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Late Pleistocene (Rancholabrean) mammals from fissure deposits in the Jurassic Todilto Formation, White Mesa mine, Sandoval County, north-central New Mexico

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Abstract

A late Pleistocene (Rancholabrean) fossil site containing partial to nearly complete articulated skeletons of large mammals preserved in fissure deposits was discovered in 2005 at the White Mesa mine near San Ysidro in Sandoval County, north-central New Mexico. The fissures are in gypsum of the Jurassic Todilto Formation. Structural analysis suggests the fissures opened to the surface during the Pleistocene in response to extension associated with the Rio Grande rift. Bones were found approximately 9–12 m (30–40 ft) below the modern land surface in three different fissures within approximately a 15-m (~50-ft) radius. Four species of large mammals are preserved in the fissures, each known from at least one partial to nearly complete skeleton: stilt-legged horse (*Equus* cf. *E. francisci*), camel (*Camelops hesternus*), extinct bison (*Bison antiquus*), and mule deer (*Odocoileus hemionus*). The most fossiliferous fissure, containing one skeleton each of a camel and a bison, was 18 cm (7 in) wide and contained bones over a depth of approximately 40–50 cm (15–20 in) and a length of approximately 3.5–4 m (11–13 ft). The camel consists of a partial skeleton of a very old individual of *Camelops hesternus* with heavily worn teeth and evidence of osteoarthritis on the articular surfaces of several limb bones and toes. The bison is a nearly complete articulated skeleton of a juvenile *Bison antiquus* with deciduous premolars, unerupted third molars, and unfused epiphyses on all limb bones. A second nearby fissure contained an articulated front limb of an advanced juvenile or young adult *Equus* cf. *E. francisci* and an articulated hind limb of a second adult *Camelops hesternus*. A third fissure had a nearly complete skeleton of a young adult female *Odocoileus hemionus*. The White Mesa mine differs from most New Mexico Pleistocene cave faunas in the predominance of articulated skeletons and the rarity of small vertebrates, although a partial skeleton of the pocket gopher *Thomomys talpoides* was found in the same fissure that produced the deer skeleton. An AMS radiocarbon date on a *Camelops* metacarpal from the White Mesa mine yielded an age of 12,910 ± 60 ^{14}C yrs B.P.

The predominance of grazing ungulates in the fissures, including horse, camel, and bison, suggests that the habitat in the vicinity during the late Pleistocene consisted of a grassland. The following is a hypothetical sequence of events that led to the preservation of partial to nearly complete skeletons of large Pleistocene mammals in very narrow fissures that were not wide enough to accommodate the living (or recently dead) animals. The fissures were open to the surface in the late Pleistocene and acted as natural traps into which the animals inadvertently fell. The fissures were wider near the surface and narrower at depth. The animals either died from falling into the fissures or were unable to climb out and starved to death. The articulated condition of the skeletons and the lack of bite marks on the bones suggest the fissures were inaccessible to predators or scavengers that would have damaged and disassociated the carcasses. The bodies of the ungulates began to decompose in the wider portion of the fissures nearer the surface. Finally, the mostly decomposed skeletons still held together by connective tissues fell and became lodged in the lower and narrower portion of the fissures where they were eventually discovered.

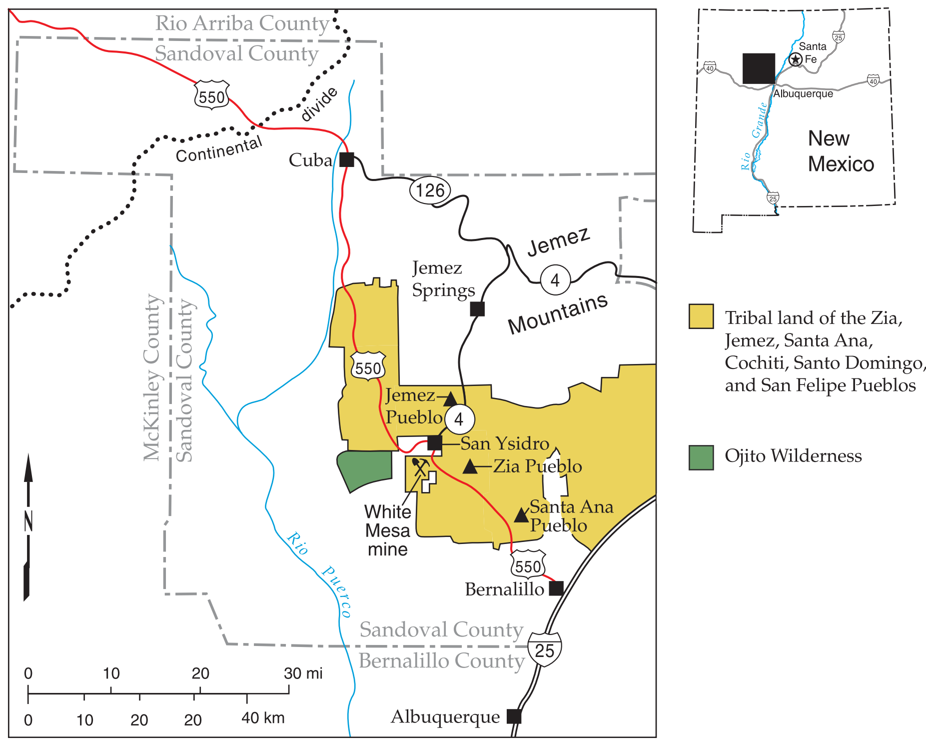

FIGURE 1—Map showing the location of the White Mesa mine, Sandoval County, north-central New Mexico.

Introduction

Workers at the White Mesa mine in Sandoval County, New Mexico, discovered several skeletons of large late Pleistocene mammals in 2005 in fissure-fill deposits developed in gypsum of the Middle Jurassic Todilto Formation. Field parties from the New Mexico Museum of Natural History, aided by the miners, in particular David Pino and Lambert Pino, collected these fossils over a period of several months in the summer of 2005. A study of the structural geology of these fissure deposits was recently published (Rinehart et al. 2006). This paper summarizes the vertebrate paleontology and taphonomy of the late Pleistocene fissure deposits from the White Mesa mine. To our knowledge, the White Mesa mine represents the first record of Pleistocene fissure deposits in New Mexico, although several Pleistocene cave sites with vertical openings functioned as natural traps.

Abbreviations used are: LF (Local Fauna); NMMNH (New Mexico Museum of Natural History). The abbreviations for tooth positions in mammals are standard, with upper case letters for upper teeth and lower case letters for lower teeth: I/i (upper/lower incisors), C/c (upper/lower canines), P/p (upper/lower premolars), and M/m (upper/lower molars). All measurements are in millimeters (mm).

Locality

The White Mesa Mine Local Fauna (NMMNH locality L-6112; Fig. 1) was collected from the White Mesa mine, operated by the American Gypsum Company on land belonging to Zia Pueblo, approximately 6 km (~4 mi) southwest of San Ysidro in Sandoval County, north-central New Mexico (35°32′N, 106°48′W). Gypsum from the White Mesa mine is mined from the ~30-m (~100-ft) thick Tonque Arroyo Member of the Middle Jurassic Todilto Formation and is used to manufacture sheetrock or wallboard. During the removal of gypsum with heavy machinery, Pleistocene fossils were discovered in three fissure-fill deposits within a radius of about 15 m (~50 ft) approximately 9–12 m (~30–40 ft) below the present land surface (Fig. 2). These fissures were open to the surface during the late Pleistocene and trapped large mammals. The site has produced articulated or associated skeletal material of five species of mammals, including a horse (*Equus* cf. *E. francisci*), a camel (*Camelops hesternus*), a bison (*Bison antiquus*), a deer (*Odocoileus hemionus*), and a pocket gopher (*Thomomys talpoides*), all of late Pleistocene (Rancholabrean) age.

Fissures and fissure-fill deposits

There were at least 44 fissures within 100 m (~325 ft) of the fossil site (locality NMMNH L-6112), only three of which contained bones, here designated fissures 1, 2, and 3. Fissure 1 contained the largest number of bones, including an articulated skeleton of a bison and an articulated skull, lower jaws, and cervical vertebrae of a camel (Fig. 3). The camel was situated above the bison skeleton in the fissure and was heavily damaged by the milling machine that originally uncovered the bones (Figs. 2, 3). Many postcranial bones of a camel of the same color of preservation and ontogenetic age as the skull and jaws were found on the surface in the vicinity of fissure 1. We are fairly certain most of these bones were originally part of an in-place articulated skeleton, before it was damaged and disassociated by the heavy machinery. Fissure 1 measured 18 cm (~7 in) in width, and the bones were found over a depth of 40–50 cm (16–20 in) within the fissure and over a length of 3.5–4 m (11–13 ft), although the unfossiliferous portion of the fissure extended many meters beyond this in both directions. The fossiliferous portion of fissure 1 was plaster jacketed and removed from the mine intact (Figs. 2, 3). The two skeletons contained in this fissure were prepared in place (i.e., the bones were cleaned but not removed) and will eventually be displayed in the Ice Age Hall at the New Mexico Museum of Natural History. Fissure 2 was located approximately 15 m (~50 ft) northwest of fissure 1 and contained a partial articulated hind limb of a camel and an articulated front limb of a horse. All exposed bones were removed from this fissure. Fissure 2 was 16 cm (~6 in) in width, and the bones were found over a depth of approximately 20–30 cm (8–10 in) and a length of approximately 2 m (~7 ft). Fissure 3 was located 10 m (~33 ft) south of fissure 1 and contained a complete deer skeleton, a partial skeleton of a pocket gopher, and several isolated bones of a small mouse-sized rodent. Besides removing all exposed bones from this fissure, we also collected a small sample of the sediment (several kilograms) for screenwashing. Fissure 3 was 25 cm (10 in) in width, and the fossils were found over a depth of approximately 20–30 cm (8–10 in) and a length of less than 1 m (~3 ft).

