



Pliocene (Blancan) vertebrates from the Albuquerque Basin, north-central New Mexico

Gary S. Morgan and Spencer G. Lucas, 1999, pp. 363-370

in:

Albuquerque Geology, Pazzaglia, F. J.; Lucas, S. G.; [eds.], New Mexico Geological Society 50th Annual Fall Field Conference Guidebook, 448 p.

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PLIOCENE (BLANCAN) VERTEBRATES FROM THE ALBUQUERQUE BASIN, NORTH-CENTRAL NEW MEXICO

GARY S. MORGAN and SPENCER G. LUCAS

New Mexico Museum of Natural History, 1801 Mountain Road, NW, Albuquerque, NM 87104

Abstract—Ten sites from the Albuquerque basin in north-central New Mexico have produced vertebrate fossils of Blancan (Pliocene) age. Five of these sites were known previously, and five new sites are described. The Loma Colorado de Abajo local fauna (new name) from Rio Rancho in Sandoval County consists of three taxa, a small land tortoise, the ground squirrel *Spermophilus* sp., and the primitive pocket gopher *Geomys* (*Nerterogeomys*) sp. The Loma Colorado *Geomys*, represented by one complete and one partial skull, is indicative of a Blancan age, but does not permit a more precise placement of this local fauna. The Belen fauna (new name) from near Belen in Valencia County is composed of a colubrid snake and five species of mammals, the talpid *Scalopus* (*Hesperoscalops*) sp., the geomyid *Geomys* (*Nerterogeomys*) cf. *G. (N.) paenebursarius*, the horse *Equus calobatus*, an antilocaprid, and the proboscidean *Stegomastodon mirificus*. *G. (N.) paenebursarius* is known only from late Blancan faunas, *E. calobatus* occurs in the late Blancan and Irvingtonian, and *S. mirificus* occurs in the middle Blancan through the early Irvingtonian. The overlapping range zone for these three species is late Blancan. The three other new sites from the Albuquerque basin, two in the vicinity of Los Lunas in Valencia County and one near Veguita in northern Socorro County, each consist of only one species of mammal. Camels are the only fossils in the Los Lunas sites, including *Hemiauchenia* cf. *H. blancoensis* and a large *Camelops* or possible giant camelid. The Veguita site has a maxilla with a complete dentition of the large horse *Equus scotti*, a species typical of late Blancan and early Irvingtonian faunas. Of the five previously known faunas: the Santo Domingo site from the northernmost Albuquerque basin in Sandoval County contains two horses, *E. calobatus* and *E. scotti*, that suggest a late Blancan age; the Tijeras Arroyo fauna has the rabbit *Hypolagus* cf. *H. gidleyi* and the horse *E. cumminsi* that indicate a middle or late Blancan age; the Laguna site includes the pocket gopher *Geomys* (*Nerterogeomys*) cf. *G. (N.) paenebursarius* found in late Blancan faunas; the Los Lunas site has the giant marmot *Paenemarmota* cf. *P. barbouri*, a species ranging in age from the early Blancan through the late Blancan; and the San Acacia site at the southern end of the Albuquerque basin contains *Stegomastodon mirificus* and an unidentified species of *Equus*. The presence in many of the Albuquerque basin faunas of mammals that occur in middle Blancan and younger faunas excludes an early Blancan (3.7–4.5 Ma) age for most of these sites. Several of these faunas appear to be late Blancan in age (1.8–2.5 Ma) based on the few age-diagnostic species present, although the absence of Neotropical immigrant mammals (the ground sloth *Glossotherium*, the glyptodont *Glyptotherium*, the capybara *Nechoerus*, and the porcupine *Erethizon*) from all Albuquerque basin Blancan faunas may be significant. The arrival of these immigrants from South America at about 2.5 Ma characterizes most late Blancan faunas from the southwestern United States, suggesting that some Albuquerque basin Blancan faunas may be middle Blancan in age (2.5–3.7 Ma).

INTRODUCTION

Tedford (1981) reviewed the Neogene vertebrate fossil assemblages from the Albuquerque basin in north-central New Mexico. These faunas range in age from early Miocene through late Pleistocene, with at least one fauna representing each North American land-mammal "age" (NALMA), from the Arikarean through the Rancholabrean. Only a few (Pliocene) Blancan vertebrate fossils have been reported previously from the Albuquerque basin. Tedford (1981) discussed specimens of Blancan age from Tijeras Arroyo in Albuquerque and a few other Blancan fossils from Santo Domingo in Sandoval County, near Los Lunas in Valencia County, and San Acacia in Socorro County. Lucas et al. (1993) reviewed the fossil mammals from the Sierra Ladrones Formation in Tijeras Arroyo, including both Blancan and early Irvingtonian (early Pleistocene) faunas.

Five new Blancan vertebrate sites from the Albuquerque basin are described in this paper, the most important of which are the Loma Colorado de Abajo local fauna from Rio Rancho in Sandoval County in the northern Albuquerque basin and the Belen fauna from near Belen in Valencia County in the southern part of the basin. Data are provided on the geology, location, vertebrate fauna, and age of these two sites. We also report isolated fossils from three other new Blancan sites in the vicinity of Los Lunas and Veguita in the southern Albuquerque basin, and present a brief review of five previously reported Blancan vertebrate sites.

The vertebrate fossils discussed in this paper are housed in the New

Mexico Museum of Natural History and Science (NMMNH) in Albuquerque and the Frick Collection of the American Museum of Natural History in New York (F:AM). Site numbers (preceded by L-) refer to NMMNH fossil localities. Map coordinates and other information on these sites are on file at the NMMNH. All measurements of fossils in this paper are in millimeters.

