Abstracts

New Mexico Geology recognizes the important research of students working in post-graduate MS and PhD programs. In this issue we begin a new series of abstracts, those of recently completed MS theses and PhD dissertations that pertain to the geology of New Mexico and neighboring states.

University of New Mexico

QUATERNARY VOLCANISM IN THE COLORADO PLATEAU–BASIN AND RANGE TRANSITION ZONE: ZUNI–BANDERA AND NEARBY VOLCANIC FIELDS, by *Tracey E. Cascadden*, 1997, PhD dissertation, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 187 pp.

Early (ca 700 ka) voluminous tholeiites in the Zuni–Bandera volcanic field (ZBVF) were followed by smaller volume alkalic, transitional, and tholeiitic basalts intermittently erupted from ca 200 ka through 3 ka. In some cases, lavas of different chemical characteristics were erupted from the same vent or from contemporaneous clusters of vents. El Calderon cinder cone erupted magmas derived from two different sources. Early alkalic eruptions, derived from a depleted (asthenospheric) source, were followed by more voluminous tholeiitic flows derived from an enriched (lithospheric) source. The tholeiite flow erupted at ca 80 ka during a high-amplitude excursion (possibly an aborted reversal) of the geomagnetic field, as indicated by a paleomagnetic direction with declination = 271°, inclination = –17° (N = 10, α_{95} = 4.4°, κ = 124). This tholeiite has higher K_2O, TiO_2, MgO, Co, Nb, Sr, Zr, and LREE contents than other ZBVF tholeiites. The Candelaria Cluster comprises four volcanoes within 4 km^2 area that erupted alkalic and transitional lavas from an asthenospheric source and tholeiitic lavas from a lithospheric source. Lavas from all four vents record moderate-amplitude paleomagnetic secular variation (declination = 32°, inclination = 56°, N = 17, α_{95} = 2.8°, κ = 189) indicating eruption within a very short time span, conceivably less than 100 yrs.

The ZBVF is located within the Basin and Range/Rio Grande rift–Colorado Plateau transition zone, where extension has thinned the crust and lithosphere with respect to the Colorado Plateau but not as much as in the more highly extended Basin and Range. Contemporaneous eruption of magmas from different mantle sources is consistent with a model in which transition-zone alkalic magmas are generated at the boundary between upwelling depleted asthenosphere and residual enriched lithosphere, and tholeiitic magmas are derived from the lithosphere. The lack of coherent chemical trends among flows erupted from different vents is interpreted to indicate that each volcano erupted lavas evolved within separate magma chambers. Chemical variation within each flow can be explained by fractionation of less than 5% each olivine and plagioclase and less than 2% ilmenite, accompanied by less than 3% assimilation of local basement rocks.

QUATERNARY EVOLUTION OF EOLIAN LANDFORMS, SOILS, AND LANDSCAPES OF THE PETRIFIED FOREST NATIONAL PARK, ARIZONA, by *Amy L. Ellwein*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 175 pp.

Quaternary eolian deposits provide one very important type of record of landscape evolution in the Petrified Forest National Park. The park is located on the periphery of the Tusayan dune field, one of the largest North American dune fields. Quaternary deposits were mapped to delineate the distribution, morphology, and soil characteristics of Quaternary deposits; this evidence, supplemented by other types of data, was used to interpret the Quaternary geologic history of the study area. The relative timing of eolian activity was constrained through characterization of stratigraphic relationships and degree of soil development in eolian deposits.

The landscapes of the study area are typical of the southern Colorado Plateau near the Little Colorado River. Where easily erodable mudstones of the Triassic Petrified Forest Formation are exposed, badlands develop; where the more resistant sandstone units outcrop, mesas and buttes form. Development of the modern landscape is largely a result of post-Pliocene fluvial incision. The location and stability of eolian landforms common to this region has been significantly affected by the hydrologic characteristics of Triassic-, Pliocene-, and Quaternary-age geologic materials.

Age estimates for eolian deposits were determined through integration of soils data and the stratigraphic relationships between eolian deposits and landforms such as fans and pediments. The eolian deposits associated with well-developed soils are estimated to be of middle Pleistocene age (100–500 ka), the eolian deposits with relatively moderate soil development are probably of middle Holocene age (2–8 ka), and the eolian deposits that exhibit only very weakly developed soils have been deposited within the last millennia (<1 ka). The study area has experienced episodic eolian activity throughout the Quaternary and is very close to the threshold for eolian activity in the modern climate.

HYDROLOGIC BUDGET ANALYSIS AND NUMERICAL SIMULATIONS OF GROUND-WATER FLOW IN LOS ALAMOS CANYON NEAR LOS ALAMOS, NEW MEXICO, by *Robert Norman Gray*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 485 pp.

A hydrologic budget analysis for the Los Alamos Canyon watershed was prepared including annual budgets for the 1993, 1994, and 1995 water years and detailed budget calculations for the upper basin and middle/upper canyon areas covering nine separate stress periods from 7/10/94 to 11/2/95 corresponding to varying alluvial aquifer behaviors. Data sources included daily measurements of precipitation and snowpack depths, streamflow discharge, and latent heat energy flux from which evapotranspiration rates were determined. Average annual precipitation rates over the watershed varied from ~23 to ~31 inches during the analyzed periods. The annual evapotranspiration component was determined to represent between ~71% and ~84% of the total budget. Annual infiltration rates were calculated as residuals to the basic hydrologic mass balance equation and ranged from ~4 to ~7 inches/yr, representing between ~14% and ~26% of the total water budget on an annual basis.

A ground-water flow model of the alluvial system was constructed using Visual MODFLOW®, which implements the U.S. Geological Survey's three-dimensional finite-difference ground-water flow code. Both steady-state and transient simulations were run. MODFLOW's drain package was used to simulate infiltration seepage from the system, while the hydrologic budget analysis results constrained the recharge and evapotranspiration stresses. The steady-state model was calibrated to well data by varying the drain conductances. The ZONEBUDGET and MODPATH codes were also utilized, and results showed that infiltration seepage dominated the loss components of the modeled system's water budget, representing ~69% of the total losses, compared to ~28% for evapotranspiration and ~3% for downgradient flow, which was characterized with an average advective velocity of 727 ft/yr. Results also quantified enhanced infiltration seepage within the Guaje Mountain fault zone. An error analysis generally corroborated the model results, and a sensitivity analysis was conducted, which showed that the model was most sensitive to errors in recharge and evapotranspiration.

LITHO- AND BIOSTRATIGRAPHY OF THE LOWER CHINLE GROUP IN EASTERN ARIZONA AND WEST-CENTRAL NEW MEXICO, WITH A DESCRIPTION OF A NEW THEROPOD (DINOSAURIA: THEROPODA) FROM THE BLUEWATER CREEK FORMATION, by *Andrew B. Heckert*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 278 pp.

Lower Chinle Group strata in west-central New Mexico and eastern Arizona comprise a 70–150-m-thick succession consisting of, in ascending order, the "mottled strata," Shinarump Formation, the Bluewater Creek Formation and equivalents, and the Blue Mesa Member of the Petrified Forest Formation. This succession rests disconformably upon the Moenkopi Formation and is disconformably overlain by the Sonsela Member of the Petrified Forest Formation. Stratigraphic data indicate that as much as 100 m of stratigraphic relief was generated during development of the Tr-4 unconformity on the Blue Mesa Member.

Detailed lithostratigraphic work in the study area reveals that Adamanian (latest Carnian) localities are separated by as much as 100 m of stratigraphic section and that most of the stratigraphic succession here is of latest Carnian age. Numerous dinosaurs, including a new theropod, from the Bluewater Creek Formation demonstrate that dinosaurs were both diverse and derived in the latest Carnian.

PROTEROZOIC METAMORPHIC AND TECTONIC EVOLUTION OF THE NORTHERN COLORADO FRONT RANGE, by *Meghan Hodgins*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 120 pp.

The Proterozoic was a time of rapid crustal accretion in southwestern North America followed by an approximately 300 m.y. history of metamorphism and deformation. The accretion began approximately 1.75 b.y. ago along the Cheyenne Belt suture zone in southern Wyoming. The region to the south of the suture zone therefore is an ideal location to study the initiation and evolution of this accretionary event. The Big Thompson Canyon in the northern Colorado Front Range exposes a sequence of metamorphosed supracrustal rocks that range in grade from sub-biotite zone to the onset of anatexis. Metamorphic and deformational studies of the Paleoproterozoic rocks indicate that this area experienced at least four generations of deformation and two distinctive metamorphic episodes separated by approximately 300 m.y. of relative stability. The early metamorphism occurred ca 1.75 Ga and consisted of high-pressure (~10 kbar), moderate-temperature (500–600°C) event followed by decompression and cooling. The second metamorphic event occurred ca 1.4 Ga and consisted of a relatively short heating event that reached garnet-staurolite grade (~550°C) at low pressure (<4 kbar) and retrogressed the earlier assemblages; in some cases new crystals of garnet and staurolite grew. There is no pervasive deformation associated with the ca 1.4 Ga metamorphic event; however, there is compelling evidence for localization of strain into areas of thermal weakening in high-grade metamorphic zones, at pluton margins, and in shear zones, such as the Moose Mountain shear zone. The timing of movement on this latter shear zone is constrained by deformational features in the ca 1.4 Ga Long's Peak–St. Vrain batholith that is deformed within the shear zone. Fabric relations indicate that deformation occurred during cooling from magmatic temperatures down to <300°C. It is therefore concluded that the Moose Mountain shear zone was active during and after the emplacement of the granite ca 1.4 Ga. The kinematic indicators within the ca 1.4 Ga shear zone along with oriented dike swarms and fold trends of the same age indicate that a northwest-southeast directed compressional and northeast-southwest directed extensional stress field existed in this area at that time.

SEDIMENTOLOGY OF MIOCENE ALLUVIAL-SLOPE DEPOSITS, ESPAÑOLA BASIN, RIO GRANDE RIFT: AN OUTCROP ANALOGUE FOR SUBSURFACE HETEROGENEITY, by *Andrika J. Kuhle*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 205 pp.

Miocene deposits derived from the hanging-wall uplift of the Pajarito fault in the Española Basin, northern Rio Grande rift, are unusually well exposed and provide the opportunity to describe deposition on a non-fan, alluvial slope. The study site, located about 40 km north of Santa Fe, New Mexico, consists of a 150-m-thick section of vertically exposed, laterally continuous strata that are dominantly finer grained than axial deposits associated with the Rio Grande.

Nine lithofacies were defined and four stratigraphic sections constructed in the area. The lithofacies are varied and range from massive, extensively bioturbated, very fine sand and silt to coarse and pebbly, bedded sand to well-sorted, eolian, fine sand. Massive lithofacies of fine sand and silt are the most abundant, followed by fine-sand channel deposits, then coarse pebbly channel deposits, and finally, well-sorted, fine-sand eolian deposits. These lithofacies are interpreted to represent numerous small channels and adjacent floodplains on an alluvial slope.

Granulometric analyses were conducted for samples representing all of the lithofacies and used to calculate empirical hydraulic conductivity. Calculated hydraulic conductivity values range over three orders of magnitude and represent a fairly continuous range of values. In the case of alluvial-slope deposits, a distinction cannot be made between channel and non-channel deposits in terms of discrete hydraulic properties because channel-fill facies vary over the entire range of values, and non-channel eolian deposits are at least as conductive as some channel deposits.

