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PLEISTOCENE VERTEBRATES FROM THE WHITE SANDS MISSILE RANGE, SOUTHERN NEW MEXICO

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ABSTRACT.—We report 12 species of vertebrates from 14 late Pleistocene (Rancholabrean) fossil sites on the White Sands Missile Range (WSMR) in southern New Mexico. Twelve of these sites, named the Lake Otero Fauna, occur in the Tularosa Basin near Alkali Flat in Doña Ana County and Alkali Spring in Sierra County and are associated with Pleistocene Lake Otero. The fossils are derived from the Otero Formation, which is predominantly composed of fine-grained gypsiferous sediments of lacustrine origin, with several thin beds high in the unit consisting of coarse volcaniclastic sands and gravels of fluvial or deltaic origin. New Mexico Museum of Natural History (NMMNH) site L-4979 consists mostly of large footprints of a proboscidean, presumably the mammoth *Mammuthus*, and smaller footprints of a camel. A green gypsiferous clay (L-4980) about 2 m higher in the section has produced several partial teeth of the horse *Equus* and nine species of small vertebrates: the frog *Rana*, a colubrid snake, a lizard, a small bird, the rabbit *Sylvilagus* cf. *S. auduboni*, a squirrel (Sciuridae), the mouse *Peromyscus*, the muskrat *Ondatra* cf. *O. zibethicus*, and the vole *Microtus*. Nine sites south of Alkali Spring have produced teeth and postcranial elements of *Mammuthus*, *Equus*, and the large camelid *Camelops*. Most of the horse fossils and a single complete camel scapula were derived from coarse-grained sediments in the Otero Formation, whereas several partial *Mammuthus* teeth were found in gypsiferous clays. A partial mammoth skeleton was discovered in 1934 near Davies Tank at the southern end of WSMR, and two teeth of *Camelops* were collected in 1930 in the vicinity of Mockingbird Gap in the northern portion of WSMR. We also discuss seven Pleistocene sites located just outside the boundary of WSMR. Two sites near Keen Spring east of the WSMR boundary in the Tularosa Basin in Lincoln County have produced *Mammuthus columbi* and the kangaroo rat *Dipodomys*. Five sites in Chupadera Arroyo north of the WSMR in the Jornada del Muerto Basin in Socorro County have produced teeth and tusk fragments of *Mammuthus*. One of the Chupadera Arroyo mammoth localities, the Mockingbird Gap Site, may be associated with a Paleoindian archaeological site.

The occurrence of *Microtus* in the Lake Otero Fauna is indicative of mesic forested habitats, whereas the frog and muskrat suggest the presence of permanent water in the Tularosa Basin during the late Pleistocene. The large grazing ungulates, including horse, camel, and mammoth, would have required extensive grasslands, as well as a permanent source of freshwater. The diverse sample of freshwater mollusks and extensive lake sediments of the Otero Formation further support the presence of Lake Otero in the Tularosa Basin during the late Pleistocene. The Lake Otero Fauna and two other vertebrate faunas from New Mexico associated with Pleistocene lakes, the Lake Estancia Fauna from Torrance County and the Lake San Agustín Fauna from Socorro and Catron counties, have many similarities, including the presence of numerous aquatic vertebrates and species that now occur farther north or at higher elevations, as well as abundant molluscan faunas. The Lake Otero Fauna provides additional evidence for cooler and wetter climatic conditions in New Mexico during the late Pleistocene.

INTRODUCTION

The Pleistocene vertebrate record from the White Sands Missile Range (WSMR) in the Tularosa and Jornada del Muerto basins in southern New Mexico consists of 12 species from 14 localities (Fig. 1). Twelve species of vertebrates from 12 localities, here named the Lake Otero Fauna, were derived from fluvial and lacustrine sediments on the western shore of Pleistocene Lake Otero, north of White Sands National Monument in northeastern Doña Ana County and southeastern Sierra County. Hawley (1983) noted the presence of vertebrate fossils in several localities near the the northwestern end of Lake Otero, north of Alkali Flat near Alkali Spring in southeastern Sierra County. We collected fossils of mammoth and horse from several of Hawley's sites. Isolated finds of vertebrate fossils on the WSMR include several mammoth teeth and a fragmentary mammoth tusk from near Davies Tank at the extreme southern end of WSMR near the White Sands Post Headquarters in Doña Ana County, and two isolated camel teeth from the vicinity of Mockingbird Gap in the northwestern portion of WSMR in southeastern Socorro County. Haynes (1970) reported mammoth from a Paleoindian archaeological site in Chupadera Arroyo north of Mockingbird Gap. Ashbaugh and Metcalf (1986) mentioned proboscidean fossils from Pleistocene deposits near Keen Spring in Lincoln County, located in the Tularosa Basin just a few km east of the WSMR boundary. We review all vertebrate fossils known from the WSMR, in particular fossils collected during our recent field work on the Lake Otero Fauna.

Most of the fossils we describe are housed in the paleontology collection of the New Mexico Museum of Natural History and Science (NMMNH) in Albuquerque. One fossil is reported from the vertebrate paleontology collection of the American Museum of Natural History (AMNH) in New York City. Almost all fossil localities mentioned in the text are NMMNH sites (designated by NMMNH locality L-). More detailed information on these sites is available in the locality files in the NMMNH paleontology collection. A Paleoindian archaeological site that may have associated late Pleistocene fossils has a number assigned by the Laboratory of Anthropology (LA) at the Museum of New Mexico in Santa Fe. Throughout this paper, the White Sands Missile Range is abbreviated as WSMR. All measurements of fossils are in mm.

LOCALITIES, GEOLOGIC SETTING, AND VERTEBRATE FAUNAS

Vertebrate fossil sites that occur within the boundaries of the White Sands Missile Range (WSMR) are mostly in the Tularosa Basin, which is bounded on the west by the Oscura, San Andres, San Augustin, and Organ Mountains and on the east by the Sierra Blanca, Sacramento Mountains, and Otero Mesa. Several of the sites near Mockingbird Gap are located in the northeastern Jor-

