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New sites of 3.1-Ma pumice beds in axial-fluvial strata of the Camp Rice and Palomas Formations, southern Rio Grande rift

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Abstract

Newly discovered pumice beds in axial-fluvial strata of the Pliocene–lower Pleistocene Camp Rice and Palomas Formations in the southern Rio Grande rift are geochemically correlated to a previously dated 3.1-Ma pumice bed at Hatch Siphon. The Lucero pumice in the Doña Ana Mountains is 1–1.5 m thick and consists of granule- and pebble-sized pumice intercalated with fluvial sand, whereas the Mud Springs pumice along the southeastern flank of the Mud Springs Mountains is 10 cm thick and is composed of sand-sized pumice. Samples from all three sites consist of vesicular, rhyolitic glass fragments and are compositionally identical, particularly with respect to Fe, Ca, and Mn, suggesting derivation from the same 3.1-Ma volcanic eruption. The composition and age of this erupted material is consistent with derivation from the Grants Ridge area, south of Mt. Taylor, implying transport to the ancestral Rio Grande via the Rio Puerco drainage system.

If the correlation is correct, the Lucero pumice, along with a bed of 1.6-Ma pumice and the constructional top of the Camp Rice Formation (~0.8 Ma), provide chronologic constraints on the rate of onlap of the northwestern Doña Ana Mountains by axial-fluvial sediment of the Camp Rice Formation. From 3.1 to 1.6 Ma, the sediment accumulation rate was 46.7 m/Ma, and the lateral rate of eastward onlap was 2 km/Ma. The corresponding values diminished to 18.8 m/Ma and 0.89 km/Ma, respectively, from 1.6 to 0.8 Ma, perhaps due to activity on the Jornada fault, which borders the northern Doña Ana Mountains.

If the correlation between the Mud Springs pumice and 3.1-Ma Hatch Siphon pumice is correct, then the Mud Springs pumice provides a reliable chronologic marker within the Palomas Formation that can be compared to existing biostratigraphic data from the same region. The 3.1-Ma Mud Springs pumice is located within the stratigraphic range of the vertebrate collection of Lucas and Oakes (1986) and is consistent with their interpretation of the fauna as medial Blancan in age (~3 Ma). In contrast, the vertebrate collection of Repenning and May (1986), which has been interpreted as very early Blancan II in age (~4.5 Ma), seems anomalously old, given the fact that it is only ~20 m beneath the Mud Springs pumice.

Introduction

Pliocene and lower Pleistocene basin fill in the southern Rio Grande rift is referred to as the Palomas Formation in the Palomas Basin and as the Camp Rice Formation in basins to the south (Fig. 1; Seager et al. 1982, 1987; Lozinsky and Hawley 1986a, b).

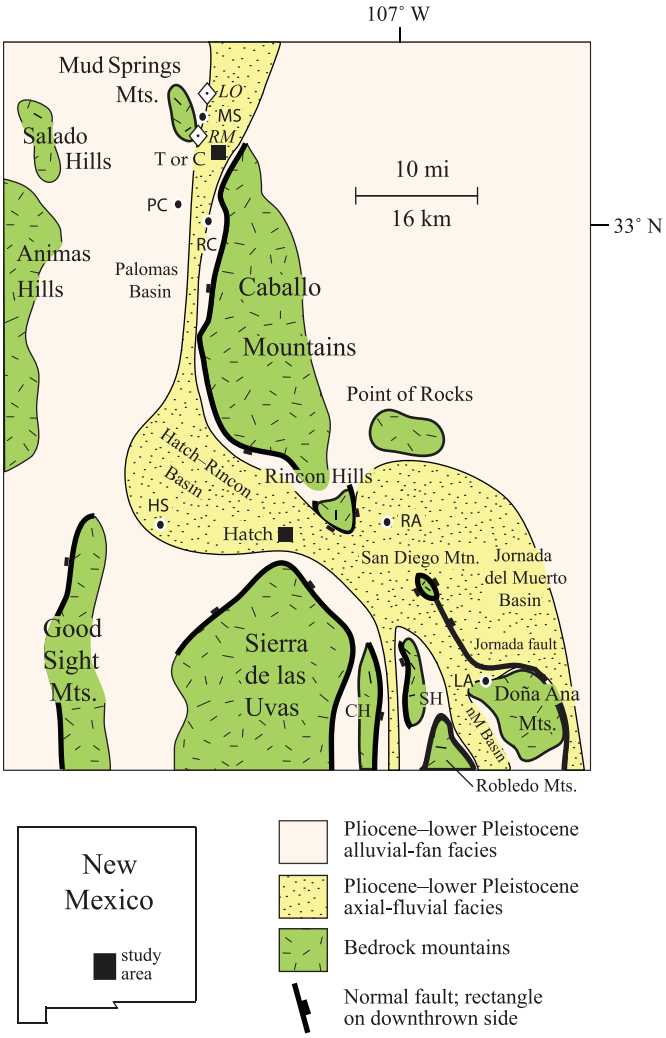

FIGURE 1—Index map of the southern Rio Grande rift, adapted from Seager et al. (1982, 1987). **CH** = Cedar Hills, **SH** = Selden Hills, and **nM** Basin = northern Mesilla Basin. Stratigraphic sections shown in Figure 2 are **LA** = Lucero Arroyo, **RA** = Rincon Arroyo, **HS** = Hatch Siphon, **RC** = Red Canyon, **PC** = Palomas Canyon, and **MS** = Mud Springs Mountains. The sites of vertebrate collections by Repenning and May (1986) and by Lucas and Oakes (1986) are designated ***RM*** and ***LO***, respectively.