The lithology of the fissure fills consists of brecciated fragments of gypsum in a matrix of poorly consolidated, silty, fine- to medium-grained gypsum sandstone with sparse quartz grains. The gypsum fragments are mostly 1–3 cm (0.4–1.2 in) in diameter, but the largest are as much as 10 cm (4 in) or more. The proportion of gypsum breccia to sand varies considerably among the various fissure deposits. The brecciated fragments make up ~25–75% of the fill. Some stratification is evident, with beds that are more or less sandy showing lateral continuity. Fissure 3 had a higher percentage of fine-grained sand than the other two fossil-bearing fissures and was the only fissure that contained small mammals.

The trends and widths of 44 fissures in the White Mesa mine floor at the level of locality L-6112 were measured (Rinehart et al. 2006). All were within a 100-m (~325-ft) radius of the fossil site and had a nearly vertical orientation. Fissure widths range from 1 to 34 cm (0.4 in to 14 in). A few of the narrower fissures are open and unfilled in spots. Many vertical joints and small fissures were evident in the gypsum highwalls of the mine a few hundred meters north and west of L-6112; several of these were 10–25 m (~30–80 ft) tall. It appears that a small amount of extension could open them to the surface. While prospecting for fossils in the Todilto Formation near San Ysidro in 1998, one of the authors (LFR) observed open fissures of unknown depth located approximately 6 km (~4 mi) northwest of L-6112. These fissures were large, steep-sided, funnel-shaped structures whose sides became more vertical at depth.

Obviously, the three fossil-bearing fissures in the White Mesa mine were open to the surface in the late Pleistocene to function as natural traps for the large mammals that became entrapped within them. The portion of the fissures closer to the surface already had been mined away when the bones were discovered by gypsum miners approximately 9–12 m (30–40 ft) below the original ground surface. In our discussions with the miners, they did not recall uncovering bones in the fissures nearer the surface.

Vertebrate paleontology

We review the paleontology of the mammals identified from the White Mesa Mine LF (NMMNH site L-6112). The specimens from the White Mesa mine are curated in the vertebrate paleontology collection of the New Mexico Museum of Natural History (NMMNH); however, the fossils remain the property of Zia Pueblo. Most of the accounts are divided into three sections, referred specimens, description, and remarks. Three of the species are members of the extinct Pleistocene megafauna, *Equus* cf. *E. francisci*, *Camelops hesternus*, and *Bison antiquus*, whereas *Odocoileus hemionus* and *Thomomys talpoides* are living species. A small mouse-sized rodent represents a sixth species in the fauna.

Order Perissodactyla
Family Equidae
Equus cf. *E. francisci* Hay 1915
Stilt-legged horse

Referred specimen—NMMNH 54152, partial front limb from fissure 2, including the distal two-thirds of the humerus, radius-ulna, carpals (scaphoid, lunar, pisiform, magnum, pyramidal, trapezoid, trapezium), metacarpal 3 (including associated sesamoids), lateral metacarpals 2 and 4, and proximal, medial, and ungual (hoof) phalanges.

Description—A nearly complete articulated front limb of an advanced juvenile or possibly a young adult stilt-legged horse *Equus* cf. *E. francisci* was found in fissure 2 (Fig. 4D). No other postcranial elements, teeth, or cranial material of a horse were found in this fissure or disassociated in the immediate vicinity, suggesting that no other parts of this skeleton were preserved. The epiphyses on the distal end of the humerus and both the proximal and distal ends of the radius-ulna are unfused, indicating this specimen was not fully mature; however, all epiphyses on the metacarpal 3 and phalanges are fused. Although this specimen was not fully adult, the fusion of the epiphyses on the metacarpal 3 and phalanges indicates these elements had ceased growing and that the measurements should be accurate. Measurements of the metacarpal 3, proximal phalanx, and medial phalanx of *Equus* cf. *E. francisci* (NMMNH 54152) from the White Mesa mine are presented in Table 1. The elongated and slender metacarpal 3 and proximal phalanx (see Fig. 4D) suggest this specimen belongs to the uncommon stilt-legged horse *Equus francisci*. Our identification is tentative (cf.) because the specimen is not fully mature, and thus we cannot be certain how much the measurements might have changed if the animal had grown to full adulthood.

Remarks—Table 1 compares measurements of the metacarpal of the horse from the White Mesa mine, tentatively referred to *E. francisci*, to measurements of three metacarpals of *E.* cf. *E. francisci* from the Nueces River in Texas (Baskin and Mosqueda 2002) and to a combined sample of about 50 metacarpals of *Equus francisci*

FIGURE 2—Field photographs of fissure fills and in-place fossils at the White Mesa mine. **A**. Fissure 1 (indicated by arrow) as it was first uncovered by the milling machine (pictured at top of photo). Mine workers David Pino and Lambert Pino are standing on either side of milling machine. **B**. Fissure 1 being excavated by NMMNH paleontologist Joshua Smith (top) and David Pino (bottom). Photo shows tools used in excavating fissure (gas-powered rock saw and rock pick in foreground, as well as various smaller rock picks and chisels on right side of fissure) and plaster jacketing technique used to protect and remove fossils from the field. The portion of the fissure at the top of the photo has been plaster jacketed, whereas the portion of the fissure in the foreground is still exposed. **C**. Fissure 1 completely excavated from surrounding gypsum of the Todilto Formation, plaster jacketed, and ready for removal from field. NMMNH paleontologist Justin Spielmann standing behind jacket. **D**. Partial articulated hind limb of *Camelops hesternus* in place in fissure 1, indicated by arrow (width of fissure is 18 cm = 7 in); **E**. Associated skull and lower jaws of *Bison antiquus* in place in fissure 1, indicated by arrow (scale is 10 cm = 4 in).

