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CENOZOIC VERTEBRATES FROM SIERRA COUNTY, SOUTHWESTERN NEW MEXICO

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Abstract—Fossil vertebrates of Eocene, Oligocene, Pliocene and Pleistocene age are known from Sierra County in southwestern New Mexico. These fossils provide important biochronological control of the ages of the sedimentary rocks that yielded them. The oldest mammal fossil known from Sierra County is a lower jaw of the brontothere *Duchesneodus uintensis* from the Rubio Peak Formation in the northern Black Range. *Duchesneodus* indicates a late Eocene age (~37-40 Ma; Duchesnean North American land-mammal "age"—NALMA). Slightly younger fossil mammals from the Rubio Peak Formation in the northern Black Range, including the oromerycid artiodactyl *Montanatylopus matthewi* and the rodent *Jaywilsonomys ojinagaensis*, are of latest Eocene age (~ 36-37 Ma; early Chadronian NALMA). Fossil mammals from the upper part of the Palm Park Formation in the southern Caballo Mountains, including the hyaenodontid creodont *Hyaenodon horridus*, the horse *Mesohippus* cf. *M. texanus*, and the oreodont *Merycoidodon presidioensis*, are also of early Chadronian age. Two species of large oreodonts from the Seventyfour Draw Local Fauna (LF) in the Black Range, *Desmatochoerus* cf. *D. megalodon* and *Megoreodon* cf. *M. grandis*, are late Oligocene (early Arikareean NALMA) taxa derived from volcaniclastic strata bracketed by tuffs dated at ~ 26 Ma and ~ 28 Ma. No Miocene mammals are known from Sierra County. The most extensive fossil mammal assemblages from Sierra County are of late Pliocene to early Pleistocene age (~ 2.0-3.6 Ma; Blancan NALMA) and come from the Palomas Formation in the Palomas and Engle basins of the Rio Grande rift. The Cuchillo Negro Creek LF is in close stratigraphic association with the 3.1 Ma Mud Springs pumice and documents the association of the gomphotheriid proboscidean *Stegomastodon primitivus*, the borophagine canid *Borophagus hilli,* and the horse *Equus scotti*, suggesting an age of between 3.1 and 3.3 Ma (late early Blancan). Based on the presence of *S. primitivus* and *E. scotti*, the Elephant Butte Lake fauna is similar in age. The Truth or Consequences LF is about 40 m lower in the Palomas Formation than the Cuchillo Negro Creek LF and the 3.1 Ma Mud Springs pumice, which together with associated magnetostratigraphic data and the presence of the lagomorph *Notolagus lepusculus* and the woodrat *Neotoma* cf. *N. fossilis*, suggests a somewhat older age within the late early Blancan (~ 3.3-3.6 Ma). The Williamsburg LF documents the co-occurrence of the mylodontid ground sloth *Paramylodon* cf. *P. garbanii*, a South American immigrant and participant in the Great American Interchange that did not appear in temperate North America until after 3.0 Ma, and the dwarf three-toed horse *Nannippus peninsulatus,* which disappeared from New Mexico before 2.6 Ma, constraining the age of this fauna to the early late Blancan (~ 2.6-3.0 Ma). The Palomas Creek fauna is similar in age based on the presence of *Nannippus peninsulatus* and the horse *Equus simplicidens* and a magnetostratigraphic section indicating referral to the uppermost Gauss Chron (2.58-3.04 Ma). The Caballo LF is the youngest Blancan fauna in Sierra County (latest Blancan; ~ 2.0-2.6 Ma) based on the presence of the glyptodont *Glyptotherium arizonae*, a South American Interchange mammal, absence of *Nannippus* (disappeared about 2.6 Ma) and *Mammuthus* (first appeared about 1.6 Ma), and magnetostratigraphic data indicating referral to the lower Matuyama Chron, above the Gauss/Matuyama boundary (2.58 Ma) and below the Olduvai Subchron (1.95 Ma). Several late Pleistocene (Rancholabrean NALMA) sites, including Alkali Flat, Alkali Spring, and Salt Creek, occur on the White Sands Missile Range in the Tularosa basin in easternmost Sierra County. The Alkali Flat and Alkali Spring sites occur in lacustrine and fluvio-deltaic deposits of the Otero Formation, and include bones and teeth of the Columbian mammoth *Mammuthus columbi*, the horse *Equus occidentalis*, and the giant llama *Camelops hesternus*, as well as trackways of a proboscidean, probably mammoth. Radiocarbon dates bracket the age of the Alkali Flat and Alkali Spring sites between 19 and 31 ka. The Salt Creek sites also contain fossils of *Mammuthus columbi*, *Equus*, and *Camelops hesternus*, as well as proboscidean tracks, and occur below a gypsum marsh deposit with a radiocarbon date of about 11 ka. Palomas Creek Cave in the Black Range in western Sierra County contains a late Pleistocene fauna consisting primarily of small mammals.

INTRODUCTION

This review of the Cenozoic vertebrates from Sierra County is one of a continuing series of contributions to the New Mexico Geological Society's Field Conference Guidebooks on Cenozoic vertebrates from New Mexico (e.g., Morgan and Lucas, 2006, Morgan et al., 2009). Sierra County in southwestern New Mexico was bisected from north to south by the through-flowing Rio Grande until 1916. However, the construction of two dams on the Rio Grande in the first half of the 20th century mostly converted the river in Sierra County to two large reservoirs, Elephant Butte Lake and Caballo Lake. Sierra County measures about 150 km from east to west, from the Tularosa Basin on the east to the Black Range in the west, and about 100 km in the north-south dimension, from the Fra Cristobal Range on the north to the Caballo Mountains in the south. Mountain ranges composed primarily of Paleozoic rocks dominate the eastern half of the county, including the San Andres Mountains, Caballo Mountains, Fra Cristobal Range, and Mud Springs Mountains, whereas the Black Range, mostly consisting of Eocene and Oligocene volcanic rocks, occupies much of the western half of the county. Exposures of Cenozoic sedimentary deposits are not particularly widespread in Sierra County, and thus Cenozoic fossil sites are rather limited in occurrence, with only 14 faunas ranging in age from late Eocene to late Pleistocene. Figure 1 is a map of Sierra County showing the location of the Cenozoic vertebrate localities discussed in the text. Figure 2 is a stratigraphic column showing the geologic formations and chronologic distribution of Cenozoic vertebrate fossil sites in Sierra County.

The oldest Cenozoic sites in Sierra County are late Eocene in age (Duchesnean and Chadronian North American land-mammal "ages"—NALMAs), and are found in two rather widely separated areas. The Rubio Peak Formation along Turkey Creek near Winston in the northern Black Range in northwestern Sierra

County contains two superposed faunas. A single fossil of a brontothere is indicative of a Duchesnean age (Lucas, 1983), whereas an early Chadronian fauna consists of two artiodactyls and a rodent (Lucas, 1986a,b; Lucas and Williamson, 1993). A second early Chadronian fauna, including a tortoise, creodont, horse, rhinoceros, and oreodont, occurs in the Palm Park Formation in the Apache graben of the southern Caballo Mountains (Lucas and Williamson, 1993; Lucas et al., 1997; Lucas and Spielmann, 2012). Among the only Oligocene vertebrates known from New Mexico are two oreodonts typical of the early Arikareean NALMA, from volcaniclastic sediments in the Seventyfour Draw Local Fauna (LF) in the Black Range in the northwestern corner of Sierra County (Tedford, 1981; Morgan and Lucas, 2003a). Miocene vertebrates are unknown from Sierra County, resulting in a long hiatus from the late Oligocene through the early Pliocene (between about 26 and 4 Ma) with no vertebrate sites.

The most diverse and widespread vertebrate faunas from Sierra County are late Pliocene and early Pleistocene in age (Blancan NALMA), occurring in axial river deposits of the Palomas Formation that crop out along the Rio Grande Valley. There are seven local faunas of Blancan age from the Palomas Formation in the vicinity of Elephant Butte Lake and Caballo Lake in Sierra County (from north to south): Elephant Butte Lake, Cuchillo Negro Creek, Truth or Consequences, Williamsburg, Palomas Creek, Kelly Canyon, and Caballo (Tedford, 1981; Lucas and Oakes, 1986; Repenning and May, 1986; Morgan et al., 2011) (Fig. 1). The Elephant Butte Lake, Cuchillo Negro Creek, Williamsburg, Palomas Creek, and Caballo faunas are dominated by large mammals, including horses, camels, and proboscideans. The Truth or Consequences and Kelly Canyon faunas contain abundant microvertebrates, including fish, birds, and small mammals. Late Pleistocene (Rancholabrean NALMA) vertebrate

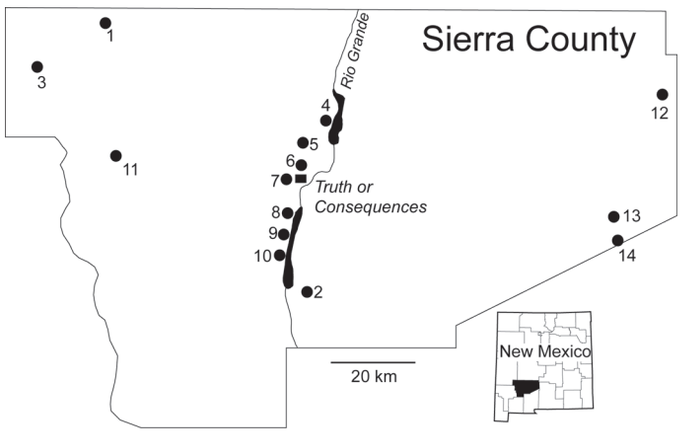

FIGURE 1. Map of Sierra County, southwestern New Mexico showing the location of Cenozoic vertebrate localities. Numbers correspond to the following sites. Eocene (Duchesnean and Chadronian NALMAs): 1. Rubio Peak Formation; (Chadronian NALMA): 2. Palm Park Formation. Oligocene (Arikareean NALMA): 3. Seventyfour Draw; Pliocene (Blancan NALMA): 4. Elephant Butte Lake; 5. Cuchillo Negro Creek; 6. Truth or Consequences; 7. Williamsburg; 8. Palomas Creek; 9. Kelly Canyon; 10. Caballo. Late Pleistocene (Rancholabrean NALMA): 11. Palomas Creek Cave; 12. Salt Creek; 13. Alkali Spring; 14. Alkali Flat.

