Abstracts

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

New Mexico Institute of Mining and Technology

REMOTE SENSING OF FIRE EFFECTS ON TAMARISK EVAPOTRANSPIRATION AND REGENERATION, by *Nicole Alkov*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 239 pp.

Millions of dollars have been spent in New Mexico to remove tamarisk from riparian lands along the Rio Grande and restore previously monotypic tamarisk areas with native species such as cottonwood and willow. Elevated evapotranspiration (ET) rates of tamarisk are a main factor in motivating the invasive species' control. One of the tamarisk removal techniques is through the use of controlled burning. In this study, Landsat and MODIS satellite imagery was used in conjunction with the Surface Energy Balance Algorithm for Land (SEBAL) computer model to compare ET and Normalized Differenced Vegetation Index (NDVI) of tamarisk covered riparian areas before and after three recent fires: (1) Mitchell fire of April 9–16, 2005, which burned 414 hectares; (2) Marcial fire of May 3–10, 2006, which burned 2,250 hectares; and (3) Bosquecito fire of June 6–9, 2006, which burned 260 hectares. By comparing the remote sensing results to field point measurements, ground water, and soil data, we evaluate the spatial and temporal ET and NDVI as a proxy for vegetation recovery after fires. Our results demonstrate: (1) Tamarisk ET rebounds much faster after fire than previously thought; tamarisk ET is established as early as one month after fire, and one year after fire tamarisk density and ET returns to pre-fire conditions. (2) The use of herbicide-burn followed by flooding is highly effective in long-term tamarisk eradication. (3) MODIS NDVI data products are able to detect the signal of fire when the fire occurs in the middle of the growing season rather than in the beginning. Concerning environmental factors such as soil regimes and ground water levels on post-fire ET, the presence of a thick clay layer, versus a shallow lense, appeared to induce capillary rise of soil moisture to reach the soil surface within an area of elevated ET at the Marcial fire site, and there appears to be a link between elevated ground water levels and elevated SEBAL-generated values for instantaneous and daily ET and Crop Coefficient data.

This thesis project will ultimately inform hydrological and ecological managers around the globe on tamarisk regenerative behavior and changes in ET post-fire, and will evaluate the effectiveness of the use of fire in river restoration projects. In addition, this thesis project illustrates the power of remote sensing of vegetation regeneration as a sophisticated, cost-effective, and accurate alternative to the costly, conventional vegetation monitoring method of point source data collection in the field by individuals.

DEVELOPMENT AND TESTING OF A SEMI-DISTRIBUTED WATERSHED MODEL: CASE STUDIES EXPLORING THE IMPACT OF CLIMATE VARIABILITY AND CHANGE IN THE RÍO SALADO, by *Carlos A. Aragón*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 143 pp.

Water supply problems are ever increasing as populations grow and supplies are finite. Policy makers have many tools at their disposal to assist in their management of limited resources. One set of tools that are gaining popularity are hydrologic models of varying levels of complexity. Models allow predictions to be made for remote areas over long time periods using limited input data. In this work, we create a semi-distributed watershed model in the Powersim software environment. The model is applied to the semiarid Río Salado and tested with varying atmospheric forcing and climate change scenarios.

The watershed model performed well at simulating point scale soil moisture. Plausible results were also demonstrated at the HRU scale when using different sets of vegetation and soil parameters. The watershed model was unable to reproduce the total discharge at the outlet of the Río Salado, however, and this is believed to be a result of lacking accurate precipitation data rather than a limitation related to model structure. The climate change scenarios provided encouraging results with regards to precipitation changes and built confidence in the capabilities of the model. We believe that this semi-distributed watershed model will be a useful tool for making water supply predictions in semiarid regions, due to its ease of use, and minimal computational and data requirements.

SOLUTE BUDGET OF THE RIO GRANDE ABOVE EL PASO, TEXAS, by *Elizabeth Marie Bastien*, 2009, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 232 pp.

The Rio Grande basin experiences a dramatic increase in total dissolved solids (TDS) with distance downstream from the headwater streams in Colorado (~40 mg/L) to the southern edge of the upper basin in El Paso (over 1,000 mg/L). High TDS concentrations can lead to human health issues, endangered aquatic life, and economic losses. Previous research from the past century primarily focused on electrical conductivity, total dissolved solids, and chloride, yet the causes remained poorly understood. In order to gain a deeper understanding of solute behavior within the Rio Grande, major ion data were compiled for eleven Rio Grande locations including data from 1905–1907, 1931–1936, and where available between 1930–2005. Chemical trends showed an overall solute load decrease with time, primarily due to flood protection structures such as reservoirs and diversion dams, the irrigation network, and a pulse of high saline water from accumulated salts flushing from previously undrained agricultural land. The Rio Grande evolves from a calcium-bicarbonate water near the headwaters into a sodium-chloride-sulfate water near El Paso. The chemical variation can in part be attributed to deep brine seepage and the presence of Elephant Butte Reservoir, where calcium, magnesium, and bicarbonate loads decreased substantially below Elephant Butte Dam. This suggests carbonate mineral precipitation within the lake. In addition, the river chemistry is altered by interaction with soil minerals as it percolates beneath agricultural fields. A mass balance model generated for water and each major ion during the decades between 1930 and 2005 computed the total discharge and load passing each reach by a summation of all known aqueous sources of solutes and of water. The water and chloride mass balance models yielded results that closely matched the measured quantities at each river cross section with percent differences varying between 0.08 and 36% for water and a negligible difference for chloride. Reactive solute models for calcium, sodium, magnesium, sulfate, bicarbonate, and potassium could not be closed with the known source quantities indicating that an additional process affected the behavior of these solutes. These residual solute quantities were attributed to mineral interactions, presumably occurring in river and irrigation channels and/or agricultural and riparian lands. A geochemical mass balance-modeling program (NETPATH) computed mineral interactions responsible for the residual solute quantities. Mineral interactions were dominated by mineral availability along the flow path, with silicate weathering processes in northern reaches transitioning into cation exchange, sedimentary dissolution, and dedolomitization processes in southern reaches. Modeling demonstrated that mineral interactions, tributary inflows, wastewater treatment plant effluents, and geologically controlled brine seepage contribute significant quantities of salt to the Rio Grande. The finding that mineral interactions significantly affect solute behavior in the river has serious implications for water quality management strategies. Unlike brine inflow or the other sources, mineral interactions cannot be controlled and might adversely interfere with proposed migration techniques.

GEOLOGY, GEOCHEMISTRY, AND GEOCHRONOLOGY OF OLIGOCENE MAFIC DIKES NEAR RILEY, NEW MEXICO, by *Melissa I. Dimeo*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 220 pp.

Mafic dikes near Riley, New Mexico, are a subswarm of the large-diameter Magdalena Radial Dike Swarm (MRDS). The MRDS radiates from the westward-younging Oligocene Socorro–Magdalena caldera cluster of the Mogollon–Datil volcanic field. The Riley dikes form the north-central portion of the MRDS and lie on the southeast corner of the Colorado Plateau. The dikes trend between north-northwest and north-northeast, perpendicular to the regional extension direction of the early Rio Grande rift. The Riley dikes are more numerous and closely spaced than elsewhere in the MRDS. This study examines the age, mineralogy, petrology, and geochemistry of the Riley dike swarm. The dikes have a lithospheric mantle source and show age correlations with local caldera-forming eruptions.

