Chapter 12

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Chapter 12

Mammalian Biochronology of Blancan and Irvingtonian (Pliocene and Early Pleistocene) Faunas from New Mexico

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ABSTRACT

Significant mammalian faunas of Pliocene (Blancan) and early Pleistocene (early and medial Irvingtonian) age are known from the Rio Grande and Gila River valleys of New Mexico. Fossiliferous exposures of the Santa Fe Group in the Rio Grande Valley, extending from the Española basin in northern New Mexico to the Mesilla basin in southernmost New Mexico, have produced 21 Blancan and 6 Irvingtonian vertebrate assemblages; three Blancan faunas occur in the Gila River Valley in the Mangas and Duncan basins in southwestern New Mexico. More than half of these faunas contain five or more species of mammals, and many have associated radioisotopic dates and/or magnetostratigraphy, allowing for correlation with the North American land-mammal biochronology. Two diverse early Blancan (4.5–3.6 Ma) faunas are known from New Mexico, the Truth or Consequences Local Fauna (LF) from the Palomas basin and the Buckhorn LF from the Mangas basin. The former contains five species of mammals indicative of the early Blancan: *Borophagus* cf. *B. hilli*, *Notolagus lepusculus*, *Neotoma quadriplicata*, *Jacobsomys* sp., and *Odocoileus brachyodontus*. Associated magnetostratigraphic data suggest correlation with either the Nunivak or Cochiti Subchrons of the Gilbert Chron (4.6–4.2 Ma), which is in accord with the early Blancan age indicated by the mammalian biochronology. The Truth or Consequences LF is similar in age to the Verde LF from Arizona, and slightly older than the Rexroad 3 and Fox Canyon faunas from Kansas. The Buckhorn LF has 18 species of mammals, including two rodents typical of the early Blancan, *Mimomys poaphagus* and *Repomys panacaensis*. The Buckhorn LF also is similar in age to the Verde LF and has affinities with the Panaca LF from Nevada. Although the Buckhorn and Truth or Consequences LFs have few taxa in common, the similarities of both faunas with the Verde LF suggest they are close in age.

Eight faunas from the central and southern Rio Grande Valley are medial Blancan in age (3.6–2.7 Ma), including the Pajarito and Belen faunas from the Albuquerque basin, the Arroyo de la Parida LF from the Socorro basin, the Cuchillo Negro Creek and Elephant Butte Lake LFs from the Engle basin, the Palomas Creek LF from the Palomas basin, the Hatch LF from the Hatch-Rincon basin, and the Tonuco Mountain LF from the Jornada basin. These faunas are characterized by the presence of taxa absent from early Blancan faunas, including *Geomys* (*Nerterogeomys*) *paenebursarius*, *Equus cumminsii*, *E. scotti*, and *Camelops*, and the absence of South American immigrant mammals found in late Blancan faunas. The Pajarito LF is directly associated with a pumice dated at 3.1 Ma. The Cuchillo Negro Creek and Elephant Butte Lake LFs are in close stratigraphic association with a basalt flow of 2.9 Ma. Magnetostratigraphy constrains the age of the Tonuco Mountain LF between 3.6 and 3.0 Ma.

The Mesilla A fauna from the Mesilla basin and the Pearson Mesa LF from the Duncan basin are late Blancan in age (2.7–2.2 Ma). Both record the association of *Nannippus* with a South American immigrant, *Glyptotherium* from Mesilla A and *Glossotherium* from Pearson Mesa, restricting their age to the interval after the beginning of the Great American Interchange at about 2.7 Ma and before the extinction of *Nannippus* ca. 2.2 Ma. Magnetostratigraphy

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further constrains the Mesilla A and Pearson Mesa faunas to the upper Gauss Chron, just prior to the Gauss/Matuyama boundary. The Mesilla B and Virden faunas occur higher in the same stratigraphic sequences as the Mesilla A and Pearson Mesa faunas, respectively, and are latest Blancan in age (2.2–1.8 Ma). Both faunas contain taxa restricted to the Blancan, including the camels *Blancocamelus* and *Gigantocamelus* from Mesilla B, and *Canis lepophagus* from Virden. The absence of *Nannippus*, and of *Mammuthus* and other genera that first appear in the Irvingtonian, support the age.

The Tijeras Arroyo fauna from the Albuquerque basin and the Tortugas Mountain and Mesilla C faunas from the Mesilla basin all possess *Mammuthus* and other mammals indicative of early Irvingtonian age. The association of *Mammuthus* and *Stegomastodon* in the Tortugas Mountain LF indicates an age younger than 1.8 Ma, after the arrival of *Mammuthus* in North America from Eurasia and before the extinction of *Stegomastodon* at about 1.2 Ma. The co-occurrence of *Glyptotherium arizonae*, *Equus scotti*, and the primitive mammoth *M. meridionalis* in Tijeras Arroyo and Mesilla C is typical of southwestern early Irvingtonian faunas. Fossils of *M. meridionalis* from Tijeras Arroyo and Mesilla C are both closely associated with dates of 1.6 Ma on pumice from the lower Bandelier tuff, making them among the oldest dated mammoths in North America. A fauna from San Antonio Mountain (SAM) Cave in the San Luis basin of northernmost New Mexico lacks large mammals, but the presence of the microtine rodents *Mictomys kansasensis*, an advanced species of *Allophaiomys*, *Lemmiscus curtatus*, and *Microtus* cf. *M. californicus* indicates medial Irvingtonian age, between about 1.0 and 0.85 Ma.

INTRODUCTION

There are 31 vertebrate fossil assemblages currently known from New Mexico that date to the time interval from the early Blancan North American land mammal ‘‘age’’ (NALMA), about 4.0 Ma (early Pliocene), through the medial Irvingtonian NALMA, about 0.8 Ma (late early Pleistocene). These faunas are concentrated in two areas of the state, the Rio Grande Valley and the Gila River Valley (fig. 12.1). The Rio Grande bisects the state from the Colorado border on the north to the Mexico and Texas borders on the south, flowing through a series of structural basins that are part of the Rio Grande rift system. A through-flowing Rio Grande apparently originated sometime in the early Pliocene after about 5 Ma, and shortly thereafter began depositing fluvial sediments that preserve vertebrate fossils. Most of the Rio Grande rift basins contain Blancan and/or Irvingtonian vertebrate fossils, from the San Luis basin on the Colorado border in the northernmost part of the state to the Mesilla basin on the Mexican border in southernmost New Mexico. The Gila River originates in the Mogollon Mountains in southwestern New Mexico and flows southwestward, eventually crossing into Arizona. Blancan vertebrate faunas have been recovered from sediments of the Gila Group in the Mangas basin and the Duncan basin in the Gila River Valley in southwestern New Mexico (fig. 12.1). Several additional Blancan faunas are known from the Gila River Valley in southeastern Arizona (Galusha et al., 1984; Tomida, 1987).

Prior to the 1980s, very few of New Mexico’s Blancan and Irvingtonian faunas had been mentioned in the literature. In their review of the ‘‘Pleistocene’’ mammals of North America, including the Blancan, which is now known to be entirely Pliocene, Kurtén and Anderson (1980) did not list a single Blancan or Irvingtonian fauna from New Mexico. Tedford (1981) summarized all of New Mexico’s Blancan and Irvingtonian faunas known at that time, including 12 Blancan faunas and 1 Irvingtonian fauna. Despite Tedford’s (1981) paper, no sites from New Mexico were mentioned in the review of North American Blancan and Irvingtonian faunas in Lundelius et al. (1987). Repenning (1987) mentioned the early Blancan Truth or Consequences Local Fauna (LF) in his review of late Cenozoic microtine rodents from North America. We summarize all studies on New Mexico Blancan and Irvingtonian faunas published since Tedford (1981) through the end of 2000, and include much new unpublished data.

MATERIALS AND METHODS

Richard Tedford’s 1981 paper on the biochronology of late Cenozoic mammalian faunas from New Mexico provided the impetus for our long-term project to collect, document, and describe all Blancan and Irvingtonian vertebrate faunas from New Mexico. Beginning in the mid-1980s and continuing to the present, paleontologists from the New Mexico Museum of Natural History and the University of New Mexico have been involved in a program to locate new faunas of Blancan and Irvingtonian age throughout New Mexico and to recollect faunas of this age discussed by Tedford (1981). Many new Blancan and Irvingtonian faunas have been discovered in New Mexico in the past 15 years (Lucas and Oakes, 1986; Repenning and May, 1986; Morgan et al., 1998; Morgan and Lucas, 1999, 2000a; Rogers et al., 2000), and extensive new fossil material has been added to many of the faunas described in Tedford's 1981 paper (Vanderhill, 1986; Tomida, 1987; Lucas et al., 1993; Morgan et al., 1997; Morgan and Lucas, 1999, 2000a, 2000b). Combining the information in Tedford's 1981 paper, which was based on fossils in the collections of the Frick Laboratory at the American Museum of Natural History, and data obtained through our fieldwork, we can now provide a fairly detailed review of the Blancan and Irvingtonian fossil record of New Mexico.

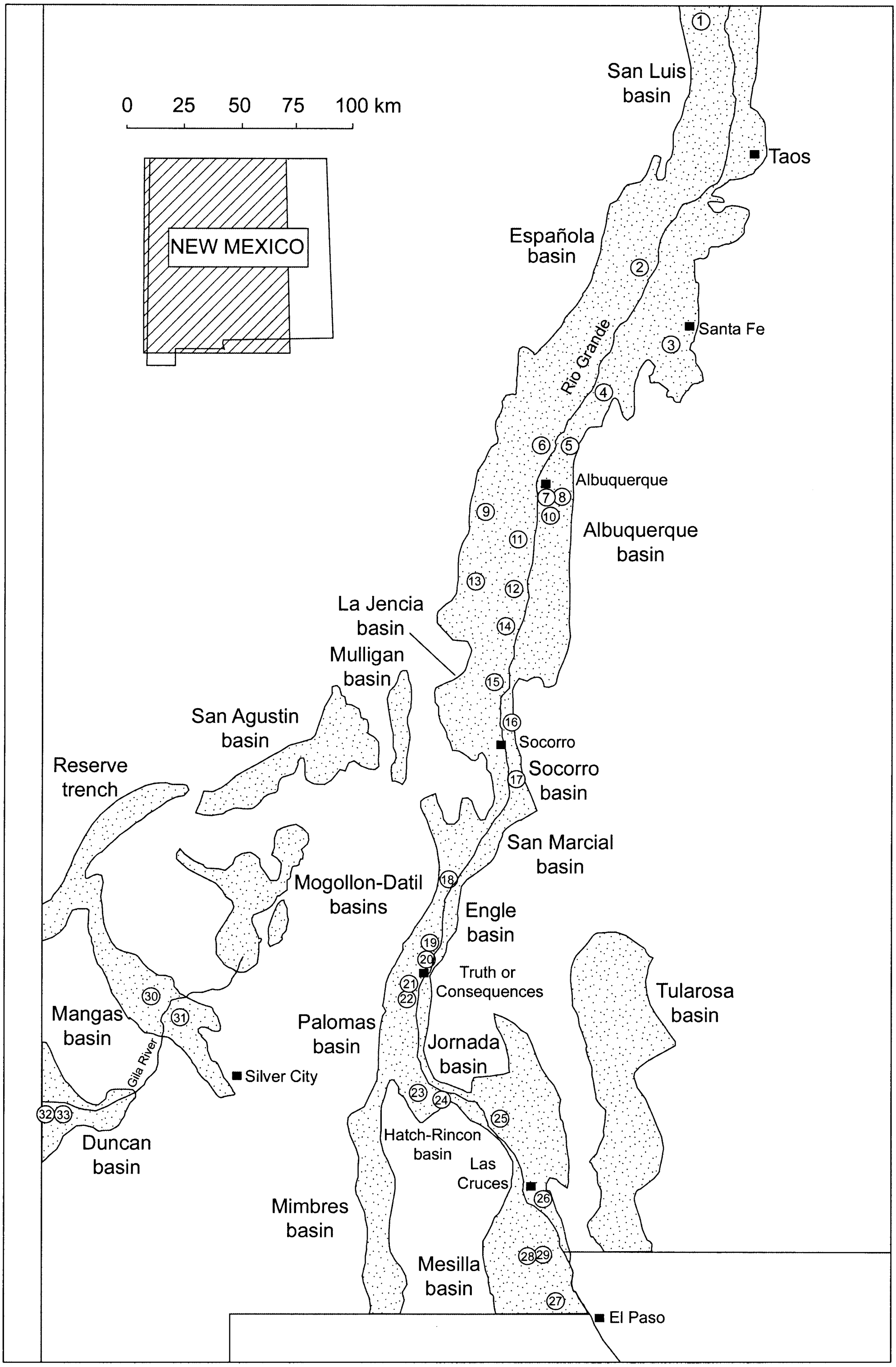
The present paper summarizes the historical, faunal, stratigraphic, and geochronologic data for all known Blancan and Irvingtonian mammalian faunas from New Mexico. Faunal lists for sites containing four or more taxa of mammals are provided in tables 12.1 and 12.2, including 15 Blancan faunas and 4 Irvingtonian faunas. Numerous additional sites with fewer than four mammals are discussed in the text. We follow Woodburne (1987: xiv) for the definitions of fauna and local fauna. Thus, a fauna is ''an assemblage of fossil vertebrates of specific taxonomic composition obtained from a number of geographically diverse sites.'' A local fauna is ''an assemblage of fossil vertebrates of specific taxonomic composition recovered from one or a few sites that are closely spaced stratigraphically and geographically.'' We follow Woodburne and Swisher (1995) for use of the age terms early, medial, and late for subdivisions of epochs (e.g., early Pliocene) and NALMAs (e.g., medial Blancan).

Space does not permit us to exhaustively review all of the 31 currently known New Mexico Blancan and Irvingtonian faunas and sites. Detailed documentation (e.g., catalogue numbers, morphological descriptions, and measurements) is not provided for specimens described in previous papers. Documentation is provided for selected fossils not previously mentioned in the literature. We give brief descriptions of certain fossils that are of critical importance to mammalian biochronology. This paper should be considered a status report because we are actively involved in fieldwork on Blancan and Irvingtonian faunas throughout New Mexico. In particular, comprehensive faunal papers are planned in the near future for the Arroyo de la Parida, Truth or Consequences, and Pearson Mesa Local Faunas, and the late Blancan and early Irvingtonian faunas from the Mesilla basin.

There are three major collections of Blancan and Irvingtonian vertebrate fossils from New Mexico. The New Mexico Museum of Natural History and Science (NMMNH) in Albuquerque and the Frick Collection (F:AM) of the American Museum of Natural History (AMNH) in New York both contain substantial collections of Blancan and Irvingtonian fossils from throughout the state. The Museum of Arid Land Biology at the University of Texas at El Paso (UTEP) has large collections from the Mesilla basin in southern New Mexico. Other New Mexico Blancan and Irvingtonian fossils consulted during this study include specimens from the Geology Museum in the Department of Earth and Planetary Sciences at the University of New Mexico (UNM) in Albuquerque, the New Mexico State University Museum (NMSUM) in Las Cruces, the University of Arizona Laboratory of Paleontology (UALP) in Tucson, and the United States Geological Survey Collection (USGS) in Denver. Site numbers (preceded by NMMNH L-) listed throughout the paper refer to NMMNH fossil localities. Field notes, map coordinates, and other information on these sites are on file in the Paleontology Collection at the NMMNH.

PREVIOUS WORK

Pliocene (Blancan) fossils were first reported from New Mexico by Needham



0 25 50 75 100 km
NEW MEXICO
San Luis basin
Taos
Española basin
Santa Fe
Rio Grande
Albuquerque
Albuquerque basin
La Jencia basin
Mulligan basin
San Agustin basin
Reserve trench
Socorro
Socorro basin
San Marcial basin
Mogollon-Datil basins
Engle basin
Truth or Consequences
Tularosa basin
Mangas basin
Palomas basin
Jornada basin
Gila River
Silver City
Duncan basin
Hatch-Rincon basin
Las Cruces
Mimbres basin
Mesilla basin
El Paso
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(1936), who described a pair of mandibles of the gomphotheriid proboscidean *Rhynchotherium* and a lower molar of the horse *Plesippus* from Santa Fe Group deposits in Arroyo de la Parida, northeast of Socorro in Socorro County. *Plesippus* is now generally regarded as a primitive subgenus of *Equus*, and is typical of Blancan faunas. Needham also reported several fossil turkey (*Meleagris*) bones from a pumice deposit of probable early Irvingtonian age in an exposure along the Rio Grande near San Antonio, also in Socorro County. Denny (1940) identified *Equus* and the gomphotheriid proboscidean *Stegomastodon* from Santa Fe Group deposits north of the Rio Salado on land now within the Sevilleta National Wildlife Refuge in the southernmost Albuquerque basin in northern Socorro County. Between 1926 and 1953, collectors working for the Frick Laboratory accumulated significant samples of Blancan and Irvingtonian vertebrates from various localities throughout New Mexico. Very few of these specimens were published until 1981, when Tedford summarized the mammalian biochronology of the late Cenozoic basins of New Mexico. Between 1926 and 1929, Joseph Rak collected fossil vertebrates on the Santo Domingo Reservation in the northern Albuquerque basin, from Hot Springs (now Truth or Consequences), Palomas Creek, and other sites west of Elephant Butte Lake in the Engle and Palomas basins, and from the Mesilla basin south of Las Cruces. Charles Falkenbach collected fossils with Rak in 1928 from Hot Springs and in 1929 from the Mesilla basin. Ted Galusha collected fossils in 1946 from the northern edge of the Isleta Reservation in southern Bernalillo County. George Pearce made collections in the Mesilla basin in 1949 and near Buckhorn in the Mangas basin in 1953.

Tedford (1981) was the first paleontologist to summarize the data on New Mexican Blancan and Irvingtonian faunas, primarily based on the previously unpublished material in the Frick Collection at the AMNH. Tedford provided a biostratigraphic framework for all subsequent work on New Mexico Blancan and Irvingtonian faunas, which has included additional work on many of the faunas he discussed, as well as the discovery of new faunas. Repenning and May (1986) provided a faunal list, brief taxonomic descriptions, and magnetostratigraphy for the early Blancan Truth or Consequences LF from the Palomas Formation in the Palomas basin near Truth or Consequences in Sierra County. Lucas and Oakes (1986) described the medial Blancan Cuchillo Negro Creek LF from the Engle basin, also from the Palomas Formation in Sierra County. In his doctoral dissertation, Vanderhill (1986) presented a detailed review of the vertebrate paleontology, magnetostratigraphy, and lithostratigraphy of late Blancan through early Irvingtonian faunas in the Mesilla basin south of Las Cruces in Doña Ana County. Tomida (1987) provided a faunal list and magnetostratigraphy for the late Blancan Pearson Mesa LF

←

Fig. 12.1. Map of New Mexico showing the location of all late Hemphillian, Blancan, and Irvingtonian fossil sites. The structural basins are named and indicated by stippling. Sites are numbered from north to south in the Rio Grande Valley (sites 1–29), followed by sites in the Gila River Valley (sites 30–33). Site names and ages are listed here. See text for more detailed information on individual sites. **1,** San Antonio Mountain (SAM) Cave, medial Irvingtonian; **2,** Puyé Formation site, late Hemphillian; **3,** Ancha sites, late Blancan; **4,** Santo Domingo, late Blancan; **5,** Western Mobile, early Irvingtonian; **6,** Loma Colorado de Abajo, early/medial Blancan; **7,** Mountainview, Blancan; **8,** Tijeras Arroyo, early Irvingtonian; **9,** Pajarito, medial Blancan; **10,** Isleta, Blancan; **11,** Los Lunas, Blancan; **12,** Belen, medial Blancan; **13,** Mesas Mojinas, Blancan; **14,** Veguita, Blancan; **15,** Sevilleta, Blancan; **16,** Arroyo de la Parida, medial Blancan; **17,** Fite Ranch, early Irvingtonian; **18,** Silver Canyon, Blancan; **19,** Elephant Butte Lake, medial Blancan; **20,** Cuchillo Negro Creek, medial Blancan; **21,** Truth or Consequences, early Blancan; **22,** Palomas Creek, medial Blancan; **23,** Hatch, medial Blancan; **24,** Rincon Arroyo, late Blancan/early Irvingtonian; **25,** Tonuco Mountain, medial Blancan; **26,** Tortugas Mountain, early Irvingtonian; **27,** Mesilla A, late Blancan; **28,** Mesilla B, latest Blancan; **29,** Mesilla C, early Irvingtonian; **30,** Buckhorn, early Blancan; **31,** Walnut Canyon, latest Hemphillian; **32,** Pearson Mesa, late Blancan; **33,** Virden, latest Blancan. Map modified from Tedford (1981).

TABLE 12.1

Faunal List of Blancan Mammals from New Mexico

The Blancan faunas are listed across the top of the table with a superscript letter that corresponds to a reference or references at the end of the table from which the faunal lists were taken. The faunas are listed in order from the oldest on the left to the youngest on the right. The presence of a species in a fauna is indicated by "X" and its absence by "—". Species listed as "X?" were tentatively identified (e.g., identified with "cf." or "?") in the original publications. Taxa marked with an asterisk (*) are based on identifications of specimens collected after the original paper on the site was published. Only faunas with four or more taxa of mammals are included in this table. Smaller finds of important Blancan taxa are discussed in the text. There are three distinct biostratigraphic levels in the Mesilla basin according to Vanderhill (1986); the mammals from his Fauna A of late Blancan age and Fauna B of latest Blancan age are listed below. Fauna C of early Irvingtonian age is listed in table 12.2.