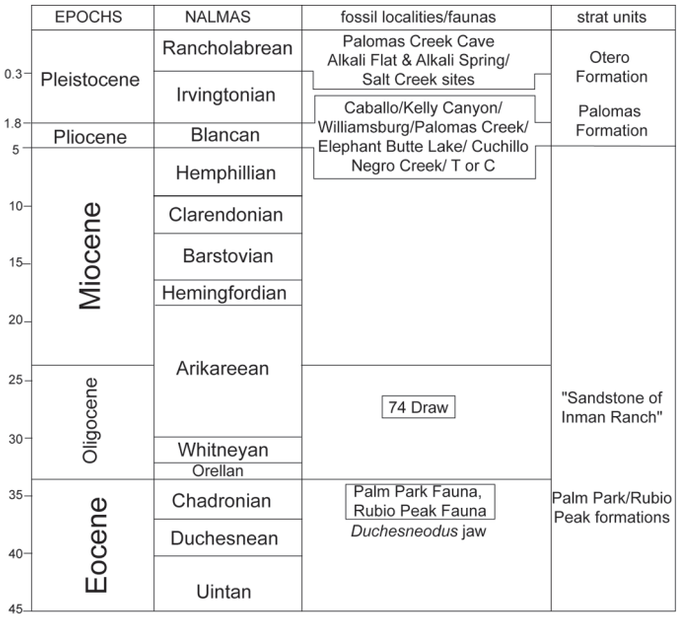

FIGURE 2. Stratigraphic column showing the geologic formations and chronologic distribution of Cenozoic vertebrate sites in Sierra County.

faunas are rather uncommon in Sierra County, with fossils known from only two areas on opposite sides of the county. The Alkali Flat, Alkali Spring, and Salt Creek sites from the Tularosa basin in easternmost Sierra County primarily consist of horses, camels, and mammoths, as well as tracks of mammoths and camels (Morgan and Lucas, 2002; Love et al., 2011, in press). The late Pleistocene vertebrate fauna from Palomas Creek Cave along the South Fork of Palomas Creek near Hermosa in the Black Range in western Sierra County contains diverse samples of rodents and other small vertebrates (Harris, 1985, 1993).

Most of the vertebrate fossils discussed here are deposited in the paleontology collection of the New Mexico Museum of Natural History and Science (NMMNH). Several small collections of Pliocene vertebrates from sites in Sierra County formerly housed in the New Mexico Bureau of Geology and Mineral Resources (NMBGMR) in Socorro and the University of New Mexico (UNM) in Albuquerque, have been transferred to the NMMNH. There are also vertebrate fossils from Sierra County in the American Museum of Natural History (AMNH) in New York, United States Geological Survey in Denver, Colorado (USGS-D), and the University of Texas at El Paso (UTEP). The fossils discussed in this paper were mostly collected from land under the jurisdiction of U. S. Government agencies, including the U. S. Bureau of Land Management (BLM), U. S. Bureau of Reclamation (BOR), U. S. Forest Service (USFS), and White Sands Missile Range (WSMR), U. S. Army. Other abbreviations used in the text are: Before Present (BP), Great American Biotic Interchange (GABI), Local Fauna (LF) and North American land-mammal "age" (NALMA). We follow the revised definition of the Pliocene-Pleistocene boundary at 2.58 Ma, marking the onset of Northern Hemisphere glaciation (Gibbard et al., 2010).

CENOZOIC VERTEBRATE LOCALITIES

Eocene

Rubio Peak Formation

Lucas (1983, p. 190, fig. 4) documented a cast of a brontothere lower jaw found by Mr. Charles Hutchins in 1961 along Turkey Creek northeast of Winston in the northern Black Range (Fig. 1, site 1). This fossil was almost certainly derived from rocks mapped as Rubio Peak Formation in this area by Hedlund (1977) and Woodard (1982), among others. The specimen Lucas (1983) illustrated was a plaster cast; however, the original fossil was later donated to the collection of the New Mexico Museum of Natural History and Science, catalogued as NMMNH P-3051 (Fig. 3). Lucas (1983) identified the lower jaw as *Duchesneodus* sp., noting that in morphology and metrics (note especially the relatively small canines and molariform premolars) it is very similar to *D. uintensis*. Based on a subsequent revision of the taxonomy of *Duchesneodus* (Lucas and Schoch, 1989) we assign this jaw to *D. uintensis*.

Duchesneodus uintensis is an index fossil of the Duchesnean NALMA, so it identifies a Duchesnean age horizon in the Rubio Peak Formation. The age of the Duchesnean is ~ 37-40 Ma (Robinson et al., 2004), and given other age data on the Rubio Peak Formation, we suspect the Duchesnean horizon is late in the NALMA, close to 37 Ma. The jaw of *D. uintensis* from the Rubio Peak Formation is the oldest fossil mammal known from Sierra County.

Lucas (1986a, b) reported a small assemblage of early Chadronian fossil mammals from the Rubio Peak Formation on the northern flank of Turkey Creek in the Black Range (Fig. 1, site 1)—the rodent *Jaywilsonomys ojinagaensis*, a large perissodactyl (possibly a brontothere), a possible hypertragulid artiodactyl, and the oromerycid *Montanatylopus matthewi*. These are mammals of early Chadronian age, best correlated to the interval Prothero and Emry (2004) termed late early Chadronian, ~ 35.7-36.5 Ma. These mammal fossils must be stratigraphically higher than the *Duchesneodus* jaw from the Rubio Peak Formation. Their estimated numerical age is consistent with an $^{40}Ar/^{39}Ar$ age of 35.3 Ma on the Kneeling Nun Tuff (McIntosh et al., 1991, 1992), which immediately overlies the Rubio Peak Formation in the northern Black Range.

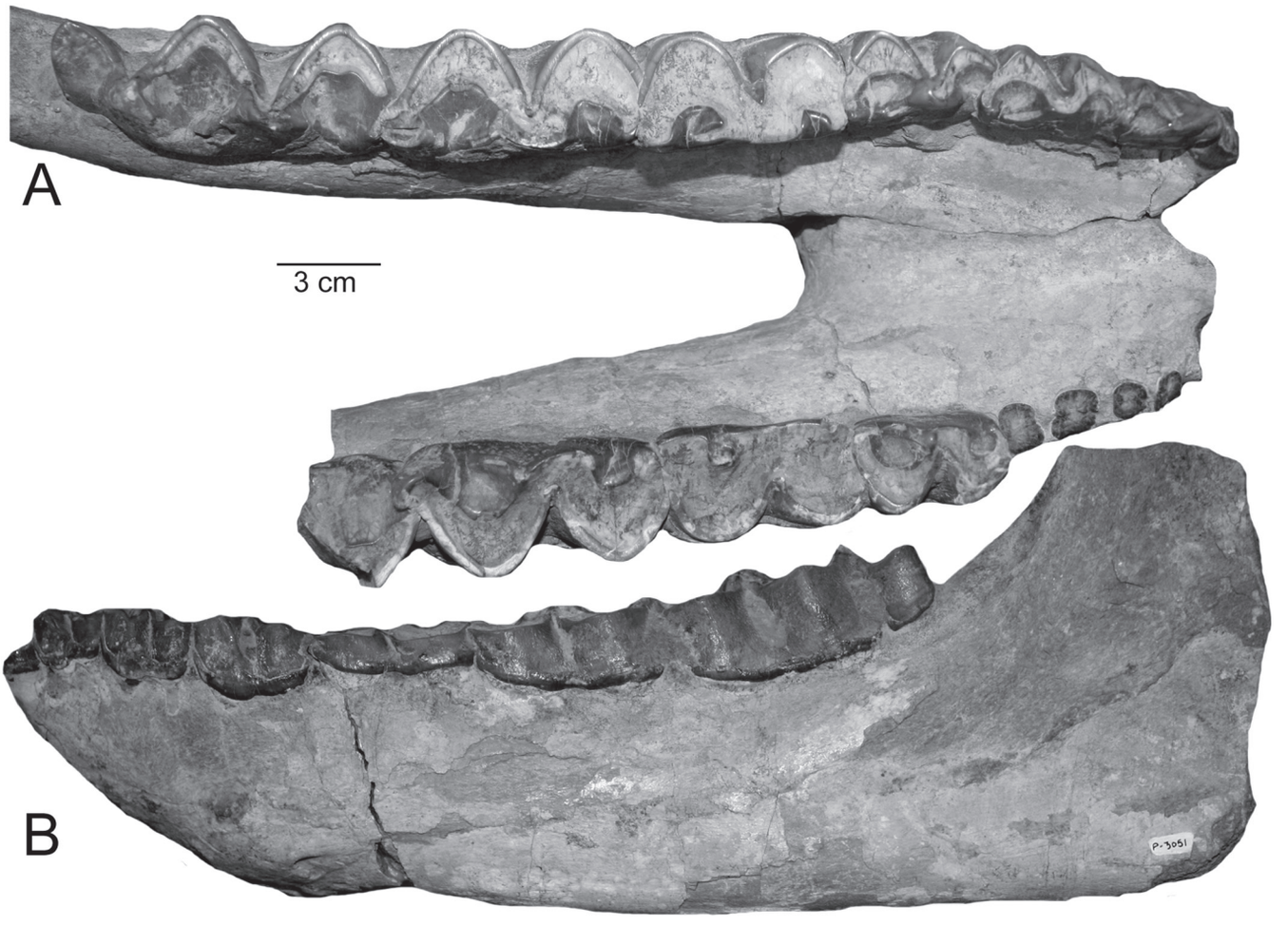

FIGURE 3. NMMNH 3051, lower jaw of *Duchesneodus uintensis* from the Rubio Peak Formation in the northern Black Range, in occlusal **(A)** and left lateral **(B)** views. Scale bar is 3cm.