This continuous range of hydraulic conductivities is in stark contrast to alluvial aquifer and reservoir models that have been developed for large river systems. These alluvial models generally distinguish between two types of deposits: channel and overbank deposits, which have distinctly different hydraulic characteristics. The typical alluvial aquifer model cannot be used to describe aquifer heterogeneity in alluvial-slope deposits.

EARLY EOCENE MICROMAMMALS IN THE SAN JOSE FORMATION, SAN JUAN BASIN, NEW MEXICO, by *Ancheng Ma*, 1997, PhD dissertation, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 216 pp.

The San Jose Formation mammal assemblages are composed of two local fauna, the Almagre and the Largo local faunas, which are from the Regina and Tapicitos Members, respectively. Intensive screenwashing of sediments from five fossil localities in the Regina Member yielded more than 5,000 mammal specimens, most of which are small mammal teeth. Study of these micromammals and review of previously collected specimens recorded 31 taxa that are first known in the San Jose faunas, including two new species. These include *Ectypodus tardus*, *Peratherium innominatum, Peratherium knighti, Peradectes protinnominatus*, *Palaeictops* sp. cf. *P. matthewi*, *Prodiacodon* sp., *Apatemys bellulus, Apatemys* sp. cf. *A. chardini*, *Apatemys* sp. cf. *A. rodens, Talpavus* sp. cf. *T. nitidus, Talpavoides dartoni*, *Pontifactor* sp., cf. *Creotarsus lepidus,* Paramyidae indet., *Miacis exiguus,* cf. *Vassacyon promicrodon, Oodectes herpestoides, Viverravus* sp. cf. *V. lutosus, Pelycodus* sp. nov., *Teilhardina* sp. cf. *T. tenuicula, Tetonius homunculus, Anemorhysis* sp., *Absarokius* sp. cf. *A. metoecus, Ignacius* sp., *Phenacolemur praecox*, *Phenacolemur* sp. cf. *P. pagei, Microsyops cardiorestes, Uintasorex* sp., *Niptomomys thelmae*, *Diacodexis* sp. nov., and *Bunophorus pattersoni*. These new findings expand the San Jose faunas up to 105 species, of which 97 species comprise the Almagre local fauna, and 28 species make up the Largo faunal assemblage. The sciuravid rodent *Knightomys reginensis* of Flanagan, 1986 was considered invalid based on a larger sample, and a new species *Knightomys* sp. nov. was established to accommodate a part of the specimens referred to the former.

Twenty-eight previously measured sections primarily in the Regina Member were correlated using certain sandstones and mudstone bands as marker beds, and known fossil localities in the Regina Member were put into a stratigraphic framework. Five fossil horizons (H-1 through H-5) in the Regina Member were recognized by stratigraphic correlations. No stratigraphic work was conducted in the Tapicitos Member.

The Almagre and Largo faunas were correlated against newly compiled standard Wasatchian faunas from Wyoming. Faunal analysis of the San Jose faunas and comparison with the standard Wasatchian faunas indicate that the Almagre fauna closely resembles the late Graybullian *Bunophorus* Interval-Zone fauna from the Willwood Formation, Bighorn Basin. The absence of the typical Lysitean taxa of Wyoming (such as *Esthonyx acutidens, Mytonomys coloradensis, Cantius abditus, Microsyops latidens, Hyopsodus powellianus, Probathyopsis lysitensis,* and *Heptodon calciculus*) in the Almagre and Largo faunas suggests an older age than Lysitean. The Largo assemblage is from a stratigraphic position higher than the Almagre, and the presence of older species in the Almagre is consistent with this fact. However, faunal analysis and statistics suggest that the Largo assemblage, even though much smaller, is similar in general faunal composition to the Almagre fauna. As a result, a late Graybullian age is assigned to these two San Jose faunas, and the strata producing these faunas are considered equivalent to the *Bunophorus* Interval-Zone in the Bighorn Basin of Wyoming.

The sedimentary and tectonic history of the Laramide San Juan Basin is also studied based on compilation and synthesis of comprehensive data achieved by previous workers. Stratigraphic relations, sediment-dispersal patterns, and depositional environments identified for the terrestrial sequence accumulated in the Laramide San Juan Basin indicate that tectonics imparted a significant control on the basin subsidence and sedimentary history. Stratigraphic geometries and structural characteristics of the terrestrial formations within the San Juan Basin indicate that two of the three previously proposed major pulses of the Laramide deformation were recorded by San Juan Basin deposition.

THE MORPHOLOGIC, GEOCHEMICAL, AND ISOTOPIC CHARACTERISTICS OF LOBATO FORMATION BASALTS IN THE CLARA PEAK AREA, JEMEZ VOLCANIC FIELD, NEW MEXICO: IMPLICATIONS REGARDING MANTLE STRUCTURE IN THE RIO GRANDE RIFT REGION AT 10-12 MA by *Sharon L. Minchak*, 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 104 pp.

A comprehensive study of the Clara Peak area Lobato Formation basalts, considering morphologic, geochemical, and isotopic issues, was the goal of this investigation. The area was found to represent a shield volcano system with the most conclusive evidence being coarse-grained gabbros and thick outcrops of structureless basalt on the slope of the inferred vent area. These outcrops are interpreted as the core and outer chilled margin, respectively, of a magma body that cooled within the subsurface volcanic neck.

Geochemical analyses indicate two predominant compositional types of basalt. A third alkalic basalt group is represented by a sample collected outside the area, from one of the oldest Lobato Formation basalt flows. The groups are differentiated by their normative mineralogy, silica and alkali oxide contents, REE patterns, and spatial occurrence in the investigation area. These compositional differences between groups suggest derivation from separate magma sources.

Five samples were analyzed for $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$. $^{87}Sr/^{86}Sr$ values ranged from 0.7040 to 0.7047, ε_{Nd} values ranged from –3.64 to +0.22. The isotopic ratios indicate a lithospheric mantle source. The ε_{Nd} values of ≤0 are lower than expected based on inferred regional lithospheric mantle ε_{Nd} values (Perry et al., 1987). This suggests Clara Peak ε_{Nd} basalt values may be due to melting of a heterogeneous lithospheric mantle and/or may indicate a lower bulk ε_{Nd} value for the lithospheric mantle in the region.

A progression from alkalic towards olivine-tholeiite basalts is consistent with a regional pure shear rifting model. As lithospheric thinning progressed, the asthenosphere-lithosphere boundary migrated upward, leading to increased degrees of partial melting and melting at shallower depths, yielding more tholeiitic compositions over time. However, the samples' enriched isotopic compositions suggest that at 10–12 Ma, as Lobato basaltic volcanism heralded the initiation of JVF activity, a thick lithospheric mantle was intact in the area.

A MID-CRUSTAL CROSS SECTION FROM THE RINCON RANGE, NORTHERN NEW MEXICO: EVIDENCE FOR 1.68 GA PLUTON-INFLUENCED TECTONISM AND 1.4 GA REGIONAL METAMORPHISM, by *Adam Siddhartha Read,* 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 95 pp.

The Rincon Range and adjacent uplifts of north-central New Mexico expose a 70-km-long transect of Paleoproterozoic rocks that displays a smooth but abrupt south to north change from subhorizontal to subvertical dominant foliation (S_2) over a distance of ~2 km. This change in dominant fabric orientation coincides with a change in metamorphic grade from near-granulite grade (~650°C, 4–6 kbar) in rocks with a subhorizontal fabric to amphibolite grade (~500°C, 4–6 kbar) in rocks with a subvertical fabric. The shallowly dipping S_2 fabric and highest temperature assemblages are centered around a 1,682 Ma granitic orthogneiss, the Guadalupita pluton, that engulfs the overturned lower limb of a ~15-km-scale north-facing F_1 fold. This suggests that granite emplacement facilitated subhorizontal flow that incorporated the granite into the core of the nappe-fold and created the ~200°C temperature gradient between near-granulite and amphibolite grade rocks. Porphyroblast-matrix microstructural studies suggest that progressive S_1/S_2 deformation coincides with regional metamorphism and took place at ca 1,682 Ma. However, metamorphic monazites aligned in S_2 yield U-Pb dates of ca 1,421 Ma, suggesting that renewed tectonism reactivated the older subhorizontal fabric during ~1.42 Ga regional metamorphism. Presently exposed middle crustal geometries reflect a superposition of major tectono-metamorphic events at 1.68 and 1.42 Ga. This study demonstrates that: (1) large temperature gradients around plutons can cause regionally heterogeneous middle crustal P-T-t-D (pressure-temperature-time-deformation) paths; (2) these sheet-like plutons may both localize and be localized by subhorizontal shear zones; and (3) bulk middle crustal rheologies are strongly influenced by thermal weakening near plutons.

LATE PALEOZOIC REMAGNETIZATION OF THE CAMBRO-ORDOVICIAN BLISS FORMATION IN THE FRA CRISTOBAL RANGE AND CABALLO MOUNTAINS, SIERRA COUNTY, NEW MEXICO, by *Eileen M. Romano,* 1997, MS thesis, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131, 172 pp.

Strata of the Cambro-Ordovician Bliss Formation, predominantly a hematitic arkosic sandstone in the Fra Cristobal Range and the Caballo Mountains, Sierra County, south-central New Mexico, yield magnetizations interpreted to indicate that these rocks were chemically remagnetized during the late Paleozoic. Remagnetization took place during the reverse polarity Kiaman supercron, probably by chemical reaction with fluids, possibly driven by tectonism (e.g., basin development during ancestral Rocky Mountain deformation). In the Fra Cristobal Range, 13 of 16 sites sampled around two Laramide-style, Precambrian basement-involved folds, yield thermal demagnetization data showing well-defined and well-grouped magnetizations of south to southeast declination and shallow inclination with a mean, using tilt-corrected site means, of declination = 154.4°, inclination = –7.6°, α_{95} = 7.0°, κ = 33.0. In the Caballo Mountains, 16 of 19 sites sampled in two localities, involving strata gently tilted in response to middle to late Cenozoic (Rio Grande rift) extension, yield thermal and chemical demagnetization data also indicating well-defined and well-grouped magnetizations of south to southeast declination and shallow inclination with a mean, using tilt-corrected site means, of declination = 162.7°, inclination = –10.4°, α_{95} = 6.9°, κ = 29.4. Based on analysis of all sites, subsequent Laramide-age compressional deformation did not result in acquisition of a secondary remagnetization during the Late Cretaceous to early Tertiary. This suggests that a likely condition for remagnetization, fluid migration possibly induced by tectonism, may not, in itself, be sufficient to remagnetize sedimentary rock. Other factors controlling the efficiency of remagnetization may also be important and should be explored; these include the long-term polarity stability of the Earth's magnetic field and the amount and chemistry of available fluids.

New Mexico State University

STRATIGRAPHIC RELATIONSHIPS OF CRETACEOUS AND PALEOGENE DEPOSITS, AND THEIR TECTONIC IMPLICATIONS; CENTRAL PELONCILLO MOUNTAINS, HIDALGO COUNTY, SOUTHWESTERN NEW MEXICO, by *German Bayona*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 143 pp.

