New Mexico Geological Society
Spring Meeting

Friday, April 24, 2009
Macey Center, 801 Leroy Place
NM Tech Campus
Socorro, New Mexico 87801

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Oral Session Chairs:	Spence Lucas, Kate Zeigler, Matt Heizler, Justin Spielman, Bill Dickinson

Schedule of Events – NMGS Annual Spring Meeting, April 24, 2009
Registration 7:30 a.m. to Noon, Macey Center, NM Tech

Geochronology of the Rocks of New Mexico and Adjacent States - Auditorium

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3. *KRAINER, K., LUCAS, S.G., and RINEHART, L.F.*
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4. *RINEHART, L.F., LUCAS, S.G., and HECKERT, A. B.*
LATERAL LINE GROOVE DEVELOPMENT AS A MEASURE OF TERRESTRIALITY IN LATE TRIASSIC METOPOSAURID AMPHIBIANS

5. *PENCE, R., LUCAS, S.G., and SPIELMANN, J.A.*
SELACHIAN-DOMINATED VERTEBRATE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS ATARQUE SANDSTONE, SEVILLETTA NATIONAL WILDLIFE REFUGE, SOCORRO COUNTY, NEW MEXICO

6. *WILLIAMSON, T.E., SHIMADA, K., and SEALEY, P.L.*
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13. *ZIMMERER, M., MCINTOSH, W.C.*
A ^{40}AR/^{39}AR GEOCHRONOLOGY AND THERMOCHRONOLOGY STUDY OF CALDERA VOLCANISM AND RELATED PLUTONIC PROCESSES, QUESTA CALDERA, NORTHERN NEW MEXICO

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25. *WILLIAMS, A.J., CROSSEY, L.J., KARLSTROM, K.E., and ASMEROM, Y.*
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ABSTRACTS

AN ANALYSIS OF MICROBIAL LIFE IN KARST SPRINGS, SOUTHERN EDDY COUNTY, NEW MEXICO AND CULBERSON COUNTY, TEXAS

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Spring systems in southern Eddy County, New Mexico and Culberson County, Texas were studied based on the presence of hydrogen sulfide emissions. Sulfur oxidizing/reducing bacteria were thought to be present due to the atmosphere around the area (smell, observation of rock, etc). Water samples were tested for pH, reduction potential, total dissolved solids, total anions (Cl^-, F^-, Br^-, NO_3^{2-}, NO_2^-, PO_4^{3-}, SO_4^{2-}, $CO_3^{\ 2-}$, etc.), and total cations (NH_4^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe, Cu, etc.). Chemical analyses specified the types of culturing that were performed. Bacteria from the streams were plated on LB agar, a general growth media and sub-cultured on LB + NaCl agar, to detect halophiles, and S6 agar, a thiosulfate media. Bacteria colonies grew on sulfur based media. Bacterial representation was widespread with a broad spectrum of bacterial types including sulfur bacteria.

TEPEE-LIKE STRUCTURES IN THE MIDDLE JURASSIC TODILTO FORMATION, WEST-CENTRAL NEW MEXICO

BERGLOF, W.R.[1], KRAINER, K.[2], and LUCAS, S.G.[3], (1) 2-39-25 Nakahara, Musashi Murayama, Tokyo 208-0035 Japan, *berglofwr@yahoo.com*, (2) Institute of Geology and Paleontology, University of Innsbruck, Innsbruck A-6020, Austria, (3) NM Museum of Natural History & Science, 1801 Mountain Road N.W., Albuquerque, NM 87104

Unusual domal or tepee-like features in the Luciano Mesa Member of the Todilto Formation near Dos Lomas in sec. 23, T13N, R10W are not known from elsewhere in the Todilto. The Todilto at Dos Lomas is 4.2 m thick and overlies eolian, crossbedded sandstone of the Entrada Formation. The lower 2.1 m are gray micritic limestone, intercalated with gray, micaceous and bituminous siltstone. Some limestone beds include abundant small angular quartz grains near the base. Above are 1.3 m of evenly bedded, thinly laminated gray lime mudstone containing a few small angular quartz grains, a few large micritic intraclasts and many ostracods. The uppermost 80 cm consist of laminated or stromatolitic and partly vuggy limestone beds (microbial crusts), some of which contain ostracods. The uppermost stromatolitic bed is about 30 cm thick, includes the domal structures, and is overlain by greenish, gypsiferous siltstone and shale of the Summerville Formation.

The domal structures are up to 2.2 m high and 1.8 m wide (n=16), and in many respects resemble tepee structures. The base is horizontal beds of evenly laminated or more commonly stromatolitic limestone. The core is up to 50 cm thick and 1 m wide at the base and consists of intensely folded or brecciated limestone and evaporites, overlain by a 10-cm-thick crust of stromatolitic limestone, which may be vuggy and contain thin beds of gray micritic limestone.

Although the domal features are in some ways fold-like, they differ from the hundreds of intraformational folds that have been observed throughout the Grants district. These intraformational folds vary in appearance and geometry but typically have mappable fold axes that in some cases can be traced for well over 100 meters. The domal structures are overlain and sealed by stromatolitic layers that are thinner above the crest of the features, thickening downward from the crests. These beds thus are domal, tepee-like structures but are not typical bioherms. The basal Luciano Mesa Member of the Todilto Formation, predominantly limestone, formed in a paralic salina that developed above the Entrada eolian sandstone. Stromatolitic limestone and tepee-like structures developed in an environment of increasing salinity and are overlain by coastal sabkha sediments of the basal Summerville Formation.

STRATIGRAPHY AND STRUCTURE OF THE LATE LARAMIDE CARTHAGE–LA JOYA BASIN, CENTRAL NEW MEXICO

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The elongate, north-northwest trending Carthage–La Joya basin of central New Mexico developed in the middle Eocene, late in the Laramide orogeny. Sedimentary strata in the basin consist of a fluviatile red-bed succession of sandstone, conglomerate, and minor mudstone as much as ~300 m thick. Sediments were derived mostly from the nearby Sierra uplift to the west, and were deposited on an east-facing, braided-alluvial piedmont system. Local inverted unroofing successions in these deposits show that the structural development and erosional history of the Sierra uplift was complex. In the

northern part of the Carthage–La Joya basin, scattered remnants of southwest-facing piedmont deposits are preserved. These deposits may provide a depositional record of the Montosa uplift to the northeast.

An axial-river facies stratigraphically intervenes between deposits of the opposing piedmont facies in parts of the northern basin, and is also present on the east flank of the basin where it shows evidence for southeasterly paleoflow. These axial-river deposits are dominated by well-rounded, varicolored quartzite clasts that appear to have been derived from the Mogollon Highland far to the west in central Arizona, and record an extrabasinal river that at times spilled over the Sierra uplift from the Baca basin.

The Carthage–La Joya basin region is extraordinarily complex structurally, but relatively few structures can be definitively shown to be Laramide. These include the thrust faults and folds of the Amado–Cañas structural zone in the west-central part of the basin and the Singleton thrust fault in the northern part. Two northeast-striking systems of high-angle Laramide faults in the northern part of the basin (the Parida and Milagro fault zones) may be related to the dextral-oblique Montosa fault system to the east. These northeast-striking zones may have provided a kinematic link between the Laramide Sierra and Montosa uplifts.

MAGMA MINGLING: A PETROLOGIC, GEOCHEMICAL, AND GEOCHRONOLOGIC STUDY OF THE SOUTHERN GRANITOID SUITE OF THE FLORIDA MOUNTAINS, NM

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The Florida Mountain pluton consists of a complex group of syenite, quartz syenite, alkali-feldspar granite, and diorite that record Cambrian-Ordovician magmatism and display a well-exposed series of magmas frozen during repeated episodes of mixing. Southern exposures of the pluton are composed of alkali-feldspar granite, alkali-feldspar syenite, syenite, hybridized magmas, mafic enclaves, and diorite dikes with varying compositional characteristics. Hybridized magmas and mafic enclaves are found in zones between sheet-like dikes of diorite and often display large 5-10 mm feldspar grains. Mixing zones display mafic enclaves with various shapes, crenulate margins, quench textures, and mineral reaction rims. These features of magma mixing were formed by the injection and mixing of mafic magma in the partially crystallized lower portion of the Florida Mountain pluton. Major and trace element data will be presented that, when interpreted in concert with petrographic and field data, delineate multiple phases of mixing.

U-PB AGES OF DETRITAL ZIRCONS FROM THE OLIGOCENE CHUSKA SANDSTONE (ARIZONA–NEW MEXICO): IMPLICATIONS FOR SAND PROVENANCE

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Exposures of the uppermost Eocene to Oligocene (35-25 Ma) Chuska Sandstone (535 m in maximum thickness) occupy ~1000 km^2 of the elongate crest of the Chuska Mountains along the NE Arizona–NW New Mexico border. The Narbona Pass Member, overlying the discontinuous Deza Bluffs Member of fluvial origin and forming most of the formation, is composed of eolian sandstone representing the central remnant of the largest Cenozoic erg known from western North America, with a reconstructed areal extent of ~100,000 km^2 (Cather et al., 2008 GSA Bull. 120:13-33).

At Narbona (Washington) Pass near Crystal and at Buffalo Pass near Lukachukai ~50 km to the north, the petrofacies of the Narbona Pass Member is arkosic (mean detrital mode ~Qm60-F35-Lt5). Of 100 detrital-zircon (DZ) grains for which concordant or nearly concordant U-Pb ages were obtained by LA-MC-ICP-MS geochronology from the Narbona Pass Member as exposed in a roadcut beside NM Highway 134 between Crystal and Narbona Pass, 90% fall (at 1σ) within the age range of 1425-1820 Ma. Prominent age peaks at 1700 Ma and 1420 Ma are interpreted to reflect derivation of the sand principally from Yavapai-Mazatzal Precambrian basement (1700 Ma age peak) intruded by Mesoproterozoic anorogenic granitic plutons (1420 Ma age peak) in central Arizona and adjoining areas. DZ populations in lower Upper Cretaceous (Turonian) Toreva and Gallup sandstones of the Black Mesa and San Juan basins display essentially identical age peaks of comparable dimensions (P=0.55 from comparative K-S analysis of Chuska and Toreva-Gallup DZ populations), and are known from paleocurrent indicators and subregional facies relations to have been derived from the same or closely similar bedrock sources lying to the southwest of the Colorado Plateau (Dickinson and Gehrels, 2008 Am. Jour. Sci. 308:1041-1082). Reworking the Narbona Pass DZ population from Toreva-Gallup sandstones is not a feasible interpretation, however, because the Cretaceous sandstones are distinctly more quartzose and less feldspathic (~Qm75-F20-L5).

Weathering and sediment transport during reworking could not be expected to enhance feldspar content and produce the arkosic sand of the Narbona Pass Member. We instead infer fluvial transport of sand northward from Precambrian source rocks, followed by deflation of alluvial plains to blow sand eastward into the Chuska erg by paleowinds having the mean azimuth recorded by cross-bedding in Chuska eolianites. Our DZ data bearing on the derivation of the arkosic sand in the Narbona Pass Member do not apply to southern Chuska outcrops near Whiskey Lake where more quartzose detrital modes (~Qm80-F15-Lt5) closely resemble sand of uncertain provenance forming the underlying Deza Bluffs Member of fluvial origin, nor to volcaniclastic sands (mean detrital mode ~Qm10-F25-Lt65) exposed at the southern fringe of the reconstructed Chuska erg along the northern flank of the Mogollon–Datil volcanic field, nor to sand along the eastern fringe of the Chuska erg where quartzolithic Isleta sands (mean detrital mode ~Qm60-F20-Lt20) from the subsurface of the Rio Grande rift closely resemble sand aggregates in the underlying Galisteo Formation and overlying Zia Formation of presumably local origin. Petrographic data thus imply areal variations in sand provenance within the Chuska erg, and in pathways for sand transport across the Chuska erg, but our DZ data reveal the provenance of voluminous arkosic sand in the central Chuska erg.

PROVENANCE INTERPRETATIONS FROM U-PB AGES OF DETRITAL ZIRCONS

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Over the past decade, the U-Pb geochronology of individual detrital-zircon (DZ) grains has become a standard methodology for inferring the provenance of sand and sandstone because: (1) zircon grains resistant to weathering and abrasion are persistent in the sedimentary environment; (2) zircon and more abundant quartz are both derived dominantly from felsic igneous rocks, and zircon ages serve as a proxy for quartz ages; (3) the ages of detrital zircons faithfully reflect the ages of source rocks because the U-Pb isotopic system is not reset in sedimentary rocks, or even in metamorphic rocks at temperatures below granulite grade; (4) the double decay scheme of the U-Pb isotopic system (^{238}U to ^{206}Pb; ^{235}U to ^{207}Pb) allows disturbed ages to be detected during isotopic analysis ($^{206}Pb^*/^{238}U$ and $^{207}Pb^*/^{235}U$ ages for a zircon grain are then not concordant, and the grain plots off the standard concordia curve for $^{206}Pb^*/^{238}U$ vs $^{207}Pb^*/^{235}U$ ages).