Eight Riley dikes were dated by the $^{40}Ar/^{39}Ar$ method as between 25.21 ± 0.30 Ma and 29.19 ± 0.26 Ma. Seven dated dikes appear to radiate northward from the coeval Sawmill Canyon, Hardy Ridge, and Mt. Withington calderas. The two youngest dated dikes trend north-northwest, and the older dikes trend north-northeast, which contradicts a simple radial pattern of emplacement from a deep westward-migrating source under the local calderas. Crosscutting relationships of the dikes in the field also contradict a simple radial emplacement pattern. The dominant northward strike of the dikes and their coeval age relationships to the calderas are

permissible of a relatively fixed magma source under the migrating caldera-forming eruptions.

Based on field occurrences, thin section textures, and mineral chemistry dikes are subdivided into: basaltic, basaltic with significant biotite, minette, analcime-bearing, and analcime-bearing speckled texture. Basaltic dikes contain phenocrystic clinopyroxene, olivine, and groundmass plagioclase ± olivine ± fine biotite. Some basaltic dikes contain phenocrystic biotite, K-feldspar ± plagioclase ± clinopyroxene ± olivine. Minettes are recognizable in the field by the presence of biotite clots. Minettes also contain K-feldspar ± clinopyroxene. Analcime-bearing dikes contain high-calcium clinopyroxene, olivine, sparse biotite, and intergrown analcime and potassium feldspar after leucite. Analcime-bearing speckled texture dikes contain partially assimilated xenoliths of sanidine, biotite, and pyroxene mixed with analcime within a groundmass of plagioclase and clinopyroxene, as observed in thin section. Electron backscatter images show speckled texture dikes contain intersertal analcime and laths of K-feldspar and plagioclase and lack apparent xenolithic or mixing textures. Magnetite is an abundant minor phase in all the dikes, and apatite is common in minettes and analcime-bearing dikes.

Most dikes near Riley probably did not reach the Oligocene land surface. About two-thirds of the basaltic and minette dike samples are autometasomatized by magmatic CO_2 ($\delta^{13}C$ = -3 to -9‰). The CO_2 autometasomatized dikes contain calcite pseudomorphs after pyroxene and olivine(?). Some dikes, usually minettes, contain finely disseminated groundmass carbonate. Analcime-bearing dikes contain little to no carbonate and contain the freshest pyroxenes. One holocrystalline basaltic dike contains little to no carbonate and is bounded by a significant (< 20 m-wide) baked wallrock aureole. This dike is interpreted as a lava flow feeder dike that degassed as it vented.

All the dike samples are potassic, and most are potassic trachybasalt or shoshonite. Analcime-bearing and minette samples have higher alkali and lower silica contents than basaltic samples. Trace element spiderdiagrams show similar patterns with extreme negative Nb and Ta anomalies and more subtle negative Ti anomalies. These anomalies, coupled with high LILE/HFSE ratios, are consistent with a magma source of partial melt of subduction-modified lithospheric mantle with some crustal contamination. Other lavas in the Mogollon–Datil volcanic field share a similar magma source.

DEFLECTION OF RÍO SALADO TERRACES DUE TO UPLIFT OF THE SOCORRO MAGMA BODY, SOCORRO, NEW MEXICO, by *Lisa Majkowski*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 68 pp.

The Socorro magma body is located in central New Mexico along the intersection of the Socorro fracture zone and the Rio Grande rift. High micro-earthquake activity corresponding to the area of the magma body indicates that it is large and currently active. While the depth and extent of the magma body have been fairly well constrained, the age of the magma body is under debate. Evaluation of the surface disruption caused by the magma body can provide clues to the duration of uplift. Specifically, given that the modern rate of vertical deflection can be measured using geodetic techniques, if the amount of deflection of a geomorphic surface above the magma body can be determined, then a minimum age for the initiation of deflection can be estimated by dividing the amount of deflection by the modern rate.

The zone of maximum uplift of the Socorro magma body is localized at the southern end of the Albuquerque Basin, near San Acacia, New Mexico. The modern inflation rate of this area of the magma body has been approximated at 2–4 mm per year, based on leveling surveys and INSAR data. There is ephemeral drainage, the Río Salado, which flows from west to east into the zone of maximum uplift and terminates at the Rio Grande. Rapid and localized uplift of the magma body should deflect the Río Salado Quaternary terrace surfaces upward from the original longitudinal profile.

Quaternary terraces of the Río Salado drainage were assessed for uplift deflection. Measurements were made of the terrace elevation above the active channel. Soil development, based on the degree of $CaCO_3$ accumulation, was used to correlate surfaces and to estimate the relative ages of the terraces. Uplift due to magma inflation should predictably produce vertical displacement of a riverbed and any associated terraces. The modern longitudinal stream and paleostream profiles of a drainage are typically subparallel, thus reflecting the equilibrium state of the drainage over time. However, in a tectonically disturbed region, the longitudinal profiles will deviate from the equilibrium condition with respect to the tectonic source, in this case, the zone of maximum uplift of the magma body. The paleostream longitudinal profiles, as indicated by a distinct sequence of marker terraces, show increasing deflection across the maximum uplift zone.

Although preservation of the Río Salado terrace surfaces is generally poor, there is one well-developed terrace that can be traced throughout the length of the research area. This marker terrace, Qt6, is distinguished by being the lowest terrace that exhibits stage III carbonate horizon development and has a profile mass carbonate content ranging from 11.28 to 13.24 g/cm^3. It is bounded below by a terrace showing weak carbonate horizon development (stage I) and above by terraces showing greater carbonate accumulation (profile mass carbonate of 15.56 g/cm^3). The Qt6 terrace was identified along the drainage using a series of large soil pits and augered soil-test holes. Elevation of the marker terrace above the active channel increases progressively downstream west to east along the Río Salado, from 11.66 to 17.20 m near the Rio Grande. The distribution of uplift inferred from the channel deflection is thus consistent with the accepted zone of maximum uplift of the magma body.

HIGH PRECISION RELOCATION OF EARTHQUAKES IN THE SOCORRO SEISMIC ANOMALY, NEW MEXICO, by *John Morton*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 181 pp.

Improved source locations for earthquakes within the Socorro Seismic Anomaly have resulted from the addition of two broadband seismic stations to the existing Socorro (SC) network and application of waveform cross-correlation (WCC) methods to improve picking consistency among events within earthquake clusters for a catalog of all locatable events from September 2004 through May 2007. Data from these new stations lead to more accurate earthquake locations and can aid in the identification of additional events falling under a quality threshold using only data from the permanent SC network. WCC allows comparison of seismic waveforms to eliminate inconsistencies in user-defined picks, thus reducing hypocentral scatter. Use of these relocation techniques aids in the identification of structures that may be responsible for anomalous uplift attributed to the Socorro Magma Body. Local seismicity is characterized by earthquake clusters, closely related events in space, with nearly half of events falling within this category. Earthquake clusters may be due to magmatic injection in the upper crust or due to a mixture of uplift and instability in the upper crust. Currently, active areas of cluster activity within the Socorro Seismic Anomaly include the area around Socorro Peak, a group of clusters running southeast from Ladron Peak, a southeast-striking structure east of SC network station CAR, and a recurring center of cluster activity near Bernardo. Seismicity patterns suggest that uplift and seismicity correlate spatially. Anomalously shallow earthquake depths and elevated seismicity near San Acacia may be caused by a shallow (< 6 km) magma body or by migration of hydrothermal fluids.