In the central Peloncillo Mountains, stratigraphic and provenance analyses of correlative Cretaceous and Paleogene rocks present in blocks bounded by high-angle, northwest-southeast-trending faults indicate that different amounts of subsidence affected three separate blocks in Early Cretaceous time. Subsequently, basement-cored uplift affected southwestern blocks in Late Cretaceous to Paleogene time, whereas deposition took place in the northeastern block. The stratigraphic and provenance results of this study document the inversion history of the northwest-trending, high-angle, reverse Wood Canyon and Goatcamp faults, which separate these blocks.

Early Cretaceous extensional tectonism and relative changes of sea level essentially controlled deposition of the Bisbee Group, which accumulated near the rift-shoulder of the Bisbee Basin. Basal fan-delta deposits of the McGhee Peak Formation, which crop out only in the southwestern Goatcamp block and unconformably rest on Permian strata, record the onset of normal fault activity along the northwest-trending faults. The overall late Aptian retrogradation observed in fan-delta, braid-delta, and shallow-marine deposits of McGhee Peak and Carbonate Hill Formations was controlled by tectonic subsidence of southwestern blocks, the Aptian–Albian transgression, and the low influx of terrigenous detritus. Early-middle Albian progradation of tidal-flat and coastal-plain deposits of the Still Ridge Formation was influenced by a regional drop of sea level and decline of normal fault activity. Resumption of normal fault activity in late Aptian time is interpreted from an abrupt difference in thickness of tidal-flat and coastal-plain deposits of the Johnny Bull Formation. Conglomerate, arkose, and subarkose present in the lower and middle parts of the Bisbee Group were derived from the Burro uplift and intrabasinal uplifts, whereas quartzose deposits present in the middle and top of the Bisbee Group were derived from a source area located farther west of the Burro uplift.

Basement-cored uplift along the Wood Canyon and Goatcamp faults, regional fold deformation, and three magmatic events controlled and accompanied deposition of the Late Cretaceous–Paleogene succession in the northeastern Stone House block. Sediment-gravity flow and volcanic deposits present in the lower part of the Bobcat Hill Formation, which rests unconformably on different parts of the Bisbee section, record two episodes of basement-cored uplift and felsic volcanism, whereas alluvial-plain deposits present in the upper part of the Bobcat Hill Formation record the waning of structural inversion that took place throughout the Late Cretaceous–Eocene Laramide orogeny. Sediment-gravity flows were likely supplied from the Wood Canyon and Goatcamp blocks and accumulated adjacent to the margin of the Laramide Hidalgo Basin, whereas alluvial volcaniclastic detritus was supplied from andesitic volcanoes present within the Hidalgo Basin. The andesite of Steins Pass and andesite intrusive rocks predate and postdate the fault-propagation fold deformation in the Stone House block. Felsic intrusive rocks, which have yielded an age of 31.6 Ma, are the youngest magmatism event in this area.

SYNOROGENIC ALLUVIAL-FAN SEDIMENTATION IN THE CRETACEOUS CORDILLERAN FORELAND BASIN: UPPER PART OF THE INDIANOLA GROUP AND BASAL NORTH HORN FORMATION, CENTRAL UTAH, by *Bradley T. Davis*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 94 pp.

The Cretaceous Cordilleran foreland basin subsided actively from Aptian through Campanian time. Subsidence of the basin during late Campanian time was augmented by subsidence that resulted from the isostatic load of a shallow, subducted slab. This was the result of increased convergence rate between the North American and Farallon plates (Lawton, 1994). Sevier thrusting progressed eastward and was episodically interrupted by out-of-sequence thrust events (Lawton et al., in press).

The Indianola Group is a coarse-grained clastic wedge located on the proximal margin of the Cretaceous Cordilleran foreland basin. Indianola clastics were derived from the Sevier orogenic terrane to the west. Three units, A, B, and C, are defined in the part of the stratigraphic section studied. Unit A records a retrogradation from an alluvial-fan complex of the underlying Reddick Canyon Conglomerate to distal alluvial deposits. Unit B is composed of debris flow and channelized conglomerates and is indicative of facies deposited on the proximal to mid-fan. Unit C deposits are also indicative of proximal to mid-fan depositional facies.

Two major controls effected the formation of the upper Indianola Group and basal North Horn Formation. The first control was the repeated recycling of resistant Precambrian quartzite clasts and less-resistant carbonate clasts, which produced deposits dominated by extremely rounded quartzite cobbles and boulders. The alluvial fan described in this study formed in a subhumid depositional environment. The second control, tectonic activity, caused fan progradation and progressive syntectonic unconformities in units A and B by uplift and tilting of the study area.

LATE TERTIARY EVOLUTION OF THE MIMBRES BASIN NEAR SAN LORENZO, NEW MEXICO, by *Jerald Douglas Dorsey*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 69 pp.

Southern New Mexico has experienced crustal extension in middle and late Cenozoic time. The extended terrain has traditionally been divided into three provinces: the Rio Grande rift, Basin and Range, and Transition Zone. The most studied and best-understood province is the Rio Grande rift, which is considered to have developed in two stages. By comparison to the southern Rio Grande rift, much less in known about the tectonic evolution of the Basin and Range and Transition Zone, primarily because of a lack of detailed geologic maps and few studies of the syntectonic sedimentary unit, the Gila Conglomerate. Sixteen stratigraphic sections of the Gila Conglomerate and five stratigraphic sections of the pre-Gila sedimentary and volcanic units were measured in the San Lorenzo area. Three lithofacies were identified consisting of the proximal fan, middle fan, and distal fan.

Study of these lithofacies within the Gila Conglomerate represents deposition within a half graben and shows several dissimilarities between the Transition Zone and southern Rio Grande rift. These differences show that the southern Rio Grande rift first developed extensional basins in early Oligocene time and that there were at least two pulses of Miocene block faulting and basin development. The study area within the Transition Zone showed no evidence for extensional basins until after 20.6 Ma and no evidence for Oligocene block faulting and basin development. Other differences between the Transition Zone and the southern Rio Grande rift include the first appearance of the ancestral Rio Grande, an axial river that occurred about 5 Ma within the Rio Grande rift (Mack and Hawley, 1997). When compared to the Mimbres Basin, there is no evidence for a Pliocene Mimbres River. Also, the southern Rio Grande rift contains basin-fill sediment of Pliocene and early Pleistocene age, but there is none present in the Mimbres Basin. Despite the many differences between the Cenozoic histories of the southern Rio Grande rift and the Mimbres Basin, there is one similarity that exists. The Miocene basins and uplifts in the southern Rio Grande rift as well as in the Mimbres Basin have a northwest trend.

CAMBRIAN PLUTONISM IN SOUTHERN NEW MEXICO: THE FLORIDA MOUNTAIN INTRUSION, by *Sheryl Denise Ervin*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 66 pp.

Late Cambrian Florida Mountains plutonic rocks present an intriguing problem in interpreting southern New Mexico's tectonic history. Alkali-feldspar granites and syenites, mapped as two distinct bodies separated by the South Florida Mountain fault (SFMF), are overlain by the locally derived Early Ordovician Bliss Sandstone. During Late Cambrian and Early Ordovician, southern New Mexico is thought to have been a passive continental margin. The presence of Cambrian-age intrusions and rapid unroofing implied by the Bliss Sandstone suggests a more active tectonic setting.

Biotite from the northern alkali-feldspar syenites resulted in an $^{40}Ar/^{39}Ar$ age of 490.5 ± 5.4 Ma. This agrees with the previously accepted $^{207}Pb/^{206}Pb$ age of 503 ± 10 Ma determined by Evans and Clemons (1988).

Geochemical and isotopic data indicate the alkali-feldspar granites evolved from parental alkali-feldspar syenites predominately by fractional crystallization with minor assimilation. $^{143}Nd/^{144}Nd$ ratios vary minimally from 0.512495 to 0.512396. Chilled mafic enclaves, $^{143}Nd/^{144}Nd$ = 0.512429 and 0.512454, derived from an enriched mantle source, are similar to parent magmas of the main body of the pluton. All samples have high Ta concentrations and low LILE/HFSE ratios, characteristic of continental rifts or hot spots.

All Florida Mountain igneous rocks are hyper solvus one-feldspar, indicating the intrusion crystallized at P_{H2O} <5 kb (<16.5 km). Rocks north of the SFMF contain orthoclase, but to the south, microcline is present. This indicates the southern rocks cooled more slowly than the northern igneous rocks and were later juxtaposed against the upper half of the pluton by Cenozoic movement along the SFMF.

Mafic enclaves with chilled margins and potassium feldspar xenocrysts (1–3 cm long), identical to phenocrysts in the alkali-feldspar granites, are abundant south of the SFMF. These enclaves are interpreted as partially mixed mafic magmas injected into the lower part of the chamber.

The presence of Late Cambrian magmatic activity and evidence for up to 16 km of erosion between 503 ± 10 Ma and deposition of the Bliss Sandstone (ca 505–478 Ma) suggest that this continental margin was atypical. Field, stratigraphic, and geochemical data suggest that southern New Mexico was experiencing extension, uplift, and magmatism during the Late Cambrian.

THE LOWER MISSISSIPPIAN TRIPON PASS LIMESTONE, EASTERN NEVADA AND WESTERN UTAH, by *Matthew C. Frye*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 101 pp.

The stratigraphic framework of the Lower Mississippian Tripon Pass Limestone in eastern Nevada and western Utah reflects hemipelagic, turbidite, and debris-flow deposition in the Antler foreland basin. Six distinct lithofacies are recognizable and together indicate deposition in a submarine fan system. Recognizable depositional facies include turbidite assemblages of distal-fan origin, channelized conglomerates and coarse sand bodies of the middle fan, and thick calcareous siltstone and fossiliferous limestone deposits of the slope and outer shelf.

Provenance interpretation of the Tripon Pass Limestone is possible due to the gross dissimilarities of the two available sources. The Roberts Mountains allochthon (the western margin of the basin) comprises siliceous deep basinal lithologies. The eastern margin of the foreland basin comprises late Paleozoic preorogenic shelfal carbonates and synorogenic limestone complexes. The Tripon Pass Limestone comprises exclusively carbonate clasts and sand grains, contains flute casts that indicate a paleoflow direction of west to southwest, and exhibits a depositional facies distribution with the most distal deposits located in the west and the most proximal deposits located to the east. The source of the Tripon Pass Limestone inevitably was the eastern margin of the Antler foreland.

Giles (1996) maintains that several flexural features formed in response to the Antler orogeny, and that these features migrated eastward throughout the Lower Mississippian. These features include a foreland basin, a forebulge on the distal margin of the basin, and a back-bulge basin. Differential uplift along the forebulge exposed the lithologic units that sourced the Tripon Pass Limestone.

The stratigraphic architecture was the result of varying controlling factors. Following an initial sediment starved phase, local tectonic uplift along the forebulge generated an abundance of sediment that left a progradational signature within the lower part of the Tripon Pass Limestone. The signature stratigraphically above is one of retrogradation, attributed to a waning sediment supply coupled with continuous subsidence and accommodation increase.

