Abstracts

New Mexico Geological Society

The New Mexico Geological Society annual spring meeting was held at New Mexico Institute of Mining and Technology (Socorro) on April 8, 1994. Following are abstracts from sessions given at that meeting. Abstracts from the other sessions will appear in future issues of *New Mexico Geology.*

Economic geology and volcanology session
(continued from May issue)

ERUPTIVE HISTORY OF THE 3.9 MA HIGH-SILICA RHYOLITE VOLCANO AT NO AGUA PEAKS, TAOS COUNTY, NEW MEXICO, by *J. M. Barker* and *R. M. Chamberlin*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

Compositionally zoned high-silica rhyolite ash-flow tuffs are commonly interpreted as the inverted equivalents of large, vertically zoned magma chambers in which silica, volatiles, and large or highly charged cations are strongly enriched at the top. In the uppermost high-silica magma zone (77.5 to 75 wt.% SiO_2, volatile free), concentrations of Rb, Nb, Ta, and U progressively decrease downward, whereas Ba and Sr antipathetically increase downward. As a working hypothesis, we suggest that the small volume (0.82 km^3), high-silica rhyolite lavas (~76% SiO_2) that form the No Agua Peaks, in north-central New Mexico, represent the discharge from a small (narrow) compositionally zoned magma chamber approximately 3.9 million years ago (published K–Ar age: 3.91 ± 0.2 Ma). Published geologic maps, Rb, Sr, and Ba concentration data from obsidian, and topographic data suggest the following eruptive history. (1) A Rb-rich, high-silica composite lava dome (interleaved pile of stubby flows) as much as 270 m high was slowly extruded over the primary conduit at "West Peak"; presumably this steep-sided dome was surrounded by a cogenetic ring or mounds of tuff breccia. (2) The composite dome then acted as a stopper and allowed vapor pressure to build in the magma column to a level approximately equivalent to 0.7% water at a nominal magma temperature of 800°C. (3) As vapor pressure exceeded lithostatic load, a slightly(?) less Rb-rich high-silica squeezed out from under the west flank of the dome to form a relatively thin (75 m), highly vesicular, flat-topped glassy flow that spread in a semicircular geometry as much as 1.2 km from the lateral vent. (4) Following another period of quiescence and vapor pressure increase, subterranean swelling induced a radial fracture on the northeast flank of the composite dome; this relatively unconstrained radial vent allowed rapid degassing of the high-silica magma, possibly by small ash-flow events. (5) Finally, late-phase low-Rb high-silica magma was then slowly extruded from the radial dike to produce three thick (120–150 m) lobate flows that pushed eastward through and around a mound of early tuff breccia, thereby forming a kipuka (opening). Preferential erosion of the soft tuff breccias from the kipuka has since formed a large depression within the thick low-Rb flows. This topographic inversion has caused earlier workers to regard the more irregularly shaped low-Rb flows as steep-sided domes above another conduit or conduits (two to four vents). Rapid chilling of the tops and steep toes of the viscous No Agua flows produced obsidian zones as much as 45 m thick. Chemical weathering (hydration) of highly fractured and vesicular obsidian zones by meteoric waters has since formed the world's largest perlite deposit at No Agua. Ore distribution was largely predetermined by the eruptive history of the No Agua volcano. Thick flows cool more slowly than thin flows so they have thicker crystalline cores and relatively less obsidian. Thin flows have thin cores and relatively more obsidian (and potential perlite) content than thick flows.

WHAT IS THE COCHITI FORMATION?, by *G. A. Smith* and *A. Lavine*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

The definition, extent, and significance of the Neogene Cochiti Formation (CF) has been a source of frustration for anyone interested in the stratigraphy of the northern Albuquerque Basin, Santo Domingo Basin, and southern Jemez Mountains. The problems leading to these ambiguities include: (1) in defining the CF, Bailey et al. (1968, USGS Bull. 1274–P) did not designate a type section and referred to a type area where strata are poorly exposed and have only limited accessibility on Indian reservations. (2) Although Bailey et al. (1968) defined the CF as sediment derived from penecontemporaneous erosion of Keres Group (KG) volcanics in the Jemez Mountains, most of the strata in the type area post-date KG volcanics. (3) The classic map of Smith et al. (1970, USGS I–571) does not represent the CF as it was defined by Bailey et al. (1968). (4) The CF was not included in the KG by Bailey et al. (1969) but was by Gardner et al. (1986, J. Geophys. Res., 91: 1763). (5) Although the CF is correlative to the Ceja Mbr of the Santa Fe Fm (Manley, 1978, USGS GQ–1446), no one has defined criteria for assignment of strata to the CF or Santa Fe Fm (or Group) where the units are interstratified. Tedford (1982, NMGS Guidebook 33:273) assigned the Ceja Mbr to the CF. (6) Gardner et al. (1986) and Goff et al. (1990, NMBMMR Geol. Map 69) extended the CF into the Jemez Mountains to include coarse sedimentary strata interbedded with KG volcanic rocks; this assignment was not made in the definition of the CF by Bailey et al. (1968). (7) Gardner et al. (1986) and Goff et al. (1990) included within the CF, vent breccias and flow breccias that Bailey et al. (1968) explicitly included within the Paliza Canyon Fm (PCF) of the KG. Bailey et al. (1968) also imply that coarse sedimentary breccias, assigned to the CF by these later workers, were intended to be included in the PCF. (8) Outcrops of interbedded lava flows and volcaniclastic breccias mapped as PCF by Smith et al. (1970) were mapped as CF by Goff et al. (1990) highlighting the problem of separately representing, even at 1:24,000 scale, interbedded volcanic and sedimentary units assigned to different formations. We are currently working on volcaniclastic facies of the KG and hope to formally resolve these problems at a later date. Our preliminary proposal is as follows: (1) CF be defined as the volcanic sands and gravels that overlie KG volcanic rocks and extend southward from the Jemez Mountains (thus preserving most of what Smith et al. [1970] mapped as CF). This removes the penecontemporaneity of CF sedimentation and KG volcanism in the Bailey et al. (1968) definition, but age cannot be part of lithostratigraphic definition. The proposed redefinition would leave the CF out of the KG but correlative to the Santa Fe Fm (or Group) and to the Puye Fm. (2) Volcaniclastic sediments interbedded with KG volcanic rocks are assigned to the appropriate KG formation (i.e. Paliza Canyon Fm; Canovas Canyon Rhyolite; Peralta Tuff Member of the Bearhead Rhyolite) based on dominant interbedded volcanic rock type. This definition preserves most of the map representation of Smith et al. (1970) and is consistent with the terminology of Bailey et al. (1968). It is also consistent with the typical assignment of interbedded volcanic and volcaniclastic-sedimentary strata to the same, rather than different, lithostratigraphic units (e.g., Rubio Peak Fm and Datil Group of NM; Conejos and San Juan Fms of CO). At a future time it may be appropriate to assign member status to volcanic and sedimentary units within the PCF. (3) The Peralta Tuff Member of the Bearhead Rhyolite grades upward into the CF in lower Peralta Canyon; we propose that the contact be placed at the top of the highest tuff encountered in any section. (4) Only sediment of entirely volcanic composition should be assigned to the CF. Where volcaniclastic and nonvolcaniclastic sediment is mixed to the south and east (e.g., under Santa Ana Mesa), strata of mixed composition should be assigned to the Santa Fe Fm (or Group), including the Ceja Mbr.