EFFECTS OF RADIATION SHELTERING AND SCATTERING FROM DISTANT LANDSCAPES ON THE ACCUMULATION AND ABLATION OF SNOW IN THE LA JARA CATCHMENT IN THE VALLES CALDERA, by *Alex J. Rinehart*, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 139 pp.

Scattering of, and sheltering from, incoming shortwave radiation by the surrounding landscape, including topography, vegetation, and snow, is an under-emphasized process in snow-dominated montane catchments, especially in regions of higher solar flux such as the southwestern United States. The sensitivity of the distribution of snow in space and time to different representations of these processes has not been clearly evaluated. I have developed a single-layer distributed snow model (DSM) that includes snow interception in the canopy and multiple representations of sheltering and scattering of shortwave radiation. Representations of sheltering include (1) only local controls by slope and aspect, (2) both local controls and remote shading where distant topography may directly block the sun and restricts the amount of visible sky, (3) both local controls and remote scattering where distant topography reflects light onto other points, and (4) combined local controls, and remote shading and scattering. There is no scattering when only local controls are considered. The visible surface controls the amount of scattered light by changing the effective landscape albedo. I have represented the effective landscape albedo as (1) local vegetation albedo, (2) local snow albedo, and (3) a dynamic mixed albedo that captures both the varying conditions of the canopy and the vegetative fraction.

I have applied the model to La Jara catchment (35.858ºN 106.521ºW) in the Valles caldera in the Jemez Mountains of central New Mexico. La Jara drains from the regional topographic high, Redondo Peak, and is a fairly homogeneous forest of subalpine fir (*Abies lasiocarpa*). La Jara contains a wide range of slopes and aspect with a predominantly south-southeast aspect. Nonetheless, Redondo Peak is highly visible to most of the catchment. The radiation sheltering on the flank of Redondo Peak, conversely, is dominated by local shading

(e.g., slope and aspect). Given the homogeneity of vegetation and topographic setting, La Jara is appropriate for this sensitivity study.

I have simulated four cases between 1 November 2004 and 5 June 2005: (1) local controls, (2) remote controls (shading and scattering) with vegetation landscape albedo, (3) remote controls with snow landscape albedo, and (4) remote controls with dynamic mixed landscape albedo. The remotely controlled case with vegetation landscape albedo has shown few differences from the local case, implying that scattered light compensates for the decrease in radiation from remote sheltering. When using snow albedo, large deviations in the dynamics of both radiation and snow cover have been found. The absorbed shortwave radiation differed from -11 W/m^2 to +6.5 W/m^2. The season maximal SWE differed by ±26 cm, while the date of maximum SWE differed from -37 days to +41 days. The total number of snow covered days over the simulation period decreased by 40 days at most. Thus, when snow albedo is used, almost all deviations indicate that scattered radiation far exceeds the effects of sheltering by remote topography. When the mixed albedo was used, the radiation and SWE were found to be nearly identical to the case when snow albedo is used.

For completeness, 16 other simulations were completed. Four of these consisted of using a uniform surface albedo of 0.6 and modeling absorbed shortwave radiation for (1) local controls, (2) local controls and remote shading, and (3) local controls and remote scattering. Parallel simulations were completed with a snow dynamics modeled, incorporating transient albedo. Remote shading was found to decrease the absorbed shortwave radiation, leading to more persistent snowpack through the simulation including snow dynamics. Remote scattering increased the absorbed radiation. When snow dynamics were used, this led to a less persistent snowpack. When vegetation hillslope albedo was used, smaller, less spatially extensive increases in absorbed radiation occurred. When snow or mixed hillslope albedo was used, the increases in absorbed radiation were found to be of greater magnitude and covering more catchment area. By comparing the cases incorporating both remote shading and scattering, and the cases applying only either shading or scattering, it was clear that the combined case was a composite of the latter cases. The hillslope representation controlled which case was more dominant. If vegetation albedo was used, then the combined case was closer to the shading case than the scattering-only case. If snow or mixed albedo was used, the converse was true. It is clear that for La Jara, distant interactions of radiation, snow, vegetation, and topography are critical to consider in regions of high radiative fluxes and rugged topography.

WEATHERING AND LANDSCAPE EVOLUTION RECORDED IN SUPERGENE JAROSITE, RED RIVER VALLEY, NORTHERN NEW MEXICO, by *Kimberly Ellen Samuels*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 157 pp.

Field and experimental work on supergene jarosite from the Red River valley (RRV), northern New Mexico, indicate that alteration scar style erosion began up to 1.5 m.y. ago, possibly in response to downcutting in the Rio Grande rift. This study is composed of three parts: two sample preparation experiments conducted with the goal of improving methods to remove potassium-bearing silicate contaminants from jarosite and a synthesis of jarosite geochronology with stable isotope compositions in an effort to constrain the regional controls on alteration scar formation in the Red River valley.

The first experiment tested whether or not hydrofluoric acid (HF) can remove silicate contaminants without incongruently dissolving jarosite, preferentially removing potassium and argon. Four aliquots of pure Peña Blanca jarosite (PB) and four aliquots of 85% PB mixed with 15% Fish Canyon sanidine (FC-2) were crushed and treated with 40 mL of 25% HF for 0, 30, 240, and 480 minutes. Secondary electron images show that jarosite dissolves during HF treatment with jarosite grains becoming pitted and rounded with time in acid. K_2O concentration of PB jarosite treated for 480 minutes ranges from 7.32 to 9.43 weight percent, which overlaps with the K_2O concentration of untreated PB jarosite (7.93 to 9.43 weight percent), indicating that HF treatment does not preferentially remove potassium. Additionally, $^{40}Ar/^{39}Ar$ ages of both untreated and treated PB overlap with each other and previously dated aliquots of PB jarosite at the 95% confidence level, suggesting that HF treatment has no impact on jarosite's plateau age.

The plateau and integrated ages for the experimental mixture of PB and FC-2 overlapped with the reproducible age for pure PB jarosite. This mixture did not yield the integrated age of 12.35 Ma expected from the complete degassing of 9.6 Ma jarosite and 28.02 Ma feldspar. This overlap suggests that the sanidine did not degas when laser-heated between 1 and 16W with a defocused beam. Jarosite is heated to 10W or less, so sanidine contamination should not affect the apparent age of RRV jarosite. Back-scattered electron (BSE) images indicated that all FC-2 was removed from the mixture after 30 minutes of HF treatment.

The second experiment tested the effects of HF treatment on supergene jarosite from the RRV. Four samples that yielded age spectra with clear evidence of contamination with older phases when dated in 2006 were treated with HF for 30 minutes and re-dated. K_2O concentrations of HF-treated RRV jarosite overlapped with K_2O concentrations of untreated RRV jarosite, indicating that RRV jarosite did not lose potassium during acid treatment. BSE images show that HF-treated aliquots of RRV samples continue to be contaminated with quartz, sanidine, and clay, including illite and chlorite. Apparent age and radiogenic yield climb after the 6W step, which may indicate that clay is degassing in these steps. If a mixture of Quaternary or Pliocene jarosite and Miocene clay degassed completely, the expected integrated age of the mixture would be 7.5–11 Ma. The integrated ages of these samples is consistently < 1 Ma, suggesting that young jarosite controls the apparent age of these samples. Large errors in apparent age may be attributed to low radiogenic yield.