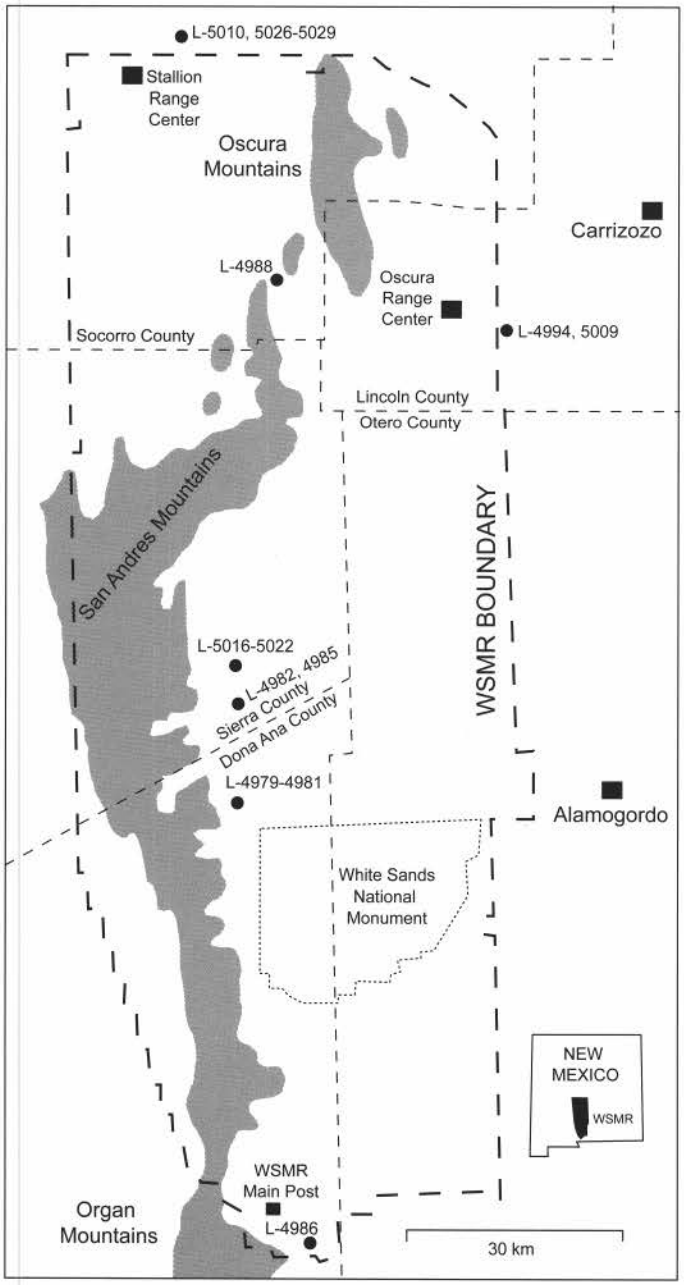

FIGURE 1. Map of White Sands Missile Range (WSMR) and vicinity showing localities for late Pleistocene fossil vertebrates. Small inset map shows location of WSMR in southern New Mexico. New Mexico Museum of Natual History (NMMNH) fossil vertebrate localities are designated by black dots and a four-digit number preceded by L- (e.g., L-4979). See text for description of fossil localities.

nada del Muerto Basin northwest and west of the San Andres and Oscura Mountains. Part of the Tularosa Basin was occupied by an extensive lake during the late Pleistocene, named Lake Otero by Herrick (1904), who also named the Otero and Tularosa formations for the Upper Cenozoic lacustrine sediments deposited by Lake Otero. Lucas and Hawley (this volume) consider Herrick's Tularosa Formation to constitute the upper part of the Otero Formation. Most of the vertebrate fossils described here are derived from the Otero Formation.

The majority of the fossil sites we describe are located along what would have been the western shoreline of Lake Otero during the Pleistocene, and are now less than 5 km from the foothills of the San Andres Mountains on the western boundary of the Tularosa Basin (Fig. 1). The large grazing mammals found at these sites, including horse, camel, and mammoth, apparently lived along the edge of Lake Otero during the late Pleistocene. The mammoth and camel tracks mentioned below and described in more detail elsewhere in this volume (Lucas et al.) almost certainly were formed in moist sediments along the lake margin.

Lake Otero Fauna

The largest and best documented vertebrate fauna on the WSMR is here named the Lake Otero Fauna, for the large Pleistocene lake that occupied the Tularosa Basin during the late Pleistocene. We found vertebrate fossils at 12 localities in northeastern Doña Ana County and southeastern Sierra County in the central part of the WSMR, between 5 and 25 km north of the White Sands National Monument (Fig. 1). These fossils were derived from strata referred to the Otero Formation by Herrick (1904) and further described by Lucas and Hawley (this volume). Vertebrate fossils occur at several different stratigraphic levels in the Otero Formation (Fig. 2). The lowest level with fossils is a pinkish-gray gypsite (unit 3, Fig. 2A) containing numerous tracks of a large proboscidean, almost certainly mammoth, and camel. This track-bearing unit is exposed on the surface of Alkali Flat at an elevation of 1195 m (3920 ft). The mammoth track site (NMMNH locality L-4979) is described in detail by Lucas et al. elsewhere in this volume. Robert Myers collected several small fragments of mammoth teeth (*Mammuthus columbi*) from the same unit that produced the tracks.

The richest site included in the Lake Otero Fauna (L- 4980) yielded 10 species of vertebrates, mostly of small body size, from a green gypsiferous clay in the Otero Formation (unit 6, Fig. 2A), about 2 m stratigraphically above the mammoth track site. Site L-4980 is located in a small arroyo about 0.5 km northwest of the mammoth track site (Fig. 1). The fine-grained lacustrine sediments at L-4980 also contain a diverse fauna of about 25 species of freshwater and terrestrial mollusks (Gordon et al., this volume). Robert Myers first found fossils at site L-4980 in September 2000. He screenwashed about a 10 kg sample of sediment from this site and recovered a frog, three species of small mammals, and numerous mollusks. We collected additional sediment samples for screenwashing from site L-4980 in December 2001 and January 2002, totalling approximately 200 kg. The 2001-2002 samples came from three different places separated by a distance of less than 100 m along the south wall of the arroyo, and were derived from the same layer about 1-1.5 m above the floor of the arroyo. Because these three sites are from the same stratigraphic level (unit 6, Fig. 2A), consist of an identical lithotype, and have a similar fauna of vertebrates and mollusks, we combined the fossil samples from these sites into a single locality, site L-4980. During a field trip by the New Mexico Archaeological Council on 9 June 1984, John Hawley, David Love, and others observed a partial mammoth molar in the side of an arroyo within 250 m