Palm Park Formation

Lucas and Williamson (1993, p. 150-151, figs. 11-13) briefly documented Chadronian fossil vertebrates from the upper part of the Palm Park Formation in the Apache Valley of the southern Caballo Mountains (Fig. 1, site 2). These were tortoise fossils plus the hyaenodontid creodont *Hyaenodon horridus* and the small rhinoceros cf. *Hyracodon* sp. Lucas et al. (1997) reported the horse *Mesohippus* cf. *M. texanus* and Lucas and Spielmann (2012) added the oreodont *Merycoidodon presidioensis* to the Palm Park fossil assemblage. The Palm Park mammals are, within biochronological resolution, the same age as the Chadronian mammals from the Rubio Peak Formation, late early Chadronian, ~ 35.7-36.5 Ma (Prothero and Emry, 2004). This numerical age is consistent with an $^{40}Ar/^{39}Ar$ date of 35.7 Ma on a tuff within the Bell Top Formation overlying the Palm Park fauna (McIntosh et al., 1991, 1992). It is noteworthy that the Palm Park and Rubio Peak Chadronian faunas share no species of mammals, even though biochronology and associated radioisotopic dates indicate they are very similar in age.

Oligocene

Seventyfour Draw

Clarence Watson collected fossils of two species of oreodonts, primitive non-ruminant artiodactyls (Mammalia: Artiodactyla: Oreodontidae), in 1974 from the western slope of the Black Range in the northwestern corner of Sierra County (Fig. 1, site 3). The oreodont site, designated the Seventyfour Draw LF (Morgan and Lucas, 2003a), is located several hundred meters south of Seventyfour Draw in the Taylor Creek drainage, just west of the Continental Divide in northwestern Sierra County at an elevation of 2,340 m. These same oreodont specimens were first reported by Tedford (1981) who thought they were derived from Gila Group strata of lower Miocene age. However, more recent geologic work in this region indicates that the oreodont-bearing strata unconformably underlie Gila Group strata, and are Oligocene in age (Eggleston, 1987). The oreodont fossils are among the very few Oligocene vertebrates recorded from New Mexico.

Tedford (1981) tentatively referred the specimens from the Seventyfour Draw site to the very large oreodont *Promerycochoerus carrikeri*, a species typical of early Miocene (late Arikareean NALMA) faunas. However, Morgan and Lucas (2003a) determined that the Seventyfour Draw oreodont fossils belonged to two different taxa, *Desmatochoerus* cf. *D. megalodon* and *Megoreodon* cf. *M. grandis*, both species typical of late Oligocene (early Arikareean) faunas. Specimens of *D. megalodon* from Seventyfour Draw are an adult lower jaw with broken teeth and a juvenile maxilla with three deciduous premolars and a partial upper first molar (Fig. 4A). Several associated postcranial elements, including a partial scapula, radius (Figs. 4E, 4F), partial ulna, partial femur, tibia (Figs. 4C, 4D), astragalus (Fig. 4B), calcaneum, cuboid, and navicular, are much larger than comparable elements of *D. megalodon*, and were identified as the larger species *Megoreodon grandis* (Morgan and Lucas, 2003a). These two oreodonts were assigned to different genera and species in a review of the Oreodontidae (Lander, 1998): *Desmatochoerus megalodon* was referred to *Eporeodon occidentalis* and *Megoreodon grandis* to *Merycochoerus superbus*. However, in a more recent review of the oreodonts, Stevens and Stevens (2007) recognized *Desmatochoerus megalodon* and *Megoreodon grandis* as valid taxa.

Desmatochoerus megalodon and *Megoreodon grandis* are best known from the lower part of the Arikaree Group in the northern Great Plains of Nebraska, Wyoming, and South Dakota (Tedford et al., 1996). The specimens of *D.* cf. *D. megalodon* and *M.* cf. *M. grandis* from the Black Range of New Mexico represent the southernmost occurrences of these two oreodonts. Strata from the lower Arikaree Group of the northern Great Plains, including the correlative Gering and Sharps formations and the overlying Monroe Creek Formation, produce the typical early Arikareean faunas (late Oligocene; Tedford et al., 2004). *D. megalodon* has its lowest occurrence at about 29 Ma and its highest occurrence near the end of the early Arikareean at about 26 Ma (Tedford et al., 1996). *M. grandis* first appears slightly later in time at about 28 Ma, and also has its highest stratigraphic occurrence in the late early Arikareean (Tedford et al., 1996). Biostratigraphic and magnetostratigraphic data establish an age range between 26 and 28 Ma (early Arikareean) for the co-occurrence of *D. megalodon* and *M. grandis* in the northern Great Plains (Tedford et al., 1996; 2004).

The Seventyfour Draw LF occurs in the Taylor Creek district in the western Black Range, an area dominated by Oligocene volcanic rocks (Eggleston, 1987; McIntosh et al., 1991). The oreodonts were collected from volcaniclastic strata consisting of thick beds of trough-crossbedded sandstone and thinner beds of conglomerate. Eggleston (1987) informally termed this unit the "Sandstone of Inman Ranch" which consists of 100 m or more of tuffaceous sandstone, siltstone, and conglomerate. The "Sandstone of Inman Ranch" unconformably overlies the Taylor Creek Rhyolite that has $^{40}Ar/^{39}Ar$ dates of 27.97 ± 0.1 Ma and 28.23 ± 0.1 Ma, with an average age of 28.1 Ma, and is unconformably overlain by the Bearwallow Mountain Basaltic Andesite that has a K/Ar age of 26.1 Ma (McIntosh et al., 1991). The lower Miocene strata of the Gila Group unconformably overlie the Bearwallow Mountain Basaltic Andesite. Eggleston (1987) suggested that a tuff in the upper part of the "Sandstone of Inman Ranch" was equivalent to the South Canyon Tuff, which has an $^{40}Ar/^{39}Ar$ age of 27.23 Ma (McIntosh et al., 1991). These dates tightly constrain the age of the Seventyfour Draw LF to between 26.1 and 28.2 Ma, with the closest age for the oreodonts probably in the vicinity of 27 Ma. The radioisotopic dates from southwestern New Mexico compare very closely with the early Arikareean age (26-28 Ma) indicated by the biostratigraphy and magnetostratigraphy of the oreodonts *Desmatochoerus megalodon* and *Megoreodon grandis* from the northern Great Plains (Tedford et al., 1996).

Pliocene and Early Pleistocene

There are seven late Pliocene and early Pleistocene (Blancan NALMA; ~ 2.0-3.6 Ma) vertebrate faunas from Sierra County.