K-FELDSPAR THERMOCHRONOLOGY OF PROTEROZOIC BASEMENT ROCKS: RECONCILING REGIONAL TECTONISM, FLUID ALTERATION, AND ARGON TRANSPORT IN MICROTEXTURALLY COMPLEX FELDSPAR, by *Robert E. Sanders*, 2008, Ph.D. dissertation, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 340 pp.

Three linked, but stand-alone studies use K-feldspar thermochronology to reconstruct tectonic and fluid histories while simultaneously evaluating the underpinnings of the method. Primary conclusions are: (Chapter 1) Disparate thermal histories across the Ancestral Rocky Mountain and Laramide-age Montezuma fault, New Mexico, demonstrate that this fault has a Precambrian ancestry and was reactivated by these younger tectonic events. Major basement denudation leading to the formation of the Great Unconformity occurred post-Grenville (1.1–0.8 Ga) as a result of intracratonic lithospheric deformation related to the assembly and insipient rifting of Laurentia; (Chapter 2) Coupled Precambrian brittle deformation and fluid infiltration in the Pecos area, New Mexico, is revealed by dating of secondary metasomatic K-feldspar, and, in a broader scope, indicates intermittent fluid pulses throughout the Neoproterozoic and Early Paleozoic related to basin development and circulation of evolved crustal fluids. Microsampling discrete areas of secondary K-feldspar in primary perthitic microcline demonstrates that K-feldspar have the potential to record both a regional thermal/cooling signature and the timing of fluid alteration at the sub-grain scale; (Chapter 3) New understanding revealed by microsampling, experimental diffusion studies, and $^{40}Ar/^{39}Ar$ dating of complex alkali feldspar populations from the Klokken syenite, Greenland, partly negate previous challenges to the fundamental assumptions of K-feldspar thermochronology. Specifically, these experiments demonstrate that both $^{40}Ar^*$ and ^{39}Ar behave similarly during laboratory degassing, and that $^{40}Ar^*$ loss under laboratory conditions does occur in a manner analogous to loss in nature.

Chapter 1 is an effort to characterize the basement thermal history of the southern Sangre de Cristo Range, New Mexico, and to evaluate the Precambrian ancestry of several prominent faults known to be active in the Phanerozoic. A suite of K-feldspar, mica, and hornblende was sampled and analyzed by the $^{40}Ar/^{39}Ar$ method. Overall, mafic mineral data and modeled K-feldspar thermal histories from the Sangre de Cristo Mountains indicate Grenville-age (ca. 1.1 Ga) initiation of basement cooling and exhumation to shallow crustal depths (< 200°C) by ca. 800 Ma, following mid-crustal metamorphism at ca. 1.4 Ga. To the east and across the Montezuma fault zone in the Las Vegas Basin, K-feldspar record younger apparent ages and modeled thermal histories indicating this basement segment was not exhumed until later between 750 and 600 Ma. Contrasts in these MDD thermal models suggest there were two episodes of faulting and differential displacement of structural blocks in the Neoproterozoic followed by reactivation during the Ancestral Rocky Mountain and Laramide orogens. No differences in K-feldspar thermal histories were observed from samples on opposing sides of the Picuris–Pecos fault zone suggesting that no significant vertical offset occurred on this fault in the Neoproterozoic. The two documented episodes of faulting and exhumation recorded by basement K-feldspars are inferred to be associated with regional tectonism related to the intracratonic contractional effects of the Grenville orogen and the subsequent extension related to rifting of Laurentia. The application of the MDD model to this particular study demonstrates that differences in modeled thermal histories for K-feldspar can be reasonably resolved by a complex geologic history and recurrent movement on a Proterozoic structure.

Chapter 2 focuses on the occurrence of secondary, metasomatic K-feldspar in fractures and in primary plagioclase in the Pecos River valley that

was identified during a regional investigation of the Sangre de Cristo Range. $^{40}Ar/^{39}Ar$ analyses of replacement feldspars are used to date the timing of fluid infiltration and feldspar precipitation in fractures and localized breccia zones to constrain when deformation occurred. Analyses yielded a wide range of total gas ages including young Neoproterozoic and Paleozoic ages that can only be explained in the context of the known regional exhumation history as mineral growth ages for feldspars that formed below the $^{40}Ar^*$ closure temperature.

Microsampling, imaging, and $^{40}Ar/^{39}Ar$ analyses of film perthite and patch perthite microtextures demonstrates that discrete age populations of secondary K-feldspar are preserved in the primary pegmatitic microcline, and that at the sub-grain scale, unaltered microcline record total gas ages similar to other primary K-feldspar in the Sangre de Cristo Range. With an improved understanding of the K-feldspar mineralogy and argon data, and utilization of other techniques including U-Pb epidote geochronology, fluid inclusion microthermometry, and gas analyses, a complex geologic history is revealed. Multiple metasomatic episodes and coeval brittle deformation related to regional tectonic activity are evident in the Pecos region. Together, chapters 1 and 2 suggest that the Pecos area experienced a rich tectonic history and low-temperature (~280°C) hydrothermal activity throughout the Neoproterozoic. Likely, fluid circulation is associated with tectonic activity related to Grenville compression and Neoproterozoic extension.

Chapter 3 revisits alkali feldspars from the Precambrian Klokken syenite intrusion, Greenland, that historically provided evidence to question the laboratory diffusive behavior of argon in feldspar and whether the behavior is analogous to diffusion in nature (cf. Parsons et al. 1988; 1999). Pristine cryptoperthites yield $^{40}Ar/^{39}Ar$ total gas ages similar to the intrusion age, but deuterically altered sub-grains of patch perthite have much younger and more complex age spectra. Unlike the Pecos situation where young patch perthite ages can be explained by fluid events long after crystallization or metamorphism, Klokken patch perthite has been convincingly interpreted to have formed shortly after syenite intrusion. Initial progress in understanding the complex Klokken data came from microsampling of patch and braid perthite subgrains that showed a bimodal distribution of ages that could be directly correlated to a textural feature. Within a predominantly patch perthite grain, braid perthite sub-domains preserve ages that are similar to the emplacement age, while patch perthites record Paleozoic ages. While this shows that with careful microsampling meaningful age information can be recovered from otherwise complex bulk data, it does not fully explain the mechanism responsible for young ages in the context of the published thermal history. An investigation into the diffusion behavior of the contrasting microtextural varieties was conducted to evaluate and recognize laboratory and natural causes that might explain the young patch perthite ages. Samples were subjected to a series of isothermal heating experiments before irradiation (650, 700, 900, 1,000, 1,100°C). Comparison of the resulting measured age spectra with MDD model spectra predicted from the degassing behavior of ^{39}Ar and known laboratory thermal history show an overall good correlation between ^{39}Ar and $^{40}Ar^*$ diffusive behavior in all samples heated to 650 and 700°C. This correlation is less robust once 900°C is reached, and changes in argon retentivities are also observed. While this has implications for the MDD method and accurate recovery of kinetic information, the lower temperature data strongly argue that the young Klokken patch perthite ages do not reflect anomalously low argon retention in nature that is then obscured by laboratory artifacts. Here it is proposed that the Klokken history is more complex than published, and a mechanism yet to be fully identified in the Klokken patch perthite has caused $^{40}Ar^*$ loss. A working model is that the highly permeable syenite units contain microporous patch perthite that has undergone fluid modification that facilitated $^{40}Ar^*$ loss. Thus, the abundant turbidity of the patch perthite provides microporosity for low-temperature fluid infiltration, in this case during the Paleozoic, and satisfies both the kinetic parameters and a plausible geologic history.