CHRONOLOGIC FRAMEWORK

We follow Berggren et al. (1995) for the placement of the Miocene/Pliocene and Pliocene/Pleistocene boundaries and Lindsay et al. (1984) and Lundelius et al. (1987) for the time ranges and boundaries of the Blancan NALMA. The Miocene/Pliocene boundary is now 5.32 Ma, and the Pliocene/Pleistocene boundary is located near the top of the Olduvai magnetic polarity subchron at 1.81 Ma (Berggren et al., 1995). Lindsay et al. (1984) placed the boundary between the Hemphillian and Blancan NALMAs in the early Pliocene at about 4.5 Ma, corresponding with a major extinction event in the North American mammalian fauna. Lundelius et al. (1987) documented a transitional interval between the Blancan and Irvingtonian, from about 1.8 to 2.2 Ma. Most characteristic Blancan mammalian genera, such as *Borophagus*, *Hypolagus*, *Nannippus*, and *Rhynchotherium*, had become extinct by 2.2 Ma (the *Nannippus* extinction datum of Lindsay et al., 1984), but most typical Irvingtonian genera did not appear until after 1.8 Ma. With the latest downward revision of the Pliocene/Pleistocene boundary by almost 0.2 Ma to 1.81 Ma (Berggren et al., 1995; until

recently most geochronologists placed this boundary at 1.64 Ma), the Pliocene/Pleistocene boundary now corresponds rather closely to the boundary between the Blancan and Irvingtonian. This boundary also now approximately coincides with the first appearance in North America of the genus *Mammuthus*, one of the defining genera of the Irvingtonian LMA.

Tedford (1981) divided the Blancan into three intervals: early Blancan (3.7–4.5 Ma), middle Blancan (2.5–3.7 Ma) and late Blancan (1.8–2.5 Ma), whereas Repenning (1987) divided the Blancan into five intervals (Blancan I–V) based on the biochronology of microtine (=arvicoline) rodents. Repenning's system is entirely dependent upon the presence of microtine rodents in a fauna to determine its age, so in many cases it has limited utility. Only one Blancan fauna from New Mexico, the Buckhorn local fauna in Grant County (Morgan et al., 1997), is known to contain microtine rodents, and consequently we have chosen to use Tedford's broader subdivisions of the Blancan.

BLANCAN VERTEBRATE FAUNAS FROM THE ALBUQUERQUE BASIN

Loma Colorado de Abajo local fauna

Geological context and locality

Loma Colorado de Abajo is a prominent hill within the city limits of Rio Rancho in Sandoval County, about 20 km northwest of Albuquerque (Fig. 1). Beginning in 1990 and continuing until 1996, Paul Knight collected several intriguing specimens of 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 fossil site is located just a few hundred meters behind the recently built Rio Rancho High School, finished in the summer of 1997, although the school did not exist when the fossils described below were collected. The fossiliferous level is in the Loma Barbon Member (queried) in the upper part of the Arroyo Ojito Formation of Connell et al. (this volume), about 8 m below the base of the overlying Ceja Member of the same formation.

Vertebrate fauna

The vertebrate fossils described here as the Loma Colorado de Abajo local fauna are limited in diversity, consisting of just three taxa, a small land tortoise and two rodents, including one species each of ground squirrel (family Sciuridae) and pocket gopher (family Geomyidae). The same stratum from which the rodent fossils were collected also contains numerous ichnofossils, including several that we interpret as possible rodent burrows. The Loma Colorado fauna differs from other New Mexico Blancan faunas in consisting entirely of small burrowing vertebrates. No specimens of larger mammals (horses, camels, proboscideans, etc.) are known from this site.

Testudinidae—A bridge peripheral (NMMNH P-27702) of a small land tortoise is identified from site L-1462. This specimen is not complete enough for a more precise identification, but resembles the same element in one of the small species of *Hesperotestudo* (= *Geochelone*).

Spermophilus sp.—A ground squirrel of the genus *Spermophilus* is identified in the fauna on the basis of a partial skull lacking the rostrum with right and left P4 (NMMNH P-26882). The skull is from a small species of *Spermophilus* in the size range of living *S. tridecemlineatus*, but a specific identification must await further comparisons. Measurements of the Loma Colorado *Spermophilus* skull are: alveolar length of maxillary tooth row (P3–M3), 8.8; breadth of palate at P4, 11.3; interorbital breadth, 7.9; antero-posterior length of P4, 1.6; width of P4, 2.1. These measurements are considerably smaller than those of *Spermophilus* cf. *S. bensoni* from the Blancan of southeastern Arizona (Tomida, 1987), a species also tentatively identified from the Blancan Buckhorn local fauna in southwestern New Mexico (Morgan et al., 1997). Tomida (1987) also reported an upper tooth of a smaller *Spermophilus* from the Blancan of southeastern Arizona that is more comparable in size with the Loma Colorado ground squirrel.

Geomys (Nerterogeomys) sp.—Three specimens from Loma Colorado de Abajo are referred to the primitive pocket gopher, *Geomys (Nerterogeomys)* sp., including a nearly complete skull with right I1, P4–M2 and left I1, M1–M3 (NMMNH P-14265); a rostrum with both incisors and palate with right and left P4–M3 (NMMNH P-26880); and a partial left mandible with the base of the incisor (NMMNH P-26881). The two skulls are identified as *Geomys* by the presence of doubly-grooved or bisulcate upper incisors, unrooted cheek teeth, and the absence of an enamel plate on the posterior surface of P4. 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 (Becker and White, 1981; Tomida, 1987), rather than anterior to the crest as in the subgenus *Geomys (Geomys)*.

Although the Loma Colorado pocket gopher sample includes one nearly complete skull and a second partial skull, these specimens are difficult to identify because many of the extinct species of *Geomys* are known only from mandibles. The Loma Colorado pocket gopher skulls are smaller than most described skulls of Blancan species of *Geomys (Nerterogeomys)*, including: *G. anzensis* and *G. garbanii* from the middle Blancan through the early Irvingtonian of the Anza-Borrego Desert of southern California (Becker and White, 1981), *G. persimilis* from middle Blancan through the early Irvingtonian of southeastern Arizona