Axial-fluvial strata in the Camp Rice and Palomas Formations, as well as in coeval formations in central New Mexico, locally contain beds composed almost exclusively of sand- and gravel-sized pumice (Cather 1988; Mack et al. 1996; Dunbar et al. 1996). Because of their monomictic nature, these pumice beds are interpreted to have been derived from single eruptive events that flooded the river with pumice, which was then transported geologically rapidly (within weeks or months) downstream. Moreover, the pumice was not repeatedly reworked into overlying beds. As a result, the pumice beds represent nearly instantaneous geologic events and are potentially important chronologic marker horizons.

In the southern Rio Grande rift, at least four distinct pumice beds were identified and dated using single-crystal sanidine $^{40}Ar/^{39}Ar$ analyses, corroborated in a few cases by reversal magnetostratigraphy (Mack et al. 1996). The most widespread of the pumice beds was dated by Mack et al. (1996) at ~1.6 Ma, suggesting correlation with the Otowi Member of the Bandelier Tuff in the Jemez volcanic field (Fig. 1, RA site). The oldest of the pumice beds, whose

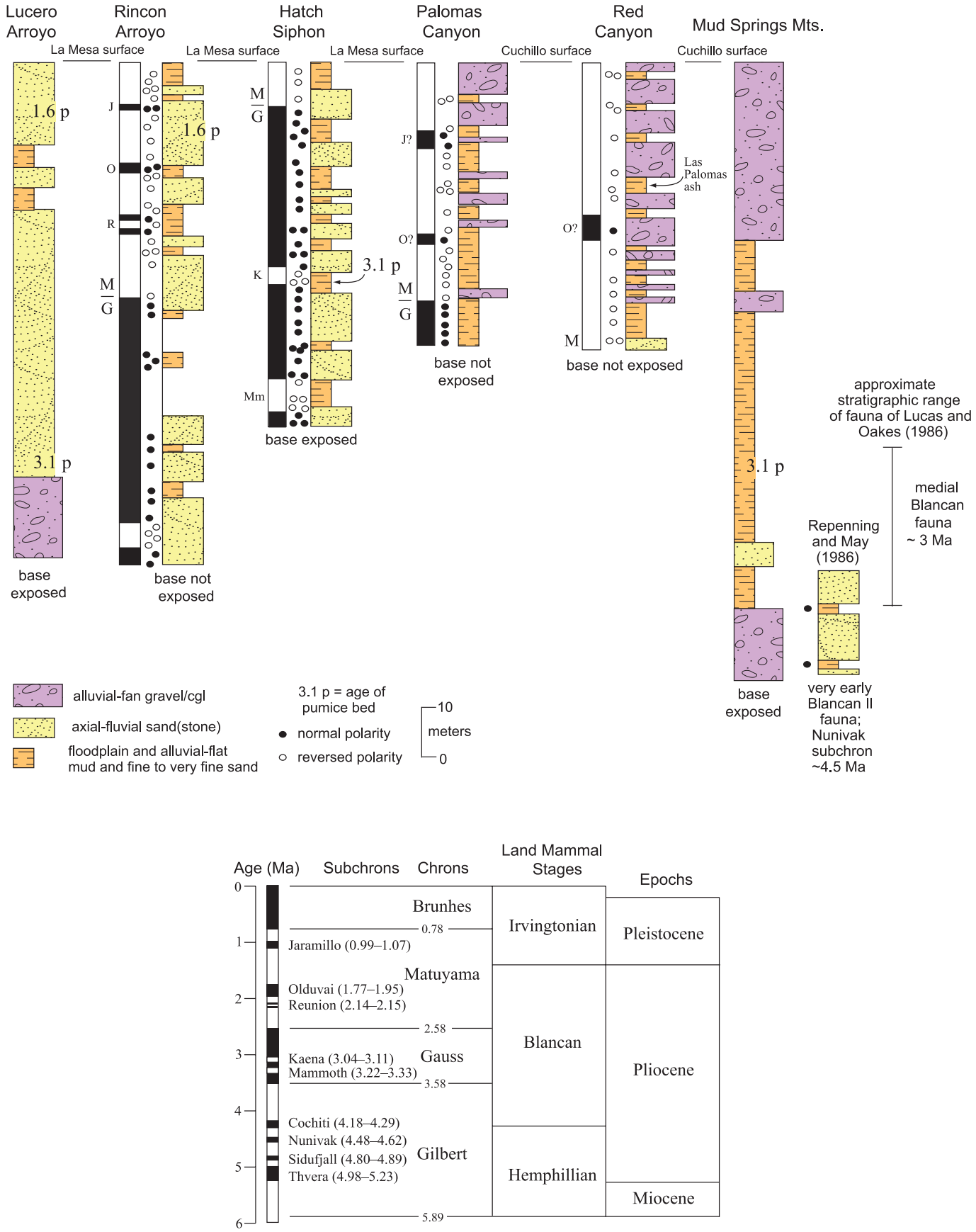

FIGURE 2—Stratigraphic sections of the Camp Rice Formation (Lucero Arroyo, Rincon Arroyo, and Hatch Siphon) and Palomas Formation (Palomas Canyon, Red Canyon, and Mud Springs Mountains), adapted from Mack et al. (1993, 1998, 2002) and Repenning and May (1986). Polarity reversal time scale is from Berggren et al. (1995), with black for normal (north) polarity and white for reversed (south) polarity. Magnetostratigraphic data of Mack et al. (1993, 1998, 2002) are shown adjacent to the Rincon Arroyo, Hatch Siphon, Palomas Canyon, and Red Canyon sections, with **M** = Matuyama Chron, **G** = Gauss Chron, **Mm** = Mammoth subchron, **K** = Kaena subchron, **R** = Reunion subchrons, **O** = Olduvai subchron, and **J** = Jaramillo subchron.

