woody encroachment and increased wildfire frequency. These modifications to wildfire regime cause a wide range of ecological and hydrologic impacts. At the low wildfire frequency end of the spectrum woody encroachment occurs, substantially reducing groundwater recharge, primarily due to longer growing season and deeper rooting depth of encroaching trees relative to grasses. At slightly higher fire frequencies fire impacts are not detectable either because they fall below a threshold value or because they are simply small in magnitude. However, in certain regions of especially high wildfire frequency, wildfires are critical generators of streamflow even at the large watershed scale, contradicting prevailing conceptual models. In such regions, wildfires create infrequent large impacts at small scales, whereas at larger scales a patchwork of wildfire occurrence yields enhanced water yields that are sustained over time. Such conditions may occur in areas with anomalously high lightning frequency. When wildfire impacts are compared to predictions of climate change impacts by 2050, we show that long-term wildfire impacts can exceed climate change impacts in certain ecoregion divisions. Finally, we implement Fuh's equation—which relates wetness index to runoff coefficient by means of water retention capacity—across 474 large watersheds covering the majority of the western USA and quantify wildfire impact on long-term water yield by watershed over the western USA.

New Mexico State University

SEDIMENTOLOGY, STRATIGRAPHY, AND GEOCHRONOLOGY FROM MIDDLE–LATE EOCENE, VOLCANIC AND VOLCANICLASTIC STRATA OF THE PALM PARK FORMATION AND OREJON ANDESITE, SOUTH-CENTRAL NEW MEXICO
Creitz, Ryan Harry, M.S.

The middle Eocene marks the terminus of Laramide deformation and initiation of the volcanic-dominated phase of the Laramide orogeny in south-central New Mexico. This tectonic transition is recorded by a suite of volcanic/subvolcanic, volcaniclastic, gypsiferous, and carbonate strata that make up the Palm Park Formation and age equivalent Orejon Andesite, Cleofas Andesite, and Rubio Peak Formation. A number of studies have focused on constraining the timing and geochemistry of the late Eocene initiation of the Rio Grande rift in southern New Mexico, yet little is known about the eruptive and depositional history just after the end of Laramide deformation and prior to the onset of rifting. Presented here are new sedimentologic, stratigraphic, geochronologic,

and provenance data from the Palm Park Formation and Orejon Andesite near Las Cruces, New Mexico.

The base of the Palm Park is marked by a progressive (erosional) unconformity with basement rocks that range in age from Paleoproterozoic–Paleocene. Basal strata consist of pebble–cobble volcaniclastic conglomerate with limestone clasts. Conglomerate units are interbedded with fossiliferous micritic limestone and gypsum-bearing strata. This lower stratigraphic interval is interpreted to represent shallow lake sedimentation and episodic lahar flows. Adjacent to a volcanic vent, proximal facies of the Palm Park consist of primarily volcanic deposits of intermediate composition that are interbedded with massive pebble–boulder volcaniclastic conglomerate with an average unit thickness >5.0 meters. These rocks are interpreted to represent lava flows and lahar debris flows. Distal strata of the Palm Park are dominated by volcaniclastic mudstone, sandstone and granule–cobble conglomerate that range in thickness from 0.01–0.5 meters. These strata are interpreted as lahar hyperconcentrated flows, water laden sheet flows, and lahar debris flows. The Orejon Andesite does not have the same stratigraphic variation as seen in the Palm Park and consists entirely of intermediate composition lava flows, pyroclastic flows, and lahar debris flows characteristic of proximal facies.

Zircons from an ash-fall tuff near the bottom and top of the Palm Park have a U-Pb age of 45.0±0.7 and 39.6±0.5 Ma respectively, whereas intermediate composition lava flows and subvolcanic units yield ages ranging from 41.6±0.7 Ma–41.0±0.6 Ma, respectively. Zircons from intermediate composition lava flows near the middle–upper Orejon Andesite have U-Pb ages ranging from 44.0±1.5–42.8±0.5 Ma and are comparable to Palm Park ages.