	Early Blancan		Early/medial Blancan			Medial Blancan					Late Blancan				
	Truth or Consequences[a]	Buckhorn[b]	Cuchillo Negro Creek[c]	Elephant Butte Lake[d]	Palomas Creek[d]	Pajarito[e]	Belen[e]	Arroyo de la Parida[d,f]	Hatch[g]	Tonuco Mountain[h]	Pearson Mesa[i,j]	Mesilla Basin[g,k] A	Mesilla Basin[g,k] B	Santo Domingo[d]	Virden[j]
Xenarthra															
Glyptodontidae															
Glyptotherium arizonae	—	—	—	—	—	—	—	—	—	—	—	—	X	—	X
Glyptotherium sp.	—	—	—	—	—	—	—	—	—	—	—	X	—	—	—
Megalonychidae															
Megalonyx leptostomus	—	—	—	—	—	—	—	X?*	—	—	—	—	X*	—	—
Mylodontidae															
Glossotherium chapadmalense	—	—	—	—	—	—	—	—	—	—	X	—	—	—	—
Paramylodon harlani	—	—	—	—	—	—	—	—	—	—	—	—	X?	—	—
Insectivora															
Soricidae															
gen. & sp. indet.	X*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Talpidae															
Scalopus (*Hesperoscalops*) sp.	X*	—	—	—	—	—	X	—	—	—	—	—	X*	—	—
Chiroptera															
Vespertilionidae															
gen. & sp. indet.	—	X*	—	—	—	—	—	—	—	—	—	—	—	—	—
Carnivora															
Canidae															
Borophagus hilli	X*	—	X	—	—	—	—	—	—	—	—	—	—	—	—
Borophagus sp.	—	—	—	—	—	—	—	—	—	X	—	—	—	—	—
Canis lepophagus	—	—	—	—	—	—	—	—	—	X	—	—	—	—	X
Procyonidae															
Bassariscus sp.	—	—	X*	—	—	—	—	—	—	—	—	—	—	—	—

TABLE 12.1
(*Continued*)

	Early Blancan		Early/medial Blancan			Medial Blancan					Late Blancan				
												Mesilla Basin[g,k]			
	Truth or Consequences[a]	Buckhorn[b]	Cuchillo Negro Creek[c]	Elephant Butte Lake[d]	Palomas Creek[d]	Pajarito[e]	Belen[e]	Arroyo de la Parida[d,f]	Hatch[g]	Tonuco Mountain[h]	Pearson Mesa[i,j]	A	B	Santo Domingo[d]	Virden[j]
Carnivora (*continued*)															
Mustelidae															
Spilogale sp.	—	—	—	—	—	—	—	—	—	—	—	—	X*	—	—
Taxidea sp.	—	X	—	—	—	—	—	—	X?	X	—	—	—	—	—
Felidae															
Felinae gen. & sp. indet.	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—
Lynx rufus	—	—	—	—	—	—	—	—	—	—	—	—	X?	—	—
Lynx sp.	—	—	—	—	—	—	—	—	X?	—	—	—	—	—	—
Machairodontinae															
gen. & sp. indet.	—	X	—	—	—	—	—	—	—	—	X	—	—	—	—
Smilodon gracilis	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Ursidae															
Arctodus pristinus	—	—	—	—	—	—	—	—	—	—	—	—	X*	—	—
gen. & sp. indet.	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagomorpha															
Leporidae															
Aluralagus virginiae	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Hypolagus vetus	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Notolagus lepusculus	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
gen. & sp. indet.	—	X	—	—	—	—	—	—	X[l]	X	—	—	X	—	—
Rodentia															
Sciuridae															
Spermophilus bensoni	—	X?	—	—	—	—	—	—	—	—	—	—	—	—	—
Spermophilus sp.	X*	—	—	—	—	X	—		—	—	—	—	X*	—	—
Geomyidae															
Geomys (*Nerterogeomys*) *minor*	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Geomys (*N.*) *paenebursarius*	—	—	—	—	—	X?	X?	—	X?	—	—	—	—	—	—
Geomys (*N.*) *persimilis*	—	—	—	—	—	—	—	—	—	—	X?	—	—	—	—
Geomys (*N.*) sp.	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Geomys (*Geomys*) sp.	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—

TABLE 12.1
(*Continued*)

	Early Blancan		Early/medial Blancan			Medial Blancan					Late Blancan				
	Truth or Consequences[a]	Buckhorn[b]	Cuchillo Negro Creek[c]	Elephant Butte Lake[d]	Palomas Creek[d]	Pajarito[e]	Belen[e]	Arroyo de la Parida[d,f]	Hatch[g]	Tonuco Mountain[h]	Pearson Mesa[i,j]	Mesilla Basin[g,k] A	Mesilla Basin[g,k] B	Santo Domingo[d]	Virden[j]
Rodentia (*continued*)															
Heteromyidae															
Dipodomys	—	—	—	—	—	—	—	—	—	—	—	—	X*	—	—
Muridae															
Baiomys sp.	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
Jacobsomys sp.	X?*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mimomys poaphagus	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—
Neotoma quadriplicata	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Onychomys sp.	—	—	—	—	—	—	—	—	—	—	—	—	X*	—	—
Peromyscus sp.	—	X*	—	—	—	—	—	—	—	—	—	—	—	—	—
Repomys panacaensis	—	X?	—	—	—	—	—	—	—	—	—	—	—	—	—
Sigmodon medius	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—
Sigmodon sp.	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Perissodactyla															
Equidae															
Equus calobatus	—	—	—	—	—	—	X?	—	—	—	—	X?	X?	X?	—
Equus cumminsii	—	—	—	—	X?	—	—	X?	—	—	X?	—	—	—	—
Equus scotti	—	—	—	—	—	—	—	X?	—	X	X	—	X	X	X
Equus simplicidens	—	X	X	X	X	—	—	X	—	X	X	—	—	—	—
Equus (*Plesippus*) sp.	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equus sp.	—	—	—	—	—	—	—	—	X	—	—	—	—	—	—
Nannippus peninsulatus	—	X	—	—	X	—	—	—	—	X	X	X	—	X*	—
Tapiridae															
Tapirus haysii	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Tapirus sp.	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Artiodactyla															
Tayassuidae															
Platygonus bicalcaratus	X*	—	—	—	—	—	—	—	—	X?	X	—	—	X?	—
gen. & sp. indet.	—	X	—	—	X	—	—	—	—	—	—	—	—	—	—

TABLE 12.1
(*Continued*)

	Early Blancan		Early/medial Blancan			Medial Blancan					Late Blancan				
												Mesilla Basin[g,k]			
	Truth or Conse-quences[a]	Buck-horn[b]	Cuchillo Negro Creek[c]	Elephant Butte Lake[d]	Palo-mas Creek[d]	Paja-rito[e]	Belen[e]	Arroyo de la Parida[d,f]	Hatch[g]	Tonuco Moun-tain[h]	Pear-son Mesa[i,j]	A	B	Santo Do-mingo[d]	Virden[j]
Artiodactyla (*continued*)															
Camelidae															
Blancocamelus meadei	—	—	—	—	—	—	—	—	—	—	—	—	X	—	—
Camelops large sp.	—	—	X*	—	X*	—	—	X*	—	—	X	—	X	—	—
Camelops sp.	—	X?	—	—	—	X	—	—	—	X	—	—	—	—	X
Gigantocamelus sp.	—	—	—	X	—	—	—	—	—	—	—	—	X	—	—
Hemiauchenia blancoensis	—	X	X	—	—	X	—	—	X	X	X	X	—	—	—
Hemiauchenia small sp.	—	X*	X*	—	—	—	—	X	—	X	—	—	X*	—	X
Palaeolama sp.	—	—	—	—	—	—	—	—	—	—	—	—	X*	—	—
Cervidae															
Odocoileus brachyodontus	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Odocoileus sp.	—	—	—	—	—	X?	—	—	—	—	—	—	X	—	—
Antilocapridae															
Capromeryx sp.	X*	—	—	—	—	—	—	X	X?	—	—	—	—	—	—
gen. & sp. indet.	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
Proboscidea															
Gomphotheriidae															
Cuvieronius sp.	—	—	—	—	—	—	—	—	—	X	—	—	X	—	—
Rhynchotherium falconeri	—	—	—	—	—	—	—	X	—	—	—	—	—	—	—
Stegomastodon mirificus	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—
Stegomastodon rexroadensis	—	—	X	X*	—	—	—	—	—	—	X	—	—	—	—
Stegomastodon sp.	X	X	—	—	—	—	—	X	—	—	—	—	—	—	—
Mammutidae															
Mammut raki	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—
Proboscidea indet.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	X

[a]Repenning and May (1986).
[b]Morgan et al. (1997).
[c]Lucas and Oakes (1986).
[d]Tedford (1981).
[e]Morgan and Lucas (2000a).
[f]Lucas and Morgan (1996).
[g]This paper.
[h]Morgan et al. (1998).
[i]Tomida (1987).
[j]Morgan and Lucas (2000b).
[k]Vanderhill (1986).
[l]There are two species of lagomorphs in the Hatch LF, small and large.

TABLE 12.2

Faunal List of Irvingtonian Mammals from New Mexico

Irvingtonian faunas are listed across the top of the table with a superscript letter that corresponds to references at the end of the table. Tijeras Arroyo, Tortugas Mountain, and Mesilla Basin Fauna C are early Irvingtonian in age, and SAM Cave is medial Irvingtonian. The presence of a species in a fauna is indicated by "X" and its absence by "—". Species listed as "X?" were tentatively identified (e.g., identified with "cf." or "?") in original publications. Taxa marked with an asterisk (*) are based on identifications of specimens collected after the original paper on the site was published. Only faunas with four or more mammal taxa are included. Smaller finds of important Irvingtonian taxa are discussed in the text.

	Early Irvingtonian			Medial Irvingtonian
	Tijeras Arroyo[a]	Tortugas Mountain[b]	Mesilla Basin Fauna C[c]	San Antonio Mountain (SAM) Cave[d]
Xenarthra				
Glyptodontidae				
Glyptotherium arizonae	X	—	X	—
Megalonychidae				
Megalonyx wheatleyi	—	—	X[e]	—
Paramylodon harlani	—	—	X	—
Insectivora				
Soricidae				
Sorex sp.	—	—	—	X
Chiroptera				
gen. & sp. indet.	—	—	—	X
Carnivora				
Canidae				
Canis armbrusteri	—	—	X	—
Canis latrans	—	—	X?	—
Canis rufus	—	—	—	X?
Vulpes vulpes	—	—	—	X
Mustelidae				
Mustela erminea	—	—	—	X
Spilogale putorius	—	—	—	X
Taxidea taxus	—	—	—	X
Felidae				
Lynx rufus	—	—	X	—
Lagomorpha				
Leporidae				
Lepus californicus	—	—	—	X
Sylvilagus sp.	—	—	—	X
Rodentia				
Sciuridae				
Cynomys ludovicianus	—	—	—	X
Sciurus aberti	—	—	—	X
Spermophilus lateralis	—	—	—	X
Spermophilus leucurus	—	—	—	X
Spermophilus tridecemlineatus	—	—	—	X
Spermophilus variegatus	—	—	—	X

TABLE 12.2
(*Continued*)

	Early Irvingtonian			Medial Irvingtonian
	Tijeras Arroyo[a]	Tortugas Mountain[b]	Mesilla Basin Fauna C[c]	San Antonio Mountain (SAM) Cave[d]
Rodentia (*continued*)				
Castoridae				
Castor canadensis	—	—	X	—
Geomyidae				
Thomomys sp.	—	—	—	X
Muridae				
Allophaiomys sp.	—	—	—	X
Clethrionomys cf. *C. rutilus*	—	—	—	X
Lemmiscus curtatus	—	—	—	X
Microtus cf. *M. californicus*	—	—	—	X
Mictomys kansasensis	—	—	—	X
Neotoma cinerea	—	—	—	X
Peromyscus cf. *P. crinitus*	—	—	—	X
Phenacomys intermedius	—	—	—	X
Reithrodontomys megalotis	—	—	—	X
Erethizontidae				
Erethizon sp.		—	—	X
Perissodactyla				
Equidae				
Equus calobatus	—	—	X?	—
Equus scotti	X	—	X	—
Equus large sp.	—	X	X	—
Equus small sp.	X	—	—	—
Camelidae				
Camelops hesternus	—	—	X?	—
Camelops sp.	X	—	—	—
Hemiauchenia macrocephala	X*[f]	—	—	—
Cervidae				
Navahoceros lascrucensis	—	—	X[e]	—
Odocoileus sp.	—	—	X?	—
Proboscidea				
Gomphotheriidae				
Cuvieronius tropicus	—	X	X	—
Stegomastodon mirificus	—	X	—	—
Elephantidae				
Mammuthus meridionalis	X	—	X?	—
Mammuthus imperator	X[f]	X	—	—

[a]Lucas et al. (1993).
[b]Lucas et al. (1999, 2000).
[c]Vanderhill (1986).
[d]Rogers et al. (2000).
[e]Occurs in Mesilla Basin fauna, but stratigraphic position unknown; early Irvingtonian age is likely.
[f]Occurs higher in stratigraphic section than remainder of Tijeras Arroyo fauna, but still Irvingtonian in age.

from the Gila Group in the Duncan basin in Hidalgo County. Lucas et al. (1993) reviewed late Blancan and early Irvingtonian vertebrate faunas from Tijeras Arroyo in the Albuquerque basin near Albuquerque in Bernalillo County. Lucas and Morgan (1996) reported the gomphothere *Rhynchotherium falconeri*, and briefly summarized the remainder of the mammalian fauna, from the medial Blancan Arroyo de la Parida LF from the Socorro basin in Socorro County. Morgan et al. (1997) described the latest Hemphillian Walnut Canyon LF and the early Blancan Buckhorn LF from the Gila Group in the Mangas basin in Grant County. Morgan et al. (1998) reviewed the medial Blancan Tonuco Mountain LF from the Camp Rice Formation in the Jornada basin north of Las Cruces in Doña Ana County. Hawley et al. (1969) and Lucas et al. (1999, 2000) discussed early Irvingtonian proboscideans and horses from gravel pits in the vicinity of Tortugas Mountain east of Las Cruces in the northern part of the Mesilla basin. Morgan and Lucas (1999, 2000a) reviewed 10 Blancan and 2 Irvingtonian faunas from the Albuquerque basin. Morgan and Lucas (2000b) described 2 late Blancan faunas from Pearson Mesa in the Duncan basin. Rogers et al. (2000) described the Irvingtonian vertebrate fauna from San Antonio Mountain (SAM) Cave from the San Luis basin in northernmost New Mexico.

CHRONOLOGY

We follow Berggren et al. (1995) for placement of the Miocene/Pliocene and Pliocene/Pleistocene boundaries and their subdivisions, and for the boundaries of the geomagnetic chrons and subchrons. The Miocene/Pliocene boundary is 5.32 Ma, and the Pliocene/Pleistocene boundary is located near the top of the Olduvai Subchron at 1.81 Ma. The Pliocene is subdivided into the early and late Pliocene, with the boundary between these subdivisions placed at the boundary beween the Gilbert and Gauss Chrons at 3.58 Ma. The Pleistocene is subdivided into the early, medial, and late Pleistocene. The boundary between the early and medial Pleistocene is the boundary beween the Matuyama and Brunhes Chrons at 0.78 Ma. The beginning of the late Pleistocene at 0.13 Ma is defined by the onset of the last (Sangamonian) interglacial.

Lindsay et al. (1984) and Tedford et al. (1987) placed the boundary between the Hemphillian and Blancan NALMAs in the early Pliocene at about 4.5 Ma. Lundelius et al. (1987) stated that this boundary was not well dated, but fell in the interval of about 4.4 to 4.0 Ma. Repenning (1987) considered the Hemphillian/Blancan boundary to be somewhat earlier (about 4.8 Ma) based on the arrival from the Old World of the immigrant microtine rodents *Mimomys* and *Nebraskomys*. The end of the Hemphillian is characterized by a major extinction event, including the disappearance of the families Rhinocerotidae and Protoceratidae, the horses *Hipparion*, *Neohipparion*, *Pseudhipparion*, *Astrohippus*, and *Dinohippus*, and the carnivores *Agriotherium*, *Machairodus*, and *Plesiogulo*.

Lindsay et al. (1984) discussed several mammalian genera that appeared at the beginning of the Blancan, including the vole *Pliophenacomys* and the pocket gopher *Geomys*, and also listed a number of genera that appeared in a relatively short interval in the early Blancan at about 3.7 Ma (their *Trigonictis* appearance datum), including: the rabbits *Nekrolagus* and *Pratilepus*; the rodents *Neotoma* and *Pliopotamys*; the carnivores *Chasmaporthetes*, *Trigonictis*, and *Ursus*; the peccary *Platygonus*; the camel *Camelops*; and the deer *Bretzia*. Lundelius et al. (1987), Tedford et al. (1987), and Woodburne and Swisher (1995) defined the beginning of the Blancan using most of the same genera mentioned by Lindsay et al. (1984) and Repenning (1987), in particular Old World immigrants such as *Mimomys*, *Nebraskomys*, *Chasmaporthetes*, *Trigonictis*, *Ursus*, *Bretzia*, and *Odocoileus*. However, according to some authors (e.g., Lindsay et al., 1984; Cassiliano, 1999), the earliest occurrences of certain of these genera are actually well above the Hemphillian/Blancan boundary, spanning an interval in the early Blancan between about 4.5 and 3.7 Ma. Cassiliano (1999) suggested that the first appearance of *Sigmodon* in the Anza-Borrego Desert sequence in southern California at about 4.3 Ma may approximate the Hemphillian/Blancan boundary. Mou (1999) documented the earliest appearance of Blancan mammals from the Panaca LF in Nevada at about 4.95 Ma. The above discussion indicates that the Hemphillian/Blancan boundary is not well dated, but can be placed in the time range of about 4.9 to 4.3 Ma.

Tedford (1981) divided the Blancan into three intervals: early Blancan (4.5–3.7 Ma), medial Blancan (3.7–2.5 Ma), and late Blancan (2.5–1.5 Ma). Repenning (1987) divided the Blancan into five intervals (Blancan I–V) based on the biochronology of microtine (= arvicoline) rodents. Repenning's system is dependent on the presence of microtines in a fauna to determine its age, so in many cases it has limited utility. Only one Blancan fauna from New Mexico, the Buckhorn LF in Grant County (Morgan et al., 1997), contains microtine rodents. Woodburne and Swisher (1995) recognized only two subdivisions of the Blancan, early Blancan (4.9–2.7 Ma) and late Blancan (2.7–1.8 Ma), with the boundary between the early and late Blancan corresponding to the beginning of the Great American Interchange at about 2.7 Ma. Tedford's (1981) subdivisions of the Blancan are the most useful for New Mexico faunas, with slight modifications as follows: early Blancan (4.5–3.6 Ma)—upper boundary corresponds to the Gilbert/Gauss boundary and the *Trigonictis* appearance datum of Lindsay et al. (1984); medial Blancan (3.6–2.7 Ma)—upper boundary corresponds to the beginning of the Great American Interchange, which is just slightly below the Gauss/Matuyama boundary; late Blancan (2.7–1.8 Ma)—upper boundary corresponds to the Plio-Pleistocene boundary, the top of the Olduvai Subchron, and the first appearance of *Mammuthus*.

Lundelius et al. (1987) documented a transitional interval between the Blancan and Irvingtonian, from about 2.2 to 1.8 Ma. Most characteristic Blancan mammalian genera, such as *Borophagus*, *Hypolagus*, *Paenemarmota*, *Equus* (*Plesippus*), *Nannippus*, and *Rhynchotherium*, became extinct by about 2.2 Ma (the *Nannippus* extinction datum of Lindsay et al., 1984). Lundelius et al. defined the Irvingtonian on the first appearance of *Lepus*, *Microtus*, *Smilodon*, *Equus* (*Equus*), *Euceratherium*, and *Mammuthus*, most of which did not appear until after 1.8 Ma. Cassiliano (1999) evaluated the biostratigraphic record for most of these genera and concluded that none were suitable for defining the Blancan/Irvingtonian boundary. He tentatively placed the Blancan/Irvingtonian boundary in the latest Pliocene between 2.15 and 1.95 Ma. The first appearance of *Mammuthus* is often used to define the Irvingtonian; however, all well-dated mammoths from North America are younger than 1.8 Ma (Lucas, 1995, 1996; Cassiliano, 1999), and are thus slightly younger than the Plio-Pleistocene boundary.

The first appearance of immigrants from outside of North America is generally considered to be of utmost importance in establishing boundaries between North American land-mammal ages (Lundelius et al., 1987; Woodburne, 1996). Thus, the appearance of *Mammuthus* would seem to be the most logical time to establish the Blancan/Irvingtonian boundary, roughly corresponding to the Pliocene/Pleistocene boundary at about 1.8 Ma. *Mammuthus* may not be the ideal genus to define the beginning of the Irvingtonian (e.g., Cassiliano, 1999), but mammoths do occur in all three early Irvingtonian faunas from New Mexico. For purposes of our discussion, we will use the first appearance of *Mammuthus* to define the beginning of the Irvingtonian at about 1.8 Ma. Lundelius et al. (1987) used a three-part subdivision of the Irvingtonian: early Irvingtonian (1.8–1.0 Ma), medial Irvingtonian (1.0–0.6 Ma), and late Irvingtonian (0.6–0.3 Ma). The boundary between the Irvingtonian and Rancholabrean corresponds to the first appearance of *Bison* at about 0.3 Ma. Repenning (1987) subdivided the Irvingtonian into two intervals (Irvingtonian I and II) based on microtine biochronology, and placed the boundary between the Irvingtonian and Rancholabrean slightly earlier, at 0.4 Ma. We follow Lundelius et al. (1987) in recognizing the early, medial, and late Irvingtonian, and the placement of the Irvingtonian/Rancholabrean boundary at 0.3 Ma.

BLANCAN AND IRVINGTONIAN VERTEBRATE FAUNAS FROM NEW MEXICO

There are 24 Blancan and 7 Irvingtonian vertebrate fossil assemblages currently known from New Mexico (fig. 12.1). These range from sites with a single species of mammal to 26 species of mammals in SAM Cave. All 31 of these assemblages are discussed below, but only those faunas with four or more species of mammals (15 Blancan and 4 Irvingtonian faunas) are listed in tables 12.1 and 12.2. Twenty-eight of these assemblages (21 Blancan and 7 Irvingtonian) are in the Rio Grande Valley and 3 Blancan faunas are in the Gila River Valley in southwestern New Mexico. The discussion of faunas generally proceeds from north to south, with the Rio Grande Valley sites followed by the Gila River Valley sites. All sites mentioned in the text and the structural basins in which they occur are indicated on the map in figure 12.1.

San Luis Basin

San Antonio Mountain (SAM) Cave: San Antonio Mountain (SAM) Cave is located in the San Luis basin about 10 km south of the Colorado border and 7 km northwest of San Antonio Mountain in Rio Arriba County in northernmost New Mexico (fig. 12.1, site 1). Several factors distinguish SAM Cave from all other Blancan and Irvingtonian localities in New Mexico, in particular, its mode of occurrence and high elevation (Rogers et al., 2000). SAM Cave is a lava tube formed in the Pliocene Servilleta Basalt, and the fossils occur in locally derived cave sediments. All other sites discussed in this paper are derived from alluvial, fluvial, or lacustrine sediments associated with the ancestral Rio Grande or Gila Rivers. SAM Cave is also considerably higher in elevation (2737 m) than any other Blancan or Irvingtonian site in New Mexico. Eleven localized sites within SAM Cave have produced vertebrate fossils, 10 of which are medial Irvingtonian in age (NMMNH sites L-4385–4390, 4392–4395) and 1 of which is Rancholabrean (NMMNH site L-4381). Among the medial Irvingtonian sites, there appears to be a range of ages from about 1.0 Ma to just after the Matuyama/Brunhes boundary at 0.78 Ma (Rogers et al., 2000). In table 12.2 and in the following discussion, we have arbitrarily combined the nine medial Irvingtonian sites in Rogers et al. (2000, table 2) that date to the late Matuyama Chron, after the Jaramillo Subchron and before the Matuyama/Brunhes boundary (between about 1.0 and 0.78 Ma). A 10th fauna (NMMNH site L-4385) occurs in normally magnetized sediments of the Brunhes Chron, but is not included here because it contains no species of mammals not found in the older sites.

The combined vertebrate assemblage from the nine medial Irvingtonian sites in SAM Cave includes a minimum of 41 species (faunal list from Rogers et al., 2000, complete list of mammals in table 2): one species of trout; 2 species of amphibians, tiger salamander (*Ambystoma tigrinum*), and chorus frog (*Pseudacris triseriata*); 3 reptiles, horned lizard (*Phrynosoma douglassii*), rattlesnake (*Crotalus viridis*), and garter snake (*Thamnophis elegans*); 9 birds, short-eared owl (*Asio* cf. *A. flammeus*), least grebe (*Tachybaptus* cf. *T. dominicus*), vireo (*Vireo* sp.), chickadee (*Parus* sp.), junco (*Junco* sp.), savannah sparrow (*Passerculus* cf. *P. sandwichensis*), sparrow (*Ammodramus*), and 2 wood warblers (Family Parulidae); and 26 species of mammals, including a shrew, a bat, 5 carnivores, 2 lagomorphs, and 17 rodents. The SAM Cave vertebrate assemblage is dominated by small species, and thus it is very difficult to make comparisons with other New Mexico Irvingtonian faunas, which are composed primarily of large mammals. Therefore, comparisons are mostly with Irvingtonian small mammal faunas outside of New Mexico, in particular, Hansen Bluff, located about 40 km northeast of SAM Cave in southern Colorado (Rogers et al., 1992). The only larger mammals in SAM Cave are the badger *Taxidea taxus* and the wolf *Canis rufus*. However, the identification of *C. rufus* from Sam Cave is questionable, and it is more likely to be the Irvingtonian wolf *C. armbrusteri* (see Berta, 1995).