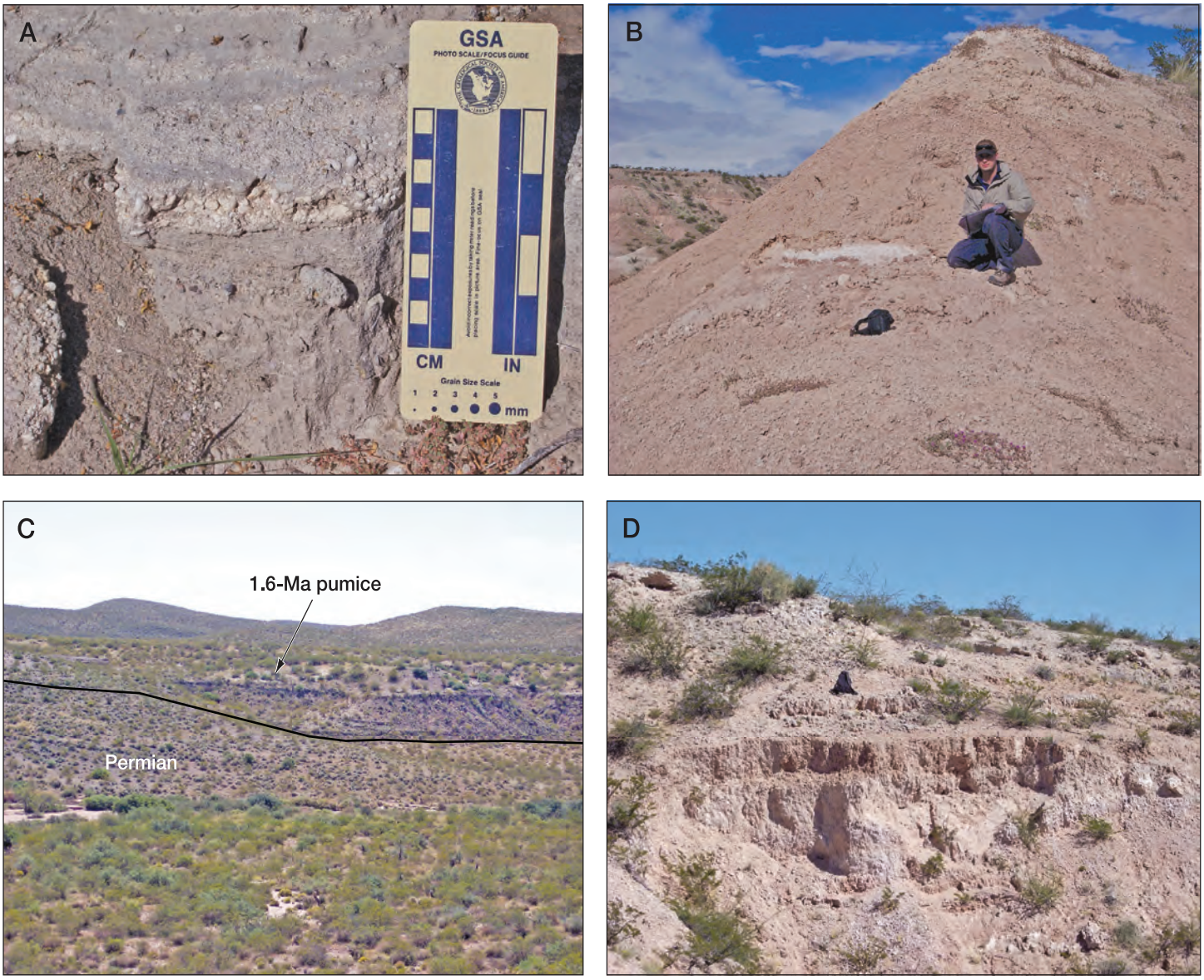

FIGURE 3—**A**—The Lucero pumice bed in the northwestern Doña Ana Mountains. **B**—The Mud Springs pumice bed interbedded with red mudstone and tan fine sand along the southeastern flank of the Mud Springs Mountains. **C**—Onlap (inclined black line) of westward-tilted Permian Abo Formation by the middle part of the Pliocene–upper Pleistocene Camp Rice Formation in the northern Doña Ana Mountains (view to south). The location of the 1.6-Ma pumice bed is shown by the arrow. **D**—Stacked mature calcic paleosols in the uppermost part of the Camp Rice Formation in the northwestern Doña Ana Mountains. Pack, which is 0.5 m high, is at the top of the stage III calcic horizon of the upper of the three paleosols. The prominent white horizon in the middle of the photo is the stage IV calcic horizon, which is overlain by a brown argillic B horizon. The stage III calcic horizon of the lowest of the three paleosols is the white horizon in lower right side of the photo. The La Mesa surface is positioned directly beneath the letter "**D**".

source, before this study, had not yet been identified, was originally recognized at only one site west of the town of Hatch (Hatch Siphon bed) and was dated at ~3.1 Ma by Mack et al. (1996) (Fig. 1, HS site). Described here are two newly discovered pumice beds called the Lucero and Mud Springs beds (Fig. 1, LA and MS sites), which are geochemically correlated to the 3.1-Ma pumice bed at Hatch Siphon. Each of the newly discovered pumice beds provides new insight into local geologic relationships.