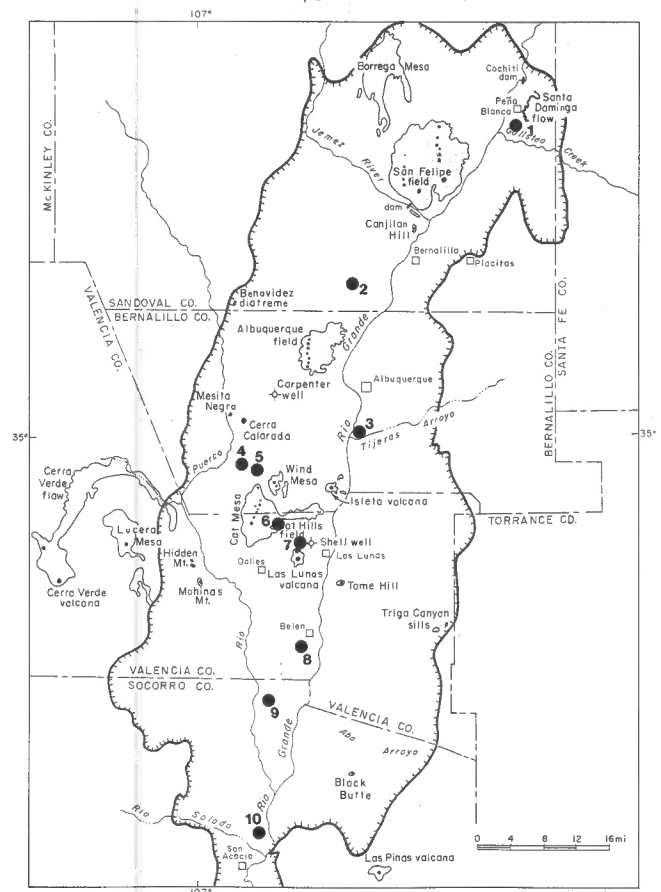


FIGURE 1. Map of the Albuquerque basin (modified from Kelley and Kudo, 1978) showing the location of Blancan vertebrate sites. The numbers on the map refer to the following faunas described in the text (numbers preceded by L- refer to vertebrate sites of the New Mexico Museum of Natural History). 1, Santo Domingo site of Tedford (1981), Sandoval County; 2, Loma Colorado de Abajo (L-1462), Sandoval County; 3, Tijeras Arroyo-lower site (L-1458), Bernalillo County; 4, Laguna site of Tedford (1981), Bernalillo County; 5, Site L-3318, Bernalillo County; 6, Site L-3738, Valencia County; 7, Los Lunas site of Tedford (1981), Valencia County; 8, Belen sites, (L-3737, 3778), Valencia County; 9, Site L-2941, near Veguita, Socorro County; 10, San Acacia site of Denny (1940), Socorro County.

(Tomida, 1987), *G. paenebursarius* from the late Blancan of south-western Texas (Strain, 1966), and *G. smithi* from the early Blancan Fox Canyon local fauna of Kansas (Hibbard, 1967). A smaller species, *G. minor*, is known from the early Blancan Rexroad fauna from Kansas and from two middle Blancan faunas, Beck Ranch in Texas and Benson in Arizona (Hibbard, 1967; Dalquest, 1978). Repenning and May (1986) also reported *G. minor* from the early Blancan Truth or Consequences local fauna from the Palomas Formation in Sierra County in central New Mexico. *G. minor* is represented almost entirely by mandibles and thus is not directly comparable to the Loma Colorado skulls. Tomida (1987) also described material of a small *Geomys* from the middle to late Blancan of southeastern Arizona. Although the excellent cranial material of the Loma Colorado *Geomys* should be sufficient for a species level identification, more detailed comparisons are needed with other Blancan pocket gopher fossils from elsewhere in the southwestern United States. There is also the possibility that these skulls represent an undescribed species.

Selected measurements of the nearly complete *Geomys* skull (P-14265) from Loma Colorado de Abajo are as follows (measurements after Becker and White, 1981): condylobasal length, 40.2; basilar length, 33.8; breadth of rostrum at premaxillary/maxillary suture, 8.9; interorbital constriction, 5.8; zygomatic breadth, 24.5. Several additional cranial measurements can be taken on both *Geomys* skulls from Loma Colorado (P-14265 first, P-26880 second): length of diastema, 12.7, 10.7; alveolar length of maxillary tooth row (P4–M3), 8.1, 7.8; width of I1, 2.3, 2.2; length of P4, 2.1, 1.8; anterior width of P4, 1.6, 1.6; posterior width of P4, 1.8, 1.7; length of M1, 1.0, 1.0; width of M1, 2.1, 2.0; length of M3, 1.5, 1.6; width of M3, 1.6, 1.6.

Only two measurements can be taken on the fragmentary *Geomys* mandible (P-26881) from Loma Colorado: width of i1, 1.9; length of diastema, 5.8. This mandible is slightly smaller than the pocket gopher mandibles from Belen and Laguna that are tentatively referred to *G. (Nerterogeomys) paenebursarius* (see below), and is more similar in size to the small species *G. (N.) minor* (Hibbard, 1967; Akersten, 1972). Although about the same size as *G. minor*, the Loma Colorado mandible is so fragmentary that a species-level identification is not warranted without more complete material.

Ichnofossils—Two nearly complete burrows (NMMNH P-26883, 26884) and four partial burrows (NMMNH P-26885) are here tentatively identified as possible rodent burrows. The burrows are composed of an indurated, reddish-colored fine sand and occur in the same stratigraphic unit as the rodent skulls. The two most complete specimens are shaped like a tall boot or thick-shafted golf club, with a long straight portion or “shaft” presumably proximal, and a shorter boot-shaped distal portion or “boot” (presumably the living chamber) that meets the “shaft” at about a 120° angle. Measurements of these burrows are (P-26883, 26884, respectively): total length, 420, 350; length of “shaft,” 380, 250; maximum diameter of “shaft,” 75, 80; length of “boot” 150, 130.

Age

The age of the Loma Colorado de Abajo local fauna is based on the presence of the pocket gopher *Geomys*. The characters of the two Loma Colorado geomyid skulls, including bisulcate upper incisors, unrooted cheek teeth, and absence of enamel on the posterior surface of P4, confirm their identification as *Geomys*, and distinguish them from earlier pre-Blancan geomyids such as *Pliogeomys* that have rooted cheek teeth. Both subgenera of *Geomys*, including *G. (Geomys)* and *G. (Nerterogeomys)*, appear about the same time in the early Blancan, with the former surviving to the present and the latter going extinct in the early Irvingtonian. The location of the mental foramen ventral to the masseteric crest in the Loma Colorado mandible confirms the presence of *Geomys (Nerterogeomys)* in this fauna. The species of *G. (Nerterogeomys)* that survive into the Irvingtonian (e.g., *G. anzensis*, *G. garbanii*, and *G. persimilis*) are considerably larger than the Loma

Colorado species. The smaller species of *G. (Nerterogeomys)* that are more similar in size to the Loma Colorado *Geomys* (e.g., *G. minor*) are restricted to the Blancan.

Belen fauna

Geological context and localities

Beginning south of the Los Lunas volcano (Cerro de Los Lunas) and extending south of Belen into northern Socorro County, badlands of the Sierra Ladrone Formation are well exposed in an east-facing escarpment just west of I-25 and several kilometers west of the Rio Grande. In the past five years, the NMMNH has received two different collections of Blancan vertebrate fossils from the Sierra Ladrone Formation southwest of Belen in Valencia County (Fig. 1).