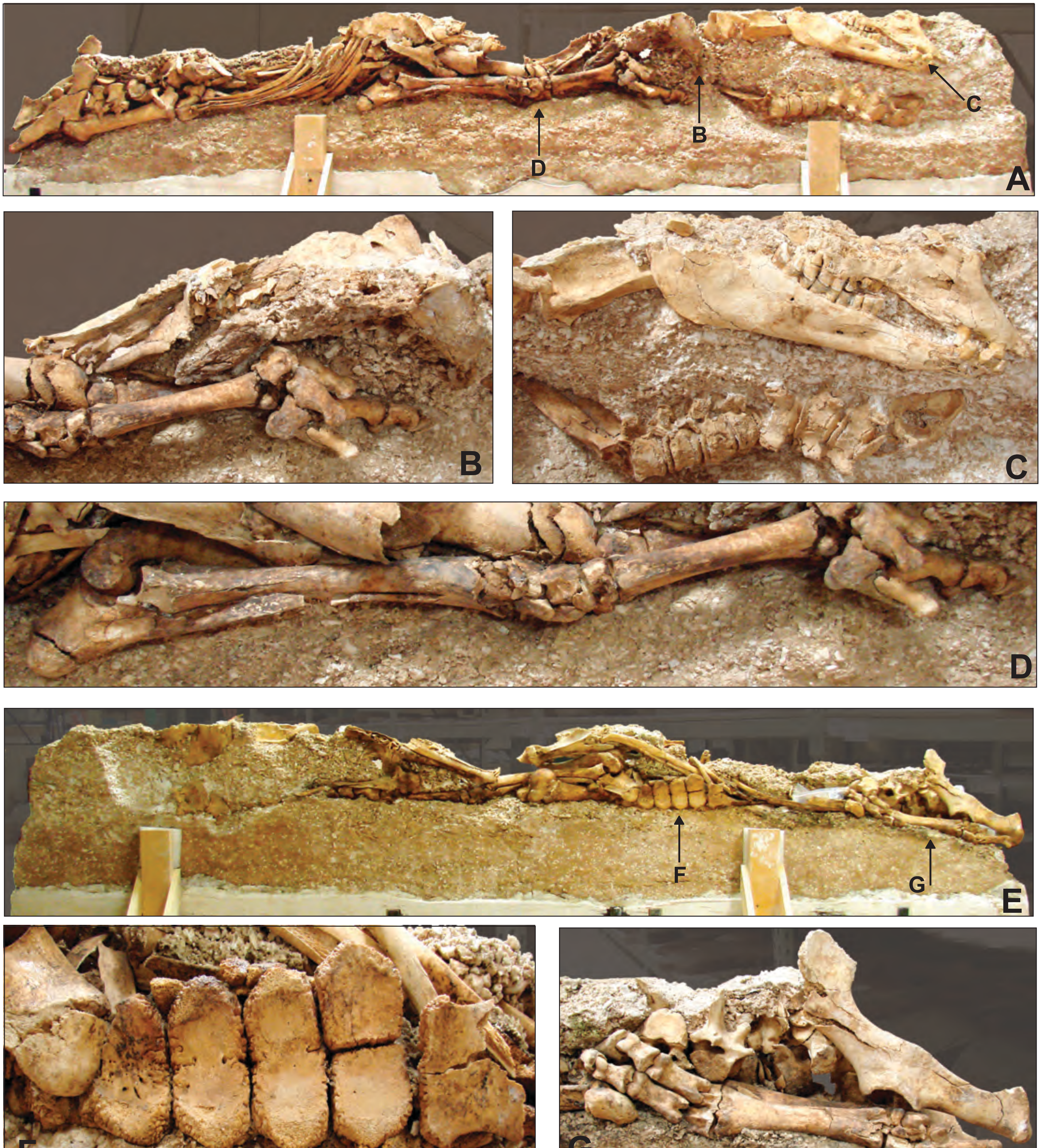

FIGURE 3—Fissure 1 from the White Mesa mine containing a nearly complete skeleton of a juvenile *Bison antiquus* and the associated skull, lower jaws, and cervical vertebrae of *Camelops hesternus*. The fissure fill was plaster jacketed in the field (see Fig. 2), and the skeletons were prepared in place but not removed. **A** and **E** are photos of the completely prepared fissure fill from the south (**A**) and north (**E**); these are the directions the fissure was facing in the field. Fissure fill is 3.0 m in length. The arrows with the smaller letters on **A** and **E** show the approximate position of the enlarged photos of portions of the fissure fill in Figs. 3**B–D**, **F**, and **G**. **B**. Partial skull, horn core, and lower jaws (top of photo) and partial articulated front limb (bottom of photo, metacarpal and phalanges; see more complete photo of this limb in **D**) of *Bison antiquus*. **C**. Partial skull, right lower jaw, and cervical vertebrae of *Camelops hesternus* (top) and articulated cervical and anterior thoracic vertebrae of *Bison antiquus* (bottom). **D**. Articulated front limb of *Bison antiquus* (radius-ulna on left, phalanges on right). **F**. Articulated series of sternebrae of *Bison antiquus.* **G**. Articulated hind limb of *Bison antiquus* (bottom of photo, phalanges on left, calcaneum on right), top of photo shows several lumbar vertebrae and innominate of *Bison antiquus*.

from many sites throughout western North America (Winans 1989). The White Mesa mine metacarpal compares very closely in measurements with the sample from the Nueces River, which is also late Pleistocene in age (Baskin and Mosqueda 2002). The much larger sample from Winans (1989) also encompasses the measurements of the White Mesa specimen; however, her sample has a greater range of variation because she included larger stilt-legged horses from the early Pleistocene (early Irvingtonian) that generally are referred to *E. calobatus* by most other workers. Winans (1989) characterized *Equus francisci* as including all stilt-legged horses having metacarpals with a ratio of length to proximal width greater than 5.0. The metacarpal from the White Mesa mine (NMMNH 54152) is 251 mm in length, and the proximal width is 48.5 mm, giving a ratio of length to proximal width of 5.2, placing this element in *Equus francisci* by Winans' definition. The Nueces River *Equus francisci* sample has a metacarpal ratio of 5.3, and Winans' sample from throughout North America has a ratio of 5.5.

For comparative purposes, Table 1 also includes measurements of the metacarpals and proximal and medial phalanges of the two most common late Pleistocene horses in New Mexico, the small, stout-legged species, *E. conversidens* (referred to *E. alas-*

TABLE 1—Postcranial measurements of *Equus* cf. *E. francisci* from the White Mesa mine compared to measurements of *E.* cf. *E. francisci* from the Rancholabrean Nueces River gravel pits from the Gulf Coastal Plain of Texas (Baskin and Mosqueda 2002), *E. francisci* from a series of North American Irvingtonian and Rancholabrean sites (Winans 1989), and *E. conversidens* and *E. niobrarensis* from Dry Cave in Eddy County, southeastern New Mexico (Harris and Porter 1980). The measurements from Baskin and Mosqueda (2002), Winans (1989), and Harris and Porter (1980) consist of means and observed ranges of samples, not measurements of individual specimens. Measurements represented by "—" indicate that the measurement was not taken.

Element, species, locality, and catalog number	Total length	Proximal width	Proximal depth	Midshaft width	Midshaft depth	Distal width	Distal depth
metacarpal							
Equus francisci							
White Mesa mine NMMNH 54152	251	48.5	32.8	28.9	24.2	42.7	32.4
Nueces River, Texas							
mean of 3 specimens	246.3	46.2	32.1	32.9	25.9	42.9	32.5
observed range	244–249	43.9–48.9	30.9–33.1	31.4–34.6	24.9–26.9	41.5–44.2	30.5–34.9
combined Rancholabrean and Irvingtonian sample[1]							
mean of 49–54 specimens	251.3	45.3	30.68	30.1	25.6	40.3	32.2
observed range	223–313	31.4–53.6	24.0–41.3	24.7–39.4	21.4–32.5	37.4–47.6	27.9–39.3
Equus conversidens							
Dry Cave, New Mexico							
mean of 5 specimens	227.8	46.5	—	31.5	24.1	42.7	—
observed range	217–235	44.1–49.5	—	30.3–32.9	22.6–25.6	39.4–45.8	—
Equus niobrarensis							
Dry Cave, New Mexico							
mean of 6–7 specimens	232.0	53.4	—	35.6	27.2	49.4	—
observed range	221–243	51.9–56.0	—	30.3–32.9	24.7–29.5	46.7–54.5	—
proximal phalanx (=phalanx 1)							
Equus francisci							
White Mesa mine NMMNH 54152	86.4	43.7	29.9	28.0	23.6	38.5	22.4
Equus conversidens							
Dry Cave, New Mexico							
mean of 4 specimens	83.5	45.0	32.9	28.3	—	38.3	—
observed range	81.2–87.2	43.2–48.5	31.5–34.8	27.2–29.4	—	37.0–40.3	—
Equus niobrarensis							
Dry Cave, New Mexico							
mean of 5–7 specimens	87.9	57.4	40.5	35.4	—	47.8	—
observed range	84.9–90.3	55.8–58.7	37.8–44.2	33.1–36.2	—	44.4–50.4	—
medial phalanx (=phalanx 2)							
Equus francisci							
White Mesa mine NMMNH 54152	46.8	42.9	28.2	35.9	21.3	39.9	24.2
Equus conversidens							
Dry Cave, New Mexico							
mean of 5 specimens	43.4	42.5	28.2	36.5	—	38.9	—
observed range	41.5–45.4	40.5–44.8	26.9–29.6	34.5–39.1	—	36.9–42.2	—
Equus niobrarensis							
Dry Cave, New Mexico							
mean of 3 specimens	49.7	51.0	33.4	42.2	—	46.7	—
observed range	49.3–50.3	49.7–51.6	33.0–33.8	41.7–42.6	—	46.0–47.2	—

[1]The combined sample of *Equus francisci* from Winans (1989) includes Irvingtonian specimens of a larger species of stilt-legged horse that some workers have separated as *E. calobatus*. Many specimens at the larger end of the observed range probably pertain to *E. calobatus*.

kae by Winans 1989) and the large, stout-legged species *E. niobrarensis* (referred to *E. laurentius* by Winans 1989). Measurements of these two horses are from late Rancholabrean specimens from Dry Cave in Eddy County in southeastern New Mexico (Harris and Porter 1980). These measurements demonstrate that the White Mesa mine metacarpal is longer than any of the 12 metacarpals of *E. conversidens* and *E. niobrarensis* from Dry Cave, with a proximal width within the range of variation of *E. conversidens* and less than the proximal width of *E. niobrarensis*. The ratio of metacarpal length to proximal width (using the mean of each sample) for the Dry Cave horses are: *E. conversidens*, 4.9; *E. niobrarensis*, 4.3. The metacarpal ratios for *E. conversidens* and *E. niobrarensis* from Dry Cave are both less than 5, indicating that their metacarpals are more robust than in *E. francisci*. The midshaft width of the White Mesa mine metacarpal is narrower than either of the stout-legged species. The metacarpal and proximal phalanx from the White Mesa horse are similar to comparable specimens of *E. francisci* and are more slender and elongated than metacarpals and proximal phalanges of the smaller (*E. conversidens*) and larger (*E. niobrarensis*) stout-legged species. *E. francisci* is rare in New Mexico, with only three other late Pleistocene records, the Balcony Room in Dry Cave and Burnet Cave, both in Eddy County, and Blackwater Draw (=Clovis site) in Roosevelt County (Harris 1993).