3.1-Ma pumice beds in south-central New Mexico

Locations and descriptions

The Hatch Siphon pumice bed is exposed ~2.8 km south of Hatch Siphon (NW ¼ sec. 10, NE ¼ sec. 9 T19S R4W Hatch quadrangle), where it ranges from 20 to 50 cm thick and can be traced laterally for only a few hundred meters. Positioned 28 m above the base and interbedded within the Camp Rice Formation, the pumice bed is composed of >80% pebble- and small cobble-sized pumice clasts, with a few outsized clasts as long as 30 cm. Based on grain support, symmetrical bedforms, and upstream-dipping, low-angle laminae, Mack et al. (1996) suggested transportation and deposition of the pumice in the ancestral Rio Grande as antidunes or dune-like bedforms without slip faces. Pumice fragments appear to be glassy and are crystal poor, although sanidine crystals were found during mineral separation processes. Single crystals of sanidine extracted from the pumice clasts provided an $^{40}Ar/^{39}Ar$ age of 3.12 ± 0.03 Ma (Mack et al. 1996), whereas reversal magnetostratigraphy placed the pumice bed in the Kaena subchron (3.02–3.11 Ma) of the Gauss Chron (Fig. 2; Mack et al. 1993; Berggren et al. 1995).

The newly discovered Lucero pumice bed in the northwestern Doña Ana Mountains is 1–1.5 m thick and is exposed within the Camp Rice Formation for ~0.5 km along the west side of a south-flowing tributary of Lucero Arroyo (SE ¼ sec. 1 T21S R1W Selden Canyon quadrangle). It consists of centimeter-scale intercalations of white, granule- and pebble-sized pumice clasts that appear glassy and aphyric, and gray fluvial sand arranged as horizontal laminae and trough crossbeds (Fig. 3A). The most common pumice size is 1–2 cm in length, although clasts as long as 5 cm are locally present.

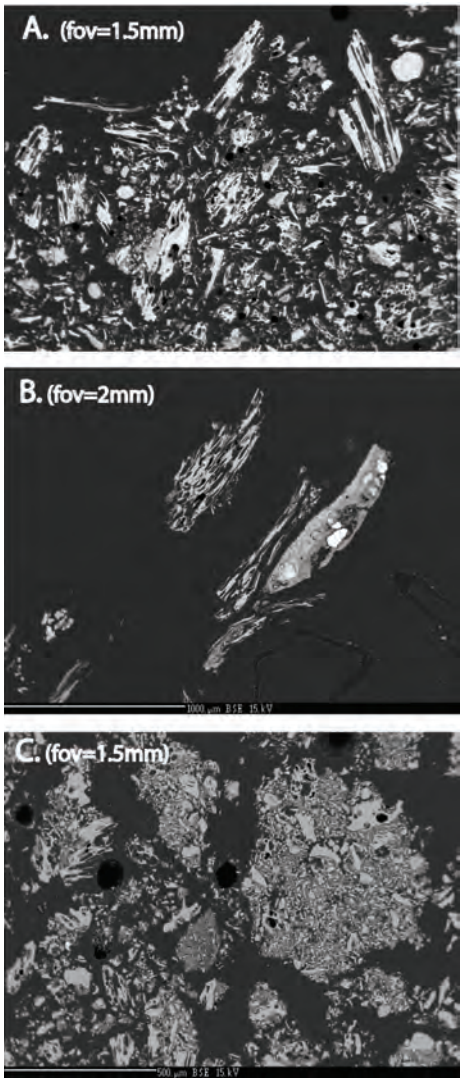

FIGURE 4—Backscattered electron images of pumice samples: **A**—Hatch Siphon pumice, **B**—Lucero pumice bed, and **C**—Mud Springs pumice bed. Glass shards are bright areas and dark area is epoxy matrix. Expanded pumice textures can be observed in all three images. Some brighter mineral fragments, probably magnetite, are also present, and a band of clay minerals is observed in the right side of the Lucero image. Field of view (fov) is noted for each figure.

Also described here for the first time is a thin (10-cm), white bed of pumice within the Palomas Formation that is exposed along the southeastern margin of the Mud Springs Mountains (SW ¼ sec. 20, NW ¼ sec. 29 T13S R4W Cuchillo quadrangle). Referred to as the Mud Springs pumice, it is interbedded with red mudstone and very fine sand and is traceable for several hundred meters on either side of the canyon in sec. 20 and for a similar distance on the north side of the canyon in sec. 29 (Fig. 3B). Unlike the pumice beds described above, the Mud Springs pumice bed consists of sand-sized pumice and is internally structureless. Because of its fine grain size and lack of current-generated sedimentary structures, it most likely was deposited from flood suspension along the western edge of the Rio Grande floodplain. Despite the fine-grained nature of the material, when examined with hand lense or binocular microscope, pumiceous structures are apparent, and the material appears glassy. No crystals are macroscopically apparent.