SINGLE-CRYSTAL $^{40}Ar/^{39}Ar$ PROVENANCE AGES AND POLARITY STRATIGRAPHY OF RHYOLITIC TUFFACEOUS SANDSTONES OF THE THURMAN FORMATION (LATE OLIGOCENE?), RINCON HILLS AND CABALLO MOUNTAINS, NEW MEXICO, by *J. D. Boryta* and *W. C. McIntosh*, New Mexico Institute of Mining and Technology and New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

The Thurman Formation was sampled in two localities along the Rio Grande rift for paleomagnetic and single-crystal $^{40}Ar/^{39}Ar$ geochronology to determine the timing and duration of deposition and sanidine provenance of the synrift basin fill. More than 300 paleomagnetic specimens (32 sites) were drilled in 25-m intervals from two approximately 400-m-thick sections of sandstones, conglomeratic sandstones, and debris flows near Johnson Spring in the Rincon Hills and Apache Canyon in the Caballo Mountains. About 60 sanidines were analyzed by $^{40}Ar/^{39}Ar$ single-crystal laser fusion from three stratigraphic horizons at both localities to determine the age and provenance of individual grains. Provenance ages span 34.9 to 27.4 Ma but cluster at ages of 34.7, 33.3–33.5, 27.6, and 27.4 Ma. Petrographic examinations show that the tuffaceous sandstones have detrital grains of quartz, plagioclase, and sanidine and detrital volcanic rock fragments of rhyolitic tuff, pumice, and deuterically altered or oxidized andesite. Opaque minerals in the rock fragments include magnetite, titanomagnetite, pyrite, ilmenite, and hematite. Authigenic cement of clay, zeolites, and hydroxides coat rims of grains and rock fragments. Clay and zeolites delicately line relict textures of pumice and tuff fragments and partially infill dissolved plagioclase grains. Specimens collected for paleomagnetic studies were examined by reflected light microscopy and by alternating field and thermal demagnetization methods to assess the magnetic mineralogy, components of remanent magnetism, and the nature of the variations in remanence. Within the Apache Canyon section of the Thurman Formation, two magnetic polarity zones are identified and, based on the position of sanidine provenance ages within pumice and matrix of debris flows, the zones may span the time near the reversal at 27.4 Ma. Sanidines from the Box Canyon Tuff, Lemitar Tuff, South Canyon Tuff, and Kneeling Nun Tuff can be distinguished at 9.5, 122, 205, and 362 m horizons based on $^{40}Ar/^{39}Ar$ dates and K/Ca. The sanidines were derived from an area more than 20 km to the west and north, where the caldera explosions of the Mogollon–Datil volcanic field and areal extent of the ash-flow tuffs are located. Sanidines dated at 27.4 ± 0.21 Ma from 1.5 cm pumice in a debris flow at 98 m represent fall material from South Canyon Tuff. Sanidines dated at ~27.6 Ma from 205, 310, and 362 m horizons have a higher K/Ca than South Canyon Tuff (27.4 ± 0.07 Ma) or the Weatherby tuff (27.6 ± 0.04 Ma) of the Boot Heel volcanic field. Correlation of the sanidine dates with the regional extent of dated tuffs, independently established paleocurrent directions, and the magnetic polarity stratigraphy show that the rhyolitic tuffaceous sands of the Thurman Formation were derived by the erosion of Box Canyon Tuff (33.5 Ma) and then Kneeling Nun Tuff (34.9 Ma) during or soon after the catastrophic eruption of South Canyon Tuff (27.4 Ma) from the Mount Withington caldera. The Thurman Formation is a syn- to posteruptive alluvial-fan sequence of stacked debris flows and conglomeratic sandstones that rapidly accumulated in an early rift basin of the Rio Grande rift. The Thurman Formation records the erosion and unroofing of Oligocene andesitic and rhyolitic volcanic rocks that may have been disrupted during the explosion of Mount Withington caldera at 27.4 Ma. Throughgoing Late Oligocene paleodrainage in central New Mexico was southward.

SEDIMENTATION, DEFORMATION, AND EROSION RELATED TO LOS LUNAS VOLCANOES, CENTRAL NEW MEXICO, by *D. W. Love*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801; *C. B. Reynolds*, 4409 San Andres Ave. SE, Albuquerque, NM 87110; *B. Hallett*, 6116 Calle Nueve NW, Albuquerque, NM 87107; *R. P. Lozinsky*, Div. Natural Sciences, Fullerton College, 321 East Chapman Avenue, Fullerton, CA 92632–2095; and *T. Niemyjski*, New Mexico Institute of Mining and Technology, Socorro, 87801

