The Dry Cave Mammalian Fauna and Late Pluvial Conditions in Southeastern New Mexico

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ABSTRACT

Forty-five species of mammals are tentatively identified from the late Wisconsin deposits of Dry Cave, 4200 ft, southeastern New Mexico. A C^{14} date associated with the fauna is 14,470 ± 250 BP. Most extralimital, extant species may now be found in the Transition Life Zone of central Wyoming; others live at present in the Southwestern high mountains. Vegetation at the time of deposition is believed to have been sagebrush grassland on northern slopes, grading into Upper Sonoran grasslands on southern slopes. Heavy riparian growth occurred in drainage ways. Groves of trees were limited to steep slopes, though individuals may have been distributed parsely elsewhere. Other late pluvial faunas in New Mexico are consistent with this interpretation. Between late pluvial times and the present, several animals that likely could survive under current conditions in nearby highlands became extinct in southern New Mexico. This probably was a result of late winter-early spring drought periods even more severe than characteristic of the Southwest today.

INTRODUCTION

In 1965, members of the Texas Speleological Society noted bones in 2 areas of Dry Cave, McKittrick Hill, Eddy Co., N. Mex. (Skinner and Lindsley, 1965) . In July, 1966, Mr. Pete Lindsley of the Texas society invited me to join an undertaking (Project Under the Hill) designed to increase knowledge of the several caves in the immediate area; specifically I was to assess the importance of the Dry Cave bone finds and take appropriate action. The initial explorations on 2—4 Sept. 1966 made it clear that important fossil faunas were present and that additional exploration and excavation would be required. Further work was done during 28—31 Dec. 1966, 21—23 March 1967, 28—30 May 1967, and 10—12 April 1968.

It early became apparent that 2 different time periods were represented. One fauna includes vertebrates now found only under more mesic and generally cooler climatic conditions; this pluvial fauna is the only one yet studied and is the one reported here. The other fauna has vertebrates expectable under climatic conditions as warm as at present. Attempts to age the latter have been unsuccessful; presumably interpluvial conditions are represented.

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As study of the pluvial fauna has progressed, it has become apparent that more excavation within the cave will be required to secure the maximum amounts of data obtainable from the deposits and that most taxa deserve study in much greater detail than has been possible in the limited time available. Yet the nature of the identified fauna, even though some identifications are tentative, reveals important new evidence on late Pleistocene environments in New Mexico and adjacent areas; delay in publication of the broad environmental interpretation until completion of all studies seems a disfavor to other workers. Therefore I have decided to publish now the preliminary information on the pluvial mammalian fauna and my interpretation of the climatic-vegetational environment represented.

Dr. J. Alan Holman, Michigan State University, has identified the amphibians and reptiles (see p. 29) ; Dr. Robert D. Weigel, Illinois State University, is studying the avian fossils; and Dr. Artie L. Metcalf, The University of Texas at El Paso, has completed study of the associated gastropod fauna, (see p. 41) . Some plant macrofossils and a few insect remains are as yet unstudied.

MODERN ENVIRONMENT

Dry Cave (= Dry Pot) is an extensive maze cavern some 15 miles west of Carlsbad, Eddy Co., N. Mex., at approximately 104° 28' 55" west longitude and 32° 22' 25" north latitude (SE1/4 Sec. 22, T22S, R24E, NMPM) . Elevation at the entrance is 4200 ft above sea level.

The cave lies within the prominence known as McKittrick Hill, with the entrance opening on a south-facing slope a short distance below the crest. A low saddle separates that part of the hill from a higher portion, Azotea Peak, 4297 ft (Fig. 1). Several other caves occur in the same anticline, one of which (McKittrick Cave) has been mentioned in the biological literature (Bailey, 1928). Dry Cave's entrance lies in such a position that the source of potential drainage into the cave is limited to the slope immediately above; thus animal and plant remains must be of very local origin or brought in by predators.

The nearest official weather reporting station is at Carlsbad, about 1000 ft lower in elevation. Data are summarized in Table 1 from Hardy (1941). The higher altitude at Dry Cave likely results in slightly greater precipitation and some decrease in temperature extremes.

Bailey (1913) places the lower border of the Upper Sonoran Life Zone at about 4000 ft in the Pecos Valley, "varying of course with

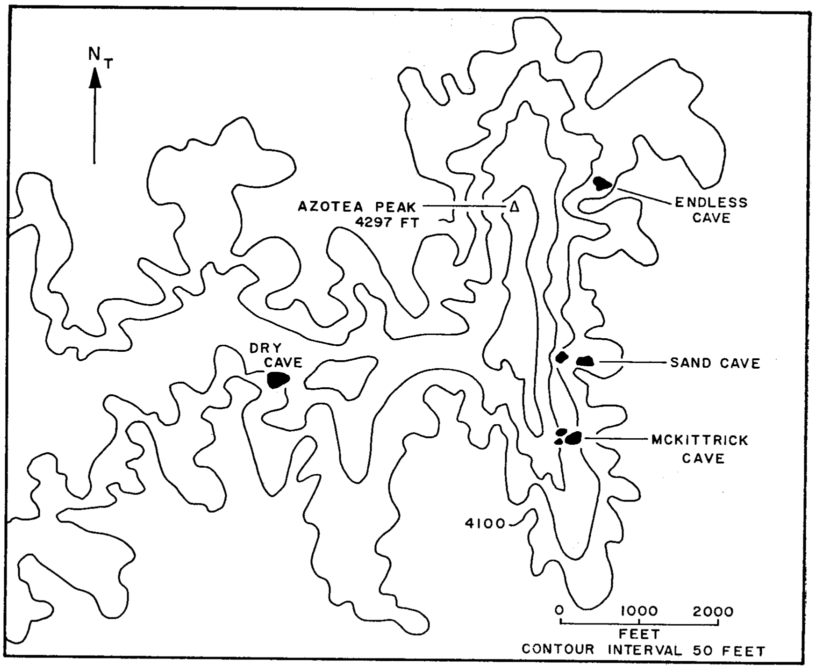

Fig. 1. Topographic relationships of Dry Cave to the upper portion of McKittrick Hill. Note particularly the restricted potential drainage area into Dry Cave.

TABLE 1

Climatic summary for Carlsbad, Eddy Co., N. Mex.