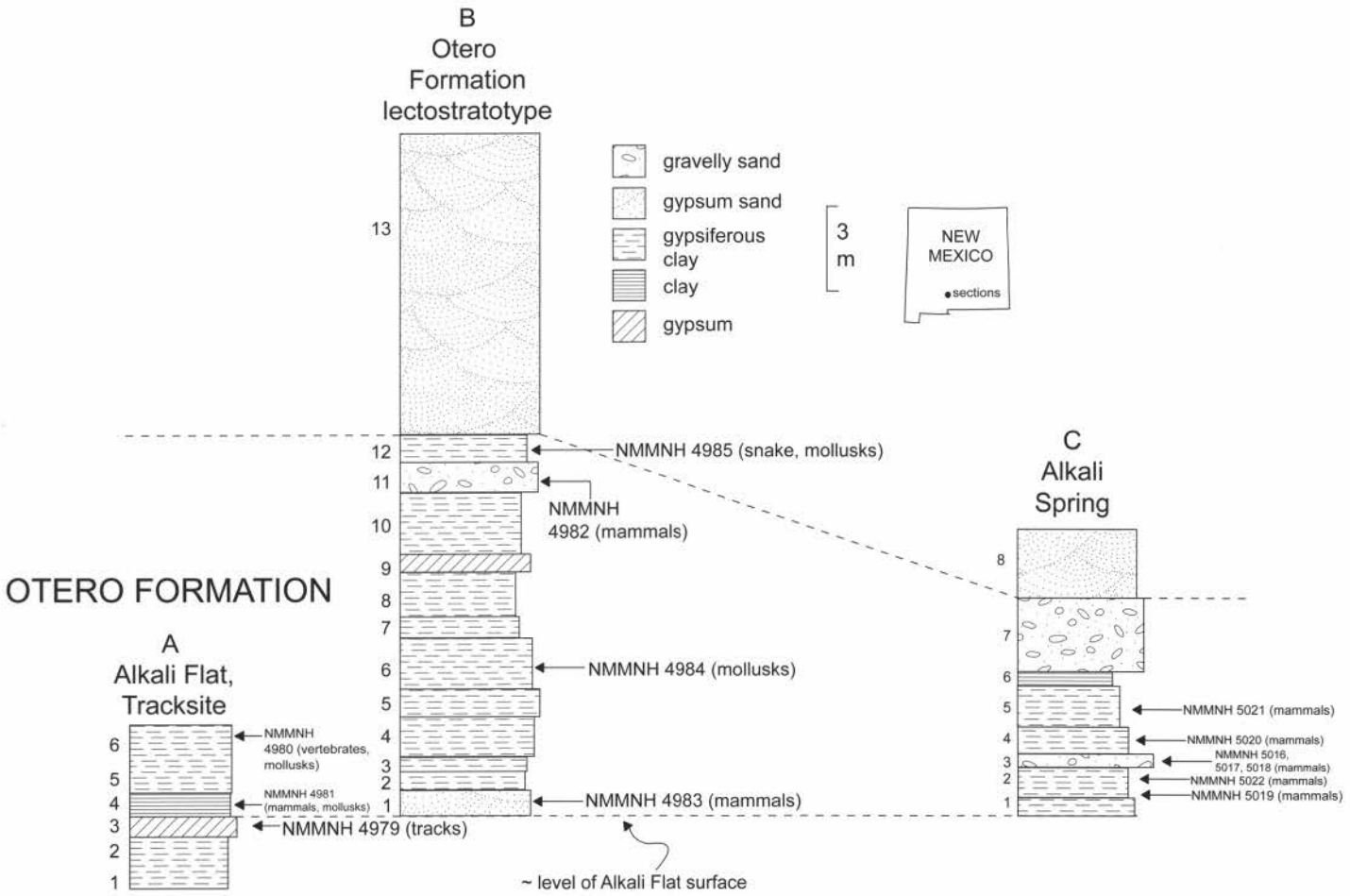

FIGURE 2. Stratigraphic sections of the Pleistocene Otero Formation on the White Sands Missile Range in southern New Mexico. Stratigraphic levels that produced fossils of vertebrates and/or mollusks are indicated by arrows and NMMNH locality numbers (e.g., L-4980). All map coordinates for the three sections are in UTM, zone 13 and use the NAD 27 datum. A. Alkali Flat section, including mammoth tracksite (sites L-4979-4981), located at 358368E, 3644477N. B. Otero Formation lectostratotype (sites L-4982-4985), base located at 358703E, 3655295N, top at 358742E, 3655392N. C. Alkali Spring section (sites L-5016-5022), base at 360577E, 3659916N, top at 360560E, 3659990N.

of the tracksite, possibly the same arroyo that contains locality L-4980. The current whereabouts of this tooth are unknown (John Hawley, oral. comm., 2002). A clay about 0.2 m above the track layer and 100 m southwest of the tracksite (L-4981) yielded a *Microtus* tooth and a fauna of freshwater gastropods.

The other sites included in the Lake Otero Fauna have produced mostly fossils of larger mammals, including horse, camel, and mammoth. NMMNH site L-4982 is located in a series of badlands that form a prominent southwest-northeast-trending escarpment about 10 km due north of sites L-4979 and 4980. Lucas and Hawley (this volume) designated a stratigraphic section in the vicinity of L-4982 as the lectostratotype of the Otero Formation. We collected a scapula and scaphoid of the horse *Equus* and a scapula of the camel *Camelops hesternus* from L-4982 in coarse sands and gravels. Site L-4982 also contained numerous unidentifiable fragments of larger bones. Bones of smaller vertebrates and mollusks are absent in this unit. The fossiliferous layer at L-4982 consists of gray, crossbedded lithic sands and gravels (unit 11, Fig 2B) near the top of the local section of the Otero Formation, about 9 m above the Alkali Flat. The bones were derived from volcaniclastic sands and gravels deposited in a river system that entered the northern edge of Lake Otero (Lucas and Hawley, this volume). All other strata in this exposure consist of fine-grained sands and clays containing abundant gypsum, representing shallow lake margin or basinal facies of Pleistocene Lake Otero. We collected and screenwashed two additional sediment samples of about 10 kg each from this same stratigraphic section in the vicinity of site L-4982. One sample (L-4984) was from unit 6, a red gypsiferous clay 4.5 m below the bone layer. The second sample (L-4985) was from unit 12, a green and red mottled gypsiferous clay just above the bone layer. The fossils recovered from sites L-4984 and L-4985 consist almost entirely of mollusks (Gordon et al., this volume). A colubrid snake vertebra (NMMNH 35630) from L-4985 is the only vertebrate fossil from these two units.

Hawley (1983) reported the presence of vertebrate fossils at four sites near Alkali Spring, but no fossils were collected. One of Hawley's sites is about 3 km east of L-4982 at the easternmost end of the badlands at the northern end of Alkali Flat, and the

other three sites are located 2-4 km north of the badlands and south of Alkali Spring (Hawley, 1983, fig. II.2). We surveyed the area discussed by Hawley and discovered vertebrate fossils at seven sites (NMMNH localities L-5016-5022; Fig. 1). The fossils occur in a sequence of lacustrine and fluvio-deltaic deposits of the Otero Formation (Lucas and Hawley, this volume) exposed along a north-south trending escarpment 2-4 km south of Alkali Spring (Fig. 1). Three of theAlkali Spring sites (L-5018-5020) produced mammoth (*Mammuthus columbi*) teeth or tooth fragments, L-5021 contained a partial mammoth tusk, L-5022 had an *Equus* mandible with two teeth, and three sites (L-5016-5018) contained miscellaneous horse and mammoth postcranial bones. The Alkali Spring sites are in the same general vicinity as the "Gunn Site," discovered in the early 1980s by Donald Wolberg of the New Mexico Bureau of Mines and Mineral Resources. Photos taken in 1982 at the Gunn Site show an *Equus* mandible with three teeth and an isolated tooth of the large camel *Camelops*. The current location of the horse jaw and camel tooth that Wolberg collected from the Gunn Site is unknown.