Exposed sections in erosional scarps northwest and southwest of Los Lunas volcano and a reflection seismic profile reveal a complex history of sedimentation, deformation, and erosion related to aggradation of the Albuquerque Basin and local tectonics adjacent to the emplacement of two volcanoes within the central basin. Low within the exposed southwest section are andesitic flows with an age of 3.88 ± 0.04 Ma. Northwest exposures reveal an angular unconformity within the basin fill with lowest fluvial beds dipping steeply or vertical. This deformation appears to correlate with emplacement of the volcano to the south. The andesitic flows and beveled, dipping beds are overlain by a thick (20 to 40 m) eolian interval, followed by 150 m of fluvial and eolian deposits and pedogenic intervals typical of upper basin fill. Within the fluvial units are glassy obsidian pebbles and pumice debris interpreted to be from the Jemez Mountains. These units are overlain by tephra and basaltic-andesite flows of the 1.219 ± 0.01 Ma Los Lunas volcano. The basin-fill units and tephra are domed around the volcano over several square kilometers; uplift of the basin fill directly beneath the trachytic dome and flows at the top of the edifice is about 166 m. Dips of the upper deformed basin fill on the flanks of the structural dome range from 5 to 20°. Several faults cut the basin fill and older volcanic units. Other faults cut the younger volcano as well. The tephra and underlying units are deformed into sharp synclines and anticlines and cut by reverse faults in northwestern exposures. Deformation took place after initial tephra deposition, but before tephra was reworked to fill the synclines. More than one tephra layer has draped over eolian dunes farther northwest, indicating intervals of time between tephra falls. After the eruptions, the domed basin fill was eroded near the volcano and redeposited in a prograding alluvial apron around the flanks of the volcano. The volcano/uplift-derived alluvium is as much as 48 m thick and consists of reworked tephra, blocks of basaltic andesite, alluvial sands and silts, eolian sands, and pedogenic horizons. A buried paleovalley cut in the domed basin fill contains as much as 0.6 m of ash from the 1.1 Ma Bandelier eruption from the Jemez caldera. A shallow seismic reflection line running northwestward from near the volcano seems to show the same structural features as those observed at the surface and appears to show the two unconformities and lower steep dip away from the volcano to a depth of about 1,000 m. Two crude rates of sedimentation may be inferred from the dates. Between 4.88 and 1.22 Ma, 148 m of sediment accumulated, suggesting a rate of 55 m/Ma. Between 1.22 Ma and present, the alluvial apron aggraded as much as 48 m, yielding a rate of 39 m/Ma. Undoubtedly, the eolian sediment took longer to accumulate than the fluvial sands and clays, and the pedogenic intervals indicate episodes of stability in the range of thousands to tens of thousands of years.

Sedimentology, geomorphology, and environmental geology session

EVIDENCE FOR THE EVOLUTION OF A LATE MISSISSIPPIAN EOLIAN ENVIRONMENT IN SOUTHWESTERN NEW MEXICO AND SOUTHEASTERN ARIZONA, by *D. J. Sivils* and *D. B. Johnson*, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801

The limited distribution of outcrops and paucity of petrographic analyses of Upper Mississippian rocks in the southwest has made detailed paleogeographic reconstructions of the Late Mississippian tenuous at best. New data from the Paradise Formation provides information about the paleogeography and paleoclimates of the region. Detailed petrographic analysis of the Paradise Formation revealed a surprising volume of detrital quartz. The quartz is found both as individual sandstone beds and as disseminated grains throughout the carbonate portion of the section. The average grain-size of the quartz is in the very fine sand to coarse silt (0.06 mm) range. The quartz is monocrystalline and angular to subrounded in shape, some grains are tabular. Sandstones and siltstones are compositionally and texturally mature. A lack of both a clay and finer silt fraction in conjunction with the degree of sorting and rounding of the very fine grained to silt-size quartz suggests an eolian origin for the clastics. The association with marine carbonates and the presence of marine fossils within the sandstones reflects the reworking of sands in a shallow-marine setting. Delivery of these clastics to the marine environment is possible by either direct or indirect means. Finer-grained sand and silt was delivered directly to the Paradise sea by eolian activity, where the material was incorporated into the carbonate sediments. Indirectly, fine sand and silt was delivered to the marine environment along the strandline by marine marginal dunes and fluvial systems meandering through the dunes. Sands and silts delivered to the sea by coastal dunes and fluvial systems were reworked by storms and marine currents and distributed as thin sand and silt bodies along the shelf. The distribution of sand and silt along the shelf was further governed by variations in relative sea level. During times of relative sea-level rise (highstands) the clastics were trapped closer to shore on the shelf and during times of relative sea-level fall (lowstands) the clastics would by-pass the inner shelf and be deposited in a more basinward position. Paleogeographic reconstructions of the Late Mississippian indicate that the Pedregosa Basin would have been in a geographic position consistent with global wind patterns and weather conditions conducive to the evolution of arid to semiarid lands. This would create a landscape not unlike the modern North African and the Persian Gulf region where fine clastics are delivered to offshore settings by eolian activity. We favor this to be a reasonable modern analog to the Late Mississippian landscape in southwestern New Mexico and southeastern Arizona.

CHARACTERISTICS OF AN EARLY PENNSYLVANIAN CYCLE IN THE BIG HATCHET MOUNTAINS OF NEW MEXICO, by *E. W. Fry* and *D. B. Johnson*, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, NM 87801

As part of a larger study of cyclic sedimentation, a locally restricted karst surface was identified in the lower (Morrowan) portion of the Horquilla Formation (Pennsylvanian–Permian) in the New Well Canyon of the Big Hatchet Mountains, southwestern New Mexico. The surface is about 40 ft above the top of the Paradise Formation (Mississippian). Although other examples of subaerial exposure are known from the upper Pennsylvanian and Permian portions of the Horquilla, this is the lowest known example. Over a distance of 2,000 ft, karst features range from nonexistent to accentuation of joints to a depth of 2 ft suggesting a surface of low relief. The surface is developed on crinoidal mudstone, with underlying rocks containing abundant micrite and a mixed restricted and normal marine biota suggesting a shallow- ☞

marine setting. A 2–5-ft-thick bioclast, intraclast packstone with small-scale crossbedding is deposited above the surface. At the base of this is a lag, containing numerous mudstone clasts and an unusual abundance of phosphatic clasts (bone?) and fish teeth. The lag infills the joints developed at and below the karst surface. Above the packstone is a 3–6-ft intraclast, ooid packstone containing large-scale trough cross-stratification up to 2 ft thick. Ooids within individual beds show considerable variation in size, and some sheltered pores show evidence of early marine cements. This sequence culminates with a crinoid-bearing wackestone/mudstone interval that contains a biota (ostracods and molluscs) suggesting eurytopic conditions. We conclude that inundation by normal-marine waters ended a brief interval of subaerial exposure. The initial phase of marine conditions was occasioned by low rates of sedimentation during which there was a thin accumulation of skeletal fish debris at the karst surface and in the eroded joints. As carbonate production commenced in occasionally agitated waters, bioclast, intraclast, and ooid production contributed to the buildup of a mud-rich shoal. With decreasing depth, the effect of agitation and circulation was decreased, and conditions returned to a restricted, mud-dominated style of upward-shoaling sedimentation completing the cycle.