NMMNH Site L-3737—Christopher Whittle and several students collected Blancan vertebrate fossils from a slightly indurated channel sandstone of the Sierra Ladrone Formation about 2 km southwest of Belen and 1 km west of I-25 just south of Sosimo Padilla Road. Fossils from this site include five species, a colubrid snake, the mole *Scalopus*, the pocket gopher *Geomys*, a large horse of the genus *Equus*, and a small antilocaprid.

NMMNH Site L-3778—Bill Wood collected vertebrate fossils from the badlands of the Sierra Ladrone Formation about 5 km southwest of Belen and 2 km west of I-25, about 4 km south of site L-3737. The most significant fossil from this site is a pair of jaws of the gomphothere *Stegomastodon mirificus*. The other fossils from this site are postcranial elements of *Equus*.

Vertebrate fauna

Because of the close proximity of sites L-3737 and 3778 southwest of Belen and their occurrence in similar strata of the Sierra Ladrone Formation, the fossils from these two sites are combined as the Belen fauna. Although not a particularly diverse assemblage, the co-occurrence of four species of mammals in the Belen fauna, including the mole *Scalopus (Hesperoscalops)* sp., the pocket gopher *Geomys (Nerterogeomys)* cf. *G. paenebursarius*, the horse *Equus* cf. *E. calobatus*, and the proboscidean *Stegomastodon mirificus*, is indicative of a Blancan age.

Colubridae—A partial skeleton of a small snake, consisting of more than 30 articulated vertebrae and associated ribs (NMMNH P-27526), was collected from NMMNH site L-3737. The vertebral morphology clearly indicates that this specimen is a colubrid snake, but we have not yet made further comparisons. Snakes have been reported from two other Blancan faunas from New Mexico. A partial skeleton of the long-nosed snake, *Rhinocheilus lecontei*, occurs in the Camp Rice Formation near Hatch, Doña Ana County, southern New Mexico (Lucas et al., 1995). Repenning and May (1986) listed the coachwhip snake, *Masticophis flagellum*, in the early Blancan Truth or Consequences local fauna from the Palomas Formation, Sierra County, central New Mexico.

***Scalopus (Hesperoscalops)* sp.**—A partial left dentary with m1–m3 (NMMNH P-27515) from site L-3737 represents the first fossil evidence of a mole (family Talpidae) from New Mexico. Moles are absent from the modern mammalian fauna of New Mexico (Findley et al., 1975), with the closest occurrence being the eastern mole, *Scalopus aquaticus*, in the Texas Panhandle. The Belen mole is referred to *Scalopus (Hesperoscalops)*, an extinct subgenus of *Scalopus* known only from the late Hemphillian and Blancan. *S. (Hesperoscalops)* is characterized by its larger size and presence of basal accessory cusps on the lower molars compared to the extant *S. (Scalopus)*. Two Blancan species of *S. (Hesperoscalops)* have been described, *S. rexroadi* from the early Blancan Rexroad and Fox Canyon faunas (Hibbard, 1953; Kurtén and Anderson, 1980) and the middle Blancan Beck Ranch local fauna of Texas (Dalquest, 1978) and *S. blancoensis* from the late

Blancan Blanco and Cita Canyon local faunas of Texas (Dalquest, 1975). *S. blancoensis* differs from *S. rexroadi* in its slightly larger size, larger basal accessory cusps, and more reduced m3. The alveolar length of the m1–m3 in the Belen mandible (8.1) is slightly larger than the same measurement in three mandibles of *S. rexroadi* from Rexroad (range of 7.2–7.8; Hibbard, 1953), but the other characters involving the reduction of the m3 and the basal accessory cusps are difficult to evaluate without further comparisons. Although the specific identity of the Belen mole must await further comparisons, its identification as a member of the extinct subgenus *Hesperoscalops* establishes a pre-Pleistocene, probably Blancan, age. The Belen specimen marks the westernmost fossil record of *Scalopus*. The occurrence of a mole in the desert southwest where no members of the Talpidae are found at present indicates that the climate and vegetation were significantly different at that time.

Geomys (Nerterogeomys) cf. G. (N.) paenebursarius—A nearly complete left dentary with I₁ and p4–m3 (NMMNH P-27516) from site L-3737 is identified as the pocket gopher genus *Geomys*, based on the presence of unrooted cheek teeth and the absence of enamel on the anterior surface of m1–m3. The location of the mental foramen ventral to the masseteric crest and the presence of square or U-shaped re-entrants on the p4 further allows referral to the extinct subgenus *Geomys (Nerterogeomys)*. The overall morphology and size of this mandible are similar to the species *G. (N.) paenebursarius* from the late Blancan of southwestern Texas (Akersten, 1972, table 2), and the Belen *Geomys* is tentatively referred to that species. Measurements of the Belen mandible are: length of diastema, 7.7; width of i1, 2.5; length of p4, 2.3; posterior width of p4, 1.9; width of m1, 2.1. The presence of *Geomys (Nerterogeomys)* establishes a Blancan or early Irvingtonian age for the Belen fauna, and the occurrence of *Geomys cf. G. (N.) paenebursarius* further suggests a late Blancan age.

Equus cf. E. calobatus—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. No complete horse teeth have been found in this fauna. One of the postcranial elements, a nearly complete juvenile metatarsal missing only the distal epiphysis (NMMNH P-27523) from site L-3737, appears to be tentatively referable to the large, stilt-legged horse, *Equus cf. E. calobatus*. Measurements of this specimen (total length, 310; estimated total length with distal end intact, 330+; proximal width, 49; midshaft width, 32) indicate an animal with longer and more slender metapodials than the common large horse in New Mexico Blancan faunas, *E. scotti*. These measurements compare closely to those of a metatarsal referred to *Equus cf. E. calobatus* from the Mesilla basin in Doña Ana County in southern New Mexico (Vanderhill, 1986, table 5.3.10). Vanderhill identified *E. calobatus* from three late Blancan and early Irvingtonian faunas in the Mesilla basin, and Tedford (1981) reported this species from the late Blancan Santo Domingo fauna in the north-central part of the state.

Antilocapridae—The distal end of a metapodial (NMMNH P-27524) from site L-3737 is identified as a small species of antilocaprid. A more precise identification is not possible without a horncore. This fossil represents the only evidence of an artiodactyl from the Belen fauna, which is unusual considering the abundance of camels in most other Blancan faunas from New Mexico.