A quantitative analysis of forebulge erosion indicates that between 300 and 750 m of forebulge strata was removed and incorporated into the submarine fan system. The Tripon Pass Limestone was responsible for extensive erosion and locally comprises approximately 25% of total foreland basin fill.

IMPLICATIONS OF ALLOCHTHOGENIC META-IGNEOUS AND CARBONATE BLOCKS IN EL PAPALOTE EVAPORITE DIAPIR, LA POPA BASIN, NUEVO LEON, MEXICO, by *Jennifer Marie Garrison*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 142 pp.

El Papalote evaporite diapir is exposed in La Popa Basin, located approximately 100 km northwest of Monterey in northeastern Mexico. The elliptical diapir has a surface exposure of 4–5 km^2. Surrounding the diapir are vertical limestone lentils that were deposited as lenses on the sides and top of the diapir as it formed during the Late Cretaceous. Contained within the diapir are large blocks (200 m diameter) of greenschist facies metaplutonic (monzonite, biotite–diorite), metavolcanic (basalt, andesite), and carbonate (mudstone, packstone, wackestone) rock. Based on rock textures and geochemical analysis, the meta-igneous blocks are divided into four main groups: high Nb metavolcanic (59–80 ppm), intermediate Nb metavolcanic (43–45 ppm), low Nb metavolcanic (25–36 ppm), and metaplutonic samples. Relatively high Nb and Ta concentrations and low La/Ta ratios in all groups suggest that the meta-igneous blocks were initially emplaced during Jurassic (?) continental rifting in northern Mexico. Fluids warmed by heat flow in the rift and/or contact with intrusions circulated through the igneous rock, creating greenschist facies conditions (T = 350°C), as evidenced by the mineral assemblages epidote–chlorite–actinolite–albite and serpentinite–brucite. $^{40}Ar/^{39}Ar$ radiometric dating of biotite in the metaplutonic blocks yielded ages of 145.6 and 146.5 Ma, which may represent the end of high heat flow in the rift and cessation of rifting in the Chihuahua trough. During the Early Cretaceous, the blocks were entrained and transported in the evaporite of El Papalote diapir. Numerical models show that it is possible to entrain blocks in the diapir from the salt/basement interface and transport them to the surface.

During Maastrichtian time, the diapir grew episodically, producing and deforming the surrounding strata and flowing laterally over the lentils. Many of the carbonate blocks are lithologically like the surrounding limestone lentils; however, the majority do not resemble units that crop out in La Popa Basin, suggesting that they were also entrained from the subsurface section.

MAGNESIUM CARBOXYLATE COMPLEXING IN AQUEOUS SYSTEMS, by *Renee' Victoria Hilton*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 126 pp.

Brucite solubility experiments were used to determine stability constants for magnesium acetate complexes in aqueous sodium acetate solutions at ionic strengths of 0.00, 0.10, 0.25, 0.50, and 0.75 molalities at 25° C. Preliminary data were generated from 50° and 75° C brucite solubility runs used to determine the suitability of new experimental designs. All brucite solubility experiments were carried out in 500 milliliter polyethylene reaction vessels submerged in thermostated water-bath systems. ICP and AAS were used to determine total magnesium in solution. Speciation determinations for the 25° C run solutions were performed using Solmineq.88: a computer program for geochemical modeling of aqueous solutions and water-rock interactions. Stoichiometries of the dominant magnesium species and the stability constant for $MgAc^+$ were determined from regression of solubility data and corresponding speciation results. The dominant magnesium species under the 25° C run conditions are Mg^{2+}, $Mg(OH)^+$, and $MgAc^+$. The stability constant for the $MgAc^+$ complex is 18.62 (Log β = 1.27 ± 0.02), a value comparable to those obtained from Smith and Martell (1977), Archer and Monk (1964), and Nancollas (1956) at 25° C. Time constraints did not permit for the allotted 30 day run duration for the 50° and 75° C brucite solubility experiments. However, preliminary data from these experiments did indicate that the implementation of electric stir plates in place of non-electric magnetic stirrers were adequate for high-temperature solubility experiments. In addition to determining the extent to which magnesium will complex with acetate under controlled conditions, the soil solutions of El Puerto Juarez, Mexico, in the Yucatan Peninsula, provided the necessary chemical parameters to model Mg-Ca-Ac complexes in natural settings. The modeled soil solutions suggested that both magnesium and calcium prefer to complex with the corresponding acetate ion in solution rather than remain as an independent ionic species. Constituents that may potentially inhibit acetate complex formation under natural conditions include the sodium and potassium ions as well as magnesium and calcium sulfates and carbonates. Speciation determinations for both the experimental and natural systems indicate that the $MgAc^+$ and $Mg(Ac)_2^0$ species are present in high proportions when acetate concentrations are greater than 0.10 molal. These complexes, as well as other metal-organic complexes, have been found to facilitate metal solubility, transport, and ultimately ore deposition in aqueous and hydrothermal fluids.

TECTONOSTRATIGRAPHIC INTERPRETATION OF UPPER CRETACEOUS TO LOWER TERTIARY LIMESTONE LENTILS WITHIN THE POTRERILLOS FORMATION SURROUNDING EL PAPALOTE DIAPIR, LA POPA BASIN, NUEVO LEON, MEXICO, by *Lela Hunnicutt*, 1998, MS thesis, Department of Geological Sciences, New Mexico State University, Las Cruces, NM 88003, 180 pp.

El Papalote evaporite diapir controlled the distribution of sedimentary facies in the southeastern part of La Popa Basin during latest Cretaceous through early Tertiary time. El Papalote diapir is flanked by a series of six discontinuous carbonate masses referred to as lentils. The six lentils formed in a complex mixed siliciclastic /carbonate marine environment. Petrographic analysis of the six limestone lentils resulted in the determination of 12 distinct lithofacies, which indicate that the basin was locally characterized by deep, normal marine to stressed marine conditions during lentil deposition. The lentils are Upper Cretaceous (Maastrichtian) to lower Tertiary (Paleocene) in age based on benthic and rare planktic foraminifera.

Horizontal and vertical sedimentation patterns encircling the diapir illustrate facies changes from east to west around El Papalote diapir. On the far eastern and western sides of the diapir siliciclastic sediments and stressed carbonate facies are dominant, controlled by the presence of the diapir as a topographic high. Evidence that the diapir was a topographic high during the time of sedimentation include: (1) discontinuous limestone in a siliciclastic-dominated basin; (2) bionutrient phosphate, which may have been derived from the diapir, within the lentils; (3) calcite precipitation from the high concentrations of calcium ions as a result of the dissolution of gypsum; (4) igneous clasts within the diapir and the lentils; (5) the "shadow effect" (Kneller and McCaffrey, 1995) observed in the siliciclastic sedimentation patterns surrounding the diapir; (6) the facies distribution; (7) bedded gypsum and halokinetic breccia at the base of lentil 1. In the central and eastern parts of the limestone surrounding the northern margin of the diapir, normal marine bryozoan-rich facies are dominant. This is interpreted as a result of the "shadow effect" caused by the diapir blocking and redirecting siliciclastic sediment around the diapir, leaving a protected area where normal marine carbonates could develop.

The vertical facies trends are divided into four types of cycles: upward-shallowing carbonate cycles, upward-shallowing stressed carbonate to siliciclastic cycles, stressed carbonate to normal marine carbonate cycles, and saline to carbonate cycles. Cycles range from a few meters to over a hundred meters thick. Lentil 1 is characterized by upward-shallowing cycles dominated by coralline red algae. The other three cycle types are present in lentils 2–6. Stressed carbonate to siliciclastic cycles are present in the far eastern and western section of the sediments surrounding the diapir. Stressed carbonate to normal marine carbonate cycles and saline to carbonate cycles are present in the central and eastern sections. The cycles are controlled by El Papalote diapir, with minor influences by regional controls including tectonics (rise of the Sierra Madre Oriental), eustasy, and climate.

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IMPROVED GEOLOGICAL CHARACTERIZATION OF OLD HYDROCARBON FIELDS WITH SPARSE CONTROL POINTS: A CASE STUDY FROM THE SULIMAR QUEEN FIELD, SOUTHEAST NEW MEXICO, by *Maqsood Ali*, 1997, PhD dissertation, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 410 pp.

The characterization of old hydrocarbon fields that are deficient in calibrated logs, cores, and reliable production data is a challenging task, and no established methodology is available in the industry. The objective of this study was to characterize an old field—the Sulimar Queen—by developing new techniques and modifying existing ones to increase the quality and quantity of data. The Sulimar Queen field is producing from the Shattuck Member of the Queen Formation and is located in southeast New Mexico. The control points available from the Sulimar Queen field consisted of a core and modern logs from only one well, two core reports, and modern log suites from four wells. Only old gamma ray and neutron logs were available from the rest of the field. During the characterization of the Sulimar Queen field, data from the Sulimar Queen field, analog reservoirs (adjacent fields), and Shattuck Member outcrops were used.

In the first step, the scale of permeability heterogeneity was established using cores from the Sulimar Queen and adjacent fields. The scale of permeability heterogeneity was found to be the same in the Sulimar Queen and adjacent fields.

A new technique for collecting and analyzing petrographic data was developed by combining minipermeameter and thin section analysis. This technique was developed in order to: (1) increase the quality and quantity of petrographic data related to permeability and (2) conserve the limited core material available from the Sulimar Queen field.

Fuzzy logic and neural network were used for the first time for petrographic data analysis and permeability prediction, respectively. Fuzzy logic algorithm was used to determine the control (ranking) of petrographic elements on permeability. The fuzzy logic algorithm is fast, unbiased, and useful in dealing with a large number of variables. Based on the results of the fuzzy logic ranking, a neural network was used successfully to predict permeability using the petrographic data.

Old gamma ray logs were first rescaled using the modern logs to increase their reliability. The rescaling of the gamma ray logs improved the identification of different porosity zones within the Shattuck Member. Rescaled gamma ray logs were used for the first time to predict porosity, sand thicknesses, and total water content.

The outcrop study of the Shattuck Member revealed that the sandstones were deposited in a mixed eolian and marine environment. The thicknesses of the sandstone units are variable and show lateral change from sandstone to evaporites. In the subsurface, similar lateral change from sandstone to evaporites is responsible for the formation of traps and the development of reservoirs in the Shattuck Member.

Information from thin sections, cores, logs, and outcrops was combined to develop the depositional model for the Shattuck Member in the Sulimar Queen and adjacent fields. The Shattuck Member was deposited in mixed lagoonal-sabkha-eolian environments. Based on the depositional model, a two layer simulation system was established. A history match of the primary performance was first achieved, and then the secondary performance was forecasted. A reasonable agreement between forecast and actual secondary performance attested to the credibility of the developed model.

^{40}Ar/^{39}Ar GEOCHRONOLOGY AND VOLCANIC EVOLUTION OF THE TAOS PLATEAU VOLCANIC FIELD, NORTHERN NEW MEXICO AND SOUTHERN COLORADO, by *Robert M. Appelt,* 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 58 pp.