U-Pb detrital zircon ages from Palm Park volcaniclastic intervals exhibit primary peaks between 41–44 Ma with secondary peaks between 1600–1800 Ma, 1350–1550 Ma, and 1000–1250 Ma. Paleoproterozoic–Cretaceous age zircons are present in nearly all samples but do not make up statistically-relevant peaks. Middle Eocene peaks are interpreted to represent detrital contributions from late-stage Laramide stratovolcanoes. Sparse Paleoproterozoic–Cretaceous detrital contributions are interpreted to reflect recycled zircons that were derived from inactive Laramide uplifts and indicate the cessation of Laramide deformation. The prevalence of middle Eocene zircons indicates a volcanic-dominated phase of orogenesis in south-central New Mexico. During this final stage of the Laramide orogeny volcaniclastic sedimentation exceeded local accommodation resulting in the infilling of paleovalleys and burial of Laramide hanging wall highlands.

VOLATILE CONTENTS AND PRE-ERUPTIVE CONDITIONS OF RHYOLITIC MAGMAS FROM THE ORGAN CALDERA, SOUTHERN NM

Lente, Jenna L., M.S.

Caldera-forming eruptions in southern New Mexico ~36 Ma created one of the most aesthetically prominent features in the region- the Organ Mountains. This project combines petrography/mineralogy, major and trace element concentrations of melt inclusions, phenocrysts and whole rocks, and volatile contents of melt inclusions to determine pre-eruptive storage conditions of the magmas of the Organ caldera. The goal is to constrain magma storage conditions of large, silicic, potentially catastrophic caldera- forming eruptions. This study geochemically examines deposits from the first and last caldera-forming eruptions from the Organ caldera, the Cueva Tuff (CT) and the Squaw Mountain Tuff (SMT). Homogeneity of major and trace elements in melt inclusions and feldspars in the CT combined with the range in H_2O contents (~2.5 to 6.5 wt. %) suggest the CT was stored in a convecting magma chamber at depths of ~4 to 9 km. Melt inclusion geochemistry indicates fractional crystallization was the dominant process of melt differentiation, and that degassing and convection caused the range of volatile contents found in the melt inclusions.

Accurate volatile contents of the SMT were not determined due to crystallized melt inclusions requiring rehomogenization, resulting in H+ diffusive loss from melt inclusions. Thus, it is not possible to constrain magma chamber depths. However, major and trace element compositions of whole rocks and gradational changes in phenocryst types and abundances suggest the SMT magma chamber was stratified.

SMT melt evolution was likely complex, including fractional crystallization and magma mixing with subsequent West Side Lavas (WSL) magmas. Injection of WSL magma possibly triggered the eruption of the SMT. This study provides insight into complex processes occurring prior to large silicic eruptions, and changes the perception of the storage conditions of the CT and SMT magmas. These eruptions did not form from one large, single, stratified magma chamber as previously suggested, but likely originated from distinctive magma chambers. Additionally, it is possible that the eruption of the SMT was larger than previously thought, and could potentially be classified as a super eruption.

USING FIELD RELATIONSHIPS AND GEOCHRONOLOGY TO EVALUATE THE FORMATION OF THE SCHOOLHOUSE MOUNTAIN CALDERA, MOGOLLON-DATIL VOLCANIC FIELD, SOUTHWEST NEW MEXICO

Swenton, Vanessa Marie, B.S.

Paleogene calderas of the Mogollon-Datil and Boot Heel volcanic fields are numerous and represent the Ignimbrite Flare-up within southwest New Mexico. These calderas were active during the episodes of dominantly felsic volcanism between ~37–23 Ma in the Mogollon Datil volcanic field (MDVF) and ~35–27 Ma in the Boot Heel volcanic field (BHVF). Eruptive activity from these calderas was relatively coeval, with ignimbrites filling the depressions of subsided calderas and extensive outflow sheets emanating away from them. The history of these calderas is marked in the stratigraphy by the characteristic tuffs, breccias, and megabreccias emplaced during the violent, catastrophic collapse.

The eruptive history of the Schoolhouse Mountain caldera (SMC) is exposed in the Burro Mountains, southwest New Mexico, within the southern MDVF.