Annual Precipitation	13.13 inches
July Average Temperature	80.5° F
January Average Temperature	44.3 ° F
Maximum Temperature Recorded	112° F
Minimum Temperature Recorded	-17° F
Growing Season	220 days

slope exposure. . . . Along the upper edge of the [Lower Sonoran] zone there is the usual overlapping of Upper and Lower Sonoran species, often resulting on gradual slopes in a complete mixture of the two zones for a considerable distance . . ." This is the situation at McKittrick Hill (Fig. 2) . Plants in the immediate vicinity include Crucifixion-thorn (*Koeberlinia spinosa*, Sotol (*Dasylirion wheeleri*), Sacahuista (*Nolina* sp.), One-seeded Juniper (*Juniperus monosperma*) , Mexican Buckeye (*Ungnadia speciosa*) , Desert Sumac (*Rhus microphylla*), Skunk-bush (Rhus trilobata), White-thorn (Acacia constricta), Mormon Tea (Ephedra sp.), Ocotillo (Fouquieria splendens), narrow leafed and broad leafed yuccas (Yucca spp.), Mahonia (Berberis trifoliolata), Hackberry (Celtis reticulata), and several cacti, including Cholla and pad types (Opuntia spp.). Some grasses occur. Creosote Bush (Larrea divaricata) grows sparsely nearby, though the upper border of the main stands are at several hundred feet lower elevation.

At present, soil is thin or absent in most places and much of the surface consists of bare limestone bedrock or of variously sized stones.

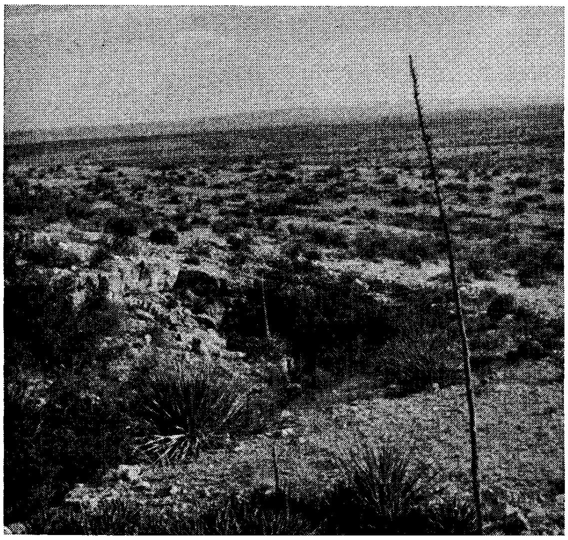

Fig. 2. Present entrance to Dry Cave. View is approximately south. The southern Guadalupe Mts. are in the background. Lechuguilla is prominent in the immediate foreground; Sotol is visible throughout the area. Shrubby growth includes *Rhus*, Ungnadia (at cave entrance), and Juniperus.

FOSSIL SITES

During initial study of the pluvial deposits, each bone-producing area that was not clearly equivalent to and contiguous with another was given a separate locality number; each specimen has been catalogued by individual number preceded by the locality number. Museum of Arid Land Biology (MALB) locality numbers referring to this fauna are 3, 4 (Bison Chamber), 6 (Harris' Pocket), and 12 (Balcony Room) (Figs. 3 and 4).

The earliest discovered fossils were in Loc. 3. This area consists of a number of interconnected passageways. The fill, absent in some

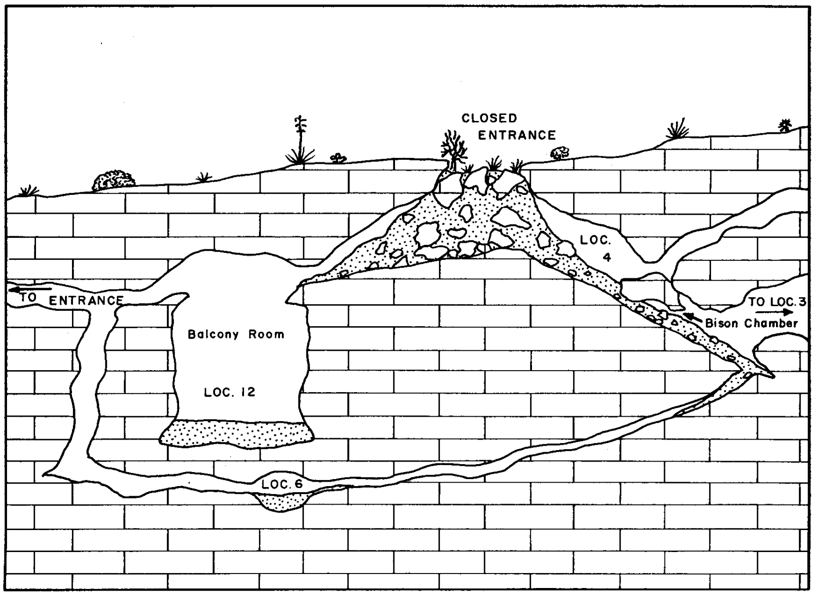

Fig. 3. Schematic sketch showing the vertical relationships between the fossil localities within Dry Cave. Not to scale.

places and seldom surpassing 2 cm in depth, appears to be composed almost entirely of country rock residue. Bones were on the surface, within the fill, and in crevices under limestone fragments. Loc. 3 was surface picked and some fill examined manually.

Attempts to trace the source of Loc. 3 fossils led to the discovery of Loc. 4. This locality is in deposits beneath a debris slope from a now closed sink which undoubtedly is the source of most of the pluvial material. Material of pluvial age blocks the passageway leading to the former entrance (which also can be located on the surface); as it spills into lower passages, the slope wash debris passes beneath a large, fallen block of limestone. A cavity beneath the block is Bison Chamber, so named because limb bones of Bison were visible when the area was first investigated. From Bison Chamber, the slope continues down an incline and the deposits eventually pinch out.