The age of the SAM Cave vertebrate assemblage is determined primarily by the biochronology of its extensive microtine (= arvicoline) rodent fauna (Rogers et al., 2000). The presence of the microtines *Mictomys kansasenis*, *Allophaiomys*, *Lemmiscus curtatus*, and *Microtus* cf. *M. californicus* helps date the oldest sites in SAM Cave. The first appearance of *M. kansasenis* is in the late early Irvingtonian Sappa Fauna of Nebraska

(1.3 Ma; Martin and Schultz, 1985). The presence of an advanced unnamed species of *Allophaiomys* indicates an age greater than 0.85 Ma, based on comparisons with the nearby Hansen Bluff fauna (Repenning, 1992; Rogers et al., 2000). SAM Cave apparently documents the evolution of the sagebrush vole *Lemmiscus* from *Allophaiomys* between about 1.0 and 0.85 Ma (Rogers et al., 2000). The occurrence of *Microtus* cf. *M. californicus* indicates that the fauna is younger than the beginning of the Jaramillo Subchron (1.07 Ma; Repenning, 1992). The red-backed vole *Clethrionomys* first appears in two SAM Cave sites that date from 0.85 Ma to just above the Matuyama/Brunhes boundary. The occurrences of *Clethrionomys* and *Lemmiscus* in SAM Cave represent the oldest records of these genera in North America (Rogers et al., 2000).

The presence of *Mictomys kansasenis*, *Allophaiomys*, *Lemmiscus curtatus*, and *Microtus* cf. *M. californicus* in SAM Cave indicates an age range between about 1.0 Ma and 0.85 Ma (Rogers et al., 2000), which places this fauna in the early part of the medial Irvingtonian. A slightly younger medial Irvingtonian site in SAM Cave contains *Clethrionomys*, and is between 0.85 and 0.78 Ma in age. SAM Cave is younger than other Irvingtonian faunas known from New Mexico, including Tijeras Arroyo, Tortugas Mountain, and Mesilla Basin Fauna C, all of which are early Irvingtonian.

Española Basin

Ancha Sites: Blancan mammals are known from two sites in the southernmost Española basin southwest of Santa Fe in Santa Fe County (fig. 1, site 3). These two sites represent the northernmost occurrences of Blancan mammals in New Mexico. A volcaniclastic unit correlative with the Ancha Formation, exposed in an abandoned cinder quarry near the Santa Fe Airport (NMMNH site L-3116), preserves a trackway (NMMNH 25583) of a large camelid, either *Camelops* or one of the giant Blancan camels (e.g., *Gigantocamelus*). The camel tracks occur in a fine-grained volcaniclastic deposit that is part of the Cerros del Rio volcanic field, dated to between 2.8 and 2.3 Ma (Koning et al., 2001). In 1999, at a second site about 10 km farther south and about 2 km west of Turquoise Hill (NMMNH site L-4321), Dan Koning collected a mandible with p4–m3 (NMMNH 30493) of the prairie dog *Cynomys* in a sandy unit about 6 m below the local top of the Ancha Formation. In a review of the fossil history of prairie dogs, Goodwin (1995) noted that the earliest fossil record of the genus *Cynomys* is late Blancan. The mandible from the Ancha Formation most closely resembles the extinct species *C. hibbardi* from the late Blancan White Rock LF in Kansas (Eshelman, 1975).

Albuquerque Basin

The Albuquerque basin has often been divided into two separate basins or subbasins, with the northern third called the Santo Domingo basin and the southern two-thirds called the Albuquerque-Belen basin (e.g., Tedford, 1981). We follow a more recent trend, which is to combine these basins and refer to them as the Albuquerque basin. We arbitrarily divide the Albuquerque basin into northern and southern portions, with the dividing line being the boundary between Bernalillo and Valencia counties. The Pliocene and Pleistocene stratigraphic units in the Albuquerque basin that are known to contain Blancan and Irvingtonian vertebrate fossils include the Ceja and Loma Barbon members of the Arroyo Ojito Formation of Connell et al. (1999) and the Sierra Ladrones Formation. The stratigraphy of Pliocene and Pleistocene geologic units in the Albuquerque basin is currently in a state of flux, and thus it is likely that some of the stratigraphic names recognized here may change in the next few years.

Santo Domingo: The Santo Domingo LF (fig. 12.1, site 4) was derived from axial river gravels of the Sierra Ladrones Formation (Smith and Kuhle, 1998), east of the Rio Grande near the Santo Domingo Pueblo in Sandoval County (Tedford, 1981). Tedford identified the horses *Equus calobatus* and *E. scotti* from the Santo Domingo fauna, both of which are known from the late Blancan and early Irvingtonian. Recent examination of fossils from Santo Domingo in the Frick Collection revealed two additional taxa, the small three-toed horse *Nannippus peninsulatus* and the large peccary *Platygonus* cf. *P. bicalcaratus*, both of which are indicative of Blancan faunas. The presence of *Nannippus* suggests an age of 2.2 Ma or older. Tedford noted that these deposits are interbedded with the Santa Ana Mesa basalts, dated at 2.67 Ma and 2.41 Ma (Smith and Kuhle, 1998), and are overlain by the lower Bandelier Tuff dated at 1.61 Ma (Izett and Obradovich, 1994). The biostratigraphic and geochronologic constraints indicate an age between 2.7 and 2.2 Ma for the Santo Domingo LF.

WESTERN MOBILE: Two species of mammals are known from the Western Mobile gravel pit (NMMNH Site L-1546; fig. 12.1, site 5), located about 3 km northeast of Bernalillo in Sandoval County (Lucas et al., 1993; Morgan and Lucas, 2000a). These fossils, including glyptodont scutes and a proboscidean tusk fragment, were collected as float and thus lack precise stratigraphic provenance, although they were almost certainly derived from the Sierra Ladrones Formation. The most diagnostic fossils from the Western Mobile site are five well-preserved interior carapacial osteoderms of the glyptodont *Glyptotherium arizonae*. These osteoderms are identified as *G. arizonae* on the basis of their large size, comparatively great thickness, and small, flat central figure (Gillette and Ray, 1981). *G. arizonae* also occurs in the early Irvingtonian Tijeras Arroyo fauna, located about 30 km south (see below). Most other published records of *G. arizonae* from the southwestern United States are early Irvingtonian in age, including Gilliland and Rock Creek in Texas, Holloman in Oklahoma (Gillette and Ray, 1981), and Mesilla Basin Fauna C from the Mesilla basin in southernmost New Mexico (Vanderhill, 1986). This glyptodont is also known from two latest Blancan sites in New Mexico, Mesilla Basin Fauna B and the Virden LF in the Duncan basin in the southwestern part of the state (Morgan and Lucas, 2000b). The Western Mobile glyptodont scutes are also significant because the location of the gravel pit at about 35°20′ North latitude represents one of the northernmost records for the genus *Glyptotherium* in North America (Gillette and Ray, 1981).

LOMA COLORADO DE ABAJO: Loma Colorado de Abajo is a prominent hill within the city limits of Rio Rancho in Sandoval County, about 20 km northwest of Albuquerque in the northern Albuquerque basin (fig. 12.1, site 6). Between 1990 and 1996, Paul Knight collected several skulls of small rodents from indurated, fine-grained reddish sandstones near the base of the exposed section on the south-facing escarpment of Loma Colorado de Abajo (NMMNH Site L-1462). The fossiliferous level is in the Loma Barbon Member in the upper part of the Arroyo Ojito Formation of Connell et al. (1999), about 8 m below the base of the overlying Ceja Member of the same formation. The Loma Colorado de Abajo LF consists of just three taxa (Morgan and Lucas, 1999, 2000a), a small land tortoise and two genera of rodents, *Spermophilus* and *Geomys*. The same stratum from which the rodent fossils were collected also contains numerous ichnofossils that appear to be rodent burrows. The Loma Colorado de Abajo LF is unique among New Mexico Blancan faunas in consisting entirely of small burrowing vertebrates.

A ground squirrel of the genus *Spermophilus* is represented in the Loma Colorado de Abajo LF by a partial skull with P4 from a small species in the size range of living *S. tridecemlineatus*. It is considerably smaller than *Spermophilus* cf. *S. bensoni* from the Blancan of southeastern Arizona (Tomida, 1987), a species tentatively identified from the early Blancan Buckhorn LF in southwestern New Mexico (Morgan et al., 1997). The Loma Colorado *Spermophilus* skull is also smaller than *S. pattersoni* and *S. matachicensis* from the late Hemphillian Yepómera Fauna in northern Mexico (Wilson, 1949; Lindsay and Jacobs, 1985). Three specimens from Loma Colorado de Abajo are provisionally referred to the primitive pocket gopher, *Geomys* (*Nerterogeomys*) *minor*, including a nearly complete skull, a rostrum with a complete dentition, and an edentulous left mandible. The two skulls are identified as *Geomys* on the basis of their bisulcate upper incisors, unrooted cheek teeth, and absence of enamel on the posterior surface of P4. Earlier pre-Blancan geomyids such as *Pliogeomys* have rooted cheek teeth. The fragmentary mandible lacks cheek teeth, but can be identified as a member of the extinct subgenus *Geomys* (*Nerterogeomys*) by the placement of the mental foramen ventral to the masseteric crest (Tomida, 1987). *Geomys* (*Nerterogeomys*) first appears in the early Blancan and becomes extinct in the early Irvingtonian. The Loma Colorado pocket gopher skulls are smaller than most described skulls of *Geomys* (*Nerterogeomys*), and compare most closely to the small species, *G. minor*, known from the early Blancan Rexroad Fauna in Kansas and Verde LF in Arizona, and the medial Blancan Beck Ranch LF in Texas and Benson Fauna in Arizona (Hibbard, 1967; Dalquest, 1978; Czaplewski, 1990). Repenning and May (1986) reported *G. minor* from the early Blancan Truth or Consequences LF from the Palomas Formation in Sierra County in central New Mexico. The Loma Colorado mandible is smaller than pocket gopher mandibles from the Pajarito and Belen faunas in the Albuquerque basin referred to *G.* (*Nerterogeomys*) *paenebursarius* (see Morgan and Lucas, 2000a). The smaller species of *G.* (*Nerterogeomys*) that are most similar in size to the Loma Colorado *Geomys* (e.g., *G. minor*) are restricted to the Blancan, whereas the species that survive into the Irvingtonian (e.g., *G. anzensis*, *G. garbanii*, and *G. persimilis*) are larger.

The age of the Loma Colorado de Abajo LF is probably early or medial Blancan. Small species of *Geomys* (*Nerterogeomys*), such as *G. minor*, are typical of faunas of this age. Also, the medial to late Blancan (older than 2.2 Ma) Mountainview LF is known from the Ceja Member of the Arroyo Ojito Formation in Tijeras Arroyo, a unit that overlies the Loma Barbon Member. The Loma Colorado de Abajo LF is stratigraphically below and thus older than the Blancan fauna from Tijeras Arroyo. However, these two faunas have no taxa in common, so more detailed biostratigraphic comparisons are not possible.

MOUNTAINVIEW: Most of the vertebrate fossils from Tijeras Arroyo, located just south of the Albuquerque International Airport in Bernalillo County, are derived from the Sierra Ladrones Formation and are early Irvingtonian in age (Lucas et al., 1993; see below). However, one locality (NMMNH Site L-1458) at the base of the exposed stratigraphic section in Tijeras Arroyo (fig. 12.1, site 7) has produced two species that are indicative of a Blancan age. This site is here named the Mountainview Local Fauna to eliminate any confusion with the younger Tijeras Arroyo Irvingtonian sites. The fossils from the Mountainview site were derived from a sandstone comprising unit 1 in the stratigraphic section of Lucas et al. (1993). The lowermost part of the section in Tijeras Arroyo, including unit 1, was referred to the Ceja Member of the Arroyo Ojito Formation by Connell et al. (1999).

Lucas et al. (1993) referred a partial mandible with p3 from Mountainview to the rabbit *Hypolagus* cf. *H. gidleyi*. This rabbit is found in late Hemphillian and Blancan faunas, but is unknown from the Irvingtonian (White, 1987). The horse *Equus* cf. *E. cumminsii* was identified from this site based on a partial skull with a nearly complete dentition and several associated postcranial elements (Lucas et al., 1993). *E. cumminsii* occurs in several medial and late Blancan sites in Texas, but is unknown from the Irvingtonian (Kurtén and Anderson, 1980). There are two other Blancan records of *E. cumminsii* from New Mexico, the medial Blancan Arroyo de la Parida LF in Socorro County (Tedford, 1981; Lucas and Morgan, 1996) and the late Blancan Pearson Mesa LF in Hidalgo County (Morgan and Lucas, 2000b).

Both mammals from the Mountainview site in the lower portion of the Tijeras Arroyo section, *Hypolagus* cf. *H. gidleyi* and *Equus* cf. *E. cumminsii*, are typical of Blancan faunas, and do not occur in the Irvingtonian. The extinction in the late Pliocene of several characteristic Blancan genera (the *Nannippus* extinction event of Lindsay et al. 1984), including *Hypolagus*, indicates that the Mountainview site is older than 2.2 Ma. *Equus* cf. *E. cumminsii* is absent from early Blancan faunas (Kurtén and Anderson, 1980). These two species suggest that Mountainview is medial to late Blancan in age (between 3.6 and 2.2 Ma). The absence of Guaje Pumice from the Ceja Member of the Arroyo Ojito Formation in the lower part of the Tijeras Arroyo section indicates that these beds predate deposition of the Bandelier Tuff at 1.6 Ma (Lucas et al., 1993).

TIJERAS ARROYO: Ten localities in Tijeras

Arroyo (fig. 12.1, site 8) have produced a significant vertebrate fauna (table 12.2) of early Irvingtonian age (Lucas et al., 1993; Morgan and Lucas, 2000a). More than 75 m of the Sierra Ladrones Formation is exposed in Tijeras Arroyo, consisting of sandstones, pumiceous sandstones, and gravels, with minor amounts of mudstone and diatomite. These sediments represent axial river deposits of an ancestral Rio Grande. The most important lithological marker in these beds is the presence of reworked Guaje Pumice derived from the Bandelier Tuff, Ar/Ar dated at 1.61 Ma (Izett and Obradovich, 1994), in the units associated with an Irvingtonian fauna (units 6–8 of Lucas et al., 1993). An extensive flora of leaves and pollen from a localized volcanic ash bed was collected in the Tijeras Arroyo section (NMMNH Site L-1445). The Tijeras Arroyo flora indicates that the cottonwood forest or bosque currently found along the banks of the Rio Grande in New Mexico dates back to the early Pleistocene (Knight et al., 1996).

The land tortoise *Hesperotestudo* and five species of mammals, including *Glyptotherium* cf. *G. arizonae*, *Equus scotti*, *Equus* sp., *Camelops* sp., and *Mammuthus meridionalis* occur together in the Tijeras Arroyo section above the Mountainview Blancan site discussed above (Lucas et al., 1993; Morgan and Lucas, 2000a). These species constitute a fairly typical fauna of early Irvingtonian age. Three additional species of mammals, a small species of *Equus*, the llama *Hemiauchenia macrocephala* and the mammoth *Mammuthus imperator*, occur somewhat higher in the Tijeras Arroyo section than the remainder of the fauna, but probably are Irvingtonian age as well.

A caudal osteoderm of a glyptodont from Tijeras Arroyo (Lucas et al., 1993) probably is not diagnostic at the species level, although this specimen almost certainly represents *Glyptotherium arizonae*. Tentative referral of this osteoderm to *G. arizonae* is reasonable as its association with *Mammuthus* rules out a Blancan age, and the Rancholabrean *G. floridanum* is restricted to the Atlantic and Gulf coastal plains (Gillette and Ray, 1981). The large horse *Equus scotti* is the most common mammal in the Tijeras Arroyo Irvingtonian fauna, represented by mandibles, isolated teeth, and postcranials (Lucas et al., 1993; Morgan and Lucas, 2000a). *E. scotti* is the typical large horse in late Blancan and early Irvingtonian faunas in the southwestern United States (Hibbard and Dalquest, 1966), and occurs in medial Blancan through early Irvingtonian faunas in New Mexico (Tedford, 1981; Morgan et al., 1998). A complete equid metacarpal from Tijeras Arroyo is more slender than metacarpals of *E. scotti*, and represents a second, smaller species of *Equus* (Hibbard and Dalquest, 1966; Harris and Porter, 1980). A partial skull of a small *Equus* occurs higher in the Tijeras Arroyo section.

Lucas and Effinger (1991) and Lucas et al. (1993) referred a mandible with left and right m3 from Tijeras Arroyo to the primitive mammoth *Mammuthus meridionalis* on the basis of its low plate count and extremely thick enamel. This is one of only two records of mammoths from New Mexico referred to *M. meridionalis*, indicating that this fauna is almost certainly early Irvingtonian. The other record consists of several partial teeth, tentatively referred to *M. meridionalis*, from an early Irvingtonian fauna in the Mesilla basin (Vanderhill, 1986). Lucas et al. (1993) referred a left M3 in a maxillary fragment from Tijeras Arroyo to the mammoth *Mammuthus imperator*. The teeth of *M. imperator* are more advanced than *M. meridionalis* in having a higher plate count, higher lamellar frequency, and thinner enamel. The *M. imperator* specimen was found about 12 m higher in the section than the remainder of the Tijeras Arroyo fauna, and thus is somewhat younger, although an Irvingtonian age is still likely (Lucas et al., 1993).

The presence of mammoths in unit 6 and above clearly establishes an Irvingtonian age for the upper part of the Tijeras Arroyo section, as *Mammuthus* is one of the defining genera for the Irvingtonian NALMA. The first appearance of *Mammuthus* in the New World occurred sometime in the early Pleistocene (early Irvingtonian) between about 1.8 and 1.6 Ma. The mammoth jaws from Tijeras Arroyo represent one of the oldest well-documented records of *Mammuthus* from North America, based on an Ar/Ar date of 1.61 Ma on Guaje Pumice from the Sierra Ladrones Formation in Tijeras Arroyo (Lucas et al., 1993; Izett and Obradovich, 1994; Lucas, 1995, 1996). Although the pumice date provides a maximum age for this site, evidence from other pumice deposits of exactly the same age farther south in the Rio Grande Valley (Mack et al., 1996, 1998) indicates that the pumice is very close in age to the fossils. The association of *M. meridionalis* with *Glyptotherium arizonae* and *Equus scotti* is indicative of an early Irvingtonian age for the Tijeras Arroyo fauna. Correlative early Irvingtonian faunas include the Tortugas Mountain LF (Lucas et al., 1999, 2000) and Mesilla Basin Fauna C (Vanderhill, 1986) from the Mesilla basin in southern New Mexico, Gilliland in Texas (Hibbard and Dalquest, 1966), and Holloman in Oklahoma (Dalquest, 1977).

PAJARITO: The Pajarito LF is located along the eastern escarpment of the Rio Puerco in southern Bernalillo County, extending from the Pajarito land grant to the northern end of the Isleta Reservation (fig. 12.1, site 9). This site was discovered in 1946 by Ted Galusha, Frick Laboratory, who collected a small sample of vertebrate fossils from just south of the northern boundary of the Isleta Reservation. According to Galusha's field notes (copy kindly provided by Richard Tedford), he found fossils in two distinct units, a lower unit with ''potato-shaped'' concretions and a pinkish sandy unit about 5 m higher in the section. We recently collected additional fossils from these same two units on the Pajarito land grant just north of the Isleta Reservation boundary. Maldonado and Atencio (1998) placed both the concretionary bed and the pink sand in their ''silt, sand, and clay lithofacies of the Isleta Reservation.'' A pumice that occurs between the two fossil-bearing units has been Ar/Ar dated at 3.12 ± 0.10 Ma (Maldonado et al., 1999). Tedford (1981) called this the Laguna site and attributed it to the Ceja Member, which was recently placed in the Arroyo Ojito Formation (Connell et al., 1999). Morgan and Lucas (2000a) renamed the Laguna site the Pajarito LF to eliminate any confusion regarding its location.

The Pajarito LF consists of eight species of vertebrates: a turtle, a bird, and six species of mammals, including three rodents, two camels, and a deer (table 12.1). The most diagnostic fossils are two pocket gopher mandibles referred to the extinct subgenus *Geomys* (*Nerterogeomys*). The Pajarito mandibles are similar in size and morphology to a *Geomys* mandible from the Belen Fauna (see below), all three of which are tentatively referred to *Geomys* (*Nerterogeomys*) *paenebursarius*, a species originally described from the late Blancan Hudspeth LF and Red Light LF in southwestern Texas (Strain, 1966; Akersten, 1972). A humerus of the ground squirrel *Spermophilus* and two rodent jaws with incisors but lacking cheek teeth are also known from the Pajarito LF. The rodent jaws represent a smaller species than *Geomys* or *Spermophilus*, but cannot be identified further pending the discovery of specimens with cheek teeth. The camelids from Pajarito represent two species, including an M3 referred to the common Blancan llama, *Hemiauchenia* cf. *H. blancoensis*, and a carpal from a larger camel, probably *Camelops*. An unidentified cervid is represented by a partial antler. Fossils occur in both the concretionary bed, which is just below the pumice dated at 3.12 Ma (Maldonado et al., 1999), and in the pink sand, which is just above the dated pumice. One of the two *Geomys* mandibles was collected from the concretionary bed and the other from the pink sand. These two specimens are indistinguishable, suggesting that these two units are similar in age. The radioisotopic date of 3.1 Ma indicates a medial Blancan age for the Pajarito LF. This age is in agreement with the evolutionary grade of the *Geomys* mandibles and with the absence of South American immigrant mammals, which first appear in North American faunas about 2.7 Ma. This site holds significant potential for new discoveries, as only a small amount of the exposed outcrop has been explored for fossils.

ISLETA: In 1999, Dave Love collected a nearly complete metacarpal of a small camelid on the east side of the Rio Grande, about 3 km northeast of the Isleta Pueblo (fig. 12.1, site 10), from strata that are probably correlative with the Arroyo Ojito Formation of Connell et al. (1999). The fossil was derived from a unit stratigraphically below the pumice-bearing sands of the Sierra Ladrones Formation that contain early Irvingtonian mammals in Tijeras Arroyo, located about 10 km to the north. This specimen is referable to the genus *Hemiauchenia*, but is considerably smaller than metacarpals of the typical Blancan species, *H. blancoensis*, known from several other Blancan faunas in New Mexico (e.g., a complete metacarpal from the medial Blancan Tonuco Mountain LF), as well as the type locality, the Blanco LF in Texas (Dalquest, 1975). A small and apparently undescribed species of *Hemiauchenia*, mostly represented by isolated postcranial elements, is found in New Mexico faunas ranging in age from early to late Blancan. Based on its stratigraphic position, the small *Hemiauchenia* metacarpal from Isleta is probably either medial or late Blancan in age.

LOS LUNAS: The Los Lunas site (fig. 12.1, site 11) is located in strata of the Arroyo Ojito Formation that underlie the Los Lunas volcano, about 7 km west of Los Lunas in Valencia County (Tedford, 1981). A mandible of the giant marmot *Paenemarmota*, a genus found in Hemphillian and Blancan faunas in western North America (Kurtén and Anderson, 1980; Zakrzewski, 1998), was collected at this site. The large size of the Los Lunas mandible suggests referral to *P. barbouri*, a species that occurs from the early through the late Blancan (Morgan and Lucas, 2000a). A K/Ar date of 1.1–1.3 Ma on the andesite of the Los Lunas volcano (Bachman and Mehnert, 1978), which overlies the strata that yielded the *Paenemarmota* jaw, provides a minimum age for the Los Lunas site (Tedford, 1981).

Several postcranial bones of a large camel were collected from the Arroyo Ojito Formation a few kilometers northwest of the *Paenemarmota* site, about 1 km north of New Mexico Route 6 (NMMNH Site L-3738; Morgan and Lucas, 2000a). These specimens, including a partial distal radio-ulna and a magnum, probably represent a large *Camelops*. A large undescribed species of *Camelops* occurs in several medial and late Blancan faunas elsewhere in New Mexico (Vanderhill, 1986; Morgan et al., 1998).