Order Artiodactyla
Family Camelidae
Camelops hesternus (Leidy 1873)
Giant llama or Yesterday's camel

Referred Specimens—NMMNH 54156, partial associated skeleton of an old individual from fissure 1, including: partial skull with I3, C, P3?, P4–M3; right and left mandibles with i1–i3, c, p4–m3; two cervical vertebrae; 11 caudal vertebrae; parts of both front limbs, including fragment of distal humerus, fragment of distal radius-ulna, fragments of the metacarpal, right and left scaphoid, right and left lunar, cuneiform, right and left magnum, right and left unciform; and left hind limb with distal femur, tibia, patella, metatarsal, distal fibula, astragalus, calcaneum, cuboid, navicular, entocuneiform, and ectomesocuneiform, and all three pairs of phalanges (two proximal, two medial, and two unguals or hoof cores) and both pairs of associated sesamoids. The metatarsal 3 and 4 and associated phalanges from this specimen are illustrated in Figure 4A.

NMMNH 54157, associated partial left hind limb from fissure 2, including metatarsal, distal fibula, astragalus, calcaneum, cuboid, navicular, entocuneiform, and ectomesocuneiform, and all three pairs of phalanges, and both pairs of associated sesamoids.

NMMNH 54158, found in vicinity of fissure 1, three pairs of associated phalanges.

NMMNH 54159, found in vicinity of fissure 1, three pairs of associated phalanges.

Description—The most complete *Camelops* skeleton (NMMNH 54156) was preserved in fissure 1, directly overlying the juvenile *Bison* skeleton described below. The orientation of the two skeletons in this fissure is shown in Figure 3A. Unfortunately, the *Camelops* skeleton was heavily damaged during the mining process, and only the ventral half of the skull, articulated lower jaws, and two cervical vertebrae were still in place in the fissure. The skull was sheared off dorsal to the toothrows, whereas the underlying articulated mandibles are virtually intact, except they are missing the coronoid and articular processes. Two cervical vertebrae, the axis, and the anterior half of the third cervical are preserved in life position just behind the skull and jaws. The atlas is probably present at the base of the skull; however, that portion of the skull is still covered by gypsiferous matrix. The rest of the postcranial skeleton was recovered as disassociated bones in the immediate vicinity of fissure 1, after the milling machine had passed over the fissure. Remarkably, many of the postcranial bones are fairly intact, in particular the distal end of the femur, tibia, patella, carpals, tarsals, metatarsal, and phalanges. The location of the bones in the immediate vicinity of fissure 1, similar preservation, and lack of duplicate elements strongly indicates that many of the elements disassociated during the mining process were probably from the same skeleton. Two sets of associated phalanges (NMMNH 54158 and 54159) were found in the vicinity of fissure 1 and may be from the front limb of NMMNH 54156, but were not associated with any limb bones. Because we could not confirm an association with NMMNH 54156, we assigned these sets of phalanges separate numbers. A second individual of *Camelops* is represented by a left hind limb consisting of the metatarsal, tarsals, and phalanges from fissure 2 (NMMNH 54157). The hind limb from fissure 1 was also from the left side, confirming the presence of at least two individuals of *C. hesternus* from the White Mesa mine.

The skull, lower jaws, teeth, and postcranial elements of *Camelops* from the White Mesa mine agree closely in morphology and size with the descriptions, illustrations, and measurements in Webb's (1965) monograph on *Camelops hesternus* from the late Pleistocene Rancho La Brea tar pits in southern California. The skull and lower jaws of NMMNH 54156 are still in occlusion (Fig. 3C), so it was not possible to take detailed dental measurements of this specimen. We were only able to measure the anteroposterior length of the teeth from the lateral side and also took several measurements of the dentary. The upper dentition of the White Mesa *Camelops* retains a large I3 (length, 21.9) on the premaxilla and a somewhat smaller canine on the anterior edge of the maxilla (length, 14.9). The I3 and C are separated by a diastema of 27 mm. There is a longer diastema of 99 mm separating C and P4. The upper cheek teeth, consisting of P4–M3, are heavily worn and were somewhat damaged in the mining process, so could not be measured. *Camelops* normally possesses P3 (Webb 1965); however, it is difficult to determine if this tooth was present in the White Mesa skull because of damage to the anterior toothrow. The lower teeth in the right dentary include the i1 and i3 (an i2 alveolus is present but the tooth is missing from this specimen), canine, and p4–m3. There is no p3 in the White Mesa mine mandible, which is typical of *Camelops*. We took the following measurements of the lower dentition and dentary of NMMNH 54156 (the individual tooth measurements are all anteroposterior lengths): c1, 23.2; p4, 22.6; m1, 27.2; m2, 33.1; m3, 56.7; occlusal length p4–m3, 134.3; total length of dentary from symphysis to posterior edge of ascending ramus, 447; length of mandibular symphysis, 121.2; length of lower diastema from c1 to p4, 97.2; depth of dentary below anterior edge of p4, 51.7. Most of these measurements are within or slightly below the range of variation observed in a sample of five skulls and jaws of *C. hesternus* from Rancho La Brea (Webb 1965). The heavily worn condition of the teeth in the White Mesa mine specimen probably accounts for their slightly smaller size compared to the Rancho La Brea sample. The cheek teeth in most hypsodont ungulates tend to be narrower at the base of the crown than in unworn or lightly worn teeth.

Measurements of two metatarsals and eight proximal phalanges from the White Mesa mine are provided in Table 2. These measurements are compared to the same two elements from a complete mounted skeleton of *Camelops hesternus* from the Universal Constructor's gravel pit in Albuquerque (NMMNH 27233) and a sample of this species from Rancho La Brea (Webb 1965). Because the bones of NMMNH 27233 are articulated it was difficult to obtain precise measurements, and thus the measurements in Table 2 should be regarded as ± 5% of the actual value. Furthermore, NMMNH 27233 is a juvenile individual with deciduous premolars and unfused ephiphyses on all limb bones and phalanges, including the distal ends of metatarsals 3 and 4 and the proximal ends of the proximal phalanges on digits 3 and 4. The measurements of these specimens should be considered minimum values and would certainly have been larger had the individual grown to adult size. The total length of the juvenile *C. hesternus* metatarsal from Albuquerque is 385 mm, which places it between the length of the two complete adult metatarsals from the White Mesa mine (383 and 389), and within the range of variation of the Rancho La Brea samples (357–388). The total length of the