Collectively, the three studies in this dissertation substantiate the validity of the MDD model and demonstrate the utility of linking it with microtextural characterization to determine accurate geologic histories recorded in complex data. The implication that discrete fluid events can modify primary feldspar microtextures, facilitate K-feldspar-K-feldspar replacement reactions, and go under-recognized questions how common this phenomenon is. As a whole, many feldspar studies report good correlation with independent geologic or geochronology information despite varied thermal, tectonic, and presumably hydrologic histories. Research presented here lays the foundation for continued efforts to recover the intricacies of the relationship between microtexture and argon transport. Advances in microanalytical techniques will clarify processes that have been developed here incipiently. Furthermore, this work identifies avenues to propel investigations of the fundamental assumptions behind the MDD technique so that the interpretations inferred from the method are geologically meaningful and accurate.

EFFECTS OF INITIAL SOIL MOISTURE ON RAINFALL GENERATION AND SUBSEQUENT HYDROLOGIC RESPONSE DURING THE NORTH AMERICAN MONSOON, by *Kinwai Tai*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 98 pp.

A moderate change in soil moisture typically alters the intensity, location, and timing of convection rainfall. From a meteorological point of view, studying the soil moisture-rainfall relationship is important for understanding rainfall generation and enhancing rainfall predictability. In the hydrological community, soil moisture plays an important role in shaping hydrologic responses which are influenced by rainfall variability and watershed antecedent wetness conditions. The interaction among soil moisture, rainfall, and hydrologic response motivates us to study the effect of initial soil moisture, rainfall, and hydrologic response in the North American Monsoon (NAM) region. To conduct our study, we couple the Weather Research Forecasting (WRF) model to the Triangulated Irregular Network (TIN)-based Real-time Integrated Basin Simulator (tRIBS) hydrologic model in a one-way, off-line mode. Our particular case study focuses on a four-day warm-season mesoscale convective storm event occurring over the upper Rio Puerco in the north-central New Mexico. To understand the impact of initial soil moisture variations on rainfall generation in the NAM region, we used the WRF meteorological model to simulate an ensemble of meteorological fields by systematically varying the soil moisture initialization in the model domains. The intercomparison of the ensemble basin-scale rainfall simulations shows that the total rainfall volume increases with increasing initial soil moisture to an uppper limit in our warm-season case study. We then use the ensemble meteorological fields to force the tRIBS model using two different scenarios: (1) fixed soil moisture initialization in tRIBS; and (2) adjusted soil moisture initializations between WRF and tRIBS (for the upper Rio Puerco watershed). The results indicate that the runoff ratio increases with increasing rainfall volume, but the trend is more pronounced and nonlinear in the adjusted initialization cases. These differences suggest that the runoff response is primarily driven by rainfall intensity in the fixed initialization, while it is the result of both rainfall intensity and antecedent wetness in the adjusted initialization. The antecedent soil moisture condition significantly shapes the runoff response through the partitioning between different runoff mechanisms and also impacts the partitioning of surface turbulent fluxes and the return of water vapor back to the atmosphere via evapotranspiration. Our high resolution and distributed modeling approach is an early attempt to understand the impact of soil moisture initializations on rainfall production, streamflow response, and evapotranspiration. We conclude that increases in initial soil moisture conditions promote an increase in rainfall, runoff production, and latent heat flux in our warm-season case study. As a result, proper soil moisture initializations in both meteorological and hydrological models should lead to improved hydrometeorological predictions.

THE $^{40}Ar/^{39}Ar$ GEOCHRONOLOGY AND THERMOCHRONOLOGY OF THE LATIR VOLCANIC FIELD AND ASSOCIATED INTRUSIONS: IMPLICATIONS FOR CALDERA-RELATED MAGMATISM, by *Matthew Joseph Zimmerer*, 2008, M.S. thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, 113 pp.

Volcanic and plutonic rocks exposed in the Latir volcanic field, Sangre de Cristo Mountains of northern New Mexico, provide a unique opportunity to study caldera-related magmatic processes, and to understand the spatial and temporal relationship between the volcanic and plutonic record. Fifty-one samples were dated using $^{40}Ar/^{39}Ar$ method. The results indicate a 10 Ma period of Latir volcanic field related magmatism. The volcanic geochronology provides point-in-time information about magmatism whereas the thermochronology of plutonic rocks establishes their emplacement and cooling history.

Volcanic rocks provide information about the earliest magmatism associated with Latir volcanic field. Precaldera volcanism began at 28.3 Ma and ended at 25.3 Ma, based on $^{40}Ar/^{39}Ar$ analysis of hornblende, biotite, and sanidine from exposed rhyolites, latites, and andesites. Combining the published geochemistry with ages of precaldera volcanism from this study indicates that the earliest magmatism was characterized by multiple, small magma chambers, rather than a single, large magma chamber. Peak magmatism occurred during the eruption of the 500 km^3 peralkaline Amalia Tuff from the Questa caldera. Sanidine analyses from eleven samples yielded a mean age of 25.23 Ma for the Amalia Tuff.

Following the eruption of the Amalia Tuff, four resurgent plutons were emplaced in the shallow crust near the center of the caldera. K-feldspar multiple diffusion domain (MDD)

thermal models indicate that the plutons cooled rapidly after emplacement. By 24.7 Ma, within 500 ka of caldera eruption, all the plutons cooled to 150°C. A biotite from the previously undated Cañada Pinabete pluton, a resurgent pluton chemically similar to the Amalia Tuff, yields an age 25.28 Ma. Because the Cañada Pinabete pluton and Amalia Tuff are geochemically similar and their ages are analytically indistinguishable, the Cañada Pinabete pluton is interpreted as non-erupted Amalia Tuff. This supports the idea that ignimbrite magma chambers may not completely drain during eruption and plutons can be directly correlated to large-scale ignimbrite sheets. The other resurgent plutons are slightly younger than the Amalia Tuff and record a compositional transition to lesser-evolved magmas. Three postcaldera rhyolites yield sanidine ages between 24.9 and 25.0 Ma indicating that volcanism was coeval with emplacement of the resurgent plutons.

After resurgent plutonism, three plutons, probably cupolas of a larger, single intrusion, were emplaced and are now exposed along the southern caldera margin. Biotite ages from the Red River, Sulfur Gulch, and Bear Canyon plutons are 24.8, 24.5, and 24.3 Ma, respectively, suggesting incremental emplacement of the larger intrusion along the southern caldera margin. K-feldspar monotonic MDD thermal histories from the individual plutons display differences of rates and timing of cooling. MDD models suggest the Red River pluton remained at a constant temperature of 300°C between 24 and 22 Ma, followed by rapid cooling at 21 Ma. One K-feldspar MDD thermal model from the Bear Canyon indicates rapid cooling at 21 Ma, but another Bear Canyon K-feldspar thermal model indicates rapid cooling at 23 Ma, followed by isothermal conditions at 200°C between 22 and 18 Ma. The unconstrained MDD thermal models suggest reheating by younger thermal events possibly related to magma emplacement.