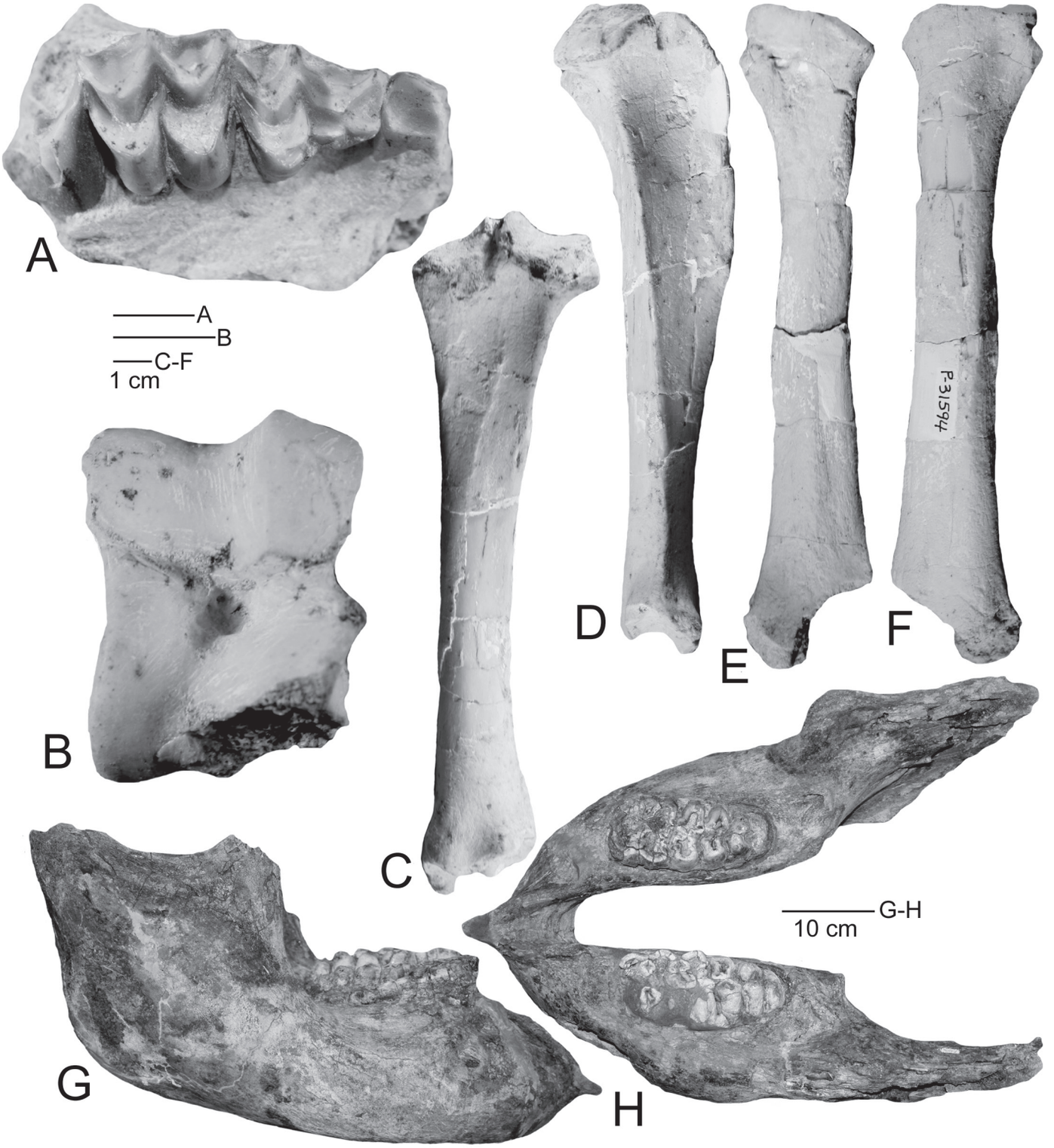

FIGURE 4. Selected Oligocene and Pliocene vertebrate fossils from Sierra County. A-F. Seventyfour Draw Local Fauna, late Oligocene (early Arikareean). **A.** *Desmatochoerus* cf. *D. megalodon*, NMMNH 31593, occlusal view of juvenile right maxillary fragment with deciduous premolars 2-4 (DP2-DP4) and partial first molar (M1). **B-F.** *Megoreodon* cf. *M. grandis*, NMMNH 31594. **B.** right astragalus; **C.** posterior view and **D.** lateral view of right tibia; **E.** posterior view and **F.** anterior view of right radius. NMMNH 46496, right and left mandibles of *Stegomastodon primitivus* in right lateral **(G)** and occlusal **(H)** views, from South Monticello Point, Elephant Butte Lake Fauna, late Pliocene (early Blancan). Scale bars are 1 cm for A-F and 10 cm for G-H.

These faunas are derived from about 50 NMMNH and AMNH fossil sites in the Palomas Formation in the Rio Grande Valley near Elephant Butte Lake and Caballo Lake (Fig. 1, sites 4-10). The three northernmost faunas, Elephant Butte Lake, Cuchillo Negro Creek, and Truth or Consequences, are located in the Engle basin, whereas the four southernmost faunas, Williamsburg, Palomas Creek, Kelly Canyon, and Caballo, are located in the Palomas basin. The Williamsburg-Mud Springs fault, which follows Mud Springs Canyon at the northwestern end of Caballo Lake, forms the boundary between the Engle and Palomas basins (Seager and Mack, 2003). The fossils from the Engle and Palomas basins were collected from a fairly narrow north-south-trending outcrop belt of the Palomas Formation less than 10 km in breadth, following the course of the modern Rio Grande Valley from South Monticello Point, about halfway along the western shore of Elephant Butte Lake, south to Caballo, about halfway along the western shore of Caballo Lake, a distance of about 40 km (Fig. 1).

The Palomas Formation encompasses all Pliocene and lower Pleistocene basin-fill deposits of the Santa Fe Group cropping out in the southern Rio Grande rift in the Socorro and San Marcial basins in Socorro County and the Engle and Palomas basins in Sierra County (Lozinsky, 1986; Lozinsky and Hawley, 1986a, b). The lithology of the Palomas Formation consists of a variety of fanglomerates, conglomerates, sandstones, siltstones, and mudstones. Conglomerates, fanglomerates, and siltstones are characteristic alluvial fan deposits of the piedmont facies of the Palomas Formation, whereas gravels and sandstones with infrequent interbedded mudstones are typical of the axial-river facies (Lozinsky and Hawley, 1986a, b). The localities for the seven Blancan faunas in Sierra County are mostly derived from ancestral Rio Grande fluvial deposits, including sands and gravels with scattered lenses of clay and conglomerates of the axial-river facies of the Palomas Formation. Figure 5 is a correlation chart showing the stratigraphic relationships of the seven Blancan faunas from the Palomas Formation in Sierra County, and their relationship to the North American land-mammal "ages" (NALMA), magnetic chrons of the Geomagnetic Polarity Time Scale (GPTS) and to several associated radioisotopic dates.

Elephant Butte Lake Fauna

The Elephant Butte Lake Fauna (Fig. 1, site 4) includes late Pliocene (late early Blancan) vertebrates from the axial-river facies of the Palomas Formation in the Engle basin on the western side of Elephant Butte Lake, from South Monticello Point south to Horse Island and west to Interstate Highway 25, and on the eastern side of Elephant Butte Lake north of Kettle Top Butte. Pliocene vertebrate fossils were first found in this area in the late 1920s by Joseph Rak and Charles Falkenbach of the Frick Laboratory at the American Museum of Natural History in New York. They collected from two general localities in the area of Hot Springs (now known as Truth or Consequences), New Mexico: "Hot Springs Lake, NM" and "2½ miles south of Hot Springs, NM." Although the precise localities and stratigraphy of the fossils collected by Rak and Falkenbach are not known, they were certainly derived from the Palomas Formation. Tedford (1981) reported Pliocene vertebrates from the vicinity of Elephant Butte Lake based on specimens in the Frick Collection, including the horse *Equus simplicidens*, the tapir *Tapirus*, and the giant camel *Gigantocamelus*. Beginning in 1978 and continuing to the present, additional fossils referable to the Elephant Butte Lake Fauna have been collected from numerous localities near Elephant Butte Lake by field crews from the NMMNH, New Mexico Bureau of Geology and Mineral Resources (NMBGMR), U. S. Bureau of Reclamation (BOR), and University of New Mexico (UNM). Morgan and Lucas (2003b) and Morgan et al. (2011) updated the Elephant Butte Lake Fauna based on these more recent collections.

The NMMNH collection from the Elephant Butte Lake Fauna contains several well-preserved specimens of the early Blancan species of the straight-tusked gomphothere *Stegomastodon primitivus* (Proboscidea; Gomphotheriidae): a nearly complete skull from Yaple Canyon, a pair of mandibles from South Monticello Point (Figs. 4G, 4H), and juvenile mandibles from Rock Canyon and Hot Springs Landing. Other key fossils from the western shore of Elephant Butte Lake include a nuchal bone of the giant land tortoise *Hesperotestudo* and a mandible and distal humerus of the giant camel *Gigantocamelus spatulus*. A lower jaw of the large horse *Equus scotti* from near Kettle Top Butte is the only fossil in either the AMNH or NMMNH from the eastern shore of Elephant Butte Lake. Although the mammalian assemblage from the Elephant Butte Lake Fauna is rather limited, *S. primitivus* is restricted to early Blancan faunas, *E. simplicidens* and *G. spatulus* are indicative of a Blancan age, and *E. scotti* is known from late early Blancan and younger faunas in the Southwest. The association of *S. primitivus* and *E. scotti* is indicative of late early Blancan (~ 3.0-3.6 Ma) faunas in New Mexico (Morgan et al., 2011).

Tedford (1981) considered the Elephant Butte Lake Fauna to be medial Blancan in age (= late early Blancan of current usage) because of the close stratigraphic association of the fossils with a basalt flow K/Ar dated at 2.9 ± 0.3 Ma from Mitchell Point at the northwestern corner of Elephant Butte Lake (Bachman and Mehnert, 1978). The Mitchell Point basalt is interbedded with sands and gravels referred to the axial-river facies of the Palomas Formation (Lozinsky and Hawley, 1986b). The Elephant Butte Lake Fauna occurs in the same general stratigraphic interval of the Palomas Formation as the Cuchillo Negro Creek LF (see below), which is closely associated with the Mud Springs pumice dated at 3.1 Ma (Mack et al., 2009). The stratigraphic relationship with the 3.1 Ma Mud Springs pumice and 2.9 Ma Mitchell Point basalt, as well as the co-occurrence of *S. primitivus* and *E. scotti*, indicate a late early Blancan age (late Pliocene; ~ 3.0-3.3 Ma) for the Elephant Butte Lake Fauna (Morgan et al., 2011).

Cuchillo Negro Creek Local Fauna

Lucas and Oakes (1986) named the Cuchillo Negro Creek LF (Fig. 1, site 5) for a series of about 15 sites that produced Blancan vertebrate fossils from the Palomas Formation in the Engle basin, north of Cuchillo Negro Creek and west of Interstate Highway 25, about 4 km north of Truth or Consequences in Sierra

County. These fossils were collected in 1983 and 1984 by UNM field crews. More recent collections between 1998 and 2007 by the NMMNH have increased to about 25 the number of sites comprising the Cuchillo Negro Creek LF (Morgan et al., 2011). The two informal members of the Palomas Formation are both represented in the area where the Cuchillo Negro Creek LF was collected. Most of the fossils were derived from the axial-river facies deposited by the ancestral Rio Grande, consisting of lenses of gravel and coarse sand, whereas a few specimens, including a partial tortoise shell and several associated horse teeth, were collected from the piedmont facies consisting primarily of sandy siltstone (Lucas and Oakes, 1986; Morgan et al., 2011). The lithology and stratigraphic relationships of the sediments containing the Cuchillo Negro Creek LF are very similar to the strata that produced the Elephant Butte Lake Fauna. This is not surprising considering these two faunas are contiguous, with the Elephant Butte Lake Fauna located just to the east of the Cuchillo Negro Creek LF, between Interstate Highway 25 and Elephant Butte Lake (Fig. 1). Lucas and Oakes (1986) proposed a "medial" or late early Blancan age (about 3.0 Ma) for the Cuchillo Negro Creek LF, based on biostratigraphy and correlation with the 2.9 Ma Mitchell Point basalt.