U-Pb ages for individual zircon grains as small as coarse silt are conveniently determined rapidly by laser ablation–multicollector–inductively coupled plasma–mass spectrometry (Gehrels et al., 2008 G^3, v. 9, no. 1), thereby allowing ~100 U-Pb grain ages to be obtained routinely from each DZ sample at acceptable cost. In practice, $^{206}Pb/^{238}U$, $^{206}Pb/^{207}Pb$, and $^{206}Pb/^{204}Pb$ ratios are measured directly, and the $^{207}Pb/^{235}U$ ratio is calculated from knowledge that all uranium in the world today has a $^{238}U/^{235}U$ ratio of 137.88 ($^{206}Pb/^{207}Pb$ can be measured more accurately than $^{207}Pb/^{235}U$). Determination of $^{206}Pb/^{204}Pb$ is required to correct for non-radiogenic common lead (dominantly but not entirely ^{204}Pb) to define relevant isotopic ratios involving radiogenic $^{206}Pb^*$ and $^{207}Pb^*$. Both the hardware and the software of analytical procedures are demanding. Best age estimates are provided by $^{206}Pb^*/^{238}U$ ages for younger grains and $^{206}Pb^*/^{207}Pb^*$ ages for older grains (with the transition age near 1.2 Ga) because age uncertainties for the former increase with age whereas age uncertainties for the latter decrease with age. Uncertainties in grain age are inherently greatest near 1.0-1.3 Ga (Grenvillean).

Grains discordant for $^{206}Pb^*/^{238}U$ and $^{207}Pb^*/^{235}U$ ages by more than a specified percentage are rejected for provenance analysis. Age spectra of the DZ grains retained are displayed as age-distribution curves (probability-density plots) generated by incorporating each U-Pb age and its analytical uncertainty as a normal distribution, and stacking the individual normal distributions into a compound curve. For comparison of DZ age spectra, visual impressions are supplemented by Kolmogorov-Smirnoff (K-S) statistical analysis. The K-S analysis calculates a probability P that two age spectra are comparable, and where $P>0.05$ there is <95% confidence that the two age spectra are not defined by grains selected at random from the same parent population (with $P=1.0$ indicating statistical identity).

Several caveats apply to provenance interpretations from U-Pb ages: (1) the range of U-Pb ages of zircons in potential source rocks must be known independently from geochronological studies for inferences of provenance to be made from DZ populations; (2) proportions of zircon grains of various ages in DZ populations do not necessarily equate to proportions of total detritus from different source rocks because the zircon contents of igneous rock assemblages vary (e.g., when arc plutons of North America are assigned a zircon fertility factor ZFF of 1.0, ZFF~2.5 for rift and anorogenic plutons, and ZFF~3.5 for plutons along the collisional Grenville orogen); (3) DZ ages reflect the ages of ultimate igneous sources for DZ grains, but cannot detect the nature of proximate sources in sedimentary strata from which durable DZ grains have been recycled.

DETRITAL MONAZITE GEOCHRONOLOGY OF ORTEGA QUARTZITE CLASTS IN PENNSYLVANIAN STRATA OF THE NORTHERN TRUCHAS UPLIFT, NORTHERN NEW MEXICO: IMPLICATIONS FOR THE SLIP HISTORY OF THE PICURIS-PECOS FAULT

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Proterozoic Ortega quartzite clasts from the Middle Pennsylvanian Flechado Formation near the Rio Chiquito at the north end of the Truchas uplift were sampled to test hypotheses for the timing of slip on the Picuris-Pecos fault (PPf), a major strike-slip fault with 37 km of dextral separation. Quartzite clasts that occur in proximal alluvial deposits and sedimentary breccias directly east of the PPf were derived from the west side of the fault. Today, only granitic gneiss is exposed west of the study area, and the nearest Ortega Quartzite exposures are in the Picuris Mountains, dextrally separated from the study area by at least 20 km.

Detrital monazite ($(Ce,La,Th)PO_4$) grains were found in 8 Ortega Quartzite clasts were examined by electron microprobe. Monazite grains were identified by producing large-scale (2x2 cm) Ce chemical maps of polished sample surfaces. This process allowed the identification of a range of sizes of monazite grains, rather than preferentially focusing on large grains that are relatively easily detected using backscattered electron imaging or petrography. Monazite grains in most samples ranged between 5 and 50 microns in diameter. Widely variable chemical composition between grains supports a detrital origin. Age determinations of the monazite grains were carried out by analyzing their U, Th, and Pb concentrations, following the method of Jercinovic and Williams (2005) with technique modifications provided by M. Jercinovic (pers. comm., 2008). This technique assumes that monazite contains no common Pb at the time of crystallization, and that Pb is produced over time by radioactive decay of Th and U isotopes that are relatively abundant in this mineral phase. The age of individual 3-4 micron diameter spots on an individual monazite grain can be determined by the analyses of these, plus a range of other, elements. The technique also allows for multiple ages to be determined on a single grain, if the grain is large enough.

A compilation of the 134 ages determined for all samples shows a distinct peak in ages at around 1.42 Ga, with a second, slightly smaller peak at 1.68 Ga. Both age peaks are represented in 6 of the 8 samples analyzed, with two samples containing only ~1.4 Ga ages. Many monazite grains in samples are characterized by ~1.7 Ga cores with younger ~1.4 Ga rims. The Ortega Quartzite in the Picuris Mountains contains only ~1.4 Ga monazite. The presence of ~1.7 Ga monazite grains quartzite from the Flechado Formation implies derivation from north of the Picuris area, suggesting that at least 30 of the 37 km of dextral separation on the PPf accumulated since the Middle Pennsylvanian. Furthermore, no trends in monazite ages are observed with stratigraphic position in the 390 m thick Flechado Formation, suggesting that no systematic change in source terranes occurred during deposition of this unit as a result of syndepositional strike-slip.

EIGHT ^{40}AR/^{39}AR SANIDINE-CRYSTAL AGES FOR CAMPANIAN (LATE CRETACEOUS) STRATA, SAN JUAN BASIN, NEW MEXICO AND COLORADO

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Between 1988 and 1996, eight altered volcanic ash beds in Upper Cretaceous strata were sampled in the San Juan Basin of New Mexico and Colorado and their ages determined using $^{40}Ar/^{39}Ar$ analyses of sanidine crystals separated from the ash layers. Nearly all the samples were dated using single-crystal methodology. All samples were collected by the author and processed by John Obradovich at the USGS campus at the Denver Federal Center. Samples were irradiated in the USGS reactor at the Federal Center and then taken to the USGS $^{40}Ar/^{39}Ar$ lab in Menlo Park, California for final processing. Sample ages were based on the monitor age of 28.02

Ma for Fish Canyon Tuff and 28.32 Ma for Taylor Creek Rhyolite (these standards yield an average age of 65.51 ± 0.01 for the K-T boundary). The stratigraphically lowest sample was collected from the Huerfanito Bentonite Bed of the Lewis Shale at an outcrop north of Cuba, NM and had an age of 75.76 ± 0.34 Ma; this bed is 380 m below the Cretaceous-Tertiary interface (base of the Ojo Alamo Sandstone) in the southern part of the basin. Six other samples were collected from ash beds in the Fruitland and Kirtland Formations and one sample was collected from another altered ash bed near the top of the Lewis Shale. The highest of these samples from an ash bed about 5 m below the K-T interface (the base of the Ojo Alamo Sandstone) yielded an age of 73.04 ± 0.25 Ma. The six intermediate ages ranged from 75.56 ± 0.41 Ma to 73.37 ± 0.18 Ma.

This data set of eight precise ages for uppermost Cretaceous rock strata in the San Juan Basin clarifies some previous interpretations of these rocks and allows for precise estimations of subsidence rates: 100-125 m/m.y.; rate of sediment accumulation: 140 m/m.y.; and rate of shoreline regression across the basin area for the shoreface Pictured Cliffs Sandstone: 53 km/m.y. Earlier authors had suggested that there was no unconformity at the base of the Ojo Alamo Sandstone at the K-T interface, but these age data prove that there is a hiatus of nearly 8 m.y. at this contact representing 7.54 m.y. of latest Cretaceous time (all of the Maastrichtian and the upper part of the Campanian) plus about 0.3 m.y. of earliest Paleocene time. (Palynologic data had previously indicated the presence of this hiatus.)

These ash-bed ages bracketed the magnetic polarity reversal from C33n to C32r allowing for a precise determination of the age of this reversal of 75.50 ± 0.19 Ma.

Vertebrate fossils identified from uppermost Cretaceous strata are largely endemic to the San Juan Basin, thus their ages have never been accurately known. The data set of eight dated ash beds in this interval now allows for precise age assignments of these fossils and thus now permit comparisons of these species with similar species from the northern part of the Western Interior, the radiometric ages of which have been known for some time.

PALYNOLOGY PRECISELY LOCATES THE CRETACEOUS-TERTIARY INTERFACE IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO

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A robust palynologic data base sharply defines the Cretaceous-Tertiary (K-T) interface at numerous localities in the San Juan Basin of New Mexico and Colorado. This important Era, Period, and Formation boundary is located at the base of the Ojo Alamo Sandstone-top of the Kirtland or Fruitland Formation throughout the New Mexico part of the basin and at the base of the Animas-top of the McDermott, Kirtland, or Fruitland Formation in the Colorado part of the basin. Over the last four decades, the last occurrence of diagnostic Cretaceous index palynomorphs (K-taxa) has been used throughout the Western Interior of North America to mark the K-T boundary in continental strata. The precision of this criterion was strikingly validated in 1981 when a cm-thick interval at the palynologic K-T boundary in the Raton Basin was found to contain the K-T asteroid-impact fall-out layer, thus joining a bio-chronologic boundary with a rock-stratigraphic unit. Since that discovery, the fall-out layer has been found at dozens of other localities throughout the Western Interior at the palynologic K-T boundary.

The principal Cretaceous index palynomorphs in the San Juan Basin are *Tschudypollis* sp. (previously named *Proteacidites*). *Tschudypollis* sp. are present in large numbers in samples from Cretaceous Fruitland and Kirtland Formation rock samples, but are never found in the overlying Paleocene Ojo Alamo Sandstone (except for rare, reworked specimens). Moreover, Paleocene index palynomorphs *Momipites tenuipolus* and *Brevicolporites colpella* have been identified from the Ojo Alamo Sandstone at several localities in the basin. Lists have been compiled of all known palynomorphs from published and unpublished sources from Cretaceous-Paleocene strata in the San Juan Basin (Fassett, 2009, in press). These lists show that 244 palynomorphs have been identified from these strata; of these, 50 taxa (20%) are present only in Paleocene strata, 143 taxa (59%) are present only in Cretaceous strata, and 51 taxa (21%) are common to Cretaceous and Paleocene strata. Thus, the K-T interface is palynologically defined in the southern San Juan Basin at the contact between the Cretaceous Kirtland or Fruitland Formation and the base of the Paleocene Ojo Alamo Sandstone; in the northern part

of the basin, this interface is between the Cretaceous McDermott Formation and the base of the overlying Paleocene Animas Formation. In addition, palynologic data in the San Juan Basin identify a significant hiatus at the K-T interface with all of the uppermost Cretaceous Maastrichtian Stage and the uppermost part of the Campanian Stage missing; in addition palynologic data suggest that the lowermost part of the Paleocene is also absent throughout the basin.

Reference: Fassett, J.E. (2009), New geochronologic and stratigraphic evidence confirms the Paleocene age of the dinosaur-bearing Ojo Alamo Sandstone and Animas Formation in the San Juan Basin, New Mexico and Colorado: Palaeontologia Electronica (in press).

PALEOMAGNETISM OF ROCK STRATA ADJACENT TO THE CRETACEOUS-TERTIARY INTERFACE IN THE SAN JUAN BASIN, NEW MEXICO AND COLORADO

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Multiple paleomagnetic sections have been obtained through rock strata adjacent to the Cretaceous-Tertiary (K-T) interface in the San Juan Basin in New Mexico and Colorado. Paleomagnetic studies of uppermost Cretaceous strata in the southern San Juan Basin have revealed the presence of an interval of reversed-polarity in the Kirtland and Fruitland Formations immediately beneath the K-T interface and an interval of normal polarity of undetermined length in underlying Cretaceous strata. (These polarity intervals were incorrectly assigned to magnetochrons C30r and C31n by some previous authors.) Subsequently, $^{40}Ar/^{39}Ar$ ages for sanidine crystals from eight altered volcanic ash beds in this same stratigraphic interval revealed that these two magnetochrons were unequivocally C32r and C33n. Because two ash-bed ages were above the magnetochron reversal and six were below, the age of the reversal was precisely determined to be 73.50 ± 0.19 Ma, thus establishing a new precise Upper Cretaceous tie-point for global geologic time scales. A magnetic-polarity section obtained in the northeast part of the San Juan Basin in Colorado (the Chimney Rock section) through the upper part of the Lewis Shale, Pictured Cliffs Sandstone, and lowermost Fruitland Formation also located magnetochrons C33n and C32r. A $^{40}Ar/^{39}Ar$ age for an ash bed in this section confirmed the identity of these magnetochrons. A cross section across the basin from southwest to northeast shows that the C32r-C33n reversal exactly parallels the Huerfanito Bentonite Bed present 335 m below in the underlying Lewis Shale indicating that there was no differential tectonism resulting in erosion or non-deposition of strata between these two geochrons in the San Juan Basin.