BELEN: Beginning south of the Los Lunas volcano and extending south of Belen into northern Socorro County, badlands representing the Arroyo Ojito Formation of Connell et al. (1999) are well exposed in an east-facing escarpment just west of Interstate Highway 25 and several kilometers west of the Rio Grande. The NMMNH has two collections of Blancan vertebrates from southwest of Belen in Valencia County (fig. 12.1, site 12). In 1992, Bill Wood collected vertebrate fossils about 5 km southwest of Belen (NMMNH Site L-3778). Fossils from this site include lower jaws of the gomphotheriid proboscidean *Stegomastodon mirificus* and postcranial elements of *Equus*. Christopher Whittle and several students collected fossils from conglomeratic sandstone and slightly indurated sandstone about 2 km southwest of Belen (NMMNH Site L-3737), about 4 km north of site L-3778. Fossils from this site include a snake, the mole *Scalopus*, *Geomys*, *Equus*, and a small antilocaprid. Because of the close proximity of sites L-3737 and 3778 southwest of Belen and their occurrence in similar strata referred to the Arroyo Ojito Formation, the fossils from these two sites are combined as the Belen Fauna (Morgan and Lucas, 2000a).

The Belen Fauna (Morgan and Lucas, 2000a) is composed of five species of mammals, including *Scalopus* (*Hesperoscalops*) cf. *S. blancoensis*, *Geomys* (*Neterogeomys*) cf. *G. paenebursarius*, *Equus* cf. *E. calobatus*, a small antilocaprid, and *Stegomastodon mirificus*. A dentary with m1–m3 from the Belen Fauna is the first mole (family Talpidae) ever reported from New Mexico, recent or fossil (Morgan and Lucas, 1999, 2000a). This mole is referred to *Scalopus* (*Hesperoscalops*), an extinct subgenus of *Scalopus* restricted to the Blancan. Three species of *S.* (*Hesperoscalops*) have been described, *S. sewardensis* from the very early Blancan Saw Rock Canyon LF in Kansas, *S. rexroadi* from the early Blancan Rexroad and Fox Canyon faunas in Kansas and the medial Blancan Beck Ranch LF in Texas, and *S. blancoensis* from the late Blancan Blanco LF in Texas (Hibbard, 1953; Dalquest, 1975, 1978; Kurtén and Anderson, 1980). The Belen dentary is tentatively referred to *S. blancoensis* based on its similarity to that species in size and morphological features. A dentary with a complete dentition from Belen is identified as the extinct pocket gopher subgenus *Geomys* (*Nerterogeomys*). The morphology and size of this mandible are similar to the species *G.* (*N.*) *paenebursarius*, also identified from the Pajarito LF, and first described from the late Blancan Hudspeth and Red Light LFs of southwestern Texas (Strain, 1966; Akersten, 1972).

The most common fossils in the Belen Fauna are postcranial elements of horses of the genus *Equus*, most of which are not diagnostic at the species level. A nearly complete metatarsal is tentatively referred to the large, stilt-legged horse, *E. calobatus*, a species known from the late Blancan Santo Domingo LF (Tedford, 1981) and from late Blancan and early Irvingtonian faunas in the Mesilla basin (Vanderhill, 1986). A well-preserved pair of mandibles with right and left m2–m3 is referred to the gomphothere *Stegomastodon mirificus*. The presence of seven lophids on m3 separates this specimen from *Rhynchotherium* and *Cuvieronius*, and the highly complicated enamel with double trefoiling distinguishes the teeth from the more primitive species *S. rexroadensis*.

Four mammals in the Belen Fauna are age diagnostic. The extinct subgenus *Scalopus* (*Hesperoscalops*) is restricted to the Blancan and the species *S. blancoensis* occurs in the late Blancan. *Geomys* (*Nerterogeomys*) *paenebursarius* is known from two late Blancan faunas in southwestern Texas (Strain, 1966; Akersten, 1972), and the medial Blancan Pajarito LF in the northern Albuquerque basin (Tedford, 1981; Morgan and Lucas, 2000a). *Stegomastodon mirificus* is known from the medial Blancan through the early Irvingtonian, and *Equus calobatus* occurs in the late Blancan and Irvingtonian (Kurtén and Anderson, 1980). The age of the Belen Fauna is either medial or late Blancan. *S. blancoensis* and *E. calobatus* occur in late Blancan faunas, but are not known from the medial Blancan, whereas *G.* (*N.*) *paenebursarius* and *S. mirificus* first appear in the medial Blancan. The lack of South American immigrants in the Belen Fauna suggests a medial Blancan age, although their absence could be related to biogeographic factors. Neotropical mammals are unknown from Blancan faunas in northern New Mexico; however, *Glyptotherium* occurs in two early Irvingtonian faunas in the Albuquerque basin, Tijeras Arroyo and Western Mobile. We tentatively place the Belen Fauna in the medial Blancan (fig. 12.2) based on similarities with other medial Blancan faunas (e.g., Pajarito) from the Arroyo Ojito Formation in the Albuquerque basin.

MESAS MOJINAS: An astragalus of a small camelid (NMMNH 29936) was collected by Richard Lozinsky in 1986 from the Arroyo Ojito Formation, southeast of Mesas Mojinas in the Gabaldon badlands west of Belen in Valencia County (NMMNH Site L-4253; fig. 12.1, site 13). In their review of the early Hemphillian (late Miocene) Gabaldon Fauna from the Popotosa Formation, which underlies the Arroyo Ojito Formation, Lozinsky and Tedford (1991) referred this specimen to *Hemiauchenia* sp. and noted that it was the only fossil recovered from post-Hemphillian strata in the Gabaldon badlands. The Gabaldon specimen is very similar to two astragali of a small *Hemiauchenia* from the early Blancan Buckhorn LF in southwestern New Mexico (Morgan et al., 1997). This small species of *Hemiauchenia* is known from several other Blancan faunas in New Mexico.

VEGUITA: A site in the Arroyo Ojito Formation about 1 km east of the Rio Puerco and 10 km northwest of Veguita in northernmost Socorro County (NMMNH Site L-2941; fig. 12.1, site 14) in the southern Albuquerque basin has produced a partial maxilla with left P2–M3 of the large horse *Equus scotti* (Morgan and Lucas, 2000a). These teeth are characterized by their large size, fairly complicated enamel pattern of the fossettes, elongated protocone with a lingual indentation, and presence of a pli caballin. *E. scotti* is the common large horse in New Mexico faunas ranging in age from medial Blancan through early Irvingtonian. A Blancan age is more likely considering that most sites from the Arroyo Ojito Formation in the southern portion of the Albuquerque basin produce Blancan mammals.

SEVILLETA: Denny (1940) found Blancan fossils in sands and gravels, probably derived from the Arroyo Ojito Formation, from bluffs west of the Rio Grande and just north of the Rio Salado in the southernmost portion of the Albuquerque basin in northern Socorro County (fig. 12.1, site 15). This site is located on land now included within the Sevilleta National Wildlife Refuge. The fauna reported by Denny consists of the gom-

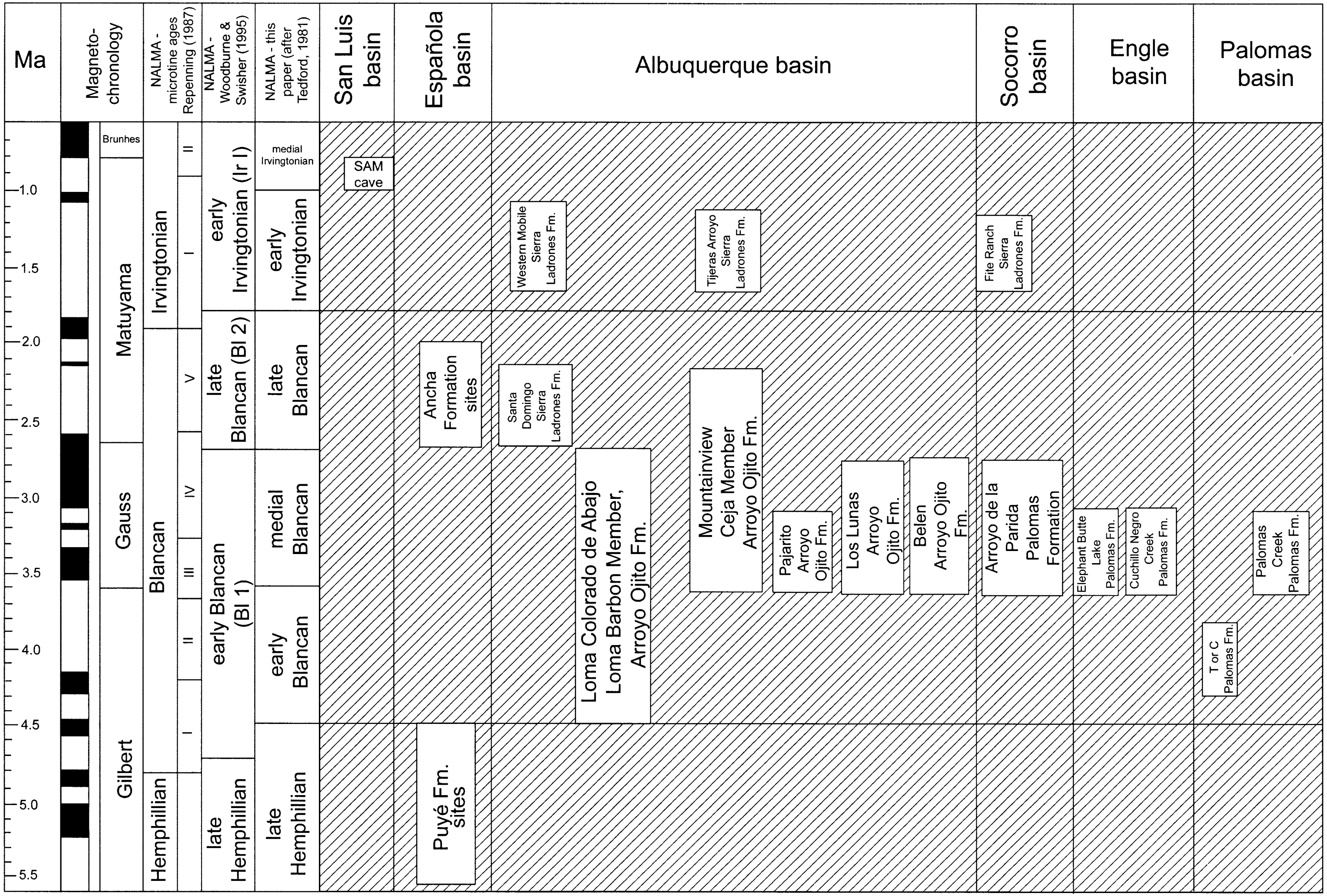

Fig. 12.2. Correlation chart showing the relative ages of late Hemphillian, Blancan, and Irvingtonian vertebrate faunas from the northern and central Rio Grande Valley in New Mexico, including the San Luis, Española, Albuquerque, Socorro, Engle, and Palomas basins. The chronological limits of the mammalian faunas are indicated by the vertical height of the boxes enclosing the fauna or site names. The lithostratigraphic unit from which each fauna or site was derived is also indicated within the box. Magnetochronology is from Berggren et al. (1995). Three systems for subdividing the Blancan NALMA are indicated to the left (Tedford, 1981; Repenning, 1987; Woodburne and Swisher, 1995).

phothere *Stegomastodon mirificus* and a tooth of *Equus*. We have not been able to relocate Denny's fossils, and thus the identifications are taken from his paper and must be considered tentative. We recently collected fossils from outcrops of the Arroyo Ojito Formation in this same general area, north of the Rio Salado on the La Joya Game Refuge. We found teeth and postcranial elements representing two species of *Equus*, *E. simplicidens* and a larger horse, tentatively identified as *E. scotti*. The Sevilleta fauna is similar to the medial Blancan Arroyo de la Parida LF, derived from the Palomas Formation about 15 km farther south in the northern Socorro basin.

Socorro Basin

Arroyo de la Parida: Vertebrate fossils were first found in Arroyo de la Parida in 1935, about 6 km northeast of Socorro, Socorro County (fig. 12.1, site 16). Needham (1936) reported a complete pair of lower jaws of the gomphotheriid proboscidean *Rhynchotherium* and a lower molar of the horse *Plesippus* (now considered a subgenus of *Equus*) from an exposure of sands and gravels of the Santa Fe Group on the south side of Arroyo de la Parida, about 2 km east of its confluence with the Rio Grande. Additional vertebrate fossils were collected from this same exposure by students from the New Mexico Institute of Mining and Technology (DeBrine et al., 1963). Curt Teichert, a well-known German invertebrate paleontologist, collected a sample of vertebrate fossils from the vicinity of Arroyo de la Parida in 1953, and donated these fossils to the American Museum of Natural History. The only locality information associated with Teichert's sample was that the fossils were collected ''about four miles north of Socorro, New Mexico.'' Based on the general locality, preservation of the fossils, and the composition of the fauna, there is little doubt that Teichert's fossils are from the area that yields the Arroyo de la Parida LF. The fossils collected by Teichert were summarized by Tedford (1981), and include three species of horses, *Equus simplicidens*, *E.* cf. *E. cumminsii*, and *E.* cf. *E. scotti*, the small antilocaprid *Capromeryx*, and the gomphothere *Stegomastodon*. Lucas and Morgan (1996) described and illustrated the mandibles of *Rhynchotherium* first mentioned by Needham, and referred them to the species *R. falconeri*, originally described from the Blanco LF in Texas. Lucas and Morgan (1996) also summarized the biostratigraphy of the Arroyo de la Parida LF, including fossils collected in 1996 by two students from New Mexico Tech, Ed Frye and Mike O'Keeffe. We visited the Arroyo de la Parida area several times during 2000 and collected numerous additional fossils from 15 different sites (Morgan et al., 2000).

The Arroyo de la Parida LF is derived from a 70-m sequence of sands and gravels that constitute the axial river (ancestral Rio Grande) facies of the Palomas Formation. The strata in the vicinity of Arroyo de la Parida are located at the northern end of the Socorro basin, representing one of the northernmost occurrences of the Palomas Formation, which has its type area about 100 km farther south in Palomas Creek near Truth or Consequences in Sierra County (Lozinsky, 1986). The Arroyo de la Parida LF is composed of 10 vertebrates: the land tortoise *Hesperotestudo*; the ground sloth *Megalonyx* cf. *M. leptostomus*; three horses, *Equus* cf. *E. cumminsii*, *E. scotti*, and *E. simplicidens*; two camelids, a large *Camelops* and a small *Hemiauchenia*; the small antilocaprid *Capromeryx*; and two proboscideans, *Rhynchotherium falconeri* and *Stegomastodon* sp. This is a fairly typical faunal assemblage found in New Mexico Blancan sites, mostly consisting of large grazing ungulates and dominated by horses of the genus *Equus*.

Five mammals from the Arroyo de la Parida LF are restricted to the Blancan, including *Megalonyx leptostomus*, *Equus cumminsii*, *E. simplicidens*, the large *Camelops*, and *Rhynchotherium falconeri*. The most age-diagnostic of these taxa is *Rhynchotherium*, a gomphothere that became extinct in the late Pliocene at about 2.2 Ma together with several other characteristic genera of Blancan mammals. The lower jaws of *R. falconeri* from Arroyo de la Parida were collected near the top of the local section of the Palomas Formation, suggesting that the entire fauna, most of which occurs some 40 m lower in the section, is older than 2.2 Ma. An early

Blancan age for the Arroyo de la Parida LF can be ruled out by the presence of *E. scotti* and *Camelops*, both of which first appear in New Mexico faunas during the medial Blancan. The absence of South American immigrants suggests an age greater than 2.7 Ma. *Megalonyx* is the only Blancan mammal of South American origin that was not a participant in the Great American Interchange. *Megalonyx* or its progenitor arrived from South America in the late Miocene about 9 Ma. *M. leptostomus* is fairly widespread in early through late Blancan faunas. The Arroyo de la Parida LF is interpreted to be medial Blancan in age (3.6–2.7 Ma), and is similar to the Cuchillo Negro Creek LF from the Palomas Formation in the Engle Basin near Truth or Consequences.

FITE RANCH: Tedford (1981) reported postcranial bones of *Equus* and *Camelops* collected by George Pearce in 1953 from pumice-bearing sands on the Dean Fite Ranch near San Antonio in the Socorro basin, Socorro County (fig. 12.1, site 17). Specimens in the F:AM collections from Fite Ranch consist of an astragalus of *Equus* and a partial metatarsal of *Camelops*. Needham (1936) reported a partial humerus, radius, and ulna of the turkey *Meleagris*, apparently from this same locality (Tedford, 1981). Needham (p. 537) described this locality as ''a bed of pumicite . . . about three and one half miles northeast of San Antonio, Socorro County, along the east bluff of the Rio Grande. It [the bed of pumicite] is underlain by some thirty feet of light-colored gravel and sand and buff silt, typical of the Santa Fe formation as developed east of the Rio Grande near Socorro'' (i.e., Arroyo de la Parida). Tedford noted that the pumice-bearing sands on the Fite Ranch were attributed to the Bandelier eruptions, indicating an age of 1.6–1.2 Ma (Izett et al., 1981; Izett and Obradovich, 1994). This would suggest an early Irvingtonian age, although the fossil vertebrates from Fite Ranch are not age diagnostic.

SAN MARCIAL BASIN

SILVER CANYON: Gary Morgan, Mike O'Neill, and Brenda Wilkinson collected a small sample of fossils in 1998 from the Palomas Formation near Silver Canyon in the San Marcial basin at the very northern end of Elephant Butte Lake in southern Socorro County (NMMNH site L-3682; fig. 12.1, site 18). The Silver Canyon site consists of three taxa of mammals, a rodent tentatively identified as the wood rat *Neotoma*, the horse *Equus*, and an indeterminate gomphothere. The most common fossils are proboscidean tooth and tusk fragments and postcranials, identifiable only as Gomphotheriidae. *Equus* is represented in the fauna by postcranial remains. A mandible of a fairly large rodent appears to be referable to *Neotoma*, although the teeth are too worn for a species-level identification. The age of this fauna cannot be determined on the basis of the fossil material currently known, although a Blancan age is most likely considering that all other vertebrate faunas so far known from the Palomas Formation are Blancan.

ENGLE BASIN

ELEPHANT BUTTE LAKE: Joseph Rak and Charles Falkenbach of the Frick Laboratory collected fossil vertebrates in the late 1920s from axial river gravels of the ancestral Rio Grande in the Engle and Palomas basins in the vicinity of Hot Springs (now called Truth or Consequences) in Sierra County. Fossils from the Engle basin on the western side of Elephant Butte Lake north of Truth or Consequences are called the Elephant Butte Lake Fauna (fig. 12.1, site 19). Tedford (1981) attributed these strata to the Sierra Ladrones Formation, but they have since been referred to the Palomas Formation (Lozinsky, 1986). The precise localities and stratigraphy of these fossils are not known; however, they were certainly derived from the Palomas Formation, and are similar in age to the nearby Cuchillo Negro Creek LF (see below). Mammals identified by Tedford from Elephant Butte Lake are the horse *Equus simplicidens*, the tapir *Tapirus*, and the giant camel *Gigantocamelus*. Since 1981, additional fossils referable to the Elephant Butte Lake Fauna have been collected in the vicinity of Rock Canyon on the western shore of Elephant Butte Lake about 5 km north of Truth or Consequences, and include the giant tortoise *Hesperotestudo*, a mandible of *Gigantocamelus* cf. *G. spatula*, and a skull of the gomphothere *Stegomastodon* cf. *S. rexroadensis*. *E. simplicidens* and *Gigantocamelus* are indicative of the Blancan, and *S. rexroadensis* suggests an early or medial Blancan age. Tedford considered these sites to be medial Blancan because of their close stratigraphic association with a basalt flow dated at 2.9 ± 0.3 Ma from Mitchell Point on the western side of Elephant Butte Lake (Bachman and Mehnert, 1978).

CUCHILLO NEGRO CREEK: Vertebrate fossils from the Palomas Formation north of Cuchillo Negro Creek in the Engle Basin in Sierra County (fig. 12.1, site 20) were named the Cuchillo Negro Creek LF by Lucas and Oakes (1986). Fossils were collected from the Cuchillo Negro Creek area in 1983 and 1984 by University of New Mexico field crews and in 1998 and 1999 by NMMNH field crews. Lozinsky (1986) recognized two informal members of the Palomas Formation in this area, the axial facies consisting of about 30 m of sand with lenses of gravel and clay and the piedmont facies consisting of about 50 m of sandy silt and conglomerate. Most of the fossils were derived from the axial facies, which was deposited by an ancestral Rio Grande. A basalt flow dated at 2.9 Ma from Mitchell Point, about 15 km north of the Cuchillo Negro Creek sites, interfingers with the axial facies of the Palomas Formation (Lozinsky, 1986).

The Cuchillo Negro Creek LF is composed of 10 species (Lucas and Oakes, 1986; this report): 3 turtles, including a small land tortoise of the genus *Hesperotestudo*, the mud turtle *Kinosternon*, and an aquatic member of the family Emydidae, and 7 mammals, including the borophagine canid *Borophagus hilli*, the procyonid *Bassariscus* sp., the equid *Equus* cf. *E. simplicidens*, the camelids *Camelops* sp., *Hemiauchenia blancoensis*, and *Hemiauchenia* small sp., and the gomphotheriid proboscidean *Stegomastodon rexroadensis*.

A nearly complete dentary with i2–3, c, and p2–m2 identified as *Borophagus diversidens* by Lucas and Oakes (1986) was referred to *B. hilli* by Wang et al. (1999). Although most *Borophagus* fossils from the early Blancan were referred to *B. diversidens* by previous authors, these specimens are more similar in size and morphology to the late Hemphillian and early Blancan species *B. hilli*. The larger and more highly derived species *B. diversidens* appears in the late early Blancan and survives until the late Blancan (Wang et al., 1999). An edentulous mandible from Cuchillo Negro Creek represents the first New Mexico Pliocene record of the ringtail *Bassariscus*. The only Blancan species of *Bassariscus*, *B. casei* from the early Blancan Rexroad Fauna in Kansas, is distinguished from the extant *B. astutus* on the basis of dental characters that cannot be observed in the Cuchillo Negro Creek jaw.

Lucas and Oakes (1986) identified the palate of a horse from the Cuchillo Negro Creek LF as *Equus simplicidens*. Two associated upper molars found in 1998 match the original dental sample. Although these teeth have several features that differ somewhat from typical *E. simplicidens* (e.g., fairly complicated fossettes and slight lingual indentation of the protocone), this species is the only Blancan *Equus* that is similar in morphology and size to the teeth from Cuchillo Negro Creek. There are three taxa of camelids from Cuchillo Negro Creek. The typical large Blancan llama *Hemiauchenia blancoensis* was reported previously (Lucas and Oakes, 1986). A small species of *Hemiauchenia* is known from an adult distal tibia. This apparently undescribed species of llama occurs in six Blancan faunas in New Mexico. A large undescribed species of *Camelops*, represented by a large proximal phalanx from Cuchillo Negro Creek, occurs in several other Blancan faunas in New Mexico (Morgan et al., 1998).

A proboscidean is represented at Cuchillo Negro Creek by a pair of mandibles with heavily worn m3s (Lucas and Oakes, 1986) and by a recently collected partial m3 in medium wear. The mandibles have a short, straight symphysis lacking tusks. The m3s of these two specimens are similar in size and dental features, including the presence of six lophids and a simple trefoil pattern. The combination of six lophids on the m3 and the absence of lower tusks excludes all other Blancan genera of proboscideans except *Stegomastodon*. The smaller number of lophids on m3 and simple trefoiling distinguish the Cuchillo Negro Creek teeth from the more advanced species *S. mirificus*, and suggest referral to the early to medial Blancan *S. rexroadensis*.