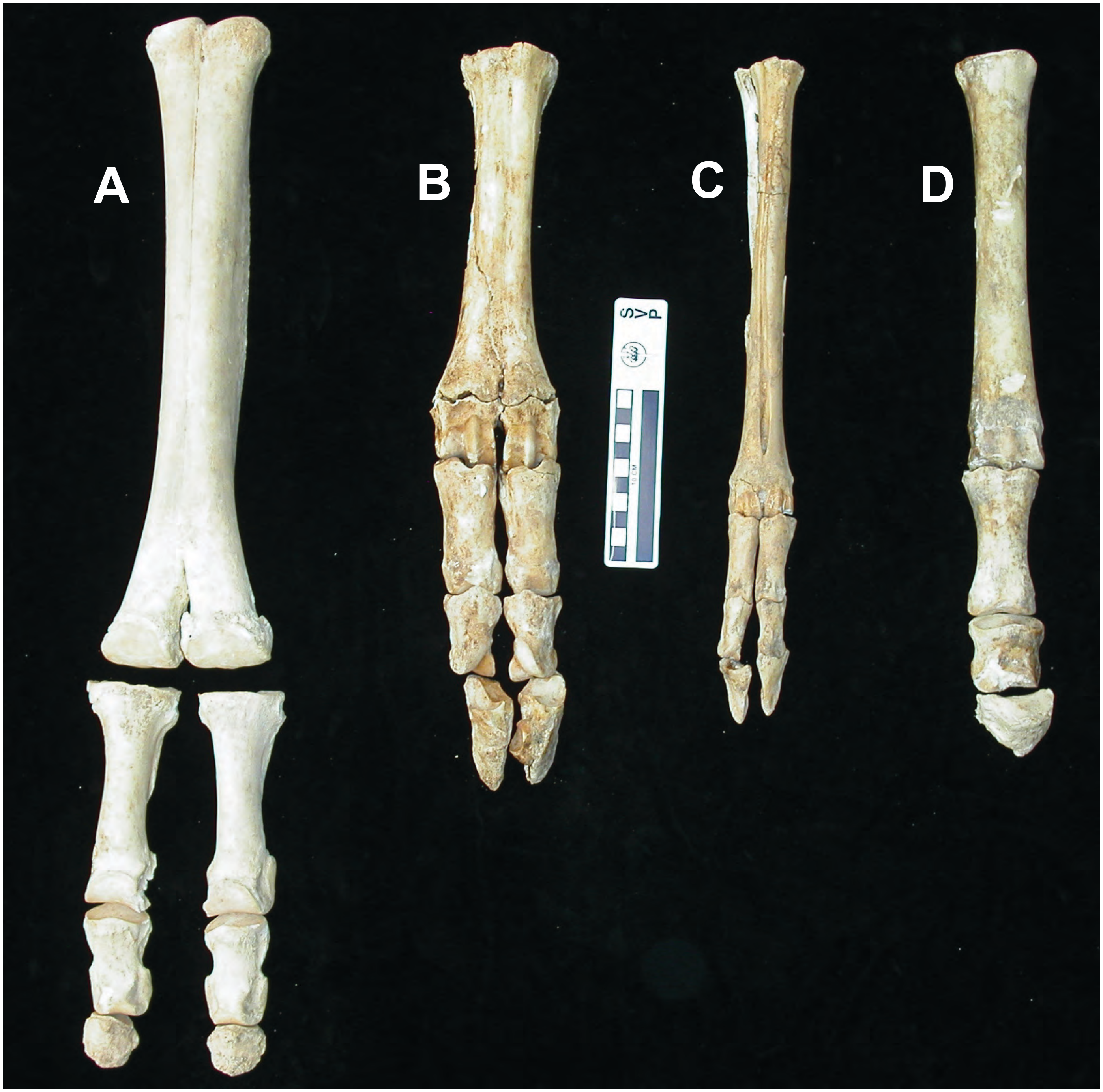

FIGURE 4—Articulated metapodials and phalanges of camel, bison, deer, and horse from the White Mesa mine. **A**. *Camelops hesternus*, metatarsal and phalanges (NMMNH 54156); **B**. *Bison antiquus*, metatarsal and phalanges (NMMNH 54154); **C**. *Odocoileus hemionus*, metatarsal and phalanges (NMMNH 54153); **D**. *Equus* cf. *E. francisci*, metacarpal and phalanges (NMMNH 54152). Scale is 10 cm (= 4 in).

proximal phalanges from the Albuquerque skeleton also compares well with proximal phalanges from White Mesa mine and Rancho La Brea. The lengths of the proximal phalanges from digit 3 (111.6) and digit 4 (115.3) of the left hind limb of the Albuquerque skeleton (NMMNH 27233) are very similar to the length of digit 3 (111.5) and digit 4 (114.8) of the left hind limb of NMMNH 54157 from the White Mesa mine. The width and depth measurements of the juvenile metatarsal and proximal phalanges from Albuquerque are somewhat less than comparable measurements from the White Mesa and Rancho La Brea samples, which could easily be explained by the fact that this individual was not an adult. On the basis of the overall similarity of the White Mesa camel with the sample from Rancho La Brea and the skeleton from Albuquerque, we confidently refer the White Mesa sample to *C. hesternus*.

Remarks—One of the more notable characters of the *Camelops* skeleton from fissure 1 (NMMNH 54156) is the extreme ontogenetic age of this individual. All of its teeth are very heavily worn. The fourth premolars (P4/p4) and first molars (M1/m1) are worn down almost to the base of the crown, particularly the upper teeth (Fig. 3C). Another indication that this skeleton represents a geriatric individual is the presence of exostoses or abnormal bone growths near the articular surfaces on several of the metapodials and toes, indicative of osteoarthritis, a typical malady of old age. Exostoses are particularly evident on the distal articular surface of the metatarsal and proximal articular surface of the proximal phalanx

TABLE 2—Measurements of metatarsals and proximal phalanges of *Camelops hesternus* from the White Mesa mine compared to measurements of these same elements in *Camelops hesternu*s from two other Rancholabrean sites, the Universal Constructor's gravel pit, Albuquerque, Bernalillo County, New Mexico, and Rancho La Brea, southern California (from Webb 1965). The measurements from Rancho La Brea are means and observed ranges for a sample of 5–7 specimens, not measurements of individual fossils. Measurements represented by "—" indicate that either the specimen was damaged or the measurement was not taken.

Element, locality, and catalog number	Total length	Proximal width	Proximal depth	Midshaft width	Midshaft depth	Distal width	Distal depth
metatarsal							
White Mesa mine							
NMMNH 54156	383	76.1	55.9	42.1	44.1	44.0 (mt3) 46.6 (mt4)	42.7 (mt3) 43.5 (mt4)
NMMNH 54157	389	80.7	58.5	48.8	—	44.3 (mt3) 43.5 (mt4)	43.3 (mt3) 44.6 (mt4)
Universal Constructor's[1]							
NMMNH 27233	385	68.2	50.4	37.7	42.0	39.1 (mt3) 36.7 (mt4)	41.3 (mt3) 40.0 (mt4)
Rancho La Brea							
mean of 5–7 specimens	375.9	78.3	56.7	45.0	42.9	44.3 (mt3) 44.7 (mt4)	44.3 (mt3) 45.4 (mt4)
observed range	357–388	74–89	53–59	40–49	39–51	41–50 (mt3) 42–56 (mt4)	43–47 (mt3) 42–50 (mt4)
proximal phalanx							
White Mesa mine[2]							
NMMNH 54156 (digit 3, hind)	126.6	53.4	—	24.1	27.5	—	31.6
NMMNH 54156 (digit 4, hind)	125.8	49.1	40.7	23.8	27.4	39.8	32.2
NMMNH 54157 (digit 3, hind)	111.5	45.3	38.1	24.6	25.3	37.3	30.6
NMMNH 54157 (digit 4, hind)	114.8	46.7	—	24.2	25.1	37.8	31.9
NMMNH 54158	110.3	44.9	36.4	21.3	24.2	36.0	27.8
NMMNH 54158	109.5	47.2	36.3	21.7	24.2	36.0	27.8
NMMNH 54159	108.2	45.4	34.6	22.9	23.3	39.3	28.5
NMMNH 54159	110.5	47.4	34.9	21.2	24.2	35.6	28.3
Universal Constructor's[1]							
NMMNH 27233 (digit 3, hind)	111.6	37.5	36.1	19.6	21.9	29.7	28.2
NMMNH 27233 (digit 4, hind)	115.3	37.4	37.6	19.9	22.5	30.7	27.4
Rancho La Brea							
front limb[3]							
mean of 9 specimens	108.4	45.2	38.7	—	—	36.6	31.1
observed range	103–114	42–51	36–43	—	—	34–42	29–34
hind limb[3]							
mean of 7 specimens	122.3	47.3	38.9	—	—	39.9	33.9
observed range	117–127	44–52	36–45	—	—	38–42	32–37

[1]NMMNH 27233 from the Universal Constructor's gravel pit in Albuquerque consists of a mounted skeleton on display. Because the bones are articulated it was difficult to obtain precise measurements. These measurements, although taken as carefully as possible, should be viewed as ±5% of the actual value. Furthermore, NMMNH 27233 is a juvenile individual, and thus these measurements should be considered minimum values.

[2]All eight specimens of proximal and medial phalanges from the White Mesa mine were collected as associated pairs. The associated specimens have the same catalog number. The phalanges are associated with a left metatarsal for specimens NMMNH 54156 and 54157. Thus, we know the toes are from the hind limb (designated "hind") and can also determine to which digit (3 or 4) the phalanges belong. For specimens NMMNH 54158 and 54159, it is not possible to determine whether the phalanges are from the front or hind limb nor to which digit they correspond.

[3]Webb (1965) divided the proximal phalanges from Rancho La Brea into front and hind limbs. Although his measurements show that the proximal phalanges of the hind limb are longer than those of the front limb (with no overlap in their observed ranges), he states just the opposite in the text (Webb 1965, p. 32). Several associated skeletons of *Camelops*, including the specimen from the Universal Constructor's gravel pit, confirm that the proximal phalanges of the front limb generally are somewhat longer than those of the hind limb. If this is true of the Rancho La Brea sample, then the measurements in Webb's tables 10 and 12 may have been transposed. Furthermore, most fossils from Rancho La Brea are disassociated, and thus it is unclear how Webb differentiated the proximal phalanges from the front and hind limbs as they are nearly identical except for size.

of NMMNH 54156 (Fig. 5C). The proximal and medial phalanges of NMMNH 54159 are also arthritic (Fig. 5D), which suggests these toes may also belong to NMMNH 54156, although as noted above we gave them separate numbers because we could not confirm a direct association.

Another interesting osteological feature of NMMNH 54156 is the presence of a spiral or "green" fracture on the distal end of the femur (Figs. 5A, 5B). The spiral break, indicated by a strongly curved surface, provides evidence that the break occurred while the animal was still alive and the bone was fresh. Breaks in dry or mineralized bone tend to be horizontal or straight, not curved. The camel apparently suffered a compound fracture of the femur when it fell in the fissure. The lack of healing or restructuring of the bone around the edges of the break suggests that the camel did not survive the fall that caused the break. The proximal two-thirds of the femur is not present and apparently became separated from the rest of the femur in the late Pleistocene at the point of the fracture.