New ^{40}Ar/^{39}Ar ages provide a refined chronological framework for the Taos Plateau volcanic field (TPVF), northern New Mexico. The TPVF is the largest dominantly basaltic volcanic field erupted in relation to the reinitiation of extension in the Rio Grande rift in the middle to late Miocene. The lavas of the TPVF include the volumetrically dominant, highly fluid olivine tholeiites of the Servilleta Basalt and lesser amounts of andesite, dacite, alkalic basalt, and basaltic andesite. Eighty-six ^{40}Ar/^{39}Ar ages were determined from 82 groundmass concentrates step-heated in a resistance furnace and four feldspar concentrates analyzed as single crystals with a CO_2 laser fusion.

The ^{40}Ar/^{39}Ar ages show that the TPVF erupted regularly from approximately 5.9 to 2.1 Ma, followed by a single small eruption at 1.1 Ma at the Mesita vent. Intermediate-composition pyroxene dacite and olivine andesite lavas were erupted episodically from 5.4 to 2.1 Ma and from 5.9 to 3.3 Ma, respectively. These intermediate composition lavas include the oldest lavas to be erupted within the TPVF. The three members (lower, middle, and upper) of the Servilleta Basalt erupted from 4.8 to 2.6 Ma. The flows of the Servilleta Basalt represent the most regularly erupted lavas within the TPVF. The basaltic andesites and related alkalic basalts erupted primarily from 4.0 to 2.0 Ma, with an additional isolated eruption at 1.03 ± 0.01 Ma (Mesita vent).

The following table compiles the ages for prominent eruptive centers within the Taos Plateau volcanic field:

Eruptive center	Age (Ma) ± error (1σ)
Cerro Montoso	5.88 ± 0.18
Guadalupe Mtn.	5.34 ± 0.08
Cerro Chiflo	5.32 ± 0.08
Cerro de la Olla	4.97 ± 0.06
Cerro de los Taoses	4.84 ± 0.04
Cerro Negro	4.84 ± 0.05
Tres Orejas	4.84 ± 0.02
Los Mogotes	4.75 ± 0.02
Cerro Mojino	4.32 ± 0.03
No Agua Peak	4.06 ± 0.05
Cerritos de los Cruz	3.94 ± 0.05
Cerro del Aire	3.69 ± 0.03
La Segita Peaks	3.53 ± 0.09
San Antonio Mtn.	3.05 ± 0.05
Red Hill	2.91 ± 0.01
Ute Mtn.	2.70 ± 0.01
Pinebetoso Peaks	2.34 ± 0.10
Mesita vent	1.03 ± 0.01

Eruptive activity in the TPVF generally tended to shift to the west and north with time. The 6–4 Ma volcanic rocks are exposed along the eastern boundary of the TPVF centered on the Red River gorge area. After 4 Ma the majority of the TPVF volcanism shifted to the western margin of the field in the Tres Piedras–San Antonio Mountain area. Two exceptions to this pattern are Ute Mountain and the Mesita vent, which erupted after 3 Ma but lie on the eastern margin of the TPVF, north of the 6–4 Ma lavas and eruptive centers. Two possible explanations for this shift in volcanism are migration of the zone of influx of new magma into the system with time or more probably, changing fault activity controlling the spatial distribution of the TPVF lavas.

ENVIRONMENTS OF FORMATION AND CONTROLS ON THE SPATIAL DISTRIBUTION OF CALCITE CEMENT IN THE SIERRA LADRONES FORMATION (PLIOCENE–PLEISTOCENE), NEW MEXICO, by *John S. Hall*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 270 pp.

Cemented features occur in fluvial sediments (deposited by the ancestral Rio Grande and its tributaries) of the Sierra Ladrones Formation (Pliocene–Pleistocene), New Mexico, and have the following description of their materials and porosity. Most samples classify as lithic arkoses, feldspathic litharenites, and litharenites. Nonframework material is dominated by either clay or calcite. Porosity is mostly intergranular macroporosity.

Calcite cements were studied to establish their hydrologic environments of formation and controls on their spatial distributions. Cements formed in phreatic, vadose-nonpedogenic, and vadose-pedogenic (?) hydrologic environments. The hydrologic environments are characterized by the following textures and features: (1) phreatic—sparite with uniform, disseminated, isopachous, poikilotopic, and drusy textures; (2) vadose-nonpedogenic—micrite with meniscus and pendant textures; and (3) vadose-pedogenic (?)—cement textures similar to those in the vadose-nonpedogenic environment plus macroscopic features such as root structures, destruction of primary sedimentary textures and structures, and a red hue. Many of the cements are of mixed vadose/phreatic origin, with vadose micrite formation preceding phreatic sparite.

All cements are >97 mole % $CaCO_3$ and have carbon and oxygen stable-isotope values that vary little. Micrite tends to have greater trace-element amounts than sparite; this difference could be controlled by either the precipitation rate or differences in the elemental composition of the pore waters. δ^{13}C values range from –10.1 to –8.9 PDB and δ^{0}18 values range from –10.3 to –7.24 PDB. Cements that are interpreted to be dominantly vadose have a wider range of δ^{13}C values that are lower overall than those interpreted to be phreatic. δ^{0}18 values are similar for both vadose and phreatic cements.

Five controls on the spatial distribution of calcite cement account for the microtextures and geometries of the cemented features: (1) fine-grained sediments concentrated vadose water from which micrite precipitated; (2) clay minerals may have buffered pH higher and provided Ca^{++}, which enhanced micrite formation; (3) early vadose micrite acted as nucleation sites for later phreatic sparite; (4) roots increased calcite saturation due to transpiration; (5) saturated precementation permeability differences among lithofacies and the architectural elements focused flow in the coarser sediments enhancing the precipitation of sparite within them; the result is that coarser architectural elements are more cemented than finer elements.

Laterally extensive (10–100 m) planar cemented features in the coarser elements decrease permeability and increase permeability heterogeneity resulting in compartmentalization of the aquifer/reservoir. This negatively affects aquifer/reservoir quality compared to similar uncemented sediments.

CONTROLS ON FAULT-ZONE ARCHITECTURE AND FLUID FLOW IN POORLY CONSOLIDATED SEDIMENTS: THE SAND HILL FAULT, CENTRAL NEW MEXICO, by *Michiel R. Heynekamp*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 73 pp.

Faults in poorly consolidated sediment and their influence on fluid flow are poorly understood, despite the fact that many of the aquifers in the southwestern United States and hydrocarbon reservoirs in the world are situated in basins filled with poorly consolidated sediment and cut by numerous faults. In order to better understand how such faults influence fluid flow, determination of the controls on fault-zone architecture is useful. In this study, I have characterized a fault that cuts poorly consolidated sediment in order to determine these controls. The Sand Hill fault, Albuquerque Basin, central New Mexico, was selected because it is exceptionally well exposed and cuts a variety of poorly consolidated sediments.

The architecture of the Sand Hill fault zone varies in a qualitatively predictable manner. The grain size and bed thickness of sediments adjacent to the Sand Hill fault controlled whether deformation was distributed or localized within the fault zone and what the contribution of each bed was to the fault zone. Where the adjacent sediments are thickly bedded and >~18% sand and clay beds are thin and rare, the fault zone is wide and structurally complex. Where the adjacent sediments are thick and ≥~18% clay and silt or thin, clay-rich beds interspersed with sub-equal numbers of thin, sand-rich beds, the zone is narrow and structurally simple.

The fault zone is preferentially cemented with respect to adjacent sediments. Cemented zones are found nearly everywhere in the hanging wall (eastern or basinward side) of the fault where the hanging-wall sediments are sands and gravels. The cemented zones are commonly flanked by elongate concretions that are believed to record the orientation of groundwater flow at the time of their formation. The elongate concretions indicate that fluid flow was dominantly subvertical and parallel to the fault zone. Previous work has indicated that flow in surrounding sediments went from northwest to southeast, toward the fault. The cements are best developed where both the hanging-wall and footwall sediments are coarse grained. These relationships imply that at the time of cement formation there was both cross-fault and fault-parallel flow.

FIELD RELATIONSHIPS AND EVOLUTION OF LEUCOCRATIC, BASIC VEINS AT EL PORTICITO VOLCANIC VENT, NEW MEXICO, by *Robert R. Horning*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 146 pp.

El Porticito is a butte composed of lava and interpreted to be the eroded remnant of a volcanic vent. It is located in the transition zone between the Colorado Plateau and the Basin and Range province in west-central New Mexico, United States of America. It is distinguished by the striking white, vertical and horizontal, millimeter- to meter-scale, coarse-grained tephritic veins that cut across the black basanite faces of the edifice. The leucocratic color of the veins is controlled by their mineralogy: black, coarse-grained augite and iron-titanium oxide crystals set in a finer-grained white groundmass consisting of alkali feldspar, nepheline, zeolites, and analcime.

Substantial whole-rock compositional variation within veins is due to variable concentrations of the relatively sparse augite and Fe-Ti oxide phenocrysts, flow segregation of the phenocrysts, and subordinately to post-emplacement alteration. Augite phenocryst compositions and morphologies record a cyclic growth history that was strongly influenced by varying Ti activity during vein melt cooling.

The veins occur within only one of the two basanites that constitute the bulk of El Porticito. Major and compatible trace-element data suggest that vein magma evolved at depth through crystal fractionation from the older, less-evolved basanite. Stratigraphic relationships indicate that vein magma then intruded the younger basanite while the latter cooled through the rheological critical melt percentage.

Geochemical modeling suggests that the basanites crystallized from distinct parent magmas that had undergone different degrees of evolution from a common mantle source in which garnet remained in the restite. Compatible trace-element concentrations preclude the evolution of one basanite from the other. The Mn and Ca contents of the cores of olivine phenocrysts found in the basanites suggest equilibration at different depths with magmas having comparable Si and Fe activities, while rim compositions reflect distinct chemical conditions in the host basanites during final crystal growth.

TRAPPING OF NONAQUEOUS PHASE LIQUIDS AT SAND/SHALE INTERFACES, by *Claire Chia-lan Hsu*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 107 pp.

Spilled nonaqueous phase liquids (NAPLs) can be trapped by relatively small-scale structures at sand/shale interfaces just as hydrocarbons are naturally trapped in larger-scale structures in oil and gas fields. When NAPLs are immobilized by trapping at sand/shale interfaces they may become a long-term source of contamination because conventional pump and treat remediation methods may not adequately remove them. At the same time, NAPLs immobilized at sand/shale interfaces can only have a limited effect on the aquifer because dispersion and dilution processes will act over some finite distance to decrease dissolved NAPL concentrations below regulatory limits. Micro-scale closure, defined as the height of the trapping feature, was measured on the upper sand surface immediately below the overlying shale for 62 locations at three sites for fluvial/alluvial and tidal-flat depositional environments. Closure volume ranged from a low of 0.56 L/m^2 to a high of 2.88 L/m^2. The average for all sites was 1.22 L/m^2. The area of each measurement ranged between 1,024 and 2,090 cm^2. Closure height of the sites could not be measured for individual features, so topographic variation was measured at each of the 62 locations. Topographic variation ranged up to a maximum of 3.3 cm, and site means ranged between 1.3 and 2.4 cm.