Bones of animals on the debris slope are veneered by a thin covering (generally 2—3 mm) of flowstone that continues over much of the slope surface. Most of the fossil bones are from a test pit in Bison Chamber and another test area in the corridor below. Under the flowstone cap (locally absent), a light yellowish stratum, variable in depth but averaging about 10 cm, lies over a dark "soil" layer having a

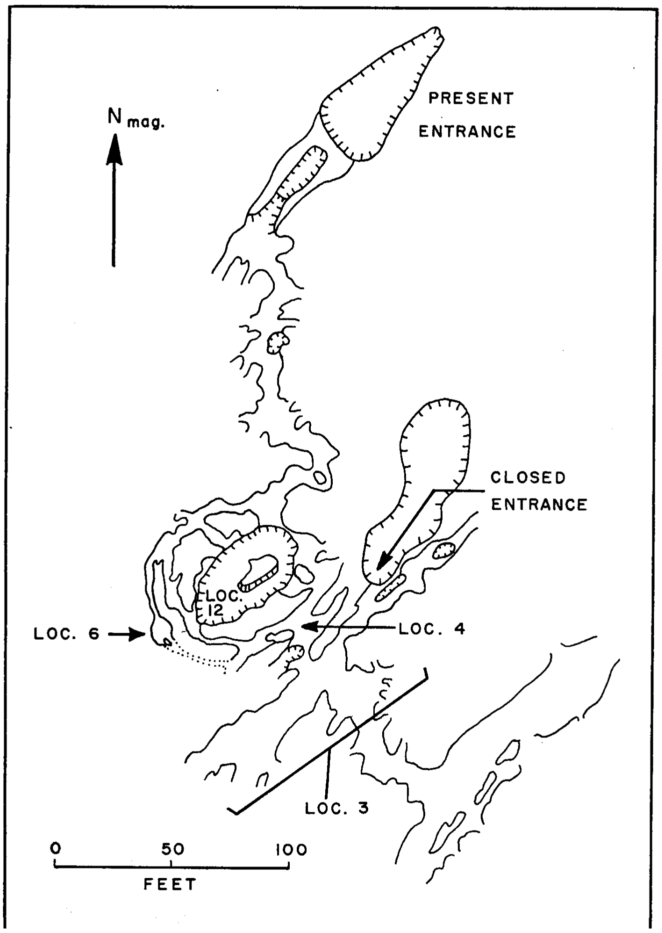

Fig. 4. Sketch showing the horizontal relationships between the Dry Cave fossil localities. Many lateral passageways are omitted and only the levels involved with the localities are shown.

thickness of at least 70 cm. Both strata are mixed with angular fragments of cave breakdown. Bone was present throughout the deposits, perhaps slightly concentrated in the light colored layer. Bison bones, likely from one individual, occurred throughout the top 45 cm of fill. Hackberry seeds were present on the surface of the flowstone and throughout the deposits beneath.

The general impression given by the distribution of the fossils in Loc. 4 is of animals having died about the cave entrance and their remains then working downslope by action of gravity, rain waters, movements of other animals, and the like, until stopped by entrapment among the limestone fragments or buried by other debris. No size sorting or special orientation was seen.

The western side of the debris slope passes through a tunnel opening onto a ledge (the "balcony") on the northeastern wall of Balcony Room. Debris washing off the ledge to the floor of the chamber (over 20 ft below) possibly was responsible for most of the fill in Balcony Room. However, the passage from the present entrance also enters Balcony Room, though high on the northwestern side. While there is no obvious evidence in the present entrance tunnel of material having been carried through the passageway, the floor of Balcony Room indicates considerable water was received from that direction; moreover, some seemingly fresh plant matter occurs on the floor surface in this area.

Balcony Room's floor is Loc. 12. Two test pits, both toward the southern side, were dug under the pressure of time to see if Pleistocene fossils were present and if there likely was a connection between the Balcony Room deposits and Loc. 6 (there was not) . One test pit was a continuation of a pit already present (possibly dug by Burnet and others in the 1930's) ; the other a new pit beside the western wall. The former is located in Fig. 4 at approximately the "0" of "LOC."; the latter, to the left of the "L" of the same word. The old pit had been dug to a depth of about 375 mm below floor level. Undisturbed fill at this level was of bat guano; below this was a light colored layer several centimeters thick; thereafter, to about 750–770 mm, a tan, silt to sandy silt fill occasionally mixed with bat guano. A poorly consolidated "false floor" was found at the lower limits of this fill. The fossil material occurred throughout, becoming most concentrated toward the bottom. Below the poorly cemented layer was a mixture of break-down products and presumed bat guano, but no identifiable bones. Limestone fragments prevented further progress at about 870 mm from the original floor level.

Locality 6 (Harris' Pocket) is an extraordinarily rich concentration of bone in a small chamber (ca. 6' x 31/2' x 31/2')located at the low spot of a small passageway. The fill appears to have come from the east, where the passage is too small to be negotiated; presumably the tunnel originates from near the toe of the debris slope of Loc. 4. The northwestern passage, through which the chamber is entered, has several areas which should have trapped bone if the source were in that direction, but none has been found. This northwestern, tunnel originates at the northern "balcony" of Balcony Room. No possible source other than these 2 tunnels is present.

Fill in Harris' Pocket showed 3 layers. On top (Stratum III) was a medium dark matrix quite variable in thickness, but averaging about 150 mm. A middle stratum (II) was predominately yellowish in color with much dung included (mostly of wood rat, Neotoma; a few poorly preserved carnivore coprolites were recovered) . Thickness varied from about 95 to 125 mm. The basal layer (I) seemingly consisted almost entirely of light colored breakdown products which were absent on bedrock slopes near the edges of the deposits and reached a maximum depth of about 20 mm toward the center.

Bone was most common in the middle layer, but not uncommon in the top layer; little occurred in the bottom stratum. Fossil elements vary in size from shrew jaws and individual bat teeth to a horse metacarpal, an artiodactyl sacrum, and large ribs. The top 2 layers obviously had been partly mixed, probably by earlier cave explorers turning around in the restricted quarters.

Wood rat dung from the middle level was collected for C^{14} dating and palynological studies; the considerable loss of organic carbon displayed by the material, however, required additional dung from disturbed areas to meet carbon requirements for dating. The resultant date, then, may be composite.

The Loc. 6 bones display differences in coloration and porosity, and a few elements have limy encrustations. Many bones are rodent chewed. Initial concentration of small animals may have been by owls (which are represented by several elements) and other predators, but the unbroken state of many of the larger bones (e.g., jack rabbit) seems to indicate entrapment by a pitfall arrangement. From what can be seen of the situation today near the closed entrance by Loc. 4, such an explanation seems feasible.

Owls would not have entered Harris' Pocket voluntarily nor, likely, would other predators. Bones of owls, of young birds such as might have fallen from nests at the old entrance, of animals probably trapped by the pitfall nature of the old entrance sink, and the differential preservation all indicate redeposition from a position nearer the old entrance. This is discussed further below.

CHRONOLOGY AND CORRELATIONS

Present stratigraphic data are insufficient for sure correlation between the 4 localities. The only date presently available is 14,470 ± 250 BP (Isotopes, Inc.; I-3365). This is from Loc. 6 and clearly places the Harris' Pocket material in the late Wisconsin, even if some mixing of upper and middle levels has resulted in a slightly "young" age.