The two youngest plutons, Rio Hondo and Lucero Peak, were emplaced 5–15 km south of the caldera. An associated study of U-Pb zircon ages suggests that the Rio Hondo pluton was possibly incrementally emplaced between 23 and 22.5 Ma. Biotite collected from multiple locations in the Rio Hondo pluton yield ages of ~21 Ma, indicating that following incremental emplacement, the different increments of the pluton cooled to 350°C at nearly the same time. K-feldspar MDD monotonic cooling models indicate a period of slow to isothermal cooling between 21 and 16 Ma. Alternatively, the unconstrained modeling results show a thermal perturbation at 16.5 Ma, which corresponds to the age of a Rio Hondo hosted rhyolite dike. A single age of 22.5 Ma from a postcaldera andesite on Brushy Mountain suggests that volcanism was coeval with the emplacement of the Rio Hondo pluton. Biotite ages are ~19 Ma from both the interior and margin of the Lucero Peak pluton. Similarly, K-feldspar cooling histories from the interior and margin of the pluton both suggest slow cooling between 19 and 16 Ma. The similarity of cooling histories between marginal and interior units, combined with the lack of robust reheating models, is interpreted to be the result of a complex emplacement history, rather than simple batch emplacement of a pluton. In summary, $^{40}Ar/^{39}Ar$ results from this study describe magmatism at different times associated with caldera volcanism, and provide insight into the relationship between the volcanic and plutonic record.

New Mexico State University

BASIN-FILL ARCHITECTURE OF THE PLIOCENE–LOWER PLEISTOCENE PALOMAS FORMATION ADJACENT TO THE INTRABASINAL MUD SPRINGS MOUNTAINS, SOUTHERN RIO GRANDE RIFT, by *Ron Foster*, 2009, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 81 pp.

Incised Pliocene–Lower Pleistocene strata of the Palomas Formation provide a nearly three-dimensional view of basin-fill architecture adjacent to the intrabasinal Mud Springs Mountains within the eastward-tilted Palomas half graben, southern Rio Grande rift, Truth or Consequences, New Mexico. The strata were divided into five facies assemblages that were mapped at the scale of 1:10,000. The assemblages represent four dispersal systems: (1) the ancestral Rio Grande (crossbedded sandstone assemblage), (2) Black Range hanging wall-derived alluvial fans (volcanic-clast conglomerate assemblage), (3) Mud Springs Mountains footwall scarp-derived alluvial fans (sedimentary, granitic, and metamorphic-clast conglomerate assemblage), and (4) Mud Springs Mountains northeastern dip slope-derived alluvial fans (sedimentary clast conglomerate assemblage). In addition, a fine-grained facies assemblage was deposited adjacent to the northeastern dip slope of the Mud Springs Mountains on Black Range-derived alluvial flats, on the Rio Grande floodplain far from the active channel, or both.

Six stages of deposition adjacent to the Mud Springs Mountains were defined, based on the location and interaction of the facies assemblages. Whereas the Mud Springs fault along the southeastern flank of the Mud Springs Mountains was inactive during deposition of the Palomas Formation, activity on the Caballo–Hot Springs fault system adjacent to the Caballo Mountains strongly influenced the locations of the ancestral Rio Grande and Black Range-derived alluvial fans. Fault activity tilted the Palomas half graben to the east, driving the axial river and Black Range-derived fans toward the Caballo Mountains.

Progressively less precipitation in the region, based on an increase through time in $\delta^{13}C$ values of pedogenic and ground water calcite in the Palomas Formation, may have decreased sediment yields from the small, low-elevation catchments in the Mud Springs Mountains. This inhibited progradation of Mud Springs-derived alluvial fans, allowing the fine-grained facies assemblage (FG) to onlap the northeastern dip slope of the Mud Springs Mountains. Larger, higher-elevation catchments in the Black Range were probably less affected by the paleoclimate change, and their alluvial fans were active throughout the history of the Palomas Formation adjacent to the Mud Springs Mountains.

STRATIGRAPHIC AND STRUCTURAL ANALYSIS OF THE LAS VENTANAS AREA, LA POPA BASIN, NUEVO LEON, MEXICO, by *Frank J. Graf*, 2009, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 100 pp.

The area of Las Ventanas in northeast Mexico contains Lower Cretaceous carbonate outcrops with 200–300 m of topographic relief that border an active gypsum mine quarrying the Jurassic Minas Viejas Formation. The Las Ventanas area is located at the juncture between two regional structural provinces. The two structural provinces are: (1) the southern margin of La Popa salt basin and (2) the northern margin of the Sierra Madre Oriental fold belt. Lower Cretaceous carbonate strata in La Popa basin were deformed by both regional tectonic shortening during the Hidalgoan orogeny and by local, syndepositional halokinesis of diapiric Jurassic Minas Viejas Formation. In contrast, Lower Cretaceous carbonate strata within the Sierra Madre Oriental are only deformed by Hidalgoan folds detached on Jurassic Minas Viejas evaporites. There have been no documented cases of salt diapirism within the Sierra Madre Oriental. Previous work has placed the Las Ventanas area in the Sierra Madre Oriental structural province. New field-based data collected in this study indicate that the Las Ventanas area contains evidence of both salt diapirism and Hidalgoan regional shortening, and therefore lies within the La Popa basin structural province. Evidence for diapirism includes: (1) a diapiric contact between Jurassic Minas Viejas evaporites and the Albian Aurora Formation, (2) stratal thinning toward the diapir, (3) rotation of strata to near vertical, vertical, and overturned orientations directly adjacent to the diapir, (4) presence of high-angle faults extending away from the diapir, (5) local mass wasting deposits or debris flows associated with failure and erosion of diapirically over-steepened strata, (6) extensive fractures and veins associated with high-angle faulting and/or diapirically rotated strata, and (7) structural trends consistent with those of La Popa salt basin.

ORIGIN AND TIMING OF BARITE MINERALIZATION ALONG LA POPA SALT WELD, NE MEXICO, by *Emily R. Haney*, 2008, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 91 pp.

Barite mineralization along La Popa salt weld in northeast Mexico was studied to determine the nature of mineralization. Two possible origins for barite mineralization were tested: (1) syndepositional cold seep and (2) late stage post-burial hydrothermal. The two modes produce barite deposits that vary in distribution, petrographic features, associated and trace mineral assemblages, and temperature of precipitation.

Detailed mapping of the barite deposits along La Popa salt weld documented the distribution along the length of the weld, and hand samples were collected from sixty different localities along and within the weld zone. Samples were taken from mineralized zones, wall rock, and altered zones for petrographic analysis in order to determine the presence of accessory minerals or micro-fossils, color variation, and alteration within the samples. Geochemical analysis of fluid inclusions in the barite, along with sulfur isotope analysis, provided information on the chemistry and temperature of the mineralizing fluids.

Barite mineralization found along La Popa salt weld occurs in intensely fractured zones and open voids that crosscut stratal boundaries. Barite mineralization is found associated with pods of remnant gypsum present along the weld zone. Field and petrographic studies of the barite show that the crystals are very pure, non-porous, and are not intercalated with sediment. No fossils were found within the barite. Trace minerals such as fluorite and quartz are associated with the barite, but there is no evidence of authigenic carbonate minerals/silica minerals or manganese oxides. Analysis of sulfur isotopes revealed a signature of $\delta^{34}S$ of +18.35 and +19.16, confirming that bacterial reduction did not occur on the sulfur within the barite. Fluid inclusion analysis on mono-phase and bi-phase secondary and pseudosecondary

inclusions indicate temperatures of barite precipitation between 85 and 107°C with salinities that range from 8.6 to 18.9%.