Stegomastodon mirificus—A well preserved pair of juvenile mandibles with right and left m2 and unerupted right and left m3 (NMMNH P-27395) from site L-3778 are referred to the gomphothere, *Stegomastodon mirificus*. The presence of seven lophids on m3 separates this specimen from both *Rhynchotherium* and *Cuvieronius*, the only other genera of gomphotheres found in North American Blancan faunas. The absence of lower tusks further distinguishes these mandibles from *Rhynchotherium*. Both the m2 and m3 are characterized by highly complicated enamel with double trefoiling. The m2 has

four lophids and measures 105.4 mm in length and 67.9 mm in maximum width. The m3s are not erupted above the gum line and thus are entirely unworn. The left m3 was removed from the crypt so it could be measured and photographed. This tooth is composed of seven lophids and has numerous accessory conulids. The m3 is 186.5 mm in length and 71.3 mm in maximum width. The total length of the left dentary is 575 mm.

Kurtén and Anderson (1980) recognized only one species of *Stegomastodon* in North America, *S. mirificus*, ranging in age from middle Blancan through early Irvingtonian. Other authors recognize several species of *Stegomastodon*, including the more primitive *S. rexroadensis*. Lucas and Oakes (1986) referred a pair of mandibles with highly worn m3s to *S. rexroadensis* from the middle Blancan Cuchillo Negro Creek local fauna in Sierra County, central New Mexico. This specimen is difficult to compare to the Belen mandible because the crown of the m3 including most of the enamel is completely worn away, whereas the Belen specimen has totally unworn and unerupted m3s. Nonetheless, there appear to be several differences between the m3s of these two *Stegomastodon* mandibles, including the presence of six lophids, single trefoiling, and relatively simple enamel in the Cuchillo Negro specimen, compared to seven lophids, double trefoiling, and complex enamel in the Belen m3. Lucas et al. (1998) described a maxilla of *S. mirificus* with right and left M2 and M3 from Tortugas Mountain near Las Cruces in Doña Ana County in southern New Mexico. Although not directly comparable to the Belen specimen because it has only upper teeth, the presence of highly complicated enamel and double trefoiling on the M3s suggests that both specimens belong to the advanced species *S. mirificus*. The Tortugas Mountain *S. mirificus* is associated with *Mammuthus*, indicating an early Irvingtonian age, whereas no mammoths have been found in association with the Belen *Stegomastodon*.

Age

Four mammals in the Belen fauna are age diagnostic. The extinct subgenus *Scalopus (Hesperoscalops)* is primarily restricted to the Blancan, although there is one species in this subgenus from the late Hemphillian. *G. (N.) paenebursarius* is known from two late Blancan faunas in southwestern Texas, Hudspeth (Strain, 1966) and Redlight (Akersten, 1972), and Tedford (1981) tentatively reported this same species from the Laguna site in the Albuquerque basin (see discussion below). *Stegomastodon mirificus* is known from the middle Blancan through the early Irvingtonian, and *Equus cf. E. calobatus* is known from the late Blancan through the Irvingtonian (Kurtén and Anderson, 1980). The age indicated by the co-occurrence of these four species appears to be the late Blancan; however, the lack of Neotropical immigrants such as glyptodonts in the Sierra Ladrone Formation in the Belen area suggests that a somewhat older middle Blancan age (between 2.5 and 3.7 Ma) is possible. Fossils referred to the glyptodont *Glyptotherium arizonae* are known from two early Irvingtonian faunas higher in the Sierra Ladrone Formation in the Albuquerque basin (Lucas et al., 1993).

Other Blancan faunas from the Albuquerque basin

Santo Domingo

The northernmost Blancan fauna in the Albuquerque basin was derived from axial gravels east of the Rio Grande in the vicinity of the Santo Domingo Pueblo in Sandoval County (Tedford, 1981). Tedford placed this site in the Santo Domingo basin, but as recognized here and by other authors in this volume, the Santo Domingo basin is the northernmost extension of the Albuquerque basin. Tedford (1981) identified the horses *Equus calobatus* and *E. scotti* from the Santo Domingo fauna. These two species are known from the late Blancan and early Irvingtonian, but Tedford (1981) favored a late Blancan age for the Santo Domingo fauna because of their similarity to the horses from the Tule Formation of Texas. Tedford (1981) noted that these deposits are interbedded with the Santa Ana Mesa basalt dated at ~2.4 Ma

(Bachman and Mehnert, 1978) and are overlain by the lower Bandelier Tuff dated at 1.61 Ma (Izett and Obradovich, 1994).

Tijeras Arroyo

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), including the glyptodont *Glyptotherium arizonae* and the primitive mammoth *Mammuthus meridionalis*. However, one locality (NMMNH Site L-1458) at the base of the exposed stratigraphic section in Tijeras Arroyo has produced two species that are indicative of a Blancan age. The fossils from this site were derived from a sandstone comprising unit 1 in the stratigraphic section of Lucas et al. (1993, fig. 2). The lowermost part of the section in Tijeras Arroyo, including unit 1, was recently referred to the Ceja Member of the Arroyo Ojito Formation (Connell and Hawley, 1998; Connell et al., this volume).

The anterior portion of a right mandible with a complete p3 (NMMNH P-12938) was referred to the rabbit *Hypolagus* cf. *H. gidleyi* by Lucas et al. (1993, figs., 4J-L). This species is found in late Hemphillian and Blancan faunas, but is unknown from the Irvingtonian (White, 1987). The horse *Equus* cf. *E. cummingsii* was tentatively identified from site L-1458 based on a partial skull with nearly complete dentition (NMMNH P-12895; Lucas et al., figs. 1A,B). This horse is characterized by its small size and simple enamel pattern on the upper cheek teeth. *E. cummingsii* occurs in several middle and late Blancan sites in Texas, but is unknown from the Irvingtonian (Kurtén and Anderson, 1980).