The deposits of Loc 6 are not clearly equivalent to those seen at Loc. 4. The flowstone cap over the upper level at Loc. 4 seems to have been formed after the last deposition from the sink and probably was itself a result of increased cave humidity following closure. Thus deposition of any portion of Loc. 6 material after Loc. 4 deposition is unlikely. Since there is no obvious correlation between any of the levels in the 2 localities, it seems most likely that Loc. 6 deposits entirely predate those of the Loc. 4 test pits (earlier deposits should be present at Loc. 4 beneath the closed entrance) . The faunal evidence, discussed later, also bears out a slightly more recent date for the Loc. 4 deposits.

Why would deposition cease at Loc. 6 but continue at Loc. 4? Probably the source tunnel to Loc. 6 became clogged with silt at the end nearest Loc. 4, blocking further deposition (such silting appears common in the southern portion of the cave) . The extraordinary richness of the Loc. 6 deposits so far from the old entrance seems to require redeposition of concentrated material (as do the features discussed earlier) . Possibly the deposits are the result of an exceptionally heavy water flow, with an unusually heavy storm carrying earlier concentrated debris from about the entrance area down to Loc. 6. Or, temporary reblocking of the sink after it had opened may have allowed a pond to form in the sink, with rebreaching releasing a sudden surge of water into the passageways below. Level I at Loc. 6 obviously represents in situ formation, but differences between Levels II and III may be the result of differential settling out of the debris rather than different times of deposition.

The relationship of Loc. 12 to localities 4 and 6 is not apparent from the sediments, due perhaps to lack of sufficient data. The test pit excavated by myself lacks the upper 375 mm of fill; notes on the sediments were not taken by the assistant at Test Pit 2.

By virtue of position, Loc. 12 should contain the equivalents of all other localities. If the hypothesis of formation of Loc. 6 deposits shortly after the opening of the entrance is correct, then the lower deposits from Loc. 12, Test Pit 1, should be partly equivalent to the deposits of Loc. 6; the equivalents of Loc. 4 should be nearer the surface, perhaps in the missing portion of Test Pit 1. Presence of *Sigmodon* in the Loc. 12 test, however, seems inconsistent with faunal evidence from localities 4 and 6.

Locality 3 fill appears to have formed mostly within the cave. A few large bones (e.g., horse metapodial) presumably have washed into the area or been carried in by man or other animal. Possibly the hypothesized early surge of water carried a few elements into this region while most others went the more direct route into Loc. 6 or into Loc. 12.

In summary, the hypothetical sequence of events is as follows: (i) Deposition at Loc. 6 between 14,000 and 15,000 BP, perhaps with Levels II and III being redeposited from nearer the entrance in one event (ii) Deposition at Loc. 4 test pits of material somewhat later than at Loc. 6; possibly deposits about equal in age to Loc. 6 are present nearer the closed entrance (iii) Loc. 12 with a complete sequence (?) (iv) Loc. 3 possibly with fossils from the entire time span, but in scanty amounts.

The faunal evidence, as the geological, indicates some chronological differences between localities 4 and 6. Differences may be partly attributable to natural sampling error, but in view of the large number of elements available from Loc. 6 (5786 catalogued vertebrate specimens), real differences between that locality and Loc. 4 (825 catalogued items) seem likely. Several species present in Loc. 4 (*Dipodomys spectabilis, Microtus ochrogaster,* and *Perognathus hispidus)* are generally associated with grassland habitats; their presence at this time but not during deposition of Loc. 6 material might reflect the onset of late pluvial warming or drying. Continued presence of the several species of microtines would indicate that such a trend was not yet well established. Locality 6 contains several species unrecorded from Loc. 4 that may indicate slightly more mesic conditions. Further work at Loc. 4 is planned to clarify the situation. Presence of *Sigmodon* at Loc. 12 may indicate warmer conditions, but the possibility that *Sigmodon ochrognathus* (primarily a Mexican mountain species) is represented rather than S. *hispidus* has not been ruled out (further work in Loc. 12 also is planned) .

MAMMALIAN FAUNA

The mammalian faunal members are listed in Table 2. Identifications are tentative in that not all possible alternative taxa have been ruled out. In most cases, however, species which might logically be involved on the basis of geography and morphology have been studied.

The list also is tentative in that not all individual specimens, particularly post-cranial elements, have been studied. For example, Loc. 12 lacks specifically identifiable cranial parts of jack rabbits—further study of the post-cranial remains may result in at least tentative identifications to species. Likewise, Loc. 6 may prove to have kinds of jack rabbits in addition to the species listed here.

TABLE 2

Dry Cave pluvial mammals listed according to the minimum number of individuals known from each locality. In several cases, counts have not been made and presence is indicated by "X". Many species will prove to have more individuals when further study is completed.

Scientific Name	Common Name	Locality			
		3	4	6	12
Sorex vagrans	Vagrant Shrew	-	-	10	-
Sorex merriami	Merriam's Shrew	-	1	10	-
Notiosorex crawfordi	Desert Shrew	1	1	-	-
Myotis spp. (4)	Mouse-eared Bats	X	X	X	X
Eptesicus fuscus grandis	Large Big Brown Bat	-	1	10	-
Lasiurus cf. cinereus	Hoary Bat	-	-	1	-
Plecotus of. townsendi	Townsend's Big-eared Bat	-	-	11	-
Sylvilagus sp.	Cottontail	X	X	X	X
Sylvilagus nuttalli	Nuttall's Cottontail	-	1	6	-
Lepus sp.	Jack Rabbit	X	X	X	X
Lepus townsendi	White-tailed. Jack Rabbit	-	-	2	-
Marmota of. flaviventris	Yellow-bellied Marmot	-	-	2	-
Spermophilus ?richardsoni	Richardson's Ground Squirrel	-	-	1	-
Spermophilus tridecemlineatus	13-lined Ground Squirrel	-	2	7	-
Cynomys (Leucocrossuromys) sp.	White-tailed Prairie Dogs	-	-	1	-
Thomomys bottae	Southern Pocket Gopher	-	1	3	1
Thomomys talpoides	Northern Pocket Gopher	-	1	7	-
Perognathus ?hispidus	Hispid Pocket Mouse	1	-	-	-
Perognathus sp. (small)	Silky Pocket Mouse	1	2	-	-
Dipodomys spectabilis	Banner-tailed Kangaroo Rat	1	1	-	-
Reithrodontomys s^{p}.	Harvest Mouse	-	1	-	1
Peromyscus ?crinitus	Canyon Mouse	-	1	2	-
Peromyscus of. maniculatus	Deer Mouse	-	2	2	1
Peromyscus leucopus	White-footed Mouse	-	(1)	t_	-
Peromyscus ?pectoralis	White-ankled Mouse	1	-	-	-
Peromyscus of. difficilis	Rock Mouse	-	-	1	-
Onychomys leucogaster	Northern Grasshopper Mouse	-	-	1	1