The camel from the White Mesa mine is the second articulated skeleton of *Camelops hesternus* reported from the late Pleistocene of New Mexico. The first skeleton discovered was mentioned above (NMMNH 27233), a 95% complete juvenile individual found as an articulated skeleton in 1979 in the Universal Constructor's gravel pit in Albuquerque, Bernalillo County (Kues 1982; O'Neill and Rigby 1982; Morgan and Lucas 2000, 2005). The Albuquerque skeleton is mounted and on display in the Ice Age Hall at the NMMNH. Ironically, the two known skeletons of *Camelops* from New Mexico represent individuals of entirely different ontogenetic ages. The White Mesa mine camel is a geriatric individual with heavily worn teeth and evidence of osteoarthritis on several bones, whereas the camel from the Albuquerque gravel pit is a juvenile individual with deciduous teeth and unfused epiphyses on most

FIGURE 5—Bones of *Camelops hesternus* from the White Mesa mine showing evidence of paleopathology. **A, B**, Distal end of femur (NMMNH 54156) with a spiral or "green" fracture, indicated by arrow in Fig. 5A; spiral fracture enlarged in **B**. **C**. Associated distal end of metatarsal and proximal ends of proximal phalanges (NMMNH 54156), arrows point to exostoses showing evidence of osteoarthritis. **D**. Associated proximal and medial phalanges (NMMNH 54159), arrows point to exostoses showing evidence of osteoarthritis. All scales are 10 cm (= 4 in).

limb bones, phalanges, and vertebrae. *C. hesternus* is one of the most common large mammals in New Mexico late Pleistocene faunas, with about 30 records distributed throughout the state (Harris 1993; Morgan and Lucas 2005).

Family Bovidae
Bison antiquus Leidy 1852
Ancient bison

Referred specimens—NMMNH 54154, nearly complete juvenile skeleton from fissure 1.

NMMNH 54155, isolated elements from a very young juvenile individual, including the distal end of a metapodial, two partial proximal phalanges, and two ungual phalanges.

Description—Two juvenile individuals of the extinct bison *Bison antiquus* were collected from the White Mesa mine. One specimen consists of a distal metapodial and four associated phalanges of a very young juvenile bison (NMMNH 54155). The second bison, a nearly complete articulated skeleton of an older juvenile from fissure 1 (NMMNH 54154), is the most intact specimen from the White Mesa mine. Most of this skeleton has been prepared in place in the fissure fill in which it was found (Figs. 3A, E), and will eventually be displayed in the Ice Age Hall at the NMMNH. To reduce the size of the field jacket containing the bones from fissure 1, which weighed over a metric ton, we removed the articulated left hind limb from the bison skeleton, including all elements from the femur to the hoof cores (ungual phalanges), as well as the caudal vertebrae. This limb was extended straight out behind the body and would have required the already large jacket to be at least a meter longer. The metatarsal and phalanges from this limb are illustrated in Figure 4B. The partial skull, lower jaws, most of the vertebral column and ribs, sternebrae, both front limbs, and right hind limb are still preserved in the semi-articulated condition in which they were found in fissure 1 (Figs. 3A–G). The partial skull, with the left horn core, premaxillae, and left maxilla, is still in semi-occlusion with the left lower jaw and the anterior portion of the right jaw. The dentition in the left dentary, anterior portion of the right dentary, and left maxilla are still intact. The top of the skull, right horn core, right maxilla, and posterior half of the right dentary were damaged by heavy machinery. We were able to salvage both the upper and lower molars (M1/m1–M3/m3) from the right side. The articulated cervical and anterior thoracic vertebrae (t1–4; Fig. 3C) are separated from the skull by a distance of approximately 30 cm (~12 in). Most of the remaining thoracic and lumbar vertebrae are present near their correct anatomical position but are somewhat jumbled. Many intact ribs are preserved, as is the articulated series of sternal elements (Fig. 3F). The right and left front limbs and right hind limb are complete and articulated (Figs. 3D, 3G) but are preserved in unnatural poses that probably resulted from the skeleton becoming lodged in a very narrow fissure after partial decomposition (see more detailed discussion below under **Taphonomy**).

The presence of deciduous premolars in the lower jaws (dp2–dp4), unerupted M3/m3s, and unfused epiphyses on all major limb bones, metapodials, and vertebral centra confirms that this skeleton is from a juvenile individual. Note the unfused epiphyses on the distal ends of metatarsals 3 and 4 in Figures 3G and 4B. We have not provided postcranial measurements of the juvenile limb bones because they would not be comparable with other published measurements, most of which are from adult individuals. Measurements of the right upper and lower molars of NMMNH 54154 are presented in Table 3. The M1/m1 are fully erupted and have undergone minimal wear on all occlusal surfaces, the M2/m2 are just barely erupted and worn only on the anterior crests, and the M3/m3 are unerupted and unworn. The M3 was damaged and could not be measured. Although the m3 is complete, the enamel is very thin so the measurements should be considered minimum values.

The left horn core of the bison from the White Mesa mine is crushed and distorted (Fig. 3B). The horn core is about 180 mm in length along the dorsal surface, which would approximate the length along the upper curve, a standard measurement for bison horn cores (McDonald 1981). Even taking into consideration that the specimen is a juvenile, the horn core is much smaller than would be expected in a juvenile giant bison *Bison latifrons*. The length of the horn core along the upper curve for *B. antiquus* ranges from 150 to 400 mm (McDonald 1981), which includes the length of White Mesa horn core (180 mm) at the small end of the size range. The comparatively small horn core is not unexpected considering the White Mesa bison is a juvenile. Based on the size of the horn core and the late Rancholabrean age of the White Mesa mine fauna, we refer this skeleton to *B. antiquus*. Although other authors have synonymized *B. antiquus* with the living *Bison bison* (e.g., Kurtén and Anderson 1980; FAUNMAP 1994), we follow McDonald (1981) who recognized *B. antiquus* as a distinct late Pleistocene and early Holocene species in his monographic review of North American *Bison*. McDonald regarded the extant *B. bison* as a late Holocene (younger than 5,000 yrs B.P.) species with smaller horn cores.

TABLE 3—Measurements of the right upper and lower molars of a juvenile *Bison antiquus* (NMMNH 54154) from the late Pleistocene White Mesa mine. The length is the maximum anteroposterior length, width is the maximum tranverse width, and height is the maximum crown height measured on the lingual surface. M3 is broken and could not be measured; m3 was unerupted but intact.

Tooth	Length	Width	Height
M1	36.7	21.0	48.6
M2	39.6	22.8	57.7
m1	33.1	16.7	47.1
m2	41.2	17.9	61.3
m3	54.7	19.7	42.5

Remarks—The majority of bison records from late Pleistocene deposits in New Mexico and elsewhere in the western United States pertain to *Bison antiquus* (McDonald 1981; Harris 1993; Morgan and Lucas 2005). There are 45 records of *Bison* from Rancholabrean sites in New Mexico, most of which have been identified only to genus because they lack the diagnostic horn cores. Only two of these records are clearly *B. latifrons*. We suspect that most of the remaining records are *B. antiquus*. Most fossils identifiable as *B. antiquus* are from latest Pleistocene sites, either cave deposits or Paleoindian sites (e.g., Blackwater Draw = Clovis site, Folsom, Sandia Cave). The radiocarbon date of 12,910 ± 60 ^{14}C yrs B.P. from the White Mesa mine confirms a latest Pleistocene age for this site.

Family Cervidae
Odocoileus hemionus (Rafinesque 1817)
Mule deer

Referred specimen—NMMNH 54153, partial skeleton of female from fissure 3, including right and left maxillae, partial frontals and parietals, petrosal, complete right mandible, partial left mandible, one posterior cervical and four anterior thoracic vertebrae, many partial ribs, left scapula, right and left humerus, right radius-ulna, proximal metacarpal, scaphoid, pisiform, cuneiform, unciform, trapezoid, right distal femur, right proximal tibia, right metatarsal, astragalus, cubonavicular, and associated proximal, medial, and distal (= ungual) phalanges.

Description—A nearly complete skeleton of a female mule deer (*Odocoileus hemionus*) was preserved in fissure 3; however, we were not able to collect the entire specimen. Much of the skull, vertebral column, and parts of the front and hind limbs were destroyed by heavy machinery. The top of the skull above the orbits, including parts of the right and left frontals and anterior parietals, is preserved, and there is no evidence of antlers or antler bases, thus the specimen is a female. Most female cervids, including *Odocoileus hemionus*, lack antlers. The specimen is a young adult. All permanent teeth are present with the M3/m3 fully erupted and lightly worn. However, the epiphyseal lines on the proximal ends of the humeri and on the vertebral centra are still apparent, and thus were not completely fused. The metatarsal and phalanges of this specimen are illustrated in Figure 4C.