Magnetic-polarity studies of the Paleocene Ojo Alamo Sandstone reveal that there is a thin, reversed-polarity interval in the lowermost part of this formation overlain by a relatively thin normal-polarity interval overlain by a thin reversed-polarity interval (all within the Ojo Alamo Sandstone), overlain by a longer normal interval extending into the lower part of the overlying Nacimiento Formation. On the basis of palynology, vertebrate paleontology, and physical geology the magnetic-polarity intervals in the Ojo Alamo Sandstone can be confidently labeled magnetochrons C29r and subchrons C29n.2n, C29n.1r, and C29n.1n. Thus, not only is all of the Ojo Alamo Sandstone Paleocene in age; these data also indicate that approximately 0.3 m.y. of lowermost Paleocene time is not represented by rock strata in the southern San Juan Basin. Because the age of the highest Cretaceous ash bed, about 5 m below the base of the Ojo Alamo and the K-T interface is 73.04 Ma, the duration of the K-T hiatus in the southern San Juan Basin is estimated to be 7.84 m.y. (73.04 – 65.2 = 7.84).

VERTEBRATE PALEONOTOLOGY OF THE PALEOCENE OJO ALAMO SANDSTONE, SAN JUAN BASIN, NEW MEXICO

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The Paleocene Ojo Alamo Sandstone is present throughout most of the New Mexico part of the San Juan Basin. This formation forms striking cliffs around much of its outcrop and consists of multi-storied fluvial deposits consisting of conglomeratic sandstone beds, coarse-grained, immature sandstone beds, and overbank mudstone and siltstone layers. The basal contact of the Ojo Alamo is thus quite distinct and easily mappable because of the marked contrast between the formation’s distinct lithology compared to the fine- to medium-grained, mature sandstones of the underlying Cretaceous Kirtland and Fruitland Formations. In addition, current-direction studies have shown that underlying Cretaceous strata were deposited by low-energy streams flowing northeastward across the basin area whereas the Ojo Alamo was deposited by very high energy streams flowing to the southeast. The age of the Ojo Alamo and its lithologic definition have been controversial for 100 years. Over the last decade or so, the rock-stratigraphic definition of this formation has reached general, though not total agreement, however its age is still hotly disputed. The Paleocene age of the Ojo Alamo has recently been established by detailed palynologic and paleomagnetic data. Those who still maintain that the Ojo Alamo Sandstone is Cretaceous and not Paleocene base their argument on the fact that the Ojo Alamo contains numerous, in-place, dinosaur or "Cretaceous" mammal fossils, mostly in the southwest part of the San Juan Basin. Because palynologic and paleomagnetic data confirm the Paleocene age of the Ojo Alamo, the dinosaurs and "Cretaceous" mammals found in this formation must represent the remains of animals that lived and died in Paleocene time.

The following dinosaurs have been identified from the Ojo Alamo Sandstone: *Alamosaurus sanjuanensis*; ?*Albertosaurus* sp., cf *Tyrannosaurus* sp.; ankylosaurid, indeterminate; dromaeosaurid, indeterminate; *Glyptodontopelta mimus*; hadrosaurids, indeterminate; nodosaurids, indeterminate; ornithomimid, indeterminate; *Richardoestesia* sp.; cf titanosaurids, indeterminate; *Torosaurus* cf *T. utahensis*; *Troodon* sp.; *Tyranosaurus rex*; and tyrannosaurid, indeterminate.

Some paleontologists have suggested that this assemblage is lower Maastrichtian to early Campanian in age whereas others maintain that it is Lancian (latest Cretaceous) in age – an age difference of 5.1 m.y. Two recent papers have stated that *A. sanjuanensis* is precisely 69.0 Ma based on an age determination of a tuff bed in the Big Bend area of West Texas. However, the authors of the Big Bend study state that their age of 69 Ma is in about the middle of their *A. sanjuanensis* zone and that this fossil ranges from late Edmontonian to Lancian or from between 73-69 Ma to the end of the Cretaceous (and possibly beyond). Furthermore, paleontologists studying the vertebrates of the North Horn Formation of Utah have indicated that *A. sanjuanensis* is present in uppermost Cretaceous (Lancian age) strata there, thus, assigning this fossil a precise age of 69.0 Ma cannot be defended. In sum, vertebrate fossils have proven to be of little value in dating Ojo Alamo Sandstone strata in the San Juan Basin.

GEO AND THERMOCHRONOLOGICAL EVIDENCE FOR THE EMPLACEMENT AND EXHUMATIONAL HISTORY OF THE TWIN LAKES BATHOLITH: IMPLICATIONS FOR THE LARAMIDE OROGENY

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New geo and thermochronological data from the Twin lakes pluton 20 miles south of Leadville, CO reveals a complex intrusion history followed by protracted exhumation. These results have important regional implications for the Laramide orogeny, Colorado Mineral Belt (COMB) plutonism, central CO exhumation, and possible links to a present-day zone of low velocity upper mantle know as the Aspen Anomaly. LA-ICPMS U/Pb zircon data show that the Twin Lakes pluton is composite with at least four intrusions of ~63, 57, 43 and 40 Ma. A fifth 36 Ma intrusion is indicated by argon mica ages. K-feldspar argon and apatite fission track (AFT) thermochronology constrain the post emplacement thermal history. K-feldspar minimum ages along a vertical transect near Huron Peak young from 36 to 31 Ma over 1.2 km of elevation. Assuming uniform exhumation, the average denudation rate for this period was ~250 m/Ma. This rate is apparently maintained until ca. 20 Ma based on AFT ages near the Twin Lakes reservoir. Assuming a 30° C/km geothermal gradient and a K-feldspar closure temperature of 175° C a paleodepth of 5.5 km at 31 Ma is estimated for the base of Huron Peak.

The presence of multiple intrusions ranging from 63 to 36 Ma at Twin Lakes challenges the long held view that a systematic temporal and spatial pattern of magmatism within the COMB may record the advance and subsequent rollback of the Farallon slab. This is because nearly the entire age range of Laramide plutonic activity is hosted in the Twin Lakes pluton, thus its seems unlikely that magmatism accurately depicts the leading edge of the slab at any given time. These new data are more consistent with the idea that the COMB magmatism reflects a long-lived zone of fertility and/ or pluton conduit throughout the early Tertiary. The data may also suggest that the Aspen Anomaly contributed to continuous CO magmatism from ~70 Ma to the present. In addition to tectonic implications, the data show that existing compilations based on argon and zircon fission track ages are inaccurate representations of COMB magmatism as both systems are unable to resolve complexities of closely spaced multiple magma injections.

USE OF COMPOSITIONAL ANALYSES OF OBSIDIAN ARTIFACTS IN UNDERSTANDING THE OCCUPATION HISTORY OF PUEBLO INDIANS IN THE CAÑADA ALAMOSA AREA, SOCORRO COUNTY, NEW MEXICO

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Comprehensive semi-quantitative X-ray fluorescence (XRF) analyses of geologic obsidian from different regions from throughout New Mexico and Arizona have established distinctive geochemical trends (especially in Zr, Nb, Rb, and Sr concentrations, possibly related to geologic source and geologic age (Shackley, 1988, 2005) that can be used to identify specific sources of archeological obsidian. In Cañada Alamosa in southwestern Socorro County, more than 500 obsidian artifacts collected from the past 10 years of excavation have been analyzed in order to study human stability, movement, and interaction in the area. Few studies in the American southwest have analyzed such a large number of samples of archaeological obsidian from one place. Analyses of these obsidian artifacts has revealed complex patterns of obsidian procurement that is quite different from earlier theories of predominant use from secondary obsidian deposits in Rio Grande gravels.

Approximately 31% of the archaeological obsidian from Cañada Alamosa originates from the Mule Creek area in Catron County and approximately 25% of the obsidian originates from the Mt. Taylor volcanic field in Cibola County. Other sources are from Gwynn Canyon (10%) and Red Hill, north of Mule Creek and the Jemez Mountains in northern New Mexico. Approximately 13% of the obsidians examined have not been correlated to a known source and could be from an unidentified local source in the San Mateo Mountains. The sample percentages by source vary between the four archaeological sites and through time. These results suggest that Pueblo Indians that lived in Cañada Alamosa from 700-1400 A.D. obtained obsidian through trade and interaction with Mogollon groups to the southwest, Tularosa Phase groups to the northwest, and Ancestral Puebloan groups to the north.

BASIN-FILL ARCHITECTURE OF PLIOCENE-LOWER PLEISTOCENE ALLUVIAL-FAN AND AXIAL-FLUVIAL STRATA ADJACENT TO THE MUD SPRINGS MOUNTAINS, PALOMAS BASIN, SOUTHERN RIO GRANDE RIFT

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Well-exposed Pliocene-lower Pleistocene strata adjacent to the intrabasinal Mud Springs Mountains (MSM), near Truth or Consequences, New Mexico provide a nearly three-dimensional view of basin-fill and records the interplay between small alluvial fans derived from the MSM, large alluvial fans derived from the Black Range (BR) and smaller fault blocks, and the axial Rio Grande. The MSM is a large (10x2 km) northwest-trending intrabasinal fault block located within the northern part of the eastward-tilted Palomas half graben. The BR constitutes the western hanging wall and the Caballo Mountains (CM) constitute the eastern footwall.

Deep canyons and badlands allow mapping of nearly 115 m of strata at the scale of 1:10,000. Alluvial-fan sediment derived from the MSM footwall extended between 50-1000 m from the mountain front before interfingering with and being replaced by BR-derived alluvial-fan sediment. Hanging wall-derived alluvial-fan sediment derived from the MSM extends further into the basin (~2.5 km) from the mountain front, where it interfingers with and is replaced by both BR-derived alluvial-fan sediment and by sediment of the axial Rio Grande. The relative abundance of Rio Grande fluvial-channel deposits increases away from the MSM and toward the footwall of the Palomas basin (CM), probably in response to contemporaneous active faulting and eastward tilting of the half graben during most of the deposition. Spread of MSM-derived alluvial fans into the basin was inhibited by low and intermittent sediment yield from small (<1 km^2) catchments in the MSM, as well as toe-cutting by the axial Rio Grande and by BR-derived fan channels, whose erosive power was related to high relief and high-elevation catchments with areas on the order of ~500 km^2.

USE OF GEOCHRONOLOGICAL AND GEOCHEMICAL DATA TO CORRELATE DEPOSITS AND DOMES FROM THE CERRO TOLEDO INTERVAL, PAJARITO PLATEAU, JEMEZ VOLCANIC FIELD

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This study compares deposits of the Cerro Toledo interval, the 360,000 year interval between the major eruptions of the Bandelier Tuff, from two deeply incised canyons located 12 km apart on the Pajarito Plateau. New $^{40}Ar/^{39}Ar$ ages and geochemical data are used to compare air-fall pumice deposits in Alamo Canyon with previously studied deposits in Pueblo Canyon to the north. Geochemical correlation of major and trace elements is performed using bivariate plots, calculation of a similarity coefficient, statistical distance, and hierarchical cluster diagrams.

The deposit in Pueblo Canyon consists of six tephras intercalated with volcaniclastic sandstone and conglomerate. Previously published $^{40}Ar/^{39}Ar$ ages for the Pueblo Canyon tephras range from 1.65 Ma to 1.25 Ma. The deposit in Alamo Canyon is composed of a basal fluvial sandy conglomerate with several thin tephras near the top of the unit, an ignimbrite containing obsidian breccia derived from collapse of a Rabbit Mountain Rhyolite dome, and an upper fluvial sandy conglomerate with tephra. The tephras from the basal conglomerate and the ignimbrite contain abundant xenocrystic sanidine derived from the underlying Otowi Member of the Bandelier Tuff.

The Rabbit Mountain Rhyolite contains sparse sanidine, so this component is poorly represented in the dated sanidine population. A tephra in the upper conglomerate yielded a 1.42 ± 0.03Ma $^{40}Ar/^{39}Ar$ sanidine age. The lack of abundant primary sanidine in the Alamo Canyon deposit favors the use of geochemical data over geochronological data for discriminating the sources of deposits in these two canyons.