Barite along La Popa salt weld is found as veins or open/space fillings and was precipitated by warm hydrothermal fluids that were active during post-Eocene time. Mineralization occurs both on the upthrown and downthrown side of the weld and is not stratally bound or restricted to halokinetic sequences but rather confined to fractured and brecciated zones within 50 m of the weld zone. The lack of fossils, porous crystal texture, and strata-bound barite deposits are evidence that the barite is not cold seep in origin. The southeastern section of La Popa weld acted as a conduit to fluids as evidenced by the presence of calcite and barite mineralization along the southeastern part of the weld. Conversely, the northwestern section of La Popa weld inhibited fluid migration which acted as an impermeable barrier to fluids due to the presence of continuous gypsum and less brecciation along this section of the weld.

GEOLOGY AND STRATIGRAPHY OF CERRO LA PAZ AND VICINITY, LA POPA BASIN, MEXICO, by *Cody W. Holbrook*, 2008, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 67 pp.

Cerro La Paz is a Lower Cretaceous carbonate outcrop with 200–300 m topographic relief that is located at the juncture between two regional structural provinces, the southern margin of La Popa salt basin and the northern margin of the Sierra Madre Oriental (SMO) fold-thrust belt, in northeast Mexico. The exposed stratigraphic units of this study in ascending order are the Minas Viejas Formation (diapiric evaporite of Late Jurassic age that is currently mined), Aurora Formation (200 m, massive limestone), Cuesta del Cura Formation (50–100 m, medium-bedded limestone), Indidura Formation (675 m, deepwater carbonate shale with thin, interbedded limestone), and the base of the Parras Shale (carbonate mudstone with abundant siliciclastics). The Lower Cretaceous carbonate strata of this study were deformed by local syndepositional halokinesis of the diapiric Minas Viejas Formation. Bedding steepened during downbuilding adjacent to the diapir, and near-vertical faults extend from the diapir at a high angle and terminate basinward. Postdepositional regional tectonic shortening during the northwest-southeast Hidalgoan orogeny increased the steepness of the Cretaceous strata that flank the diapir and created disharmonic folds in the Indidura Formation northwest of Cerro La Paz. New cleavage data acquired from these folds indicate a shortening direction of ~035°. The results of this study differ from recent work, which interpreted the deformed strata as a thrust fault. Evidence for diapirism includes: (1) a local unconformity between Late Jurassic evaporite and Lower Cretaceous strata, (2) stratal onlapping and thinning toward the diapir, (3) exotic clasts within the diapir derived from diapiric extrusion (unseen in the SMO), (4) high-angle faults oriented radially to the evaporite-carbonate contact, and (5) Jurassic evaporite is present hundreds of meters above its usual stratigraphic position in the hinge of the fold.

STRATIGRAPHY, SEDIMENTOLOGY AND GEOCHRONOLOGY OF LOWER AND MIDDLE JURASSIC ROCKS NEAR RANCHO SAN MARTIN DEL RINCON, NORTH-CENTRAL SONORA, MEXICO, by *William J. Leggett*, 2009, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 184 pp.

Three Lower to Middle Jurassic units crop out in the area southwest of Rancho San Martin del Rincon, 12 km northwest of Cucurpe, Sonora, Mexico. The Lower Jurassic Basomari Formation is an > 800-m-thick succession of volcaniclastic conglomerate and litharenite beds and subordinate reworked volcanic flows. The Lower Jurassic El Bajio Rhyolite Porphyry is a plagioclase-quartz porphyry and is interpreted as a hypabyssal intrusive unit. The Rancho San Martin Formation is a > 550-m-thick succession of volcaniclastic conglomerate and litharenite beds, andesitic lava flows, rhyolitic ash flow tuffs, and subordinate quartz-rich eolianite and lacustrine limestone beds.

U-Pb geochronology on detrital and igneous zircons provides improved age constraints for these units. The Basomari Formation was deposited between 191.4 ± 3.6 and 189.2 ± 1.1 Ma. The El Bajio Rhyolite Porphyry was emplaced at approximately 180.6 ± 1.3 Ma. Rhyolite tuffs in the Rancho San Martin Formation yield ages of 170.1 ± 1.7 and 168.4 ± 1.6 Ma, but detrital zircons indicate a maximum depositional age of 176 Ma.

Stratigraphic, sedimentological, and geochemical analyses indicate these units record deposition and volcanism within and adjacent to the Cordilleran–Nazas arc during the Early and Middle Jurassic. Basomari strata are primarily composed of volcanic material eroded from andesitic volcanic rocks, but also contain quartz silt, and granitic and gneissic boulder clasts that yielded U-Pb ages of 1,748.2 ± 9.1 and 1,730 ± 11 Ma. The El Bajio Rhyolite Porphyry indicates arc magmatism in the area during the latter part of the Early Jurassic.

The Rancho San Martin Formation records intermediate to silicic arc magmatism and associated volcaniclastic sedimentation in an intra-arc basin during the Middle Jurassic. Eolianites in the lower part of this unit record the input of sand from ergs in the Western Interior of North America and indicate that the Sonoran portion of the Cordilleran–Nazas arc was a low-standing feature. Middle Jurassic normal faults and lacustrine deposition provide evidence for an extensional tectonic regime. Major element compositions indicate andesitic to rhyolitic compositions for volcanic rocks, and trace element compositions support a continental arc origin.

STRATIGRAPHY, SEDIMENTOLOGY, AND GEOCHRONOLOGY OF UPPER JURASSIC ROCKS OF THE ALTAR–CUCURPE BASIN IN THE VICINITY OF CUCURPE, NORTH-CENTRAL SONORA, MEXICO, by *David J. Mauel*, 2008, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 174 pp.

Dominant tectonic influences on Late Jurassic continental rifting of southwestern Laurentia remain debated. Stratigraphy, sedimentology, geochronology of the Cucurpe Formation provide new insights for comparing existing models. The Cucurpe Formation forms the fill of the Altar–Cucurpe Basin, a narrow Late Jurassic depocenter that trended north-northwest for approximately 350 km in northern Sonora. Overlying Lower Cretaceous strata form the fill of the Bisbee Basin.

The Cucurpe Formation represents an upward-coarsening succession of prodeltaic marine slope debris-flow and turbidity deposits. New U-Pb zircon geochronology and a Kimmeridgian ammonite (*Idoceras* cfr. *densicostatum*) constrain the age of the Cucurpe Formation to between ~161 and 150 Ma (early Oxfordian–early Tithonian). The Cucurpe Formation unconformably overlies the Middle Jurassic Rancho San Martin Formation and is unconformably overlain by Bisbee Group strata. Geochronology of the basal Morita Formation indicates a maximum depositional age of 138.7 ± 2.1 Ma and a hiatus of ~15 m.y. between Cucurpe and Morita deposition. This hiatus records uplift and deformation resulting from accretion of the Guerrero terrane.

Detrital zircon and petrographic provenance data indicate primary sources for the Cucurpe Formation and lowest Bisbee Group strata. Lower Cucurpe strata were derived dominantly from Middle Jurassic arc sequences. The upper part of the Cucurpe Formation is dominated by syneruptive silicic volcanic detritus and water lain reworked tuffs. Lower Bisbee Group strata were derived from Middle Jurassic arc sequences, uplifted Caborcan basement and Paleozoic–Lower Jurassic cover, and volcanic rocks of the accreted Guerrero terrane.