According to Hawley (1983, p. 28), "The 1200 m contour line that roughly marks the perimeter of the almost enclosed basin north of Alkali Flat also approximates the outcrop zone of thin pebble gravel layers with vertebrate (mammalian) fossils." The dominant rock types in these fossiliferous pebble gravels are intermediate volcanics that indicate more distant source areas to the northeast in the vicinity of Sierra Blanca and Carrizozo, rather than closer source areas in the San Andres Mountains located less than 10 km to the west (Hawley, 1983; Lucas and Hawley, this volume). We collected vertebrate fossils from these pebble gravels, unit 3 in our stratigraphic section from the Alkali Spring area (Fig. 2C). A thick gravel unit higher in the Alkali Spring section (unit 7, Fig. 2C) contained only bone fragments. Alternating red and green gypsiferous lacustrine clays of the Otero Formation in the Alkali Spring section (units 2, 4, 5, Fig. 2C) also produced vertebrate fossils, primarily teeth and a partial tusk of a mammoth.

Vertebrate Fauna

Table 1 is a list of the 12 species of vertebrates from the Lake Otero Fauna, including one amphibian, two reptiles, a bird, and eight mammals. Nine species of small vertebrates were recovered by screenwashing fine-grained lake sediments from site L-4980: the frog *Rana*, a small snake, a lizard, a bird, the rabbit *Sylvilagus*, and four rodents-a sciurid, the mouse *Peromyscus*, the muskrat *Ondatra*, and the vole *Microtus*. The other 11 sites in the Lake Otero Fauna (Fig. 1) primarily consist of isolated teeth and postcranial elements of large mammals, including the horse *Equus*, the large camelid *Camelops*, and the mammoth *Mammuthus*.

The most common vertebrate in the Lake Otero Fauna is the freshwater frog *Rana*, with 77 identifiable fossils representing a minimum of five individuals based on the ilium. *Rana* is present only at site L-4980. Six species of *Rana* presently occur in New Mexico, all of which live in freshwater habitats such as streams, rivers, lakes, and marshes (Degenhardt et al., 1996). None of these frogs are now found in the Tularosa Basin, but several species of *Rana* are found in the Rio Grande and Pecos River.

TABLE 1. Late Pleistocene vertebrates from the Lake Otero Fauna, Tularosa Basin, Doña Ana and Sierra Counties, southern New Mexico.

Class Amphibia			
	Order Anura (frogs and toads)		
		Family Ranidae	
			Rana sp. (aquatic frogs)
Class Reptilia			
	Order Squamata		
		Suborder Serpentes (snakes)	
		Family Colubridae	
			unidentified species of small snake
		Suborder Sauria (lizards)	
			unidentified species of small lizard
Class Aves			
	unidentified species of small bird		
Class Mammalia			
	Order Rodentia		
		Family Sciuridae	
			unidentified species of squirrel
		Family Muridae	
			Microtus cf. *M. pennsylvanicus* (vole)
			Ondatra cf. *O. zibethicus* (muskrat)
			Peromyscus sp. (mouse)
	Order Lagomorpha		
		Family Leporidae (rabbits)	
			Sylvilagus cf. *S. auduboni* (desert cottontail)
	Order Perissodactyla		
		Family Equidae	
			Equus laurentius species group (Niobrara horse)
	Order Artiodactyla		
		Family Camelidae	
			Camelops hesternus (yesterday's camel)
	Order Proboscidea		
		Family Elephantidae	
			Mammuthus columbi (Columbian mammoth)

The abundance of *Rana* in the Lake Otero Fauna supports geologic evidence for the presence of a large freshwater lake in the Tularosa Basin during the late Pleistocene (Herrick, 1904; Lucas and Hawley, this volume). A small colubrid snake is also fairly common in the Lake Otero Fauna, represented by 18 identifiable specimens, mostly isolated vertebrae from L-4980. We also identified a single snake vertebra from L-4985. There are almost 50 species of snakes in the family Colubridae from New Mexico (Degenhardt et al., 1996), so an identification of the Lake Otero fossils to the genus or species level is not possible without examination by a specialist on fossil snakes. The snake vertebrae may actually represent two species, as they seem to fall into two size categories, a small and very small species of colubrid. Lizards are identified in the fauna by three dentary/maxillary fragments from L-4980. Birds are represented by a mandibular fragment and partial vertebra of an small unidentified species. The most intriguing bird fossils are what appear to be eggshell fragments from site L-4980. These fragments are thin and gently curved, shiny and textured on the external surface, and consist of two distinct layers.

Five species of small mammals occur in the Lake Otero Fauna. With the exception of two specimens, all of the small mammals are from site L-4980. A partial lower third premolar (NMMNH

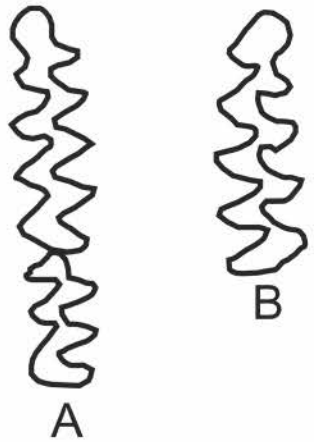

FIGURE 3. Lower dentition of *Microtus* from the late Pleistocene Lake Otero Fauna (NMMNH site L-4980), White Sands Missile Range, Doña Ana County, New Mexico. A. Left m1-m2, NMMNH 35614 (length of m1, 3.6 mm). B. Right m1, NMMNH 35557 (length of m1, 3.8 mm).

35554) is very similar to the same tooth in the desert cottontail *Sylvilagus auduboni*, the common species of rabbit currently found in the Tularosa Basin (Findley et al., 1975). An unidentified squirrel (family Sciuridae) is represented by several partial teeth. Two teeth (NMMNH 35556, 35593) and a jaw fragment (NMMNH 35594) are referred to the small mouse *Peromyscus*, but are not complete enough for further identification. A partial molar (NMMNH 35619) from L-4980 and an edentulous maxillary fragment (NMMNH 35648) from L-5018 are tentatively referred to the muskrat *Ondatra*. These two specimens are identified as *Ondatra* primarily on the basis of their large size, as they are too large to belong to any other member of the vole subfamily Arvicolinae from New Mexico. The presence of *Ondatra* in the Lake Otero Fauna is significant because the living species *Ondatra zibethicus* is semiaquatic and is usually found in the vicinity of lakes and marshes (Findley et al., 1975).