Both mammals identified from site L-1458 in the Tijeras Arroyo section, *Hypolagus* cf. *H. gidleyi* and *Equus* cf. *E. cummingsii*, are typical of Blancan faunas, and do not occur in the Irvingtonian. The extinction in the late Pliocene (about 2.2 Ma) of several characteristic Blancan genera, including *Hypolagus*, *Borophagus*, *Rhynchotherium*, and *Nannippus*, is considered one of the most important biochronological events in the late Blancan (Lindsay et al., 1984). The presence of *Hypolagus* indicates that site L-1458 is older than 2.2 Ma. *Equus* cf. *E. cummingsii* appears to be absent from early Blancan faunas (Kurtén and Anderson, 1980). These two species suggest this site is middle to late Blancan in age (between 2.2 and 3.5 Ma). Pending the discovery of additional mammalian taxa, a more precise placement of this fauna within the Blancan is not possible. The absence of Guaje Pumice from the Ceja Member of the Arroyo Ojito Formation in the lower part of the Tijeras Arroyo section indicates these beds predate deposition of the Bandelier Tuff at about 1.6 Ma (Lucas et al., 1993). Strata of the overlying Sierra Ladrones Formation in Tijeras Arroyo contain both Guaje Pumice and early Irvingtonian mammals, indicating an age younger than 1.6 Ma (Lucas et al., 1993).

Laguna and Los Lunas sites

Tedford (1981) mentioned two sites in the southern portion of the Albuquerque basin that have produced specimens of Blancan mammals. He attributed these two sites to the Ceja Member of the Santa Fe Formation of Kelley (1977), although more recent stratigraphic work would place these sites in either the Sierra Ladrones Formation or the Arroyo Ojito Formation. The Laguna site of Tedford (1981, p. 1019) is about 15 km northwest of Isleta in southern Bernalillo County, "...where the northern boundary of the Isleta Pueblo Grant crosses the Ceja del Rio Puerco..." This site contains small mammal, bird, and turtle remains. The most diagnostic fossils from the Laguna site are two *Geomys* jaws, including a right mandible with i1, p4-m3 (F:AM 87461) and a right mandible with i1, p4-m2 (F:AM 87462). These two mandibles are referred to the extinct subgenus *Geomys* (*Nerterogeomys*) based on the placement of the mental foramen ventral to the masseteric crest and by the U-shaped reentrant angles on the p4s (Becker and White, 1981; Tomida, 1987). The Laguna geomyid mandibles are similar in size and morphology to the *Geomys* mandible from the Belen site, which was tentatively referred to *Geomys*

(*Nerterogeomys*) *paenebursarius*, a species originally described from the late Blancan of Texas (Strain, 1966, Akersten, 1972). Tedford (1981) also referred the Laguna mandibles to *G. (N.)* cf. *G. paenebursarius*. The Belen and Laguna *Geomys* mandibles are slightly smaller in some measurements than typical *G. paenebursarius* from the Hudspeth and Redlight local faunas in southwestern Texas (Akersten, 1972, table 2), and will require further comparisons for a definite species identification. Measurements of the Laguna *Geomys* mandibles are (F:AM 87461, 87462, respectively): width of i1, 2.2, 2.0; length of p4, 2.3, 2.1; posterior width of p4, 1.8, 1.8; width of m1, 1.9, 1.9. Another locality (NMMNH site L-3318) near Tedford's Laguna site has produced a camel tooth from a greenish to tan, fine-grained facies in the Sierra Ladrones Formation. This tooth, a left M3 (NMMNH P-25588), is tentatively referred to the common Blancan camel, *Hemiauchenia* cf. *H. blancoensis*.

The Los Lunas site of Tedford (1981, p. 1018) is located in deformed strata that underlie andesites of the Los Lunas volcano about 7 km west of Los Lunas in northern Valencia County, "...near where State Highway 6 ascends the Cejita." The only fossil Tedford reported from this site was 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). This specimen (F:AM 87460) consists of a partial right dentary with the base of the incisor and the roots of p4-m1. The only measurements that can be taken on this mandible are the width (5.8) and depth (8.9) of the lower incisor. These measurements are at the upper end of the size range for lower incisors of *P. barbouri*, and are considerably larger than incisors of the two smaller Hemphillian species, *P. sawrockensis* and *P. mexicana* (comparative measurements from Zakrzewski, 1998, table 1). On the basis of its large size, the Los Lunas mandible is tentatively referred to *P. barbouri*, a species that occurs from the early Blancan through the late Blancan. 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.

Just a few kilometers northwest of Tedford's Los Lunas site, about 1 km north of New Mexico Route 6 and just west of the Atchison, Topeka, and Santa Fe Railroad (NMMNH site L-3738), Dave Love collected several bones of a large camel from sediments of the Sierra Ladrones or Arroyo Ojito formations. These specimens, including a partial distal radio-ulna (NMMNH P-27511) and a magnum (NMMNH P-27512), represent either a large individual of *Camelops* or one of the genera of giant camels (e.g., *Blancocamelus* or *Gigantocamelus*). The magnum (width, 51.1; length, 53.5; height, 32.9), is near or slightly larger than the maximum size for the magnum of *C. hesternus* (comparative measurements from Webb, 1965, table 10). A large undescribed species of *Camelops* occurs in several Blancan faunas in southern New Mexico (Vanderhill, 1986; Morgan et al., 1998), and the giant camels are typical of the Blancan, but are generally absent from Irvingtonian faunas. Therefore, the camel fossils from Site L-3738 are indicative of a Blancan age, whether they belong to a large *Camelops* or a giant camel.

Veguita

A site in the Sierra Ladrones Formation about 1 km east of the Rio Puerco and 10 km northwest of Veguita in northernmost Socorro County (NMMNH Site L-2941) in the southern Albuquerque basin has produced a partial maxilla with left P2-M3 (NMMNH P-25563) of the large horse *Equus scottii*. 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 plicaballin. *E. scottii* is the common large horse in New Mexico faunas ranging in age from the middle and late Blancan (e.g. Arroyo de la Parida and Tonuco Mountain) through the early Irvingtonian (e.g., Tijeras Arroyo and Mesilla basin). A Blancan age is more likely considering that most sites from the Sierra Ladrones Formation in the southern portion of the Albuquerque basin produce Blancan mammals.

San Acacia

A Blancan fauna is known from the extreme southern end of the Albuquerque basin near San Acacia in northern Socorro County (Denny, 1940). This site is located just north of the Rio Salado on the western side of the Rio Grande, presumably from the Sierra Ladrones Formation, as this site is near the type area of the Sierra Ladrones Formation of Machette (1978). The fauna reported by Denny (1940, p. 93) from the San Acacia site consists of the gomphothere *Stegomastodon mirificus* and an undetermined species of *Equus*. We have not examined these fossils, so the identifications are taken from Denny's paper and must be considered tentative. The San Acacia site is similar to the middle to late Blancan Arroyo de la Parida local fauna, derived from the Sierra Ladrones Formation about 15 km farther south in the northern part of the Socorro basin (Tedford, 1981; Lucas and Morgan, 1996).