SOILS AND GEOMORPHOLOGY AS A KEY TO CARBON CYCLING TIMES IN PALO DURO CANYON, CENTRAL RIO GRANDE RIFT, NEW MEXICO, by *C. J. Treadwell*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

Landscape evolution in Palo Duro Canyon, a Rio Grande tributary, has implications for carbon storage and cycling times in semiarid drainage basins. The drainage basin of Palo Duro is large enough to collect the discharge needed to downcut through the Llano de Manzano pediment/piedmont surface that bounds the southeastern side of the Albuquerque–Belen Basin. As a result of this process, the lower valley of Palo Duro contains a nested suite of terraces estimated to range from late Pleistocene to latest Holocene in age. Following terrace formation, the first stage of landscape development is manifested by truncation of soils at the front of the terrace, while soils at the back and middle are buried by colluvium. Erosion of previously formed terraces contributes colluvial material to the younger terrace surface. The colluvial clasts have rinds of pedogenic carbonate that enhance carbonate accumulation in the younger terrace soils. This represents carbon "recycling" within the terrestrial reservoir. As base level drops, gullies incise the terrace. The gullies establish a dendritic drainage pattern that exploits the junction between the terrace and the adjoining scarp. At this second stage, the terrace is isolated from the scarp and no longer receives colluvium. The gullies intercept colluvium and divert it from the terrace surface into the main channel. This event is significant because accumulation of pedogenic carbonate in terrace soils is no longer augmented by colluvial contributions. In a third stage of landscape development, colluvium is stripped from the back of the terrace by the intercepting gully. Early Holocene terrace treads are spatially isolated, but the latest Holocene terrace is not; this indicates that 10^4 years are required for stage two to be completed. Late Pleistocene terrace treads are isolated and colluvium has been stripped from the terrace back, so the third stage of development takes approximately 10^5 years to attain. These time scales of landscape development are critical because in stage one there is an overall carbon gain and carbon as pedogenic carbonate on colluvial pebbles is recycled back into the soils. At stage two, however, these clasts are diverted from the surface by the intercepting gullies. This process contributes to carbon loss from the landscape. In stage three of landscape development, the rate of carbon loss increases because colluvium containing carbonate is lost from the landscape. These stages of landscape evolution indicate initial gains of carbon followed by gradually accelerating losses of carbon from the drainage basin for late Pleistocene to present.

Upcoming geologic meetings

Conference title	Dates	Location	Contact for more information
Clovis Gem & Mineral Show	Aug 6–7	Roy Walker Community Center Clovis, NM	Clovis Gem & Mineral Society, Inc. P.O. Box 1815 Clovis, NM 88102-1815
Denver Gem & Mineral Show	Sept. 16–18	Denver, CO	Denver Council Box 621444 Littleton, CO 80162 (303) 233-2516
New Mexico Geological Society Fall Field Conference	Sept. 28–Oct. 1	Mogollon Slope NM & AZ	Orin Anderson NMBMMR Socorro, NM 87801 (505) 835-5122
Porphyry Copper Deposits from Alaska to Chile Symposium	Oct. 5–7	Tucson, AZ	Jim Laukes U of A Extended Univ. 1955 E. 6th St. Tucson, AZ 85719-5224 1-800-955-8632
New Mexico Mining Association meeting	Oct. 9–10	Holiday Inn Pyramid Albuquerque, NM	NMMA P.O. Box 8369 Santa Fe, NM 87504 (505) 820-6662
39th New Mexico Water Conference—Albuquerque's Water Future	Nov. 3–4	Convention Center Albuquerque, NM	WRRI Cathy Ortega Klett Box 30001 Dept. 3167 NMSU Las Cruces, NM 88003 (505) 646-4337
West Texas Geological Society Fall Field Conference	Nov. 10–13	Big Bend region	WTGS P.O. Box 1595 Midland, TX 79702 (915) 683-1573
15th New Mexico Mineral Symposium	Nov. 12–13	Macey Center Socorro, NM	Judy Vaiza NMBMMR Socorro, NM 87801 (505) 835-5232

JEMEZ RIVER TERRACES: PRELIMINARY CONSTRAINTS ON QUATERNARY INCISION, TERRACE AGES, AND BREACHING OF THE VALLES CALDERA, JEMEZ MOUNTAINS, NEW MEXICO, by *J. B. Rogers*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

The Jemez Mountains volcanic field in northern New Mexico erupted catastrophically at 1.12 Ma, depositing the upper Bandelier Tuff (UBT) and forming the 20-km-wide Valles caldera (VC). San Diego Canyon (SDC), containing the Jemez River (JR), provides the only outlet from the VD through a breach in the southwestern caldera rim. Twenty-four kilometers downstream from the breach, I have mapped and surveyed terrace deposits and buried axial gravels. Terrace treads, terrace remnants, and buried gravels are at elevations of roughly 194, 187, 176, 120, 79, 51, 31, 20, 14, 10, 7, and 5 m above the modern JR channel. A river gravel buried beneath the UBT, 176 m above grade, provides a well-dated end-point from which to calculate incision rates as well as data on the depth of a paleo-SDC. The average incision rate over the last 1.12 Ma is at least 0.26 m/ka assuming the overlying thickness of UBT to have been 117 m (conservative). Many researchers have speculated on the timing of the first breaching of the VD with estimates ranging from roughly 1 Ma to 0.48 Ma. Thirteen post-UBT rhyolite domes, flows, and tuffs within the caldera have been dated by previous workers. Among the youngest of these is the Banco Bonito flow (BB), dated at about 130–205 ka (Self et al., 1991, J. Geo. Res., 96: 4107). The first appearance of BB clasts on the 20-m terrace provides a maximum age for it and a minimum age for the higher terraces. The highest appearance of caldera-derived volcanic clasts is within the gravels of a terrace remnant breaching of the VC. Rhyolite gravels have been found within a terrace remnant 120 m above grade, but, at present, their source is unknown. Petrographic matching of caldera-derived rhyolite clasts to dated rhyolites and amino-acid data from fossil gastropods preserved within terrace deposits are being attempted in order to better constrain the terrace ages and the timing of breaching events.