FIELD, PETROGRAPHIC, AND GEOCHEMICAL EVIDENCE FOR THE ORIGIN OF THE "WHITE BEDS" IN THE CAMP RICE FORMATION (PLIOCENE-LOWER PLEISTOCENE), RINCON HILLS SOUTHERN RIO GRANDE RIFT

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Neogene basin fill within the Rio Grande rift and Basin and Range contain distinctive light-colored beds less than 2 m thick, which are often referred to as "white beds". These beds originate from a variety of processes, most commonly precipitation of opal from laterally flowing geothermal fluids, and volcanic ash fall, with or without digenetic alteration. Three distinct "white beds" are exposed within the Camp Rice Formation (Pliocene-lower Pleistocene) of Rincon Arroyo of south-central New Mexico. Preliminary field observations have determined these beds are laterally persistent and change in composition northward from fossiliferous silica deposits to microcrystalline carbonate and finally to massive clay.

Previously published research has suggested the "white beds" originate from siliceous sinter deposits associated with a geothermal system, or the precipitation of silica from a spring-fed cienega. However, neither of these hypotheses has been researched in detail, nor have they suggested a mechanism for the changes in composition that occur laterally within the beds.

The purpose of this study is to investigate origin of these beds using field work, petrology, and geochemistry. Presently, field observations have documented the locations of where compositional changes occur and their geographic extent. Measured sections have determined the "white beds" were deposited within a predominately fluvial setting, and have given insight into upper and lower contacts of each bed. In the near future, petrology will be used to observe the mineralogy and texture of each composition within the beds. Samples that are too fine-grained to be studied using petrography will be analyzed using x-ray diffraction, and scanning electron microscopy.

EXHUMATION AND COOLING HISTORY OF NEW MEXICO BASED ON LOW TEMPERATURE THERMOCHRONOLOGY

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Low temperature thermochronology, which includes fission-track and (U-Th)/He analysis of the mineral apatite, is a powerful tool for constraining the cooling history of rocks between 40 and 110°C, corresponding to crustal depths <4 km. Most of the low temperature thermochronology data for New Mexico are apatite fission-track (AFT) age and track length results from elevation traverses through mountain ranges and from drillholes on the High Plains and in the San Juan Basin. A few (U-Th)/He dates on apatite (AHe) have been determined for the Sandia Mountains and the High Plains.

The combined data sets record at least four pulses of cooling related to tectonically driven exhumation, changes in heat flow, and river drainage integration. The oldest episode of cooling is related to 50 to 75 Ma Laramide deformation and is recorded by AFT data from the Santa Fe Range, northern Sierra Nacimiento, Zuni Mountains, and Los Pinos Mountains. Middle Cenozoic cooling that began 25 to 30 Ma related to regional scale changes in mantle density and heat flow in the vicinity of the San Juan and Mogollon-Datil volcanic fields are recorded by AFT and AHe data on the High Plains. Miocene (<25 Ma) cooling associated with uplift and erosion of rift flank uplifts on the margins of the Rio Grande rift is observed in many mountain ranges, including the Sandia, Sierra Ladron, Caballo, Mud Spring, San Andres, and Sacramento mountains and the Black Range.

AFT and AHe data from the San Juan Basin indicate that the integration of the San Juan River with the Colorado River system was important in controlling the latter stages of cooling of this significant oil-producing province.

At times, unexpected low-temperature thermochronology results can lead to surprising discoveries. For example, Oligocene AFT cooling ages in the Pecos River valley of the Sangre de Cristo Mountains have been useful in mapping out a previously unrecognized, largely unexhumed Oligocene pluton. In addition, Miocene cooling ages from clasts in the Eocene Baca Formation were key in defining the extent of a Miocene fossil hydrothermal system east of Socorro.

RADIOCARBON AGE CONTROL FOR SACRAMENTO MOUNTAIN-DERIVED ALLUVIAL FAN DEPOSITS NEAR ALAMOGORDO, NEW MEXICO, AND RELATED GEOMORPHIC AND SEDIMENTOLOGIC INTERPRETATIONS

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Twenty-one radiocarbon ages were obtained from charcoal and gastropod samples in alluvial fan deposits shed from the Sacramento Mountains near Alamogordo, New Mexico. The stratigraphic context of these samples and their ages (presented here as conventional radiocarbon years) give temporal and spatial constraints for sedimentation and incision events. Where sampled from the same bed, the charcoal and gastropods returned similar ages (± 200 yrs). Three charcoal samples collected from the older, late Pleistocene unit yielded ages of: 41.32 ± 1.0, 27.01 ± 0.16, and 20.32 ± 0.11 ka. Inset > 3 m into this late Pleistocene unit is a gravel that returned a C-14 age of 10.99 ± 0.06 ka from charcoal in its upper buried soil. A ~50 cm-thick, stage II+ calcic soil horizon overlain by a 10-15 cm-thick, argillic(?) soil horizon lies between strata dated at 20.32 ± 0.11 and 3.96 ± 0.4 ka.

The age constraints of this relatively common soil horizon and the inset gravel indicate widespread incision between 20 and 11 ka. Significant aggradation occurred between 6 and 3 ka, both in the proximal and distal parts of the alluvial fans. These middle Holocene deposits are relatively coarse-grained in the proximal areas of the fans. In the distal areas, the middle Holocene deposits consist of internally massive, clayey-silty sand (mostly very fine- to medium-grained) with sparse, gravelly channel-fills. Weak cumulic soils, marked by gypsum accumulation and ped development, are present in the clayey-silty sand. Widespread erosion and incision of the alluvial fans occurred between approx. 3-1.5 ka, followed by back-filling of arroyos. Over the last century, deep incision has occurred on alluvial fans of large drainages, particularly in finer-grained sediment north of Alamogordo.

Having numerous radiocarbon ages reduces uncertainty and allows identification of possible reworking of older charcoal. One case of possible charcoal reworking is found at the mouth of Mule Canyon located ~7 km south of Alamogordo in a 3 m-thick deposit containing charcoal dated at 8.75 ± 0.07 ka. Overlying the aforementioned inset gravel (11 ka), this deposit may possibly correlate to the widespread 3-6 ka aggradation, considering its somewhat anomalous age and the fact that it overlies a soil with illuviated clay and a stage I+ to II calcic (+ gypsum) horizon.

THE CARBONIFEROUS/PERMIAN BOUNDARY IN THE BIG HATCHET MOUNTAINS, SW NEW MEXICO (USA)

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The Carboniferous/Permian boundary (CPB) has been defined by the first occurrence of the conodont species *Streptognathodus isolatus* and the fusulinid *Sphaeroschwagerina* (base of the *Sphaeroschwagerina vulgaris – S. fusiformis* Zone), with a poorly exposed type section located along Aidaralash Creek near Aktobe in the southern Ural Mountains (northern Kazakstan) within a succession of hemipelagic pelitic sediments and intercalated sandstone beds. In the Big Hatchet Mountains in southwestern New Mexico (Hidalgo County), the entire Pennsylvanian and part of the Lower Permian (Wolfcampian) is represented by a thick succession composed of shallow marine limestone of the Horquilla Formation.

At New Well Peak, the Horquilla Formation is approximately 1000 m thick and can be divided into three members. The CPB lies within the upper member, which consists of a succession of dm-bedded gray to dark gray, predominantly micritic, fossiliferous limestone. Intercalated are indistinctly bedded to massive limestone intervals 3.3-4.5 m thick and limestone with chert nodules. The most common microfacies is bioclastic wackestone to packstone with a highly diverse fossil assemblage. Most abundant are fusulinids, smaller foraminifers, calcareous algae, echinoderms, brachiopods, bryozoans, gastropods and *Tubiphytes*. The limestone accumulated in a shallow, open marine environment with normal salinity. Carbonate sedimentation was periodically interrupted as indicated by red mudstone layers, resulting in a cyclic succession. Thin paleocaliche beds containing alveolar root structures at the top of the limestone intervals/base of the red mudstones indicate short periods of subaerial exposure. The Horquilla Formation was deposited on the stable shelf of the Pedregosa Basin. The cycles are interpreted to be caused by glacioeustatic sea-level fluctuations.

At New Well Peak, the CPB can be drawn with fusulinids (first appearance of *Pseudoschwagerina*) as well as with conodonts (first appearance of *Streptognathodus isolatus*). Accessibility, excellent outcrop quality, abundance of fossils (including fusulinids and conodonts) and the uniform facies across the C/P boundary favor the New Well Peak section as a potential new type section (GSSP) for the Carboniferous/Permian boundary.

LITHOSTRATIGRAPHY AND SEDIMENTOLOGY OF THE UPPER TRIASSIC LAMY AMPHIBIAN QUARRY, SANTA FE COUNTY, NEW MEXICO

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The Lamy Amphibian Quarry in Santa Fe County, New Mexico is stratigraphically low in the Upper Triassic (Adamanian) Garita Creek Formation. First discovered and collected by Harvard University in 1938, then reopened by the National Museum of Natural History (Smithsonian) in 1947 and in the 1960's, in 2008 the New Mexico Museum of Natural History opened the quarry a fourth time. The quarry mostly produces well-preserved, disarticulated bones of the large temnospondyl amphibian, *Buettneria perfecta*. Some phytosaur material and sparse dinosaur/dinosauromorph bones are present together with a microfauna of amphibian and fish bones, scales, and teeth. The quarry bonebed is 3 m above the top of the Santa Rosa Formation in a 4-m-thick mudstone interval overlain by a 1.5 m-thick multistoried channel sandstone complex. The uppermost Santa Rosa conglomerate contains large bone fragments of phytosaur, metoposaur and aetosaur and underlies 2 m of red mudstone/siltstone at the base of the Garita Creek Formation. This unit is overlain by 2 m of red and green, massive, mottled mudstone with small, sparse, carbonate concretions and abundant *Paleophycus* burrows that contains the bonebed. The bones are coated with a thin (~ 1mm) carbonate layer and show moderately well-developed SW-NE orientation (most flow is to the NE), indicating the bones are allochthonous to the bonebed, having been transported there and current aligned to some extent. A 10- to 20-cm-thick bed of yellowish-brown mudstone with carbonate concretions up to 8 cm in diameter overlies the bonebed and is overlain by a channel sandstone that has numerous large plant stems and a few possible bone fragments. The bonebed-bearing mudstone complex shows lateral continuity for hundreds of meters and represents distal floodplain and floodplain pond facies. Within these facies, intercalated siltstone and fine-grained sandstone stringers represent individual sheetflood deposits. The uppermost yellowish-brown mudstone with concretions is a paleosol. The overlying crossbedded channel sandstone complex has erosively cut into the mudstone beds. Its multistoried character implies fluctuations in the flow regime.

MULTIPLE EPISODES OF FAULTING IN THE CENTRAL FLORIDA MOUNTAINS, LUNA COUNTY, NEW MEXICO

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Intricately faulted Paleozoic strata and subjacent syenite basement in the central Florida Mountains have been interpreted to record low-angle thrust faults that commonly emplaced younger strata over older strata or basement. Faults near Mahoney Park on the west range flank were re-examined in November 2008 in order to test hypotheses regarding fault origin and timing. Both normal- and reverse-separation faults are present in the study area.

Reverse separation faults strike E-W to NW, have moderate to steep southerly dips, and emplace Cambrian syenite on Ordovician strata and Ordovician to Silurian strata over Devonian strata. They are cut by normal separation faults that trend NW, NE and E-W, with moderate dips of about 55º to both NW and SE. Both sets of faults are truncated by a single normal-separation fault, termed the Mahoney Park fault (MPF), which strikes 322 and dips 41-45º SW; the fault extends through the study area, juxtaposes Ordovician through Mississippian hanging-wall strata above syenite, and merges to the southeast without deflection into the trend of the South Florida Mountains fault (SFMF; Clemons, 1998), with a fault plane attitude of ~320 75º SW. The SFMF emplaces syenite over Devonian strata near its juncture with the MPF, and thus preserves reverse separation, but it parallels a nearby normal-separation fault that is a splay or southeastward continuation of the MPF and may have reactivated the SFMF.

Cross-cutting relations indicate that reverse separation faults preceded most normal separation faults. Reverse separation faults have long been regarded as a product of Late Cretaceous-Paleogene Laramide orogenesis. These faults are cut by the moderately dipping normal faults, which are in turn truncated at the MPF. The age of the MPF is not constrained, but its trend parallels the strike of the upper Eocene Rubio Peak Formation, which constitutes most of the central range, but not more northerly strikes of Miocene strata to the north. We postulate that Rubio Peak tilting represents footwall uplift coordinate with offset on the MPF, suggesting that MPF offset is early Miocene, older than north-south range-bounding faults that tilted the Miocene strata. Our preliminary findings indicate that complex fault relationships in the central Florida Mountains evidently resulted from multiple episodes of offset.