Lucas and Oakes (1986) proposed a medial 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. They suggested that the Cuchillo Negro Creek LF is similar to the Rexroad Fauna in Kansas and the Benson Fauna in Arizona. The presence of *Camelops*, a genus that supposedly did not appear until after 3.7 Ma (Lindsay et al., 1984), is indicative of a medial Blancan age, and *Stegomastodon rexroadensis* occurs in both early and medial Blancan faunas. The absence of South American immigrant mammals indicates a pre-late Blancan age (older than 2.7 Ma). The presence of *Borophagus hilli* suggests an early Blancan age according to Wang et al. (1999), although this same species occurs in the medial Blancan Hagerman Fauna in Idaho. A more precise age determination for the Cuchillo Negro Creek LF must await the discovery of additional age-diagnostic taxa, or other data such as magnetostratigraphy. In the near future, we intend to determine the relative stratigraphic position of this fauna compared to the better known early Blancan Truth or Consequences LF, located about 5 km farther south.

Palomas Basin

Truth or Consequences: The Truth or Consequences LF is derived from fine-grained sediments of the Palomas Formation in a roadcut on Interstate 25 about 2 km south of Truth or Consequences in Sierra County (Repenning and May, 1986; fig. 12.1, site 21). The site was discovered by Arthur Harris of the University of Texas at El Paso and then worked in the early 1980s by Charles Repenning and Steven May of the U.S. Geological Survey in Denver. Gary Morgan, Paul Sealey, and Spencer Lucas began work at this site in 1997 and have added numerous taxa to the fauna, including both large and small species (table 12.1). Repenning and May recovered most of their fossils by excavation, whereas the more recent NMMNH collections have been obtained primarily through screenwashing.

The stratigraphic section that includes the Truth or Consequences LF is composed of about 20 m of poorly consolidated sand and pebbly sand, with two interbedded mudstone layers, referred to the Palomas Formation. Most of the vertebrate fossils occur in greenish to reddish mudstones in the lower third of the roadcut. The preservation of fossils in these mudstones is excellent, and includes numerous mandibles, maxillae, and partial skulls of both small and large mammals. We recently recovered fossils of aquatic species, including a duck and two partial shells of emydid turtles, in fine sand at the base of the local section. Fine-grained units are uncommon and discontinuous within the axial river facies of the Palomas Formation, which is dominated by sands and gravels.

The Truth or Consequences LF, as originally described by Repenning and May (1986), consisted of 13 species: 4 reptiles, including the mud turtle *Kinosternon*, the box turtle *Terrapene*, the fence lizard *Sceloporus*, and the coachwhip snake *Masticophis*; and 9 mammals, including the rabbits *Hypolagus vetus* and *Notolagus lepusculus*, the pocket gopher *Geomys* (*Nerterogeomys*) *minor*, the cotton rat *Sigmodon*, the rice rat cf. *Oryzomys*, the wood rat *Neotoma quadriplicata*, the horse *Equus* (*Plesippus*), the deer *Odocoileus brachyodontus*, and the gomphothere *Stegomastodon*. Recent additions to the fauna include an aquatic emydid turtle, another snake, a duck and a galliform bird, and six mammals—a shrew, the mole *Scalopus*, a small sciurid, the large canid *Borophagus* cf. *B. hilli*, the peccary *Platygonus* cf. *P. bicalcaratus*, and the small antilocaprid *Capromeryx*. The Truth or Consequences LF is now composed of 23 species, including 15 mammals (table 12.1), making it one of the most diverse Blancan vertebrate faunas from New Mexico.

Many of the mammals from the Truth or Consequences LF are age diagnostic, several of which suggest an early Blancan age. Repenning and May (1986) referred the small rabbit to *Notolagus lepusculus*, a species named by Hibbard (1939) from the late early Blancan Rexroad 3 Fauna of Kansas (Blancan II of Repenning, 1987). The larger rabbit was identified as *Hypolagus vetus*, a species known from the Hemphillian through the medial Blancan (White, 1987). The pocket gopher was referred to the small species *Geomys* (*Nerterogeomys*) *minor*, described from Rexroad 3 (Hibbard, 1950, 1967). The primitive wood rat *Neotoma* (*Paraneotoma*) *quadriplicata* is intermediate in size between the oldest species of pack rat, *N.* (*P.*) *sawrockensis* from the very early Blancan Saw Rock Canyon LF in Kansas, and *N.* (*P.*) *quadriplicata* from Rexroad 3 (Hibbard, 1941, 1967). Repenning and May (1986) tentatively referred a small sigmodontine rodent to the extant genus *Oryzomys*. Czaplewski (1987) noted that the *Oryzomys* from Truth or Consequences was similar to his new genus *Jacobsomys* from the early Blancan (about 4 Ma) Verde LF in Arizona, but was smaller than the Verde species *J. verdensis*. The *Sigmodon* from Truth or Consequences, referred here to *S. medius*, may represent one of the earliest records of this genus. Czaplewski (1987) also recorded *S. medius* from the Verde LF.

The Truth or Consequences LF consists primarily of microvertebrates. Because of the rarity of large mammals, it is difficult to make biostratigraphic comparisons with other New Mexico Blancan faunas, most of which are composed of large vertebrates. The cervid *Odocoileus brachyodontus*, identified from Truth or Consequences by a maxillary fragment and antler, was first described from the early Blancan Fox Canyon Fauna of Kansas (Oelrich, 1953). *Odocoileus* appears in the early Blancan as an immigrant from the Old World. It is one of the genera whose first appearance helps to define the beginning of the Blancan (e.g., Woodburne and Swisher, 1995). The rostrum of a large peccary is similar to the large species *Platygonus bicalcaratus*. Although the genus *Platygonus* supposedly appeared at the beginning of the medial Blancan at about 3.6 Ma (Lindsay et al., 1984), an occurrence in the early Blancan would not be surprising. A p2 of *Borophagus* is similar in size and morphology to the p2 of *B. hilli* from Cuchillo Negro Creek, a species known elsewhere from the late Hemphillian and early Blancan (Wang et al., 1999). Fossils of *Equus* (*Plesippus*), *Capromeryx*, and *Stegomastodon* are too incomplete for further identification. *Nannippus* and camelids are both absent from the Truth or Consequences LF.

Repenning and May (1986) suggested an early Blancan age (between 4.2 and 4.0 Ma, early Blancan II of Repenning, 1987) for the Truth or Consequences LF based on both biostratigraphy and magnetostratigraphy. Repenning and May (1986) correlated the Truth or Consequences magnetostratigraphic section of 11 normally magnetized samples from three levels to the Nunivak Subchron of the Gilbert Chron, primarily on the basis of the similarity of its fauna with other faunas from the Nunivak or the next oldest normal subchron in the Gilbert (Sidufjall), and a more primitive aspect than faunas (e.g., Rexroad 3) derived from the next youngest normal subchron in the Gilbert (Cochiti). They gave an age range of 4.20–4.05 Ma for the Nunivak, but the age of this subchron has since been revised downward to 4.62–4.48 Ma (Berggren et al., 1995). The correlation of the Truth or Consequences magnetostratigraphic section to the Nunivak Subchron should be considered tentative since it was based on a few samples through a limited stratigraphic section (Mack et al., 1993). We intend to measure a longer stratigraphic section of the Palomas Formation through the Truth or Consequences LF, in hopes of determining the stratigraphic position of this fauna relative to three other nearby Blancan faunas from the Palomas Formation, Cuchillo Negro Creek and Elephant Butte Lake to the north and Palomas Creek to the south. We anticipate that a more detailed magnetostratigraphic section eventually will be taken through this section.

PALOMAS CREEK: Joseph Rak and Charles Falkenbach collected fossil vertebrates in 1927 and 1928 from exposures of the distal piedmont facies of the Palomas Formation southwest of Hot Springs (= Truth or Consequences) in Palomas Creek, Sierra County (Tedford, 1981; fig. 12.1, site 22). Palomas Creek is the type area of the Palomas gravel, now called the Palomas Formation (Lozinsky, 1986). The Palomas Creek LF is in the Palomas basin about 8–10 km southwest of the Truth or Consequences LF. Palomas Creek has a fairly diverse Blancan fauna composed of nine species (table 12.1, after Tedford, 1981): the tortoise *Hesperotestudo* and eight mammals, including the pocket gopher *Geomys* (*Geomys*); the cotton rat *Sig-*

modon medius; the horses *Nannippus peninsulatus*, *Equus simplicidens*, and *E.* cf. *E. cumminsii*; a peccary; a large *Camelops*; and the mastodont *Mammut raki*. *Nannippus*, *E. simplicidens*, *E. cumminsii*, and the large *Camelops* are characteristic of New Mexico Blancan faunas. The absence of South American immigrants suggests a pre-late Blancan age. The type mandible of *Mammut* (= *Mastodon*) *raki* (Frick, 1933) from Palomas Creek is one of the few known Blancan *Mammut*, and the only one referred to a species other than *M. americanum*, the typical Pleistocene mastodon (Lucas and Morgan, 1999).

Magnetostratigraphy and radioisotopic dates provide additional geochronologic data pertaining to the age of Palomas Formation in the Palomas basin (Mack et al., 1993, 1998). K/Ar dates on basalts in the Palomas basin include a flow dated at 4.5 $\pm$ 0.1 Ma in the western part of the basin that is either below or within the lowermost Palomas Formation and a flow dated at 3.1 $\pm$ 0.1 Ma interbedded with alluvial fan conglomerates of the Palomas Formation in the eastern part of the basin (Seager et al., 1984; Mack et al., 1998). A magnetostratigraphic section in the Palomas Formation from Palomas Creek sampled mostly reversely magnetized strata referred to the Matuyama Chron, but included about 10 m of normally magnetized strata referred to the Gauss Chron at the bottom of the section (Mack et al., 1993). The precise stratigraphic position of the Palomas Creek fossils is unknown, but the paleomagnetic data strongly suggest the fauna was derived from low in the section. The combination of magnetostratigraphy and biostratigraphy indicates a medial Blancan (3.6–2.7 Ma) age for the Palomas Creek LF.

Hatch-Rincon Basin

HATCH: Blancan and early Irvingtonian fossils occur in the Camp Rice Formation in southern New Mexico, from Hatch and Rincon Arroyo in the Hatch-Rincon basin in northern Doña Ana County south through the Jornada and Mesilla basins and into Texas. Hawley (1978) mentioned the presence of Blancan fossils from the vicinity of Hatch, but did not list any taxa. Paul Sealey and NMMNH field crews collected vertebrate fossils in 1990 and 1998 from the Camp Rice Formation about 5 km west of Hatch (fig. 12.1, site 23). The Camp Rice Formation is unconformably underlain by Miocene red beds of the Rincon Valley Formation in the vicinity of Hatch. This is similar to a stratigraphic section about 30 km southeast of Hatch in the Jornada basin near Tonuco Mountain, where the Tonuco Mountain LF was collected (Morgan et al., 1998). The only fossil previously reported from Hatch is a partial skeleton of the long-nosed snake *Rhinocheilus* (Lucas et al., 1995).

On the basis of fossils in the NMMNH collection, the Hatch LF is composed of 12 species: the land tortoises *Gopherus* and *Hesperotestudo*, the mud turtle *Kinosternon*, *Rhinocheilus*, and eight species of mammals (table 12.1) including two unidentified rabbits, the pocket gopher *Geomys* (*Nerterogeomys*) cf. *G.* (*N.*) *paenebursarius*, the badger *Taxidea*, a small cat probably of the genus *Lynx*, the horse *Equus*, the camelid *Hemiauchenia* cf. *H. blancoensis*, and the small antilocaprid *Capromeryx*. Land tortoises are the most abundant members of the Hatch fauna. Specimens of mammals are less common, particularly ungulates. *Equus* is represented by fragmentary teeth, *Hemiauchenia* by postcranial remains, and *Capromeryx* by a single tooth. Two leporids are present based on two distal femora of very different size. *Taxidea* is identified from a distal radius. Badgers are known from two other New Mexico Blancan faunas, Buckhorn and Tonuco Mountain (Morgan et al., 1997, 1998). The small cat is represented by a maxillary fragment with a partial P4 (NMMNH 25308) that compares well in size and other features to *Lynx rexroadensis*, known from late Hemphillian and Blancan faunas (MacFadden and Galiano, 1981). Two pocket gopher mandibles (NMMNH 25324, 25329) from Hatch are similar to mandibles referred to *Geomys* (*Nerterogeomys*) *paenebursarius* from the Belen and Pajarito Faunas in the Albuquerque basin (Morgan and Lucas, 2000a).

The age of the Hatch LF is somewhat uncertain because most of the mammalian taxa are not identifiable below the generic level. A medial Blancan age is suggested by the faunal and stratigraphic similarity to the nearby Tonuco Mountain LF (Morgan et al., 1998). A pre-late Blancan age is indicated by the lack of South American immigrant mammals that appeared in faunas after 2.7 Ma. A magnetostratigraphic section in the Camp Rice Formation at Hatch Siphon, located several kilometers west of the badlands that produced the Hatch LF, samples essentially the entire Gauss Chron, including both the Kaena and Mammoth Subchrons (Mack et al., 1993). The lowermost part of the section does not cross the Gilbert/Gauss boundary and is thus younger than 3.6 Ma, whereas the upper 10 m samples the Matuyama Chron. The Hatch Siphon section is similar to the magnetostratigraphic section for Cedar Hill that contains the medial Blancan Tonuco Mountain LF (Mack et al., 1993; Morgan et al., 1998; see below), further supporting a medial Blancan age for the Hatch LF.

RINCON ARROYO: Several fragmentary teeth and partial metapodials of *Equus* were collected from the Camp Rice Formation in Rincon Arroyo by Paul Knight and Paul Sealey. Rincon Arroyo is in the Hatch-Rincon basin in northern Doña Ana County about 10 km east of Hatch (fig. 12.1, site 24). The most significant aspect of Rincon Arroyo is the detailed geochonologic data available for the stratigraphic section, including magnetostratigraphy (Mack et al., 1993) and a dated pumice-clast conglomerate (Mack et al., 1998). The lower half (about 50 m) of the Rincon Arroyo section is in the Gauss Chron and the upper portion (also about 50 m) is in the Matuyama Chron, and includes the Reunion, Olduvai, and Jaramillo subchrons (Mack et al., 1993). Between the Olduvai and Jaramillo subchrons in the upper part of the section is a pumice-clast conglomerate dated at 1.60 Ma, which correlates with the lower Bandelier eruption (Mack et al., 1998). The Rincon Arroyo section crosses the Blancan/Irvingtonian boundary at the top of the Olduvai Subchron in the upper third of the section. Unfortunately, Rincon Arroyo is not particularly fossiliferous, and the few fossils recovered so far are not age diagnostic. Future field work in Rincon Arroyo hopefully will yield additional mammal fossils from this well-dated section.

JORNADA BASIN

TONUCO MOUNTAIN: The Tonuco Mountain LF is a medial Blancan vertebrate assemblage from the Cedar Hill area southeast of Tonuco Mountain (also called San Diego Mountain) in northern Doña Ana County, southern New Mexico (Morgan et al., 1998; fig. 12.1, site 25). The fossils are derived from the axial river facies of the Camp Rice Formation in the western Jornada Basin. The stratigraphic section of the Camp Rice Formation at Cedar Hill consists of about 50 m of sandstone and conglomerate, with a minor component of sandy mudstone, and is unconformably underlain by Miocene red beds of the Rincon Valley Formation (Morgan et al., 1998).

The Tonuco Mountain LF is composed of 16 species: the mud turtle *Kinosternon*, the land tortoises *Gopherus* and *Hesperotestudo*, a duck, and 12 mammals including an indeterminate rabbit; the badger *Taxidea*; the coyote-like canid *Canis lepophagus*; the borophagine canid *Borophagus* sp.; the horses *Nannippus peninsulatus*, *Equus simplicidens*, and *E. scotti*; the peccary *Platygonus* cf. *P. bicalcaratus*; the camelids *Camelops*, *Hemiauchenia blancoensis*, and a small *Hemiauchenia*; and the gomphothere *Cuvieronius*. Among these taxa, *Borophagus*, *C. lepophagus*, *N. peninsulatus*, *E. simplicidens*, *P. bicalcaratus*, and *H. blancoensis* are indicative of the Blancan, and several of these taxa help to further limit the age of this fauna within the Blancan. *E. simplicidens* is absent from very early Blancan faunas, *Platygonus* and *Camelops* supposedly do not appear until the beginning of the medial Blancan (Lindsay et al., 1984), and most Blancan records of *Nannippus* in the southwestern United States predate the Gauss/Matuyama magnetic reversal at 2.6 Ma. The absence of South American immigrants suggests the fauna is older than 2.7 Ma, the earliest date for the onset of the Great American Interchange. The biostratigraphic data restrict the age of the Tonuco Mountain LF to the medial Blancan (between 3.6 and 2.7 Ma). A magnetostratigraphic study of the Camp Rice Formation at Cedar Hill helps to further constrain the age of this fauna (Mack et al., 1993). The entire Cedar Hill section is within the Gauss Chron (younger than 3.6 Ma), and the fossiliferous interval is below the top of the Kaena Subchron (older than 3.0 Ma). The combination of biostratigraphic and magnetostratigraphic data limit the age of the Tonuco Mountain LF to the medial Blancan, between 3.6 and 3.0 Ma.

MESILLA BASIN

Two Blancan and two early Irvingtonian vertebrate faunas occur in the Camp Rice Formation in the Mesilla Basin, Doña Ana County, southern New Mexico (Tedford, 1981; Vanderhill, 1986; Lucas et al., 1999, 2000). In his doctoral dissertation, Vanderhill (1986) referred to these faunas as Faunule A (late Blancan), Faunule B (latest Blancan/earliest Irvingtonian), and Faunule C (early Irvingtonian) of the Mesilla basin, but did not apply formal names to them. We follow the letter designations of Vanderhill (1986) for the faunas from the southern Mesilla basin, from Chamberino south to the Mexican border near Santa Teresa; however, we use the terms Mesilla Basin Fauna A, B, and C (shortened to Mesilla A, B, and C) to conform to the nomenclature as discussed above under Methods (i.e., the Mesilla basin vertebrate assemblages fit the definition of faunas, rather than faunules or local faunas). The three faunas from the southern Mesilla basin are stratigraphically superposed and differ in age, as documented by both biostratigraphy and magnetostratigraphy (Vanderhill, 1986), and thus should eventually be assigned formal names to eliminate confusion. The Tortugas Mountain LF includes two early Irvingtonian sites in the northern Mesilla basin (Lucas et al., 1999, 2000) that were included in Fauna (= Faunule) C by Vanderhill (1986). Mesilla Basin Fauna C is here restricted to the early Irvingtonian fauna from the southern Mesilla basin.

Vertebrate fossils were first collected in the southern Mesilla basin in 1929 by Joseph Rak of the Frick Laboratory. George Pearce, also of the Frick Laboratory, returned to the southern Mesilla basin in 1949 and accumulated a sizeable collection, including a giant tortoise shell, several glyptodont shells, and a nearly complete tapir skeleton. Tedford's (1981) summary of the Mesilla basin fauna was based on the Frick fossils (F:AM) now housed in the AMNH. The largest collection of fossils from the Mesilla basin was amassed from the 1950s through the 1980s by William Strain, Arthur Harris, and their students at the University of Texas at El Paso (UTEP). The UTEP and F:AM collections formed the basis for the detailed review of the vertebrate paleontology, lithostratigraphy, and magnetostratigraphy of the Mesilla basin faunas by Vanderhill (1986) in his doctoral dissertation. Beginning in 1999, field crews from the NMMNH began collecting fossils from the Camp Rice Formation in the vicinity of Chamberino and La Union in the southern Mesilla Basin, and discovered a microvertebrate site near Chamberino in the latest Blancan portion of the Camp Rice Formation. The discussion of the southern Mesilla Basin faunas is primarily abstracted from Vanderhill's (1986) unpublished dissertation, with additional data from recent field work.

TORTUGAS MOUNTAIN: Vertebrate fossils have been known for 40 years from gravel pits in the northern Mesilla Basin (Ruhe, 1962; Hawley et al., 1969). The Tortugas Mountain LF includes fossils collected from two gravel pits near Tortugas Mountain, several kilometers east of Las Cruces in Doña Ana County (Lucas et al., 1999, 2000; fig. 12.1, site 26). These pits expose axial river sands and gravels of an ancestral Rio Grande in the upper part of the Camp Rice Formation. A palate of *Stegomastodon*, two mandibles of *Cuvieronius*, and isolated teeth of *Mammuthus* were collected from a gravel pit on the northwestern side of Tortugas Mountain (NMMNH site L-3537). A palate of *Cuvieronius*, a *Mammuthus* tooth, and several teeth and postcranial elements of *Equus* were found from about the same stratigraphic level in the Inman Gravel Pit (NMMNH site L-3649), about 3 km north of Tortugas Mountain (Hawley et al., 1969; Tedford, 1981; Vanderhill, 1986; Lucas et al., 1999, 2000).