The most common small mammal in the Lake Otero Fauna is the vole *Microtus*, with 15 identifiable teeth representing a minimum of five individuals based on the presence of five left lower first molars (m1). There is also a partial lower first molar of *Microtus* from L-4981. The most complete specimen of *Microtus* in the Lake Otero Fauna is a left lower jaw with the first and second molars (NMMNH 35614: Figs. 3, 4A). We compared measurements and morphological characters of the m1 in the Lake Otero *Microtus* to the m1 in the four species of *Microtus* currently known from New Mexico, *M. longicaudus*, *M. mexicanus*, *M. montanus*, and *M. pennsylvanicus*, all four of which occur in mesic montane forests at much higher elevations than the Tularosa Basin (Findley et al., 1975). The length of the m1 in four specimens of *Microtus* from Lake Otero ranges from 3.3-3.8 mm, with a mean of 3.5 mm. This is larger than the m1 of any of the four extant species of New Mexico *Microtus*. The morphology of the fossil m1s, including the shape of the anterior loop and the presence of six closed triangles, is most similar to m1s of *M. montanus* and *M. pennsylvanicus*, both of which are now restricted to mountain ranges much farther north in New Mexico. The two species of *Microtus* currently found in the Sacramento Mountains east of the Tularosa Basin, M. *longicaudus* and *M. mexicanus*, have only five closed triangles on m1, and are thus unlike the Lake Otero *Microtus*. On ecological grounds, *M. pennsylvanicus* would have been more likely to occur near Lake Otero, as this species is usually found in the vicinity of permanent water in New Mexico and elsewhere in the western US (Findley et al., 1975). Harris (1995) identified *M. pennsylvanicus* from the late Pleistocene Pendejo Cave on Otero Mesa in Otero County, located about 90 km southeast of the Lake Otero fossil sites.

The fossils of the horse *Equus* from the Lake Otero Fauna, most of which consist of tooth fragments or isolated postcranial elements, were collected from coarse fluvial or deltaic sediments (site L-4982, unit 11, Fig. 2B and sites L-5016-5018, and 5022, unit 3, Fig. 2C). A nearly complete scapula (NMMNH 35627) from L-4982 and a sacrum (NMMNH 35644, Figs. 4C, 4D) from L-5017 are the two most complete postcranial elements of *Equus*. A jaw fragment with a nearly complete left p3 or p4 (NMMNH 35654, Fig. 4E) represents a medium-sized species of *Equus* tentatively referred to the *Equus laurentius* species group following Winans (1989). Measurements of NMMNH 35654 are: total length, 30.6 mm; maximum width, 16.7 mm. These measurements compare closely with measurements of the p3 and p4 of *E. niobrarensis* from Dry Cave in Eddy County, New Mexico (Harris and Porter, 1980), a species since referred to the *E. laurentius* group (see Winans, 1989; Harris, 1993). A partial upper molar (NMMNH 35624) from site L-4980 appears to be from a similar-sized species of *Equus*. *E. laurentius* is the least common horse in Pendejo Cave, whereas the smaller *E. alaskae* is more abundant (Harris, 1995).

We collected a complete scapula (NMMNH 35628; Fig. 4B) of the large camel *Camelops* from a coarse gravelly sand (unit 11, Fig. 2B) at site L-4982. The total length of this scapula is 490 mm, which is within the observed range of total length measurements (475-510 mm) for eight scapulae of *Camelops hesternus* from Rancho la Brea in southern California (Webb, 1965, table 9). *C. hesternus* is the typical species of large camelid in late Pleistocene faunas from New Mexico (Harris, 1993), and the Lake Otero scapula is confidently referred to that species. Two upper teeth of *C. hesternus* from Mockingbird Gap in the northern portion of the WSMR are discussed below.

Fossils of the mammoth *Mammuthus columbi* were found at five sites in the Lake Otero Fauna: tracks and two small tooth fragments from the main track site on Alkali Flat (L-4979) and four sites south of Alkali Spring, including a tooth fragment from L-5018, two partial teeth from L-5019, a partial tooth from L-5020, and a partial tusk from L-5021. The tusk is not actually diagnostic of a mammoth, but there is no evidence of another proboscidean in this fauna. There were two proboscideans in New Mexico during the late Pleistocene. The most common, the Columbian mammoth, *Mammuthus columbi*, is known from more than 40 localities throughout the state (Lucas and Effinger, 1991). The American mastodont, *Mammut americanum*, was much rarer, identified from only four sites in the state (Lucas and Morgan, 1996).

Most of the *Mammuthus* fossils in the Lake Otero Fauna came from low in the stratigraphic section of the Otero Formation in fine-grained gypsiferous clays of lacustrine origin. Although