AN ADDITIONAL ENIGMATIC VERMIFORM FOSSIL FROM THE UPPER PENNSYLVANIAN (VIRGILIAN) ATRASADO FORMATION (MADERA GROUP) OF CENTRAL NEW MEXICO

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A small number of enigmatic vermiform fossils from the Upper Pennsylvanian (Virgilian) Kinney Quarry *Lagerstätte* in the Manzanita Mountains of central New Mexico have previously been documented. We add here an additional example to this record. The specimen (NMMNH P-57873) is preserved as a part and counterpart on laminated calcareous shale from Kinney unit 3. Unit 3 contains a mixture of terrestrial and aquatic faunas. The specimen consists of an elongate fossil that is at least 60 mm long. It is likely preserved in dorso-lateral aspect. There are approximately 40 regularly alternating dark and light transverse bands on the long axis. The dark areas are covered by a thin carbonized layer showing fine striations. The bands are about 1 mm wide and 3 mm long. There were likely more of these but the preservation is indistinct toward the presumed posterior. The other end of the specimen is relatively well preserved and we interpret this as the anterior. It shows three appendages extending from a relatively thick, light colored band. There is no indication of a separate head. The appendages resemble an onychophoran oral papilla and antennae. There are at least 26 irregularly spaced, cone-shaped appendages along the likely ventro-lateral margin. These leg-like structures are about 2 mm long and about 1 mm at their base. They have no indications of claws, setae or aciculae. There were probably more along the length but the preservation is indistinct towards the posterior. The opposite margin, which we interpret as dorso-lateral, appears somewhat irregular. Several cone-shaped appendages can be seen along the posterior end, which may indicate that the specimen was rotated into a dorso-ventral orientation along this portion. P-57873, despite the carbonized surface, lacks any recognizable structures that indicate it is a plant. It is more likely a segmented, soft-bodied animal. The conspicuous leg-like structures could be lobopodia or parapodia, which would indicate a possible polychaete or onychophoran identity. The overall morphology of the body is more indicative of an onychophoran.

THE JORNADA DEL MUERTO IMPACT STRUCTURE

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A circular feature located in the Jornada del Muerto valley in southern New Mexico, visible only on satellite photographs, has been interpreted to be a meteor-impact crater. The crater has a diameter of about 8-miles and an area of 50 square miles. It is accessible via Sierra County Road No. 013 that splits the middle of the crater and follows the route of the historic 1598 Camino Real. The crater's surface has a gentle slope of 3.5 to 0.7 % on the east side of the Caballo Mountains. The crater edge stands out in aerial/satellite photos as a consequence of the dense band of vegetation that highlights at least 60 % of the crater's perimeter. This band of vegetation is probably a result of the groundwater-boundary conditions that may have caused dissolution of the broken Permian limestone strata at depth at the interface and subsequent local depressions. Magnetometer surveys across the vegetation-marked edges indicate a disturbed, mega-breccia bedrock in lateral contact with apparently uniform crater-fill deposits. The impact may have occurred at (or near) the end of deposition of the Mesaverde Formation in the southern part of the Western Interior Seaway establishing a maximum age. The Paleocene alluvial fan deposits of the Laramide Love Ranch Formation, that overlie the crater's footprint and probably partially fill the crater, establish a probable minimum age that is near the K/T boundary or about 65.5 Ma. It is unlikely that iridium or shocked quartz will be found on the surface.

NEW MEXICO'S FOSSIL RECORD: DETERMINATION OF GEOLOGICAL AGES FOR CAMBRIAN-PLEISTOCENE ROCKS USING BIOCHRONOLOGY

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New Mexico (NM) has an extensive fossil record that ranges in age from Late Cambrian to Pleistocene. Most early Paleozoic (Cambrian-Devonian) strata in New Mexico are of marine origin, and their ages are determined primarily by biochronology using cephalopods, brachiopods and/or conodonts. Late Paleozoic (Carboniferous-Permian) rocks in NM are a mixture of marine and nonmarine facies. Non-fusulinid and fusulinid forams are the primary biochronological tools in the marine strata, although some brachiopod- and conodont-based biochronology has been undertaken.

Nonmarine Permian red beds yield biochronologically significant tetrapod (amphibian and reptile) fossils; some provide the basis for part of a global scheme of Permian tetrapod biochronology. Triassic strata in NM are wholly of nonmarine origin and yield tetrapod and plant fossils useful for biochronology. Part of a Triassic global timescale using tetrapod biochronology is based on Upper Triassic fossils from NM. The state has a sparse Jurassic fossil record, almost totally nonmarine, and of limited biochronological utility.

Cretaceous strata in NM are a mixture of marine and nonmarine rocks, and the Upper Cretaceous marine strata yield numerous fossils of ammonoids that are a key part of one of the most detailed biochronological schemes of the Phanerozoic. Nonmarine Cretaceous biochronology is based on tetrapods and palynomorphs, particularly in the Campanian-Maastrichtian. All Cenozoic rocks in NM are of nonmarine origin, and they yield extensive and biochronologically useful fossil mammal assemblages of Paleocene, Miocene, Pliocene and

Pleistocene ages. Paleocene mammal-dominated assemblages from NM are the basis of two land-mammal "ages" used throughout western North America.

In NM, biochronology has been and will remain the primary means of age determination throughout much of the Cambrian-Pleistocene section, in part because of the abundance and utility of fossils, but also because of the dearth of radioisotopically-datable rocks and the general lack of reliable magnetostratigraphic data or correlations prior to the Cretaceous. Refinement of biochronological age determinations thus will remain crucial to progress in many aspects of the study of the geology of NM, from local histories of sedimentation to regional tectonics.

PENNSYLVANIAN STRATIGRAPHY AND CONODONT BIOSTRATIGRAPHY IN THE CERROS DE AMADO, SOCORRO COUNTY, NEW MEXICO

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We measured seven overlapping sections on different fault blocks to construct a complete Pennsylvanian section in the Cerros de Amado of Socorro County. At the base of the Pennsylvanian section, the Sandia Fm unconformably overlies Precambrian basement and is a 162-m-thick cyclic succession of siliciclastics (notably quartzose sandstone and conglomerate) and limestones (mostly coarse-grained bioclastic wackestone/packstone). The overlying Gray Mesa Fm is 164 m thick and, following Rejas, we divide it into three members named by Thompson: Elephant Butte Mb (117 m of limestone and shale with a prominent 10-m-thick sandstone bed above the Warmington lst. at the base), Whiskey Canyon Mb (13 m of very cherty limestone) and Garcia Mb (57 m of diverse limestone, conglomerate, sandstone and shale). The overlying Atrasado Fm is ~ 300 m thick of interbedded silicilclastic (mostly shale and arkosic sandstone) and varied limestones. We recognize the formation rank units of Thompson and Rejas as members of the Atrasado Fm (ascending order): Bartolo, Amado, Coane, Adobe, Council Springs, Burrego, Story, Del Cuerto and Moya. The Atrasado Fm is mostly shallow marine facies with some nonmarine siliciclastics. The Bursum Fm caps the Pennsylvanian section in the Cerros de Amado and is as much as 105 m of red-bed siliciclastics and limestones.

Fusulinids are not common in the Pennsylvanian section in the Cerros de Amado, so we undertook sampling for conodonts. They indicate the following ages: (1) Atokan—47 m above the base of the Sandia Fm; (2) early Desmoinesian (Cherokee)—Elephant Butte, Whiskey Canyon and lower Garcia members of Gray Mesa Fm; (3) late Desmoinesian (Marmaton)—upper Garcia Mb of Gray Mesa Fm and Bartolo Mb of Atrasado Fm; (4) early Missourian—Amado Mb of Atrasado Formation; (5) late Missourian—Coane, Adobe, and Council Spring members of Atrasado Fm; (6) middle Virgilian—Del Cuerto and Moya members of Atrasado Fm. The conodont ages are consistent with the few fusulinid horizons we located, and fusulinids indicate that the Bursum Formation in the Cerros de Amado is early Wolfcampian in age. A striking aspect of the entire Cerros de Amado Pennsylvanian section is the degree to which coarse siliciclastics are present at various levels, indicating a strong tectonic influence on local sedimentation throughout the Middle-Late Pennsylvanian.

THE PENNSYLVANIAN SECTION AT WHISKEY CANYON, MUD SPRINGS MOUNTAINS, SIERRA COUNTY, NEW MEXICO

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The Pennsylvanian strata exposed at Whiskey Canyon in the Mud Springs Mountains of Sierra County, New Mexico (secs. 1-2, T13S, R5W) are a nearly 500 m thick section with extensive fusulinid assemblages that M. L. Thompson first described in detail in 1942; he named the Mud Springs, Armendaris and Bolander groups and their constituent formations based on type sections in Whiskey Canyon. The base of the Pennsylvanian section is not exposed in Whiskey Canyon, and is 4 m of fossiliferous limestone of Thompson's Apodaca Formation. The overlying Mud Springs Group consists of the Hot Springs Formation (27 m of interbedded limestone and shale) overlain by the

Cuchillo Negro Formation (7.6 m of cherty limestone and coarse-grained sandstone). The overlying Armendaris Group begins with the Elephant Butte Formation (20 m of interbedded shale and limestone, with a basal *Chaetetes*-bearing limestone called the Warmington Limestone Member), followed by the Whiskey Canyon Limestone (44 m of very cherty, fossiliferous limestone) capped by the Garcia Formation, 59 m of interbedded limestone and shale with a prominent limestone pebble conglomerate at its base.

The overlying Bolander Group is 62 m of varied fossiliferous limestones, most nodular or cherty. Thompson did not describe the post-Bolander Pennsylvanian strata in Whiskey Canyon, but we can tentatively assign these strata to units he named in the Oscura Mountains of Socorro County. These are the Veredas Group (Coane, Adobe and Council Springs formations), 58 m of mostly cherty limestone, Hansonburg Group (Burrego and Story formations), 35 m of mostly nodular fossiliferous limestone, and the Keller Group (Del Cuerto and Moya formations), 73 m of mostly shale capped by nodular limestone. The overlying Bursum Formation is 85 m of siliciclastic red beds and interbedded limestone.

Although we can recognize the lithostratigraphic units Thompson named in the Whiskey Canyon section, the boundaries of many do not correspond to easily mapped, distinctive lithologic changes. Most of his formations are units too thin to map and/or are lithologically composite, so they are not readily recognized as distinctive lithosomes. Despite this, many of the lithostratigraphic units Thompson named can be recognized as member- or bed-rank units of utility in local and regional stratigraphy.

VERTEBRATE BIOCHRONOLOGY OF THE CRETACEOUS-PALEOCENE TRANSITION, SAN JUAN BASIN, NEW MEXICO

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In the San Juan Basin of northwestern New Mexico, Upper Cretaceous-Paleocene vertebrate fossil assemblages (assigned to the Kirtlandian, Edmontonian, Puercan and Torrejonian land-vertebrate "ages" [LVAs]) allow precise correlations that are consistent with available radioisotopic dating and magnetostratigraphy. The Fruitland Formation and overlying Kirtland Formation yield the vertebrate assemblage used to define the Kirtlandian LVA, which is associated with radioisotopic ages of 73-75.5 Ma and a relatively long normal polarity chron most reasonably identified as chron 33n. The base of the Naashoibito Member of the Ojo Alamo Formation is a substantial unconformity overlain by a vertebrate assemblage of Late Cretaceous age, although opinions diverge as to whether it is Edmontonian or Lancian. We prefer to assign it to the former, in part based on the association with a radioisotopic age of 69 Ma in Texas of the characteristic Naashoibito sauropod dinosaur *Alamosaurus*, and in part based on our re-evaluation of the mammals reported from the Naashoibito Member, some of which have been misidentified, and all of which do not provide conclusive evidence of a Lancian age.

The Naashoibito and overlying Kimbeto Member of the Ojo Alamo Formation are in an interval of reversed polarity, and palynostratigraphy has long been used to place the base of the Paleocene at the base of the Kimbeto Member. We regard all dinosaur bones in the Kimbeto Member as reworked, and we also recognize a substantial unconformity at its base. The oldest Paleocene vertebrates in the San Juan Basin are the fossil-mammal-dominated assemblages used to define the Puercan and Torrejonian LVAs. The Puercan and Torrejonian mammals are part of an extensive correlation web from Montana to New Mexico, correlated to magnetostratigraphy that assigns them to the youngest portion of chron 29r through the oldest portion of chron 26r. The integration of vertebrate biochronology and magnetostratigraphy in the San Juan Basin is consistent with other correlations in the Western Interior that place the youngest dinosaur fossils in uppermost Cretaceous, not Paleocene, strata.

$^{40}Ar/^{39}Ar$ GEOCHRONOLOGY OF MANGANESE OXIDE MINERALS: A MINERALOGICAL BASIS FOR SUCCESSFUL ANALYSES

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Manganese oxide minerals (MnOx), specifically cryptomelane [$K_{1-1.5}(Mn^{4+},Mn^{2+})O_{16}$] but including others, have been dated by the $^{40}Ar/^{39}Ar$ method with variable degrees of success. In most occurrences, MnOx minerals are very fine grained and often banded. Almost all MnOx minerals display significant solid solution behavior and vacancies are common in their structures. In addition, a number of the minerals (esp. cryptomelane) have high and low temperature forms. MnOx minerals are often intimately intermixed from the macro to micron scale within a single sample. MnOx minerals are typically contaminated with other mineral phases, especially from the weathering environment. All of these characteristics lead to the potential for argon/potassium loss, excess argon, recoil, contamination, and low radiogenic yields that affect the final age determination.