Combined field observations and field mapping, U-Pb and $^{40}Ar/^{39}Ar$ geochronology, sanidine compositions, whole rock major and trace element geochemistry, and Sr isotope geochemistry provide insight into the evolution of the SMC and a detailed account of the caldera collapse. These techniques provide a more accurate age of caldera formation, place units of the SMC into a caldera model, correlate intracaldera units with regional outflow sheets, and provide context to these units within the MDVF, Boot Heel volcanic field, and the Ignimbrite Flare- up. The precise age of the formation of the SMC was determined by definitively associating units of the Kerr Canyon sequence with the collapse of the SMC and by dating the matrix material of the collapse breccias within it. Boulder clasts up to 30 m in length were surrounded by tuff in both the upper megabreccia and the newly identified lower megabreccia in this sequence. Sanidine crystals from matrix material of the upper megabreccia yielded a prominent $^{40}Ar/^{39}Ar$ age peak of 34.93 ± 0.01 Ma, with minor peaks at 35.3 Ma, 35.6 Ma, and 35.9 Ma. These minor peaks are interpreted as represented xenocrystic contamination from the regionally extensive 35.33 ± 0.10 Ma Kneeling Nun Tuff (McIntosh et al., 1991). Without a date from the lower megabreccia, the upper megabreccia matrix age of 33.93 Ma represents the minimum age of the formation of the SMC. Two rhyolite boulder clasts from the megabreccia yielded $^{40}Ar/^{39}Ar$ ages of 35.34 ± 0.02 Ma and 35.32 ± 0.01 Ma, both of which are coeval with the Kneeling Nun Tuff. The Kerr Canyon sequence culminates with a voluminous biotite-rich ash-flow tuff and several finer-grained ash-flow and air-fall intervals. A sandstone layer in the upper Kerr Canyon sequence is interpreted as representing a hiatus in eruptive activity and marks the contact with the overlying Mangas Creek sequence.

Sanidine compositions have aided in correlating SMC tuffs with regional ignimbrites, and provided evidence to suggest the caldera source of these tuffs. Tuffs previously collectively identified as the "Box Canyon Tuff" were interpreted as being sourced from the SMC, where the Cherokee Canyon Tuff was identified as an intracaldera tuff (McIntosh et al., 1991). McIntosh et al. (1991) used the average age of all the units to represent the age of the caldera. Sixteen samples postulated to be sourced from the SMC were analyzed via electron microprobe, including all of the "Box Canyon Tuff." All analyzed samples contained sanidine phenocrysts with ~Or65 with the exception of the McCauley Ranch Tuff and the Cherokee Canyon flow, which contained notably lower orthoclase percentages of Or43 and Or55, respectively. BaO concentrations among clasts and matrix material of the Kerr Canyon sequence, and Bell Top Formation Tuff 5 are similar to those of the Kneeling Nun Tuff.

Strontium isotope geochemistry has provided additional insight into the evolution of the SMC. There are no significant trends with whole rock initial $^{87}Sr/^{86}Sr$ over time and no overall correlation with inverse Sr among rocks of the SMC. Variations in isotope data may be a result of (1) these units being sourced from a different caldera system; (2) these units were influenced by injected magma that rejuvenated the magma system sourcing the SMC; or (3) sanidines from these rocks being chemically altered from weathering. Increased biotite phenocryst abundances in the biotite-rich tuffs of the upper Kerr Canyon sequence support the potential rejuvenation of the magma system through periodic injection of magma.

Units of the Knight Peak region, thought to be potential outflow sheets sourced from the SMC (this study) are still of unknown source. Geochronology, variations in unit thickness, and whole rock geochemistry from this study has allowed for the conclusion that the JPB Mountain tuff and units of the C-Bar Canyon sequence may possibly be sourced from the SMC. The "Kneeling Nun Tuff of Hedlund 1978" and the overlying lava flow of Malpais Hills are too young to be derived from the SMC and may be sourced from other calderas within the MDVF and/or BHVF.