With the obvious exception that it lacks antlers, the White Mesa deer skeleton compares closely in most respects with a modern skeleton of an adult male *Odocoileus hemionus* from the Rio Chama Wilderness in northern New Mexico (NMMNH mammalogy collection, specimen 1076). Table 4 provides measurements of the upper and lower dentition of the White Mesa deer and modern *O. hemionus*, and Table 5 provides comparative measurements of several postcranial elements from these same two skeletons. The limb bones of the modern and Pleistocene specimens are very similar in size; however, the teeth of the fossil deer are uniformly larger. The fossils are from a young adult female, whereas the comparative skeleton is a full adult male with well-worn teeth and four-point antlers. Male cervids are almost always larger than females. We suspect that a larger sample of *O. hemionus* from New Mexico would include larger individuals with teeth similar in size to the White Mesa deer.

TABLE 4—Measurements of the upper and lower dentition of late Pleistocene *Odocoileus hemionus* from the White Mesa mine (NMMNH 54153) compared to a recent specimen of *O. hemionus* from New Mexico (NMMNH mammalogy 1076). The length is the maximum anteroposterior length, and the width is the maximum tranverse width.

Tooth and locality	Length	Width
P2		
White Mesa	13.3	12.9
Recent, NM	12.2	10.1
P3		
White Mesa	14.2	15.6
Recent, NM	11.6	11.9
P4		
White Mesa	13.8	13.8
Recent, NM	11.4	12.5
M1		
White Mesa	20.2	16.1
Recent, NM	15.7	14.3
M2		
White Mesa	21.5	17.3
Recent, NM	17.0	16.5
M3		
White Mesa	19.1	16.2
Recent, NM	16.3	14.8
p2		
White Mesa	10.6	6.7
Recent, NM	10.9	5.5
p3		
White Mesa	14.7	9.0
Recent, NM	12.5	8.0
p4		
White Mesa	17.5	9.8
Recent, NM	14.1	8.1
m1		
White Mesa	19.5	11.3
Recent, NM	14.8	10.0
m2		
White Mesa	21.6	12.0
Recent, NM	17.4	10.2
m3		
White Mesa	25.6	10.9
Recent, NM	21.9	10.1

Remarks—There are fewer than 10 Pleistocene records of *Odocoileus hemionus* from New Mexico, most of which are from caves (Harris 1993). *O. hemionus* is currently one of the most common and widespread large mammals in New Mexico, with many records from the western two-thirds of the state, including the area around the White Mesa mine in Sandoval County (Findley et al. 1975). Mule deer are browsers on oak, juniper, pine, fir, and other coniferous and deciduous trees and shrubs (Findley et al. 1975), suggesting that there were some forested areas near the White Mesa fissures in the late Pleistocene. The other three species of large mammals from the White Mesa mine fauna are grazers.

Order Rodentia
Family Geomyidae
Thomomys talpoides (Richardson 1828)
Northern pocket gopher

Referred specimen—NMMNH 54160, partial associated skeleton from fissure 3, including palate with right and left P4–M3, left mandible with i1, p4–m3, two caudal vertebrae, proximal end of ulna, metacarpal, proximal end of femur, metatarsal, proximal phalanx, and ungual phalanx.

Description—A partial skeleton of a small pocket gopher was discovered in fissure 3 in association with the *Odocoileus hemionus* skeleton. This specimen is referable to *Thomomys* rather than the other common genus of pocket gopher in New Mexico, *Geomys*, based on the "pear-shaped" upper and lower molars. The M1 and M2 of *Thomomys* are rounded lingually and pointed labially, whereas the lower m1 and m2 are just the opposite, pointed lingually and rounded labially. The upper and lower molars of *Geomys* are elliptical in shape and are not pointed. Furthermore, the posterior edge of P4 and anterior edge of m1–m3 lack enamel in *Geomys*, whereas these surfaces have enamel in *Thomomys* and the fossils.

There are two common extant species of *Thomomys* in New Mexico, *T. bottae* and *T. talpoides*. There are several dental differences between these two species that can also be observed in the fossils from the White Mesa mine. On the M1 and M2 of *T. talpoides* and the fossil, the enamel band on the anterior edge of the teeth is concave anterolingually, whereas the enamel on the posterior edge is broadly convex. In *T. bottae*, the lingual portion of M1/M2 is concave on both the anterior and posterior surfaces, giving the teeth a narrower and more pointed or pinched appearance than in *T. talpoides* and the fossils. The M3 in *T. talpoides* and the fossil is more elongated anteroposteriorly (longer than wide) than *T. bottae,* in which this tooth is essentially round. The anterior loph (protolophid) of p4 in *T. talpoides* and the fossil lacks enamel and is noticeably smaller than the posterior loph (metalophid). The p4 in *T. bottae* has a thin band of enamel on the lingual surface of protolophid, which is longer than the metalophid. The labial margins of m1 and m2 of *T. talpoides* and the fossil lack enamel and are flattened or slightly convex, whereas there is a distinct concave lingual indentation on the labial edges of m1 and m2 in *T. bottae*. A third species of *Thomomys*, *T. umbrinus*, occurs in the Animas Mountains in Hidalgo County in the extreme southwestern corner of New Mexico (Findley et al. 1975). The dental morphology of *T. umbrinus*, in particular the shape of the upper and lower molars, is similar to that of *T. bottae* and differs from *T. talpoides* and the fossil. The small size and overall morphology of the upper and lower cheek teeth of the pocket gopher from the White Mesa mine are similar to *T. talpoides* in all of the characters described above, and the fossil (NMMNH 54160) is referred to that species.

Remarks—*Thomomys talpoides* presently occurs in meadows and parklands in coniferous forests at higher elevations in the northern mountains of New Mexico, including the Jemez, Sangre de Cristo, and San Juan ranges, whereas *T. bottae* is abundant and widespread throughout the western two-thirds of the state in a variety of habitats at lower elevations (Findley et al. 1975). The fossil record reveals that *T. talpoides* was more widespread in New Mexico during the late Pleistocene. Harris (1993) reported *T. talpoides* from several late Pleistocene cave deposits in mountain ranges in the southeastern part of the state where this species no longer occurs, including Pendejo Cave at the southern end of the

TABLE 5—Measurements of the humerus, radius-ulna, and metatarsal of late Pleistocene *Odocoileus hemionus* from the White Mesa mine (NMMNH 54153) compared to a modern specimen of mule deer from New Mexico (NMMNH 1076 mammalogy).

Element and locality	Total length	Proximal width	Proximal depth	Midshaft width	Midshaft depth	Distal width	Distal depth
humerus							
White Mesa mine	235	56.4	69.4	22.6	28.4	44.4	43.6
Recent, New Mexico	238	52.5	64.9	22.9	27.7	44.5	38.6
radius-ulna							
White Mesa mine	249	45.3	24.7	26.2	17.2	39.6	29.9
Recent, New Mexico	247	42.1	23.9	25.1	14.3	40.1	28.1
metatarsal							
White Mesa mine	267	33.7	—	20.3	21.6	37.1	26.5
Recent, New Mexico	276	28.7	32.2	17.1	20.1	33.9	22.4

Sacramento Mountains in Otero County and Algerita Blossom Cave, Dark Canyon Cave, and Dry Cave in the Guadalupe Mountains in Eddy County. The only other published Pleistocene record of *T. talpoides* from the state is Sheep Camp Shelter from the Chaco Canyon area in southeastern San Juan County, where this pocket gopher also no longer lives. *T. talpoides* is not currently found in the vicinity of White Mesa, which at an elevation of almost exactly 6,000 ft (1,830 m), supports a piñon-juniper woodland that provides a more suitable habitat for the widespread and ecologically tolerant *T. bottae*. However, *T. talpoides* occurs in the Jemez Mountains in Sandoval County approximately 40 km (25 mi) north of the fossil site, but approximately 2,000–3,000 ft (~600–900 m) higher in elevation. The late Pleistocene occurrence of *T. talpoides* in New Mexico reflects the distribution of many other small mammals in which species now confined to montane coniferous forests in the northern mountain ranges occurred much farther south and at lower elevations. It has been hypothesized that the more widespread occurrence of these montane mammals was associated with the expansion of their preferred coniferous forest habitats during the late Pleistocene caused by cooler temperatures and greater available moisture at that time (Harris 1985).

RODENTIA, family, genus, and species indeterminant

Referred specimen—NMMNH 54161, distal end of tibia-fibula.

Remarks—The screenwashed concentrate from fissure 3 contained the distal end of a tibia-fibula (NMMNH 54161) that is much smaller than *Thomomys talpoides* and has a different morphology. This specimen is not complete enough to allow an identification of this species to the family level or below, although it does establish the existence of at least one other small rodent in the fauna. Because of the unusual field conditions at the White Mesa mine, we could only wash a small sample of sediment, but we suspect that a larger fauna of small mammals was present, particularly in fissure 3.