Sand-box experiments were also conducted to see if micro-scale features have NAPL trapping potential. The results suggest that for NAPLs to be trapped at greater than residual saturation, the trap closure height must be greater than the capillary rise of water into the NAPL. A closure of 4.0 cm effectively trapped Marvel Mystery Oil™ when the average grain size was 1.5 mm, but it failed to do so at smaller grain sizes. The experimental results are adequately reproduced by Hobson's Formula, which states that the height of capillary rise is inversely proportional to grain size and is also a function of the physical properties of the NAPL. Further calculations using Hobson's Formula suggest that traps containing coarse-grained materials are effective for some NAPLs at closures approaching 1 cm, while fine-grained sands required minimum closures of slightly less than 1–5 m or more to trap NAPLs.

TEMPORAL VARIABILITY OF PRECIPITATION RECHARGE IN SEMI-ARID NEW MEXICO, by *Anne K. Kearns*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 45 pp.

The high level of dependence upon ground water in the American Southwest has led to the rapid depletion of those resources. Future population and economic pressures will force further increases in the extraction of ground water, perhaps at the expense of the economic well being of the region. Recent studies support the probability of diffuse precipitation recharge, but none have quantified it on a long term basis. The objective of this study was to verify the possibility of significant quantities of diffuse precipitation recharge.

One hundred years of actual precipitation data from near Las Cruces, New Mexico were used as input to a one-dimensional numerical model to explore this concept. Four soil textures (two sandy loams, a loamy fine sand, and a clay) were simulated in soil profiles, some 2, some 6 m deep, both barren and vegetated. Barren, loamy, fine-sand soils showed continuous recharge throughout the evaluated time period. This decreased to five major periods of possibly substantial recharge when vegetation was simulated. Barren and vegetated sandy-loam soils both displayed recharge during these five periods. Sandy loam and even clay soils showed localized recharge under ponded conditions as if enhanced by surface runoff.

Climate conditions supporting the initiation of recharge include both single, very large rainfall events and gradual soil moisture content increases. Recharge periods ended if 2 consecutive yrs had below average rainfall. El Niño conditions didn't correlate well with the five recharge periods, but eastern Pacific cyclones were responsible for the two, single, largest rainfall events, both of which initiated major recharge periods and may be responsible for the perpetuation of other periods as well.

GEOCHEMISTRY AND ORIGIN OF GRANITOID XENOLITHS FROM THE NAVAJO VOLCANIC FIELD, FOUR CORNERS AREA, SOUTHWEST UNITED STATES, by *Natalie Latysh*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 240 pp.

Granitoid xenoliths from six diatremes in the Navajo volcanic field (NVF) fall into three main age populations, 1,745–1,720 Ma, 1,700–1,640 Ma, and 1,452–1,412 Ma, which are similar to ages of exposed Proterozoic granitoids in the southwestern United States. All three age populations are similar in mineralogical and chemical composition, and deformation/alteration textures are pervasive. The xenoliths range in composition from diorite to granite, with granites greatly dominating, and most are metaluminous ($Al_2O_3/(CaO+Na_2O+K_2O)<1$) I-types. In this respect, they are unlike most exposed Proterozoic plutons in the Southwest, where slightly peraluminous A-types dominate. There are no obvious correlations between granitoid age, diatreme composition, texture, geographic locality, xenolith chemical composition, or degree of alteration within the granitoid xenolith suite.

Based on trace-element discriminant diagrams, NVF granitoids are arc types, and on primitive-mantle normalized plots, they show negative Ta-Nb, Th, P, and Ti anomalies. Chondrite-normalized REE patterns are enriched in LREE with Eu anomalies ranging from positive to negative. Geochemical modeling and Nd isotopic data indicate that parent granitoid magmas cannot be produced from partial melting of associated metasediment xenoliths. Most successful models for the granites involve vapor-absent melting of diorite/tonalite sources, similar in composition to some of the xenoliths. Negative Ta-Nb anomalies are inherited from arc sources and negative Th, P, and Ti anomalies may be produced by fractionation of monazite, apatite, and ilmenite, respectively. It would appear that granitoids of all three ages were derived from similar juvenile crustal sources.

SOIL, LANDSCAPE, AND VEGETATION INTERACTIONS IN A SMALL SEMI-ARID DRAINAGE BASIN: SEVILLETA NATIONAL WILDLIFE REFUGE, NEW MEXICO, by *Dennis R. McMahon*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 205 pp.

Slope aspect-related microclimatic factors can induce distinct contrasts in vegetation, particularly where the contrasted slopes have north vs. south orientations. The initial driving force for these contrasts is the variation in solar radiation with the north-facing slopes receiving less direct winter sunlight than the south-facing slopes. However, an investigation of the vegetation, soils, and surface topography on opposing slopes of a small drainage basin suggests that the vegetation itself, as well as the microtopography and soils, affect a feedback to each surface, enhancing the vegetation contrasts through time.

The study area, a small, first-order drainage basin with north-south oriented sideslopes on the Sevilleta National Wildlife Refuge in west-central New Mexico, contains distinct vegetation patterns across the basin. The south-facing slopes are covered by creosote grassland with 14% total grass whereas the north-facing slopes host a juniper grassland with 21% total grass. Similar contrasts are observed in the soils data, where the north-facing slope soils have significantly finer textures and a higher percentage of organic carbon in the profiles. Investigation of the microtopography and surface-runoff features across the basin suggests that the greater density of grasses on the north-facing slopes may help dissipate runoff energy and more effectively retain surface water, organic matter, carbonate dust, silt, and clay. The retention of silt and clay, as well as carbonate dust and organic matter, has the effect of increasing the moisture-holding capacity of the soils, which, in turn, can support greater biomass production on those slopes.

These observations suggest that although the initial driving forces for the vegetation contrast are exogenic factors, such as variations in solar radiation, the extent of the contrast increases through time as a function of endogenic feedback mechanisms such as pedogenesis and the evolution of surface microtopography.

MONITORING INFILTRATION OF ATMOSPHERIC CHLORIDE ACROSS THE LAND SURFACE IN CENTRAL NEW MEXICO, by *James W. Moore*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 141 pp.

The objective of this study was to develop analytical methods and establish a field site to determine deposition rates of atmospheric chloride to the land surface in central New Mexico. I determined chloride deposition rates with a wet-dry precipitation collector, a standard precipitation collector, a dust collector 2.25 m off the ground, and a set of 39 columns packed with leached sand to measure accumulation of chloride in artificial soil profiles. The monitoring project is scheduled to last 5 yrs. After 6 mos of monitoring, chloride deposition rates determined with the columns ranged from 19 to 190 mg Cl m^{-2} yr^{-1}. Chloride deposition rates determined with the precipitation collectors over the same timespans ranged from 14 to 44 mg Cl m^{-2} yr^{-1}. The average chloride deposition rate determined with the dust collector was 110 mg Cl m^{-2} yr^{-1}.

^{40}AR/^{39}AR GEOCHRONOLOGY OF THE MIOCENE SILICIC LAVAS OF THE SOCORRO–MAGDALENA AREA, NEW MEXICO, UNITED STATES OF AMERICA, by *Hal H. Newell*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 215 pp.

^{40}Ar/^{39}Ar dating of mineral separates provides a precise chronology for the Miocene silicic volcanism in the Socorro–Magdalena area contemporaneous with the evolution of the central Rio Grande rift. The volcanism is apparently associated with the formation of the Socorro accommodation zone. This study increases the resolution and accuracy of the ages of silicic lavas erupted from the area.

^{40}Ar/^{39}Ar dates on mineral separates were obtained by single-crystal laser fusion, laser step-heating, and incremental furnace heating procedures. The most precise ages (typically ± 0.5 to 1%) were produced from sanidine mineral analyses. Ages on additional mineral pairs of plagioclase, biotite, or hornblende from individual rock samples allowed comparisons between the various mineral ages. The apparent ages of all biotite separates are older than the more accurate age results from sanidine from corresponding samples. No definitive explanation for the older apparent ages of the biotites was discovered. All methods of analysis for the biotite data yielded older ages, including isochron analysis, which should exclude the influence of homogeneously distributed excess ^{40}Ar. Plagioclase and hornblende results were the least precise and did not produce reliable ages.

EFFECTS OF SMALL-DISPLACEMENT FAULTS ON THE PERMEABILITY DISTRIBUTION OF POORLY CONSOLIDATED SANTA FE GROUP SANDS, RIO GRANDE RIFT, NEW MEXICO, by *John M. Sigda*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 140 pp.

The abundance of faulted sediments throughout many regions of continental crustal extension, such as the western United States, stands in strong contrast to our relatively poor understanding of their hydrologic importance. Faults in poorly consolidated sediments, like those in well-indurated rocks, range from tens of kilometers to mere meters in length and from kilometers to millimeters in displacement. Yet, important differences with faults in well-indurated rocks have been noted: faults in poorly consolidated sediments display unique structural features and can crosscut the thick vadose zones and underlying aquifers found in sediment-filled basins such as those supplying water to the western United States' rapidly growing population. Little is known about the hydrologic properties of such faults. In contrast, hydrologists and petroleum geologists have long known faulting can exert potent controls on flow of hydrocarbons and ground water in well-indurated rocks, often dramatically changing their saturated hydraulic properties. Recent studies have documented faulting-induced changes in permeability ranging between three and eight orders of magnitude in crystalline and well-indurated porous sedimentary rocks. Does faulting alter the single fluid-phase permeability of poorly consolidated sediments just as significantly?

The following hypotheses were tested as the first step to answering this question: Small-displacement faulting can create significant changes to the single fluid-phase permeability of poorly consolidated sands within the Rio Grande rift, and single fluid-phase permeability changes within poorly consolidated sand fault zones are caused by deformational and diagenetic processes such as comminution and alteration of grains. The hypothesis tests focus on uncemented, small (< 1 m) and moderate (≥ 2.5 m) displacement to fault zones in sands to eliminate confounding effects from juxtaposition of differing lithologies.

More than 1,000 in situ measurements were collected with air and gas mini-permeameters at two faulted Santa Fe Group outcrops within the Rio Grande rift. The spatial variability of permeability within the undeformed and fault-zone sands was quantified using variography. Point-count analysis of epoxy-impregnated thin sections provided estimates of porosity, grain size, and mineral composition. X-ray diffractometry determined clay-size fraction mineral composition. Scanning electron microscopy afforded visual comparison of deformed and undeformed sands.

Deformed sand intrinsic permeability decreases as much as two to three orders of magnitude relative to undeformed sands. Exhibiting values on the order of 10 darcies, average undeformed sand permeability is less variable than average permeability within fault zones. Low fault zone permeability reduction is positively correlated with low macroporosity and average pore and grain sizes, reorientation of elongate grains, large clay-size fraction and clay mineral abundance, diagenetic alteration of feldspars, and redistribution of clays to form grain coatings and other pore-occluding microstructures. Calcite cement abundance was negligible in both deformed and undeformed samples.

Results support the hypothesis that deformational and diagenetic processes associated with small-displacement faults can significantly alter the original single fluid-phase permeability of poorly consolidated sands.

STRATIGRAPHY, DEPOSITIONAL SYSTEMS, DIAGENESIS, AND STABLE ISOTOPE GEOCHEMISTRY OF THE PARADISE FORMATION (LATE MISSISSIPPIAN), BIG HATCHET MOUNTAINS, HIDALGO COUNTY, NEW MEXICO, by *David J. Sivils*, 1997, PhD dissertation, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 280 pp.