The Cuchillo Negro Creek LF is composed of 12 species (Lucas and Oakes, 1986; Morgan and Lucas, 2003b; Morgan et al., 2011): four turtles, including two tortoises of the genus *Hesperotestudo*; the mud turtle *Kinosternon*; and an aquatic member of the Emydidae; and eight mammals, the borophagine canid *Borophagus hilli*; the ringtail *Bassariscus* sp.; the horses *Equus scotti* and *E. simplicidens*; three camels, *Blancocamelus meadei*, *Camelops* cf. *C. traviswhitei*, and *Hemiauchenia blancoensis*; and the gomphothere *Stegomastodon primitivus*. Key fossils for establishing the biochronology of the Cuchillo Negro Creek LF are lower jaws of *B. hilli* and *S. primitivus*, associated upper teeth of *E. scotti* and *E. simplicidens*, a complete radius-ulna of *B. meadei*, and several specimens tentatively identified as *C. traviswhitei*. The genus *Camelops* supposedly did not appear until after 3.6 Ma (Lindsay et al., 1984) and *S. primitivus* is limited to early Blancan faunas (~ 3-4 Ma; Morgan and Lucas, 2011). The presence of *B. hilli* also supports an early Blancan age, as this species is restricted to latest Hemphillian and early Blancan faunas (Wang et al., 1999). *E. simplicidens* occurs in early Blancan and early late Blancan faunas (~ 2.6-4.0 Ma) in New Mexico, whereas *E. scotti* is known from late early Blancan through early Irvingtonian faunas in the Southwest. The absence of South American immigrant mammals indicates a pre-late Blancan age (older than 3 Ma). The Mud Springs pumice bed occurs about 3-4 km southwest of the outcrops that produce the Cuchillo Negro Creek LF and within the same stratigraphic interval of the Palomas Formation (Mack et al., 2009) (Fig. 6). The Mud Springs pumice was geochemically correlated with the Hatch Siphon pumice with an $^{40}Ar/^{39}Ar$ age of 3.12 ± 0.03 Ma (Mack et al., 1996; 2009). The association with the 3.1 Ma Mud Springs pumice, the co-occurrence of *S. primitivus*, *B. hilli,* and *E. scotti*, and the absence of Interchange mammals, tightly constrains the age of the Cuchillo Negro Creek LF to between 3.1 and 3.3 Ma (Fig. 5).

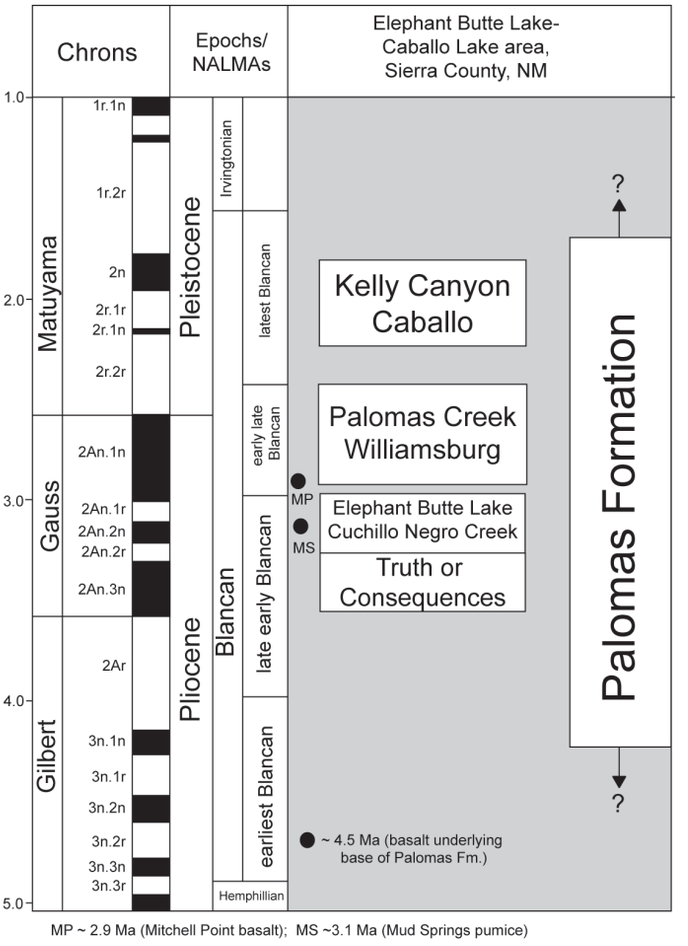

FIGURE 5. Chart showing the stratigraphic relationships of the seven Blancan vertebrate faunas from the Palomas Formation in Sierra County, New Mexico, and their correlation to the North American land-mammal "ages" (NALMA), magnetic chrons of the Geomagnetic Polarity Time Scale (GPTS) and to several associated radioisotopic dates.

Truth or Consequences Local Fauna

The Truth or Consequences LF (Fig. 1, site 6) occurs in a road-cut on Interstate 25 about 1 km west of Truth or Consequences in Sierra County in the southernmost portion of the Engle basin. The site was discovered by Arthur Harris of the University of Texas at El Paso (UTEP) and then worked in the early 1980s by Charles Repenning and a field crew from the U.S. Geological Survey in Denver (Repenning and May, 1986). NMMNH field crews began excavating and screenwashing the Truth or Consequences site in 1997 and continue to work there. Fossils from the Truth or Consequences LF are housed in the NMMNH, USGS-D, and UTEP. The stratigraphic section of the Palomas Formation that includes the Truth or Consequences LF is composed of about 25 m of poorly consolidated sand and pebbly sand, with two interbedded mudstone layers about 1 m in thickness in the bottom third of the outcrop (Fig. 6). The fossils occur primarily in the mudstones, including numerous mandibles and maxillae and hundreds of isolated teeth and postcrania of small mammals and a few specimens of larger mammals. A 0.5 m thick greenish, silty sand just below

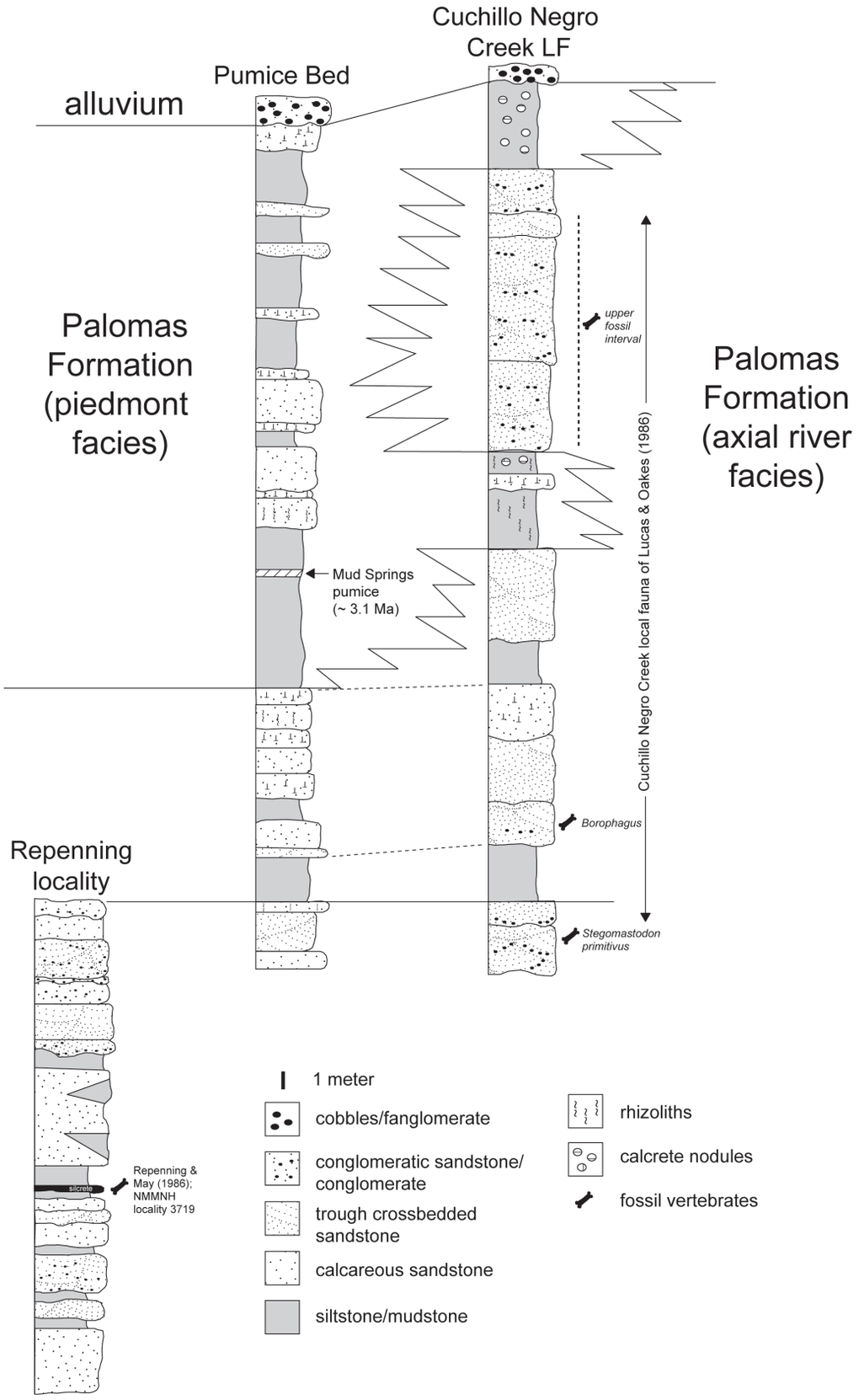

FIGURE 6. Measured stratigraphic sections of the Palomas Formation at the Truth or Consequences LF (left), Mud Springs pumice bed (middle) and Cuchillo Negro Creek LF (right). From Morgan et al. (2011).

the lower of the two mudstones contains mostly aquatic species, including fish, several partial shells of turtles, and several species of birds.