Tephra correlations

Samples of pumice from the Hatch Siphon, Lucero, and Mud Springs beds were geochemically analyzed using electron microprobe analysis to assess whether or not they were derived from the same volcanic eruption. Analyses were carried out using a Cameca SX-100 electron microprobe at New Mexico Tech for samples mounted in epoxy and polished with pure diamond powder suspended in deionized water. The pumice was lightly crushed before being mounted in epoxy. Samples were examined using backscattered electron (BSE) imagery, and selected areas were quantitatively analyzed. Elements analyzed included Na, Mg, Al, Si, P, S, F, Cl, K, Ca, Ti, Mn, and Fe. An accelerating voltage of 15 kV and a probe current of 10 nA were used. Peak count times of 20 seconds were used for all elements with the exception of Na (40 seconds), F (100 seconds), Cl (40 seconds), and S (40 seconds). Beam size depended on the size of the particles in the sample, and the largest possible beam size that most closely matched individual particle diameters, up to 25 microns, was always used. For samples discussed here, all shards were analyzed using a 25 or 20 micron beam, minimizing the problem of sodium volatilization that can occur when smaller beam sizes are used (Nielsen and Sigurdsson 1981). Between 10 and 20 points were analyzed on each sample, and multiple glass fragments were analyzed in each sample in order to assess sample homogeneity. The microprobe analyses are normalized to 100 wt.% oxide values in order to directly compare samples that have undergone different amounts of hydration. The geochemical compositions of the samples were then compared using statistical difference methods (Perkins et al. 1995).

The volcanic textures of the three samples are apparent in BSE images (Fig. 4). All three samples are composed of vesicular glassy fragments that appear to be characteristic of explosive volcanic eruptions (Heiken and Wohletz 1984), although the vesicularity of the three samples appears slightly different. The Hatch Siphon and Lucero samples (Figs. 4A, 4B) contain abundant stretched vesicles, whereas the Mud Springs sample has a higher proportion of round vesicles (Fig. 4C), although stretched vesicles are also observed. This difference in vesicle shape might initially be interpreted as a difference in eruptive source for the Hatch Siphon and Lucero pumices as compared to the Mud Springs pumice. However, ranges in vesicle shape have been observed within single eruptive events as a function of changing conditions within the volcanic conduit (Polacci et al. 2003), so do not preclude the three samples in this study from being derived from the same eruptive event. Also, the grain size of the Mud Springs sample is much finer than the other two samples and is interpreted to have formed in a different environment than the other two samples. Perhaps the finer grain size or lower energy deposition mode of the Mud Springs sample favored more equant particles with rounder vesicles. The consistent brightness of fragments in the BSE images suggests that the material is largely composed of glass. If the glass were altered to the point that clay minerals were forming, a non-uniform BSE brightness would be seen, and it is not observed in these samples. Few crystals are seen, either embedded in glassy fragments or free in the sample matrix, consistent with observations made at the hand-sample scale. Furthermore, no microlites are observed in the glass. The uniformity of BSE signal from different fragments suggests that the glass composition is uniform within each sample, rather than representing a range of compositions.

When analyzed quantitatively, the glass compositions are all rhyolitic, are uniform within samples, and are similar between samples (Table 1). The uncorrected analytical totals range from ~93 to 96 wt.% oxides, indicating that some degree of hydration has taken place. The level of hydration is consistent in all three samples, and although the hydration may have resulted in some alkali mobility (Cerling et al. 1985), the other elements are likely to have been unaffected. The compositional uniformity is demonstrated by the relatively low standard deviation within each sample, which is generally within the range of variation found for multiple analyses of a homogeneous glass standard reference material (Table 1). The similarity between samples can be qualitatively observed simply by comparing the compositions of the three samples (Fig. 5; Table 1) and observing that the concentrations of most elements overlap within analytical error. For comparative purposes, Figure 5 also shows the composition of a sample of the Tsankawi Pumice of the Tshirege Member of the Bandelier Tuff. Elements that are particularly important for geochemical correlations include those with the lowest analytical standard deviation, such as Fe, Ca, and Mn, which are strikingly similar for the three samples.

A more rigorous comparison can be made using the statistical difference techniques described by Perkins et al. (1995). Using this technique, a "D" (difference) value is assigned to a pair of tephra compositions by summing the differences between sets of elements in the two samples, and weighting the differences by the analytical error for given elements. Using this technique, a D value of <4 indicates that the two samples are compositionally identical for typical electron microprobe analytical errors. The D values between Hatch Siphon–Lucero, Lucero–Mud Springs, and Mud Springs–Hatch Siphon are 2.33, 1.78, and 0.69, respectively. This confirms that these samples are compositionally indistinguishable and are very likely to be products of the same volcanic eruption, and therefore of the same age.

TABLE 1—Average major element composition of tephra shards as determined by electron microprobe.

Sample name	N	P_2O_5	SiO_2	SO_2	TiO_2	Al_2O_3	MgO	CaO	MnO	FeO	Na_2O	K_2O	F	Cl	Total
Mud Springs mean	20	**0.01**	**75.95**	**0.01**	**0.02**	**13.06**	**0.00**	**0.51**	**0.13**	**0.71**	**3.51**	**5.57**	**0.49**	**0.03**	100
standard deviation		0.02	0.53	0.01	0.02	0.59	0.00	0.05	0.03	0.06	0.12	0.26	0.08	0.01	
Lucero mean	19	**0.02**	**75.55**	**0.00**	**0.02**	**13.28**	**0.00**	**0.53**	**0.12**	**0.71**	**3.53**	**5.71**	**0.45**	**0.06**	100
standard deviation		0.02	0.19	0.01	0.02	0.10	0.01	0.06	0.03	0.04	0.23	0.41	0.09	0.06	
Hatch Siphon Draw mean	10	**0.01**	**75.16**	**0.02**	**0.02**	**13.55**	**0.01**	**0.51**	**0.13**	**0.71**	**3.97**	**5.26**	**0.62**	**0.02**	100
standard deviation		0.01	0.19	0.02	0.02	0.14	0.02	0.02	0.03	0.05	0.17	0.34	0.14	0.01	
Grants Ridge pumice*	21	**0.01**	**76.02**		**0.03**	**13.40**	**0.00**	**0.46**	**0.12**	**0.71**	**4.10**	**4.65**	**0.49**		100
			0.54		0.03	0.12		0.03	0.04	0.04	0.13	0.14	0.05		