TABLE 2—Continued

Scientific Name	Common Name	Locality 3	 4	 6	 12
Sigmodon sp.	Cotton Rat	-	-	-	1
Neotoma mexicana or cinerea	**Mexican** or Bushy-tailed **Wood** Rat (or both)	-	-	2	-
Neotoma of. albigula	White-throated Wood Rat	-	-	1	-
Microtus longicaudus	Long-tailed **Vole**	-	1	6	-
Microtus mexicanus	Mexican Vole	1	3	14	-
Microtus ochrogaster	**Prairie Vole**	-	2	-	-
Lagurus curtatus	Sagebrush **Vole**	-	1	10	-
Ondatra zibethicus	Muskrat	-	-	1	-
Erethizon dorsatum	Porcupine	-	-	1	-
Canis latrans	Coyote	-	-	2	-
Vulpes of. velox	Swift Fox	-	-	2	-
?Ursus	Bear	-	-	-	1
Mustela frenata	Long-tailed Weasel	-	-	2	-
Equus spp.	Horses	1	1	1	-
Equus ?conversidens	Extinct Horse	-	-	1	-
Cf. Antilocapra	Pronghorn	1	-	?	-
Bison sp.	Bison	-	1	-	-

t Found on surface--may not be Pleistocene.

DISCUSSION

Several prominent faunal elements are now found in the high mountain forests of northern New Mexico. Not unreasonably, the finding of Lepus townsendi, Marmota flaviventris, and Neotoma cinerea in fossil faunas has led to the simple interpretation that these boreal forests migrated south and to lower altitudes more or less as units during Pleistocene pluvials. Such was the interpretation, for example, of presence of these species in Burnet Cave in the Guadalupe Mts. (Murray, 1957). However, Harris and Findley (1964) pointed out in a study of a late Pleistocene fauna from north-central New Mexico that these animals also occur in other habitats and that their presence in conjunction with non-forest forms may actually indicate an open habitat such as now exists even farther to the north.

This is the condition represented by the Dry Cave fauna. A large proportion of the animals occur now in the Transition Life Zone of central Wyoming adjacent to Upper Sonoran grasslands (specifically, Natrona and Converse counties—see Long, 1965) . There is some intergradation with the Upper Sonoran biota. Transition zone species common to the Dry Cave fauna and central Wyoming are listed in Table 3. Such habitat is not the familiar Ponderosa Pine forest of the Southwestern mountains, however—instead, the countryside is (as described by Cary, 1917) "in its greater part open and treeless." Cary further describes the zone: "Sagebrush, yellow pine, and grasses are prominent types of vegetation in the Wyoming Transition area. The sagebrush . . . , the most widely distributed shrub, usually occurs in pure growth, while the yellow pines are restricted largely to the lower mountains, foothills, and rough tracts. . . .On streams along the bases of the mountains generally the zone is marked by narrow-leafed cottonwood ... , diamond willow, and usually by a dense shrubbery of Rocky Mountain birch, black and red haws, cornel, wild gooseberry and currant, serviceberry, and silverberry; on foothill and lower mountain slopes both in the forest as undershrubs and in the open, by Rocky Mountain and creeping junipers. . ."

TABLE 3

Mammals recorded from the Transition Life Zone of central Wyoming (Cary, 1917; Long, 1965) and also occurring in the Dry Cave Local Fauna.

Sorex vagrans
Sorex merriami
Eptesicus fuscus
Plecotus townsendi
Lasiurus cinereus
Sylvilagus nuttalli
Lepus townsendi
Marmota flaviventris
Spermophilus richardsoni
Spermophilus tridecemlineatus
Cynomys (Leucocrossuromys) sp.
Erethizon dorsatum
Thomomys talpoides
Neotoma cinerea
Microtus longicaudus
Microtus ochrogaster
Lagurus curtatus
Ondatra zibethicus
Onychomys leucogaster
Peromyscus maniculatus
Canis latrans
Vulpes velox
Ursus sp.
Mustela frenata
Antilocapra sp.
Bison sp.

Two of the small mammals (Spermophilus tridecemlineatus and Microtus ochrogaster) listed in Table 3 are more typically Upper Sonoran Life Zone creatures, with the bulk of their range in the grasslands to the east. A few other small forms occur in the Wyoming Upper Sonoran more or less marginally (Sorex merriami, Plecotus townsendi, Spermophilus richardsoni, Marmota flaviventris, Thomomys talpoides, Neotoma cinerea, Ondatra zibethicus, and Peromyscus *maniculatus),* but are commoner in higher life zones (Cary, 1917; Long, 1965) .

TABLE 4

Mammals occurring in the Dry Cave deposits and in the Southwest, but which are unknown from central Wyoming.

Notiosorex crawfordi
Myotis velifer
Thomomys bottae
Neotoma mexicana±
Neotoma albigula
Microtus mexicanus
Sigmodon sp.
Dipodomys spectabilis
Peromyscus difficilis
Peromyscus pectoralis$
Peromyscus crinitus

± Possibly not represented
$ Possibly not Pleistocene

Several mammals (Table 4) do not now occur as far north as central Wyoming, but do occur today in the Southwest. These forms are inseparably associated with many of the northern species in the deposits.

The Transition Life Zone of central Wyoming exists under the relatively dry conditions of approximately 7–15 inches of precipitation, though tending more toward the latter figure. Summers are fairly cool (average July temperatures generally between 60° and 70° F). It is under this climate that the vegetation described by Cary (1917) occurs. Many mammals, which farther south are limited to moist, cool highlands, live here successfully at lower altitudes, often under conditions of less actual annual precipitation. Their success may be due as much to lack of notable seasonality of precipitation during the growing season as to increased effectiveness of the moisture because of cooler temperatures. Conditions in the central Wyoming sagebrush grasslands are quite similar to those a short distance to the east, where Upper Sonoran grasslands thrive under somewhat greater precipitation but also generally warmer summer temperatures.