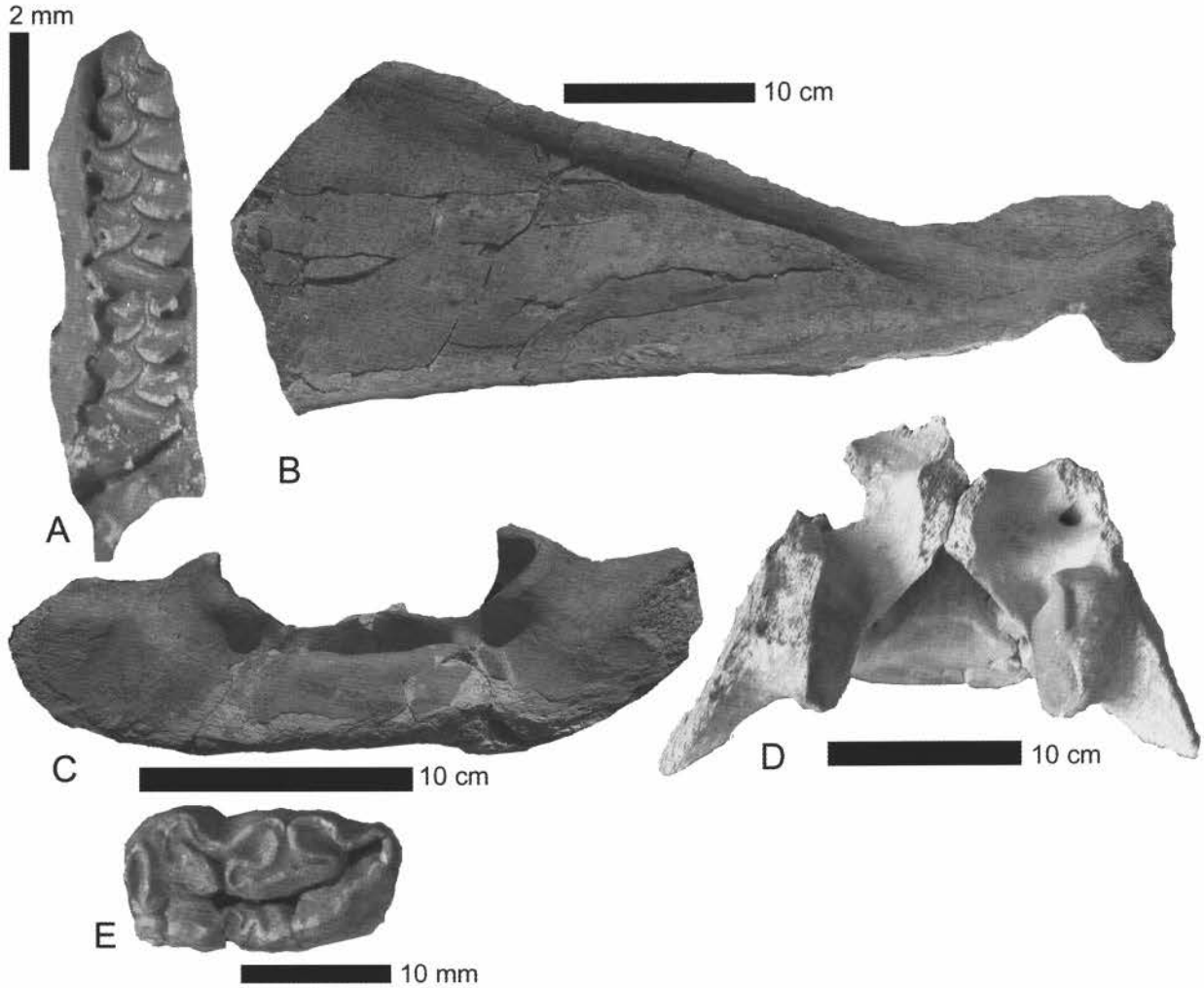

FIGURE 4. Mammal fossils from the the late Pleistocene Lake Otero Fauna, White Sands Missile Range, Doña Ana County, New Mexico. A. left mandible with m1-m2 of *Microtus*, NMMNH 35614, site L-4980. B. scapula of *Camelops hesternus*, NMMNH 35628, site L-4982. C. anterior view and D. dorsal view of sacrum of *Equus*, NMMNH 35644, site L-5017. E. occlusal view of left p3/p4 of *Equus laurentius*, NMMNH 35654, site L-5022.

none of the teeth from the Lake Otero Fauna are complete enough for plate counts or most measurements, the partial teeth and tooth fragments are almost certainly referable to the late Pleistocene mammoth *Mammuthus columbi* on the basis of their complicated and very thin enamel. Measurements of the enamel thickness of partial teeth of *M. columbi* from the Lake Otero Fauna are (means and observed ranges are from five measurements of enamel thickness): NMMNH 35625, mean 2.6 mm, observed range 2.3-2.8 mm; NMMNH 35649, mean 3.0, observed range 2.8-3.2; NMMNH 35651, mean 2.8, observed range 2.7-2.9; NMMNH 35652, mean 3.1, observed range 2.8-3.4. The closest previous records of *M. columbi* are from the Mockingbird Gap Site in Chupdera Arroyo in Socorro County, about 80 km north of the Lake Otero sites (see discussion below), and from several sites in the Sacramento Mountains, including the Dry Gulch Site near Nogal in Lincoln County, about 90 km to the northeast (Hay, 1924; Lucas and Effinger, 1991; Leach et al., 1999).

Davies Tank

Several mammoth (*Mammuthus*) fossils have been found in the vicinity of Davies Tank (NMMNH locality L-4986) at the extreme southern end of WSMR in Doña Ana County (Fig. 1). The site is located 3 km southwest of Davies Tank, 6 km southeast of the White Sands Post Headquarters, and just a few hundred meters west of the Condron Air Field. We visited the Davies Tank locality with Robert Myers on 5 December 2001, and he showed us the general area where a partial proboscidean tusk was found in early 2001 by WSMR archaeologists. We examined a photograph of this tusk in the ground, but it was too poorly preserved to be collected. The tusk is from a proboscidean, but is not specifically identifiable, although it is probably from *Mammuthus* based on the previous occurrence of mammoth fossils from near Davies Tank.

Two photographs of a partial mammoth skeleton excavated by E. L. Little, Jr. on the Cox Brothers Ranch September 18, 1934,

were reproduced as figures 4.1 and 4.2 in Wessel et al. (1997). Their photographs show several mammoth limb bones on the surface and two large teeth still in place, apparently the lower m2 and m3 of a mammoth, probably *Mammuthus columbi*. The Cox Brothers were the landowners prior to the founding of the WSMR (Wessel et al., 1997). We also collected a tooth fragment of the horse *Equus* (NMMNH 35631) and several other bone fragments at the Davies Tank site in December 2001.

Keen Spring

Ashbaugh and Metcalf (1986) described a Pleistocene molluscan fauna consisting of 38 species from sediments in the vicinity of Keen Spring, located just outside the eastern boundary of WSMR. On the basis of fossils found by Robert H. Weber, Ashbaugh and Metcalf (1986, p. 19) also mentioned the occurrence of proboscidean remains from sediments near Keen Spring. Robert Weber donated to the NMMNH a mammoth tooth plate he collected near Keen Spring in July 1964. According to Weber's notes, this tooth plate was from a disarticulated skeleton of a mammoth preserved in spring deposits about 0.5 km southwest of Keen Spring and 4 km west of Oscuro in southwestern Lincoln County (NMMNH locality L-5009, Fig. 1). The mammoth occurred in diatomaceous, highly gypsiferous, clayey silty sands that also contained associated gastropods, bivalves, and ostracods. We refer the mammoth tooth plate from Keen Spring (NMMNH 35635) to the late Pleistocene species *Mammuthus columbi* on the basis of its thin, complicated enamel. The mean of five measurements of enamel thickness on this tooth plate is 2.8 mm, with an observed range of 2.6-3.1 mm.

In January 2002, we collected a sample of about 10 kg of silty sediments from a site 1 km southwest of Keen Spring (NMMNH locality L-4994, Fig. 1), and about 0.5 km west of L-5009. Screenwashing of these sediments resulted in the recovery of several bones and teeth of small mammals, as well as about ten species of terrestrial and freshwater mollusks. The only identifiable vertebrate fossil from L-4994 is the lower fourth premolar of the kangaroo rat *Dipodomys*. Measurements of the Keen Spring *Dipodomys* p4 (NMMNH 35632) are: total length, 1.3 mm; anterior width, 0.8 mm; posterior width, 1.2 mm. No fossils of *Dipodomys* were recovered from the large sediment sample we screenwashed from site L-4980 along the western shore of Pleistocene Lake Otero in northern Doña Ana County, about 80 km southwest of Keen Spring. This might reflect a difference in the paleoecology of these two sites, as kangaroo rats are unknown from Pleistocene lake deposits in New Mexico (see Morgan et al., 2001 and discussion below). The three species of *Dipodomys* currently known from New Mexico are among the most common and widespread desert rodents in the state (Findley et al., 1975).

Mockingbird Gap

The American Museum of Natural History (AMNH) and New Mexico Museum of Natural History (NMMNH) each have single teeth of the large camel *Camelops* found near Mockingbird Gap (NMMNH locality L-4988) in southeastern Socorro County in the northwestern portion of the WSMR (Fig. 1). The map coordinates of the locality where these camel teeth were found are unknown. Both teeth were collected by Tom Charles of Alamogordo in September 1930, long before the WSMR was founded in the 1940s. According to notes in the AMNH, Mr. Charles found the camel teeth about 6 to 8 feet below the surface while digging a well. The tooth in the NMMNH still has a small amount of adhering sediment, consisting of a medium-grained gypsiferous sand. The two camel teeth from Mockingbird Gap compare closely in size and morphology with the late Pleistocene species *Camelops hesternus* (see Webb, 1965, table 5). Measurements (in mm) of the AMNH M3 are: anteroposterior length, 41.4; anterior width, 21.9; posterior width, 18.4; maximum crown height, 55.5. Only two measurements can be taken on the posterior half of the left M1 or M2 in the NMMNH collection (NMMNH 35629): posterior width, 17.2; maximum crown height, 55.9.