The Truth or Consequences LF, as originally described by Repenning and May (1986), consisted of 13 species: four reptiles, the mud turtle *Kinosternon*, the box turtle *Terrapene*, the fence lizard *Sceloporus*, and the coachwhip snake *Masticophis*; and nine mammals: the rabbits *Hypolagus vetus* and *Notolagus lepusculus*; the rodents *Geomys minor*, *Sigmodon medius*, cf. *Oryzomys* sp. and *Neotoma quadriplicata*; the horse *Equus simplicidens*; the deer *Odocoileus*; and the gomphothere *Stegomastodon*. Morgan et al. (2011) more than doubled the vertebrate faunal list from the Truth or Consequences LF, adding several species of small fish, at least one and possibly two species of aquatic emydid turtles, another snake, two species of bird, and eight mammals. Morgan et al. (2011) identified five large mammals that were not included in the original faunal list from this site, all of which are typical of Blancan faunas: the megalonychid ground sloth *Megalonyx leptostomus*, the canid *Borophagus* cf. *B. hilli*, the coyote-like canid *Canis* cf. *C. lepophagus*, the large peccary *Platygonus bicalcaratus* and the small antilocaprid *Capromeryx tauntonensis*. Morgan et al. (2011) also added a shrew (Soricidae), the mole *Scalopus*, a small sciurid, and the small cricetid rodent *Jacobsomys* (identified as *Oryzomys* by Repenning and May, 1986). The Truth or Consequences LF thus has more than 25 species, including 17 mammals, making it one of the most diverse Blancan vertebrate faunas from New Mexico (Morgan and Lucas, 2003b; Morgan et al., 2011).

Many of the mammals from the Truth or Consequences LF are diagnostic of the Blancan, several of which suggest an early Blancan age. The small rabbit *Notolagus lepusculus* is typical of early Blancan faunas and the larger rabbit *Hypolagus vetus* is known from the Hemphillian through the early Blancan (White, 1987, 1991). The pocket gopher *Geomys* (*Nerterogeomys*) *minor* and the primitive wood rat *Neotoma* (*Paraneotoma*) *quadriplicata* are also characteristic of early Blancan faunas. A small sigmodontine rodent from Truth or Consequences is similar to the extinct genus *Jacobsomys* from the early Blancan Verde LF in Arizona (Czaplewski, 1987). A lower jaw of *Capromeryx* appears to be referable to *C. tauntonensis*, the oldest species in the genus from the late early Blancan Taunton LF in Washington (Morgan and Morgan, 1995).

Repenning and May (1986) proposed a very early Blancan age (~ 4.0-4.2 Ma) for the Truth or Consequences LF based on biostratigraphy and magnetostratigraphy. They correlated the Truth or Consequences LF with the Nunivak Subchron of the Gilbert Chron (C3n.2n; 4.05-4.20 Ma) on the basis of paleomagnetic samples with normal polarity from three stratigraphic levels within the site. The age of the Nunivak has since been revised downward to 4.48-4.62 Ma (Berggren et al., 1995), which would place this fauna in the earliest Blancan. However, a basalt dated at 4.5 Ma that underlies the Palomas Formation (Seager et al., 1984), a nearby dated pumice of 3.1 Ma only slightly higher in the Palomas Formation (Mack et al., 2009), an alternative interpretation of the magnetostratigraphy, and mammalian biochronology all suggest a much younger late early Blancan age for the Truth or Consequences LF (Fig. 5). The 3.1 Ma Mud Springs pumice occurs about 3 km northwest of the Truth or Consequences LF (Mack et al., 2009), and only about 40 m higher in the local stratigraphic section of the Palomas Formation (Fig. 6). The normal polarity of the sediments from the Truth or Consequences section suggests correlation with the lowermost portion of the Gauss Chron (C2An.3n; 3.33-3.58 Ma). The mammals from the Truth or Consequences LF are most similar to late early Blancan faunas (~ 3.0-3.6 Ma) from Benson in Arizona, Rexroad in Kansas, and Hagerman in Idaho. An age range of ~ 3.3-3.6 Ma (late early Blancan) for the Truth or Consequences LF is well constrained by a date of 3.1 Ma on the overlying Mud Springs pumice, the normal polarity of all paleomagnetic samples, and the biostratigraphy of the fossil mammals (Fig. 5).

Williamsburg Local Fauna

The Williamsburg LF occurs in strata of the Palomas Formation exposed in a roadcut on Interstate Highway 25, several hundred meters south of Mud Springs Canyon and about 1 km north of the town of Williamsburg, Sierra County (Fig. 1, site 7). The Williamsburg LF was collected by NMMNH field crews between 2007 and 2011. The fossils are derived from a silty fine sand, indurated in places, about 3 m in thickness and located from 2-5 m above the base of the local section. The Williamsburg LF lacks associated radioisotopic dates or paleomagnetic stratigraphy, and the occurrence of this fauna in the Palomas basin just south of the Williamsburg-Mud Springs fault prevents lithostratigraphic correlation with somewhat older early Blancan faunas in the Engle basin north of this fault. Although the Williamsburg LF consists of only seven taxa of mammals, four species are diagnostic of Blancan faunas: the small mylodont ground sloth *Paramylodon* cf. *P. garbanii*, the pocket gopher *Geomys paenebursarius*, the cotton rat *Sigmodon medius*, and the dwarf three-toed horse *Nannippus peninsulatus*. The youngest occurrence of *Nannippus* in New Mexico and Arizona is in the early late Blancan in sediments from the uppermost Gauss Chron (~ 2.6-3.0 Ma; Morgan et al., 2008a). Mammals of South American origin involved in the late Pliocene and early Pleistocene phase of the Great American Biotic Interchange (GABI), including *Paramylodon*, first appeared in the southwestern United States in the early late Blancan at about 3.0 Ma or shortly thereafter. The co-occurrence of *Paramylodon* and *Nannippus* constrains the age of the Williamsburg LF to the early late Blancan (latest Pliocene; 2.6-3.0 Ma; Fig. 5).

Palomas Creek Fauna

The Palomas Creek Fauna is derived from exposures of the Palomas Formation in Palomas Creek, northwest of the village of Las Palomas at the northwestern end of Caballo Lake, about 8-10 km southwest of Truth or Consequences in southern Sierra County (Fig. 1, site 8). Joseph Rak and Charles Falkenbach of the Frick Laboratory collected fossil vertebrates in the late 1920s from the Palomas Formation at a site they called “Las Palomas Creek, 7 miles south of Hot Springs, NM.” Morgan and Lucas

(2003b) and Morgan et al. (2011) called this fauna Palomas Creek. A magnetostratigraphic section in Palomas Creek included about 10 m of normally magnetized sediments at the bottom of the section, referred to the upper Gauss Chron (2An.1n; 2.58-3.04 Ma) (Mack et al., 1993).

Tedford (1981) reported a Blancan mammalian fauna from Palomas Creek composed of eight species: the rodents *Geomys* and *Sigmodon*, the horses *Nannippus*, *Equus simplicidens*, and *E.* cf. *E. cumminsii*, a peccary, a camel, and the mastodon *Mammut raki*. More recent field work by the NMMNH has added the tortoise *Hesperotestudo* and the ground sloth *Megalonyx leptostomus* to the Palomas Creek Fauna, and the two rodents have been identified to species, *Geomys paenebursarius* and *Sigmodon medius* (Morgan et al., 2011). *N. peninsulatus, E. simplicidens*, and *E. cumminsii* are characteristic of New Mexico Blancan faunas, whereas the large camel *C. traviswhitei* and the rodents *G. paenebursarius* and *S. medius* are typical of late early and late Blancan faunas in New Mexico and Arizona. The presence of *Nannippus*, which does not occur above the Gauss/Matuyama boundary in New Mexico and Arizona, strongly suggests the Palomas Creek Fauna was collected from the lower 10 m of the Palomas section in strata from the upper Gauss Chron. The combination of magnetostratigraphy and biostratigraphy indicates an early late Blancan (~ 2.6-3.0 Ma) age for the Palomas Creek Fauna (Fig. 5).

Kelly Canyon Local Fauna

The Kelly Canyon LF was collected from a roadcut in the Palomas Formation on U. S. Highway 85/NM State Highway 187, about 1 km west of Caballo Lake, 6 km south of Palomas Creek, and 5 km north of Caballo (Fig. 1, site 9; Morgan et al., 2011). The site was discovered by Michael Pasenko and a crew from the Environmental Planning Group in April 2010 and collected by NMMNH crews in May and September 2010. The fossils are derived from a 10-20 cm thick layer of light-colored diatomite and a correlated unit several cm thick consisting of greenish sandy silt and clay, both of which overlie a 3 m thick, unconsolidated sand at the base of the outcrop. Except for a few surface finds of bird bones, most of the fauna has been obtained by screenwashing the diatomite unit, which has produced a mostly freshwater microvertebrate fauna, including small fish, frogs, salamanders, snakes, birds, the woodrat *Neotoma*, and the extinct muskrat *Ondatra idahoensis*. The dominance of aquatic vertebrates in the Kelly Canyon LF, as well as the diatomite and other fine-grained sediments, point to a quiet, freshwater depositional environment such as a pond or lake. The only age-diagnostic mammal known from the fauna is *O. idahoensis*, which is indicative of late Blancan faunas. The presence of *O. idahoensis* and the geographic proximity and similar elevation of the Kelly Canyon LF to the Caballo fauna (see below), suggest a late Blancan age (~ 2.0-2.6 Ma).