The majority of published dating studies utilizing MnOx involved those formed during the supergene (weathering) process. Utilization of manganese minerals of hydrothermal origin has produced more precise results probably because of larger grain sizes and the ability to produce purer mineral separates. Dating of pure hydrothermal cryptomelane separates at the MCA mine in the Luis Lopez mining district resulted in plateau ages of 6.31 ± 0.08 Ma. Additional dating in the Magdalena district manganese deposits has revealed additional complexities with respect to multiple mineral phases and their intergrowths. The dating of supergene MnOx minerals (mixed cryptomelane, todorokite, and an unidentified silicate) from a manganocrete in the Red River drainage produced an age of 64.6 ±1.1 Ma in a debris flow dated at 4220 ± 40 yrs by ^{14}C analysis of charcoal. The variability of age dating results, even in coarse-grained hydrothermal MnOx minerals, illustrates the importance of sample selection and characterization in any successful dating project.

LARAMIDE VOLCANISM, PLUTONISM, AND PORPHYRY COPPER DEPOSITS IN SOUTHWESTERN NEW MEXICO

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New Mexico is located at the eastern edge of one of the world's great metal-bearing provinces. There are nine known Laramide porphyry copper deposits in New Mexico: Santa Rita (58.3 Ma, $^{40}Ar/^{39}Ar$), Tyrone (Burro Mountains district; 54.5 Ma, $^{40}Ar/^{39}Ar$), Little Rock (Burro Mountains district), Copper Flat (Hillsboro district, 75 Ma, $^{40}Ar/^{39}Ar$), Hanover-Hermosa Mountain (Fierro-Hanover district, 57.6 Ma, $^{40}Ar/^{39}Ar$), Lone Mountain (51.5 Ma, K/Ar), Gold Lake (White Signal district), McGhee Peak (Peloncillo Mountains), and the newly discovered Lordsburg porphyry copper deposit (58.5 Ma, $^{40}Ar/^{39}Ar$). Additional Laramide skarn and polymetalic vein deposits in New Mexico formed in Paleozoic limestones and dolomitic limestones adjacent to calc-alkaline plutonic rocks emplaced during the Laramide compressional event; most of these areas have potential for additional porphyry copper deposits.

Unlike the regional Tertiary plutons, which are related to caldera volcanism, the Laramide plutons appear to be the roots of andesitic volcanoes. The geology of the Hillsboro district is dominated by Cretaceous andesite flows (75.4 Ma, $^{40}Ar/^{39}Ar$), breccias, and volcaniclastic rocks. The Copper Flat quartz monzonite porphyry stock intruded the vent of the volcano and hosts porphyry copper mineralization, whereas two additional stocks are unmineralized (Warm Springs quartz monzonite, 74.4Ma, $^{40}Ar/^{39}Ar$). $^{40}Ar/^{39}Ar$ dating of the Lordsburg andesites (67.9 to 66.3 Ma) suggest that volcanism was older than the porphyry. At Santa Rita, $^{40}Ar/^{39}Ar$ ages of different intrusions suggests a long-lived igneous system between 59.3 to 56.4 Ma.

Compositions of the Laramide intrusive rocks vary regionally and with time from early mafic and silica-poor diorites and monzonites to more siliceous and felsic monzogranites, quartz diorites, and monzogranites . They are typically calc-alkaline to mildly alkaline. Laramide volcanic rocks in New Mexico have arc-like chemical characteristics. This suggests volcanism was the result of dehydration of the subducting Farallon plate beneath the North American plate. Mineral exploration is currently underway in the Lordsburg and Lone Mountain districts. The Santa Rita and Tyrone districts are currently being mined.

VOLCANISM, PLUTONISM, AND MINERALIZATION ALONG THE CAPITAN LINEAMENT AND ADJACENT CHUPADERA MESA AREA, CENTRAL NEW MEXICO

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The intersection of the Capitan Lineament (CL) and the Lincoln Country Porphyry Belt (LCPB) is a region of intense volcanism, plutonism, and mineralization. The CL is an E-W structure that focused volcanism, plutonism, and mineralization across central NM. The diversity of igneous rocks and mineral deposits in this region suggests highly fractionated and differentiated magmas. The existing K-Ar and $^{40}Ar/^{39}Ar$ ages* indicates that magmatism occurred during multiple pulses, rather than one single event.

The eastern-most intrusion along the CL is the 27.9 Ma Railroad dike, whereas the calderas in the Socorro and Magdalena Mts (24.3-32.1 Ma*) define the western limit. The LCPB is a N-S belt of Tertiary porphyritic calc-alkaline to alkaline rocks that were emplaced in three pulses: 36-5-38.2 Ma, 26-30 Ma, and 26-28 Ma and are associated with Au-Ag-Te veins, REE-Th-U veins, Fe (±Au) skarns, and porphyry Mo deposits. Three compositionally complex stocks intrude the Sierra Blanca volcanics (36.5-38.2 Ma): Bonito Lake (26.6 Ma), Three Rivers (36.36 Ma*), and Rialto (31.4 Ma). The 28.8 Ma* Capitan pluton forms the eastern part of the LCPB and is the largest Tertiary intrusion in NM. The zoned Capitan pluton is associated with Fe skarns and REE-Th-U-Au vein deposits.

The unmineralized Carrizozo lava flow (near Carrizozo) is the youngest of the volcanic rocks along the CL (3-4, 10-11 ka). The E-W trending Jones Camp dike south of Chupadera Mesa is 27.9 Ma and the NE-SW trending Chupadera Mesa dike (southern Torrance Co) is 30.2 Ma. Additional dike swarms are found throughout the Chupadera Mesa area.

East of Socorro several small deposits of Cu-Ag-U (±Fe, Au) and Rio Grande rift (RGR) barite-fluorite-galena deposits are found along faults, are not directly associated with igneous activity, and could represent migration of mineralizing fluids along rift structures. $^{40}Ar/^{39}Ar$ ages and field relationships suggest that RGR deposits formed during the last 12 m.y. coincident with the later stages of rifting in central NM. Most of the available ages of igneous activity are K/Ar dates; detailed, high precision geochronology will be required to fully understand the relationships between regional volcanism, plutonism, and mineralization.

* denotes $^{40}Ar/^{39}Ar$ ages from NM Geochron Laboratory. All other ages are K-Ar ages from literature.

GEOCHEMICAL AND GEOCHRONOLOGICAL ANALYSIS OF THE CUCHILLO MOUNTAIN LACCOLITH, SIERRA COUNTY, NEW MEXICO

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Recent studies of the Sierra Cuchillo laccolith and surrounding volcanic sequences have refined the geochronology and petrologic understanding of the area. New U-Pb zircon data on the laccolith, previously dated at 49 Ma by Jahns (1978), place intrusion and cooling at 38.6 ± 0.7 -1.2 Ma. The laccolith is a fine-grained granitic intrusion containing at least three pegmatite-like concentric zones of alteration formed by late-stage volatile fluids. The source of the laccolith, at least in part, is assimilated Precambrian crust. This is supported by zircon cores dated at 1.455 Ga ± 15 Ma.
Six volcanic packages surround Sierra Cuchillo; two have been hypothesized as being related to the laccolith (McMillan, 1978). The original interpretation of these sequences places the undifferentiated Latite-Andesite sequences directly above the Mesozoic equivalent to the Dakota Sandstone. This is overlain by the Dacite-Rhyolite sequence (Jahns, in press). U-Pb zircon dating places

the Latite-Andesite sequence at 36.2 $\pm$ 0.7 Ma, and the Dacite-Rhyolite sequence at 36.6 $\pm$ 0.7 Ma. Geochemically the Latite-Andesite sequence is very similar to the Sierra Cuchillo laccolith containing a Sr concentration of 837 ppm, and a Nb concentration of 9 ppm. The Dacite-Rhyolite sequence contains slightly higher concentrations of Rb, Th, Nb, Zr, and Y in the basal member, but the top member is similar to Sierra Cuchillo.

Many smaller intrusions surround the Sierra Cuchillo laccolith including the Willow Springs dome and the Vindicator sill. The samples from the Vindicator sill, dated at 37.7 $\pm$ 0.7 Ma, have trace element concentrations very similar to Sierra Cuchillo. These samples indicate that the sill should actually be considered part of the laccolith. Small rhyolitic intrusions, formally considered satellite intrusions, contain zircons of 28.0 Ma. These are also geochemically distinct from Sierra Cuchillo with extremely high Nb (79-200 ppm), and Y (36-93 ppm) concentrations, and extremely low Sr concentrations (9-16 ppm).

The Sierra Cuchillo laccolith is unique among igneous rocks of similar age. Most mid-Tertiary rhyolitic rocks were erupted from large calderas with regional ash-flow sheets. Sierra Cuchillo was emplaced at a shallow depth, and may correlate only to local, rather than regional, volcanic sequences.

HYDROGEOLOGIC CONTROL OF IGNEOUS DIKES ON GYPSUM KARST DEVELOPMENT IN SOUTHEASTERN EDDY COUNTY, NEW MEXICO

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Igneous dikes have been described in the Castile Formation of southeastern Eddy County, NM. This study has been conducted to determine if there is a relationship between gypsum karst development and igneous dikes in the Castile Formation in Eddy County, New Mexico. The igneous dikes are thought to have an affect on the local hydrology and associated karst development around them. To conduct this research a surface survey of the area around the dike was done to find and document karst features and geology. Also, randomly generated areas away from the dikes were surveyed to use as a control. A T-Test was run to determine if there is a significant difference between karst development around the dike and in the control areas. ArcGis, which was used to analyze the data collected, shows a relationship between the karst development and igneous dikes.

A SKULL AND PARTIAL SKELETON OF THE OREODONT *MERYCHYUS MAJOR* (MAMMALIA: ARTIODACTYLA: MERYCOIDONTIDAE) FROM THE MIOCENE POPOTOSA FORMATION, BOSQUE DEL APACHE NATIONAL WILDLIFE REFUGE, SOCORRO COUNTY, NEW MEXICO

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In February 2008, David Love, Richard Chamberlin, and Colin Cikoski discovered an associated upper and lower jaw of an oreodont, eroding from the wall of an arroyo on the Bosque del Apache National Wildlife Refuge near San Antonio, Socorro County, central New Mexico. In March 2008, Gary Morgan and Warren Slade visited the site and collected the oreodont fossil, consisting of a skull and jaws and associated partial skeleton. The fossil is preserved in an indurated, fine-grained sandstone of fluvial origin derived from the Miocene Popotosa Formation.

Preparation of the oreodont specimen has revealed an almost 100% complete skull and still-attached lower jaw and partial articulated postcranial skeleton consisting of a nearly complete set of cervical, thoracic, lumbar, and sacral vertebrae, most of the ribs (still attached to the thoracic vertebrae), both wrists (distal radius-ulna, carpals, proximal metacarpals), and a partial left hind limb (innominate, femur, tibia, fibula, tarsals). An unusual feature is the preservation of an ossified larynx and the delicate hyoid bones. The Bosque de Apache oreodont is identified as the species *Merychyus major* (family Mercoidodontidae, subfamily Ticholeptinae). The skull is one of the largest known for this species and is also characterized by the retracted narial opening, short nasals, long rostral premaxillary suture, broad and shallow lacrimal fossa, shallow zygomatic arch, inflated braincase, long paroccipital and postglenoid processes, and hypsodont dentition, particularly the molars.

The biostratigraphic distribution of *Merychyus major* is restricted to the late Miocene, from the early late Clarendonian to the early late Hemphillian North American land mammal ages (about 6-10 Ma). The only absolute age control on the Popotosa Formation in this area is a radiometric date of 8.57 ± 0.26 Ma on a basaltic lava flow that lies within the formation about 1 km north of the oreodont site. The only other vertebrate fauna from the Popotosa Formation is from the Gabaldon Badlands west of Belen in Valencia County, about 100 km north of the oreodont site. The mammalian biostratigraphy of the Gabaldon Badlands fauna indicates a late Miocene age (7-9 Ma; early Hemphillian).

ANTIBIOTIC-PRODUCING CHARACTERISTISC AND SPECIATION OF BACTERIA IN PARKS RANCH CAVE, EDDY COUNTY, NEW MEXICO

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The ability to produce antibiotics, which reduce the reproduction rate of other competitors, is an evolutionary mechanism that some bacteria exhibit in order to survive. Organic material rarely enters caves in the desert due to low rainfall, resulting in a deficiency of nutrients inside the cave. Bacteria in caves live under stressful conditions and constantly are competing; therefore, bacteria found in caves are likely to produce antibiotics. This study was conducted to assay bacteria in Parks Ranch Cave, Eddy County, New Mexico, for antibiotic-producing characteristics and to identify the bacteria.