Notes: Background counts were obtained using one-half the times used for peak counts. Analyses are normalized to 100 wt.%. N equals number of analyses. Analytical precision, based on replicate analyses of standard reference materials of similar composition to the unknowns, are as follows (all in wt.%): P_2O_5 ± 0.02, SiO_2 ± 0.47, SO_2 ± 0.01, TiO_2 ± 0.03, Al_2O_3 ± 0.12, MgO ± 0.07, CaO ± 0.02, MnO ± 0.06, FeO ± 0.06, Na_2O ± 0.55, K_2O ± 0.27, F ± 0.1, and Cl ± 0.03.

*Sample GR95-15 from WoldeGabriel et al. 1999.

A possible eruptive source for these samples may be a rhyolitic eruptive sequence located on East Grants Ridge, located in the southwestern part of the Mt. Taylor volcanic field (Keating and Valentine 1998; WoldeGabriel et al. 1999). This sequence consists of a set of pyroclastic deposits comprising ashfalls, surges, and ignimbrites, overlain by rhyolitic domes. The geochemical composition of pumice from the very uppermost part of the ignimbrite unit is very similar to the pumice and ash samples from the Las Cruces area (Table 1). Of particular note in these analyses are the very high F content of the late-erupted East Grants Ridge pumice, which match those of the pumice and ash from the Hatch Siphon, Lucero, and Mud Springs samples. Furthermore, the age of the East Grants Ridge rhyolite, dated by K-Ar at 3.3 ± 0.16 Ma (Lipman and Mehnert 1979), is similar to the $^{40}Ar/^{39}Ar$ age of 3.12 ± 0.03 Ma for the pumice bed at Hatch Siphon (Mack et al. 1996). If the East Grants Ridge pumice is the source of the pumice beds in southern New Mexico, then the pumice must have been brought to the ancestral Rio Grande via the Rio Puerco tributary system.

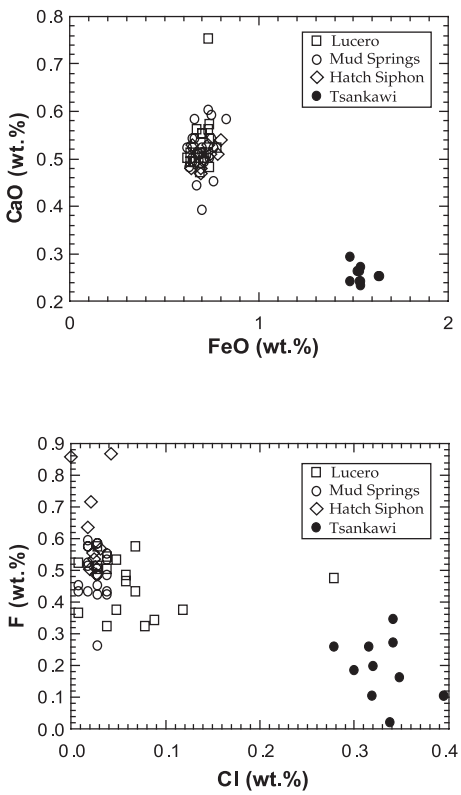

FIGURE 5—Chemical variation diagrams for the Lucero, Mud Springs, and Hatch Siphon tephra, as well as a sample of the Tsankawi Pumice of the Tshirege Member of the Bandelier Tuff for comparison. Each symbol represents an individual geochemical analysis on a glass shard, means of which are shown in Table 1. Average analytical errors for elements displayed are shown in the lower right corner of each graph.

Onlap of the northwestern Doña Ana Mountains

The Doña Ana Mountains constitute the hanging wall of the westward-tilted northern Mesilla half graben, whose footwall is the Robledo Mountains (Fig. 1; Seager et al. 1987; Mack and Seager 1990). Throughout Pliocene and early Pleistocene time, the northwestern margin of the Doña Ana Mountains was progressively onlapped by axial-fluvial sediment of the Camp Rice Formation (Figs. 1, 6). If the correlation presented in this study is correct, then three chronologic markers within the Camp Rice Formation allow calculation of the rates of sediment accumulation and onlap of the range.

The oldest chronologic marker in the onlap succession is the Lucero 3.1-Ma pumice bed. Although it does not directly overlie bedrock, its base can be projected 30 m eastward across the modern arroyo to an unconformable contact with the Permian Abo Formation (Fig. 6). Also present in the northwestern Doña Ana Mountains is the 1.6-Ma pumice bed, which directly onlaps the Permian Abo Formation in an eastward and southward direction (Fig. 3C). The upper chronologic marker is the La Mesa geomorphic surface, which constitutes the constructional top of the Camp Rice Formation (Seager et al. 1976). Regionally, the La Mesa surface is bracketed between the base of the Brunhes Chron (0.78 Ma) and the top of the Jaramillo subchron (0.99 Ma) and is considered to be ~0.8 Ma (Fig. 2; Mack et al. 1993, 1998, 2006). Approximately 30 m of Camp Rice fluvial sediment is exposed beneath the La Mesa surface on the north side of Lucero Arroyo, but the upper part of this section has been removed by erosion south of the arroyo (Fig. 6). Consequently, the onlap rate is calculated by projecting the elevation of the La Mesa surface southward onto exposures of the Permian Abo Formation.