With the exception of several *Equus* fossils figured in Hawley et al. (1969) that we cannot locate, the Tortugas Mountain LF consists of three species of proboscideans (Lucas et al., 1999, 2000), the gomphotheres *Cuvieronius tropicus* and *Stegomastodon mirificus* and the mammoth *Mammuthus imperator*. Tortugas Mountain is only the sec-

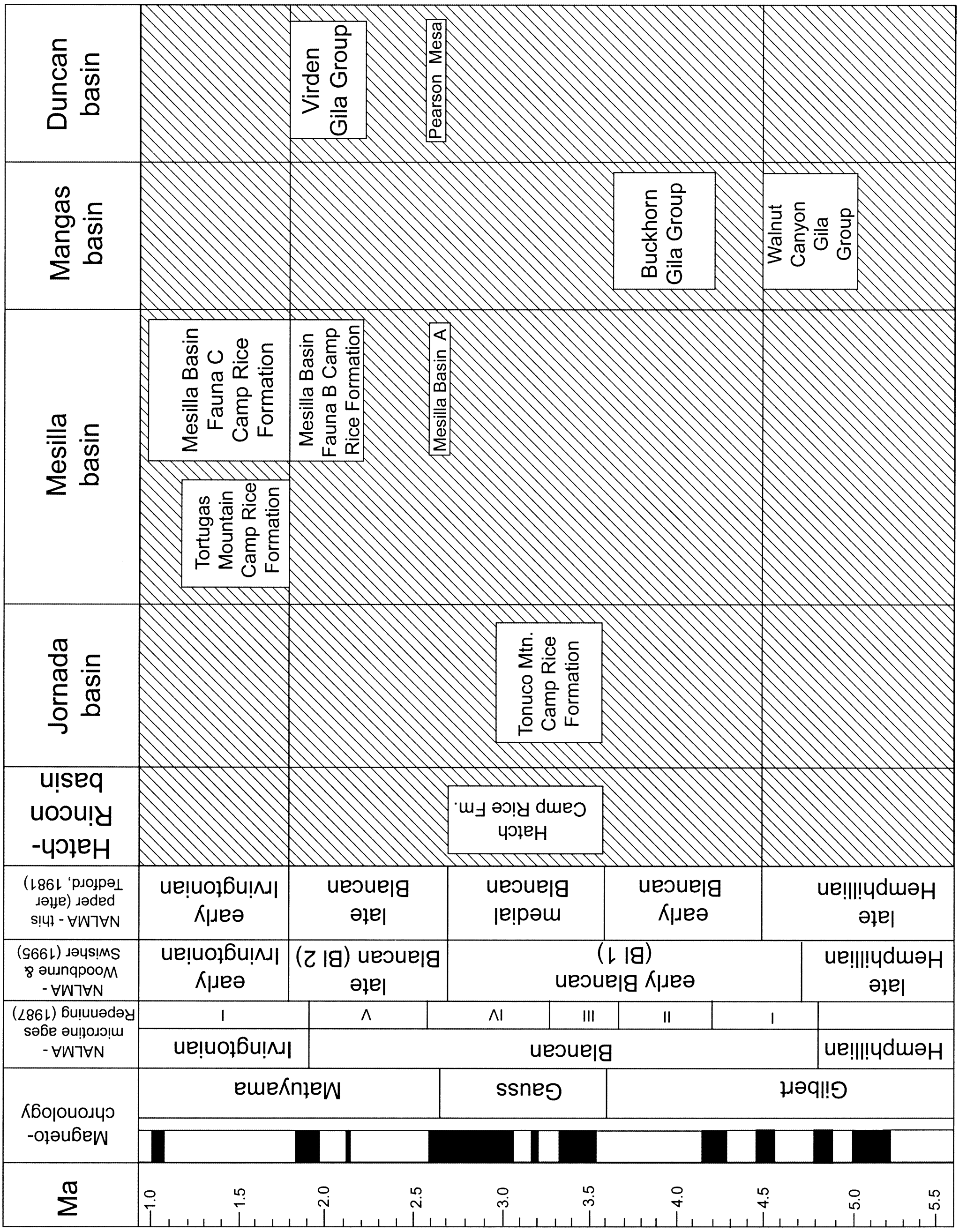

Fig. 12.3. Correlation chart showing the relative ages of late Hemphillian, Blancan, and Irvingtonian vertebrate faunas from the southern Rio Grande Valley and Gila River Valley in New Mexico, including the Hatch-Rincon, Jornada, Mesilla, Mangas, and Duncan basins. Other notes as for figure 12.2.

ond site that records the co-occurrence of *Cuvieronius*, *Stegomastodon*, and *Mammuthus*, the other being the early Irvingtonian Gilliland LF from the Seymour Formation in Texas (Hibbard and Dalquest, 1966). *Cuvieronius* is not particularly age diagnostic in North America, as this genus first appears in the Blancan and survives until the early Rancholabrean (Morgan and Hulbert, 1995). However, the association of *Stegomastodon* and *Mammuthus* is important biochronologically because these two genera have only a limited period of overlap in the early Irvingtonian, after the arrival of *Mammuthus* across the Bering Land Bridge from Eurasia (about 1.6 Ma) and before the extinction of *Stegomastodon* (about 1.2 Ma). The presence of *Mammuthus* clearly establishes an Irvingtonian age for the Tortugas Mountain LF. At present there are no confirmed records of mammoths in North America older than 1.6 Ma (Lucas, 1995, 1996; Cassiliano, 1999). The mammoth teeth from the Tortugas Mountain LF, identified as *M. imperator* by Lucas et al. (1999, 2000), are very similar to mammoth teeth from other early Irvingtonian sites, including *M. haroldcooki* from Gilliland, Texas (Hibbard and Dalquest, 1966) and Holloman, Oklahoma (Dalquest, 1977) and *M. hayi* from Leisey Shell Pit, Florida (Webb and Dudley, 1995). The youngest well-dated record of *Stegomastodon mirificus* is from Tule Canyon in the Texas Panhandle, where this species is associated with mammoths and several species of horses in a volcanic ash at the base of the Tule Formation dated at between 1.3 and 1.2 Ma (Izett, 1977; Tedford, 1981; Madden, 1983). An age between 1.6 and 1.2 Ma is indicated for the Tortugas Mountain LF based on the association of *Mammuthus* and *Stegomastodon*.

MESILLA BASIN FAUNA A: There are three vertebrate faunas from the Camp Rice Formation in the southern Mesilla basin, from Chamberino south to Santa Teresa near the border with Mexico (Vanderhill, 1986). Faunas A and B are late Blancan in age, and Fauna C is early Irvingtonian. Mesilla Basin Fauna A (hereafter shortened to Mesilla A) is the oldest and least well known of the three southern Mesilla basin faunas, probably because exposures of the lower part of the section are less extensive than in the upper part of the sequence (Vanderhill, 1986; fig. 12.1, site 27). The vertebrate assemblage from Mesilla A is composed of only six species (table 12.1; from Vanderhill, 1986): the catfish *Ictalurus*, the softshell turtle *Apalone* (= *Trionyx*), the glyptodont *Glyptotherium*, the horses *Nannippus peninsulatus* and *Equus* cf. *E. calobatus*, and the llama *Hemiauchenia blancoensis*. The presence of *Glyptotherium* confirms a late Blancan or younger age (younger than 2.7 Ma) for this fauna, as the first appearance of South American immigrants, including *Glyptotherium*, in North American faunas defines the beginning of the late Blancan. The presence of *Nannippus* indicates an age greater than 2.2 Ma.

Magnetostratigraphic data for the Camp Rice Formation strata from which the Mesilla A fauna was derived further restrict its age (Vanderhill, 1986). Mesilla A occurs in normally magnetized sediments in the upper Gauss Chron between the Kaena Subchron (3.04 Ma) and the Gauss/Matuyama boundary (2.58 Ma). Mesilla A is one of only six southwestern Blancan faunas that documents the presence in the upper Gauss Chron (between 3.0 and 2.6 Ma) of South American immigrant mammals. Although 2.7 Ma is often cited as the first appearance datum for South American immigrants in North America, and is used here as the boundary between the medial and late Blancan, the timing of the first appearance in southwestern Blancan faunas of mammals that participated in the Great American Interchange is not firmly established, but occurred sometime between 3.0 and 2.6 Ma. There are no confirmed records of Interchange mammals in Blancan faunas north of Mexico that predate the Kaena Subchron at 3.04 Ma. However, several new records of South American immigrants from central Mexico appear to be early Blancan (Miller and Carranza-Castañeda, 2001, 2002).

MESILLA BASIN FAUNA B: Mesilla Basin Fauna B (hereafter shortened to Mesilla B) is the most diverse late Blancan fauna in New Mexico (fig. 12.1, site 28). Vanderhill (1986: table 1) listed 16 species from Mesilla B: two turtles, the aquatic emydid *Trachemys* and the land tortoise *Hesperotestudo*; and 14 mammals including *Glyptotherium arizonae*, the mylodont gound sloth *Paramylodon* cf.

P. harlani, the rabbits *Aluralagus virginiae* and a larger *Lepus* or *Sylvilagus*, the small cat cf. *Lynx rufus*, the sabercat *Smilodon gracilis*, the horses *Equus* cf. *E. calobatus* and *E. scotti*, the large tapir *Tapirus haysii*, the camelids *Blancocamelus meadei*, *Gigantocamelus* cf. *G. spatula*, and *Camelops*, the deer *Odocoileus*, and the gomphothere *Cuvieronius*. Our recent fieldwork in the Camp Rice Formation near La Union has added four species of large mammals to the Mesilla B fauna (table 12.1).

We recently discovered a new microvertebrate site near Chamberino in the southern Mesilla basin (NMMNH site L-2971), from the same stratigraphic level as Vanderhill's Mesilla B. This site occurs stratigraphically about 5 m below the lowest occurrence of *Mammuthus* in the Chamberino section. The Chamberino microsite is being actively screenwashed at the present time. Preliminary identifications add at least 11 species to the Mesilla B fauna: two snakes, a lizard, a small passerine bird, and seven mammals including the mole *Scalopus*, the ground squirrel *Spermophilus*, the pocket gopher *Geomys*, the heteromyid rodent *Dipodomys*, the cotton rat *Sigmodon*, the grasshopper mouse *Onychomys*, and the skunk *Spilogale*. Combining Vanderhill's Faunule B with our Chamberino site, the Mesilla B fauna now has 25 species of mammals, making it the most diverse Blancan mammal fauna in New Mexico.

Mesilla B has a diverse assemblage of mammals, but only a few taxa are age diagnostic. Many species occur in both late Blancan and early Irvingtonian and younger faunas. Vanderhill (1986) correlated Mesilla B with the transitional interval between the Blancan and Irvingtonian (2.2–1.8 Ma). Two genera typical of the Blancan, the giant camels *Blancocamelus* and *Gigantocamelus*, occur in Mesilla B. The presence of the South American immigrant xenarthrans *Glyptotherium arizonae* and *Paramylodon* cf. *P. harlani* confirms that Mesilla B is late Blancan or younger. *G. arizonae* is supposedly restricted to early Irvingtonian sites elsewhere in the southwest (Gillette and Ray, 1981). However, the type locality of *G. arizonae*, Curtis Ranch in the San Pedro Valley of Arizona, although considered earliest Irvingtonian by most workers (e.g., Lundelius et al., 1987; Repenning, 1987), is best regarded as latest Blancan owing to the absence of *Mammuthus* and other typical Irvingtonian genera (Lindsay et al., 1990). There are also late Blancan records of *G. arizonae* from Florida (Morgan and Hulbert, 1995). The rabbit *Aluralagus virginiae* appears to be restricted to Blancan/Irvingtonian transitional faunas. The only other faunas where *A. virginiae* has been identified (referred to *Hypolagus virginiae* by Tomida, 1987), Curtis Ranch and the San Simon Power Line, both in southern Arizona, are similar in age to Mesilla B. *Smilodon gracilis* and *Tapirus haysii* are typical of early Irvingtonian faunas, but both are known from the late Blancan. Previous southwestern records of *S. gracilis* are restricted to the early Irvingtonian, but this sabercat occurs in several Florida late Blancan faunas (Berta, 1987; Morgan and Hulbert, 1995). *T. haysii* is known from late Blancan faunas in Texas and Colorado (Strain, 1966; Hager, 1974; Hulbert, 1995).

Magnetostratigraphic data for Mesilla B (Vanderhill, 1986) indicate that the zone containing this fauna spans the time period from the Gauss/Matuyama boundary to the Olduvai Subchron (between about 2.6 and 1.8 Ma). Faunal evidence suggests that Mesilla B falls in the younger half of this interval, as typical Blancan taxa that went extinct by about 2.2 Ma (*Hypolagus*, *Nannippus*, and *Rhynchotherium*) are absent from this fauna. Pending the discovery of additional age-diagnostic taxa in the Mesilla B fauna, particularly among small mammals, this fauna is here considered to be latest Blancan (latest Pliocene) in age, between 2.2 and 1.8 Ma.

MESILLA BASIN FAUNA C: The uppermost portion of the Camp Rice Formation in the southern Mesilla basin (fig. 12.1, site 29) contains *Mammuthus*, and is thus Irvingtonian or younger in age. Mesilla Basin Fauna C (hereafter shortened to Mesilla C) is correlative with the early Irvingtonian Tortugas Mountain LF near Las Cruces (Lucas et al., 1999, 2000) in the northern Mesilla basin. Among Irvingtonian faunas in New Mexico, Mesilla C has the most diverse sample of large vertebrates (table 1, from Vanderhill, 1986), consisting of 17 species: the land tortoises *Gopherus* and *Hesperotestudo* and 15 species of mammals, including *Glyptother-*

ium arizonae; *Paramylodon harlani*; the megalonychid ground sloth *Megalonyx wheatleyi*; the beaver *Castor canadensis*; the wolf *Canis armbrusteri*; a smaller coyote-like *Canis* sp.; the bobcat *Lynx rufus*; three horses, *Equus* cf. *E. calobatus*, *E. scotti*, and a large *Equus*, *Camelops* cf. *C. hesternus*; the cervid *Navahoceros lascrucensis*; the deer *Odocoileus*; the gomphothere *Cuvieronius tropicus*; and the mammoth *Mammuthus* cf. *M. meridionalis*.

The first appearance of *Mammuthus* in North America as an immigrant from Eurasia occurred sometime around 1.6 Ma (Lucas, 1995, 1996; Cassiliano, 1999). The primitive mammoth *Mammuthus meridionalis*, identified from Mesilla C (Vanderhill, 1986), occurs only in early Irvingtonian faunas, and is quickly replaced by (or evolved into) more advanced mammoths variously referred to *M. haroldcooki*, *M. hayi*, and *M. imperator*, which are also present in the early Irvingtonian. Although *Glyptotherium arizonae* is supposedly restricted to early Irvingtonian faunas in the southwestern United States (Gillette and Ray, 1981), fossils referred to this species from Mesilla B and Virden appear to be latest Blancan. The large wolflike canid *Canis armbrusteri* is found only in Irvingtonian faunas, with the oldest record of this species from the early Irvingtonian Leisey Shell Pit LF in Florida (Berta, 1995). The living beaver *Castor canadensis* is restricted to Irvingtonian and younger faunas in North America. A supposed late Blancan record of *C. canadensis* from the Haile 15A LF in Florida (Robertson, 1976) is based on a femur that is not diagnostic at the species level.

Mesilla C is most similar to early Irvingtonian faunas from the southern Great Plains, such as Gilliland and Rock Creek in Texas (Hibbard and Dalquest, 1966) and Holloman in Oklahoma (Dalquest, 1977), that contain *Glyptotherium arizonae*, *Paramylodon harlani*, *Equus scotti*, *E. calobatus*, and *Mammuthus* sp. Magnetostratigraphy for the interval that produces the Mesilla C fauna (Vanderhill, 1986) suggests correlation with the upper Matuyama Chron, spanning the time interval from just after the Olduvai Subchron (1.81 Ma) to just prior to the Jaramillo Subchron (1.07 Ma). Mack et al. (1996) obtained Ar/Ar dates on three pumice beds from the Camp Rice Formation near La Union, in the vicinity where many of the fossils from both Mesilla B and C were collected. A pumice dated at 1.59 Ma occurs about 30 m below the La Mesa surface (local top of the Camp Rice Formation in the La Union section) and a pumice dated at 1.32 Ma occurs about 10 m below the top of the section (Mack et al., 1996: fig. 2). Although these radioisotopic dates cannot currently be precisely correlated with the magnetostratigraphy and biostratigraphy, it appears that all of the Mesilla C fossils were collected from above the 1.59 Ma pumice date, which provides a maximum age for this fauna. It is likely that some fossils assigned to Mesilla C were collected from strata above the 1.32 Ma pumice date. The combination of biostratigraphy, magnetostratigraphy, and radioisotopic dates suggests an age between 1.6 and 1.1 Ma for Mesilla C (Vanderhill, 1986; Mack et al., 1996).

Mangas Basin

BUCKHORN: The Buckhorn LF is derived from 14 sites located between 3 and 10 km northwest of Buckhorn in northern Grant County, southwestern New Mexico (Morgan et al., 1997; fig. 12.1, site 30). The fossils occur in unconsolidated sands, silts, and muds through a stratigraphic interval of about 20 m in the upper part of the Gila Group in the Mangas basin. The abundance of aquatic vertebrates in several of the Buckhorn sites, including fish, frogs, flamingos, rails, and ducks, as well as the lithology of the sediments, suggests a freshwater depositional environment, possibly a large lake. The Buckhorn LF is the most diverse Blancan vertebrate faunal assemblage known from New Mexico, composed of 33 species, including 14 lower vertebrates and 19 mammals (Morgan et al., 1997). The nonmammals include three species of small fish, the frog *Rana*, the salamander *Ambystoma*, two unidentified colubrid snakes, a lizard, and six birds—the flamingo *Phoenicopterus*, two ducks, a rail, the turkey cf. *Meleagris*, and a small perching bird. The mammalian fauna of 19 species includes a microchiropteran bat; a rabbit; the ground squirrel *Spermophilus* cf. *S. bensoni*; *Repomys* cf. *R. panacen-*

sis; the vole *Mimomys poaphagus*, *Peromyscus* sp., and *Baiomys* sp.; four carnivores including the badger *Taxidea*, a bear, a small feline, and a large machairodontine; two horses, *Nannippus peninsulatus* and *Equus simplicidens*; a peccary, three camelids, *Camelops* sp., *Hemiauchenia blancoensis*, and a small *Hemiauchenia*, an indeterminate ruminant, and *Stegomastodon*.

Many of the mammals from the Buckhorn LF are indicative of a Blancan age, including *Mimomys*, *Repomys* cf. *R. panacaensis*, *Nannippus peninsulatus*, *Equus simplicidens*, and *Hemiauchenia blancoensis*. Several taxa allow for a more precise placement within the Blancan. The presence of a primitive species of the arvicoline rodent *Mimomys* and the absence of Neotropical immigrants suggest a pre-late Blancan age (older than 2.7 Ma). The occurrence of *Equus simplicidens* and a large species of *Mimomys* (subgenus *Ogmodontomys*) excludes very early Blancan faunas. The evolutionary stage of two of the Buckhorn rodents, *Mimomys* (*Ogmodontomys*) *poaphagus* and *Repomys* cf. *R. panacaensis*, is most consistent with a late early Blancan age (between about 4.2 and 3.6 Ma; Blancan II of Repenning, 1987) for the Buckhorn LF.

The Buckhorn LF and the Truth or Consequences LF from the central Rio Grande Valley both appear to be early Blancan in age on the basis of comparisons with early Blancan faunas outside of New Mexico; however, the mammalian faunas from these two sites have virtually no age-diagnostic taxa in common, particularly among the small mammals. *Mimomys*, the extinct ''cricetid'' genus *Repomys*, and the tiny sigmodontine *Baiomys* occur in the Buckhorn LF, whereas the Truth or Consequences LF is dominated by the wood rat *Neotoma*, the cotton rat *Sigmodon*, and the small extinct sigmodontine genus *Jacobsomys*. The Buckhorn and Truth or Consequences faunas must have sampled different habitats or perhaps differ enough in age to have allowed significant change in the small mammal fauna. Other early Blancan faunas that are broadly correlative with Buckhorn are the Verde LF in Arizona (Czaplewski, 1987, 1990), the Panaca LF in Nevada (May, 1981; Mou, 1997, 1999), and the Rexroad 3 and Fox Canyon faunas from Kansas (Hibbard, 1938, 1941, 1950, 1967; Repenning, 1987).

There are currently no radioisotopic dates or magnetostratigraphic data that would provide additional information on the age of the Buckhorn LF. There are several volcanic ash beds in the Buckhorn section, but they are too altered to provide accurate radioisotopic dates. The latest Hemphillian Walnut Canyon LF occurs in Gila Group strata about 25 km southeast of the Buckhorn LF (Morgan et al., 1997; fig. 12.1, site 31). The latest Hemphillian age (earliest Pliocene; 5.0–4.5 Ma) of the Walnut Canyon LF provides a maximum age for the Buckhorn LF. These two faunas have no taxa in common, indicating that the Hemphillian/Blancan boundary occurs somewhere in the section separating them. Further fieldwork in the region between Buckhorn and Walnut Canyon should allow a more precise stratigraphic placement of these two faunas.

Duncan Basin

PEARSON MESA: Exposures on Pearson Mesa south of the Gila River in the Duncan basin along the New Mexico-Arizona border have produced a diverse assemblage of late Blancan vertebrate fossils from strata of the Gila Group (fig. 12.1, sites 32, 33). Most of Pearson Mesa is located in Hidalgo County in southwestern New Mexico, but the northwestern point of the mesa extends into Greenlee County in southeastern Arizona. About three-fourths of the 76 NMMNH fossil sites located on Pearson Mesa are in New Mexico and the rest are in Arizona. The stratigraphic section at Pearson Mesa consists of more than 60 m of sandstones, mudstones, and sedimentary breccias referred to the Gila Group. The lower 15 m of this section contains the three-toed horse *Nannippus peninsulatus* and the horse *Equus simplicidens*, together with rarer specimens of many other taxa, the most significant of which is the mylodont ground sloth *Glossotherium* cf. *G. chapadmalense*. This assemblage, the Pearson Mesa LF (Tomida, 1987; Morgan and Lucas, 2000b; fig. 12.1, site 32), is indicative of a late Blancan age. A latest Blancan fauna, the Virden LF (fig. 12.1, site 33), occurs in the upper 20 m of the section at Pearson Mesa, and is discussed below.

The Pearson Mesa LF consists of 16 species of vertebrates: the land tortoise *Gopherus*, a large and a small species of the land tortoise *Hesperotestudo*, the box turtle *Terrapene*, a heron, and 11 mammals, including *Glossotherium* cf. *G. chapadmalense*; a small cat and a larger machairodontine sabercat; the pocket gopher *Geomys* (*Nerterogeomys*) cf. *G. persimilis*; the horses *Nannippus peninsulatus*, *Equus cumminsii*, *E. scotti*, and *E. simplicidens*; the peccary *Platygonus bicalcaratus*; the camelid *Hemiauchenia blancoensis*; and the gomphothere *Stegomastodon rexroadensis*. The presence of *Nannippus* in the Pearson Mesa LF indicates an age greater than 2.2 Ma, whereas *Glossotherium* does not appear in North American faunas until the late Blancan, indicating an age less than 2.7 Ma. Other taxa from the Pearson Mesa LF that provide some indication of age include *Geomys* (*N.*) *persimilis*, *Platygonus bicalcaratus*, and *Stegomastodon rexroadensis*. *G.* (*N.*) *persimilis* occurs in medial Blancan through early Irvingtonian sites in the southwestern United States. Tomida (1987) noted that the presence of this pocket gopher in the lower part of the Pearson Mesa section suggested placement in the uppermost Gauss Chron. *Platygonus bicalcaratus* apparently is restricted to medial and late Blancan faunas, and *Stegomastodon rexroadensis* occurs in the early and medial Blancan. The mandible of *Stegomastodon* upon which this record is based (F:AM 23338) is from an imprecisely located site in the vicinity of Pearson Mesa, and is of unknown stratigraphic position. A mandible of similar morphology, referred to *S. rexroadensis*, occurs in the medial Blancan Cuchillo Negro Creek LF (Lucas and Oakes, 1986). The medial Blancan Duncan Fauna is located near Duncan, Arizona, less than 10 km northwest of Pearson Mesa (Tomida, 1987), and thus it is possible that the *S. rexroadensis* mandible was derived from lower in the Gila Group section than strata that produce the Pearson Mesa LF.

The association of *Nannippus* with *Glossotherium* provides the most significant biostratigraphic information regarding the age of the Pearson Mesa LF. The first appearance of South American immigrants in North American faunas, following the onset of the Great American Interchange at about 2.7 Ma, defines the beginning of the late Blancan. The only time interval during which these two genera coexisted in southwestern faunas was between 2.7 Ma (the beginning of the Interchange) and 2.2 Ma (the *Nannippus* extinction datum of Lindsay et al., 1984). A paleomagnetic section from Pearson Mesa (Tomida, 1987) further restricts the age of the lower portion of the section, including the Pearson Mesa LF, to the upper Gauss Chron (3.0–2.6 Ma). Combining the biostratigraphic and magnetostratigraphic data for the Pearson Mesa LF would seem to tightly constrain the age of this fauna between 2.7 Ma (earliest appearance of *Glossotherium*) and 2.6 Ma (Gauss/Matuyama boundary). Although the timing of the first arrival of South American immigrants in North America is not precisely known, Pearson Mesa is important because it is one of only six sites in the southwestern United States that records the presence of South American Interchange mammals in the Gauss Chron, indicating an age greater than 2.6 Ma.

VIRDEN: A substantial thickness (about 30 m) of Gila Group strata in the middle of the Pearson Mesa section has not yet produced fossils, including a 9-m-thick breccia at the top of this unfossiliferous interval that may represent a hiatus (Morgan and Lucas, 2000b). Just above this breccia, at about the 45 m level in the section and continuing for about the next 10 m, vertebrate fossils occur at several localities on Pearson Mesa. This fauna differs significantly from the underlying Pearson Mesa LF, and is here named the Virden Local Fauna for the nearby village of Virden, New Mexico (fig. 12.1, site 33). Exposures in the upper portion of the Pearson Mesa section are not as extensive and tend to be more vertical than lower in the section, and consequently the Virden LF is not as abundant or diverse as the Pearson Mesa LF. Nonetheless, the presence of *Glyptotherium arizonae* and the absence of *Nannippus* in the Virden LF indicate that this fauna is younger than the Pearson Mesa LF, either latest Blancan or earliest Irvingtonian in age. The only taxa these faunas share are a large land tortoise and *Equus scotti*.