THE IMPACT OF SOIL PROPERTIES ON URANIUM MIGRATION, LOS ALAMOS NATIONAL LABORATORY, by *P. Watt*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131; *P. Longmire*, Los Alamos National Laboratory, CST-10 Group, Los Alamos, NM 87545; and *L. McFadden*, Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

A study of soil chemical and physical properties relevant to processes influencing uranium contaminant transport was conducted within Los Alamos County, New Mexico. Data from 22 soil profiles provide detailed geochemical and morphological information on each soil horizon from profiles sampled at numerous uncontaminated sites in and around Los Alamos National Laboratory (LANL). Site selection emphasized: (1) a variety of geomorphic settings and soil types representative of the region and (2) soils with similar properties to those located at past or potential waste disposal sites. This strategy enables data from such locations to provide background information for comparison with samples from contaminated sites. Data from uncontaminated areas indicate significant variability and complexity in soil properties. For example, clay content varies from <3 to >63 wt.%, pH values range from 5.15 to 8.21, and carbonate content from <0.1 to >29 wt.%. Total uranium concentrations in uncontaminated LANL soils ranged from 2.17 to 6.73 ppm (U, (IV) and U, (VI)). Positive correlations exist between some pedogenic properties and uranium concentrations. Correlations include an association between organic carbon content and uranium concentration and between carbonate content and uranium concentration. No apparent correlation exists between cation exchange capacity and uranium concentration nor between dithionite extractable iron and uranium content. It appears that clay content and presence of iron oxide or oxyhydroxide coatings on clays do not significantly impact uranium concentration in these soils, even though mixed-layer clays exist in at least some profiles. Organic-rich and/or carbonate-rich horizons are not present in many of the soil profiles sampled at Los Alamos; where they are present, they are typically relatively thin and poorly developed. Nevertheless, uranium in these soils is hypothesized to be associated with solid organic material and calcium carbonate. Sorption, complexation, and co-precipitation are probably the dominant processes controlling uranium distribution in these soils. We conclude that (1) any or all of these interactions may be pertinent to the ability of a given soil to retard or facilitate the migration of uranium through the profile and (2) most, if not virtually all of the uranium in uncontaminated soils could be derived from chemical weathering of the volcanic parent material and subsequently redistributed in the profile.

LEAD DISTRIBUTION AND AVAILABILITY IN CONTAMINATED SOILS AT THE CUBA SMELTER SITE, SOCORRO, NEW MEXICO: A MICROMORPHOLOGICAL, TEXTURAL, AND MINERALOGICAL STUDY, by *C. P. Wolf* and *P. S. Mozley*, Department of Geoscience, New Mexico Institute of Mining and Technology, Socorro, NM 87801; and *G. S. Austin*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

Traditional methods for determining health threats caused by lead (Pb) contamination do not fully characterize Pb availability. Standard U.S. Environmental Protection Agency (EPA) procedures reveal total Pb concentration in ppm using a portable x-ray fluorescence unit (XRF), but this procedure may not be truly indicative of a particular site's health hazards. The abandoned Cuba smelter site is such a site. At the Cuba smelter site, elevated Pb levels in soils range from 900 to 9600 ppm, whereas background levels are near 50 ppm. Based on the EPA's "action level" of 500–1,000 ppm Pb the site poses a possible health hazard for nearby residents. Several factors beyond metal concentration, such as mineralogy, must be considered. Sampling was conducted in January 1993. Thirty-three soil samples of the upper three inches of loose surficial material were collected for particle size, chemical, and x-ray diffraction (XRD) analyses. The soil's Pb concentration, pH, acid-neutralizing potential (ANP), and net-acid-producing potential (NAPP) were determined. Five samples were impregnated with epoxy to preserve soil textures and relationships. After impregnation the samples were cut and mounted as thin sections for petrographic and microprobe analyses. XRD has shown the dominant soil minerals are quartz, feldspar, calcite, and clay minerals. Chemical analyses including pH, ANP, and NAPP indicate an alkaline environment. Examination with the microprobe shows galena as the main Pb-bearing phase. Each galena grain examined has an aluminosilicate coating. Mineralogical and textural examination of the Pb-contaminated soils from the Cuba smelter site indicate airborne and onsite/direct contact pathways are the most significant threat. If ingested, Pb may be soluble in the digestive tract because of lack of anglesite armoring. However, an aluminosilicate coating encases the Pb grains and may act to retard dissolution in the digestive tract. Pb is immobile in the alkaline soils of the Cuba smelter site and consequently is not a threat to the local ground water.

A PRELIMINARY BIOGEOCHEMICAL SURVEY AT THE COPPER FLAT PORPHYRY DEPOSIT NEAR HILLSBORO, NEW MEXICO, by *R. J. Duncan*, New Mexico Institute of Mining and Technology, P.O. Box 3458 C/S, Socorro, NM 87801

A preliminary biogeochemical survey was conducted in areas around the Copper Flat Cu–Mo porphyry deposit. The purpose of the survey was to determine if copper and molybdenum were available for uptake by plants in the surrounding areas. Further work was done to determine the method by which uptake occurred in *Juniperous Monosperma, Quercus Emoryi,* Cactus (variation-Prickly Pear), *Prosopis Glandalusa*, and several other species. This provided a setting as to whether this type of sampling program could be used as a viable exploration tool in this area. Results indicated anomalous values of copper and trace amounts of molybdenum in the area sampled. Soil pH indicated that copper was readily available for supergene mobilization, while molybdenum was not. The molybdenum available for uptake by the plants is in the form of the molybdate ion, MoO_4^-, the highest oxidation state of molybdenum (Pendias). This presents a useful tool in laboratory analysis of molybdenum. Normal wet chemical methods for analyzing soil and rock samples for molybdenum (usually in the form of MoS_2) are complex and very time consuming because molybdenum is very insoluble in acids. The higher oxidation state of the molybdenum available to plants makes it easier to put the sample into solution for analysis.

ENVIRONMENTAL GEOCHEMISTRY OF STREAM SEDIMENTS FROM THE UPPER PECOS RIVER, NORTHERN NEW MEXICO: A PROGRESS REPORT, by *L. A. Brandvold* and *V. T. McLemore*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

Water quality of the Pecos River has regional and international concerns as the demand for water for agriculture, municipal, domestic, and recreational uses increase in eastern New Mexico, west Texas, and Mexico. An earlier study of the geochemistry of water and stream- and lake-sediment samples from along the entire Pecos River in New Mexico indicated that mercury, copper, lead, and zinc concentrations are elevated in stream-sediment samples above and immediately below the Pecos mine waste dumps, suggesting that the waste dumps may be potential sources. Outcropping zones of mineralization and outcropping rocks in the immediate area are also potential sources (McLemore et al., 1993). A more-detailed study of the upper Pecos River, from the Pecos Wilderness Area southward to Villanueva, was undertaken to examine the sources of the elevated metal values and to determine the effect on water quality. The geology of the upper Pecos drainage basin is diverse, and rocks range in age from Proterozoic through Recent. The largest mining district in the Pecos River drainage basin is the Pecos mining district (also known as Willow Creek). Total production from the Pecos mine from 1927 to 1944 amounted to over 2 million tons of ore containing 0.4% Cu, 2.9% Pb, 9.1% Zn, and some gold and silver. No mill tailings are at the mine site because the ore was transported to Alamitos Canyon for processing. Mineralization occurs in Proterozoic igneous and metamorphic rocks, which are overlain by unmineralized Paleozoic sedimentary rocks. Ore consisted of sphalerite, galena, and chalcopyrite in a gangue of quartz, chlorite, pyrite, and sericite. The stream-sediment samples from the tributaries draining into the Pecos River and from the Pecos River contain predominantly quartz, amphiboles, feldspars, and traces of zircon, rutile, magnetite, ☞