Approximately 70 m of axial-fluvial sediment exists between the 3.1-Ma and 1.6-Ma pumice beds in the northwestern Doña Ana Mountains, indicating a sediment accumulation rate (ignoring compaction) of 46.7 m/Ma (Fig. 6). The lateral rate of eastward onlap between the two pumice beds is 2 km/Ma. Sediment accumulation and onlap rates between 1.6 Ma and 0.8 Ma decreased to 18.8 m/Ma and 0.89 km/Ma, respectively. Independent evidence for slow and intermittent sediment accumulation during deposition of the upper 12 m of the section is indicated by the presence of three mature calcic paleosols developed in fluvial sand (Fig. 3D). The middle of the three paleosols displays stage IV morphology, whereas the others are stage III (Gile et al. 1966; Machette 1985). These paleosols indicate short periods of fluvial sedimentation followed by tens to hundreds of thousands of years of landscape stability and soil formation, during which time the Rio Grande was far removed from the northern Doña Ana Mountains.

The La Mesa surface along the northern flank of the Doña Ana Mountains has been offset by ~45 m by an east-west-trending segment of the Jornada fault (Fig. 1; Seager et al. 1976, 1987). Mack et al. (1994) and Perez-Arlucea et al. (2000) suggested that activity on this fault segment may have occurred during the latter stages of deposition of the

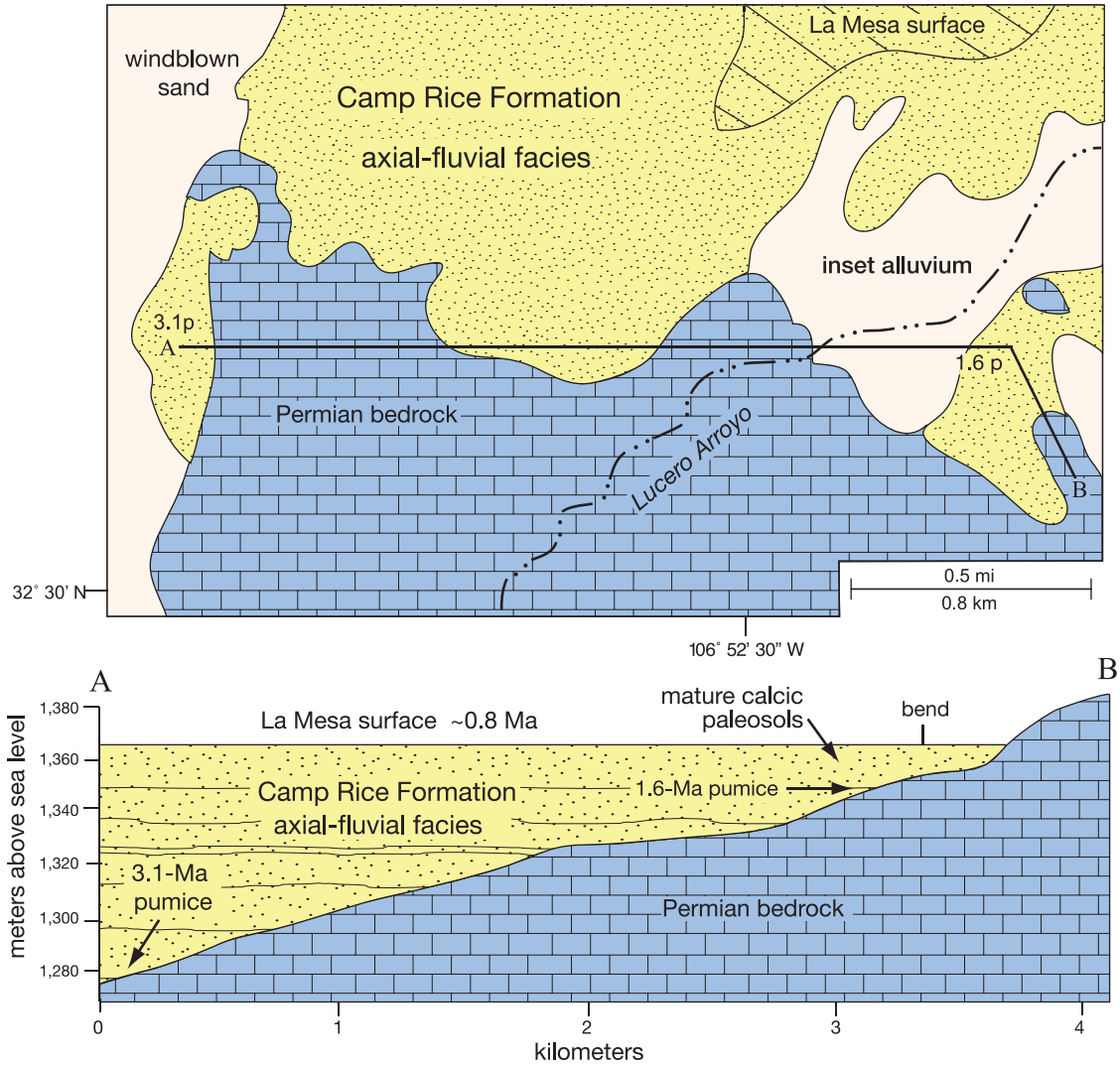

FIGURE 6—Generalized geologic map and cross section (~9.5 × vertical exaggeration) of the northwestern Doña Ana Mountains adapted from Seager et al. (1976). **3.1 p** = location of Lucero pumice bed, which is interpreted to be ~3.1 Ma; **1.6 p** = location of 1.6-Ma pumice bed. Cross section schematically depicts the eastward onlap of Permian bedrock by axial-fluvial sediment of the Pliocene–lower Pleistocene Camp Rice Formation.