The samples were cultured at sites inside the cave. The bacterial colonies from the cave were tested for antibiotic-producing characteristics against Escherichia coli and Staphylococcus saprophyticus. The colonies were also identified using identification flow charts. Bacteria in Parks Ranch Cave did not have the antibiotic-producing characteristics for the cultures against which they were tested. Pseudomonas fluorescens has been shown in other studies to produce antibiotics. Pseudomonas aeruginosa is a pathogenic bacterium that targets immuno-compromised individuals. These two Pseudomonas species were found at the same site, indicating that some species may still be competing for nutritional sources.

SELACHIAN-DOMINATED VERTEBRATE FOSSIL ASSEMBLAGE FROM THE UPPER CRETACEOUS ATARQUE SANDSTONE, SEVILLETTA NATIONAL WILDLIFE REFUGE, SOCORRO COUNTY, NEW MEXICO

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We have relocated and recollected the fossil vertebrate locality in the Upper Cretaceous (Turonian) Atarque Sandstone on the Sevilleta National Wildlife Refuge first documented by Baker and Wolberg in the 1980s. The locality is now NMMNH 5153 and yields numerous teeth and bone fragments from a 0.7-m-thick localized intrabasinal ferruginous conglomerate of limestone, tooth, bone, bivalve shell and chert pebbles in a section of fine-grained sandstone near the top of the Atarque Sandstone. Virtually all of the teeth and bones from this bed were broken prior to fossilization, so based on the lithjology of the bonebed and the preservation of the fossils, we interpret this fossil site as an allochthonous assemblage in a storm deposit.

The following selachian taxa were previously known to be present in this assemblage: *Hybodus* sp., *Ptychodus whipplei*, *P.* cf. *P. mammillaris*, *Chiloscyllium greeni*, *Scapanorhynchus raphiodon*, *Cretodus semiplicatus*, cf. *Paranomodon* sp., *Squalicorax falcatus*, *Rhinobatos* sp., *Pseudohypolophus mcnultyi*, *Ischyrhiza schneideri* and *Ptychotrygon triangularis*. Our collection duplicates many of the selachian taxa previously known from this assemblage, and also includes numerous teleost, especially pycnodonts. Turtle bones and dromaeosaur teeth are also present, indicating a freshwater/terrestrial component to the assemblage. *Scapanorhynchus* dominates the assemblage, and the sedimentology, terrestrial taxa, assemblage diversity and rarity of *Ptychodus* suggest a relatively nearshore association.

GEOTHERMAL STUDIES IN THE ALBUQUERQUE BASIN AND ALONG LA RISTRA SEISMIC PROFILE, NEW MEXICO

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Heat flow data in the Albuquerque Basin and along La Ristra seismic line, which crosses New Mexico from NW to SE, show high values associated with the Rio Grande rift and the Jemez lineament. The data profile is interpreted to indicate a thermal source under the rift axis having a mid-step depth of ~ 65 km, coincident with the mid-depth of the lowest seismic velocity anomaly along La Ristra. The heat flow anomaly and recent volcanism show the low seismic velocity region at depth under the Rio Grande rift is caused both by increased temperature as well as partial melting.

A second thermal source is suggested at ~ 33 km depth, near the Moho. Along La Ristra profile a wedge of the Colorado Plateau lies between the Rio Grande rift and the Jemez Lineament, as indicated by lower heat flow values. Heat flow returns to intermediate values near the eastern boundary of the Rio Grande rift, suggesting a thermal regime somewhat similar to the Colorado Plateau. Seismic studies indicate slow seismic velocities extend across the southeastern flank of the rift (e.g. the northern Tularosa Basin). Perhaps ray paths, which traverse the southward broadening Rio Grande rift, influence the seismic analysis, or perhaps the deep seismic anomalies are too young to be recognized in near surface geothermal gradients. More recent heat flow data in the Albuquerque Basin indicates an axial thermal anomaly that significantly narrows north of ~ 35 ^{o}N. These data suggest mid and upper crustal heat sources associated with deeply penetrating faults and/or crustal intrusions.

LATERAL LINE GROOVE DEVELOPMENT AS A MEASURE OF TERRESTRIALITY IN LATE TRIASSIC METOPOSAURID AMPHIBIANS

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Several workers have proposed that Late Triassic metoposaurid amphibians became increasingly aquatic during their ontogenetic development. Our data document moderately strong negative allometry (allometric constant = 0.76) in the femur diameter of *Buettneria perfecta* from the Lamy (NM) Amphibian Quarry. Femur diameter is a measure of limb bone strength and must increase in positive allometry (allometric constant ~ 1.5) to maintain constant stress on the bones throughout growth. We conclude that large, adult *Buettneria* were water-bound, whereas the juveniles were probably much more terrestrial. This provided ecological separation of adults and juveniles, and explains the absence of small juveniles in all major water-deposited metoposaur death assemblages.

Lateral line systems are arrays of water motion sensing organs present in fishes and aquatic amphibians. Where lateral line organs are present over dermal bone, they are housed in well-defined grooves in the bone. Adult *Buettneria* from Lamy have deep, wide, lateral line grooves in their skulls in an established pattern. In contrast, a small juvenile *Buettneria* skull from St. Johns, AZ, shows extremely poorly developed lateral line grooves. We propose that because lateral line organs are useless except in water, the undeveloped nature of the grooves represents additional evidence of terrestriality in this juvenile metoposaur and that the grooves would become fully developed as the animal became fully aquatic.

We also note poorly developed lateral line grooves on a partial *Apachesaurus* skull from Apache Canyon, NM. The grooves here are reduced to a barely-discernable string of slightly larger pits in the already pitted skull texture. *Apachesaurus* has been considered to be a somewhat terrestrial metoposaur because of its more elongate vertebrae that show robust rib facets. The poorly developed lateral line grooves in *Apachesaurus* seem to substantiate the more terrestrial habitat of this metoposaur. Thus, the extent of lateral line groove development is an additional measure of the terrestriality of these animals. Reduced lateral line groove development strengthens the idea of a terrestrial juvenile and an aquatic adult *Buettneria*, and of terrestriality in *Apachesaurus*.

^{40}AR/^{39}AR GEOCHRONOLOGY OF JAROSITE: THE EFFECTIVENESS OF HF IN REMOVING SILICATE CONTAMINANTS

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Two experiments were conducted to test the effectiveness of hydrofluoric acid (HF) in removing K-bearing silicates from jarosite [$KFe_3(SO_4)_2(OH)_6$] prior to dating by the $^{40}Ar/^{39}Ar$ method. In the first experiment, four aliquots of pure Peña Blanca jarosite (PB; 9.50 ± 0.06 Ma) and four aliquots of 85% PB mixed with 15% Fish Canyon sanidine (FC-

2; 28.02 Ma) were crushed and treated with 40 mL of 25% HF for 0, 30, 240, and 480 minutes. Secondary electron images show that jarosite begins to dissolve during HF treatment with jarosite grains becoming pitted and rounded with time in acid. However, K_2O concentration of PB jarosite treated for 480 minutes overlap with K_2O concentrations of untreated PB jarosite. Additionally, $^{40}Ar/^{39}Ar$ ages of both untreated and treated PB overlap with each other and with previously-dated aliquots of PB jarosite at the 95% confidence level, suggesting that HF treatment has no impact on the plateau age. FC-2 was absent from all treated samples, suggesting that 30 minutes in HF is sufficient to remove silicate contaminants.

The second experiment tested the effectiveness of HF in removing silicates from supergene jarosite. Four samples from the Red River Valley, NM (RRV) that yielded age spectra with clear evidence of contamination with older phases when dated in 2006 were treated with HF for 30 minutes and re-dated. K_2O concentrations of HF-treated RRV jarosite overlapped with K_2O concentrations of untreated RRV jarosite. Back-scattered electron images show that silicates, including sanidine and illite (ca. 25 Ma), continue to contaminate HF-treated aliquots of RRV samples. However, the integrated ages of these samples is consistently less than 1 Ma, suggesting that young jarosite, rather than Miocene silicates, controls the apparent age of these samples. Large errors in apparent age may be attributed to low radiogenic yield.

Supergene jarosite yields geologically-reasonable ages when silicate contamination is minimized with HF. However, further work with in-situ dating techniques may improve both precision and accuracy when dating jarosite and other supergene phases.

A GIANT SEA TURTLE (CHELONIA: PROTOSTEGIDAE?) FROM THE LATE CRETACEOUS (LATE CAMPANIAN) PIERRE SHALE, RATON BASIN, NORTHEASTERN NEW MEXICO

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Sea turtles, specifically members of the family Protostegidae, reached gigantic size (up to 4 m long) during the Late Cretaceous and have been documented extensively from the deposits of the Western Interior Seaway in the mid-continent of North America. Here, we describe the first record of a giant sea turtle from New Mexico. NMMNH (New Mexico Museum of Natural History and Science) P-16079 and P-16104 consist of three carapace fragments of a large sea turtle that were recovered from the Pierre Shale of the Raton basin, Turkey Creek Canyon area, Colfax County, New Mexico. The fragments are all very thick, with a maximum thickness of 4.2 cm, and possess dermal patterning that consists of a series of thin, radial grooves. Portions of this material have previously been identified as mosasaur cranial elements, but the thickness and dermal patterning of the specimens are not consistent with a mosasaur.

The New Mexico carapace fragments compare well with material of *Archelon ischyros*, a giant protostegid sea turtle recovered from the Pierre Shale of Kansas and South Dakota. However, the lack of more extensive material precludes a genus- or species-level identification. The index ammonoids *Didymoceras* and *Baculites* collected from nearby localities indicate a late Campanian age, either the *Didymoceras cheyennense* or *Baculites compressus* zones, for the turtle fossils. This first recognition of a giant sea turtle from New Mexico adds to our knowledge of the marine fauna along the western margin of the Late Cretaceous Western Interior Seaway.

LITHOSTRATIGRAPHY AND VERTEBRATE BIOSTRATIGRAPHY OF THE TRIASSIC SECTION AROUND CARTHAGE, SOCORRO COUNTY, NEW MEXICO

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The Triassic outcrops of south-central New Mexico have received relatively little study, compared to contemporaneous strata in the north-central and east-central parts of the state. Triassic sections to the north of Carthage, Socorro County (T05S, R02E), encompass the Middle Triassic Moenkopi Formation and Upper Triassic Chinle Group (Shinarump and San Pedro Arroyo formations). The Moenkopi Formation (Anton Chico Member) overlies the siltstone-dominated Artesia Group and is mostly cross-bedded sandstones and less common beds of mudstone, silstone and intraformational conglomerate. Fragmentary capitosauroid amphibian material near the top of the unit are the only fossils collected from the Moenkopi Formation near Carthage and are consistent with assigning it a Perovkan (Anisian) age.

The Shinarump and San Pedro Arroyo formations unconformably overlie the Moenkopi Formation near Carthage; this is the Tr-3 unconformity, a hiatus of about 10 million years. The San Pedro Arroyo Formation is interbedded mudstone and sandstone except for the Ojo Huelos Member, which is a prominent limestone interval, with occasional conglomeratic lenses that are fossiliferous, and can be used regionally as a marker bed. Lithology within the Ojo Huelos ranges from clean lime mudstone to brecciated and pisolitic limestone. Fossils from the San Pedro Arroyo Formation are characteristic of Late Triassic tetrapod faunas in being metoposaur- and phytosaur-dominated. Abundant fossils of large metoposaurid amphibians have been recovered from the lower part of the San Pedro Arroyo Formation and the Ojo Huelos Member. Abundance of large metoposaurids corresponds to the previously established "metoposaurid acme zone" within the Chinle and suggests a pre-Revueltian age for the lower part of the San Pedro Arroyo Formation, including the Ojo Huelos Member.

Isolated phytosaur bones and teeth are found in the San Pedro Arroyo within and above the Ojo Huelos Member, but do not provide genus- or species-level identifications. Thus, the precise age of the upper San Pedro Arroyo Formation is uncertain due to the lack of diagnostic and biostratigraphically useful fossils. The Upper Cretaceous Dakota sandstone and/or a thin section of Upper Jurassic Morrison Formation unconformably overlies the San Pedro Arroyo Formation near Carthage.

PRELIMINARY ASSESSMENT OF WIND EROSION PATTERNS IN COPPICE DUNE MANEUVER AREAS, WHITE SANDS MISSILE RANGE, NEW MEXICO

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Past research has shown that mesquite coppice dune areas are an important location of wind erosion activity in the Chihuahuan Desert, and that land disturbance from anthropogenic activities such as military training increases vulnerability to wind erosion. With this in mind, we are investigating aeolian sediment transport and deposition in the southern maneuver area of White Sands Missile Range (WSMR), New Mexico, to identify spatial and temporal patterns of sand and dust movement and to identify areas that may be relatively more resistant to wind erosion given potential anthropogenic disturbance. Soil mass transport through wind and the particle size distribution of airborne sand and dust are being measured. Twenty-four passive dust and sand monitoring sites were set up at WSMR (ten in the non-maneuvering area and fourteen in the maneuvering area), and samples have been collected on a seasonal basis for approximately one year.