In contrast to the situation in Wyoming, there is a marked spring drought period in much of the Southwest. In general, this is best developed in southeastern New Mexico and adjacent Texas, the proportion of winter-spring precipitation to summer moisture increasing to the west and north. In lowland areas, stored winter precipitation is not sufficient to allow forbs and grasses to grow throughout the period from the start of the growing season to the beginning of the summer rains. As a result, mammals reliant on such growth for food or cover are limited to higher altitudes where winter precipitation is sufficient to carry growing plants through this period of moisture deficiency.

The area with the majority of extant species found in Dry Cave is a region of intergradation between a Great Basin Transition Life Zone biota and an Upper Sonoran biota, though the former is most prominent. The precipitation is relatively low, but rather evenly spread throughout the year; there is no pronounced spring-early summer drought. How can the forms listed in Table 4 be reconciled with such a climate type? As pointed out by several authors (see Slaughter, 1967) , northern animals tend to be limited in their southern distribution by warm season conditions, but southern animals tend more to be limited by winter conditions. Dalquest (1965) , among others, has suggested an absence of the southward-striking cold fronts that now so severely affect the southern plains. Thus the winters may have been almost as mild as they are now when cold fronts are not moving through the area, and animals now limited in their northern extent by such periodic cold spells were free to expand their ranges to the north.

Among the climatic conditions in Wyoming that cannot be transported to the south are insolation values. Although the Dry Cave area may quite reasonably have been under a general precipitation-air mass regimen such as to approximate conditions much farther north, insolation values must have remained Southwestern in character, albeit modified by increased cloud cover. Effect of such insolation would be particularly exaggerated on south-facing slopes. Temperature differences between north and south slopes must have been greatly accentuated over those now found either to the north or in the Southwest. Presence of southern animals on these slopes in close proximity to more northerly types is to be expected.

Biotic conditions at the time of deposition are reconstructed as follows. Gentle north-facing slopes supported good growths of sagebrush (Artemisia tridentata) intermixed with grasses. Junipers probably grew in suitable areas and possibly other scattered conifers were present. Mammals limited mostly to these slopes included Sylvilagus nuttalli, Thomomys talpoides, Spermophilus richardsoni, Cynomys (Leucocrossuromys) sp., Onychomys leucogaster, Neotoma cinerea, and Lagurus curtatus.

On south-facing slopes, well developed grassland, possibly with occasional Ponderosa Pines intermixed, covered the area, though sagebrush, junipers, and the like would be present locally. Limited mostly to these slopes were Notiosorex crawfordi, Spermophilus tridecem-

lineatus, Thomomys bottae, Perognathus hispidus, Dipodomys spectabilis, Neotoma albigula, Sigmodon sp., *Microtus mexicanus,* and *Microtus ochrogaster.*

Several forms would be expected more or less commonly on both slopes: *Sorex merriami, Lepus townsendi* (if *Lepus californicus* was not present; otherwise, *L. townsendi* likely would be most common in grassland habitat), *Perognathus sp.* (dependent somewhat on the species actually involved), *Reithrodontomys* sp., *Peromyscus maniculatus, Canis latrans, Vulpes velox, Ursus* sp., *Mustela frenata, Equus* spp., *Antilocapra sp.,* and *Bison* sp.

Certain forms would be most frequent along drainage ways or where sinks and other irregularities allowed somewhat more mesic conditions to prevail. Here, riparian trees, shrubs, and forbs would offer protection to *Sorex vagrans* and *Microtus longicaudus; Ondatra zibethicus* would be associated with permanent pools. Possibly spruce and fir trees occurred on steep northern slopes above the riparian vegetation.

Marmots were limited mostly to rocky outcrops. *Peromyscus difficilis* and *Peromyscus crinitus* also are rock dwellers, but the former likely was mostly confined to northern exposures and the latter (if actually present) to southern.

Presence of prairie dogs and relatively large sized pocket gophers implies a considerably deeper soil mantle than found today, with *Cynomys* indicating at least several feet of fill in some areas.

Forty percent of the herptile fauna identified by Holman occur now in central Wyoming. The remainder of the fauna exists at low elevations in southeastern New Mexico, though most species occur somewhat farther north also. The amphibians and reptiles, then, seem to show the same general mixture of warm and cold elements as the mammals, but the warm faunal elements dominate. This is not surprising since examination of herptile ranges (Stebbins, 1966) shows central Wyoming has few cold faunal elements to contribute. In the Southwest, we may expect late Pleistocene herptile faunas to be more similar to those of the Holocene than are mammalian faunas.

Other late Pleistocene pluvial faunas fit well into the model proposed here. Deposited at an elevation about 400 ft higher than Dry Cave, the Burnet Cave fauna does not seem to represent a situation more mesic, though Murray (1957) hypothesized spruce-fir forest extending down to about 4500 ft in the Guadalupe Mts. on the basis of the fauna. The deposits likely represent a time period starting slightly later than that of Dry Cave since similar or possibly slightly more xeric conditions are represented despite the higher altitude; a C14 date of 7432±300 has been questioned on faunal and cultural grounds (Wormington, 1957). Animals probably present at the start of deposition included Marmota flaviventris, Neotoma mexicana, N. cinerea, Microtus mexicanus, and M. longicaudus. A mountain form of Sylvilagus floridanus, Dipodomys ordi, Neotoma lepida (probably = N. stephensi) , Vulpes macroura (= V. vulpes) , and V. velox may represent an Upper Sonoran grassland habitat with pinyon-juniper woodland in suitable locations. Finally, Sylvilagus auduboni, Lepus alleni, Cynomys ludovicianus, Cratogeomys castanops, and ?Pappogeomys may represent appearance of desert grassland. Unfortunately stratigraphic data are lacking (Murray, 1957), so such a sequence is conjectural.

Hermit Cave, also in the Guadalupe Mts. and at an elevation of between 5800 and 6000 ft, dates approximately 12–13000 BP (Hester, 1960). Shrews from this cave were studied by Findley (1965) and found to represent Notiosorex crawfordi, Sorex nanus, and a small sized Sorex vagrans (individuals from Dry Cave also are smaller than present Vagrant Shrews from the nearby Sacramento Mts.). These identifications suggest that Sorex merriami, which tends to occur in somewhat more arid circumstances than other Southwestern members of the genus Sorex, lived in the more xeric conditions at lower elevations and S. vagrans in the more mesic lower elevation habitats; that at Hermit Cave, habitats xeric enough to be dominated by S. merriami were absent, leaving S. vagrans living in situations similar to its habitat at lower altitudes while S. nanus inhabited the more mesic areas. It seems likely, as Findley (1965) suggests, that a relatively mesic forest was present and we might tentatively suggest a lower Canadian Life Zone habitat, at least on north-facing slopes. Presence of Notiosorex may indicate once again the exaggerated differences between slopes and also that the area was not far from the lower margin of the Canadian zone. Since Lindeborg (1960) has taken a Desert Shrew from postclimax Pinus ponderosa in northeastern New Mexico, nearby slopes did not necessarily have to bear extremely xeric vegetation.