garnet, sphene, monazite, and mica. Clay minerals are rare, but total clay content, primarily as kaolinite, increases downstream. Traces of pyrite, chalcopyrite, and galena were found only in panned concentrates at the mine site along Willow Creek. Stream-sediment samples collected from the Pecos River near the mine at Willow Creek, immediately above Willow Creek, and immediately below Willow Creek are elevated in copper, lead, and zinc. The metal concentrations decrease downstream. A second area of elevated metal values was found at the confluence of Alamitos Canyon and the Pecos River (at the town of Pecos). Stream-sediment samples from Alamitos Canyon below the mill site are elevated in copper, lead, and zinc suggesting that the mill tailings may be a source for the elevated levels. Stream-sediment samples collected farther downstream from Pecos are low in copper, lead, and zinc. Preliminary studies to determine the form of the metal ions in the sediments suggest that the metals are concentrated in the crystalline or mineral phase as opposed to adsorption to metal hydroxide, organic, clay, or dissolved phases. Furthermore, the metal concentrations (copper, lead, and zinc) are higher in stream-sediment samples collected during the Fall 1992 compared to stream-sediment samples collected during the Summer 1993. This difference, in part, may be due to scouring of the river channel and dispersion of sediment during spring runoff. Surface and ground water samples from along Willow Creek and the Pecos River, both above and below the mine site, are similar in chemical composition. However, seeps from the mine waste dump are low in pH (e.g., acidic) and contain elevated levels of sulfate and metals. However, water samples of the Pecos River below the mine waste dumps contain low dissolved levels of copper, lead, and zinc.

PUMICE MINING AND ENVIRONMENTAL CONCERNS IN NEW MEXICO, by *G. S. Austin*, New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico 87801

Pumice is a volcanic rock, commonly rhyolitic, used as building material since the Roman Empire because of its light color, light weight, and cellular structure. It also has been used extensively as an abrasive. In 1993, 492,000 metric tons (mt) of pumice and pumicite (very finely divided pumice fragments) valued at $14.9 million were produced in the United States by 12 producers, three of them in New Mexico. Oregon was the largest domestic producer of pumice and pumicite, followed in descending order by New Mexico, California, Arizona, Idaho, and Kansas. New Mexico's active pumice mines are in the south and east flanks of the Jemez Mountains where the Guaje Pumice Bed of the Bandelier Tuff and El Cajete Member of the Valles Rhyolite are mined. An area of past mining for pumice is East Grants Ridge north of Grants. Other pumice sites include water-laid lump pumice and pumicite near San Antonio, New Mexico, and scattered deposits in the Mogollon–Datil volcanic field of southwest New Mexico. Much of New Mexico's active pumice mining is on federal land in the Jemez Mountains, principally land administered by the U.S. Forest Service (USFS). The USFS requires a number of steps to be taken before a permit is issued, including the submission of an operating plan. The plan outlines all activities at the proposed mine from preliminary work through actual mining to completion of reclamation. As mandated by the National Environmental Policy Act (NEPA), an environmental study must be completed to analyze the potential effects of mining on local environments. Professional surveys must be completed to determine the presence or absence of prehistoric and historic artifacts or features and endangered species of plants or animals. The information in these surveys can delay or in some cases prevent mining. More often, however, the operating plan is modified to incorporate any additional protective measures that were identified in the environmental analysis. Public involvement is sought in determining whether a plan will be approved. This is done through the USFS contacting groups or individuals who have expressed interest in the past, publishing notices, and holding public meetings. The USFS is required to monitor the mining operation once a plan is approved. A reclamation bond is collected, and the mining company is released from its obligations outlined in the operation plan only after all required reclamation has been completed. A balanced approach, in which the need for minerals is considered along with the need for proper reclamation of mining sites, is necessary to maintain a productive industry in a scenic area of New Mexico.

Basalts of New Mexico session

GEOCHRONOLOGY AND GEOCHEMISTRY OF BASALTS OF THE ZUNI–BANDERA VOLCANIC FIELD: A REVIEW AND UPDATE, by *A. W. Laughlin*, ICF Kaiser Engineers, Inc., Los Alamos, NM 87544; *F. V. Perry*, Los Alamos National Laboratory, Los Alamos, NM 87545; and *G. Woldegabriel*, Los Alamos National Laboratory, Los Alamos, NM 87545

Basaltic volcanism with the 2,500-km^2 Zuni–Bandera volcanic field has been episodic, beginning at about 700 ka with the eruption of voluminous tholeiitic lavas in the southern and western parts of the field. These lavas include the Fence Lake flow and the basalts of the North Plains. These flows were of low viscosity, and individual flows traveled up to 100 km from probable sources beneath younger cinder cones and flows of the Chain of Craters. Activity along the Chain of Craters was more complex with the eruption of both alkalic and tholeiitic lavas and an apparent younging toward the northeast along the chain. Three flows with vents near the northeast end of the chain have conventional K–Ar apparent ages of about 150 ka. Dates on three other tholeiitic vents from northeast of the Chain of Craters (El Calderon, Twin Craters, and El Tintero) range from 92 to about 70 ka. The two youngest flows within El Malpais National Monument are the alkalic Bandera flow and the tholeiitic McCartys flow, which erupted about 11 and 3 ka, respectively. Both of these very young flows are voluminous, covering large areas within the national monument. The results of about 100 chemical analyses of basalts from the Zuni–Bandera volcanic field have been compiled and statistically analyzed. In general, the tholeiitic basalts are relatively homogenous in composition despite their age differences. Silica contents range from 47.5 to 53%, MgO contents from 6.2 to 10.5%, K_2O from 0.18 to 0.96%, and Mg numbers from 58 to 63. With the exception of El Calderon, the tholeiitic vents appear to be monogenetic. Results from El Calderon will be reported by Cascadden et al. (this abstract volume). The relative homogeneity in composition for the tholeiites probably reflects the larger degrees of partial melting ($\sim$10%) required to generate these basalts. Compositional variability is much greater within the alkali basalts, and it is possible to "fingerprint" many of these flows. Within the alkali basalts, SiO_2 ranges from 44 to 54%, MgO from 5 to 11%, K_2O from 1.1 to 2.4%, and Mg numbers from 49 to 65. Again, most of the vents appear to be monogenetic. Our data suggest that only the Paxton Springs volcano was polygenetic.