The Virden LF consists of seven species: the land tortoise *Hesperotestudo* and six mammals, including *Glyptotherium arizonae*, the coyote-like canid *Canis lepophagus*, *Equus scotti*, *Camelops*, a small *Hemiauchenia*, and an indeterminate proboscidean. The glyptodonts in the Virden LF, represented by osteoderms, a cranial fragment, and several postcranial elements, are referable to the large species *G. arizonae*. Glyptodonts first appear in southwestern faunas in the early late Blancan (upper Gauss Chron) in sites equivalent in age to the Pearson Mesa LF (e.g., Hudspeth and Cita Canyon in Texas and 111 Ranch in Arizona), but these occurrences represent the smaller species *G. texanum*. Glyptodonts are unknown from the Pearson Mesa LF. Although previous records of *G. arizonae* indicated that this species was restricted to the early Irvingtonian in the southwestern United States (Gillette and Ray, 1981), there are now late Blancan records of this species from Curtis Ranch in Arizona, Mesilla B, and Virden, as well as Florida (Morgan and Hulbert, 1995).

Associated mandibles of a medium-sized canid, similar in size and morphology to the coyote-sized species *Canis lepophagus*, were found in association with *Glyptotherium* osteoderms in the upper portion of the Pearson Mesa section. *C. lepophagus* is restricted to the Blancan, including the late Blancan Cita Canyon and Red Light faunas in Texas (Akersten, 1972) and the late Blancan 111 Ranch fauna in Arizona (Galusha et al., 1984; Tomida, 1987). A pair of lower jaws from Virden represents a small species of *Hemiauchenia*. These mandibles are from an adult with well-worn teeth, but are very small compared to other known species of *Hemiauchenia*, such as the Blancan *H. blancoensis* and the Irvingtonian and Rancholabrean *H. macrocephala*. A small *Hemiauchenia* occurs in several New Mexico Blancan faunas, including Cuchillo Negro Creek, Tonuco Mountain, and Buckhorn, as well as two early Irvingtonian sites in Florida (Morgan and Hulbert, 1995). *Equus scotti* is one of the most common horses found in southwestern early Irvingtonian faunas, but this species also occurs in medial and late Blancan sites in New Mexico.

The presence of *Glyptotherium arizonae* and the absence of diagnostic Blancan indicators (e.g., *Nannippus*) suggests that the Virden LF is distinctly younger than the underlying Pearson Mesa LF, probably either latest Blancan or earliest Irvingtonian (between 2.2 and 1.6 Ma). The presence of *Canis lepophagus*, a species unknown from the Irvingtonian, suggests that a latest Blancan age is more likely. Tomida's (1987) Pearson Mesa paleomagnetic stratigraphy does not include the upper 20 m of the section (Morgan and Lucas, 2000b), and thus we currently have no magnetostratigraphic data for this fauna. Paleomagnetic samples from the upper portion of the section recently collected by G. Mack should help clarify the age of the Virden LF.

BIOCHRONOLOGY AND CORRELATION

There are 24 Blancan and 7 Irvingtonian sites in New Mexico that have produced fossil mammals. Four or more species of mammals are known from 15 of the Blancan and 4 of the Irvingtonian sites (faunal lists in tables 12.1 and 12.2, respectively). Throughout the preceding discussion, we have provided information on the ages of the 31 sites and the biochronology of the individual taxa. Here we summarize the biochronology of New Mexico Blancan and Irvingtonian sites, with correlation to well-known faunas from elsewhere in western North America. These data are preliminary because we are still actively involved in fieldwork at several of the richer sites, particularly those with diverse small mammal faunas (e.g., Buckhorn, Chamberino, and Truth or Consequences). New taxa are still being added to the various faunal lists, but for most of the sites listed in tables 12.1 and 12.2, enough taxa are present to provide an accurate indication of age, at least within the major subdivisions of the two NALMAs (e.g., medial Blancan, early Irvingtonian). We also review all relevant radioisotopic dates and magnetostratigraphic data pertaining to New Mexico Blancan and Irvingtonian sites. The correlation charts in figures 12.2 and 12.3 summarize the current state of our knowledge on the age of the sites discussed in the text. Figure 12.4 correlates the New Mexico Blancan and Irvingtonian

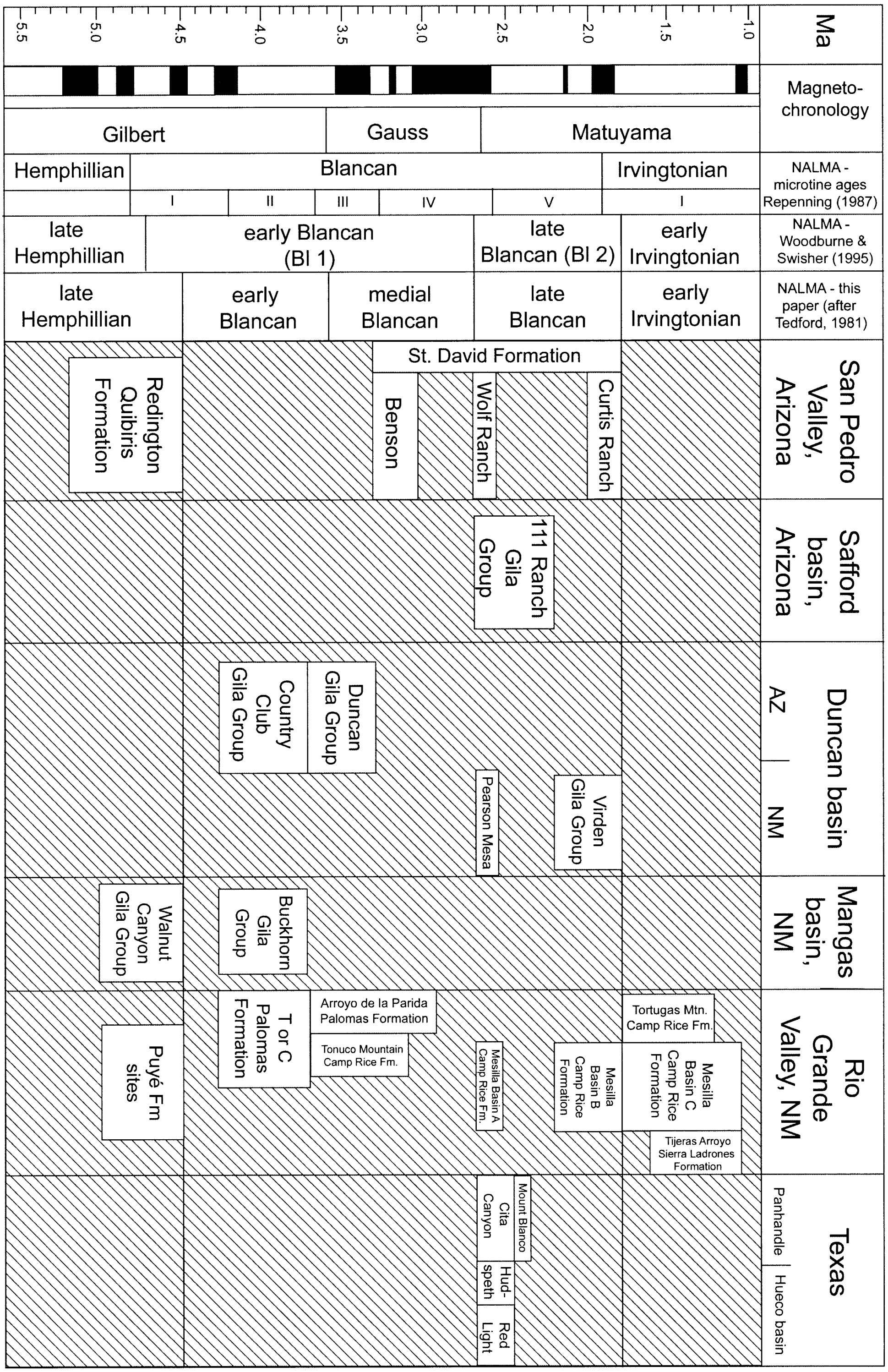

Fig. 12.4. Correlation chart showing the relative ages of late Hemphillian, Blancan, and Irvingtonian vertebrate faunas from New Mexico compared to faunas of similar age from Arizona and Texas. Other notes as for figure 12.2.

faunas with well-known faunas from Arizona and Texas. Not all of the Blancan and Irvingtonian sites from New Mexico are included in the correlation charts. All sites listed in tables are included in the correlation charts, as well as selected faunas with fewer than four mammals that contain age-diagnostic taxa.

With two exceptions, all Pliocene vertebrate faunas in New Mexico are Blancan, ranging in age from about 4.5 to 1.8 Ma. There is a restricted interval of time in the earliest Pliocene (between 5.3 and 4.9–4.5 Ma, depending on the placement of the Hemphillian/Blancan boundary) that is included within the next older NALMA, the Hemphillian. Most Hemphillian faunas are late Miocene in age (9.0–5.3 Ma), including the well-known faunas from the type area of the Chamita Formation in the Española basin in northern New Mexico (MacFadden, 1977; Tedford, 1981), which are late early to early late Hemphillian (about 7–5.5 Ma). The Walnut Canyon LF from the Gila Group in the Mangas basin in southwestern New Mexico (Morgan et al., 1997; fig. 12.1, site 31; figs. 12.3, 12.4) has two horses, *Astrohippus stocki* and *Dinohippus mexicanus*, that are very similar to horses from the latest Hemphillian (earliest Pliocene) Yepómera Fauna from Chihuahua in northern Mexico (Lance, 1950; MacFadden, 1984). The lower Puyé Formation in the Española basin (fig. 12.1, site 2) has produced a palate with most of the upper cheek teeth of *D. mexicanus*, indicating that at least part of the Puyé Formation is latest Hemphillian in age as well (figs. 12.2, 12.4).

The Mangas Basin in southwestern New Mexico is the only place in the state where a Blancan fauna occurs in stratigraphic superposition above a Hemphillian fauna. We measured two stratigraphic sections in Gila Group sediments in the Mangas Basin in Grant County (Morgan et al., 1997), a 76-m section incorporating the latest Hemphillian Walnut Canyon Horse Quarry (NMMNH site L-2922) and a 57-m section incorporating several sites included in the early Blancan Buckhorn LF (in particular, the Buckhorn microvertebrate site, NMMNH site L-2912). We have not yet been able to correlate these two sections, although the Walnut Canyon fossils occur at least 50 m below the lowest Buckhorn sites in the composite Gila Group section in the central Mangas basin. The Walnut Canyon LF compares closely to the Yepómera Fauna, one of the youngest known Hemphillian faunas (Lindsay et al., 1984), whereas the Buckhorn LF is early, but not earliest, Blancan. These age relationships suggest two possibilities: (1) there may be a hiatus in the Gila Group section or (2) there may be an older, and as yet undiscovered, earliest Blancan fauna in the intervening unmeasured section. Although separated by less than 1 m.y., the Walnut Canyon and Buckhorn faunas have no taxa in common, indicating that the major extinction event documented at the Hemphillian/Blancan boundary (Lindsay et al., 1984; Tedford et al., 1987) occurs somewhere in the section between these two sites. The horses *Astrohippus* and *Dinohippus* are common in the Walnut Canyon LF, but both disappear at the end of the Hemphillian. The microtine rodent *Mimomys*, a Eurasian immigrant and one of the genera whose first appearance in North America defines the beginning of the Blancan (Repenning, 1987; Tedford et al., 1987), is one of the most common mammals in the Buckhorn LF.

Repenning (1987) subdivided the Blancan into five ‘‘subages’’ (Blancan I–V) based on microtine (= arvicoline) rodent biochronology. Although Repenning’s system is very useful if a site contains one or preferably more species of microtine rodents, he provided only limited data for other mammal groups. Only one Blancan fauna in New Mexico, the Buckhorn LF, contains microtines. Faunas dominated by large mammals, which include most Blancan faunas from New Mexico, are difficult to correlate using Repenning’s microtine biochronology. Lundelius et al. (1987) and Woodburne and Swisher (1995) used a two-part subdivision of the Blancan: early Blancan (= Rexroadian of Schultz et al., 1978; BL1 of Woodburne and Swisher, 1995) and late Blancan (= Senecan of Schultz et al., 1978; BL2 of Woodburne and Swisher, 1995). The boundary between their early and late Blancan corresponds to the arrival at about 2.7 Ma of immigrant xenarthrans and caviomorph rodents from South America and several microtine rodents from Eurasia. We have found it useful, following Tedford (1981), to subdivide the early Blancan of Lundelius et al. (1987) and Woodburne and Swisher (1995), a time interval of nearly 2 Ma (between about 4.5 and 2.7 Ma), into the early and medial Blancan, with the boundary between these subages corresponding to the boundary between the Gilbert and Gauss Chrons at about 3.6 Ma. Where possible, we correlate New Mexico Blancan and Irvingtonian faunas with Repenning's microtine biochronology.

First appearances of Eurasian immigrant mammals have been used to define the beginning of the Blancan (between 4.9 and 4.3 Ma) in North America, including: the mustelid *Trigonictis*, the hyaena *Chasmaporthetes*, the bear *Ursus*, the microtine rodents *Mimomys* and *Nebraskomys*, and the cervids *Bretzia* and *Odocoileus* (Lundelius et al., 1987; Tedford et al., 1987; Woodburne and Swisher, 1995). However, according to Lindsay et al. (1984), some of these first appearances occurred later, at about 3.7 Ma, which they designated the *Trigonictis* appearance datum. In addition to *Trigonictis*, other genera they listed as first appearances about 3.7 Ma include *Chasmaporthetes*, *Ursus*, the rabbits *Nekrolagus* and *Pratilepus*, the pocket gopher *Thomomys*, the wood rat *Neotoma*, the muskrat *Pliopotamys*, the peccary *Platygonus*, the camel *Camelops*, and the mastodont *Mammut*.

In part, the discrepancy in the ages of the first occurences of certain genera used to define the Blancan is related to differences of opinion regarding the age and correlation of the White Bluffs LF in Washington (Gustafson, 1978, 1985), the earliest Blancan fauna that contains a diverse sample of both large and small mammals. Most other very early Blancan faunas (e.g., Concha in Chihuahua, Mexico; Saw Rock Canyon, Kansas; and Verde, Arizona) consist predominantly of small mammals (Lindsay et al., 1984; Czaplewski, 1987, 1990; Lundelius et al., 1987; Repenning, 1987). Lindsay et al. and Lundelius et al. considered White Bluffs to be early Blancan (3.9–3.7 Ma; Blancan II of Repenning, 1987), but not earliest Blancan, and a correlative of the Fox Canyon Fauna in Kansas and slightly older than the Hagerman Fauna in Idaho. Repenning thought White Bluffs was considerably older (about 4.3 Ma, Blancan I). If the White Bluffs LF is 4.3 Ma in age, then this fauna represents the oldest documented occurrence of many of the genera listed above, including *Trigonictis*, *Ursus*, *Nekrolagus*, *Thomomys*, *Platygonus*, and *Mammut*. The first appearance of *Neotoma* appears to be in the Saw Rock Canyon LF in Kansas, which most workers (e.g., Lundelius et al., 1987; Repenning, 1987) regard as one of the earliest Blancan faunas in North America (early Blancan I, 4.8–4.3 Ma). Many of the genera used to define the beginning of the Blancan occur in the Anza-Borrego Desert stratigraphic sequence, but have their lowest occurrence well above the Hemphillian/Blancan boundary (Cassiliano, 1999). Cassiliano suggested that the lowest stratigraphic occurrence of the cotton rat *Sigmodon* in the Anza-Borrego sequence at about 4.3 Ma may be close to the Hemphillian/Blancan boundary.

Two of the most diverse Blancan faunas from New Mexico, the Truth or Consequences LF from the Palomas Formation in the Rio Grande Valley (Repenning and May, 1986) and the Buckhorn LF from the Gila Group in the Gila River Valley (Morgan et al., 1997), are early Blancan in age. Even though these two faunas have almost no age-diagnostic mammals in common, comparisons with Blancan faunas outside of New Mexico indicate that the Truth or Consequences and Buckhorn faunas are similar in age (late early Blancan = Blancan II, about 4.2–3.8 Ma).

Repenning and May (1986) considered the Truth or Consequences LF to be early Blancan based on the somewhat more primitive nature of its mammalian fauna compared to the Fox Canyon and Rexroad 3 faunas from Kansas. The primitive wood rat *Neotoma* (subgenus *Paraneotoma*) from Truth or Consequences is intermediate in size between the smaller *N. sawrockensis* from the earliest Blancan Saw Rock Canyon LF and the larger *N. quadriplicata* from early Blancan Rexroad 3 (Repenning and May, 1986). The Truth or Consequences *Neotoma* is similar to *N. vaughani* from the early Blancan (Blancan II, about 4.2 Ma) Verde LF in Arizona (Czaplewski, 1990). The small sigmodontine rodent *Jacobsomys* from Verde appears to be present at Truth or Consequences (Czaplewski, 1987). The deer from Truth or Consequences, *Odocoileus brachyodontus*, was first described from Fox Canyon (Oelrich, 1953). Truth or Consequences shares three species of small mammals with the early Blancan Rexroad 3 Fauna, *Notolagus lepusculus*, *Geomys minor*, and *Sigmodon medius*. *G. minor* and *S. medius* also occur in the Verde LF, which seems to have the closest faunal similarity with Truth or Consequences.

The Truth or Consequences LF occurs in normally magnetized sediments that were correlated with the Nunivak Subchron of the Gilbert Chron (Repenning and May, 1986). These authors gave an age range of 4.20–4.05 Ma for the Nunivak, but the currently recognized age range of this subchron is somewhat older, from 4.62–4.48 Ma (Berggren et al., 1995). A K/Ar date of 4.5 Ma on a basalt flow below or within the lowermost Palomas Formation provides a maximum age for the Truth of Consequences LF (Seager et al., 1984; Mack et al., 1998). A more complete magnetostratigraphic section must be obtained for the strata of the Palomas Formation containing the Truth or Consequences site before this fauna can be accurately correlated to the geomagnetic polarity time scale (GPTS). We suspect that the Truth or Consequences LF actually may correlate to the next youngest normal subchron in the Gilbert, the Cochiti, with an age range of 4.29–4.18 Ma (Berggren et al., 1995). Repenning (1987) considered Truth or Consequences to be similar in age to Verde, somewhat younger than White Bluffs, and slightly older than Rexroad 3 and Fox Canyon.

The Buckhorn LF has 18 species of mammals compared to 15 species from the Truth or Consequences LF; however, many of the Buckhorn taxa are not age diagnostic or are identified only to the family or genus level (Morgan et al., 1997). The most age-diagnostic mammals from the Buckhorn LF are the rodents *Mimomys* (*Ogmodontomys*) *poaphagus* and *Repomys* cf. *R. panacensis*. The Buckhorn *Mimomys* is most similar to *M. poaphagus* from Fox Canyon and Rexroad 3 (Hibbard, 1941, 1950; Zakrzewski, 1967) and Verde (Czaplewski, 1990), larger than *M. panacaensis* from the Panaca LF in Nevada, and differing from the latter species in certain dental features (Mou, 1997). A single tooth of *Repomys* from Buckhorn is similar to *R. panacaensis* from Panaca (May, 1981). The Buckhorn LF is most similar to late early Blancan (Blancan II of Repenning, 1987) faunas such as Fox Canyon, Rexroad 3, and Verde, and appears to be somewhat younger than early Blancan (Blancan I) faunas such as Panaca, White Bluffs, and Saw Rock Canyon. Repenning (1987) placed the Panaca LF in the medial Blancan (Blancan III, about 3.3 Ma), whereas Mou (1997, 1999) considered Panaca to be much older, early Blancan I (4.9–4.6 Ma). There are no other geochronologic data associated with the Buckhorn LF that would help determine its age. The stratigraphic section that produced the Buckhorn LF contains several volcanic ash beds, but these are too highly altered for radioisotopic dating. In the near future, we hope to obtain magnetostratigraphic data for the Gila Group section containing both the early Blancan Buckhorn LF and the latest Hemphillian Walnut Canyon LF.

Three faunas derived from the Palomas Formation in the Rio Grande Valley, Cuchillo Negro Creek, Elephant Butte Lake, and Palomas Creek, are considered medial Blancan following Tedford (1981) and Lucas and Oakes (1986), although the presence of the large canid *Borophagus hilli* from Cuchillo Negro Creek (see discussion below) may be indicative of an early Blancan age (Wang et al., 1999). The Elephant Butte Lake and Cuchillo Negro Creek faunas consist almost entirely of large mammals, and thus have few taxa in common with the Truth or Consequences LF. They share two species, *Equus simplicidens*, found throughout much of the Blancan, and *Stegomastodon rexroadensis*, restricted to early and medial Blancan faunas. *Borophagus hilli* from Cuchillo Negro Creek, and tentatively identified from Truth or Consequences, occurs primarily in late Hemphillian and early Blancan faunas (e.g., Saw Rock Canyon and White Bluffs), but is known from at least one medial Blancan fauna, Hagerman, Idaho (Wang et al., 1999). Tedford placed the Elephant Butte Lake sites in the medial Blancan because of their stratigraphic association with a basalt flow from Mitchell Point at the northern end of Elephant Butte Lake (K/Ar date of 2.9 ± 0.3 Ma; Bachman and Mehnert, 1978). Lucas and Oakes (1986) assigned the Cuchillo Negro Creek LF to the medial Blancan, and correlated this fauna with Rexroad and Benson.

The Palomas Creek LF shares one species of small mammal, *Sigmodon medius,* with the Truth or Consequences LF, but *S. medius* also occurs in medial Blancan faunas, including the type locality, Benson, Arizona (Martin, 1979). A mandible from Palomas Creek is the only record of the extant subgenus of *Geomys* known from the Blancan of New Mexico. Other mammals from this fauna indicative of a Blancan age are *Nannippus peninsulatus*, a large *Camelops*, and *Mammut raki*. The presence of *Nannippus* and absence of Neotropical immigrants suggest a pre-late Blancan age (older than 2.7 Ma), whereas the presence of *Camelops* indicates a post-early Blancan (younger than 3.6 Ma). *Mammut* is rare in the Blancan, but is known from the early Blancan White Bluffs LF and the medial Blancan Hagerman Fauna. A magnetostratigraphic section from Palomas Creek suggests the fossils came from strata referred to the upper Gauss Chron (Mack et al., 1993), indicating a medial Blancan age (between 3.0 and 2.7 Ma) for the Palomas Creek LF.

Further study of the mammalian taxa and other geochronologic data should eventually clarify the age relationships among the four vertebrate faunas from the Palomas Formation in the vicinity of Elephant Butte Lake, including Truth or Consequences, Elephant Butte Lake, Cuchillo Negro Creek, and Palomas Creek. The stratigraphic sections containing these four faunas have not been precisely correlated to one another to determine their relative positions within the Palomas Formation and their stratigraphic position with respect to relevant radioisotopic dates. We hope to obtain detailed magnetostratigraphic sections for the individual sites containing Blancan faunas.

Five other sites from the Rio Grande Valley, Pajarito, Belen, Arroyo de la Parida, Hatch, and Tonuco Mountain (fig. 12.1), are medial Blancan in age (3.6–2.7 Ma). In addition to mammalian fossils, three have associated magnetostratigraphy and/or radioisotopic dates. The Pajarito LF is not diverse, but contains *Geomys* (*Neterogeomys*) cf. *G. paenebursarius* and *Camelops*, and is directly associated with an Ar/Ar date of 3.12 Ma on pumice (Maldonado et al., 1999), establishing a medial Blancan age.