Williams Cave, near the southern end of the Guadalupe Mts., lies at an elevation of about 4900 ft and contained a number of late Pleistocene mammals (Ayer, 1937). In light of later knowledge, several identifications cannot be considered accurate, but small mammals

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[1] This specimen should be reexamined to investigate the possibility that the closely related Mexican plateau species, *Lepus callotis, is* represented—the latter species would make more sense zoogeographically.

include *a* Cynomys, apparently of the white-tailed group; a cottontail even smaller than the Brush Rabbit (Sylvilagus bachmani) and thus there is at least a small possibility that the Great Basin Pygmy Rabbit (Sylvilagus idahoensis) is represented; and a wood rat identified as Neotoma albigula albigula but said to be in some ways similar to N. lepida (probably N. stephensi). Restudy of this fauna might show these forms to be Great Basin species.

An important, but undated, late pluvial fauna is that of the Isleta Caves (Harris and Findley, 1964). It includes Sylvilagus floridanus (a Great Plains form of the species), Neotoma cinerea, Microtus sp. (most like M. pennsylvanicus, a grassland hydrosere species, and *M.* montanus, a Great Basin form), Lagurus cf. curtatus, Marmota flaviventris, Vulpes vulpes, and *V.* velox. Once again there is a mixture between faunas of sagebrush grassland (N. cinerea, Lagurus, and Marmota) and of grasslands *(S.* floridanus and *V.* velox) .

The Isleta Caves fauna is similar in many ways to the Recent fauna of southeastern Wyoming and adjacent north-central Colorado (Harris and Findley, 1964) rather than central Wyoming. In view of the relatively high elevation (ca. 5630 ft) of the Isleta sites, and the more northern and western position, the fauna likely represents a later time than does that from Dry Cave. The eastern grasslands extended farther west and to higher elevations than in Dry Cave times and the Transition Life Zone fauna may be more dilute. A time near 11,000 BP may be hypothesized.

Only one other New Mexican fauna dating from the late Wisconsin and containing numerous small mammals has been published. This is the Brown Sand Wedge local fauna of Blackwater Draw (Slaughter, 1964) . This is essentially a grassland fauna with the addition of a few woodland and a possible Transition Life Zone species. Of particular interest are Sorex cinereus, Sciurus cf. arizonensis, Peromyscus cf. truei, Microtus ochrogaster, M. pennsylvanicus, and M. cf. mexicanus as representative of generally more northern situations or of higher altitude habitats; Dasypus bellus and Sigmodon hispidus are of southern affinities.

Although Sorex cinereus is predominantly a shrew of higher altitudes today, it does descend to Upper Sonoran Life Zone habitat at elevations as low as 3800 ft in Wyoming (Long, 1965). During the Pleistocene it extended its range as far south as San Josecito Cave in Nuevo Leon (Findley, 1953), probably mostly in a grassland context. Microtus ochrogaster and M. pennsylvanicus likewise are mainly grassland forms. In the more arid Southwest, M. pennsylvanicus tends to be associated particularly with sedge beds (Harris, 1963) and under those conditions, summer temperature does not appear to be a severely limiting factor in New Mexico and northern Mexico. Along the San Juan River near Bloomfield, M. pennsylvanicus endures a July mean temperature of 74.7° F and extreme summer temperatures as high as 106° F (Hardy, 1941).

Peromyscus truei today is limited fairly strictly to pinyon-juniper woodland, but occasionally does descend into heavy riparian vegetation and sagebrush wash types of habitat near such woodland; in extreme northwestern New Mexico, it occurs rarely as much as several miles from woodland conifers (Harris, 1963). Thus, woodland may have occurred on nearby steeper southern slopes, with grassland on leveler ground. Microtus mexicanus now is primarily associated with Ponderosa Pine forest, but frequently is found in rather dry meadows within such forests. It may have occurred near Blackwater Draw on northerly slopes, possibly with some scattered Pinus ponderosa.

Presence of a gray squirrel indicates deciduous riparian growth occurred along Blackwater Draw, while D. bellus and S. hispidus indicate mild winter temperatures (Slaughter, 1964).

The above interpretation fits closely that of Slaughter (1964), though given here with somewhat more detail, and seems to fit in well with the other faunas discussed. At this east-central New Mexican site, some 3000 ± years later than the more southerly Dry Cave deposits, occurred a predominately Upper Sonoran grassland-woodland fauna with cooler northerly slopes bearing remnants of a Transition Life Zone biota. It seems likely that conditions were beginning to ameliorate slightly from those seen at Dry Cave—very possibly a more complete Transition zone fauna was present earlier, at the probably moister time represented by the preceding Gray Sand member (Slaughter, 1964).

Also fitting into this picture of sagebrush grassland animals far to the south at lower elevations in New Mexico during the late Pleistocene is a. record of Sagebrush Grouse (Centrocercus urophasianus) from the Little Hatchet Mts. of southwestern New Mexico (Howard, 1962).

That at least some faunal elements extended far south of Dry Cave during the Pleistocene is indicated by a partial skull tentatively identified as Cynomys cf. gunnisoni, collected by Dr. A. L. Metcalf from late Quaternary sediments (?Neville) along Hwy 118 ca. 5 miles south of Alpine, Brewster Co., Texas (MALB 13-1). This is over 300 miles southeast of its current known range and about 150 miles from Dry Cave.

On the basis of the several relatively large faunas now known from New Mexico, we can reconstruct much of the late pluvial climatic-vegetational environment of the region. Decreased summer temperatures with relatively mild winters and a precipitation regimen that included ample winter-spring precipitation resulted in a complex mixture of northern and southern elements rather than a simple downward shift of the nearby mountain biota. The only eastern animals thus far seen to reach the area are those that even now span the northern or central Great Plains.