University of New Mexico

A MULTI-PROXY STALAGMITE RECONSTRUCTION OF THE CLIMATE OF SOUTHWESTERN NORTH AMERICA FROM THE MIDDLE TO LATE HOLOCENE

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The seasonal balance of moisture has a significant effect on natural ecosystems and culture in southwestern North America (SWNA), and it thus is necessary to understand the cause of this moisture variability in order to better predict the scope of potential future changes. Studies of modern SWNA climate indicate that most of the annual moisture at this site comes from monsoonal summer precipitation and a lesser amount of Pacific winter moisture. The climate of the Holocene is of particular interest for constraining natural variability of interglacial climates prior to any anthropogenicinfluence. An overall transition to a wetter Late Holocene climate in SWNA has been established by different climate proxies, and a definable shift in climate around 4.2 ka is observed in records from various locations around the world. However, the lack of highly resolved records in SWNA limits our ability to determine the mechanisms and timing of this climate shift in this region. In this study we present a high-resolution U-Th dated speleothem record from ~6500 to ~1000 yr BP of oxygen and carbon stable isotopes, Sr and Ba trace elements, grayscale, and $^{234}U/^{238}U$ isotope ratios from two caves in southeastern New Mexico. Our data suggests the climate of the Middle Holocene was warmer and dominated by monsoonal precipitation, and the Late Holocene was cooler and experienced an increase in winter precipitation. Our record further suggests this shift occurred around 4.2 ka. High-frequency climate variability observed in SWNA during the Late Holocene has been attributed to an active ENSO/PDO system, yet this was limited by lack of direct comparison with the Middle Holocene. Spectral and wavelet analyses from this study show interdecadal and decadal variation observed in the Late Holocene that is not observed in the Middle Holocene, suggesting that strengthened ENSO/PDO activity is responsible for the increased moisture observed in SWNA during the Late Holocene by increasing winter precipitation.

OBSERVED CHANGES IN CLIMATE AND STREAMFLOW IN THE UPPER RIO GRANDE BASIN

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Observed streamflow and climate data are used to test the hypothesis that climate change is already affecting the streamflow volume derived from snow accumulation in ways consistent with climate model-based projections of 21st century streamflow. Annual and monthly changes in streamflow volume and surface climate variables on the upper Rio Grande (URG) near its headwaters in southern Colorado are assessed for water years 1958–2015. Trends in discharge are examined together with variations in snow water equivalent and surface climate variables. Results indicate that temperatures in the basin have increased significantly primarily in the winter and spring seasons, April 1 snow water equivalent has decreased by approximately 25%, and streamflow has declined in the runoff season, but small increases in precipitation have reduced the impact of declining snowpack on streamflow. Changes in the snowpack-runoff relationship are noticeable in hydrographs of mean monthly streamflow, but most apparent in the changing ratio of precipitation (rain+snow, and snow water equivalent) to streamflow and in regression statistics. The observed changes impact our ability to predict streamflow on a seasonal basis and affect long-term water management of the Rio Grande.

THE DYNAMIC GEOMORPHIC SETTING OF THE LATE PLEISTOCENE HARTLEY MAMMOTH SITE: BURIAL AND SKELETAL PRESERVATION IN A SLUMP-BLOCK DEPRESSION NEAR ABIQUIU, NEW MEXICO

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Near Abiquiu in northern New Mexico, the skeletal remains of two mammoths were discovered in the summer of 2014 in the near-surface deposits of a very small alluvial channel. The channel occupies a depression on the backtilted top of a Toreva slump block, a highly unusual setting for a mammoth burial. Geomorphological investigation of the site has provided insight into processes leading to burial and preservation of the remains, as well as local environmental change. Field mapping of sediment sources and LiDAR scans of the contributing slope basin and slump bench provided a map of geomorphic features and surficial geologic deposits. To better understand the geomorphic context of the mammoth remains, termed the 'Hartley Mammoth,' six soil pits from the mapped surficial geologic deposits were described in the field. Bedrock and soil samples were analyzed using x-ray fluorescence (XRF), loss on ignition (LOI), x-ray diffraction (XRD) and particle size analysis. Bone collagen from a limb fragment returned a calibrated ^{14}C age for one mammoth of about 33 ka. On the mammoth site slump bench, discontinuous bouldery footslope colluvial deposits show clay films and stage l to l+ carbonate, and were likely deposited shortly following slumping due to failure of oversteepened slump scarps. The deposit surrounding the mammoth remains consists of cobbles and small boulders of sandstone supported by a muddy matrix; this texture strongly suggests that the remains were buried by a debris flow. The debris-flow deposit created a high point in the channel, so that subsequent flow was diverted off the downslope edge of the slump block, protecting the mammoth remains from later erosion. Ped-face carbonate coatings (stage I+) in the debris-flow deposit indicate a greater age than the relatively well-sorted and stratified alluvial deposits in the channel above the debris flow. Following mammoth burial, incremental deposition of finer footslope colluvium continued to the present. Overall, field observations, XRF and XRD analyses indicate that despite the ~33 ka age of the mammoth, very little chemical weathering and limited soil development has occurred in the debris flow and other surficial deposits of apparent late Pleistocene age in this dynamic environment.