Camp Rice Formation and may have been responsible for the decrease in sediment accumulation rate after 1.6 Ma.

Age of the Palomas Formation in the nothern Palomas Basin

The northern Palomas Basin has some of the best-exposed, most complete stratigraphic sections of Pliocene–lower Pleistocene basin fill in the southern Rio Grande rift. Designated the Palomas Formation by Lozinsky and Hawley (1986a, b), these strata are coeval to the Camp Rice Formation to the south (Mack et al. 1993, 1998, 2006).

Reversal magnetostratigraphy from two stratigraphic sections provides age constraints for the upper part of the Palomas Formation in the northern Palomas Basin. At Red Canyon, the upper 55 m of the Palomas Formation correlates to the Matuyama Chron (Figs. 1 and 2; Mack et al. 2002). Present within the Red Canyon section is the Las Palomas ash (Lozinsky and Hawley 1986b), which has been correlated to the Cerro Toledo eruptions (1.59–1.22 Ma; Spell et al. 1996) in the Jemez volcanic field (M. Machette, written comm. 1982; cited in Lozinsky and Hawley 1986b). However, the data used in this correlation are not presented by Lozinsky and Hawley (1986b). Magnetostratigraphy is also available for the upper part of the Palomas Formation at Palomas Canyon, where the lower 9 m has been correlated to the upper Gauss Chron and the upper 45 m has been correlated with the Matuyama Chron, including the Olduvai and Jaramillo subchrons (Figs. 1 and 2; Mack et al. 1993). These magnetostratigraphic data suggest that the constructional tops of the Palomas (Cuchillo surface) and Camp Rice (La Mesa surface) Formations are coeval (Fig. 2; Mack et al. 1993, 1998, 2002).

The Palomas Formation in the northern Palomas Basin is also well exposed along the southern flank of the Mud Springs Mountains, where vertebrate biostratigraphy has been applied to the lower part of the section (Fig. 1). Repenning and May (1986) collected vertebrate fossils from a 20-m-thick interval of axial-fluvial sediment exposed approximately 1.8 km south-southeast of the Mud Springs pumice bed (Figs. 1 and 2). Within their section they recorded normal polarity from two thin (<1 m) mudstones that are stratigraphically separated by ~12 m. The vertebrate fauna was assigned to the very early Blancan II land mammal stage, and normal polarity was correlated to the Nunivak subchron of the Gilbert Chron, which is bracketed between 4.48 and 4.62 Ma (Fig. 2; Berggren et al. 1995). Lucas and Oakes (1986) also collected vertebrate fossils from the Palomas Formation at a site approximately 3.5 km north-northeast of exposures of the Mud Springs pumice bed (Figs. 1 and 2), correlating the fauna to the medial Blancan stage (~3 Ma). Although it is not possible to physically trace beds between the two vertebrate sites, there appears to be stratigraphic overlap between them, using elevation to correlate the horizontal strata (Fig. 2). This is difficult to reconcile given the presumed ~1.5 Ma age difference between the two faunas.

Correlation of the Mud Springs pumice bed with the 3.1-Ma Hatch Siphon pumice bed provides a reliable chronologic marker in the lower part of the Palomas Formation along the southern flank of the Mud Springs Mountains and constitutes an important test of existing biostratigraphic data (Fig. 2). The Mud Springs pumice bed is located within the stratigraphic range of the vertebrate collection of Lucas and Oakes (1986) and is consistent with their interpretation of the fauna as medial Blancan (~3 Ma). The position of the Mud Springs pumice bed is also consistent with the biostratigraphy of Repenning and May (1986), because it is stratigraphically above their faunal interval (Fig. 2). However, the Mud Springs pumice bed is only ~20 m above the top of the interval sampled by Repenning and May (1986), despite a reputed age difference of ~1.4 Ma. This would require a sediment accumulation rate from the top of the section sampled by Repenning and May (1986) to the 3.1-Ma Mud Springs pumice bed of ~14 m/Ma, which is less than half of the rate (~36 m/Ma) for the interval from the 3.1-Ma Mud Springs pumice bed to the Cuchillo surface (~0.8 Ma). There is no evidence between the faunal interval of Repenning and May (1986) and the Mud Springs pumice bed for anomalously low sediment accumulation rates nor for an erosional disconformity capable of removing tens of meters of stratigraphic section. Consequently, the age designation of the faunal interval by Repenning and May (1986) would appear to be anomalously old.

Conclusions

Pumice beds are important chronologic markers in Pliocene–lower Pleistocene axial-fluvial strata of the southern Rio Grande rift and were originally dated using $^{40}Ar/^{39}Ar$ radioisotopic analysis and reversal magnetotstratigraphy. In this study, newly discovered pumice beds (Lucero and Mud Springs pumices) are correlated to a 3.1-Ma pumice bed at Hatch Siphon using volcanic textures and microprobe analysis of elemental geochemistry. These Hatch Siphon, Lucero, and Mud Springs pumices may be sourced in the East Grants Ridge rhyolitic volcanic complex, possibly related to a stratigraphically high ignimbrite unit. The tephrochronologic approach is especially valuable in these cases, because of the fine grain size of the Lucero and Mud Springs pumices, which would be difficult to date radioisotopically. Once correlated, the newly discovered pumices provide new insight into local geologic relationships, including sediment onlap rates in the northern Doña Ana Mountains and a test of biostratigraphy in the Mud Springs Mountains.

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