Chupadera Arroyo Sites

The only published record of Pleistocene vertebrates from the Jornada del Muerto Basin is a brief mention of mammoths from the Mockingbird Gap Site, a Paleoindian archaeological site (LA-26748) located about 40 km north of Mockingbird Gap in Chupadera Arroyo (Haynes, 1970; Weber and Agogino, 1997). Mockingbird Gap is a Clovis occupation site preserved in a low deflated ridge line consisting of channel-slope deposits (Haynes, 1970; Weber and Agogino, 1997; Wessel et al., 1997). Many authors have mentioned the presence of mammoths in the Mockingbird Gap Paleoindian Site (Haynes, 1970; Kurtén and Anderson, 1980; Harris, 1985; 1993; Lucas and Effinger, 1991; Kirkpatrick and Weber, 1996). On the basis of information provided by Robert Weber, Haynes (1970) noted the occurrence of mammoths from Mockingbird Gap, but he listed the record only as "mammoth" in a table of Clovis sites. Kurtén and Anderson (1980) cited Haynes' Mockingbird Gap mammoth record as *Mammuthus jeffersonii* (now synonymized with *M. columbi*). Several subsequent authors (Harris, 1985; 1993; Lucas and Effinger, 1991; Kirkpatrick and Weber, 1996) have also mentioned *M. colombi* from Mockingbird Gap. There is some question about the association of the mammoth fossils with Paleoindians in the Mockingbird Gap Site. According to Robert Weber (in litt, 17 March 2002), "There is no definitive evidence that this was a mammoth kill by the Clovis occupants of the site as the tooth enamel fragments are from a surface scatter in a fringe area of the site that contained no associated Clovis artifacts." No radiocarbon dates are available for the Mockingbird Gap Site; however, if the mammoth fossils do occur with Paleoindian artifacts, this association would indicate a latest Pleistocene age (11-12,000 yrBP).

Robert Weber provided us with information on five additional fossil sites he discovered in the vicinity of Chupadera Arroyo in the northern Jornada del Muerto Basin in southeastern Socorro County, just outside the northern boundary of the WSMR (NMMNH localites L-5010, 5026-5029; Fig. 1). These sites are located northwest of the Oscura Mountains and just a few km north of Pleistocene Lake Trinity, a lake that developed in the northern Jornada del Muerto Basin at about the same time as

Lake Otero formed in the Tularosa Basin (Neal et al., 1983; Kirkpatrick and Weber, 1996). The Chupadera Arroyo sites yielded isolated mammoth tooth enamel and tusk fragments that occurred as highly-eroded surface scatters resulting from weathering decomposition. There is no evidence that these isolated tooth and tusk fragments are representative of more complete skeletal remains of mammoths (R. H. Weber, in litt., 28 January 2001).

Weber donated to the NMMNH mammoth tooth enamel and/or tusk fragments from three sites near Chupadera Arroyo: four enamel fragments (NMMNH 35636) and a tusk fragment (NMMNH 35637) from NMMNH site L-5010; seven enamel fragments (NMMNH 36076) from site L-5027; three enamel fragments ((NMMNH 36077) and two tusk fragments (NMMNH 36078) from site L-5029. These tooth fragments are referred to *Mammuthus columbi* on the basis of their thin, complicated enamel. Measurements of the enamel thickness of tooth fragments of *M. columbi* from sites L-5010 (NMMNH 35636) and L-5027 (NMMNH 36076) in Chuapdera Arroyo are (means and observed ranges are from five measurements of enamel thickness): NMMNH 35636, mean 2.9 mm, observed range 2.7-3.0 mm; NMMNH 36076, mean 2.4 mm, observed range 2.3-2.6.

DISCUSSION

Prior to this study, the published record of fossil vertebrates from the White Sands Missile Range was almost nonexistent. The mammoth footprint site on Alkali Flat was widely known among geologists and paleontologists in New Mexico, and was the subject of several newspaper articles, but this site had not been mentioned previously in the scientific literature (also see Lucas et al., this volume). Hawley (1983) mentioned the occurrence of mammalian fossils from four sites in the vicinity of Alkali Spring. We report vertebrate fossils from three of Hawley's sites. Wessel et al. (1997) reproduced several old photographs from the 1930s that showed a partial mammoth skeleton from near Davies Tank.

The vertebrate record now consists of 12 species from 14 sites in four general areas on the WSMR (Fig. 1, Table 1). *Mammuthus* and *Equus* are known from the vicinity of Davies Tank at the southern end of WSMR in Doña Ana County (NMMNH locality L-4986). Three localities on the western edge of Alkali Flat in northeastern Doña Ana County have produced vertebrate fossils: mammoth and camel footprints and *Mammuthus* tooth fragments from site L-4979 (see Lucas et al., this volume); nine species of small vertebrates and *Equus* from L-4980 (Table 1) which is the richest site on WSMR; and a single tooth of the vole *Microtus* from L-4981. About 10-20 km north of the Alkali Flat sites, ten sites south of Alkali Spring in southeastern Sierra County have produced vertebrate fossils, mostly of large mammals. Three sites occur in the lectostratotype section of the Otero Formation (see Lucas and Hawley, this volume), located in a series of northeast-southwest trending badlands at the northern end of Alkali Flat. *Equus* and *Camelops* are present at L-4982, a snake vertebra was recovered from L-4985, and Hawley (1983, fig. II.2) mapped a site at the extreme eastern end of the badlands that we did not visit. A few km farther north, fossils of *Equus* and *Mammuthus* are present at seven sites in the vicinity of Alkali Spring (NMMNH L-5016-5022). Hawley (1983, fig. II.2) mapped and briefly discussed three of the Alkali Spring sites. The northernmost fossil vertebrate site on WSMR consists of two teeth of *Camelops* from near Mockingbird Gap in southeastern Socorro County (L-4988).