Caballo Local Fauna

The Caballo LF is derived from about ten sites in the Palomas Formation near the village of Caballo, midway along the western shore of Caballo Lake about 16 km southwest of Truth or Consequences in southern Sierra County (Fig. 1, site 10; Morgan et al., 2011). NMMNH field crews collected the Caballo LF between 2007 and 2010, primarily from roadcuts along Interstate Highway 25 and U. S. Highway 85, from Seco Creek south to Las Animas Creek. Large land tortoises of the genus *Hesperotestudo* are among the most common members of the Caballo LF, including one nearly complete shell and several partial shells. The large mammal fauna from Caballo includes the glyptodont *Glyptotherium arizonae*, the horse *Equus scotti*, the camelid *Hemiauchenia*, the cervid *Navahoceros*, and the gomphothere *Stegomastodon*. Most of the large vertebrates from Caballo are found in both late Blancan and early Irvingtonian faunas in New Mexico and elsewhere in the southwestern United States, including *G. arizonae*, *E. scotti*, and *Stegomastodon*. However, the abundance of large land tortoises is more characteristic of New Mexico late Blancan faunas. Large individuals of *Hesperotestudo* became uncommon in New Mexico during the early Irvingtonian and disappeared after about 1 Ma. The absence of *Nannippus* and *Mammuthus* from the Caballo Fauna is also significant, indicating a latest Blancan age, younger than 2.6 Ma (disappearance of *Nannippus* in New Mexico) and older than 1.6 Ma (first appearance of *Mammuthus*, marking the beginning of the Irvingtonian NALMA).

Mack et al. (1993) analyzed the magnetostratigraphy of the Palomas Formation stratigraphic section in Las Animas Creek, located just south of an extensive roadcut on I-25 that has produced the largest sample of fossils of the Caballo LF. The Las Animas Creek and Palomas Creek (see above) magnetostratigraphic sections are similar, with a thin interval at the base referable to the upper Gauss Chron (2.58-3.04 Ma), overlain by a longer section of the Matuyama Chron (1.21-2.58 Ma). The vertebrate fossils from the Caballo LF occur in the middle of the section, above the Gauss/Matuyama boundary (2.58 Ma) and below the Olduvai subchron (1.95 Ma). The magnetostratigraphy indicates an age of ~2.0-2.6 Ma, which agrees with a late Blancan age from the biochronology (Fig. 5).

Late Pleistocene

Palomas Creek Cave

Harris (1985, 1993) reported a late Pleistocene (Rancholabrean) fauna from Palomas Creek Cave (UTEP site 82), located along the South Fork of Palomas Creek near the old mining town of Hermosa in the Black Range in western Sierra County (Fig. 1, site 11). Richard Smartt excavated and screenwashed cave sediments from several test pits in Palomas Creek Cave during the 1980s and 1990s; however, the diverse small vertebrate fauna is mostly unpublished. Harris (1985, 1993) listed four small mammals from Palomas Creek Cave, the pocket gopher *Thomomys bottae*, the bushy-tailed woodrat *Neotoma cinerea*, the vole *Microtus* cf. *M. longicaudus*, and the rabbit *Sylvilagus* cf. *S. floridanus*, as well as three large mammals, the swift fox *Vulpes* cf. *V. velox*, the horse *Equus* sp., and the mountain sheep *Ovis canadensis*. No radiocarbon dates are available from Palomas Creek Cave. The fauna is late Pleistocene in age based on the

presence of an extinct species of *Equus* and *Neotoma cinerea*, an extralimital species now restricted in New Mexico to the Sangre de Cristo, Jemez, and San Juan Mountains in the northern part of the state (Findley et al., 1975). Fossils from Palomas Creek Cave are housed in the NMMNH and UTEP collections.

Salt Creek

In the past five years, Dave Love and Bruce Allen of the NMBGMR and Robert Myers of the White Sands Missile Range (WSMR) have discovered several new late Pleistocene sites along Salt Creek on the WSMR in easternmost Sierra County, about 25-30 km north of the Alkali Spring sites (Fig. 1, site 12; Love et al., 2011; in press). The highest fossiliferous unit in the local stratigraphic section along the incised banks of Salt Creek is a gypsum marsh deposit ranging up to nearly 3 m in thickness. This unit contains an aquatic vertebrate fauna consisting of fish and amphibians, as well as gastropods, ostracodes, and foraminifera. Radiocarbon ages on organic matter from the gypsum marsh deposit range from 10,900 ^{14}C years Before Present (yr BP) at the base to 10,130 yr BP near the top (Love et al., 2011, in press). Several fragmentary bones of the horse *Equus* and an astragalus of the muskrat *Ondatra* were collected from grayish-green, fine-grained alluvial deposits about 1-2 m below the gypsum marsh deposits. Love and Dan Koning collected a nearly complete humerus of the large camel *Camelops hesternus* from a pebble-gravel channel, also beneath the gypsum marsh. Underlying the pebble-gravel channel, near the base of the exposures along Salt Creek, is a brown to gray, fine-grained alluvium, the top of which contains tracks similar to the proboscidean and camel trackways from the shores of Pleistocene Lake Otero in the Alkali Flat area discussed below. Love and Allen also observed large mammal tracks in Pleistocene basin fill deposits exposed in blowouts in the Salt Creek area (Love et al., in prep.). A basin-fill deposit along Salt Creek contained two partial proboscidean tusks, probably the Columbian mammoth, *Mammuthus columbi*. All vertebrate fossils from the Salt Creek sites on the WSMR are housed in the NMMNH.

Alkali Spring and Alkali Flat

Morgan and Lucas (2002) described the late Pleistocene (Rancholabrean) Lake Otero Fauna from 12 sites on the WSMR in southeastern Sierra County and northeastern Doña Ana County. Nine of these sites are located near Alkali Spring in Sierra County (Fig. 1, site 13), occurring in a series of lacustrine and fluvio-deltaic deposits of the Otero Formation (Lucas and Hawley, 2002; Allen et al., 2009). Coarse sands and gravels representing fluvio-deltaic deposits high in the Otero Formation have produced a scapula of the large horse *Equus occidentalis* and a scapula of the large extinct llama *Camelops hesternus*. Several partial teeth and tusks of the Columbian mammoth *Mammuthus columbi* and a lower jaw with two teeth of *E. occidentalis* were recovered from fine-grained, gypsiferous lake deposits somewhat lower in the Otero Formation section near Alkali Spring (Morgan and Lucas, 2002). The Lake Otero Fauna has also produced an abundant fauna of mammal tracks, in particular several trackways of a large proboscidean, probably mammoth, but also including camel tracks (Lucas et al., 2002, 2007; Allen et al., 2006). The mammal tracks are found primarily in fine-grained, gypsiferous lake sediments in the Alkali Flat area on the WSMR and White Sands National Monument (WSNM) in Doña Ana County. However, in 2007, GSM and Dave Love observed and measured two mammoth trackways, one with 14 tracks and the second with six tracks, from the northern extent of Alkali Flat in the southeastern corner of Sierra County (Fig. 1, site 14). Radiocarbon dates from plant fragments associated with the mammoth tracksites range from 31,020 to 31,640 yr BP, whereas radiocarbon dates from ostracodes, plant fragments, and charcoal from deposits overlying the tracksites range from 19,430 to 22,800 yr BP (Lucas et al., 2007; Allen et al., 2009).

DISCUSSION

Eocene sedimentary rocks have a very limited outcrop area in Sierra County. Late Eocene vertebrates are known from two widely separated areas, the Rubio Peak Formation in the northern Black Range in northwestern Sierra County and the Palm Park Formation in the southern Caballo Mountains in the south-central region of the county (Lucas, 1983, 1986a,b; Lucas and Williamson, 1993; Lucas et al., 1997; Lucas and Spielmann, 2012) (Fig. 1). A single Duchesnean mammal, the brontothere *Duchesneodus uintensis*, from the Rubio Peak Formation in the northern Black Range, indicates an age of about 37 Ma, although possibly as old as 40 Ma. This same brontothere has been identified in Duchesnean faunas from the Galisteo Formation in Sandoval and Santa Fe counties in north-central New Mexico (Lucas, 1982). The Rubio Peak Formation and the Palm Park Formation also contain somewhat younger latest Eocene (Chadronian) mammals, and have associated radioisotopic dates of 35-36 Ma (McIntosh et al., 1991, 1992). Even though the Rubio Peak and Palm Park Chadronian faunas are separated by 75 km and several mountain ranges, the biochronology of the fossil mammals, radioisotopic dates, volcaniclastic lithology, and stratigraphic position suggest a similar early Chadronian age of between 35 and 37 Ma (Lucas and Williamson, 1993). The only other possible Chadronian fauna from New Mexico consists of a partial skeleton of a primitive artiodactyl from the Palm Park Formation in the Robledo Mountains in Doña Ana County, located about 50 km southeast of the Palm Park Formation outcrops in the southern Caballo Mountains (Lucas and Williamson, 1993).

The Seventyfour Draw LF in the Black Range in northwestern Sierra County is one of only two Oligocene vertebrate faunas known from New Mexico. The two large oreodonts identified from Seventyfour Draw, *Desmatochoerus* cf. *D. megalodon* and *Megoreodon* cf. *M. grandis*, occur in a volcaniclastic sandstone bracketed by radioisotopic dates of about 26 and 28 Ma. This is very similar to the age of these oreodonts in the northern Great Plains based on biostratigraphy and magnetostratigraphy (Tedford et al., 1996; 2004). The only other Oligocene vertebrate fossils known from New Mexico are artiodactyl tracks from a volca-

niclastic unit in the San Mateo Mountains in Socorro County, just north of Sierra County (Ferguson, 1986; Lucas, 2001).