BIOCHRONOLOGY

Ten Blancan vertebrate sites are present in the Albuquerque basin (Fig. 1). Most of these sites contain diagnostic Blancan mammals, but only a few of these localities have species that permit a more precise placement of the fauna within the Blancan. Figure 2 is a correlation chart that includes most of the Blancan faunas from the Albuquerque basin discussed in the text. The long potential time ranges for most of the Blancan sites from the Albuquerque basin are a reflection of their low diversity (only one of the ten sites has more than two species of mammals) and their overall lack of species that are age-diagnostic within the Blancan. Five of the localities contain a single species of mammal, including the two Laguna sites, the two Los Lunas sites, and the Veguita site, whereas the Santo Domingo, Loma Colorado, Tijeras Arroyo, and San Acacia sites have only two species of mammals each. The Belen fauna with five species of mammals is the only more diverse Blancan fauna from the Albuquerque basin.

No faunas from the Albuquerque basin are clearly early Blancan in age. Several of the age ranges for the sites listed in Figure 2 do include the early Blancan because these sites contain long-ranging species of mammals that occur throughout the most of the Blancan. For example, the giant marmot *Paenemarmota* cf. *P. barbouri* from the Los Lunas site is known from faunas ranging in age from early Blancan through late Blancan (Kurtén and Anderson, 1980). The primitive pocket gopher subgenus *Geomys* (*Nerterogeomys*), identified from Loma Colorado, Laguna, and Belen, first appears in the early Blancan and disappears in the early Irvingtonian. The mandibles from Laguna and Belen are tentatively referred to *Geomys* (*Nerterogeomys*) *paenebursarius*, a species found elsewhere in late Blancan sites. The geomyid skulls from Loma Colorado have not yet been identified to the species level, and thus the age range for this site in Figure 2 extends downward to include the early Blancan.

Among the ten Blancan sites in the Albuquerque basin, the Belen fauna appears to have the best possibility for refining its age within the Blancan. Three species of mammals from Belen help to limit the age of the fauna within the Blancan, *Geomys* (*Nerterogeomys*) cf. *G.* (*N.*) *paenebursarius*, *Equus* cf. *E. calobatus*, and *Stegomastodon mirificus*. The pocket gopher *Geomys* (*Nerterogeomys*) *paenebursarius* is known from the late Blancan Hudspeth and Redlight local faunas in southwestern Texas (Strain, 1966; Akersten, 1972), and this same species is tentatively identified from the Laguna site in the Albuquerque basin (Tedford, 1981; this report). The large, stilt-legged horse *Equus calobatus* is known from the late Blancan through the Irvingtonian (Kurtén and Anderson, 1980). The gomphothere *Stegomastodon mirificus* occurs from the middle Blancan through the early Irvingtonian. The overlapping range zone of these three species is late Blancan.

Most of the Blancan sites from the Albuquerque basin appear to be either middle Blancan (2.5–3.7 Ma) or late Blancan (1.8–2.5 Ma). The lowest site in Tijeras Arroyo contains two species of mammals, *Hypolagus gidleyi* and *Equus cumminsii*, that are restricted to the Blancan (White, 1987; Lucas et al., 1993). *E. cumminsii* is found in middle and late Blancan faunas and the genus *Hypolagus* disappears in

the late Blancan at about 2.2 Ma, along with a number of other diagnostic Blancan genera (the *Nannippus* extinction event of Lindsay et al., 1984), indicating that the Tijeras Arroyo Blancan site is older than 2.2 Ma. Furthermore, the sediments in this lowest Tijeras Arroyo site, referred to the Ceja Member of the Arroyo Ojito Formation, lack Guaje Pumice, and thus predate the Bandelier Tuff (1.61 Ma). Strata higher in Tijeras Arroyo are referred to the Sierra Ladrones Formation and contain the primitive mammoth *Mammuthus meridionalis* and the glyptodont *Glyptotherium arizonae*. *G. arizonae* also occurs in Sierra Ladrones strata in a gravel pit in southern Sandoval County (Lucas et al., 1993). Both *M. meridionalis* and *G. arizonae* are indicative of an early Irvingtonian age (1.0–1.8 Ma). The Irvingtonian strata in the Tijeras Arroyo section also contain reworked Guaje Pumice, indicating an age younger than 1.61 Ma (Lucas et al., 1993).

Mammuthus is conspicuously absent from the Sierra Ladrones Formation in the southern half of the Albuquerque basin, providing strong evidence that these strata are pre-Pleistocene in age (older than 1.8 Ma). The lack of Neotropical immigrant mammals from Blancan sites in the southern Albuquerque basin, as well as the Arroyo de la Parida local fauna from the northern Socorro basin (Tedford, 1981; Lucas and Morgan, 1996), suggests the possibility of a middle Blancan age (between 2.5 and 3.7 Ma). The first appearance in southwestern Blancan faunas of Neotropical immigrants, including the ground sloth *Glossotherium*, the glyptodont *Glyptotherium*, the capybara *Neocoelus*, and the porcupine *Erethizon*, occurred at about 2.5 Ma, if not slightly earlier (Galusha et al., 1984; Lindsay et al., 1984).

The youngest Blancan site in the Albuquerque basin appears to be the Santo Domingo fauna from the northernmost extension of the basin in Sandoval County (Fig. 2). The two horses from Santo Domingo, *Equus calobatus* and *E. scotti*, occur in both late Blancan and early Irvingtonian faunas. The similarity of these horses to horses from the Tule Formation of Texas, and the correlation of basalts interbedded with the Santo Domingo deposits with a radioisotopic date of 2.5–2.6 Ma, led Tedford (1981) to suggest a late Blancan age for the Santo Domingo fauna.