In addition to sites within the WSMR, we also document seven other Pleistocene vertebrate sites located just outside the boundaries of WSMR, but still within either the Tularosa Basin or Jornada del Muerto Basin (Fig. 1). Ashbaugh and Metcalf (1986) mentioned proboscidean remains from a site near Keen Spring (L- 5009) in the Tularosa Basin just a few km east of the WSMR boundary near Oscuro in southwestern Lincoln County. We identify the Keen Spring proboscidean as *Mammuthus columbi* and also report the occurrence of the kangaroo rat *Dipodomys* in a second site near Keen Spring (L-4994). We also briefly mention five sites in the vicinity of Chupadera Arroyo (L-5010, L-5026-5029) at the northern end of the Jornada del Muerto Basin, which are just north of the northern boundary of WSMR in southeastern Socorro County. The only species present in the five Chupadera Arroyo sites is the mammoth *Mammuthus columbi*. The single published record of Pleistocene vertebrates in the Jornada del Muerto Basin is the occurrence of *M. columbi* in the Mockingbird Gap Paleoindian site in Chupadera Arroyo (Haynes, 1970; Kurtén and Anderson, 1980; Harris, 1985, 1993; Lucas and Effinger, 1991; Kirkpatrick and Weber, 1996).

The previously published Pleistocene vertebrate record from the general vicinity of the White Sand Missile Range in southern New Mexico primarily consists of late Pleistocene (Wisconsinan) cave deposits, although none of these caves are located within the boundaries of WSMR. A series of latest Pleistocene packrat midden deposits in Rhodes Canyon in the San Andres Mountains on the WSMR primarily contained plant remains (Van Devender and Toolin, 1983; see discussion below). The best known of the cave deposits are Pendejo Cave from Otero Mesa in Otero County on the east side of the Tularosa Basin (Harris, 1995) and Conkling Cavern and Shelter Cave in the Organ Mountains in Doña Ana County on the west side of the Tularosa Basin (Thompson et al., 1980; Harris, 1985, 1993, 1997). Radiocarbon dates on Pendejo Cave range from about 14,000 to more than 55,000 yrBP, from mid to late Wisconsinan (Harris, 1995). A late Wisconsinan radiocarbon date of 11,330 yrBP was obtained on sloth dung (*Nothrotheriops shastensis*) from Shelter Cave (Van Devender and Spaulding, 1979; Thompson et al., 1980). No dates are available for Conkling Cavern, although its age is considered late Wisconsinan (Harris, 1993). All three of these cave deposits share *Equus*, *Camelops*, and *Microtus* with the Lake Otero Fauna. The cave sites lack *Mammuthus*, but this is probably a paleoecological bias relating to the rarity of mammoths in the mountains. The *Microtus* from the Lake Otero Fauna is tentatively referred to the rarer of the two species of voles in Pendejo Cave, *M. pennsylvanicus*, a species that inhabits areas with a constant supply of water, such as Pleistocene Lake Otero. Both the cave faunas and the Lake Otero Fauna provide evidence that the late Pleistocene in southern New Mexico was characterized by cooler and more mesic conditions than at present (Harris, 1985, 1995, 1997).

Van Devender and Toolin (1983) provided important information on the late Pleistocene (late Wisconsinan) vegetation and

climate of the Tularosa Basin based on their studies of packrat or woodrat (*Neotoma*) middens on the east side of the San Andres Mountains in Sierra County. The packrat middens analyzed by Van Devender and Toolin (1983) were from Rhodes Canyon on WSMR and ranged in elevation from 1690-1740 m. The Rhodes Canyon packrat middens are about 20-30 km northwest of the Lake Otero fossil sites and are 500-600 m higher in elevation. Four of the Rhodes Canyon samples are late Pleistocene in age, with radiocarbon dates ranging from 10,290-14,920 yrBP. Plants identified from these packrat midden samples indicate that the late Wisconsinan vegetation in upper Rhodes Canyon (down to an elevation of about 1600 m) consisted of a mixed conifer forest dominated by douglas fir, ponderosa pine, and blue spruce, and that at lower elevations in the Tularosa Basin these mesic trees were replaced by an open juniper-oak woodland. The Tularosa Basin currently supports an arid Chihuahuan desert grassland (Van Devender and Toolin, 1983). There are no radiocarbon dates for the Lake Otero fossil sites, so we cannot directly correlate them with the radiocarbon dates from the Rhodes Canyon packrat middens. We are fairly certain, however, that the Lake Otero sites are late Pleistocene in age, despite their lack of *Bison*, the defining genus for Rancholabrean (late Pleistocene) faunas. Harris (1995) noted the rarity of *Bison* in late Pleistocene sites west of the Guadalupe and Sacramento Mountains.

More mesic or wetter climatic conditions in New Mexico during the late Pleistocene are strongly indicated by the presence of several large lakes such as Pleistocene Lake Otero. Vertebrate faunas are associated with three large Pleistocene lakes in New Mexico: Lake Otero in Doña Ana and Sierra Counties in the Tularosa Basin in southern New Mexico (described here), Lake Estancia in the Estancia Basin in Torrance County in east-central New Mexico (Morgan et al., 2001), and Lake San Agustín in Socorro and Catron Counties in west-central New Mexico (Weber, 1994; unpublished fossils in the NMMNH collection). These Pleistocene lake sites have fairly diverse vertebrate faunas, but they are not well known. The three faunas have several features in common, including abundant aquatic vertebrates, the presence of species that now occur farther north or at higher elevations, and the occurrence of large grazing ungulates, as well as diverse molluscan faunas. The two most abundant vertebrates in the Lake Otero Fauna are the aquatic frog *Rana* and the vole *Microtus*, and large ungulates are represented by horse, camel, and mammoth. At the present time, all four species of voles of the genus *Microtus* known from New Mexico occur at much higher elevations in mesic montane forests (Findley et al., 1975). The Lake Estancia fauna (Morgan et al., 2001) consists of a horse (*Equus*) and three aquatic species, cutthroat trout (*Oncorhynchus clarki*), tiger salamander (*Ambystoma tigrinum*) and a duck (Anatidae). The cutthroat troat is a cold-water fish no longer found in the Estancia Basin (Bachhuber, 1989).

Weber (1994, p. 11) reported numerous species of fossil vertebrates from late Pleistocene sites associated with Lake San Agustín, including horse, camel, bison, mammoth, and short-faced bear, as well as many species of small vertebrates, including fish, frog, salamander, water birds, pigmy rabbit, ground squirrel, muskrat, and vole. A fossil site (NMMNH locality L-3901) on the grounds of the Very Large Array (VLA) operated by the National Radio Astronomy Observatory west of Magdalena in western Socorro County is located in a basin included in Pleistocene Lake San Agustín by Weber (1994). The VLA site has produced mammoth (*Mammuthus columbi*), as well as a microvertebrate fauna, including small fish, the frog *Rana*, the salamander *Ambystoma*, the mud turtle *Kinosternon*, a duck (Anatidae), the vole *Microtus*, and the muskrat *Ondatra*. The vertebrate fauna from the VLA site and the fauna listed by Weber (1994) from Pleistocene Lake San Agustín are very similar. Weber's fossils were collected from sites that are widely distributed throughout the three conjoined basins that compose Pleistocene Lake San Agustín (Robert Weber, in litt, 17 March 2002). The Lake San Agustín and Lake Otero faunas share at least six taxa, including horse, camel, mammoth, vole, muskrat, and frog. The frog and muskrat are characteristic of aquatic habitats, and the vole is typical of more mesic montane environments.

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