TEMPORAL, SPATIAL, AND CHEMICAL PATTERN OF QUATERNARY BASALTIC VOLCANISM IN THE ZUNI–BANDERA VOLCANIC FIELD, CIBOLA COUNTY, NEW MEXICO, by *J. E. Andrew* and *A. M. Kudo*, Department of Earth and Planetary Science, University of New Mexico, Albuquerque, NM 87131

Field investigations of the Chain of Craters area of the Zuni–Bandera volcanic field suggest a strong temporal, spatial, and chemical pattern of Quaternary basaltic volcanism. At least six episodes of volcanism can be defined in this area. The first episode consists of large-volume tholeiitic flood-basalts. The second episode consists of alkali-basalts that have relatively low volumes of lava but form high cinder cones. Peridotite xenoliths are associated with these cinder cones. The third episode consists of transitional basalts, between alkalic and tholeiitic basalts. This stage is represented by strongly aligned cinder cones, which become younger and more tholeiitic to the northeast, away from the second stage cinder cones. The fourth episode consists of tholeiitic basalts, forming lava shields and a few small cinder cones. This tholeiitic volcanism continues to the northeast of the earlier transitional episode volcanism. Other tholeiite flows occur throughout the area, being extruded at or in close proximity to second- or third-episode cinder cones. The fifth stage of volcanism consists of glomerocrystic basaltic andesites. These flows occur near or actually extrude from fourth-episode vents. The glomerocrysts occur mostly as radiating euhedral plagioclase crystals, with subhedral pyroxene and olivine crystals in them, and rounded clots composed of pyroxene and olivine crystals. The sixth episode is composed of both alkalic and tholeiitic basalts, with compositions in the same ranges as those of the second and fourth episodes, respectively.

$^{40}Ar/^{39}Ar$ GEOCHRONOLOGY OF LATE MIOCENE TO PLEISTOCENE BASALTS OF THE ZUNI–BANDERA, RED HILL–QUEMADO, AND POTRILLO VOLCANIC FIELDS, NEW MEXICO, by *W. C. McIntosh*, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM 87801

New $^{40}Ar/^{39}Ar$ age determinations of basalts from the Zuni–Bandera, Red Hill–Quemado, and Potrillo volcanic fields have been obtained as part of an ongoing study exploring intercalibration of the $^{40}Ar/^{39}Ar$ dating technique with other methods (including ^{14}C, ^{3}He, and ^{36}Cl) of dating young basaltic rocks. Procedures used in this study include resistance-furnace and laser step-heating of phenocryst-free "whole-rock" matrix concentrates and separates of xenocrystic anorthoclase. Approximately two-thirds of matrix concentrate samples yield consistent plateau of isochron ages with precisions on the order of ±15 to ±100 ka (1 sigma); these data are interpreted as relatively accurate records of eruption age. The remaining one-third of matrix concentrate samples have low radiogenic yields and non-flat age spectra probably related to hydration of matrix glass and/or alteration of plagioclase. Neither isochrons nor age spectra from matrix concentrates indicate significant excess argon. Anorthoclase xenocrysts from some localities in the Potrillo volcanic field give nearly flat, high radiogenic yield, precise (±2 to ±20 ka) age spectra interpreted as records of eruption age of the enclosing basaltic host rock. Anorthoclase xenocrysts from other localities give strongly climbing age spectra potentially indicative of incomplete degassing of ^{40}Ar prior to eruption. Results from matrix concentrates of basalts of the Potrillo field range from 59 ± 10 ka for a lava in Potrillo maar to 902 ± 70 ka for a reversed-polarity lava near the western part of the volcanic field. Paired samples of anorthoclase xenocrysts and matrix concentrates from two flow in the western part of the volcanic field give nearly concordant ages, which illustrate the potential for anorthoclase xenoliths to yield precise, accurate eruption ages (flow 1: anorthoclase = 521 ± 17 ka, matrix = 475 ± 23 Ma; flow 2: anorthoclase = 847 ± 2 ka, matrix = 916 ± 67 ka). $^{40}Ar/^{39}Ar$ ages from several localities agree well with He exposure ages determined by E. Anthony, W. Williams, and J. Poths. One basalt from Malpais maar gives widely discordant $^{40}Ar/^{39}Ar$ (405 ± 20 ka) versus He exposure (54 ka) ages. If both data are correct, they may reflect an interval of post-eruption burial by surge deposits followed by erosional exhumation of the flow surface. Results from matrix concentrates of basalts from the Red Hill–Quemado volcanic field range from 0.71 ± 12 ka to 7.92 ± 0.2 Ma and indicate regular periodic basaltic volcanism in this area from 8 Ma to the present. Intervals between eruptions were generally 0.5 to 1.0 million years, except for an apparent eruptive hiatus from 2.5 to 5.2 Ma. Basalts from the Zuni–Bandera volcanic field have so far proven difficult to date by the $^{40}Ar/^{39}Ar$ method, compared with units from the Potrillo and Red Hill–Quemado fields. Many of the young (<0.5 Ma), low-potassium, tholeiitic lavas give low radiogenic yields and disturbed age spectra. A matrix concentrate from one young alkalic basalt, the Bandera flow, yields a flat spectrum with a plateau age of 41 ± 7 ka, significantly older than the 10 ka ^{14}C date obtained by W. Laughlin from charcoal beneath the cinder deposit associated with the flow. Abundant anorthoclase xenocrysts from this cinder deposit yield ages as old as 633 ± 70 ka, indicating incomplete gassing of excess or inherited ^{40}Ar present in the xenocrysts prior to eruption. It is possible that small amounts of xenocrystic contaminants are responsible for the anomalously old results from the matrix concentrate sample from the Bandera flow. Samples from the Cebollita Mesa basalts, older lavas exposed near the eastern edge of the Zuni–Bandera volcanic field, yield flat age spectra and plateau ages ranging from 3.5 to 4.1 Ma.