Four species of mammals from the Belen LF provide an indication of age (Morgan and Lucas, 2000a). A mole mandible is most similar to *Scalopus* (*Hesperoscalops*) *blancoensis* from the late Blancan Blanco LF in Texas (Dalquest, 1975). *Geomys* (*Neterogeomys*) *paenebursarius* also occurs in the Pajarito and Hatch faunas, as well as in two late Blancan faunas in southwestern Texas (Strain, 1966; Akersten, 1972). *Equus calobatus* is known elsewhere in New Mexico from the late Blancan Santo Domingo LF and from late Blancan and early Irvingtonian faunas in the Mesilla basin (Tedford, 1981; Vanderhill, 1986). *Stegomastodon mirificus* is restricted to medial Blancan through early Irvingtonian faunas. Two mammals from Belen do not occur elsewhere prior to the late Blancan (*S. blancoensis* and *E. calobatus*), whereas two other species (*G. paenebursarius* and *S. mirificus*) are known from medial Blancan faunas. The similarity in stratigraphic occurrence to the nearby Pajarito LF and the absence of South American immigrants indicates a medial Blancan age is more likely (between 3.1 and 2.7 Ma).

The Arroyo de la Parida LF from the Palomas Formation in the Socorro basin has five species of mammals that are restricted to the Blancan (Morgan et al., 2000), *Megalonyx leptostomus*, *Equus cumminsii*, *E. simplicidens*, a large *Camelops*, and *Rhynchotherium falconeri*. Early Blancan can be ruled out by the presence of *E. cumminsii*, *E. scotti*, and *Camelops*, all of which first appear during the medial Blancan. *Rhynchotherium* became extinct in the late Blancan at about 2.2 Ma. The absence of South American immigrants suggests an age greater than 2.7 Ma. The mammalian fauna indicates a medial Blancan age (3.6–2.7 Ma) for the Arroyo de la Parida LF. No other geochronologic data are currently available for Arroyo de la Parida. Other faunas from the Palomas Formation farther south in the Engle and Palomas basins are either early or medial Blancan.

The Hatch LF from the Camp Rice Formation in the Hatch-Rincon basin shares *Geomys* (*Nerterogeomys*) *paenebursarius* with the Pajarito and Belen faunas. A medial

Blancan age is further indicated by the lack of South American immigrants and the faunal and stratigraphic similarity to the Tonuco Mountain LF (Morgan et al., 1998). A magnetostratigraphic section in the Camp Rice Formation at nearby Hatch Siphon (Mack et al., 1993) does not cross the Gilbert/Gauss boundary but samples most of the Gauss Chron, including both the Kaena and Mammoth Subchrons, and is thus between 3.6 and 2.6 Ma. The Hatch Siphon section is similar to the Cedar Hill magnetostratigraphic section (Mack et al., 1993) that contains the Tonuco Mountain LF (Morgan et al., 1998), further supporting a medial Blancan age for the Hatch LF (between 3.6 and 2.7 Ma).

The Tonuco Mountain LF from the Camp Rice Formation in the Jornada basin has six species of mammals that are indicative of the Blancan: *Canis lepophagus*, *Borophagus* sp., *Nannippus peninsulatus*, *Equus simplicidens*, *Platygonus* cf. *P. bicalcaratus*, and *Hemiauchenia blancoensis*. *E. simplicidens* is absent from very early Blancan faunas, *Camelops* and *E. scotti* appear in the medial Blancan, and most Blancan records of *Nannippus* predate the Gauss/Matuyama magnetic reversal at 2.6 Ma. The absence of South American mammals suggests the fauna is older than 2.7 Ma. The biostratigraphic data restrict the age of the Tonuco Mountain LF to medial Blancan. A magnetostratigraphic section in the Camp Rice Formation at Cedar Hill (Mack et al., 1993) can be directly correlated with the Tonuco Mountain LF. The Cedar Hill section is entirely within the Gauss Chron, and the fossiliferous interval is below the top of the Kaena Subchron (older than 3.0 Ma). Biostratigraphic and magnetostratigraphic data constrain the age of the Tonuco Mountain LF to the early medial Blancan (3.6–3.0 Ma).

About 10 sites in New Mexico of medial Blancan age (3.6–2.7 Ma) are among the least well constrained by biostratigraphy in the state. Many medial Blancan sites are identified primarily by lack of characteristic early or late Blancan taxa, rather than by the presence of taxa that are diagnostic of the medial Blancan. Lindsay et al. (1984) listed a number of genera whose first appearance at about 3.7 Ma defines the beginning of what we recognize as the medial Blancan. However, many of these taxa are either unknown from New Mexican Blancan faunas (e.g., *Chasmaporthetes*, *Trigonicitis*, *Ursus*) or also occur in early Blancan faunas (e.g., *Neotoma*, *Platygonus*). Furthermore, no medial Blancan fauna currently known from New Mexico has a rich microvertebrate sample, although several sites do contain small mammals, including *Geomys* (*Nerterogeomys*) *paenebursarius* from Pajarito, Belen, and Hatch, *Scalopus* (*Hesperoscalops*) *blancoensis* from Belen, and *Geomys* (*Geomys*) sp. and *Sigmodon medius* from Palomas Creek. A medial Blancan age can be firmly established for the Pajarito, Hatch, and Tonuco Moutain faunas from associated geochronologic data. Pumice Ar/Ar dated at 3.12 Ma (Maldonado et al., 1999) is in direct association with the Pajarito LF. An Ar/Ar date of exactly the same age (3.12 Ma) on a pumice-clast conglomerate from Hatch Siphon (Mack et al., 1998) can be correlated with the Hatch LF. A magnetostratigraphic section from Hatch Siphon (Mack et al., 1998) can be correlated with the Gauss Chron (3.58–2.58 Ma). A magnetostratigraphic section from Cedar Hill (Mack et al., 1993) can be directly correlated with the Tonuco Mountain LF and indicates an age between 3.58 and 3.04 Ma.

Because the medial Blancan is difficult to characterize biostratigraphically, an argument could be made that it should be included in the early Blancan (e.g., Lundelius et al., 1987; Woodburne and Swisher, 1995). Careful study of early Blancan (e.g., White Bluffs) and medial Blancan (e.g., Hagerman) faunas that have extensive samples of both large and small mammals, as well as associated magnetostratigraphy and radioisotopic dates, should help to clarify the faunal and time relationships between these two intervals. The best solution might be to recognize Repenning's five Blancan microtine zones (Blancan I–V) as subdivisions of the Blancan that are defined by their faunas of both microtine rodents and other mammals. For now we recognize a medial Blancan interval that corresponds with the Gauss Chron (3.58–2.58 Ma), with the exception that the upper boundary is defined by the first appearance of Neotropical immigrant mammals at about 2.7 Ma, slightly before the end of the Gauss.

Five faunas from New Mexico are late Blancan in age (2.7–1.8 Ma): Santo Domingo, Mesilla Basin Faunas A and B, Pearson Mesa, and Virden. Late Blancan faunas are recognized by the first appearance of Neotropical immigrant mammals at about 2.7 Ma. With the exception of Santo Domingo, the remaining four late Blancan faunas from New Mexico have one or more taxa of Neotropical immigrants. Repenning (1987) also noted several first appearances of Eurasian microtine rodents at about this same time (Blancan V), including the lemming genera *Mictomys* and *Synaptomys*. Microtine rodents are unknown from New Mexican late Blancan faunas. The five late Blancan faunas from New Mexico appear to separate into two groups, three faunas (Santo Domingo, Mesilla A, and Pearson Mesa) that contain *Nannippus*, and are thus older than 2.2 Ma (early late Blancan, 2.7–2.2 Ma), and two faunas (Mesilla B and Virden) that lack *Nannippus*, and thus appear to be younger (latest Blancan, 2.2–1.8 Ma).

The Santo Domingo LF from the Sierra Ladrones Formation in the Albuquerque basin has four species of mammals, none of which are definitively late Blancan. The presence of *Nannippus peninsulatus* suggests the fauna is older than 2.2 Ma, whereas *Equus calobatus* and *E. scotti* occur in medial Blancan through early Irvingtonian faunas. According to Tedford (1981), the strata that produced the Santo Domingo LF are interbedded with the Santa Ana Mesa basalts, K/Ar dated at 2.67 and 2.41 Ma (Smith and Kuhle, 1998), and are overlain by the lower Bandelier Tuff, Ar/Ar dated at 1.61 Ma (Izett and Obradovich, 1994). The combination of biostratigraphy and radioisotopic dates constrains the age of the Santo Domingo LF between 2.7 and 2.2 Ma.

Mesilla Basin Fauna A from the Camp Rice Formation in southernmost New Mexico (Vanderhill, 1986) and the Pearson Mesa LF from the Gila Group in southwestern New Mexico (Morgan and Lucas, 2000b) are similar in age. The association of *Glyptotherium* with *Nannippus* in the Mesilla A fauna clearly establishes a late Blancan age, as the only interval during which these two genera coexisted in southwestern faunas was between 2.7 Ma (the beginning of the Great American Faunal Interchange) and 2.2 Ma (the *Nannippus* extinction datum of Lindsay et al., 1984). Magnetostratigraphic data for Mesilla A indicate correlation with the upper Gauss Chron (Vanderhill, 1986), restricting the age of this fauna to older than 2.58 Ma.

The Pearson Mesa LF also documents the association of *Nannippus* with a Neotropical immigrant, the mylodont ground sloth *Glossotherium chapadmalense*. The first appearance of *Glossotherium* and *Glyptotherium*, as well as several other Neotropical immigrants discussed below, identifies the onset of the Great American Interchange at about 2.7 Ma, and defines the beginning of the late Blancan. A magnetostratigraphic section from Pearson Mesa (Tomida, 1987) further restricts the age of the lower portion of the section, including the Pearson Mesa LF, to the upper Gauss Chron (3.0–2.6 Ma). Biostratigraphy and magnetostratigraphy for Pearson Mesa and Mesilla A seem to tightly constrain the ages of these faunas between 2.7 Ma (earliest appearance of Neotropical immigrants) and 2.6 Ma (Gauss/Matuyama boundary).

The exact timing of the onset of the Great American Interchange in North America has not been firmly established, although it is well documented that the first appearance of South American immigrants in the southwestern United States occurred in the upper Gauss Chron, sometime between the top of the Kaena Subchron (3.04 Ma) and the Gauss/Matuyama boundary (2.58 Ma). Six late Blancan sites in the southwestern United States record the first appearance of South American mammals in the upper Gauss Chron: 111 Ranch (Galusha et al., 1984) and Wolf Ranch (Harrison, 1978) in Arizona, Pearson Mesa (Tomida, 1987; Morgan and Lucas, 2000b) and Mesilla Basin Fauna A (Vanderhill, 1986) in New Mexico, and Cita Canyon (Lindsay et al., 1976) and Hudspeth (Strain, 1966; Vanderhill, 1986) in Texas. At 111 Ranch, the best documented of these six faunas (Galusha et al., 1984), Neotropical mammals appear in the uppermost Gauss, and thus the date of 2.7 Ma has often been cited as the first appearance datum for Neotropical immigrants in North America (e.g., Woodburne and Swisher, 1995), as well as the boundary between the early and late

Blancan (or medial and late Blancan as used here). The first appearance datum for two genera of Neotropical xenarthrans (*Glyptotherium* and *Glossotherium*) and two genera of Neotropical caviomorph rodents (*Neochoerus* and *Erethizon*) is within the upper Gauss Chron, including: *Glossotherium* at Pearson Mesa and Cita Canyon; *Glyptotherium* at Cita Canyon, Hudspeth, Mesilla A, and 111 Ranch; the capybara *Neochoerus* at 111 Ranch; and the porcupine *Erethizon* at Wolf Ranch. Several other sites document the occurrence of Neotropical immigrants in the early Matuyama Chron (2.6–2.2 Ma), including the Blanco LF in Texas (Dalquest, 1975; Lindsay et al., 1976, 1984) and the Anza-Borrego Desert in California (Opdyke et al., 1977; Cassiliano, 1999). Two additional genera of Neotropical xenarthrans, the armadillo *Dasypus* and the pamapthere *Holmesina*, as well as *Glossotherium* and *Neochoerus*, occur in the early Matuyama Chron in the Macasphalt Shell Pit LF in southern Florida (Morgan and Ridgway, 1987; Jones et al., 1991; Morgan and Hulbert, 1995). No early or medial Blancan (4.5–2.7 Ma) sites north of Mexico are known to contain Neotropical mammals involved in the Great American Interchange. However, several faunas from central Mexico suggest that the initial migration of South American mammals across the Panamanian Isthmus may have occurred as early as 4.7 Ma (Miller and Carranza-Castañeda, 2001, 2002). We use 2.7 Ma for the beginning of the Interchange in the southwestern United States, with the understanding that detailed stratigraphic and geochronologic studies of sites in central Mexico may eventually push back the recognized age of onset of Interchange in tropical North America.

Mesilla B and the Virden LF occur higher in the same stratigraphic sequences as the Mesilla A and Pearson Mesa faunas, respectively. The Mesilla B mammalian fauna contains three taxa restricted to the Blancan, the large camelids *Blancocamelus*, *Gigantocamelus*, and an undescribed *Camelops*. Other typical Blancan genera such as *Nannippus* are absent from Mesilla B, suggesting the fauna is younger than 2.2 Ma. The rabbit *Aluralagus virginiae*, identified from Mesilla B (Vanderhill, 1986), is known elsewhere only from Blancan/Irvingtonian transitional faunas, including Curtis Ranch and San Simon Power Line in southern Arizona (Tomida, 1987). Three other species from Mesilla B, *Glyptotherium arizonae*, *Smilodon gracilis*, and *Tapirus haysii*, are more typical of early Irvingtonian faunas, but are also known from the late Blancan. The type locality of *G. arizonae*, Curtis Ranch in Arizona, although considered early Irvingtonian by most workers (e.g., Lundelius et al., 1987; Repenning, 1987), has more recently been placed in the latest Blancan (Lindsay et al., 1990). There are also five late Blancan records of this glyptodont from Florida (Morgan and Hulbert, 1995). Likewise, most records of *S. gracilis* are from the early Irvingtonian, but this small sabercat is also known from several Florida late Blancan faunas (Berta, 1987). *T. haysii* occurs in late Blancan faunas in Texas and Colorado (Strain, 1966; Hager, 1974; Hulbert, 1995). *Mammuthus* is absent from Mesilla B, but appears higher in the same stratigraphic sequence in Mesilla C. Magnetostratigraphic data for Mesilla B (Vanderhill, 1986) place this fauna in the time interval between the Gauss/Matuyama boundary and the Olduvai Subchron (2.6–1.8 Ma). Biostratigraphic evidence indicates that Mesilla B belongs in the younger half of this interval (2.2–1.8 Ma).

The Virden LF from the Duncan basin in the Gila River Valley has *Glyptotherium arizonae* but lacks *Nannippus*, indicating that this fauna is younger than the Pearson Mesa LF, derived from Gila Group strata about 45 m lower in the same section. Although glyptodonts first appear in southwestern faunas in the early late Blancan (about 2.7 Ma), these early occurrences represent the smaller species *G. texanum*. As discussed above, *G. arizonae* is now known from both latest Blancan and early Irvingtonian faunas in the southwest, as well as late Blancan and early Irvingtonian faunas in Florida (Morgan and Hulbert, 1995). *Canis lepophagus* from Virden is restricted to the Blancan, and occurs in the late Blancan Cita Canyon and Red Light faunas in Texas (Akersten, 1972) and the late Blancan 111 Ranch in Arizona (Galusha et al., 1984; Tomida, 1987). The presence of *C. lepophagus* strongly indicates a Blancan age for the Virden LF, while the presence of *G. arizonae* further suggests that the fauna is very late Blancan.

Mesilla B and Virden appear to be similar in age based on the occurrence of the large *Glyptotherium arizonae* and the absence of *Nannippus* and *Mammuthus*. Taxa restricted to the Blancan are known from each fauna, including *Blancocamelus* and *Gigantocamelus* from Mesilla B and *Canis lepophagus* from Virden. *Nannippus* does occur in lower stratigraphic units in both the Mesilla Basin and Pearson Mesa sections, suggesting that the Mesilla B and Virden faunas are younger than the *Nannippus* extinction datum at 2.2 Ma. *Mammuthus* is absent from Mesilla B, but occurs higher in the same stratigraphic sequence in the Mesilla C fauna. Biostratigraphy, magnetostratigraphy, and radioisotopic dates constrain the age of Mesilla B to the latest Blancan (2.2–1.8 Ma). Biostratigraphic correlation indicates that the Virden LF belongs in this age range as well.

Three early Irvingtonian faunas from New Mexico contain more than five species of mammals: Tijeras Arroyo, Tortugas Mountain, and Mesilla Basin Fauna C (figs. 12.2–12.4; table 12.2). *Mammuthus*, whose first appearance defines the beginning of the Irvingtonian (Lundelius et al., 1987), is known from all three of theses faunas. The co-occurrence in the Tijeras Arroyo fauna of *Glyptotherium arizonae*, *Equus scotti*, and *Mammuthus* is typical of southwestern early Irvingtonian faunas (1.6–1.0 Ma), including Gilliland in Texas (Hibbard and Dalquest, 1966) and Holloman in Oklahoma (Dalquest, 1977). Mandibles of *Mammuthus meridionalis* from Tijeras Arroyo represent one of the most primitive mammoths known from North America (Lucas and Effinger, 1991; Lucas et al., 1993). This specimen is also one of the oldest well-documented records of *Mammuthus* from North America (Lucas, 1995, 1996), based on its association with pumice derived from the lower Bandelier tuff (Lucas et al., 1993). The lower Bandelier tuff has an Ar/Ar date of 1.61 Ma (Izett and Obradovich, 1994). Although this date provides a maximum age for the Tijeras Arroyo mammoth, similar ages on pumice deposits farther south in the Rio Grande Valley, including the southern Mesilla basin (Mack et al., 1996, 1998), suggest that deposition of widespread fluvially transported pumice beds at about 1.6 Ma was essentially synchronous with the formation of the lower Bandelier tuff in the Jemez volcanic field in northern New Mexico.

The Tortugas Mountain LF from the northern Mesilla basin (Lucas et al., 1999, 2000) contains three proboscideans, *Cuvieronius tropicus*, *Stegomastodon mirificus*, and *Mammuthus imperator*. *Mammuthus* arrived from Eurasia in the early Pleistocene about 1.6 Ma. The youngest well-dated record of *Stegomastodon* is from Tule Canyon in the Texas Panhandle, where it is associated with *Mammuthus* in a volcanic ash at the base of the Tule Formation dated between 1.3 and 1.2 Ma (Izett, 1977; Tedford, 1981; Madden, 1983). Thus, the co-occurrence of *Stegomastodon* and *Mammuthus* defines a restricted interval of time in the early Irvingtonian, between about 1.6 and 1.2 Ma, after the arrival of *Mammuthus* and before the extinction of *Stegomastodon*. The Tortugas Mountain LF is similar in age to the Gilliland LF in Texas, which is the only other fauna that documents the association of *Cuvieronius*, *Stegomastodon*, and *Mammuthus* (Hibbard and Dalquest, 1966).

Among New Mexico's early Irvingtonian faunas, Mesilla C in the southern Mesilla basin has the most diverse sample of large mammals (Vanderhill, 1986). Three species from Mesilla C clearly establish an Irvingtonian age, *Mammuthus* cf. *M. meridionalis*, the wolflike *Canis armbrusteri*, and the beaver *Castor canadensis*. The primitive mammoth *M. meridionalis* occurs only in early Irvingtonian faunas, *C. armbrusteri* first appears in the early Irvingtonian and becomes extinct in the late Irvingtonian (Berta, 1995), and the extant *C. canadensis* is limited to Irvingtonian and younger faunas. The Mesilla C fauna is very similar to early Irvingtonian faunas from the southern Great Plains, including Gilliland and Rock Creek in Texas (Hibbard and Dalquest, 1966) and Holloman in Oklahoma (Dalquest, 1977), that document the association of *Glyptotherium arizonae*, *Paramylodon harlani*, *Equus scotti*, *E. calobatus*, and *Mammuthus*. The magnetostratigraphy of Mesilla C (Vanderhill, 1986) suggests correlation with the interval in the Matuyama Chron from just after the

Olduvai Subchron (1.81 Ma) until just prior to the Jaramillo Subchron (1.07 Ma). Ar/Ar dates of 1.59 Ma and 1.32 Ma on pumice beds from the Camp Rice Formation near La Union agree, suggesting an age between 1.6 and 1.1 Ma for Mesilla C (Vanderhill, 1986; Mack et al., 1996).

We recognize the beginning of the Irvingtonian based on the first appearance of *Mammuthus* in the early Pleistocene between 1.8 and 1.6 Ma. Cassiliano (1999) could not precisely determine the position of the Blancan/Irvingtonian boundary, suggesting an age range between 2.15 Ma and 1.95 Ma (latest Pliocene). He analyzed the utility of several genera to define the Blancan/Irvingtonian boundary (e.g., *Mammuthus*, *Smilodon*, *Lepus*), and found none of these genera to be appropriate. One of the most difficult problems encountered by Cassiliano (1999) was that *Mammuthus*, the most frequently cited genus for defining the beginning of the Irvingtonian, is absent from the two most complete stratigraphic sequences in North America that span the Blancan/Irvingtonian boundary, the San Pedro Valley in Arizona (Johnson et al., 1975; Lindsay et al., 1990) and the Anza-Borrego Desert (also known as the Fish Creek-Vallecito Creek section) in southern California (Opdyke et al., 1977; Cassiliano, 1999).

Two stratigraphic sequences from New Mexico, Tijeras Arroyo and the southern Mesilla Basin, contain early Irvingtonian faunas with *Mammuthus* superposed above Blancan faunas. *Mammuthus* fossils from Tijeras Arroyo and Mesilla C, referred to *M. meridionalis*, are among the oldest dated mammoths in North America, as both are closely associated with radioisotopic dates of 1.6 Ma on pumice from the lower Bandelier tuff. Mammoths from Wellsch Valley, Saskatchewan (Barendregt et al., 1991) and Thornton Beach, California (Madden, 1980, 1995) were thought to be older than 1.5 Ma, but both sites are now known to be considerably younger (Barendregt et al., 1991; Lucas, 1995, 1996; Cassiliano, 1999). All other early Irvingtonian records of *Mammuthus* are younger than 1.5 Ma.

The southern Mesilla Basin may possess one of the most important stratigraphic sequences in North America for determining the first appearance of *Mammuthus* and the placement of the Blancan/Irvingtonian boundary. *Mammuthus* occurs in a fairly complete stratigraphic sequence that spans the late Blancan and early Irvingtonian. The stratigraphic sequence of the Camp Rice Formation in the vicinity of La Union and Chamberino in the southern Mesilla Basin contains two diverse superposed mammalian faunas, the latest Blancan Mesilla B and early Irvingtonian Mesilla C, as well as the late Blancan Mesilla A at the base of the section that documents the association of *Nannippus* and *Glyptotherium*. Further study of this important sequence is ongoing, and will include detailed correlation of magnetostratigraphy (Vanderhill, 1986), radioisotopic dates (Mack et al., 1996), lithostratigraphy, and biostratigraphy.

The youngest Irvingtonian fauna in New Mexico is San Antonio Mountain (SAM) Cave from the San Luis basin near the Colorado border. Magnetostratigraphy and microtine rodent biochronology constrain the age of the SAM Cave fauna to the medial Irvingtonian; however, SAM Cave contains nine individual sites with a range of ages between about 1.0 and 0.7 Ma (Rogers et al., 2000). The four oldest sites in SAM Cave contain the microtines *Mictomys kansasensis*, an advanced species of *Allophaiomys*, *Lemmiscus curtatus*, and *Microtus* cf. *M. californicus*, indicating ages between about 1.0 and 0.85 Ma, in the early part of the medial Irvingtonian. A slightly younger medial Irvingtonian site in SAM Cave contains *Clethrionomys*, and is between 0.85 and 0.78 Ma in age. The occurrences of *Lemmiscus* and *Clethrionomys* in SAM Cave represent the oldest records of these two genera in North America.

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