Discussion

New Mexico has produced a wealth of Pleistocene vertebrates, with more than 200 known localities from both caves and open or stratified sites (Harris 1993, 2005; Morgan and Lucas 2005). Fissure deposits containing Pleistocene vertebrate fossils are extremely rare in New Mexico. Articulated skeletons (bones in life position) and associated skeletons (bones from one individual but not articulated) are uncommon in New Mexico Pleistocene fossil sites, whether in caves or open sites derived from alluvial, fluvial, or lacustrine deposits. Most New Mexico Pleistocene sites contain isolated fossils, such as partial jaws, isolated teeth, limb bones, toe bones, vertebrae, etc. Articulated skeletons of large Pleistocene mammals are found more often in open sites than in caves in New Mexico, including: a 95% intact articulated juvenile *Camelops hesternus* skeleton from a gravel pit in Albuquerque (Kues 1982; O'Neill and Rigby 1982; Morgan and Lucas 2000); a 75% complete articulated skeleton of the large extinct horse *Equus niobrarensis* from the Jemez Springs site in Sandoval County (Morgan and Lucas 2005); partial skeletons of at least five individuals of the Columbian mammoth *Mammuthus columbi* from the Blackwater Draw (=Clovis) site near Portales in Roosevelt County (Lundelius 1972); a 25% complete associated skeleton of *M. columbi* from the Dry Gulch site near Nogal in the Sacramento Mountains in Lincoln County (Leach et al. 1999); and the front half of an articulated skeleton of the flat-headed peccary *Platygonus compressus* from Navajo Lake in McKinley County (Lucas and Smartt 1995). The best known example of an articulated skeleton from a New Mexico Pleistocene cave deposit is the partially mummified complete skeleton of the Shasta ground sloth *Nothrotheriops shastensis* from Aden crater west of Las Cruces in Doña Ana County (Lull 1929). Aden crater is a vertical lava cave that functioned as a natural trap. The sloth fell through a vertical opening to the cave floor some 30 m (~100 ft) below the entrance. Among New Mexico Pleistocene sites, Aden crater is perhaps the most functionally similar to the fissures at White Mesa mine, although the geological conditions are totally different. Several late Pleistocene caves in the Guadalupe Mountains in Eddy County in southeastern New Mexico, including Dry Cave and Muskox Cave, have vertical openings that served as natural traps for large mammals (Logan 1981; Harris 1985).

Age

We submitted a fragment of a metacarpal from the associated *Camelops hesternus* skeleton (NMMNH 54156) in fissure 1 at the White Mesa mine to Beta Analytic, Inc. in Miami, Florida, for radiocarbon (^{14}C) dating. All radiocarbon dates on bones processed by Beta Analytic are now done using AMS (accelerator mass spectrometry) on bone collagen, which is highly accurate and can be performed on very small samples. The camel metacarpal produced an AMS radiocarbon date of 12,910 ± 60 ^{14}C yrs B.P. (Beta-223635). The skeletons of the camel, horse, bison, and deer were all deposited at about the same level in the three fissures, which were located in proximity to one another (within 15 m = 50 ft or less), and thus it seems very likely that these fossils are all about the same age. The overall condition of the bones from the White Mesa mine is excellent, and they appear to have undergone little if any mineralization. Apparently, the bones were covered with sediment shortly after the death of the animals and have been deeply buried since the late Pleistocene, before their discovery in 2005.

Taphonomy

One of the most interesting aspects of the White Mesa mine fauna is determining how the large mammal skeletons became trapped in extremely narrow fissures, eventually resulting in their preservation as fossils. Taphonomy is the study of the biological and geological processes involved in the formation of fossil sites, in other words, the processes that affect a fossil between the death of the organism and its eventual burial and preservation. In the case of the White Mesa mine—what led to the transformation of a living community of large mammals in the late Pleistocene to a series of skeletons literally squeezed into narrow fissures far below the present land surface? Several features of the skeletons provide important clues relating to the taphonomy of this intriguing fossil site. Most importantly, almost all of the fossils preserved in the fissures consist of partial to nearly complete articulated skeletons. The site contains essentially no isolated or unassociated fossils of large mammals. The largest fissure (fissure 1) contained a nearly complete (about 95%) *Bison antiquus* skeleton. The bison skeleton was overlain by a partial (about 30% complete) *Camelops hesternus* skeleton. The camel skeleton was seriously damaged by heavy machinery, and thus it is difficult to determine how much more of the skeleton was originally present but destroyed. Some of the skeletal elements of the camel, found disassociated on the surface in the immediate vicinity of the fissure, were virtually intact. However, there were also literally hundreds of unidentifiable fragments of bone that could well represent much of the remainder of the skeleton.

Fissure 2 contained articulated limbs of two different species of large mammals, a partial hind limb of *Camelops hesternus* and a partial front limb of *Equus* cf. *E. francisci.* We cannot be certain of the completeness of the skeletons in fissure 2 before their being uncovered during the mining process. However, we found no disassociated bones or teeth of horses or camels in the vicinity of fissure 2, which leads us to believe that this fissure probably did contain just these two isolated limbs. Fissure 3 contained a partial articulated skeleton of a female mule deer *Odocoileus hemionus* that was probably almost 100% complete before it was damaged during the mining process. Because the sediment in this third fissure was finer grained and contained less gypsum breccia than the main fissure, we screenwashed a small sample of the sediment. This screenwash sample produced a partial skeleton of the small pocket gopher *Thomomys talpoides* and an isolated partial limb bone of a much smaller rodent.

Articulated skeletons of large vertebrates are rare in fossil sites because many biological (predators, scavengers, decomposition) and geological (erosion, weathering) processes begin acting upon the carcass of an animal immediately following its death. These processes typically cause a skeleton to become disassociated or totally destroyed before it can be covered by sediment and eventually preserved as a fossil. For a skeleton to remain essentially intact, it must either be buried rapidly or preserved in a situation where it is unavailable to scavengers. The miners who uncovered the skeletons estimated that they first encountered bones approximately 9–12 m (30–40 ft) below the present ground surface. Furthermore, they were reasonably certain that no bones were present in these same fissures closer to the surface. Obviously, the fissures must have been open to the surface during the late Pleistocene to function as natural traps, "capturing" and then entombing the skeletons of horse, camel, bison, and deer. We have no reliable way to determine how deep the fissures were relative to the late Pleistocene ground surface. Several meters of Holocene alluvium and approximately 4–5 m (~15 ft) of Jurassic Morrison Formation currently overlie the Todilto Formation and are bulldozed away before mining the gypsum. It is probably reasonable to assume that the Pleistocene ground surface was near the present level or perhaps slightly higher, allowing for some erosion of the underlying Morrison Formation before the deposition of the Holocene alluvium.

The following is one possible scenario for the formation of the White Mesa mine site, based on the available evidence. The fauna is composed primarily of large grazing mammals, including horse, camel, and bison. Thus, during the late Pleistocene the fissures in the underlying Todilto gypsum evidently opened to the surface in an area of grasslands. The unsuspecting ungulates fell into the open fissures, tumbling downward as much as 10 m or more (approximately 30–40 ft). If the animals were not killed in the fall they were certainly injured, and were unable to climb back out and eventually died of starvation. Several of the skeletons are nearly complete, articulated, and lack tooth marks, suggesting that the entrapped ungulates were not accessible to predators (if the animals were still alive) or scavengers. Fissure 1 is much too narrow (18 cm = 7 in) to accommodate the undecomposed carcasses of a camel or bison, suggesting these animals died in a wider portion of the fissure closer to the surface. After death and the subsequent decomposition of most of the soft tissues, in particular the large muscle masses and organs, the skeletons then fell into the deeper and much narrower portion of the fissures where they eventually became buried in gypsiferous sediment and preserved. Because the skeletons and isolated limbs were mostly intact, we presume the bones were still held together by connective tissue (tendons and ligaments). The presence of pliable connective tissues, coupled with the absence of bulky muscles, would help explain how several of the articulated bison limbs in fissure 1 were preserved in unnatural poses. The isolated limbs of the camel and horse in fissure 2 apparently became separated from the remainder of the carcasses. The rest of the skeletons of these two animals may have been lodged higher in the fissure and either were not preserved as fossils or were destroyed during earlier mining, or are still present deeper in the fissure and have not yet been uncovered.

Another explanation for the presence of skeletons in fissures that are now too narrow to accommodate the body of the animals contained within them is that the fissures may be narrower than they were in the Pleistocene. Although gypsum is subject to mobilization, we could find no geological evidence (foliations of the gypsum or fissure-fill) or biological evidence (crushed or deformed bones) that the fissures were compressed after the skeletons were entombed within them (Rinehart et al. 2006).

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Notice

The White Mesa mine is located on Zia Pueblo tribal land and may not be entered without permission of the governor's office of Zia Pueblo and the American Gypsum Company operations office.

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