Miocene (5.3-23.0 Ma) sedimentary rocks are not exposed in Sierra County, although Miocene strata are found in adjacent Socorro County to the north and Doña Ana County to the south. The Miocene Popotosa Formation, widely distributed in Socorro County, has produced a skeleton of the oreodont *Merychyus major* from the Bosque del Apache National Wildlife Refuge (Morgan et al., 2009b). Biostratigraphy and an $^{40}Ar/^{39}Ar$ date of 8.57 Ma on a basalt flow in the Popotosa Formation overlying the oreodont skeleton indicate a late Miocene age (late Clarendonian NALMA; ~ 9-10 Ma). Miocene strata of the Rincon Valley Formation in northern Doña Ana County have yielded a carpal element of the Miocene rhinoceros *Teleoceras* from the vicinity of Tonuco Mountain (Morgan et al., 1998). The similarity of this fossil to the late Miocene rhino *Teleoceras fossiger* and a K/Ar date of 9.6 Ma for the Selden Basalt Member of the Rincon Valley Formation (Seager et al., 1984) indicate a late Miocene age (late Clarendonian or early Hemphillian NALMA; ~ 7-10 Ma).

There is a hiatus of more than 20 million years between the late Oligocene Seventyfour Draw LF (~ 27 Ma) and the next oldest vertebrate faunas from Sierra County of late Pliocene age (~ 3.5 Ma). The Blancan faunas in the Rio Grande Valley in Sierra County are probably a result of the integration of the Rio Grande throughout much of New Mexico by early Pliocene time, followed by the extensive deposition and accumulation of sediments during the Pliocene and lower Pleistocene (Mack et al., 1997, 1998; Morgan and Lucas, 2003b). Blancan faunas from the Palomas Formation in Sierra County can be subdivided into two groups based on their slightly different ages. The three northern faunas from the Engle basin, Cuchillo Negro Creek, Elephant Butte Lake, and Truth or Consequences are older, late Pliocene in age (late early Blancan; ~ 3.0-3.6 Ma). Biostratigraphic characteristics of these faunas include: the presence of the borophagine canid *Borophagus hilli* and the gomphothere *Stegomastodon primitivus*, both of which went extinct in the early Blancan; presence of the horse *Equus scotti*, which first appeared in the latter part of the early Blancan; and absence of South American mammals typical of the Interchange, which first appeared about 3 Ma. An age range of ~ 3.0-3.3 Ma for the Cuchillo Negro Creek LF and the correlative Elephant Butte Lake Fauna is supported by the association of the former fauna with the 3.1 Ma Mud Springs pumice (Mack et al., 2009; Morgan et al., 2011). The small mammals from the Truth or Consequences LF, including the lagomorphs *Hypolagus vetus* and *Notolagus lepusculus* and the rodents *Geomys minor*, *Neotoma* cf. *N. fossilis*, and *Jacobsomys*, suggest a slightly older age. They are similar to small mammals from other southwestern early Blancan faunas such as Rexroad, Kansas and Benson, Duncan, and Verde in Arizona (Repenning and May, 1986; Tomida, 1987; Czaplewski, 1990). The biostratigraphy and stratigraphic occurrence of the fossils 40 m below the 3.1 Ma Mud Springs pumice suggest the Truth or Consequences LF, although also late early Blancan in age, is somewhat older (~ 3.3-3.6 Ma) than the Cuchillo Negro Creek and Elephant Butte Lake faunas.

The four Blancan faunas that occur south of the Williamsburg-Mud Springs fault in the Palomas basin are somewhat younger, ranging in age from latest Pliocene (early late Blancan, ~ 2.6-3.0 Ma) for the Williamsburg and Palomas Creek faunas to earliest Pleistocene (latest Blancan; ~2.0-2.6 Ma) for the Caballo and Kelly Canyon faunas. The Williamsburg LF documents the association of the ground *Paramylodon* cf. *P. garbanii*, a participant in the Interchange that appeared after 3 Ma, and the last hipparionine horse *Nannippus peninsulatus*, that became extinct in New Mexico and Arizona by ~ 2.6 Ma. The presence of *Nannippus* in Palomas Creek, together with the occurrence of this fauna in strata correlated with the uppermost Gauss Chron (2.58-3.04 Ma), suggest a close correlation with Williamsburg. The presence of the South American immigrant glyptodont *Glyptotherium arizonae*, the absence of *Nannippus*, and magnetostratigraphic data that correlate to the lower Matuyama chron (1.95-2.58 M) indicate an age of ~ 2.0-2.6 Ma for the Caballo LF. The occurrence of the extinct muskrat *Ondatra idahoensis* suggests a similar late Blancan age for the Kelley Canyon LF.

Axial river deposits of the Palomas Formation are known in Sierra County north of South Monticello Point, which is only 20 km south of the border with Socorro County, and south of Caballo, which is about 20 km north of the border with Doña Ana County, but have not yet produced vertebrate fossils. Plio-Pleistocene faunas derived from the Palomas Formation are known from Silver Canyon and Tiffany Canyon in southern Socorro County, as well as the late early Blancan Arroyo de la Parida LF from the northern part of the county (Morgan et al., 2008b). We have surveyed outcrops in southernmost Sierra County south of Caballo near Oasis in Percha Creek and Greenhorn Arroyo, mapped as the axial river facies of the Palomas Formation (Seager and Mack, 2003), but have not yet recovered vertebrate fossils in this area. The Camp Rice Formation in northern Doña Ana County has produced two late early Blancan faunas from 35-50 km southeast of the Caballo sites, the Hatch and Tonuco Mountain LFs (Morgan and Lucas, 2003b). These two faunas are similar in age to the late early Blancan Cuchillo Negro Creek and Truth or Consequences LFs from the Palomas Formation in Sierra County.

The trend of extensive Plio-Pleistocene fluvial deposition and preservation of Blancan faunas occurs throughout the Rio Grande Valley in New Mexico (Morgan and Lucas, 2003b), from the Albuquerque basin (Santo Domingo, Mountainview, Mesa del Sol, and Belen faunas) in Sandoval, Bernalillo, and Valencia counties, south through the Socorro basin in Socorro County (Arroyo de la Parida LF) to the Hatch-Rincon basin (Hatch LF), Jornada del Muerto basin (Tonuco Mountain LF), and Mesilla basin (Anapra and La Union faunas) in Doña Ana County in southernmost New Mexico. The Rio Grande aggraded from perhaps several hundred meters below its present level to roughly 100 m above its present level by about 850 ka ago (Connell et al., 2005). The river entrenched through its own older deposits during the past 850 ka, exposing the strata that produce Blancan vertebrate faunas. The onset of this period of deposition may correspond with warmer, wetter climatic conditions in southwestern North America during the Pliocene (Thompson, 1991). The abun-

dance of giant land tortoises (*Hesperotestudo*) in Pliocene faunas in Sierra County supports the idea of a warmer, frost-free climate at this time (Morgan and Lucas, 2003b). The Gila River Valley in southwestern New Mexico shows a similar trend of sediment deposition and preservation of vertebrate faunas during the Pliocene, including the Blancan Buckhorn, Pearson Mesa, and Virden faunas (Morgan et al., 1997; 2008a).

Late Pleistocene (Rancholabrean) vertebrate sites are surprisingly rare in Sierra County compared to other regions of New Mexico (Harris, 1993; Morgan and Lucas, 2005). Two widely separated regions of the county have produced late Pleistocene faunas. The easternmost portion of Sierra County, east of the San Andres Mountains, encompassing a portion of the Tularosa basin on the White Sands Missile Range, has produced a number of late Pleistocene vertebrate sites. About ten Rancholabrean fossil sites from the Otero Formation along the shores of Pleistocene Lake Otero at the northern end of Alkali Flat and near Alkali Spring in Sierra County have produced teeth and bones of large mammals, including the horse *Equus*, the camel *Camelops*, and the mammoth *Mammuthus* (Morgan and Lucas, 2002), as well as trackways of mammoths and camels (Lucas et al., 2002, 2007; Allen et a., 2006). Radiocarbon dates for the track-bearing lake deposits suggest an age of 31-32 ka, whereas radiocarbon dates from deposits overlying the tracksites range from 19-23 ka. Somewhat farther north in the Tularosa basin in Sierra County, Pleistocene sediments along Salt Creek have produced fossils of these same three genera of large mammals (Love et al., 2011, in press). The Salt Creek sites underlie a marsh deposit with a radiocarbon date of about 11 ka at its base (Love et al., 2011, in press). Between the San Andres Mountains on the east and the Caballo Mountains and Fra Cristobal Range on the west lies the Jornada del Muerto basin. Late Pleistocene sites may occur in the Jornada del Muerto basin in Sierra County; however, virtually no paleontological field work has been conducted there. A few late Pleistocene sites are known from the Jornada del Muerto basin to the north in Socorro County (Morgan et al., 2009a).

Harris (1985, 1993) briefly mentioned fossil vertebrates from Palomas Creek Cave in the southern Black Range in western of Sierra County, about 140 km west of the Tularosa basin Pleistocene sites and over 2,000 feet higher in elevation, at about 6,100 feet (1,860 m). Although no radiocarbon dates are available, the Palomas Creek Cave fauna is almost certainly late Pleistocene in age, as are most other fossiliferous cave deposits in southern New Mexico (Harris, 1985, 1993). Other caves occur in the Paleozoic limestone bedrock in the vicinity of Palomas Creek Cave, suggesting that new Pleistocene cave faunas may be discovered with further exploration in this area.

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C.T. Griswold and sign of skull & crossbones ("This hill is not foolproof") in Hermosa Canyon, Sierra County New Mexico, ca 1935. NMBGMR Photo Archive No. p-01690