The Paradise Formation is exposed in a distinctive thin belt along the eastern flank of the Big Hatchet Mountains. It is a mixed carbonate-clastic sequence situated between the underlying Lower Mississippian Escabrosa Group and the overlying Pennsylvanian/Permian Horquilla Limestone. The Paradise measures 130 m in thickness and can be informally divided into three distinctive members that are traceable not only in the Big Hatchets but over the known extent of the formation. Each member is composed of a limited number of distinctive lithofacies, which are repeated in some 30 coarsening-upward cycles ranging from 2 to 12 m in thickness. Although the average biotic diversity is rather uniform, diversity does vary greatly at the meter scale. These wide variations of diversity are consistent with the cyclic nature of sedimentation reflected in the vertical development of lithofacies. Interpretations of lithofacies coupled with relative biotic diversity data suggest that deposition of the Paradise Formation occurred on a shallowly dipping carbonate ramp. Carbonate and detrital clastic sedimentation was controlled by relative changes in sea level. Paleogeographic reconstructions and the presence of eolian-derived quartz sands and silts redeposited in a marine setting suggest arid conditions existed during Paradise time. The best modern analog for the Paradise is the Persian Gulf, both in regard to facies types and their distribution as well as the overall geographic setting.

Glacioeustasy acted as the primary control on sea level during Paradise time and governed sedimentation patterns and development of cycles within the Paradise Formation. Three scales of cycles have been identified within the Paradise forming a sequence stratigraphic hierarchy or a single 2nd order cycle, three 3rd order cycles consisting of the three members, and 30 4th/5th order scale cycles. The high frequency 4th/5th order cycles are of similar duration to coeval cycles described from the Black Warrior Basin and from Britain. The influence of eustasy also acted to control the distribution of coarse-grained detrital clastics through cyclic reciprocal sedimentation.

Diagenesis significantly altered the sediments and rocks of the Paradise Formation. Two types of sparry calcite cements are recognizable, a low-magnesium calcite spar and a ferroan calcite spar. The low-magnesium spar cement is restricted to the lower part of the section, while the ferroan cement is found throughout the section. Petrographic and compaction data suggest that the low-magnesium calcite cements are early and likely reflect freshwater diagenesis, while the ferroan cements are most likely formed later during burial diagenesis of the Paradise at a depth of at least 600 m. Water compositions derived from isotopic data are compatible with both of these interpretations and suggest that the low-magnesium calcite spar was precipitated from waters with an isotopic composition of –4‰ $\delta^{18}O(H_2O)$ SMOW and that the ferroan spar was precipitated from waters with an isotopic composition of –1‰ $\delta^{18}O(H_2O)$ SMOW. Dolomitization and silicification are extremely rare in the Paradise. All of these diagenetic processes acted to reduce the porosity and permeability of the Paradise to near zero, effectively rendering the Paradise useless as a reservoir for any type of fluid. The pervasive nature of diagenesis is recognizable in the stable-isotopic signatures of whole-rock and carbonate components. Even carbonate components composed of more stable low-magnesium calcite, such as brachiopods, show effects of diagenesis and isotopic alteration. Isotopic data from the lower Paradise indicates that several diagenetic events acted on the sediments. The isotopic pattern developed in the lower Paradise is consistent with the cyclic nature of the Paradise.

The most interesting findings about the Paradise Formation in the Big Hatchet Mountains is how significant cyclicity was during Paradise time in governing patterns of sedimentation and that these cycles can be correlated worldwide indicating how influential and important eustasy was during the Late Mississippian.

ENVIRONMENTS OF DEPOSITION WITHIN THE CARBONATE MEMBERS OF THE SAN ANDRES FORMATION (LEONARDIAN–GUADALUPIAN), CENTRAL SOCORRO COUNTY, NEW MEXICO, by *Jeffery Robert Stone*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 103 pp.

Environments of deposition within the carbonate members of the San Andres Formation (Leonardian–Guadalupian) in central Socorro County, New Mexico, are dominated by lithotypes suggesting low-energy, restricted marine subtidal and intertidal facies. Two types of cyclic sedimentary sequences aided interpretation of environments of deposition and correlation between stratigraphic sections. Correlation between cyclic sedimentary sequences allowed an estimation of time synchronous changes in relative sea level between stratigraphic sections. Asymmetric shallowing-upward sequences describe five of the six sedimentary sequences that can be correlated between sections.

Paleogeographic relief, accentuated by a broadly dipping, extensive shallow-marine shelf, may have influenced sedimentation. Consistently shallower environments of deposition, limited biotic diversity, and thin, incomplete sequences within eastern and northwestern stratigraphic sections during early sedimentary cycles suggest that residual topography of the Pedernal Positive Element and the Joyita Positive Element may have affected sedimentation through cycle 3. Cycle 4, characterized by a symmetrical sedimentary sequence, contains higher-diversity subtidal deposits and probably represents the farthest incursion of marine conditions into central New Mexico during San Andres time. Asymmetric sequences 5 and 6 are dominated by highly variable intertidal and possibly supratidal deposits leading into evaporitic units of the Four Mile Draw Member.

Two thin asymmetric sequences occurring below cycle 1 in the eastern stratigraphic section may testify to an early marine incursion into the easternmost region of the field area. Absence of these two cycles within northwestern and western sections of the field area suggests that the Joyita Positive Element may have inhibited development of marine sedimentation before cycle 1.

THE GEOCHRONOLOGY OF THE RATON–CLAYTON VOLCANIC FIELD, WITH IMPLICATIONS FOR VOLCANIC HISTORY AND LANDSCAPE EVOLUTION by *Joseph R. Stroud*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 70 pp.

$^{40}Ar/^{39}Ar$ data from the Raton–Clayton volcanic field, New Mexico, provide a concise record of the eruptive history and landscape evolution in the field. Previous workers have examined the field relations, petrology, and geochemistry of the field, but only a limited geochronologic effort has been made. Sixty-five basaltic to andesitic groundmass concentrates were analyzed by $^{40}Ar/^{39}Ar$ step heating. Eruption ages were determined from well-defined age spectra plateaus or from isochrons. Precision of individual age determinations is typically ± 2–8% (2 sigma). The results indicate that the geochemically defined Raton phase was erupted in two distinct episodes: 9.0–7.3 Ma and 5.6–3.5 Ma. The Clayton phase erupted from 3.0 to 2.2 Ma, and the Capulin phase from 1.68 Ma to 56 ka. Volcanic activity at Sierra Grande stratovolcano overlaps in time with the Raton and Clayton phases from 3.8 to 2.6 Ma.

Elevation of mesa tops coupled with age determinations can be used to estimate rates of erosion in the volcanic field. Erosion rates in the east-central part of the field are minimal; lavas as old as 3.5 Ma have no significant erosional relief. Erosion is greater in the northwestern part of the field where mesas stand as high as 490 m above the local base level. Basalt flows capping the mesas near Raton have been dated at 7.8 Ma and 3.6 Ma, with only a small difference in elevation between them. This suggests little or no erosion occurring between 7.8 Ma and 3.6 Ma. The erosional relief of the ca 3.6 Ma mesa, together with a 1.2 Ma basalt flow with 120 m of erosional relief, suggests an average erosion rate of 115 m/Ma since 3.6 Ma. The onset of increased erosion around 3.6 Ma may reflect climate change in this area.

HYDROGEOLOGIC CHARACTERIZATION OF THE FLOODPLAIN THAT LIES BELOW THE URANIUM MILL TAILINGS REMEDIAL ACTION SITE AT SHIPROCK, NEW MEXICO, by *Bernadette Bígiigaa' Tsosie*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 303 pp.

A study was undertaken at the U.S. Department of Energy's UMTRA site at Shiprock, New Mexico, to determine the behavior of the NO_3^- and SO_4^{2-} contaminant plume within an unconfined aquifer in the floodplain. To characterize the aquifer, data were obtained from monitoring well logs, water-level measurements, electrical conductivity, refraction seismic data, and water chemical analyses. Lithologies from monitoring well logs and seismic refraction were used to define the floodplain stratigraphy and possible fractures in Mancos Shale. The fractures provide conduits for contaminants to be transported from the terrace onto the floodplain aquifer and eventually into the San Juan River. The stratigraphy consists of alluvial gravels overlying coarser outwash gravels that were deposited on a strath terrace cut into the Mancos Shale. Ancestral channels are identified by variation in the thickness of stratigraphic units from the monitoring well logs, seismic refraction data, and isopachs for the surface of the Mancos Shale, the outwash gravels, and the more recent alluvium. The ancestral channels and a thicker outwash gravel bed may be major factors controlling the ground-water and contaminant flow directions in the floodplain aquifer. The outwash gravels contain larger pore space than the alluvium providing a preferential flow path. The finer-grained alluvium may inhibit ground-water movement and retard contaminant flow directions. However, during high river flows the retardation effect decreases as water levels rise in the aquifer. Water-level measurements were collected on a monthly basis to determine the interaction between the flow in the San Juan River and the floodplain aquifer. Discharge from Bob Lee Wash is recharging the unconfined floodplain aquifer throughout the year. Electrical conductivity surveys on the floodplain identified the vertical and horizontal extent of a contaminant plume. Movement of the contaminant plume was difficult to determine from chemical water analyses in abandoned and existing monitoring wells because they were sampled inconsistently over the last 11 yrs. Furthermore, the density of wells was insufficient to adequately characterize the contaminant plume over the entire floodplain. Comparison of chemical analyses and electrical conductivity readings were used to determine if movement of the plume varies with flows in the San Juan River. Correlations of all four results indicate the general direction of ground-water flow and how lithology influences the groundwater and contaminant movements within the floodplain. The ground-water flow direction is controlled by the lithological changes from the smaller grain size alluvium to the larger size gravels and by the ancestral channels in the Mancos Shale beneath the floodplain. The contaminant plume has a similar flow direction as the ground water.

CONSTRAINTS ON THE TIMING AND CHARACTER OF PROTEROZOIC DEFORMATION AND METAMORPHISM IN THE SAN ANDRES MOUNTAINS OF SOUTH-CENTRAL NEW MEXICO, by *Kurt Macy Vollbrecht*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 98 pp.

Proterozoic rocks in the San Andres Mountains of south-central New Mexico show evidence for a single penetrative foliation that developed during one progressive, syn-plutonic, deformational event. This is in contrast to most other Proterozoic exposures in central and northern New Mexico where multiple foliations and deformational events have been described. Much controversy is centered on the timing of the “main” deformational event in New Mexico. In particular, deformation is proposed to have occurred either at 1.6 Ga during the Mazatzal orogeny or at 1.4 Ga accompanied by widespread plutonism or at both times. Most studies of the Proterozoic history of southwestern North America have been limited to insights into the timing and character of D_2 deformation, due to a near-universal overprinting of D_1 structures by D_2. Within the San Andres Mountains, this overprinting does not exist, and the age and character of D_1 deformation has been determined.