More material was moved in late spring than any other period, and the least amount of material was moved during the summer, consistent with the expected seasonality of wind erosion in the Chihuahuan Desert. Particle size distributions are consistent with a saltation-sandblasting-dust production mechanism. Concentrations of deposited PM10 (airborne particles smaller than 10 microns) were highest in collectors 1.7m off the ground. Preliminary results show that amounts of transported and deposited sediments were independent of site location (maneuvering area or non-maneuvering area).

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AQUEOUS GEOCHEMISTRY OF THE SPRINGS AND WELLS OF THE SEVILLETA NATIONAL WILDLIFE REFUGE: UTILIZING NATURAL TRACERS TO IDENTIFY HYDROCHEMICAL FLOWPATHS

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The Rio Grande is well studied as a regionally important surface-water source, but the small, poorly characterized springs that surface within the Rio Grande rift are also a vital water source. Several of these springs have water chemistries that suggest a mixing of larger volume meteoric recharge with small volume, deeply sourced fluids. It has been hypothesized that deep-seated faults within the rift provide conduits for the ascent of deeply derived fluids, while others have proposed that upwelling sedimentary basin brines represent a significant salinity input to the modern river. This study has developed the first hydrochemical data on a comprehensive suite of springs and wells in the

Sevilleta National Wildlife Refuge (NWR), and we continue to test and refine existing models for water quality in the rift using hydrochemistry (major and trace elements, Cl/Br, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$, ^{3}H, $\delta^{234}U$, and $^{87}Sr/^{86}Sr$), microbial characterization and geochemical modeling along a series of transects within the rift.

This suite of geochemical tracers is being used to analyze the geochemistry of 26 surface samples and 13 wells in and near the Sevilleta NWR. Our goal is to apply hydrochemical and microbiological analyses of these springs and groundwaters to a rift-wide model for subsurface flow paths. Results from major ions, trace elements, stable isotopes of H and O, and $^{87}Sr/^{86}Sr$ indicate the interaction of five distinct hydrochemical facies, several of which suggest that deeply derived fluids are mixing in this system. Continued analyses of major ions for temporal variation, and the addition of $\delta^{234}U$, $\delta^{13}C$, $\delta^{18}O$ and δD analyses, will allow for a high-resolution hydrochemical image of the sources of these waters and their impact on the water quality of the Rio Grande.

A NEW GIGANTIC PYCNODONT FISH FROM THE UPPER CRETACEOUS JUANA LOPEZ MEMBER, MANCOS SHALE OF NEW MEXICO

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Pycnodonts are extinct neopterygian fishes that lived from the Late Triassic through the middle Eocene, spanning approximately 175 million years where they became particularly diversified during the Jurassic. Over 650 pycnodont species have been described, but 70 percent are known only by their dental remains (e.g., isolated teeth and tooth plates) that are largely characterized by heterodontous crushing teeth.

Isolated teeth from the Juana Lopez Member of the Mancos Shale at Mesa Prieta (NMMNH locality L-5999) represent a new species of a large pycnodont. Vomerine teeth of this new taxon are large, dome-shaped, and robust, generally with two parallel to subparallel apical ridges that tend to run transversely and may be connected at their middle. They resemble the teeth of "*Coelodus*" *streckeri* described from the Turonian of Kansas, which has different apical ridge morphology. Comparison with other more complete pycnodont fossils suggests that the new New Mexican species is one of the largest pycnodonts, likely exceeded 1 m total length (TL) and possibly as much as about 1.2 m TL. Based on its large size and distinctive crushing-type teeth, it is interpreted to be a durophagous fish.

The teeth were recovered from exposures of the shale interval between the upper and lower calcarenite beds of the Juana Lopez Member. These deposits also yield the ammonite *Prionocyclus macombi*, a distinctive index taxon that defines the *P. macombi* Zone. This ammonite zone is within the middle or upper Turonian. Although the Juana Lopez Member is rich in bioclastic debris and has been termed a "fish-tooth conglomerate," this is the first documentation of a pycnodont from this unit in New Mexico. The Juana Lopez Member is also rich in shelled macroinvertebrates, including the oyster *Lopha lugubris*, an unidentified inoceramid bivalve, and the ammonite *Coilopoceras colleti*. NMMNH Locality 5999 yields abundant isolated teeth of durophagous shark *Ptychodus whipplei* and occasionally teeth of piscivorous-type sharks such as *Squalicorax* cf. *S. falcatus* and *Cretodus* sp. New Mexico, like other middle to late Turonian faunas of the Western Interior Seaway, was probably dominated by durophagous fishes that presumably affected the benthic macroinvertebrate community.

A BRIEF HISTORY OF THE USE OF PALEOMAGNETISM AND MAGNETOSTRATIGRAPHY IN GEOCHRONOLOGIC APPLICATIONS IN NEW MEXICO

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The study of the magnetic properties of minerals and rocks and the geochronologic applications of these properties is a relatively new sub-discipline of geology. Whereas initial applications of paleomagnetism and magnetostratigraphy tended to focus solely on igneous rocks, especially lava flows, advances in technology now allow us to develop accurate geomagnetic polarity chronologies for a wide variety of sedimentary rock types. Examples of the application of paleomagnetic techniques for geochronologic purposes in New Mexico cover many rock types across the state. Individual lava flows in the Boot Heel and Mogollon silicic volcanic fields in southwestern New Mexico have been accurately dated using a combination of radioisotopic dating and paleomagnetic techniques.

Geomagnetic polarity chronologies have been developed for sedimentary strata ranging from the Upper Permian Quartermaster and Dewey Lake Formations near Carlsbad through Triassic strata in northern and eastern New Mexico and Upper Cretaceous-Paleocene strata in the San Juan Basin to Plio-Pleistocene Camp Rice and Palomas strata in southern New Mexico. Instrumentation is now refined enough to measure magnetic remanence in fine-grained magnetite in marine limestones, opening a whole new area of research. In addition, New Mexico is home to the locality where the Jaramillo polarity event was first documented. The Jaramillo event is a short-duration normal polarity event that occurred about 1 Ma, during the Matuyama reverse polarity chron and has proven useful for the correlation of very young strata.

EXAMINING NEW POSSIBILITIES FOR THE AGE OF UPPER TRIASSIC STRATA IN NORTHERN NEW MEXICO USING MAGNETOSTRATIGRAPHY

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The Upper Triassic Chinle Group has long been considered to be Late Triassic in age, based on palynostratigraphy and vertebrate biostratigraphy. Deposition was thought to have begun during the Carnian stage and end in late Norian to earliest Rhaetian time. In the Chama Basin of northern New Mexico, strata below the Poleo Formation have been designated Carnian in age based primarily on vertebrate biostratigraphy. Strata above and including the Poleo Formation are considered Norian in age and uppermost strata, termed Rock Point Formation, were originally assigned a Rhaetian age, then a late Norian age, based on palynostratigraphy and vertebrate biostratigraphy.

A more complete and continuous composite magnetostratigraphy for the Chinle Group in the Chama Basin, and a new detrital zircon (DZ) date from the top of the Bluewater Creek Formation, Zuni Mountains, western New Mexico, change previous age assignments for Chinle Group strata. The DZ date implies that no Carnian-age strata are preserved in New Mexico and that Chinle deposition began in early to middle Norian time. Most Chinle strata yield magnetizations with south or north-seeking declinations and shallow inclinations (e.g., Poleo Formation grand mean: D = 183.1º, I = 0.3º, α_{95} = 5.7º, k = 33.9, N/No = 20/30 sites), which are interpreted as primary, Late Triassic magnetizations. There is no evidence of remagnetization of these strata.

Magnetostratigraphic correlations corroborate the DZ date and indicate that uppermost strata in northern New Mexico are not time equivalent to true Rock Point strata in Utah and Arizona nor to the Redonda Formation in eastern New Mexico. Uppermost Chinle Group strata in the Chama Basin are Rhaetian to possibly earliest Hettangian in age. A revision of age assignments of these strata changes the biostratigraphic framework utilized for correlations. For example, the aetosaur *Aetosaurus*, used as a Norian index fossil, is found in uppermost Chinle Group strata in the Chama Basin, thus extending its age range into the late Rhaetian. The dinosaur *Coelophysis*, considered Norian in age, is late Rhaetian to earliest Hettangian in age.

A ^{40}AR/^{39}AR GEOCHRONOLOGY AND THERMOCHRONOLOGY STUDY OF CALDERA VOLCANISM AND RELATED PLUTONIC PROCESSES, QUESTA CALDERA, NORTHERN NEW MEXICO.

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A conceptual model for relating pluton assembly to caldera eruptions and associated volcanism was developed using ^{40}Ar/^{39}Ar dating of volcanic and plutonic rocks associated with the Questa Caldera, Latir volcanic field. The volcanic geochronology provides point-in-time information about magmatism whereas the thermochronology of exposed plutonic rocks establishes their emplacement and cooling histories. ^{40}Ar/^{39}Ar dating indicates that volcanism spanned 6 Ma and the plutons experienced various emplacement and thermal histories.

Precaldera volcanism began at 28.3 Ma and ended at 25.3 Ma. The combination of the published geochemistry with ages of precaldera volcanism from this study suggests that the earliest magmatism was dominated by multiple, small magma chambers, rather than a single, large magma chamber. The Questa caldera formed during the eruption of the Amalia Tuff. Sanidine from thirteen samples yielded a mean age of 25.23 ±0.05 Ma for the Amalia Tuff.

Four resurgent plutons were emplaced, crystallized, and rapidly cooled to 150ºC within 500 ka of caldera collapse. A biotite from the previously undated Canada Pinabete pluton yielded an age 25.28 ±0.08 Ma. Because the Canada Pinabete pluton and Amalia Tuff are geochemically similar and the ages are analytically indistinguishable, the Canada Pinabete pluton is interpreted as non-erupted Amalia Tuff. This supports the idea that not all ignimbrite magma chambers completely empty during eruption and some plutons can be directly correlated to large-scale ignimbrite sheets. Three post-caldera rhyolites yielded sanidine ages between 24.9 and 25.0 Ma indicating volcanism was coeval with emplacement of the resurgent plutons.

Following resurgent plutonism, plutons were emplaced along the southern caldera margin and south of caldera margin. In contrast to resurgence, these plutons exhibit protracted and complex cooling histories. U-Pb zircon and $^{40}Ar/^{39}Ar$ biotite ages combined with K-feldspar multiple diffusion domain thermal modeling indicate the various thermal histories of the postcaldera plutons is attributed to incremental emplacement and subsequent reheating events. An age of 22.5 Ma from a postcaldera andesite suggests that volcanism was coeval with the youngest pluton emplacement.

AGE OF PLUTONS IN SOUTHWESTERN NEW MEXICO AND THEIR RELATIONSHIP TO CALDERA FORMATION AND MINERALIZATION

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Recent $^{40}Ar/^{39}Ar$ dating provides a start to advancing our understanding of how plutons in southwestern New Mexico relate to caldera volcanism and mineralization. Unlike the well-established geochronology of southwest NM caldera volcanism, only a sparse dataset exists for the regional plutons. Eleven $^{40}Ar/^{39}Ar$ dates from the plutons indicate a variety of relationships to the regional caldera volcanism and mineralization. Some caldera-related plutons were emplaced either syn-caldera collapse or as late as ~3 m.y. after caldera formation. Caldera-independent plutons are less understood, largely because they lack detailed geochronology and thermochronology.

Some plutons are exposed within or adjacent to calderas. Three plutons in southwestern New Mexico are spatially associated with calderas. One caldera-pluton pair, the Juniper caldera and Animas quartz monzonite stock, have indistinguishable ages of 33.6 Ma, which suggests that the pluton is associated with the magmatic system that caused caldera collapse. The temporal relationships of the other caldera-plutons pairs, Organ caldera (36.2 Ma) /Organ batholith (33.3 Ma) and Steins Caldera (34.4 Ma)/Granite Gap stock (33.1 Ma), indicate that plutons are as much as 3 m.y. younger than caldera formation. Mapping suggests the Organ pluton is made up of multiple intrusions; the granite of Granite Peak (youngest), Sugarloaf Peak quartz monzonite and Organ Needle quartz syenite (oldest). This might represent slow cooling of syn-caldera emplaced plutons or prolonged growth of a subcaldera batholith. A study of caldera-related plutons in the Latir volcanic field, northern NM, suggests that plutons record the timing of peak and waning stage of caldera magmatism.

Some of the regional plutons are located as much as 80 km away from known calderas. Ages of eight plutons range from 32.6 to 39.1 Ma, but in general are older than the caldera-related plutons and several are related to tungsten, molybdenum, and beryllium mineralization. The origin of the intrusions is not well understood, but some may represent unerupted magma chambers or roots of calderas, which were eroded or buried beneath rift sediments. Additional geochronology is necessary to understand the relationships of caldera-related plutonism, caldera-independent plutonism, mineralization, and volcanism.