Canadian Life Zone vegetation occurred onto lower mountains than at present, probably to around 6000 ft or slightly less in southeastern New Mexico during the time under consideration. The possibility cannot be ruled out that some prominent elements (including quite possibly spruce itself) may have mingled with Ponderosa Pine to a greater degree than common at present. If so, they may have extended to very low altitudes along stream valleys, accounting for increased spruce pollen in the plains to the east (Wendorf, 1961). There is no evidence in the faunas considered here for or against such a possibility, but there is evidence that the Canadian Life Zone biota did not extend to as low as 4200 ft as a unit during the times represented by the faunas.

The Transition Life Zone, rather than being well developed Ponderosa Pine forest, was more typical of the zone far to the north. Areas without prominent relief were primarily covered by Big Sagebrush, associated shrubs, and various grasses. Only on steeper slopes did *Pinus ponderosa* occur in groves. The zone probably extended somewhat below 4000 ft on northerly slopes and to near 6000 ft or above on south-facing slopes.

The Upper Sonoran Life Zone extended on southern slopes from at least as high as 4200 ft in southeastern New Mexico to an unknown lower limit. Probable connections between pinyon-juniper woodland in the Big Bend region of Texas with the Edwards Plateau (Wells, 1966) indicates an Upper Sonoran biota throughout lower altitudes of New Mexico and western Texas. As shown by Wells (1966), Lower Sonoran elements apparently were present mixed with Upper Sonoran species, at least on southern exposures.

Mild winters and cool summers, in conjunction with greater temperature differences between slopes, allowed a somewhat greater degree of mixing of vegetational life zones. Even today, extremely steep slopes in such mountains as the Magdalenas in central New Mexico may bear some Upper Sonoran plants immediately across small, steep-walled canyons from spruce groves. Even greater differences can be expected between similarly steep slopes during the late Pleistocene.

As temperature and moisture relationships changed rapidly at the end of the Pleistocene, animals dependent on evenly distributed precipitation, large amounts of moisture, or cool temperatures became locally extinct, remaining in the Southwest only where highland regions met their requirements.

There is considerable fossil evidence in southern New Mexico of mammals that now occur no farther south than the high mountains of northern New Mexico. These fossil species include Marmota flaviventris from a number of localities (a summary is given by Murray, 1957) ; Neotoma cinerea at Isleta, Burnet Cave, and Dry Cave; Lepus townsendi at Burnet Cave and Dry Cave; and Sylvilagus nuttalli at Dry Cave.

Why have some of these species been able to maintain themselves in northern mountain ranges but not in apparently suitable mountain habitats in the south? One possible explanation is that the southern highlands have a climatic history different, at least in degree, from those of the north. One animal, in particular, seems to give a hint as to what this factor might be. Numerous authors have discussed the Yellow-bellied Marmot as an indicator of climate. Stearns (1942) and Murray (1957) accepted presence of marmot at low elevations as indicating a life zone depression of some thousands of feet. These authors based their arguments on supposed lower elevational limits in the Southwest of 9600 ft and 11,000 ft respectively.

But marmots occur in extreme northwestern New Mexico at elevations slightly below 6000 ft (Harris, 1963). This may well be an artificial depression in their ecological range since they are living adjacent to a creek fed by irrigation runoff, but the record serves to show that temperature is not the factor preventing occupation of lower elevations—instead, sufficient water to provide green fodder during the active season of these hibernators seems to be the limiting element. If the mountains of Arizona and southern New Mexico are excepted, marmots occur in the West where there is sufficient winter and early spring precipitation to support green plants during the critical spring-early summer drought period, regardless of elevation. At present, approximately 2 in. of winter precipitation seems to be sufficient in the southern Rockies.

Elimination of marmots from the Arizonan and southern New Mexican mountains must have occurred after any mesic corridors between them and the northern mountain masses had been broken; otherwise repopulation would have occurred. Quite possibly populations in the southern Rockies also were affected, but migration back into such areas from the north would be possible. Isolated ranges south of the Sangre de Cristo-Jemez ranges now lack marmots even where distances to those highland masses are short.

This situation implies a late or post Pleistocene climatic pattern (not necessarily synchronic throughout the region) in which a severe winter-early spring period of precipitation deficiency was prominent and resulted in extermination of marmots even in now suitable locations in the southern high mountains. Supposition of a long interval of such seasonal drought is not necessary, and survival of spruce, fir, and other mesophytes indicates tolerance limits of these plants were not reached. (Survival rather than recolonization over short gaps is indicated in many mountains by presence of animals dependant on spruce-fir forest—e.g., Tamiasciurus hudsonicus. Some other ranges—see Wells, 1966—may have been repopulated by mesophytes via "sweepstakes" recolonization.)

A total annual precipitation deficit was not necessarily present—summer rains may even have been greater than at present, as suggested by Martin, et al. (1961) for the Southwestern Altithermal. There is widespread survival of microtines in the same southern mountains from which marmots were eradicated. This suggests that summer-fall rains regularly provided sufficient food and cover to support voles through their time of greatest stress, the period from late fall until commencement of spring growth.

The ecology of such forms as Lepus townsendi, Neotoma cinerea, and Sylvilagus nuttalli is not well enough known to support claims that the same factors limit them as limit marmots; however, the present distributions are suggestive that such may be the case.

Several other mammals of mesic habitat are absent from the mountains east of the Rio Grande and south of the southern Rockies, though present in high mountain masses west of the Rio. These include Gapper's Red-backed Mouse, Cleithrionomys gapperi; Abert's Squirrel, Sciurus aberti (recently introduced by man into the Sandia-Manzano chain, however) ; the Golden-mantled Ground Squirrel, Spermophilus lateralis; and the Montane Vole, Microtus montanus. These are unknown as fossils in the area and may be forms that never reached these southeastern mountain outposts; or, these species may have been extirpated by late or post Pleistocene events.

The times represented by the faunas discussed here are after the presumed peak of glaciation and shed little light on the problem of maximum life zone depressions during the classical Wisconsin. Wells' (1966) evidence from the Big Bend suggested to him that a depression as great as any during the Wisconsin continued up through the times involved here. Work on the Llano Estacado (Wendorf, 1961), how-ever, indicated a peak of spruce pollen during the Tahoka Pluvial (estimated at 15,000 to 22,500 BP), and thus a probable greater life zone depression at a time earlier than the Dry Cave fauna. It is not unlikely that the Big Bend and adjacent areas had a precipitation-air mass regimen somewhat modified from areas to the north and west by virtue of their geographic positions, but until further evidence is examined, knowledge of Wisconsin events in the Southwest must remain unsatisfactory.

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