U-Pb zircon geochronology of a siliceous tuff or sill from the base of the upper Altar Formation indicates the lower Altar Formation is older than 163.0 ± 1.5 Ma. This and compositional similarities support correlation of the lower Altar Formation to the Middle Jurassic Topawa Group and the upper Altar Formation to the Cucurpe Formation.

Revision presented here of the Mesozoic stratigraphy of the Cucurpe–Tuape region indicates that several conglomeratic units, formerly interpreted as deposits of Late Jurassic pull-apart basins, are not of Late Jurassic age. The restriction of Upper Jurassic conglomerate to limited aerial exposures of Glance Conglomerate casts doubt on the widespread distribution of Late Jurassic pull-apart basins.

TESTING THE LATE CRETACEOUS KAIPAROWITS–MESAVERDE FLUVIAL CONNECTION: A DETRITAL ZIRCON U-PB GEOCHRONOLOGIC AND PETROGRAPHIC PROVENANCE APPROACH, by *Beth Ann Welle*, 2008, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 136 pp.

Detrital-zircon analysis of Upper Cretaceous (Campanian) strata of southern and east-central Utah provides an opportunity to examine long-distance dispersal systems and test correlations of continental strata. Sandstone samples from fluvial strata of the Kaiparowits Formation (n = 5) from the Kaiparowits Plateau of southern Utah and Mesaverde Group (Neslen, Bluecastle Tongue of Castlegate, Farrer, and Tuscher Formations; n = 7) from the Book Cliffs north of Green River confirm correlations of the Kaiparowits Formation with post-Castlegate strata of the Mesaverde Group. Thrust-belt derived sublitharenite and quartzarenite of the Neslen and Bluecastle Tongue formations, respectively, lack Mesozoic grains and contain a broad spectrum of Archean (Neslen peak at 2,700 Ma), Proterozoic (peaks at ~1,700, 1,400, 1,100, 1,000, and 580 Ma), and Paleozoic (peaks at 528 and 413 Ma) grains that record recycling of Proterozoic, Paleozoic, and Jurassic sandstones exposed in uplifted thrust

sheets. South-derived feldspathic litharenite of the Kaiparowits, Farrer, and Tuscher Formations contain Proterozoic grains (peaks at ~1,700, 1,400, and 1,100 Ma) and a diverse population of Mesozoic grains (Triassic–Jurassic peaks at 200, 178, and 150 Ma; Cretaceous peaks at 98, 80, and 76 Ma). Archean grains are rare to absent.

The Precambrian grain ages are consistent with ultimate derivation from basement sources in the southwestern U.S., and the Mesozoic grains were derived from magmatic arc rocks of the southwestern U.S. TuffZirc ages for the six youngest grains from three Kaiparowits samples are statistically indistinguishable from $^{40}Ar/^{39}Ar$ ages on bentonitic tuffs at the same stratigraphic horizons (76–74 Ma) and TuffZirc ages from the Farrer Formation. TuffZirc data also indicate that the Tuscher Formation is older (74–72 Ma) than previously inferred. Statistical analyses, including Overlap-Similarity and Kolmogorov-Smirnoff Statistical tests, in conjunction with young grain ages and detrital age spectra, corroborate petrographic evidence that Kaiparowits rivers connected northward with the river system that deposited the Farrer Formation.

PALEOSOLS AND SEQUENCE STRATIGRAPHY OF LOWER PERMIAN ROCKS, SOUTH-CENTRAL NEW MEXICO, by *Henry J. Zollinger*, 2008, M.S. thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, New Mexico 88003, 81 pp.

The Lower Permian Abo member of the Hueco Formation of south-central New Mexico contains paleosols that formed on interfluves between incised valleys, on fluvial terraces within incised valleys, and on aggrading floodplains of the Early Permian landscape. Interfluve and fluvial-terrace paleosols display features developed during two distinct soil forming events. The first soil forming event occurred while the paleosols were in the vadose zone above the water table. Key pedogenic features include vertical root traces, pedogenic calcic nodules, vertic features, and argillans. The second soil-forming event records waterlogging of the soils and is characterized by gley color mottling, precipitation of goethite and ankerite, and development of veins and lenses of sparry calcite. The polygenetic character of the paleosols is consistent with initial formation for thousands to tens of thousands of years on well-drained interfluves and fluvial terraces, followed by invasion of the paleosols by a rising water table that locally may have been brackish.

The most reliable way to identify interfluves associated with Type 1 depositional sequences is by high-resolution correlation in which a sequence boundary on the floor of an incised valley is traced to its adjacent interfluves. Mature, polygenetic paleosols like those in the Abo member may not be enough by themselves to unequivocally identify an interfluve, but will provide confirmation of the physical correlation. Recognition of interfluve paleosols in other geologic settings could be hampered by erosion or intermittent deposition on the interfluve, climate change during paleosol formation, or a wet climate during the initial development of the interfluve paleosol.

University of New Mexico

STRATIGRAPHY, PALEOMAGNETISM AND MAGNETOSTRATIGRAPHY OF THE UPPER TRIASSIC CHINLE GROUP, NORTH-CENTRAL NEW MEXICO AND PRELIMINARY MAGNETOSTRATIGRAPHY OF THE LOWER CRETACEOUS CEDAR MOUNTAIN FORMATION, EASTERN UTAH, by *Kate E. Zeigler*, 2008, Ph.D. dissertation, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, New Mexico 87131, 224 pp.

The Upper Triassic Chinle Group is prominent in Mesozoic stratigraphy of the American Southwest. Revisions to Chinle Group nomenclature in the Chama Basin, northern New Mexico, include abandoning the term Zuni Mountains Formation, incorporating the lower member of the Salitral Formation into the Shinarump Formation, and the lower member of the Petrified Forest Formation into the Poleo Formation.

New paleomagnetic and magnetostratigraphic data have been compiled from the Chama Basin. Sampling at all sections focused primarily on hematitic mudrocks, using a block sampling technique. These rocks typically carry a well-defined magnetization residing primarily in pigmentary hematite, with laboratory unblocking temperatures below 660°C. All Chinle strata, except Shinarump Formation, typically yield magnetizations with either south or north-seeking declinations and shallow inclinations (e.g., Poleo Formation grand mean: D = 183.1°, I = 0.3°, α_{95} = 5.7°, k = 33.9, N/No = 20/30 sites), and are interpreted as primary, Late Triassic magnetizations.

Paleomagnetic poles for each unit seem to indicate little or no apparent polar wander during deposition of most Chinle strata, followed by an abrupt shift of poles to the northeast from inferred Rock Point strata. These paleomagnetic poles could provide further evidence for a Late Triassic "stillstand," but more likely corroborate new age data suggesting there is no Carnian strata preserved. Pole positions also imply that strata termed Rock Point Formation in the Chama Basin are not correlative to either Rock Point strata in Arizona and Utah or to the Redonda Formation in eastern New Mexico. They are most likely time-correlative to the Triassic–Jurassic Moenave–Wingate Formations. A topographic high was present during Rock Point deposition in the late Norian, and no upper Norian strata were deposited in the modem Chama Basin region.

The Cedar Mountain Formation is well exposed in central Utah, and is one of few documented Lower Cretaceous sedimentary sequences in the western United States. Samples from 14 sites in the lower Cedar Mountain Formation provide preliminary paleomagnetic data to assess the possibility of constructing a robust magnetostratigraphy. A reverse polarity interval demonstrates that lower Cedar Mountain strata were deposited before the Cretaceous long normal and are probably Barremian in age.