Most of the ten Blancan sites reported here from the Albuquerque basin cannot be restricted to one of the three subdivisions of the Blancan, although an early Blancan age can be ruled out for five of the faunas. There are three species of horses in the Albuquerque basin Blancan faunas, none of which are known from the early Blancan (Kurtén and Anderson, 1980). *Equus calobatus* from the Santo Domingo and Belen faunas and *E. scotti* from Santo Domingo and Veguita are known primarily from late Blancan and early Irvingtonian faunas (Kurtén and Anderson, 1980; Tedford, 1981), although there is now fairly good evidence from the Mesilla basin and Tonuco Mountain faunas in southern New Mexico that both of these horses occur in the middle Blancan as well (Vanderhill, 1986; Morgan et al., 1998). *E. cumminsii* from Tijeras Arroyo is a middle to late Blancan species. The presence of the pocket gopher *Geomys* (*Nerterogeomys*) *paenebursarius* in the Laguna and Belen sites further supports the late Blancan age suggested by the horses. The absence of taxa is difficult to interpret in the context of biochronology; however, the absence of *Mammuthus* from strata of the Sierra Ladrones Formation in the southern Albuquerque basin almost certainly indicates a pre-Pleistocene age. The lack of evidence of Neotropical immigrant mammals in the Sierra Ladrones sites from the southern Albuquerque basin may be significant, and may indicate that these sites are actually middle Blancan in age (between 2.5 and 3.7 Ma). We choose to be conservative and consider the ages of these sites to be either middle or late Blancan (between 1.8 and 3.7 Ma). Further clarification of the ages of the vertebrate faunas from the Albuquerque basin will require the discovery of additional vertebrate fossils or the implementation of other geochronologic techniques, such as paleomagnetic stratigraphy or radioisotopic dates.

ACKNOWLEDGMENTS

Paul and Samara Knight, David Love, Christopher Whittle, and Bill Wood generously donated fossils to the New Mexico Museum of

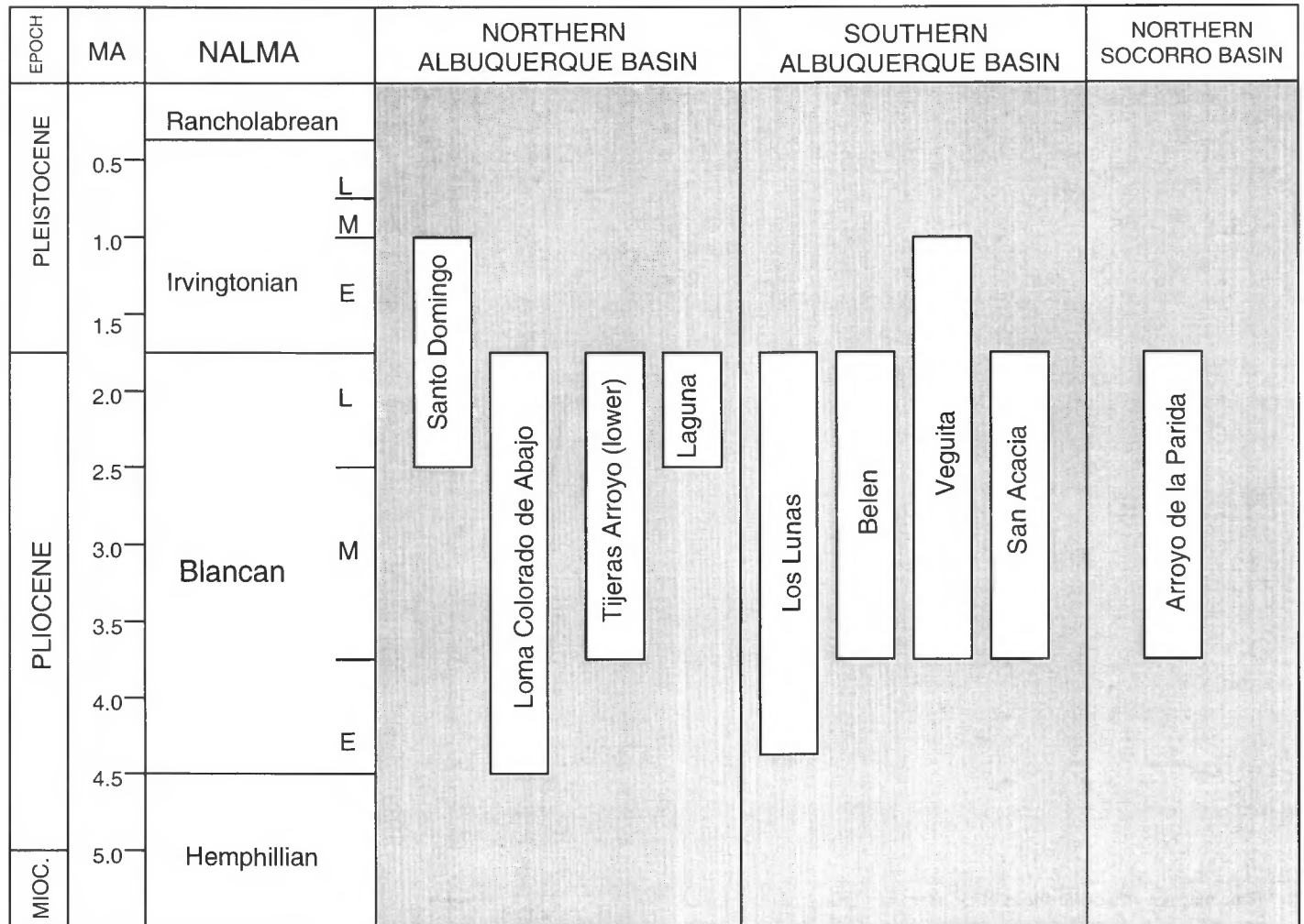


FIGURE 2. Correlation chart showing the chronologic relationships of Blancan vertebrate faunas from the Albuquerque basin. Not all sites discussed in the text are included on this chart, only those sites with age diagnostic species of mammals. The boundary between the northern and southern Albuquerque basin is arbitrarily drawn at the Bernalillo County/Valencia County line. The vertical height of the bar representing each fauna corresponds to the possible time range for the fauna. The Arroyo de la Parida local fauna from the northern part of the Socorro basin is indicated on the chart because it is similar to several faunas from the southern part of the Albuquerque basin and is also derived from the Sierra Ladrones Formation, the geologic unit that produced most of the Albuquerque basin Blancan faunas.

Natural History. We are very grateful to Jerald Harris for the timely preparation of the rodent skulls from Loma Colorado de Abajo. We thank Drs. Sean D. Connell, H. Gregory McDonald, and Richard H. Tedford for helpful comments on the manuscript. Dr. Tedford kindly loaned us several Blancan fossils from the Albuquerque basin housed in the American Museum of Natural History. This is the third contribution in our long-term project to document and describe all Blancan vertebrate faunas from New Mexico (Morgan et al., 1997, 1998).

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