IN SITU-PRODUCED ^{14}C IN LATE QUATERNARY LAVA FLOWS OF THE ZUNI–BANDERA VOLCANIC FIELD, NEW MEXICO, by *W. M. Phillips, N. A. Lifton, J. Quade,* and *A. J. T. Jull,* Department of Geosciences, University of Arizona, Tucson, AZ 85721

The buildup of in situ-produced radiocarbon ($^{14}C_{is}$) is potentially useful for dating geomorphic surfaces exposed over the last 2,000 to 20,000 years. We are developing techniques for extracting $^{14}C_{is}$ from the McCartys, Bandera, and Twin Crater flows of the Zuni–Bandera volcanic field. Our samples are from pahoehoe flows with clear indication of original surfaces. Surface samples consist of the upper 2 to 4 cm of unshielded, horizontal pahoehoe slabs with less than 1-cm erosion and no evidence for shielding by soils, aeolian sediments, or nearby objects. All of the flows are dated by one or more previously published conventional radiocarbon dates. Shielded samples greater than 2 m below flow surfaces were taken from lava tubes and roadcuts. The shielded samples test our ability to remove contaminant ^{14}C and to detect subsurface ^{14}C production mechanisms. The principal challenge is removing contaminant ^{14}C from rock surfaces covered with rock varnish and lichens. Our most promising method involves adapting conventional carbon extraction techniques used for $\delta^{13}C$ measurements to sample sizes of 15 to 40 grams. Samples of this size are required in order to extract statistically significant amounts of $^{14}C_{is}$. Whole-rock samples are coarsely crushed, leached in solutions of concentrated HCl and HNO_3 to remove carbonates and rock varnish, thoroughly rinsed in distilled water, and heated at 600°C for 1 hour. The sample is then fused at 1,200°C for 2 hours on a vacuum line in a circulating atmosphere of O_2 at 50 torr. CO_2 extracted from the sample is trapped in liquid nitrogen, purified, then reduced to graphite. The activity of ^{14}C in the graphite is determined with accelerator mass spectrometry. Preliminary results indicate that shield samples contain less than 7×10^4 atoms $^{14}C\ gm^{-1}$, indicating removal of most contaminant ^{14}C. A surface sample from the McCartys flow contains 2.16×10^5 atoms $^{14}C\ gm^{-1}$. Conventional ^{14}C dates on charcoal from rootlets at the base of the McCartys flows give calibrated ages of 3,332–3,292 and 3,271–3,074 cal yr bp (1σ). The apparent $^{14}C_{is}$ production rate from the McCartys surface is 37 ± 10 ^{14}C atoms $gm^{-1}\ SiO_2yr^{-1}$ (normalized to rock surface, sea level, and latitude >60°; rock density $2.5 \pm 0.2\ g\ cm^{-3}$, absorption mean free path $160 \pm 15\ g\ cm^{-2}$, geographic latitude 35.08°). This production rate is significantly greater than rates of 19 ± 3 ^{14}C atoms $gm^{-1}\ SiO_2\ yr^{-1}$ determined by other workers using a 17,800 cal yr bp surface. Further work is needed to determine if this variation in production rate is real.

EL CALDERON, A POLYGENETIC BASALTIC CINDER CONE IN THE ZUNI–BANDERA VOLCANIC FIELD, CIBOLA COUNTY, NEW MEXICO: PALEOMAGNETIC AND GEOCHEMICAL EVIDENCE, by *T. E. Cascadden,* Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131; *J. Carney,* ICF Kaiser Engineering, Inc., Los Alamos, NM 87544; *A. W. Laughlin,* Los Alamos National Laboratory, Los Alamos, NM 87545; *K. Reid,* ICF Kaiser Engineers, Inc., Los Alamos, NM 87544; and *A. M. Kudo,* Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque, NM 87131

Paleomagnetic and whole-rock geochemical data suggest that the El Calderon (EC) cinder cone in the Zuni–Bandera volcanic field (ZBVF) is polygenetic. The main flow, Laguna B, is tholeiitic. Laguna B contains 18–20% modal olivine, 16–41% modal clinopyroxene, and 21–35% modal plagioclase. A representative sample from the flow contains 0.80% K_2O, 1.55% TiO_2, 0.25% P_2O_5, 200 ppm Ba, 343 ppm Sr, 185 ppm V, 324 ppm Cr, 138 ppm Zr and 20 ppm Nb. Laguna B yields a highly distinctive, west and shallow negative paleomagnetic direction (declination = 274°, inclination = −19°; group mean for six sites, α_{95} = 4.5°, κ = 221). Thus, Laguna B erupted during a high-amplitude excursion or aborted reversal of the Earth's magnetic field. This unusual direction was noted in one EC site by Champion et al. (1988, JGR, 93, 11,667–11,680) and interpreted as a transitional field. An $^{40}Ar/^{39}Ar$ date of 79 ± 23 ka for Laguna B suggests the flow is latest Quaternary; a correlation with the Blake event (about 100 to 114 ka; Herrero–Bervera and Helsley, 1993, SEPM Spec. Pub. 49, pp. 71–87) is permissible. Paleomagnetic and geochemical data distinguish Laguna B from an underlying tholeiitic flow, Laguna A, previously mapped as part of the El Calderon flow (Maxwell, 1986, USGS Map I-595). A representative sample from Laguna A contains 0.52% K_2O, 1.16% TiO_2, 0.15% P_2O_5, 107 ppm Ba, 243 pm Sr, 176 ppm V, 294 ppm Cr, 84 ppm Zr, and 13 ppm Nb. Laguna A yields a north, moderate positive paleomagnetic direction (declination = 359°, inclination = 59°; group mean for three sites, α_{95} = 10.1°, κ = 149.8), clearly distinguishing it from the overlying Laguna B flow. Paleomagnetic data are permissive of, but not conclusive for, a correlation of the Laguna A flow with tholeiites at Laguna Pueblo, 45 km east of the nearest exposed Laguna A flows. Laguna Pueblo flows yield a north, moderate positive paleomagnetic direction (declination = 353°, inclination = 57°; group mean for six sites, α_{95} = 3.9°, κ = 289.8) that is statistically indistinguishable from the Laguna A direction. Laguna Pueblo flows contain 6–14% modal olivine, 11–17% clinopyroxene, and 62–67% modal plagioclase. Major, minor, and trace element data from Laguna Pueblo flows are indistinguishable from Laguna A data. Late-stage scoria eruptions at the EC cinder cone were alkalic. A representative sample from EC scoria contains 1.10% K_2O, 1.90% TiO_2, 0.37% P_2O_5, 256 ppm Ba, 483 ppm Sr, 209 ppm V, 368 ppm Cr, 178 ppm Zr, and 26 ppm Nb. Thus, EC cinder cone is polygenetic. It has certainly undergone two stages of eruption (Laguna B and late-stage alkalics), which may have been preceded by an earlier eruptive stage (Laguna A). Chemical variation from the Laguna B flows to the late-stage alkalic scoria represents a reasonable basaltic fractionation trend. The source of Laguna A is uncertain, but minor oxide and trace element chemical differences between Laguna A and B may also represent a reasonable fractionation trend between eruptions from the EC vent.

(*Continues in next issue*)