U/Pb dating of igneous zircon from the late-syntectonic Strawberry Peak pluton gives a minimum age for D_1 of ca 1,630 Ma. A maximum age of ca 1,650 Ma is based on U/Pb zircon ages of metavolcanic rocks. Microstructures, mineral assemblages, and microprobe data indicate that regional deformation occurred at middle- to upper-greenschist facies conditions, whereas microstructures and mineral assemblages proximal to late- and post-tectonic intrusive bodies indicate slightly higher grade conditions. Interpretation of kinematic indicators (S-C fabrics, asymmetric porphyroclast systems, shear bands) suggest that D_1 was predominately a sinistral strike-slip event with a minor dip-slip component. $^{40}Ar/^{39}Ar$ thermochronology records reheating to ca 500° C at 1.4 Ga. Thin-section analyses indicate this event was short lived and was not accompanied by deformation. On the basis of this work, I conclude that 1.6 Ga deformation is recorded throughout New Mexico, whereas the effects of 1.4 Ga deformation appear to be limited to the northern and central parts of the state, possibly due to large-scale heterogeneous strain.

LEAD DISTRIBUTION AND AVAILABILITY IN CONTAMINATED SOILS AT THE ABANDONED CUBA SMELTER SITE, SOCORRO, NEW MEXICO, by *Christopher P. Wolf*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 69 pp.

Availability and distribution of lead (Pb) in soils were investigated at the Cuba smelter site in Socorro, New Mexico. The Cuba smelter was active from 1881 until the start of World War I (about 1915) and processed Pb ores from mining districts near Socorro. The site was deemed a potential health hazard by the State of New Mexico in 1990. In 1991, an X-ray fluorescence (XRF) study determined that soils exceeded the EPA action level of 500 parts per million (ppm) Pb, so a remedial cleanup occurred, which was completed in 1994.

Availability and distribution of Pb in soils are used to predict potential health threats. Availability is a qualitative term used to describe what fraction of Pb in a system will react with soil solutions, gastrointestinal fluids, or ground water. A more specific availability term is bioavailability, which is a measure of absorption and utilization by an organism (plants and animals). Distribution describes Pb partitioning between grain sizes.

Physical and chemical parameters were determined for soils collected adjacent to the former smelter foundation on a natural terrace (CS-I) and from a fallow agricultural field directly east of the smelter (CS-II). These two areas had elevated Pb levels determined during the XRF survey by EPA contractors. Slag samples were collected from near the smelter foundation, also. Availability was evaluated by determining the mineralogy of Pb-bearing phases and considering the solubility of the minerals in these soils. Pb distribution was determined using atomic absorption (AA) directly on bulk, sand, and clay fractions. Silt values were then calculated.

The grain size is dominantly sand on the terrace and silt in the field. Soils are alkaline as indicated by pH values of 7.2 to 7.9 and negative values for net acid producing potentials (NAPP).

Soil Pb concentrations range from 900 ppm to 9,600 ppm. Terrace samples have the highest Pb concentrations in the clay-size fraction, but the highest Pb concentrations in agricultural field samples are in the sand-size fraction. Pb-bearing phases identified include galena, chalcopyrite, pyrite, slag, and Pb-oxides. Minerals present in the soils were calcite, feldspars, quartz, and clay minerals. The clay minerals were illite, mixed-layer illite/smectite (I/S), smectite, and kaolinite.

Soil conditions at the Cuba smelter site reduced Pb availability. Sulfide minerals showed no signs of alteration. Galena was insoluble in the dry alkaline soils and did not oxidize to form anglesite armoring. Slag formed glassy rims surrounding eutectic textures of lead and copper sulfides and did not show signs of devitrification. Pb-oxides were always associated with clay minerals, and these clay minerals coated all soil particles including galena. Slag and/or clay minerals armored all Pb phases. The potential health hazard was reduced by the Pb mineralogy and soil chemistry present at the Cuba smelter site.

CONTROLS ON SOIL SALINITY IN THE RIO GRANDE FLOODPLAIN, BOSQUE DEL APACHE NATIONAL WILDLIFE REFUGE, NEW MEXICO, by *Deborah Steven*, 1997, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 38 pp.

The prediction of soil salinity in the Rio Grande floodplain is difficult because of the variability of salinity levels over distances of just a few meters. The salinity levels within the soils of this study area are a result of the interaction between ground-water depth, floodplain stratigraphy (soil texture), landforms, and vegetation.

Thirty-nine observation wells were installed along four 1-mi-long transects perpendicular to and just west of the Rio Grande within the Bosque del Apache National Wildlife Refuge. Soil samples were taken during drilling and analyzed for salinity levels and soil texture. Soil texture was determined in the lab, and paleotopography was identified from aerial photographs. Since the beginning of the Middle Rio Grande Project in 1948 and the closure of flood-control dams in the 1960s and 1970s, the river has been constricted to one stabilized channel. However, previous near-river landforms, such as abandoned channels, can be clearly seen from both historical (1938) and current (1996) aerial photographs. Each near-channel landform has its own characteristic stratigraphy. These stratigraphic units have textures that range from coarse gravely sand to fine-grained clay. There is a relationship between paleolandforms, stratigraphy, and salinity levels. The highest salinity or electroconductivity (EC) levels were recorded within or at the top of a clay layer in all soil profiles of this study. The lowest EC was recorded within profiles that contain only sand. The pattern of EC determined from soil samples is consistent with electromagnetic induction (EM) surveys conducted along the same transect area. Ground-water levels fluctuate seasonally and may affect salinity concentrations on a short-term basis. Vegetation is primarily saltcedar (*Tamarix chinensis*), a phreatophyte that might be contributing to salt levels within the ground water as well as the top soil.

CONTROLS ON ISOTOPIC COMPOSITION OF PEDOGENIC CARBONATE IN THE SEVILLETA NATIONAL WILDLIFE REFUGE, NEW MEXICO, by *Christa M. Vindum*, 1998, MS thesis, Department of Earth and Environmental Science, New Mexico Institute of Mining and Technology, Socorro, NM 87801, 80 pp.

The relationships between the stable carbon isotope composition of pedogenic carbonate, slope aspect, soil development, and vegetation was considered within a small semi-arid first-order drainage basin. The basin is composed of north- and south-facing slopes as well as a transitional east-facing section. Sixteen soil pits were excavated within study site, located in the Sevilleta National Wildlife Refuge. Fine matrix carbonate of each soil pit was sampled and analyzed for $\delta^{13}C$ and $\delta^{18}O$. Distinct vegetation patterns vary from 28% C3 and 72% C4 plants on the north-facing slope to 51% C3 and 46% C4 plants on the south-facing slope. The transition zone varies from 3% C3 and 88% C4 on the northeast-facing slope to 37% C3 and 47% C4 on the southeast-facing slope. Soil development varies from well-developed, north-facing soils with regular carbonate distribution to irregular carbonate distribution within the coarser, poorly developed, south-facing soils. The large variations in pedogenic carbonate isotope values show how the relationship between vegetation, slope aspect, and soil development can vary significantly over a small area.

The carbon isotope composition of the pedogenic carbonate decreased with increasing depth on the north-facing slope, whereas the carbon isotope composition on the south-facing slope soils did not show a systematic pattern with depth. The $\delta^{13}C$ of laminar carbonates, located within the headslope transition zone, show diffusion curves with depleted isotope values. This depletion possibly represents a lack of vertical translocation through the soil profile. Carbon isotope compositions vary between –7.3‰ and 0.3‰ throughout the drainage basin. This large $\delta^{13}C$ variation can be explained by the changes of C3 and C4 proportions in vegetation on each slope and the differences in soil development. Oxygen isotopic values vary between 30.0‰ and 17.7‰. The oxygen isotope data show evaporative enrichment down the soil profile in all soils.

New Mexico Geological Society
1999 Fall Field Conference—Albuquerque geology

Panorama of Santa Fe Group outcrops in Cañada Pilares looking east (right) to north (left). Visible are the correlated Piedra Parada (**Tzp**) and Chamisa Mesa (**Tzc**) members and type section of the Cañada Pilares Member (**Tzr**), Zia Formation, and the lower part of the Cerro Conejo Member (**Taj**) of the Arroyo Ojito Formation. From Tedford, R. H., and Barghoorn, S., 1999, Santa Fe Group (Neogene), Ceja del Rio Puerco, northwestern Albuquerque Basin, Sandoval County, New Mexico; *in* Pazzaglia, F. J., Lucas, S. G., and Austin, G. S. (eds.), Albuquerque geology: New Mexico Geological Society, Guidebook 50, pp. 327–335, fig. 4.

The 50th annual field conference of the New Mexico Geological Society will traverse the Albuquerque Basin, Sandia Mountains, Hagan Basin, and surrounding area September 22–25, 1999. Five separate trips will leave from conference headquarters, the Albuquerque Hilton at Menaul and University.

On Thursday's field trip, "From Albuquerque to Placitas, Hagan Basin, and Espinaso Ridge," conference attendees will be chauffeured in buses to the Hagan Basin. The focus of the trip is the geologic, structural, geomorphic, and paleoclimatic history of north-central New Mexico. En route seven stops will allow for discussion on several controversial subjects: (1) the role played by basement structure in shaping later tectonic events, (2) the enigmatic ancestral Rocky Mountain orogeny, (3) a tale of two Laramides, (4) footwall uplifts and the Rio Grande rift, (5) the regional significance of the Tuerto Gravel and Ortiz pediment, and (6) contemporary hydroenvironmental issues. The day will end with a traditional barbecue at the New Mexico Museum of Natural History and Science in Albuquerque.

Participants will choose between two all-day trips on Friday, Trip 1, "From Albuquerque to Tijeras, Cedar Crest, and Sandia Crest," or Trip 2, "From Albuquerque to San Ysidro, Loma Creston, La Ceja, and Sand Hill fault."

En route to Sandia Crest, Trip 1 will make five stops: (1) in Tijeras Canyon to view the inferred base of the Sandia granite, (2) at Cedar Crest to compare the Jurassic strata exposed in the Tijeras syncline with the Jurassic section in Hagan Basin, (3) at the "great unconformity" between Proterozoic granites and Pennsylvanian sedimentary rocks to discuss glacioeustatically driven Pennsylvanian sedimentation and local Laramide faulting, (4) to examine probable Mississippian-age quartzite, and (5) at Sandia Crest to ponder the age of the uplift.

Those who choose Trip 2 will examine in detail the Neogene stratigraphy, sedimentology, structure, and geomorphology of the Albuquerque Basin along the lower Rio Jemez valley. Trip leaders will present revisions to the stratigraphic nomenclature for the Santa Fe Group in the northern part of the basin.

Plan on a car caravan to one of the final two half-day trips, Trip 1, "From Albuquerque to Tijeras, Cedro Canyon trilobite locality, and Kinney Brick Quarry," or Trip 2, "Geomorphic and hydrologic response in Estancia Basin to late Pleistocene and Holocene climate change." Abundant and exceptionally well preserved fossils in a thicker-than-normal paralic facies make the Kinney Quarry a remarkable Late Pennsylvanian locality for paleontological and paleoenvironmental study. Farther east in the Estancia Basin, the climatic changes that preceded and accompanied the Last Glacial Maximum are preserved as shoreline deposits of the pluvial Lake Estancia. The road log describes geomorphic, paleohydrologic, and geologic features that document change in salinity and lake level, the final pulse of glacial climate, and middle Holocene desiccation.

Registration information:
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General information about the conference or hotel accommodations:
Dr. Les McFadden, Department of Earth and Planetary Sciences, UNM, Albuquerque, NM 87131-1116, (505) 277-4204, lmcfadnm@unm.edu

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